OCS Study
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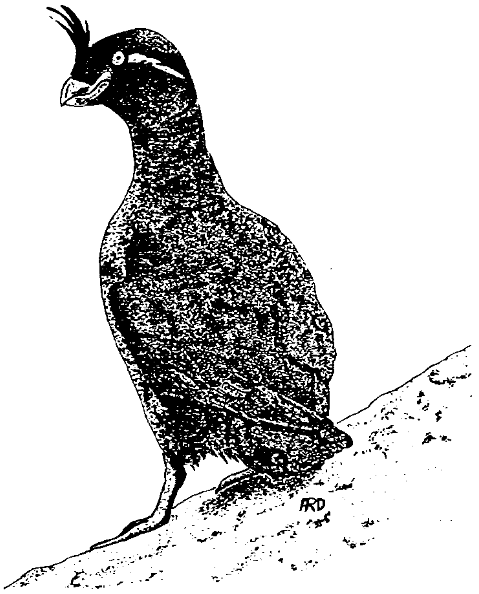
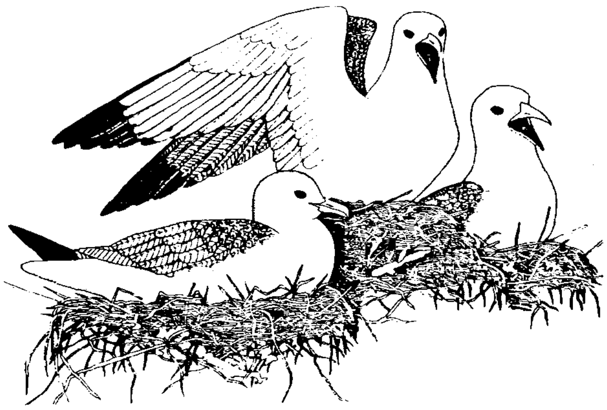
Alaska Fish and Wildlife Research Center

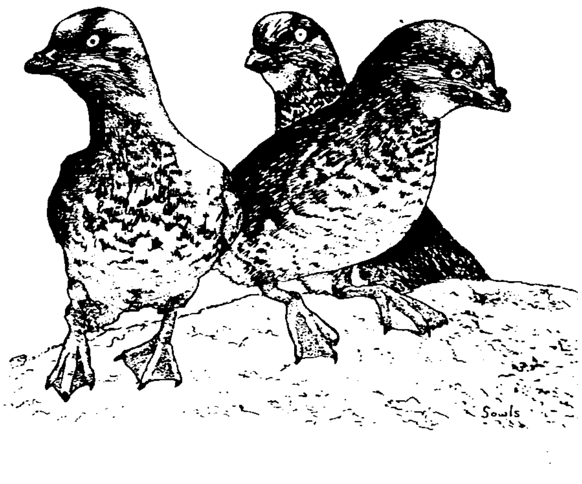
Monitoring Seabird Populations in Areas
of Oil and Gas Development on the
Alaskan Continental Shelf:

Populations, Productivity, and Feeding Habits of Seabirds on St. Lawrence Island

Final Report







OCS Study
MMS 88-0022

Populations, Productivity, and Feeding Habits of Seabirds on St. Lawrence Island, Alaska

Final Report

by

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ABSTRACT

A field camp was established at Kongkok Bay near the southwest cape of St. Lawrence Island and occupied continuously from 24 May to 2 September 1987. Permanent study plots were selected for both cliff and crevice-nesting species, and regular observations were made throughout the breeding season to document attendance patterns, breeding phenology, and success. Periodic collections of adults offshore and of chick meals in the colonies were used to determine the food habits of study species. Additional plots for population monitoring of murres and kittiwakes were established in colonies near Savoonga on the north side of the island, and counts were made there between 23 July and 1 August. Shore based work was supplemented with offshore studies of seabird foraging distribution from the USFWS vessel TIGLAX between 18 August and 3 September 1987.

Populations of all study species in the Kongkok Bay area increased since the last study of seabirds there (murres 20%, kittiwakes 87%, Least Auklets 8%, Crested Auklets 44%). Pelagic Cormorants, Common Murres, and Thick-billed Murres exhibited average, or above average, breeding success at Kongkok in 1987. Black-legged Kittiwakes exhibited near-total reproductive failure. Crested and Least Auklets had high levels of breeding success after the effects of observer disturbance were taken into account. Predation by microtine rodents and foxes was a significant source of chick mortality on auklets.

Feeding concentrations were found primarily north of Gambell in the Anadyr Strait or western Chirikof Basin. Kittiwakes were dispersed widely over the study area. Diets of all species studied were normal and, with the exception of kittiwakes, there was no evidence of problems in obtaining food.

Current methods for assessing population changes in cliff-nesting species are considered adequate, but better techniques are needed for crevice-nesting auklets. Time-lapse photography offers the greatest potential for monitoring auklet numbers. A protocol is suggested for monitoring populations of murres, kittiwakes, and auklets at colonies in the Bering and Chukchi Seas. It calls for annual visits to selected colonies during two stages of the nesting cycle to assess numbers and breeding productivity.

The breeding failure of Black-legged Kittiwakes on St. Lawrence Island in 1987 was part of a pervasive syndrome of failure in this species observed throughout the Bering Sea and Gulf of Alaska in recent years. The causes of recurrent, widespread breeding failure need to be identified if kittiwakes are to have a role in area-wide population monitoring during the period of Alaskan development by the oil and gas industry.

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Chapter 1. Introduction

1.1. General Introduction

Some 1.8 million seabirds of 12 species breed on St. Lawrence Island in the northern Bering Sea (Fig. 1.1), making this one of the largest aggregations of breeding seabirds in the subarctic Pacific. Colonies of Least (Aethia pusilla) and Crested Auklets (Aethia cristatella) alone, totaling 1.5 million birds, contain a substantial proportion (perhaps 20%) of these species' world populations (Sowls et al. 1978). Critical nesting and foraging habitat of St. Lawrence Island seabirds has, to date, remained mostly free from industrial disturbance or alteration. However, there is a possibility of adverse effects on either or both components of the birds' environment from potential oil spills associated with oil tanker traffic and/or oil development activities in the Norton Basin.

Potential adverse effects to seabird populations on St. Lawrence Island are especially important because of the value of this resource to subsistence users. Of the total seabirds used for subsistence purposes in the northern Bering and Chukchi Seas, as much as 70 percent of the bird harvest and 50 percent of the egg harvest may be taken by the villages of Gambell and Savoonga on St. Lawrence Island. Regulating agencies and the petroleum industry have a responsibility to ensure the continued availability of this resource for traditional human use.

This report presents the results of field studies conducted on St. Lawrence Island in 1987 by the Fish and Wildlife Service in cooperation with the Minerals Management Service, Alaska OCS Region. Studies were intended to obtain background information on local seabird populations and productivity in 1987 and to establish permanent study plots for long-term monitoring of seabirds on the island.

While federal responsibility for regulatory management and effects assessment during OCS development clearly includes the marine habitats of seabirds, pertinent studies are scarce in comparison with land-based work. Most at-sea studies have been carried out on an incidental basis during oceanographic cruises, and many basic questions about seabird movements and habitat requirements at sea remain unanswered. Therefore, we complemented our

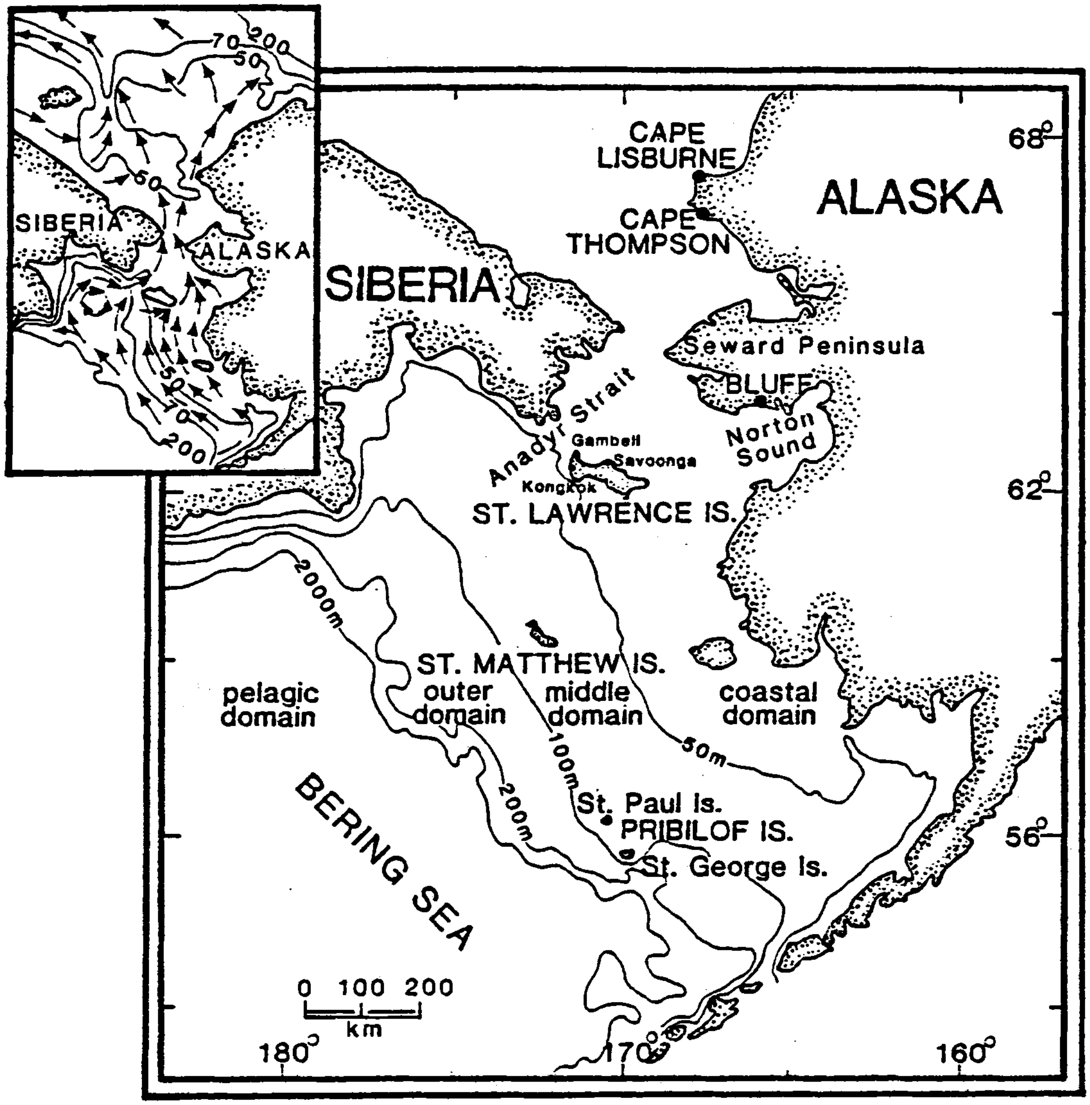

Figure 1.1. Location of St. Lawrence Island in the Bering Sea. Study areas were in Kongkok and Savoonga. Characteristic water masses in the Bering Sea roughly defined by 50 m (coastal domain), 50-100 m (middle domain), 100-200 m (outer domain), and 200 m (pelagic domain) bathymetric contour lines. Inset shows major currents in Bering Sea (after Springer et al. 1987).

work at colonies in 1987 with observations of seabirds in adjacent waters. The Fish and Wildlife Service vessel M/V Tiglax was our study platform and 17 days of ship time were dedicated to surveys in late August and early September.

The remainder of this introductory chapter provides a brief overview of our objectives, study sites and methods, and a synopsis of prior seabird investigations on St. Lawrence Island. Chapter 2 presents results pertaining to populations and breeding biology of cliff-nesting birds (murres, kittiwakes, and cormorants), and Chapter 3 addresses the same topics for the crevice-nesters (auklets). The at-sea distribution of feeding aggregations and time-dependent use of pelagic habitats is discussed in Chapter 4. Chapter 5 summarizes our major findings and recommendations for monitoring seabirds on St. Lawrence Island, and Chapter 6 outlines a broader program of seabird monitoring for the Bering and Chukchi Seas. Population counts, documentation of permanent census plots, and incidental information gathered during this study are included as appendices to this report.

1.2. Objectives

The major objectives of this project were as follows:

1. Design and implement a monitoring protocol for detecting long-term trends in populations and productivity of seabirds on St. Lawrence Island.

2. Obtain standard measures of population numbers and productivity during the 1987 breeding season for Black-legged Kittiwakes, Thick-billed Murres, Least Auklets, and Crested Auklets.

3. Determine the food habits of auklets, murres, and kittiwakes, and identify key foraging areas in the nearshore waters of St. Lawrence Island.

4. Analyze historical data on seabird populations of St. Lawrence Island and compare with results from 1987.

5. Assess the adequacy of data collected through 1987 for detecting future effects of the oil and gas industry on St. Lawrence Island seabirds.

1.3. Study Area

St. Lawrence Island (ca. 63° 30' N, 170° 30' W) lies about 200 km west of the Alaskan mainland and about 60 km east of the Chukotsk Peninsula of Siberia (Fig. 1.1). Although most of the eastern and southern portions of the island are unsuitable for breeding by seabirds, precipitous cliffs and glacially-formed talus slopes provide habitat for large numbers of cliff-nesting and crevice-nesting species at Kongkok Basin on the southwest coast, and near the communities of Gambell and Savoonga on the north coast (Fig. 1.1). The avifauna, climate, and habitat characteristics of St. Lawrence Island have been described in detail elsewhere (Fay and Cade 1959, Bedard 1969a,b, Sealy 1975).

We conducted most of our studies on Least and Crested Auklets, Common and Thick-billed Murres (*Uria aalge* and *U. lomvia*), Black-legged Kittiwakes (*Rissa tridactyla*), and Pelagic Cormorants (*Phalacrocorax pelagicus*) at Kongkok. We also obtained data on murre and kittiwake attendance at a study site east of Savoonga. We examined the diet composition of auklets and murres collected nearshore at Gambell and Kongkok, and from chick meals collected at the auklet colony in Kongkok. We conducted offshore surveys of bird distribution and abundance off Kongkok, and in areas north of Gambell into the Anadyr Strait.

The large, diverse seabird populations of St. Lawrence Island are sustained by highly productive waters surrounding the island, and in particular, by northward flowing Anadyr water to the west and northwest (Fig. 1.1). This water originates as a bifurcation of the Bering Slope Current that traverses the Bering Sea along the continental shelf break (Coachman et al. 1975). This cold, saline, and nutrient-rich water stimulates primary production along the Anadyr Strait, and carries with it a considerable biomass of large copepods, including *Neocalanus plumchrus* and *N. cristatus*, species more typical of outer and pelagic domains of the Bering Sea (Springer et al. 1987). These and other zooplankton species (especially *Thysanoessa* spp. euphausiids) provide abundant food for auklets at St. Lawrence Island as well as for planktivorous pelagic fish like Arctic cod (*Boreogadus saida*), which in turn sustain large populations of piscivorous seabirds including murres and kittiwakes.

1.4. Previous Studies

Observations on the avifauna of St. Lawrence Island date from at least 1881, and numerous summary reports have been published since then, notably by Friedmann (1932), Murie (1936), Fay and Cade (1959), and Sealy et al. (1971). Fay and Cade (1959) gave the first thorough account of the ecology of seabirds nesting on St. Lawrence Island. They provided information on breeding status, approximate (order of magnitude) population sizes, major breeding areas and habitat use, phenology, and some details on diets, of 26 seabird species.

Rigorous studies of seabird ecology were initiated in 1964 by Bedard (1967, 1969a, 1969b), who focused on the planktivorous _Aethia_ genus of alcids including Crested (_A. cristatella_), Least (_A. pusilla_), and Parakeet auklets (_A. psittacula_). Between 1964 and 1967, Bedard collected detailed data on habitat characteristics, breeding densities, diets, and foraging behaviors of all three _Aethia_ auklets at two main study sites: Sevuokuk Mountain, near the community of Gambell on the northwest cape of St. Lawrence Island, and Kongkok Basin, near the southwest cape of the island. With more data collected in breeding areas near Savoonga, in the north-central part of the island, Bedard was able to generate total population estimates for all three alcids on St. Lawrence Island. Bedard collected large samples of food items from both adult and nestling auklets, providing the most extensive historical data set on diets of any seabirds from St. Lawrence Island. Bedard reported little on aspects of breeding phenology or success of auklets.

In 1966 and 1967, Sealy conducted research on breeding biology and phenology, and factors affecting breeding success, of the three _Aethia_ auklets studied by Bedard, as well as on the Horned Puffin (_Fratercula corniculata_) at Sevuokuk Mountain (Sealy 1968, 1973, 1975, 1981, 1982; Sealy and Bedard 1973). Although these represent the first detailed reports on breeding biology of alcids at St. Lawrence Island, some aspects of phenology and particularly breeding success remain to be examined in detail. Data on diets were reported, but little or no information was given by Sealy on population densities of the different alcids.

S.R. Johnson censused murres (spp.) along a portion of the west coast of St. Lawrence Island in 1972 (unpubl. data, reported in Searing 1977). Based on observations made over about a month at Owalit Mountain near Kongkok Basin, he reported on growth and development of Common and Thick-billed Murre chicks, providing some details on phenology of breeding in these species (Johnson and West 1975).

Searing (1977) investigated the ecology of cliff-nesting birds at Kongkok Bay between 31 May and 1 September 1976. Although his sample sizes for some species were small, he reported fairly detailed information on attendance patterns and breeding phenology of 12 different seabird species including Crested, Least, and Parakeet Auklets, Tufted (*Lunda cirrhata*) and Horned Puffins, Pigeon Guillemots (*Cepphus columba*), Thick-billed and Common Murres, Pelagic Cormorants (*Phalacrocorax pelagicus*), Glaucous (*Larus hyperboreus*) and Herring (*L. argentatus*) Gulls, and Black-legged Kittiwakes. His data were minimally sufficient to estimate breeding success in Least Auklets, murres, and Black-legged Kittiwakes. He also collected small samples of each of these species (except kittiwake) for diet examinations.

Searing censused most of the seabirds nesting in the Kongkok Basin and provided estimates of Least and Crested Auklet populations which could be compared with Bedard's estimates of 1964-1967. He established six study plots on Owalit Mountain for monitoring Common and Thick-billed Murre, and kittiwake populations. Extrapolating from these plots to total nesting habitat, Searing generated the first detailed estimates of murre (spp.) and kittiwake populations at Kongkok Bay, which could be compared to Johnson's (unpubl.) approximate estimates made in 1972.

Aerial surveys conducted in 1977 and 1978 (Ramsdell and Drury 1979, Drury et al. 1981) provided some data on seabird numbers, colony locations, and offshore feeding areas around St. Lawrence Island. The most recent water-based survey was conducted by Roseneau (reported in Roseneau et al. 1985; Springer and Roseneau 1985). Roseneau's work was restricted to a one-month period (14 July-15 August) in 1981, and most effort was concentrated on conducting counts of murre and kittiwake numbers present at colonies at Kongkok Basin and on the north coast near Savoonga. Roseneau re-located 4 of 6 study plots established by Searing at Kongkok, allowing a direct comparison of numbers in this colony. From limited data, Roseneau estimated breeding phenology of murres, kittiwakes, and Least Auklets, and provided estimates of growth rates in kittiwakes and Least Auklets. Samples of murres and kittiwakes were collected for stomach content examinations, and frequent observations were made on flight directions of alcids to and from offshore foraging areas. The diets of murres and kittiwakes from this study have recently been reported and discussed in context of marine food webs in the northern Bering Sea (Springer et al. 1987).

