FINAL REPORT

SOME ASPECTS OF THE ECOLOGY OF CLIFF-NESTING SEABIRDS AT KONGKOK BAY, ST. LAWRENCE ISLAND, ALASKA, DURING 1976

By

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INTRODUCTION

The process of selling oil leases along the outer continental shelf of Alaska has already begun. Leases in the northern Bering Sea-Norton Sound area are expected to be sold during 1979. Offshore oil-drilling activities in the northern Bering Sea region will probably begin soon thereafter. Before such activities begin it is important to know what effects they may have on the marine ecosystem. It is especially important to know both the potential for disturbance to nesting seabirds from such activities and the potential for the destruction of these birds from accidental oil spills.

The National Oceanic and Atmospheric Administration (NOAA) has initiated a program to provide baseline data on the species and populations of birds that may be exposed to impacts from petroleum development on the outer continental shelf of Alaska. During 1975, NOAA initiated a series of studies of seabird colonies at various sites along the coast of Alaska. Only one of these studies was located in the northern Bering Sea-Norton Sound area. In order to expand the scope of the studies in the Bering Sea-Norton Sound area, the present study was initiated during 1976 to provide data on the phenology, abundance, productivity and food habits of the major seabird species that nest on St. Lawrence Island.

The seabirds of St. Lawrence Island were little studied previous to 1964. Since then, four species or species groups have been studied; two of these studies were of auklets (Bédard 1967, 1969a,b; Scaly 1968, 1975; Scaly and Bédard 1973), one of murres (Johnson and West 1975), and one of Horned Puffins (*Fratercula corniculata*) (Scaly 1973). Ornithological observations prior to these studies have been summarized by Fay and Cade (1959). Recent phonological data for seabirds on St. Lawrence Island have been reported by Thompson (1967], Scaly (1967), and Johnson (in press). Throughout this report, I have made an attempt to compare the data collected during 1976 with the existing published and unpublished data for seabirds on St. Lawrence Island.

The primary objectives of the present study were to document

1. the breeding season phenology of seabirds at Kongkok Bay with major emphasis on
   (a) the arrival of birds in the St. Lawrence Island area,
   (b) the arrival of birds on the cliffs and talus slopes,
   (c) the initiation and peak of laying,
   (d) the initiation and peak of hatching, and
   (e) the initiation and peak of fledging;
2. the numbers of birds in the Kongkok Bay area;
3. the reproductive success of
   (a) Least Auklets (*Aethia pusilla*) and Crested Auklets (*Aethia cristatella*),
   (b) Common Murres (*Uria aalge*) and Thick-billed Murres (*uris lomvia*), and
   (c) Black-legged Kittiwakes (*Rissa tridactyla*); and
4. the food habitats and feeding areas of
   (a) Least and Crested Auklets, and
   (b) Common and Thick-billed Murres.

Secondary objectives of this study were to document

1. the relation of auklet density to the physical features of their habitat; and
2. the rates and patterns of growth of chicks of Least and Crested Auklets.

The results of this study, when combined with those of other NOAA seabird studies, will provide baseline information that can be used both to assess the potential impacts of the proposed offshore oil developments on the seabird populations of the area and to develop environmental recommendations to mitigate these impacts.

The emphasis of the following report has been placed on the most abundant seabird species in the Kongkok Bay area. These species include Least Auklet, Crested Auklet, Common Murre and Thick-billed Murre and Black-legged Kittiwake. In order to avoid unnecessary repetition, the report is organized according to the following major headings: Phenology, population estimates, breeding biology and food habits and feeding areas.

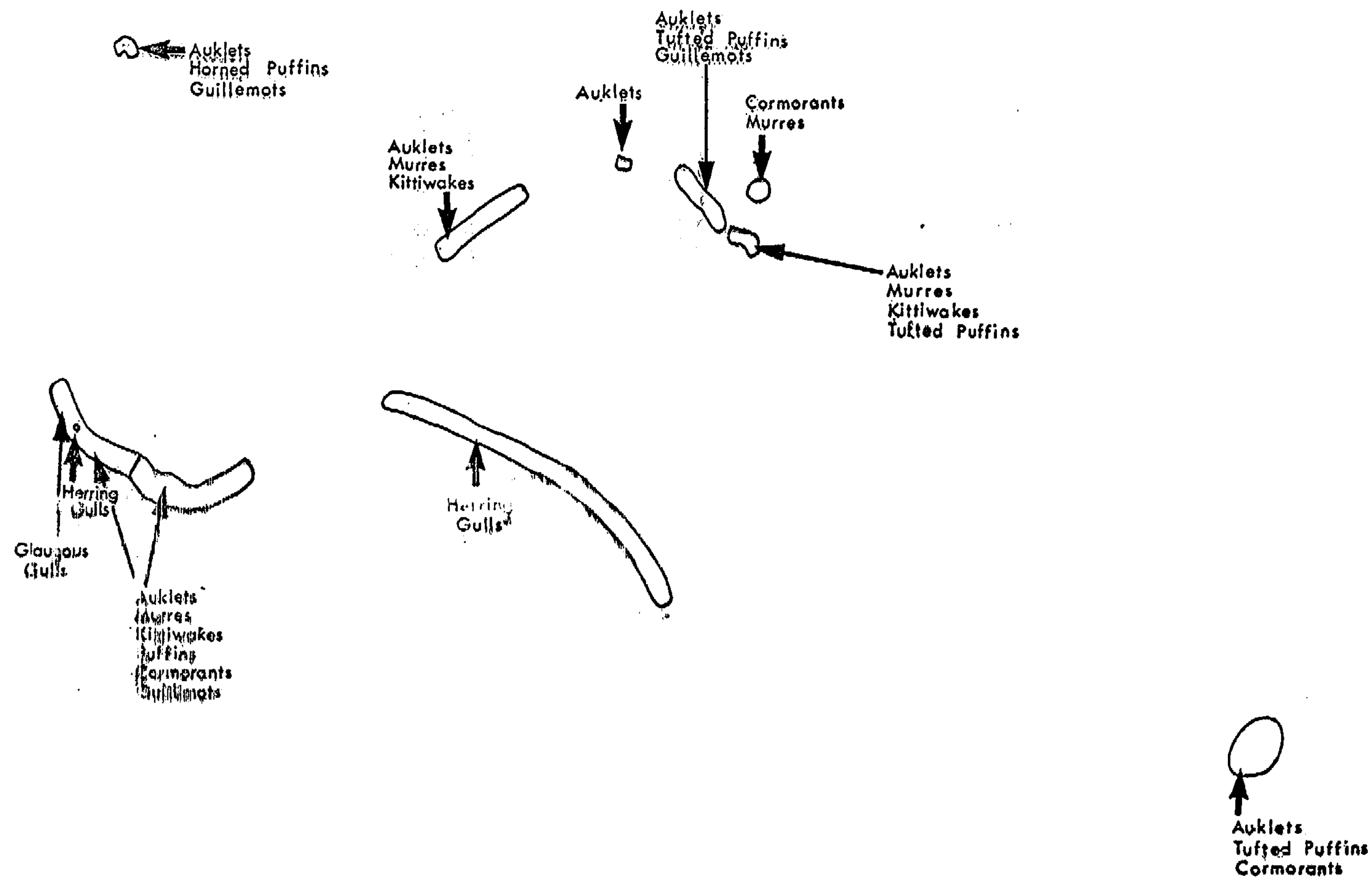
STUDY AREA

St. Lawrence Island, Alaska, lies in the Bering Sea approximately 200 km southwest of Nome, Alaska, and 64 km southeast of the Chukotsk Peninsula, U.S.S.R. The area of St. Lawrence Island is approximately 5100 km^2. More than two-thirds of the island is low-- <60 m above sea level (ASL)--and wet. Most upland portions of St. Lawrence Island are located in three mountain ranges: the Kinipaghulghat Mountains, the Kookooligit Mountains, and the Poovoot Range. Most of the sea-cliffs and talus slopes that are heavily used by seabirds are part of the latter two mountain ranges.

The locations of the major breeding colonies of seabirds on St. Lawrence Island are presented in Figure 1. The information presented in Figure 1 is not a complete atlas of seabird colonies on St. Lawrence Island, but rather it represents a summary of colony locations that have been reported in the literature.

This study was conducted in the Kongkok Bay area (63°24'N; 171°49'W) on the southwestern portion of St. Lawrence Island, at the southwest end of the Poovoot Range. The study area included the region from Galuk to near Tatik Point (Figure 2); the main areas investigated were the cliffs and talus slopes of Owalit Mountain and a large cirque basin, locally known as Kongkok Basin, which is located on the side of Ivekan Mountain. St. Lawrence Island has an arctic maritime climate characterized by milder winters and cooler summers than are experienced in arctic continental areas (Fay and Cade 1959:76). Although summer temperatures at Gambell seldom exceed 10° to 15°C, the temperatures at Kongkok Bay are normally higher. Appendix 1 gives the maximum and minimum temperatures that were recorded at Kongkok Bay during the period from 31 May to 1 September 1976.

A general account of the vegetation and climate of St. Lawrence Island and a review of botanical work is included in Fay and Cade (1959). Hultén (1969) and Young (1 971) described the vascular flora of St. Lawrence 1s1 and. With the exception of these general works, almost no botanical information is available for Kongkok Bay. The predominant vegetation in the Kongkok Bay area is composed of lichens, grasses and several species of forbs.


Auklets
Horned Puffins
Guillemots
Auklets
Murres
Kittiwakes
Auklets
Auklets
Tufted Puffins
Guillemots
Cormorants
Murres
Auklets
Murres
Kittiwakes
Tufted Puffins
Herring
Gulls
Glaucous
Gulls
Auklets
Murres
Kittiwakes
Puffins
Cormorants
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Herring
Gulls
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Cormorants

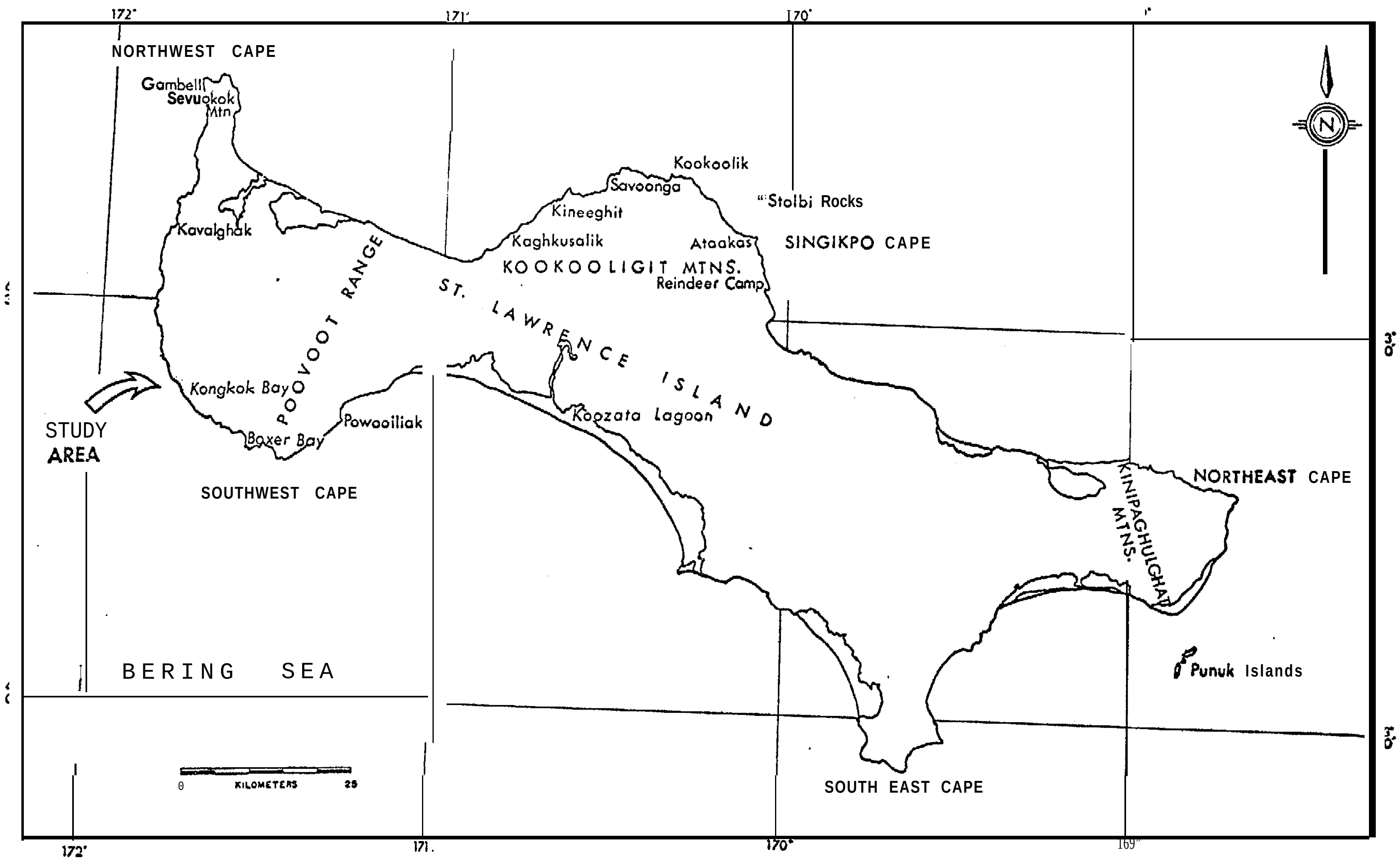

FIGURE 1. Map of St. Lawrence Island and Location of Study Area. Overlay depicts location of known seabird colonies and the species present at each.

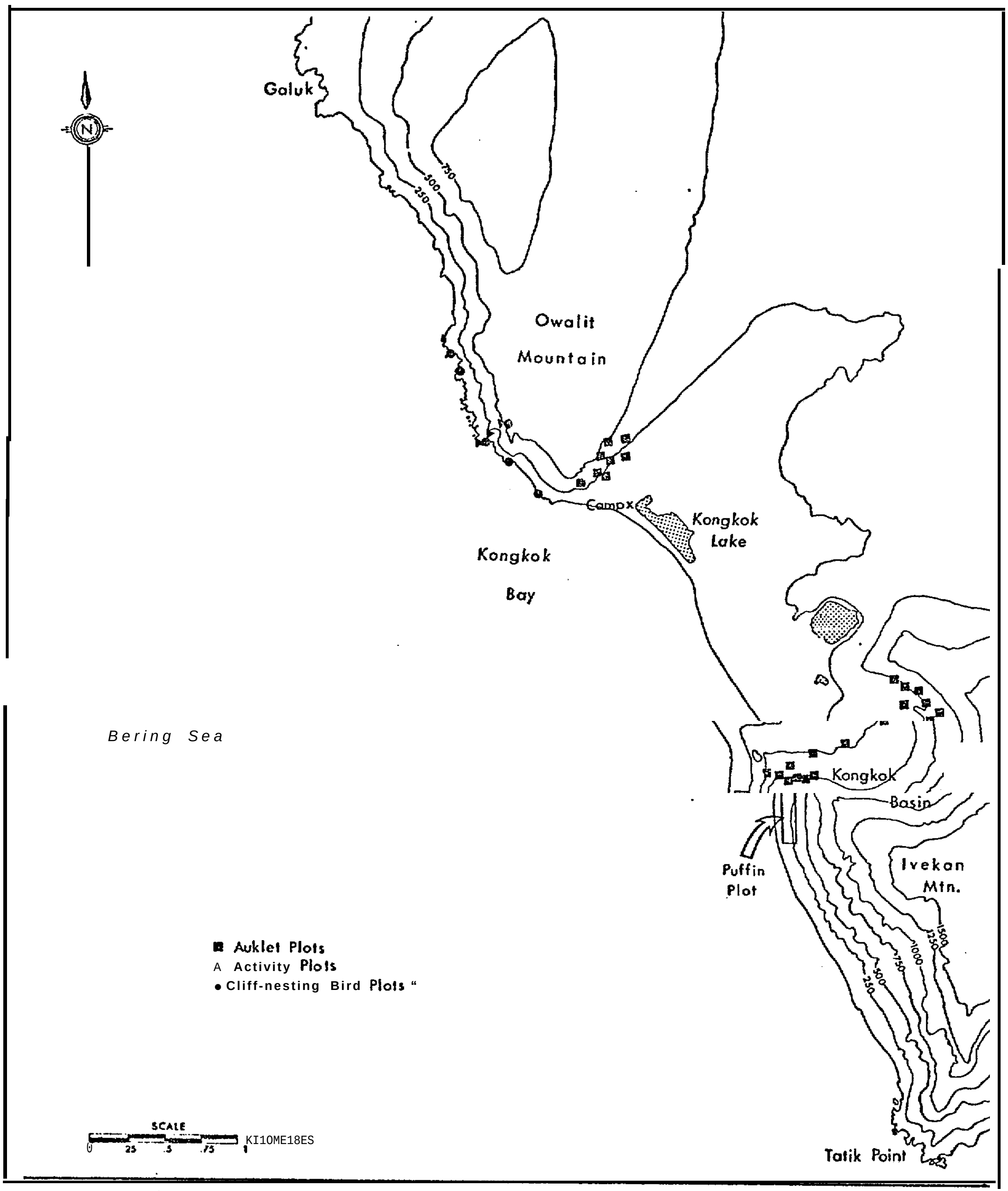

FIGURE 2 . Location of Study Plots at Kongkok Bay. See Figure 1 for location of study area relative to St. Lawrence Island.

Seabird Nesting Habitat

Inland Talus Slopes

Kongkok Basin is an immense area of inland talus slope in the shape of a huge amphitheater (see Plate 1, page 22); it rises from about 75 m ASL to over 400m in height. Almost all of the area on the sides and floor of the basin is covered with scree. The talus slope on the southeast-facing (inland) side of Owalit Mountain (see Plate 2a, page 25) begins about 30 m ASL and extends to approximately 200mASL and to a distance of about 750 m inland. A more detailed analysis of the talus characteristics is found in the results section below.

Three species of auklets, Crested, Least, and Parakeet Auklets (*Cyclorrhynchus psittacula*), nest on the talus slopes in the Kongkok Bay area. Crested and Least Auklets, the most abundant of the three species, occupy the talus slopes on both Owalit and Ivekan mountains.

Maritime Talus Slope

The outer (seaward) wall of Kongkok Basin is a very unstable talus slope rising directly from the ocean. The lower portion of this slope is steeper than the inland talus slopes and contains several outcrops of non-fractured parent rock. These areas are used extensively by Horned Puffins and are used to a lesser extent by Tufted Puffins (*Lunda cirrhata*) and Pigeon Guillemots (*Cepphus columba*). Several very large stacks also occur in this area. These stacks are occupied by nesting Horned and Tufted Puffins, Pigeon Guillemots, Pelagic Cormorants (*Phalacrocorax pelagicus*), Glaucous Gulls (*Larus hyperboreus*) and Herring Gulls (*Larus argentatus*). Parakeet Auklets are present in small numbers on the cliffs and maritime slopes of Owalit Mountain.

Sea-cliffs

The southwest face of Owalit Mountain falls off to sea-cliffs that range in height from less than 20 m to more than 200m (see Plate 2b, page 25). Although sea-cliffs extend from Galuk to Boxer Bay (a distance of more than 15 km), only 4 km of these cliffs were included in the study area, and only about 1 km was intensively investigated. Nine species of seabirds nested on these cliffs:

- Thick-billed Murres
- Common Murres
- Black-legged Kittiwakes
- Pelagic Cormorants
- Glaucous Gulls
- Parakeet Auklets
- Tufted Puffins
- Horned Puffins
- Pigeon Guillemots

METHODS

Phenology

The study was initiated on 14 May 1976 and continued until 3 September 1976. Initial observations of the arrival of birds in the St. Lawrence Island area were made at Gambell (14 May to 26 May 1976). One preliminary trip was made to Kongkok Bay on 19 May 1976; a field camp there was occupied almost continuously from 27 May until 3 September.

Detailed observations were made throughout the study in order to determine the initiation dates and peak dates of

1. arrival in the St. Lawrence Island area,
2. arrival on the nesting cliffs and slopes,
3. nest building (when applicable),
4. egg-laying,
5. hatching, and
6. fledging

for as many species as possible. Throughout this study, primary emphasis was placed on Least and Crested Auklets, Common and Thick-billed Murres, and Black-legged Kittiwakes. Information was collected opportunistically about the other, less abundant species.

Population Estimates

Talus-nesting Birds

In order to calculate the density of breeding Least and Crested Auklets in the Kongkok Bay area, 24 quadrats were established on the talus slopes. Eight of these quadrats were randomly located along the east slope of Owalit Mountain and 16 quadrats were located in Kongkok Basin (Figure 2). Previous to selection of plot locations in Kongkok Basin, the basin was divided into two strata based on gross characteristics of the scree. Eight quadrats were randomly selected in each stratum.

In order to compare data collected on auklets during the present study with data collected by Bédard (1967, 1969a), the methods used to census auklets during this study were identical to those used by Bédard. Each plot was a square 14.2 m to a side (approximately 200 m^2). The four corners of each plot were marked with wooden stakes (topped with brightly coloured flags); plots were subsequently permanently marked with cement spikes.

To avoid disturbance, birds were counted through a spotting telescope at a minimum distance of 50 m. The numbers of Least and Crested Auklets were tallied every 1/2 hr. Counts were made between 05:00 and 08:00 Bering Daylight Time (BDT)* from 2 to 19 June (see Appendix 2). These time and date intervals were chosen to minimize the number of immature auklets that would be counted on the plots. The number of immature auklets on the breeding slopes varies with the time of year and the time of day. Bédard (1967;101) found that immature auklets did not occur in significant numbers until 5 to 10 June and did not reach peak abundance until about 20 June. Furthermore, he noted that during mid-June the peak numbers of adult Least and Crested Auklets were present on the slopes between 05:00 and 08:00 while the peak numbers of immature auklets on the nesting slopes did not occur until after 08:00. All censuses were completed well before immature auklets became abundant on the nesting slopes.

The estimated number of auklets on each plot was taken as the average of the second, third and fourth highest counts made on that particular plot. This method was proposed by Bédard (1969a:387). While I disagree with Bédard's reasons for eliminating one, and only one, of the high counts (because high counts may not occur once, or only once), I concur that low counts are not meaningful when one attempts to estimate auklet numbers. To permit comparisons with Bédard's data, I calculated the number of auklets per plot using Bédard's method.

In order to find potential correlations between the density of auklets and the physical features of their nesting habitat, the following characteristics of each plot were measured:

1. direction towards which the plot faces (0-3600),

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*05:00 BDT = 15:00 Greenwich Mean Time. BDT used throughout this report.

2. approximate altitude of the plot (in feet ASL),
3. average slope (in degrees from horizontal),
4. percent of plot covered with scree,
5. distance of the plot to the edge of continuous talus cover (in metres),
6. depth of scree (in centimetres),
7. sphericity of the particles (1 = angular to 5 = round),
8. approximate average volume of the particles (in m^3), and
9. average diameter of the particles (in decimetres).

The percent scree cover; depth of scree; and sphericity, volume, and diameter of the particles were measured for each plot by establishing 10 randomly selected subplots of 1 m^2 and by measuring all characteristics of each reachable rock within each subplot. This method was thought to be superior to Bédard's (1969a) technique of selecting rocks for measurements of particle size by stretching a string along one rim of the quadrat and by measuring every reachable rock intersected by the string. (Bédard also selected rocks for sphericity measurements in a similar manner.) Although both transect and subplot methods are biased (larger particles have a greater probability of being sampled and will therefore result in overestimates of the characteristics being measured), it was felt that the subplot method sampled both large and small particles more evenly than transect methods and therefore reduced the bias caused by particle size.

The percent of each 200m^2 plot covered with scree was also estimated; both estimates of scree cover (whole plot estimate plus subplot estimate) were averaged to obtain a final value.

Stepwise multiple regression analyses (SMRA) of auklet densities in relation to the physical characteristics of the plots were conducted through use of the BMDO2R program (Dixon 1973). Potential predictor variables (e.g., slope, volume of scree, etc.) were added to the regression model one at a time until the addition of a new variable failed to significantly reduce ($P \leq 0.1$) the variance of the estimate of the dependent variable. Plots of the residuals for each variable were analyzed to ensure that none of the assumptions of SMRA were violated (Draper and Smith 1966).

Cliff-nesting Birds

Two types of surveys were used to estimate the number of birds on Owalit Mountain. The first method involved counts of birds on plots and was conducted throughout the entire season. The second method involved a one-day survey of the cliffs of Owalit Mountain during which only the numbers of murres and kittiwakes were counted.

In order to obtain estimates of the number of birds that nested on the cliffs of Owalit Mountain and the changes in their numbers over the season, six plots of variable sizes were established (Figure 2). All plots extended from top to bottom of the cliff projection on which they were situated. These plots were situated in areas where a suitable landing' site for the boat existed--hence were not randomly located. In several cases, landing sites became unusable due to growth of algae which coated the steeply inclined rocks and made landing impossible. When this occurred, censuses of plots that were surveyed from these landing sites had to be discontinued. Appendix 3 lists the area of each plot and the dates on which each plot was surveyed. Plots were surveyed at approximately the same time of day (10:00-12:00) throughout the season.

Where possible, the numbers of individuals, pairs, young, and nests were counted for each species that was observed on the plots. Photographs of the plots were taken to obtain a permanent record.

The numbers of birds on the plots were converted to approximate densities and extrapolations were made over the entire cliff area of Owalit Mountain. The estimated number of birds was adjusted when necessary by multiplying the estimate by a correction factor developed from the graphs of activity cycles discussed below.

During the late incubation period of murres (26 July) a survey of the cliffs from Galuk to Kongkok Bay was conducted. A second observer was present during this survey and each observer made independent counts of both murres and kittiwakes. A similar survey from Kongkok Bay to Boxer Bay was planned but an extended period of rough seas prevented its completion.

Counts of murres and kittiwakes made during the entire cliff survey were conducted between 10:00 and 12:00. The results of the cliff survey were adjusted in the same way as the estimates from the counts of birds on the plots. A correction factor developed from graphs of activity cycles was applied to the number of birds counted during the cliff survey. This resulted in an adjusted estimate of the numbers of murres and kittiwakes that were present during the cliff survey. '

Activity Cycles

The numbers of birds on the cliffs vary with time of day and for some species from day to day (Tuck 1960; Drent 1965; Swartz 1966; Nettleship 1972; Birkhead 1976; and others). Studies were conducted to determine the diel cycles in the occupancy of nesting sites by cliff-nesting seabirds on St. Lawrence Island in order to correct the population estimates for this variation. Periodic censuses (see Appendix 4 for dates and times of counts) of birds on three plots were made. The locations of these plots are shown in Figure 2. Counts were conducted during the periods 11-27 June and 11-19 July.

Although Horned and Tufted Puffins and Pigeon Guillemots were included in the above plots, a series of counts conducted from 30 July to 6 August was obtained specifically for these three species. These counts were normally conducted three times per day over a plot 310 m long and 35 m high (total area = 10850 m^2) located on the seaward face of' Kongkok Basin (Figure 2). Counts of birds were made while walking along the beach beneath these low cliffs.

Where definite diel rhythms of abundance were evident, a correction factor was calculated from the ratio of birds present on activity plots during the count period (10:00-12:00) to the number of birds present on activity plots at the peak of the diel cycle. This correction factor was then applied to the extrapolated estimates of the numbers of birds of each species that were present on the sea-cliffs of Owalit Mountain.

Breeding Biology

Least and Crested Auklets

Auklet eggs were located by searching beneath boulders on the talus slope. These efforts were begun on 23 June and were continued until the first young was found. When a nest was discovered, the site was marked and the egg was periodically checked until it pipped, whereupon it was checked daily until hatching. Chicks were weighed and measured at intervals of 2 to 4 days until they left the nest sites.

Murres

The locations of all murre eggs on two plots were marked on a sketch map. The selection of these plots was determined by their accessibility and by the visibility of the nesting ledges. The status of each egg was recorded periodically throughout the incubation period. Similarly, upon hatching, the chicks were monitored until they fledged. This method of measuring productivity is not entirely accurate because, on crowded ledges, it is difficult to be certain that the same egg or chick is being monitored throughout the season due to movement of birds on the ledges. The alternative to this method of monitoring breeding success involves marking eggs and banding young. However, the process of marking eggs and young causes considerable disturbance to the murre colony and greatly affects productivity (Birkhead 1976). Also, due to physical changes in the cliffs, ledges that had been accessible in past years were no longer reachable (S. R. Johnson, pers. comm.*). Observation of eggs and chicks on plots proved to be reasonably accurate and resulted in only minimal disturbance to nesting murres.

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*S.R. Johnson, LGL Limited, Environmental Research Associates, Edmonton, Alberta, Canada.

Food Habits and Feeding Areas

Collection

A small number of Least and Crested Auklets and Common and Thick-billed Murres were shot with a 12-gauge shotgun or obtained from Eskimo hunters in order to determine the types of foods that were being eaten by these species. Least and Crested Auklets were collected from 8 to 16 July. I attempted to collect these species when they were feeding off-shore. Murres were collected from 9 to 18 June. Because the feeding areas of murres were located more than 25 km from shore, these species were collected while they were *en route* to the cliffs from their feeding areas.

During late August, a small number of Least and Crested Auklets were netted while bringing food to their young; these birds were forced to regurgitate the food material from their sublingual pouch (see Bédard [1969b: 1028]; Speich and Manuwal [1974] for a description of the sublingual pouch of auklets).

Within 6 hours of collection, the oesophagi, proventriculi and gizzards from birds that were collected and the regurgitated food samples from auklets that were captured were preserved in 10% formalin.

Sorting and Counting

The oesophagus, proventriculus, and gizzard of each bird was opened, scraped and washed with water; the contents were sieved through a #20 plankton net (75μ mesh size). Specimens or parts of specimens were sorted to the lowest possible taxon with the aid of a dissecting microscope and stored in 5% formal in. The numbers of food organisms were calculated either by direct counts or by estimation using subsampling techniques. When it was not possible to count individuals, the organism was recorded only as "present".

Feeding Areas

Notes were kept on the movements of birds to and from feeding areas and on the feeding flocks of birds in and around the Kongkok Bay area. These notes provided a partial delimitation of the feeding-locations used by seabirds that nested in the Kongkok Bay region.

RESULTS AND DISCUSSION

Phenology

Least and Crested Auklets

The chronology of events in the breeding cycle of the Least Auklet on St. Lawrence Island during 5 years is summarized in Table 1. The arrival of Least Auklets during 1976 apparently occurred later than the average arrival date based on the period from 1964 to 1967. Because the dates of first hatching and fledging during 1976 were apparently similar to or slightly earlier than these dates during 1964 to 1966, it is probable that a few eggs were laid earlier than 1 July when the first eggs were found. Back-dating from the date of first observed hatch during 1976 (using Scaly's [1968] calculated incubation period of 31.2 days) suggests that the first Least Auklet eggs were laid on 24 June. Because information on the date of initiation of hatching can be more accurately (and more easily) obtained than information on the date of initiation of laying (or of fledging], the back-dated calculation of 24 June is probably the best estimate of the exact date of first egg-laying. Although Least Auklets arrived on the nesting slopes 5 to 9 days later during 1976 than during the period from 1964 to 1966, the initiation of laying occurred at a similar or slightly earlier date. However, laying by this species began almost 2weeks later during 1976 than during 1967 (an "early" year, see below). Few dates of initiation of egg-laying by Least Auklets are reported in the literature for other areas of the Bering Sea; these records are summarized by Scaly (1968).

Although Crested Auklets arrived in the vicinity of St. Lawrence Island at approximately the same time during the 5 years for which data are available, Crested Auklets, like Least Auklets, began landing on the nesting slopes of Owalit Mountain approximately one week later than during previous years (29 May; Table 2) when the slopes were approximately 50% snow-covered (Plate 2a, page 25). Neither Least Auklets nor Crested

TABLE 1. Breeding Phenology of Least Auklets on St. Lawrence Island.

EVENT	YEAR 1964	1965	1966	1967	1976
First seen in offshore leads			15 May[1]	10 May[1]	
First seen from shore	15 May[1]	18 May[1]	21 May[1]		
First seen on nesting slopes	20 May[1]	22 May[1]	24 May[1]	20 May[2]	29 May
First eggs found (first eggs laid)[3]	(26 June)[1]	(28 June)[1]	24 June[2]	12 June[2]	1 July (24 June)
Peak of laying			2 July[2]	16 June[2]	
First young found	28 July[1]	30 July[1]	27 July[2]	15 July[2]	25 July
Peak of hatching			1 August[2]	22 July[2]	29 July
First young fledged	26 August[1]	28 August[1]	28 August[2]	15 August[2]	24 August
Peak of fledging			1 September[2]	20 August[2]	

[1]Bédard (1967)

[2]Sealy (1968)

[3]Back-dated using mean incubation period of 31.2 days (Scaly 1968)

TABLE 2. Breeding Phenology of Crested Auklets on St. Lawrence Island.

EVENT	YEAR				
	1964	1965	1966	1967	1976
First seen in offshore leads			18 May[1]	13 May[2]	
First seen from shore	15 May[1]	18 May[1]	20 May[1]		21 May
First seen on nesting slopes	20 May[1]	22 May[1]	24 May[1]	18 May[2]	29 May
First eggs found (first eggs laid)[3]	(22 June)[1]	(24 June)[1]	30 June[2]	14 June[2]	1 July (27 June)
Peak of laying			3 July[2]	24 June[2]	
First young found	28 July[1]	30 July[1]	‘2 August[2]	-“19 July[2]	2 August
Peak of hatching			~11 August[2]	“29 July[2]	11 August
First young fledged	26 August[1]	27 August[1]	5 September[2]	1 September[2]	Later than 3 September
Peak of fledging			9 September[2]	3 September	-

[1]Bédard (1967)

[2]Sealy (1968)

[3]Back-dated using mean incubation period of 35.6 days (Scaly 1968)

Auklets landed in Kongkok Basin until 2 June at which time the slopes there were still approximately 60% snow-covered.

