Environmental Assessment of the Alaskan Continental Shelf

Annual Reports of Principal Investigators for the year ending March 1978

Volume III. 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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RECEPTORS -- BIRDS

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ANNUAL REPORT

NOAA OCSEAP Contract: 01-5-022-2538
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March 31, 1978

Population Dynamics and Trophic Relationships of Marine Birds in the Gulf of Alaska and Southern Bering Sea

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April 1, 1978

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ABSTRACT

Site-specific studies of marine birds were conducted at 8 locations in the Gulf of Alaska and southern Bering Sea during the 1977 field season. Although the studies did not adequately consider all species or habitats in the regions concerned, the locations contained diverse habitats and species assemblages which were believed to be at least representative of other colony locations in the northen Gulf and southern Bering Sea. Studies at 6 locations focused on traditional "seabirds" while two studies focused primarily on shorebirds or shorebirds and waterfowl. Species best represented on the study areas included murres, Tufted and Horned Puffins, Black-legged Kittiwakes, Glaucous-winged Gulls, and Pelagic Cormorants. Other species such as the Northern Fulmar and some small alcids were represented on only one study area. The present report provides a brief synopsis of the results of seabird colony studies conducted under RU 341 during the summer field season of 1977. A high seasonal and local variability in production indicates that continuing studies will be required to adequately evaluate average long-term productivity over a broad geographic region.

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I. INTRODUCTION

This study of the population dynamics and trophic relationships of marine birds is part of a more comprehensive program for the evaluation of the status and ecology of marine birds inhabiting the outer continental shelf of Alaska. Work conducted in research unit 341 is designed to (1) permit evaluation of the nature and extent of potential impacts associated with OCS development; (2) develop means to prevent, minimize, and/or mitigate adverse impacts and (3) establish information necessary for monitoring changes in populations or habitats that may occur. These objectives serve both the Bureau of Land Management's immediate need for information during the leasing process, and the Secretary of the Interior's need for information on which to base lease decisions and his continuing responsiblity for protection of fish and wildlife resources.

The specific objectives of this research unit are:

1. To determine the location, size, and species composition of nesting colonies of seabirds, and summarize such information in an atlas of Alaskan seabird colonies.

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

3. To determine the amount, kinds, and trophic levels of prey utilized by key seabird species, primarily in the Kodiak and lower Cook Inlet lease sale regions.

4. To describe normal mortality as reflected by dead birds found on beaches.

The present report provides a brief synopsis of the results of studies conducted under RU 341 during the summer field season of 1977. More detailed discussion of specific colony studies, as well as of feeding ecology and trophic relationships, beached bird surveys and the colony catalog is contained in the appended reports. These include the following:

1. Avifaunal Assessment of Nelson Lagoon, Port Moller, and Herendeen Bay, Alaska - 1977 by R. Gill, et al.

2. Breeding and Population Ecology of Fulmars at Semidi Islands, Alaska, with Observations on the Reproduction of Sympatric Seabird Species by S. Hatch.

3. Studies of Marine Birds at Ugaiushak Island, Alaska by D.H.S. Wehle.

4. Population Ecology and Trophic Relationships of Marine Birds at Sitkalidak Straits, Kodiak Island - 1977 by P.A. Baird and R.A. Moe.

5. The Breeding Biology of Marine Birds at Chiniak Bay, Kodiak Island, 1977 by D. Nysewander and E. Hoberg.

6. Dynamics of Marine Bird Populations on the Barren Islands, Alaska by D.A. Manuwal et al.

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The most visible of potential impacts on birds from OCS development will be the death and littering of beaches with carcasses of oiled birds as a result of catastrophic oil spillage from platforms, pipelines, terminal and storage facilities and tankers. A second category of direct impacts may result from human disturbances associated with human occupation and of transportation and construction activities near nesting habitats or foraging areas. Because of the large populations of birds in waters adjacent to Alaska, which exceed the total of birds in the remainder of the northern hemisphere, losses resulting from an oil spill off the coast of Alaska may be much larger than ever before experienced. Indirect impacts such as occur through contamination or reduction of food resources, causing lower survival or reproductive rates may, however, be even more important, as such changes may result in long term reduction in populations or preclude recovery of populations subjected to losses from oil spills.

Studies encompassed in research unit 341 have been developed to specifically address the following questions:

1. What are the critical species and habitats of marine birds and where are these located, i.e., where do concentrations of breeding and foraging birds occur?

2. When will birds be most vulnerable to OCS activities, i.e., what is the chronology of events in the biology of breeding birds, including changes in population at colonies from the onset of site occupying in the spring through departure in fall?

3. What are the kinds and amounts of foods utilized by key species of marine birds and are there seasonal variations?

4. What is the relationship between food selected and food availability?

5. What are the relationships of foods used by one species to those used by other species of birds or to marine mammals and fishes?

6. What are the principal factors governing reproductive success?

7. What is the potential for and rate of recovery of selected species of marine birds if their populations are reduced significantly?

8. What is the extent of annual and geographic variation in the breeding success of marine birds and how does this variation relate to the potential for recovery?

9. What are the causes and seasonal patterns of mortality of marine birds?

Addressing the above questions will directly facilitate assessments of the potential and anticipated effects of OCS oil and gas development.

II. CURRENT STATE OF KNOWLEDGE

James C. Bartonek and Calvin J. Lensink's "Review of the Literature and A Selected Bibliography of Published and Unpublished Literature on Marine Birds of Alaska" contains a list of more than 900 references published on birds of the coastal and marine environments, with emphasis on those birds occurring in Alaska and adjacent waters. They also made a cursory review on a geographic basis of some of this information.

There have been a number of published papers pertaining to the conservation of birds occurring in the coastal and marine environments including those by Sowl and Bartonek (1974), Bartonek et al. (1971), King (1973), King et al. (in press), Bourne (1970, 1976a) and Nisbet (in press). The literature is now becoming replete with accounts of the effects of oil contamination on marine birds. The first order 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) provide an annotated bibliography on the problem of oil pollution of birds and cover the literature between 1922 and 1973. Assessment of impacts on marine birds from OCS oil and gas developments in Alaska is discussed in USDI (1976 a,b, 1977).

A more detailed account of the current status of knowledge for our study sites is contained in the appended individual field reports.

III. STUDY AREAS

During 1977, studies were primarily conducted at seven locations in the northern Gulf of Alaska and one in the southern Bering Sea (Figure 1). Studies of population dynamics, feeding ecology and beached bird surveys were concentrated in the northern Gulf of Alaska and lower Cook Inlet. Work in the southern Bering Sea and Copper River Delta (see Appendix XI) concentrated on habitat use and trophic relationships of shorebirds.

Because of the diversity of species and habitats which may be affected by petroleum developments a single study site may not realistically be considered as representative of an entire region. The selection of study sites for seabird colony work was based on several factors including their location in relation to OCS lease regions, the probability of their being impinged upon by spilled oil, abundance and diverstiy of habitats they contained, the occurrence of key species, the status of information already available, and logistic accessiblity. The characteristics of individual sites are briefly summarized below; detailed descriptions are provided in the specific study reports appended to this summary.

Nelson Lagoon, Port Moller, Herendeen Bay

A broad study of avian use of this area was initiated in FY 76 and was continued through FY 77. The study was terminated at the end of FY 77 after a 2-year study period.

The study area is the largest estuarine area on the north side of the Alaska Peninsula. It is of primary importance for migrant shorebirds and waterfowl although, it is also used by lesser numbers of other groups of marine birds. The study in Nelson Lagoon represents the only substantive effort directed toward habitat use and trophic relationships of shorebirds within that region, and data from the study area may be at least partially representative of other similar estuarine areas of the Peninsula. Coastal habitats along the north side of the Peninsula will be vulnerable to onshore developments in Bristol Bay lease area and to offshore activities and transporation of oil from St. George Basin, Norton Sound, and Hope Basin lease areas.

Semidi Islands

Intensive studies at the Semidi Islands were initiated in FY 76 and continued through FY 77. Like the Nelson Lagoon study this study was terminated at the end of FY 77.

Few areas in the northern hemisphere are comparable to the Semidi Islands with respect to the diversity and abundance of breeding seabirds. Nineteen species of seabirds are known to breed in these islands with a total population exceeding 2 million birds. The study area contains the only large colony of Northern Fulmars in the Gulf of Alaska and, except for incidental information obtained in the Pribilofs, is the only area in which information on this species has been obtained. This site was selected for study primarily on the basis of the large size and importance of its colonies, and the presence of species not found in other study areas. Colonies on the Semidis will be most vulnerable to developments in the Kodiak and Aleutain lease sale regions.

Ugaiushak Island

Studies on Ugaiushak Island were initiated by the U.S. Fish and Wildlife Service in 1974 and were continued with OCSEAP funding in FY 76 but were terminated at the end of FY 77. The island has a diverse assemblage of species readily accessible to observers based on the island, thus increasing the likelihood for substantive results with minimal effort. This study area is situated near the Kodiak and Aleutian lease sale regions.

Chiniak Bay and Sitkalidak Strait

Reconnaissance studies were initiated on colonies in Chiniak Bay in 1975 and continued through 1976. Substantially increased effort was devoted to the area in FY 77. Studies at Sitkalidak Strait were initiated in FY 77. Both studies will continue through FY 78.

The Kodiak Archipelago contains more than 175 colonies of marine birds, but species assemblages and their habitat requirements are not as diverse as in the Semidi Islands or the Barren Islands discussed below. Those colonies, which vary in size from as few as 10 to more than 200,000 birds, would be most vulnerable to offshore and onshore developments in the Kodiak lease sale region and possibly from the lower Cook Inlet and northeastern Gulf of Alaska lease sale regions. The area is of particular interest because, of all study areas, it provides maximum opportunity to integrate colony studies with those of pelagic distribution and trophic relationships, as well as to integrate studies of birds with those of other biophysical oceanographic disciplines. For these reasons and because of the existence of a road system and other logistic aids, year-round studies are more feasible in this area than in any other.

Barren Islands

Reconnaissance level studies at the Barren Islands were intiated by the U.S. Fish and Wildlife Service in 1974 and were continued in 1975. A more intensive, OCSEAP - supported effort was started in FY 76 and was continued with FWS funding in FY 77. This study will continue with FWS funds through FY 78, providing for an intensive study period of three years.

The Barren Islands contain one of the largest and most diverse populations of seabirds within the northern Gulf of Alaska, the total number of birds dependent on the area probably exceeding one million. The population will be vulnerable to development in the Kodiak, lower Cook Inlet, and Northeast Gulf of Alaska lease sale regions.

Wooded Islands

Intensive studies were begun at the Wooded Islands in FY 76. They were continued through FY 77, for a total study period of two years.

Colonies of marine birds in the Wooded Islands, which are located on the seaward side of Montague Island, are vulnerable to impacts associated with offshore development in both the Northeast and Northwest Gulf of Alaska regions as well as to tanker traffic from Prince William Sound. The islands contain a diverse assemblage of species which are representative of other colonies in the region except for the presence of Fork-tailed Storm Petrels which are not found at other locations, thus are of significant interest in this study.

The primary site of studies of feeding ecology and trophic relationships is in the nearshore waters off the east side of Kodiak Island, Beached bird surveys generally took place on selected beaches in lower Cook Inlet, northeastern Gulf of Alaska and on northeastern Kodiak Island.

Specific sites are identified in the appended report pertaining to this work.

IV. METHODS

Although the scope and objectives of the site-specific colony studies are similar for each location, methodologies differ significantly because of differences in size of colonies, physical characteristics, and habitats and species present. In all instances, including feeding ecology and beached bird surveys, methods are those developed, implemented, and standardized by OCSEAP investigators during the past 3 years.

A detailed description of methods is presented in each site-specific or task-specific report appended to this summary report.

V. RESULTS

Table 1 provides an index to more detailed information contained in the appended reports of seabird colony studies upon which the following species accounts are based. The table also indicates the location of information on incidental or less intensively studied species not treated here.

Northern Fulmar (*Fulmarus glacialis*)

Breeding Distribution and Abundance

There are 10 to 12 more or less distinct breeding grounds of Fulmars in Alaska, however four major colonies comprise more than 99 percent of the total population:

475,000 Semidi Islands, Gulf of Alaska

450,000 Chagulak Island, Central Aleutians

77,000 St. George Island, Central Bering Sea

220,000+ St. Matthew Island, Central Bering Sea

The population at Semidi Islands was studied intensively during the 1976 and 1977 breeding seasons.

Nesting Habitat

At Semidi Islands Fulmars most commonly occupy slopes of 60 degrees to nearly vertical cliffs, but occasionally occur on slopes of 40 degrees or less. Fulmars are generally confined to the upper, vegetated portions of cliffs, however suitable habitat of any exposure and elevation is used. Nest-sites are usually established on a soil substrate but occasionally on bedrock or unconsolidated sand and rubble with no vegetative cover. A few birds nest amongst boulders at the bases of cliffs. Most nesting terrain is lushly vegetated by mid-summer with *Elymus arenarius* being the most important cover plant. Typical nesting densities are one nest-site per 1 to 4 m^2 although pairs occasionally nest 10 to 15 m from their nearest neighbor. Although most suitable habitat is now occupied at Semidi Islands, nesting space does not appear to be limiting.

Breeding Phenology

The nesting period of Fulmars at Semidi Islands in 1977 extended from early June to late September (Figure 2). The incubation period, determined to the nearest day in 52 cases, averaged 48.4 days and ranged from 46 to 51 days. The fledging period (hatching to departure) of Fulmars averages 53 days and ranges from 49 to 58 days (Mougin 1967).

Production

Fulmars lay a single egg which is not replaced if lost. At Semidi Islands two-thirds (67 percent) of the population of nest-site holders are breeding birds. Total population has been estimated at 475,000 (237,550 pairs) and reproductive success in 1977 was 51 percent (Table 2). Thus, an estimated 81,000 young Fulmars were produced at Semidi Islands in 1977.

Factors Affecting Production

Reproductive success of Fulmars showed a better than three-fold increase in 1977 over 1976, which was almost entirely due to differential hatching success. Predation by Glaucous-winged Gulls and ravens on unattended eggs is the most common proximate cause of breeding failure but there is every indication that annual variation in food availabiltiy is the principal factor governing reproductive performance. Associated with the higher level of breeding success in 1977 were a less pronounced pre-laying exodus, shorter incubation shifts, and earlier initiation of molt in umemployed birds, each of which suggests improved food availability in 1977 compared to the previous year. There appears to be a critical period around the time of egg-laying when food supply and the nutritional status of breeding birds largely determines the outcome of the season's nesting effort.

Colony Attendance

Fulmars probably begin visting their breeding sites at Semidi Islands on an intermittent basis at least 2-3 months before the first eggs are laid. Maximum numbers of birds on land at any time during the year occur in April and May when periods of peak nest-site attendance alternate with spells of total absence from the vicinity of the islands for several days. Synchrony in colony attendance during this period is apparently effected by unified responses to changes of weather. During the egg and nestling phases of the breeding cycle attendance at the cliffs is more or less variable depending on weather patterns and the number of failed breeders in the colony. In general, the population of birds on land on any given day after the first week in June represents no more than 25-50 percent of the population in attendance during the pre-egg stage.

Fork-tailed and Leach's Storm Petrels (Oceanodrama furcata and O. leucorhoa)

Breeding Distribution and Abundance

The breeding distribution of both Leach's and Fork-tailed Storm Petrels in Alaska extends from Forrester Island in the extreme southeastern portion of the state through, but not north of, the Alaska Peninsula and Aleutian Islands. Due to the nocturnal habits and nature of the nesting habitat of storm petrels, numbers and sizes of colonies are poorly known. It is clear from pelagic censusing, however, that Fork-tailed Storm Petrels are one of the more numerically abundant pelagic birds breeding in Alaska. Breeding populations of storm petrels numbering in the hundreds of thousands are known from Forrester Island (Leach's and Fork-tailed Storm Petrels), Barren Islands (Fork-tailed Storm Petrels) and Buldir Island in the western Aleutians (Leach's and Fork-tailed Storm Petrels). Numerous smaller colonies are also known but the present quality of information is such that colonies of the same magnitude as those mentioned may well exist which have not yet been located. Research on storm petrels in 1977 was confined to the large population at Barren Islands and a smaller (< 3,000) mixed colony of Leach's and Fork-tailed Storm Petrels at Wooded Islands. The latter site comprises the most northerly known breeding grounds of either species in the Pacific.

Nesting Habitat

Fork-tailed Storm Petrels appear to be opportunistic in their choice of nesting sites, either digging burrows where soil depth is sufficient or occupying natural cavities of suitable proportions. Eight percent of "empty" Tufted Puffin burrows were used by petrels at Barren Islands. At this site, nesting densities were found to be highest along the bases of slopes where an accumulation of talus and boulders provides a high level of local relief. Newly created nesting habitat is readily occupied. In 1977 birds nested in the rubble of a mudslide which had occurred in 1976 as well as in artificial nest boxes provided experimentally.

At Wooded Islands storm petrels typically dig burrows under clumps of grass but also under logs, stumps, tree roots and rocks, and in sod beneath dense brush. Fork-tailed Storm Petrels also nested in crevices on rocky slopes.

Leach's Storm Petrels nested exclusively in soil burrows at Wooded Islands, the only location at which this species was studied.

Breeding Phenology

Leach's and Fork-tailed Storm Petrels exhibited markedly asynchronous breeding schedules at Wooded Islands where they nest sympatrically (Figure 3). Approximately seven weeks separated the onset of egg-laying in these two species with some Leach's Storm Petrels not completing the breeding cycle until early November. Breeding phenology of Fork-tailed Storm Petrels at Barren Islands was more similar to Leach's than Fork-tailed Storm Petrels at Wooded Islands. Petrels probably begin visiting their nesting sites in the Gulf of Alaska during March, although there is presently no direct information on this point.

Since Fork-tailed Storm Petrels have been found to leave their eggs unattended for periods of up to 7 days during incubation, elapsed time between laying and hatching may range from 39 to 68 days. For this reason the periods over which hatching and fledging occur are much more protracted than the egg-laying period. The number of days of actual incubation required for full development of the embryo appeared to range from 38 to 42. The fledging period (hatching to departure) of 64 chicks at Wooded Islands averaged 61.5 days.

Production

Table 3 summarizes data obtained in 1977 on reproductive success of Fork-tailed Storm Petrels. At Wooded Islands three separate estimates were made based on samples of nests in soil habitat, rocky slope habitat and soil habitat protected from River Otter (*Lutra canadensis*) predation. The available data indicate that, in the absence of mammalian predators, storm petrels are capable of 60-70 percent breeding success, or 0.6-0.7 young per breeding pair.

At Barren Islands 76 percent of all monitored petrel burrows were entered at least once, and 68 percent of these were used for breeding. Egg removal experiments showed that nearly 75 percent of Fork-tailed Storm Petrels which lose their eggs will produce replacement clutches within 3-6 weeks after egg-loss.

Too few nests of Leach's Storm Petrels could be monitored at Wooded Islands to permit a meaningful assessment of reproductive success in this species.

Factors Affecting Production

As indicated above, predation by River Otters was the major cause of nest failure in storm petrels at Wooded Islands. Otters were ineffective in reaching nests located in rocky habitat and reproductive success in such areas was not significantly different from that found within the otter exclosure. Otters preyed directly upon adult birds, therefore the effects of significant losses incurred in any one year will persist for a number of years. From the number of remains of adult petrels found outside burrows it was estimated that otters took about 23 percent of the breeding population of Fork-tailed Storm Petrels using soil habitat in 1977. Clearly, the presence of this or a similar predator over several successive seasons could severly reduce or eliminate a small population such as occurs at Wooded Island. Predation by River Otters was also known to occur at Barren Islands, however the effect of a small number of otters on this large population would appear to be comparatively minor.

Flooding of nest-sites during heavy rains was a principal cause of nesting failure at Barren Islands. The presence of an impermeable covering such as a rock ceiling or overhang protecting nestlings from direct exposure to rain was a decisive factor in breeding success in 1977.

Only 1 percent of eggs laid by Fork-tailed Storm Petrels at Barren Islands proved to be infertile.

Storm petrels are highly sensitive to disturbance and frequently desert if disturbed early in incubation. In 1977 attempts were made at both study sites to minimize this effect by checking burrows only after the breeding cycle was well underway. Since some eggs may thus be laid and lost without detection, reproductive success under these circumstances is bound to be somewhat overestimated. On the whole, however, production figures for 1977 are considered to be fairly accurate.

Colony Attendance

Regular observation and quantification of the nocturnal activity of Fork-tailed Storm Petrels at Barren Islands indicated that peak numbers of birds at the colony occur during the pre-egg stage, followed by a consistent decline throughout the remainder of the season. Indeed, there may be as much as a thirty-fold decrease in the number of birds in the air over the colony between late May and mid-August. The population in attendance during the pre-egg stage may include up to 50 percent nonbreeders. Occupation of breeding birds with incubation and feeding and the departure of failed and nonbreeding birds accounts for the decline in population as the season progresses.

Cormorants (*Phalacrocorax* spp.)

Breeding Distribution and Abundance

The Pelagic Cormorant (*P. pelagicus*) is primarily a bird of marine coastal waters and is seldom found very far inland. In Alaska it breeds from Forrester Island to Bering Strait and throughout the Aleutian Islands. Colonies are most frequently of small groups (e.g. 5 to 100 pairs in Chiniak Bay).

The Double-crested Cormorant (*P. auritus*) breeds primarily from Prince William Sound west into the eastern Aleutian Islands and north along the Alaska Peninsula. This species occasionally nests on interior lakes. Colonies tend to consist of just a few pairs. Double-crested Cormorants frequent bodies of fresh water while the other two species rarely, if ever, associate with fresh water.

The Red-faced Cormorant (*P. urile*) is the most common breeding cormorant in the Aleutians and Pribilof Islands. In the last hundred years this species has spread its breeding range eastward. Colonies are presently found in southwestern Prince William Sound.

Data used in this summary are from five locations: Barren Islands, Sitkalidak Strait, Ugaiushak Island, and Chowiet Island in the Semidi Islands. Our best estimates of numbers of birds of each species at each site are: 1) East Amatuli Island in the Barren Islands: 150 Pelagic Cormorants; 2) the inner portion of Chinaik Bay: 782 Pelagic and 280 Red-faced Cormorants; 3) Sitkalidak Strait: 50 Pelagic and 120 Red-faced Cormorants; 4) Ugaiushak Island: 72 Double-crested, 281 Pelagic and 1,233 Red-faced Cormorants; 5) Chowiet Island: 60 Pelagic and 1,310 Red-faced Cormorants.

Cormorants do not appear to be highly philopatric and nest-sites, even whole colonies, are often moved from year to year. In 1977 at both Ugaiushak and Chowiet Islands cormorants increased up to 400 percent over the numbers seen breeding in 1976. At Chiniak Bay Pelagic Cormorant nests increased almost 200 percent while Red-faced Cormorants decreased 30 percent compared with a census conducted two years previously. These observations suggest that birds readily immigrate into new areas or that an especially strong year class resulting from high production in a previous year was recruited to the breeding stock in 1977.

Nesting Habitat

The Double-crested Cormorant builds its nests on rounded shoulders and broad ledges along cliffsides, in contrast to the Pelagic Cormorant which prefers more precipitous terrain (Drent, et al. 1964). The Red-faced Cormorant is also found breeding on steeper cliffs and Gabrielson (1959) suggests that this species occupies broader ledges than does the Pelagic Cormorant.

Breeding Phenology

Cormorants were present at all study sites prior to the arrival of field parties (mid-April).

Egg-laying of Double-crested Cormorants at Ugaiushak Island ranged from 26 May to 10 June with hatching ranging rom 8 July to 20 July (Figure 4). The first fledglings were seen 28 August. The incubation period in this species averages about 28 days and age at departure of chicks from their nests takes place at 40 to 50 days of age (van Tets, 1959).

Egg-laying of Pelagic Cormorants at four sites ranged from 23 May to 14 July (Figure 5). Hatching ranged from 25 June to 15 August and the first fledglings were seen at the four sites between 10 and 20 August. Ugaiushak Island was earliest, followed consecutively by Chowiet Island in the Semidis, Chiniak Bay, and the Barren Islands. Eggs were laid at the Barren Islands colony as late as 14 July while all other colonies had finished egg-laying by 17 June. The reason for this difference was not determined but renesting following failure is a likely explanation. The incubation period of Pelagic Cormorants averages about 31 days and the fledging period ranges widely from 40 to 60 days (Van Tets 1959, Drent et al. 1964).

Egg-laying of Red-faced Cormorants ranged from 16 May to 14 June at Ugaiushak Island (Figure 4). Hatching at this site extended from 19 June to 16 July with fledging beginning about 9 August. This phenology (particularly egg-laying) is essentially a week advanced over that of Pelagic Cormorants at the same site. Other field camps did not obtain direct evidence of a similar relationship, but did find many indirect indications (e.g. comparisons of chick weights, percentages of chicks fledged by a given date, etc.) which suggested Red-faced Cormorants do initiate egg-laying earlier than Pelagic Cormorants. There are no published records of incubation and fledging periods for Red-faced Cormorants, but comparisons of the inititation of egg-laying and hatching at Ugaiushak Island suggest that incubation probably lasts from about 32 to 34 days. Chicks of this species typically remained in the nest for 49-50 days at Ugaiushak Island.

Production

The mean clutch size of Pelagic Cormorants varied from 2.84 at the Barren Islands to 3.48 at Chiniak Bay. Average breeding success ranged from 0.67 to 1.95 chicks fledged per nest attempt (Table 4). In summary, reproductive success was good for this species at both Chiniak Bay and Ugaiushak Island, intermediate at the Barren Islands, and poor at the Semidi Islands.

The mean clutch size of Red-faced Cormorants at Ugaiushak Island was 3.08. Average breeding success measured at three sites ranged from 0.03 to 1.91 chicks fledged per nest attempt (Table 5). Reproductive success for this species in 1977 was good at Chiniak Bay, moderately good at Ugaiushak Island, and essentially a total failure at the Semidi Islands.

Double-crested Cormorants on Ugaiushak Island had a mean clutch size of 2.67 eggs per completed clutch. There were 0.77 chicks fledged per nest attempt and 0.95 chicks fledged per nest with eggs (Table 6). Some birds renested after failure of their first attempt. These produced an average of 1.43 chicks per nest.

Factors Affecting Production

The presence or lack of avian predators (gulls, ravens, and crows) often determines the degree of egg loss. All of the cormorant colonies in Chiniak Bay did well except for two associated with crow colonies and subject to predation by eagles. In 1977 heavy rains during the latter part of the summer caused widespread chick mortality and destruction of nests. Starvation and predation by River Otters were additional causes of mortality at the Barren Islands.

Food

No detailed observations were made of prey items taken by cormorants, but incidental notes and observations indicate that Capelin (*Mallotus villosus*) and Sandlance (*Ammodytes hexapterus*) are probably two of the most important prey species. All cormorants usually forage in near-shore waters. None were ever observed over three kilometers from Ugaiushak Island.

Pelagic Distribution

Cormorants are strictly nearshore in distribution. The Double-crested Cormorant has been known to make trips to fresh water for food even though nesting on saltwater.

Pacific Eider (*Sommateria mollissima v-nigra*)

Breeding Distribution and Abundance

Pacific Eiders nest ubiquitously along the coast in the Gulf of Alaska and Bristol Bay. Only a few "colonies" of 100 or more birds are presently known, although possibly 10,000 or more pairs nest along coastal Alaska from Cape Newenham to Prince William Sound. The Kodiak region probably supports 3,000 to 4,000 breeding pairs, and Bristol Bay may have 5,000 to 6,000 breeding pairs. The largest known colonies (Shaiak Island and Nelson Lagoon in Bristol Bay) have only 200 breeding pairs each, and most nesting birds are found scattered along the coast throughout the species' breeding range. In 1977, three areas were studied: Nelson Lagoon (7 islands, 200 pairs total), Chiniak Bay (7 islands, 30 to 35 pairs total), and Ugaiushak Island (30 to 40 pairs).

Nesting Habitat

Areas used for nesting are usually fox-free islands in protected lagoons, or coastal bays. This species seems to prefer dense stands of tall grass located close to water, but has been known to nest along drift lines on beaches, near abandoned buildings, and under trees or brush.

Breeding Phenology

The Pacific Eider in Alaska is both a migratory (northern and western coasts) and a resident species (Kodiak Basin and southern Bristol Bay). Thus, first arrival differs considerably between nesting areas. Pairs generally begin investigating possible nesting sites about 1 week before laying eggs. Females normally lay eggs May through June although clutches may be initiated as late as early July (Figure 6). Hatching generally occurs late-June through July, however there may be as much as a two week difference between areas. Fledging dates are extremely difficult to determine, as young leave the nest with the female at two days of age.

Production

In 1977 one or more young hatched in 63 to 77 percent of observed nests at the three study sites (Table 7). Clutch size exhibited a great deal of variability, averaging 3.4 to 4.8 eggs per nest but ranging from 1 to 10 eggs. Brood size at hatching averaged 3.3 to 4.2 ducklings per nest. Replacement cluthces are laid only if the first clutch is destroyed early in incubation. At Nelson Lagoon replacement clutches were significantly smaller than first clutches and first clutches initiated early were larger than late clutches.

Factors Affecting Production

Production is dependent on many factors, primarily weather, food resources, presence of natural predators, and human destruction. Weather related mortality of eggs is probably rare in the southern portion of the eider's range. Long-term studies necessary to evaluate the overall effect of weather on production have not been conducted within our study area. Eggs of eiders are rarely taken for food by local inhabitants, and intermittent disturbance of colonies by human visitation does not appear to reduce productivity unless natural predators such as gulls, ravens, and crows are also in the area. The most devastating event that can occur in an eider colony (other than physical changes of the island) is the introduction of foxes, dogs, or other large land mammals. Foxes have been known to eliminate virtually all of the nests on small islands, and the absence of eider colonies on islands inhabited by foxes is well documented.

Foods and Feeding Areas

Eiders generally feed in intertidal areas, and in waters to 40 fathoms. Samples of feeding birds were collected only at Nelson Lagoon where they generally fed on *Mytilus edulis*, *Macoma* sp., *Saduria entamon*, and crustacea during summer months. Information on food habits during other seasons is not available.

Glaucous-winged Gull (*Larus glaucescens*)

Breeding Distribution and Abundance

Glaucous-winged Gulls are one of the more ubiquitous species throughout southern coastal Alaska, but local breeding populations are generally relatively small. They range from St. Lawrence Island in Bering Sea west throughout the Aleutians and south to northwest Washington. Populations at seven locations where gulls were studied in 1977 ranged from 325 breeding pairs at Cliff and Zaimka Island in Chiniak Bay to 1,270 at Ugaiushak Island (Table 8). Gulls nested either in small but dense colonies, usually on isolated offshore rocks, or in more scattered colonies on larger islands. They were often so scattered as to be essentially solitary (nearest neighbor $>$50m).

Nesting Habitat

Glaucous-winged gulls nested in mixed-meadow-umbel habitat preferentially. However, they seemed quite flexible in this regard. Some gulls nested on sea rocks nearly devoid of vegetation. Others chose steep slopes inclined to 60° or more.

Near human population centers subsistence use or other disturbance may push gulls into a type of nesting habitat they would not normally choose. This effect may then override any natural preference for nesting habitat.

Breeding Phenology

The arrival of gulls on nesting colonies preceded our arrival at field camps. Egg-laying at all study areas started between the last week in May and first week in June (Figure 7). Replacement clutches were laid up to a month after the first appearance of eggs in some colonies. The incubation period of Glaucous-winged Gulls averaged 28-30 days.

Hatching began around 20 June at most colonies and lasted until mid-July. At colonies which had been heavily egged, dates of first hatching were latest (18 July).

Fledging of chicks commenced within the same two-day period (19-20 July) at two sites on Kodiak Island (Chiniak Bay and Sitkalidak Strait). Fledging began 12 days later at Wooded Islands. The brooding period of Glaucous-winged Gull chicks is about 3½ weeks.

There was an influx of 2,000 gulls into the vicinity of Ugaiushak Island during the last two weeks of August, but no such population changes were noted at any of the other study sites. Glaucous-winged Gulls overwinter around Kodiak but apparently do not winter near the Wooded Islands colony which was almost completely deserted by 24 September. In the Kodiak area, gulls form winter flocks which seem to be segregated by age class. Fledgings began to form rafts of single age class groups on 1 September at Sitkalidak, and tended to remain in these groups during feeding activities.

Production

Altogether, 347 nests were followed at all study sites to determine reproductive success. Average clutch sizes ranged from 2.18 to 2.64 eggs per successful nest (Table 8). At Sitkalidak gulls on truly colonial areas laid larger clutches than those in more scattered or solitary situations. The mean number of eggs hatched per successful nest varied much more than did clutch size: 1.4 eggs/nest at Sitkalidak to 2.35 eggs/nest at Chiniak Bay. The mean number of eggs hatched per successful nest in Sitkalidak Strait varied from 2.06 in inaccessible, colonial nesting areas to 1.16 in scattered, more accessible nesting areas. These differences are a direct reflection of human predation. It should be noted, however, that egg mortality was 40 percent at Ugaiushak Island, an area isolated from humans.

Because gull chicks typically leave the immediate vicinity of their nest-sites at a young age the actual number of yound reared to fledging was difficult to determine. However, our data indicate that the number of yound fledged per breeding pair ranged from 1.17 to 1.79.

Factors Affecting Production

Near human settlements the main factor affecting the reproductive success of gulls is often egging by local residents. At Sitaklidak the number of young produced per breeding pair ranged from 0 on heavily egged plots to 2.16 on more inaccessible plots. At Nelson Lagoon only 3.9 percent of gull nests survived to hatching because of egging.

The stage at which mortality occurred varied with nesting density, eggs being more susceptible in scattered colonies. However, since chicks in these areas disappeared more readily into the vegetation, an accurate assessment of their mortality was particularly difficult. In those colonies where chick mortality could be monitored, falling from cliffs and avian predation were important factors contributing to losses amounting to 7.5 to 18.5 percent.

Food

Glaucous-winged Gulls are catholic in their choices of food. At Sitkalidak Strait, fish comprised the bulk of the diet, with Capelin occurring in 78 percent, and Sandlance in 23 percent of regurgitation samples from chicks. Invertebrates such as mussels and tube worms occurred in 23 percent of chick regurgitations.

The adults' diet in the Sitkalidak area was more varied, especially in June and late August through September, when chitons, clams, shrimp, salmon, mussels, sea urchins and starfish appeared in food samples. At Barren Islands Glaucous-winged Gulls took mussels, limpets, squid, Sandlance, Pacific Cod, (*Gadus macrocephalus*), Capelin and storm petrels.

The body length of fish taken by gulls averaged 128 mm at Sitkalidak and ranged from 50 to 100 mm at Ugaiushak Island.

Mew Gull (*Larus canus*)

Breeding Distribution and Abundance

Mew Gulls have been found breeding from the vicinity of Juneau west to Unimak Island and north to and along the northern slopes of the Brooks Range. This species also breeds in interior Alaska. Mew Gulls rarely nest colonially in the Yukon delta, interior Alaska, and the northern slopes of the Brooks Range; however, small colonies (usually 25-50 breeding pairs) do occur along the coast of the Gulf of Alaska. Three larger colonies have been observed in the Gulf of Alaska: Mary Island in Chiniak Bay, Kodiak Island (200 breeding pairs), Bendel Island in the Shumagin Islands (300 breeding pairs, E.P. Bailey, pers. comm.), and Belkofski near King Cove (100-200 pairs, Murie 1959). A colony of 75-100 pairs has been previously reported at Amee Island near Old Harbor, Kodiak Island (G.A. Sanger and local residents, pers. comm.). In 1977 only 25-30 pair were noted and the decrease is thought to be related to the frequent egging activities of local residents.

Data used in this summary were collected at two locations: Mary Island in Chiniak Bay, Kodiak Island, and Nelson Lagoon (estimated population 35-40 pairs).

Nesting Habitat

Strong (1974) found Mew Gulls nesting in the Yukon delta. All nests were on islands in ponds and each pair, with one exception, nested at least 200 yards from the nearest neighboring pair, or on a different pond. Marsh or lake habitat is preferred for nesting. Most nests are on the ground though a few have been found in trees on Kodiak Island (Dick et al. 1976).

Breeding Phenology

Mew Gulls arrived at Nelson Lagoon on 19 April and had established territories by 25 April. They are present all winter in the Kodiak region and territories are occupied by the beginning of May or earlier.

Egg-laying in Chiniak Bay began about 19-20 May and peaked near the end of May (Figure 8). Barth (1955) and Bianki (1967) found an incubation period of 26 days in this species. Hatching began in Chiniak Bay on 15 June and peaked on 24 June with the mode (middle two-thirds) extending from 19 to 29 June. The last hatching was noted on 14 July. Eggs hatching 10-14 July were those which resulted from renesting after first clutches were destroyed.

Thirty-five days is the usual fledging period (Barth 1955, Bianki 1967). The first young fledged at Nelson Lagoon on 16 July while the first fledglings were seen at Mary Island in Chiniak Bay during the first week of August. These dates suggest a two week difference in phenology between the two sites.

Production

Mean clutch size was 2.86 at Nelson Lagoon (n=7) and 2.63 at Chiniak Bay (n=66). Productivity was estimated at Mary Island in Chiniak Bay through a banding and recovery program carried out just before and after a large dieoff of chicks caused by severe storms. The estimate ranged between 0.6 and 1.0 chicks per nest attempt (Table 9). Bianki (1967) notes that Mew Gull chicks experience relatively high fledging mortality at times, but that as a rule this species averages about 1.5 fledglings per breeding pair.

Factors Affecting Production

During laying and incubation at Chiniak Bay, the two most common mortality factors were human egging activity and egg damage or disappearance caused by unidentified avian predators. Mortality in the chick stage in 1977 resulted primarily from starvation and exposure during the last two weeks before fledging. Some chicks were killed by large gulls and a River Otter, but many chicks were found dead on beaches, untouched by predators. It appears that severe storms and/or a food shortage were the most important factors contributing to poor fledging success in 1977.

Food

Little is known of actual prey items taken by this species at Chiniak Bay. Mew Gulls are not usually observed in seabird feeding flocks. Bianki (1967) found this species eating plants, berries, worms, crustaceans, insects, mollusks, starfish, fish, and amphibians.

Pelagic Distribution

This species is common in nearshore waters but is rarely seen at locations distant from land.

Black-legged Kittiwake (*Rissa tridactyla*)

Breeding Distribution and Abundance

Black-legged Kittiwakes are found breeding from Glacier Bay in southeast Alaska north to Cape Lisburne in the Chuckchi Sea and west through the Aleutian Islands. The total breeding population of kittiwakes in Alaska is presently estimated at 2.1 million birds. These are distributed amongst some 250 more or less distinct colonies ranging in size from a few 10's or 100's of pairs to 100,000 birds or more. Data used in this summary are from six locations: Wooded Islands (2,250 birds) East Amatuli Island in the Barren Islands (18,300), the inner portions of Chiniak Bay (3,036), Sitkalidak Strait, Kodiak Island (4,766), Chowiet Island of the Semidi Islands (15,600) and Ugaiushak Island (9,000).

Colonies vary in numbers of active nests from year to year. A comparison between 1975 and 1977 census data for five colony sites in Chiniak Bay shows this variation, but the overall totals are similar.

Nesting Habitat

Black-legged Kittiwakes usually nest on ledges and crevices of bare rock cliffs with most colonies found on islands. Middleton Island has a sizeable population of kittiwakes that nest on dirt hills and bluffs. Frazer and Sowls (pers. comm.) have also reported kittiwakes nesting on a shipwreck on Middleton Island.

Breeding Phenology

Kittiwakes were present at all six study sites upon arrival of field parties (mid-April to June). Aerial surveys in March (Harrison, pers. comm.) indicate that adult birds may arrive at colonies as early as the latter part of that month.

Egg-laying of first clutches commenced between 3 and 11 June and extended to 29 June at the latest (Figure 9). Replacement clutches were initiated at Sitkalidak Strait as late as 15 July. The incubation period of kittiwakes averages about 28 days (Swartz 1967). Hatching at most sites in 1977 ranged from 1 to 26 July with some eggs at Sitkalidak Strait hatching as late as 14 August.

The fledging period of 35 chicks at Semidi Islands ranged from 34-48 days, averaging 40.4 days. Swartz (1967) found an average of 44 days for the fledging period of kittiwake chicks at Cape Thompson. Most investigators left their study areas before all chicks had fledged, but fledging appears to occur between 15 August and 3-8 September in the Gulf of Alaska.

Production

Average production at the six study sites ranged from 0.63 to 0.78 chicks fledged per nest attempt (Table 10). One colony in Chiniak Bay produced 1.23 chicks per nest attempt, but another only produced 0.3 chicks per nest attempt. Reproductive success may vary considerably between individual colonies, but overall it was relatively higher and more uniform at most sites in 1977 as compared to 1976 when many breeding failures were recorded. Mean clutch sizes ranged from 1.62 to 1.91 eggs, higher than average clutch sizes recorded from the Pribilof Islands (Hunt 1977).

Factors Affecting Production

Production in smaller colonies of kittiwakes appears to be limited by predation and weather while large colonies appear to be influenced more by food resources. The larger clutch sizes and greater range of productivities at smaller colonies support this conclusion. Experiments on Ugaiushak Island involving artificial increases in clutch size showed that kittiwakes could successfully rear a larger than normal brood and were not limited by food at that location in 1977. The lack of predators in Chiniak Bay appeared to allow the very high success of a colony on Kulichkof Island. Similarly, a decreased level of predation pressure at Wooded Islands in 1977 resulted in improved productivity compared to the previous year. Avian predators are effective primarily during the egg stage. Severe storms occurring during the chick stage affected kittiwake breeding success at Ugaiushak Island and Sitkalidak Strait in 1977. Storms did not affect success appreciably at either the Semidi Islands or Chiniak Bay.

Food

Capelin and Sandlance were the predominant prey items found at all study sites. At Ugaiushak Island *Ammodytes* was the most frequently observed food item during the first half of the nestling period while Wallege Pollock (*Theragra chalcogramma*) and Caplein became more important in the latter part of the nestling period.

Differences were found at Kodiak Island between the diets of kittiwakes collected offshore and those at colonies, the latter including both adults and chicks. The percentages of Capelin were similar (60% and 61.2% by volume), but Sandlance were more frequent prey items at colonies (43.1% compared to 8.5%). Other prey items recorded inshore and offshore were Pacific Sandfish (*Trichodon trichodon*), Walleye Pollock, salmon eggs, unidentified Gadidae, euphausids (*Thysanoessa* sp.), shrimp (*Pandalopsis* and other species), and polychaetes.

Colony Attendance

Daily counts at Semidi Islands indicated great variation in colony attendance until egg-laying. During the nesting period the total number of birds on the cliffs varied only between 50 and 75 percent of the maximum numbers recorded in May. Coulson and White (1956) have indicated that there are usually 1.2 birds per nest present at any given time.

Pelagic Distribution

Detailed information on the pelagic distribution of Black-legged Kittiwakes in 1977 is available only for the Kodiak area. Kittiwakes were found more on the continental shelf than in bays in May. The number of birds over the shelf decreased as the summer passed, especially after hatching, with August the low point. The population of kittiwakes in the bays around Kodiak peaked from July to September. After September kittiwakes left the bays and even the shelf populations dropped. Kittiwakes apparently migrate along the shelf edge or move to the open sea at this time.

Arctic and Aleutian Terns (*Sterna paradisea* and *S. aleutica*)

Breeding Distribution and Abundance

Arctic Terns breed along the coast from the North Slope of Alaska south to British Columbia and throughout the Aleutian Islands, and inland to all regions of Alaska. Aleutian Terns are found only in coastal habitat from Norton Sound south to the Copper River Delta in the Gulf of Alaska.

In 1977 only two study sites (Sitkalidak Strait and Chiniak Bay) afforded the opportunity to gather information on phenology and production in these two species. By far the largest population of terns was at Sitkalidak Strait with a total of 2340 birds (53 percent Arctic and 47 percent Aleutian Terns). At Chiniak Bay approximately 60 percent of 430 birds were Arctic Terns.

In Sitkalidak Strait, terns nested on three islands, one of which was comprised only of Arctics. These three islands were within 7 km of each other, and 10 km from the native village of Old Harbor. At Chiniak, terns nested on five colonies within an 8 km radius, and 17 km from the town of Kodiak. There were two mixed species colonies and three monospecifc colonies of Aleutians at the latter study site.

Nesting Habitat

Terns nested in grassy habitat and avoided mixed-meadow-umbel vegetation. Likewise, the vegetation around tern nests is relatively low compared to other parts of the islands on which they nest. There was no difference between the two species in choice of vegetation type, height or cover.

Nesting densities varied with habitat and species. Arctic Terns exhibited a greater distance to nearest neighbor and nested on areas with greater slopes than did Aleutians. Both parameters lessened the probability of aggressive interactions tending to interfere with nesting behavior. In monospecific colonies, Arctic Terns had smaller nearest neighbor distances than in mixed colonies while the reverse was true for Aleutian Terns.

Breeding Phenology

Arrival dates for terns were not obtained since field observations were begun after the birds had arrived at both study sites. Laying by Aleutian Terns commenced about the same time at both sites but the breeding cycle of Arctic Terns at Chiniak Bay was a week to ten days advanced over populations at Sitkalidak (Figure 10). Egg-laying spanned a period of a month due to the destruction of some first clutches by avian or human predators.

Hatching began around 20 June and lasted until mid-July. Incubation periods were about the same for both species (21-23 days). At Chiniak Bay Arctic Terns were four days ahead of Aleutian Terns in hatching while at Sitkalidak they were two days behind.

Fledging occurred in mid-July for both species and continued through the first week in August. Brooding periods were not determined because tern chicks left the nest-site soon after hatching and were difficult to locate. The fledging strategies of the two species differed markedly. Arctic Terns left the nesting area as soon as they could fly, and started feeding themselves immediately. They were often chased or attacked by adults of both species, but most frequently by Arctics. Aleutian fledglings remained at their nest-sites for two weeks after they had fledged and continued to be fed by the adults. They were never attacked by adults of either species.

Arctic Terns began staging in large numbers in Chiniak Bay around 26 July. They had all left Sitkalidak Strait by 15 August. Few Aleutian Terns remained in Chiniak Bay after 20 August, and all had left Sitkalidak Strait by 30 August. There were never large groups of non-breeding or post-breeding terns in Sitkalidak Strait. Chiniak Bay, then, is a staging ground for the fall migration of terns while the Sitkalidak Strait area is not.

Production

Many first clutches were destroyed by various agents including ravens, gulls, and humans. Both species of terns laid replacement clutches.

Arctic Terns produced larger clutches than did Aleutians at both study sites (Table 11). Clutches were slightly larger at Chiniak Bay in both species. The mean number of chicks hatched per nest was also greater for Arctic than Aleutian Terns, and was higher at Chiniak than at Sitkalidak. Hatching success in mixed colonies was higher for Aleutian Terns at both study sites. Hatching success of Aleutian

Terns in an isolated colony in Chiniak Bay was lower than the average for Arctic Terns at that study area, but higher than the figures for either species at Sitkalidak. Monospecific colonies of Arctic Terns at Sitkalidak exhibited the lowest hatching success (43 percent).

Data on fledging success (chicks fledged/chicks hatched) are available from the Sitkalidak study area only. The fate of tern chicks was difficult to follow, therefore minimum and maximum possible fledging rates are given in Table 11. Maximum values assume that all chicks not followed for the entire flightless period survived to fledging. Minimum values assume that every such chick died. Fledging success and overall breeding success were somewhat higher for Arctic than Aleutian Terns.

Factors Affecting Production

Total combined mortality of eggs and chicks was 39.6 percent for Aleutian Terns and 29.3 percent for Arctic Terns. Arctic Terns seemed to be more affected at the egg stage while mortality of Aleutian Terns was concentrated at the chick stage. Egging and avian predation were important causes of egg mortality for both species (4 percent in Arctic and 16.7 percent in Aleutian Terns). Additional mortality of Arctic Tern eggs resulted from rolling out of the nest and death at pipping during excessively hot weather in June. These two factors may be related to the fact that Arctic Tern nests were located on areas with steeper slope and perhaps less cover.

Of the two species, Aleutian Tern chicks seemed more susceptible to the elements. Mortality of chicks from exposure was 12.5 percent and 6.5 percent for Aleutian and Arctic Terns, respectively. This difference may be due to Aleutian Tern adults being behaviorally more inclined to leave their young exposed. Increases in the death rate of Aleutian Tern chicks coincided with heavy storms.

Additional mortality of Aleutian Tern chicks was probably due to starvation. Measurements of chick growth at Sitkalidak showed that Arctic Terns grew much faster than Aleutian Terns. They fledged at 106 percent of adult weight while Aleutian Terns did so at 80 percent. Adult Aleutian Terns were sometimes prevented from entering feeding flocks and were often harassed by Arctic Terns as they returned to the colony to feed their chicks. In such instances returning birds were driven to the ground or forced to relinquish their bill loads of fish.

Food

Fish comprised the greater part of the diet for both species of terns at Sitkalidak. Arctic Terns ate fish more exclusively (94 percent by volume) than did Aleutian Terns (86 percent). Seventy-four percent of the diet of Arctic Terns was composed of Capelin and Sandlance while the diet of Aleutian Terns was 56 percent Capelin and sculpins. Aleutian Terns took a greater variety of prey over all seasons, notably many more fish species and also insects and isopods, than did Arctic Terns. However, both species fed their chicks exclusively fish.

Mean prey length differed between adults and chicks of both species, with chicks always receiving the larger prey. Likewise, Arctic Terns took larger prey than Aleutian Terns. Average prey size changed through time, with the largest prey being taken in July. A decrease in prey length in August, concomitant increase in variety of prey, and increased mortaltiy of Aleutián Tern chicks may reflect a change in food availability at this time.

Common and Thick-billed Murres (Uria aalge and U. lomvia)

Breeding Distribution and Abundance

Collectively, the two murre species may be the most numerous of all pelagic birds breeding in Alaska, with a combined population exceeding 8 million birds. The Alaskan breeding range of Common Murres extends from Forrester Island in southeast Alaska, throughout the Gulf of Alaska and Aleutian Islands and north to Cape Lisburne in the Chukchi Sea. The range of Thick-billed Murres overlaps that of Common Murres but extends only as far east as Middleton Island in the Gulf of Alaska. The three sites at which murres were studied in 1977 all contained mixed colonies of Thick-billed and Common Murres although the latter species predominated in each case. Best available population estimates for both species combined in these study areas are 91,000 murres on two islands in the Barren Islands group, 9,200 on Ugaiushak Island and 600,000 birds on nine islands of the Semidi Islands group.

Nesting Habitat

Although they occasionally nest on a soil substrate, murres occupied only ledges of bare rock cliffs in the three locations where they were studied in 1977.

Breeding Phenology

Thick-billed and Common Murres were present at all three study sites upon the arrival of investigators. Murres exhibited considerable geographical variation in nesting phenology in 1977. In Common Murres egg-laying commenced on or about 5 June at Semidi Islands but not before 24 June at Ugaishak Island just 50 miles to the north (Figure 11).

A spot check of murres at Barren Island on 15 August indicated that 28 percent of surviving eggs of Thick-billed Murres had hatched (n=46) compared to 77 percent of eggs of Common Murres (n=149), suggesting a difference in nesting phenology of a week or more between the two species at this location.

The incubation period of both murre species averages about 33 days (Tuck 1961). Age at departure from the cliffs was believed to be 15-18 days for most chicks at Ugaiushak Island in 1977 (Wehle, pers.

comm.) but about 30 days for most chicks in the Semidi Islands. Thus, although the timing of egg-laying differed by 19-20 days between these two sites, chicks went to sea during approximately the same period, at markedly different ages and presumably different weights.

Production

Data on the reproductive success of murres obtained in 1977 are summarized in Table 12. Due to the difficulty of monitoring a sufficiently large sample of nests on crowded ledges without resorting to interference, the available data are indicative only of a two- to three-fold difference in reproductive success on disturbed and undisturbed study plots.

Factors Affecting Production

Human disturbances resulting in panic flights during the incubation or chick stages may radically reduce production by exposing eggs or young to avian predators or the danger of falling off of ledges. There was evidence of a fairly high rate of natural predation on eggs by Glaucous-winged Gulls at Barren Islands. The skill and assiduousness displayed by incubating murres probably vary in relation to breeding experience and food supply.

Tuck (1961) found that 80 percent of failed Thick-billed Murres were capable of producing at least one replacement clutch so long as the first egg was lost within five days of having been laid. It was believed that at least 15 of 41 pairs (37 percent) of Common Murres on a disturbed plot at Ugaiushak Island replaced lost eggs.

Food

Capelin (*Mallotus villosus*) comprised the bulk of the diet of murre chicks at Ugaiushak Island in 1977. Other fish species identified in 120 samples collected at this site included Chum Salmon (*Onchorhynchus keta*), Walleye Pollock, Pacific Herring (*Clupea harengus*) and Pacific Sandlance.

Both Capelin and Pacific Sandlance were identified in the diet of murre chicks at Barren Islands.

Average percent composition of prey (by volume) in the stomachs of 27 adult Common Murres collected in the Kodiak region from late May to mid-September was as follows:

Capelin	41%
Unidentifiable Fish	22%
Unidentifiable Osmeridae	15%
Pacific Sand Lance	11%
Unidentifiable Gadidae	7%
Walleye Pollock	4%

Since all of the unidentifiable osmerids were probably Capelin and all of the unidentifiable gadids were probably pollock, the diet of adult Common Murres was largely restricted to three fish species in the following proportions:

Capelin	72%
Pacific Sandlance	14%
Walleye Pollock	14%

Colony Attendance

Daily counts of Common and Thick-billed Murres at Semidi Islands indicated intermittent attendance on the breeding ledges during the pre-egg stage. Attendance during the nesting period generally varied between 60 and 75 percent of the maximum numbers observed in April and May. Larger fluctuations were related to weather, lowest numbers coinciding with gale force winds and highest attendance occurring on days following gales. All-day watches at Semidi Islands indicated that numbers of murres on the ledges remained fairly constant throughout the better part of the day with changes occurring primarily in the early morning and late evening.

Horned Puffin (*Fratercula corniculata*)

Breeding, Distribution and Abundance

Horned Puffins breed from Forrester Island in southeast Alaska, west through the Aleutian Islands and north to Cape Lisburne in the Chukchi Sea. Colony size varies markedly from individual pairs scattered along the coast to immense aggregations numbering over 100,000. An example of the latter would be Chowiet Island in the Semidi Island group.

This account includes data from three locations where Horned Puffins were studied in 1977: Barren Islands, Ugaiushak Island, and Semidi Islands. The population of Horned Puffins in the Barren Islands is approximately 13,000 birds with the majority of these on East Amatuli Island. Approximately 18,000 Horned Puffins are found on Ugaiushak Island during the breeding season and several hundred thousand birds breed at Semidi Islands.

Nesting Habitat

Horned Puffins tend to nest in rocky habitats, whether under beach rocks, in talus, or in rocky crevices. This preference for rocky surroundings undoubtedly reduces competition with Tufted Puffins (*Lunda cirrhata*) for nest-sites. It is noteworthy that on Puffin Island in Kotzebue Sound where very few Tufted Puffins are found, approximately 7,000 Horned Puffins nest in burrows. Large areas of suitable rocky habitat which would typically be needed to support the 10,000 Horned Puffins found there are lacking.

Breeding Phenology

Breeding phenology of Horned Puffins at all three study sites was remarkably similar in 1977 (Figure 12). Arrival dates for the Barren Islands, Ugaiushak Island, and Semidi Islands were 21 May, 20 May, and 21 May respectively. Egg-laying of Horned Puffins, both within colony sites and between colony sites, was highly synchronized. The average incubation period is 42 days according to Sealy (1973) and the same figure was determined for Horned Puffins in the Barren Islands in 1977 (range = 40-46 days, n = 13). The nestling period of puffin chicks at Barren Islands was 40 days (n=2). Sealy (1973) gives a nestling period of 38 days for birds on St. Lawrence Island.

In all cases, investigators left the islands prior to fledging. However, based on chick size and previously published data, fledging at all three sites occurred during the first three weeks in September. No data on the departure of adult birds from the colonies are available.

Production

Hatching success and fledging success varied considerably from site to site (Table 13). However, overall breeding success was similar at Barren Islands (64 percent) and Ugaiushak Island (69 percent). Hatching success was much higher on the Barren Islands than Ugaiushak but the reverse was true for fledging success. Hatching success at Semidi Islands was comparatively low, but the majority of eggs which failed to hatch were apparently deserted after disturbance associated with the checking of nests. Combining the weighted values for hatching success obtained at Barren Islands and Ugaiushak Island and values for fledging success from all three study sites gives the following averages for reproductive performance of Horned Puffins in 1977:

Chicks hatched/Egg laid - 0.79 (N = 82)
Chicks fledged/chicks hatched - 0.72 (n = 32)
Chicks fledged/Egg laid - 0.57

Clearly, larger sample sizes at individual sites are desirable.

Detailed information regarding the proportions of breeders and nonbreeders at colonies is difficult to obtain for this species. At Barren Islands 64 percent of 22 sites frequented by Horned Puffins were actually used for breeding.

At Ugiaushak Island 30 percent of a sample of 10 breeding females replaced their clutch of one egg after its removal.

Factors Affecting Production

Weather and food resources appear to be two principal factors affecting the breeding success of Horned Puffins. At the Barren Islands, improved weather in 1977 over 1976 may have resulted in higher production while at Ugaiushak Island an apparent improvement in food availability resulted in increased production in the second year of study. Any disturbance of Horned Puffins, especially during the incubation stage can have a serious deleterious effect on production.

Food

Horned Puffins depend on a limited number of prey species as food for chicks. At the Barren Islands, Capelin and to a lesser extent Sandlance, were the most important fish species brought to young. On Ugaiushak Island, Sandlance was the principal prey species while Capelin was of secondary importance. Additional prey species recorded from bill loads at Barren Islands included Pacific Cod, Pacific Sandfish (*Trichodon trichodon*), and White-spotted Greenling (*Hexagrammos stelleri*).

Colony Attendance

Horned Puffins exhibit great variation in the number of birds at the colony at specifc times throughout the breeding season. In daily counts of rafting birds made throughout the breeding season at Semidi Islands, peak numbers of puffins occurred during the pre-egg stage, on one day during the incubation phase of the nesting cycle, and on one day during hatching. On a number of occasions over the course of the season, no birds were present on the waters immediately surrounding the colony. This phenomenon points to the difficulty of obtaining accurate population estimates for this species based on quick surveys.

Tufted Puffin (*Lunda cirrhata*)

Breeding Distribution and Abundance

Tufted Puffins are one of the most widely distributed seabirds in the eastern North Pacific. In Alaska, they are found from Forrester Island in the extreme southeast portion of the state, west through the Aleutians and north to Cape Lisburne. Colony size varies from a few pairs to more than 100,000 pairs as found in the Barren Islands. The center of abundance of Tufted Puffins in Alaska is from Kodiak Island, west through the Aleutains.

Data incorporated into this summary are primarily from six locations: Wooded Islands (estimated population 4,000), Barren Islands (190,600), Cliff Island in Chiniak Bay (2,188), Aimee, Cathedral and Sheep Islands in Sitkalidak Strait (10,000), Ugaiushak Island (14,000) and Nelson Lagoon (36).

Nesting Habitat

Tufted Puffins typically nest in burrows located in grassy habitats at cliff edges, slopes above cliffs, and tops of islands. Less frequently, Tufted Puffins nest in rocky habitats (Sealy 1973). At the Nelson Lagoon study site a small colony of puffins occupied burrows located on four narrow sand islands with an average elevation of only 1.5m above mean high - high water. Sowls (pers. comm.) reports Tufted Puffins nesting in a shipwreck on Middleton Island.

Breeding Phenology

Dates of first arrival of Tufted Puffins in 1977 are known for four sites: Wooded Islands, 4 May; Ugaiushak Island, 10 May; Semidi Islands, 5 May; and Nelson Lagoon, 8 May. Egg-laying occurred from late May through late June with a peak during the first two weeks in June (Figure 13). Data from Ugaiushak, Barren Islands and Wooded Islands indicate that the incubation period of Tufted Puffins is normally 45-47 days but may range from 42 to 50 days. Hatching at all sites occurred from mid-July to mid-August. Estimated average duration of the nestling period was 46 days at Ugaiushak Island and 47 days at Barren Islands. Fledging began in late August at most sites, however field studies were generally discontinued before more detailed information could be obtained. It was estimated that 86 percent of the Tufted Puffin chicks at Sitkalidak had fledged by 6 September. All chicks produced in the small colony at Nelson Lagoon had fledged by 25 September.

Production

Breeding success varied widely between six colonies under observation in 1977 (Table 14). The highest levels of production were recorded at Chiniak Bay and Ugaiushak Island where human disturbance was minimal. The lowest production was 0.02 chicks fledged per egg laid at Wooded Islands.

At all study sites except Nelson Lagoon a considerable proportion of burrows were not used by breeding pairs. At Sitkalidak 72 percent of 93 burrows were used. The figures for Barren Islands and Wooded Islands were 46 percent and 60 percent, respectively. At Ugaiushak Island 11 percent of 35 burrows never had birds associated with them. Of the remaining 31 burrows which were entered at least once during the season, 15 (48 percent) were not used for breeding. Thus, only 46 percent of all burrows under observation were used by breeding birds at this site.

Seven of 10 breeding females were believed to have produced replacement clutches after experimental removal of their eggs at Ugaiushak Island.

Factors Affecting Production

At Ugaiushak Island improved food availability was believed to have been responsible for increased production in 1977 over 1976. Investigators at Sitkalidak determined that 50 percent of chick mortality was through starvation as Capelin, a principal food of young puffins, disappeared from the study area during the nestling period. Predation by River Otters was the principal cause of the total breeding failure recorded at Wooded Islands. Otters as well as desertion of burrows after disturbance, proved important at the Barren Islands.

At Sitkalidak, Tufted Puffins nesting in areas of deeper soil, and thus having deeper burrows, had higher breeding success than puffins nesting in areas of shallow substrate.

Tufted Puffins are very susceptible to disturbance, possibly even more so than Horned Puffins, and will desert their nests at the slightest provocation. Such tendency has hampered investigators in their attempts to study this species.

Food

Food of nestling Tufted Puffins at Ugaiushak Island, Barren Islands, Chiniak Bay, and Sitkalidak Strait was primarily Capelin and Pacific Sandlance. Additional prey items found in bill loads at Ugaiushak Island were Walleye Pollock, Saffron Cod (*Eleginus gracilis*), squid, and octopus. Other known prey items include Pacific Sandfish and Sockeye Salmon (*Oncorhynchus nerka*) identified in the diet of nestling Tufted Puffins at Sitkalidak, and Pacific Cod, Kelp Greenling (*Hexagrammos decagrammus*) and Prowfish (*Zuprora silenus*) recorded at Barren Islands.

Offshore collections at Kodiak Island revealed that the fish species taken most often by adult Tufted Puffins was Capelin (64.8 percent by volume). Other prey included Walleye Pollock (5.7 percent), Euphausiids (*Thysanoessa sp.*, 4.7 percent) and squid (4.0 percent). At Sitkalidak, adult Tufted Puffins also took polychaetes and shrimp (Decapoda) in small quantities.

Colony Attendance

Prior to egg-laying at Ugaiushak Island, Tufted Puffins were alternately present and absent from the colony in 3-day intervals. At Barren Islands, investigators identified a 3-5 day on-off cycle of colony attendance during the pre-egg stage.

VI. DISCUSSION AND CONCLUSIONS

Consideration of the information presented above on the breeding phenology of various Alaskan seabird species in 1977 permits the following generalizations:

a. Individual species behave independently with respect to breeding phenology when two or more multispecific seabird colonies are compared. Thus, for example, murres commenced breeding earlier at Semidi Islands than Ugaiushak Island in 1977, but the reverse was true for cormorants. These colonies are located only 50 miles apart.

b. Some species exhibit a great deal of geographic variation in breeding phenology (e.g. murres and storm petrels) while others appear to be highly synchronized throughout the Gulf of Alaska (e.g. Horned and Tufted Puffins).

c. Considered collectively, species of seabirds breeding in in the Gulf of Alaska lay the majority of their eggs from about 15 May to 1 July. It is during this period that breeding birds will be most sensitive to direct disturbance (e.g. noise or presence of humans on or near colonies).

A primary objective of seabird colony studies conducted under RU 341 is the estimation of average annual productivity in as many species as possible, emphasizing those species deemed most likely to be significantly affected by OCS oil development and/or those which are amendable to the accurate determination of reproductive success. Only with such information at hand can an assessment be made of the capability and rates of recovery of seabird populations following the loss of a significant segment of actual or potential breeding stock.

Previous work conducted in Alaska, and elsewhere in arctic and subarctic regions, has demonstrated a great deal of both annual and geographic variability in reproductive success among seabirds. Given the duration of colony studies conducted thus far under RU 341 (2 years or less in all cases) it is clearly not possible to derive a reliable figure for average annual productivity for any species at a single colony. Therefore, the only procedure available is to assume that the geographic variation in breeding performance of a given species observed in a given year is representative of the variability that would be realized over the course of many years at one location. Thus, using the present data from a number of sites studied in 1977, average productivity (expressed as the number of young produced per breeding pair) would be estimated for several exemplary species as follows:

Pelagic Cormorant 1.72 (range 1.48 - 2.05)
Glaucous-winged Gull 1.4 (range 1.17 - 1.79)
Black-legged Kittiwake 0.95 (range 0.70 - 1.46)
Fork-tailed Storm Petrel 0.56 (range 0.33 - 0.68)
Tufted Puffin 0.51 (range 0.02 - 0.80)

However, the weakness of the underlying assumption is evident when, for example, the present data for Black-legged Kittiwakes are compared to the results of studies on this species conducted in 1976. In the latter year many colonies throughout the state experienced nearly total reproductive failure while predation at six sites in the Gulf of Alaska in 1977 was uniformly higher and varied only between 0.70 and 1.46 young produced per breeding pair.

Thus, an even more serious problem underlies any attempt to predict population responses to sudden and significant increases in mortality using information presently available. This is the failure to adequately account for reproductive pattern, as well as average reproductive rate, in such calculations. Reproductive pattern may be viewed as a combination of the temporal distribution and magnitude of increments to the breeding stock. In kittiwakes, for example, it appears that the reproductive pattern at many colonies is characterized by one or more years of widespread reproductive failure alternating with especially productive years. It is easily shown that under these cicumstances a discrete population takes much longer to recover significant losses than would be predicted on the basis of long-term average productivity alone. Indeed, under not unreasonably extreme circumstances, a theoretically viable population may actually go to extinction.

In summary, due to the short-term nature of seabird colony studies, we presently have neither sufficient data for any species to permit an accurate estimation of average annual productivity and the use of an overly simplified model to predict rates of population recovery, nor can we adequately characterize reproductive pattern and thereby develop more realistic models.

VII. NEEDS FOR FURTHER STUDY

This brief review of studies on nesting colonies of seabirds in the Gulf of Alaska indicates significant species, geographical, and seasonal differences in production of young. Because accurate information on productivity, or the capacity of populations to replace losses, is critical to evaluation of potential long-term impacts from OCS development, it seems clear that studies of nesting colonies should continue at a number of locations until an adequate assessment of this variation can be made. Studies should focus on variations that are caused by changes in availabiltiy of food or those caused by large scale climatic or oceanographic phenomena, which may also relate to food supply, as such factors appear to be of primary long-term importance to establishment of reproductive rates and patterns. Local phenomena, such as predation, seasonal differences in habitat, human interference, etc., are of secondary importance, although they must be considered both as "noise" within the system, and because factors causing local variations in production may be controlable, thus providing means of partially mitigating the adverse effect of OCS development.

Because of the apparent importance of food in determining overall productivity of birds within a region, studies on colonies should be integrated to the greatest extent possible with other studies, in particular those of trophic dynamics, and of distribution patterns of birds at sea, as the latter are almost certainly related to variation in the distribution and abundance of food. We consider the value of trophic studies, regardless of the care or detail with which they are planned and conducted, to be relatively limited, unless the results of such studies ultimately contribute to a better understanding of reproduction, growth, and survival of species which are of primary public concern - commercial fishes, marine mammals, and marine birds.

Any experimental studies, such as the effects of oil contamination of food or of eggs, or disturbance of colonies by aircraft or other human activity, should be conducted in conjunction with a more comprehensive study of a colony or colonies, as experimental results will be impossible to evaluate without simultaneous evaluation of the natural factors affecting the population.

At the present time there is no substantive work being conducted on birds of estuarine habitats. This omission is particularly critical in Bristol Bay and the Southern Bering Sea where large numbers of shorebirds, ducks, and geese depend on lagoon systems located on the north side of the Alaska Peninsula. Such habitat is highly vulnerable to pollution by oil, and continuation of studies in this region should be given serious consideration. Such studies would be most effective if integrated with studies of invertebrate resources, as intertidal organisms, which provide the main source of food for birds, are also among those most seriously affected by oil pollution.

This preliminary synthesis of information on individual species, which relies primarily on one year's data from the Gulf of Alaska, indicates the need for a more comprehensive synthesis of information on individual species from all seasons and regions. This synthesis may follow the general format of the present summary, but should include maps of breeding locales and seasonal patterns of distribution at sea, and tabular or graphical illustration of seasonal and geographic variation in chronology of breeding seasons, reproductive success, and food utilization. This would permit detailed analysis of the relationships of these major components of the life history to each other, and to the continued survival of individual species when they are subjected to additional stresses resulting from OCS development or other anthropogenic perturbations of the marine ecosystem.

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Table 1. Index to information on breeding biology of various seabird species contained in the appended field camp reports.

Study Area	Northern Fulmar	Storm Petrels	Cormorants	Terns	Glaucous-winged Gulls	Black-legged Kittiwakes	Mew Gulls	Murres	Tufted Puffin	Horned Puffin	Common Eider	Others
						Species						
Wooded Is.		x			x	x			x			Black Oystercater Parakeet Auklet Pigeon Guillemot
Barren Is.		x	x		x	x		x	x	x		Black Oystercatcher Parakeet Auklet Ancient Murrelet
Chiniak Bay			x	x	x	x	x		x		x	
Sitkalidak			x	x	x	x			x			
Ugaiushak I.			x		x	x		x	x	x	x	Parasitic Jaeger Pigeion Guillmot
Semidi Is.	x		x		x	x		x		x		Parakeet Auklet Rhinoceros Auklet
Nelson Lagoon					x				x		x	

Table 2. Reproductive success of Fulmars at Semidi Islands in 1977.

No. Eggs in sample	386
Percentage infertile eggs	6.3
No. chicks hatched	267
No. chicks fledged	197
Chicks hatched/egg laid	0.692
Chicks fledged/chicks hatched	0.738
Chicks fledged/ eggs laid	0.510

Table 3. Reproductive success of Fork-tailed Storm Petrels at two colonies in 1977.

	Barren Is.	Wooded Is.		
		Soil	Soil/Exclosure	Rocky Slope
No. Burrows known to contain eggs 1/	100 2/	204 3/	25 3/	33 4/
No. eggs hatched	84	72	21	27
No. chicks fledged	58	49	17	21
Chicks hatched/ eggs laid	0.84	0.35	0.84	0.82
Chicks fledged/ chicks hatched	0.69	0.68	0.81	0.78
Chicks fledged/ eggs laid	0.58	0.24 (0.33) 5/	0.68	0.64

1/ Burrows first checked at varying stages in the nesting cycle, thus breeding success will be somewhat overestimated.

2/ Burrows first checked near end of incubation.

3/ Burrows first checked at varying stages during incubation.

4/ Most burrows located and checked only after chicks had hatched.

5/ Figure in parentheses adjusted for possible disturbance.

Table 4. Observations on the productivity of Pelagic Cormorants in 1977.

	Barren Islands	Chiniak Bay 1/	Semidi Islands	Ugaiushak Is.
No. Nests in Sample	63	26	6	44
No. Nests with eggs	63	25		42
Mean clutch size	2.84	3.48		3.45
No. eggs hatched	115	60		
No chicks fledged	102	37	4	86
Chicks hatched/ eggs laid	0.64	0.69		0.65
Chicks fledged/ chicks hatched	0.89	0.62		0.86
Chicks fledged/ eggs laid	0.57	0.43		0.59
Chicks fledged/ nest started		1.42	0.67	1.95
Chicks fledged/ known breeding pair	1.62	1.48		2.05

1/ Chiniak Bay studies also included plots on which 171 chicks fledged from 127 nests.

Table 5. Observations on the productivity of Red-faced Cormorants in 1977.

	Chiniak Bay	Semidi Islands	Ugaiushak Island
No. Nests in sample	57	110	51
No. Nest with eggs			49
Mean clutch size			3.08
No. eggs hatched			
No. chicks fledged	109	11	66
Chicks fledged/ chicks hatched			0.90
Chicks fledged/ eggs laid			0.44
Chicks fledged/ nest started	1.91	0.03	1.29
Chicks fledged/ known breeding pair			1.35

Table 6. Observations on the productivity of Double-crested Cormorants at Ugaiushak Island in 1977.

No. Nests in sample	26
No. Nest with eggs	21
Mean clutch size	2.67
No. eggs hatched	
No chicks fledged	20
Chicks hatched/eggs laid	0.38
Chicks fledged/chicks hatched	1.00
Chicks fledged/eggs laid	0.36
Chicks fledged/nest started	0.77
Chicks fledged/known breeding pair	0.95

Table 7. Observations on the productivity of Pacific Eiders at three locations in 1977.

	Nelson Lagoon	Chiniak Bay	Ugaiushak Island
Population Size	200	30-35	30-40
No. nests in sample	97	19	9
Clutch size			
mean	4.76	4.6	3.44
range	1-10	2-7	1-6
Percentage of nests hatching one or more eggs	77.3	63.2	75.0
Ave. brood size at hatching	40.3	4.2	3.33

Table 8. Populations and productivity of Glaucous-winged Gulls at six study sites in 1977.

	Wooded Islands	Barren Islands	Chiniak Bay	Sitkalidak Strait	Semidi Islands	Ugaiushak Island
Population size	400	400	325	940	950	1270
No. nests in sample	27	44	33	50	63	130
Mean clutch size	2.6	2.45	2.64	2.54	2.54	2.18
No. eggs hatched			75	91	143	168
No. chicks fledged	37	59	46	59 1/		
Chicks hatched/eggs laid			0.86	0.72	0.89	0.61
Chicks fledged/chicks hatched			0.61	0.91	0.47 2/	
Chicks fledged/eggs laid	0.51	0.55	0.53	0.69	0.39 2/	
Chicks fledged/known breeding pair	1.37	1.34	1.39	1.79	1.17 2/	

1/ Only at this study area was the fate of chicks actually followed through to fledging.

2/ Data from a subsample of only 6 nests.

Table 9. Observation on the productivity of Mew Gulls on Mary Island, Chiniak Bay, 1977.

No. Nests in sample	66
No. Nests with eggs	60
Mean clutch size	2.63
No. eggs hatched	132
Chicks hatched/eggs laid	0.835
Chicks fledged/nest attempt	0.6-1.0 1/

1/ Based on estimates of the total number of nest attempts by two different methods.

Table 10. Observations on the productivity of Black-legged Kittiwakes in 1977.

	Wooded Islands	Barren Islands	Chiniak Bay, Kodiak Is.	Sitkalidak Str., Kodiak Is.	Semidi Islands	Ugaiushak Island
No. Nests in sample	435	49	210	136	61	57
No. Nests with eggs	312	49	177	114	54	52
Mean clutch size	1.62	1.76	1.91	1.56	1.63	1.89
No eggs hatched		71	287	132	64	71
No. chicks fledged	275	44	25	101	38	44
Chicks hatched/ eggs laid		0.33	0.85	0.70	0.73	0.73
Chicks fledged/ chicks hatched		0.62	0.90	0.77	0.60	0.62
Chicks fledged/ eggs laid	0.54	0.51	0.77	0.54	0.43	0.45
Chicks fledged/ nest started	0.63		1.23 (0.78)1/	0.74	0.62	0.77
Chicks fledged/ known breeding pair	0.88	0.90	1.46	0.89	0.70	0.85

1/ Figure in parentheses incorporates data from one additional colony for which an estimate of chicks fledged per nest started is available (combined sample size 409 nests).

Table 11. Observations on the productivity of Arctic and Aleutian Terns at two study sites in 1977.

	Chiniak Bay		Sitkalidak Strait	
	Arctic Tern	Aleutian Tern	Arctic Tern	Aleutian Tern
Population Size	360	242	1275	1065
No. Nests in sample	96	44	44	37
Mean clutch size	2.21	1.84	2.05	1.6
No. eggs hatched	181	71	74	48
No. chicks fledged				
MIN			15	8
MAX			49	26
Chicks hatched/ eggs laid	0.85	0.88	0.58	0.65
Chicks hatched/ nest	1.89	1.61	1.68	1.30
Chicks fledged/ chicks hatched				
MIN			0.20	0.17
MAX			0.66	0.55
Chicks fledged/ eggs laid				
MIN			0.14	0.11
MAX			0.45	0.37
Chicks fledged/ known breeding pair				
MIN			0.34	0.22
MAX	1.53 1/		1.11	0.70

1/ maximum possible extrapolated from mortality

Table 12. Observations on the productivity of Common (CM) and Thick-billed (TBM) Murres in 1977.

	Barren Is. Disturbed Plot	Ugaiushak Island			
		Disturbed		Undisturbed	
	CM	CM	TBM	CM	TBM
No. eggs in sample	242 1/	56	3	4	6
No. chicks hatched	149	22	1	4	5
No. chicks fledged		10	1	4	5
Chicks hatched/eggs laid	0.62 2/	0.39	0.33	1.0	0.83
Chicks fledged/chicks hatched		0.45	1.0	1.0	1.0
Chicks fledged/eggs laid		0.18	0.33	1.0	0.83
Chicks fledged/breeding pair		0.24 2/	0.33	1.0	0.83

1/ Plot first observed 11 July, approximately 3 weeks after onset of egg-laying.

2/ 15 eggs were believed to be replacements for lost first clutches.

Table 13. Observations on the productivity of Horned Puffins in 1977.

	Barren Islands	Ugaiushak Island	Semidi Islands
Hatching Success			
No. of eggs in sample	14	68	37
No. eggs hatched	13	52	25
No. eggs deserted	1	8	8-10
Chicks hatched/ egg laid	0.93	0.76	0.68
Fledging Success			
No. of chicks in sample	13	11	8
No. Chicks fledged	9	10	4
No. Chicks deserted	1		
Chicks fledged/ chicks hatched	0.69	0.91	0.50
Breeding Success			
chicks fledged/ egg laid	0.64	0.69	—

Table 14. Observations on the productivity of Tufted Puffins at six study sites in 1977.

	Wooded Islands	Barren Islands	Chiniak Bay	Sitkalidak Strait	Ugaiushak Island	Nelson Lagoon
Hatching Success						
No. of eggs	56	56	35	67	99	
No. eggs hatched	26	28	31	41	82	
No. eggs deserted		28	4			
Chicks hatched/ egg laid	0.46	0.50	0.89	0.61	0.83	
Fledging Success						
No. of Chicks	26	28	22	41	21	7
No. chicks fledged	1	22	20	36	20 4/	5
Chicks fledged/ chicks hatched	0.04	0.79	0.91	0.88	0.95	0.71
Breeding Success						
Chicks fledged/ egg laid	0.02	0.39 1/	0.80 2/	0.54	0.79	
Chicks fledged/ visited burrow			0.67 3/			

1/ includes desertion caused by human disturbance.
2/ maximum figure as initial burrow check was made late in incubation.
3/ includes all burrows in sample visited by puffins.
4/ only 6 had fledged - production figure based on healthy chicks.

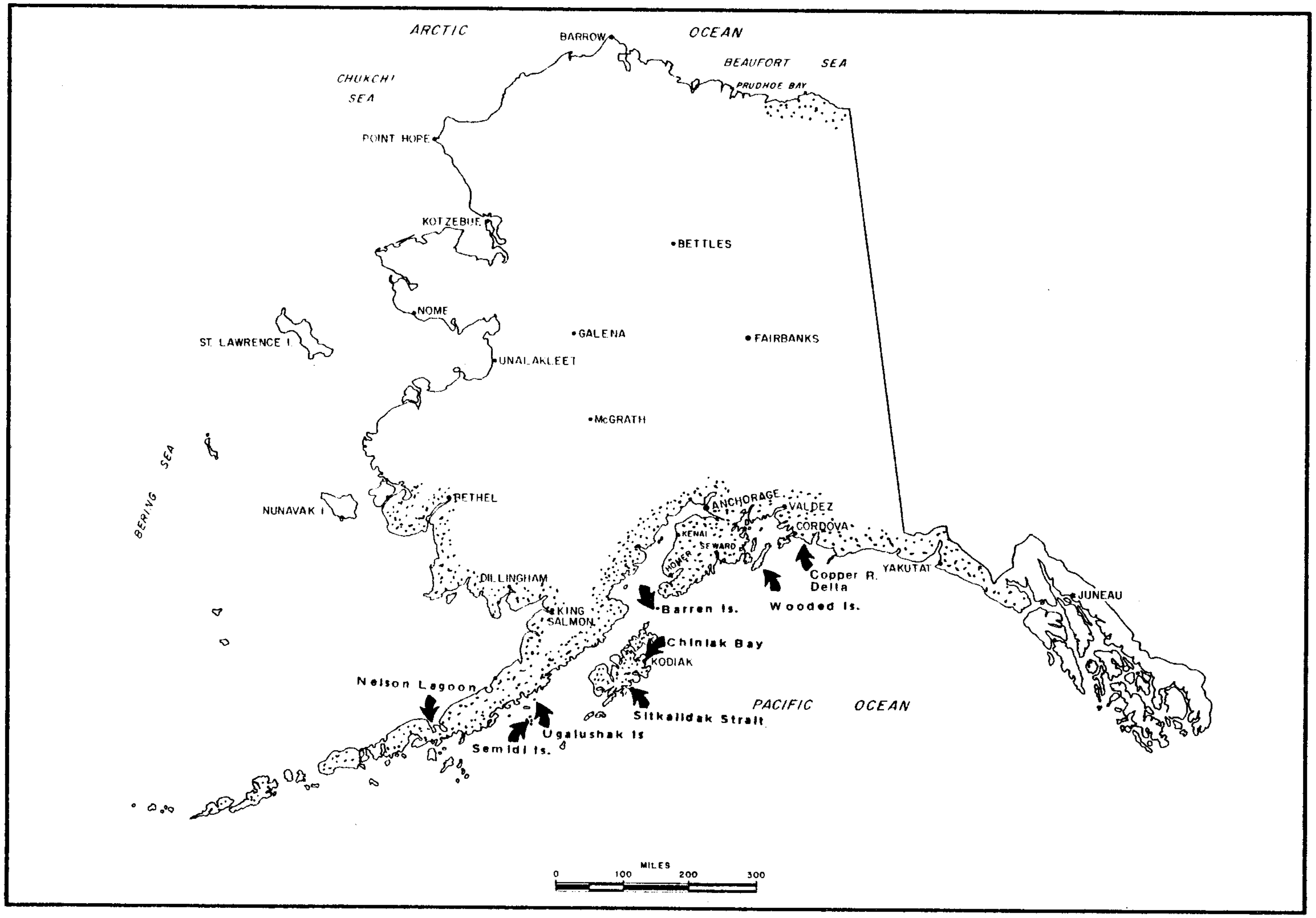

Figure 1. Location of study sites for research conducted under RU 341 in 1977.

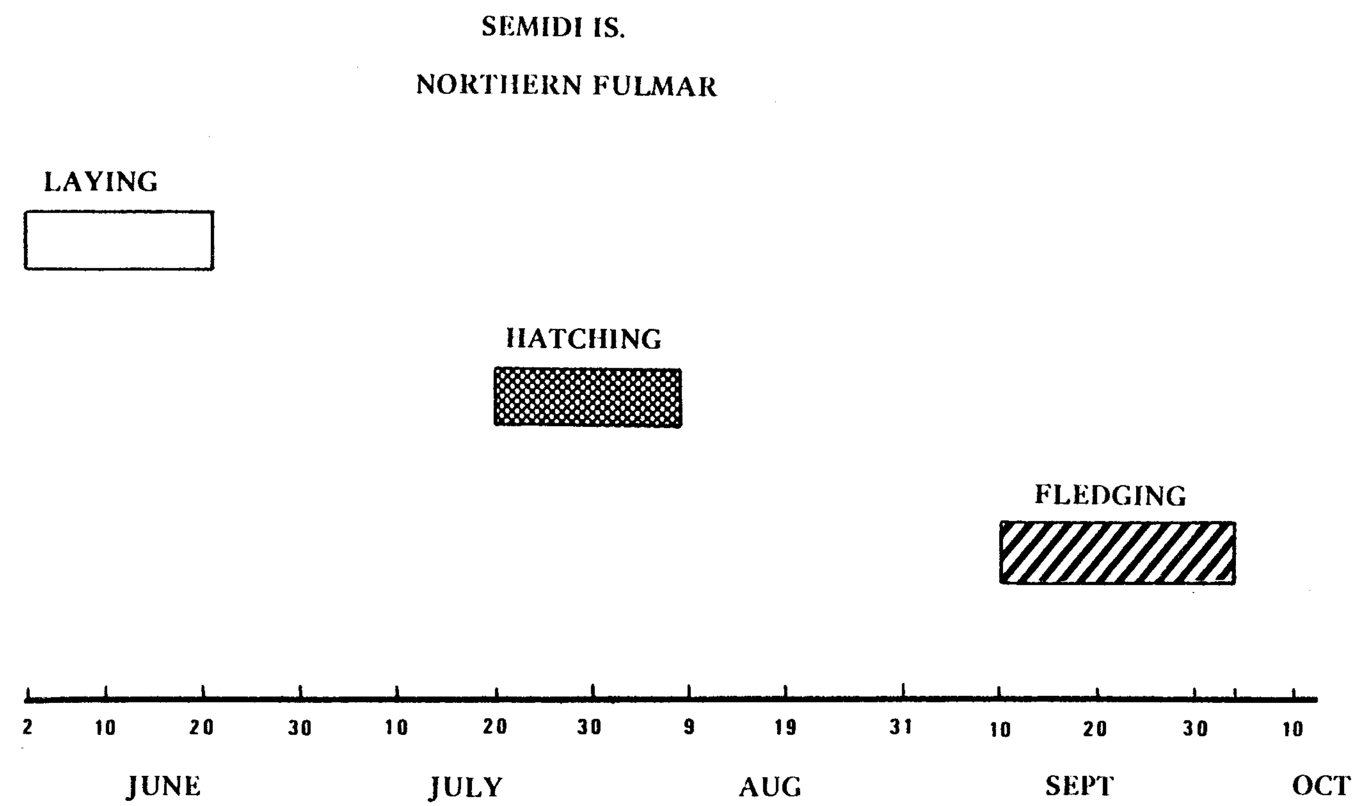

Figure 2. Breeding phenology of Northern Fulmars at Semidi Islands in 1977.

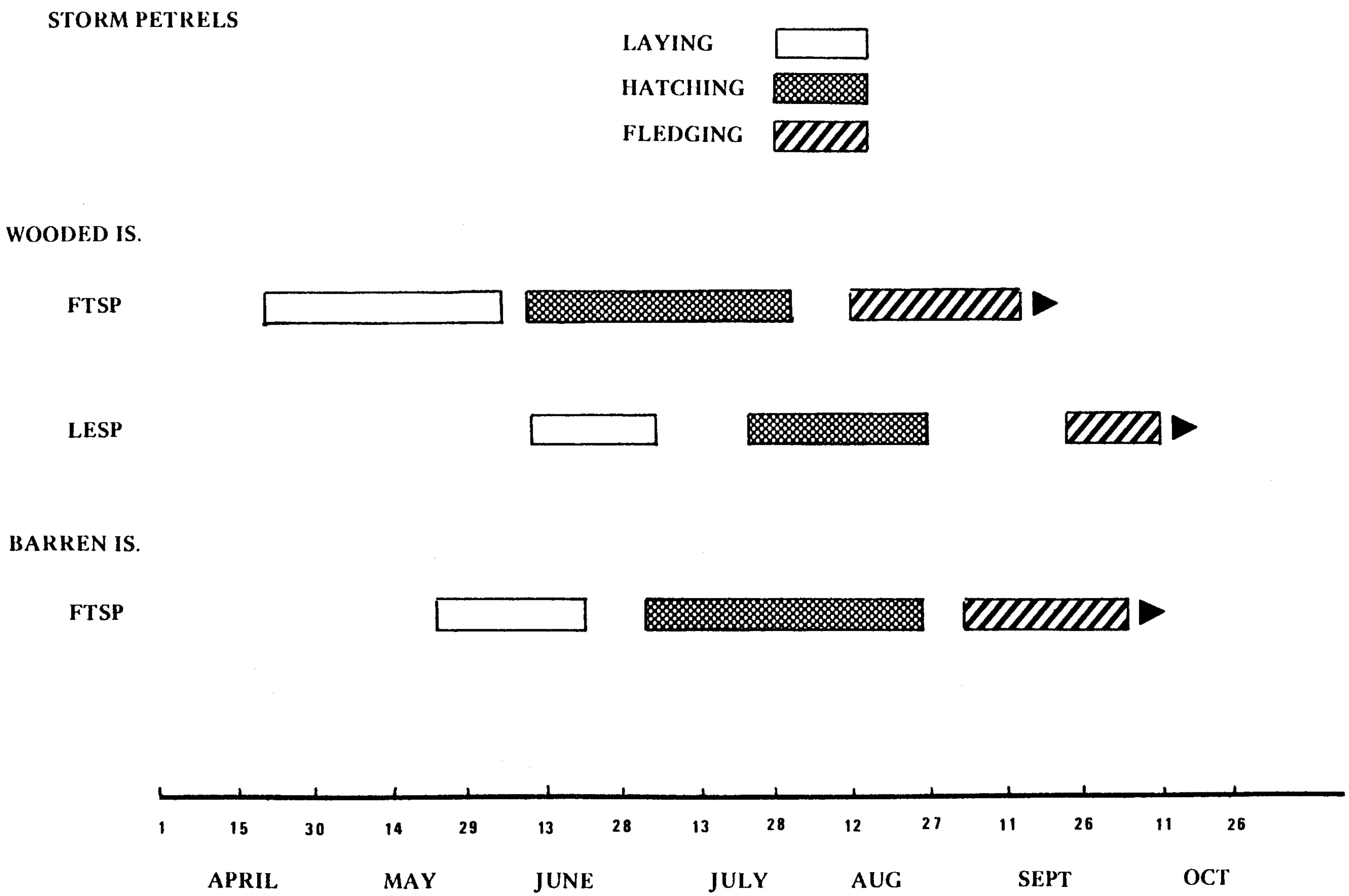

Figure 3. Breeding phenology of Fork-tailed and Leach's Storm Petrels at two study sites in 1977.

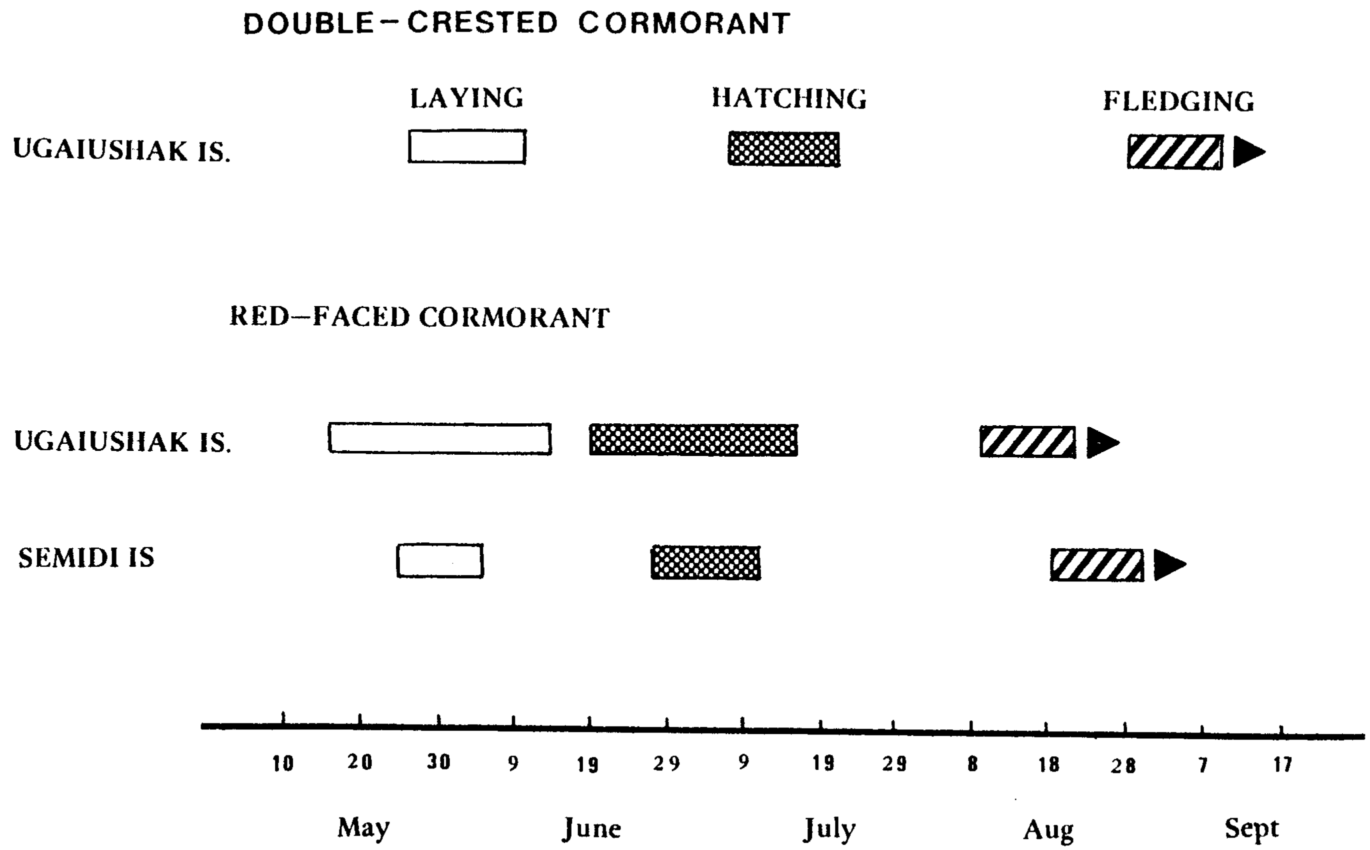

Figure 4. Breeding phenology of Double-crested and Red-faced Cormorants in 1977.

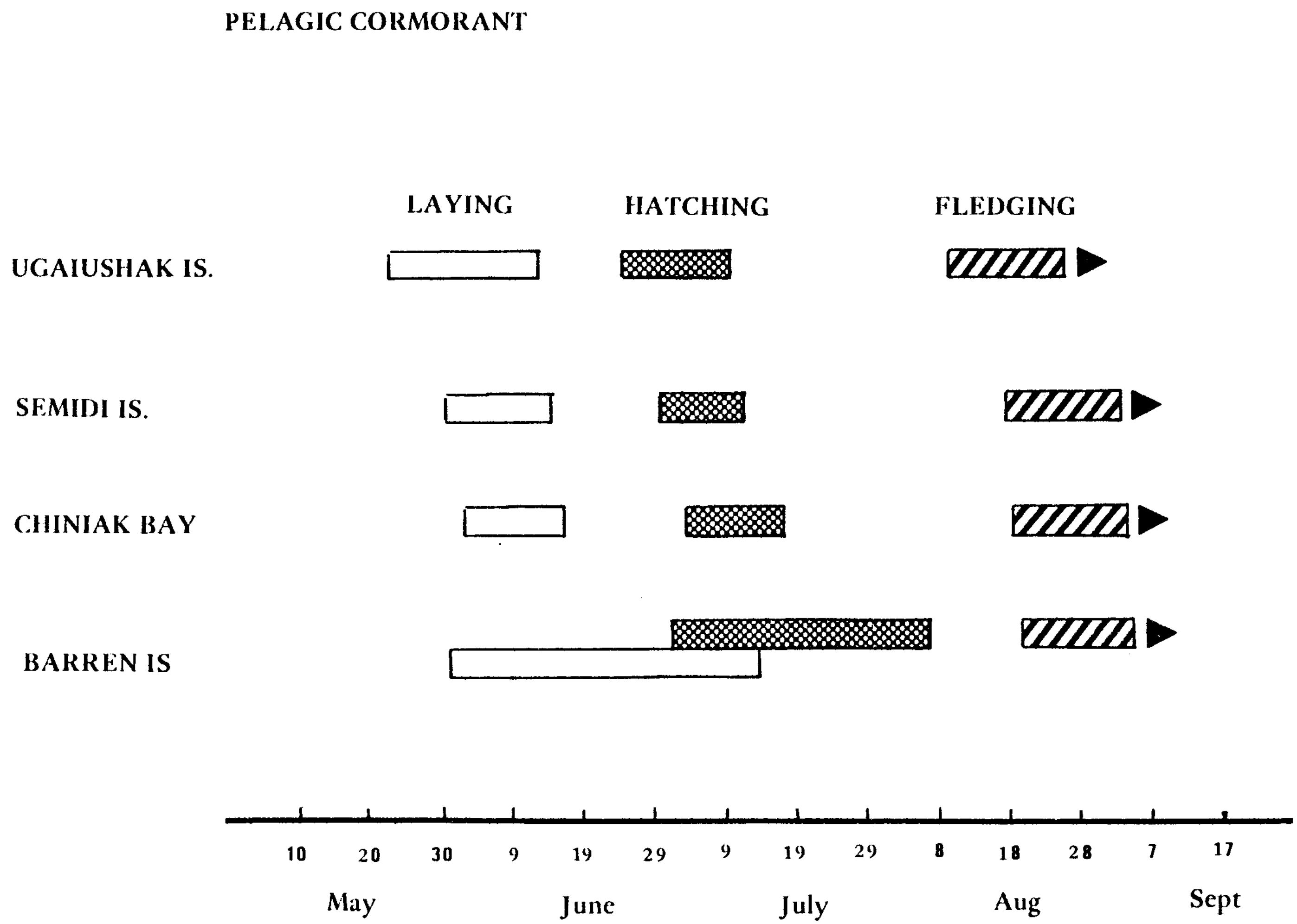

Figure 5. Breeding phenology of Pelagic Cormorants at four study sites in 1977.

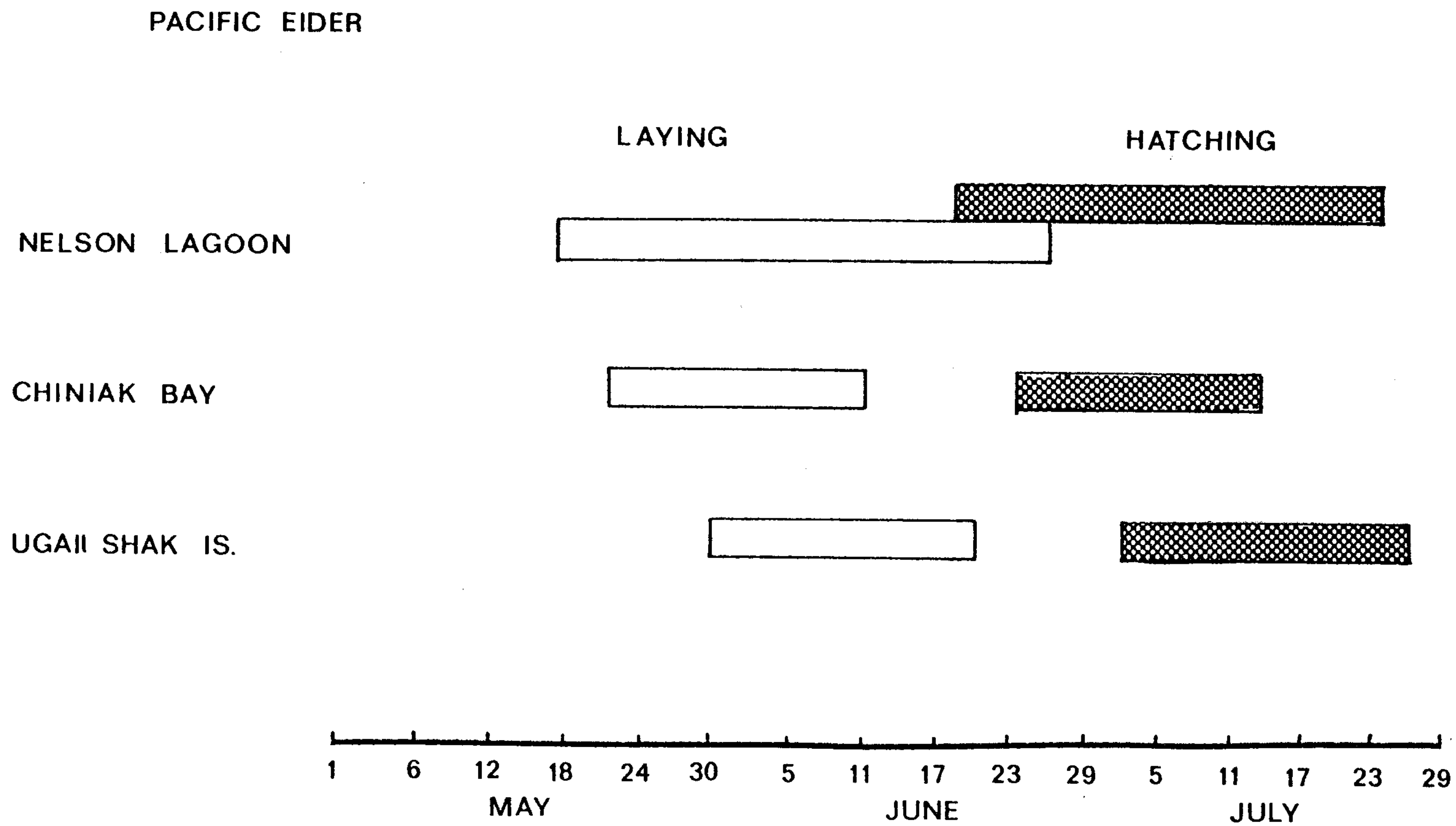

Figure 6. Breeding phenology of Pacific Eiders at three study sites in 1977.

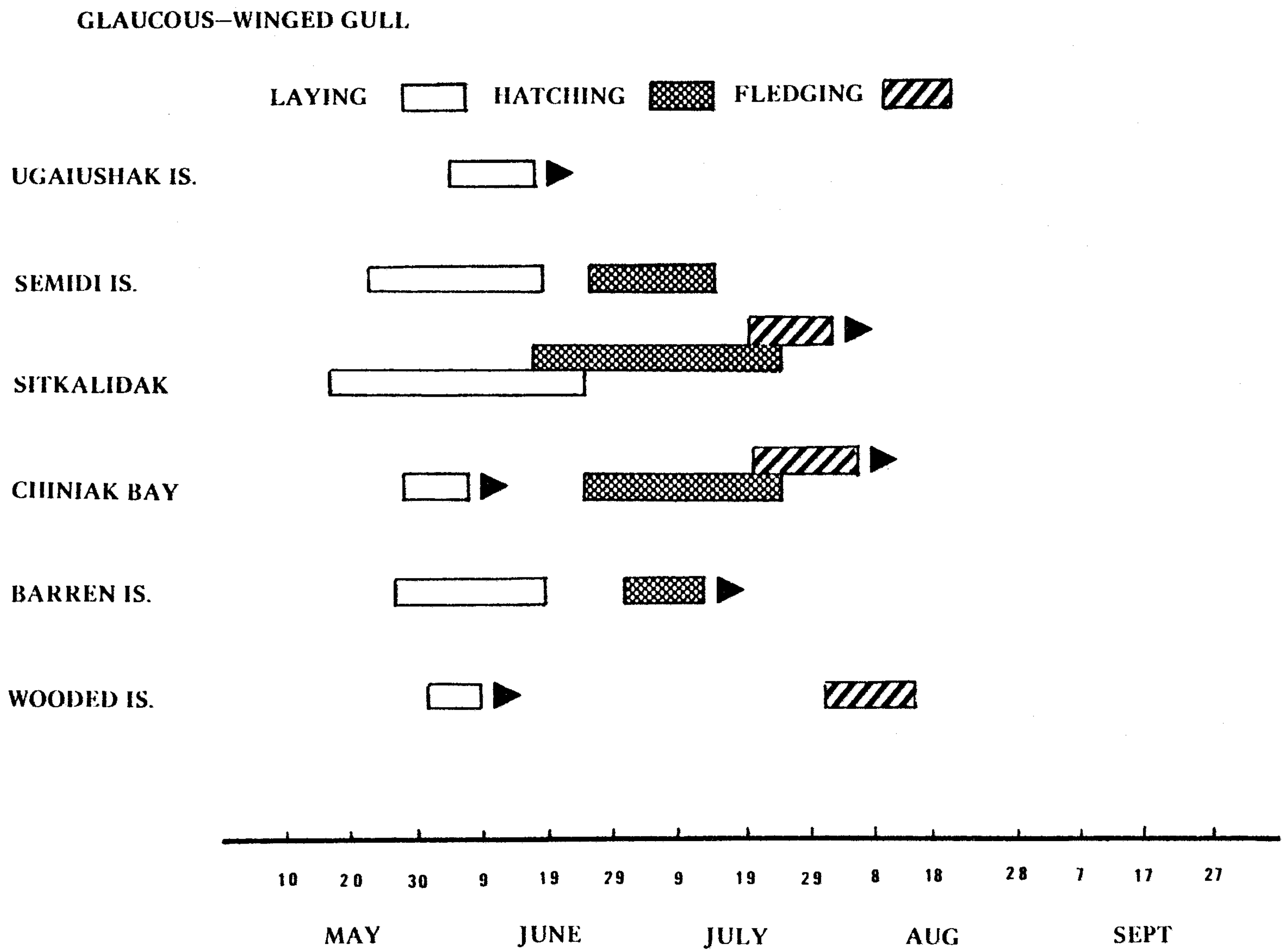

Figure 7. Breeding phenology of Glaucous-winged Gulls at six study sites in 1977.

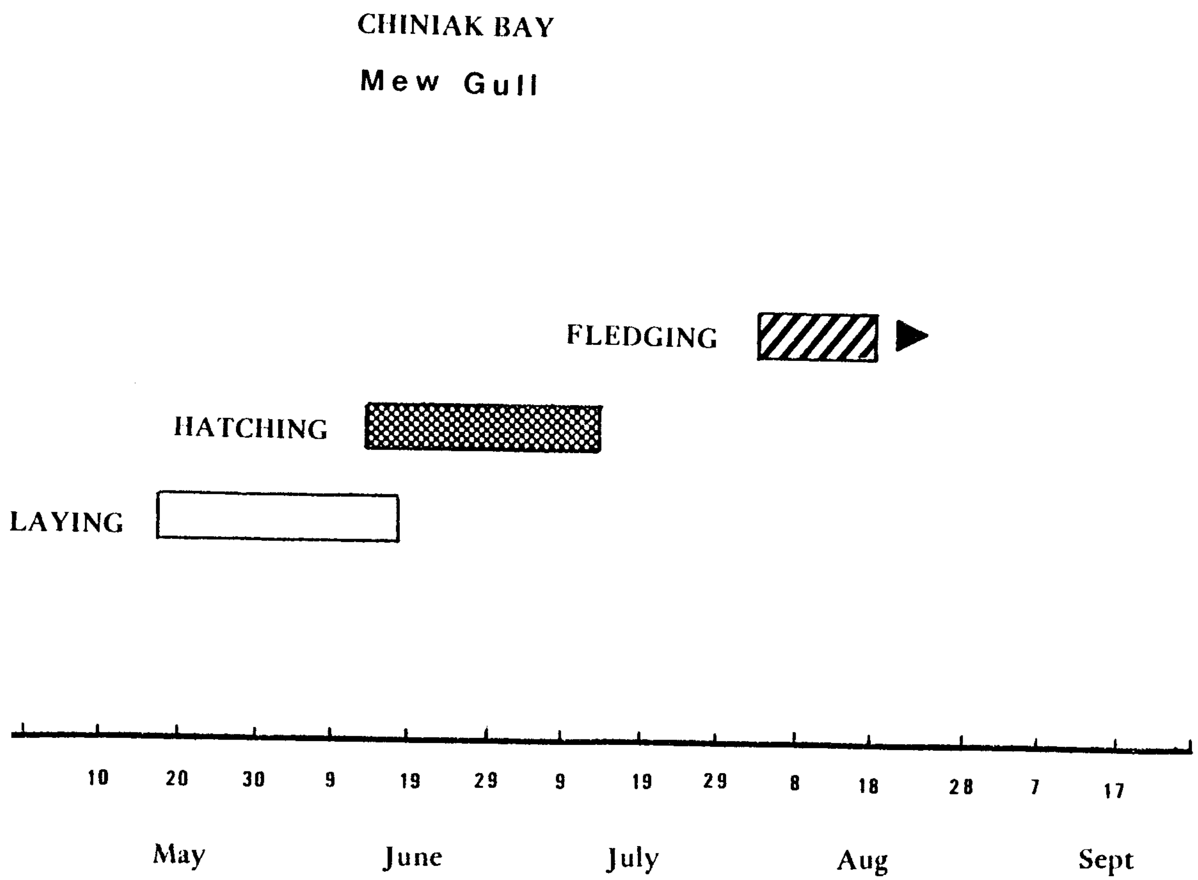

Figure 8. Breeding phenology of Mew gulls at Chiniak Bay, Kodiak Island, 1977.

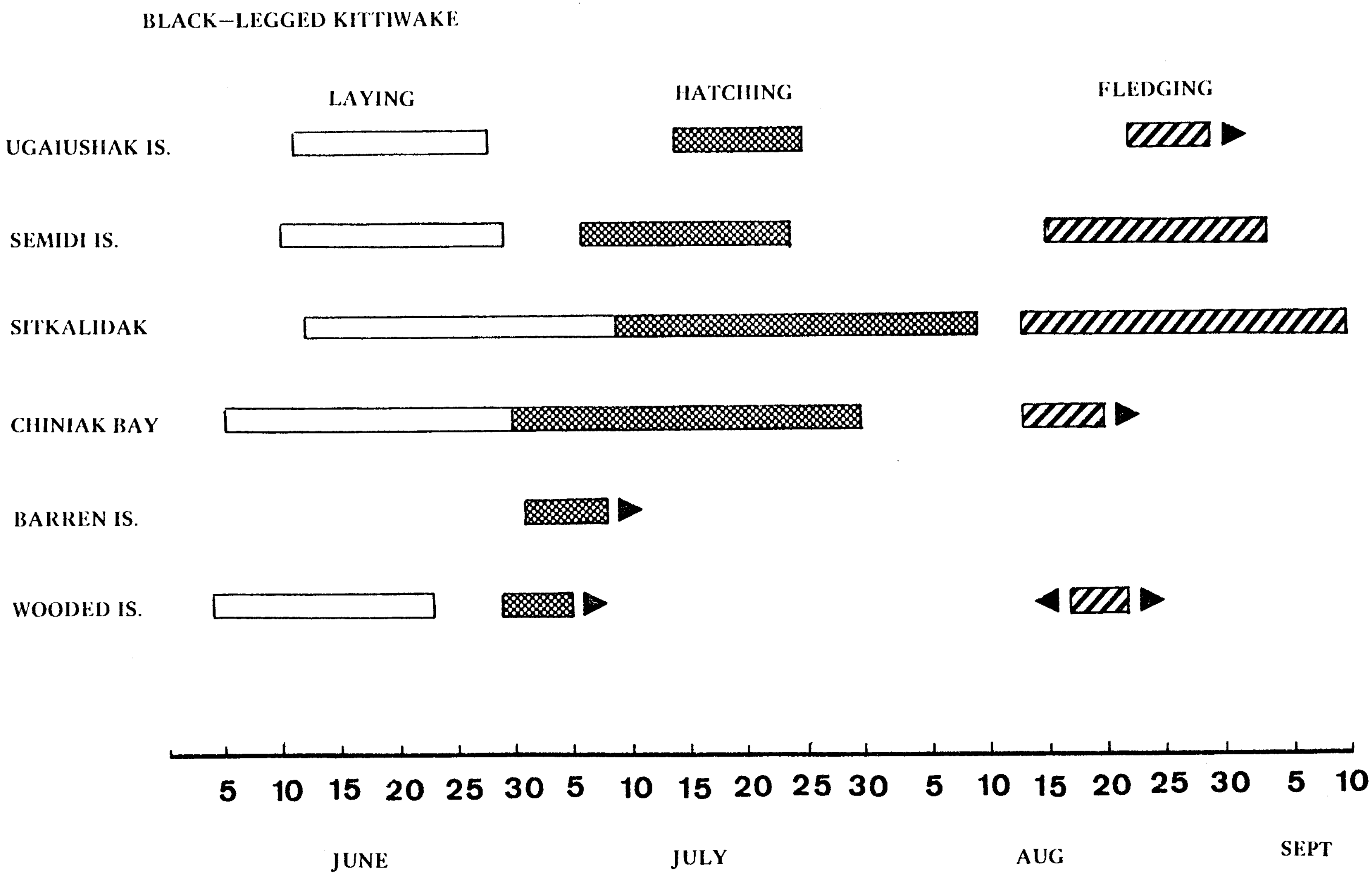

Figure 9. Breeding phenology of Black-legged Kittiwakes at six study sites in 1977.

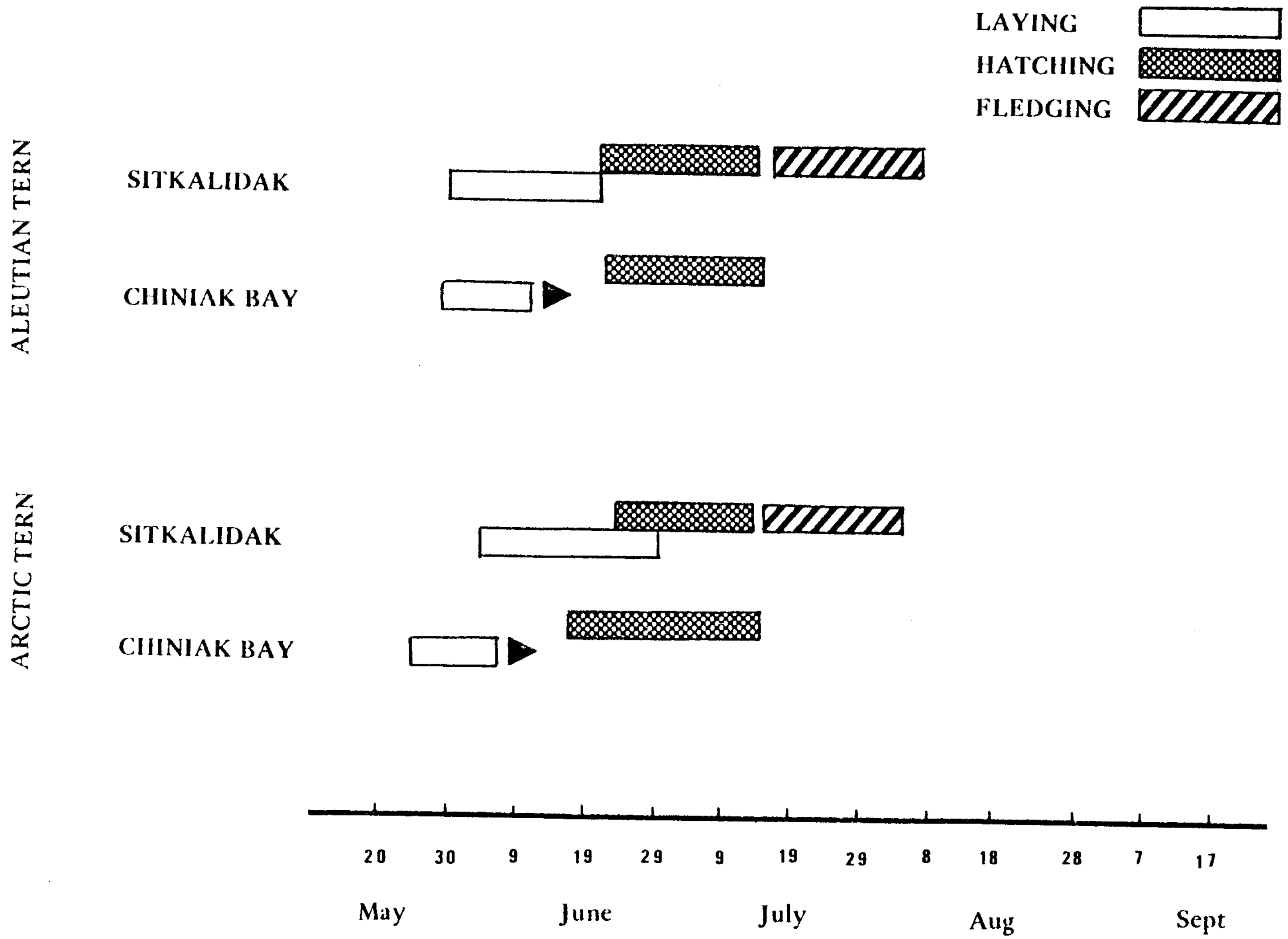

Figure 10. Breeding phenology of Arctic and Aleutian Terns at two study sites in 1977.

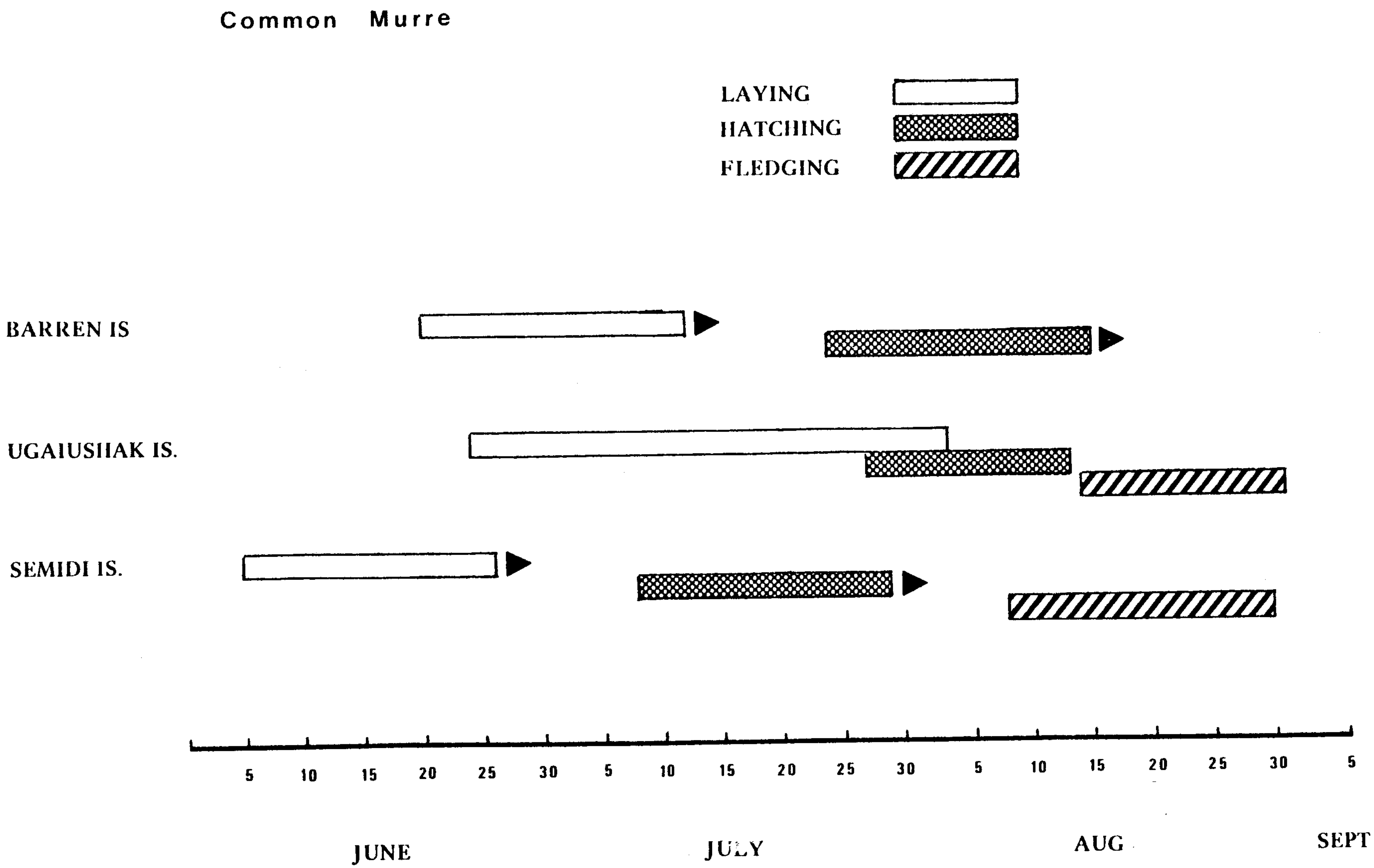

Figure 11. Breeding phenology of Common Murres at three study sites in 1977.

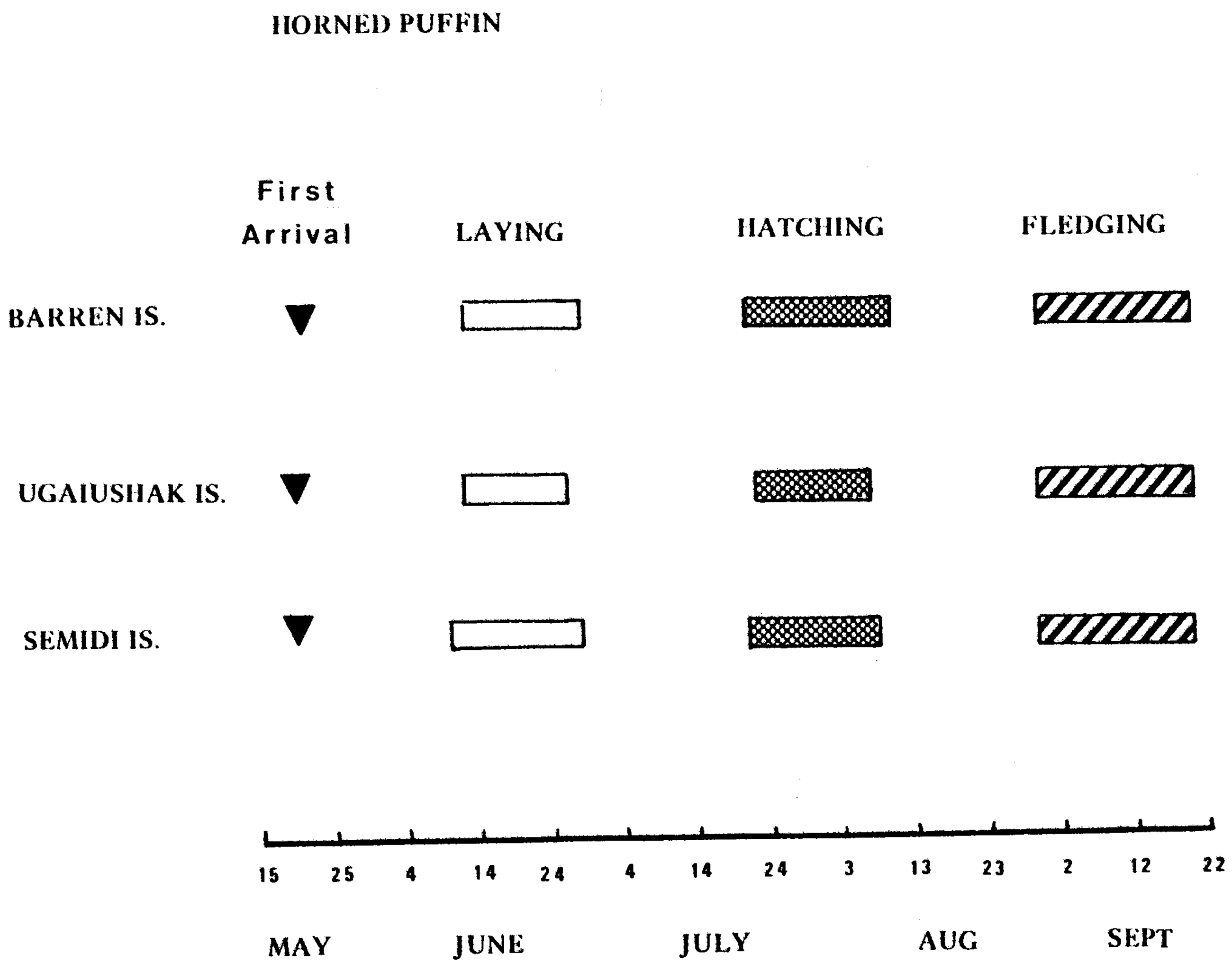

Figure 12. Breeding phenology of Horned Puffins at three study sites in 1977.

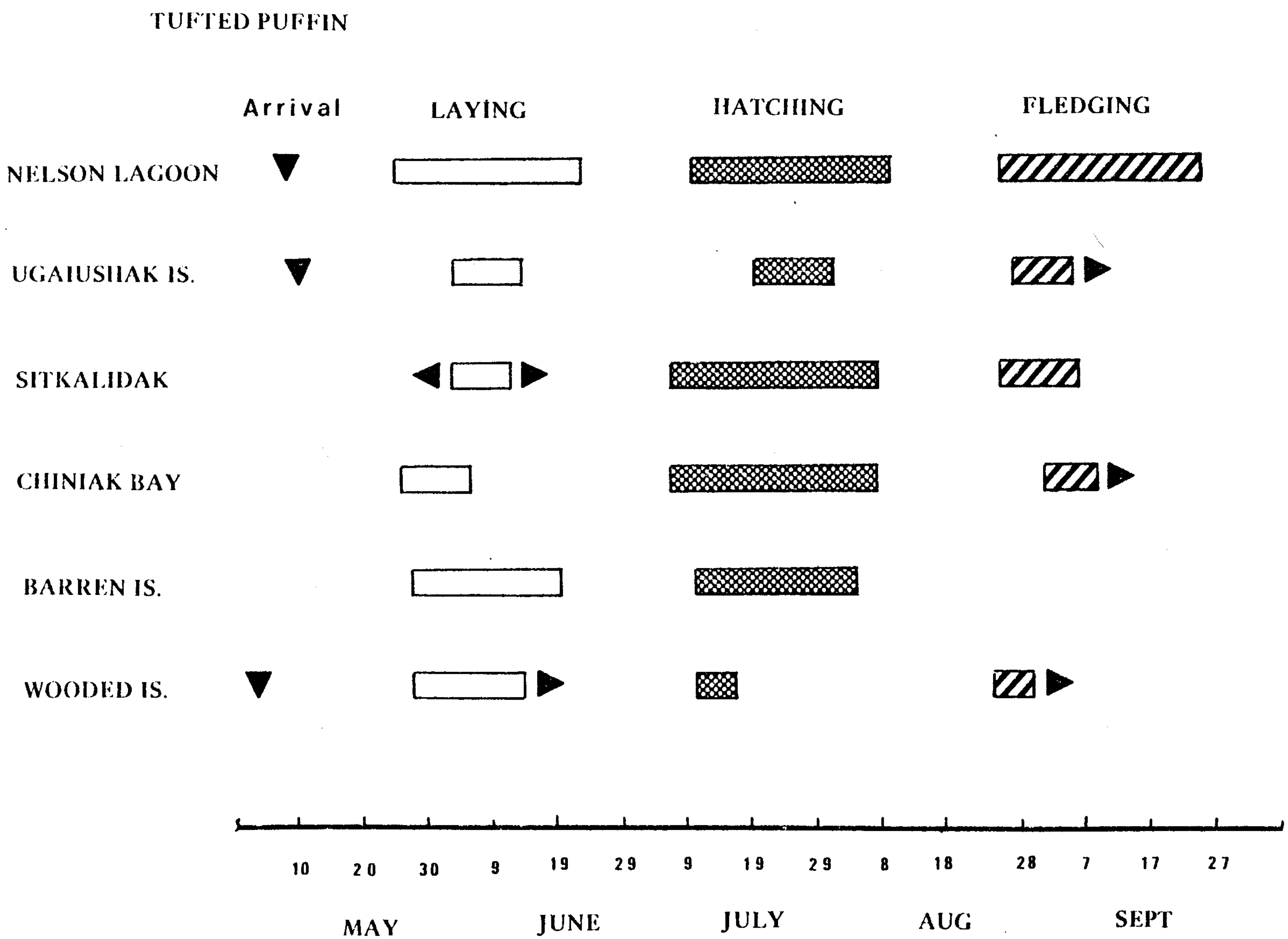

Figure 13. Breeding phenology of Tufted Puffins at six study sites in 1977.

APPENDIX I

NOAA OCSEAP Contract: 01-05-022-2538
Research Unit: 341
Principal Investigators: C. J. Lensink
K. D. Wohl
Reporting Period: April 1, 1977 to
March 31, 1978

ANNUAL REPORT

AVIFAUNAL ASSESSMENT OF NELSON LAGOON, PORT MOLLER, AND HERENDEEN BAY, ALASKA - 1977

By

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April 1, 1978

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I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS AND GAS DEVELOPMENT.

The objectives of this, the second year of a planned two year study were:

1. To conduct general avifaunal assessments of Nelson Lagoon, Port Moller and Herendeen Bay.
   a. To determine the number and distribution of each species relative to other species, to periods of the breeding season, and to characteristics of available habitat within the colony or study area.
   b. To provide estimate of production or nesting success of principal species.
   c. Catalog colony sites and identify important feeding and roosting areas.
   d. Determine migration strategies of major shorebird and waterfowl species.
2. Identify and evaluate the importance of intertidal substrates for breeding and migratory shorebirds and waterfowl.
3. Collect, incidental to the above, observations on marine mammals and identify and map major plant communities within the study area.
4. Identify what activities associated with oil and gas development may impact these wildlife populations.
5. Recommend mitigative measures to offset negative effects of offshore and onshore development.

The Nelson Lagoon complex (consisting of Nelson Lagoon, Herendeen Bay, and Port Moller) is the largest estuarine area along the Bristol Bay shoreline. It supports a diverse avifauna found nowhere else along the Alaska Peninsula. Included are impressive numbers of Steller's and King Eiders, Emperor Geese, Oldsquaw and Black Scoter. Each fall the Lagoon also hosts some twenty species of shorebirds numbering in the 10's of thousands.

While the value of the Alaska Peninsula terrace as a breeding area can not be dismissed, its overwhelming importance is that of a staging area for migratory, post-breeding and wintering birds. These include local birds as well as birds coming from breeding grounds in arctic Alaska and Siberia.

The productivity of many of these lagoons far exceeds that of equivalent areas of the adjacent Bering Sea, and the larger lagoons have tidal exhanges equivalent to the flow volume of major rivers.

The vast meadows of aquatic vegetation and super abundant benthic faunas create an ideal situation for migratory, molting and wintering birds to obtain the energy reserves needed to sustain them through these demanding processes and periods. The physiographic nature of the estuarine areas, coupled with post-breeding changes in social structure, force birds into much greater concentrations than found on the breeding grounds. Because of this, the birds become extremely vulnerable to oil contamination from offshore and onshore spills. Similarly, onshore developments in support of mineral exploitation pose an equal threat and should be strictly regulated. The relatively deep water port capabilities and associated developments of Port Moller have, in our opinion, equal or greater potential impact to waterbird populations than those associated with offshore development and spills.

II. INTRODUCTION

A. General Nature and Scope of the Research

This report is part of a study of the population dynamics and trophic relationships of marine birds in the Gulf of Alaska and southern Bering Sea. Its objectives are 1) to evaluate the status and ecology of marine birds with emphasis on population numbers, productivity and trophic dynamics, and 2) to present information necessary to identify and evaluate potential resource impacts and develop means for preventing or mitigating adverse impacts.

The Alaska Peninsula is probably the most noticeable physiographic feature of the Alaskan land mass. The north shore shelves off gradually into the shallow waters of the Bering Sea, forming a low coastal plain with a comparatively even coastline. The rugged volcanic Aleutian Range runs the length of the Peninsula, and on the south side breaks off into the deeper waters of the Pacific Ocean. Consequently, the avifauna of the Peninsula is quite diverse and in part characteristic of the land conformations. On the south side are tremendous numbers of breeding seabirds. The area is also favored by numerous wintering seaducks as it stays ice free year round. Since expansive intertidal substrates are limited on the south side, the area receives little use by shorebirds. In contrast, the north side of the Peninsula has few colonial nesting species, excepting gulls and terns, but because of its extensive intertidal substrates the area is heavily used by vast numbers of shorebirds and waterfowl; especially during fall migration.

Despite this seemingly sharp contrast in bird use, the near and onshore habitats of both sides of the Peninsula are used by populations of certain species during both migration and winter. The west end of the Peninsula at Unimak Pass is a major thoroughfare for spring and fall bird migrations between the Gulf of Alaska and Bering Sea. Virtually the entire breeding populations of several species pass along the Peninsula and through Unimak Pass twice each year. During fall, most of these populations stop along the various estuaries of the north Peninsula to molt and build fat reserves used in their often extensive transoceanic migrations to wintering quarters in temperate and tropical latitudes. Other populations, depending on ice conditions, remain along the north Peninsula through winter and forage extensively in these estuarine systems.

Our research examines the importance of one of these estuaries and relates this system to other segments of annual avian cycles.

B. Specific Objectives

In light of the objectives listed in the summary, this study is divided into three parts: (1) We examined the temporal and spatial distribution of waterfowl and shorebirds in the Nelson Lagoon system. We identified important feeding and roosting areas used during migration and winter. (2) We also identified principal food resources supporting these populations. What items were required during migration and molt and were these items changing in the birds' diets as well as in the benthic communities? (3) We looked at migration strategies of several shorebird and waterfowl species. How long do individual birds remain in the estuary and where do they go and via what routes? Are birds using Nelson Lagoon also being exposed to potential adverse impacts from mineral development by stopping in other OCS areas, both in and out of Alaska?

C. Relevance of Problems of Petroleum Development

While multi-year studies are desired to fully understand the dynamics of a system such as Nelson Lagoon, we realize that time and monetary restraints allow us to investigate only the more relevant aspects. These in turn will hopefully allow for predictions about impacts which development of mineral resources may bring.

III. CURRENT STATE OF KNOWLEDGE

The literature is now becoming replete with accounts of the effects of oil pollution on seabirds. Bourne (1968) and Vermeer and Vermeer (1974) have summarized much of this literature; Hunt (1977) has related oil to several species of seabirds common to the Bering Sea. These reviews emphazize the high susceptibility of alcids and diving ducks to spilled oil; much more so in winter when large concentrations of these birds occur.

Except for Smith and Bleatney's (1969) discussion of an oil pollution incident in Nova Scotia involving Purple Sandpipers, the effects of oil spills on littoral zone communities and their subsequent effects on shorebirds, both direct and indirect, are poorly known. It appears that shorebirds are capable of avoiding direct contact with spilled oil but build up a thin coating of oil from wading in tide pools. We suspect that oil particle injestion by foraging shorebirds and contamination of benthic food organisms may have a greater impact on shorebird populations than has been observed to date. Much more work needs to be directed at this aspect of shorebird ecology.

Until recently, the specific bird resources which might be impacted by mineral development in the Bristol Bay and southeast Bering Sea areas were largely unknown. Previous avifaunal studies of these areas have often been cursory and confined to brief periods in late spring and early fall; none covering more than a few consecutive months.

The Alexander Stone Expedition of 1903 (Chapman 1904) represents the first effort to catalog the birds of the Port Moller-Herendeen Bay area. This was followed by the Stoll-McCracken Expedition of 1929 (Jaques 1930) which also centered its studies around the Port Moller area. Combined, the two expeditions reported on only 30 species from the Port Moller-Herendeen Bay area. Murie (1959), in his faunal survey of the Alaska Peninsula and Aleutian Islands in 1937-1938, added little new information about the bird life of this segment of the Peninsula.

McKinney (1959) was apparently the first to investigate the Nelson Lagoon area; however, his efforts were directed at only three or four species and for only a two week period in May 1958. In the mid 1950's, the U.S. Fish & Wildlife Service (FWS) began conducting spring waterfowl surveys on the Peninsula. While these have never been flown south of Ugashik they provide data from which inferences can be made about the waterfowl of the central peninsula for the same period. From 1964 there exists a spring waterfowl survey, also conducted by the FWS, with considerable information about the Port Moller-Nelson Lagoon area. It was not until the early 1970's, however, that significant data on late summer and early fall bird use of the area became available. Several aerial and ground surveys conducted by the Alaska Department of Fish and Game (Arneson 1976) and the FWS provide good quantitative data on waterfowl and other waterbird use of the area; particularly Nelson Lagoon. These references are cited as: G. V. Byrd, E. P. Bailey, and R. D. Jones, Jr., pers. comm. or unpublished data.

Pelagic and inshore avifauna off Port Moller and Nelson Lagoon have only recently been looked at (King and McKnight 1969; Bartonek and Gibson 1972). While these investigations are major contributions and increase our understanding of occurrence and abundance of birds in the Bristol Bay region, there still remain gaps in our knowledge of bird use in this area; especially in winter.

IV. STUDY AREA

The study area is located centrally along the north side of the Alaska Peninusla (Fig. 1). The combined area of 540 km2, comprised of Nelson Lagoon (100 km2), and Herendeen Bay (200 km2) represents the largest estuarine area along the northern Alaska Peninsula.

The north central portion of the Alaska Peninsula is typified by a broad lowland extending inland 10-20 km to the base of the Aleutian Range. Several river systems originating in the Aleutian Range drain out over the lowlands to Bristol Bay. The Peninsula coastline is relatively regular and comprised of numerous sand beaches, low terraces and alluvial fan deposits.

The extensive intertidal mud and sand flats are the most noticeable feature of the western Bristol Bay coastline and particularly so within the study area. Over 230 km2 of intertidal flats are exposed at MLLW (mean lower-low water) in the Port Moller-Nelson Lagoon area. Open water covers an additional 265 km2 of the study area at MLLW. Coastal sand dunes (8.2 km2), barrier islands (4.8 km2), upland heath (16 km2), and salt meadows (10 km2) comprise the remaining major habitat types within the study area.

The major freshwater source to the estuary comes from the combined discharge of the Caribou and Sapsuck Rivers and enters Nelson Lagoon at its western end. Several additional smaller drainages feed the shoreline and headlands of Herendeen and Moller Bays.

The tidal regime of the study area is typical of that along the west coast of North America with two high and two low tides occuring in a 24 hour period. The mean diurnal tide range at Port Moller is approximately 3.2m.

Weather during 1977 was quite variable. Mean monthly maximum and minimum temperatures were recorded as: May 7^{o}, $-2^{o}C$; June 11^{o}, $6^{o}C$; July 13^{o}, $9^{o}C$; August 13^{o}, $9^{o}C$; September 10^{o}, $4^{o}C$. The water temperature on 26 May at mid-channel, opposite our cabin, was $3^{o}C$. Between 15 June and 15 October water temperature ranged between 9^{o} $10^{o}C$. By 15 October water temperature had dropped to $4^{o}C$. The estuarine waters are usually ice free between mid-April and October. Prevailing winds between May and September are from the NW and SE. Precipitation at Nelson Lagoon averages 25 inches per year. Prevailing NW and NE winds during winter keep snow cover to a minimum along the immediate coastal portions of the estuary.

V. SOURCES, METHODS AND RATIONAL FOR COLLECTING DATA

During 1977 the study was conducted from 18 April through 15 October. Seven investigators participated in the study for a total of 389 person-days.

Methods

1. Aerial Censuses. Censuses of feeding and roosting shorebirds and waterfowl were made from a Piper Super Cub and Cessna 185. Censuses were flown at an elevation of between 50 and 75 m and at an airspeed of 75 knots. The pilot plus one observer conducted most censuses. Only the observer counted shorebirds but often relied on the pilot to locate concentrations of birds. Censuses

were flown between 1.5 hours before or after low, slack tide. Census duration averaged 45 minutes. Numbers were recorded on magnetic tape and later transcribed to census forms (030 Format). Censuses were conducted by first flying the edge of the substrate/water interface since shorebirds, especially, were found concentrated along this area during early stages of each low tide. We then returned to survey other portions of each census area as we saw bird concentrations. The airplane invariably disrupted concentrations of foraging shorebirds; however, we found most concentrations re-settled within several hundred meters of their initial area. We feel duplicate counts from any one area or between areas were, therefore, at a minimum. During most of the study, birds were recorded in groups of 100's except during peak migration in September and early October when we often counted in groups of 1000's.

Shorebirds were usually identified to species except during late June through August when populations of Western Sandpipers (Calidris mauri), Dunlins (C. alpina pacifica) and Least Sandpipers (C. minutilla) occurred together over much of the study area. For purposes of this study these species were recorded as "small sandpipers" during aerial censuses. Populations of each were subsequently determined from periodic comparisons of population ratios of all three species. These were derived from ground censuses conducted usually within 72 hours of an aerial census. Only ground and aerial censuses conducted over the same area or similar substrate types were used for such comparisons. We found numbers of C. minutilla, however, to be too small and the species' occurrence too irregular to accurately evaluate use patterns for each census area.

Numbers of Short-billed (Limnidromus griseus) and Long-billed Dowitchers (L. scolapacius) were similarily derived but presented less of a problem since the two species exhibited different habitat preferences and only briefly overlapped in occurrence during the study.

2. Ground Censuses. Several fixed ground census stations were established. These were censused on the average of twice a week during migration and once a week otherwise. Counts were made with aid of 8X binoculars and a 15X wide angle spotting scope. All birds were identified to species. Numbers, activity and habitat utilization were also recorded. A second type of fixed ground census was conducted twice weekly at two hour intervals. Similar data were recorded and correlated with daily tidal cycles (038 Format).

3. Reproductive Success.

A. Common Eiders (Somateria mollissima v-nigra)

Nesting islands were searched weekly beginning in May. Nests were individually marked and re-visited weekly. Female adult eiders were individually marked to follow brood dispersal.

B. Arctic (Sterna paradisaea) and Aleutian Terns (S. aleutica)

Line transects were established within colonies and checked approximately every three weeks for Arctic Terns and monthly for Aleutian Terns. Counts of adults over each colony were obtained during each visit.

C. Glaucous-winged Gulls (Larus glaucescens)

Counts of adults in attendance at colonies were obtained from aerial and ground censuses. Several 625 m2 plots were established within colonies to monitor productivity. Rank growth of Elymus prevented us from following these to fledging.

4. Migration Studies.

Shorebirds were captured using a rocket net at high tide roosts. Birds were sexed, weighed, checked for molt, banded, and color marked. Turnover times of birds within the Lagoon were derived by noting numbers and color codes of previously marked birds. Such information is essential in deriving figures of overall bird use of a particular area or estuarine system.

5. Trophic Studies.

Two fixed 50m long intertidal transects were established and sampled every three weeks beginning in early June prior to the arrival of large numbers of migrant shorebirds and waterfowl. A total of 5, 1 liter samples was taken randomly at 5 meter intervals along each transect. Samples were rough sorted in the field and preserved in 10% buffered formalin. In conjunction, 3 each Dunlin, Rock and Western Sandpipers were collected every 2 weeks while foraging on or near the transects. Stomachs were immediately injected with 10% buffered formalin and removed. From our analysis we hope to determine 1) benthic population levels prior to and during migratory bird use, and 2) prey items used by migratory birds during molt and premigratory fat build up.

6. Weather

Weather data, including temperature, wind direction and speed, cloud cover, visibility and precipitation were recorded 5 times daily.

VI. RESULTS

A. Numbers and Activities

1. Waterfowl. Twenty-five species of waterfowl have been recorded for the study area. The combined temporal abundance of these species between May 1976 and October 1977 is presented in figure 2. Peak numbers occurred during fall migration both years but substantial numbers, mostly King

and Common Eiders, Oldsquaw, and Emperor Geese, wintered in the Lagoon system in 1976-1977. However, the Lagoon remained ice free that winter and the numbers of waterfowl recorded may be abnormally high. Individual occurrence and abundance data for the six major waterfowl species are presented in figures 4 and 5.

2. Shorebirds. Twenty-three shorebird species are known for Nelson Lagoon. The occurrence and abundance of all shorebirds is shown in figure 3, while figures 6-8 depict individual data for the nine major species using the Lagoon system. In both figures the comparatively larger number of birds recorded in 1977 is due to our including an additional census area not used in 1976. For a detailed analysis of Dunlin and Western Sandpiper use of the Lagoon see the appended paper presented at the 1978 Pacific Seabird meeting.

B. Feeding and roosting areas

1. Waterfowl. Figures 9 and 10 depict critical foraging, molting and roosting areas of Emperor Geese, Steller's and Common Eider, Oldsquaw and Black Scoter. The areas depicted represent overall use of the Lagoon by a species during its stay in the Lagoon. Shifts in foraging and roosting site preferences occur depending on time of year and weather conditions.

2. Shorebirds. A detailed description of feeding and roosting areas is appended to last years annual report(Gill et al. 1977). Little change in these patterns was detected during 1977 excepting a noted increase in the use of Mud Bay by Dunlin in September and October and by Whimbrel (*Numenius phaeopus*) in August. Figure 11 depicts major shorebird feeding and roosting areas.

C. Reproductive Success

1. Common Eider. Common Eiders were present on our arrival on 18 April. Although some courtship activity was observed in April, most birds were paired prior to our arrival. Pairs began selecting nest sites on 18 May, three weeks after the snow and ice was gone from the nesting islands.

Nests were found on 7 fox free barrier islands. Most nests (99% of 97) were surrounded by beach rye (*Elymus mollis*), the predominant vegetation on the islands. Three nests (3% of 97) were placed in stands of *Angellica lucida*.

Nests were placed an average 15 m from the beach/vegetation interface (range 0.5 to 50 m, N=97). Most islands that were used by eiders for nesting were 50 m or less wide, with the widest island 100 m wide. Thus, all nests were with in 50 m of the water.

The first Common Eider egg was laid on 18 May, and birds appeared to be well into egg laying by 30 May. Most nests were found after egg laying was completed, thus dates for clutch initiation of most nests were determined by back-dating from hatching dates. Many nests (42.7% of 75) were initiated by 29 May, 68.0% of the nests were begun by 10 June, and all nests were begun by 27 June.

The minimum clutch size at hatching ranged from 1 to 10 eggs, and averaged 4.76 eggs per clutch in 1977; an increase from the 41.7 eggs per nest over that observed in 1976 (Fig. 12). Seventy-five of 97 nests in 1977 had 1 or more eggs hatch, and averaged 4.03 eggs hatching per nest (Fig.13).

Hatching dates were bi-modally distributed, with peaks of hatching occurring on 25-29 June and on 15-19 July (Fig. 14). Nests that had eggs that hatched early had significantly more eggs per nest ($F=7.975$, $df = 1.72$, $p = 0.006$). Nests that had eggs that hatched early averaged 5.11 eggs per nest and 4.83 ducklings per nest, whereas nests that had eggs that hatched late averaged only 4.33 eggs per nest and 3.90 ducklings per nest.

2. Glaucous-winged Gulls. Gulls established territories on barrier islands prior to our arrival on 18 April, and maintained territories throughout the pre-laying period. A total of 782 nests was found among the 30,25x25 m plots. Egg laying began 23 May, and peaked on 10 June. Modal egg laying occurred 30 May to 22 June. Eggs began hatching 2 July, with most hatching 2-24 July. Only 31 nests (3.9% of 782) had one or more eggs hatch. Fledging dates of young were not determined.

D. Trophic Relationships.

Waterfowl. See appended report on Steller's and Common Eider feeding ecology.

Shorebirds. Data are presently being analyzed.

VII & VIII. DISCUSSION AND CONCLUSIONS

Our two years at Nelson Lagoon have only begun to identify, let alone bring together, the myriad of processes and principles inter-acting to make the Lagoon the important waterbird area that it is. Our first year's effort was directed at identifying the species using the Lagoon and developing occurrence and abundance patterns. From these we found noticeably different uses of littoral substrates by different groups of birds. We began a detailed study of this during fall of 1976, and continued it through October 1977. We went a step further in

1977 and began looking at the distribution of benthic food resources as a possible indicator of bird distribution. This was done in conjunction with an extensive study of bird turnover rates during summer and fall cycles, e.g. post-breeding dispersal, molt and pre-migratory staging.

While much of our data has yet to be analyzed, particularly shorebird feeding information, we can now make general, but we believe fundamental, assumptions regarding the Lagoon system and waterbird use and dependency upon this system. Chief among these is that the Nelson Lagoon complex is a unique estuarine system among the many found along the Bristol Bay and Bering Sea coastlines. This is due in part to its size, tidal regime, configuration, relationship with the deeper Herendeen and Moller Bays, and its location with respect to normal ice advance in Bristol Bay.

Nelson Lagoon and other estuaries, therefore, support somewhat different faunal groups and numbers; and while we might eventually understand the dynamics of one such system, we can not blanketly apply this knowledge to other estuarine systems in Bristol Bay or Alaska. What little comparative data we have among Port Heiden, Nelson Lagoon and Izembek Lagoon indicates the three systems support quite different avifaunas at virtually any given time of year. And while some of these populations may utilize all three systems, they apparently do so at different times. Accounting for this may be different food sources utilized in each system during different events in the avian cycle, e.g. molt versus migration. Not to be discounted, however, is the possibility that while a single species can use all three systems, each system might support a distinct sub-population of that species. These lagoon specific populations could come from different breeding grounds and probably utilize different wintering grounds or portions thereof. Our data from Dunlin and Western Sandpiper support this.

IX. NEEDS FOR FURTHER STUDY

Further study needs are both short and long term. Needed long term (5 + years) studies include continued monitoring of use patterns of Nelson Lagoon by major waterfowl and shorebird species. Trends in numbers and temporal and spatial distribution and abundance in the system must be known before impacts from potential oil and gas development can be assessed. Of more importance, however, is the initiation of similar long term studies of adjacent Port Heiden and Izembek Lagoons to determine species dependency and interchange between and among other estuarine systems. Despite the Bering Sea/Bristol Bay lease schedule being put off indefinitly, if any continuity of data collection is to be maintained there should be continued study of these areas, even at a much reduced level. Such studies would initially entail extensive population census work coupled with large scale capture and marking programs. The latter would, as we discovered this year, provide additional information on species dependency on habitats within other OCS lease areas, both in and outside of Alaska.

A second long term study is urgently needed to better determine the relationship between benthic faunal communities and the avian communities they support. Even if birds escape the direct effects of an oil spill, their food resources could be impacted from oil contamination and supressed below a level sufficient to sustain them.

Of a short term nature (1-2 years) are studies of the importance of the Alaska Peninsula to breeding stocks of waterfowl and shorebirds. While we now have ideas of the numbers of birds using Bristol Bay littoral habitats, it remains unclear as to their natal orgins. In order to adequately assess the vulnerability of a species population to OCS activities we need to know all aspects of its annual cycle; especially for those species which winter in Alaskan OCS waters. It is also critical to know what percentage of a species population is dependent on an estuarine system such as Nelson Lagoon. For instance, we now feel that most of the Alaska breeding population of Bar-tailed Godwits is staging on Nelson Lagoon and possibly other nearby estuaries prior to its trans-pacific fall migration. Similarly, the majority of the Alaska Emperor Goose population uses Nelson Lagoon for periods each spring and fall.

X. SUMMARY OF JANUARY - MARCH QUARTER

The quarter was spent analyizing and writing up data accumulated during the past field season.

ACKNOWLEDGMENTS

We are indebted to the villagers of Nelson Lagoon for allowing us to conduct studies over much of their lands. The hospitality which they extended and the knowledge they shared with us is most appreciated.

Peter Kust, Butch Gundersen, and Don and Warren Johnson are especially thanked for their help in providing logistics and conducting aerial surveys. The Peter Pan Seafoods Co. is also thanked for making their facilities available during our stay.

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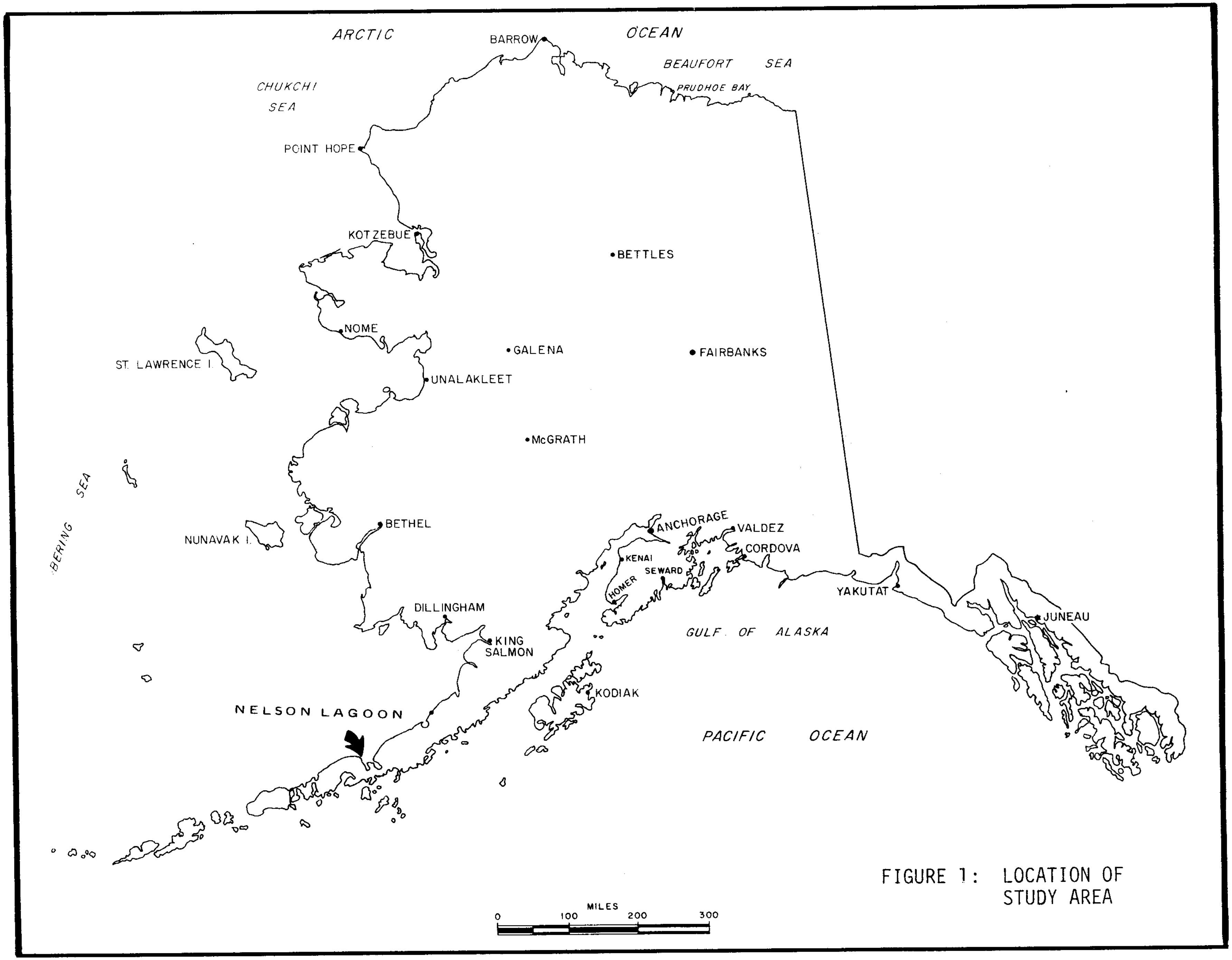


FIGURE 1: LOCATION OF STUDY AREA

FIGURE 2. Temporal abundance of waterfowl at Nelson Lagoon 1976-1977.

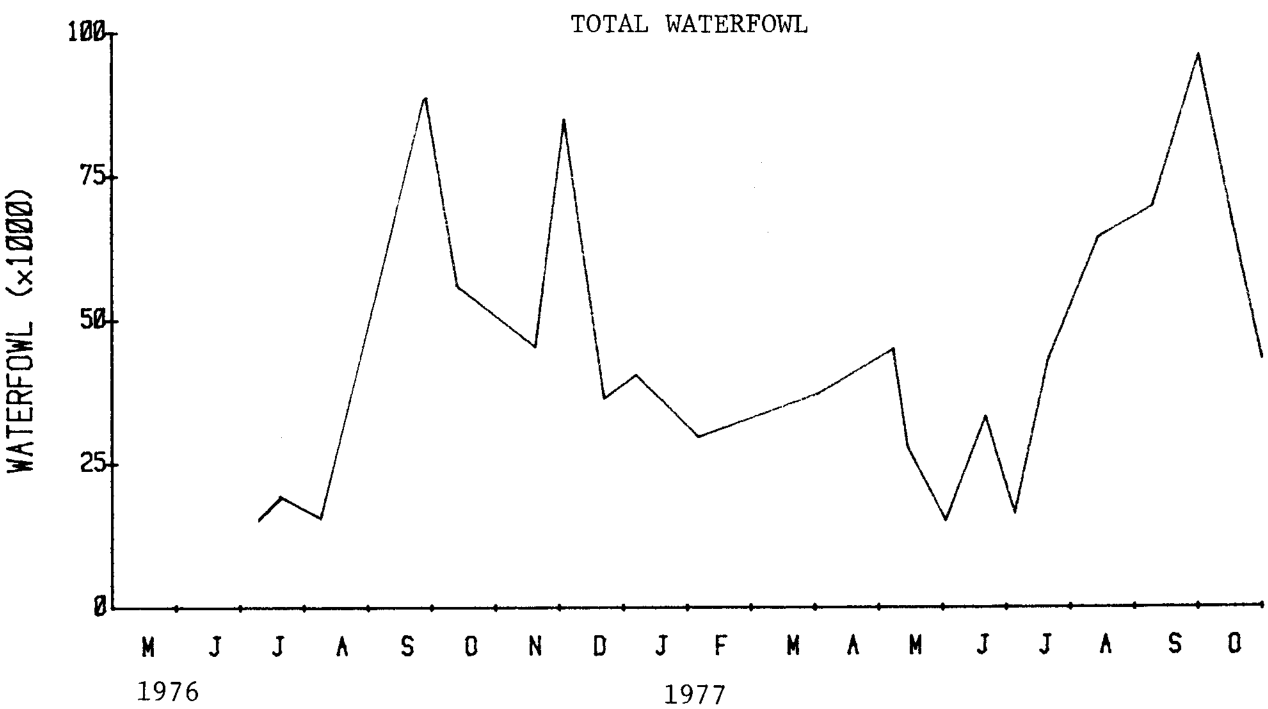


FIGURE 3. Temporal abundance of shorebirds at Nelson Lagoon 1976-1977.

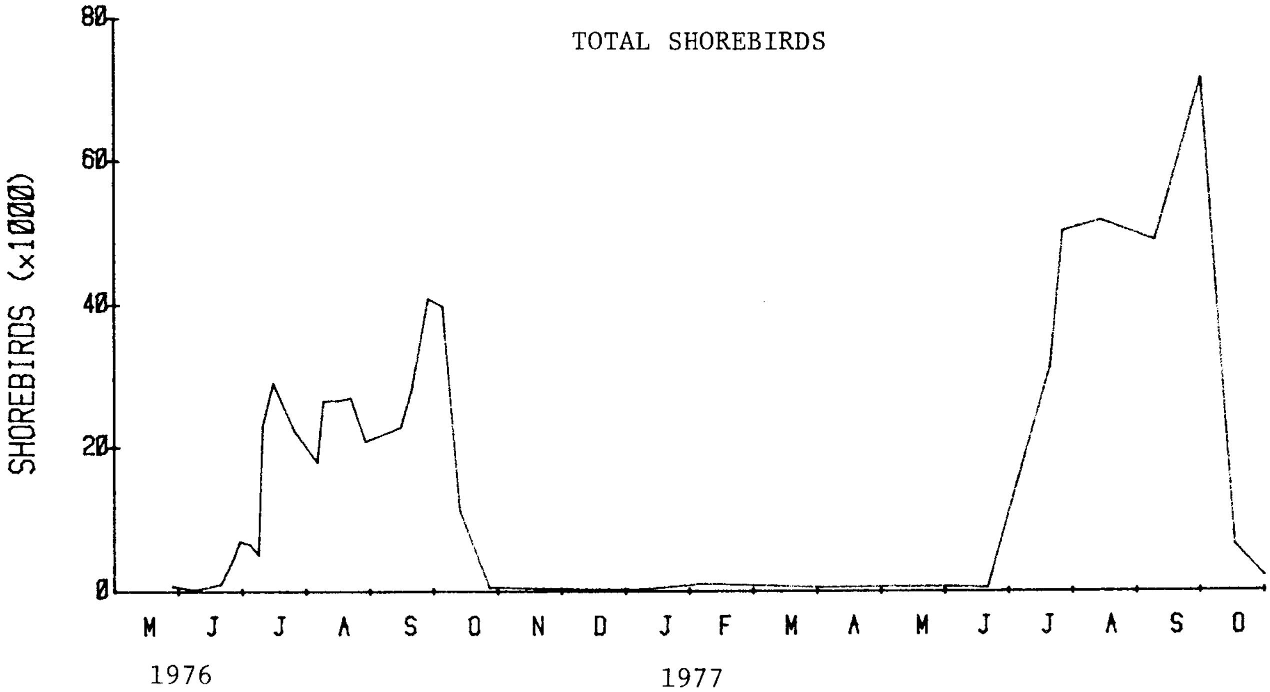


FIGURE 4. Occurrence and abundance of major waterfowl species.

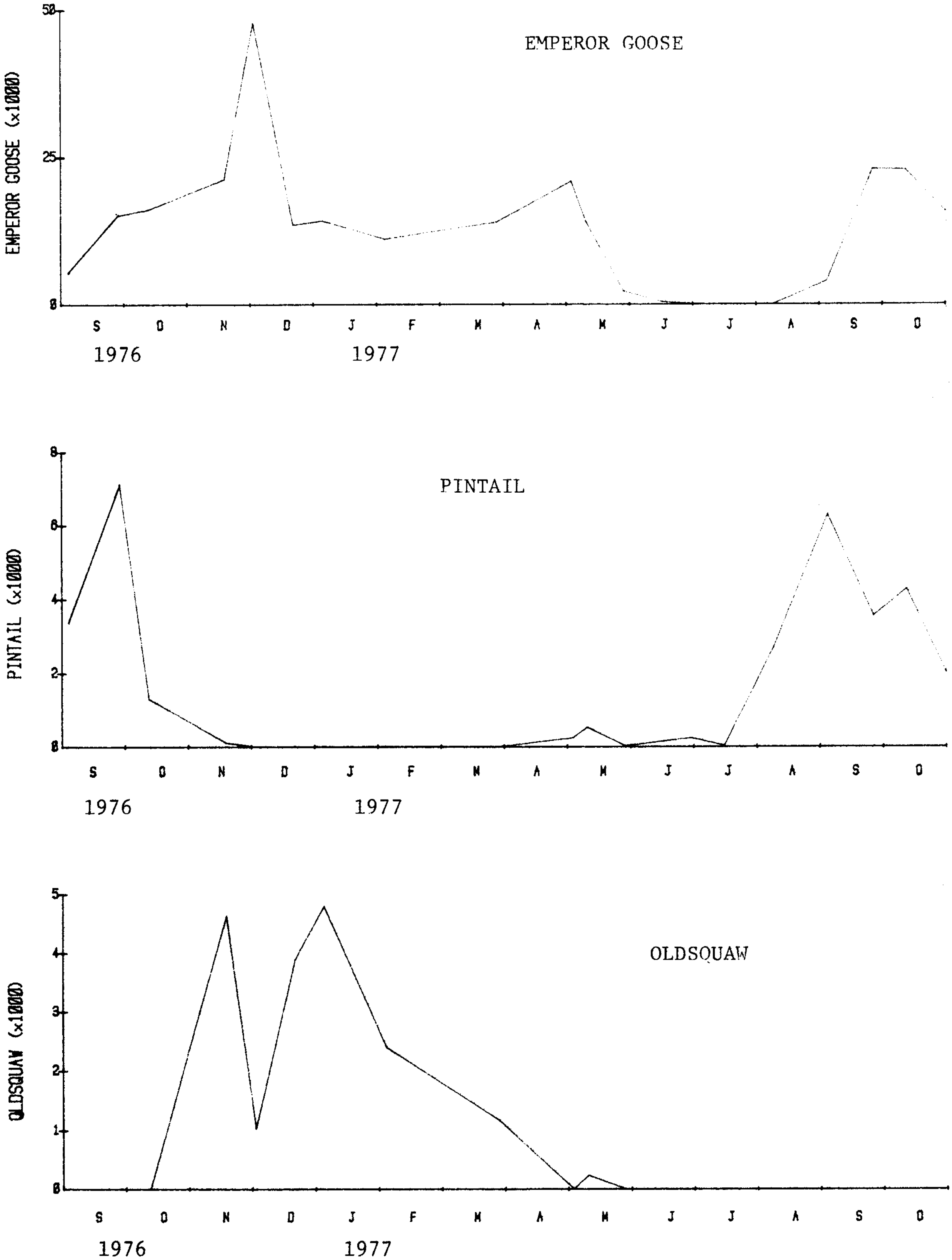


FIGURE 5. Occurrence and abundance of major waterfowl species.

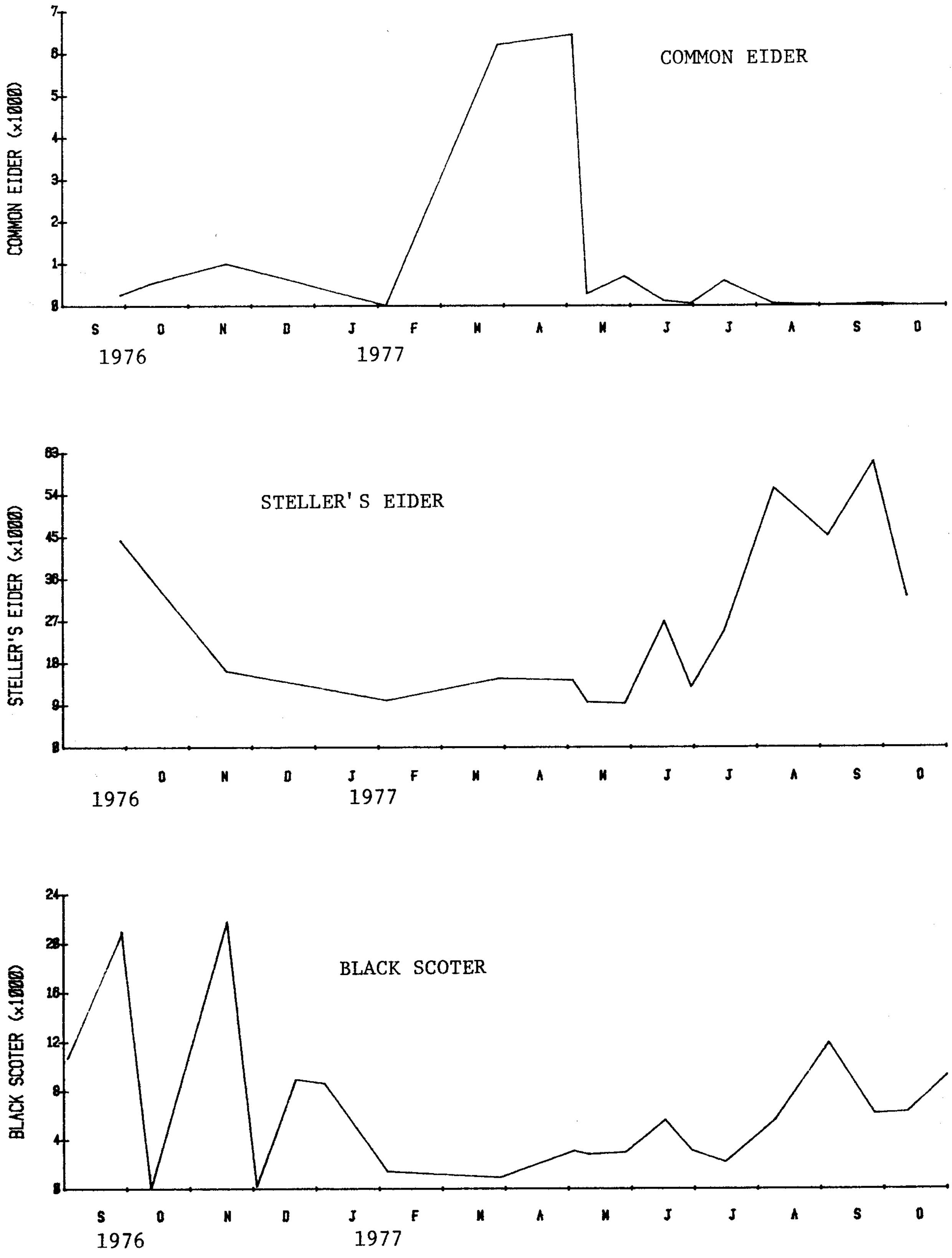


FIGURE 6. Occurrence and abundance of shorebird species at Nelson L.

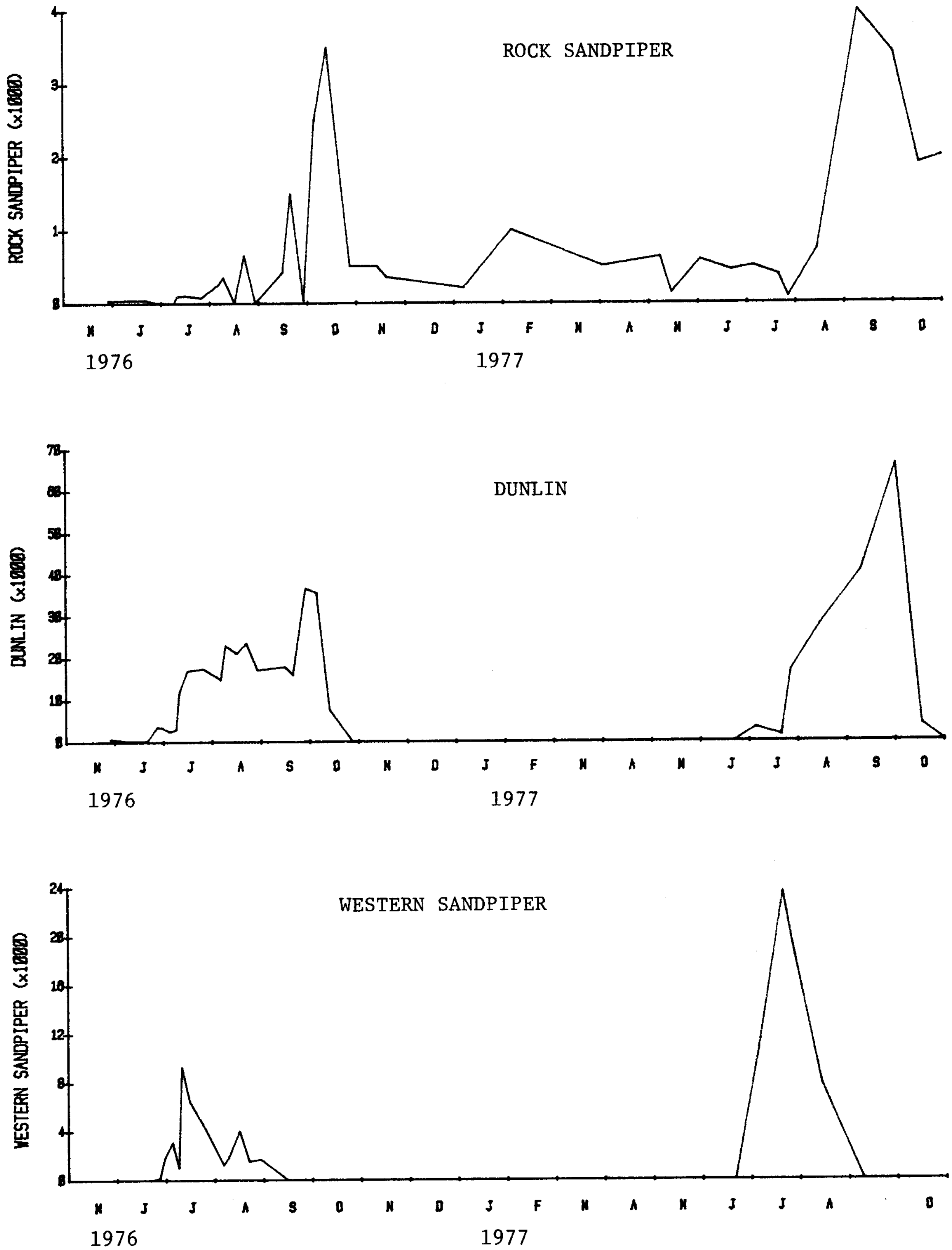


FIGURE 7. Occurrence and abundance of shorebird species at Nelson L.

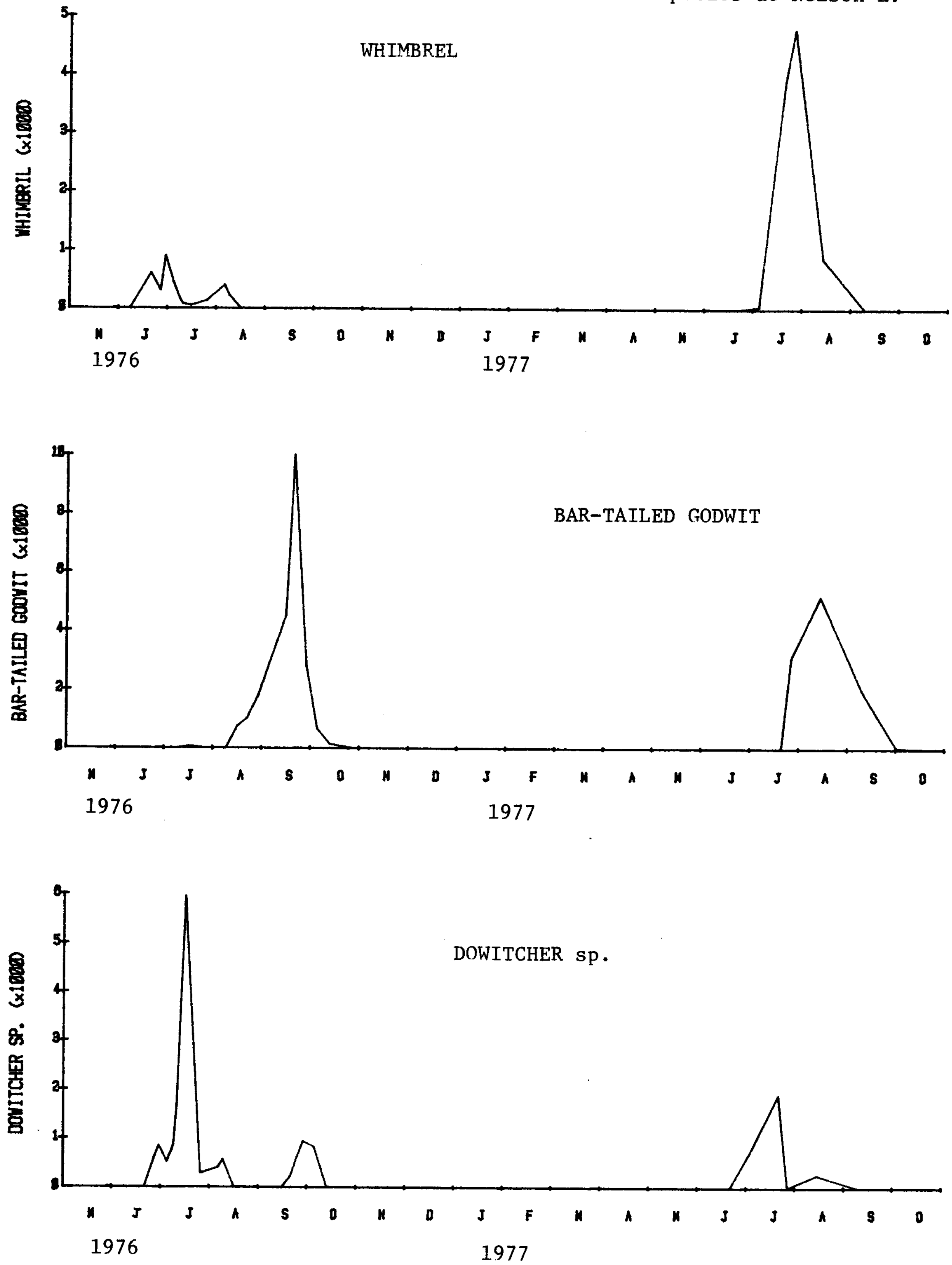
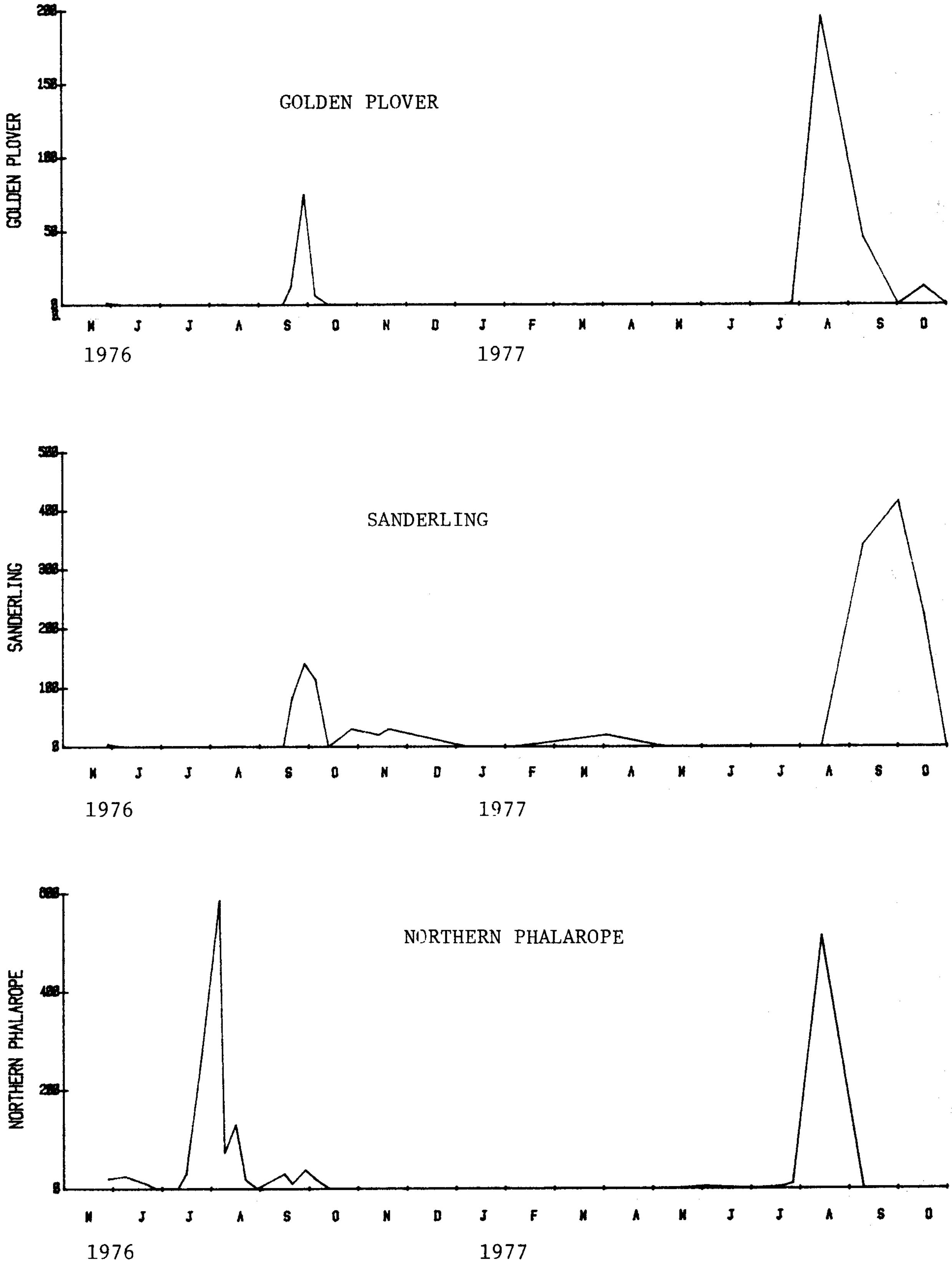


FIGURE 8. Occurrence and abundance of shorebird species at Nelson L.



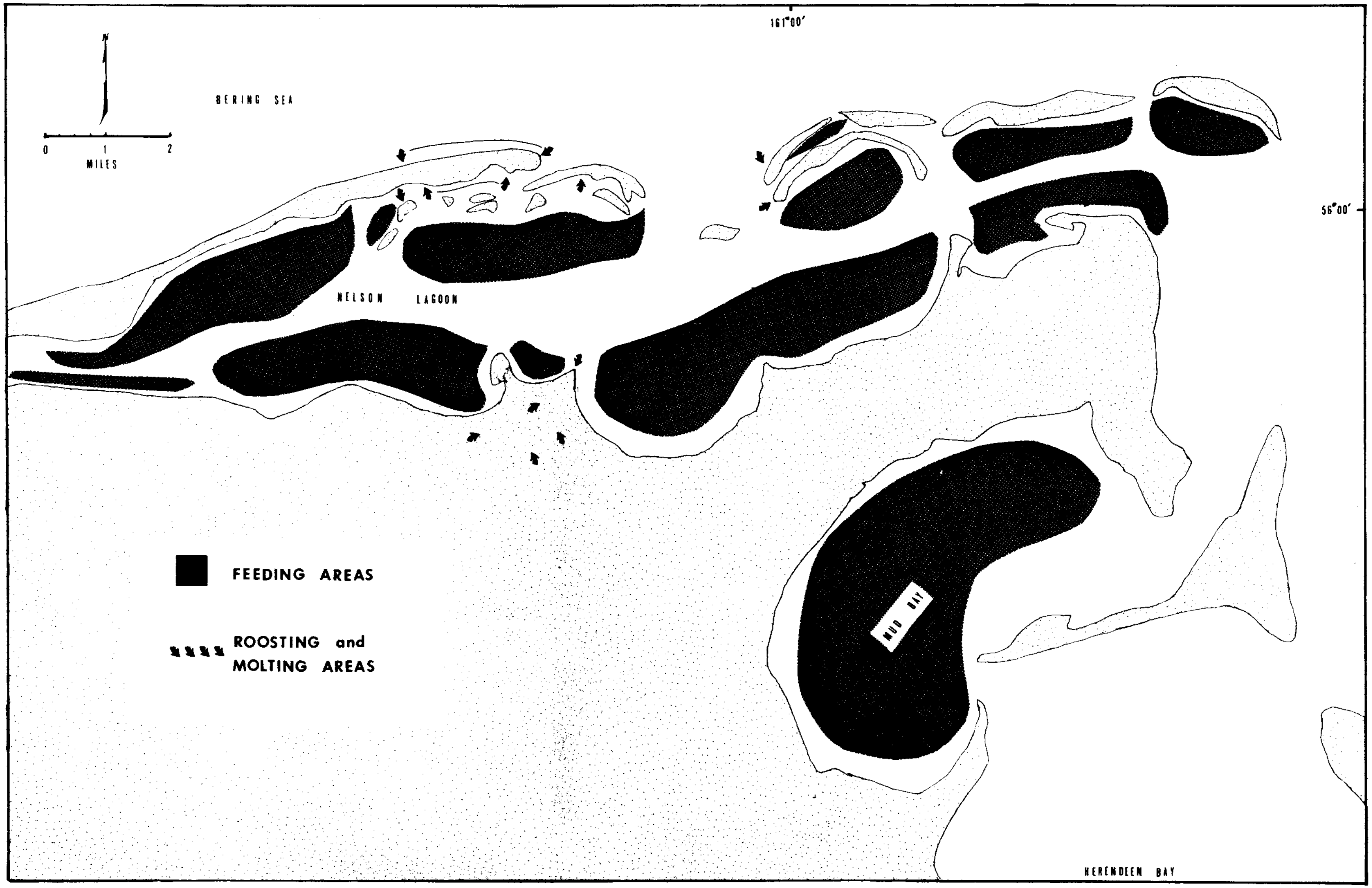


FIGURE 9. Critical feeding and roosting areas of Emperor Geese (August - May).

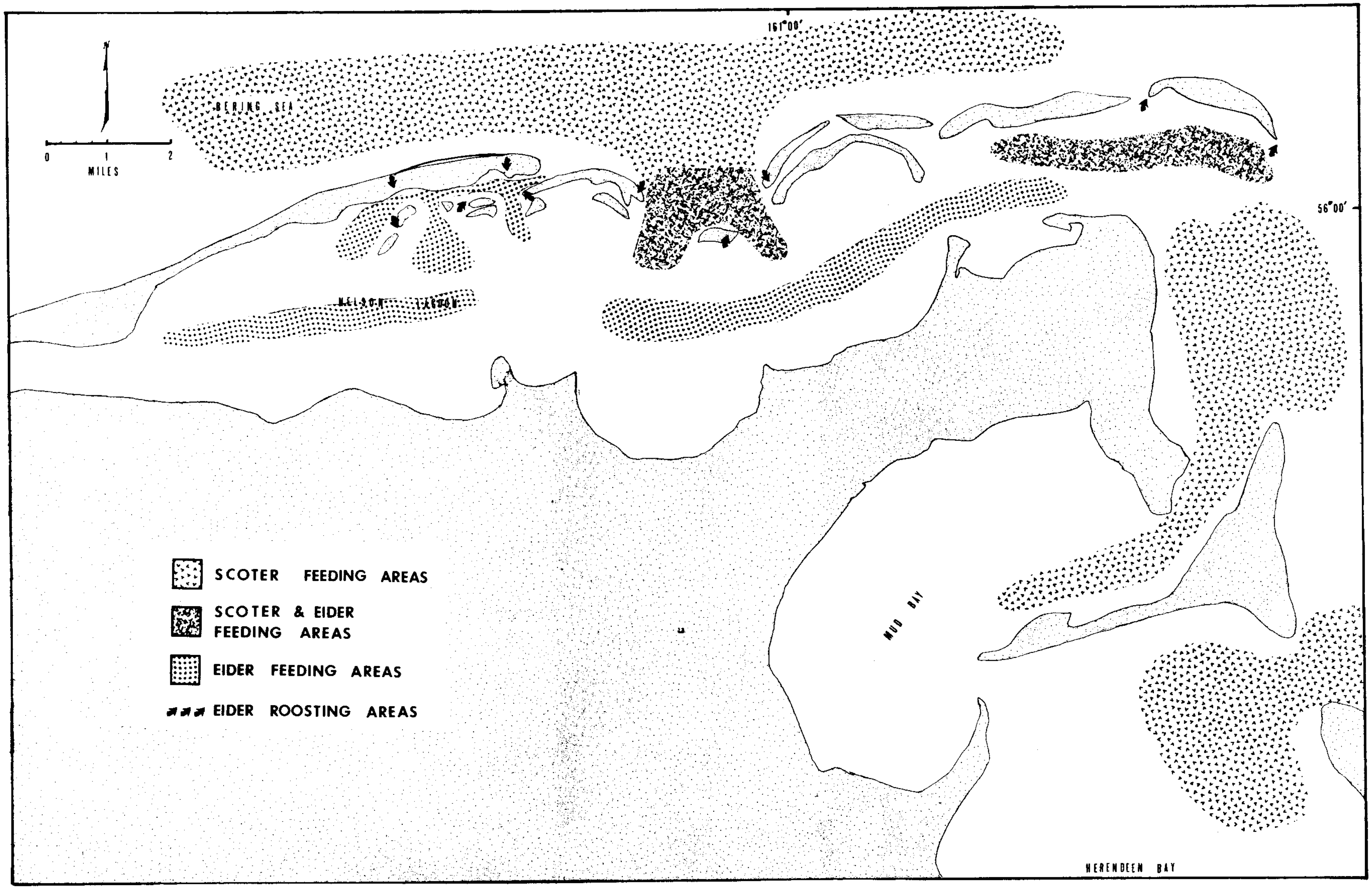


FIGURE 10. Critical feeding and roosting areas of Steller's, Common and King Eiders and Black, White-winged and Surf Scoters. Steller's Ediers and Black and White-winged Scoters molt over much of the same areas (June - August).

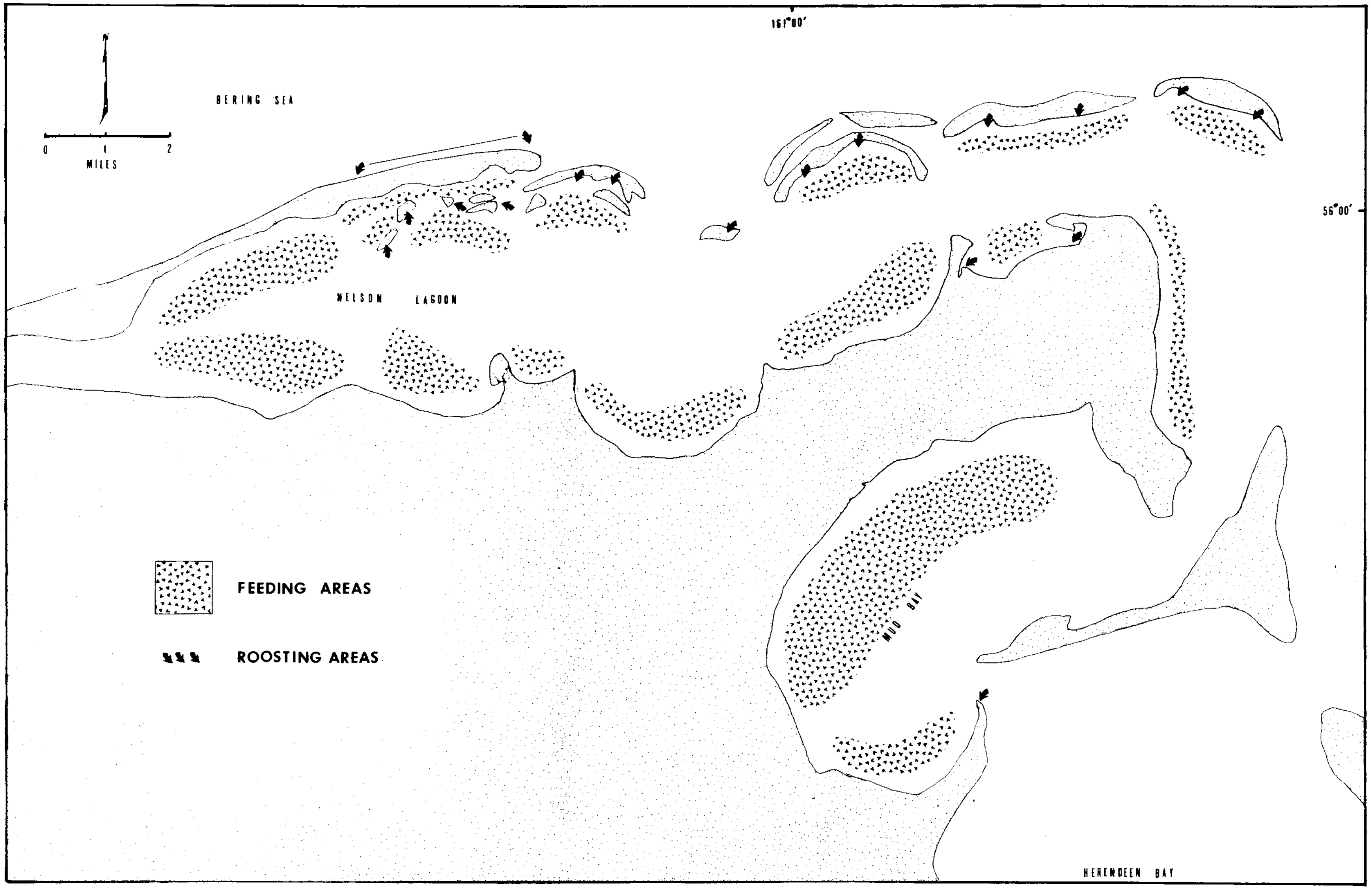


FIGURE 11. Feeding and roosting areas of Dunlin, Western and Rock Sandpipers, Bar-tailed Godwit, Whimbrel and Short- and Long-billed Dowitchers (June - October).

FIG. 12. MINIMUM CLUTCH SIZES OF COMMON EIDERS.

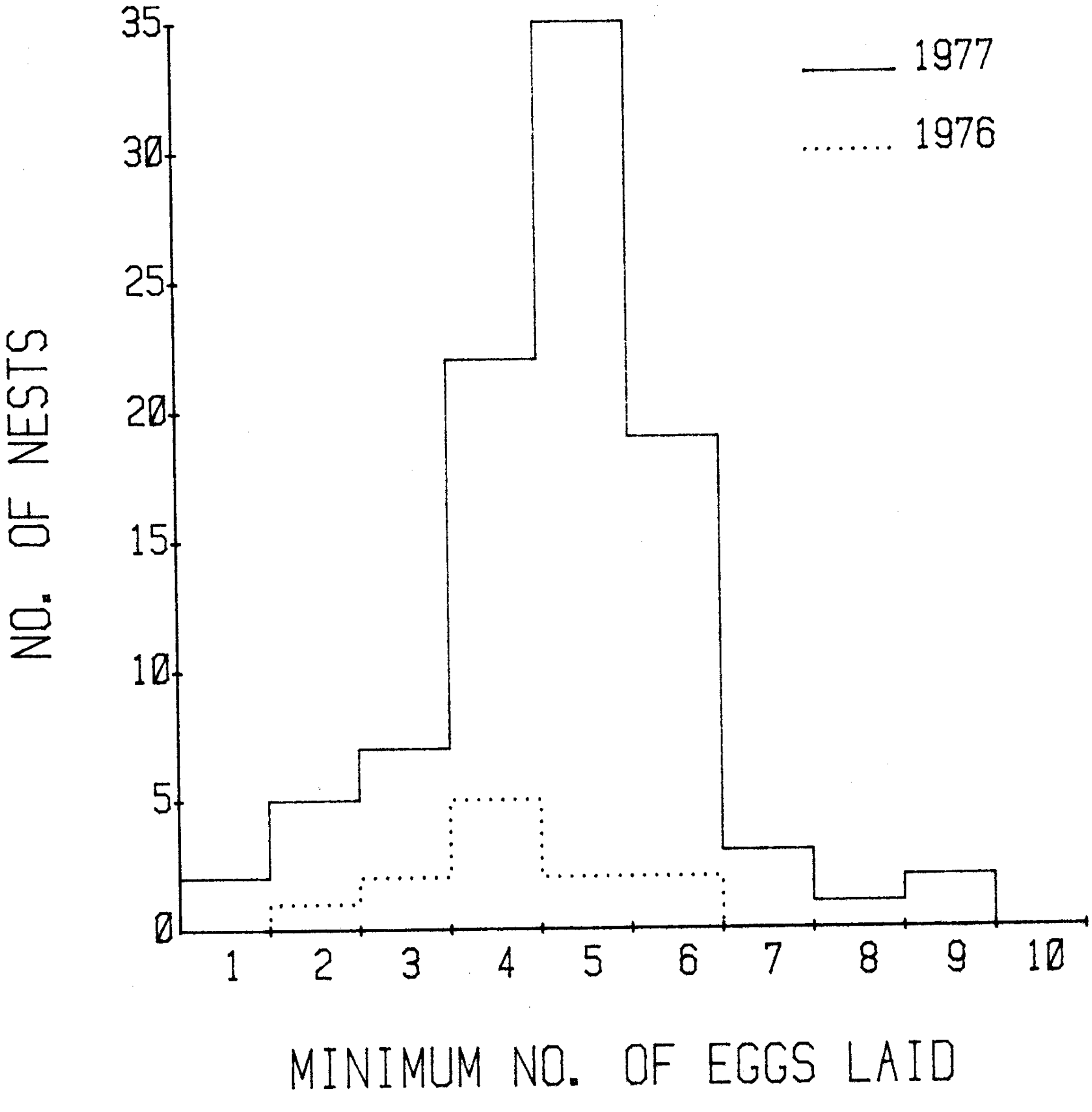


FIG. 13. NUMBER OF EGGS HATCHED PER NEST OF COMMON EIDERS.

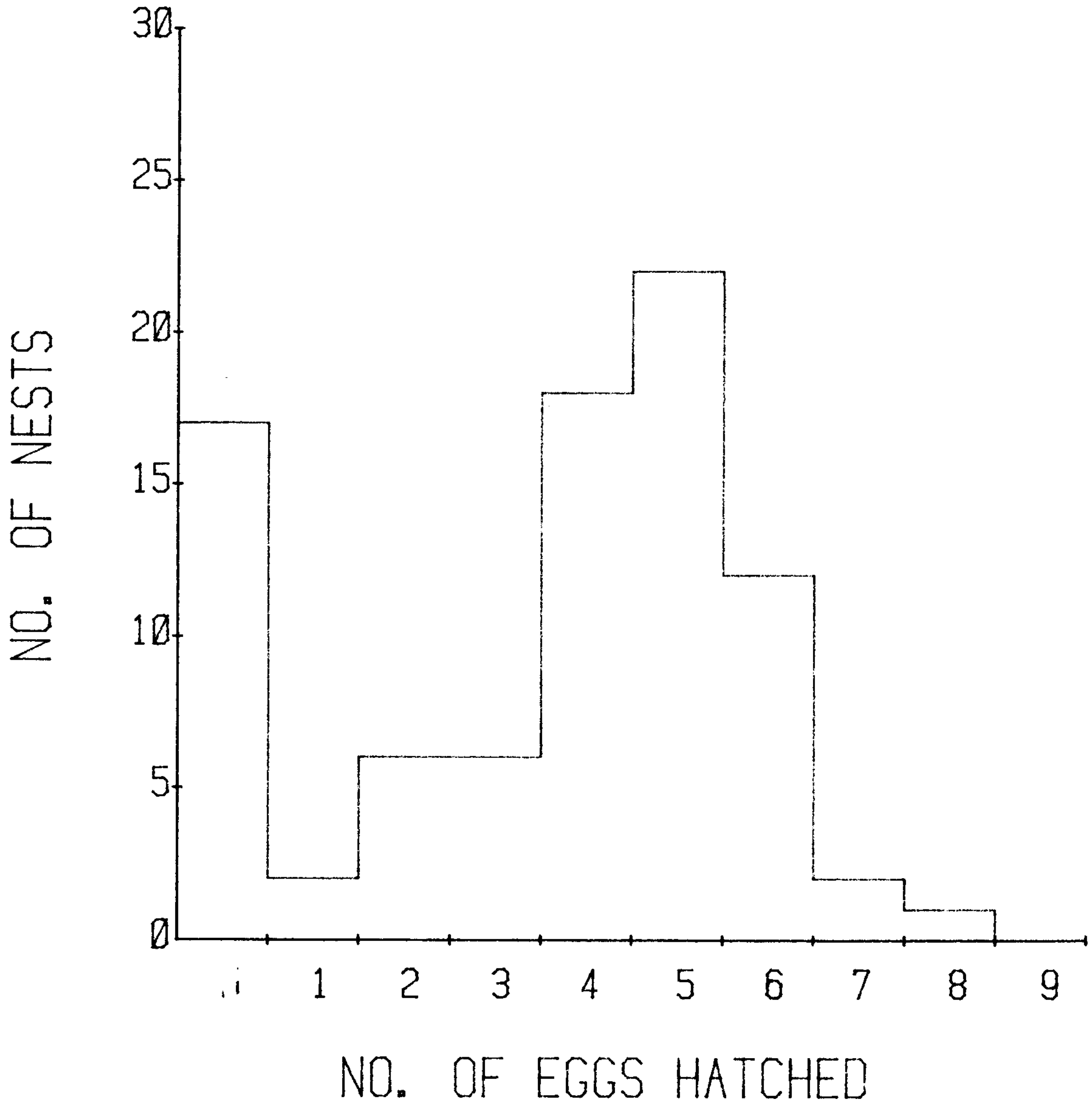
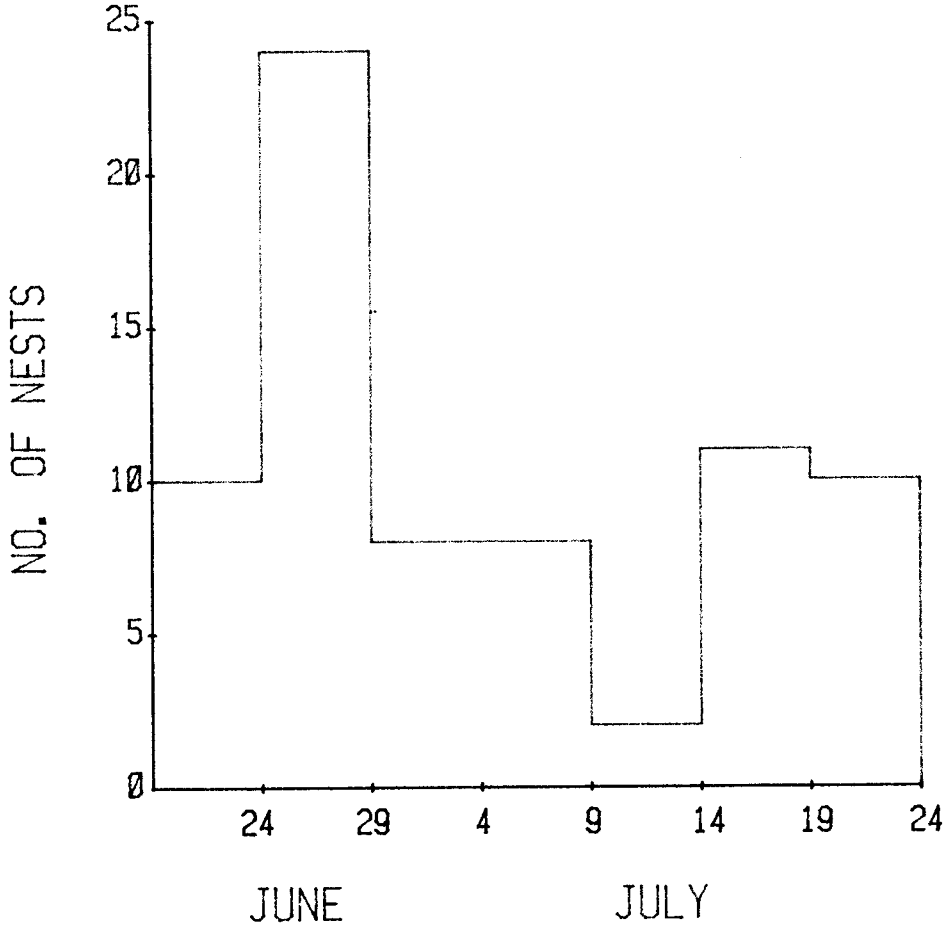


FIG. 14. HATCHING DATES OF COMMON EIDERS.



APPENDIX A

AUTUMN MIGRATION OF DUNLIN AND WESTERN SANDPIPERS FROM THE ALASKA PENINSULA

Abstract

Nelson Lagoon, along the north central Alaska Peninsula, is an important molting and staging area for autumnal migrant shorebirds (see 1976 PSG Shorebird Symposium). During 1977, approximately 1000 each Dunlin and Western Sandpipers were color banded and dyed using rocket-netting at high tide roosts as a capture technique. From these preliminary data collected at time of capture and from subsequent resightings we have developed 1) age and sex composition of birds using Nelson Lagoon, 2) turnover times of birds within the Lagoon, 3) patterns of intra-lagoon movements between roosting and foraging areas, and 4) dispersal and migration strategies of Dunlin and Western Sandpipers from the area.

Western Sandpipers use the Lagoon for approximately 30 days, build moderate fat reserves and depart in early August, following the Alaska and British Columbia coastline. Dunlin, however, use the Lagoon for approximately 110 days, go through a complete molt, build heavy fat reserves and depart in early October on, we believe, a trans-Pacific migration to Oregon and California; this being induced and aided by large anti-cyclonic low pressure systems originating in the Bering Sea each year at this time.

INTRODUCTION

In 1976 we studied the occurrence and abundance of shorebirds along the northcentral Alaska Peninsula at Nelson Lagoon. I reported our preliminary findings during the Shorebird Symposium at last year's PSG meeting.

We returned to Nelson Lagoon in April 1977 to elucidate several aspects of the ecology and population dynamics of migrant shorebirds using the Lagoon and other similar estuaries along the Alaska Peninsula. Specifically, we were interested in 1) age and sex ratios of major migrant species and the occurrence of each 2) turnover times of birds using the Lagoon 3) patterns of intra-lagoon movements between roosting and foraging areas and how these related to periods of molt and pre-migratory fat deposition, and 4) dispersal and migration strategies of birds staging on Nelson Lagoon.

During 1977 we concentrated our efforts on Dunlin and Western Sandpipers. The following data, collected between April and October, were derived from both aerial and ground censuses and from capturing and marking approximately 1200 each Dunlin and Western Sandpipers. Culmen length and plumage differences were used to sex and age both species. Birds were color-marked with picric acid and color-banded with a split red/blue plastic leg band. The color scheme and placement of the bands on the legs "knee" was changed approximately every two weeks.

RESULTS

In looking at the data we see that both Dunlin and Western Sandpipers exhibited similar occurrence patterns between 1976 and 1977 (Figure 1). The greater numbers recorded in 1977 are accounted for by our including an additional census area not used in 1976.

The natal origin of these two species populations is still questioned. Since both species breed on the Alaska Peninsula, the Dunlin more commonly so, portions of the two populations are undoubtedly local. However, recent band recovery data suggests that an unknown segment of the Western Sandpiper population is coming from breeding grounds in north Bristol Bay and possibly the Kuskokwim coast. We suspect most Dunlin are breeding on the Alaska Peninsula. As an aside, band recovery data from birds banded at Nelson Lagoon and of birds banded elsewhere but recovered at Nelson Lagoon indicate that San Francisco Bay is the wintering area for most of the Dunlin staging on Nelson Lagoon each fall.

In looking at occurrence of Western Sandpipers we find that adult males and females arrive simultaneously following breeding, however, females greatly outnumber males (Figure 2). This changes dramatically in mid-July when males become more abundant. This change in sex composition of AHY birds coincides with the arrival of the first HY birds. Adult female Westerns depart by 1 August. Most adult males also depart by early August, however, small numbers remain through the month. Birds of the year showed no significant difference in occurrence or composition between sexes (t - test, $p > 0.1$). Numbers of young birds increased steadily until departure in early September.

Adult male and female Dunlin exhibited no significant difference in occurrence and composition between sexes; however, after 1 July males predominated in all of our catches (t - test, $p > 0.1$) (Figure 3). Birds of the year first appeared in mid-August with numbers remaining relatively constant through departure in early October.

This obvious difference in use of the Lagoon by the two species prompted us to look for associated differences in their dispersal and migration patterns. We, here, present the following hypothesis regarding migration strategies of the two species: Western Sandpipers staging on Nelson Lagoon migrate to their winter quarters via the Gulf of Alaska and British Columbia coastlines. Dunlin, however, depart on an overwater migration initiated and aided by a large anti-cyclonic weather system originating in the Bering Sea each fall. We believe the following data support this hypothesis.

Sightings of banded and color-marked birds are presented in Figure 4. To date, we have received 30 "Bird-days" of sightings: 20 from Western Sandpipers and 10 from Dunlin. Of note are the two Western sightings from the Prince William Sound area and the comparatively large number of sightings from the Vancouver-northwest Washington area. Western sightings began on 4 August at Hinchinbrook Island, Prince William Sound and followed on succeeding days on a north to south gradient. Our last sighting was at Imperial Beach, San Diego County on 9 September. Since adult Western Sandpipers go through post-nuptial molt soon after arriving on their wintering grounds we expect few, if any, additional sightings of color-dyed birds.

The pattern of color-marked Dunlin was quite different from that of Western Sandpipers. Sightings of what appear to be 7 different birds occurred between 14 - 26 October: five from the

San Francisco Bay area and one each from northwest California and Oregon. We have received no reports of sightings north of Tillamook, Oregon and there was no sequential pattern in reported sighting dates as with Westerns and as one might expect if birds were migrating along the Gulf of Alaska-British Columbia coastline. Furthermore, we know from census and banding data that the Dunlin seen at Bolinas Lagoon, Marine County, California on 14 October was still at Nelson Lagoon on 9 October and not suspected of leaving the Lagoon until the 10th or 11th of October when 90% of the 60,000 + Dunlin present on the Lagoon departed. A similar mass exodus of Dunlin occurred at Nelson Lagoon between 8 - 12 October 1976. This 24 - 48 hour interval between departure from the Lagoon and arrival on the wintering grounds is important, as will be shown in later discussion.

Further support of our hypothesis lies in the recorded differences in the timing and comparative amounts of pre-migratory fat deposition between the two species. Adult Western Sandpipers began fat deposition in mid-July and continued at an increasing rate until departure in early August (Figure 5). During this period, males and females added 13 and 9 percent of their respective post-breeding body weights. Between arrival and departure at Nelson Lagoon, HY birds increased their post-fledging weights by approximately 8 percent.

Dunlin, on the other hand, did not begin to put on fat until completion of their post-nuptial molt in early September (Figure 6). Beginning the last week of September fat deposition increased rapidly in both HY and AHY birds. Compared to Western Sandpipers during this immediate pre-migratory period, both male and female adult Dunlin increased their respective post-breeding weights by an average 35 percent. HY Dunlin averaged a 23 percent increase over their immediate post-fledging weights.

If Dunlin do partake of a long, overwater migration as we propose, they would require considerable energy reserves. Using flight range formulas developed by McNeil and Cadieux, (1972 a, b) and Raveling and LeFebvre (1967) and incorporating regression equations developed by Stan Senner, U. of Alaska, to derive fat free weights given wing length and live weight, we were able to calculate theoretical flight ranges for both species immediately prior to their respective fall departures.

Figure 7 presents the flight range frequencies for a sample of AHY and HY Dunlin captured on 9 October. The histogram represents the combined ranges of male and female birds since we found no significant difference between the flight range capabilities of the two sexes. The mean range for adult birds, flying at 50 mph and unaided by winds, was 2300 statute miles. The great circle, or shortest distance between Nelson Lagoon and San Francisco Bay is approximately 2000 miles. Given this, approximately 70% of Lagoon Dunlin population could be expected to reach their wintering grounds via an overwater route without aid of winds. However, only 40% of the HY birds could make such a journey at that time. If Dunlin were using a coastal route only 25% of the adult population could complete the 2800 mile trip without having to stop to replenish fat reserves. Such a layover would require an additional 24 - 48 hours in their travel time between Nelson Lagoon and northcentral California.

The flight range of adult Western Sandpipers was considerably shorter than that of Dunlin (Figure 8). With a flight speed of 50 mph and no favorable winds, adult Westerns had a mean range of 1100 miles. Less than 5% of the population was capable of flying farther than 2000 miles at time of departure in early August. Young Westerns had a mean flight range of approximately 600 miles upon their departure in late August. While neither AHY nor HY birds, therefore, appear capable of an overwater migration similar to that of Dunlin, their energy reserves are quite adequate to take them to Prince William Sound or the Copper River Delta where they could "refuel" for the remainder of their migration. Based on the two sightings from these areas it does, indeed, appear that this is what they do.

The fact that Dunlins are capable of a long, overwater flight is further supported by their, and shorebird's in general, ability to use favorable weather systems during migration. Pressure pattern flying has been well documented for several species of shorebirds migrating each fall from the Gulf of St. Lawrence and Nova Scotia to northern South America. More applicable, however, are the data of Robert Jones of our office who has determined that Black Brant staging on Izembek Lagoon, approximately 100 miles west of Nelson Lagoon, avail themselves of a large, low pressure system on their non-stop migration across the northeast Pacific to their wintering grounds along the west coast of Baja.

From weather data taken at Nelson Lagoon and from subsequent analysis of synoptic weather charts, we know that a series of low pressure systems occur in the Bering Sea and Gulf of Alaska beginning in September each year. Such a system tracking from the southeastern Bering, through the Aleutians and into the northeast Pacific occurred between 10-12 October this year. We feel this particular low was responsible for initiating the sudden departure of the Nelson Lagoon Dunlin population. The weather before, during and after this period is presented in Figure 9. Arrows indicate wind flow and numbers reflect wind speed in mph.

Dunlin departing Nelson Lagoon on this system would have had favorable winds in excess of 35 mph from sea level to above 7,000' for approximately 3/4 of their journey. This coupled with the energy savings associated with flock or formation flying, estimated at $\geq$ 20%, would have allowed 99% of the adult Dunlin population, based on the 9 October sample, to reach its wintering grounds via a transoceanic migration route. Such a flight would require between 24 - 28 hours in the air. However, given these same conditions, still, only 55% of the HY Dunlin could have completed the migration at that time, and only 20% of the Western Sandpiper population could have made such a journey if they departed the Lagoon in August under similar weather conditions.

The comparatively small percentage of HY Dunlin capable of completing an overwater migration at the time the majority of the population departed can probably be accounted for thusly; taking into consideration the obvious higher mortality of HY birds. Although we were unable to sample the approximately 6,000 Dunlin remaining in the Lagoon following the departure of the main population, we suspect a major percentage was HY birds. Since HY birds comprised between 12-17 percent of our captures during September and October, there were, therefore, approximately 9,000 HY birds in the Lagoon during the 28 September census. If 55 percent of these were capable of completing the migration and did leave with the other birds between 11-12 October, then approximately 4,000 of the 6,000 Dunlin remaining in the Lagoon on 13 October were HY birds. At the rate both HY and AHY birds were building fat reserves, those birds remaining would have put on sufficient fat within a matter of days to allow them to depart on migration. We feel it unlikely that HY birds incapable of an overwater migration would use a coastal route and then adapt a different migration strategy in succeeding years. It follows, then, that if these late birds do eventually build sufficient fat reserves for a migration, that they, too engage in pressure pattern flying to carry them on an overwater route. Two such systems occurred over the Alaska Peninsula and Gulf of Alaska between 15-20 October this year, during which the remainder of the Dunlin capable of migrating are suspected of leaving.

Presented by R. E. Gill, USFWS, Anchorage, Alaska at the 1978 PSG meeting, Victoria, B.C. 19-22 January 1978.

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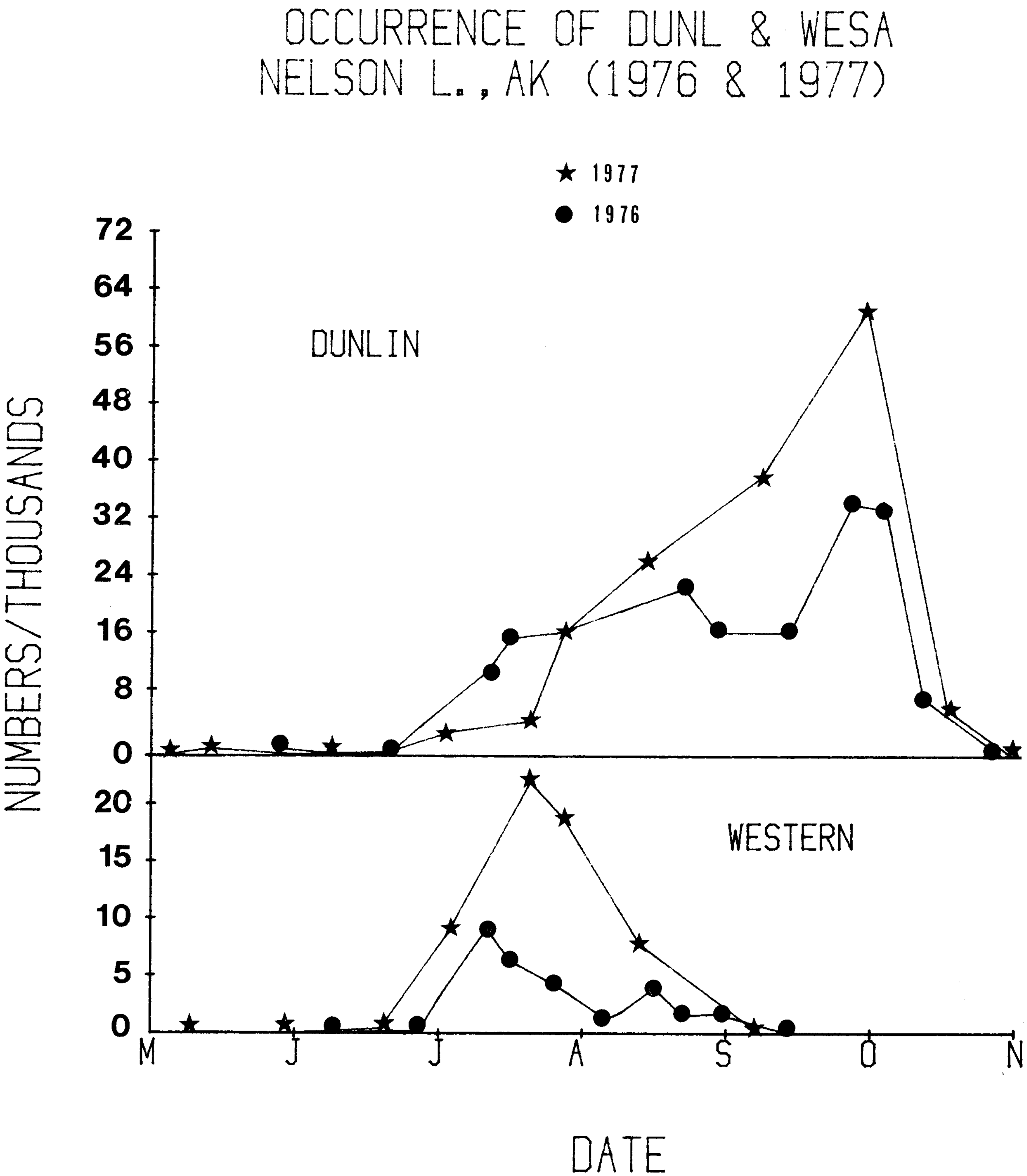
FIGURE 1.



OCCURRENCE OF DUNL & WESA
NELSON L., AK (1976 & 1977)
1977
1976
72
64
56
48
40
32
24
16
8
0
DUNLIN
20
15
10
5
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WESTERN
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FIGURE 2.

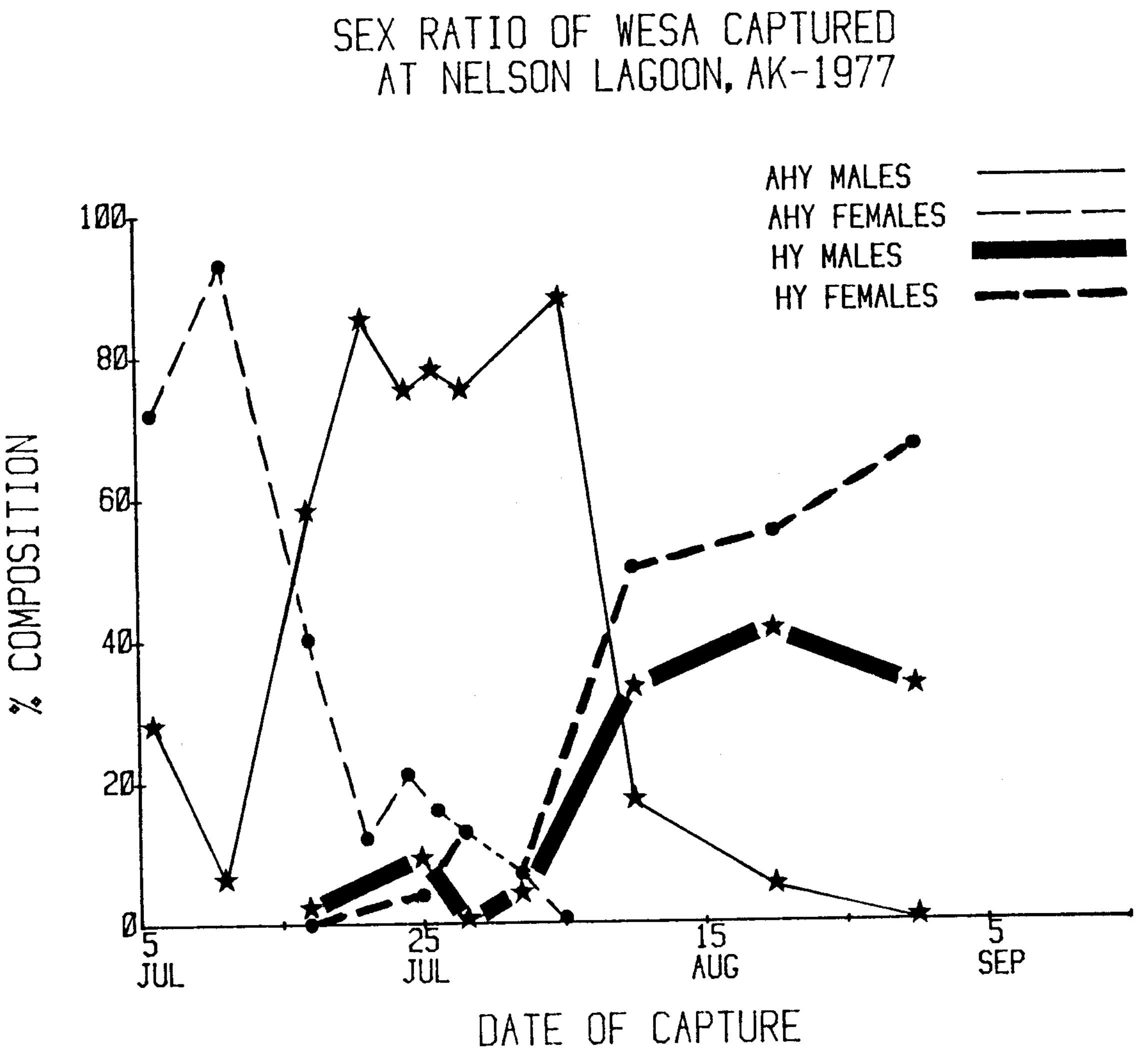
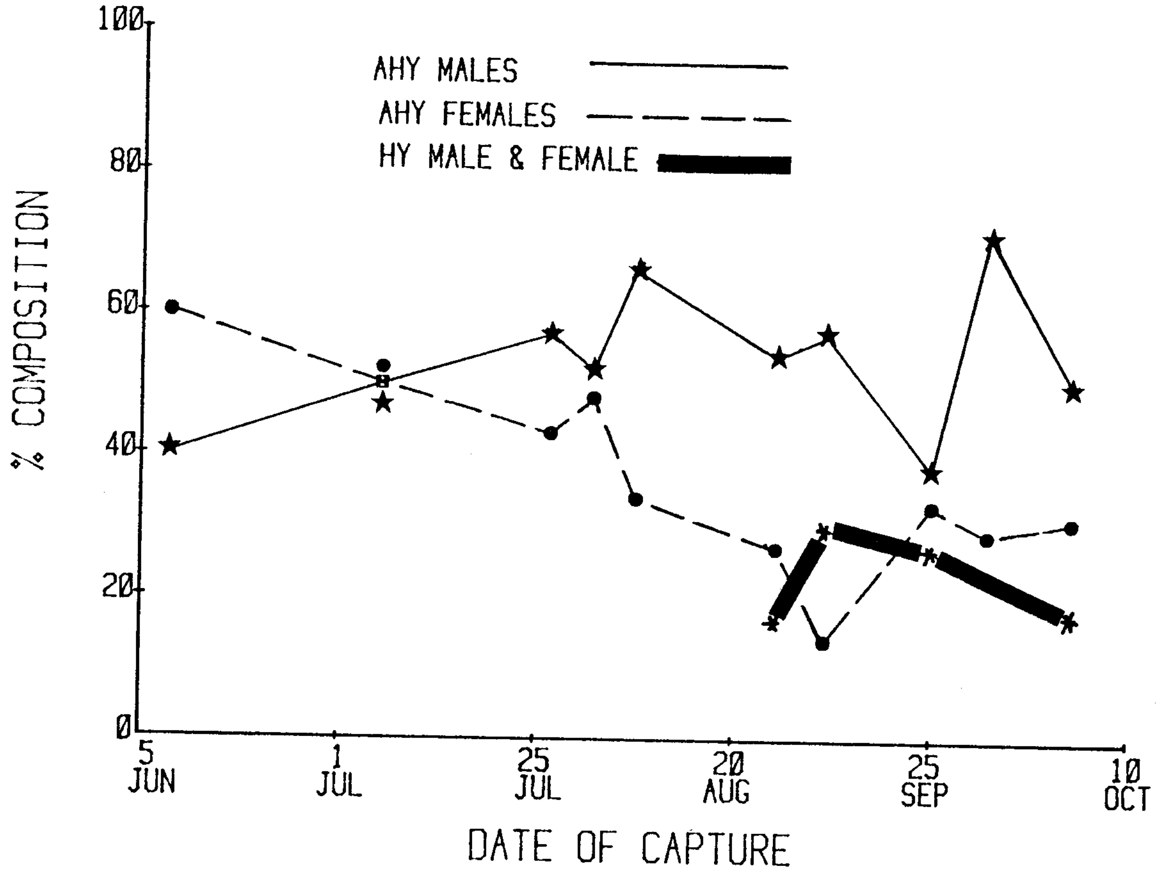

SEX RATIO OF WESA CAPTURED
AT NELSON LAGOON, AK-1977
AHY MALES
AHY FEMALES
HY MALES
HY FEMALES
100
80
60
40
20
0
% COMPOSITION
5
JUL
25
JUL
15
AUG
5
SEP
DATE OF CAPTURE

FIGURE 3.

SEX RATIO OF DUNLIN CAPTURED AT NELSON LAGOON, AK-1977



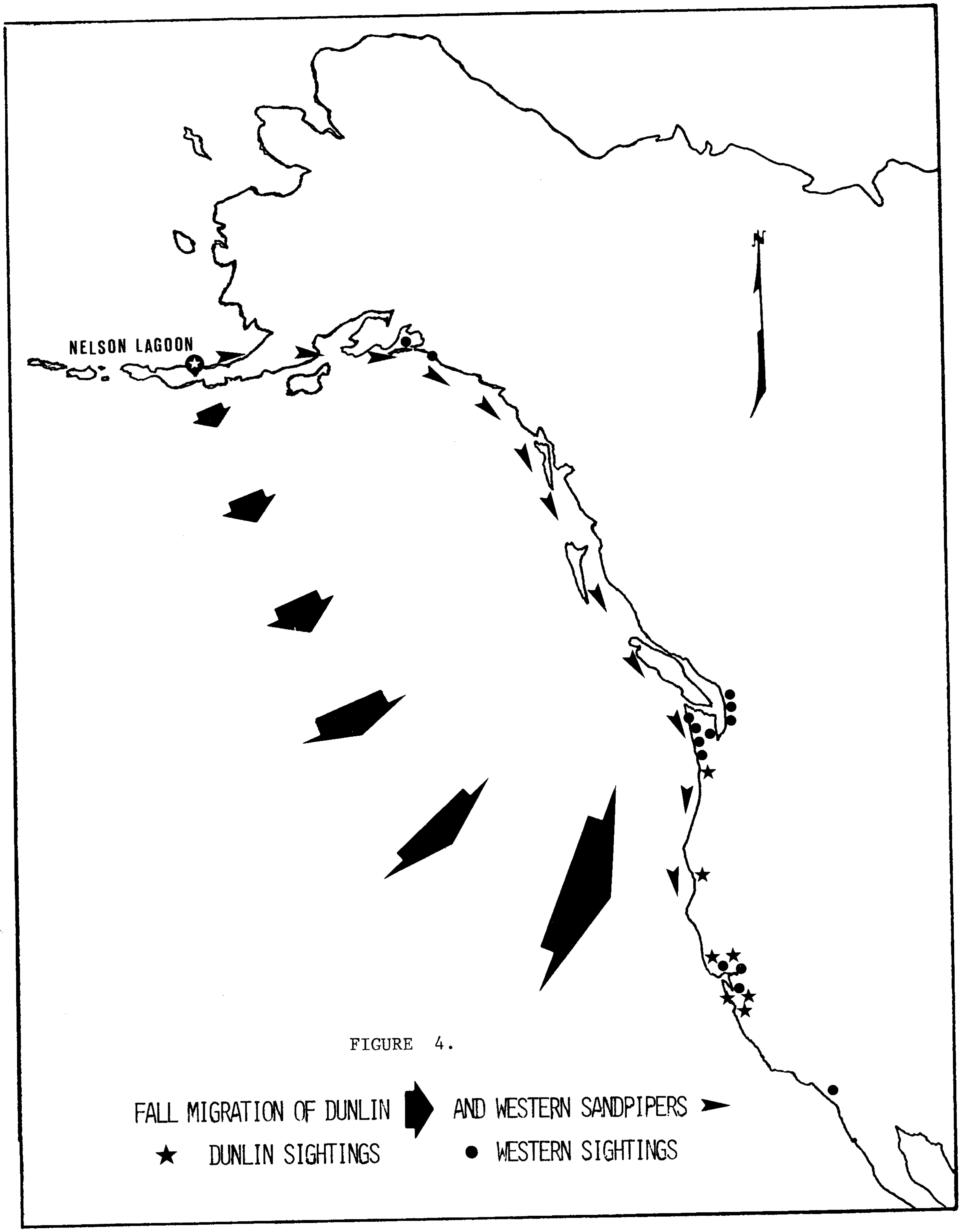

NELSON LAGOON
N
FALL MIGRATION OF DUNLIN
AND WESTERN SANDPIPERS
DUNLIN SIGHTINGS
WESTERN SIGHTINGS

FIGURE 4.

FIGURE 5.

WEIGHT CHANGE IN WESA
NELSON LAGOON, AK-1977

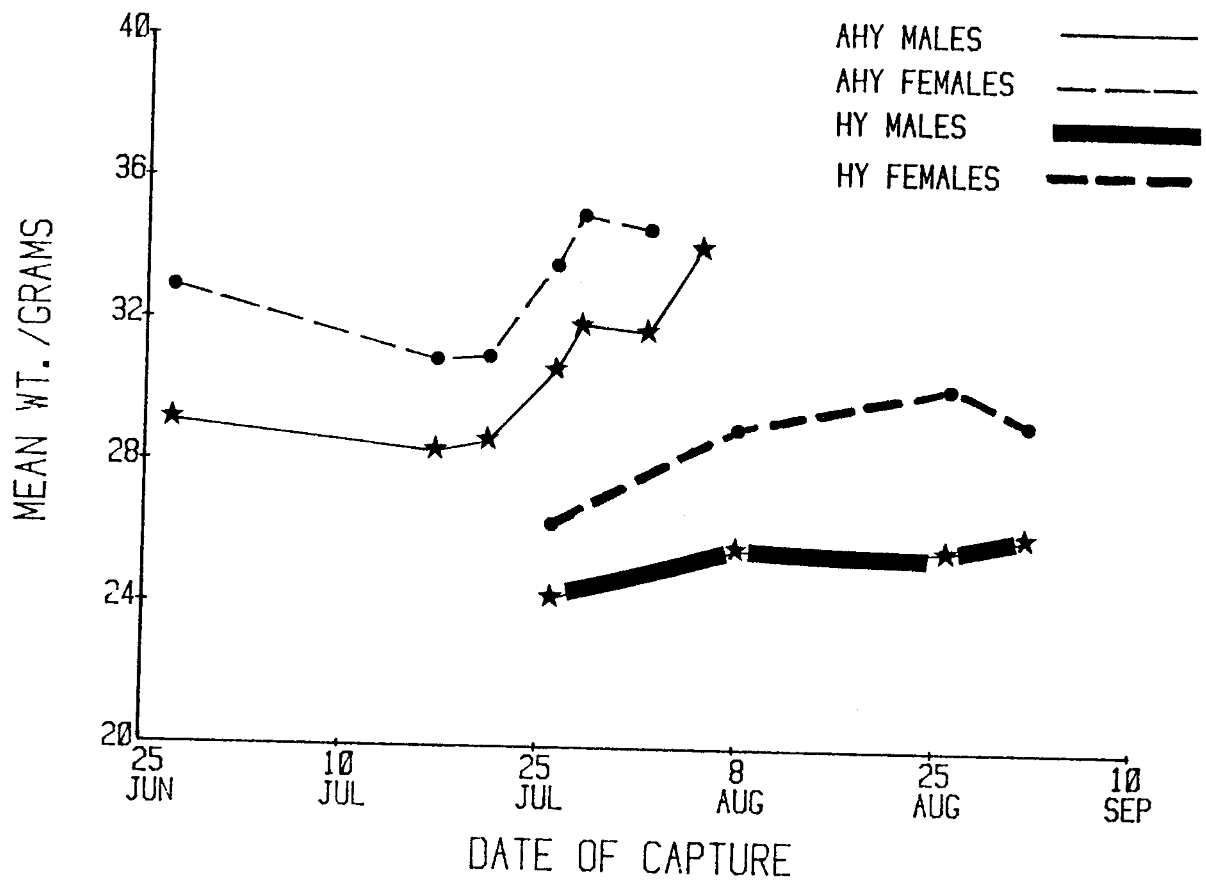


FIGURE 6.

WEIGHT CHANGE IN HY & AHY DUNLIN
NELSON LAGOON, AK - 1977

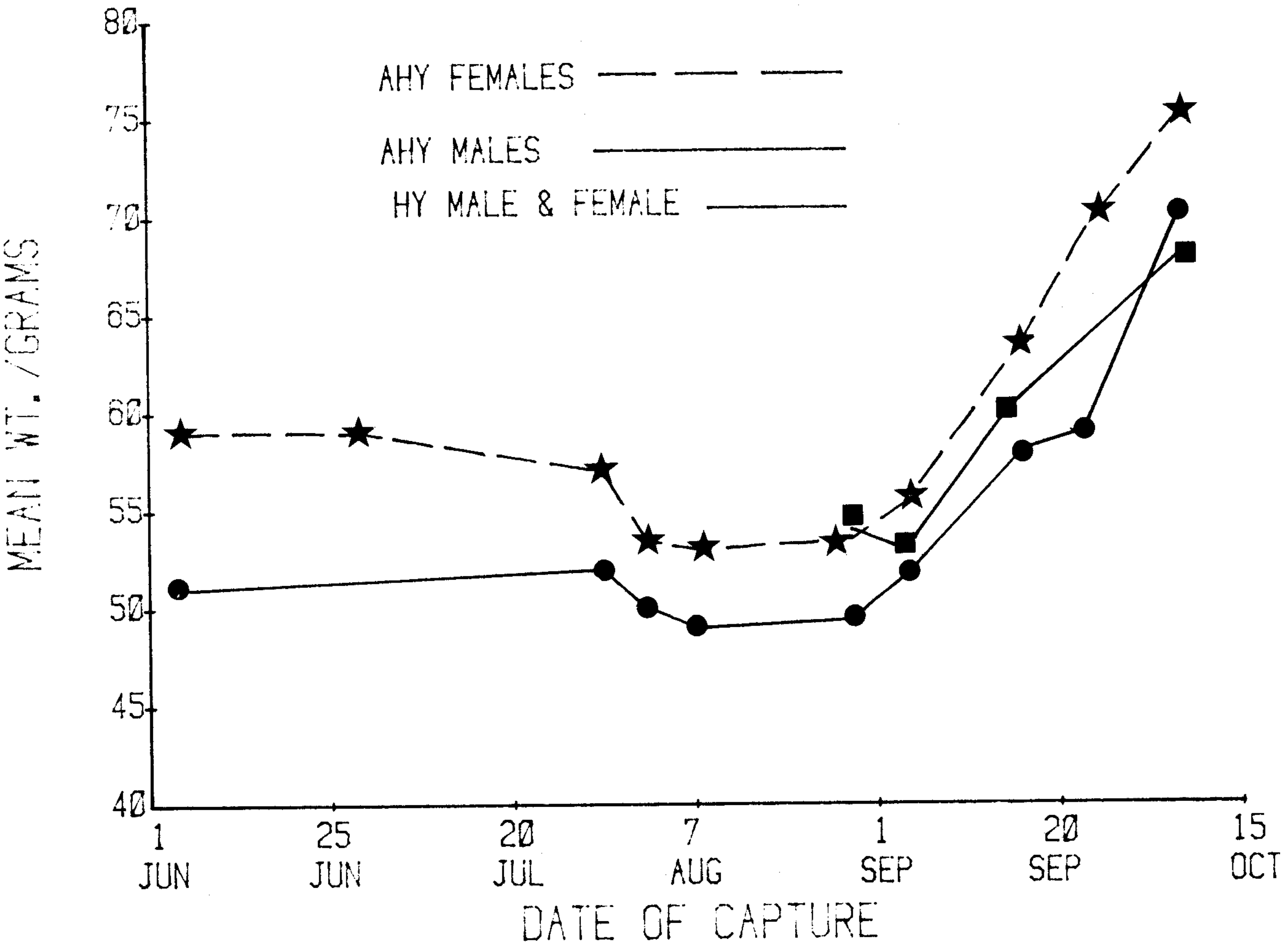


FIGURE 7. Flight range of AHY and HY Dunlin, Nelson Lagoon Alaska - 1977.

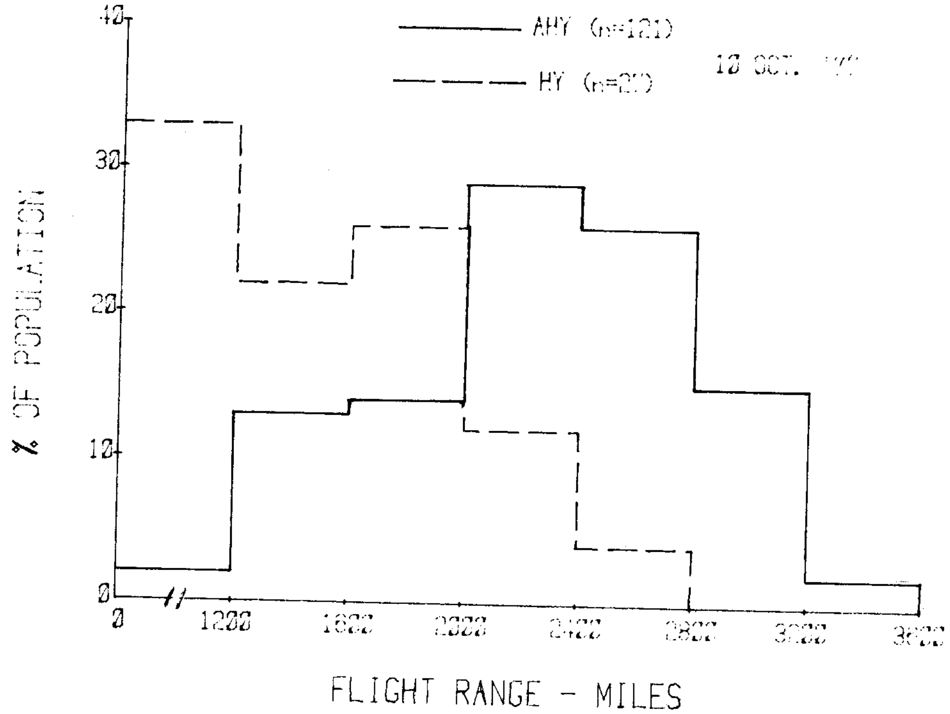


FIGURE 8. Flight range of AHY and HY Western Sandpipers, Nelson Lagoon, AK - 1977.

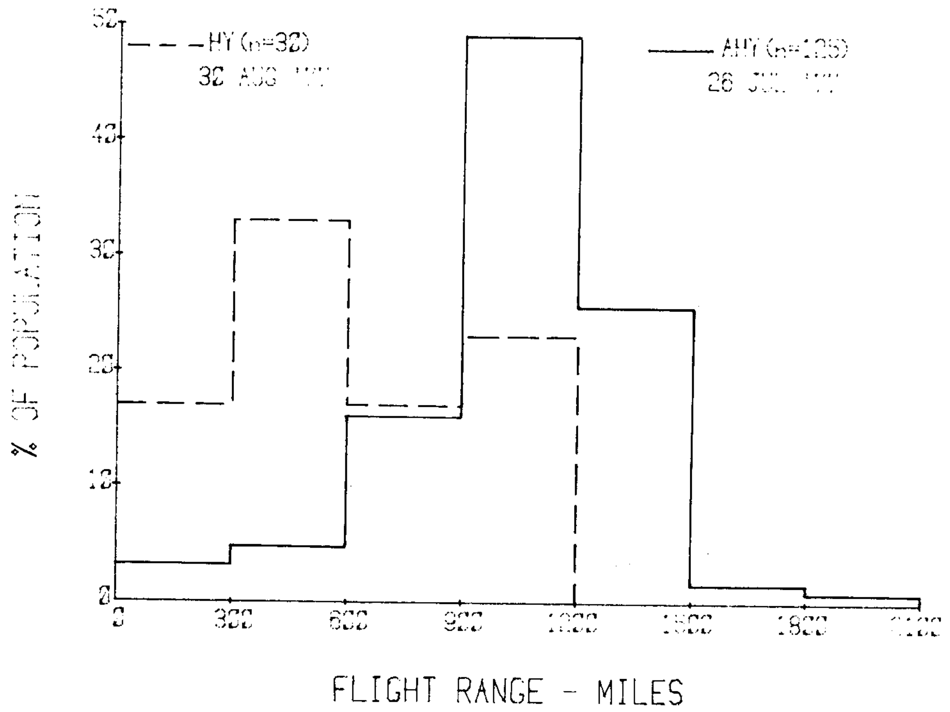
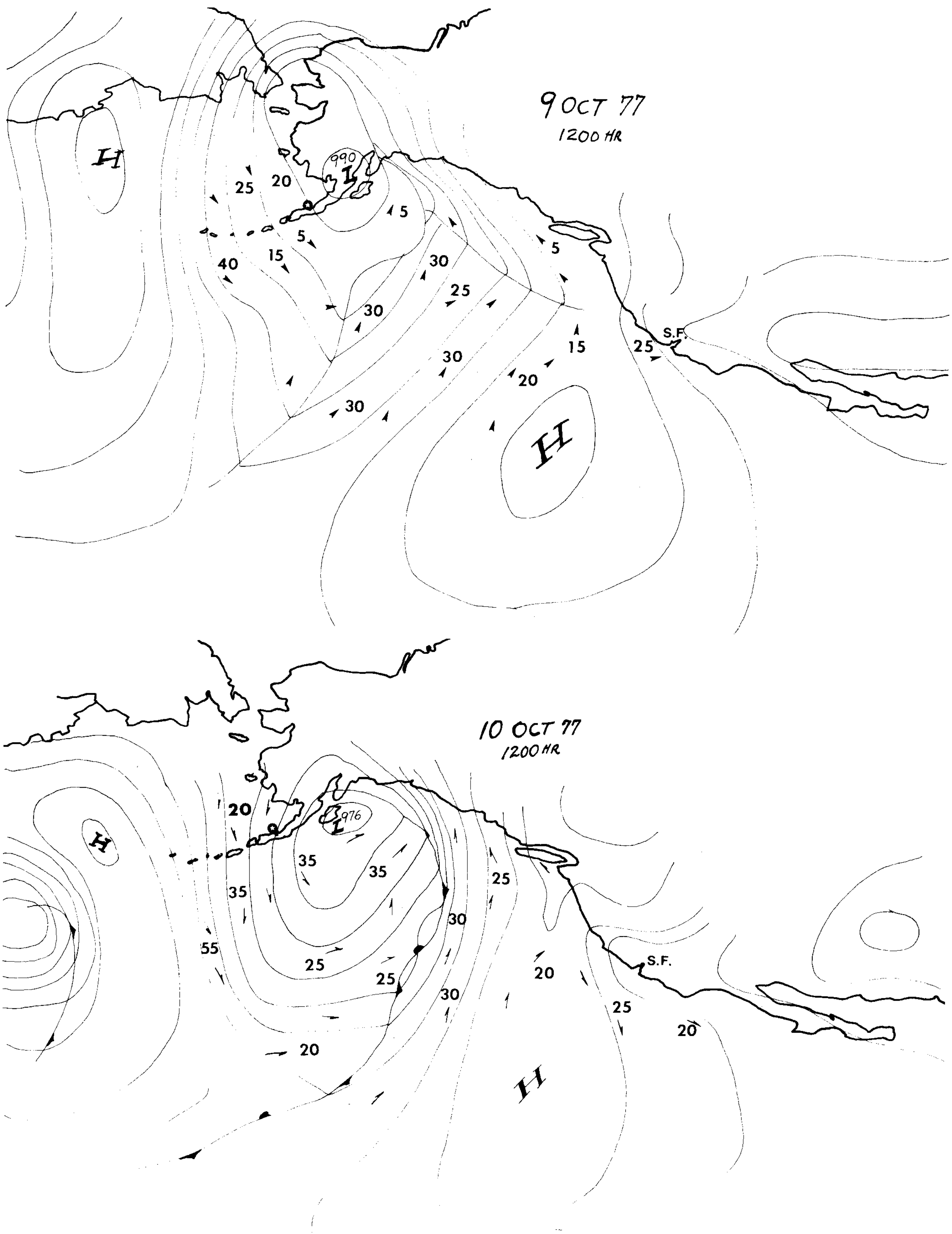


FIGURE 9.