N.M. Harrison and G.L. Hunt, University of California, Irvine, conducted studies of auklet foraging distributions and diets near St. Lawrence Island in three years from 1984-1986. Their work, though of short duration each year, represents the most thorough analysis to date of auklet foraging patterns in the Bering Sea. Results are as yet unpublished.

1.5. General Methods and Rationale

Birkhead and Nettleship (1980) coined the terms Type I and Type II methods to denote two possible approaches to monitoring populations. Their discussion pertained specifically to murres, but the ideas apply equally well to other colonial seabirds, particulary cliff-nesting species. Briefly, Type I methods entail frequent, time-consuming observations on study plots throughout the breeding cycle, from which the number of breeding pairs per plot is known, as is the fate of all eggs and nestlings. Other information such as the activity cycles of adults is generally obtained in such studies. Type II methods involve replicate counts of the number of birds per plot and provide an index of population size over the period of observations. This approach is always less time-consuming than a Type I study but is inadequate for estimating breeding success.

We decided that Type I methods were needed to meet the immediate objectives of this project, since it had been more than 10 years since the last intensive studies of seabirds on St. Lawrence Island (Searing 1977), and because further documentation of breeding schedules and activity cycles seemed desirable for designing a longer-term program of frequent visits to this site. We employed

Type II methods for cliff-nesting birds at our secondary study area near Savoonga, on the assumption that activity patterns there were reasonably similar to colonies at Kongkok Bay. Type II methods (possibly modified as described in Chapter 6) should suffice for monitoring seabird populations at either study site in the future.

During months of the year when seabirds are visiting their breeding colonies, they continue to spend much of their time at sea where birds, or the prey populations on which they depend, may be affected by oil pollution. The likelihood of birds encountering an oil spill in a given area can only be judged when we know if they go there regularly to feed. Shipboard surveys were intended specifically to address the question of persistence and predictability of feeding areas. Through replication of fixed transects near major breeding colonies, we hoped to learn about temporal changes in the distribution of foraging birds.

1.6. Acknowledgements

We thank the Sivuqaq and Savoonga Native Corporations and councils of Gambell and Savoonga for permission to work on St. Lawrence Island. We are most grateful to Lane Iyakitan of Gambell for his assistance with field work. His expert knowledge of the bird life and the Kongkok study area, as well as his hard work, keen sense of humor, and generosity, greatly contributed to the success of our studies. We are similarly indebted to Alex and Calvin Akeya for assistance with field work near Savoonga. We also thank Darlene Apangalook for her enthusiastic assistance in Gambell with collecting birds for diet studies. We appreciate the help and interest of many other St. Lawrence Island residents, including Edna and Gerome Apatiki, Lewis and Vivian Iyakitan, Lewis Iyakitan, Jr., Farrell Iyakitan, George Noongwook, Gerrard and Esther Kanooka, Leonard Apangalook, and Simeon Oettilian. Assistance with field work on St. Lawrence was also provided by Joel Hubbard and Bruce Rasmussen and we thank them for their efforts.

The shipboard component of this study was implemented with the capable support of Captain Al Bayer and his crew of the U.S.F.W.S. vessel the *M/V Eagle-Tiglax*. Bird observations and collections of oceanographic data, zooplankton, and birds were conducted with the added assistance of Amy Stone, Gary Lingle, Carl Swafford, Ann-Marie Furman, and Roger Dwork.

Identification of prey items in murre stomach collections were made by W. Lidster under contract with LGL, Alaska. We thank Kathy Frost and Alan Springer for help in identifying fish otoliths. Auklet prey items were identified by Alan and Martha Springer and Amy Stone.

We especially appreciate the outstanding job of typing and editing of this report conducted by Jeri Riffle, Martha Ronaldson and Sharon Rudd of the Alaska Fish and Wildlife Research Center.

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Chapter 2. Biology of cliff-nesting species: Common and Thick-billed Murres, Black-legged Kittiwakes, and Pelagic Cormorants

2.1 Introduction

Despite its high latitude and situation on the relatively impoverished 'coastal domain' of the Bering Sea, the waters around St. Lawrence Island support a large, diverse population of seabirds and marine mammals. Well known for its immense auklet populations, St. Lawrence Island also hosts the largest murre colonies in the northern Bering Sea, and lesser numbers of other seabirds, including Black-legged Kittiwakes (Sowls et al. 1978, Roseneau et al. 1985).

These large bird populations result from St. Lawrence Island's close proximity to highly productive Anadyr water which orignates as a bifurcation of the Bering Slope Current to the south, and flows north between St. Lawrence Island and the Chukotsk Peninsula of Siberia (Fig. 1.1). This cold, saline, nutrient-rich Anadyr Current not only promotes high productivity to the west and north of St. Lawrence Island, it also carries with it a zooplankton fauna typical of outer domain and pelagic food webs. This supports large numbers of planktivorous auklets as well as Arctic cod (<u>Boreogadus saida</u>), which in turn support the piscivorous murres and kittiwakes. As top trophic-level predators, the breeding and feeding success of murres and kittiwakes on St. Lawrence Island thus reflect local oceanographic conditions and prey availability.

As well, both murre species are about equally abundant on St. Lawrence Island, where they breed in mixed colonies. Closely related and similarly-sized congeners, Common and Thick-billed Murres are generally segregated into boreal and arctic regions, but overlap extensively in subarctic areas and/or in areas where differing water masses converge and offer access to a greater abundance and variety of prey types. This appears to be the situation at St. Lawrence Island, in contrast to murre colonies to the east in Norton Sound where Common Murres predominate in warmer coastal shelf waters (Springer et al. 1987).

Thus, although Common and Thick-billed Murres are very similar in many aspects of their biology, differences in their breeding and feeding ecology at St. Lawrence Island provide a focus for assessing factors which may regulate piscivorous seabird populations in the region. For this purpose, and in an attempt to assess competitive interactions, we collected data on habitat use, attendance patterns and breeding phenology, reproductive success, and diets of Common and Thick-billed Murres in summer, 1987, at St. Lawrence Island.

We also studied the breeding biology of piscivorous Black-legged Kittiwakes and, to a much lesser extent, Pelagic Cormorants. These species provide an interesting contrast to murres. Unlike murres, which eat mostly Arctic cod and can dive deeply to catch their prey, kittiwakes at St. Lawrence Island tend to feed more on sandlance (Ammodytes hexapterus) and capelin (Springer et al. 1987), and must obtain their prey from the surface. Furthermore, kittiwakes have for many years exhibited low breeding success and occasional breeding failures throughout much of their range in Alaska (Hatch 1987). Because of St. Lawrence Island's geographic position on the inner domain of the Bering Sea, but proximity to productive Anadyr waters, kittiwake breeding success there offers an interesting comparison to success at colonies in other oceanographic regions.

Similarly, Pelagic Cormorants provide a contrast to both murres and kittiwakes as they tend to feed more on benthic fish and invertebrates (A. Springer, pers. comm.), but can dive to considerable depths (DeGange and Sanger 1987). Unlike kittiwakes, they have exhibited relatively high breeding success over much of their range in Alaska (Hunt et al. 1981, DeGange and Sanger 1987).

These data were collected within the framework of an overall program by the Minerals Management Service to monitor seabird populations in the Bering Sea in anticipation of offshore oil exploration and development. To further this goal, we also established and documented permanent study plots for murres and kittiwakes on the south and north side of St. Lawrence Island, and conducted censusing counts at these plots. Some of these plots were identical to plots surveyed by Searing (1977) in 1976, and allow for a comparison of populations between years.

2.2 Methods

2.2.1 Study Area

St. Lawrence Island (ca. 63° 30' N) lies about 200 km west of the Alaskan mainland, and about 60 km east of the Chukotsk Peninsula of Siberia. Owing to its central location at the mouth of the Bering Strait, St. Lawrence Island is exposed to Anadyr water to the west (originating from the outer domain), central domain water to the south, and coastal domain water to the east (Fig. 1.1). Most of the eastern and southern parts of the island are unsuitable for breeding by seabirds, but some 2 million seabirds (14 species), including ca. 300,000 murres and 3,000 kittiwakes breed on precipitous cliffs near the Southwest Cape/Kongkok Bay area, and to the east and west of Savoonga on the north coast (Fig. 1.1).

The avifauna, climate, habitats, and local oceanography of St. Lawrence Island have been described in detail elsewhere (Fay and Cade 1959, Bedard 1969a,b, Sealy 1975, Coachman et al. 1975, Springer et al. 1987).

2.2.2 Attendance and Productivity

Methods employed here to monitor attendance and productivity of murres and Black-legged kittiwakes were those recommended by Birkhead and Nettleship (1980) and adopted by other investigators (e.g., Gaston and Nettleship 1982, Harris et al. 1983, Piatt and McLagan 1987, Hatch and Hatch in press). In brief, study plots were chosen and delineated on polaroid photos and sketch maps for subsequent monitoring. For censusing purposes, numbers of birds attending sites within the boundaries of plots were counted regularly throughout the breeding season (Type II study, Birkhead and Nettleship 1980). Counts were conducted during midday when attendance was most stable. Sub-samples of some plots were examined more closely to assess breeding phenology and success of species under consideration (Type I study, Birkhead and Nettleship 1980). These plots were carefully sketched and individual site-holders were observed near-daily throughout the breeding season to monitor egg-laying, chick hatching and fledging, and losses of eggs or chicks.

A total of 16 study plots for murres and kittiwakes were established in 1987. At Kongkok Bay, six plots were monitored from 28 May to 2 September 1987 on Owalit Mountain and one plot near Tatik Point (Fig. 2.1). Six of

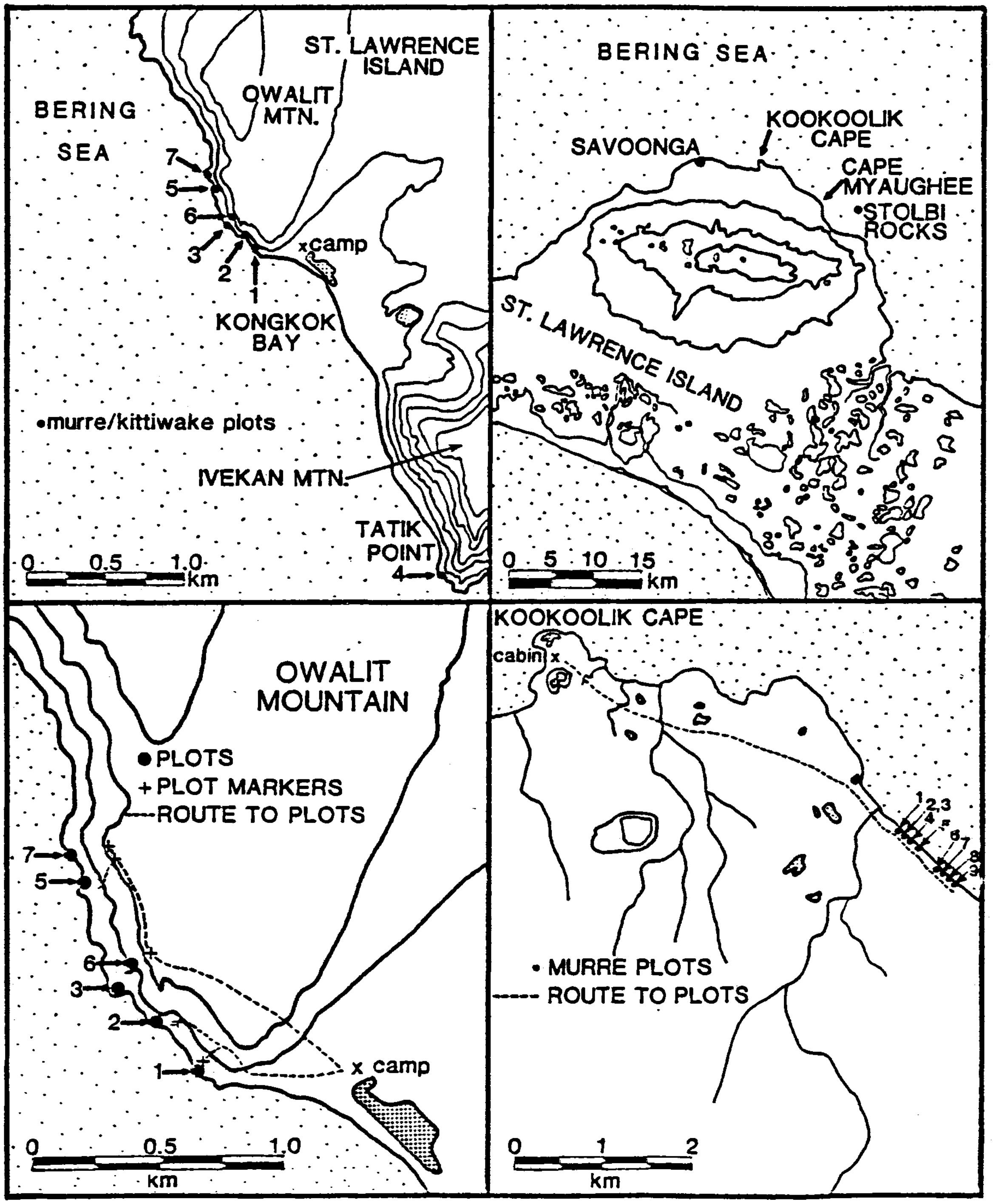

Figure 2.1. Locations of murre and kittiwake study plots at Kongkok (Owalit Mountain) and east of Savoonga.

these seven plots (1-6) were located from photographs taken by Gary Searing during his studies in 1976. All these plots (except No. 4) were counted frequently through the breeding season for census purposes (Type II study). A total of nine plots were established for Type II monitoring at colonies east of Savoonga at the north coast (Fig. 2.1), and counts were made of murres and kittiwakes attending these plots between 23 July and 1 August. Photographs, sketches, and directions for relocating all 16 of these plots are provided in Appendices.

Two plots (A and B, subplots of Plots 1 and 2, respectively) located near the field camp at Kongkok were mapped and Type I studies of murre and kittiwake productivity were conducted. Observations were made from ca. 10 m (Plot A) and 100 m (Plot B) using spotting scopes, and required ca. 6-8 h per day during egg-laying/incubation, and shorter periods thereafter, to assess nest-site status of most (ca. 90%) site-holders on each day. Gaps in observations occurred only infrequently during periods of heavy rain or dense fog. An additional subplot at census Plot 5 was observed for kittiwake productivity, but visits were only made every 5-10 days, so productivity estimates are undoubtedly inaccurate. Low-lying clouds prevented observations at this plot for most of August. Owing to evacuation of the field camp on 2 September, Type I observations of murre and kittiwake fledging were incomplete.

To compare habitat use and productivity of Common and Thick-billed Murres on different breeding sites, individual sites were characterized at Plots A and B, using a system devised by Gaston and Nettleship (1981). For each potential breeding site (occupied by all site-holders whether breeding successfully or not), the following data was obtained: i) number of neighbors (0, 1, 2, and 3 or more); ii) slope of the ledge (either level or sloping outward); iii) type of site (narrow ledge, platform ledge, or small crevice in cliff); and iv) number of walls adjacent to site (0, 1, and 2 or more).

Diurnal attendance patterns were studied through the breeding season by a combination of i) all-day counts at Plot 2 in Kongkok and Plot 5 near Savoonga, and ii) the use of 8 mm time-lapse cameras at Plots 1 and 7 at Kongkok. Counts were conducted, or extracted from time-lapse film, at 1 h intervals through the day (visibility permitting).

2.2.3 Murre Diets

Murres (n = 315) were collected at sea for studies of diet composition from 13 May to 13 August. Early samples (May - 12 June) were obtained from murres harvested by Natives at Gambell and preserved by freezing; all others were obtained by us at Kongkok Bay and were preserved by treatment with 5% formalin followed by storage in 70% isopropanol. Food items were subsequently identified in the laboratory using appropriate taxonomic keys. Because food items were usually in an advanced state of decomposition, fish were identified from otoliths and invertebrates were identified from persistent parts like rostra, jaws, beaks, etc. Numbers of prey consumed were estimated by counting pairs of similarly-sized otoliths (fish), pairs of jaws (e.g., polychaetes), or individual rostra or telsons (crustaceans). Contents of ventriculi and proventriculi were examined and reported separately because each presents a different picture of prey composition owing to differential digestion of different prety (e.g., zooplankton vs. fish, Gaston and Nettleship, 1981).

2.2.4 Environmental Data

Weather variables recorded daily at Kongkok included windspeed and direction, visibility, sea state, maximum and minimum temperatures, presence or absence of fog, precipitation (cm), and barometric pressure. The range of daily tidal oscillations was calculated from tidal tables.

2.2.5 Data Analysis

Simple statistical tests (e.g., t-tests, χ^2 tests) were conducted by hand using equations given by Sokal and Rohlf (1981). All other statistical tests or calculations (e.g., coefficients of variation, ANOVA) were conducted on computer using statistical procedures available on SAS (1985).

To assess breeding site characteristics influencing murre breeding success, site-holders were classified as to whether they laid an egg, hatched a chick, or fledged a chick. Thus, each site had three binary response variables associated with a classification according to the four site characteristics described previously. To determine the influence of site characteristics on laying, hatching, and fledging success, we used logistic regression analyses (Birkhead et al. 1985) available on SAS (FUNCAT procedure for categorical modeling).

Breeding phenology was assessed from Type I data, and median laying, hatching, and fledging dates were calculated from raw data collected on a daily basis for first eggs only (i.e., replacement eggs were ignored in assessing phenology). For convenience, phenological data are presented as cumulative percent ogives (Belopol'skii 1957) using data grouped over 3 d intervals.

2.3 Results

2.3.1 Breeding Phenology

All study species were observed nearshore from Gambell on arrival in May (Table 2.1). Pack-ice was very heavy in early May and slowly receded north in late May. During this period, bird abundance varied dramatically nearshore as large flocks of murres, auklets, and kittiwakes shifted around between open leads in the ice. Pelagic Cormorants were first observed nearshore on 8 May, and low numbers were seen regularly through May.

By the time we arrived at Kongkok and study plots were located, murres, kittiwakes, and cormorants were already occupying breeding ledges, although attendance was highly variable at this time (see below). Because they were not observed carefully, first eggs of cormorants were not seen until 14 June. Based on subsequent observations of hatching, however, eggs were probably laid in late May - early June. First eggs of all other species were observed on 20-21 June, and median laying occurred around 1 July. Common Murres laid eggs slightly earlier than Thick-billed Murres and kittiwakes, although in general, laying phenology of these species was very similar (Table 2.1, Figs. 2.2, 2.3). Many kittiwakes laid a second egg, with a mean interval between eggs of ca. 2 d (n = 7, mean ± s.e. = 1.93 ± 0.28 d).

Egg-laying rates declined more quickly after median laying than they increased prior to median laying, leading to an asymmetrical pattern of laying

Table 2.1. Timing of the main events in the breeding cycles of Common and Thick-billed Murres and Black-legged Kittiwakes at St. Lawrence Island in 1987.

Event	Common Murre	Thick-billed Murre	Black-legged Kittiwake
Arrival Nearshore before*	May 7	May 7	May 7
Ledge Attendance before*	May 28	May 28	May 28
First Egg	June 21	June 20	June 20
Median Laying	June 29	July 1	July 1
First Chick	July 20	July 26	July 16
Median Hatching	August 2	August 3	July 27
First Fledging	August 13	August 16	August 23**
Median Fledging	August 25	August 26	August 27**

* Observations were not conducted prior to these dates so they represent minimum first arrival dates. No murres were observed nearshore on 20-21 April.