The events in the breeding cycle of Crested Auklets during 1976 were generally 1 to 2weeks later than during the years 1964 to 1967. As with Least Auklets, some difficulty exists in identifying the initiation of nesting of Crested Auklets. The first egg was found on 1 July. However, back-dating (using Scaly's [1968] calculated incubation period of 35.6 days) yields a nest initiation date of 27 June.

The timing of hatching for Least and Crested Auklet eggs is presented in Figure 3. Although the date of initiation of laying was approximately the same for both species, the peak of hatching was almost 2 weeks later in Crested Auklets.

Early and late nesting seasons are apparently related to the amount of snow on the breeding cliffs and the rate at which it disappears. This relationship has been described for auklets on St. Lawrence Island by Scaly (1975). During 1966 and 1967 a "late" and an "early" season occurred, respectively. During 1966 snow covered 95% of the breeding slopes when auklets arrived; the breeding season was delayed and eventually some birds laid their eggs on the snow (Scaly 1975). The timing of onset of laying during 1976 was quite similar to the timing that occurred during 1966. Plate la shows that snow cover was very heavy in Kongkok Basin on 9 June 1976 and still persisted to a large extent as late as 24June (Plate lb) and 28 June (Plate lc). Eggs were first found in the snow-free areas on 1 July; no eggs were found on-the snow. Snow cover was still present along the rim of the basin on 20 August (Plate id).

Crested Auklets typically nest in areas of deeper scree with larger boulders than do Least Auklets (see "Population Estimates" section and Bédard 1969a). These areas provide larger interstices among talus boulders, which Crested Auklets require as nest sites. However, these interstices fill with snow and ice during the winter, and, due to their greater depth, they become snow-free later than sites used by Least Auklets. The date of

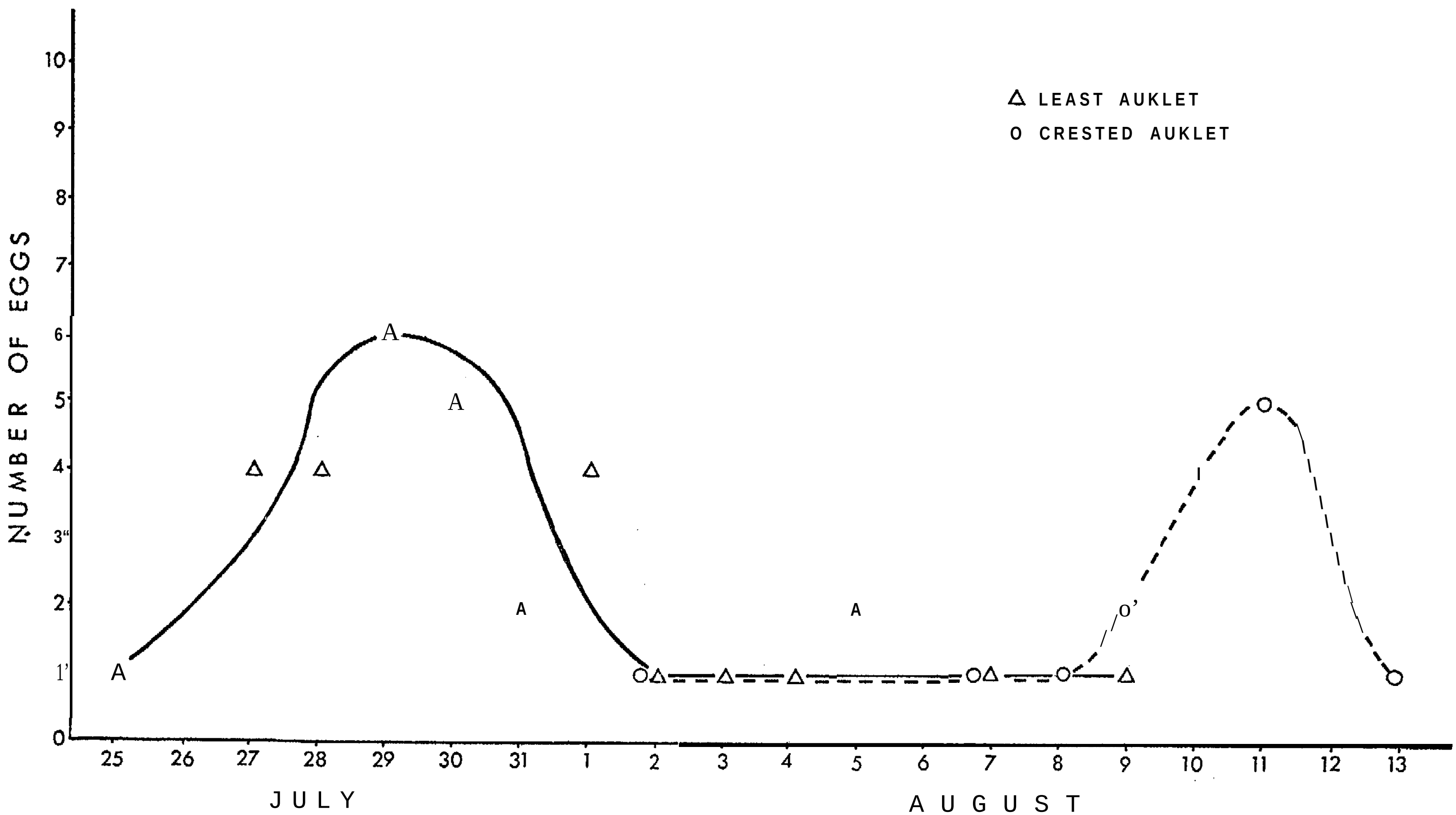


FIGURE 3, Number of Monitored Least and Crested Auklet Eggs that Hatched each Day during 1976.

A. 9 June 1976

B. 24 June 1976

C. 28 June 1976

D. 20 August 1976

PLATE 1. Snow Cover Conditions in Kongkok Basin during Summer, 1976.

first laying of Crested Auklets during 1976 was about 3 days later than that of Least Auklets. Also, Crested Auklets have an incubation period which lasts about 4 days longer than the Least Auklets' incubation period. The difference in the timing of initiation of laying and the length of the incubation period accounts for a 1 week difference between the initiation of hatching of Least and Crested Auklets. However, the majority of Crested Auklet eggs did not hatch until 2 weeks after those of Least Auklets (Table 1 and 2, Figure 3); this difference was probably caused by a delay in the laying of eggs by *most* Crested Auklets due to the late presence of snow and ice in their nest sites.

Common and Thick-billed Murres

Although some murres spend the winter in the open water near Kongkok Bay (Fay and Cade 1959:122), most murres that nest on St. Lawrence Island winter south of the pack ice (Gabrielson and Lincoln 1959:481). Johnson (in press) found 483 Thick-billed Murres and only one Common Murre in a sample of murres killed by hunters at St. Lawrence Island during the spring of 1973. Thus it appears that, in the vicinity of St. Lawrence Island, Common Murres arrive later than do Thick-billed Murres. The first off-shore concentrations of murres seen by Gambell residents during 1976 were recorded during late April (see Table 3 for phenology of events in the breeding season of murres). During 1953, Fay and Cade (1959) reported first seeing murres in numbers during the latter half of April. Johnson (in press) reported that 1 arge numbers of murres were present off the west coast of St. Lawrence Island in mid-April 1973. Although murres were present in the w stern St. Lawrence Island area by the latter part of April, during 1976, they did not begin to frequent the nest ledges until 28 May.

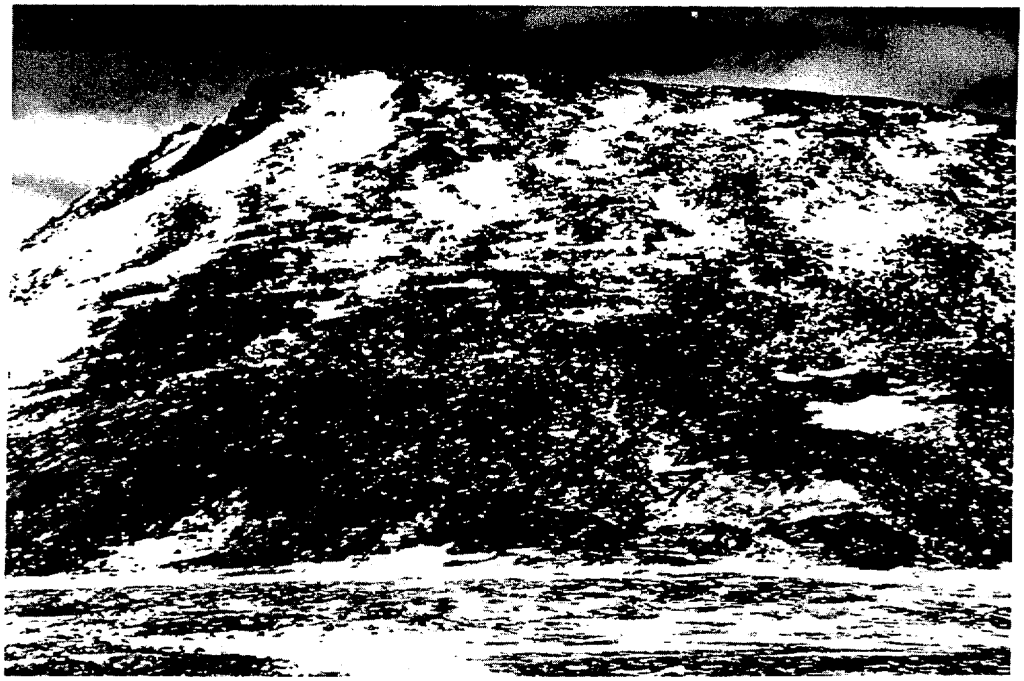
Much of the sea-cliff area was covered with snow during early June (Plate 2b). Many seabird species including murres (Tuck 1960:111-112; Birkhead 1976), kittiwakes (Belopol'skii 1957:115; Uspenski 1956:99), and puffins (Nettleship 1972:250) have courtship displays and activities that

TABLE 3. Breeding Phenology of Cliff-nesting Species on St. Lawrence Island during 1976.

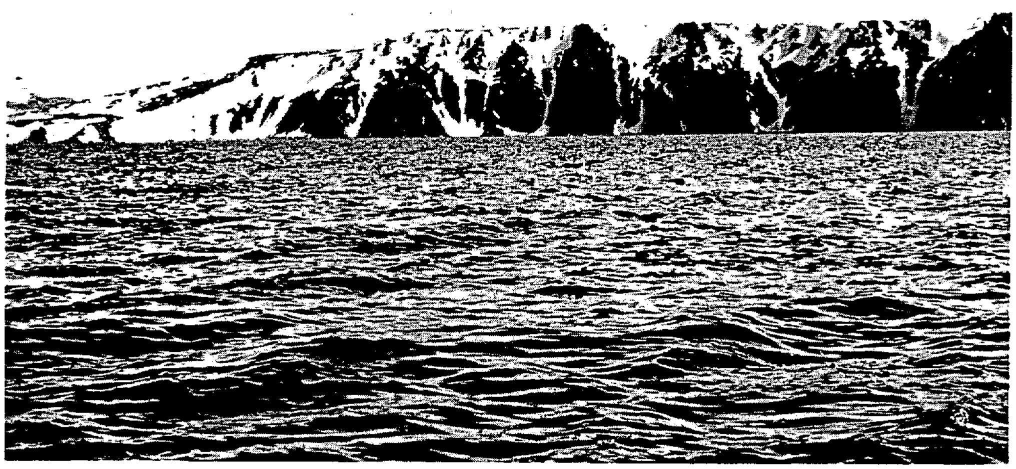
EVENT	BLACK-LEGGED KITTIWAKE	PELAGIC CORMORANT	MURRE SPP.	GLAUCOUS GULL
First seen in offshore leads			Late April	Winter Resident
First seen from shore	16 May	Late April	14 May*	Winter Resident
First seen on cliffs	27 May†	27 May†	28 May	27 May†
Initiation of nesting	8 June	2 June	N/A	30 May
First eggs found	29 June	13 June	28 June	2 June
Peak of laying			1-9 July	2-13 June
First young seen		29 June	31 July	
Peak of hatching			4-9 August	-
First fledgling seen	22 August	12 August	21 August	13 July
Peak of fledging			27 August	

*First day of observations at Gambell, St. Lawrence Island was 14 May 1976.

†No seabirds were observed at Kongkok Bay on 19 May 1976. First day of continuous observations at Kongkok Bay was 27 May 1976.



A. 29 May 1976



B. 19 June 1976

PLATE 2. Snow Cover Conditions on Owalit Mountain during Summer, 1976.

take place on the nesting slopes and ledges. Because courtship activities could not begin until the birds were able to occupy ledges, the presence of snow on the nesting cliffs until mid-June may have been the proximate factor that delayed the nesting activities of most seabirds at Kongkok Bay during 1976. Uspenski (1956:35) states that the onset of sexual activity of murres is in part controlled by the external stimulus of the nesting ledges. Unlike auklets which, during late seasons, are able to lay eggs soon after the snow cover leaves (Scaly 1975:534), murres require a certain amount of time after the ledges become free of snow to complete their courtship activities. The onset of laying in murres would thus be delayed to a greater extent than the onset of laying in auklets during years of late snow cover.

Over a 7-year-period between 1950 and 1957, Fay and Cade (1959) reported that Common Murres laid eggs between the middle and the end of June. They stated that Thick-billed- Murres may nest even earlier. During 1976, however, murres did not begin laying until 28 ,June and the peak of laying did not occur until the first week of July.

Similarly, the peak of hatching occurred somewhat later during 1976 than during 1950 to 1957. Fay and Cade (1959) reported a peak of hatching during the first week of August. During 1976, although hatching began on 31 July, the peak did not occur until 9 August (Figure 4). Hatching during 1976 was also later than hatching during 1972 which began on 30 July (peak on 4 August) (S.R. Johnson, pers. comm.). During 1972, departure of chicks from the cliffs commenced on 18 August and reached a peak 3 days later on 21 August (Johnson and West 1975). In contrast, departure of chicks during 1976 commenced on 21 August and did not reach a peak until 27 August (Figure 4). Some chicks still had not fledged when this study ended on 3 September 1976.

Black-legged Kittiwakes

The timing of events in the breeding season of the Black-legged Kittiwake is summarized in Table 3. Fay and Cade (1959) reported that kittiwakes were first seen near Gambell on 9 May during 1953 and 11 May during

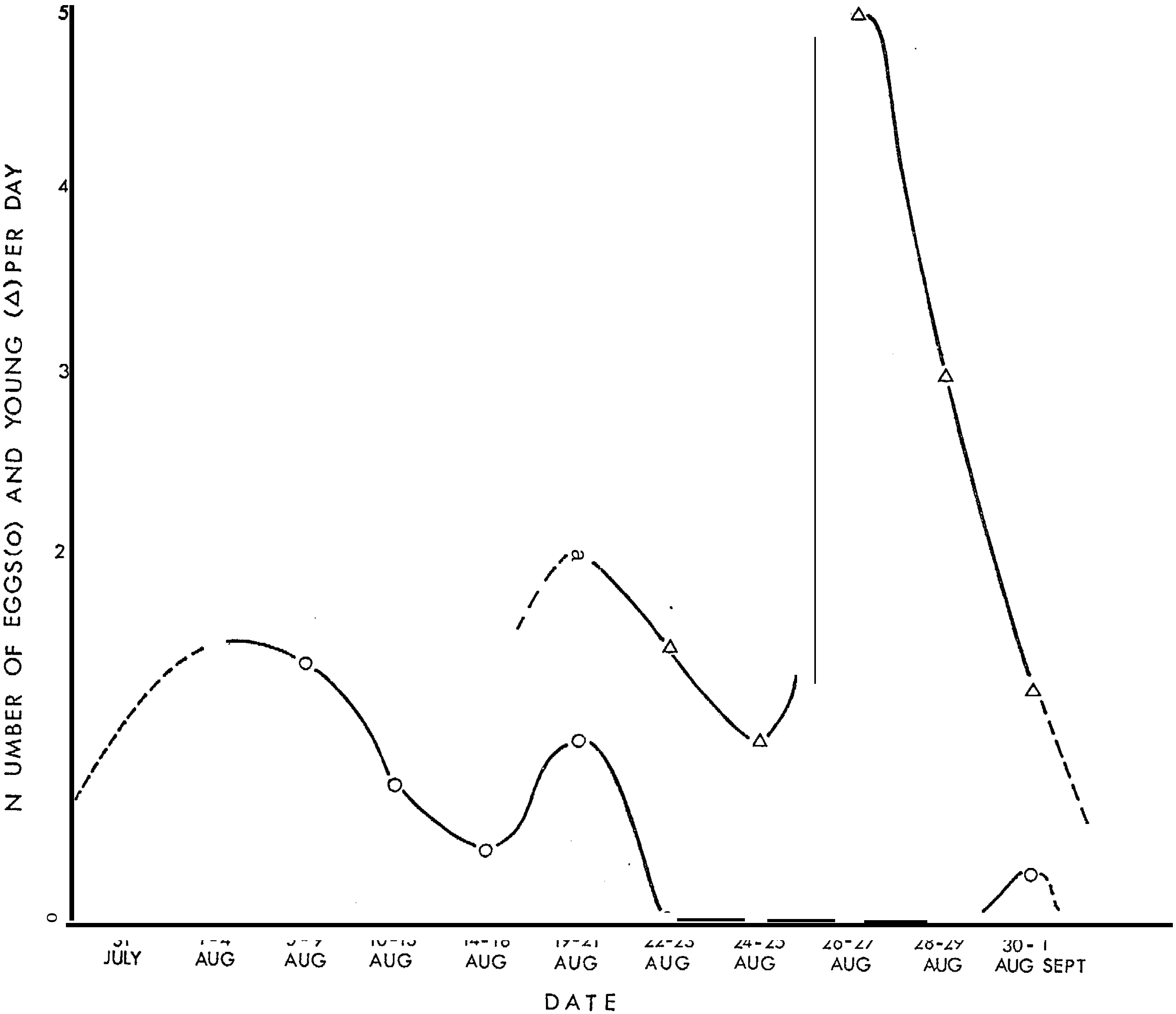


FIGURE 4. Number of Monitored Murre Eggs that Hatched and Murre Young that Fledged each Day during 1976.

1954. During 1973, kittiwakes were present at St. Lawrence Island by 29 April (Johnson in press). During 1976 I arrived at Gambell on 14 May but did not observe kittiwakes until 16 May. No kittiwakes were present on the cliffs at Kongkok Bay during my visit there on 19 May, but small numbers were present on the breeding ledges when I returned on 27 May.

The first sign of nest building during 1976 was noted on 8 June, the first eggs were located on 29 June, and the first fledgling was seen on 22 August. Based upon data gathered from 1950 to 1957, Fay and Cade (1959) stated that kittiwakes do not begin nesting until late June. This presumably refers to the initiation of egg-laying rather than actual nest construction. The nesting chronology of Black-legged Kittiwakes on St. Lawrence Island was apparently not delayed during 1976, whereas other cliff-nesting species arrived about one week later than normal.

The probable explanation is as follows:

1. Most kittiwakes that arrived at the cliffs during late May and early June occupied stacks (which were snow-free) rather than ledges (which were snow-covered).
2. Kittiwakes nested on the lower portions of the cliffs, which became snow-free earlier than upper portions.

The nesting chronology of kittiwakes at Kongkok Bay during 1976 will be further discussed in the 'Breeding Biology' section below.

Other Species

The phenology of events in the breeding season of Pelagic Cormorants and Glaucous Gulls is summarized in Table [illegible]. In addition, scattered phenological information was obtained for the less abundant species at Kongkok Bay.

Parakeet Auklets were first seen from shore at Gambell on 17 May; they were not observed on the cliffs at Kongkok Bay on 19 May, but were present there when I returned to Kongkok Bay on 27 May. Arrival dates given by Fay and Cade (1959) for this species are 17 May 1952, 15 May 1953, 11 May

1954 and 12 May 1956. Arrival dates of Parakeet Auklets during other years are presented in Table 4.

TABLE 4. Arrival Dates in May of Parakeet Auklets near Gambell, St. Lawrence Island.

First Seen	1964[1]	1965[1]	1966[1]	1967[1]	1973[2]	1976[3]
In Offshore Leads		13	9	4	14	-
From Shore	15	18	20	-	-	17
On the Nesting Slopes	19	21	24	-	-	27[4]

[1]Sealy and Bédard (1973:61).

[2]Johnson (in press).

[3]Present study.

[4]At Kongkok Bay.

During 1976, Parakeet Auklets apparently arrived in the St. Lawrence Island area about the same time as they arrived during other years, but, like Least and Crested Auklets, they did not occupy their nesting slopes until later than usual. The breeding seasons of all three auklets on St. Lawrence Island during 1976 were even later than the late breeding seasons of 1966. Although no eggs were found on the snow, Parakeet Auklets were still seen on snow-covered nest sites during mid-July. It is suspected that many Parakeet Auklets were prevented from nesting during 1976 because of the heavy and prolonged snow conditions on the brow of Owalit Mountain.

During 1976, Tufted Puffins were first observed from shore on 17 May. Horned Puffins were not seen until 25 May but may have been present earlier. Fay and Cade (1959) stated that during their period of study (1950-1958) Horned Puffins arrived between 15 and 20 May--3 to 4weeks earlier than the arrival of Tufted Puffins. During 1966 and 1967, Scaly (1973: 109) first recorded Horned Puffins at St. Lawrence Island on 28 and 26 May, respectively. Eskimo hunters first saw this species offshore from Gambell on 8May during 1973 (Johnson in press). During 1976, Horned

Puffins were present on the cliffs at Kongkok Bay when I arrived on 27 May; Tufted Puffins were first seen on the cliffs on 28 May. A summary of arrival dates of Horned and Tufted Puffins on St. Lawrence Island is presented in Table 5.

TABLE 5. Spring Arrival Dates of Horned and Tufted Puffins on St. Lawrence Island, Alaska (adapted from Scaly 1973:109).

Year	Horned Puffin Arrival Date	Tufted Puffin Arrival Date
1952	17 May	4 June
1953	15 May	?
1954	22 May	?
1958	?	23 May
1961	5 May	?
1966	28 May	23 May
1967	26 May	26 May
1973*	8 May	early May
1976†	25 May	17 May

*Johnson (In press).

i-Present Study

Pigeon Guillemots were first observed from shore on 16 May but according to local residents they had been present in offshore areas since late April. A few Black Guillemots (*Cepphus grylle*) or Pigeon Guillemots may winter in the St. Lawrence Island area (Ryder cited by Fay and Cade 1959). During 1966, Scaly (1967) first observed Pigeon Guillemots at Gambell on 17 May. Pigeon Guillemots were present on the cliffs at Kongkok Bay when I arrived on 27 May. The first young of this species were seen on 24 August but they did not become abundant on the water at Kongkok Bay until 26 August.

Herring Gulls were first seen at Gambell on 15 May, but they may have been present earlier. They were present near Gambell after the first week in May during 1973 (Johnson in press). None were seen at Kongkok Bay on 19 May 1976 but several Herring Gulls were present there when I returned on 27 May.

Population Estimates

Least and Crested Auklets

Table 6 presents the estimated number of auklets in the Kongkok Bay colonies during 1966 (Bédard 1969a:391) and 1976. The three dimensional nature of auklet nesting habitat precludes total counts of auklets even in a small area because an unknown percentage of birds remain out of sight beneath the talus boulders. Therefore, these estimates should be taken more as an index of population size rather than as a population estimate.

The extent of snow cover is an important factor that influences the number of auklets that can be counted. Data from two plots indicate the degree to which the number of auklets present on snow-free plots were underestimated. Approximately 380 auklets were counted on plot AB02 when this plot was 99% snow-covered but only 90 auklets were counted when the snow-cover receded to 50% of the plot. Similarly, the number of auklets that were counted on plot AB06 declined from about 270 when the plot was 99% snow-covered to 190 when the plot was only 5% snow-covered*. As rock crevices become available, many auklets spend a great portion of their time out of sight among the rocks. Therefore, counts of auklets on plots with over 90% snow-cover are probably more accurate representations of the number of auklets that nest on the plots than are counts of auklets on plots with less snow cover. Counts of auklets on plots with less than 90% snow cover probably result in an underestimate of the true number of birds that are present. However, because most plots were snow-free, or nearly so, when auklets began to land on the talus slopes, the majority of plots could not usefully be censused for auklets when they were more than 90% snow-covered. Therefore, for comparative analysis of the number

*Unfortunately, censuses of other plots either were not initiated until the snow covered less than 50% of the plots or censuses were terminated when plots were more than 50% covered. In both situations, the number of auklets counted did not change significantly from day to day.

TABLE 6. Summary of the Number of Least and Crested Auklets in the Kongkok Bay Colonies during 1966 and 1976.

Location	Area (m²) of Nesting Habitat[c]	Density of Breeding Birds/200m²		Total Number Breeding Birds[c]		Total Number Birds, Breeding and Non-breeding[g]		Number of Birds In Colony
		Least	Crested	Least	Crested	Least	Crested	
Kongkok Basin[a]	715,000	34.4	29.9	123,000	107,000	189,000	165,000	354,000
Kongkok Basin[b]	715,000[d]	-	-	240,000[f]	127,000[f]	369,000	195,000	"564,000[f]
Stratum 1	624,000[h]	67.0	35.6	209,000	111,000	322,000	171,000	
Stratum 2	45,000[h]	39.0	5.6	9,000	1,000	14,000	2,000	
Total	669,000[h]	65.1[e]	33.6[e]	218,000	112,000	336,000	173,000	509,000
Owalit Mtn.[b]	35,000	63.8	13.6	11,000	2,000	17,000	3,000	20,000

[a]Data from Bédard (1969a) for 1966

[b]Data for 1976 from present study

[c]Figures rounded to nearest 1000

[d]Based upon area of basin given by Bédard (1969a:391)

[e]Weighted mean of strata 1 and 2

[f]Extrapolation from Stratum 1 only in order to maintain comparison with Bédard (1969a)

[g]Assumes 35% of population are non-breeding birds (Bédard 1969a:386)

[h]Area of basin calculated in field during 1976

of auklets that are present on each plot, it was necessary to use only the numbers of birds that were counted on plots that were relatively snow-free. Accordingly, results of censuses from plots were used only when the plots were less than 50% covered with snow. Using this method, the results are comparable from plot to plot even though they are an underestimate of the total number of auklets that are present.

The data from the two plots with 99% snow-cover suggest that the estimate of approximately 500,000 auklets in Kongkok Basin underestimates the actual number of auklets there by 33% to 50%. If this is so, then the actual number of auklets present in Kongkok Basin is between 750,000 and 1 million birds.

During the 10 years between 1966 and 1976, auklet numbers in the Kongkok Basin colony increased a total of 59%. Much of this increase was due to a 95% increase in the number of Least Auklets. However, Crested Auklets also showed an 18% increase. Unfortunately, there are no data between 1966 and 1976 that would indicate whether the population change has been a steady increase, a rapid increase, or a combination of increases and decreases. Also, there is no information available to determine whether the population is still increasing, whether it has stabilized, or whether it has begun to decrease in numbers.

In order to arrive at the population estimates presented in Table 6, extrapolations were made over the area from which plots were randomly selected. However, large areas of talus also exist on the seaward side of both Owalit and Ivekan mountains; these areas could not be sampled from shore. Densities of auklets in these areas appeared to be similar to the inland talus slopes that were sampled. The auklets present on these slopes add greatly to the total number of auklets present in the Kongkok Bay area.

Relation of Density to Habitat Characteristics

Bédard (1969a) investigated several environmental characteristics that could operate with a complex of regulators to determine the set point of auklet numbers on St. Lawrence Island. Set point refers to the mean level about which the population 1 evel fluctuates (Wilbert 1969). Bédard

(1967, 1969a) used a correlation approach in order to identify the characteristics which were most closely associated with auklet density. I attempted to investigate the correlation between auklet numbers and their breeding habitat in more detail. I compared auklet density to the physical characteristics of 24 plots by using stepwise multiple regression analysis (SMRA) as described above. Table 7 presents the simple correlation coefficient between each pair of variables. "

Least Auklets

After analysis of the residuals, no evidence of violations of the normality, homoscedasticity or linearity assumptions was found. The results of SMRA are presented in Table 8. The density of Least Auklets was very strongly related to the predictor variables. The regression model apparently accounted for 77.9% of the variance, but this value is undoubtable an overestimate of the real predictability of population density from the physical characteristics of the plots; too few plots were censused (in relation to the number of predictor variables considered) to permit determination of the actual percentage of the variance explained (Lane 1971).

Least Auklets were positively correlated with the number of Crested Auklets. The number of Crested Auklets, however, is also related to several habitat characteristics such as depth, etc. (see below and Table 7), and the number of Least Auklets may be related to some of these same habitat features. Aggressive encounters between Least and Crested Auklets, though limited, might tend to result in a negative correlation between the numbers of both species. Bédard (1969a) found such a negative correlation to exist. However, as depth (and therefore the number of Crested Auklets) increases, the number of interstices (i.e., potential Least Auklet nest sites) also increases; thus, the density of Least Auklets, the density of Crested Auklets and depth should all be positively correlated when auklets are present in relatively high densities. Under low density conditions, Least Auklets may be able to nest to a greater extent in areas free, or nearly so, of Crested Auklets.

TABLE 7, Matrix of Simple Correlation Coefficients for Variables Considered as Potential Predictors of Auklet Densities.*

	VARIABLE	PLOT CHARACTERISTICS: DIRECTION	ALTITUDE	SLOPE	PERCENT SCREE	DISTANCE TO EDGE	DEPTH OF SCREE	DEPTH S.D.	SCREE CHARACTERISTICS: SPHERICITY	SPHERICITY S.D.
PLOT CHARACTERISTICS	Direction	1.000	-0.586	0.162	-0.048	-0.502	-0.405	-0.261	0.279	0.385
	Altitude		1.000	0.024	-0.405	0.590	-0.265	-0.102	-0.556	-0.684'
	Slope			1.000	-0.180	0.019	-0.150	-0.016	0.004	0.104
	Percent Scree				1.000	-0.145	0.624	0.110	0.131	0.342
	Distance To Edge					1,000	0.266	0.455	-0.341	-0.337
	Depth of Scree						1.000	0.705	0.266	0.359
	Depth S.D.							1.000	0.412	0.361
SCREE CHARACTERISTICS	Sphericity								1.000	0.840
	Sphericity S.D.									1.000

	VARIABLE	SCREE CHARACTERISTICS: VOLUME	VOLUME S.D. (BETWEEN SUBPLOTS)	VOLUME S.D. (WITHIN SUBPLOTS)	DIAMETER	DIAMETER S.D. (BETWEEN SUBPLOTS)	DIAMETER S.D. (WITHIN SUBPLOTS)	AUKLET NUMBERS: NUMBER OF CRESTED AUKLETS	NUMBER OF LEAST AUKLETS
PLOT CHARACTERISTICS	Direction	0.046	0.139	0.065	-0.163	0.082	-0.105	-0.735	-0.340
	Altitude	-0.254	-0.253	-0.216	-0.226	-0.403	-0.291	0.210	-0.070
	Slope	0.056	0.067	0.135	-0.032	-0.029	0.038	-0.247	0.271
	Percent Scree	0.110	0.054	0.189	0.239	0.098	0.272	0.538	0.333
	Distance to Edge	0.042	-0.060	0.080	0.211	-0.158	0.071	0.347	-0.273
	Depth of Scree	0.431	0.281	0.444	0.669	0.354	0.629	0.744	0.412
	Depth S.D.	0.691	0.590	0.692	0.771	0.560	0.753	0.379	0.071
SCREE CHARACTERISTICS	Sphericity	0.711	0.718	0.543	0.431	0.799	0.529	-0.035	-0.031
	Sphericity S.D.	0.557	0.537	0.533	0.390	0.616'	0.563	0.006	-0.016
	Volume	1.000	0.975	0.922	0.842	0.894	0.829	0.072	-0.031
	Volume S.D. (Between Subplots)		1.000	0.898	0.727	0.910	0.753	-0.023	-0.077
	Volume S.D. (Within Subplots)			1.000	0.827	0.738	0.899	0.101	0.005
	Diameter				1.000	0.700	0.883	0.230	0.138
	Diameter S.0. (Between Subplots)					1.000	0.720	0.030	-0.019
	Diameter S.D. (Within Subplots)						1.000	0.264	0.150
AUKLET NUMBERS	Number of Crested Auklets							1.000	0.440
	Number of Least Auklets								1.000

*Correlations are significant at $P < 0.05$ if their absolute values lie between 0.404 and 0.515,
$P < 0.01$ if their absolute values lie between 0.515 and 0.630,
$P \le 0.001$ if their absolute values exceed 0.630.

TABLE 8. Multiple Regression Equation for the Density of Observed Least Auklets. A stepwise analysis of 16 potential predictor variables (Table 7) was used.†

Dependent Variable	Constant	Independent (Predictor) Variable	Significance Level of Partial Correlation	Simple Correlation Coefficient
Number of Least Auklets	=2.14	+(1.49 ± 0.33) (Slope)	***	+ 0.271
		-(0.31 ± 0.05) (Distance to edge of talus)	***	-0.273
		+(0.78 ± 0.27) (Depth of scree)	***	+ 0.412
		-(188.76 ± 51.18) (Sphericity S. D.)	***	- 0.016
		+(0.59 ± 0.28) (Number of Crested Auklets)	**	+ 0.440

R= 0.88 Variance Explained = 77.9% SE= 17.21

†Table presents the coefficient of each predictor variable within the equation, its standard error, the significance level of the partial correlation for each variable,

(*) $0.1 \geq P > 0.05$

* $0.05 \geq P > 0.01$

** $0.01 > p > 0.001$

*** $p < 0.001$

and the simple correlation coefficient of each variable with the independent variable.