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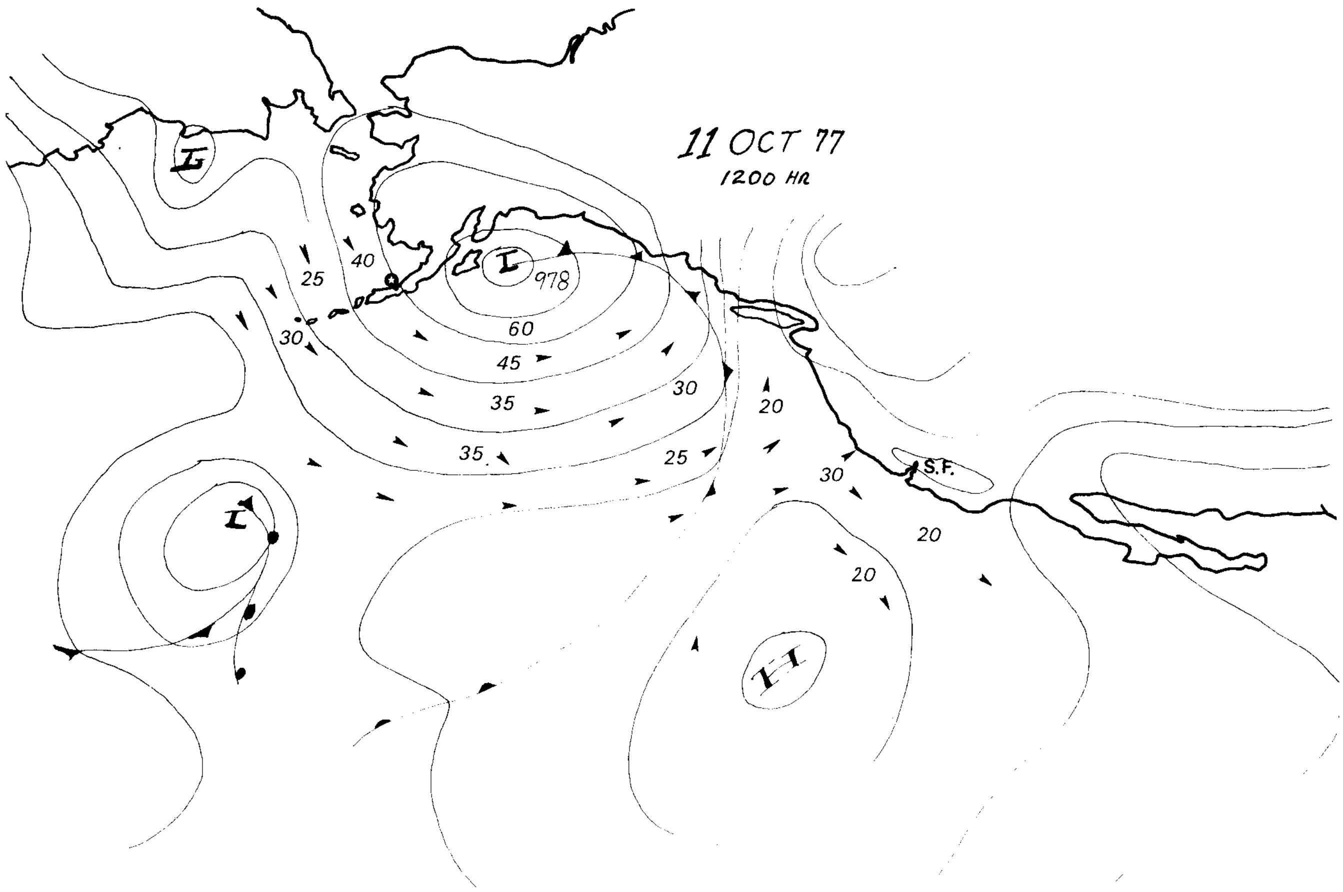
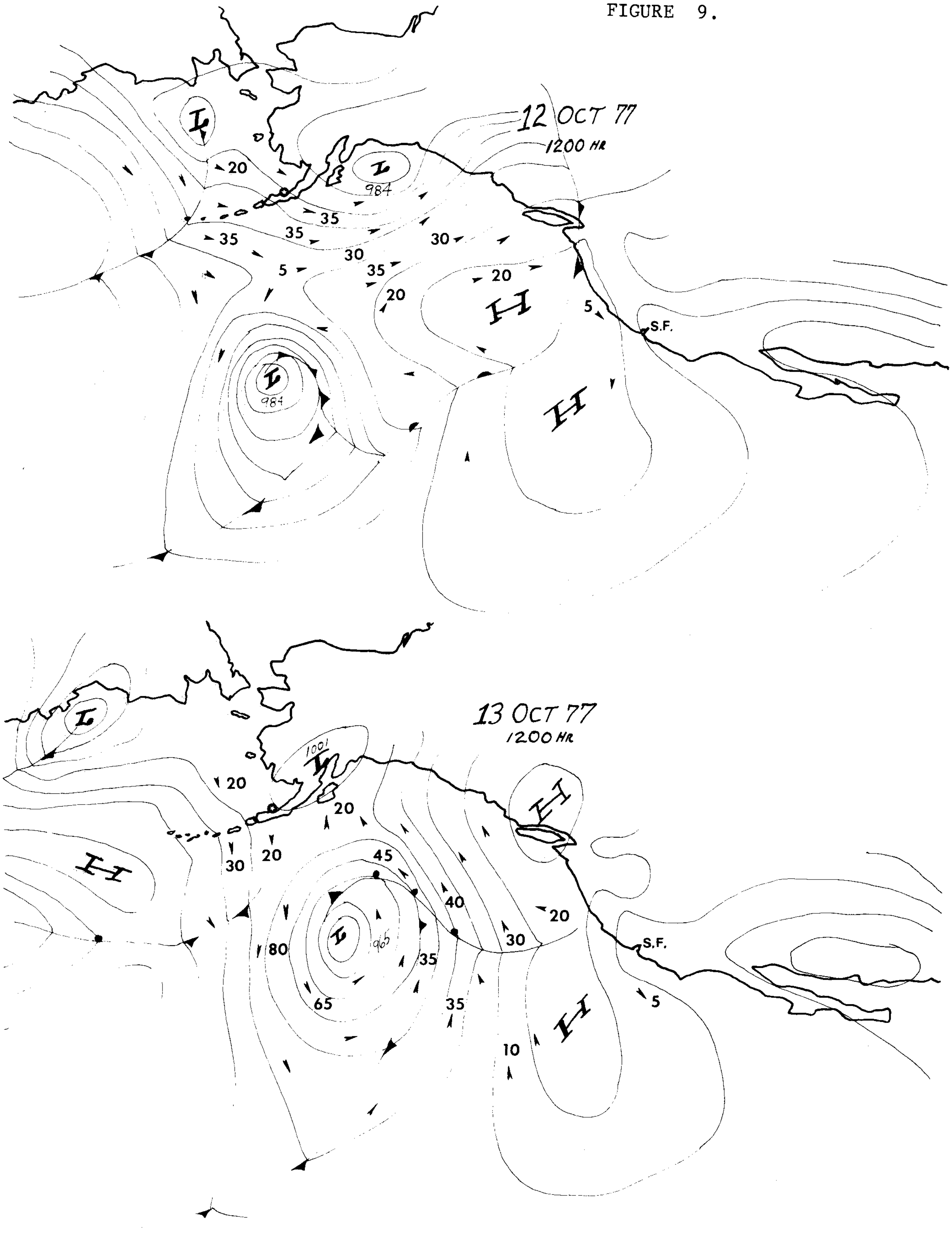


Figure 9. Weather conditions between 9-13 October 1977. We believe Dunlin departed Nelson Lagoon late on the 10th and used favorable winds through the 11th. Beginning early the 12th winds began to shift and by the 13th would have been unfavorable for any westward movement.

FIGURE 9.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APPENDIX B

The Feeding Ecology of Steller's Eiders

Abstract

The feeding ecology of Steller's Eiders (Polysticta stelleri) was studied 18 April to 15 October 1977 at Nelson Lagoon, Alaska (56°00'N, 161°10'W). Eiders fed by head dipping and upending in water 10 to 20 cm deep, and by diving in water to 6 m deep. Food items were taken from 40 mm below the substrate surface to immediately above the substrate surface. Feeding was timed with daily tidal fluctuations, with maximum feeding occurring at low tide when food items were most available. The method of feeding was dependent on the depth of the water during feeding.

Eiders fed primarily on Mytilus edulis and Anisogammarus pugettensis, although birds took small amounts of polychaetes, the isopod Saduria entomon the pelecypods Mya sp. and Macoma sp., shrimp, and gastropods. The type of food taken varied throughout the season, with 85.7% of the food in May being Anisogammarus pugettensis, with increasing amounts of Mytilus edulis and Macoma sp. taken until the flightless period in August and September. Eiders fed exclusively on Mytilus edulis or Macome sp. during the flightless period. Possibly, Steller's Eiders select pelecypods when flightless. After the flightless period, birds took all types of invertebrates available, reflecting the generally opportunistic nature of Steller's Eiders.

Margaret R. Petersen, US Fish & Wildlife Service, OBS-CE, Suite 110, 800 A Street, Anchorage, AK 99501

Presented at the Pacific Seabird Group Meeting, 19-22 January 1978, Victoria, B.C.

Introduction

The Steller's Eider (Polysticta stelleri) is a common seaduck that breeds along the coasts of Alaska and Siberia, and winters in ice free areas along the Alaskan Peninsula Aleutian Islands, and Commander Islands (Dement'ev and Gladkov 1967, Kistchinski 1973, Bellrose 1976, Johnsgard 1976, Palmer 1976). Little is known about the summer moulting concentrations of subadult and adult eiders. Most studies deal with courtship behavior (Johnsgard 1960, 1962, 1964, McKinney 1965), banding returns (Jones 1964), and foods (Cottam 1939). Nelson Lagoon is one of several lagoons along the Alaskan Peninsula where spring and fall concentrations of Steller's Eiders have been reported of up to 100,000 birds (Jones 1965). Summer concentrations of 10,000's of birds were first reported at Nelson Lagoon by Gill et al (1977); other areas along the Alaskan Peninsula may have large concentrations of eiders in the summer, although adequate survays have not been conducted.

The primary objective of this study was to determine how Steller's Eiders have adapted to a lagoon environment. Specific objectives were to 1) determine the timing of moult migration to the lagoon, 2) determine the extent of use of the lagoon by each age class and sex, 3) characterize the roosting and feeding areas utilized by the eider, and 4) determine the feeding methods and foods of Steller's Eiders.

Study Area and Methods

The study was initiated 18 April and concluded 15 October 1977, at Nelson Lagoon, Alaska. Nelson Lagoon (Fig. 1) is located on the north central Alaskan Peninsula, about 100 miles east of Cold Bay, and is part of the 540 sq. km. Port Moller-Herendeen Bay - Nelson Lagoon complex. The study was restricted to the 100 sq. km. Nelson Lagoon and adjacent barrier islands where most of the eiders are found. The tidal regime is one of 2 highs and 2 lows during each 24 hour period, with a 3.2 meter mean diurnal range. The water in the lagoon, is shallow with channels running to 10 meters deep at high tide. Substrates at Nelson Lagoon range from rock-sand intertidal to mud-sand flats, which have been previously described by Gill et al (1977).

Counts of birds were conducted at 3 week intervals from an airplane flying over the study area during the third and fifth hour of the ebb tide. Ratios of adult males to subadults were determined by ground counts. Second year males and females, and yearling males and females are lumped as subadults due to problems of seperating age classes of birds at a distance (Palmer 1976, pers. obs.). Similarly, third year males and adult males are lumped as adult males, since they are difficult to separate unless in the hand. No adult females were ever positively identified.

Feeding and roosting birds were censused every 3 days at 2 hour intervals from 0800 hours to sunset (total of 42 days). Periodic observations during the night were made with a star-light scope to determine if the birds were feeding. The age, sex, and activity of each bird was determined during each census. Feeding behavior terminology follows that of Bryant & Leng (1975).

Groups of 3 feeding birds were collected at 3 week intervals. The oesophagus, proventriculus, and gizzard of each bird was immediately injected with 10% buffered formalin after it was collected. The entire stomach was then stored in 50% alcohol for later analysis. Food data are presented as the aggregate percent volume and percent occurance (Swanson, et al 1974) for each type of food.

Results

Moult Migration and Moult - Subadults migrated to Nelson Lagoon in early May, and were present through August. Adult males began migrating to the lagoon in early August, and were present through October (Fig. 2).

Subadults peaked at 53,000 birds in August, and departed by mid-September. Adult males peaked at 54,000 birds by the end of September, and began leaving the lagoon by October. Thus, while Steller's Eiders were present in Nelson Lagoon April through October, the subadult and adult segments of the population used the lagoon during different times of the year.

Subadults moulted their flight feathers beginning 1 August, remained flightless for about 3 weeks, and left the lagoon almost immediately after they regained flight. Adult males moulted their flight feathers almost immediately after their arrival in late August, remained flightless through mid-September, and began departing the lagoon by mid- October. Although there were flightless birds in the lagoon over a 6 week period, there was little or no overlap of the timing of the subadult and adult flightless periods.

Feeding Activity - Eiders fed by diving in water to 6 meters deep, and head-dipping and up-ending in water 10 to 20 cm deep. There was no significant difference in the method as the season progressed. For those reasons, age classes and sexes of birds are lumped for each tide cycle. When feeding, eiders dived 79.5% of the time (102,656 of 129, 105 observations) and head-dipped 20.5% of the time (26,449 of 129,105 observations). Up-ending was rarely observed.

The timing of feeding by eiders was correlated with the stage of the tide; with most feeding centering around the low tide (Fig. 3). Eiders fed during the daylight hours and at night. Birds dived at any stage of the tide, but dived predominantly on a rising tide 2 to 3 hours after the low tide. Birds began head-dipping and up-ending as the tide ebbed, continued through the low tide and 2 hours after the tide flooded. Birds roosted during the high tide; generally 2 hours before the high tide and until 3 hours after high tide.

Favored roost areas of both subadults and adults were barrier islands and the lagoon spit, although sand bars subject to flooding on extreme tides were frequently used. Roost areas were adjacent to feeding areas, and birds fed as they moved off the roost areas. Roosting birds were found at or near channels, and birds were never far from "deep" water.

Foods - Pelecypoda and crusteacea were the primary foods taken by volume and by occurance during the summer (Table 1). The pelecypod Mytilus edulis was the primary invertebrate taken throughout the season, followed by grammarid amphipods. Most grammarid amphipods have been identified as Anisogammarus pugettensis. The polychaete Eteone longa was found in 71% of all stomachs, but only comprised 5% of the volume.

The aggregrate percent volume of pelecypods and amphipods taken by eiders changed as the season progressed (Fig. 4), with the amount of pelecypods (primarily Mytilus edulis) increasing until July, and the amount of amphipods decreasing until August. During the flightless period (August through mid-September), eiders took only pelecypods, and did not resume taking amphipods until after the flightless period. The average length of Mytilus edulis taken by eiders increased significantly until August (F= 50.669, P= 0.000) when average lengths of Mytilus remained around 9 mm. (Fig 5). Probably, the increasing lengths of Mytilus taken by eiders reflects the early summer growth of Mytilus. There was no consistant change in the average lengths of Mytilus from August to October, reflecting the largest average size of Mytilus Steller's Eiders take. Larger Mytilus were available and were taken throughout the study by Pacific Eiders (Somateria mollissima v-nigra), a much larger eider.

Discussion

Moult - Subadult and adult Steller's Eiders exhibit a typical moult migration pattern of migrating to a special area prior to the moult, and aggregrating in huge flocks during the flightless period as described by Salomonsen (1968). As with other eiders, Steller's Eiders are temporally segregated during the flightless period (Bellrose 1976, Johnsgard 1976, Palmer 1976). Unlike what is assumed with other eiders, subadult male and subadult female Steller's Eiders are flightless prior to the adult males, and the timing of the flightless periods do not overlap.

Possible, such segregation reduces competition for food resources, but it was not determined whether or not there were sufficient food resources at Nelson Lagoon to support both groups of flightless birds at one time. Adult males are with the breeding females until the eggs hatch, and, as suggested by Jones (1965), their timing of arrival to the moulting areas may in part reflect the timing of the breeding season, and the nesting success of breeding birds. Subadult eiders do not migrate to the breeding grounds, and their timing of migration to the moulting areas and subsequent flight feather moult may be relatively constant from year to year, and would not be influenced by the presence or absence of adult males.

Roost areas of eiders at Nelson Lagoon are normally open gravel or sand beaches and adjacent to channels, and are near feeding areas. Channels are frequently used as escape areas from avian and mammalian preadators, as well as by flightless eiders while swimming to feeding areas. Roost areas must be near feeding areas when the birds are in the primary moult, since the birds cannot fly to distant feeding areas. Possibly, the combination of open beaches, accessible escape areas, and abundant food resources are requirements of summer moulting areas for eiders.

Feeding Behavior - During the summer, Steller's Eiders take invertebrates that are abundant in the benthic and epibenthic regions of Nelson Lagoon, from 40mm below the substrate surface to immediatley above the substrate surface. Invertebrates are only available to head-dipping birds at low tide, and food organisms must be aquired by diving once the water has risen above the neck length of an eider. Birds feed when the water is shallowest during the 12 hour tide cycle; feeding when the least amount of energy need be expended to get food.

Foods - Eiders take primarily Amphipods in the early summer, pelecypods (*Mytilus edulis*) during the flightless period, and all types of available invertebrates in the late summer. Such a pattern is in part due to selection by the eiders for a particular type of food, and in part due to a variation of availability of each type of food,. Early in the summer, amphipods are the predominant food available, as *Mytilus edulis* are extremely small and unavailable in large quantities. After the *Mytilus* have grown larger, eiders take them in increasing amounts. During the flightless period, eiders apparently select *Mytilus edulis* or *Macoma* sp. as amphipods were present in the lagoon and were never found in the stomachs of flightless eiders. It should not be concluded that Steller's Eiders require pelecypods for flight feather growth, simply because that is what they take. Simmarily, whether or not eiders initiate flight feather moult in response to available necessary food is left to conjecture. After the growth of the flight feathers is completed, eiders seem to take whatever invertebrates they find, as there were wide fluctuations of the aggregrate percent of each type of invertebrates within samples of feeding birds.

Conclusions

Possibly the entire subadult segment of Steller's Eiders was in Nelson Lagoon in the summer of 1977, but to state that the observations of 1977 were "typical" of the eider, and that Nelson Lagoon is a typical feeding area could be erroneous. However, Nelson Lagoon is an important feeding area for subadult eiders during the summer, and an important moulting area for subadult and adult eiders. At Nelson Lagoon, eiders fed by diving, head-dipping, and up-ending, and feeding areas of Steller's Eiders can be characterized by 1) abundant invertebrates that are regularly available twice daily at low tide, 2) the areas used for feeding by flightless birds are within swimming distance of roost areas, and 3) the pelecypods Mytilus edulis and Macome sp. are available when eiders are moulting their flight feathers.

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Table 1.

Foods of Steller's Eiders at Nelson Lagoon -

May to October 1977

Species	Agg. %	% Occ.
Pelecypoda	50.4	96.4
Mytilus edulis	46.2	89.3
Mya sp.	trace	25.0
Macoma sp.	2.5	3.6
Clinocardium nuttallii	trace	3.6
Crustacea	41.9	78.6
Saduria entomon	trace	14.3
Crangon septemspinosa	trace	7.1
Gammarid Amphipod	40.8	75.0
Barnacle	trace	3.6
Polychaete	7.3	75.0
Eteone longa	5.0	71.4
Pectinaria sp.	2.3	17.9

N = 28 AHY birds

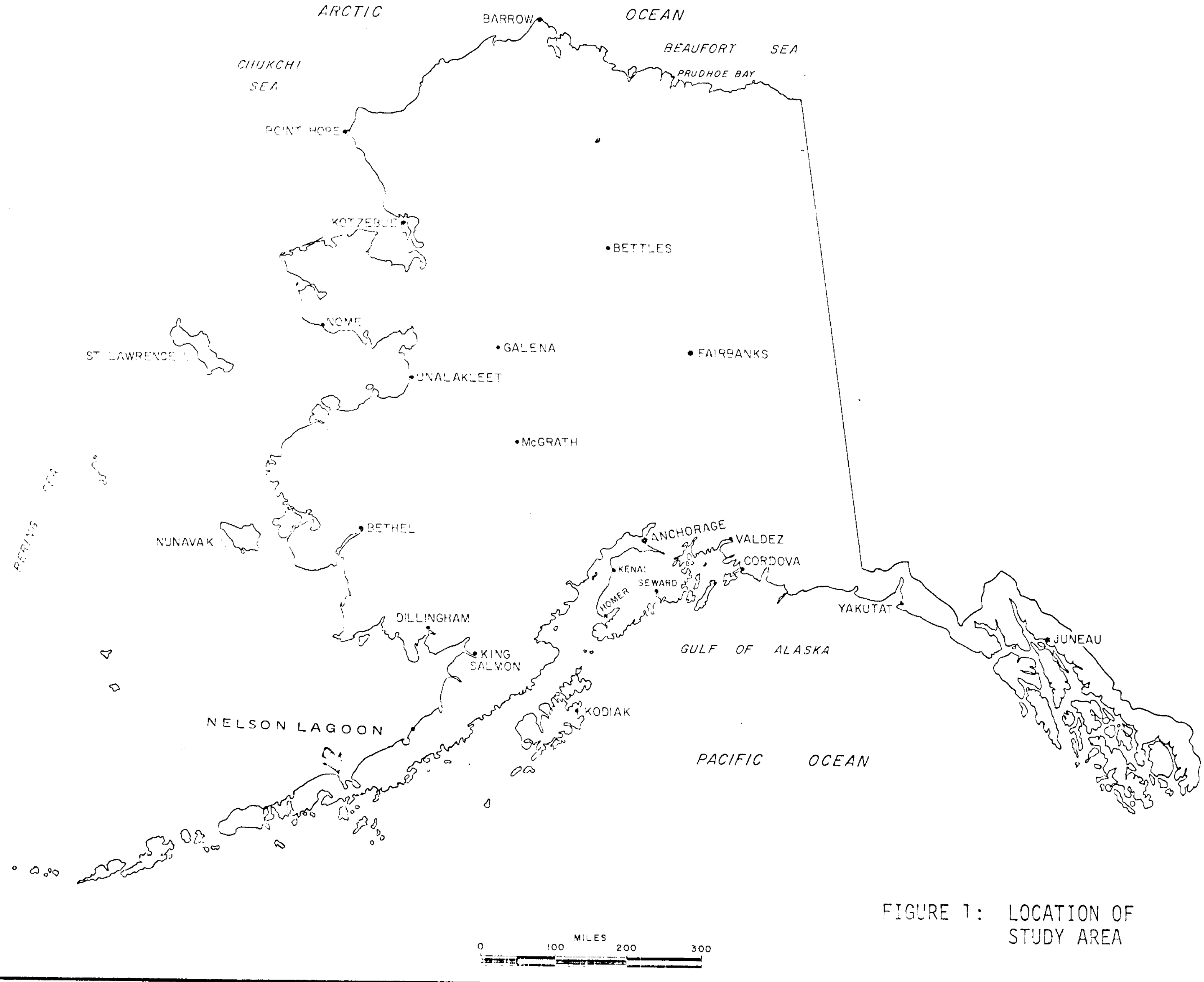


FIGURE 1: LOCATION OF STUDY AREA

Fig. 2. Numbers of subadult and adult Steller's Eiders at Nelson Lagoon.

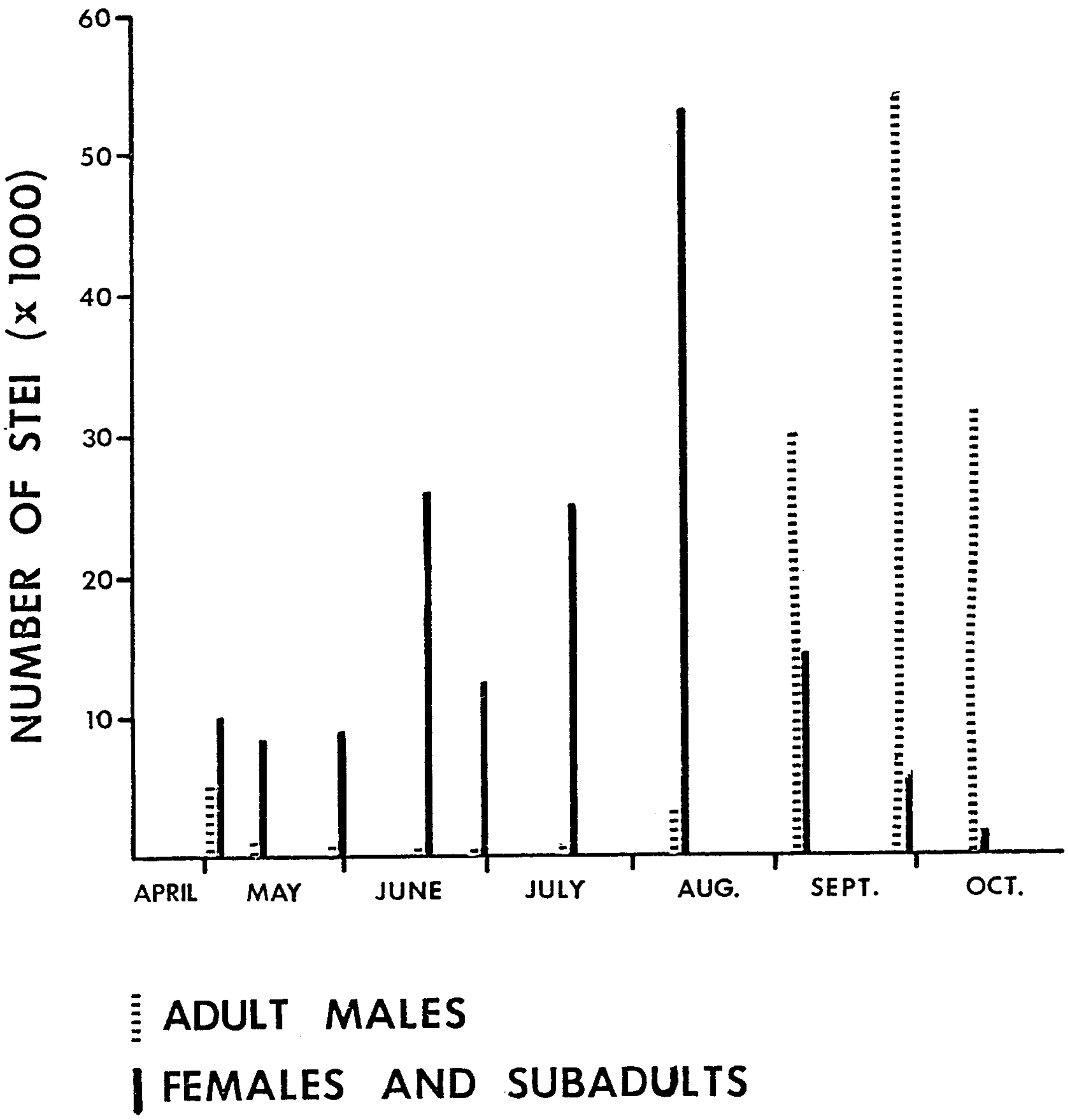


FIG. 3. ACTIVITY OF STELLER'S EIDERS AS RELATED TO TIDE STAGE

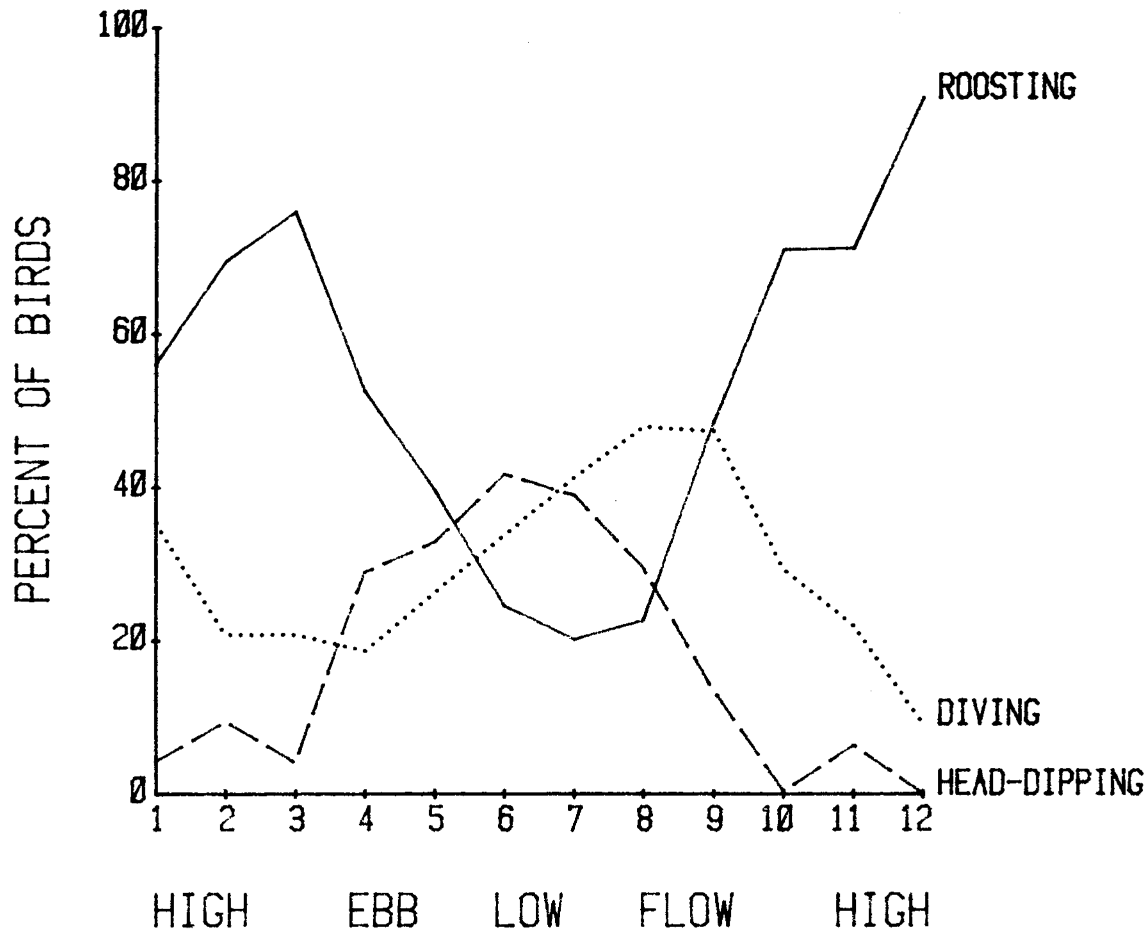
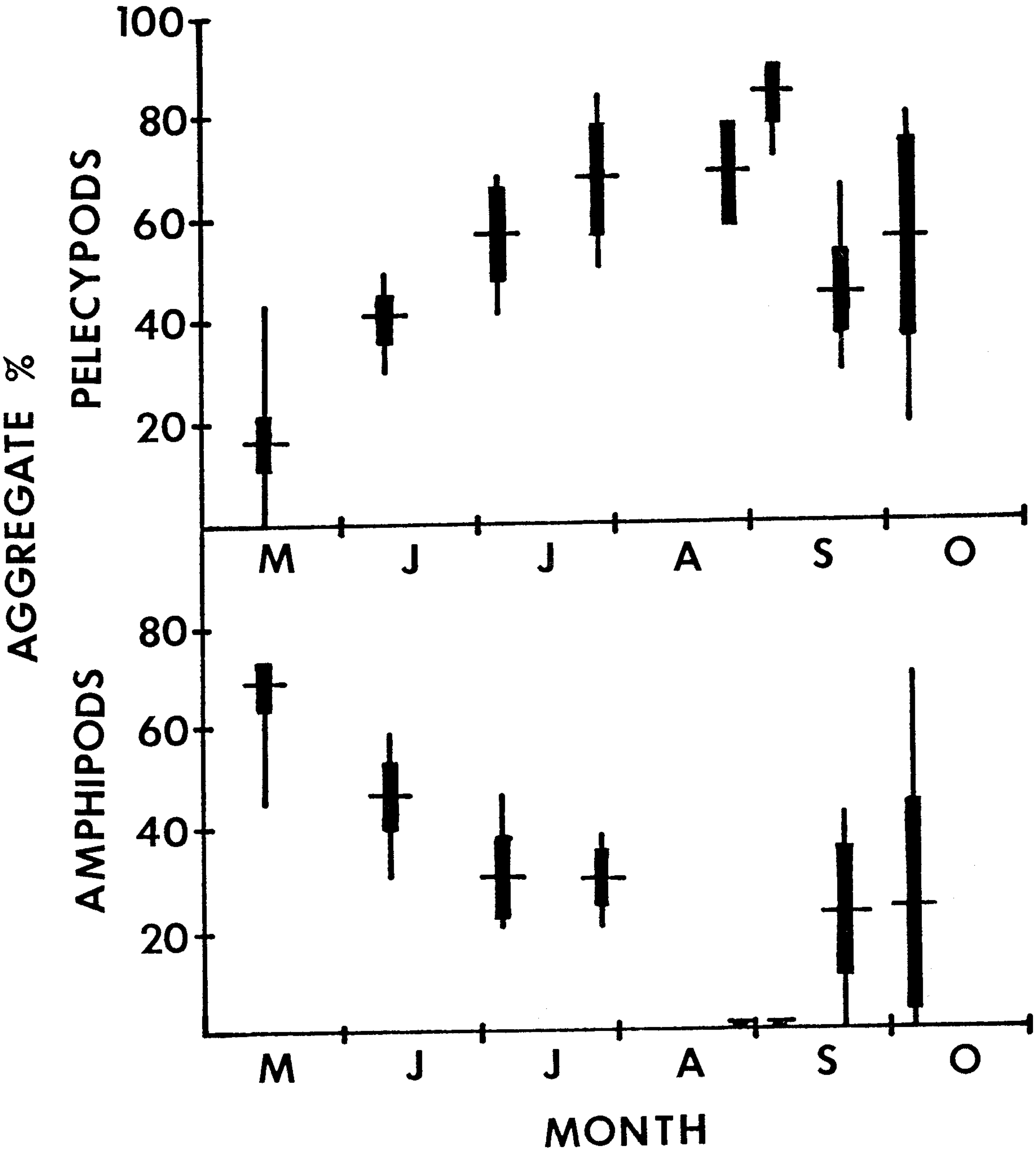
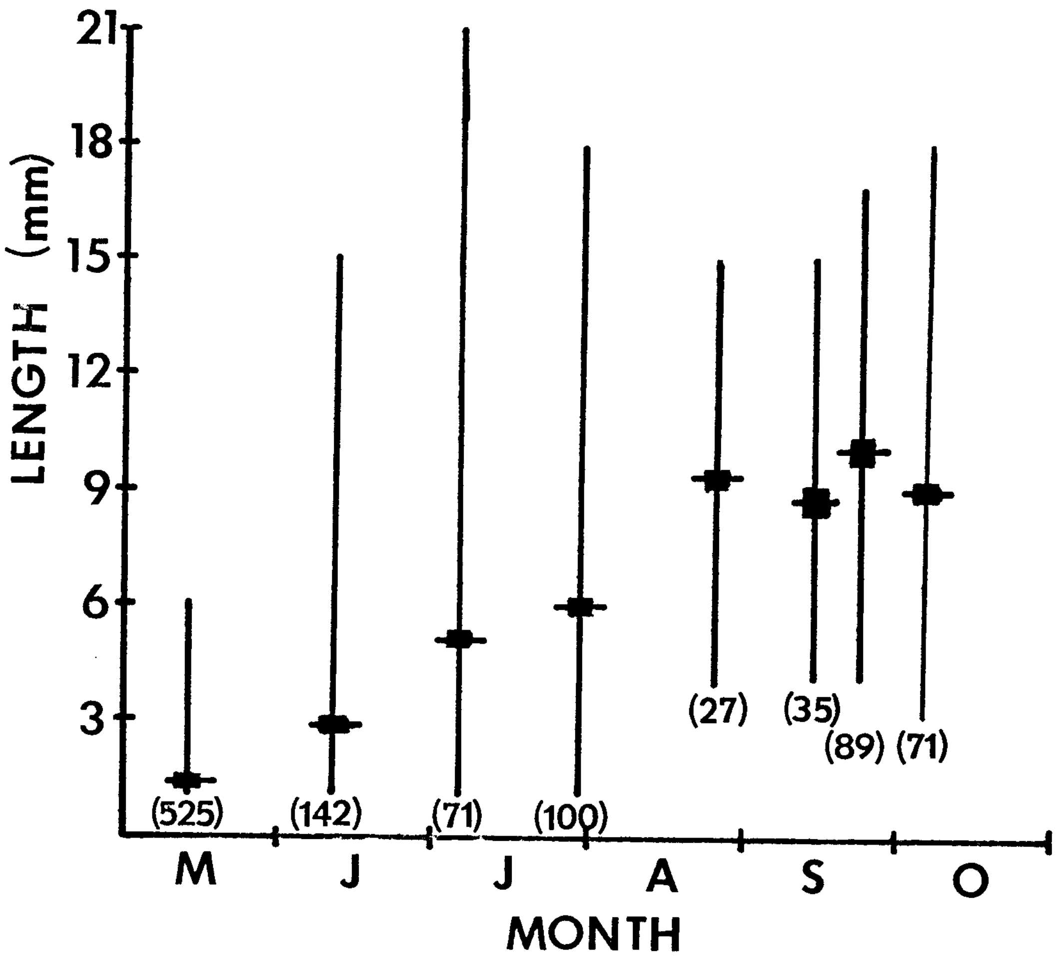


Fig. 4. Changes in foods of Steller's Eiders throughout the summer.



(range, 2 S. E., mean)

Fig. 5. Average lengths of Mytilus edulis taken by Steller's Eiders.



(range, 2 S. E., mean, no. of Mytilus edulis measured)

APPENDIX C

Unusual Nest Site Selection By Tufted Puffins

Despite the Tufted Puffin having the greatest breeding distribution of any North Pacific seabird, its nesting habitat preferences over this area are generally quite restricted. Nesting is confined to rocky oceanic islands or continental headlands where nests are placed in burrows or rocky crevices or occasionally on vegatated plateaus; all well above tidal influence. Nowhere did we find reference to Tufted Puffins nesting in an estuarine environment or substrate subject to tidal inundation.

We, here describe an instance of Tufted Puffins nesting in an estuary on substrate occasionally flooded by tides. Nesting chronology, nest site selection and nesting adaptation to this unique situation will be discussed.

During the summers of 1976-1977 we found Tufted Puffins nesting on four, narrow sand islands along the northcentral Alaska Peninsula at Nelson Lagoon (56°N, 161° 10'W). The islands lie approximately 1.3km inland from the Bering Sea and are protected from the sea by a long (5km), narrow sandspit. All islands have a uniformly low, flat profile averaging 1.5m above MHHW (mean higher-high water). The island banks have a moderate to near vertical slope. Each island is circumscribed by a gently sloping, narrow, sand/gravel beach, averaging less than 6 degree slope, which extends to broad intertidal mudflats. Beach rye grows over most of each island and is used as nesting cover by approximately 2000 pairs of Glaucous-winged Gulls and 200 pairs of Common Eiders. No foxes were evident on any of the islands used for nesting by Tufted Puffins.

The entire Lagoon breeding population of Tufted Puffins consists of between 14 - 18 pairs; hardly a major breeding colony. The 1977 nesting chronology is presented in (Figure 1). The first adult was observed on 8 May; the majority of adults arrived between 15 - 30 May. During this latter period "inspection flights" over the islands were common. Observed courtship behavior included bill clasping, both on the water and in front of burrows, and what I have labled as "false takeoffs" where one adult runs along the beach or on the water with its head lowered and copulation.

For fear of inducing abandonment, we did not check burrows for eggs until mid-July when we felt incubation was well along. At that time we found week old chicks in two burrows and warm eggs in three others. Those burrows with nesting cavities beyond our reach were not excavated to determine their status.

We banded and followed the growth of 7 chicks during 1977 (Figure 2). All chicks exhibited a rather uniform growth rate, averaging 19 grams per day. Fledging, for the 6 chicks which we assumed were successful, occurred at between 38 - 41 days and at an average weight of 585 grams. Fledging weights ranged between 520 and 625 grams. This nestling period is in contrast to the 47, 44 to 47, and 54 to 59 days reported by other investigators at colonies at similar latitudes in the Gulf of Alaska. Fledging weights of chicks at these other sites averaged between 35-50 grams less than those of Nelson Lagoon birds.

We collected no food habits information for Nelson Lagoon Puffins, so can only assume the comparatively faster growth rates and higher fledging weights of Nelson Lagoon birds were attributed to an abundant and non competelive food supply. Short-tailed shearwaters occurred occasionally throughout the summer.

When considering the possible reasons for the shorter nestling period it is also interesting to look at the relationship among burrow location, timing of fledging, and the occurrence of high tides and storm generated flood tides. The vertical tide range at Nelson Lagoon is approximately 5.4m. As a point of reference, MHHW was figured at 3.3m above 0.0 datum. The highest predicted high tides occur at 4.2m above datum. The mean burrow height was 87cm above MHHW, or at the approximate level of the highest high tides unaffected by winds or storms. During 1977, nine of 18 burrows had entrances lower than the highest predicted tides.

Generally, the highest high tides occur each year beginning late August and continue through December. This is also the period of the most frequent and severe storms which might compound tide height. Indeed, the observed storm tide line from the previous fall and winter on all the islands was well above all but two of the active burrows in 1977. Between 22 - 26 August 1977 the first in a series of potentially damaging high tides occurred at Nelson Lagoon. This series flooded 3 burrows and was probably responsible for the death of at least one chick. It was during, or shortly after, this same series of tides that at least 3 chicks are suspected of fledging. Another series of high tides, this one affected by strong NW winds, occurred between 15-19 September. We feel that at least two chicks, with 4 September weights of 520 and 570 grams and wing lengths of 139 and 138 mm, respectively, fledged just prior to this series of tides. During this series of tides the burrow of one of these chicks was buried under sand as a result of wave and wind action.

It, thus, appears that Tufted Puffins are at least marginally successful at nesting in this unusual situation due to accelerated chick growth probably associated with an abundant and non-competitive food supply; which in turn allows for a shorter nestling period. Fledging then occurs just prior to or during the first potentially destructive flood tides which occur in late August and early September each fall.

Presented by R. E. Gill, USFWS, Anchorage, AK at the 1978 PSG meeting Victoria, B.C. 19-22 January 1978.

TUPU NESTING CHRONOLOGY
NELSON LAGOON, AK - 1977

n = 14 pairs

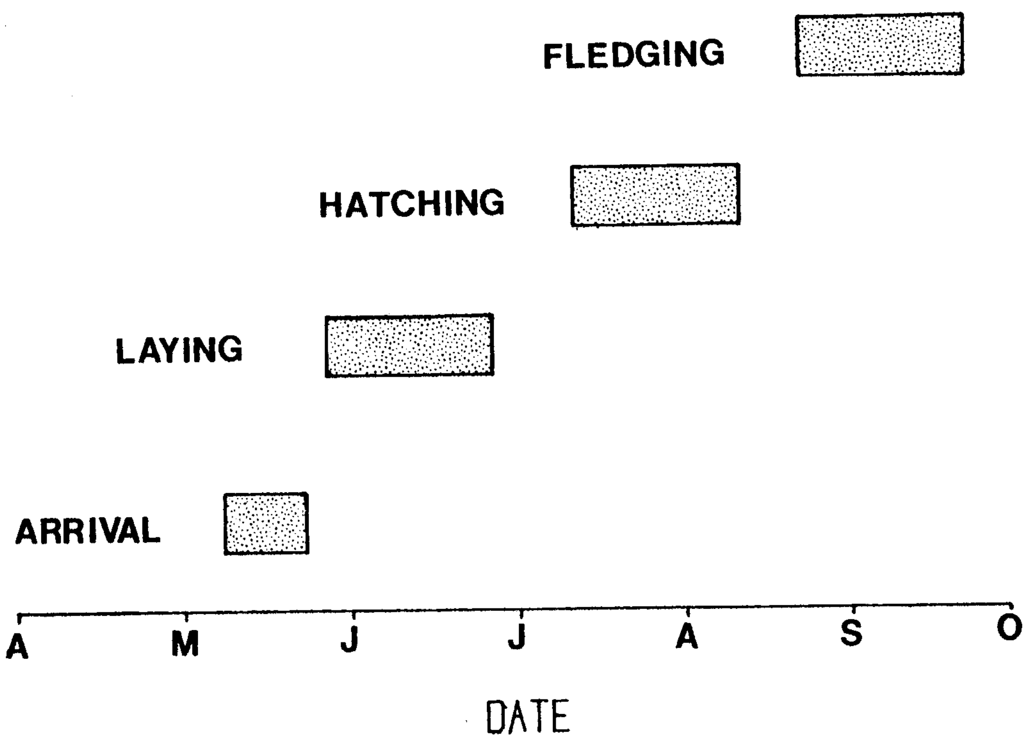
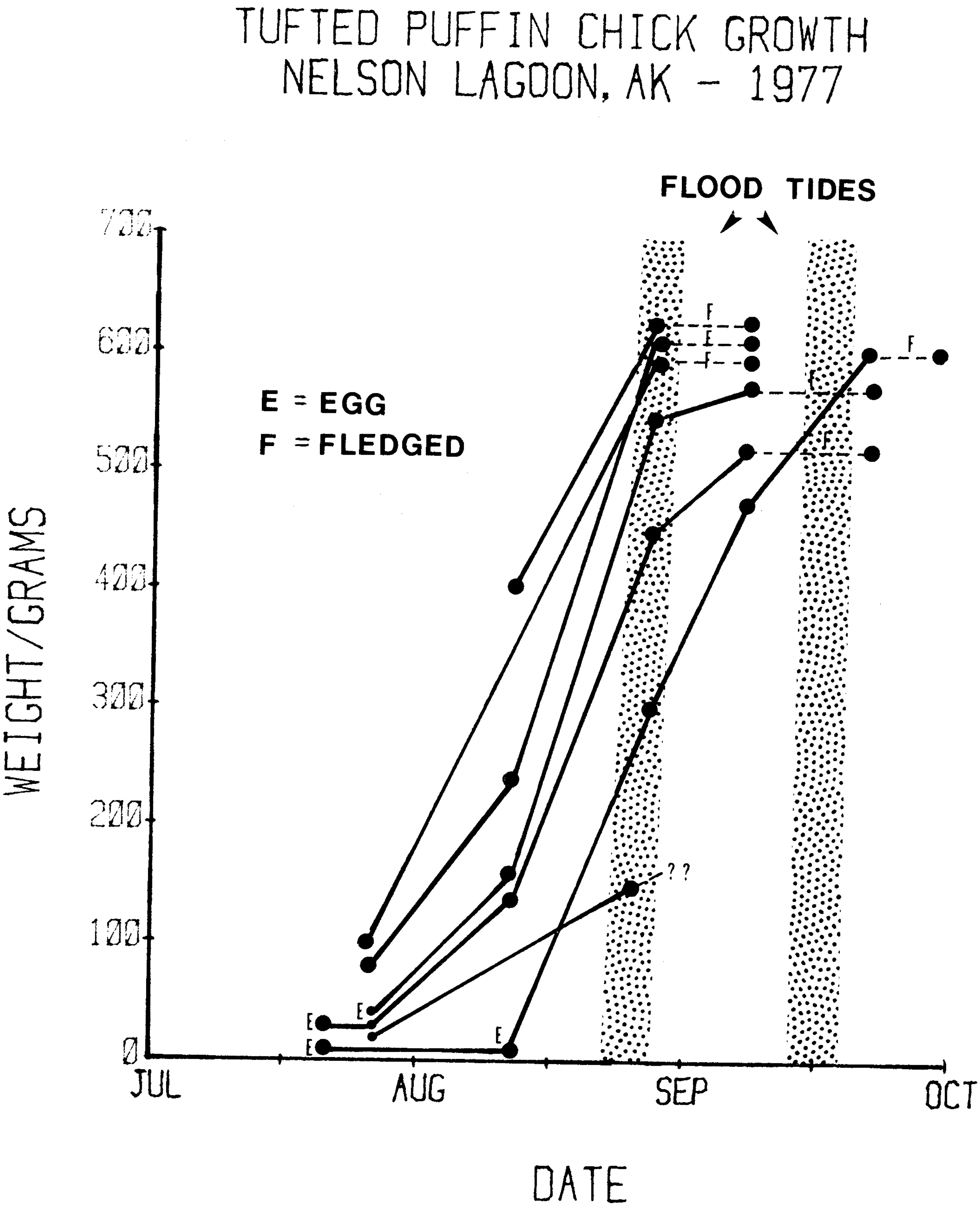


FIGURE 1.

FIGURE 2.


TUFTED PUFFIN CHICK GROWTH
NELSON LAGOON, AK - 1977
FLOOD TIDES
E = EGG
F = FLEDGED
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300
400
500
600
700
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AUG
SEP
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DATE
??

APPENDIX II

NOAA-OCSEAP Contract: 01-5-022-2538
Research Unit : 341
Principal Investigators: C. J. Lensink
K. D. Wohl
Reporting Period: April 1, 1977 to
March 31, 1978

ANNUAL REPORT

BREEDING AND POPULATION ECOLOGY OF FULMARS AT SEMIDI ISLANDS, ALASKA, WITH OBSERVATIONS ON THE REPRODUCTION OF SYMPATRIC SEABIRD SPECIES

By

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April 1, 1978

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ABSTRACT

A population of some 475,000 Northern Fulmars occupy over 40 miles of coastline at Semidi Islands during the breeding season. In 1977 egg-laying spanned the period 2-21 June, hatching occurred from 20 July - 8 August and fledging probably began about 10 September with the last young Fulmars departing during the first week in October. Nesting phenology was four days later in this year than in 1976. Reproductive success was 51 percent for 386 breeding pairs, representing more than a three-fold increase over production in the 1976 season. Associated with the higher level of breeding success were a less pronounced pre-laying exodus, shorter incubation shifts and earlier initiation of molt in unemployed birds, each of which suggests greater food availability in 1977. There appears to be a critical period around the time of egg-laying when food supply and the nutritional status of breeding birds largely determines the outcome of the season's nesting effort. Information on the foraging range and feeding areas of Fulmars breeding at Semidi Islands is needed, and could best be obtained through coordinated onshore and aerial observations. An open nesting habit, high degree of fidelity to nest-site and mate and individual variation in body color render the Fulmar at Semidi Islands uniquely suited to a study of the dynamics of population structure and productivity.

Observations on phenology and production in other seabirds breeding at Semidi Islands indicated that, for most species, the timing of breeding was very similar while reproductive success was higher in 1977 compared to the previous year.

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I. INTRODUCTION

Nineteen species of seabirds are known to breed at Semidi Islands. At least six species and one species group (Uria spp.) number over 100,000 individuals and their combined population probably exceeds 2 million birds. These species, in approximate order of abundance, are Common and Thick-billed Murres (Uria aalge and U. lomvia), Northern Fulmar (Fulmarus glacialis), Horned Puffin (Fratercula corniculata), Black-legged Kittiwake (Rissa tridactyla), Tufted Puffin (Lunda cirrhata) and Parakeet Auklet (Cyclorrhynchus psittacula). So far as is known there are no other Fulmar colonies of any consequence in the Gulf of Alaska. The principal objective of field work conducted at Semidi Islands in 1977 was a continuation of a study of the reproductive ecology of this species begun in 1976. Supplemental information on the breeding phenology and productivity of other seabird species was gathered subject to time constraints imposed by this primary activity. All data on Glaucous-winged Gulls (Larus glaucescens), kittiwakes and murres were gathered by Martha Hatch who also assisted in every aspect of the Fulmar study. Field work in 1977 began on 26 April and terminated on 1 September.

II. STUDY AREA

The Semidi Islands are located in the western Gulf of Alaska approximately 40 miles (64 km) from the nearest mainland (Figure 1). Their general physical and biological characteristics have been described previously (Troyer 1972, Hatch 1977, Leschner and Burrell 1977).

Weather data collected during the 1977 field season are summarized in Table 1.

III. METHODS

Methods of observation of Fulmars were similar in every respect to those employed in the first year of study (see Hatch 1977). The population at Semidi Islands consists of a mixture of color phases among which mating occurs indiscriminately. Fulmars occupy uniquely located nest-sites with a high degree of nest-site and mate fidelity from year to year. Therefore, the methods employed in the course of this study include the permanent identificaton of individual nest-sites in photographs and classification of the occupants as to color. These efforts were intensified in 1977 with a view to capitalize on the use of color variation as an aid to research. The sample of individually monitored nest-sites was increased to 540. In 260 of these one member of the pair is individually known while at 20 nest-sites both birds are known. In addition, it has been possible to establish the sexes within 70 mixed pairs by observing the birds in copulation during the pre-egg stage.

Methods used in gathering information on other seabirds are indicated under their respective species accounts.

IV. RESULTS 1. Northern Fulmar

Distribution and Abundance

The Semidi Islands present some 55 miles (89 km) of coastline of which approximately 43 miles (69 km) are occupied by Fulmars in greater or lesser density during spring and summer (Figures 2a and 2b). With an estimated total population of 475,000 the islands may comprise the greatest breeding aggregation of the species in its Pacific range. This figure is derived from an intensive census conducted in a 2 km study area on Chowiet Island in 1976 (Hatch 1977) and boat surveys of all the remaining coastline in 1976 and/or 1977. Since most of these surveys took place during the pre-egg stage when attendance at the colony is highly variable from day to day, estimates were based on the apparent density of nest-sites in all areas of occupied habitat rather than the actual number of birds seen. These estimates relied heavily upon the author's familiarity with the islands, the species, and its habitat acquired over the course of this study.

Phenology

Fulmars probably begin visiting their breeding sites during March or early April at Semidi Islands, although there is presently no direct information on this point. There is thus a rather protracted period of intermittent colony attendance before the onset of egg-laying during the last week of May or first week of June. In 1977 egg-laying began on 2 June, four days later than in 1976, and continued through 21 June, a period of 20 days (Figure 3). Aside from a single egg which appeared on the 25th day after the initiation of egg-laying, all eggs in the 1976 sample were also laid in a 20 day period.

Hatching this year spanned the period 20 July to 8 August. The incubation period, determined to the nearest day in 52 cases, averaged 48.4 days (S.D. 1.01, range 46-51). Since no young Fulmars had left the cliffs by 1 September fledging dates are calculated using Mougin's (1967) data on the fledging period of Atlantic Fulmar chicks ($\bar{x}$ = 53.2 days, range 49-58 days, S.D. = 2.01, n = 47). In 1977 the first chicks probably fledged at Semidi Islands on or about 10 September, the last during the first week in October. With the departure of the last chicks the breeding grounds are probably devoid of all adults and young until the following March or April.

Production

Overall reproductive success showed a better than three-fold increase in 1977 over 1976, which difference was almost entirely due to differential hatching success (Table 2, Figure 4). The extremely high rate of egg-loss during the first week or two after laying observed in 1976 was not realized in 1977 while the mortality of chicks was similar both in timing and magnitude. As in 1976, survival of chicks attaining the age of about two weeks was very high. Therefore, the figure 51 percent is considered an accurate assessment of breeding success even though field studies were discontinued before any chicks had fledged. A relatively sharp increase in chick mortality occurring soon after or associated with the act of fledging might reasonably be expected. Such mortality is rarely determinable in bird species, therefore successful breeding is generally considered to be the rearing of young to fledging.

Factors Affecting Production

The only known predators on eggs of Fulmars at Semidi Islands are Glaucous-winged Gulls and Common Ravens (*Corvus corax*). Fulmars lose eggs to gulls and ravens only to the extent they leave them unattended for short periods. A dramatic difference in the prevalence of this behavior in the two years of study accounted for the higher hatching success observed in 1977.

Infertile eggs comprised about 6 percent of the total laid in both 1976 and 1977.

Fulmar chicks are first left unattended when one to two weeks old. Gulls and ravens undoubtedly take young unattended chicks on occasion, but this seems to be uncommon and has not been actually observed. More important in 1977 was significant mortality associated with severe and persistent rainstorms during August. Thus, a few chicks were observed dead in their nests following particularly wet weather.

For reasons not outwardly apparent many chicks prove inviable despite seemingly careful brooding and favorable weather conditions. These are discovered dead in their nests within a few days after hatching. Their numbers account for the greater part of total chick mortality.

Duration of Incubation Shifts

Daily observation of mated light and dark phase birds provided data on the duration of incubation shifts (Table 3). In 1977 the sexes of 50 breeding pairs were determined in the manner previously described. Since the initial shift by known females exceeded 1 day in only 10 percent of observed cases, the sexes of individuals in an additional 151 pairs used in the table have been assigned with a high degree of confidence. Only complete shifts, i.e., those not interrupted by egg-loss or hatching, are included in the present analysis.

Each of the first three shifts by males and females alike were significantly shorter in 1977 than 1976 ($P < 0.01$, t test). For example, the length of the initial shift by males was reduced by over three days (41 percent) in 1977 as compared to 1976. In 1976 the average duration of incubation shifts in 11 pairs whose eggs survived to hatching ranged from 3.46 to 7.50 days, excluding the first brief spell by females. The mean of these values was 5.95 days which is significantly greater ($P<0.01$) than the comparable value of 4.43 days calculated from the 1977 data for 144 successful pairs. Here the comparison is based on samples of 11 and 144 pairs rather than the total number of incubation shifts recorded, thereby allowing for the likelihood that shifts are not independently variable, i.e., there are consistent individual differences.

The share of the sexes in incubation was nearly equal in 1977 (Table 4). Males assumed a somewhat greater share of the burden in 1976, especially during the first half of the incubation period.

Growth

Figure 5 and Table 5 summarize the data obtained in 1977 on nestling weight gain and growth in wing, tarsus and culmen. Nest-sites selected for growth studies were used only for this purpose and chicks were measured every other day from hatching. Measurements of nine adult females and seven adult males have been added at the end of the table for reference.

Age-weight curves for 1976 and 1977 were nearly identical. The principal difference exhibited between years was a relative lack of synchronization of individual feeding schedules in 1977 compared to 1976. In order to illustrate this, growth data have been analyzed in a manner previously described (Hatch 1977) and presented in Figure 6. On only one occasion late in the nestling period did the collective gain in weight of all chicks measured differ significantly from the value expected under the hypothesis that chicks gained or lost weight independently of one another. These results contrast with those of a similar analysis of 1976 growth data (Hatch 1977). It is concluded that those factors which operated to synchronize the food gathering activities of parents in 1976 were not manifested to the same extent in 1977.

Molt

The percentage of birds in the air undergoing primary molt was determined daily from 30 June to 3 September in 1977. Prior to mid-July the contingent of Fulmars in wing molt consists entirely of failed and non-breeding birds. A comparison between years indicates that wing molt in these groups was initiated 10 to 12 days earlier, on the average, in 1977 (Figure 7). Moreover, since breeding phenology was four days later in 1977 the difference in timing of the molt cycle was about two weeks with respect to the breeding cycle.

Nest-site Attendance

Changes in nest-site attendance over the course of the 1977 breeding season are illustrated in Figure 8. The pattern is basically similar to that observed during the 1976 season (Hatch 1977) with the highest peaks in attendance during the pre-egg stage alternating with periods of absence for several days. There was, however, a less pronounced pre-laying exodus in 1977 with birds being nearly or entirely absent from the cliffs for only two days immediately preceding the onset of egg-laying compared to a corresponding period of nine days in 1976.

On days of peak attendance in April and May approximately 75 percent of the total population of nest-site holders was present (Figure 9). No more than 40 percent of maximum possible attendance was observed during the remainder of the breeding season (Figure 10). Daily attendance during the incubation and chick-rearing phases of the breeding cycle exhibited far less variability in 1977 than 1976, a reflection of the fact that birds actively engaged in breeding comprised a much larger segment of the population present at the cliffs throughout the season.

In Figure 11 the attendance patterns of unsuccessful breeders in 1976 and 1977 are compared. In 1977 failed birds spent relatively more time at their nest-sites during the first two weeks after nest failure. Moreover, a considerable proportion of failed sites were occupied as late as 6 to 10 weeks following failure.

During the pre-egg stage pairs often spend several consecutive days together at their nest-sites (Figure 12). During June and July, however, pairs actively engaged in breeding constitute only a minor portion of the total number of pairs occupying nest-sites (Figure 13). Once chicks are several weeks old they are frequently accompanied by both parents.

The counts upon which Figure 8 is based were generally made between the hours 0900 and 1600. Eight all-day watches were conducted between 10 May and 21 August at a study plot comprising about 130 nest-sites to determine the extent of diurnal fluctuations in colony attendance. The general trend on all days but 21 August was a gradual increase in numbers over the course of the day with maximum attendance occurring in the evening (Figures 14 a - h). Minimum counts, generally those made soon after dawn, represented 60 to 80 percent of daily maxima. The wide diurnal range in nest-site attendance observed on 21 August reflects, in part, the greater mobility of parents once their chicks are well-along. But this watch was further exceptional in having followed a strong southeasterly gale on the previous day during which nearly the entire adult population had evacuated the cliffs.

Color Phases

Data on the composition of the Semidi Islands Fulmar population with respect to color phases have been derived from 215 nest-sites selected without regard to the morphology of their occupants (Table 6).

Color phase designations follow the classification scheme offered by Fisher (1939, 1952). A comparison of the observed distribution of mixed pairs with that expected under the hypothesis of non-assortive mating indicates that birds of all color phases mate indiscriminately.

Nest-site Fidelity and Breeding Status

Changes in the breeding status at 225 nest-sites observed in both 1976 and 1977 are summarized in Table 7. The proportion of sites occupied by breeding birds closely approximated two-thirds in both years. However, the 1977 breeding sites included half of the sites at which eggs were not laid in 1976. This was just offset by the conversion to non-breeding status of one fourth of the sites at which breeding took place in 1976. One would expect the proportion of breeders in a large, presumably fairly stable population to remain relatively constant from year to year. However, the above relationships were not expected based on what is known of adult mortality, duration of the pair-bond, nest-site fidelity and length of the period of immaturity in the Fulmar. Specifically, apparent recruitment to the breeding stock of 50 percent of the non-breeding nest-site holders of the previous season does not jibe with the notion that immature Fulmars occupy nest-sites for 4 to 5 years before breeding (Fisher 1952). Similarly, 23 percent failure to lay at breeding sites of the previous season is unaccountable in terms of an estimated annual adult mortality of 6 percent (Dunnet et al. 1963). The latter would affect at most 12 percent of breeding sites each year and result in non-breeding only to the extent that birds whose mates fail to return in the spring are unable to find new partners and breed in the same season.

The data in Table 7 refer only to the breeding status at selected nest-sites and do not provide a history of breeding status in individual birds. We do have some additional information afforded by the inclusion in the sample of individually known birds. Due to the relatively small sample of known individuals in the first year of study the problems raised probably cannot be satisfactorily resolved with data presently at hand. Changes of mate and nest-site occurring at greater frequency than has previously been supposed may account in large part for the discrepancies mentioned above. Thus it may be unnecessary to hypothesize considerable non-breeding among experienced breeders occurring on a regular basis. Nevertheless, there were in 1977 at least eight cases where one or both members of a non-breeding pair were known to have participated in breeding in 1976.

V. DISCUSSION AND CONCLUSIONS CONCERNING FULMAR REPRODUCTIVE ECOLOGY

Associated with a much higher level of breeding success in 1977 than in the previous year were a less pronounced pre-laying exodus, shorter incubation shifts, less variable attendance at the colony, and earlier molt in unemployed birds. In addition there was a stronger tendency for unsuccessful breeders to linger at the colony after failure. These observations, considered both individually and collectively, suggest that Fulmars were favored by a more abundant food supply or one closer at hand in 1977. Judging from the timing of nest failure in 1976 and contrasts between years in the behavior of breeding birds it is further hypothesized that Fulmars were on a higher nutritional plane at the outset of the 1977 breeding season. They therefore exhibited a stronger reproductive drive and were more tenacious of their eggs. Although predation was the immediate cause of egg loss in both years there was no noticeable difference in the level of predation pressure, i.e., the populations of gulls and ravens were unchanged. Food supply appears to exert early control over breeding success by determining the capability of adults to incubate and hatch their eggs rather than markedly affecting the growth and survival of young. The time of onset and spread of egg-laying seem to be relatively fixed. Thus there may be a critical period for two to three weeks before and after egg-laying when food supply and the physiological condition of adults largely determines the outcome of the season's nesting effort.

In contrast to the previous year there was a lack in 1977 of any striking correlation between weather and colony attendance or food gathering behavior. This may have been partly due to an actual difference in foraging behavior. Probably of greater importance, however, were the absence of a large, mobile population of unemployed birds and the comparative monotony of weather patterns in 1977.

From the fact that incubation shifts average 4 to 6 days and occasionally last up to 12 or 13 days it is clear that the potential foraging range of breeding Fulmars is very great. Studies of similarly adapted procellariids indicate that a range of 500 miles (800 km) or more is entirely possible. Breeding Manx Shearwaters (Puffinus puffinus) have been recovered from 300 to 600 miles (480 - 960 km) from their breeding grounds (Lockley 1953). This is believed to be exceptional, however, especially during the chick rearing period when an operational range of about 200 miles has been considered realistic for both Fulmars and Manx Shearwaters (Fisher 1952, Harris 1966). Even so, Serventy (1967) obtained clear evidence of food-gathering by parent Short-tailed Shearwaters (Puffinus tenuirostris) some 500-1000 miles (800 -1600 km) from their breeding grounds. Reasonable estimates of the foraging range of fulmars breeding at Semidi Islands have been portrayed in Figure 15.

This study has shed some light on the relationships between Fulmars and their food supply in the breeding season. In particular, any environmental change affecting in a substantial way the food supply or foraging patterns of Fulmars during the latter half of May and early June may be expected to have a direct and significant impact on reproduction.

VI. NEEDS FOR FURTHER STUDY

In view of the above considerations it is apparent that information on the foraging range and feeding areas of Fulmars breeding at Semidi Islands would be of particular value in assessing the possible effects of offshore petroleum development on this species. This could best be obtained through a scheme of coordinated onshore and aerial observations during the pre-egg stage. It is not unusual, when fulmars are absent from the cliffs in April and May, that scarcely a bird can be seen anywhere near the islands using a telescope from shore. Yet within a few days nearly the entire population of half a million birds are found back at their breeding sites once again.

Given this situation, transects 100 miles or more in length should be flown radially from the islands both during periods of peak attendance and periods of total absence from the cliffs for maximum effectiveness. Although there is undoubtedly a considerable population of pre-breeders which remains at sea at all times, a comparison of pelagic densities measured under these circumstances would clearly indicate whether Fulmars from Semidi Islands disperse widely or concentrate at specific feeding grounds. While foraging patterns during the pre-egg stage are probably similar to those of unemployed birds and off-duty members of breeding pairs later on, the situation at any other time in the breeding cycle would be considerably confused by the lack of mass movements of Fulmars to and from the breeding grounds.

The collection of adult Fulmars either at sea or near the breeding grounds has not proved to be very effective in the study of food habits. However, the technique of capturing and collecting regurgitations from adults returning to feed young has been successfully employed at Prince Leopold Island in the Canadian Arctic (D.N. Nettleship, pers. comm.) and this approach should be taken in further field studies at Semidi Islands.

This study has perhaps been fortunate in having encompassed an exceedingly poor year as well as what was probably a very good year with respect to environmental conditions affecting the reproductive performance of Fulmars. This comes at the sacrifice of having no clear picture of what constitutes a normal or average year. The study has been designed in such a manner that case histories of individual nest-sites compiled over several successive seasons would permit an evaluation of annual turnover of individuals on study plots, spatial variations in productivity within the colony and the effects of breeding experience on reproductive performance. The dynamics of nest-site ownership and breeding status may be very relevant from the standpoint of predicting population responses of Fulmars to environmental disturbance depending on whether these matters are largely inflexible features of the life history or subject to proximate environmental control. With information presently available such problems cannot be addressed rigorously, although there is the capability to answer these and similar questions in relatively few seasons using present techniques.

VII. RESULTS 2. Other Species

Red-faced and Pelagic Cormorants (Phalacrocorax urile and P. pelagicus)

Cormorants nested in two locations on Chowiet Island in 1977 (Figure 16). Neither of these sites was used in 1976 while two other sites occupied in that year were not colonized. On 20 May 1,310 adults and 620 nests were counted in the larger colony at the north end of the island. Approximately 5 percent (25-30 nests) of the population were Pelagic Cormorants, all of the remainder being Red-faced Cormorants. The estimated total population of the island at this time was 1,500 which represents at least a four-fold increase over the maximum number of cormorants believed to have inhabited Chowiet Island at any time in 1976. Since no other colonies of cormorants were found on any of the other islands in either year the difference is further believed to reflect considerable immigration from outside the Semidi Islands.

Study plots comprising 116 nests were established on 27 May and checked on six occasions during the nesting cycle (Table 8). Although egg-laying was not monitored, a fair idea of the timing of hatching was obtained (Figure 17) from which it is estimated that the majority of eggs were laid over a 22 day period from 25 May to 15 June. The average clutch size in 16 nests of Red-faced and Pelagic Cormorants observed just prior to hatching (25 June) was 2.88 eggs (2 one-egg clutches, 1 two-egg clutch, 10 three-egg clutches and 3 clutches of four eggs). The final visit to the colony was made on 18 August when all but a small fraction of chicks would have been too young to have fledged. In the whole colony only 15 nests, including 4 of Pelagic Comorants, were still active. Each active nest contained but one chick. Thus, total production from this colony of some 1,500 birds amounted to 15-20 young. Due to the infrequency of visits the causes of such an extremely low nesting success can only be surmised. Although the actual proportion of nests which ever contained eggs is unknown, both hatching and fledging success appeared to be very low. Nests were observed with the aid of a spotting scope from a sufficiently great distance that human disturbance was probably not significant. The colony was situated immediately adjacent to the largest colony of Glaucous-winged Gulls on the island so that the natural level of egg predation was probably high. Heavy rains in August are believed to have destroyed many nests during the chick stage.

Six pairs of Pelagic Cormorants built nests at the other colony site on the west side of Chowiet Island between 6 June and 9 July. Of these, four pairs were known certainly to have produced eggs with the first egg being laid on 12 June. Only one pair successfully hatched any of their eggs and this nest was destroyed soon afterwards.

Parasitic Jaeger (Stercorarius parasiticus)

Parasitic Jaegers first arrived on Chowiet Island on 12 May in both 1976 and 1977. The first of two eggs in one nest observed in 1976 hatched on 4 July.

The estimated total population on Chowiet in 1977 was 50 adults, most of which occupied a 50 acre (20 ha) area at the extreme northern end of the island. No nests were found in this area, but the number of recently fledged young observed about the island in August indicated that many of these birds had successfully bred. Color phases of adults ranged from very dark (about 80 percent) through intermediate (about 15 percent) to the typical light form (5 percent or less).

Glaucous-winged Gull

The total population of Glaucous-winged Gulls on Chowiet Island in May and June was estimated at 900 - 1,000 adults. Ninety nests were numbered and flagged on 20 May before any eggs had been laid in one of the larger colonies (colonies F and G of Leschner and Burrell 1977, combined). On 27 May one nest contained a full clutch of three eggs, therefore egg-laying commenced on or about 23 May. Nests were not revisited until just prior to hatching (25 June) when the average clutch size in those nests containing eggs was 2.54 (Table 9). Back-dating from the observed hatching distribution (Figure 18) indicates that egg-laying spanned a period of about 23 days from 23 May to 15 June with a peak around 4 June. Additional information gained from five visits to these nests in June and July are summarized in Table 10. A quantitative assessment of breeding success is not possible since neither the proportion of marked nests which ever contained eggs nor the survival rate of chicks after leaving the immediate area of their nests was determined. However, over the period they were observed survival of eggs and chicks appeared high, as did the number of fledged young observed about the island in August compared to the previous year.

The fate of nests in a small colony located near camp (colony A of Leschner and Burrell 1977) was followed more closely. Six 3-egg clutches were laid between 5 June and 18 June. Hatching success was 83.3 percent (15 of 18 eggs); every pair hatched at least 2 eggs. One pair raised three chicks to fledging, two pairs raised two chicks each and three pairs produced no fledged young. Fledging success of chicks was 46.7 percent. Overall breeding success (young fledged per egg laid) was 38.8 percent or 1.17 young produced per breeding pair. Breeding success of these birds was probably lowered due to frequent disturbance, especially during the chick stage. Measurements of young were taken at intervals of 3-4 days (Figure 19). When these data are compared to those obtained by Vermeer (1963) in British Columbia the following differences are noted. Five chicks at Semidi Islands gained an average of about 37 g per day between the ages of 6 and 16 days compared to an average of 28 g per day for 30 to 40 chicks in the earlier study. Also, the weights obtained for two chicks aged 26 and 27 days exceed the maximum values recorded at these ages by Vermeer in samples of 31 and 41 chicks, respectively.

Black-legged Kittiwake

Kittiwakes occupied cliffs prior to our arrival on 26 April but did not begin gathering nest material until 24 May. A study plot of 61 nests was established as they were being built. Seven of these were never completed while eggs were laid in 54 nests between 10 June and 29 June (Figure 20). Hatching spanned the period 6 - 24 July. Fledging was first observed on 15 August. By 1 September 92 percent of surviving chicks had fledged and the remaining 8 percent probably fledged by 3 September. The fledging period of 35 chicks ranged from 34 to 48 days and averaged 40.4 days. Fledging is here considered to be the initial flight from the nest although chicks frequently continue to spend some time there for several days before final departure. For this reason the apparent fledging period based on brief daily observations is likely to be somewhat overestimated.

An average of 0.70 young were raised per breeding pair (Table 11). Most egg mortality seemed to be caused by incubating birds themselves who were observed on several occasions to inadvertantly roll eggs out of their nests. Predation by gulls and ravens was probably also a factor though this was not actually observed. A minimum of 6 eggs survived the full term of incubation but failed to hatch, suggesting an infertility rate of 8-9 percent. Most chick mortality was accountable in terms of a reduction in brood size rather than nest destruction. Both chicks were successfully raised to fledging in only 2 of 25 nests which initially contained 2 young. One member of a brood seemed generally to fall out of the nest within the first half of the nestling period. Storms were not believed to have destroyed any nests. All observations of kittiwakes were made from a distance with the aid of a spotting scope, therefore human disturbance was not a factor in nesting success.

The seasonal pattern in colony attendance in kittiwakes is illustrated in Figure 21. Counts of seven study plots were made daily between 0900 and 1600 hours. While attendance during the pre-egg stage was highly variable, the total number of birds on the cliffs from the onset of egg-laying until the onset of fledging varied only between 50 and 75 percent of the maximum count for the season. These data will aid in the interpretation of population estimates of kittiwakes based on brief visits to colonies. However, the pattern itself will vary depending on the level of production in a given year.

Common Murre and Thick-billed Murre

Both murre species are abundant (est. 600,000) breeders at Semidi Islands, although Common Murres probably comprise no less than 80 percent of the population. Unless indicated otherwise the two species are not distinguished for the purposes of the present discussion.

Common Murres were believed to have begun laying on 5 June. The first murre chicks were noted on the water on 8 August and the last chicks left the cliffs on 30 August, suggesting an egg-laying period of around three weeks. Fledging appeared to be at its peak around 15 August. Breeding phenology was known precisely for one pair of Thick-billed Murres. The egg was laid on 12 June, hatching occurred on 15 July and fledging on 18 August, giving an incubation period of 33 days and a fledging period of 34 days.

No quantitative assessment of breeding success is possible except to say that production was, by all appearances, substantially higher in 1977 than in the previous year.

Daily counts of murres on 10 study plots were made between 0900 and 1600 hours throughout the season (Figure 22). Colony attendance of murres exhibits a good deal of variability throughout the breeding season and is especially responsive to prevailing weather conditions. During the period when murres were occupied with incubation and the rearing of chicks, the three days with lowest attendance coincided with strong southeasterly gales. Attendance rebounded to peak levels on each of the three days following these storms.

Figure 22 shows that virtually all adult murres had left the cliffs by 1 September. Similar counts of murres made in 1976 showed a decline in numbers nearly identical in timing to that observed in 1977. Since murres were believed to have begun laying on or about 6 June in 1976 it appears that breeding phenology was very similar in the two years.

The diurnal pattern of colony attendance on seven days from 10 May to 21 August is illustrated in Figure 23. The number of murres on the cliffs generally rose by 20 - 30 percent in the early morning, underwent a similar decline at dusk, but remained fairly constant throughout the better part of the day.

Parakeet Auklet

Parakeet Auklets were present at their colonies upon our arrival on 26 April. Counts of auklets on the water were made daily from the same location between 0700 and 0900 hours (Figure 24). Although the breeding status of these birds is uncertain, such counts must frequently form the basis of population estimates in this species. Therefore, it is important to note the degree of variability in colony attendance.

Virtually all adults and presumably all young had left the vicinity of Semidi Islands by 7 August.

Least Auklet (*Aethia pusilla*)

Leschner and Burrell (1977) confirmed the existence of a small breeding colony of Least Auklets on Chowiet Island in 1976. Auklets were first noted in the same location on 21 May in 1977. A maximum of 13 individuals was recorded in daily observations. Least Auklets were last seen on 19 July.

Rhinoceros Auklet (*Cerorhinca monocerata*)

Data on phenology and production of Rhinoceros Auklets were obtained in the largest of three colonies of this species on Chowiet Island (colony 1, sub-colony 2 described by Leschner and Burrell 1977). A study plot of 30 burrows was established in early May and checked on six occasions during the breeding cycle. Egg-laying is estimated to have begun about 16 May, peaked around 23 May and ended by about 10 June (Figure 25).

Only 57 percent of the burrows under study were used by breeding birds and at most 4 young may have fledged from these (Table 12). Nesting failure occurred early in the nestling stage for the most part. Of 12 known chicks 3 survived as of our last visit on 24 July with weights ranging from 122g to 166g and estimated ages of 2-3 weeks. Nine chicks died within the first 2-3 weeks of life; two disappeared while seven were found dead in their burrows. The causes of high chick mortality were unknown. Human disturbance was not believed to be an important factor due to the infrequency and timing of visits. In most cases adult auklets had never had any contact with the investigators.

Tufted Puffin

Tufted Puffins first arrived in the waters around Chowiet Island on 5 May in 1977. They were first observed landing at their nest-sites on 10 May. No further data on phenology or production were obtained.

Horned Puffin

Horned Puffins first arrived in the waters around Chowiet Island on 17 May in 1976 and 20 May in 1977. In 1977 this species was known to have begun laying at least by 12 June when one egg was seen. Thirty-seven nests were located just prior to the onset of hatching and checked at intervals of several days (Figure 26). From these data it is estimated that egg-laying began about 10 June, peaked around 18 June and was largely completed by 30 June.

Of 37 eggs monitored for hatching 25 (68 percent) eventually hatched while 12 (32 percent) did not. The majority of the latter were apparently deserted after disturbance; some may have been infertile. Too few chicks could be monitored throughout the nestling period to permit a meaningful estimate of fledging success. However, of eight chicks whose progress was followed, four were surviving when last checked on 30 August and probably fledged. One chick disppeared, one was found dead, apparently from exposure, and two chicks located within 2m of each other were found dead in their nests and partially eaten. The latter were both well-advanced, robust chicks with full stomachs which had very evidently been killed rather than simply scavenged, although the identity of the predator remains an enigma.

Series of measurements of several Horned Puffin chicks are presented in Figure 27. During the first 25 days of life chicks gained an average of about 9g body weight per day.

Daily counts of Horned Puffins on the water were made between 0700 and 0900 hours from the same location (Figure 28). Typically nesting in inaccessible crevices, this species is notoriously difficult to census. Population estimates of Horned Puffins in Alaska are often necessarily based on the number of birds seen during brief visits to colonies. Therefore, it is important to note the extreme variability in numbers which will affect the quality of these estimates.

VIII. SUMMARY AND CONCLUSIONS

Table 13 and Figure 29 summarize the data obtained in 1977 on phenology and production in various seabird species breeding at Semidi Islands. Phenology of most species was very similar in 1976 and 1977. Production was higher in 1977 in those species studied with the exception of cormorants and possibly Rhinoceros Auklets. There are indications that a seasonally variable food supply was the principal factor governing the reproductive performance of most species, which effect has been best doecumented in the case of the Fulmar.

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Table 1. Semidi Islands weather summary, May - August, 1977.

	TEMPERATURE (°C)											
	Extremes		Avg. Daily	Avg. Daily		Precipitation		Wind Direction (No. Days)				
MONTH	Max.	Min.	Max.	Min.	Mean	% Days	Total (mm)	NE	SE	SW	NW	CALM
May	11.7	-1.7	8.1	1.6	4.9	55	67	4	0	10	9	8
June	15.0	2.8	12.2	6.4	9.3	43	56	0	6	1	9	14
July	18.3	5.6	14.3	8.4	11.4	58	105	4	9	2	9	7
August	16.7	5.6	14.4	9.3	11.9	74	173	2	16	4	1	8

Table 2. Reproductive success of Fulmars at Semidi Islands, Alaska in 1976 and 1977.

	1976	1977
No. Eggs in Sample	208	386
Percentage Infertile Eggs	6.0	6.3
No. Chicks Hatched	46	267
No. Chicks Fledged	31	197
Chicks Hatched/Egg Laid	0.221	0.692
Chicks Fledged/Chicks Hatched	0.674	0.738
Chicks Fledged/Egg Laid	0.149	0.510

Table 3. Comparative data on the duration of incubation shifts of Fulmars at Semidi Islands in two years.

Duration of Shift (days)	Percentage Frequency									
	1st (F)		2nd (M)		3rd (F)		4th (M)		5th (F)	
	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977
Under 1	49	63								
1	19	28		3		7	4	5	10	3
2	8	6		15	6	11	4	6	5	13
3	13	2	3	18	10	24		22		20
4	8	< 1	5	21	16	28	15	27		33
5	2		11	15	16	17	15	21	30	15
6	2		22	9	13	10	4	11	15	9
7			8	10	13	2	12	5	25	5
8			5	2	19	< 1	12	1	5	3
9			24	4	3	< 1	15		5	< 1
10			16	1	3		12	< 1	5	
11			3			< 1	4			
12			3	< 1						
13							4			
Sample Size	53	201	37	183	31	178	26	175	20	172
Mean	1.49	0.79	7.57	4.97	5.71	3.84	6.92	4.19	5.70	4.06
Standard Error	.19	0.04	0.37	0.16	0.38	0.12	0.57	0.12	0.52	0.12

Table 3. Comparative data on the duration of incubation shifts of Fulmars at Semidi Islands in two years. (continued).

Duration of Shift (days)	Percentage Frequency									
	6th (M)		7th (F)		8th (M)		9th (F)		10th (M)	
	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977
Under 1										
1		2		3		2		2		6
2		7		4	11	6		6		6
3	13	15		18		12		13		14
4	6	23	17	30	11	22		23	50	26
5	13	31	50	19	56	25	40	26	50	24
6	13	9	8	12	22	17	60	18		17
7	31	8	8	9		8		9		2
8		3	17	2		3		3		3
9	19			1		1		1		1
10	6	<1		<1						
11		<1		<1						
12										
13										
Sample Size	16	169	12	164	9	155	5	148	2	133
Mean	6.50	4.58	5.58	4.57	4.78	4.88	5.60	4.74	4.50	4.37
Standard Error	.53	0.13	0.40	0.14	0.40	0.13	0.24	0.13	0.50	0.14

Table 3. Comparative data on the duration of incubation shifts of Fulmars at Semidi Islands in two years. (continued)

Duration of Shift (days)	Percentage Frequency									
	11th (F)		12th (M)		13th (F)		14th (M)		15th (F)	
	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977
Under 1										
1	50	7		5		8		10		14
2		8		10		22		33		36
3		25	100	26		35	100	27		29
4	50	28		28	100	15		12		21
5		18		20		10		3		
6		13		7		3				
7		1		2		5				
8				1		2				
9		1		1						
10										
11										
12										
13										
Sample Size	2	112	2	87	1	60	1	30	0	14
Mean	2.50	3.88	3.00	3.90	-	3.35	-	2.83	-	2.57
Standard Error	1.50	0.14	0	0.16	-	0.21	-	0.20	-	0.27

Table 4. Mean duration (in days) of incubation shifts of male and female Fulmars, Semidi Islands, Alaska.

	MALES	FEMALES
1976	6.44	5.65
1977	4.38	4.22

Table 5. Growth of Fulmar Chicks, Semidi Islands, 1977.

Age (days)	N	Weight (g)		Wing (mm)		Total Tarsus (mm)		Culmen (mm)	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
0	14	65	57-69	24	22-26	25	24-26	19.9	18.8-21.2
1-2	38	82	69-106	25	23-27	26	25-28	20.0	18.3-21.4
3-4	38	108	70-141	27	24-30	28	26-31	20.7	18.7-22.6
5-6	39	142	102-192	29	25-33	30	27-33	21.7	20.2-23.9
7-8	37	172	89-260	32	26-37	33	30-36	22.8	20.8-25.2
9-10	37	206	130-320	36	28-43	36	31-40	24.0	21.4-26.8
11-12	37	238	156-335	40	31-46	38	33-43	24.8	21.8-28.0
13-14	37	283	167-405	44	33-55	40	34-45	25.7	22.7-29.2
15-16	37	339	168-485	50	36-63	42	36-48	26.8	23.8-30.7
17-18	37	398	211-550	56	40-73	44	38-50	27.7	24.9-31.8
19-20	37	448	238-610	66	44-84	47	40-53	28.7	25.8-31.8
21-22	37	506	290-670	76	49-102	49	42-55	30.0	26.3-34.7
23-24	37	584	325-710	89	57-120	51	45-56	31.0	27.9-35.5
25-26	36	633	410-790	103	65-133	53	47-58	32.1	28.7-36.3
27-28	36	682	455-870	117	75-152	55	49-59	33.1	29.6-37.5
29-30	34	748	510-965	133	90-166	56	51-61	34.0	30.4-38.0
31-32	30	791	575-935	146	110-176	57	52-61	34.7	31.8-38.7

(continued)

Table 5. Growth of Fulmar Chicks, Semidi Islands, 1977. (continued)

Age (days)	N	Weight (g)		Wing (mm)		Total Tarsus (mm)		Culmen (mm)	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
33-34	22	828	695-1075	159	122-183	58	53-63	35.3	32.1-38.6
35-36	16	838	675-990	170	138-194	58	54-62	36.1	33.4-38.9
37-38	8	854	725-995	179	155-200	59	54-63	35.7	33.5-39.4
39-40	4	858	765-1000	198	192-207	60	57-61	35.7	33.8-39.8
41-42	3	878	770-935	207	200-219	60	57-62	36.5	34.4-40.0
43-44	1	790	-	228	-	57	-	34.5	-
45-46	1	820	-	235	-	57	-	34.9	-
Adult Males	7	654	610-710	320	310-325*	63	62-65*	39.2	38.3-41.2
Adult Females	9	576	520-650	302	280-320*	58	57-59*	36.3	35.0-37.9

*Sample sizes are 5 males and 7 females.

Table 6. Color phase composition of the Semidi Islands Fulmar population with a test for nonassortive mating.

Color phase Designation	DD	D	L	LL	TOTAL
No.	346	22	46	16	430 (215 pairs)
%	80.5	5.1	10.7	3.7	100

Possible Pairs	Expected Occurrence Under Random Mating		Observed Occurrence
	Proportion	x215	
DD/DD	0.648	139	137
DD/L	0.172	37	40
DD/D	0.082	17	17
DD/LL	0.060	13	15
L/L	0.011	2	2
L/D	0.011	2	1
L/LL	0.008	2	1
D/D	0.005	1	0
D/LL	0.004	1	2
LL/LL	0.001	0.2	0

$$X^2 = \sum \frac{(\text{observed}-\text{expected})^2}{\text{expected}} = 3.78 \text{ (N.S.)}$$

Table 7. Breeding status at 225 Fulmar nest-sites observed in 1976 and 1977 at Semidi Islands, Alaska.

Category	Number	Percent
Breeding sites, 1976	150	66.7
Nonbreeding sites, 1976	75	33.3
1976 breeding sites converted to nonbreeding status in 1977	35	23.3
1976 nonbreeding sites converted to breeding status in 1977	37	49.3
Breeding sites, 1977	152	67.6
Nonbreeding sites, 1977	73	32.4

Table 8. Observations on the productivity of Red-faced (RFC) and Pelagic (PC) Cormorants, Semidi Islands, 1977.

	No. Apparently Active Nests			
	Study Plots		Whole Colony	
DATE	RFC	PC	RFC	PC
27 May	110	6	c.600	c.30
25 June	47	6		
30 June	36	6		
4 July	22	6		
8 July	17	6	75	25
14 July	9	5		
18 August	3	4	15 Total	
No. Chicks Fledged per Nest Started	0.03	0.67	0.024	

Table 9. Clutch sizes observed just prior to hatching (25 June) and initial brood sizes of Glaucous-winged Gulls, Semidi Islands, 1977.

	No. Eggs	No. Clutches	No. Chicks	No. Broods
	1	6	1	9
	2	17	2	19
	3	40	3	32
Total	160	63	143	60

Mean Clutch Size - 2.54 eggs
Mean Initial Brood Size - 2.38 chicks

Table 10. Summary of Observations on the productivity of Glaucous-winged Gulls, Semidi Islands, 1977.

	No.	Percent
Nests Marked during Pre-Egg Stage	90	100
Nests containing eggs just prior to Hatching, 25 June	63	70
Nests Hatching one or more Young	60	66.7
Total Eggs, 25 June	160	100
Eggs Eventually Hatched	143	89.4
Eggs Disappeared before Hatching	9	5.6
Addled Eggs	5	3.1
Eggs Found Cold	1	0.6
Died during Hatching	2	1.3

Table 11. Productivity of Black-legged Kittiwakes, Semidi Islands, 1977.

Eggs Laid		Eggs Hatched		Chicks Fledged	
No.	No. Nests (n=61)	No.	No. Nests (n=54)	No.	No. Nests (n=39)
0	7	0	15	0	3
1	20	1	14	1	34
2	34	2	25	2	2
3	0	3	0	3	0

Average Clutch Size - 1.63 eggs

Hatching Success of Known Eggs - 64/88 = 72.7%

Fledging Success of Known Chicks - 38/64 = 59.4%

Young Fledged Per Egg Laid - 0.43

Young Fledged per Nest with Eggs - 0.70

Young Fledged per Nest Started - 0.62

Table 12. Observations on the Productivity of Rhinoceros Auklets, Semidi Islands, 1977.

Total Breeding Population in Colony 1/	- 219 pairs
No. Burrows in Study Plot	- 30
Proportion of Burrows known to be Active (Eggs Laid)	- 17/30 = 57%
Hatching Success of Known Eggs 2/	- 13/17 = 76%
Maximum possible Fledging Success of Known Chicks	- 3/12 = 25%
Probable Breeding Success	- 3/17 = 18%
Maximum Possible Breeding Success	- 4/17 = 24%

1/Leschner and Burrell (1977)
2/Assuming one egg last checked 24 July eventually hatched.

Table 13. Summary of data collected on phenology and production in various seabird species, Semidi Islands 1977.

Species	Population 1/	First Arrival	Departure	Egg-Laying	Avg Clutch Size	REPRODUCTIVE SUCCESS: Eggs Hatched/Eggs Laid	Chicks Fledged/Chicks Hatched	Chicks Fledged/Eggs Laid	Chicks Hatched/Nests Started 2/	Chicks Fledged/Nest Started 2/
Northern Fulmar	475,000			2 June - 21 June		0.692	0.738	0.510		
Cormorants	1,500			27 May - 15 June	2.88					0.024
Parasitic Jaeger	50*	12 May								
Glaucous-winged Gull	1,000*			23 May - 18 June	2.54				1.60	
Black-legged Kittiwake	260,000			10 June - 29 June	1.63	0.727	0.594	0.430		
Murres	600,000		Most by 30 Aug.	5 June - 26 June						
Parakeet Auklet	58,000		All by 7 Aug.							
Least Auklet	15*	21 May	All by 19 July							
Rhinoceros Auklet	800*			16 May - 10 June		0.76	0.25	0.18		
Tufted Puffin	Several 100,000's	5 May								
Horned Puffin	Several 100,000's	20 May		10 June - 28 June						

1/ Figures marked (*) are for Chowiet Island only; otherwise total populations are estimated for Semidi Islands. Data from personal observations and/or Leschner and Burrell (1977).

2/ Actual proportion of nests which ever contained eggs is unknown.

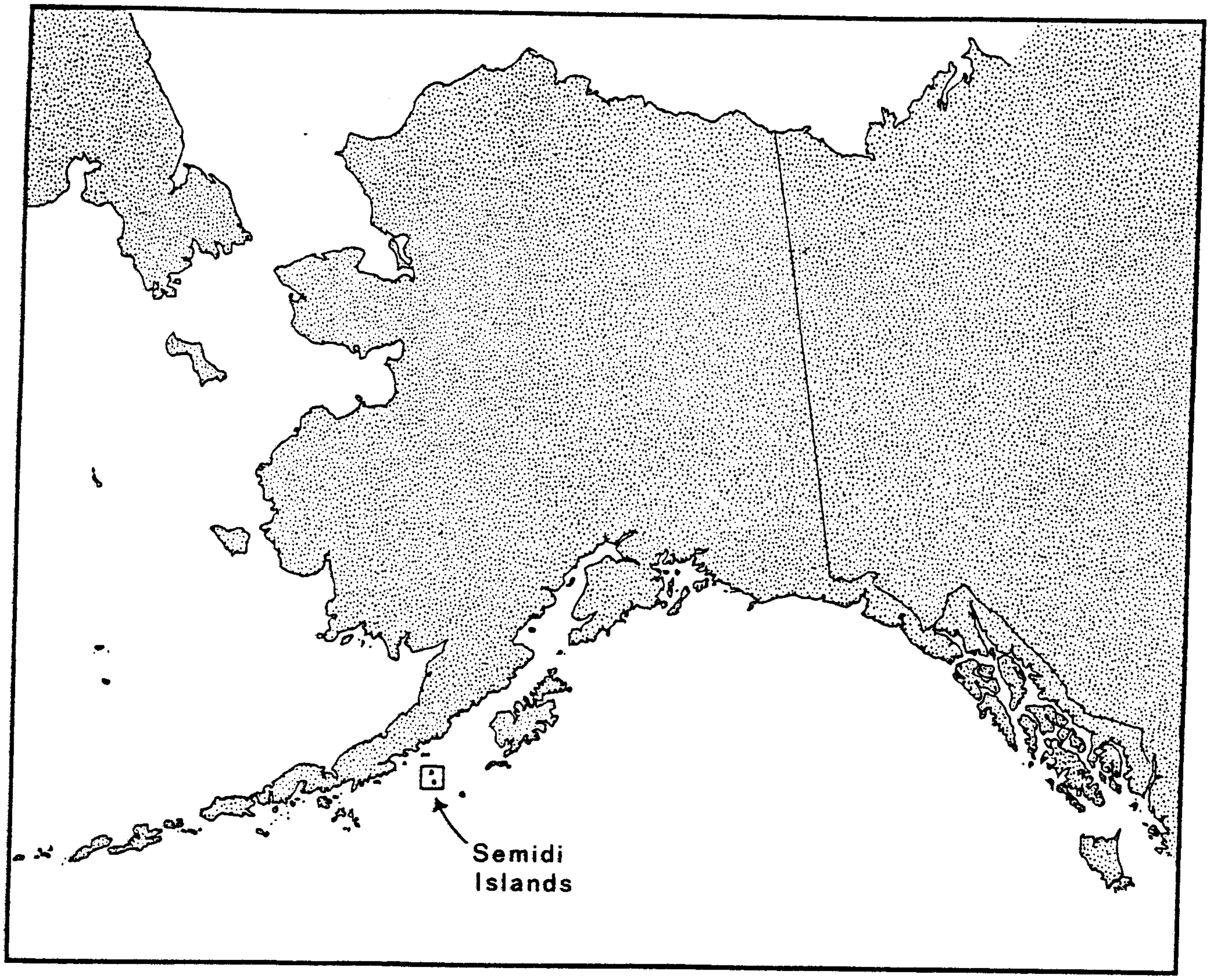

Figure 1. Location of the Semidi Islands in the western Gulf of Alaska.

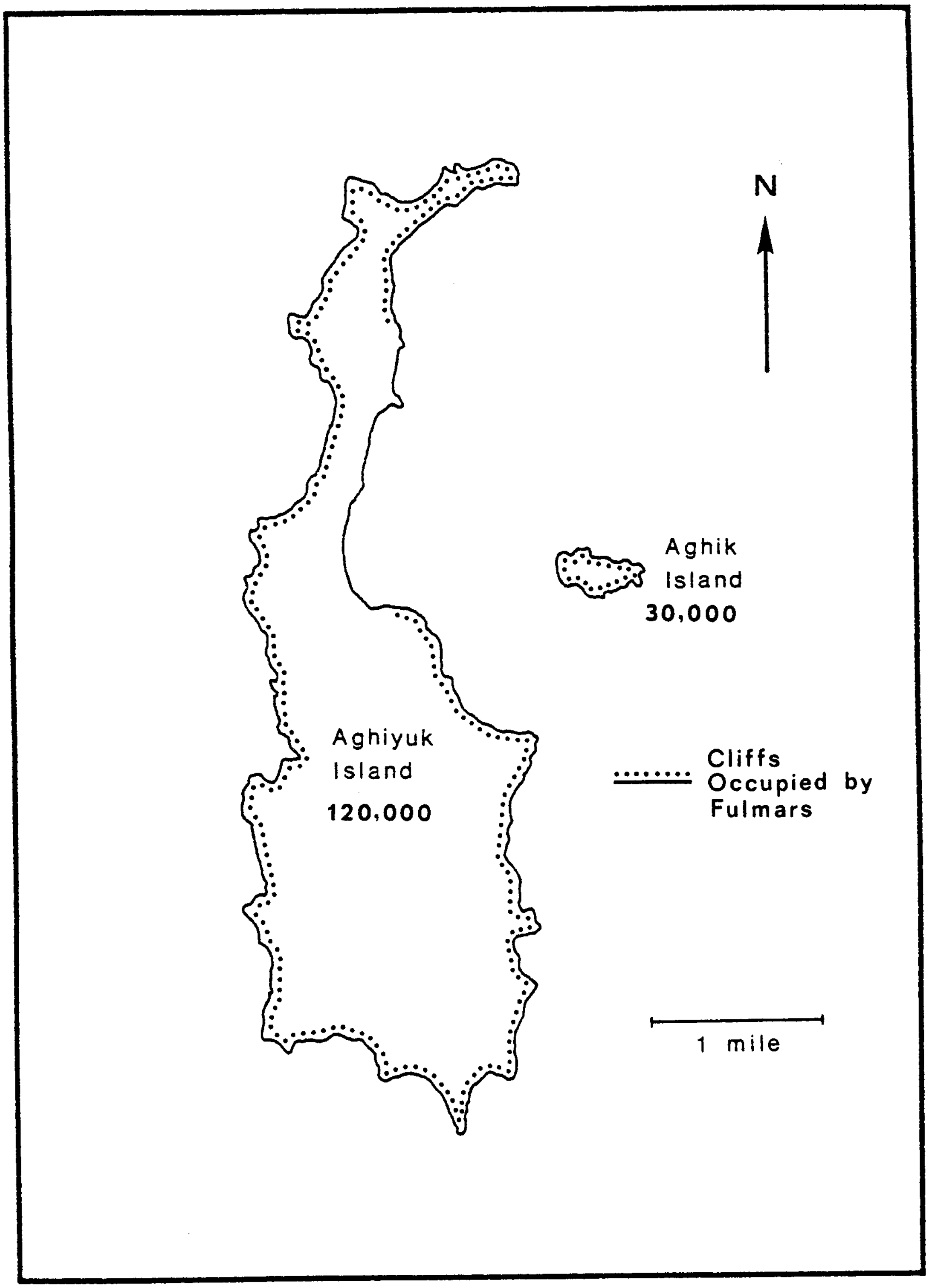

Figure 2a. Distribution and abundance of Fulmars at Semidi Islands, Alaska.

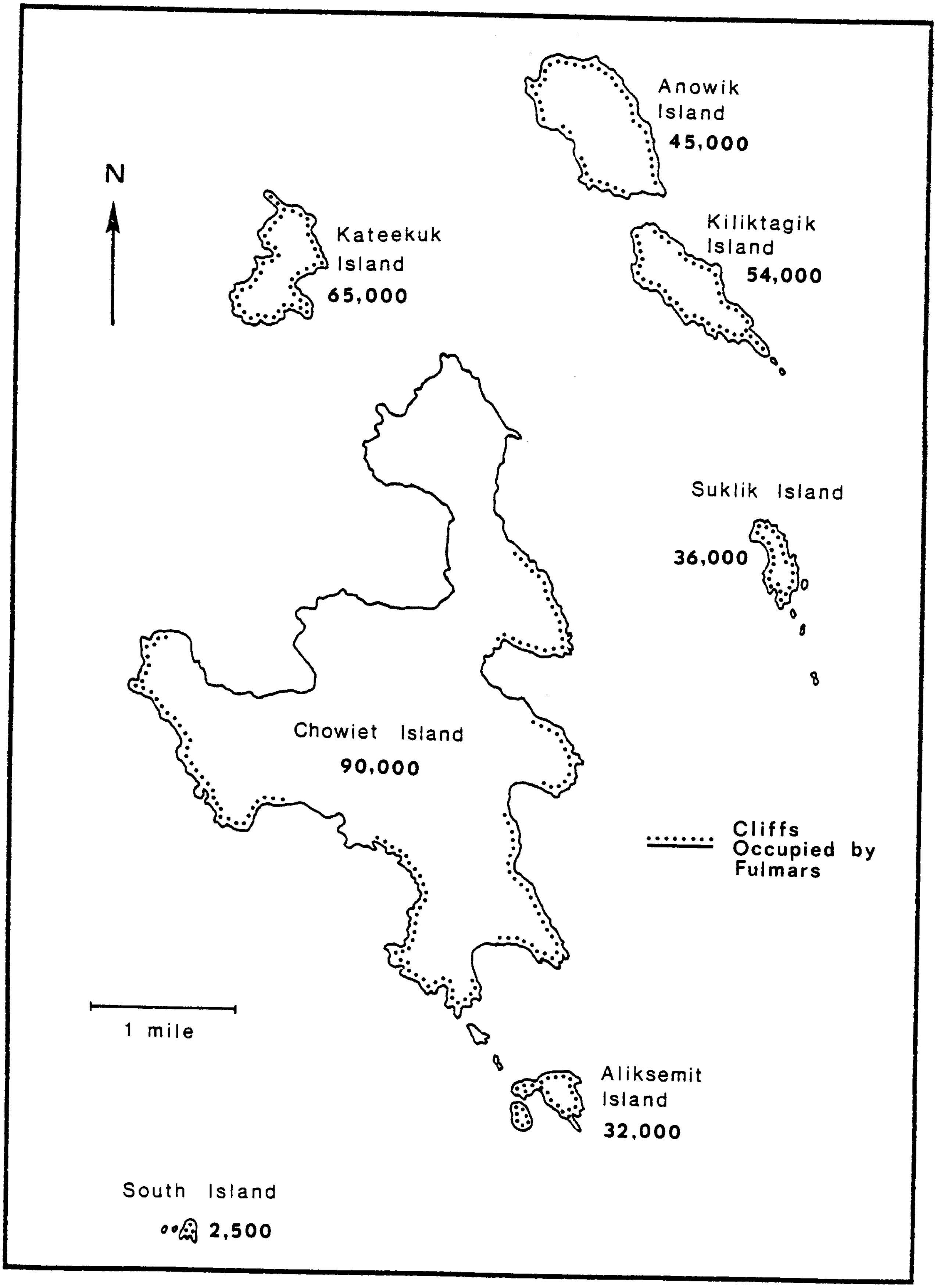

Figure 2b. Distribution and abundance of Fulmars at Semidi Islands, Alaska.

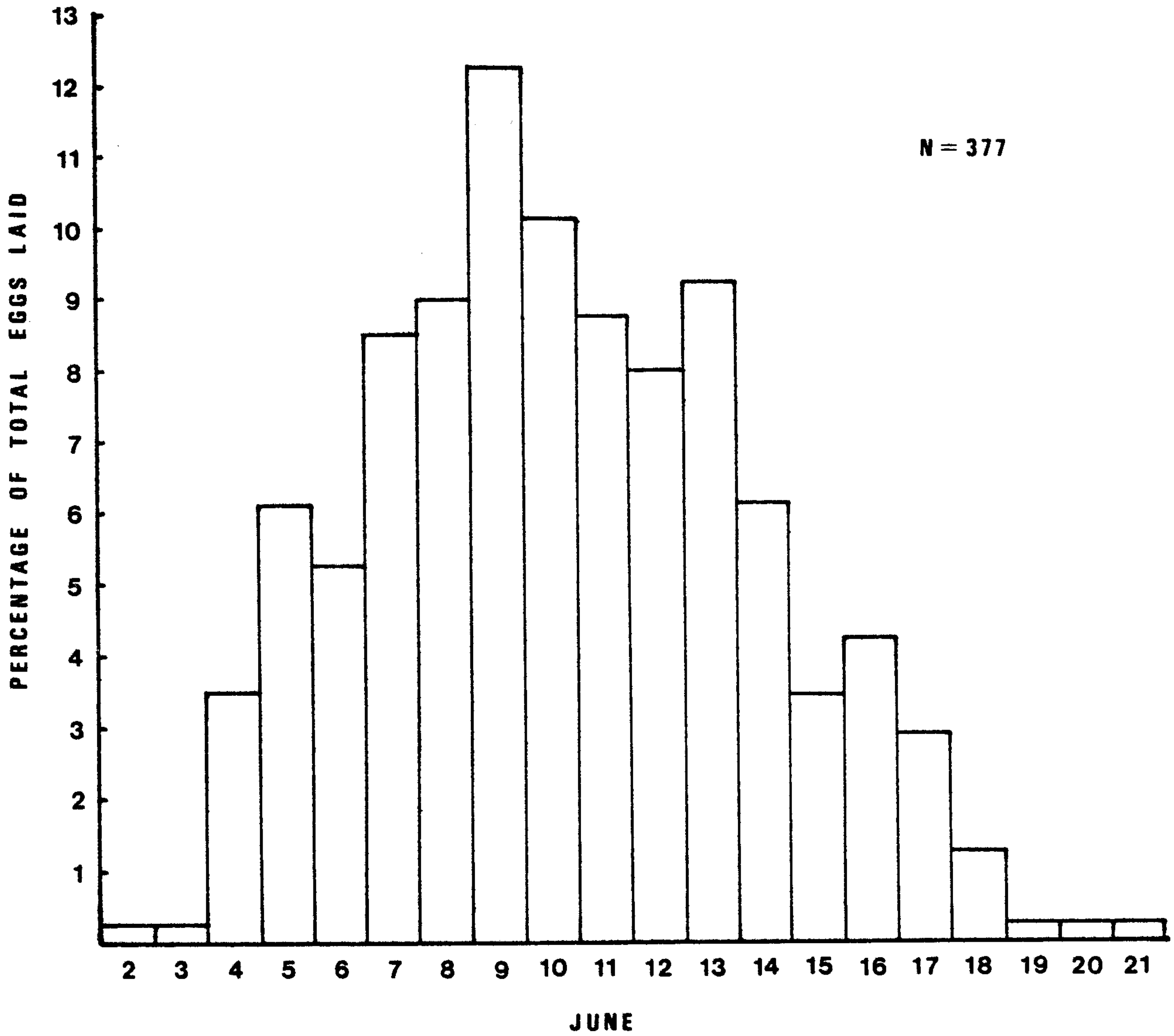

Figure 3. Egg-laying of Fulmars, Semidi Islands, 1977.

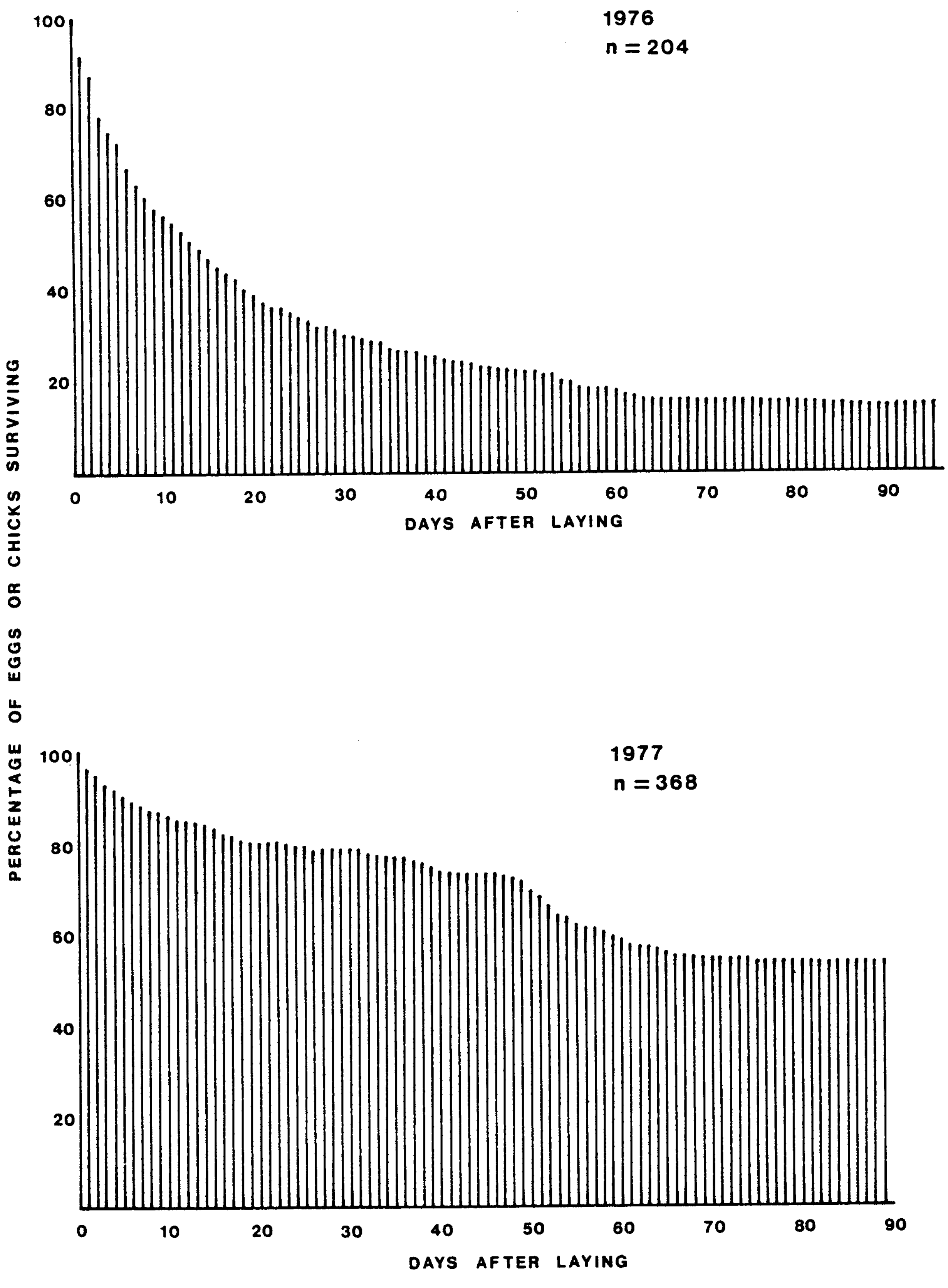

Figure 4. Survivorship of Fulmar eggs and nestlings at Semidi Islands in 1976 and 1977.

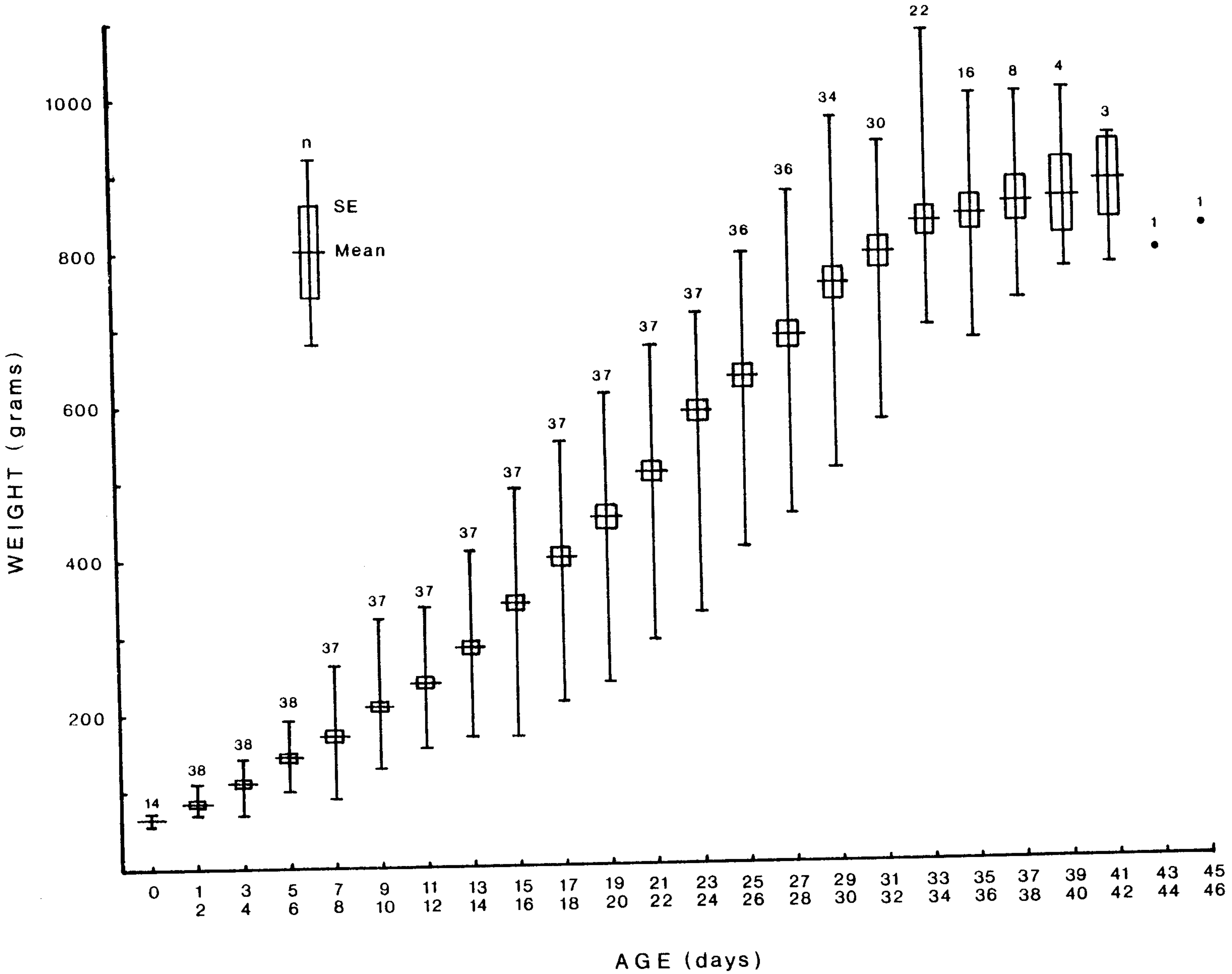

Figure 5. Weight gain of Fulmar nestlings, Semidi Islands, 1977.

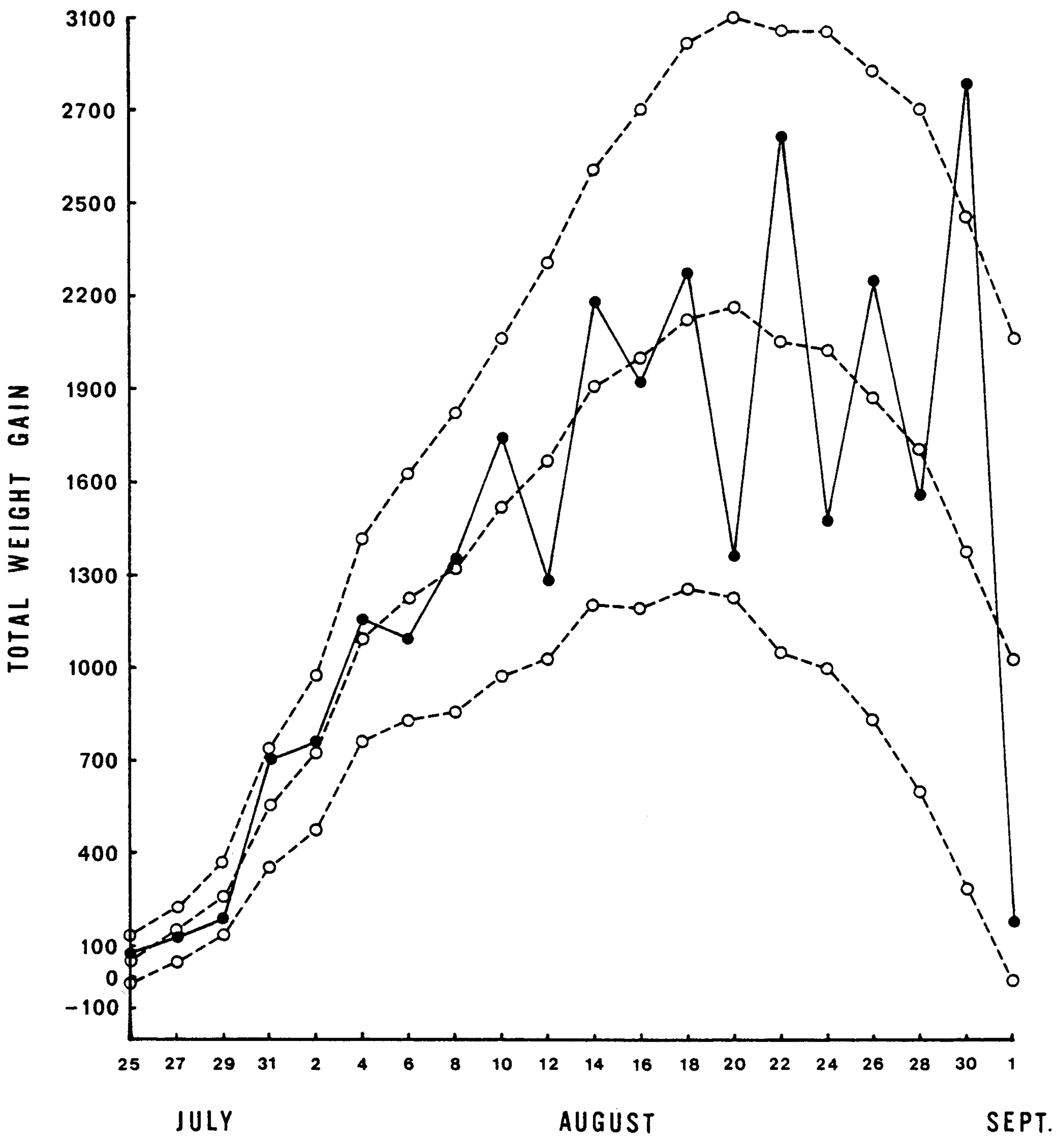

Figure 6. Collective gain or loss in weight of Fulmar nestlings between measurements, Semidi Islands, 1977 (solid line). Broken lines indicate the expected total weight gain and 95 percent confidence limits of same.

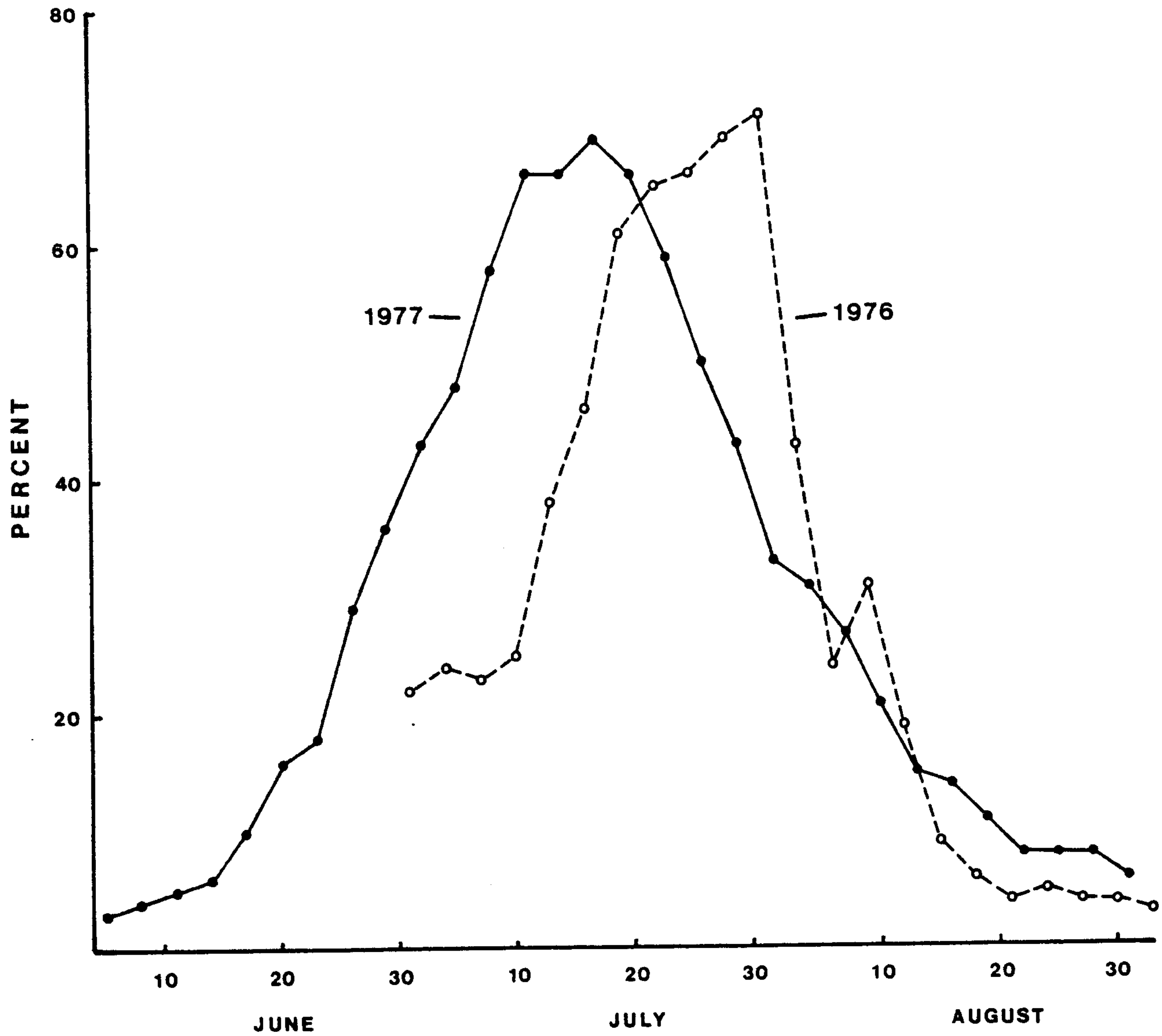

Figure 7. Percentage of Fulmars in the air undergoing primary molt over the course of the breeding season, Semidi Islands, Alaska.

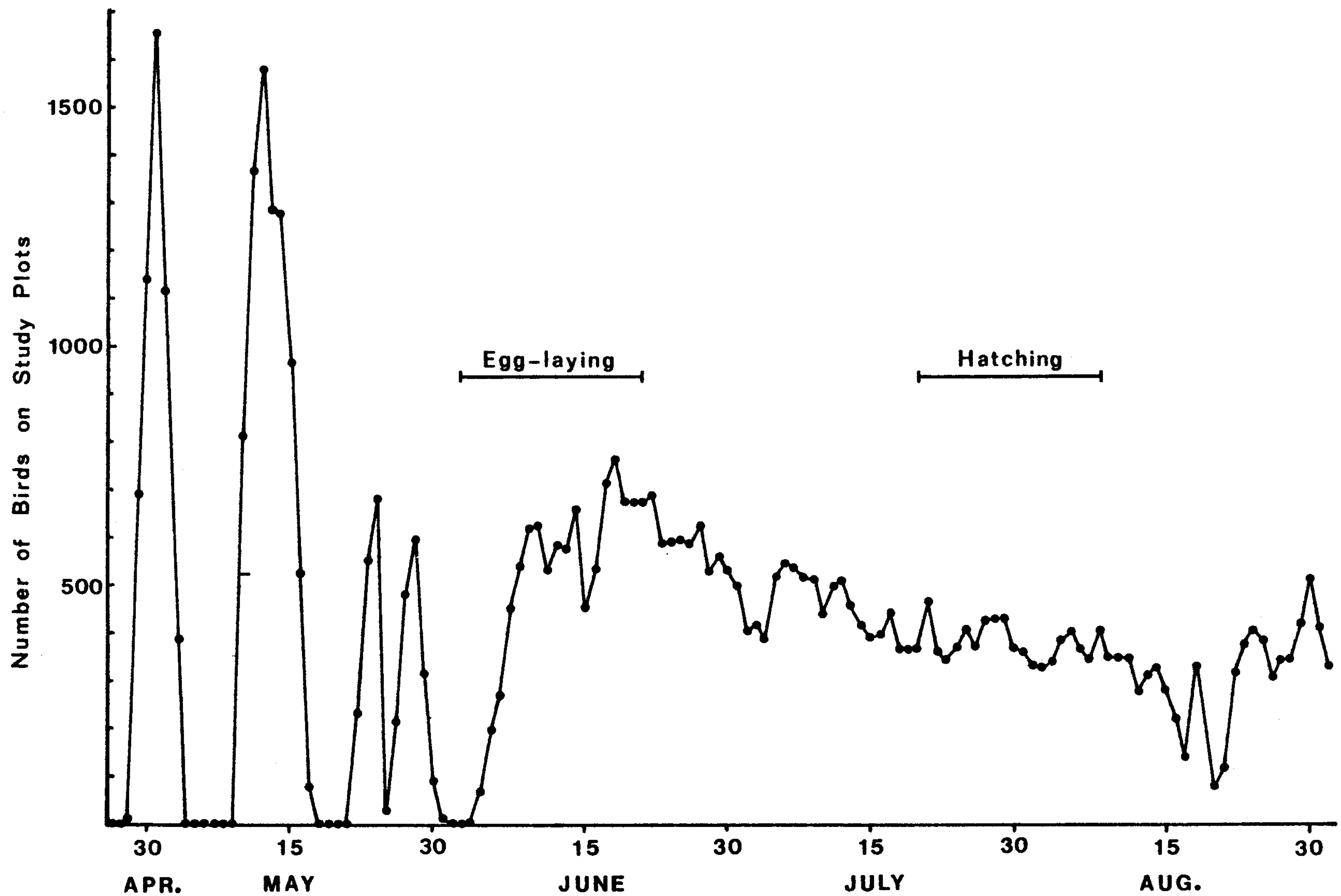

Figure 8. Attendance of Fulmars at nest-sites during the breeding season, Semidi Islands, 1977.

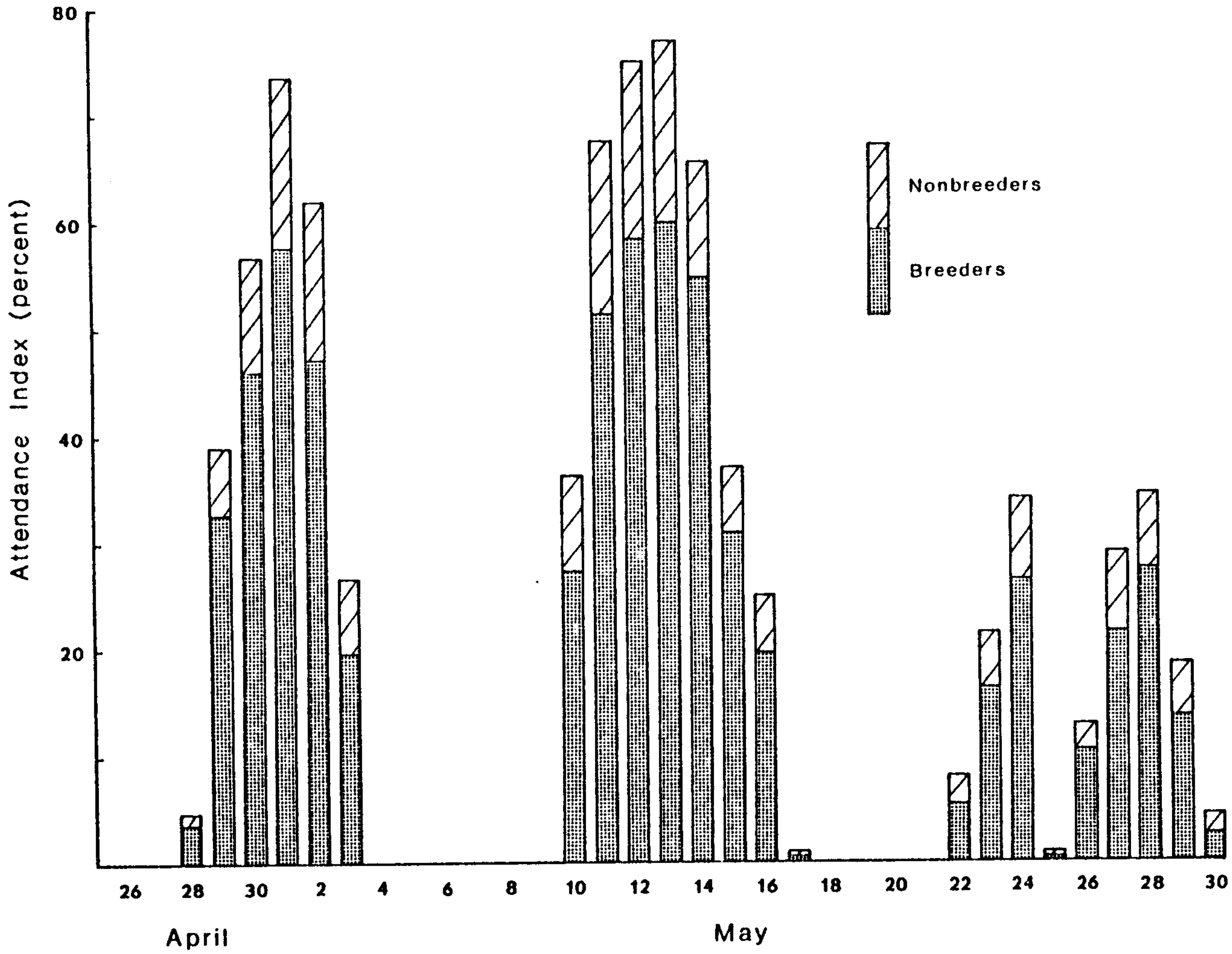

Figure 9. Attendance of Fulmars at nest-sites during the pre-egg stage, Semidi Islands, 1977. Note: Two birds occupying all sites under observation would constitute 100 percent attendance.

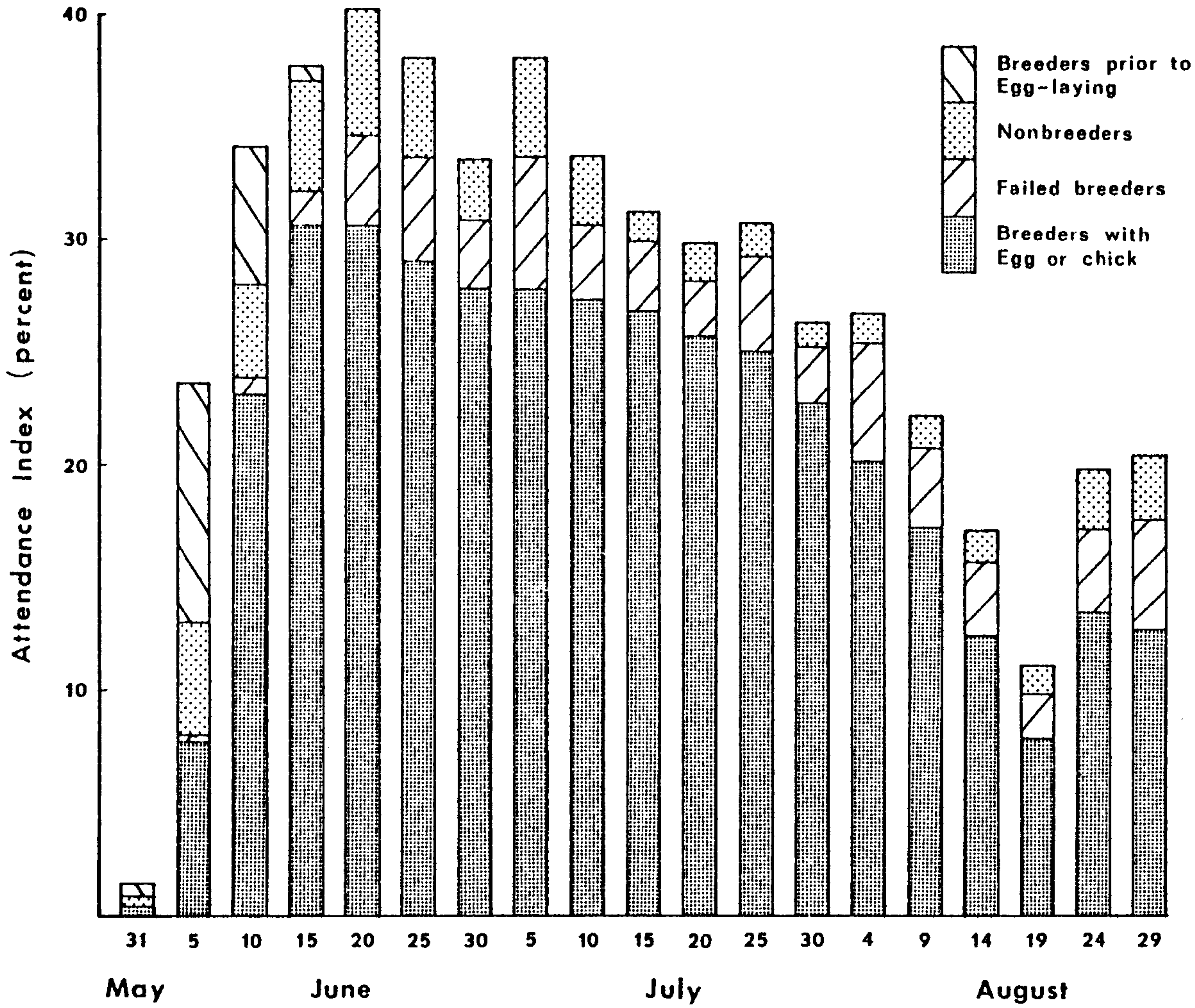

Figure 10. Breeding status of Fulmars at nest-sites summarized by five-day periods beginning on the dates indicated, Semidi Islands, 1976. Note: Two birds occupying all sites under observation would constitute 100 percent attendance.

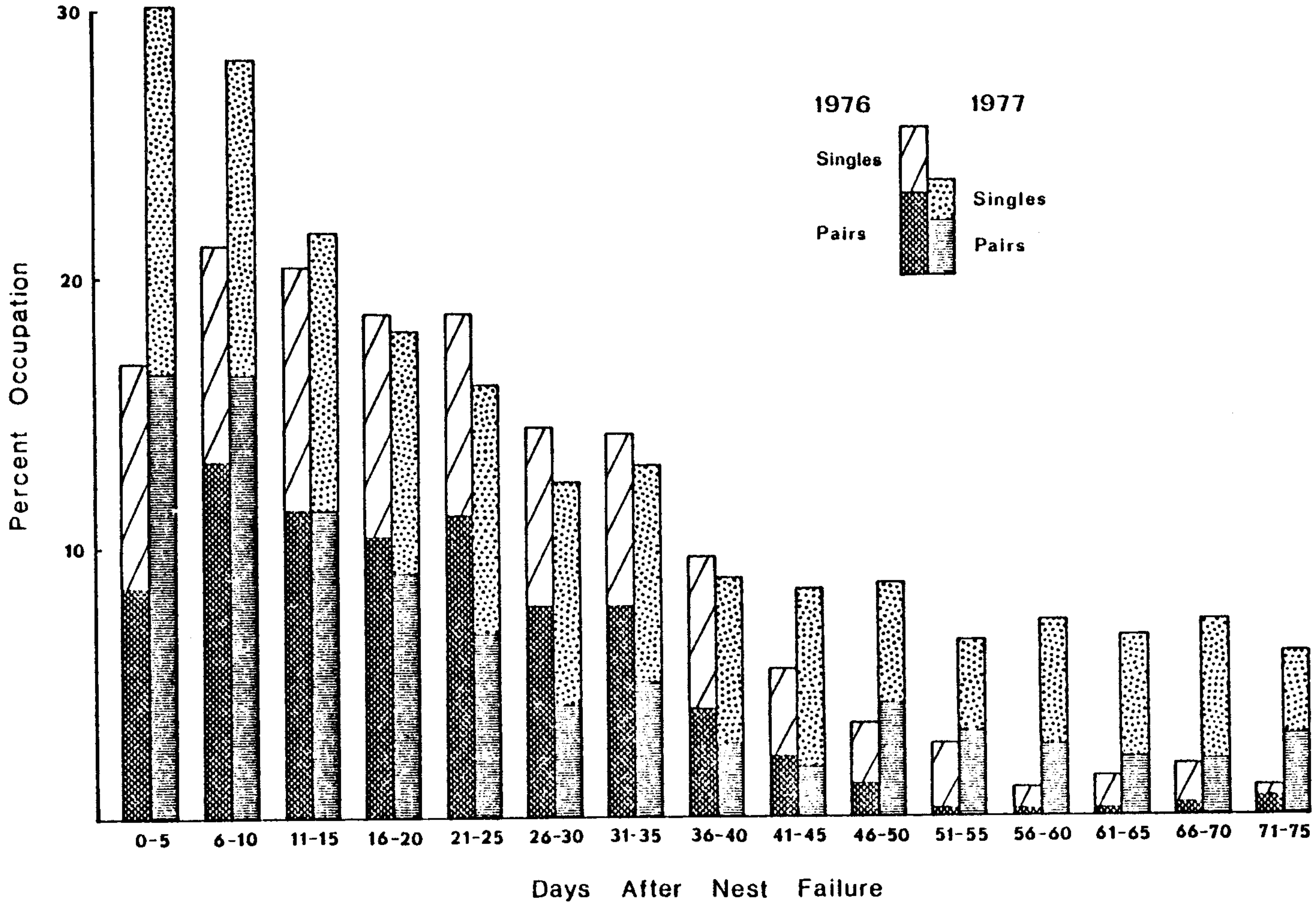

Figure 11. A comparison of nest-site attendance of failed breeders at Semidi Islands in 1976 and 1977.

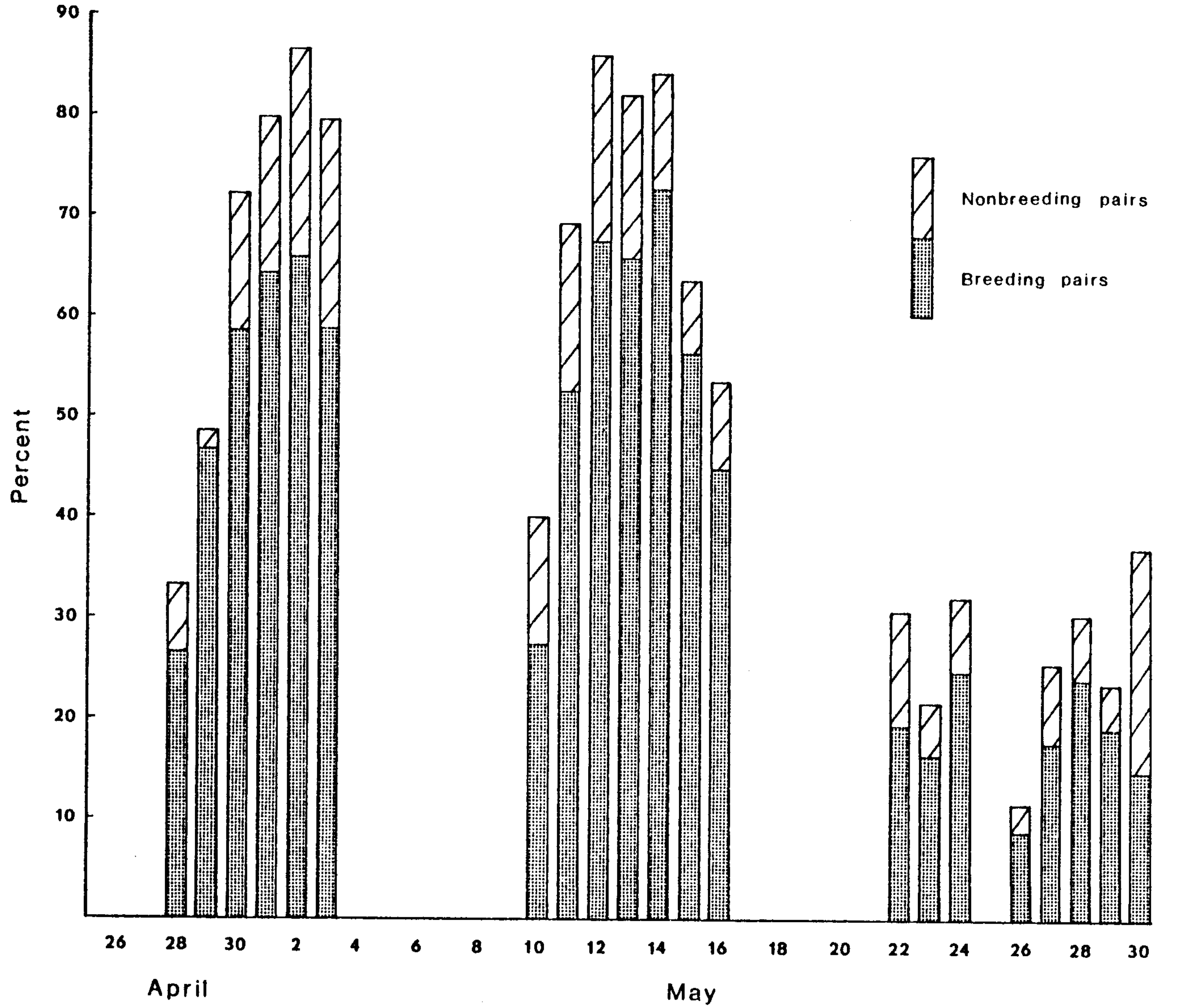

Figure 12. Percentage of occupied Fulmar nest-sites containing pairs during the pre-egg stage, Semidi Islands, 1977.

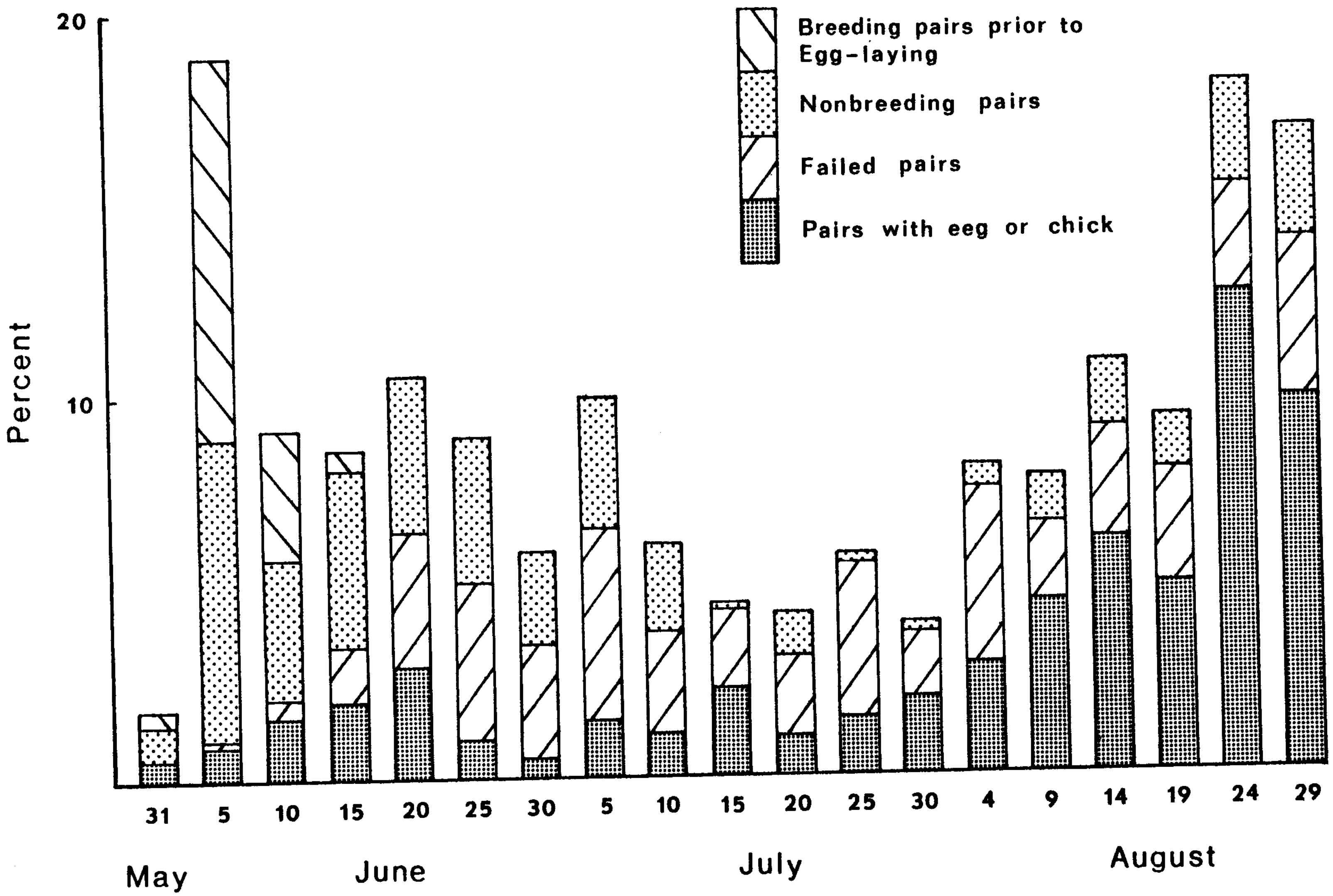

Figure 13. Percentage of occupied Fulmar nest-sites containing pairs, summarized by five-day periods beginning on the dates indicated, Semidi Islands, 1977.

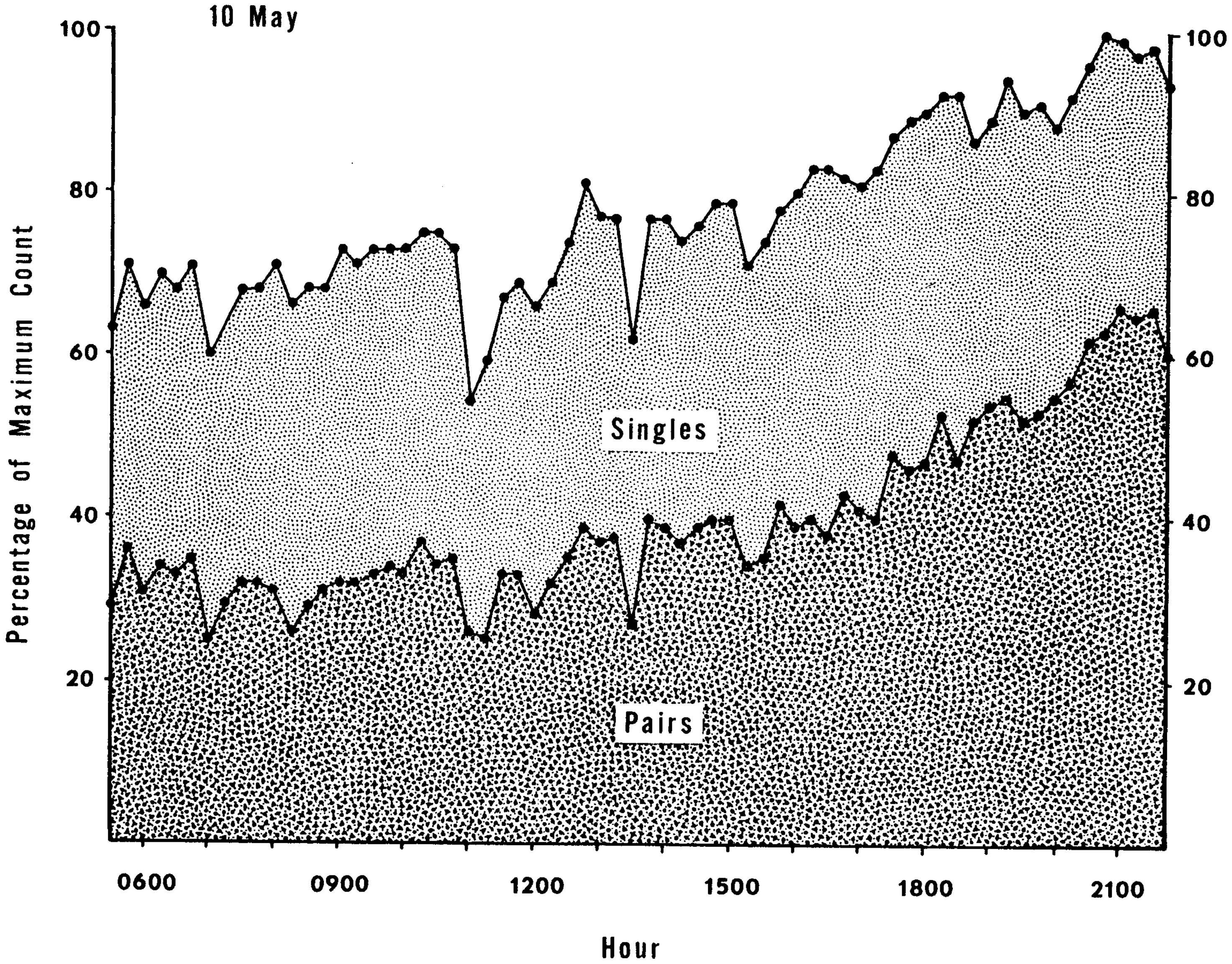

Figure 14a. Diurnal rhythm in colony attendance of Fulmars at Semidi Islands, 1977.

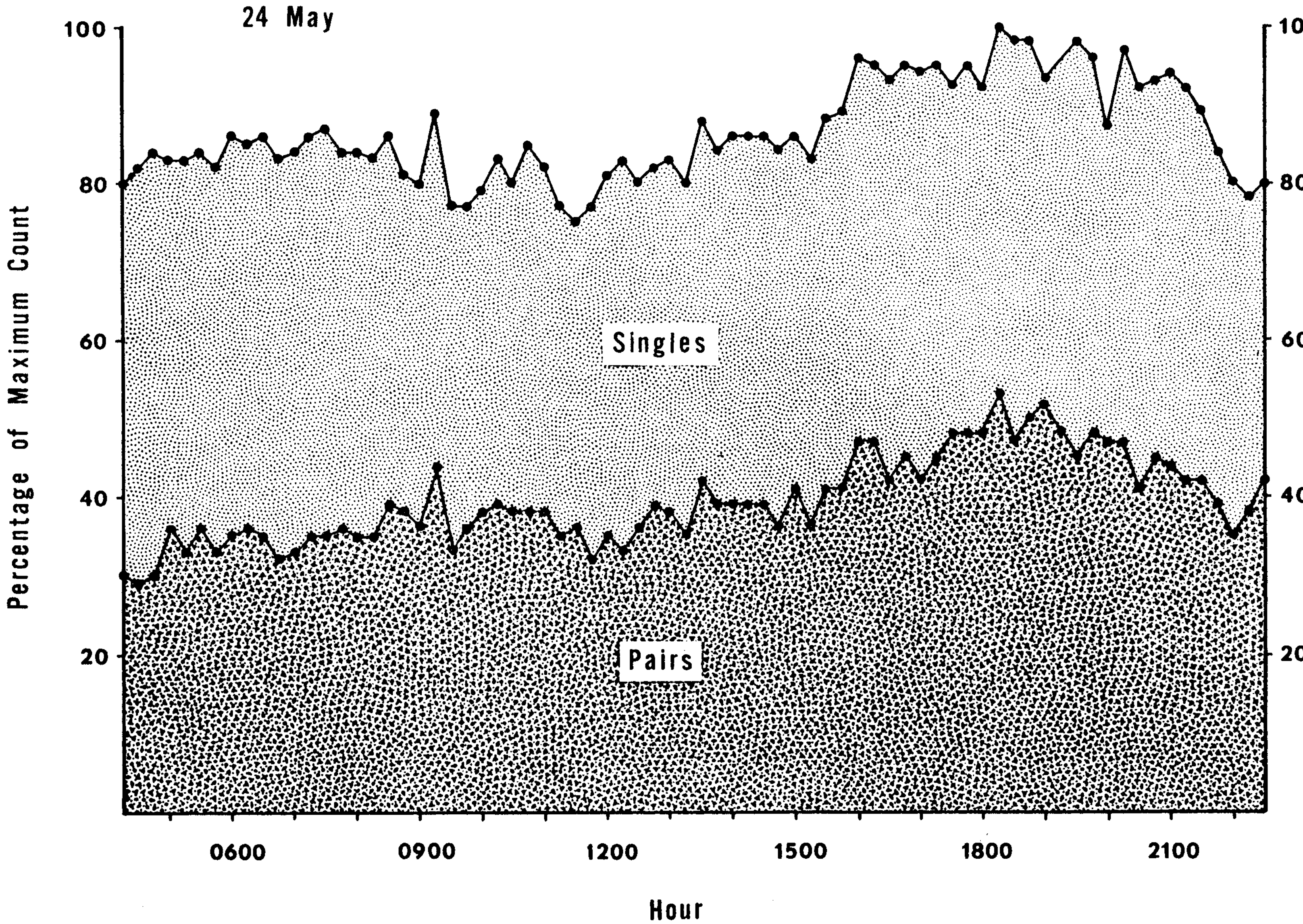

Figure 14b. Diurnal rhythm in colony attendance of Fulmars at Semidi Islands, 1977.

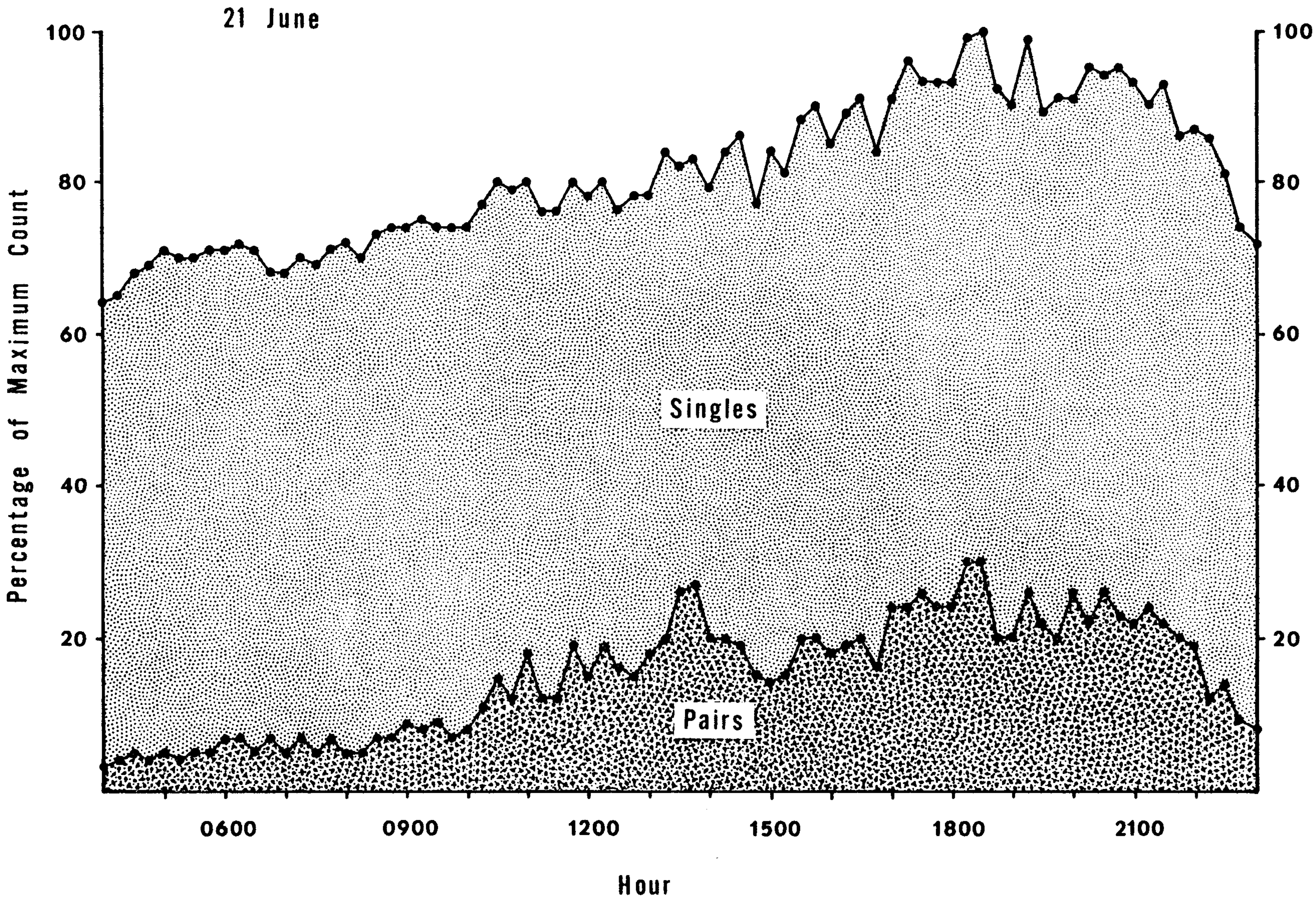

Figure 14c. Diurnal rhythm in colony attendance of Fulmars at Semidi Islands, 1977.

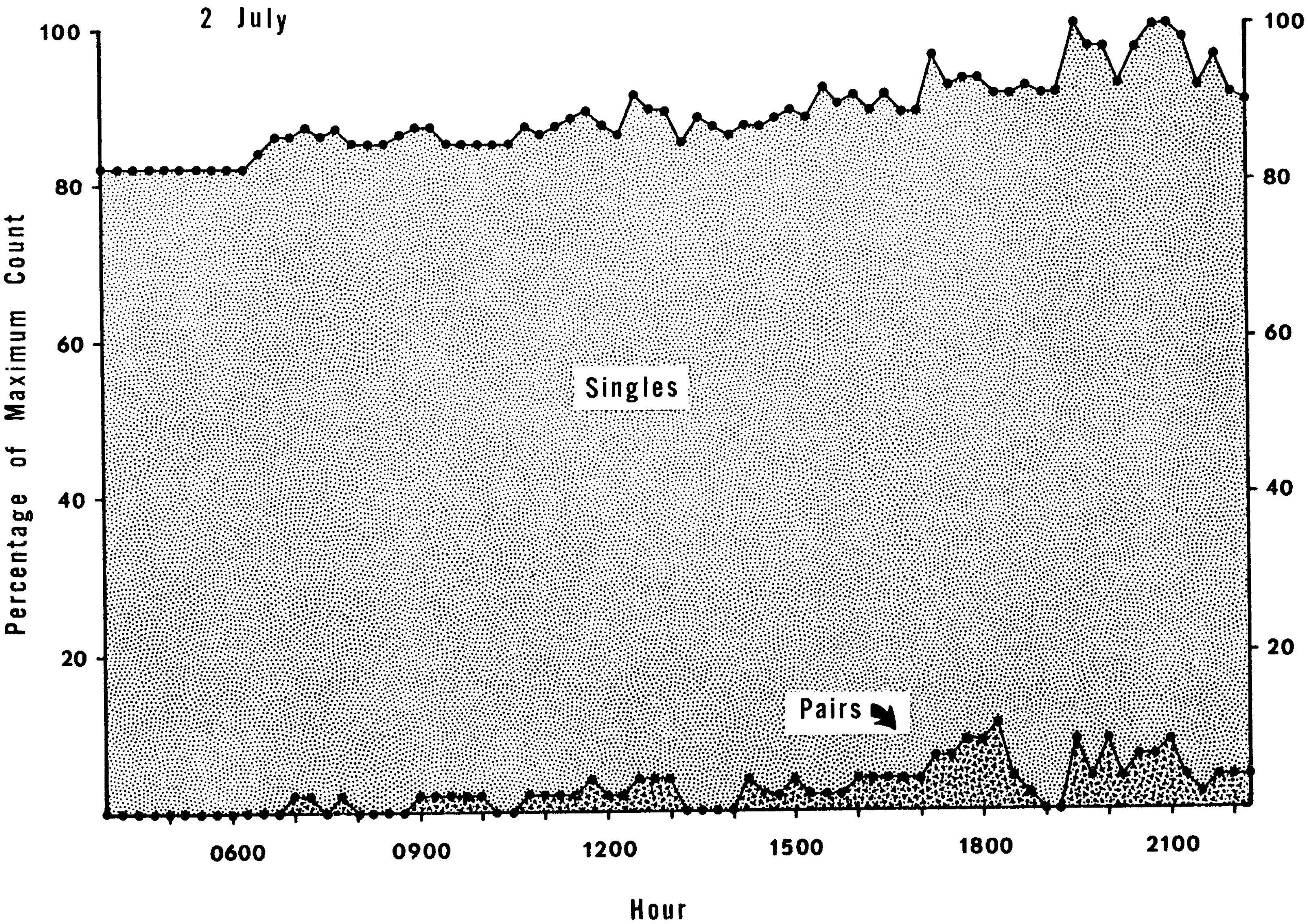

Figure 14d. Diurnal rhythm in colony attendance of Fulmars at Semidi Islands, 1977.

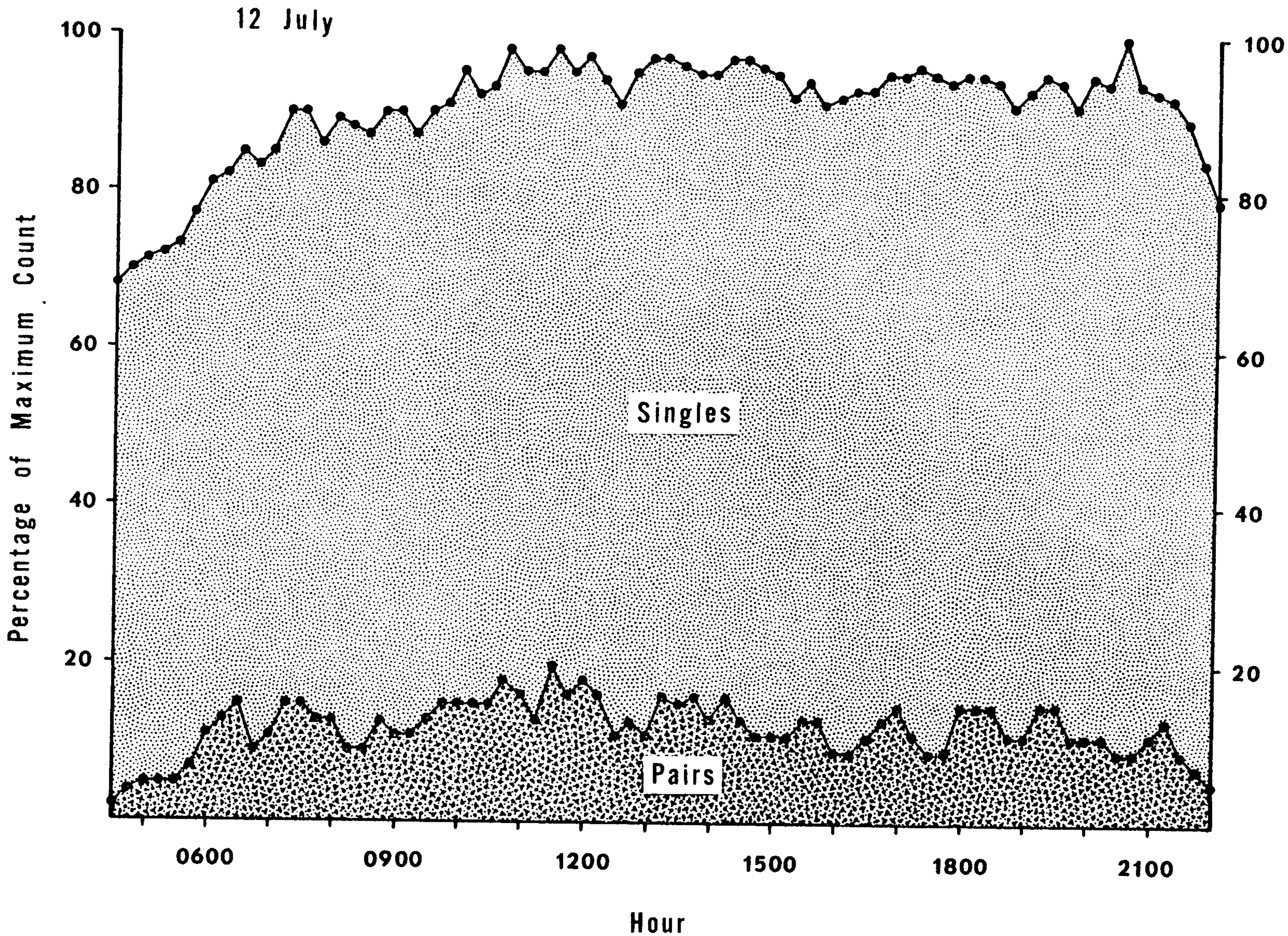

Figure 14e. Diurnal rhythm in colony attendance of Fulmars at Semidi Islands, 1977.

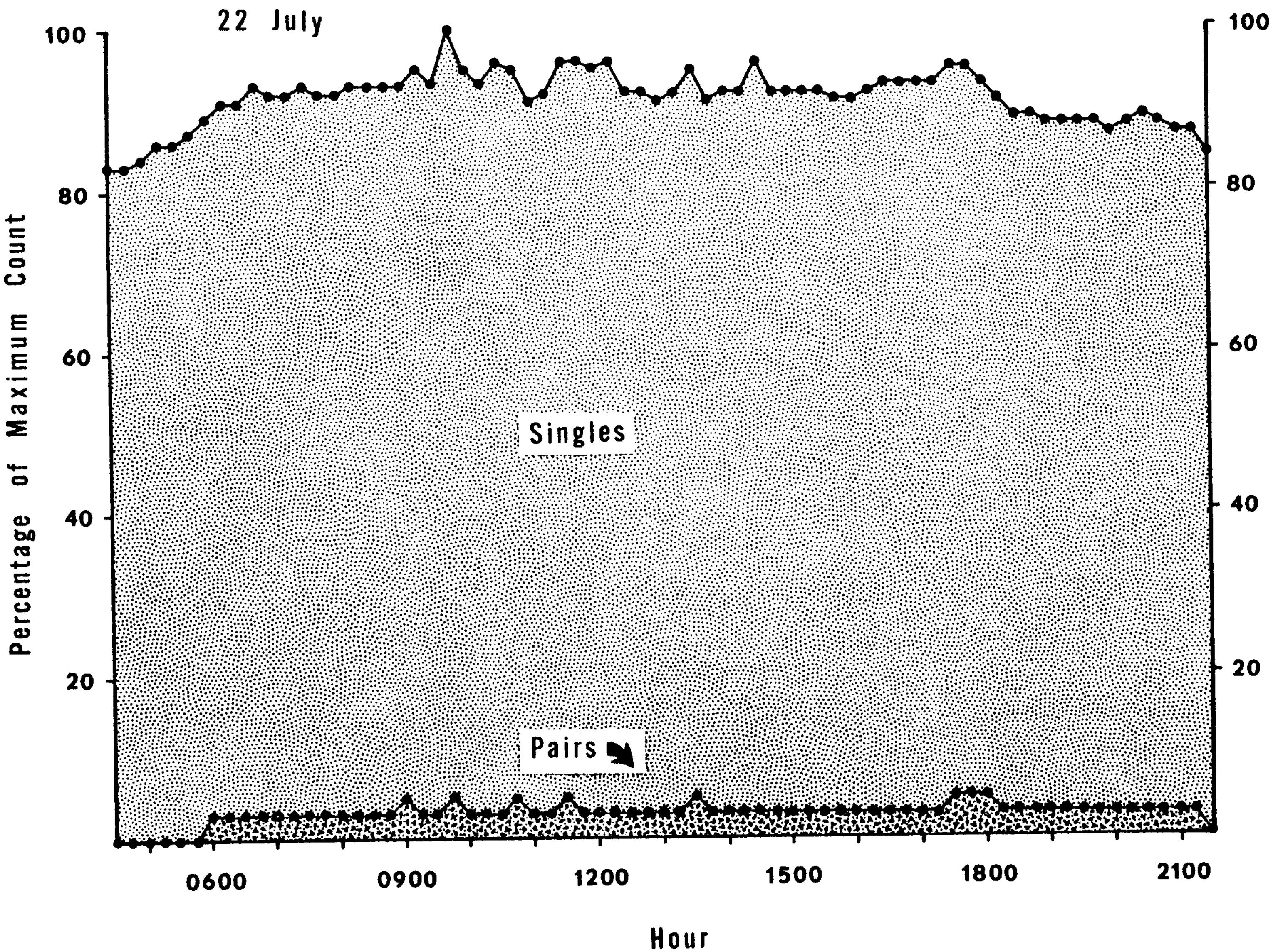

Figure 14f. Diurnal rhythm in colony attendance of Fulmars at Semidi Islands, 1977.

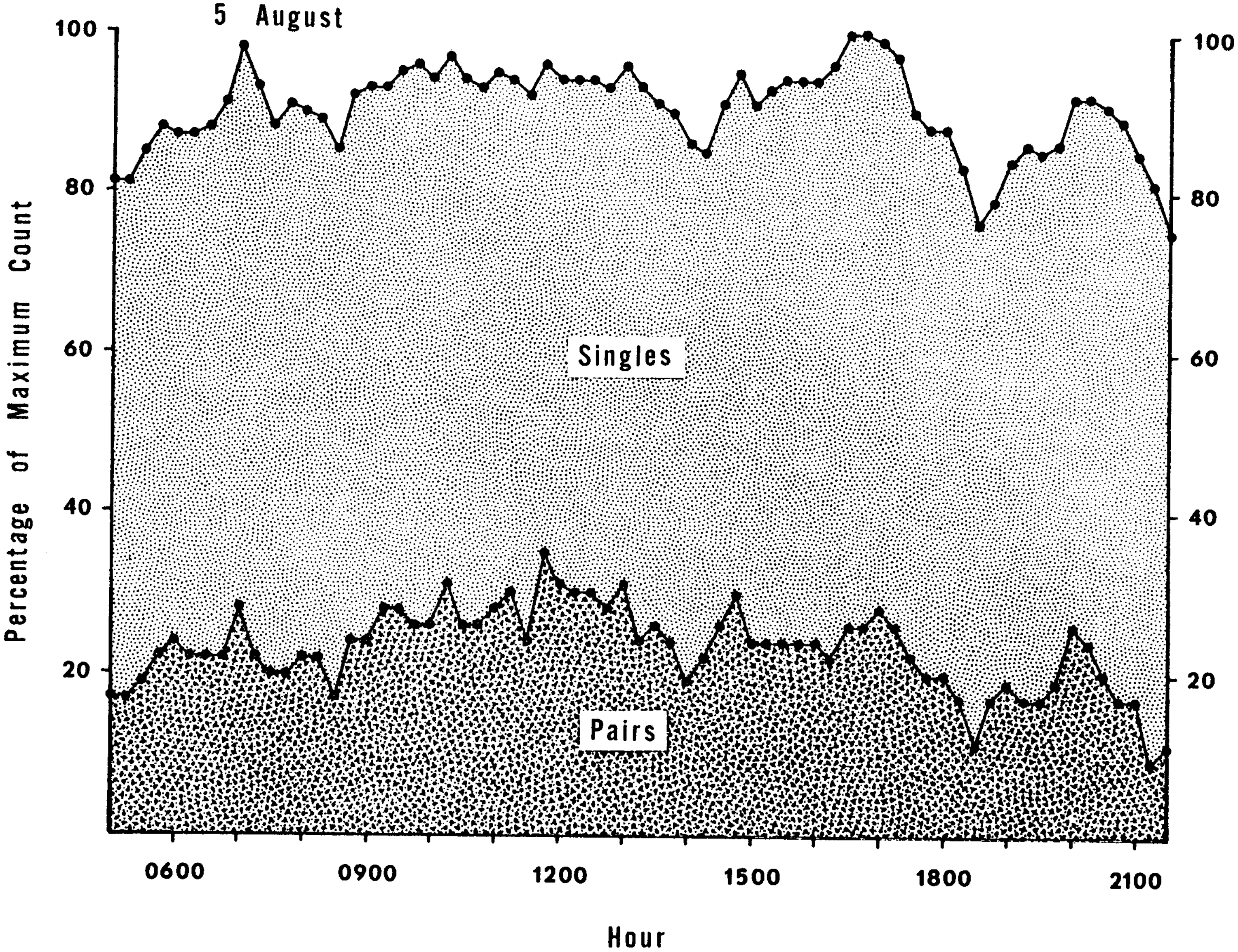

Figure 14g. Diurnal rhythm in colony attendance of Fulmars at Semidi Islands, 1977.

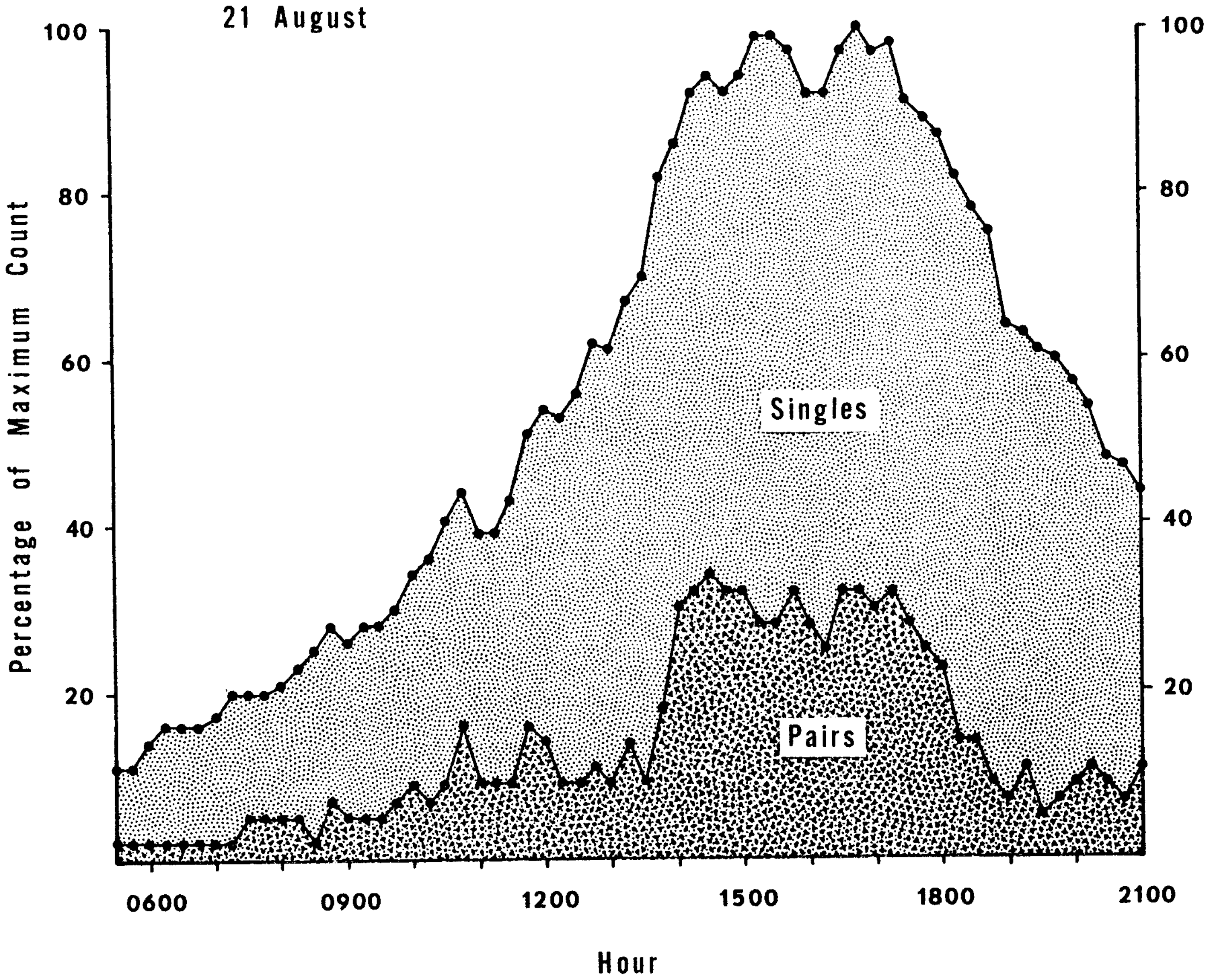

Figure 14h. Diurnal rhythm in colony attendance of Fulmars at Semidi Islands, 1977.

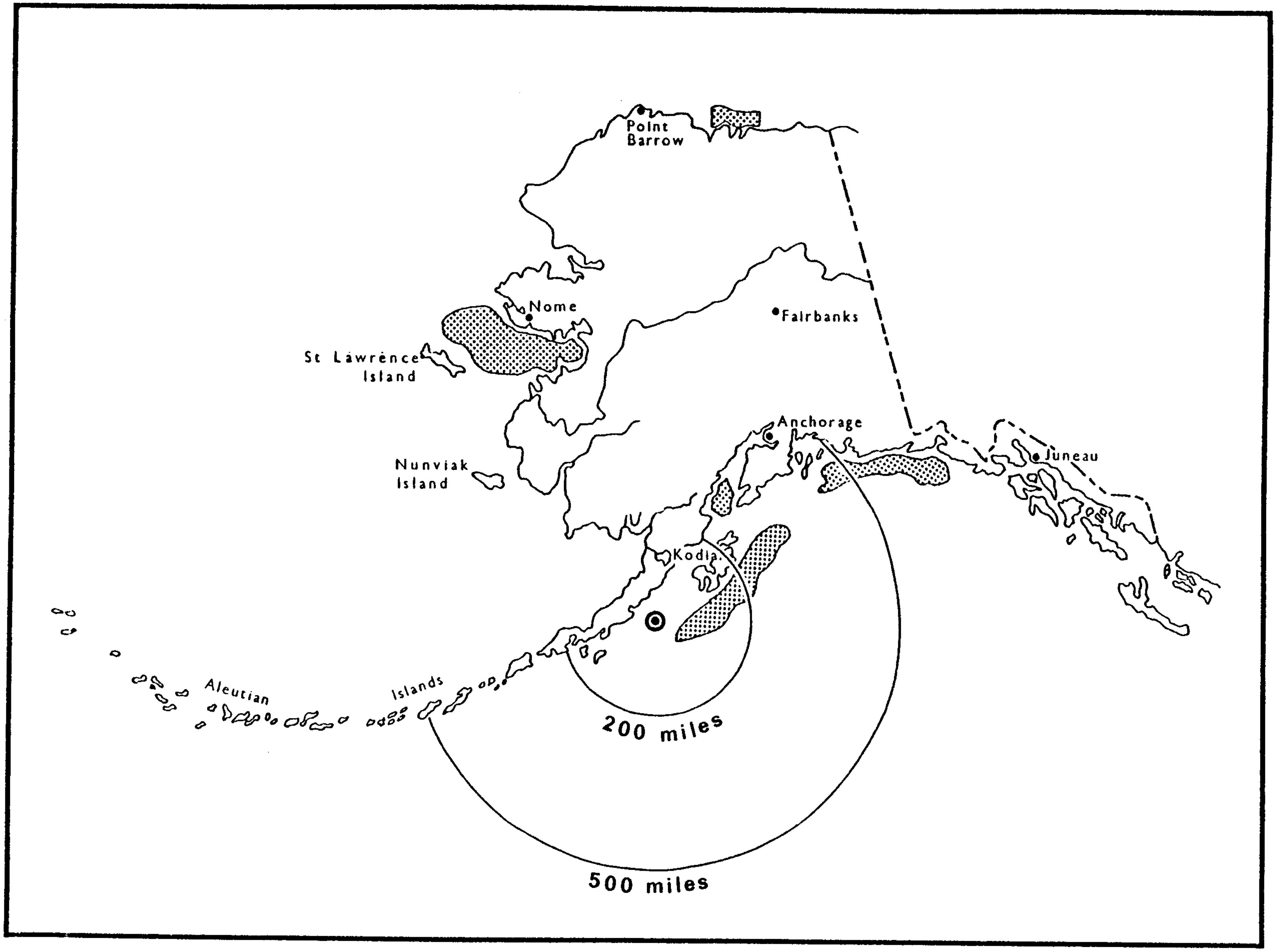

Figure 15. Potential foraging range of Fulmars from Semidi Islands in relation to outer continental shelf areas currently under consideration for leasing.

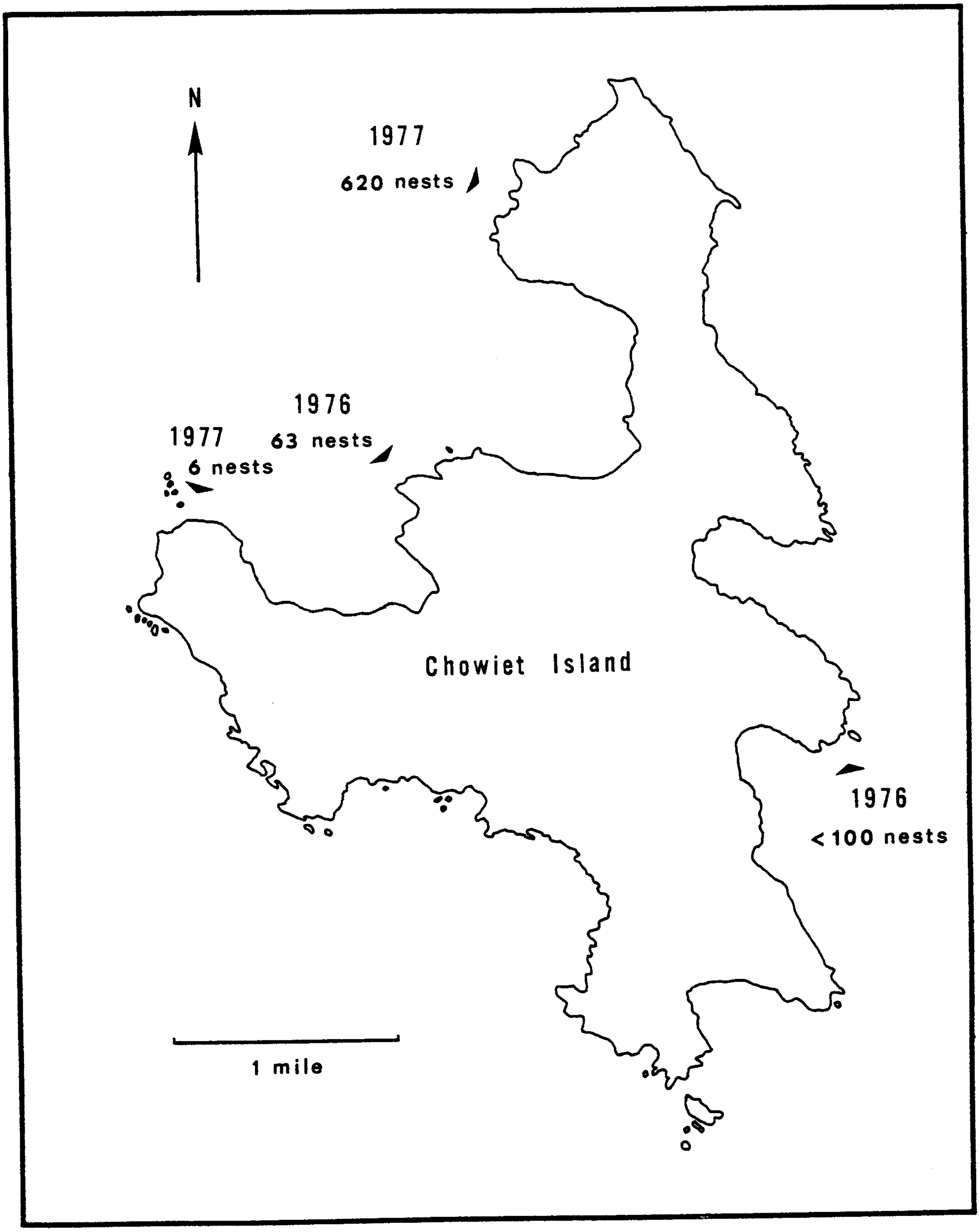

Figure 16. Locations of colonies of Red-faced and Pelagic Cormorants on Chowiet Island in 1976 and 1977.

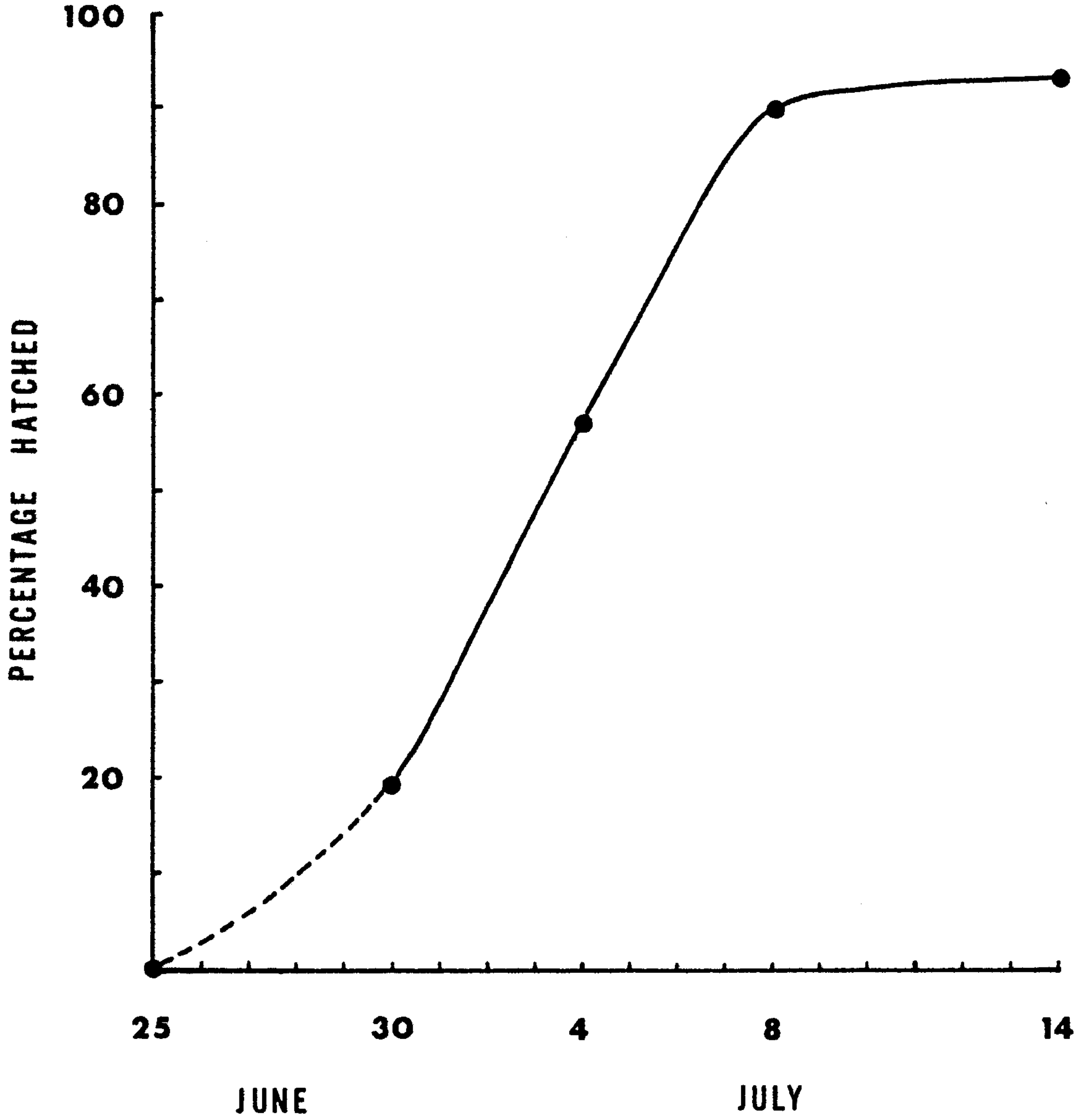

Figure 17. Hatching curve of Red-faced and Pelagic Cormorants, Semidi Islands, 1977.

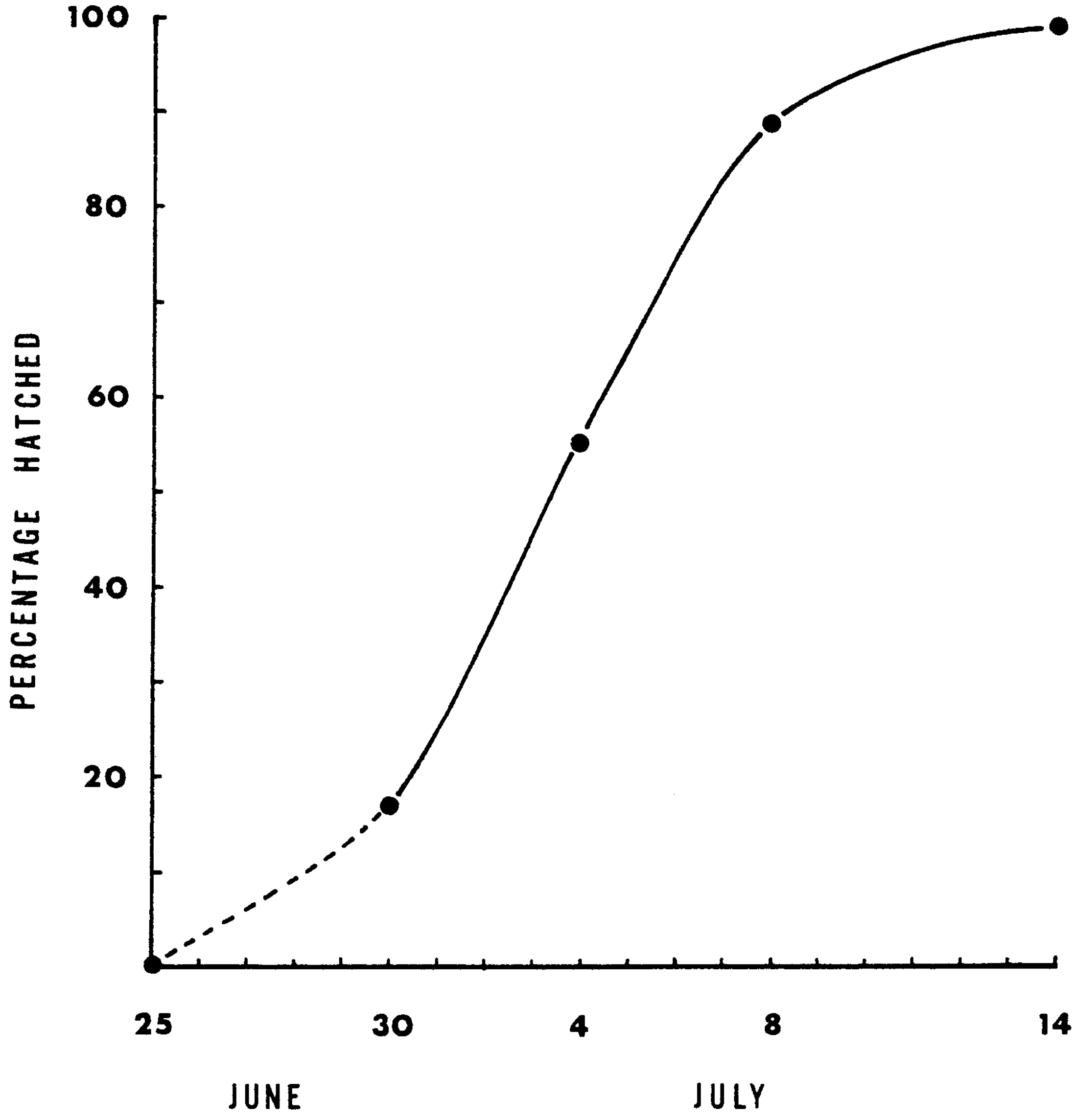

Figure 18. Hatching curve of Glaucous-winged Gulls, Semidi Islands, 1977.

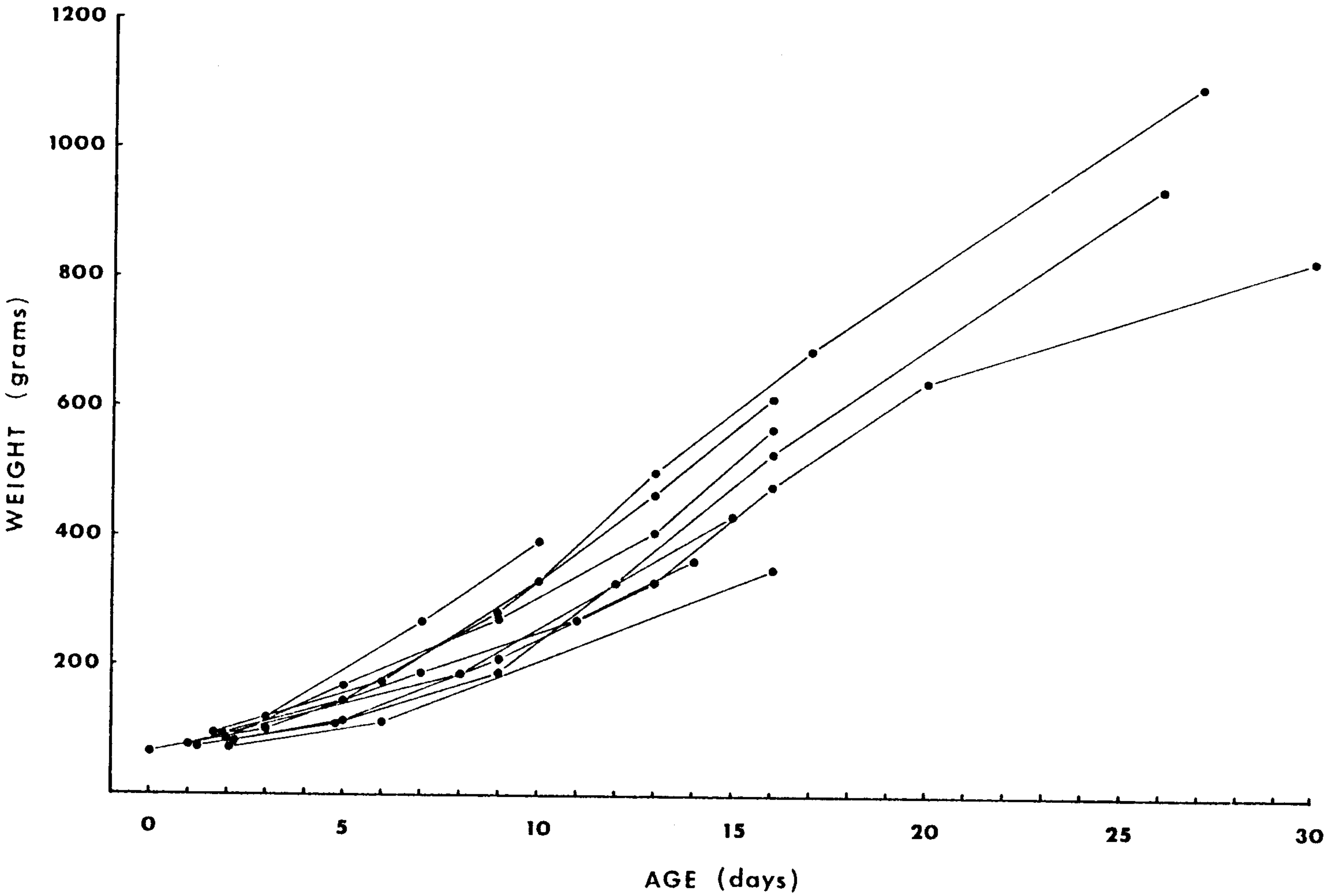

Figure 19. Growth of Glaucous-winged Gull chicks, Semidi Islands, 1977.

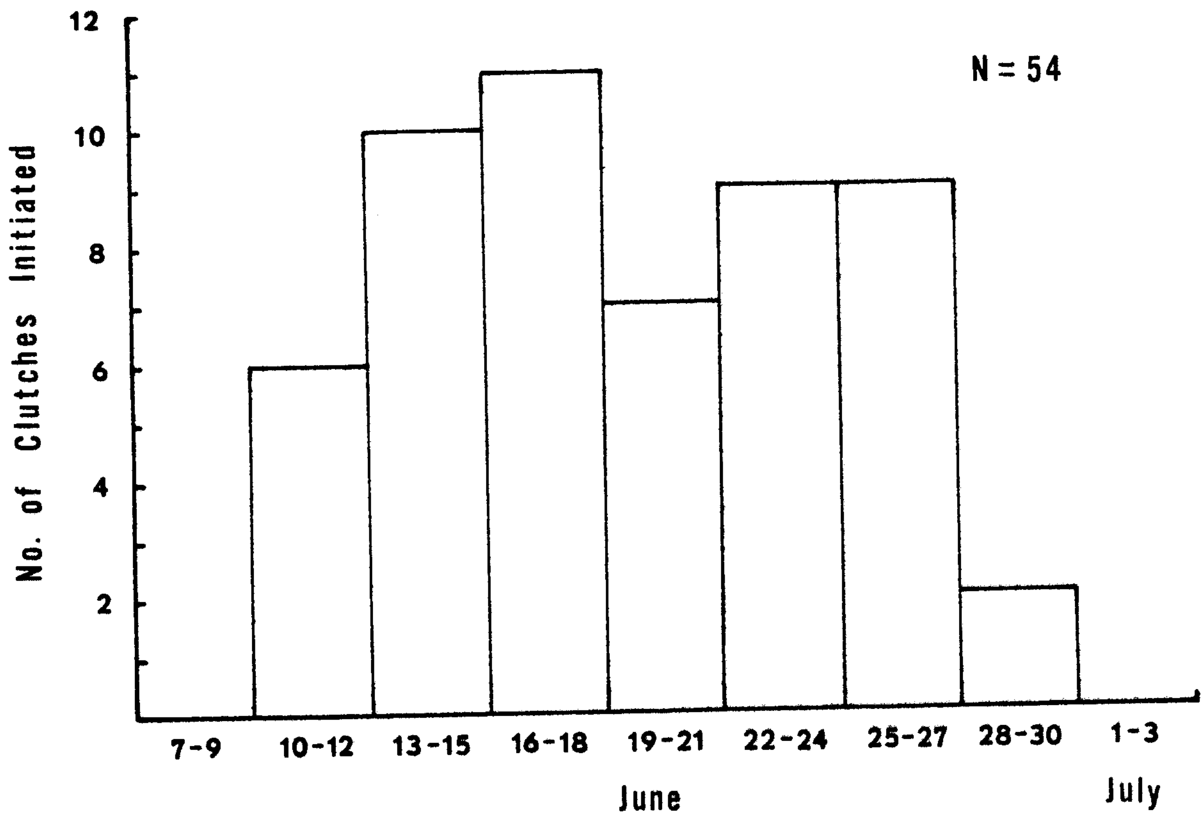

Figure 20. Egg-laying of Black-legged Kittiwakes at Semidi Islands, 1977.

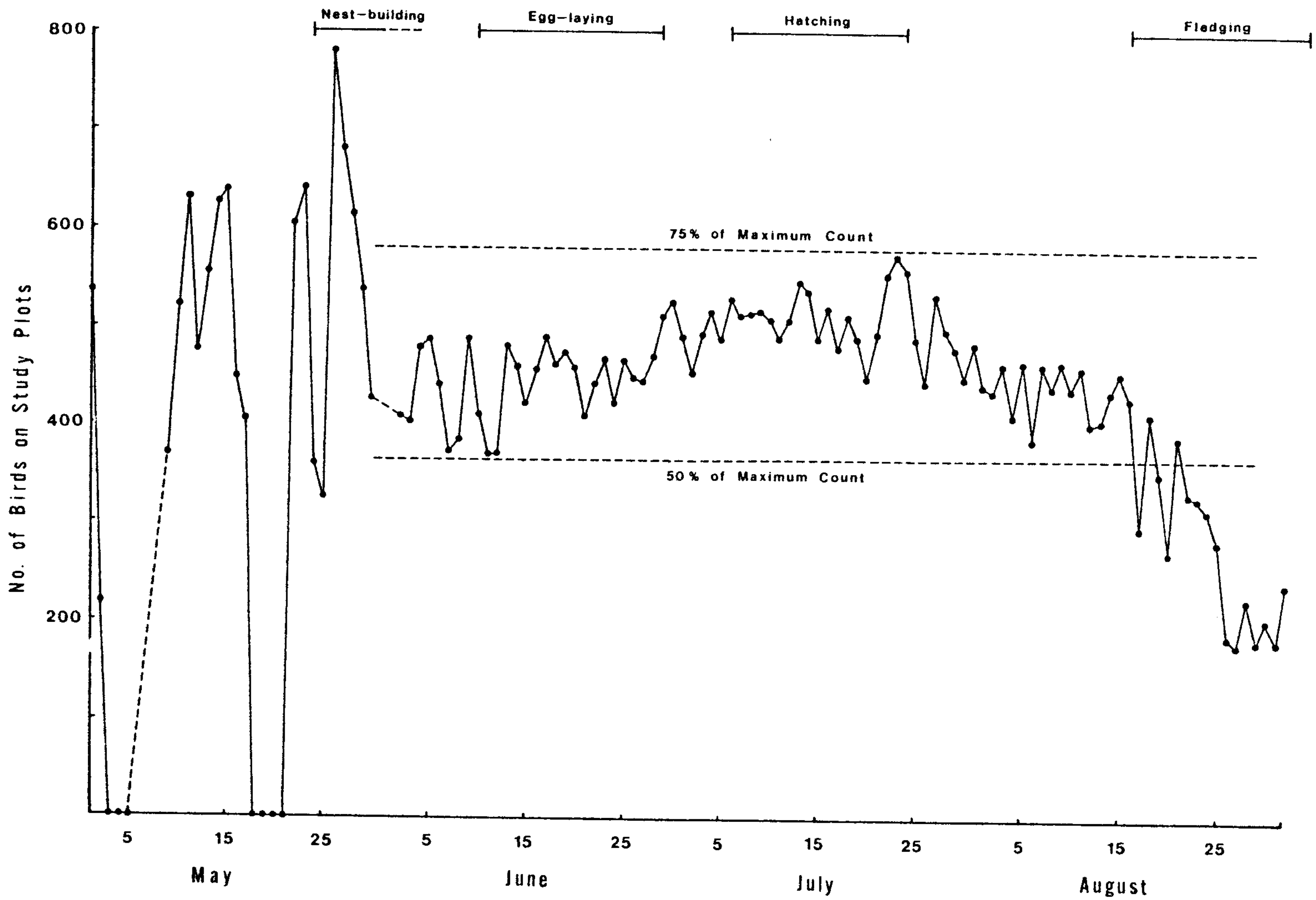

Figure 21. Seasonal changes in the population of Black-legged Kittiwakes occupying cliffs at Semidi Islands in 1977. Data from 7 study plots on which a total of approximately 450 nests were built.

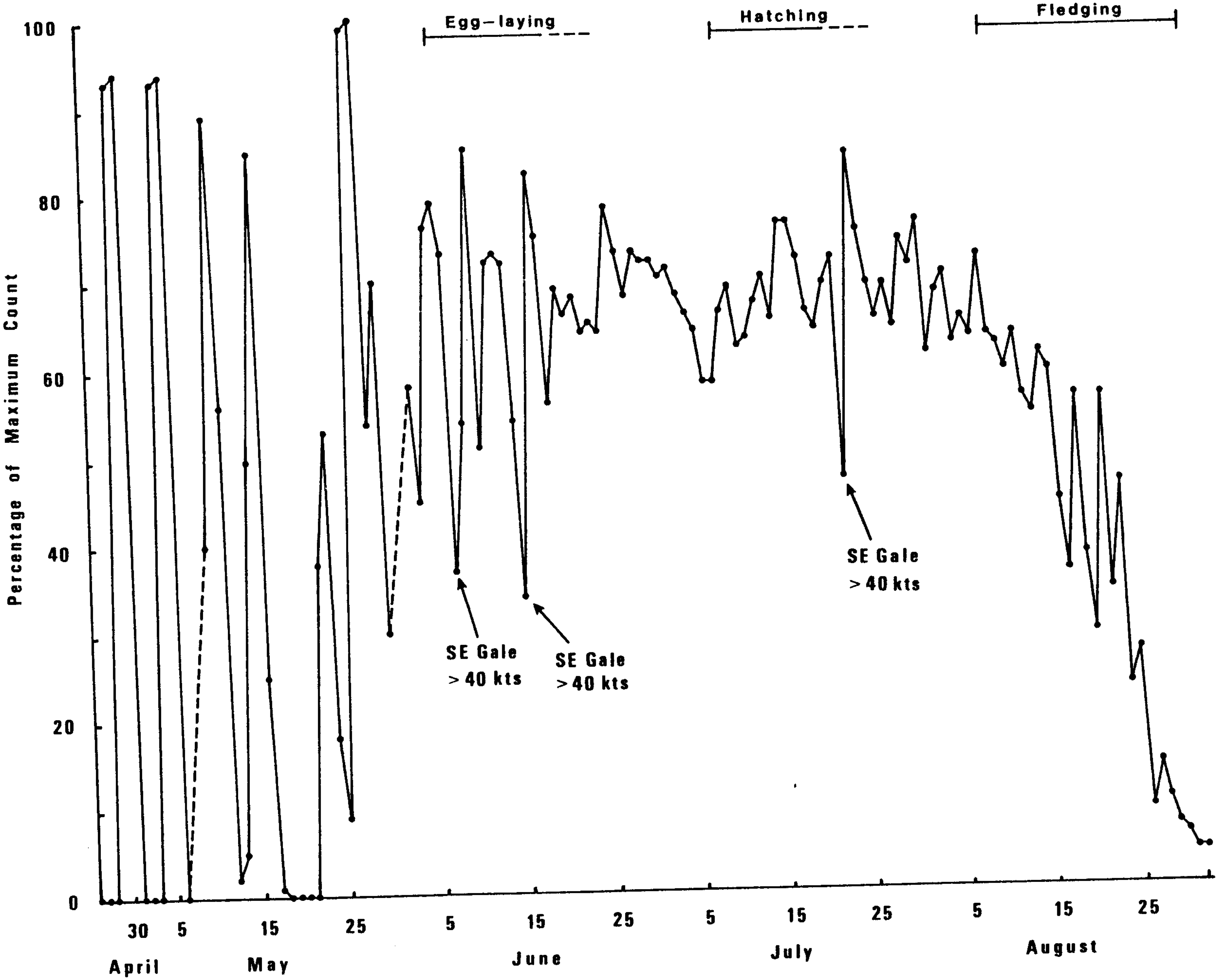

Figure 22. Seasonal changes in the population of Common and Thick-billed Murres occupying cliffs at Semidi Islands in 1977.

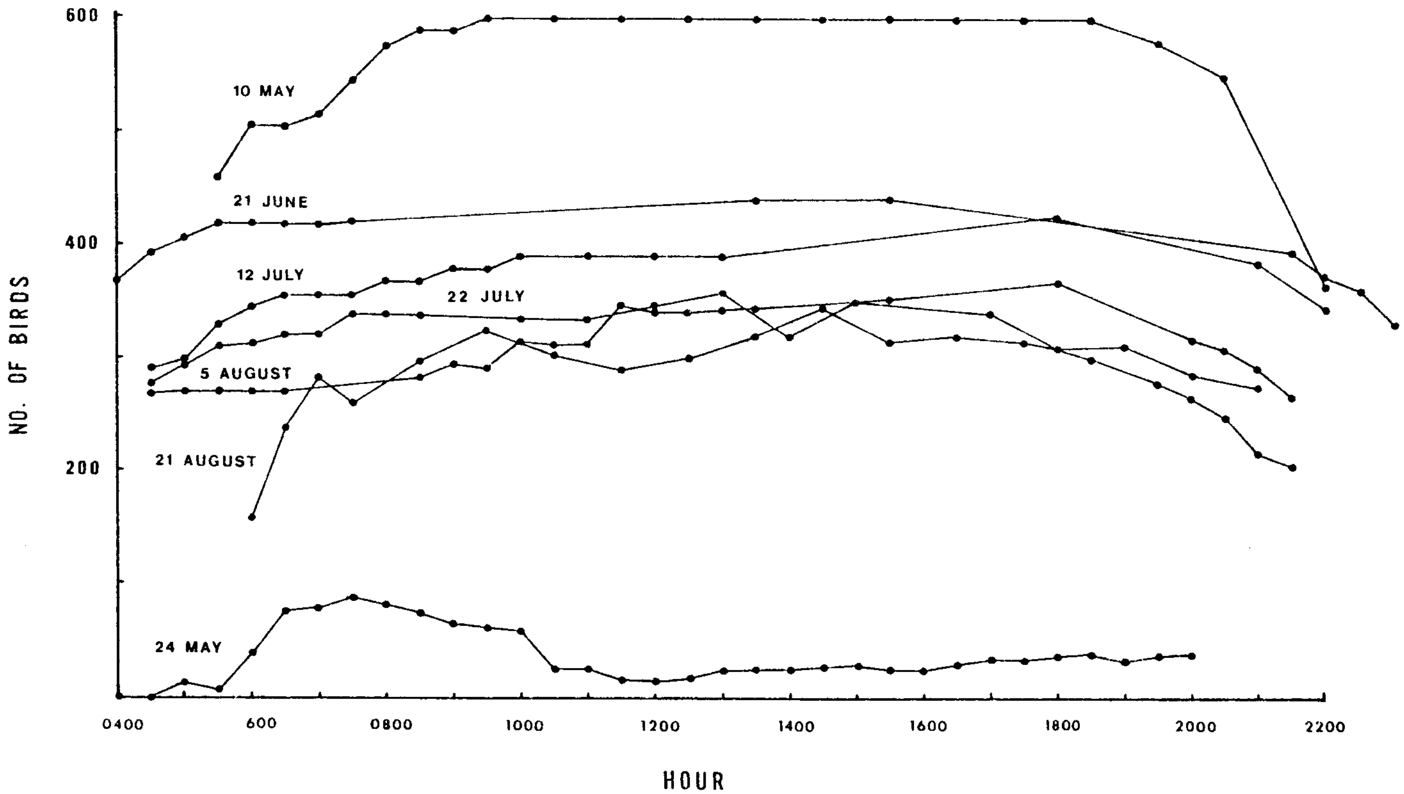

Figure 23. Diurnal rhythm in colony attendance of Common and Thick-billed Murres at Semidi Islands, 1977.

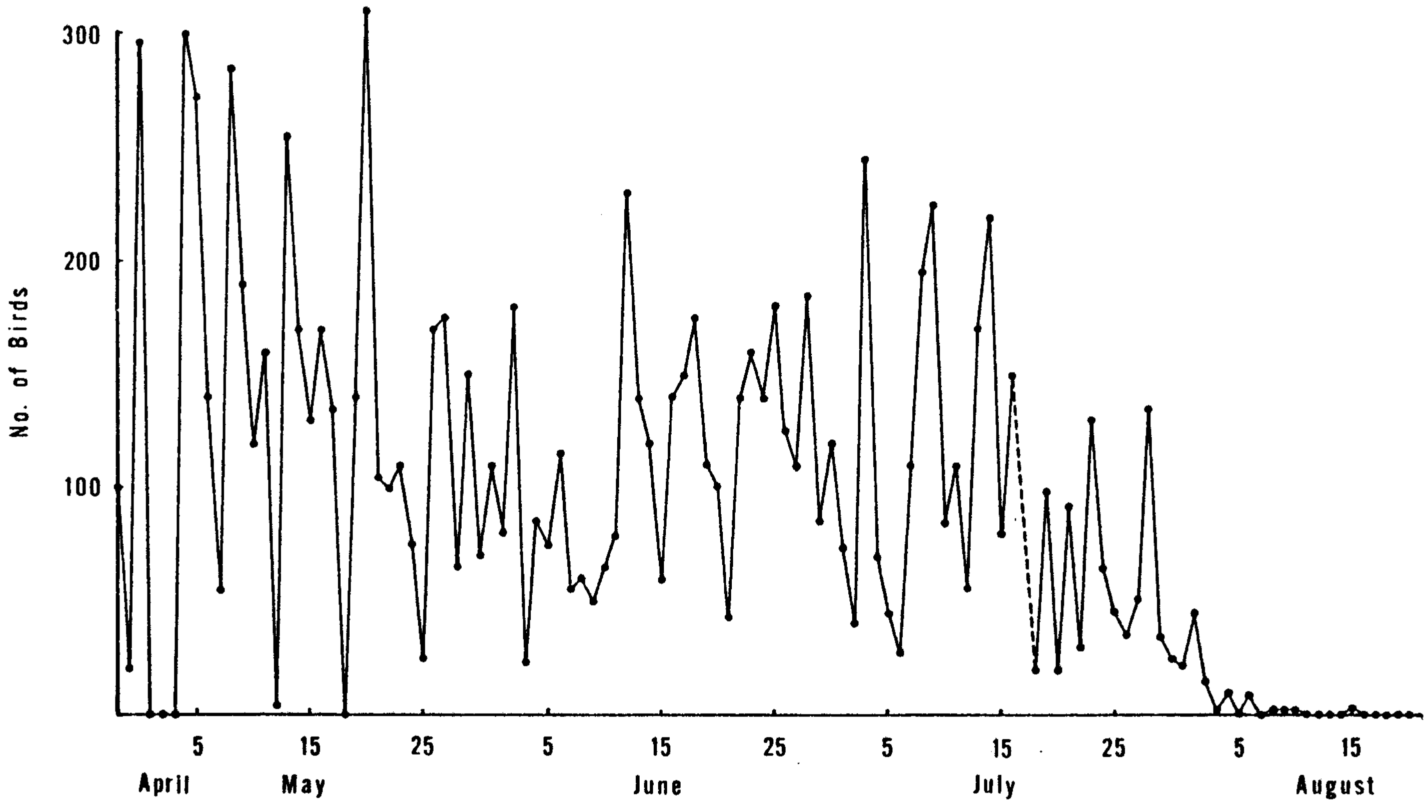

Figure 24. Daily counts of Parakeet Auklets on the water made at the same time and location, Semidi Islands, 1977.

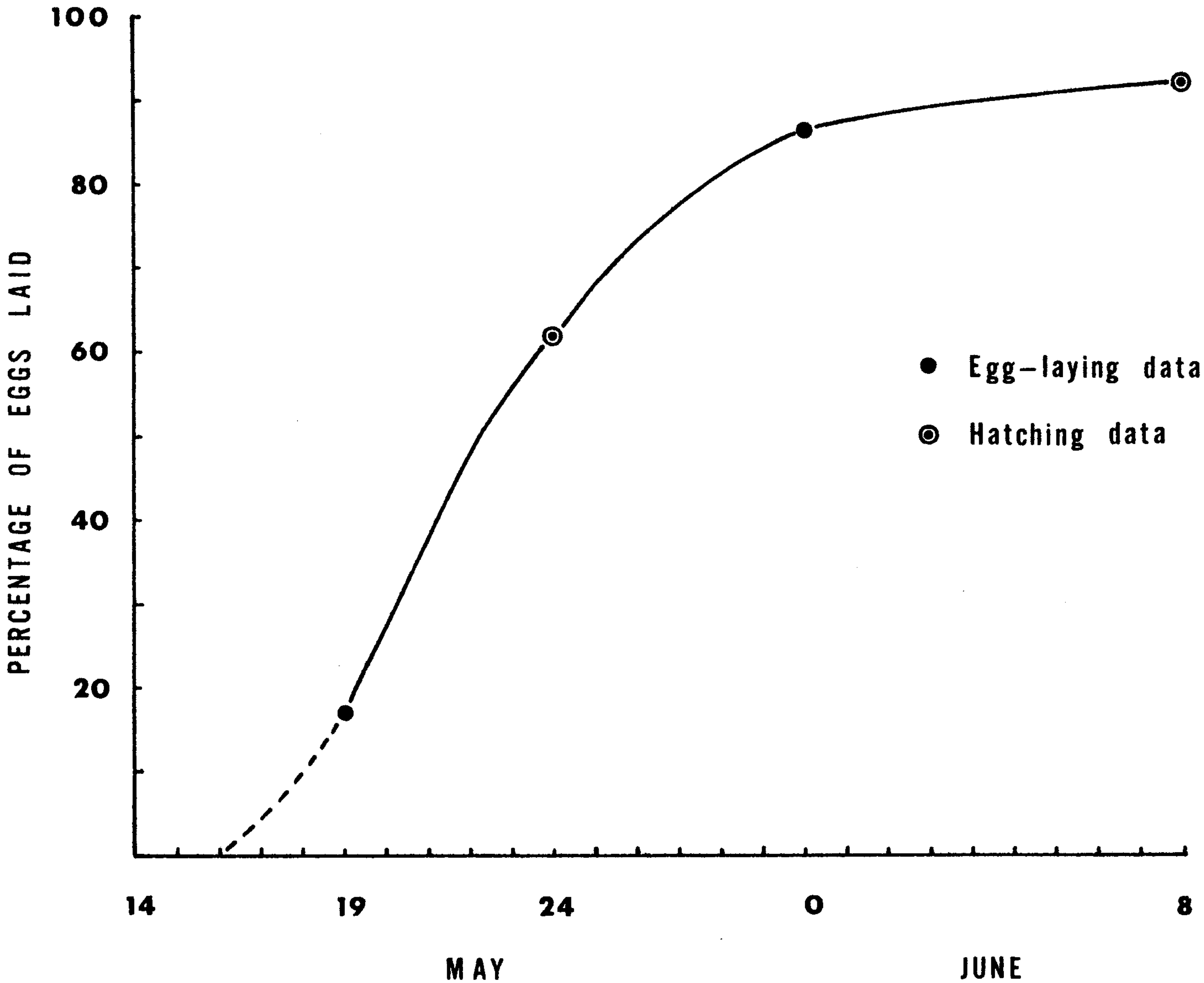

Figure 25. Egg-laying curve of Rhinoceros Auklets, Semidi Islands, 1977.

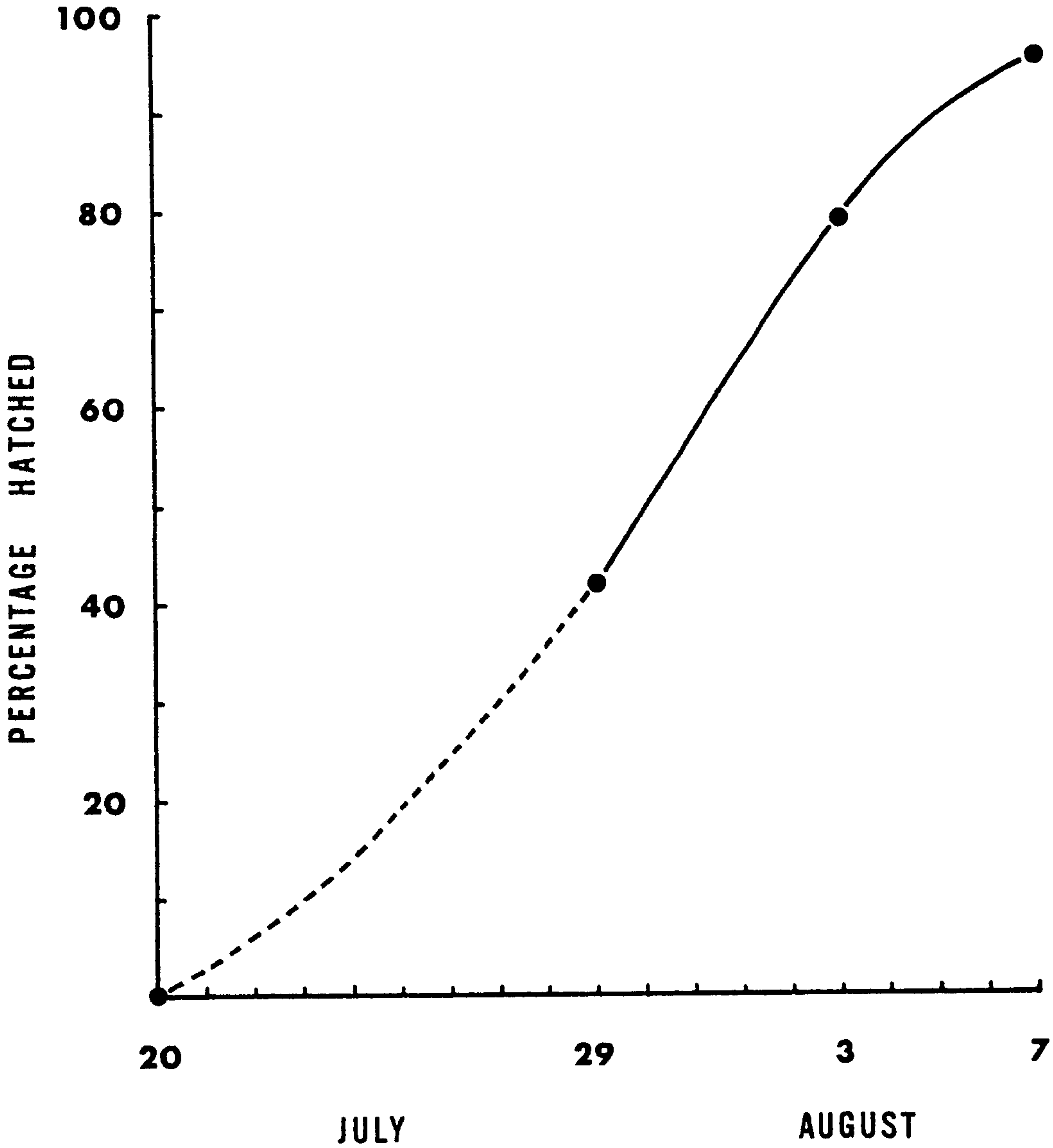

Figure 26. Hatching curve of Horned Puffins, Semidi Islands, 1977.

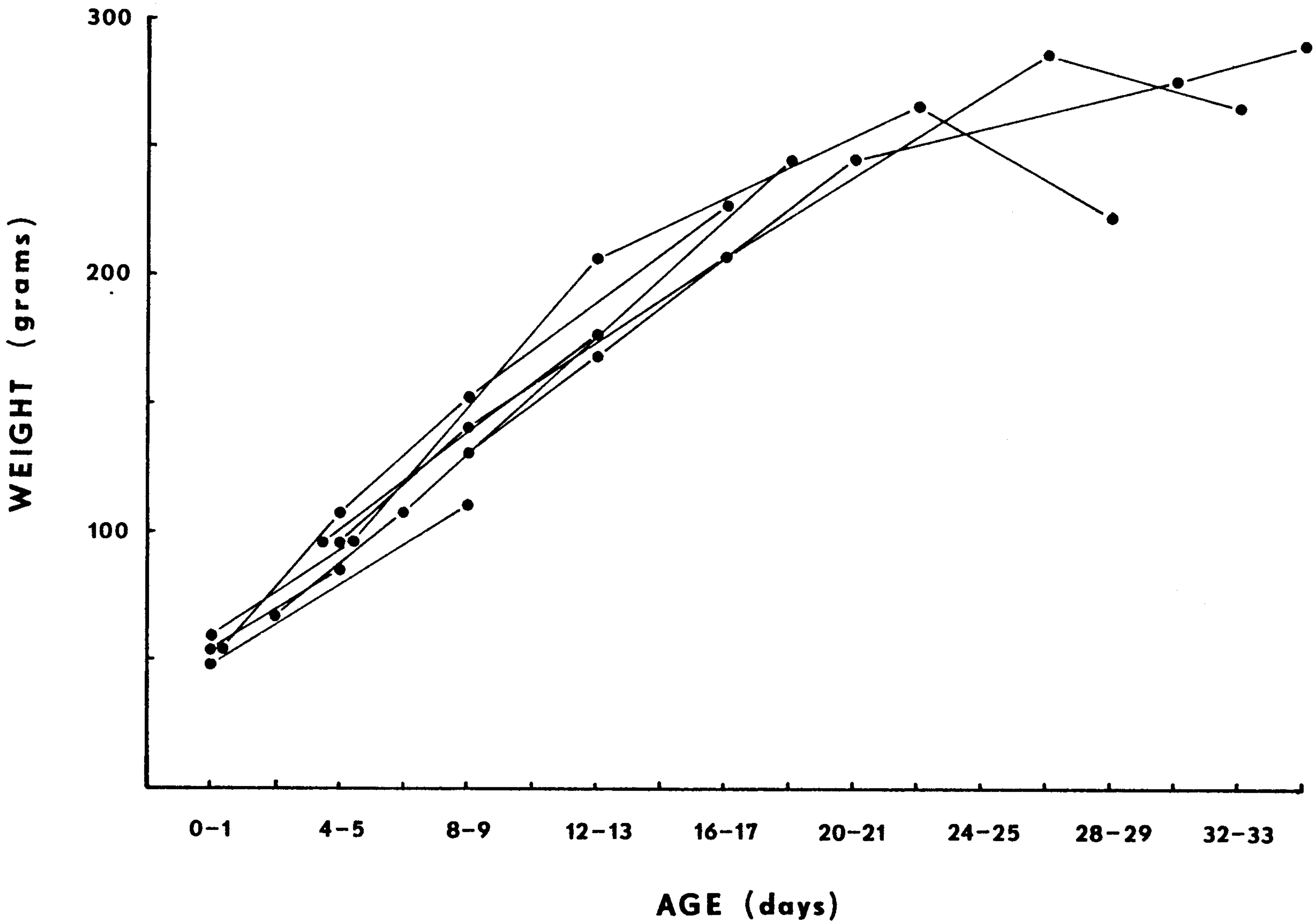

Figure 27. Growth of Horned Puffin chicks, Semidi Islands, 1977.

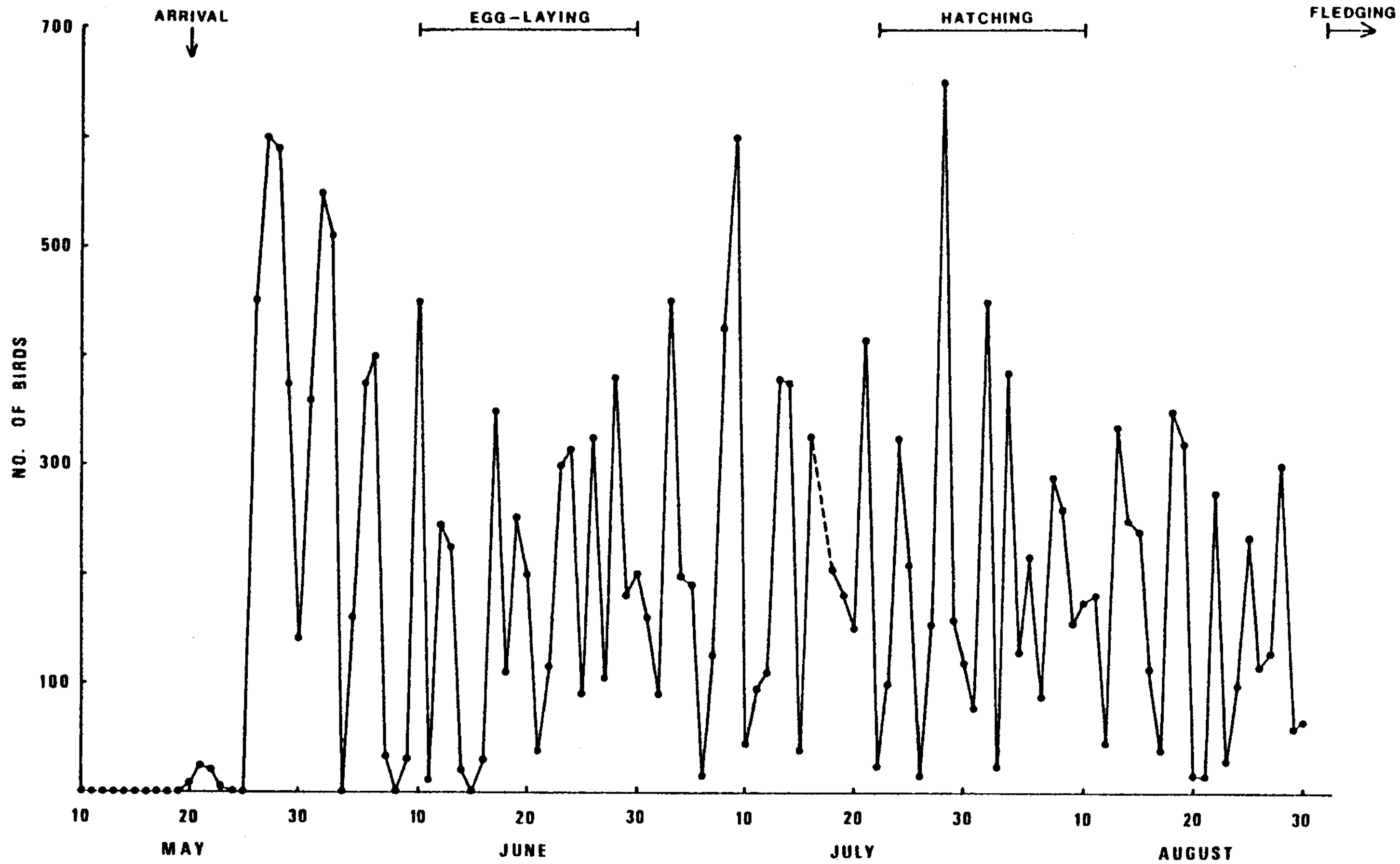

Figure 28. Daily counts of Horned Puffins on the water made at the same time and location, Semidi Islands, 1977.

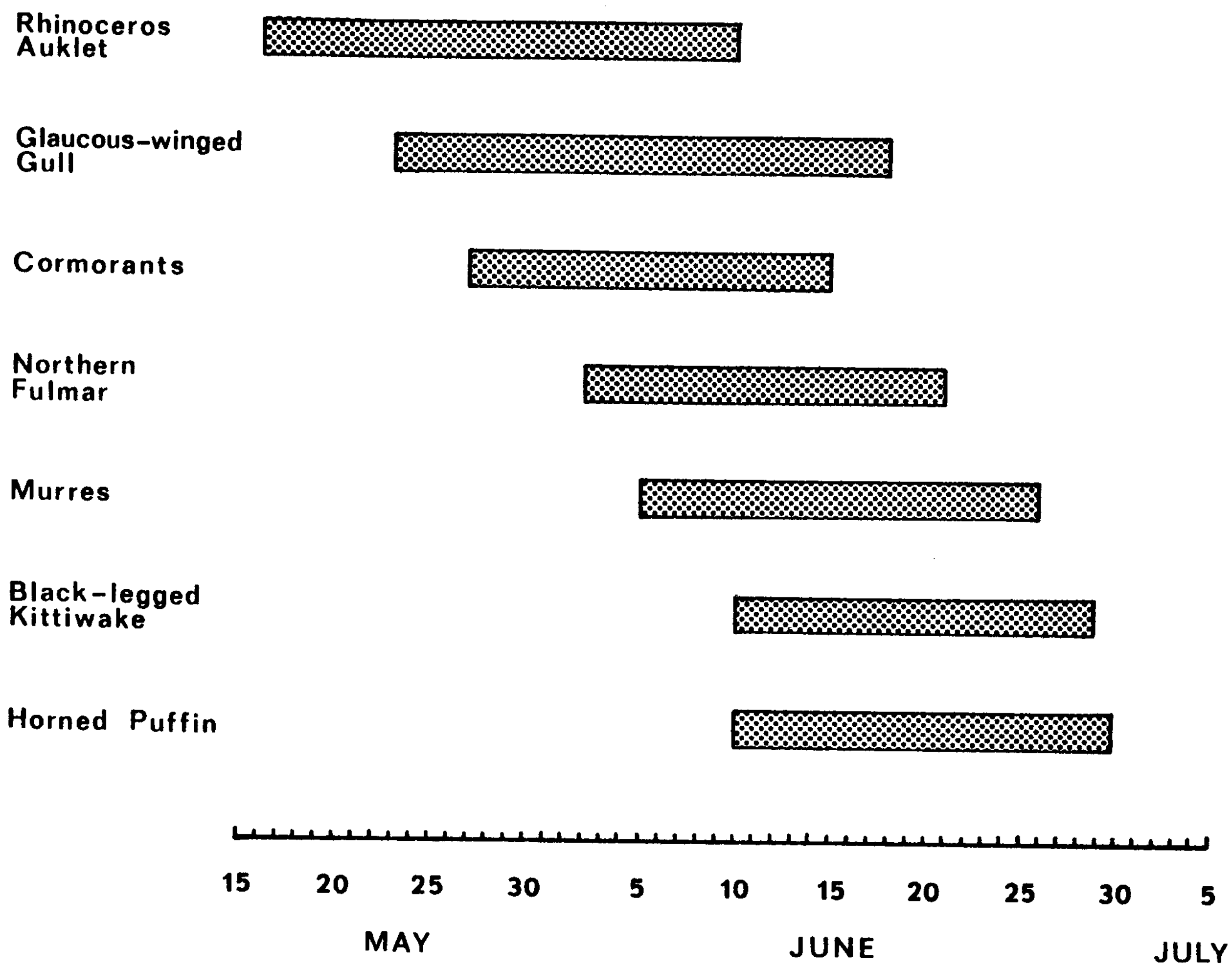

Figure 29. Egg-laying period of various seabird species at Semidi Islands in 1977.

APPENDIX III

NOAA-OCSEAP Contract: 01-5-022-2538
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ANNUAL REPORT

STUDIES OF MARINE BIRDS ON UGAIUSHAK ISLAND

By

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April 1, 1978

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I. INTRODUCTION

This study of the birds of Ugaiushak Island is one of several site specific studies of marine birds conducted as part of the BLM/NOAA Outer Continental Shelf Environmental Assessment Program (OCSEAP). The objectives of these studies include:

1. To determine the number and distribution of each species relative to other species, to determine periods of the breeding season, and the characteristics of available habitat within the colony or study area.

2. To provide estimates of production or nesting success of principal species.

3. To establish and describe sampling areas or units which may be utilized in subsequent years or by other persons for monitoring the status of population.

4. To determine the amount and kinds of foods utilized by principal species, when possible to determine the relationship of food selected to that available, and to describe daily foraging patterns.

5. To describe the phenology of events in the biology of breeding birds including changes in population from the onset of site occupancy in the spring through departure in the fall.

6. To provide a comparison of current data with recent historical data.

The Ugaiushak Island seabird colony is a part of a large complex of colonies included in the proposed Shumagin Islands National Wildlife Refuge. Birds from these colonies would be vulnerable to any extensive pollution by oil in the Western Gulf of Alaska such as may occur with the development of petroleum in Kodiak Basin.

This study of populations and ecology of the marine avifauna of Ugaiushak Island continues studies conducted on this island in 1974 and 1976. In 1977, Duff H.S. Wehle and his field assistant Brian E. Lawhead were present on Ugaiushak Island from 23 April to 29 August.

II. CURRENT STATE OF KNOWLEDGE

The United States Fish and Wildlife Service (USFWS) began studies of marine birds on Ugaiushak Island in 1974 with two investigators, George Divoky and Gus VanFleet, present throughout the breeding season. These workers sought to initiate long-term studies of survival by banding known-age birds. A report entitled "Work Conducted on Ugaiushak Island in 1974" summarizing their banding activities is available from the USFWS Office of Biological Services.

In 1976, personnel of the Office of Biological Services (OBS) occupied Ugaiushak Island from 24 May through 2 September. Duff H.S. Wehle was on the island for the entire period, Eric Hoberg from 24 May through 11 July, and Kevin Powers from 28 July through 2 September. The objectives of this study were to:

1. Determine the numbers of seabirds on the island.
2. Map all seabird nesting areas.
3. Determine breeding chronology and productivity for as many species as possible.
4. Evaluate feeding habits and define foraging areas.
5. Continue long-term studies of survival by banding young of the year.
6. Evaluate current mortality through surveys of beaches for presence of dead birds.

In addition to these major objectives, Wehle conducted an intensive study of the feeding ecology and breeding biology of the Tufted Puffin (Lunda cirrhata), Hoberg conducted an intensive study of endoparasites in nine species of seabirds and Powers conducted a detailed survey of the island flora. The investigators maintained a daily checklist of all birds observed on the island and conducted a survey of intertidal flora and fauna. Results of these studies were presented in the annual report for Research Unit (RU) 341/342 for the year ending March 1977.

III. STUDY AREA

Ugaiushak Island (56°47' N, 146°41'W) is approximately 13km south of the Alaska Peninsula and 126 km northeast of the village of Chignik (Fig. 1). With a total area of about 170 hectares, the island consists of two major parts, referred to as East Island and West Island, separated by a narrow isthmus (Fig. 2). Much of the coastline, especially along the southwester half of West Island and virtually all the southwestern side of East Islanc is composed of vertical cliffs up to 100 m in height. The coastline from Murre Point north to Eagle Point is primarily rock or boulder beach backed by steep vegetated slopes or vertical cliff. The eastern coastlin of both East and West Islands are composed of gradual ledge backed by steep slopes or cliff. The interior of West Island is divided along its northwest-southeast axis by a ridge extending from just north of Gull Point to just north of Kittiwake Lake. The highest points on the island extend from Murre Point to Eagle Point with the elevation of Ugaiushak Summit estimated to be about 170 m above sea level. A small valley runs between this area of high elevation and the previously mentioned ridge. At the western end of this valley lies Kittiwake Lake, a small body of water with a maximum depth of about a meter. The eastern side of West Island and all of East Island is relatively flat. The most notable topographic features of East Island are two holes, Hole-in-the-Wall and Devil's Hole, located on either side of Cormorant Cove, which are open from the surface of the ground down to the sea about 50m below. Crowber (Empetrum nigrum) associations dominate West Island, whereas Elymus-umbelifera communities prevail on East Island.

Small offshore rocks or ledges are located near Eagle Point in Peninsula Bay, Ascent, Secluded Bay, and Middle Finger. The latter are particularly hazardous to navigation, being above water only during very low tides.

Approximatley 3km south of Gull Point lies Ugaiushak Reef, a narrow rock ledge about 1km in length. At the southernmost end of the reef is a small rock outcropping rising about 10m out of the water. This rock is the major hauling-out area for a colony of sea lions which numbers about 450 animals.

Camp was located at the western end of Isthmus, at the site of an old fox farmer's cabin. This cabin was used for cooking, storage, and laboratory space. A wood frame tent was erected alongside the cabin and served as the main domicile in both 1976 and 1977. Suitable drinking water was obtained from a small ground water flow next to camp. As this source of water sometimes ran dry, it was necessary to store water after each major rainfall. The freshwater of Kittiwake Lake was not suitable for drinking due to heavy use by kittiwakes and gulls for bathing. Driftwood was abundant on Isthmus and Log Beach and was used as the major fuel source for heating. Fishing around the island was excellent throughout the summer with sculpin, greenling, rockfish, and halibut being most frequently caught.

During low tide, Guillemot Cove is closed off from Peninsula Bay by a shoal and thus provides a protected area for mooring a small boat. The shoreline of Guillemot Cove is composed of sand, gravel, and small boulders and affords the best landing site on the island for a small boat or float plane.

IV. METHODS, RESULTS AND DISCUSSION

Oceanodroma furcata (Fork-tailed Petrel)

Fork-tailed Petrels were observed throughout their colony in the higher elevations from Eagle Point southwest to Murre Point during our first night walk around the island on 5 May. Birds were heard within the talus around Saddle Peak during the daylight hours on 15 May, probably indicating that egg-laying and incubation had begun by that period. Two nests with eggs were located on 11 and 21 June on Saddle Peak. One of these nests was not checked again due to its precarious position within the loose talus. The other nest contained a newly hatched chick (maximum of 3-4 days old) on 15 July. The chick was still present in the nest when we left the island on 28 August.

Phalacrocorax auritus (Double-crested Cormorant)

Double-crested Cormorants were present on Ugaiushak Island when the field party arrived 23 April. From 23 April to about 12 May, birds were seen on ledges in the vicinity of Cormorant Cove. Beginning about 12 May, some Double-crested Cormorants left this area and were found on the highest ledges of the Main Talus cliff. For the next two weeks, birds were observed in varying numbers in both locations. In 1976, nesting of Double-crested Cormorants was confined to the cliff face along Cormorant Cove, and from here south about 150m along the southwest cliff face of East Island. In

1977, only a portion of this area was used for nesting. No birds nested in CSP (Cormorant Study Plot) #01 in 1977, whereas an estimated 15-20 pairs nested on the Main Talus cliff which had no active nests in 1976.

Censuses of all active Double-crested Cormorant nests on Ugaiushak Island were conducted in 1974 and 1976. In 1974, Divoky reported 26 nests, and in 1976, Wehle reported 34 nests and estimated the total population to be about 68 birds. A census of all individual birds was conducted during the early evening hours when all birds appeared to be on the breeding ledges for the night on 25 May, 1977. A total of 72 birds were observed. Thirty-three of these were on the Main Talus cliff and the remaining 39 were seen between Cormorant Cove and Oystercatcher Beach.

Two study plots were established to monitor the breeding phenology and production of this species. CSP #05 was located on the southwest facing cliff of East Island between Cormorant Cove and Oystercatcher Beach (Fig. 3). Fourteen nests were monitored in this plot by observation from vantage points along the clifftop; daily (weather permitting) from 18 May to 21 June, and irregularly thereafter. CSP #06 encompassed several wide ledges at the very top of Main Talus cliff, just over the clifftop from Ugaiushak Summit (Fig. 4). Twelve observations of this study plot were made throughout the season from a vantage point on an outcropping of the cliff face. The nests were also accessible by rope from the clifftop.

Double-crested Cormorants began nest-building on 10 May. Egg-laying of the first clutches (not including replacement clutches) ranged from 26 May to 10 June with the mode of laying occurring between 27 May and 2 June.

First-laid clutches had a mode of hatching between 8 July and 20 July. The relative number of Double-crested Cormorant nests at laying and hatching stages are shown in five-day intervals from 10 May to 30 July in Fig. 5. Most chicks were still present on the breeding ledges when last checked on 27 August, even though some of the chicks were 48 days old.