** Based on sample of only nine chicks, most of which were hatched early (see text).

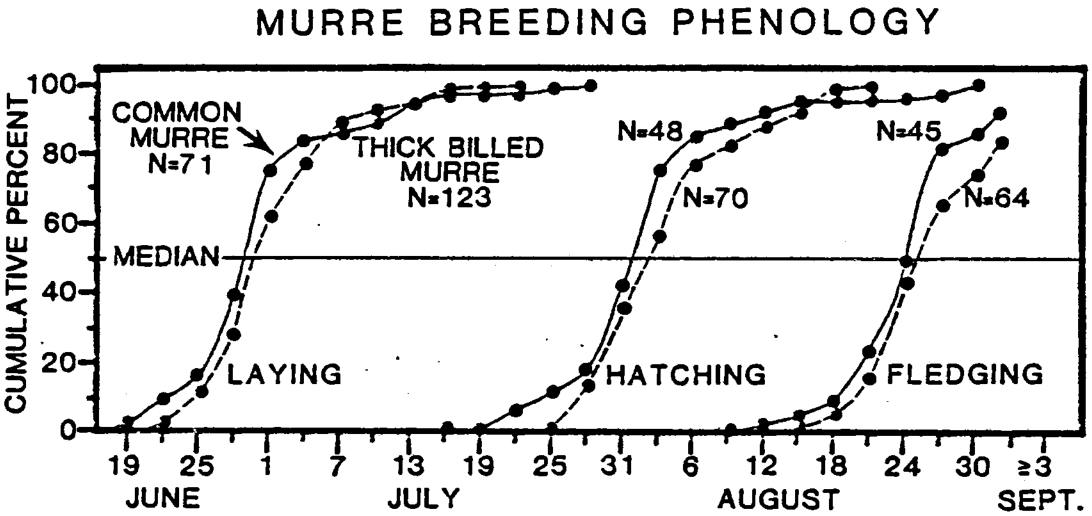

Figure 2.2. Breeding phenology of Common and Thick-billed Murres.

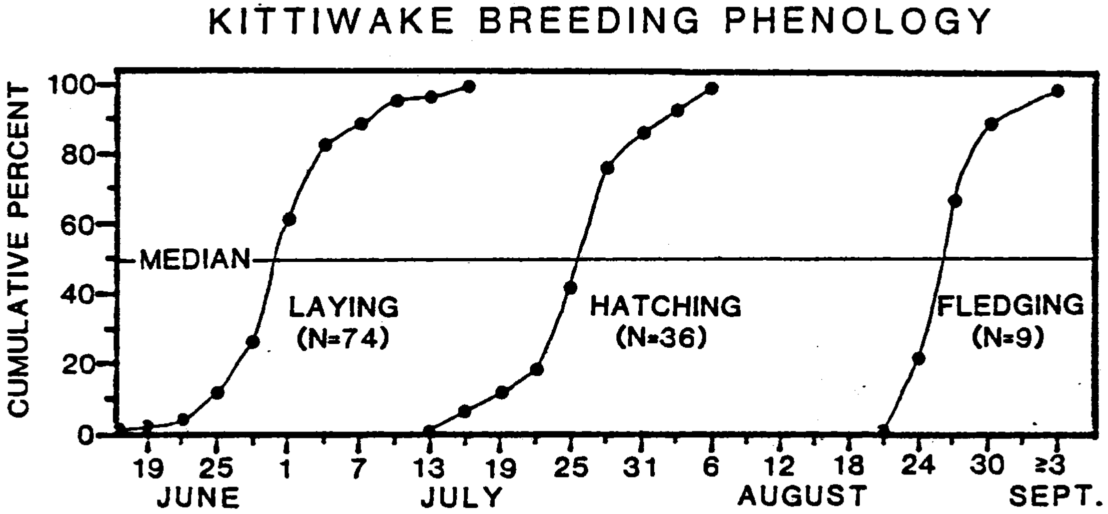

Figure 2.3. Breeding phenology of Black-legged Kittiwakes.

phenology in all species (Figs. 2.2, 2.3). This assymetric pattern was subsequently reflected in hatching phenology as well.

Egg-laying (first eggs) overlapped slightly with hatching in all species. First to hatch were Pelagic Cormorants (23 June), followed much later by kittiwakes, Common Murres, and finally Thick-billed Murres in late July (Table 2.1). Median hatching of chicks followed the same phenology (Table 2.1, 2.2). Kittiwakes exhibited an average incubation period of ca. 28 d for first eggs (n = 35, mean ± s.e. = 27.6 ± 0.30), whereas murres incubated for ca. 34 d (Common Murre: n = 32, 34.0 ± 0.40 d; Thick-billed Murres: n = 49, 33.8 ± 0.32 d)). No kittiwakes replaced lost eggs, but many murres did (see below) after about two weeks (Common Murre: n = 7, 14.0 ± 0.93 d; Thick-billed Murre: n = 9, 15.6 ± 0.32 d).

Cormorant chicks were the first observed to fledge (11 August) and median departure of last cormorant chicks to fledge was around mid-August (Table 2.2). Common Murres started fledging slightly earlier than Thick-billed Murres in mid-August (Table 2.1), and both species reached mid-fledging around 25-26 August (Table 2.1, Fig. 2.2). Murre fledging occurred rapidly over a 10 d period in late August, but was delayed near the end during a period of strong winds and rough sea conditions. Most (56%) chicks fledged in six days when windspeeds were less than 5 mph. Owing to our departure on 2 September, we did not observe the completion of fledging by all chicks. The average chick-rearing period by murres was ca. 24-25 d (Common Murre: n = 41, mean ± s.e. = 24.0 ± 0.43; Thick-billed Murre: n = 29, 24.6 ± 0.43 d). Few kittiwake chicks survived to fledging age (see below), but nine chicks did survive to 30+ d from hatching (mean age of eight chicks before departure from the nest: 34.6 ± 1.1 d). Kittiwake chicks usually return frequently to their natal nest following successful fledging (Roberts 1988), but this was not observed for these eight chicks. This observation, coupled with the fact that kittiwake chicks usually remain 40-45 d in their nest before fledging, suggests that these chicks may not have survived after having left the nest. In any case, the apparent duration of kittiwake chick-rearing (Fig. 2.3) is misleading because these chicks hatched early (most before median fledging), therefore shifting the fledging curve well to the left of expected dates of fledging (ca. 5-10 September).

Table 2.2. Aspects of Pelagic Cormorant breeding biology on St. Lawrence Island, 1987.*

No. of nests monitored	31	
No. of breeding pairs (% nests)	16	(52%)
Median clutch size (range)**	3	(1-5)
No. eggs hatched/laid (%)	41/45	(91%)
No. chicks fledged/no. eggs hatched (%)	34/41	(83%)
No. chicks fledged/eggs laid (%)	34/45	(76%)
No. chicks fledged/breeding pair (ratio)	34/16	2.1
Median date of first chick hatching	ca. 30 June	
Median date of last chick departure	ca. 16 August	

* Data collected over 3-5 d intervals and therefore productivity and phenology estimates only approximate.

** It was difficult to observe eggs in many nests, therefore clutch sizes were probably underestimated.

2.3.2 Breeding Success

Pelagic Cormorants were studied incidentally to other species, and the status of nest-sites was monitored much less frequently (3-5 d intervals). Thus, clutch sizes were likely underestimated, leading to an overestimate of hatching and fledging success (Table 2.2). Nonetheless, our estimate of 2.1 chicks produced per breeding pair is probably valid because active nests with large chicks were easily monitored.

Common Murres exhibited (Table 2.3) higher hatching and fledging rates on Plot B than Plot A (subplots within Plots 2 and 1, respectively), yielding a significantly ($p<0.05$) higher overall breeding success on Plot B (71%) than on Plot A (51%). This was partially due to higher predation rates at Plot A by Arctic foxes (Alopex lagopus, 12% vs 0%) and Glaucous Gulls (Larus hyperboreus, 6% vs 0%). At both plots, poor hatching success (67% overall) contributed most to a moderate overall breeding success rate (60%). Most egg losses (both plots combined) were from unknown sources (62%), with infertility (23%), fox predation (8%), gull predation (4%), and dislodgement (4%) accounting for the remainder of hatching failures. Although 27% of birds losing first eggs laid replacement eggs, the success of these replacements was substantially lower than first eggs (Table 2.3). Chick fledging success rates (90% overall) were much higher than egg hatching success rates (Table 2.3), presumably because chicks are less vulnerable to accidental loss, and most mortality at high-risk sites occurs during incubation (Birkhead and Nettleship 1987b). All chick losses were from unknown causes except for one observation of predation by a Glaucous Gull. A few chicks were not observed to fledge, but were assumed to have done so in estimates of breeding success because they were all older than 18 d, and no chick mortality was observed for chicks older than 14 d. Many murres observed on plots were present from the beginning of observations and throughout the breeding period. If these site-holders are included in calculations of overall breeding success, then only 44% of all Common Murres present bred successfully. Similarly, k-values (the ratio of breeding pairs to total attending; Birkhead and Nettleship 1980) calculated for murres (spp.) at Plots A and B were 0.45 and 0.44, respectively.

Table 2.3. Breeding success of Common and Thick-billed Murres at two study plots on St. Lawrence Island in 1987.

	Common Murre			Thick-billed Murre		
	Plot A	Plot B	Total	Plot A	Plot B	Total
Total no. pairs	49	58	107	97	74	171
No. pairs not laying (%)	11(22.4)	25(43.1)	36(33.6)	24(24.7)	24(32.4)	48(28.1)
First eggs----------						
No. of pairs	38	33	71	73	50	123
No. eggs hatched (%)	23(60.5)	25(75.8)	48(67.6)	40(54.8)	30(60.0)	70(56.9)
No chicks fledged (%)	21(91.3)	24(96.0)	45(93.8)	37(92.5)	27(90.0)	64(91.4)
Percent fledging success	55.3	72.7	63.4	50.7	54.0	52.0
Replacement eggs----						
No. of pairs	5	2	7	10	0	10
No. eggs hatched (%)	3(60.0)	1(50.0)	4(57.1)	8(80.0)	-	8(80.0)
No chicks fledged (%)	1(33.3)	1(10.0)	2(50.0)	4(50.0)	-	4(50.0)
Percent fledging success	20.0	50.0	28.6	40.0	-	40.0
Overall hatching* success (%)	60.5	74.3	66.7	57.8	60.0	58.7
Overall fledging* success (%)	84.6	96.1	90.4	85.4	90.0	87.2
Overall breeding* success (% BS)	51.2	71.4	60.3	49.4	54.0	51.1
BS including non-layers (%)	44.0	43.1	43.9	42.3	36.5	39.8

* No significant difference between species in overall hatching (χ^2=1.72), fledging (χ^2=0.40), or breeding (χ^2=2.59) success comparing total data from both plots (1 df in all cases).

Thick-billed Murre hatching and fledging rates were similar at both Plots A and B, yielding an overall breeding success of 51%. As with Common Murres, lower rates of hatching success (59%) contributed most to their moderate breeding success. Most egg losses were from unknown sources (58%), with infertility (18%), fox predation (11%), gull predation (4%), dislodgement (7%), and breakage (2%) accounting for the remainder of hatching failures. Of those birds that lost eggs, 18% re-laid. A much lower proportion (40%) of re-laid eggs were successful (Table 2.3). Chick fledging success (87%) was much better than hatching success, and all losses were from unknown causes. As with Common Murres, some chicks were not observed to fledge, but as all were older than 17 d of age, we assumed they fledged for estimates of breeding success. If non-laying site-holders are incuded in estimates of breeding success, then only 40% of birds bred successfully (Table 2.3).

Overall, fox predation for both species and plots accounted for 4% of total egg losses and 9% of losses for which we could determine a cause. Although much of the sheer cliff habitat used by murres was inaccessible, Arctic foxes were surprisingly agile and capable of exploiting many breeding ledges on the periphery of colonies. Besides direct losses, foxes sometimes caused panic flights from the ledges resulting in egg losses from dislodgement or breakage. During the incubation period, we frequently saw Arctic foxes carrying murre eggs away from the plots. Arctic foxes were seen patrolling colony areas almost every day during incubation. On one occasion, a fox was observed caching a murre egg at a site between Plots 1 and 2. In summary, predation by Arctic foxes was a significant source of mortality for murres, especially at Plot 1. After incubation, however, foxes were rarely observed near murre plots and most prey observed were Crested Auklets (see Chapter 3).

Although we only observed one instance of murre egg predation by Glaucous Gulls, it is likely that many of the 'unknown' losses were due to gulls. During incubation, gulls were frequently observed perched on or patrolling murre ledges. On at least five occasions, Glaucous Gulls were observed harassing incubating murres by pecking at their heads, pulling on their tails or wings, or pushing in an attempt to move the adult murre off its egg. Murres usually stayed their ground, however, and neighbors would sometimes come to the aid of harassed individuals, forcing the gull to leave. In fact, we never actually saw a gull succeed in getting eggs this way, but suspect it happened occasionally given the frequency of attempts. No Glaucous Gull were breeding in the vicinity of Plots 1 and 2, but at Plot 7, we saw a nest surrounded by 13 or more broken murre eggs suggesting that some gulls rely heavily on murre eggs during this part of the breeding season.

Overall, Common Murres exhibited higher hatching, fledging, and breeding success than Thick-billed Murres (Table 2.3), although none of the differences were statistically significant (owing in part to the small sample sizes). To assess the influence of breeding site characteristics on breeding success, we quantified the use of different habitats by successful breeders of each species. First, it was evident that each species preferred to breed on different types of ledges (Table 2.4). Common Murres used mostly platform-type ledges, facing one rock wall, and tended to co-occupy these sites with 1, 2, and 3 or more neighbors (Table 2.4). In contrast, Thick-billed Murres more often bred on narrow ledges or in small crevices on rock faces with 1 or 2 walls, and had a greater tendency to breed alone or co-occupy these sites with just one neighbor (Table 2.4). However, some of these factors are interrelated. For example, there was no room for neighbors on crevice-type breeding sites used by Thick-billed Murres whereas platforms used by Common Murres could accommodate many neighbors. Similarly, the number of walls was related to site-type.

The success of murres varied with habitat type (Tables 2.5 and 2.6). Although nearly equal numbers of both species occupied sloping and level sites, a significantly higher proportion of birds on level sites laid eggs. Once having laid an egg, ledge slope did not significantly affect hatching and fledging success by Common Murres, but it did for Thick-billed Murres (Tables 2.5 and 2.6). Although laying, hatching, and fledging success varied considerably for both species depending on ledge type or number of walls (Table 2.5), none of these differences were significant as determined by logistic regression analysis (Table 2.6), owing partly to the fact that these parameters were interrelated with slope and neighbors. Finally, both species were significantly influenced by neighbors, independent of other effects. Common Murres had a tendency to lay eggs on sites co-occupied by 1, 2, and 3 or more neighbors, whereas in contrast, Thick-billed Murres tended to lay eggs

Table 2.4. Characteristics of sites occupied by Common and Thick-billed Murres at St. Lawrence Island, Alaska.

	Common Murre			Thick-billed Murre	
Site character	n	%		n	%
Slope			NS		
Level	50	51.6		79	48.2
Sloping	47	48.4		85	51.8
Type			****		
Narrow ledge	2	2.1		60	36.6
Crevice	13	13.4		63	38.4
Platform	82	82.5		41	25.0
Walls			**		
0	20	20.6		16	9.8
1	60	61.9		97	59.1
2+	17	17.5		51	31.1
Neighbors			****		
0	13	13.4		70	42.7
1	30	30.9		65	39.6
2	29	29.9		28	17.1
3+	25	25.8		1	0.6

Note: χ^2 tests for heterogeneity between species for each character: slope, $\chi^2=0.28$, 1 df, NS; type, $\chi^2=89.5$, 2 df, $P<0.0001$ (****); walls, $\chi^2=9.6$, 2 df, $P<0.01$ (**), neighbors, $\chi^2=61.0$, 3 df, $P<0.0001$.

Table 2.5. Proportions of Common and Thick-billed Murres laying eggs (L), hatching eggs (H), and fledging chicks (F) on sites with different characteristics.

Site Characteristic		Common Murre				Thick-billed Murre			
		n	% L	% H	% F	n	% L	% H	% F
Slope:	Level	50	82	68	64	79	85	72	68
	Sloping	47	62	79	75	85	64	54	43
Type:	Narrow Ledge	2	100	100	100	60	75	71	67
	Crevice	13	69	78	67	63	81	59	52
	Platform	82	72	71	68	41	61	60	46
Walls:	0	20	75	60	53	16	63	30	30
	1	60	70	79	77	97	71	67	57
	2+	17	77	69	62	51	82	67	61
Neighbors:	0	13	54	71	57	70	79	53	47
	1	30	70	76	74	65	71	74	69
	2	29	76	68	68	28	68	68	50
	3+	25	80	75	68	1	100	100	100

Note: Percent hatching and percent fledging calculated from those birds laying eggs (%L x n).

Table 2.6. Contribution of site characteristics to egg-laying, hatching, and chick-fledging in Common (CM) and Thick-billed (TM) Murres determined by logistic regression analysis.

Site* Characteristic	Sample**	Egg-laying CM	Egg-laying TM	Hatching CM	Hatching TM	Fledging CM	Fledging TM
Slope	ASH	$P<0.05$	$P<0.01$	NS	$P<0.001$	NS	$P<0.0001$
	LAY			NS	$P<0.05$	NS	$P<0.01$
Type	ASH	NS	NS	NS	NS	NS	NS
	LAY			NS	NS	NS	NS
Walls	ASH	NS	NS	NS	NS	NS	NS
	LAY			NS	NS	NS	NS
Neighbors	ASH	$P<0.05$	$P<0.01$	$P<0.05$	$P<0.05$	NS	$P<0.05$
	LAY			NS	NS	NS	NS

* Site characteristics: slope = level or sloping; type = narrow ledge, crevice, or platform; walls = 0, 1, or 2+; neighbors = 0, 1, 2, or 3+.

** Sample: ASH - all site holders; LAY - only birds laying eggs.

where 0 to 1 neighbor co-occupied sites. Once having laid an egg, both species tended to have the highest fledging success in the presence of one neighbor, although this effect was not statistically significant.

Overall breeding success by Black-legged Kittiwakes was very low at all plots examined (Table 2.7). About 1/4 of nest-building pairs did not lay eggs, about 1/2 laid one egg, and the remaining 1/4 laid 2-egg clutches. Only about 40% of eggs hatched. Of those eggs not hatching, 41% disappeared from unknown causes (after a mean ± s.d. incubation time of 15.9 ± 7.3 d, n = 48), 41% were left unattended for long periods or were abandoned which resulted in egg mortality, 17% were attended but failed to hatch (after mean ± s.d. incubation time of 35.9 ± 6.8 d, n = 10), and 2% were lost to predation by Glaucous Gulls.

Very few of the eggs that did hatch produced fledging chicks (ca. 20%, Table 2.7), leading to very low overall breeding success rates (ca. 8-10%). Most chicks disappeared from unknown causes (72%) after an average of 12 d (mean ± s.d., 12.0 ± 7.9, n = 26) in the nest. Others (19%) were left unattended for long periods which may have resulted in losses from hypothermia or predation (mean ± s.d. time in nest: 13.4 ± 5.9 d, n = 7). A few chicks (8%) were victims of sibling aggression and may have died as a result (mean ± s.d. time in nest: 3.3 ± 1.5, n = 3).

Plot B produced zero chicks, whereas Plot A produced 0.15 chicks/nest, for an overall breeding success of 0.085 chicks/nest at Type I plots. Less intensive observations at Plot 5 suggested similar levels of breeding success (0.11 chicks/nest). Because all these chicks left earlier than would normally be expected (see Section 2.3.1 above), and some were still present in the nest on last days of observation (Table 2.7), true breeding success was likely lower than the maximums indicated in Table 2.7.

2.3.3 Attendance Patterns

Diurnal patterns of murre attendance were examined at three plots in the Kongkok study area, and at one plot in the Savoonga study area (Fig. 2.4). During the pre-laying period, attendance peaked between 0700-1100 h and then

Table 2.7. Breeding success of Black-legged Kittiwakes at three study plots on St. Lawrence Island in 1987.