The bottom line of the table presents the multiple correlation coefficient, the percentage of the variance that is accounted for by the regression equation and the standard error of the estimate.

After the effect of the number of Crested Auklets present on the plot was considered, Least Auklet numbers were correlated with the distance of the plot from the nearest edge of continuous scree. This correlation was negative. The numbers of Least Auklets on the plots were positively correlated with the angle of slope. Therefore, numbers of Least Auklets were largest on very steeply oriented plots and smallest on the more nearly level plots. The angle of slope normally would be expected to affect the size of the boulders that are present because large rocks would presumably tend to accumulate in areas of lower slope. However, examination of Table 7 and the steps of SMRA (Table 9) revealed no strong correlations between slope and rock size. Perhaps geologic agents such as frost heaving, etc. result in extensive mixing of the talus (Bédard 1969a:387) which serves to destroy any correlation between slope and rock size.

The number of Least Auklets was negatively correlated with the standard deviation of the sphericity of the talus boulders. (Because there is a high degree of correlation [0.840] between the standard deviation of the sphericity and the sphericity measurement itself [once the standard deviation of the sphericity was considered in the equation], the sphericity measurement would not improve the fit of the regression line significantly and therefore did not enter the equation. For the purposes of this discussion, the standard deviation of the sphericity is considered to be equivalent to the sphericity.) Thus, more Least Auklets were found on plots with angular rocks than on plots in which the rocks tended toward an oval or round shape.

The density of Least Auklets was also highly correlated with the depth of scree. More auklets tended to occur on plots with deeper scree. Probably either the increased number of interstices between rocks in deeper talus creates more nest sites, or, if territories are partitioned on a three-dimensional scale, an increased depth would also increase the number of territories that could be located within a 200m^2 plot.

TABLE 9. Stepwise Multiple Regression Analysis of the Density of Least Auklets[1].

Variable	STEP 1	2	3	4	5
VARIABLES INCLUDED					
Number of Crested Auklets	+*	+***	+***	+***	+**
Distance to Edge of Scree		-**	-***	-***	-***
Slope			+***	+***	+***
Sphericity S.D.				-*	-***
Depth					+***
VARIABLES EXCLUDED					
Direction	-ns	-ns	-(*)	- ns	-ns
Altitude	-ns	+ns	+ns	- ns	+ns
Slope	+*	+***			
Percent "Scree	+ns	-ns	-ns	+ns	-ns
Distance to Edge of Scree	-*				
Depth of Scree	+ns	+ns	+ns	+***	
Depth S.D.	-ns	+ns	+ns	+**	+ns
Sphericity	-ns	-ns	-*	+ns	+ns
Sphericity S.D.	-ns	-ns	-ns		
Volume	-ns	-ns	-ns	+ns	-ns
Volume S.D. (Between Subplots)	-ns	-ns	-ns	+ns	-ns
Volume S.D. (Within Subplots)	-ns	-ns	-ns	+ns	-ns
Diameter	+ns	+ns	+ns	+**	+ns
Diameter S.D. (Between Subplots)	-ns	-ns	-ns	+ns	-ns
Diameter S.D. (Within Subplots)	+ns	+ns	-ns	+ns	+ns

[1]Columns labeled 1-5 are the partial correlations of the predictors to the density of Least Auklets. The significance levels (as in Table 8) refer to the partial correlations after the variables in the upper section have been included in the model.

Crested Auklets

The basic assumptions of SMRA were not violated during the regression analysis involving the density of Crested Auklets as the dependent variable. 'The results of SMRA are presented in Table 10. The density of Crested Auklets was very strongly correlated to the variables used as predictors (Tables 10 and 11). The resultant regression equation apparently accounted for 89.4% of the variance, but, as for the regression analysis involving the density of Least Auklets, the value is undoubtable overestimated.

The number of Crested Auklets observed on the plots was negatively correlated with the extent to which the plot was oriented away from SSW (the direction of nearest water). Therefore, plots that faced SSW had the highest density of Crested Auklets.

Crested Auklet density was also correlated with the depth, the standard deviation of the volume (considered to be identical to volume), and the diameter of the boulders. However, all three of these variables are highly correlated with each other. Thus deeper scree was found in areas where there were larger particles; higher numbers of Crested Auklets were present in these areas than on plots with more shallow scree composed of smaller sized particles.

The density of Crested Auklets was also significantly correlated ($P < 0.01$) with the percent of the plot that was covered with scree. The percent of scree cover was also correlated with the depth of scree. However, once depth was considered in the regression model, percent of scree cover did not significantly reduce the variance; thus, percent of scree cover was not incorporated into the regression equation.

The results of SMRA of the habitat characteristics of Least and Crested Auklets differ from the results of Bédard (1967, 1969a). However, Bédard assumed that the density of auklets was correlated with the percentage of the quadrat that was occupied by the birds (approximately

TABLE 10. Multiple Regression Equation for the Density of Observed Crested Auklets. A stepwise analysis of 1-6 potential predictor variables (Table 7) was used.†

Dependent Variable	Constant	Independent (Predictor) Variable	Significance Level of Partial Correlation	Simple Correlation Coefficient
Number of Crested Auklets	=57.10	-(0.30 ± 0.05) (Direction)	***	- 0.735
		+(0.75 ± 0.10) (Depth of scree)	***	+ 0.744
		+(0.05 ± 0.02) (Volume S.D., within subplots)	**	+ 0.101
		-(15.23 ± 3.58) (Diameter of scree)	***	+ 0.230

R= 0.945 Variance Explained = 89.4% SE= 7.81

†Presented as in Table 8.

TABLE 11. Stepwise Multiple Regression Analysis of the Density of Crested Auklets*.

Variable	Step 1	Step 2	Step 3	Step 4
VARIABLES INCLUDED				
Depth of Scree	+***	+***	+***	+***
Direction		-***	-***	-***
Diameter			-***	-***
Volume S.D. (Within Subplots)				+**
VARIABLES EXCLUDED				
Direction	-***			
Altitude	+**	+ns	+ns	+ns
Slope	-ns	-ns	-ns	-ns
Percent Scree	+ns	+**	+*	+*
Distance to Edge of Scree	+ns	-ns	-ns	-ns
Depth S.D.	-ns	-*	-ns	-ns
Sphericity	-(*)	-ns	+ns	+ns
Sphericity S.D.	-*	+ns	+ns	-ns
Volume	-*	-(*)	+*	+ns
Volume S.D. (Between Subplots)	-(*)	-ns	+*	+ns
Volume S.D. (Within Subplots)	-(*)	-ns	+**	
Diameter	-**	-***		
Diameter S.D. (Between Subplots)	-(*)	-ns	+ns	+ns
Diameter S.D. (Within Subplots)	-(*)	-(*)	+ns	-ns
Number of Least Auklets	+ns	+ns	-ns	ins

*Columns labeled 1-4 are the partial correlations of the predictors to the density of Crested Auklets. The significance levels (as in Table 8) refer to the partial correlations after the variables in the upper section have been included in the model.

equal to the percent scree cover) and the depth of the scree; he adjusted the densities to correct for variations in these parameters. Bédard then used these adjusted densities and found them to be highly correlated with the average diameter of the talus boulders on the plots. Apparently, the only other parameter Bédard measured at Kongkok Basin was the altitude of the plots (Bédard did not measure the angle of slope at Kongkok where the slope can differ widely). The resultant simple linear regression between the common logarithm of the corrected density and the average diameter of boulders on the plots accounted for 98.6% and 82.4% of the variability for Least and Crested Auklets, respectively (Bédard 1969a). The models constructed for the 1976 auklet data which used uncorrected auklet densities explained less of the variance for Least Auklet densities but explained a slightly higher portion of the variance for Crested Auklet densities.

It should be noted that the simple correlations expressed in Table 7 and column 4 of Tables 8 and 10 are not the same as the partial correlations expressed in Tables 9 and 11 and column 3 of Tables 8 and 10. A partial correlation measures the degree of correlation between pairs of variables when other variables are held constant (Sokal and Rohlf 1969: 540). Simple linear correlation measures the correlation between pairs of variables when other variables are ignored (Fryer 1966:438). When dealing with intercorrelated variables, the addition of one variable to the model will lower the partial correlation of other related variables. The degree to which the partial correlation is affected by the inclusion of one variable in the model is proportional to the amount of correlation between the two predictor variables (Richardson 1974:314). Many of the independent variables considered in the previous regression analyses are correlated with each other and therefore could be substituted for one another in the model. Parameters that have entered the model, therefore, are representative of groups of interrelated variables and may not themselves represent a cause-and-effect relationship with density.

Common and Thick-billed Murres

Activity Cycles

The pattern of daily murre presence on the breeding cliffs during June and July is presented in Figures 5 and 6. During June maximum numbers were present on the cliffs between 04:00 and 12:00; numbers gradually declined in the afternoon and evening then increased from low or near low numbers at 24:00 to high or near high numbers at 04:00. The pattern of activity was similar but less distinct during July.

Tuck (1960:120) found that the numbers of Thick-billed Murres on the cliffs during June at Cape Hay, Bylot Island, N.W.T., Canada, (74°N latitude) changed little throughout the day. His results during July, were similar to those recorded at Kongkok Bay, St. Lawrence Island, (63°N latitude) during June, 1976. Birkhead's (1976:156) data from Skomer Island, Wales, (52°N latitude) show that Common Murres were present in high and nearly constant numbers from 08:00 to 20:00 throughout the season and were nearly absent from the cliffs at night.

Because of the rather high' and stable numbers of murres on the breeding cliffs of Owalit Mountain during the morning hours, no correction factor was necessary for the following estimates of the number of murres present on the cliffs.

Estimates

Estimates of the number of murres were based upon counts made during mid to late July (see Nettleship 1976a:21; Birkhead 1976:154). The density of murres on five plots was calculated to be 10.6/100 m^2. Densities ranged from a low of 1.8/100 m^2 to a maximum of 45.7/100 m^2. Extrapolation of the average density of murres over the 150,000 m^2 cliff area of Owalit Mountain resulted in an estimated total of 15,900 murres.

Counts made independently by two observers during a cliff survey on 26 July 1976 yielded 15,495 and 15,875 murres. These are probably underestimates of the total number of murres present on the cliffs because all

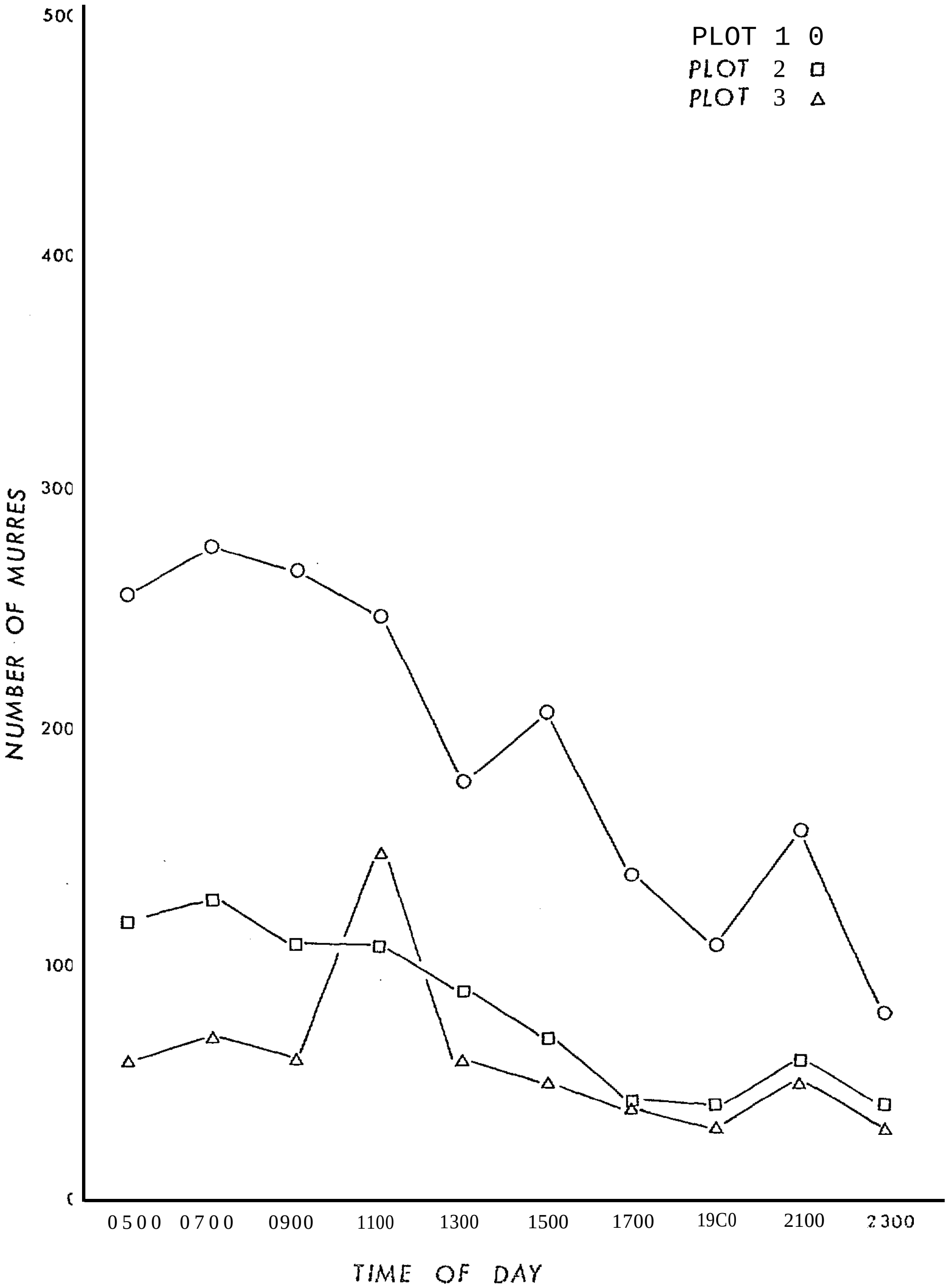


FIGURE 5. Average Number of Murres Present on the Three Activity Plots at Various Times during the Day between 11 and 27 June 1976.*

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* Appendix 4 presents the number of birds per hour present on the activity plots during each day of observation.

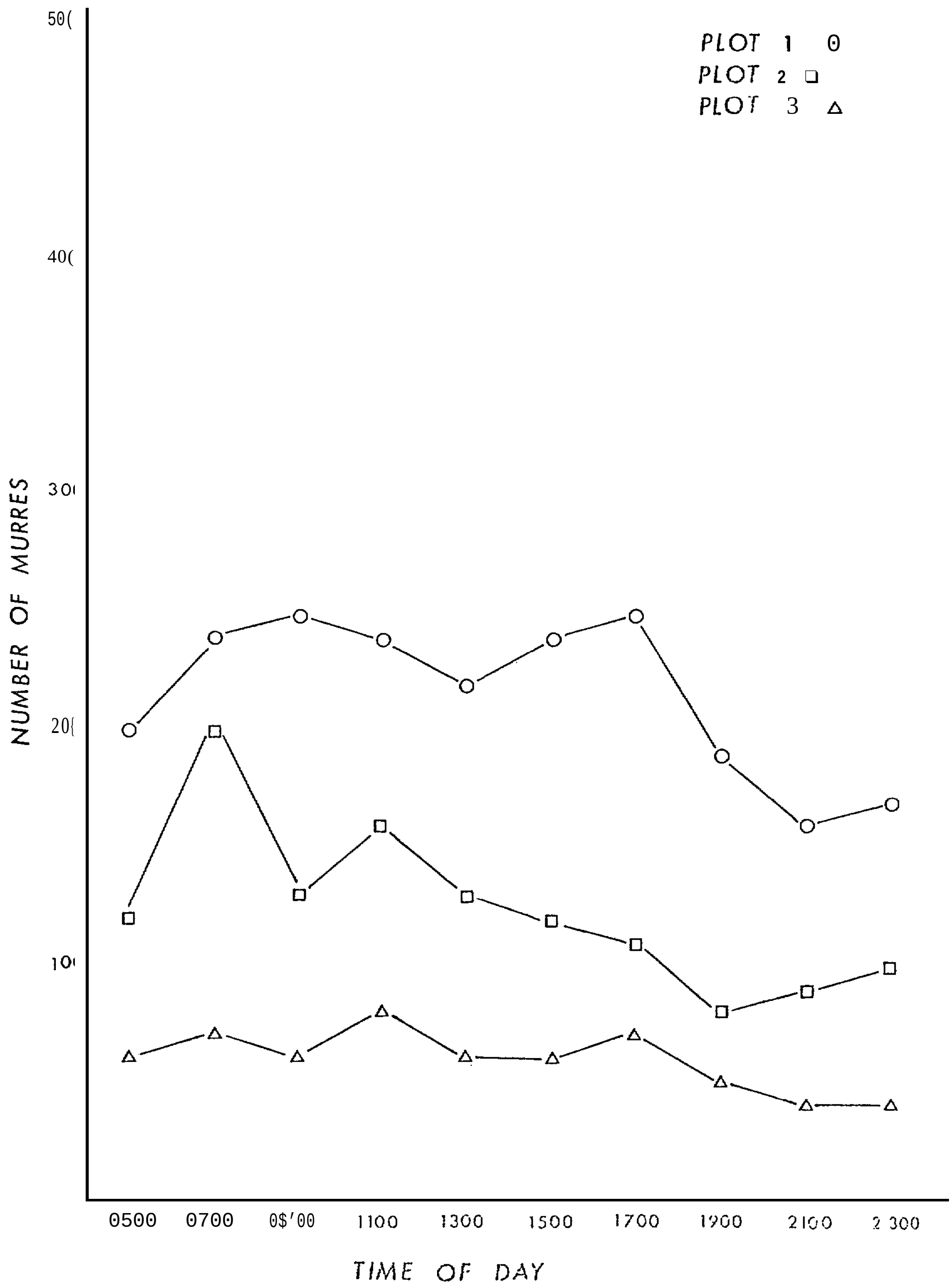

FIGURE 6. Average Number of Murres Present on Three Activity Plots at Various Times during the Day between 11 and 19 July 1976 (see also Appendix 4).

murres on ledges could not be seen from the boat; however, the closeness of the two counts to each other and to the extrapolated estimate from the plots is striking.

One previous estimate of the number of murres on the cliffs of Owalit Mountain was made by S.R. Johnson (pers. comm.) during 1972. During surveys made on 12 and 14 August 1972 Johnson estimated approximately 60,000 murres on Owalit Mountain--almost four times the number present during 1976.

Although the reduction in the number of murres on the breeding ledges at Kongkok Bay from 1972 to 1976 was possibly due to an actual population decline, the reduction may also have been the result of the late presence of snow cover on the breeding ledges. The prolonged snow cover could have caused reduced numbers of murres on the ledges in several ways:

1. Birds may not have attempted to land on the snow-covered ledges. After the ledges had remained snow-covered for a longer than normal period of time, many birds may have left the Kongkok Bay area.
2. Birds that eventually landed on the cliffs after the snow had melted may not have been able to breed successfully (due to regression of the follicles, etc. } and may have left the Kongkok Bay area early.
3. Birds that failed to breed due to the prolonged presence of snow on the cliffs may have remained in the Kongkok Bay area but may have spent less time on the ledges than did incubating birds. Hence, I probably have underestimated the total number of birds present on the ledges by extrapolating from the weekly counts of birds on the plots.

Based upon a sample of 2560 murres that were identified to species, the ratio of Common to Thick-billed Murres on Owalit Mountain during 1976 was approximately 1:2. Fay and Cade (1959) reported that they found large fluctuations in the ratio of Common to Thick-billed Murres ranging from 1:2 to 1:100. Apparently, the ratio that is obtained is dependent upon where (on the cliffs) the counts are made. Although my data are few in this respect, no Common Murres were seen on the cliffs above 50 m. This is probably due to the fact that Common Murres prefer wider ledges than do Thick-billed Murres (Tuck 1960:80; Birkhead 1975:58; and others); nearly all of the ledges above 50 m were extremely narrow.

Black-legged Kittiwakes

Activity Cycles

The numbers of kittiwakes that were present on the breeding cliffs throughout the day differed greatly between June and July (Figures 7 and 8). More kittiwakes were present in the morning than in the evening during June, but this trend was reversed during July. The maximum number of kittiwakes that was counted on activity plots during July was 1.39 times the number counted on the activity plots between 10:00 and 12:00--the period during which the cliff plots were censused. Therefore, the estimates of kittiwake numbers that are presented below have been adjusted by a correction factor of 1.39.

Estimates

Extrapolated estimates of the number of kittiwakes present on the cliffs were based upon counts made during mid to late July. The average density of kittiwakes on the six plots was 0.8/100 m^2 and ranged from 0.0/100 m^2 to 5.2/100 m^2. The total corrected estimate of kittiwakes on the sea cliffs of Owalit Mountain based upon counts of birds on the plots was 1670. The average density of kittiwake nests on the plots was 0.4/100 m^2. Assuming that there is one pair of kittiwakes per nest, the extrapolated estimate of the number of breeding kittiwakes for the Owalit Mountain area is 1200 associated with 600 nests. During the cliff survey on 26 July, approximately 1380 kittiwakes were counted by both observers; the corrected estimate of the number of kittiwakes present on that date was 1920. Therefore, there were between 1700 and 1900 kittiwakes on the cliffs during mid to late July 1976, but only 60% to 70% of these birds were associated with nests.

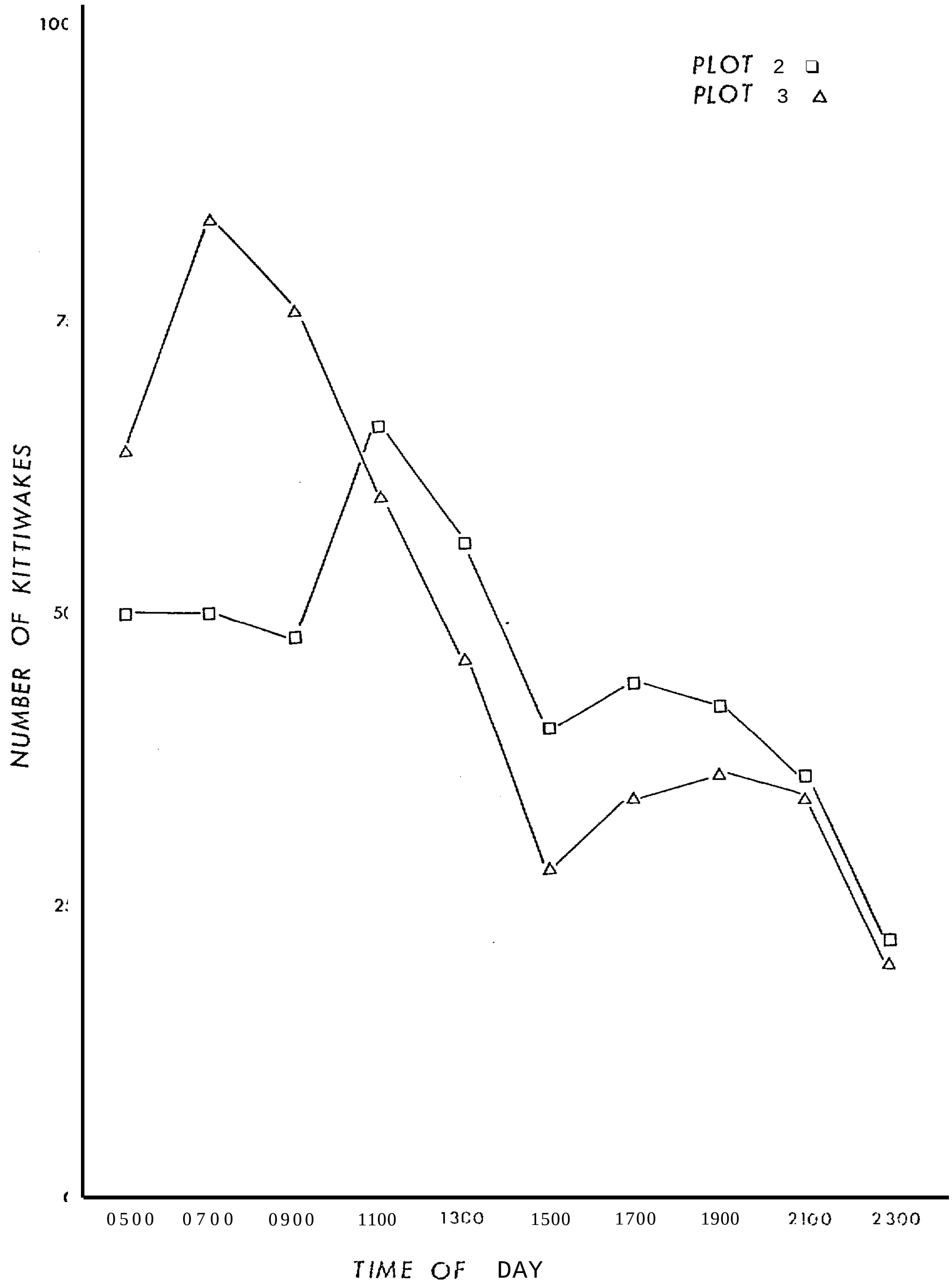

FIGURE 7. Average Number of Black-legged Kittiwakes Present on Two Activity Plots at Various Times during the Day between 11 and 27 June 1976 (no kittiwakes were present on Plot 1; see also Appendix 4).

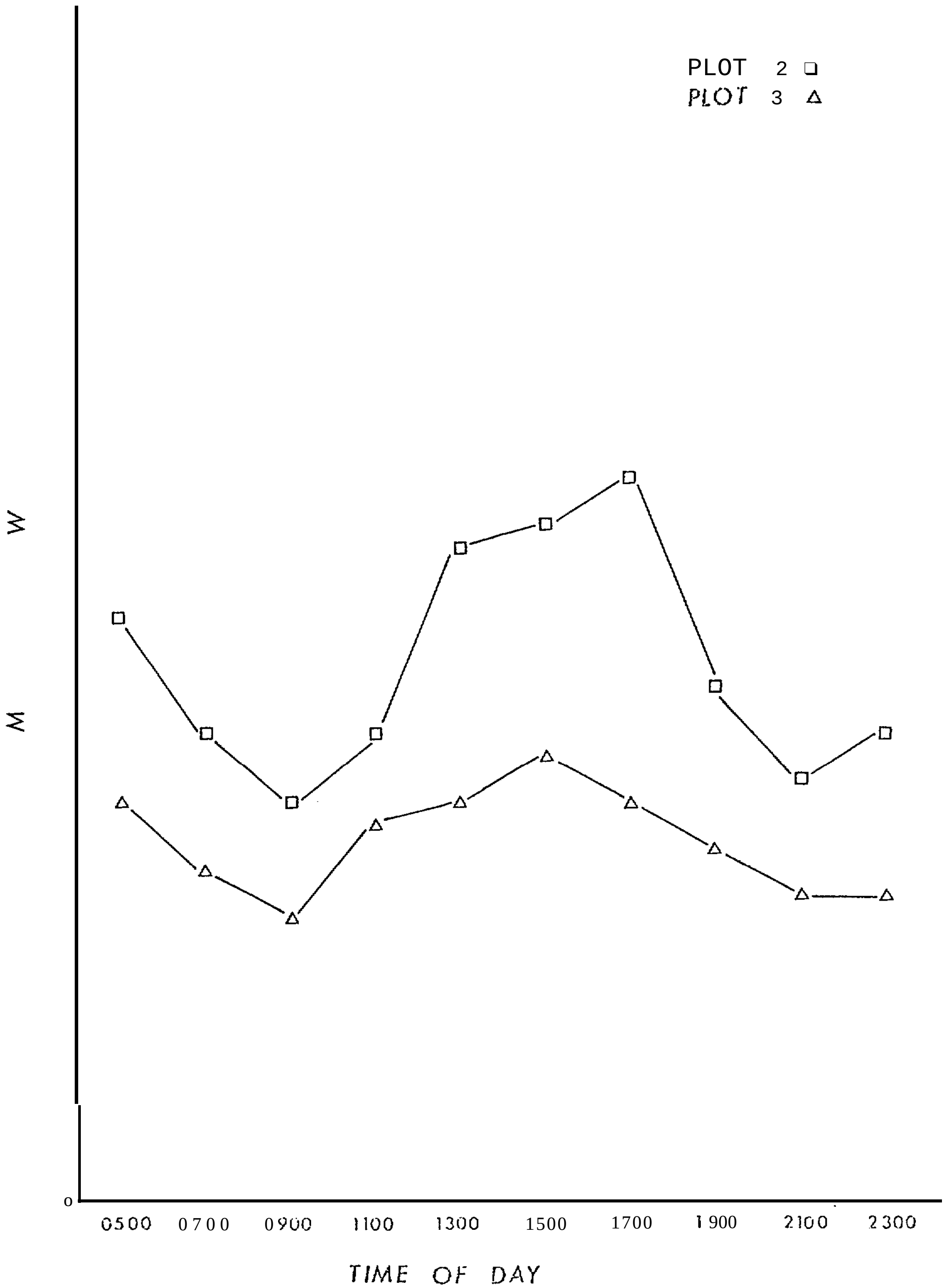

FIGURE 8. Average Number of Black-legged Kittiwakes Present on Two Activity Plots at Various Times during the Day between 11 and 19 July 1976 (no kittiwakes were present on Plot 1; see also Appendix 4).

Some of the difficulty of accurately estimating kittiwake numbers during 1976 was probably due to the fact that many kittiwakes did not lay eggs and a significant number did not even build nests. The latter situation may account for the discrepancy between estimates of kittiwake numbers based upon the number of nests and those based upon counts of birds. Therefore, the estimate based upon the number of nests is a better estimate of the number of breeding kittiwakes. However, because many kittiwakes that built nests did not lay eggs, even this estimate may be an overestimate of the number of kittiwakes that bred.

S.R. Johnson (pers. comm.) counted approximately 2000 kittiwakes during 1972 on a portion of the same cliffs that I surveyed during 1976. My count on this portion of the cliffs was only *225* kittiwakes. An even greater contrast between years exists when the number of kittiwake nests is considered. Johnson counted 1458 nests in this area during 1972 compared to an estimated 85 nests that were present there during 1976. The lower number of kittiwakes per nest during 1972 (1.3) than during 1976 (2.6) was probably another result of the differences in breeding success of kittiwakes during the two years. During 1972, most kittiwakes that nested apparently bred successfully (S.R. Johnson pers. comm.). Each member of an incubating pair is likely to spend a considerable amount of time feeding away from the nest; these birds have a lower probability of being counted. During years of partial breeding failure such as 1976, although kittiwakes may spend less total time on the ledges than during years in which they breed more successfully, both members of a pair may be present at their nest during periods when kittiwakes are present at the cliffs in peak numbers. Also, non-nesting (subadult) birds would be present on the cliffs (Coulson and White 1958); these "extra" birds could account for the excess of two birds per nest that was noted during the present study.

Large fluctuations in the number of breeding kittiwakes from one year to the next have been described in a colony in eastern Canada (Maunder and Threlfall 1972:790). It is unknown whether large declines in the number of breeding kittiwakes result from a reduction in the population of kittiwakes or merely from the absence of kittiwakes at the cliffs. Failure to arrive or remain at the cliffs may be due to factors such as late seasons, lack of sufficient food resources, lack of nesting space, or a change in the age ratio that favours young birds which may not remain on the breeding cliffs.

Pelagic Cormorants

Activity Cycles

The activity patterns of Pelagic Cormorants were inconsistent between plots (Figures 9 and 10). The number of cormorants on both Plots 1 and 2 did not fluctuate greatly during the day because most birds that were counted during both June and July were incubating eggs or young. There were no nests of Pelagic Cormorants on Plot 3. Cormorants on this plot were possibly members of nesting pairs that were preening and drying their feathers on the flat portion of the plot. The large increase in the numbers of Pelagic Cormorants on Plot 3 between 09:00 and 17:00 was probably due to the influx of birds returning from feeding trips. A low number of birds on the plot (e.g., between 04:00 and 10:00) probably indicates that a large number of birds were at sea feeding. Because of the variable nature of the data, no correction factor was developed for the estimate of the number of Pelagic Cormorants.

Estimates

Estimates of the number of Pelagic Cormorants that bred on the Owalit Mountain cliffs were based upon counts of birds and nests on six plots during June and early July. The average density of cormorants on the plots was 0.2/100 m^2 and ranged from 0.0/100 m^2 to 0.6/100 m^2. Extrapolation of these densities on the entire cliff area of Owalit Mountain resulted in a total estimate of 300 Pelagic Cormorants.