Production data for the 26 nests (not including replacement clutches) monitored in CSP #05 and CSP #06 are given in Table 1. It was not possible in every case to determine if mortality occurred at the egg stage or the chick stage since some adults sat so tightly on their nests that the contents could not be seen regularly until the chicks were about a week old. Observations on four such nests are listed separately in Table 1 and are referred to as "B" nests. "A" nests are those for which the stage at which mortality occurred was known. The mean clutch size of "A" and "B" nests combined was 2.67 eggs. Hatching success of known eggs and fledging success of known chicks for "A" nests were 35.7% and 100% respectively. Fledglings were defined, in this case, as chicks which were fully feathered and had attained adult size, even though they were still present on the breeding ledges. Combining the data for "A" and "B" nests gives 0.95 young fledged per nest with eggs and 0.77 young fledged per nest started.

Replacement clutches were laid in seven of eleven nests in which first clutches were lost. This occurred between 5 July and 15 July. The initial size of replacement clutches was not determined. However, when last checked on 27 August, four of these nests contained two chicks, two contained one chick, and one was empty. Assuming these chicks fledged, production for the two study plots combined would have been 1.43 chicks fledged per nest with eggs.

The chief cause of egg mortality in this species was predation by Glaucous-winged Gulls (Larus glaucescens) and Ravens (Corvus corax). Nests were observed only from a distance during incubation. Human disturbance probably was not a factor in egg mortality.

Double-crested Cormorants generally foraged within 3km of the island throughout the breeding period. No samples of food items brought to the young were obtained though Capelin (Mallotus villosus) was suspected to have been an important part of their diet.

Phalacrocorax urile (Red-faced Cormorant)

Red-faced Cormorants were present on Ugaiushak Island when the field party arrived 23 April. During late April and the first two weeks in May, birds were regularly observed on the southwest cliff face of East Island from Isthmus to Oystercatcher Beach, on the tip of Gull Point, and on Goose Rock. Large rafts of Red-faced Cormorants and Pelagic Cormorants were also common in Gulf Bay. Red-faced Cormorants were first observed on the breeding ledges on 2 May in the 1976 CSP's #02, #03, and #04 in Cormorant Cove. Birds were present in these plots thereafter through our departure 28 August. Between 11 May and 15 May the majority of the Red-faced Cormorants present on the southwest cliffs of East Island moved to the Main Talus cliff from Murre Point to Saddle Peak. Cormorants did not use these ledges in 1976. During the following week, about half of these birds returned to the breeding ledges on East Island. Those birds which had remained there had built large nests by this time. On 25 May, a census of individual Red-faced Cormorants was conducted during the early evening hours when it appeared all the birds were on the breeding ledges for the night. The census revealed 398 birds on the East Island cliffs. In 1976, all Red-faced Cormorants nested on East Island, and it was estimated from a count of active nests during early incubation that the total population for Ugaiushak Island was 364 birds, or roughly the same as censused in that area again in 1977. In 1977, this species also bred on Main Talus cliff and 835 birds were recorded during the 1977 census of that area making the total for the island 1233 birds, or 3 1/2 times that of 1976. In conjunction with this fluctuation in the number of breeding Red-faced Cormorants from 1976 and 1977, it was noticed in 1976 that although cormorants did not breed on the Main Talus cliff, the cliff face below many of the ledges was whitewashed, indicating the presence of breeding birds there in a previous year. It is also noteworthy that in 1976 some 60 Red-faced and 40 Pelagic Cormorants nested on Central Island, while no birds were observed there this year. Hatch (pers. comm.) reported that the cormorant colony on Chowiet Island in 1977 established its breeding site approximately 5km from where they bred in 1976.

Four study plots were established to monitor the breeding chronolgy and production of this species (Fig. 6). Study plots #01 (Fig. 7), #02 (Fig. 8), and #04 (Fig. 9) were located in the same place as those of the same number in 1976. CSP #01A was located at the entrance to Hole-in-the-Wall and contained five Red-faced Cormorant nests, and one Pelagic Cormorant nest (Fig. 10). CSP #02 and #04 were monitored from a canvas blind located on the opposite side of the cove. Incubation rhythms, courtship behavior, and other aspects of breeding biology of both Red-faced and Pelagic Cormorants were observed from this blind with minimum disturbance to the birds. These two plots were monitored daily from 12 May to 20 June and periodically thereafter. A few nests were accessible in both of these plots by climbing down into Cormorant Cove from its most inland point or by landing in the intertidal zone with a Zodiac. In either case, it was then necessary to climb the loose rock cliff face to the Red-faced Cormorant nests typically located over 25m above sea level. A climbing rope was used on several occasions but only under dry conditions due to the extreme danger involved. CSP #01 and #01A were observed from vantage points along the nearby clifftops with similar frequency to the other two plots. A few nests in each of these plots were accessible with the aid of a climbing rope.

Red-faced Cormorants began nest building as early as 29 April in the East Island colony. Egg-laying ranged from 16 May to 14 June with the mode of laying occurring between 25 May and 7 June. Hatching ranged from 19 June to 16 July with the mode occurring between 26 June and 14 July (Fig. 11). Fledging probably began about the second week in August, but specific dates were not obtained. It was estimated that three-quarters of the Red-Faced Cormorant chicks had fledged by 28 August.

Production data for first clutches in 51 nests monitored in CSP's #01, #01A, #02, and #04 are given in Table 2. In 13 nests, referred to as "B" nests, it was not possible to determine if mortality occurred at the egg or chick stage and these are considered separately in Table 2. "A" nests are those for which the stage at which mortality occurred was known. The mean clutch size of "A" and "B" nests combined was 3.08 eggs. Hatching success of known eggs and fledging success of known chicks for "A" nests were 38.8% and 89.5% respectively. Fledglings were defined as those chicks which were fully feathered and had attained adult size even though they may still have been present on the breeding ledges. Combining the data for "A" and "B" nests gives 1.35 young fledged per nest with eggs and 1.29 young fledged per nest started. No data on replacement clutches were obtained for this species.

The chief cause of egg mortality in this species was predation by Glaucous-winged Gulls and Ravens. As nests were observed from a distance during incubation, human disturbance probably was not an important factor in egg mortality.

Red-faced Cormorants appeared generally to forage within 3km of Ugaiushak Island throughout the breeding period. No samples of food items brought into the young were obtained though Capelin was suspected to have been an important part of their diet.

Phalacrocorax pelagicus (Pelagic Cormorant)

Pelagic Cormorants were present on Ugaiushak Island when the field party arrived 23 April. During late April and the first two weeks of May, Pelagic Cormorants were observed with Red-faced Cormorants on the southwest cliff face of East Island from Isthmus to Oystercatcher Beach, on the tip of Gull Point, and on Goose Rock. Large rafts of both species were observed frequently in Gull Bay. On 2 May, Pelagic Cormorants were first observed on the breeding ledges in the 1976 CSP's #02, #03, and #04 in Cormorant Cove. Birds were present in these plots thereafter through out departure 28 August. Between 11 and 15 May, a small percentage of the Pelagic Cormorants followed the same pattern of movement exhibited by Red-faced Cormorants previously described, with most birds returning to the East Island colony during the following week. On 25 May, a census of individual Pelagic Cormorants was conducted with 224 being counted on the East Island colony and 57 on Main Talus cliff. In 1976, all Pelagic Cormorants nested on East Island, and it was estimated from a count of active nests made during the early incubation period that the total population for Ugaiushak Island was 114 birds. Thus, the Pelagic Cormorant population on Ugaiushak Island in 1977 was approximately 2 1/2 times that in 1976, a similar situation to that observed for Red-faced Cormorants.

The same four study plots established to monitor the breeding chronology and production of Red-faced Cormorants were used for Pelagic Cormorants (Figures 6-10).

Pelagic Cormorants began nest building as early as 12 May. Egg-laying ranged from 23 May to 13 June with the mode occurring between 27 May and 5 June. Hatching ranged from 25 June to 10 July with the mode occurring between 25 June and 7 July (Fig. 12). Fledging probably began during the first or second week in August, though specific dates were not obtained. It was estimated that three-quarters of the Pelagic Cormorant chicks had fledged by 28 August.

Production data for first clutches in 44 nests are given in Table 3. In 18 nests, referred to as "B" nests, it was not possible to determine if mortality occurred at the egg or chick stage and these are considered separately in Table 3. "A" nests are those for which the stage at which mortality occurred was known. The mean clutch size of "A" and "B" nests combined was 3.45 eggs. Hatching success of known eggs and fledging success of known chicks for "A" nests were 64.6% and 86.3% respectively. Fledglings were defined as those chicks which were fully feathered and which had reached adult size, even though they may still have been present on the breeding ledges. Combining the data for "A" and "B" nests gives 2.05 young fledged per nest with eggs and 1.95 young fledged per nest started. No data on replacement clutches were obtained for this species.

The chief cause of egg mortality in this species was predation by Glaucous-winged Gulls and Ravens. As nests were observed from a distance during incubation, human disturbance was probably not an important factor in egg mortality.

Pelagic Cormorants concentrated their foraging efforts within 3km of the island throughout the breeding season. No samples of food items brought to the young were obtained but as with other cormorant species, Capelin was suspected to have been an important part of their diet.

Somateria mollisima (Common Eider)

Common Eider females were present on Ugaiushak Island throughout our stay from 24 April to 28 August. Male eiders were also present on 24 April but most left the island between 24 June and 5 July.

A total of nine nests were located: one on the northeast side of East Island, three on Gull Point, and five along the Gulf Bay coastline of West Island. Eight nests were located in 1976. In general, nests were located in small patches of Elymus along rocky outcroppings of the coastline. It is believed that only a small portion of the actual nests were found, due to heavy vegetation and a relatively light searching effort. A maximum or 62 adult eiders was observed on a single day in 1977, and it is estimated that between 30 and 40 pair of Common Eiders bred on Ugaiushak Island. Mean clutch size was 3.44 eggs. Egg mortality was 26% and 75% of the nests with eggs hatched ducklings. Two of the nine nests contained at least one Glaucous-winged Gull egg. One of these nests was incubated by a Glaucous-winged Gull, and the other by a Common Eider. The first ducklings were observed on the water on 1 July, and creches were observed daily, particularly in Gulf Bay and Peninsula Bay, through our departure on 28 August.

Haliaeetus leucocephalus (Bald Eagle)

Two adult pairs of Bald Eagles and at least four subadult birds were present on the island when the investigators arrived in late April. One adult pair nested in the same location as in 1976, atop Eagle Peak. On 26 April, two eggs were present in this eyrie. On 30 May, one of these eggs had hatched. The second egg was found broken on 4 June with a fully developed but dead chick inside. The single chick fledged from the nest on 20 August. This eyrie was checked periodically throughout the nestling period for prey remains. New prey items found in the nest on each visit were recorded (Table 4). Fish appeared to be the principle food of adult birds in May, prior to the arrival of seabirds to the island. Horned Puffins (at least 19), and both Common and Thick-billed Murres (at least 23 combined) were the prey items most frequently found in the nest during the nestling period.

One pair of adult eagles was observed throughout the summer in the vicinity of the East Island eyrie used in 1976. At times, these birds were seen perched at their former nest site, but were also observed carrying nesting material to a new site about 50m north. Although both eyries were checked periodically throughout the summer, no evidence of reproductive effort was observed. This same pair was also observed on Ugaiushak Reef during several of our visits there, but no nesting activity was indicated.

Subadult eagles were present on the island in varying numbers throughout the summer. From the time of our arrival through 11 May, and from 14 June through 28 August, no more than four subadult eagles were recorded daily. However, from 12 May through 14 June, daily counts recorded up to ten subadults. This period of time corresponded to the pupping of Harbor Seals. During this period, subadult eagles were continuously observed on intertidal rocks or on cliff tops above the Harbor Seals. Subadult eagles were observed on several occasions eating the afterbirths of seal pups as well as dead pups. It was not known whether eagles actually killed seal pups, perhaps taking advantage of those sick, injured, or left unguarded by adults, or fed only on those which had died of other causes. In either event, seven carcasses were found which had been eaten by eagles. It was estimated that eagles probably fed on at least two to three times this number. Movement of subadult Bald Eagles onto Ugaiushak Island during the pupping period of Harbor Seals was also observed in 1976 and is probably due to the short-term abundance in food supply, i.e., afterbirths and seal pups.

Two adult Bald Eagles were present throughout the summer at the site of the 1976 eyrie on Central Island. Production of this eyrie was not determined in 1977.

Falco peregrinus (Peregrine Falcon)

In 1976, one pair of Peregrine Falcons bred on Ugaiushak Island and fledged one chick. In 1977, three birds were seen on 2 May, two birds on 15 and 19 May, and a single bird regularly through 21 June. Thereafter, a single bird was observed only occasionally, the last observation being on 16 August. The single bird seen regularly through 21 June was repeatedly observed in the same area of Saddle Peak and each time exhibited typical "kakking" behavior, possibly indicating a nest nearby. However, no nest was located. I believe that if this bird was a member of a pair actively engaged in breeding, the attempt failed early in the nesting cycle.

Haematopus bachmani (Black Oystercatcher)

Black Oystercatchers were present throughout our stay on the island. Six nests were monitored. Mean clutch size was 2.67 eggs, egg mortality was 31%, and 67% of the nests with eggs hatched chicks. As in 1976, nests were located around the island on virtually all gravel or boulder beaches. It was estimated that between 25 and 35 pairs bred on the island in 1977, approximately the same number as in 1976.

Stercorarius parasiticus (Parasitic Jaeger)

Parasitic Jaegers were first observed on the island on 2 May. It was estimated that six pair of jaegers nested on the tundra on the plateau behind camp. Only one nest was located in August containing a single chick. A maximum of ten birds was regularly observed during June and July, an increase of four birds over 1976. From 30 July through August, higher numbers were seen with a maximum of 29 at one time. The highest number recorded during August in 1976 was 16 individuals. As in 1976, it was not known whether the increase in numbers was due only to the appearance of recently fledged young. An influx of migrating birds may also have contributed to this increase. In either event, 1977 showed approximately a two-fold increase in the number of Parasitic Jaegers resident on Ugaiushak Island during the breeding season.

Larus glaucescens (Glaucous-winged Gull)

The four major gull colonies on Ugaiushak Island were censused repeatedly in the early evening from 9 May to 9 June. It was felt that during this period the maximum number of gulls were on the colony as these dates roughly corresponded to the establishment of the colonies through the onset of laying. The East Island colony was censused both by walking through the colony and counting the number of individual birds from various vantage points, and by counting the number of individuals on the coastline from the Zodiac. The Gull Point colony was censused by a direct count of all birds visible from selected vantage points. Birds in the Kittiwake Bluffs colony were counted from Plover Ridge and from the southeastern side of Ugaiushak Summit with the aid of binoculars. Finally, individual birds in the Main Talus colony were counted from the Zodiac. The maximum number of nests or individuals counted in each of these colonies in 1976 and 1977 are given in Table 5.

The significance of differences revealed by the censuses in these two years is questionable due to the techniques involved. This is especially true for the East Island, Gull Point, and Kittiwake Bluffs colonies. The difference in the Main Talus colony between the two years is realistic and was obvious from simply being around the colony for extensive periods both years. The reason for this difference is unknown, although it is possible that some of the birds which nested at Main Talus in 1976 nested at Kittiwake Bluffs in 1977, thus accounting for the observed increase in this colony from 1976 to 1977. However, this increase still does not account for all the gulls missing from Main Talus in 1977.

The East Island, Kittiwake Bluffs, and Gull Point colonies were checked daily to determine the onset of laying. The dates when eggs were first found in each colony in 1976 and 1977 are given in Table 6.

Nests in all four colonies were randomly sampled to determine clutch size. The clutch size frequencies at the four colonies in 1976 and 1977 are given in Table 7. Although there was a great deal of variation between the two years within the same colony, the general trend for all four colonies combined was a similar frequency of single egg clutches while two egg clutches decreased and three egg clutches increased from 1976 to 1977.

Egg mortality for each of the four colonies in 1977 was:

East Island	37%	Gull Point	46%
Kittiwake Bluffs	58%	Main Talus	19%

The major source of egg mortality appeared to be predation by Glaucous-winged Gulls from the same colony, although Ravens probably contributed to egg loss as well.

Of 274 eggs laid within the four study plots, 168 hatched chicks, giving 0.61 chicks hatched for each egg laid. As Glaucous-winged Gull chicks left the nest shortly after hatching and were extremely difficult to relocate in the dense vegetation, we were not able to obtain any data on the number of chicks which survived to fledging. However, in addition to those nests monitored in the above study plots, clutch sizes were manipulated in 17 nests by the investigator. These nests were located in areas in which chicks were naturally confined by their surroundings or were fenced in with chicken wire so that they could be relocated with relative ease throughout their nestling period. The clutch sizes given to these nests were as follows: four 1-egg clutches, one 2-egg clutch, two 3-egg clutches, and ten 4-egg clutches. The purpose of the increased clutch size for the ten nests was to see if adults were able to raise to fledging a larger than normal number of young. If they were able to do this, it would suggest that food resources were not limiting reproduction during the nestling period. Of these 17 nests, three raised a single chick to fledging, one raised two chicks, five raised three chicks, and seven raised four chicks to fledging weight. Both egg mortality and chick mortality were 6%. Thus, seven out of ten experimental pairs whose clutch sizes were increased to four eggs were able to raise as many chicks to fledging. This, in addition to the increased frequency of three egg clutches laid in 1977 as compared to 1976, supports the contention that food resources were not limiting Glaucous-winged Gull reproduction in 1977.

Numerous regurgitated samples of food brought by adults to the young were examined from 8 July to 28 August. The predominant food item was Pacific Sandlance (Ammodytes hexapterus) which typically measured 5-10cm in length. A single load of these fish brought in to young was typically composed of 20-40 individual fish. Adult birds continued to feed chicks fish of similar size throughout the nestling period. Although other fish species were occasionally observed, there was no doubt that Pacific Sandlance were the most important source of food for gull chicks throughout the nestling period. Large schools of sandlance were observed in close proximity (within 3km) to Ugaiushak Island during the month of August, and it was assumed that Glaucous-winged Gull adults confined their feeding effort to the waters immediately surrounding the island.

During the month of August an influx of subadult gulls was observed on Ugaiushak Island. Approximately 2000 subadult birds were estimated to reside on the island during the latter half of the month. Birds occupied the plateau behind camp as well as the area around Goose Rock and Gull Point. A similar immigration was not observed in 1976. The reason for its occurence in 1977 is unknown.

Rissa tridactyla (Black-legged Kittiwake)

Black-legged Kittiwakes were present on the island in high numbers when the investigators first arrived on 23 April. Two study plots were established to monitor the breeding biology of this species. Hole-in-the-Wall afforded an excellent opportunity to make daily counts of the number of kittiwakes in a specific area and also served as a control plot for production, as this colony could be observed through the top of Hole-in-the-Wall without entering the plot and hence without creating any disturbance which might lead to egg loss or desertion. The number of kittiwakes within Hole-in-the-Wall was counted on a near daily basis from 2 May to 5 July. Thereafter, counts were made at irregular intervals throughout the remainder of the season (Table 11). On 23 May a maximum of 154 birds was counted, and a maximum of 72 nests were counted on 23 June. A total of 31 chicks was counted in the study plot on 27 August, giving 0.43 fledglings produced per nest started. This figure is probably low as a result of some chicks having already departed the colony for staging areas nearby or wandered from their nests to locations where they could not be observed.

A second study plot was established in Kittiwake Bluffs at the same location used in 1976. This plot was referred to as KSP (Kittiwake Study Plot) #04 in both years (Fig. 13). This plot afforded approximately 100 accessible nests which could be reached by walking around the intertidal zone at low tide from Square Bay Beach to Kittiwake Bluffs. The ledges in this area were wide and easy to climb under dry conditions. Nests were marked with a numbered tongue depressor inserted partially under the nest. A piece of brightly colored flagging tape was affixed to the protruding end to aid in the relocation of each nest. A total of 101 nests were monitored in this study plot. Fifty-seven of these nests were used to determine nesting chronology and production. Nesting chronology is summarized in Table 8 and Fig. 14

The production statistics for the two years indicate a general reproductive failure in 1976 compared to a rather successful reproductive effort in 1977. The reason for the 1976 failure is unknown. However, lack of sufficient food resources is one of the more likely possibilities. In 1977, we experimentally increased the clutch size of 29 nests to see if kittiwakes could raise a greater than normal number of chicks to fledging. In this experiment, 20 nests were given 3-egg clutches at the beginning of incubation, and an additional three nests were given 3-egg clutches of starred or pipped eggs at hatching. Also, two nests were given 4-egg clutches at the beginning of laying and four additional nests were given 4-egg clutches of starred or pipped eggs at hatching. Production data for these experimental nests are given in Table 10. The data presented in this table indicate 85.0% and 50.0% hatching success of eggs introduced at the onset of incubation for the 3-egg clutches and 4-egg clutches respectively. Combined fledging success was 52.5% for chicks from all experimental 3-egg clutches. The twenty-three 3-egg clutches produced 1.35 fledglings per nest while the six 4-egg clutches produced 1.67 fledglings per nest. Results from these experiments support the contention that reproduction in kittiwakes was not limited by food in 1977. The lower fledging success in experimentally manipulated nests was probably the result of the physical limitations of incubating and rearing three or four chicks in an average sized nest. The lower hatching success for experimental 4-egg clutches was also probably the result of physical limitations. Human disturbance during the experimental procedure undoubtedly increased egg and chick mortality. Nevertheless, the number of young fledged per nest with eggs was much greater than observed in the 57 control nests.

Adequate food resources during the egg-laying period was further substantiated by egg-relaying experiments. Eggs were removed from 12 nests with 2-egg clutches immediately after the second egg was laid. Females in seven (58.3%) of these laid one more egg, four did not lay another egg, and one nest was lost two days following the removal of the first clutch. Of the seven nests in which a third egg was laid, three hatched chicks, eggs remained unhatched in three and one nest was lost. In addition to these twelve nests, single eggs were removed from three nests with 1-egg clutches. Females in all three nests laid one more egg. Chicks hatched from two of these nests, the third nest was lost.

The primary causes of egg mortality throughout the colony were probably predation by Glaucous-winged Gulls and Ravens, and the breakage of eggs in poorly secured nests.

The major source of chick mortality was undoubtedly weather conditions during the nestling period. Twenty-nine consecutive days of rain were recorded from 25 July through 22 August, encompassing nearly the entire nestling period of kittiwakes. Rock and mud slides washed many nests from the cliffs, and chicks which ventured from the safety of the nest cup were seen on numerous occasions to lose their footing and plummet to the base of the cliff. It was believed that avian predators (gulls, ravens, and eagles) had only a small affect on the mortality of kittiwake chicks in 1977.

Feeding flocks of kittiwakes ranging from 50 to several hundred birds were observed within 3km of Ugaiushak Island throughout the field season. During April, May, and June foraging flocks were concentrated at a greater distance from the island than during July and August. Large surface schools of Ammodytes and Mallotus were abundant in July and August within several hundred meters of the shore. During the first half of the nestling period, Ammodytes remained the most frequently observed food item. However, Theragra chalcogramma and Mollotus villosus were also consistently observed. It appeared that the diet of small chicks was limited to Ammodytes. As chicks grew and were able to ingest larger fish, Theragra and Mollotus became more important parts of their diet.

Beginning in mid to late July and continuing through August, an influx of subadult kittiwakes was observed on Ugaiushak Island. It was estimated that between 4000 and 6000 subadult birds were present on the Island and Ugaiushak Reef by the end of August in addition to the estimated breeding population of 8-10,000. Although the number of subadults increased as birds of the year fledged, the initial influx may have been the result of migrating young of the year from more northerly colonies and/or unexplained movement of yearling birds. Such an influx was not observed in 1976.

Uria aalge and *U. lomvia* (Common Murre and Thick-billed Murre)

Due to the difficulty of distinguishing Common from Thick-billed Murres at a distance, the following discussion refers to both species except where stated otherwise.

Murres were censused on Ugaiushak Island in 1976. The estimated total population of both species combined was 8,500-10,000 birds. The highest count of murres at one time in 1977 was made at 06:30 on 22 May when 10,000+ murres were counted in a single raft off Murre Point. The count was made from Ugaiushak Summit. From this count, it was estimated that the total murre population for the island in 1977 was 12-15,000 birds. The ratio of Common to Thick-billed Murres was estimated to be between 10 and 15 to one.

Murres were present around the Island when the field party arrived on 23 April. From this time until the first week in June, the birds were seen each day rafted in the waters off Murre Point and Kittiwake Bluffs in numbers varying from hundreds to thousands. The birds occupied breeding ledges which on other days were nearly completely vacated. During this period of intermittent attendance at the colony, murres were observed to leave the vicinity of the island *en masse* between 16:00 and 18:00 with the entire population having dispersed by 20:00. In a survey around the island between 21:30 and 22:30 on 12 May, we observed only two murres either on the ledges or rafted offshore. The exodus from the island followed the same route each day (Fig. 14). Rafts between Murre Point and Kittiwake Bluffs slowly broke up as a steady stream of birds flew southeast between Gull Point and Ugaiushak Reef. From there the birds flew eastward across the mouth of Gulf Bay and past the fingers at the south end of East Island. Using binoculars from Ugaiushak Summit, we then observed the birds flying northeast up Shelikof Strait. Murres began to remain at the colony at night during the week of 6-13 June, after which birds were present around the island continuously through our departure 28 August.

The small murre colony in Hole-in-the-Wall afforded the best opportunity to make counts of murres on specific ledges throughout the breeding season (Table 11). Birds were counted from above, looking down through the top of Hole-in-the-Wall, without causing them to flush. In this colony, murres occupied nine ledges among nesting kittiwakes (Fig. 16). The number of birds of each species was counted on a near daily basis from 2 May to 5 July. Thereafter, counts were made at irregular intervals throughout the remainder of the season. A maximum of 142 Common Murres and 11 Thick-billed Murres was recorded on these nine ledges. The data presented in Table 11 can be used in future years to assess fluctuations in the number of murres present in the colony.

Common Murres were first observed to copulate on 30 May and copulations were observed daily in the murre colony beginning about 18 June.

Three study plots were established in the Kittiwake Bluffs murre colony to obtain information on productivity of murres. Study Plot #04 was located in the same area as KSP #04 (Fig. 13). Access to this plot was via the intertidal zone from Square Bay Beach. The plot consisted of two principal ledges located one above the other although birds also used small rock outcroppings and depressions around these ledges. The number of birds within the study plot was determined periodically throughout the season. From these counts, it was estimated that 41 pairs of Common Murres and three pairs of Thick-billed Murres used these ledges. The plot was checked every two days from 24 June through 21 July and periodically thereafter. New eggs were weighed, measured, and numbered with a permanent ink marker. As all the adult birds flushed during these visits, human disturbance was an important cause of egg mortality. A total of 56 eggs were laid in this study plot by Common Murres from 24 June through 3 August. It was thought that 41 of these eggs were first clutches while the remaining 15 eggs were replacement clutches. Thirty-four of the 56 eggs laid were lost, giving an egg mortality of 61%. Twenty-two chicks hatched on this plot, of which ten fledged, giving a chick mortality of 55%. Thus, 0.18 chicks were fledged per egg laid. The three pairs of Thick-billed Murres in this study plot each laid one egg. Two of these eggs were lost and not replaced, giving an egg mortality of 66%. The third pair successfully fledged their chick, giving a chick mortality of 0% and 0.33 chicks fledged per egg laid.

Study Plot #01 was located in a geomorphologically delineated area on the east cliff face of Murre Cove. From repeated counts throughout the breeding season we estimated 14 pairs of Common and 25 pairs of Thick-billed Murres occupied the plot. Observations were made from the opposite side of the cove with the aid of binoculars. As the birds did not flush during our checks, it was not always possible to accurately determine if eggs or chicks were present. It appeared that only four of the 14 pair of Common Murres laid eggs and that all four of these eggs hatched and fledged chicks. Thus both egg and chick mortality was 0% and there was 1.0 chick fledged for each egg laid. It is strongly suspected, however, that more eggs were laid but were lost to predation or breakage. Only six eggs were known to have been laid by the 25 pairs of Thick-billed Murres. However, as with the Common Murres, it was suspected that more eggs were laid but were lost during incubation. Of the six observed eggs, five were successfully hatched and all five chicks fledged. Thus, egg mortality was 17%, chick mortality 0%, and 0.83 chicks were fledged per egg laid.

Study Plot #03 was located in a geomorphologically delineated area on the west cliff face of Murre Cove. Observations of this plot were made from the opposite side of the cove with aid of binoculars. As in Study Plot #01, birds did not flush from the cliff during checks, so it was not always possible to accurately determine if eggs or chicks were present. This study plot was composed entirely of Thick-billed Murres. Twenty-two pairs of birds nested on small discrete ledges or rock outcroppings on the cliff face. Eggs were observed in 19 of the 22 nests occupied by pairs throughout the breeding season. Of these 19 eggs, nine were successfully hatched and six chicks fledged. Thus, egg mortality was 53%, chick mortality was 33%, and 0.32 chicks fledged per egg laid.

Predation by Glaucous-winged Gulls and Ravens was probably the major source of egg mortality in Study Plots #01 and #03. However, predation on eggs of murres appeared much higher in 1976 than in 1977, possibly a result of the greater availability of kittiwake eggs and young in 1977.

A total of 120 samples of food items brought to the chicks by the adults were collected from the ledges of the Kittiwake Cave, Kittiwake Bluffs, Murre Cove, and Square Bay colonies between 20 and 24 August. Chicks in all stages of growth were encountered, though the majority of chicks were probably at least a week old by 20 August. Sampling areas were predominantly used by Common Murres. In general, Thick-billed Murre ledges were not accessible. Samples were obtained by simply picking up the fresh whole fish found on specific ledges in each of these colonies on each of the four days. Measurements of length and weight were taken on each prey item when possible. The relative frequency of each of the prey items obtained and their measurements are given in Table 12.

Cepphus columba (Pigeon Guillemot)

Pigeon Guillemots were present around Ugaiushak Island throughout the field season. Guillemots were censused between 06:00 and 08:00 on 22 May. This date preceded the initiation of egg-laying. At this time of day, most breeding pairs engage in courtship display in the nearshore waters. Counts were made of birds on the water and on shore from the Zodiac. A total of 473 birds was recorded with the highest numbers being observed between Guillemot Cove and Eagle Point (180 birds), between Eagle Point and Saddle Beach Point (125 birds), and at South Wash-out Beach (60 birds). The census was repeated between 08:00 and 10:00 on 27 May. A total of 401 birds was recorded with more birds being observed on the shore than during the 22 May census. In 1976, a census conducted on 27 June recorded 176 guillemots present around the island. Differences in time of day and stage of nesting cycle probably account for the differences between the 1976 and 1977 censuses.

Three nests, all with two eggs, were located during the incubation period; one on the northeast beach of Guillemot Cove and two at South Wash-out Beach. Two nests that Divoky had marked in 1974 were not used in 1976 or 1977. Of the three active nests one was deserted and the other two each hatched two chicks. Egg mortality was 33%. Three more nests were located during the nestling period; one on the northeast beach of Guillemot Cove and two at South Wash-out Beach. Two of these nests had one chick and one had two chicks. Two of the three nests with two chicks successfully fledged only one. The third nest fledged both chicks. Both nests with one chick successfully fledged the single chick. Over-all chick mortality was 25%. From the four nests in which clutch size was known there were 0.5 chicks fledged per egg laid, assuming no more than two eggs were laid per nest.

Several samples of fish brought into the chicks by adults were collected. Several more samples were observed with the aid of binoculars and identified as the adults sat in the water near the nest with the fish held in their bills. The most important food item appeared to be the Red Irish Lord (Hemilepidotus hemilepidotus). Average prey size observed during August was 130-160mm. One fresh specimen measuring 130mm weighed 20.0g. Capelin (Mallotus villosus) was also fed to the chicks but in much smaller numbers. One Capelin obtained measured 140mm.

Fratercula corniculata (Horned Puffin)

Horned Puffins first arrived at Ugaiushak Island on 20 May when four birds were observed. Two Horned Puffins were seen on 21 May, and several hundred birds on 22 May. A maximum of three birds per day was observed from 23-25 May. Thereafter, except for 3, 8, and 11 June when less than six birds were seen per day, thousands of puffins were present around the island throughout the remainder of the breeding season.

Eight PSP (Puffin Study Plots) were established to monitor the breeding chronology and production of Horned Puffins (Fig. 17). PSP #10 was the same as PSP #04 in 1976. This plot was used to determine the onset of egg-laying. PSP #11 and #12 had the highest density of birds per unit area. However, observations in these two areas were limited since nests deep within the talus were not accessible. PSP #13, located in the small talus area above Square Bay Beach, was used for egg-relaying experiments and the study of chick growth. PSP #5A, #5B, #5C, and #5D were comprised of nests located under beach rocks and in crevices along the eastern coastlines of West Island and East Island. These nests were used to monitor the timing of hatching and to obtain data on growth rate of chicks.

Horned Puffins tended to nest in rocky surroundings whether under beach rocks, in talus areas, or in crevices of ledges. Hence, it was very difficult to locate a nest prior to the appearance of an egg. Thus, accurate data on the time of egg-laying could not be obtained directly. Once an egg was located, the nest was marked with a numbered tongue depressor and brightly colored flagging tape. PSP #10 was searched for eggs on 11, 14, 17, and 21 June with 0, 1, 7, and 17 eggs being located on these dates respectively. The plot was then not checked again until the onset of hatching in order to minimize human disturbance. At that time only a few additional nests with chicks or eggs were located indicating that peak egg-laying probably occurred around 14-21 June. Hatching dates of 44 chicks in PSP #5A, #5B, #5C, #5D, and #10 were known to the nearest day, and their mode of hatching (period in which two-thirds of the chicks hatched) was 25-30 July (Fig. 18). Assuming an incubation period of 42 days (Sealy 1973), the mode of laying for these 44 eggs occurred between 13 and 18 June. None of 11 chicks whose growth was monitored had fledged by the time the investigators left the island on 28 August. It was thought, based on body weights and plumage development, that the first of these chicks would have fledged around 30 August. Extrapolating from the mode of known hatching dates and the length of the nestling period (Sealy 1973), the mode of fledging would have been 1-6 September.

A total of 68 nests was located in all study plots. Eggs were hatched in 52 (76%) of these. Of the remaining eggs, eight did not hatch as a result of desertion, infertility, etc., four were lost, and four chicks died during hatching.

The weight, length, and width of freshly laid puffin eggs in 1976 and 1977 are given in Table 13.

In 1977, the weight loss of five eggs during the incubation period was obtained by subtracting the weight of the starred egg from its initial weight. Weight loss ranged from 6.5g to 10.5g with a mean loss of 9.3g, approximately 12% of the fresh egg weight.

Egg relaying experiments were conducted in 1977 to determine if Horned Puffins are capable of replacing lost eggs. Eggs were removed within two days of their appearance in ten nests. The nests were then checked at about two-day intervals for the presence of a second egg. Second eggs appeared in three of the ten nests 16-20 days after the first egg was removed. Since few accessible puffin nests were available, these eggs were left in the nests rather than removed to see if a third egg might be laid. However, none of these replacement eggs were incubated. In one of these nests the second egg was later moved into the corner of the rock crevice in which the nest was located. The nest was then rebuilt and a third egg laid sometime between 6-18 days after the second egg. Although we could not be sure that the same pair was involved, nest sites did not appear to be limiting and the laying of the third egg occurred between 21 July and 2 August which corresponded to the hatching period for the rest of the population. Thus, replacement eggs did appear in 30% of those nests from which the first egg was removed, and there is some evidence to suggest that puffins may be capable of laying a third egg.

Hatching weights of six chicks were obtained in 1977. The mean hatching weight was 47.5g with a range of 45.0g to 52.0g.

Growth of 11 chicks was monitored from the time of hatching to the time investigators left the island on 28 August. One of the 11 chicks died during the nestling period. Assuming all the others fledged, fledging success of known chicks was 91%. As of 28 August, nine of the ten chicks ranged from 21 to 34 days of age. Their mean weight was 346g with a range of 238g to 403g. One chick which was not checked on 20 August is omitted. Growth rates of all ten Horned Puffin chicks are shown in Figures 19 and 20.

Four sets of Horned Puffin twins were artificially created by placing two-day old chicks together in the same nest. Growth rates were measured in each pair through 28 August (Figures 21-28). In one set, one of the chicks died about mid-way through the nestling period while the other maintained the average growth rate of a single chick. One chick in each of two sets grew at the same rate as a single chick while the twins of these two sets grew at a slower rate than typical single chicks. In the fourth set, both chicks grew at the same rate as typical single chicks. These experiments suggest that food resources were not limiting reproduction of Horned Puffins during the nestling period.

No quantitative data on the food brought to nestlings by adults was obtained. However, Ammodytes hexapterus was the most commonly noted prey species. Typical specimens measured 6-10cm in length. Mallotus villosus was also thought to be an important part of the diet of puffin nestlings.

Lunda cirrhata (Tufted Puffin)

Tufted Puffins first arrived at Ugaiushak Island 10 May, on which date 101 birds were seen. On 11 and 12 May 150 and 114 birds respectively were observed. Between 4-500 were seen on 13 May. Thousands of Tufted Puffins were present around the island from 14-16 May. In the following three days, a maximum of 13 birds per day was observed. This was followed by three days of attendance by thousands of birds, then three days during which a maximum of 50 birds per day was observed. This three-day cycle continued through 3 June, when a peak in attendance was followed by a single day of low attendance on 4 June. Thereafter, thousands of puffins were present daily at the island throughout the remainder of the breeding season (Fig. 29).

Nine PSP (Puffin Study Plots) were established to study the breeding chronology and productivity of Tufted Puffins (Fig. 30). PSP #1A and #1B were located in the same area as PSP #01 in 1976. These two plots were used primarily to collect data on the chronology of nesting and for chick growth rate experiments. PSP #2 was the same plot as used in 1976 when 15 individual adult puffins were banded, one in each of 15 burrows. In 1977, these burrows were checked to see if the marked birds had returned to the same burrow. PSP #4A, #4B, and #4C were new in 1977 and were located in the same area as PSP #2. They were used for egg-twinning experiments, egg-relaying experiments, egg-recognition experiments, and the collection of data on chronology of nesting, productivity, and growth of chicks. PSP #7 was a part of 1976 PSP #03. This plot was used to assess production and percent burrow utilization. PSP #8 was new in 1977 and used primarily for observation of birds throughout the breeding season. A blind was established in this plot, and a total of 68 burrows were marked with numbered stakes and flagging tape. Information on behavior, colony attendance, burrow utilization, percent of actively breeding adults, productivity, growth rates, and food items fed to young were obtained from this study plot. A cairn was built to indicate the location of the blind.

Tufted Puffins were present on the breeding areas of the island when they first returned 10 May. During their period of intermittent attendance at the island, birds were observed both on colony and in large rafts just offshore. Copulation was first observed on 13 May and excavation of burrows in PSP #8 began on 15 May.

In early May, burrows in all study plots were marked with numbered stakes or tongue depressors and a plastic flag affixed to a meter-high wire stake to aid in their relocation after the vegetation had grown. Burrows whose nest chamber could not be reached through the burrow entrance were accessed by an observation hole dug into the nest chamber and covered with plywood, rocks, or plugged with sod between visits. Burrows in PSP numbers 1A, 1B, 4A, 4B, 4C, 6, and 8 were checked on 21 and 27 May and thereafter at 1-2 day intervals through 14 June for the presence of eggs. Figures 31 and 32 show the relative number of burrows at laying, hatching, and fledging stages in five-day intervals from 25 May to 5 September in 1976 and 1977. The chronologies of the nesting season for Tufted Puffins on Ugaiushak Island in 1976 and 1977 are compared in Table 14.

The length of the incubation period, defined as the interval from the laying of the egg to the complete emergence of the chick, was determined for Tufted Puffins in both 1976 and 1977 (Table 15).

The weight, length, and width of freshly laid Tufted Puffin eggs were measured in 1976 and 1977. These data are presented in Table 16.

In 1977, weight loss of nine eggs during the incubation period was obtained by subtracting the weight of the starred egg from its weight as a freshly laid egg. Weight loss ranged from 10.0g to 16.5g with a mean loss of 12.6g, approximately 13% of the fresh egg weight.

Hatching weights were obtained on nine and 22 chicks in 1976 and 1977, respectively. The mean hatching weight was 60.9g with a range of 52.5g to 74.0g in 1976 and 61.9g with a range of 44.5g to 71.0g in 1977.

Production statistics for all study plots combined in 1976 and 1977 are given in Table 17.

Tufted Puffins had only begun to fledge in 1976 and 1977 when the field party departed from the island. Hence, fledging success of known chicks, number of young fledged per nest with eggs, and number of young fledged per active burrow could not be determined for the monitored burrows. Data on those chicks which did fledge and on those which remained in burrows at the time of the last check by the investigator are presented in Table 18.

The nestling period is defined as the interval from complete emergence from the eggshell to departure from the burrow. In 1976 the nestling period for seven chicks whose hatching and fledging dates were known averaged 45.9 days and ranged from 43-44 days to at least 48 days. In 1977 fledging dates were known only to within four days.

Egg-relaying experiments were conducted in 1977 to determine if Tufted Puffins would lay a second and third egg if the first and second eggs were lost. Eggs were removed from ten burrows within two days after they were laid. The burrows were then checked at intervals of several days for the presence of a second egg. Replacement eggs appeared in seven of the ten burrows sometime between 10 and 21 days after the first egg was removed. Five of these seven nests were excavated within a few days after removal of the first egg while the burrows in which replacement eggs were not laid were also excavated. Each of the second eggs was removed within a couple days after it was laid and burrows were checked at intervals of several days thereafter for the presence of a third egg. No burrows contained a third egg. This experiment indicates that 70% of breeding puffin females lay a second egg after the first egg is lost and that they apparently will not lay a third egg. It should be noted that we could not be sure the same pair was responsible for both eggs found in each of the seven burrows. However, the presence of unused burrows nearby, suggesting little or no competition for burrows, and the fact that the second eggs were laid two to four weeks after the mode of laying for the population lend strong support to the contention that both eggs were laid by the same female.

Eggs removed from burrows during the egg-relaying experiments were used for egg-twinning experiments. Each of the ten eggs removed was placed in a burrow in which an egg had been laid within the previous two days. Burrows were then checked periodically throughout the incubation period to determine if both eggs were being incubated. In three burrows the eggs were incubated alternately. None of these eggs hatched. Two nests were deserted probably due to human disturbance during checking. In five burrows, a single egg was incubated, two of which were successfully hatched. The length of the incubation period for both of these eggs was greater than 50 days. In one of these five burrows a chick died while hatching.

Soil temperature of nest chambers in Tufted Puffin burrows was measured in PSP numbers 1A, 1B, 4A, and 6 on 4 May (approximately a month before peak egg-laying), during peak egg-laying, and during peak hatching. Temperatures were obtained by inserting a soil thermometer approximately 2-4cm into the soil on the bottom of the nest chamber. The results were as follows:

	$\bar{x}$ T °C	N
4 May	2.1	65
Egg-laying	9.0	23
Hatching	14.5	4

Fifteen adult puffins were banded in 1976, one in each of 15 burrows in PSP #2. These burrows were checked in 1977 for the presence of banded adults to see if birds used the same burrow in successive years. Eggs were laid in seven of these burrows in 1977. One banded bird was captured in each of two burrows, in both cases the same burrow in which it was banded in 1976. Four of the other five burrows were checked daily for five consecutive days but no birds were captured and the burrows were then deserted. In the remaining burrow the same unbanded adult was captured four times before the burrow was deserted.

The percentage of birds on the colony actively engaged in breeding was determined by regular observation of 35 burrows in PSP #8. The results of this study were as follows:

35 total burrows in this study plot

- 4 (11%) of these never had birds associated with them
- 31 (89%) of these had birds associated with them at some point during breeding
  - 12 (39%) of these hatched chicks
  - 4 (13%) of these had eggs laid in them which did not hatch
    - 2 (50%) of these were deserted immediately after the egg was laid and the adults were not at the burrow again during the breeding season
    - 2 (50%) of these were deserted later in incubation and at least one of the adults was observed regularly at the burrow throughout the remainder of the breeding season
  - 15 (48%) of these never had an egg laid in them
    - 7 (47%) of these had birds associated with them only during the pre-egg stage
    - 8 (53%) of these had birds associated with them throughout the breeding season

Of the 31 burrows active in the pre egg-laying season, 77% remained active throughout the summer but only 52% had eggs laid in them. Thus, we suspect that in 1977 only slightly over one-half of the Tufted Puffins present on the breeding colonies during the breeding season were actively engaged in breeding.

Growth rates of ten Tufted Puffin singles (Figures 33 and 34) and three pair of artificial twins (Figs. 35 to 40) were measured at 1-5 day intervals throughout the nestling period. Initially, six sets of twins were created by placing two-day old chicks together in the same burrow. In three cases both chicks were alive on 27 August when they were last checked. In two cases one chick died soon after twinning. One chick died about mid-way through the nestling period when its twin forced it into part of the burrow where it could not regularly receive food from the adults. Two of the three sets of twins which did live had slower growth rates than an average single chick while the third set exhibited growth rates comparable to an average single chick. An analysis of the growth rate in the ten Tufted Puffin single chicks was undertaken using the logistic growth equation described by Ricklef (1967). The mean weight for the ten chicks was computed at five-day intervals throughout the nestling period and these values were used to compute conversion factors. Using Ricklef's terminology, the estimated asymptote was 549g, K = 0.152m, Ka/e = 30.68g gained per day, KR/e(100) = 3.87% of adult body weight gained per day, and T_{10-90} = 28.9 days for the chicks to grow from 10% to 90% of their adult body weight.

Thirty-one bill loads of food brought to nestling puffins were collected in 1977. Samples were collected by observing adults entering burrows with food from a blind in PSP #8, running to the burrow, pulling the plug to the nest chamber, and retrieving the food items before the chick began to eat them. This method proved very successful. An additional 33 bill loads were observed from the blind. With the aid of binoculars the number and species of fish present in each load were counted and identified. The 64 samples were composed of 350 individual food items which had the following species breakdown:

Ammodytes hexapterus	287	Mallotsus villosus	42
Theragra chalcogramma/ Eleginus gracilus*	17	Oncochynchus keta	2
Octopus (species ?)	1	Squid (species ?)	1

* Relative numbers of each species not available at time of this writing.

Ammodytes were present in 41 of the 64 loads and were the only species represented in 33 samples in which an average of 8.0 fish were carried per load. Mallotus were present in two size classes, one from 11-14cm and the other 8-10cm. Mallotus were present in 23 bill loads and were the only species represented in 19 loads. In 16 of these, the fish were in the 11-14cm size range and an average of 1.2 fish were carried per load. The other four loads were composed of fish between 8-10cm in length and an average of 4.25 fish were carried per load. Theragra/Eleginus were present in nine bill loads, only one of which was composed entirely of these species.

For the 31 bill loads collected, the mean weight was 14.41g per load with a range of 5g to 34g per load. The mean length and weight and their ranges for each of the four fish species observed in Tufted Puffin bill loads are given in Table 19.

Cerorhinca monocerata (Rhinoceros Auklet)

Rhinoceros Auklets were observed periodically around the island throughout the summer. Birds were most frequently observed in Peninsula Bay at dusk and dawn, although they were occasionally seen elsewhere around the island during the day. As in 1976, birds exhibited typical puffin "fly-bys" around Log Beach and were seen flying ashore in that vicinity, but no nests were located after extensive searching. Because of the frequency and time of observations, it was strongly suspected that these auklets bred on Ugaiushak Island. However, even during August, when they presumably would have been feeding young, no birds were observed carrying fish to the island.

Synthliboramphus antiques (Ancient Murrelet)

Ancient Murrelets were observed on only three occasions during the field season. On 14 and 24 May, nine and seven birds, respectively, were observed in Peninsula Strait, 2-4km from Ugaiushak Island. On 12 June, three more birds were seen in Peninsula Strait and two birds were observed at the mouth of Gulf Bay.

In 1974, Divoky observed six young heading for the sea and captured two adults in mist nets while banding petrels. In 1976, Wehle found a dead adult on 19 June, and an abandoned egg on 24 July. In 1977 a cracked egg, apparently left from 1976, was found (on 25 May) in a shallow burrow in vegetated talus on the west side of Eagle Point. This nest was not active and no other nests were located. The left wing of an adult Ancient Murrelet was found in the eagle eyrie on Eagle Point on 21 June. A dead adult with a broken left wing was found along side a Glaucous-winged Gull nest on Main Talus beach on 22 June.

Cyclorrhynchus psittacula (Parakeet Auklet)

Parakeet Auklets were first observed on 15 May and regularly thereafter through mid-August in the vicinity of Eagle Point. In 1976 and 1977 birds were heard within rock crevices of the boulder beach on the west side of Eagle Point. Extensive searches were conducted in this area in both years, however no nests were located. It was suspected that birds bred deep within the more narrow, inaccessible crevices. We estimated approximately 40 pair were resident on the island.

Corvus corax (Common Raven)

Three pair of Ravens were regularly observed around the island through the end of April and May.

On 25 April a nest with six eggs was located in the same nest site used in 1976 in Cormorant Cove. By 5 June only three eggs remained in this nest and the adults had discontinued incubation. This pair remained on the island throughout the rest of the summer. The nest was probably deserted as a result of disturbance caused by the investigators while monitoring cormorant study plots nearby.

A second nest was located about halfway up the northwest cliff face of Murre Point on 26 April. This nest site was not used in 1976. The nest was believed to contain eggs on 26 April, judging by the behavior of the adults. On 25 May young could be heard but not seen when the adults brought food into the nest. Fledglings were first observed flying about Main Talus and Saddle Peak on 10 July.

A third pair of Ravens was frequently seen in the vicinity of Square Bay during late April and May. No nest was ever located and this pair apparently left the island in late May or early June.

The Raven nest used in 1976 in Kittiwake Bluffs was not used this year.

Ravens were observed to prey heavily on murre, kittiwake, and cormorant eggs, and were also seen eating the afterbirths of seals as well as dead seal pups.

Banding

In an attempt to build populations of known-age birds on Ugaiushak Island, birds were banded in 1974, 1976, and 1977. The long-range objectives of this banding effort are threefold: (1) to assess population dynamics; (2) to obtain information on migration and homing; (3) to aid in making behavioral observations at breeding sites.

Three-hundred and sixty-four birds of the year and two adults were banded on Ugaiushak Island between 10 July and 28 August 1977. U.S. Fish and Wildlife Service (USFWS) metal bands were placed on the right leg and a single blue plastic band was placed on the left leg of all young of the year excluding Glaucous-winged Gull chicks. These received a blue plastic band on each leg in addition to the single metal band.

A total of 1817 birds have been banded on Ugaiushak Island. The number and age of each species banded is given in Table 20.

This year four Pelagic Cormorants carrying USFWS metal bands and red plastic bands were observed on the island. The red plastic bands indicated these birds were banded by Divoky in 1974. Three Double-crested Cormorants were also observed this year carrying USFWS metal bands but without color bands. These birds were presumably banded by Divoky in 1974. Finally, one Glaucous-winged Gull in subadult plumage was observed carrying both a USFWS metal band and a color band. Again, this bird was banded by Divoky in 1974.

Specimens Collected

Twenty-four specimens were collected for analysis of stomach contents in the vicinity of Ugaiushak Island from 14 May to 4 August 1977 (Table 21). Stomach samples were placed in 10% buffered formalin solution and submitted to USFWS Office of Biological Services-Coastal Ecosystems (OBS-CE) for analysis.

Beached Bird Surveys

Beached bird surveys were conducted on five areas around Ugaiushak Island throughout the field season (Fig. 41). Survey areas #01 and #03 were surveyed daily, #04 and #05 twice weekly, and #02 once every two weeks. Areas #01 through #05 were boulder beaches whereas area #02 was a rock ledge with small pockets which tended to collect flotsam. Seven beached birds were located in these survey areas during the field season (Table 22). All other beaches on the island were surveyed at least monthly. However, no additional beached birds were located. None of the beached birds observed showed evidence of oiling or fouling with fishing line, plastic, or other debris. In 1976 there were no beached birds located on any of the island beaches during the breeding season.

Mammals

Whales:

Twelve observations of whales in the vicinity of Ugaiushak Island and one observation near Central Island were made during the 1977 field season. No whales were seen during the 1976 field season. Observations ranged from 28 April to 29 July with ten of the 13 observations occurring in the period from 23 May to 24 June. Identification of species was made in 11 of the 13 observations, with probable species recorded for the other two. Of the 11 positive identifications, four were Fin Whales (*Balaenoptera* physalus), two were Humpback Whales (Megaptera novaeangliae), two Killer Whales (Orcinus orca), two Minke Whales (Balaenoptera acutorostrata), and one Gray Whale (Eschrichtius glaucus). Data for each observation are given in Table 23.

Phoca vitulina (Harbor Seal)

Harbor Seals were seen daily around Ugaiushak Island throughout the field season. In 1976 the pre-pupping population was estimated to be 150-200 animals. In 1977 we estimated this population to be 275-325 animals. The difference between the two years is probably the result of more intensive censusing in 1977 than in 1976. The majority of the seals hauled-out on Seal Rocks, Goose Rock, and on North Wash-out Beach. Lesser numbers hauled-out on South Wash-out Beach, Shag Rock, and along the coastline of Secluded Bay and Guillemot Cove. Counts of adults and pups were made periodically at these locations from 19 May through 23 June (Table 24, Fig. 42), which roughly corresponds to the pupping season. Pupping probably began around 19 May, as on this date we found a tide pool near North Wash-out Beach containing bloody water. However, no sign of a pup or afterbirth was present. The first pup was seen on 22 May at Seal Rocks. Peak pupping was estimated to have occurred between 30 May and 14 June. From 19 May to 23 June, a maximum of 300 individual adults and 173 pups was recorded.

In 1977, as in 1976, subadult Bald Eagles increased in number on Ugaiushak Island during the pupping period of Harbor Seals. Subadult eagles were seen on several occasions to eat the carcasses of seal pups, and seven such carcasses were later located. It was estimated that eagles probably ate at least two to three times this number of pups. No direct observations of predation on pups by subadult eagles were made, hence it was unknown whether eagles actually killed pups, perhaps taking the weak, sick, injured, or those left ungarded by adults, or fed only on pups which had already died.

Glaucous-winged Gulls, Ravens, and Eagles were observed on numerous occasions feeding on the afterbirths of seals.

On 24 June a pod of four Killer Whales was observed apparently chasing seals in the vicinity of Goose Rock. Seals were seen leaving the water en masse for high rocks along the beach. The whales exhibited a frenzied behavior, swimming quickly back and forth along the coastline, periodically breaching from the water, splashing about, and sounding for only very short periods. A male Killer Whale was twice observed lunging approximately one-third of its length out of the water and over the beach and sliding back into the water. The pod of whales remained in this area for about 45 minutes before moving out towards Ugaiushak Reef. No observations of actual predation on the seals were made.

On 26 May a fishing vessel out of Chignik with a native crew hunted Harbor Seals around Eagle Point and Seal Rocks. After firing about 15 shots, the crew noticed me observing them and came ashore. They said they were hunting seal for meat but gave conflicting stories as to whether they actually secured any animals. The following day we found one dead adult seal in the intertidal area of Eagle Point. As Ravens and gulls had been pecking at it, it was not possible to tell if it had been shot. This was the only dead adult seal we found all season.

Eumetopias jubata (Steller Sea Lion)

Small groups of Steller Sea Lions were observed swimming around Ugaiushak Island and two adult bulls were found on Ugaiushak beaches in 1976. These animals were probably from a colony resident on Ugaiushak Reef, approximately 3km south of the island. At the southernmost end of the reef is a small rock out-cropping rising about 10m out of the water. This rock served as the major hauling-out area. Although the colony was not visited by the field party in 1976, crew members aboard the USFWS charter vessel Nordic Prince reported a colony of sea lions present on this rock on 7 June. In 1977 six trips were made to Ugaiushak Reef by Zodiac from the island to census the animals. It was possible to approach the rock to within 100m by Zodiac without unduely alarming the animals. The results of the censuses were:

Date	Sea Lions	Date	Sea Lions
28 April	24	22 May	150-200
1 June	350+	12 June	400-450
4 July	400+	23 August	300-350

The 24 animals observed on 28 April were presumably all bulls establishing territories. Cows began to arrive in early to mid-May. Peak numbers were recorded in June and July, however the majority of the colony was still present on 23 August. During each visit, we tried to determine the reproductive status of the colony. Interestingly, we never observed a sea lion pup during any of our visits. This may have been due to the poor visibility of the center of the colony from the Zodiac. However, it would seem that if pups were present we would have seen them around the periphery of the colony in June or in nurseries around the rock in July. The only evidence that sea lions might have produced young this year was that Glaucous-winged Gulls on the island regularly regurgitated pellets composed of the hair of sea lion pups during June.

Small groups of sea lion bulls were periodically seen swimming around Ugaiushak Island throughout the field season.

Unidentified Shrew

Numerous shrews were accidentally collected in a five-gallon pail set out to catch ground water as it flowed over a rock ledge near camp. Skulls from five specimens were collected and taken to the University of Alaska for identification. Identification had not been made at the time of this writing.

Short-eared Owls (Asio flammeus) were present on the island from 3 May through 8 June. Several pellets from these birds contained bones of a small mammal, believed to be these shrews.

Ursus arctos (Brown Bear)

Brown Bears were observed on Ugaiushak Island by USFWS personnel in 1974 and 1976. The bears apparently swam from the Alaska Peninsula perhaps by way of Central Island. In both years, a single bear was observed on only one day. The actual duration of the bears' visits was unknown. In 1976 a large hole measuring about 2m in diameter by 0.5m in depth was dug by the bear at the southeastern end of East Island, just above the rocky shoreline. At least five of these holes were located around Ugaiushak Island in 1977, having been dug in previous years. Judging by the vegetative cover of last year's hole this year it was thought that some of the holes observed were at least five years old. The reason why bears swim nearly 13km from the mainland to Ugaiushak Island and the purpose of the holes is unknown. There does not appear to be a correlation between the location of these holes and the nesting of any of the island's seabirds. No bears or newly excavated holes were observed in 1977 on the island, although two bears were seen on the shore of Nakalilok Bay during a trip to the mainland by the field party on 25 August.

Enhydra lutris (Sea Otter)

Sea Otters were regularly observed around Ugaiushak Island throughout the field season. A maximum of four individual adults and one pup was observed on any single day. The estimated maximum population for the island was six animals.

Weather

Weather data were collected on Ugaiushak Island from 28 April to 28 August 1977 (Table 26). Data collected included maximum temperature, minimum temperature, wind velocity, wind direction, wave height and amount of precipitation. Temperature readings were taken at approximatley 22:00 each evening and are given in degrees Fahrenheit. Wind velocity was estimated without the use of wind gauge. Wave height was estimated in both Gulf Bay (GB) to the south of the island and Peninsula Bay (PB) to the north. A rain gauge was used to measure the amount of precipitation in each 24-hour period with readings taken at approximately 22:00. Measurements of precipitation are in millimeters.

V. CONCLUSIONS

Fifteen species of Charadriiformes, nine species of Passeriformes, two species of Falconiformes, and one species of Anseriformes nested on Ugaiushak Island in 1977. Four other species, Rhinoceros Auklet, Cassin's Auklet, Gray-cheeked Thrush, and Wilson's Warbler were suspected to breed on the island, although no nests were located. The island was regularly used by 39 species of migrant birds and was visited occasionally by 27 other species of birds. In addition to the avifauna, Ugaiushak was the summer residence of 300-500 Harbor Seals, 400-500 Steller Sea Lions, and six Sea Otters. The island has also been visited by Brown Bears, and at least five species of whales have been see in its nearshore waters. Thus, although consisting of only about 170 hectares, Ugaiushak Island's habitat and strategic location relation to abundnt food resources and migration routes allows it to support a high diversity of species.

This report has emphasized the great deal of variation observed between 1976 and 1977 in several aspects of the reproductive ecology of most seabird species studied. Although the reasons for the variation observed are unknown, I believe that availability of food resources is probably the most important single factor. In examining food resources in relation to breeding productivity, evidence from Black-legged Kittiwakes on Ugaiushak Island in 1976 indicates that availability of food resources during the winter and spring may be important in determining reproductive effort. In fact, the apparent lack of sufficient food resources during the breeding season in 1976 was reflected in lower productivity of most species while an apparent abundance of food resources during the breeding season in 1977 was reflected in higher breeding success, more rapid growth of young, and the immigration of large numbers of subadult birds.

VI. NEEDS FOR FURTHER STUDY

The extreme variability of interrelated factors affecting a mixed species seabird colony has been emphasized during three years of investigations on Ugaiushak Island. The size, location, and even presence of breeding populations has changed from one year to the next. Major differences in the prodution of young have been found between years. Subadult birds of several species appear to visit the island on an irregular basis.

The purpose of the BLM/NOAA Outer Continental Shelf Environmental Assessment Program (OCSEAP) is, in part, to establish baseline information on populations and species composition of seabird colonies, breeding chronology, productivity, foraging areas, and trophic relationships. Such information should represent a norm with which data collected in future years may be compared. It is evident that such a norm cannot be established in even three years of investigation.

At this point, we know that Ugaiushak Island supports large, diverse, and generally accessible populations of seabirds. Study plots have been established for each major species, living quarters are available for investigators, and two years of preliminary data have been obtained. The island is easily accessible by boat or float plane. In short, Ugaiushak Island is an ideal location for a continuous long-term study. Such a study would not involve great expense nor require that investigators be present throughout the breeding season. The island is approximately 22 running hours by boat (at nine knots) or 1 1/2 hours by plane from Kodiak. Average round trip by chartered plane in 1977 was $380. Thus, it would be practical to place investigators on the island for one or two short periods during the breeding season. It is recommended that investigators be present during the last week in May, and the first two weeks in June. Populations are at a maximum and egg-laying by most species occurs during this period. A return trip in August would allow assessment of production on study plots, a census of immigrating subadults, collection of food samples, and a continuation of the banding program.

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Table 1. Relative frequency of clutch sizes, initial brood sizes, and number of young fledged by Double-crested Cormorants in 1977. Replacement clutches are not included.

# eggs	# nests A	# nests B	# chicks	# nests A	# nests B	# fledglings*	# nests A	# nests B
0	5	0	0	16	?	0	16	2
1	4	0	1	1	?	1	1	0
2	6	0	2	3	?	2	3	1
3	3	2	3	0	?	3	0	1
4	3	2	4	2	?	4	2	0
5	1	0	5	0	?	5	0	0

* fully feathered chicks of adult size, but still present in nest.
A egg and chick mortality known separately.
B egg and chick mortality known collectively.

Table 2. Relative frequency of clutch sizes, initial brood sizes, and number of young fledged by Red-faced Cormorants in 1977. Replacement clutches are not included.

# eggs	# nests A	# nests B	# chicks	# nests A	# nests B	# fledglings*	# nests A	# nests B
0	2	0	0	24	?	0	25	0
1	6	0	1	1	?	1	2	2
2	9	0	2	4	?	2	3	4
3	10	2	3	7	?	3	6	6
4	11	8	4	2	?	4	2	1
5	0	3	5	0	?	5	0	0

* fully feathered chicks of adult size which still may have been present on breeding ledges.
A egg and chick mortality known separately.
B egg and chick mortality known collectively.

Table 3. Relative frequency of clutch sizes, initial brood sizes, and number of young fledged by Pelagic Cormorants in 1977. Replacement clutches are not included.

# eggs	# nests A	# nests B	# chicks	# nests A	# nests B	# fledglings*	# nests A	# nests B
0	2	0	0	8	?	0	12	0
1	0	1	0	3	?	1	0	3
2	2	2	2	1	?	2	1	7
3	14	2	3	7	?	3	10	7
4	11	8	4	4	?	4	3	1
5	1	3	5	0	?	5	0	0

* fully feathered chicks of adult size which still may have been present on breeding ledges.
A egg and chick mortality known separately.
B egg and chick mortality known collectively.

Table 4. Prey remains collected from a Bald Eagle eyrie, Ugaiushak Island, 30 May - 6 August 1977.

Seabirds	No.	Percent
Murre (spp)	23	46
Horned Puffin	19	38
Parakeet Auklet	2	4
Black-legged Kittiwake	2	4
Cormorant (spp)	1	2
Tufted Puffin	1	2
Ancient Murrelet	1	2
Glaucous-winged Gull	1	2
Total	50	100

Other Items	No.
Fish species (*Theragra chalcogramma* *Hemilepidotus hemilepidotus* unidentified sculpin)	5
Unidentified songbird	1
Harbor Seal afterbirth	1

Table 5. Number of Glaucous-winged Gull nests or individuals censused in the four major gull colonies on Ugaiushak Island in 1976 and 1977.

	1976	1977
East Island	376 nests	553 birds
Gull Point	110 nests	235 birds
Kittiwake Bluffs	54 nests	176 birds
Main Talus	600 birds	308 birds

Table 6. Dates when the first nests with eggs were located in major Glaucous-winged Gull colonies on Ugaiushak Island 1976 and 1977.

	1976		1977	
Colony	Date	Clutch size/nest	Date	Clutch size/nest
East Island	9 June	1,1	4 June	1
Gull Point	14 June	1	4 June	1
Kittiwake Bluffs	6 June	1,2	4 June	1,1,1,2
Main Talus	15 June	1,2,3,3	------	-

Table 7. Clutch size frequency of Glaucous-winged Gulls on Ugaiushak Island 1976 and 1977.

	One egg				Two egg				Three egg			
	1976		1977		1976		1977		1976		1977	
	N	%	N	%	N	%	N	%	N	%	N	%
East Island	10	35.7	6	15.8	13	46.4	7	18.4	5	17.9	25	65.8
Gull Point	10	32.3	10	29.4	10	32.3	8	23.5	11	35.4	16	45.1
Kittiwake Bluffs	10	31.2	14	50.0	15	46.9	6	21.4	7	21.9	8	28.6
Main Talus	8	21.6	8	26.7	16	43.2	10	33.3	13	35.2	12	40.0
TOTALS	38	29.7	38	29.2	54	42.2	31	23.9	36	28.1	61	46.9

Table 8. Chronology of nesting season for Black-legged Kittiwakes on Ugaiushak Island in 1977.

	First	Mode	Last
Nest building	3 June	3 - 8 June	25 June
Laying	11 June	15 - 22 June	28 June
Hatching	14 July	16 - 10 July	25 July
Fledging	22 Aug.	25 - 31 Aug.*	?

* estimated

Table 9. Relative frequency of clutch sizes, initial brood sizes, and number of young fledged in Kittiwake Study Plot #04 during 1976 and 1977.

# eggs	# of nests 1976	# of nests 1977	# chicks	# of nests 1976	# of nests 1977	# fledglings	# of nests 1976	# of nests 1977
0	15	5	0	50	11	0	58	25
1	28	9	1	6	22	1		20
2	17	41	2	4	23	2	2	12
3	0	2	3	0	1	3	0	0
Total	60	57		60	57		60	57

Table 10. Hatching, breeding, and fledging success of Black-legged Kittiwake nests with artificially determined clutch sizes, Ugaiushak Island 1977.

# Eggs	# Nests	# Chicks	# Nests	# Fledglings	# Nests	Hatching Success[1]	Breeding Success[2]	Fledging Success[3]
3*	20	0	1	0	6			
		1	0	1	1			
		2	6	2	13			
		3	13	3	0	85%	45%	53%
3**	3	0	0	0	1			
		1	0	1	1			
		2	1	2	0			
		3	2	3	1	89%	44%	50%
4*	2	0	0	0	1			
		1	0	1	0			
		2	2	2	1			
		3	0	3	0			
		4	0	4	0	50%	25%	50%
4**	4	0	0	0	0			
		1	0	1	1			
		2	1	2	2			
		3	0	3	1			
		4	3	4	0	50%	44%	57%
TOTAL						83%	44%	53%

1 - Percent of eggs hatching
2 - Percent of eggs producing fledglings
3 - Percent of chicks fledged
* - Clutch size determined at beginning of incubation
** - Clutch size determined at beginning of hatching using starred or pipped eggs

Table 11. Counts of murres and Black-legged kittiwakes on ledges in Hole-in-the-wall, Ugaiushak Island, 1977.

Date	Time	LEDGE NUMBER COMU/TBMU 1	2	3	4	5	6	7	8	9	TOTALS COMU	TBMU	BLKI
May													
2	13:15	4/1	1/0	18/2	25/0	0/0	15/0				63	3	76
3	15:15	0/0	0/0	0/0	0/0	0/0	0/0				0	0	16
4	15:50	6/5	0/2	29/1	36/0	3/0	20/0				94	8	90
5	15:50	6/5	0/1	20/1	1/0	0/0	14/0				41	7	124
6	18:15	0/0	0/3	2/1	0/0	0/0	0/0				2	4	102
7	13:15	3/5	0/4	27/1	37/0	4/0	17/0				88	10	63
8	13:30	6/5	0/4	28/1	43/0	4/0	18/0				99	10	89
9	16:45	0/0	0/3	18/1	1/0	1/0	11/0				31	4	125
10	14:15	5/4	0/4	4/1	35/0	1/0	21/0				66	9	113
11	14:40	0/0	0/3	0/0	24/0	0/0	21/0				45	3	124
12	11:05	5/5	0/3	29/0	37/0	9/0	28/0	15/0			123	8	94
	17:10	5/2	0/3	23/0	34/0	5/0	24/0	18/0			109	5	100
13	14:00	5/5	0/4	33/2	39/0	4/0	28/0	19/0			129	11	84
14	13:35	5/5	0/4	30/0	38/0	10/0	25/0	17/0			125	9	94
15	18:10	5/2	0/3	16/0	35/0	0/0	18/0	8/0			82	5	132
18	16:30	0/0	0/0	0/0	0/0	0/0	0/0	0/0			0	0	84
19	12:45	4/5	0/4	23/0	37/0	7/0	23/0	16/0			110	9	104
	21:20	0	1	2	15	0	11	0			29		108
20	18:20	6/3	0/2	27/1	28/0	7/0	19/0	0/0			87	6	139
22	15:05	3/3	0/4	27/0	35/0	7/0	20/0	21/0			113	7	109
23	19:00	0	0	0	0	0	0	0			0	0	154
25	13:50	2/2	0/4	20/1	38/0	1/0	20/0	4/0			85	7	97
	15:00	3/1	0/4	20/1	37/0	1/0	19/0	10/0	4/0		94	6	107
26	17:15	6/5	0/3	31/2	38/0	11/0	21/0	10/0	0/0		117	10	128
27	17:05	5/4	0/4	26/1	34/0	8/0	18/0	24/0	3/0		118	9	111
28	14:05	5/5	0/4	31/2	35/0	13/0	22/0	35/0	0/0		141	11	114
	19:00	3/2	0/3	19/1	27/0	10/0	14/0	1/0	0/0		74	6	133
29	18:45	4/3	0/4	20/1	35/0	4/0	20/0	0/0	0/0		83	8	120
30	19:25	2/2	0/2	15/1	35/0	5/0	12/0	12/0	1/0		82	5	123
31	19:25	4/2	0/2	15/1	33/0	6/0	15/0	10/0	3/0		86	5	130
June													
1	19:55	2/3	0/2	22/1	34/0	11/0	18/0	17/1	2/0		106	7	136
2	16:20	5/2	0/3	27/1	37/0	11/0	27/0	1/0	7/0		115	6	116
3	20:30	2/1	0/2	17/1	25/0	6/0	7/0	2/0	1/0		60	4	126
4	19:35	0/2	0/2	7/1	6/0	0/0	16/0	1/0	0/0		30	5	141
5	17:05	3/2	0/4	27/1	38/0	12/0	20/0	3/0	3/0		106	7	135
6	17:00	4/4	0/4	26/1	37/0	8/0	18/0	6/0	3/0	17/0	119	9	127
7	16:55	4/1	0/2	14/1	18/0	8/0	11/0	0/0	0/0	0/0	55	4	77

Table 11. Continued

Date	Time	LEDGE NUMBER COMU/TBMU 1	2	3	4	5	6	7	8	9	TOTALS COMU	TBMU	BLKI
June													
9	16:05	5/5	0/2	25/2	31/0	13/0	19/0	22/0	4/0	13/0	132	9	97
10	16:30	5/5	0/4	26/1	31/0	10/0	15/0	33/0	3/0	13/0	136	10	99
11	14:55	5/5	0/3	21/1	28/0	8/0	17/0	4/0	3/0	9/0	95	9	--
12	20:20	3/2	0/2	16/0	25/0	4/0	13/0	0/0	2/0	2/0	66	4	95
13	18:40	4/5	0/3	22/1	28/0	7/0	15/0	11/0	0/0	6/0	93	9	114
14	18:30	5/3	0/2	22/1	28/0	8/0	12/0	0/0	1/0	0/0	76	6	98
16	19:15	4/2	0/2	25/1	33/0	8/0	17/0	4/0	2/0	0/0	93	6	113
17	20:10	3/4	0/2	21/1	29/0	8/0	17/0	8/0	2/0	15/0	103	7	103
18	20:10	3/4	0/2	19/1	24/0	7/0	15/0	0/0	0/0	0/0	68	7	125
19	19:15	3/4	0/2	24/1	35/0	8/0	17/0	0/0	0/0	15/0	102	7	127
20	19:45	3/4	0/3	23/1	36/0	8/0	15/0	4/0	2/0	17/0	108	8	120
23	15:15	5/4	0/4	22/2	32/0	8/0	16/0	15/0	3/0	12/0	113	10	103
25	15:00	5/3	0/4	21/2	31/0	8/0	17/0	28/0	1/0	17/0	128	9	114
27	15:10	3/3	0/2	23/2	32/0	10/0	16/0	21/0	0	5/0	110	7	120
28	13:30	4/3	0/2	17/1	31/0	9/0	19/0	10/0	0	9/0	99	6	100
29	19:25	6/6	0/4	22/1	36/0	9/0	20/0	19/0	0	16/0	128	11	119
30	14:15	4/4	0/3	23/1	32/0	9/0	16/0	9/0	0	20/0	113	8	105
July													
1	15:25	6/4	0/4	24/2	32/0	6/0	17/0	6/0	4/0	23/0	118	10	115
2	20:00	3/4	0/3	24/1	37/0	7/0	17/0	7/0	2/0	15/0	112	8	115
3	18:56	7/5	0/4	26/1	38/0	11/0	20/0	14/0	5/0	21/0	142	10	117
4	19:05	3/5	0/4	26/1	33/0	8/0	19/0	5/0	4/0	17/0	115	10	108
5	19:05	4/3	0/2	25/1	21/0	9/0	15/0	---storm tide-----			74	6	87
8	15:05	3/6	0/3	23/2	34/0	8/0	17/0	33/0	3/0	17/0	138	11	103
12	19:50	3/4	0/2	24/1	39/0	11/0	22/0	28/0	2/0	18/0	137	7	101
14	17:25	5/4	0/3	22/1	35/0	9/0	19/0	18/0	4/0	18/0	130	8	115
16	17:10	6/4	0/4	24/2	34/0	10/0	18/0	17/0	3/0	15/0	127	10	106
19	18:35	5/3	0/3	27/1	38/0	12/0	19/0	9/0	4/0	17/0	121	7	118
23	17:15	3/5	0/4	22/1	40/0	11/0	20/0	7/0	4/0	17/0	124	10	117
August													
3	15:00	3/5	0/4	21/2	31/0	9/0	21/0	---storm tide-----			85	11	93
27	19:30	3/6	0/2	17/0	0	9/0	10/0	0	0	0	39	8	135

Table 12. Relative frequency and measurements of prey items fed to murre chicks.

	Rel. fq.		Length			Weight		
	N	%	N	x	s	N	x	s
Mallotus villosus (Capelin)	104	86	104	132.2	9.1	26	13.9	2.1
Oncorhynchus keta (Chum Salmon)	5	4.2	5	138.0	22.5	1	9.5	-
Theragra chalcogramma (Walleye Pollock)	7	5.8	3	113.7	21.4	-	-	-
Clupea harengus pallasi (Pacific Herring)	1	0.8	7	91.4	5.7	-	-	-
Ammodytes hexapterus	3	2.5	1	148.0	-	1	21.5	-

Table 13. Weight, length, and width of Horned Puffin eggs in 1976 and 1977.

	Weight			Length			Width		
	x	s	N	x	s	N	x	s	N
1976	75.6	4.11	17	67.2	2.30	17	45.9	1.07	17
1977	74.8	5.61	36	66.7	2.91	36	45.8	1.40	36

Table 14. Chronology of the nesting season for Tufted Puffins on Ugaiushak Island, 1976 and 1977.

	colony established[1]			egg-laying[2]	hatching[3]	fledging[3]
1976	?	-	30 May	1-11 June	17-20 July	27 Aug. - ?
1977	10 May	-	5 June	4-14 June	20 July-1 Aug.	27 Aug. - ?

1 - date of first arrival to date of permanent occupancy
2 - period in which two-thirds of the sample was engaged in this activity
3 - date first chick was observed fledged

Table 15. Length of the incubation period, in days, for Tufted Puffins in 1976 and 1977.

	$\bar{x}$	s	range	N
egg-laying to total emergence...				
1976	46.8	1.59	44-45 to 52	16
1977	46.2	2.88	42-43 to 52-54	19
starred to pipped..............				
1976	3.0	1.41	2 to 4	2
1977	3.1	2.07	1 to 8	11
pipped to total emergence.......				
1976	1.4	0.55	1 to 2	5
1977	2.3	1.20	1 to 5	19
starred to total emergence......				
1976	2.6	1.72	2 to 6	7
1977	4.3	2.73	1 to 12	16

Table 16. Weight, length, and width of Tufted Puffin eggs in 1976 and 1977.

	weight			length			width		
	x	s	N	x	s	N	x	s	N
1976	94.7	7.79	41	72.9	3.18	41	49.3	1.47	41
1977	93.9	5.67	39	73.5	2.53	46	49.0	1.57	46

Table 17. Production statistics for Tufted Puffins in all study plots combined in 1976 and 1977.

	1976	1977
Total number of burrows	94	167
Burrows with eggs	52	99
Burrows with eggs/total number of burrows	55%	59%
Burrows to hatch chicks	31	82
Burrows to hatch chicks/burrows with eggs	60%	83%
Burrows to hatch chicks/total burrows	33%	49%

Table 18. Number and weights of Tufted Puffin chicks which fledged or still remained in burrows as of last date checked in 1976 and 1977.

		1976	1977
Number of chicks monitored		50	21
Number of chicks fledged by last check[1]		19 (38%)	6 (29%)
Weight of fledged chicks	$\bar{x}$	567	556
	s	37.2	37.3
	high	642	609
	low	509	496
Number chicks at fledging weight[2] but not fledged by last check		21 (42%)	7 (33%)
Weight of chicks of fledging weight not fledged	$\bar{x}$	563	548
	s	36.6	43.5
	high	623	635
	low	510	504
Number chicks below fledging weight not fledged		3 (6%)	7 (33%)
Weight of chicks below fledging weight not fledged	$\bar{x}$	469	385
	s	35.5	64.5
	high	490	461
	low	428	327
Chick mortality as of last check		7 (14%)	1 (5%)
Fledging success of known chicks as of last check[3]		43 (86%)	20 (95%)

1 - Date of last check in 1976 was 2 September and in 1977 it was 27 August
2 - Fledging weight considered 500 grams
3 - Assuming all chicks living as of last check fledged

Table 19. Mean and range of length (in cm) and weight (in grams) of fish species collected in Tufted Puffin bill loads in 1977.

	Ammodytes		*Mallotus*		*Theragra/Eleginus*		*Oncochynchus*	
	length	weight	length	weight	length	weight	length	weight
N	124	27	28	26	15	13	2	2
$\bar{x}$	7.9	1.6	9.7	5.6	7.4	2.7	14.9	24.5
s	0.92	0.36	1.90	4.86	0.85	1.04	1.84	13.44
high	11.7		13.6	18.5	8.9	4.5	16.2	34.0
low	6.0	.75	8.2	2.25	6.4	1.25	13.6	15.0

Table 20. Number, age, and species of birds banded on Ugaiushak Island in 1974, 1976, 1977

	1974		1976		1977		Totals	
	adlt	yg/yr	adlt	yg/yr	adlt	yg/yr	adlt	yg/yr
Fort-tailed Storm Petrel	123	0	49	0	0	0	172	0
Leach's Petrel	1	0	0	0	0	0	1	0
Double-crested Cormorant	0	37	0	0	0	0	0	37
Red-faced Cormorant	0	124	0	0	0	11	0	135
Glaucous-winged Gull	0	612	0	14	0	85	0	711
Black-legged Kittiwake	7	108	8	9	0	68	7	185
Ancient Murrelet	1	0	0	0	0	0	1	0
Pigeon Guillemot	1	45	0	0	0	6	1	51
Tufted Puffin	0	50	15	55	0	64	15	169
Horned Puffin	3	19	3	0	0	25	6	44
Common/Thick-billed Murre	29	0	-	-	-	-	29	0
Common Murre	-	-	0	0	0	74	0	74
Thick-billed Murre	-	-	0	0	0	1	0	1
Song Sparrow	0	0	10	0	2	0	12	0
Savannah Sparrow	0	0	4	0	0	0	4	0
						Total	1817	

Table 21. SPECIMENS COLLECTED UNDER FEDERAL PERMIT NO. 7-SC25 AND STATE OF ALASKA PERMIT NO. 75-155.

No.	Subpermittee	Species	Specimen ID Number	Area Collected	Date	Sex	Age	Remarks and Disposition of Specimens
			FW7060-35-					
1	D.H.S. WEHLE	COMU	001	UGAIUSHAK I.	14.V.77	M	ADLT.	SKELETAL PREPARATION, DT* PRESERVED
2	"	"	002	"	"	M	"	"
3	"	TUPU	003	"	17.V.77	M	"	DT, CARCASS DISC**
4	"	"	004	"	"	M	"	" "
5	"	"	005	"	"	M	"	" "
6	"	"	006	"	24.V.77	M	"	" "
7	"	COMU	007	"	"	M	"	" "
8	"	BLKI	008	"	"	M	"	" "
9	"		009	"	01.VI.77	F	"	" "
10	"	"	010	"	"	M	"	" "
11	"	COMU	011	"	"	M	"	" "
12	"	TUPU	012	"	"	M	"	" "
13	"	HOPU	013	"	"	M	"	" "
14	"		014	"	"	M	"	" "
15	"	"	015	"	"	F	"	" "
16	"	"	016	"	"	F	"	" "
17	"	"	017	"	12.VI.77	F	"	" "
18	"	"	018	"	"	F	"	" "
19	"	BLKI	019	"	"	F	"	" "
20	"		020	"	"	F	"	" "
21	"	"	021	"	"	M	"	" "
22	"	"	022	"	"	F	"	" "
23	"	HOPU	023	"	4.VIII.77		IMM.	STUDY SKIN PREP.
24	"	COMU	024	"	"	M	ADLT.	CARCASS Disc.

* Digestive tract
** Discarded

Table 22. Beached birds located on Ugaiushak Island in 1977.

Species	Date	Area #	Location
Northern Fulmar	23 June	01	Guillemot Cove Beach
Thick-billed Murre	20 July	02	East Island
Common Murre	3 August	03	Gulf Bay Beach
Black-legged Kittiwake	3 August	03	Gulf Bay Beach
Horned Puffin	14 August	04	Log Beach
Black-legged Kittiwake	22 August	05	Square Bay Beach
Common Murre	24 August	01	Guillemot Cove Beach

Table 23. List of whales observed at Ugaiushak Island, 1977.

Date:	28 April
Time:	18:00
Location:	2km south of Gulf Bay
Direction:	SSW
Size:	Large
Color:	Black
Spout Height:	25-30'
Spout Shape:	Columnar
Number:	5-7+
Probable Species:	Blue, Fin, or Sei
Comments:	Animals far off to see well. No dorsal fin seen 5-7 blows repeated simultaneously in about 10 sec. Seas calm.

Date:	23 May
Time:	14:25
Location:	2km south of Gulf Bay
Direction	SW
Size:	Large
Color:	Sides mottled
Spout Height:	15'
Spout Shape:	Puffy
Number:	3+
Probable Species:	Gray, Humpback
Comments:	No dorsal fin seen. Seas rough.

Date:	25 May
Time:	19:30
Location:	2km NE of Ugaiushak I.
Direction:	W
Size:	Large
Color:	-----
Spout Height:	15-20'
Spout Shape:	Columnar
Number:	6-8
Probable Species:	Humpback
Comments:	Dorsal fin seen. Seas rough. Wind dispersed spout rapidly -.shape uncertain.

Date:	25 May
Time:	20:30
Location:	1km NNE of Ugaiushak I.
Direction:	E
Size:	Large
Color:	Black?
Spout Height:	15-20'
Spout Shape:	Puffy
Number:	5
Probable Species:	Humpback
Comments:	Observed strongly arched back with small dorsal fin, slightly hooked. No flukes seen.

Table 23. Continued

Date:	27 May
Time:	08:00
Location:	200m off of Main Talus
Direction:	NW
Size:	Large
Color:	Black
Spout Height:	20'
Spout Shape:	Columnar
Number:	3
Probable Species:	Fin
Comments:	Viewed from atop Ugaiushak Summit. Hooked dorsal fin toward posterior. Moving very slowly. Identification certain.

Date:	29 May
Time:	15:15
Location:	250m off of Kittiwake Bluffs
Direction:	SE
Size:	Large
Color:	Black
Spout Height:	15-20'
Spout Shape:	Columnar
Number:	2
Probable Species:	Fin
Comments:	Viewed from atop Plover Ridge. Hooked dorsal fin toward posterior.

Date:	30 May
Time:	19:10-19:35
Location:	1-1.5km east of East Island
Direction:	S
Size:	Large
Color:	Black
Spout Height:	15-20'
Spout Shape:	Columnar
Number:	6-10
Probable Species:	Fin
Comments:	Observed at close range. Possible calf present.

Date:	11 June
Time:	14:35
Location:	Gulf Bay
Direction:	N to W to S
Size:	35-40'
Color:	Dark gray mottled with white
Spout Height:	10'
Spout Shape:	Bushy
Number:	1
Probable Species:	Gray
Comments:	Dorsal surface of pectoral fins and flukes whitish, head covered with barnacles, back spotted with white, no dorsal fin, knobs atop tail.

Table 23. Continued

Date:	12 June
Time:	14:00
Location:	1km SSE of Central Isalnd
Direction:	W
Size:	Large
Color:	Black
Spout Height:	----
Spout Shape:	----
Number:	2
Probable Species:	Fin
Comments:	Black back with sickle-shaped dorsal fin toward posterior.

Date:	12 June
Time:	17:15
Location:	Lkm N of Goose Rocks
Direction:	SW
Size	----
Color:	Black with white below dorsal fin
Spout Height:	----
Spout Shape:	----
Number:	4
Probable Species:	Killer Whale
Comments:	One animal with dorsal fin of 5+', two with dorsal fins about half that size, and one calf. Moved from Goose Rocks, past Seal Rocks, and SW past Eagle Pt.

Date:	24 June
Time:	19:30
Location:	Goose Rocks
Direction:	NE
Size:	----
Color:	----
Spout Height:	----
Spout Shape:	----
Number:	4
Probable Species:	Killer Whale
Comments:	Description same as for those observed on 12 June. Observed chasing Harbor Seals around Goose Rock. Pod headed for Ugaiushak Reef.

Date:	24 July
Time:	19:50-20:25
Location:	1km north of Saddle Peak in Peninsula Strait
Direction:	SW
Size:	small
Color:	Black
Spout Height:	----
Spout Shape:	----
Number:	1
Probable Species:	Minke
Comments:	Hooked dorsal fin.

Table 23. Continued

Date:	29 July
Time:	14:30
Location:	200m north of Eagle Point
Direction:	W
Size:	Small
Color:	Black
Spout Height:	----
Spout Shape:	----
Number:	1
Probable Species:	Minke
Comments:	Smaller than Fin Whale. Sickle-shaped dorsal fin toward posterior of body.

Table 24. Counts of adult Harbor Seals and pups from 19 May to 23 June, 1977.

	SEAL ROCKS		GOOSE ROCKS		N.WASH-OUT BCH.		SECLUDED BAY	
DATE	TIME	COW/PUP	TIME	COW/PUP	TIME	COW/PUP	TIME	COW/PUP
MAY								
19					21:00	30+/0		
23	21:30	?/2-3						
24	13:30	124/0						
25	16:05	99+/0						
26	14:30	133/0			14:45	14/0		
29	17:00	88/1	19:00	34/0			15:30	15/1
30	15:50	62/4	15:00	48/5	15:00	22/0	16:55	9/1
			20:05	56/4	20:05	15+/0		
31	15:15	52/7	14:10	25/3	17:00	9/4		
			18:00	15/11				
JUNE								
1	18:00	63/15	14:30	27/7	15:15	19/5	18:30	16/5
2	16:00	16/8	13:00	30/10			17:00	8/2
	19:45	28/5+					19:15	13/2+
3			20:40	20/13	19:30	19/5		
4	15:00	29/17	20:50	37/30			15:30	11/8
5			21:50	50/27	21:20	13/10	16:00	7/5
6			13:45	107/48	16:00	18/5	16:00	11/9
			14:45	70/38				
8			14:00	76/47	14:45	41/12	17:15	8/8
9							16:30	22/15
10								
11			17:30	133/64	19:00	38/17		
12	17:15	60+/?	17:15	160/78	18:45	35/10		
13			15:40	108/62				
14	20:45	93/53	17:30	119/67	18:00	32/15	14:45	12/9
17					19:50	26/7+		
23			13:25	111/81	15:00	18/10		

Table 24. Continued

	S. WASHOUT BCH.		SHAG ROCK		GUILL. COVE		MAXIMUM TOTALS
DATE	TIME	COW/PUP	TIME	COW/PUP	TIME	COW/PUP	COW/PUP
MAY							
19							30+/0
23							?/2-3
24							124/0
25							99+/0
26							147/0
29							137/2
30			17:25	2/0			151/10
31	18:45	21/8					107/22
JUNE							
1	13:45	10/4	20:00	1/0			136/36
2	19:00	7/?	21:00	1/0			78/22+
3	19:05	17/12					56/30
4			16:30	3/1			80/56
5	20:30	19/18	12:00	5/1			94/61
6	16:30	9/6	19:00	2/1			147/69
8	15:00	24/17	14:45	3/2			152/86
9			15:00	4/3			26/18
10			17:15	3/1			3/1
11	19:00	22/11					193/92
12	19:00	25/18	17:45	9/6	20:45	11/10	300/122+
13					16:05	29/24	137/86
14	18:30	18/14	16:05	2/2	17:15	15/13	291/173
17	18:30-19:45	39/35					65/42+
23							129/91

Table 25. Weather Data collected on Ugaiushak Island from 23 April to 23 August, 1977.

DATE	TMAX	TMIN	WIND	SEAS GB	SEAS PB	RAIN	COMMENTS
APRIL							
23	-	-	20NW	4-5	3	YES	ARRIVED ISLAND 13:35. SHOWERS
24	53	37	20NW	1	3-4	1	RAIN IN MORNING, SNOW IN AFTERNOON
25	54	38	20-45NW	1-2	4+	0	CLEAR, SUNNY
26	55	38	20-45NW	2	4-5	0	CLEAR, SUNNY; WIND DECREASING IN EVENING
27	66	32	10-20	2	<2	0	CLEAR, SUNNY; SEAS VERY CALM IN EVENING
28	44	38	5-15SSE	2-3+	1-2	0.15	CLOUDYIN AM, RAIN AND FOG IN PM
29	49	42	5-15SE/SW	4-5+	3-4	0.39	PARTLY SUNNY; RAIN AND FOG BEGINNING 22:00
30	40	40	10-25SE	5+	3+	0.09	PARTLY SUNNY; HAIL,RAIN,AND INCR. WINDS IN PM
MAY							
1	44	42	30-45SE/N	6-7	4-5	0.30	FOG,RAIN; MODERATING IN EVENING
2	53	43	10-20NW	3-4	3+	0	PARTLY SUNNY, SEAS DECR. IN EVE.
3	47	39	10-25+W	2	3-4	0	MOSTLY SUNNY, WINDS DECR. IN EVE.
4	48	42	10-25S	3-4	3+	0.06	OVERCAST, FOGGY. SHOWERS.
5	50	43	5-20S	3+	2-3+	0.30	FOG AND MIST IN AM. CLEAR IN EVE.
6	55	41	5-20+S	2-3	2-3	0.05	MOSTLY SUNNY. RAIN IN EVE.
7	58	41	5-20S	2+	3+	0.02	SNOW,RAIN,HAIL,PARTLY SUNNY
8	55	37	5-20N/W	3+	2-3+	0	LIGHT SNOW, CLEAR IN EVE.
9	48	32	5-15S	4+	1+	0.19	RAIN ENDING IN AM. FOG REST OF DAY
10	48	42	5-20NE/S	3+	1-2	0.12	OVERCAST. SHOWERS
11	44	42	5-15NE	3	1-2	0.30	OVERCAST. FOGGY. WIND INCR. IN EVE.
12	52	42	20-30NE	2	6+	0.11	CALM IN EVE.
13	70	39	5-10W	1	2+	0	MOSTLY SUNNY
14	64	40	5-20S	2+	2+	0	MOSTLY SUNNY
15	57	38	5-15S	1-2	1-2	0	MOSTLY SUNNY
16	48	42	10-20NE	3+	3+	0.23	FOGGY. STEADY RAIN IN EVE.
17	51	40	10-25N	3+	3-4	0.48	WIND INCR. THRU DAY
18	40	36	15-30NW	2-3	3-4+	0.70	3-4INCHES SNOW
19	50	32	10-20S	3-4+	1-2	0.05	RAIN/SNOW SHOWERS
20	51	38	10-20S	3-4+	1-2	0.05	HAIL/RAIN SHOWERS
21	55	36	5-15S	3+	1	0	MOSTLY SUNNY
22	60	36	5-20S	2-3+	1-2	0.02	MOSTLY SUNNY. LIGHT RAIN/MIST IN EVE.
23	52	36	10-25S	3-4	2+	0.22	MOSTLY SUNNY
24	58	35	5-25SW/NE	1-3	1-3	0.05	MOSTLY SUNNY. RAIN SHOWERS
25	56	39	10-25+NW	2+	2-3	0	MOSTLY SUNNY
26	60	36	5-20SW	2-3	1-2	0	OVERCAST
27	54	40	5+NE	1	1	0	OVERCAST
28	53	41	5-10NE	3+	1-2	0.04	OVERCAST. MIST IN EVE. SEAS FLAT CALM
29	65	40	5-15+N	3+	1-2	0	SUNNY AM. OVERCAST PM
30	61	42	10-25WNW	2	3-4	0	MOSTLY SUNNY
31	63	43	20-40+WNW	2	3-4	0	SUNNY. WINDS BUILDING

Table 25. Continued

DATE	TMAX	TMIN	WIND	SEAS GB	SEAS PB	RAIN	COMMENTS
JUNE							
1	70	43	5-10NW	<1	<1	0	SUNNY
2	72	46	5-15+NW	1	1	0	SUNNY. WINDS INCR. IN EVE.
3	62	45	20-50NW	2-3	3-4	0	OVERCAST
4	68	42	5-20NW	1-2	2	0	SUNNY. WIND INCR. IN EVE.
5	62	41	5-15NW	1	2+	0	MOSTLY SUNNY
6	57	42	5-15SW	2+	1	0	SUNNY
7	50	47	10-25SW	5-6	2+	0.60	OVERCAST,FOGGY,STEADY RAIN
8	49	47	5-10SW	4-5	1-2	0.41	OVERCAST,FOGGY,MISTY
9	53	47	5-10E/NE	1-2	1	0.16	HEAVY FOG
10	52	48	5-15NE	2-3	2-3	0.07	HEAVY FOG,CONSTANT WIND
11	53	49	5-10NE	2-3	1-2+	0.15	HEAVY FOG, MIST. STARTING TO BREAK-UP 17:0(
12	62	48	<5	2+	1	0	PARTLY SUNNY,FOG BANKS
13	61	48	5-10SE	2+	1	0	FOGGY,LIGHT MIST
14	53	48	20-45+E	6	3-4	0,02	FOG,MIST,RAIN SHOWERS
15	51	50	25-50NE	6+	6+	0.24	GALE
16	54	49	10-30SE	3-6	2-5	0.20	OVERCAST. STORM BREAKING
17	55	50	15-20SE	3-4	2-3	0.08	OVERCAST.LITTLE SUN
18	54	48	10-20NE	2-3	1-2	0.04	MOSTLY CLOUDY
19	60	47	5-20NE	1-2	2-3	0.09	CALM/CLEAR IN AM. FOG,RAIN IN EVE.
20	60	49	5NW	1	<1	0.01	PARTLY SUNNY. LIGHT RAIN
21	70	51	5-10NW	<1	<1	0	MOSTLY SUNNY
22	63	49	5-10NW	1	1	0.07	LIGHT RAIN.
23	62	50	5-10NE	1-2	1-2	0	MOSTLY SUNNY
24	72	52	5W	3-4	2+	0	SUNNY
25	78	52	5SE	1-2	<1	0	MOSTLY SUNNY IN AM. CLOUDY IN PM.
26	73	51	5-10SE	1-2	1	0	MOSTLY SUNNY
27	77	50	5-15W	1-2	1	0	SUNNY
28	72	50	5+W	1-2	<1	0	SUNNY
29	71	51	5-15NW	1-2	<1	0	SUNNY
30	77	59	10-25NW	1-2	2-3	0	SUNNY

Table 25. Continued

DATE	TMAX	TMIN	WIND	SEAS GB	SEAS PB	RAIN	COMMENTS
JULY							
1	72	53	20-35+NW	2-3+	3+	0	SUNNY
2	61	51	25-50NW	2-3+	3+	0	SUNNY
3	79	50	15-30NW	2+	2-3	0	MOSTLY SUNNY
4	72	48	5-20NW/SW	1-2+	1-2	0	SUNNY
5	56	46	5-15+NE	2-4	2+	0	OVERCAST, MIST/RAIN IN EVE.
6	56	52	5-15E	3-4	1-2	0.15	OVERCAST, MIST/RAIN ALL DAY
7	55	52	5-10E	2-3	1+	0.61	OVERCAST, MIST/RAIN/FOG
8	57	52	5-10E	1-2	1+	0.30	OVERCAST, MIST/RAIN/FOG
9	64	52	5-15W/NW	1+	1+	0	MOSTLY CLOUDY, CLEARING IN EVE.
10	71	49	5W	1-2	1	0	SUNNY, CLOUDY IN EVE.
11	62	50	5-10NE	2+	1	0.18	OVERCAST, BLOWING MIST
12	64	54	10-20NW	1-2	1-2+	0.18	OVERCAST IN AM.,CLEAR IN PM.
13	64	47	10-20S/W	1-2	1	0.04	OVERCAST, RAIN SHOWERS
14	63	54	5W	1	1	0.07	OVERCAST, RAIN SHOWERS
15	72	48	5-15NW	1	1-2	0	SUNNY
16	76	46	5NW	1	1	0	SUNNY
17	74	46	5W	1+	1-2	0	SUNNY
18	81	54	5-15W	1-2	1-2	0	SUNNY
19	74	55	10-25W	1-2	2+	0	MOSTLY SUNNY
20	74	53	5-20WNW	1	1-2	0	SUNNY
21	61	50	15-25+SE	2-3	2+	0	OVERCAST, MIST AND HEAVY WINDS IN EVE.
22	58	55	15-25SE	2-3+	3+	0.22	OVERCAST, BLOWING MIST
23	61	57	15-30+NE	2	3+	0	PARTLY SUNNY
24	63	56	5-15NE	1-2	1-2	0	PARTLY SUNNY
25	62	58	5-15SE	2-3+	1+	0.53	OVERCAST IN AM., RAIN IN PM.
26	57	55	5-10SSE	3-4+	2	1.73	RAIN. RAIN. RAIN.
27	63	54	5-15E	2+	2+	0.03	PARTLY SUNNY. FOG/MIST IN EVE.
28	60	56	5-20E	3+	3+	0.23	OVERCAST, BLOWING MIST
29	58	55	5-15SE	2	2	0.07	OVERCAST, BLOWING MIST
30	58	55	5-20ESE	2+	2+	0.48	OVERCAST, BLOWING MIST
31	60	55	5-25+E	2-3	2-3	0.14	OVERCAST, BLOWING MIST

Table 25. Continued

DATE	TMAX	TMIN	WIND	SEAS GB	SEAS PB	RAIN	COMMENTS
AUGUST							
1	64	55	5-20E	3+	3+	0.02	SUNNY IN AM. CLOUDY AND RAIN IN EVE.
2	59	56	5-45NE/SE	6-8	3-4+	0.26	OVERCAST
3	61	56	5-20SSE	3-4	2-3	0.04	CLEAR IN AM. AND PM. RAIN IN EVE.
4	57	57	10-35+S	3-6	4-6	0.32	OVERCAST
5	56	56	5-20SE	4-5	3-4	0.10	OVERCAST
6	56	54	5-40NE	4-5	4-5	0.24	OVERCAST
7	61	54	5-30NW/NE	2-4	1-2	0.38	OVERCAST
8	61	55	5-30SE	2-3	2-3+	0.18	RAIN IN AM. CALMING IN EVE.
9	59	55	5-20NE	1-2	2-3	0.23	HIGH OVERCAST IN AM. MIST IN EVE.
10	59	56	5-25ESE	3-4	2-3	0.60	OVERCAST. BLOWING MIST
11	61	55	10-50E	3	3-4	1.07	OVERCAST
12	58	56	5-30E	3	4-5	0.68	OVERCAST. BLOWING MIST
13	59	56	5-20NE/SE	3-4	2-3	0.34	OVERCAST. FOG
14	59	56	5-20SE	2-3	1-3	0.06	HIGH OVERCAST. BLOWING MIST
15	61	55	5-15SW	2-3	1-2	0.02	HIGH OVERCAST. BLOWING MIST
16	57	55	10-40NE	3-4	4-5	1.67	BLOWING MIST
17	59	57	5-35SE	5-6	3-4	0.52	BLOWING MIST. FOG
18	59	56	5-15S	2-3	1-2	0.01	BLOWING MIST. FOG
19	58	55	5-30NE/SE	3-4	3-4	0.50	STEADY RAIN
20	61	57	5-40+E	4-5	4-5	0.05	SUNNY IN AM. RAIN IN EVE.
21	61	57	5-20E	2-3	1-2	0.025	PATCHY FOG. OVERCAST AND MIST IN EVE.
22	62	54	5-15E	1-2	1-2	0.06	HIGH OVERCAST. PARTLY SUNNY
23	81	54	5-25NW	1-2	1-2	0	SUNNY
24	63	53	5-15SW	1-2	1	0	PARTLY SUNNY
25	78	56	5-15S	1-2	1-2	0	HIGH OVERCAST. PARTLY SUNNY. LIGHT RAIN
26	60	55	5-15S	1-2	1	0.13	OVERCAST. MIST IN EVE.
27	68	55	5-20E/NW	1	1	0	HIGH OVERCAST. PARTLY SUNNY
28	79	55	5-25WNW	1-2	1-2	0	SUNNY

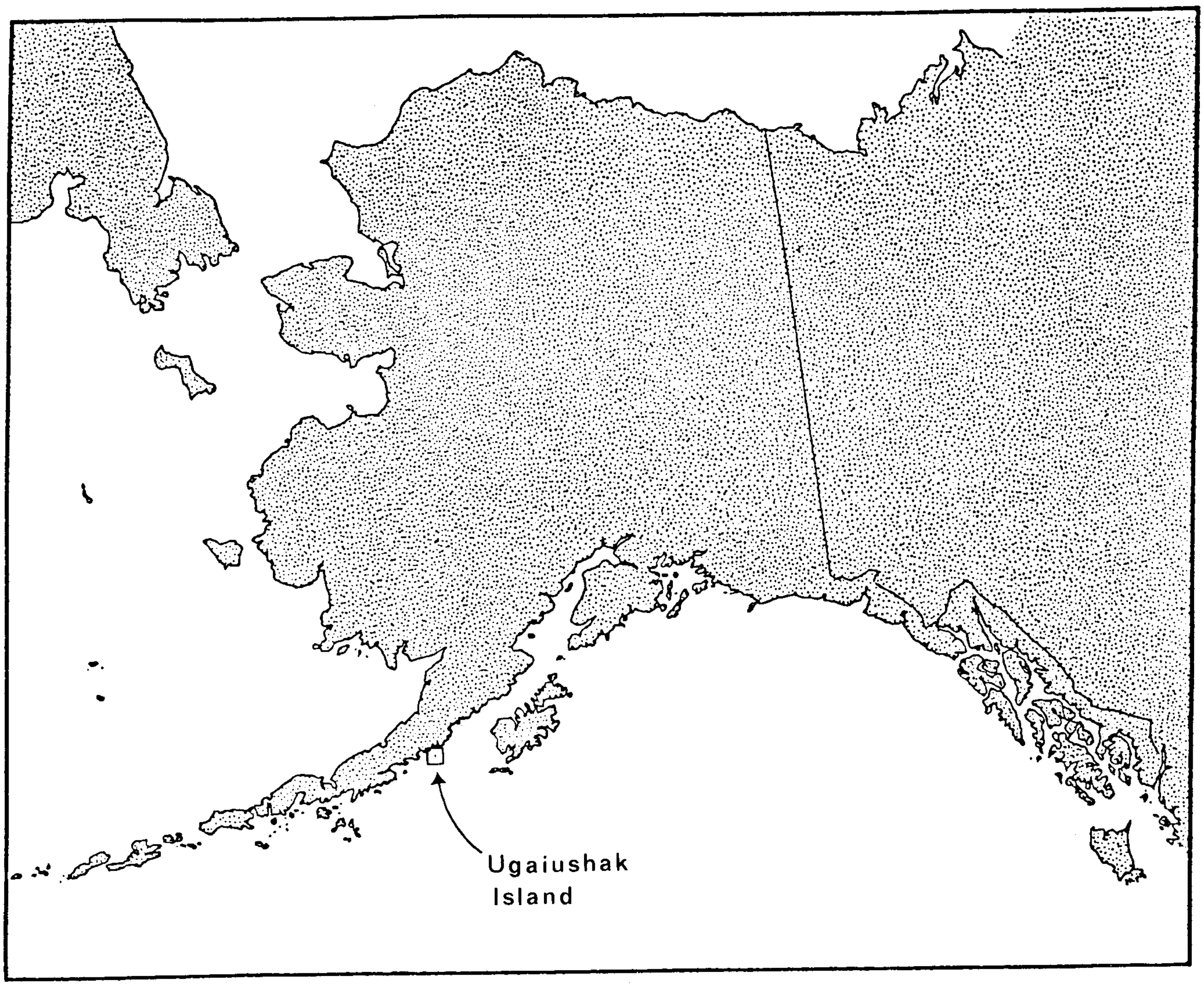

Figure 1. Location of Ugaiushak Island.

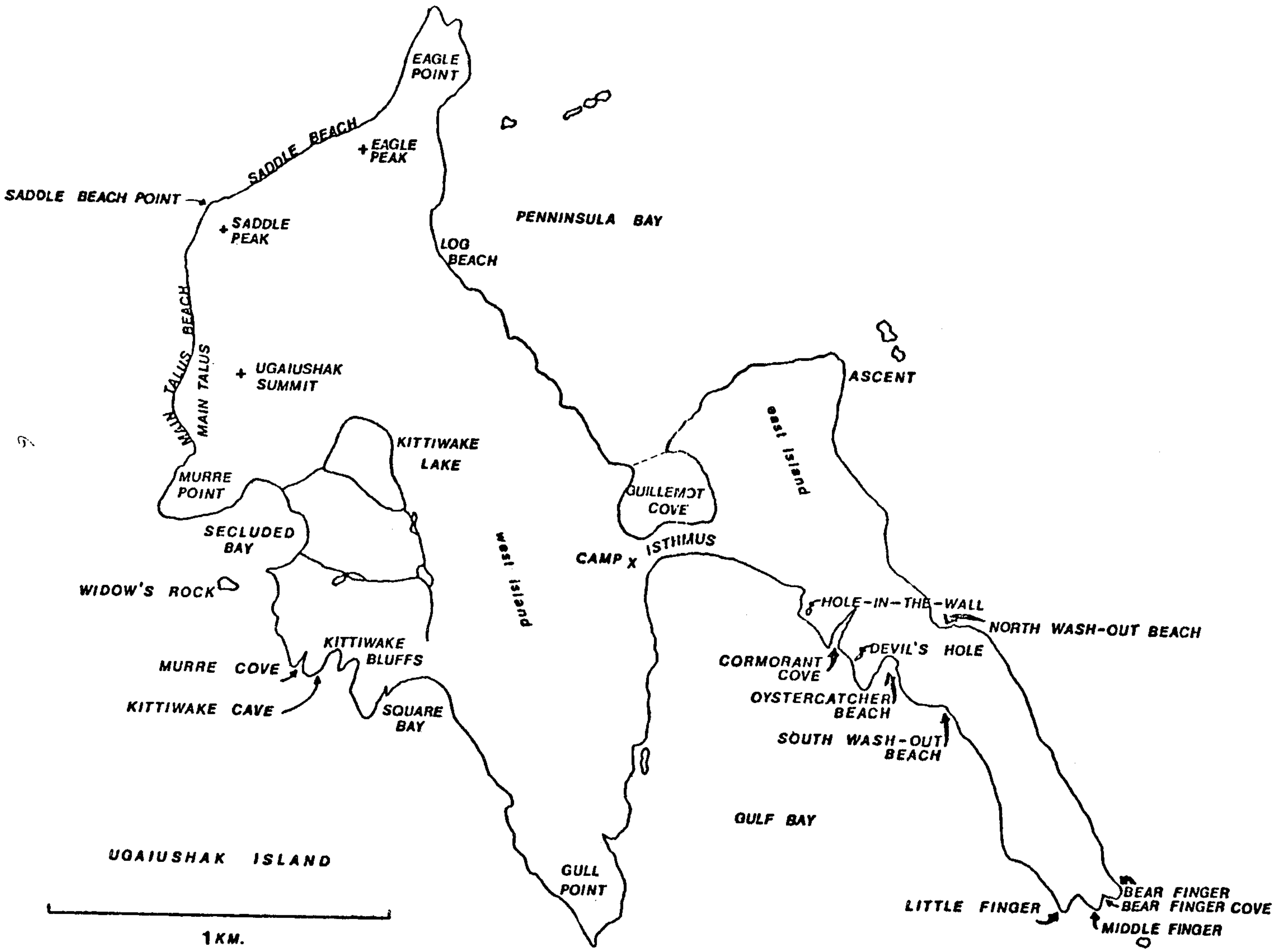

Figure 2. Map of Ugaiushak Island.

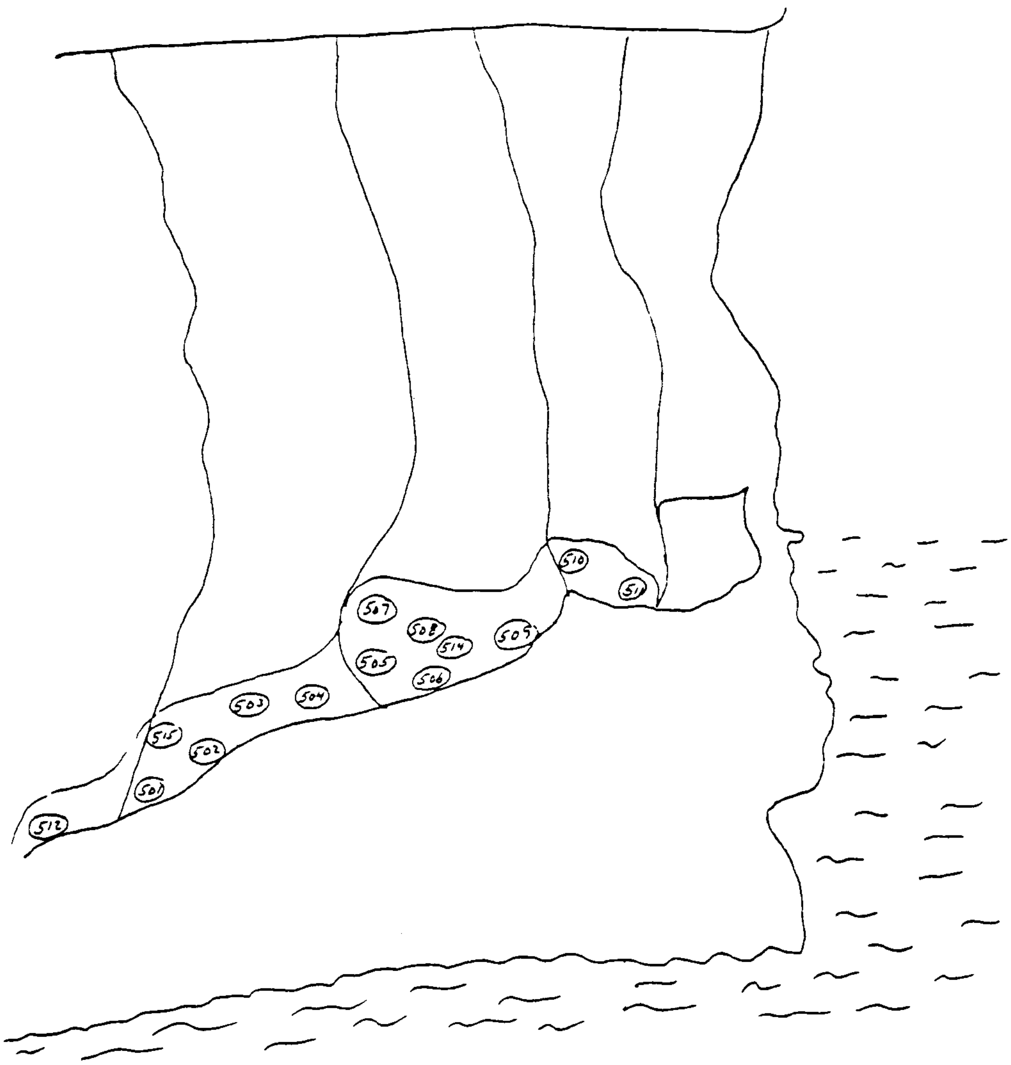

Figure 3. Location of Double-crested Cormorant nests in CSP #05.

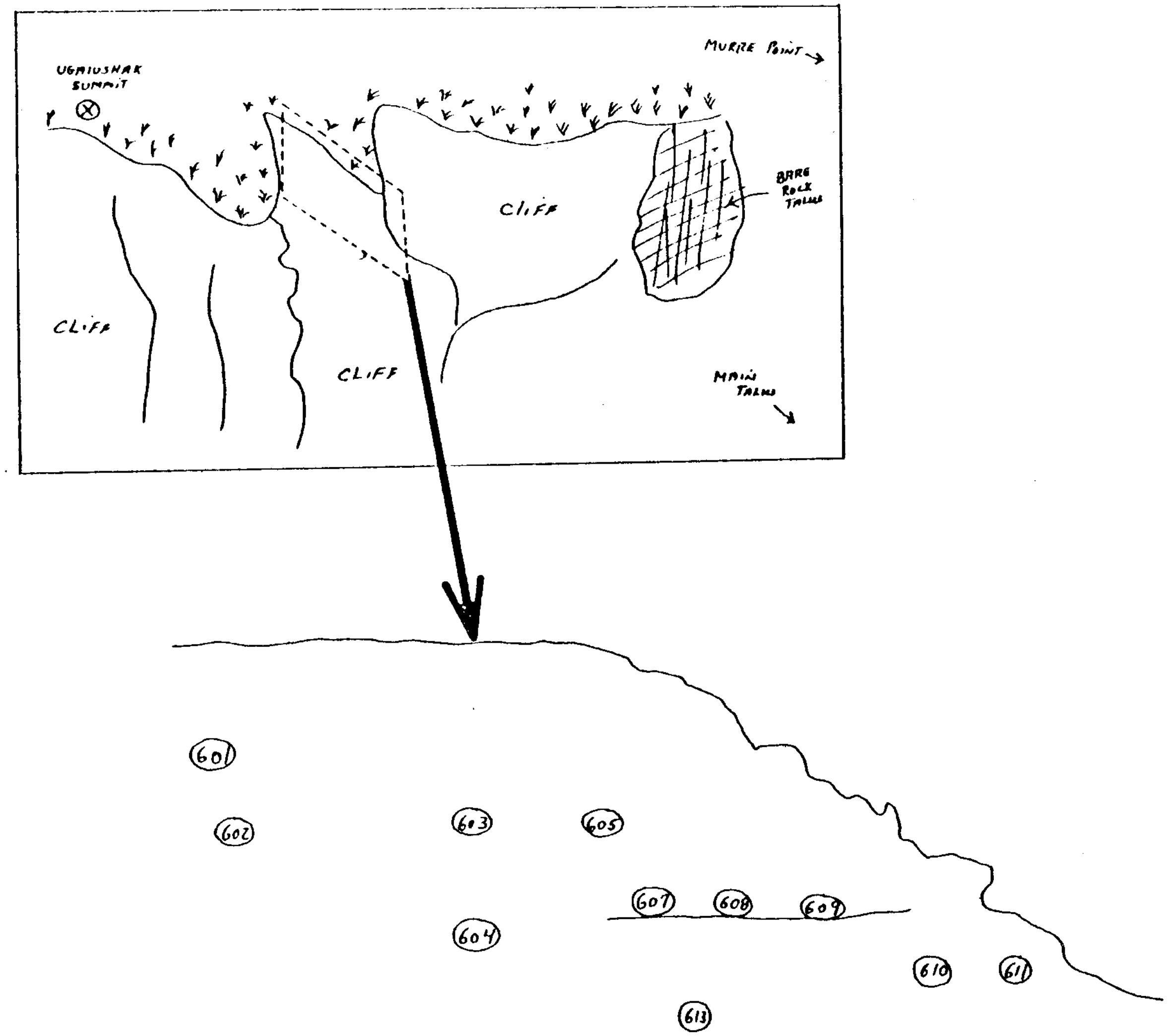

Figure 4. Location of Double-crested Cormorant nests in CSP #06.

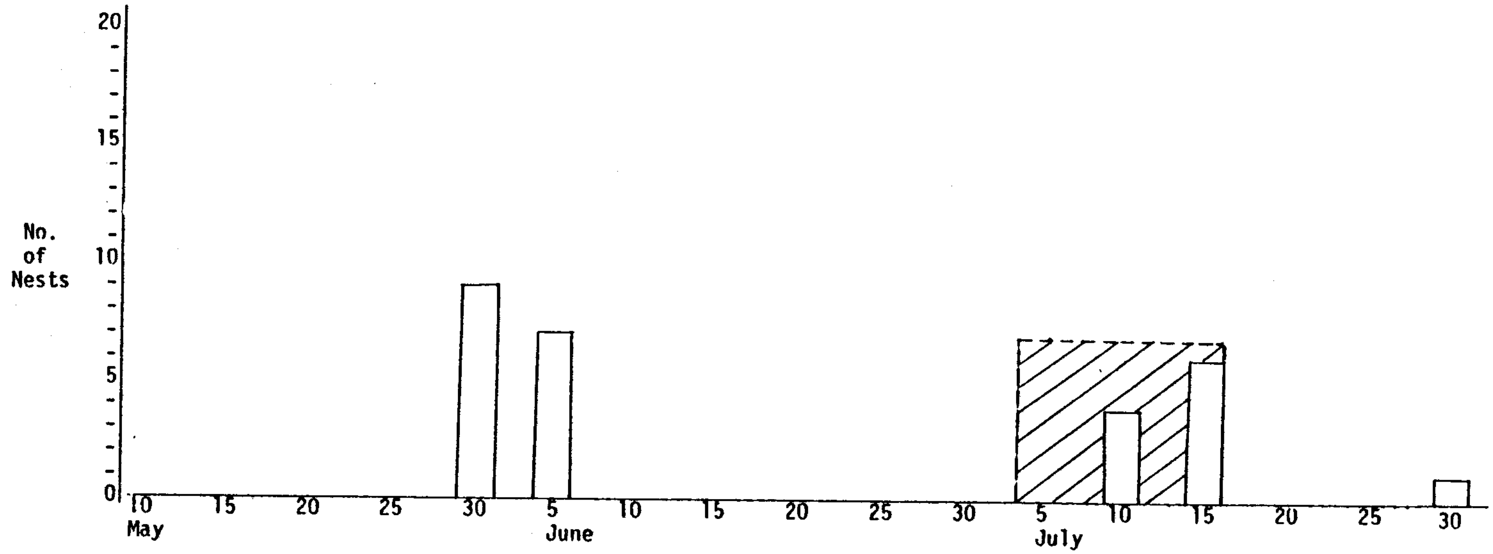

Figure 5. Relative number of Double-crested Cormorant nests at laying and hatching stages shown in 5-day intervals from 10 May to 30 July 1977. Relaying occured between 5 and 15 July in seven nests.

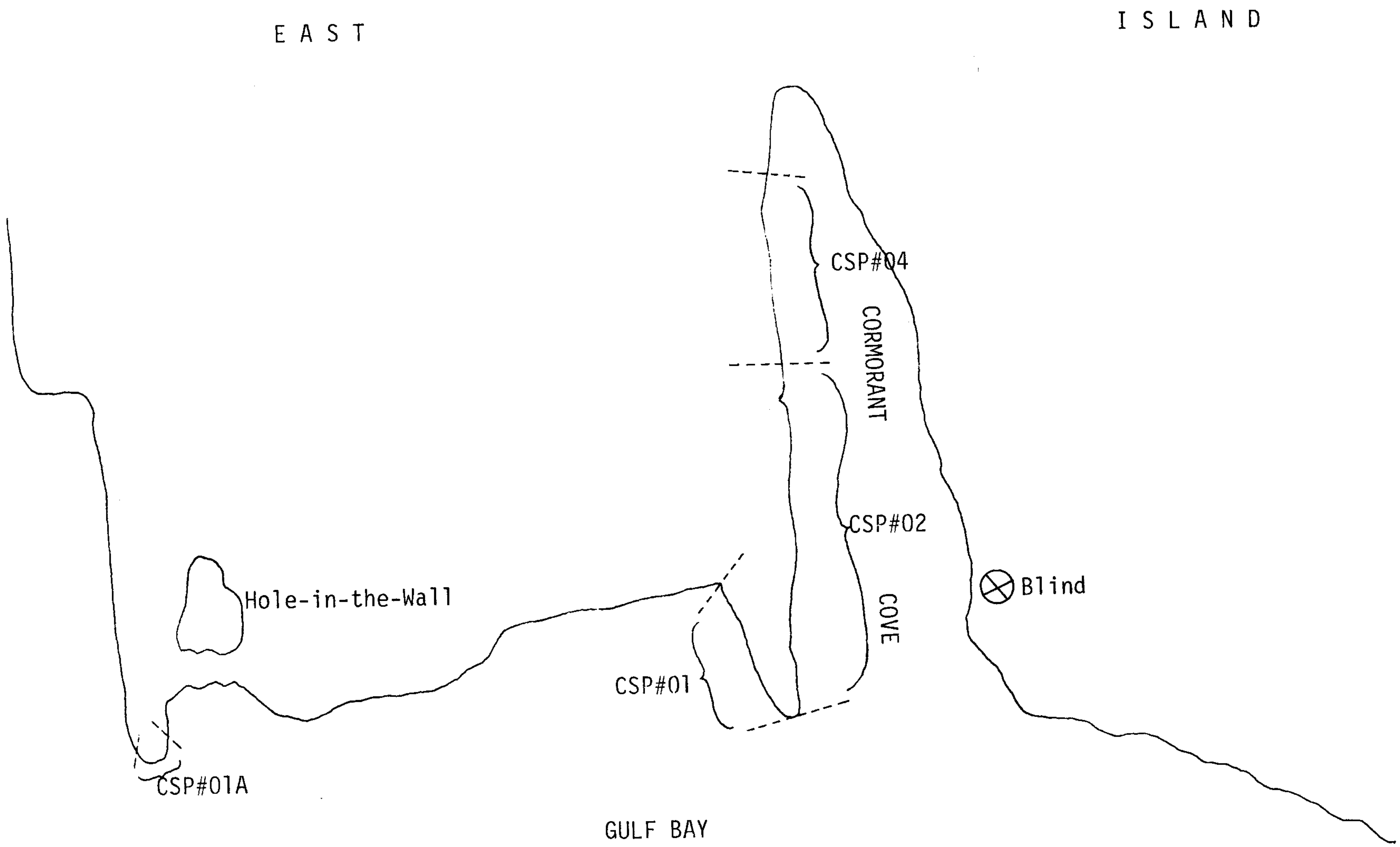

Figure 6 . Location of Red-faced and Pelagic Cormorant study plots.

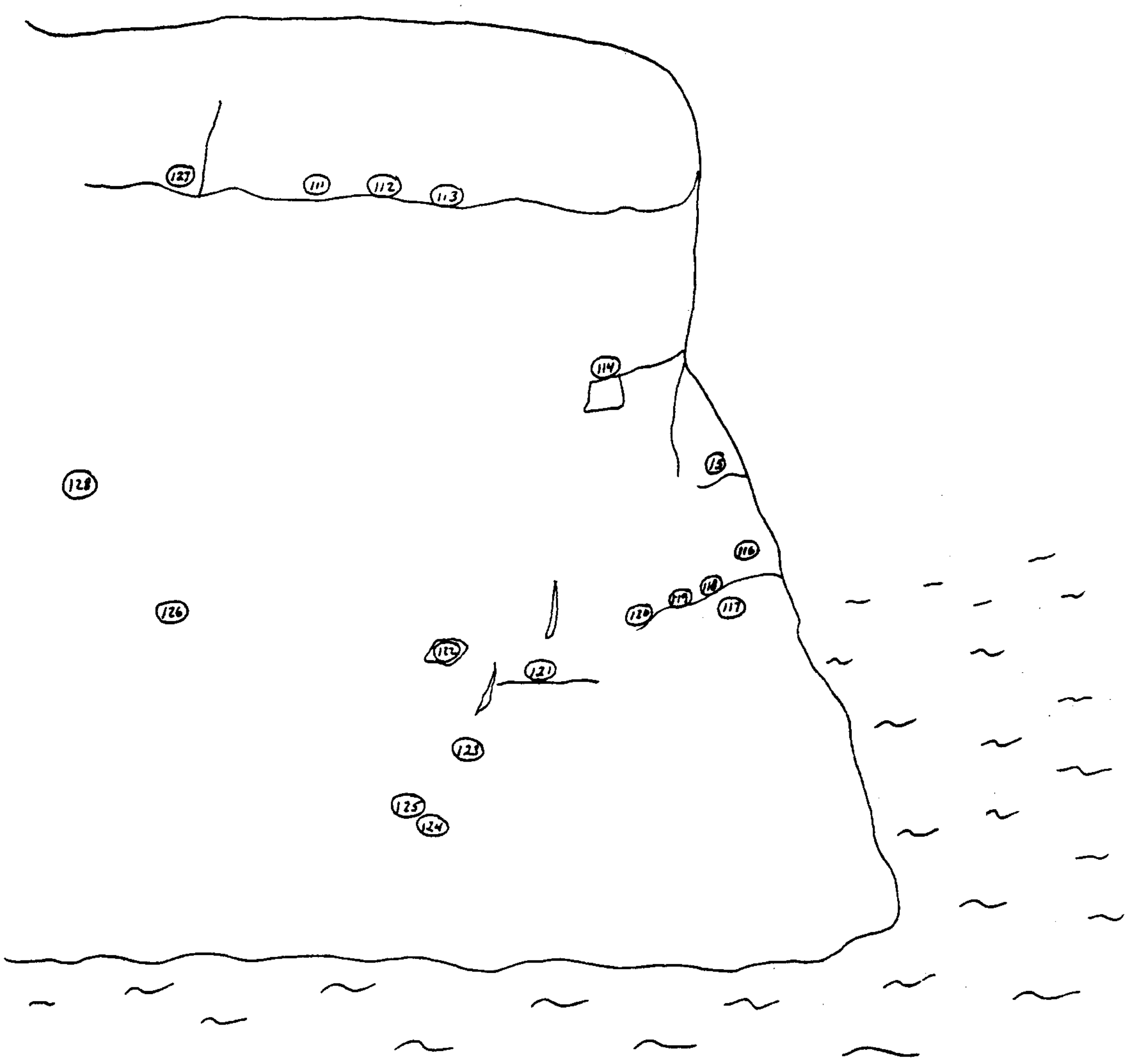

Figure 7. Location of Red-faced and Pelagic Cormorant nests in CSP #01.

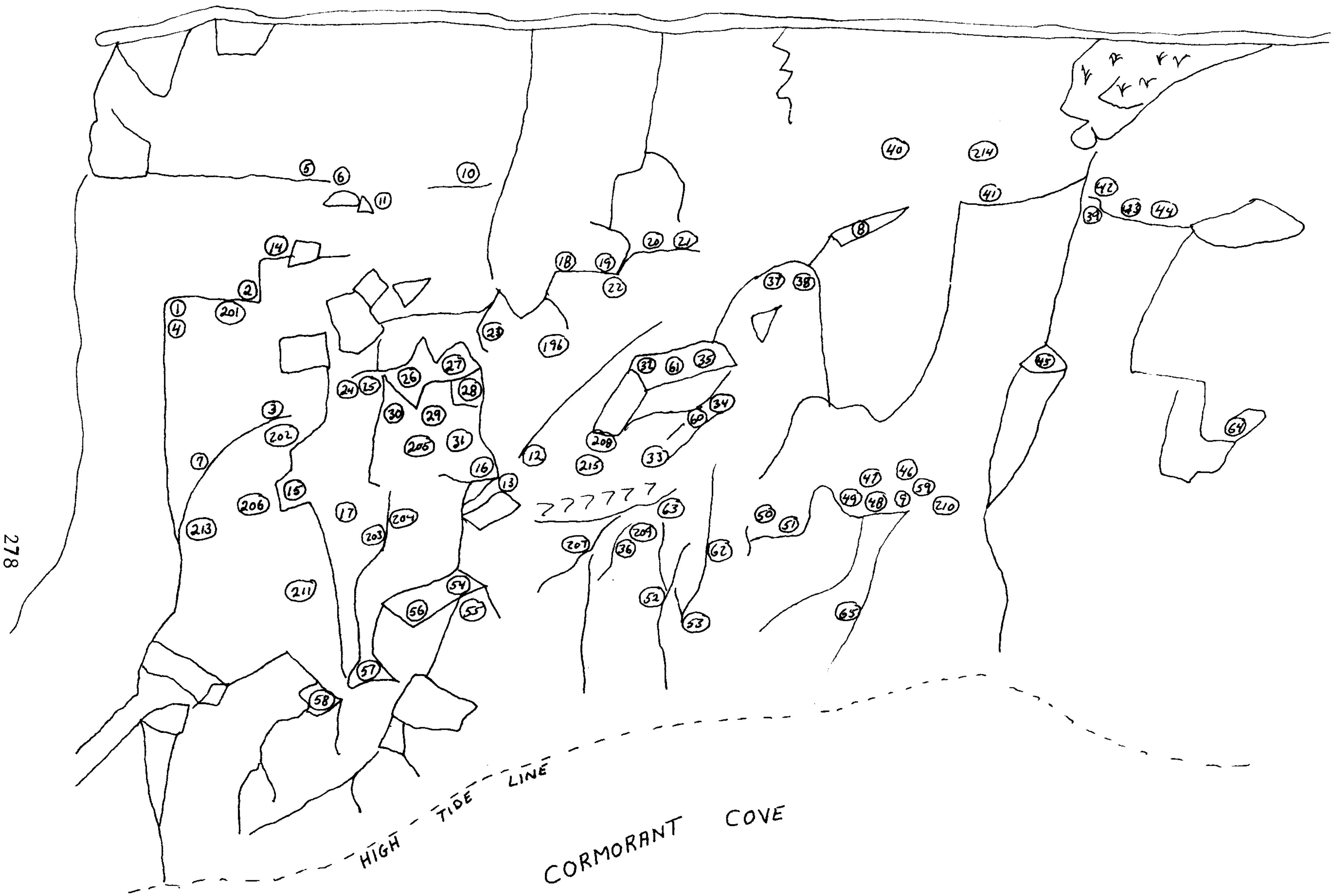

Figure 8 . Location of Red-faced and Pelagic cormorant nests in CSP #02.

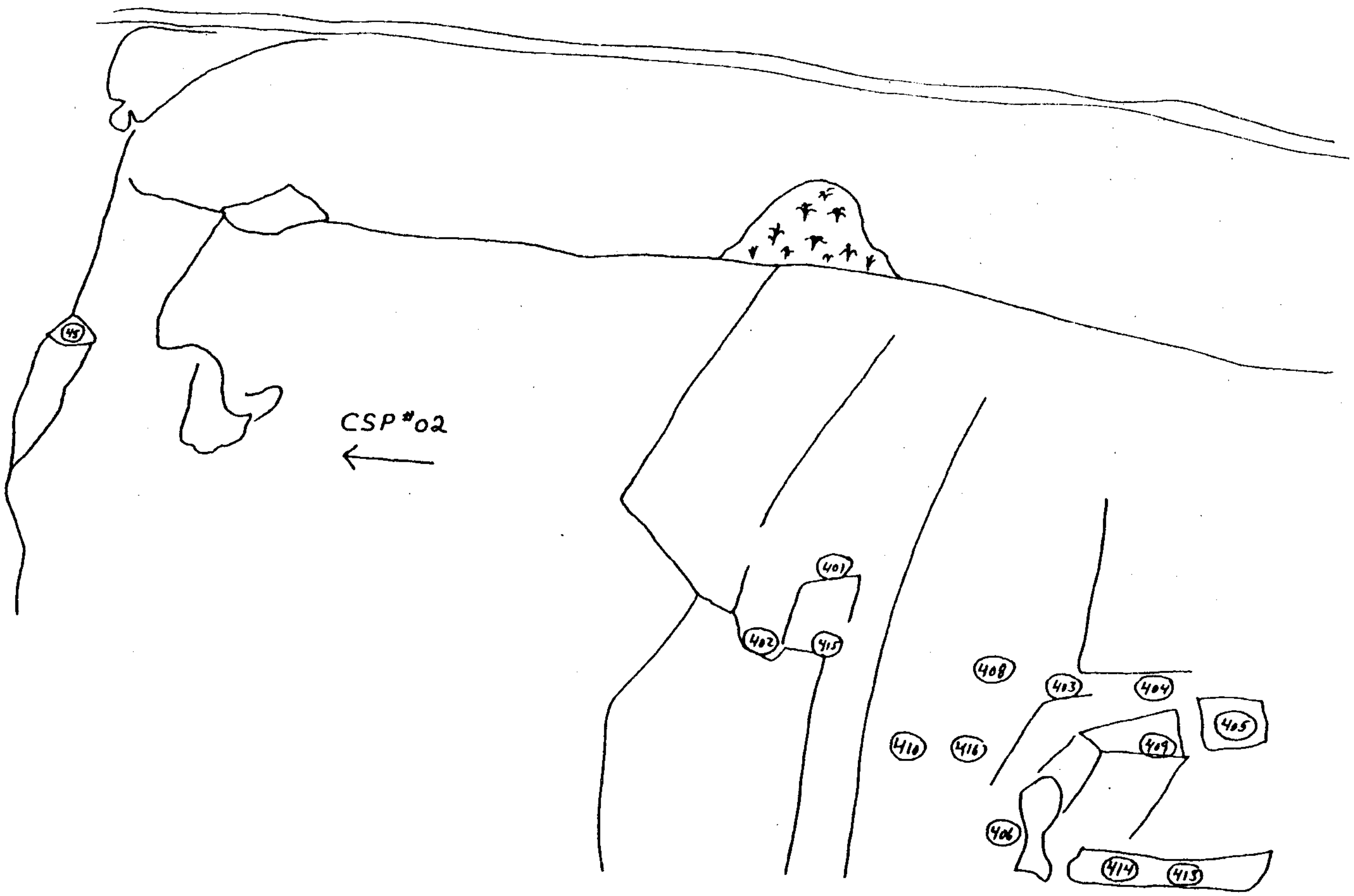

Figure 9. Location of Red-faced and Pelagic Cormorant nests in CSP #04.

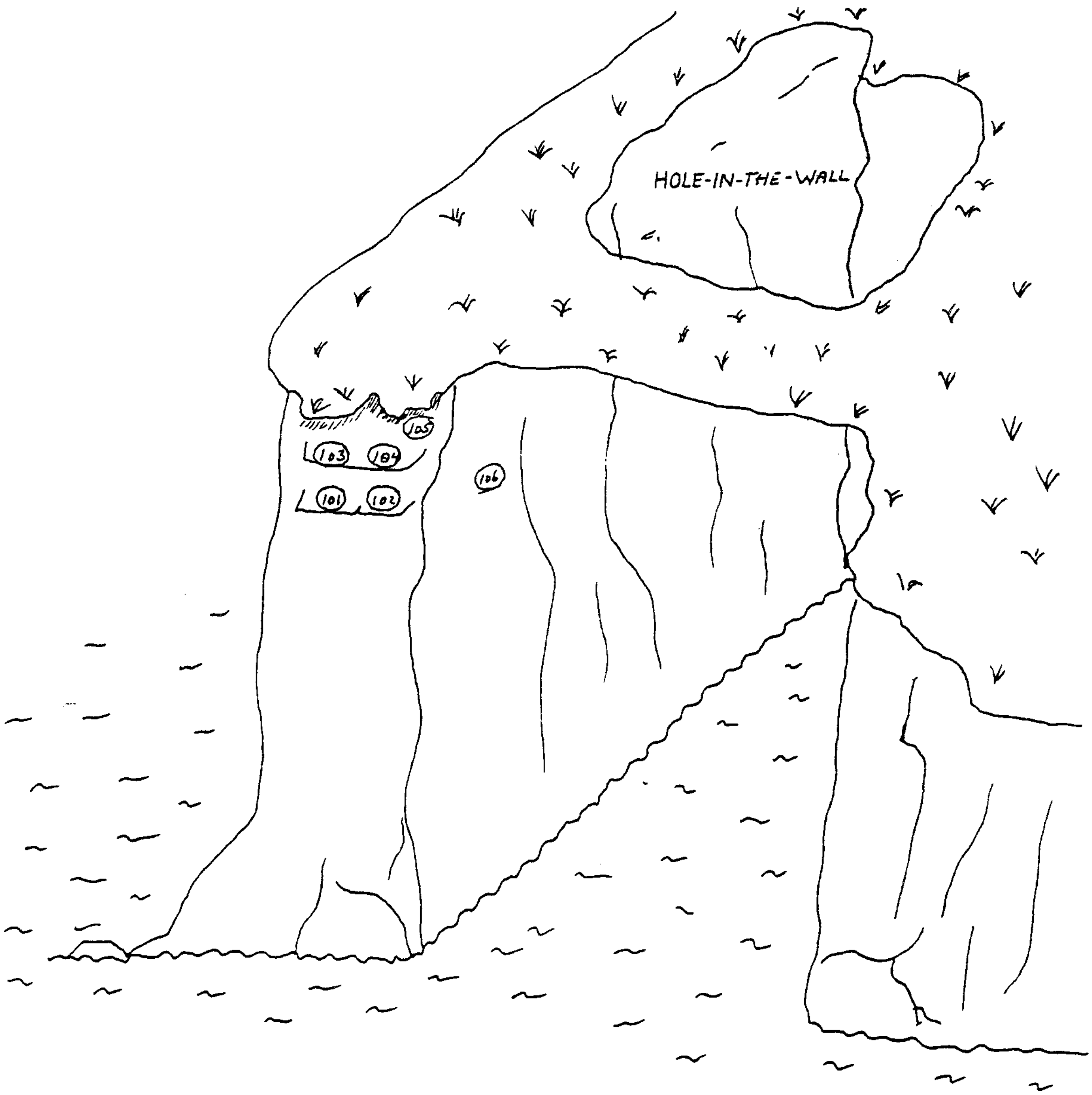

Figure 10. Location of Red-faced and Pelagic Cormorant nests in CSP #01A.

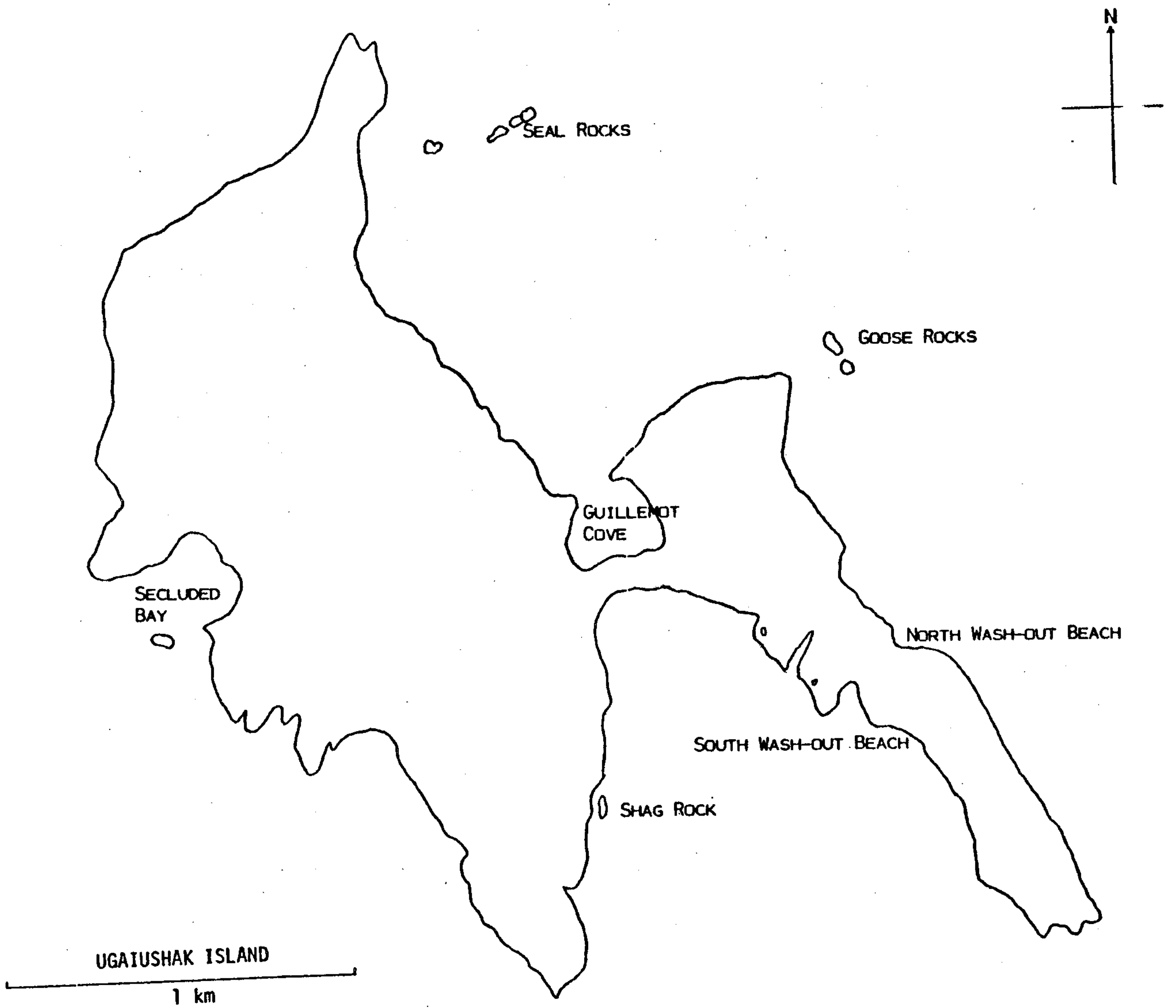

Figure 42. Location of counts of adult Harbor Seals and pups from 19 May to 23 June.

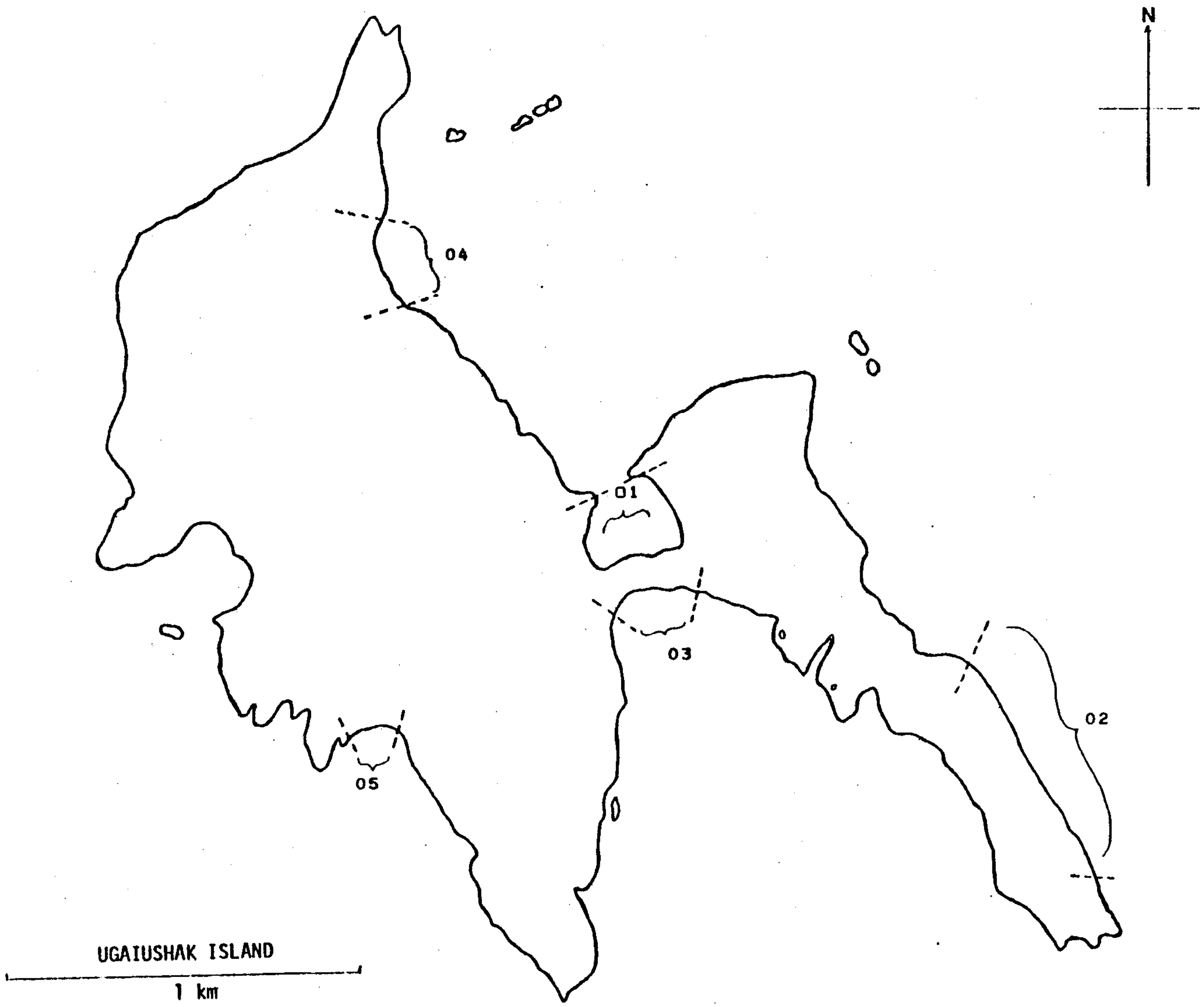

Figure 41. Location of Beached Bird Survey areas.

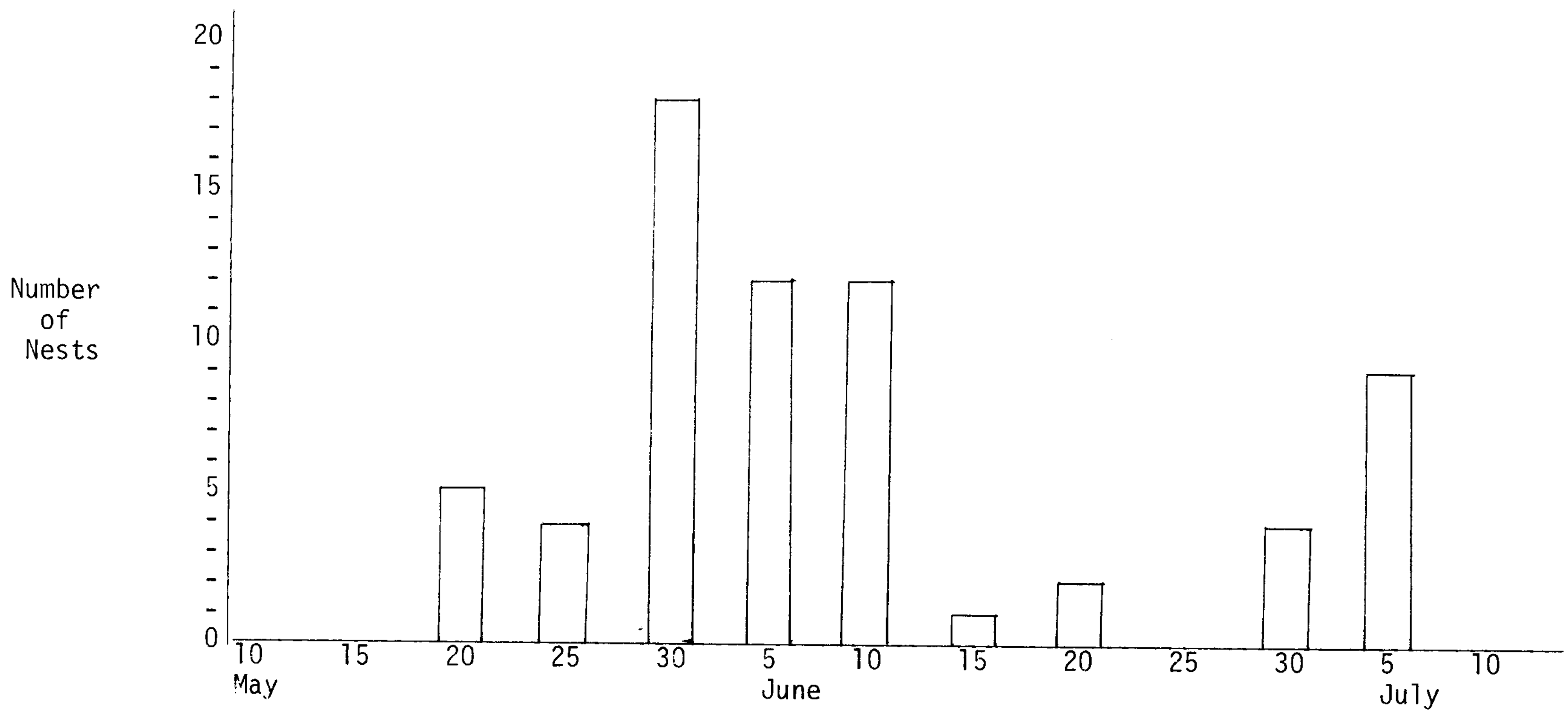

Figure 11. Relative number of Red-faced Cormorant nests at laying and hatching stages shown in 5-day intervals from 10 May to 10 July.

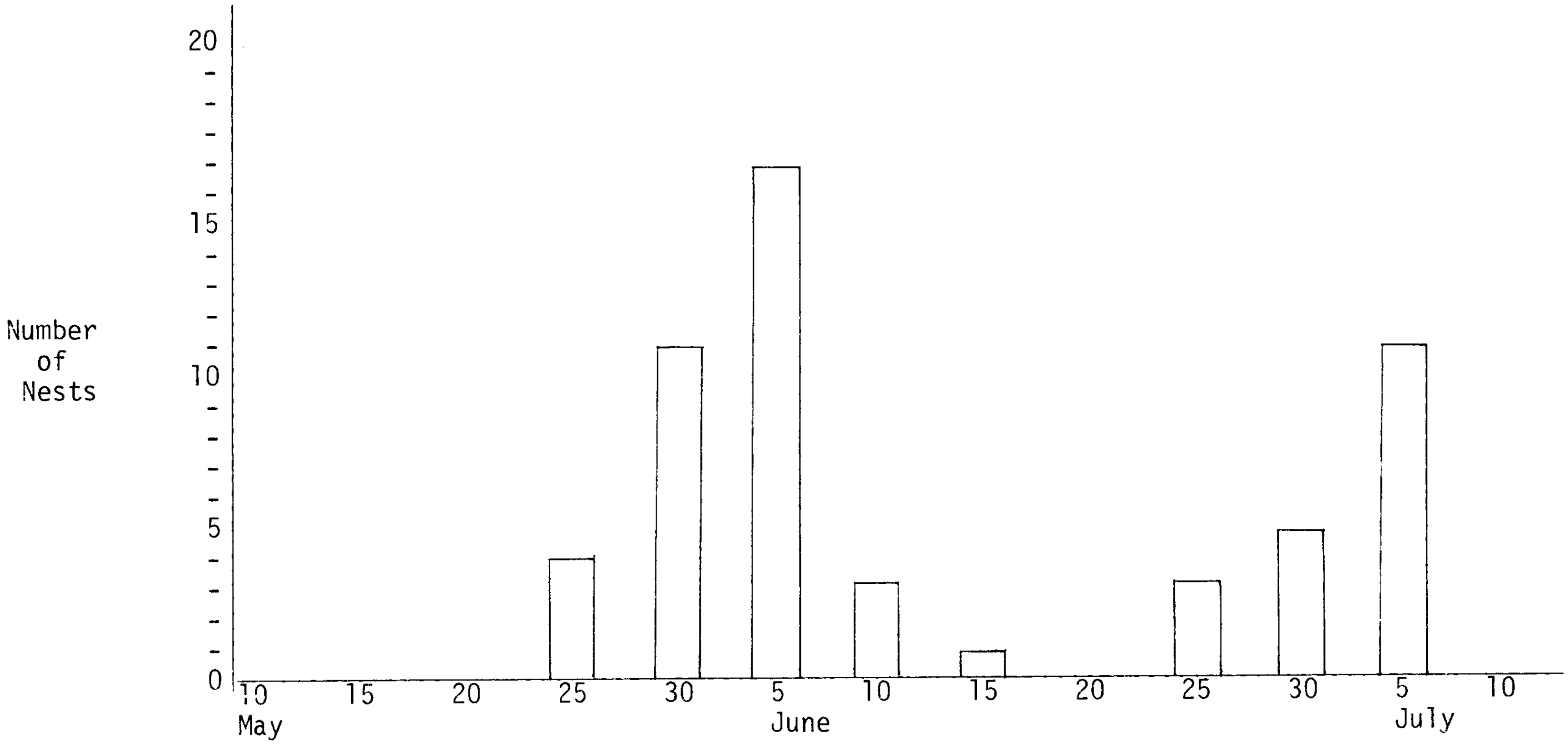

Figure 12 Relative number of Pelagic Cormorant nests at laying and hatching stages shown in 5-day intervals from 10 May to 10 July.

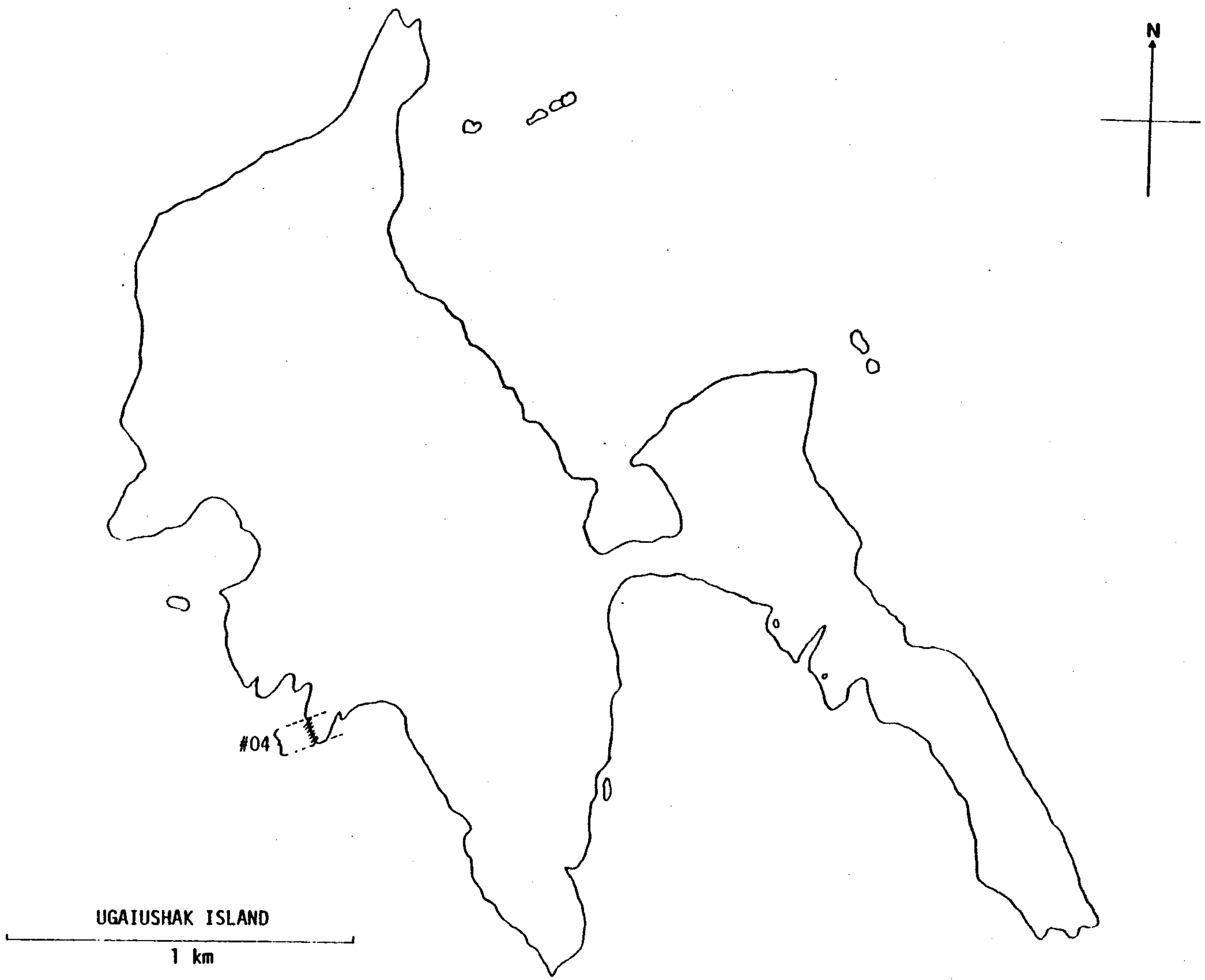

Figure 13. Location of murre study plot #04 and Black-legged Kittiwake study plot #04.

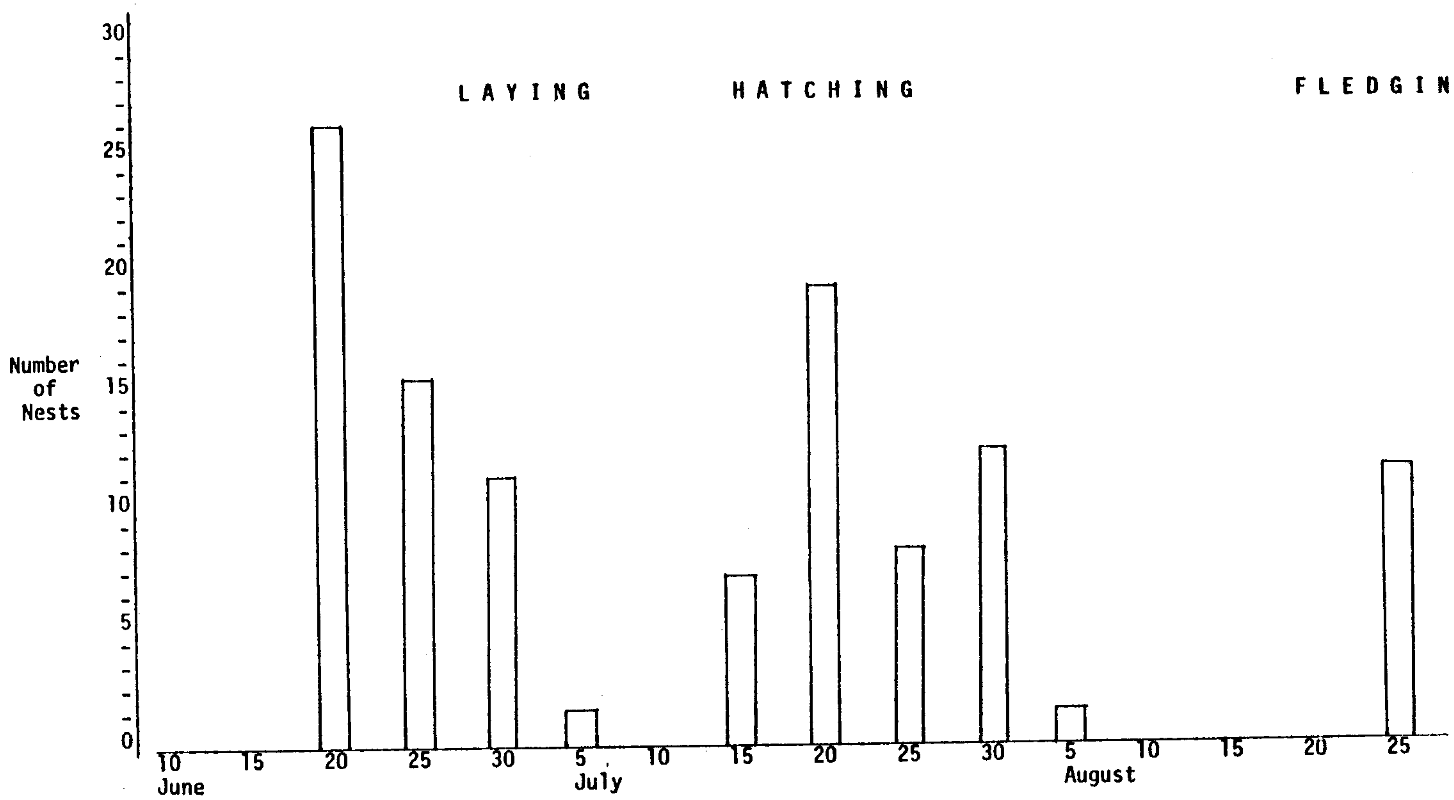

Figure 14. Relative number of Black-legged kittiwake nests at laying, hatching, and fledging stages in 5-day intervals in 1977. (Note: no data obtained of fledging after 25 August).

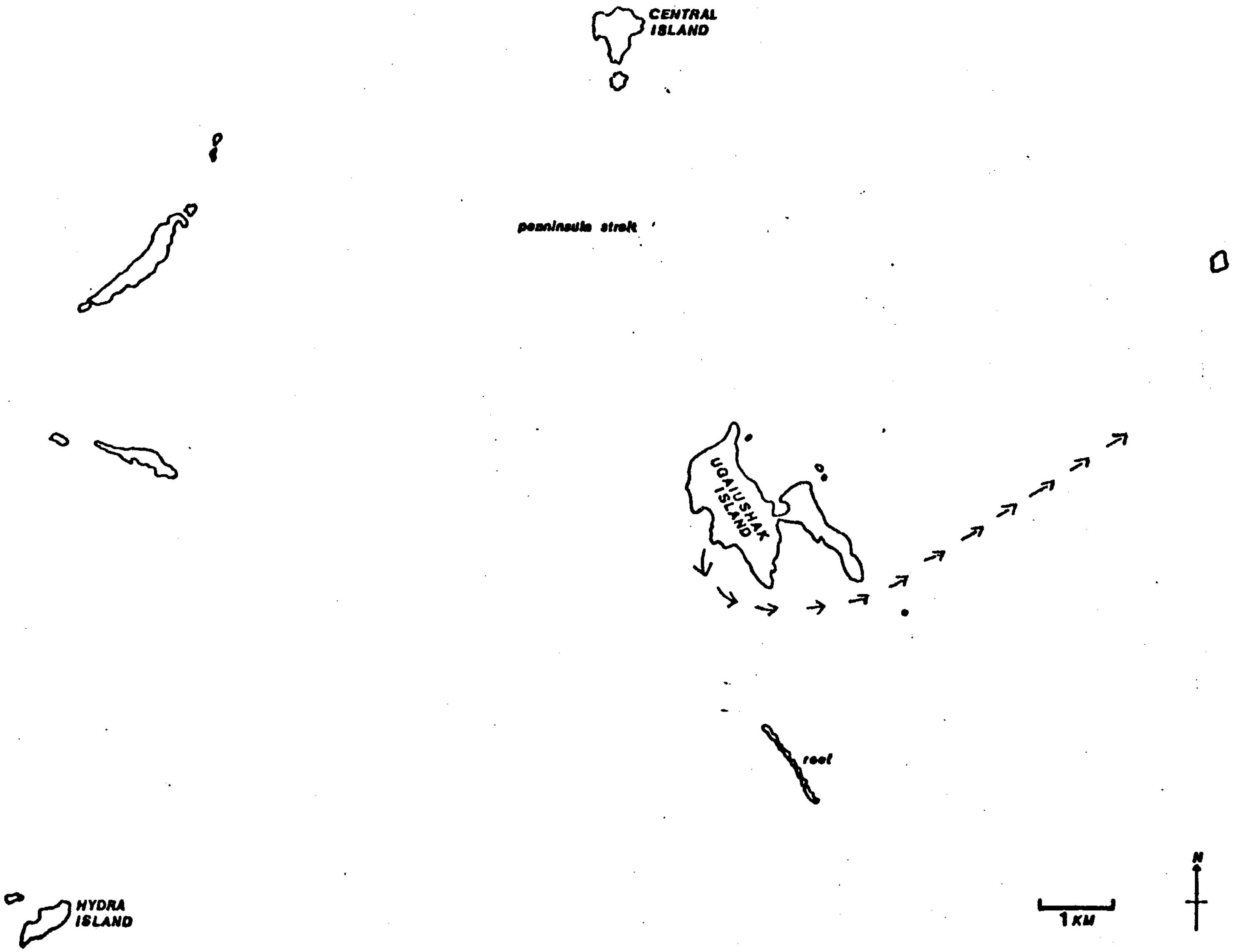

Figure 15. Route of murres during late afternoon exodus from Ugaiushak Island in pre-egg stage.

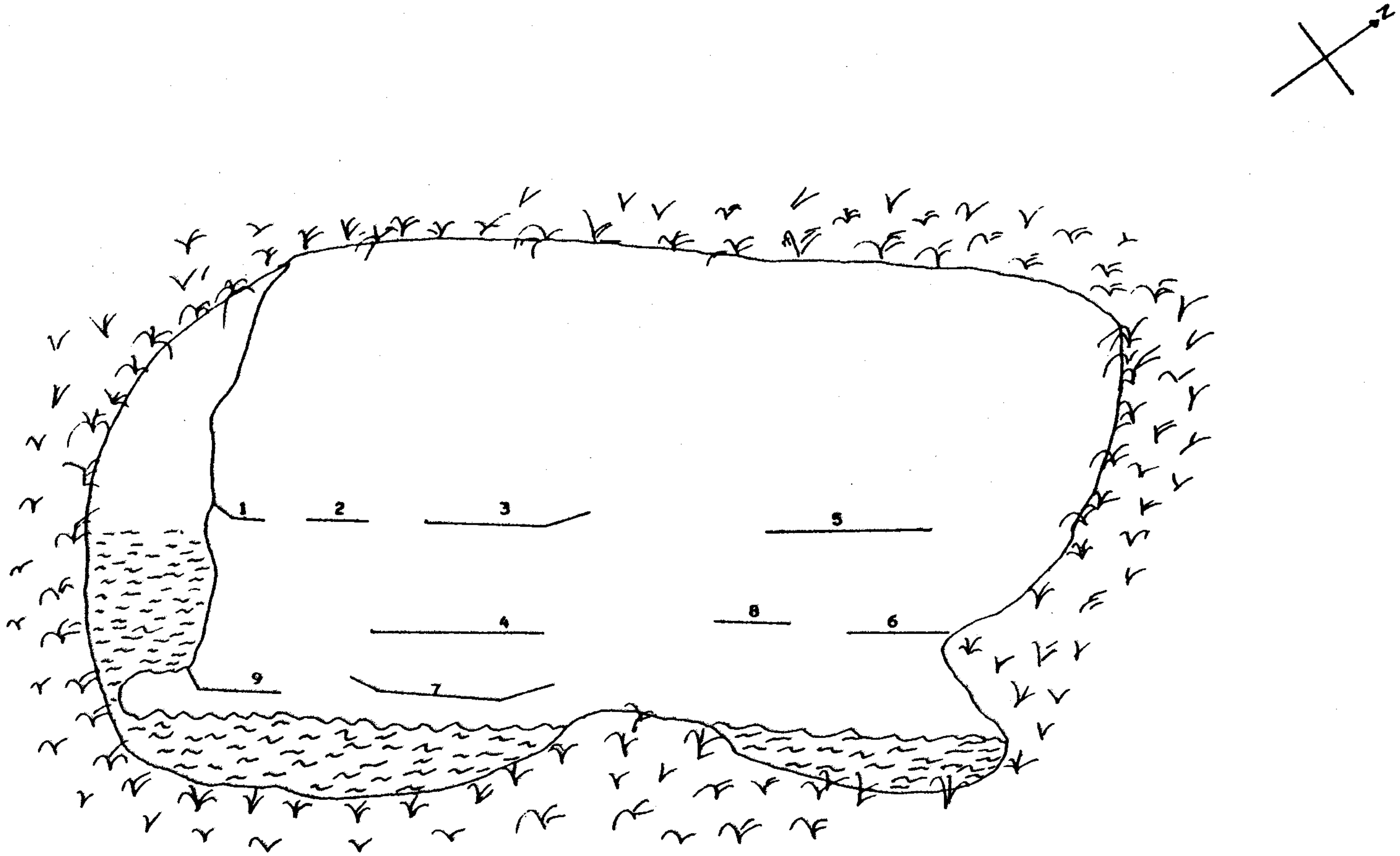

Figure 16. Location of murre study ledges looking down through top of Hole-in-the-Wall.

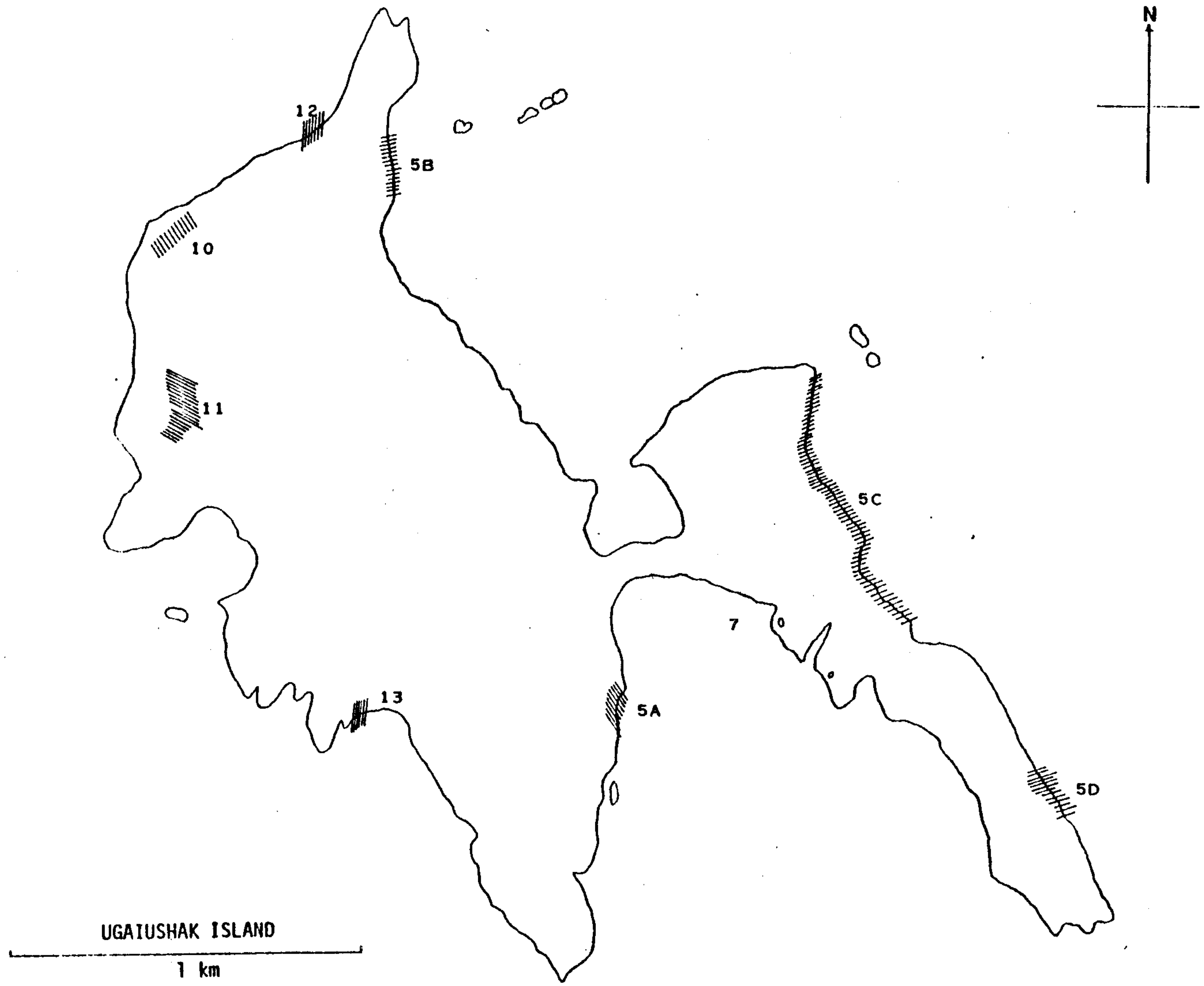

Figure 17. Location of Horned Puffin study plots in 1977.

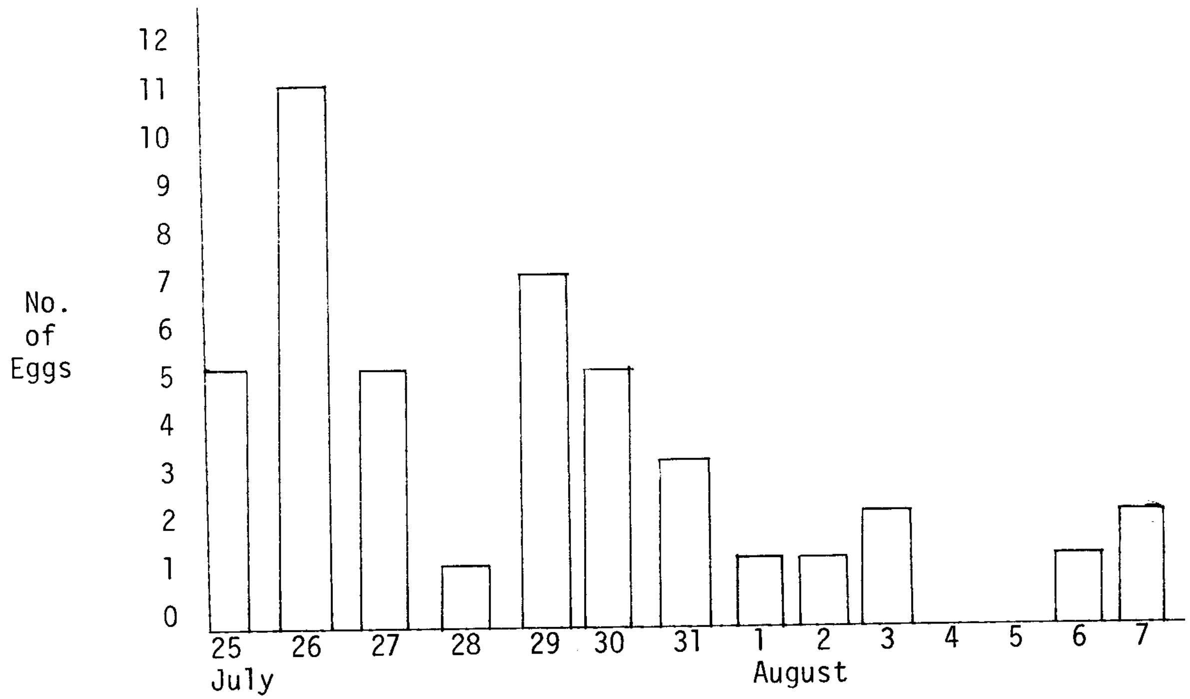

Figure 18. Dates of hatching of 44 Horned Puffin eggs in 1977.

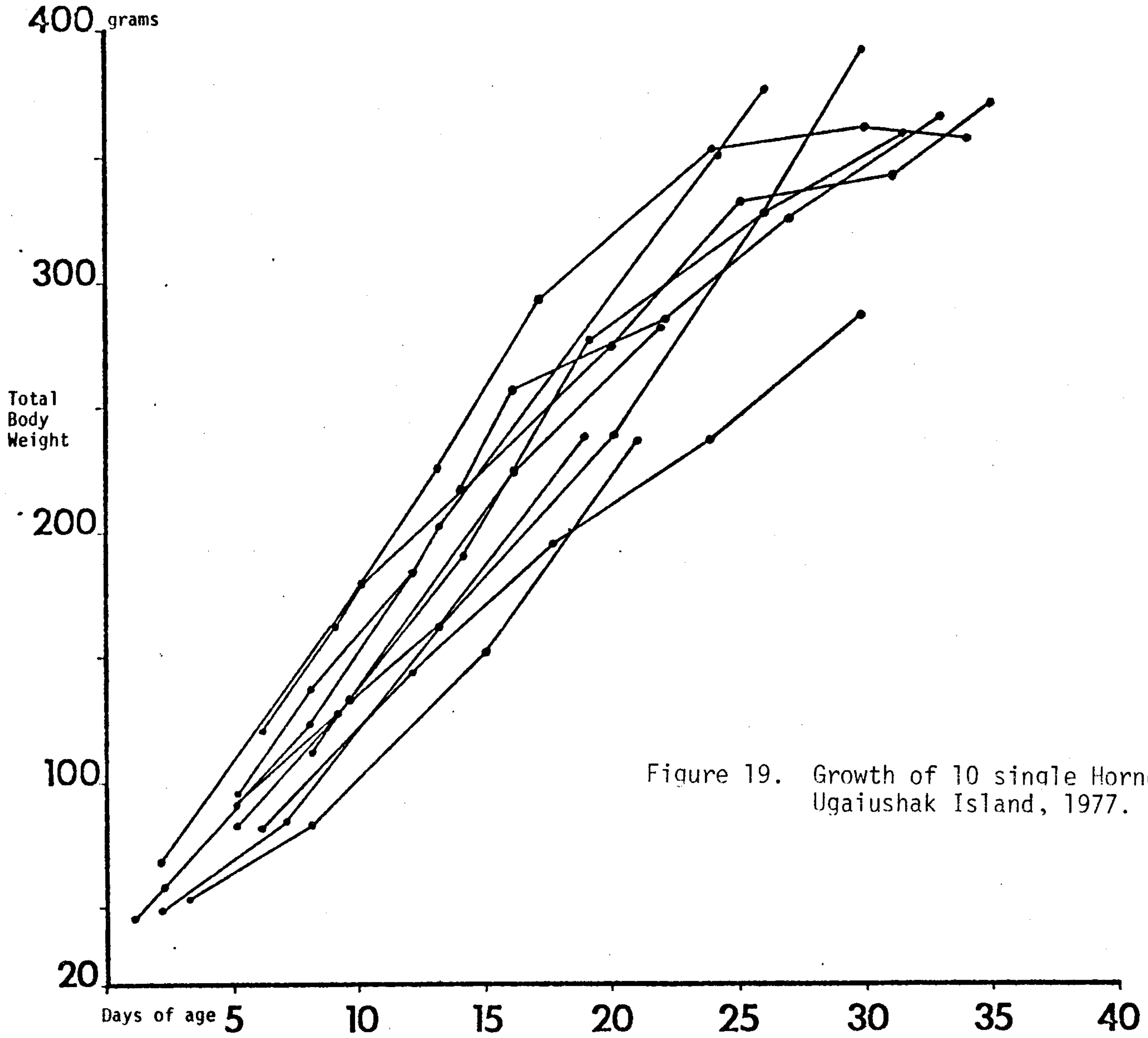

Figure 19. Growth of 10 single Horned Puffin chicks, Ugaiushak Island, 1977.

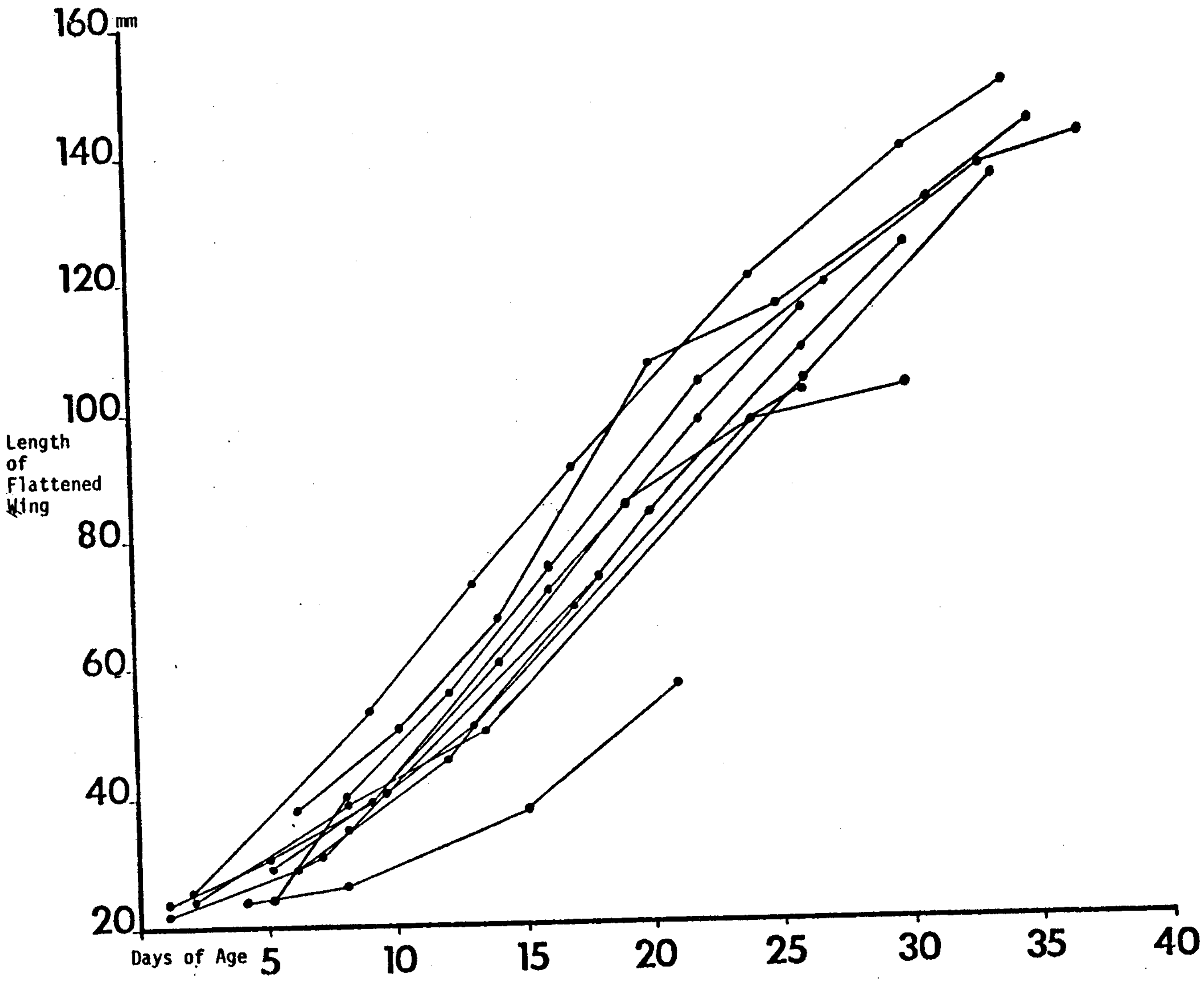

Figure 20. Growth of 9 single Horned Puffin chicks, Ugaiushak Island, 1977.

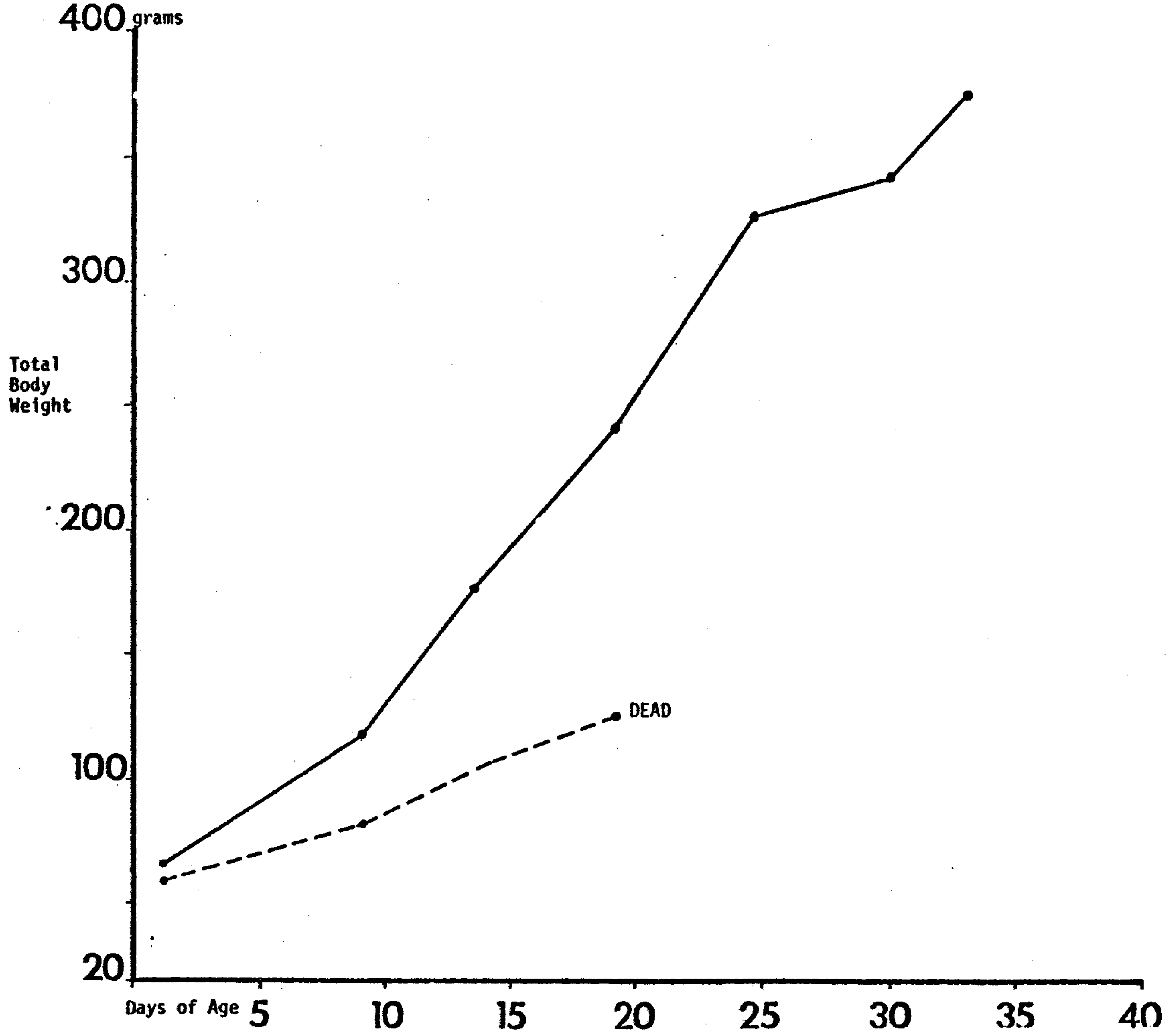

Figure 21. Growth of Horned Puffin twins, Ugaiushak Island, 1977.

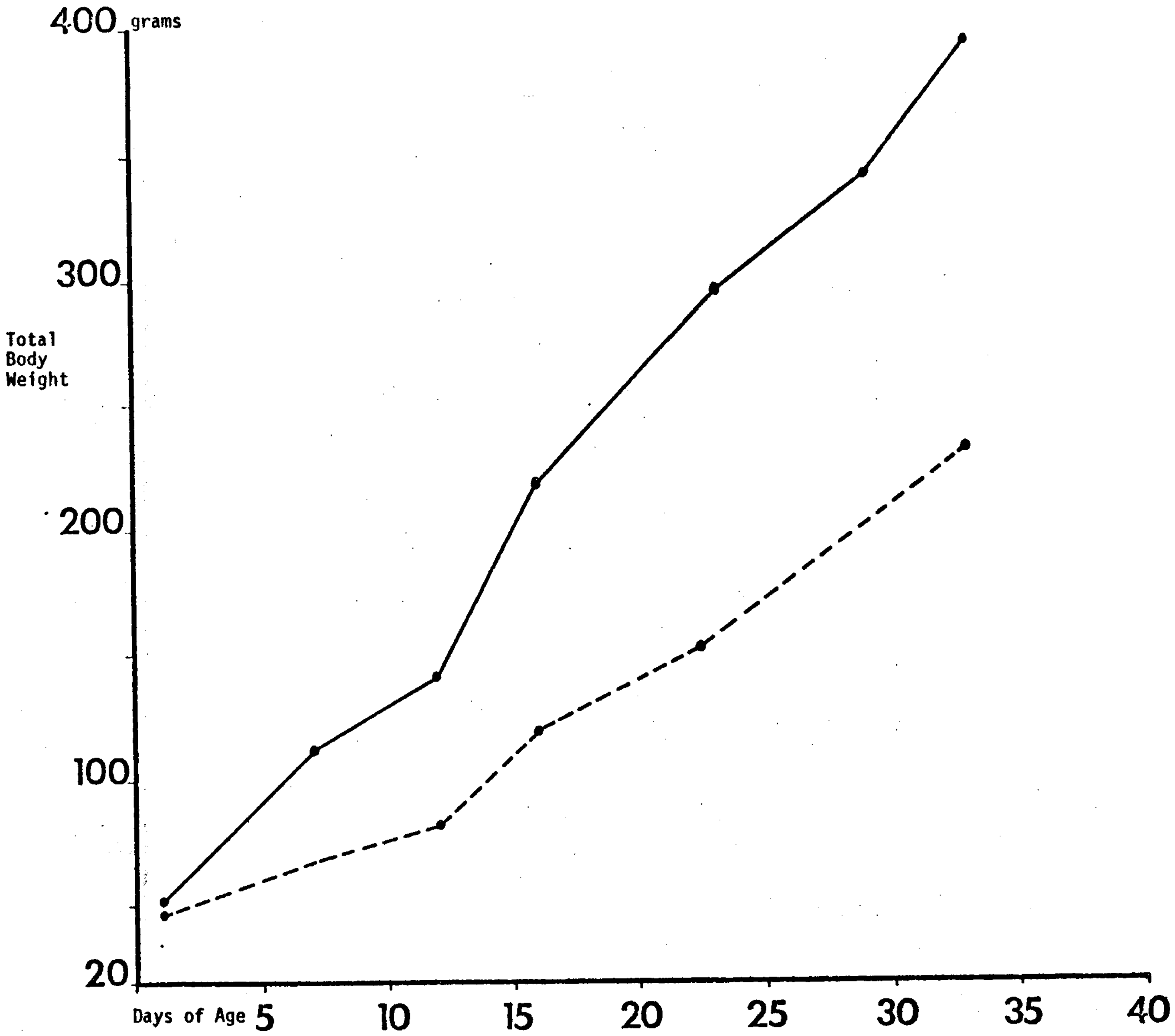

Figure 22. Growth of Horned Puffin twins, Ugaiushak Island, 1977.

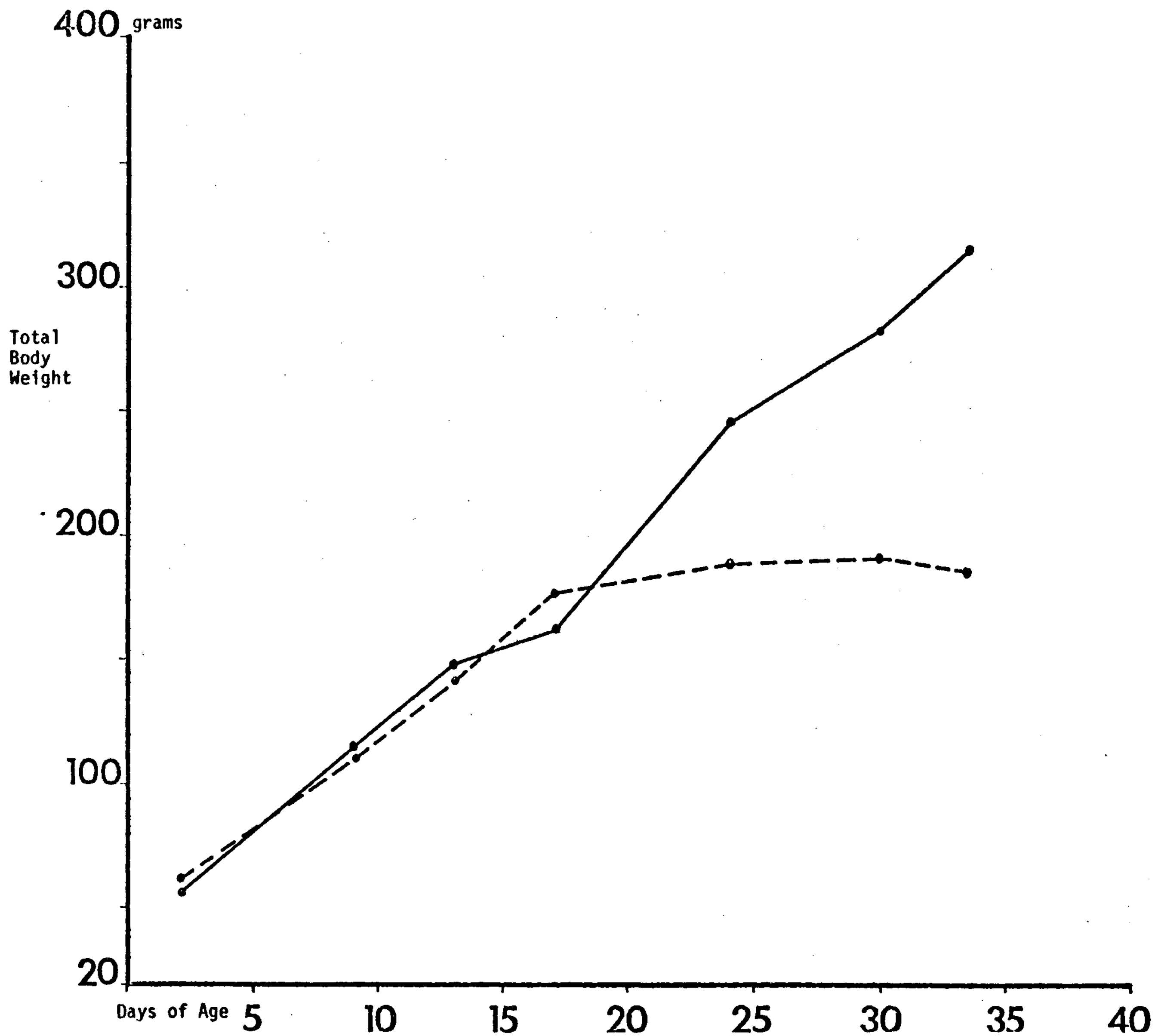

Figure 23. Growth of Horned Puffin twins, Ugaiushak Island, 1977.

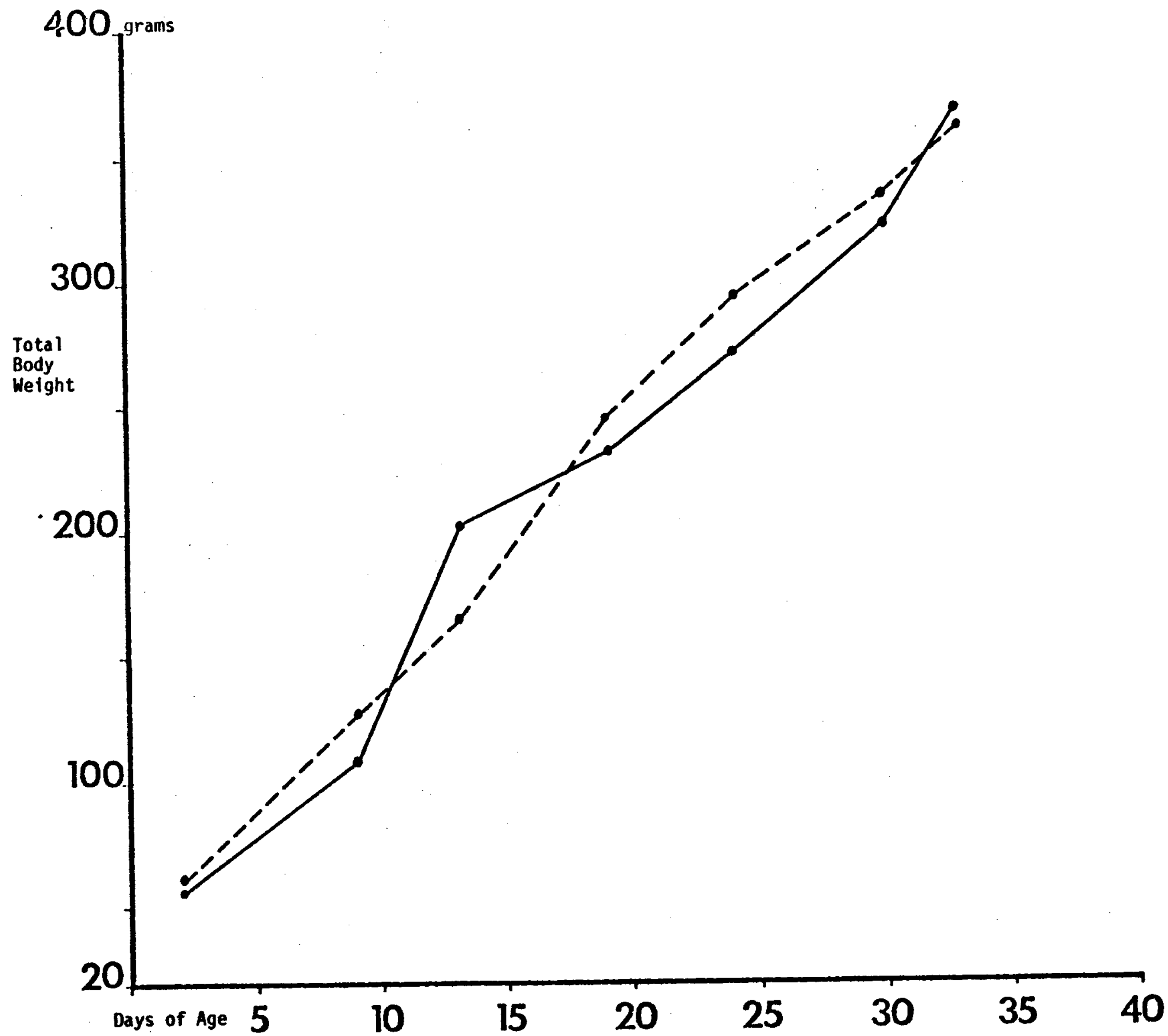

Figure 24. Growth of Horned Puffin twins, Ugaiushak Island, 1977.

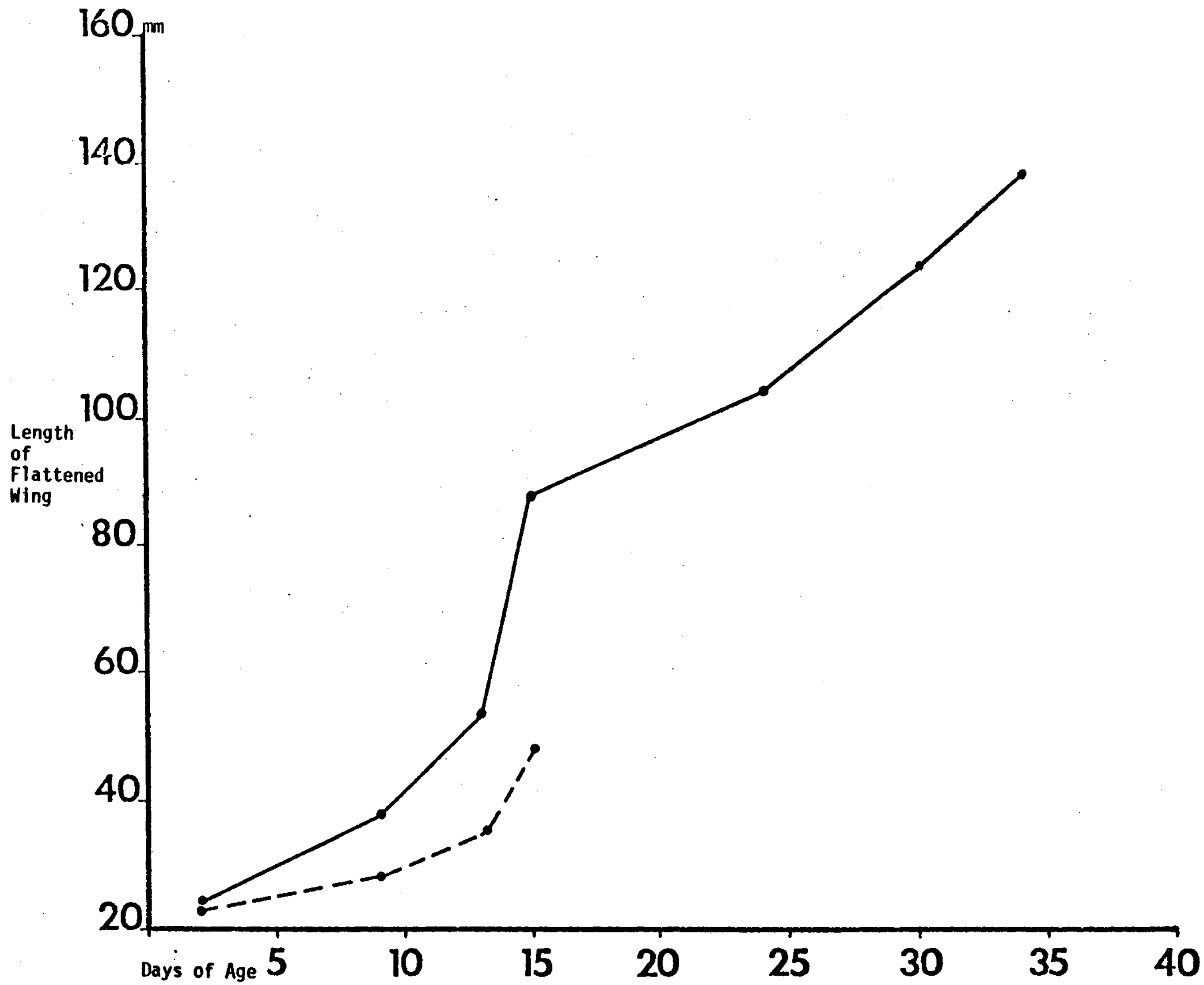

Figure 25. Growth of Horned Puffin twins, Ugaiushak Island, 1977.

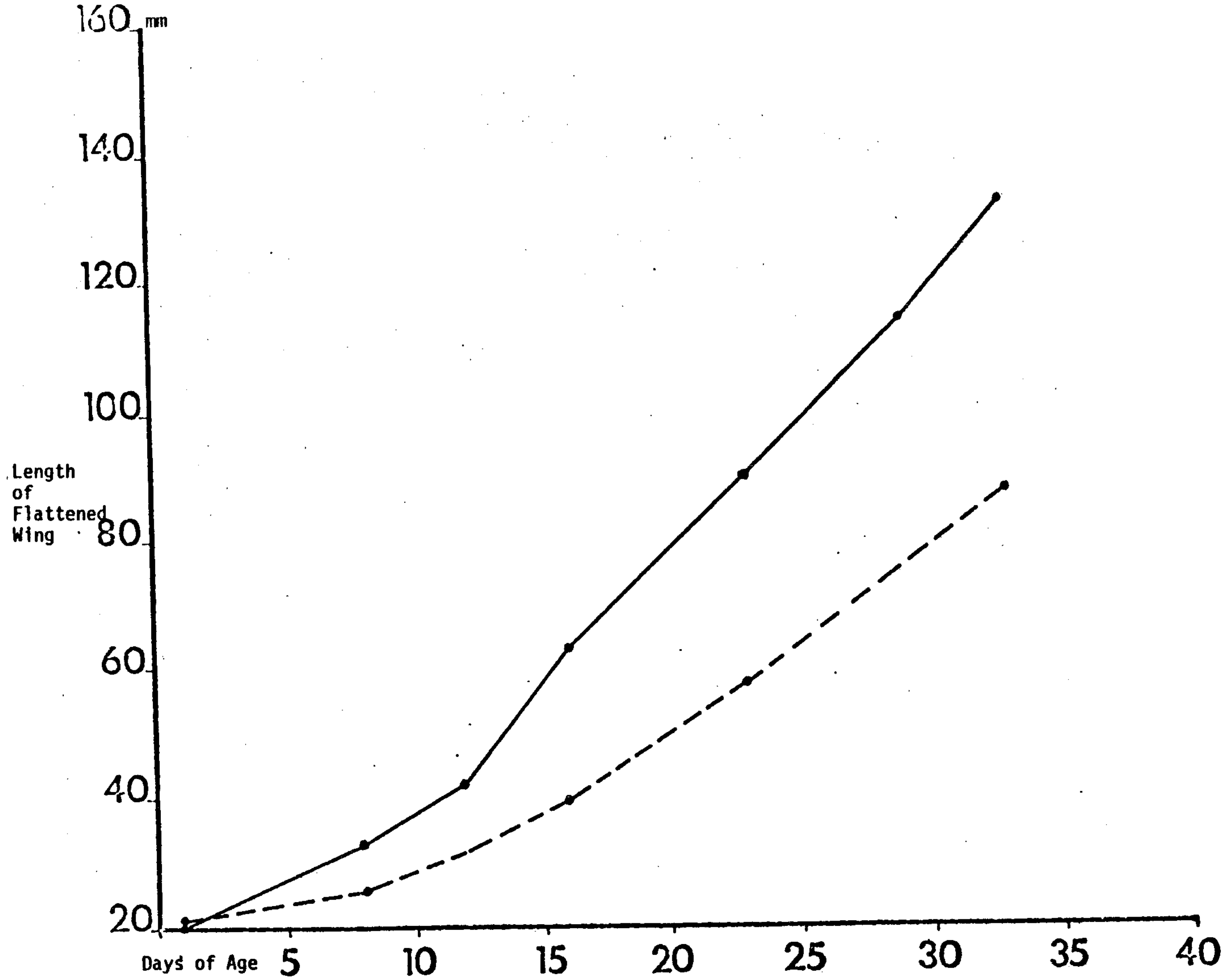

Figure 26. Growth of Horned Puffin twins, Ugaiushak Island, 1977.

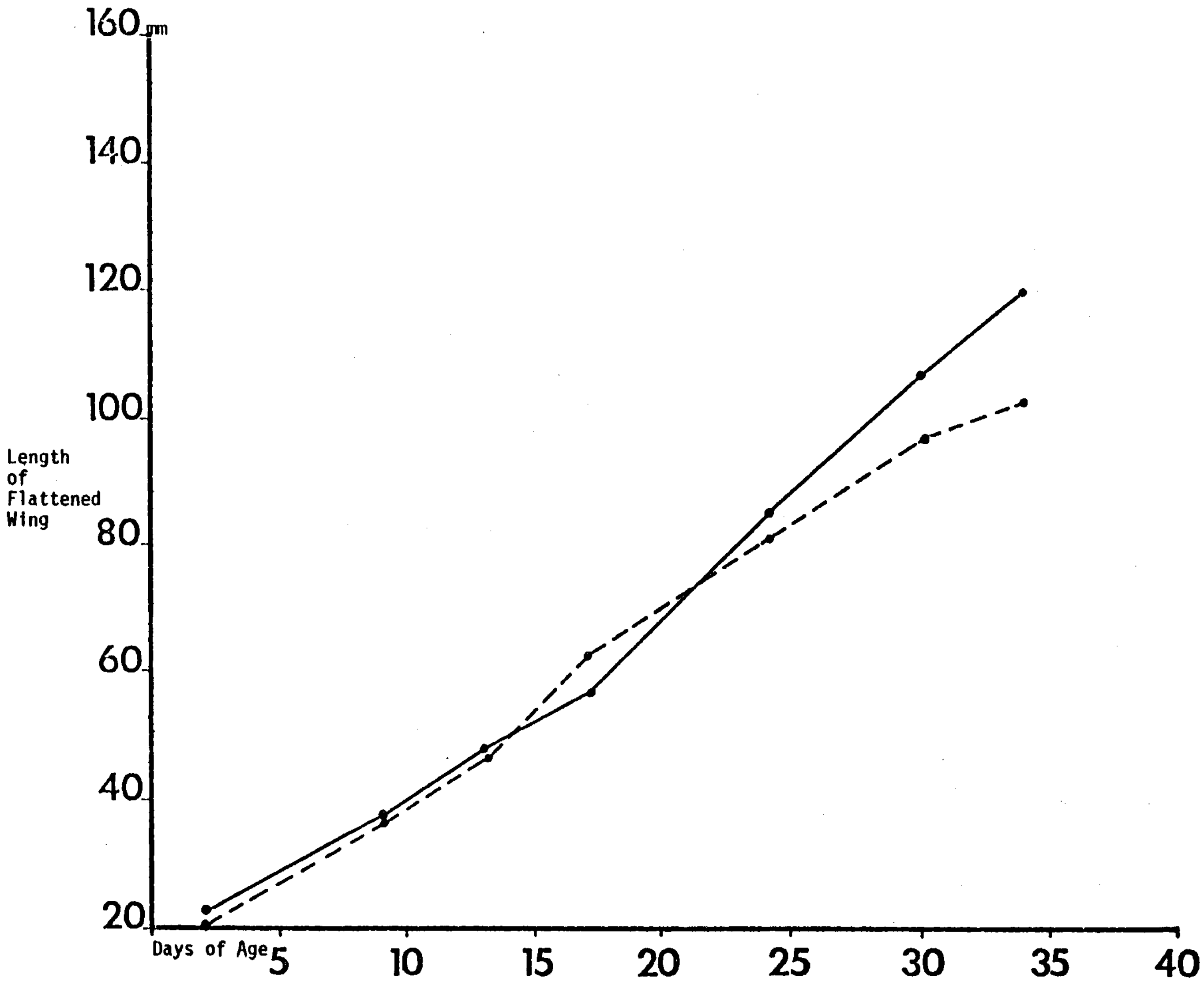

Figure 27. Growth of Horned Puffin twins, Ugaiushak Island, 1977.

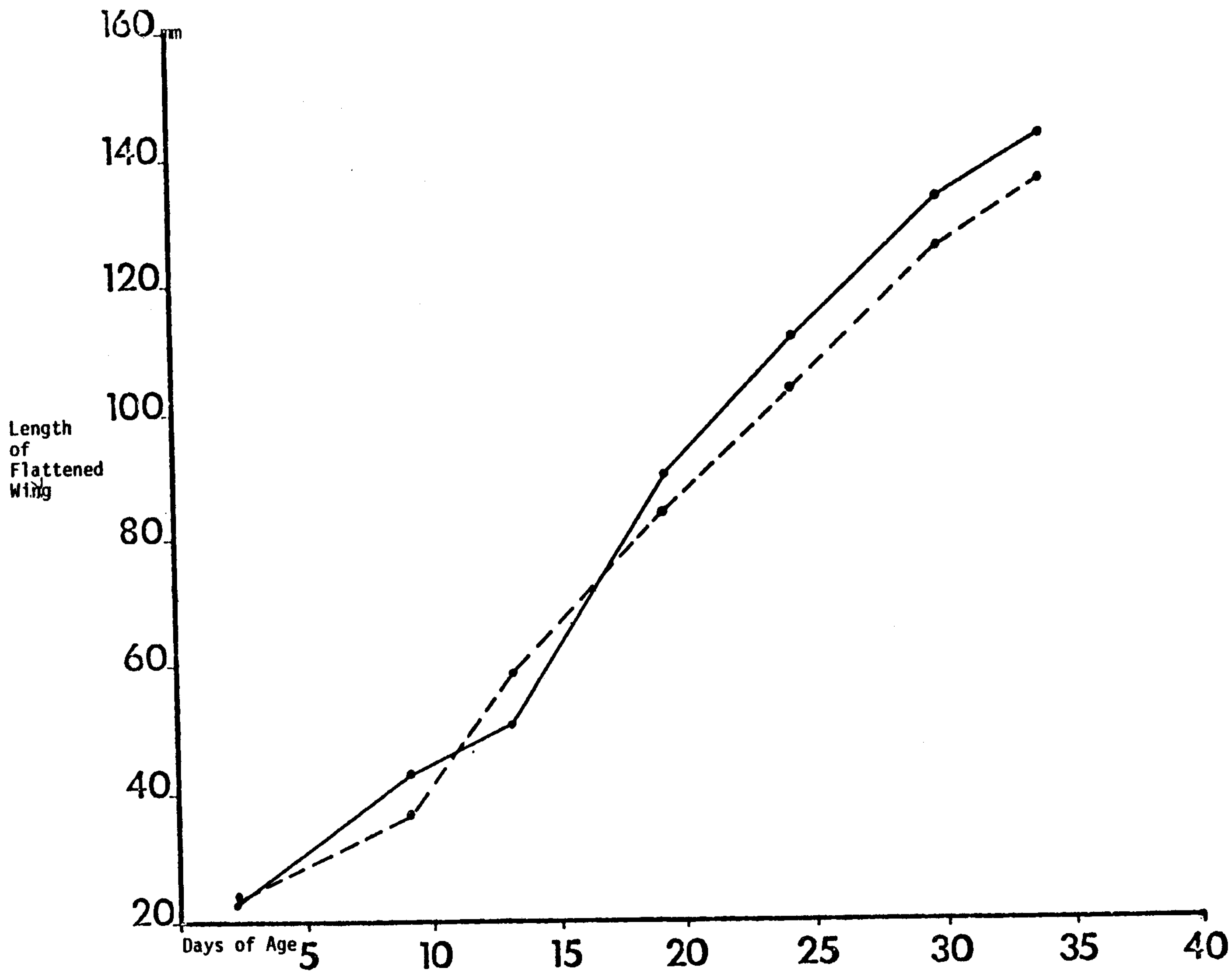

Figure 28. Growth of Horned Puffin twins, Ugaiushak Island, 1977.

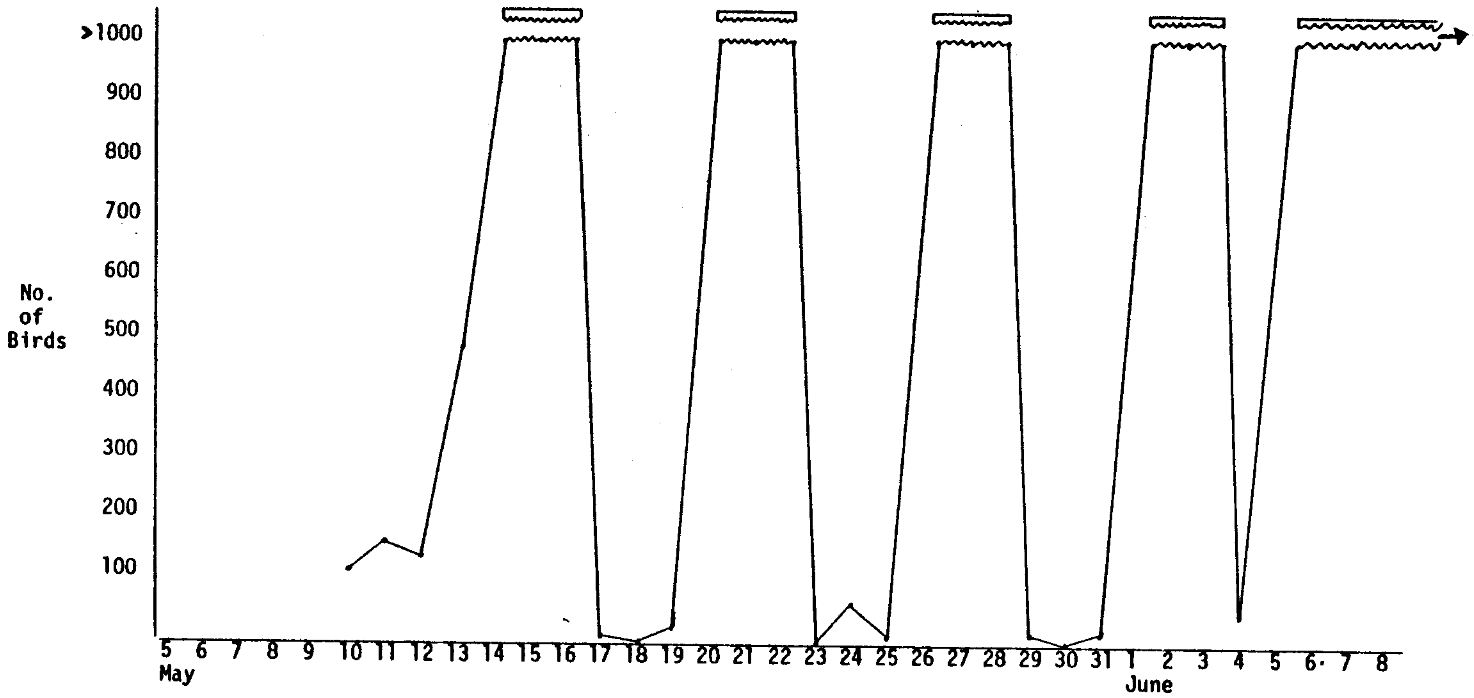

Figure 29. Number of Tufted Puffins observed at Ugaiushak Island from first arrival, 10 May, to establishament of permanent residence, 5 June.

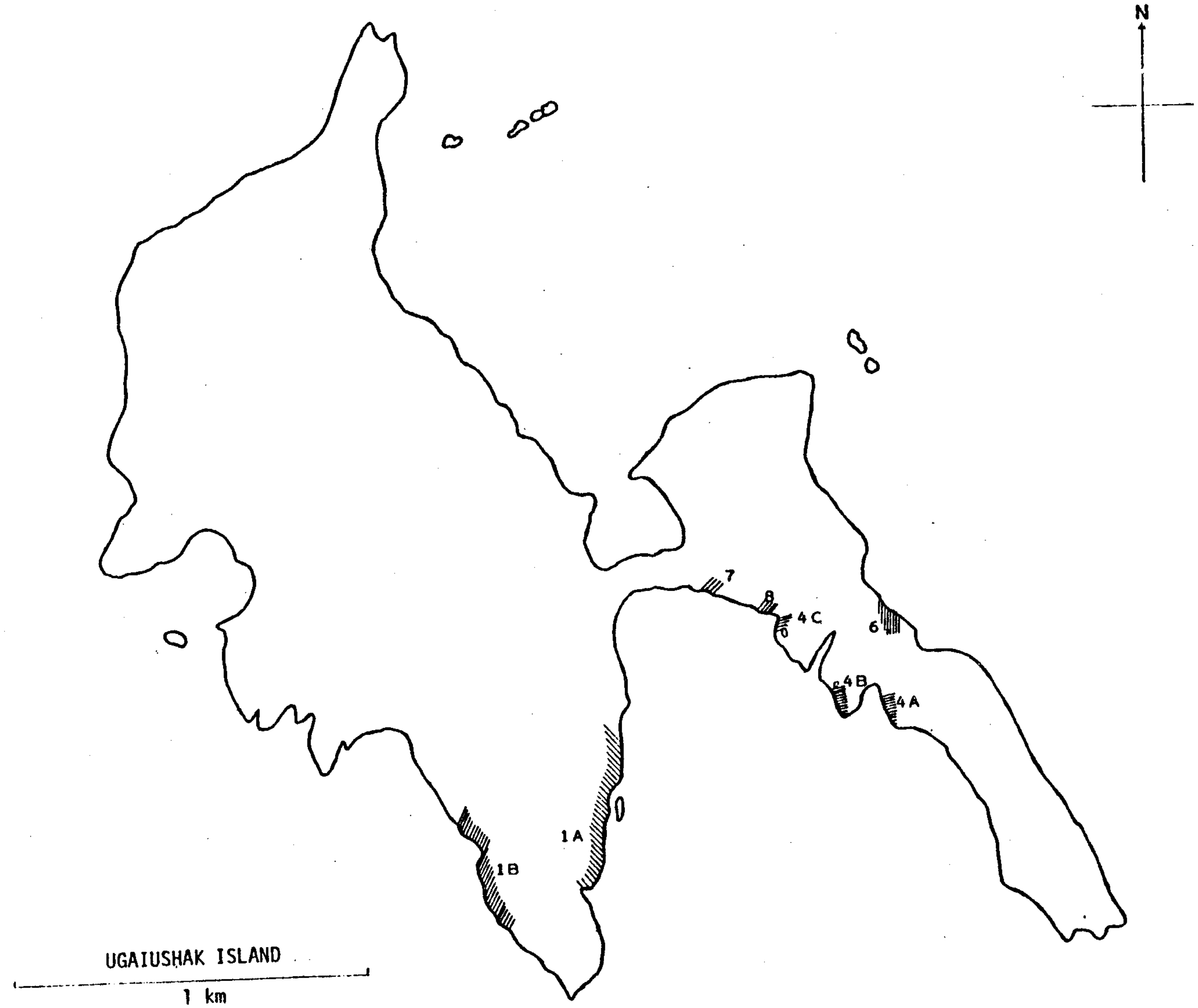

Figure 30. Location of Tufted Puffin study plots.

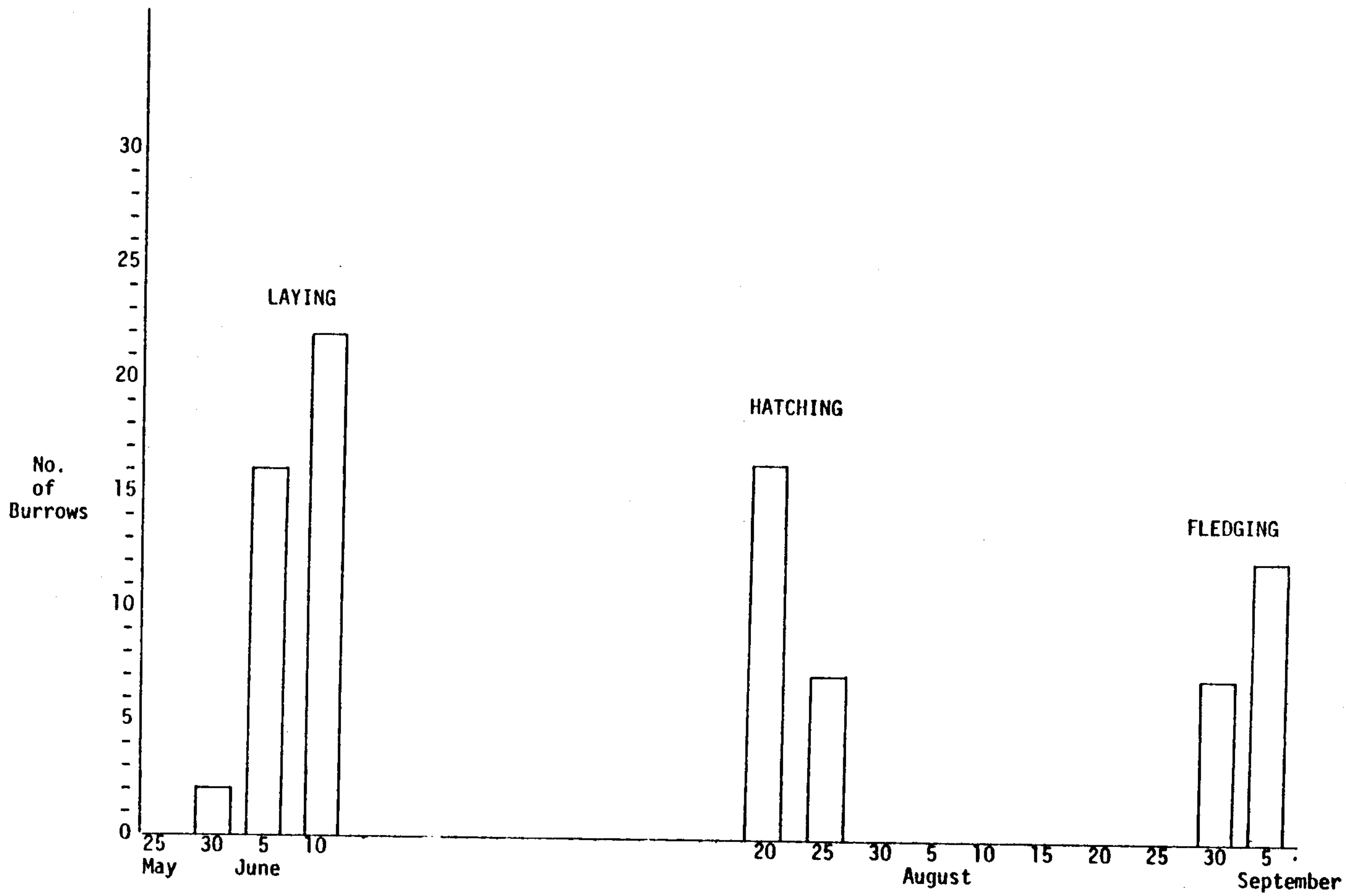

Figure 31. Relative number of Tufted Puffin burrows at laying, hatching, and fledging stages in 5-day intervals in 1976. (Note: eggs were laid in 11 additional burrows after 11 June when regular checking of burrows was discontinued; also data were obtained on fledging after 2 September).

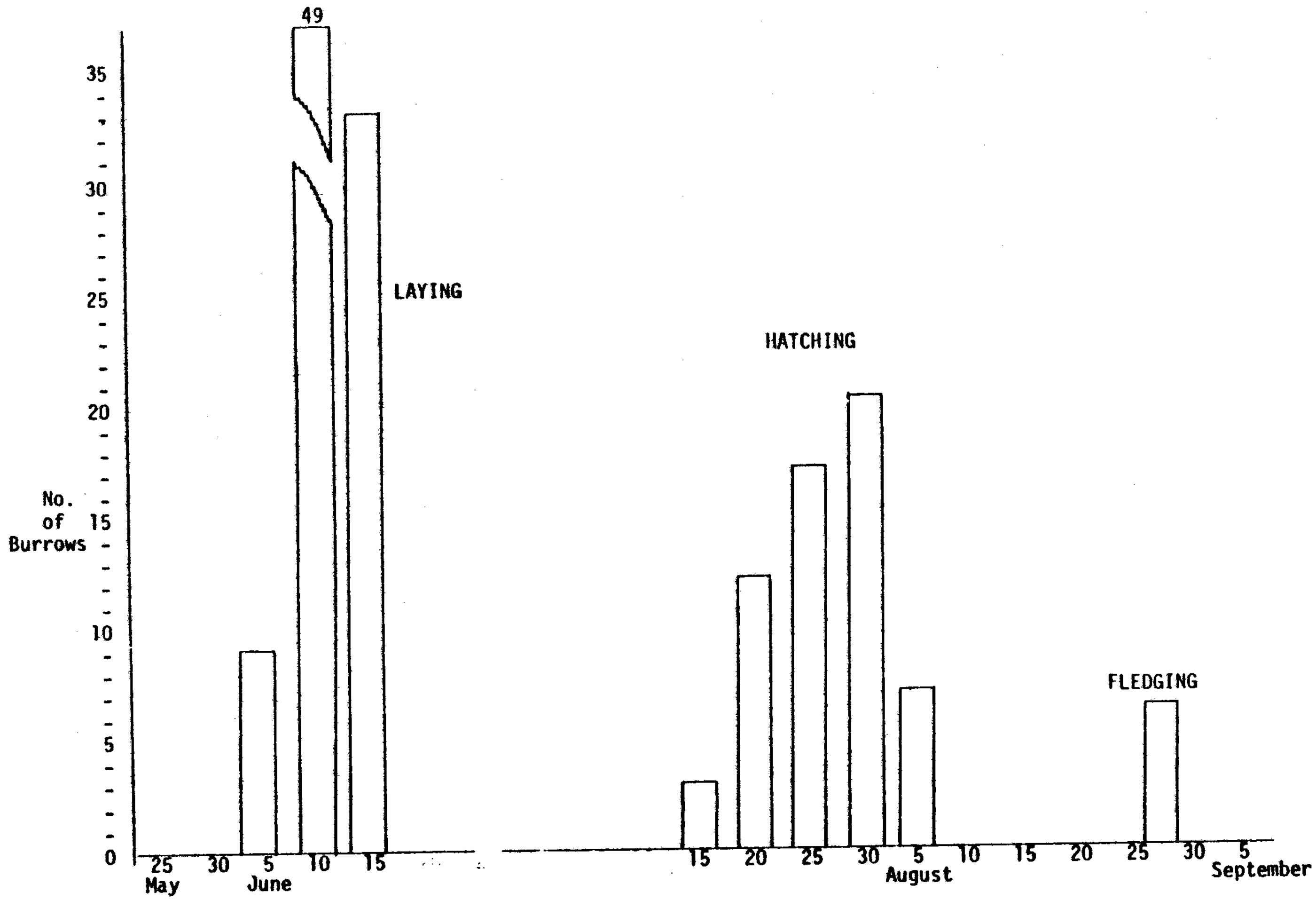

Figure 32. Relative number of Tufted Puffin burrows at laying, hatching, and fledging stages in 5-day intervals in 1977. (Note: eggs were laid in 34 additional burrows after 14 June when regular checking was discontinued; also, no data obtained on fledging after 28 August).

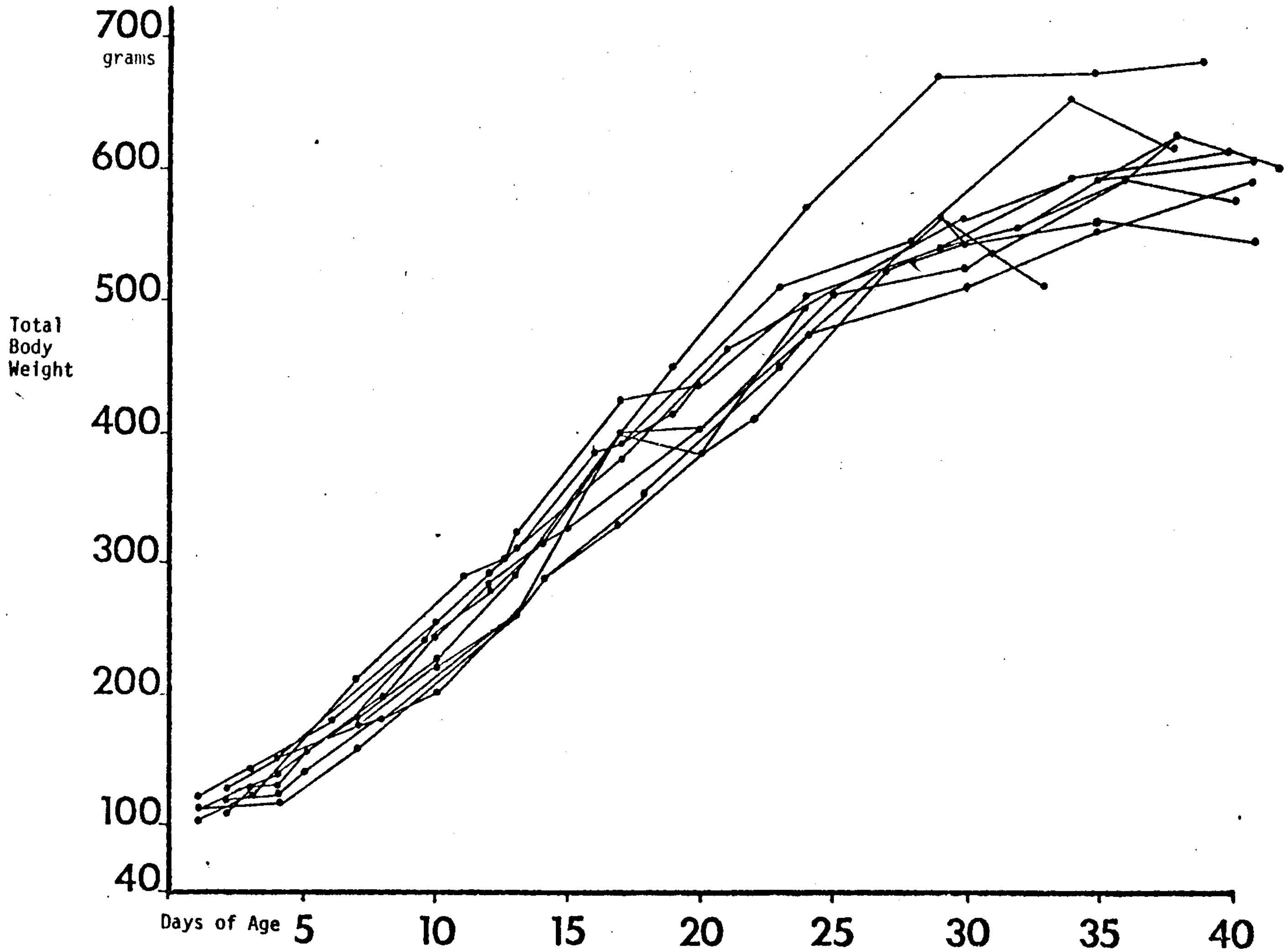

Figure 33. Growth of Tufted Puffin singles, Ugaiushak Island, 1977.

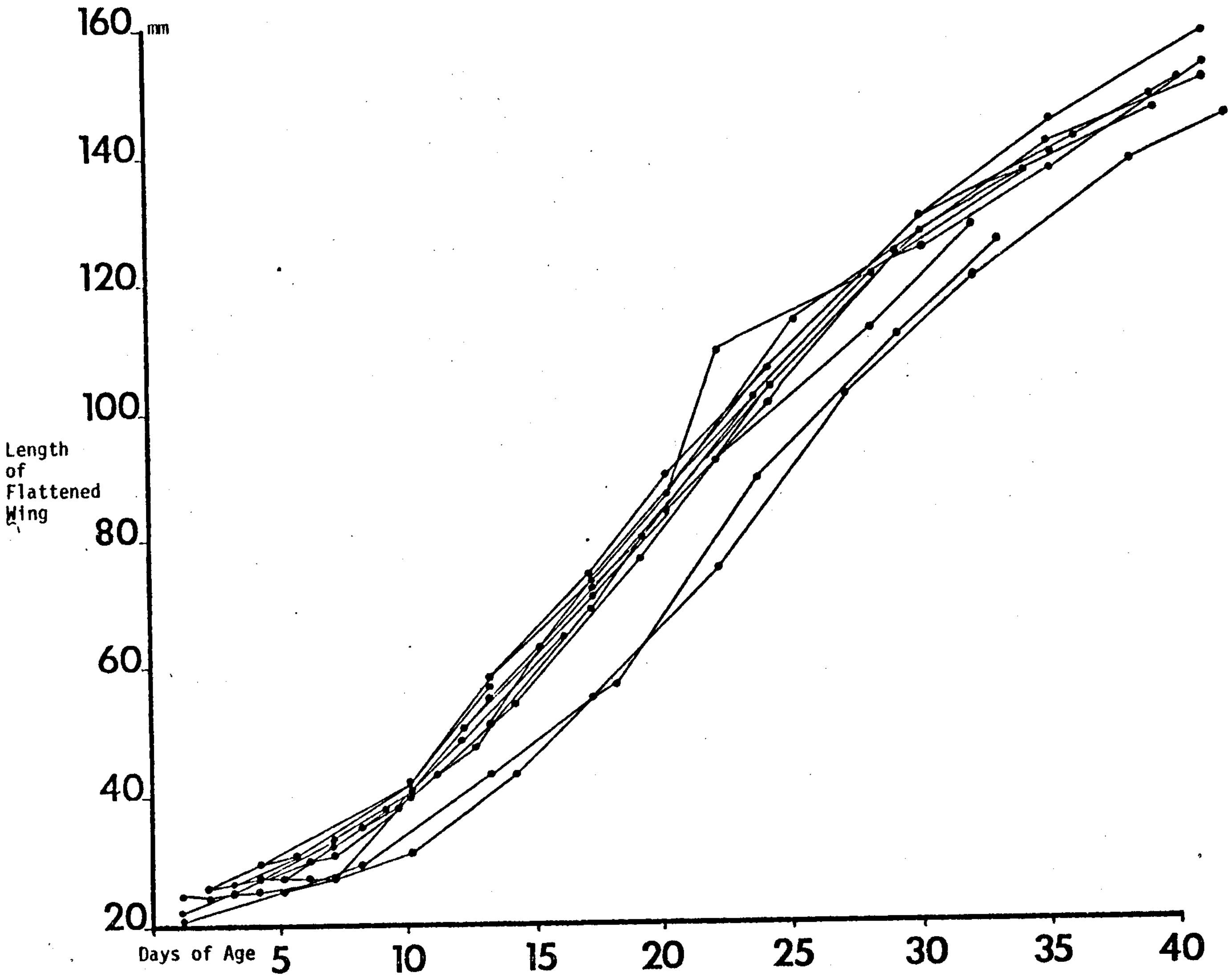

Figure 34. Growth of Tufted Puffin singles, Ugaiushak Island, 1977.

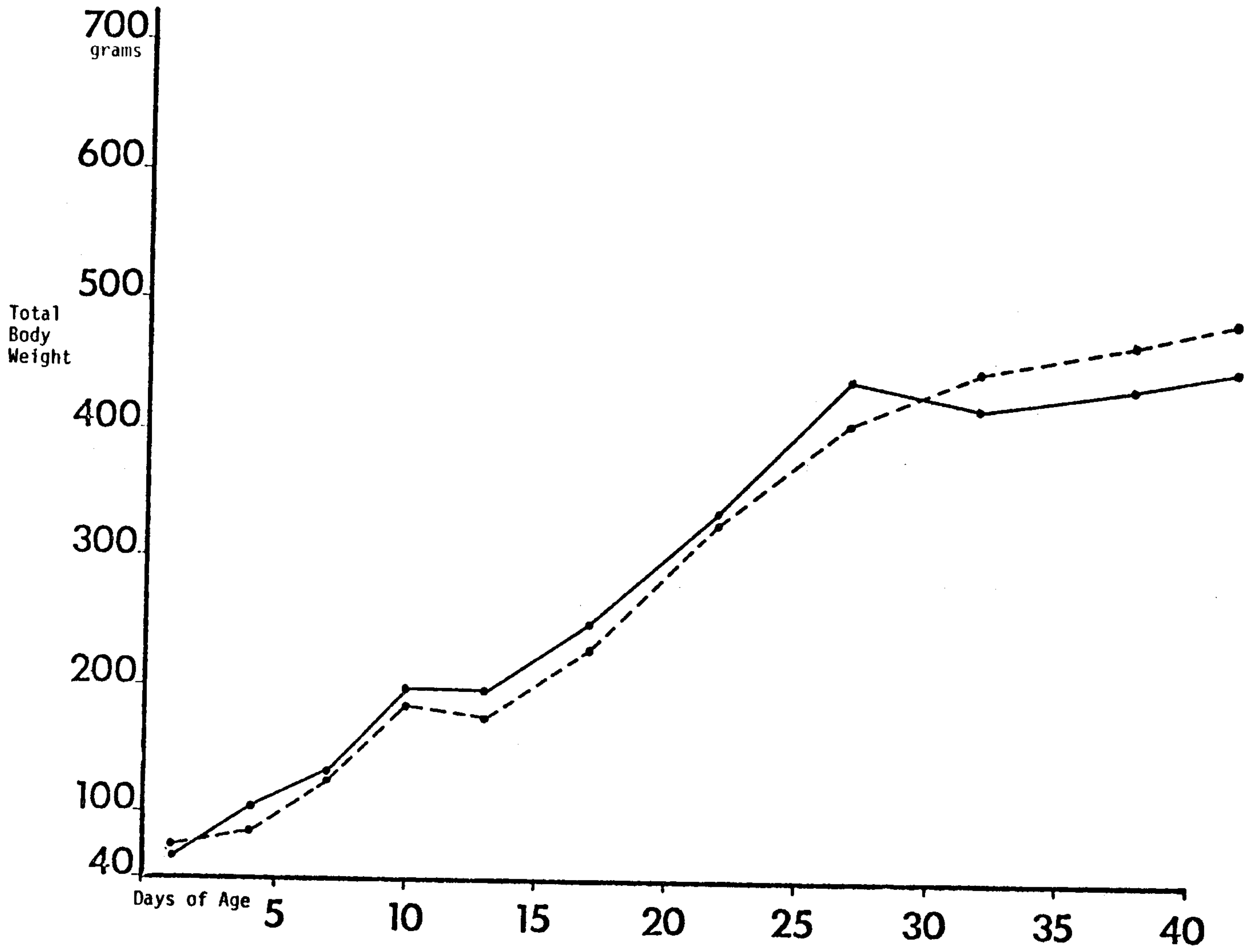

Figure 35. Growth of Tufted Puffin twins, Ugaiushak Island, 1977.

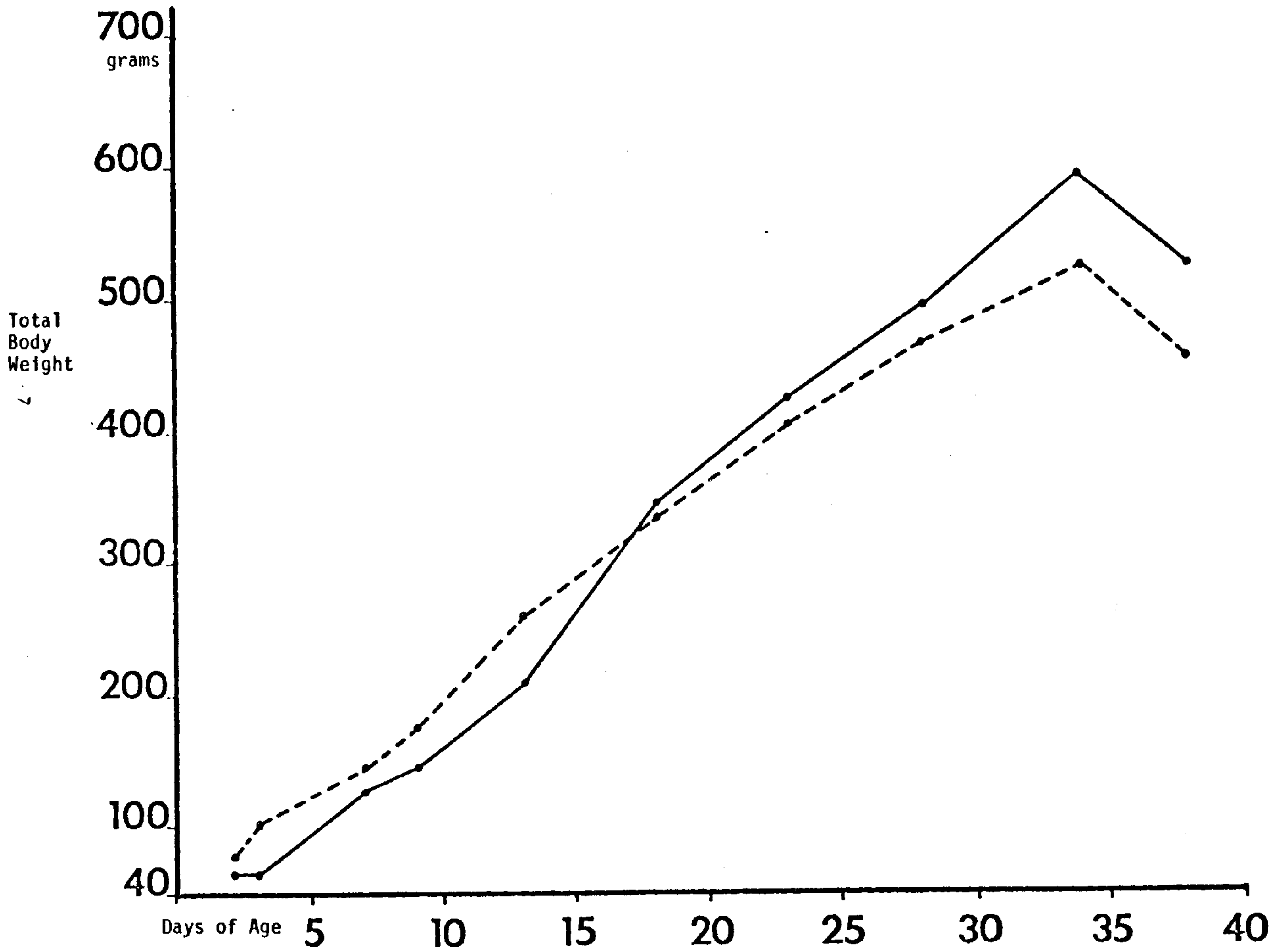

Figure 36. Growth of Tufted Puffin twins, Ugaiushak Island, 1977.