	Plot A		Plot B		Total (A&B)		Plot 5	
	n	%	n	%	n	%	n	%
Total no. of nests	60		46		106		64	
No. 0 egg clutches	11	(18.3)	21	(45.7)	32	(30.2)	15	(23.4)
No. 1 egg clutches	27	(45.0)	17	(37.0)	44	(41.5)	33	(51.6)
No. 2 egg clutches	22	(36.7)	8	(17.4)	30	(28.3)	16	(25.0)
No. eggs re-laid	0		0		0		-	
Total no. eggs	71		33		104		65	
No. eggs hatched	34	(47.9)	11	(33.3)	45	(43.3)	27	(41.5)
No. chicks fledged	9*	(26.5)	0	(0.0)	9	(20.0)	7**	(25.9)
Max. breeding success								
(no. fledged/eggs laid)		(12.7)		(0.0)		(8.6)		(10.8)
(no. fledged/nest)		(15.0)		(0.0)		(8.5)		(10.9)

* One of nine chicks had not left the nest at the end of the study. Fledging and maximum breeding success calculated assuming all chicks had fledged successfully, but there is some doubt about this (see text).

** Plot 5 kittiwakes were not checked frequently enough to observe fledging (see text), but seven chicks older than 30 d were present on the last day of observations (Aug. 27), and might have fledged successfully. Maximum breeding success was calculated assuming all seven chicks fledged.

declined slowly until ca. 1700 h when numbers stabilized around early morning levels. Through incubation and hatching, attendance was generally stable through most of the day with no consistent decreasing or increasing trend in early or late hours of the day. Overall, numbers were most stable during midday (1300-1700 h) when Type II census counts were conducted. No data were obtained on attendance during the chick-rearing period. Attendance patterns were similar between Kongkok and Savoonga colonies in late July.

Kittiwake attendance was examined over similar time periods at Kongkok only (Fig. 2.5). There were no consistent trends and in general, numbers were most stable during midday hours (1300-1700) when Type II census counts were conducted.

Seasonal patterns of murre and kittiwake attendance were typical for these species (Piatt and McLagan 1987, Hatch 1988) with: i) large fluctuations occurring during the pre-laying period, ii) relatively stable attendance through incubation and hatching, iii) a slight increase in attendance during chick-rearing (except kittiwakes), and iv) decreasing and irregular attendance during fledging (Figs. 2.6 and 2.7). Observations from Plots 3-7 were less frequent from mid-July onwards because other duties limited time available to check these distant plots, and weather conditions (particularly low-lying clouds) made counting difficult, especially in August.

Nonetheless, birds at all plots exhibited similar patterns of attendance (Figs. 2.6 and 2.7). There were significant between-plot correlations in murre attendance for most plot-plot comparisons (14/15 Spearman rank correlations significant, $r = 0.47 - 0.87$, $p < 0.05$), with correlations being generally weaker between distant plots. Similarly, kittiwake attendance was usually correlated between plots (8/10 correlations significant, $r = 0.48 - 0.67$). Murre and kittiwake attendance was significantly correlated on three of five plots where they co-occurred. Few inter-correlations in attendance at nine Savoonga plots (not shown, 9 d between 23 July and 1 August) were significant (3/28 cases) probably because a lower number of counts were conducted over a brief period when numbers were relatively stable (Type II census period). Murre attendance at Savoonga and Kongkok were also not significantly correlated.

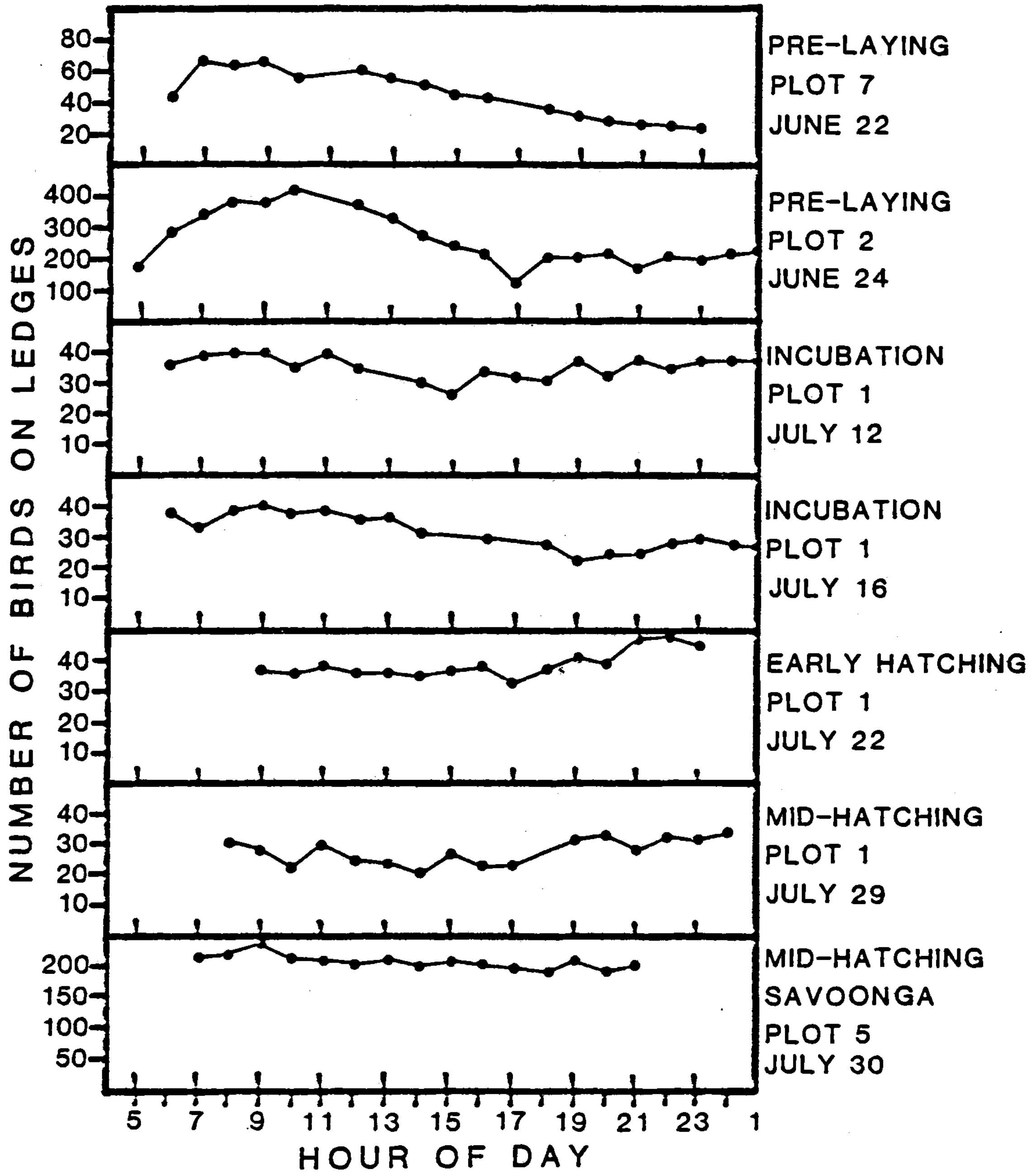

Figure 2.4. Diurnal attendance patterns of murres (spp.). Data from time-lapse film (Plots 1 and 7) and observer counts (Plots 2 and 5).

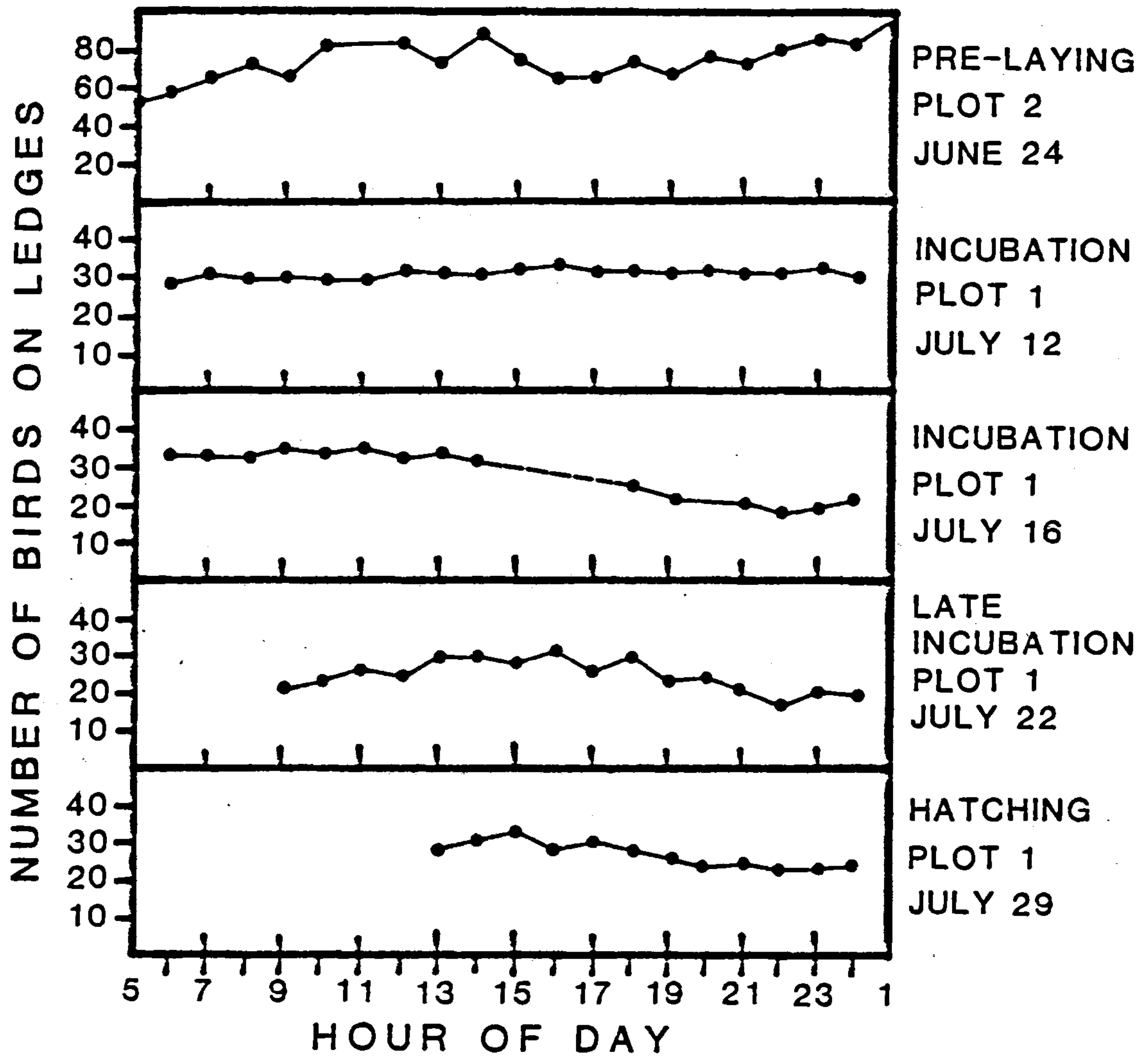

Figure 2.5. Diurnal attendance patterns of Black-legged Kittiwakes. Data from time-lapse film (Plot 1) and observer counts (Plot 2).

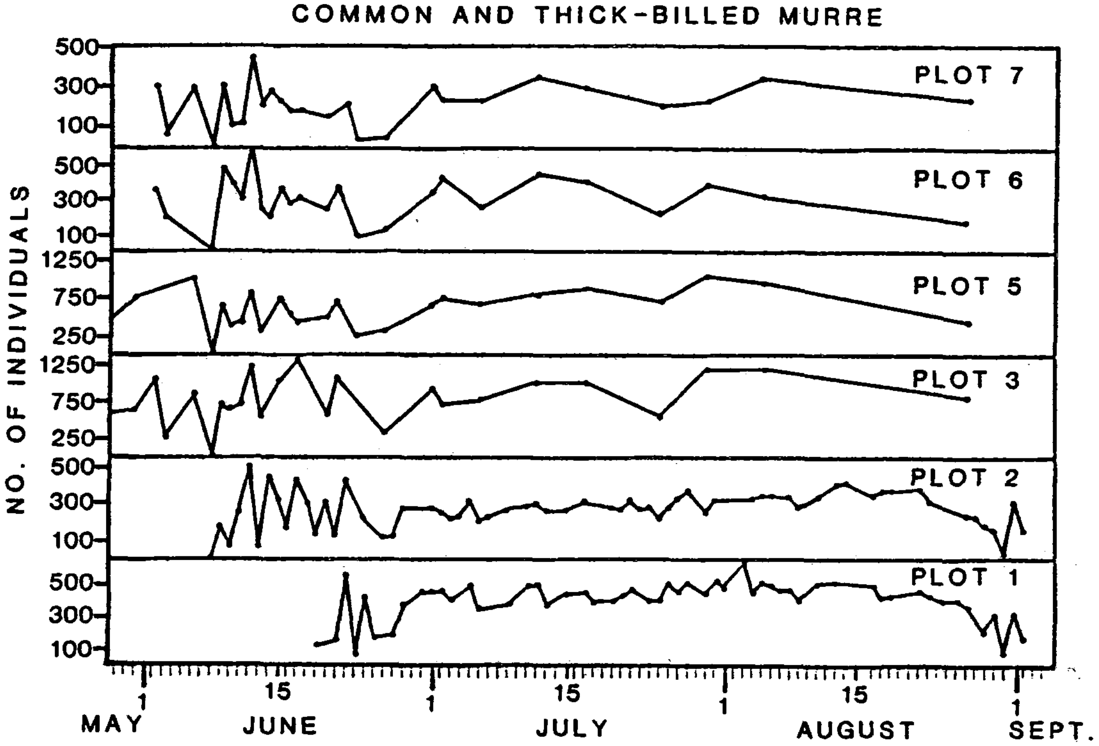

Figure 2.6. Seasonal attendance patterns of murres (spp.) on six plots at Kongkok.

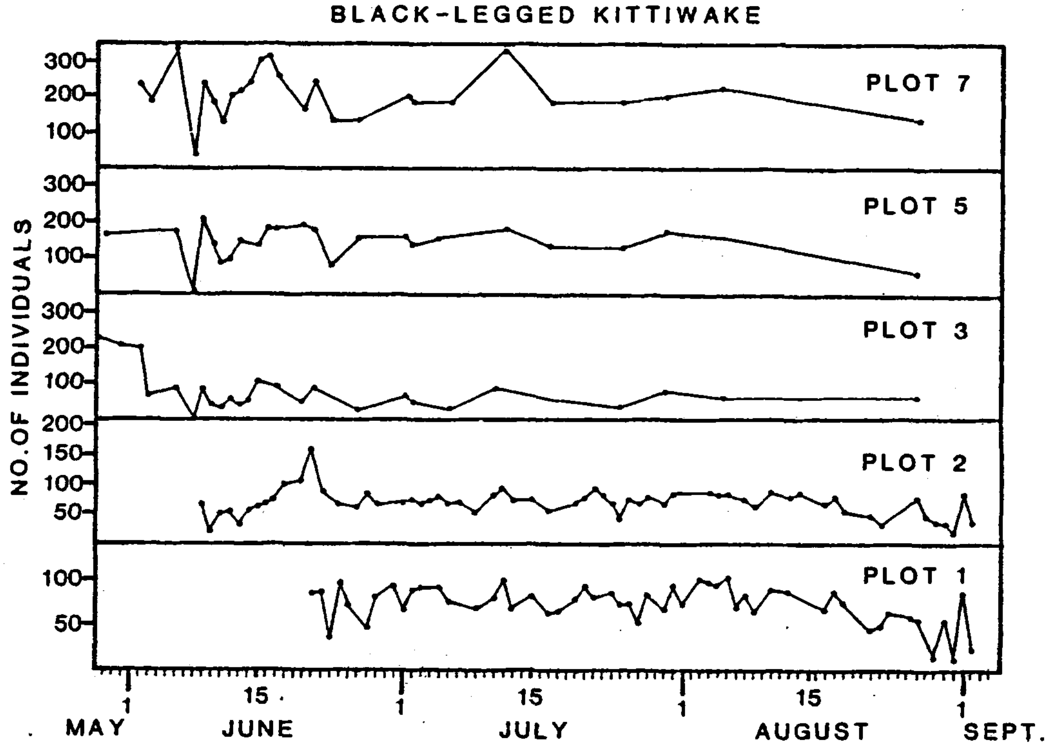

Figure 2.7. Seasonal attendance patterns of Black-legged Kittiwakes on five plots at Kongkok.

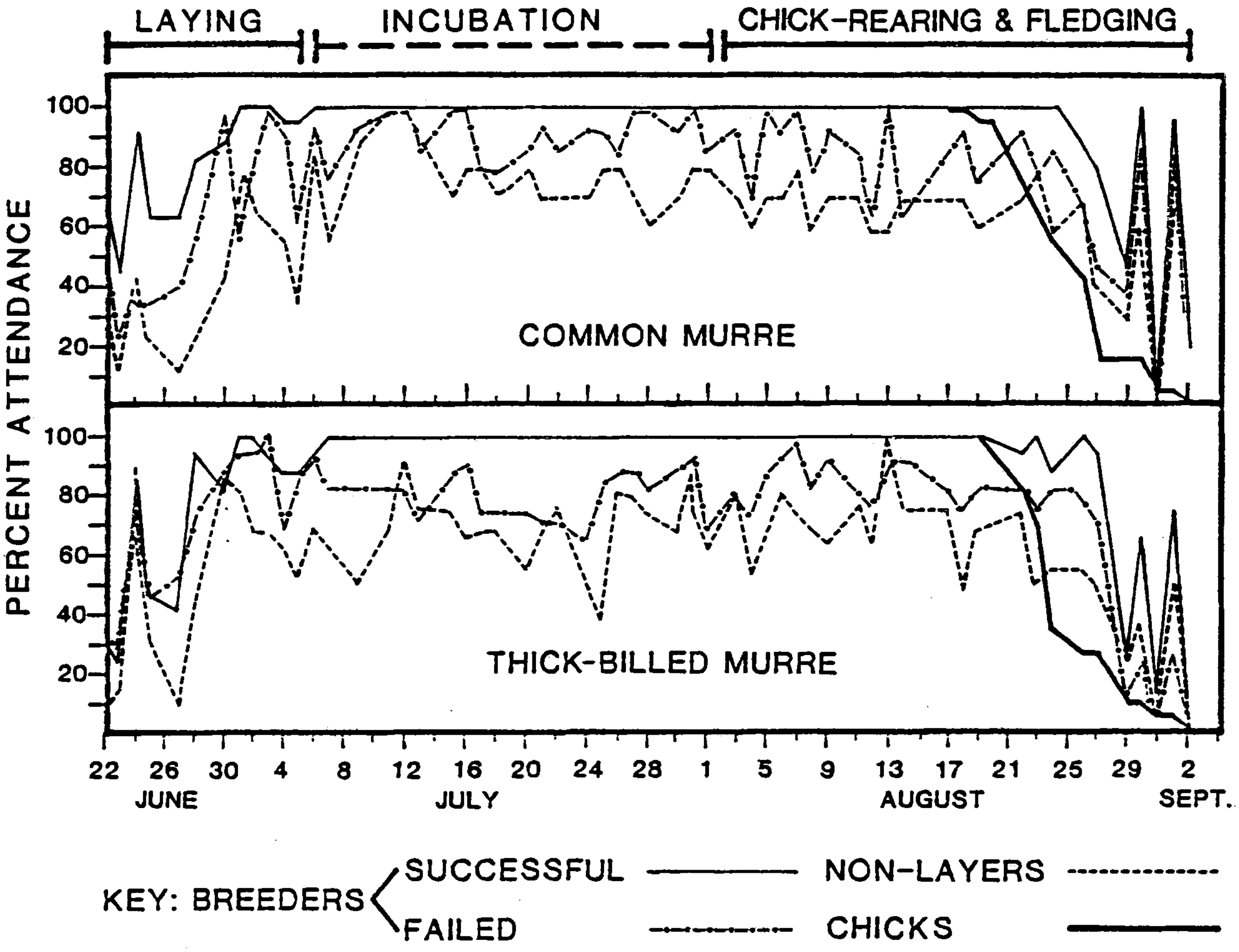

Figure 2.8. Seasonal attendance patterns of sucessful breeding, failed breeding, and non-laying Common and Thick-billed Murres and their chicks at Plot A. Attendance expressed as percent of maximum attendance of each class. For successful breeders, only data for those fledging chicks by 2 September used in the analysis.