The average density of cormorant nests on the plots was 0.1/100 m^2. Therefore, the number of breeding cormorants was estimated to be 300 on 150 nests. Additional, non-breeding cormorants were probably also present

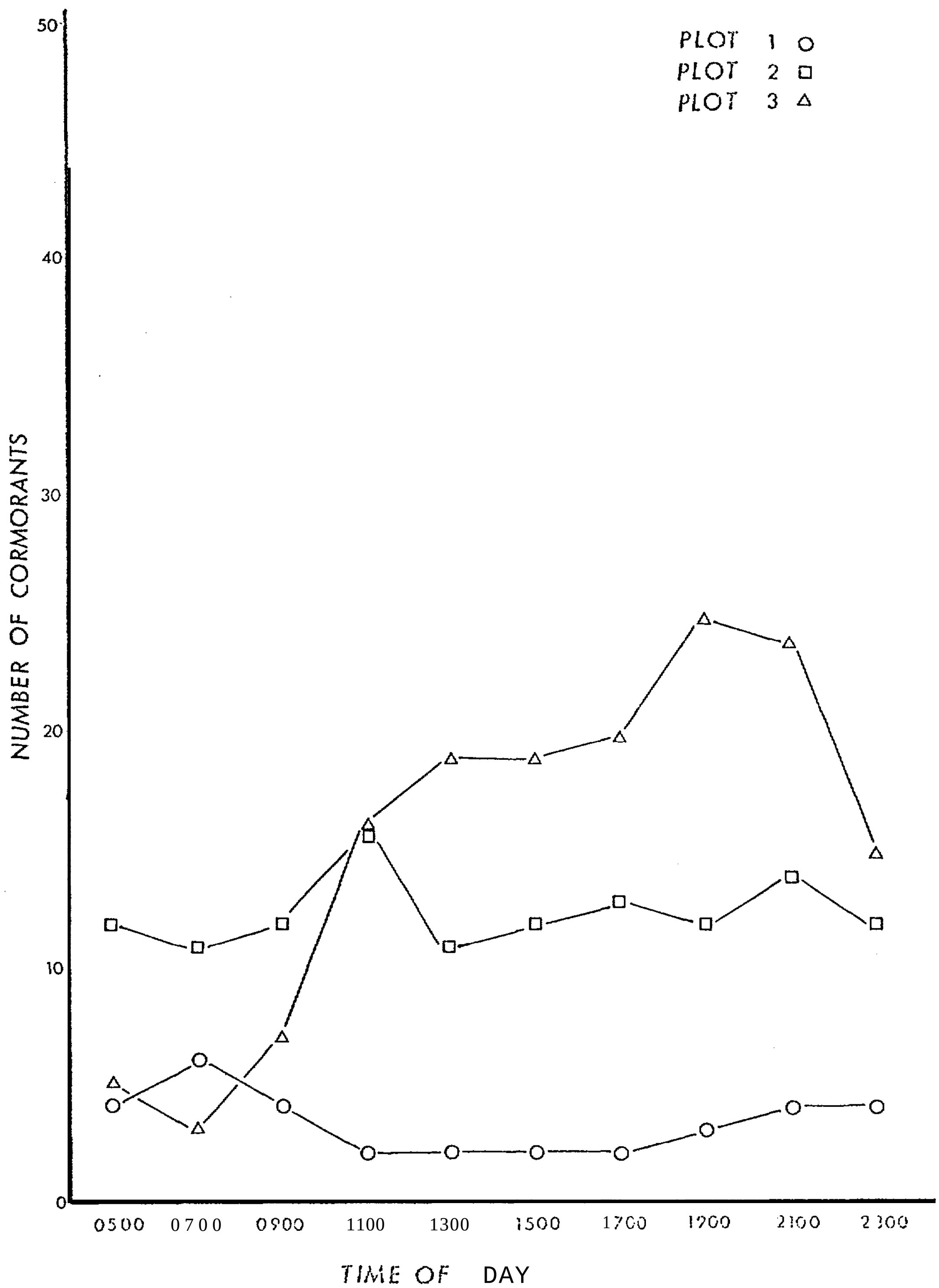

FIGURE 9. Average Number of Pelagic Cormorants Present on the Three Activity Plots at Various Times during the Day between 11 and 27 June 1976 (see also Appendix 4).

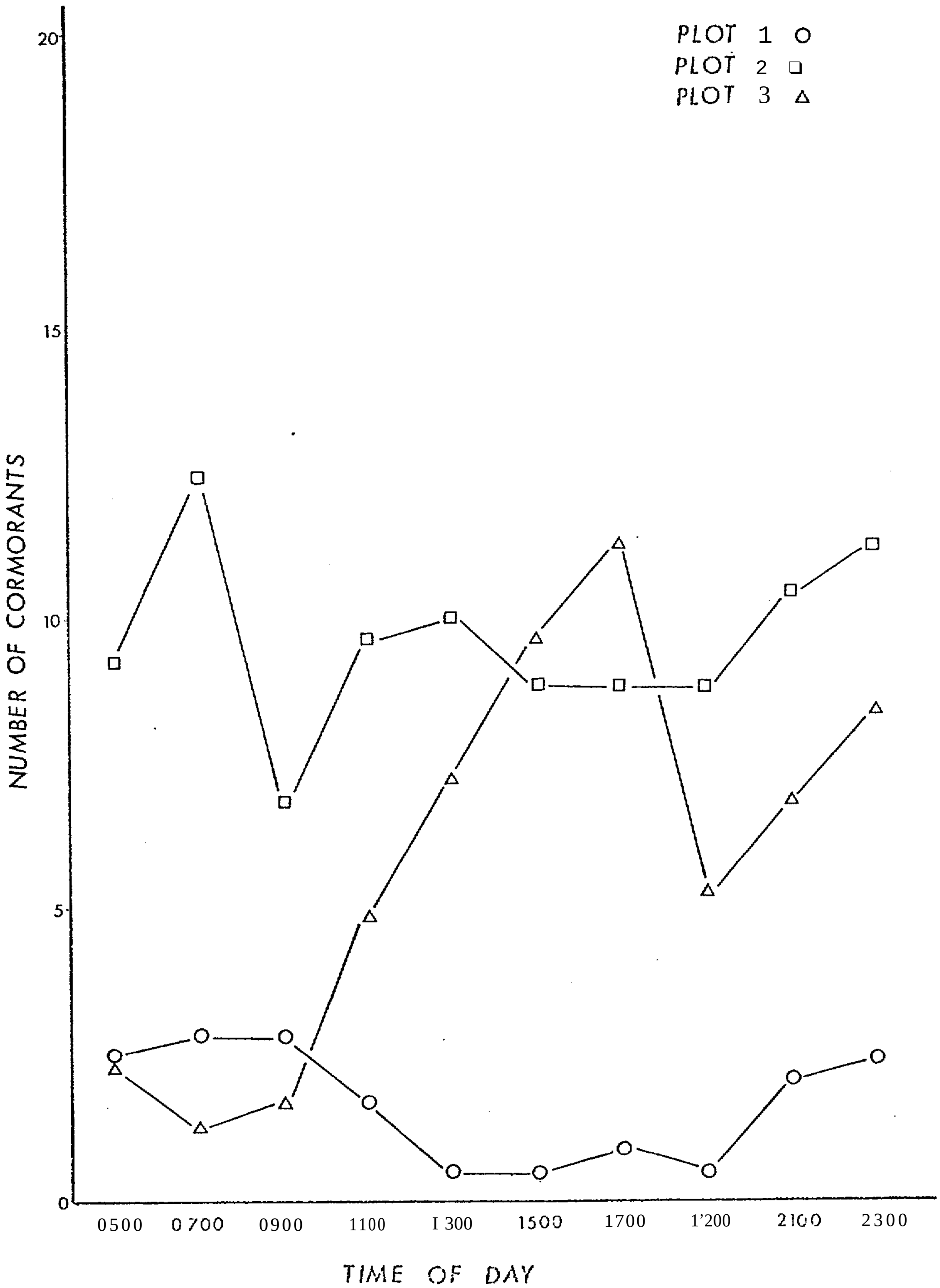

FIGURE 10. Average Number of Pelagic Cormorants Presenton the Three Activity Plots at Various Times during the Day between 11 ant-1 19 July 1976 (see also Appendix 4).

on the breeding cliffs (Palmer 1962:353). During August 1972, S.R. Johnson (pers. comm.) counted 58 nests on a portion of the Owalit Mountain cliffs (less than 1/3 of the total cliff area of Owalit Mountain); he estimated that 116 adult cormorants were associated with these nests.

Glaucous Gulls

Too few Glaucous Gulls were present on the plots to obtain an accurate density figure on which to base an estimate of the numbers present on the study area. Eight Glaucous Gull nests with eggs were located on two sea stacks in the study area and several more nests were present but were not accessible to me. I observed up to 20 Glaucous Gulls together at the base of Owalit Mounatin and I suspect that between 25 and 30 Glaucous Gulls were present and breeding on the cliffs of Owalit Mountain. In addition, an unknown number of immature gulls were present but they apparently roamed widely and could not be associated solely with the Owalit Mountain cliffs.

Parakeet Auklets

Activity Cycles

Parakeet Auklets were present on the cliffs in peak numbers between 06:00 and 08:00 each day during both June and July (Figures 11 and 12). During June, the numbers of Parakeet Auklets decreased during the late morning hours to a point where virtually no Parakeet Auklets were present on the cliffs after 14:00. During July, however, Parakeet Auklets remained on the cliffs later in the day; their numbers did not decline markedly until after 15:00. The number of Parakeet Auklets counted at the peak period was 1.27 times the number of auklets counted between 10:00 and 12:00. This correction factor was applied to the estimates of Parakeet Auklets below.

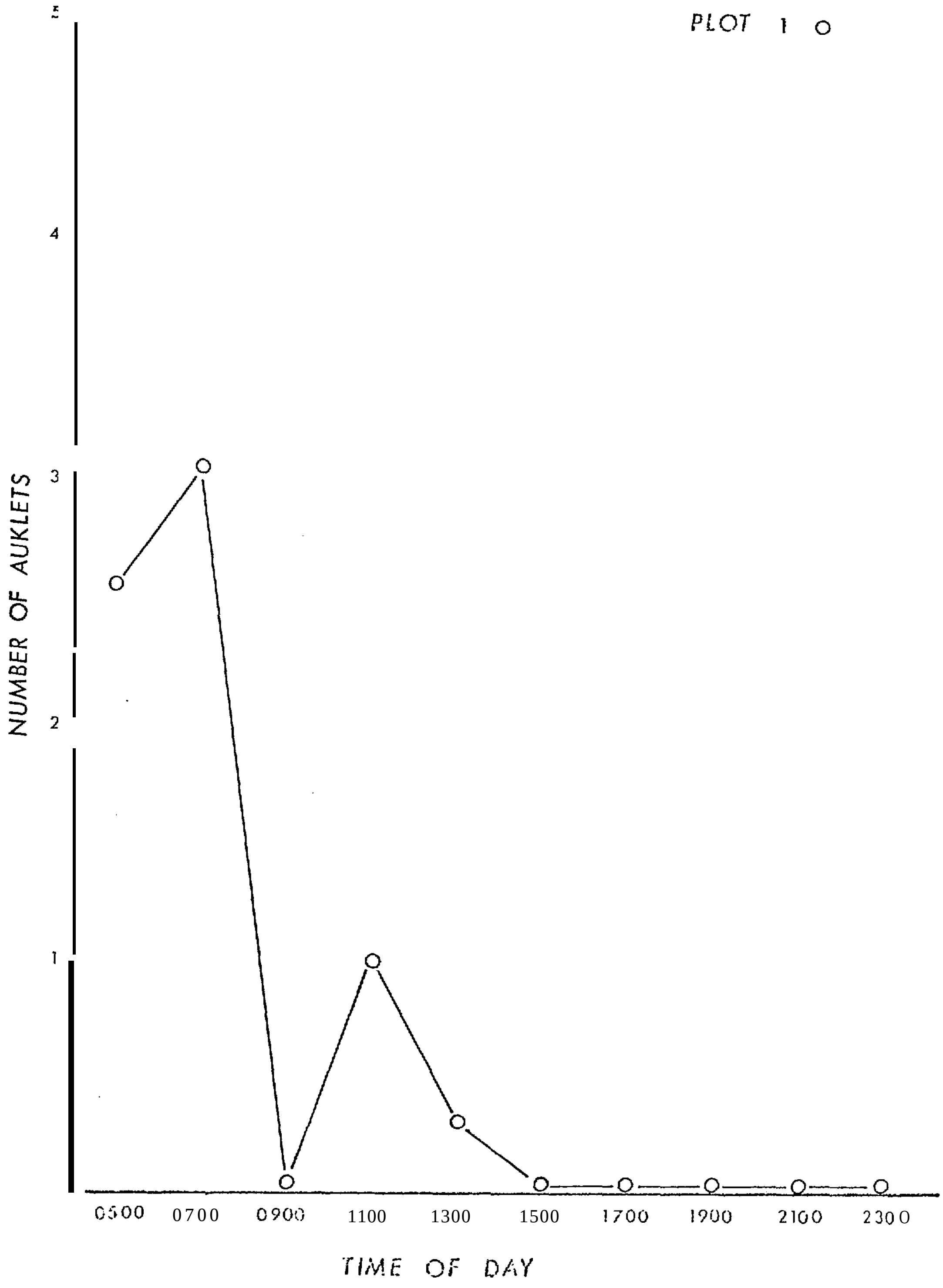

FIGURE 11. Average Number of Parakeet Auklets Present on One Activity Plot at Various Tines during the Day between 11 and 27 June 1976 (no auklets were present on Plots 2 or 3; see also Appendix 4).

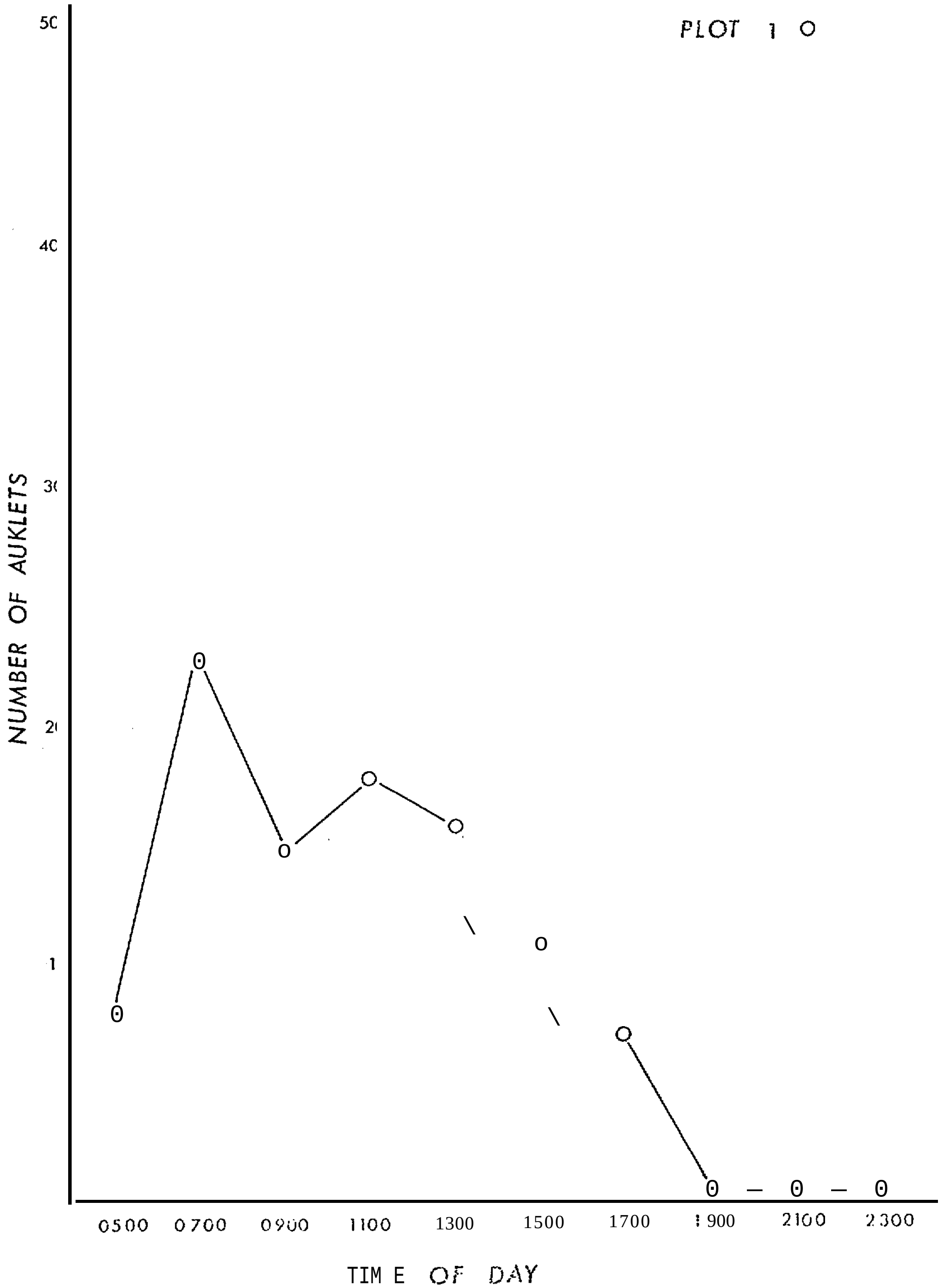

FIGURE 12. Average Number of Parakeet Auklets Present on One Activity Plot at Various Times during the Day between 11 and 19 July 1976 (no auklets were present on Plots 2 or 3; see also Appendix 4).

Estimates

The density of Parakeet Auklets on six plots that were surveyed during mid-July ranged from 0.0/100 m^2 to 2.6/100 m^2 and averaged 0.3/100 m^2. After applying the correction factor, an estimated 600 Parakeet Auklets were present on the cliff area of Owalit Mountain during peak attendance. Counts of Parakeet Auklets on the cliff plots were made incidental to counts of true cliff-nesting species. Most Parakeet Auklets nested under large boulders near the crest of Owalit Mountain and therefore were not counted on the cliff plots. I suspect that estimates of Parakeet Auklet numbers on Owalit Mountain that are based on the densities found on the plots are underestimated by 50 to 66 percent. Thus, it is very likely" that between 1200 and 1800 Parakeet Auklets nested on Owalit Mountain. Parakeet Auklets were by far the least numerous of the auklets; they comprised less than 1% of the auklet population of the Kongkok Bay area.

Tufted Puffins

Activity Cycles

A very distinct diurnal pattern of Tufted Puffin presence on the cliffs was evident during June (Figure 13). Peak numbers of Tufted Puffins were present on the cliffs between 08:00 and 10:00 and again between 20:00 and 22:00. Low numbers occurred during midday (approximately between 14:00 and 16:00) and probably throughout the night (24:00-06:00). The activity pattern during July was less distinct and did not show a low during midday (Figure 14). However, the pattern of low numbers present at night was still evident. A correction factor of 1.57 was used to calculate the numbers of Tufted Puffins present at peak periods during the day from counts at 10:00 to 12:00.

Estimates

Tufted Puffins nested in the steeply sloping grassy areas immediately above the cliff ledges as well as in cracks on the ledges themselves. Because all plots that were censused extended from the grassy top (when

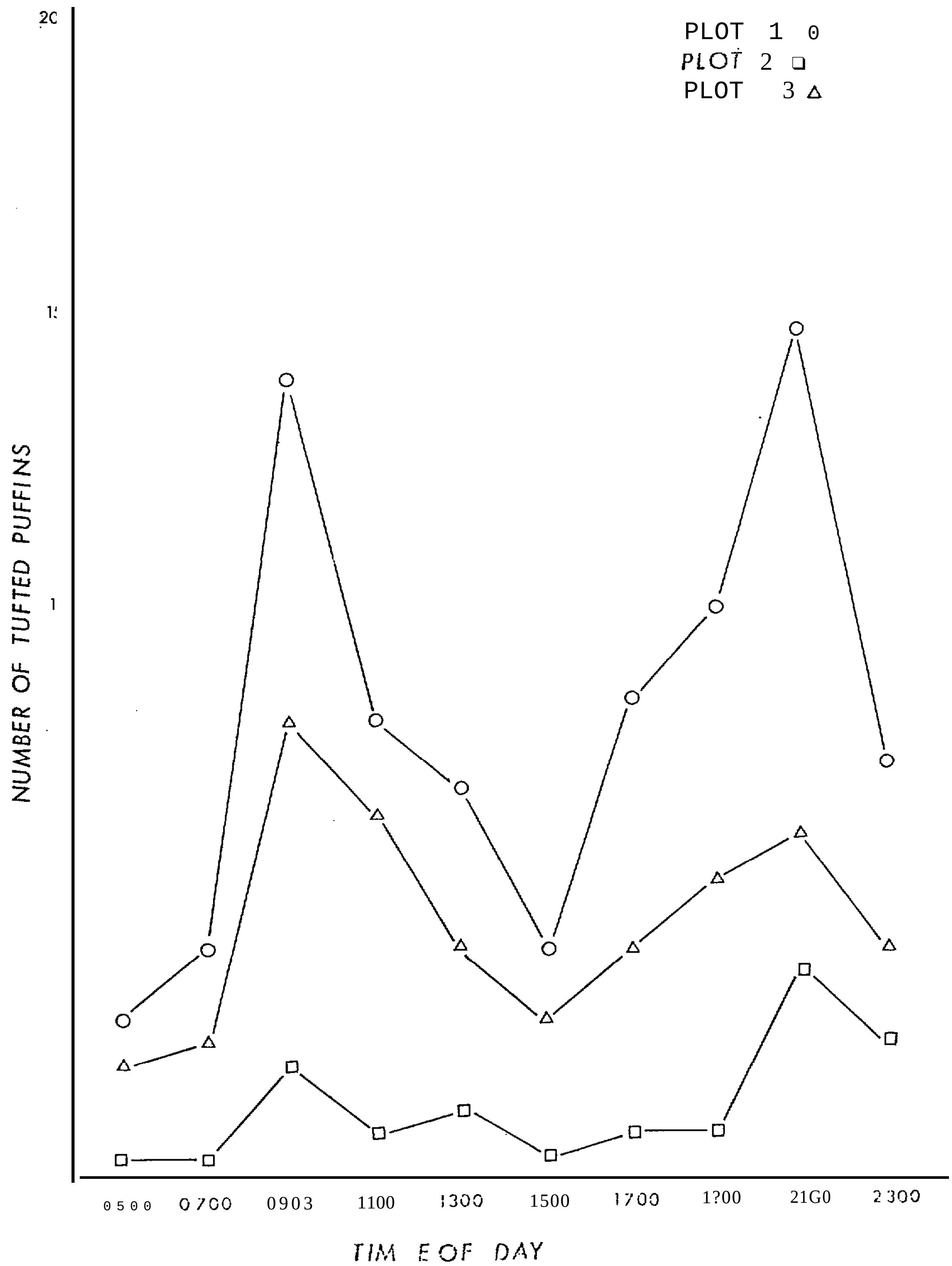

FIGURE 13. Average Number of Tufted Puffins Present on the Three Activity Plots at Various Times during the Day between 11 and 27 June 1976 (see also Appendix 4).

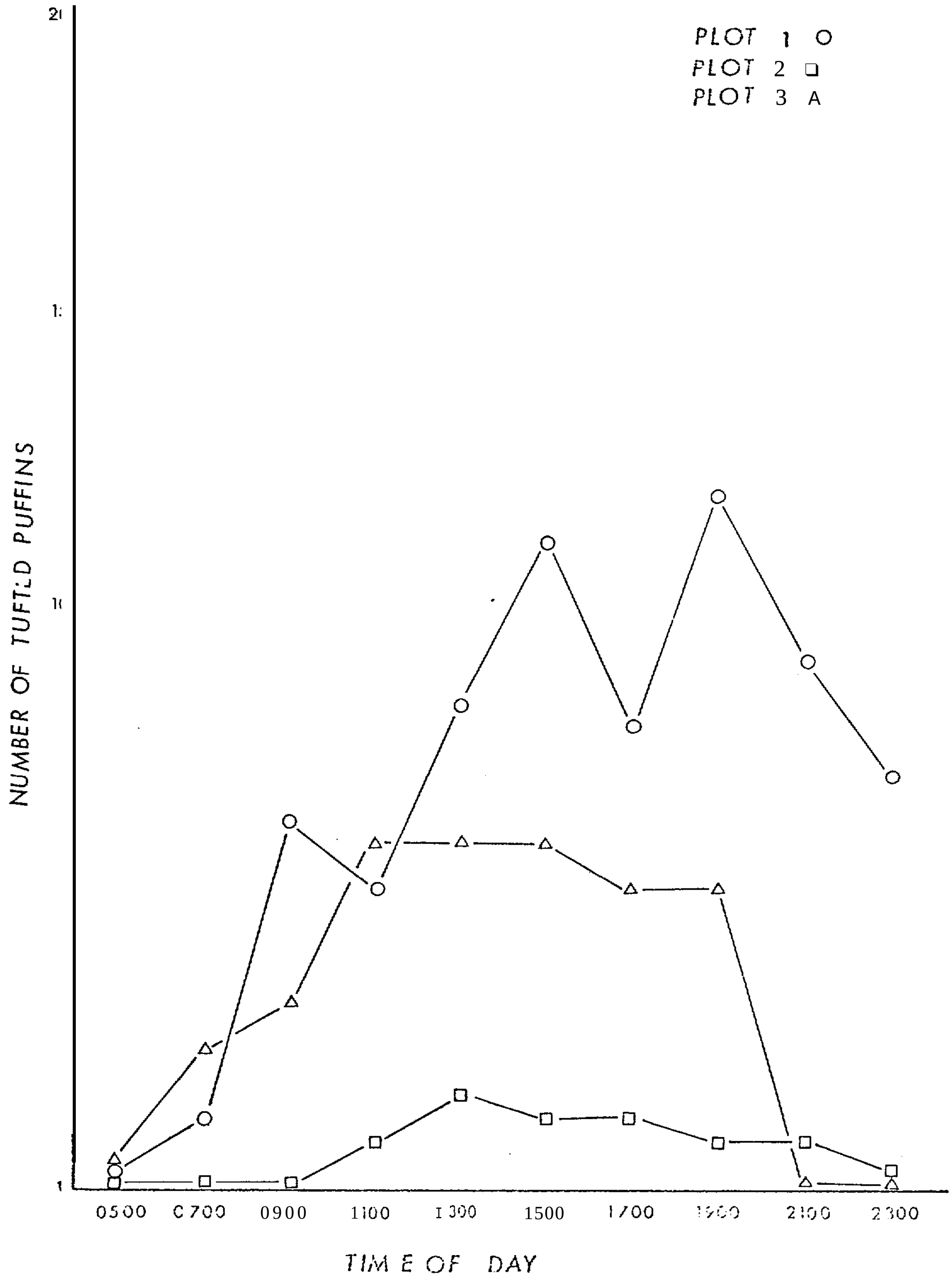

FIGURE 14. Average Number of Tufted Puffins Present on the Three Activity Plots at Various 'Tines during the Day between 11 and 19 July 1976 (see also Appendix).

present) of the cliffs to the bottom of the cliffs, a reasonably accurate estimate of Tufted Puffin numbers should result from extrapolations of the density of Tufted Puffins on the plots. However, estimates of puffin numhers based on counts of birds are complicated by the quasi-cyclical nature of puffin activity (Nettleship 1972:249-250). In order to account for these quasi-cyclical fluctuations in puffin numbers (see Horned Puffins below) the maximum density of Tufted Puffins observed during censuses conducted on several different days during the pre-egglaying phase was used as the basis of the estimates (see Nettleship 1976a:23).

The density of Tufted Puffins ranged from 0.0/100 m^2 to 1.4/100 m^2 on six plots and averaged 0.3/100 m^2. The corrected estimate of the number of Tufted Puffins on Owalit Mountain is approximately 740.

Horned Puffins

Activity Cycles

Horned Puffins were present on the cliffs in largest numbers between 18:00 and 22:00 during June and July (Figures 15 and 16). In order to determine whether Horned Puffin numbers on St. Lawrence Island fluctuated on a 4 to 5-day-cycle as noted by Nettleship (1972:249-250) for Common Puffins (*Fratercula arctica*) at Great Island, Newfoundland, a count of Horned Puffins was made three times each day, from 30 July to 6 August. (Nettleship [1976 a:23] suggests that the best time to census Common Puffins is during the pre-egglaying period. However, due to large amounts of snow under avalanche conditions near the puffin plot at Kongkok Bay, the plot was inaccessible until after egg-laying began.) The results are presented in Figure 17. Peak Horned Puffin numbers again occurred during the evening period (approximately 20:00) with low numbers normally occurring during the early morning hours. Large fluctuations in the number of Horned Puffins were noted over a 6-day-period beginning with a day of low numbers, then 4 days of high numbers, followed by another day of low numbers. During the low period, the number of puffins counted was near zero, even though birds were present on the plot (incubating) at this time. Thus, there is a

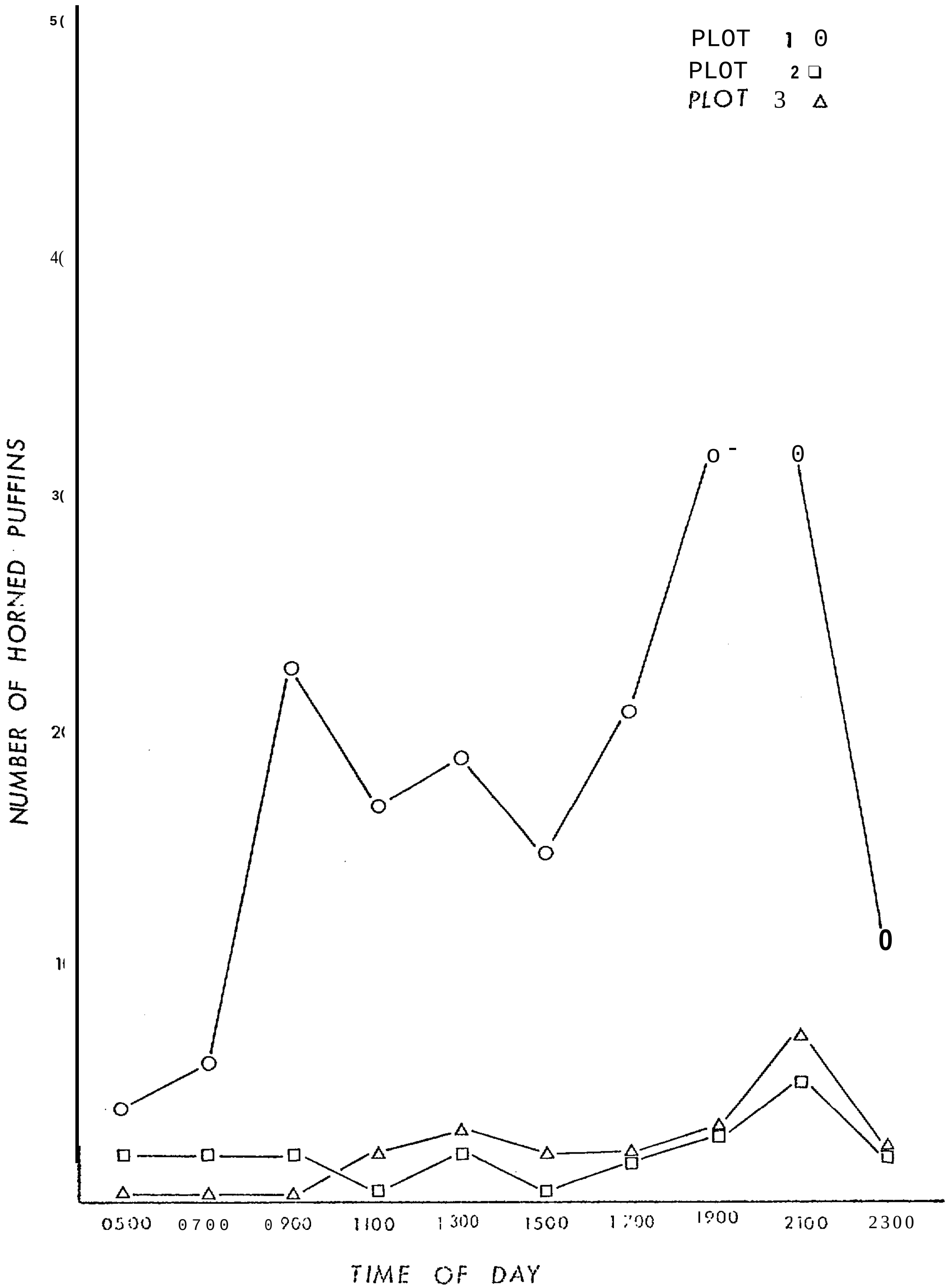

FIGURE 15. Average Number of Horned Puffins Present on the Three Activity Plots at Various Times during the Day between 11 and 27 June 1976 (see also Appendix 4).