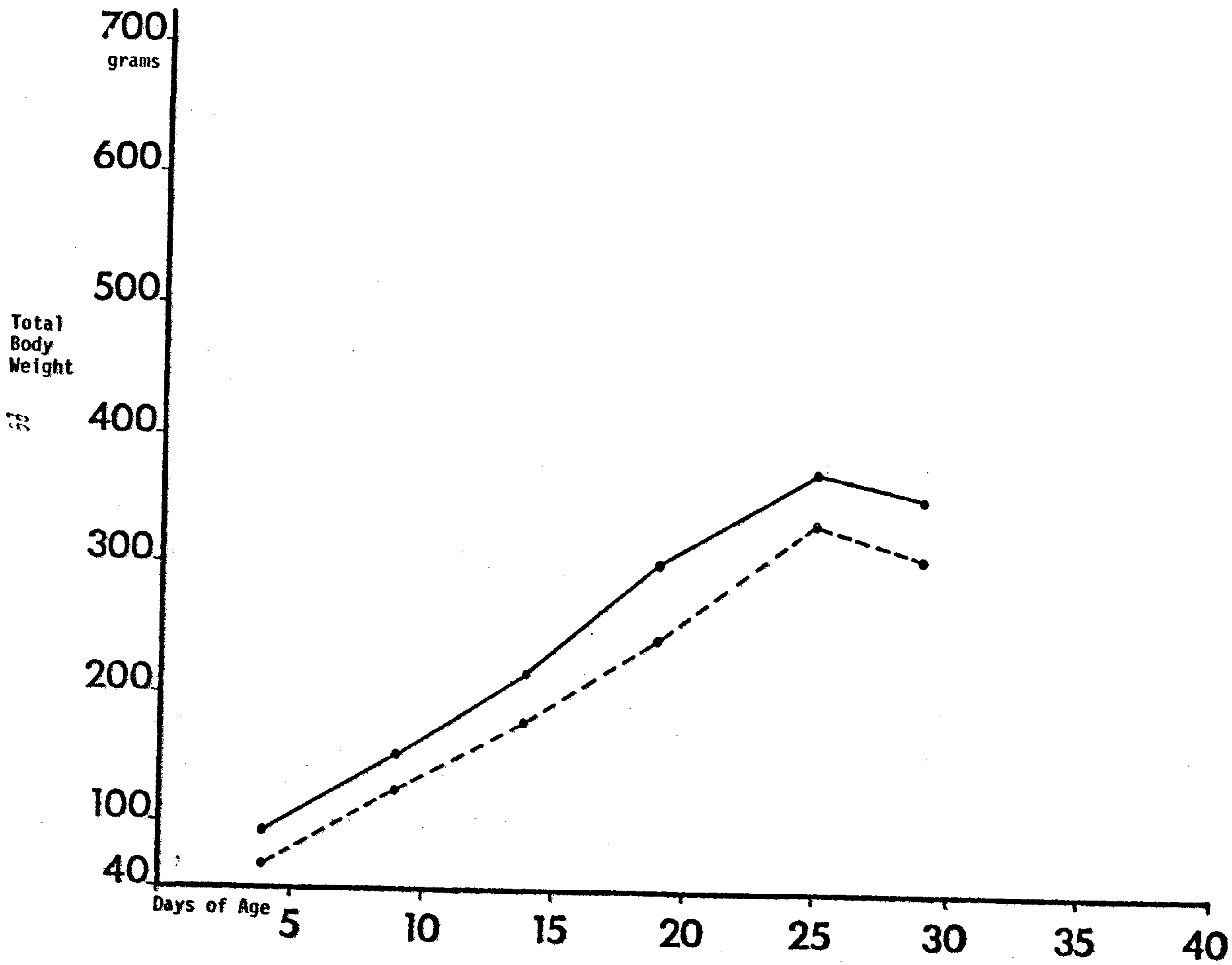

Figure 37. Growth of Tufted Puffin twins, Ugaiushak Island, 1977.

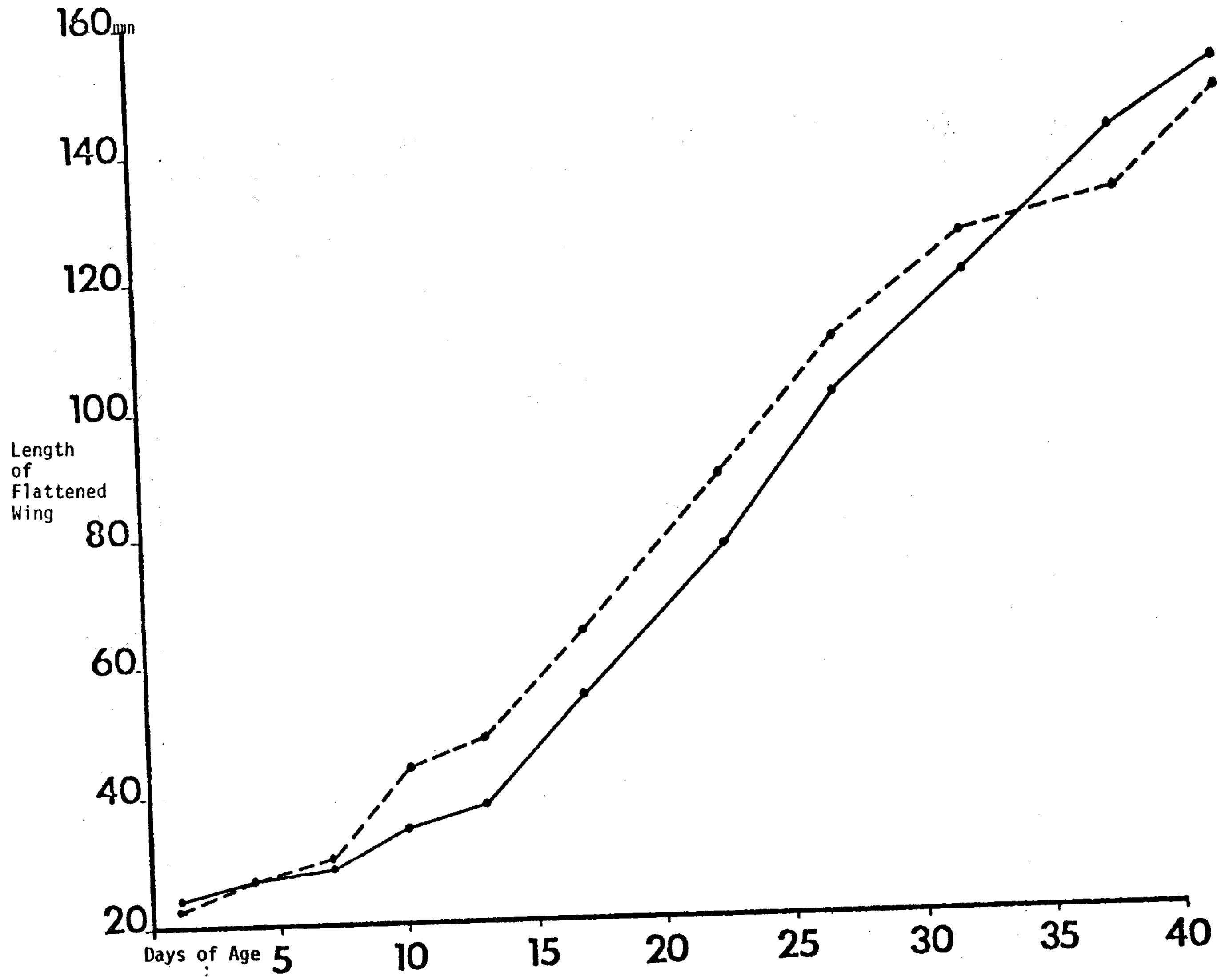

Figure 38. Growth of Tufted Puffin twins, Ugaiushak Island, 1977.

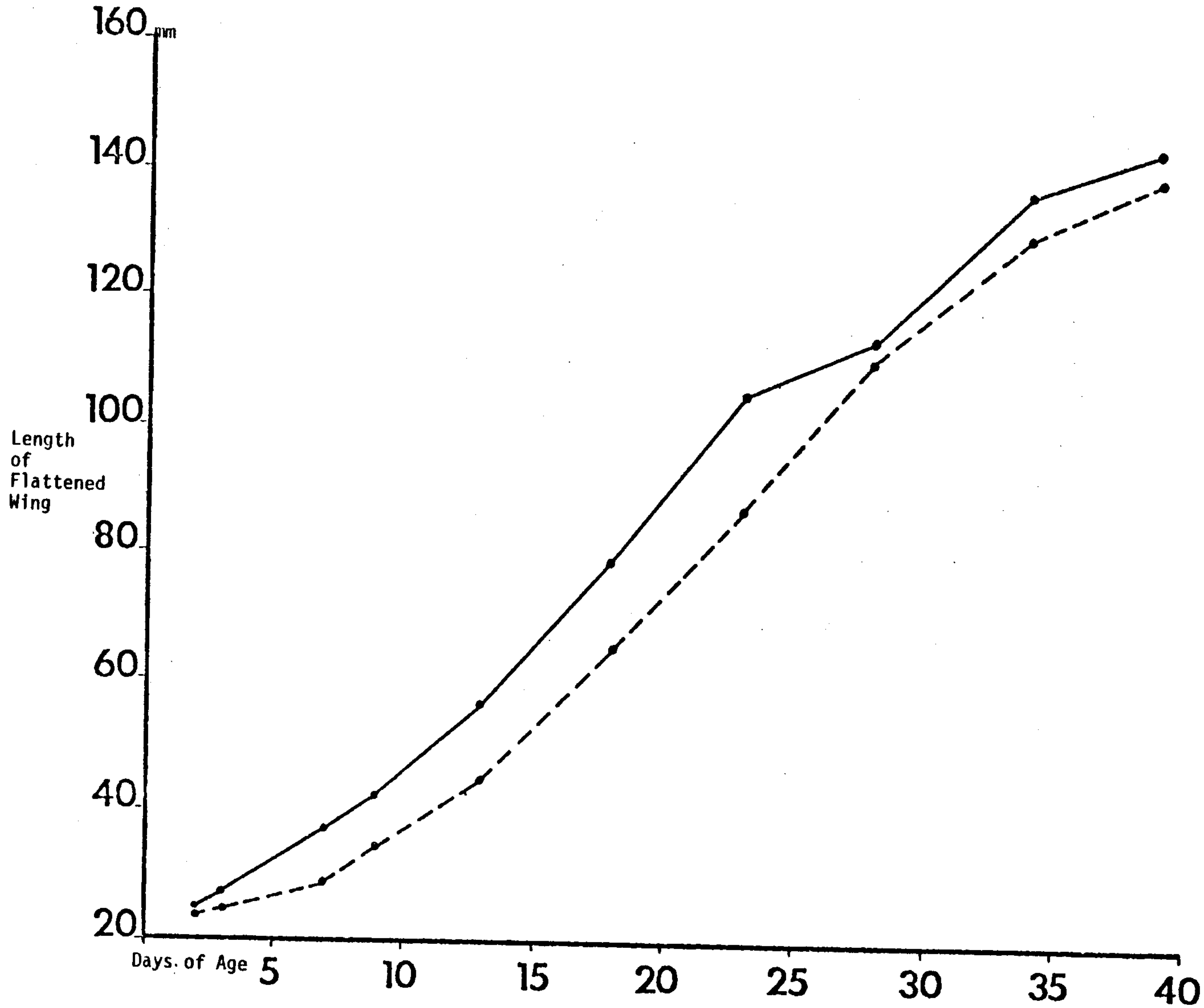

Figure 39. Growth of Tufted Puffin twins, Ugaiushak Island, 1977.

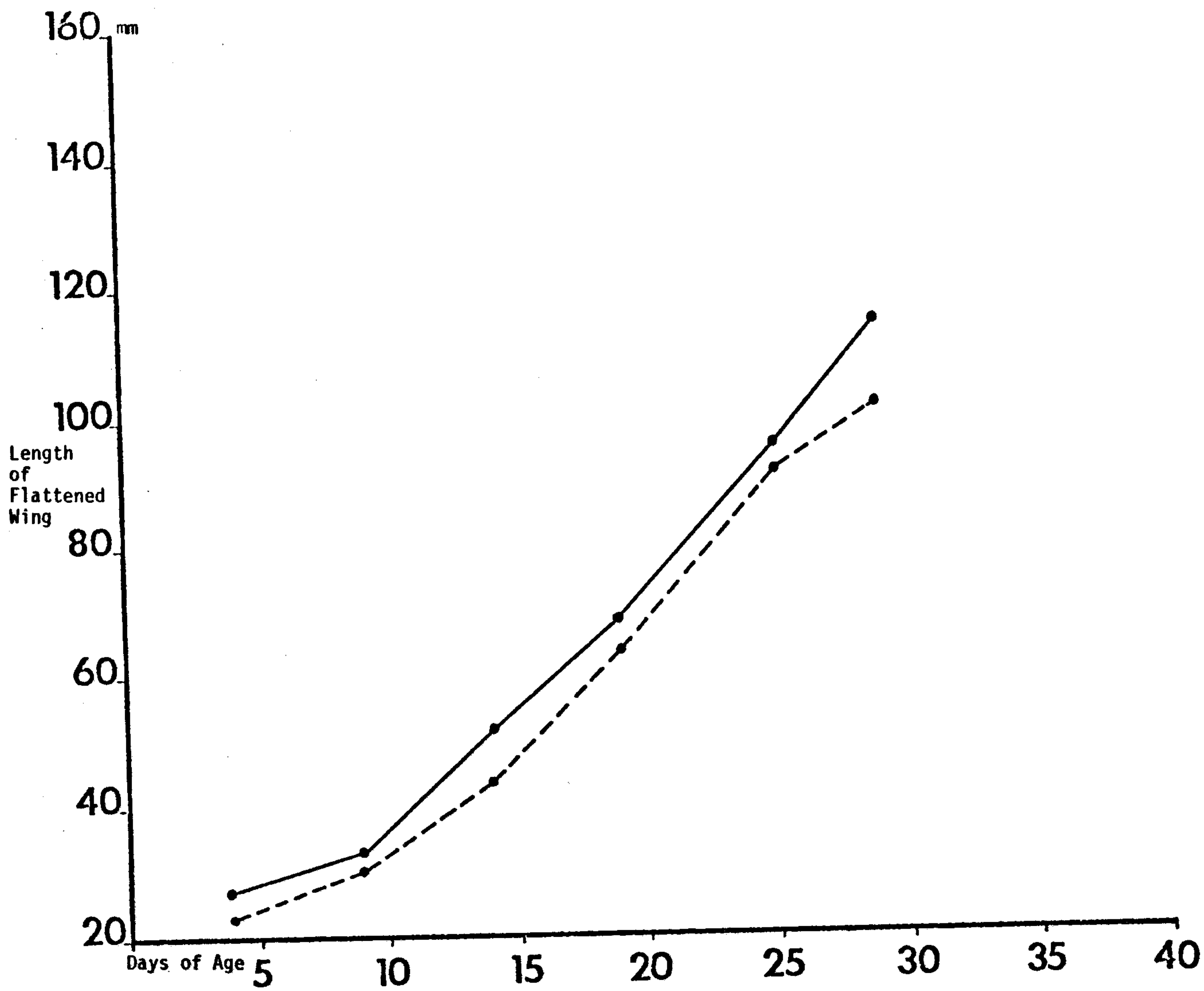

Figure 40. Growth of Tufted Puffin twins, Ugaiushak Island, 1977.

APPENDIX IV

NOAA-OCSEAP Contract: 01-5-022-2538
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ANNUAL REPORT

THE BREEDING BIOLOGY AND FEEDING ECOLOGY OF MARINE BIRDS IN THE SITKALIDAK STRAIT AREA, KODIAK ISLAND, 1977

By

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April 1, 1978

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I. INTRODUCTION

The purpose of our study at Sitkalidak Strait, Kodiak Island, Alaska was to collect information on the breeding biology and feeding ecology of five major species of birds: Black-legged Kittiwakes, Tufted Puffins, Arctic and Aleutian Terns, and Glaucous-winged Gulls. This information is necessary in order to assess the pre-drilling avian ecology at Sitkalidak. Areas of the Outer Continental Shelf nearby are soon to be drilled and until this study, there had been no ecological assessment of the avifauna in the area.

Specifically, the long-range goals of all the OBS field studies are to determine abundance and distribution of important species of seabirds in strategic areas and to try to determine natural variation in numbers of their populations; to monitor the phenology of these populations so that critical time periods in the breeding cycle can be fully assessed; to learn preferred or critical breeding habitat of these species in case the physical environment may somehow become altered; to learn the average productivity and normal mortality of these species, to be used as a baseline against which studies in future years may be compared; to find the average growth rates of the chicks in the pre-drilling time period as a partial indicator of the health of a population, to be used as baseline again for future comparison; and finally to discover the trophic relationships of these species so that in the OCSEAP integrated studies plan, their place in the ecosystem can be determined and these relationships can then be monitored throughout all oil and gas activity to see if they change. In addition, in our study, we wanted to see if any one factor in the Sitkalidak Strait area, especially nest-sites and food tended to be in short supply.

Except for the surface nesters (Glaucous-winged and Mew Gulls, Aleutian and Arctic Terns) which suffer heavily from egg-gathering activities by the local residents, the seabird species breeding in the Sitkalidak Strait region are at present relatively undisturbed by human activities. Offshore oil and gas development will bring more people, tanker traffic, and potential pollution such as human wastes and oil to this region. Therefore, the assessment of the pre-drilling avifauna ecology is essential.

II. METHODS

Distribution and Abundance:

The census techniques we used in the Sitkalidak area were basically those outlined by Nettleship (1976) with some variations according to our particular situation. We censused cliff nesters, such as Black-legged Kittiwakes and cormorants by counting each nest individually from a zodiac 30-50m from the colonies during the last part of the incubation period. We censused Tufted Puffins by estimating number of burrows from a zodiac and then ground-truthing this estimate. We censused gulls and terns also from a Zodiac by counting the number of birds on or above the colony and then comparing this number with our nest estimates extrapolated from transect counts.

The population estimates of birds that nested in small numbers in the area, such as Horned Puffins, Pigeon Guillemots, and Red-breasted Mergansers, were based on counts made at various times during the breeding season. These counts, in some cases, were then applied to the extent of the nesting habitat available, for an estimate of the size of the breeding population.

Nesting Habitat and Breeding Biology

We used the transect method to study the breeding biology and nest-site selection of all five species studied: Glaucous-winged Gulls, Tufted Puffins, Black-legged Kittiwakes, and Arctic and Aleutian Terns. Specific procedures and methods are outlined in each species section.

Feeding Ecology

The distribution of the birds on the water, their use of this habitat for feeding activities and the trophic relationships of these birds was more difficult to assess than was the nesting habitat. We undertook several approaches to acquire this information. Transects were run seaward from Cathedral Island aboard the Yankee Clipper, a vessel chartered by the USFWS for pelagic studies of seabirds in the Kodiak area. These were made on 22 June, 12 July, 11 and 12 September. Continuous observations were made of the movement of birds in and out of the strait from 1030 on 11 July to 1500 on 12 July from Lagoon Point (Figure 1). The location of feeding flocks, their composition, size, and time of occurrence were recorded whenever we encountered them. Likewise we collected three birds of each of the following species: Black-legged Kittiwakes, Tufted Puffins and terns of both species, every five days whenever possible, and subsequently analyzed their stomach contents. We also collected regurgitations of chicks opportunistically. As described later, we conducted continuous watches of selected nests of Arctic and Aleutian Terns, Black-legged Kittiwakes and Tufted Puffins in order to determine chick-feeding effort and nest-site attentiveness of the adults. From these observations, to be fully described later, we tried to determine a baseline of feeding rates of the chicks and correlate this with their growth and mortality.

TUFTED PUFFIN

Distribution and Abundance

Methods:

We estimated the number of Tufted Puffin burrows on Amee, Nut, Granite and Cathedral Islands on 16 July, which was during the initial stages of hatching. We feel confident that our estimates were good because on Amee and Cathedral Islands we had marked all the burrows in selected sample plots, of known numbers of burrows, with flags one meter high which could easily be distinguished from offshore. These gave us accurate visual indices of the burrow densities in the various habitats which we could use in censusing the entire colonies.

Because the daily cycles of attendance at the colony by Tufted Puffins severely limits a population estimate based on counts of adults at any given time (Wehle, 1976, Amaral, 1977), we did not rely on such counts for the estimates, but we did count the number of puffins in the air, on the colony and rafting offshore for both Amee and Cathedral Islands to correlate with our estimates based on burrow counts. On 19 July we censused Sheep Island using the same methods.

In order to ground-truth the offshore census, on 5 September we divided the habitat on Cathedral Island into three major categories based on density: type one with approximately 1 burrow/m^2, type two with .6 burrows/m^2, and type three with .08 burrows/m^2, and measured the extent of each habitat type on the colony. From this we obtained a more accurate estimate of the total number of burrows on the colony.

Results: Censusing

The estimate of burrow numbers based on visual assessment of the colonies from offshore was within 3.6% of the census based on the direct field census of Cathedral Island (Table 1). Of the 93 burrows in all the sample plots, 30.0% did not contain eggs. This percent varied from 18.8% on the Amee Island plot to 42.1% on Amee Rock. Using the mean percent for unoccupied burrows, the inner Sitkalidak Strait area supported 4,950 breeding pairs of Tufted Puffins in 1977 (excluding Table Island).

By far the greatest concentration of Tufted Puffins was on Cathedral Island which supported 85.3% of the total Sitkalidak Strait population (Figures 2 and 20). Here, as on the other colonies, the birds were nesting in a doughnut-shaped colony with the highest densities along the immediate edge and decreasing toward the island's center.

the inshore waters during late May so that by mid-June the densities of puffins in these waters far surpassed those in the shelf waters (Figure 16). This indicates a movement from the pelagic situation onto the colonies. We did not observe first arrival of the birds on the colonies. By the time we arrived they had already begun to lay eggs. When we first examined the burrows in the sample plots on 3 June, 23.1% had eggs, and by 12 June 90.4% of the burrows had eggs. The first chick hatched on 7 July, and by 24 July, 84.6% of the chicks had hatched. The peak of hatching occurred between 20-24 July when 43.6% of the chicks hatched (Figure 17). The last chick hatched on 8 August. The first chicks fledged between 22-26 August and by our last visit to the colonies on 6 September 86% of the chicks had fledged. By 11 September, most of the puffins had left the area (Table 3, Figures 9-15).

We observed slightly varying chronologies on different sample plots representing different types of habitat on Cathedral Island (Figure 18). The densest plot, plot 7, had 92.9% of its chicks hatched by 24 July while plot 5 had 60.0% hatched by this date and plot 4 only 50.0%.

Non-breeding birds began to come into the Sitkalidak Strait area after the first week of July, roughly coincident with the onset of hatching. At this time we observed increased activity on the colony (i.e., excavation of vacant burrows, large numbers of birds on the colony and rafting offshore) and began to collect birds with no brood patches and undeveloped gonads.

The departure of the puffins from Sitkalidak Strait coincided with the fledging of the young, which began around 25 August. By late August the puffins had almost completely left the bays and fjords, and by the later part of October they had vacated the waters of the shelf as well.

Nesting Habitat

Methods:

We set up seven transects on Cathedral Island, one on Amee Island, one on Amee Rock and two on Sheep Island in mid-June, 1977 (Figure 20). All plots began at the outer perimeter of each island and ran towards the island's center, terminating with the last burrow that we could find. In most cases, the plots included only those burrows within one meter on each side of the transect line, but in areas of light density, such as on Amee Island and Sheep Island, the plots were wider to include a reasonable sample size. We reached the nest chambers in all the burrows and made "windows" whenever necessary, which we plugged with clumps of dirt.

This island was more precipitous than the others and had extensive sod-covered slopes in which the puffins nested in high numbers. The altitude of the other islands was much lower and they had less slope. On these, the puffins nested only along the immediate perimeters.

Results: Distribution of birds away from the colonies

The movements of Black-legged Kittiwakes and Tufted Puffins in and out of Sitkalidak Strait on 11-12 July are summarized in Figures 3-8 and Table 2. The puffins were in late incubation, and thus were not engaged in feeding chicks at this time. The most striking feature of these movements is the continued exodus from the strait on both days by both species, with a very low rate of return. Unfortunately, the entire width of the strait was not in view (Figure 1) so birds could have been moving out of the strait along the southern shore and returning via the northern side. The weather during the transects was mild (Table 4).

Both the kittiwakes and puffins were moving out with coincident peaks and the outward movements were usually correlated with feeding flock activity, at least in the morning (Figures 7,8). From a preliminary analysis, feeding flock activity was correlated with the tides. We cannot determine whether or not birds are continuing seaward once the feeding flocks dissipate. There were no feeding flocks observed beyond the mouth of Sitkalidak Strait during the shipboard transect on 12 July, although they were abundant near the mouth of the strait and farther in (Figure 14).

The ship-based transect, run seaward from Cathedral Island on 22 June, shows that the puffins were concentrated within 2-3 miles of the island, near the mouth of McDonald Lagoon with the eastern mouth of Sitkalidak Strait being of secondary importance (Figures 9 and 13). On 12 July the numbers of puffins steadily increased from the mouth of the strait to Cathedral Island as did the numbers of feeding flocks (Figures 10 and 14). The transects were not run farther seaward than the mouth of the strait on either day, but general observations were that the puffins were much more abundant within the strait itself.

We suspect that the puffins were obtaining food for the chicks reasonably close to the colony because of the number of times per day the chicks were fed (up to 6 feedings per day). To be able to make so many daily food trips the adults would have to obtain this food close to the colony.

Phenology

Methods and Results:

The surveys of the bays and fjords in the Ugak Bay and Sitkalidak Strait regions of Kodiak Island showed that the puffins were moving into

At each nest site we measured the slope, nearest neighbor distance, distance from the edge, the height and percent cover of each species of vegetation at laying and at hatching, and the soil depth. We considered the depth of the soil to include the mouth of the burrow itself and the slope to be the original slope before the burrow was excavated.

Results:

The vegetative cover was considerably less on the densest puffin plot, but this is probably a result of the density, not the cause of it. Nettleship (1972) found the angle of the slope to be positively correlated with both the burrow density and higher productivity of Common Puffins in Newfoundland, and Amaral (1977) found the density of Tufted Puffin burrows to increase with the slope in the Barren Islands. A similar correlation was apparent with the Tufted Puffins at Sitkalidak. In addition to slope, soil depth was important, and it was often inversely correlated with the angle of the slope. We calculated a measure of what we call "effective depth", the horizontal distance available to the puffins for their burrows. This gave us the limit to the maximum burrow length. We used the following formula:

$$\text{Effective depth} = \frac{\text{soil depth (cm)}}{\text{tan slope (deg.)}}$$

We then grouped the effective depths observed into classes. The numbers of burrows in the different classes of effective depths (Table 8) varies considerably between the sample plots and it is interesting to note that the two plots that had the greatest number of burrows with effective depths greater than 150 cm (Cathedral Island plot 7 and Amee Rock plot) also had the highest productivity and the earliest hatching dates. It would seem then that the birds are selecting these sites first, possibly using the criteria of effective depth for this selection.

Reproductive Success

Methods:

We monitored 67 burrows on our disturbed transects every four days. We determined laying, hatching, and fledging dates as best possible. We also determined cause and time of chick and egg mortality. In addition, we monitored the growth rate of chicks.

Results and Discussion: Productivity and Mortality

The mean number of young fledged per nest with eggs for all plots was 0.537 (SD 0.171, range 0.286 - 0.750) (Tables 5, 6).

We also excavated 54 burrows in an undisturbed area on Cathedral Island which we did not go near till mid-August, and these had 0.742 fledglings per all nests (including those that never had eggs). Any differences in the productivity of these two areas might be because of our own disturbance with a subsequent nest abandonment. To test this, we analyzed the fledging success on a heavily disturbed plot versus the undisturbed plots and did not include the abandoned burrows from the disturbed plot in this analysis. The productivity of the heavily disturbed plot then becomes 0.786 fledglings per burrow, which is in close agreement with the undisturbed plots (Table 5).

Mortality at the egg stage accounted for 80.6% of the total mortality. Certainly some of this is directly related to our disturbance. Not including the abandoned eggs in this assessment, 76% of the total mortality occurred before the chicks hatched (Table 7).

The greatest mortality factor for eggs was their disappearing or rolling from the burrows. However, this mortality was not correlated with the effective depth of the burrow (Table 9).

We do not know why so many eggs were disappearing or rolling out from the burrows. There were a few cases where they had obviously been accidentally rolled out by a panicking bird, but more often an egg would be gone from or found below a burrow from which it would be difficult to roll out on its own. At times obvious recent digging did coincide with an egg's disappearance so perhaps adult puffins contributed to eggs rolling out. Of the 13 eggs that disappeared or rolled out, four (30.8%) of these did so after 15 July. Beginning with the first part of July some non-breeders were arriving in the area and there were signs of activity at burrows formerly vacant. It is plausible that these birds were at times entering burrows not well-defended, claiming them for their own, and digging out the egg during their renovation activities. A similar situation was recorded for two species of tropic birds by Stonehouse (1962), but the intruders here were adults with full reproductive capabilities, and not immature birds. Certainly before we can make any statements on this matter we need many more behavioral observations on the colonies themselves, especially during the period of influx by non-breeders.

Fifty percent of the chick mortality could be attributed to starvation. Starvation was closely linked with hatching time, for of the three chicks that starved, two hatched after the first week of August, which is well after the modal hatching period.

The highest productivity was in plot 7 of the Cathedral Island colony. Of the plots on Cathedral Island, this plot also had the greatest density and the earliest hatching. This plot may be preferred for some reason by the puffins because it is the first selected (based on the earlier hatching) and the most heavily used.

Feeding Ecology

Methods:

We collected 44 Tufted Puffins between 8 June and 4 September, 1977 (Figure 28). Immediately following collection, we poured 100% formalin down the esophagus of the birds. Within an hour of collection we removed the upper digestive tract of the birds and placed them in labeled plastic bags with a 10% formalin solution. We identified the food contents in the laboratory after we returned from the field camp in September.

Obtaining samples of chick food proved a problem. Other workers (Wehle, 1976, Amaral, 1977) have collected bill loads from incoming adults by capturing them in mist nets. While this method has the advantage of obtaining data on the specific delivery times and the amount and species in each delivery, it does not provide information on the total amount of food brought daily to a particular chick and it often causes nest abandonment. Mainly because of this latter problem, we chose not to use this method in the Sitkalidak study.

To procure data on the amount of food brought daily to burrows containing chicks of known age, we taped the chick's bill shut with masking and filament tape (Figure 19) so they could not eat any food brought in by the adults. The chicks were still able to move around freely.

Because the feeding activity was heaviest in the morning and evening, we found the best procedure was to tape the chicks at noon on one day and return the following noon to collect what food was left in the burrow during the interval. At this time, we untaped the chicks and fed them canned tuna to compensate for the fish we took. Because a considerable variation in individual feeding rates was evident, in some cases we re-taped the chicks for an additional 24 hours to see if the feeding patterns were consistent from day to day. In all, 30 chicks were taped for 24 hours and 12 were taped for 48 hours.

Results and Discussion:

Capelin (Mallotus villosus) was by far the most important prey species for the Tufted Puffins at Sitkalidak Strait during the 1977 breeding season (Tables 10-12). It occurred in 77.8% of the samples, provided 79.5% of the total numbers of food items taken, accounted for 58.5% of the total weight of food brought back for the chicks and made up 97.9% of the stomach content weight of the adults. Sand Lance (Ammodytes hexapterus) was second in importance, accounting for 12.6% of the total numbers of food items taken. It was of more importance as chick food and made up 23.0% of the total weight of their diet, while it only accounted for 2.1% of the total weight consumed by the adults.

The diets of the adults and the chicks were similar although some prey species, such as Pacific Sandfish (Tricodon tricodon) and Sockeye Salmon smolt (Oncorhynchus nerka), were found only in the diet of the chicks, while others, such as polychaetes and shrimp, were eaten only by the adults. The size of the prey items probably is important in this difference. The Pacific Sandfish and the Sockeye Salmon smolt were slightly larger than the other fish species taken and therefore more economical as chick food rather than as adult food.

The lengths of the Capelin taken by the puffins increased with the season (Figure 29). In June 84% of the Capelin in the stomachs were between 60-80mm long but in August only 22% were of this length. The chicks were eating Capelin predominately in the 80-100mm size class in August, and 55% of the Sand Lance brought in for the chicks at this time had a range of 90-100mm.

Based on percent frequency of occurrence, the availability of Capelin to the Tufted Puffins changed little as the season progressed although it appeared to decline slightly beginning in mid-August (Table 12). In August, other fish were taken by the adults, but only occasionally, and earlier in the season only invertebrates were taken along with Capelin. The data on chick food only adequately cover the latter part of August and early part of September, but they show that Capelin were consistently fed to the chicks throughout that period but became less important in terms of food mass provided as the other species, such as Pacific Sandfish and Walleye Pollock, became more important as the summer progressed (Figures 30 and 31). The loads that were exclusively Capelin became fewer while those exclusively Sand Lance increased, suggesting a possible increase in the availability of the latter species (Table 14).

Chick Feeding:

There was much variability in the frequency with which the adults brought in food for their chicks (Tables 15, 16, and 17). For the 30 chicks that did not lose their tape during the day, the weight of food brought in by the adults ranged from 0-113.5g. An average of 21.4% of the chicks were not fed in a 24-hour period. The mean daily load per chick was 28.0g (SD 31.7). For the 12 chicks that were monitored for two consecutive days, the total weight of food brought in by the adults for both days ranged from 0-180.5g. In this 48-hour period, only 8.3% of the chicks were not fed. The mean load for two consecutive days was 62.2g per chick per 48 hours (SD 55.6). The mean weight of food per feeding was 19.3g (n=10; SD=6.3) and the loads ranged from 13.5-35.0g. From this we estimated that each adult makes an average of 0.65 feeding trips per day, based on the entire population of chicks from 19-40 days of age. Age of the chick dictated how much it received. Chicks 19-30 days old received a mean of 28.9g per day (SD 37.8; range 0-113.5g; n=15) while chicks 31-40 days old received a daily mean of 15.9g (SD=12.1; range 0-39.5g; n=13). This difference is significant (P=.048). We do not know if the puffins reduce the number of feeding trips as the chicks approach fledging or if the amount of food brought in each trip becomes less, because we did not monitor the nests that well.

We monitored the daily weight change of two puffin chicks of about the same age for eight consecutive days. One chick went through three days during which it received no food, followed by a day in which it gained 91 grams (23.6% of its body weight Table 18). The other chick was not fed for two days during the eight-day period, but these two days were not consecutive. Wehle (pers. comm.) found that a captive Tufted Puffin chick would alternately gorge itself one day and refuse fish the next, suggesting that the chicks are adapted to irregular feeding patterns.

The food supply for the Tufted Puffins in Sitkalidak Strait seemed to be consistent in 1977 because almost all of the 41 chicks monitored had steady growth rates (Figures 21-27). However, 50% of the chicks that hatched after 25 July (n=6) died of starvation, suggesting a possible decline in food resources at the end of the breeding season.

The ability of the puffins to obtain enough food for their chicks did not seem to be affected by storms. The last part of July and much of August was plagued by severe storms, but when these storms are compared with the growth curves of puffin chicks (Figure 32) there seems to be no correlation. Perhaps this is because the chicks are adapted to sporadic feedings.

During the last third of August, most of the feeding of the puffin chicks took place in the early morning, with a second surge of feeding activity beginning in the evening and continuing until dark. On 22-23 August, 66.7% of the food samples were left in the burrows between 0700-1300 (Table 15). On 23 August counts were made throughout the day of Tufted Puffins returning to the colony with bill loads, and the results show a peak of activity between 0700-0800, with a lesser peak beginning at 1800 (Table 19). Very few birds were seen bringing food to the colony between 0900-1800.

BLACK-LEGGED KITTIWAKE

Distribution and Abundance

Methods: We censused the Black-legged Kittiwake population at Sitkalidak Strait on 3 July by counting all nests on the Cathedral and Nut Island and Amee Rock colonies. We defined "nest" as a structure with sufficient nesting material to retain eggs. None of the chicks had hatched at this time, and in our sample plots, all clutches had been completed. We took Polaroid photographs of the entire shoreline of Cathedral Island and outlined each sub-section of the island directly onto the photographs. The other large colony was at Ghost Rocks (Figure 33) which we did not census until 15 August, so the nest count from this census may be lower than the actual number of nests originally built. We made sketch maps of the Ghost Rocks colony, indicating the location of the nests on each. All photographs, maps, and data sheets are filed with the OBS Colony Catalog and are not included in this report.

At-Sea distribution. The movements of the Black-legged Kittiwakes in and out of Sitkalidak Strait are discussed in the section on Tufted Puffins and the data indicate that the birds are concentrating their feeding efforts within Sitkalidak Strait (Figures 34-37).

Results: There were 2380 pairs of Black-legged Kittiwakes breeding in inner Sitkalidak Strait in 1977. Most of this population (86.4%) was on Cathedral Island with three much smaller colonies on Nut Island and Amee and Ghost Rocks (Figure 33). Of the birds nesting on Cathedral Island, 63% (or 54.7% of the total inner Sitkalidak population) were concentrated on three rocks just off the island's eastern tip, while 19% were on two islets off its western end. Only 18% of the Cathedral Island population was on the main island.

Phenology

Results and discussion: The Black-legged Kittiwakes began moving into the bays and fjords in late May so that by late June their numbers there were at a peak. Birds were on the colonies when we arrived on 28 May and by 3 June nest construction was well underway. By 13 June the first egg was laid, and the peak of egg-laying occurred between 15-19 June during which time 55.3% of the nests in the sample plots on Cathedral Island contained eggs (Figure 39). The last clutch was initiated on 1 July. Second clutches were undertaken by approximately 10% of the birds and these were laid between 3-9 July.

The breeding chronology varied between sample plots. The plot on Lesser Kittiwake Rock, a rock just offshore from Cathedral Island had nests with eggs before any of the other plots did. By 14 June, 33.3% of the birds had begun to lay in this plot and by 19 June, 83% of their clutches had been started. On the other plots, none of the birds had begun clutches by 14 June and by 19 June only 54.8% had started laying (range 47.4%-63.6%).

The first chick in the Sitkalidak Strait area hatched on 9 July and the last chick, a relay, hatched on 9 August (Figure 40). The first chick fledged on 13 August and most of the chicks had fledged when we last visited the colony on 9 September. Although most of the chicks had fledged in early September, some adults were still at the nest sites and were participating in behavior such as billing that looked like pre-laying behavior.

Black-legged Kittiwake adults remained in high densities in the Sitkalidak Strait region throughout the breeding season, but by the end of October they had almost completely vacated these areas (Table 20, Figure 38). Fledgings began rafting up in single age-class groups by late August, and tended to remain in these groups. A few kittiwakes of all age classes probably remain in the Kodiak area throughout the winter.

Coulson and White (1959) found that age and experience of the adults only partially accounted for the time of breeding of Black-legged Kittiwakes in Great Britain. More important, they felt, was the density within a 5-foot radius of the nest, and those birds with the highest density of neighbors laid their eggs earlier. This density was usually determined by rock structure and the dates of breeding correlated with ranges in nesting densities rather than ranges in age of the breeding adults. Although we had no way of determining the ages of the breeding birds in this study, the birds in the plots with the higher mean nesting density (plots LKWR 1 and CI 2, Table 21) had earlier mean clutch initiation dates than those with lower mean nesting densities.

On 22 June we visited the Boulder Bay kittiwake colony, a large colony of ca. 50,000 pairs nesting densely on the cliff faces. Although the visit was hurried, we made quick egg counts in various sections of the colony and found 49 (43.4%) of the nests empty, 39 (34.5%) with one egg, and 25 (22.1%) with two eggs. Several pairs of birds were copulating and many were carrying nest material. One adult and two immature Bald Eagles were seen at the colony when we arrived, and there was some sign of predation on the eggs. More work must be done with this colony in future field seasons to compare the productivity and phenology of large colonies with smaller ones such as those of Sitkalidak Strait.

Habitat Selection

Methods: We set up four plots on the Cathedral Island colony. Three of these were in small sub-colonies on the main island and one was in a large sub-colony on an offshore rock (Figure 41). Two of the plots on the main island (1 and 2) included every nest in the sub-colony. In the third plot the nests were more-scattered and we used a sharp bend in the cliff as the plot boundary, although nests continued beyond it. To define the offshore rock plot we also used natural topographic barriers. During the breeding season with the aid of a rope and an upper belay we were able to reach every nest in the plots on the main island This was not possible with the offshore rock plot without excessive disturbance to the nests, so here we made a detailed map showing the location of each nest and obtained chronology and productivity data by viewing the nests from above. However after the chicks had fledged we reached all these nests using an upper belay in order to determine habitat selection. We obtained growth measurements on a few chicks that we could reach near the top of the colony. To determine habitat selection we measured the height above water, distance from the top of the cliff ("top" being defined as any slope less than 45°), horizontal distance to water, nearest neighbor distance, amount of overhang above the nest, the ledge width, and the size of any ledges adjacent to the nest. We then attempted to correlate these independent variables with the hatching and fledging success of each nest by using a multiple regression analysis.

Results: We did not analyze differences in habitat selection between plots. These will be included in the 1978 report. However, we did determine correlations between habitat and reproductive success, and these will be discussed in that section.

Reproductive Success

Methods:

We checked all kittiwake plots every four days (136 nests) noting dates of laying, hatching, and fledging, as well as hatching and fledging success. In addition, we monitored growth of the chicks on all of the main Cathedral Island plots and on reachable nests on the Lesser Kittiwake Rock plot. We also noted causes and dates of mortality of chicks and eggs.

Results and Discussion:

The mean clutch size for Black-legged Kittiwakes was 1.66 (Table 28). Two of the plots (CI 1 and 3) suffered heavy predation. The mean clutch size without these plots was 1.79, which is close to that recorded by other workers, e.g. 1.85 (Maunder and Threlfall, 1972), 1.84 (Swartz, 1966), 2.05 (Coulson and White, 1958), 1.96 (Belopol'skii, 1961), 1.94

(Cullen, 1957). In these plots (CI 2 and LKWR 1), the frequency distribution was 20% with one egg, 79% with two, and 1% with three, which is similar to that found by other workers, e.g. 16% (1), 82% (2), and 2% (3) in Newfoundland (Maunder and Threlfall, 1972).

Of the 114 nests with eggs in all the sample plots, 36 (31.6%) hatched one chick, 48 (42.1%) hatched two chicks, and 30 (26.3%) hatched none. Of the nests with chicks, 51 (60.7%) fledged one, 26 (31.0%) fledged two, and 7 (8.3%) fledged none. The mean number of young fledged per nest with eggs was .849.

Of the 191 eggs laid, 59 (30.9%) failed to hatch. Nearly half of this loss was due to predation, presumably by Bald Eagles. The remaining eggs lost were equally accounted for by exposure to storms, disappearing or being infertile (Table 29).

Thirty-one (23.5%) of the chicks failed to fledge. The greatest cause of chick mortality was exposure to storms, which accounted for 48.4% of the chick mortality. The second greatest cause was their disappearing which accounted for 32.2% of the chick mortality. Most of this mortality occurred in nests with two chicks. This may be due to the difficulty that brooding adults may have in protecting more than a single chick from severe storms and the possibility of chicks' falling out of overcrowded nests.

Bald Eagles were often seen at the Cathedral Island colony during June either flying over the colony or roosting on offshore rocks near the island's eastern end. They are probably responsible for the heavy predation which occurred between 18-25 June on plots 1 and 3 of the main island. On 25 June all but one of the eight nests with eggs in plot 3 were empty and all of the 6 nests with eggs by 19 June were empty in plot 1. This predation continued until 25 June, after which time eagles were not seen in the vicinity of Cathedral Island. It is likely that their feeding efforts were then directed to the salmon that were beginning to spawn. Of the 13 nests that lost their full clutches to predation, 9 relaid, and of these, 7 (77.8%) fledged chicks. The other two plots (Cathedral Island 2 and Lesser Kittiwake Rock 1) were little affected by such predation. What predation did occur on the Lesser Kittiwake Rock plot was that by Glaucous-winged Gulls which were nesting in very close proximity to these kittiwakes.

While the egg mortality was highest in plots 1 and 3 on Cathedral Island, the chick mortality was greater in plot 2 on Cathedral Island and the Lesser Kittiwake Rock plot. Both of these plots had their chicks hatching earlier than the other two plots (Figure 40) and by 25 July almost all of the chicks in these plots had hatched while only

33.3% of the chicks in plot 1 and 50.0% of the chicks in plot 3 had hatched by that date. Beginning on 21 July the weather began to deteriorate, and on 27 July 6.85 inches of rain fell in 24 hours. Much of the kittiwake chick mortality was caused by this storm. Lesser Kittiwake Rock was particularly vulnerable because these nests were on an exposed east-facing cliff with little protection from the prevailing winds. Also, the chicks in this plot were older than those in the other plots at this time and less able to get full protection from the adult, especially in 2-chick nests. Gordon (1928) found two weeks of continuous bad weather when the chicks were young to completely eliminate chicks in a kittiwake colony in Scotland. But most other workers have found that during seasons of less severe weather, deaths by falling are the main cause of chick mortality (Coulson and White, 1958, Maunder and Threlfall, 1972, Swartz, 1966).

The results of the multiple regression analysis (Tables 22-26) are reviewed by each plot as follows:

Cathedral Is. 01: The densest part of this plot was in the area with the least slope. This was midway between the top of the cliff and the water. Eggs were laid earlier in the steeper part of the plot near the top, yet these nests hatched fewer chicks. Avian predation accounts for the lower hatching success of these nests with earlier laying dates.

Cathedral Is. 02: The densest part of this plot was near the bottom, and was not correlated with slope. Birds on nests with less slope laid earlier, hatched more young, and had larger clutches. This plot did not suffer from avian predation.

Cathedral Is. 03: The densest part of this plot was in the area with the greatest slope. The eggs here were laid earlier, and the clutch size was larger. In spite of heavy predation, the adults in these nests also hatched more chicks and fledged more young. Predation was heaviest on the scattered nests on wide ledges.

Lesser Kittiwake Rock 01: Nests in this plot were denser nearer the top than the bottom. Birds on nests with greater slope laid more eggs, hatched more chicks, and fledged more young. However, eggs were not laid earlier in nests with greater slope.

The multiple regression analysis (Table 22) does not show any strong correlation between the week laid and any of the independent habitat variables measured. Cathedral Island plots 1 and 3 suffered heavy predation and had many re-lays which greatly complicates the interpretation of the results. For this reason, these two plots are not considered in this analysis. Ledge width is inversely correlated with the week of egg-laying in both CI plot 2 and LKWR plot 1, but this is likely a result of its positive correlation with nearest neighbor distance (Table 22). The number of eggs per clutch increased slightly in those nests whose clutches were initiated later in one plot (LKWR1) (Table 24).

No single component of the nesting environment was correlated with productivity in all of the plots. The slope was positively correlated with productivity in both the Lesser Kittiwake Rock plot and Cathedral Island plot 3, but it was negatively correlated with productivity in Cathedral Island plots 1 and 2.

Productivity is apparently influenced by the interactions of the entire matrix of environmental parameters at each nest site, and the range of these interactions is determined by the variance of each parameter within a given plot.

Feeding Ecology

Methods:

Food samples. We collected 33 Black-legged Kittiwakes between 8 June and 4 September, 1977. We removed their upper digestive tracts and subsequently placed them in a labeled plastic bag with 10% formalin. We obtained regurgitations easily from the chicks at all stages of their development and we collected, weighed, and fixed these in 10% formalin for later identification in the laboratory. Usually we collected regurgitations during our routine monitoring of the sample plots, but occasionally we made specific trips for such collections. Chicks from which we obtained regurgitations were fed tuna in compensation. We collected 150 regurgitations between 10 July and 9 September.

Foodwatches. On 11 August from a rock 50m from the colony we watched the activities of six marked kittiwake nests on Lesser Kittiwake Rock from 0600-1500. We recorded the time of the arrivals and departures of each adult and the times chicks were fed in order to determine nest attentiveness and feeding rates. At 3-hour intervals we weighed the chicks and collected regurgitations to correlate weight change with observed feedings. This procedure had to be suspended after 1500 because of bad weather.

On 22 and 23 August between 0630-2100 we watched the activities of seven kittiwake nests on a rock off Cathedral Island from a vantage point 40 m away. We recorded the same information as on 11 August, but the chicks were only weighed three times during each day.

Results: Capelin (Mallotus villosus) was the most important component of the kittiwakes diet at Sitkalidak Strait during the 1977 breeding season (Tables 30, 31 and 32). It occurred in 60.0% of the food samples provided 43.7% of the total numbers of food items taken and 55.2% of the weight taken by adults. Sand Lance (Ammodytes hexapterus) approached Capelin in importance, occurring in 43.1% of the samples and accounting for 37.9% of the total numbers taken. It played a much more significant role as chick food than it did as adult food for it only made up 3.7% of the total numbers taken by the adults yet accounted for 43.6% of the numbers of prey items eaten by the chicks. Part of this difference between chick and adult food may be because the adult sample covers 1 June-11 September while the chick sample only covers 10 July - 8 September and this may be biased towards a period when Ammodytes was most abundant.

There seemed to be a change in the ratio of Sand Lance to Capelin in the kittiwake diet as the summer progressed (Figure 42). The frequency with which Capelin appeared in the regurgitations steadily decreased in August while that of Sand Lance increased. Not only did the consumption of Sand Lance increase during August but other food items, such as Walleye Pollock and the eggs and milt of Sockeye Salmon (which were scavenged at the spawning streams) also began to increase in frequency in the diet of the kittiwakes at this time. Further, the frequency of mixed-prey species regurgitations steadily increased in August (Table 13) suggesting that food may have begun to be more difficult to obtain with the decrease in Mallotus villosus. Such a change in the types of prey items may reflect an alteration in the availability of certain prey species.

A very similar feeding situation apparently occurred in Newfoundland where Maunder and Threlfall (1972) found Capelin also to be the most important food source for kittiwakes with Sand Lance and offal from a fish-meal plant taking on greater importance toward the end of the breeding season.

The marked surge of Pandalopsis dispar at Sitkalidak in September coincided with shrimp fishery activity in the waters within 1-10 km of the colony, and the birds would obtain this prey by following the fishing boats.

The lengths of the Capelin taken generally increased as the season progressed (Figure 43). In June, 58% of the Capelin were between 70-90 mm long, but by August only 21% were of this length. The lengths of the Sand Lance taken approximated those of the Capelin.

Chick feeding. The following observations support the hypothesis that the food supply was not limiting the productivity of the Black-legged Kittiwakes nesting in the Sitkalidak Strait area during 1977: First, there were no observations of a chick's starving to death because of the inability of the parents to secure enough food. There were two cases where one of the chicks of a two-chick brood starved to death but both of these were out of the nest itself and unable to reach the adults bringing in food to the nest. Second, food was sufficiently abundant to support a breeding population not in tight synchrony because there was little difference in the growth rates of chicks hatching over a 32-day period (7 July - 9 August) (Figure 44). And finally, chicks reared with another chick did not have growth rates below those reared singly (Figures 45 and 46).

Based on the results from the three all-day watches of selected kittiwake nests (Tables 33 and 34), the adults brought food to single-chick nests an average of 2.3 times a day (SD 1.1, range 1-4), while they brought food to nests with two chicks an average of 3.8 times daily (SD .46, range 3-4). This difference is statistically significant ($P < .05$). One of the chicks (chick #21 of the 11 August watch) was considerably younger than all the other chicks, and so was not considered in the analysis because of the possibility of its age influencing the number of times it was fed.

The amount of food brought to each chick was estimated by the weight gain of a chick during a three-hour interval in which it was observed. Chicks from single-brood nests received a mean of 11.3 g (SD 6.1), while each individual in nests with two chicks received a mean of 15.0 g (SD 7.3). This difference is not significant ($P > .05$).

These results demonstrate that the adults do not respond to an increased brood size by bringing in more food each time but rather by making more frequent trips. We found that the adults usually respond to the chick that is more aggressive in its pecking, and that such behavior probably is caused by greater hunger. The feeding pattern for all three of the broods in the two-chick nests observed on 22-23 August was for one chick to receive more food the first day while the other chick received more the following day.

In addition to a variation in feeding patterns caused by the number of chicks in the nest and possibly by their age, it appears that there is individual variation in the ability of a breeding pair to supply the young with food as well. On 11 August one chick (#19) was fed only once and suffered a loss of 9 g between 0600-1500 while all the other chicks gained weight during the same period. Examining the growth rates of these chicks (Figures 45 and 46) shows that this pattern probably occurred consistently throughout the nestling period of this chick. This situation may be a reflection of an adult's inexperience (Coulson and White, 1958).

GLAUCOUS-WINGED GULLS

Introduction

Glaucous-winged Gulls are probably the most ubiquitous species in Sitkalidak Strait but they are nowhere abundant. In some places they were truly colonial and in others they were solitary nesters.

Glaucous-winged Gulls are considered a trash bird by the local people and they are often shot for crab bait or for target practice and their nests are often egged. Despite this disturbance, the gull population seems to have a healthy replacement rate when 1976 and 1977 figures are compared (Table 47). In some areas with islands more accessible to humans, nests are egged numerous times, so that all relayings are unsuccessful. In general, a greater number of gulls attempt to nest than actually are successful so that the nesting density decreases markedly as the season progresses. Likewise, there is an ever-increasing population of non-breeding gulls. This population reaches a peak in mid August when the adult non-breeders are joined by the first, second, and third year immatures which have been residing outside the Inner Sitkalidak Strait area during the earlier summer months.

The main obstacle in studying Glaucous-winged Gulls was human interference. The eggs of the gulls were gathered by natives from early June through July. The islands nearest the native village of Old Harbor were egged the most intensely even though the gull populations there were not as large as on the far islands. The islands were also used intensively for recreation. All easily accessible areas in the Sitkalidak Strait area were visited at least once by eggers.

Methods

One of our goals in this study was to compare nesting success of truly colonial type Glaucous-winged Gulls and the more solitary or scattered nesters to see if human disturbance influenced them. Likewise we wanted to see if there were any differences in habitat selection betwee these populations. We also wanted to discover the prey lengths and types taken by the gulls in order to try to determine the gull's position in the food web.

The truly colonial areas of the Glaucous-winged Gulls at Sitkalidak Strait were all inaccesssible to humans; one was on a sea stack (Amee Rock) which we could only reach by climbing ropes; the other was on a precipitous wave-beaten sea rock (Lesser Kittiwake Rock) (Figure 49). The solitary nesting areas were all on easily accessible islands: Cathedral, Amee, and Sheep. The latter two islands were 5 and 2 1/2 km from the native village of Old Harbor while Cathedral was 8 1/2 km from it. We chose two plots of 22 nests each on the two colonial areas. which composed the entire two colonies from cliff edge to cliff edge, and we established seven transects on Cathedral Island for the solitary nesting areas (N=45 nests). We followed the fate of fourteeen nests on the two islands nearest the village, but since the gull nests on these islands were heavily egged, the breeding and productivity data were rather inconclusive.

Since egging was such a large cause of egg mortality in Glaucous-winged Gulls, we decided to set up accessible and less accessible transects among the solitary nesters to see if accessibility influenced this type of nester also. We chose three pairs of transects that had one horizontal and one vertical transect within each pair. We also chose one very steep vertical transect for comparison. Our reasoning was that the horizontal transects had easier access and would have a greater chance of being egged, while the vertical transects were on steep slopes reaching to the cliff edge and were not conducive to egging searches by natives.

Each of the solitary transects started at the cliff edge and continued inland steeply away from the cliff. The horizontal plots formed a "T" with the vertical plots.

Habitat Parameters

When the nests were first constructed, we measured the distance along the transect and the distance from the midline of the transect for each nest in our study areas. At time of laying we measured the height and cover of the various species of plants within a 50 cm radius around the nest, we measured the slope of the nest, the distance to the nearest neighbor, and distance to the edge of the cliff. For nests without eggs, we measured these parameters at peak laying of the birds on the plot. At first hatching, we again measured the height and cover of the vegetation within a 50 cm radius of each nest. We visited each plot on the average of once every four days. We later will attempt to correlate habitat parameters and nesting success.

Chronology and Reproductive Success

We kept a log of the choronology for each nest, noting when it was first constructed, when the eggs were laid, when the chicks were hatched and if possible, when the chicks fledged. We also noted when chicks or eggs disappeared or died and the causes of this mortality. We noted number of nests started, number of eggs laid, number of chicks hatched and fledged. During the chick stage we measured the culmens, tarsi, wings and weight of the chicks at each visit to determine growth rates.

Feeding Ecology

We collected regurgitations opportunistically from the chicks on our transects. The chicks would often regurgitate whenever we picked them up, so the prey items were easily obtained in this way. We placed the regurgitations in a labeled plastic bag and added 10% formalin within four hours after the collection. We performed all the above measurements and collections for all nests, eggs and chicks on the transects and also on the plotless nests on Amee and Sheep Islands.

Phenology

We did not arrive in time to observe the setting up of the Glaucous-winged Gull nesting areas so we do not know the preferred nesting sites. However, we did arrive before most of the gulls had begun to lay. The earlest clutches were laid at the colonial sites, and extrapolating back from hatching dates, we found that the first eggs laid there were on 15 May. On 30 May we found the first scrapes of Glaucous-winged Gulls along the crests of the hills on Cathedral Island and especially on the steep mixed-meadow slopes. Outside our transects we found a nest with one egg on this date. A few immature (first through third year) gulls were present at this time.

On 3 June, in the Cathedral Island colonies, copulation was still occurring and the gulls were becoming much more nest-site tenacious. The adult gulls nesting on the accessible islands, Amee, Cathedral, and Sheep, were not as nest-site tenacious as were the ones nesting on the sea stacks and sea rocks. The approach-flight distance for those on the main islands was 50 meters while the distance for the gulls on the sea stacks was 10 meters. Perhaps gulls that are not so site-tenacious are in less preferred nesting habitat. If this is true, it may correlate with better nesters choosing preferred sites with inferior (less nest-site tenacious) nesters choosing marginal habitat.

On 6 June on our transects we found the first nests with eggs on the near-town islands: Amee and Sheep ($\bar{x}$ =2.5 and $\bar{x}$ = 1.0 eggs/nest respectively). By 9 June, both the nests on Amee had been egged but the one on Sheep was still undisturbed. We met or saw natives on the islands at almost every visit through the month of June. They collected both Mew and Glaucous-winged Gull and also tern eggs.

The eggs of the solitary nesters both on the horizontal and vertical plots were first laid on 12 June. Eggs that were laid earliest on the horizontal plots were taken by natives so that if a clutch were started later in the season it had a greater chance of surviving. The steep vertical plots remained untouched by the eggers. The sea rocks and stacks also remained untouched by the eggers.

By the tenth to twelfth of June, egg laying by the gulls was well underway on all islands. On Cathedral, there was still a lot of egging by natives, and this activity was most evident in the compartative horizontal plots.

Because of storms, we could not climb Amee Rock for a week and a half, and when we finally did have access to it on 28 June, we found that chicks had hatched in the ten days we had been absent, and that three of these chicks were older than a week and weighed over 300 grams, which means they hatched about 17 June (Figure 51). The nests at Cathedral Island followed those on Amee Rock, and we saw the first starring of eggs on 2 July. On 9 July, chicks were hatching on the vertical plots. Due to egging, only the eggs on the vertical solitary plots hatched early in July (9th). The first eggs to hatch on the horizontal plots did so on 21 July, two weeks after those on the vertical plots. The majority of chicks on the vertical plots had hatched by 18 July and on the horizontal plots by 25 July. On the other three islands, Cub, Amee, and Sheep, no chicks had yet hatched. By the third week in June, the only nest remaining active in our study plot on Sheep Island was one hidden under a 70 cm <u>Heracleum</u> plant. All the others--Mew and Glaucous-winged--had been egged (Table 35).

Mid-July was a peak for hatching of chicks for all colonies (Figures 50-53-58). On 14 July we found two large chicks (830g and 610 g: 19-22 days old) on Cormorant Head (Figure 49), a colony that we did not study but which was also rather inaccessible, and was advanced chronologically. These weights compare with a 93 gram average on Cathedral Island, a 210 gram average on Lesser Kittiwake Rock, and an extrapolated 460 gram average on Amee Rock on this date.

On 20 July we saw the first fledglings, and by 5 August on Amee Rock we saw fledglings still being fed at the nesting area. At Lesser Kittiwake Rock on the same date, a near- fledging chick slid off the cliff into the water and an adult, presumably the parent, flew down immediately and sat next to it in the water. The adults seem more attached to their chicks at fledging time than do birds of other species. However, once the chicks had been flying for a few days, the adults no longer fed them even though the chicks would food-beg and often would fly after the adults.

One of the disadvantages to the gull chicks of the nest sites on the sea stacks or cliff edges of the islands was the height of these stacks or cliffs. We found three chicks near fledging ($\bar{x}$ wing=22.3 cm) that had died from falling. Likewise, some chicks fledged before they were strong fliers and were not able to get back up on the colony. We did not learn the fate of these chicks.

In the first week of September, the fledglings began to raft up in large numbers. We observed flocks of only fledglings flying in the straits and this grouping by age class was also true of Black-legged Kittiwakes. When we departed the Sitkalidak Strait area on 14 September, there were still many gulls, both adults and immatures of all age classes in the area.

Nesting Habitat

Results

Solitary-type Colonies. The nesting sites the gulls chose varied widely within the nesting area of the more solitary nesting gulls. There was a significant difference in the habitat parameters between horizontal and vertical plots (Table 36). The horizontal plots had a greater vegetation volume around the nests than did the vertical plots (68 cm, 72% cover vs 26 cm 31% cover). The vegetation volume however was correlated with distance from the cliff edge and also with slope. The vegetation was lower and less dense near the seaward edges of the plots and these two parameters also varied inversely with slope--the greater the slope, the less vegetation. Vertical plots of course had significantly greater slope. The steepness (16°) and lack of vegetation on the vertical plots were comparable to that of the sites on Lesser Kittiwake Rock whereas the steepness (8°) and high dense vegetation of the horizontal plots were comparable to that of the sites on Amee Rock.

Colonial - type Colonies The greatest densities and least nearest neighbor distances of all the gull nesting areas were on Amee and Lesser Kittiwake Rocks, the two colonial areas. Yet, the only consistency in habitat between the truly colonial areas was their inaccessibility. Other than that, there was no similarity in habitat. There was a marked difference in vegetation height and cover (vegetation volume) between them.

The one sea stack, Amee Rock, had a substrate and vegetation virtually identical to that of the "typical" gull colony--umbels and mixed meadow vegetation on not much of a slope. It had a lot of umbel type vegetation which was high ($\overline{x}$= 65 cm) and dense $\overline{x}$ cover = 80%). The mean slope of the colony was low (4°). The sea rock, Lesser Kittiwake Rock, was as densely covered with gull nests as was Amee Rock, but the habitat was atypical of Glaucous-winged Gulls. In fact, it was almost Kittiwake-like in that the slope was steep and there was little vegetation. It had very little vegetation ($\overline{x}$ height = 18.3 cm, $\overline{x}$ cover = 20%) and the slope was steep ($\overline{x}$ = 17°). The mean nearest neighbor distance ($\overline{x}$ = 250 cm) was not significantly different from that on Amee Rock ($\overline{x}$ = 310 cm respectively) and the nest density was the same.

Near Islands The nesting habitat of the Glaucous-winged Gulls on the near islands (Amee and Sheep) was varied within each island but it also was very different from the habitat on any of the other more productive study sites. Both Sheep and Amee Islands tended to have more of a grassland cover with few woody plants or few umbels.

Discussion - Nesting

Glaucous-winged Gulls seem to be non-selective with respect to vegetation volume or species of vegetation in their choice of nest sites. In the non-colonial situation, slope of the nesting habitat is important in nest site selection with respect to productivity. The vertical steeper plots had more nests per hectare and the nearest neighbor distances were smaller perhaps indicating preference for the vertical habitat. However, in the two relatively inaccessible colonial-type areas, there was no difference in density or in nearest neighbor distance. This suggests that some other environmental factor, perhaps predator accessibility to the nests, is acting on the nest site preference of these gulls. There is more variation between the two dense colonial areas with respect to nest-site parameters than there is between the colonial and solitary nesting situations. It is imperative that we observe the setting up of these nesting sites, both colonial and solitary because then we can make sounder judgements about which factors in the habitat are most important for the gulls. Are the colonial sites preferred for their inaccessibility to predators (especially human) and thus become colonial sites with as many gulls packing into an area as possible, or do all areas start out at the same time with the same density and packing and only later do the colonies fill up? Likewise, does egg-laying commence first on the colonial plots due to social facilitation or to some undetermined environmental factor? Answers to these questions in part will help explain the mechanism underlying the breeding biology of Glaucous-winged Gulls.

Reproductive Success

Mortality-Results

The mortality in the three major groupings of nesting areas varied considerably. The colonial areas averaged 18.2% at Amee Rock and 23.8% at Lesser Kittiwake Rock (combined=20.9%). In the solitary areas, the vertical plots averaged 20% and the horizontal plots averaged 27.3% (combined=21.9%). Egging was the major cause of mortality in the very accessible horizontal plots of the solitary-type nesters. Only the vertical plots had any avian predation. Likewise the chicks that died pipping were in the vertical plots (Table 37).

In the colonial areas there was a variety of mortality factors, but egging was not one (Table 38). Mortality occurred more in the chick stage for the colonial nesters than for the solitary ones. This mortality at the chick stage, 30% of the mortality at Amee Rock and 20% at Lesser Kittiwake Rock was due to chicks' falling off the cliff edge. Steepness of slope at Lesser Kittiwake Rock also accounted for at least 20% of total mortality (29% of egg mortality) due to eggs' rolling out of the nest.

The islands nearest the town of Old Harbor, Sheep and Amee, were heavily egged so that only one Glaucouswinged Gull nest per plot (8000 m^2 on Sheep, 2000 m^2 on Amee) was successful on each island. Two natives related to us that the Mew Gull populations on Amee Island five years ago were in the hundreds, but in 1977 we found a population under fifty birds. The natives stated that this decline was because of egging and that one year they had gleaned over 200 eggs from the Amee Island Mew Gull nests. This kind of decline shows how great an effect on gull populations that human disturbance can have.

Productivity-Results

The mean clutch size of Glaucous-winged Gulls on all colonies was approximately the same (Tables 39-40-42-43) ($p > 0.05$). However, since there was differential mortality at various stages for the three main colony types, the hatching success varied among them. For solitary-type nesters, hatching successs was lowest on the norizontal plots (64%) and highest on the vertical plots (80%)($p < 0.001$). The colonial nesters had an intermediate hatching successs (76%) which was not significantly different from that of the nesters on the vertical plots ($p > 0.05$). The mean number of chicks hatching on the colonial plots and vertical plots was approximately the same ($\bar{x}$ = 1.9 and 2.0 chicks per nest respectively) while the mean number of chicks hatching per nest on the horizontal plots was significantly lower ($\bar{x}$ = 1.4, $p < 0.01$).

Fledging rates were almost impossible to obtain for the solitary nesters because the chicks disappeared into the 60-80 cm high umbels after about two weeks of age. On the colonial areas, fledging rates were easier to obtain but they were also inaccurate. Many chicks ran from us and to keep them from jumping off the cliff edges, we would not pursue and recapture them. We assumed, as in the terns, that any chick that survived through the first two weeks after hatching would fledge. As for the terns, we determined a minimum and a maximum fledging rate. For the minimum rate we assumed that every chick we did not recapture died. For the maximum rate we assumed that every chick we did not recapture lived.

Because we had only a few recaptures on Cathedral Island, in the solitary nesting area (Table 43, 45), a discussion of the growth rates of these chicks are meaningless. In comparison, the chicks on the two sea rocks, Amee and Lesser Kittiwake Rocks in the colonial areas were more easily recaptured. The growth rates for the chicks in these two colonies were similar both by date (Table 44) and by age of chick (Table 43, (Figures 60, 61).

Mortality and Productivity--Discussion

The reproductive success of Glaucous-winged Gulls varied with type of colony and type of plot. Likewise, the stage at which this successs was affected varied with colony and with plot.

The reproductive success in the horizontal plots was affected at the egg stage in June. Eggs disappeared mainly due to egging and this egging also occurred on the less dense, easily accesssible colonies on island as close to the native village. We only compared statistically the transects on Cathedral Island and on the sea rocks. The horizontal plots which were very accessible to eggers had a higher egg mortality--due mainly to egging--than did the less accessible vertical plots and relatively inaccessible sea rocks. Once, however, the chicks made it through the egg stage, the reproductive success between accessible and inaccessible colonies was not significantly different. The mortality in the colonial areas was due primarily to eggs' rolling out or chicks' falling over the cliff.

Thus, the Glaucous-winged Gull colonies with the highest reproductive success occurred in areas relatively inaccesssible to humans. It seems as if human predation is one of the biggest mortality factors on gulls. Not only are their eggs taken by natives, but also the more accessible nests are constantly disturbed by eggers or picnicers. This disturbance can entail stepping on eggs or simply flushing the adult off the nest. The latter exposes the chick or egg to weather which is a mortality factor in both the chick and egg stages. Likewise, human disturbance may prevent an adult from bringing in food to the chick, and this may influence mortality and growth rates of the chicks. Thus, the nests that are least accessible to humans would have fewer mortality factors to contend with and thus have a greater reproductive success. On highly accessible areas we found that cover was an important factor in a clutch's not being egged. Nests that were hidden from view had a higher egg survival than did more exposed nests. On relatively inaccessible areas such as the sea stacks, cover made no difference in survival rate.

On the more accessible Cathedral Island, slope also was important in minimizing human predation. Eggs that were laid in steeper areas nearer the cliff edges had a higher survival rate at the egg stage than did those farther from the edge in flatter areas probably because native eggers did not cover that area. Thus these factors all are correlated with accessibility.

We do not know if being in a true colonial situation is more conducive to reproductive success than being in a solitary nesting situation. Environmental factors such as slope and vegetation obscure the picture at present because we do not know how the various nesting areas are first set up.

If being in an inaccessible area is the main factor for reproductive success among Glaucous-winged Gulls at Sitkalidak Strait, there are some important genetic questions we should start asking about the future direction these populations are going to take.

Feeding Ecology

Introduction

Since Glaucous-winged Gulls were such a dominant part of the feeding flocks at Sitkalidak Strait, their feeding ecology was important to study. However, with respect to other species in the area, their numbers were few. Thus we did not collect any adults for analysis of their stomach contents.

Glaucous-winged Gull chicks, like most Larid chicks, regurgitate when frightened, so we found it opportunistic to collect their regurgitations on each visit to the study sites and by doing this, develop some idea of how the Glaucous-winged Gulls fit into the ecosystem trophically. Opportunistically we also collected pellets or dropped food that was from adults only.

Results and Discussion

We found that a greater variety of food was being taken by the adults than was being fed to the chicks and that this variety was greatest in early June and in late August through mid-September. During these months we found sea urchin, crab, mussel, chiton, and limpet remains, and in August and September we found these plus salmon, shrimp, and starfish remains. During the height of the chick stage in July, we did not find these food items at the nest sites. However, in order to determine if the adult diet indeed changes, we would have to collect adult gulls.

The switch to a more varied food supply by the adults may indicate a decrease in the numbers of the regular prey fish frequenting the Sitkalidak Strait area. This switch qualitatively was also true for Aleutian Terns and for Black-legged Kittiwakes. Since the salmon were running in the streams around Sitkalidak in late August and early September we occasionally found their remains near the gull nests or their eggs in the kittiwake regurgitations. The whole salmon were too large for the gull chicks to eat and we never observed the adults tearing off chunks of the larger fish and feeding them to the chicks. It is rather common for birds like Larids to be opportunistic when an abundant food source like salmon appears. However, this temporary source may not have been adequate. We have indirect evidence that food may have been limiting in late August because one chick that was laid very late (16 August) in the season (it was a relay), died from starvation during a time when there were no storms. Its fat content was "1" the lowest category for the amount of fat in a bird. This coincides in time with our finding a dead Aleutian Tern fledgling which was at 62% of Adult weight.

Chick food. Glaucous-winged Gulls fed their chicks fish, a majority of which was Mallotus villosus (Capelin), averaging 102.4 cm in length (Table 46). These fish are significantly larger than were the fish the terns of both species were feeding themselves or their chicks (p 0.001). Since we did not collect Glaucous-winged Gull adults, we have no comparison between adult and chick prey as we do with other species in this study.

ARCTIC AND ALEUTIAN TERNS

Introduction

Arctic and Aleutian Terns are recent additions to the fauna of Sitkalidak Strait, Kodiak Island, Alaska. Older Natives in the area relate that terns were not present in the early part of this century. Likewise, there is no native word for either of the two species. At Sitkalidak Strait there were two mixed species tern colonies and one monospecific Arctic Tern colony during the breeding season of 1977 (Figures 62 A & B, Table 67). It appears that there were fewer terns of both species in 1977, due mainly to a decrease in numbers on Amee Island. Cub Island had no terns on it in 1976 but was colonized by Arctics in 1977.

Objectives

We wanted to study the comparative ecology of Arctic and Aleutian Terns and to determine the ways in which they fit into the ecosystem. We compared nestsite preference and nesting success on two mixed species colonies: Sheep and Amee Islands. We also compared the habitat on the monospecific Cub Island colony with that on the other islands to see if nestsite preferences differed in this situation, and if so, if this different habitat influenced nesting success.

We also compared feeding ecology of the two species to see if they were somehow segregating the prey resource. We also wanted to try to determine where the terns fit into the broad trophic ecosystem of the Sitkalidak Strait area.

Methods

We set up random transects on each of the three islands. These transects varied in length, starting at the edge of the nesting area usually in the island's center and continuing to the water's edge. They were all five meters wide. We studied all nests of both species that fell within these transects.

Nesting Habitat

In order to determine nesting habitat, we measured the following parameters at time of nest construction: vegetation height and cover within a 30 cm radius of each nest, slope, and nearest neighbor distance. We also obtained data via plotless points of the habitat available to terns on the islands to determine if the terns were preferentially selecting a certain habitat type. These data have not yet been analyzed. We also wanted to see if type of habitat influenced reproductive success. At hatching we again measured the vegetation height and cover.

Chronology and Reproductive Success

Every four days we monitored each transect and noted date of nest construction, dates of egg laying, hatching and chick fledging. We noted times and causes of mortality as well as clutch size, and numbers of chicks hatched and fledged. We also measured weights, tarsi, culmens, and wings of the chicks each time as indices of growth of the chicks.

Feeding Ecology

We attempted to collect three adults of each species every five days. We also collected regurgitations as they occurred. Tern chicks regurgitate readily when handled. Regurgitations were placed in labeled plastic bags and 10% formalin was added within four hours of collection. We also made detailed observations on the feeding behavior of the two species both on and off the colony.

Phenology

Terns of both species were well into the courtship stage when we arrived 27 May. On this date we found no nests on any of the islands, and saw courtship feeding in many of the paired Arctics but in few of the Aleutians. There was also much intraspecific aggression at this stage. It is interesting to note that there was great diurnal variation in number of birds on the colony from late May through the first week in June.

On 30 May there were no nests completed of either species on all islands but by 2 June, on our transects on Sheep Island, we found five Aleutian nests with eggs ($\bar{x}$=1.4 eggs/nest) which means the first eggs in the transect were probably laid 31 May (Figures 63-67). By 6 June, the first Arctic nests on our plots had been constructed: twelve on Amee Island ($\bar{x}$=1.7 eggs/nest) and one on Sheep Island (2 eggs) and nine on Cub Island (0.66 egs/nest). Earliest laying dates for Arctics were thus 31 May for Amee, 2 June for Sheep and 4 June for Cub. At this point, the Arctic adults were becoming very aggressive and nest-site tenacious. They often dive-bombed us. A few Aleutians attacked us also but not with the aggression of the Arctics. They were also less nest-site tenacious.

By 9-10 June, nest building and laying by Arctic and Aleutian Terns were well underway on all islands. On 21 June the first Arctic and Aleutian chicks had hatched (thus incubation period = 21 days) and also on this date we found new nests with eggs for both species. This range of a month in laying dates was probably due to egging by the natives, with the later clutches being relays. We found new Arctic nests being constructed through 30 June.

It is an interesting aside to note that on Amee and Cub Islands, the islands with the greatest slope, the eggs in nests of both species at the crests of the colonies were hatching first. This may indicate some preference in habitat.

The Arctic Tern chicks on Sheep Island were the first to fledge, and did so on 15 July. Because the tern chicks were difficult to locate after a week or so of age, we do not know exactly when the chicks on our transects fledged. Using 21 June, the first hatching date, gives an 18 day brooding period for the chicks, which probably is a little low.

If the Arctic Tern chicks remained in the water, they were usually dive-bombed by adult Arctics and occasionally by an Aleutian adult. Once they swam ashore or became airborne, they were no longer attacked. This attack behavior occurred at all three islands. Also at this time, the Arctic fledglings were feeding themselves.

Aleutian Terns first fledged on 16 July, giving them a similar (but probably an underestimated) brooding period. However, unlike Arctic fledglings, they remained on the colony, usually around the nest-site. Even though they were strong fliers, they were still fed by the adults at this time. They were never hassled by adults of either species as were the Arctic fledglings. The fledglings would often fly after an adult, food-begging, but would never fly more than 50 meters from the nest site.

By mid-August, most of the Arctic Terns had left the Sitkalidak Strait area. The small percentage of adults that remained at this time were carrying fish, indicating they still had chicks. By 16 August, all Arctics had left the area. All Aleutian Terns had departed Sitkalidak Strait by 30 August.

Nesting Habitat

Results

Both tern species seemed to choose different habitat sites for their nests (Table 68). On all colonies, Arctic Terns had a greater slope of the nest site than did the Aleutian Terns (p 0.05). In fact, Aleutian nests were rarely found on slopes and usually they were on the flat crests of the islands. On the monospecific Arctic Tern colony, the slope was significantly greater than that on the Sheep Island Arctic Tern colony. Height and volume of vegetation did not vary significantly between species or among colonies.

On Amee Island the Arctic Tern nearest neighbor distance was significantly greater than that of the Aleutians, and on the monospecific Arctic colony on Cub Island, the nearest neighbor distance was significantly less than that on the mixed colonies. This greater tolerance in nearest neighbor distance for an aggressive species may indicate that Cub Island has some overriding beneficial factor so that Arctic Terns would choose this island on which to nest over other islands and thus pack together in greater numbers. However, as we show later on, this apparent preference is perhaps more a species-packing due to a limited habitat available for nesting, because the hatching success, numbers hatching, fledging success, and numbers fledging were lower on Cub Island than on any other island.

Discussion

It seems that Arctic Terns choose areas with greater slope in which to nest. At first, the possible reasons behind this choice are not apparent. A greater slope would make it easier for eggs to roll out of nests, which in fact we found was a high cause of egg mortality. However, greater slope of an area gives an illusion of less crowding because when birds are on their nests, they are not eye to eye. In fact they would see each other less readily, and for an aggressive species like the Arctic Tern, this would mean less time spent in aggressive behavior and more time spent in attending the nest. The other way for the terns to avoid aggressive encounters would be to have greater nearest neighbor distances. As Table 68 shows, this is exactly what happened. On colonies with less slope (e.g. Sheep Island) the nearest neighbor distance for the Arctic Terns was greatest. On islands with more slope, the nearest neighbor distance decreased.

Aleutian Terns are not an aggressive species so that the nesting strategy of the Arctics would not be important for them. This is exactly what we found. On Amee Island the Aleutians had a small nearest neighbor distance but chose nest sites with greater slope than on Sheep Island. As yet we have no explanation for the large nearest neighbor distance on Sheep Island for this species.

Reproductive Success

Mortality-Results

Overall, there was a higher percent mortality in Aleutian than in Arctic Terns (39.6% vs. 29.3%) (Table 69). However, taken colony by colony and by species, the monospecific Arctic Tern colony had the highest mortality, 54.8%. The lowest mortality, 28% for Aleutians and 10.7% for Arctics occurred at Amee and Sheep Islands, respectively (Table 70).

On all islands, each individual mortality factor accounted for about 4% (Tables 71.72). For Arctic Terns, the largest mortality factors were embryos dying, eggs rolling out, and chicks dying at pipping (Table 69). On Sheep Island, their major mortality was 3.6% from exposure at the chick stage. For Amee Island, their highest mortality, 8%, was from disappearance of the egg, probably from avian predation or egging. However, on the monospecific Arctic colony on Cub Island, eggs rolling out of the nest or dying from exposure or at pipping (usually caused by exposure also) were the highest moratality factors. The greatest mortality of Arctic Tern eggs occurred during the hotter temperatures in the season, from late June to early July. Much of this mortality was during pipping - probably from overheating.

For Aleutian Terns, the largest mortality factors were eggs disappearing, probably due to predation and egging, and chicks dying from exposure (Table 69). The greatest percentage of Aleutian Tern egg mortality occurred from 5 - 11 June in the early incubation stage (Table 48 and Figures 69,70). Some chick mortality was during the heat wave of early July but greater mortality occurred during the low temperatures and heavy rains of 1030 July (12.5%). Greatest mortaliy at Amee and Sheep Islands was from eggs disappearing (14% and 22% respectively).

Growth Rates-Results

We weighed and measured wings, tarsi, and culmens of all locatable chicks once every three to five days throughout the chick stage. The data are quite variable by date in part because the laying was spread out over such a long period of time (Figures 68-72). As mentioned before, the range in laying dates was probably due to weather and to egging. Both of these mortality factors destroyed first clutches. The last known Arctic egg was laid 30 June and the last known Aleutian egg was laid 21 June. This is a range of approximately one month for laying dates for both species. The first fledglings were seen the 16th and 15th July for Aleutians and Arctics respectively so in the growth rate means (Tables 49-53), one week old chicks (hatching around the 20th of

July) and fledglings are being combined. This gives not much meaning to the growth curves .

Comparing growth and age of chicks yields a better index of chick growth (Tables 54-56). However, the problem of range of laying dates still remains. A week-old chick for instance in June will be influenced by an entirely different set of ecological factors than a week-old chick in August, and it is these factors which in part control the growth of the chicks.

Mortality and Growth Rates-Discussion

The mortality factors for the terns are directly related to habitat and behavior. Arctic Terns usually chose the steeper areas of the islands in which to nest, with the most extreme example of this in the monospecific colony on Cub Island. Here the slope averaged 17° and the nests were often built up away from vegetation and thus more exposed than nests on other islands. Almost 12% of the Arctic Tern eggs laid on Cub Island rolled out while another 26.2% of the eggs were probably killed by exposure. The greatest percentages of chick or egg losses for Arctic Terns that occurred on Cub Island were at the nests which were more exposed. Many of the eggs in exposed nests addled during the heatwave of early June (Figures 85,86).

The Arctic Tern population on Cub Island may really be a distinct population from the rest of the terns at Sitkalidak. We have reason to believe this because Cub Island was just colonized this year, and the population of Arctics that nested on it in 1976 laid a significantly greater number of eggs per clutch. However, a greater percentage of their eggs died in the embryo stage and more of their chicks succumbed at hatching than for any other population of Arctic Terns. This may somehow be related to the habitat on Cub Island, but there may also be some other factor--perhaps one regulating population size--acting here that is not immediately apparent.

Aleutian Terns usually nested near the crests of the islands and on flatter ground. Most of their loss of eggs and chicks was from disappearance of the egg (probably avian and human predation) and from exposure of the chicks to storms. This may be due to the fact that they were less aggressive than the Arctic Terns and are less apt to defend their nests as well. Most of the mortality of Aleutian Tern eggs occurred in the early incubation stage and was probably due to egg predation. This is understandable because Aleutian Terns are not very aggressive anyhow, and at this early incubation stage, the nest attentiveness of any bird is low due to reduced hormonal levels. The other period of high Aleutian chick mortality was during the storms of late July. The mortality rates of the young of the two species of terns seem to be approximately equal during the early brooding stages in July. In late July and in August however, the mortality of Aleutian chicks, especially those 1-2 weeks old, increased while that of Arctic chicks of all ages remained the same. Chicks that were hatched late in the season were downy at this time when heavy storms occurred. Their mortality may be due in part to weather in combination with the lower nest-site tenacity of the Aleutians. Aleutian Tern adults were easily disturbed from their nests but were slow in returning--much slower than Arctics (see also Table 64 for comparisons of nest attentiveness between these two species). Because of this lack of nest tenacity, many of the downy chicks were left exposed and were quickly wetted down and subsequently died from exposure.

The mortality of chicks also may have increased during late July and August because of what we believe was a decrease in the food supply, which may incidentally be weather-correlated. This decrease, in combination with the possible difficulty of Aleutians not only in entering mixed feeding flocks but also in procuring food for their large young at this time would increase mortality of the chicks. Certainly it contributed to a slower growth rate of the surviving chicks. Partial evidence for this is our comparisons of weights of chicks at this time. We found Arctic chicks to be fledging at 106% of adult weight, while Aleutians were fledging at 82%. Also, on 14 August on Cathedral Island, we found a dead Aleutian fledgling from Amee Island and it weighed 76 grams (62% of the mean adult weight). It had no fat on it. On the colonies we found dead chicks with ages ranging from 21 to 35 days. At this time we also caught live chicks in a mist nest and found their ages to range from 21 to 26 days of age. The fledglings' weights were low, with a mean of 87.5 (71% of mean adult weight). One 34 day old chick weighed 93 grams but had a wing of 20.6 cms, indicating slow growth. This again is probably due to a poor food supply perhaps brought about in part by storms. We have reason to believe that the food supply in Sitkalidak Strait had decreased or was inaccessible at this time, and this idea will be discussed in the prey section.

Productivity Results

Arctic Terns had a larger clutch size than did the Aleutians in all colonies (Table 57). The monospecific Arctic Tern colony had the greatest clutch size of all ($\overline{x}$ = 2.35). The percent chicks hatching on Sheep Island was greater for Arctic Terns (84%, $\overline{x}$ 1.9 chicks per nest) than for Aleutians (57% $\overline{x}$ = 1.0). On Amee Island, the reverse was true with 47% of Arctic eggs hatching ($\overline{x}$ = 0.7) and 73% of Aleutian eggs hatching ($\overline{x}$ = 1.1). The Cub Island Arctic Terns had the lowest hatching success, 43% ($\overline{x}$ = 1.12).

Fledging success varied also among the colonies. Because tern chicks are difficult to locate due to their cryptic coloration, wandering habits, and the high vegetation, we established two fledging figures: minimum and maximum. Minimum fledging rates do not include any tern that was not located again. In this case, we assumed that all terns not recaptured died. Maximum fledging rates include all terns we could not relocate. In this case, we assumed that all terns not recaptured lived to fledging. Of course, both of these figures are not correct, the one being a gross underestimate, the other, an overestimate of what really happened. For lack of a better index of success, we will use both these rates.

In all cases, Arctic Terns had higher fledging rates than did Aleutians. On Sheep Island where Arctics fledged a minimum of 0.41 and a maximum of 1.66 chicks per nest, Aleutians fledged 0.21 and 0.83 respectively. The minimum fledging rates then are 20% for Arctics and 10% for Aleutians while the maximum rates are 83% for Arctics and 47% for Aleutians. The minimum number of fledglings for Arctics and Aleutians on Amee Island was relatively the same (0.37 and 0.38 respectively) but the maximum number fledged was 0.75 for Arctics and 1.0 for Aleutians. However, the minimum fledging rate for Arctis was greater (38%) than for Aleutians (23%) while the maximum rate was equal (62%).

On Cub Island the Arctics had the least number minimum fledge (0.05 chicks per nest) and also a low maximum fledge (0.78 chicks per nest). They also had the lowest minimum fledging rates for both species (2%) and the lowest maximum rate for Arctics (52%) which was near the lowest Aleutian rate of 47% on Sheep Island.

Because there were differences in reproductive success between the two species of terns and among the three colonies, we ran a stepwise multiple regression analysis to see if any of the habitat variables strongly influenced this success.

There was a weak negative correlation between number of eggs laid and vegetation volume at laying. However, the correlation became too varied among species and colonies to compare when number of chicks hatched was the dependent variable (Tables 58-62).

On Sheep Island there is a strong positive correlation between number of chicks hatched and vegetation volume for Aleutian Terns but no correlation for Arctics. On Amee Island there is negative correlation between number of chicks hatched and vegetation volume both at laying and hatching for Aleutian Terns but no correlation for Arctics.

This apparent reversal may simply mean that some other environmental factor that is present on say Amee but not on Sheep is overriding any effect that vegetation volume may have on number of chicks hatched.

For both species it appears that there is a greater hatching rate if eggs are laid later in the season. This is probably a result of egging by the natives. They quit egging later in the season so that clutches laid after the first onslaught have a better chance of making it to hatching. This was true also for the Glaucous-winged Gulls.

For terns of both species on all colonies, the number of chicks hatching and the hatching rate were negatively correlated with slope. We observed a high incidence of eggs rolling out of the nests in the steeper areas of the colonies. Terns, unlike gulls, did not roll eggs back into the nest if they rolled out.

Productivity-Discussion

Because the Arctic Terns on Cub Island had a significantly greater clutch size than the Arctics on the other islands, and because this island was newly colonized, they may possibly be a separate population that does not interbreed with populations from the other islands. Even though the clutch size was greatest on this island, these terns had the lowest hatching and fledging success.

Arctic Terns were most successful on Sheep Island (85% hatching and 20-83% fledging success), and in terms of number of young fledged per egg laid, the Sheep Island population was highest (0.41 minimum-1.66 maximum). At this point, we have no insight into why the Arctics were so successful on Sheep.

Aleutian Terns were most successful on Amee Island (73% hatching and 23.62% fledging success) and in terms of numbers of young fledged per egg laid, the Amee population again was highest (0.38 minimum - 1.0 maximum). There was a weak negative correlation between number of chicks hatching and vegetation volume on Amee. This may be due to the Aleutians' somehow having a difficult time finding or approaching their nest sites, and possibly in being hassled by the aggressive Arctic Terns. If this is the case, then, the lower vegetation would enable the Aleutians to locate their nests more quickly and perhaps thus avoid attacks by Arctics.

Feeding Ecology

We approached the investigation of the feeding ecology of terns in three ways. First, we made detailed observations of feeding flocks throughout the season, noting species composition, numbers of each species, and inter and intraspecific behavior within the flock. Second, we made all day food watches on a sample of active Arctic and Aleutian nests on a mixed colony on Amee Island. This consisted of watching five nests of each species all day. In addition to this we ran transects on all colonies every three to four days and monitored chick growth and fledging success. Finally, we collected food samples from adults and chicks of both species and compared these qualitatively and quantitavely.

Foodwatches

We conducted the foodwatches at three different stages of the chicks' development: early chick (1-2 weeks old), late chick (3-4 weeks old), and fledgling stages. These foodwatches were from dawn to dusk. Data gathered were number of times and when a chick was fed, number of attempted feedings, number of visits an adult made to the nest and how long it remained, and numbers and durations of chases of the adults. The purpose of these foodwatches was to give us an insight into distance to the foraging sites and also into attendance to the chicks by the adults. The feeding rates could be related to growth rates of the chicks.

Feeding behavior--Arctic and Aleutian Terns

Both species of adult terns foraged during daylight. Chicks were left unattended on the colony during adult foraging sorties. After the first week, the chicks did not remain at the nest but rather stayed in the high vegetation as far as 15 meters from the nest. When they were fed, it would be at a feeding station. More than one brood would share a feeding station, and there could be multiple feeding stations per nest. The feeding stations were species-specific.

Times of feeding

We found that neither Arctic nor Aleutian terns fed their chicks at random times throughout the day ($p < 0.05$) (Figures 78 - 81). Instead, feeding times were clumped, yet the feeding times of the two species did not coincide exactly. The peaks of feeding activity usually occurred one to two hours before high tide or one to two hours after low tide. The feeding of the chicks on 18 July also coincided with observed feeding flock activity in the vicinity of the colony.

Nest-site Attendance

From our all-day food watches we found that Arctic Terns seemed to be better providers of food than did the Aleutians. They also seemed to be more nest-attentive than the Aleutians (Tables 63-64). They made a greater number of visits to both chicks and eggs than did the Aleutians in the early brooding stage, and spent a greater percent of their time brooding the chicks than did the Aleutians. Aleutians, however, spent more time on the nest incubating the egg. These behaviors may be correlated with times of mortality between the two species. Arctic chicks died more at the egg stage and more Aleutian chicks died at the chick stage. This difference may be directly related to behavior of the adult at the nest, and the change in this behavior through time.

Adult Arctic Terns were more successful in delivering food to their chicks during the early brooding stage than were the Aleutian adults. In the late brooding stage this percentage of successful feedings by the Arctics increased almost 25%. There is no comparable figure for the Aleutians at the late date. The number of feedings by Arctics increased likewise throughout the season but remained approximately the same for Aleutians. This is important with respect to growth rates of the chicks.

At all stages, Aleutian Terns were chased by other adult terns. During the early and late brooding stages, most of the chases were by Arctic Terns which often forced the Aleutians to the ground or made them drop their bill load. The chases by Aleutians were not as violent nor as long. Arctic Terns were never chased by Aleutians. Even without overt chases by other adults, however, Aleutian Terns would often take 20-30 minutes to approach their nests whereas Arctics would fly to the nest directly.

The chicks of the two species also exhibited very different feeding strategies at the fledgling stage. As soon as the Arctic chicks were able to fly, they went directly to the water. They started feeding themselves immediately and were often attacked by adult terns, mainly Arctics. Within a period of a few weeks after the first Arctics fledged, most of the Arctic terns--adults and chicks--were gone from the colony.

Aleutian chicks hatched about the same time as Arctic chicks and also fledged about the same time. However, they remained at the nest and were fed by their parents for about two weeks after they fledged. We have evidence also that they do not grow as fast as the Arctics. At fledgling stage, they were only 80% of adult weight while Arctic chicks were heavier than adults (106%).

Prey Items

There was a significant difference in length of prey items between Arctic and Aleutian Terns. Within each species there was a significant difference between chicks and adults with respect to prey length. Likewise, through time, the prey length changed. It was larger in July than in June, but fell in August.

Fish was the major prey item in the tern diets, and since fish grow constantly, so that an age class of fish in any one month should be larger than the one in the previous month, we would expect there to be a simultaneous increase in the length of prey taken throughout the season or at least a leveling off once the maximum prey length had been reached. A decrease in prey length as we found in August is definitely not what we would expect.

Arctic Terns

Arctic Terns' diet consisted of 94% fish (Table 65). Mallotus villosus (Capelin) and Ammodytes hexapterus (Sand Lance) accounted for 74% of the prety items. Chicks were always fed fish. The only invertebrates we ever found in the stomachs of adult terns were Euphausiids, and these appeared only 6% of the time.

There was a significant difference in prey length between chick and adult prey over all months ($p < 0.01$). Likewise, there was a significant difference within chick or adult prey lengths throughout the breeding season.

Aleutian Terns

Fish were the principle prey item (86%) in the diet of Aleutian Terns throughout the season (Table 66). The variety of fish prey species was large (7) but Mallotus villosus (Capelin) comprised 39% of the prey items overall. Sculpins were next in importance (17%) followed by Ammodytes hexapterus and two unidentified fish species.

The diet the adults provided for the chicks consisted exclusively of fish, whereas the adults were taking a lot of Insecta and other invertebrates such as Isopoda.

The mean prey length of food given to the chicks was 74.6 cm while that taken by the adults was 58.0 cm ($p < 0.001$).

Comparisons in prey length between Arctic and Aleutian Terns

There was a significant difference in length of prey taken over all seasons by Arctic and Aleutian Terns. Arctics took larger prey overall. We compared prey length over the breeding season between Arctic and Aleutian Tern adults: 74.6 cm for Aleutians, 80.53 cm for Arctics (Figure 82). This was significant at the 0.05 level. We also compared the difference in prey fed the two species of chicks. The mean for Aleutian chicks, 74.57 was significantly lower (p 0.02) than the mean for Arctic chicks, 95.18 cm.

Food size by season

For both species, there was a qualitative change and a significant change in prey length over the season (Figure 83). In July, the average size of fish taken by both species was approximately the same. The species of fish taken were mainly *Ammodytes hexapterus* and *Mallotus villosus*. However, in late July and August, the size of prey fed the chicks was disproportionate between the two species. Arctic Terns were still feeding fairly large fish to their chicks, but the Aleutians had switched to more invertebrates, a greater variety of fish species, notably sculpins, and to smaller prey in general. This switch for the Aleutians but not for the Arctics may indicate not only differences in foraging strategy, but also differences in abilities to enter or remain in mixed feeding flocks due to lack of aggression. It may also reflect differences in seasonal prey availability. The choice of prey of smaller lengths for Aleutians may be by default so it is important to study Aleutian Terns in an area of allopatry.

In summary we believe that Aleutian and Arctic terns do not feed their chicks at random times throughout the day but that the times follow a tide change and may be correlated to feeding flocks that occur at these changes. The two species do not have exactly similar periods of feeding and their behavior on the colony differs markedly. The Arctics have higher percent successful feedings and the number of feedings increases throughout the season while the number for Aleutians remains the same. Arctic terns are more aggressive and are not chased when they bring in food but Aleutians are. The fledglings exhibit very different feeding ecologies with the Arctics leaving the nest immediately at fledging, and the Aleutians remaining at the nest for two weeks after they fledge.

The Aleutians are also less aggressive off the colony and do not enter readily into mixed feeding flocks. They are rarely found in these flocks and are sometimes chased by Arctics upon trying to enter the flocks.

On the whole, Aleutian terns select smaller prey than do the Arctics and this was most apparent during the late brooding and fledging periods when the prey size decreased and the variety of prey increased for the Aleutians. Rain and low temperatures may act synergistically with a decrease in prey availability and may decrease the chances for Aleutians to find food and to increase the mortality of the chicks. At fledging, the two species exhibit vastly different strategies with the Arctic chicks, at adult weight, leaving the breeding grounds immediately after fledging, often being attacked by Arctic adults. The Aleutian chicks at 80% of adult weight remain at the nest site even though they can fly, and are still fed by the adults.

FEEDING FLOCKS

We observed feeding flocks from 02 June through 09 September. They formed usually along convergence currents especially in areas where there was a rapid change in bottom topography (Figure 84).

If the feeding flocks were composed of terns, kittiwakes, other gulls and puffins, the terns were always the initiators of the feeding assemblages. We call them the nucleus species. Kittiwakes and gulls would arrive next and the puffins and cormorants always appeared last in the flocks.

Our hypothesis for which species initiated the feeding flocks is based on observation. We believe that the strongest fliers--the ones that can fly slowly or even hover--and thus which can carefully scan an area of the water--are the nucleus species. Those species can efficiently cover a wide expanse of water, often at great heights and can thus presumably spot the fish schools more easily. If terns were not a part of the feeding flock, then the kittiwakes and gulls would initialize them. They too are strong fliers.

Evidence for visual input as a prerequisite for feeding flock formation is that whenever there was wind or rain which distorted the water, there were by far fewer feeding flocks. Thus it makes sense that species with the greatest command over the water visually--the strong slow fliers--would first locate the prey underwater.

As more birds joined a feeding flock, the feeding behavior would change. This was directly correlated with numbers of birds feeding and not with length of time the flock had been in existence.

The initial feeding behavior of terns, kittiwakes and gulls is surface plunging. The birds dive into the water from a height of 3-4 meters and sometimes completely submerge, other times only partially. They remain underwater from one to three seconds. However, when the density of birds becomes such that it blocks diving access to the water, these three species alter their feeding behavior to that of surface seizing: they sit on the water and pick up prey on the surface. Often when they switch to this type of feeding, the puffins and cormorants will have arrived although they sometimes arrive at the surface-plunging stage. If the latter is the case, the behavior soon switches after their arrival because when they land in a flock it is usually in the middle. The feeding behavior of cormorants and puffins is that of long deep dives.

Most feeding flocks lasted 10-20 minutes (n=20) and if they were of longer duration, they did not remain in one physical place but were rather dynamic, shifting over distances of hundreds of meters. Sometimes the large flocks were bimodal in structure with either one of the modes having the majority of birds at any one time.

The species departed the feeding flocks in the same order in which they arrived. Ten to twenty minutes after the feeding had stopped, Tufted Puffins would still be sitting on the water, but not diving. They would at this time, occupy the center of the area where the feeding flock had been. A few gulls and occasionally kittiwakes would remain on the fringes of this group. They too would be feeding.

We observed association between avian and mammalian feeding assemblages in 10% of the observed flocks. However, we did not make extensive enough observations to determine which class of animals was cueing in on the prey first. Marine mammals would often surface right in the center of the flocks in the area with the densest number of birds.

A feeding flock is dynamic with birds arriving and leaving constantly. One erroneous assumption that many people make is that birds leaving the flock have fed. We collected numerous birds, especially kittiwakes, leaving feeding flocks, and many of these had empty digestive tracts. Many more hours of observation must be made before the dynamics of feeding flocks are thoroughly understood.

Abundance and Distribution

Table 73 and Figure 84 show where most of the observed feeding flocks were located and the size of these flocks. Note that more flocks and also larger flocks occurred near Cathedral Island. In this area, the bottom of the straits changes abruptly. This change produced many convergence currents and many of the feeding flocks in this area we found at convergence lines. There seems to be no correlation between tide height or time to high or low tide and the occurrence or size of the feeding flocks. (Table 73). More systematic observations are needed in order to make sure this is true.

A simultaneous feeding flock watch plus colony foodwatch is imperative in order to fully understand the relationship between timing of feeding by the adults and delivery of food to the chicks. We observed feeding flocks and a colony simultaneously only once and found times of feeding of chicks correlated with times of feeding flocks ($\bar{x}$ = 20 minutes lag time between feeding flocks and chick feeding).

Black-legged Kittiwakes, Glaucous-winged Gulls, and Tufted Puffins accounted for 89% of the birds in the feeding flocks (Table 74).

Ninety-five percent of all feeding flocks had adult Black-legged Kittiwakes present, 90% had Tufted Puffins present and 80% had Glaucous-winged Gulls. Fifty-five percent had cormorants and 35% had Arctic Terns. Thus, a relatively small number of species composed most feeding flocks.

Glaucous-winged Gull feeding behavior

Glaucous-winged Gulls were always a composite of the feeding flocks we observed. There were never very many, but they were always part of the original nucleus along with Black-legged Kittiwakes. They comprised on the average 15% of the birds in a feeding flock, but occurred in 80% of the flocks.

Glaucous-winged Gulls were one of the first arriving species, after terns, to a feeding flock. They were often dominant over kittiwakes and terns, probably because of their size. Although we did not collect any gulls, from observations it appeared that they were usually successful in the feeding flocks. Fledglings were generally unsuccessful and would often be on the periphery of the flocks, sometimes picking up floating pieces of debris or seaweed.

The adult gulls, both Glaucous-winged and Mew, and the kittiwakes, fed similarly, surface plunging at the beginning of a feeding bout. The gulls, because of their larger size, seemed to influence the feeding behavior of the Black-legged Kittiwakes. When the feeding flock grew to a certain size, the gulls first would change their behavior from surface plunging to that of surface-seizing. When they were sitting in the water feeding, the kittiwakes could no longer plunge-dive above them and would soon change their own behavior to that of surface-seizing. All three species would then sit on the surface of the water and surface-seize any prey they could reach within about a 50 centimeter radius.

Arctic Tern feeding behavior

Arctic Terns were the nucleus species of all flocks in which they appeared. They arrived first and the gulls and then puffins and cormorants would follow. Terns of both species always occupied the highest stratum during the surface-plunging stage, and would dive through the gull-kittiwake stratum. Presumably their position was due to better visual acuity combined with their ability to hover. When the feeding phase changed to surface-seizing, they would sometimes sit on the surface of the water like the gulls, and seize prey, but often at this point they would leave. We would occasionally see monospecific Arctic Tern flocks and the feeding behavior would follow this same behavior.

We occasionally saw Arctic Terns feeding alone either surface-plunging or skimming along the surface. From our collection sample size of two, they were neither more or less successful than terns feeding in a flock.

Within a flock there was usually not any overt aggression between terns and other species. Occasionally we spotted deference/submission of one species to another--usually a smaller to a larger species. Aleutian terns were occasionally prevented from joining feeding flocks composed of Arctic terns, kittiwakes, Mew and Glaucous-winged Gulls, and Tufted Puffins. On one occasion we observed a single feeding Arctic Tern defending a large feeding territory 15 meters wide. This aberrant behavior may be related to prey availability and not solitary feeding, but with such a small sample size and no simultaneous prey sampling we cannot make any conclusions about it.

Aleutian Tern feeding behavior

The feeding strategies of Aleutian Terns are virtually unknown. Even though the Aleutian terns occupied 52% of the nesting sites at Sitkalidak Strait, we saw them in mixed feeding flocks only 5% of the time and we only observed a purely Aleutian Tern feeding flock once, close to their larger colony on Sheep Island.

When we did observe both Aleutians and Arctics in a flock, their numbers in the nesting areas were approximately equal. Likewise we observed Arctics chase Aleutians from feeding flocks but not the reverse.

It is our hypothesis that because of the absence of observations of Aleutian Terns in feeding flocks, and also the discovery of insect parts in their digestive tracts, that we believe that they must feed inland. This would be a perfect example of species coexistence and ecological segregation of the feeding niche. However, we never observed Aleutian Terns feeding inland on our three overland surveys.

Aleutians may prefer insects and thus seek out inland foraging areas or they may take them by default due to the aggression of the Arctics. In order to test this we would have to find an area where only Aleutians occurred. This would also enable us to test the hypothesis that the Aleutians align themselves with the more aggressive Arctic Terns in order for protection from predators.

Black-legged Kittiwake : feeding behavior

Black-legged Kittiwakes fed in a similar way to Glaucous-winged Gulls. They surface-plunged at the beginning of the feeding flock but would change to surface-seizing when the flock became dense. They were often the nucleus species of the flocks and were also one of the first species to leave.

Tufted Puffin : feeding behavior

Tufted Puffins were one of the last species to arrive at the feeding flocks and often came from a few kilometers away. They usually landed near the middle of the flocks and then proceeded to dive after the prey. Once the feeding flock had dispersed the puffins remained in a loose aggregation, sitting on the water no longer diving. They often stayed in the vicinity for up to 30 minutes after they quit feeding.

MAPPING

Arctic and Aleutian Terns

Cub Island

The Arctic Tern plot on Cub Island begins at the benchmark on the highest point of the island and continues on a course of 273° with a width of 2 1/2 meters on either side, for 90 meters (Figure 45).

Amee Island

The permanent marker for all three tern plots is located 30.7 meters at 278° magnetic from the USGS benchmark which is located on the south hill of Amee Island (Figure 46). All three tern plots are five meters wide and they all start at the permanent marker. The courses are all sighted down the center of the transects so that there is a strip 2 1/2 meters wide on either side of the sighting line. Plot T-1 continues for 150 meters at 143° magnetic from the marker. Plot T-2 continues for 59 meters at 203° magnetic from the marker. Plot T-3 (which was not used by terns in 1977) continues for 30 meters at 338° magnetic from the marker. The extent of the entire tern colony is also shown in Figure 46.

Sheep Island

The tern transect on Sheep Island is located six meters at 156° from the permanent USGS benchmark marker on the peak of the easternmost and also highest hill (Figure 47). The transect continues from this point, 248° to the western edge and 68° to the eastern edge of the island. Terns of both species nest in all areas of the island except the indicated marsh.

Glaucous-winged Gulls

Amee Island

Both Glaucous-winged and Mew Gull areas are indicated on the map (Figure 46). Glaucous-winged Gulls prefer North Head and Mew Gulls prefer the low area between the two heads, although a few scattered nests are found on South Head. Amee Island is not an important gull colony at this time, so we did not establish permanent transects.

Sheep Island

Both Glaucous-winged and Mew Gulls were scattered throughout the island with no true colonial situation. The area that we censused is indicated on the map (Figure 47).

Amee Rock

The Glaucous-winged Gull colony covers the entire top of Amee Rock. (Figure 46). Nests are found under the high umbel vegetation.

Lesser Kittiwake Rock

Glaucous-winged Gulls occupy the entire sloping south side of Lesser Kittiwake Rock (Figure 48).

Cathedral Island

Cathedral Island is the largest of the islands and is divided into four areas for mapping purposes. Each area has its own area (Figure 48).

Plots G-1 and G-2 The location stake for Plots G-1 and G-2 can be found by sighting at 173.5° magnetic, 21.5 meters from marker B. Plot G-1, the horizontal plot, begins 10.3 meters at 155° magnetic from marker B. The beginning of vertical Plot G-2 is found at 11.3zmeters at 55° magnetic from the location stake.

Plots G-3 and G-4 Plots G-3 and G-4 are located near marker C. Their location stake is 52 meters at 88° magnetic from marker C. Horizontal plot G-3 is located 6.25 meters at 23° magnetic from the location stake. Vertical Plot G-4 is located 30.6 meters at 29° magnetic from the stake.

Plots G-5 and G-6 The location stake for plots G-5 and G-6 is 53 meters at 167° magnetic from marker D. The beginning of Plot G-5 is 15 meters at 60° magnetic from the stake. The beginning of G-6 is 38.5 meters at 150° magnetic from the location stake.

Plot G-7 Vertical plot G-7 is 190° magnetic and 44.3 meters from marker A. The beginning of the plot is located 30 meters at 225° magnetic from this location stake.

Tufted Puffin

All Tufted Puffin plots are sighted from the permanent locator markers to a marked post (Figures 46, 47, 48). The beginning of the plots is at the marked post at a certain distance and bearing from the permanent locator markers. All puffin plots continue to the cliff edge and are one meter wide unless noted. All sightings are magnetic.

Cathedral Island

Plot 1: 355 and 41 meters from marker A.
Plot 2: 315 and 50 meters from marker A.
Plot 3: 315 and 50 meters from marker A.
Plot 4: 353 and 60 meters from marker B.
Plot 5: 211 and 92 meters from marker C.
Plot 6: 16 and 53 meters from marker C.
Plot 7: 63 and 78 meters from marker C.

Amee Island

The permanent marker to locate the Tufted Puffin transect is a large rock on South Head, next to the eastern landing beach (Figure). The puffin transect is 148 and 5.75 meters from this marker and continues to the cliff edge.

Sheep Island

The beginning of Tufted Puffin transect #2 is sighted from the permanent Sheep Island marker which is at the peak of the easternmost hill. Plots are 5 meters wide and continue to the cliff edge.

Plot 2: 360 and 1575 from the marker.
Plot 3: Begins 18 meters northeast from the beginning of Plot 2.

Black-legged Kittiwake

Cathedral Island (Figure 48)

Plot 1: 128° and 88 meters from marker D.
Plot 2: 98° and 102 meters from marker D.
Plot 3: 188° and 88 meters from marker D.

Lesser Kittiwake Rock northeast face.

ANNOTATED LIST OF OTHER BIRDS

Pigeon Guillemot

Nowhere abundant in the Sitkalidak region, the Pigeon Guillemot was an ubiquitous breeder throughout the area. We make censuses of birds rafting just offshore on 9,10, and 13 June, and found a total of 520 birds in the middle Sitkalidak Strait area. The birds at this time were displaying in pairs, so we estimated that there were 260 breeding pairs of Pigeon Guillemots in the area.

Two nests were located on Amee Island and another on Cathedral, but they were not monitored regularly so we have no data on the productivity or breeding chronology.

Horned Puffin

Suitable Horned Puffin nesting habitat was scarce in the Sitkalidak Strait area. About 40 pairs were nesting in cracks on Cathedral Island and perhaps 10 pairs were nesting in similar situations on Amee Island. We frequently saw 5-10 birds on the waters near Sheep Island and presumed that they were nesting there, although the island is very low and offers no broken cliffs suitable for nesting. It is possible that they were nesting in small talus along the island's perimeter.

At the end of July we began to see higher numbers of Horned Puffins, especially off Cathedral Island. The maximum was 29 July when 83 birds were seen in the Cathedral Island waters. These may have been non-breeders.

Shorebirds

Sitkalidak Strait offered little habitat suitable for shorebirds and the only one that nested there was the Black Oystercatcher. However, beginning on 30 June we occasionally saw scattered numbers of various shorebirds on the beaches and intertidal areas. A favorite site of congregation was a low, graveled spit jutting from the south side of Cub Island. The following is a synopsis of the sightings by species:

Western Sandpiper:

30 June - 10 at west end of Sheep Island.
10 July - 13 at west end of Sheep Island.
23 July - 5-10 on Cub Island spit with 10 Black Turnstones.
27 July - 5-10 on Cub Island spit with 10-15 Black Turnstones.
21 August - 35 on beach on eastern side of Sitkalidak Island.

Black Turnstone:

05 July - 3 on Amee Island beach.
23 July - 10 (8 adults, 2 immatures) on Cub Island spit.
25 July - 15 on Cub Island spit.
27 July - 10-15 on Cub Island spit.

Lesser Yellowlegs:

23 July - 4 feeding on tidal flat, Amee Bay.

Northern Phalarope:

20 July - 45 in winter plumage feeding in waters off Cub Island.
09 August - single bird feeding in convergence line off Cathedral Island.
21 August - 40 feeding in splash zone on beach on eastern side of Sitkalidak Island. 10-20 in convergence line near Cathedral Island.

Dunlin:

01 August - two on Cub Island spit. Molting into winter plumage.

Wandering Tattler:

01 August - one on Cub Island spit.
09 August - 5 on beach at Old Harbor.
13 August - two at west end of Sheep Island.
21 August - one along shore near mouth of Port Hobron.

Golden Plover:

21 August - 3 moulting into winter plumage foraging in mudflat at mouth of McDonald Lagoon.

Black Oystercatcher:

21 June - nest located on western side of Cub Island - apparently abandoned.
09 July - 20 seen at Nut Island.
03 July - 8 seen at Nut Island.
23 July - 15 seen on Cub Island spit.
07 September - 19 on Cub Island spit.

ANNOTATED LIST OF MAMMALS

Marine mammals were not prevalent in the Sitkalidak Strait area. There were no breeding grounds there for any of the pinnipeds and the few mammals we did see may have been immatures passing through. The mammals appeared in only 10% of the feeding flocks which may indicate that the food available is not the preferred prey for marine mammals, hence their absence from the area.

Harbor Seal

We saw Harbor Seals regularly throughout the summer, with the first sighting on 10 June off Sheep Island, and the last on 7 September near the Cub Island rocks. Favorite hauling areas were the rocks off the north side of Nut Island and the rocks below Lesser Kittiwake Rock. We had six sightings in June, six in July, five in August, and two in September (Table 75).

Stellar's Sea Lion

We saw a Stellar's Sea Lion once only. It was swimming west of Cathedral Island below the Black-legged Kittiwake Plot #1 on 25 June.

Harbor Porpoise

Harbor Porpoises were the second most common marine mammal at Sitkalidak Strait. They were the species of mammal most common in the feeding flocks we observed. We had three sightings in June, one in July, eight in August, and one in September (Table 76). Half of our sightings were when the porpoises were feeding.

Minke Whale

Sighting of Minke Whales was sporadic although they were the most common marine mammal in the Inner Sitkalidak Strait area. We had a lot of sightings early in the season. These sightings decreased with time as the season progressed. In the early sightings, we observed the Minkes breeching. These sightings were always from our support vessel, the Yankee Clipper. We suspect that the act of breeching may have been in response to the vessel. Most of the other sightings were of the whales in mixed feeding flocks. We had one sighting in May, three sightings in June, fifteen in July, and four in August (Table 77).

Sea Otter

We saw one sea otter eating a king crab at 1000 on 19 June, southeast, 100 meters off Cathedral Island.

Beaver

We saw beavers twice, both times swimming 15 meters off our camp beach, 28 May and 18 June.

Red Fox

We had three sightings of red foxes: 2 June, 28 June, and 17 July. Each time the fox ran from us. In the Sitkalidak area they are not tame as they are on islands such as the Shumagins.

DATA GAPS

The most obvious data gap is that the study only covers a single season. Very few definitive statements can be made about the breeding ecology of the seabirds at Sitkalidak Strait other than what occurred during the 1977 season. Much time was spent this season orienting ourselves to the area and trying to determine how we best could efficiently obtain the most data. Hopefully other workers will have the time to fill in the gaps we have in our data, which should include:

1. A better analysis of the nesting habitat by observations of any competition by adults for the nest sites as well as an assessment of any unused habitat. This entails arriving at the study site before the birds set up their nesting territories.

2. A better record of the movements of birds in and out of the strait throughout the season by monitoring day-long sea watches from Lagoon Point at various times during the season.

3. A better record of the distances birds nesting in Sitkalidak Strait are traveling for food by making more shipboard transects throughout the season and continuing them beyond the mouth of the strait, and an analysis of the feeding effort by more monitoring of the nests in food-watches, as we did this year.

4. A better understanding of the feeding ecology by collecting more samples of chick food (especially for the puffins) throughout the season and by sampling the availability of the prey directly with tow nets.

5. A better record of the breeding ecology at the very large Boulder Bay kittiwake colony that can be compared with the colonies in Sitkalidak Strait.

EFFECTS OF OIL SPILLS

The most obvious danger of offshore oil development in the Kodiak waters are oil spills. The vulnerability of seabirds to such spills has been well documented (Vermeer and Vermeer 1974, 1975) and need not be reviewed in depth here. One effect of oil spills in the marine environment is a decrease in the available food supply because of the depth or contamination of prey species which have succumbed to or have accumulated the toxic fractions of oil (Payne and Penrose 1974). Another is the buldup of toxic hydrocarbons in the birds themselves as a result of the ingestion of contaminated prey (Alaska OCS office 1977).

Any oil slicks in the Sitkalidak Strait area during May through September could also have a direct effect on the seabirds by oiling any birds rafting off the colonies or feeding in the strait. Convergence lines and tide rips were found to be important feeding areas for all species, and it is here that much of the oil would accumulate, presenting a serious threat.

The impact of related activities, such as the onshore development of support facilities and increased shipping activities, would be less dramatic than that of oil spills but would be severe if uncontrolled. Certainly no development should take place that directly reduces the nesting areas presently used. Onshore development and shipping activities also should not be close enough to existing colonies to cause abnormal disturbances to the nesting birds.

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Colony	No. burrows	No. birds
Amee Island	450	453
Cub Island	162	---
Nut Island	210	---
Sheep Is.	90	---
Granite Is.	130	---
Cathedral Island	5750	4534
	(6028)*	---

* based on field assessment of habitat

Table 1.

Results of the Tufted Puffin censuses for each Colony in Sitkalidak Strait, Kodiak Island, Alaska, during the 1977 breeding season. Unless otherwise indicated, the burrow counts were made from a boat 30-40 m offshore and included all burrows. See figure 2 for the colony locations.

Table 2: Summary of Tufted Puffin and Black-legged Kittiwake movements past Lagoon Pt., Sitkalidak Strait, 11-12 July 1977

Number of Birds seen per 10 minute watch*

Beginning Time		Tufted Puffin In	Tufted Puffin Out	Black-legged Kittiwake In	Black-legged Kittiwake Out
11 July					
1030		9	76	0	31
1055		3	57	0	16
1125		6	36	0	18
1155		11	60	0	6
1225		0	98	2	27
1255		4	55	1	1
1325		4	40	0	4
1355		12	32	12	14
1425		1	25	0	0
1455		6	11	6	1
1525		10	31	1	2
1555		2	44	1	14
1625		0	5	1	6
1655		0	39	0	18
1825		2	28	2	10
1855		0	9	0	3
1925		0	3	0	0
1955		0	22	0	11
2025		0	8	0	4
2055		0	22	0	17
2125		0	63	0	21
2153		0	40	0	1
	SUB-TOTAL	70	804	26	225
12 July					
0540		5	17	0	5
0555		1	8	0	2
0625		1	5	0	8
0655		1	8	0	1
0725		0	18	0	9
0755		1	21	0	5
0830		0	78	0	40
0857		0	14	0	5
0928		1	109	0	38
0955		0	186	0	47
1025		1	19	0	19
1055		0	16	0	15
1225		0	151	0	38
1255		1	116	0	27
1333		2	69	0	7
1400		4	24	0	4
1425		5	158	0	46
1507		1	35	2	21
	SUB-TOTAL	24	1052	2	337
	TOTAL	94	1856	28	562

*In : Flying in from the sea, generally torward colonies
Out: Flying seaward

Distance from Cathedral Is. (miles)	NUMBER OF BIRDS															
	Black-legged Kittiwakes								Tufted Puffins							
	flying and on water				in feeding flocks				flying and on water				in feeding flocks			
	June 22	July 12	Sept. 11	Sept. 12*	June 22	July 12	Sept. 11	Sept. 12	June 22	July 12	Sept. 11	Sept. 12	June 22	July 12	Sept. 11	Sept. 12
5 - 1	0	-	2	-	0	-	0	0	21	-	5	-	0	-	0	0
1 - 2	0	-	2	61	0	-	0	0	186	-	1	7	0	-	0	0
2 - 3	5	-	1	73	0	-	0	0	103	-	0	3	0	-	0	0
3 - 4	0	20	3	85	0	30	0	0	21	56	0	3	0	110	0	0
4 - 5	0	112	0	55	0	0	0	0	49	174	4	2	0	0	0	0
5 - 6	24	29	5	29	0	113	0	0	32	104	1	8	0	121	0	0
6 - 7	4	0	0	23	0	30	0	0	96	68	4	2	0	0	0	0
7 - 8	0	0	3	33	0	20	0	0	97	73	1	3	0	10	0	0
8 - 9	-	25	-	-	-	25	-	-	-	27	-	-	-	3	-	-

* Almost all of the Kittiwakes on 12 Sept. were flying back to the colonies.

Table 3.

Results of shipboard transects made in Sitkalidak Strait during the 1977 breeding season.

Date	Time	Weather	Wind	Seas
22 June	0930 - 1010	patchy low clouds	SKNE	1⁻ chop
12 July	1515 - 1545	patchy low clouds	----	calm
11 Sept.	1235 - 1315	clear	10-15K SE	1-3⁻ chop
12 Sept.	0630 - 0705	clear	----	1⁻ chop

Table 4.

Environmental conditions and times of the four transects made in Sitkalidak Strait during the 1977 breeding season.

Colony	Plot No.	No. Eggs		No. Chicks		No. Fledglings	
		0	1	0	1	0	1
Cathedral Is.	04	1	11	6	6	7	5
	05	6	8	9	5	11	3
	06	2	7	7	2	7	2
	07	4	16	6	14	8	12
	15	-	-	-	-	14	9
	16	-	-	-	-	10	9
	17	-	-	-	-	7	5
Total CI*	-	13	42	28	27	33	23
Amee Rock	01	8	11	11	8	12	7
Amee Is.	04	2	9	8	3	8	3
Sheep Is.	03	3	5	5	3	5	3
Total All Colonies*		26	67	52	41	58	36

* Totals do not include Cathedral Island plots 15-17.

Table 5.

The number of eggs, chicks, and fledglings in each of the 10 Tufted Puffin sample plots at Sitkalidak Strait, Kodiak Island, Alaska. 1977.

Colony	Plot #.	No. visits	total No. burrows w/ eggs	total No. burrows w/o eggs	Hatching success of known eggs (%)	Fledging success of known chicks (%)	No. young fledged per nest with eggs	No. active nests/m
Cathedral Is.	04	18	11	1	54.5	83.3	.445	.367
	05	16	8	6	62.5	60.0	.375	.471
	06	13	7	2	28.6	100.0	.286	.389
	07	18	16	4	87.5	85.7	.750	.842
	All Plots	--	42	13	64.3	85.2	.548	.571
Amee Rock	01	11	11	8	72.7	87.5	.636	.306
Amee Is.	04	15	9	2	33.3	100.0	.333	.265
Sheep Is.	03	8	5	3	60.0	100.0	.600	.208
All Colonies	--	--	67	26	61.2	87.8	.537	.427

Table 6.

Productivity of each of the seven Tufted Puffin sample plots at Sitkalidak Strait, Kodiak Island, Alaska. 1977.

STAGE	Mortality Cause	COLONY								
		Cathedral Island					Amee Is.	Amee Rock	Sheep Is.	Total
		Sample Plot				Total				
		04	05	06	07					
Egg	Disappeared or Rolled Out	2 (18.2)*	2 (25.0)	3 (42.9)	1 (6.3)	8 (19.0)	4 (44.4)	1 (9.1)	0	13 (19.4)
	Abandoned	2 (18.2)	1 (12.5)	1 (14.3)	1 (6.3)	5 (11.9)	0	0	1 (20.0)	6 (9.0)
	Infertile	1 (9.1)	0	1 (14.3)	0	2 (4.8)	2 (22.2)	2 (18.2)	0	6 (9.0)
	Total egg mort.	5 (45.5)	3 (37.5)	5 (71.5)	2 (12.6)	15 (35.7)	6 (66.6)	3 (27.3)	1 (20.0)	25 (37.4)
Chick	Starved	1** (16.6)	1 (20.0)	0	1 (7.1)	3 (11.1)	0	0	0	3 (7.3)
	Disappeared	0	0	0	1 (7.1)	1 (3.7)	0	1 (12.5)	0	2 (4.9)
	Burrow Flooded	0	1 (20.0)	0	0	1 (3.7)	0	0	0	1 (2.4)
	Total Chick mort.	1 (16.6)	2 (40.0)	0	2 (14.2)	5 (18.5)	0	1 (12.5)	0	6 (14.6)

* per-cent in parentleses

** per-cent of chicks hatched

Table 7.

The mortality in each of the seven Tufted Puffin sample plots at Sitkalidak Strait, Kodiak Island, Alaska. 1977.

Table 8.

The distribution of burrows in each range of effective depth in the seven Tufted Puffin sample plots at Sitkalidak Strait, Kodiak Island. 1977.

Colony	Plot No.	Effective Soil Depth						No. eggs disappeared or rolled out	
		0-25	25-50	50-75	75-100	100-150	150		
Cathedral Is.	04	0	1 (9.1)	4 (36.4)	4 (36.4)	1 (9.1)	1 (9.1)	2 (18.2)	11
	05	2 (25.0)	1 (12.5)	2 (25.0)	2 (25.0)	0	1 (12.5)	2 (25.0)	8
	06	0	2 (28.6)	0	1 (14.2)	2 (28.6)	2 (28.6)	3 (42.9)	7
	07	0	1 (6.2)	1 (6.3)	1 (6.3)	5 (31.3)	8 (50.0)	1 (6.3)	16
Amee Rock	01	0	1 (9.1)	0	2 (18.2)	1 (9.1)	7 (63.7)	1 (9.1)	11
Amee Island	01	0	4 (44.4)	3 (33.3)	1 (11.1)	1 (11.1)	0	4 (44.4)	9
Sheep Island	01	0	4 (80.0)	1 (20.0)	0	0	0	0	5
Total all colonie		2	14	11	11	10	19	13 (19.4)	

* per-cent in parentleses

Table 9.

Number of Tufted Puffin burrows at each effective soil depth in which the eggs disappeared or rolled out. ($\Sigma 5.03$; $X^2=11.07$)

Effective Soil Depth					
0 - 25 n = 2	25 - 50 n = 14	50 - 75 n = 11	75 - 100 n = 11	100 - 150 n = 10	> 150 n = 19
0	6 (42.9)*	1 (18.2)	4 (33.3)	2 (25.0)	2 (10.0)

* per-cent of total number of burrows at each soil depth.

Table 10.

A summary of the food items taken by Tufted Puffin chicks and adults at Sitkalidak Straits, Kodiak Island, Alaska, during the 1977 breeding season. Stomachs: n=34; bill loasds and food left in burrows: n=56; total no. prey items, adults = 342; total no. prey items, chicks = 332.

FOOD ITEMS	% frequency of occur.			% total numbers			% total weight
	chick	adult	combined	chick	adult	combined	chick
Capelin	75.0	82.4	77.8	64.9	93.3	79.5	58.5
Sand Lance	37.5	2.9	24.4	25.8	.3	12.6	23.0
Pacific Sandfish	14.2	0	8.9	3.1	0	1.5	6.0
Walleye Pollock	14.3	2.9	10.0	3.7	1.5	2.6	5.1
Sockeye Salmon	8.9	0	5.5	1.6	0	.8	6.5
Gadidae	0	2.9	1.1	0	.3	3.2	0
Cephalopoda	1.8	8.8	3.3	.3	3.2	1.8	.3
Octopoda	1.8	0	1.1	.6	0	.3	.4
Polychaeta	0	2.9	1.1	0	.3	.2	0
Decapoda (shrimp)	0	5.8	2.2	0	.6	.4	0

Table 11. The total stomach content weight of prey species taken by adult Tufted Puffins in Sitkalidak Strait during the 1977 breeding season.

Capelin 563.5g (97.9%)

Sand Lance....... 12.0g (2.1%)

Table 12.

Frequency of occurrence of food items in adult Tufted Puffins collected at Sitkalidak Strait, Kodiak Island, Alaska. 1977

TIME PERIOD	PREY SPECIES						
	Cape-lin	Sand Lance	Walleye Pollock	Gadidae	Poly-chaeta	Cephal-opoda	Decapoda (shrimp)
01-15 June (n=6)	5 (83.3)*				1 (16.7)	1 (16.7)	
16-30 June (n=8)	8 (100.0)						
01-15 July (n=4)	3 (75.0)					1 (25.0)	
16-31 July (n=4)	4 (100.0)						1 (25.0)
01-15 Aug. (n=5)	4 (80.0)	1 (20.0)					
16-31 Aug. (n=4)	3 (75.0)		1 (25.0)			1 (25.0)	
01-15 Sept. (n=3)	2 (66.7)			1 (33.3)			
Total	29 (85.3)	1 (2.9)	1 (2.9)	1 (2.9)	1 (2.9)	3 (8.8)	1 (2.9)

*per-cent frequency of occurrence in parenthesis

Table 13.

Per-cent frequency of occurrence of various types of regurgitations from Black-legged Kittiwake chicks as they changed with time.

Time Period	Regurgitation Composition							
	Sand Lance Only	Caplein Only	Other Only	Sand Lance & Capelin	Sand Lance & Other	Capelin & Other	Other Mixed	Total Mixed
10-20 July	14.3	71.4	--	14.3	--	--	--	14.3
21-31 July	11.8	76.5	5.9	5.9	--	--	--	5.9
01-09 Aug.	38.1	42.9	4.8	14.3	--	--	--	14.3
10-19 Aug.	26.3	26.3	--	36.8	5.3	5.3	--	47.4
20-31 Aug	36.4	18.2	9.1	18.2	--	4.5	13.6	36.3
01-08 Sept	38.9	5.6	5.6	11.1	5.6	22.2	11.1	50.0

Table 14.

Per-cent frequency of occurrence of various types of Tufted Puffin burrow loads as they changed between 21 August and 05 September, 1977.

Time Period	Sample Size	Burrow-load Composition			
		Capelin Only	Sand Lance Only	Capelin Mixed	Other Mixed
21-25 Aug.	20	45.0	5.0	40.0	10.0
26-31 Aug.	15	33.3	6.7	53.3	6.7
01-05 Sept.	6	16.7	16.7	33.3	16.7

Chick Age (days)	22 August							23 August							Total wt. both days
	Loads 0700-1300			Loads 1300-2130			Total	Loads 0700-1300			Loads 1300-2100			Total	
	wt. (grams	Species	No.	wt. (grams	Species	No.	wt. (grams)	wt. grams	Species	No.	wt. grams	Species	No.	wt. (gram)	
43	—	—	—	—	—	—	—	17.5	Sockeye Pollock Sand Lan.	1 1 1	0	—	—	17.5	—
42	9.3	Pollock Capelin	1 1	17.8	Capelin Octopus	4 2	27.1	—	—	—	—	—	—	—	—
31	21.1	Capelin	7	0	—	—	21.1	29.0	—	—	10.5	Capelin	3	39.5	70.6
30	17.3	Capelin Tricodon	3 1	0	—	—	17.3	0	—	—	10.0	Capelin	3	10.0	27.3
28	47.3	Capelin Pollock	10 2	0	—	—	47.3	0	—	—	0	—	—	—	47.3

Table 15.

A summary of food brought to Tufted Puffin chicks on 22 and 23 August, 1977. Cathedral Island Colony, Sitkalidak Straits.

Chick Age (days)	1400 Aug. 24 - 1400 Aug. 25			1400 Aug. 25 - 1400 Aug. 26			Total both days (grams)
	weight (grams)	Species	No.	weight (grams)	Species	No.	
33	25.5	Capelin	3	—	—	—	—
40	0	—	—	—	—	—	—
40	0	—	—	—	—	—	—
18	67.0	Capelin Sand Lance	11 7	113.5	Capelin Sand Lance	15 16	180.5
19	95.7	Capelin Sand Lance	18 10	9.5	Capelin Sand Lance	3 1	105.2
37	13.0	Capelin	1	—	—	—	—
29	0	—	—	0	—	—	0
28	98.7	Capelin Sand Lance Sockeye	18 1 1	40.7	Sockeye Pollock Capelin	1 1 1	139.4

Table 16.

A summary of food brought to Tufted Puffin chicks between 1400 August 24 and 1400 August 26, 1977. Cathedral Island Colony, Sitkalidak Strait.

Chick Age (days)	1400 Aug. 25 - 1400 Aug. 26			1400 Aug. 26 - 1400 Aug. 27			Total both days (grams)
	weight (grams)	Species	No.	weight (grams)	Species	No.	
28	11.2	Capelin	3	0	—	—	11.2
31	18.6	Capelin Squid	3 1	—	—	—	—
23	74.5	Sand Lance Capelin	16 15	4.3	Sand Lance	1	78.8
19	10.3	Capelin Sand Lance	2 2	32.8	Capelin Sand Lance	3 3	43.1
35	10.3	Capelin	3	25.9	Sand Lance Capelin	6 1	35.2
34	8.3	Capelin	2	0	—	—	8.3

Table 17.

A summary of the food brought to Tufted Puffin chicks between 1400 August 25 and 1400 August 27, 1977. Cathedral Island Colony, Sitkalidak Straits.

Table 18.

Daily weight change in two Tufted Puffin chicks in the latter part of the nestling period. Sitkalidak Strait, Kodiak Island, Alaska. 1977.

Date	Chick No.	
August	8	9
22	+17.3g*	+47.3g*
23	+10.0g*	0g*
24-25	-32g	+39g
25-26	-14g	+15g
27	-14g	+55g
28	+91g	+87g
29	+32g	-16g
30	+16g	+37g

* weight of food left in burrow, not actural change in body weight.

Table 19.

Frequency of Tufted Puffin adults returning to the colony with bill loads at various times on 23 August, 1977.

Time	Length of Observation	No. adults with bill loads
0715	1 min.	22
0730	1 min.	19
0900-1400	—	Very few
1400-1800	—	Very few
1815	5 min.	14
1915	5 min.	7
2015	5 min.	19

Species	May-June		June		July		August		Sept.		Oct. - Nov.	
	Bays fjord	shelf	Bays fjord	shelf	Bays fjord	shelf	Bays fjord	shelf	Bays fjord	shelf	Bays fjords	shelf
Tufted Puffin	4.5	5.3	16.7	3.6	18.5	5.2	18.6	3.2	1.3	5.0	0.1	0.3
Black-Legged Kittiwake	3.5	4.4	5.9	1.9	17.1	2.5	11.8	0.6	11.1	0.7	2.4	0.9

Table 20.

Mean numbers of Tufted Puffins and Black-legged Kittiwakes per km^2 in Ugak and Sitkalidak bays and fjords and the adjacent shelf and trenches between 23 May and 14 November, 1977. Data Based on Shipboard transects made by USFWS personnel for RU337.

Table 21.

Mean habitat variables of Black-legged Kittiwake nests in the four sample plots of the Cathedral Island Colony, Sitkalidak, 1977.

Variable	Sample Plot							
	CI 01		CI 02		CI 03		LKWR 01	
	mean	SD	mean	SD	mean	SD	mean	SD
Nearest neighbor distance (cm)	69.8	47.3	53.6	19.6	62.3	22.1	52.0	36.8
Horizontal distance to water (m)	5.06	4.67	1.01	.59	2.57	1.75	5.83	3.23
Nest width (cm)	22.1	3.3	23.6	4.2	25.0	6.6	23.8	6.1
Slope (degrees)	65.9	7.3	69.1	3.7	71.2	6.1	71.5	10.2
Size adjacent ledge (see code)	1.14	1.97	.82	1.59	1.52	1.91	2.15	1.88
Heigth above water (m)	5.12	.99	4.09	1.07	2.48	.87	7.26	2.40

Size adjacent ledge code:

0. no ledge
1. Length and depth both less than that of nest.
2. Length less than but depth greater than that of nest.
3. Length greater than but depth less than that of nest.
4. Lenght and depth both greater than that of nest.

Table 22.

Correlation coeffecients of habitat variables with the mean nearest neighbor distance of Black-legged Kittiwake nests. Sitkalidak, 1977.

Variable	Sample Plot			
	CI 01	CI 02	CI 03	LKWR 01
Slope	-.34	.03	.28	.22
No. eggs	-.17	.05	-.38	-.01
Week laid	.24	.06	.45	.13
Ledge width	.15	.34	.05	.24
Distance of top	-.20	-.30	-.31	.15
Ht. above water	-.65	.02	-.28	-.26
Horizontal distance to water	.75	-.11	.09	-.17

Table 23.

Correlation coeffecients of habitat variables with week of clutch initiation of Black-legged Kittiwake nests. Sitkalidak, 1977.

Variable	Sample Plot			
	CI 01	CI 02	CI 03	LKWR 01
Slope	-.63	-.21	.36	-.01
No. eggs	.25	--	.13	.22
Ledge width	-.30	-.20	-.15	-.21
Distance of top	-.44	-.20	-.36	.11
nearest neighbor dis	.24	.06	.45	.13
Horizontal distance to water	.54	.25	-.37	.03

Table 24.

Correlation coeffecients of habitat variables with clutch size of Black-legged Kittiwake nests. Sitkalidak, 1977.

Variable	Sample Plot			
	CI 01	CI 02	CI 03	LKWR 01
Slope	-.05	-.27	-.20	.44
Ledge width	-.09	.22	-.10	-.03
Distance to top	-.17	.28	.01	.19
nearest neighbor dis	-.17	.05	-.38	-.01
Week laid	.25	--	.13	.22
Horizontal distance to water	.17	-.26	.15	-.09

Table 25.

Correlation coeffecients of habitat variables with the number of chicks hatched in Black-legged Kittiwake nests. Sitkalidak, 1977.

Variable	Sample Plot			
	CI 01	CI 02	CI 03	LKWR 01
Slope	-.38	-.38	.40	.39
Week laid	.81	.29	.64	.02-
Ledge width	.03	.28	-.18	.04
Distance to top	-.54	.26	-.27	.09
Ht. above water	.15	-.36	.27	.08
Horizontal distance to water	.61	-.23	-.16	-.14
Nearest neighbor dis	.20	.17	-.02	.06

Table 26.

Correlation coeffecients of habitat variables with the per-cent of chicks fledged (No. chicks fledged/No. of chicks hatched) in Black-legged Kittiwake nests. Sitkalidak, 1977.

Variable	Sample Plot		
	CI 01	CI 03	LKWR 01
Slope	-.58	.33	.05
Ledge width	.22	.18	-.10
Distance of top	-.39	.21	-.16
Ht. above water	.23	-.13	.07
Horizontal distance to water	.16	.19	.13
Nearest neighbor dis	-.08	.08	-.04

Table 27.

Productivity of each of the Black-legged Kittiwake sample plots at the Cathedral Island Colony, Sitkalidak Strait, Kodiak Island, Alaska. 1977

Plot No.	No. visit	Total No. nests		Hatching success of known eggs (%)	Fledging success of known chicks (%)	No. young fledged per nest with eggs (%)	No. young fledged per nest started (%)	No. nests/ m^2
		with eggs	with out eggs					
CI 01	19	16	5	47.8	81.8	.563	.430	.182
CI 02	17	20	5	77.8	71.4	1.11	.800	.923
CI 03	19	20	6	55.6	86.7	.650	.500	.535
LKWR 01	18	58	6	76.2	73.6	.983	.920	.254
Total all Plots	--	114	22	70.2	76.5	.849	.740	--

Table 28.

The number of eggs, chicks, and fledgings in each of the four Black-legged Kittiwake sample plots at the Cathedral Island Colony, Sitkalidak Strait, Kodiak Island, Alaska. 1977.

Plot No.	No. eggs				No. chicks			No. fledglings		
	0	1	2	3	0	1	2	0	1	2
CI 01 *	5	9	7	0	14	4	3	14	5	2
CI 02 **	5	4	16	0	8	5	12	10	9	6
CI 03 ***	6	13	7	0	15	7	4	15	8	3
LKWR 01	6	12	45	1	15	20	29	20	29	15
Total	22	38	75	1	52	36	48	59	51	26

* includes 5 relays which are considered here as separate nests.
** includes 1 relay
*** includes 3 relays

Table 29.

The mortality in each of the four Black-legged Kittiwake sample plots at the Cathedral Island Colony, Sitkalidak Strait, Kodiak Island, Alaska. 1977. Egg mortality per-cent based on total number of eggs laid. Chick mortality based on number of chicks hatched.

STAGE	Mortality Cause	Sample Plot				
		CI 01	CI 02	CI 03	LKWR 01	Total
EGG	Avian Predation	10	0	11 (40.7)	3 (2.9)	24 (12.6)
	Exposure to Storm	0	0	1 (3.7)	8 (7.6)	9 (4.7)
	Infertile	2 (8.7)	1 (2.8)	0	8 (7.6)	11 (5.8)
	Disappeared	1	4 (11.1)	0	4 (3.8)	9 (4.7)
	Other	0	2 (5.6)	0	4 (3.8)	6 (3.1)
	Total egg mortality	13 (56.5)	7 (19.4)	12 (44.4)	27 (25.7)	59 (30.9)
CHICK	Avion Predation	0	0	0	1 (1.3)	1 (.8)
	Exposure to Storm	2 (20.0)	2 (6.9)	1 (6.7)	10 (12.8)	15 (11.4)
	Disappeared	0	2 (6.9)	0	8 (10.3)	10 (7.6)
	Starved **	0	2 (6.9)	0	0	2 (1.5)
	Other	0	2* (6.9)	1* (6.7)	0	3 (2.3)
	Total chick mortality	2 (20.0)	8 (27.6)	2 (13.3)	19 (24.4)	31 (23.5)

* caused by our own disturbance

** both of these chicks were out of the nests and unable to reach the parents bringing in food.

Table 30.

A summary of the food items taken by Black-legged Kittiwake chicks and adults at Sitkalidak Straits, Kodiak Island, Alaska, during the 1977 breeding season. Stomachs: n=22; regurgitations: n=108; total no. prey items, stomachs = 82; total no. prey items, regurgitations = 425.

FOOD ITEMS	% frequency of occurrence			% total numbers		
	chick	adult	combined	chick	adult	combined
Cap	59.3	63.6	60.0	42.2	52.4	43.7
Sand Lance	50.0	9.1	43.1	43.6	3.7	37.9
Walleye Pollock	7.4	13.6	8.5	3.8	3.7	3.1
Pacific Sandfish	2.8	0	2.3	1.0	0	1.0
Sockeye Salmon eggs & milt	4.6	0	3.1	4.3*	0	3.5
Pandalopsis	6.5	18.2	8.5	5.2	36.6	10.2
Decapoda (shrimp)	0	4.5	.8	0	1.2	.2
Polychaeta	0	4.5	.8	0	2.4	.4

* For comparitive purpose, 4g considered to be equivalent to one prey item.

Table 31. The per-cent of the total weight of each prey species found in the stomachs of Black-legged Kittiwake adults collected at Sitkalidak Straits, Kodiak Island, Alaska. 1977.

FOOD ITEMS	% TOTAL WEIGHT
Capelin	55.2
Sand Lance	4.0
Walleye Pollock	3.1
Pandalopsis	37.3

Table 32.

Frequency of occurrence of food itmes in adult Black-legged Kittiwakes collected at Sitkalidak Straits, Kodiak Island, Alaska. 1977.

Time Period (sample size)	PREY SPECIES					
	Capelin	Sand Lance	Walleye Pollock	Pandalopsis	Decapoda (Shrimp)	Polychaeta
01-15 June (n=3)	2				1	
16-30 June (n=3)	3					
01-15 July (n=4)	3	1				
16-31 July (n=2)	2					
01-15 Aug. (n=3)	3					
16-31 Aug. (n=3)	1	1				1
01-15 Sept. (n=4)			3	4		
TOTAL (n=22)	14	2	3	4	1	1
% frequency of occurrence	63.6	9.1	13.6	18.2	4.5	4.5

Table 33.

Summary of feeding frequencies and weight change during a 16-hour watch of 6 Black-legged Kittiwake nests on 11 August 1977, at Sitkalidak Strait.

Chick No.	Age (days)	0600 - 0900			0900 - 1200			1200 - 1500			Total 0600 - 1500			Total No. Feedings 0600-2100
		A	B	C	A	B	C	A	B	C	Δ wt.	Total wt + regurg.	No. Feedings	
19	32	-19	0	0	+10	0	1	0	0	0	-9	-9	1	1
20	28	+7	0	1	-1	0	1	+25	0	1	+31	+31	3	4
21	13	-5	15	1	+8	0	1	+9	0	1	+12	+27	3	5
47a	32	-6	0	0	-1	0	0	+7	17	1	0	+17	1	2
47b	28	+10	0	1	+22	0	1	+9	0	1	+41	+41	3	4
59	28	+4	0	1	-7	0	0	+29	0	2	+20	+20	3	3
60a	28	+9	0	1	-2	0	0	+10	0	1	+17	+17	2	3
60b	28	+25	0	1	-12	0	0	-4	15	1	+9	+24	2	3

Column A: Change in body weight in grams during the 3-hour period under consideration.
Column B: Weight, in grams, of any regurgitations occurring during the last weighing.
Column C: Number of feedings during the 3-hour period under consideration.

Table 34.

Summary of feeding frequencies and weight change during two consecutive 15-hour watches of five Black-legged Kittiwake nests on 22-23 August 1977, at Sitkalidak Strait.

Chick No.	Age (days)	Δ Body wt. + regurg. wt. on 22 Aug. (grams)	No. feed-ings 22 Aug.	Δ Body wt. + regurg. wt. on 23 Aug. (grams)	No. feed-ings 23 Aug.	Total Δ Body wt. + regurg. 22-23 Aug.	Total No. Feedings 22-23 Aug.
1a	23	+56.0	4	-17.5	2	+38.5	6
1b	19	-3.5	3	+9.5	3	+6.0	6
2	22	-11.0	2	-10.0	1	-21.0	3
3a	23	-25.0	3	+17.8	4	-7.2	7
3b	22	+13.0	4	-3.0	3	+10.0	7
4a	24	-1.0	4	+28.0	4	+27.0	8
4b	22	+4.0	4	+22.5	4	+26.5	8
6	19	+6.0	2	+28.0	3	+34.0	5

Table 35

Fate of gull nests, Sheep Island, 1977

Species	Date 1st	Egg Clutch Size	Date Egged	Relay	New Size	Clutch Fate
GWGU	6-10 June	1	6-22 June	no	0	0 hatch
GWGU	6-10 June	3	10-16 June	yes 1-15 July	2	2 fledge
GWGU	22 June	2	---	---	---	1 hatch 24 July
MEGU	6-10 June	3	10-16 June	no	0	0 hatch
MEWGU	6-10 June	0				
MEGU	6-10 June	0				
MEGU	6-10 June	0				

Table 36

Habitat Parameters, Glaucous-winged Gulls, Sitkalidak Strait 1977.

Parameter	Colonial Sites Amee Rock	Colonial Sites LKWR	Solitary Sites Vertical	Solitary Sites Horizontal
Vegetation height	65 cm	18.3 cm	26 cm	68 cm
Vegetation cover	80%	20%	31%	72%
Slope	4°	17°	16°	8°
Nearest neighbor distance	310	250	670	565
Density (active nests per dekameter)	8	8.5	2.5	1

Table 37.

Causes of mortality, Solitary-type Glaucous-winged Gulls Sitkalidak Strait 1977

Cause of Mortality: eggs	Type of Plot	Percent Mortality
Infertile	Horizontal	0
	Vertical	3.3%
Disappeared - probably egged	Horizontal	18.2%
	Vertical	3.3%
Died pipping	Horizontal	0
	Vertical	3.3%
Shell Damage	Horizontal	9.1%
	Vertical	6.7%
Avian Predation	Horizontal	0
	Vertical	3.3%
Total	Horizontal	27.3%
	Vertical	20.0%

Table 38.

Causes of Mortality, Colonial and Solitary-nesting Glaucous-winged Gulls, Sitkalidak Strait 1977.

Cause of Mortality	Colony Type	Percent Mortality	Cause of Mortality	Colony Type	Percent Mortality	Cause of Mortality	Colony Type	Percent Mortality
Rolled out	Colonial	4.7%	Died pipping	Colonial	4.5%			
	Solitary	0		Solitary	2.4%			
Egg disappeared	Colonial	4.8%	Avian predation (Egg)	Colonial	4.5%			
	Solitary	4.9%		Solitary	2.4%			
Shell damage	Colonial	2.4%						
	Solitary	7.3%						
Egg died	Colonial	2.4%	Chick Starved	Colonial	2.4%			
	Solitary	0		Solitary	0			
Infertile	Colonial	3.5%	Chick fell overcliff	Colonial	4.8%			
	Solitary	2.4%		Solitary	0 %			
Egged	Colonial	0	Total	Colonial	34.0%			
	Solitary	22 %		Solitary	41.4% (19.4% minus egging)			

Table 39.

Reproductive success, Glaucous-winged Gulls Horizontal Plots, Cathedral Island

Plot	Attempted nests	Successful nests (%)	$\bar{x}$ eggs laid per attempted nest	$\bar{x}$ eggs laid successful nest	$\bar{x}$ chicks hatched per successful nest (%)	Min. chicks fledged per successful nest	Max. chicks fledged per successful nest	Max. chicks fledged per attempted nest
G-1	6	5 (83.3%)	1.67	2.0	2.0 (55.5%)	0	1.0	0.83
G-3	5	1 (20%)	0.5	2.0	1.0 (50%)	0	1.0	0.20
G-5	5	0 (0%)	0	0	0 (0%)	0	0	0
Total	16 (including G-5)	6 (37.5%)	1.09	2.0	1.16 (58%)	0	1.0	0.55

Table 40.

Reproductive success, Glaucous-winged Gulls Vertical Plots, Cathedral Island

Plot	Attempted Nests	Successful Nests	$\bar{x}$ Eggs Laid per Attempted Nest	$\bar{x}$ Eggs Laid per Successful Nest	$\bar{x}$ chicks hatched per successful nest (%)	Min. Chicks Fledged per successful nest	Max. Chicks fledged per successful nest	Max.fledged per attempted nests
G-2	3	2 (66.7%)	1.67	2.5	2.0 (80%)	0	2.0	1.33
G-4	10	3 (30%)	0.06	2.0	1.0 (33.3%)	0	1.0	0.2
G-6	8	5 (62.5%)	1.25	2.0	2.0 (100%)	0.33	2.0	1.25
G-7	8	6 (75%)	2.0	2.67	2.16 (180%)	0	2.16	1.62
Total	29	16 (55.7%)	1.28	2.31	1.86 (67.5%)	0.06	1.8*	1.0

*includes 2 nests still with eggs on last visit

Table **41.**

Reproductive success, Glaucous-winged Gulls. Lesser Kittiwake Rock.

Attempted No. nests	Successful nests (%)	$\bar{x}$ eggs laid per attempted nest	$\bar{x}$ eggs laid per successful nest	$\bar{x}$ chicks hatched per successful nest (%)	Min. chicks fledged	Max. chicks fledged	Max. chicks fledged per attempted nest
22	16 (72.7%)	1.91	2.8	2.06 (73.6%)	1.73	1.88	1.36

Table **42.**

Reproductive success, Glaucous-winged Gulls, Amee Rock.

Attempted Nests	Successful nests	$\bar{x}$ eggs laid per attempted nest	$\bar{x}$ eggs laid per successful nest % successful	$\bar{x}$ chicks hatched per successful nest	Min. chicks fledged	Max. chicks fledged	Max. chicks fledged per attempted nest
22	16 (72.7%)	1.91	2.78	1.69 (70.4%)	1.0	1.56	1.13

Table 43.

Growth rates of the solitary Cathedral Island Glaucous-winged Gull colonies - by date - 1977.

Date	Mean chick weight in grams Horizontal	Vertical
9 July		76.5
13 July	79	107.2
17 July		103.9
20 July		256.5
21 July	135.7	152.8

Table 44.

Growth rates of the colonial Glaucous-winged Gull colonies - by date 1977.

Date	Mean chick weight in grams LKWR	Amee Rock
18 June		
29 June		300
3 July		155.6
5 July		89.6*
9 July	149.4	
13 July	210	
17 July	255.4	
21 July	259.1	
22 July		788.5
24 July	372.8	
28 July		
29 July	469.5	767.4
1 August		732.4
4 August	702.1	
5 August	915	
8 August	850.5	1148
14 August	876.2	
18 August	962.3	
24 August	450*	
27 August	631*	
5 September	822*	

*new chick included

Table 45.

Mean weights of Glaucous-winged Gull chicks by ages 1977

Age	Solitary nesters Horizontal	Solitary nesters Vertical	Colonial nesters LKWR	Colonial nesters Amee Rock
0	73.5		70	59
1			85	87.5
2		100		
3			107	110
4			100	110.5
5			205.5	159
6		192		
7			210	
8		239	308	
11			315	
13			480	
14			443.5	
18				775
19			630	
20			680	
22				854
23			890	
24			760	990
26				890
29			1045	
30			1020	
32				1125
33				1080
35			1012	

Table 46

Prey Composition, Glaucous-winged Gull chick Regurgitations, Sitkalidak Strait 1977

Prey Species	Frequency of Occurrence	Mean Total Length
Mallotus villosus	78%	102.4 cm
Ammodytes Hexapterus	23%	153.5 cm
Unidentified fish	56%	--
Mussel	11%	9 mm
Tube Worm	11%	--

Table 47. Census figures of Glaucous-winged Gulls, Sitkalidak Strait. Breeding birds only.

Colony	1976 # birds counted	1977 # birds counted
Sheep Island	50	50
Cub Island	100	10
Amee Island	200	60
Amee Rock	--	36
Nut Island	60	40
Cathedral Island	200	660
Granite Islands	120	36
Lesser Kittiwake Rock	--	32
Cormorant Head	--	16
Total	610	940

Table 48.

Times of tern mortality: all colonies. Sitkalidak Strait, 1977.

$\overline{x}$ date	Species	N	% mortality
29 May - 4 June	---	--	---
5 - 11 June	Arctic	2	1.63%
	Aleutian	4	8.33
12-18 June	Arctic	2	1.63
	Aleutian	2	4.17
19-25 June	Arctic	5	4.07
	Aleutian	2	4.17
26 June-2 July	Arctic	10	8.13
	Aleutian	3	6.25
3-9 July	Arctic	9	7.32
	Aleutian	1	2.08
10-16 July	Arctic	7	5.69
	Aleutian	3	6.25
17-23 July	Arctic	2	1.63
	Aleutian	--	--
24-30 July	Arctic	1	0.81
	Aleutian	3	6.25
31 July-6 August	--	--	--
7-13 August	Arctic	--	--
	Aleutian	1	2.08
14 Aug-3 September	---	--	--

Table 49.

Growth rates in the Sheep Island Tern Colony - by date. 1977

Date	Mean chick weight in grams Arctic Tern	Aleutian Tern
27 June	17	-
30 June	22.8	23.7
10 July	23.7	22
15 July	72.3	28.8
19 July	85.6*	95.8
25 July	108	90.2
30 July	89.7*	116.5
6 August	114	102.4
13 August	-	113

*includes newly hatched chick

Table 50.

Growth rates in the Amee Island Tern Colony - by date. 1977

Date	Mean chick weight in grams Arctic Tern	Aleutian Tern
26 June	27	28.3
28 June	30	20
1 July	85	24
4 July	323?	53
10 July	128?	98.3
15 July	118	53.3*
19 July	-	29.3*
23 July	-	53.7*
28 July	98	69 *
1 August	-	95
6 August	-	113
8 August	-	100
16 August	-	87.5
18 August	-	97
19 August	-	97.2

*includes 1-2 day old chick

Table 51.

Growth rates of the Cub Island Arctic Tern Colony - by date. 1977

Date	Mean chick weight in grams
28 June	15.3
1 July	14.0
4 July	53.0
15 July	111.0

Table 54. Growth rates in terns: Sheep Island colony, 1977.

Age	Chick Weight in Grams	
	Arctic Terns	Aleutian Terns
0	14	15
1	27.5	20
2		25
4	30.2	
6		43
8	67	
13		99
21	107.5	
26		117
27		127

Table 55. Growth rates in terns: Amee Island colony, 1977.

Age	Chick weight in Grams	
	Arctic Terns	Aleutian Terns
0	15	14
1	18	21
2	23	28
3		20
4		34
5		47
6	56	
8		60
10		85
13		111
17		125
18		118

Table 56.

Growth rates in Cub Island Arctic Terns - by age. 1977

Age in days	Chick weight in grams
0	14
1	18
2	14
7	31
18	136

Table 57. Reproductive Success, Arctic and Aleutian Terns, Sitkalidak Strait 1977

Species	Colony	$\bar{x}$ Number Eggs Laid	$\bar{x}$ Number Chick hatched	Min. $\bar{x}$ No. Fledged	Max. $\bar{x}$ No. Fledged	$\frac{\bar{x}\ \text{hatch}}{\bar{x}\ \text{laid}}$ x 100%	$\frac{\bar{x}\ \text{min.fledge}}{\bar{x}\ \text{hatch}}$ x 100%	$\frac{\bar{x}\ \text{max.fledge}}{\bar{x}\ \text{hatch}}$ x 100%
Arctic Tern	Cub Island	2.35	1.12	0.05	0.78	43%	[illegible]2%	52%
Arctic Tern	Amee Island	1.7	0.7	0.37	0.75	47%	38%	62%
Arctic Tern	Sheep Island	2.1	1.9	0.41	1.66	84%	20%	83%
Aleutian Tern	Amee Island	1.6	1.1	0.38	1.0	73%	23%	62%
Aleutian Tern	Sheep Island	1.6	1.0	0.21	0.83	57%	10%	47%
Arctic Tern	All	2.05	1.24	0.28	1.06	58%	20%	65.6%
Aleutian Tern	All	1.6	1.05	0.30	0.92	65%	16.5%	54.5%

Correlation Matrices
Arctic and Aleutian Terns
Sitkalidak Strait 1977

Table 58. Amee T-1 - Aleutian Terns

	Week laid	Dist. Edge	Total Vigetation laying	Total Vigetation hatching	slope	NN Dist.
# Eggs laid	-0.605	-0.707	-0.127	+0.559	-0.133	
# Chicks hatch	-0.309	-0.694	-0.236	+0.004	-0.417	
Min. # chicks fledge	-0.352	-0.163	0.317	+0.443	-0.309	
Max. # chicks fledge	-0.214	-0.435	-0.428	+0.004	-0.274	
% chicks hatch	-0.049	-0.694	-0.236	-0.744	-0.557	
Min. % chicks fledge	-0.37	0.13	0.286	0.67	-0.252	
Max. % chicks fledge	-0.214	-0.435	-0.428	0.004	-0.224	

Table 59. Amee T-1 - Arctic Terns

	Week laid	NN Dist	Dist Edge	Total Vegetation laying	Total Vegetation hatching	slope
# Eggs laid	-0.342	-0.373	0.540	-0.089	0.120	0.640
# Chicks hatch	-0.114	-0.628	0.512	0.281	-0.046	0.059
Min. # fledge	-0.078	-0.036	0.106	0.555	0.304	0.170
Max. # fledge	-0.114	-0.628	0.512	0.281	-0.046	0.059
% chick hatch	0.043	-0.410	0.257	0.430	-0.222	-0.304
Min. % fledge	-0.078	-0.036	0.106	0.555	0.304	0.170
Max. % fledge	-0.234	-0.333	0.471	0.610	0.089	0.069

Correlation Matrices
Arctic and Aleutian Terns
Sitkalidak Strait 1977

Table 60. Sheep Island - Aleutian Terns

	Week laid	NN Dist.	Dist. edge	Total laying	Vegetation hatching	slope
# Eggs laid	-0.231	-0.109	0.010	-0.278	0.790	0.023
# Chicks hatch	0.355	-0.031	0.087	-0.209	0.645	0.075
Min. # fledge	0.133	-0.077	0.160	-0.038	-	-
Max. # fledge	0.319	-0.045	0.201	-0.400	0.522	0.245
% Chicks hatch	0.471	-0.039	-0.044	-0.214	0.005	-0.064
Min. % fledge	0.111	-0.077	0.135	-0.066	-	-
Max. % fledge	0.419	0.055	0.211	-0.394	0.333	0.278

Table 61. Correlation Matrix

Sheep Island Arctic terns

	Week laid	NW Dist.	Dist Edge	Total Lay	Veg. Hatch	Slope
# Eggs	-0.106	0.221	-0.071	-0.138	0.100	0.538
# Hatch	-0.091	0.468	-0.050	0.090	0.137	0.456
Min. fledge	-0.226	-0.045	0.198	0.067	-0.396	0.080
Max. fledge	-0.154	0.559	-0.023	0.089	0.34	0.393
% hatch	-0.032	0.575	-0.060	0.185	0.117	0.245
Min. % fledge	-0.260	-0.037	0.181	0.066	-0.396	0.021
Max. % fledge	-0.144	0.344	-0.052	-0.043	0.168	0.155

Table 62. Correlation Matrix

Cub Island Arctic terns

	Week laid	NW Dist.	Dist Edge	Total Lay	Veg. Hatch	Slope
# Eggs	-0.177	0.244	0.092	0.095	0.145	0.049
# Hatch	0.340	0.235	0.434	-0.377	0.137	-0.274
Min. fledge	-0.114	-0.019	0.294	-0.160	-0.245	-0.189
Max. fledge	0.533	-0.417	0.133	-0.413	0.278	-0.004
% hatch	0.475	0.094	0.397	-0.424	0.101	-0.278
Min. % fledge	-0.114	-0.019	0.294	-0.160	-0.245	-0.189
Max. % fledge	0.377	-0.365	0.094	-0.329	0.265	0.131

Table 63. Feeding behavior and nest-site attendance, Arctic and Aleutian Terns. Amee Island, Sitkalidak Strait, 1977.

TIME	SPECIES	$\bar{X}$ NUMBER FEEDINGS PER DAY	$\bar{X}$ PERCENT SUCCESSFUL FEEDINGS	$\bar{X}$ INTERVAL BETWEEN FEEDINGS	$\bar{X}$ NUMBER CHASES PER DAY	$\bar{X}$ DURATION OF CHASE (minutes)
Early Brooding (6-7 July)	Arctic	2.0	50.%	161.8	0	0
	Aleutian	3.4	34.6 %	21.7	2.8	2.4
Late Brooding (18 July)	Arctic	4.25	73.9 %	75.6	0	0
	Aleutian	3.14	—	371.0	—	7.
Fledging (19 Aug)	Aleutian	3.0	75 %	55.1	4.	15.

Table 64.

Comparisons in nest attentiveness of Arctic and Aleutian Terns, Sitkalidak Strait 1977.

Species	Contents of Nest	Early brooding Stage		Late Brooding Stage		Fledging Stage
		x No. Visits	x % Time on Nest	x No. Visits	x % Time on Nest	x No. Visits
Arctic	Egg	15.75	25.8	21	8.14	---
	Chick	15.75	16.3	5	---	---
Aleutian	Egg	6.0	31.1	---	---	---
	Chick	8.0	11.4	---	---	3.0

Table 65.

Prey Composition, Arctic Terns, Sitkalidak Strait, 1977.

Month	Age	Prey Species	Relative Frequency	$\bar{x}$ weight	% of body weight	% frequency occurrence	$\bar{x}$ total length	Relative volume	grams x vol.
June	Adults	M. villosus	100%	3.2 g	2%	80%	86.8 mm	100%	320
		empty	--	--	--	20%	--	--	--
July	Adults	M. villosus	14%	1.05 ḡ	--	25%	95.9 mm	33.3%	34.97
		A. hexapterus	57%	--	--	13%	--	17 %	--
		Unid. fish	21%	0.1 ḡ	--	38%	--	35 %	3.5
		Euphausiid	7%	0.7 g	3%	13%	21 mm	15 %	10.5
		Empty	--	--	--	13%	--	--	--
	Chicks	Hexagrammus stelleri	100%	2.3 g	15%	100%	74.7 mm	100 %	230
August	Chicks	M. villosus	40%	3.9 g	--	33.3%	94.0 mm	33 %	128.7
		A. hexapterus	20%	0.5 g	--	33.3%	101.1 mm	33 %	16.5
		A. hexapterus*	40%	6.0 g	4%	33.3%	103.6 mm	33 %	198
Total (all months) (chicks & adults)		M. villosus	58%	2.1 g	2%	41%	89.8 mm	50 %	105
		A. hexapterus	16%	3.3 g	4%	18%	102.4 mm	21 %	69.3
		H. stelleri	5%	2.3 g	15%	6%	74.7 mm	7 %	16.1
		Unid. fish	16%	--	--	18%	--	15 %	--
		Euphausiid	5%	0.7 g	0.03%	6%	21.0 mm	6 %	4.2
		Empty	--	--	--	12%	--	--	--

*taken from chicks feeding themselves

Table 66.

Prey Composition, Aleutian Terns, Sitkalidak Strait, 1977.

Month	Age	Prey Species	Relat. Freq.	$\bar{x}$ weight	% of body weight	% frequency occurrence	$\bar{x}$ total length	relative volume	grams x volume
June	Adults	Blepsias cirrhosus (sculpin)	--	0.5 g	3%	50%	--	50%	25
		Insecta	--	--	--	50%	--	50%	--
July	Adults	M. villosus	75%	2.1 g	2%	50%	73.6 mm	50%	105
		Unid. fish	--	--	--	--	--	50%	--
	Chicks	M. villosus	75%	1.4 g	3%	67%	89.9 mm	50%	70
		T. trichodon	25%	2.3 g	12%	33%	65.4 mm	50%	115
August	Adults	Synidothea cinera (Isopoda)	--	0.35 g	0.5%	50%	11.4 mm	50%	17.5
		Insecta	--	0.35 g	0.5%	50%	--	50%	17.5
	Chicks	M. villosus	13%	1.5 g	--	14%	85.4 mm	17%	25.5
		A.hexapterus	25%	2.5 g	1%	29%	76.5 mm	8%	20
		T.trichodon	13%	3.8 g	--	14%	74.0 mm	17%	64.6
		Sculpin	25%	1.4 g	--	14%	49.1 mm	17%	23.8
		Unid.fish A	13%	1.9 g	2%	14%	--	17%	32.3
		Unid.fish B	13%	1.2 g	1%	14%	--	8%	9.6
Total* (all months) (chicks & adults)		M.villosus	39%	1.67g	--	33%	80.9 mm	31%	51.77
		A.hexapterus	11%	2.5 g	1%	13%	76.5 mm	12%	30
		T.trichodon	11%	3.1 g	--	13%	69.7 mm	15%	46.6
		Sculpin	17%	0.95 g	--	13%	--	15%	14.25
		Unid.fish	17%	1.55 g	1.5%	20%	--	19%	29.45
		Isopoda	6%	0.7 g	0.5%	7%	11 mm	4%	2.8
		Insecta	--	0.7 g	0.5%	7%	--	4%	2.8

*these total relative frequencies do not account for Insecta.

Table 67. Census figures of Arctic and Aleutian Terns, Sitkalidak Strait. Breeding birds only.

Colony	1976 # birds counted	1977 # birds counted
Sheep Island		
Arctic	700	825
Aleutian	present	735
Amee Island		
Arctic	5000	370
Aleutian	3000	330
Cub Island		
Arctic	0	80
Aleutian	0	0
Total		
Arctic	5700	1275
Aleutian	3000	1065

Table 68 . Nesting Habitat, Arctic and Aleutian Terns, Sitkalidak Strait, 1977.

Species	Colony	X Nearest Neighbor Distance	x Total Vegetation Laying *	x Total Vegetation Hatching *	Slope
Arctic	Cub Island	109.7 cm ±62.7SE	1.88 ±0.5SE	1.99 ±0.5 SE	13.1° ±9.37SE
Arctic	Amee Island	276.8 ±40.6	1.57 ±0.001	1.57 ±0.004	12.7° ±7.06
Arctic	Sheep Island	335.1 ±179.6	1.54 ±0.36	1.75 ±0.47	9.8° ±4.73
Aleutian	Amee Island	92.2 ±11.87	1.48 ±0.26	1.57 ±0.37	4.4° ±3.88
Aleutian	Sheep Island	415.5 ±177.6	1.65 ±0.46	1.57 ±0.55	6.38° ±4.75

*in arcsin

Table 69.

Percent total mortality, Terns, Sitkalidak Strait 1977.

Colony	No. of chicks possible	Species	% Mortality*
Sheeep Island	56	Arctic	10.7%
(79 nests)	23	Aleutian	52.2
	110**	total	32.7
Amee Island	25	Arctic	28.0
(33 nests)	25	Aleutian	28.0
	50	total	28.0
Cub Island (17 nests)	42	Arctic	54.8
All colonies	123	Arctic	29.3
(43 nests Arctic)	48	Aleutian	39.6
(37 nests Aleutians)	202	Total	36.1

* excludes mortality caused by observers.
** includes mortality of undetermined species.

Table 70.

Causes of tern mortality by species. Sitkalidak Strait 1977.

Cause of mortality	Species	% mortality
Egg disappeared	Arctic	2.4
	Aleutian	16.7
Egg rolled out	Arctic	4.9
	Aleutian	2.1
Infertile	Arctic	0.8
	Aleutian	4.2
Shell damage	Arctic	2.4
	Aleutian	0
Egg deserted	Arctic	1.6
	Aleutian	2.1
Exposure: egg	Arctic	0.9
	Aleutian	0
Avian predation	Arctic	1.6
	Aleutian	0
Embryo died	Arctic	5.7
	Aleutian	0
Died pipping	Arctic	4.9
	Aleutian	2.1
Exposure: chick	Arctic	1.6
	Aleutian	8.3
Chick starved	Arctic	0
	Aleutian	2.1
Chick dead: unknown cause*	Arctic	2.4
	Aleutian	2.1
Total	Arctic	29.3%
	Aleutian	39.6%

*probably due to exposure

Table 71.

Causes of Arctic Tern mortality by colony. Sitkalidak Strait, 1977.

Colony	Cause of mortality	% mortality
Amee Island	Egg disappeared	8%
	Egg rolled out	4
	Infertile	4
	Shell damage	4
	Avian predation	4
	Died pipping	4
Sheep Island	Egg disappeared	1.8
	Exposure: egg	1.8
	Died pipping	1.8
	Exposure: chick	3.6
	Chick dead: unknown cause	1.8
Cub Island	Egg rolled out	11.9
	Egg deserted	4.8
	Shell damage	4.8
	Avian predation	2.4
	Egg died	16.7
	Died pipping	9.5
	Chick dead: unknown cause	4.8

Table 72.

Causes of Aleutian Tern mortality by colony. Sitkalidak Strait, 1977.

Colony	Cause of mortality	% mortality
Amee Island	Egg disappeared	12%
	Infertile	4
	Egg deserted	4
	Chick starved	4
	Exposure: chick	4
Sheep Island	Egg disappeared	21.7
	Egg rolled out	4.3
	Infertile	4.3
	Died pipping	4.3
	Exposure: chick	13.0
	Chick dead: unknown cause	4.3

Table 73.

Feeding Flocks - Sitkalidak Strait 1977.

Location	Site	Date	Time	Minutes to Tide low	Minutes to Tide high	Tide at time of feeding flock (feet)
100 m SE Sheep Is.	35	2 June	1000	-169	+217	1.94
300 m SW Sheep Is.	16	2 June	1200	-289	+ 97	5.24
1-2 km NE Cathedral	65	8 June	2130	+216	-157	5.33
2 km SE Cathedral	101	13 June	1830	-121	+260	4.47
150 m E Amee Is.	41	17 June	1700	+128	-186	4.18
Camp Bay	24	20 June	1000	- 52	+340	0.25
Hobron Head	80	7 July	1000	+ 80	-350	2.32
Camp Strait	40	7 July	1100	+ 20	-450	1.18
Nut-Granite Straits	113	16 July	1110	-245	+140	4.12
Nut-Granite Straits	180	16 July	1115	-250	+135	4.22
300 m off Amee	122	22 July	1230	-120	+271	2.90
Camp Straits	26	4 August	1100	- 64	+325	1.68
Camp Straits	122	4 August	1115	- 79	+310	1.98
Camp Bay	63	6 August	0800	+195	-146	4.17
Near Inner Granite Is.	42	9 August	1100	+202	- 85	4.57
Near Inner Granite Is.	110	9 August	1145	+217	-190	4.66
200 m off LKWR	176	11 August	0755	-183	+200	3.02
300 m NE LKWR	144	11 August	1059	-367	+ 16	5.76
50 m off LKWR	63	11 August	1408	+138	-173	4.16
50 m off LKWR	73	11 August	2007	-221	+152	6.02

Table 74.

Feeding Flock Composition, Sitkalidak Strait 1977

Species	N_a	$\overline{X}_b$	S	$\overline{X}$%	No. Flocks	% Occurrence
BLKI	611	32.16	28.37	39%	19	95%
GWGU	233	14.56	11.59	15%	16	80%
TUPU	541	30.06	20.38	35%	18	90%
ARTE	102	14.57	8.83	7%	7	35%
PFCO	10	1.67	0.82	1%	6	30%
UNCO	19	4.75	2.5	1%	4	20%
HOPU	8	4.00	1.41	1%	2	10%
IMM GWGU and MEGU	24	8.00	3.46	2%	3	15%
IMM BLKI	11	5.50	6.36	1%	2	10%
RBME	2	2.00	0	0.1%	1	5%

(a) total # feeding flocks observed = 20
(b) $\overline{X}$ birds/feeding flock = 81.8 ± 49.6

Table 7.5

Sightings of Harbor Seals, Sitkalidak Strait, 1977

Date	Time	Location	No.	Activity
10 June	1000	west of Sheep Is.	1	swimming
19 June	all day	off Cathedral Is.	1	basking/swimming
25 June	1600	rocks NW of Cub Is.	1	basking
27 June	2130	20 m off Camp Cove	2	swimming/playing
29 June	1030	west of Cathedral Is.	1	swimming
29 June	1530	rocks NW of Nut Is.	1	hauled out
2 July	1200	west of Cathedral Is.	1	swimming
14 July	1145	south off Cormorant Head	2	swimming
17 July	2030	off Lesser Kittiwake Rock	1	swimming
23 July	--	off Lesser Kittiwake Rock	1	swimming
24 July	--	South off LKWR	1	swimming
29 July	--	NW off Cathedral Is.	1	swimming
4 August	1300	west off Cathedral Is.	2	swimming
11 August	1230	off Innerach	1	swimming
11 August	2100	off Innerach	1	swimming
18 August	1210	south off LKWR	1	swimming
18 August	1430	off Lesser Kittiwake Rock	1	feeding
4'Sept.	1700	Cathedral Straits	1	swimming
7 Sept.	--	Cub Is. rocks	10	hauled out

Table 76.

Sightings of Harbor Porpoises, Sitkalidak Strait 1977

Date	Time	Location	No.	Activity
L&				
17 June	0900	Outer Granite Rock	2	feeding
20 June	0900	Amee Bay	1	feeding
20 June	1900	Hobron Bay	2	mixed f. flock
20 June	1930	off Nut Is.	1	mixed f. flock
21 June	1100	off Cathedral Is.	1	mixed f. flock
21 June				
21 June	1130	Port Hobron convergence line	1	mixed f. flock
21 June	1330	Amee Bay	1	mixed f. flock
20 July	0900	off Nut Is.	1	swimming
4 August	1100	Camp Cove	2	swimming
12 August	--	off Lesser Kittiwake Rock	1	mixed f. flock
13 August	--	Camp Cove	2	swimming
15 August	1015	off Cormorant Head	2	swimming
15 August	1400	off Ghost Rocks	1	swimming
18 August	1300	Cathedral Straits	2	near f. flocks
27 August	--	Camp Cove	2	swimming
27 August	--	Cathedral Straits	1	swimming
31 August	2000	Cathedral Straits	2	swimming
1 Sept.	--	Cathedral Straits	5	swimming

Table 77.

Date	Time	Location	No.	Activity
27 May	1300	Cathedral Straits	1	breeching
21 June	1100	off Cathedral Is.	1	mixed f. flock
21 June	1230	east of Cub Is.	1	
25 June	2000	Port Hobron convergence lines	1	f. flock remnant
25 June	2000	Cathedral Straits	1	swimming
4'July	1115	north of Amee Rock	1	mixed f. flock
4 July	1145	Port Hobron	1	mixed f. flock
5 July	2200	convergence west of Amee Is.	1	swimming
12 July	1700	SW off Cathedral Is.	2	breeching
13 July	1300	S off Cathedral Is.	1	swimming
13 July	1400	E off Cathedral Is.	1	swimming
16 July	1100	convergence, Nut Straits	2	mixed f. flock
16 July	1430	S off Cathedral Is.	1	swimming
17 July	1200	N off Cathedral Is.	1	swimming
17 July	1430	between Nut and Granite Is.	1	swimming
18 July	0954	off Amee Is.	1	mixed f. flock
19 July	1400	1 km off Cub Is.	1	swimming
29 July	1530	Hobron Straits	1	swimming
11 August	1410	W off Lesser Kittiwake Rock	1	mixed f. flock
11 August	1717	E off Lesser Kittiwake Rock	1	swimming
15 August	1255	off Cormorant Head	2	swimming
31 August	1300	NW off Lesser Kittiwake Rock	1	swimming

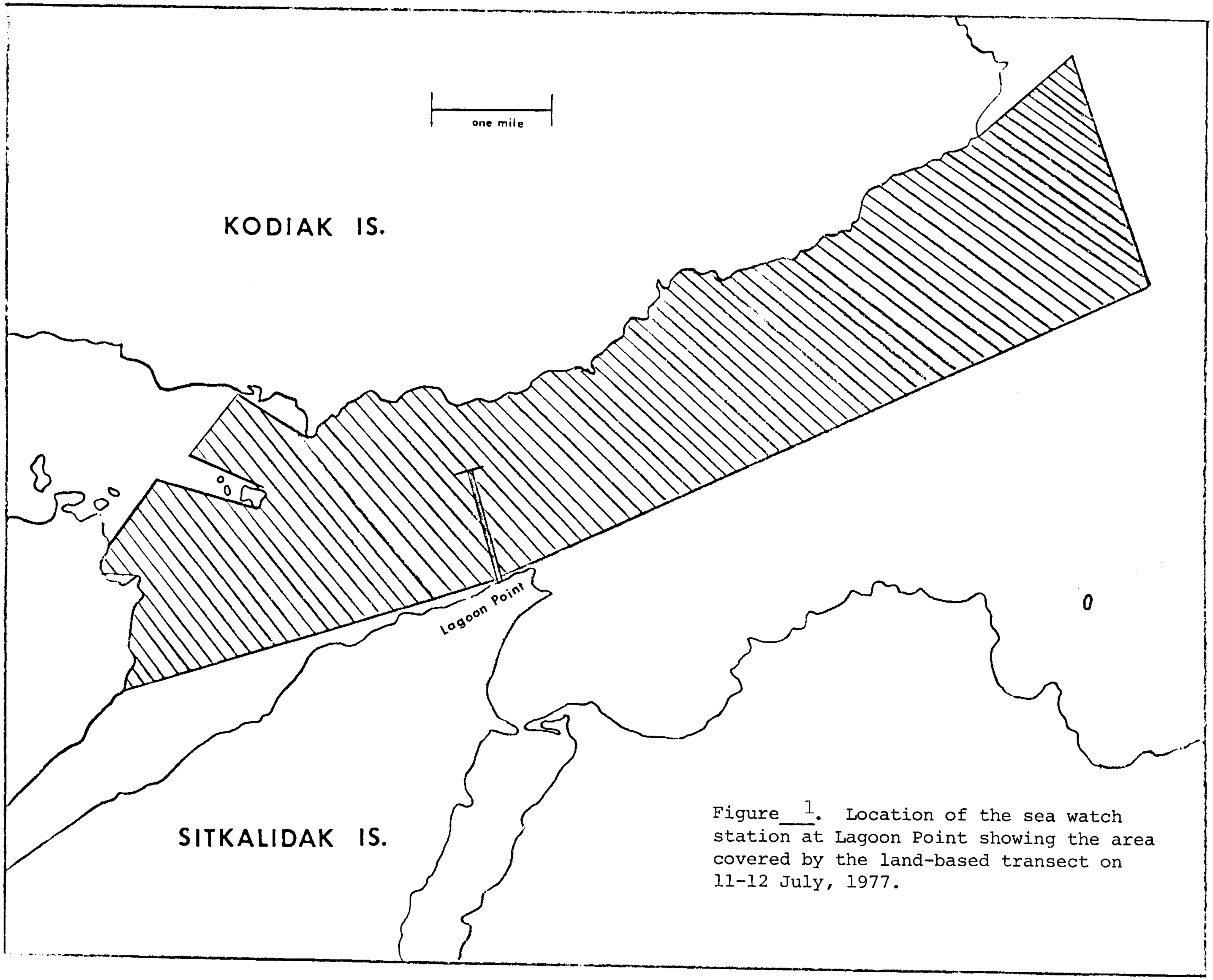


Figure 1. Location of the sea watch station at Lagoon Point showing the area covered by the land-based transect on 11-12 July, 1977.

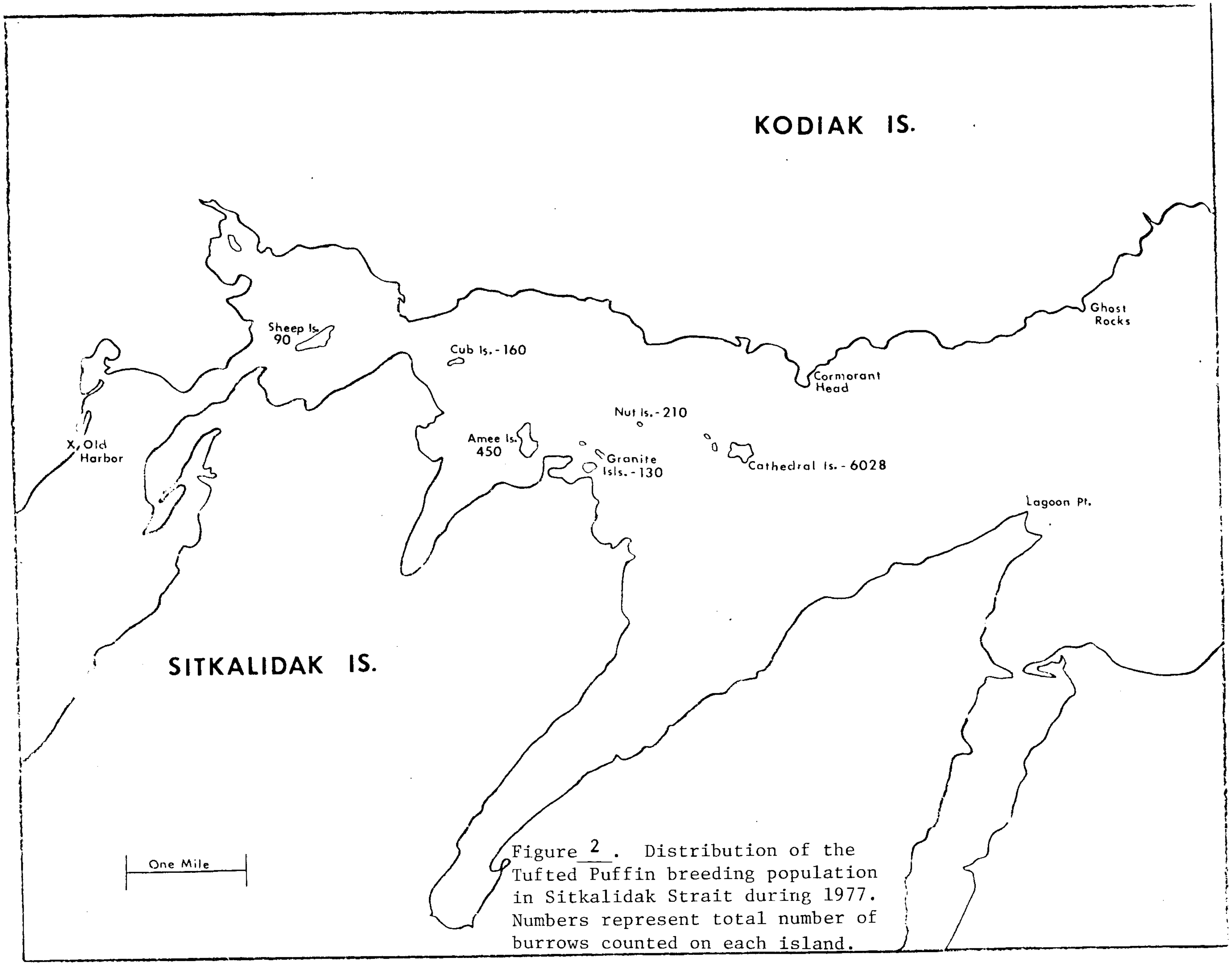


Figure 2. Distribution of the Tufted Puffin breeding population in Sitkalidak Strait during 1977. Numbers represent total number of burrows counted on each island.

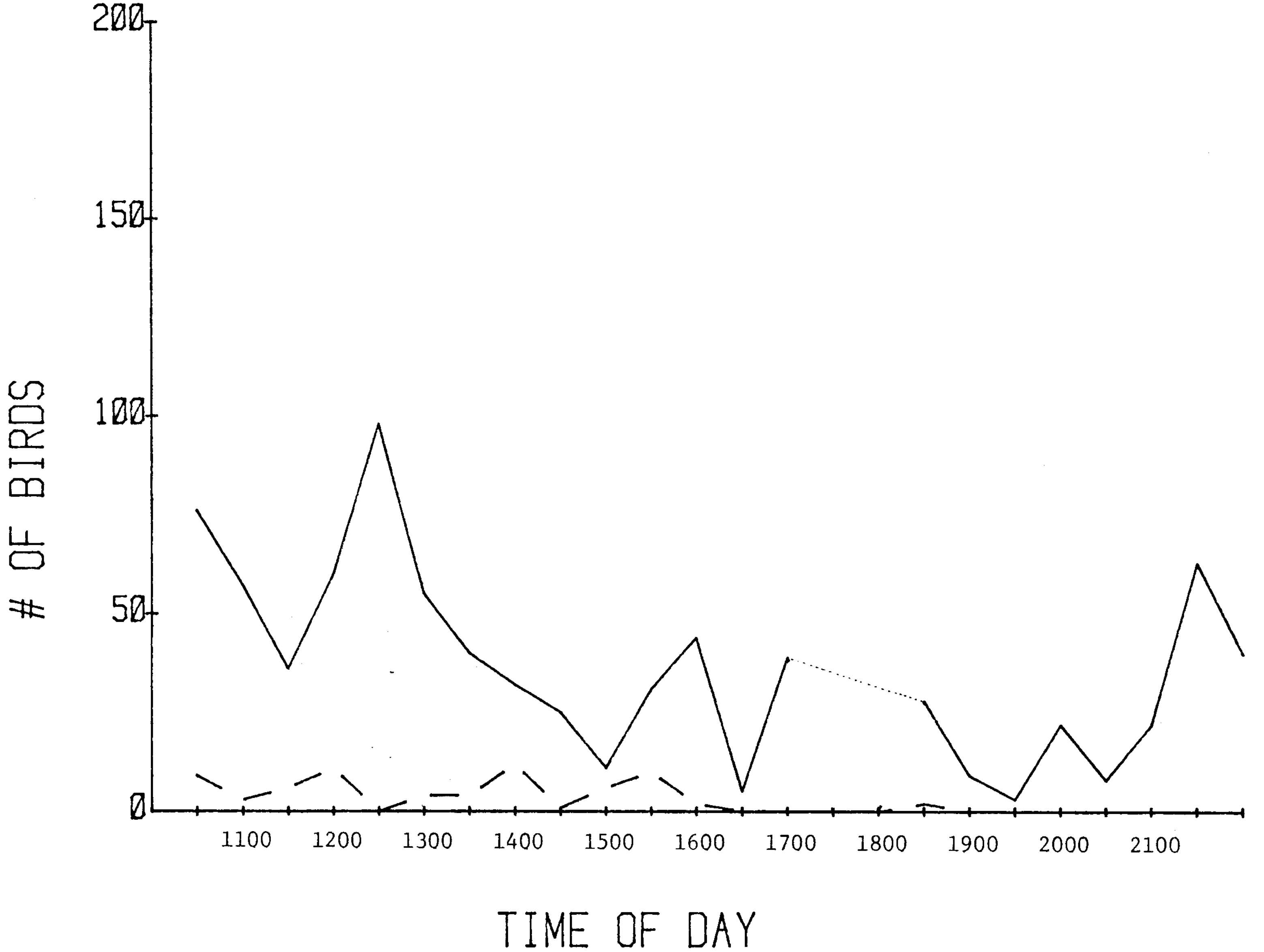


Figure 3 . Tufted Puffin movements in and out of Sitkalidak Strait as observed from Lagoon Point on 11 July, 1977. Birds flying out: solid line. Birds flying in: dashed line.

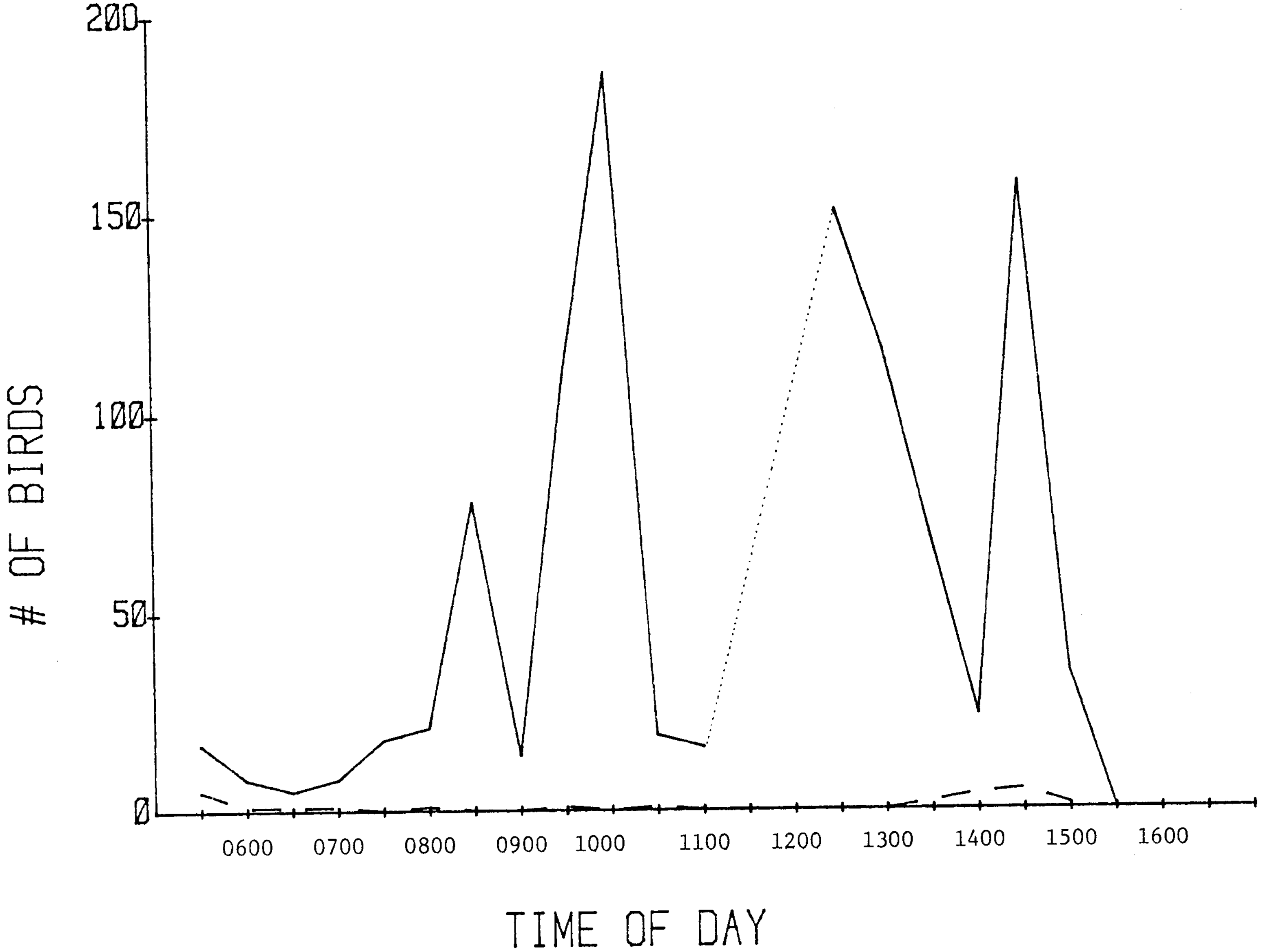


Figure 4. Tufted Puffin movements in and out of Sitkalidak Strait as observed from Lagoon Point on 12 July, 1977. Birds flying out: solid line. Birds flying in: dashed line.

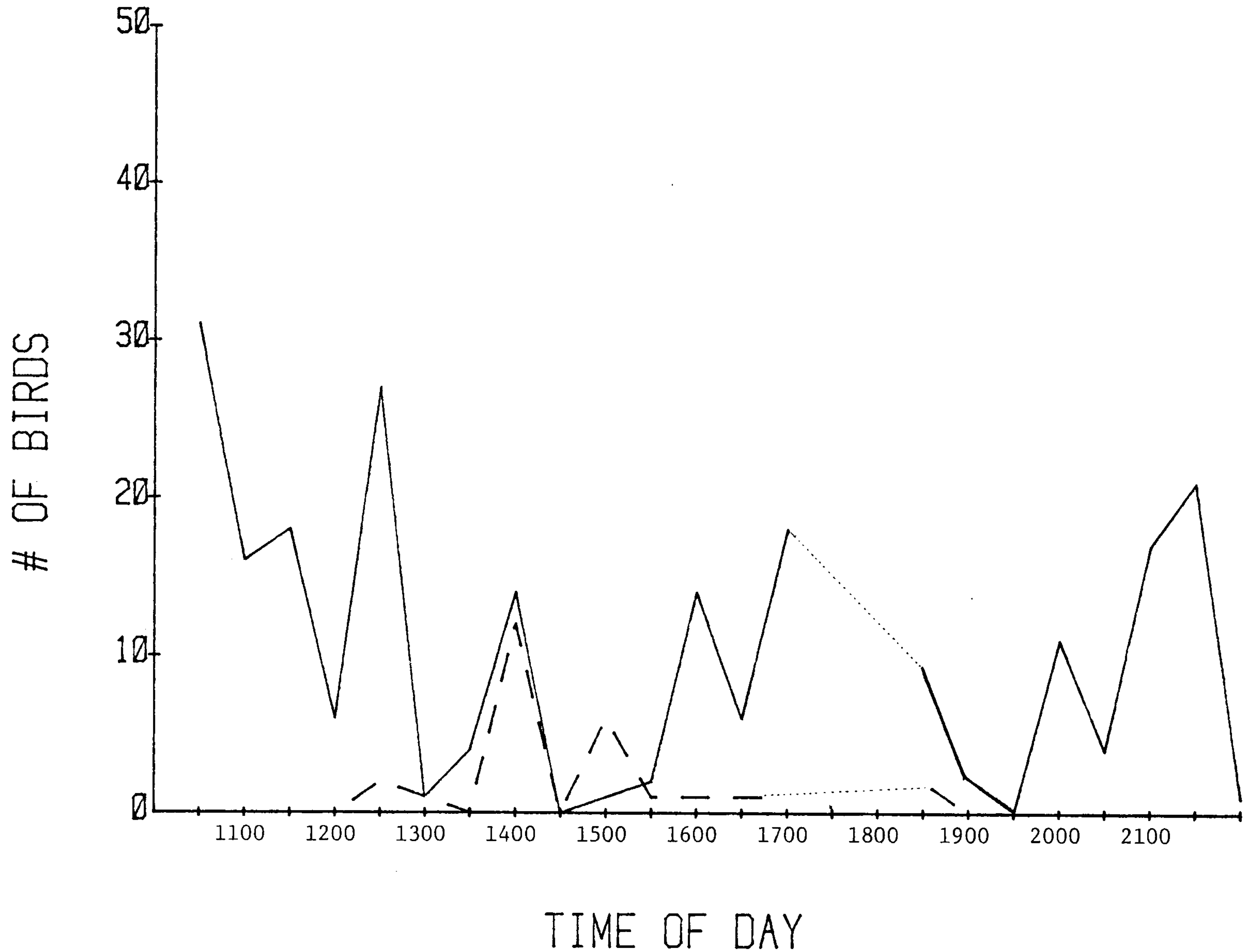


Figure 5 . Black-legged Kittiwake movements in and out of Sitkalidak Strait as observed from Lagoon Point on 11 July, 1977. Birds flying out: solid line. Birds flying in: dashed line.

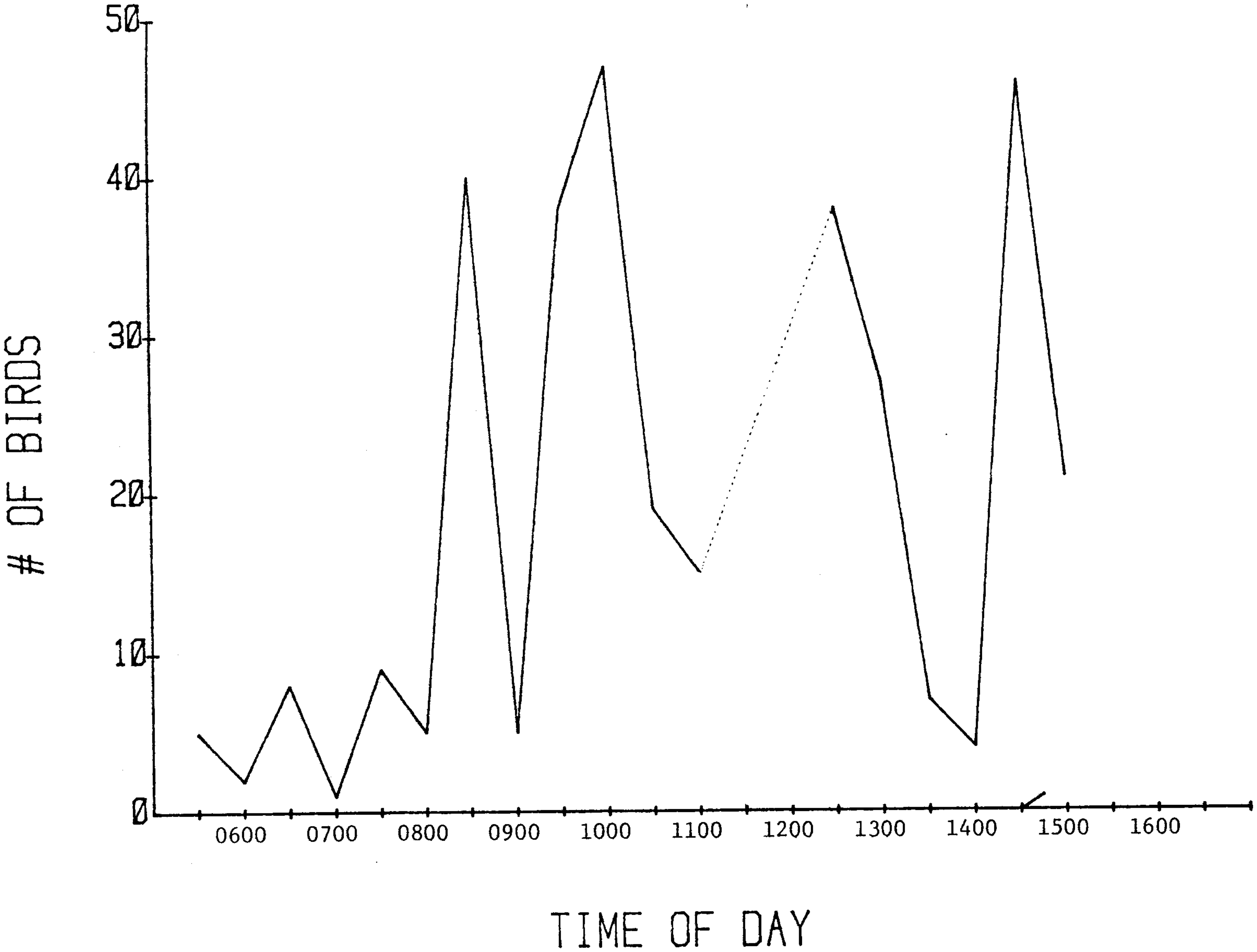


Figure 6 . Black-legged Kittiwake movements in and out of Sitkalidak Strait as observed from Lagoon Point on 12 July, 1977. Birds flying out: solid line. Birds flying in: dashed line.

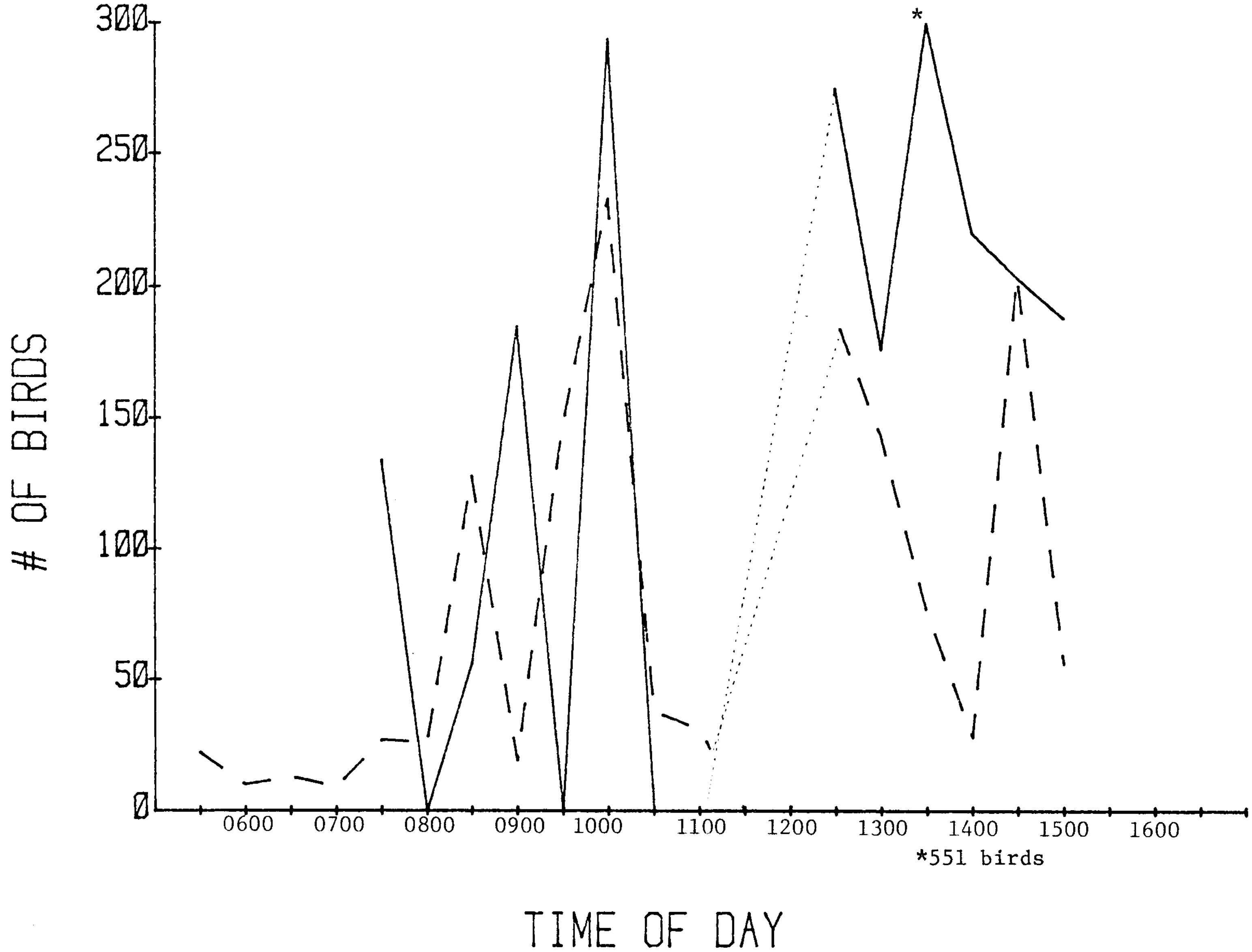


Figure 7 . Combined outward movements of Black-legged Kittiwakes and Tufted Puffins correlated with mixed feeding flock activity in the waters of central and outer Sitkalidak Strait, 12 July, 1977. Birds flying out: dashed line. Birds in feeding flocks: solid line.

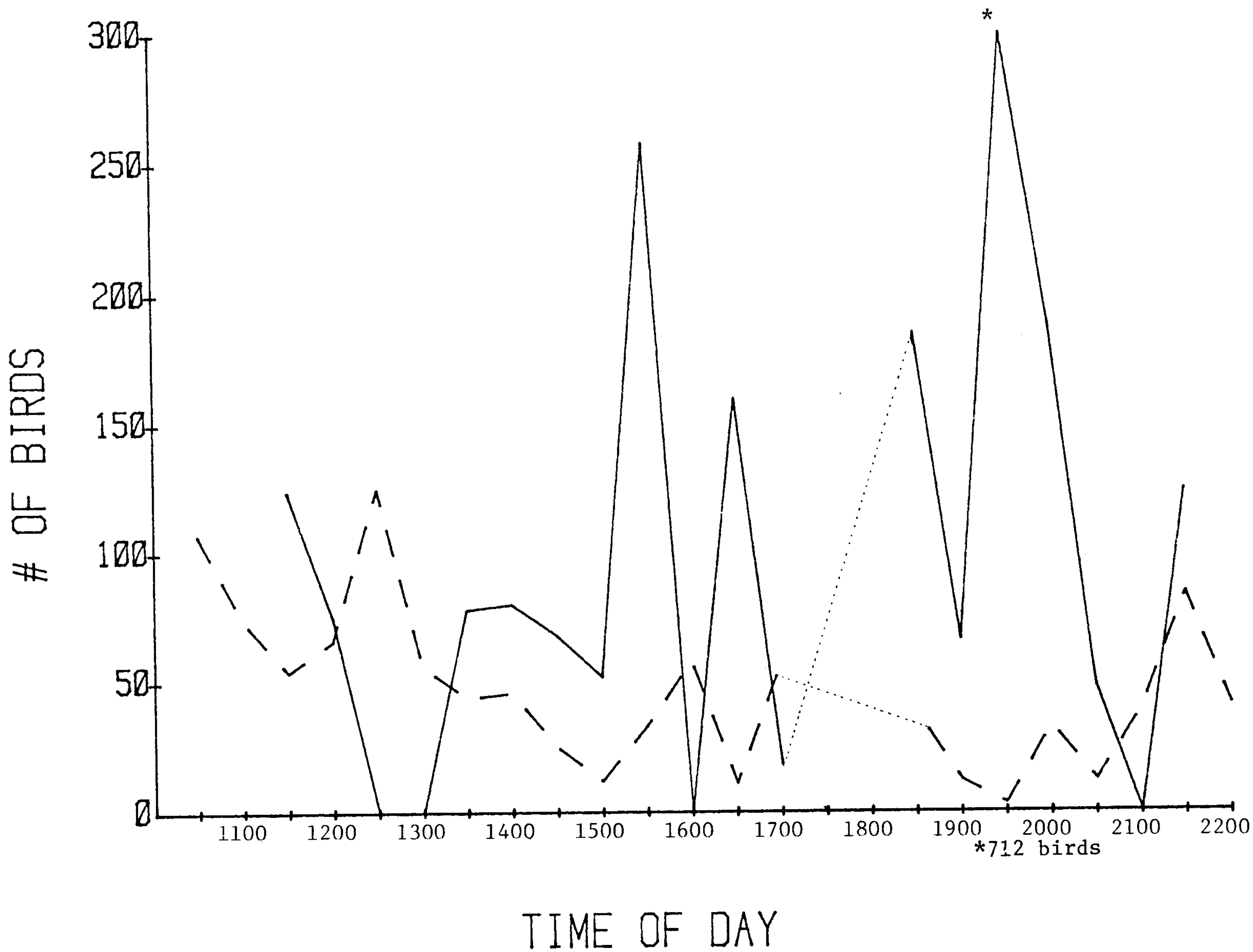


Figure 8. Combined outward movements of Black-legged Kittiwakes and Tufted Puffins correlated with mixed feeding flock activity in the waters of central and outer Sitkalidak Strait, 11 July, 1977. Birds flying out: dashed line. Birds in feeding flocks: solid line.

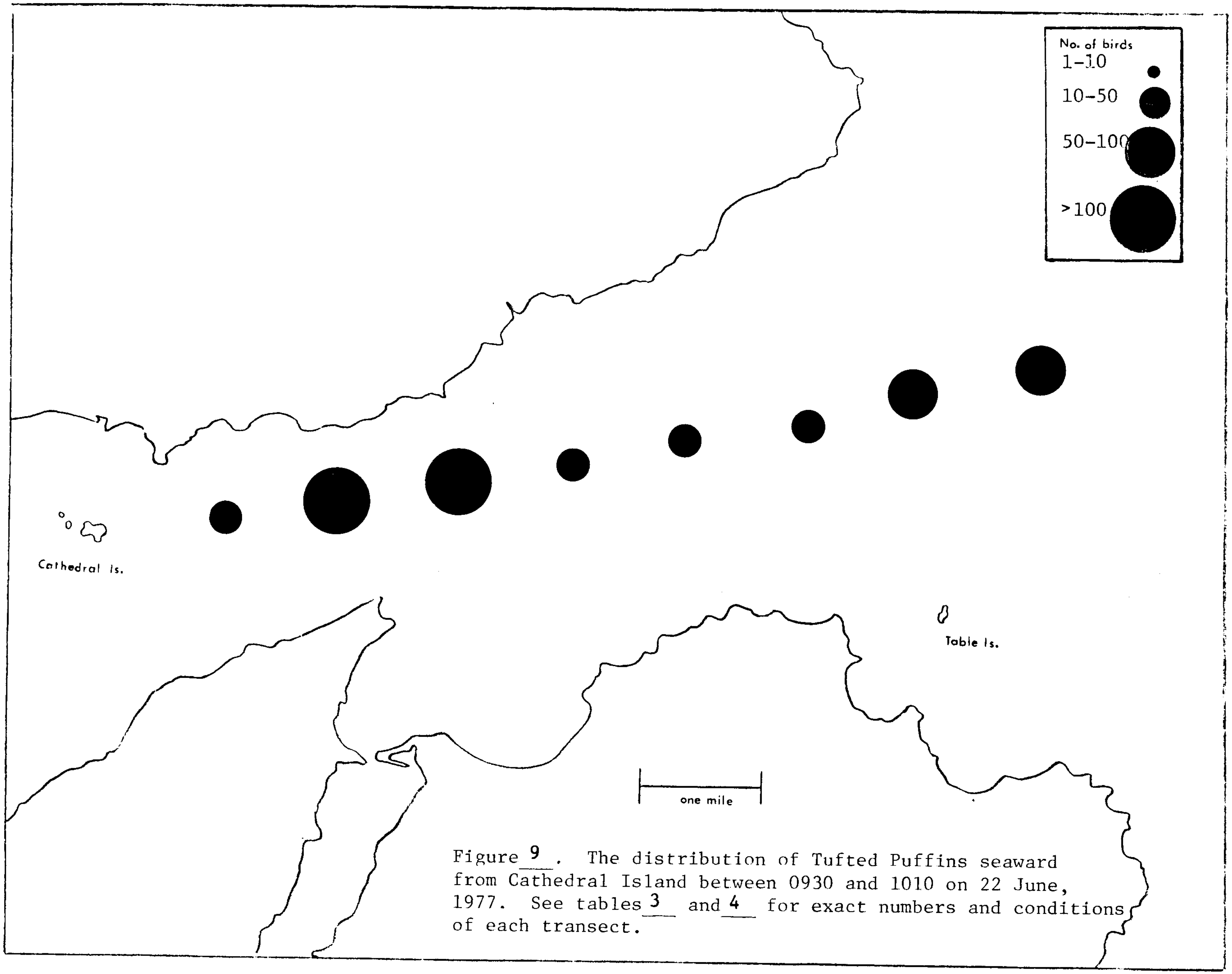


Figure 9. The distribution of Tufted Puffins seaward from Cathedral Island between 0930 and 1010 on 22 June, 1977. See tables 3 and 4 for exact numbers and conditions of each transect.

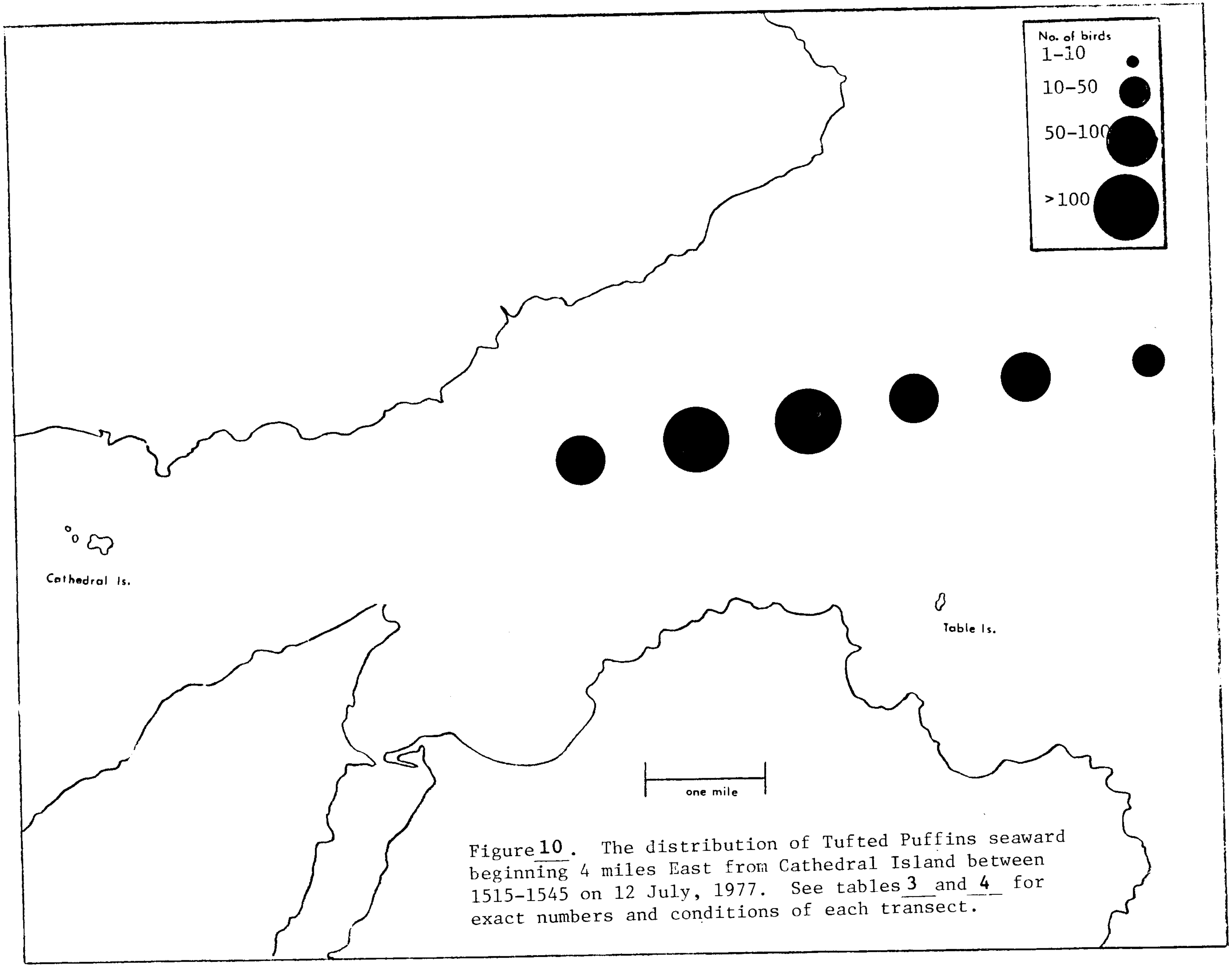


Figure 10. The distribution of Tufted Puffins seaward beginning 4 miles East from Cathedral Island between 1515-1545 on 12 July, 1977. See tables 3 and 4 for exact numbers and conditions of each transect.

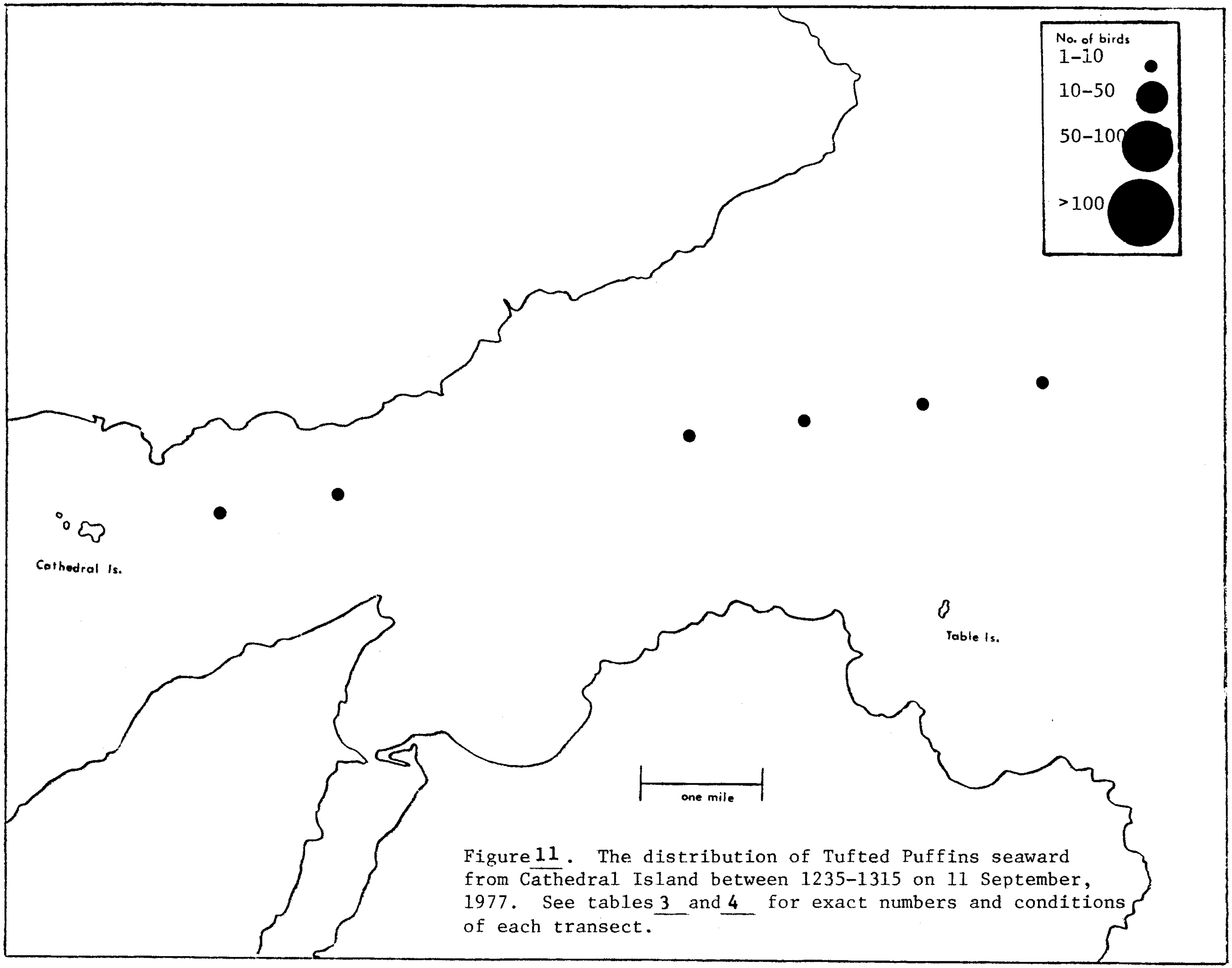


Figure 11. The distribution of Tufted Puffins seaward from Cathedral Island between 1235-1315 on 11 September, 1977. See tables 3 and 4 for exact numbers and conditions of each transect.

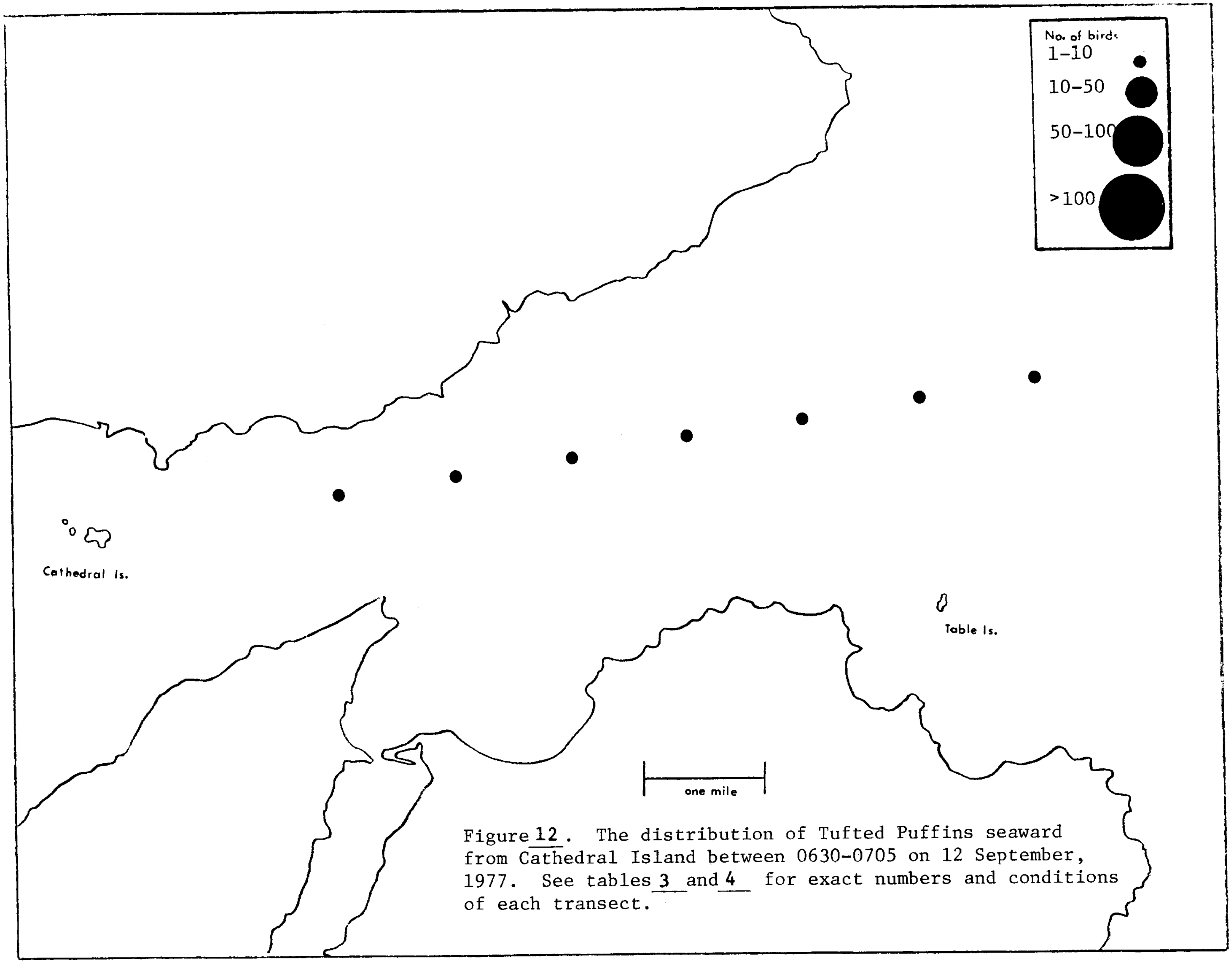


Figure 12. The distribution of Tufted Puffins seaward from Cathedral Island between 0630-0705 on 12 September, 1977. See tables 3 and 4 for exact numbers and conditions of each transect.

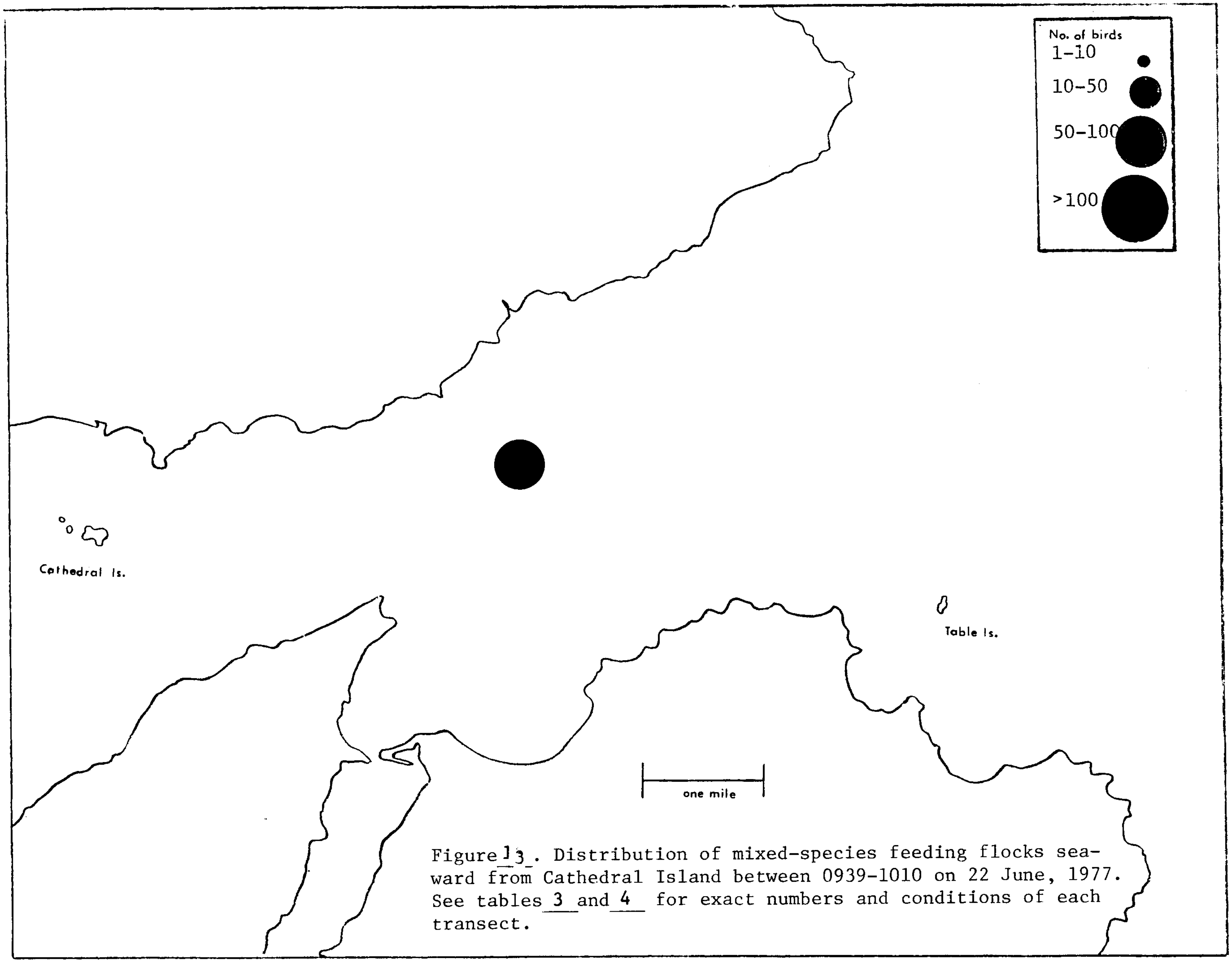


Figure 13. Distribution of mixed-species feeding flocks seaward from Cathedral Island between 0939-1010 on 22 June, 1977. See tables 3 and 4 for exact numbers and conditions of each transect.

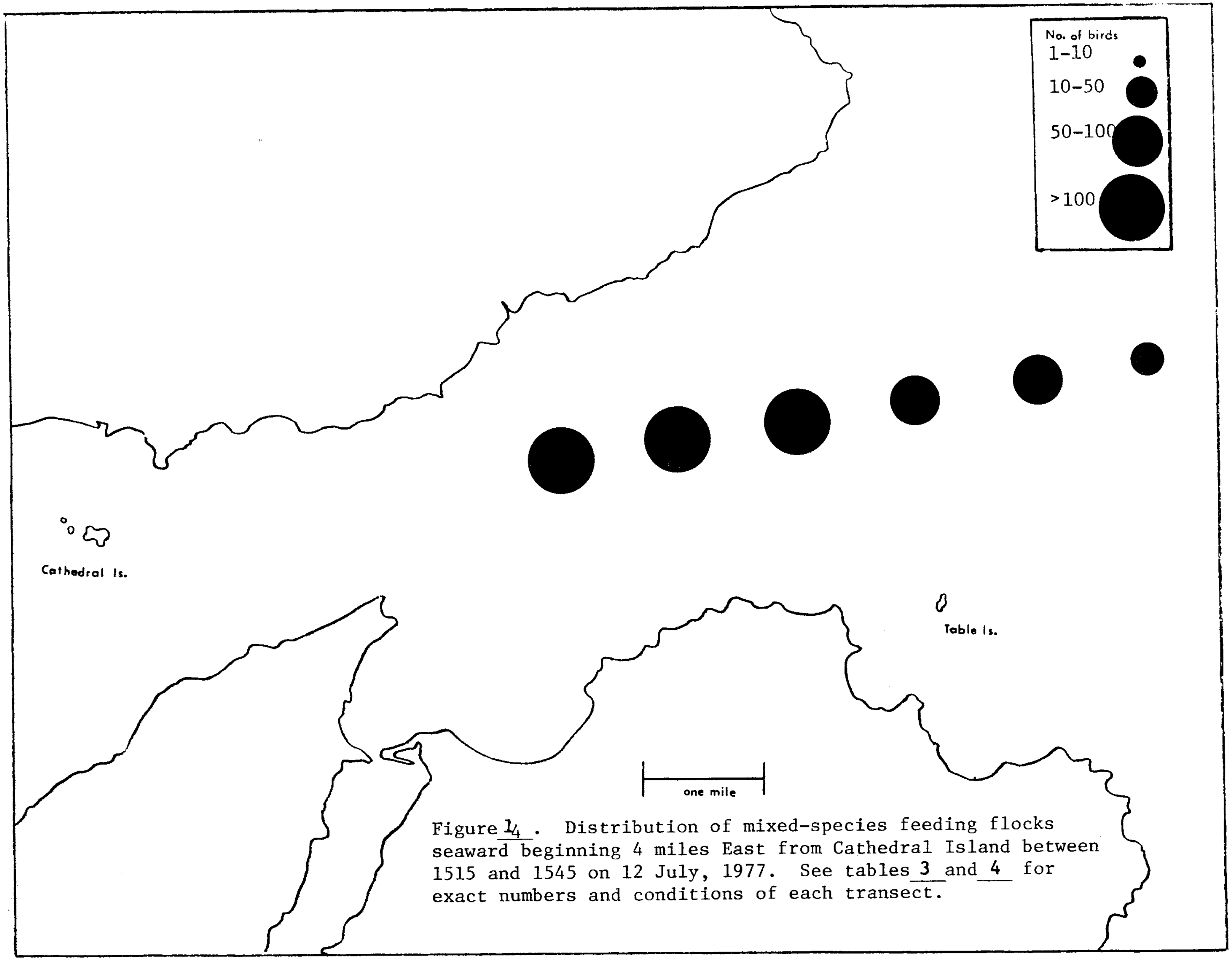


Figure 14. Distribution of mixed-species feeding flocks seaward beginning 4 miles East from Cathedral Island between 1515 and 1545 on 12 July, 1977. See tables 3 and 4 for exact numbers and conditions of each transect.

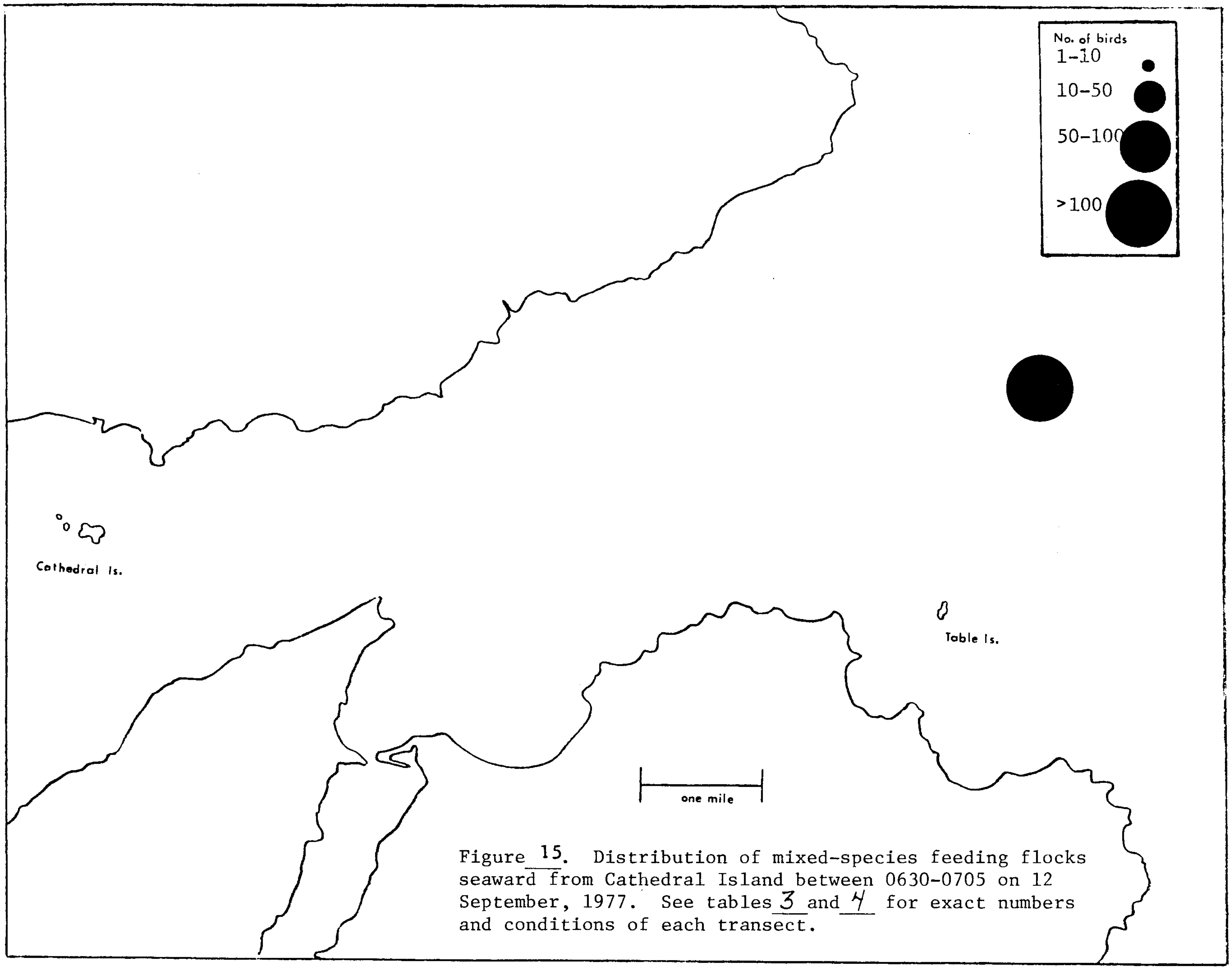


Figure 15. Distribution of mixed-species feeding flocks seaward from Cathedral Island between 0630-0705 on 12 September, 1977. See tables 3 and 4 for exact numbers and conditions of each transect.

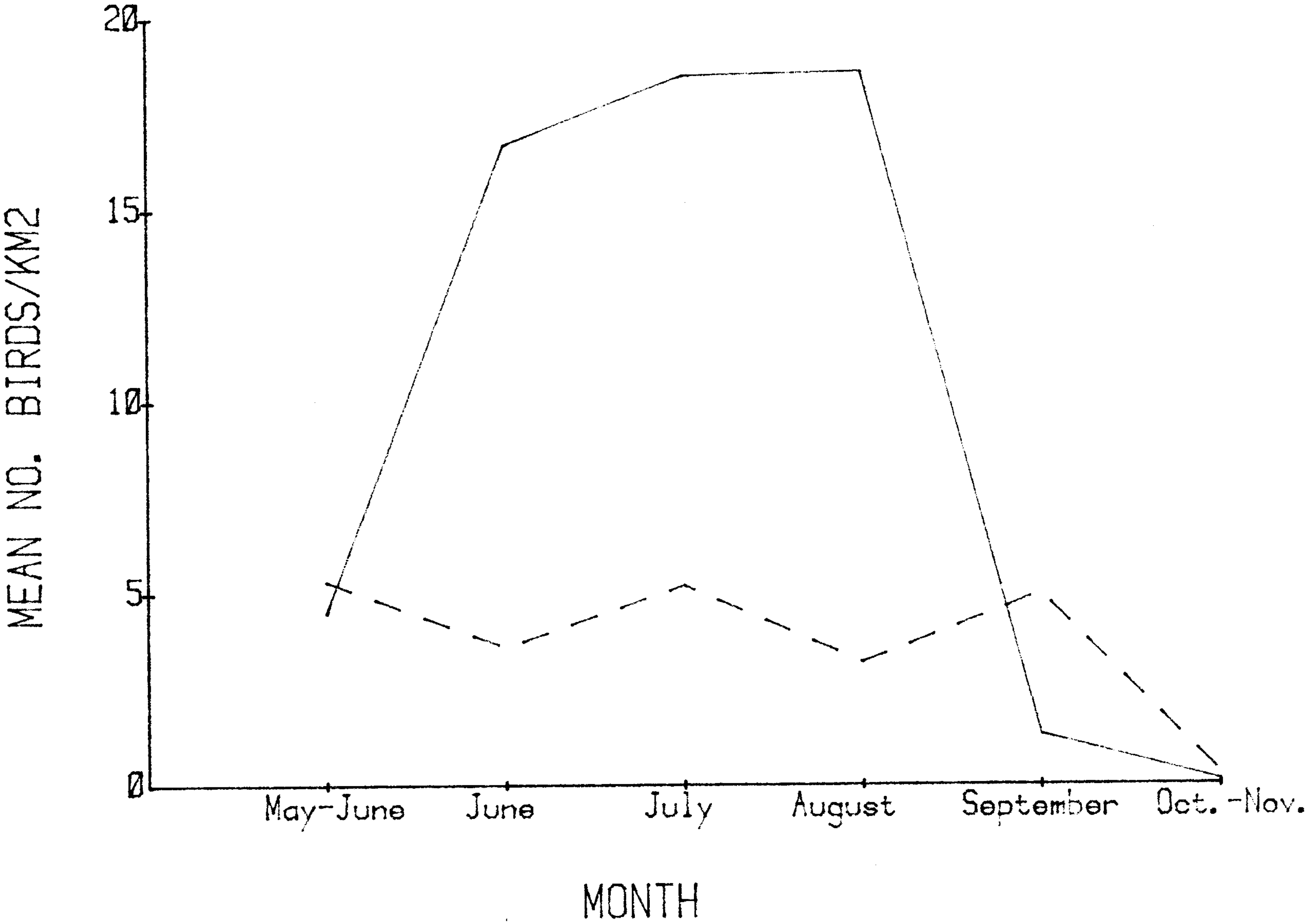


Figure 16. Mean number of Tufted Puffins per Km^2 in the waters off south-central Kodiak Island between 23 May and 14 November, 1977. Data based on shipboard transects made by USFWS personnel under RU 337. Solid line: bays and fjords; dashed line: shelf.

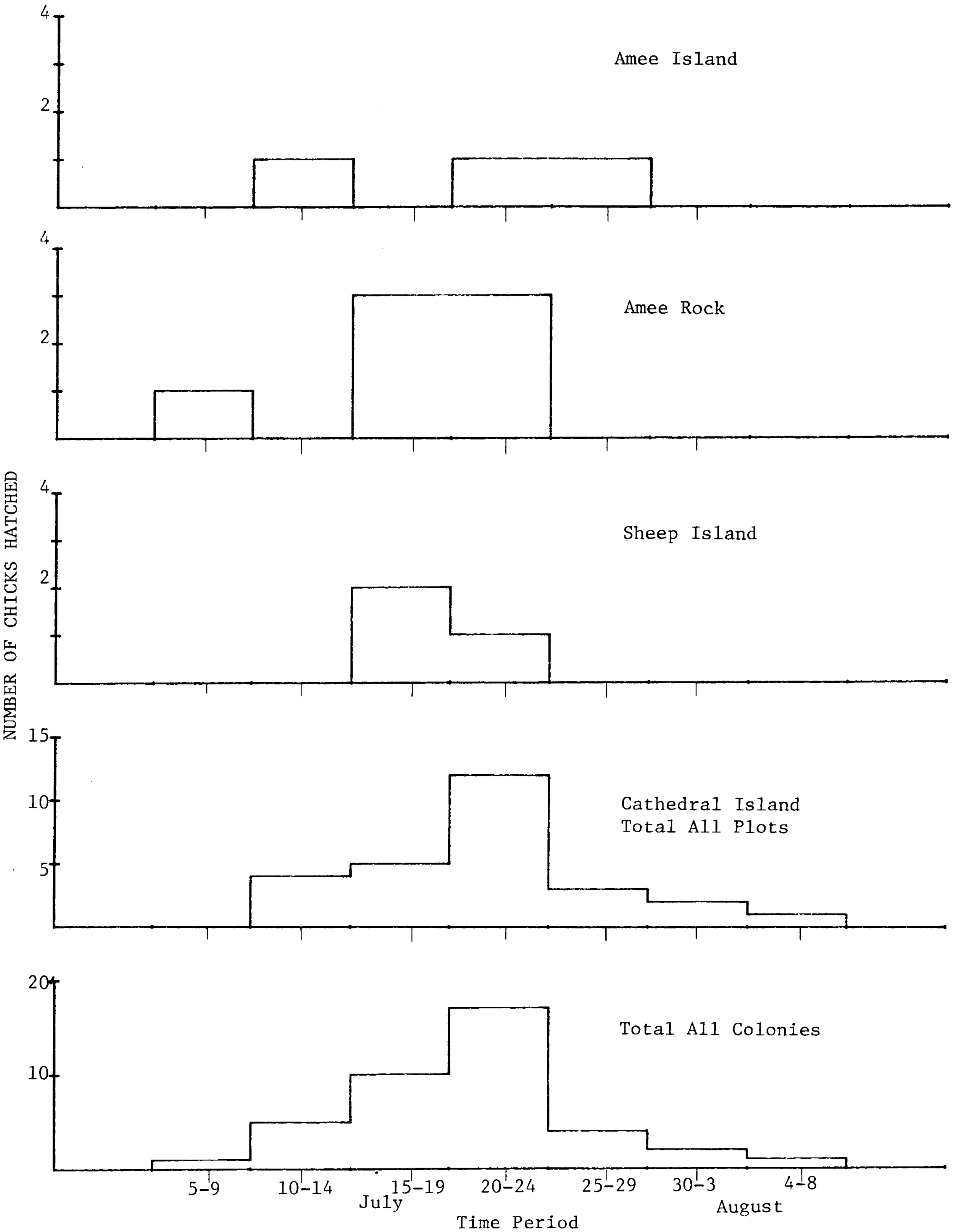


Figure 17. Hatching dates of the Tufted Puffins in four colonies, Sitkalidak Strait, Kodiak Island, Alaska. 1977.