Table 2.8. Mean numbers (±S.E.) of murres and kittiwakes attending plots at Kongkok Bay, and comparison to counts by Searing (1977).[a]

		Murre				Kittiwake		
Plot	Year	n	Mean	S.E.	% TbM	n	Mean	S.E.
1	1987	27	464	10.5	75	27	81	2.5
	1981	4	372	15.0	45	1	55[b]	--
	1976	5	343	37.2	--	5	55	8.5
2	1987	24	305	8.7	51	24	76	2.5
	1981	5	253	27.1	57	0	?	--
	1976	5	336	22.9	--	5	29	1.9
3	1987	8	926	82.2	--	8	62	7.5
	1981	1	540	--	--	0	?	--
5	1987	8	835	47.5	18	8	156	6.6
	1981	2	265	15.0	--	1	23[b]	--
6	1987	8	354	29.9	--	8	0	--
	1981	1	245	--	--	0	?	--
	1976	5	247	21.5	--	0	0	--
7	1987	8	271	19.9	--	8	217	18.9
Total	1987	8	3107	181.0	40[c]	8	584	36.6

[a] Means calculated using only data collected between the end of egg-laying and the beginning of fledging. Differences in counts between 1976 and 1987: Plot 1 murre $t=3.13$, 30 df, $p<0.01$; kittiwake $t=2.93$, 30 df, $p<0.01$; Plot 2 murre $t=1.27$, 27 df, NS; kittiwake $t=17.8$, 27 df, $p<0.0001$; Plot 6 murre $t=2.38$, 8 df, $p<0.05$.

[b] Number of kittiwake nests observed, not individual birds.

[c] Percentage of murres that were Thick-billed (TbM) on plots 1, 2, and 5.

Table 2.9. Numbers of murres and kittiwakes attending plots east of Savoonga between 23 July - 1 August 1987.

	Murre				
Plot	n	Mean	S.E.	% TbM	Kittiwake*
1	9	526	6.6	39	6
2	9	97	2.6	63	0
3	9	93	3.2	51	1
4	9	41	0.9	25	0
5	9	215	2.8	67	0
6	9	104	1.7	72	8
7	9	123	2.4	69	9
8	9	357	5.6	14	2
9	9	691	8.4	59	31
Total	9	2247	16.0	48	57

* Total number of active kittiwake nests observed.

Murre attendance patterns were examined in more detail by considering attendance of non-layers, successful breeders, and failed breeders separately (Fig. 2.8). For both murre species, the attendance patterns of all birds were similar prior to egg-laying and at the end of fledging. During incubation and chick-rearing, however, one breeding adult was always present at the site (attendance by both members of a pair was usually quite brief as they exchanged 'nest' duty). Thus, virtually all of the variability in attendance during the egg/chick period was due to fluctuations in attendance of failed breeders (c.v. = 11.5% and 12.5% for Common and Thick-billed Murres, respectively) and non-laying site-holders (c.v. = 14.6% and 20.8%, respectively). Failed breeders spent more time attending sites than non-layers, and of these birds, Thick-billed Murres (mean attendance = 81% and 69%, respectively) spent less time attending than Common Murres (mean attendance = 90% and 75%, for failed and non-layers, respectively, Fig. 2.8). Attendance of non-layers and failed breeders was strongly correlated within $r_s = 0.78 - 0.82$, $P<0.0001$) and between species ($r_s = 0.59 - 0.70$, $P<0.0001$) during the egg/chick period.

Environmental factors contributed to the variability in attendance of murres and kittiwakes. Considering all data up to pre-fledging from Plots 1 and 2, both murre ($r_s = 0.44$, $P<0.01$) and kittiwake ($r_s = 0.52$, $P<0.001$) attendance was negatively correlated with windspeed, and positively correlated with maximum air temperatures (murre: $r_s = 0.40$, $P<0.01$; kittiwake: $r_s = 0.35$, $P<0.05$). Wind effects were more pronounced prior to egg-laying ($p<0.05$, $r_s = -0.61$ and -0.43) than during incubation/pre-fledging (ns, $r_s = -0.30$ and -0.29). Correlations of murre and kittiwake attendance with maximum air temperature were weaker and insignificant when considered over each stage of the breeding cycle. No consistent significant correlations were observed between bird attendance and barometric pressure, the range of tidal oscillations, amount of rain, or presence/absence of fog.

2.3.4 Population Trends

For the plots we could compare, there were significant differences in numbers of birds observed between 1976 and 1987 (Table 2.8). Murre numbers increased significantly on two plots, and declined (non-significantly) on another plot. Similarly, kittiwake numbers increased significantly on two plots, but did not change on the third plot (none breeding). Based on these rather limited samples, it appears there has been a slight increase in murre and kittiwake populations at Owalit Mountain between 1976 and 1987.

Searing (1977) monitored six plots in 1976 for murre and kittiwake attendance in the Kongkok Bay area. Although we had polaroid photos of those plots (provided by Searing), and located them all, we can only compare data from three plots to Searing's 1976 counts (Table 2.8). Only counts conducted between the incubation-prefledging period are used for comparison. Plots 1 and 2 were close to the field camp and easily viewed from land. Both Searing and us conducted more counts of these plots than any others. Plot 6 could be viewed from the top of Owalit Mountain, but owing to time and weather constraints, was counted less frequently. Searing counted Plot 3 from the water, and we counted it from land, so they cannot be compared. In addition, Searing's Plot 3 counts were conducted during the pre-laying period and were extremely variable. Plot 4 could be counted only by boat. It is not clear whether we counted the same area as Searing, and like Searing, we only counted it a few times during pre-egg laying. It was not possible to compare Plot 5 counts for the same reasons as Plot 3 counts (above). We established a new plot (7) that had not been censused by Searing. We also established nine new plots at colonies to the east of Savoonga (Table 2.9). We have documented the location and perimeters of all plots (Kongkok 1-7, Savoonga 1-9) in the Appendices. All plots can be counted from land. Thus, in the future, comparisons can be made to 1987 mean counts of 3,107 murres (40% Thick-billed) and 584 kittiwakes at Kongkok (Plot 4 not included and should be dropped), and 2,247 murres (48% Thick-billed) and 57 kittiwakes at Savoonga (Tables 2.8 and 2.9).

Roseneau et al. (1985) counted murres and kittiwakes at St. Lawrence in 1981, and obtained several counts on each of Plots 1 and 2, and a few counts of other plots (Table 2.8, Roseneau and Springer, unpubl. data collectedbetween July 23 and August 9, 1981). Their counts of murres at Plots 1 and 2 (obtained recently) corroborate our finding that murre numbers increased at Plot 1 and declined at Plot 2 since 1976. Counts at other plots further indicate there has been an increase in both murre and kittiwake populations at Kongkok (Table 2.8).

Roseneau et al. (1985) also provided the first and only near-total census of murres on St. Lawrence Island which will be useful for assessing large-scale population fluctuations, if they occur in the future. Based on Roseneau et al.'s counts, our plots include about 9% of murres on Owalit Mountain in the south, and 11% of murres to the east of Savoonga on the north coast (after adding our plots to Roseneau's).

2.3.5 Murre Diets

A total of 226 Thick-billed Murres and 89 Common Murres were collected for analyses of diets (Tables 2.10 and 2.11). None of the Common Murre stomachs (proventriculi) contained food, and only one contained nematode parasites (Contracaeucum spp.). Of 89 gizzards (ventriculi) examined, 12% were empty. Fish occurred in 97% of gizzards, and invertebrates (polychaete) in only 1% of gizzards. Cods dominated the diet completely (Table 2.10). Of the cods, Arctic cod (95%, Boreogadus saida) were most abundant, followed by walleye pollock (5%, Theragra chalcogramma). Two other fishes identified both occurred in 3% of gizzards: capelin (Mallotus villosus) and sandlance (Ammodytes hexapterus). Most Common Murres were collected between mid-June to mid-July (Table 2.12), and there was little change in diet composition over this month.

Thick-billed Murres had a much more varied diet than Common Murres (Tables 2.10 and 2.11); fish were less common and invertebrates much more common. Nematodes were also much more abundant in gizzards, and especially stomachs. Again, Arctic cod (94%) dominated among the gadids, with walleye pollock (5%) and Saffron cod (1%, Eleginus gracilis) comprising the remainder. A small number of other fish taxa were found, including capelin, sandlance, gunnels (Pholididae), snailfishes (Cyclopteridae), sculpins (Cottidae), and eelpouts (Zoarchidae). Of the invertebrates, amphipods (Parathemisto spp. and others), and euphausiids (Thysanoessa spp. and others) were most abundant. Although decapods were less numerous, they occurred most frequently next to amphipodsand were generally much larger than other invertebrates, thus providing more food value per item consumed. Decapods identified included Eualus and Pandalus shrimps, and Hyas and Chionocetes crabs.

Table 2.10. Contents of Common and Thick-billed Murre stomachs from St. Lawrence Island, 1987.*

	Common Murre		Thick-billed Murre			
	Ventriculus		Ventriculus		Proventricu.	
	n	%	n	%	n	%
Number examined	89		226		226	
Number empty	11	(12)	38	(17)	181	(80)
Frequency of fishes	76	97	156	83	17	37
Frequency of invertebrates	1	1	89	47	31	69
Frequency of nematodes	1	(1)	17	(8)	65	(29)
Frequency of occurrence of:						
Gadidae	66	85	136	72	12	27
Unidentified fish	9	12	21	11	4	9
Osmeridae	2	3	0	0	0	0
Ammodytidae	2	3	2	1	1	2
Pholididae	0	0	2	1	0	0
Cyclopteridae	0	0	1	<1	0	0
Cottidae	0	0	1	<1	0	0
Zoarchidae	0	0	1	<1	0	0
Numbers of:						
Fish	271	100	468	100	26	100
Gadidae	244	90	428	92	21	81
Unidentified fish	23	9	31	7	4	16
Osmeridae	2	1	2	1	0	0
Ammodytidae	2	1	3	1	1	4
Pholididae	0	0	1	<1	0	0
Cyclopteridae	0	0	1	<1	0	0
Cottidae	0	0	1	<1	0	0
Zoarchidae	0	0	1	<1	0	0

* Values in parentheses are percent frequencies among total birds examined, others are percent frequencies or numbers among birds with some food remains in their stomach. Some prey identifications await final verification.

Table 2.11. Invertebrates in the diet of Thick-billed Murres at St. Lawrence Island, 1987.*

	Ventriculus		Proventriculus	
	n	%	n	%
Number examined	226		226	
Number empty	38	(17)	181	(80)
Frequency of occurrence of:				
Amphipoda	42	22	24	53
Decapoda	42	23	9	20
Euphausiiacea	5	3	3	7
Crustacea	7	4	1	2
Cephalapoda	6	3	0	0
Polychaete	8	4	0	0
Numbers of:				
Invertebrates	1414	100	1823	100
Amphipoda	1273	90	1124	62
Decapoda	69	5	37	2
Euphausiiacea	36	3	661	36
Crustacea	9	1	1	1
Cephalapoda	9	1	0	0
Polychaete	18	1	0	0

* Values in parentheses are percent frequencies among total birds examined, others are percent frequencies or numbers among birds with some food remains in their stomach.

Diets of Thick-billed Murres were observed from early May to mid-August (Fig. 2.9). The frequency of occurrence of fish peaked at the beginning, middle, and end of this study period. Arctic cod dominated in diets throughout this period, and there was little seasonal variation in fish diet composition. Invertebrates usually occurred less frequently than fish, but two peaks in occurrence were observed in late May and mid-August. Again, there were no clear seasonal trends in composition, although most euphausiids were taken in late May, and amphipods were taken mostly in late May and late August.

Weights of Common and Thick-billed Murres varied little over summer (Table 2.12), indicating that food was probably not scarce for most of the season. However, both species exhibited a sharp decline in weight in mid-July (incubation), but recovered this weight by mid-August. In contrast to most areas where they co-exist, Thick-billed Murres were significantly heavier than Common Murres.

2.4 Discussion

2.4.1 Breeding Biology

The phenology of breeding for all cliff-nesting species appeared to be normal in 1987, although there are few data with which to compare. Searing (1977) provided some information on breeding phenology of all species and with few exceptions, all his dates for first or peak laying, hatching, and fledging were about a week later than we observed in 1987. However, 1976 was an unusual year for seabirds in the northern Bering Sea and Chukchi Sea, owing to colder than average water temperatures and delayed availability of prey for seabirds (Springer et al. 1984). Phenology in 1987 was more similar to that observed for murres and kittiwakes by Johnson in 1972 (reported in Roseneau et al. 1985) and by Roseneau et al. (1985) during their visit in 1981. Neither of thse years was considered unusual for seabirds in the northern Bering Sea (Roseneau et al. 1985, Springer et al. 1984, 1987).

There was considerable variation in breeding success between species observed in 1987. Pelagic Cormorants were most successful in fledging 2.1

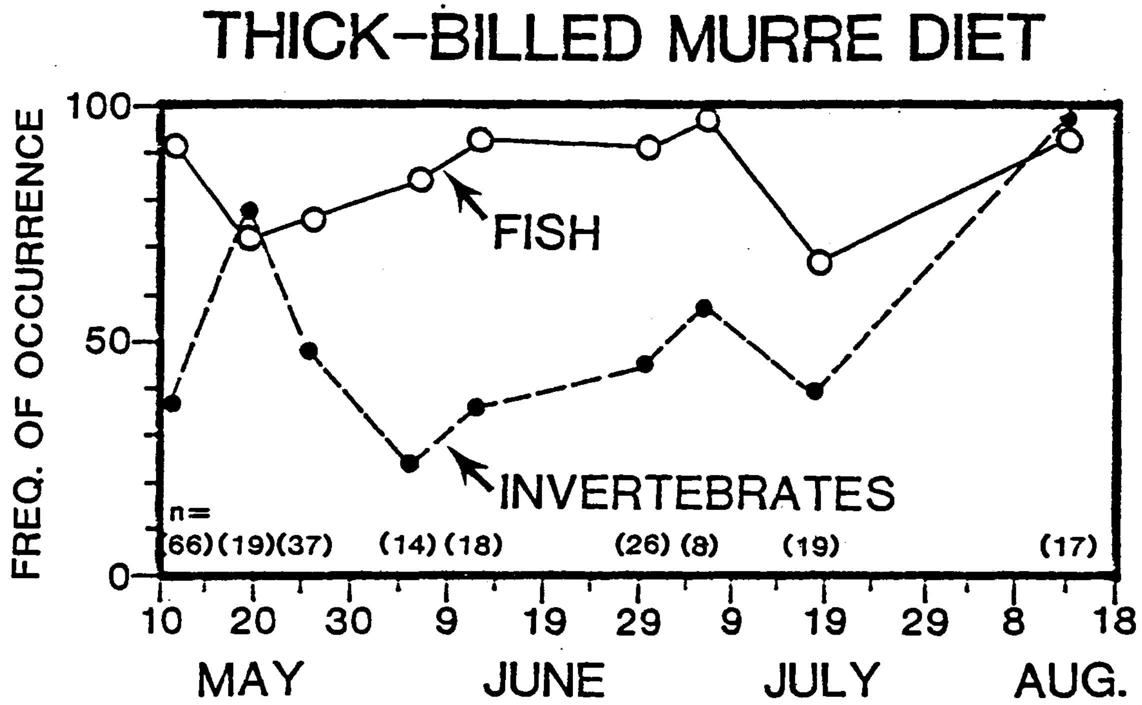

Figure 2.9. Seasonal variation in occurrence of fish and invertebrates in the diet of Thick-billed Murres.

Table 2.12. Mean body mass (±S.E.) of Common and Thick-billed Murres from St. Lawrence Island in 1987.

	Common Murre			Thick-billed Murre			
Date	n	Mean	S.E.	n	Mean	S.E.	Stage
May 13	-	-	-	37	1067	15.5	Pre-laying
May 20	-	-	-	19	999	15.0	Pre-laying
June 12	50	957	7.6	26	1000	17.5	Pre-laying
June 30	6	1012	14.7	26	1022	13.7	Incubation
July 18	26	868	14.1	18	899	14.6	Incubation
August 13	2	905	5.0	17	1006	19.6	Chick-rearing
Total *	84	932	6.2	143	1009	6.8	

* The overall difference in mass between species is highly significant ($p<0.0001$, $t=8.37$, $df=225$).

chicks per breeding pair (although half of all nests produced no eggs). This was higher than the success observed by Searing (9 nests, 1.5 chicks/nest) but similar to that observed by Johnson in 1981 (58 nests, 2.6 chicks/nest; reported in Searing 1977).

Common and Thick-billed Murres exhibited moderate overall breeding success rats of 60% and 51%, respectively, in 1987. Searing did not distinguish murre species in his study, but gave an average breeding success of 61%, which was similar to our results. Johnson (in Searing 1977) gave an estimate of about 41% breeding success for murres (spp.), but he disturbed chicks and likely reduced breeding success considerably (Searing 1977). His estimate of hatching success (71%) was slightly higher than what we observed in 1987 (67% and 59% for Common and Thick-billed Murres, respectively).

Our observations revealed a near total breeding failure of Black-legged Kittiwakes on St. Lawrence Island in 1987 (maximum success of ca. 0.09 chicks/nest). Similarly, Searing observed a total breeding failure of kittiwakes in 1976, and he found only two 1-egg clutches among about 50 nests checked. In contrast, about 75% of kittiwakes in 1987 laid eggs and 2-egg clutches were common (ca. 25%). Only about 40% of eggs hatched, however, and most chicks died before reaching two weeks of age (presumably from starvation). Both our results and Searing's contrast with Roseneau et al.'s observations of ca. 0.9 chicks/nest produced in 1981.

Overall, these observations of differential breeding success among species are difficult to interpret. Pending assimilation of further data, there is nothing to indicate that 1987 was an unusual year oceanographically, and there was nothing unusual about the diets of murres (see below) or auklets (see Chapter 3). Murre breeding success was low compared to normal success rates in the Atlantic Ocean (Harris and Birkhead 1985), but above average for murres in many regions of the Bering Sea (Hunt et al. 1981b, Johnson and Baker 1985, Murphy et al. 1986). Similarly, Pelagic Cormorant breeding success was average compared to rates in the southeastern Bering Sea (Hunt et al. 1981b). Kittiwakes, on the other hand, did as poorly as they have in other years when widespread kittiwake breeding failures were observed throughout the Bering Sea (e.g., 1976, 1984, 1985; Hatch 1987). In the absence of information on physical oceanography, prey availability and diet composition of kittiwakes in 1987, we can only speculate on the causes of the failure.

Given that both murres and cormorants, which feed on similar prey as kittiwakes over much of their ranges (Hunt et al. 1981a, Springer et al. 1984, 1986, 1987), exhibited better than average breeding success, we assume that it was the distribution rather than abundance of prey that limited kittiwake breeding success. Either prey were available only to murres and cormorants because of their diving abilities, or they were located at distances too great to be profitably exploited by kittiwakes, or a combination of both factors may have influenced kittiwake foraging success (see also Springer et al. 1984 for a discussion of environmental factors influencing prey availability to seabirds in the Chukchi Sea). Our shipboard observations conducted in late August (Chapter 4) support the suggestion that the prey of murres were found at great distances from the study area, and we observed no large feeding aggregations of kittiwakes.