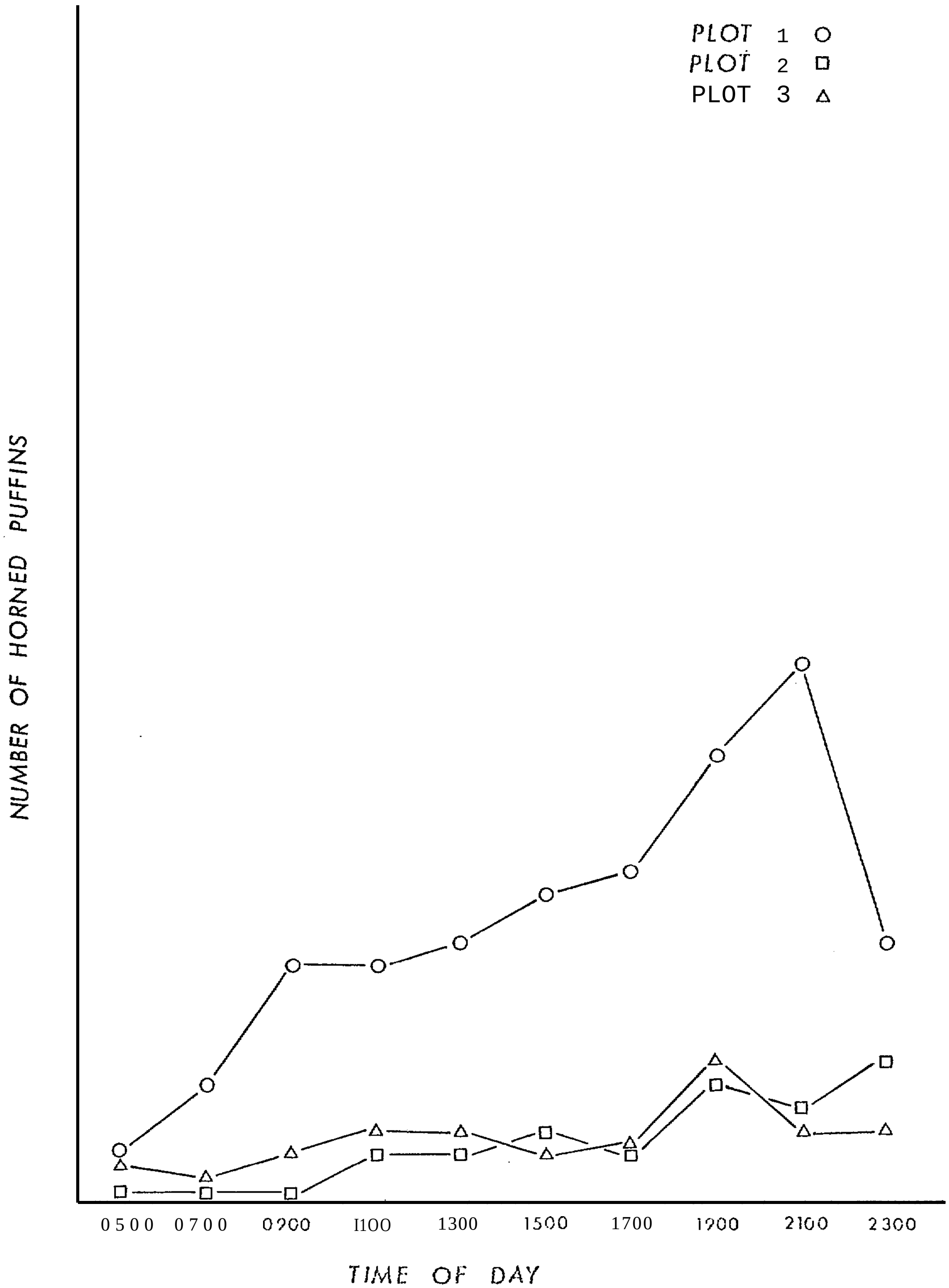

FIGURE 16. Average Number of Horned Puffins Present on the Three Activity Plots at Various Times during the Day between 11 and 19 July 1976 (see also Appendix 4).

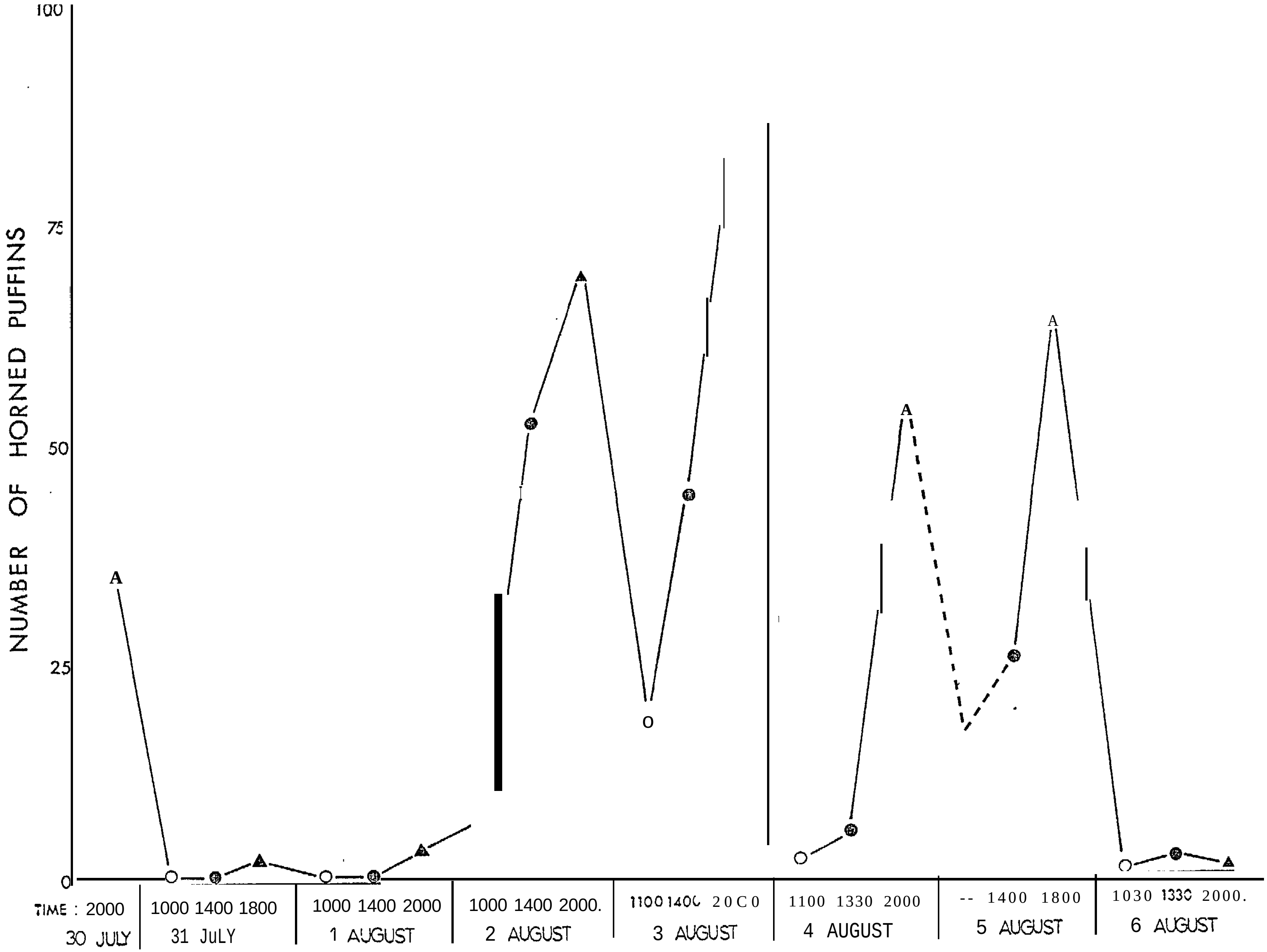

FIGURE 17. Number of Horned Puffins Observed during Daily Plot Censuses Conducted between 30 July and 6 August 1976.

diurnal cycle and there are strong day-to-day fluctuations in numbers detectable apparently varying on a 6-day-cycle. A correction factor of 1.89 was calculated for use in estimating Horned Puffin numbers.

Estimates

The complexity of puffin activity cycles makes estimation of their numbers by counting individual birds very difficult. However, due to the inaccessibility of puffin nest sites on Owalit Mountain, it was impossible to estimate numbers by counting burrows as suggested by Nettleship (1976: 22). Therefore, population estimates of puffins had to be based on counts of birds. In order to account for the day-to-day fluctuations in detectability, estimates were based upon the maximum density of birds observed on plots during several days during the pre-egglaying stage (early June).

The density of Horned Puffins on six plots ranged from 0.1/100 m^2 to 0.3/700 m^2. A corrected estimate of 570 Horned Puffins on Owalit Mountain was calculated from the average density of 0.2/100 m^2.

Pigeon Guillemots

Activity Cycles

The pattern of activity of Pigeon Guillemots was somewhat similar for the June and July periods (Figures 18 and 19). Pigeon Guillemots were generally found in the largest numbers during the morning. The numbers of Pigeon Guillemots gradually declined until about 16:00, then began to increase until about 20:00. The morning peak lasted later during July than during June. Counts of Pigeon Guillemots were made while counting Horned Puffins between 30 July and 6 August; the results are presented in Figure 20. The numbers of Pigeon Guillemots on the plot fluctuated mostly between 10 and 20 birds, but no diurnal rhythm could be detected.

At Novaya Zemlya, U.S.S.R. , Uspenski (1956:82) noted that Black Guillemots showed a definite diurnal rhythm. Guillemots were most active during the morning and congregated on shore near nest sites during the

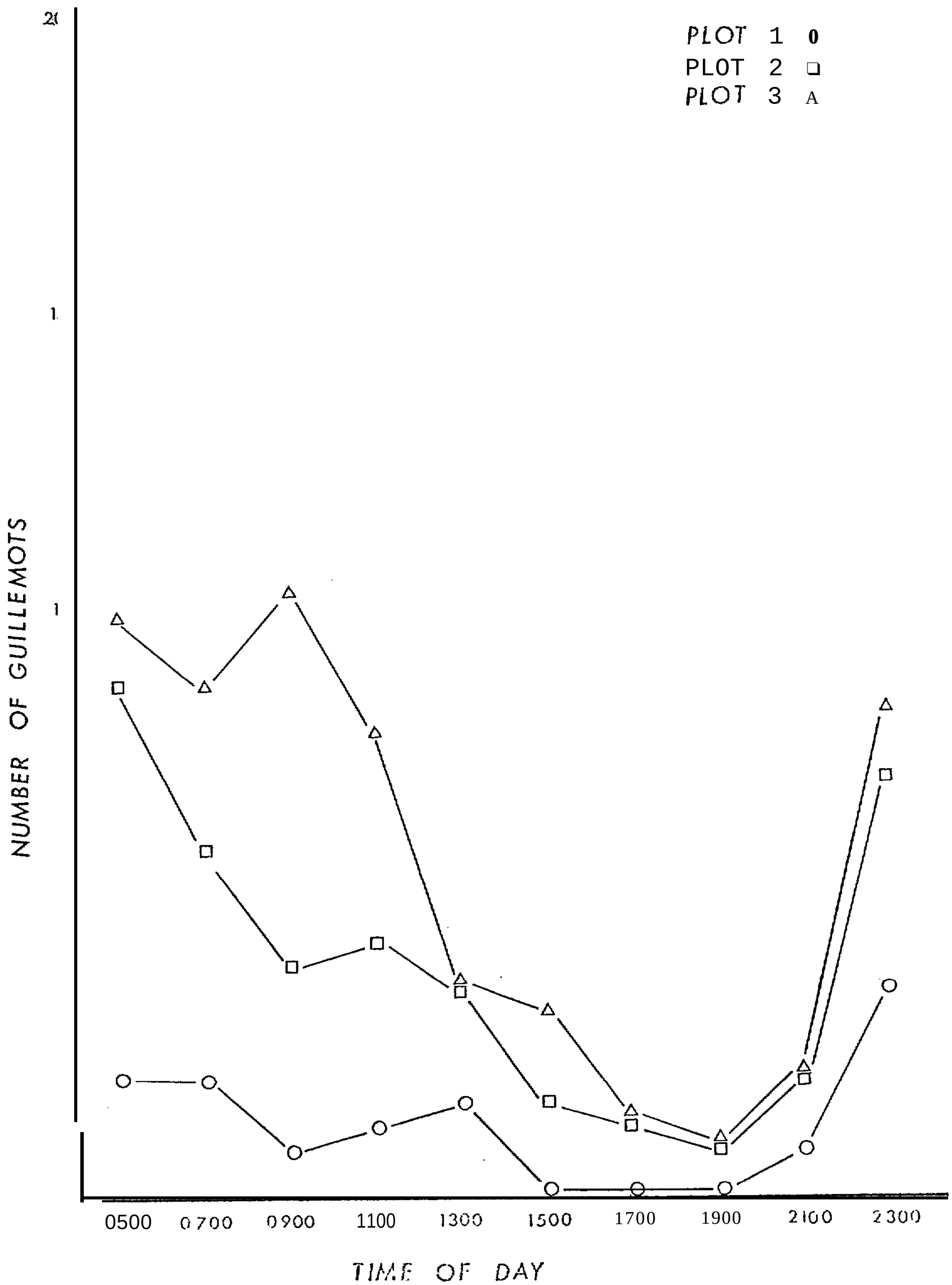

FIGURE 18. Average Number of Pigeon Guillemots Present on the Three Activity Plots at Various Times during the Day between 11 and 27 June 1976 (see also Appendix 4).

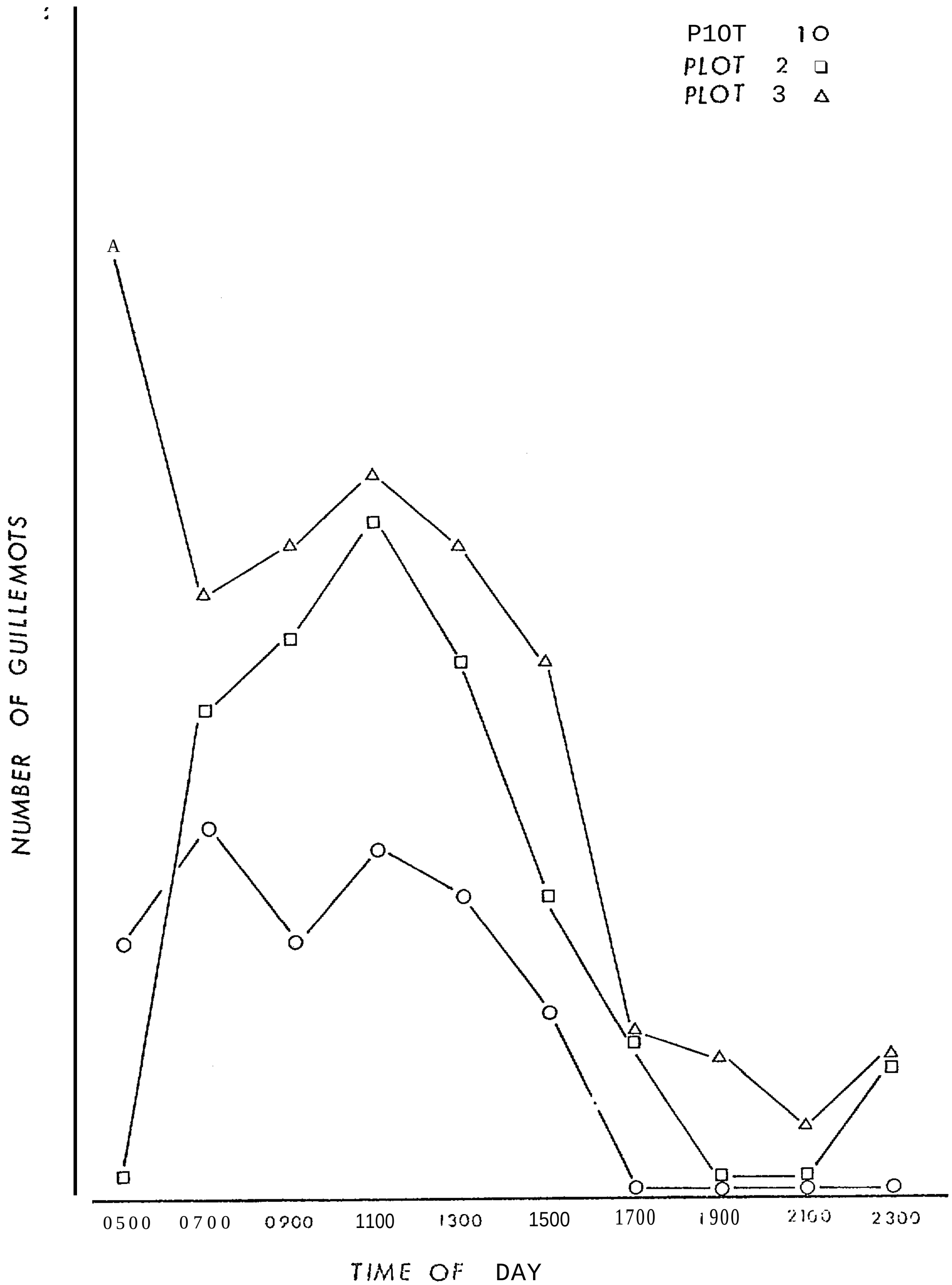

FIGURE 19. Average Number of Pigeon Guillemots Present on the Three Activity Plots at Various Times during the Day between 11 and 19 July 1976 (see also Appendix 4).

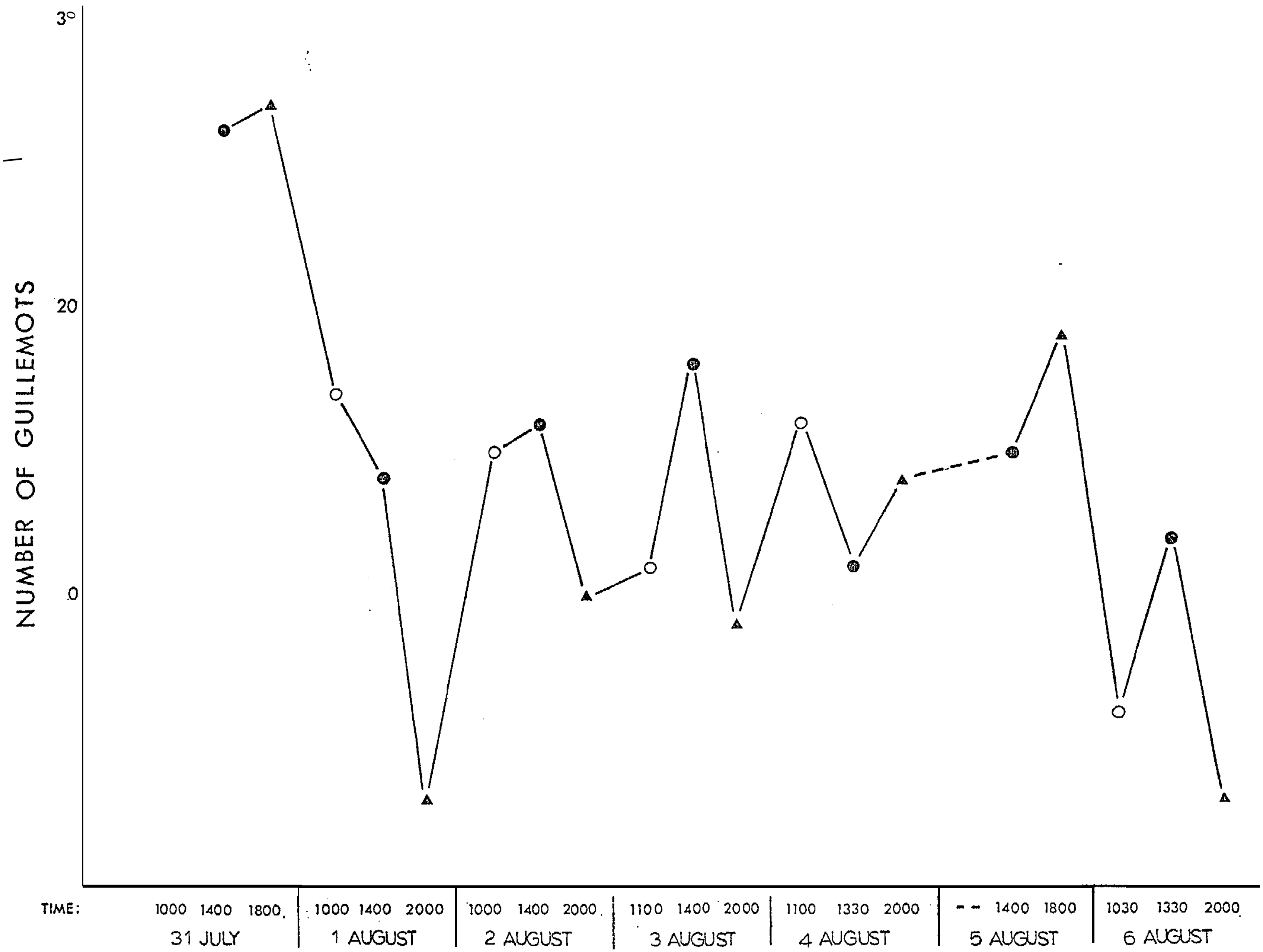

FIGURE 20. Number of Pigeon Guillemots Observed during Daily Plot Censuses Conducted between 31 July and 6 August 1976.

evening and night. Drent (1965:101), working on Pigeon Guillemots at Mandarte Island, British Columbia, found that the length of time guillemots spent at the colony was greatest during the latter half of June and the first half of July; full attendance occurred from dawn to early afternoon. By mid-August only breeding birds remained at the colony all morning. However, Drent found that guillemots (other than incubating or brooding birds) did not spend the night at the colony. Observations of increasing numbers during the evening suggest that guillemots may have spent the night on shore at St. Lawrence Island. No correction factor for the estimates of Pigeon Guillemot numbers was developed because relatively high numbers of birds were present between 10:00 and 12:00, especially during July.

Estimates

Pigeon Guillemots were found in low densities on the lower cliffs; they were virtually absent from the upper cliffs. Because Pigeon Guillemots were not regularly found on the cliffs above 50 m and because the bottom portion of Plot 6 did not reach the water line, this plot was not used when calculating Pigeon Guillemot density.

An estimated 150 Pigeon Guillemots were present on the cliffs at an average density of 0.1/100 m^2. However, because Pigeon Guillemots used only the lowest portion of the cliffs for nesting, the density of guillemots is not comparable to that of other cliff-nesting species. Therefore, the density of Pigeon Guillemots is perhaps best presented as 28 Pigeon Guillemots per kilometre of beach between Kongkok Bay and Galuk.

Herring Gulls

One Herring Gull nest was present on a ledge of a large stack just outside of Kongkok Basin. It is estimated that about 2 to 4 Herring Gulls were present in the vicinity of the study area, but none bred on Owalit Mountain.

Breeding Biology

Least Auklets

Breeding Success

Seventy Least Auklet eggs were located and-monitored throughout the incubation period. Because eggs were found at various stages of the incubation period, the hatching success determined in this study may be higher than the actual hatching success.

Hatching success of 70 eggs was 49%. However, some egg mortality was due to our disturbance of the nest sites. Five eggs were deserted soon after we discovered them; an additional eight eggs were predated between the time we discovered them and the next time we visited them. Most of the predation was thought to have occurred because of the use of surveyor's tape to mark the nests; the red flagging tape as well as the egg was usually removed by the predator. This procedure for marking nests was subsequently discontinued and cairns were used instead. Predation by Glaucous Gulls and Arctic Foxes was greatly reduced thereafter. Of the 57 eggs that were not immediately deserted or predated, 34 hatched--a hatching success of 60%.

Twelve eggs that failed to hatch were infertile or eggs in which the embryo died, usually at an early stage; four of these eggs were eventually predated. Six eggs were broken either by settling rocks, by predators (egg dropped while predator was attempting to remove it), or by rocks dislodged byme while checking nests. One adult Least Auklet was predated on its egg while incubating; the embryo eventually died.

Movements of short distances from the nest by prefledged young often resulted in my being unable to find the chick. Consequently, determination of the percentage of Least Auklets that fledged was more difficult than determination of hatching success. Of the 34 young that hatched successfully, nine survived to normal fledging age (approximately 32 days) and presumably fledged, seven died or were predated, and the fates of 18 were unknown. Once pre-fledged young leave the nest site, it is not known whether they continue to be fed by their parents. If not, then most, if not all, of the 18 chicks that left their nest before the age of fledging probably died. I suspect that most of these pre-fledging movements of chicks were due to our disturbance. If these birds are omitted from the calculation of fledging success, 56% of the young fledged (n = 16).

The overall breeding success (from egg to fledged chick) of Least Auklets during 1976 was calculated to be 34%. Using this value, the number of young fledged by the estimated 218,000 breeding Least Auklets in Kongkok Basin during 1976 was estimated to be 37,000 chicks.

Growth of Young

The weights of Least Auklet chicks at each day of age is plotted in Figure 21. No attempt has been made to transform the measurements (*cf.* Rickleffs 1967). The average rate of weight-gain during the period of maximum growth (5-24 days of age) was calculated to be approximately 3.7 ± 0.9 g/day (n = 10). This rate of weight-gain is complicated by the facts that some chicks had just been fed before being weighed and that others, which eventually died, gained very little weight--perhaps due to the death of one or both parents.

Most Least Auklet chicks that were measured attained adult body weight (~90.5g*) at approximately 24 days of age and then lost about 17% of their weight by the time they fledged. Scaly (1968:111) reported that Least Auklets attained 98% of adult body weight at 25 days of age but lost only 10.5% before fledging.

The growth of the primary feathers was less variable among Least Auklet chicks than was weight (Figure 22). The rate of primary development

*See Appendix 5 for weights and measurements of Least and Crested Auklets.

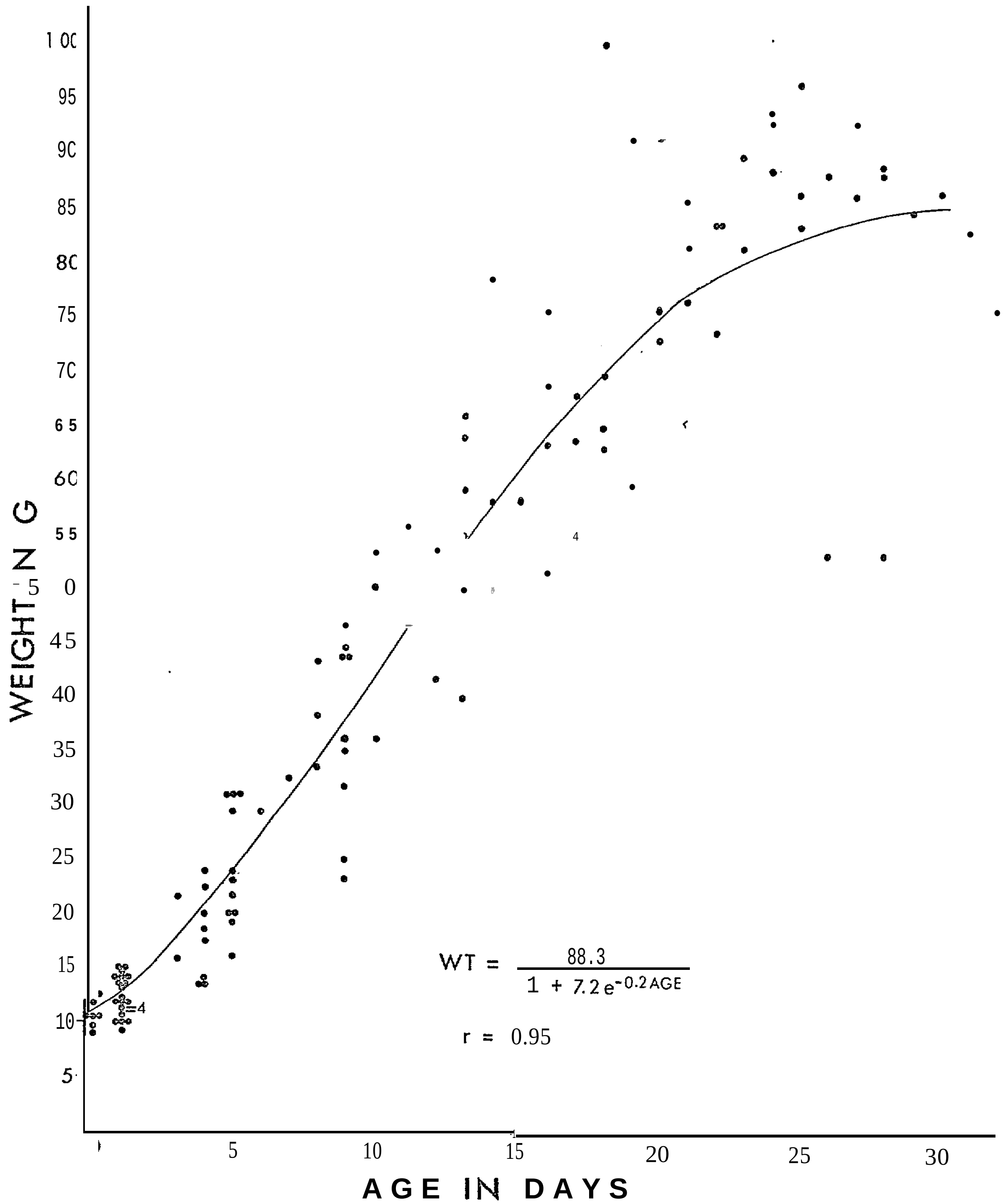

FIGURE 21. Weight of Least Auklet Chicks at each Day of Age during the Nestling Period.

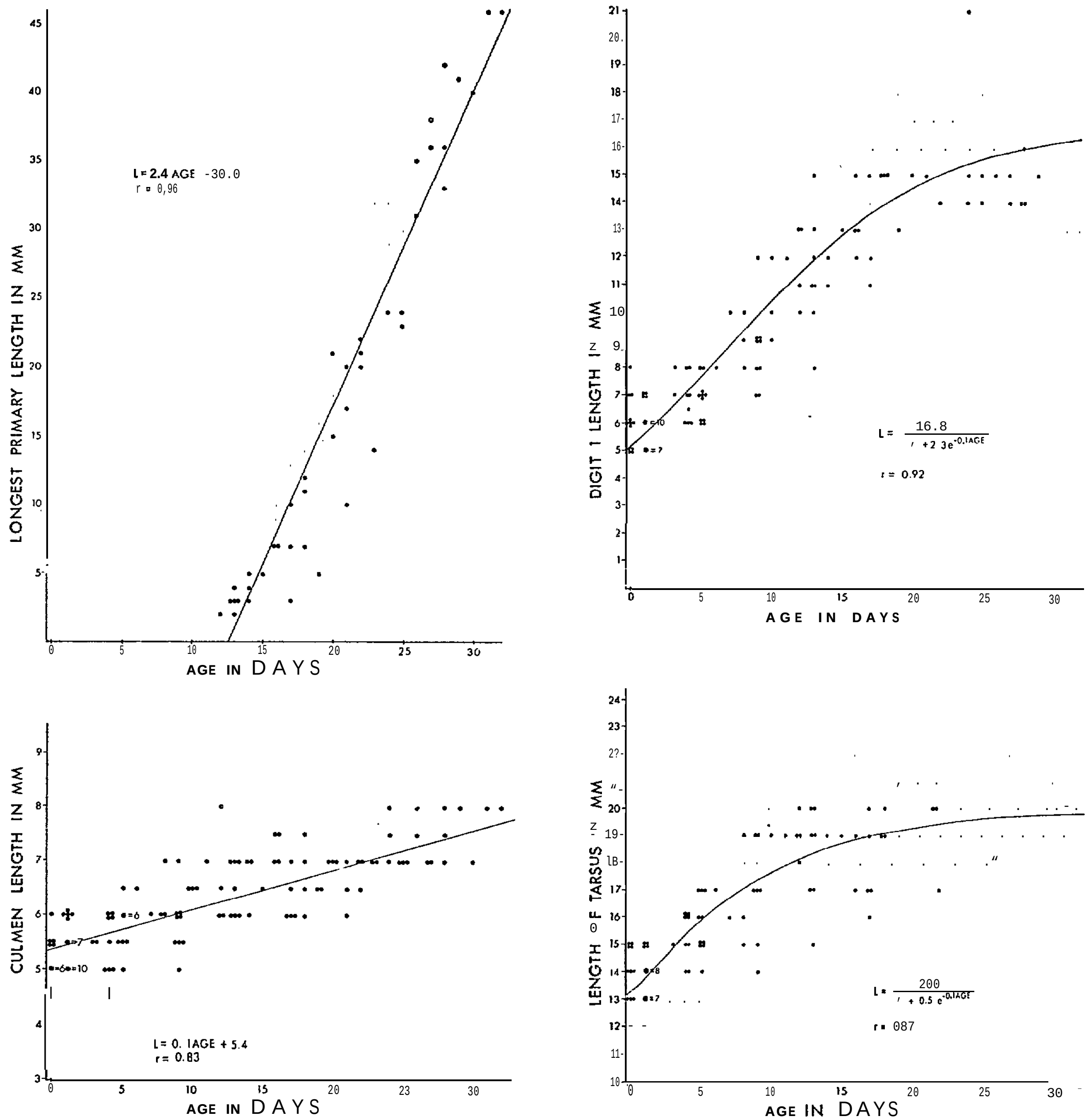

FIGURE 22. Length of Primary, Digit One, Culmen and Tarsus of Least Auklet Chicks at each Day of Age during the Nestling Period.

was quite linear. Eruption of the primaries (i.e., eruption of juvenile feather from sheath, not neossoptile) began at about 11 days of age; the primaries were approximately 80% of adult length (adult length = 59.4 mm) at *31* days of age (fledging). Scaly (1968:114) reported that the length of the primaries in pre-fledged Least Auklets was 88.8% of adult length.

Measurements of first digit, culmen, and tarsometatarsus (tarsus) of young Least Auklets are subject to measurement error and therefore must be interpreted with caution. Digit 1 grew steadily in Least Auklets until about 18 days of age; after that little additional growth occurred (Figure 22). The culmen grew from about 5 mm at age O days to between 7 mm and 8 mm--about 75% of adult size--at about 23 days of age (Figure 22). The tarsus grew steadily until the chick was approximately 10 days of age at which time the tarsus was almost fully grown (Figure 22). Until the chick is about 30-days old, walking is its only method of locomotion; therefore, rapid development of the tarsus may be adaptively significant for the survival of young auklet chicks beneath the rocks.

Crested Auklets

Breeding Success

Of the 48 Crested Auklet eggs that were found during 1976, only 11 hatched successfully. However, as with Least Auklets, my activities prevented some eggs from hatching. Six eggs were deserted shortly after being found and five were predated between the time they were found and the first time they were checked. If these eggs are omitted from the sample, 30% of the eggs that were laid hatched. The hatching success of the Crested Auklet (30%) is significantly lower than the hatching success of Least Auklets (60%) ($P < 0.01$; $X^2 = 6.894$; df = 1). Failure of eggs to hatch was due to predation (24%), breakage (8%) and infertility or death of the embryo (68%).