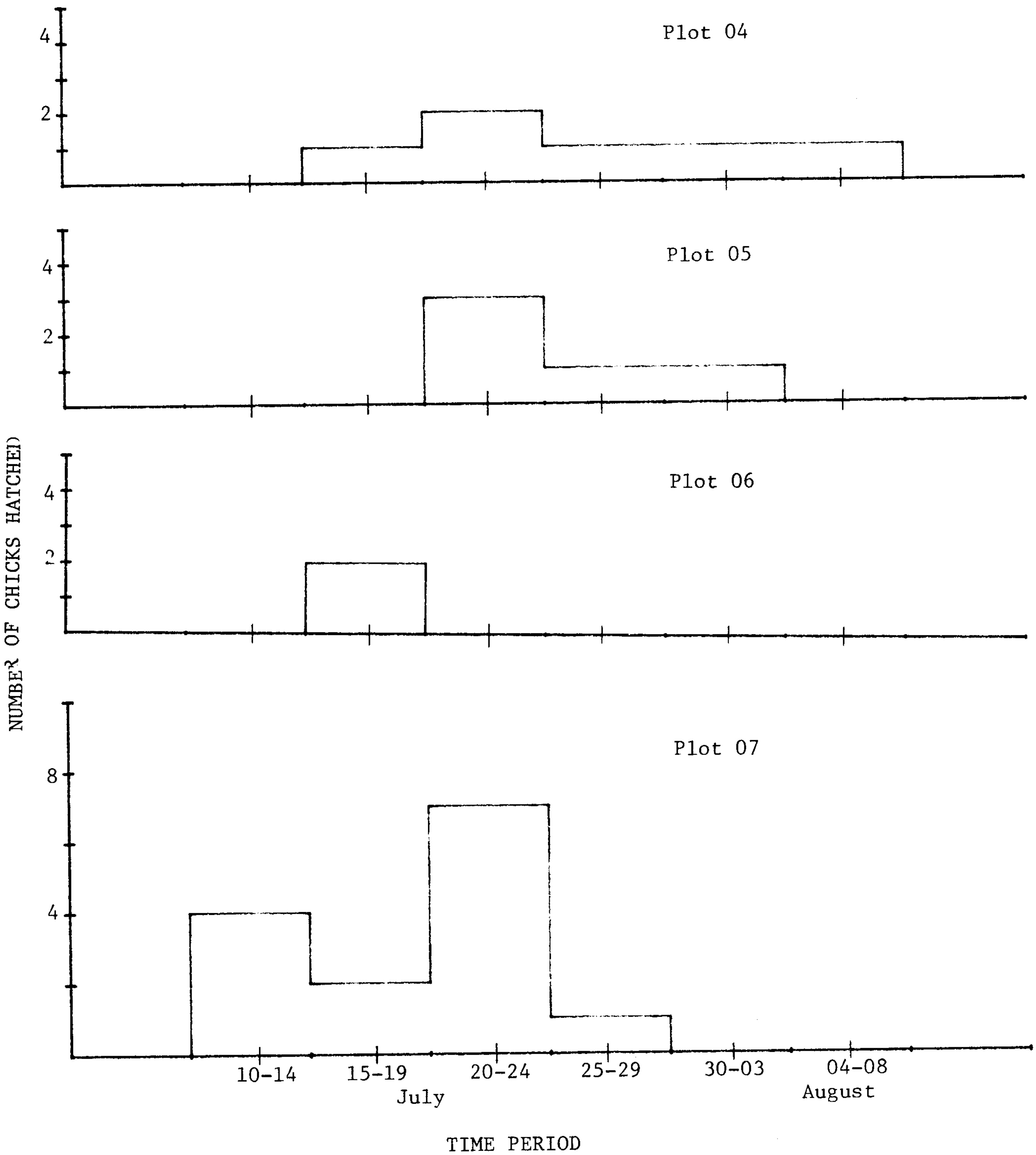


Figure 18. Hatching dates of the Tufted Puffins in the four plots on Cathedral Island, Sitkalidak Strait, Kodiak, Alaska. 1977.

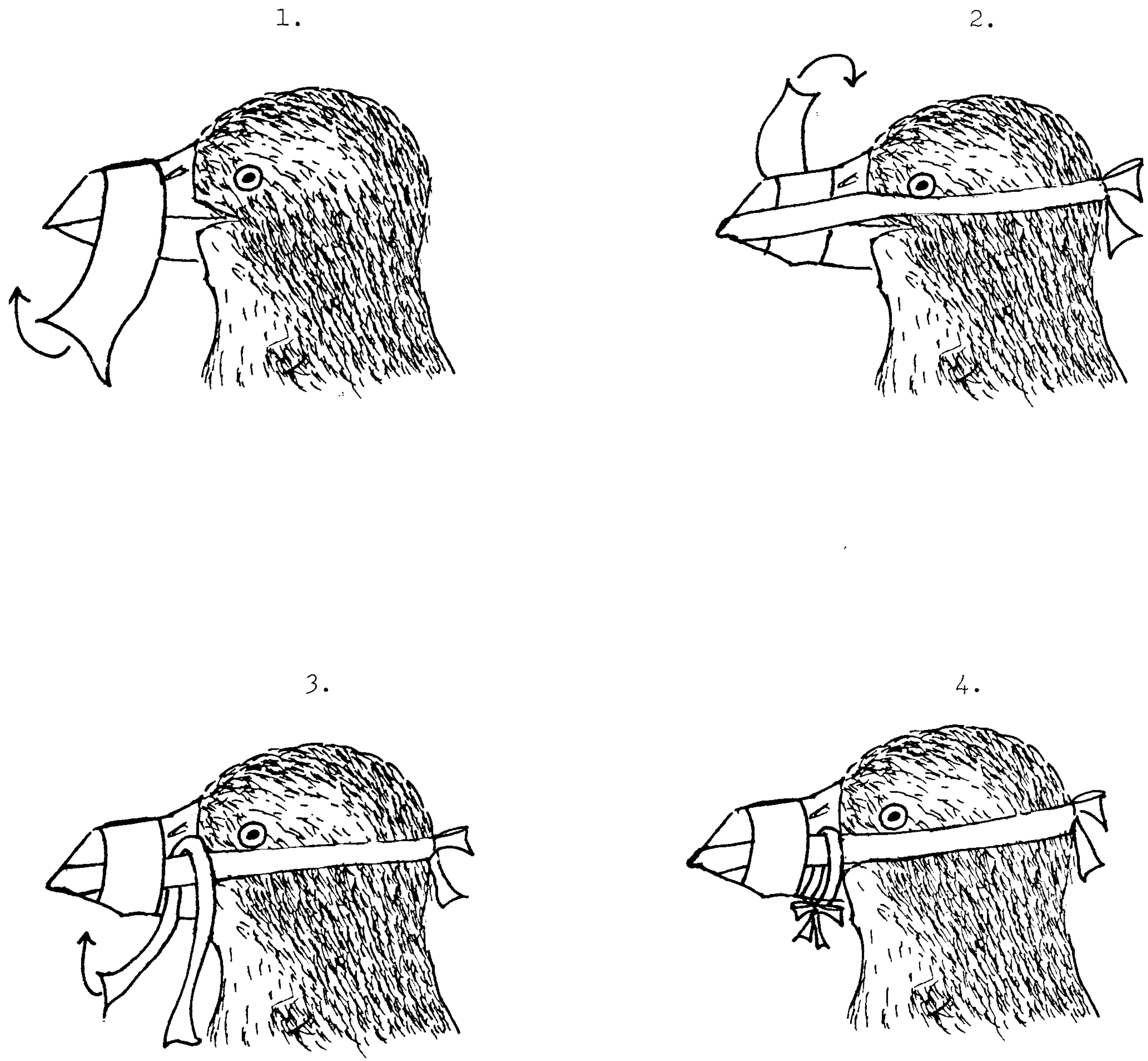


Figure 19. Muzzle for Tufted Puffin chicks.

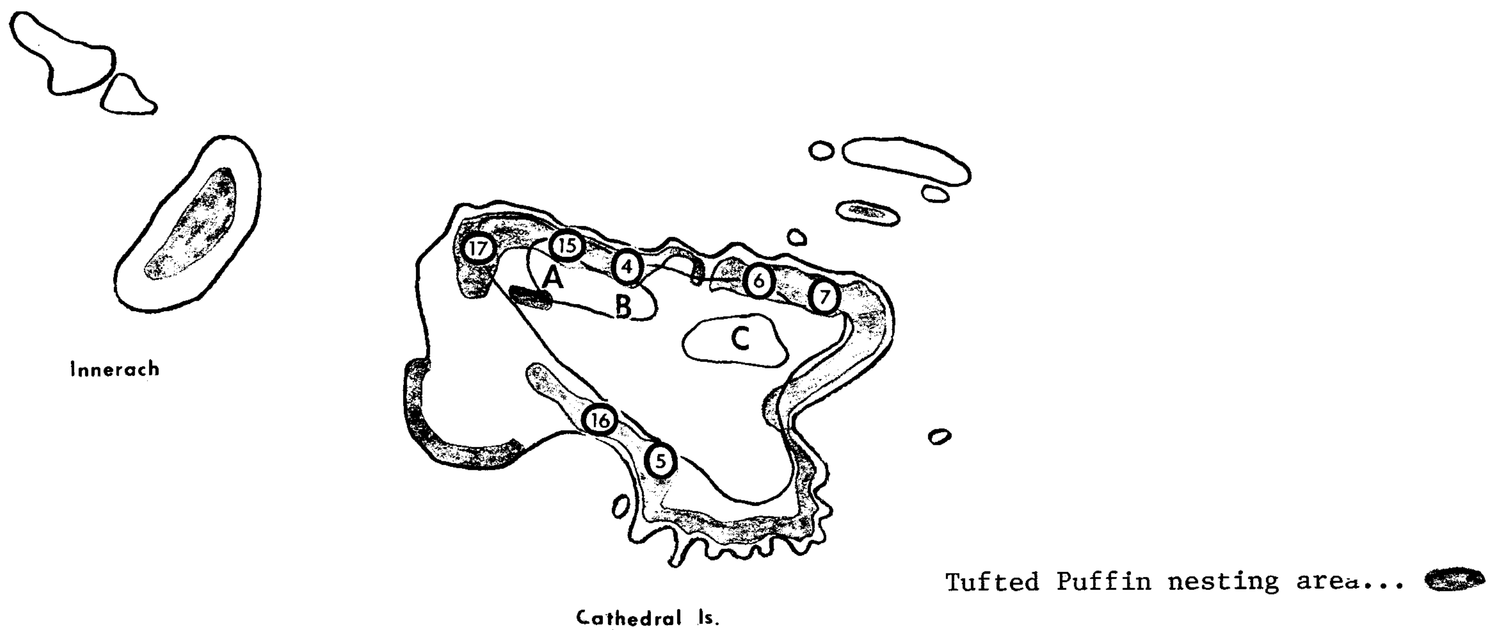


Figure 20. The Tufted Puffin colony on Cathedral Island showing the location of the seven sample plots. Points A, B, and C are fixed stations from which the plots may be located by future investigators (see appendix).

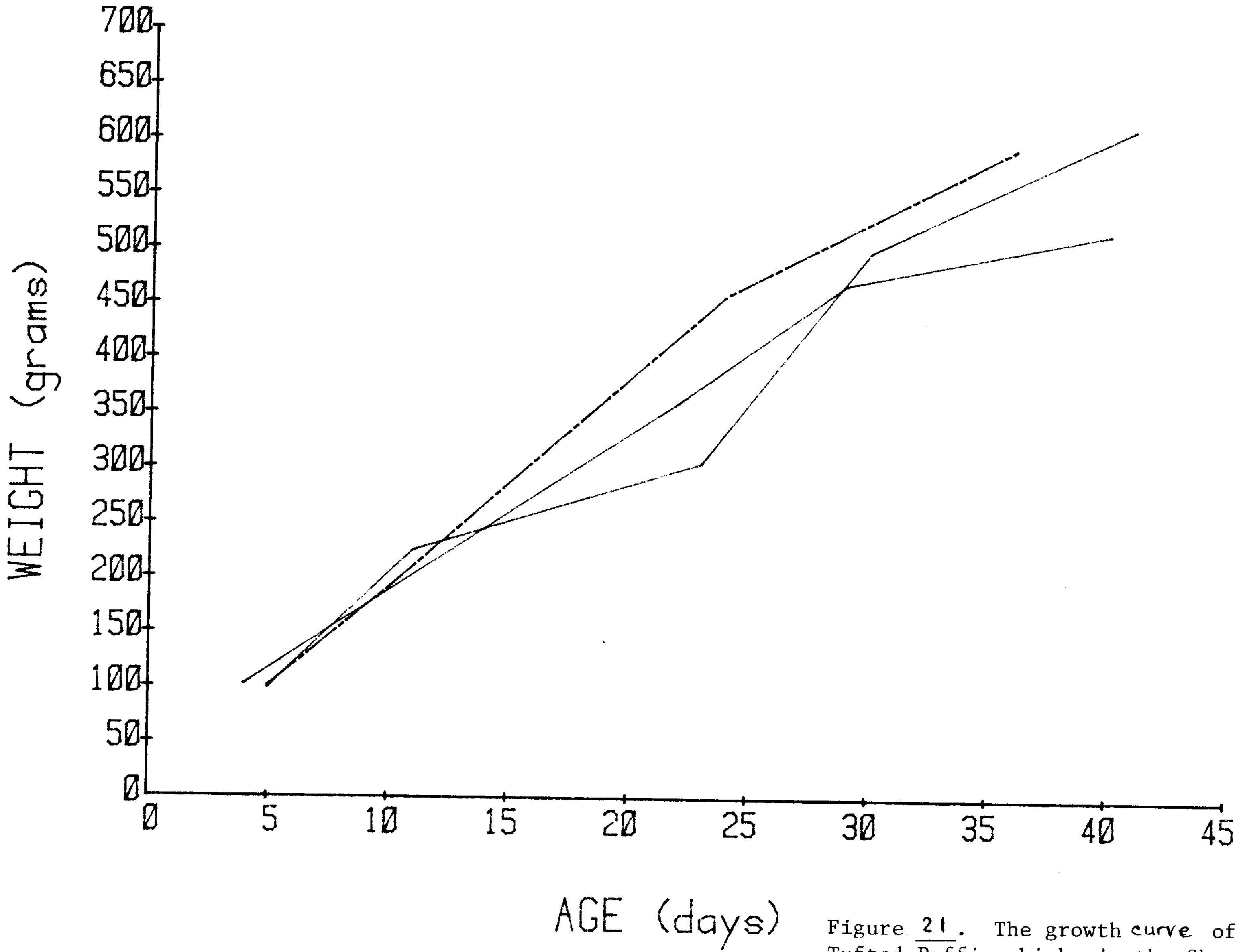


Figure 21. The growth curve of the Tufted Puffin chicks in the Sheep Island sample plot during the 1977 breeding season.

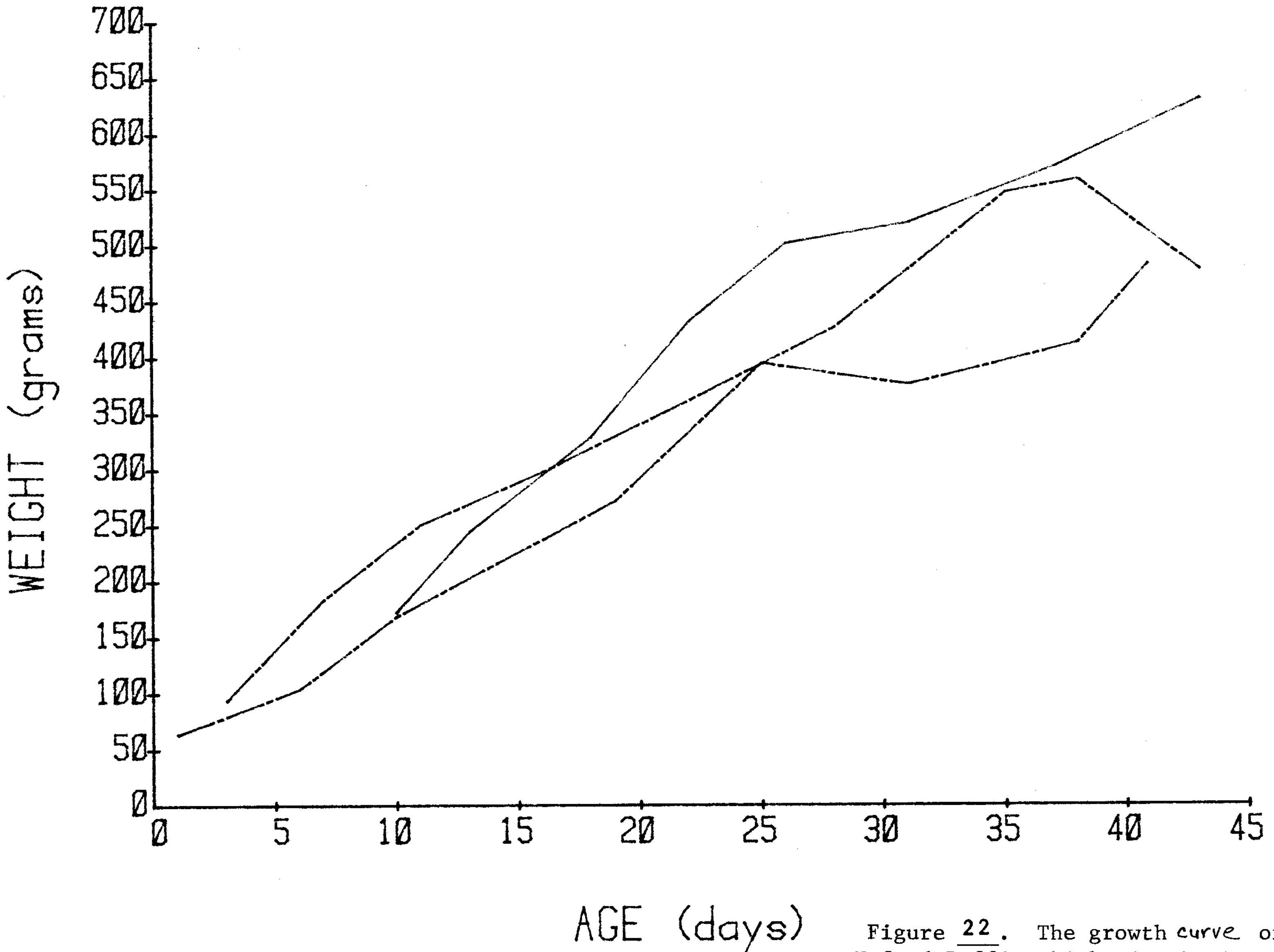


Figure 22. The growth curve of the Tufted Puffin chicks in the Amee Island sample plot during the 1977 breeding season.

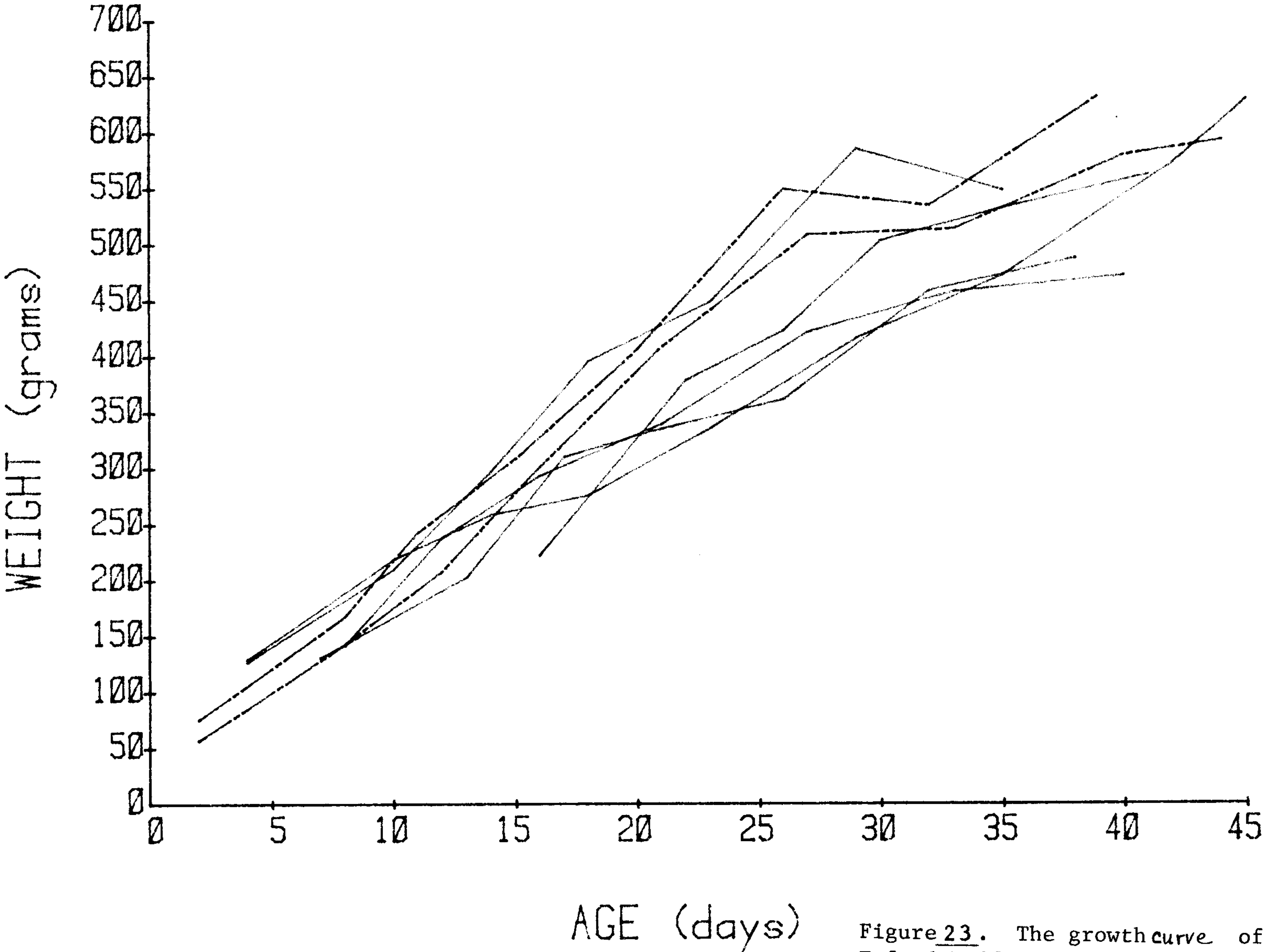


Figure 23. The growth curve of the Tufted Puffin chicks in the Amee Rock sample plot during the 1977 breeding season.

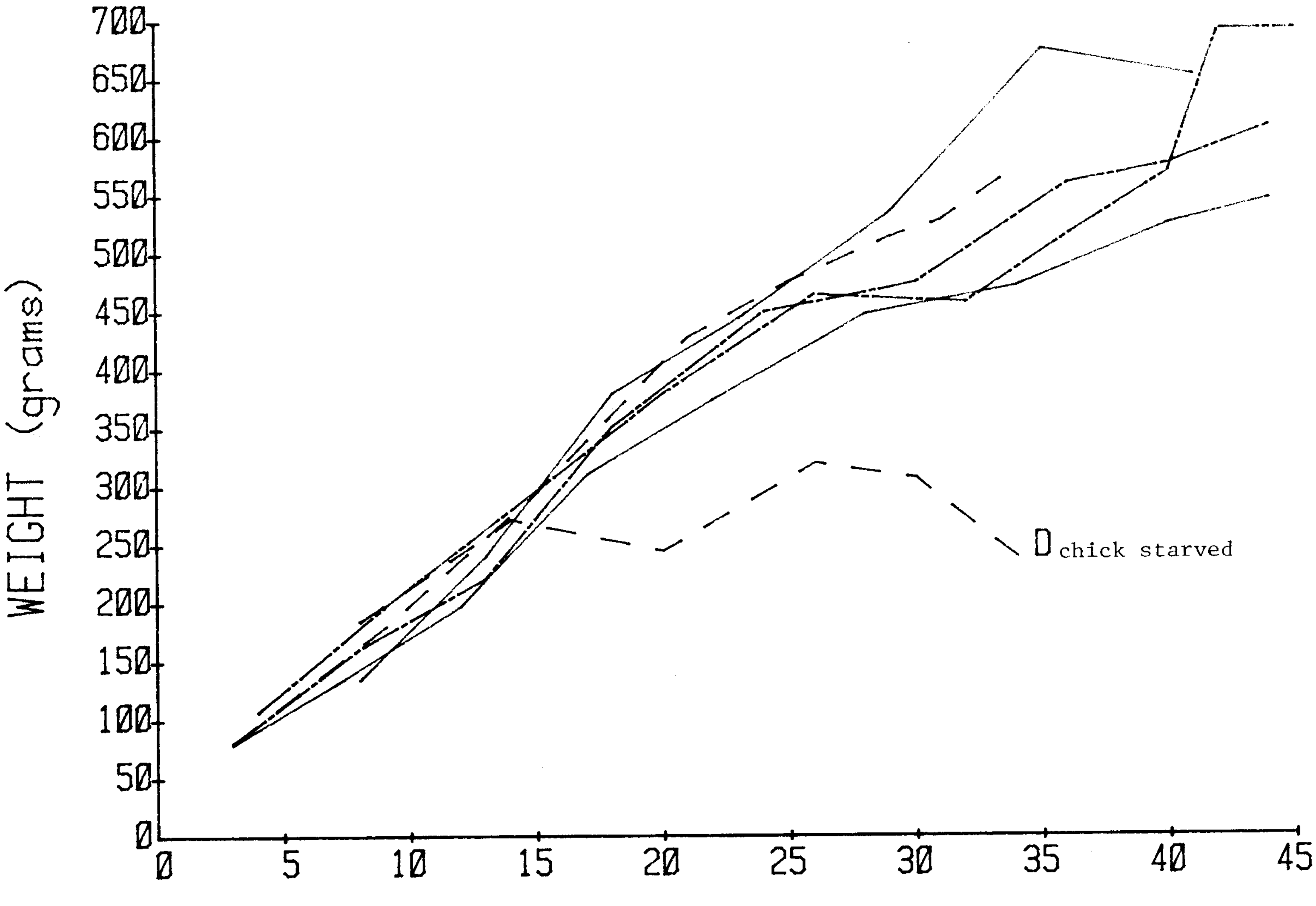


Figure 24. The growth curve of the Tufted Puffin chicks in plot 04 of the Cathedral Island colony during the 1977 breeding season.

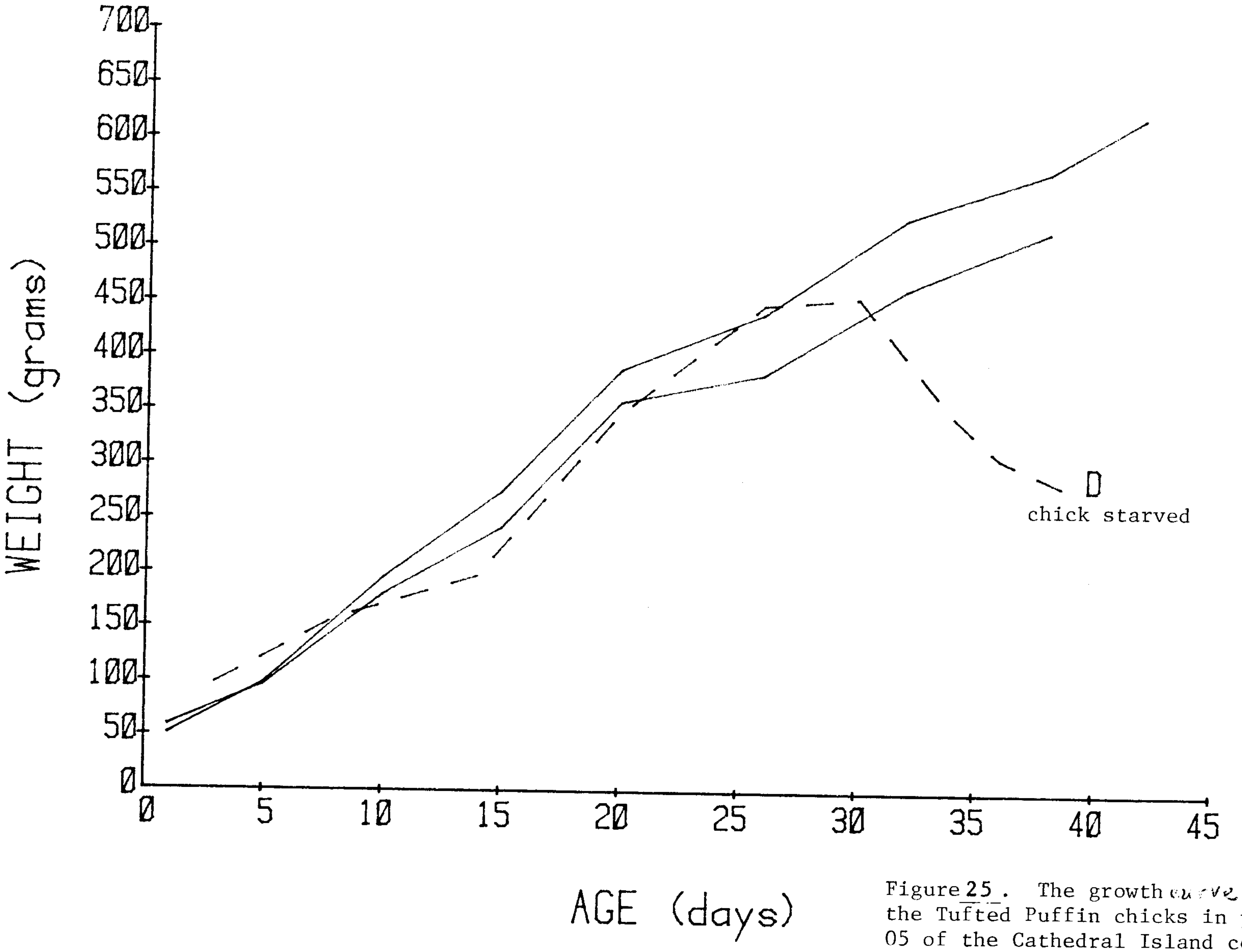


Figure 25. The growth curve of the Tufted Puffin chicks in plot 05 of the Cathedral Island colony during the 1977 breeding season.

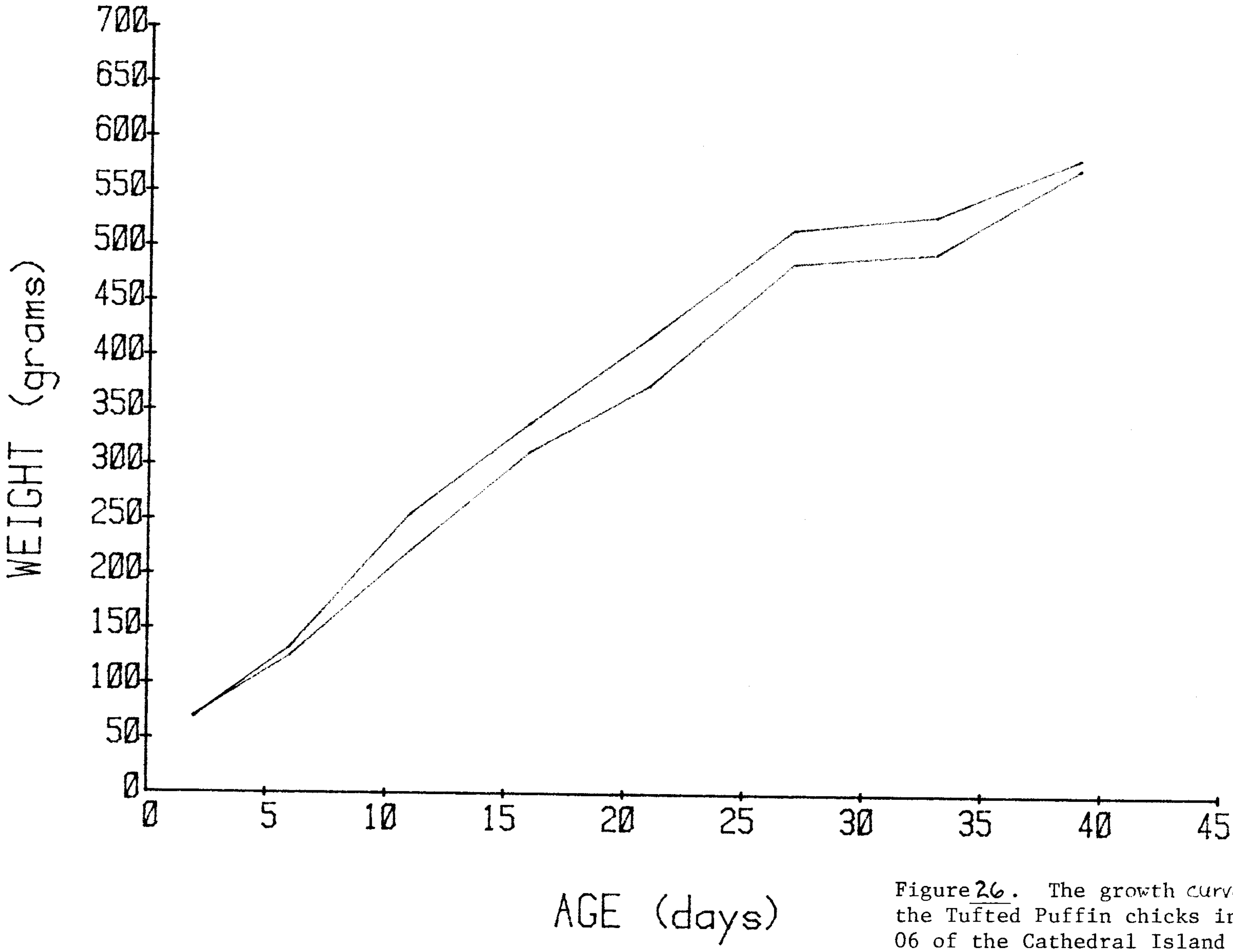


Figure 26. The growth curve of the Tufted Puffin chicks in plot 06 of the Cathedral Island colony during the 1977 breeding season.

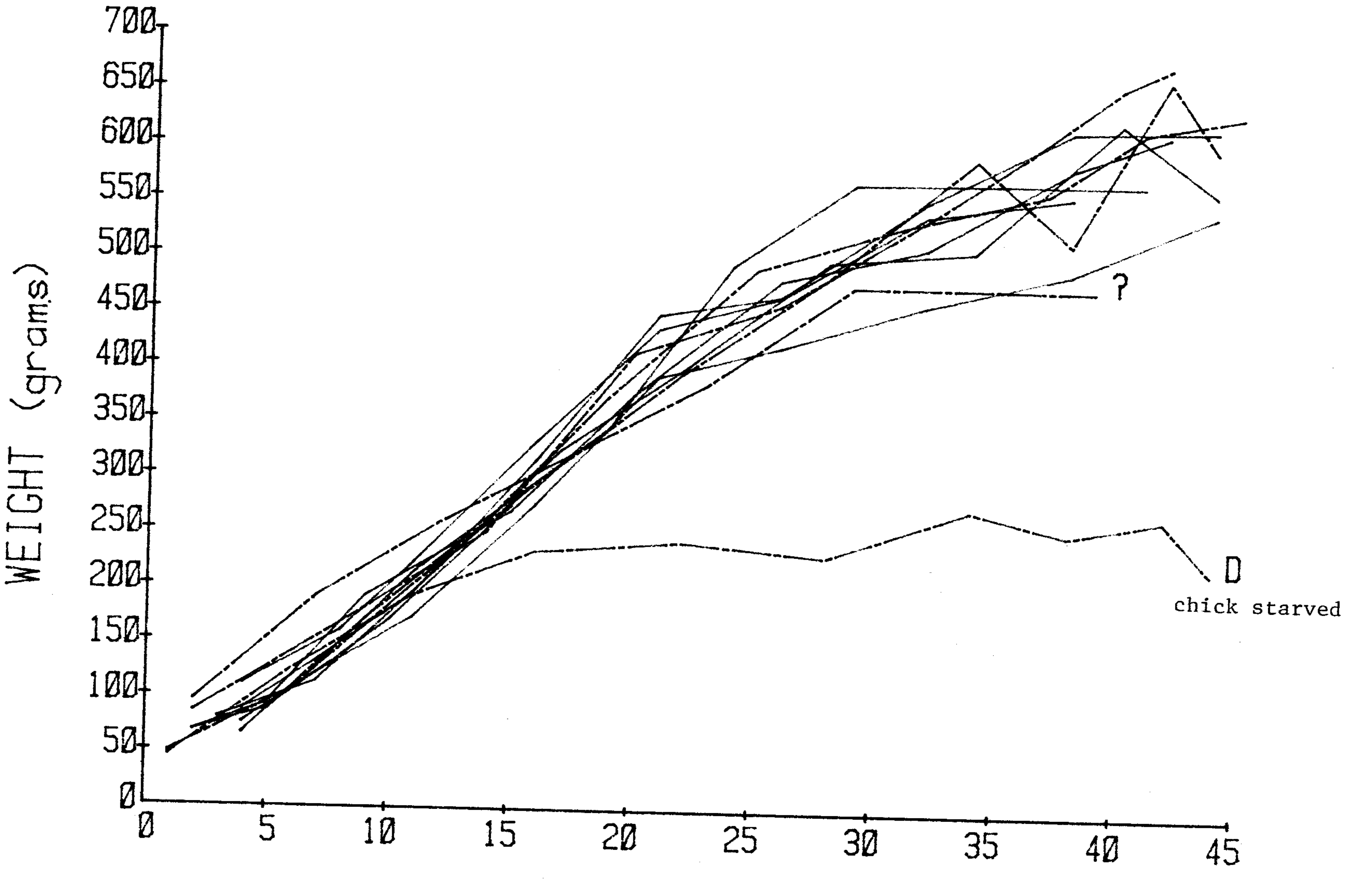


Figure 27. The growth curve of the Tufted Puffin chicks in plot 07 of the Cathedral Island colony during the 1977 breeding season.

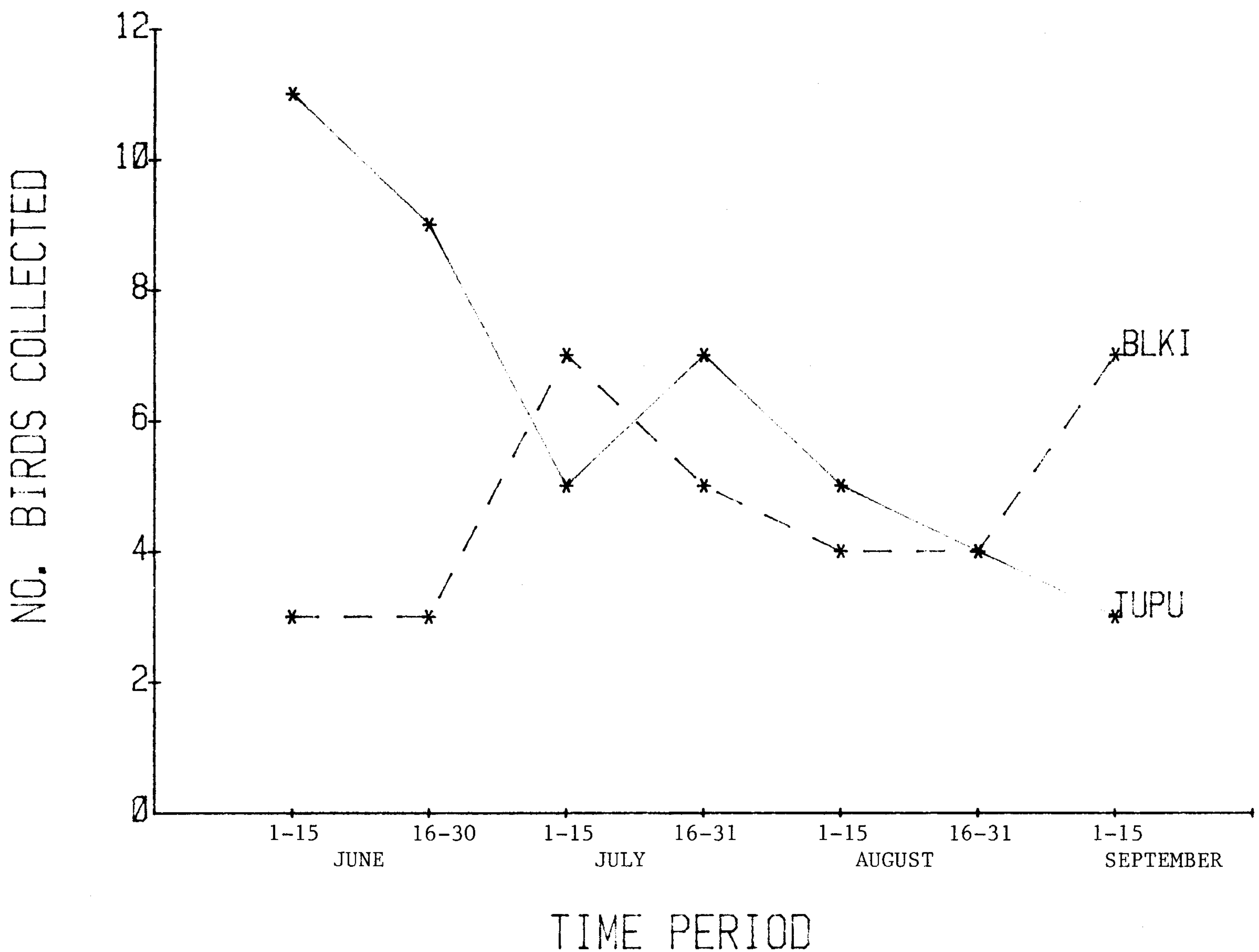


Figure 28. The numbers of Black-legged Kittiwakes and Tufted Puffins collected in bi-weekly periods at Sitkalidak Strait, Kodiak Island, Alaska. 1977.

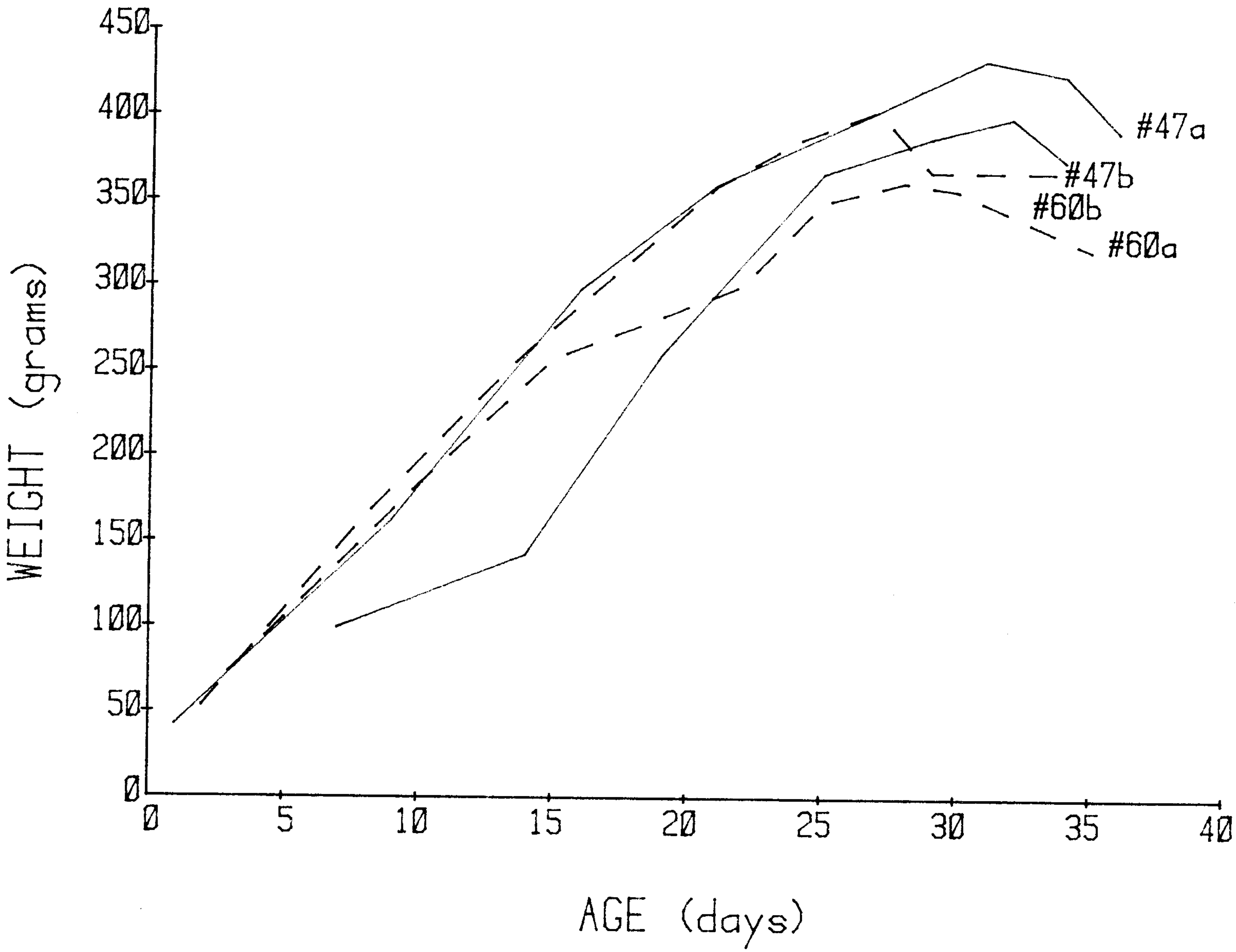


Figure 28A. Growth curve of each chick in the two-chick Black-legged Kittiwake nests observed 11 August during the Lesser Kittiwake Rock food watch.

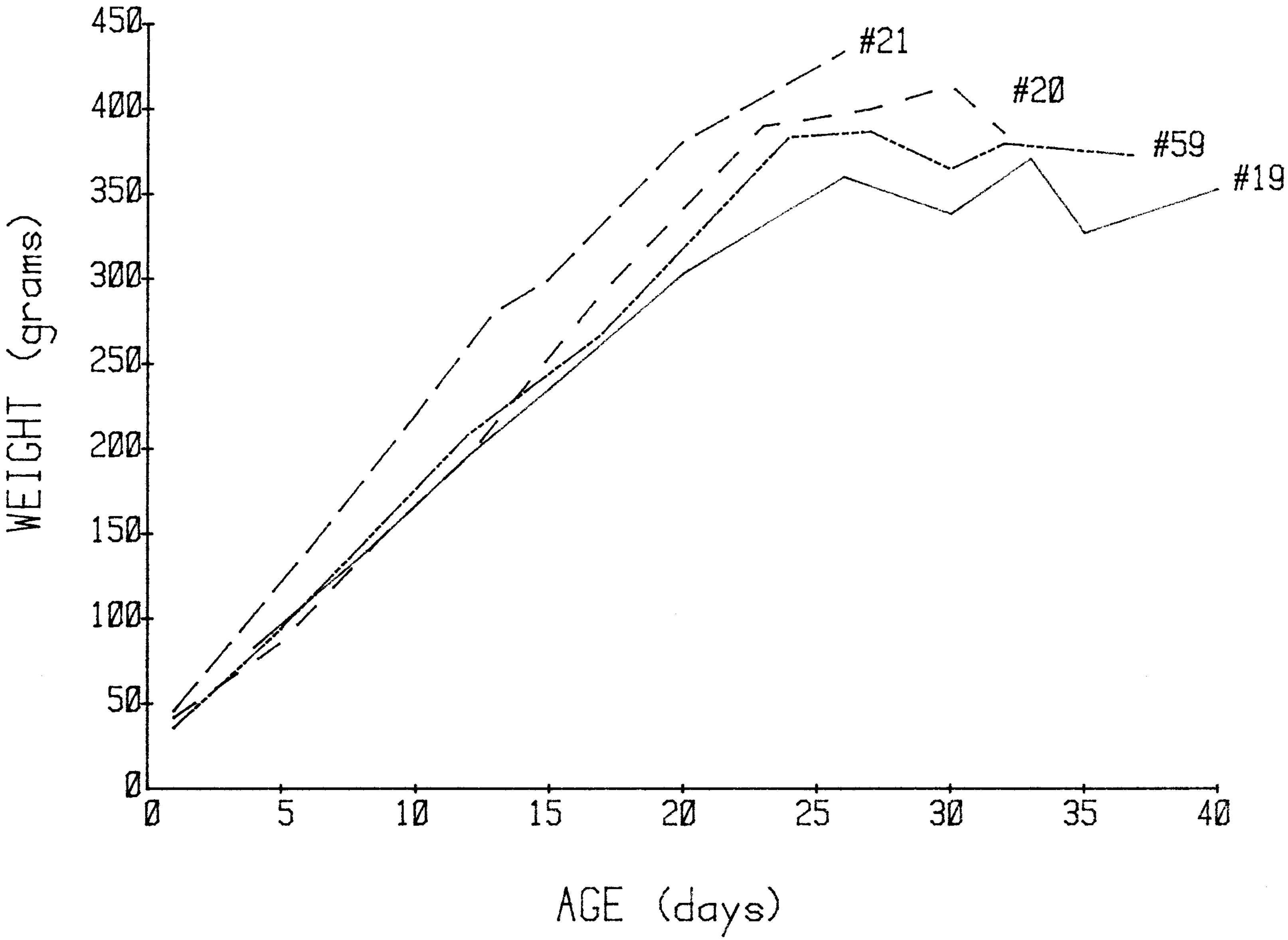
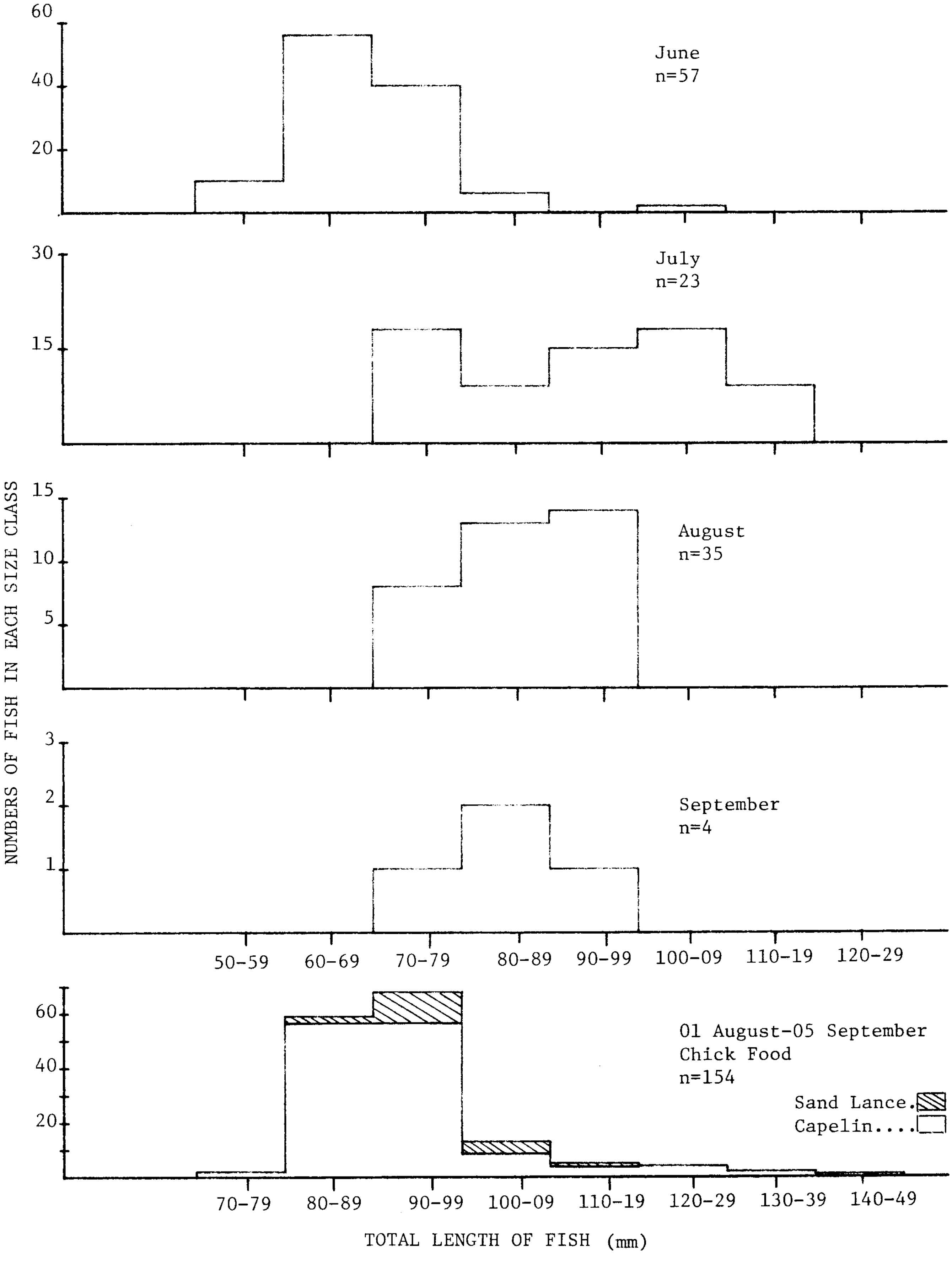
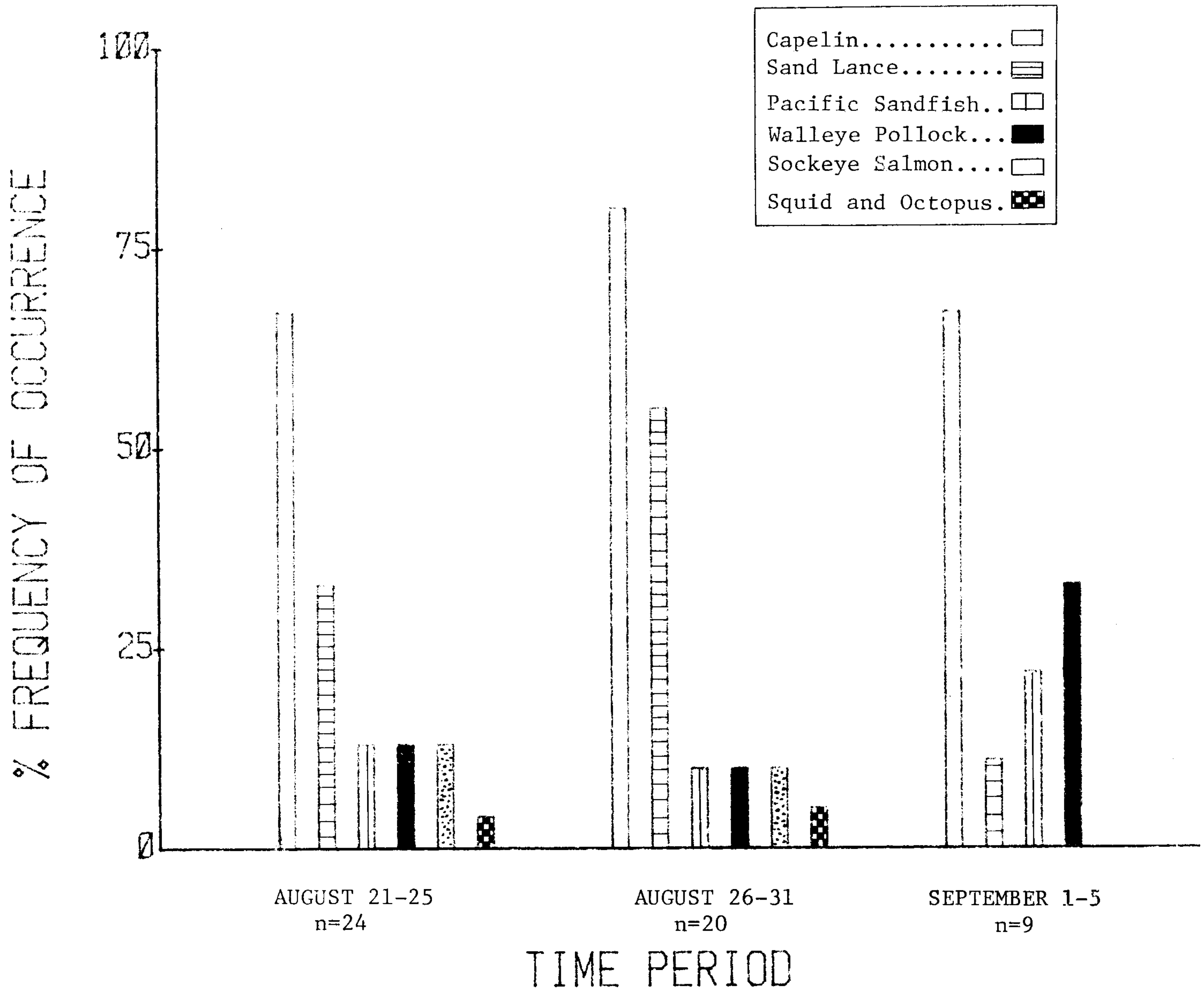


Figure 28B. Growth curve of each chick in single-chick Black-legged Kittiwake nests observed 11 August during the Lesser Kittiwake Rock food watch.

Figure 29. Distribution of total lengths of Capelin taken by Tufted Puffins during the summer of 1977 at Sitkalidak Straits. The top four graphs are based on stomach contents of adults. The bottom graph is based on food brought in for the chicks and includes Sand Lance. Note that the x-axis of the bottom graph differs from the others.


60
40
20
June
n=57
30
15
July
n=23
15
10
5
August
n=35
3
2
1
September
n=4
50-59
60-69
70-79
80-89
90-99
100-09
110-19
120-29
60
40
20
01 August-05 September
Chick Food
n=154
Sand Lance.
Capelin....
70-79
80-89
90-99
100-09
110-19
120-29
130-39
140-49
NUMBERS OF FISH IN EACH SIZE CLASS
TOTAL LENGTH OF FISH (mm)



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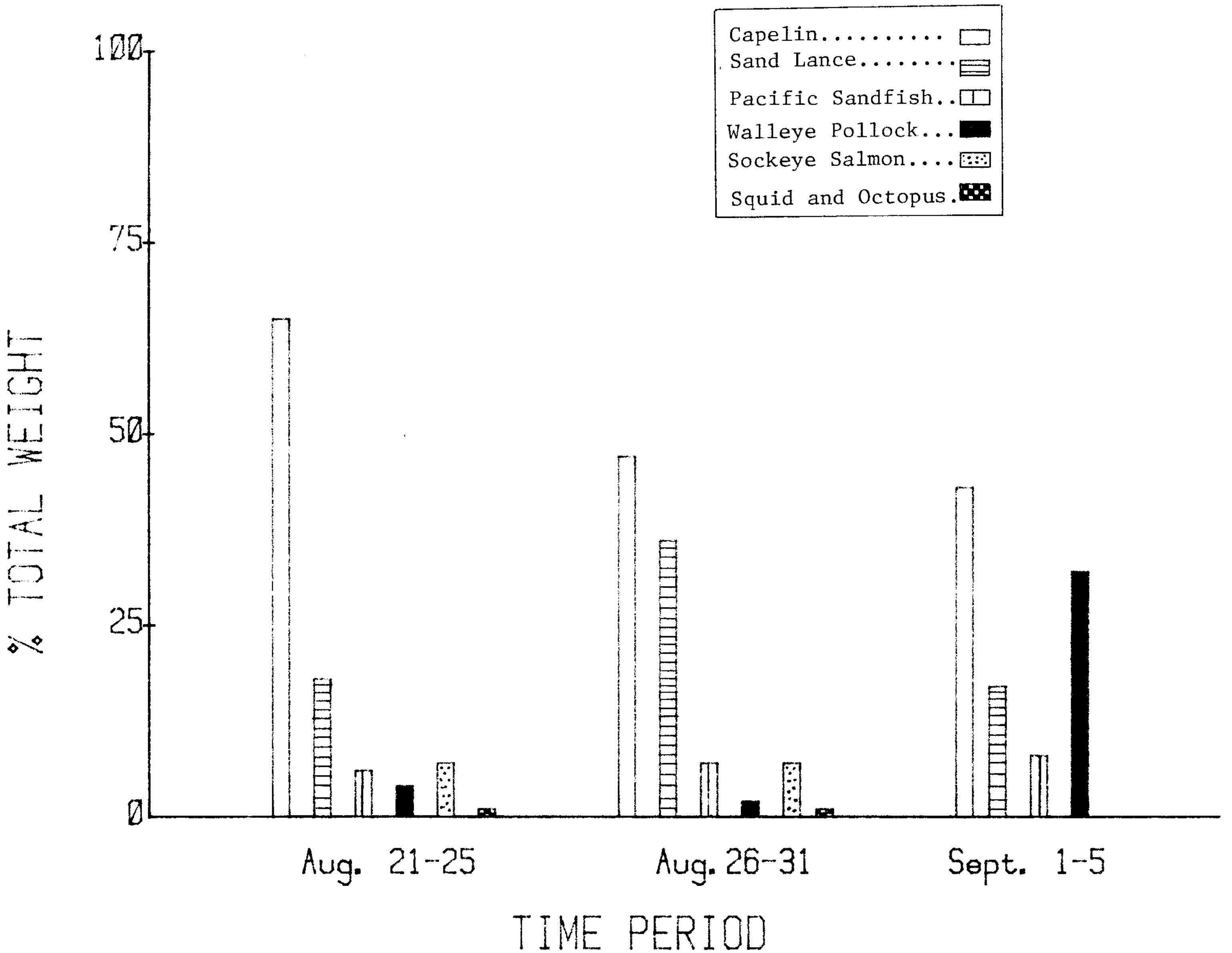

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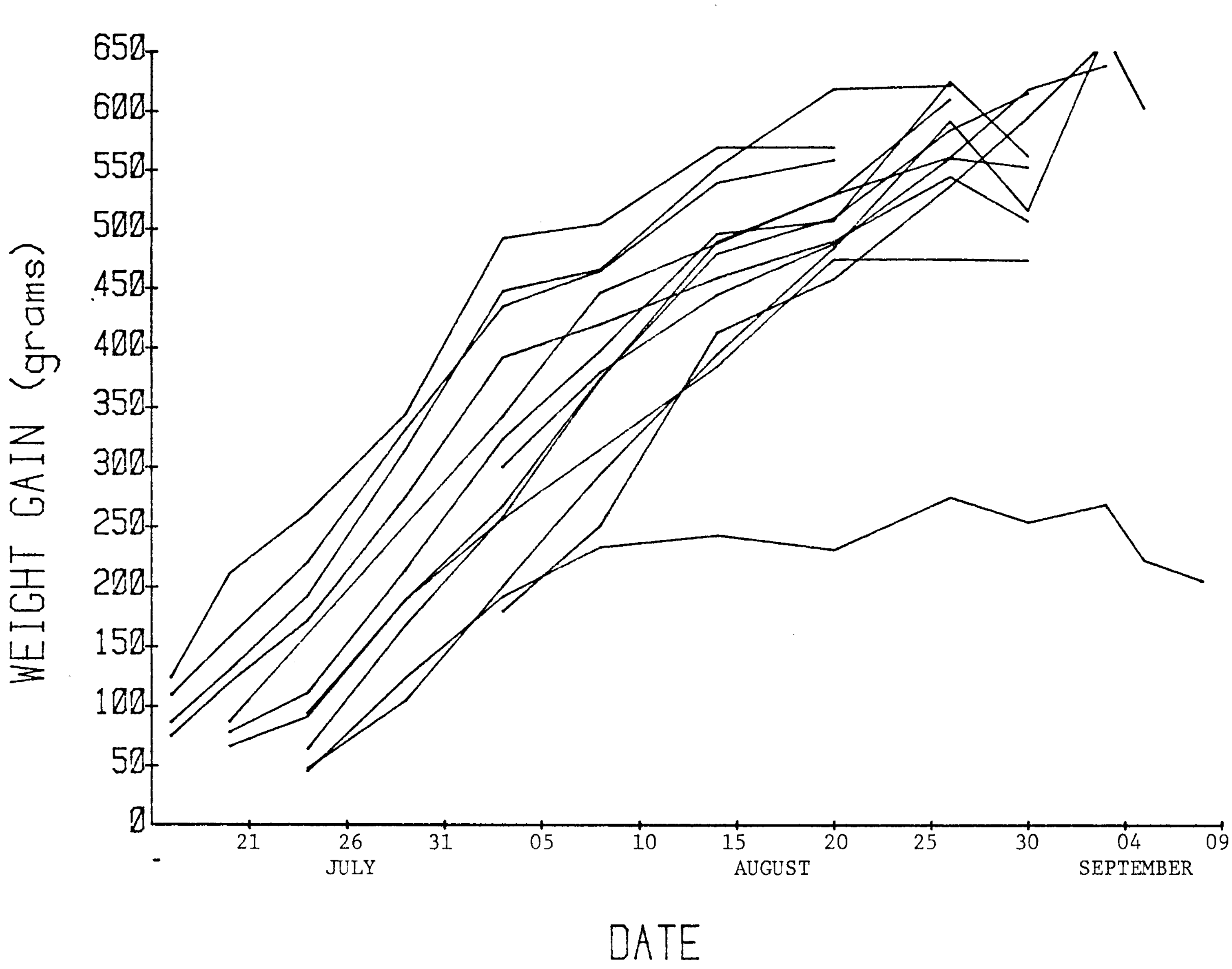

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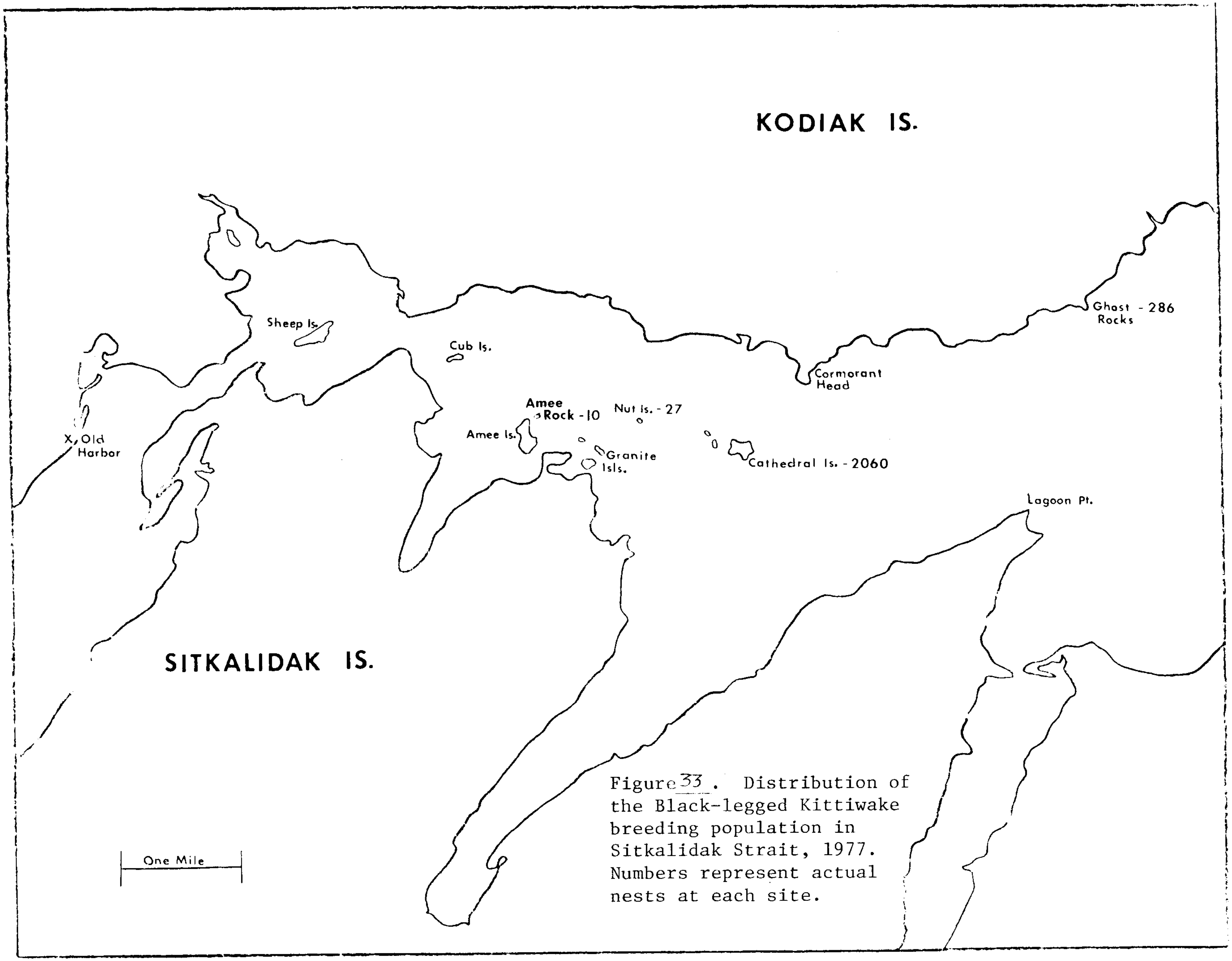

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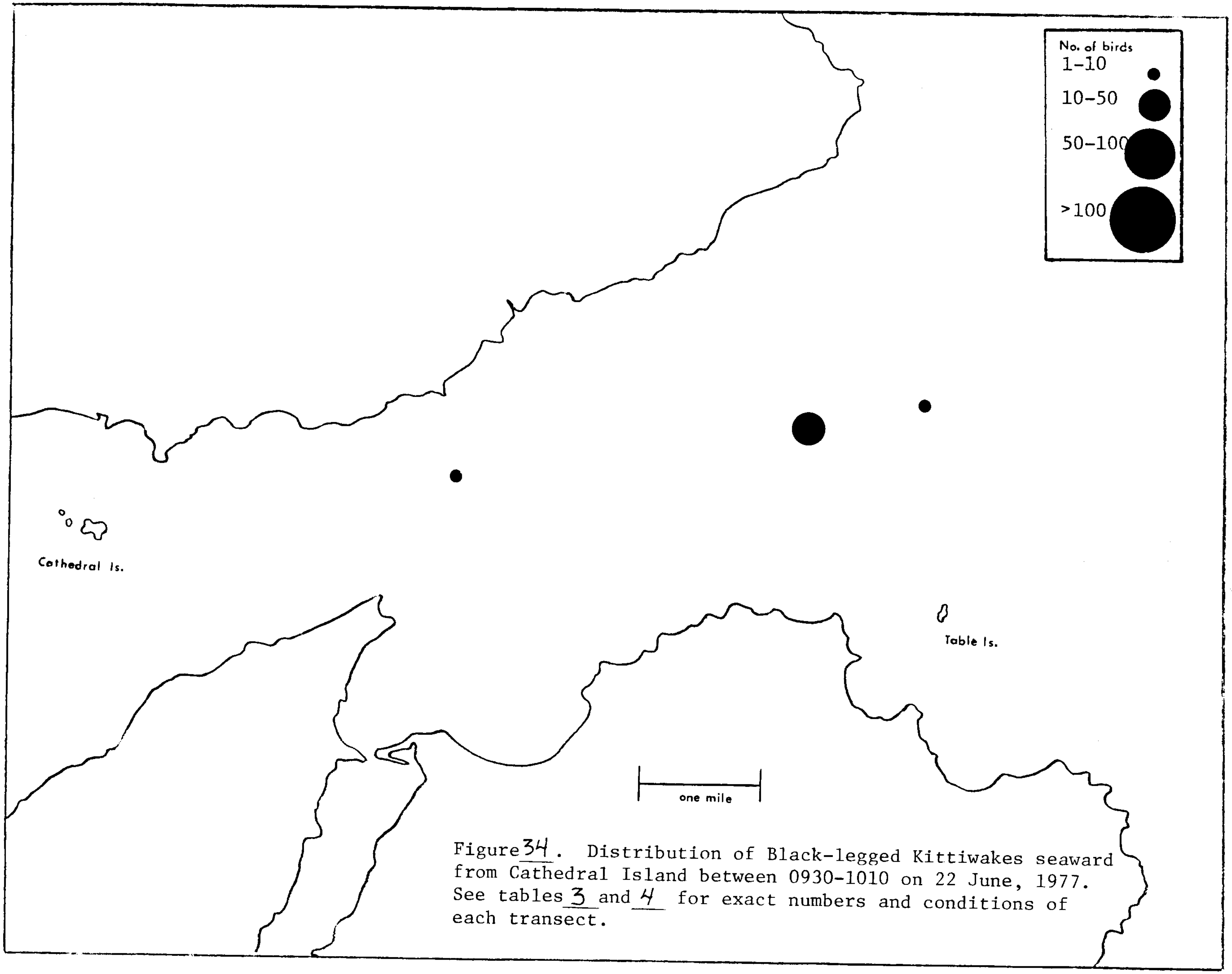

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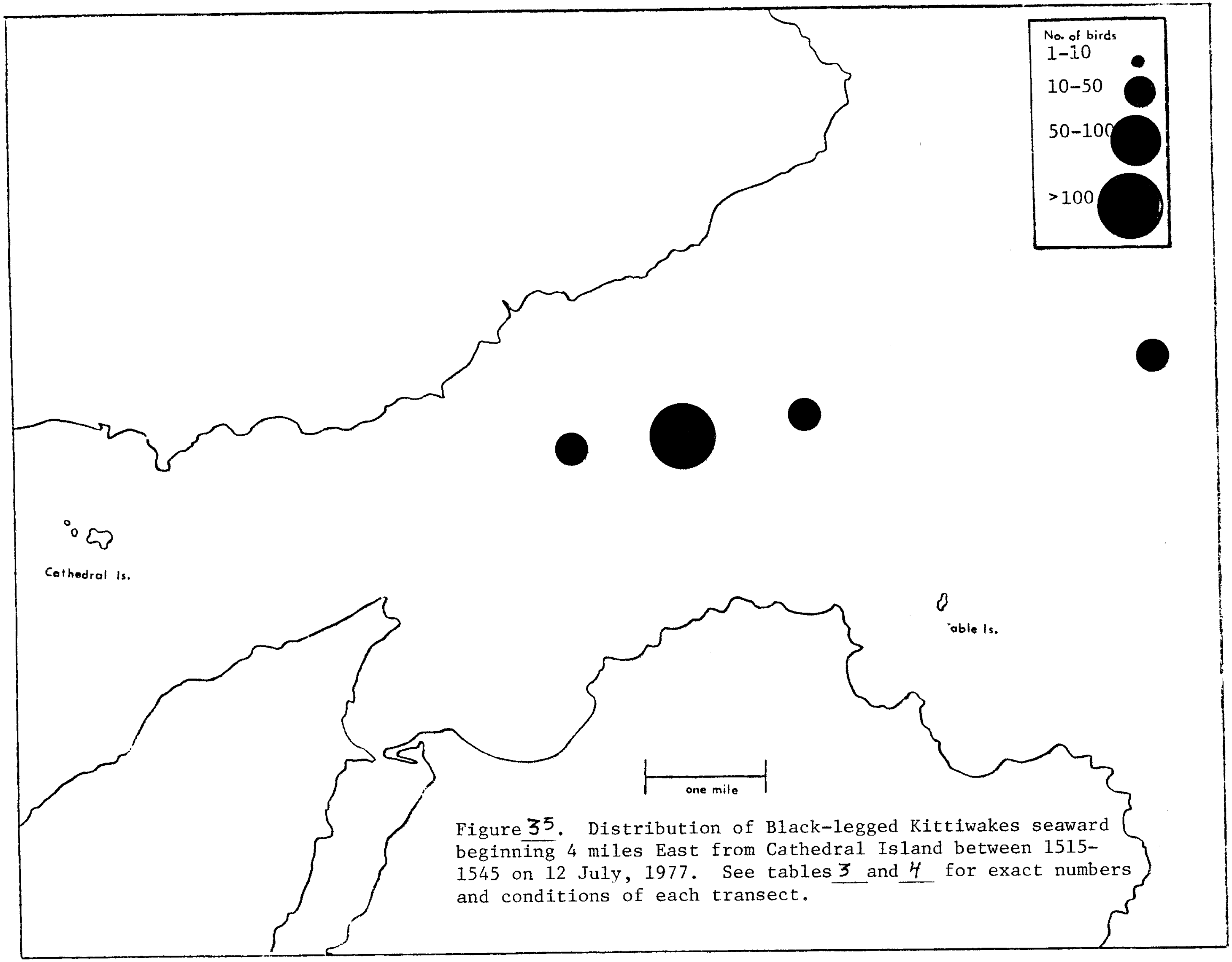

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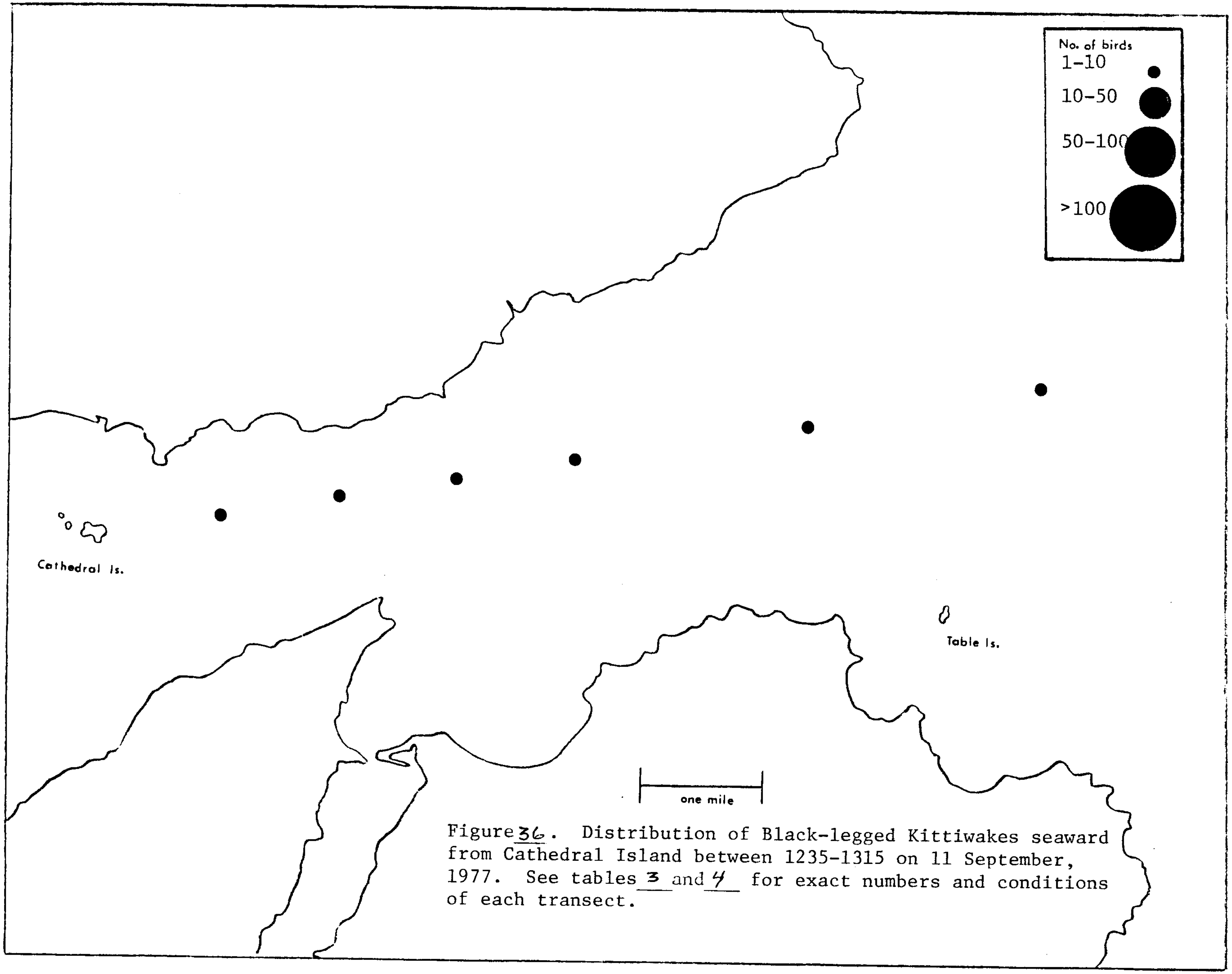

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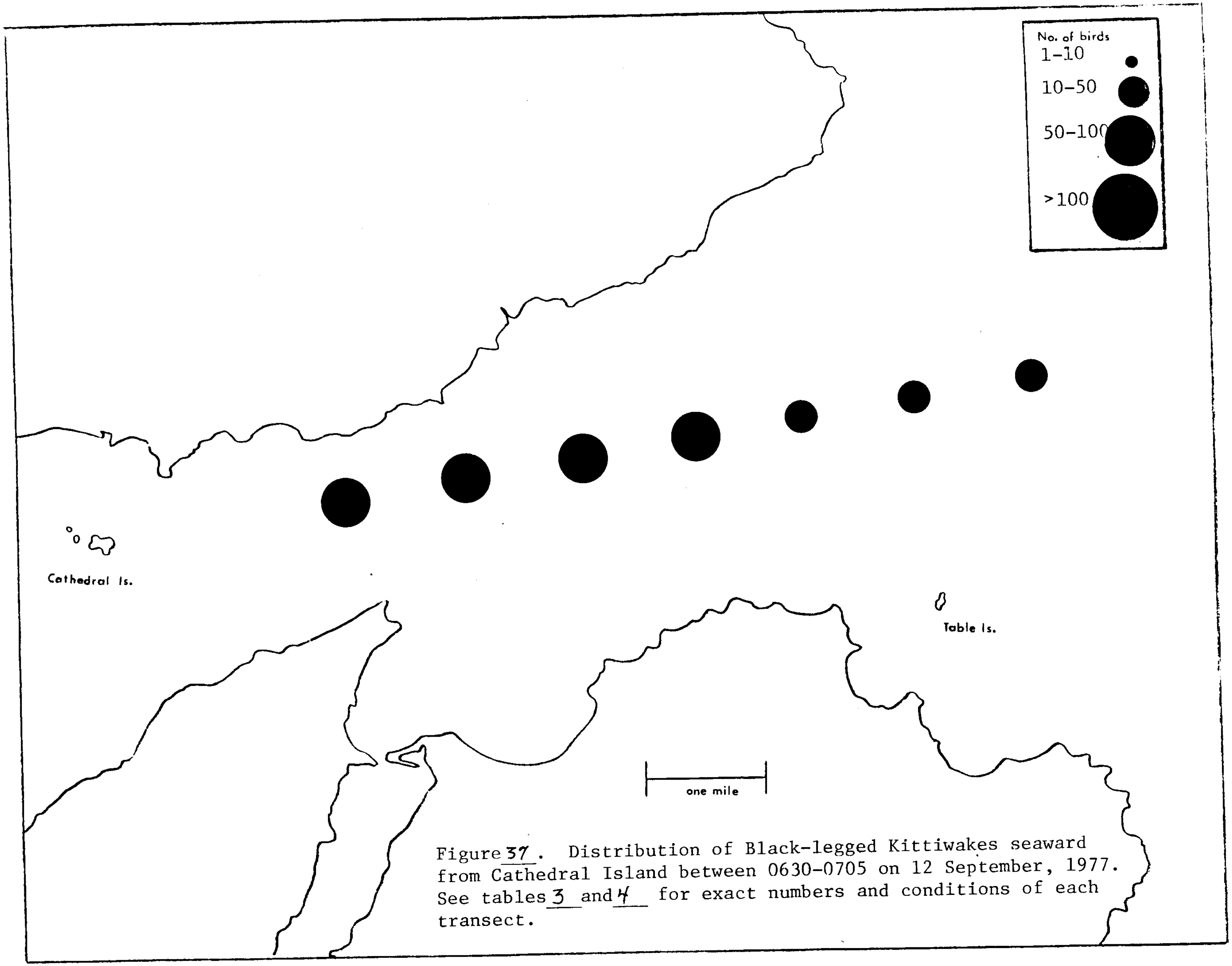

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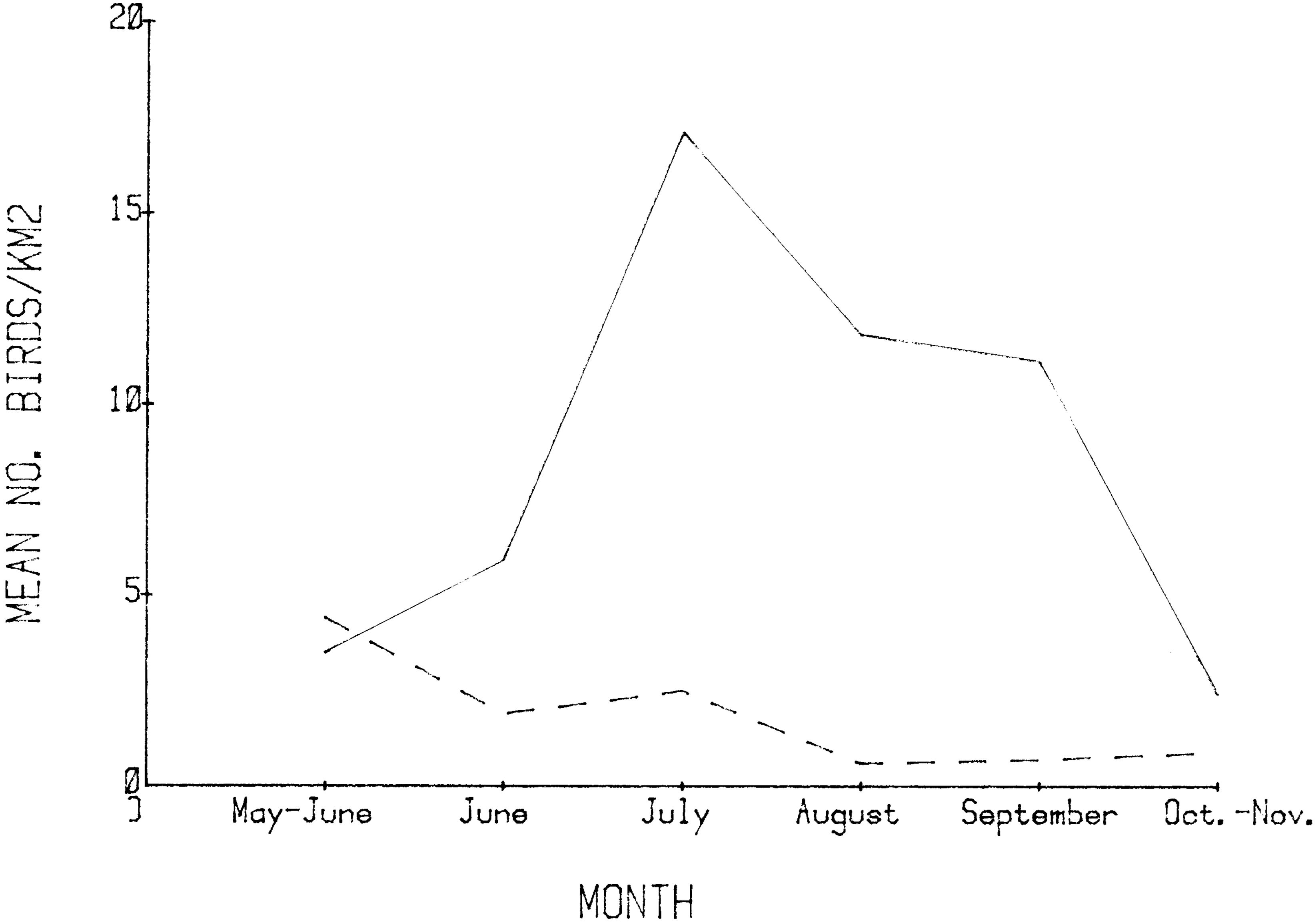

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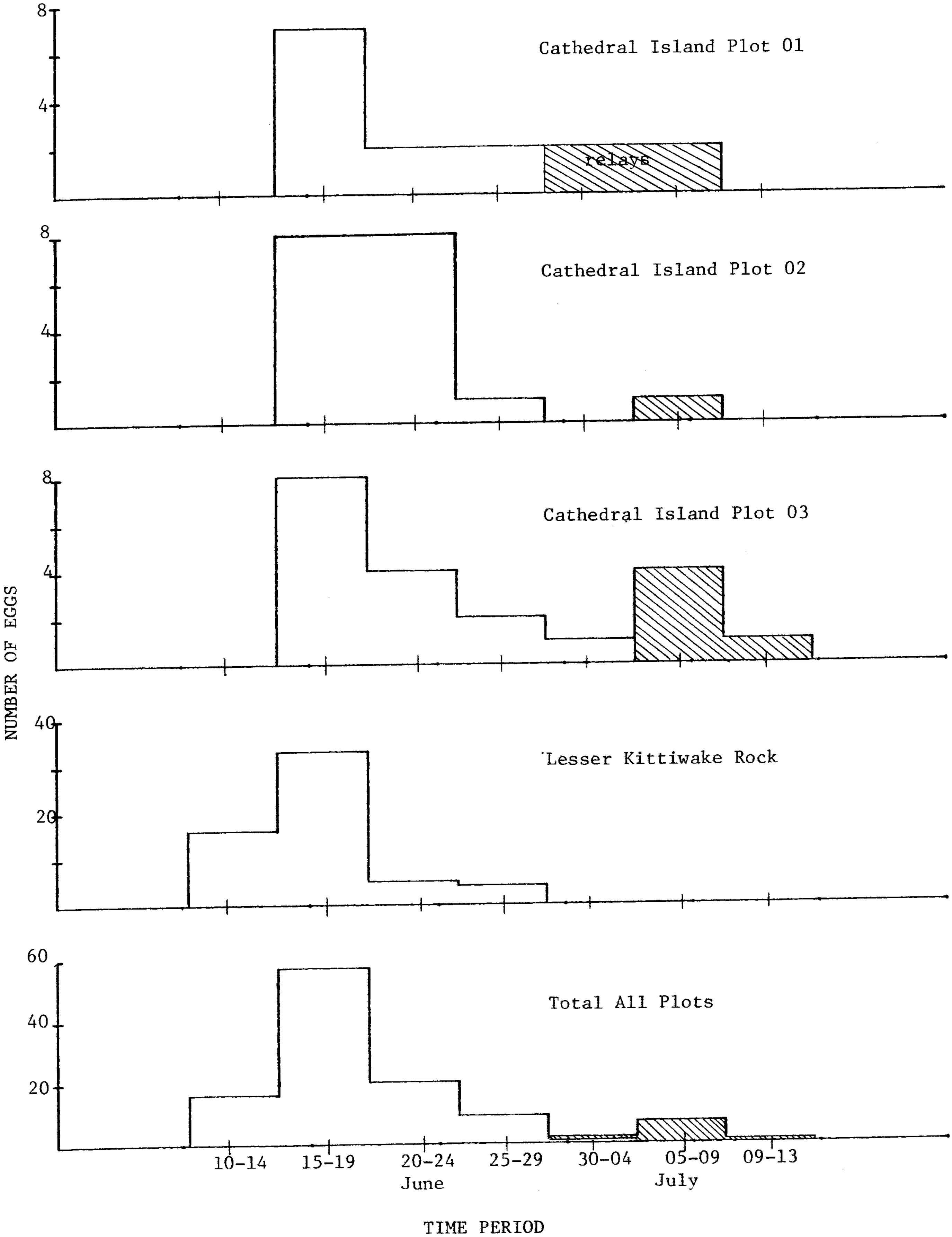

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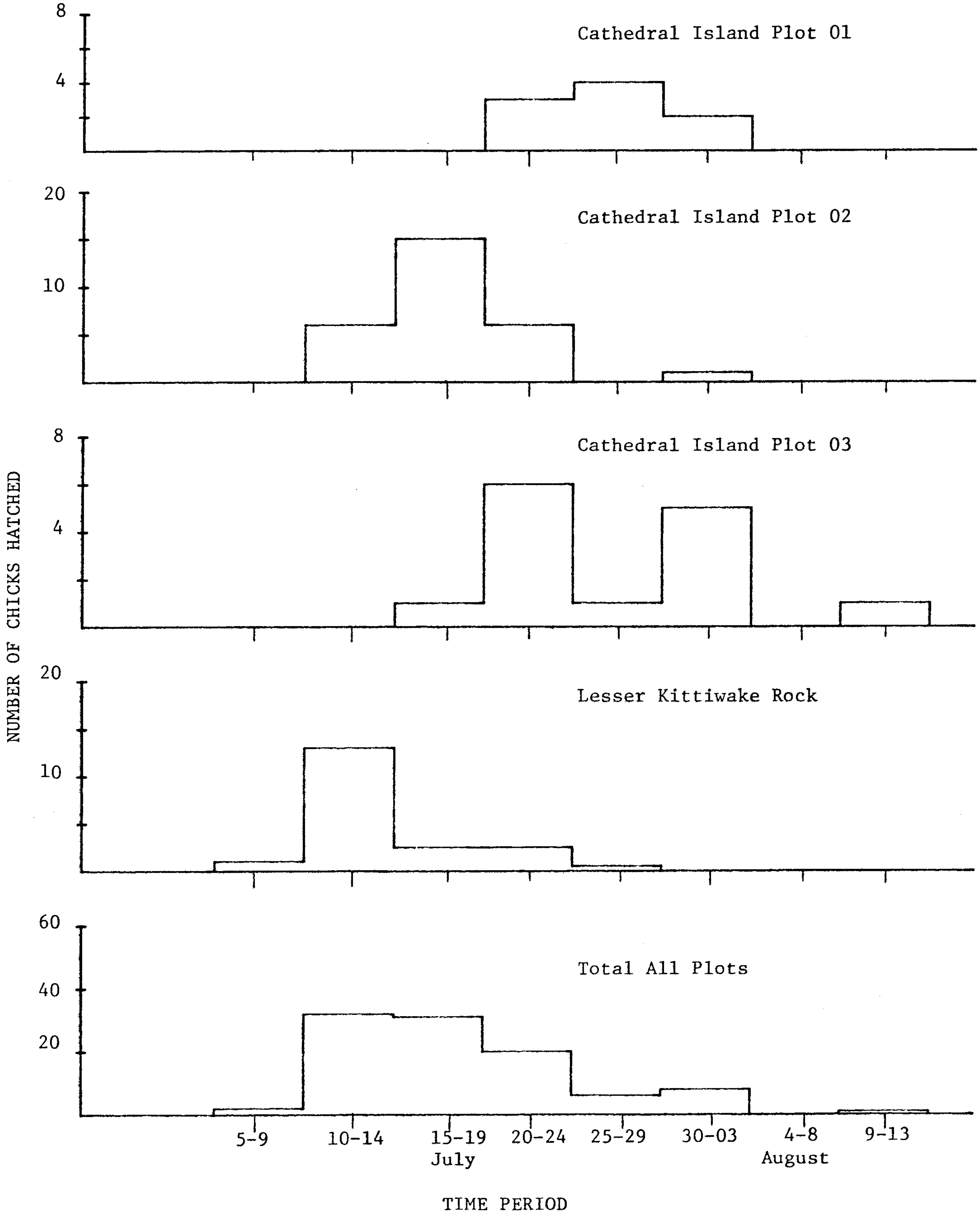

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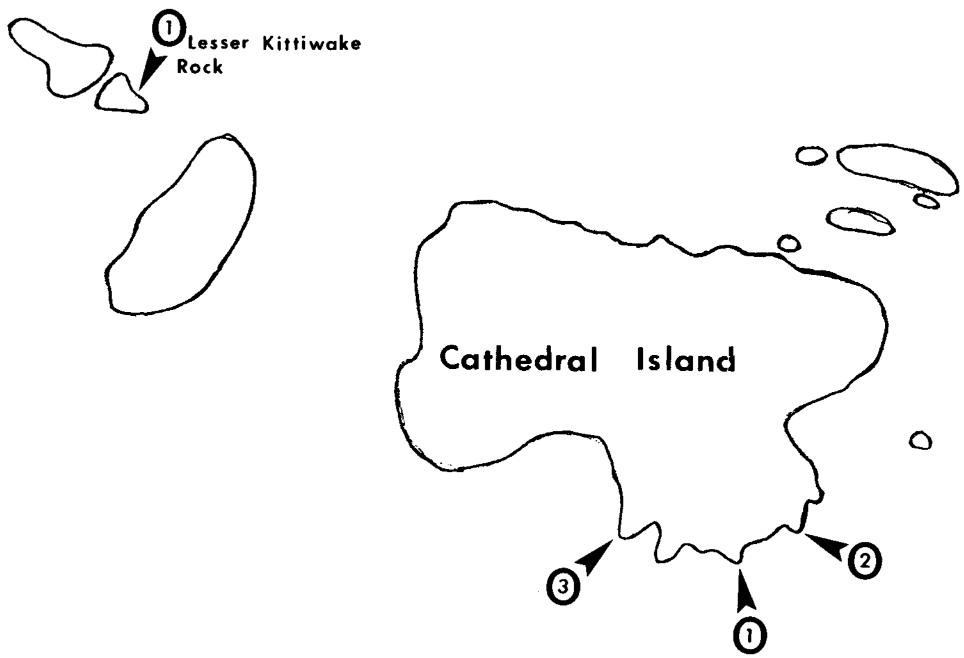

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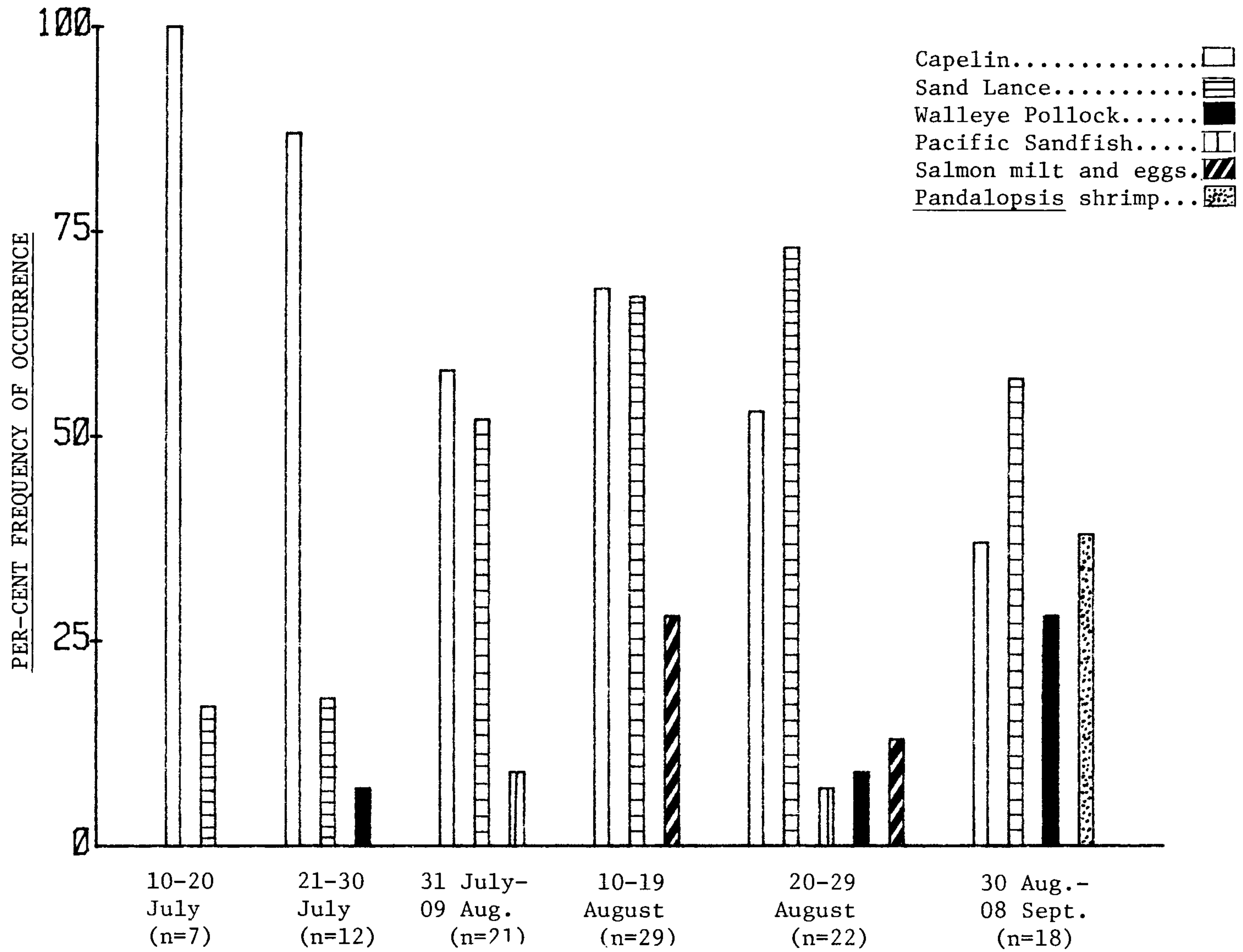

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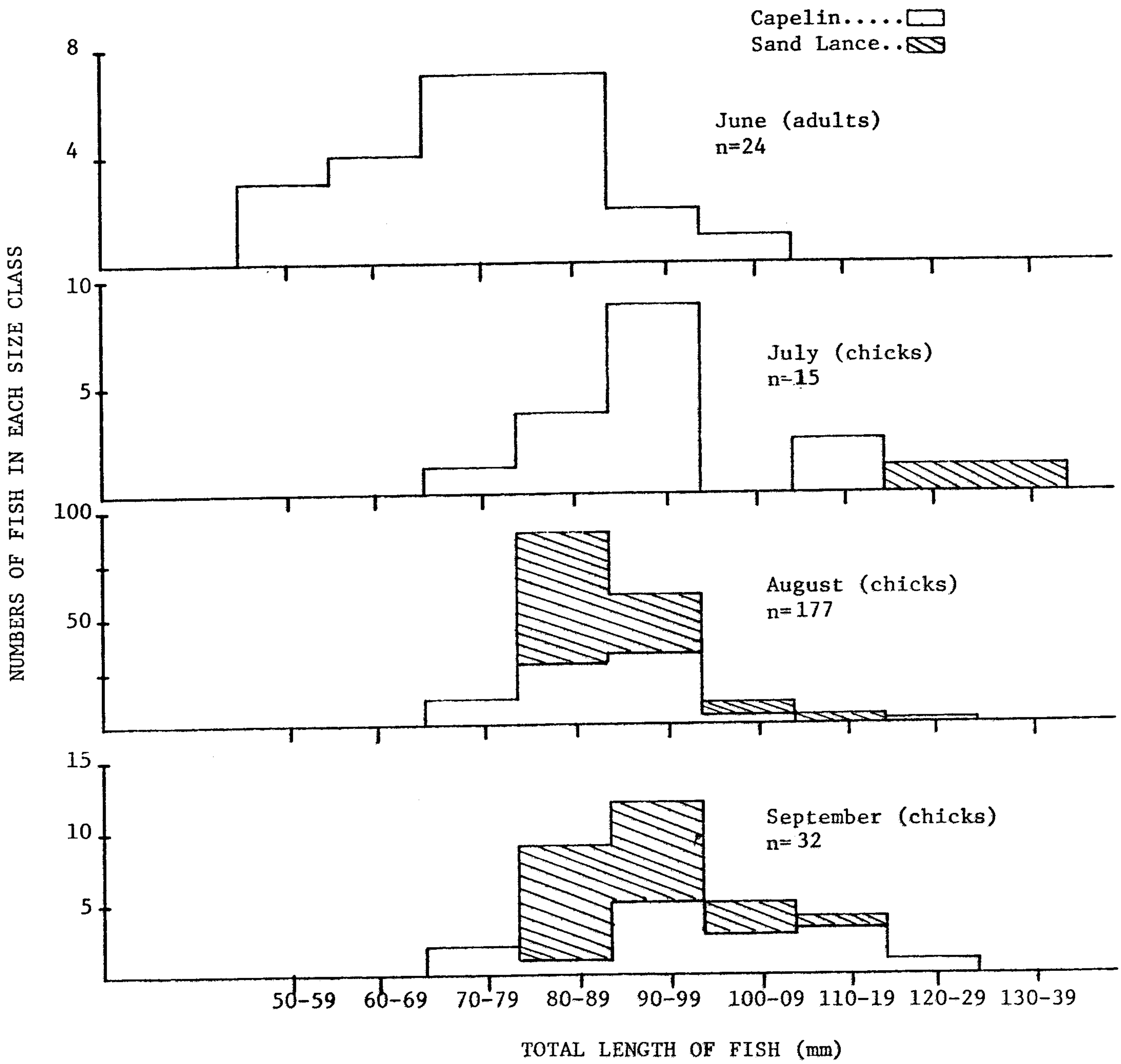

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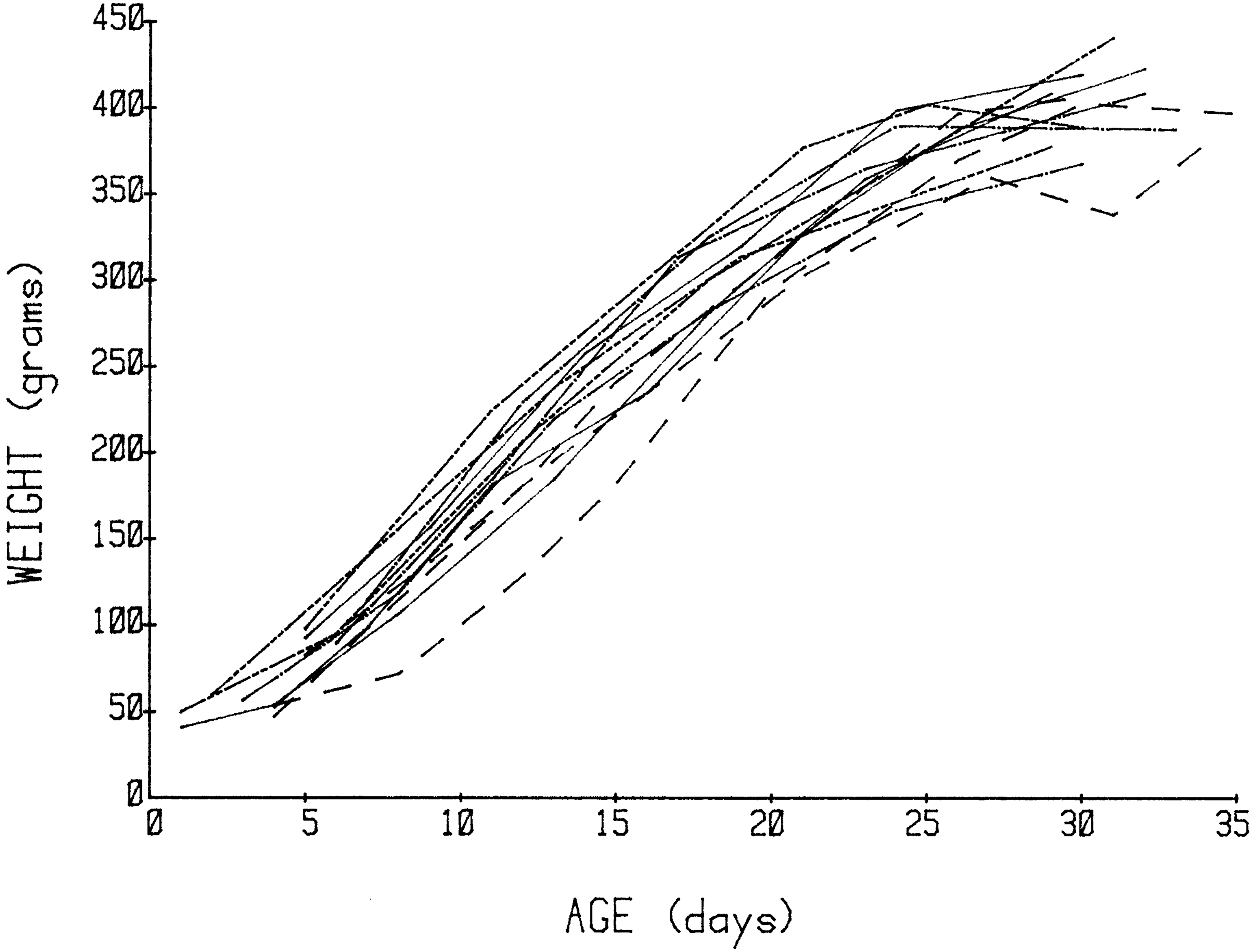

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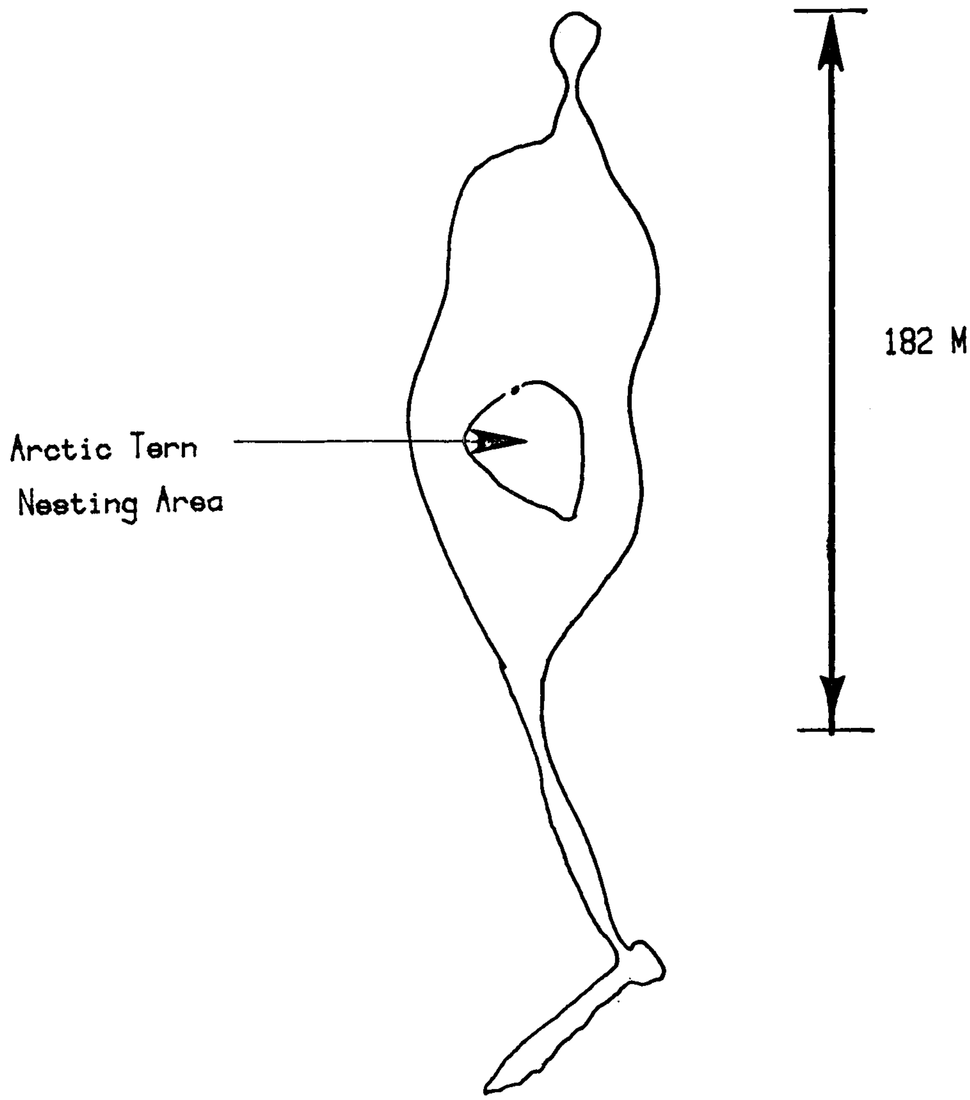

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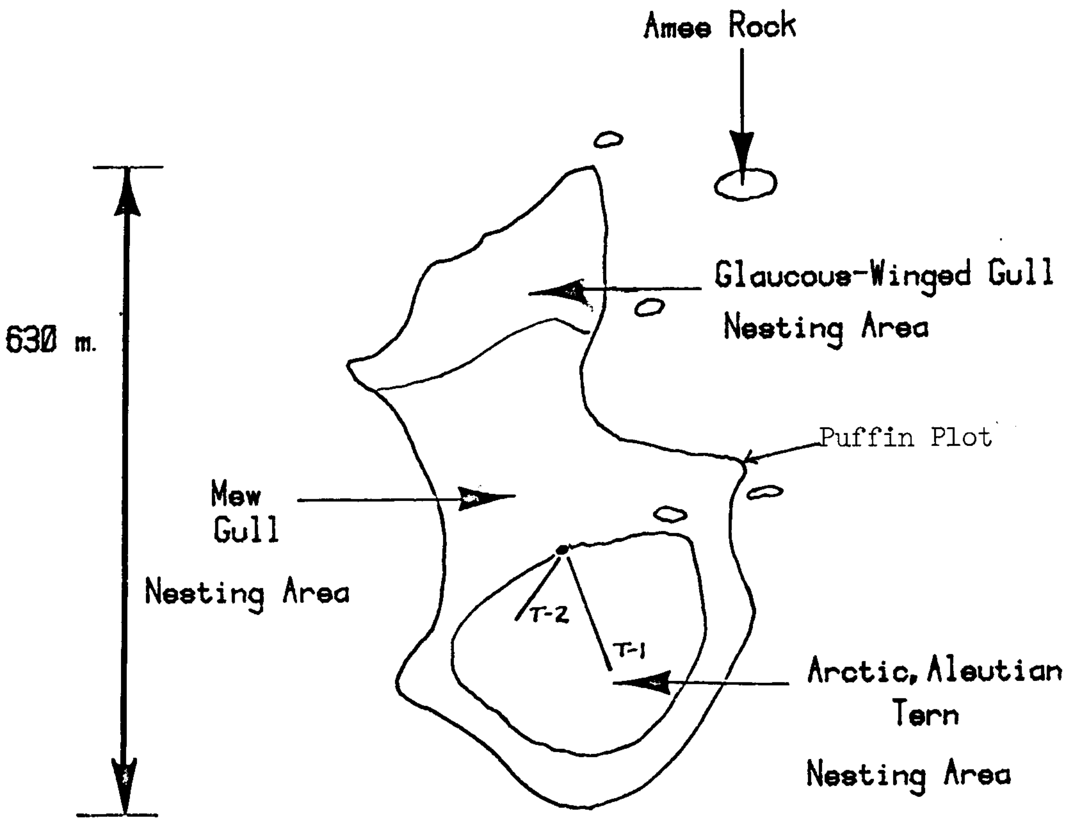
AMEE ISLAND



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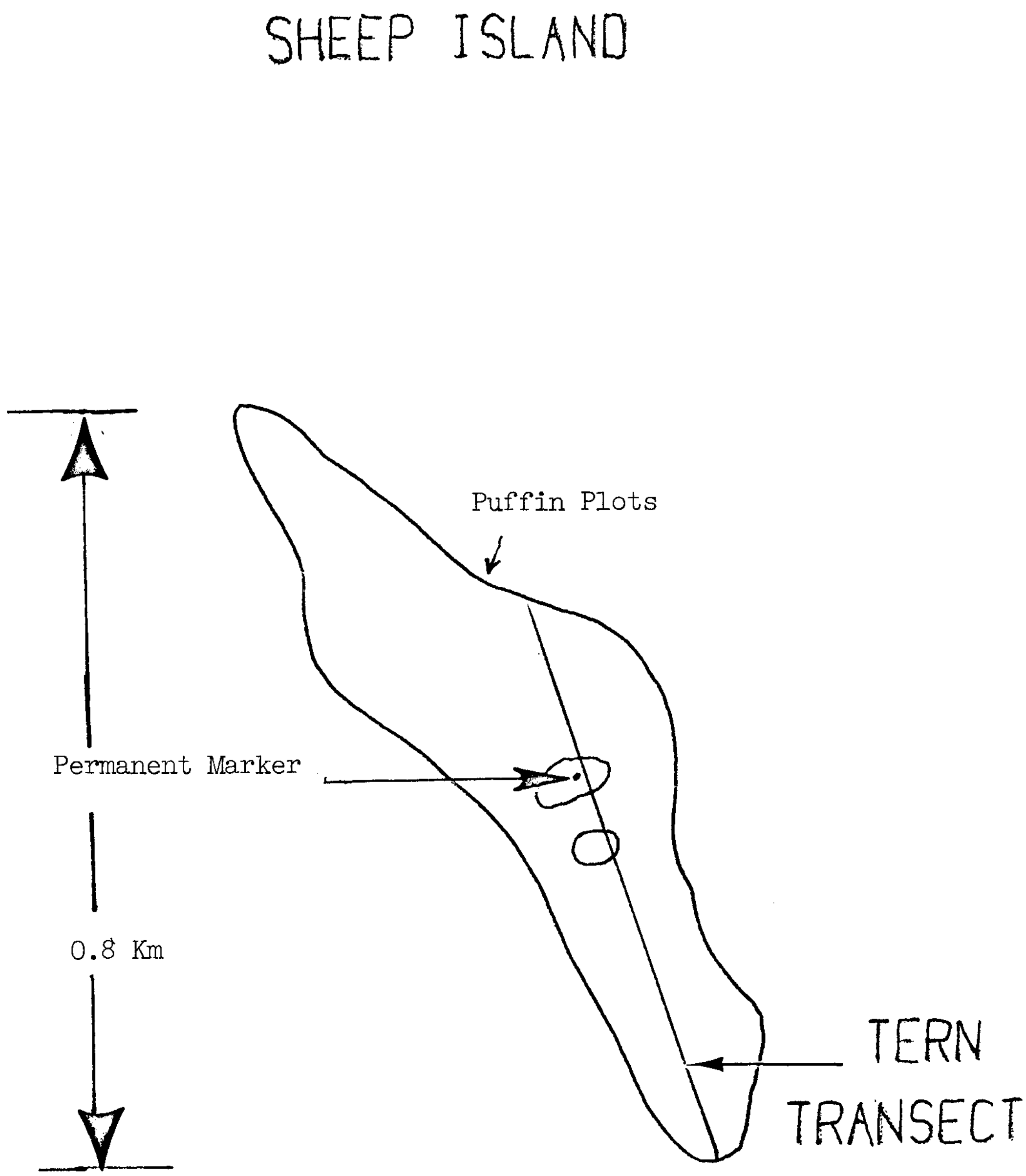

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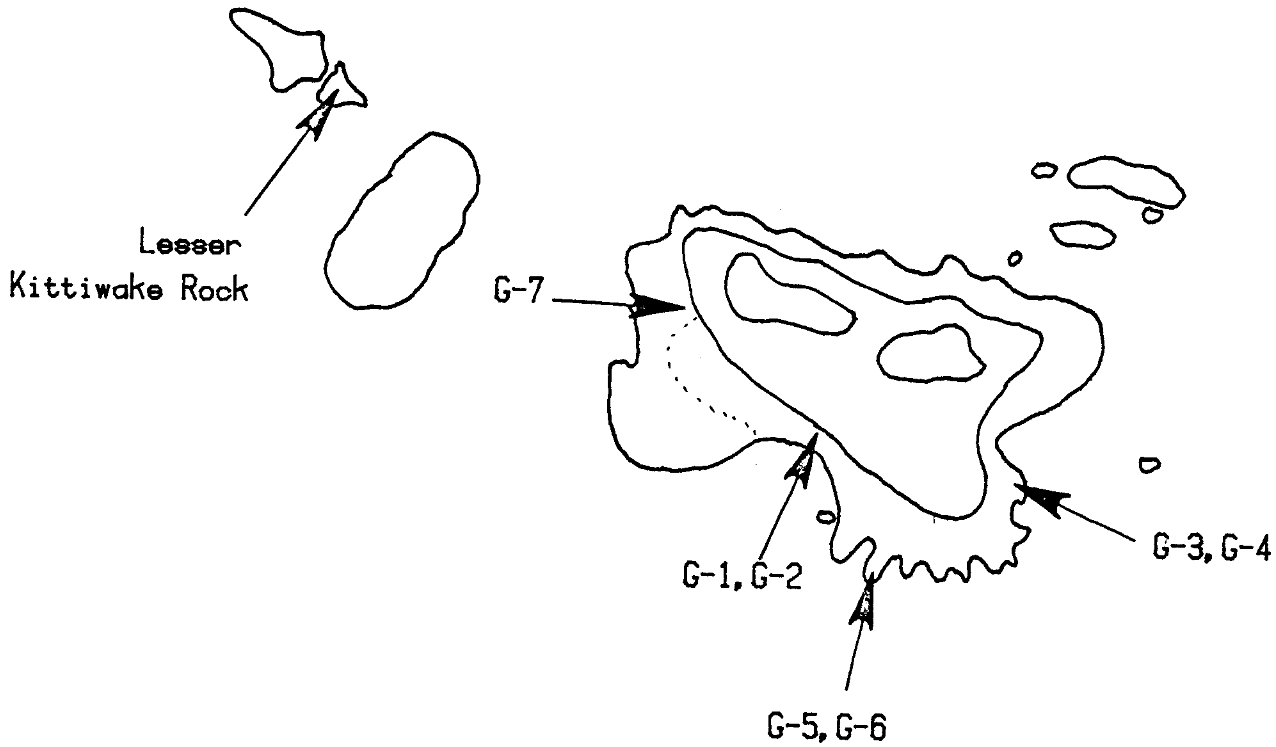

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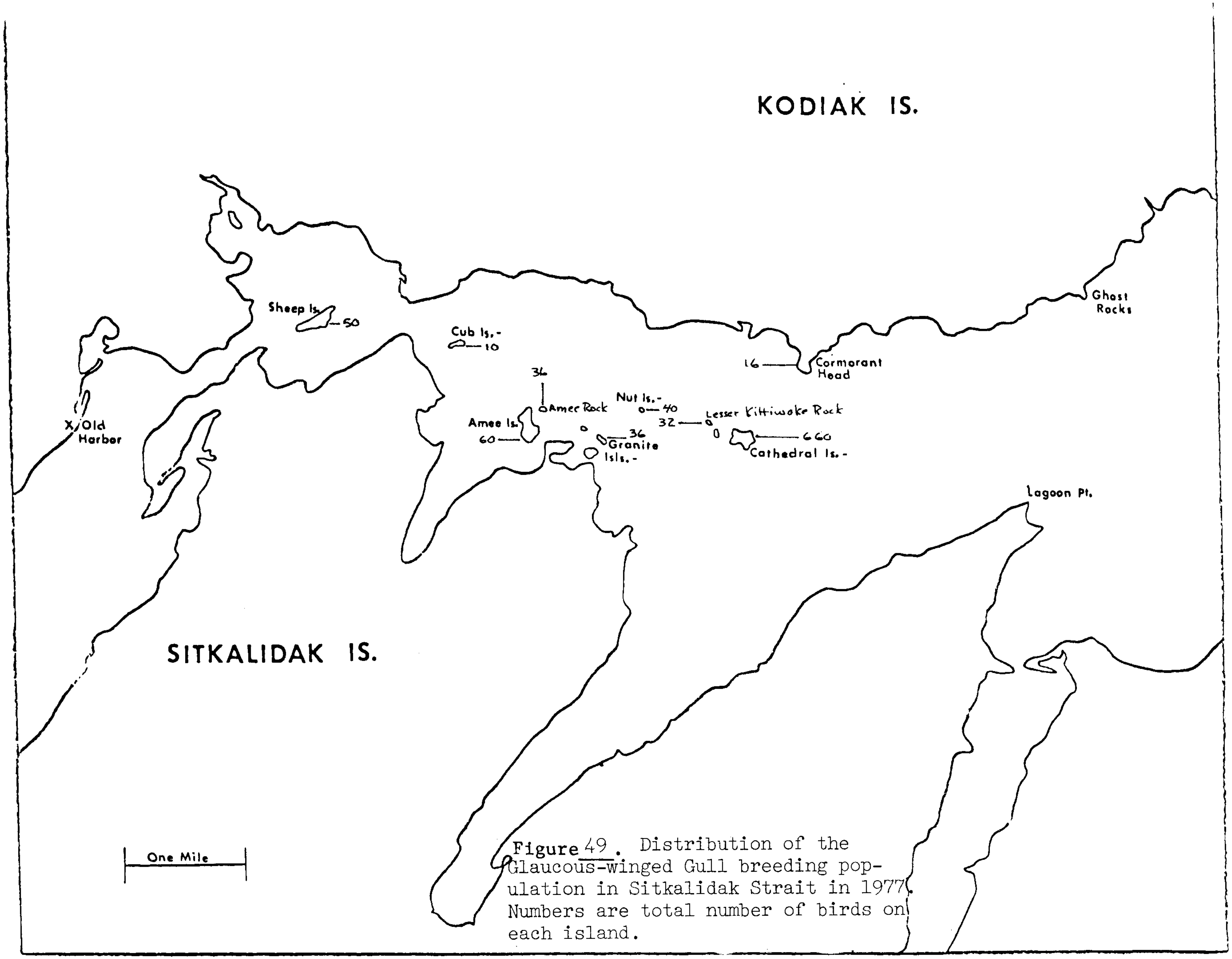

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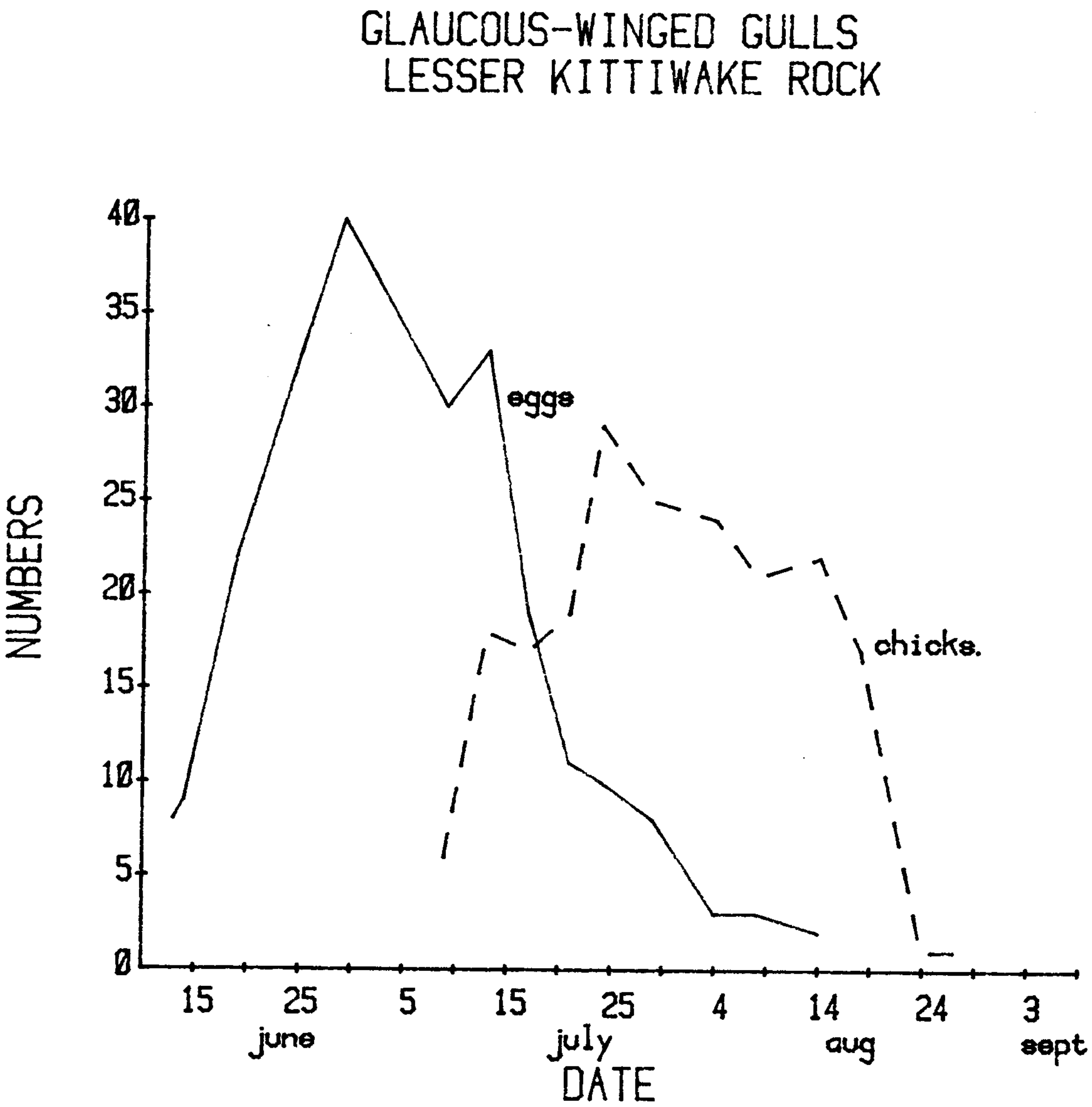

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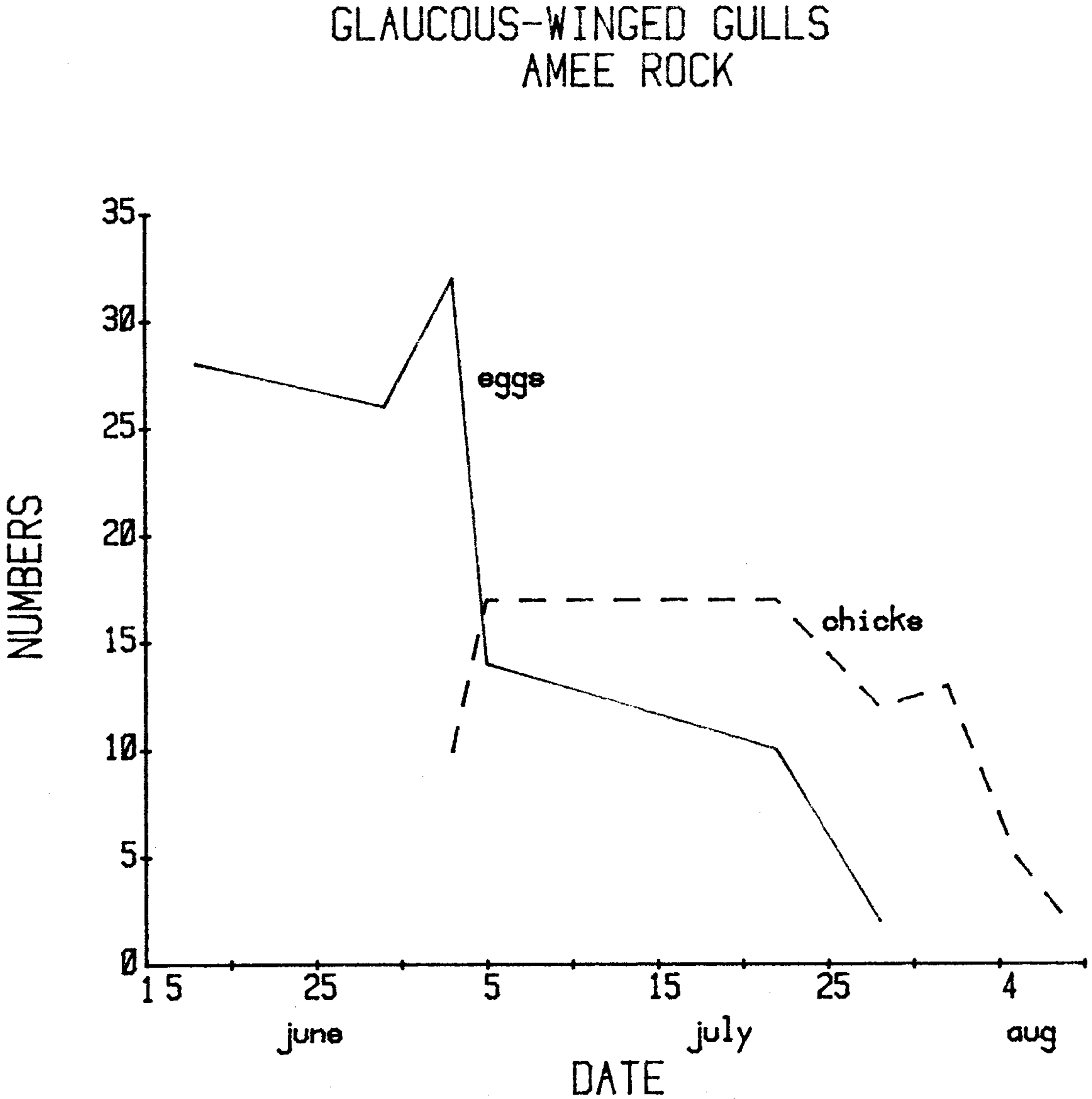

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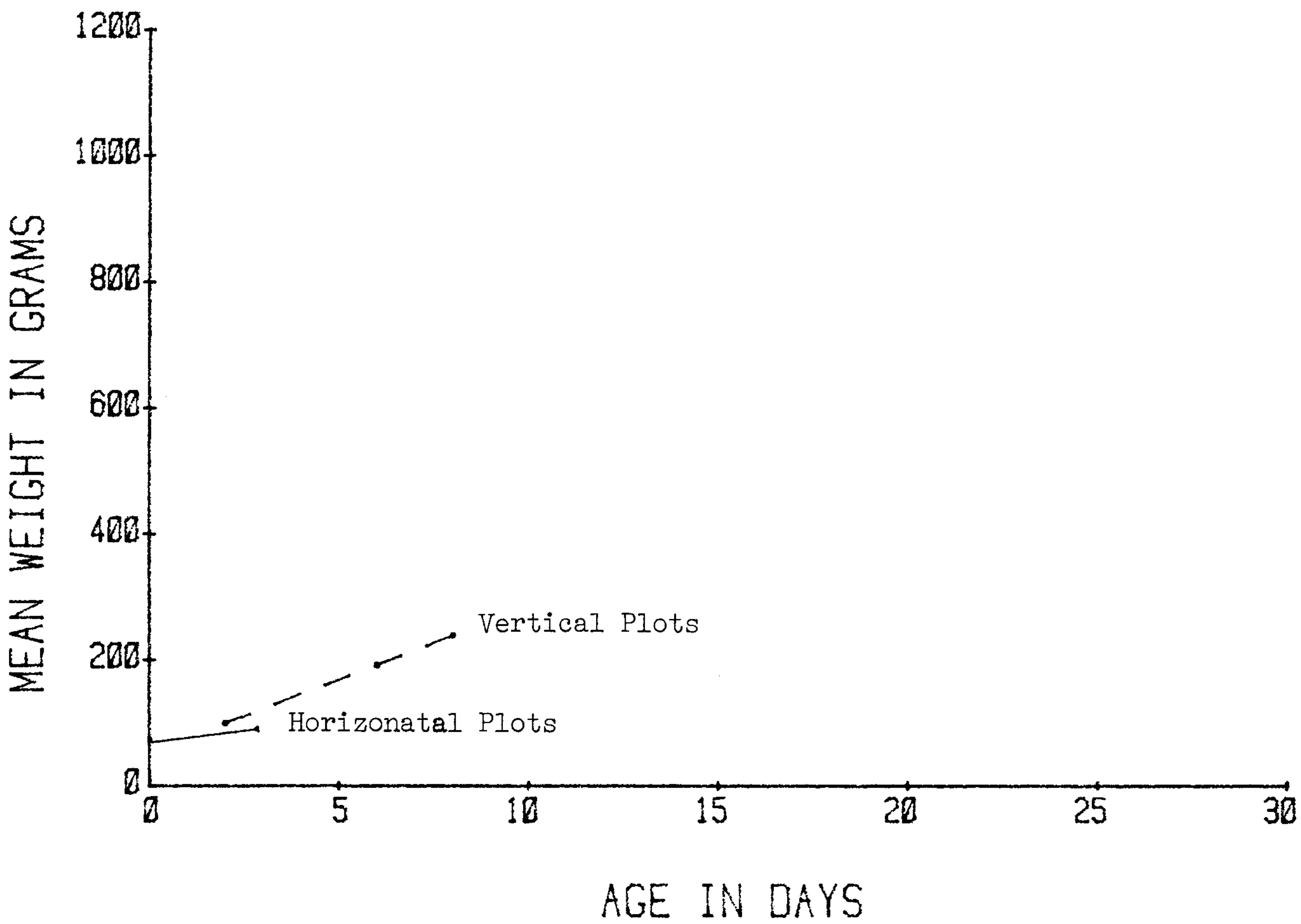

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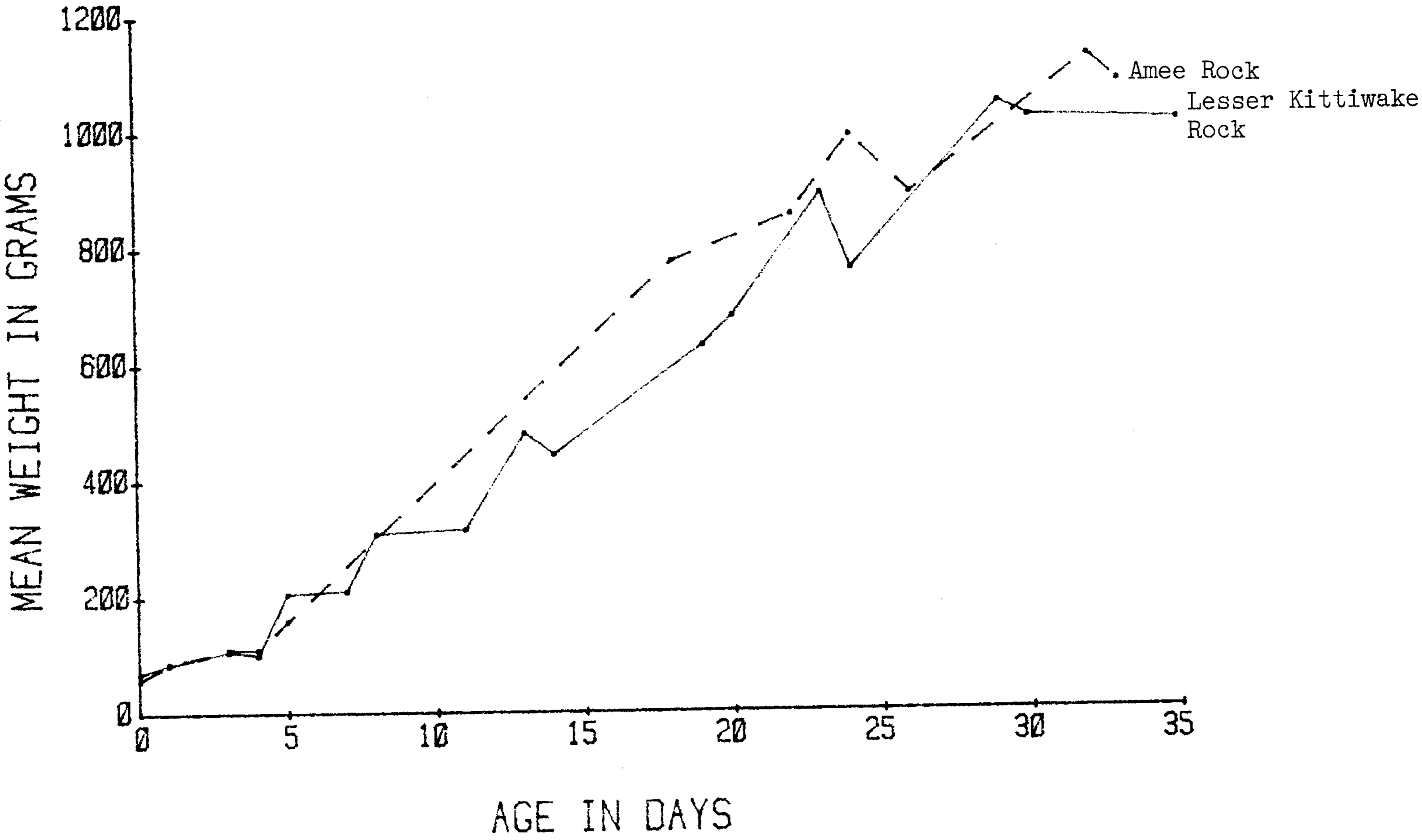

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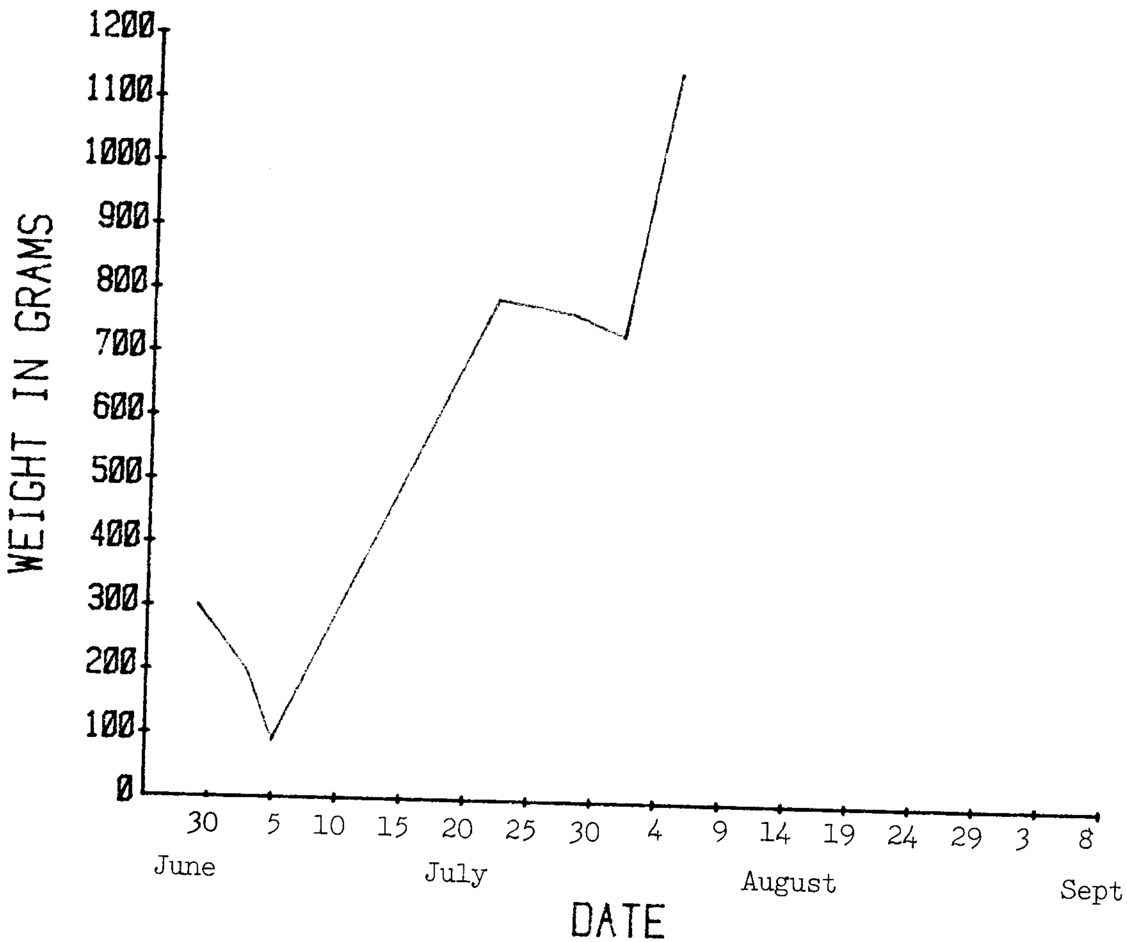

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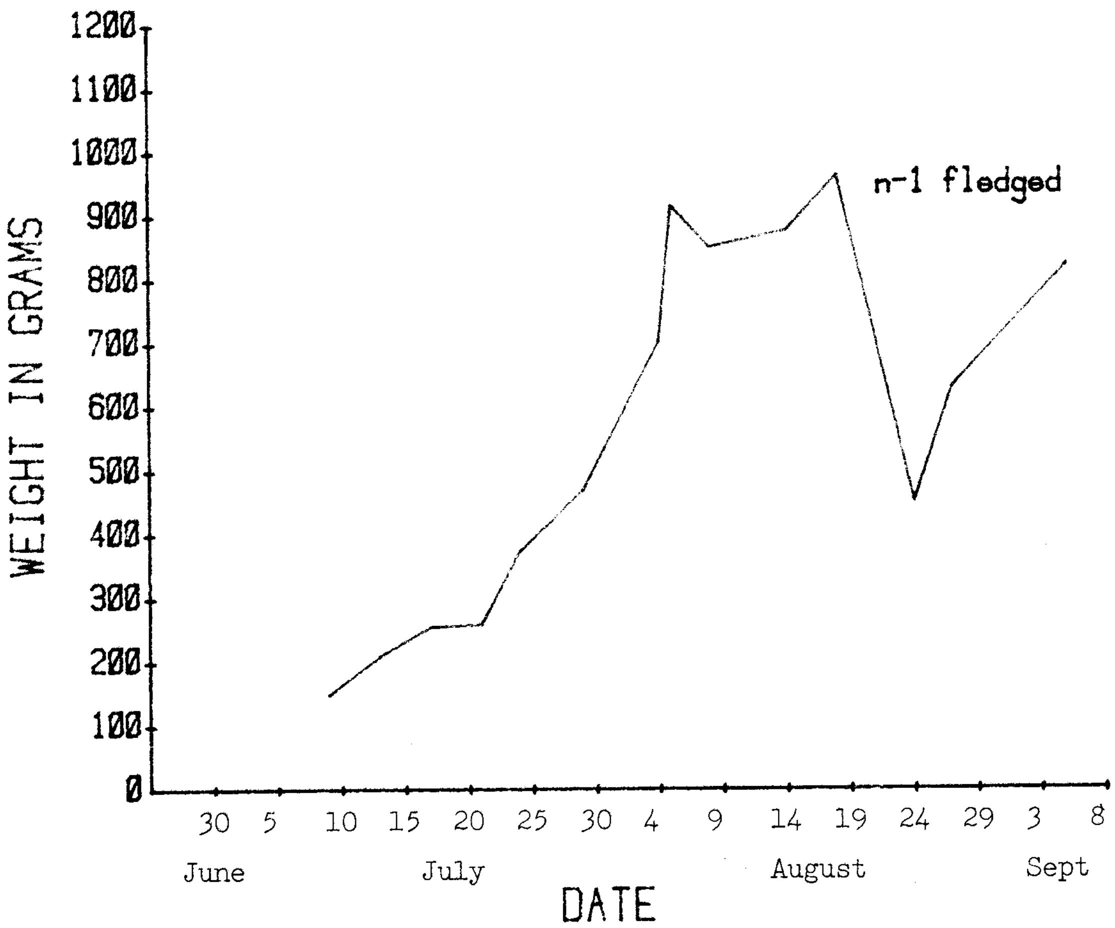

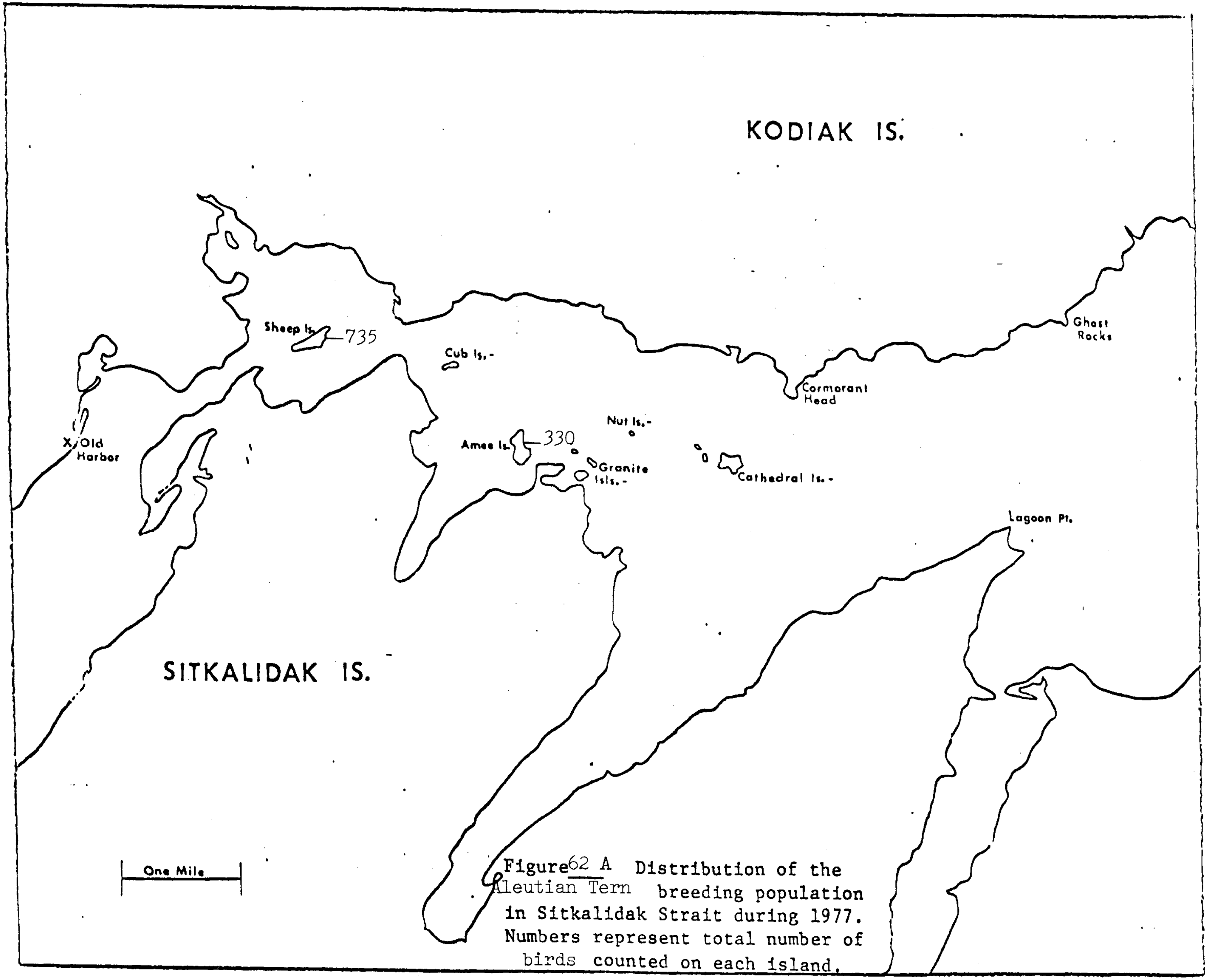

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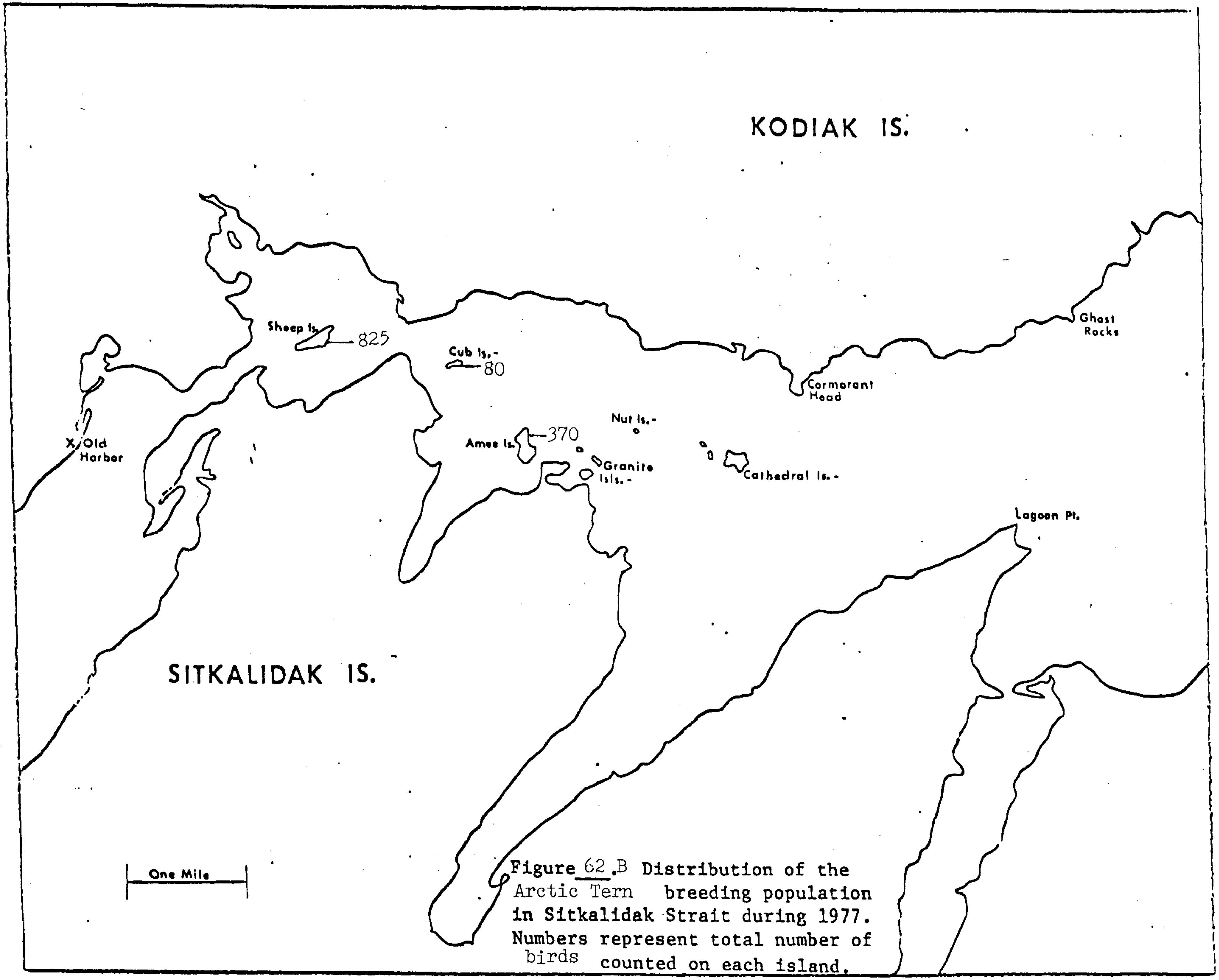

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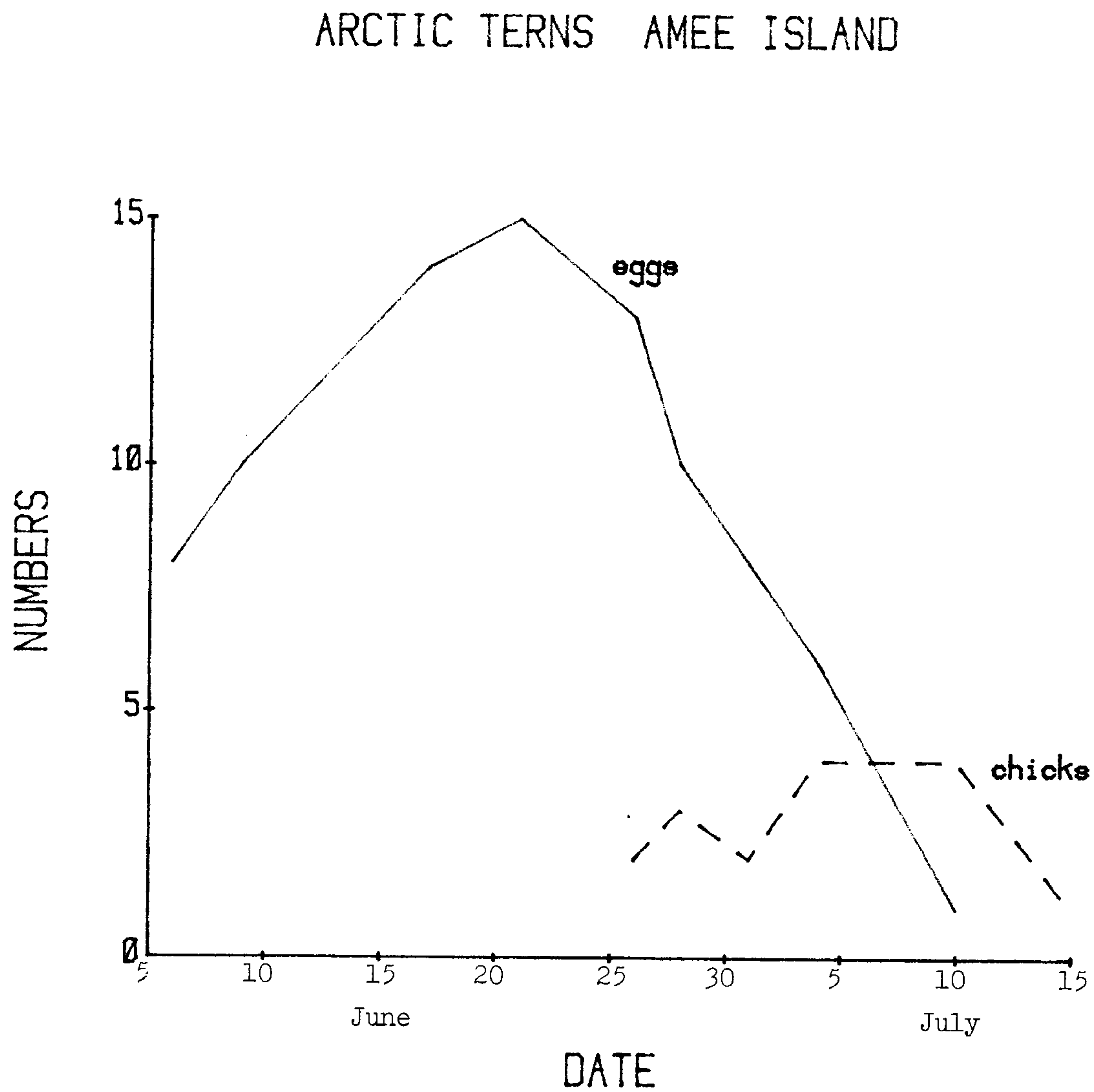

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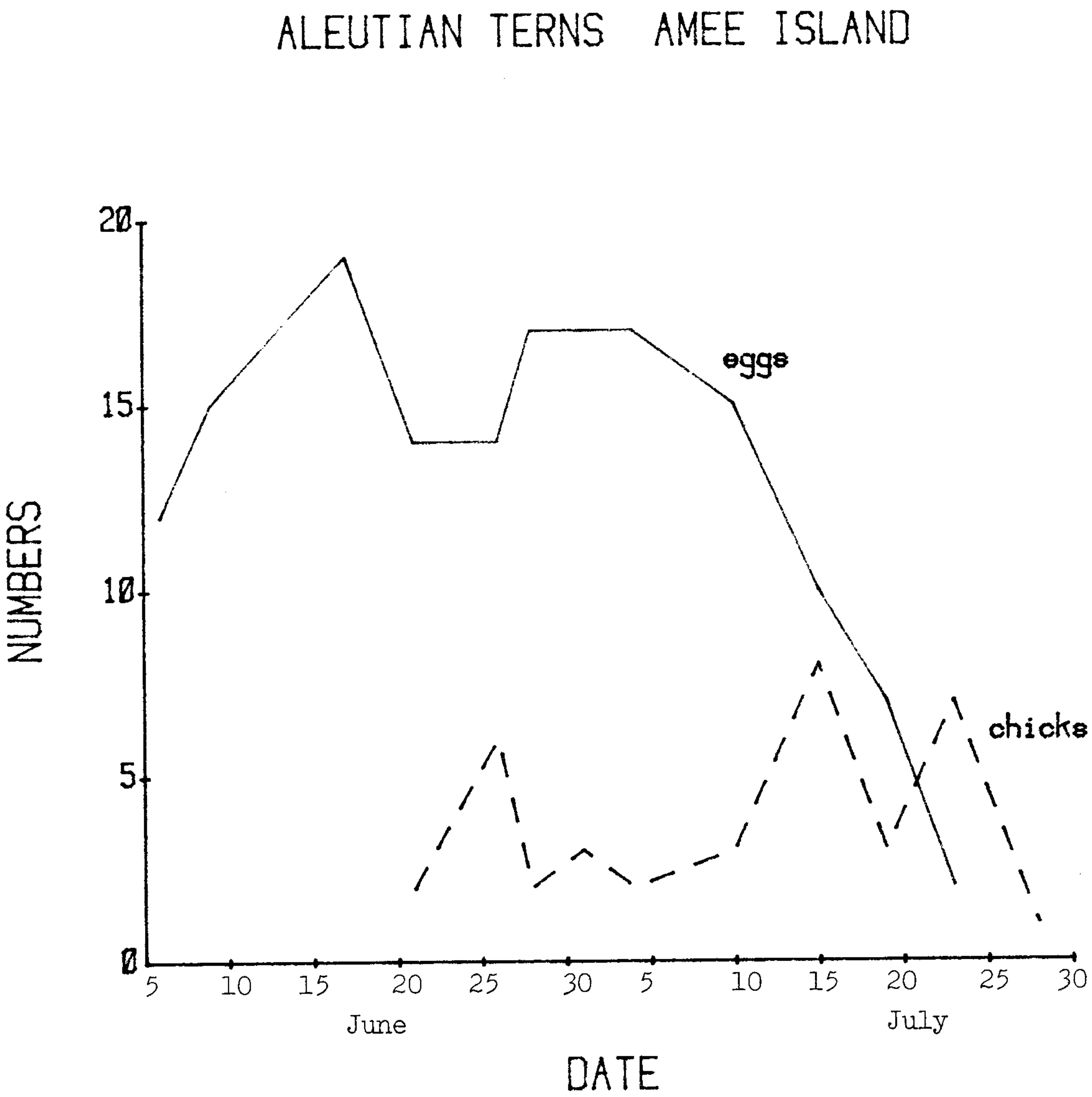

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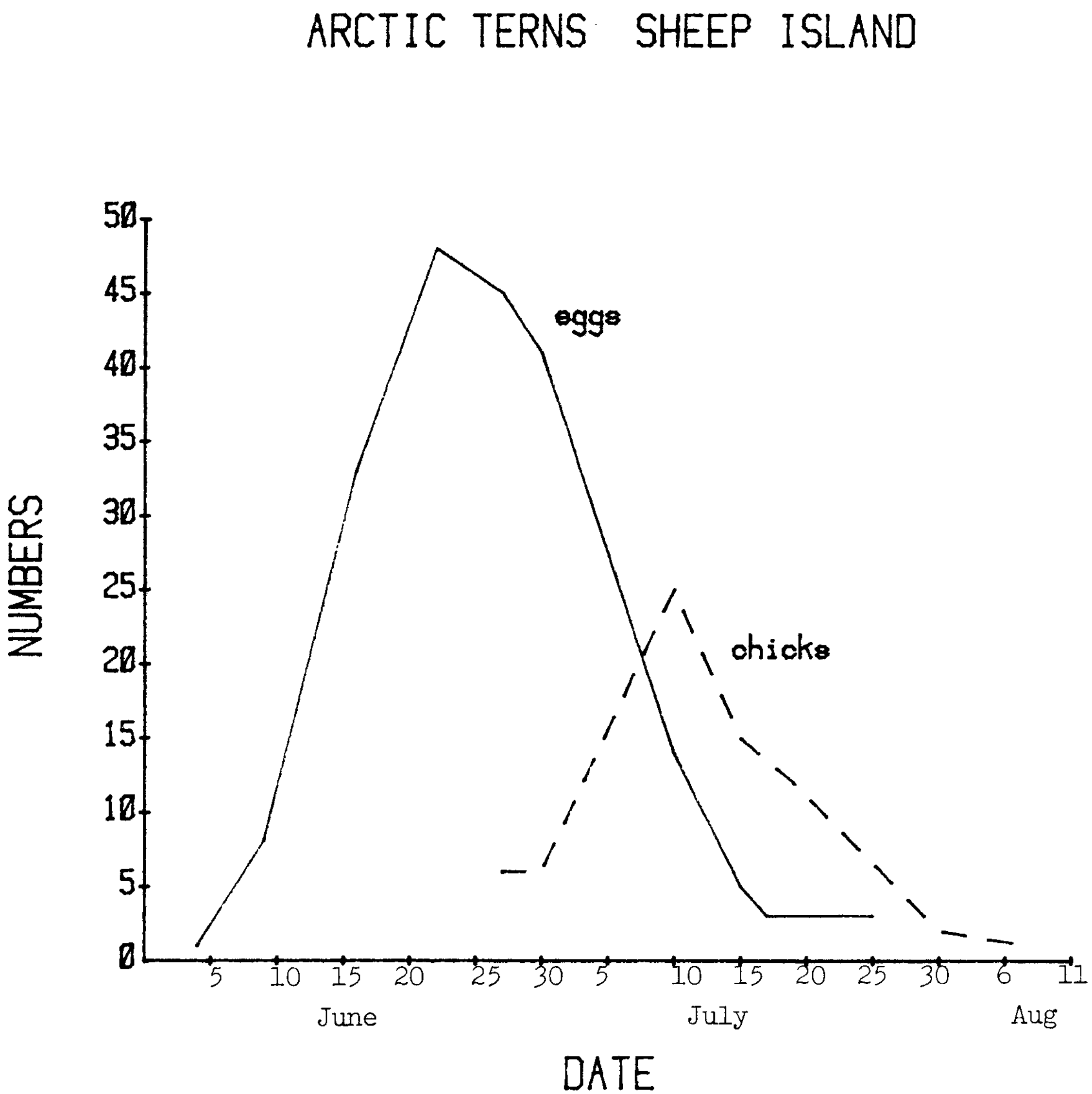

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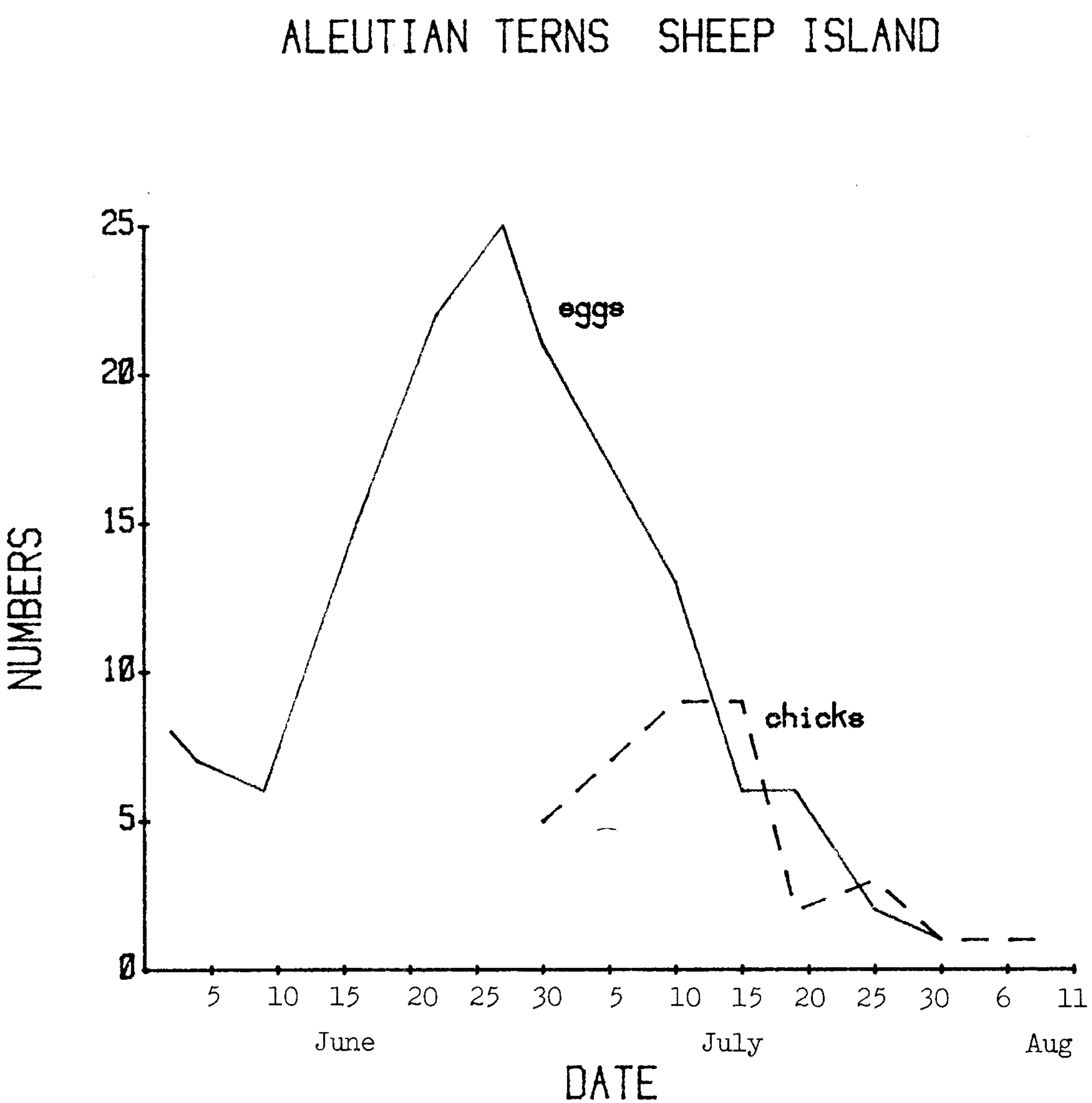

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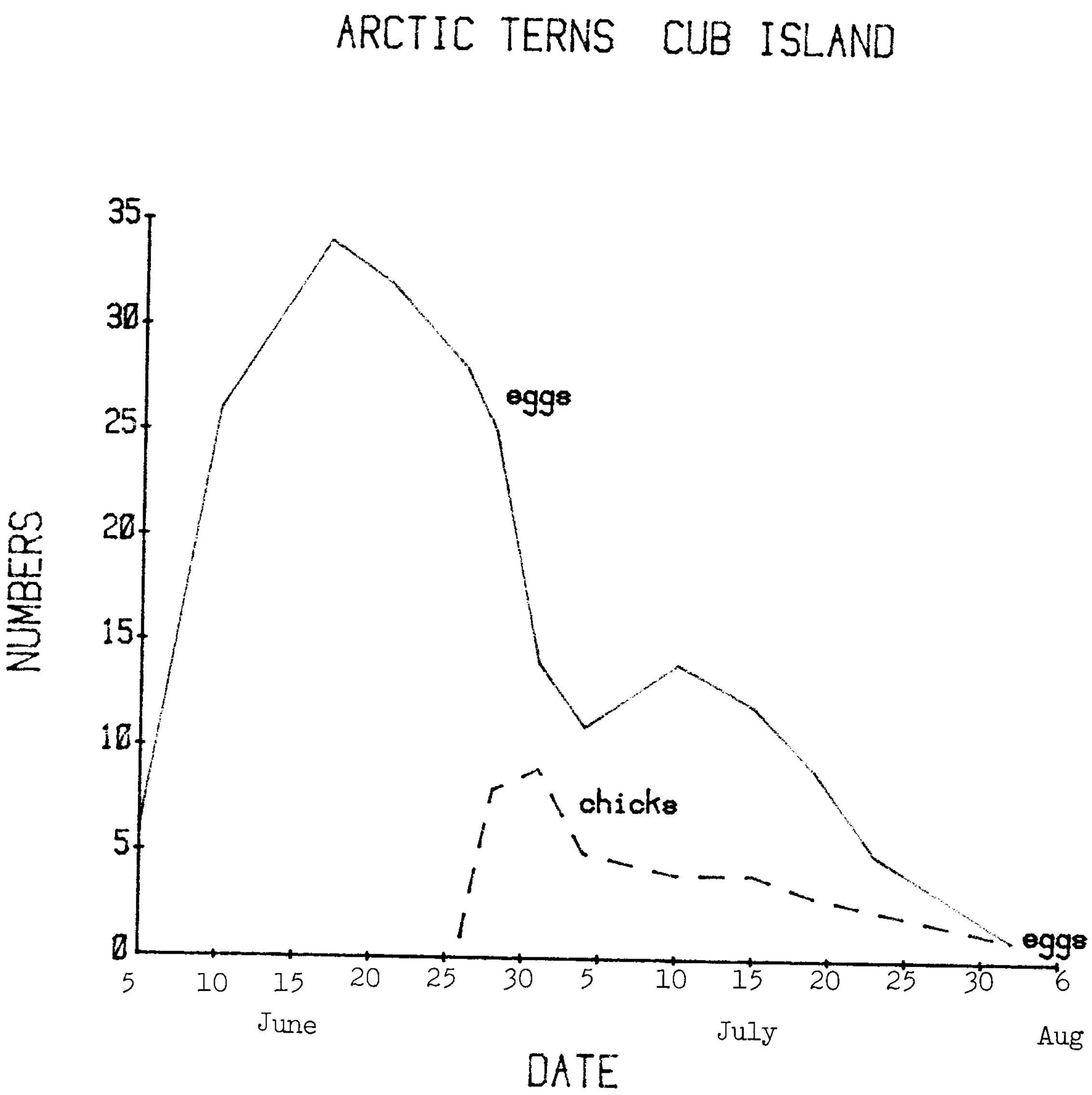

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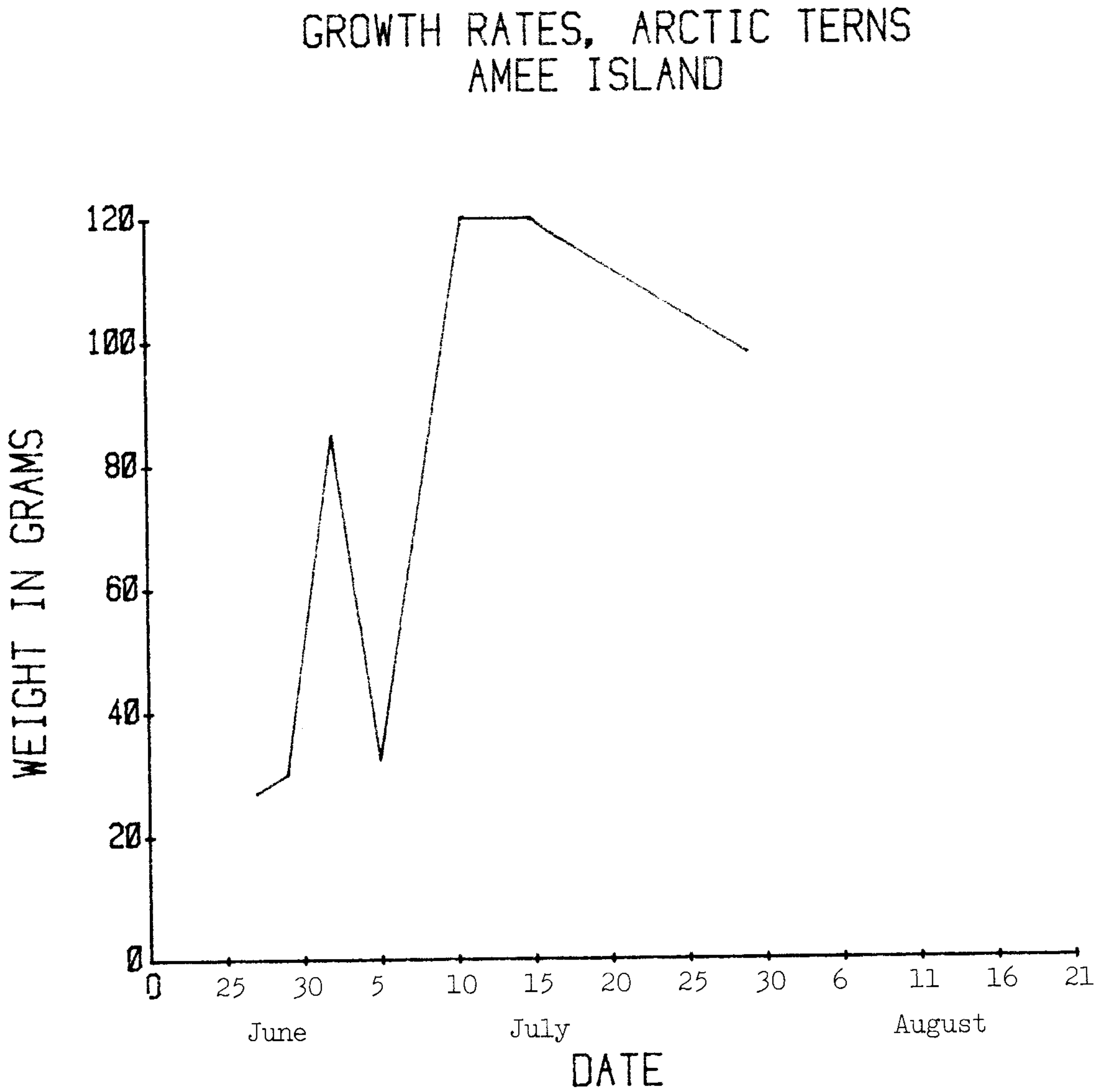

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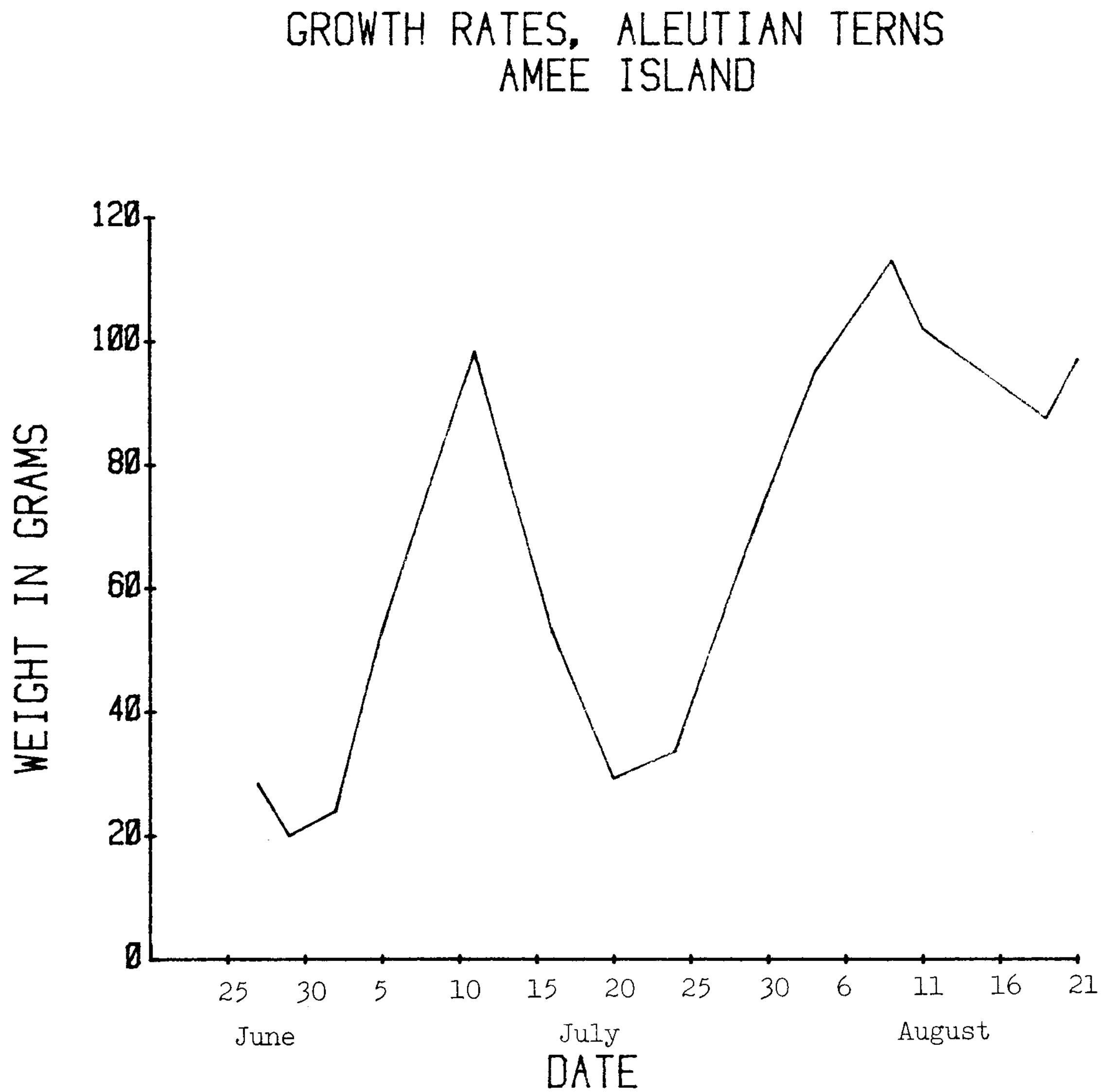

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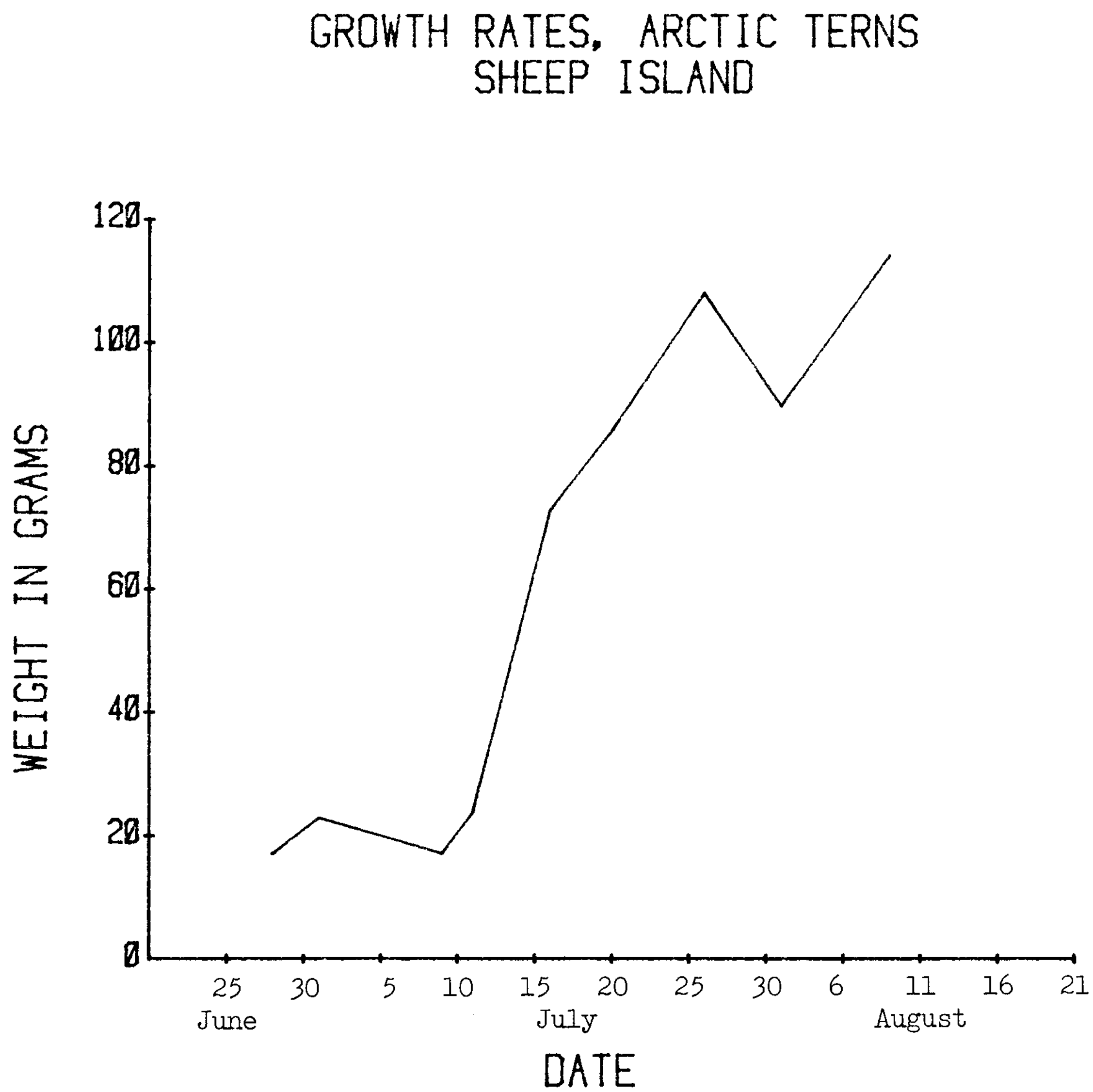

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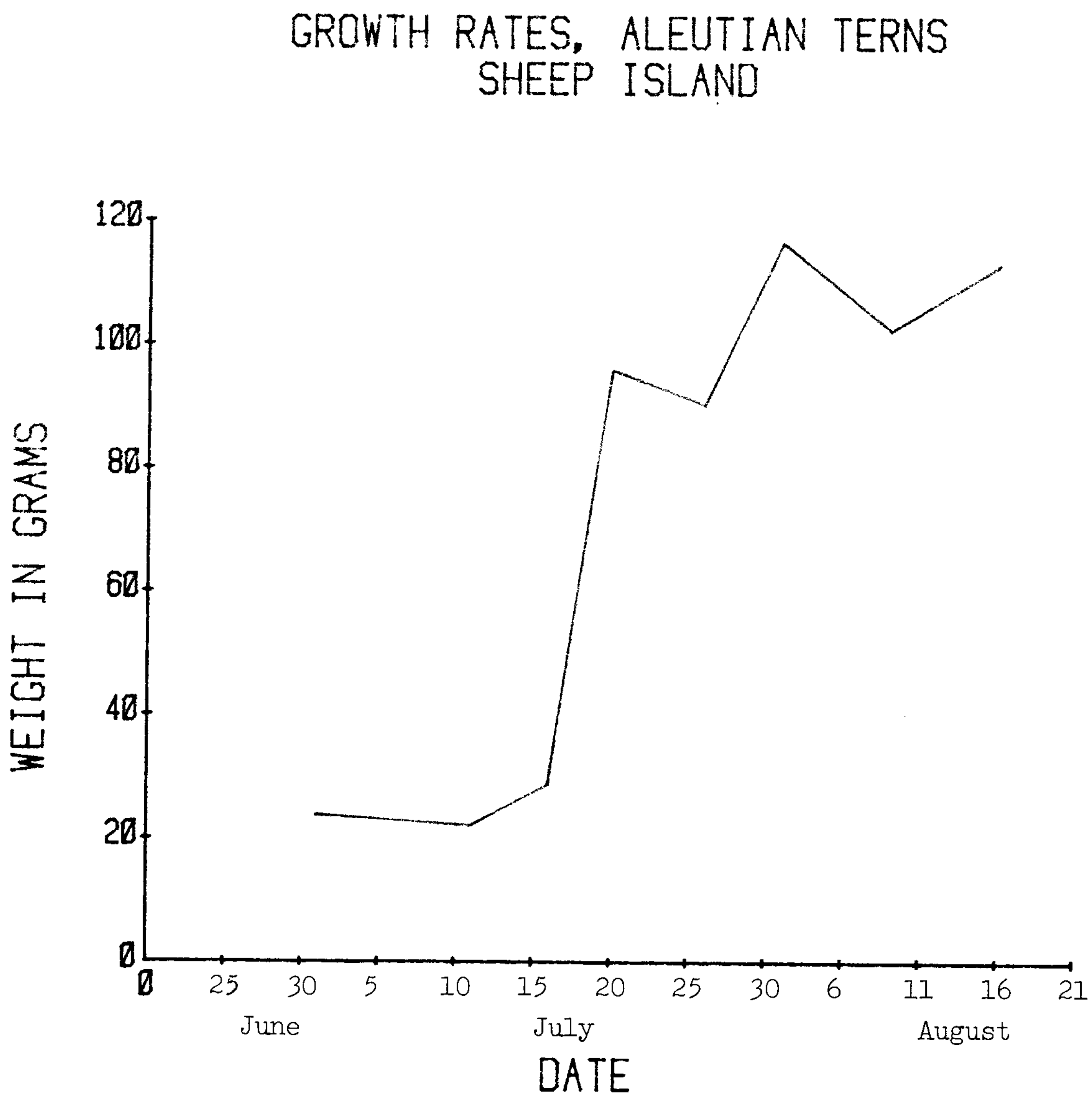

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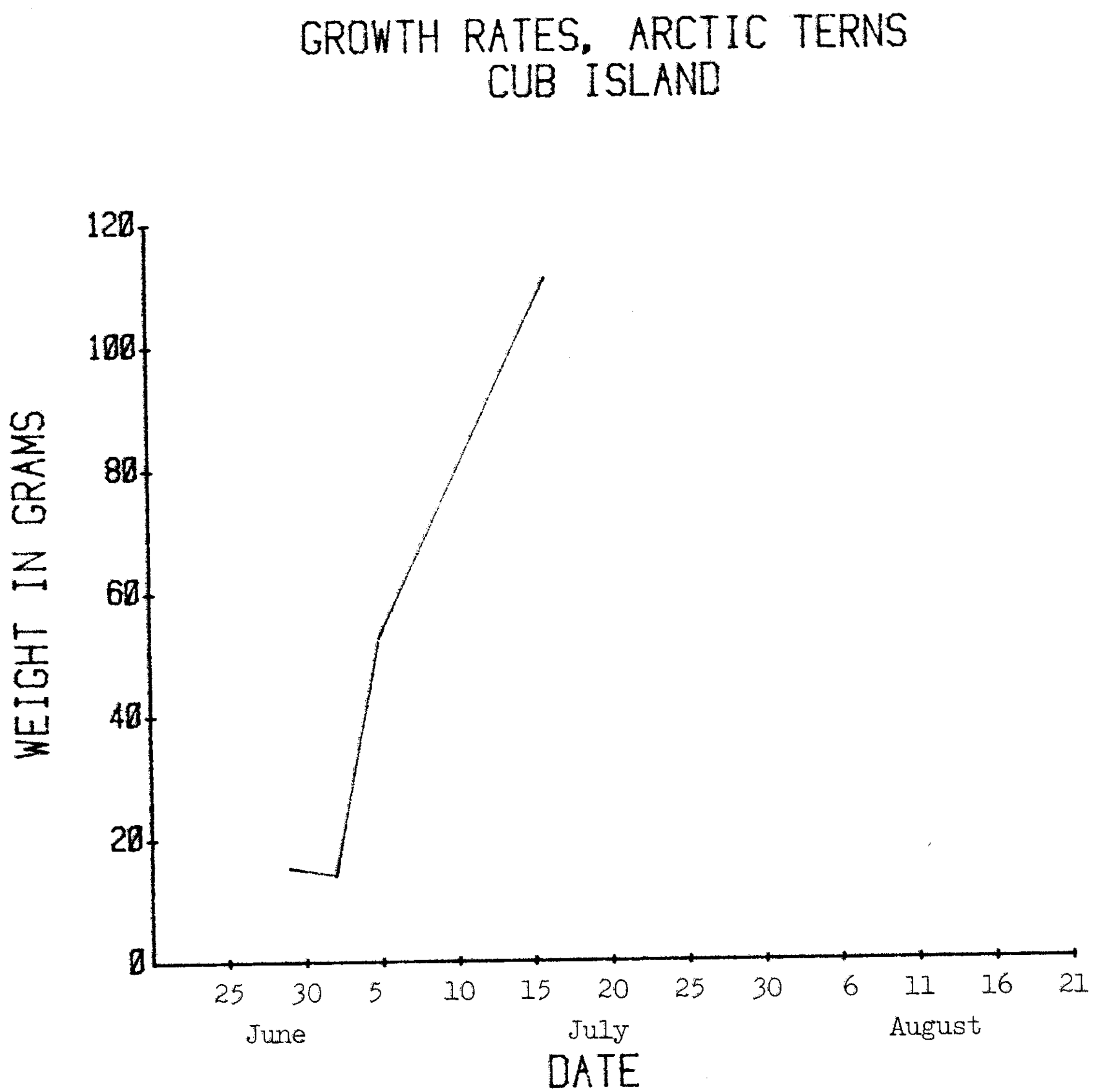

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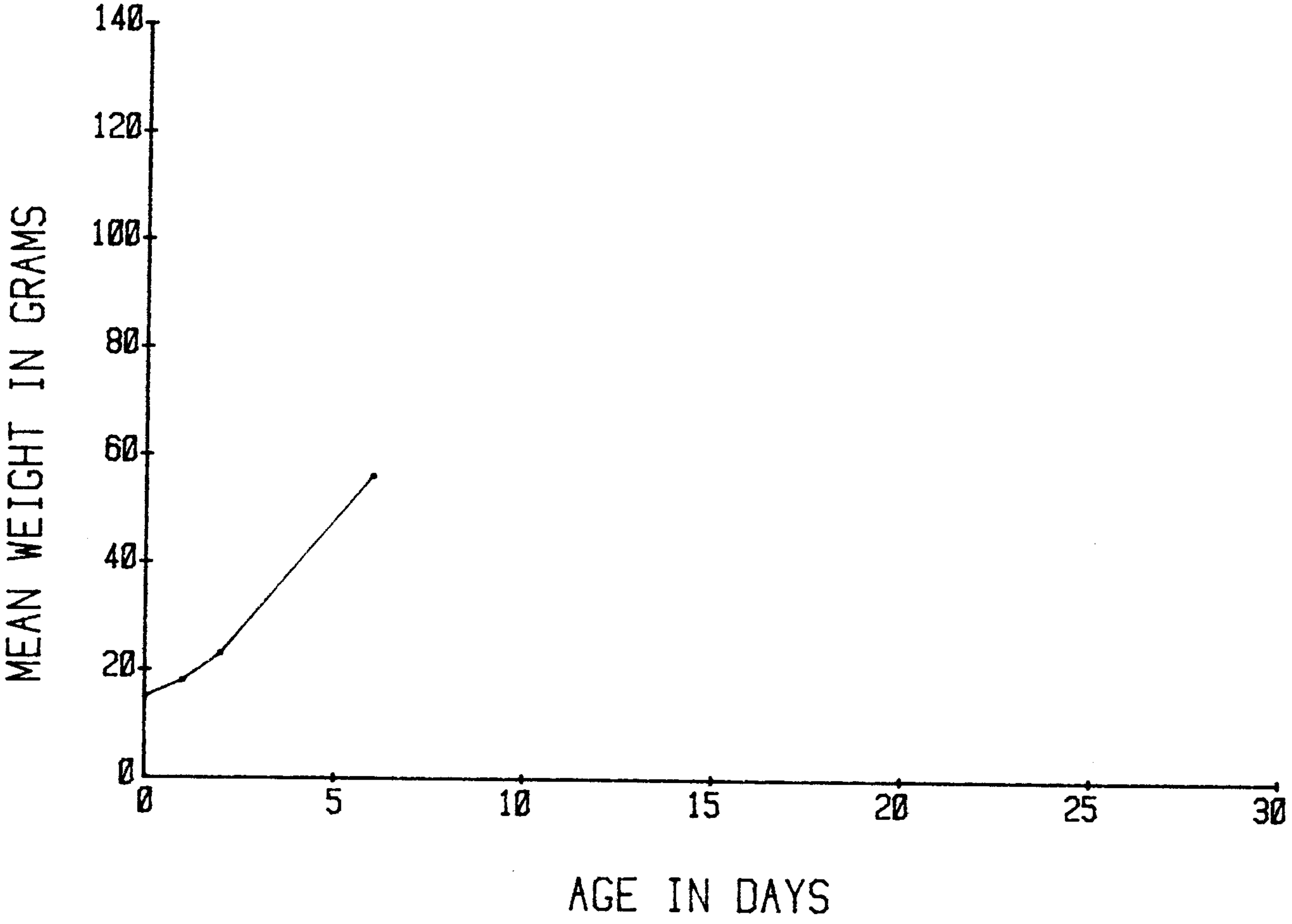

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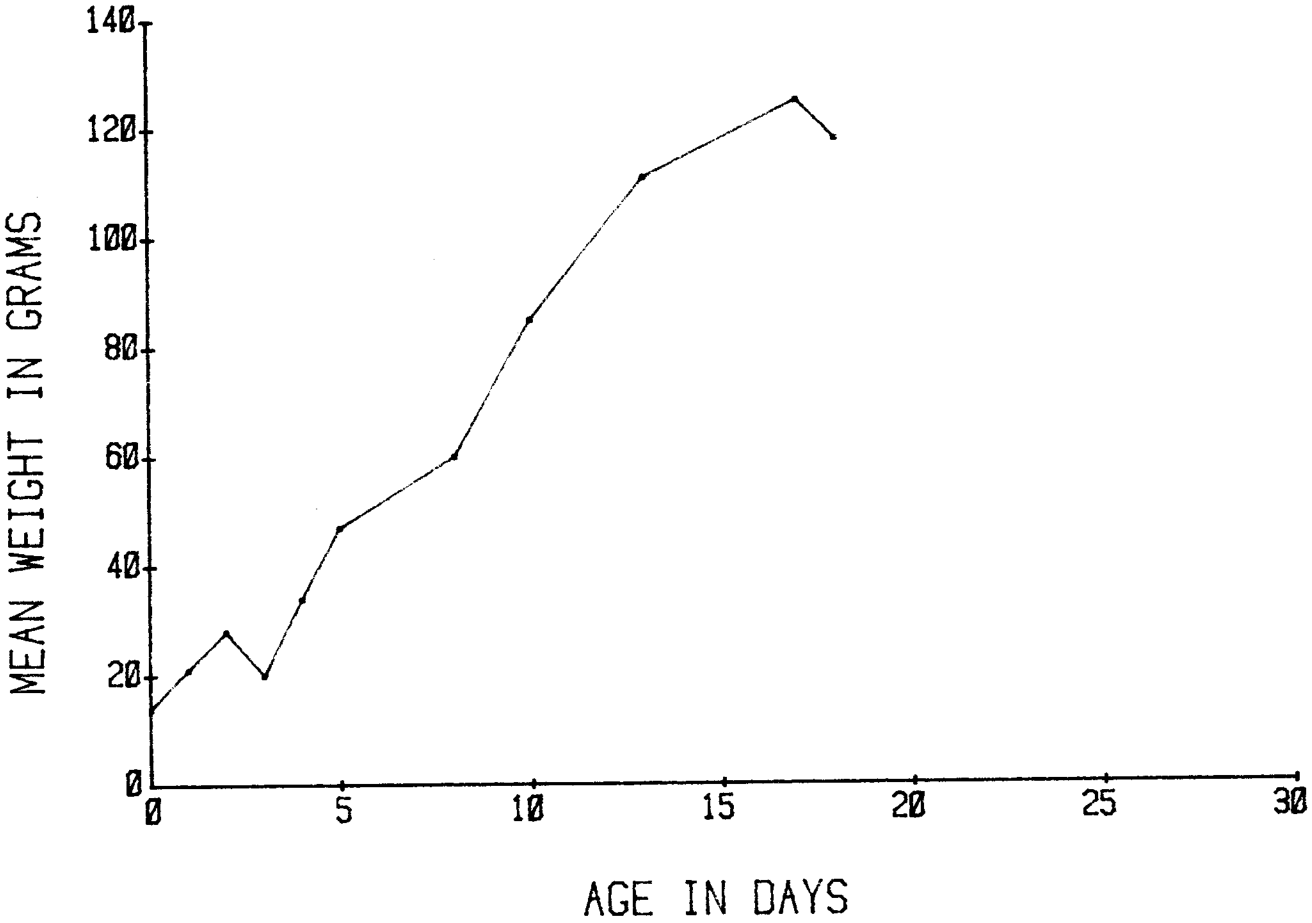

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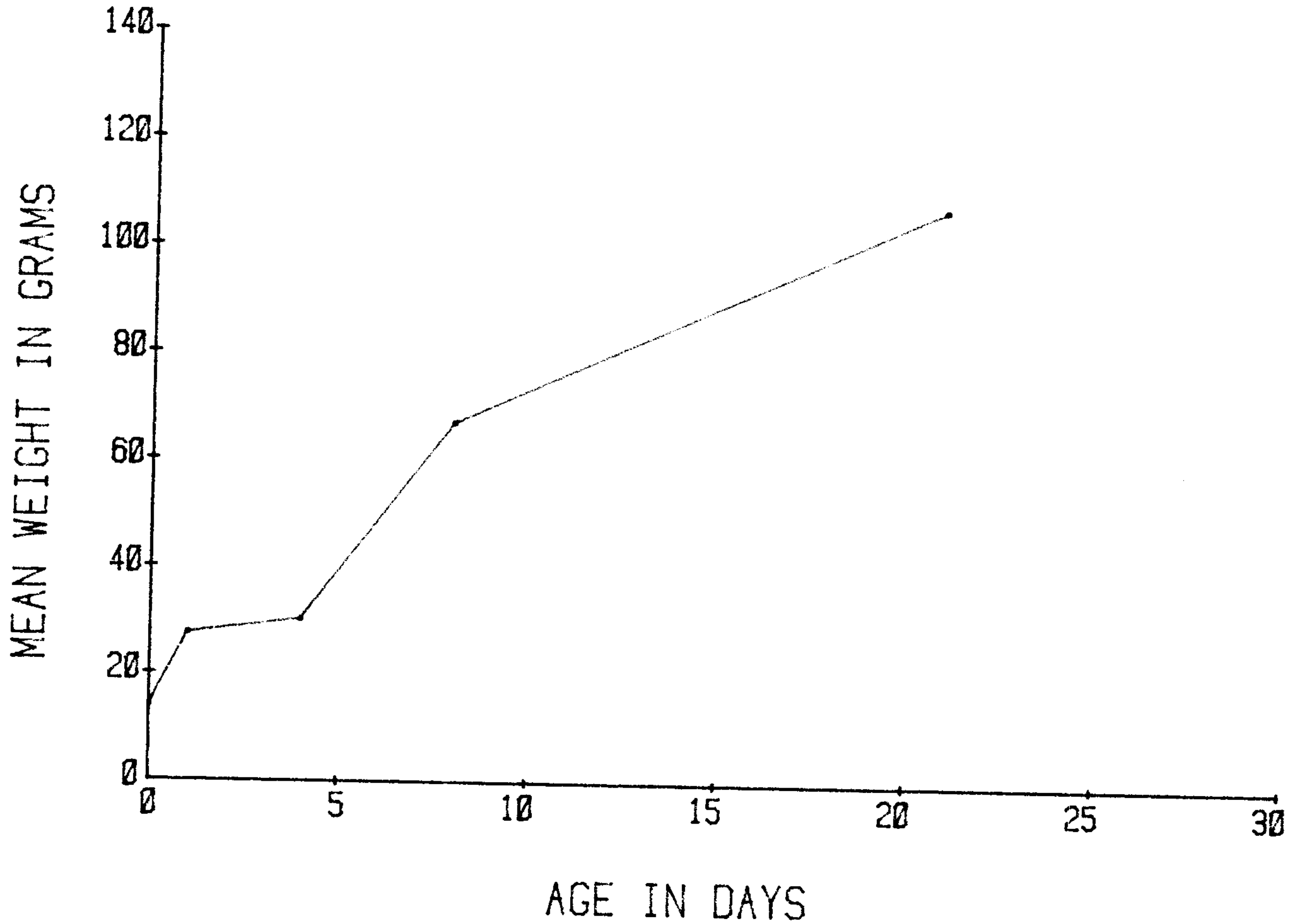

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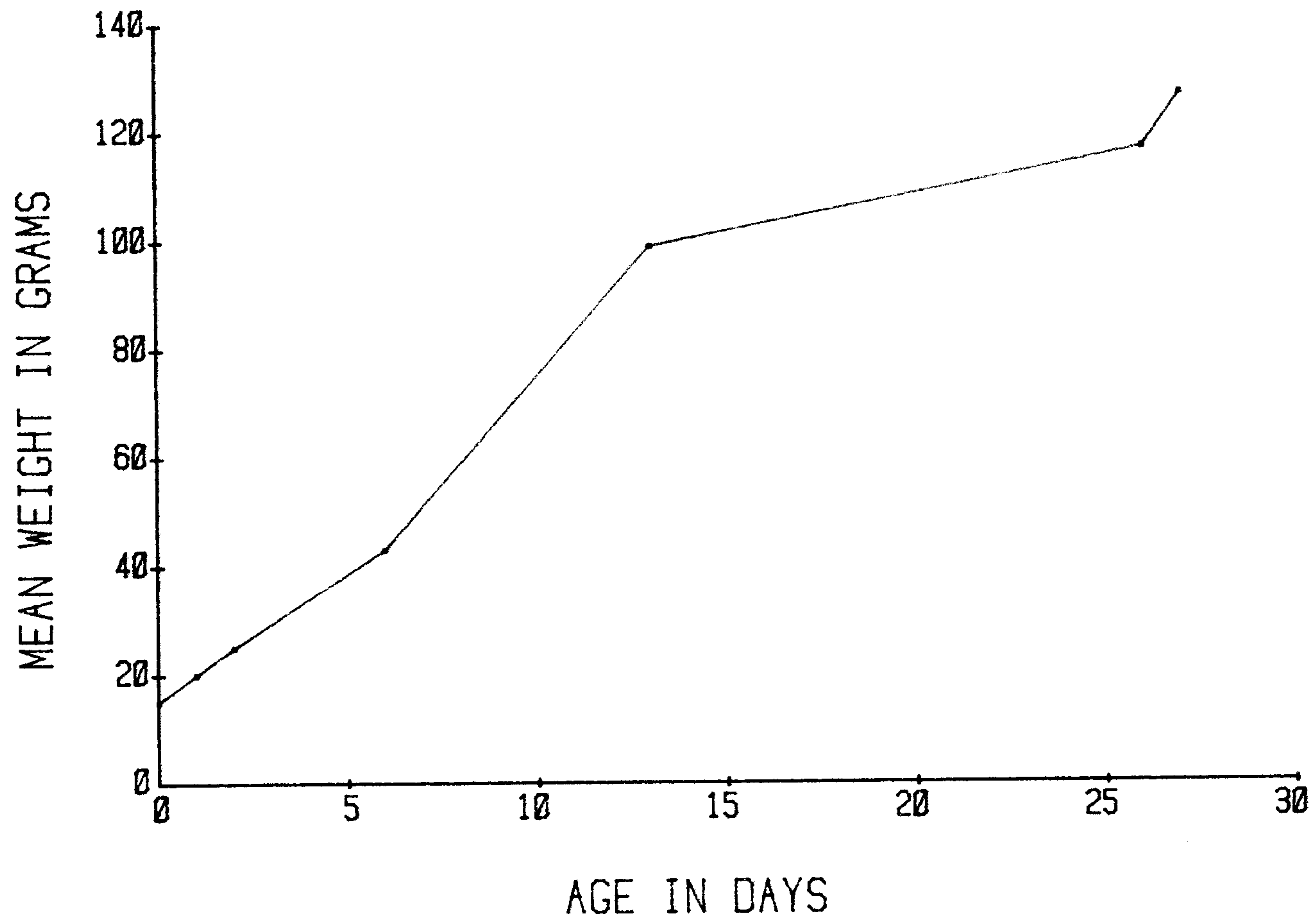

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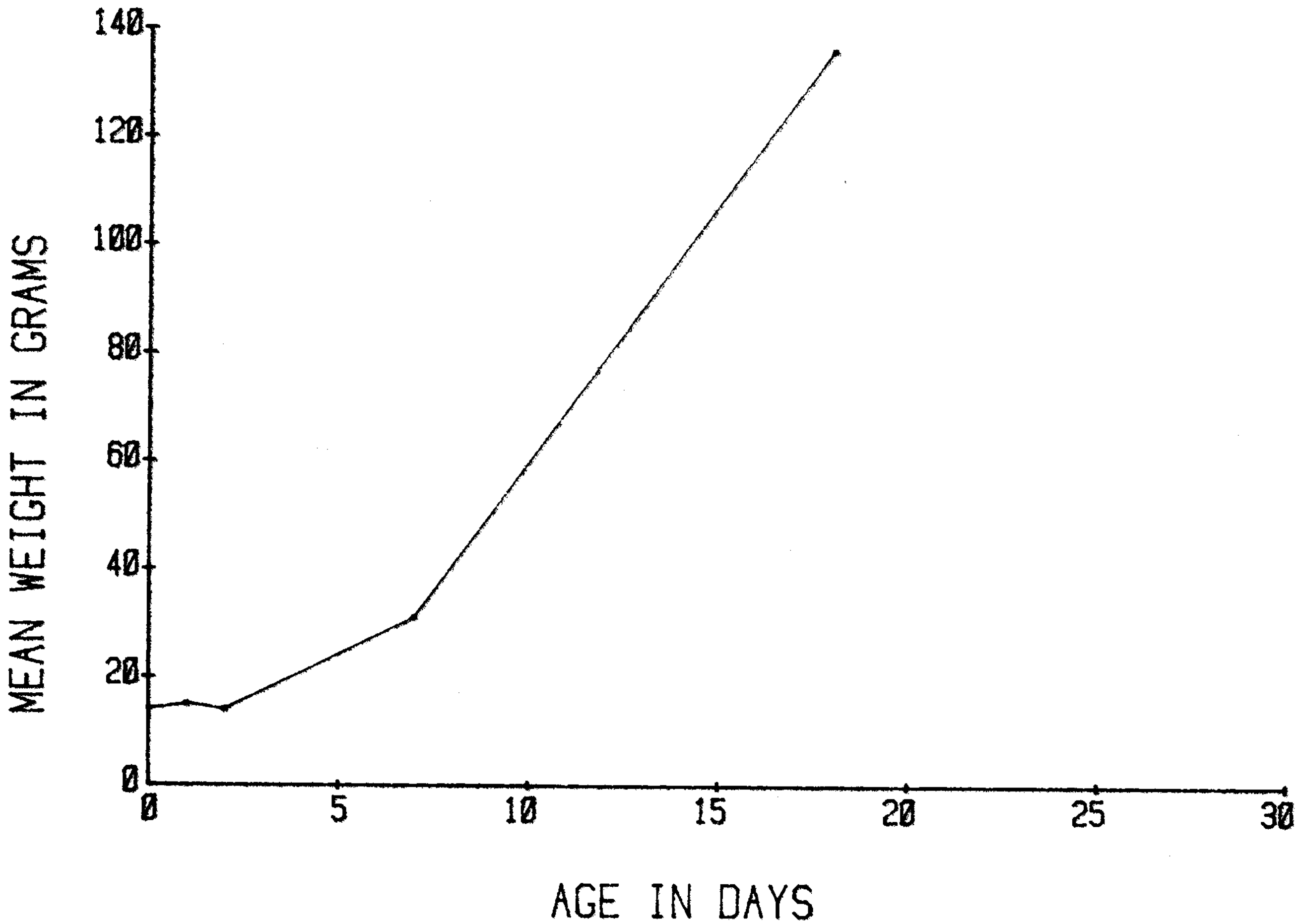

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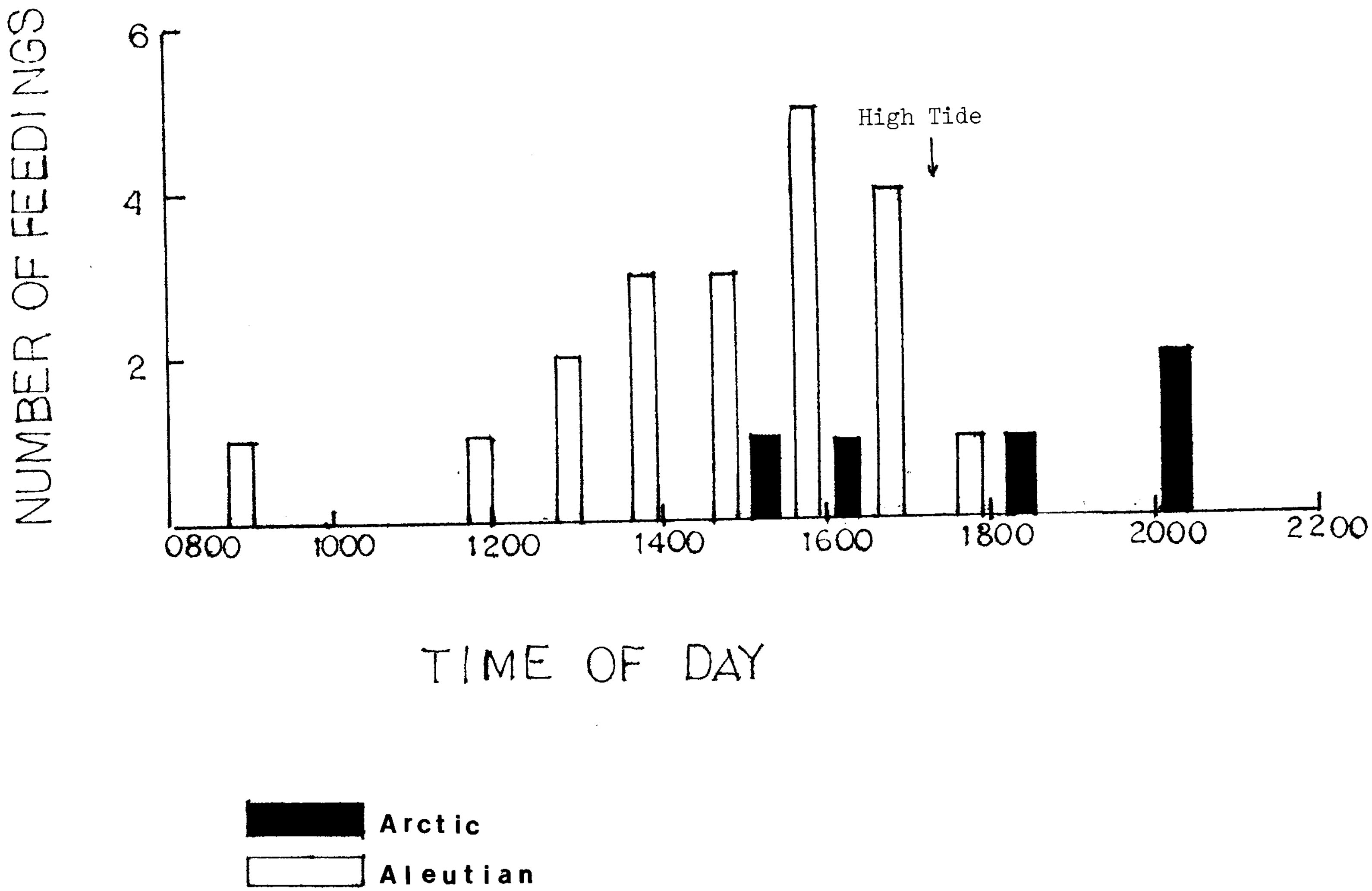

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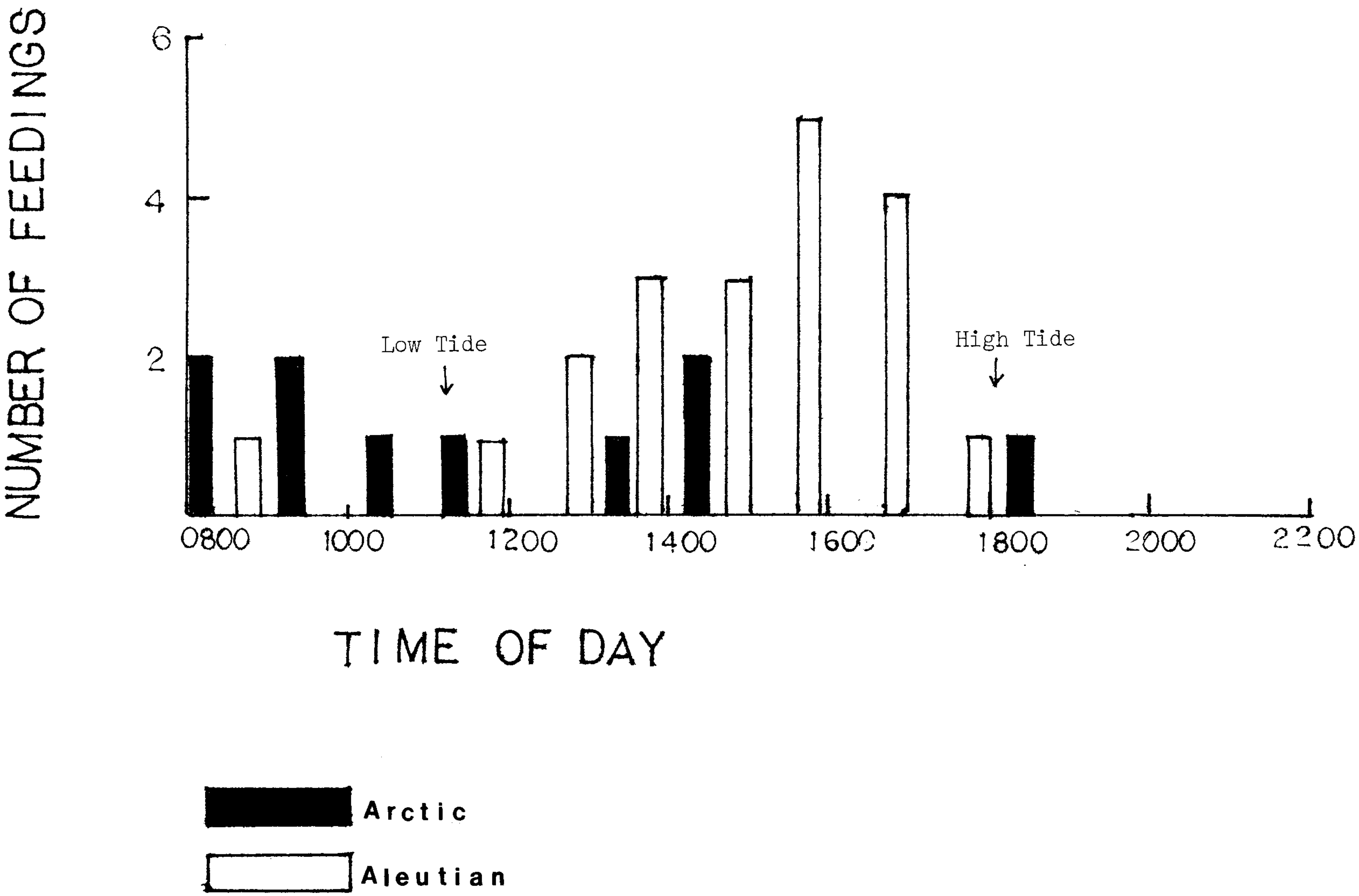

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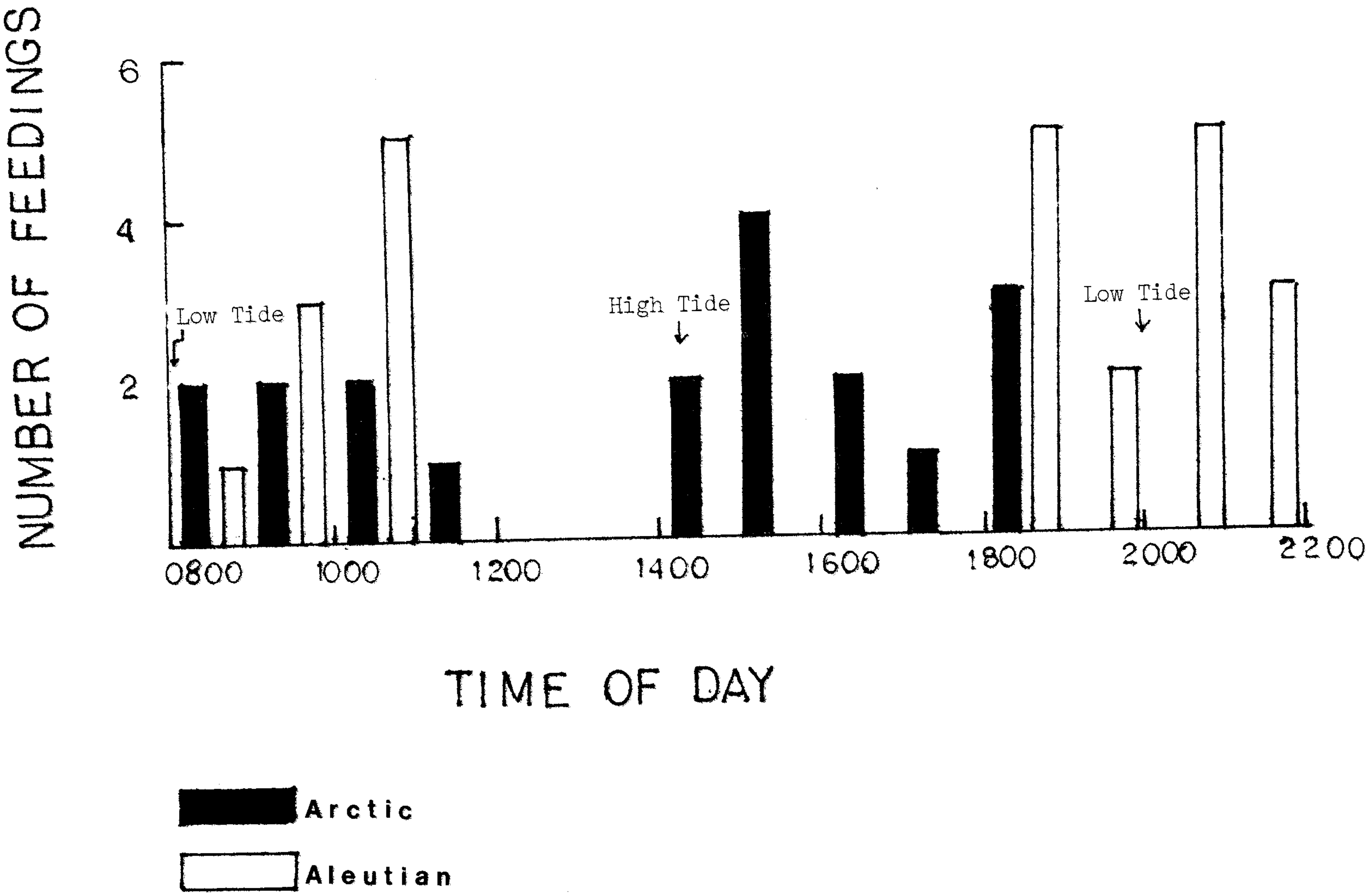

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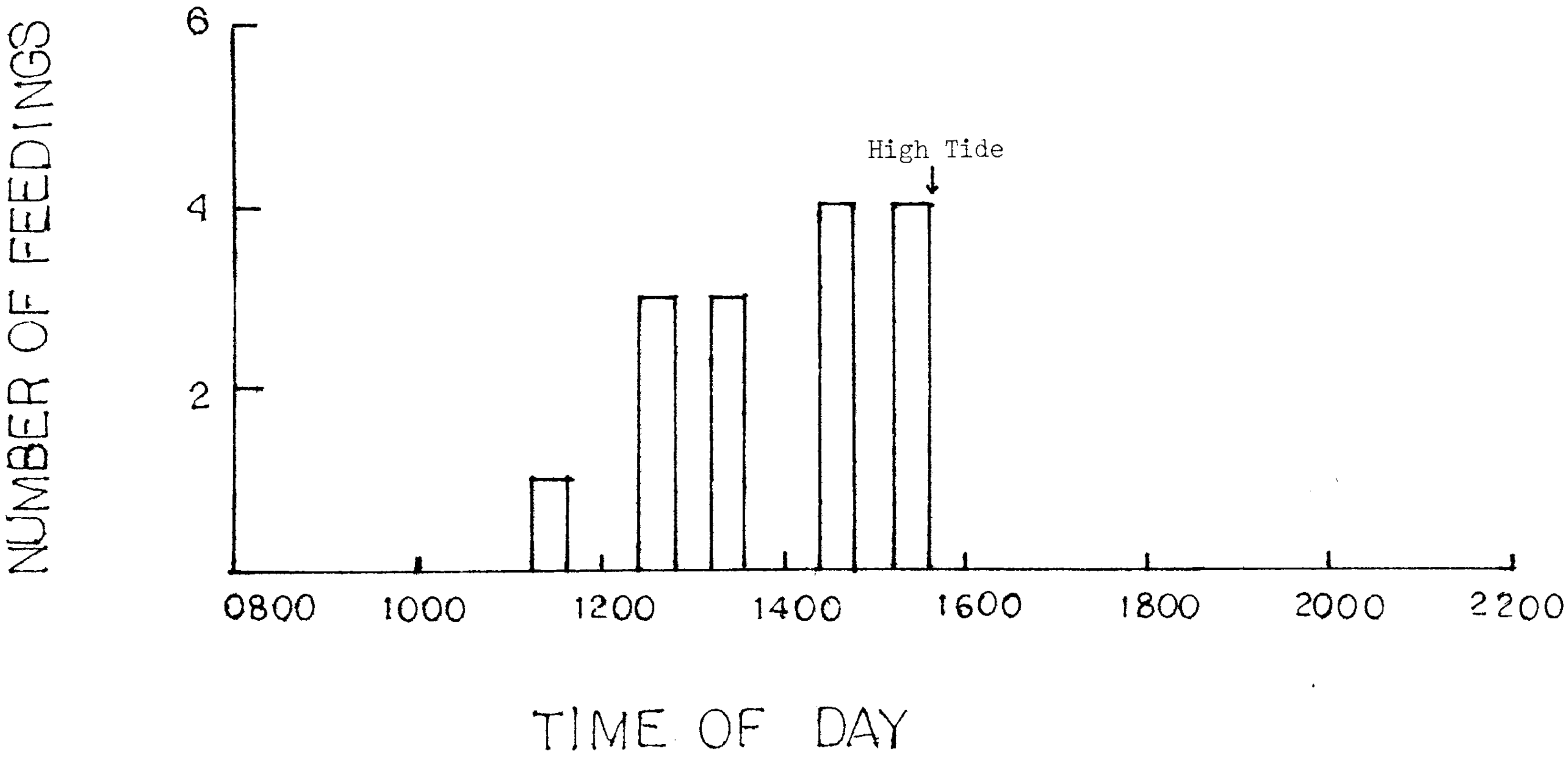

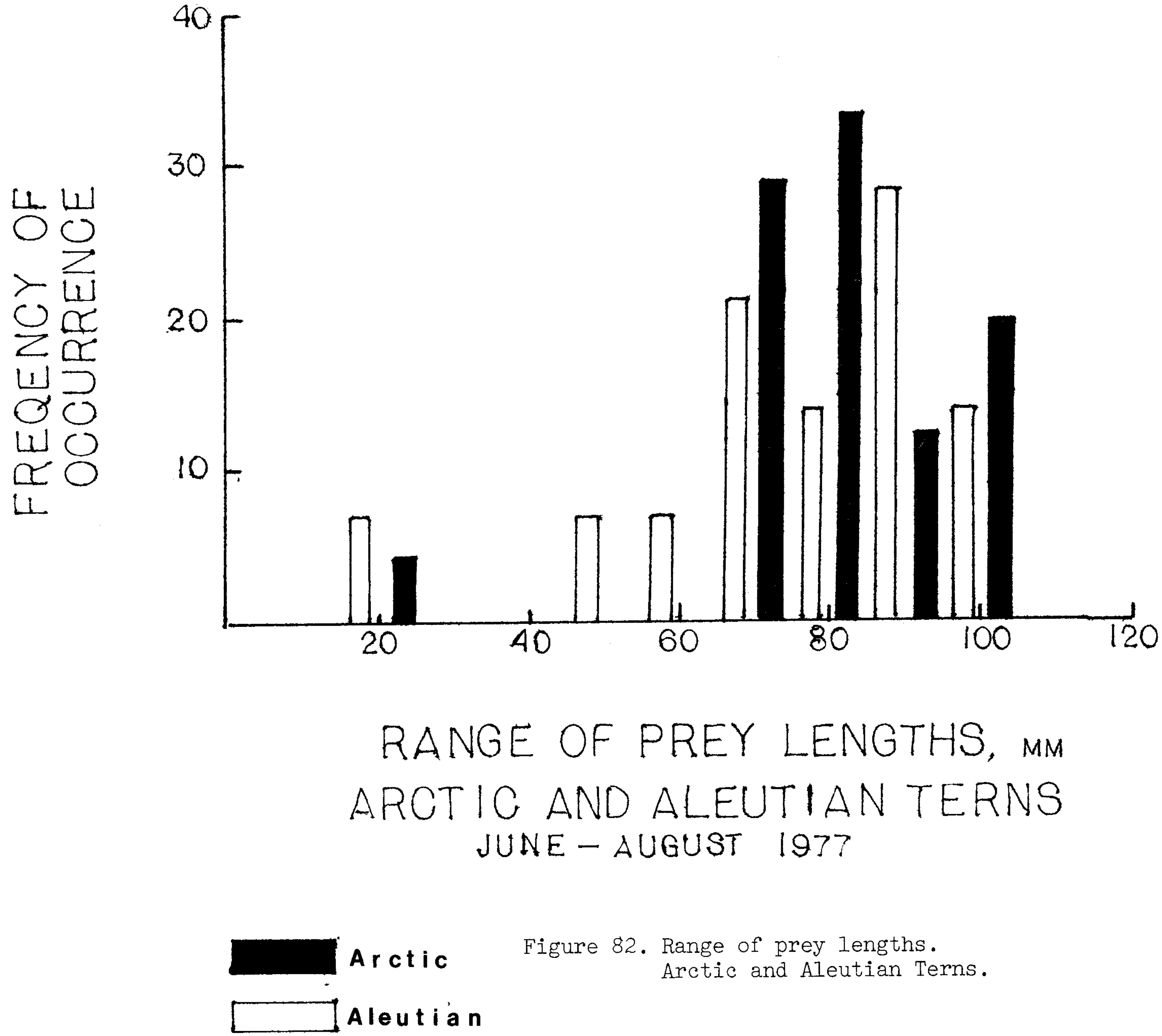

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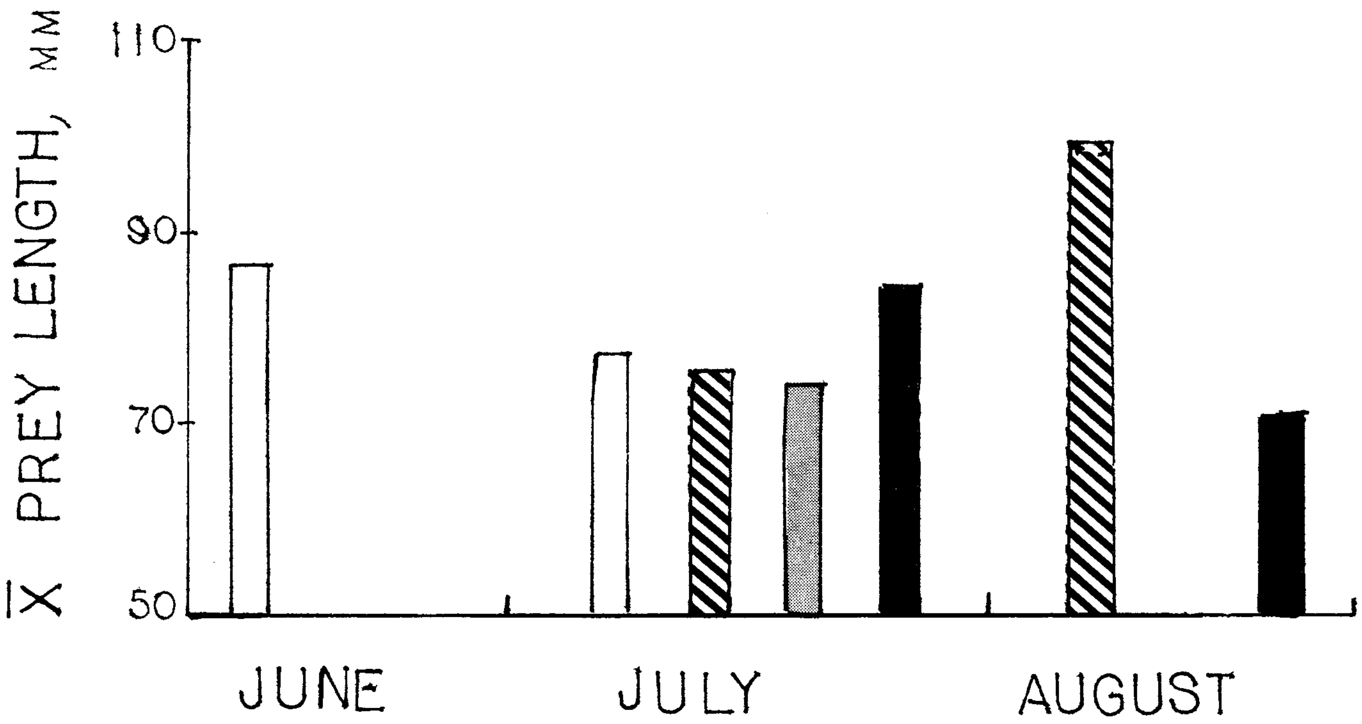

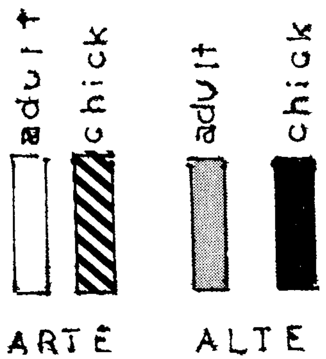

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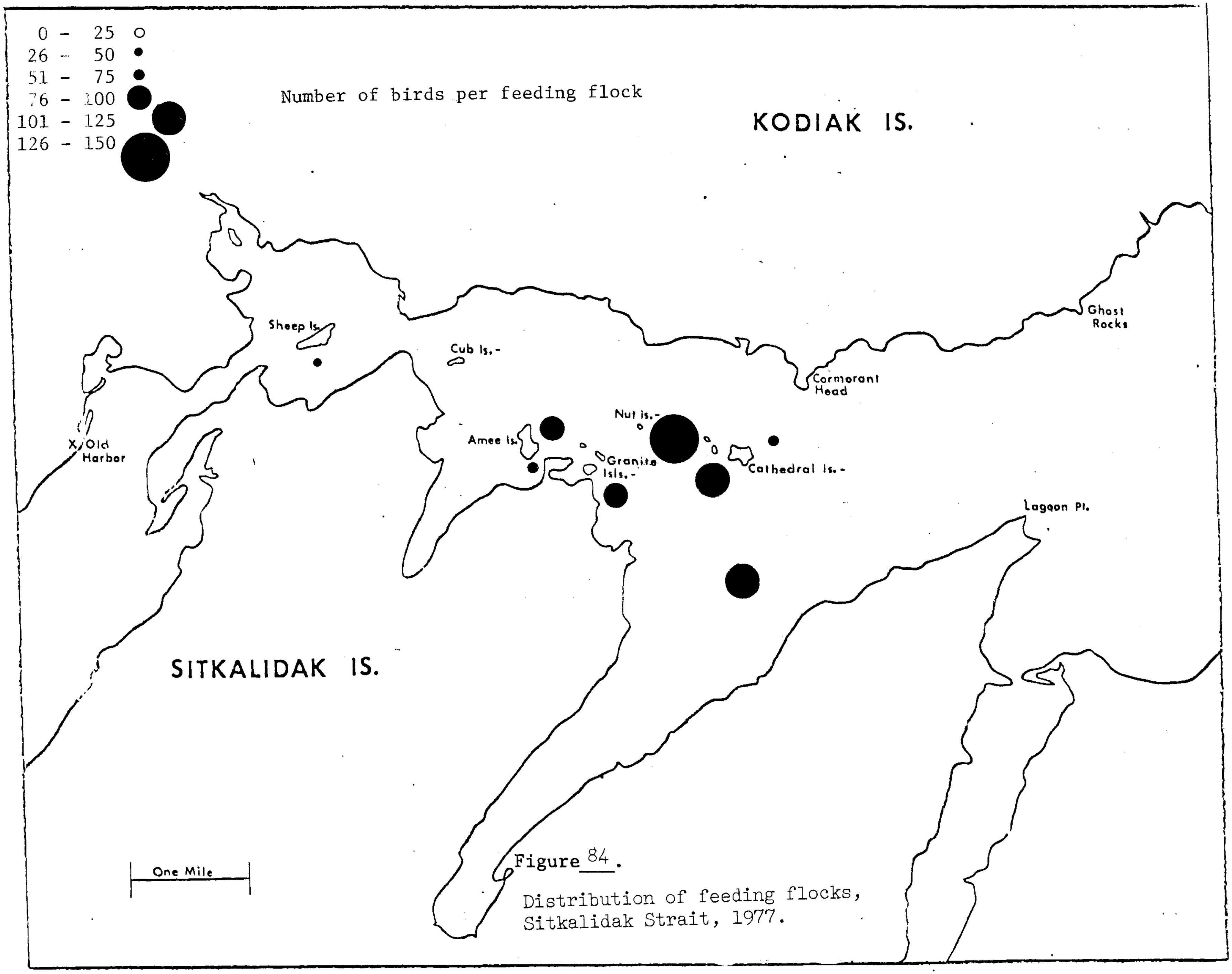

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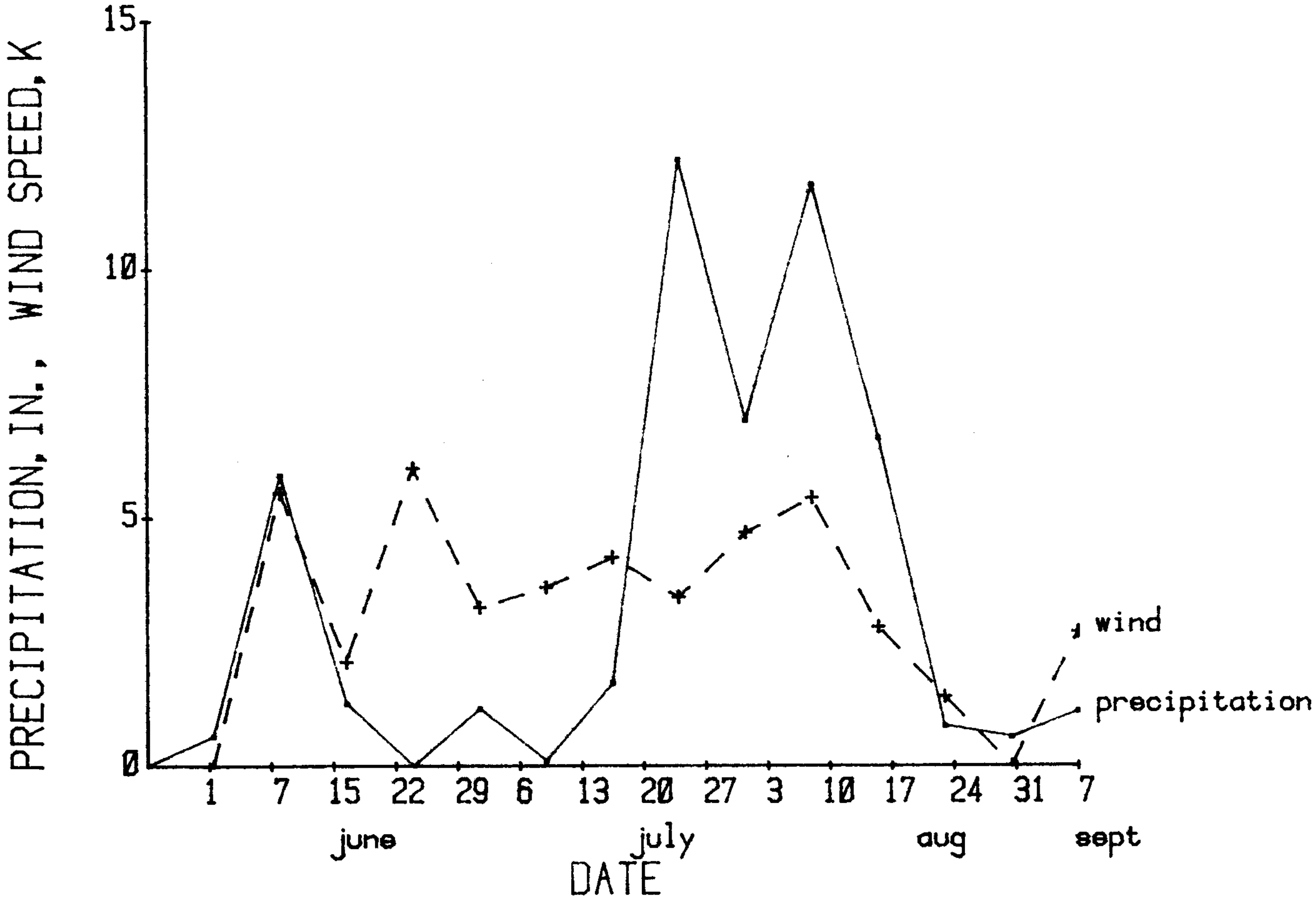

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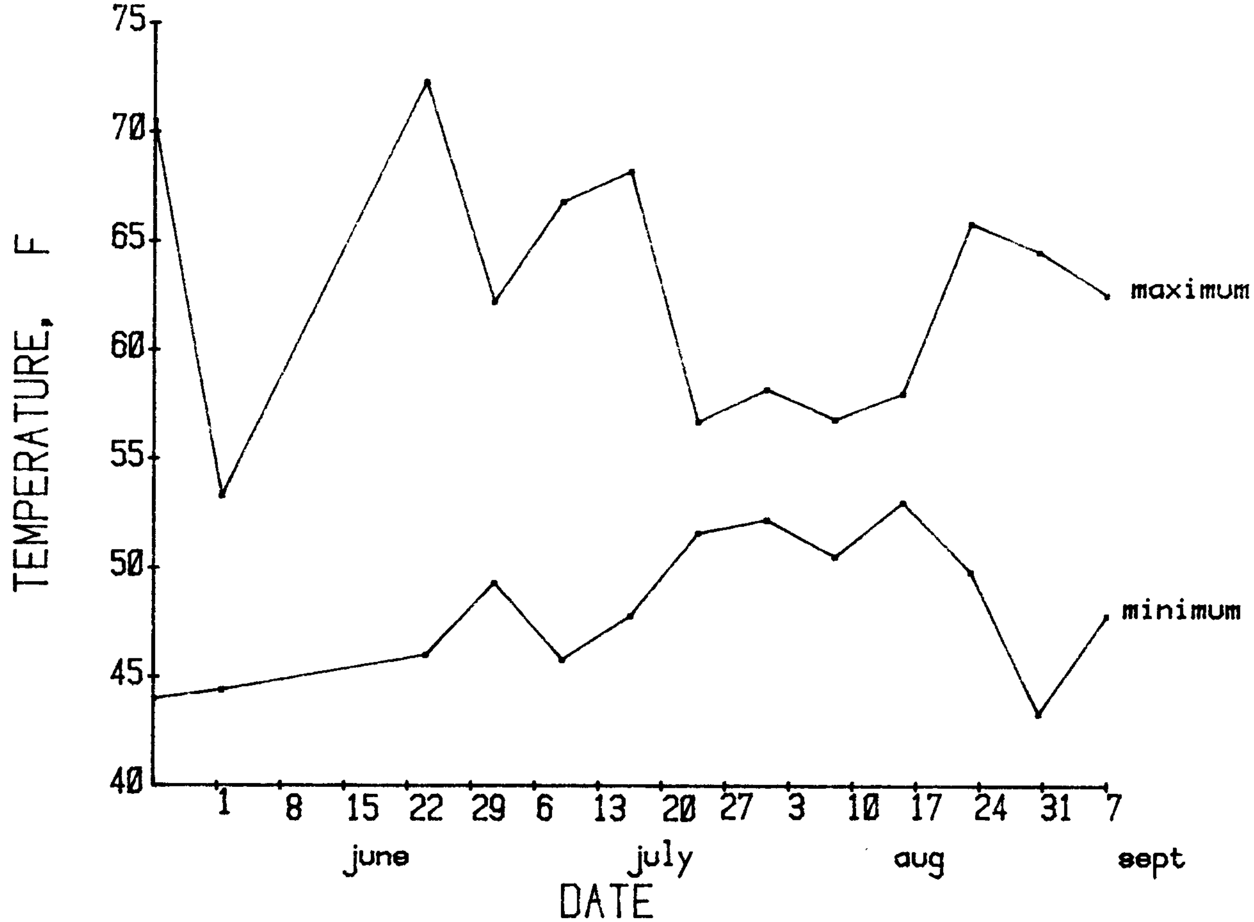

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NOAA-OCSEAP Contract: 01-5-022-2538
Research Unit: 341
Principal Investigator: C. J. Lensink
Report Period: April 1, 1977 to March 31, 1978

ANNUAL REPORT

THE BREEDING BIOLOGY OF MARINE BIRDS ASSOCIATED WITH CHINIAK BAY, KODIAK ISLAND, 1977

By

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Office of Biological Services - Coastal Ecosystems
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ABSTRACT

Ten island breeding colonies of seabirds were censused and studied in varying degrees in the inner portions of Chiniak Bay while two tern colonies were monitored on mainland Kodiak.