Because they are closely related and of similar mass, the breeding success rates of Common and Thick-billed Murres provide an interesting contrast to each other. In general, Common Murres are most abundant in the nearshore zone and inner domain of the Bering Sea continental shelf, whereas Thick-billed Murres predominate in outer or pelagic domain waters (Sowls et al. 1978, Springer et al. 1987). At St. Lawrence Island, however, both species occur in near equal abundance and they overlap extensively in use of breeding habitat. Thus, if competition occurs between these species, we might expect to find evidence of it at St. Lawrence Island.

Like Birkhead and Nettleship (1987), who studied Common Murre and Thick-billed Murres on the Gannet Islands, Labrador, we found similar marked differences between species in use of cliff habitat, and murre breeding success varied with site characteristics. In general, Common Murres tended to breed on platform ledges, with one adjacent wall, and in the presence of more than one neighbor. Thick-billed Murres tended to breed on narrow ledges or crevices, with one or more adjacent walls, and usually alone or with one neighbor. The most important factor influencing overall breeding success in both species was the slope of the breeding ledge. Significantly more birds laid eggs on level sites, and breeding success of Thick-billed Murres that laid eggs was greater on level sites. This suggests that sloping sites are sub-optimal and may be used more by less experienced breeders or immature birds. Similarly, both species were influenced by neighbors. More Common Murres laid eggs when two or more neighbors were present, but the converse was true for Thick-billed Murres. Neighbors had no significant effect on fledging success, but both species did better in the presence of at least one neighbor. Thus, for both species, the initial site selection with regard to neighbors and slope (above) may account for subsequent differences in success between sites, site selection, and may largely depend on the breeding experience or age of the bird selecting the site.

As long as sites were level, Thick-billed Murres bred most successfully on narrow-ledge or crevice-type breeding sites, whereas Common Murres faired equally well in crevices as on platforms (although 82% bred on platforms). This observation is in marked contrast to the situation observed by Birkhead and Nettleship (1987) where Thick-billed Murres bred mostly on narrow ledges but had significantly higher success on broad ledges. For this reason, Birkhead and Nettleship advanced the hypothesis that Common and Thick-billed Murres competed for breeding sites at the Gannet Islands, and that this competition resulted in an overall lower breeding success for Thick-billed (63%) than Common Murres (82%). They further suggested that competition favored Common Murres because of their agility and size.

At St. Lawrence Island, however, both species fared best at sites they occupied most, and there was little evidence for competition. In addition, St. Lawrence Island is unusual in that Thick-billed Murres are actually larger than Common Murres and both species occur in near-equal abundance (unlike the Gannet Islands where Common Murres predominate by 40:1). Despite these conditions, Common Murres exhibited a higher overall breeding success (60%) than Thick-billed Murres (51%), as they usually do in areas of sympatry and allopatry (Birkhead and Nettleship 1987). If competition for breeding sites was not a key factor mediating breeding success, then we must look further for an explanation.

An alternative hypothesis is that the breeding success of each species is limited by food and foraging behavior. In our study area, and in many other areas of sympatry and allopatry, Common Murres eat only pelagic schooling fish during the breeding season, whereas Thick-billed Murres eat a greater variety of prey including benthic fishes and invertebrates (Springer et al. 1984, Bradstreet and Brown 1985, Piatt 1987). It is highly likely that pelagic schooling fish require less foraging time and effort to capture than dispersed benthic fishes and small invertebrates, and therefore should offer a higher energetic rate of return for foraging birds (Piatt 1988). In support of this hypothesis, we have observed at St. Lawrence Island and elsewhere (Hatch, unpubl. data), that non-laying and failed Thick-billed Murres spend less time at the colony than Common Murres, suggesting that they spend more time foraging at sea.

While this hypothesis might explain why Thick-billed Murres usually exhibit lower breeding success than Common Murres, it does not explain why Thick-billed Murres do not increase their productivity by increasing consumption of more profitable prey. Clearly, Thick-billed Murres choose to prey more on invertebrates, and it is this behavioral constraint that distinguishes them most from Common Murres in terms of foraging (Bradstreet and Brown 1985). Over the short-term, such a behavioral adaptation may appear to make Thick-billed Murres less competitive than Common Murres, but over the long-term and during periods when pelagic fish densities are reduced, Thick-billed Murres may have a competitive advantage over Common Murres (Piatt 1987, 1988). Just such a situation now appears to be occurring in northern Norway where, following a crash in capelin stocks, Common Murres are failing completely whereas Thick-billed Murres are managing to reproduce, albeit at lower levels than normal (Vader 1988).

2.4.2 Attendance Patterns

Attendance patterns of murres were typical of this species, both within days and through the season (Birkhead 1978, Gaston and Nettleship 1981). Like Searing (1977) we found that in June, diurnal attendance exhibited a broad peak early in the day with gradually declining numbers thereafter. Later in the season, no consistent trend was evident, and numbers were fairly stable through the day, especially in the afternoon and early evening. Kittiwakes exhibited no consistent diurnal trends, and numbers attending were also stable through most of the day. Thus, our counts conducted in midday provide a reasonable index of bird numbers attending on a daily basis.

Like Gaston and Nettleship (1982), we found that from egg-laying to the beginning of fledging, non-breeders and failed breeders accounted for most of the variation in daily attendance of Thick-billed Murres. Slater (1980) suggested that attendance by Common Murres is largely determined by breeding birds, but our evidence is to the contrary and suggests that like Thick-billed Murres, variablity in attendance depends mostly on non-breeder or failed breeder attendance behavior. In our study, it appeared that the non-layer/ failed breeder population of Thick-billed Murres spent less time attending than Common Murres. We agree with Gaston and Nettleship (1981) that murre attendance is probably determined by feeding conditions around the colony, and therefore, our observations may indicate that Thick-billed Murres spend more time foraging than Common Murres (see 'Breeding Biology' above).

In Gaston and Nettleship's study in the Canadian Arctic, non-laying site-holders accounted for only ca. 10% of cliff populations, and breeding success was generally higher for Thick-billed Murres than what we observed at St. Lawrence Island. Thus, the non-layers and failed breeders at their study sites constituted a smaller proportion of total birds attending than we observed, where ca. 30% of site-holders did not lay eggs and ca. 45% of breeders failed. This emphasizes the importance of these birds in determining attendance patterns at St. Lawrence Island, and suggests that inter-year variability in attendance (and census counts) may vary considerably with the numbers of birds attempting to breed and breeding success.

For both species, we could find no consistent relationships between attendance and any environmental variables except windspeed. Wind effects were most pronounced during the pre-egglaying period when birds were not constrained to attend sites because of incubation or chick-rearing duties. The negative effect of windspeed in attendance by murres has been demonstrated at many, but not all, murre colonies (Birkhead 1978, Slater 1980, Gaston and Nettleship 1981, Piatt and McLagan 1987). As Gaston and Nettleship (1981) suggested, the effects of wind are generally observed on very windy days only, and counts for Type II censusing should not be carried out on these days.

2.4.3 Population Trends

Our conclusions about population trends are limited by the small number of plots that we could compare with previous studies. Given this constraint, we tentatively conclude that murre and kittiwake populations at Kongkok have increased since Searing's study 11 years ago. A more reliable estimation of population trends will be possible when our plots, comprising about 10% of murre and kittiwake populations at Kongkok and east of Savoonga, are monitored again in the future.

The total numbers of murres at Kongkok (Owalit Mountain) have been censused several times since 1972 (by Johnson in 1972, Searing in 1976, and Roseneau et al. in 1981). All these estimates were derived from water-based counts of the entire colony on one or two days. Searing (1977) also estimated total numbers by extrapolating densities observed on plots to total colony area, but provided no indication of how he measured total area. Data from these censuses suggest that murre numbers at Owalit declined from 32,000 individuals in 1972 to 16,000 in 1976 and increased again to 34,000 in 1981. Roseneau et al. (1985) suggested the decrease in 1976 was probably explained by indirect effects of unusually cold environmental conditions that may have reduced the number of birds breeding. The apparent decrease in 1976 may have reflected a decrease in attendance by failed and non-breeders, rather than a long-term change in the population. The constraints of single-day water-based counts and the potential for wide variations in water-based counts by different observers limits an ability to comment futher on apparent population fluctuations.

No other murre colonies in this region have exhibited a similar trend over this same period: murre populations at Cape Lisburne (Fig. 1.1) have remained stable, at Cape Thompson have declined slightly, and at Bluff have declined consistently (Roseneau et al. 1985, Murphy et al. 1986). It is interesting that Roseneau et al. counted almost identical numbers of murres in 1981 as Johnson in 1972, suggesting a slight increase of ca. 6%. We observed an increase (ca. 21%) on three plots between 1976 and 1987. A consistent slow increase of ca. 0.6 - 0.8% per annum since 1972 could account for increases observed by both Roseneau et al. and us. Thus, we tentatively conclude that murre and kittiwake populations on St. Lawrence Island have slowly increased since 1976, and possibly since 1972 as well. Subsequent monitoring of our study plots in the future may allow later investigators to assess whether this trend is real.

2.4.4 Murre Diets

The diets of murres collected at St. Lawrence Island in 1987 were similar to diets observed in previous years. Searing (1977) collected 18 murres in mid-June, of which 12 had empty proventriculi. From this limited sample, it appeared that Common Murres took mostly fish (unidentified), although decapods or amphipods were present in four of six stomachs examined. Thick-billed Murres ate a much greater variety of prey, with fish occurring in only three of eleven stomachs, and with decapods and amphipods occurring in most stomachs with food present. It is tenuous to draw any conclusions from comparisons between our samples and Searing's, but two observations are of interest: i) species differences in diets were broadly comparable in as much as Thick-billed Murres ate many more invertebrates (especially decapods and amphipods) than Common Murres in both years, and, ii) Common Murres ate more invertebrates in 1976 than did those we sampled in June 1987, possibly indicating a scarcity of fish in that year.

Springer et al. (1987) collected 32 Thick-billed Murres and 14 Common Murres in late July - early August 1981. Like us, they observed that both murres consumed predominantly Arctic Cod (86% and 77%, by weight, respectively), with walleye pollock, saffron cod, sandlance, capelin, and sculpins rounding out the fish diets. Also like us, they observed a much higher frequency of occurrence of invertebrates in Thick-billed Murre (33%) than Common Murre diets (7%). Amphipods and euphausiids dominated in the invertebrate portion of Thick-billed diets.

Overall, our results and those of previous investigators indicate that Arctic Cod are the most important prey of murres at St. Lawrence Island, and there has been little change in diets over the period examined. This contrasts with observations of Arctic cod - saffron cod - sandlance dominated murre diets at Cape Thompson and Cape Lisburne to the north (Springer et al. 1984); saffron cod - sandlance diets at Bluff, Norton Sound, to the east (Springer et al. 1987); and with walleye pollock dominated diets to the south at St. Matthew Island (Springer et al. 1986) and the Pribilof Islands (Hunt et al. 1981a). This pattern fits with the known distribution of Arctic cod in the northern Bering Sea, where it is restricted to cold Arctic waters and generally does not range very far south of St. Lawrence Island (Frost and Lowry 1981, Springer et al. 1987). Saffron cod and sandlance tend to be concentrated in coastal Alaskan waters on the inner domain of the Bering Sea whereas pollock dominate in the middle and outer domain (Springer et al. 1987).

Few data have been obtained on murre diets in spring for any area of Alaska. We were fortunate in being able to collect samples of Thick-billed Murres from early May through mid-August. These data indicate that fish were consistently of high importance in diets, and of these fish, Arctic cod always predominated with little variation in fish diet composition. The occurrence of invertebrates was more variable, however, with peaks occurring in late May and late August, perhaps in conjunction with zooplankton blooms at these times (Bedard 1969b, Springer et al. 1987). No obvious trends in zooplankton composition were evident, although euphausiids (Thysanoessa spp. and others) were mostly taken in late July.

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Chapter 3 - Biology of Crevice-nesting Species:
Least and Crested Auklets

3.1 Introduction

Least (Aethia pusilla) and Crested Auklets (A. cristatella) are the most abundant planktivorous seabirds in the North Pacific (ca. 6 and 2 million, respectively) and their breeding populations overlap completely in the Bering Sea (Sowls et al. 1978). Crested Auklets (ca. 270 g) are much larger than Least Auklets (ca. 85 g), and this size difference reduces resource overlap and competition for breeding habitat (Bedard 1969a) and food (Bedard 1969b). Both species lay their eggs in natural crevices found in the rubble of boulder fields or glacially-formed talus slopes. Owing to logistical difficulties, however, few detailed studies of their breeding biology have been undertaken. These data are essential for monitoring and interpreting population fluctuations.

The pioneer study of Least, Crested, and Parakeet (A. psitticula) Auklet breeding biology was conducted by Sealy (1968) on St. Lawrence Island (Fig. 1.1); site of the largest auklet colonies in Alaska and also of Bedard's studies on feeding ecology and habitat selection of auklets (Bedard 1969a, 1969b). Sealy (1968) studied chick growth and development (Sealy 1973), and factors influencing breeding phenology (Sealy 1975) and survival of eggs and chicks (Sealy 1982). Neither Sealy nor Bedard estimated breeding success of Least or Crested Auklets.

Searing (1977) also studied auklet breeding biology on St. Lawrence Island and provided the first tentative estimate of breeding success for Least Auklets. Searing's results are questionable, however, because he seriously disturbed the auklets he was studying and markedly lowered their breeding success (Searing 1977). From a limited study conducted on Buldir Island in 1976, Knudtson and Byrd (1982) estimated Least Auklet breeding success and provided the only published estimate of Crested Auklet breeding success. Roby and Brink (1986) provided the only other estimates of Least Auklet breeding success based on a careful study conducted on the Pribilof Islands in 1981-1982. Although all the above investigators have acknowledged the negative effect observers have on auklet breeding success, none have quantified this disturbance factor. This is essential for realistic and comparable estimates of auklet breeding success.

There are some published data on attendance patterns or average densities of Least or Crested Auklets at their breeding colonies. Bedard (1969a) published population estimates for auklets on St. Lawrence Island. He based his estimates on counts of birds on plots during early morning hours of the the pre-egglaying period, but provided no data on diurnal or seasonal attendance patterns with which to assess errors associated with his censuses. Byrd et al. (1983) and Roby and Brink (1986) demonstrated that both Least and Crested Auklets exhibit marked diurnal attendance patterns with peak attendance in morning and evening hours, and that these patterns change through the breeding season. They also monitored the net movements of breeding and non-breeding auklets to and from breeding sites. Based on all their data, these authors suggested when and how auklets might be best censused. Techniques are still being refined, however, and there is no consensus yet on the best methods for monitoring auklet populations.

The diets of Least and Crested Auklets have been studied at St. Lawrence Island (Bedard 1969a, Searing 1977, Springer and Roseneau 1985), the Pribilof Islands (Hunt et al. 1981, Roby and Brink 1986), and St. Matthew Island (Springer and Roseneau 1985). At St. Lawrence Island, Least and Crested Auklets eat primarily copepods and euphausiids, respectively, typical of outer domain water carried north by the Anadyr Current (Fig. 1.1). Thus, diet composition not only provides useful information with which to interpret breeding success (or failure) and competitive interactions between the auklet species, it provides some insight into the biological oceanography of the region (Springer and Roseneau 1985).

Our study of Least and Crested Auklets was conducted on St. Lawrence Island in summer, 1987. One purpose was to estimate breeding success of both species and to measure the effect of natural (e.g., weather and predation) and human disturbances on these estimates. Selected Least Auklet study sites were subjected to different levels of observation intensity. Owing to smaller numbers, Crested Auklets were studied at only one (high) level of observation intensity. Chicks of both species were weighed and measured throughout the chick-rearing period. Breeding phenology and success (at different disturbance levels), chick growth rates, and predation rates were estimated for both species. We also monitored diurnal and seasonal attendance patterns of Least and Crested Auklets to: i) identify components of variation in attendance, ii) develop a protocol for censusing populations, and, iii) compare density estimates with those of previous studies to assess population trends. Diets of Least and Crested Auklet were also examined during the chick-rearing period to assess food availability and compare with diets in previous years.

3.2 Methods

3.2.1 Study Area and Plots

This study was conducted in the Kongkok Bay area (63° 24' N, 171° 49' W) on the southwestern corner of St. Lawrence Island (Fig. 1.1). The avifauna, climate, and types of habitat to be found on St. Lawrence Island, have been described elsewhere (Fay and Cade 1959, Bedard 1969b, Sealy 1975).

Sixteen 200 m^2 auklet study plots were established on the southeast-facing (inland) talus slope of Owalit Mountain (Fig. 3.1). At least 20,000 auklets (ca. 2:1 least/crested) breed on these slopes (Searing 1977). All 16 plots were thoroughly checked 3-4 times over 13 days during the early egg-laying period to locate eggs, check the status of previously located eggs, and mark breeding sites. Some eggs were located after minor excavation, but most were located with careful line-of-sight searching using strong flashlights. Every effort was made to minimize disturbance to breeding habitat. All searches and later site checks were conducted during mid-day (1400-2000 h A.S.T.) when attendance by adults on the slopes was minimal.

One set of eight plots (Intensive) was subsequently checked every day weather permitted through the egg-hatching period (ca. 27 July - 13 August), every 2-4 days up to early fledging (ca. 25 August), and every day possible after that until 2 September when the field camp was evacuated. Weights and wing chord length measurements of Least Auklet chicks were obtained from these plots only.

Least Auklet breeding sites in the other set of eight plots on Owalit Mountain (Control) were examined only four times (ca. once a week in August)

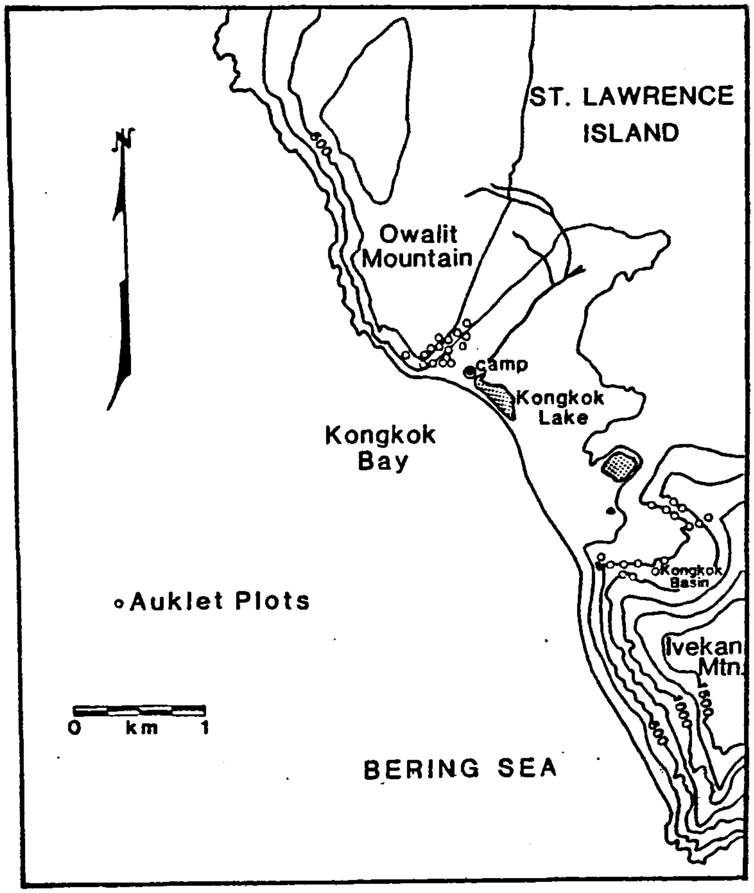

Figure 3.1. Location of auklet study plots on Owalit Mountain and in Kongkok Basin.

after the initial egg searches. To further minimize disturbance, Least Auklet chicks were not handled on these plots. The final check on these plots was especially thorough and included excavation to determine the status of breeding sites.