As with the Least Auklet, the fledging success of Crested Auklets is difficult to calculate. One Crested Auklet chick was still alive at the end of the study on 3 September but was only 23 days old; another chick was known to have died. The fate of the remaining nine chicks was unknown. Because of the small sample size, no percentage of fledging or of overall breeding success could be calculated for Crested Auklets.

Growth of Young

The weight of Crested Auklet chicks at each day of age for which data are available is presented in Figure 23. Crested Auklet chicks apparently did not have a lower rate of growth during the first few days after hatching than during the rest of the nestling period. The rate of growth over the entire nestling period was approximately 8.9 $\pm$ 1.9 g/day. Due to loss of chicks and an initial small sample size, the oldest chick that was measured was only 23 days old; this chick was only 5.7% below adult weight. However, a 21-day-old chick that was measured weighed only 210 g--78.5% of adult weight (adult weight = 267.1 g). Scaly (1968:111) found that Crested Auklets reached 90.8% of average adult weight in 27 days then lost 11% of their weight before fledging.

Unfortunately, I was able to monitor only two Crested Auklet chicks past 17 days of age. Therefore, I have few data on the growth of primary feathers of Crested Auklet chicks because primaries (shafts) first erupted from their sheath at about 11 days of age. Based on very few measurements, however, the rate of growth appears to be quite linear (Figure 24) and is similar to the pattern of growth of Least Auklet primaries presented above (Figure 22). One 23-day-old Crested Auklet chick had a primary feather that was 33.9% of adult length (adult length = 85.5 mm). This rate of growth is comparable to that of the Least Auklet. By the time that Crested Auklets are ready to fledge, their primaries are about 84.5% fully developed (Scaly 1968:114).

The growth of the first digit of Crested Auklet chicks was less variable than for Least Auklets (Figure 24), perhaps because feathering occurred at a later age in Crested Auklets than in Least Auklets and consequently"there was less measurement error. The rate of growth was

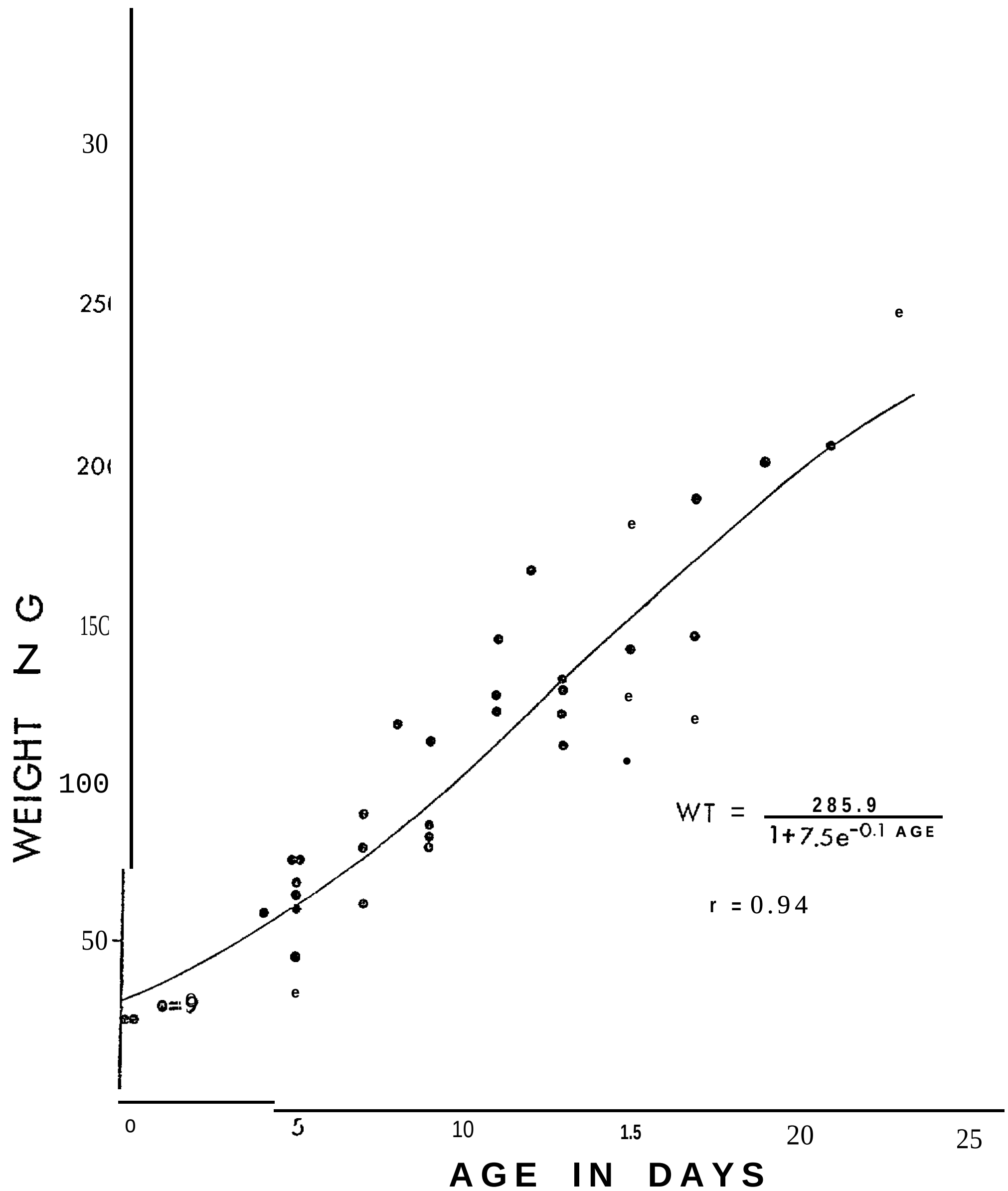

FIGURE 23. Weight of Crested Auklet Chicks at each Day of Age during the Nestling Period.

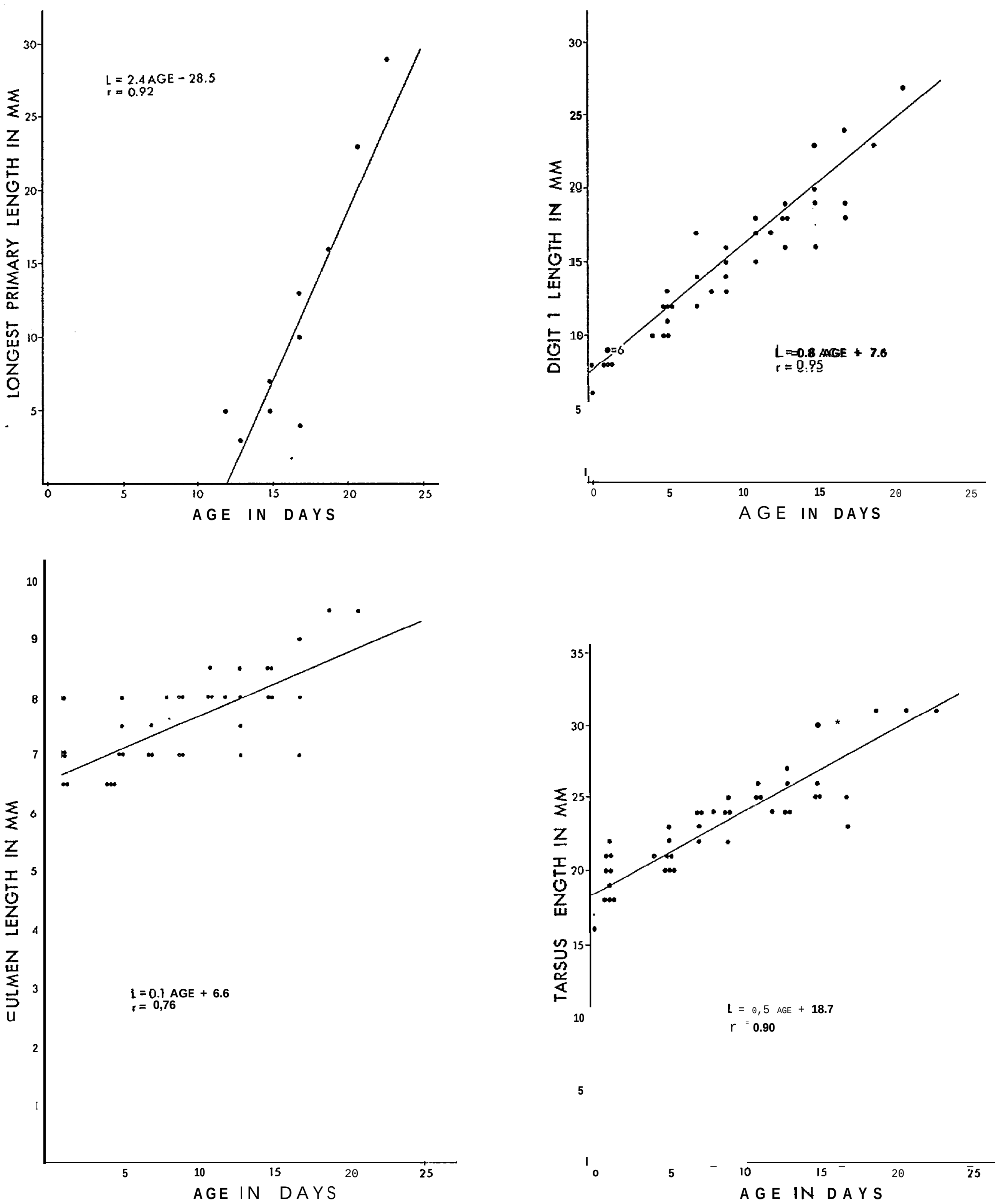

FIGURE 24. Length of Longest Primary, Digit One, Culmen and Tarsus of Crested Auklet Chicks at each Day of Age during the Nestling Period.

apparently linear until the chicks were at least 21 days old. Culmen measurements are difficult to assess. The culmen did not appear to grow substantially during the first two weeks of the nestling period (Figure 24). At hatching, Crested Auklet chicks had a culmen approximately 49% of adult length (adult length = 13.3 mm). At 15 days of age the average length of the culmen was still only 62% of adult length. Much of the growth of the" culmen of Crested Auklets may not occur until the period previous to initiation of breeding rather than during their first summer. As with the Least Auklet, Crested Auklet chicks were born with well developed tarsi and underwent rapid growth of this portion of the leg (Figure 24). The tarsi of some chicks reached adult size (28.5 mm) by 15 days of age. For most chicks, however, adult tarsus length is probably not reached until they are about 20 days old.

When the measurements of chicks are taken as a percentage of average adult size, the rates of growth of Least and Crested Auklet chicks during the period of maximum rate of growth were not significantly different (Table 12). This supports the conclusions of Scaly (1968) that the patterns of growth in Least and Crested Auklets are similar.

Murres

The eggs and chicks of Common and Thick-billed Murres are considered together in this section. Seventy-one murre eggs were monitored throughout the incubation period. The presence of an egg on the ledge was usually not confirmed until a varying but unknown stage of the incubation period. Therefore, the calculated hatching success is probably higher than the actual hatching success.

A total of 47 eggs hatched successfully--a hatching success of 66%. This rate of success is not significantly different ($0.1 < P < 0.5$; $X^2 = 0.9132$; df = 1) from the 70.5% hatching success recorded at Kongkok Bay during 1972 (n = 200; Johnson pers. comm.). Swartz (1966:632) recorded

TABLE 12. Results of Partial Analysis of Covariance of the Homogeneity of Slope between Regression Lines*. Simple linear regressions were performed on four growth parameters taken as a percentage of average adult size of Least and Crested Auklets and the age of chicks in days.

Growth Parameter (%/day)	Rate of Growth (Slope) Least Auklet	Crested Auklet	F-Value	Degrees of Freedom	Level of Significance
Weight	3.7	3.4	0.6331	1,31	0.50> P > 0.25
Primary	3.2	2.7	1.4376	1,15	0.25 > P > 0.10
Culmen	0.9	0.9	0.0102	1,27	p > ().75
Tarsus	2.7	2.3	1.0007	1,24	0.50> P > 0.25

*Sokal and Rohlf (1969:448).

a hatching success of approximately 75% (n = 183) during 1961 at Cape " Thompson, Alaska. The hatching success of murres on Novaya Zemlya, U.S.S.R. , was given as 50% (Uspenski 1956:66) (year and number of eggs observed were not given). Thick-billed Murres on Prince Leopold Island in the eastern Canadian Arctic had an 84% hatching success (n = 885) during 1975 (Nettleship 1976b). This hatching success was significantly higher ($P < 0.001$; $x^2 = 14.194$; df = 1) than the hatching success on St. Lawrence Island during 1976.

The hatching success of murre eggs was influenced by the date of laying. Table 13 presents the number of eggs laid between 3 July and 18 August according to their fate (hatched *vs* unhatched). The mean laying date of eggs that failed to hatch was 14 July (n = 24); the mean laying date of eggs that hatched successfully was 19 July (n = 47). Eggs that were laid before 9 July had a 54% hatching success, those laid between 9 and 31 July had a 71% hatching success, and those laid thereafter had an 88% hatching success. Eggs that were laid early, therefore, had a lower hatching success than did those that were laid later in the season. This phenomenon was also noted by Birkhead (1976:41) for Common Murres in Wales. He also found that eggs that were laid later than the mean laying date also suffered greater loss. Birkhead attributed the increased rate of loss of eggs laid early and of those laid late to conditions of low murre density which made eggs more vulnerable to predation. Only a few birds would have eggs previous to the peak period of laying; these eggs would be subject to more intensive predation and would have less protection by neighboring murres, most of which would not yet have eggs. Late laying by murres would result in increased egg mortality only if eggs were subject to more predation than were chicks. This appears to be true in the present study, but the small amount of data on predation of eggs and chicks and the low number of eggs that were laid late precludes further analysis.

The fledging success of murres that hatched during 1976 was calculated to be 88% (n=40). This percentage is based on the assumption that chicks of approximately 3 weeks of age that left the ledges had fledged successfully. Only five chicks in my samples were thought to have died before

TABLE 13. Distribution of Laying Dates of Unhatched Versus Hatched Eggs of Murres.

Date Egg Laid Before	Number That Did Not Hatch	Number That Hatched
3 July	8	9
9 July	5	6
18 July	5	12
25 July	4	13
31 July	1	0
4 August	0	6
13 August	0	1
18 August	1	0
Total	24	47
Mean Laying Date	14 July	19 July

they fledged. These chicks were washed off a lower ledge at a very young age during one of two severe storms that occurred during August, 1976. Such storms are thought to be the cause of the occurrence of unattended prefledging chicks at sea (Greenwood cited by Birkhead 1976:26).

The fledging success during 1972 (58%, n=141; S.R. Johnson pers. comm.) was significantly lower than the fledging success during 1976 ($p<0.01$; $\chi^2=10.49$; df=1). Part of this difference may have been due to the fact that murre chicks were measured every second day during 1972, whereas during 1976 no chicks were handled, and disturbance to nesting murres was minimal. Also, the data collected" during 1972 on which the 58% estimate of fledging success was based yield a minimum estimate (i.e., chicks that may have moved out of the plot or into unreachable crevices were counted as not fledged when their fate was unknown). Only birds whose fate was known were used to formulate my estimates for 1976.

Uspenski (1956:68) correlated the survival of chicks with average summer temperatures. He presented data on chick mortality and observations on temperature conditions for 3 years at Novaya Zemlya, U.S.S.R. According to Uspenski the summer of 1949 was unusually cold and murre chicks suffered a 68.8% loss. During an average year, 1948, 54.3% of the chicks died. The lowest mortality of chicks (51.7%) occurred during 1950--the warmest of the 3 years. These estimates of chick mortality were probably higher than natural chick mortality because of disturbance by man; Uspenski attributed 60% to 80% of chick mortality during his study to human disturbance.

The overall breeding success (from egg to fledged chick) ofmurres was estimated to be 61% (n = 66). This compares with a breeding success of only 41% in a disturbed study area during 1972 (Johnson and West 1975: 110). Birkhead (1976:41) found that the breeding success of murres in Wales differed greatly among sub-colonies which were at different densities. High density aggregations (> 10 murres/m^2) had an average breeding success of 87.5%; medium density aggregations (approximately 5.5 murres/m^2) had an average density of 74%; and sparse density aggregations (approximately 2.5 murres/m^2) had a breeding success of 30.8%. During 1976 murres at Kongkok Bay occurred at a density of only 0.4 murres/m^2, yet they had a breeding success comparable to murres at medium density during Birkhead's study. Further study of the breeding success of murres at different densities on St. Lawrence Island is needed in order to determine if reproductive rates of Bering Sea murres are actually higher than the rates of European murres at similar densities. The reproductive effort of murres on Owalit Mountain during 1976 was estimated to be 4850 chicks, based on 61% overall breeding success and a breeding adult population of 15,900 birds.

To avoid disturbance to nest sites, murre chicks were not measured during 1976. The growth and development ofmurre chicks on St. Lawrence Island are discussed by Johnson and West (1975).

Black-legged Kittiwakes

Results of NOAA-OCSEAP avifaunal studies in the Chukchi and northern Bering seas during 1976 indicated that kittiwakes had poor or no reproductive success at most colonies. The Kongkok Bay colony on St. Lawrence Island was no exception. Many kittiwake pairs built nests and on 7 June, one pair was observed copulating. However, only two clutches (of one egg per clutch) were found in over 50 nests that were checked and only one possible fledgling was seen in the study area.

The failure of kittiwakes to breed cannot be explained on the basis of data from a single colony. By looking at the timing, nature and degree of failure at colonies throughout the Bering and Chukchi seas, factors that led to the breeding failure of Black-legged Kittiwakes during 1976 can perhaps be identified. There was no evidence that kittiwakes (or any other species) at St. Lawrence Island were affected by spring storms that might have reduced or delayed the reproductive effort. It is interesting to note that of those species that were studied at Kongkok Bay, kittiwakes were among the few whose timing of breeding events was not noticeably later than the timing during previous years.

Although few kittiwakes laid eggs, most kittiwake pairs remained at their nests throughout the summer. In stormy weather during July and August, as many as 1000 kittiwakes gathered on Kongkok Lake. This number probably represents most of the kittiwakes that were present in the Kongkok Bay area during 1976. Therefore, although kittiwakes remained attached to nest sites throughout the summer, normal incubation patterns (i.e., amount of time spent at the nest) were apparently altered.

Glaucous Gulls

Nine Glaucous Gull nests were located, seven of which were clustered in a small colony on a medium-sized sea stack. One of these nests was empty. The average clutch size of the remaining eight nests was 2.8 ± 0.5 eggs (range = 2 to 3). Unfortunately, all nine Glaucous Gull nests became inaccessible after June; therefore no hatching data were obtained. Two eggs from one nest were pipped on 29 June.

Pelagic Cormorants

I was able to obtain clutch sizes from nine Pelagic Cormorant nests, two of which were monitored until the young fledged. The average clutch size was 2.4 ± 1.33 eggs per nest (range = 1 to 4). The two nests that I was able to follow throughout the nestling phase both had a clutch of four eggs. One of these pairs hatched three eggs, the other hatched two eggs; all five of these chicks fledged.

A count of the numberofyoung/nestwas conducted on one census plot between 5 and 22 August. The average number of Pelagic Cormorant chicks per nest during August was 1.5 ± 1.1 (range = 0 to 3; n = 12 nests). Therefore, if the average clutch size was 2.4 eggs per nest, then the hatching success was approximately 63%. However, because this estimate was based on a very small sample size, and the average clutch size and hatching success were not based upon the same nests, the estimate may be subject to considerable error. The number of Pelagic Cormorant chicks that fledged from Owalit Mountain during 1976 was estimated to be about 225, based on an estimated adult population of 300 and production of about 1.5 chicks per nest.

During 1972, S.R. Johnson (pers. comm.) counted 148 young at 58 nests--a clutch size of 2.6 young per nest. Apparently, Pelagic Cormorants had low breeding success at Kongkok Bay during 1976.

Food Habits and Feeding Areas

The food habits of Least and Crested Auklets at St. Lawrence Island have been thoroughly described by Bédard (1969b). The scope of the present study was not as extensive as this earlier study and, therefore, comparisons with the work by Bédard have been made with caution. Recent studies (Weins and Scott 1975 and others) have stressed the importance of analyzing seabird diets in terms of relative energy content rather than in terms of occurrence of food items.

Estimates of the relative energy content of various food species are usually dependent upon factors that convert measured lengths or partial lengths of organisms to some estimate of energy content (volume, wet weight, dry weight). However, because such conversion factors were only available for some and not all of the food taxa identified, food data have been analyzed in terms of percent occurrence and percent frequency. Percent occurrence is taken to be

$$\frac{\text{\# of stomachs containing a given food taxon}}{\text{\# of stomachs examined}} \times 100.$$

Percent frequency is taken to be

$$\frac{\text{\# of organisms of a given food taxon found in stomachs}}{\text{\# of organisms of all food taxa found in stomachs}} \times 100.$$

Least Auklets

Food Habits

The numbers and taxa of food organisms that were found in the stomachs of 10 Least Auklets collected in Kongkok Bay between 10 and 16 July 1976 are presented in Table 14*. The frequency of occurrence of each major taxon in the stomachs of Least Auklets and the percent occurrence of each taxon in terms of the numbers of individuals as a percentage of the total number of

*A detailed list of food organisms by size classes is found in Appendix 6.

TABLE 14. Numbers of Individuals Of Food Organisms Found in Stomachs of Least Auklets of the Kongkok Bay Colony that were Collected between 10 and 16 July 1976.†

Amphipods								Decapods		Cumaceans	Copepods		Other Crustaceans	Other Invertebrates	Fish	
								Hippolytidea (larvae)	Zoea						Adults	Larvae
Anonyx sop.	*Atylus tridens*	*Calliopiella* spp.	*Ischyrocerus* spp.	*Dulichia* spp.	*Achotropus* sop.	*Metopa* spp.	*Pontoporeia affinus*			*Diastylis bidenticulata*	*Neocalanus plumchrus*	*Calanus marshallae*				
	1	8*		6				149	20				P			9
P		2	P					226	7		1					
		11*	1					136	2		1				1	3
			P	6				187	3			2				
		14*		5	1	1	1	10:	6	13	1					11
			P	1				96	4						?	
			1+	2				97	1							
								58+	1							1
5	1	1	P				1				3	1·		2		
1	1	44*	9	10	2			217	8							z-3

†Each line represents the stomach (or gular pouch) contents of one bird. "P" indicates that a particular organism was present but *was not* measured or counted. No empty stomachs were collected.

*Young from brood pouch not counted.

individuals is presented in Figure 25. The reader is referred to Hartley (1948) and Swanson and Bartonek (1970) for a discussion on the limitations of this type of analysis. Although both amphipods and decapods were found in nearly all Least Auklet stomachs, and copepods and fish were found in the majority of them, decapods were by far the most abundantly consumed food item in terms of numbers; in terms of biomass, decapods probably comprised a still greater proportion of the diet of Least Auklets.

During the early summer periods (previous to July) of 1964-1966, Least Auklets fed primarily on copepods and decapods (Bédard 1969b); copepods apparently made up a much greater proportion of their diet during the early summer periods from 1964-1966 than during 1976 (Table 15). Part of this apparent difference was due to the temporal distribution of the sampling effort; while Bédard (1969b) collected birds throughout the early summer portions of 3 years, I collected Least Auklets only between 10 and 16 July 1976. During Bédard's study, large numbers of copepods and amphipods (amounts varied among years) were eaten by auklets previous to mid-July; decapods formed the major portion of the diet during July.

Copepods were the major food items brought to young Least Auklets by adults during both studies (Tables 16 and 17 and Figure 26). However, the major species from 1964 to 1966 was *Calanus marshallae** whereas, during 1976, *Neocalanus plumchrus* formed the largest portion of the diet of the nestlings.

The fact that *C. marshallae* was not taken by Least Auklets during 1976 may have been due to one or more of the following:

1. Either N. *plumchrus* was very abundant during 1976 or *C. marshallae* was present only in low numbers,
2. C. *marshallae* was abundant but locally distributed off Northwest Cape where Bédard sampled and *N. plumchrus* was abundant but locally distributed at Kongkok Bay where I collected my samples,

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**Calanus marshallae* = *C. finmarchicus*.

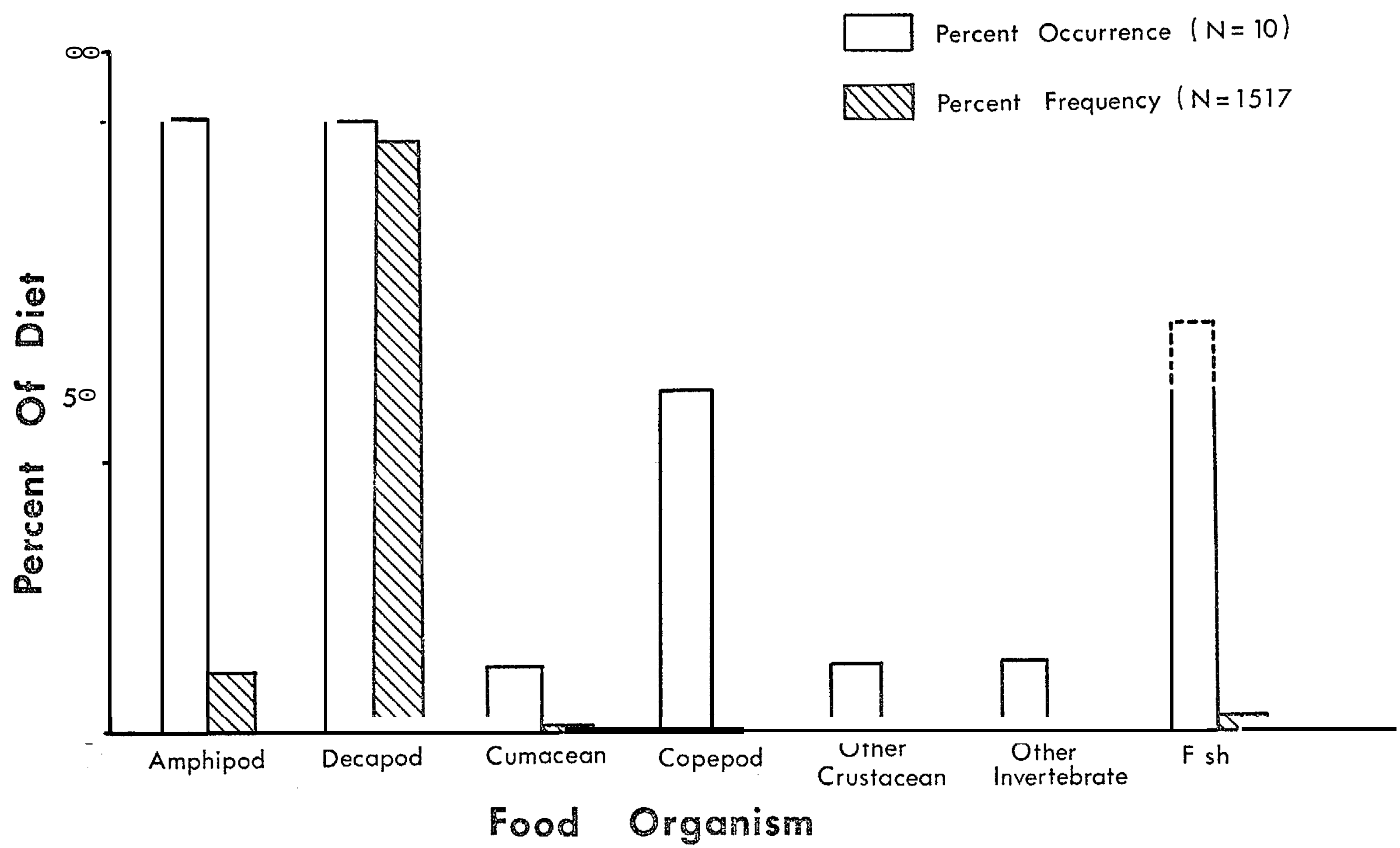

FIGURE 25. Diet of Least Auklets from the Kongkok Bay Colony Collected between 10 and 26 July 1976.

TABLE 15. Comparison of the Percent Frequency of Various Food Items in the Diet of Least Auklets between the Early Summer Periods of 1964-1966 (n=17580) and 1976 (n=1517). Data for 1964-1966 taken from Bédard 1969b).

Food Item	1964-1966	1976
Amphipods	14	9
Euphausids	1	0
Decapods	34	87
Mysids	2	0
Cumaceans	0	1
Copepods	42	1
Gastropod	2	0
Fish	1	2

TABLE 16. Numbers of Individuals of Food Organisms Found in the Gular Pouches of Least Auklets of the Kongkok Basin Colony that were Collected during Mid-August, 1976. *

Amphipods			Decapods		Mysids		Copepods							Other Crustaceans	Molluscs		Other
Hyperiidae		Other	Pandalidae	Larvae			Adults			Copepodites							
Parathemisto spp.	Other				*Paracanthomysis* Spp.	Other	*Neocalanus plumchrus*	*Eucalanus bungii*	*Calanus marshallae*	*Neocalanus plumchrus*	*Neocalanus cristatus*	*Eucalanus bungii*	*Calanus marshallae*		*Limacina helicina*	Other	
2							37			403	5		2				
6		1	6		17	1	33	1		695	6		2	1		P	
2							12	1		299	2		13				
							7		5	191			39			P	
13		2	25		1		120	2	4	1600			3		12	P	
			1			1	73			251			152			P	
1		1	1				76			1137	3		31		4		
10		1+	3	1			67	1	3	914	1	1	30		2	P	P(Plant)
7			6	1	5		49			638	2		18			P	
3						1	13			698		1	9			P	
9	1	4		2		3	61		4	1107	9	1	18	1	8	P	
	3			1			48	1	1	518	3		12				

*Presented as in Table 14.

TABLE 17. Comparison of the Percent Frequency of Various Food Items between the Diets of Least and Crested Auklets during the Chick-rearing Period.[1]

	Least Auklet		Crested Auklet	
	1964-1966[2]	1976[3]	1964-1966[4]	1976[5]
Amphipods				
Hyperiids I[6]	1.9	0.4	0.4	0.2
II	0.4	0.3	1.4	0.1
III	0.1	<0.1	0.6	0.0
Gammarids I	0.4	0.0	0.0	0.0
II	0.2	0.0	<0.1	0.0
III	<0.1	0.0	0.0	0.0
Decapods[7] I	<0.1	<0.1	<0.1	0.2
II	<0.1	0,4	0.0	0.2
III	0.0	<0.1	0.0	0.0
Caridae I	0.8	0.0	<0.1	0.0
II	2.3	0.0	4.4	0.0
Mysids I	0.0	<0.1	0.0	0.0
II	0.2	0.3	0.4	<0.1
III	<0.1	0.0	0.3	0.0
Copepods				
Neocalanus plumchrus[8] I	0.0	90.5	0.0	96.8
Neocalanus cristatus[8]	1.6	0.3	7.0	0.5
Eucalanus bungii	0.2	0.1	<0.1	0.1
Calanus marshallae[8] I	88.9	3.6	28.7	1.7
Euphausids				
Thysanoessa spp. I	0.3	0.0	0.0	0.0
II	2.2	0.0	4.2	<0.1
III	0.2	0.0	51.8	<0.1
Cumaceans I	0.0	0.0	0.0	0.0
II	0.2	0.0	<0.1	0.0
Gastropod				
Limacina	<0.1	0.49	<0.1	0.2[9]
Fish II	0.7	0.0	<0.1	0.1(?)
III	1.7	0.0	0.2	0.0

[1]Data for 1964-1965 from Bédard (1969b)
[2]n=124 pouches; 87632 food organisms
[3]n=12 pouches; 9613 food organisms
[4]n=135 pouches; 20893 food organisms
[5]n=12 pouches; 8766 food organisms

[6]Size categories are from Bédard (1969b)
I 0,0-7.0 mm
II 7.1-15.0 mm
III 15.0 mm and over
[7]Includes Megalopa stages, not Zoea
[8]Mostly copepodite stage V
[9]Includes unidentified Gastropod

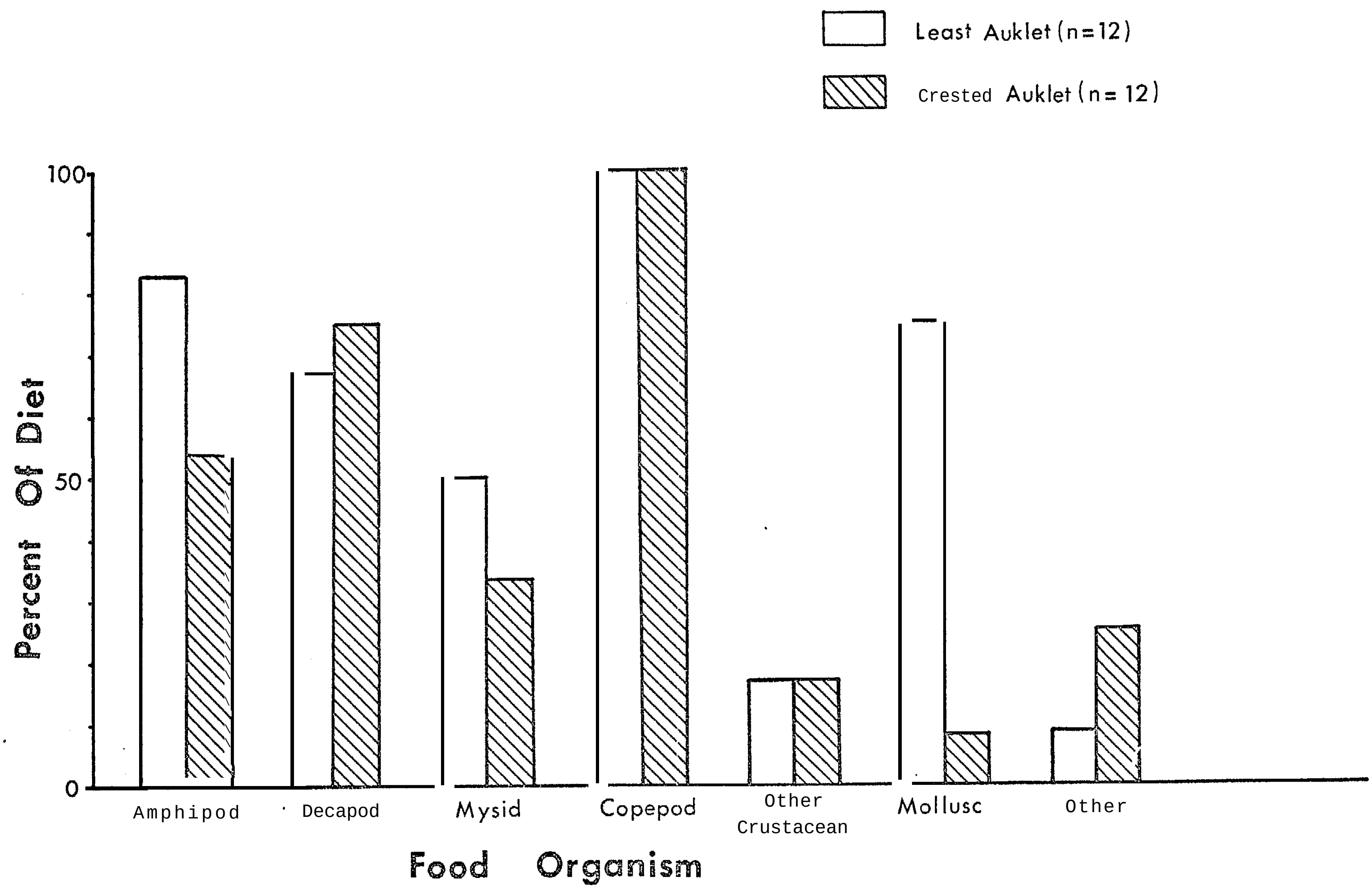

FIGURE 26. Percent Occurrence of Various Food Taxa Fed to Chicks of Least and Crested Auklets from the Kongkok Bay Colony during Mid-August 1976.