The number of cliff nesting birds overall for the bay was similar to that found in 1975 by Dick, but individual colonies had changed in their composition and numbers.

Breeding phenology was determined for the eight major species of the study while incidental notes were gathered on seven other study species. Productivities were gathered only on the eight major study species: Black-legged Kittiwake, Tufted Puffin, Pelagic and Red-faced Cormorants, Mew and Glaucous-winged Gulls, and Arctic and Aleutian Terns.

Black-legged Kittiwakes overall raised 0.78 chicks per nest attempt. Tufted Puffins had a maximum possible productivity of 0.67 chicks per nest attempt. Pelagic Cormorants fledged 1.35 young per nest attempt while Red-faced Cormorants had a productivity of 1.91 young per nest attempt. A minimum figure of productivity for Glaucous-winged Gulls at one high density plot was 1.15 young per nest attempt. Storms and predators greatly lessened the success of the Mew Gull and the two tern species, but estimates of surviving chicks are attempted.

One hundred and twelve birds were collected for food and parasite analysis. A roughsort indicates that Sandlance (*Ammodytes hexapterus*), Capelin (*Mallotus villosus*), euphausids (*Thysanoessa raschii*), and unidentified Gadidae are the major food items found in the three major species collected: Black-legged Kittiwake, Tufted Puffin, and Common Murre.

Four sea mammals and seven birds were found in the 25.6 kilometers of beach walked the summer of 1977.

Banding of young birds with U.S. Fish and Wildlife leg bands was done on Puffin, Zaimka, and Mary Island between 4 and 8 August. This involved a total of 349 birds of three species: 267 Glaucous-winged Gulls, 75 Mew Gulls, and 7 Arctic Terns.

I. INTRODUCTION

Lease sales are imminent for many portions of the continental shelf areas surrounding Kodiak Island. The town of Kodiak and parts of Chiniak Bay are slated to be staging and resupply areas. Two Kodiak oil spills in January and March 1970 have already indicated what adverse impacts offshore shipping can have: at least 10,000 birds died with the possibility of 100,000 birds having been killed (Bureau of Land Management, 1976). If marine birds are valid indication of the health of the food chain and there is increasing evidence to support this concept, then it is essential to continue expanding baseline data and monitoring studies of the marine birds in the region.

The authors arrived in Kodiak on 8 June 1977. The field work began in earnest on 13 June and continued until the end of August. Ten island breeding colonies involving thirteen species of marine birds were found within a radius of 5-7 kilometers of the Kodiak small boat harbor and three mainland colonies of terns were available from the island road system. Four of these island colonies and two of those on the mainland were used for intensive study sites (a visit every 3-5 days) while the remaining were visited only 2-4 times during the entire summer.

There were five specific objectives for the 1977 summer field work:

1. To set up sample plots on breeding colonies as a monitoring system.
2. To describe the local phenology of the reproductive biology of certain species such as the Black-legged Kittiwake, the Tufted Puffin, and others determined in the field.
3. To provide estimates of productivity of species mentioned in objective 2.
4. To determine major food items of the breeding species mentioned in objective 2.
5. To expand both the beached bird surveys and the bird-banding program.

II. CURRENT STATE OF KNOWLEDGE

The coastal waters of Kodiak Island provide excellent habitat for large numbers of both breeding and wintering seabirds and waterfowl. Some general and historical species' accounts like "The birds of Kodiak Island, Alaska" by Herbert Friedmann (1935) are available, but until recently this important resource was largely ignored by wildlife biologists.

In 1975 the U. S. Fish and Wildlife Service (Office of Biological Services - Coastal Ecosystems, Anchorage) initiated three primary types of studies in Chiniak and southern Marmot Bays: 1) beached bird surveys (Dick, 1976); 2) small boat censuses of inshore waters (Dick, et. al., 1976a); and 3) census and cataloguing of seabird breeding colonies (Dick, et. al., 1976b, 1976c). In 1976 some sample plots on breeding colonies were established in Chiniak Bay, but the primary emphasis was colony census work centering around Afognak Island. Much of the remaining Kodiak Island shoreline was censused for breeding colonies and this data will be published in a catalogue of Alaskan seabird colonies (U. S. Fish and Wildlife Service, in preparation).

In the winter of 1976-77 Matt Dick began more intensive collections of seabirds for purposes of analyzing some of the trophic relationships of the marine birds wintering in the Chiniak Bay region. John Trapp (1977) conducted aerial surveys March 9-14, 1977 which covered more than 90% of the Kodiak Island coastline. The staff of the Kodiak National Wildlife Refuge had previously conducted ship-board surveys along much of the coastline in February of 1973 and 1975 (U.S. Fish and Wildlife Service, 1973 and 1975) while the Alaska Department of Fish and Game conducted aerial transects of Kodiak and Afognak Islands' coastal waters in February and March of 1976 using a stratified-random design (Arneson, 1977).

III. STUDY AREAS

Ten of the seabird colonies utilized in this study were found in the inner portions of Chiniak Bay: Women's Bay, St. Paul Harbor, Woody Island Channel, and Middle Bay (Figure 1). Six of the ten colonies were located on islands smaller than 0.5 kilometer in length while only one colony (excepting those of terns) was found on the mainland (Kodiak Island proper).

The small offshore islands utilized most by seabirds are almost all similar in structure. Most range between 15 and 30 meters in height and are ringed by sloping to vertical, bare or partly vegetated, broken or sheer sea cliffs or by steep vegetated sea slopes. The island periphery vegetation is a beach rye (*Elymus arenarius*) - umbelliferous herb association with bluejoint (*Calamagrostis canadensis*) grass replacing the beach rye on the top and interior of the islands. Shrubs and trees were sparse or absent.

Puffin, Zaimka, and Mary Islands had high levels of human activity and intermittent low levels of egging while the remaining islands all (except Viesoki which had no human disturbance) had low levels of human activity associated with them and essentially little or no egging activity. Mary Island also had intermittent naturally occurring mammalian predators.

The three tern colonies studied on mainland Kodiak were located at the heads of Kalsin and Middle Bay. The colony at Middle Bay was located in coastal lowland between the American River and the outer active beach drift line. One tern colony at Kalsin Bay was located in coastal lowland on the shore of the Olds River while the second colony was on a low deltaic island at the mouth of the Olds River. Restrictive factors at Middle Bay were grazing by cattle (nests were stepped on), low levels of human activity, intermittent natural mammalian predators, and domestic predators like dogs. The Kalsin Bay colonies had less human disturbance, but the other limiting factors were similar.

The climate of Chiniak Bay is influenced by the marine environment characterized by moderately heavy precipitation, cool temperatures, high cloud and fog frequency with little or no freezing weather. The summer months usually have the least rainfall, but 1977 was an exception. The first part of the summer was normal or drier than normal, but a series of storm systems moved into the Kodiak area from the middle of July to the middle of August bringing rain at the average rate of 1.27 inches per day. The past overall mean precipitation for the month of August (1949-74) was 4.65 inches. The highest previous mean for August was 9.30 inches in 1964. In just the first thirteen days of August 1977, 15.2 inches had been recorded at Kodiak. Storms can occur in August, but those this summer appeared to be more severe than normal.

IV. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Censuses and Densities

All cliff-nesting seabirds were censused on the ten islands or colony sites in the study area. Density of nest sites of gulls, terns, and puffins were determined by line transects or quadrat sampling (Nettleship, 1976) with care to include data from the periphery of colonies or low density sites. Burrow occupancy and/or attendance by nocturnal species were estimated by placing toothpicks upright in burrow entrances. This data is compared with eggs found in the same burrows.

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 also gathered on the scattered nests of species like Horned Puffin, Pigeon Guillemot, Black Oystercatcher, and Common Eider.

Black-legged Kittiwake (*Rissa tridactyla*)

The colony on Kulichkof Island was visited every 4 to 5 days during hatching and most of the chick stage. Nests were not individually marked. The colony was subdivided into six sub-areas for nest-checking purposes, but data were combined since total nest numbers were consistently similar and sub-area data varied from visit to visit. This variation was due to the difficulty of censusing the denser parts of the colony. All censusing was done from clifftop vantage points.

The colony at Gibson Cove was used for just productivity studies. Two visits on 16 and 20 June ascertained nesting attempts while two visits on 11 and 20 August recorded the number of chicks. All censusing was done from a dory immediately offshore from the colony.

Tufted Puffin (*Lunda cirrhata*)

All of the productivity work on this species in Chiniak Bay was done on Cliff Island because it had shallower soil as well as both peripheral and slope burrows. A line transect (15 meters) and a quadrat (10 x 10 meters) were laid out on 26 June and checked for activity by toothpicking the burrow entrances. To reduce soil erosion and nest desertion by adults, the two sample plots were checked only three times: 1) late in incubation; 2) during hatching; and 3) just before fledgling (only on quadrat). The quadrat lay in entirety on the cliff slope while the line transect also samples some of the island top. The line transect included all burrows that lay within one meter of either side of the transect.

A few burrows on Puffin Island were frequently checked to discover the beginning of hatching, but this was not done on Cliff Island because of the tendency for adults to abandon at this stage in their breeding phenology.

Pelagic and Red-faced Cormorants (*Phalacrocorax pelagicus* and *P. Urile*.)

Intensive phenology work was done only on Kulichkof Island where Pelagic Cormorant nests were mixed in with the kittiwake colony. The cormorant nests in the kittiwake colony were censused every 4-5 days during hatching and most of the chick stage.

The remaining cormorant nests on Kulichkof plus portions of colonies on Bird, Puffin, Cliff, and Zaimka Islands as well as Gibson Cove were checked for productivity by two or three visits: 1) once or twice during the middle of incubation (14-21 June); and 2) once about 1-2 weeks before fledgling (4-12 August). All of the islands mentioned above except Kulichkof had both species nesting.

Glaucous-winged Gull (*Larus glaucescens*)

The same quadrats were checked in 1977 that Matt Dick set up in 1976; 1) 3 10 x 10 meter quadrats of low density nesting habitat on Cliff Island; 2) 6 10 x 10 meter quadrats of low-density on Zaimka Island; and 3) 1 irregular larger sample plot (766 sq. meters) of high-density nesting habitat on Zaimka. Nests were marked and all plots were visited every 4-6 days during hatching.

The high-density plot was also checked for chick productivity on 6 August since geographical and water conditions restrained most if not all chicks from wandering far from nest sites.

Mew Gull (*Larus canus*)

Essentially the same quadrats were run on Mary Island as those set up in 1976 by Matt Dick. The south colony had 11 quadrats (10 x 10 m) arranged linearly so as to cross from periphery to periphery of the colony. The northeast colony had 5 quadrats (10 x 10 m) lined up mostly in the middle of the colony.

Nests were marked in those plots and the plots were monitored every 4-5 days during hatching for phenology purposes. Estimates of productivity were made by comparing ratios of banded chicks near fledging/ total number of chicks clustered nearshore to banded/non-banded dead chicks found on beaches two weeks later.

Arctic and Aleutian Terns (*Sterna paradisaea*, and *S. aleutica*)

Three colonies were monitored for phenology during incubation and hatching: 1) a mixed species colony on Mary Island; 2) a small Aleutain Tern colony along the Olds River at the head of Kalsin Bay.

Individual nests were marked and much time was devoted to finding every nest in a sub-colony. Densities were obtained from nearest neighbor measurements and habitat quadrats (usually 10x 10 m) that were taken from the four habitats the large colony on Mary Island occupied.

Trophic Ecology

Collection of seabirds were made periodically to determine diet and parasites. The two primary study species, Tufted Puffin and Black-legged Kittiwake, were collected by the systematic serial method recommended by Sanger (pers. comm.). This necessitated the collection of three individuals of each species every five days, if possible. Birds actively feeding away from colony sites were collected and these birds were evaluated in terms of reproductive condition, feeding habits, plumage, and general morphological data. Stomach contents of collected birds as well as food samples brought to chicks were preserved for identification and quantification at a later date.

Mortality

Beached bird surveys were run monthly or bimonthly on the four strips established in 1975 by Matt Dick. Four addtional beaches were surveyed in 1977.

Banding young with U.S. Fish and Wildlife leg bands was emphasized during the first week of August for two species: Mew and Glaucous-winged Gulls. These species were selected because of the high probability of recoveries.

IV. RESULTS AND DISCUSSION

Censuses and Densities

Variations were noticed in numbers of active nests of three cliff-nesting species of seabirds between 1975 and 1977 (Table 1). The nesting population of kittiwakes remained relatively constant with increases at Gibson Cove and Kulichkof Island countering the decreases at Viesoki Island. Red-faced Cormorants increased nest numbers in 1977 at essentially every island except Viesoki which decreased so greatly from 1975 that the 1977 overall total was lower than 1975. Pelagic Cormorant nests increased almost twofold in 1977 compared to 1975 nesting.

Burrow or ground nesting colonial seabirds are hard to totally census and hence mean nesting densities of sample plots were used for monitoring purposes of the five species studied in Chiniak Bay (Table 2). The distance to nearest nest of the same species was used in evaluating and monitoring nest densities.

Two sample plots of Tufted Puffins on Cliff Island were used to extrapolate an estimate of the breeding pairs on the island. One quadrat (100m2) had 74 burrows and 61 appeared active. Of the 61, nest chambers or burrow ends could be reached in 30 and only 25 had eggs. The line transect (30 m2) had 30 burrows and 26 appeared active. Of the 26 nest chambers or burrow ends were reached in 12 and in these, only 10 had eggs. Since 35 of 42 reached to the end were active in 130 m2, then a similar proportion of all active burrows (found by toothpick method) would be 73 or 80 active burrows out of the total 97 burrows that appeared active. The variation depends on whether each plot is extrapolated separately or together. Using the lower figure, 73 active burrows in 130 m2, gives an estimate of the breeding population as 1094 pairs for Cliff Island since there were 1949 m2 of habitat being used for burrows. This estmate may be high as there may have been different burrow densities in the total habitat used than those recorded in the sample plots. Matt Dick estimated 400 breeding pairs in 1975 on Cliff Island.

The nesting densities of Mew and Glaucous-winged Gulls are similar as are the mean distances of nearest neighbor nests ($t = 0.17$, d.f. = 103, $P > .95$), but they utilize two different habitats. The Glaucous-winged Gull used the *Elymus*, *Calamagrostis*, or umbel plant associations for nesting with highest densities found toward the island perimeter. The Mew Gull had its highest nesting densities in more interior portions of islands where *Calamagrostis* was dominant. Even though there were low and high density nesting plots for each species, the differences in mean distance of nearest nest are not significant for either species ($t=1.56$, d.f.=59, $P > .10$; $t=1.37$, d.f.= 62. $P > .10$). Behavioral needs apparently require a certain amount of clumping even in less desirable habitat.

Arctic Tern nesting density varied from 7 to 13 nests per square dekameter with a mean of 10.6 nests. The mean distance of the nearest neighbor nest was 2.13 ± 0.08 m. Aleutian Terns had two nesting strategies in 1977. On Mary Island where they nested with the Arctic Tern colony, they were clumped in several points along the perimeters of the Arctic Tern colony. The Aleutian Tern nests subsequently had a higher density (13 nests per square dekameter) and a significantly smaller distance between neighboring nests of 1.38 ± 0.10 m ($t=4.52$, d.f.=105, $P < .01$). When the Aleutian Terns nested by themselves at the heads of bays, the mean distance of nearest neighbor nests expanded significantly to 30.99 ± 4.34 m ($t=9.81$, d.f.=31, $P < .01$).

Breeding Phenology and Productivity

Black legged Kittiwake

The sample plot on Kulichkof Island included almost all of the nesting kittiwakes found there (210 of 218 nests). The colony utilized approximately 630m2 of cliff face with most of the nests found between 5 and 12 meters above sea level on the cliff faces. This gave a nesting density of 33 nests per square dekameter.

Field work began just after egg laying had begun. Intensive observation from then on indicated that all egg loss occurred during the first two weeks of July (78% between 9 and 15 July). Hence an extrapolation of laying dates from hatching dates would be fairly accurate since avian predation was limited in time and amount. An incubation time of 28 days (Swartz, 1966) was used for this extrapolation. Hatching began on 2 July and peaked on 10 July with the mode (middle two thirds) occurring between 7 and 20 July (Figure 2). This would mean that egg laying started about 4 June peaking on 12 June. The last known hatching date was 26 July making egg laying end during the last week of June. Generally speaking, the 1977 Chiniak Bay breeding phenology is 1-2 weeks behind that of Hinchinbrook Island 1976-77 (Nysewander and Knudtson, 1977; Sangster, pers. comm.) and a few days earlier than that at Sitkalidak Island in 1977 (P. Baird and A. Moe, pers. comm.)

The mean number of eggs per completed clutch for the Kulichkof Island colony was 1.91. Hatching success of known eggs (n=338) was 84.9% and fledging success of known chicks (n=287) was 90.2% This gave a productivity of 1.23 chicks fledged per nest attempt or 1.46 chicks fledged per nest with eggs. Table 3 compares this reproductive success with that at Gibson Cove where only 0.30 chicks fledged per nest attempt.

Predation appeared to be the mortality factor that caused the difference found in kittiwake reproductive success between Gibson Cove and Kulichkof Island. Although the Gibson Cove colony was studied only periodically, Bald Eagles were observed twice carrying off kittiwake chicks while crows and magpies were quite abundant and nesting nearby. The only avian predators noticed at Kulichkof Island were the low number of Glaucous-winged Gulls nesting on the island. As mentioned, essentially no noticeable kittiwake egg loss occurred at Kulichkof Island until the first two weeks of July. This egg loss occurred just as most of the kittiwake hatching began and just after the hatching peak of the Glaucous-winged Gulls.

The only mortality caused by human disturbance occurred on 18 July when 5 chicks fell from nests into the water while we were checking nests. This type of chick loss (17.8% of total chick mortality) did not occur either before or after this time during our visits.

Table 4 lists the egg, chick, and fledging distributions found during different reproductive stages on the Kulichkof Island colony.

The egg and clutch data were taken on 30 June while brood data were collected on 18 July. Fledging data were gathered 4 August. The number of three egg clutches and one nest that managed to fledge three chicks indicate the high reproductive success noted on Kulichkof Island this year.

Tufted Puffin

One quadrat (100m2) had a slope density of 1.04 active burrows per square meter. The island top measured by the line transect (20m2) had a density of 0.08 active burrows per square meter. The overall mean of 0.56 burrows per square meter was very similar to that found in the Barren Islands (0.54) by Amaral in 1976.

Hatching began on 10 July and peaked on 19 July with a mode occurring between 14 and 25 July (Figure 3). The last known hatching was 8 August. Using a 45 day incubation period (Sealy, 1973), this would mean that egg laying began 26 May peaking on 4 June and that fledging probably peaked somewhere during the first week of September. This phenology for Chiniak Bay was essentially the same as that found in the Barren Islands and Prince William Sound in 1976 (Amaral, 1977 , Nysewander and Knudtson, 1977).

Hatching success of known eggs (n=35) was 88.6% while fledging success of known chicks (n=22) was 90.2% (Table 5). This gave a productivity of 0.67 chicks fledged per nest attempt or 0.80 young fledged per nests with eggs. This is essentially the same as that found at Hinchinbrook Island in 1976 (Nysewander and Knudtson, 1977), but much higher than that found at the Barren Islands (0.28) by Amaral (1977). Nettleship (1972), however, found a success rate for Common Puffin similar to that found for Tufted Puffins in Chiniak Bay. My experience with intensive or daily studies of both Tufted Puffins and Rhinoceros Auklets on Destruction Island leads me to believe that these daily studies greatly lower the reproductive success of puffins. Visiting this species a minimum of three visits at certain less critical times at Prince William Sound and Chiniak Bay appear to support this hypothesis. The three periods of time primarily used this year in Chiniak Bay for checking puffin burrows were as follows: 1) 26-28 June, late incubation; 2) 14-19 July, hatching; and 3) 23 August, fledging.

Table 6 lists the egg, chick, and fledging distributions found during different reproductive stages at the Cliff Island plots.

Pelagic and Red faced Cormorants

The intensive phenology and productivity plot for cliff nesting species on Kulichkof Island included only 26 of the 71 Pelagic Cormorant nests found on the island. The density of the phenology plot was 4.1 nests per square dekameter of utilized habitat while the density of the remaining 45 nests was 11.5 nests per square dekameter of suitable habitat used. Nesting densties of cormorants

(2 species mixed) on seven other islands varied from 2.7 - 9.3 nests per square dekameter. The overall colony mean for Chiniak Bay (2 species combined) was 6.2 nests per square dekameter.

Hatching for Pelagic Cormorants began on 4 July peaking on 11 July with the mode extending from 9 to 14 July (Figure 4). The last hatching was noted on 18 July. Using a 31 day incubation period (Van Tets, 1959), this would make egg laying begin on 3 June peaking on 10 June. This makes the Pelagic Cormorant phenology in Chiniak Bay about a week ahead of that of Black-legged Kittiwake which are nest-site competitors (Dick, 1975). No phenology was gathered on Red-faced Cormorants in 1977 at Chiniak Bay due to the late start of field work.

The mean number of eggs per completed clutch for Pelagic Cormorants was 3.48 on Kulichkof Island. Hatching success of known eggs (n=87) was 69.0% and fledging success of known chicks (n=60) was 61.7%. This gave a productivity of 1.42 young fledged per nest attempted or 1.48 young fledged per nest with eggs (Table 7). Productivity by nest attempt of Pelagic Cormorants varied on five other islands from 0.13 - 1.94 young fledged with the six island mean being 1.35 young fledged. Red-faced Cormorants had a five island mean productivity of 1.91 chicks fledged per nest attempt. Both of these averages were lowered by the essentially total breeding failure of either species on Zaimka Island. This is attributable to the colony of crows breeding on Zaimka as well as the human disturbance that is common on that island. The crows were observed several times taking eggs when people scared the cormorants off their nests.

Both species did well on the remaining islands and Red-faced Cormorants were more successful than Pelagic Cormorants in almost every case where they nested together (X2 = 10.4, P = .01).. The inclusion of highly successful single species (Pelagic Cormorant) colonies like Kulichkof Island still shows Red-faced Cormorants to have been more successful in producing fledglings (X2 = 4.44, P > .05)

Table 8 compares reproductive success, phenology, and breeding parameters of Pelagic Cormorants nesting in Chiniak Bay with those of Mandarte Island (Drent, et. al. 1964) and Cape Peirce (Dick, 1975). It appears that Chiniak Bay birds are intermediate in all categories Although the southern site has higher overall success and clutch size, there is an inverse relationship between hatchings and fledging success in northern versus southern colonies. Northern colonies appear to have greater hatching success and lower fledging success than southern colonies. Possibly, this indicates that gulls and crows are important mortality causes in the south while predation by eagles, food, or weather may be more important limiting factors in the north. Chiniak Bay was interesting in this respect in that crows certainly elminiated breeding on Zaimka Island, but most of the cormorant colonies were not bothered by avian predators even when humanly disturbed. This lack of predation contrasts greatly with this author's experience with cormorant colonies in Washington.

The two study plots on Kulichkof Island point up how either human disturbance, association with kittiwake nests, and/or cormorant nest density does affect the reproductive success of Pelagic Cormorants. The cormorants associated with the kittiwakes in our intensive study area produced 1.48 young per nest attempt 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 which was significantly different ($X2 = 4.05$, $P > .05$). Since nesting gull populations are low (see discussion under Glaucous-winged Gull section) and crows are clumped in their distribution at this time, weather and possibly food appeared to be more important. The unusually heavy rainfall and storm from mid-July to August caused some noticeable losses. Only two chicks fell from their nests due to human disturbance.

Table 9 lists the egg, chick, and fledgling distributions found during different reproductive stages on the Kulichkof Island intensive study plot. The egg and clutch data were taken on 26 June while brood data were collected on 14 July. Fledging data were gathered 4 August. This was 1-2 weeks before fledging, but the young would leave the nest too easily during that last week.

Glaucous-winged Gull

The low density sample plots on Cliff Island (300 m2) included 10 nests of the total estimated 20-25 nests found on the island. The low density plots on Zaimka Island (600 m2) included 13 nests while the high density plots (766 m2) contained 40 nests. Dick (1976 b) estimated 400 breeding pairs on Zaimka island in 1975, but the 1977 breeding population seemed smaller (250-300 pairs). The mean density for the low density plots was 2.6 nests per square dekameter while the high density plot had 5.2 nests per square dekameter. As mentioned earlier, the mean distance to nearest nest of the same species was not significantly different between low and high density plots. The general impression of Chiniak Bay is that there is plenty of gull nesting habitat not being used compared to that seen by this author in Puget Sound and Washington State. This lower level of gull population may be due to several of the following mortality factors: 1) This species is the main one egged by local residents; 2) At least 15 of the smaller boats in the Kodiak Tanner Crab fleet use gulls for hanging bait taking between 11,000 and 15,000 birds annualy (up to 80 per day per boat: Dick, 1977); 3) Large gulls are usually winter food limited and thus winter conditions may be more severe in Kodiak than in Washington with fewer garbage dumps to carry them over. At any rate, the lower number of large gulls certainly reduces egg predation pressure on the other seabirds nesting in the bay.

Hatching began for this species on 25 June peaking on 2 July with the mode extending from 28 June to 4 July. The last hatching of initial clutches was on 11 July, but as seen in Figure 5 a second peak of hatching occurred because of re-nesting attempts caused by native egging. Egging by natives usually occurred early in June, but some was observed on Puffin Island on 22 June. The hatching of re-nest attempts extended from 15 to 25 July. Using a 28 day incubation time (Vermeer, 1963), this would indicate that egg laying began 28-29 May with the peak around 4-5 June.

The mean number of eggs per completed clutch for the Zaimka-Cliff Islands' plots was 2.64. Hatching success of known eggs (n= 87, 51) was 86.2-92.2%, while the minimum fledging success of known chicks (n=75) was 61.3% (Table 10). This gave a productivity of 1.15 chicks fledged per nest attempt or 1.39 chicks fledged per nest with eggs.

Since most of the egging occurred before field work began this season, the hatching success figures do not measure this mortality. Vermeer (1963) found in Glaucous-winged Gulls in British Columbia that were not subject to egging a hatching success of 71-83%, a fledging success of 65-75%, a mean clutch size of 2.82, and mean productivities that ranged from 1 to 1.7 fledgling per nest attempt. It would appear that Chiniak Bay gulls have better hatching success, but that productivities are no better than those found in the southern more dense colonies. However, additional years of data are needed because reproductive success is quite variable in seabirds from year to year.

Table 11 lists the egg and chick distributions found in Chiniak Bay in 1977.

Mew Gull

Bianki (1967) found that *Larus canus* in the Soviet Union had a strong nesting preference for maritime meadows with soil base while much lesser densities of nesting sometimes occurred in crowberry habitat. Densities ranged from 0.03 to 0.06 nests per square dekameter. In contrast, the Mew Gulls in Chiniak Bay nested solely on maritime meadows completely avoiding the beach rye water periphery vegetation but the mean nesting densities ranged from 1 to 5.5 nests per square dekameter (Table 2). Dick et. al. (1976b) estimated 60 breeding pairs in 1975 on Mary Island. In 1977 the south colony covered approximately 3640 m2 while the northeast colony covered 4100 m2. Visually, we estimated 200 breeding pair while extrapolation from densities found in sample plots gave an estimate of 340 breeding pair. I feel the latter estimate is high because the total colony probably included more low density nesting area than that covered by the sample plots.

Hatching began in Chiniak Bay on 15 June peaking on 24 June with the mode extending from 19 to 29 June (Figure 6). The last hatching was noted on 14 July. It is felt that nests hatching 10-14 July were re-nests after egging since these nests were all associated with Glaucous-winged Gull nests that had been egged. Using 26 days as the incubation length(Barth, 1955; Bianki,1967), egg laying in Chiniak Bay apparently began around 19-20 May peaking near the end of May. This makes the species one of the earliest to lay eggs in Chiniak Bay. Figure 7 illustrates how the Mew Gull phenology is definitely ahead of the Glaucous-winged Gull. Mew Gulls are similar to terns in having the peak of hatching occur before the Glaucous-winged Gull peak of hatching.

The mean number of eggs per completed clutch for the Mary Island Mew Gull plots was 2.63. This is quite similar to that found by Bianki (1967): 2.6 with range of 2.3-2.8. Hatching success of known eggs (n=158) in Chiniak Bay was 83.5% ranging from 77.8 to 86.5% (Table 12) while Bianki (1967) had hatching successes of 76.9% (range 66-81.9%).

Fledging success is quite difficult to estimate since chicks disperse so widely and there are few physical features to contain them. On Mary Island the chicks migrated towards water's edge in 1977 as they neared the time of fledging. On 5 August (somewhat late due to intense storms during the previous 3 weeks) we banded 75 chicks found in the beach vegetation. There were 335 other chicks who escaped to or were already in the water even though most all were flightless. The heavy storm activity continued for another week. On 11 August I found 1 banded chick out of 12 dead chicks on beaches at the head of Women's Bay. Some chicks were even observed far from water wandering through the Bell Flats housing area at the head of Women's Bay, pushed there no doubt by the prevailing easterly storm winds. On 20 August we revisited Mary Island and found 128 dead Mew Gull chicks of which 12 were banded. Comparisons of these ratios would suggest that a maximum of 199 chicks had survived and possibly less. This would give a productivity of 0.6-1.0 chicks per nest attempt depending upon the colony estimates (200-340 breeding pairs). Bianki (1967) notes that Larus canus chicks have a relatively high fledging mortality at times, but that as a rule this species averages about 1.5 fledglings per pair.

In the egg stage the two most common mortality factors were human egging activity and egg damage or disappearance (unknown bird predator). Mortality in the chick stage in 1977 was primarily that of starvation and exposure during the last two weeks prior to fledging. Some chicks were killed and/or harassed by Glaucous-winged Gulls picking at the chicks' heads. About the same time, a River Otter arrived on Mary Island and proceeded to devastate the tern colonies and essentially eliminate much if not all of this productivity in 1977. Some Mew Gulls were taken by a mammalian predator and possibly the appearance of the Otter may have driven the Mew Gull chicks prematurely to the water's edge. However, many chicks died on the beaches untouched by bird or mammal.

Thus it appears that the unusual storm activity and/or food shortages were the most important factors that changed a very good hatching success into a fledging failure. Mew Gulls are not observed in seabird feeding flocks. Perhaps the storm drove forage fish out of the nearshore waters where Mew Gulls feed. At any rate, no other seabird species breeding in Chiniak Bay was affected by the storms to the degree that Mew Gulls were.

Table 13 lists the egg and chick distribution found on Mary Island in 1977.

Arctic and Aleutian Terns

The mean number of nests per square dekameter for Arctic Terns on Mary Island was 10.6 with a range between 8 and 13 nests. The highest densities were found in the maritime meadows with the lowest found on hillsides. Intermediate densities occurred near the water's edge. On Mary Island the Aleutian Terns nested only on the maritime meadows just adjacent to the Arctic Tern Colony. Their nesting density was 13 nests per square dekameter. Apparently the Aleutian Tern nests were more dense in this situation as the nearest nest of the same species was a mean distance of 1.38 meters while Arctic Terns had a mean distance of 2.13 meters. Aleutian Terns nesting by themselves at the heads of bays had a nearest neighbor mean distance of 30.99 meters, thereby utilizing a very different nesting strategy. Bianki (1967) found lower densities in the Soviet Union where 75% of all tern nests were found within 3 and 20 meters of each other. On Mary Island in Chiniak Bay, the Arctic Tern nests covered roughly 1166m2 while Aleutian Tern nests covered 206m2. This would give colony estimates of 130-140 breeding pairs for Arctic Terns and 27 pairs for Aleutian Terns on Mary Island. Specifically, we marked and monitored 96 Arctic and 23 Aleutian Tern nests on Mary Island with an additional 22 Aleutian Tern nests checked at Kalsin and Middle Bay.

Hatching of Arctic Terns began on 18 June peaking on 26 June with the mode occurring between 23 June and 5 July (Figure 8). Aleutian Terns began hatching on 22 June peaking on 1 July with a mode running from 27 June to 10 July (Figure 9). The last hatching of either species was around 15 July. This would mean that egg laying begins during the last part of May and the first week of June with the Aleutian Tern essentially 4 days behind the Arctic Tern in phenology.

The mean number of eggs per completed clutch was 2.21 for Arctic and 1.84 for Aleutian Terns. Hatching success of known eggs was 85.4% (n=212) for Artic Terns on Mary Island while Aleutain Terns were 95.2% (n=42) successful on Mary Island and 79.4% (n=39) successful on mainland Kodiak (Table 14). All of these compare favorably with those averages found by Bianki (1967) in the Soviet Union (62.7-82.0%) and Hawksley (1957) in Canada (64%). However, most all tern studies report that fledging mortality varies more from year to year than does hatching mortality or success.

Lemmetyinen (1973) reported that most of this mortality occurs in the first two weeks after fledging. Most researchers mention the lethal influences of inclement weather and high winds on tern chicks due to starvation. In certain cases mammals prey heavily on fledlings. In 1977 at Chiniak Bay both of these mortality factors occurred. A River Ottor showed up for a week on Mary Island and apparently killed many tern chicks. On 5 August we found 34 predated chick carcasses at or near sites. The intense storm activity during this period also took its share of mortality. The exact extent and proportion of mortality is hard to ascertain since tern chicks do not usually congregate near the water's edge in the visible way that Mew Gulls did. Bianki (1967) had productivities ranging between 1 and 1.19 chicks per breeding pair while Hawksley (1957) had 0.5 fledging per pair. It would seem that the Mary Island Colony had no better and possibly worse success.

Tables 15 and 16 list the egg and chick distributions found in Chiniak Bay in 1977.

Incidental Notes on Additional Breeding Species

Horned Puffins (*Fratercula corniculata*) were common in Chiniak Bay, but their nesting is distributed much like the Pigeon Giullemot — low density scattered over shorelines of numerous islands. One nest was monitored on Zaimka Island and hatching occurred on 21 July.

One nest of Pigeon Guillemot (*Cepphus columba*) was monitored on Zaimka Island and hatching occurred on 12 July. On 14 April Matt Dick censused 202 Pigeon Guillemots along 14 kilometers of shoreline in the Near Island group (includes Popof, Kulichkof, and Bird Island). It is unlikely that these all nest in that area, but this census does give some idea of densities (14.4 birds/km) found in the Chiniak Bay region.

Black Oystercatchers (*Haematopus bachmani*) were found nesting on Zaimka Island (3 pairs), Cliff Island (1 pair), Blodgett Island (1 pair), and Mary Island (1+ pairs). Nesting was probable on Puffin, Kulichkof, and Bird Islands, but the breeding attempts may have failed as no nests were found near hatching on these islands this year. Hatching in 5 nests extended from 15 June to 14 July with the majority occurring during the third week of June. Hatching success of known eggs (n=13) was 84.6% but past studies (Nysewander, 1977) have shown that nesting attempts were probably missed.

The Common Eider (*Somateria mollissima*) was a common but low density breeding species in Chiniak Bay in 1977. Most islands had 2 or 3 nests with Mary Island having 11 nests. Hatching ranged from 22 June to 14 July. Hatching success of known eggs (n=84) was 59.5%. The female and brood leave the nest and island soon after hatching and are rarely, if ever, seen after that.

Nests of Red-breasted Merganser (Mergus serrator) were found on Mary and Puffin Islands. One nest hatched between 6-8 July and the other hatched sometime after 9 July.

A few nests of Semipalmated Plover (Charadrius semipalmatus) and Least Sandpiper (Calidris minutilla) were monitored at the heads of Kalsin and Middle Bays. The one plover nest hatched on 28 June while the two sandpiper nests hatched on 26 and 29 June.

Trophic Ecology

One hundred and twelve birds were collected for food and parasite analysis. A roughsort has been completed and Table 17 lists the species or items found in each of the nine bird species collected. Attempts were made to collect three species in feeding flocks away from colony sites: Common Murre, Tufted Puffin, and Black-legged Kittiwake. The other species or samples were incidentally collected mostly for parasite analysis or were regurgitations at colony sites. The percentage of prey by frequency or volume is not available now, but will be included in the expanded feeding program planned next year at this site.

Mortality

Eight beached bird surveys covering 14.9 kilometers were conducted along the road system that extends from Kodiak to Narrow Cape. These surveys were run every two weeks during the summer. Four sea mammals and seven birds were found in the 25.6 kilometers of beach walked the summer of 1977. For further detail, refer to the beached bird survey reports consolidated overall for the Gulf of Alaska by Kent Wohl, (U.S. Fish and Wildlife Service, OBS-CE).

Banding of young with U.S. Fish and Wildlife leg bands was done on Puffin, Zaimka, and Mary Island between 4 and 8 August. This involved a total of 349 birds of 3 species: 267 Glaucous - winged Gulls, 75 Mew Gulls, and 7 Arctic Terns.

VI. NEEDS FOR FURTHER STUDY

The research in 1977 at this study area gives a single estimate of productivities. Without two or more years of research at any one spot, it becomes impossible to separate normal population fluctuations from those caused by oil pollution or development.

Now that some baseline data of productivity is available, it is possible to disturb some colonies so as to answer some feeding or trophic questions: 1) the food brought to young measured by regurgitations; 2) why immature murres feed in Chiniak Bay; and 3) how this all compares with resources available (which the Kodiak integrated OCS study may supply).

Chiniak Bay offers some unique opportunities to develop some baseline data on breeding biologies of marine birds that have no published data on them. The lack of predators makes feasible the study of both the Pelagic and Red-faced Cormorants. We intend to expand our work on the latter species since nothing is known about it and it is a common Alaskan species. The presence of Aleutian Tern colonies and an unusual Mew Gull colony afford similar opportunities.

One of the critical times for marine birds in Chiniak Bay is the winter when numerous waterfowl and alcids frequent the bay. These types of birds have long been recognized as those most vulnerable to oil pollution. Yet the winter populations and trophic relationships have had the least research and effort devoted to them. The OCSEAP program in Kodiak should not end without some additional effort to fill in this data gap.

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Table 1. Variations in Cliff-Nesting Seabirds on Breeding Colonies, Inner Chiniak Bay, 1975 and 1977

Species	Island	Number of Nests 1975	1977
Black-legged Kittiwakes	Zaimka	20	0
	Gibson Cove	114	199
	Kulichkof	104*	218
	Holiday	5	5
	Viesoki	1306	1096
	Total	1549	1518
Pelagic Cormorant	Bird	56	100
	Kulichkof	25	71
	Gibson Cove	0	50
	Puffin	39	31
	Cliff	0	5
	Zaimka	17	25
	Holiday	43	58
	Blodgett	0	47
	Viesoki	22	4
	Total	202	391
Red-faced Cormorant	Bird	3	31
	Gibson Cove	0	10
	Puffin	17	33
	Cliff	2	2
	Zaimka	22	21
	Holiday	0	23
	Blodgett	0	5
	Kulichkof	5	0
	Viesoki	103	14
	Total	152	139

* Data missing in 1975, and 1976 data substituted (Dick, pers. comm.).

Table 2. Nesting Densities of Certain Colonial Burrow or Ground Nesting Seabirds in Chiniak Bay.

Species (n=nests) (m^2=area)	Mean Number of Nests Per Square Dekameter	Mean Distance ± S.E. of Nearest Neighbor Nest (in meters)
Tufted Puffin	56.2	--
n=42 m^2=130		
Glaucous-winged Gull		
Low Density n=21 m^2=900	2.6	3.77 ± 0.23
High Density n=40 m^2=766	5.2	3.07 ± 0.29
Mew Gull		
Low Density n=4 m^2=400	1.0	4.33 ± 0.59
High Density n=60 m^2=1100	5.5	3.31 ± 0.22
Arctic Tern n=87 m^2=820	10.6	2.13 ± 0.08
Aleutian Tern		
Colonial Mixed Species Island Site n=22 m^2=170	13.0	1.38 ± 0.10
Semi-Colonial Single Species Mainland Site n=11 m^2=?	---	30.99 ± 4.34

Table 3. Reproductive Success of Black-legged Kittiwake in Chiniak Bay 1977.

Reproductive Success	Sample Plots: Gibson Cove	Sample Plots: Kulichkof Island	Sample Plots: Combined
Sample Size (nest attempts)	199	210	409
Hatching of Known Eggs	-	287/338 = 84.0%	-
Fledging of Known Chicks	-	259/287 = 90.2%	-
Mean Number of Young Fledged/ Nest Attempt	0.30	1.23	0.78
Mean Number of Young Fledged/ Nest with Eggs	-	1.46	-

Table 4. Egg, Chick, and Fledging Distribution of Black-legged Kittiwake in 1977 at Kulichkof Island, Chiniak Bay.

Number of Nests Containing:	Reproductive Stages: Eggs Laid	Chicks Hatched	Fledglings
0	33	39	54
1	24	57	64
2	145	112	96
3	8	2	1

Table 5. Reproductive Success of Tufted Puffin in Chiniak Bay 1977.

Reproductive Success	Cliff Island		
	Quadrat ($100M^2$)	Line Transect ($30M^2$)	Combined
Sample Size (nest attempts)	30	12	42
Hatching of Known Eggs	22/25 = 88.0%	9/10 = 90.0%	31/35 = 88.6%
Fledging of Known Chicks	20/22 = 90.9%	-	-
Mean Number of Young Fledged/ Nest Attempt	0.67	-	-
Mean Number of Young Fledged/ Nest with Eggs	0.80	-	-

Table 6. Egg, Chick, and Fledgling Distribution of Tufted Puffin in 1977 at Cliff Island, Chiniak Bay.

	Number of Nests Containing	
Reprod. Stages	0 eggs or chicks	1 egg or chick
Eggs Laid	25 (18/7)	35 (25/10)
Chicks Hatched	29 (21/8)	31 (22/9)
Fledglings	(2$\overline{3}$/–)	($\overline{20}$/–)

Only the quadrat was checked for fledgling. The differences in earlier stages between quadrat and line transect noted respectively in the parentheses.

Table 7. Reproductive Success of Pelagic and Red-faced Cormorant in Chiniak Bay 1977.

	Sample Plots		
	Pel. Cormorant Phenology (1 Island)	Pel. Corm. Productivity (6 Islands)	R. F. Corm. Productivity (5 Islands)
Sample Size (nest attempts)	26	127	57
Hatching of Known Eggs	60/87 = 69.0%	-	-
Fledging of Known Chicks	37/60 = 61.7%	-	-
Mean Number of Young Fledged/Nest Attempt	1.42	1.35	1.91
Mean Number of Young Fledged/Nest with Eggs	1.48	-	-

Table 8. Comparison of Reproductive Success and Data on Pelagic Cormorants at Three Sites in the Northeastern Pacific Ocean.

Study Sites	Cape Peirce 1970 [1]	Chiniak Bay 1977	Mandarte Island 1957-59[1]
Egg-laying	15-24 June	3 June-17 June	26 May-4 Aug
Clutch Size Range	1-5	1-6	1-6
Mean Clutch Size	3.1-3.2	3.5	3.8
Hatching Success	78%	69%	50%
Fledging Success	56%	62%	76%
Productivity	1.33	1.42-1.48[2]	1.97

[1]Data sources are Dick (1975) and Drent et al (1964).

[2]It is unclear whether productivites of Cape Peirce and Mandarte Island are chicks fledged per nest attempt or nests with eggs, but both respective figures at Chiniak Bay fall in between the two other sites.

Table 9. Egg, Chick, and Fledgling Distribution of Pelagic Cormorants on Kulichkof Island, Chiniak Bay 1977.

	Reproductive Stages		
Number of Nests Containing:	Eggs Laid	Chicks Hatched	Fledgling
0	1	6	8
1	0	1	2
2	3	4	11
3	7	9	3
4	15	6	1

Table 10. Reproductive Success of Glaucous-Winged Gull in Chiniak Bay 1977.

Reproductive Success	High Density Zaimka Is. ($766M^2$)	Low Density Cliff & Zaimka ($800M^2$)	Combined
	SAMPLE PLOTS		
Nest Attempts (nests with eggs)	40 (33)	23 (19)	63 (52)
Hatching of Known Eggs	75/87 = 86.2%	47/51 = 92.2%	122/138 = 88.4%
Fledging of Known Chicks	46/75 = 61.3%*	-	-
Mean Number of Young Fledged/ Nest Attempt	1.15*	-	-
Mean Number of Young Fledged/ Nest with Eggs	1.39*	-	-

*This is a minimum figure since some chicks may have moved away from nesting area.

Table 11. Egg, Chick, and Fledgling Distribution of Glaucous-winged Gull in Chiniak Bay 1977

Number of Nests Containing:	Reproductive Stages		
	Eggs Laid	Chicks Hatched	Fledgling
0	11	15	-
1	4	3	-
2	11	16	-
3	36	29	-
4	1	0	-

Table 12. Reproductive Success of Mew Gull in Chiniak Bay 1977.

Reproductive Success	SAMPLE PLOTS - Mary Is.		
	South Colony ($1000\ M^2$)	N.E. Colony ($500\ M^2$)	Combined
Nest Attempts (nests with eggs)	43 (38)	23 (21)	66 (60)
Hatching of Known Eggs	90/104 = 86.5%	42/54 = 77.8%	132/158 = 83.5%
Fledging of Known Chicks	-	-	-
Mean Number of Young Fledged/ Nest Attempt	-	-	199/340 = 0.59*
Mean Number of Young Fledged/ Minimum Number of Nests	-	-	199/200 = 1.0*

*Estimate based on extrapolation from nest density, total colony areas, chick counts and banding near fledging, and percentages of banded chicks in beached bird counts.

Table 13. Egg and Chick Distribution of Mew Gulls in Chiniak Bay 1977

Number of Nests Containing:	Reproductive Stages	
	Eggs Laid	Chicks Hatching
0	6	8
1	5	8
2	13	27
3	41	22
4	1	1

Table 14. Reproductive Success of Arctic and Aleutian Tern in Chiniak Bay 1977.

Reproductive Success	Study Sites Arctic Tern Mary Is.	Aleutian Tern Mary Is.	Aleutian Tern Mainland
Sample Size	97	23	22
Hatching of Known Eggs	181/212 = 85.4%	40/42 = 95.2%	31/39 = 79.4%
Fledging of Known Chicks	-	-	-
Mean Number of Young Fledged/ Nest Attempt	-	-	-
Mean Number of Young Fledged/ Nest with Eggs	less than* 1.53	-	-

*This estimate of the maximum possible productivity comes from subtracting number of chick carcasses found (River Otter predation) from total chicks hatched.

Table 15 Egg and Chick Distributions of Arctic Terns in Chiniak Bay 1977

Number of Nests Containing:	Reproductive Stages: Egg Laying	Reproductive Stages: Chick Hatching
0	1	7
1	8	17
2	60	55
3	28	18

Table 16 Egg and Chick Distributions of Aleutian Terns in Chiniak Bay 1977

Number of Nests Containing:	Reproductive Stages: Egg Stages	Reproductive Stages: Chick Hatching
0	0	3
1	8	12
2	35	28
3	1	1

Table 17. Prey Items Taken by Nine Seabird Species in Chiniak Bay, June - August 1977.

Rissa tridactyla (n=15)

- Sandlance (*Ammodytes hexapterus*)
- Capelin (*Mallotus villosus*)
- Unidentified fish
- Plant material
- Spruce needles

Lunda cirrhata (n=33)

- Sandlance
- Capelin
- Unidentified fish
- Plant material

Uria aalge (n=11)

- Capelin
- Unidentified Gadidae
- Unidentified fish
- Euphausids (*Thysanoessa raschii*)
- Plant material

Larus glaucescens (n=32)

- Capelin
- Unidentified fish
- Fish eggs
- Mussels (*Mytilus edulis*)
- Unidentified Pelecypoda
- Chiton
- Insects (Diptera)
- Plant material

Puffinus tenuirostris (n=3)

- Euphausids (*Thysanoessa* spp.)
- Capelin
- Unidentified fish
- Squid beaks (Cephalopoda)

Fratercula corniculata (n=13)

- Unidentified fish

Sterna paradisaea (n=3)

- Surf Smelt (*Hypomesus pretiosus*)
- Rock Greenling (*Hexagrammos lagacephalus*)
- Decapod

Xema sabini (n=1)

- Unidentified fish

Phalacrocorax pelagicus (n=1)

- Sea Urchin (Echinoidea)

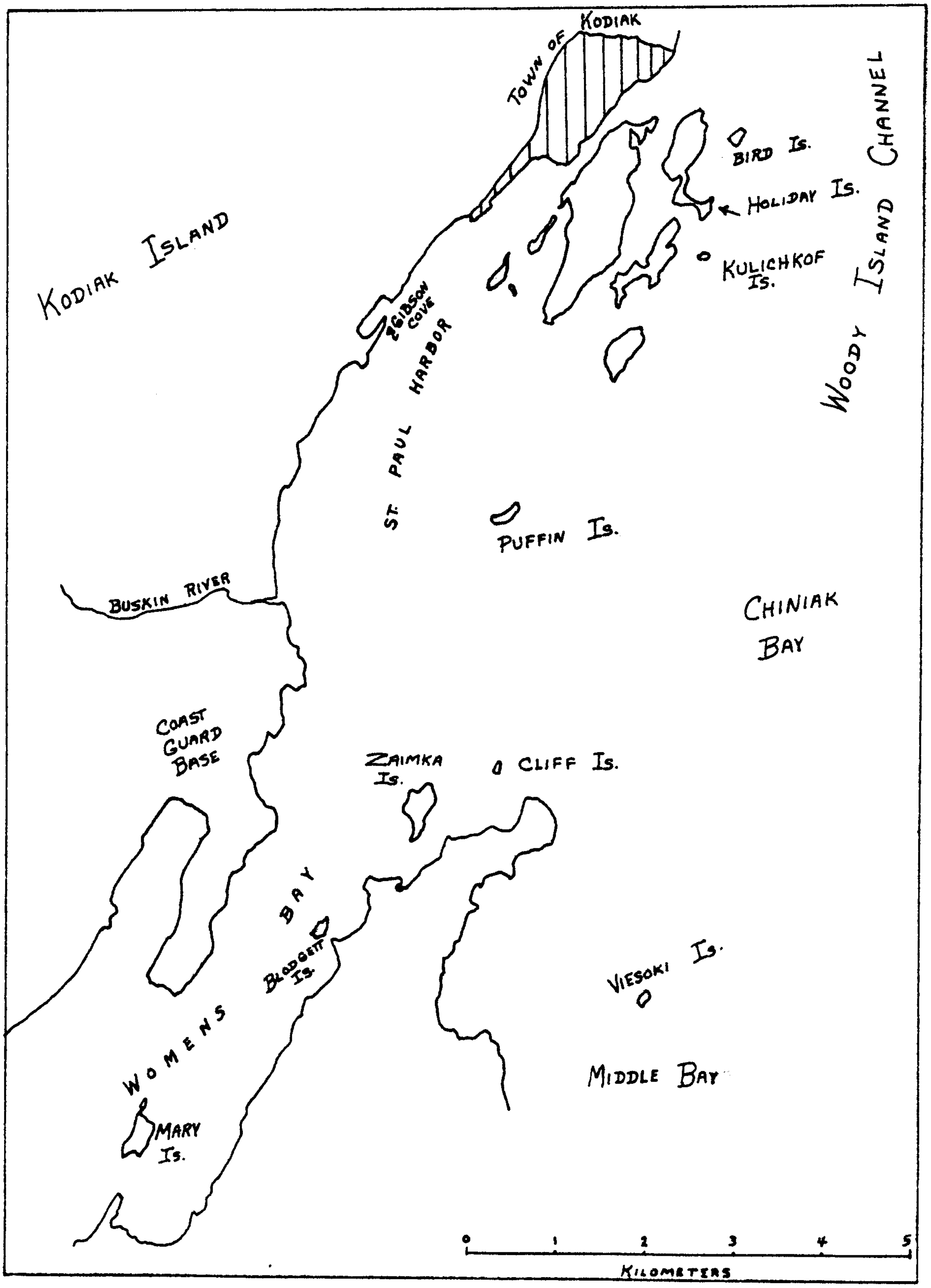

Figure 1. Study Sites in Inner Chiniak Bay.

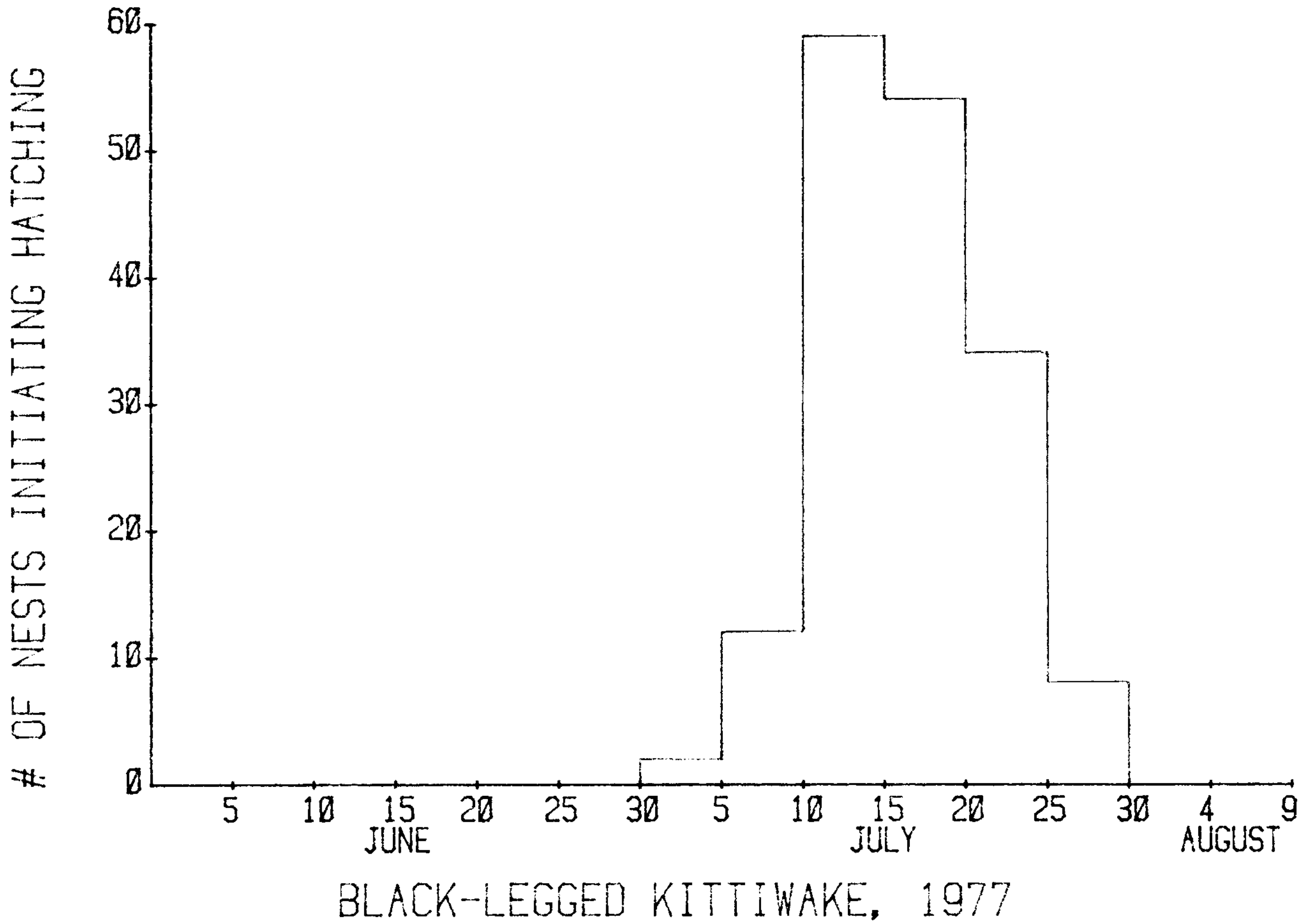

Figure 2. Hatching Phenology of Black-legged Kittiwake in Chiniak Bay 1977.

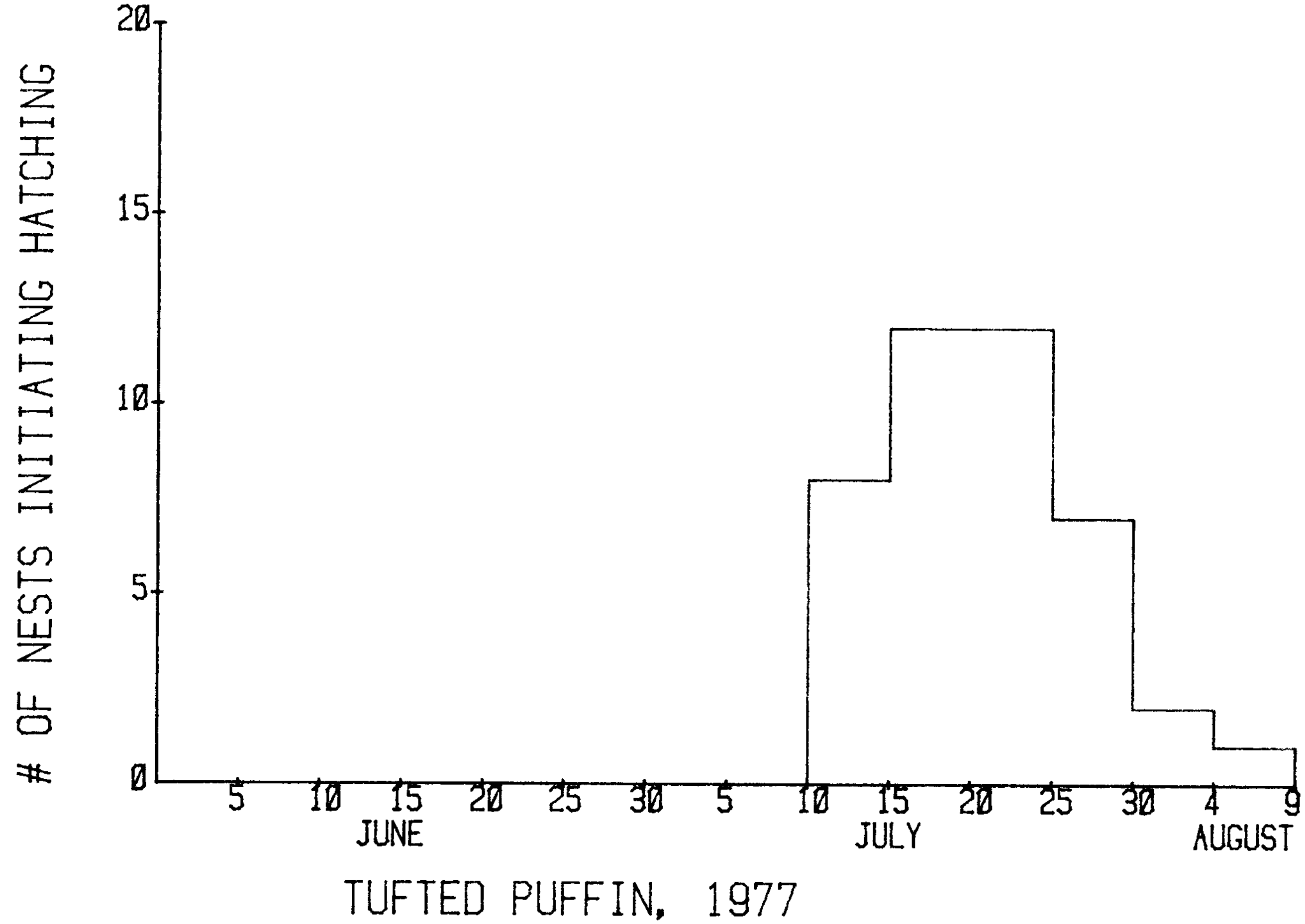

Figure 3. Hatching Phenology of Tufted Puffin in Chiniak Bay 1977.

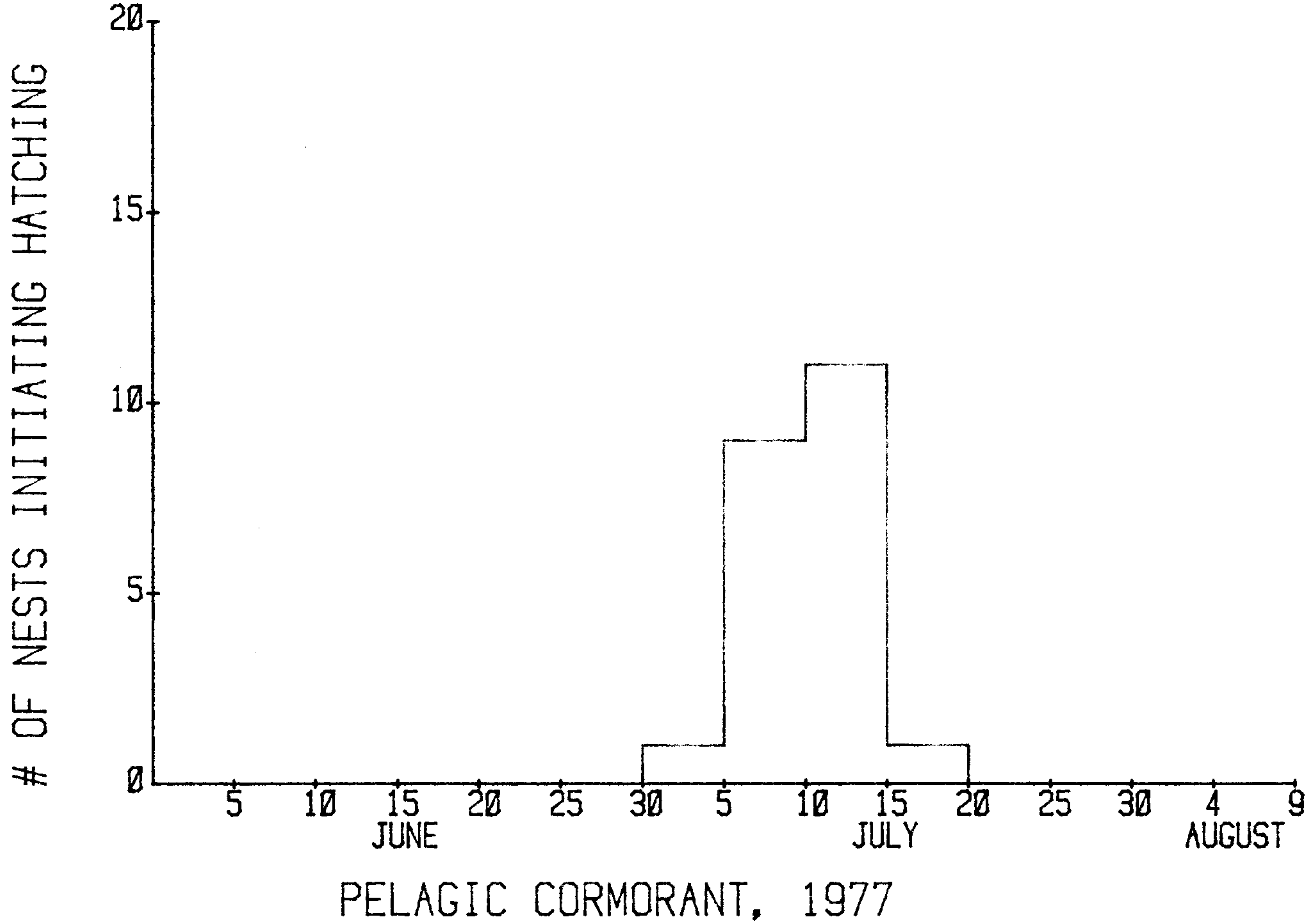

Figure 4. Hatching Phenology of Pelagic Cormorant in Chiniak Bay 1977.

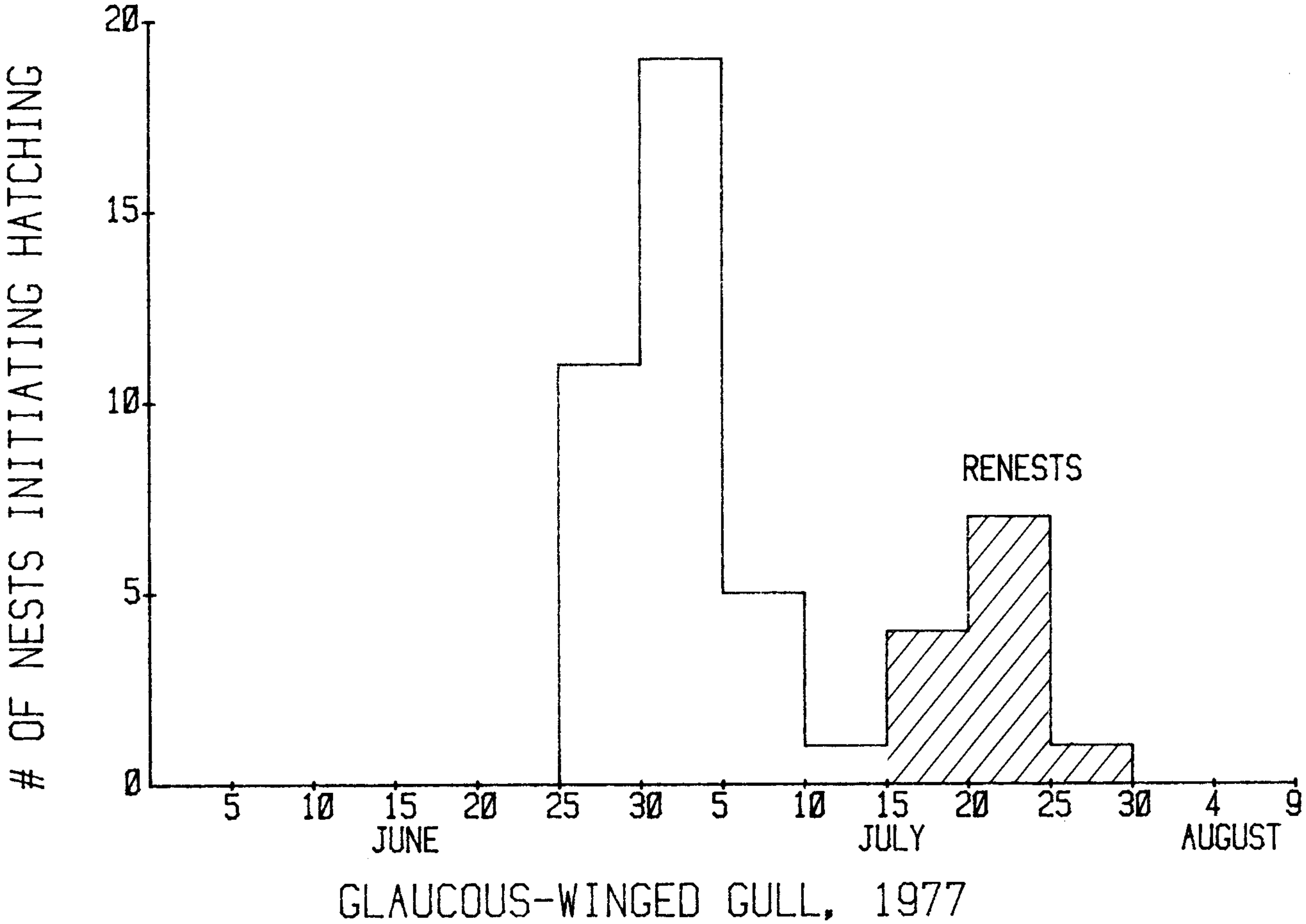

Figure 5. Hatching Phenology of Glaucous-winged Gull in Chiniak Bay 1977.

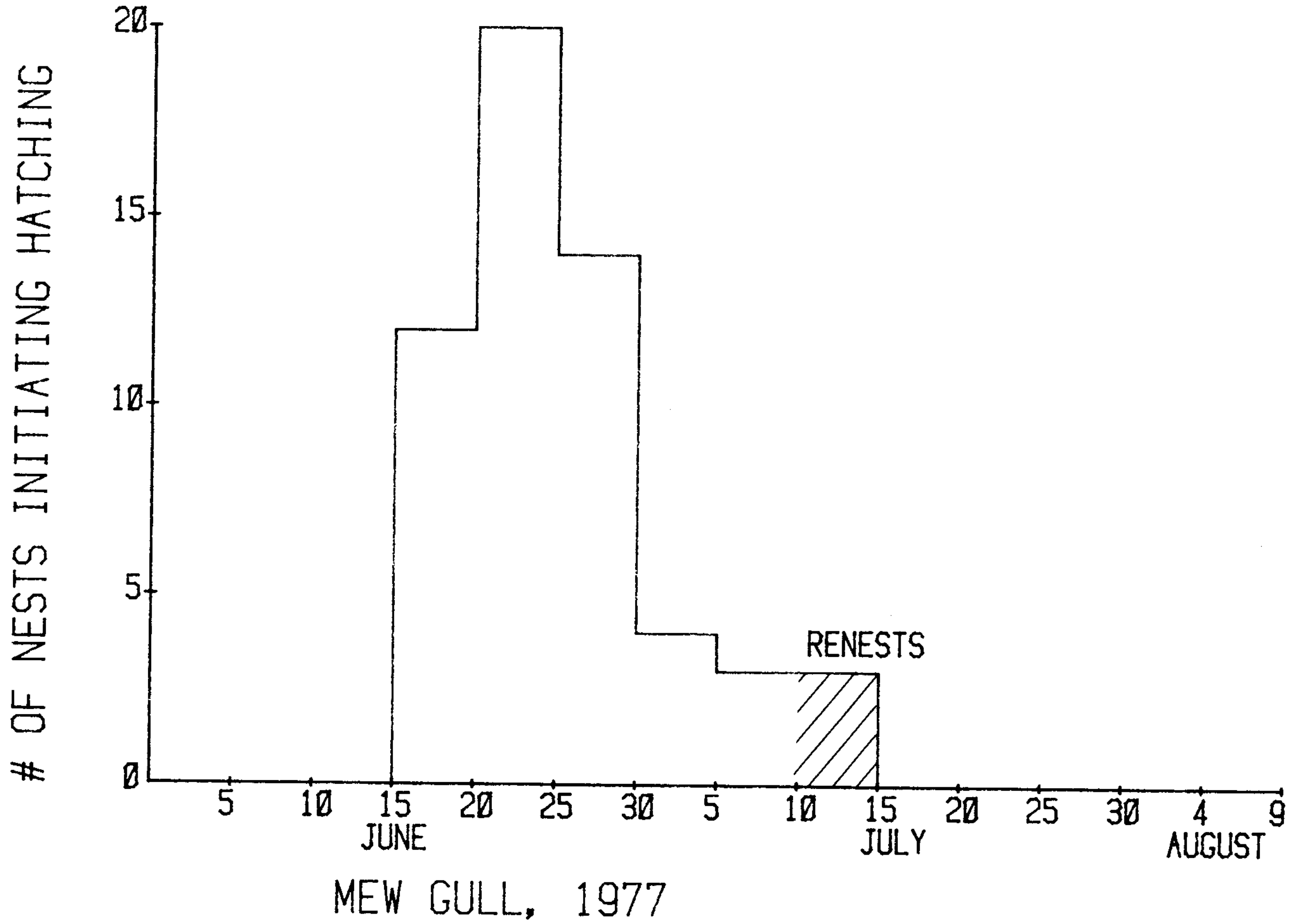

Figure 6. Hatching Phenology of Mew Gull in Chiniak Bay 1977.

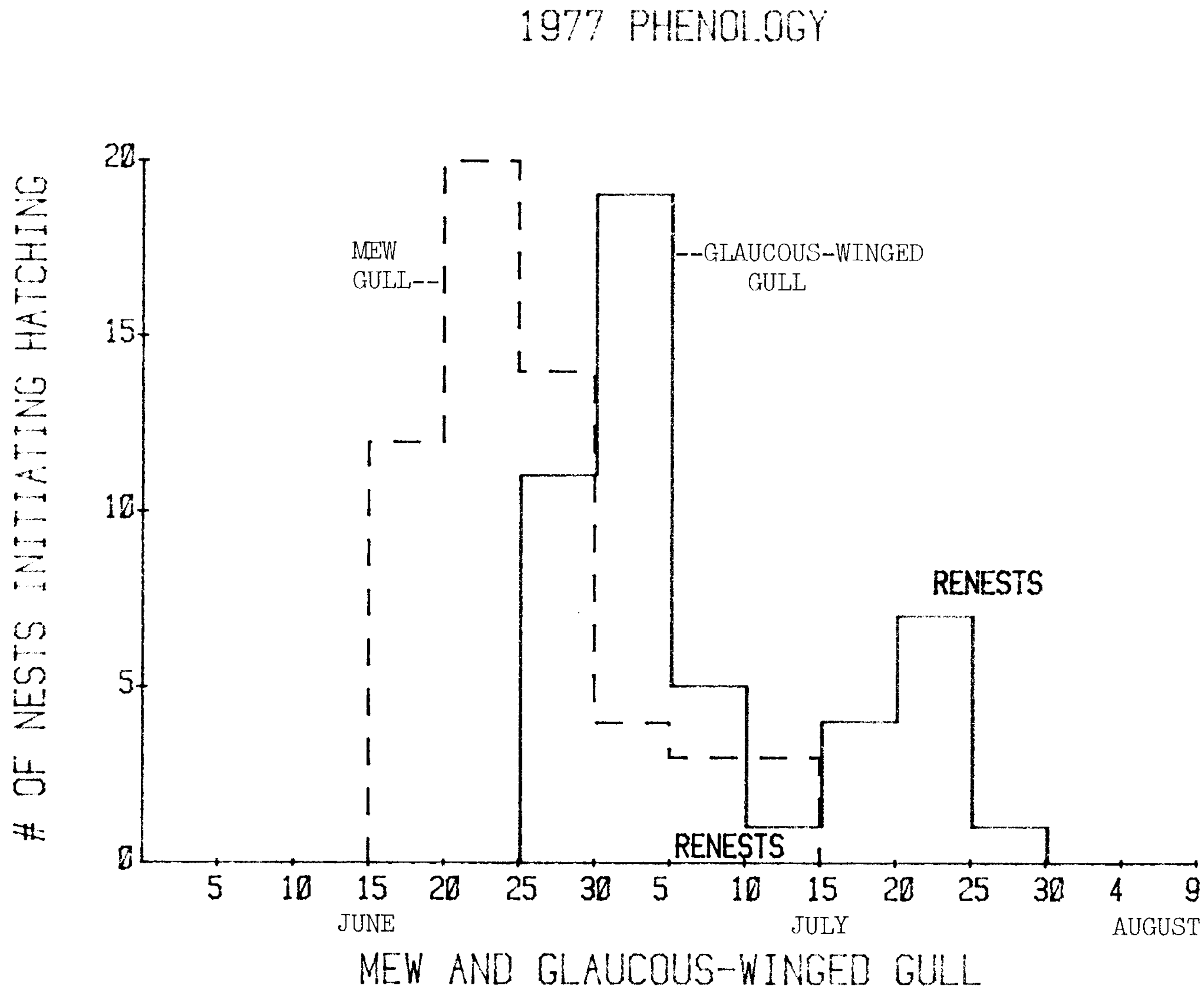

Figure 7. Comparison of Hatching Phenology of Mew and Glaucous-winged Gull in Chiniak Bay 1977.

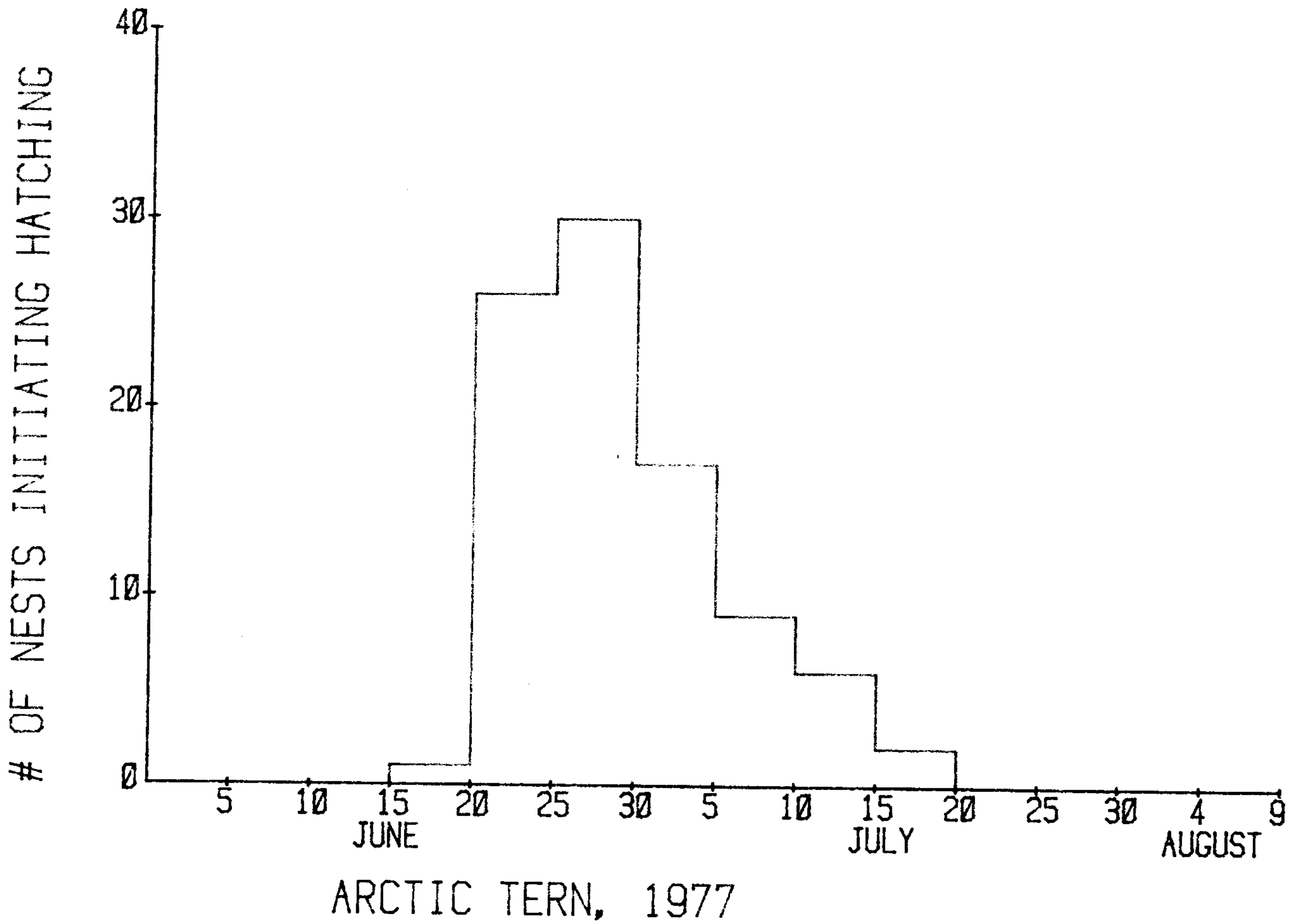

Figure 8. Hatching Phenology of Arctic Tern in Chiniak Bay 1977.

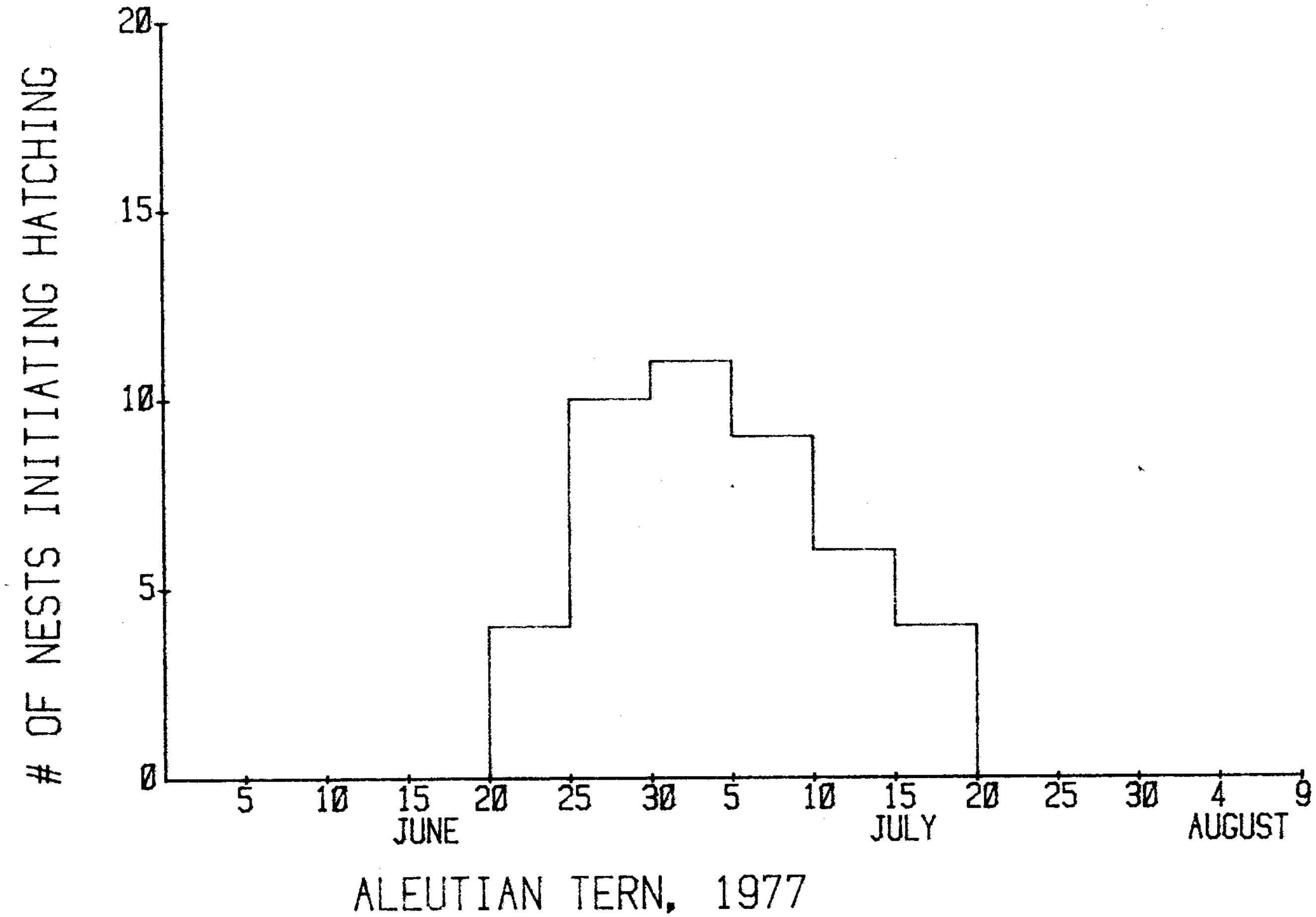

Figure 9. Hatching Phenology of Aleutian Tern in Chiniak Bay 1977.

APPENDIX VI

NOAA-OCSEAP Contract: 01-5-022-2538
Research Unit: 341
Principal Investigators: C. J. Lensink
K. D. Wohl
Report Period: April 1, 1977 to
March 31, 1978

ANNUAL REPORT

DYNAMICS OF MARINE BIRD POPULATIONS ON THE BARREN ISLANDS, ALASKA

by

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U.S. Fish and Wildlife Service
Office of Biological Services - Coastal Ecosystems
800 A Street, Suite 110
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April 1, 1978

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INTRODUCTION

This report summarizes research conducted in the Barren Islands, Alaska, by the Wildlife Science Group, College of Forest Resources, University of Washington. We have not repeated the description of the Barren Islands (Figure 1) found in our annual report of 1976 (Manuwal and Boersma 1976). During the 1977 field season research was allocated in the following manner: Fork-tailed Storm Petrel--Ted and Pamela Simons, Nat and Genie Wheelwright; Pelagic Cormorant--same; Black Oystercatcher--Mike Amaral; Glaucous-winged Gull--Wheelwrights; Black-legged Kittiwake, Common and Thick-billed Murres--Simons and Amaral; Parakeet Auklet, Ancient Murrelet, Horned and Tufted Puffins, and predation--Amaral. The field season extended from May 17 to August 24, 1977.

OBJECTIVES

1. To determine the local distribution, abundance, and nesting requirements of all breeding seabirds.

2. To determine the productivity of as many breeding species as possible.

3. To determine the types and quantities of food consumed by selected seabird species.

4. To evaluate the effect of future oil development on the biology of marine birds breeding on the Barren Islands.

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METHODS

In general, our methods were similar to those discussed in Manuwal and Boersma (1976). Additional detailed description of methods is found in sections on Fork-tailed Storm Petrels and Tufted and Horned Puffins.

RESULTS AND DISCUSSION

FORK-TAILED STORM PETREL

The Fork-tailed Storm Petrel (Oceanodroma furcata) is the northern most in distribution of five species of storm petrels found breeding along the western coast of North America. Due to its nocturnal habits and remote breeding colonies very little is known about its breeding biology and population structure. Aside from a recent study in northern California by Harris (1974) the only published materials on Fork-tailed Petrels are incidental accounts by early researchers, e.g., Bent (1922), Clay (1925), Richardson (1960), and Willet (1914). Despite the apparent abundance and probable importance of this species in marine ecosystems, no methods have yet been devised to estimate population size and structure. Furthermore, little is known of the behavior of Fork-tailed Petrels. These aspects were investigated during the 1977 field season. Studies on the basic breeding biology of this species were continued from the previous season and new investigations into habitat selection and the importance of egg neglect and artificial nest sites were initiated.

Methods

Population Size and Structure

All of the research on Storm Petrels was conducted on East Amatuli Island. This colony is by far the biggest and most important nesting site in the Barren Islands. By locating an isolated subcolony of breeding petrels on East Amatuli, an attempt was made to conduct a mark and recapture exercise to estimate the size of the breeding population. This subcolony, approximately 30 meters in diameter, was located in an area at least 75 meters from the nearest significant concentration of breeding birds. On six evenings throughout the summer a 35-foot mist net was placed across this colony shortly after sunset. Netting continued through the night until activity at the colony had ceased. Netted birds were removed, banded, weighed, scored for brood patch development and released. The degree of brood patch defeathering was scored as follows: 0--totally feathered, 1--partially defeathered; 2--totally defeathered, not vascularized, 3--totally defeathered, vascularized. Recaptures were also weighed, scored, and recorded. To avoid introducing error into the estimate due to methodology, all netting was done in the same location for approximately the same time interval throughout the season.

Activity Cycles

A method was developed to monitor the activity patterns of attending birds. Initially general observations of behavior and activity were made at several locations on East Amatuli to determine what aspects of petrel activity at the colony could be quantified. A subcolony 10 meters square was chosen in June and subsequent observations were made at this location. The vegetation was cleared from this plot and each burrow was marked with a numbered flag. Two poles 2 meters high were placed 10 meters apart at the edges of the plot. The burrows within the plot were checked throughout the summer to determine their status. Observations of activity at this subcolony were made periodically during the season so that trends in activity and behavior patterns could be established. The following activities were recorded:

1. The number of birds flying between two poles 10 meters apart in a one-minute interval.

2. The frequency of aerial calling.

3. The frequency of calling from the ground and from within burrows.

4. The frequency of aerial chases.

5. The frequency of hovering over burrows.

Observations began shortly after sunset and continued until activity at the colony had ceased. Activity was monitored constantly throughout the night and recorded at 10-minute intervals. Observations were made from a blind located adjacent to the subcolony by utilizing a Javelin brand night vision scope. Vocalizations and the interaction of individual birds on the ground, in the air, and within burrows were also recorded.

Behavior

In conjunction with the behavioral observations made during the monitoring of activity cycles, a study of the behavior of individual birds and selected pairs was also undertaken. For this purpose a second blind was placed adjacent to several active burrows in which the occupants could be observed directly. Observations were made directly from the blind when light permitted and at other times by utilizing the night vision scope.

By continuously monitoring a single chick during two one-week intervals during the season, the feeding patterns and load capacities of adults were also determined. Chick weights were obtained from a 100-gram pesola scale. Growth measurements were made in millimeters with a steel caliper.

The significance of parental recognition was examined by switching groups of known-aged chicks in three age categories. Thirty chicks in all were switched. Ten in the 1-5-day class, 10 in the 15-20-day class, and ten over 35 days. Survival and growth of each chick was checked ten days after switching to determine parental response. The location of known age chicks for the switching experiment provides hatching date data for 40 chicks as well as additional information on colony attendance and chick mortality factors.

The weight loss of incubating adults was estimated by weighing several adults over a 12-hour period. A single adult was weighted prior to and following a 36-hour incubation shift.

The incubation and attendance patterns of adults were monitored by using specially designed and constructed event recorders. Five recorders were successfully used in 1977 (Figure 2). The device consisted of two components, a switch tube, and a recording mechanism. The switch tube was placed over the entrance of an active burrow and left for several days to prevent undue disturbance. Then a free-swinging gate which acted as a two-way switch was installed in the tube. This switch activated the recording mechanism consisted of two solenoid-driven pens, a clock-driven recording drum, and a six-volt latern battery. The recording drum made one revolution in 12 hours. Thus by attaching a calibrated strip of paper on the drum each evening it was possible to determine the temporal sequence of attendance at these burrows. By excavating the nest chamber and placing a piece of clear plastic with a removable plywood cover over the chamber, it was possible to observe the interior of the burrow without disturbing its occupant. When an egg was laid in a burrow prepared in this manner, one member of the pair was then marked with orange paint to permit individual identification. Thus, by checking these burrows each evening, recording which individual was present and noting the information provided by the recorders, it was possible to construct the attendance patterns and incubation rhythm of five pairs of petrels. After hatching, the chicks were weighed and measured daily and growth patterns were correlated with attendance data provided by the event recorders.

In addition to the five recorder-monitored burrows, fifteen other burrows in which the nest was visible or which had been modified with windows were also checked daily through the summer. This provided supplementary information on attendance and breeding chronology. In cases where eggs were laid, individuals were color marked and incubation patterns noted. As in the recorder burrows, chick growth data was collected. Chicks were weighed daily on a 100-gram pesola scale while wing and tarsus growth were recorded every other day.

Habitat Selection

A study of habitat selection was undertaken to determine habitat specific densities of breeding petrels and to identify factors related to the habitat and actual nest site which could be correlated with breeding success. Three transects each approximately 350 meters long were set out on compass bearings early in May. These transects intersected all of the major habitat types in which nesting petrels were observed. Transects were divided into quadrats ten meters long and three meters wide and each quadrat was marked with a numbered flag. Transect number 1 extended from the creek at the northeast edge of the valley across a boulder field at the base of the slope and continued up through the empetrum carpet of the steep valley wall to a rock outcrop at approximately 1000 feet. Transect number 2 began in the fellfield at the south end of the valley and extended along the east side of the valley through a large boulder field and terminated in the extensive terraced empetrum below the lake. The third transect extended up the west side of the valley beginning in the low, wet meadow adjacent to the stream through the grassland and boulder fields of the lower slope and terminated above an extensive talus field at approximately 350 feet.

An estimate of burrow occupancy was made in each quadrat by placing toothpick lattices at the mouth of each burrow or cavity and checking for displacement on three separate occasions. Toward the end of the incubation period every cavity within the boundaries of each 10 x 3-meter quadrat was checked to determine whether or not it was being utilized by a nesting pair. Each cavity containing an egg was marked with a numbered flag and left undisturbed for several weeks. These burrows were checked late in the nestling phase to determine hatching success. Finally, the remaining successful burrows were checked late in August to determine nesting success. All chicks were weighed, measured, and banded. Evident sources of mortality were noted. A number of features of the habitat as well as the burrow itself were measured. In each quadrat the following aspects of the habitat were recorded:

1. Slope--measured with an Abney level.

2. Elevation--measured with a Thommen altimeter/barometer.

3. Exposure.

4. Vegetation type.

5. Vegetation height--measured in centimeters at five point in each quadrat.

6. Soil depth--measured as follows: A five-meter-long rope was suspended between two poles down the center of each quadrat. The rope was then lowered until it contacted the ground at a single point. The distance between the rope and the ground was measured at 20-centimeter intervals and the standard deviation of these 25 measurements was calculated as an index of local relief within each quadrat.

8. Substrata--characterized by visual inspection. Boulder size was indicated according to the following classification. Small--less than 1/2 meter in diameter, medium--1/2 to 1 1/2 meters in diameter, large--greater than 1 1/2 meters in diameter.

Correlations between these factors and breeding density along each transect was then determined.

Several aspects of the burrow itself were also measured in an attempt to identify factors associated with breeding success. The following variables were measured on all burrows in which eggs were laid:

1. Burrow depth--measured in centimeters from the entrance to the nest site.

2. Entrance diameter--measured in centimeters.

3. Burrow wetness--burrows were scored on a scale of 0 to 3 according to the following system: 0--totally dry, 2--damp soil, 2--very wet soil, some standing water, 3--flooded.

4. Nest material--scored on a scale of 0 to 3 according to the following system: 0--no nest material, 1--incomplete layer of nest material, 2--complete layer of nest material less than one centimeter thick, 3--complete layer of nest material over one centimeter thick.

Correlations between these factors and breeding success were then determined.

Nest Boxes

The feasibility of utilizing artificial nest boxes to increase breeding densities of storm petrels was examined. Two types of boxes were constructed. Type 2 boxes were totally enclosed, 6-sided boxes, 18 inches long, and 6 inches square. A 2 1/2-inch entrance hole was drilled at ground level on one end and a small hinged door was built into the roof at the rear of the box to allow for inspection of the contents. The other style of box, Type 1, was simply an L-shaped arrangement of two pieces of wood joined to form the roof and entranceway for the nest chamber. A 2 1/2-inch hole also provided the entrance in these boxes. Sixty boxes were constructed, thirty of each style. Thirty boxes were placed within an established colony and thirty were placed in an adjacent area where no petrels were nesting. The L-shaped boxes were sited by digging an open-ended through and inserting the box to provide a roof and entrance, thus creating a burrow formed with soil on four sides and plywood on two sides. The complete nest boxes were dug into the soil and secured with dirt and rocks. Each box was marked with a numbered flag. Toothpick barriers were placed over the entrance of each box and attendance was monitored several times a week throughout the summer. In late August each box was carefully inspected to determine its utilization during the summer.

Results and Discussion

Population Size and Structure

Mist netting at the subcolony took place on six nights from mid-June to early August. Three hundred and twenty birds were banded and a total of four recaptures occurred (Table 1). The mean adult weight and brood patch scores are given in Table 2. Unlike 1976, mean adult weight remained quite stable throughout the season. This may indicate that food resources for storm petrels are variable from season to season and that food may have been slightly more abundant in 1977. Brood patch scores are somewhat surprising in light of the other population data. Mean scores throughout the summer remained very close to 2.0 or totally defeathered. Only three individuals, captured in early June, were scored zero. The implication is that all of the birds attending the colony are indeed breeding. This conclusion conflicts with our interpretation of the mark and recapture and activity cycle data which also reflect population size and composition.

The initial mark and recapture data taken over a one-week interval, June 13 to 20, were in general agreement with our observations of population levels in 1976 and 1977. That is, that large numbers of birds appear to be attending the colony for a short period early in the season after which attendance drops off rather dramatically. The initial population estimate of 1848 birds was considerably higher than our maximum estimate (600 birds) of the number of breeding birds that we would expect to be inhabiting the subcolony. This estimate was obtained by direct inspection of the burrows in the subcolony and extrapolated from maximum breeding densities found during habitat selection studies. Surprisingly our population estimates continued to increase throughout the remainder of the summer. Examination of the activity cycle data and inspection of the subcolony suggest that over the course of the summer several assumptions of the mark and recapture model may be violated. First of all, individuals may learn to avoid the mist net after having been captured. Second, activity cycle data indicate that individuals are apparently emigrating from the colony throughout the summer; and third, inspection of the subcolony in mid-summer revealed that heavy rain storms had destroyed a large proportion of the burrows within the subcolony. Each of these factors would have caused our population estimates to rise.

These results are by no means conclusive. Developing the capacity to make simple estimates of storm petrel population size and composition even within a single breeding colony will require considerable more study. When this data is viewed in conjunction with activity cycle data, several new interpretations emerge and are used to develop a hypothetical model.

<u>Activity Cycles</u>

Activity was grouped into three time periods which represent the pre-egg, incubation, and nestling phases of the breeding season. Data for the pre-egg stage are rough estimates reconstructed from notes and tape recordings from several locations on East Amatuli. Early in the season a suitable location to monitor activity had not yet been located. Nonetheless these estimates are most certainly very conservative and probably represent minimum mean values. In some cases activity such as calling in various contexts was too frequent to quantify precisely during this period. Counts of the number of flying birds, frequency of hovering and aerial chasing were made using the same methods employed in the following sampling periods. All of the information from the incubation and nestling periods was collected from a blind at a 10 x 10-meter sample plot.

Two important interpretations can be made from this information. First of all, there is a consistent decline in the number of birds attending the colony and in the frequency of various behaviors during the course of the breeding season. Figure 3 further illustrates the drop in attendance over the course of the summer and points out the importance of day length on arrival times. Second, the frequency of vocalizations drops to insignificant levels late in the season and two other aspects of behavior, hovering and aerial chasing, virtually disappear. The fact that these behaviors drop out later in the season suggests that they relate to the demands of courtship and pair formation which occur early in the summer. The dramatic drop in colony attendance indicated by the aerial counts correlates well with the initial mark and recapture estimate and our observations that many more birds seem to be attending the colony early in the season than are actually breeding. This conclusion was further reinforced by the fact that we found numerous nonbreeding birds attending the colony late into the season. A number of burrows in our study plots were visited regularly all summer, several of these occasionally contained pairs of adults during the day, others had nests built in them although no eggs were laid.

By combining the information on population size and activity cycles, a hypothetical model can be constructed (Figure 4). Early in the season the population builds to a maximum level. Egg laying has not begun and large numbers of birds attend the colony to undertake courtship activities and select nest sites. Perhaps 50% of these birds are nonbreeders. In early June, point A, egg laying begins and attendance levels drop to pointB since many birds begin incubating and some nonbreeders depart. Breeding failures and the departure of nonbreeders continues to reduce population levels through late July, point C. In late July the remainder of nonbreeders depart and population levels drop to point D. Breeding failures continue to reduce population levels until in late August successful breeders represent approximately 45% of the entire breeding population.

This model is mostly hypothetical at this point but does correlate well with our observations and data for 1977. Considerably more study will be required before firm conclusions can be drawn. Nonetheless, it is essential in developing the capacity to manage seabird populations and monitor impacts upon them that we be able to estimate population levels and identify major classes of individuals within these populations.

Behavior and Breeding Chronology

In late May and early June tremendous numbers of petrels return to the colony each evening to engage in a variety of activities. Dense flocks of flying birds circle the colony throughout the short night. Members of these flocks call continuously in flight, circling low in a zig-zag pattern over the colony apparently in search of a mate or a nest site. During this period birds are often involved in aerial chases. These occur when one or more birds congregate at or above a location on the ground and begin to pursue a single individual in a chaotic flight around the colony. We noticed that chases often followed the attraction of birds to a spot on the ground where a single individual was giving a distinctive call. Two easily identified types of calls were detected. The most common call was a raspy four- or five-syllable call which descended in pitch and volume. The second was a piercing high pitched single-syllable call which was often given five or more times in succession. The four-syllable call was heard in a wide variety of circumstances especially in flight, while the high-pitched call was only given by individuals on the ground or within burrows. The single-syllable high-pitched call is given by individuals observed on the ground which subsequently become involved in aerial chases. Another frequently observed component of social behavior during this period is hovering over burrows. Individuals were often observed circling particular burrows in a figure eight pattern. Frequently as a bird passed over a burrow in the middle of a flight loop, it would pause for one or two seconds to hover above the burrow. This often occurs when a bird inside the burrow is calling, although it is also common over unoccupied burrows.

The significance of these aspects of behavior are difficult to assess but an incident which occurred late in the season provided some clues. Several burrows were monitored daily throghout the summer. Typically, adult petrels regularly visited burrows prior to egg laying. Occasionally during this period both members of the pair would remain in the burrow during the day. Copulation may occur during this time, although it was never observed. Several days prior to egg laying a nest composed of a dry vegetation woven into a loose mat is often built. Within several days of nest building a single egg is laid and incubation begins. In one of our monitored burrows one member of the pair was apparently lost shortly after the egg was laid as it was not observed after the first week of incubation. The other adult which had been color-marked continued to incubate on a regular schedule for several more weeks. It then deserted the nest but returned two weeks later and over the course of several nights it buried the egg below the nest site. This is a seemingly common practice as it was noted at a number of failed nests. This bird returned to the burrow for the next two nights during which it consistently called using the high-pitched single-syllable call. This call was apparently attractive as a number of individuals responded to it by flying past the burrow or hovering over it and giving the more common four-syllable call. On the third night a new bird appeared in the burrow. Both individuals were observed for several hours. Their activity consisted of alternating bouts of overt aggression, calling, and mutual preening. Typically, after resting side by side with its new partner, the original occupant would initiate calling by giving the high-pitched call. Its partner would respond with the four-syllable call and they would then alternate calling, both giving the four-syllable call for up to one minute. Bouts of calling were often followed by mutual preening in which the birds would alternately preen or carefully nibble at the face, head, and nape area of its partner. Preening was occasionally interrupted by outbursts of aggression by the occupant toward its new mate. Both birds remained in the burrow the following day at which time they were collected and sexed by dissection. The original occupant of the burrow was a male and its new partner was a female.

More observations are necessary before any of these points are confirmed. Adult male petrels select and defend a nest site prior to pair formation. The high-pitched call is a sex-specific male vocalization which is used to advertise a nest site and attract a mate. Hovering over burrows is probably associated with pair formation as well as orientation to a nest site itself. Aerial chases may represent courtship behavior or result from conflicts between males and over nest sites.

The nest site appears to represent a valuable resource to breeding petrels and acts as a focal point of activity throughout the breeding season. To examine the intensity of orientation of adults to a particular burrow, an investigation of parental recognition was undertaken. Thirty known-age chicks, ten in each of three age classes were removed from their burrows and exchanged with a chick of the same age. Chicks were weighed and measured prior to switching and again after ten or more days. It seems clear that adults do not have the capacity to identify their own chicks even as late as five weeks into the nestling period (Table 4). This conclusion reinforces the notion that the primary orientation of adults during the breeding season is to the burrow site itself.

Obtaining known-aged chicks for the recognition experiment permitted the tabulation of hatching dates for 40 chicks (Figure 5). Although hatching reached a peak in mid-July, it was asynchronous, extending over six weeks. This pattern may suggest that the food resources required for breeding are available over an extended period during the summer. This factor combined with rather severe and sporadic weather patterns could account for the extended breeding season.

Thus far no field method of sexing petrels has been discovered. The sex specificity of the calls will be determined next season and should it be validated, it would be of considerable value in future research on this species.

Behavior during incubation is somewhat limited. Individuals brood the egg almost constantly, rising occasionally to change position or turn the egg. While on the egg roughly equal amounts of time are spent sleeping, preening, and resting. Adults were often observed to sleep with their heads tucked under their wing. While sleeping, respiration was detectably deliberate and reduced in frequency. This behavior may represent a physiological adaptation to conserve energy during incubation. The only occasions on which incubating adults left the burrow and returned shortly thereafter were as a result of intrusions into the burrow by a strage adult. Several times incubating adults forcibly ejected intruding birds from their burrows and prolonged struggles outside the burrow commonly resulted. On two occasions oil was ejected by one or both birds on their opponent. This is a common habit in petrels when they are disturbed although there are few accounts of its use in intraspecific aggression in the literature.

An examination of behavioral patterns during the incubation or nestling period was conducted by utilizing five event recorders and carefully monitoring the activity of ten pairs of nesting petrels throughout the season (Figures 6-10). Figure 5 represents a typical pattern of attendance. Following egg laying, adults share incubation duties by alternating incubation shifts of from one to five days. In many cases incubation continues uninterrupted from one shift to the next. Numerous exchanges between members of a pair were observed during incubation. The interactions of the pair were similar to those observed during courtship. Communication between the pair was characterized by vocalizations and mutual preening about the face and head. Following the arrival of one member of the pair, both birds would often stand face to face, calling constantly for several minutes using the four-syllable call. Calling was often followed by bouts of mutual preening and billing after which the newly arrived mate would begin incubating and its mate would depart. Frequently incubation was interrupted as adults would depart before being relieved by their mate. Eggs were capable of withstanding considerable periods of cooling while remaining viable. The data from all five recorder monitored pairs is summarized for the incubation period in Table 5. Mean shift length varied from 3.14 days to 1.87 days per adult with an overall mean of 2.54 days. Incubation shifts varied from one to five days with a three-day shift being the most common (Table 6, Figure 11). Adults generally shared equally in incubation although discrepancies of up to 26% of the total incubation period did occur. The total number of days of incubation varied by only four days, ranging from 38-42 days while the total egg stage ranged from 45-57 days. This difference is a function of the number of cold days during the egg stage which ranged from 6-17 days averaging 8.10 days per nest.

In an attempt to determine the energetic costs of incubation, several adults were weighed over incubation spans ranging from 12 to 36 hours. The results are presented in Table 7. Average weight loss of approximately 7% of body weight per day. Assuming an average adult weight of 58 grams during this period, this would amount to an average weight loss of approximately 20% over a three-day incubation shift and 30% over a five-day shift. The latter probably represents a physiological maximum as five-day shifts are very rare.

Prior to hatching, pipped eggs are frequently deserted for several days or longer. This phenomenon may occur as a mechanism to ensure that adults are present in the burrow when hatching takes place. The incubation shifts of the adults also reflect this adaptation. Mean shift length is reduced in the second half of incubation and shorter shifts predominate prior to hatching (Table 6). The observation of an adult and a chick during the hatching process revealed that the presence of an adult during and immediately following hatching may be critical to the survival of the chick. In the case observed the adult actually assisted the chick in emerging from the shell by placing its bill inside the partially opened shell and shaking its head from side to side. When the chick was free of the shell the adult brooded it immediately and continued to do so until the chick's down was dry. Within two hours of hatching the adult began to feed the chick and feeding took place every two to three hours during the three days the chick was brooded. Feeding was often initiated by the chick which would jostle the adult and cheep constantly when it wished to be fed. In response the adult would orient itself at 90° to the chick and allow the chick to feed from its lower mandible and from the back of its throat. The chick fed constantly in this manner often for three or four minutes at a time. Food material regurgitated by the adults consisted of a well digested oil liquid, the components of which were never distinguishable.

The period following hatching is a critical time for petrel chicks during which they are quite dependent on an adult for survival. The majority of chick mortality which we observed in 1977 occurred in the initial phase of the nestling period. The ability of adults to find food and return to the colony during this brief period seems critical to nesting success.

The feeding patterns for five pairs of petrels are represented in Figures 6-10. Attendance and load size are highly variable. Feeding varied from twice in a single night to once in three days. Loads delivered by the individual adults ranged from less than three grams to almost twenty and presumably reflect the variability in the abundance in food resources. When food is available adults are able to deliver tremendous amounts of food to chicks in a single evening which may result in chick weight gains of over 65%. Adults are capable of delivering loads equal to 30% of mean adult body weight during this period.

The observation of a single color-marked pair from a blind permitted us to determine the actual load capabilities and attendance patterns for individual adults. The pair was observed over two one-week intervals, one following hatching in mid-July, the other late in the nestling period in August. Adults share equally in feeding the chick. During the initial period the chick was fed four times by each adult. Adult A averaged 8.5 grams per delivery. Adult B averaged 8.9 grams. During the period in late August the chick was fed three times by each parent. Load sizes increased averaging 13.2 grams for adult A and 14.2 grams for adult B (Figure 12). Chick weight losses were calculated and averaged between 10% and 15% of body weight per day.

The examination of attendance patterns during the incubation and nestling phases gives some insight into the potential foraging range of Fork-tailed Storm Petrels during the breeding season. Fork-tailed Storm Petrels are commonly observed in the open ocean considerable distances from the breeding colonies. It would not be unreasonable to assume that they are capable of traveling 200 kilometers or more in a single day and perhaps even greater distances. The closely related Leach's Storm Petrel (Oceanodroma leucorhoa) is commonly observed over 300 kilometers from its breeding colonies in California (Ainley 1975). Since Fork-tailed Storm Petrels are frequently away from the breeding colony for three or four days at a time, it is likely that their foraging ranges extend for considerable distances from the Barren Islands. Individuals from this colony could theoretically be ranging within a 500-kilometer radius from the island and possibly far greater distances. Thus, it is important in assessing the impact of oil development on this species to consider its vulnerability over a large geographical area surrounding the breeding colony.

Egg Neglect in the Fork-tailed Storm Petrel

Egg neglect occurs regularly in many Procellariiform birds. The embryo of the Fork-tailed Storm Petrel, in particular, can tolerate frequent periods of abandonment during incubation. Of 34 nests in which chicks hatched, the mean number of days of egg neglect was 11.5. Embryos survived intervals of up to 7 days of continuous desertion during which burrow temperatures averaged 10°C. Depending upon the incidence of egg neglect, incubation periods extended from 39 to 68 days ($\overline{x}$ = 50.5 days). The number of days of actual incubation, rather than the length of the incubation period including egg neglect, appears to determine hatching. Increased egg neglect was associated with lower growth rates and higher chick mortality.

Torpor in Chicks

When unattended and unfed during their first week, chicks can fall into torpor. Body temperature becomes almost slightly higher than burrow temperature (11°-13°C), breathing rates decline, and pulse rate decreases. Homeothermy is not fully developed until the age of 3 to 5 days, and even at the age of 27 days the chicks are capable of achieving a partial state of torpidity when temporarily abandoned, with body temperatures as low as 22°C. Adult body temperatures range from 37°C to 39°C.

Asynchrony of Egg Laying and Hatching in the Fork-tailed Storm Petrel

The first egg of the Fork-tailed Storm Petrel was discovered on 23 May. Egg laying thus began a week later in 1977 than during the previous year. This summer, egg laying continued until 21 June, when the last egg was laid. Egg laying was quite constant and asynchronous throughout the first half of the egg-laying period, declining during the second half (Figures 13 and 14).

Consequently, the period of hatching was also extended. In fact, due to differential incidence of egg neglect, which affects incubation time, the hatching period was nearly twice as long as the egg-laying period. The first egg hatched on 3 July. When we left the island on 26 August, one egg had recently pipped and had not yet hatched.

Replacement Clutches

In the event of oil-related egg mortality, we attempted to discover if Fork-tailed Storm Petrels were capable of replacing eggs. Therefore we removed eggs from 36 nests (the eggs were subsequently used in an incubation experiment to determine resistence of the embryo to chiling). Within three to six weeks, eggs were laid in 27 (75%) of the nests. While a small proportion of the newly laid eggs were from new pairs, most of the eggs were shown to be replacement clutches. Previously, replacement clutches were unknown in the Fork-tailed Storm Petrel.

The conditions of this experiment, however, were unusual since the eggs were removed. Typically, if an egg fails to develop, the adults eventually reject it without replacing it. Therefore it is unlikely in the event of an oil spill which caused egg mortality that Fork-tailed Storm Petrels would lay replacement clutches.

Reproductive Success of the Fork-tailed Storm Petrel

In order to estimate reproductive success of the Fork-tailed Storm Petrel, we marked 100 nests near the end of the incubation period and checked them weekly thereafter. Disturbance was minimal since adults were never handled, vegetation was not cleared, and chicks were removed to be weighed only after adults had ceased brooding and were absent. The results were as follows:

	Number	%
Total number of eggs	100	100
Eggs which hatched	84	84
survived	58	58
died	26	26
Eggs which did not hatch	16	16
infertile	1	1
abandoned, fertile	8	8
ejected from the nest by parents	7	7
Total hatching success		84
Total reproductive success		58
Chick mortality		31

Habitat Selection

The results of the study on habitat selection and productivity are presented in Table 8 and Tables 9-11 (in Appendix). In Table 8 cavity utilization and reproductive success in each transect are tabulated. Approximately 75% of the cavities checked were entered early in the season and 68% of those eventually had eggs laid in them. Overall hatching success is estimated at 60% for 1977, somewhat higher than the 53% estimate in 1976. Estimates of reproductive success were calculated on the basis of the number of chicks over two weeks old surviving at the time of our departure in late Augsut. Overall nesting success in 1977 was estimated at 44%. It is important to note that estimates of success varied by 23% ranging between 31% and 54% in the three areas examined. This variability can be attributed to differences in the severity of flooding which was a principle cause of nesting failures in 1977.

Inspection of the data relating habitat characteristics with nesting density reveals that several key factors correlate well with the observed distributin of nest sites. Nesting habitat is created as a result of the topography of the island and the geologic processes acting upon it. Although Storm Petrels were observed nesting in a variety of habitat types throughout the island, over 80% of the breeding birds encountered on our transects were found in habitats created as a result of four primary factors. These factors are the position on and steepness of the slope, substrata, soil depth, and local relief. Nesting densities are highest along the base of slopes where talus and boulders of adequate size accumulate to provide high levels of local relief. At higher elevations soil and talus do not accumulate, local relief is minimal and few suitable nesting cavities exist. On the valley floor soil accumulation is maximal and local relief is low here as well. Storm Petrels are utilizing a rather narrow band of habitat which we perceive as areas of high local relief along the base of certain slopes. Relief values on a per-burrow basis average at least two times higher than the average value for unoccupied quadrats.

Factors related to the burrow itself were contrasted for successful and unsuccessful burrows within each transect. Entrance diameter and depth showed little correlation with success and the amount of nest material showed a slight correlation. The most obvious factor related to success was the wetness of the burrow. Average wetness scores for unsuccessful burrows were over two and one-half times higher than those for successful burrows. Data for known sources of mortality reveal that flooding was a major cause of mortality in 1977. Descriptive information from all of the burrows monitored indicates that burrows containing a rock ceiling or overhand were highly successful. The presence of an impermeable covering which apparently protected nestlings from direct exposure to rain was an important component of nestling success in 1977.

By mapping habitat specific densities and using estimates obtained through the mark and recapture exercise, accurate estimates of population size throughout the season can be calculated. These estimates are contingent upon the availability of adequate large-scale aerial photos.

Nest Boxes

Boxes placed within an established colony, area two, were visited more frequently than those outside an established colony, area one (Figure 15). It will be important to continue to monitor the utilization of these boxes in the future as it will provide some indication of the rate at which new nesting areas are colonized. Storm petrels appear to be opportunistic in their use of nest sites and we found them nesting in virtually every habitat type on the island including the rubble of a mudslide which had occurred in 1976. It seems that all that is required is a cavity of suitable proportions. Petrels were found nesting in isolated locations over 100 meters from their nearest neighbor with no apparent reduction in breeding success.

Ninety percent of the boxes in area two were entered over the season in contrast to twenty-seven percent in area one (Table 12). A total of eight boxes all in area two had nests built in. In spite of the fact that the boxes were not put out until after the initiation of egg laying, one box was used by a breeding pair in 1977. A chick hatched in this box in late July and was thriving when we departed at the end of August. No discrimination was observed between the two types of nest boxes which were tested.

These results are encouraging and it seems probable that many more boxes will be used by breeding pairs next season. It is evident that nest boxes can be used to increase the density of breeding birds within established colonies and they may be valuable in the future management of this species.

Petroleum Experiments with Storm Petrels

Because of their mode of foraging, Fork-tailed Storm Petrels would be highly likely to be affected by an oil spill. Since they are attracted to and feed on oil from whales and seals, it is conceivable that they come into contact with crude oil slicks. Petrels settling on the water near an oil slick could absorb oil in their breast feathers which they would then transfer to their egg during incubation.

In order to assess the effect of crude oil on the surface of the eggs of Fork-tailed Storm Petrels, we applied c. 0.5 ml of North Slope crude oil (ARCO) to approximately one-third of the surface of 10 eggs early in the incubation period. The nests were not disturbed thereafter except to ascertain if the egg had been abandoned. After 60 days the eggs were opened. Three of the eggs had been ejected from the nests, presumably undeveloped. Six had discolored shells and showed no sign of development of the embryo. The tenth egg apparently had been replaced after rejection of the oiled egg since the shell was not discolored and the embryo had developed.

Surface application of crude oil on eggs of the Fork-tailed Storm Petrel, then, appears to disrupt normal development of the embryo, probably by interfering with normal gas exchange or by leaching toxic hydrocarbons through the shell.

The effects of ingestion of oil (by feeding on affected organisms, for example) was not examined in this study, but Grau et al. (1977) showed in the case of Japanese Quail that it could reduce hatchability of eggs.

PELAGIC CORMORANTS

Pelagic Cormorants were observed breeding on East and West Amatuli, Ushagat, Sugarloaf, and Nord Islands. The largest colony was located on the southwest headland of West Amatuli Island and it contained an estimated 1,000 pairs. This colony also contained a small number of Red Faced Cormorants although relative numbers of each species were not obtained. A smaller colony of 75 pairs of Pelagic Cormorants located 100 meters north of East Amatuli Cove was monitored during the season. The peculiar feature of both of these colonies is that both were much smaller in 1976. Cormorants appear to change their nesting locations periodically and this may make long-term analysis of population trends difficult in this area.

Sixty-three Pelagic Cormorant nests were monitored on six occasions throughout the summer. Breeding chronology and success is illustrated in Figures 16-17. Egg laying began about June 1 and continued through mid-July. Hatching was initiated around June 25 and continued into early August. The first fledglings were noticed on the water on August 20.

Major sources of chick mortality appear to be starvation, falls from the nest, landslides, and predation by river otters. While at the colony on July 19 we observed an otter emerge from the water and eat three cormorant chicks and two eggs in a matter of several minutes. Incidence of otter predation was noted on nesting cormorants and nests are frequently washed from the cliff face. Approximately 25% of the nests at the large colony on West Amatuli were destroyed by heavy rains in mid-August.

Twenty-eight nestlings were banded and weight data was obtained on three occasions. Weight data is presented in Table 13.

Our final visit to the colony on August 11 demonstrated the adverse effect of human disturbance on cormorants late in the season. The nearly full grown chicks became extremely agitated by our presence and several fell from their nests attempting to escape. Others ran uphill away from the nesting ledges and disappeared into the adjacent vegetation. To prevent further disturbance we remained at a distance from the colony and consequently our final estimate of breeding success (Table 14) is based on a reduced sample of ten nests. Human disturbance of cormorant colonies prior to fledging should be kept to a minimum as it may substantially reduce breeding success.

BLACK OYSTERCATCHER

Between 15 and 20 breeding pairs of Black Oystercatchers occur in the Barrens during the summer months. Three nests on East Amatuli and one nest on West Amatuli Island were monitored in 1977. Two of the nests were located in gravel high on the beach; the other two nests were located about 10 m above sea level on outcrops of rock. All nests were in close proximity to exposed rocks in intertidal areas.

Egg laying extended from May 20 to June 2 and all four nests contained 3 eggs. Hatching occurred from June 16-27 and in one nest the incubation period lasted 26 days. At hatching, nestlings weighed 27 and 36 g, respectively, mean 32 g (n = 6).

One adult and three nestlings were color banded on East Amatuli Island. Feeding frequency and nestling diet was observed during two 12-hour watches with a spotting scope from a distance of 30 m. Although this data has not yet been analyzed, some results were immediately obvious: both adults take an active part in feeding the nestlings, the three chicks were not fed equally, and more than 75 percent of the nestling diet consisted of limpets.

Table 15 summarizes breeding success for the four nests monitored. One nestling was known to have been killed by a River Otter. Figure 17A shows the rate of growth of three oystercatcher nestlings on East Amatuli Island. By age 25-30 days, the nestlings are extremely ambulatory. At 33 days of age they left the vicinity of the nest and were soon capable of flight.

GLAUCOUS-WINGED GULL

At least four Glaucous-winged Gull (Larus glaucescens) colonies are known from East Amatuli Island. The largest covers the southwestern peak at an elevation of approximately 450 m. Another colony, consisting of about 35 pairs, is found along a ridge on the northeastern side of the island. Smaller coonies have been established on the south-central slope and near the lighthouse.

The gulls, although present by 21 may, did not begin to lay eggs until shortly after 27 May. Nests from the previous year were not reused; instead new nests were constructed. In contrast to observations from 1976, all clutches had been completed by 19 June in the largest colony. Nests were spaced from 2 to 20 m apart. Angelica and Festuca sp. are the dominant vegetation types.

Food samples located in the colonies reflected the catholic tastes of the Glaucous-winged Gull. They included mussels, limpets, squid, sandlance, Pacific cod, capelin, and remains of larger fish. Petrel remains were found in several castings.

Tables 16 and 17 present estimates of reproductive success in 1977 and records of breeding phenology.

BLACK-LEGGED KITTIWAKES

Forty-nine Black-Legged Kittiwake nests were monitored on three occasions in 1977. This colony on the south side of East Amatuli was the same colony visited in 1976. Breeding chronology and success are illustrated in Figure 18. Egg laying began in early June and the average clutch size was 1.76 eggs per nest. Hatching began the first week in July. Hatching success is calculated at 83 percent for 86 eggs monitoed. Most nestlings were near fledging by the third week in August. Reproductive success up to fledging was calculated as 51 percent (Table 18). This estimate is probably low as some chicks had fledged prior to August 15 when it was calculated.

Reproductive success prior to fledging was quite high for Kittiwakes in 1977. Starvation and storm related mortality appear to have been the primary causes of reproductive failures in the Barren Islands. Nestlings appeared in excellent condition prior to fledging but large numbers of dead fledglings were noted on the water following a period of bad weather in mid-August. Weights and measurements of 15 fledgling found dead on August 15 are presented in Table 19. Woller (1977) gives 390 grams as mean adult weight in Kittiwakes. The mean weight of these dead fledglings was 369 grams which may indicate that mortality was due to difficulty in finding food. Severe weather during this period is probably responsible for this difficulty and may be a critical factor influencing breeding success in this species.

We estimate that there are 8,000 pairs of Kittiwakes on East Amatuli Island and another 1150 pairs on East Amatuli Light rock.

THE BREEDING BIOLOGY OF TUFTED AND HORNED PUFFINS

The Tufted Puffin (Lunda cirrhata) and Horned Puffin (Fratercula corniculata) are two of nine species of alcids breeding in the Barren Islands. Tufted and Horned Puffins occur on all of the seven named islands in the group. Although the Fork-tailed Storm Petrel is probably the most numerous of the breeding birds on the islands, the Tufted Puffin is probably the most important in terms of total biomass.

The objectives of this study were as follows: to (1) determine the number and distribution of puffins breeding in the Barren Islands, (2) outline their basic breeding biologies, (3) determine nestling diet, (4) estimate overall breeding success, and (5) identify certain behaviors or aspects of their reproductive ecologies that would help assess the vulnerability of these species to oil development in Alaskan waters. The following discussion synthesizes data collected May 14 to September 6, 1976, and June 13 to August 26, 1977.

Methods

With the exception of Carl and Nord, the Barren Islands were each circumnavigated and traversed several times in 1976 and 1977. For most of the islands population estimates for Tufted Puffins are based on actual burrow counts from land and boat, and counts of birds during hours of peak colony attendance.

For particular colonies on East Amatuli Island, numerous seawatch data assisted in making crude population estimates. To examine the density of Tufted Puffins nesting in different habitats on East Amatuli, four major colony types were differentiated. A 10 x 10 m quadrat was randomly designated within each of the areas; four to six quadrats were sampled within each habitat type at different locations and altitudes on the island. We obtained information on the physical, vegetative, and edaphic characteristics for each of the quadrats. Slope was measured with a Silva hand compass and an Abney level. Soil depth was approximated by randomly inserting a wire rod 20 times into the substrate and averaging. We estimated burrow density by traversing the colony and by counting the number of burrows in the quadrats. Aerial photos and a USGS topographic map were used to estimate the area of each habitat type on the island. The percentage of occupied burrows was calculated and used to adjust the final estimate.

Census of Horned Puffins presents special problems, as nest sites are hidden in crevices or beneath rocks. Horned Puffin population estimates were made by direct counts at peak colony attendance times for small colonies and by observing the percentage of Horned Puffins in offshore rafts, in flight, and on the cliffs for large mixed species colonies.

Egg-laying

Although observations were made of puffin colonies on West Amatuli, Sud, and Sugarloaf Islands, the studies described herein were conducted entirely on East Amatuli Island (Figure 19). In 1976 85 Tufted Puffin burrows in colony 1 were monitored for egg-laying activity. Egg checks were made at 5-day intervals until an egg was found. Burrows greater than 60 cm in length were accessed and the opening carefully covered with wood. Approximately 33% and 45% of the burrows required excavation and covers in 1976 and 1977, respectively.

In 1977 we did not visit colony 1 until hatching time was near (July 10). A total of 100 burrows were monitored. Egg-laying for 1977 was calculated by subtracting the known incubation period of 45 days from the day of hatching of known age chicks.

Egg-laying in Horned Puffins was monitored in 14 nests in 1976 and 20 nests in 1977. Egg checks were made every 3 days; when an egg was found, the nest site was not revisited until hatching was suspect (38 days later).

Fresh egg weights were determined using a 100- or 300-gram Pesola scale. Egg dimensions were measured with Venier metric calipers.

Incubation. The laying-hatching interval of 8 Horned Puffins eggs was observed in colony A. A Yellow Springs recording thermometer was used to measure surface brood patch temperature. A banjo probe was held firmly against the brood patch for 10 minutes and the highest value recorded. Banjo probes were also taped to a Tufted and Horned Puffin egg. The temperature of the attended (and unattended) egg was recorded without disturbing the incubating bird. Body temperatures of adult and nestling puffins were measured by sliding a thermocouple down the esophagus and recording the maximum value after 5 minutes.

Growth rate. The growth and development of puffin nestlings was monitored by visiting the nest site at 4- to 5-day intervals. All chicks were weighed between 0900-1400 hours with a 100-, 300-, 500-, or 1000-gram capacity Pesola scale. Culmen and diagonal tarsus were measured with Venier metric calipers; wing length was measured along an unflattened right wing. We banded nestlings at 20-25 days of age with United States Fish and Wildlife Service aluminum bands #5 and blue young-of-the-year pigeon bands #6.

Analysis of growth was made by comparing logistic curves fitted to the weight data. Weights of chicks of unknown age were interpolated from these curves. Logistic curves and their parameters were obtained by the graphical method described by Ricklefs (1967, 1968).

Nestling food. To examine food species composition, seasonal variation, and weight, we collected bill loads of fish destined for puffin nestlings. The most effective method was to place several large mist nets (3 cm mesh) across a Tufted Puffin colony and wait for adults to return. After becoming entangled in the net, most puffins dropped their fish and flew off. Many adult puffins were captured by this method and were weighted, measured, and banded before release. We caution the use of this procedure at a colony where growth rates or behavior is being monitored because of possible desertions. Occasionally, fish were found lying about the colony or at the burrow or crevice entrance.

Due to the nature of their nesting crevices, Horned Puffins could not be readily approached or mist netted. Some food samples were found outside or below the nesting crevices. Other samples were collected by startling the incoming adult as it approached the nest site with fish.

Fish samples were weighed to the nearest 0.5 gram with a 30- or 50-gram capacity Pesola scale. Total length in mm was recorded and representative samples were preserved in formalin. Mike Amaral keyed the fish samples using Hart (1973). Verification of species identification was made by Dr. Arthur Welander (Taxonomist, College of Fisheries, University of Washington) and Colin Harris (Fisheries Research Institute, University of Washington). Partial bill loads are treated separately in the analysis. Most samples were collected between 1200-1800 hours; there was no indication that prey species composition or weight per load varied throughout the day. Attempts at cleptoparasitism by Glaucous-winged Gulls were observed ancillary to the collection of bill loads.

Results

Population censusing. Tufted Puffins are the most numerous of all the alcids breeding in the Barren Islands. Approximately 95,300 pairs of Tufted Puffins and 6,510 pairs of Horned Puffins inhabit the Barrens during the spring and summer months (Table 20). These population estimates combine results from numerous surveys in 1976 and 1977. Estimates from Bailey's original census in July 1975 are included for comparison.

The largest concentration of puffins in the Barrens occurs on East Amatuli. The south-facing maritime slopes of this elongate island provide nesting habitat for an estimated 25,000 pairs of Tufted Puffins and 3,000 pairs of Horned Puffins. In total, I estimate that 46,500 pairs of Tufted Puffins and 5,035 pairs of Horned Puffins occur on East Amatuli Island during the breeding season (May-September; Figure 20).

Arrival and pre-egg-laying activity. Tufted Puffins were already present in the waters around the Barren Islands at our arrival on May 14, 1976, and May 20, 1977. The first sighting of Horned Puffins in the vicinity of Wast Amatuli Island occurred on May 20 and May 21, 1976 and 1977, respectively. The number of puffins rafting offshore increased steadily for the next several days. For both puffin species visitation of nest sites generally occurs about one week after their return to the waters around the colony.

During this early land-orientation period, activity consists of flying by the colony, often making several passes, then resettling within rafted puffins 0.2-0.5 km offshore. These offshore rafts or "staging flocks" occur in distinct areas of water below the cliffs and are composed of many hundreds to thousands of birds. From mid-May to mid-June, puffins in these rafts are engaged in courtship and copulatory behaviors (Figure 21). The mean duration of 10 Tufted Puffin copulations was 48 seconds (range 15-155 sec) and 35 seconds for 4 Horned Puffin copulations (range 25-40 sec).

On several occasions during this period we have seen rafts of puffins southeast of East Amatuli numbering 15-20,000 birds. This figure represents 20 percent of the island's entire puffin population. Clearly, this staging activity increases the vulnerability of puffins to surface oil pollution during the pre-egg period.

Colony attendance prior to egg-laying is sporadic. Unquantified observations on East Amatuli in 1976 and 1977 suggest a 3- to 5-day "on-off" attendance pattern which may be explained in terms of energetics. Puffins do not appear to be feeding while engaged in staging flock behaviors. Hence, the energy expensive activities such as passing flights, courtship, copulation, nest-site selection, nest building, territory defense, and egg formation in females are a substantial cost in energy used. In addition, food may be distant or sparsely distributed early in the breeding season, thus attributing to a 3- to 5-day fast while at the breeding colonies followed by a similar time spent foraging at sea.

Habitat preference. Horned and Tufted Puffins occur sympatrically in about half their breeding ranges. However, their population numbers on areas of sympatry vary greatly, suggesting that competition at some level is operating (Sealy 1973a). Bedard (1969b) contends that the selection of different nesting habitat is one means by which sympatric species of alcids coexist. Horned Puffins are principally rock-crevice nesters (Stejneger 1885; Swartz 1966; Kenyon and Brooks 1960; Klein 1959) while Tufted Puffins prefer burrow nest sites in grassy slopes (Dawson 1909, 1913; Sealy 1973a; Cody 1973).

On East Amatuli Island puffins occupy nest sites from 5 m above sea level to the top of Puffin Peak, 469 m. Tufted Puffin colonies exist on nearly all sea-facing slopes around the island. Although most Tufted Puffins excavate burrows in areas of suitable soil accumulation (>30 cm), about 500-1000 pairs, or 1%-2% of the population utilize rock crevices. With only two exceptions, all Horned Puffin nesting situations that I observed in the Barren Islands (>200 pairs) were in natural rock crevices. Unlike Tufted Puffins which occupy slopes from 12 m to the summit, Horned Puffins nest only in crevices at or below the cliff edge and are not encountered above 200 m. No dense colonies of Horned Puffins occur on East Amatuli. Instead, this species is thinly distributed about the periphery of the island either in cliffs or in rocky outcrops in Tufted Puffin colonies.

We made a general survey of the island to determine the different habitat types in which Tufted Puffins were nesting. Four colony types are recognized and various environmental parameters were measured in each of the 20 quadrats sampled. A representative sample of this data is presented in Table 21 and is discussed below:

1. Steep sea-facing slopes (>45°). Most puffins on East Amatuli nest in this habitat type. Average burrow density for six 10-m sample quadrats is 0.48 burrows per m^2.

2. Gradual slope (<45°). This habitat type supports only low densities of Tufted Puffin burrows. Average burrow density for five 10-m sample quadrats is 0.18 burrows per m^2.

3. Cliff edges (areas adjacent to 90° slopes). Soil at cliff edges supports high densities of Tufted Puffins. Density decreases with distance from the edge and varies in relation to the slope of the terrain. Average density for four quadrats is 0.44 burrows per m^2.

4. Rock crevices or beneath talus. At two different locations on East Amatuli, Tufted Puffins nest beneath talus or in crevices between boulders. In four quadrats the average density is 0.45 burrows per m^2. Although the density of puffins nesting in crevices is high, the relative scarcity of this habitat type reduces its overall importance.

Our observations on East Amatuli suggest that, as in the Common Puffin (Nettleship 1972), distance from cliff edge and angle of slope of the terrain are the two most important variables influencing burrow density. Soil depth, topographic relief, and vegetation may also to a lesser extent influence nesting distribution.

Egg laying. For Tufted Puffins the interval between first arrival at colony and first egg laying was at least two weeks in 1976. For Horned Puffins the arrival-first egg interval was 26 days in 1976 and 23 days in 1977.

Tufted and Horned Puffins lay a single, creamy-white egg which is about 12 percent and 12.5 percent of their adult body weight, respectively. Average weights and dimensions of puffin eggs are presented in Table 22.

The Tufted Puffins in study colony 1 exhibited both synchrony and constancy of egg laying in 1976-1977 (Figure 22). For Horned Puffins the egg-laying period was also similar for the two years--the major difference being a slightly extended egg-laying period in 1977 (Figure 22).

Incubation. From observations of a pair of Horned Puffins that nested within 10 m of the blind, we confirmed that as in most species which lack sexual diamorphism, both sexes share the incubation duties. Horned Puffins appeared to exchange incubation duties in the early evening (1730-1830 hours) when maximum numbers of birds were gathered on colony.

Observations of three pairs of marked Tufted Puffins confirmed that both sexes share the incubation duties in this species as well. In general incubation shifts were short with exchanges taking place in early morning and early evening.

Both sexes of Tufted and Horned Puffins develop two lateral, bare vascularized brood patches during the breeding season. Temperatures of fully developed brood patches are compared to body and egg temperatures in incubating puffins (Table 23).

The difference between the temperature of attended Tufted and Horned Puffin eggs is probably due to the orientation of the banjo probe on the egg. Both eggs were successfully incubated to hatching.

In order to examine the percent of egg weight loss during incubation, and the behavior of newly hatched puffin chicks, five Tufted Puffin eggs were collected on June 15 and artificially incubated by a Bantam hen. Egg temperatures were recorded daily and egg weight was recorded at 2-day intervals. The brood patch temperature of the chicken ranged from 38.5 to 40.0°C and compared closely with brood temperatures of Tufted Puffins in my sample. Attended egg temperatures ranged from 31.0 to 40.2°C, mean 36.2°C. The chicken successfully hatched one nestling, two others died while pipping, and two eggs proved infertile. Table 24 presents the percent of weight loss for the 5 eggs during incubation. Since the eggs were not of known age when collected, only approximate weight losses can be computed. It is interesting to note that infertile eggs also undergo a pattern of weight loss similar to that exhibited by the 3 fertile eggs (Figure 23).

The mean laying-hatching interval for eight Horned Puffin eggs on East Amatuli in 1977 was 42 days (range 40-46 days). This compares with 40.2 days, the mean length of incubation for 5 eggs in 1976. Although laying-hatching intervals for Tufted Puffin eggs were not studied in 1977, for 11 eggs the previous year the mean length of incubation was 45.2 days (range 43-53 days).

Nestling phase. Hatching occurred in Tufted Puffins between July 10 and 31 in 1976 and between July 11 and August 4 in 1977. Hatching intervals for the Horned Puffin were July 22-31 and July 21-August 10 for 1976, 1977, respectively. The puffin nestling that was artificially incubated required 34 hours from pipping (first crack) to hatching.

At hatching Tufted and Horned Puffin chicks weigh about 68 grams (n = 23) and 55 grams (n = 7), respectively. Nestlings of both species hatch with an internal food reserve (the yolk sac) which assists them nutritively the first few days of life. In four Tufted Puffin nestlings that died at hatching, the yolk sac measured about 40 x 30 mm in size and weighed from 8-21.5 grams (mean 13.5 grams). In the four nestlings dissected, the yolk sac comprised from 12.1 to 28.5% (mean 19%) of the nestling weight at hatching.

Newly hatched puffin chicks are brooded by an adult for the next several days. Twelve Horned Puffins attended their chicks for an average of 6.5 days (range 4-10 days) after hatching. Tufted chicks do not attend their chicks as long as Horned Puffins. In 54 pairs, brooding by Tufted Puffins usually ended after 4 days and in many cases the chick was unattended on the second day. Sealy (1967), in experiments on thermoregulation by a Horned Puffin nestling found that by the sixth day the chick was able to maintain its initial body temperature after being exposed to ambient temperature of 9°C for 50 minutes. It is probable that Tufted Puffin chicks, due to their slightly larger size and the sheltered environment of the burrow, achieve thermoregulatory stability at an even earlier age.

Nestling food. Puffins deliver food to their young in the nest until the young are well developed. Chicks remain in the nest until fledging at which time they flutter down to sea to assume an apparently independent existence. The initial food delivery to newly hatched young is probably stimulated by vocalizations of the chick. A bright orange puffin bill was used to stimulate feeding in a day-old Tufted Puffin nestling that I hand reared. Although the orange bill acted as a "releaser" stimulating feeding in one case, another newly hatched chick ate readily from the hand or picked fish off the floor of the nest without the bill stimulus. The silvery color of the fish appeared to be a greater stimulus than the orange bill of an adult. Hence, puffin nestlings quickly learn to eat fish that is dropped near them in the nest. We observed a Tufted and Horned Puffin nestling less than 1 day old eat a fish that measured 95 mm (total length) and weighed 5 g.

Within the family Alcidae many species carry only fishes (or large worms such as polycheates) to their nestling(s) while they themselves have a much more diversified diet (Bedard 1969b). Puffins feed exclusively fish or squid to the young while their own diet may consist of mollusks, crustacea, and polycheates as well (Bent 1919; Cody 1973; Sanger in Frazer 1975; Wehle 1976). On East Amatuli Island the most important food items (in number, weight, and frequency of occurrence) brought to the young by both puffin species were Capelin, *Mallotus villosus*, and Sand Lance, *Ammodytes hexapterus* (Table 25). Sand Lance did not appear in the Tufted Puffin nestling diet in 1976, however it comprised 30 percent of Tufted Puffin bill loads in 1977. Similarly, Sand Lance, comprising 16 percent of Horned Puffin bill loads in 1976 increased in occurrence to 52 percent of the bill loads in 1977 (Table 26).

Horn (1966) discusses various indices by which the degree of "overlap" in comparative ecological studies can be measured. Morisita (in Horn 1966:419) presents an index of overlap appropriate in comparative studies of diet. The calculated index of overlap varies from 0 when the samples are completely distinct (containing no species in common) to about 1 (Morisita 1959:69,75) when the samples are identical with respect to proportional species composition. This index reveals a high degree of overlap (0.96) and (0.94) in nestling food brought to Tufted and Horned Puffin chicks on East Amatuli Island in 1976 and 1977, respectively. When the data for both years is pooled, the index reveals a 0.90 degree of overlap in the nestling diet of the two species. The mean size (total length) of Capelin and Sand Lance delivered by Tufted and Horned Puffins was similar, i.e., 105 and 104 mm, and 90 and 104 mm, respectively. Feeding rhythm data (presented later in the chapter) does not indicate a temporal separation in food delivery patterns. Hence, it is possible that both puffins were foraging in the same general area.

Feeding rate. Several authors have found that the weight of a feeding, the number of fish per load, and the number of feedings per day increase as the nestling grows and requires more energy (Lockley 1934; Drent 1965; Cody 1973). Early in chick rearing, Tufted Puffins carried an average of 1.3 $\pm$ S.E. 0.6 (n = 27) fish per delivery. In the middle and latter part of the nestling period the number of fish carried per load increased significantly ($P < 0.01$) to 3.8 $\pm$ S.E. 1.7 ($n = 79$). Possibly the artifact of a smaller sample size, a similar increase in number of fish per delivery over time was not observed for the Horned Puffin.

Table 27 compares the average weight per load delivered to Tufted and Horned Puffins in 1976 and 1977. Tufted Puffins carried on average more fish and heavier loads than Horned Puffins. The heaviest single specimen brought in by a Tufted Puffin was a 78-g Prowfish that measured 118 mm total length. The heaviest single fish delivered by a Horned Puffin was a 19-g Capelin that measured 138 mm. Although puffins generally brought more fish or more loads per day to older chicks, no tendency to select larger individual prey for older nestlings was evident.

We examined diel colony feeding rhythms and number of daily feeds per chick during the middle nestling period for both puffin species (Figure 24). The Tufted Puffin colony monitored for feeding rhythm contained approximately 25 nestlings, therefore at 102 deliveries each chick received about 4 feeds per day. In addition the frequency of food deliveries to 5 marked burrows was monitored on August 21, 1976. The number of feeds per day ranged from 2 to 6 with an average of 3.8 per nestling.

The Horned Puffin colony monitored for feeding rhythm data contained 9 nestlings. The number of feeds per chick ranged from 2 to 6 with an average of 3.3 feeds per day.

As evidenced in Figure 24, adult puffins spend considerable time each day fishing for their nestling. My observations in 1976 (see Amaral 1977) indicate that in both species there was a tendency for adults to invest more time fishing (assuming that absence from the colony is related to fishing effort) as the energy requirements of the chicks increase.

During the entire chick-rearing period in 1976 and 1977, in which we observed over 2000 fish deliveries, there were only 10 incidents of attempted cleptoparasitism. All were unsuccessful aerial or ground attacks of Glaucous-winged Gulls on Tufted Puffins. It is unlikely that Glaucous-winged Gulls have any measurable effect on the chick feeding success of puffins on East Amatuli Island.

Descriptive development. Descriptive data on 21 Tufted and 11 Horned Puffin nestlings in 1976 and 35 Tufted and 12 Horned Puffin nestlings in 1977 were used to compile a general pattern of prefledgling growth for the two puffin species. Nestlings were described in detail at least once every 5 days; therefore, loss of the egg tooth and primary feather growth may occur a few days earlier than indicated. At hatching, puffin chicks are clothed in charcoal grey down and are soon capable of moving about. Horned Puffins are slightly smaller in size (Table 28), have white down on the abdomen, and a horn-like projection above the eye. Otherwise, the two species are very similar in appearance.

In Tufted Puffins, the egg tooth present on the upper mandible at hatching disappears at 12 to 20 days of age. The eruption of primary wing feathers occurs between 10 and 15 days of age. As feathers erupt and unfurl, down is lost and at about 45 days of age the nestling is completely feathered. Culmen and eye color lighten during development and become more adult-like in character.

In Horned Puffins, the egg tooth is lost at 15 to 18 days of age, and primary wing feathers erupt at 10 to 12 days of age. Nestlings are fully feathered at 35 to 38 days, and culmen and eye color undergo a similar change during development. The first juvenile plumage exhibited by the nestlings at fledging is quite different from the nuptial plumage of the parents.

Growth rate. To compare growth rate in birds, Ricklefs (1968) recommends the fitting of one of three asymptotic equations to growth curves. Curve-fitting reduces growth data to simple and comparable measures of the entire course of growth. This method yields more information about intra- and interspecific variations in growth than simpler methods. Table 29 presents a comparison of growth parameters for the two puffin species in 1976 and 1977. The growth data for both species fit the logistic equation. The equation for the logistic growth curve is

$$\frac{dW}{dt} = KW \left[1 - \frac{W}{A}\right]$$

where W is the weight of the growing bird, t is time, A is the final asymptote, and K is a constant related to overall growth (Ricklefs 1967:979). Another and perhaps better index of overall growth (Hussell 1972) is the instantaneous growth rate KR/4 x 100 at the inflection point of the fitted logistic curve.

Also useful in growth rate comparison is Rickle f's (1967:981) reciprocal form of dW/dt. This represents the amount of time required to complete 10 to 90 percent of the asymptote weight and is calculated by the formula

$$t_{10-90} = \frac{C_{90} - C_{10}}{dW/dt}$$

where C is a conversion factor, W is the weight of the growing bird, and t is time. This is a practical index because it varies directly with temporal features related to growth (such as the length of the incubation or nestling period) and is useful in making comparisons between species whose growth curves are fit by different equations.

The growth parameters of Tufted and Horned Puffins are remarkably similar. Since the puffins are closely related species, this is the situation one might expect. In addition, each has a clutch size of one, they are about equal in feeding capacity, and they utilize a common pool of prey food species.

In both years Horned Puffin nestlings exhibited a slightly faster growth rate (K) than Tufted nestlings. Also, both species had slightly higher K values in 1976 than in 1977. The longer t_{10-90} value of the

Tufted Puffin is probably due to its larger size since larger species, as compared with smaller, usually take longer to fledge (Lack 1968).

Figure 25 illustrates weight change in 21 and 35 Tufted and 11 and 12 Horned Puffin nestlings, 1976 and 1977, respectively. The growth patterns for the two species are similar. Tufted Puffin nestlings during the period of maximum growth (t_{10-90}) gained 16.7 g per day in 1976 and 16.3 g per day in 1977, whereas Horned Puffin nestlings gained 13.4 g per day in 1976 and 12.7 g per day in 1977. The variation and irregularities in the curves are probably normal inherent weight deviations from a sample of this size.

Although "supra-adult" body weights are not normally achieved by alcid nestlings, a pronounced prefledging weight recession is exhibited by semi-precocial alcids (Sealy 1973b). Tufted Puffin nestlings attained maximum weight (76 percent adult weight) between 39 and 46 days of age (mean 43.3), while for Horned Puffins maximum nestling weight (71 percent adult weight) was attained between 36 and 40 days of age (mean 37.5). Various explanations for pre-fledging weight recession are discussed in Sealy (1973b) and Harris (1974). Although conflicting evidence exists (Lockley 1934; Myrberget 1962; Cody 1971), puffins and most alcids probably undergo a pre-fledging weight recession due to the combination of three factors: a voluntary restriction of feeding, increased activity (e.g., wing flapping, walking), and loss of water during tissue maturation (Drent 1965; Ricklefs 1968; Sealy 1973b; Harris 1974; Wilson 1977).

Tufted Puffin nestlings fledged at 70 percent adult body weight. Nine nestlings weighed the night before departure from the nest averaged 550 g (S.E. 21.0) and ranged from 510 to 585 g. Two Horned Puffin nestlings fledged at about 69 percent adult weight and weighed 400 and 428 g, respectively. The average nestling period for Tufted and Horned Puffins was 47 and 40 days, respectively.

Figure 26 illustrates the growth pattern as changes in mean wing length for the two species. As in Figure 25, the patterns of growth are similar. The greater uniformity of the growth curves in Figure 26 demonstrates that wing length growth is relatively consistent regardless of variable weight gains.

Fledging. Departure from the nest probably occurs just after nightfall. On September 1, 1976, we observed 3 Tufted Puffin fledglings en route in the Common Puffin (Lockley 1934); the fledglings were flightless. I observed 2 Tufted Puffin fledglings scurry across the beach; upon entering the sea they made several short dives surfacing farther from shore each time.

If one-third of the estimated 102,000 breeding pairs of puffins in the Barren Islands produced fledglings, then in late August to mid-September as many as 30,500 flightless puffins would be in the Barren Islands area of the Gulf of Alaska. Therefore, time is of critical importance in assessing the ecological insult of oil pollution on populations of breeding birds.

Breeding success. Hatching success and the percentage of nests that produced fledglings are combined to estimate overall breeding success (Table 30). In both years a significant proportion (i.e., 45 and 46 percent, respectively) of the Tufted Puffin burrows did not contain eggs although nearly all burrows showed sign of entry and/or occupancy. This percentage of active but "empty" burrows may be related to historical population size or may be an indication of the number of nonbreeders in the population. In any case these burrows are an important consideration when estimating breeding population size by burrow density investigations. Storm Petrels occupied 8 percent of the "empty" Tufted Puffin burrows in 1976, and 4 percent in 1977. Cohabitation of a Tufted Puffin and a Storm Petrel occurred in one burrow; both pairs successfully raised a nestling. One "empty" Horned Puffin crevice in 1977 contained a Storm Petrel.

Although most desertions in the study colonies can be attributed to my disturbance, I have unquantified data which suggests a 5 to 10 percent natural desertion rate. Puffins are extremely sensitive to disturbance during the incubation period. Of the 28 eggs that were deserted, 11 were in burrows that I had not reached into.

A storm during the nestling period in 1976 accounted for high mortality among Horned Puffin nestlings. Mortality of nestlings is most severe when storms occur during the early stages of chick rearing. Although heavy rains fell in August 1977, precipitation was not accompanied by persistent high winds. Hence, the higher breeding success of Horned Puffins in 1977 is largely attributable to more favorable weather conditions.

Tufted Puffin nestlings are evidently better protected in their deep burrows. Nevertheless, some storm-related mortality did occur both years as heavy rains flooded burrows or led to cave-ins (Table 31).

Energetics of Puffins--A Scenario for the Barren Islands

Horned Puffin

From wild birds, we know that Horned Puffins feed their young four times per day with 15 g of fish per load. Therefore, for a 40-day nestling period, a chick would consume 2400 g of fish. We estimate the annual production of Horned Puffins in the Barren Islands to be around 2000 fledglings. Consequently, this species would feed their young about 4,800,000 g of fish each year.

Tufted Puffin

We hand-reared one Tufted Puffin chick for 47 days. During this time, it consumed 3500-4000 g of food. From wild birds, we know that adults make four trips per day to the young. Each load weighs about 20 g so that during a nestling period of 47 days, the young would receive 3760 g of food. The annual production of Tufted Puffins is about 29,243 fledglings. Consequently, this species would need 109,953,681 g of fish each year.

For both species, then, about 250,000 pounds of fish are needed each year to sustain the puffin populations at their present levels.

ANCIENT MURRELET

Perhaps as many as 200-300 pairs of Ancient Murrelets (Synthliboramphus antiquus) occur on East and West Amatuli Islands in May and June (Manuwal and Boersma 1976). In 1977 five Ancient Murrelet nests were found on East Amatuli Island. Four nests were located in earthen burrows and one pair utilized a crevice beneath rock talus. Four of the five nests were found on a slope along the west side of East Amatuli Cove about 10 m above sea level. Of the five nests, two contained unsuccessful eggs from the previous year. Three of the nests were active and contained two egg clutches in 1977. Four eggs were weighed and measured; mean egg dimension were 61 x 38.5 mm, while mean weight was 44 g (approximately 24 percent adult body weight).

On June 28 two newly hatched Ancient Murrelet nestlings were found. Sealy (1976) reported that the incubation period of Ancient Murrelets was 35 dyas, hence these eggs were laid about May 26. The nestlings weighed 27 and 27.5 g, respectively, and were brooded by an adult. With the night vision scope an unsuccessful attempt was made to observe fledging behavior. The nestlings fledged the evening or early morning of June 29-30. The fledglings weigh approximately 15 percent of adult body weight (27/182) when leaving the nest. This is also the percent adult weight of fledglings on Langara Island reported by Sealy (1976).

Two of the three active nests on East Amatuli Island produced fledglings. Eggs in the third nest were deserted after both adults were banded.

PARAKEET AUKLET

With the exception of Smith Island in Prince William Sound, the 900-1000 pairs of Parakeet Auklets (Cyclorrhynchus psittacula) in the Barren Islands represent the easternmost colony of this species (Manuwal and Boersma 1976). Parakeet Auklet colonies vary in size from 10-200 pairs and were located on five of the seven Barren Islands.

About 50 pairs of auklets nest on the west slope above East Amatuli Cove. Approximately 30 nest sites were examined and all were located in crevices either in vertical or horizontal cracks in the parent rock material or beneath boulders. The actual egg site was inaccessible in all but one of the 30 crevices. Hence, we have no meaningful data on diet or breeding success.

The following information was obtained from the one accessible nest site on East Amatuli Island. Both members of the pair were present on June 18 when the egg was laid. Incubation was shared by both the male and female. Hatching occurred on July 24, thus the incubation period was 37 days. Two hours after hatching the nestling weighed 33 g and brooding ensued almost continuously for the next 10 days. Both adults take an active part in feeding the chick. On an all-day watch on August 9 the nestling received a total of four feedings. During the course of growth the nestling gained approximately 7 g per day. Primary wing feathers erupted by day 8 and the egg tooth was lost by day 14.

On day 31 it weighed 222 g or 79 percent of adult body weight (280 g). Figure 27 illustrates changes in weight and wing length for the one nestling monitored on East Amatuli Island. Sealy and Bedard (1973) estimated that Parakeet Auklets, like puffins, attain maximum nestling weight several days prior to fledging.

COMMON AND THICK-BILLED MURRES

Bailey (1976) estimated that 45,500 pairs of murres occur in the Barren Islands during summer and that two-thirds of these breed on East Amatuli Island. Although Common Murres (Uria aalge) predominate on the nesting ledges and comprise 100 percent of certain colonies, overall 10 to 15 percent of the murre population on East Amatuli Island are Thick-billed Murres (U. lomvia).

The eastern headland of East Amatuli Island is characterized by steep cliffs of exposed weathered bedrock. Although there was a small murre colony of 500 pairs located on the southern edge of the island, most murres nested on East Amatuli Lighthouse and the rocky eastern headland (Figure 28).

From counts of incubating birds we estimate that 5000 pairs of murres occupy East Amatuli Lighthouse. On July 11, 1977, the lighthouse colony was visited and a grid 17.6 square meters in size was market in the densest part of the colony. One-hundred seventy-four eggs were counted within the grid for a nesting density of 10 eggs per square meter. Although this density appeared high, Tuck (1961) reported that the core of a Common Murre colony on Funk Island often had a density exceeding 30 eggs per square meter.

The mean of 10 eggs weighed on July 11 was 112 g (range 85-126 g). Hatching success for 242 eggs on the lighthouse colony was estimated when the colony was revisited on August 15, 1977 (Table 32).

Fifty nests, 75 percent of which were occupied by Thick-billed Murres, were monitored in study colony 1. On August 15, 25 percent of the eggs had hatched, 8 percent had disappeared, and the remainder were still being incubated.

Weight and wing measurements were recorded for 20 Common Murre nestlings on August 15. The average weight of 6 newly hatched murre nestlings was 86 g; average wing length was 25 mm. Weights of the 20 nestlings ranged from 75 to 290 g. The nestlings were aged according to growth measurements in Tuck (1961:157); egg laying and hatching intervals were interpolated from these estimates (Figure 29). Three fish, two Capelin and one Sand Lance, were found on colony, presumably brought to murre nestlings as food.

A small colony of Glaucous-winged Gulls also nest on the lighthouse. Both adult and nestling gulls (that had not yet attained flight) were observed eating murre eggs. Over 50 broken murre eggs were found in the gull colony. This circumstantial evidence suggests that gull predation may significantly reduce breeding success of murres.

Murre nestlings depart for sea at about 20 to 22 days of age. Soon after adults and nestlings have left the cliffs, adults undergo a post-nuptial molt (Tuck 1961). At this time both adults and fledglings are incapable of flight and consequently are more vulnerable to surface oil pollution.

PREDATION

During 1976 and 1977 there were several potential predators on East Amatuli Island. These included the Northern Raven, Corvus corax, Glaucous-winged Gull, Peregrine Falcon, Falco peregrinus, Bald Eagle, Haliaeetus leucocephalus, and River Otter, Lutra canadensis. There was no indication of predation by ravens or gulls. Bald eagles were known to take a few puffins but the extent of eagle predation on puffins is unknown. Puffin remains were often found below perches frequented by eagles, but it is unclear whether the puffins were carrion or were actually captured by the eagles. The remains of four adult Tufted Puffins attributable to peregrine predation were found on the upper slopes in 1976. In 1977, peregrines killed seven adult Tufted Puffins in a monitored colony of 35 pairs (Table 33). One of the puffins killed was a bird we banded the previous year in the same location (band no. 756-18946). All peregrine kills were characterized by two or three deep lacerations on the skull and the body cavity was neatly pulled inside-out. Bald eagles and falcons were occasionally observed harassing puffins causing panic flights off the colony.

River Otters, not previously reported in the Barren Islands (Bailey, pers. comm.) were present on East Amatuli Island in both 1976 and 1977. The prey items utilized by a 3- and 4-member family of otters in 1976 and 1977, respectively, included both juvenile and adult puffins (Table 34). The otters were opportunistic predators, taking many Storm Petrels early in the breeding season, and puffin nestlings as they became available.

Considering the thousands of puffins inhabiting East Amatuli Island, predation probably has little effect on the breeding success of the puffin populations. In conclusion, many different factors can potentially lower breeding success; among these, desertion both before and after hatching and storm mortality during early chick rearing appear to be the two most important causes of breeding failure for the puffins on East Amatuli Island.

TAR/OIL BALLS FOUND ON EAST AMATULI ISLAND IN 1977

In 1976 we did not find any tar or oil on the beaches. The first indication of the presence of oil occurred in mid-May 1977 when Nat Wheelright and Ed Bailey found an oiled Common Murre on West Amatuli Island. We first found tar balls on East Amatuli on 22 June 1977. A 100 m stretch of beach was walked on four dates in July (Table 35).

The Effects of Oil on Seabirds

The Barren Islands project was funded to gather baseline information particularly on seabirds, which would be useful in determining the human use and management requirements necessary for maintaining the present seabird population. One of the major negative impacts on seabird populations in the Barren Islands may be oil related damage. Considerable effort has been devoted to gathering information on reproductive success, growth, and storm mortality on a variety of seabirds nesting in the islands. Unfortunately, two years of data can hardly be considered representative of natural variations, but at least our data reflects some of the parameters impacting survival.

The greatest controversies in the battle to prevent oil introduction are waged over the effects such an introduction will have on the biological system. To begin to assess effects, one must first know where the oil is likely to go, what lives in those regions of the waters, and how those individual organisms are physiologically and behaviorally affected by oil. The Barren Islands with their sizable seabird and marine mammal populations could sustain severe damage from oil because of its current regime. Tidal variation is great and fishermen regard the islands as some of the more hazardous fishing areas because of the strong tidal currents and frequent storms. Oil coming to the islands is likely to be widely disbursed. Because of the currentss and winds, cleanup equipment can generally be considered useless in the Barren Islands. The rocky beaches and kelp beds characteristics of the islands also make them particularly sensitive to oil. These areas act as traps where toxicities build up but are not easily flushed (Holmes 1969). To make matters worse, the least damaging mechanical cleanup method is impossible to use in these areas (Gatteleir et al. 1973). The extent of damage on the habitat or physiography of an area will depend on the oil type, oil dosage, oceanographic conditions, meteorological conditions and turbidity.

Many organisms that seabirds feed upon will undoubtedly be killed or contaminated. There is a large body of evidence that oil from a sudden spill may be quite toxic to fish (Nelson-Smith 1972). Crude oil spilled in Puerto Rico killed fish (Diaz-Piferrer 1962). Generally larvae and eggs were more likely to succumb than adults. It is believed that adult fish and some fry will try to avoid the oil (Patten 1977).

Intertidal species of mollusks, gastropods, and echinoderms tend to be quite resistant to petroleum products, while arthropods such as crabs and shrimp are sensitive (Craddock 1977). Of course, any intertidal organism could be killed as a result of coating and smothering. Behavioral changes associated with oil may have the greatest impact on seabird food sources. For example, snails exposed to oil retract into their shells and may be swept away and later die (Boesch et al. 1974).

If the organisms are not killed they will be a reservoir of oil for some time. Clams contaminated by a spill still had residue after nine years (CEQ 1974). Oil compounds do not now appear to be magnified through the food chain as are pesticides and heavy metals. Since predators such as plaice preferentially eat contaminated shrimp over clean shrimp (Blackman and Mackie 1974), there is potential for long-term recycling of oil through the community and food web. These subtle and long-term impacts on seabirds through the food supply are not well understood. Hatchability and yolk structure changes of seabird eggs after a single dose of crude oil is known for some birds (Grau et al. 1977). Ingestions of small amounts of oil, either directly or from the food, could drastically lower reproductive success. It is well known that even oil on the outside of the egg arrests development (Bourne 1969). We found Fork-tailed Storm Petrel eggs died when only partly oiled. Thus seabirds which ingest oil by eating contaminated prey species may have lower reproductive success which could result in a long-term population decline. Scientific concern should focus not only on major spills but on small chronic amounts of oil entering the system. Ingestion of oil from prey species may have dramatic effects on seabird populations over a long period.

Even small amounts of oil will harm seabirds. Oil on the feathers adds weight and reduces the insulation (Holmes and Cronshaw 1977). Death because of exhaustion or increased metabolism leading to starvation would not be viewed as directly oil related when, in reality, it is. Laboratory studies show that birds which have ingested oil are stressed and are more likely to die than birds which have not consumed oil (Holmes and Cronshaw 1977). Oil compounds the effects of cold, storms, and other stresses. Because the wind and tidal currents in the Barren Islands are particularly extreme, seabirds may die more frequently from small amounts of oil. Contamination of the feathers may reduce the flight efficiency by increasing the weight and changing individual feather configuration. If adults, as a response to oiling, must consume more food, less food will be fed to the young. It is unlikely that the adult would be able to forage as efficiently when oiled. In any case, young will grow slower and die. Thus, small amounts of oil may be nearly as catastrophic as large amounts.

During the Santa Barbara spill, loons and grebes made up most of the seabirds killed (Straughan 1971). Diving birds may be more likely to die directly from oiling. It seems reasonable to divide seabirds into three groups based on where they forage: inshore or intertidal, near shore, and open ocean. The inshore and intertidal shore birds are likely to be impacted by oil from ingestion of contaminated prey. Prey density and community structure changes caused by oil will affect these populations more greatly than direct oiling. Long-term oil-related changes will have the greatest population impact. Near shore feeders such as puffins, auklets, and cormorants die directly from becoming oiled. Puffin colonies have been decimated by spills (Parslow 1967). Since large numbers of puffins remain in the water around the Barren Islands, massive deaths could be caused by just one spill. The mixing actions by the wind and tidal currents suggest oil would be spread quickly throughout the islands. Thus the most damage wil be done directly from contacting oil. Offshore feeders such as the Fork-tailed Petrel which feed considerable distances from the islands may not be subject to oiling as much as near-shore feeders since the oil will be disbursed and patchy. Petrels may be attracted to oil spills. However, it is reasonable to expect that ingestion of oil from the prey will have the greatest impact. Several species of copepods will ingest oil (Spooner 1969). Slow long-term population changes are the most likely results of oil spills. Since small amounts of oil may change community structure and affect seabirds via the food chain, these species may prove to be good, long-term indicators of environmental change due to oil pollution.

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Table 1. Mark and recapture of Fork-tailed Storm Petrels on East Amatuli Island, Alaska.

Date	A Number caught	Number marked	B Number marked in area	A x B	ΣA x B	C Recaptures	ΣRecaptures	ΣA x B / ΣC Total pop.
6/13	56	56						
6/20	66	64	56	3,696	3,696	2	2	1,848
6/27	66	66	110	7,260	10,956	0	2	5,478
7/5	64	63	173	11,072	22,028	1	3	7,342
7/18	64	63	236	15,104	37,132	1	4	9,283
8/5	21	21	299	6,279	43,411	0	4	10,852

Table 2. Adult weight and brood patch scores obtained from mist-netted adult storm petrels. SD: one standard deviation.

Date	Number	Mean weight (gm)	SD	Mean brood patch score	SD
June					
13	56	57.6	4.5	2.3	0.9
20	66	60.2	4.2	1.9	0.4
27	66	58.0	3.0	1.8	0.4
July					
5	64	57.6	3.3	2.0	0
18	64	62.3	3.9	2.0	0.2
August					
5	21	61.4	4.5	2.0	0

Table 3. Activity cycle data. May 25-30 estimates from several locations. June 21-August 15 counts from 10 x 10-meter sample plots. Counts represent mean nightly maximums.

Sample period	Aerial Counts	Calls Air	Calls Ground	Calls Burrow	Hovering	Chases
May 25-30	150+	200+	100+	50+	50+	20+
June 21-July 8	32.5	32.8	17.4	8.3	4.6	1.6
August 10-15	4.75	1.0	0.5	0.5	0	0

Table 4. Parental recognition experiments on Fork-tailed Storm Petrels.

Age (days)	Number switched	Number survived*	Success (%)
1-5	10	8	80
15-20	10	10	100
35+	10	9	90

*Survival is assumed if weight is maintained or increased for at least ten days.

Table 5. Incubation shifts of Fork-tailed Storm Petrels on the Barren Islands in 1977.

Pair		Incubation days	Incubation shifts	Mean shift length	Total (%)	Cold days	Egg stage total
1	A	22	7	3.14	52	8	50
	B	20	7	2.86	48		
2	A	15	8	1.87	37	17	57
	B	25	10	2.50	63		
3	A	15	7	2.14	40	8	45
	B	23	7	3.29	60		
4	A	22	10	2.20	55	12	52
	B	18	9	2.00	45		
5	A	21	7	3.00	51	9	50
	B	20	9	2.20	49		
6	A	19	7	2.70	48	6	46
	B	21	7	3.00	52		

Table 6. Mean incubation shifts for various parts of the incubation period.

Mean Shift Length	
first 1/2	2.80
second 1/2	2.30
overall	2.54
mean cold days	8.10

Table 7. Weight loss of incubating Fork-tailed Storm Petrels.

Adult	Time (hours) 0	12	36
1	60.75	59.0	
2	62.0	59.5	
3	60.5	58.5	55.0

Mean weight loss: 2.0 g/12 hr.

Table 8. Utilization of crevices by Fork-tailed Storm Petrels on East Amatuli Island.

Transect number	Crevices	Entered (%)	Eggs (%)	Chicks (%)	Success (%)
1	112	76	85	69	54
2	117	70	67	49	31
3	112	82	53	61	46

Table 9. Transect data on habitat selection and productivity of Fork-tailed Storm Petrels (transect 1).

Quadrat	No. eggs	No. chicks	Slope (°)	Altitude (m)	Relief	Vegetation height (cm)	Soil depth (cm)
1			12	30	4.1	32.4	53.4
2	6	4	13		22.1	87.2	29.6
3	6	5	23		18.2	80.2	24.4
4	2	2	25		11.5	65.4	13.6
5	2	1	22	45	9.5	68.4	12.0
6	5	2	24		10.1	94.8	12.2
7			23		7.2	56.8	11.8
8	5	3	24		11.0	57.8	25.2
9	1	1	25		6.1	51.4	8.0
10			25	72	8.4	53.8	18.5
11			26		6.4	48.0	18.0
12	4	3	26		10.6	53.6	22.2
13	6	3	26		10.1	57.0	14.8
14			24		7.2	39.2	10.4
15			25	93	5.2	21.2	8.8
16	2	1	26		5.9	31.6	10.4
17			28		5.6	23.0	8.6
18			28		6.6	7.2	16.0
19			28		6.6	7.4	13.8
20			28	109	2.9	6.8	16.6
21			28		4.1	7.4	21.0
22			31		4.5	7.4	20.8
23			31		6.7	7.0	18.8
24			31		6.0	7.2	11.5
25			26	138	9.3	52.4	6.6
26			34		6.8	61.6	1.4
27			34		10.6	65.5	3.2
28			36		6.9	61.5	5.8
29			37		5.2	20.4	14.8
30			36	162	7.1	7.2	18.8
31			36		3.3	2.2	0
32	1	1	39		22.9	4.8	0
33			39		10.3	7.0	8.4
34			39		8.1	7.0	16.8
35	2	1	39	195	12.5	7.2	18.6
36	1	0	45		6.6	6.6	16.8
37			37		5.5	4.4	17.0
38			37		11.0	5.8	15.0
39			37		5.6	6.6	15.2
40	1	0	40	225	3.5	6.0	19.0
41	2	2	40		3.7	7.0	24.2

Table 9. (continued)

	Entrance diameter (cm)	Depth (cm)	Nest material scale	Wetness scale
Successful	10.3	35.8	2.04	0.54
Unsuccessful	11.2	13.3	1.0	1.16

Table 10. Transect data on habitat selection and productivity of Fork-tailed Storm Petrels (Transect 2).

Quadrat	No. eggs	No. chicks	Slope (°)	Altitude (m)	Relief	Vegetation height (cm)	Soil depth (cm)
1			8		3.3	13	23.2
2			8		6.9	13	21.2
3			8		5.4	37.6	26.4
4			0		8.2	29.4	27.6
5			0	48	4.6	27.8	27.4
6			2		5.3	25.8	24.2
7			3		9.6	16.8	37.2
8			4		4.7	28.6	33.4
9			7		9.1	33.2	36.8
10			7	52.5	4.8	32.0	21.8
11			6		2.5	36.6	30.8
12			19		19.7	49.2	30.4
13	7	1	21		35.3	89.4	25.0
14	10	6	14		23.4	82.4	23.6
15	4	1	18	61.5	23.1	73.8	22.4
16	4	1	12		36	59.6	37.0
17	5	2	17		19.2	78.2	22.0
18	1	0	18		11.7	79	20.8
19	2	1	20		11.3	67.4	15.8
20	1	0	17	78	7.3	50.6	12.0
21			17		5.7	59.0	15.8
22			27		6.6	58.0	14.0
23			28		6.2	50.6	25.0
24			19		11.6	41.4	8.6
25			17	97.5	12.3	40.2	6.8
26			16		10.1	34.0	7.2
27	1	1	16		6.5	44.6	14.8
28			20		9.3	15.6	9.8
29			22		2.1	7.0	8.4
30			22	111	5.8	6.4	4.4

	Entrance diameter (cm)	Depth (cm)	Nest material scale	Wetness scale
Successful $\overline{X}$	9.0	33.1	1.67	0.58
Unsuccessful $\overline{X}$	9.8	28.2	1.52	1.60

Table 11. Transect data on habitat selection and productivity of Fork-tailed Storm Petrels (Transect 3).

Quadrat	No. eggs	No. chicks	Slope (°)	Altitude (m)	Relief	Vegetation height (cm)	Soil depth (cm)
1			9	6.9	4.4	35.5	23.0
2			10		3.2	34.6	23.8
3			10		6.4	36.4	20.0
4			8		6.0	27.2	11.0
5			8	12	5.0	32.3	8.8
6			5		3.1	26.4	3.8
7			7		4.5	50.6	26.4
8			8		5.3	23.8	23.8
9			11		7.8	11.0	13.2
10	1	0	13	19.5	14.7	14.4	8.4
11			13		5.2	14.4	13.6
12	4	2	14		15.0	45.0	23.6
13	3	2	23		17.2	70.8	21.8
14	3	2	21		12.3	71.2	19.6
15	14	6	25	30	17.9	73.0	26.6
16	1	0	29		21.6	30.0	11.6
17	1	1	25		4.2	19.6	5.6
18	1	1	25		5.1	14.2	5.0
19			25		5.3	9.6	2.6
20			22	58	3.9	5.6	1.2
21			22		13.2	4.8	2.6
22			25		5.6	5.8	2.8
23			29		7.6	7.6	3.6
24			29		5.0	6.6	1.8
25			29	78	3.6	14.6	4.8
26			26		6.2	30.3	7.2
27			23		3.2	21.8	7.4
28			23		3.5	23.0	2.2
29			23		4.2	20.6	4.2
30			23	102	4.9	38.6	5.8

	Entrance diameter (cm)	Depth (cm)	Nest material scale	Wetness scale
Successful $\overline{X}$	9.2	28.9	1.5	0.71
Unsuccessful $\overline{X}$	9.9	25.0	1.0	1.92

Table 12. Storm Petrel nesting in artificial wooden nest boxes on East Amatuli Island.

Location	Boxes with >5 entrances	Nests built	Boxes entered (%)	Entrances
Area 1	0	0	0.27	12
Area 2	10	8	0.90	131
Type 1	6	4		
Type 2	4	4		

Area 1--Outside established colony
Area 2--Within established colony
Type 1--Half box
Type 2--Whole box

Table 13. Pelagic Cormorant nestling weights. Chicks with the same numerical prefix are from the same nest.

Chick	Approximate	Weight (g)		
no.	hatching date	6/27	7/5	7/19
14A	6/26	27	188	1075
14B	6/28		133	1060
15A	7/4		33	310
15B	7/2		37	555
16A	6/30		148	1199
16B	6/29		175	1300
16C	6/31		105	905
17A	7/28		162	1094
17B	7/30		146	1000
17C	7/30		136	1135
18A	7/4		39	651
18B	7/5		34	570
18C	7/7		-	444
18D	7/4		42	698

Table 14. Reproductive success of Pelagic Cormorants.

Average clutch size	2.84
Hatching success	0.64
Nesting success	0.57
N = 63 nests, 179 eggs	

Table 15. Breeding success of four Black Oyster-catcher nests in the Barren Islands, 1977.

Nest No.	No. of eggs	Number hatched	No. of chicks fledged	Percent success
1	3	3	3	100
2	3	3	2	67
3	3	3	1	33
4	3	2	1	33
TOTAL	12	11	7	58

Table 16. Glaucous-winged gull (*Larus glaucescens*) colonies on East Amatuli Island, 1977.

	Colony 1	Colony 2
Number of nests in sample	32	12
Mean clutch size	2.47 $\pm$0.76	2.42 $\pm$0.66
Estimated reproductive success	52%	58%
Chick mortality	>18%	>19%
Estimated population size (pairs)	150	17*

*There were at least two other colonies of Glaucous-winged gull colonies on East Amatuli Island with populations of ca. 5 and 35 pairs, respectively.

Table 17. Breeding phenology of Glaucous-winged gulls.

Date	No. eggs	No. chicks	Total egg/chick mortality
27 May	0*	--	--
19 June	79	0	0
1 July	52	12	13
3 July	38	18	23
14 July	2	44	33
14 August	0	? vegetation	?** too high

*On nearby Sud Island a single egg was found on 25 May.

**Three banded chicks were found dead, two apparently the victims of river otters and one of starvation.

Table 18. Reproductive success of Black-Legged Kittiwakes.

Average clutch size	1.76
Hatching success	0.83
Nesting success	0.51

N = 49 nests, 86 eggs

Table 19. Weights and measurements of dead Kittiwake fledglings found August 15, 1977.

Chick no.	Weight (g)	Wing length (mm)	Tarsus (mm)	Culmen (mm)
1	412	229	40.5	29.5
2	395	250	40.3	31.0
3	340	238	44.5	31.5
4	305	220	40.0	31.0
5	*	220	41.5	34.0
6	*	224	43.5	29.0
7	404	251	42.5	31.0
8	435	255	43.2	31.1
9	345	245	39.5	29.1
10	*	226	42.4	29.0
11	340	242	44.0	29.4
12	*	258	41.9	29.5
13	321	197	42.0	28.2
14	422	265	42.0	29.0
15	335	238	42.6	30.0
$\overline{X}$	369	239	42.0	30.0

*Individuals partially eaten.

Table 20. Estimated puffin populations (pairs) in the Barren Islands, Alaska, 1976-1977.

Species	Ushagat	Nord	Sud	Carl	Sugarloaf	East Amatuli	West Amatuli	Source
Horned Puffin	150	—[1]	175	—[1]	400	5,035	750	This study
	125	20	200	20	300	6,500	6,500	Bailey 1976
Tufted Puffin	50	—	750	—	6,000	48,500	40,000	This study
	50	2,500	500	500	4,750	47,500	46,500	Bailey 1976

[1] Island not visited.

Table 21. Different habitat types and respective burrow densities for the Tufted Puffin on East Amatuli Island, Alaska, 1977.

Habitat type	Aspect	Slope	Dominant vegetation[1]	Average soil depth (cm)	Altitude (m)	Rock surface (%)	Relative relief[2]	Density Number of burrows/m^2
Steep slope	130° SE	58°-80°	He la An lu El mo	40.7	110	20	3	0.68
Cliff edge	280° W	90°	El mo An lu Carex	39.0	35	2	2	0.65
Rock talus	220° S	35°-37° Near cliff edge	An lu moss Festuca	23.0	354	65	3	0.50
Steep slope	150° SE	45°-50°	He la El mo	34.7	124	2	2	0.42
Rock talus	10° N	32°	An lu moss Festuca		408	75	3	0.38
Steep slope	130° SE	47°-55°	He la An lu El mo Festuca	41.0	92	10	2	0.35
Gradual slope	160° SE	36°-46°	El mo He la An lu	43.0	82	5	1	0.33

Table 21. (Continued)

Habitat type	Aspect	Slope	Dominant vegetation[1]	Average soil depth (cm)	Altitude (m)	Rock surface (%)	Relative relief[2]	Density Number of burrows/m^2
Gradual slope	10° N	32°-42°	An lu He la El mo Festuca	30.0	98	50	3	0.17
Cliff edge	210° S	34°-37°	El mo Festuca He la	28.0	49	0	0	0.15
Gradual slope	250° SW	35°-40°	El mo He la An lu	27.8	76	0	0	0.13
Gradual slope	130° SE	30°-34°	Em ni He la An lu	22	79	5	2	0.07

[1]Vegetation key as follows:

He la = *Heraculum lanatum*
An lu = *Angelica lucida*
El mo = *Elymus mollis*
Em ni = *Empetrum nigrum*

[2]Relief scale as follows:

0 = uniform terrain; no grass hummocks, rocks, etc.
1 = slight relief; rocks and hummocks to 0.3 m high.
2 = moderate relief; 50% area or less with rocks and hummocks 0.3-3.6 m high.
3 = extreme relief; >50% area interspersed with rocks and hummocks 0.3-1.0+ m high.

Table 22. Mean weights and dimensions of Puffin eggs on East Amatuli Island, Alaska, 1976 and 1977.

Year	Sample size	Mean egg weight (g)	Sample size	Mean egg dimensions (mm)
		Horned Puffin		
1976	3	74.8 (73.5-76)	5	66.7 x 45.6
1977	5	76.2 (68-88)	5	66.0 x 44.8
		Tufted Puffin		
1976	32	92.8 (84-107)	51	73.1 x 48.4
1977	12	95.1 (86-106)	11	72.8 x 48.9

[1]Range in parenthesis.

Table 23. Temperatures of fully developed brood patches compared to body and egg temperatures in incubating puffins.

Species	Mean brood patch dimensions (mm)	Mean brood patch temperature (C°)	Mean body temperature (C°)	Mean attended	Mean unattended	Source
Horned puffin	55 x 27(4)[2]	38.0(3)	40.1(3)			Sealy 1973a
	51 x 23(1)	38.5(1)		26.2(3)	15.0(3)	This study
Tufted puffin		38.2(1)	40.0(1)			Sealy 1973a
	56 x 24(5)	39.1(5)	41.0(2)	34.3(3)	11.2(3)	This study

[1]Esophageal temperature.

[2]Sample size in parenthesis.

Table 24. Approximate egg weight loss during an artificial incubation experiment.

Egg number	Starting weight (g)	Ending weight (g)	Total weight loss (%)	Weight loss (5)	Length of time (days)
1	100	78	22	22	4
2	86	69	17	19.7	3
3	92	74.5	17.5	19.0	3
4	95	79	16	16.8	3
5	102	89	13	12.7	2
Mean	95	78	17	18.0	3

*Eggs 1 and 5 were infertile.

Table 25. Species of fish brought to puffin chicks on East Amatuli Island, Alaska, July-August 1977.

Species	Number	Total (%)	Number loads	Frequency occurrence
		Tufted Puffin		
Mallotus villosus (Capelin)	86	57.0	33	62.3
Ammodytes hexapterus (Sand Lance)	46	30.3	14	26.4
Gadus macrocephalus (Pacific Cod)	9	6.0	3	5.7
Hexagrammos decagrammus (Kelp Greenling)	4	3.0	1	1.8
Squid (unidentified)	4	3.0	1	1.8
Trichodon trichodon (Pacific Sandfish)	1	0.7	1	1.8
TOTAL	150	100.0	53	99.8
		Horned Puffin		
Ammodytes hexapterus	30	51.7	8	38.1
Mallotus villosus	26	44.8	11	52.4
Gadus macrocephalus	1	1.7	1	4.7
Trichodon trichodon	1	1.7	1	4.7
TOTAL	58	99.9	21	99.9

Table 26. Species of fish brought to puffin nestlings on East Amatuli Island, Alaska, in 1976 and 1977.

Species	1976 Number	1976 Total (%)	1977 Number	1977 Total (%)
Tufted Puffin				
Mallotus villosus (Capelin)	104	94.5	86	57.0
Ammodytes hexapterus (Sand Lance)			46	30.3
Gadus macrocephalus (Pacific Cod)			9	6.0
Hexagrammos decagrammus (Kelp Greenling)			4	3.0
Squid (unidentified)	4	3.6	4	3.0
Trichodon trichodon (Pacific Sandfish)			1	0.7
Zaprora silenus (Prowfish)	2	1.8		
TOTAL	110	99.9	150	100.0
Horned puffin				
Ammodytes hexapterus (Sand Lance)	3	15.8	30	51.7
Mallotus villosus (Capelin)	14	73.7	26	44.8
Gadus macrocephalus (Pacific Cod)			1	1.7
Trichodon trichodon (Pacific Sandfish)	1	5.2	1	1.7
Hexagrammos stelleri (White-spotted Greenling)	1	5.2		
TOTAL	19	99.9	58	99.9

Table 27. Number of fish per delivery and average weight of puffin bill loads collected August 4-September 1, 1976, and July 21-August 21, 1977.

Species	Year	Number of full loads	Average No. fish/delivery	Number of full loads	Average weight per load (g)
Tufted Puffin	1976	79	3.8 range 1-8	24	14.9 range 2-36.5
	1977	58	3.4 range 1-8	28	20.4 range 9-35.0
Horned Puffin	1976	26	1.5 range 1-3[1]	9	10.7 range 3-19.0[2]
	1977	20	3.2 range 1-7	13	17.0 range 3-35.0

[1]Statistically significant difference between species in 1976 ($P < 0.01$, $t = 7.10$). Difference between species not significantly different in 1977 ($P < 0.05$).

[2]Difference between species not significantly different either 1976 or 1977 ($P < 0.05$).

Table 28. Weight and body measurements of puffin chicks at hatching and just prior to fledging.

Species	Weight (g)	Wing length (mm)	Culmen (mm)	Tarsus (mm)	Sample size
Tufted Puffin (within 36 hours of hatching)	68	25.3	22	26.6	23
Fledging[1]	550	152.2	39.2	44.3	10
Horned Puffin	55	23.7	18.4	25.6	7
Fledging	414	155	31.5	40	2

[1]Fledging = departure from the nest and in most cases measurements were made the day of departure.

Table 29. A comparison of specific growth parameters for Tufted and Horned Puffin nestlings on East Amatuli Island, Alaska, 1976 and 1977.

Year	Asymptote A	Adult weight W	$R = \frac{A}{W}$	Fledging weight FW	$\frac{FW}{W}$ (%)	K	$\frac{KA}{4}$ (g/day)	$\frac{KR}{4} \times 100$ (%/day)	t_{10-90} (days)
				Tufted Puffin					
1976	600	784	0.765	550	70.2	0.111	16.7	2.14	39.3
1977	595	784	0.758	550	70.2	0.110	16.3	2.08	40.1
				Horned Puffin					
1976	440	600	0.733	414	69.0	0.122	13.4	2.24	35.9
1977	445	600	0.742	414	69.0	0.114	12.7	2.12	38.4

Table 30. Breeding success of the Tufted and Horned Puffins on East Amatuli Island, 1976 and 1977.

Year	Number of nest sites	Percent with eggs	Percent eggs deserted	Percent hatched	Percent chicks deserted	Percent fledged[1]	Percent success[2]
			Tufted Puffin				
1976	85	47	60	40	13	69	28
1977	100	56	50	50	14	79	39
			Horned Puffin				
1976	14	100	21	79	9	36	29
1977	22	64	7	93	8	69	64

[1]Percent of nestlings that fledged.

[2]Overall success in the percent of eggs successful to fledgling.

Table 31. Fate of Tufted and Horned Puffin nestlings on East Amatuli Island in 1976 and 1977.

Year	Sample size	Number fledged	Number disappeared	Number deserted	Storm mortality
			Tufted Puffin		
1976	16	11	1	2	2
1977	39	31	2	4	2
			Horned Puffin		
1976	11	4	1	1	5
1977	13	9	2	1	1

Table 32. Hatching success of Common Murres on East Amatuli Lighthouse, 1977.

No. of chicks	No. of eggs	No. of dead chicks	No. disappeared	Hatching success (%)
109	35	5	93	47-60

Table 33. Summary of Peregrine predation on East Amatuli Island in 1977.

Adult Tufted Puffin	Juvenile Glaucous-winged Gull	Adult Storm Petrel	Adult Black-legged Kittiwake
13	6	5	1

Table 34. Summary of River Otter predation on East Amatuli Island in 1976 and 1977.

Species		Number of carcasses	Total (%)	Number of carcasses	Total (%)
Fork-tailed Storm Petrel	(adult)	75	76	62	57.0
	(juvenile)			9	8.3
	(egg)			11	10.1
Tufted Puffin	(adult)	3	3	5	4.5
	(juvenile)	10	10	5	4.5
Pelagic Cormorant	(juvenile)			3	2.8
	(egg)			2	1.8
Isopod (unidentified)				3	2.8
Parakeet Auklet	(adult)	1	1	2	1.8
Horned Puffin	(adult)	1	1	2	1.8
Glaucous-winged Gull	(adult)	1	1	1	0.9
	(juvenile)	2	2	1	0.9
Pleuronectid (Flatfish)		2	2		
Hexagrammos superciliosus (Rock Greenling)		2	2		
Black-legged Kittiwake	(juvenile)	1	1		
Shoveler	(adult)			1	0.9
Black Oystercatcher	(juvenile)			1	0.9
Dermasterius imbricata (Starfish)		1	1	1	0.9
TOTAL		99	100	109	99.9

Table 35. Incidence of tar balls on West and East Amatuli Islands during the summer of 1977.

Date (1977)	No. balls	Total weight[1] (g)
10 July	23	29
13 July	27	47
21 July	81	48
31 July	25	33
Total	156	157

[1]Size range 0.4-3.0 cm.

Figures 1 and 2 have been omitted.

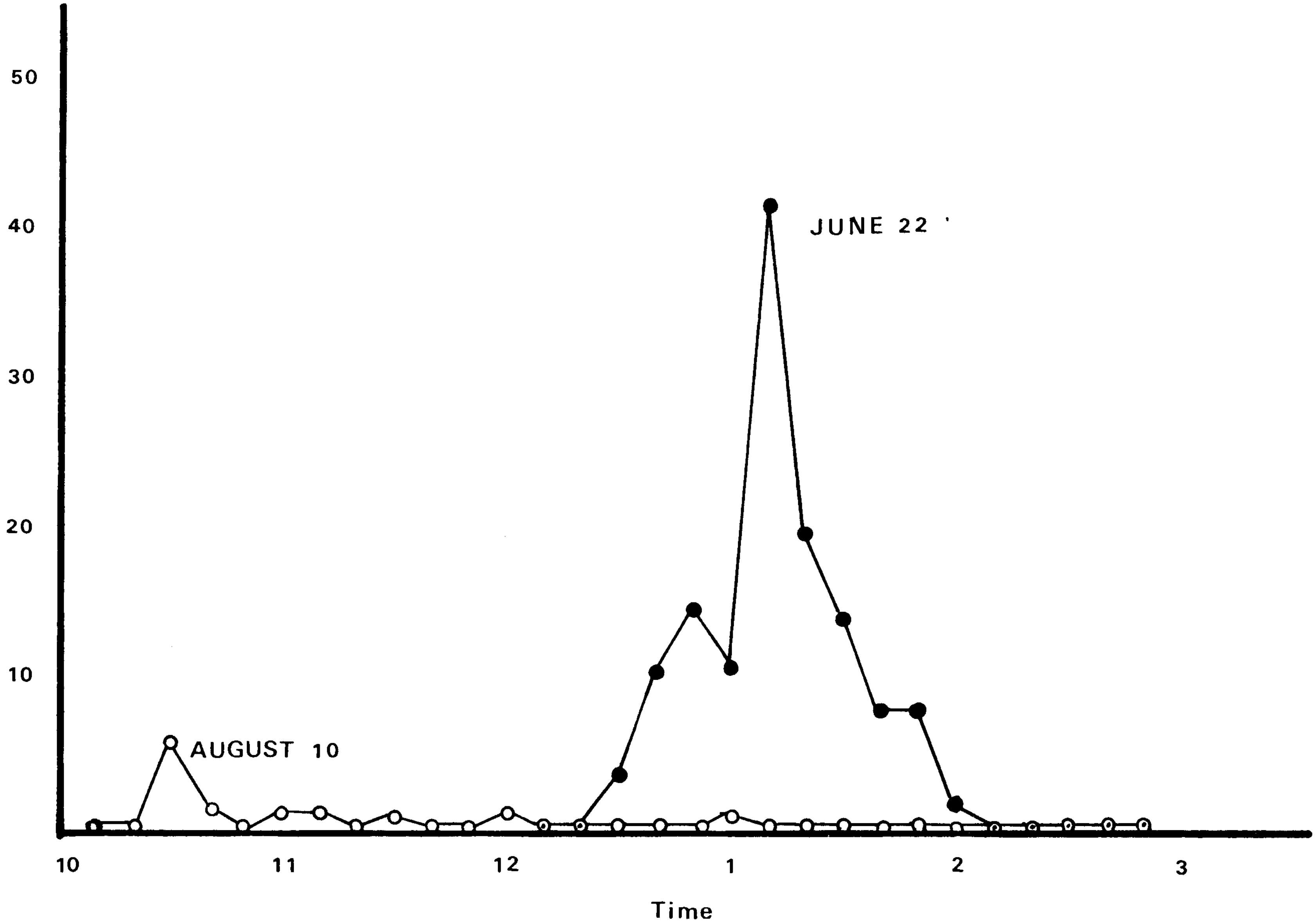


Figure 3. One minute aerial counts of flying storm petrels on 22 June and 10 August 1977.

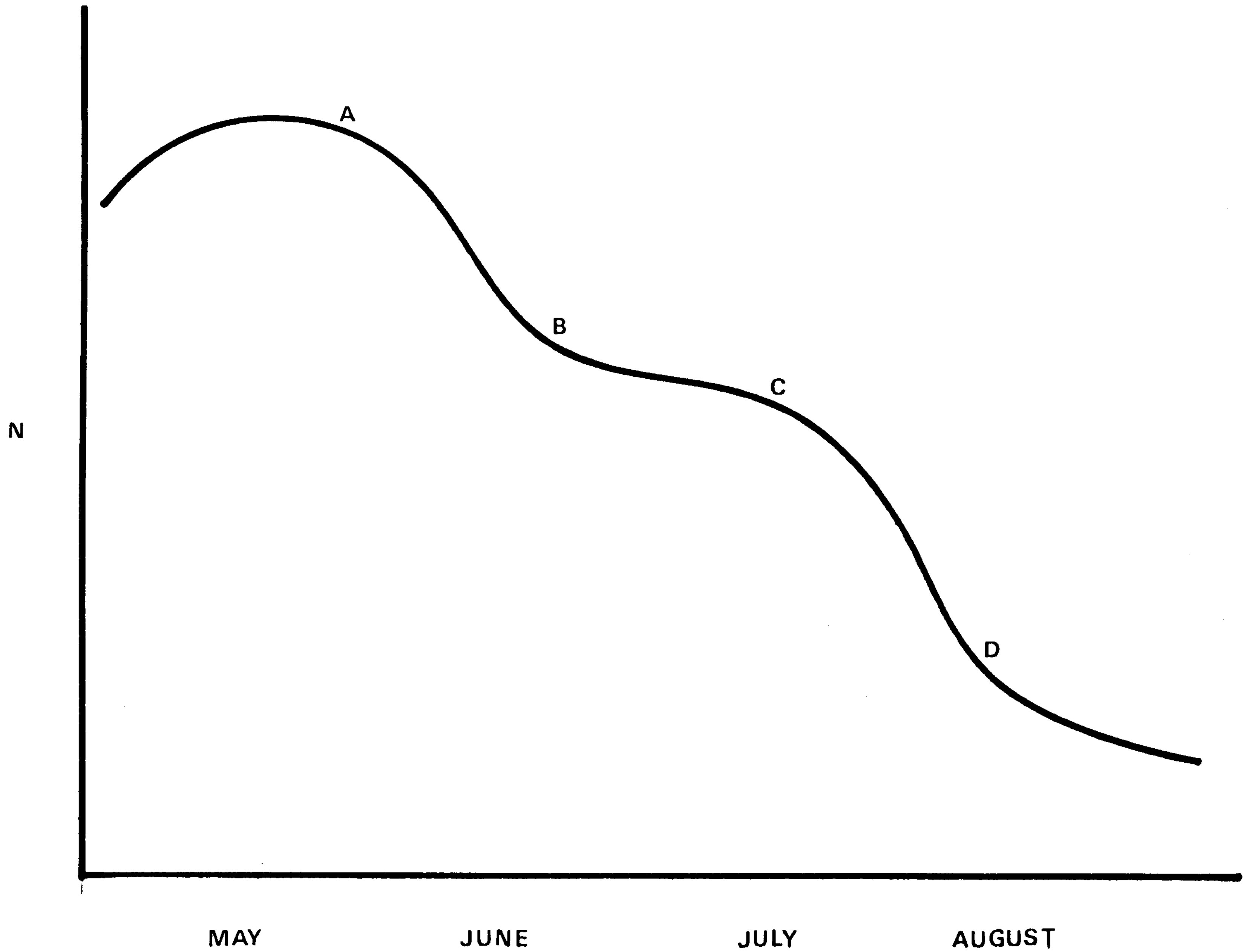


Figure 4. Hypothetical model of colony attendance by storm petrels.

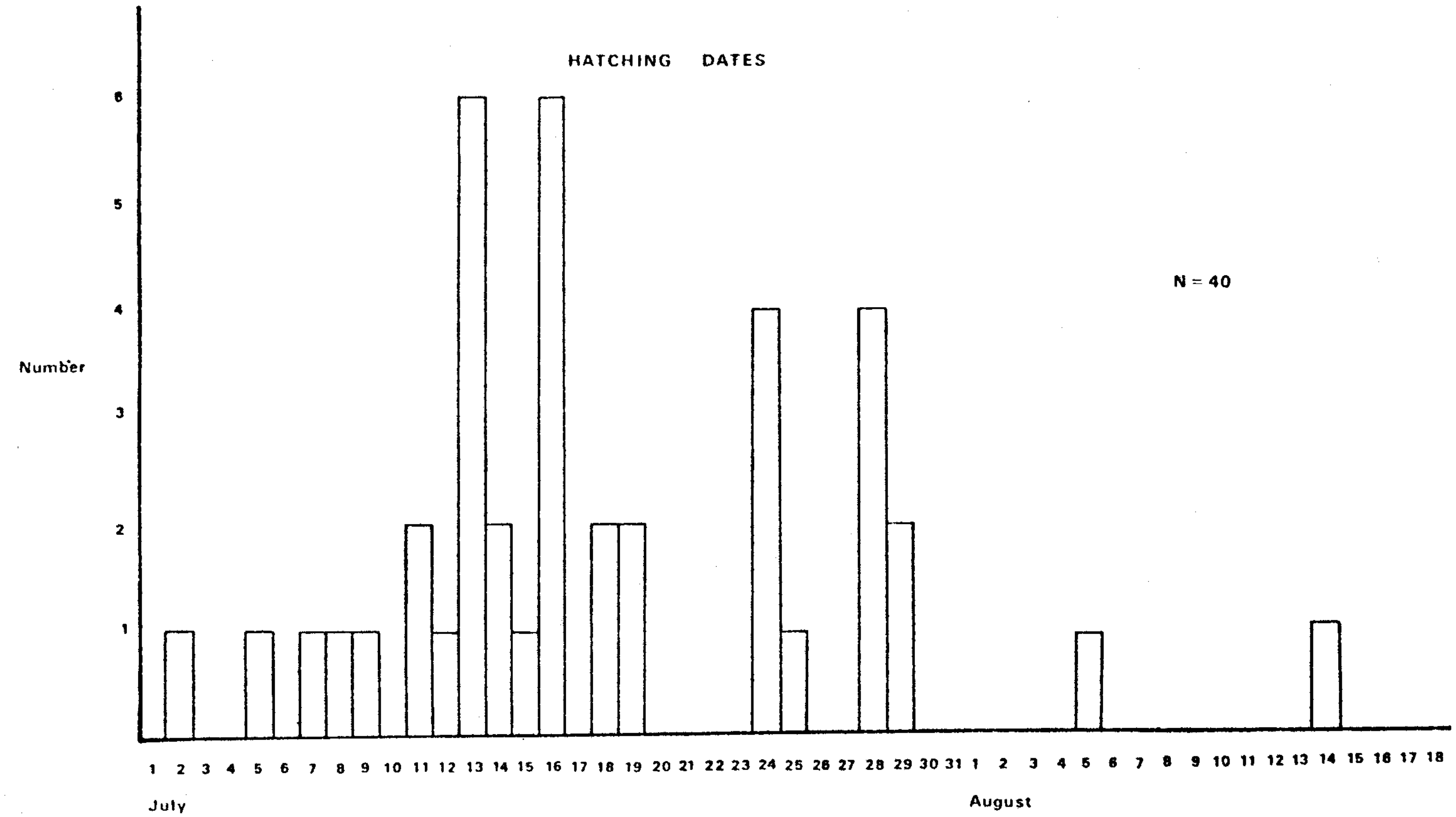


Figure 5. Hatching dates for storm petrels during 1977.

May 27	28	29	30	31	June 1	2	3	4	5	6	7	8	9	10	11	12	13
- †	?	?	A	A	B	B	B	B	A	A	B	B	B	B	A	A	A

14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	July 1
-	-	B	B	B	A	A	A	B	B	B	B	B	-	-	A	B	B

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
B	A	A	A	-	-	-	B	B	-	A ǂ	B	B	A	B	-	*	*
															11	15	15

20	21	22	23	24	25	26	27	28	29	30	31	August 1	2	3	4	5	6
*	*	* *	-	*	*	-	*	*	*	*	*	-	*	-	*	*	*
17	24	26	22	24	27	24	32	39	43	42	44	38	47	36	40	48	51

chick weight (gms)

7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
*	*	*	*	*	* *	-	-	*	-	* *	-	*	-	*	* *	-	*
53	51	52	55	59	68	62	52	56	51	58	52	67	57	66	88	75	92

† egg laid

ǂ egg hatched

* single visitation on preceeding night

* * double visitation

A adult A

B adult B

— burrow not entered or cold egg

? unknown adult present

Figure 6. Event recorder data for storm petrel pair number1.

May					June												
27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13
*	*	*	*	*	*	*	A	-	B	B	B	A	A	A	B	B	B
							†										

																	July
14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1
A	A	A	A	-	B	B	B	A	A	-	-	B	B	B	A	A	A

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
A	B	B	B	-	A	A	A	A	A	B	-	-	-	A	A	B	B

												August					
20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6
-	B	A	B	A	A	-	B	*	*	-	-	*	*	*	*	-	* *
				‡		13		15	18	17	16	20	23	25	26	24	39

chick weight (gms)

7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
-	*	*	-	*	* *	-	*	-	-	* *	-	*	*	-	* *	-	* *
31	35	39	33	36	46	39	40	36	31	51	45	52	54	48	67	65	88

† egg laid

‡ egg hatched

* single visitation on preceeding night

* * double visitation

A adult A

B adult B

— burrow not entered or cold egg

? unknown adult present

Figure 7. Event recorder data for storm petrel pair number 2.

May					June												
27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13
*	-	-	-	-	*	*	A †	-	B	B	B	-	-	A	A	A	A

																	July
14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1
B	B	B	-	A	A	A	A	-	B	B	B	B	A	A	A	-	B

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
B	B	B	-	A	A	A	B	B	A	A	A	-	B	B	A	A	A

												August					
20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6
B	B	A	A	B	*	*	*	*	*	*	* *	*	*	_	*	*	_
				‡	10	16	19	19	21	22	23	32	27	32	28	29	36

chick weight (gms)

7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
-	-	*	_	_	*	*	_	_	*	*	*	_	*	_	* *	*	* *
31	28	38	31	29	37	41	36	35	42	46	55	48	45	43	72	73	95

† egg laid

‡ egg hatched

* single visitation on preceeding night

⁑ double visitation

A adult A

B adult B

— burrow not entered or cold egg

? unknown adult present

Figure 8. Event recorder data for storm petrel pair number 3.

May					June												
27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13
–	–	*	–	*	*	*	*	*	*	A	–	A	B	B	B	–	A
										†							

																	July
14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1
A	B	–	–	–	A	A	B	B	A	A	A	B	–	–	A	B	B

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
A	A	A	A	–	–	–	B	B	A	A	A	A	B	B	B	–	A

												August					
20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6
A	B	B	B	–	A	A	B	A	A	B	B	*	B	*	*	–	*
									‡			15		19	21	18	26

7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
*	–	*	–	*	–	–	*	–	* *	–	*	*	–	*	*	*	–
26	23	30	25	40	32	30	36	32	48	41	49	49	44	52	58	61	56

chick weight (gms)

- † egg laid
- ‡ egg hatched
- * single visitation on preceeding night
- * * double visitation
- A adult A
- B adult B
- – burrow not entered or cold egg
- ? unknown adult present

Figure 9. Event recorder data for storm petrel pair number 4.

May					June												
27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13
*	–	–	*	?	–	*	*	*	?	–	–	–	A B	–	–	–	?

																	July
14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1
–	?	–	A †	–	–	–	–	B	B	B	–	–	A	A	B	B	B

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
–	–	–	A	B	B	B	–	A	A	A	B	B	B	A	A	A	A

												August					
20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6
B	B	–	–	–	B	B	B	B	A	–	B	B	A	–	B	B	A

7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
A	B	B	–	–	A	B	B ‡	A	B	–	–	*	*	*	–	* *	–
										13	11	14	16	19	17	28	25

chick weight (gms)

† egg laid
‡ egg hatched
* single visitation on preceeding night
** double visitation
A adult A
B adult B
– burrow not entered or cold egg
? unknown adult present

Figure 10. Event recorder data for storm petrel pair number 5.

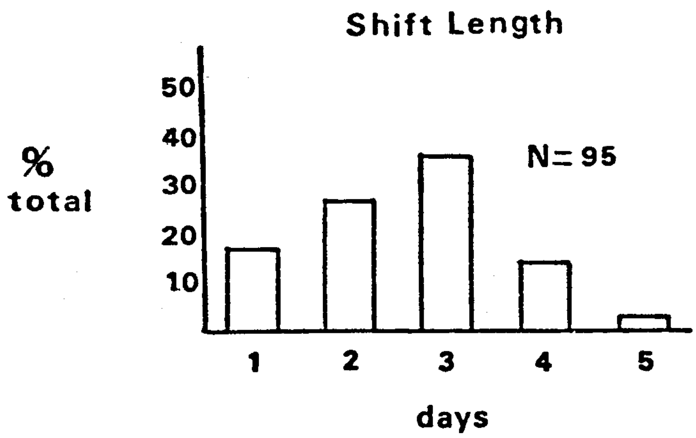


Figure 11. Incubation shifts of Fork-tailed Storm Petrels.

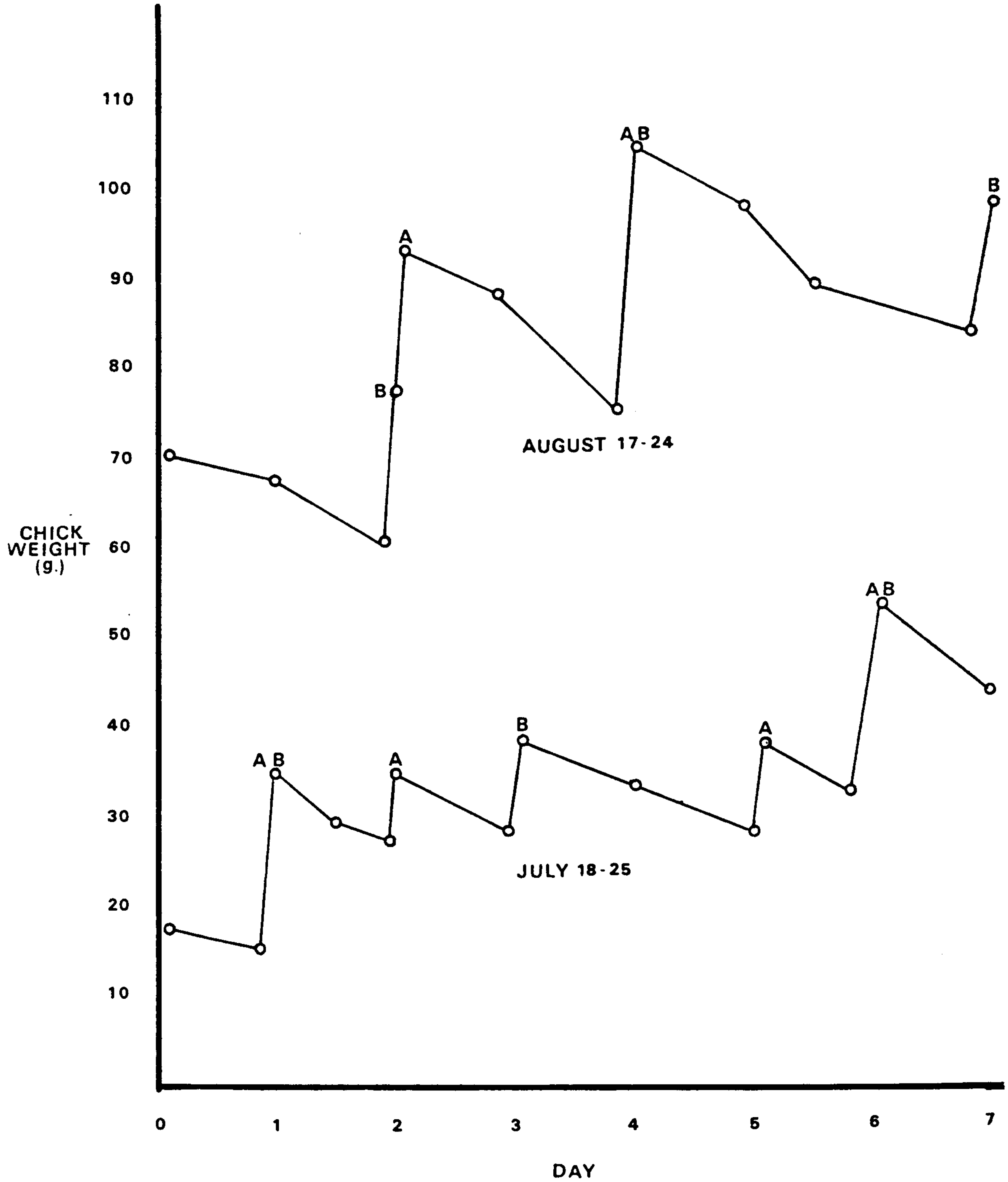


Figure 12. Chick feeding patterns early and late in the nestling phase. A indicates adult A; B indicates adult B.

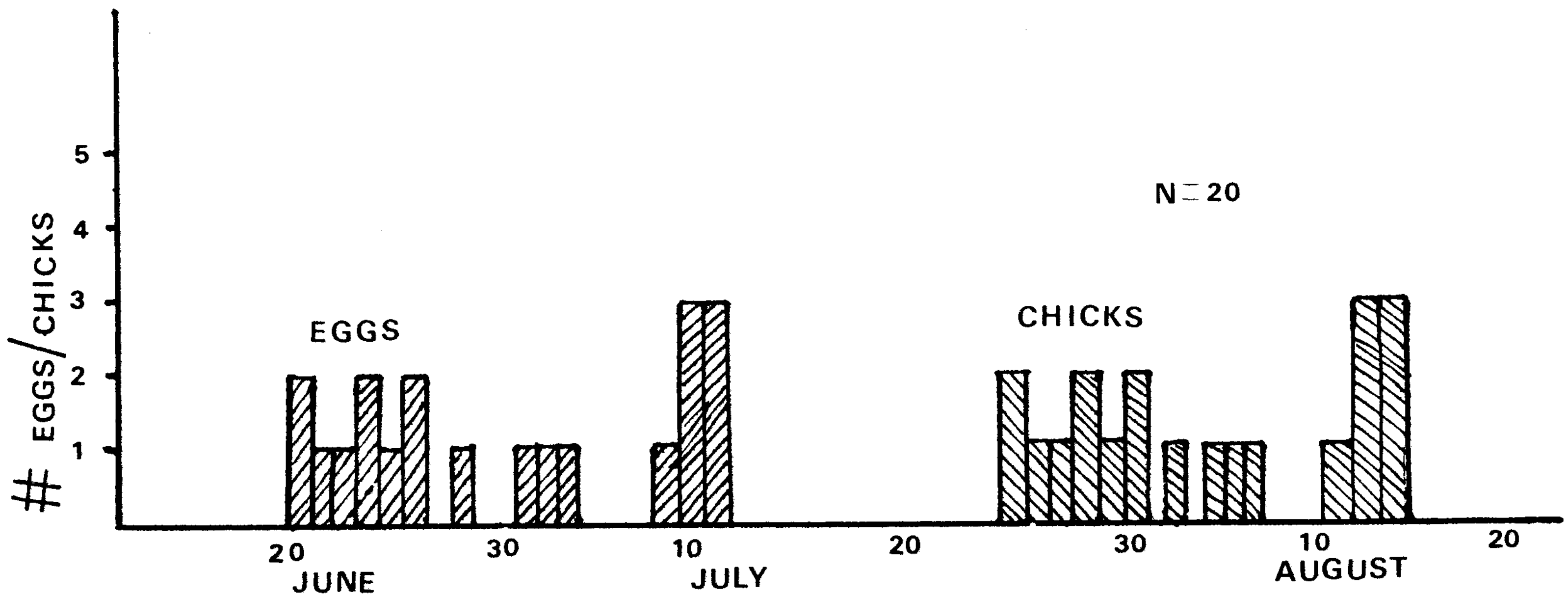


Figure 13. Phenology of egg-laying and hatching of Fork-tailed Storm Petrels.

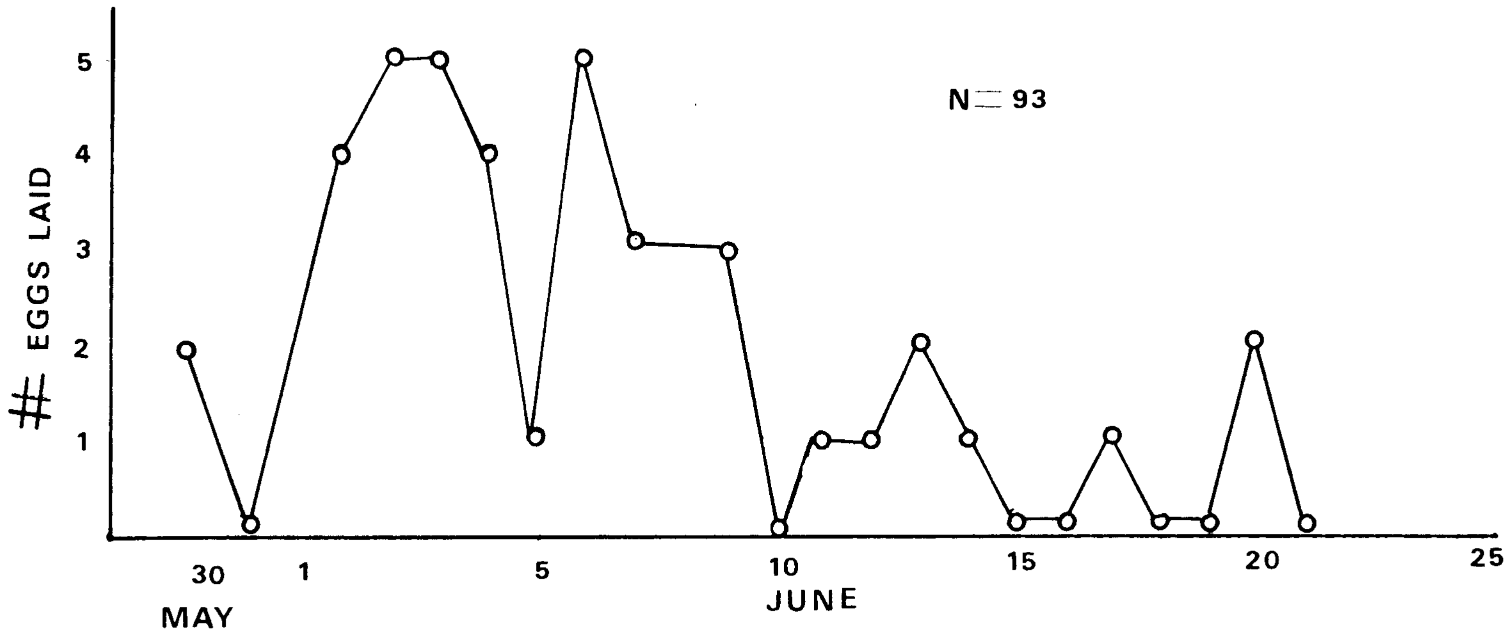


Figure 14. Egg Laying, Fork-tailed Storm Petrel. Barren Islands 1977.

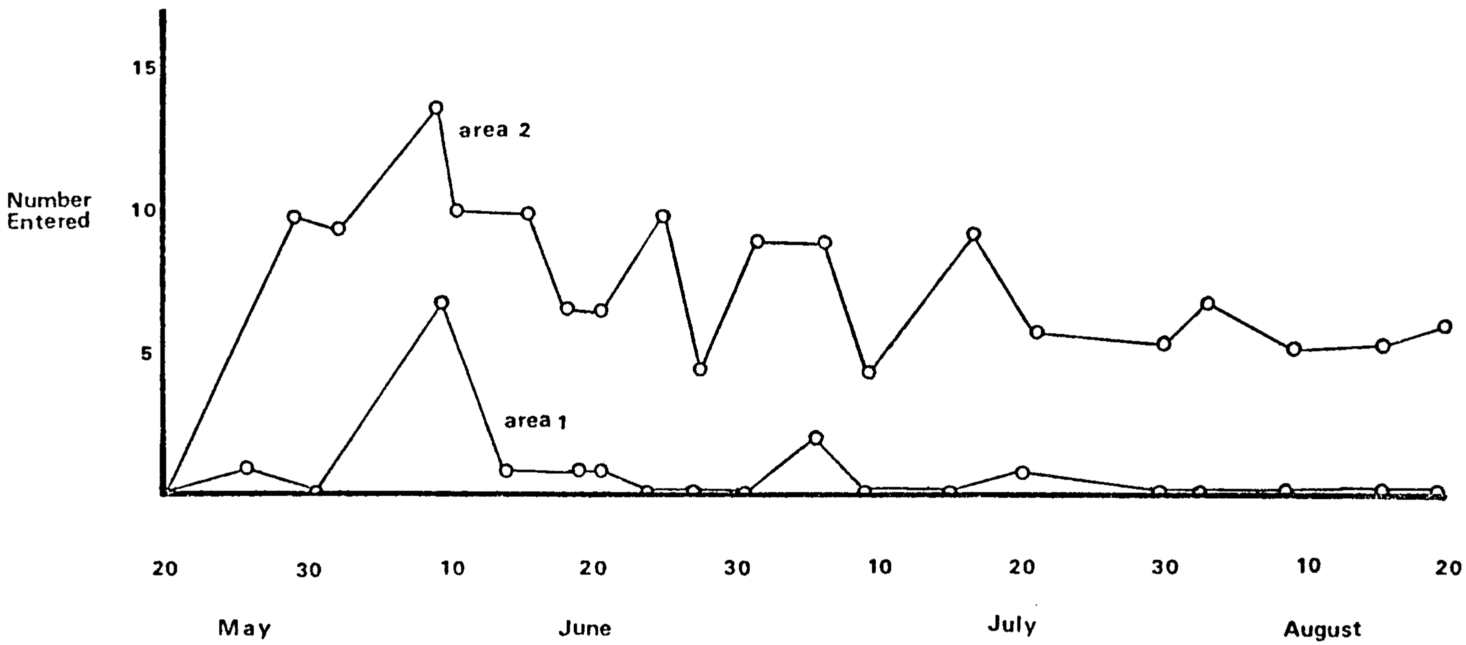


Figure 15. Nest box attendance by storm petrels.

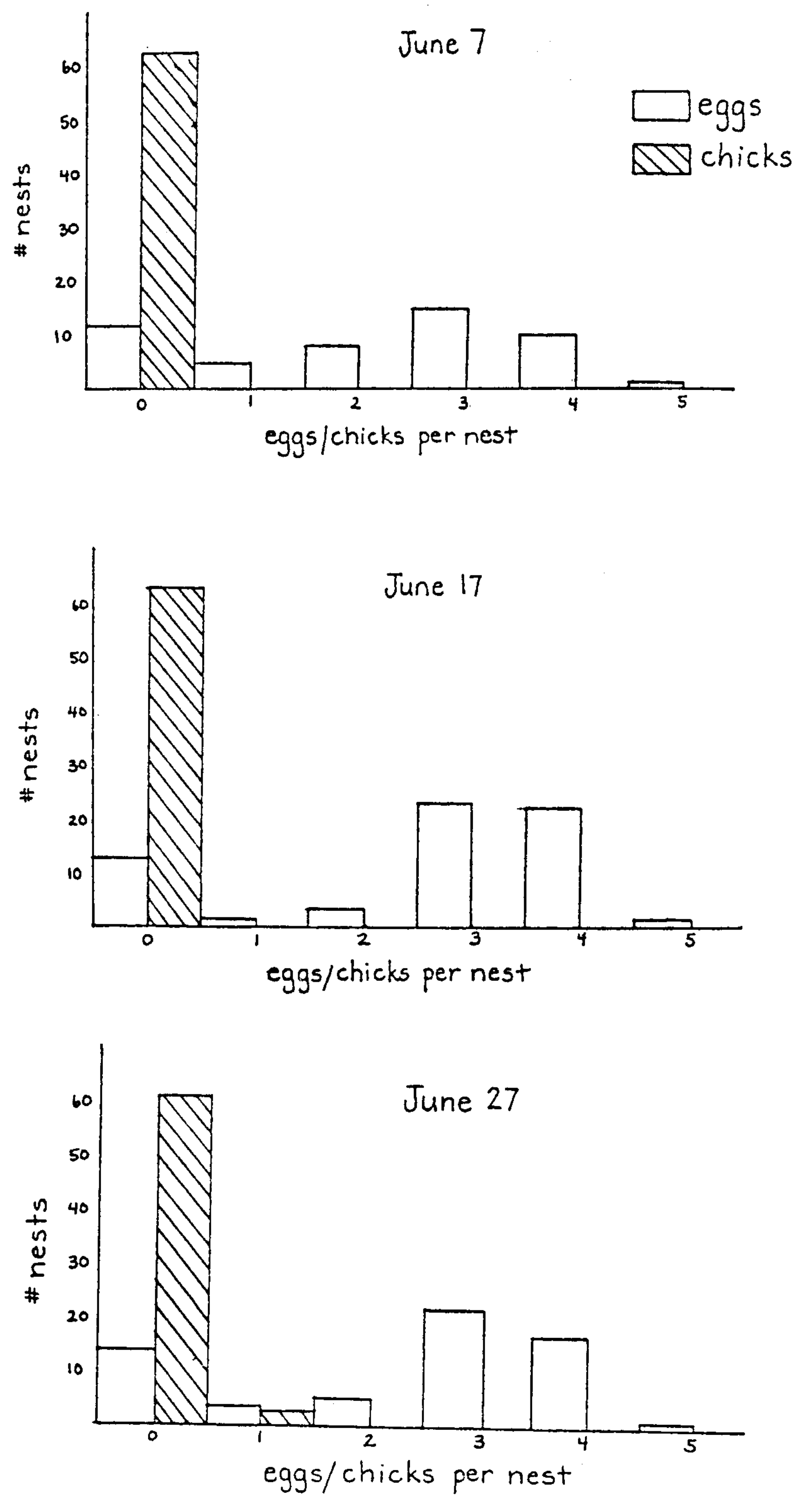


Figure 16. Breeding status of Pelagic Cormorant nests on East Amatuli Island on 7, 17 and 27 June 1977.

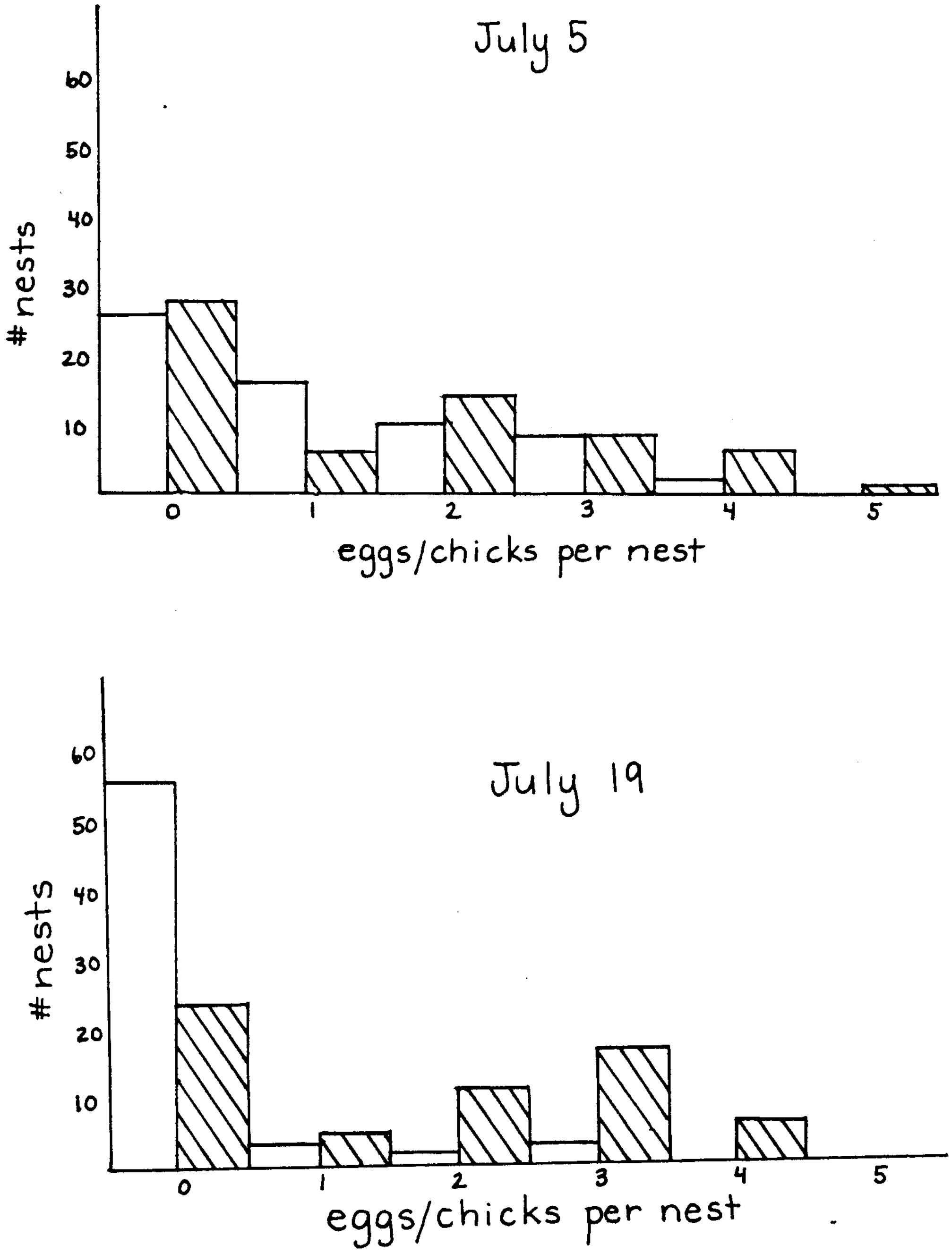


Figure 17. Breeding status of Pelagic Cormorant nests on East Amatuli Island on 5 and 19 July 1977.

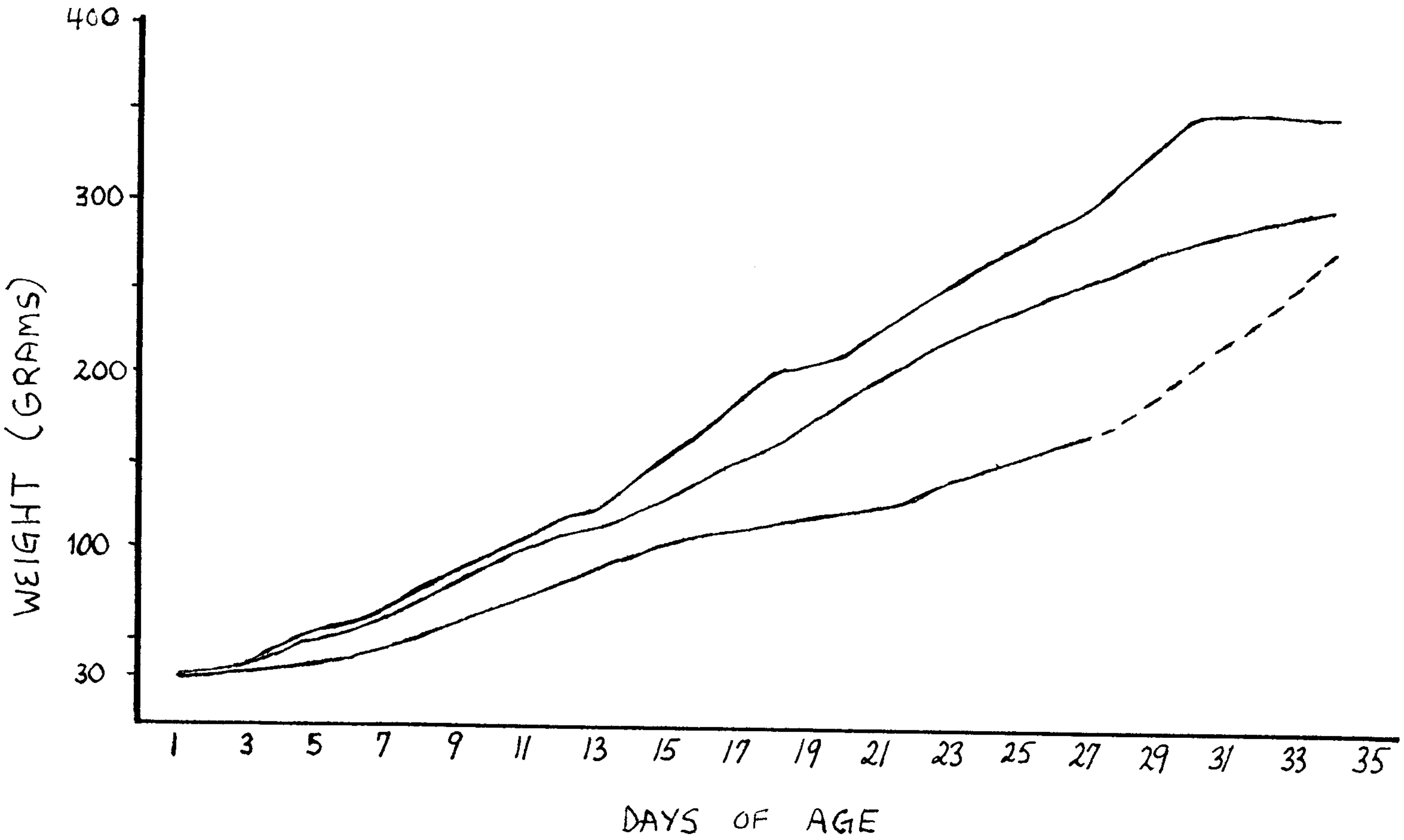


Figure 17a. Growth of three Black Oystercatcher Nestlings on East Amatuli Island in 1977.

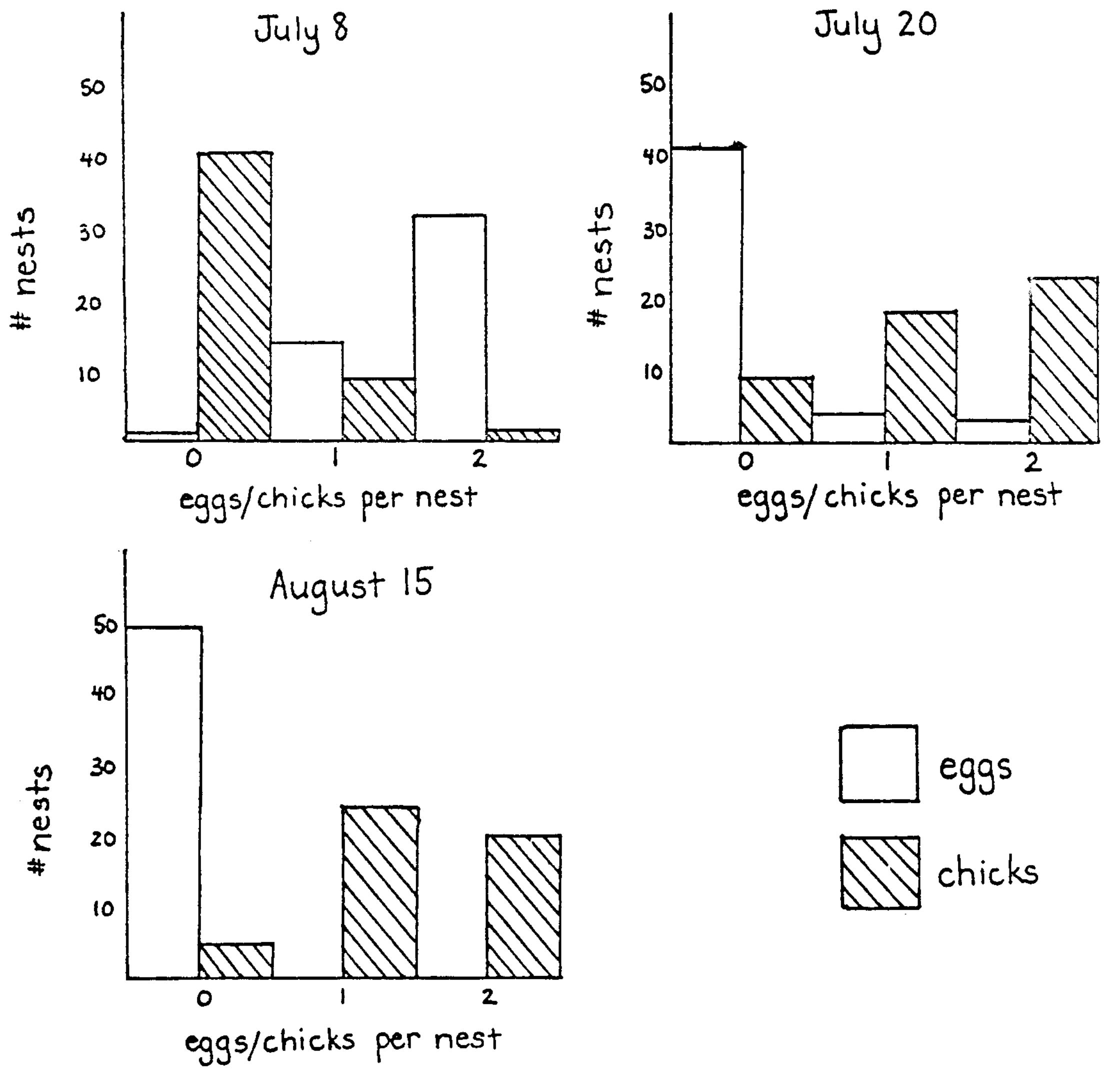
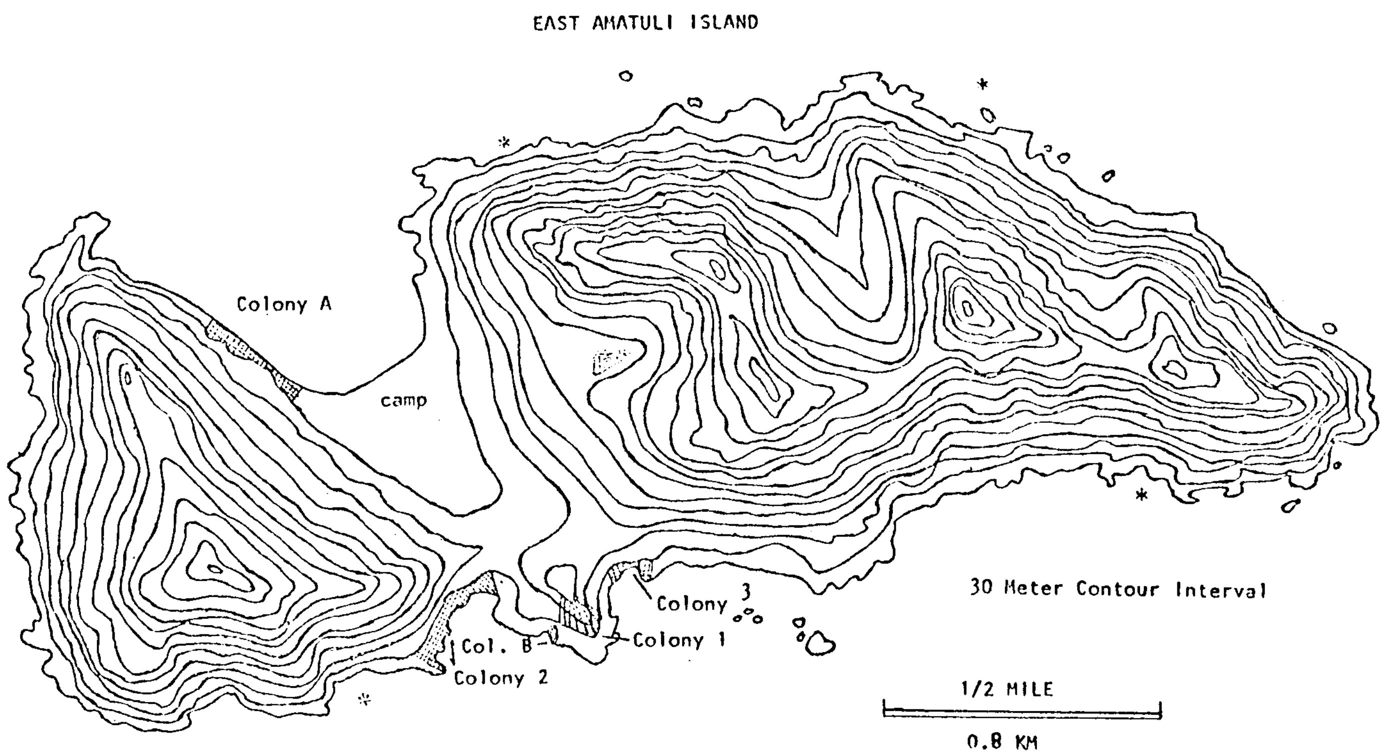


Figure 18. Contents of kittiwake nests on 8 and 20 July and 15 August.