Owing to smaller numbers located, Crested Auklet breeding sites were examined on all 16 Owalit plots with the same level of intensity as the 'Intensive' Least Auklet study plots. Crested Auklet chicks were weighed and measured in whichever of these 16 plots they could be obtained.

Another set of 8 plots on the north-facing talus slope of Kongkok Basin (Fig. 3.1) were searched for Least Auklet eggs between 23-25 July. These plots were subsequently checked twice prior to chick fledging to determine breeding site status. As in the Owalit Control plots, the final check on these plots was particularly thorough. The Kongkok plots differed substantially from the Owalit plots in that: i) observer disturbance in Kongkok was minimal compared even to the Control plots on Owalit where observers were on the slope everyday checking sites, weighing chicks, and/or walking to study sites of other seabird species, ii) Least Auklet densities were higher at Kongkok, and total numbers far greater (ca. 200,000 birds, Bedard 1969a), and, iii) exposure to voles and other predators was not as great in Kongkok Basin (see Discussion).

3.2.2 Monitoring Breeding Success and Chick Growth

It is difficult to monitor the progress of auklet breeding sites because neither species actually builds a nest. Eggs are laid in crevices among rocks on the talus slopes, and for protection against predators (e.g., Arctic fox, Alopex lagopus), eggs are hidden from sight and not easily accessible. Nonetheless, many eggs and chicks were easily monitored, once found, with little more effort than shining a light in a crevice. More required diligence and agility. Specific written instructions with reference to orange spray-painted marks on rocks were very useful in re-locating breeding sites.

Eggs and chicks (in particular) sometimes disappeared during the study and it was difficult to assess the fate of those lost. Some were undoubtedly taken by predators, others may have rolled/crawled out of sight temporarily, or permanently re-located, or died. Whereas some chicks were observed on almost all site checks, others were only seen periodically. The presence of fresh feces (usually red-stained), feather sheaths, down, and spilled chick meals provided reliable evidence of continued use of a 'nest' chamber. However, some chicks left no readily observable sign of their presence.

Chick movements were more common towards the end of the fledging period, making estimation of fledging dates difficult or impossible in some cases. Of 369 eggs/chicks monitored, 17 eggs (4.6%) and 64 chicks (17.3%) disappeared without trace. Although this is a problem common to all auklet studies, human disturbance appeared to be the major cause of egg/chick disappearance and breeding success estimates can be interpreted accordingly (see Results).

It was difficult to unequivocably establish the first occurrence of eggs at breeding sites. Because a breeding site was not obvious until an egg was actually found, and there was no way of knowing whether a 'new' egg was not, in fact, missed on a previous check, our estimates of egg-laying dates (and hence incubation periods) are likely biased.

Estimates of hatching success were undoubtedly biased because eggs found at a late stage of incubation are more likely to hatch than those found early (Mayfield 1961, 1975). To correct for this, overall egg hatching success rates were calculated (Mayfield 1975) by i) dividing the total number of egg-days observed by the total number of eggs lost to yield the egg survival rate/day, ii) multiplying this rate by itself n times, where n is the average number of incubation days, yielding the egg survival rate/season, and, iii) multiplying this rate by the proportion of eggs surviving to hatching age that actually hatch. This yields a corrected hatching success rate which adjusts for those eggs which were laid and lost without being observed by us.

Adult body weights were obtained from specimens collected from hunters in Gambell prior to setting up camp in Kongkok, and from birds shot later in Kongkok Bay for diet studies.

In describing chick growth rates, we followed Sealy (1973) and Gaston (1985) in determining the 'instantaneous growth rate' at the inflection point of the growth curve to yield an estimate of the maximum growth rate of chicks. The maximum growth rate probably provides the best basis for intra- and interspecific comparisons of growth in alcids (for a detailed discussion see Gaston 1985). Maximum growth rates from this and other studies were determined by fitting the steepest possible tangent to smoothed growth curves (Gaston 1985). Because both asymptotic and fledging weights vary considerably within and between study areas, median chick weights were also calculated for comparative purposes as the mid-weight between hatching and asymptotic weights (Gaston 1985). Another useful comparative parameter determined from growth curves was t_{10-90}, the time (days) it took for chicks to grow from 10 to 90% of asymptotic weight (Ricklefs 1967).

3.2.3 Monitoring Attendance and Censusing

Auklet attendance was monitored in two ways. First, we conducted total counts of all auklets present on Owalit (200 m^2) study Plots 1-8 (see Appendices) every 0.5 h on 11 days through the breeding season. Second, we set up 8 mm time-lapse cameras on three plots (7, 3, and 6) to monitor attendance of birds in relatively small areas (ca. 5 m^2). Time-lapse photos were taken every 5 min using an intervalometer to control film speed. Films were later developed and auklet numbers were counted in the lab using a time-lapse projector. The longest time series was obtained from Plot 3, and overall we collected complete diurnal attendance data on 71 different days through the breeding season. Attendance patterns were analyzed using nested ANOVA and variance component procedures available on SAS (1985). The effects of weather variables (see Section 2.2.3) on auklet attendance were tested by measuring Spearman rank correlations.

Although we suggest new methods for censusing (see Discussion), we compared our census counts of Least and Crested Auklets on Owalit Mountain (8 200 m^2 plots) and Kongkok Basin (16 200 m^2 plots, Fig. 3.1) with those of Searing (1977) and Bedard (1969a) using the same technique described in detail by Bedard (1969a). As suggested by Bedard, our census counts at Owalit were conducted during the pre-egglaying period (June). Owing to time and weather constraints, our counts at Kongkok were not conducted until late July. We corrected for seasonal variations by conducting Owalit and Kongkok counts simultaneously in July, and then extrapolating the Kongkok counts based on differences observed between the June and July Owalit counts. In calculating the density of auklets on plots, we followed Bedard (1969a) and Searing (1977) by selecting the four highest counts at each plot as representing 'true' densities of breeding birds, and deleting the highest count to obtain an average from the next three highest counts.

3.2.4 Diet Collections

We obtained samples of food being delivered to chicks in two ways. First, we mist-netted adult auklets on their breeding habitat at Owalit Mountain, and retrieved the contents of food in their gular pouches. Most birds regurgitatd upon hitting the net, and so we laid large sheets of plastic on the ground below the net to catch the food. Samples were preserved in 5% formalin for later analysis. Mist-netting worked effectively for Least Auklets, and 56 samples were obtained between 7 August and 1 September. Only five Crested Auklet samples were obtained over this period using mist-nets. Remaining food samples from 18 Least and 49 Crested Auklets were obtained from gular pouches of adults collected by shooting at-sea near Kongkok (Booshu camp, ca. 5 km away) on 30 August. These samples were also preserved in 5% formalin for later analysis in the lab. All food samples were sub-sampled and sorted to identify composition (to species level if possible), and total numbers and weights of differing taxa were extrapolated (e.g., see Springer and Roseneau 1985).

3.3 Results

3.3.1 Breeding Phenology

Least and Crested Auklets were first observed nearshore at Gambell on 15 May, and birds were seen in attendance at Sevuokuk Mountain near Gambell on 18 May. Full attendance by adults at breeding sites on Owalit Mountain (Kongkok) was observed by 2 June. Between 3-26 June, periodic inspection of breeding habitat took place at Owalit and Kongkok. These inspections revealed evidence of previous breeding activity (old egg shells and allantoic membranes) and fresh feces indicated new activity among the talus rocks.

First eggs were found on 27 June at Owalit (4 Least and 1 Crested). It was impossible to assess laying phenology because of the difficulty in determining laying dates (see Methods). A small number of eggs were monitored from the day of laying to hatching to yield estimates of auklet incubation periods (Table 3.1). With hatching data (Tables 3.1 and Fig. 3.2), this suggests that median laying occurred around 1-2 July.

Only four eggs (out of 369, or 1.1%) were suspected to have been re-lays (Table 3.2). All were found being incubated by adults with the remains of a broken, recently laid egg close by. Without having observed the sequential laying, however, we cannot be certain they were second eggs rather than broken and abandoned eggs of other birds. Therefore, these eggs were treated as first eggs in assessing phenology.

Hatching was highly synchronous and skewed slightly to the right of median hatching (Fig. 3.2). About 80% of Least and Crested Auklet eggs hatched over a 7 and 10 day period, respectively.

Fledging of Least Auklets was also highly synchronous (ca. 80% over 7 d) and skewed to the right (Fig. 3.2). With longer incubation and fledging periods (Table 3.1), Crested Auklets would have reached median fledging around 6 September. Fledging had just begun a few days prior to our departure on 2 September.

3.3.2 Breeding Success

Least Auklet hatching success varied with intensity of study and location (Table 3.2). Hatching success was highest at Kongkok and lowest at the Intensive study plot on Owalit Mountain. The biggest difference between sites was in the high rates of non-hatching/abandonment at the Intensive study plots, and in the higher predation of eggs on Owalit plots. The Owalit Control and Kongkok plots were monitored much less frequently than the Intensive plots, and therefore a higher proportion of eggs suffered an

Table 3.1. Breeding phenology of Least and Crested Auklets on St. Lawrence Island in 1987.

	Least Auklet			Crested Auklet		
	n	Mean ± S.E.	Range	n	Mean ± S.E.	Range
Incubation period	31	30.1 ± 0.51	25-39	20	33.8 ± 0.63	29-40
Fledgling period	34	29.3 ± 0.37	25-33	6	33.2 ± 0.05	27-36
	n	Date		n	Date	
Median laying date	*	1 July		*	2 July	
Median hatching	76	30 July		75	4 August	
Median fledging	38	28 August		*	6 September	

* Extrapolated from incubation/fledging period and median hatching dates.

Table 3.2. Breeding success of Least and Crested Auklets on St. Lawrence Island in 1987.

		Least						Crested	
		Intensive		Control		Kongkok		Intensive	
		n	%	n	%	n	%	n	%
Frequency of visits		28		7		3		28	
Total eggs found		109	100.0	101	100.0	56	100.0	103	100.0
Egg losses due to:									
Non-hatch/abandoned		24	22.0	7	6.9	3	5.4	14	13.6
Unknown		4	3.7	13	7.9	4	7.1	4	3.9
Breaking		2	1.8	4	4.0	1	1.8	5	4.9
Vole predation		3	2.8	1	1.0	0	0.0	2	1.9
Eggs re-laid*		2	-	1	-	-	-	1	-
Hatching success	A	76	69.7	76	75.3	48	85.7	78	75.7
(Mayfield estimate)	B		66.4		69.8		80.5		65.6
Chick losses due to:									
Disappearance		16	(21.1)**	16	(21.1)	6	(12.5)	18	(23.1)
Death		12	(15.8)	5	(6.8)	3	(6.3)	6	(7.7)
Vole predation		7	(9.2)	1	(1.3)	0	(0.0)	2	(1.9)
Fledging success	C	41	(53.9)	54	(71.1)	39	(81.3)	50	(64.1)
Breeding Success	AxC		37.6		53.5		69.7		48.5
(Mayfield estimate)	BxC		35.8		49.6		65.5		42.0
Maximum estimate							82.1		89.9

* Not included in calculations, see text.

** Values in parentheses are percentage of hatched eggs.

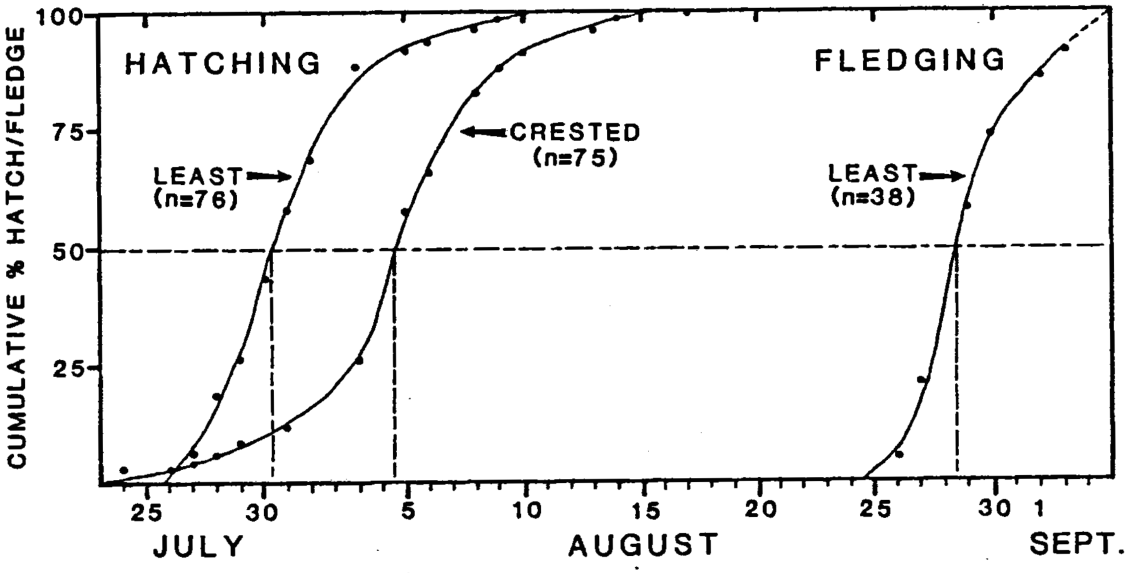

Figure 3.2. Breeding phenology of Least and Crested Auklets.

unknown fate (disappeared). Some of these unknown losses probably resulted from eggs rolling out of the breeding site, while some unknown proportion were undoubtedly lost to predation by voles and Arctic foxes. The fate of Crested Auklet eggs on Owalit was similar to that observed for Least Auklets on Intensive plots, with a high proportion of monitored eggs not hatching or being abandoned and a small proportion suffering from vole predation (Table 3.2).

Hatching success was re-evaluated using the Mayfield (1975) method to account for egg-losses that might not have been observed by us. Because the Intensive plots provided the most complete assessment of egg success, egg survival rates from the Intensive plots were applied to the Control and Kongkok plots to calculate overall hatching success (Table 3.2). Estimates of hatching success calculated using the Mayfield method were ca. 5-10% lower than estimates made from raw data (Table 3.2).

Least Auklet fledging success also varied markedly between study sites (Table 3.2). As with hatching success, chick disappearance and predation rates were higher on the disturbed Owalit plots. Crested Auklet chick mortality rates were similar to those of Least Auklets on Owalit. A much higher proportion (15.8%) of Least Auklet chicks died from unknown causes on the Intensive plots than on the other plots. Both chick disappearance and mortality at Intensive plots may have been elevated by our disturbance and handling of chicks for measurements. Overall, 38% and 30% of all dying/disappearing Least and Crested Auklet chicks, respectively, were handled by us. Death rates were much lower on Control and Kongkok plots (Table 3.2).

Vole predation rates were highest on Intensive Least and Crested Auklet plots. It is likely that predation rates were also high at the Control Owalit plots, but went unobserved owing to the lower frequency of monitoring visits. Voles did not usually kill chicks outright, but rather removed some flesh from lower back or flank regions. Death or disappearance usually followed vole attacks by a few days. Thus, many of the 'disappeared' chicks on the Control plots were killed by voles and/or exposure, but vanished between site checks (removed by adult or scavenger, buried, washed away, etc.).

About 50% of auklet chick losses occurred within the first week of hatching (Fig. 3.3), and over half of these losses were due to death from unknown causes. Much of this death may have resulted from our handling of chicks compounded with hypothermia of unattended and/or exposed chicks. Attendance of chicks by adults dropped off rapidly with chick age (Fig. 3.4), reflecting the gradual development of homeothermy of chicks in the first week of life (Sealy 1968). More than twice as much rain fell between 2-17 August (5.1 cm) than in the previous two months of June and July (2.1 cm), and much of this fell over two periods (2-3 and 9-12 August) immediately following chick hatching (Fig. 3.2). Many dead chicks were found saturated with water, and it is likely that rain contributed significantly to chick mortality.

Vole predation was most intense on chicks between 5-20 d old (Fig. 3.3). This pattern probably reflects a decrease in chick protection by attending adults after the first few days of life (Fig. 3.4), and an increase in mobility and ability for defense against voles in later stages (20+ d); with the vulnerable period in between.

Losses were greatly reduced as chicks exceeded an age of 20 d, and no chick losses were observed after 22 days (Fig. 3.3). The proportion of chicks that simply 'disappeared' increased with age up to 22 d. Some of these 'disappeared' chicks may have wandered from the breeding site (and starved or were predated), and this was likely exacerbated by our disturbance of habitat and adult chick-feeding activities. Wandering of chicks did not resume until late in the chick-rearing period as chicks approached fledging and became physically active. Most of these chicks were re-located on repeated checks, or could be located with a little exploration of neighboring habitat. Any chicks that could not be re-located after surviving to 23+ d were assumed to survive for estimates of breeding success.

Overall breeding success estimates on different study plots reflected hatching and fledging rates (Table 3.2). On Intensive plots, Crested Auklets (48.5%) exhibited higher breeding success than Least Auklets (37.6%). The impact of observer disturbance is evident from the fact that Least Auklet breeding success was substantially higher (53.5%) in the Control Owalit plots. Still higher success at Kongkok (69.7%) reflects not only decreased

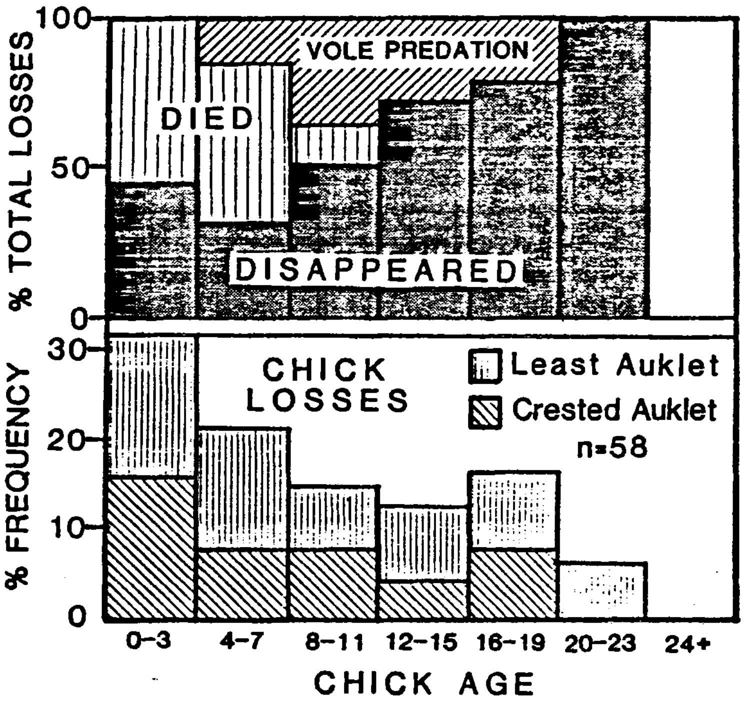

Figure 3.3. Sources and frequency of auklet chick mortality with age of chick. (Age of chicks in days).