3. The identity of N. *plumchrus* or *C. marshallae* was mistaken by either myself or Bédard and they are in fact the same species.

In summary, the food habits of auklets during 1976 appeared to be similar to those presented by Bédard (1969b) for 1964-1966. Collection of birds during the very early portion of the summer was not possible during 1976; during this period, Least Auklets fed primarily on amphipods and mysids during 1964, and on amphipods and copepods during 1965 and 1966 (Bédard 1967). Decapods formed the major portion (in terms of numbers) of the diet during the month of July during all years (1964-1966 and 1976) but copepods formed a substantial portion during the month of July of 1964, 1965 and 1966; amphipods were taken in large numbers during early July 1966 (Bédard 1967). Copepods were the major food items brought to young Least Auklets by adults during August of all years.

Feeding Areas

My observations of Least Auklet feeding behaviour in the Kongkok Bay area differ somewhat from those of Bédard (1969b) of Least Auklets in the Gambell area. Least Auklets that fed in the Kongkok Bay area normally remained within 2 km of shore (Figure 27) and generally fed alone, in pairs, or in very loose aggregations; Least Auklets were never observed feeding in dense flocks as described by Bédard (1969b:1034). As suggested by Bédard (1969b:1034) the major portion of the Kongkok Bay colony apparently feeds off the northwest cape of St. Lawrence Island; my observations suggest that the birds that remain in the Kongkok Bay area probably represent less than 10% of the colony.

Crested Auklets

Food Habits

The stomachs of all Crested Auklets that were collected during 1976 were either empty or contained only a few food organisms (Table 18). Therefore, no analysis of these stomachs has been attempted. Bédard (1967) found that,

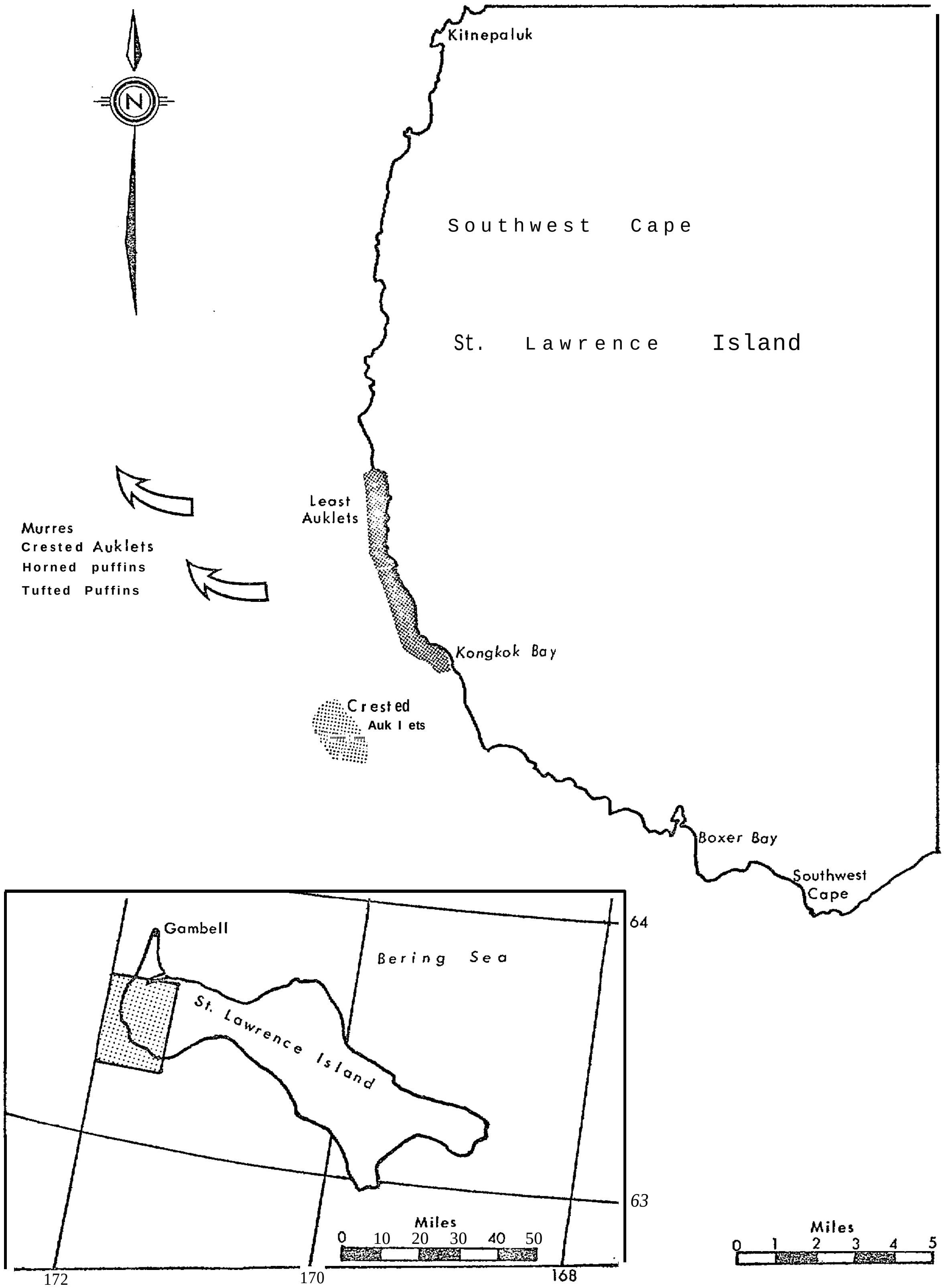

FIGURE 27. Feeding Areas of Seabirds in the Kongkok Bay Area. Insert shows portion of St. Lawrence Island enlarged above.

TABLE 18. Numbers of Individuals and Species of Food Organisms Found in Stomachs of Crested Auklets of the Kongkok Bay Colony that were Collected on 18 July 1976.*

Amphipods			Cumaceans	Molluscs	Other Invertebrates
Anonyx nugax	*Dulchia* spp.	Other	*Diastylis bidenticulata* (Sub-adult)	*Limacina helicina*	
	P				
P					
				1	
				5	
	2	2	2	1	
					1

*Presented as in Table 14. In addition, 12 stomachs were empty, 6 contained grit only, and 2 contained plant material and grit only.

during July; Crested Auklets fed primarily on mysids and euphausids in 1964, euphausids and hyperiids during 1965, and mysids and hyperiids during 1966. Gammarids were also taken in large quantities previous to July, especially during 1966.

Food items that were brought to young Crested Auklets by adults during 1976 included mostly copepods (96.8% by numbers; Tables 17 and 19). During the period from 1964 to 1966, Crested Auklets fed their young primarily euphausids (56.0%) and copepods (35.7%). During the nestling periods of 1964, 1965 and 1966, euphausids comprised 80% to 90% by volume of the content of gular pouches. These data indicate that a noticeable shift in the late-season food source may have occurred during 1976. Almost no euphausids were taken during mid-August 1976. Because a greater expenditure of energy would be required to obtain an equal volume of smaller organisms unless the density of these small organisms is high, or their mobility is less, a shift from euphausids of more than 15.1 mm in length to copepods (of the species *N. plumchrus*) of less than 7.0 mm in length may reflect a great abundance of the copepod, *N. plumchrus*. Also, the facts that both Least and Crested Auklets fed their young primarily on *N. plumchrus* during 1976 and that neither of these species took *N. plumchrus* during 1964-11966 indicates that a "bloom" of this food species had apparently occurred during 1976. Alternatively, a decrease in the availability of euphausids may have necessitated a shift to an alternate food item. Hence, auklets may have been forced to expend extra energy in order to feed their young.

Feeding Areas

As with the Least Auklet, my observations during the summer of 1976 suggest that most Crested Auklets that nest at Kongkok Bay feed in the vicinity of Northwest Cape of St. Lawrence Island (see Bédard 1969b:1034). Those birds that feed in the Kongkok Bay area apparently do so approximately 5 to 8 km or more southwest of Kongkok Bay (Figure 26). A few Crested Auklets join the feeding flights of murres and puffins and head west--perhaps to the coast of the Chukotsk Peninsula, U.S.S.R. (see below).

TABLE 19. Numbers of Individuals of Food Organisms Found in the Gular Pouches of Crested Auklets of the Kongkok Basin Colony that were Collected during Kid-August 1976. *

Amphipods			Decapods		Mysids		Copepods							Other Crustaceans	Molluscs		Other
Hyperiidae		Other	Pandalidae	Larvae			Adults			Copepodites							
Parathemisto spp.	Other				*Paracanthomysis* spp.	Other	*Neocalanus plumchrus*	*Eucalanus bungii*	*Calanus marshallae*	*Neocalanus plumchrus*	*Neocalanus cristatus*	*Eucalanus bungii*	*Calanus marshallae*		*Limacina helicina*	Other	
			1				163	2		880	4		6				
			P				6			510							
			19		1		37			441	5		13	P		P	1(unid. copepod)
2	P						37	1		463	1		11				
2			P				39			641	1		20			P	
							55			602		5	13				P(fish?)
			1				23	1		690			4		3		
2	,		4	1			55			525	14		12	2		P	
2		1	1		1		38	2		8'80	2		7		2	P	
4						P	49			452	5	1	12			P	
7			5	1			126			1189	6		43		3	P	2
1			3		1		34			549	2		7			P	

● Presented as in Table 14.

Common and Thick-billed Murres

Food Habits

Few food items were found in the stomachs of Common and Thick-billed Murres that were collected from 9 to 18 June 1976. Murres tended to feed at long distances from Kongkok Bay; therefore, I was able to collect birds only as they returned to the breeding cliffs. Due to the high rate of metabolism in murres (Johnson and West 1975) and the rapid rate of digestion of food by seabirds in general (Cottom and Hanson 1938; Tuck and Lemieux 1959; Uspenski 1956; Tuck 1960; Swartz 1966; Johnson, unpublished data), most food ingested by murres at their feeding areas was already digested when I collected the birds near Kongkok Bay.

Table 20 presents a summarized description of the stomach contents of 11 Thick-billed Murres and 7 Common Murres. Because of the small sample size, the two species of murres were combined for analysis. From Table 20 and Figure 28 it can be seen that during mid June, fish and crustaceans (especially amphipods and decapods) were ingested with the greatest regularity.

Invertebrates were taken more frequently by murres in the St. Lawrence Island area than in other areas of the Bering and Chukchi seas (Table 21). The types of invertebrates taken in the St. Lawrence Island area were apparently different from those taken in other areas of the Bering Sea and in the Chukchi Sea; the small data base on which this statement is based, the different years during which the data were collected and the biases in the method of analysis that was used should not be overlooked. Euphausids and "squids" were regularly ingested by murres in the southern Bering Sea-Bristol Bay area; these were the major invertebrates in the murres' diet (Ogi and Tsujita 1973). Squid also comprised a part of the diet of 26% of the murres (primarily Thick-billed Murres) collected near the Pribilof Islands. Amphipods and decapods as well were found to be taken frequently by Common and Thick-billed Murres, respectively, in the Pribilof Island area (Preble and McAtee cited by Storer 1952). Apparently, euphausids and

TABLE 20. Number of Individuals of Food Organisms Found in Stomachs of Murres of the Kongkok Bay Colony that were Collected between 9 and 18 June 1976. *

Species	Amphipods					Cumaceans	Decapods	Other Crustaceans		Other Invertebrates			Other		
	Anonyx nugax	*Atylus tridens*	*Ampelisca* spp.	*Parathemisto* spp.	Other	*Diastylis bidenticulata*	*Eualus fabricii*	*Mysis littoralis*	Other	*Spirorbis* spp.	Hydrozoa	Araneae	Fish	Plant	Grit
Thick-billed Murre	16	2				3	1								
	3														
			3			1	40								
							P			1	1				
							1								
													P	P	P
							P							P	P
									P						P
														P	
							F							P	P
													P	P	
Common Murre													P		
							P								
													P		
				P											
													P	P	
	3				P		1 (Sp)							P	
		1											P		

*Presented as in Table 14. In addition, 12 stomachs were empty, 10 contained plant material only, 1 contained grit only, and 1 contained plant material and grit only,

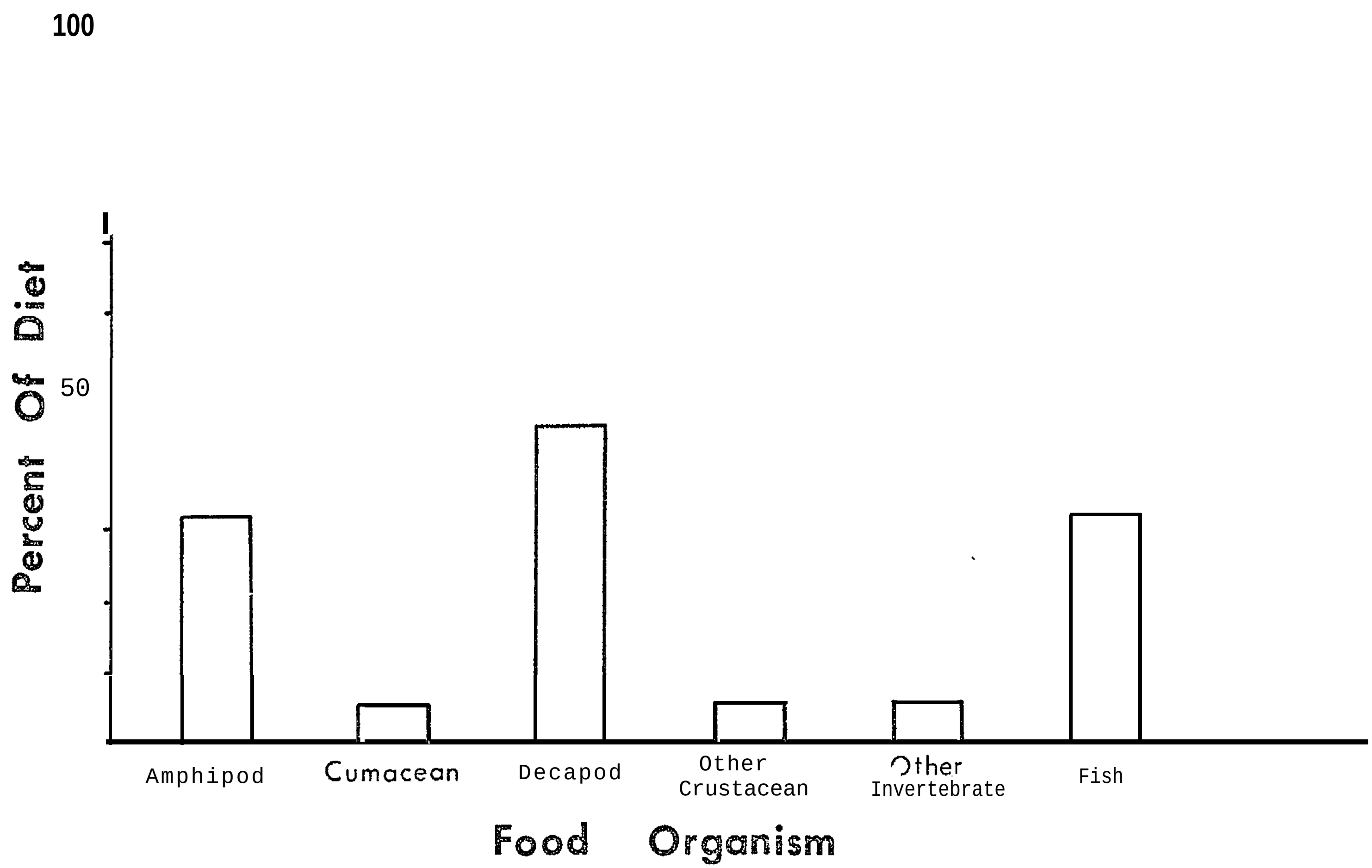

FIGURE 28. Percent occurrence of Various Food Taxa in the Diet of Murres (n=18) at Kongkok Bay, St. Lawrence Island, between 9 and 18 June 1976.

TABLE 21. Percent Occurrence of Food Organisms in the Diet of Murres in the Bering and Chukchi Seas.

	Bristol Bay[1] (55° -58°N)	Pribiloff Islands[2] (57°N)	St. Lawrence Island[3] (63°N)	Cape Thompson[4] (63°N)
Fish	44	49	33	74
Crustaceans		25	67	
Euphausids	26		0	
Amphipods	2		33	
Decapods		25	44	
Other			22	
Molluscs	12	26	0	
Other Invertebrates			11	
Total Invertebrates			72	25
Other	56		74	52

[1]Ogi and Tsujita (1973).

[2]Preble and McAtee (cited by Storer 1952); data are in terms of percent frequency.

[3]Present study.

[4]Swartz (1966).

"squids" are not part of the diet of murres in more northerly latitudes as no squids were found in specimens from St. Lawrence Island or Cape Thompson. Amphipods and decapods occurred frequently in stomachs of murres collected from St. Lawrence Island waters; organisms from these taxa were eaten less frequently bymurres at Cape Thompson (Swartz 1966).

Fish were eaten by a slightly lower percentage of murres in the St. Lawrence Island area than in other areas of the Bering Sea and by a much lower percentage of murres in the St. Lawrence Island area than in the Chukchi Sea.

It is not known whether these apparent differences in the diet of murres at different latitudes are due to different levels of abundance of the various prey items, to seasonal differences in the diet of murres, or are artifacts of the different methods of selecting murres for food habits analysis. It should also be noted that differential digestibility of hard and soft food organisms will result in large biases in stomach content data regardless of the method of analysis.

Feeding Areas

Most murres that nested at Kongkok Bay apparently fed off the northwest cape of St. Lawrence Island or well out to sea (>20 km) in a west and northwesterly direction from Kongkok Bay (Figure 27). During all months of the present study, large southerly flights of murres were observed along the west coast of St. Lawrence Island; these flights were apparently composed of murres which were returning from feeding grounds near Northwest Cape. A lesser number of murres was observed leaving the cliffs of Owalit Mountain and flying in a direct line for the Anadyr Gulf. These birds were often accompanied by either Horned Puffins, Tufted Puffins, Crested Auklets or Parakeet Auklets. Flocks of murres with individual puffins or auklets were also seen on the return flight along the same route. The location to which these birds flew is unknown, but presumably their feeding areas were off the coast of the Chukotsk Peninsula in the Anadyr Straits.

SUMMARY

The timing of the 1976 breeding season was later than average for most of the species that were studied. Table 22 compares the phenology of the 1976 breeding season of species for which comparative information is available with the phenology of these species during earlier years. Large fluctuations in the timing of events during the breeding season are characteristic of birds that breed in arctic areas. The fact that nearly all species of seabirds at Kongkok Bay nested late during 1976 indicates that climatic factors (i.e., prolonged snow-cover on the breeding cliffs) were the probable cause of the retarded season during 1976.

During the last decade, large changes have occurred in the number of seabirds that occupy the cliffs and talus slopes at Kongkok Bay. The estimated numbers of auklets in Kongkok Basin increased 59% from 1966 to 1976. Most of this increase was the result of a 95% increase in the numbers of Least Auklets (to 336,000) whereas Crested Auklets increased by only 18% (to 173,000). The numbers of Common and Thick-billed Murres and Black-legged Kittiwakes that nested at Kongkok Bay during 1976 were substantially lower than the numbers that nested there during 1972. Murres showed a four-fold decrease in numbers from approximately 60,000 in 1972 to about 15,000 in 1976. The number of kittiwakes present during 1976 was only 12.5% of the number present at Kongkok Bay during 1972. Rather than being caused by an actual population decline, the lower numbers of murres and kittiwakes on the nesting ledges may have been caused by birds that failed to breed due to the late season. The numbers of seven other species of seabirds that nested at Kongkok Bay were also estimated; however, the lack of comparative estimates from previous years did not permit me to determine whether their numbers had increased or decreased.

Table 23 presents-the estimates of seabird populations at Kongkok Bay during 1976; these estimates are summarized in relation to estimates from other years and at other colonies on St. Lawrence Island.

TABLE 22. Summary of Phenology of the Breeding Season of Seabirds at Kongkok Bay during 1976 and Relation to "Normal" Breeding Chronology.

Event and Species	CHRONOLOGY Normal	1976	COMMENTS
Arrival in St. Lawrence Island Area			
Least Auklets	15-21 May	?	Normal?
Crested Auklets	15-20 May	21 May	Slightly late
Murres	late April	earlier than 14 May	Late?
Black-legged Kittiwakes	29 April-n May	16 May	Late
Parakeet Auklets	15-20 May	17 May	Normal
Tufted Puffins	early May-4 June	17 May	Normal
Horned Puffins	5-28 May	25 May	Slightly late
Arrival on Cliffs			
Least Auklets	20-24 May	29 May	Late
Crested Auklets	18-24 May	29 May	Late
Murres	?	28 May	Late?
Black-1 egged Kittiwakes	?	27 May	Normal ?
Parakeet Auklets	19-24 May	27 May	Late
Initiation of Laying			
Least Auklets	12-28 June	1 July	Normal or Late
Crested Auklets	14-30 June	1 July	Late
Murres	early to late June	28 June	Slightly late?
Black-1 egged Kittiwakes	late June	29 June	Normal
Initiation of Hatching			
Least Auklets	15-30 July	25 July	Normal
Crested Auklets	19 July-2 August	2 August	Slightly late
Murres	30 July	31 July	Slightly late
Initiation of Fledging			
Least Auklets	15-28 August	24 August	Normal
Crested Auklets	26 August-5 September	later than 3 September	Slightly late?
Murres	18 August	21 August	Late

TABLE 23. Summary of Nesting Seabird Populations on St. Lawrence Island, Alaska[1].

Species	Location	YEAR ±1957[2]	±1966[3]	1972[4]	1976[5]
Pelagic Cormarant	Owalit Mountain			100[6]	300
Glaucous Gull	Boxer Bay	50			
	Owalit Mountain				24-30
Herring Gull	Koozata Lagoon	100			
	Ivekan Mountain				2-4
Black-legged Kittiwake	Owalit Mountain			2000'	1700-1900
Murres	St. Lawrence Island	100,000			
	Owalit Mountain			60,000	16,000
Pigeon Guillemot	Owalit Mountain				150
Parakeet, Auklet	Sevuokok Mountain	Few	2000		
	Kaghkusalik Point	Few			
	Savoonga	Very Few			
	Singikpo Cape	Many			
	Tatik Point-Boxer Bay	Many ,			
	Owalit Mountain				1200-1800
Crested Auklet	Kongkok Basin	[500,000	165,000		173,000
	Ivekan Mountain		20,000		
	Reindeer Camp		37,000		
	Ataakas-Kookoolik		185,000		
	Savoonga		34,000		
	Kineegkit		8,000		
	Sevuokok Mountain		72,000		
	Owalit Mountain SW		5,000		
	Owalit Mountain SE				3,000
	Tupurpuk and Sitiilekk		40,000		
	Powooiliak		8,000		
Least Auklet	Sevuokok Mountain	100,000's	111,000		
	Kongkok Basin	500,000	189,000		336,000
	Tatik Point-Boxer Bay	500,000 (does not include Kongkok Basin)	25,000		
	Reindeer Camp		20,000		
	Ataakas-Kookoolik		128,000		
	Savoonga		51,000		
	Kineeghut		14,000		
	Owalit Mountain SW		8,000		
	Owalit Mountain SE				17,000
	Tupurpuk & Sitiilekk		75,000		
	Powooiliak		14,000		
Horned Puffin	Murphy Bay	1000-2000			
	Sevuokok Mountain		1,500		
	Owalit Mountain				600
	Punuk Islands				
Tufted Puffin	Punuk Islands	"large populations"	"honey-combed with burrows"		
	Sevuokok Mountain	None	500		
	Tatik Point- Powooiliak	"locally common"			
	Owalit Mountain				750

[1] Numbers are approximations.

[2] Fay and Cade 1959,

[3] Bédard 1969; Scaly and Bédard 1973; Thompson 1967; Scaly 1973

[4] S.R. Johnson pers. comm.

[5] Present study.

[6] Counted on less than 1/3 of Owalit Mountain.

The density of Least Auklets was found to be correlated with the angle of slope of the talus, the distance from the edge of the talus, the depth of scree, the sphericity of the talus boulders and the number of Crested Auklets. The density of Crested Auklets was correlated with the degree to which the talus slope faced the bay, the depth of scree and the size (volume and diameter) of the talus boulders.

Basic data were obtained on the breeding success of Least and Crested Auklets, Common and Thick-billed Murres, and Black-legged Kittiwakes and on the growth rates of Least and Crested Auklets in order to provide baseline data for comparison of the breeding effort of seabirds on St. Lawrence Island during 1976 with the breeding effort of other years and of other areas." Least Auklets hatched 60% of their eggs whereas Crested Auklets hatched only 30% of their eggs. The growth rates of Least and Crested Auklet chicks were not significantly different from each other--Least Auklets gained an average of 3.7 gin/day (4.1% of adult weight),'Crested Auklets gained 8.9 gin/day (3.3% of adult weight). The breeding success of murres (from egg to fledged chick) was 61%. Only 4% of the Black-legged Kittiwake nests contained eggs. The nesting failure of kittiwakes during 1976 was apparently widespread throughout the northern Bering and Chukchi seas.

During July, 1976, the main items in the diet of Least Auklets were decapods. Copepods comprised the major portion of the foods that were fed to young Least and Crested Auklets. Presumably, the copepod species, *Neocalanus plumchrus*, was especially abundant during August, 1976. As a result, auklets shifted from the "normal" foods that are taken at this time of year to take advantage of the N. *plumchrus* "bloom". Murres were noted to take mainly fish, amphipods and decapods. Invertebrates were apparently taken in greater numbers by murres in the St. Lawrence Island area than in other areas of the Bering and Chukchi seas.

Relative to other areas in the St. Lawrence Island waters, the Kongkok Bay area is not heavily used by seabirds as a feeding area. Apparently, most seabirds that nested in the Kongkok Bay area fed along the northwest cape of St. Lawrence Island where strong currents through the Anadyr Straits cause extensive mixing and result in very "rich" waters.

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A P P E N D I C E S

APPENDIX 1. Maximum and Minimum Recorded Temperatures (°C) at Kongkok Bay, St. Lawrence Island, during the Period from 31 May to 1 September 1976.

	TEMPERATURE			TEMPERATURE			TEMPERATURE	
DATE	LOW	HI	DATE	LOW	HI	DATE	LOW	HI
31 May	-1	11	1 July	2	18	1 August	-	-
1 June	1	8	2	0	12	2	-	-
2	0	9	3	3	13	3	15	16
3	-1	11	4		-	4	8	18
4	1	6	5			5	5	20
5	2	5	6	2	12	6	-	-
6	1	15	7			7	5	7
7	0	15	8	1	20	8		-
8	1	10	9	1	19	9		-
9	-	-	10	1	20	10	3	15
10	-	-	11	5	20	11		-
11	-3	13	12	1	21	12		-
12	0	19	13	5	25	13	7	15
13	0	12	14	5	23	19	6	13
14			15	4	13	15	4	12
15}	3	12	16	3	10	16	3	13
16	1	3	17	4	10	17	3	13
17	1	7	18	-	-	18	6	13
18	0	11	19	-	-	19	1	13
19	1	14	20	-	-	20	2	15
20	2	11	21	-	-	21	3	16
21	2	18	22	6	16	22	5	14
22	1	12	23	5	14	23	5	13
23	-	-	24	6	14	24	7	14
24	1	10	25	6	16	25	8	15
25	0	18	26	8	19	26	6	18
26	1	23	27	7	20	27	-	-
27	4	22	28	8	16	28	1	14
28	2	15	29	6	14	29	5	13
29	1	11	30	5	14	30	5	16
30	1	20	31	6	16	31	10	15
						1 Sept.	7	17

APPENDIX 2. Number of Counts of Auklets Conducted on 24 Plots between 05:00 and 08:00 from 2 to 19 June 1976. AØ refers to plots on Owalit Mountain. AB refers to plots in Kongkok Basin.

PLOT NUMBER	JUNE 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
AØ 01	1	5	3	4		6												
AØ 02	1	4	3	4		6												
AØ 03		4	3	3		6												
AØ 04		3	3	1		6												
AØ 05	1	4	3	4		6												
AØ 06				3		6												
AØ 07				3		6												
AØ 08				3		6												
AB 01											5	6			2			
AB 02															2			
AB 03												6			2			
AB 04							3				5	5			1			
AB 05												6			1			
AB 06											5	5			1			
AB 07											5	6			1			
AB 08											5	6			1			
AB 09															1		7	7
AB 10															1		7	6
AB 11															1		7	6
AB 12															1		7	6
AB 13															1		7	6
AB 14															1		7	6
AB 15															1		7	6
AB 16															1		7	6

APPENDIX 3. Approximate Areas of Six Cliff Plots on Owalit Mountain and Dates on Which these Plots were Censused.

PLOT NUMBER	AREA*	JUNE					JULY				AUGUST			SEPTEMBER
		8	13	19	25	29	4	9-11	18-19	27	5	13	22	1
1	1070	x	x			x		x	x	X	x	x	x	x
2	2930	x	x			x		x	x	x	x	x	x	x
3	4390	.	x											
4	1950		x					x						
5	2010		x					x						
6	16140			x	x		x	x	x	x	x			x

*in m^2.

APPENDIX 4. Number of Birds Per Hour on Three Activity Plots during Each Day of Observations.

MURRE

	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
PLOT 1										
11							22.0	12.4		
12							83.4	55.0		
J 18						302,0	295.7			
U 19				268.0	265.0					
N 24								176.0	147.0	71.6
E 25	248.0	270.0	258.0		124.5			175.0	158.0	
26					116.3	130.8				
27				203.0	182.0	173.5				
AVG	248.0	270.0	258.0	235.5	172.0	202.1	133.7	104.6	152.5	71.6
PLOT 2										
11							5.0	1.0		
12							18.2	13.5		
J 18						85.5	71.0			
U 19				89.0	122.0					
N 24								61.0	55.3	32.2
E 25	115.0	117.5	98.5		82.0			46.0	36.0	
26					41.7	34.0				
27				106.5	60.5	54.5				
AVG	115.0	117.5	98.5	97.7	76.5	58.0	31,4	30.4	45.6	32.2
PLOT 3										
11							9.0	9.3		
12							12.0	12.0		
J 18						59.5	69.7			
U 19				123.7	123.5					
N 24								42.0	36.5	24.0
E 25	53.0	59.5	54.0		37.0			34.0	39.0	
26					36.0	29.0				
27				151.0	23.5	24.0				
AVG	53.0	59.5	54.0	137.3	55.0	37.5	30.2	24.3	37.8	24.0

APPENDIX 4. Number of Birds Per Hour on Three Activity Plots during Each Day of Observations.

MURRE

	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
PLOT 1										
4			272.0							
11				247.5	124.5			230.0	147.5	159.0
J 12		215.0								
U 13	195.0	248.0	230,0	237.0	177.0	163.0	176.0			
L 14				229.0	240.5	225.0	231.0			
Y 15			228.0	137.0						
19				291.0	286.0	295.0	305.5	138.0		
AVG	195.0	231.5	243.3	228.3	207.0	227.7	237.5	184.0	147.5	159.0
PLOT 2										
4			0.0							
11				146.5	96.0			66.0	84.5	89.0
J 12		175.0								
U 13	113.0	206.0	230.0	147.5	60.5	56.5	47.0			
L 14				197.0	210.0	149.5	137.0			
Y 15			136.0	174.0						
19				101.0	112.5	134.5	120.0	68.0		
AVG	113.0	190.5	122.0	153.2	119.8	113.5	101.3	67.0	84.5	89.0
PLOT 3										
4			0.0							
11				122.5	59.5			33.0	28.5	27.0
J 12		72.0								
U 13	54.0	55.0	62.0	36.5	35.5	31.0	37.0			
L 14				47.0	60.0	78.0	88.0			
Y 15			88.0	98.0						
19				55.0	46.5	49.0	46.5	46.0		
AVG	54.0	63.5	50.0	71.8	50.4	[illegible]	57.2	39.5	28.5	27.0

Time of Day

APPENDIX 4. Number of Birds Per Hour on Three Activity Plots during Each Day of Observations.