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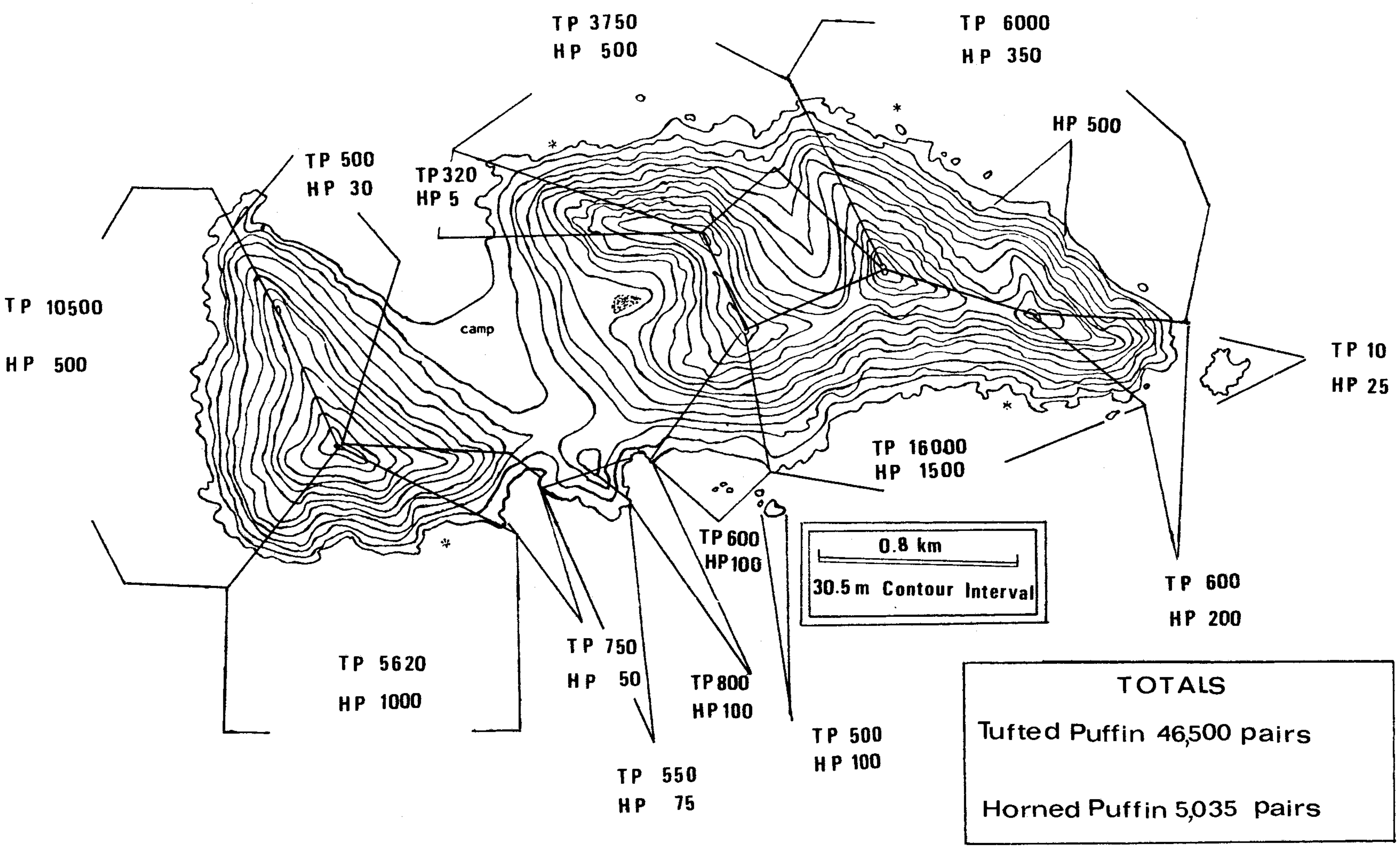
EAST AMATULI ISLAND



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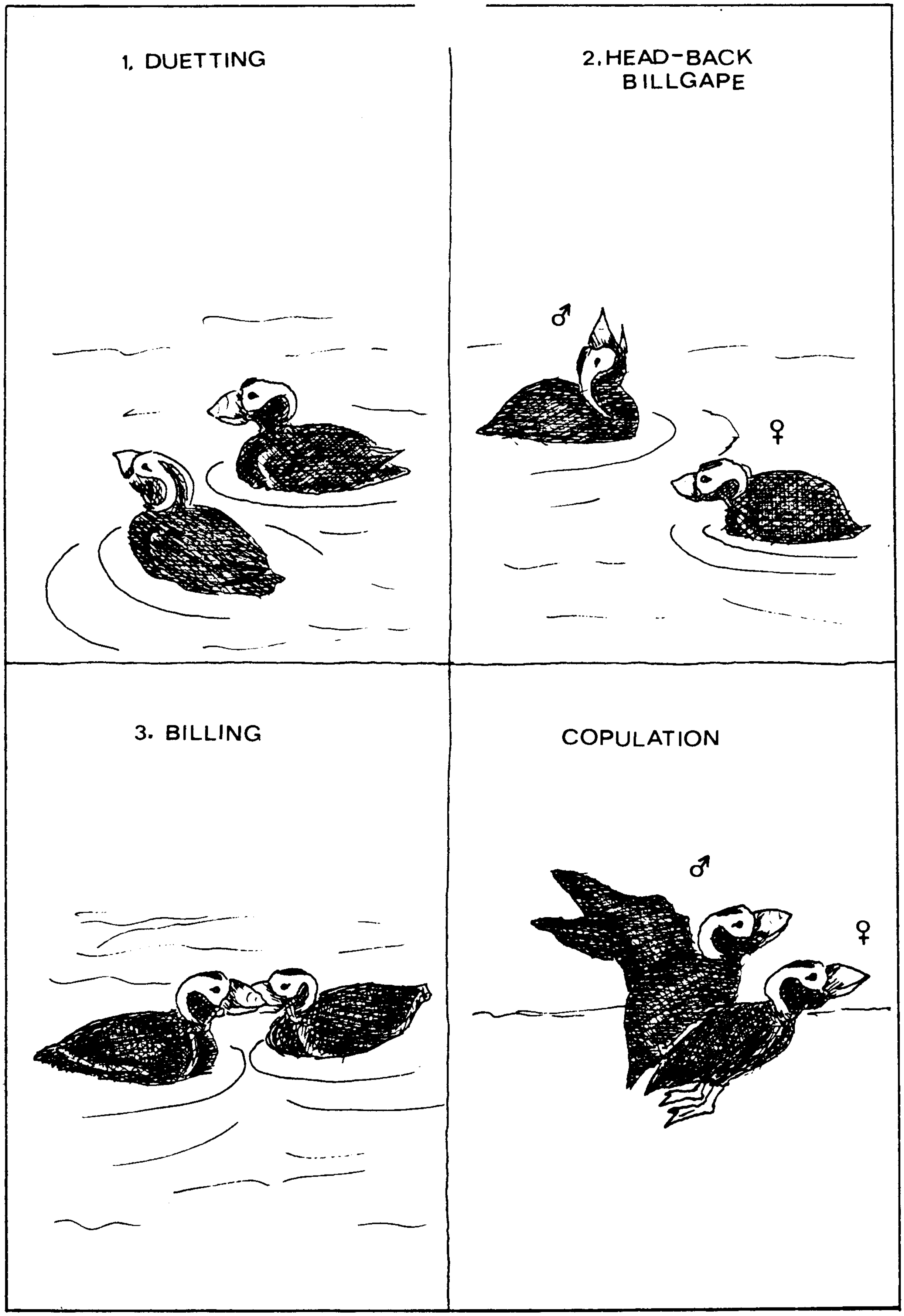

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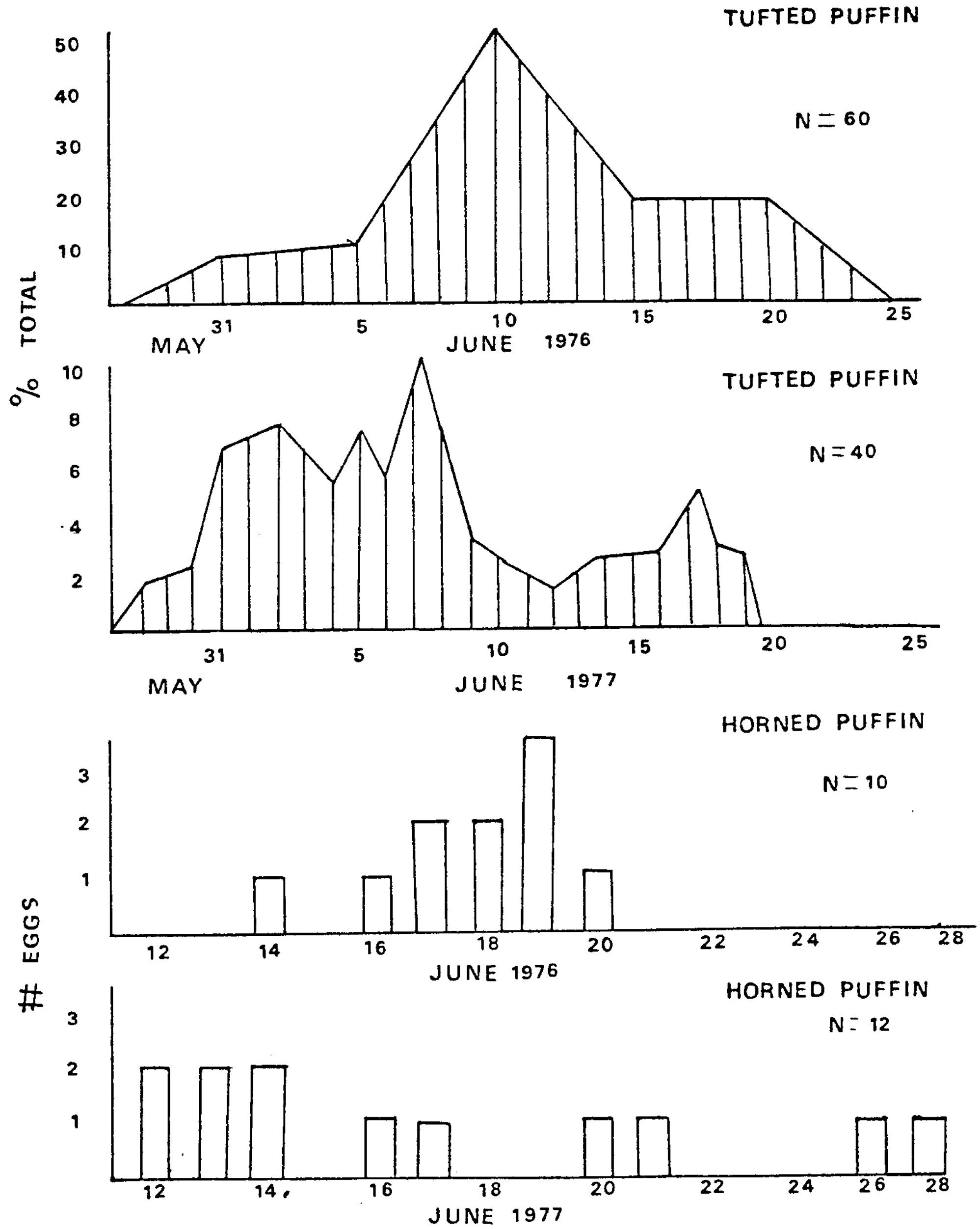

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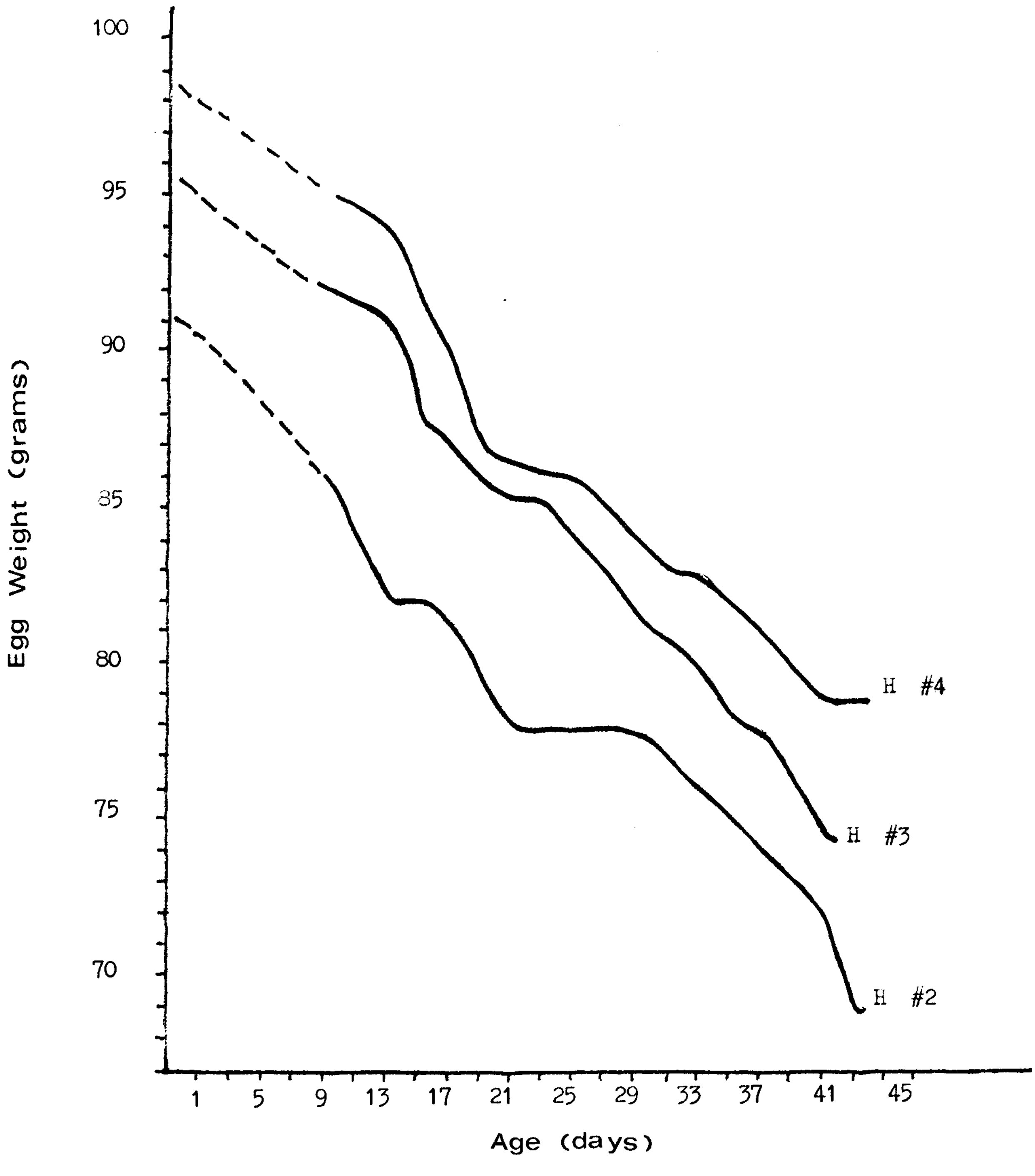

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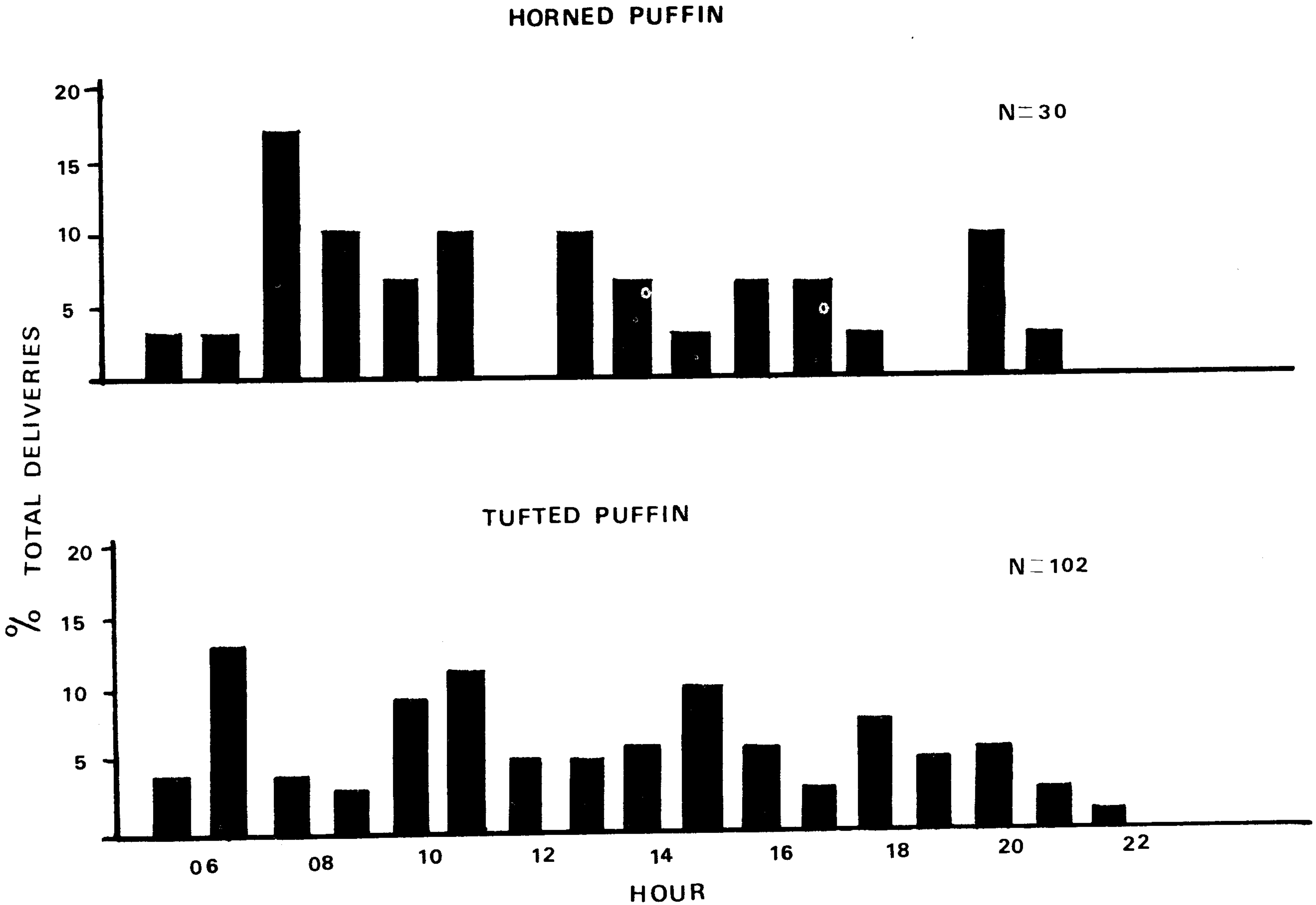

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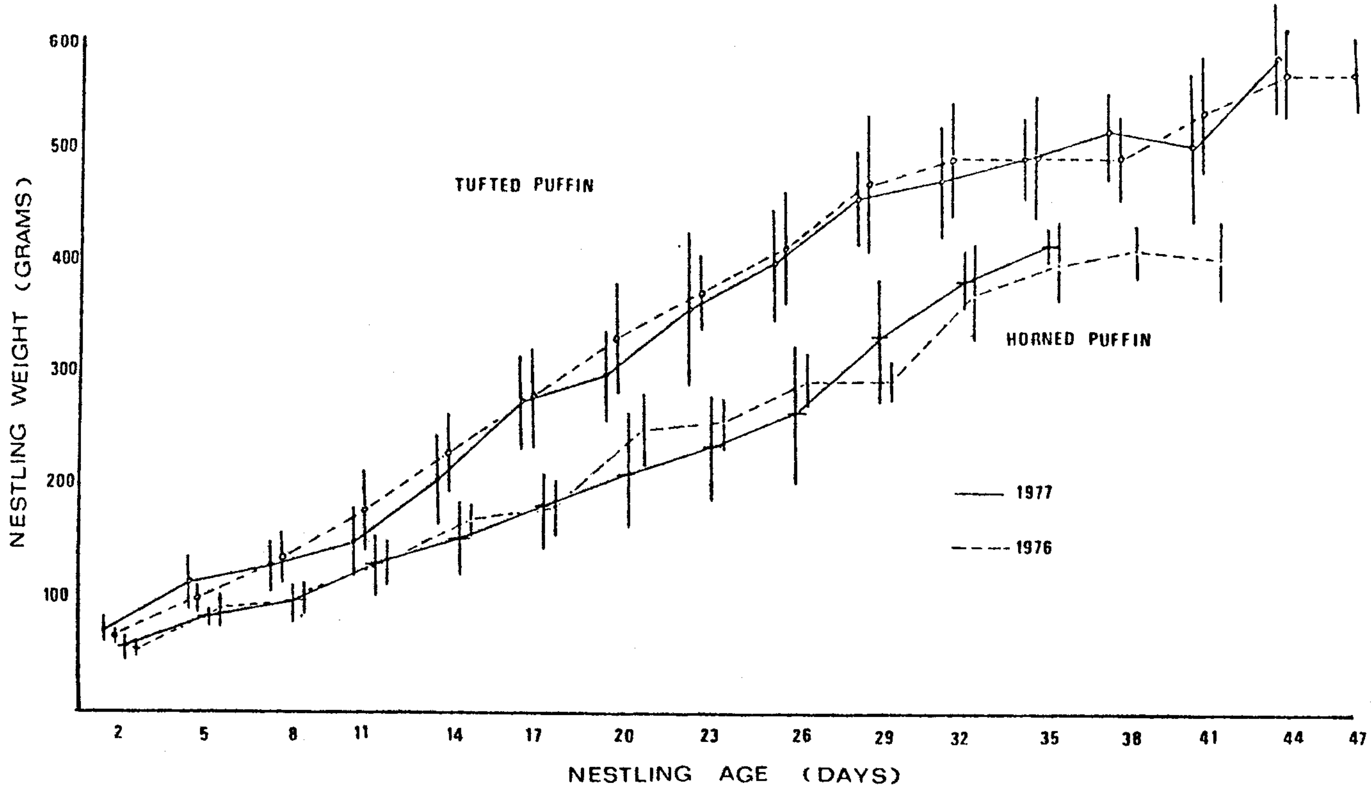

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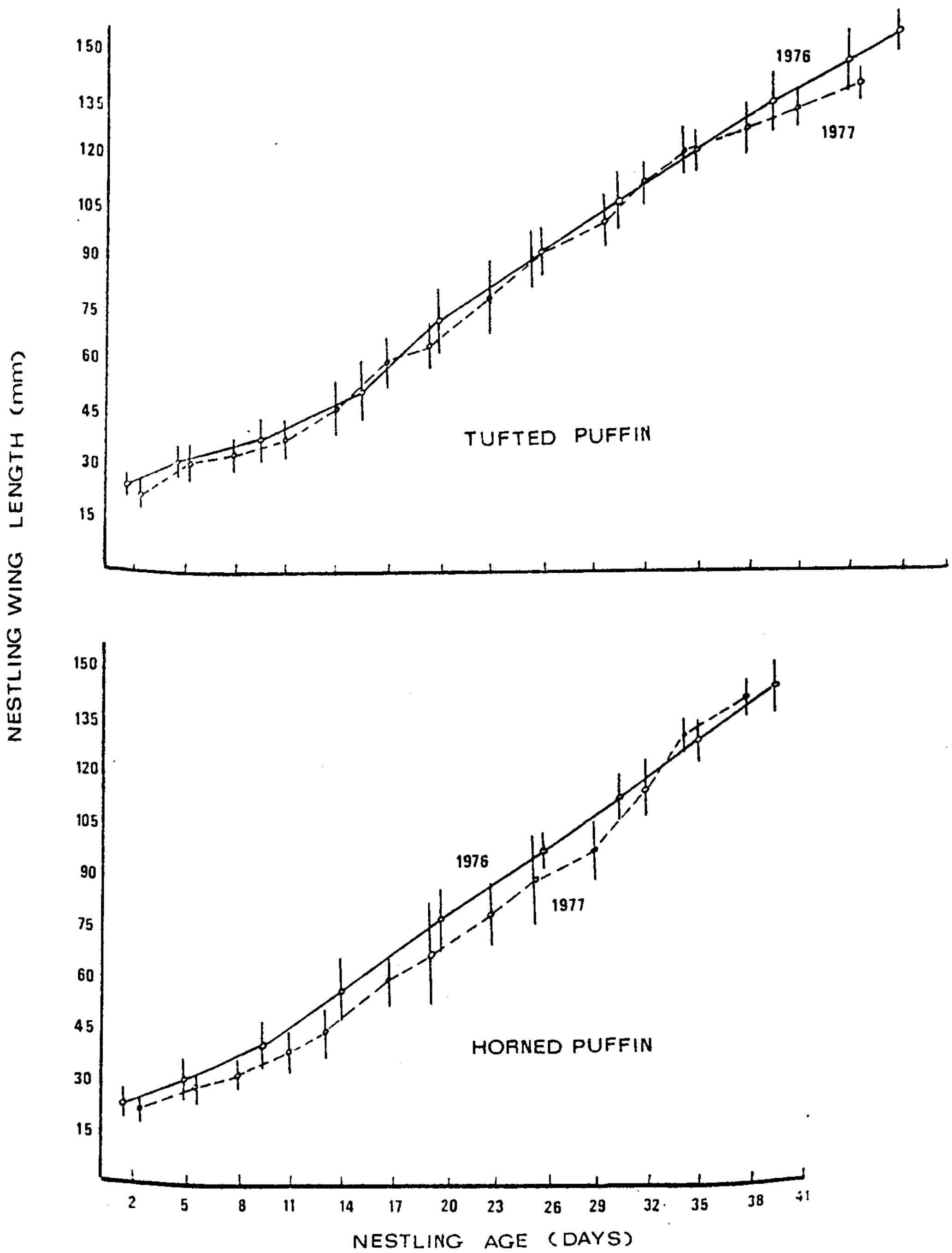

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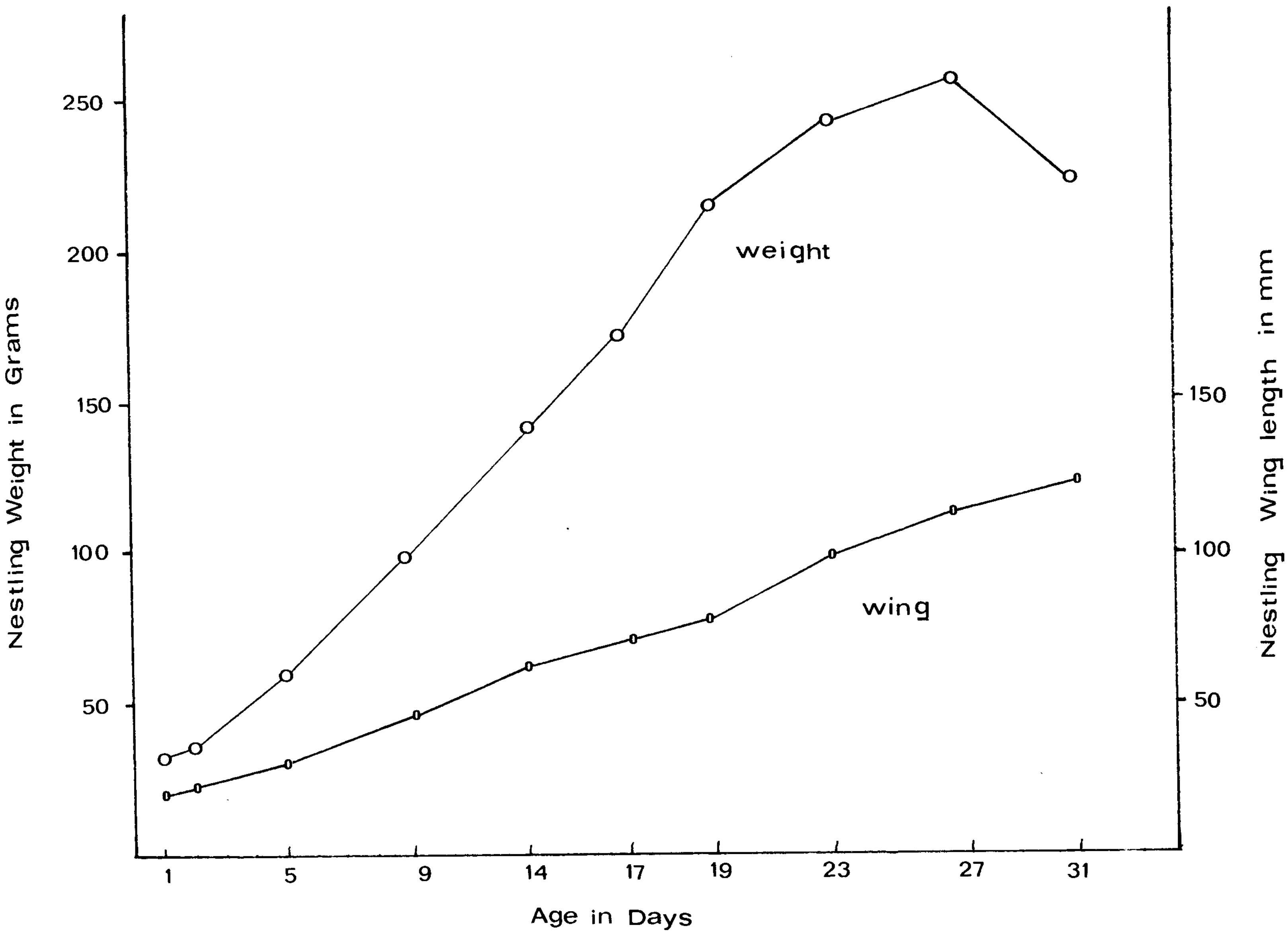

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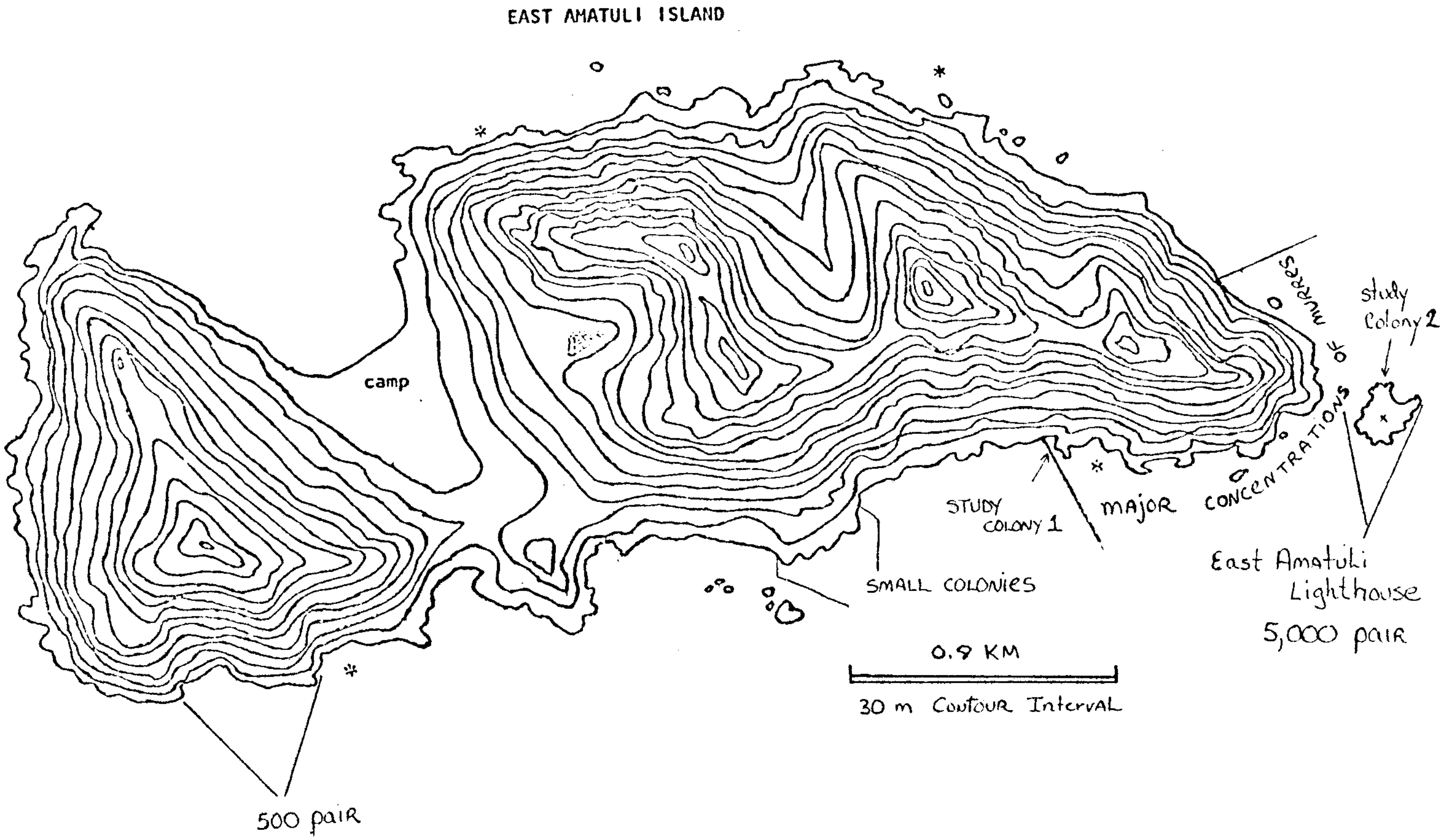

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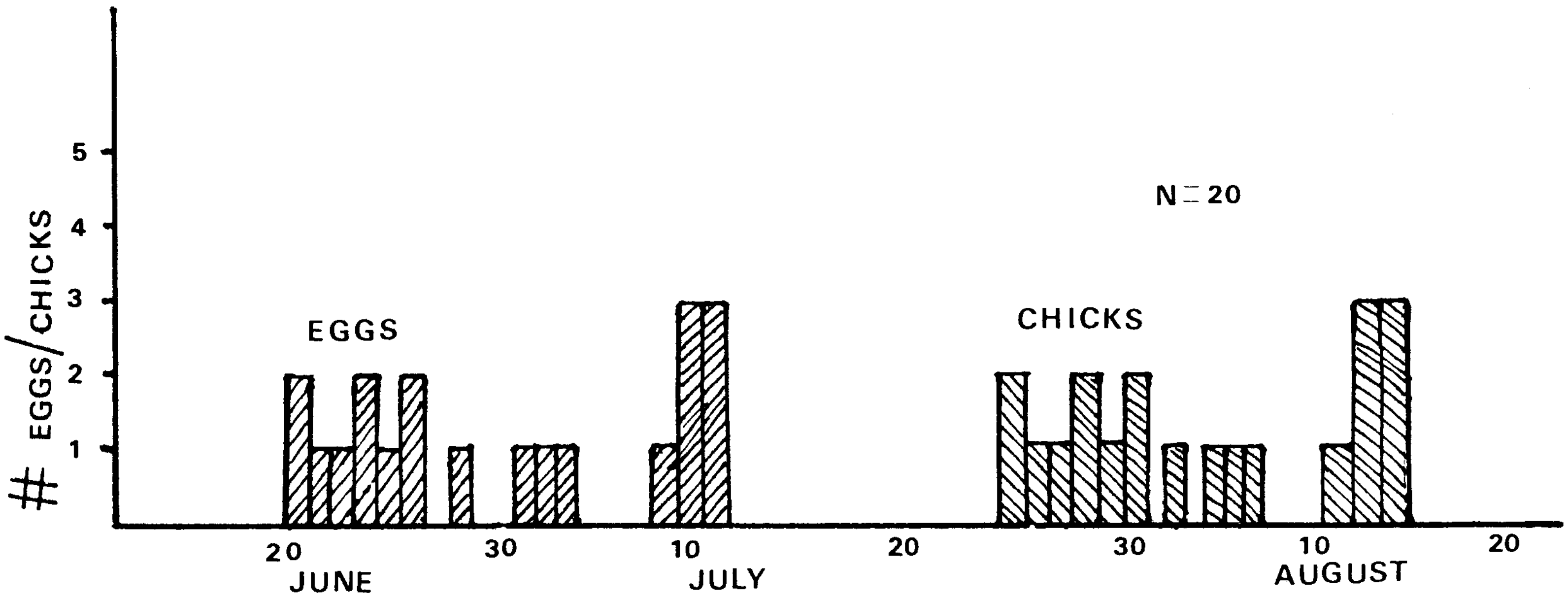

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APPENDIX VII

NOAA-OCSEAP Contract: 01-5-002-2538
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ANNUAL REPORT

COMMUNITY STRUCTURE OF SEABIRDS OF WOODED ISLAND, ALASKA

by

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1 April 1978

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This study was funded by the Bureau of Land Management through interagency agreement with the National Oceanic and Atmospheric Administration and the U.S. Fish and Wildlife Service, Office of Biological Services-Coastal Ecosystems. We are indebted to Drs. Calvin J. Lensink and James C. Bartonek of the U.S. Fish and Wildlife Service for arranging finances and providing especially important supplies including bird bands and outboard motors.

We thank the Chugach National Forest for permitting us to conduct marine bird and mammal research within the Wooded Islands area. Special thanks go to the staff of the Cordova Work Center for allowing us use of warehouse space and vehicles during the hectic days of leaving for, and coming back from Wooded Islands, and for their concern and efforts to resupply our field camp. Without their logistical support, this project would not have been possible.

Special credit goes to Pete Isleib of Cordova for providing us with data from previous surveys of birds in the Wooded Islands area, for providing a description of the study area, and for arranging transportation to Wooded Islands for us in 1977. Both Pete Isleib and the 1977 crew of the commercial crab-boat Sunward Blaine made our early season fieldwork possible.

The 1976 field season was made very successful by the able assistance of Jim Sherwood. We were very grateful for his enthusiasm, knowledge, and companionship during the long hours of each day (and night) in the field. We were assisted in 1977 by Alice Stickney and Martha Eliassen. We are grateful to both for their volunteered and helpful assistance. Thanks to Alice for her help during censuses and observations and particular thanks to Martha for her dedication and responsibility in doing a variety of tasks under wet and windy conditions.

I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS

The main objective of this study is to obtain information about the breeding distribution, abundance, phenology, and productivity of seabirds using Wooded Islands in the Gulf of Alaska. Major seabird species on Wooded Islands, and those discussed in this report are (in order of abundance): Tufted Puffins, Fork-tailed Storm Petrels, Black-legged Kittiwakes, Leach's Storm Petrels, Glaucous-winged Gulls, Cormorants (Double-crested, Pelagic, and Red-faced), Pigeon Guillemots, Common Murres, Parakeet Auklets, and Horned Puffins.

This group of islands is situated 50 km southwest of Hinchinbrook Entrance, the oil tanker route out of Valdez, and 110 km west of OCS oil and gas lease sites which are being explored now. The counter-clockwise currents of the Gulf may bring oil from these areas to the Wooded Islands and surrounding waters. Thus, information collected in this study is necessary baseline data for environmental impact statements and future analysis of the effects of oil spills in the area.

II. INTRODUCTION

Seabirds are an important component of the marine ecosystem, yet they are some of the least understood avian species in Alaska. Basic biology and ecological relationships are not understood for many seabird species and at many colonies information on bird distribution and abundance is lacking. Increased OCS development and oil transport in the northern Gulf of Alaska necessitates collection of baseline information on the seabird species of the area.

Wooded Islands, on the southeast tip of Montague Island outside of Prince William Sound, have one of the largest seabird colonies in the northern Gulf. Since little information on the seabird species, number, and general biology of the Wooded Islands seabird colonies has been collected, this study is designed to provide a baseline of information on the seabirds of the area.

Objectives

1. Obtain information on the breeding distribution and abundance of all seabird species using Wooded Islands,
2. determine the phenology of all breeding seabird species,
3. delineate colony sites and describe nesting habitat of all seabird species,
4. determine productivity and study factors affecting productivity of Fork-tailed Storm Petrels, and
5. make incidental observations on: seabird and shorebird migration, seabird food habits, seabird mortality, species and abundance of other birds, and distribution and abundance of marine mammals at Wooded Islands.

Justification

Wooded Islands are vulnerable to both oil pollution and direct human disturbance. Oil transport in the northern Gulf began in August 1977. Wooded Islands are located along the tanker route out of the pipeline terminal in Valdez (U.S.D.I. 1972). The major oil and gas lease areas in the northern Gulf are 110 km east of Wooded Islands. Since the general water currents in the northern Gulf flow in a counter-clockwise direction, oil spilled along the tanker route, or in the lease areas could reach Wooded Islands. Roughly 48 percent of any oil spilled in the drilling areas is expected to reach nearby Montague Island (U.S.D.I. 1976). Clearly, as oil development and transport in the northern Gulf increases, the probability of oil contamination of the marine environment increases. Nisbet (in prep.) considers oil pollution the greatest threat facing north Pacific seabirds.

Wooded Islands are also near population centers (about 110 km by air from both Cordova and Seward) and are thus faced with increased human use and disturbance. The islands may become an attraction to tourists and residents because of their location and the number of breeding seabird species. Without proper management, humans could have considerable affect on the nesting seabirds (Sowl 1974).

Most of the seabird studies in Alaska have dealt with one or two species at small segments of large colonies. Intensive research on small colonies resulting in accurate estimates of bird distribution and abundance is lacking. The only published study of a seabird colony in the northern Gulf of Alaska is that of Rausch (1958). This study was only a description of the birds present during a 15-day period in June. Nisbet (in prep.) suggests that certain colonies should be selected and intensively studied to provide accurate baseline information. Because of their relatively small size, easy access, and species diversity, Wooded Islands provide a place for such intensive study.

Thus, baseline information on the seabird colonies of Wooded Islands will be useful for monitoring the effects of oil pollution in the marine environment in the northern Gulf, and for management decisions on recreational use of the area. The small size of the colonies relative to some found in other geographic areas of the state is advantageous in allowing accurate census work, complete coverage of the colony, and minimum expenditure for long term coverage. The proximity of the islands to oil development and transportation corridors will allow future monitoring of pollution near the sources.

III. CURRENT STATE OF KNOWLEDGE

Little seabird work has been done on Wooded Islands previous to this study. Isleib, Haddock, Bergman, and Divoky have made surveys of the seabird colonies at Wooded Islands in 1972, 1973, and 1974 (Isleib, pers. comm.). Their estimates of seabird populations are presented in Table 1. Isleib and Kessel (1973) reviewed avian distribution and abundance in the northern Gulf of Alaska.

James Brooks, Alaska Department of Fish and Game, conducted studies of Steller sea lion (*Eumetopias jubata*) food habits and activities on Fish Island in the late 1950's. Sandegren (1970) also studied sea lion behavior on Fish Island during 1967 and 1968.

Some basic biological information of the seabird species nesting on Wooded Islands, and information on closely related species has been collected in other areas. These studies have been consulted for comparison and in development of methods for this study.

IV. STUDY AREA

Description

Wooded Islands are located at 147°25'W, 59°52'N (Fig. 1). Four islands (Wooded, Tanker, South and Fish) make up the group along with numerous exposed offshore rocks (Fig. 2). Montague Island, 75 km long and 15 km wide, is the nearest large land mass. This island is part of the southwestern border of Prince William Sound. A more detailed description of each island is given in Lehnhausen *et al*. (1977).

Surrounding Waters

A number of tide rips occur between the four islands (Figs. 3, 4, and 5). These are important factors to the birds and to small boat operation. Between West Spit of Wooded Island and Montague Island there is a major tide rip that can cause high standing waves preventing small boat travel. All three species of scoters were observed on the north side of this on a number of occasions. Killer whales were seen moving through this area on two occasions, and a fin whale was seen lingering in the area on one occasion. Depending on the tidal stage another tide rip occurs between Tanker Island and the East Spit of Wooded Island. Pigeon guillemots, black-legged kittiwakes, glaucous-winged gulls and cormorants were often seen using the southward projecting rip during receding tides. The rip between Tanker and Eagle Rock is very obvious during most flooding tides due to disturbance of the water surface. At certain times many birds including tufted puffins, black-legged kittiwakes, glaucous-winged gulls, and pigeon guillemots used the north side of the rip area. During April and May of 1977, migrating gray whales used this tide rip area extensively. Another small rip occurs between Eagle Rock and West Point of Fish Island. To the east of Fish Island, a large tide rip is associated with many offshore rocks. Tufted puffins were seen rafting near this tide rip daily. Glaucous-winged gulls and black-legged kittiwakes were often seen in the area. The only rip which was noticed around South Island was off the northwest end. Glaucous-winged gulls, kittiwakes, pelagic cormorants, and scoters were observed in this area on one occasion.

Four kelp beds were discovered in the waters of the island group. A large bed was found in the vicinity of the tide rip off the north end of South Island. It extended along the west side of the island in the strait next to Montague Island. On the north side of the tide rip between West Spit of Wooded Island and Montague Island is another small kelp bed. Just northwest of the Seal Rocks is a large kelp bed that was used heavily by sea otters. The last kelp bed is just north of the East Point of Fish Island. This bed became obvious after storms because tons of kelp washed ashore at Landing Cove on Fish Island.

Weather

Weather conditions during 1977 were in general more severe than in 1976. More days were characterized by some type of precipitation and usually accompanied by wind. Snow flurries occurred in early May and low temperatures continued through May. At the time of departure in early October temperatures had not dropped as low as those recorded in early May, although light snow was observed on peaks of Montague Island in late September. Mild, sunny weather was sporadic but extended periods occurred during the following periods: last week of April, last week of May and first week of June, and last 2 weeks of August and first 2 weeks of September. The 2 largest storms occurred during the first week of May and of August. Climatological information gathered throughout 1977 is summarized in Table 2.

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Field observations were made daily during 15 May to 3 September 1976, and 21 April to 3 October 1977. Two base camps were established in 1976: a main camp on Wooded Island and a smaller, semi-permanent camp on Fish Island. In 1977 the main camp was established on Fish Island on 25 April and removed on 3 October. Temporary camps were used on Tanker and South Islands. Transportation between islands and Patton Bay on Montague Island was by a Zodiac Mark II compact raft with 25 hp or 10 hp motors.

Miscellaneous observations were made of: weather conditions, species of flowering plants, and number, time, and activities of humans visiting Montague and Wooded Islands.

Data collection for cliff nesting birds was made from land-based observation points, and occasional counts were made from the Zodiac. Since nearly all cliff areas could be observed from points on land, boat observations were not of major importance. During cliff-nesting seabird censuses, nonbreeding birds were separated from breeding birds. Resting, feeding and loafing sites were also censused periodically. Photographic records of all cliff-nesting areas were made.

Surface and burrow nesting birds were studied using techniques outlined by Nettleship (1976). Burrow activity was determined using the lattice method described by Wilbur (1969), and by direct observation in the nest (Drent et al. 1964). Intensive study areas for both cliff and burrow nesting species were delineated for careful observation of nest fate.

When possible, birds were banded with U.S. Fish and Wildlife Service bands for future identification. Young of the year were banded with red plastic color leg bands in 1976. According to U.S. Fish and Wildlife instructions, all gull chicks were double banded with aluminum bands, and red plastic leg bands in 1976.

VI and VII. RESULTS AND DISCUSSION

Avian Abundance, Distribution, Habitat Use, Production, and Factors Affecting Production

Twenty-seven species of pelagic seabirds, shorebirds and seaducks were observed in the area of Wooded Islands throughout the 1976 and 1977 field seasons (Table 3). In addition, 8 species of marine mammals, 4 species of terrestrial mammals (Table 4), and 25 species of terrestrial birds were recorded in the area (Table 5). Other bird and mammal species were observed only in spring and fall, presumably during migration (Table 6). Each bird species or group of species are discussed separately. Mammal data are listed and discussed last.

Fork-tailed and Leach's Storm Petrels

As in 1976, abundance of the Fish Island storm petrel colony was studied most intensively in 1977. During 1977, seven storm petrel subcolony areas, totalling 3,112 m^2 in the grass-umbel community were mapped (Fig. 6). Five hundred and ten storm petrel burrows and 424 tufted puffin burrows were located in these areas. In addition, 23 isolated burrows were found away from the sub-colonies. In the salmonberry habitat where burrow density was less than .05 burrows/m^2, ten, 10 x 12 m plots were chosen randomly along the cliff edge (1,200 m^2 total area sampled). Each plot was mapped. Fork-tail nests were located in rocky slope habitat by listening at night for calling birds. Though over 130 burrow locations were marked in this manner, only 33 nests were accessible with excavation.

All burrows, active or inactive, were checked a minimum of 3 times throughout the summer -- May, late June-July, and late August-September. Active burrows were not disturbed during incubation except for the initial check to avoid causing nest desertions. After hatching, chicks were weighed daily and measured every three days (between 4:00 and 9:00 p.m. in most instances) until fledging.

Mist netting was conducted in the rock habitat only to avoid affecting nesting success in soil areas. In all, 414 fork-tails and 1 Leach's storm petrel were netted, measured and banded. Dates of mist-netting and numbers caught are shown in Table 7.

Call counts were conducted at night, at 5 day intervals throughout the summer, as weather permitted. Storm petrel calls could not be heard over strong winds or rain, so counts could not be made on several occasions. The results of 1976 and 1977 call counts are shown in Table 8.

Predation was studied by examining each sub-colony for signs of predation at 5-day intervals. River otter scat was collected at den sites and scent-marking areas around Fish Island. Common raven castings were collected from the raven aerie. Common raven, peregrine falcon and bald eagle middens were examined for remains of storm petrels. Observations of predators, including time, activity and location were recorded.

Distribution

In 1977 the investigator confirmed that fork-tailed storm petrels also nested on South and Tanker Islands. After night searches on both islands, two nests were found on each.

Fork-tails were heard calling on the upper portion of South Island over soil and rock habitat. Careful searching both in the day and at night revealed no burrows on the upper soil covered area of this island. However, several fork-tails were heard calling from rock crevices on the lower rocky areas of the island. In order to reach the nests excavation was necessary. Only 2 could be reached by excavation; each contained a well-developed egg on 7 June. Both nests were later deserted. Probably fewer than 100 fork-tail pairs nest on South Island.

On Tanker Island, fork-tails were heard calling only above rocky slope habitat (Fig. 7). Two nests were located. One had a 16-day old chick on 10 July; the other contained a pair of fork-tail adults. Tanker Island may be used by up to 50 pairs of fork-tails.

Leach's storm petrels were heard calling in flight over South Island, however none were heard calling from burrows. No Leach's storm petrels were ever heard calling over or around Tanker Island.

Fish Island's storm petrel colony is the largest of the colonies in the Wooded Islands group. The rest of the information presented in this report was collected at Fish Island.

Habitat Use

Fork-tailed storm petrels used the same habitat in 1977 as described in 1976. Soil burrows in grass-clumps of *Elymus* sp. and *Calamagrostis* sp. were the most frequently used habitat on the upper plateau of Fish Island. Burrows were also located under logs, stumps, tree roots and rocks, and in sod beneath dense stands of salmonberry, *Rubus spectabilis*. Most storm petrel nests isolated from sub-colony areas were in the latter category. As mentioned in 1976, fork-tails also use crevices in rocky slopes on Fish Island. By listening for storm petrels calling in the rocky slope areas at night, 130 burrow locations were marked between 16 June and 20 July. Of these, only 33 were reached by excavation of the rocks. The other burrows were not reachable.

Nesting success, phenology, mean fledging weights and mean length of fledging for rock and soil habitat are compared in Table 9. Nesting success, defined as the proportion of nests known to have contained eggs which fledged young, was significantly higher in rocky slope habitat ($p = .01$, d.f. = 1,2 x 2 contingency table). Peak hatching and fledging dates were earlier in the rocky slope area than in the soil area. These differences suggest a fork-tail preference for rocky slope habitat. However, the higher nesting success is mainly attributable to differences in predation pressure. High soil moisture, or predation may account for the later peak of hatching in soil habitat.

Leach's storm petrels used only soil burrows in 1976 and 1977. Despite many nights spent searching for storm petrel burrows in rocky slope habitat, no Leach's storm petrels were heard calling. Also, during mist-netting operations over the rocks, less than 0.2 percent of the birds captured were Leach's storm petrels. While mist-netting over the soil covered area,10 percent of the birds captured were Leach's. Leach's may not use rock crevices for nesting due to competition for nest sites with fork-tails. However, most previous studies of Leach's storm petrels have shown them to use soil burrows most extensively (Wilbur 1969, Harris 1974, DeGange et al. 1976, Vernon Byrd, pers. comm.). Since 62.4 percent of the soil burrows on Fish Island are not used by breeding storm petrels of either species, there is probably no shortage of available nest sites in soil habitat. [Wilbur (1969) reports that 51.8 percent of the burrows he examined did not contain eggs. DeGange et al. (1976) report that in 3 different areas of Petrel Island 34.7, 28.8 and 44.4 percent of the burrows were inactive. Fish Island has a higher percentage of inactive (without egg) burrows than any of these.]

Population Estimate

In 1976, several difficulties were encountered in trying to arrive at an estimate of storm petrels nesting on Fish Island. As a nocturnal species, storm petrel populations are notoriously difficult to census. Mist-netting using the Schnabel capture-recapture estimate, and transects proved to be unsatisfactory methods for population estimation in 1976.

This past season, due to early arrival in the field, all subcolonies on the upper island grass-umbel area could be mapped before vegetation growth (Fig. 6). Thus a total count of storm petrel burrows was possible in this area. In the remaining salmonberry community, dense vegetation and a burrow density of less than 1 burrow per 20 m^2 prohibited a total count. Two-stage sampling was used with 10 primary units of 10 m x 12 m plots chosen randomly along the cliff edge. Areas of 1 m^2 were used as secondary units. The estimate of sampling variance for the derived estimate of burrows was negligable. In all, the upper soil covered portion of Fish Island has an estimated 661 storm petrel burrows, of which 262 had eggs in 1977. Thus, 524 breeding fork-tails (262 active burrows x 2 adult birds) use Fish Island's upper soil area.

Estimates in 1976 for upper Fish Island were substantially higher than the 1977 count. Several reasons for this were discussed in the 1976 annual report including assumptions of the Schnabel method not being met, an accurate estimate of available habitat not being possible from available aerial photos, and estimation of burrow density based on small sample sizes. A portion of the difference may also be attributable to an actual decline in the number of breeding birds, as river otters took over 150 fork-tails in 1976, many of which were breeders.

In relation to estimates derived from netting capture-recapture techniques, another source of error was recognized in 1977. Harris

(1974) suggests that storm petrels do not wander about the island colonies, but visit only specific sites. However, in 1977, over 20 birds first captured and banded above the soil areas of upper Fish Island were re-captured over the rocky slope areas of lower Fish Island. Thus, in contrast to Harris's suggestion [and in agreement with Wilbur's(1969) observations of Leach's storm petrels] fork-tailed storm petrels (at least non-breeders) do move around the colony during flighting activities. Therefore, many of the birds banded in 1976 and assumed to belong to the upper island subcolonies may have been birds that utilize rocky slope subcolony areas. This may account in part for the large estimates arrived at in 1976 by the Schnabel method, and for the large number of birds banded.

The rocky slope areas presented an even more formidable problem of estimation. The only evidence of storm petrels in the rocky slopes is their nocturnal calling from crevices,rare diurnal calling, and the peeping of chicks. Burrows can be located by listening at night; marking the area where the calls seem to be coming from; then excavating the area the following day. However, of 130 burrows located in this manner, only 33 could be excavated or reached. There is no method of determining what percentage of the nests one is able to mark by listening for calling birds. In the upper island soil areas fewer than 30 fork-tail burrows could be located by listening. This is less than 12 percent of the active burrows on the upper island. However, storm petrels nesting in soil burrows called less frequently than fork-tails nesting in rocky slope areas. Thus, the percentage of active burrows locatable by calls in soil habitat is not applicable to rocky slope habitat. For this reason, seven permanent transects, 10 m wide by the length of the slope were placed randomly around the island's rocky slope habitat as shown in Fig. 6. Each transect was examined on 3 non-consecutive, overcast nights in search of calling storm petrels. The number of areas where storm petrels were heard calling in each transect are shown in Table 10. The rocky slope on the west end of Fish Island is the most important nesting area for fork-tails in rocky slope habitat. This area was mapped as shown in Fig. 6. In all 15 nights were spent in this area to locate the area of 58 burrows. Only 12 of these could be reached, however. Unlike anywhere else on Fish Island fork-tails were often heard calling during the day in this area. This may indicate a very high density of nests (much greater than indicated by the map) or the interconnection of rock crevices resulting in more diurnal interactions of storm petrels. Non-breeding birds appear to wander around through the crevices during the day. [In soil habitat where most burrows do not connect, non-breeders could not wander around and the incidence of interactions resulting in vocalizations could be expected to be lower.]

In 1977, mist netting was conducted in rocky slope areas. In 27 nights of netting, 414 fork-tails were captured and banded (mean = 15.33 birds/night). This compares to 43 nights of netting in soil habitat in 1976, with 810 fork-tails captured and banded (mean = 18.8 birds/night). Since the mean number of birds captured per night in each area is not significantly different, the actual number of breeding birds in each area is probably similiar. Thus probably 250-300 pairs of breeding fork-tails nest in the rocky slope areas of Fish Island. About 1,000 breeding fork-tail adults with an unknown number of non-breeders utilize Fish Island.

In the long term, a comparison of the number and location of storm petrel burrows will be of more value than a population estimate with its associated sources of error. For this reason, each major subcolony was carefully mapped showing location and activity of all burrows. These are presented in Figure 6.

In 1977, only 19 possible Leach's storm petrel burrows were located in the soil areas of upper Fish Island. Of these 19 Leach's storm petrel burrows, only 6 had eggs. Using the Schnabel method an estimate of 205 breeding pairs of Leach's storm petrel was derived in 1976. This was clearly too high an estimate. By setting up a porportion:

> number of fork-tails banded in 1976:actual number of active burrows on upper Fish Island 1977::number if Leach's storm petrels banded in 1976:estimated number of Leach's storm petrel burrows on the island;

an estimate near 30 breeding pairs is derived. In 1976, with 120 burrows examined, 21 Leach's storm petrel burrows were identified, 80 of which had eggs (about 10 percent of the active burrows were Leach's). In 1977, of 533 burrows examined only 19 were utilized by Leach's storm petrels, and only 5 had eggs (about .02 percent of the active burrows were Leach's storm petrels). Proportionally, Leach's storm petrels occupied fewer burrows in 1977 than in 1976. Other observations further indicate a decrease in population size from 1976 to 1977. Peak call counts were lower in 1977 than 1976, as shown in Table 8. Further in 1976, 25.11 percent of the storm petrels killed by predators were Leach's; in 1977, only 9.5 percent of the birds killed by predators were Leach's, indicating Leach's storm petrels were present as a smaller proportion of the storm petrel population in 1976. Further all Leach's storm petrel burrows, active and presumably successful in 1976, were not active in 1977. There are three possible reasons for this observed decline in the number of Leach's storm petrels:

1. River otters took at least 54 Leach's storm petrels in 1976. This could have caused the decline in call counts and the number of breeding pairs returning in 1977.

2. An actual decline caused by some mortality at sea.

3. Crossin (1974) suggests that at least some Leach's storm petrels may only breed every other year. If so, Fish Island might have a biannual fluctuation of Leach's storm petrel numbers. This explanation of the change in population size could account for the fact that all known 1976 Leach's storm petrel burrows, were inactive in 1977.

Clearly at least one more year of study is needed to determine if the latter explanation is plausible.

Phenology

Fork-tailed storm petrels in soil habitat nested about 10-15 days later in 1977 than in 1976, as shown in Table 9 and Fig. 8. In 1977, the first eggs were laid on 30 April. Peak egg-laying occurred during 11-20 May in 1977. In 1976, back-dating from hatching, egg-laying began near 16 April. Peak egg-laying was estimated from hatching dates as 21-30 April 1976.

Actual hatching dates were obtained in both 1976 and 1977. Using these dates and estimated hatching dates based on wing length measurements, hatching also began and peaked at a later date in 1977 than in 1976 (Fig. 8). Since the 1976 field season ended on 3 September many storm petrels had not yet fledged. Presumably, however, peak fledging occurred later in 1977 than 1976.

Interestingly the nesting chronology of fork-tails in 1977 for rocky habitat was earlier than that in soil habitat (Fig. 9). Indeed 1976 soil chronology and 1977 rocky slope chronology are similar. Three possible reasons for this are: 1) Rocky slope habitat is preferred habitat of fork-tails so that older, more experienced and presumably earlier breeding birds nest in rocky slopes. 2) Since most soil burrows had standing water in them in late April, fork-tails nesting in soil burrows may have delayed egg-laying until burrows dried out. In rocky areas, drainage was not a problem, so egg-laying could begin earlier. 3) River otter predation may have caused the delay in soil breeders by removing a high percentage of early breeders thus causing an apparent delay in the peak of egg-laying or by having done so in the past sufficiently to select for later breeders. More research is needed to determine which explanation is correct. The nesting chronology of fork-tailed storm petrels at Fish Island is compared with that of other fork-tail colonies in Table 11. As might be expected, nesting begins later at Fish Island, the northernmost colony, than any other colony on the west coast. Interestingly, however, the Aleutian colony studied by V. Byrd and the Barren Islands colony have a later chronology though at a lower latitude.

In 1977, another effort was made to obtain incubation periods. Twenty burrows were checked daily until an egg was found. The investigator then did not disturb the burrow for forty-two days. The burrow was then checked daily, without removing the adult, to obtain an exact hatching date. River otters destroyed 11 of the incubation burrows, but 9 incubation periods were obtained (Table 12). As shown the mean incubation period was 48.4 ± 5.59 days, but the range of figures varies from 42 to 59 days. Egg neglect has been reported in storm petrels (Pefaur 1974, and N. Wheelwright, pers. comm.) and probably accounts for the wide range of figures. In 1976, when incubation shifts were looked at, many eggs were left cold then later incubated. However, since none of these hatched, the neglect may have been caused by the investigator's disturbances.

Growth of chicks was followed by daily weight measurements and measurements of wing, tarsus, culmen and longest primary every third day. These data have not been analyzed yet. Results will be presented as part of a thesis to be completed in Spring 1978.

Fledging periods - hatching to fledging-and fledging weights of 1976 and 1977 are compared in Table 9. While 1976 data may be biased by a small sample of the first fledglings of the season, the mean fledging weight of a fork-tailed chick was lower in 1976 than in 1977; 63 gm and 73.4 gm respectively.

Only a small sample of Leach's storm petrels could be obtained in either 1976 or 1977 because so few birds nest on Fish Island. The results are shown in Table 13, but a comparison of phenology can probably not be justified on the basis of such small samples. Table 14 compares known phenology of Leach's storm petrels at Fish Island with phenology of Leach's storm petrels at other latitudes.

Production and Factors Affecting Production

In 1976 an estimate of fork-tail nesting success was obtained only for the soil areas. In 1977 three separate fork-tail nesting success figures were obtained: nesting success of 1) soil habitat exposed to river otter predation; 2) soil habitat protected from river otter predation; and 3) rocky slope habitat (Table 9). Nesting success in the soil habitat [exposed to predation] in 1977 (24.7 percent) was lower than the 1976 estimate (31.0 percent). Causes of nest failure included: egg desertion, chick died of starvation, chick killed by adult and predation of adults and/or chicks by river otter, common raven, and possibly by glaucous-winged gull, peregrine falcon or bald eagle.

In 1977, to study the effects of river otter predation on storm petrel nesting success, a river otter exclosure was set up in soil habitat. Nesting success was significantly higher within the exclosure (68.0 percent) than outside the exclosure (24.7 percent) as compared by a 2 x 2 contingency table (p = .001, d.f. = 1). Nest failure outside the exclosure could largely be attributed to river otter and common raven predation on breeding adults.

Of all the eggs that failed to hatch in the subcolonies of unprotected soil areas, 71.8 percent had remains of adult birds in front of the burrow. If these burrows are not included in nesting success calculations, nesting success outside the exclosure would not be significantly different from that found within the otter exclosure (61.2 percent and 68.0 percent, respectively). Thus river otter and common raven predation are having a large effect on fork-tail nesting success in soil areas of Fish Island.

Both inside and outside the exclosure, egg desertion and chick dying of possible exposure were also important sources of nest failure.

In rocky slope areas in 1977, nesting success was not significantly different from nesting success within the otter exclosure. Thirty-three burrows in the rocks were excavated and monitored. Nesting success of these burrows,63.6 percent, was not significantly different from the nesting success found in the otter exclosure, 68.0 percent (p = .01, d.f. = 1,2 x 2 contingency). Since burrows with newly hatched chicks were easiest to find in the rocks, actual nesting success may be somewhat lower than indicated by the calculated percentage. Of those burrows in the rocks located before the eggs hatched (6), 4 or 66 percent successfully hatched. Since these eggs were located late in incubation, and because burrow excavation may have caused some birds to desert their eggs, this estimate of hatching success is probably not accurate. However, the high nesting success in the rocky slope habitat is a result of an absence of river otter predation. Of the 33 nests examined, only one failed as a result of otter predation. In the soil areas, over 100 nests failed as a result of otter predation. Since equal numbers of breeding storm petrels occur in each area, rocky slope areas must provide protection from river otters to storm petrels.

Predation

River otters, as mentioned, were the major cause of nest failure in soil areas. Otter scat was collected to determine what percentage of their diet was storm petrels. These have not yet been analyzed. All storm petrel subcolonies nesting in soil were checked at 5-day intervals for signs of predation. As shown in Fig. 10, otter predation occurred mainly during late egg laying. This was also the period when non-breeding fork-tails visited the island extensively. Remains of fork-tails found outside of burrows with deserted eggs were assumed to be the remains of breeding birds. Any bias resulting from non-breeders being killed in front of burrows with eggs is probably compensated for by breeders killed before an egg was laid, or killed away from their burrow. In this way, an estimated 46.8 percent of the fork-tails killed by otters were thought to be breeding birds. Since Fish Island supports 524+ breeders in the upper soil area, and 103 birds thought to be breeders were killed by otters, otters may have taken as much as 23 percent of the breeding population of fork-tails. This represents a serious mortality source. Most studies of seabird population dynamics have estimated annual adult mortality at 5-10 percent (Lack 1954, 1966, Harris 1966, Harris 1969, Perrins et al. 1973).

Whether or not river otters would eventually wipe out the soil-nesting fork-tails depends upon: 1) the rate at which the storm petrel population in protected rocky slope areas was growing and immigrating to soil areas, and 2) influx of storm petrels from other colonies.

Leach's storm petrels seemed to be more susceptible to river otter predation than fork-tails. In 1976 86 Leach's and 810 fork-tails were captured and banded - thus 10.6 percent of the storm petrels on Fish Island were Leach's. However, river otters took 14.6 percent Leach's. In 1977 5 of 262 burrows with eggs were Leach's burrows. This is less than 2.0 percent. Yet, 9.4 percent of the storm petrels killed by river otters were Leach's.

Common ravens were the second most important predator. On several occasions they were observed flying around during storm petrel flighting activities. Several remains of fork-tails were found in raven middens and castings contained storm petrel remains.

Remains of storm petrels found away from burrows were assumed to be kills by avian predators, as river otters were apparently more active during twilight periods when flighting activity would have ceased. Glaucous-winged gulls, bald eagles and peregrine falcons may have taken some storm petrels also, though no evidence of this was found. Glaucous-winged gulls and bald eagles were occasionally observed at night. Timing of avian predation is shown in Fig. 11.

Human Disturbance

In 1977 the investigator tried to reduce human induced nest desertions by avoiding disturbance of the birds during incubation. By digging doors into some deep burrows after chicks hatched, some chicks may have been taken by predators. By assuming these chicks would have fledged, adjusted nesting success figures can be calculated. Overall, nesting success in soil areas was 24.7 percent. If all chicks that died of predation through doors are assumed to have fledged, an adjusted nesting success figure of 32.9 percent is reached. Since river otters dug into the back of burrows without access doors, however, some of the chick loss may not actually be a result of human disturbance.

Cormorants

Distribution and Abundance

Of the four islands in the Wooded Islands group only Tanker Island was not used by cormorants during 1976 and 1977. Nesting occurred on Wooded and South Islands while on Fish Island the offshore rocks and some cliff ledges were used for loafing. The water area below the Bird Cliffs was used by cormorants for resting and bathing (190 pelagics noted on 21 June). Pelagic, double-crested, and red-faced cormorants were present in both years with pelagics being most abundant (approximately 90 percent) red-faceds being least abundant. Only 3 red-faced cormorants were observed on 22 June 1977 on the Middle Slope at Wooded Island. Double-cresteds were only seen on loafing rocks or flying. The largest concentration of cormorants (primarily pelagics) was 556 on the offshore rocks off the east side of South Island on 6 June 1977. Data for 1977 are given below.

Phenology and Production

Middle and Grotto Slopes of the Bird Cliffs were first observed to be occupied by cormorants (33 birds) on 1 June. Birds were observed carrying nest material to ledges where bowls were being built on 6 June. During 1976, cormorants attempted nesting but failed. In 1977 nesting areas were established on all slopes of the Bird Cliffs. Nineteen possible nests were seen on 21 June on Middle Slope. Only 2 nests on the Grotto slope and 5 nests on East Slope were seen on 29 July. At this same time only 2 nests (one with one chick; one with four chicks) on the Bird Cliffs were seen containing chicks which were about three-fourths grown. On South Island only one pair of pelagics was observed on a nest on 7 June. No cormorants were on South Island or the offshore rocks on 24 September.

Harlequin Duck and Scoters

As in 1976 harlequin ducks and all 3 species of scoters (black, surf, and white-winged) were observed in the Wooded Islands area. Harlequins were not seen around Fish Island during 1977 as they had been in 1976. Eleven birds on 4 May 1977 is the highest number seen around Wooded Island. The mouth of Nellie Martin River and the nearshore area at Patton Bay were also used by harlequins. On 7 May 1977 10 birds were in this area. Breeding plumaged males were seen in both areas.

Scoters were primarily observed on the waters north of the islands and Patton Bay. Throughout the 1977 field season, mixed flocks ranging in size from a couple birds to 175 (on 23 May) were observed. The Patton Bay area was the most extensively used area and where the largest congregations occurred. Birds seemed to prefer the area just seaward of the surf break along the beach.

Glaucous-winged Gull

Distribution and Abundance

Glaucous-winged gulls were observed on all islands at some time, on the surrounding waters, and on the beaches at Jeanie Lake area and Patton Bay. South Island contained the highest abundance of nesting gulls (estimated 75 pairs) while Wooded Island, the only other island with nesting birds, harbored approximately 25 pairs. Certain spits and offshore rocks of all 4 islands were used extensively by nonbreeding (estimated at 150 birds) and loafing birds. Gulls also frequented the beach area east of Jeanie Lake and Patton Bay beach area, both on Montague Island.

Phenology

Glaucous-winged gulls were in the area throughout the field season. Gulls were in the general areas where nests were found in 1976. A nest containing three eggs was observed on 1 June in 1977. In 1976 the first clutches were probably initiated between 1 June and 3 June with the first 3 egg clutches being observed on 10 June. This indicates egg-laying was slightly earlier in 1977. Hatching dates were not obtained in 1977. Chicks fledged during the first 2 weeks of August in 1977 while in 1976 fledging occurred during the second and third weeks of August. South Island was almost completely deserted by glaucous-winged gulls on 24 September. During the last 2 weeks of August, and all of September, gulls were observed only on or over open water and at loafing sites.

Production

South Island contained the highest number of breeding glaucous-winged gulls in both 1976 and 1977. In 1977 a large plot 20 m wide and 45 m long was established at the northeast end of South on a vegetated rocky slope. On 7 June the plot was thoroughly searched for nests. Each nest was plotted on a grid. The plot was again searched on 5 August when chicks could be captured, measured, banded, and location noted. A total of 72 eggs were found in 27 nests for an average clutch size of 2.6. Only one nest contained one egg, 7 nests contained 2 eggs, and 19 nests contained 3 eggs. Sixteen additional nest bowls contained no eggs. On 5 August 37 chicks were located in the plot. This represents a success of 51 percent of the eggs previously located. The estimate may be slightly low since some chicks may have moved off the area before we searched it.

Black-legged Kittiwakes

During 1977 black-legged kittiwake phenology and production were observed at the Bird Cliffs on Wooded Island. The 3 observation points established in 1976 were again used in 1977 (Lehnhausen et al. 1977). Periodically (12 times) during the field season, counts of total birds, single birds on nests, and pairs on nests were made from these observation points. As in 1976 production estimates were obtained from intensive observations of the birds nesting on the Middle Slope section of the Bird Cliffs. Using a spotting scope from the observation point, the contents of many nests were seen. On 21 and 22 June sketches of the Middle Slope were made with each nest located in relation to major cliff features and other nests. At this time the number of eggs present in observable nests was recorded. The number of chicks in all observable nests was added to these sketches on 29 July. Black-and-white 35 mm photos using a 400 mm telephoto lens were taken of the entire Middle Slope for comparison with similar photos taken in 1976. These photographs will provide a valuable permanent record of number of nests and nest locations for future monitoring of the colony.

Phenology

Observations of kittiwakes were first made on 22 April 1977. At this time no birds were present on the nesting ledges but approximately 2,050 were rafted on the water below the Bird Cliffs. Further observations of the cliffs were not made until 4 May at which time birds were on the nesting ledges. On 16 May no new nest building activity was evident although some sites where nests occurred in 1976 could be identified. No eggs were observed on 1 June although birds were seen carrying nest material and trampling on the nest edge. On 6 June when observations were again made a one-egg nest and a two-egg nest were noted. Therefore, egg-laying was initiated sometime between 1 and 6 June, which corresponds closely to the 4 June to 10 June initiation period in 1976. First hatching dates were not obtained in 1977 but probably occurred sometime between 27 June and 1 July (estimating from a 25-day incubation period). In 1976 the first chick was observed on 6 July but could have hatched during the previous week, thus corresponding closely to the estimated hatching for 1977. A mixture of large and small chicks was seen on 29 July indicating an asynchronous spread of egg-laying and hatching dates, although only a few eggs were laid after 22 June. The first fledgling was observed over the water north of Wooded Island on 17 August. Assuming a 6-week nesting period, this probably represents one of the earliest birds to fledge. From late August until the end of the field season fledgling kittiwakes were observed throughout the area feeding in the offshore waters and roosting on the tide rocks.

Production

In 1977 the Middle Slope intensive study area contained 435 identifiable nests, compared to 417 in 1976. This probably represents a small increase in the population of kittiwakes using the area. An estimated 1,125 pairs nested on the whole Bird Cliffs in 1976 while in 1977, 1,175 pairs are estimated to have nested there.

During 1977 kittiwake production on the Middle Slope section was higher than that of 1976. One hundred and nine nests were observed containing a total of 177 eggs on 21-22 June. On 29 July these same nests contained 107 chicks (see Table 15 and exclude nests containing no eggs). This represents a survival from mid-incubation to late-chick growth of 0.60. This figure probably approximates the fledging success since in late-July most of the chicks were in mid- to late-development. Of 196 observable nests (including empty nests) there were 222 eggs or 1.13 eggs/nest. Average clutch size for 143 nests (231 eggs) was 1.6 eggs. One 3-egg clutch was observed on the Middle Slope. On 2 August 1976 there were 0.39 chicks/nest (136 chicks/345 nests) while on 29 July 1977 there were 0.88 chicks/nest (275 chicks/312 nests).

Mortality

Ravens, peregrine falcons, bald eagles, and glaucous-winged gulls were thought to have contributed to kittiwake mortality and nesting failures in 1976. All of these predators were again in the area in 1977 and could have caused some mortality, although no bald eagle-kittiwake interactions were observed. An active raven nest was located at the edge of the East Slope nest area in 1976 but not in 1977, and no nest was found on Wooded Island. A raven was observed carrying an egg over Wooded Island on 6 June, but ravens were not as evident around the Bird Cliffs as in 1976. The lack of raven (and possibly eagle)predation may have accounted for the increased reproductive success observed. Kittiwakes remains were found near the peregrine falcon eyrie on Wooded Island and a peregrine falcon was seen killing an adult kittiwake over Fish Island on 14 September. Kittiwakes attempted nesting on South Island but no chicks were observed on 5 August probably due to the large population of glaucous-winged gulls using the area. A similar breeding failure was observed in 1976 on South Island.

Habitat Use

Kittiwakes were observed feeding in the waters surrounding the islands throughout the field season. From mid-July on, feeding aggregations containing many species but usually predominantly kittiwakes were seen around the island. The area below the Bird Cliffs at Wooded Island was used extensively by rafting kittiwakes. Birds in this area were seen bathing, loafing, and picking up debris for nest material. Beach areas around the mouths of Jeanie Lake stream (outflow of Jeanie Lake) and Nellie Martin River (Patton Bay) were often used by kittiwakes. The birds aggregated on the beach near where the stream or river enters the ocean. Kittiwakes also frequented Jeanie Lake which required a flight of about 185 m over the beach area. Most of the offshore exposed rocks and tidal rocks were used by loafing birds. Major loafing locations for kittiwakes were East Point offshore rocks at Fish Island, southeastern part of the spit going southeast off Tanker Island, Seal Rocks, Roost Rock below the Bird Cliffs at Wooded Island and the lower part of the cliffs, and the southeast offshore rocks at South Island.

Shorebirds

Only 3 shorebirds were in the Wooded Islands area throughout both field seasons. During 1977 black oystercatchers were observed in the same area as in 1976. No nests were located on Wooded Island but a flock of 7 was observed on the beach of Anchor Bay. One of these birds was a partial albino also observed in 1976. Two nests were located on South Island on 8 June. One nest had 3 pipping eggs and the other had 2 eggs. Also, 2 chicks were found together but not associated with a nest. On Fish Island only 1 nest was located but a second pair probably nested there since adults were defending an area. Four adults were observed on Tanker Island on 10 July and probably had chicks. Small groups of up to 5 birds were observed at Jeanie Lake beach and Patton Bay beach. The largest single group of black oystercatchers was 16 observed in 1977 on 12 September around Fish Island.

Semipalmated plovers definitely nested on Patton Bay beach and most likely on the beach of Anchor Bay at Wooded Island. A nest containing 4 eggs was found on the Patton Bay beach between the pre-1964 tide line and the present highest tide line. None of the eggs in this nest hatched. Defensive adults were around the beach area of Anchor Bay throughout the summer. A flock of 50 semipalmated plovers flew over the Patton Bay beach on 12 August. This was the largest number observed and normally 10-15 were seen on the beach area in 1977.

Least sandpipers were seen only on Patton Bay beach in both years. In 1977 2 nests were located in the grassy marsh area landward of the pre-1964 drift logs. Each nest had 4 eggs which disappeared (presumably hatched) between 6 and 16 July. An estimated 20 birds used the Patton Bay beach area in 1977.

Parakeet Auklet

Distribution and Abundance

As in 1976, parakeet auklets were only observed in the vicinity of Fish Island. In 1977 the area just offshore south of East Point was used in addition to those areas described in 1976. First observations of parakeet auklets were in the early morning of 13 May 1977 Birds probably arrived on the colony at an earlier date, but early morning observations had not been previously made. Activity was found to be almost exclusively limited to early morning hours prior to hatching. Activity and behavioral observations were made during the early morning hours from mid-May to mid-June. The highest count obtained was 34 auklets observed at one time on 14 May. At 19:10 on the same day a flock of 60 birds thought to be parakeet auklets was seen on the water about 4 km north of Harbor Point. An estimated 25 birds used the Fish Island area in 1976 while in 1977 15 pairs are known to have nested there. The low 1976 figure was due to fewer observations. The 1977 figure is a very accurate census with probably one or two pairs being missed. In addition to breeding birds, a group of about 15-20 non-breeders visited the island from mid- to late-July. These birds could usually be told from breeders by the lack of a swollen neck caused by full gular pouches. Additional evidence for these being non-breeders and possibly some juveniles was the observation of a color banded (red) bird. In 1976 one chick was color banded on Fish Island. The 1977 bird may have been the same individual or one which came from another area of the coast, but definitely only a 1 year old.

Phenology

Nests were located after the eggs hatched when adults frequently entered to feed the chick. Of the 14 nest entrances located, only 4 could be dug into far enough to reach the chicks. Continuous growth measurements could be made on 3 of these and the fourth chick was measured only once. Sealy and Bedard (1973) reported an incubation period of 35 days and a fledgling period of 35.5 days. By backdating using these figures, egg-laying probably occurred between 25 May and 2 June and hatching occurred between 29 June and 7 July 1977. Fledging dates were obtained for only 2 chicks. One chick fledged on 2 August and the second on 11 August. The last parakeet auklet was observed near the shore of Harbor Point on 18 August.

Production

All of the 14 nests located probably contained chicks since twittering vocalizations came from the nest area after the adult entered. Of the three chicks monitored daily, two fledged and one died in the nest. This latter chick had reached about one half of its development before it started losing weight. Desertion by the adults may have been due to our disturbance of the rocks and partially blocking the entrance. An additional chick was found wandering in the rocks at the north side of East Point. The chick was cut in a couple places and later died. The nest this chick belonged to was never located.

Pigeon Guillemot

Distribution and Abundance

Pigeon guillemots were observed near all islands during both 1976 and 1977. In 1977 the birds utilizing Fish Island were studied intensively. Only a few observations were made of birds around the others islands. On 10 July at 09:50, 8 were seen flying around west end of Tanker Island. Five pairs were estimated to have nested on Tanker Island in 1976, and a similar number probably nested there in 1977. Up to 5 birds were seen in Anchor Cove of Wooded Island in 1977 while no guillemots were observed near the area in 1976. No observations were made of the area where birds were in early 1976, although a few were occasionally seen to the east below the Bird Cliffs. On South Island 6 birds were observed on 5 August, while an estimated 2 pairs nested there in 1976. This probably represents little or no change in the population using south. Twenty-two definite nest sites were located on Fish Island. The estimated total population of breeding birds was 25 pairs. In 1976 30 pairs were thought to have nested there but it was probably a slightly high estimate. No change in abundance was evident between the two years.

Phenology

In 1977, few guillemots were observed until early morning observations were initiated on 13 May. Birds had probably been in the area for some time but only a few were seen during non-morning times. After eggs were laid and especially after hatching, activity was spread throughout daylight hours. Egg-laying dates were not obtained but using Thoresen and Booth's (1958) figure of 31 days for average incubation and back dating from chick growth measurements, egg-laying occurred from 21 May to 14 June. Hatching was estimated to have occurred from 20 June to 15 July. The earliest known fledging occurred on 4 August but a couple chicks may have fledged as early as 26 July. The last known fledging was on 6 September. The last pigeon guillemot adult was seen around Fish Island on 5 September. During mid- to late-July an increase in activity was observed. During the day pairs were often seen flying by cliff face areas. A couple of times birds were seen going into a crack or hole then coming out and flying off. Groups of up to 10 were seen roosting together on several shore rocks. These birds may have been non-breeders coming to the colony for the first time.

Production

Of the 22 nests located, only 2 did not contain eggs. Seven nests were known to have contained chicks since adults were seen carrying fish to the nest, although the exact number of chicks was not known. Three nests contained only one egg. Two of these nests were deserted while the other fledged the chick. Ten nests contained 2 eggs or chicks. Of these, one had both eggs deserted and 6 had both chicks fledge. Both chicks died shortly after hatching in 1 nest while in the other 2 nests one chick died but the other one fledged. One of these latter chicks may have died by choking on a fish.

Common Murre

Common murres were observed in 1977 near Fish and Wooded Islands but not South Island as in 1976. Presumably, murres nested on the Middle Slope of the Bird Cliffs as in 1976, but no eggs or chicks were observed in 1977. Thirty pairs are estimated to have nested on Wooded Island in both years. Two attempted copulations by different pairs were observed on 16 May 1977. At this same time the highest count of 24 birds rafted on the water below the Bird Cliffs was obtained for 1977. A wide ledge to the east of the main nest crack was used to a small extent by birds landing and loafing (no nesting observed on the ledge) during 1976. This ledge was more heavily used (up to 13 birds at one time) in 1977, but nesting still did not occur there. Small numbers (up to 10) were frequently seen associated with tufted puffin rafts north of Fish Island. Also, the area between the islands and Montague Island (to the south of Patton Bay) was used by murres. Twenty-five were on the water in this area on 12 June 1977.

Horned Puffins

Horned puffins were observed around Fish, Wooded, and South Islands, but landings occurred only on Fish and South Islands. The same number of birds were estimated to have used the islands in both years (10 pairs). In the evening of 14 May 1977 the first horned puffins were observed near a tufted puffin raft. Early morning hours seemed to be the most active time for horned puffins. One definite nest was found on Fish Island. On 21 July 1977 an adult was observed in this nest but the nest contents could not be seen. An egg was seen in the nest on 3 August, then when the nest was checked again on 15 August a small chick was present. The chick was not seen again on subsequent nest checks. Horned puffins were last observed around Fish Island on 11 September 1977.

Tufted Puffin

Abundance and Distribution

Abundance and distribution of tufted puffins in 1977 was very similar to that of 1976. Birds utilized the same areas on the islands and on the surrounding waters as in 1976. Only a few observations were made of puffins on South, Wooded, and Tanker Islands due to more intensive work on Fish Island which harbors the most puffins. From general observations the number of tufted puffins utilizing South Island was 150-200 pairs. This estimate is somewhat lower than the 400 pairs estimated in 1976. A small decline did seem to have occurred although it may not be as large as indicated. The 1976 estimate was probably high (300 pairs may have been more accurate) since the number was estimated by the amount of suitable habitat. Very little of the cliff edge and the rocky slopes were occupied by tufted puffins.

Areas occupied by puffins in 1977 on Wooded Island were essentially the same as in 1976, except for one location. A 10 m^2 area of steep grassy slope on the north edge of the East Slope which had a relatively high number of nesting tufteds in 1976 was severely eroded. Much of the soil and vegetation had sloughed off the cliff face during the winter resulting in fewer birds being able to nest in the area. The highest count obtained at Wooded Island was 322 rafted below the Bird Cliffs on 21 June. This count probably represented a breeding population of about 200 pairs. In 1976 an estimated 225 pairs were nesting in the Bird Cliffs area. Little or no change probably occurred between the two years. The birds displaced due to the landslide may have occupied other areas in the cliffs.

The rocky slope transect established at the southwest side of Tanker Island in 1976 was again conducted in 1977. In the lower 45 m of this transect, 36 burrows (17 known active) were found in 1976 and 34 (16 known active) in 1977. A small decrease in the number of puffins using the area was apparent from the amount of activity, particularly in the upper parts of the slope. This may have been due to desertion caused last year and the birds not returning in 1977. Sixteen adults were banded in the transect in 1976. Upon searching the nests the following year, no banded birds were found. Cliff edge areas were not searched on Tanker Island in 1977. Six hundred and fifty pairs were estimated to be using Tanker Island in 1976. This was almost a complete count of burrows, and activity was not determined. Therefore, 650 pairs was probably a high estimate. The population changed little from 1976 to 1977.

In order to obtain a more accurate idea of bird activity and precise replicate data that would be more meaningful for future monitoring, Fish Island birds were studied intensively. By concentrating efforts at Fish Island, information which could not be gathered in 1976 due to the extent of work, was obtained in 1977. Phenology, daily activity patterns, nesting habitat utilization, production, and mortality of puffins were monitored.

No change in tufted puffin abundance on Fish Island was observed from 1976 to 1977. In 1976 an estimated 1,125 pairs nested on the island. As a result of the more intensive work in 1977, this estimate may be a little high, and 900-959 pairs is probably a more accurate estimate for the 2 years. Over 50 days of intensive observations on activity and raft counts were made throughout the summer. Previous to egg-laying the highest raft count was 940 on 14 May. On 20 June during mid-incubation, the highest raft count (1,515) for the season was obtained. As will be discussed later, this latter count probably included non-breeding birds.

Transects to obtain nest density, nest measurements, activity, and production were conducted along the cliff edge and on the rocky slopes as in 1976. The rocky slope transect in an unvegetated boulder slope at the west end of the main island established in 1976 was repeated in 1977. Thirty-four nests were located in 1976 with 21 of these known to be active while in 1977 only 25 nests were found with 13 of them known to be active. In 1976 this transect was run when most of the chicks were hatched thus less desertion was probably caused than in 1977 when the transect was run during early hatching. The decrease of activity and breeding in the transect may have been due to common raven harassment. A pair of ravens nested on the cliff face immediately above the transect in 1977, while in 1976 the nest was on the other side of the island. Puffins frequently flew from the slope when ravens went in or out of the nest area. Also, the birds seemed to be more susceptible to disturbance by us than last year. An additional 11 rocky slope transects were established and the results of all transects are shown in Table 16. Along the cliff edge, 21 burrows in the first 80 m of the 1976 transect were monitored throughout the season for phenology. An additional 55 m of the cliff edge transect were searched starting 20 m from the end of the 1976 transect. The 1977 continuation contained 0.30 burrows per m^2 compared to 0.18 (corrected from 0.11 reported in the 1976 report) found in the 1976 section. This difference is merely a result of less area of habitable cliff edge being sampled in 1976.

Phenology

In addition to the above-mentioned 21 burrows, 72 other burrows were monitored for phenological activity and chick growth. Large numbers of tufted puffins were not seen around the island until 4 May. Previous to this only a few birds were observed flying at a distance by the island. First landings on the island occurred on 4 May, so there was no delay between arrival and occupation of the island. Only after egg-laying began were birds found in the burrows during mid-day. Copulations were first observed on the morning of 13 May. The first egg was found on

30 May, so egg-laying began during the last few days of May. Peak egg-laying occurred during the first 2 weeks of June (Table 17). The earliest chicks were found on 10 July in the rocky slope transect at Tanker Island. On Fish Island the first chick in the monitored burrows was found on 15 July. Since the first chicks in 1976 were found on 8 July, phenology in 1977 may have been a little later. Egg-laying dates were not obtained in 1976 except the first was observed on 28 May on Fish Island. A bird was seen in the same burrow on 22 May 1976 so it probably contained an egg then, since in 1977 birds were not found in burrows during mid-day before egg-laying. This observation further supports an earlier phenology in 1976. From 7 nests in 1977 where the exact egg-laying and hatching dates were known within one day, the incubation period has a maximum range of 42-50 days. Due to predation, fledging dates were not obtained this last year. The only chick which may have successfully fledged from a monitored burrow did so between 24 and 26 August. Raft counts were highest in the end of June and early July, possibly as a result of non-breeding and immature birds visiting the colony. In mid-summer many birds were noticed on parts of the cliff face where no burrows could have been. General departure from the colony could not be obtained due to predation and desertion. During August total numbers declined drastically and continued decreasing in September.

Production

Of the 93 monitored burrows, only 56 or 60 percent of them contained eggs. The difference between the mean length of burrows containing eggs (x = 98.1 cm) and those not containing eggs (x = 79.0 cm) was significant (t = 1.66, p = 0.05, 80 d.f.). This difference may be due to shorter burrows being only partially dug and incomplete chambers. It may also indicate a preference by breeding birds to lay eggs in deeper burrows. Of the 56 burrows containing eggs, only 26 (46 percent) hatched, 21 (37 percent) were deserted, and 9 (16 percent) disappeared. Successful chick rearing was limited to a few burrows located on the cliff face. In all other habitat, no chicks were found surviving predation. Growth measurements were begun on a number of chicks in cliff edge, grassy slope, and rocky slope areas but all were preyed on by river otters or ravens. Along the cliff edge artificial access "doors" were removed by predators to get at chicks so our disturbance may have made it easier for them to get into the burrows, but burrows were also entered or dug into through the natural entrance. Carcasses and skins (completely eaten bird) of chicks were constantly found along the cliff edge and in the rocky slopes. In the East Point petrel exclosure puffin burrows were thought to be safe from otter predation. Chicks began disappearing from the burrows and later a small pile of carcasses was found outside the exclosure near where otters climbed over the fence (after most storm petrels had fledged). A number of eggs were found with only a rectangular hole chipped in the side, presumably preyed on by ravens. Ravens were observed a number of times carrying eggs and what looked like parts of chicks. Predation was not nearly as severe in 1976 when only a few chick carcasses (less than 5 with heads taken off and uneaten) were found.

Only 1 bird banded in 1976 was sighted in 1977 (#796-72324). In 1976 it was caught on 1 July in the tall vegetation about 3 m back from the cliff edge. It was seen across from the blind on 29 May 1977. No burrows were within about 2 m of the bird in both years.

Other Alcids

In addition to the 3 other alcid species (rhinoceros auklets, marbled murrelets, and ancient murrelets) observed in 1976, a fourth species, Cassin's auklet was observed on 14 June 1977 and again sporadically as late as September. The first bird observed happened to get caught in a mist net set for storm petrels. The net was over a boulder beach in front of a rocky slope on Fish Island. The bird did not have a brood patch. It was banded and released that same night. Single birds were occasionally seen later on the water north of Fish Island in August and September. A dead Cassin's auklet was found on the 18 September 1977 beach survey at Patton Bay. These sightingsare the second record of this bird in the North Gulf Coast-Prince William Sound region (Isleib and Kessel 1973).

Only 2 rhinoceros auklets were observed in 1976, both near Tanker Island. In 1977 rhinoceros auklets were frequently observed within tufted puffin rafts north and west of Fish Island during June and July. The first birds (2) were observed in this area on 29 May 1977. The highest number observed at one time was 11 on 28 June 1977. Around dusk on 4 and 5 July rhinoceros auklets were seen flying very low and making a number of passes over Harbor Point, but no landings were observed.

Marbled and ancient murrelets were observed in both 1976 and 1977. Marbled murrelets were the most numerous and were in the area throughout the field season. Evidence for breeding in the area included a pair collected at the mouth of Patton Bay (the female contained a fully shelled egg) and 2 dead chicks with egg-tooth intact on Patton Bay beach. The largest number of marbled murrelets observed was approximately 150 on 4 June. These birds were scattered in small groups (2-4 birds) on the water between Fish and Montague Islands.

Ancient murrelets were only observed on 20 August 1976 and in late August and in September 1977. Only winter plumaged birds were seen An estimated 5 birds probably used the area.

Terrestrial and Non-marine Birds

Though 50 species of non-marine birds use Wooded Islands, most of these are not expected to be affected by oil pollution. Terrestrial birds that use seabirds for food, scavenge beached remains, or feed on tidal and intertidal organisms could be affected by floating oil or chronic oil pollution.

Up to 25 Canada Geese use the intertidal areas of Montague Island and the upper storm tide-inundated area during May and early June. In 1976 Canada Geese nested on Wooded Island but were not observed in 1977.

Bald Eagles were observed using all the islands and offshore rocks of the area. Two active nests occurred on Wooded Island in 1976, however only one active nest was used in 1977. Fish Island had one inactive eagle nest in both years. In 1977, however, two mature-plumaged eagles were seen carrying sticks to the nest. A pair of ravens resting nearby harassed the eagles continually and appeared to drive the eagles away on some occasions. South Island had one active eyrie in 1977.

Bald Eagles were often observed scavenging along the beaches of Montague and Fish Island. One was observed feeding on sea lion after-birth during June. Eagles also fed on carcasses of seals and sea lions washed up on Patton Bay beach. Eagles were observed stooping on tufted puffins but were not successful on these occasions. Eagles were seen flying around Fish Island during storm petrel flighting activities and some remains of fork-tails were found beneath the eagle nest on Fish Island. The remains of a pelagic cormorant were also found beneath the eyrie. During August and September, spawned out salmon were important in their diet.

During both 1976 and 1977, one active peregrine falcon eyrie was located on Wooded Island at the northwest tip of the eastern point of Anchor Bay. We did not examine the nest to avoid disturbance but in both years only one fledging was observed in August. Examination of a midden site near the eyrie yielded the remains of several shorebirds; the only one we could positively identify was a spotted sandpiper. The midden also contained the remains of a murrelet and a Leach's storm petrel. No remains of kittiwakes were found in 1977, but a peregrine capture of an adult kittiwake was observed in late September.

Common ravens nested on Fish Island in both 1976 and 1977. A pair nested on Wooded in 1976 only. The pair on Fish Island raised 4 chicks to fledging in both 1976 and 1977. In 1976 the pair on Wooded fledged 3 young. Ravens preyed on kittiwakes at Wooded Island in 1976. On Fish Island in 1977 a search of the midden area below their nest yielded the remains of 6 fork-tailed storm petrels, 1 adult pigeon guillemot, and the heads of 10 Irish Lord fish (Hemilepidotus sp.). Ravens were also observed carrying tufted puffin eggs and on one occasion taking a puffin egg from a burrow. Ravens also took tufted puffin chicks, as evidenced by developing feather sheaths found in raven castings.

Song and fox sparrows, varied thrushes, and occasionally dark-eyed juncos, tree, savannah, and golden-crowned sparrows used washed up kelp as a foraging area. These species could be adversely affected by washed up oil. Oil might be picked up on the feet or feathers or ingested. Oil would probably affect the rich invertebrate avifauna of the kelp, also, thus indirectly affecting these terrestrial birds.

Migration

Spring migration had begun when we arrived on 21 Arpil 1977 and continued into early June in both 1976 and 1977. The less obvious fall migration began in late July, and early August in both years. Certain species, such as swans, merely passed over the area without landing (Table 6). Bad weather may cause some of these migrants (such as loons) to settle in the area until more favorable conditions occur. Some species seemed to stop in the area frequently and stay around for a short period of time (red-necked grebes, wandering tattlers). In the fall, waterfowl migration was not evident. Shorebirds and passerines tended to slowly come and go through the area. A small flock of rock sandpipers (40 birds) and black turnstones (10 birds) were seen on Fish Island in early spring and in the fall of 1977. The rock sandpipers were in transitional plumage in the spring. These birds may have been winter residents of the area.

Large aggregations of migrant birds were recorded several times in 1976 and 1977. During a storm on 23 May 1976 just offshore to the north of Wooded Island were 407 arctic loons, 18 red-necked grebes, and 350 other seabirds. On 5 June, 17 June, and 27 July 1976 sooty shearwaters were seen close by Fish Island. The largest group was 2,700 to the south of Fish Island on 5 June 1976. In 1977 a large flock of shearwaters estimated at 100,000 was first observed on 1 May. They appeared to arrive from the northwest (Patton Bay). Shearwaters (mostly sooty) were seen for the next 4 days offshore to the north and east, and at times, passing close by Wooded Islands.

Marine Mammals

Steller's Sea Lion

Fish Island's Steller sea lion colony normally uses 2 portions of the island: the southeast end (Rookery Point), for breeding, and the northern end (Harbor Point) for resting and loafing.

Before and during pupping, about 700 sea lions hauled out on the Rookery Point rocks and about 300 used the Harbor Point area. We observed the first pup on 28 April 1977. This pup was born unusually early however. Most cows did not give birth until early June, 14 and 27 June. Our estimates ranged from 200 to 600 animals indicating a drop in the number of animals hauled out on Fish's shore. During late September, sea lions began congregating at Harbor Point and a noticeable increase in the number of adults and pups occurred. On 28 September, we counted 2,012 adult sea lions and 70 pups at Harbor Point. This may be a result of fewer animals of the colony being out to sea, or from an influx of animals. According to the Alaska Department of Fish and Game, sea lions do move around the Gulf of Alaska in the fall, so this increase probably relfects an influx of animals.

Alaska Department of Fish and Game branded sea lion pups at Fish Island in 1976. None of these pups were sighted as yearlings. However, other animals branded in various areas of Prince William Sound by ADF&G were observed. Animals originally branded at Sugarloaf Island, Marmot Island, and Seal Rocks were observed throughout the summer. An ear-tagged sea lion observed at Wooded Islands in 1976 was tagged in British Columbia according to the ADF&G.

Harbor Seal

In 1977, a visit to South Island in early June revealed that Harbor Seals used the island for pupping. On 8 June, we counted 36 seals with 10 newly born pups. Since the animals were using the only landing site on the island, we could not avoid disturbing them on this visit. We were unable to return to South Island again until much later in the summer when the pups were well grown, so our disturbance probably had little effect on the seals. We observed seals throughout the summer around Fish Island in small numbers. On 10 July, 88 were hauled out on te east spit of Tanker Island. Throughout August, 100 to 150 hauled out on Eagle Rock just offshore of Fish Island.

On 23 July, 2 dead seals were found washed up at the beach at Patton Bay. Cause of death could not be determined but one had a broken cranium.

Sea Otters

All the waters near the islands and north into Patton Bay were used by sea otters. Sea otters were usually observed singly or in groups of 2 or 3, however some larger groups were seen. Five to 10 animals were observed on each trip to Patton Bay, however on 16 July 1977 over 20 sea otters, many with pups, were congregated in the south east corner of Patton Bay. The kelp beds northwest of Seal Rocks often contained 4 or 5 animals. On 16 May 1977 11 animals were observed in this area. On 5 August 1977 10 were observed in the kelp beds on the southwest side of South Island.

Sea otter pups were first seen on 8 May 1977. Two pups and 2 adults spent most of the summer of 1977 in the nearshore areas of Fish Island. Sea otter populations appeared to remain the same over the summers of 1976 and 1977.

Other Marine Mammals

Dall porpoise were not observed in 1976, but were seen occasionally in 1977. Eight to 10 animals were the most observed. While porpoises were observed east of Fish Island, we most commonly observed them in the waters between Fish and Montague Islands.

Many whales including gray, fin, humpback, and killer whales were sighted during 1977 (Appendix II). A dark whale without a visible spout and with a somewhat triangular dorsal fin was sighted on 14 June 1977. It was possibly a sperm whale, but identification was not positive. In 1976 only fin and killer whales were observed.

Gray whales were verycommon in the nearshore waters around the islands from our arrival on 21 April until 4 May 1977. Occasional sightings were made after the latter date. Assuming the animals were only migrating through the area, probably upwards of 100 moved through the area. Gray whales were often observed in the tide rips, and quite often were within 300 m of shore.

Killer whales were spotted irregularly throughout the summer of 1977 but in 1976, they were only observed during spring and fall. The largest pod observed was 17 on 25 July 1977, but most pods numbered less than 10 animals. Fin whales were observed in late August only. Two humpbacks were sighted between Fish and Wooded Island on 1 September 1977. Several unidentified whales were also noted throughout the 1977 field season.

Beached Carcass Survey

The 3.5 km beach at the west end of Patton Bay was an excellent location for beached bird and mammal surveys. Only the 3 km section north of Nellie Martin River to the start of the rocky shore at the north end was used for surveys. The beach was walked approximately every 10 days in 1976 and 1977, weather permitting. The entire beach was searched intensively by walking 2 to 4 abreast while going away from and coming back to the Nellie Martin River. Scavenging brown bears, river otters, and bald eagles may have removed some remains between surveys.

In 1977 bird and mammal remains were found more often than in 1976. This probably reflects the more windy and stormy conditions of 1977. Late August and early September surveys yielded immature birds. Oil pollution during this time could be particularly serious as inexperienced young would have more difficulty than adults avoiding oil slicks. Results are given in Table 18 for 1977 and 1976 results are in Table 7 in Lehnhausen et al (1977).

VIII. CONCLUSIONS

Increased Human Activity

Wooded Islands may become an attraction to tourists and residents of Alaska because of their accessible location and the variety of breeding seabirds and marine mammals they harbor. As suggested by Nisbet (1975) small, accessible seabird colonies may be useful in educating the public and creating public awareness of and concern for seabird resources. Whether or not Wooded Islands becomes a center for public education, human disturbance of both the seabirds and marine mammals may need to be reckoned with soon.

In both 1976 and 1977, commercial fishermen visited Wooded Islands. Some of these fishermen harassed sea lions by pulling in close to the rocks, spooking the animals from shore then shooting seabirds for target practice and fish bait. In 1977, one group was shooting birds just offshore from the main breeding area of pigeon guillemots, parakeet auklets and tufted puffins. Fishermen also used the protected cove on the north side of Wooded Island for anchorage. Boats were often anchored within 50 m of the active Peregrine Falcon aerie. Daily activities and pastimes of fishermen (including rifle, shotgun, and pistol shooting) could disturb the peregrines as well as other species in the area.

Private planes buzzed Wooded Islands on three occasions in 1976 and on 10 occasions in 1977. Tufted Puffins were panicked by the planes and left their burrows <u>en-masse</u>. During these mass departures, eggs and chicks may be trampled or occasionally knocked from the burrows. We did not observe the effects of aircraft on other seabird species. However, Hunt (1975) states that kittiwakes and murres are greatly disturbed by the approach of aircraft and leave the cliff <u>en-masse</u>. The eggs, chicks, and occasionally whole nests of such cliff nesting birds may be knocked off the ledge during the exodus. Steller's sea lions were panicked by aircraft and most left their haul-out rocks. During the rush to the sea, many animals were caught beneath others. Pup deaths and injuries, as well as injuries to adults and juvenal animals sometimes result and if frequent, could affect the colony. In addition to private plane traffic, Coast Guard helicopters and planes often flew quite low over the island. In the future, airplanes and helicopters ferrying supplies and personnel to and from drilling and production platforms, tugboats and other support services may severely affect seabird and marine mammal use of the islands. Particular caution in the placement of support system, oil drilling platforms and location of airplane and boat routes will be necessary to avoid such disturbances.

Nearby Patten Bay and Jeanie Lake on Montague Island were frequently used by recreationists from Cordova, Seward and Anchorage. In 1976, in late August, 4 separate planeloads of people had flown into the area. At least 17 people other than ourselves were on the beach at Patten Bay. In 1977, nearly 30 people in 8 separate planes were on Patton Bay during a single day in August. On 15 occasions that we visited Patton Bay, only twice were other people not present. We talked to many of these people and most expressed their thoughts of visiting the islands. Clearly recreational use of the area is increasing now. Visitors to Wooded Islands may disturb the seabirds and marine mammals by their activities. Both Harbor Seals and Steller Sea Lions are easily frightened by the outline of a standing person. Loud noises often frighten the alcids and kittiwakes. Burrow nesting seabirds such as tufted puffins and storm petrels may also suffer from people walking on the upper soil covered areas and crushing earthen burrows. When a burrow is crushed, the nest (containing egg or chick) is almost always deserted.

An additional threat to burrowing seabirds is presented by visitors, whether fishermen, as occurs now, or outdoor recreationists, as will soon occur. Predators, such as rats, cats and dogs have wiped out many colonies of seabirds where they have been accidentally or intentionally introduced. Such introductions are very difficult to control and could cause severe damage to the burrowing seabird populations, particularly as they are already preyed upon by river otters.

Trash is often left behind by visitors to Patton Bay and Jeanie Beach. While this is not a problem now, such trash could provide additional food for avian predators such as glaucous-winged gulls, common ravens, northwestern crows and bald eagles. As had been learned in the Atlantic, artificially high populations of avian predators can be a serious threat to seabirds.

Oil and gas development in the Gulf of Alaska is expected to create an influx of people into Alaska. U.S. Department of the Interior (1976) predicts the number of people employed in Alaska will rise from 113,000 in 1973 to 218,000 in 1983, almost a two-fold increase. Clearly the influx of people and resulting increased human use of the area caused by this development could indirectly affect the seabirds and marine mammals on Wooded Island. Careful planning of the development and regulation of island visitation will be necessary to preserve the seabird and marine mammal colonies.

Assessment of Probable Impacts of Oil, Gas, and Other Developments

Oil Pollution

Wooded Islands and the surrounding waters are threatened with oil pollution in the near future. Outer Continental Shelf oil and gas exploration has already begun in the northern Gulf of Alaska. Oil tankers are carrying crude oil south by Wooded Islands from the Valdez terminal of the Trans-Alaska oil pipeline. Since currents in the Gulf flow in a counter-clockwise direction, oil spilled near Hinchinbrook Entrance or in the lease area near Kayak Island may be expected to reach Wooded Islands. Royer (pers. comm.) indicates that oil spilled near Kodiak also could be carried to Wooded Islands by a counter-current from the southwest.

The effects of oil spills on Wooded Islands seabirds and other birds using the area depends largely upon the amount of oil spilled, the time of year of the spill, the stage of tides, wind velocity when oil reaches Wooded Islands area, and the success of clean-up measures. Direct oiling reduces the insulative value of feathers and often results in hypothermia and consequent death (Erickson 1963, Bourne 1968). Oiled birds attempt to preen their plumage to remove such deposits. In the process, oil is ingested and this may cause death (Hartung and Hunt 1966, Hartung 1967).

At Wooded Islands, bird species most susceptible to spilled oil include those which derive most of their food in marine waters, especially by diving (loons, seaducks, alcids) and surface seizing (storm petrels, phalaropes, and larids). Of the Wooded Islands avifauna, storm petrels, loons, seaducks, larids, and alcids spend nearly all of their feeding time at sea. These are also the species most often found dead as a result of oil pollution in the marine environment (Vermeer and Anweiler 1975:475).

Gulls, alcids, seaducks, loons, and phalaropes also tend to land on and feed in calmer water after flying to new feeding and resting sites. Since oil calms choppy waters, these are the very locations where birds would land and hence become contaminated (Curry-Lindahl 1960). Especially susceptible are tufted puffins which often rafted in numbers exceeding 1,000 birds. A single oil slick in the area during May and June when tufted puffin rafts are largest, could result in massive mortality. Later in the summer, rafts are smaller but constant interchange of birds to and from nests occurs. During winter alcids would be more widely distributed and simple incidents of mass mortality would be unlikely. However, the net effect might be similar since wintering birds in molt are unable to fly, and have a much smaller chance of avoiding a spill. Also, molting sea ducks and alcids are especially susceptible to oil spills because their only locomotion is by swimming or walking.

Cormorants, harlequin ducks, black oystercatchers, wandering tattlers, glaucous-winged gulls, black-legged kittiwakes and pigeon guillemots extensively use the intertidal rocks of Wooded Islands throughout the summer for feeding and loafing. Because of heavy wave action and large tidal fluctuations in the area, oil will likely wash on to these rocks. Birds visiting the rocks later for roosting or feeding would undoubtedly become oiled.

Table 19 lists the degree and timing of susceptibility of birds to the direct effects of oil pollution. As mentioned above, birds in nearshore coastal waters would be most affected. Those in the intertidal zone and driftwood would be affected to a lesser degree (Table 19). Species in the zone affected by spray might be contaminated by oil droplets thrown on shore by wind and wave action. This could cause extensive mortality to eggs if oil droplets reached them while exposed or when an incubating bird brooded the eggs. Likewise, eggs above the spray influence might die if the incubating bird applied its oiled breast to the eggs. Patten (pers. comm.) found that even one microliter of Prudhoe Bay crude oil would kill developing embryos in freshly laid glaucous-winged gull eggs. Presumably, recently laid eggs of other seabirds would be just as susceptible.

The greatest effect of oil pollution on gulls, petrels, and shearwaters may be a result of chronic oil pollution. The effects of this may be manifested in lower population size, nesting success, and nesting density. The small size of the Wooded Islands colony allows accurate estimates of gull populations and precise delineation of nesting habitat and measurements of nesting success for both storm petrels and gulls. Growth rates of young birds may also reflect availability and abundance of food. Since chronic oil pollution may affect food supplies, changes in growth rates may reflect changes in food availability related to chronic oil pollution. Growth measurements were obtained for fork-tailed storm petrels, pigeon guillemots, parakeet auklets and tufted puffins. The effects of chronic oil pollution on these seabirds may be detected by a long-term monitoring program.

Oil spills also affect bird populations by killing or contaminating their food source (Evans and Rice 1974). Zooplankton and some invertebrates retain and/or concentrate hydrocarbons when exposed to low levels of oil pollution (Lee 1975, Neff and Anderson 1975, Stainken 1975). Effects of oil pollution on intertidal organisms may persist through successive seasons (Carter 1976). The contamination of these foods would affect most shorebirds and some alcids and seaducks. Contamination of intertidal invertebrates would be a serious loss to staging shorebirds during late July, August, and September. Since fishes often are mobile enough to avoid oil spills (Rice 1973), piscivorous birds such as loons, gulls, terns, and alcids probably would have a food source available.

Beached carcasses of oiled birds and mammals might be unsuitable for such scavengers as gulls, ravens, otters and bears. Other contaminated foods include vegetation near the high tide and storm tide lines.

The net result of contamination of these foods and feeding areas would be movement of birds to other feeding areas which likely would be of lower quality and/or already occupied by other staging birds which are also competitors for a limited food supply.

Oil may cause indirect effects which lower survival of birds (Evans and Rice 1974). For instance, oil taken into the eyes or ingested could affect feeding behavior. Likewise, oil may obscure food items of plunge divers like terns and kittiwakes, and of surface-seizers like storm petrels, phalaropes and gulls. This, in turn, could force them away from contaminated areas, but may result in competition with other birds.

In summary, oil spills can produce a variety of direct and indirect effects which reduce the survival of birds. All possible caution should be used to minimize the probability of a large oil spill. Chronic low level oil pollution especially should be minimized. It is potentially more dangerous to the ecosystem than catastrophic spills since food organisms may concentrate hydrocarbons and remain contaminated for several years (Evans and Rice 1974).

Marine mammals could be seriously affected by oil pollution. The 900 Steller sea lions, 150 harbor seals, and 20 sea otters around Wooded Islands would be the species most affected by oil pollution. Of these, the sea otter is highly susceptible to oil pollution because it depends on its clean, dense fur for insulation. The other species depend on layers of fat for insulation.

Sea otter, harbor seal, and sea lion females giving birth to young and also the young until they achieve mobility would be very susceptible to direct oiling. If oil reached haul out or resting areas on shore, then these sites probably would be vacated. Other sites might be occupied to capacity or of a less secure nature. The result would be a decline in use of the Wooded Islands area. Similarly, if food became contaminated or unavailable, then animals would vacate the area.

Direct oiling might cause irritation of only mucous membranes. Exposure to oil has been found to cause eye damage and blindness in seals (Smith and Geraci 1974). The seriousness varied with the length of exposure.

Marine mammals migrating by Wooded Islands including killer whales, gray whales, humpback whales and fin whales would most likely avoid oil spills. However, gray whales migrated through the vicinity of the Santa Barbara spill despite attempts to reroute them outside the Channel Islands (Norris 1974 as cited in U.S.D.I. 1976). Of potential danger to whales and porpoises is absorption or adsorption of oil through or on the mucous membrane lining the blowhole. This area remains open near the surface and may become oiled. Such oil exposure could create a thin film of oil over the lungs and respiratory passages, with the same effect as pneumonia, including death (U.S.D.I. 1976).

The effects on marine mammals of such food contamination and low level chronic pollution would be difficult to assess without periodic monitoring of their populations, especially during the pupping or calving season (May through July).

In view of the danger of oil spills, the most rigid safety standards must be strictly enforced. To give a few examples, transportation of oil should be by tankers equipped with double hulls and separate ballast tanks; pipelines should have an extra set of automatic shut-off valves if pressure should drop below normal; and drilling platforms must be capable of withstanding both wind and wave action. Should an oil spill occur, booms and other clean-up devices must be stationed nearby for immediate deployment.

Baseline Monitoring Program

Although it would be best to continue our present intensity of study at Wooded Islands, monetary and time constraints will limit future efforts to monitoring only a few indicator species. For this reason, we have established representative transects, nesting plots, and carcass surveys to monitor the avian community at Wooded Islands.

Criteria for choosing indicator species might include breeding birds that have: (1) a high position in the food chain, (2) a high degree of site tenacity, (3) a dispersed nesting distribution, (4) at least moderate abundance, and (5) little annual variation in density. Such birds would be most readily affected by the biological magnification of contaminants in the food chain. Strongly site tenacious birds are more likely to show the effects of disturbance to a small area than are free-ranging birds. If the birds normally show only a small amount of annual variation in breeding numbers, then the effects of disturbance should be readily noticeable.

Because of small population sizes and annual variations of seabird species on Wooded Islands, we have chosen storm petrels, black-legged kittiwakes, and 3 alcids as indicator species.

Unfortunately, due to heavy river otter predation, storm petrel populations on soil areas of Fish Island probably will show annual variations in density and probably a decline in the number of nesting birds. Fork-tailed storm petrels nesting in rocky slope areas of Fish Island are not subject to river otter predation and the density and number of nesting birds in those areas probably would not fluctuate under normal circumstances. However the rocks that protect these birds from predation also make their nests difficult to locate and monitor. The most useful monitoring of storm petrels that can be done at Wooded Islands is a yearly comparison of phenology and chick growth rates. According to Lack (1966) the probable limiting factor for storm petrel egg-laying is the length of time required for the female to form the large egg. This period probably varies according to the amount of food available. Thus, variations in the timing of egg-laying may reflect variations in food availability at sea. Storm petrels often leave their eggs unincubated thereby lengthening the period between laying and hatching dates (N. Wheelwright pers. comm.). If food resources at sea are scarce, storm petrels would likely leave the egg unincubated for longer periods of time thus delaying hatching. Nesting phenology would reflect food availability at sea. Chick growth rates, particularly changes in weight, would also reflect food availability. Since chronic oil pollution would most likely reduce food availability, changes in growth rates of chicks and nesting phenology would likely reflect the level of chronic oil pollution at sea.

The amount of information to be gained by future monitoring of fork-tail colonies depends largely upon the number of visits to the island, the length of visits and the timing of visits. Following are recommendations for obtaining further information on fork-tailed storm petrels at Fish Island.

1. Timing of visit: A visit in late June would provide an estimate of the percent active burrows (burrows with eggs), an opportunity to mist net with high catches and recaptures, and possibly, if several chicks had hatched, an opportunity to obtain growth rates using the techniques designed by Ricklefs and White (1975).

A visit in the second or third week of July would allow an estimate of percent active burrows, hatching success, some possibility of recaptures, an estimate of the numbers of birds taken by predators, and an excellent opportunity to obtain growth rates, and by aging chicks, an estimate of phenology.

A visit in mid-August would allow an estimate of fledging success, growth rates, percent active burrows, estimate of predation and a small chance of obtaining recaptures during mist netting, an a picture of phenology.

2. Number and length of visits: A short visit in mid-July followed by another short visit in mid-August would provide the most information. Both hatching and nesting success could be estimated, predation could be measured, the July visit would allow mist netting when flighting and juvenal birds are present, thus increasing chances of recaptures; and more accurate estimates of growth rates and phenology would be possible. At least one day of each visit would be needed for storm petrel work.

If only one visit is possible, growth rates will not be obtainable unless the visit lasts 6 or 7 days with chicks being measured at the beginning and end of this period.

3. Activities during visit: Fork-tailed storm petrels may be easily monitored in soil areas, but monitoring of rocky slope areas will be difficult. Unfortunately, because of differences in predation, nesting success in the two areas are very different. Phenology was different in 1977. While the information has not been completely analyzed, there are some indicationsthat growth rates may also vary between the two habitats. Thus, to get an accurate idea of storm petrel biology at Fish Island a sample from both habitats is needed.

Plots 3,6, & 7 as located in Fig. 6 will provide the most information in the shortest amount of time. We recommend that Plot 6 be run first, Plot 7 secondly, and finally Plot 3 if time allows. The number of burrows, number of burrows with eggs, number with chicks and the number with remains (and how many remains), should be noted. Weight and wing measurements of the chicks would be most useful if time is limiting. The number of burrows and nesting success for each area mapped and monitored in 1977 are presented in Table 20.

More precise maps of these plots showing the location and previous activity of burrows are in prepartion. Painted depressors were used to mark burrows, however these may become weathered and unreadable. Even so, the total number of burrows and associated activities should be comparable. A daily check of burrows containing eggs in mid-July would be necessary to determine if the eggs were deserted or still developing. A single check would not reveal this information since eggs are often left unincubated for up to five days.

Ten transects were placed randomly around the rocky slope area of lower Fish Island. The placement of these transects (10 m wide by the length of the slope) is shown in Fig. 5. Each transect was run on 3 non-consecutive overcast nights to mark burrow locations. The total number of burrow locations found in each transect is given in Table 10. Future researchers may wish to run these transects to obtain comparative figures. However if time is limiting, the effort would be better spent mist netting and examining the rocky slope area on the west side of Fish Island as shown in Fig. 5. This area offers the best opportunity for finding reachable storm petrel nests. Locations should be marked at night and excavated during the day. Very few can be reached without excavation. Location and excavation of nests in rocky slope areas is greatly simplified when chicks hatched. The young are often disturbed by the noises around their nest and peep loudly thus leading one's excavations in the right direction. Due to the various contortions and rock removals necessary to reach nests located in 1977, we did not deem it feasible to permanently mark burrow locations.

Since over 1,200 storm petrels are banded and over 100 are of known age, we hope mist netting will be conducted in the future to obtain recaptures and learn more about movements, age of return to the colony and fidelity. In 1977 we did not net in the same areas as 1976 and still caught over 20 recaptures, future researchers should have an excellent chance of obtaining many recaptures. In 1976 fledgings were banded with aluminum bands and red color bands, and in 1977 fledgings were not color banded.

Leach's storm petrels:

Examination of Plot 6 will probably yield the most Leach's storm petrel burrows. There is not a distinguishing size variation between fork-tailed and Leach's eggs, so one must find the adult on the egg in order to tell for certain a given egg is a Leach's egg. Listening at night, mist netting and examination of remains will provide the most information on the presence of Leach's storm petrels. Probably little information will be collectable on this species since few nest on the island and their breeding phenology is much later than any other species on the island.

Black-legged kittiwake information can be gathered very easily from the Middle Slope intensive study area. Sketches of every visible nest have been made in both years and black-and-white photos taken of the entire slope. This same operation should be done in subsequent years. If time permits, production can also be estimated since the observation point is at the cliff edge and above the majority of the nests. Nest contents could be identified using a spotting scope and easily recorded on sketches or photographs. Census counts of the other two slopes could be done in a couple hours to obtain a total population estimate for the Bird Cliffs.

Parakeet auklets and pigeon guillemots may show annual variation in the number of breeding birds, but because of their small populations and visible activities, these species can be easily censused at nearly anytime throughout May and June. Chicks may be located in July and comparative growth measurements made. Since these 2 alcids use nearshore waters more extensively than tufted puffins, storm petrels, or kittiwakes, variations in their populations could reflect levels of nearshore oil pollution which would not affect other species. Further, since these species were not preyed upon by river otters, their populations would not decline as a result of predation.

During May, we obtained highest counts between sunrise and 0800. During June activity during the day increased and accurate censuses on Fish Island could be made between sunrise and 1200, though early counts would still be preferable. Nests can be most easily located by watching adults bringing in food to the young during July. Counts of most of the nearshore waters and the rocky slopes below could be made from 2 major vantage points (cliff edge northeast of Raven Tree and the southwesternmost point of the cliff edge above West Point). The most productive area to search for nests would be the rocky slope just west of Harbor Point and at the base of Harbor Point.

Based on the 2 years' of information, the most accurate method for estimating the breeding population of tufted puffins on Fish Island would be intensive burrow searching. In rocky slope and cliff face areas burrows are difficult to locate because of the low density. Determining activity is often more difficult. Locating burrows in the rocks during incubation could cause high desertion and locating them after hatching biases the number of eggs present since naturally deserted eggs would be difficult to locate. Counts of inactive burrows are probably under-estimated in rocky slope and cliff face areas since the presence of a bird or chick is usually necessary to find the nest. The rocky slope transect at the base of West Point on Fish Island was conducted in both years and would be the best transect to monitor puffin activity in the rocks. Also, if time permitted, the rocky slope transect on Tanker Island would be valuable. Both transects were marked with rock cairns at the top and bottom of the slopes, although some cairns did not last between the 2 years. Cliff edge burrows are more easily monitored. Because many burrows may not be used by breeders, and the percentage of burrows with eggs may vary from year to year, a large number of burrows should be dug into in order to check their status. It may be desirable to monitor the same burrows year after year to keep disturbance to a minimum. This could act as good comparative data over a number of years, but could bias any attempts to extrapolate to other areas. The 25 m section of cliff edge (starting at the first point of land north of the farthest south petrel net site on top) where burrows were monitored in 1977 would be a good location for such monitoring and also for production estimates and chick growth measurements since all burrows have been dug into. The number of burrows along the cliff edge is quite variable depending on the suitability of the soil. Also, certain sections of the cliff edge may provide more successful burrows or at least a higher percentage of use by breeding birds. The cliff edge transect (start is at the point above south sea lion rookery) begun in 1976 and continued in 1977 could be used to obtain number of burrows active and possibly success. Raft counts and concurrent fly-by activity counts give a poor estimate of breeders or total population. Counts before egg-laying may be representative of the breeding population but this needs to be tested since some birds may not be visiting the colony every day at this time. The value of raft and fly-by counts is their easy repeatability. Since all birds in a specific area are counted and the counts replicated over a number of days, a precise set of data is obtained that would be relative to other years (assuming the birds use the same areas to raft year after year, which was true for 1976 and 1977). This may be very useful in simply monitoring the population. Evening counts were made from the observation point above East Point, while morning counts were made from the observation point northeast of Raven Tree.

At least one beached bird survey should be conducted at Patton Bay from Nellie Martin River 3 km northwest to the bouldery beach. If longer periods are spent in the area, then surveys should be done every 10 days for comparison with the surveys conducted in 1976 and 1977.

Good estimates of productivity in small colonies such as Wooded Islands, and careful monitoring, could be useful in detecting low level affects of chronic oil pollution. Early detection of chronic oil pollution and its affects could be of major importance in correcting the problem before the pollution reached high levels and major affects at larger and more distant colonies become noticeable.

IX. NEEDS FOR FURTHER STUDY

This study was designed to obtain baseline information on the seabird colonies of Wooded Islands. During 1976 and 1977 breeding areas were delineated, population estimates were made, and estimates of nesting success were obtained for some species. Glaucous-winged gulls, horned puffins, and pigeon guillemots may show wide fluctuation in population size over relatively short periods of time as indicated by comparisons of 1972 and 1974 estimates (Isleib, pers. comm.) with those obtained in 1976 and 1977 (Table 1). Detection of the effects of oil pollution and human activity without yearly surveys of indicator species may be difficult, since normal fluctuations in the populations could cause a major decline. Attribution of the decline to oil pollution would thus be refutable.

Providing that good baseline information is obtained, changes in population sizes could be detected and the effects of oil pollution quantified. Nisbet (in prep.) indicates that changes in seabird populations can be more accurately established in small colonies. The small size of the Wooded Islands colony provides the opportunity for accurate measurement of population size changes. Since the islands harbor species susceptible to oiling (i.e. alcids) and species susceptible mainly to chronic oil pollution (i.e. storm petrels), they provide a suitable location for measurement of the effects of both sorts of contamination. Those species which do not normally show large fluctuations in numbers over a short period of time, particularly storm petrels, also allow measurement of the effects of low levels of chronic oil pollution as reflected in their reproductive success. Therefore, we have suggested a yearly monitoring program for five indicator species breeding on Wooded Islands, and a beached carcass survey to assess seabird losses to weather, pollution, and other causes of mortality.

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Table 1. Estimated numbers of seabirds occurring in the Wooded Islands area based on 1972 and 1974 surveys by Isleib (pers. comm.) and this study in 1976 and 1977.

Species	1972	1974	1976	1977
Fork-tailed Storm Petrel	Estimated many 100's of pairs	3,000 pairs	5,000+ birds	1,000 breeders[1] 1,000+ non-breeders
Leach's Storm Petrel			400+ birds	<60 breeders[1] 100+ non-breeders
Pelagic Cormorant	72 nests	29 nests	250 birds for all cormorants	27 nests
Double-crested Cormorant		6 nests		500-550 for all species
Red-faced Cormorant		8 nests		2 birds
Glaucous-winged Gull	50 pairs	348 pairs	75 pairs 200 non-breeders	100 pairs 100 non-breeders
Black-legged Kittiwake	780 pairs	1,680 pairs	1,175 pairs	1,225 pairs
Common Murre	present	5 pairs	30 pairs	30 pairs
Parakeet Auklet	100+ pairs		25 birds	15 pairs
Pigeon Guillemot	500 pairs	31 pairs	47 pairs	42 pairs
Tufted Puffin	7,000 pairs	4,550-5,050 pairs	2,400 pairs	1,700-1,850 pairs
Horned Puffin	300 pairs	54-104 pairs	10 pairs	10 pairs
Rhinoceros Auklets	15+ pairs		2 birds	11 birds
Ancient Murrelet	present	present	6 birds	5 birds
Marbled Murrelet			12 birds	50+ pairs

[1]Represents a more accurate estimate in 1977 than 1976 rather than an actual decline in numbers.

Table 2. Summary of 1977 weather at Wooded Islands.

	April[1]	May	June	July	August	September
Highest Maximum Temp. (°C)	9.5	14.5	18.5	24	23	21
Lowest Maximum Temp.	5	5	10	12	13	11
Highest Minimum Temp.	1	6	10.5	12	13	11
Lowest Minimum Temp.	1	0	3.5	7	8	4
Mean Maximum Temperature	7.4	9.4	14.5	16.7	16.7	14.8
Mean Minimum Temperature	0	3.1	8.4	10.1	10.9	7.5
Days of 100% Cloud Cover	2	11	11	19	17	10
Days of Precipitation	2	21	16	24	24	8
Total Recorded Precipitation (mm)	snow & rain	156+	73+	111+	209+	176+

[1]Data only for last 4 days of month.

Table 3. Summer resident pelagic seabirds, shorebirds, and seaducks observed around Wooded Islands in 1976 and 1977.

Fork-tailed Storm Petrel	Black Oystercatcher	Common Murre
Leach's Storm Petrel	Semipalmated Plover	Pigeon Guillemot
Double-crested Cormorant	Least Sandpiper	Marbled Murrelet
Pelatic Cormorant	Wandering Tattler[1]	Ancient Murrelet
Red-faced Cormorant	Glaucous-winged Gull	Cassin's Auklet[2]
Harlequin Duck[1]	Herring Gull[1]	Parakeet Auklet
White-winged Scoter[1]	Mew Gull[1]	Rhinoceros Auklet[2]
Surf Scoter[1]	Black-legged Kittiwake	Horned Puffin
Common Scoter[1]	Arctic Tern	Tufted Puffin

[1]Non-breeders
[2]Species observed only in 1977.

Table 4. Mammals observed in the Wooded Islands area in 1976 and 1977.

Shrew sp.	Sperm Whale?[1]	Steller Sea Lion
Killer Whale	Mink	Harbor Seal
Fin Whale	River Otter	Black-tailed Deer
Gray Whale[1]	Sea Otter	Humpback Whale[1]
Dall Porpoise[1]		

[1]Species observed only in 1977.

Table 5. Summer resident terrestrial and non-marine birds observed in the Wooded Islands area in 1976 and 1977.

Canada Goose	Black-billed Magpie	Yellow Warbler
Bald Eagle	Common Raven	Blackpoll Warbler
Peregrine Falcon	Northwestern Crow	Wilson's Warbler
Common Snipe	C.-b. Chickadee	Pine Grosbeak*
Rufous Hummingbird	Brown Creeper	Hoary Redpoll
Violet-green Swallow	Varied Thrush	Common Redpoll
Tree Swallow	Hermit Thrush	Savannah Sparrow
Bank Swallow	Ruby-crowned Kinglet	Fox Sparrow
Cliff Swallow*	Water Pipit	Song Sparrow
Steller's Jay*	Bohemian Waxwing*	

*Observed only in 1977.

Table 6. Migrant birds observed in the Wooded Islands area from 12 May to 1 September 1976 and from 21 April to 3 October 1977.

Common Loon*	King Eider	Dunlin*
Arctic Loon	Common Merganser	Upland Plover*
Red-necked Grebe	R.-b. Merganser	Lesser Yellowlegs
Sooty Shearwater	Sharp-shinned Hawk	Spotted Sandpiper
Slender-b. Shearwater*	Marsh Hawk*	Hudsonian Godwit
Great Blue Heron*	Merlin*	Whimbrel
Trumpeter Swan*	American Kestrel*	Northern Phalarope
Whistling Swan	Osprey	Pomarine Jaeger*
Black Brant	Golden Plover*	Parasitic Jaeger
White-fronted Goose	Black-bellied Plover*	Long-tailed Jaeger
Mallard	Surfbird	Bonaparte's Gull
Pintail	Black Turnstone	Aleutian Tern*
Green-winged Teal	Ruddy Turnstone*	Black Swift*
American Wigeon	Semi-p. Sandpiper*	Belted Kingfisher*
Northern Shoveler	Western Sandpiper	Yellow-b. Sapsucker*
Greater Scaup	Baird's Sandpiper	Empidonax sp.*
Bufflehead*	Rock Sandpiper	Olive-s. Flycatcher*
Oldsquaw*	Pectoral Sandpiper*	Winter Wren

Table 6. Continued

Golden-crowned Kinglet*	White-winged Crossbill*
Northern Shrike*	Dark-eyed Junco*
Townsend's Warbler*	Tree Sparrow*
Rusty Blackbird*	Harris' Sparrow*
Pine Siskin*	White-crowned Sparrow
Red Crossbill*	Golden-crowned Sparrow
	Lapland Longspur*

*Observed only in 1977.

Table 7. Dates of mist-netting and number of fork-tailed storm petrels captured in 1977 on Fish Island.

Date	Number of Fork-tailed storm petrels	Number of Recaptures
6 May	5	-
9 May	26	2
10 May	3	-
12 May	31	3
18 May	53	3
20 May	30	5
25 May	37	5
31 May	14	4
2 June	1	-
5 June	41	-
14 June	9	-
15 June	2	-
23 June	15	-
24 June	5	-
25 June	19	-
28 June	17	1
29 June	8	-
1 July	1	1
6 July	49[1]	-
7 July	12[1]	1

Table 7. Continued

Date	Number of Fork-tailed storm petrels	Number of Recaptures
9 July	1	-
10 July	2	-
18 July	23[1]	2
24 July	1	-
2 August	2	-
14 August	2	-
12 September	4	-

[1] Two mist nets set up in different areas.

Table 8. Number of Fork-tailed and Leach's storm petrel calls/15 seconds at peak counts in 1976 and 1977. Four, 15 second counts were made at 15 minute intervals from nightfall until no more storm petrels were calling. Number shown is the average of four counts at the peak 15 minute interval.

Date 1977	Number of Fork-tail Calls	Number of Leach's Calls	Date 1977	Number of Fork-tail Calls	Number of Leach's Calls
			26 April	2	0
			27 April	6	0
			30 April	19	1
			2 May	16	0
			14 May	15	1
			15 May	23	3
			18 May	11	0
			24 May	11	1
			29 May	2	1
			2 June	17	1
			9 June	35	2
14 June	42	6	11 June	20	2
24 June	18	4	18 June	10	0
28 June	30	5	26 June	1	0
5 July	3	4	2 July[1]	12	2
8 July	5	6			
10 July	34	20			
12 July	2	22			

Table 8. Continued

Date 1977	Number of Fork-tail Calls	Number of Leach's Calls	Date 1977	Number of Fork-tail Calls	Number of Leach's Calls
27 July	10	18			
1 August	6	10	3 August	8	1
10 August	1	8	13 August	3	3
			20 August	0	3
			29 August	0	0
			2 September	0	0
			4 September	0	3
			5 September	0	1

[1]High winds and rain prevented call counts throughout most of July in 1977.

Table 9. Nesting success, fledging weight, and phenology of Fork-tailed storm petrels in 1976 and 1977 on Fish Island.

	1976	1977		
	Soil Habitat	Soil Habitat	Soil-Otter Exclosure	Rocks
Nesting success[4]	31%	24.7%	68.0%	63.6%
Mean fledging weight	63.0 gm (5)[1]	73.41 gm (30)	70.56 gm (15)	72.58 gm (12)
Mean fledging period (hatching & fledging)	62.75 (8)	61.44 days (32)	61.93 days (16)	59.14 days (16)
Hatching spread	3 June - 11 July	13 June - 1 August	12 June - 22 July	10 June - 30 July
Hatching peak	6-10 June and 16-20 June[2]	1-5 July	26 June - 5 July	16-20 June
Fledging spread	7 August - ?[3]	12 Aug. - > 3 Oct.	18 Aug. - 28 Sept.	14 Aug. - 5 Sept.
Fledging peak	16-20 August	26-31 August	26-31 August	16-20 August

[1]Sample size is indicated in parentheses.

[2]Two peaks occurred in 1976, see Figure

[3]Field season ended on 3 September. Several fork-tails had not yet fledged.

[4]Nesting success defined as the percentage of burrows known to have contained eggs which fledged young.

Table 10. Number of fork-tailed storm petrel burrow locations found after spending three non-consecutive, overcast nights in rocky slope transects in 1977 on Fish Island.

Transect	Number of Burrow Location	Number of Burrows Reached
A	4	0
B	7	4
C	2	0
D	25	11
E	9	2
F	20	5
G	1	0
H	1	0
I	6	2

Table 11. Nesting chronology of fork-tailed storm petrels at Wooded Islands in comparison with other locations.

Location	Latitude	Year	Dates: Egg-laying (Range / Peak)	Dates: Hatching (Range / Peak)	Dates: Fledging (Range / Peak)	Source
Fish Island	59°52'N	1976	16 April - 25 May 21-25 April	3 June - 11 July 6-20 June	7 August 16-20 August	This study
		1977[1]	30 April - 5 June 11-20 May	13 June - 1 Aug. 1-5 July	12 Aug. - 1 Oct. 26-31 August	This study
		1977[2]	21 April - 5 June 1-5 May	10 June - 30 July 16-20 June	14 Aug. - 15 Sept. 16-20 August	This study
Barren Islands	58°57'N	1976	--	26 June - 24 Aug. 21-26 July	--	D. Manuwal & D. Boersoma pers. comm.
Buldir Island	52°21'N	1976	--	15 May - 30 June 15 May-30 May	--	V. Byrd pers. comm.
Forrester Is.	54°48'N	1976	27 April - 6 June 4-14 May	7 June - 18 July 15-25 June	--	DeGange *et al*. 1976
		1915	--	-- 5-15 June	--	Willet 1915
Trinidad Rock, Calif.	41°02'N	1974	18 March - 16 July mid April	-- Early May	-- Mid-July	Harris 1974

[1]Nesting chronology in soil habitat in 1977.

[2]Nesting chronology in rocky slope habitat in 1977.

Table12. Length of fork-tailed storm petrel incubation periods at Fish Island in 1977.

Date Egg Laid	Date Hatched	Length
23 May	11 July	49
8 May	26 June	49
21 May	2 July	42
25 May	23 July	59
16 May	10 July	55
1 May	15 June	46
15 May	30 June	46
9 June	27 July	48
14 May	26 June	42
		$\bar{m}$ = 48.4 s = 5.59

Table 13. Nesting chronology of Leach's storm petrels on Fish Island in 1976 and 1977.

Nest Number	Estimated Egg-laying Date	Hatching Date	Estimated Fledging Date
1976			
1	8 June	-	-
2	15 June	-	-
3	26 June	7 August[1]	-
4	6 June	18 July	26-30 September
5	30 June	11 August	10-20 October
6	12 July	>23 August	25 Oct. - 1 Nov.
1977			
1	11 June	23 July	23-28 September
2	15 July	27 August	1-5 November
3	23 June	4 August	8-13 October
4	5 July	16 August	20-25 October

[1]Estimated hatching date based on wing length of chick.

Table 14. Nesting chronology of Leach's storm petrels at Fish Island as compared with other areas.

Location	Latitude	Year	Egg-laying	Hatching	Fledging	Source
Fish Island	59°52'N	1976	8 June-12 July	18 July-23 Aug.	26 Sept.-1 Nov.	This study
		1977	11 June-5 July	23 July-27 Aug.	23 Sept.-5 Nov.	This study
Forrester Is.	54°48'N	1915	peak 29 June	-	-	Willett 1915
Forrester Is.	54°48'N	1976	17 June-peak 28 June	2 Aug.-9 Aug.	-	DeGange *et al.* 1976
Buldir Island	52°21'N	1975	30 May-30 July peak 30 June-15 July	-	-	V. Byrd pers. comm.
Trinidad Rocks, California	41°02'N	1965-1969	6 May-8 July peak 21 May-3 June	16 June-22 June peak 1-14 July	-	Harris 1974
Farallon Is.	37°04'N	1972	9 May-16 June peak 19 May-6 June	-	-	Ainley *et al.* 1976

Table 15. Summary of black-legged kittiwake nests observed containing known contents. Eggs observed on 21-22 June, chicks observed on 29 July 1977.

Number of Eggs	Number of Chicks	Number of Nests
0	0	35
	1	3
	2	2
1	0	19
	1	20
	2	8
2	0	14
	1	20
	2	24
	1 egg & 1 chick	3
		149

Table 16. Summary of tufted puffin transects conducted during 1977 on Fish Island.

Location	Approx. Area Searched, m^2	No. Nests Found	No. with Eggs	No. undetermined	No. Inactive	No. with Chicks
Cliff face	--	10	--	0	5	5[b]
Grassy slope[a]	--	4	2	0	1	1
Cliff edge						
Southeast area[a]	480	23	13	0	10	5
East Point exclosure	330	100	9	24	47	20
East Point 1977 transect	330	101	29	14	58	-
Puffin Point[a]	150	59	35	0	24	15
Petrel Point exclosure	258	50	6	19	23	2
Crooked Tree[a]	30	6	5	0	1	5

[a]Burrows monitored continuously so number of chicks represents those eggs that hatched. All other burrows or nests were visited at only one point in time.

[b]Only chicks observed which probably successfully fledged.

Table 16. Continued

Location	Approx. Area Searched, m^2	No. Nests Found	No. with Eggs	No. undetermined	No. Inactive	No. with Chicks
Rocky Slope						
West Point transect						
1976	896	34	5	11	3	15
1977	896	25	13	10	2	3
#49	490	2	1	1	0	0
#63	434	0	0	0	0	0
#91	602	0	0	0	0	0
#133	840	3	1	2	0	0
#147	826	16	5	4	5	2
#217	546	20	3	4	10	3
#273	322	2	2	0	0	0
#371	672	3	2	1	0	0
#441	658	13	1	6	3	3
#497	574	0	0	0	0	0
#511	434	0	0	0	0	0

Table 17. Egg-laying dates for 48 monitored tufted puffin burrows in 1977.

Date	Number of Burrows
31 May & before	3
2 - 5 June	12
6 - 9 June	16
10 - 14 June	10
15 - 18 June	7

Table 18. Dead organisms and oil pollution found during beach surveys at Patton Bay, summer 1977.

Date	Organism
23 April	1 black-legged kittiwake, 2 tufted puffins, 1 unidentified small gull (wings), 1 dark phase northern fulmar
7 May	1 shearwater, 1 tufted puffin
23 May	2 shearwaters
1 June	1 yearling steller sea lion
12 June	3 shearwater sp.
24 June	1 common murre in fish net, 2 adult-sized harbor seals
6 July	none
16 July	1 Sitka black-tailed deer (female: 2-3 years old) 1 small harbor seal
28 July	1 ancient murrelet, 1 shearwater sp., 1 unidentified mass of white feathers, 1 immature bald eagle (wing), 1 marbled murrelet (winter plumage), 100s of small tarballs (1cm-10cm diameter)
6 August	none, many oil patches on beach
17 August	1 black-legged kittiwake, 1 northern fulmar
28 August	1 marbled murrelet chick
9 September	1 marbled murrelet chick, 1 immature black-legged kittiwake, 1 pigeon guillemot chick, 1 black-footed albatross
18 September	2 tufted puffin chicks, 1 Cassin's Auklet

Table 19. Estimated degree and time[1] of susceptibility of Wooded Islands birds to oiling of plumage and ingestion of oil based on percent of time birds spend on the water, their feeding behavior and their reaction to oil patches.

Species	Unlikely to be Susceptible	Location of Oil				
		Nearshore Waters	Intertidal Sand and Gravel Beaches	Intertidal Boulder Beaches	Driftwood Zone	Spray Affected Zone
Common Loon		High:Apr-May				
Arctic Loon		High:Apr-May				
Red-necked Grebe[2]		High:Apr-May				
Sooty Shearwater[2]		High:May-July				
Slender-billed Shearwater[2]		Low:July-Aug				
Fork-tailed Storm Petrel[2]		Low:Apr-Oct				
Leach's Storm Petrel[2]		Low:Apr-Oct				
Double-crested Cormorant		High:Apr-Oct		Mod:Apr-Oct		Mod:June-Aug
Pelagic Cormorant		High:Apr-Oct		Mod:Apr-Oct		Mod:June-Aug
Red-faced Cormorant		High:Apr-Oct		Mod:Apr-Oct		Mod:June-Aug
Great Blue Heron	X					
Whistling Swan	X					
Trumpeter Swan	X					
Canada Goose			Low:Apr-Oct		Low:Apr-Oct	

[1]Only for months of April through October.

[2]Storm petrels and shearwaters spend most of their time over the sea at greater distances from land and would presumably be better able to avoid an oil spill than a diving species.

Table 19. Continued

Species	Unlikely to be Susceptible	Location of Oil: Nearshore Waters	Intertidal Sand and Gravel Beaches	Intertidal Boulder Beaches	Driftwood Zone	Spray Affected Zone
Black Brant		Mod:Apr-June				
White-fronted Goose			Low:May			
Shoveler			Low:Apr-June			
Mallard			Low:Apr-June,Aug			
Pintail			Low:Apr-June,Aug			
American Wigeon			Low:Apr-June			
Green-winged Teal			Low:Apr-June,Aug			
Greater Scaup		Mod:Apr-June				
Bufflehead		Mod:Apr-June				
Oldsquaw		Mod:Apr-June				
Harlequin Duck		High:Apr-Oct				
King Eider		High:Apr-May				
White-winged Scoter		High:Apr-Oct				
Surf Scoter		High:Apr-Oct				
Common Scoter		High:Apr-Oct				
Common Merganser		High:Apr-Oct				
Red-breasted Merganser		High:Apr-Oct				
Sharp-shinned Hawk	X					
Bald Eagle			Low:Apr-Oct	Low:Apr-Oct	Low:Apr-Oct	
Marsh Hawk					Low:Apr-May	

Table 19. Continued

Species	Unlikely to be Susceptible	Location of Oil: Nearshore Waters	Intertidal Sand and Gravel Beaches	Intertidal Boulder Beaches	Driftwood Zone	Spray Affected Zone
Osprey	X					
Peregrine Falcon			Low:Apr-Oct			Low:Apr-Oct
Merlin	X					
Sparrow Hawk	X					
Black Oystercatcher			Mod:Apr-Oct	Mod:Apr-Oct		Mod:Apr-Oct
Semipalmated Plover			Mod:Apr-Oct			
American Golden Plover			Low:Apr-May			
Black-bellied Plover			Mod:Aug-Sept			
Surfbird				Mod:Aug-Sept		Mod:Aug-Sept
Ruddy Turnstone				Mod:Aug-Sept		Mod:Aug-Sept
Black Turnstone				Mod:Apr-June Aug-Oct		Mod:Aug-Sept
Western Sandpiper			Mod:May, Aug-Sept			
Least Sandpiper			Mod:May-Oct		Mod:May-Oct	
Baird's Sandpiper			Mod:Aug			
Pectoral Sandpiper			Mod:Aug-Sept	Mod:Aug-Sept		
Rock Sandpiper				Mod:Apr-May Aug-Oct		Mod:Apr-May Aug-Oct
Dunlin			Low:Apr-May			
Upland Plover	X					

Table 19. Continued

Species	Unlikely to be Susceptible	Location of Oil: Nearshore Waters	Intertidal Sand and Gravel Beaches	Intertidal Boulder Beaches	Driftwood Zone	Spray Affected Zone
Lesser Yellowlegs				Mod:Aug		Mod:Aug
Wandering Tattler			Mod:Apr-Oct	Mod:Apr-Oct		Mod:Apr-Oct
Spotted Sandpiper			Mod:Apr-Oct			Mod:Apr-Oct
Hudsonian Godwit	X					
Whimbrel			Mod:Apr-May Aug-Sept			Mod:Aug-Sept
Common Snipe	X					
Northern Phalarope		High:May Aug-Oct				
Parasitic Jaeger	X					
Long-tailed Jaeger	X					
Glaucous-winged Gull		Mod:Apr-Oct	Low:Apr-Oct	Mod:Apr-Oct	Low:Apr-Oct	Low:May-Aug
Herring Gull			Low:Apr-Oct	Low:Apr-Oct		
Mew Gull		Mod:Apr-Oct		Low:Apr-Oct		
Bonaparte's Gull		Mod:Apr-July				
Black-legged Kittiwake		Mod:Apr-Oct	Low:Apr-Oct	Low:Apr-Oct		Low:May-Aug
Arctic Tern			Low:Apr-Oct			
Aleutian Tern			Low:Aug			
Common Murre		High:Apr-Oct				
Pigeon Guillemot		High:Apr-Oct		Low:Apr-Aug		Low:Apr-Aug

Table 19. Continued

Species	Unlikely to be Susceptible	Location of Oil: Nearshore Waters	Intertidal Sand and Gravel Beaches	Intertidal Boulder Beaches	Driftwood Zone	Spray Affected Zone
Marbled Murrelet		High:Apr-Oct				
Ancient Murrelet		High:Apr-Oct				
Cassin's Auklet		High:June-Oct				
Parakeet Auklet		High:May-Oct		Low:Apr-Aug		Low:Apr-Aug
Rhinoceros Auklet		High:June-July				
Horned Puffin		High:May-Oct		Low:May-Oct		Low:May-Oct
Tufted Puffin		High:May-Oct				Low:May-Oct
Black Swift	X					
Rufous Hummingbird	X					
Belted Kingfisher	X					
Yellow-bellied Sapsucker	X					
Violet-green Swallow	X					
Tree Swallow	X					
Bank Swallow	X					
Barn Swallow	X					
Cliff Swallow	X					
Steller's Jay	X					
Black-billed Magpie	X					

Table 19. Continued

Species	Unlikely to be Susceptible	Location of Oil: Nearshore Waters	Intertidal Sand and Gravel Beaches	Intertidal Boulder Beaches	Driftwood Zone	Spray Affected Zone
Common Raven				Low:Apr-Oct	Low:Apr-Oct	Low:Apr-Oct
Northwestern Crow			Low:Apr-Oct	Low:Apr-Oct	Low:Apr-Oct	Low:Apr-Oct
Chestnut-backed Chickadee	X					
Brown Creeper	X					
Winter Wren	X					
Varied Thrush					Low:Apr-Oct	
Hermit Thrush	X					
Golden-crowned Kinglet	X					
Ruby-crowned Kinglet	X					
Bohemian Waxwing	X					
Water Pipit			Low:July-Sept	Low:July-Sept		
Northern Shrike	X					
Yellow Warbler	X					
Townsend's Warbler	X					
Blackpoll Warbler	X					
Wilson's Warbler	X					
Rusty Blackbird	X					
Pine Grosbeak	X					
Hoary Redpoll	X					
Red Crossbill	X					

Table 19. Continued

Species	Unlikely to be Susceptible	Location of Oil				
		Nearshore Waters	Intertidal Sand and Gravel Beaches	Intertidal Boulder Beaches	Driftwood Zone	Spray Affected Zone
White-winged Crossbill	X					
Savannah Sparrow	X					
Dark-eyed Junco	X					
Tree Sparrow	X					
Harris' Sparrow	X					
White-crowned Sparrow	X					
Golden-crowned Sparrow	X					
Fox Sparrow				Low:Apr-Oct	Low:Apr-Oct	Low:Apr-Oct
Song Sparrow				Low:Apr-Oct	Low:Apr-Oct	Low:Apr-Oct
Lapland Longspur	X					

Table 20. Fish Island storm petrel nesting colonies mapped as shown in Figure 6.

Area	Area Mapped (m^2)	Number of Burrows	Number with Eggs	Burrows per m^2	Active Burrows per m^2	Percent Nesting Success
1	220	51	5[1]	.23	.02	0.0
2	240	19	11	.08	.05	10.0
3 Exclosure	392	115	27	.29	.07	68.0
4	741 (364)[2]	38	17	.10	.05	26.3
5	601 (391)[2]	27	19	.07	.05	10.5
6	368	129	33	.35	.09	48.0
7	942	143	79	15	08	23.7
8 Salmonberry plots	1200	39	21	03	01	19.0

[1] River otters killed many petrels in this subcolony in 1976. Few burrows were re-occupied in 1977.

[2] Burrows in these areas were not found beyond 7 m of the cliff edge. Density is thus based on the area within 7 m of the cliff edge though the area within 12 m of the cliff edge was searched.

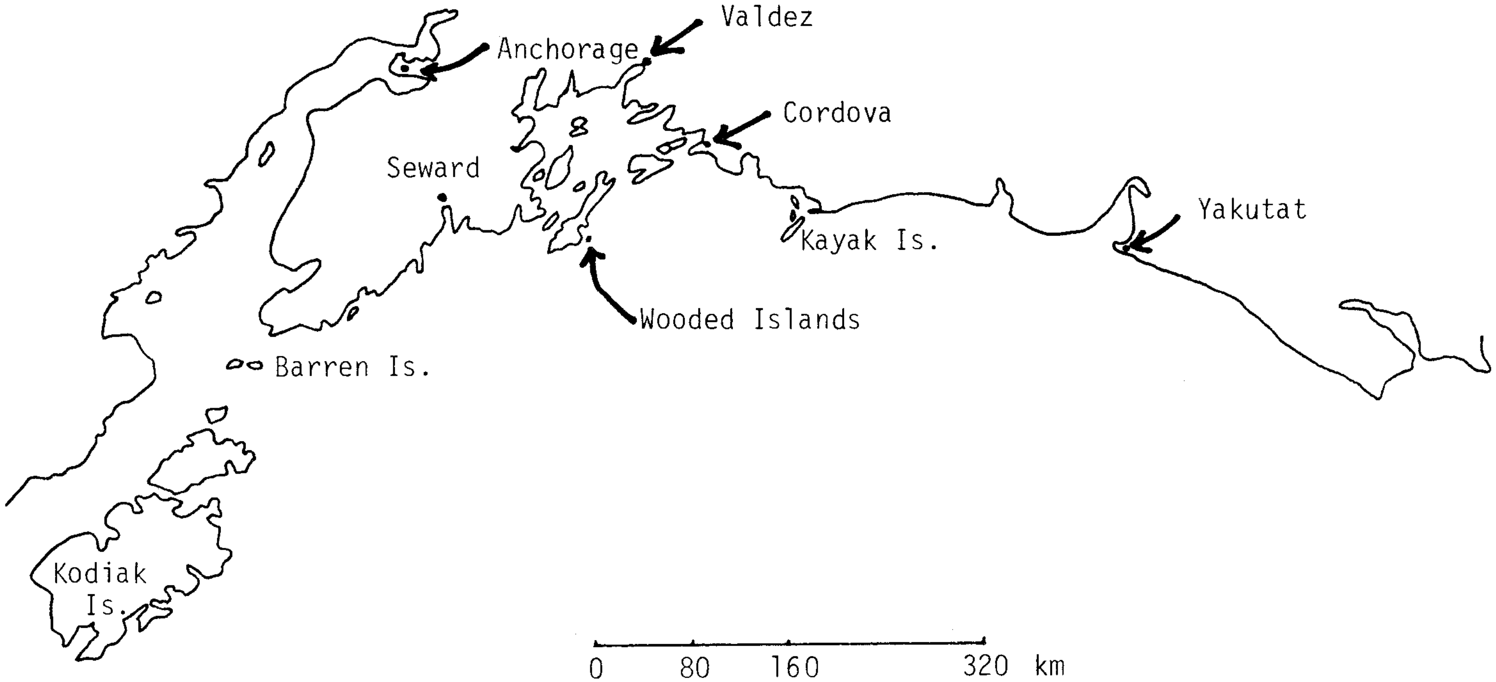

Fig. 1. Location of Wooded Islands in relation to other areas in the northern Gulf of Alaska.

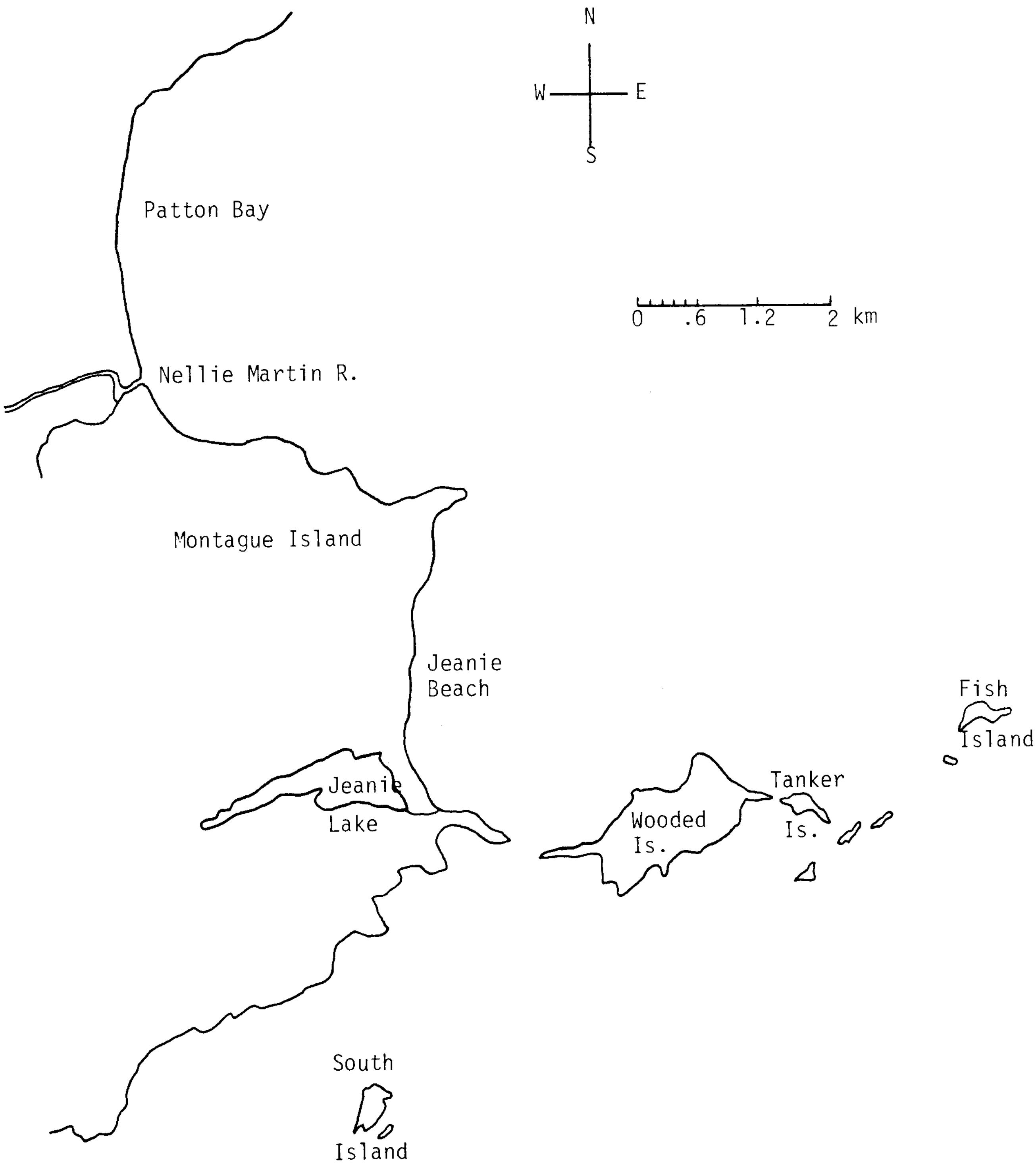

Fig. 2. Wooded Islands study area including parts of Montague Island and the surrounding waters.

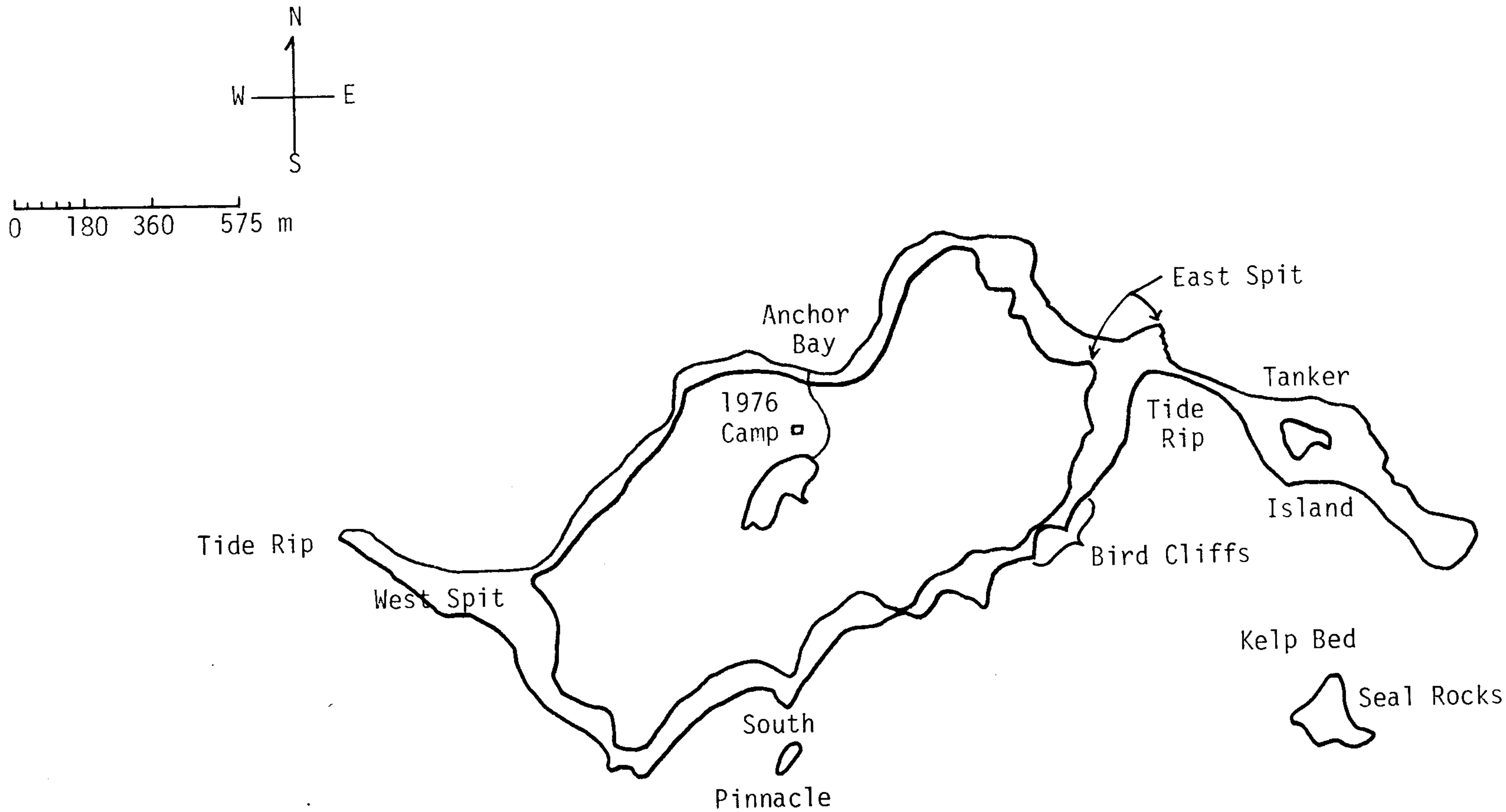

Fig. 3. Wooded and Tanker Islands showing location names, tide rips, and kelp beds.

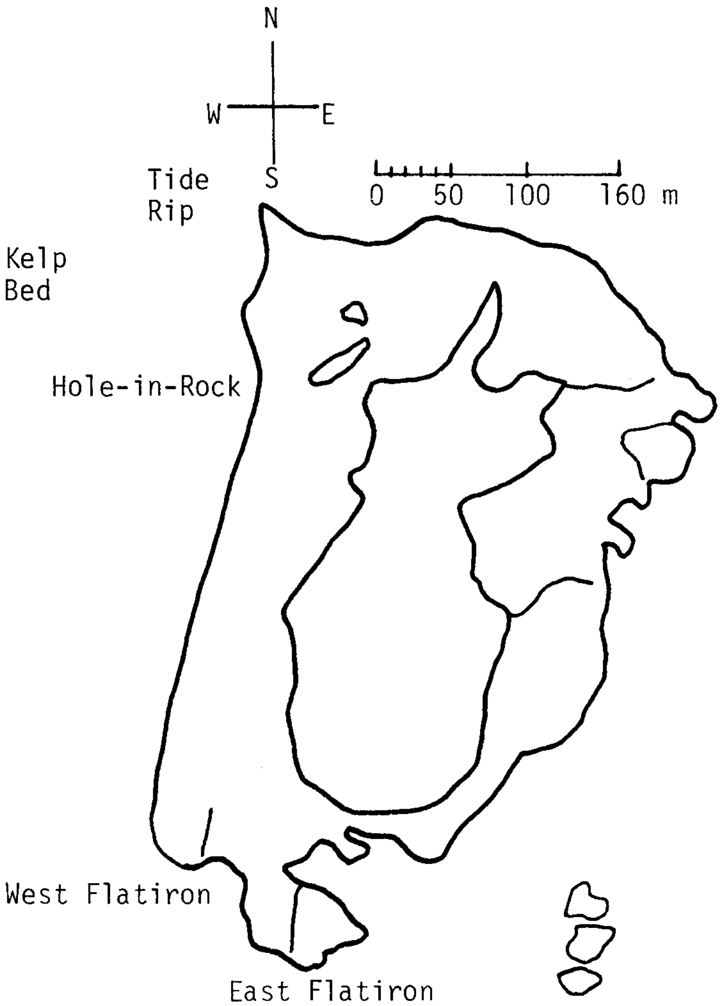

Fig. 4. South Island showing location names, tide rip, and kelp bed.

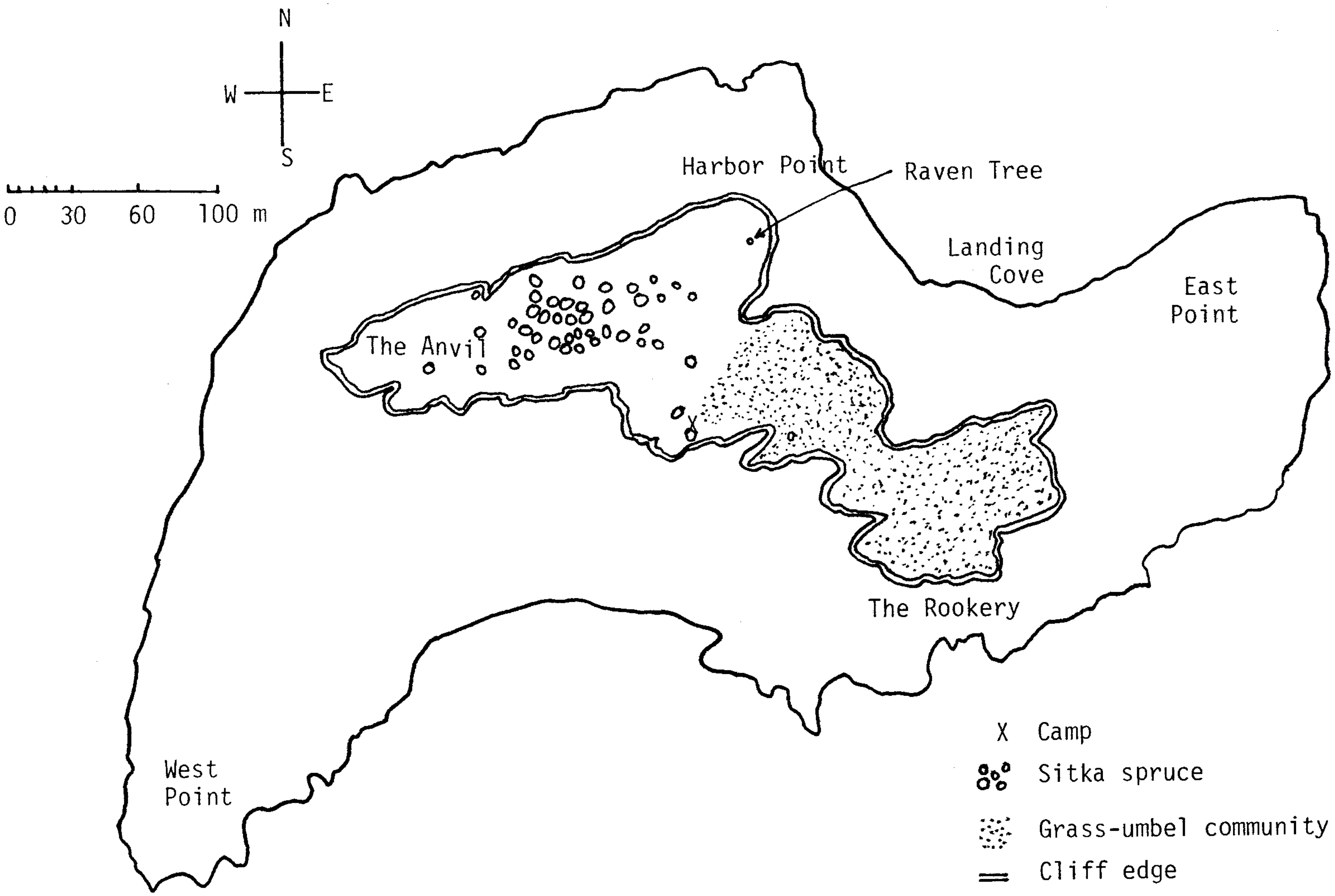

Fig. 5. Fish Island showing location names, general topography and vegetation.

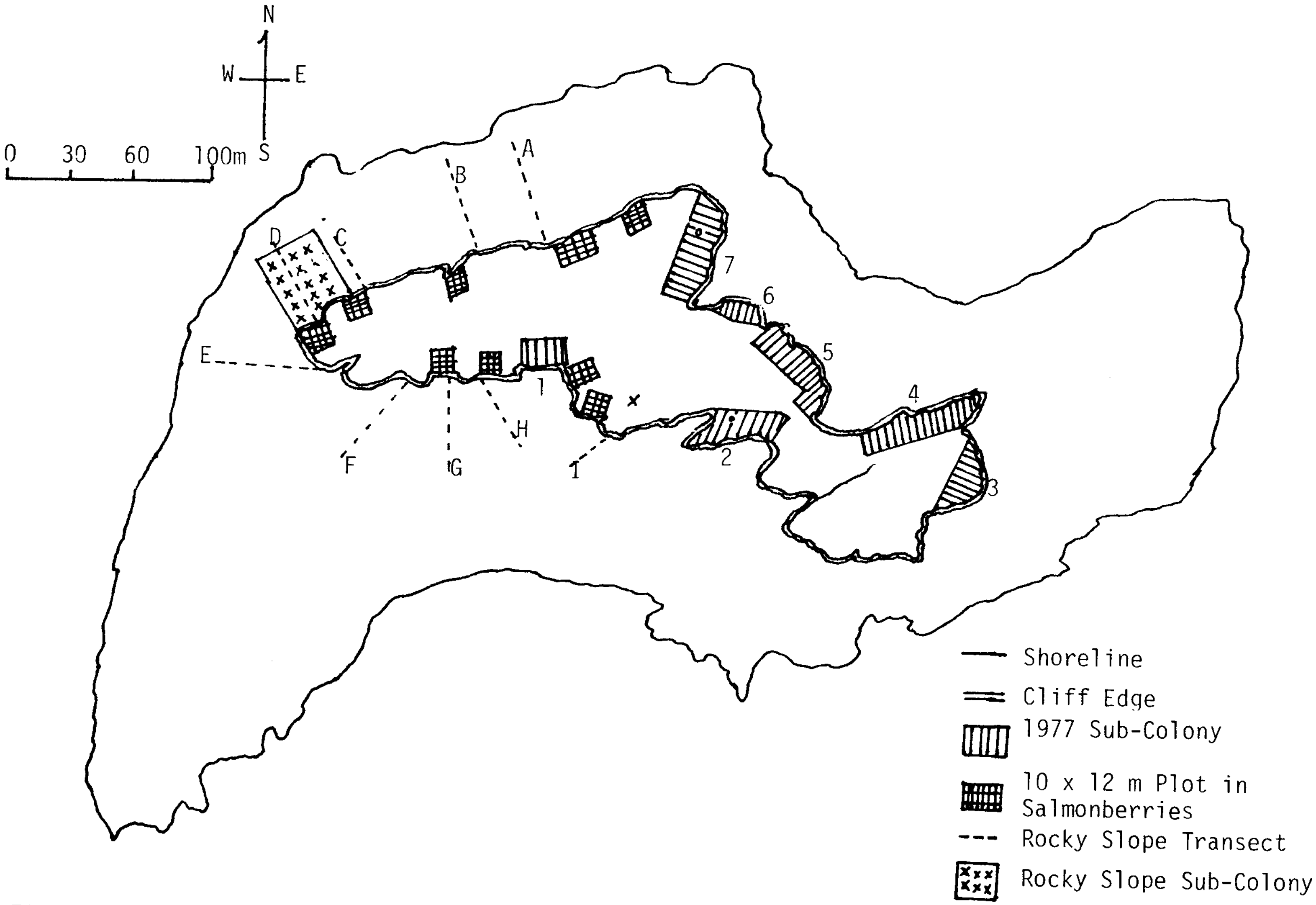

Fig. 6. Location of mapped fork-tailed storm petrel sub-colonies, randomly chosen plots in salmonberry habitat, midlines of randomly chosen transects on rocky slope habitat, and major sub-colonies in rocky slope habitat on Fish Island.

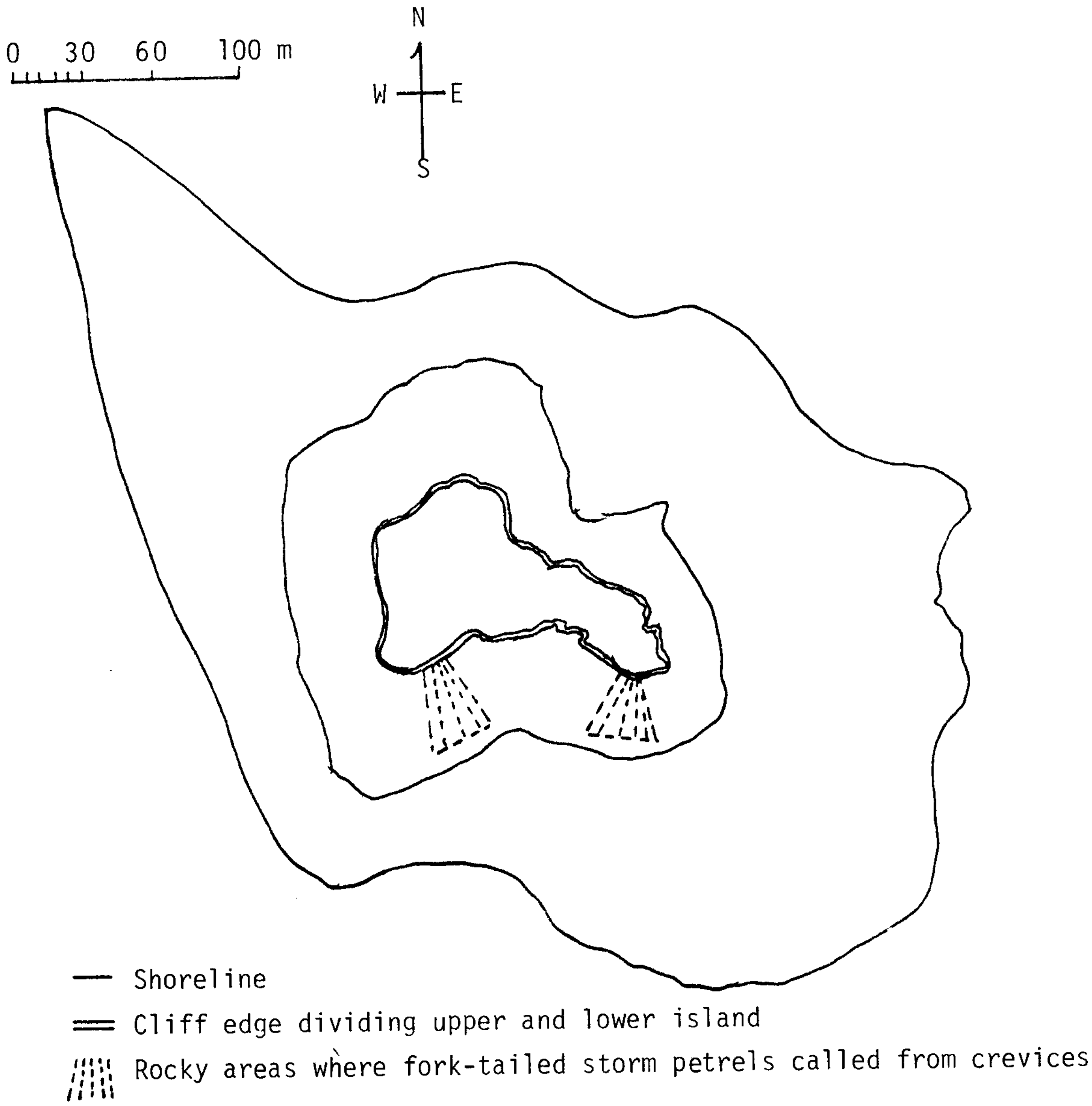

Fig. 7. Rocky slope areas on Tanker Island where fork-tailed storm petrels were heard calling from crevices. No storm petrels were observed or heard on the upper portion of the island.

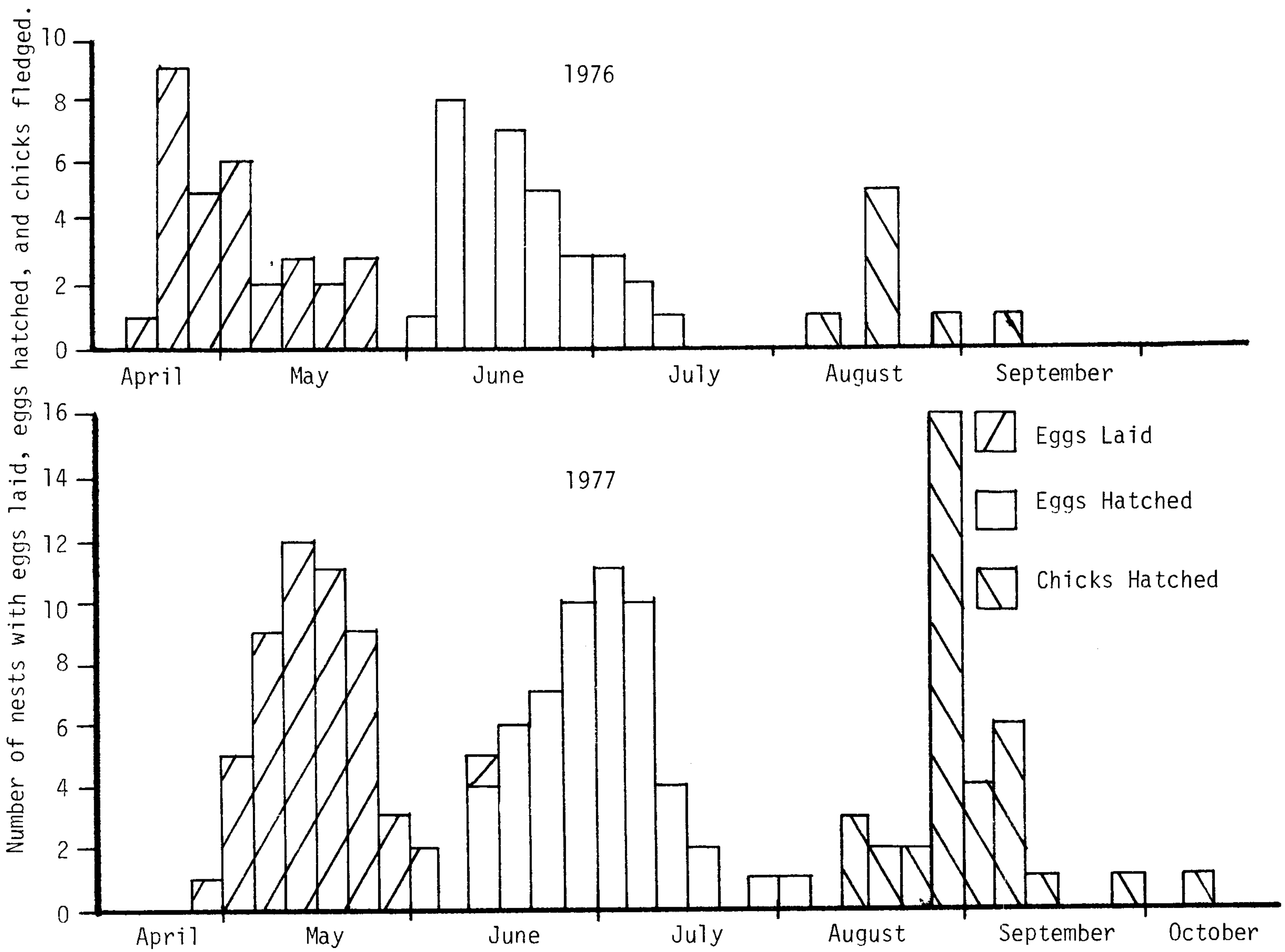

Fig. 8. Phenology of fork-tailed storm petrel nesting in soil areas on Fish Island during 5-day intervals in 1976 and 1977.

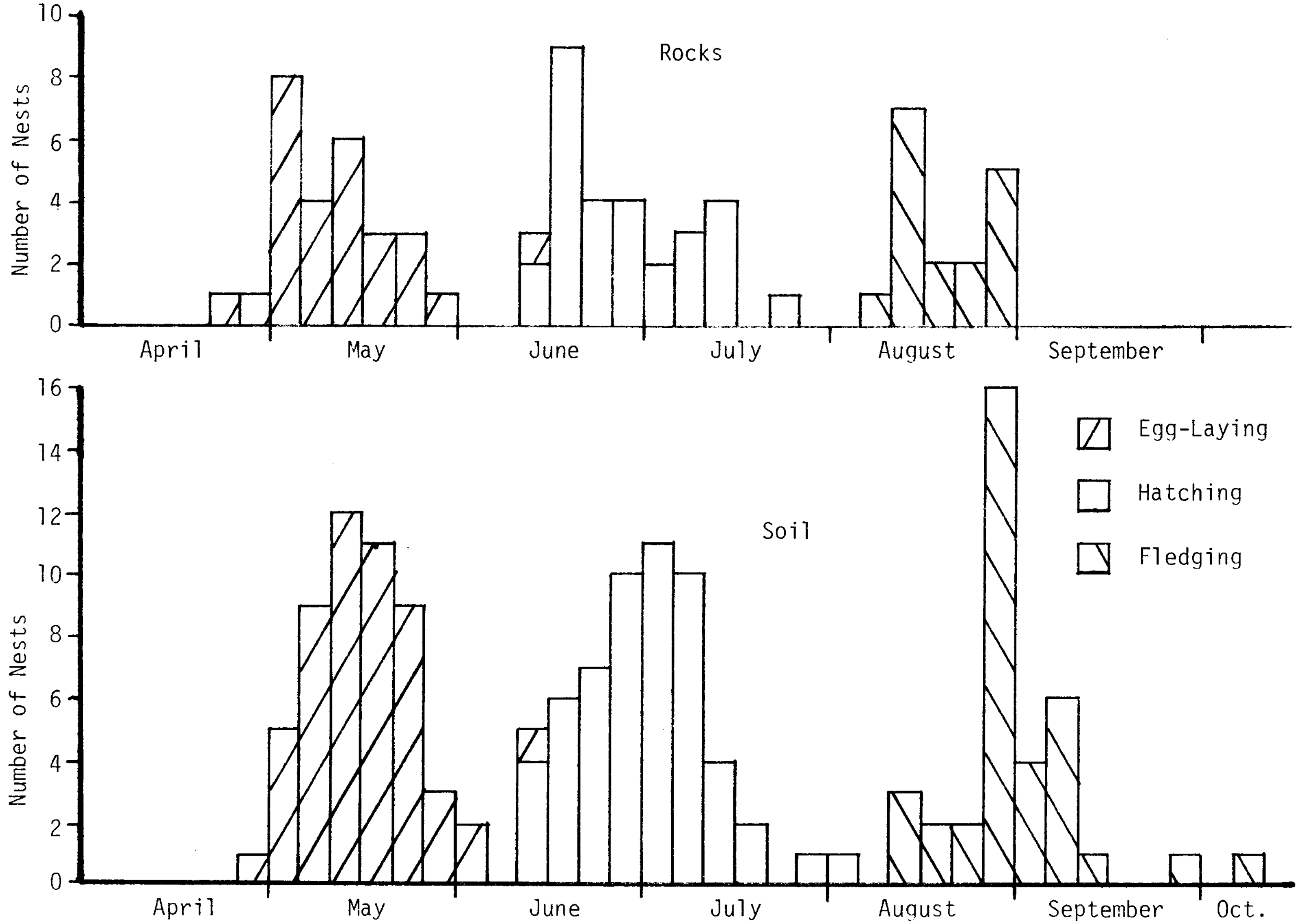

Fig. 9. Nesting chronology of fork-tailed storm petrels in rock and soil habitats on Fish Island, 1977.

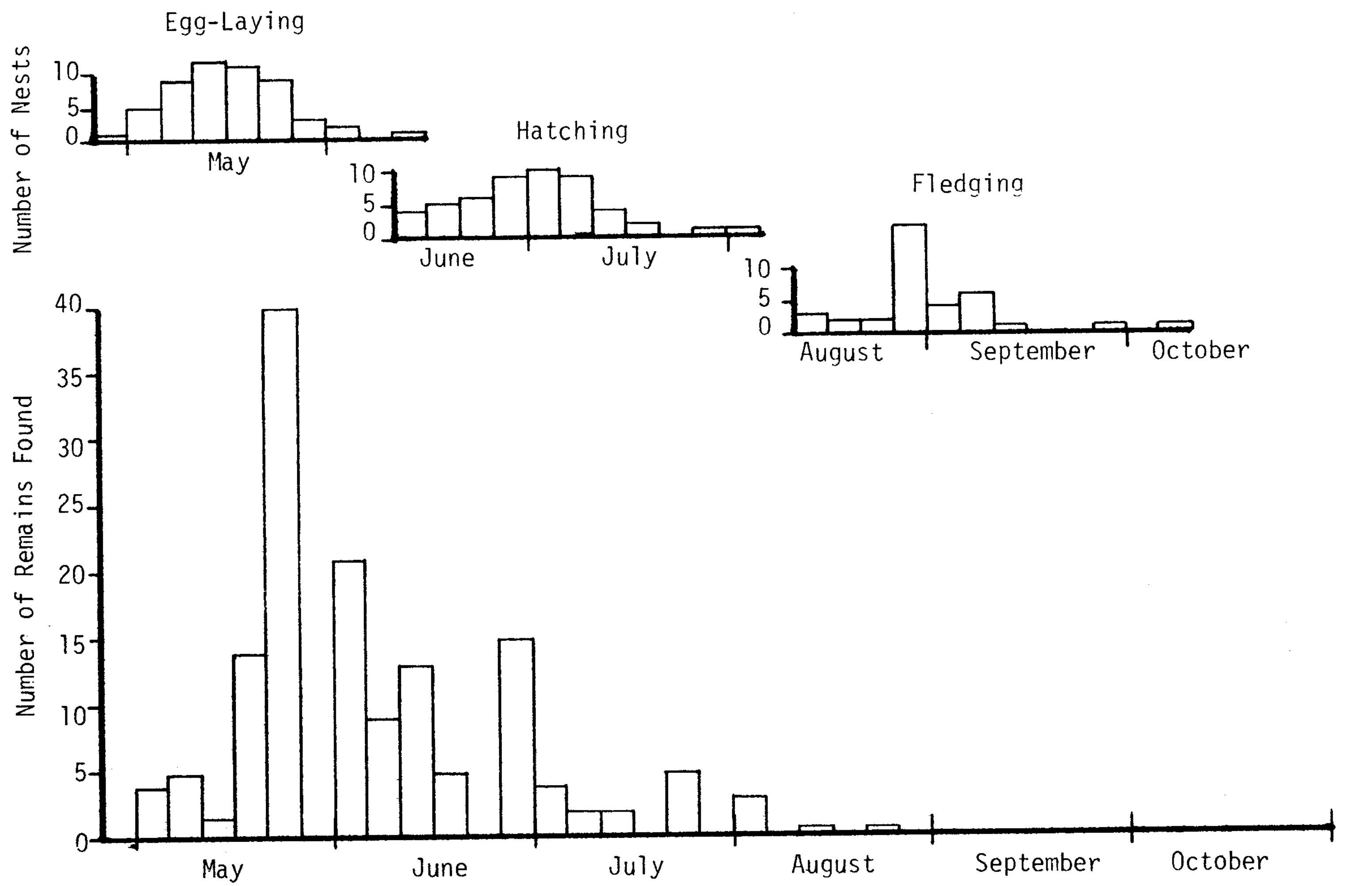

Fig.10. Timing of river otter predation on fork-tailed storm petrels at Fish Island as related to phenology.

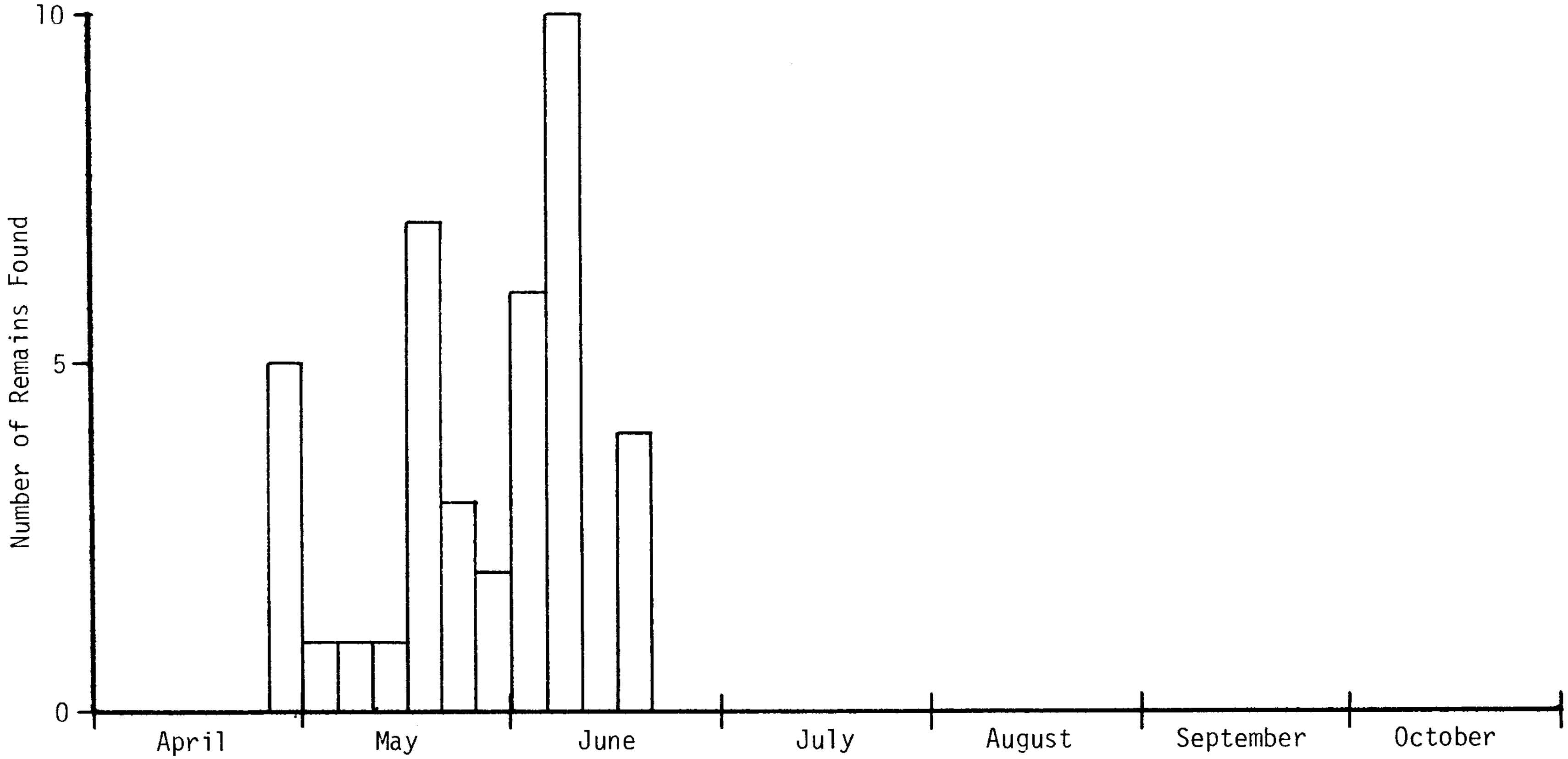

Fig. 11. Timing of avian predation on fork-tailed storm petrels at Fish Island.

Appendix VIII

NOAA-OCSEAP Contract: 01-5-022-2538
Research Unit: 341
Principal Investigators: C.J. Lensink
K.D. Wohl
Reporting Period: April 1, 1977 to
March 31, 1978

Annual Report

The feeding ecology and Trophic Relationships of Key Species of Marine Birds in the Kodiak Island Area, May-September 1977

By

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April 1, 1978

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INTRODUCTION

Studies of the feeding ecology and trophic relationships of marine birds have been a part of the NOAA BLM Outer Continental Shelf Environmental Assessment Program (OCSEAP) in Alaska since its inception. The general objectives, rationale, methods, and preliminary results of such studies by the U.S. Fish and Wildlife Service in 1975 and 1976 were described in previous annual reports (Sanger and Baird 1977; Lensink et al 1976). Included in these studies was pelagic work in the northwestern Gulf of Alaska on cruises aboard NOAA vessels. Birds were collected opportunistically for feeding habits studies on many of the cruises. Along with a few birds collected in the Chiniak Bay area of Kodiak Island in winter (Dick 1977), and collections of bill loads and regurgitations on nesting colonies, these samples number 153 specimens of 15 species (Sanger & Baird 1977). Data from these samples will be completed when our computer capabilities are in operation.

In 1977 we concentrated our efforts under this research unit in the Kodiak Island area. This was primarily because the leasing schedule for the Kodiak Basin had been moved up and the Kodiak archipelago and surrounding waters harbor large numbers of breeding and migrant marine birds. Commercial air transportation to and around Kodiak is readily available, so the area is logistically more feasible for long-term studies than many areas in Alaska. This work included intensive studies of breeding biology at a number of sites in Chiniak Bay (Nysewander and Hoberg 1978), in Sitkalidak Strait (Baird and Moe 1978), and studies of the birds' feeding ecology, distribution and abundance at sea.

This report focuses specifically on the feeding studies conducted at sea in 1977. Details of the pelagic distribution and abundance of the birds are reported by Gould et al (1978), but aspects pertinent to the feeding studies are summarized here. Baird and Moe (1978) discuss those specialized aspects of feeding ecology pertinent to breeding biology. An integration and synthesis of this information with the data reported here will be covered in subsequent reports.

CURRENT STATE OF KNOWLEDGE

Sanger and Baird (1977) discussed the general state of knowledge of the feeding ecology of marine birds in the eastern North Pacific Ocean and the Bering Sea. Investigations of the feeding ecology of marine birds in Alaska have continued in many areas (Hunt 1977; Drury 1977; Divoky 1977). Laboratory analyses of the backlog of stomach samples collected as part of RU-341 in 1975-76 has been completed for all but a few of the lower priority species, but a thorough analyses and synthesis of resulting data is still lacking. A major portion of our effort under this RU will be directed toward accomplishing this task.

Through this report and Baird and Moe (1978), we will just begin to understand feeding ecology of a few key species of birds present in the Kodiak Island area in spring and summer. Fall and winter data remains particularly lacking. However, Dick (1977), and a study in the Chiniak Bay area of Kodiak currently being conducted as part of this RU, will give a better idea of the winter feeding ecology of marine birds in the nearshore area of Kodiak.

Nothing is known about food web relationships among marine birds and the other biota in the ecosystem of the Kodiak area. The interdisciplinary food web studies planned for this spring and summer will help rectify this situation. Further, it is unknown if there are annual variations in the feeding habits of marine birds, or if such variations reflect changes in prey availability. It is also unknown how productivity on the colonies may be affected by annual changes in prey availability or prey species composition. The longer that the integrated studies are continued, the better able we will be to understand annual variations and their affect on the ecosystem.

STUDY AREA

This study was conducted in the general area off northeastern Kodiak Island, from Marmot Bay south to the Geese Islands, and over the shelf to about 45 km offshore of the major headlands (Figure 1). Bird collections for feeding habits studies were concentrated in and offshore from Marmot and Chiniak Bays in the north, and in the area around Sitkalidak Island in the south. In the Sitkalidak area, the collections were mostly in two general areas: 1. Within and just offshore of the mouth of the northern end of Sitkalidak Strait and Kiliuda Bay, between Cape Barnabas and Dangerous Cape, and 2. Within and off the mouth of the southern end of Sitkalidak Strait, between Two Headed Island and Black Point. Further details about the study area in general are reported by Gould et al (1978).

METHODS

Field Methods

The work was conducted aboard a chartered boat, the M/V Yankee Clipper, a 58' vessel with a Westport, semi-planing hull. Navagtion and position fixes were usually determined by radar and fathometer, and sometimes by dead reckoning. The vessel offered excellent visibility forard and abeam from the pilot house.

Bird collections for feeding habits studies, and transect counts of the birds for density estimates, were conducted from 26 May through 19 September, on cruises of 11 to 24 days duration during the five time intervals listed in Table 1. The nominal track followed for transect censuses during the cruises is indicated in Figure 1; Gould et al (1978) indicate the departures from this nominal track. The weather dictated to a large extent the order in which the track was transited.

Gould et al (1978) give details of the methods used in transect observations. A knowledge of the densities of birds in an area, determined at the same time the birds are sampled for stomach contents analyses, is important in studies of their feeding ecology.

The density data (number of birds per km^2 of sea surface) provide a means of estimating total numbers of birds in a given area on the same time basis that their feeding habits are studied. These estimates are important if estimates of the total consumption of prey for a given area are to be made, and are essential information for ecosystem modeling.

During the transect counts, feeding behavior and the size and species composition of feeding flocks was noted and recorded. The behavior of the birds was observed in some detail before actual collection; these observations lasted from a few minutes to as long as an hour and a half depending on the circumstances. On two instances, one of our biologists (Forsell) SCUBA dived beneath large flocks of Short-tailed Shearwaters to observe their underwater swimming and feeding behavior.

Most of the birds were collected when they were encountered during the transect counts in feeding situations, or when they were otherwise concentrated enough to collect several at the same time and place. Most of the time collections were accomplished by putting the vessel's skiff (a 17' Smokercraft with a 25 hp outboard engine) over the side with two or three biologists aboard and motoring a km or more away from the vessel to collect with a shotgun. Less frequently, specimens were collected from the Yankee Clipper herself.

Usually within five minutes of collection, the specimens were weighed with a small spring scale to the nearest ten g, and their stomachs were injected with 10% buffered formalin through 5 mm tygon tubing inserted through their bill. They were tagged with a label indicating weight and time of collection. The specimens were processed within an hour or two by making standard measurements on each bird, and the digestive tract was removed and preserved in 10% buffered formalin in a plastic "whirlpak". Among the measurements made which are particularly pertinent to feeding ecology studies are body weight, bill width and fat index. The fat index is a numerical but subjective expression of the amount body fat. The bill width is defined as the distance at the angle of the commissure from one inside edge of the bill to the other, with the bill held open at an angle of 30° to 45°.

The general rationale was to collect birds only if they appeared to be actively feeding. Attempts were made to collect a series of at least five birds of each species in each situation. Attempts were made to sample such series of each of the five key species as closely as possible in time and space so as to determine trophic interactions as closely as possible. For the most part, collections were obtained immediately preceding, during and immediately following the transect counts; this was generally between 0800 and 1800, but there were exceptions. Due to the small vessel crew (two, only one of whom could operate the vessel), our work was limited to about 12 to 15 hours in the middle of the day. A series of birds was collected at the same location at two hour intervals, from 0600 until 2100 hours once in September.

Closely associated with the work aboard the *Yankee Clipper* was the work at Sitkalidak Strait on nesting colonies on Cathedral Island and other colonies nearby. This is described in detail by Baird and Moe (1978). The work was focused on the Tufted Puffin, Black-legged Kittiwake, Glaucous-winged Gull, and Arctic and Aleutian Terns. Included were intensive observations on the feeding behavior and frequency, collections of adult birds for stomach analyses, and collection of bill loads and regurgitations of food carried by parent birds to chicks on the nests. Feeding studies were less intensive in the Chiniak Bay colony studies (Nysewander and Hoberg 1978), but they too will be helpful in understanding the feeding ecology of birds in the Kodiak area.

Laboratory Methods

We continued to use the basic laboratory methods described by Sanger and Baird (1977). A continuing effort was made to strengthen our prey and prey part reference collection. Standard taxonomic keys were used. Each time we encountered a prey species new to us, or of questionable identity, it was sent to a specialist for identification.

A method of extrapolating whole fish lengths from measurements of their parasphonoid bone (Sanger and Baird 1977) was considerably improved. Whole Capelin (*Mallotus villosus*) and Pacific Sandlance (*Ammodytes hexapterus*) were measured to mm total length. They are the two most importnat prey species in summer for most of the marine bird community in the Kodiak area (see below). Their skeletons were fleshed out and the parasphenoid bones (P-bones) and vertebral columns were removed and measured to the nearest mm. The vertebral column was measured from the base of the skull to the end of the caudal bone assembly. Regression equations for the relationships between these measurements and total lengths were calculated, and used to extrapolate whole prey length whenever needed. A manuscript (Hironaka, Fukuyama and Sanger, in prep.) describing this method is being prepared for publication.

The P-bone, which lies in the skull along the roof of the mouth, seems to persist in good condition in bird stomachs. It is easily recognized and is of a highly characteristic shape, so it has been very useful for identification of fish species as well as for extrapolation of original lengths. We have photographs and reference examples of the P-bone of juvenile Walleye Pollock (*Theragra chalcogramma*), True Cod (*Gadus macrocephalus*), Pacific Herring (*Clupea harengus*) and Pacific Sandfish (*Trichodon trichodon*).

Otoliths were occasionally used to identify fishes (Morrow 1977), but these bones have been relatively rare in our stomach samples. When present they were often digested beyond taxonomic usefulness. The relatively small size of fishes eaten by the birds have accordingly small and delicate otoliths, making them not as useful a taxonomic tool as in pinniped feeding studies (Kajimura and Sanger 1975), for example.

Data Analyses

The basic data on prey used in this report are identity, aggregate percent volume and percent frequency of occurrence. Considered on the bird specimens themselves are preliminary analyses of the fat index, bill width, body weight, percent of net body weight comprised by the stomach contents (food percent of body weight), and the index of filling, i.e., the food percent of body weight expressed as the percent of the maximum observed such percent for that species (Skalkin 1963). Depending on bird species and other factors, these data are compared by time interval (cruise), time of day, and area. In the preliminary treatment in the report, the data are broadly grouped by "northern area" and "southern area" without regard to distance offshore or specific bay or other area of collection. The northern area includes all samples from the Chiniak/Marmot Bay region, i.e., everything north of latitude 57°20' North, and the southern area includes samples south of here, mostly from the area around Sitkalidak Island.

RESULTS

Numbers of Birds Sampled

A total of 428 specimens of the five key species was collected in this study. These are summarized by species, cruise period and general area of collection in Table 1. Of the total, 373 (87%) had food in their stomachs. There was a certain amount of inconsistency in the distribution of numbers of specimens by time and general area, due to vagaries in the distribution of the birds. About 25 specimens of nine other species were also collected; these will be discussed in subsequent reports. Included were one or more specimens of Northern Fulmar, Fork-tailed Storm Petrels, Glaucous-winged Gull, Sabine's Gull, Northern Phalarope, Parasitic Jaeger, Cassin's Auklet and Marbled and Kittlitz's Murrelet. The statistical adequacy of the numbers of birds sampled are discussed below.

Kinds of Major Prey Types Eaten

Figure 2 shows the aggregate percent volume of prey for each of the five key species averaged for the entire study period. Specific aspects of the prey eaten by each bird species will be discussed below. Figure 2 clearly shows that, by volume, fish are the most important type of prey in late spring and summer. Fish are relatively more important for the Alaskan breeding species than for the shearwaters, which are summer migrants from the southern hemisphere. Fish comprised 100% of the diet of Common Murres, 97.2% for Black-legged Kittiwakes and 93.3% for Tufted Puffins. In contrast, 76% of the diet of Sooty Shearwaters was fish, and only 41.9% of the Short-tailed Shearwater diet was fish. Euphausiids were quite important (47%) for Short-tailed Shearwaters, and gonatid squid was more important to the shearwaters than the Alaska breeders. The Sooty Shearwater diet was 24% squid; squid comprised only 4% of the diet of Tufted Puffins and Common Murres and kittiwakes had no squid in their stomachs.

Capelin dominated the volume of fish eaten by a large degree. The importance of this prey species becomes even more apparent when one considers that the unidentifiable osmeridae and some of the "unidentifiable fish" were likely Capelin as well; no whole osmerids other than capelin were present in the stomachs. Other fish species present in the stomachs were Pacific Sandlance, which formed 11% of the diet of Common Murres, and Walleye Pollock, which formed 6% of the diet of Tufted Puffins and 11% of the diet of Common Murres (if one assumes that the unidentifiable gadidae in the murres were pollock).

Species Accounts

Following are aspects of a preliminary analysis of feeding ecology of each of the five key species. General highlights of the pelagic distribution and densities are included, but the reader is directed to Gould et al (1978) for details about distribution and abundance in specific bays and other areas. General remarks on the distribution of feeding flocks are included where appropriate. The species accounts include selected aspects of the pelagic distribution and feeding behavior (in the broad sense), feeding habits (species composition and sizes of prey) and aspects of the birds' biological or physiological condition pertinent to an understanding of their feeding ecology.

Sooty Shearwater (*Puffinus griseus*)

General Background and Pelagic Biology. Sooty Shearwaters were scattered in relatively low densities. None of the shearwaters seen in late May-early June were positively identified as sooties. A few were seen mixed with the much more abundant Short-tailed Shearwater flocks by mid-June, and relatively small flocks (up to a few thousand birds at once) were seen from June through September. They seemed to be more prevalent in the northern part of the study area than the south. They occurred in Marmot Bay in July off Pillar Cape, but they were otherwise noted only over the shelf. Their presence among the large (up to 60 thousand birds) flocks of short-tails did not become evident until we were able to observe several at close range from the skiff. They were much more wary of the *Yankee Clipper* than the Short-tailed Shearwaters, and they were actually observed feeding on only three occasions. One large mixed-species feeding flock seen off southern Sitkalidak Island in August included several hundred sooties, a few hundred Short-tailed Shearwaters, 1,000 Black-legged Kittiwakes, and up to about 100 each of Parasitic and Pomarine Jaegers, Fork-tailed Storm Petrels, Northern Fulmars and Tufted Puffins. The larger of these species had fresh Capelin in their stomachs.

Feeding Habits. Thirty-five Sooty Shearwaters were collected, of which 33 (94.3%) had food in their stomachs (Table 1). Except for a sample of 16 birds taken in September, six or seven birds were collected each cruise. This species generally ate fish (76% of their diet) with most of this being Capelin and unidentifiable osmerids (67%) (Figure 2). Capelin were present in 71% of the sooties collected (Table 2). Polychaete worms were present in one bird each taken in August and September.

Percent volume of squid and fish in the sooties' diet changed in inverse proportion from June through September (Figure 3). Squid comprised most (55%) of their diet in June. Squid were present in no less than 65% of the birds taken in a given cruise (Figure 4), showing that this prey was consistently important to Sooty Shearwaters. Fish, again mostly Capelin or unidentifiable osmerids, increased from 45% to 95% occurrence in the sooties from June through September. No other fish species besides Capelin was identified in the stomachs.

Sixteen of the 35 birds (45.7%) had measurable Capelin in their stomachs. Figure 5 indicates the length frequency distribution of the measurable capelin from the Sooty Shearwaters. The Capelin lengths in the Sooty Shearwaters ranged from 55 mm to nearly 140 mm, with a modal length of about 85 mm.

Amount of Food Eaten The most, and greatest proportion of body weight of food found in any one of the birds was 102 g, or 11.7% of the body weight. The food percent of the body weight was generally low (Figure 6). In nearly 80% of the birds it was 3% or less and in only two birds was it 10% or greater. The frequency histogram of the filling index (Figure 7) reflects the same trend; 85% of the birds had a filling index of 40% or less. A plot of the filling indices on a graph of time of day and date (not included here) was inconclusive. Only five birds were collected earlier than 1200 in the day; none were collected earlier than 0930 nor later than 1745.

Biological Data Figure 8 shows the bill width data for the five key species, separated by sex. The mean, range and 95% confidence interval is shown. At 17.2 mm on the average (one mm wider for 4 females), Sooty Shearwaters had the widest bills of the five species, but the average was wider (to a high degree only when compared to Black-legged Kittiwakes, i.e., there was no overlap in the 95% confidence intervals. The data on net body weight (Figure 9) and fat index (Figure 10) both show little change from June through August, but an increase in September. These data no doubt reflect the annual pre-migratory fattening necessary before the shearwaters can embark on their long migration to the southern hemisphere for the breeding season.

Short-tailed Shearwater (Puffinus tenuirostris)

Pelagic Biology and General Background The Short-tailed Shearwater is probably the single most abundant species of marine bird occurring in Alaska waters. The exact timing of their migration from the southern hemisphere is not yet well known, and it probably varies annually. They probably begin arriving over the shelf of the northern Gulf of Alaska by late April - early May (Shuntov 1972; Gould et al 1978). They occurred in the study area, generally over the shelf, during each month of the study. The average density of shearwaters in late May - early June was 51 birds/km^2 (Table 3). Since none of the shearwaters seen then were identified as sooties, this figure probably included all or mostly short-tails. The highest shearwater densities (74 birds/km^2) occurred in August. Unknown numbers of sooties were present then, but they were still far fewer than the short-tails. Most of the shearwaters were over the shelf within a few miles offshore from the headlands but they also occurred as far offshore as the surveys transited. In August and September they occurred in flocks of up to a few thousand birds off Whale Passage at the mouth of Kizhuyak Bay, out of sight of the open ocean.

The birds were usually seen flying, but it was impossible to tell if the flights were local movements within the Kodiak area, or birds passing through. We had several opportunities to observe feeding Short-tailed Shearwaters at close range. The short-tails typically fed by pursuit plunging (Ashmole 1971; see also Wiens et al 1978, and Guzman 1976), in flocks ranging from several hundred to a few thousand birds within a relatively small area.

A particularly noteworthy example of atypical feeding behavior bears mentioning in some detail. At 1200 on 22 June, on a flat-calm day about 5 miles off the mouth the south entrance to Sitkalidak Strait, Sanger, Juan Guzman and Doug Forsell were able to row their skiff into the middle of a sitting flock estimated at 8-10,000 birds. We observed their feeding and general behavior for about 1.5 hours at distances as close as 10 m. A pattern soon because evident as we watched the birds from the drifting skiff. The birds were grouped in scattered, loosely defined "sub-flocks of 20 to 100 or 200 birds. Scattered birds sporadically immersed their heads beneath the water for several seconds, turning them back and forth, apparently looking for prey (i.e., "peering" behavior). When one bird apparently saw something, presumably food, it would "run" a few steps across the water and dive beneath. The running was apparently necessary to gain enough momentum to plunge beneath the surface. The action of the one bird would immediately precipitate a like reaction by the rest of the sub-flock which would focus on the spot the first bird dived. The length of time the birds stayed under water varied between about 15 and 30 seconds with a modal time of about 20 seconds, but it was difficult to determine this precisely because it was impossible to follow individual birds. Upon resurfacing, the shearwaters usually shook down their prey by rising up in the water by flapping their wings and paddling their legs while shaking their upper body rapidly.

This behavior continued off and on for the duration of the time we observed the birds. Except for the brief periods that the shearwaters pattered across the water and dived beneath, there was little hurry about this behavior; it was methodical and deliberate, with no resemblance to the feeding frenzies which beat the water to a froth usually associated with feeding shearwaters. Subsequent examination of the stomach contents of the birds collected from this flock revealed that they had eaten euphausiids (*Thusanoessa inermis* and *T. spinifera*) almost exclusively. The euphausiids were thus not right at the surface, but had to have been within 5-7 m of it, the maximum depth shearwaters are probably able to dive.

Feeding Habits One-hundred-sixty Short-tailed Shearwaters were collected in this study, of which 142 (88.8%) had food in their stomachs. This species was fairly evenly represented in the collections among the five sampling periods (Table 1). Due to their behavior of consistently flocking in large numbers and their easy approachability, samples could be collected nearly at will. We were better able to sample series of specimens of this species at the same time and place than the others.

Thysanoessa euphausiids comprised nearly half (47%) of the overall diet of Short-tailed Shearwaters (Figure 2). Capelin were also important (20%), and with the unidentifiable osmerids, comprised about 28% of the diet. Together with Sandlance (4%) and unidentifiable fish (10%), fish totaled about 42% of their diet (Table 2). Squid equaled about 9% of their diet by volume, but had an overall frequency of occurrence of 29% (Table 2) so their importance is greater than suggested by volume alone.

There were definite seasonal changes in the occurrence of prey in the short-tail stomachs. The percent composition by volume (Figure 11) and frequency of occurrence (Figure 12) both shows that euphausiids were relatively more important earlier in the season, but diminish in both occurrence and volume by September. Fish generally showed an inverse relationship to the squid, and comprised 92% of the diet in September when they occurred in all birds collected. Squid accounted for 25% of prey volume in late May - early 13 June, but steadily decreased in importance, comprising only 1% of the volume in September. However, the frequency of occurrence of squid was never lower than 17% (August), and was acutally 30% in September.

Capelin and unidentifiable osmerids together comprise only 3.5% of the frequency of occurrence (one bird) in June (Figure 13), but occurred in nearly 60% of the stomachs by September. Similarly, percent volume of Capelin/osmerids increased from none at the start of the study to over 50% in September. (Figure 11)

The overall lengths of Capelin in Short-tailed Shearwater stomachs ranged from 55 to 155 mm, with a modal length of about 90 mm (Figure 14). The data are scanty, but the length frequency distribution of Capelin eaten in July suggests a bi-modal length distribution (which suggests two year classes of fish), with modes at about 70 mm and 130 mm; no fish in the 90-110 mm range were found then.

Amount of Food Eaten Short-tailed Shearwaters displayed the highest food percent of body weight of the five key species (20%, or 125 g of food in a 625 g bird), but the birds collected still tended to have relatively little in their stomachs (Figure 15). Thirty-five of the birds (28%) had a food percent of stomach contents of 0.1% or less, and in 81% of the birds it was 5% or less. Only four of the birds (2.5%) had a figure in excess of 15%. The filling index data (Figure 16) shows that nearly a third of the birds had only 1% or less of the proportion of food as the fullest. In 62% of them it was 10% or less, and only 14 birds (about 9%) had a filling index in excess of 50%.

Biological Data The width of Short-tailed Shearwater bills averaged about 15.3 mm, nearly 2 mm smaller than their congeners the Sooty Shearwaters, but there was overlap in their 95% confidence intervals (Figure 8). The bill widths of the short-tails is very similar to the Tufted Puffins, but it is significantly larger than Black-legged Kittiwakes and significantly smaller than Common Murres on the average (Figure 8).

From late May through August, the average net bodt weight of the Short-tailed Shearwaters ranged between about 630 and 680 g (Figure 9), but it dropped to about 510 g in September. This is curious, because the weight should increase by September, in preparation for migration to the southern hemisphere, such as observed in the Sooty Shearwaters (Figure 9). The smaller average September weight is possibly an artifact of the relatively small sample size (7 females, 5 males), or it possibly represents a different population or age class of birds. An error in weighing technique in the field seems to be ruled out because the other four species were not similarly affected.

The seasonal changes in fat index (Figure 10) follow the same general trend as the body weight: The averages ranged from about 2.5 to 3.8 until September, when they dropped to 1.4 for the seven females and 1.2 for the five males. These means are lower than earlier samples (except for a slight overlap in the 95% confidence interval with females in June). Low fat indices occurred in July and (for males) June, probably reflecting the physiological drain of molting on the birds at that time. The August fat indices are higher than those in July, but then in September they dropped to their lowest values. This pattern is no doubt related to the low body weights at that time.

The reduced fat index and weight in September was possibly related to kind of prey in the diet. September was marked by the highest proportion of fish in their diet, and the lowest proportion of squid and euphausiids (Figure 11). The fat index in particular may be related to the kind of food eaten. The fat index can be considered to be an integration of the quality of food eaten over some unknown period of time immediately prior to collection. Studies on shorebirds (i.e., Mascher 1966; Minton 1969) have shown that some species can add fat to their bodies at a rate of 10% or more per day prior to migration, so it seems possible that the fat index could be an integration of the quality of food eaten for a very few days immediately prior to when a bird was collected.

Assuming that the food in the shearwater stomachs at the time of collection is the same type that determined their amount of fat at the time of collection, determining the degree of correlation between fat index and the volume of a given prey type would determine the influence of that prey on the amount of fat. Figure 17 shows the relationship between average fat indices and average volume of euphausiids in the diet, plotted by cruise. The data from male and female birds are plotted separately. The sample size is small (n=10, i.e., five cruises each for each sex) and the correlation coefficient is relatively low (r=0.70) when the data are fitted as a first degree polynomial. When the data are fitted as a second degree polynomial, the correlation coefficient is much better (r=0.90). Either way, however, the general trend suggests that the fat index is positively correlated with the amount of euphausiids in the diet.

Black-legged Kittiwake (Rissa tridactyla)

Pelagic Biology and General Background. The Black-legged Kittiwake is the second most abundant Alaskan breeding bird occurring over Kodiak Island waters (Sowls 1978). Birds associated with all colonies between southern Afognak Island and the Sitkalidak Island area number about 169 thousand; most of these (ca. 128 thousand) are from south of Ugak Island.

The densities of birds for each leg of the cruise were separated between the bays and waters over the continental shelf, and the average densities are shown plotted in Figure 18; the two lines represent the 95% confidence interval around the mean. Densities over the shelf were generally lower than 4 birds/km^2, with little or no difference between months. In the bays, however, densities increased dramatically between June and July, from about 5 to 17 birds/km^2, and they remained high through September. The high densities in the bays correspond to the chick stage on the colonies.

Away from colonies, the kittiwakes tended to be dispersed. Flocks occurred apparently in response to localized food sources or from social roosting. 70% to 80% of all sightings of flying birds were of individuals. Kittiwakes occurred more frequently in bays and fjords (85-91% of transects there) than over the continental shelf (40% of transects). Feeding flocks of kittiwakes ranged in size from a few up to an estimated 1,400 birds (average-39), and occurred up to 20 miles from land and 25 miles from the nearest colony. During the chick stage, feeding flocks occurred only out to ten miles from land and 17 miles from the nearest colony.

As we learned with increasing frustration as the field season progressed, birds that appeared to be feeding in flocks, i.e., milling in a restricted area close to the water, alighting on and diving momentarily beneath water, often had very little or no food in their stomachs. There is no sure reason for the scarcity of food in "feeding" birds. The kittiwakes were likely milling over prey, but the prey may have been too deep in the water for them to reach. A number of times Tufted Puffins and shearwaters were collected along with the kittiwakes in multi-species "feeding" flocks. If a comparison of prey among these species shows Capelin to be in the divers, but not the kittiwakes this suspicion will be confirmed.

Feeding Habits

Eighty-two (93.2%) of the 88 kittiwakes collected had food in their stomachs. Capelin comprised nearly 45% of the volume of all prey species (Figure 2). The unidentifiable osmerids were most likely capelin, so at 60-65% of their diet, the importance of Capelin to Black-legged Kittiwakes in the Kodiak area is evident. Sandlance, and pollock plus unidentifiable gadids, each accounted for 9% of the prey volume. Together with unidentifiable fish, fish made up 97% of the diet of the kittiwakes. *Thysanoessa* euphausiids, clams and polychaete worms together comprised the remaining 3% of the diet (Figure 2).

Seasonal changes in the aggregate percent volume of prey in the diet of kittiwakes are evident (Figure 19). Capelin/osmerids clearly dominated the diet except in September, when Sandlance and gadids were each slightly more important. *Thysanoessa* euphausiids averaged 15% of the diet in May-June, but were then absent until September when they comprised 40% of the diet of one of the 26 birds collected. Figures 20 and 21 compare the seasonal changes in prey volume in the kittiwake stomachs between the northern and southern areas. The same general trend as the composite data (Figure 19) is seen, except euphausiids and gadids were present only in the southern area in early June; the lone kittiwake with euphausiids in September noted above was collected in the northern area. Otherwise, trends in prey composition were similar for the two areas.

The frequency of occurrence of prey in the kittiwakes repeats the general patterns as their volumetric composition (Figures 22 through 24). However, a relatively wider variety, but lower incidence of prey is noted in September (Figure 22), and *Thysanoessa* euphausiids were in all four birds collected on June 1 in the southern area (Figure 24).

The composite prey length frequency data is noted in Figure 25. We attempt to show here simultaneously the length frequency of each prey in each of the two areas. The fish in the kittiwake stomachs ranged in length from about 50, to nearly 140 mm (modal about 90-100mm). The mean length of euphausiids was about 23 mm, considerably smaller than the fish. It seems that euphausiids would have to be extremely abundant for it to be energetically profitable for the kittiwakes to eat them.

Amount of Food Eaten The weight of the preserved stomach contents ranged from empty to 43.4 g. Most of the kittiwakes had very little or nothing in their stomachs (Figure 26). Forty-eight birds (54%) had food weights of 1% or less than their body weight, and 85% had food weights of 4% or less. The maximum observed food weight percent of body weight for Black-legged Kittiwakes in our data base is 12.2%, and the maximum observed in these samples was 8.4%.

The maximum observed filling index in these samples was 69% (i.e., 8.4% of the 12.2% maximum Figure 27). Generally, these data reflect the trend of Figure 26 that there was not much in the kittiwake stomachs; 60% of the birds had a fullness index of 10% or less.

There are two possible reasons that the birds we collected had little in their stomachs: 1) Black-legged Kittiwakes generally subsist by several small feedings per day, or 2) Even though we sampled the kittiwakes when they exhibited "feeding behavior", they may have actually fed at times of the day other than when we collected them. Figure 28 suggests that there was no apparent relationship between the time of day that the birds were collected and their filling index. However, as Figure 29 demonstrates, we sampled the kittiwakes during approximately the middle third of the day. The evening, and particularly the early morning hours were not sampled. Samples during these hours are needed before we can draw conclusions regarding the significance of the sparsely filled stomachs from these samples.

Biological Data Black-legged Kittiwakes have the narrowest average bill width of the five species (Figure 8). There was little or no variation in the net body weight from May through August, but the September weights of males and females were lower than the preceding months (Figure 9). There is no ready explanation for this; it could be tied in with the breeding cycle in the continued demands of large chicks on the nests. Possibly the drop in weight was related to food availability or the kinds of prey eaten. As noted above, Capelin formed a relatively low proportion of their diet in September compared to earlier months, and gadids and Sandlance had relatively greater proportions. The birds begin to molt into their winter plumage by September, and this could also have reduced the body weight. Eleven of the 19 birds with weight data in September were fledglings and averaged 365 g, falling in the range of all 19.

Data on seasonal changes in the fat index is inconclusive (Figure 10). There was no significant difference from May through August. Quite curiously, the females had less fat than the males in September. The females had the lowest average fat index of any similar group of birds for the entire study periods, while the males had the highest fat index. The 11 fledglings collected had an average fat index of 3.1; five of the six of these which could be sexed were males.

Common Murre (*Uria aalge*)

Pelagic Biology and General Background. The Common Murre is the third of the key species breeding in Alaskan waters, but it is relatively rare around Kodiak Island. The best estimate of numbers associated with colonies located within the study area is 2,300 birds (Sowls 1978). Common Murres are possibly just now expanding their range into the Sitkalidak Strait area. During reconnaissance surveys in the area in June 1976, very few murres were seen there. However, in 1977 they were fairly common at sea for the duration of the study (Table 3). They were mostly concentrated in the outer part of the bays and inlets, particularly so in the outer part of Chiniak Bay and the northern (eastern) entrance to Sitkalidak Strait. Moreover, they were discovered roosting, up to 20 birds at once, on 19 June at the kittiwake colony at Inner Right Cape at the mouth of Kiliuda Bay. A few were also seen around the kittiwake colonies at Boulder Bay, and at Cathedral Island (up to six) (Baird and Moe 1978). In Sitkalidak Strait as they were most frequently encountered in tide rips and convergence lines, in flocks of three or four, occasionally up to 10-15 birds. Out of the 45 birds collected (see below), 44 were sub-adults as determined by bursa length (average about 20 mm). If these birds were representative of all those in this area, this area bears continued watching for a potential range expansion. Presumably, potential pioneering birds in a new area are most likely sub-adults (Lack 1954).

Average densities (Table 3) at sea were highest in September ($9/km^2$), and lowest in July (1.5/km2). These densities belie the low number of birds breeding in the area. Murres were relatively rare more than a few miles offshore from the major headlands.

Feeding Habits Forty-five Common Murres were collected for stomach analysis, and 27 (60%) of these had food in their stomachs (Table 1). This proportion of stomachs with food is by far the lowest among the five species.

The Common Murre was the only species studied that was exclusively piscivorous (Figure 2). Capelin plus unidentifiable osmerids comprised 56% of their overall diet, and Sandlance, and Pollock plus unidentifiable gadids comprised about 11% each. Again bearing in mind the small sample sizes, the Common Murre appeared to be somewhat more varied in its fish diet than the other species. Capelin and unidentifiable osmeridae comprised 100% of their diet in June, but otherwise they formed no more than 50% of their diet (Figure 30). Pollock plus unidentifiable gadids comprised 66% of their diet in late May-early June, and 25% in August; Sandlance comprised 37% of their diet in September. The frequency of occurrence data (Figures 31 and 32) generally reflect the same trend as the prey volume data.

The modal length of the measurable fishes consumed by the murres was about 90 mm, and the range was 65 to 125 mm (Figure 33). Sandlance, with a modal length of about 95 mm, were about 5 mm longer than the Capelin.

Amount of Food Eaten. The maximum amount of food found in the stomach of a Common Murre in this study was 72.6 g, 6.7% of its body weight. As briefly noted above, this species had the least amount of food in their stomachs among the five species studied. Ninety-one percent of the birds had a food percent of their body weight of only 2% or less (Figure 34), a trend reflected by the filling index data (Figure 35). Of the 43 birds graphed here (no weights were taken on two of the 45 collected), 40 (93%) had a filling index of 50% or less. Most of the birds were collected in the middle of the day, and the fact that the Common Murres had less in their stomachs than the other species suggests that they are relatively more nocturnal in their feeding than the other species.

Biological Data The bill widths of the murres averaged about 17 mm, and were wider than all other species except the Sooty Shearwater (Figure 8). A small amount of overlap was noted between the murres (lower 95% C.I. = 16.38 mm for males, 16.47 mm for females) and male Tufted Puffins (upper 95% C.I. = 16.52 mm).

Individual body weights of murres ranged from about 880 g to 1,280 g (except for a 410 g immature included in the September data) (Figure 9). The small sample sizes make it impossible to tell if there were seasonal changes in body weight. The fat indices tended to be low (Figure 10), averaging about two for the season; only one bird (in May) had a fat index of four.

Tufted Puffin (*Lunda cirrhata*)

General Background and Pelagic Biology This species is the second most abundant breeding marine bird in the Kodiak area. An estimated 150 thousand breed within the study area (Sowls 1978), and an undetermined number of subadult birds are associated with the colonies during the breeding season.

Their average pelagic density ranged from less than one at the start of the study to 16 birds per km^2 in July at the peak of the chick stage (Table 3). At this time, the birds were particularly concentrated in the outer part of the bays and were rarely seen more than a few kilometers offshore. Even though their estimated breeding population is lower than the kittiwakes, their average pelagic density was higher.

Their average density for September (3.1 birds/km^2) was markedly lower than the 12.2 August figure; many of the birds seen in September were immatures, suggesting that adults had already begun their post breeding migration to oceanic waters. Shuntov (1972) noted the abrupt post-breeding seaward migration of Tufted Puffins from the Bering Sea, and a similar phenomenon is probably happening in the Kodiak area.

Tufted Puffins were often observed feeding in association with Black-legged Kittiwakes, particularly in eastern Sitkalidak Strait (see also Baird and Moe 1978). Puffins feed by pursuit diving (Ashmole 1971), i.e., chasing their prey underwater by swimming with wings (primarily) and feet, and grasping them one at a time in their bill; they may or may not be swallowed underwater. Puffins are able to dive to considerable depths, and probably get much of their food from mid-depths to the bottom while in the bays and inlets of the Kodiak area.

Feeding Habits One-hundred Tufted Puffins were collected in the course of this study; 89 of these had food in their stomachs. Numbers of specimens were fairly well divided among the first four study periods (21-28 birds each), but only six birds were sampled in September. This species was largely piscivorous in its diet (Figure 2, Table 2). Fish comprised 91% of the average volume of stomach contents, and Capelin and unidentifiable osmerids accounted for most (66%) of this. On the average, euphausiids were eaten by 6% of the birds, and squid by 12% (Table 2). Trace amounts of Pacific Sandfish, crab larvae and pelagic polychaete worms were also present in the Tufted Puffin stomachs.

Capelin comprised no less than 35% of the diet of the Tufted Puffins in each of the five study periods, and well over 80% in July and August (Figure 36). Pollock occurred in their diet only in August, when they comprised 20% of the average volume in the 25 birds collected. Sandlance were present in August and September, but occurred in fair amounts (15%) only in September. Euphausiids were present only in August (17% of the average volume). Squid were present each study period except June, but they only represented more than a slight fraction of the diet during the first cruise (13% of volume), and again in September (17%).

Fish as a whole occurred in the stomachs in no fewer than 67% of the birds sampled in any one cruise (Figure 37). Squid occurred in 20-25% of the birds during three of the time periods (12% of total frequency of occurrence, Table 2), and euphausiids were present in 25% of the birds taken in August. The frequency of occurrence of fish prey by species is indicated in Figure 38; generally, they repeat the patterns discussed above.

Tufted Puffins had enough measurable Capelin in their stomachs to permit separation of the length frequency data by time period (Figure 39). Generally, the Capelin ranged from about 35 mm to 125 mm in length, with an overall modal length of about 80 mm. From late May through July, their modal length in the puffins increased from about 65 mm to 85 mm, where it remained through September. This would seem to indicate a growth in the ambient Capelin rather than the birds eating progressively larger Capelin from May through July. But it isn't clear why the size of the Capelin apparently remained the same from July through September. The modal length of the Sandlance, eaten only in August and September, was about 95 mm. The euphausiids eaten in August (*Thysanoessa inermis*, *T. spinifera* *T. raschii*; not graphed in Figure 39) had a modal length of about 25 mm.

Amount of Food Eaten Tufted Puffins repeated the trend of the other species in generally having little in their stomachs. Of the 99 birds with body weight data, 52% had a food percent of body weight figure of 1% or less, and in 90% of the birds it was 5% or less (Figure 40). The highest food percent of body weight figure was 10.5%, and only 5 (2%) of the birds had a value greater than 8%. The index of filling (Figure 41) generally reflects the above trend: 91% of the birds had a filling index of 50% or less.

Biological Data With an average bill width of about 16 mm, the Tufted Puffins are similar to the Short-tailed Shearwaters (Figure 8). At the 95% confidence interval, their mean bill width is greater than the Black-legged Kittiwake, it is less than the Common Murre, but it overlaps with both shearwaters.

The overall body weights ranged from 540 to 985 g. (Figure 9). The males averaged about 850 g, and the females about 795 g. No seasonal change in body weight was evident.

The puffins generally had little fat throughout the study (Figure 10). The fat index was 4 on one bird in September, and 3 on a few more, but it averaged about 1.5 for all birds sampled. No seasonal change in the fat index was apparent.

Feeding Relationships

A full assessment of the trophic relationships among the five key bird species will be made when the data has been more completely analyzed. In particular, when these data have been synthesized with the feeding data of Nysewander (1978) and Baird and Moe (1978), a reasonably complete picture of the feeding ecology and trophic relationships of the key species of marine birds in the Kodiak area in May-September 1977 should emerge.

Meanwhile, a few general observations on the birds and their prey are possible. Figure 42 attempts to show at the same time the overall importance of the major prey types to each bird species by pooling the data from all specimens collected. It allows the examination of the data from the standpoint of the prey as well as the birds. Three criteria for "importance" of the prey are used: 1. The aggregate percent volume, omitting birds with empty stomachs. This gives an idea of the importance of a prey species in terms of biomass; 2. The average frequency of occurrence in the birds. This ignores how much, but gives an idea of how persistently the prey was consumed, and; 3. The frequency of occurrence by time period, i.e., what percentage of the five cruises the prey was found in at least one bird. This factor ignores both volume and frequency of occurrence by number of birds, but it gives an idea of the extent of time over which the species ate the prey.

Clearly, Capelin were overwhelmingly important to the birds. They were relatively less so to Short-tailed Shearwaters (the most abundant bird species in the Kodiak area) than the other four species. But even in the short-tails they showed up on 80% of the cruises, in nearly 30% of the birds, and comprised nearly 30% of the volume. By their sheer numbers, Short-tailed Shearwaters are probably one of, if not the major avian consumer of Capelin in the Kodiak Island area. Sandlance and Pollock were far less important in terms of biomass, but Sandlance were fairly persistent (20%-40% of the cruises in all species except the Sooty Shearwater), and Pollock showed up in all three of the Alaskan breeders on 60% to 80% of the cruises. Moreover, since Baird and Moe (1978) report a higher frequency and volume of Sandlance and Pollock in food samples from Black-legged Kittiwakes and Tufted Puffins in Sitkalidak Strait than we report here, the overall importance of these two prey species to birds is probably greater than this preliminary assessment suggests.

The two major invertebrate prey types, euphausiids and squid, were generally less important than the fishes, particularly to the breeding species. However, squid were very important to both species of shearwater. They occurred in both species on all cruises, in 70%

(24% volume) of the Sooty Shearwaters and 30% (9% volume) of the Short-tailed Shearwaters. Squid occurred in Tufted Puffins on 80% of the cruises, and in 12% of the birds. After Capelin, squid were actually the most important prey type to the puffins.

Euphausiids (mainly *Thysanoessa inermis*, some *T. spinifera* and *raschii*) were generally less important than squid. However, they were very important to Short-tailed Shearwaters (present all cruises, in 47% of the birds, and comprising 47% of their diet), and were eaten in some numbers by the kittiwakes and puffins. Pelagic polychaete worms showed up sporadically in both shearwater species and the puffins, but they were of minor importance even in these species.

The Tufted Puffin ate all five of the major prey types in varying degrees, while the Short-tailed Shearwaters and Black-legged Kittiwakes contained four each of the prey types, and Common Murres ate three prey types and Sooty Shearwaters only two.

Statistical Adequacy of Samples

We have had a continuing concern over the adequacy of the sizes of the samples of birds we have collected for the feeding studies. This has been particularly true in this study, where a comparison of samples on a geographic and temporal basis is an important part of the study. A large part of determining the statistical adequacy of sampling in this study is in deciding what constitutes a sample.. That is, what areal and temporal frame of reference should be used to distinguish a given sample? The ideal adequate sample would have all of the birds collected at the same time and place. But for marine birds, that ideal is rarely possible or practical. The numeral 30 is often cited as the minimum sample size for statistical significance. However, the Short-tailed Shearwater is the only species where it would be possible to sample this number of birds at the same time and place. And even then, it may be hard to consistently sample this number. The very act of collecting birds from a flock at sea usually disperses them, except for the kittiwakes and sometimes other gulls, who are often attracted to the scene.

As noted above, attempts were made to collect at least five birds of a species at the same time and place. This was often impossible, but sometimes more than this were collected. A thorough statistical analysis of all of the samples is beyond the scope of this report, but two brief statistical tests were conducted. In the first, outlined in Table 4, the variation in the percent volume of Capelin in samples of 15 birds was determined. It was impossible to compile a sample of 30 birds from the same cruise for most species, and even the

15-bird samples had to be obtained by pooling collections from different days for a given cruise. In the case of the Common Murres and Sooty Shearwaters, samples from the northern and southern areas had to be pooled to achieve even the 15-bird sample. The coefficient of variation in the percent volume of Capelin in individual birds is excessively large in each case (Table 4). The predicted sample sizes needed, given this amount of variation, ranged from 476 to 9,006 birds per area and cruise, obviously an artifact of the small sample size. Also, it may have been due to natural variations resulting from pooling samples from different dates and areas. Ideally, the birds in a sample should have eaten their prey at the same time. The proportions of prey species in a stomach may change with stage of digestion, and unless the birds contained prey all at the same stage of digestion, their proportions could be biased. At the very least, this simple test shows the pitfalls in pooling samples too widely scattered in time and space. Except in the relativelt rare cases of sampling a few birds from a very large flock, as noted below, this suggests that our samples have generally been too small.

In a few cases, a large number of Short-tailed Shearwaters were sampled together. On 29 May, 21 were collected off Sitkalidak Island; a random sub-sample of five of these was selected. Table 5 summarizes calculations made on these two samples, using the mean and standard deviation of the percent volume of euphausiids and squid in individual birds. A student's "t" test gave a t value of 0.04 for the euphausiids, and a probability of correlation coefficient greater than 0.90, while the squid had a t value of 0.25, and a correlation coefficient of greater than 0.88. Thus, a sample of five birds from a large flock which had recently fed at about the same time would adequately sample the larger population.

Interpolation of Fish Lengths From Their Parts

An accurate characterization of the trophic level(s) of a prey species probably depends largely on an accurate knowledge of their size frequency and distribution. If so, it is important to have a large enough sample size of prey from the stomachs to accurately reflect the size frequency distribution of the prey. Whole, and thus readily measurable fish have been relatively rare in the stomachs of the birds we have studied. Thus, the utility of being able to extrapolate original fish lengths from the lengths of their parts is mainly in increasing the sample size of measurable fish.

For prey parts to be useful in extrapolating original whole prey sizes they should be readily identifiable to species and their lengths should accurately reflect the whole prey length. The vertebral column and P-bone of Capelin and Sandlance are two such parts which meet these criteria. A regression of the vertebral column length on the total length of 67 Capelin (Figure 43) had a high degree of correlation (r=.99), as did the regression of the P-bone length on total length of 63 Capelin (r=.97, Figure 44). A similar relationship for the vertebral columns of 112 Sandlance (Figure 45) is also highly correlated (r=.96), but for the regression of P-bone length on total length (Figure 46), it is not quite so high (r=.85), perhaps because of the small sample size (n=34).

Table 6 summarizes data on the combined numbers of vertebral columns and P-bones of Capelin and Sandlance as a proportion of their total measurable numbers. In the Short-tailed Shearwater and Common Murre, the parts comprised about a third of the total measurable fish, and in the other three species, the parts comprised well over half. The overall average proportion of parts in all measurable Capelin and Sandlance in the five species was 61%. Clearly, the use of these extrapolations have been useful in increasing the sample sizes of measurable fish.

Prey Reference Collection

A number of species, and parts of species were added to our taxonomic reference collection over the past year. The current total inventory of species and their parts in the collection is listed in Table 7.

GENERAL DISCUSSION AND CONCLUSIONS

It should be emphasized that this report is a preliminary assessment of data collected over one four-month period. Accordingly, broad generalizations should be avoided. There had been little precedent for this type of study, i.e., simultaneously studying the feeding ecology, distribution and abundance of marine birds at sea, repeated over several months in succession.

We decided to concentrate on the five "key" species suspected to form most of the numbers and biomass of the marine bird community in the Kodiak Island area in spring and summer. Our observations bear out this suspicion (Table 3). Bearing in mind the preliminary nature of the study, we offer the following tentative conclusions regarding the key species of marine birds and their prey:

1. In terms of numbers and biomass, the Short-tailed Shearwater is the most important species. Other key species are Black-legged Kittiwake, Tufted Puffin, Sooty Shearwater and Common Murre. We are aware that criteria besides numbers and biomass may determine other "key" species, but such a determination is beyond the scope of this report.

2. Capelin is overwhelmingly the most important prey species to marine birds. Walleye Pollock and Pacific Sandlance are also key prey species, though of lesser importance than Capelin.

3. The macroplanktonic euphausiid crustacean, Thysanoessa inermis is very important to Short tailed Shearwaters, and sporadically important to Black-legged Kittiwakes and Tufted Puffins. Two other euphausiids, T. spinifera and T. raschii, have been presenet in the birds' diet, but are of lesser importance.

4. Gonatid squid are key prey of Short-tailed and Sooty Shearwaters, and occasionally to Tufted Puffins.

We are just beginning to understand the winter situation. We know there is a dramatic shift in the species compostion of the marine bird community in the Kodiak area from summer to winter. The Common Murre is the only summer key species which remains in numbers in the Kodiak area over winter. A few Black-legged Kittiwakes stay around, but the other three key species in summer are essentially gone from the area from fall through early spring. Large numbers of marine waterfowl such as White-winged Scoters and Oldsquaw form the bulk of numbers and biomass in winter. Consequently, we may expect an equally dramatic shift in kinds and numbers of prey consumed in winter. The winter aspects of our broader study will be addressed in subsequent reports.

The possiblity of the kind of prey influencing the physiological condition of birds, such as suggested by the amount of euphausiids in the diet of Short-tailed Shearwaters influencing their fat index, suggests that an understanding of the biomass of prey consumed only tells part of the story of trophic relationships. The energy value of different prey, as well as their assimilation rates in the birds, will have to be understood before trophic relationships can be understood beyond the preliminary level presented here.

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Table 1. Summary of cruise dates and numbers of key species of marine birds collected for feeding habits studies in the Kodiak area, May - September 1977. No. = Chiniak/Marmot area. So. = Sitkalidak area.

NUMBER OF BIRDS COLLECTED																		
Cruise Dates	Sooty Shearwater			Short-tailed Shearwater			Black-legged Kittiwake			Common Murre			Tufted Puffin			TOTALS		
	No.	So.	Tot.	No.	So.	Tot.	No.	So.	Tot.	No.	So.	Tot.	No.	So.	Tot.	No.	So.	Tot.
26 May 05 June	0	0	0	0	27	27	4	4	8	6	1	7	21	2	23	31	34	65
12-29 June	6	1	7	5	25	30	4	8	12	3	4	7	12	9	21	30	47	77
06-29 July	4	2	6	17	28	45	5	16	21	6	10	16	8	14	22	40	70	110
11-23 August	0	6	6	40	4	44	13	8	21	2	5	7	16	12	28	71	35	106
07-19 September	10	6	16	8	6	14	9	17	26	8	0	8	3	3	6	38	32	70
TOTALS	20	15	35	70	90	160	35	53	88	25	20	45	60	40	100	210	218	428
Empty N			2			18			6			18			11			55
Stomachs %			5.7			11.2			6.8			40.0			11.0			12.8

Table 2. Mean frequency of occurrence and mean percent volumetric composition of major prey-types in the five key species of marine birds in Kodiak Island waters, May-September 1977.

Sample Size (n)	Sooty Shearwater			Short-tailed Shearwater		
	35		33	158		142
Prey Type	$\bar{X}$ Frequency of Occurrence		$\bar{X}$ % Composition,[2] by Volume	$\bar{X}$ Frequency of occurrence		$\bar{X}$ % Composition,[2] by volume
	N	%		N	%	
Total Fish[1]	26	74	76	72	46	42
Capelin & Un. Osmeridae	23	66	67	45	28	28
Pollock & Un. Gadidae	0	0	0	0	0	0
Sandlance	0	0	0	6	4	4
Euphausiids	0	0	0	74	47	47
Squid	25	71	24	46	29	9
Polychaeta	2	6	+	5	3	1

1 Includes unidentifiable fish.

2Excludes birds with empty stomachs.

Table 2 (cont.) Mean frequency of occurrence and mean percent volumetric composition of major prey-types in the five key species of marine birds in Kodiak Island waters, May-September 1977.

Sample Size (n)	Black-legged Kittiwake			Common Murre			Tufted Puffin		
	88		82	45		27	100		89
Prey Type	$\overline{X}$ Frequency of Occurrence		$\overline{X}$ % Composition by Vol.[2]	$\overline{X}$ Frequency of Occurrence		$\overline{X}$ % Composition by Vol.[2]	$\overline{X}$ Frequency of occurrence		$\overline{X}$ % Composition by Vol.[2]
	N	%		N	%		N	%	
Total Fish[1]	82	93	97	27	60	100	85	85	91
Capeline & Un. Osmeridae	53	60	61	24	53	56	65	65	66
Pollock & Un. Gadidae	11	12	8	6	13	11	8	8	6
Sandlance	7	8	8	3	7	11	2	2	4
Euphausiids	5	6	2	0	0	0	6	6	5
Squid	0	0	0	0	0	0	12	12	4
Polychaeta	0	0	0	0	0	0	1	1	+

1 Includes unidentifiable fish.

2 Excludes birds with empty stomachs.

Table 3. Average estimated densities of five key species of marine birds in the northeast Kodiak area, May-September 1977.

		$\bar{X}$ Density, Birds per km^2			
Time Period	No. of 10-min. Transects	Sooty & Short-tailed Shearwaters	Black-legged Kittiwake	Common Murre	Tufted Puffin
26 May - 5 June	266	50.9	3.8	5.2	0.5
18-29 June	240	67.3	2.0	3.2	5.2
6-29 July	306	67.8	8.1	1.5	15.8
11-23 August	243	74.0	4.1	1.8	12.2
7-19 September	211	37.5	12.0	9.3	3.1
TOTALS	1,266	59.5	6.0	4.2	7.4

Table 4. Statistical data on the percent volume of osmerid fishes in samples of 15 birds each of Sooty Shearwaters (SOSH), Short-tailed Shearwaters (STSH), Black-legged Kittiwakes (BLKI), Common Murres (COMU) and Tufted Puffins (TUPU).

Statistical Parameter	Bird Species				
	SOSH	STSH	BLKI	COMU	TUPU
$\bar{X}$ percent volume	84.7	77.8	20.0	26.6	85.3
Standard Deviation	34.5	40.4	41.4	45.8	35.0
Coefficient of Variation	41	52	207	171	41
Predicted Sample Needed	9,006	354	6,190	476	566

Table 5. The mean and standard deviation of the percent prey volume in a sample (n=21) and random subsample (n=5) of Short-tailed Shearwaters, and their corresponding "t" values and probability coefficients.

Prey Type	Bird Sample Size	$\bar{X}$ %	S. D.	"t" Value	Probability Coefficient
Euphausiids	$n_1=21$	75.3	39.9	0.04	0.90
	$n_2=5$	76.0	40.0		
Squid	$n_1=21$	16.1	35.2	0.25	0.88
	$n_2=5$	20.2	44.3		

Table 6. Capelin and Sandlance vertebral columns and parasphenoid bones as a proportion of total measurable fish taken from the stomachs of five key species of marine birds from the Kodiak Island area, May-September 1977.

Bird Species	Number of Measurable Fish			
	Total	Whole Fish	Vert. Cols. + P-bones No.	Vert. Cols. + P-bones % of Total
Sooty Shearwater	106	46	60	57
Short-tailed Shearwater	167	114	53	32
Black-legged Kittiwake	49	20	29	59
Common Murre	65	41	24	37
Tufted Puffin	318	54	264	83
TOTALS	705	275	430	61%

Table 7. Species present in the OBS-CE reference collection, as of March 1978. Each species is represented by at least one whole specimen, plus parts as indicated: O = otolith; P = parasphenoid bone; V = vertebral column.

FISHES	
Allosmerus elongatus	
Ammodytes hexapterus	O,P,V
Clupea harengus pallasi	O,P
Gadus macrocephalus	O
Gasterosteus aculeatus aculeatus	
Hemilepidotus hemilepidotus	
Hexagrammos decagrammus	
Hexagrammos stelleri	
Hexagrammos lagocephalus	
Hypomesus pretiosus pretiosus	P
Lampanyctus beringensis	
Lumpenus sagitta	
Mallotus villosus	O,P,V
Pholis laeta	
Pleurogrammus monopterygius	
Pungitius pungitius	
Scorpaenidae sp.	
Spirinchus starksi	
Spirinchus thaleichthys	
Tarletonbeania crenularis	
Thaleichthys pacificus	
Theragra chalcogramma	O,P,V
Trichodon trichodon	P,V
Triglops sp.	
Triglops pingeli	
EUPHAUSIACEA	
Euphausia pacifica	
Thysanoessa inermis	
Thysanoessa raschii	
Thysanoessa longipes	
Thysanoessa spinifera	
ISOPODA	
Pentidotea sp.	
Saduria entomon	
DECAPODA	
Cancer magister	
Crangon septemspinosa	
Hymenodora frontalis	
Lebbeus polaris	
Pandalopsis ? sp.	
Pandalus borealis	
Pandalus goniurus	
Telmessus cheiragonus	?
BRANCHIPODA	
Anostracan sp.	
CUMACEA	
Cumella vulgaris	
MYSIDACEA	
Neomysis intermedia	
COPEPODA	
Harpactacus sp.	
AMPHIPODA	
Caprellidea	
Caprella californica	
Gammaridea	
Anisogammarus pugettensis	
Anonyx nugax	
Atylus collingi	
Calliopius laeviusculus	
Cyphocaris anonyx	
Cyphocaris challengeri	
Eusirid sp. (?)	
Eusiridae sp. (?)	
Gammaridea sp. B	
Gammaridea spp.	
Halice sp. (?)	
Haustoriid sp. A; sp. B	
Leucon sp.	
Melphidippa sp.	
Paracallisoma alberti	
Paraphoxus sp.	
Protomedeia sp.	

Table 7. (Cont'd.)

Hyperiidea
Cranocephalus scleroticus
Hyperia medusarum f. hystrix
Hyperietta stephenseni
Hyperoche mediterranea
Hyperoche medusarum
Lanceola clausi
Lanceola loveni
Lanceola sayana
Lycaea pulex
Oxycephalus clausi
Paraphronima crassipes
Paraphronima gracilis
Parathemisto libellula
Parathemisto pacifica
Parathemisto japonica
Phronima sedentaria
Primno macropa
Proscina sp. (?)
Scina borealis
Scina rattrayi
Scina stebbini
Scypholanceola vanhoeffeni
Streetsia challengeri
Syrrhoe crenulata
Tryphaena malmii
Vibilia australis
Vibilia caeca
Vibilia sp.

GASTROPODA
Aplexa sp.
Clione limacina
Limacina helicina
Littorina sitkana
Lymnaea sp.
Margarites rhodia
Odostomia sp.
Oenopota sp.

PELECYPODA
Astarte rollandi
Clinocardium muttallii
Gemma ? sp.
Glycymeris subobsoleta
Humilaria kennerleyi
Liocyma fluctuosa
Macoma balthica
Macoma expansa
Mya sp.
Mysella ? sp.
Mytilus edulis
Nuculana sp.
Nucula tenuis
Orobitella ? sp.
Protothaca staminea
Sphenia ? sp.

POLYCHAETA
Ampharetidae sp.
Arenicolidae sp.
Capitella capitata
Eteone californica
Eteone longa
Glycinde picta
Heteromastus sp.
Heteromastus filiformis
Mediomastus sp.
Nephtys ciliata
Nephtys longosetosa
Nephtys ricketsi
Owenia sp. #1
Owenia fusiformis ?
Pectinaria granulata
Pholoe minuta
Polydora caulleryi
Polydora quadrilobata
Spio filicornis
Spionidae sp.
Spiophanes bombyx
Syllidae sp.

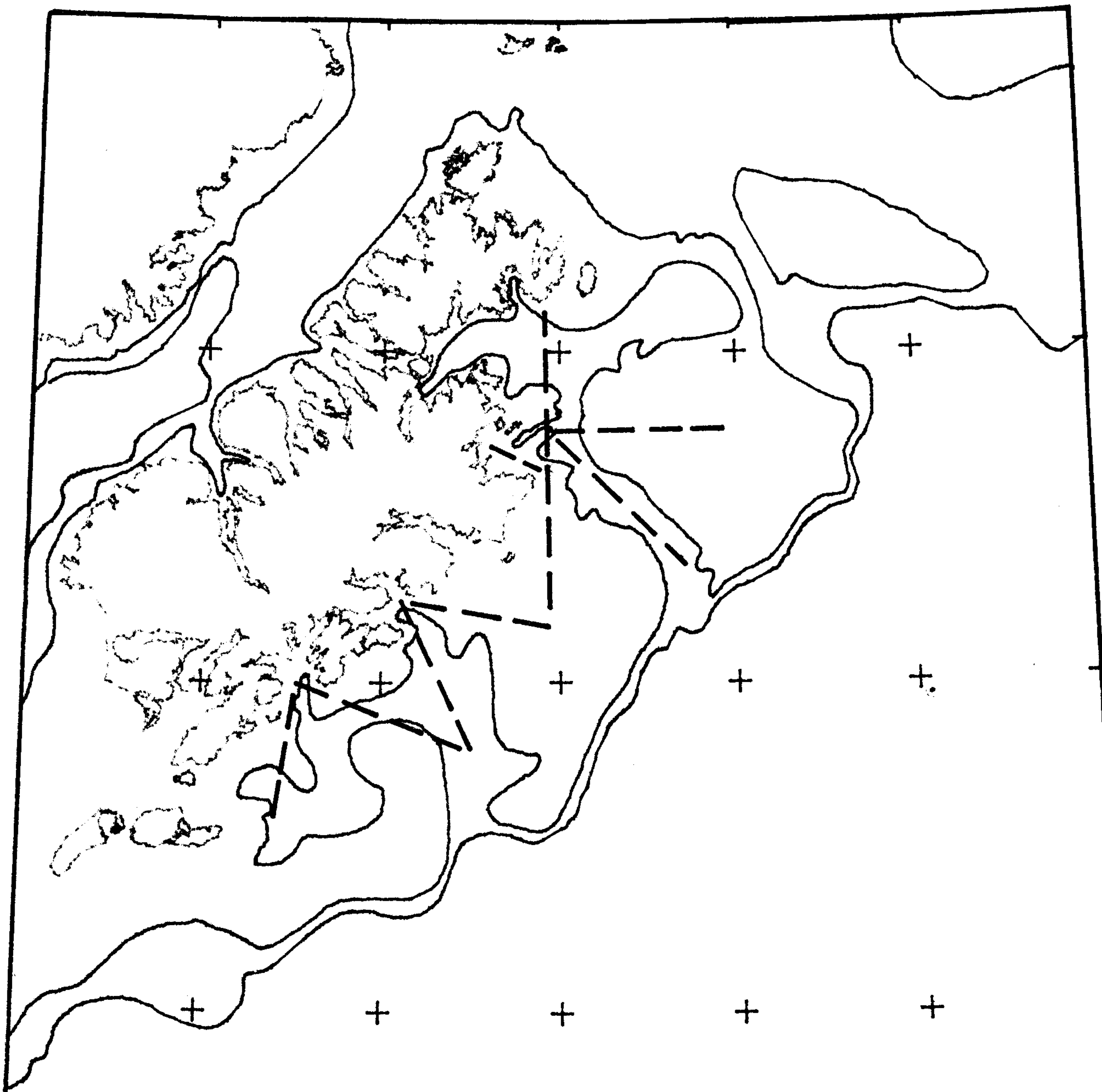
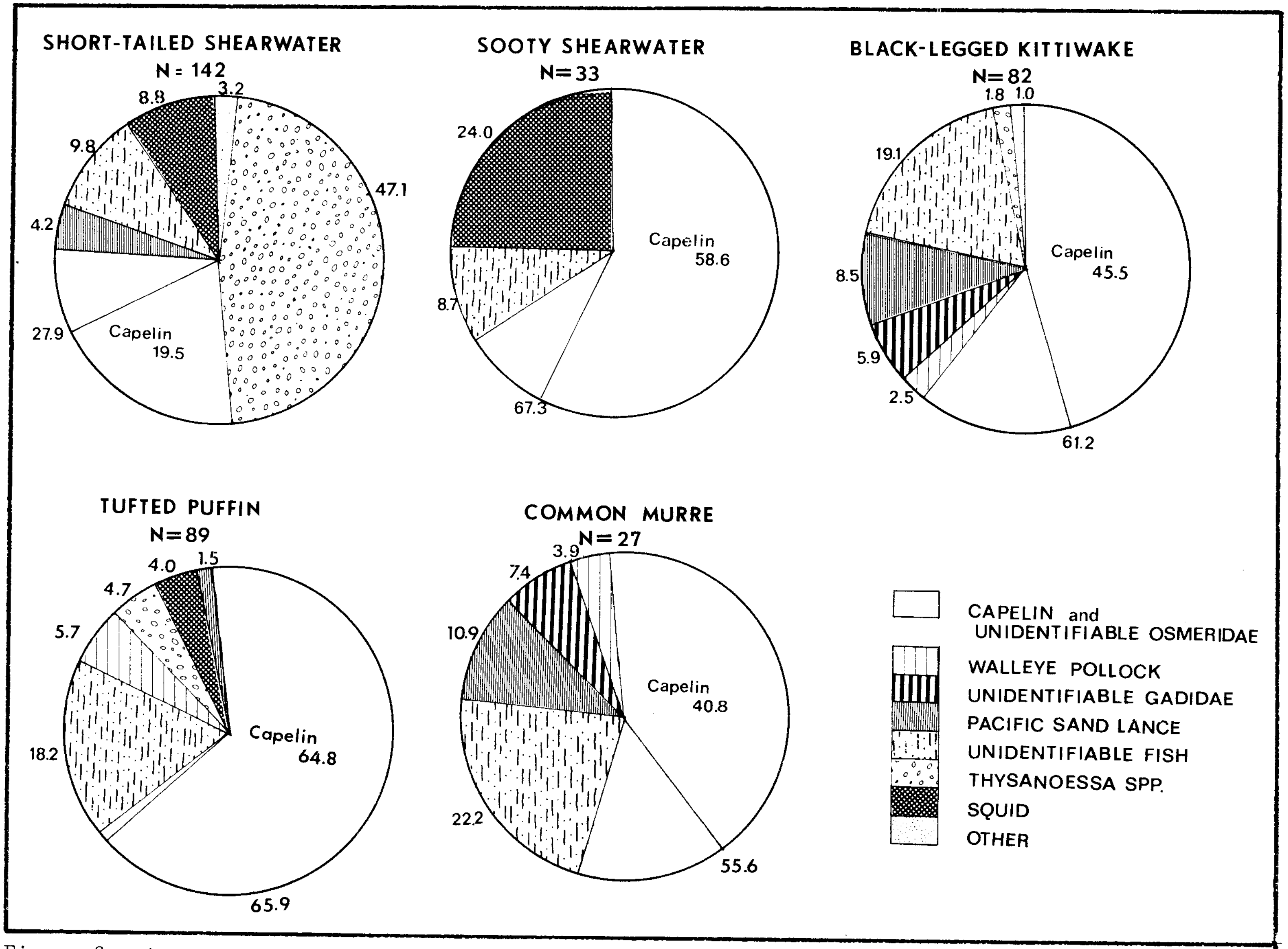


Figure 1. General study area off Kodiak Island showing nominal cruise track (- - - - - - -). Wavy lines indicate 100 m and 200 m depth contours.



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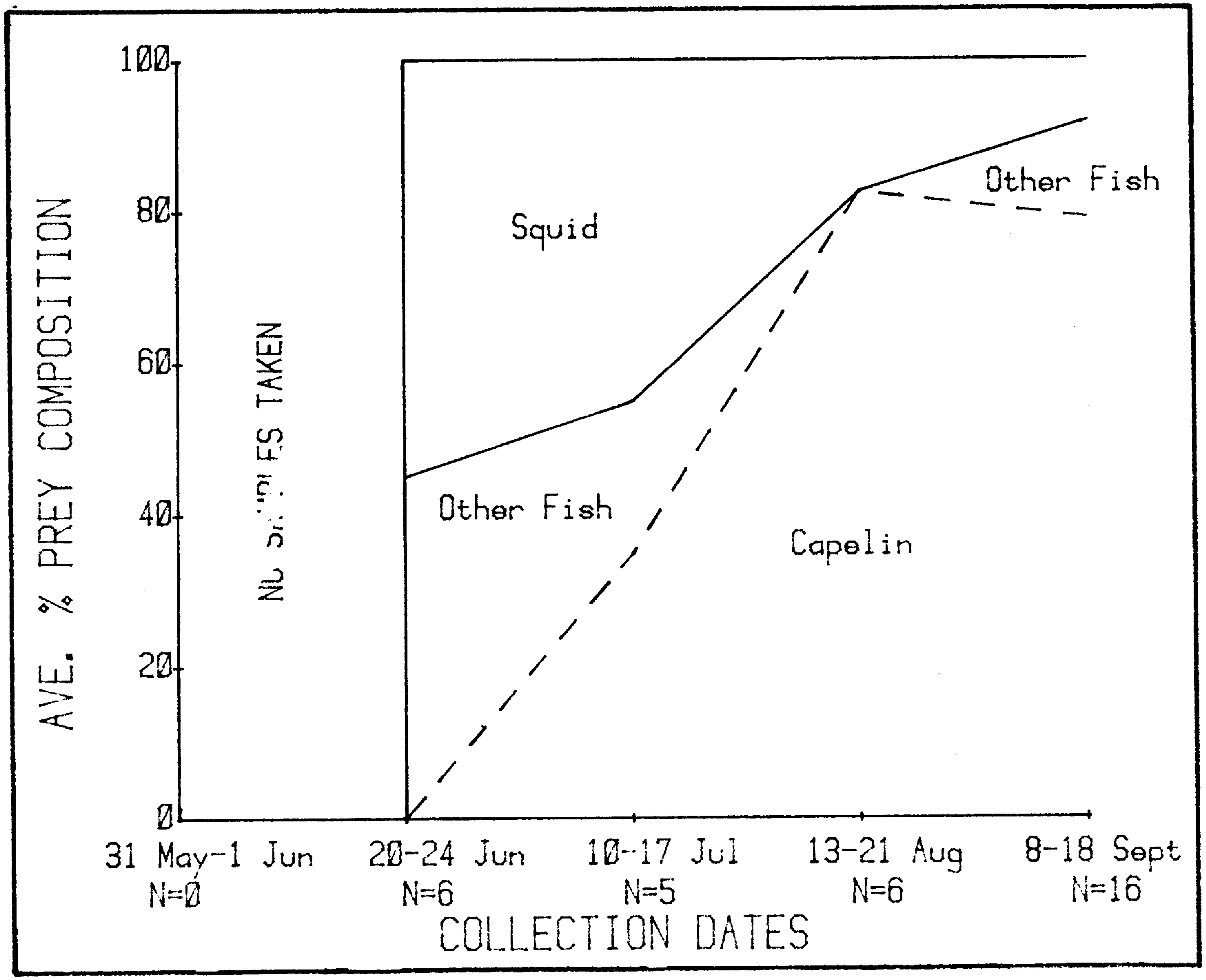
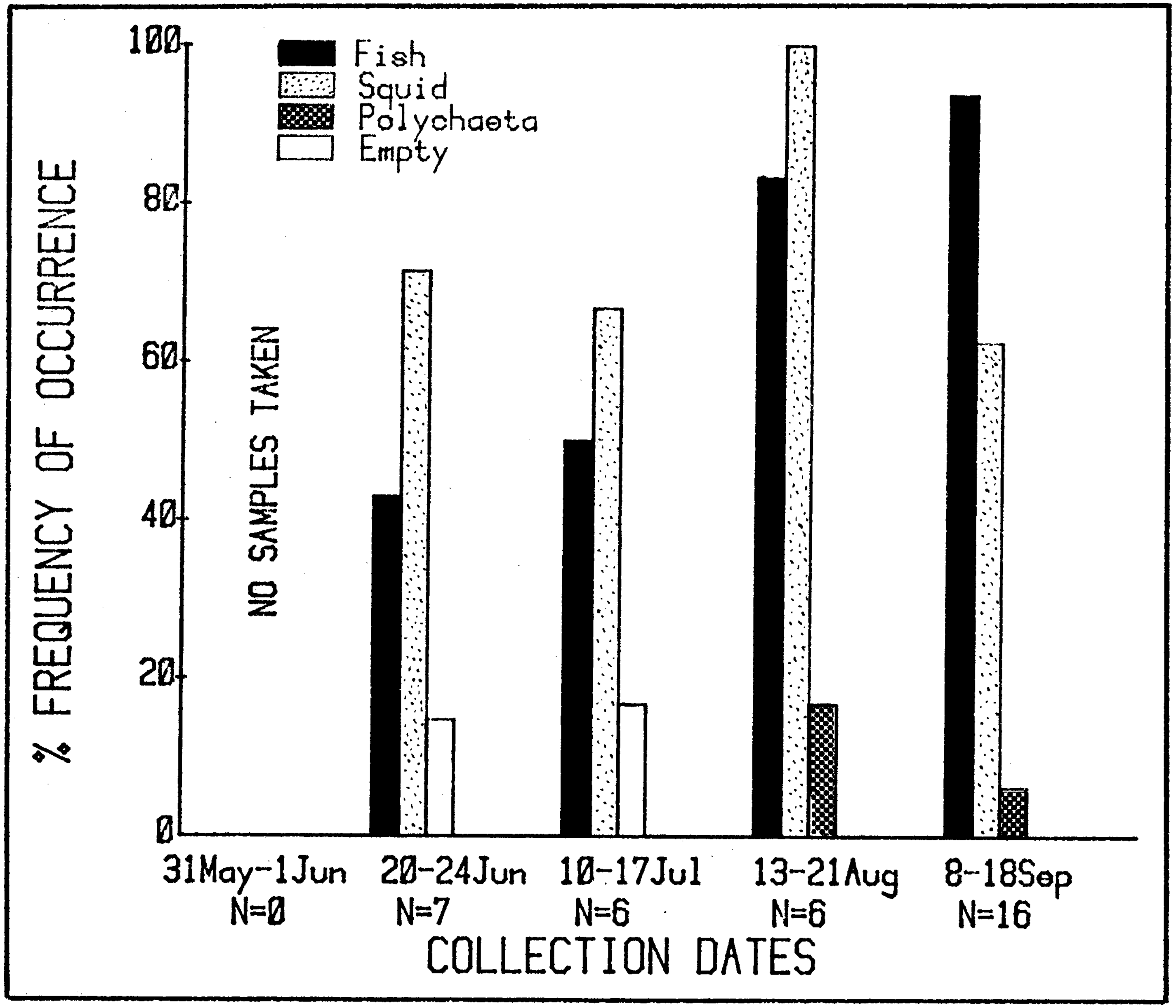


Figure 3. Seasonal changes in the percent volume of prey in Sooty Shearwaters from the Kodiak Island area, 1977.



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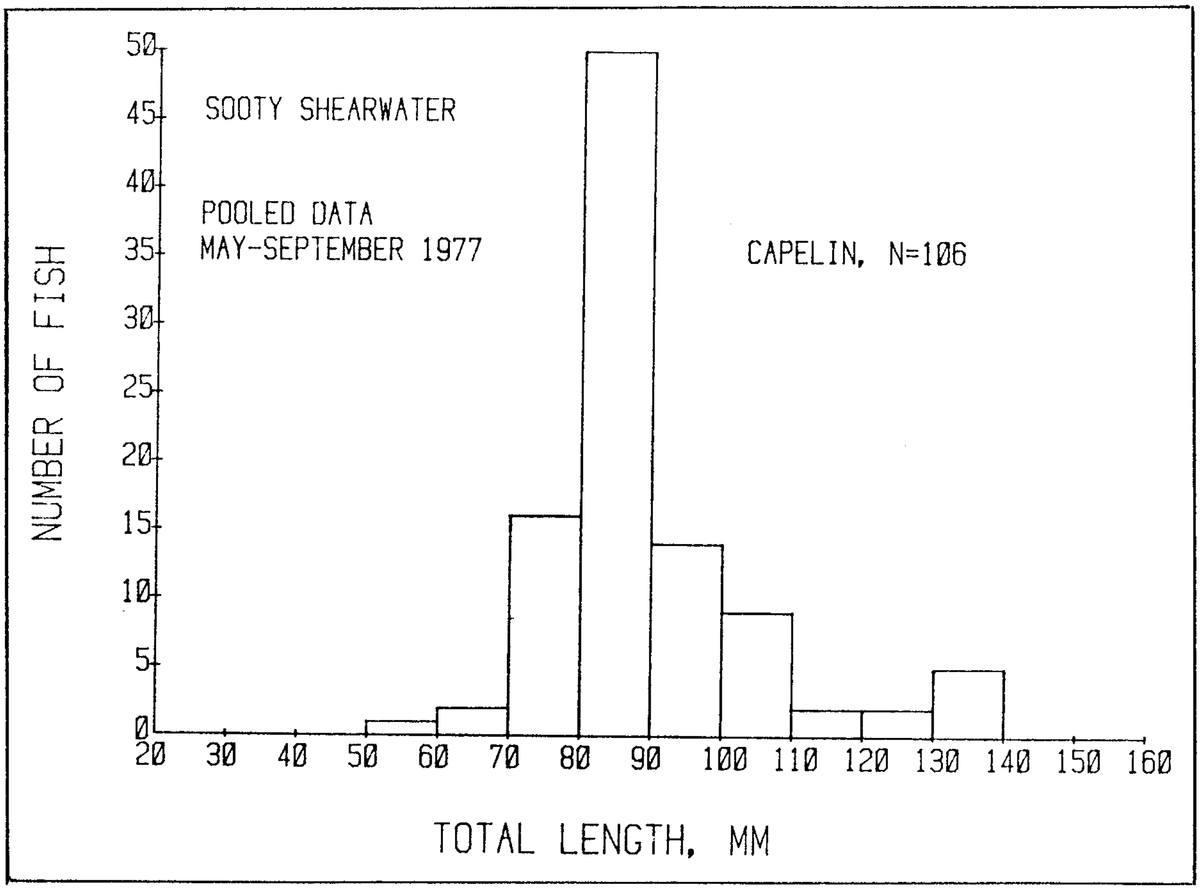

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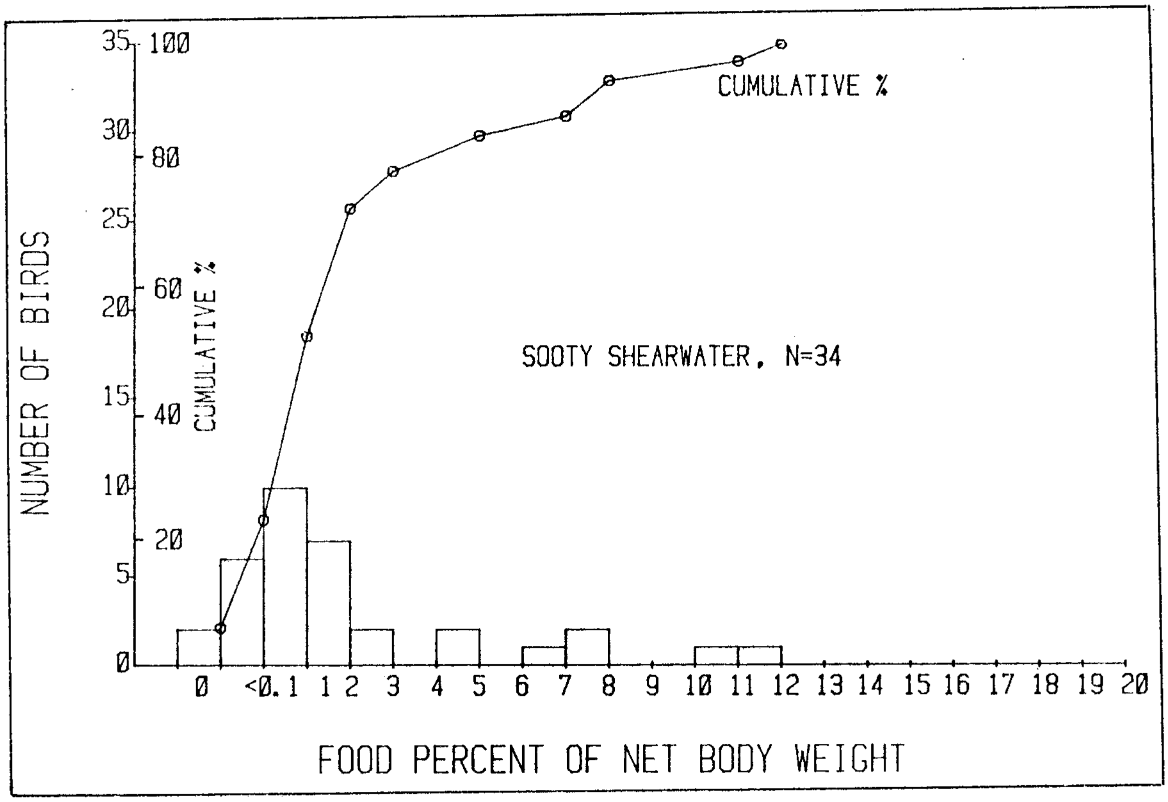

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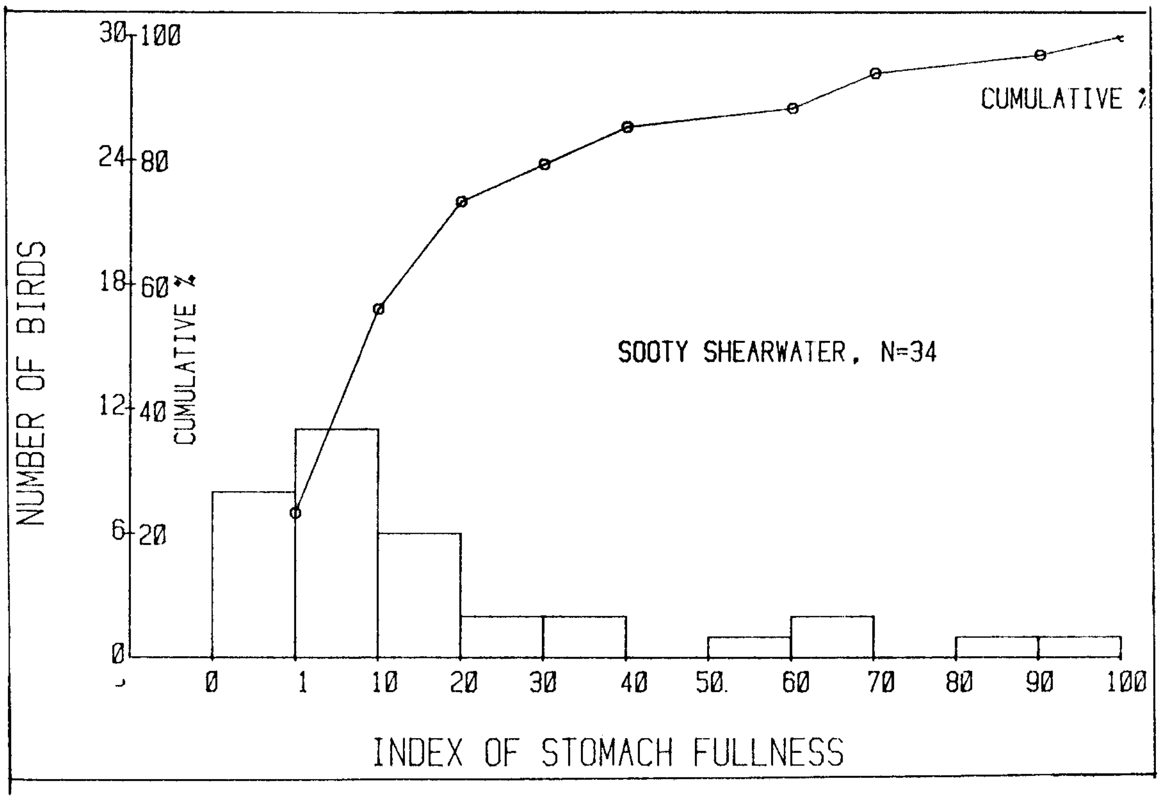

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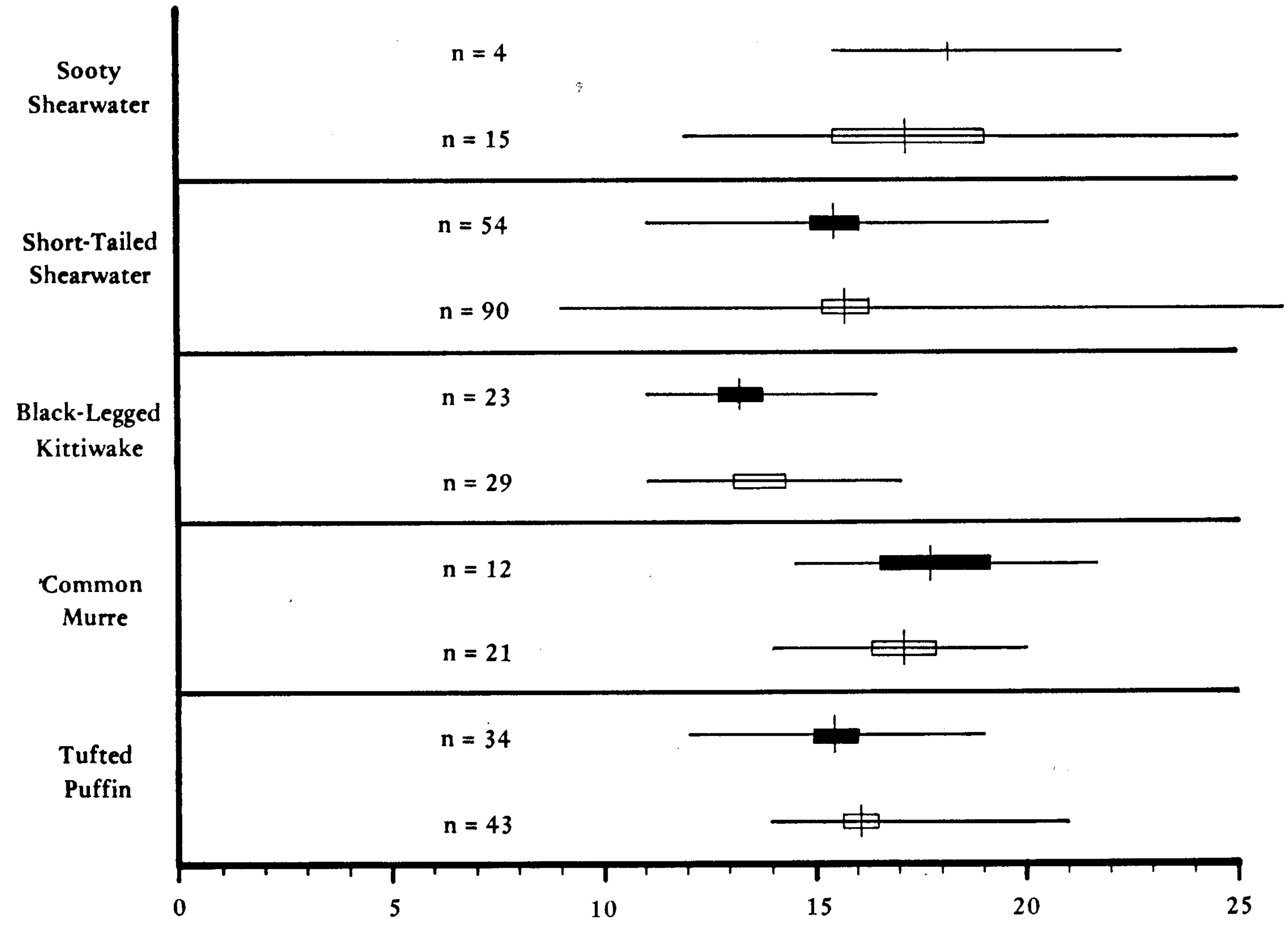

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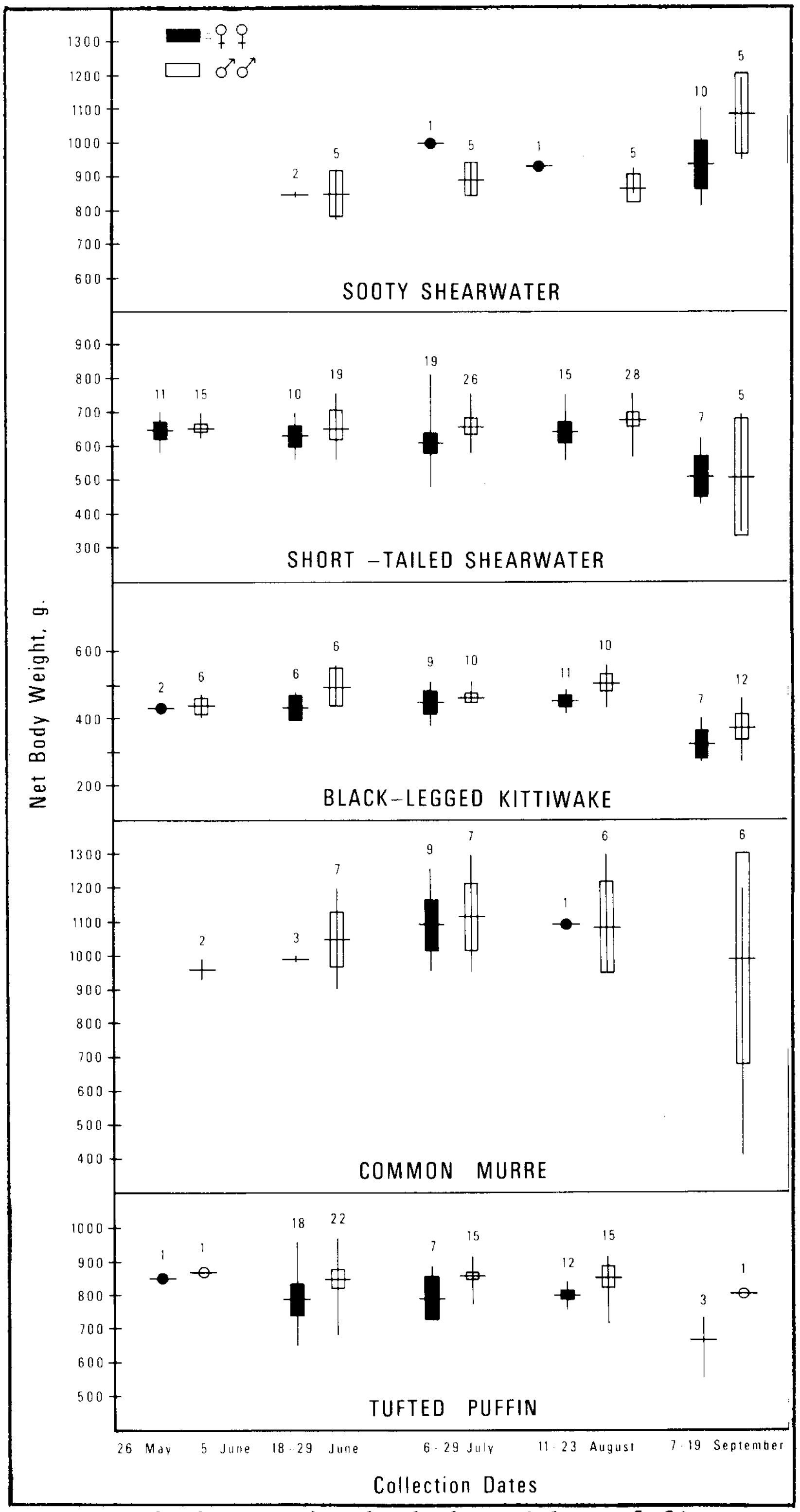

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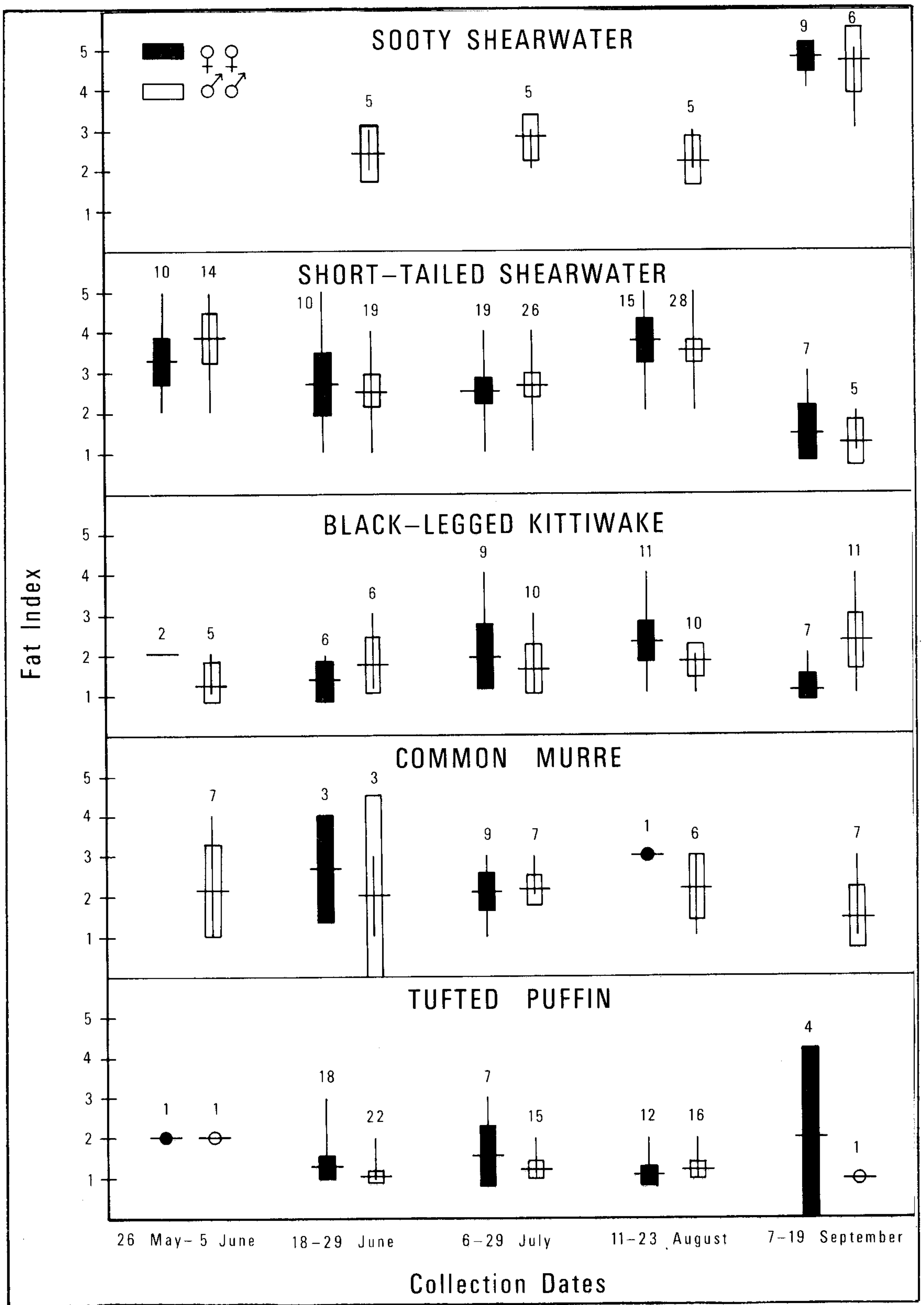

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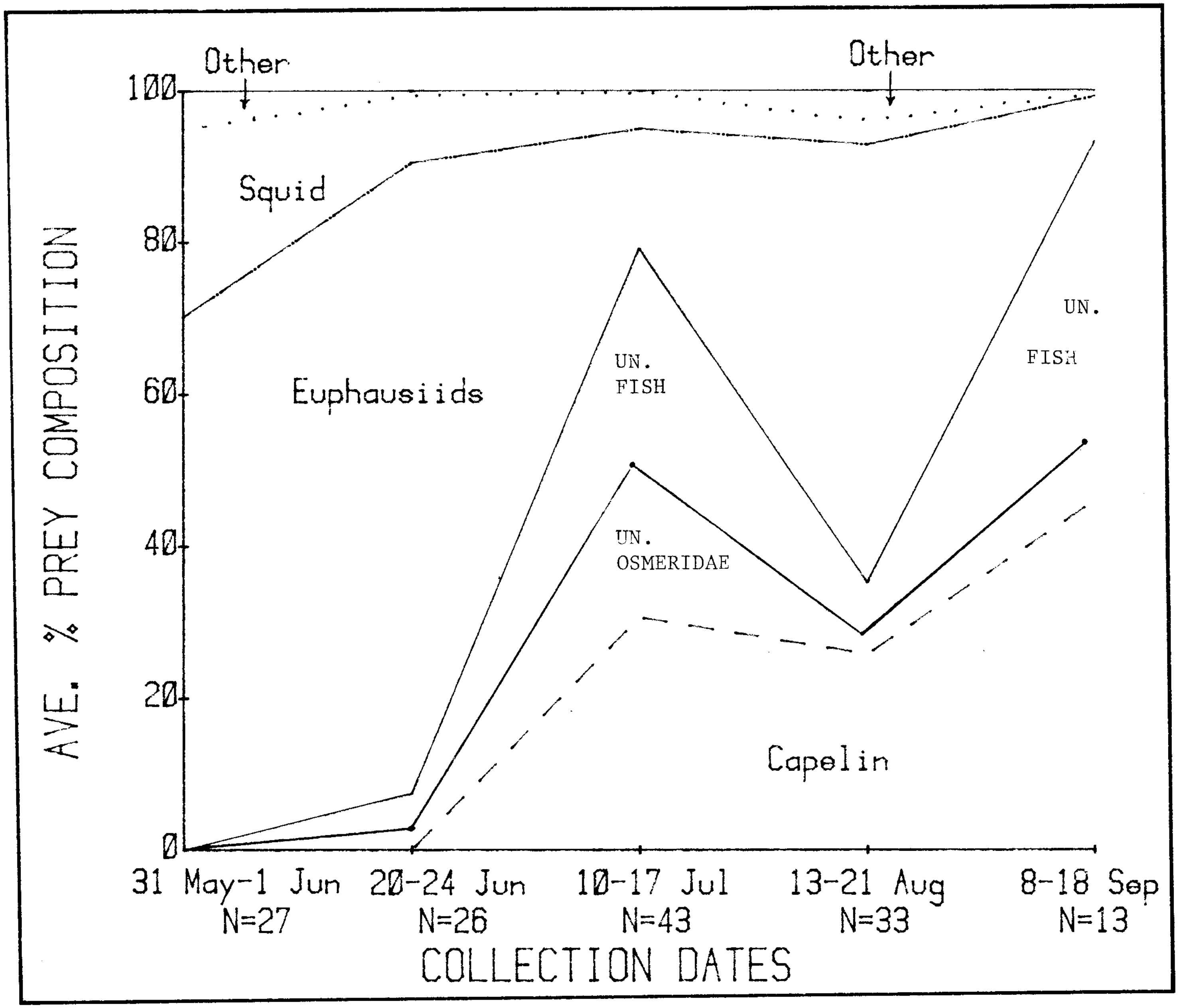

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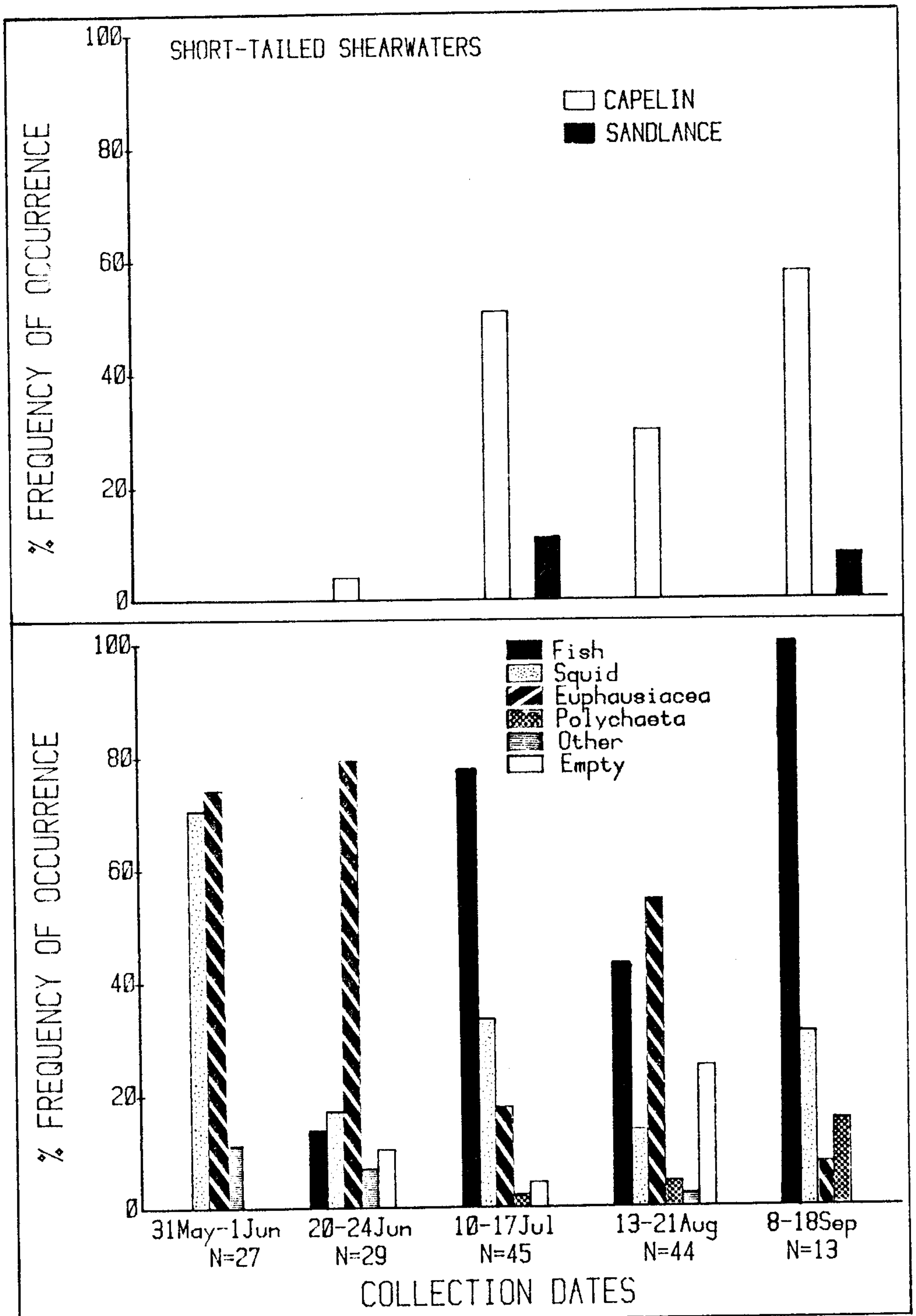

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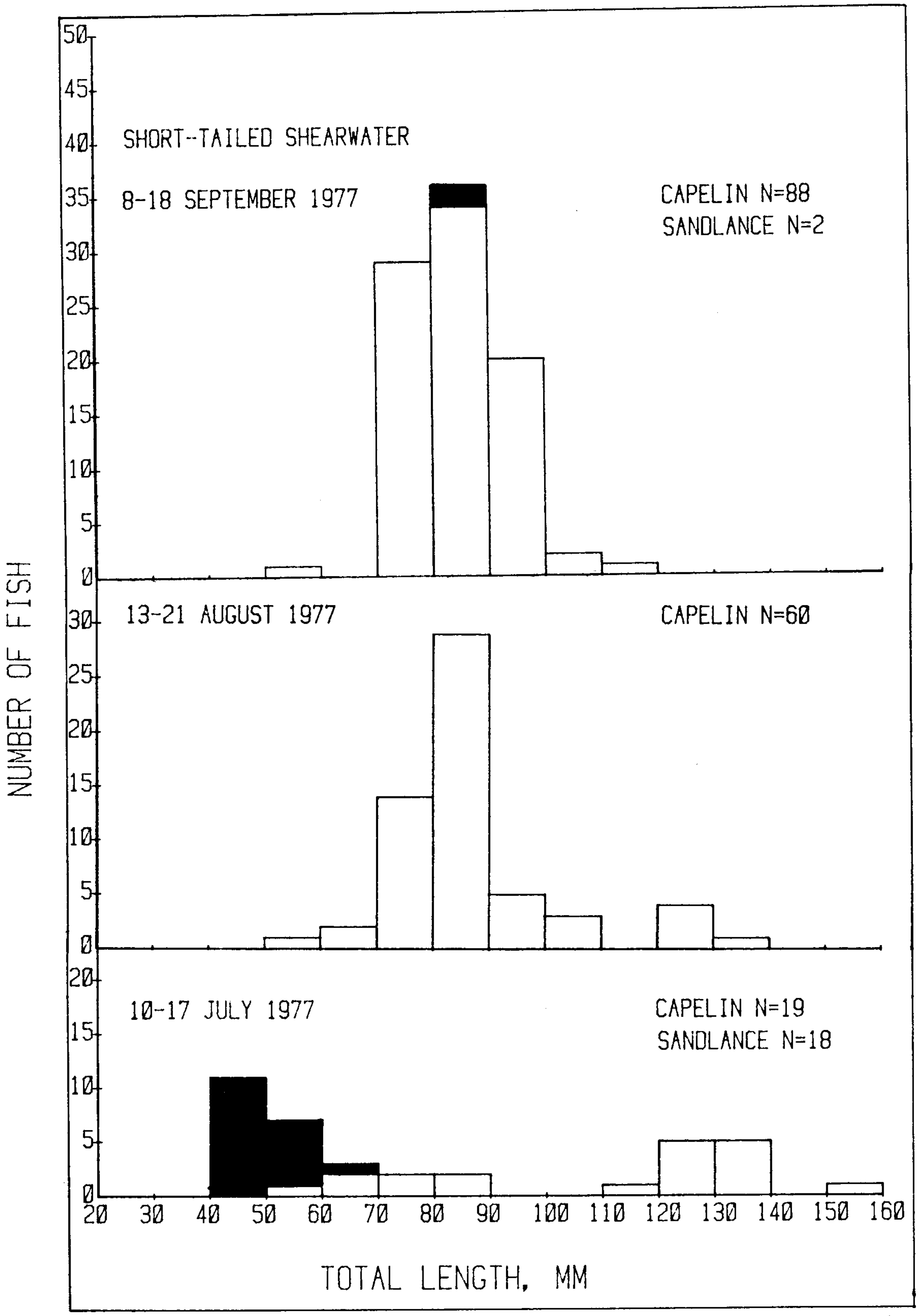

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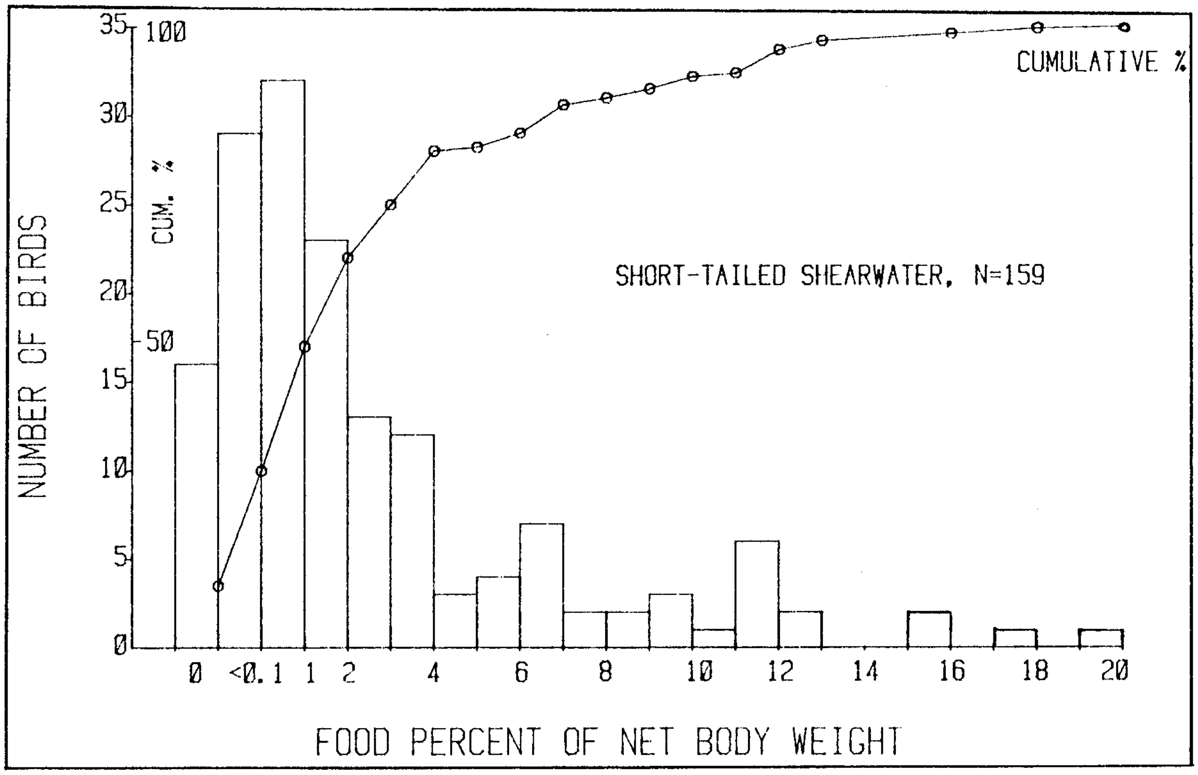

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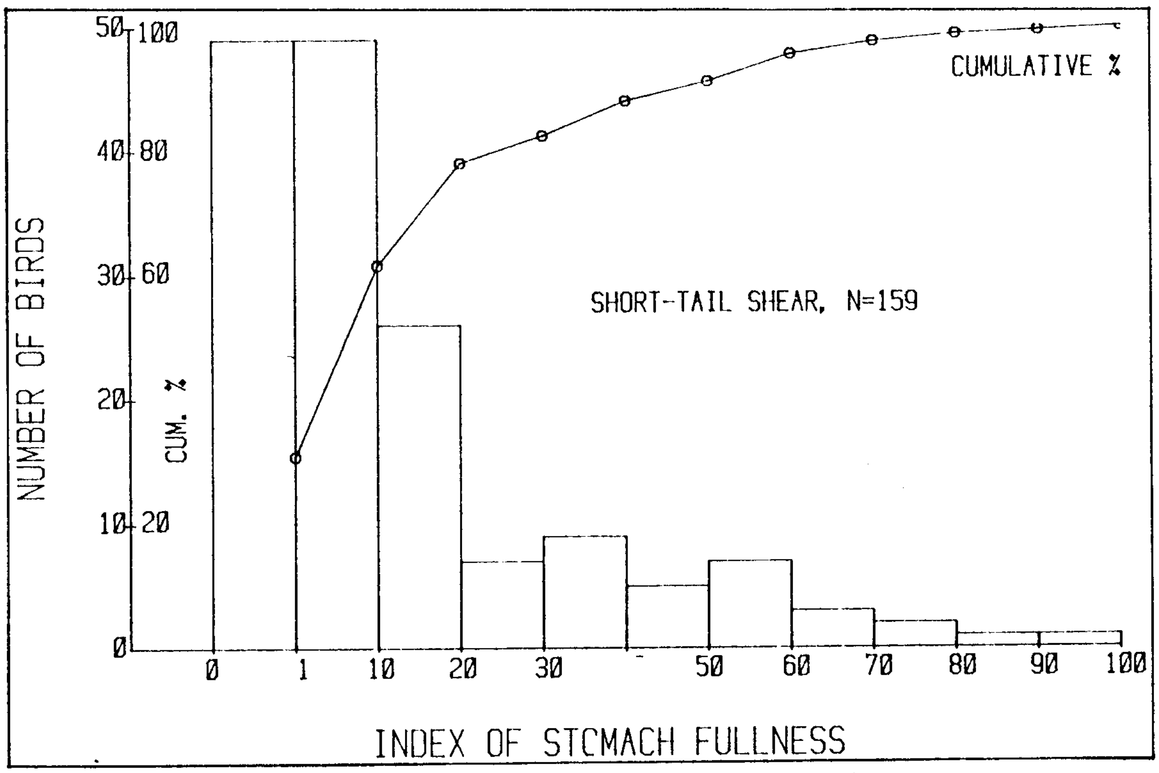

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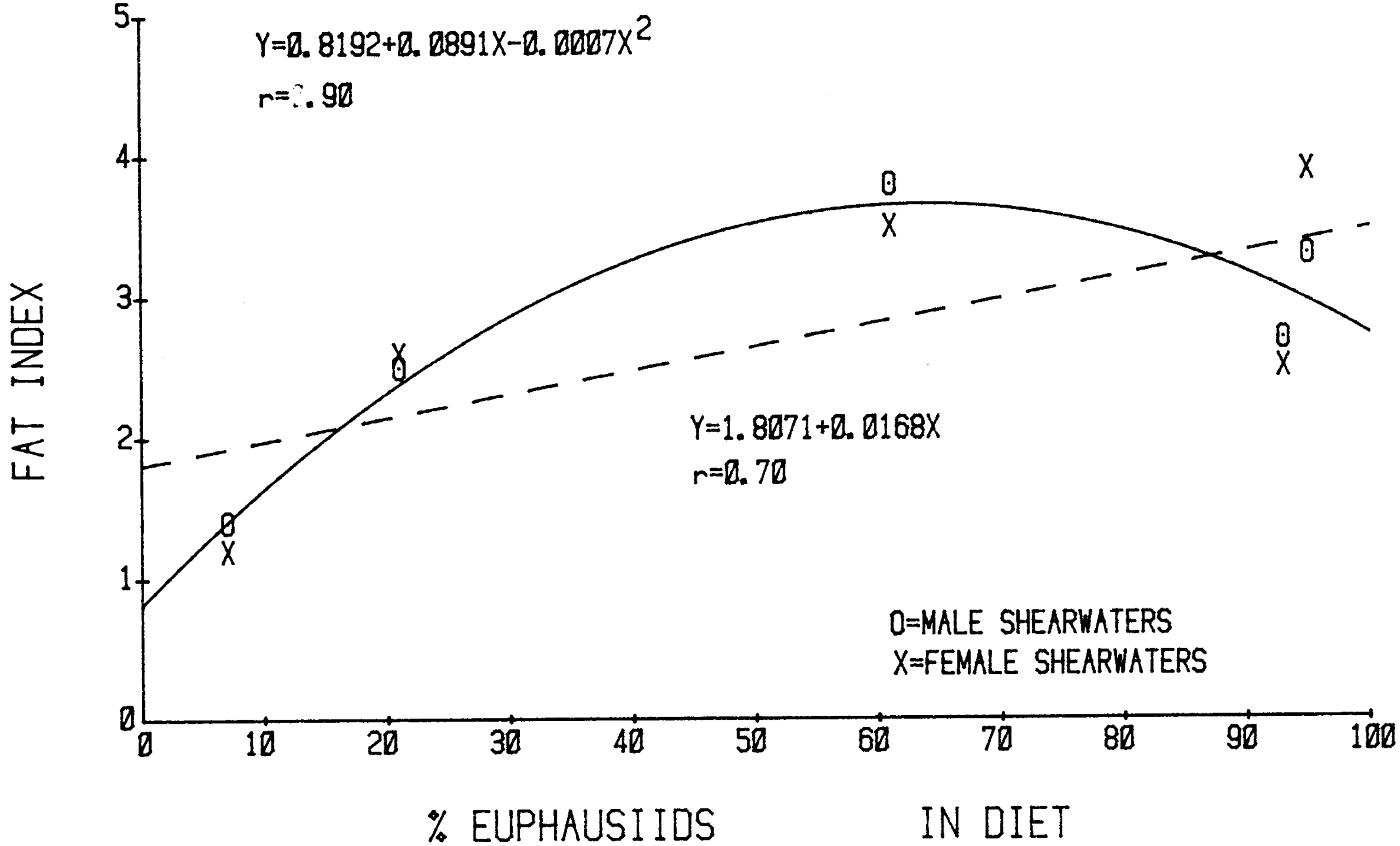

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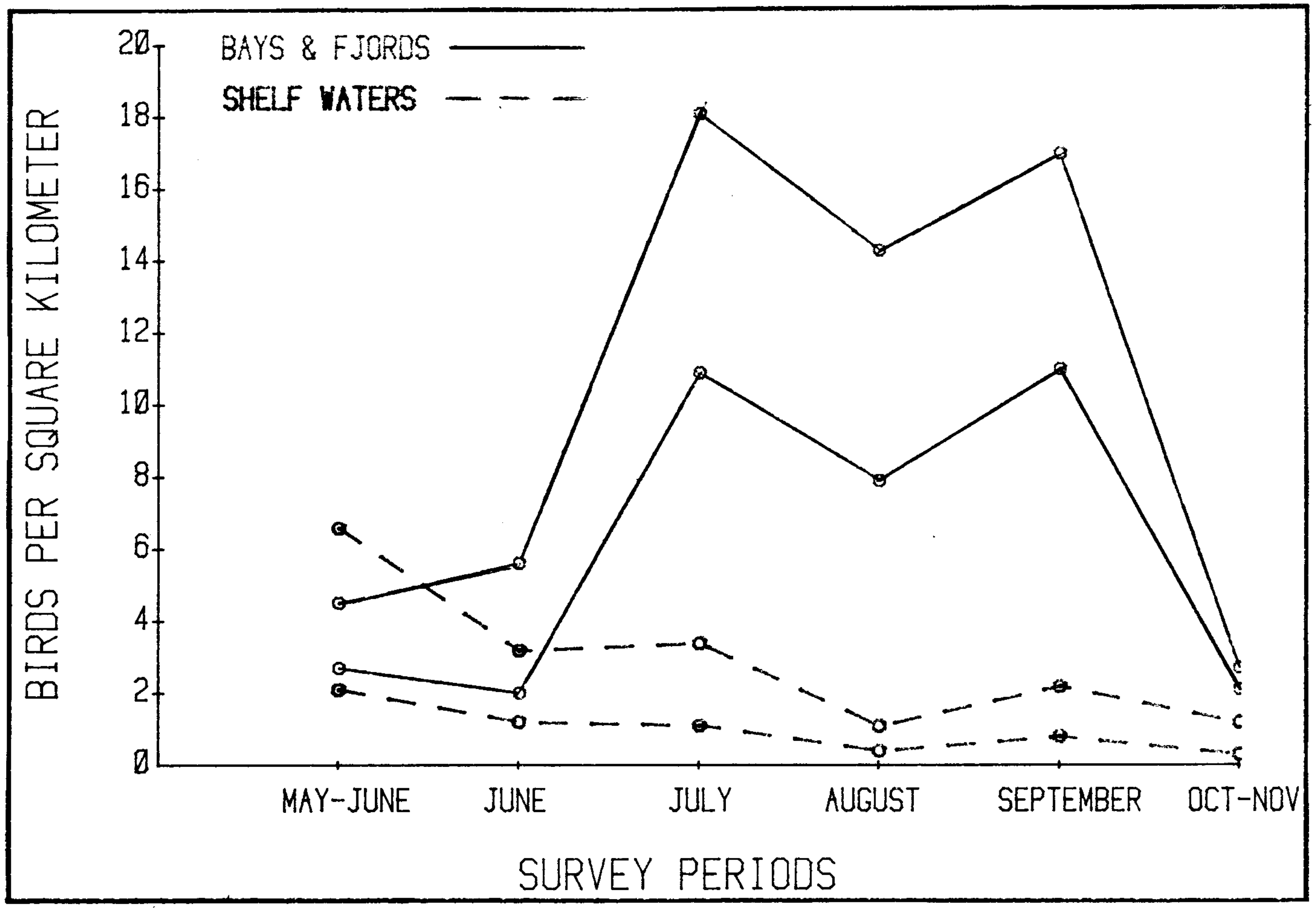

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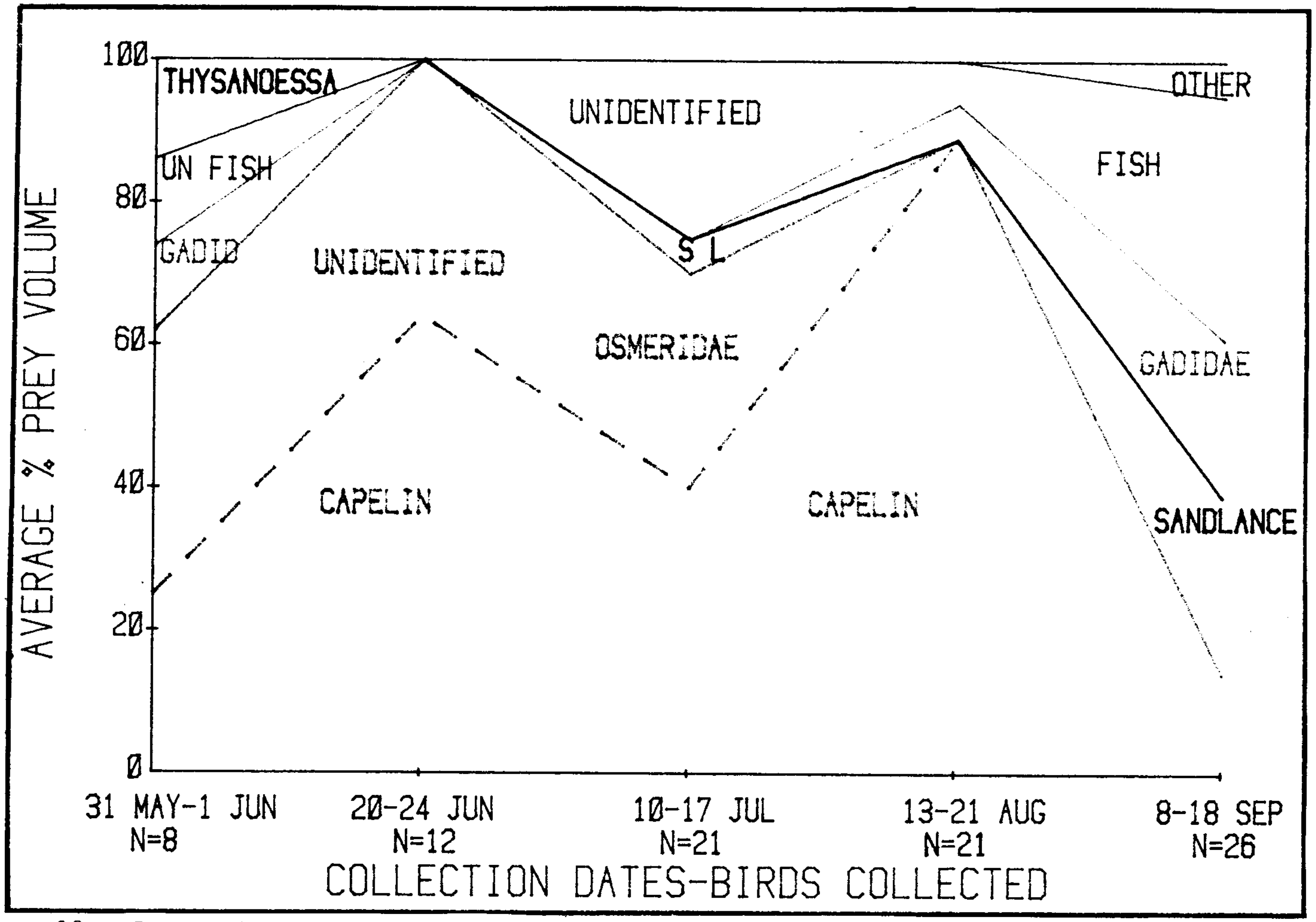

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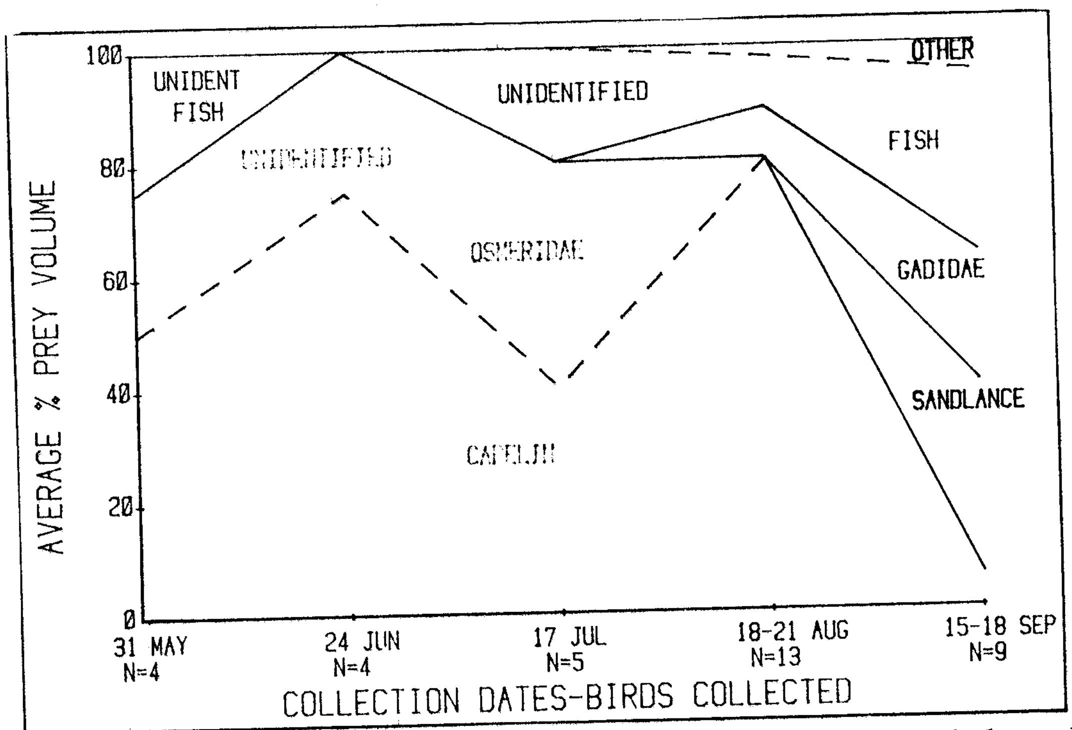

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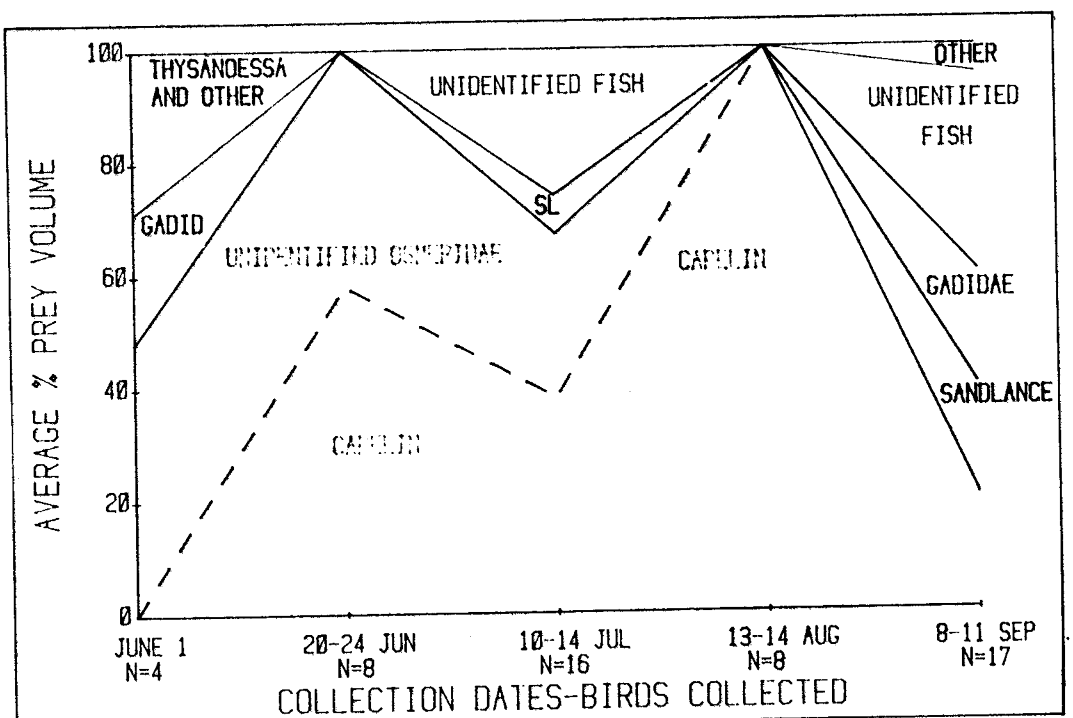

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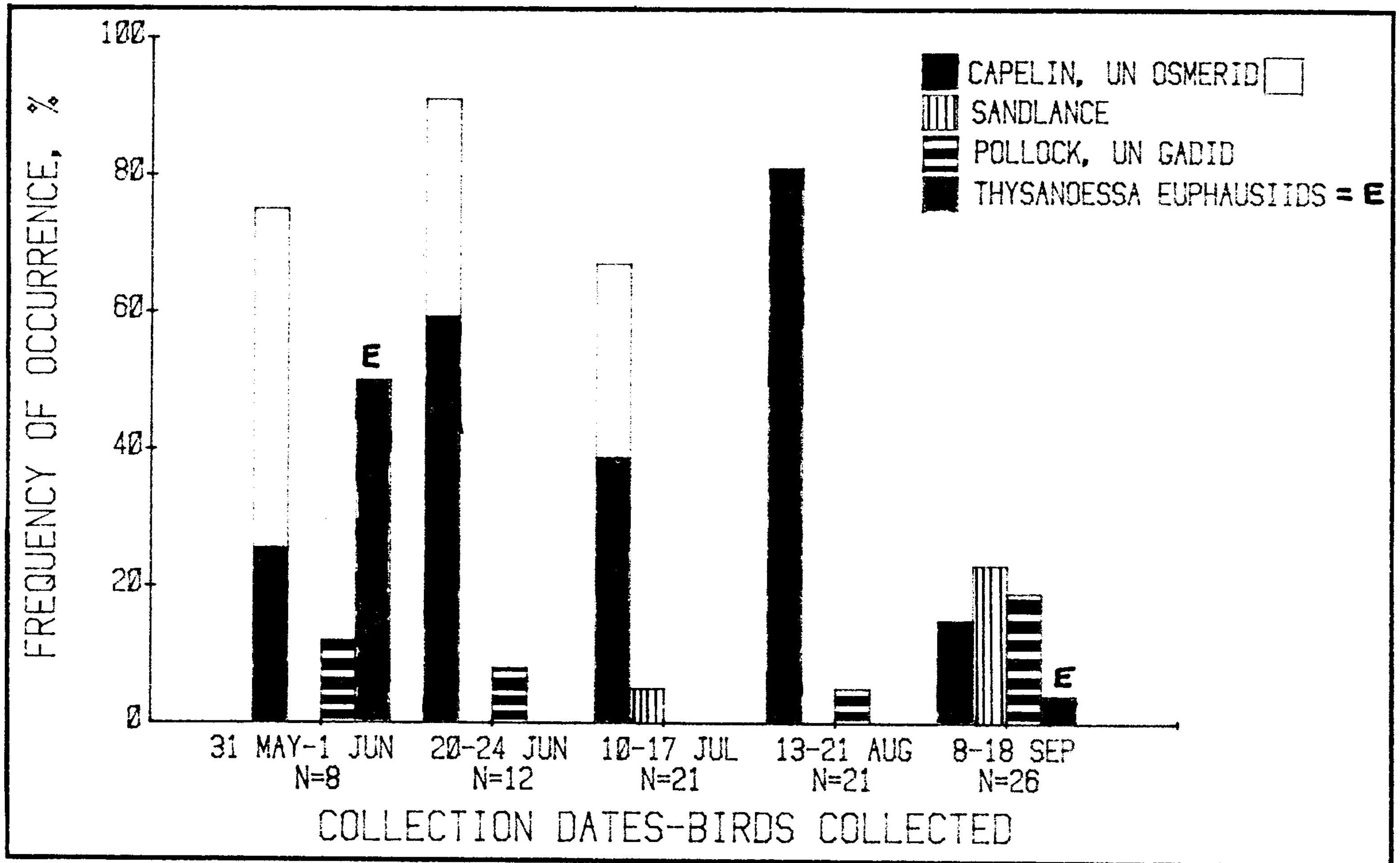

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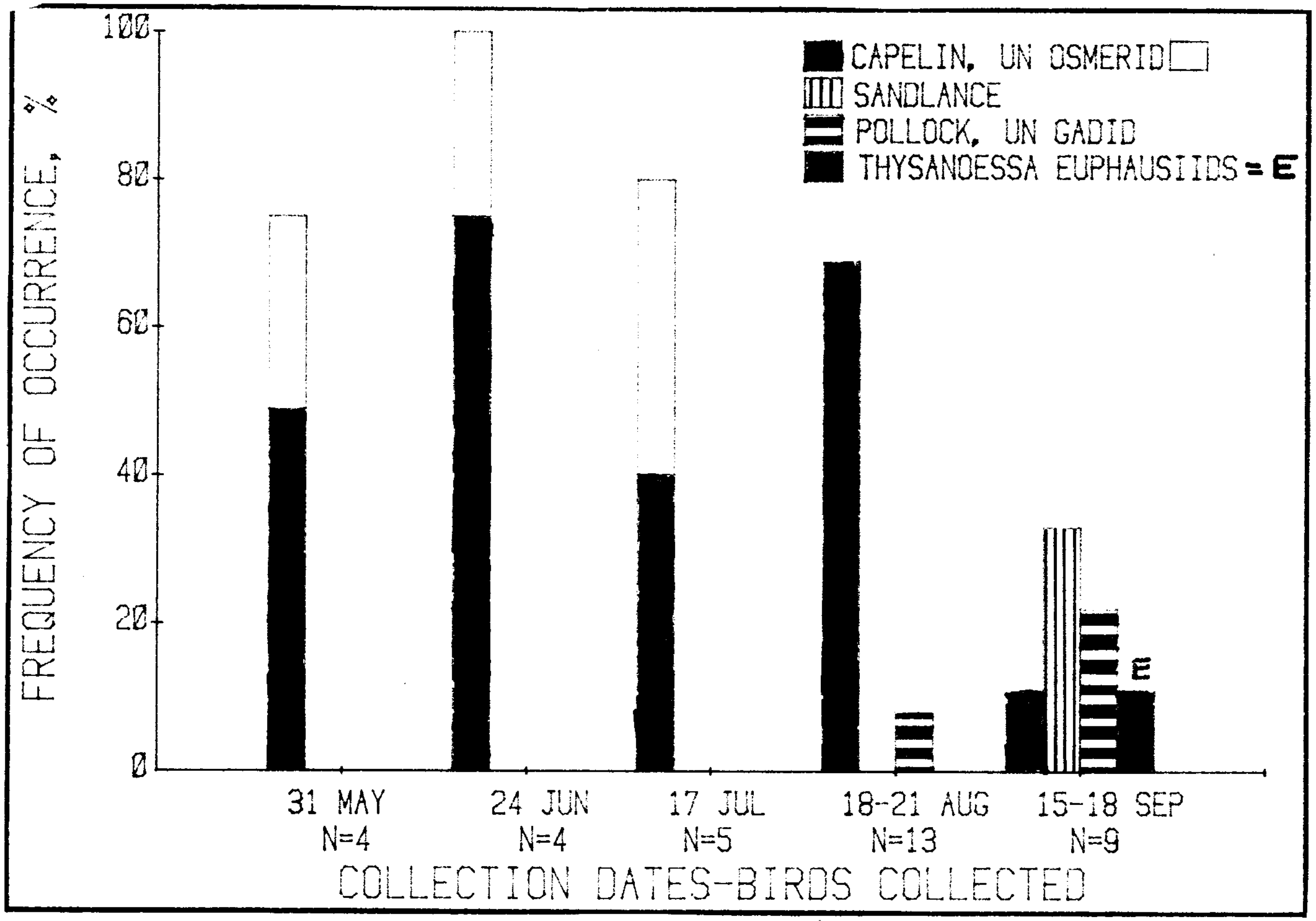

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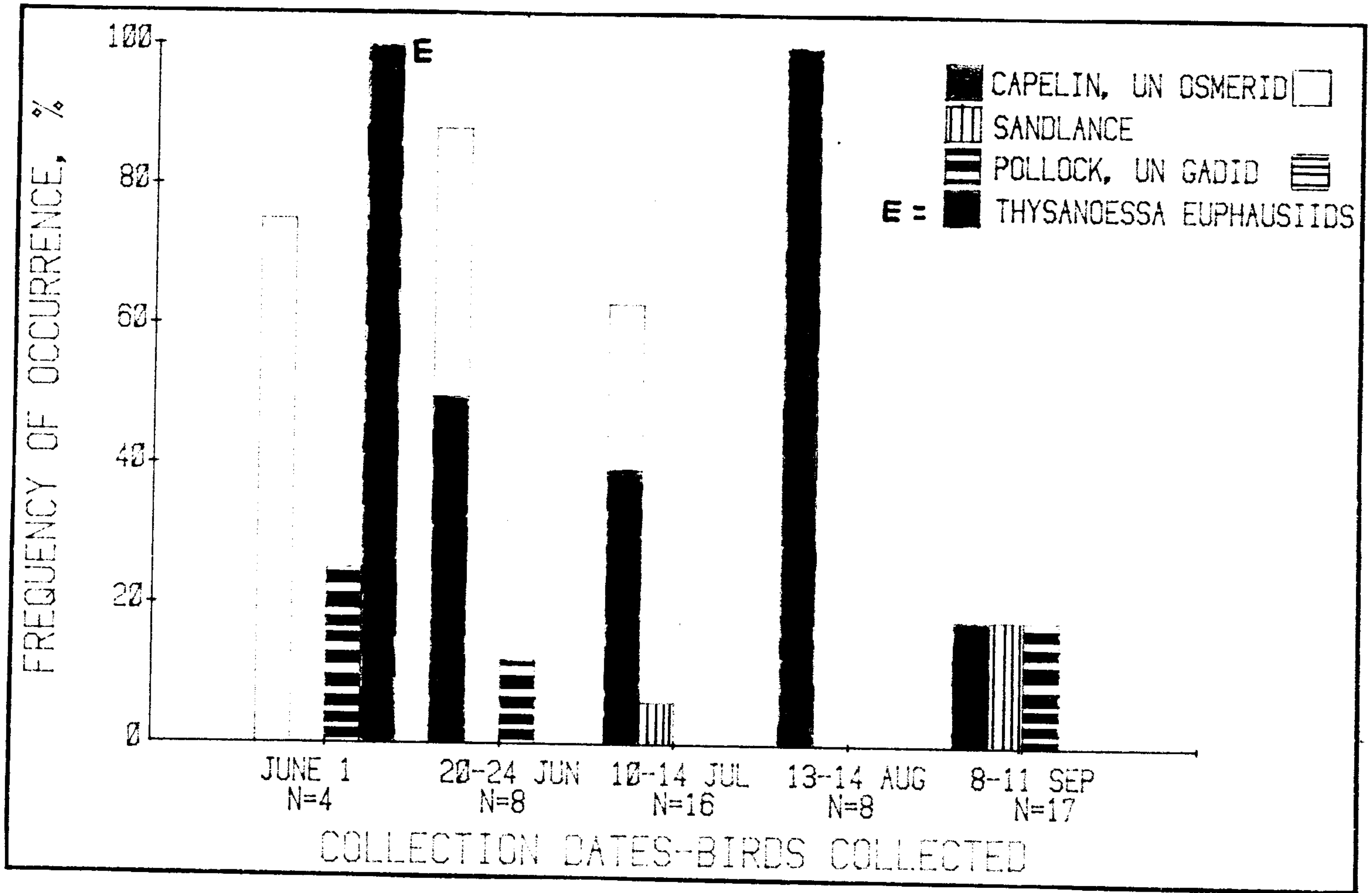

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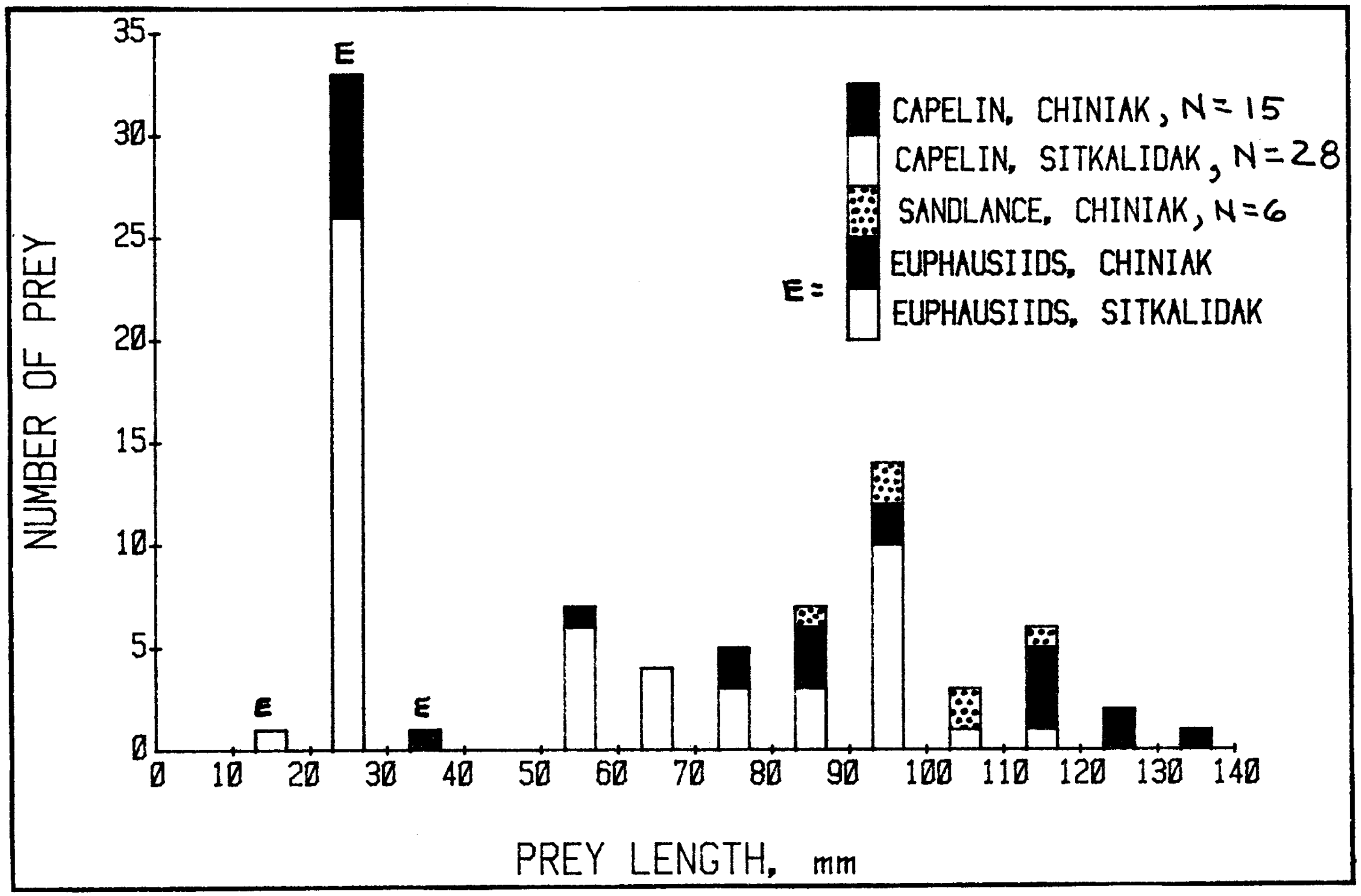

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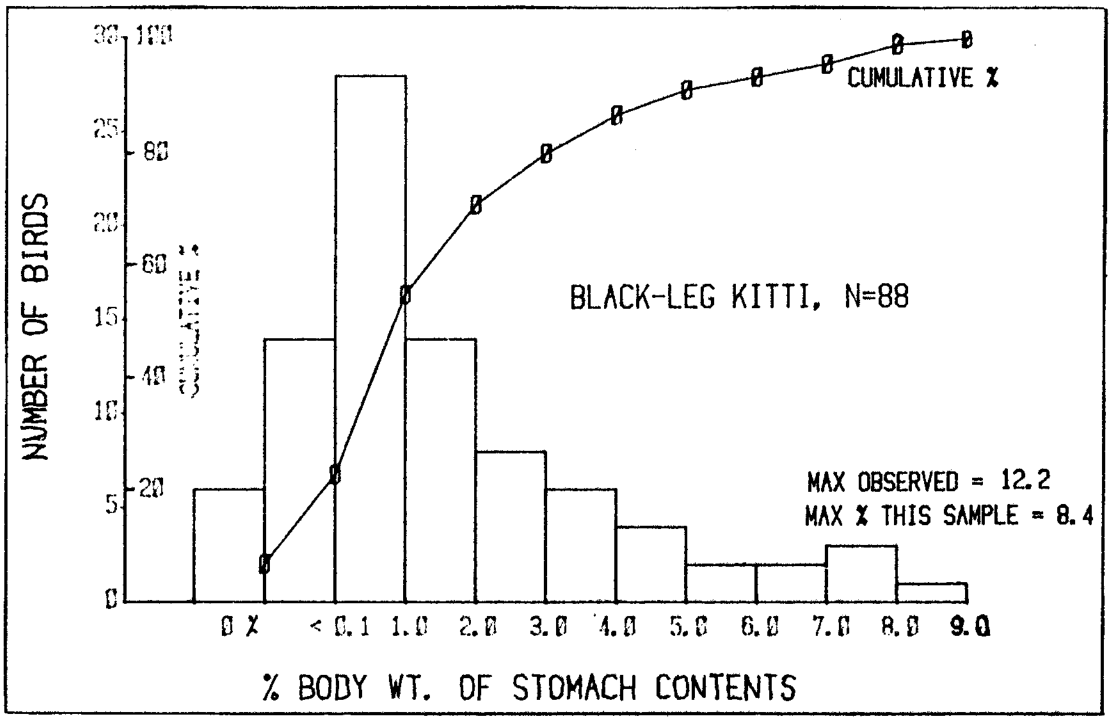

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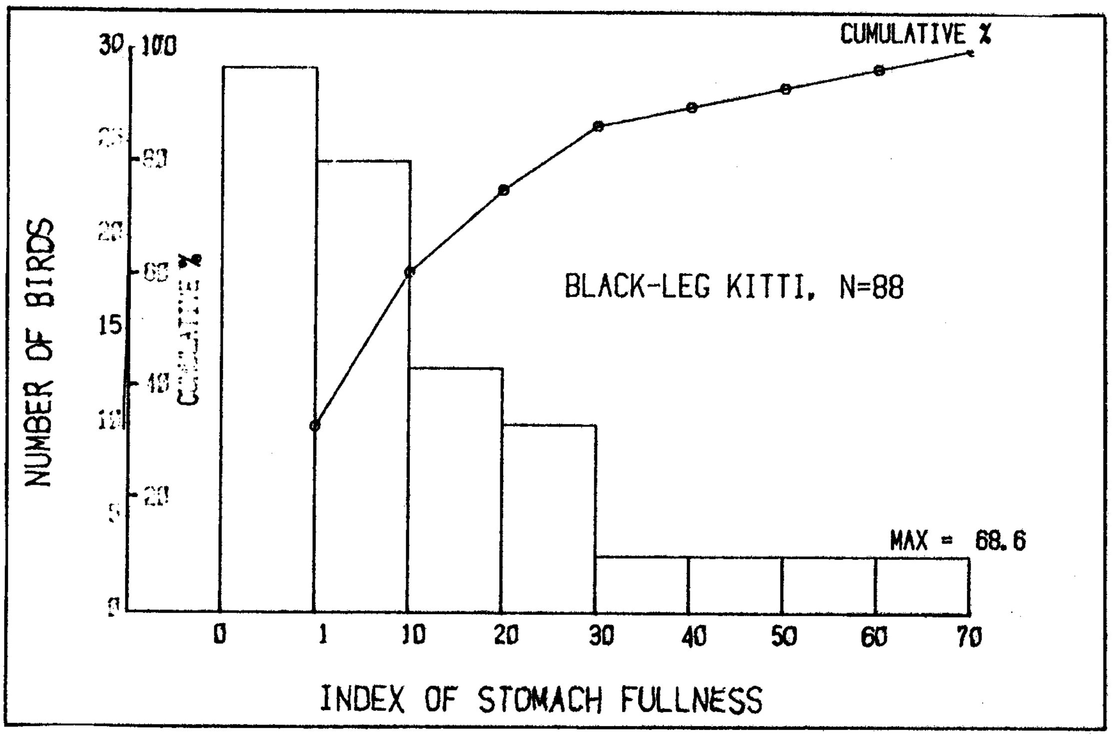

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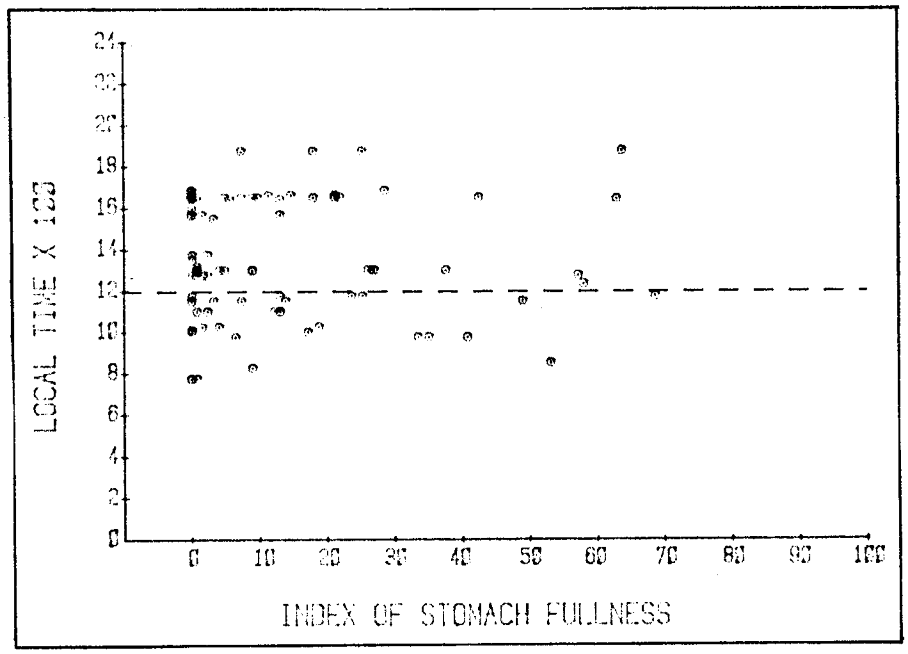

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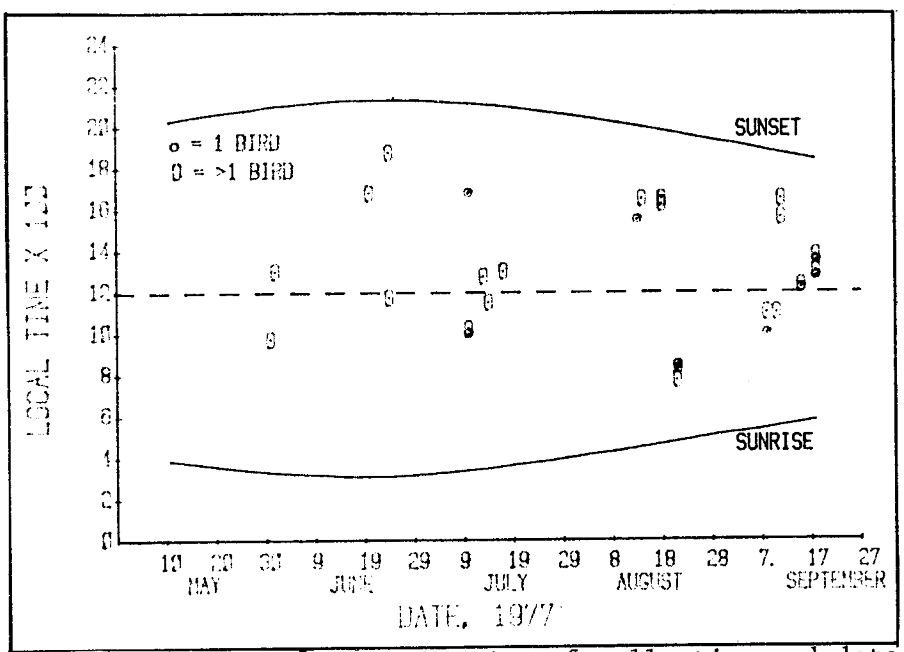

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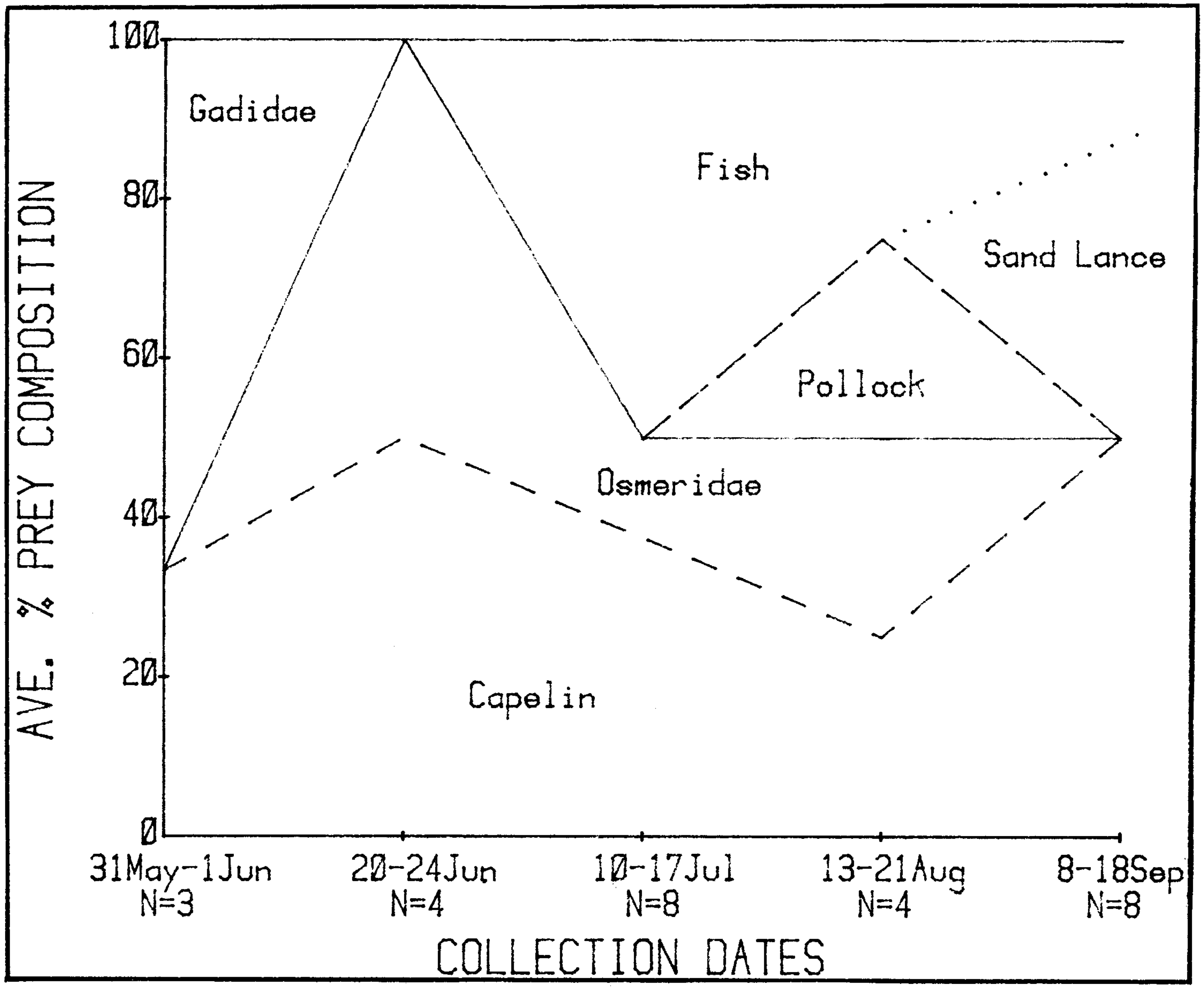

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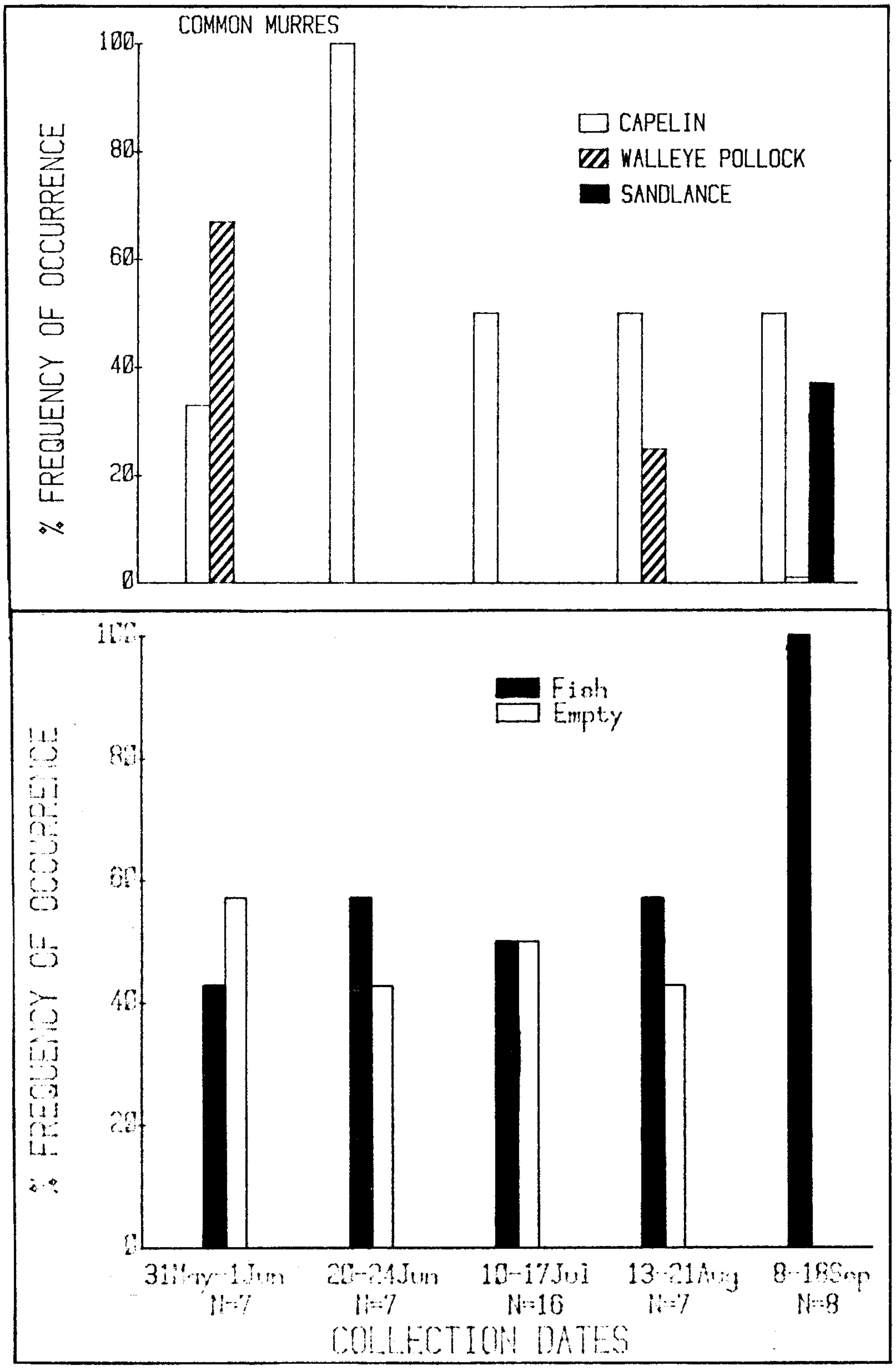

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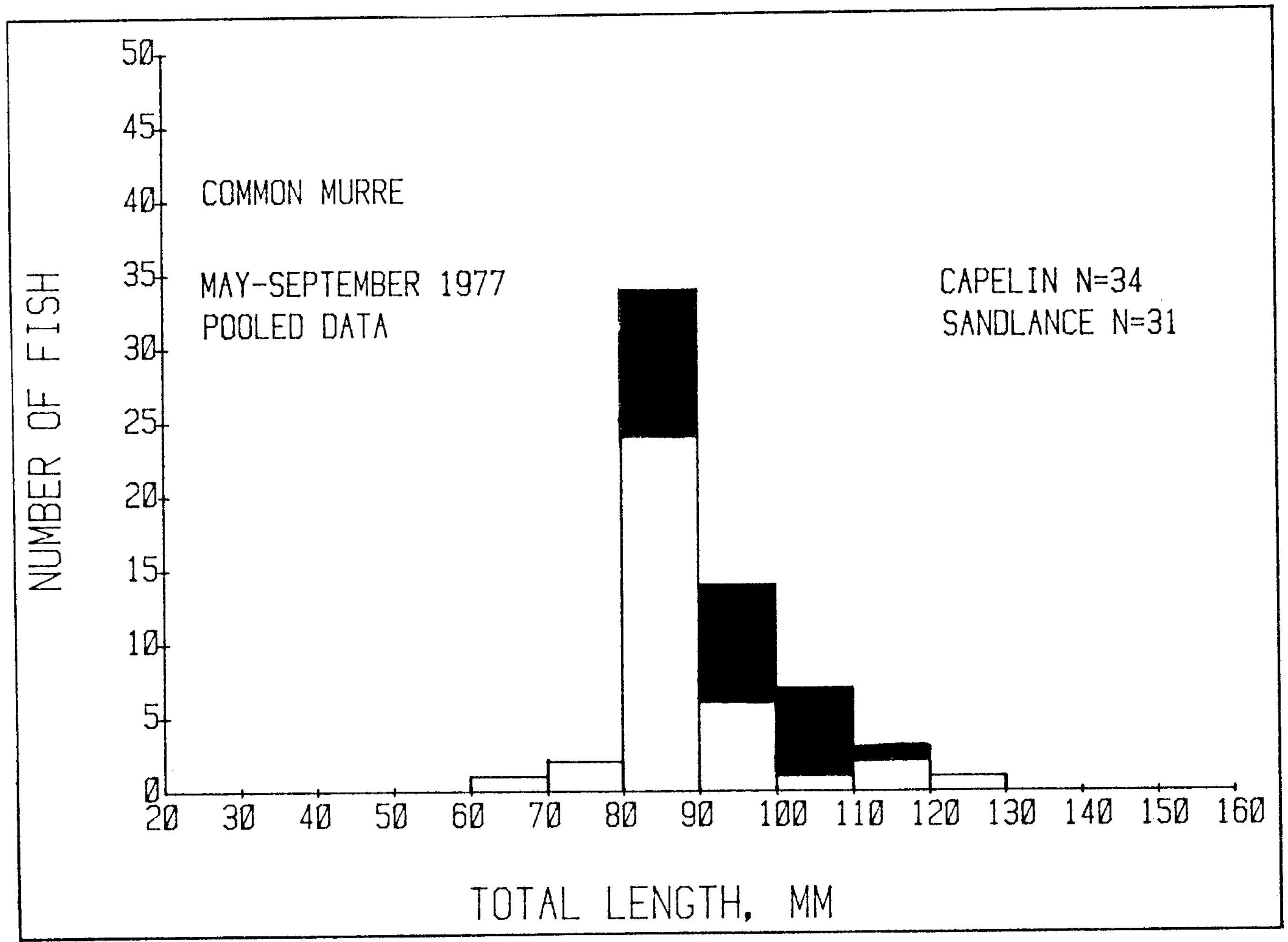

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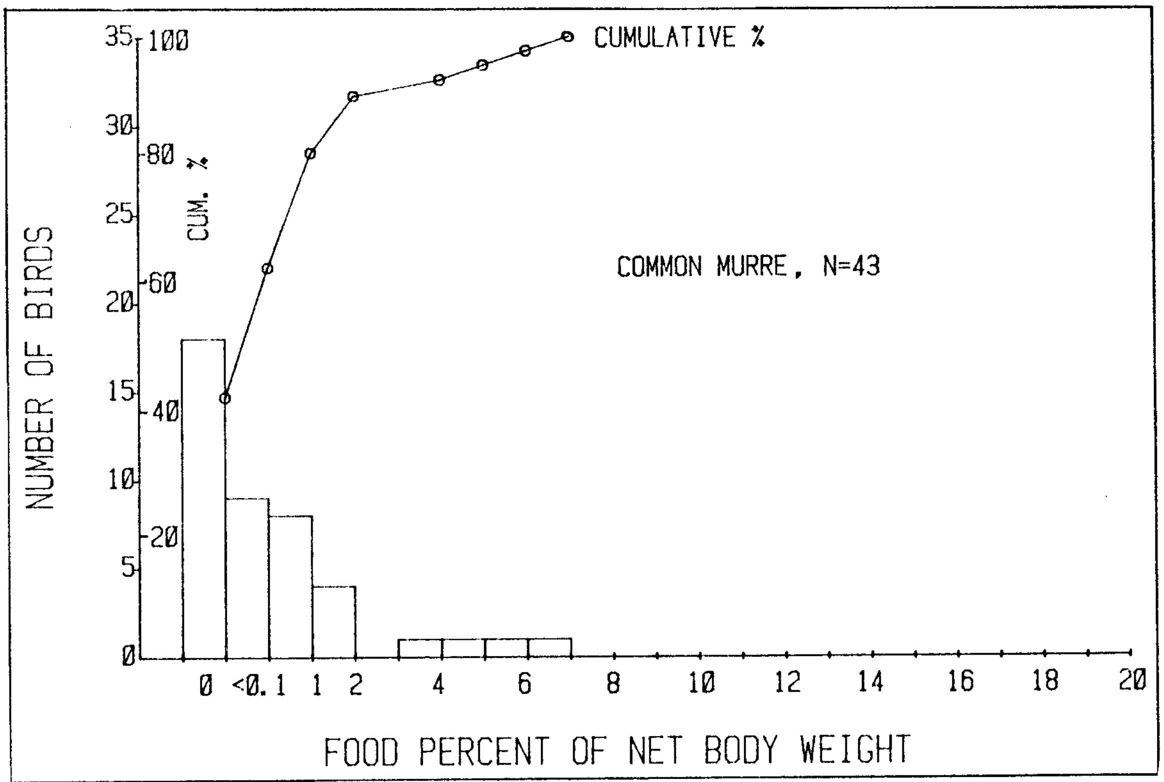

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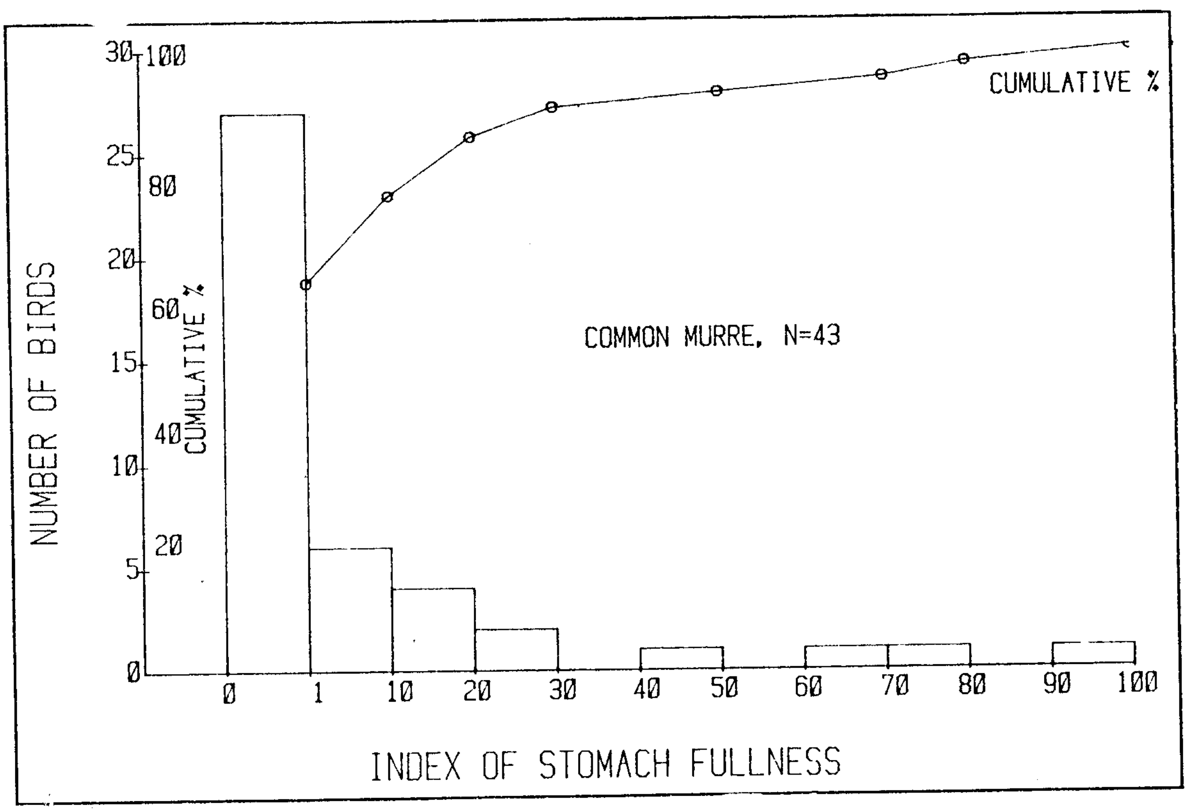

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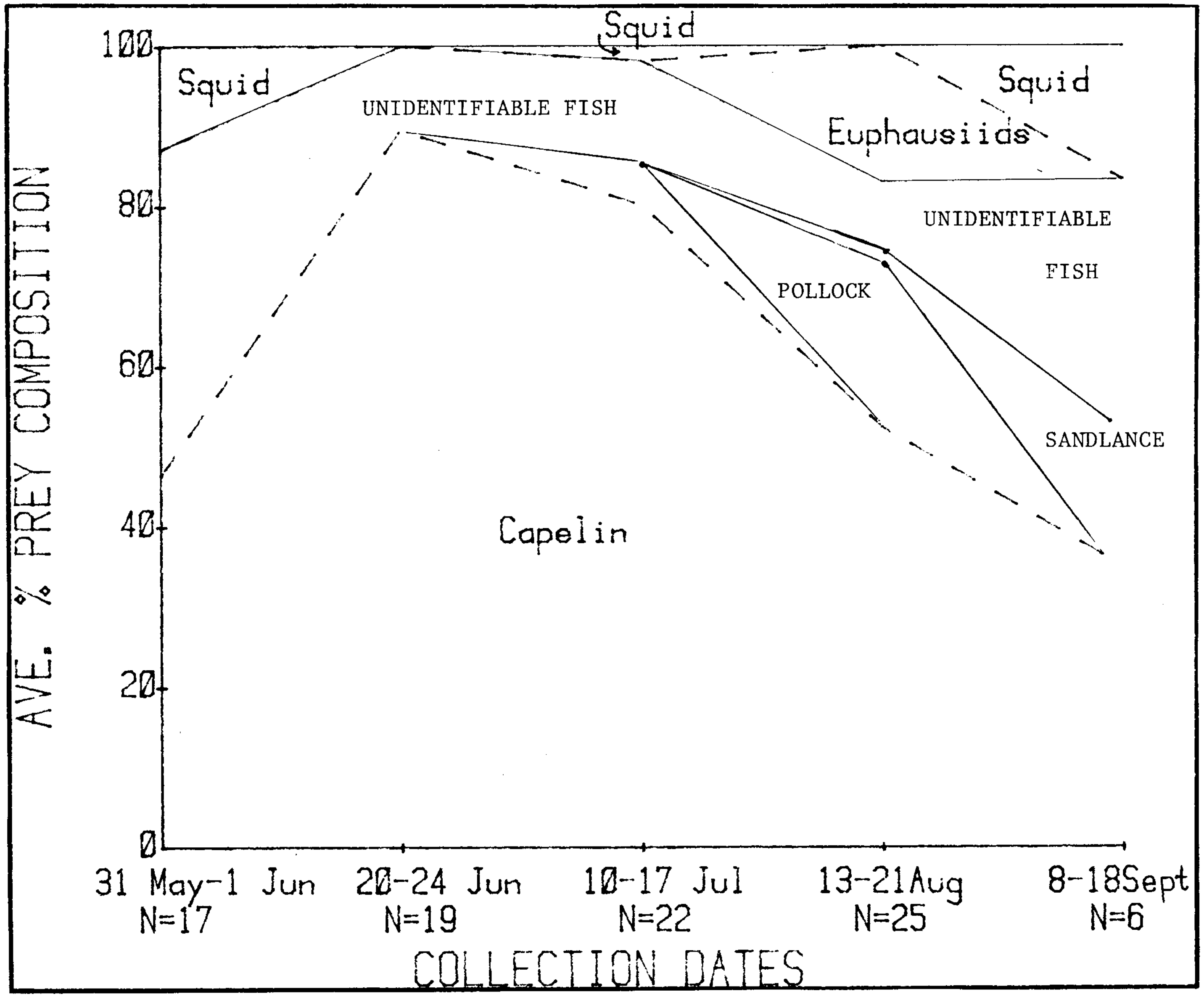

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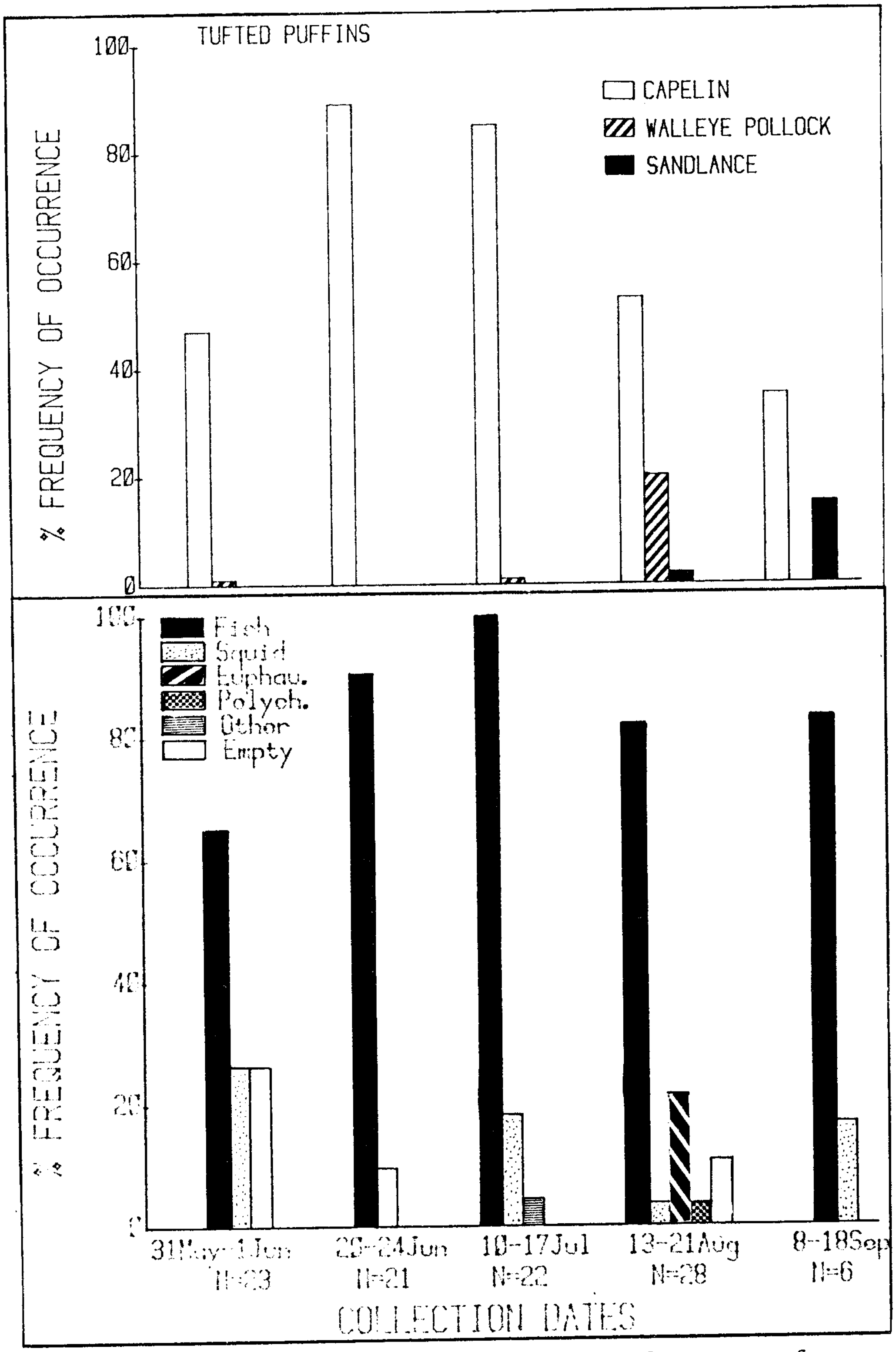

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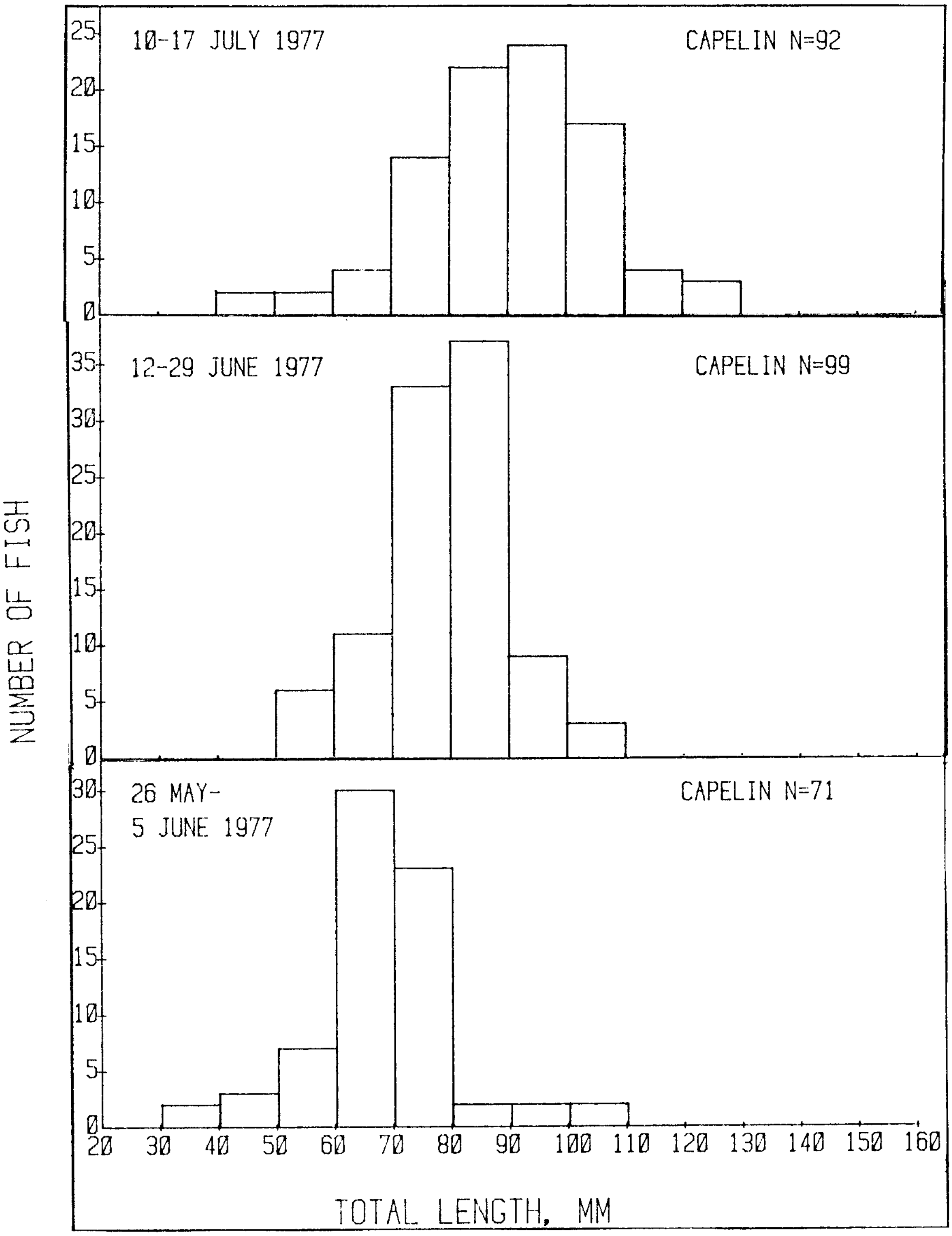

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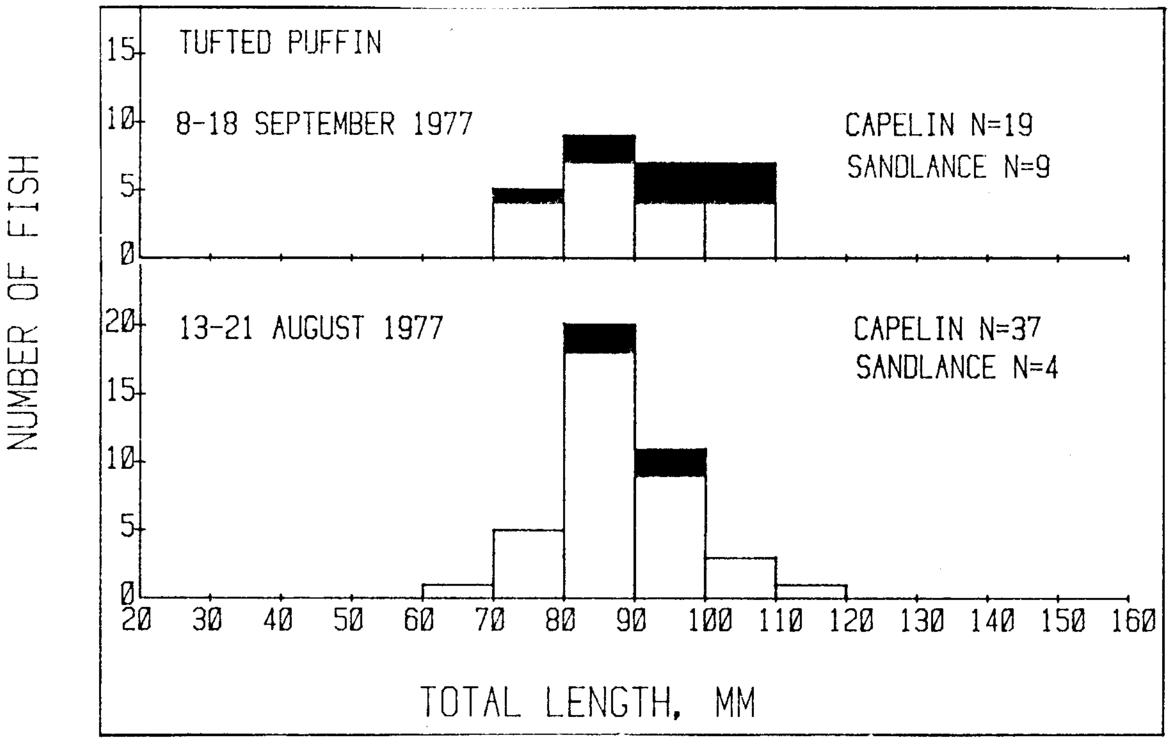

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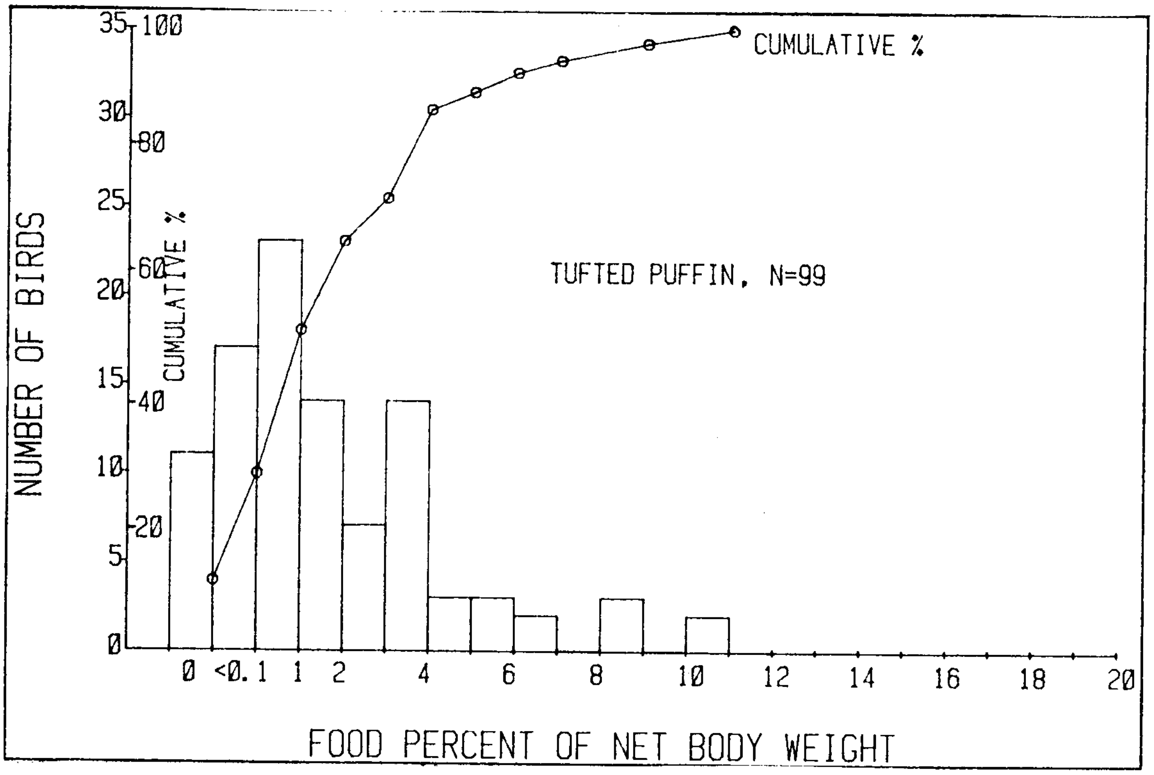

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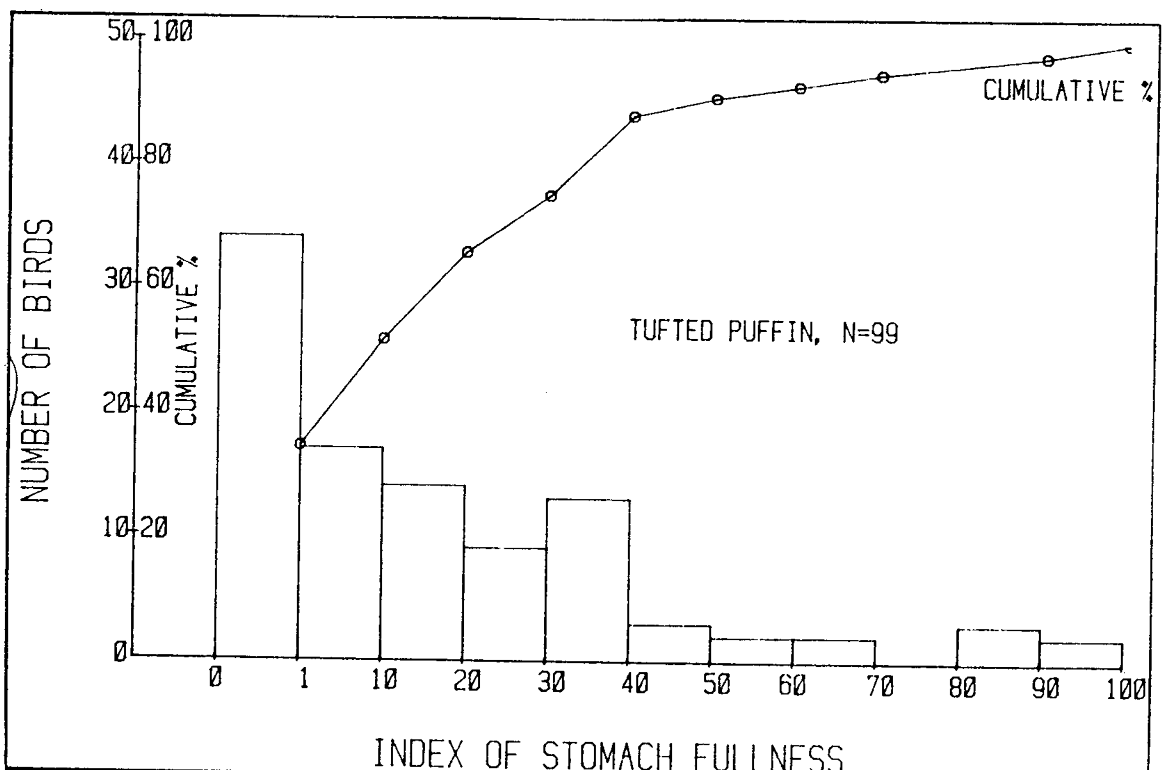

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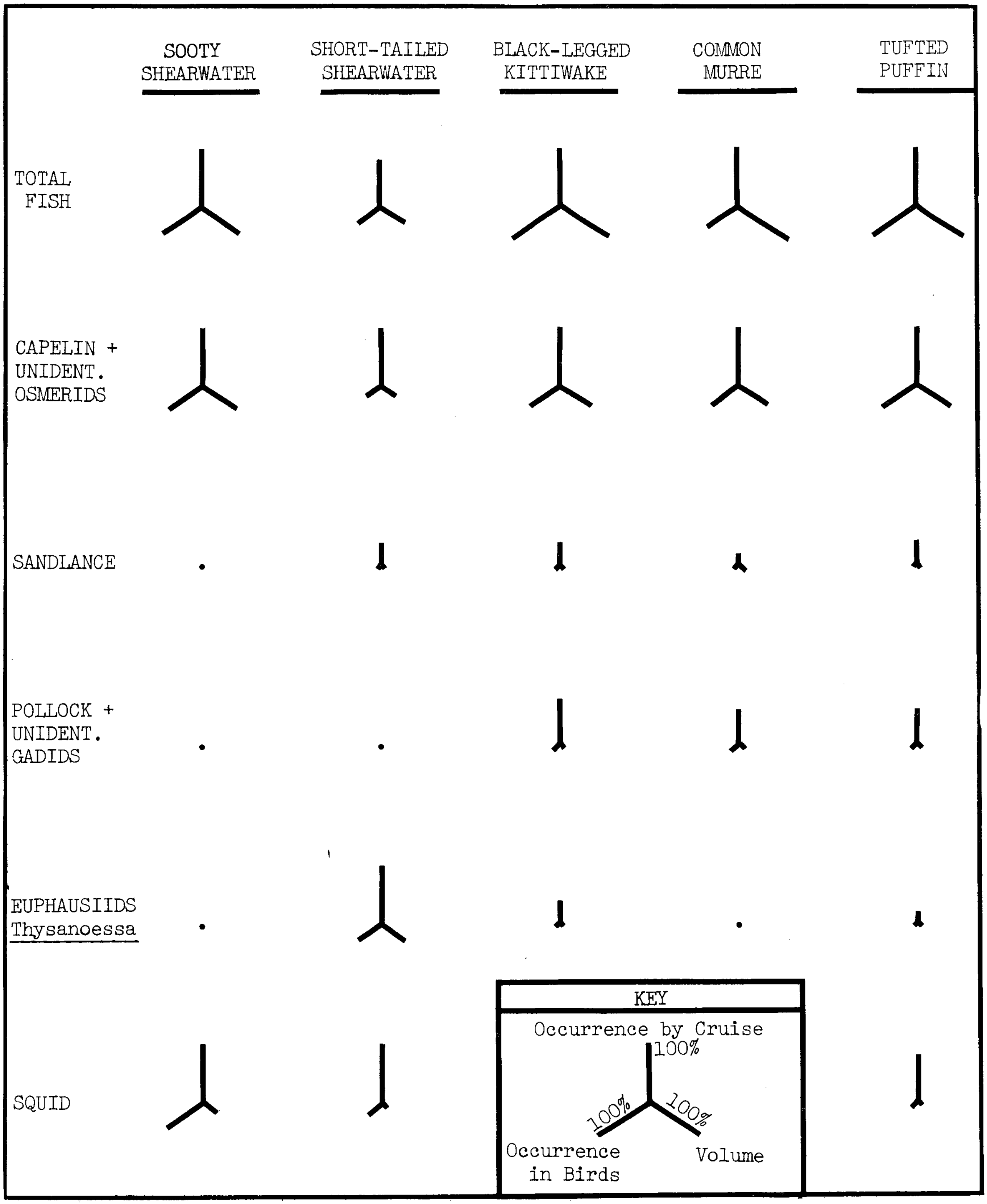

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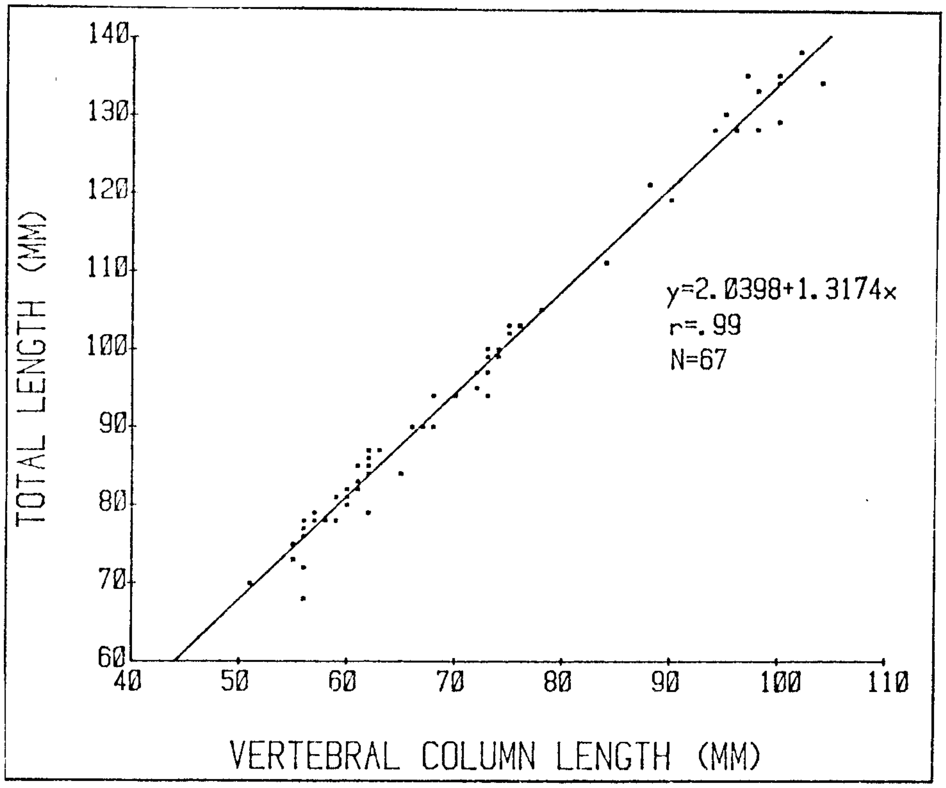

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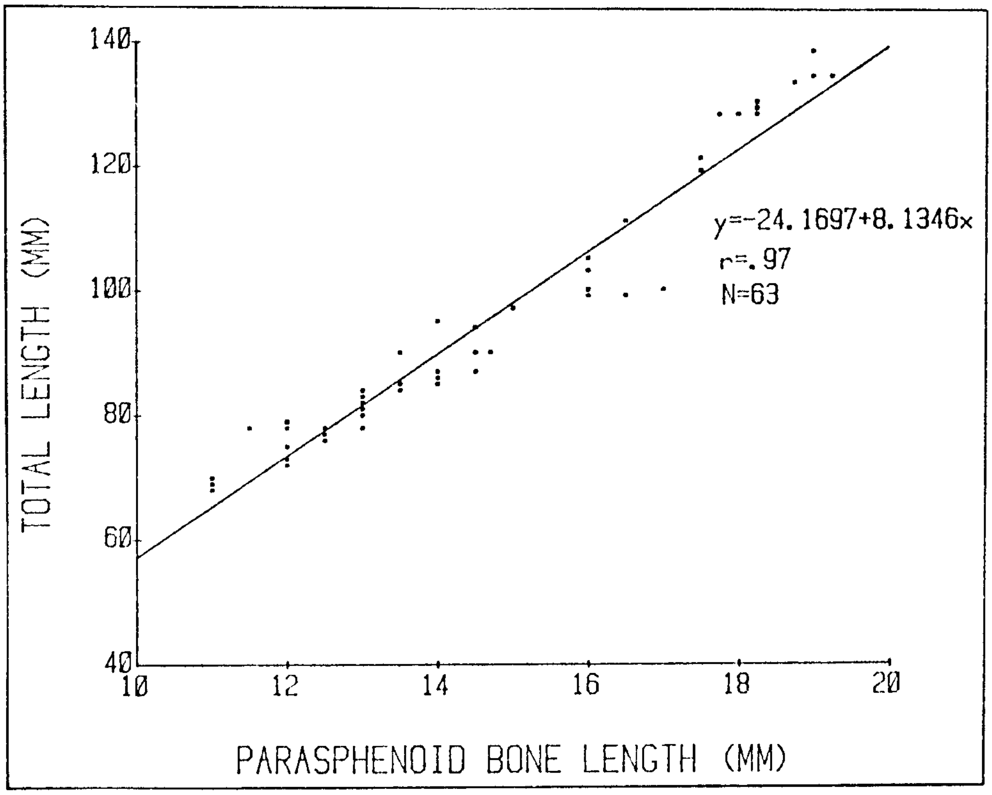

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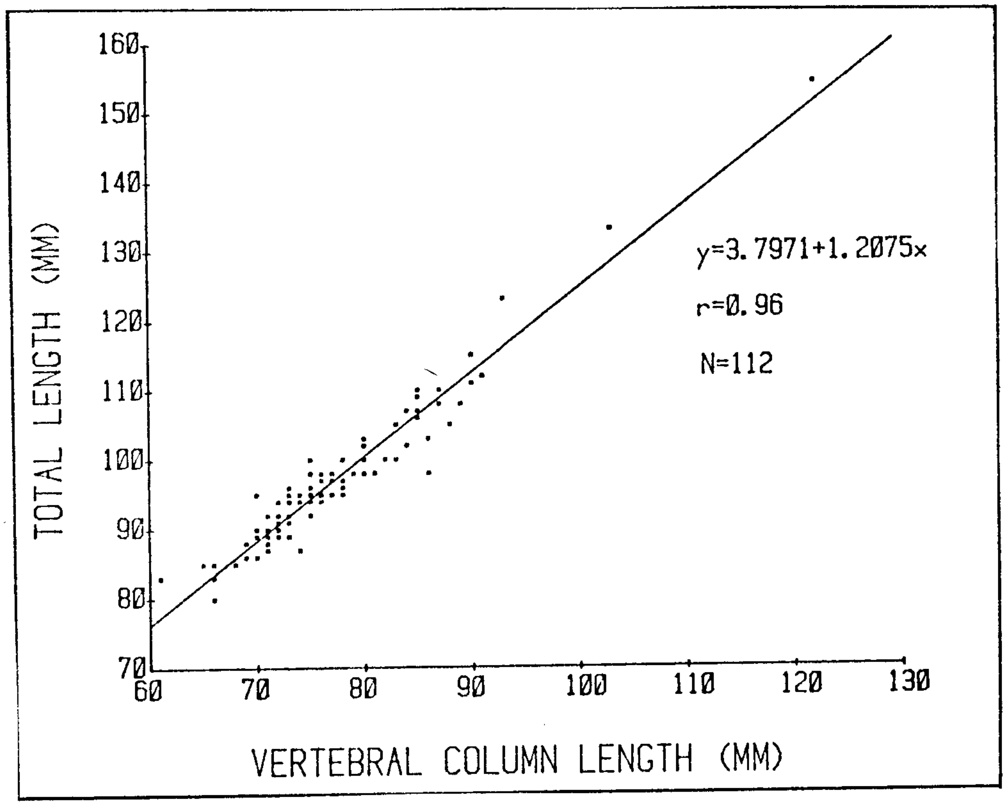

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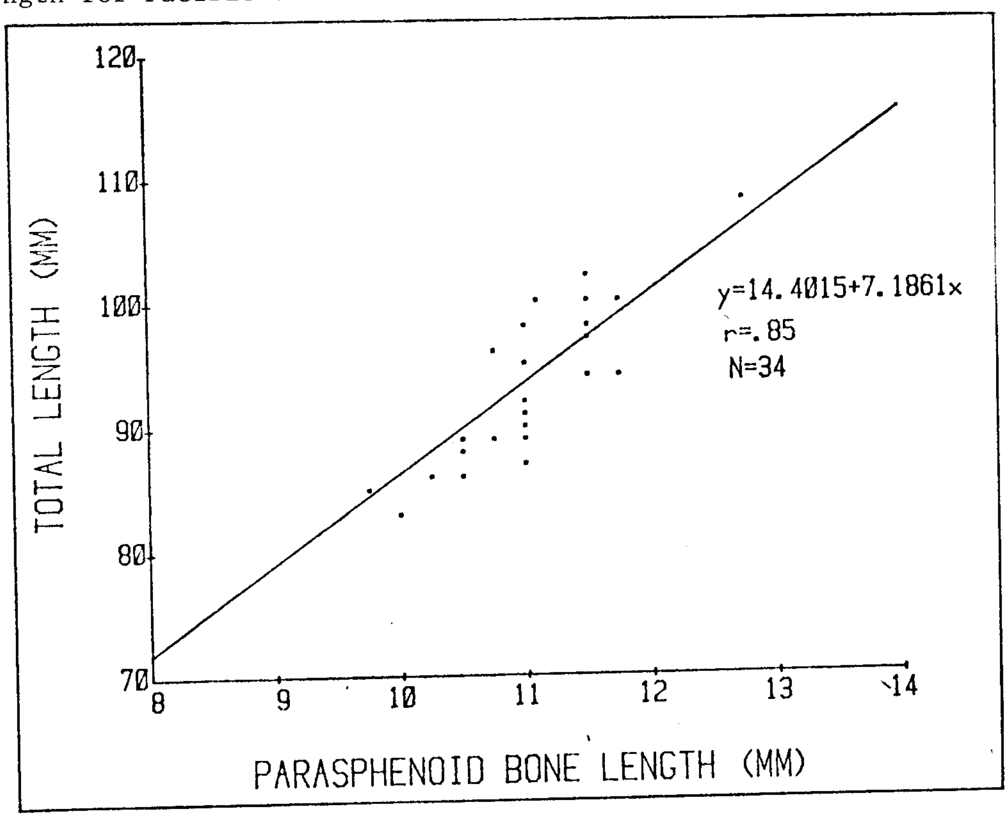

Figure 46. Relationship between total length and parasphenoid bone length for Pacific Sandlance.

APPENDIX IX

NOAA-OCSEAP Contract: 01-5-002-2538
Research Unit: 341
Principal Investigator: C. J. Lensink
K. D. Wohl
Report Period: April 1, 1977 to
March 31, 1978

ANNUAL REPORT

"Catalog of Alaskan Seabird Colonies"

By

Art Sowls

U.S. Fish and Wildlife Service
Office of Biological Services-Coastal Ecosystems
800 A Street - Suite 110
Anchorage, Alaska 99501

1 April 1978

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I. INTRODUCTION

The objective of the colony catalog is to provide information on location, species composition and populations for Alaskan seabird colonies. Data are organized for quick access at whatever level is needed for management and scientific queries. The system includes a file containing the original data, references and maps, and photographs when they are available. This file is located in the Anchorage office of the U.S. Fish and Wildlife Service, Office of Biological Services Coastal Ecosystems.

A computer format was devised for colony catalog data but OCSEAP management has decided that the written summary within the catalog would be sufficient for BLM's needs. Thus the data have not yet been digitized and this has delayed final analysis. The U.S. Fish and Wildlife Service plans to computerize the catalog data on its own system so that quick analysis and updating will eventually be possible.

The colony catalog is now in the final stages of preparation and will be published before October 1, 1978. A synopsis of data obtained during the past year is thus not presented here. The present report gives, 1) an update on the preparation of the final catalog, 2) a statewide summary of three seabird species and 3) recommendations for further study.

II. CATALOG STATUS

Funding for the colony catalog ends October 1, 1978. The final report will be printed at U.S. Fish and Wildlife Service expense in St. Louis. The final camera-ready product would be ready to send for printing by June 1, and printing should be completed in one or two months. Maps for the entire state are nearly completed, except for the Aleutian Islands. We are waiting for an Aleutian Islands National Wildlife Refuge report before compiling information on that area.

Page size for the final report will be 12 x 15 inches. Maps and tables will follow the format of the sample presented in the October, 1977, quarterly report. Maps will be 1:500,000 scale showing colony location and a color dot overlay for identifying relative colony size at a glance. Tables of population data will be presented on pages facing the maps.

III. SPECIES SUMMARIES

Certain key species can serve important roles in OCS environmental monitoring. Seabirds are highly visible, represent a high trophic level in the marine ecosystem, and are relatively easy to study. For these reasons they are good indicators of the ocean's health. Seabirds will also be the first and most obvious casualties in an oil spill catastrophe.

There are over 30 species of true seabirds in Alaskan waters. Some of these will be more useful as indicators than others, depending on such factors as accumulated baseline data, ease of studying, range, and abundance. Tufted and Horned Puffins and Black-legged Kittiwakes are species which have been suggested as important indicators and which fit the above requirements. Puffins spend much time on the water and are therefore particularly vulnerable to oil spills. They can be used to assess the direct impact of a major spill. Kittiwakes are less directly vulnerable since they spend little time on the ocean's surface. They can, however, serve as indicators of long term environmental pollution because easily monitored population changes will likely result from degredation of the food supply.

Black-legged Kittiwake

Black-legged Kittiwakes have a broad circumpolar breeding distribution. In Alaskan waters they breed from Cape Lisburne south, throughout the Aleutians to the west, and to Glacier Bay in the east (Figure 1). The largest colonies are found in the Bering Sea (Cape Newenham, Cape Pierce, Nunivak Island, and the Pribilof Islands) and the Gulf of Alaska (Middleton Island, Kodiak Island complex, and the Semidi Islands).

Black-legged Kittiwakes nest as single pairs or in colonies of over 100,000 pairs. Colony sites include offshore islands, rocks and mainland cliffs. Although most colonies are next to the open sea, some are in fyords often near glaciers. One such colony in Glacier Bay is over 90 miles from the open sea. Sixteen hundred kittiwakes nest on a shipwreck on Middleton Island but this is the only "unnatural" site known in Alaska.

The colony catalog contains information on 249 Black-legged Kittwake colonies with an estimated total of 2,123,000 birds (Figure 2). This population estimate should be considered minimum since: 1) there are probably undiscovered colonies, at least small ones, 2) non-breeding birds may not attend colonies, and 3) we suspect a general underestimation of colony sizes in the catalog data. An overall reasonable guess of the Alaskan Black-legged Kittiwake population would be 2½ -3 million birds.

Horned Puffin

The world breeding distribution of Horned Puffins is restricted to the North Pacific from Cape Lisburne in the north, to the Sea of Okhotsk in the west and Forrester Island in the east (Figure 3). The largest concentration of individuals is in the north-central Gulf of Alaska (Figure 4).

Horned Puffins not only nest in colonies but are scattered as singles or small groups along suitable coastlines. Most pairs are crevice nesters but some will nest in burrows. The largest known aggregation of birds on any one island is 108,000 for Chowiet Island.

The colony catalog contains information on 66 colony sites with an estimated 690,000 birds. This figure is probably quite low because of the difficulty in censusing scattered pairs and very large colonies. Several hundred thousand additional birds, for example, are likely to exist in the Semidi Islands for which we have an estimate only for Chowiet Island.

Tufted Puffin

Tufted Puffins breed in the North Pacific from Cape Lisburne in the north to Hokkaido in the west and southern California in the east (Figure 5). The major part of the Alaskan population is found in the north-central Gulf of Alaska, Aleutian Islands and Bristol Bay (Figure 6).

Tufted Puffin colonies vary from a few pairs to over 250,000 on Kaligagan Island. Burrows are the prefereed type of nesting location.

The colony catalog has information on 461 tufted Puffin colonies with an estimated total of 1,956,000 birds. This figure, however, is probably quite low for the same reasons as listed for kittiwakes and Horned Puffins and the actual Alaskan population is probably on the order of four million.

IV. RECOMMENDATIONS FOR FURTHER STUDY

Colony catalog funding from OCSEAP will terminate Oct. 1, 1978 and has been used for passive data collecting only. Colony catalog data from site intensive bird studies has expanded the data base considerably, but there remain gaps for which active field efforts should be made.

Active colony cataloging should be continued to fill data gaps and to upgrade the less reliable data. Emphasis should be placed on: 1) Key species that are considered the best environmental indicator species and those who's range and population are restricted enough to be particularly vulnerable to oil development. 2) Initial surveying of regions that have received little or no attention to date. Regions in most need are: Eastern Aleutians, Southeastern Alaska, Alaska Peninsula south, Nunivak, and St. Lawrence Is. These areas are not adjacent to OCS lease areas, but must be considered in any ecosystem modeling. Colonies in these regions are adjacent to tanker routes and will suffer from any general degradation of the coastal environment.

Considering the varied possiblities for logistic support presently available, a tremendous amount of data for the colony catalog could be gathered at relatively minor cost.

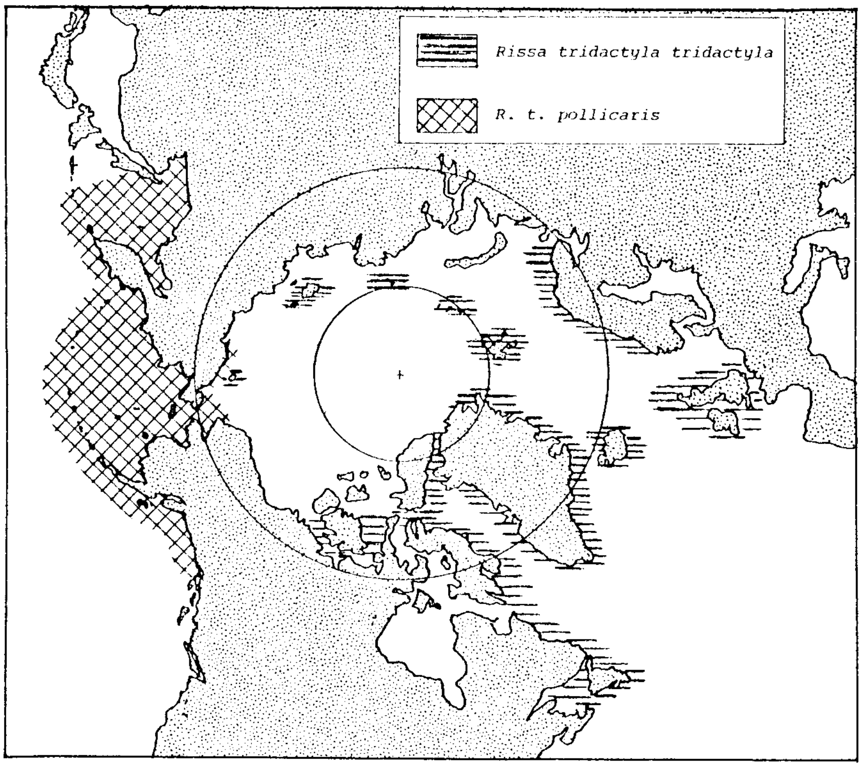

Figure 1. Breeding distribution of the Black-legged Kittiwake.

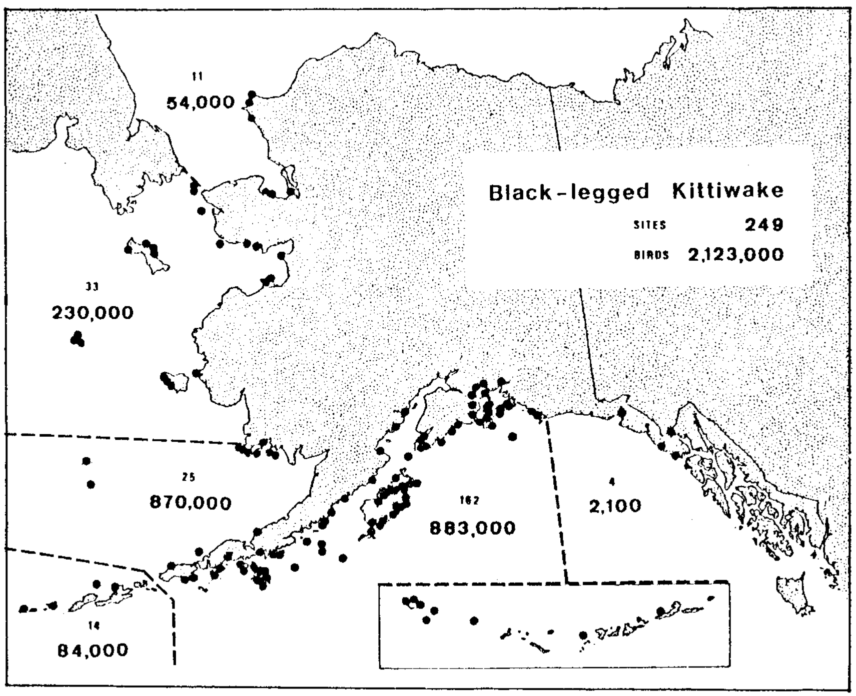

Figure 2. Locations of Black-legged Kittiwake colonies and estimated estimated numbers for six regions of Alaska.

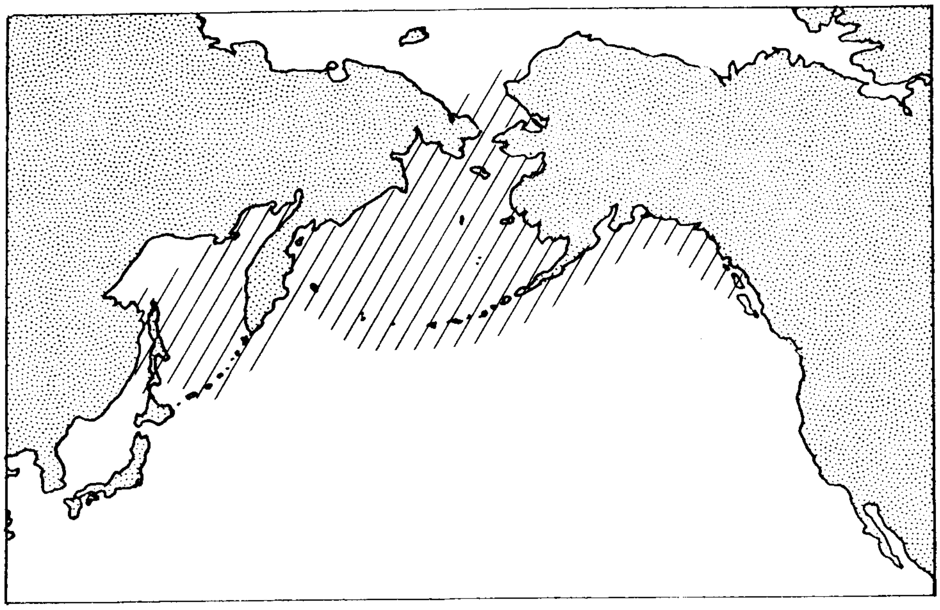

Figure 3. Breeding distribution of the Horned Puffin.

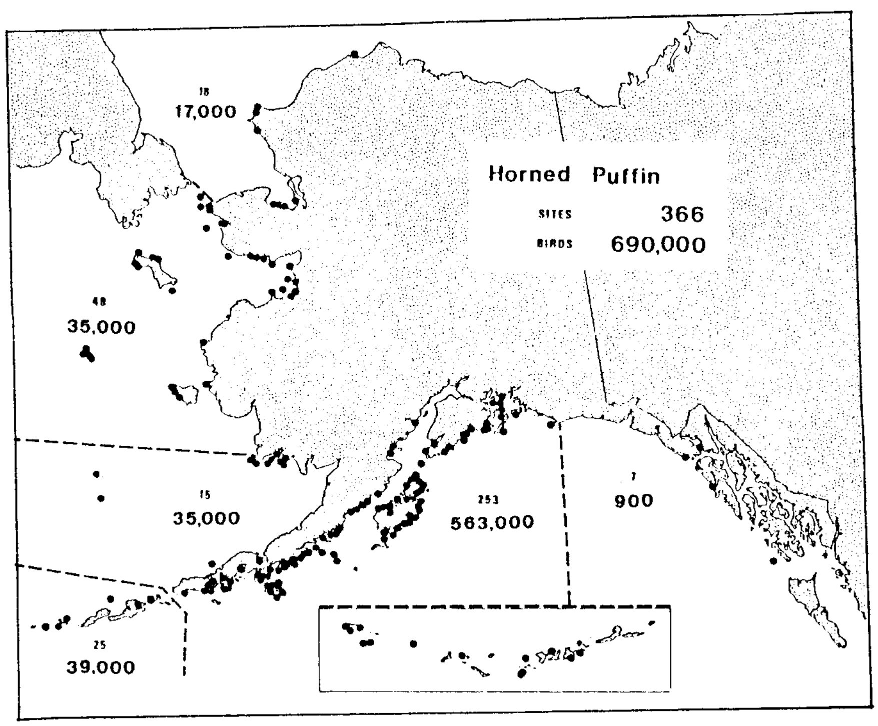

Figure 4. Locations of Horned Puffin colonies and estimated numbers for six regions of Alaska.

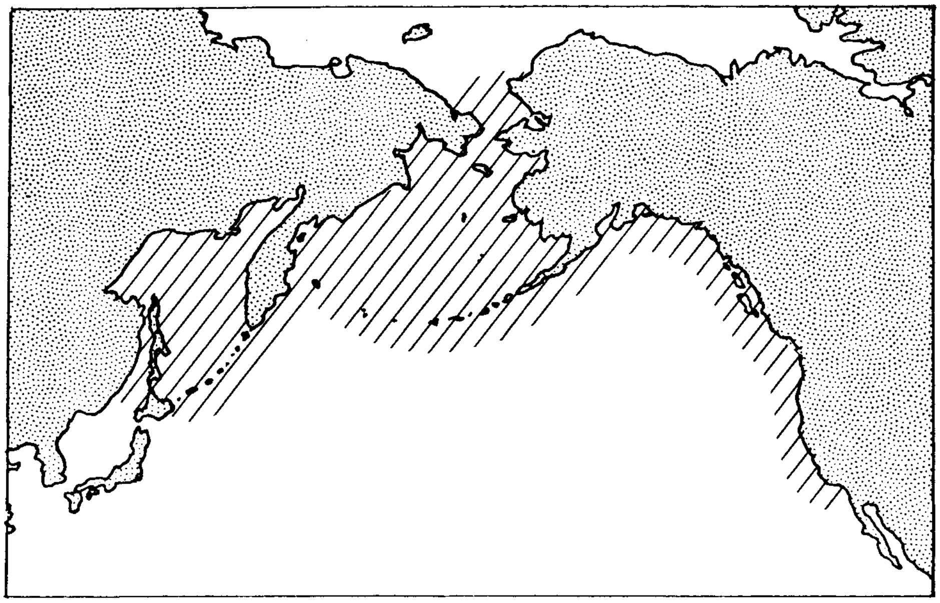

Figure 5. Breeding distribution of the Tufted Puffin.

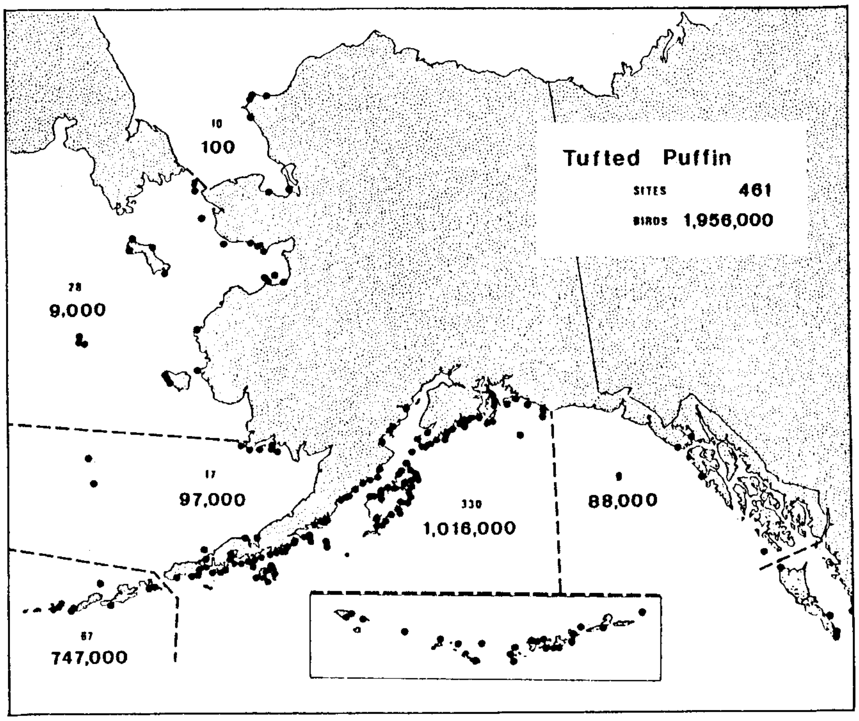

Figure 6. Locations of Tufted Puffin colonies and estimated numbers for six regions of Alaska.

APPENDIX X

Contract: 01-5-022-2538
Research Unit: 341
Principal Investigators: C. J. Lensink
K. D. Wohl
Reporting Period: April 1, 1977
to
March 31, 1978

ANNUAL REPORT

SURVEY OF BEACHED MARINE BIRDS IN ALASKA

By

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Office of Biological Services - Coastal Ecosystems
800 A Street - Suite 110
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April 1, 1978

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I. INTRODUCTION

Exploration, extraction, and transportation of oil and gas on the outer continental shelf of Alaska and concomitant onshore and offshore activities will result in spilled oil and other human perturbations of coastal habitat and will present potentially serious hazards to marine bird resources. BLM (USDI 1976 a,b, 1977) states that anticipated oil spillage, based on peak production figures, will be about 45,000, 72,000, and 41,000 barrels of oil annually in Northeast Gulf of Alaska, Lower Cook Inlet, and Northwest Gulf of Alaska (Kodiak) OCS regions, respectively. According to BLM, during the 25-year life of oil and gas production, total spillage in the above three OCS regions will be about [450,000], 615,000, and 433,000 barrels of oil.

The most visible of potential biologic insults on marine birds and most emotionally charged issue of oil pollution is the death and littering of beaches with carcasses of oiled marine birds. Because of the large populations of marine birds adjacent to Alaska, which exceed the remainder of the marine bird resources in the Northern Hemisphere, losses resulting from an oil spill off the coast of Alaska may be greater than ever before experienced.

There are no direct means for measuring mortality of marine birds except during the short period they are congregated on their breeding sites. Major sources of mortality are a matter of conjecture and many incidents of mass mortality or "wrecks" likely go undetected. However, since carcasses of birds and mammals float and are relatively durable they are frequently washed ashore following their death at sea. It follows that their appearance on coastal beaches provides an indication of the temporal, and geographic patterns of normal mortality as well as evidence of the character of hazards affecting the survival of these animals.

This inquiry will clearly provide valuable information about the demography of seabird mortality during the pre-offshore development period. If those government agencies having a legislative mandate for protecting wildlife resources wish to take legal action to prosecute polluters for damages to marine birds, it will be necessary to maintain the greatest documentation of pre-development patterns of mortality.

II. OBJECTIVES

The objectives of the beached marine bird and mammal survey program are to:

A. Establish a temporal, spatial, and frequency index of normal mortality as evidenced by observing dead birds and mammals on selected beaches in the northern Gulf of Alaska.

B. Determine the longevity of beached birds and mammals on beaches.

C. Determine the period of floatation for various species of marine birds.

D. Determine the factors which lead to a bird's arrival on a beach, i.e., correlate geographic and seasonal occurrence of carcasses with causes of death, prevailing ocean currents, wind directions, storms, incidence of pollution and other environmental phenomena.

III. CURRENT STATE OF KNOWLEDGE

Surveys of beached birds, casual and unsystematic as they were, started over five decades ago along the coasts of Britain, The Netherlands and subsequently other Northwest European countries. More systematic but still unorganized surveys were initiated by the Royal Society for the Protection of Birds and the Seabird Group in Britain and Ireland in 1966 (Bourne and Bibby 1975). Better organized and coordinated surveys were started in Britain, Ireland, Belgium and The Netherlands in 1967 and Denmark in 1968 (Joensen and Hansen 1977). Since 1969 the surveys have expanded throughout most Southwest and Northwest European countries into what is now the International Beached Bird Survey. From 1969 to 1973 there have been five surveys conducted annually between September and March, and the kilometers covered per survey have increased from about 470 to 3300.

The first systematic surveys of beached birds in the Western Hemisphere were organized in 1971 by Point Reyes Bird Observatory in California and were conducted entirely as a volunteer effort. From 1971 to 1975 the number of beaches surveyed in California increased from 9 to 35; surveys conducted annually increased from 78 to 383 and the kilometers surveyed increased from 184 to 1179 (Ainley 1976). More recently (1974) a survey has been organized on Canada's east coast by that country's Department of Environment, Environmental Protection Agency (Lock, pers. comm.).

Since 1975, the Department of the Interior's U.S. Fish and Wildlife Service in Alaska has conducted surveys of beached marine birds and mammals on an intermittent and opportunistic basis and ancillary to other bird investigations conducted as part of the Bureau of Land Management-funded/National Oceanic and Atmospheric Administration-managed Outer Continental Shelf Environmental Assessment Program. In addition, various biologists representing a variety of federal and state agencies in Alaska have conducted surveys sporadically since at least 1970. Not until November 1977 was a bonafide systematic beached bird survey program initiated in the northern Gulf of Alaska by the Fish and Wildlife Service's Office of Biological Services as part of the BLM/NOAA OCSEA Program. There are 15 beaches comprising 35 km regularly surveyed; a rather modest beginning for a state with about 54,400 km of coastline. An organized effort to conduct surveys on a year-round basis involving volunteer help will also be started in 1978 to expand our geographic coverage.

The literature is now replete with accounts on the effects of oil contamination on seabirds following catastrophic as well as less noticeable spillages of oil. Many references document the numbers of dead seabirds found after particular incidents or die-offs attributed to various other causes. Vermeer and Vermeer (1974) summarize such incidents from 1922 to 1973 in an annotated bibliography. Summaries of regularly conducted surveys of beached birds in California, western Europe and the British Isles are provided by Ainley (1972-76), Joensen and Hansen (1977), Bibby and Bourne (1971-72, 1974), Croxall (1975), Bourne and Devlin (1969-71), and Bourne and Bibby (1975).

IV. STUDY AREA

Surveys of beached marine birds and mammals are conducted on as regular a basis as weather will permit at 15 locations in the northern Gulf of Alaska - four in Lower Cook Inlet, four in Northeastern Gulf of Alaska and seven in northwest Gulf of Alaska (Kodiak Island). These 15 beaches are shown in Figure 1 and listed in Table 1. They comprise a total of 35.0 km with 12.3 km in LCI, 14.0 km in NEGOA and 8.7 km in NWGOA.

In addition to the 15 year-round survey transects, there are 34 other locations, comprising about 84 km in the northern Gulf and Bering Sea regions, where surveys have been conducted on an opportunistic basis since 1974. These are also shown in Figure 1 and listed in Table 1.

V. METHODS

The technique used in conducting surveys of beached marine birds and mammals was relatively simple and followed procedures well established through long experience of such organizations as the Royal

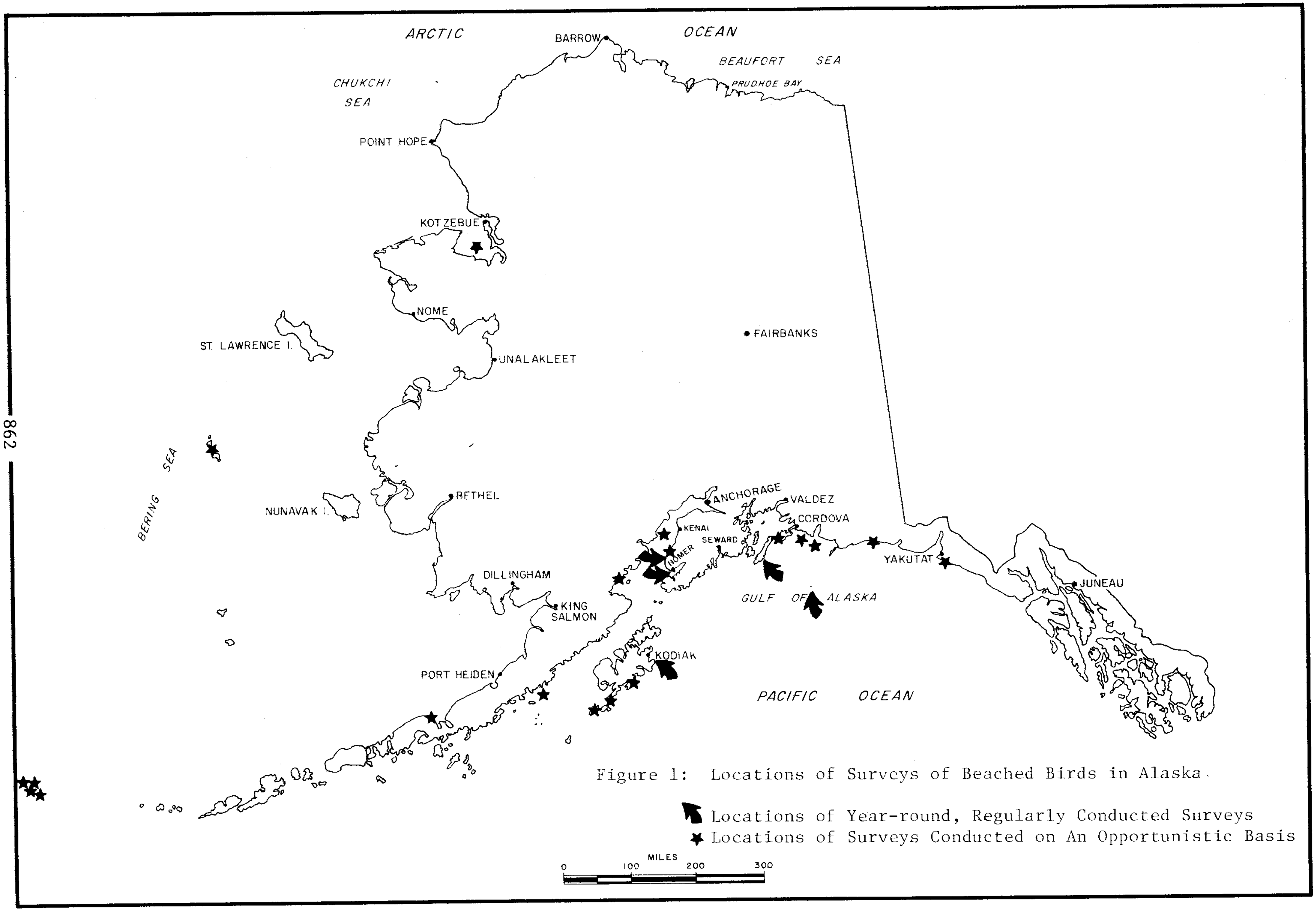

Figure 1: Locations of Surveys of Beached Birds in Alaska.

Locations of Year-round, Regularly Conducted Surveys

Locations of Surveys Conducted on An Opportunistic Basis

Table 1. Locations of Beached Marine Bird and Mammal Survey Transects Conducted by USFWS, Alaska

Place Name	Location				Length of Transect (Km)
	Begin		End		
	Lat. (N)	Long. (W)	Lat. (N)	Long. (W)	
N. E. Gulf of Alaska					
*Yakutat					5.0
*Cape Yakataga					5.0
Montague Island					
Patton Bay	59°56'24"	147°30'00"	59°54'54"	147°30'00"	3.0
*Jeanie Cove					
*Wooded Island					
*Fish Island					
Hinchinbrook Island					
*Hook Pt.	60°20'54"	146°16'12"	60°20'54"	146°17'54"	3.0
*Nuchek Beach					1.0
*Egg Island	60°22'30"	145°43'36"	60°21'48"	146°46'30"	10.0
*Strawberry Island	60°13'00"	144°44'42"	60°13'24"	144°50' 0"	6.5
Middleton Island					
M.I. #1	59°27'42"	146°18'36"	59°27'40"	146°17'55"	3.0
M.I. #2	59°27'40"	146°17'55"	59°26'55"	146°18'55"	4.0
*M.I. #3	59°24'42"	146°20'18"	59°24'30"	146°22'12"	4.0
*M.I. #4	59°24'24"	146°20'18"	59°24'20"	146°22'00"	2.0
*M.I. #5	59°24'20"	146°22'00"	59°24'40"	146°21'48"	3.5
M.I. #6	59°24'40"	146°21'48"	59°27'42"	146°18'36"	4.0
Resurrection Bay					
*Seward Beach					2.4
Lower Cook Inlet					
Whiskey Gulch	59°49'30"	152°49'24"	59°30'30"	152°48'42"	2.0
Anchor River	59°46'40"	152°51'48"	59°45'24"	152°51'30"	2.3
Homer Spit	59°36'00"	151°25'06"	59°37'18"	151°27'54"	3.8

Table 1. (cont'd.)

Place Name	Location: Begin Lat. (N)	Location: Begin Long. (W)	Location: End Lat. (N)	Location: End Long. (W)	Length of Transect (Km)
Coal Bay	59°36'42"	151°26'18"	59°38'06"	151°29'06"	4.2
*Kalgin Island					
*Swamp Creek	60°23'36"	151°58'42"	60°21'30"	152°00'00"	6.0
*Chisik Island					
*Amakdedori River					3.0
*Clam Gulch	60°15'15"	151°23'30"	60°18'45"	151°23'00"	8.0
*Cape Kasilof	60°22'15"	151°22'30"	60°18'45"	151°23'00"	6.5
N. W. Gulf of Alaska					
Kodiak Island					
English Point	57°43'22"	152°28'19"	57°43'33"	152°27'47"	0.7
Happy Beach	57°41'06"	152°28'12"	57°41'18"	152°28'30"	0.7
Middle Bay	57°38'48"	152°29'06"	57°39'06"	152°30'18"	1.7
Bushy Point	57°39'06"	152°28'06"	57°39'24"	152°27'36"	1.2
Mayflower Creek	57°38'54"	152°26'06"	57°39'06"	152°26'18"	0.6
Kalsin Bay	57°35'06"	152°38'12"	57°35'36"	152°26'00"	1.8
Narrow Cape	57°27'06"	152°19'30"	57°28'06"	152°19'36"	2.1
*Pasagshak Bay					5.0
Sitkalidak Island					
*Ocean Bay	57°07'	153°11'	57°04'	153°13'	0.2
*Three Sisters Rocks	57°13'	153°09'	57°13'	153°08'	0.8
Ugaiushak Island					
*Guillemot Cove					1.0
*Log Beach					0.3
*Saddle Beach					1.2
*Main Talus Beach					1.4
*Secluded Beach					1.0
*Kittiwake Bluff					0.5

Table 1. (cont'd.)

Place Name	Location				Length of Transect (Km)
	Begin		End		
	Lat. (N)	Long. (W)	Lat. (N)	Long. (W)	
*Square Bay					0.2
*Isthmus Beach					0.3
*Cormorant Cove					0.5
*Oystercatcher Beach					0.5
*South Wash-Out Beach					0.5
*North Wash-Out Beach					0.8
Aleutian Islands					
Kanaga Island					
*Lakeside Pt.					
*Southwest Beach					
Bobroff Island					
*Northwest Beach					
Buldir Island					
*Northeast Pt.					
Little Kiska Island					
*Northwest Beach					
Bering Sea					
Nelson Lagoon					
*Lagoon Pt.					6
*Cabin Beach					5.6
*St. Matthew Island					
*St. M.I. No. 1					
*St. M.I. No. 2					
*St. M.I. No. 3					
*St. M.I. No. 4					
*St. M.I. No. 5					

Table 1. (cont'd.)

Place Name	Location: Begin Lat. (N)	Location: Begin Long. (W)	Location: End Lat. (N)	Location: End Long. (W)	Length of Transect (Km)
*St. M.I. No. 6					
*St. M.I. No. 7					
*Pinnacle Island					

*Not regular survey sites

Society for the Protection of Birds, [British] Seabird Group and Point Reyes Bird Observatory. An investigator searched a 0.6 to 4.2 km stretch of a designated beach on a regular monthly basis. Two passes were made along each transect (by foot or ATV), covering the low tide line on the first pass and the storm line on the return trip. Data such as species, number, sex and age (when available), degree of oiling, location and probable cause of death were recorded for each carcass encountered. Other data that were recorded are indicated on the USFWS "Beached Bird and Marine Mammal" computer format. All dead birds and marine mammals were examined for standard or colored markers. Rare specimens were collected and disposed of in accordance with established federal and state procedures.

After examination, all carcasses were either deposited above the high tide mark or, to determine the persistence or longevity and movements of carcasses on a beach, marked with plastic flagging and left on the beach.

Although not analyzed at this time, environmental data obtained from the Environmental Data Service's Marine Weather Log and ocean current information obtained from other OCSEAP investigators will be used to correlate the occurrence of beached birds and mammals with such physical phenomena. To determine floatation times for various marine bird species a sample of dead birds will be banded, weighed, and systematically released at sea in the vicinity of various beached bird survey areas. Those marked specimens will be recorded when resighted on the beach, weighed to determine weight loss and visual appearance described. As a control, other dead specimens will be put in a sea water aquarium of varying water temperatures to determine floatation periods.

VI. RESULTS AND DISCUSSION

In March 1978 the program of beached marine bird surveys described above will be only five months old. During that period we conducted a total of 54 surveys on the 15 beaches we cover on a regular basis. The month of January was missed at Middleton Island and Kodiak, and Patton Bay has been surveyed only in March due to inclement weather conditions. During those 54 surveys we covered a total of 128.6 km of beach which yielded a total of 99 marine bird and 5 marine mammal carcasses. Ten different marine bird and 5 marine mammal species were observed. None of the carcasses were oiled.

Tables 2, 3, & 4 summarize our results to date. Five months of surveys are obviously not adequate to present a clear pattern of mortality, thus a detailed analysis of present data is unwarranted. Results thus far confirm that murres are certainly the most numerous and consistently observed species on all beaches in the northern Gulf, followed by Short-tailed Shearwaters (Table 3). Major species groups in order of abundance were alcids 67%, procellariids 12%, all waterfowl 10%, larids 9%, and others 4%. This pattern is generally similar to that associated with oil spill incidents in which alcids and sea ducks appear to be more vulnerable than other species; however, the relatively high incidence of procellariids contrasts with situations observed after oil spills and this may reflect one important characteristic of the unnatural pattern of pollution-induced mortality.

The greatest numbers of carcasses per Km appeared in November and March with average values being 1.35 and 1.33 birds per Km, respectively (Table 4). The relatively low number of carcasses from December through February does not follow the pattern of mortality observed on Northwest European coasts. According to Bibby and Bourne (1975), mortality tends to increase from a minimum in summer to a maximum in January and February.

Causes of mortality are generally a matter of conjecture; however, field examination of dead birds to date has revealed that starvation and apparent death from exposure is the leading cause of death. Only one individual examined, a murre at Middleton Island, revealed fat reserves typical of a healthy, living bird. As more data are accumulated a more thorough analysis can be attempted.

An objective of this project is to determine the longevity of bird and mammal carcasses on the beach where they are deposited. Middleton Island was selected for this task because there are no mammalian predators on the island and there is an adequate sample of carcasses. Although several species of avian predators occur year-round on the island, they generally do not scavenge beached birds in favor of the more abundant and readily available population of rabbits.

Each corpse observed on the beach was tagged with plastic flagging of various colors. Results of resightings thus far are very sporadic but have shown that 100% of beached carcasses may be observed after a period of one week. From 0% to 17% of the tagged carcasses were observed after one month, although from 0% to 75% and from 0% to 37% have been observed after two and three-month periods. The inconsistent nature of these results indicates that the data base is still insufficient for proper analysis.

A murre tagged on the north end of Middleton Island was subsequently resighted on a transect on the west side of the island after a three-month period. This was the only observation of a carcass which had moved from one transect to another.

As more data accumulate an analytical problem that will be investigated is how the incidence of beached birds and mammals varies seasonally with the presence or absence of predators or scavengers, relative size and species composition of bird and mammal populations at sea, floatation periods for various species, direction of prevailing winds and ocean currents, and occurrence of storms and other natural phenomena in the marine environment.

It appears increasingly clear that locations where corpses wash ashore must be related to patterns of atmospheric and oceanic circulation rather than any particular features of the beaches concerned. Many of our transects were strategically selected primarily because of their natural accumulation of large amounts of drift material, including bird and mammal corpses. Consequently, the frequency of occurrence at those prime collecting sites is not likely to be similar to adjacent beaches and should not be interpreted as representative of the entire coastline in a given region.

Table 2. Summary of Beached Marine Bird and Mammal Surveys in the Northern Gulf of Alaska, November 1977 to March 1978

Place Name	Length of Transect (km)	Total No. of Surveys	Total Km Surveyed	Total Birds Found	Total Marine Mammals Found	Birds Per Km	Marine Mammals Per Km	Percent of Birds Oiled	Percent of Marine Mammals Oiled	Total Bird Species	Total Marine Mammal Species
N. E. Gulf of Alaska											
Patton Bay	3.0	1	3.0	1	0	.33	0	0	0		
Middleton Is. #1	3.0	4	12.0	21	2	1.33	.13	0	0		
Middleton Is. #2	4.0	4	16.0	23	1	1.43	.06	0	0		
Middleton Is. #6	4.0	3	12.0	25	1	.83	.08	0	0		
Total	14.0	12	43.0	70	4	1.62	.10	0	0	8	4
Lower Cook Inlet											
Whiskey Gulch	2.0	5	10.0	3	0	.30	0	0	0		
Anchor River	2.3	4	9.2	1	0	.10	0	0	0		
Homer Spit	3.8	5	19.0	4	0	.21	0	0	0		
Coal Bay	4.2	4	16.8	9	0	.53	0	0	0		
Total	12.3	18	55.0	17	0	.30	0	0	0	2	0
N. W. Gulf of Alaska (Kodiak Is.)											
English Pt.	0.7	3	2.1	3	0	1.43	0	0	0		
Happy Beach	0.7	4	2.8	0	0	0	0	0	0		
Middle Bay	1.7	3	5.1	0	0	0	0	0	0		
Bushy Pt.	1.2	3	3.6	0	1	0	.28	0	0		
Mayflower Creek	0.6	3	1.8	0	0	0	0	0	0		
Kalsin Bay	1.8	4	7.2	2	0	.28	0	0	0		
Narrow Cape	2.0	4	8.0	7	0	.37	0	0	0		
Total	8.7	24	30.6	12	1	.39	.03	0	0	6	1
Grand Total	35.0	54	128.6	99	5	.77	.04	0	0	10	5

Table 3. Bird Carcasses per Km of Beached Surveyed by Species, November 1977 to March 1978.

Species	NEGOA	LCI	NWGOA	TOTAL
Northern Fulmar (*Fulmarus glacialis*)	.07	0	0	.02
Short-tailed Shearwater (*Puffinus tenuirostris*)	.21	0	0	.07
Oldsquaw Duck (*Clangula hyemalis*)	.02	0	.03	.02
Harlequin Duck (*Histrionicus histrionicus*)	0	0	.03	.01
Steller's Eider (*Polystieta stelleri*)	0	0	.03	.01
White-winged Scoter (*Melanitta delgandi*)	.02	.04	0	.02
Black Scoter (*Melanitta nigra*)	.02	0	.03	.02
Unidentified Duck	.02	0	0	.01
Glaucous-winged Gull (*Larus glaucescens*)	.05	0	.07	.04
Black-legged Kittiwake (*Rissa tridactyla*)	.09	0	0	.03
Unidentified Gull	0	0	.07	.02
Thick-billed & Common Murre (*Uria spp.*)	1.12	.27	.10	.50
Unidentified Bird	0	0	.03	.01
Total Bird Corpses	70	17	12	99
Species	8	2	6	10
Total Kilometers	43.0	55.0	30.6	128.6
Beached Birds/Km	1.62	.30	.39	.77

Table 4. Results of Beached Marine Bird and Mammal Surveys in the northern Gulf of Alaska, November 1977 to March 1978.

	Nov.	Dec.	Jan.	Feb.	Mar.
Total Kilometers	29.7	28.0	12.3*	27.8	29.3
Total Bird Carcasses	40	6	0	15	39
Total Marine Mammal Carcasses	1	1	0	0	3
Birds/Km	1.35	.21	0	.54	1.33
Marine Mammals/Km	.03	.04	0	0	.13

*Only includes those beaches in lower Cook Inlet

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APPENDIX XI

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ANNUAL REPORT

Nutritional Significance of Copper-Bering Intertidal System to Spring-Migrating Shorebirds Breeding in Western Alaska

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I. Summary

In the year ending 1 April 1978, significant new dimensions were added to an appraisal of the Copper River Delta system as critical habitat for Dunlins and Western Sandpipers in spring migration. Selective field work was conducted at other sites in Alaska along the migratory-to-breeding continuum of localities between the Copper Delta and north-western Alaska. Predictions made last year about the differing physiological/behavioral/ migration dynamics of the two species have been borne out by the documentation of predicted major stopovers by westerns in Kachemak Bay, Lower Cook Inlet and the virtual absence of Dunlins from that region, as predicted. Close cooperation with Arneson (RU 3) and Gill (RU 341, Nelson Lagoon) has proven to be mutually advantageous in both putting the Copper Delta into context, and verifying that postulated different migration strategies characterize the two species in fall as well as in spring movements.

Both species appear to be highly susceptible to any intertidal habitat degradation in the C-BRD system, although of the two, the Dunlin shows a higher degree of obligate habitat dependency on the C-BRD system itself. By contrast, current understanding leads us to regard habitat degradation in Lower Cook Inlet as at least as serious a threat to westerns as similar events in the Copper-Bering system. A final report of this phase of work is expected to be ready on 1 October 1978. Perturbation experiments (small plot oiling, exclosure pens) are under consideration for possible renewal proposals in 1979.

II. Introduction

Expanding on the work of Senner (1977), the purpose of the present study is to evaluate the importance of the Copper-Bering River Delta system (C-BRD system, Fig. 1) in the context of the annual cycle of two abundant shorebirds - Western Sandpiper (Calidis mauri) and Dunlins (C. alpina pacifica). Additionally, we may gain new insight into the way northern-breeding birds secure and expend the energy and nutrients necessary for migration and reproduction.

Specific project objectives have been articulated as a set of questions:

A. How much nutritional and energetic gain is made by birds between Controller and Hartney Bay, and how does this gain relate to spring migratory and breeding physiological status?

B. What are present-day conditions, e.g., trophic dynamics in this supposedly sensitive region, against which future status (following energy developments) can be compared?

C. If denied any feeding opportunities in the C-BRD system (as a result of cataclysmic or chronic disturbance) would the breeding success of the two species-populations be seriously jeopardized?

D. Can evidence for past fluctuations in breeding ranges or success be correlated with events on the delta intertidal system (such as the 1964 earthquake)?

E. At what rate do Dunlins and Western Sandpipers move through the Copper-Bering system? Are differing consumptive strategies during migration reflected in differing rates of passage? How much time do individual birds spend in the C-BRD system in which they are susceptible to the direct effects of oil or other pollution? Must individual birds achieve a certain level of fat reserves before they leave the system?

F. To what extent do shorebirds enroute between the Copper River delta and the Yukon-Kuskokwim delta stop to feed in the Lower Cook Inlet (Fig. 2)? What route do they follow between C-BRD system and Cook Inlet?

G. What is their physiologic state when they arrive at breeding grounds such as Hooper Bay in the Yukon-Kuskokwim delta?

Applications of the information obtained in this study will primarily be used in documenting or refuting the suggested importance of this unique, heavily used geomorphic feature and habitat. The results may be useful in specifically indicating protective measures (legislation, leasing stipulations, regulation and permitting) by state and federal resource management agencies.

Several potentially damaging petroleum-related developments underway or proposed in the northern Gulf of Alaska make these objectives pertinent. Marine tankers travel to and from Valdez daily, transporting oil from the terminus of the trans-Alaska pipeline. The tankers pass through Hinchinbrook Entrance west of the C-BRD system. One OCS lease sale has been held and exploration initiated east of Kayak Island. A second sale is scheduled offshore of the C-BRD system in June, 1980.

III. Current State of Knowledge

The C-BRD system is strategically located in the spring migratory routes of at least two shorebird species-populations bound for western Alaska breeding grounds. Dunlins and Western Sandpipers enter the north Gulf coast region in vast numbers during the first two weeks of May. Isleib and Kessel (1973) report that they constitute more than half the 20 million waterfowl and shorebirds using the system during spring migration.

The following is a summary of pertinent background information:

1. Virtually all adults of the two sympatric, congeneric species, which migrate up the Pacific coast, stop and feed in this region. No other geographically restricted zone, nor temporally restricted phenomenon elsewhere between Baja California and western Alaska, has been identified as a site of concentration and feeding for comparable percentages of these breeding populations.

2. Nearby terrestrial and aquatic habitats in early May of most years are largely unavailable for feeding because of persistent heavy snow and ice cover. Hence, the sandpipers are largely obligate users of the intertidal system.

3. Dunlins prey heavily on the bivalve Macoma balthica, while Western Sadpipers take a variety of intertidal invertebrates including molluscs, amphipods, and larval insects (Senner, 1977). Intertidal invertebrates are vulnerable to the damaging effects of oil pollution, especially chronic discharges. Shaw et al. (1976) and Taylor et al. (1976) have studied the effects of oil on M. balthica in Prince William Sound and believe that M. balthica is a good "indicator" of oil pollution in a sediment environment.

4. Besides having different food habits, Western Sandpipers and Dunlins have a different "strategy" for using the intertidal habitat. Dunlins have a strong tendency to feed at the falling tide line and "loaf" through high tide periods. Westerns, on the other hand, feed both at water's edge and away from the tide line, and continue to feed through the high tide period (Senner, 1977).

5. The occurrence of many bivalve molluscs in the diet of both sandpiper species raises the possibility that the mollusc shells are a source of calcium for pre-breeding adults. MacLean (1974) showed the use by several Calidris spp. of lemming teeth as a calcium source on arctic breeding grounds.

6. Individual birds may spend as few as 30 hours on the Copper-Bering deltas, before essentially being "impelled from behind" by the influx of new arrivals (Isleib, pers. comm.). Therefore, individual birds may have as few as two or three tide periods in which there are exposed mudflats on which to feed.

7. Fat is the primary source of energy for long-distance migratory flights in birds (Odum et al., 1961), and variations in whole body weight can usually be attributed to variations in fat reserves (Page and Middleton, 1972). Probably having flown non-stop from the Puget Sound region, both Dunlins and Western Sandpipers arrive in the eastern C-BRD system with depleted fat reserves (Senner, in prep.). Based on whole body weights of specimens collected in 1976, Dunlins leaving the western end of the C-BRD system have replenished their fat reserves. In 1976, however, Western Sandpipers showed no weight increase as they moved across the C-BRD system (Senner and Norton, 1977; Senner, in prep.).

8. In May 1976 there was a report of one to two million small shorebirds, probably Western Sandpipers, at Kachemak Bay, Lower Cook Inlet (Erikson, 1977). Based on estimations of the potential flight ranges of Western Sandpipers and Dunlins leaving the C-BRD system, Senner (in prep.) predicted that many Western Sandpipers needed an

intermediate stop at suitable sites in Lower Cook Inlet while enroute between the C-BRD system and western Alaska. Such a feeding stop was not believed necessary for Dunlins following the same migration route.

IV. Study area

Within the C-BRD system, Kanak Island and Hartney Bay were the primary study sites (Fig. 1). Specific sites are described in Senner (1977); the region and intertidal system are characterized in Isleib and Kessel (1973) and Rosenberg (1972).

The second major study area was Kachemak Bay, lower Cook Inlet; specifically, the Fox River flats at the head of the bay and the Mud Bay flats inside the Homer Spit (Fig. 3). These sites are described in Erickson (1977); the Kachemak Bay as a whole is characterized in Wennekens et al. (1975).

Secondary study sites were Hooper Bay in the Yukon-Kuskokwim Delta and Capes Espenberg and Krusenstern in the Kotzebue Sound area (Fig. 2); the latter are described in Schamel and Tracy (1977) and Connors (1977, respectively).

V. Methods

A. Study Period

Senner, Norton, and two field assistants were in the C-BRD system for purposes of banding, collecting, and observing shorebirds from 26 April to 24 May, 1977. Aerial surveys, ground observations, and specimen collection were performed at Kachemak Bay by a field assistant from 30 April to 21 May. Norton and West made a brief excursion plagued by foul weather and an airline strike to Hooper Bay, 13-19 May, to collect specimens arriving on the breeding grounds. Senner was at Cape Espenberg and Norton at Cape Krusenstern from 28-30 May to collect sandpiper specimens.

B. Banding and Marking

For the purpose of determining turnover rates at individual sites in the C-BRD system, and at sites across the system, sandpipers at Kanak Island were captured with mist nets or walk-in traps, banded with an aluminum U.S. Fish and Wildlife Service leg band, marked with a colored feather glued to a central rectrix (after West et al., 1968), and released. Live weight, culmen length, and flattened wing length of each captured bird were recorded for use in analyses of fat levels, flight ranges, and morphometric comparisons with other populations.

C. Aerial and Ground Observations

Kanak Island: Throughout daylight hours shorebird activities were observed. Numbers, species composition, behavior, etc. were noted. A special effort was made to spot marked birds and record the color of the feather attached to individual birds. Using charter aircraft three roundtrips were flown between Kanak Island and Cordova, usually flying low over the water's edge in the intertidal zone for the purpose of spotting marked birds. Numbers, species composition (so far as possible), and locations of concentrations were noted.

Hartney Bay: One hundred and twenty-two censuses were conducted (by D. Matkin) on an hourly basis through half tide cycles (i.e., high to low or low to high) on two transects established as part of an earlier study (full methodology described in Senner, 1977). Additionally, sandpiper flocks on the mudflats were continually scanned for the presence of marked birds; total number and species composition were estimated and noted.

Kachemak Bay: Six aerial surveys, one hour before high tides, were flown over the Fox River flats in a Cessna 172 (including pilot plus one observer). Survey techniques replicated those described in Erickson (1977); see Figure 3 for survey areas. Three trips were made on foot to the Fox River flats, in part for the purpose of verifying the species composition of shorebirds flocks seen from the air. Additionally, a 500 m transect was censused as it was exposed following a high tide on 12 days at Mud Bay.

D. Specimen Collection and Analysis

Calidis sandpipers were collected in the C-BRD system (Kanak Island, mouth of Eyak River, and Hartney Bay), at Kachemak Bay (Mud Bay, Fox River flats), Hooper Bay, Cape Espenberg, and Cape Krusenstern. Table 1 shows the numbers and species at each location.

From each specimen the following was recorded in the field: 1) fresh weight, 2) culmen length, 3) flattened wing length, and 4) sex. Stomach contents were removed as soon as possible and placed in buffered formalin.

Stomach samples were processed at the University of Alaska to determine: 1) identity of food items, 2) numbers of food items, 3) size and weight of whole food items, 4) total weight, and 5) numbers and weights of non-food items such as grit (see Senner, 1977).

Frozen bird carcasses were transported to the University of Alaska where they are being processed to obtain fat-free dry weight, lipid and water weights (West and Meng, 1968; Johnson and West, 1973), fatty acid "signatures" (West and Meng, 1968; West and Peyton, 1972), and total calcium (MacLean, 1974).

VI. Results

A. Censuses, Surveys, and Observations

General observations at Kanak Island showed that in 1977, unlike 1976, Western Sandpipers, Dunlins, and other shorebirds were able to make extensive use of supratidal brackish and freshwater wetlands for feeding purposes. In most years, during late April and early May, this habitat is largely unavailable because of snow and ice cover.

Some 6,961 shorebirds (Charadrii) were recorded on censuses of the two Hartney Bay transects. Species composition by percentages is shown in Figure 4. Estimated peak daily numbers of all shorebird species at Hartney Bay are shown in Figure 5.

Figure 6 shows the numbers of Western Sandpipers and Dunlins recorded on the Mud Bay transect (in Kachemak Bay). These numbers are believed to include 80 percent of all sandpipers in Mud Bay at the time of each census. Note that peak numbers were recorded on 6 May, the same day the peak number of "small sandpipers" were recorded in Fox River aerial surveys (Fig. 7). Results of aerial surveys at three sites in western Cook Inlet are shown in Figure 3.

B. Banding and Marking

On Kanak Island 279 Western Sandpipers were captured, banded, and marked. Only two Dunlins were captured and processed; about 25 additional sandpipers of miscellaneous species were captured and banded (not color-marked).

Color-marked Western Sandpipers which were resighted after their release on Kanak Island are listed, along with the interval between release and resighting, in Table 2. No color-marked Western Sandpipers were resighted off of Kanak Island in the C-BRD system or elsewhere. No banded westerns were recaptured live on Kanak Island, although two were shot.

These two Western Sandpipers had been on Kanak Island 3 and 4 days, respectively, and showed -0.5 g and +6.0 g weight changes, respectively. Additionally, a single banded Least Sandpiper (Calidis minutilla) was recaptured 3 days after its initial capture and release. It showed a weight loss of 0.5 g.

C. Food Habits

Stomach contents from all specimens, with the exception of those from Capes Espenberg and Krusenstern, have been sorted, and most identifications are complete. Final identifications and data analysis are underway.

Figure 8 shows the percent composition on a numeric basis of food items in the stomachs of Western Sandpipers and Dunlins from Hartney Bay and the Fox River flats at Kachemak Bay. Macoma balthica predominates in the Dunlin stomachs at both locations, while Western Sandpipers, particularly at Hartney Bay, show considerable diversity in prey selection (at least as represented by remains in stomach).

D. Analyses of Specimens

Fresh, whole weights

Fresh, whole weights of Dunlins and Western Sandpipers collected in the C-BRD system and at Kachemak Bay are shown in Table 3. Weights of 1976 specimens were reported in Senner and Norton (1977).

Between Kanak Island and Hartney Bay, both female Dunlins and Western Sandpipers showed significant weight gains. Males of both species showed weight gains too, although in both cases the differences were not significant (small sample sizes were a problem here).

Mensural characters

Analyses of culmen and wing lengths for 1976 and 1977 are not yet complete. Table 4 presents the mean culmen lengths of 1976 and 1977 specimens collected at Bodega Bay, CA (Fig. 2) and in the C-BRD system. The Bodega Bay specimens were collected by P. G. Connors in 1976.

Comparisons of values within years indicates two "anomalous" values. Culmen lengths for Dunlin males at the Eyak River in 1976 are significantly ($P < .05$) longer than samples from Bodega and Hartney Bays. Male Western Sandpipers at Hartney Bay in 1976 have significantly shorter ($P < .05$) culmen lengths than males at the three other locations.

Also of interest are changes in mean culmen lengths over time through the migration period. As an example, Table 5 presents mean culmen lengths for Dunlin males before and after 10 May 1976 at three locations in the C-BRD system. Although sample sizes are small, note the longer culmen lengths in the later period and that there are no significant differences in the mean values between the three sites, within the respective periods. Note also the narrow ranges of the values in the later period.

Total calcium

Calcium digests are complete on all 1976 specimens from the C-BRD system. The data are not yet summarized and analyzed. Percent Ca values ranged from 2.147 to 5.510 percent of dry carcass weight for both Western Sandpipers and Dunlins (both sexes), more than a twofold difference. However, a cursory inspection of the data does not reveal any obvious trends or differences between species, sexes, or among locations.

Lipid levels

Lipid extractions are complete on all 1976 specimens from Bodega Bay and the C-BRD system. Calculations of fat indices (g fat/g fat-free dry wt) allows comparison between populations and species. Mean fat indices for all completed specimens are shown in Table 6.

Within the C-BRD system, lipid levels as reflected in the mean fat indices do not differ significantly among Western Sandpipers of either sex. Values for westerns at Bodega Bay are about the same in males and lower in females.

For Dunlins, Bodega Bay values are higher than those at Kanak Island, significantly so ($P < .05$) for female Dunlins. Mean fat indices for both sexes are higher at Hartney Bay than at either Kanak Island or the Eyak River.

Comparing the species at the western end of the C-BRD system, Hartney Bay, Dunlins of both sexes are significantly ($P < .05$) more fat than westerns of the respective sexes.

Fatty acid signatures

Thin layer chromatographic separations of total extracted lipids to obtain triglycerides for fatty acid analysis are partially complete. Only a few fatty acid signatures have been obtained and no trends are yet evident.

VII. Discussion

Trophic relationships

Trophic relationships of Western Sandpiper and Dunlins are considered in detail in Senner (1977). Data presented in Figure 8 are consistent with those in Senner (1977). Dunlins in the C-BRD system prey most heavily on *Macoma balthica*, an abundant intertidal mollusc which is susceptible to the effects of oil pollution (Shaw *et al*., 1975; Taylor *et al*., 1976). Western Sandpipers take some molluscs, including *M. balthica*, but also a variety of other intertidal invertebrates.

No previous food habits study had been conducted for these sandpiper species at Kachemak Bay, and the results there are similar to those reported for the C-BRD system. Note that two-thirds of the Western Sandpipers collected at the Fox River flats had eaten *M. balthica*, and on a numeric basis, they accounted for 30(+) percent of the western's diet. Analysis of the stomach contents of Mud Bay sandpipers will provide a more complete picture of Kachemak Bay trophic relationships.

Migration dynamics

Reports by Senner (1977; in prep.) and Senner and Norton (1977) have begun to complete a "picture" of spring migration in which the C-BRD system is placed in the context of an entire annual cycle. Gill (1978) has contributed greatly to our understanding of fall migration for Western Sandpipers and Dunlins. Following is a brief discussion of the results reported above as they contribute to our understanding of the dynamics of migration.

Based on museum and other specimens, Senner (in prep.) showed that mean body weights of Dunlins increased with time during migration along the Pacific Coast, while weights of Western Sandpiper showed little change. Dunlins, and probably Western Sandpipers too, are believed to make overwater flights from the Vancouver area to the C-BRD system (Senner, in prep.). However, Senner (in prep.), hypothesized that in general, Western Sandpiper migration was characterized by short "hops" relative to the longer flights of Dunlins. Gill's (1978) recoveries of marked birds showed these generalizations to be true for Dunlins and Western Sandpipers during fall migration.

The fact that the mean fat indices for Western Sandpipers at Bodega Bay are the same as, or lower than, values from within the C-BRD system (Table 6) suggests that Bodega westerns are not making long overwater flights originating at Bodega Bay. They probably continue at least as far as Vancouver, where their high mean whole weights (Senner, in prep.) suggest greater fat reserves. Dunlins, on the other hand, having high fat reserves (Table 6) at Bodega Bay, may well be able to leave directly for the Alaskan coast. This is apparently what some do, in reverse, during fall migration (Gill, 1978). Further work with flight range estimates based on known or estimated fat reserves (after McNeil and Cadieux, 1972) will be useful in clarifying this matter further.

Senner (in prep.) and Senner and Norton (1977) proposed that Dunlins enter the C-BRD system with depleted fat reserves, move from east to west across the system, and leave the west end of the system with replenished fat reserves (based on changes in whole weights). Western Sandpipers were also believed to enter the system with depleted reserves, but in 1976 they showed no gain in weight across the C-BRD system.

Lipid analysis of 1976 specimens showed that lipid levels generally paralleled changes in whole weights. Assuming this relationship holds for 1977 specimens, Western Sandpipers in 1977 will show an increase in fat reserves across the C-BRD system. To what the difference between 1976 and 1977 weight patterns can be attributed is not known. One environmental factor which differed, however, is the amount of snow and ice cover. As noted in the results, there were extensive fresh and brackish water sites available for feeding purposes, thus enabling Western Sandpipers to feed regardless of the tide cycle (cf. Senner, 1977).

Fundamental to our hypothesized pattern of movement and weight deposition across the C-BRD system is that we are sampling members of the same population at each site. For this reason morphometric measurements such as culmen lengths may be important (cf. Evans, 1964). Culmen measurements for female Dunlins and Western Sandpipers are essentially the same at Bodega Bay and within the C-BRD system (Table 4). In the males of both species, these are some anomalous values (mauri bills are short at Hartney Bay and alpina bills are long at the Eyak River). A combination of small sample sizes and the timing of specimen collections may account for these deviations. Note in Table 5 that mean culmen lengths in Dunlin males were longer after 10 May, the period when the 7 males were collected at the Eyak River. Furthermore, within the later time period, the mean values at the three sites do not differ significantly ($P > .05$).

Although these considerations may explain the anomalous values, at present it is prudent to conclude that the culmen length data neither support nor refute the assumption that the same populations are being sampled at different sites. The data in Table 5 do, however, raise the intriguing possibility that within the Dunlin subspecies pacifica there are populations with different culmen lengths passing through the C-BRD system at different times. This is not implausible as work in progress by Senner and Schamel (IAB, Univ. of Alaska) suggest that different breeding populations of pacifica have different culmen lengths. This prospect will be examined in more detail as data analysis proceeds.

The fact that of the two Western Sandpipers marked and later collected at Kanak Island, one had gained 6 g, indicates the potential for remaining at a single site and replenishing fat reserves. Turnover rates at Kanak Island ranged from 0 or 1 to 4 days, with 4 days likely being a maximum stop caused, in part, by trauma associated with the capture and handling of the individual birds (cf. Thompson, 1974).

Since no marked sandpipers were seen after leaving Kanak Island, we, again, cannot say whether these same birds stopped elsewhere in the C-BRD system. That no marked birds were seen again is not particularly surprising considering the probability of spotting one of 279 marked birds among millions of birds scattered through the vast C-BRD system. However, it is certainly possible that some birds make only a single stop in the system. A "decision" to stop once, or several times, might well hinge on a variety of variables - e.g., physiologic status, weather, and feeding conditions.

Based on estimated flight range potentials of sandpipers at Hartney Bay (birds believed to be ready to leave the system) Senner (in prep.) predicted that Western Sandpipers would need an intermediate stop(s) at sites such as are found in lower Cook Inlet before reaching breeding grounds in western Alaska. It was predicted that Dunlins, on the other hand, had no need of intermediate stops and, thus, would be poorly represented among the small sandpipers surveyed at Kachemak Bay. Our 1977 surveys in Kachemak Bay indicate that the sandpiper flocks overwhelmingly consisted of westerns (Fig. 6). For example, at Mud Bay on 6 May there were an estimated 25,000 westerns compared to only 600 Dunlins (6 May was the peak day in Kachemak Bay).

Whether the Western Sandpipers stopping in lower Cook Inlet can account for the millions using the C-BRD system is unknown. With the exception of limited survey work in 1976 (Erikson, 1977) and 1977 (this study), Lower Cook Inlet is essentially unstudied so far as shorebird migrations are concerned. This may change as Paul Arneson, Alaska Dept. of Fish and Game, is planning a survey program on lower Cook Inlet's west side during early May 1978.

VIII. Conclusions

Western Sandpipers and Dunlins arrive in the C-BRD system with depleted fat reserves, having made long, probably nonstop, overwater flights from the Puget Sound-Vancouver area (perhaps from points farther south for some Dunlins). In "normal" years, when snow and ice cover the supratidal wetlands, the sandpipers are largely confined, for feeding, to the intertidal zone of the C-BRD system. Both Westerns Sandpipers and Dunlins prey on a variety of intertidal invertebrates, with Dunlins relying most heavily on Macoma balthica.

Within the C-BRD system, movements are generally from east to west across the system. Many birds probably stop several times to feed before leaving the western end of the system, although some birds may only stop at a single site before leaving the area entirely. Turnover rates at Kanak Island for Western Sandpipers are a maximum of four days, and general observations suggest this is true elsewhere in the C-BRD system.

Western Sandpipers at the western extreme of the C-BRD system are less fat than are Dunlins and appear to make use of intermediate stopping points such as Kachemak Bay. Most Dunlins probably fly directly, nonstop, from the C-BRD system to the Bering Sea coast.

Although there are still many unanswered questions regarding the spring migrations of those two, congeneric sandpiper species, application of the critical habitat criteria proposed by Senner (1977) leads to a conclusion that the C-BRD system is a critical habitat in the annual cycle of both Dunlins and Western Sandpipers.

IX. 4th Quarter Operations

Laboratory work in the fourth quarter included the processing of all stomach contents samples (1977), with the exception of those from specimens collected at Capes Espenberg and Krusenstern. Lipid and calcium extractions on all 1976 specimens were completed; analyses of 1977 specimens were initiated.

Laboratory work remaining includes final identification of some organisms found as stomach contents and processing samples from Espenberg-Krusenstern specimens (about 25 total). Lipid extractions on all 1977 specimens will be completed. Calcium and fatty acid analyses will be performed on a subsample of specimens.

A few days of field work are planned for spring migration, 1978. Personnel will be located at Hartney Bay, southwest of Cordova, during the first 10 days of May, to band and color-mark Western Sandpiper and Dunlins. We hope to gain further insights into turnover rates at the western extreme of the C-BRD system.

Project completion, including submission of final reports, is targeted for 30 September 1978. A milestone chart is shown in Figure 9.

As of March 1978, approximately $22,900 out of $26,000 had been spent.

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Table 1. Specimens collected in 1977 field season.

	C-BRD System		Kachemak Bay		Y-K Delta	Northwest Ak	
	Kanak Island	Hartney Bay	Fox River	Mud Bay	Hooper Bay	Cape Espenburg	Cape Krusenstern
Dunlin	23	34	3	4	2	14	6
Western Sandpiper	20	32	15	14	1	4	12

Table 2. Summary of color-marking activity and results on Western Sandpipers on Kanak Island, May 1977.

Date/Time[†] (May 1977)	Number Color-Marked w/Feather	Feather Color	Number Resighted (feather color)	Number Different Individuals Resighted	Days Elapsed Since Capture - Initial Release (min-max)
1/12:00	28	white	-	-	-
2	10	white	4-5 (white)	at least 2	0-1
4/04:15	9	yellow	-	-	-
5	2	yellow	-	-	-
7	12	yellow	-	-	-
9	19	yellow	-	-	-
10/09:00	15	red	1 (red)	1	0
11	60	red	-	-	-
12	30	red	1 (red)	1	0-2
13/09:15	39	orange	2 (red)	2	1-3
14	20	orange	1 (orange)	1	0-1
			1 (red or orange)	1	0-4
/12:00	11	turquoise	2* (red)	2	4 and 3
15	24	turquoise	-	-	-
16	-	-	1 (turquoise)	1	1-2

[†]Time at which a "new" feather color was first used.

*Collected

Table 3. Fresh, whole weights of Dunlins and Western Sandpipers collected in the C-BRD system and Kachemak Bay in 1977.

Sex	Location: C-BRD System: Kanak		C-BRD System: Hartney		Kachemak Bay (both sites lumped)
Western Sandpiper					
M	25.4 ± 1.90[1] (7)		27.4 ± 1.92 (9)	*	30.0 ± 2.95 (11)
F	27.0 ± 1.37 (13)	*	28.8 ± 2.81 (20)	*	31.5 ± 2.21 (18)
Dunlins					
M	53.8 ± 5.67 (7)		56.6 ± 5.63 (14)		56.3 ± 5.07 (4)
F	56.5 ± 4.51 (14)	*	64.8 ± 7.27 (18)		64.0 ± 2.65 (3)

[1] $\bar{x}$ SD
(N)

*Respective pairs of values significantly different (P < .05) as determined by t-test.

Table 4. Mean culmen lengths of Dunlins and Western Sandpipers collected in 1976 and 1977 at Bodega Bay, CA, and in C-BRD system.

	Bodega Bay	Kanak		Eyak	Hartney	
Sex	1976	1976	1977	1976 only	1976	1977
Dunlin						
			*			
M	37.1 ± 1.28[1] (7)	37.3 ± 1.91 (18)	37.2 ± 1.76 (8)	38.7 ± 0.89 (7)	* 36.8 ± 1.32 (25)	36.7 ± 0.95 (14)
F	40.4 ± 1.14 (4)	41.2 ± 1.73 (18)	39.7 ± 1.29 (14)	40.5 ± 1.40 (7)	40.9 ± 1.50 (31)	40.6 ± 1.72 (17)
Western Sandpiper						
			*	*		
M	23.2 ± 0.91 (12)	23.3 ± 0.94 (41)	23.3 ± 0.55 (6)	23.3 ± 1.39 (16)	* 22.2 ± 0.83 (11)	22.5 ± 1.10 (11)
F	27.0 ± 1.10 (9)	27.2 ± 1.10 (27)	26.4 ± 1.00 (14)	27.1 ± 0.97 (11)	27.4 ± 1.38 (7)	26.0 ± 1.20 (20)

[1] $\bar{x}$ (mm) ± SD
(N)

*Respective pairs of values significantly different ($P < .05$) as determined by t-test.

Table 5. Mean culmen lengths of male Dunlins in the C-BRD system in 1976. The migration period is divided into two intervals for comparative purposes.

Date	Location	N	$\bar{x}$ SD	Range (mm)
1-10 May	Kanak Island	15	37.0 ± 1.93	33.0 - 40.1
11-22 May		3	38.9 ± 0.78	38.0 - 39.5
1-10 May	Eyak River	-	-	-
11-22 May		7	38.7 ± 0.88	37.7 - 40.0
1-10 May	Hartney Bay	18	* 36.3 ± 1.25	32.7 - 38.2
11-22 May		9	37.6 ± 1.13	36.0 - 39.7

*Pair of values significantly different (P < .05)

Table 6. Mean fat indices (g fat/g fat-free dry wt) of Dunlins and Western Sandpipers at Bodega Bay, CA and in C-BRD system (1976 specimens).

Sex	Bodega		Kanak	Eyak		Hartney
Western Sandpiper						
M	0.30 ± 0.222[1] (12)		0.39 ± 0.166 (41)	0.33 ± 0.115 (16)		0.24 ± 0.085 (11)
F	0.13 ± 0.067 (9)	*	0.29 ± 0.158 (27)	0.33 ± 0.161 (11)		0.32 ± 0.111 (7)
Dunlin						
M	0.48 ± 0.266 (7)		0.35 ± 0.121 (18)	0.31 ± 0.062 (7)	*	0.54 ± 0.222 (25)
F	0.64 ± 0.082 (4)	*	0.31 ± 0.112 (18)	0.33 ± 0.154 (7)	*	0.53 ± 0.197* (31)

(Brackets with * in the table connect Kanak M–Hartney M Dunlin, Kanak F–Hartney F Dunlin, Hartney Western Sandpiper M–Hartney Dunlin M, and Hartney Western Sandpiper F–Hartney Dunlin F.)

[1] $\bar{x}$ ± SD (N)

*Respective pairs of values significantly different (P < .05) as determined by t-test.

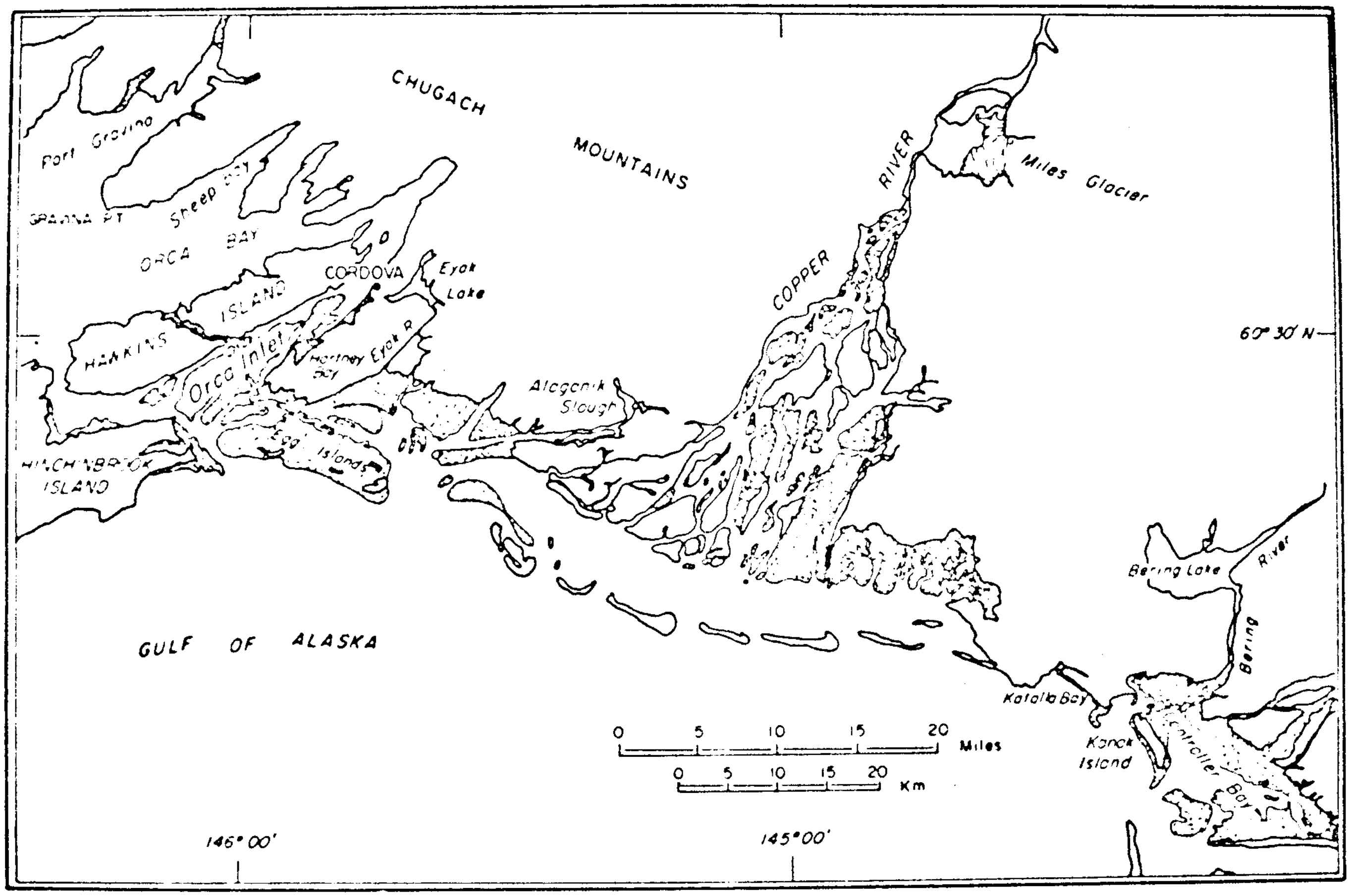

Fig. 1. Map of Copper-Bering River Delta system. Primary study sites were located at (from east to west) Kanak Island, the mouth of the Eyak River, and Hartney Bay.

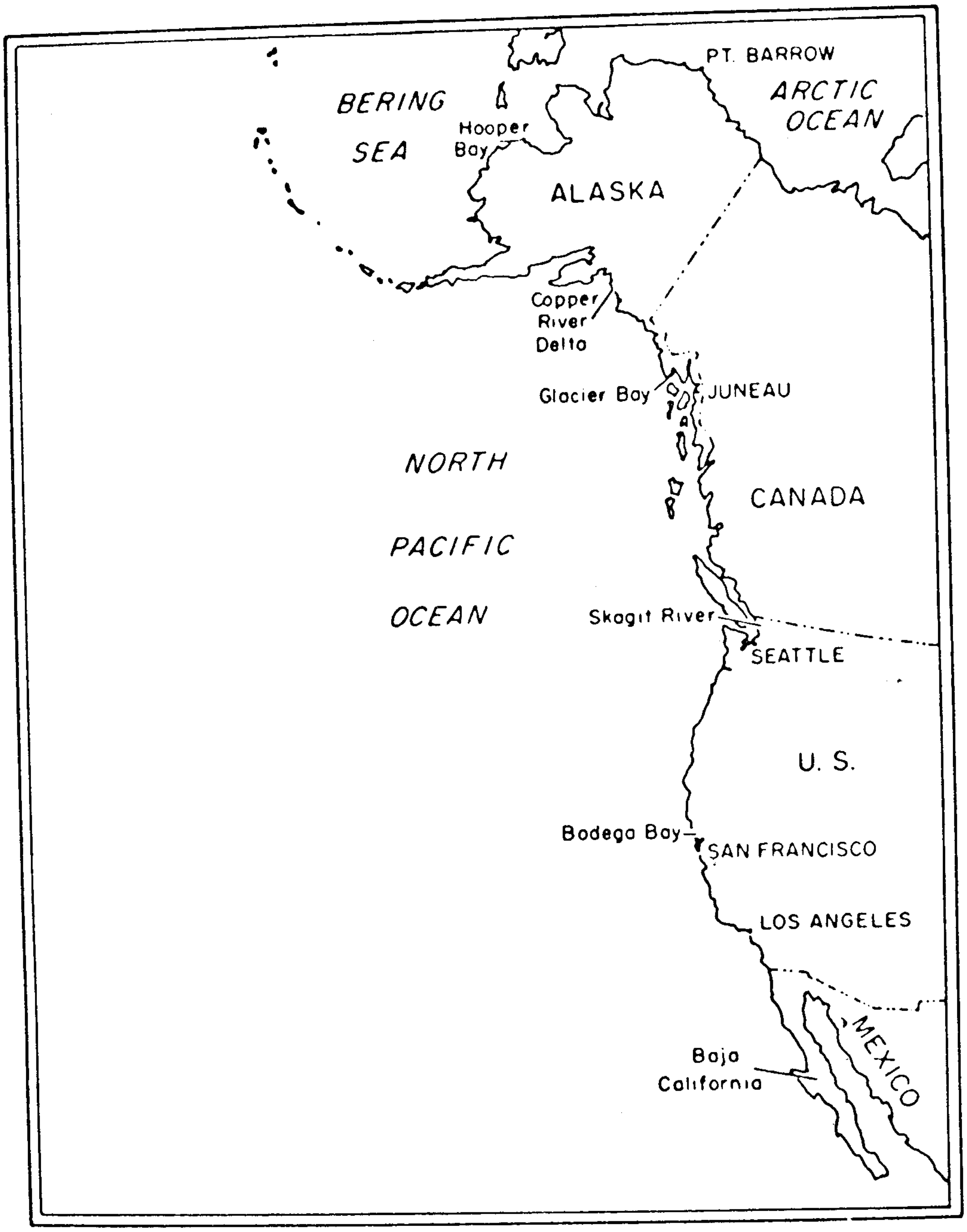

Fig. 2. Map of the western coast of North America.

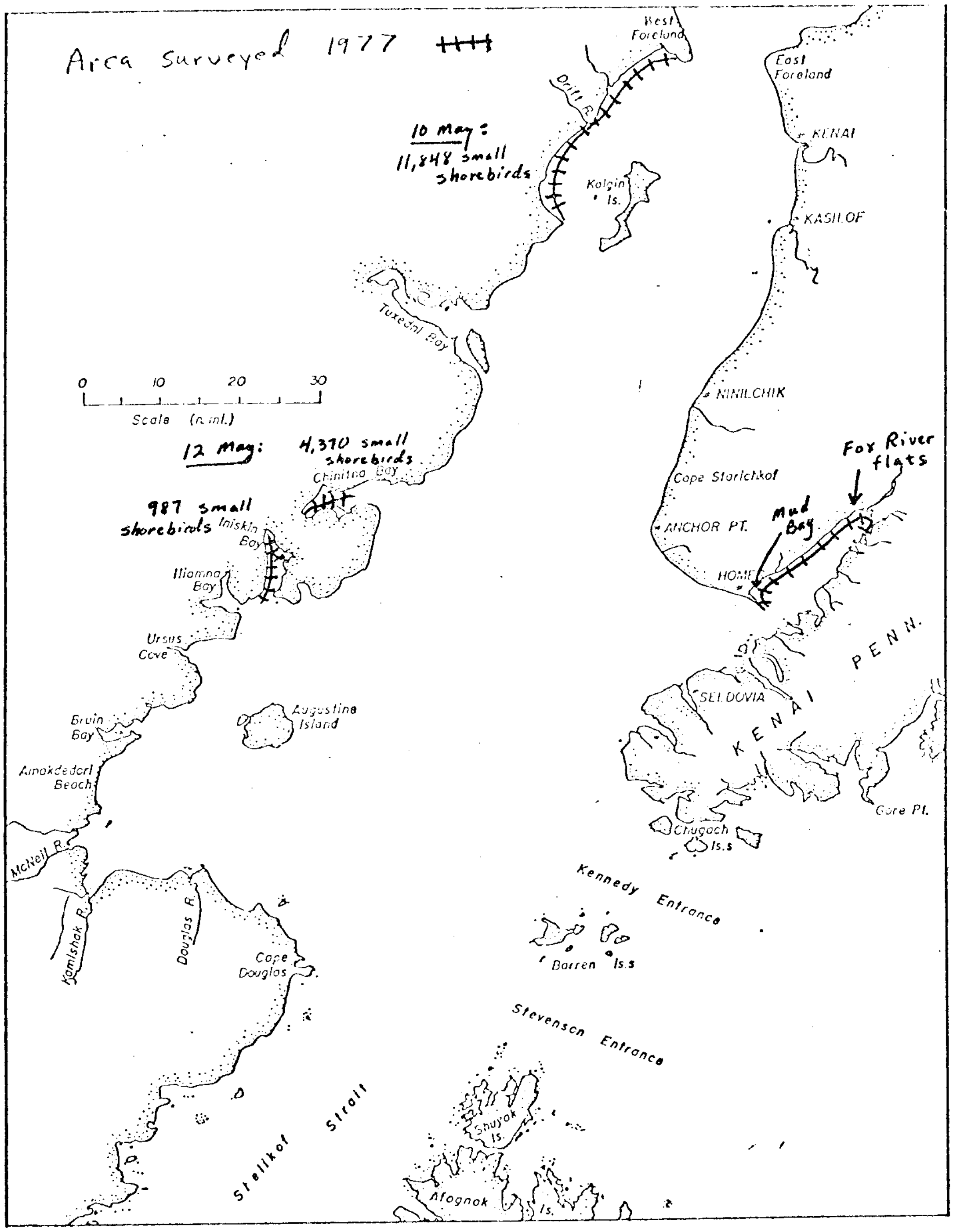

Fig. 3. Map of Lower Cook Inlet showing areas surveyed in 1977 and number of small shorebirds seen on three surveys on the west side of the inlet.

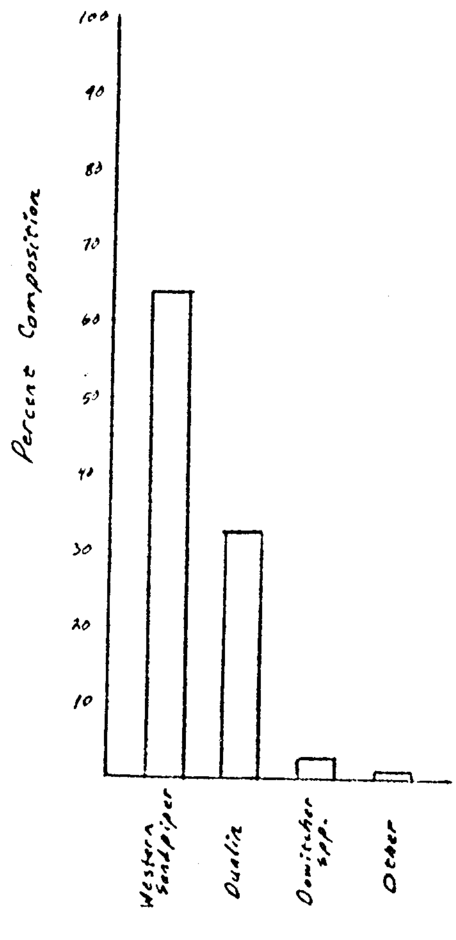

Fig. 4. Relative abundance of different shorebird species at Hartney Bay. Includes all censuses of two transects between 1 and 16 May 1977. N = 6,961 birds. "Other" category includes Semipalmated Plover (*Charadrius hiaticula*), Ruddy Turnstone (*Arenaria interpres*), Sanderling (*Calidris alba*), and Whimbrel (*Numenium phaeopus*).

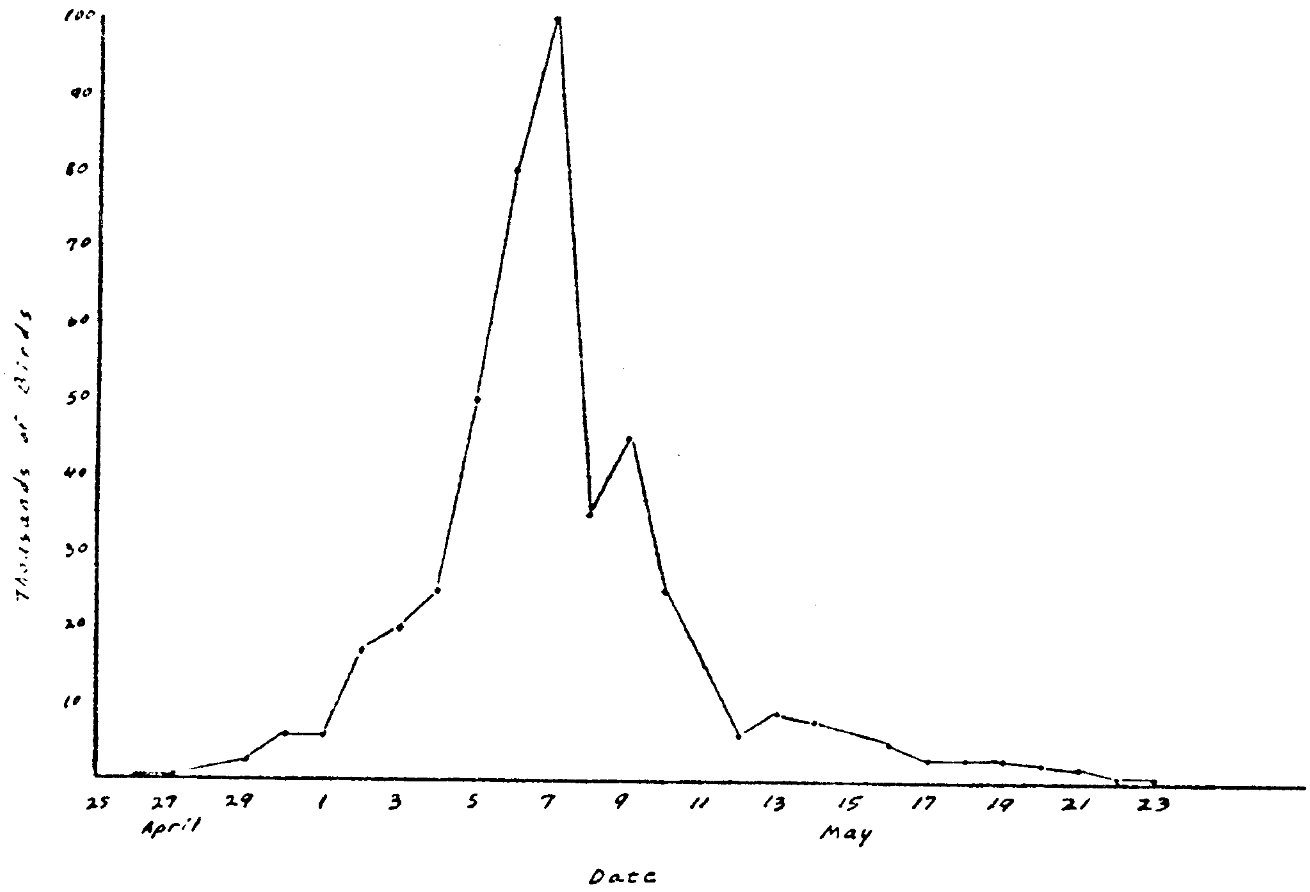

Fig. 5. Estimated peak daily numbers of all shorebird species at Hartney Bay during spring migration, 1976.

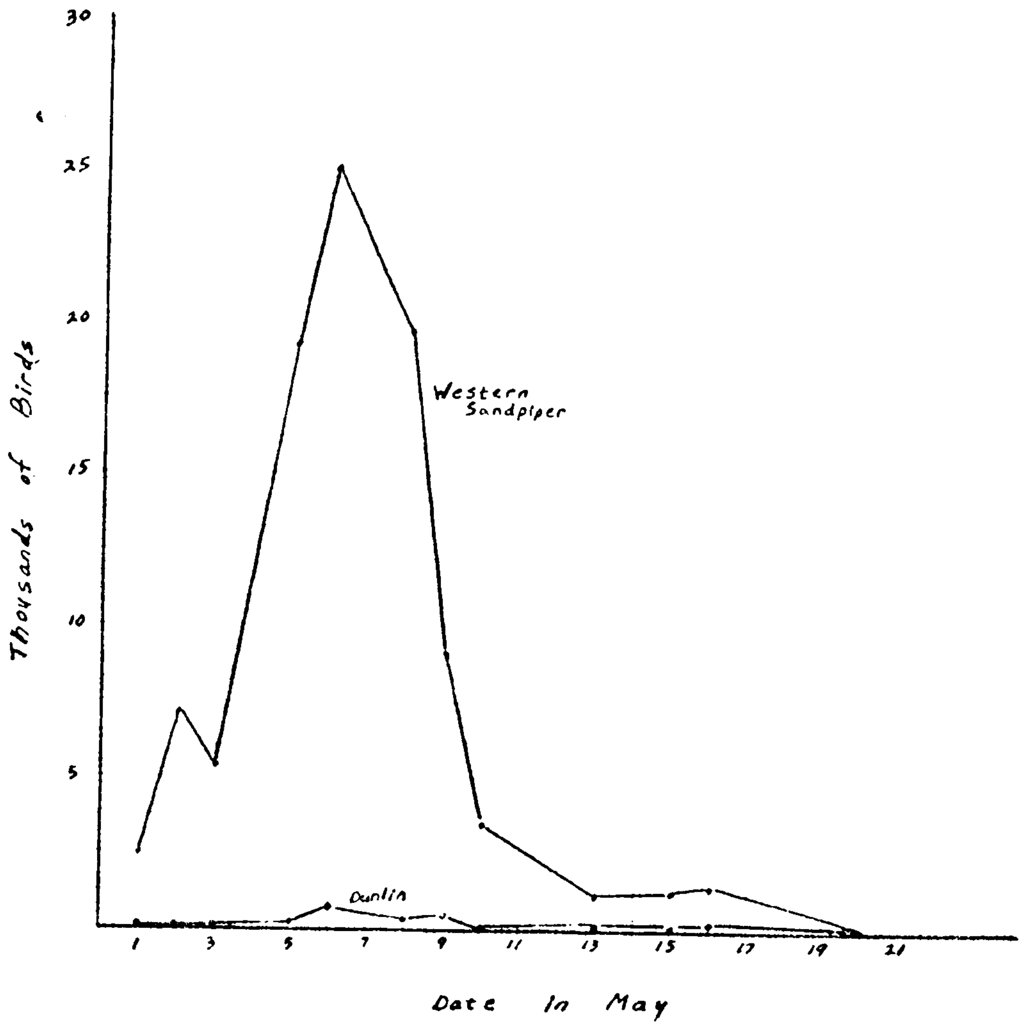

Fig. 6. Number of Western Sandpipers and Dunlins recorded on censuses of intertidal transect at Mud Bay, Kachemak Bay, 1977.

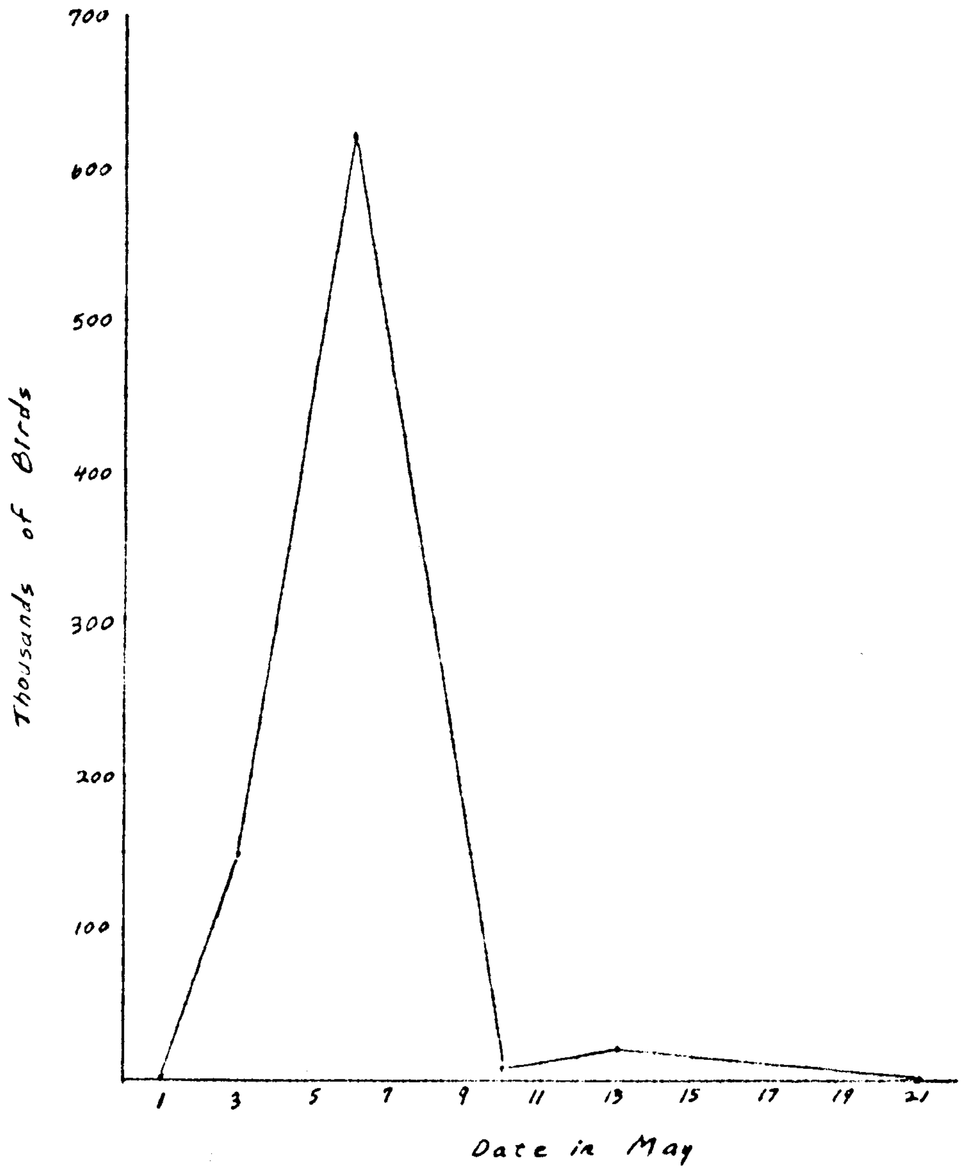

Fig. 7. Number of small shorebirds estimated on aerial surveys of the Fox River flats, Kachemak Bay, 1977.

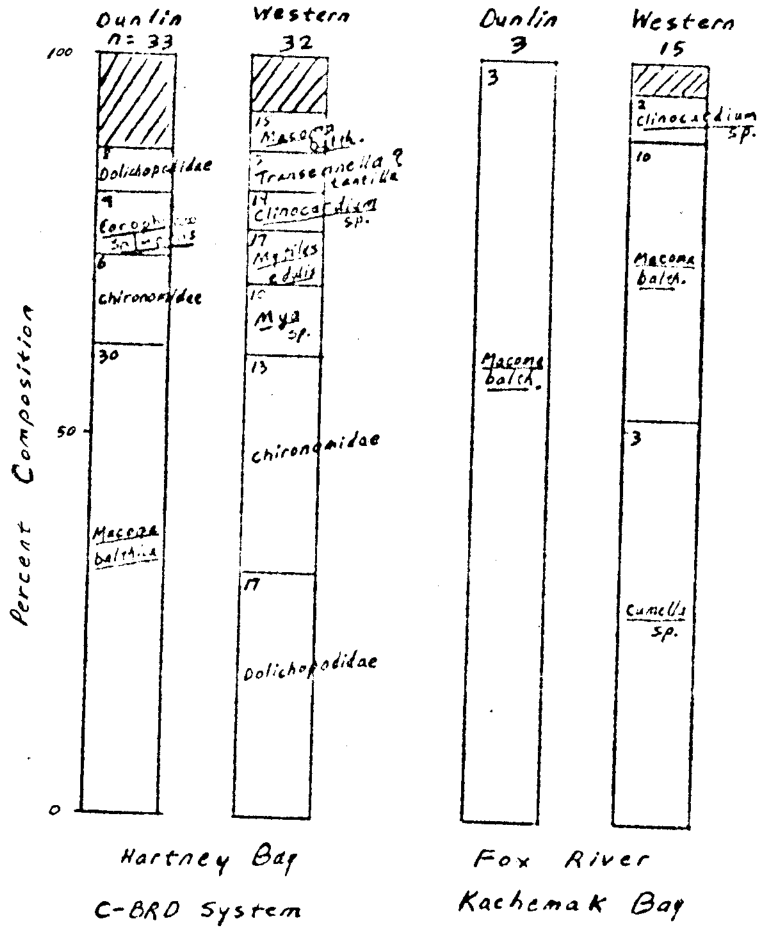

Fig. 8. Stomach contents of Dunlins and Western Sandpipers collected at Hartney Bay and the Fox River flats during spring migration, 1977. Contents are expressed as percent composition of total food on a numeric basis. Slashed bars show the sum of food items which, individually, comprise less than 5 percent of total food items. Numbers within the bars indicate stomachs in which the respective taxa were present.

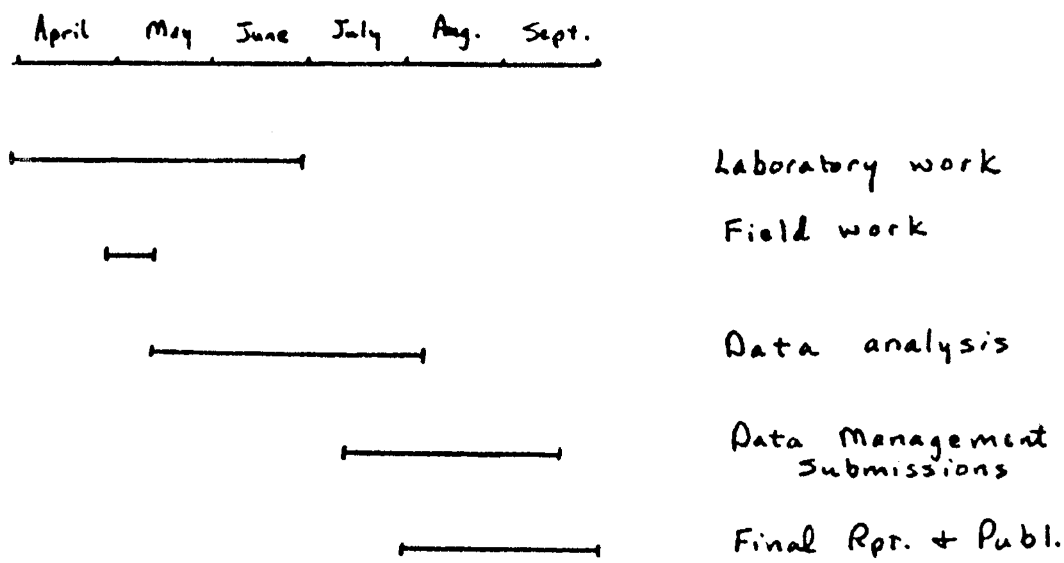

Fig. 9. Milestone chart for work remaining in FY78.