KITTIWAKE

	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
PLOT 1										
JUNE 11							0.0	0.0		
12							0.0	0.0		
18						0,0	0.0			
19				0.0	0.0					
24								0.0	0.0	0.0
25	0.0	0.0	0.0		0.0			0.0	0.0	
26					0.0	0*O				
27				0.0	0.0	0,0				
AVG	0.0	0.0	0.0	0.0	0.0	0+0	0.0	0.0	0.0	0.0
PLOT 2										
JUNE 11							37.0	47.7		
12							52.0	43.5		
18						34.5	34.7			
19				40.3	40.0					
24								36.0	34.3	20.4
25	48.5	48.5	46.0		87.5			33.0	34.0	
26					45.7	28.3				
27				88.5	46.5	52.5				
AVG	48.5	48.5	4A. 0	64.4	54.9	38.4	41.2	40.1	34.1	20.4
PLOT 3										
JUNE 11							28.0	32.4		
12							39.6	39.0		
18						25+5	29.0			
19				71.3	95.5					
24								40.0	34.8	18.2
25	63.0	82.0	75,0		32.5			24.0	28.5	
26					17.3	20•5				
27				44.0	28.8	31,0				
AVG	63.0	82.0	75,0	57.7	43.5	25."7	32.2	33.9	31.6	18.2

APPENDIX 4. Number of Birds Per Hour on Three Activity Plots during Each Day of Observations.

KITTIWAKE

PLOT 1

Day	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
4			0.0							
11				0.0	0.0			0.0	0.0	0,0
J 12		0.0								
U 13	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
L 14				0.0	0.0	0.0	0.0			
Y 15			0.0	0.0						
19				0.0	0.0	0.0	0.0	0.0		
AVG	0.0	0.0	0.0	0.0	0.0	0,0	0.0	0.()	0.0	O*O

PLOT 2

Day	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
4			0.0							
11				37.0	57.5			49.0	35.0	38.0
J 12		33.0								
U 13	48.0	45.0	46.0	43.5	39.0	44.5	42.0			
L 14				44.0	54.0	47,0	40.0			
Y 15			53.0	54.0						
19				13.0	65.5	79.5	96.0	35.0		
AVG	48.0	39.0	33.0	38.3	54.0	57.0	59.3	42.0	35.0	38.0

PLOT 3

Day	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
4			0.0							
11				26.5	25.5			24.0	2[illegible].0	24.0
J 12		30.0								
U 13	32.0	21.0	26.0	20.5	32.5	37.0	32.0			
L 14				47.0	41.0	39.0	33.0			
Y 15			43.0	38.0						
19				21.0	27.5	33.0	31.5	[illegible]		
AVG	32.0	25.5	23.0	30.6	31.6	36.3	32.2	28,0	24.0	24.0

Time of Day

APPENDIX 4. Number of Birds Per Hour on Three Activity Plots during Each Day of Observations.

PELAGIC CORMORENT

	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
PLOT 1										
11							0.0	1.0		
12							1.0	1.0		
J 18						2.0	1.0			
U 19				1.0	1.0					
N 24								3.0	3.0	3.0
E 25	3.0	5.0	3.0		1.5			3.0	3.0	
26					0.0	0.0				
27				2.0	0.3	0.0				
AVG	3.0	5.0	3.0	1.5	0.7	0.5	0.7	2.0	3.0	3.0
PLOT 2										
11							11.0	12.4		
12							11.4	9.0		
J 18						14.5	13.3			
U 19				12.7	10.5					
N 24								12.0	12.8	11.0
E 25	11.0	10.0	11.0		9.5			11.0	12.5	
26					9.3	10.5				
27				17.5	9.8	9.5				
AVG	11.0	10.0	11.0	15.1	9.8	11.5	11.9	11.1	12.6	11.0
PLOT 3										
11							19.0	26.4		
12							19.4	15.5		
J 18						11.5	17.3			
U 19				13.7	20.0					
N 24								19.0	18.3	14.0
E 25	4.0	2.5	6.5		11.0			34.0	28.5	
26					17.0	14.3				
27				16.0	20.8	28.5				
AVG	4.0	2.5	6.5	14.8	17.7	18.1	18.6	23.7	23.4	14.0

APPENDIX 4 Number of Birds Per Hour on Three Activity Plots during Each Day of Observations

[illegible]

		4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
PLOT 1											
	[illegible]			3.0							
	11				1.5	0.0			0.0	1.5	2.0
J	12		3.0								
U	13	2.0	2.0	2.0	1.0	0.0	0.0	0.0			
L	14				1.0	0.0	0.0	1.0			
Y	15			2.0	2.0						
	19				1.0	0.0	0.0	0.0	0.0		
	AVG	2.0	2.5	2.3	1.3	0.0	0.0	0.3	0.0	1.5	2.0
PLOT 2											
	4			0.0							
	11				10.0	10.0			8.0	10.0	11.0
J	12		12.0								
U	13	9.0	12.0	10.0	8.5	11.0	8.0	8.0			
L	14				9.0	9.0	9.0	8.0			
Y	15			9.0	8.0						
	19				10.0	8.5	8.5	9.5	9.0		
	AVG	9.0	12.0	6.3	9.1	9.6	8.5	8.5	8.5	10.0	11.0
PLOT 3											
	4			0.0							
	11				1.5	2.5			3.0	6.5	[illegible]
	12		0.0								
	13	2.0	2.0	0.0	1.0	0.0	5.5	9.0			
	14				5.0	11.0	13.0	9.0			
	15			4.0	2.0						
	19				13.0	13.0	9.5	15.0	7.0		
	AVG	2.0	1.0	1.3	4.5	6.6	9.3	11.0	5.0	6.5	8.0

Time of Day

APPENDIX 4. Number of Birds Per Hour on Three Activity Plots during Each Day of Observations.

[illegible] AUKLET

	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
PLOT 1										
11							0+0	0, o		
12							0.0	0.0		
J 18						0.0	0.0			
U 19				1.3	0.5					
N 24								0.0	0.0	0.0
E 25	10.0	12.0	O*()		1.5			0.0	0.0	
26					0.0	O*O				
27				5.5	1.5	0.5				
AVG	10.0	12.0	0.0	3.4	0.9	0.2	0.0	O*O	0+0	0.0
PLOT 2										
11							O*O	O*O		
12							0.0	0.0		
J 18						O*O	0.0			
U 19				0.0	0+0					
N 24								O*O	0.0	0.0
E 25	0.0	0+0	0.5		O*O			0+0	0.0	
26					0,0	0.0				
27				0.0	0,0	0.0				
AVG	0 . 0	0.0	0*5	0.0	0.0	0,0	0.0	0.0	O*O	0.0
PLOT 3										
11							0.0	0,0		
12							0.0	0.0		
J 18						0.0	0.0			
U 19				0.0	0.0					
N 24								0.0	()+ o	0.0
E 25	0.0	0.0	O*O		2 'o			0.0	0.0	
26					0.()	0.0				
27				0.5	0.0	O*O				
AVG	0.0	0 . 0	0+0	0.3	0.5	0.0	0.0	0,0	0+0	0.0

APPENDIX 4. Number of Birds Per Hour on Three Activity Plots during Each Day of Observations.

PARAKEET AUKLET

	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
PLOT 1										
4			12.0							
11				19.5	20.0			0.0	0.0	0,i)
J 12		25.0								
U 13	7.0	19.0	15.0	8.5	2.5	2.5	O*O			
L 14				8.0	13.5	6.0	1*o			
Y 15			15.0	24.0						
19				26.0	23.0	22.0	17.0	0.0		
AVG	7.0	22.0	14.0	17.2	14.8	10.2	6.0	0.0	O*O	0.0
PLOT 2										
4			O*()							
11				0.0	0.0			O*O	0.0	0.0
J 12		0.0								
U 13	1.0	0, ()	0.0	0.0	0.0	0.0	0.0			
L 14				0.0	1.0	0.0	().()			
Y 15			0.0	0.0						
19				1.0	0.0	0.0	0.0	O*()		
AVG	1.0	0.0	0.0	0.2	0.3	0.0	0,0	o*o	0.0	0.()
PLOT 3										
4			0.0							
11				0.5	2.5			O*O	o.o	0.()
J 12		0.0								
U 13	0.0	2.o	0.0	0.5	0.0	0.0	0.0			
L 14				0.0	0.0	0.0	0,0			
Y 15			2.0	0.0						
19				3.0	2.0	0.5	1..0	0.0		
AVG	0.0	1.0	0+7	0.8	1.1	0.2	0*3	0,0	0.0	().0

Time of Day

APPENDIX 4. Number of Birds Per Hour on Three Activity Plots during Each Day of Observations.

HURN 11 PUT IN

	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
PLOT 1										
11							9.0	8.3		
12							30.2	31.0		
J 18						26.5	21.3			
U 19				27.7	35.0					
N 24								30.0	18.5	9.8
E 25	3.0	5,5	22, 0		24.0			53.0	44.5	
26					9.7	11.5				
27				3.5	3.3	4.0				
AVG	3.0	5,5	22.0	15.6	18.0	14.0	20.2	30.6	31.5	9.8
PLOT 2										
11							0.0	0.4		
12							1.8	3.5		
J 18						0*0	1.3			
U 19				0.0	0.0					
N 24								2.0	3.3	1.4
E 25	1.0	1,0	1.0		2.0			3.0	4.0	
26					0.0	0.0				
27				1.0	0.3	0.0				
AVG	1..0	1.0	1.0	0.5	0.6	0.0	1.0	2.2	3.6	1.4
PLOT 3										
11							0.0	1.4		
12							2.6	3.0		
J 18						1.0	1.0			
U 19				1.7	3.0					
N 24								1.0	8.8	0.6
E 25	0.0	0.0	0'5		2.0			3.0	3.5	
26					2.7	2.8				
27				1.0	0.3	0*O				
AVG	0.0	0.0	0.5	1.3	2.0	1.2	1.2	2.1	6.1	0.6

APPENDIX 4. Number of Birds Per Hour on Three Activity Plots during Each Day of Observations.

HORNED PUFFIN

PLOT 1

	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
4			13.0							
11				9.5	11.5			19.0	22.5	10.0
J 12		6.0								
U 13	1.0	3.0	2.0	5.0	1.0	3.5	2.0			
L 14				10.0	13.5	17.0	16.0			
Y 15			12.0	14.0						
19				6.0	13.5	17.0	21.0	18.0		
AVG	1.0	4.5	9.0	(3. s	9.9	12.5	13.0	18.5	22.5	10.0

PLOT 2

	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
4			0.0							
11				0.0	1.0			5.0	3.5	5.0
J 12		1.()								
U 13	0.0	O*O	0.0	0.0	O*O	0.0	0.0			
L 14				().0	2.5	2.5	0.0			
Y 15			0.0	2.0						
19				4.0	2.0	4.5	3.5	4.0		
AVG	0.0	0.5	0.0	1+2	1.4	2.3	1.2	4.5	3.5	5.0

PLOT 3

	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
4			0.0							
11				2.0	0.5			4.0	2.5	2.0
J 12		“1.0								
U 13	1.0	0.0	1.0	1.5	0.5	0.0	0.0			
I 14				2.i)	2.5	1.5	3.0			
Y 15			1.0	0.0						
1%'				3.0	3.5	2.5	1.5	6.0		
AVG	1.0	0.5	0.7	1.7	1.8	1.3	1.5	5.0	2.5	2.0

Time of Day

APPENDIX 4. Number of Birds Per Hour on Three Activity Plots during Each Day of Observations.

[illegible]

	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
PLOT 1										
11							2.0	3.7		
12							11.2	10.0		
JUNE 18						9.5	11.3			
19				15.0	22.0					
24								10.0	11.3	7.0
25	2.5	3.5	13.5		4.0			15.0	17.5	
26					0.0	1.0				
27				0.5	0.3	0.0				
AVG	2.5	3.5	13.5	7.7	6.6	3.5	8.2	9.7	14.4	7.0
PLOT 2										
11							0.0	0.0		
12							0.4	0.0		
JUNE 18						0.0	1.3			
19				0.0	1.0					
24								0.0	0.0	2.0
25	0.0	0.0	1.5		2.0			2.0	6.5	
26					0.3	0.0				
27				1.0	0.3	0.0				
AVG	0.0	0.0	1.5	0.5	0.9	0.0	0.6	0.5	3.3	2.0
PLOT 3										
11							1.0	2.3		
12							3.8	5.0		
JUNE 18						5.0	5.7			
19				11.3	9.5					
24								4.0	3.3	3.6
25	1.5	2.0	7.5		1.5			8.0	8.0	
26					1.3	0.8				
27				0.5	1.5	1.0				
AVG	1.5	2.0	7.5	5.9	3.5	2.[illegible]	3.5	4.8	5.6	3.6

APPENDIX 4. Number of Birds Per Hour on Three Activity Plots during Each Day of Observations.

[illegible]

	Date	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
PLOT 1											
	4			7.0							
	11				4.0	4.5			11.0	9.0	7.0
J	12		1.0								
U	13	0.0	1.0	3.0	0.0	0.5	0.0	0.0			
L	14				9.0	13.0	20.5	7.0			
Y	15			8.0	7.0						
	19				4.0	13.5	11.5	16.0	12.0		
	AVG	0.0	1.0	6.0	4.8	7.9	10.7	7.7	11.5	9.0	7.0
PLOT 2											
	4			0.0							
	11				1.0	1.0			1.0	0.5	0.0
J	12		0.0								
U	13	0.0	0.0	0.0	0.5	0.0	0.0	0.0			
L	14				0.0	3.0	0.5	0.0			
Y	15			0.0	1.0						
	19				0.0	0.5	2.5	2.5	0.0		
	AVG	0.0	0.0	0.0	0.5	1.1	1.0	0.8	0.5	0.5	0.0
PLOT 3											
	4			0.0							
	11				1.5	2.0			1.0	0.0	0.0
J	12		3.0								
U	13	0.0	1.0	1.0	2.0	2.0	2.0	1.0			
L	14				4.0	7.0	7.5	3.0			
Y	15			8.0	7.0						
	19				14.0	11.0	7.0	11.0	9.0		
	AVG	0.0	2.0	3.0	5.7	5.5	5.5	5.0	5.0	0.0	0.0

Time of Day

APPENDIX 4. Number of Birds Per Hour on Three Activity Plots during Each Day of Observations.

PIGEON GUILLEMOT

PLOT 1

		4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
	11							0,0	0.0		
	12							0.0	O*O		
J	18						0.0	0.0			
U	19				1.7	2.5					
N	24								0,0	0.5	3.4
E	25	1.5	1.5	0.5		1.5			0.0	0+0	
	26					1.0	0.0				
	27				0.0	0.3	0.5				
	AVG	1.5	1.5	0.5	0.8	1.3	0.2	0.0	0.0	0.3	3.4

PLOT 2

		4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
	11							0.0	o.1		
	12							1.4	1.0		
J	18						0.0	0.7			
U	19				3.3	3.5					
N	24								0.0	2.0	7+0
E	25	8.5	5.5	3.5		4.5			0 . 0	1.5	
	26					3.3	1.8				
	27				5.0	1.3	2.0				
	AVG	8.5	5.5	3.5	4.2	3.1	1.2	O*7	0.3	1.8	7.0

PLOT 3

		4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
	11							0.0	().1		
	12							0.4	0.0		
J	18						3.0	2.0			
U	19				8.0	6.5					
N	24								1,0	2,5	8,0
E	25	9.5	8.5	10.0		1.0			0.0	0.5	
	26					3.7	2.8				
	27				7.0	2.0	3.0				
	AVG	9.5	8.5	10.0	7.5	3.3	2.9	0.8	0.3	1.5	8+0

APPENDIX 4. Number of Birds Per Hour on Three Activity Plots during Each Day of Observations.

FIG I G/ I0U1LLIENOT

PLOT 1

	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
4			1.0							
11				3.5	3.5			0.0	0.0	0.0
J 12		6.0								
U 13	2.0	0.0	3.0	0.0	0.0	0.5	0.0			
L 14				3.0	2.0	0.0	0.0			
Y 15			2.0	3.0						
19				5.0	4.0	3.5	0.0	0.0		
AVG	2.0	3.0	2.0	2.9	2.4	1.3	0.0	0.0	0.0	0.0

PLOT 2

	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
4			0.0							
11				5.5	6.0			0.0	0.0	1.0
J 12		5.0								
U 13	0.0	3.0	3.0	3.0	4.0	2.5	0.0			
L 14				2.0	1.5	4.5	3.0			
Y 15			11.0	9.0						
19				9.0	6.0	0.5	0.5	0.0		
AVG	0.0	4.0	4.7	5.7	4.4	2.5	1.2	0.0	0.0	1.0

PLOT 3

	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
4			0.0							
11				9.0	4.5			0.0	0.5	1.0
J 12		0.0								
U 13	8.0	10.0	4.0	5.0	4.0	3.5	2.0			
L 14				2.0	5.5	3.0	0.0			
Y 15			12.0	7.0						
19				7.0	7.5	7.0	1.5	2.0		
AVG	8.0	5.0	5.3	6.0	5.4	4.5	1.2	1.0	0.5	1.0

Time of Day

APPENDIX 5. Sex and Measurements of Specimens and Live-captured Adult Birds at Kongkok Bay, 1976.

SPECIES	DATE	SEX	WEIGHT	WING[1]	PRIMARY	TARSUS	CULMEN
Least Auklet	10 July 1976	M	83g	116mm	56mm	20mm	10mm
		M	92	121	55	18	10
		M	91	121	63	21	10
		F	94	123	58	19	10
		F	106	127	62	19	9
		M	85	121	67	19	10
		M	93	128	61	20	10
		F	84	121	55	20	9
		M	83	127	59	21	10
		M	104	128	58	19	10
	16 July 1976		82	122	54	18	7
	28 August 1976	F	88	121	58	20	9
	AVERAGE[2]		90 + 8	123 + 4	59 + 4	20 + 1	10 + 1
Crested Auklet	6 June 1976	F	285g		95mm	27mm	12mm
	8 July 1976	F	262	190mm	81	33	13
		M	291	188	87	29	14
		M	291	186	88	27	12
		F	227	172	81	26	18
		M	266	182	84	29	13
		F	239	185	85	29	14
		F	250	181	87	28	15
		F	248	181	79	30	12

APPENDIX 5.(Cent'd)

SPECIES	DATE	SEX	WEIGHT	WING[1]	PRIMARY	TARSUS	CULMEN
Crested Auklet (cent'd)	8 July 1976	M	281g	188mm	87mm	30mm	14mm
		M	281	189	87	30	14
		M	268	175 “	84	28	13
			289	185	81	26	13
		M	265	187	84	29	13
		F	288	188	85	29	12
		M	281	184	85	27	13
		M	270	180	79	30	13
		F	231	187	89	30	18
		F	288	181	82	29	12
		F	258	184	87	26	13
		F	267	178	85	28	12
		M	269	189	92	29	13
		M	250	180	88	27	13
		F	265	181	87	29	12
			240	170	91	28	12
		M	273	185	85	27	13
		M	288	185	84	30	14
	AVERAGE	M	275 + 12				
		F	259 ± 21	183: 5	86+4	29 + 2	13 + 2
Parakeet Auklet	8 July 1976	F	265g	206mm	91mm	21mm	151nm
		M	284	197	92	32	17
Common Murre	8 June 1976	M		264mm	110mm	54mm	58mm
	9 June 1976	M	1000g	267	129	51	
		F	950	271	124	50	54
		M	1000	261	118	55	55
	12 June 1976		1150	288	123	44	44
		M	1 COO	273	122	41	62
		F	1040	290	116	48	45

APPENDIX 5.(Cent'd)

SPECIES	DATE	SEX	WEIGHT	WING[1]	PRIMARY	TARSUS	CULMEN
Common Murre (cent' d)	13 June 1976	M	900g	268mm	111mm	40mm	46mm
		M	950	279	122	39	42
	18 June 1976	M	925	268	123	35	42
		F	1000	277	123	37	43
		M	1050	274	122	37	46
		M	1075	278	116	41	46
		F	900	264	113	36	44
		M	950	276	119	38	44
	10 July 1976			280	128	40	44
	AVERAGE		992 ± 70	274 ± 8	120 + 6	43 + 7	48 ± 6
Thick-billed Murre	8June 1976	M		292mm	120mm	54mm	54mm
	9 June 1976	M	1190g	299	131	40	40
		M	815	301	134	40	43
		F	1025	281	122	49	49
		M	1075	289	127	51	53
		M	915	276	121	44	43
		F	1025	286	126	43	41
	10 June 1976	M	1040	299	130	49	55
	12 June 1976		925	295	130	47	48
	13 June 1976	M		306	129	43	41
	14 June 1976	F	1025	288	120	39	42
	18 June 1976	F	1050	279	135	49	48
		F	1025	298	124	48	
		F	1025	288	124	43	
		M	1175	295	127	42	45
		F	1050	295	127	40	40
		M	950	282	123	39	
		M	1100	300	128	39	42
		M	1075	282	132	40	
		F	1075	286	129	40	40

APPENDIX 5.(Cent'd)

SPECIES	DATE	SEX	WEIGHT	WING[1]	PRIMARY	TARSUS	CULMEN
Thick-billed Murre (cent'd)	18 June 1976	F	10509	289mm	119mm	40mm	42mm
		M	1000	287	131	39	38
		M	1050	284	127	38	45
		M	1150	276	126	39	40
		M	1075	288	136	40	42
		M	1025	299	123	41	42
		M	1200	283	126	37	39
		M	1100	202	124	39	39
		M	1150	290	133	35	41
		F	1100	294	137	39	44
	27 July 1976	M	800	292	125	34	37
	AVERAGE		1043 + 95	287: 18	127 + 5	42 + 5	43 + 5

[1]Wing length measured from elbow to tip of longest primary.

[2]No significant difference between the measurements of males and females except where reported otherwise. Average + one Standard Deviation.

APPENDIX 6. Numbers of Food Organisms by Size Classes Eaten by Murres and Auklets of the Kongkok Bay Colony during 1976.

The methods of measuring and counting food organisms found in the stomachs and sublingual (gular) pouches of the birds that were collected are as follows:

1. Mysids (*Mysis oculata* and *Paracanthomysis kurilensis*).

Because rostra were frequently broken off, mysids were measured from the anteriomost margin of the eye to the end of the telson. When animals were incomplete, only telsons were counted; the numbers were distributed proportionally among the measured categories when more than 10 telsons were present. When less than 10 telsons were present, the telsons were counted and entered under the 'present' (P) column.

2. Copepods (*Calanus* spp., *Neocalanus* spp., *Eucalanus bungii* and copepodites of all species).

Adults and copepodites were treated separately. Copepodites were separated into IV and V stages (the adult is the sixth stage).

Copepods were measured from the anterior part of the cephalosome (forehead) to the proximal fork of the caudal rami (the rami were often broken off). When numbers were large (>200), a random subsample of at least 25% was taken. All individuals in the subsample were measured and specimens in the remaining sample were counted. The specimens that were counted only were distributed into size categories according to the proportions found in the measured specimens of the sub-sample.

The urosomes of damaged (partial) animals were counted; the numbers were distributed among all species according to the proportions found in the particular sample.

3. Amphipods

i. *Parathemisto* spp. (*japonica & pacifica*).

Parathemisto spp. were measured from the front of the head (not including the antennae) to the end of the telson. The telsons of partial animals were measured to estimate the total length when there were more telsons than heads; when there were more heads than telsons, the head diameter (at its widest point} was used to estimate total length.

ii. Other amphipods

Other amphipods were measured (from the rostrum to the end of the telson) in 3 mm categories. For partial animals, the telsons were measured to estimate total length.

4. Decapods (*Eualus fabricii*, and others).

Adult decapods were measured and counted using the same techniques that were used for amphipods. Larvae (mysis stage) of Hippolytidae and Pandalidae were treated in the same manner as were the mysids except that 1 mm length intervals were used.

Young from brood pouches were not counted but marked as present.

5. Cumaceans (*Diastylis bidenticulata*).

Cumaceans were measured from the rostrum to the end of the telson. No partial animals were found.

6. *Limacina helicina*. Only the spiral bodies of these pteropods were found. The diameter at the widest point was measured to the nearest millimetre.

7. Fish. Fish larvae, either Cottidae or Scorpaenidae, were counted but could not be accurately measured because few specimens were complete.

Where bones or otoliths were found, adult fish of unknown species were assumed to have been present. No counts or measurements could be made.

8. The unidentified gastropod could be neither measured nor counted; they were recorded only as 'present'.

9. Plant material and grit (stones etc.) were recorded only as 'present'.

10. Crustacean larvae (protozoea, zoea and megalops, probably of decapods) were counted--all were less than 1 mm in length.

11. Pieces of crustaceans (e.g., legs or antennae) when present without any measurable parts of the species from which they came, were assigned to the lowest possible taxonomic level and recorded simply as 'present'.

APPENDIX 6. Indices for Determining Total Length from Partial Body Length.

Species	Total Length (mm)	Urosome + Telson Length (mm)	Head Diameter (mm)
Parathemisto spp. (last urosome segment + telson & uropods)	0-3	>1	>0.5
	3-6	1-1.75	0.5-1
	6-9	2-2.5	1-1.5
	9-12	2.5-3.25	>1.5
Ischyrocerus spp. (as *Parathemisto*)	6-9	1.5-2	
	9-12	>2	
(*Dulichia* spp.) (as *Parathemisto*)	3-6	>2	
	6-9	2-3	
	9-12	>3	
Calliopiella spp. (telson + uropods)	3-6	0.5-1.3	
	6-9	1.5-2	
	9-12	>2	
Atylus spp. (as *Calliopiella*)	3-6	>1	
	6-9	1-1.75	
	9-12	1 .75-2.5	
	15-18	>3	
Anonyx nugax (2 urosome segments + telson & uropods)	3-6	>2.0	
	6-9	2.5-3	
	9-12	3.5-5	
	12-15	>5	
Decapods (*Eualus fabricii*) (last urosome segment+ telson & uropods)	12-15	6-7	
	15-18	7-8	
	18-21	8-9	
	21-24	9-1o	
	24-27	10-11	
	27-30	11-11.5	
	30-33	11.5-12	
	33-36	12-13	
	36-39	13-14	
	39-42	14-15	
	42-49	>15	
Others	Either complete and, therefore, measured, or no whole specimens were available.		

APPENDIX 6. Numbers of Each Size Class of Food Organisms Found in Stomachs of Least Auklets.

Amphipods																										Decapods		Cumaceans			Copepods			Other Crustaceans	Other Invertebrates	Fish		Plant	Crit
Anonyx spp.			*Atylus tridens*					*Calliopiella* spp.				*Ischyrocerus* spp.			*Dulchia* spp.					*Achotropus* spp.		*Metopa* spp.	*Pontoporeia affinus*		Other	Hippolytidea (larvae)		*Diastylis bidenticulata*			*Neocalanus plumchrus*		*Calanus marshallae*			Adult	Larvae		
3-6	6-9	P	3-6	6-9	9-12	12-15	15-18	0-3	3-6	6-9	9-12	6-9	9-12	P	3-6	6-9	9-12	12-15	P	6-9	P	6-9	6-9	9-12	6-9	5-6 6-7 7-8 8-9 P	Zoea	3-6	6-9	9-12	3-4	4-5	3-4						
							1	*	6	1	1					5	1									10 77 59 3	20							P			9		
		P							2					P												12117 8510 2	7				1								
								•	7	4		1														6 6 8 6 0 2	2				1					P	3		P
														P	1	2	3									17 92 72 6	3						2					P	
								•	5	9					1	3		1		1		1	1			1 6 7 3 3 2	6	1	1	1	1						11		
														P	1											1 1 5 2 3 0 2 1	4									?		P	ʼ
													1	P			1		1							18 51 22 6	1												
																										29 24 5 P	1										1		
3	2		1						I					P										1		30 14s 42 8 P					2	1	1	1(unid. cumacean)	1(unid. diptera)				P
	1			1				●	2 6 1 6 2			S	4			10					2				3	2 3 9 6 9 3 3 2	8										2-3		P

● Young from brood pouch.

APPENDIX 6. Numbers of Each Size Class of Food Organisms Found in Gular Pouches of Least and Crested Auklets (Amphipods, Decapods, Mysids).

Continued on next page.

Species	Amphipods														Decapods										Mysids							
	Hyperiidae							Other							Pandalidae									Larvae								
	Parathemisto spp.					Other																			*Paracanthomysis* spp.					Other		
	0-3	3-6	6-9	9-12	P	3-6	6-9	3-6	6-9	9-12	12-15	15-18	18-21	P	5-6	6-7	7-8	8-9	9-10	10-11	12-15	24-27	P		3-6	6-9	9-12	12-15	P	9-12	12-15	P
Least Auklets		1	1																													
		4	2											(*Dulchia* spp.) 1			2	2	2						1		15	1				1
			2																													
	1	5	4	3					1	1					4	1	2	1	3		3	1	1		1							
																	1										1					
		1											(*Atylus tridens*) 1								1											
		5	5						1					1			2	1						1								
		5	1	1																4			2	1			3	1	1			
		3																														1
		6	2	1			1	2	1	1														2							3	
						1	2																	1								
Crested Auklets																1																
															3	8	3	5														
			2											(*Anonyx* spp.) P																		
		2																					P									
	1	1															2		2													
		2							1 (gammarid)														1						1			
		2	2																													P
		5	2															1	1				3									
			1														1	1					1				1					

APPENDIX 6. Numbers of Each Size Class of Food Organisms Found in Gular Pouches of Least and Crested Auklets (Copepods, Other Crustaceans, Molluscs). Continued from previous page.

Species	Copepods												Other Crustaceans							Molluscs	
	Adults				Copepodites								Euphausidae					Hippolytidae	Other		
	Neocalanus plumchrus 3-4	*Neocalanus plumchrus* 4-5	*Eucalanus bungii* 6-7	*Calanus marshallae* 3-4	*Neocalanus plumchrus* 3-4	*Neocalanus plumchrus* 4-5	*Neoc. cristatus* 7-8	*Neoc. cristatus* 8-9	*Eucalanus bungii* 5-6	*Eucalanus bungii* 6-7	*Calanus marshallae* 2-3	*Calanus marshallae* 3-4	9-12	12-15	15-18	18-21	P	6-9	P	*Limacina helicina* 1-3	Other
Least Auklets	1	36			205	198		5				2									
	1	32	1		427	268		6				2						1			P
	1	11	1		184	115		2				13									
		7		5	118	73						39									P
		120	2	4	1022	678					3									12	P
	52	21			152	99					9	143									P
		76			687	450		3				31								4	
	3	64	1	3	592	322		1		1		30								2	P[1]
	1	48			437	201	2					18									P
		13			485	213			1			9									P
		61		4	768	399	9			1		18								8	P[1]
		48	1	1	312	206	2	1				12									
	1	162	2		458	422	4					6									
		6			300	210															
	3	34			320	121	5					13									P[2]
	2	35			298	165	1					11									
		39		1	431	210		1				20									P
	4	51			377	225			5			13[3]									
		23	1		488	202						4								3	
	1	54			338	187		14				12	1						P		P
		38	2		577	303		2				7								2	P
	3	46			261	191	5			1		12									P
		126			902	287	6					43								3	P
		34			349	200	2					7									P[4]

[1] Plant remains also present
[2] Also 1 unidentified copepod present
[3] Fish remains also present
[4] Also 2 unidentified organisms present

APPENDIX 6. Numbers of Each Size Class of Species of Food Organisms Found in Stomachs of Crested Auklets.

Amphipods				Cumaceans	Molluscs	Other Invertebrates	Grit
Anonyx nugax	*Dulchia* spp. 6-9	*Dulchia* spp. P	Other 6-9	*Diastylis bidenticulata* 9-12	*Limacina helicina*		
		P					
P							
					1		
					5		
	2		2	2	1		P
						1 (unid. tick)	

APPENDIX 6. Numbers of Each Size Class of Food Organisms Found in Stomachs of Common and Thick-billed Murres.

Species	Amphipods: *Anonyx nugax* 6-9	*Anonyx nugax* 9-12	*Anonyx nugax* 12-75	*Atylus tridens* P	*Atylus tridens* 6-9	*Atylus tridens* 9-72	*Amplesica* spp. 21-24	*Parathemisto* spp.	Other	Cumaceans: *Diastylis bidenticulata* 12-15	*Diastylis bidenticulata* 15-18	*Diastylis bidenticulata* P	Decapods: *Eualus fabricii* 12-?5	15-18	21-24	24-27	27-30	30-33	33-36	36-39	39-42	42-45	P	Other Crustaceans: *Mysis littoralis* 27-30	Other	Other Invertebrates: *Spirobis* 1-5	Hydrozoa	Araneae	Other: Fish	Plant	Grit
Thick-	1	9	6		2					2	1										7										
billed																															
Murres		2	1																					1							
							3					1	1		1	2	5	1	0	1	2	9	”								
																							P			1	1				
																													P	P	P
																							P							P	P
																									P						P
																												1		P	
																							P							P	P
																													P	P	
C m n																															
Murres																													Q		
																							P								
								P																							
	1		2						P		1																		P	P	
																														P	
				1																											
																													P		

*Young from brood pouch.