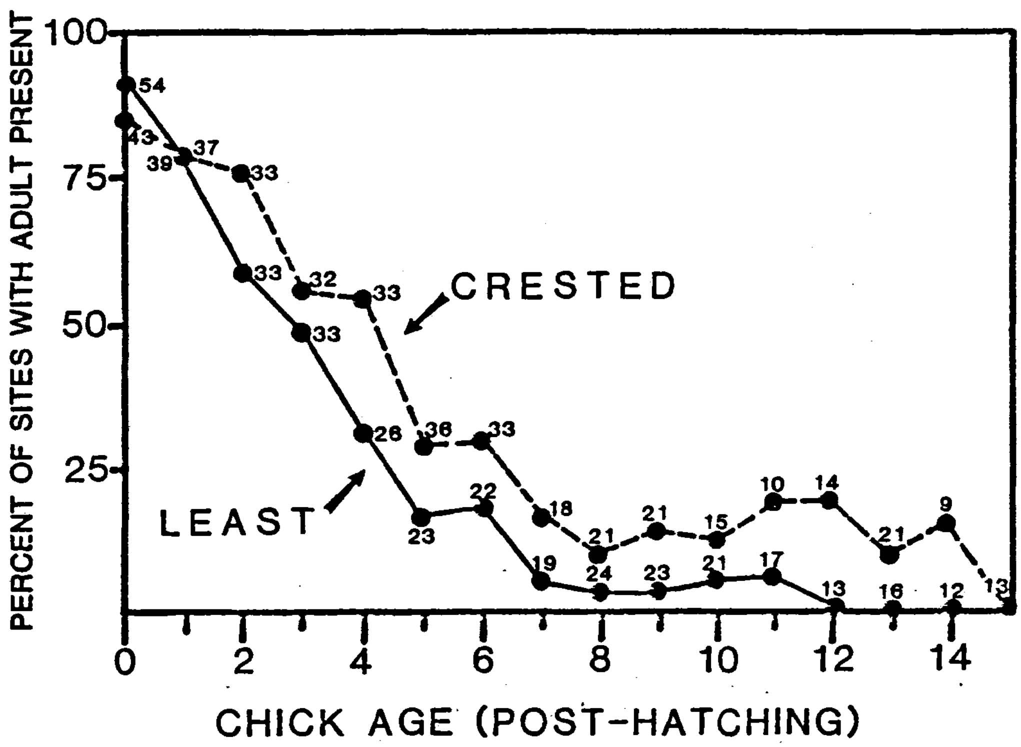

Figure 3.4. Frequency of attendance of adult auklets with chicks of varying age(days). Sample sizes indicated next to each data point.

disturbance, but much lower (or absent) vole predation. Using hatching success estimates calculated by Mayfield's method, overall breeding success estimates were reduced by only 1.8-6.5%.

Two factors, direct human disturbance at nesting sites and unaccountable disappearance, clearly influenced breeding success estimates. If we assume that estimates of Least Auklet breeding success at Kongkok were the most reasonable, and divide the 10 unknown/disappeared egg and chick losses proportionately between all possible outcomes (i.e., 7 chicks fledge), then breeding succcess might have been as high as 82%. Crested Auklets were studied at only one (high) level of intensity. If they were to exhibit the same proportional increase in breeding success as Least Auklets between the Intensive and Kongkok plots (i.e., 1.9-fold improvement), then Crested Auklet breeding success might have been as high as 89.9%.

3.3.3 Chick Growth

The weight of Least Auklet chicks increased steadily for about 21 days post-hatching, after which mean weights decreased slightly before climbing to asymptotic weight at 27 d post-hatching (Figs. 3-5). The average weight of chicks older than 22 d, or at fledging, were about the same (100% and 103%, respectively) as adult weights in late June (Table 3.3). Mean weight-at-age decreased steadily after chicks reached asymptotic weight (Fig. 3.5). After an initial lag as primaries developed, wing chord lengths increased steadily to 90.1% of adult wing lengths at 31 d post-hatching.

Crested Auklet chicks exhibited similar growth patterns, although data were not obtained on any chicks older than 32 d post-hatching (Fig. 3.5). Weights increased steadily up to 23 d post-hatching and declined slightly before reaching asymptotic weight at 29 d post-hatching. No fledging weights were obtained, but the average weight of chicks older than 22 d post-hatching was similar (98.4%) to adult weights in mid-July (Table 3.4). Crested Auklet chick wing chord lengths increased with age after an initial 5 d lag (Fig. 3.5) and the maximum chord length recorded was 85.3% of adult wing chord lengths (Table 3.3).

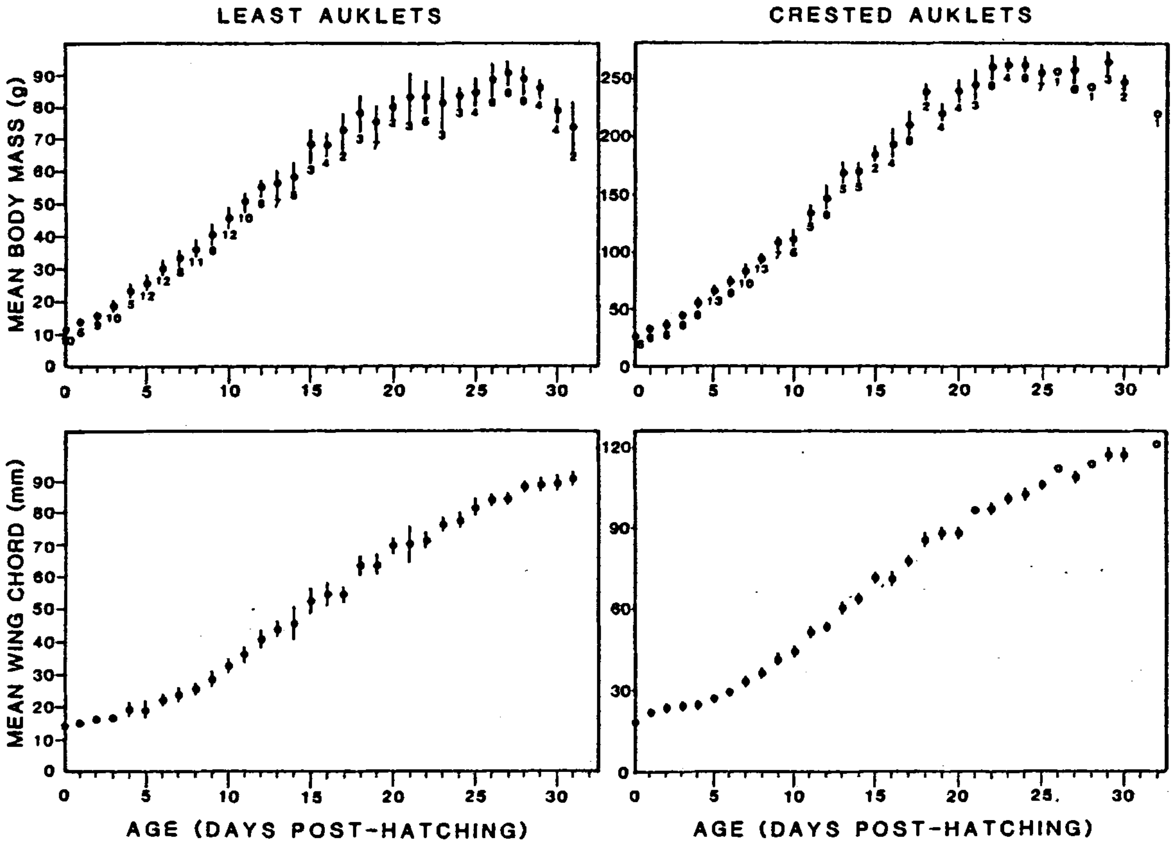

Figure 3.5. Increase in body mass and wing chord length with age of auklet chicks.

Table 3.3. Weights and wing chord lengths of adult and chick auklets from St. Lawrence Island, 1987.

	Least Auklet			Crested Auklet		
	n	Mean ± S.E.	Range	n	Mean ± S.E.	Range
Adult weight (g)						
May 18-20				18	283 ± 5.6	250-315
June 6	18	86.6 ± 1.5	77-101	6	272 ± 6.0	256-298
June 30	8	82.0 ± 1.8	76- 90	34	260 ± 2.4	227-285
July 18				22	265 ± 3.2	228-294
Chick weight (g)						
Asymptote	6	90.8 ± 3.1	81-100	3	269 ± 6.1	258-279
Fledgling	12	82.2 ± 2.8	72- 99			
22+ days	46	85.0 ± 1.3	64-105	38	261 ± 2.8	221-290
Wing length (mm)						
Adult	18	97.6 ± 0.5	95-102	20	143 ± 0.9	137-153
Fledgling	12	87.9 ± 1.1	83- 95	1	122 (max)	

Maximum growth rates of Least and Crested Auklet chicks were similar to those observed in other years and locations (Table 3.4), although growth rates were lowest in 1976. St. Lawrence Island growth rates were generally higher than those observed at St. Matthew Island in 1982-83, but lower than growth rates at the Pribilof Islands in 1981-82 (Table 3.4). Crested Auklet growth rates were higher in 1987 at St. Lawrence Island than in any other year of study (Table 3.4).

3.3.4 Attendance Patterns

Diurnal patterns of individual auklet attendance were extremely variable when examined at small temporal and spatial scales. Figure 3.6 shows the numbers of Least and Crested Auklets sitting on a ca. 5 m^2 area of talus slope at 5 min intervals on 21 June. There are no obvious patterns, except that both species were absent for ca. 12 h in the middle of the day (note broken scale in Fig. 3.6), and numbers were lower for a shorter period in the evening. The timing of presence and absence periods varied through the summer, but the erratic patterns shown in Fig. 3.6 were typical on all days observed.

Although it is not obvious from Fig. 3.6, Least and Crested Auklet numbers were negatively correlated with each other on most days observed (73%, n = 77), and many (48%) correlations were significant. Significant positive correlations were found on 10% of days.

Figure 3.7 reveals diurnal auklet attendance patterns viewed at a larger scale: total numbers observed on eight 200 m^2 plots on Owalit Mountain at 0.5 h time intervals. Several features stand out: i) Least and Crested Auklet attendance is correlated significantly on these and most (94%) of 77 time-lapse counts when data were integrated over 0.5 h intervals, ii) both species increase attendance rapidly in the morning, attendance declines slowly until all birds leave by late-morning/midday, and birds return in lower abundance in late evening, iii) the duration of morning attendance increases through the breeding season, iv) attendance ends completely by late chick-rearing (see Fig. 3.2 also), and v) there are large day-to-day variations in attendance.

Table 3.4. Auklet growth parameters*.

Species	Location	Year	MGR (g/d)	Mid-wt.	t (d) 10-90
Least Auklet	SLI	87	4.9	51.4	20
	SLI	81	4.7	-	-
	SLI	76	4.4	50.5	19
	SLI	66-67	5.3	49.7	18
	PRI	81-82	5.7	53.9	17
	SMI	82	4.9	-	-
	SMI	83	3.9	-	-
Crested Auklet	SLI	87	12.8	147.8	17
	SLI	76	11.1	146.0	20
	SLI	66-67	12.5	144.9	22

* Studies conducted by us in 1987 on St. Lawrence Island (SLI), Roseneau et al. (1982) in 1981, Searing (1977) in 1976, Sealy (1968) in 1966-67; by Springer et al. (1983, 1985) in 1982-83 on St. Matthew Island (SMI); and by Roby and Brink (1986) on the Pribilofs (PRI) in 1981-82. MGR is maximum growth rate; mid-wt. is the average weight of chicks mid-way through growth to asymptotic weight; and t 10-90 is the time (days) for growth between 10 and 90% of asymptotic weight.

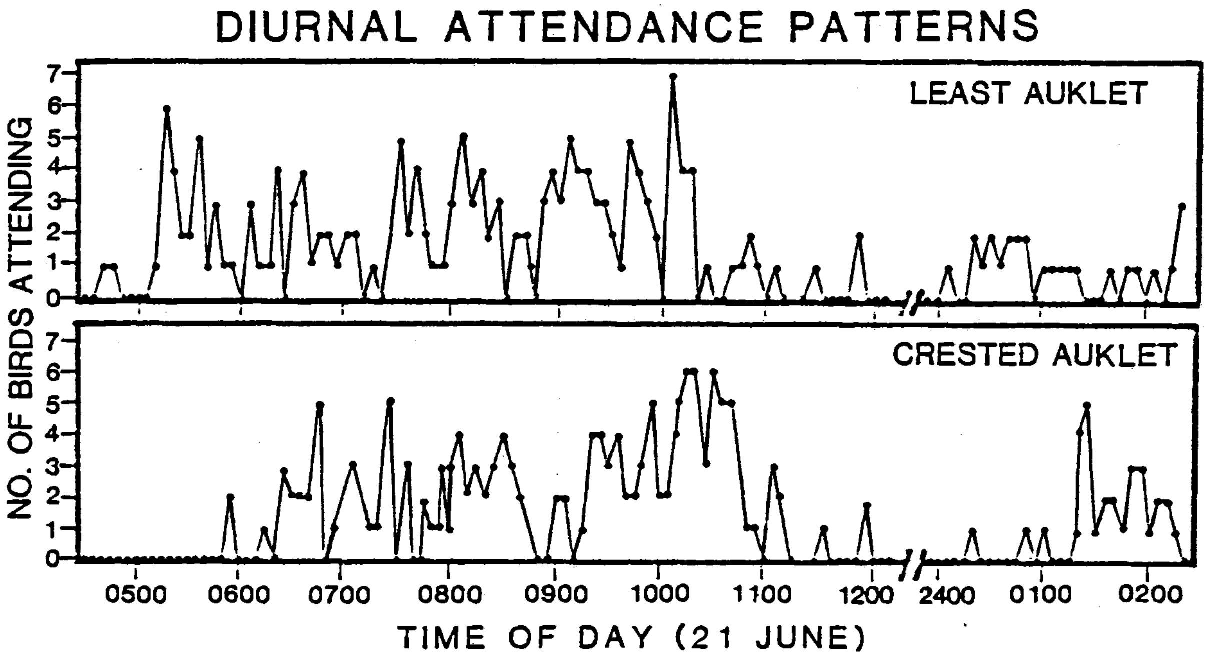

Figure 3.6. Diurnal attendance patterns of auklets at Plot 3 on 21 June 1987, as determined from time-lapse film. Counts made at 5 min intervals from 0430 - 0220 h B.S.T. (Note break in time between 1210 - 1155 h; no auklets were in attendance during these hours).

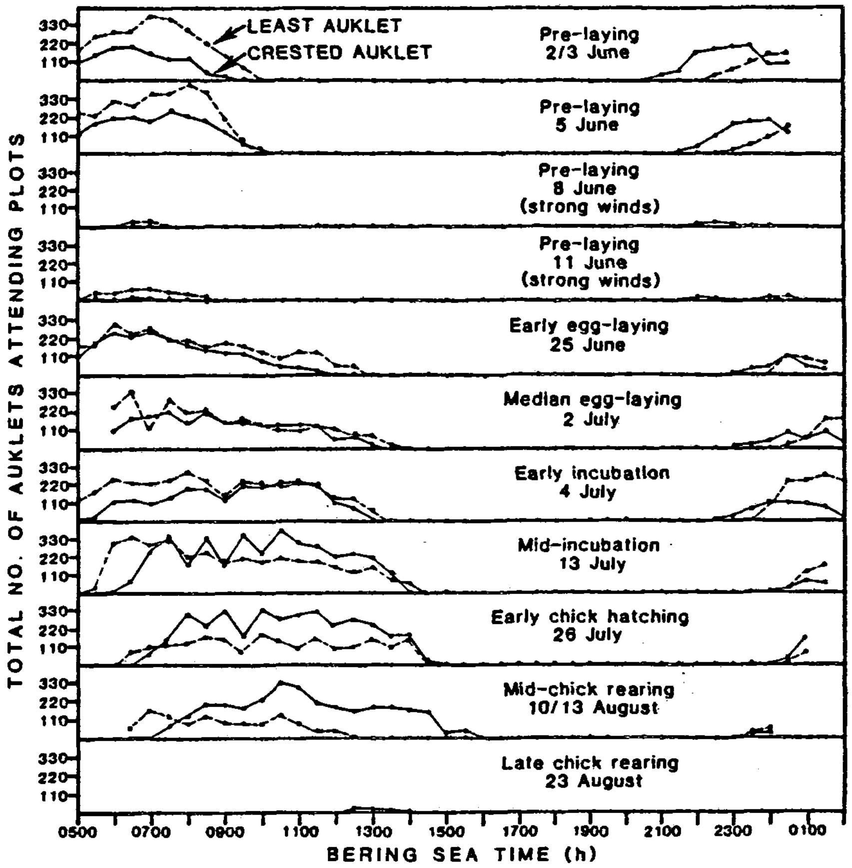

Figure 3.7. Diurnal attendance patterns of auklets in different periods of their breeding season. Counts of eight plots on Owalit Mountain at 0.5 h intervals.

Analysis of the components of variation (Table 3.5) indicates that within-day variation accounts for most of the total variability in auklet attendance observed in Fig. 3.7. Variations in attendance at different plots, and variations in attendance between different plots over a day also contribute significantly to total variation, but these effects are swamped by within-day variations (Table 3.5). Variation not accounted for (error, due to other factors like observer, wind, predators, etc.) accounted for most variance after within-day effects.

After removing within-day variations from the analysis, and using only data from 0600-0900 B.S.T. (period used for censusing by Bedard 1969a), we found that between-day and between-plot variations accounted for much of the total varations in attendance, although the proportion of variance due to error remained high (Table 3.6).

Attendance patterns, and variations in attendance, were examined more closely using data from time-lapse film. Although time-lapse techniques are limited by the low number of birds recorded on plots, this is more than compensated for by the large number of 5 min counts that can be conducted within hours, days, and periods of the breeding season. Time-lapse counts appear to be representative of attendance over larger areas. Strong significant correlations (Least: mean r = 0.67 ± 0.096; Crested: mean r = 0.62 ± 0.23) between time-lapse (integrated over 0.5 h) and observer counts were observed on all days except August 23, when few auklets attended the colony (Fig. 3.7). By grouping data into hours and months, we obtain an integrated picture of auklet attendance to which we can assign error terms (Fig. 3.8). This integrated data reveals a clearer picture of attendance than the observer counts (Fig. 3.7) because the between-day variance is masked. In most respects, patterns revealed by both techniques are similar. More evident from the time-lapse data, however, is the marked increase in Crested Auklet attendance in July while Least Auklet attendance remained at similar levels between months.

Another way to examine between-day and seasonal variability is to plot auklet attendance integrated over each day against date (Fig. 3.9). This shows more clearly how large daily variations can be, and how Crested Auklets

Table 3.5. Components of variation in attendance of Least and Crested Auklets at plots 1-8 on Owalit Mountain, St. Lawrence Island. Nested ANOVA using all data.

		Least Auklet			Crested Auklet		
Source	df	F	P<	% Var	F	P<	% Var
Plot	7	39.5	0.0001	2.5	120.8	0.0001	8.6
Period of summer	3	174.2	0.0001	5.2	144.8	0.0001	6.2
Day (within period)	7	65.5	0.0001	0.0	64.2	0.0001	0.0
Time (within period)	33	123.7	0.0001	49.0	80.0	0.0001	38.7
Plot * period	21	4.0	0.0001	1.4	7.0	0.0001	2.0
Plot * day	49	1.7	0.01	0.3	2.8	0.0001	0.0
Plot * time	230	2.3	0.0001	4.3	4.2	0.0001	17.3
Error	3143	--	—	37.2	—	—	26.3

Table 3.6. Components of variation in attendance of Least and Crested Auklets at plots 1-8 on Owalit Mountain, St. Lawrence Island. Nested ANOVA on counts conducted between 0600-0900 h Bering Sea Time.

		Least Auklet			Crested Auklet		
Source	df	F	P<	% Var	F	P<	% Var
Plot	7	28.5	0.0001	11.8	41.0	0.0001	22.9
Period of summer	3	58.6	0.0001	0.0	47.6	0.0001	10.2
Day (within period)	7	78.8	0.0001	45.7	21.9	0.0001	13.4
Plot * period	21	1.9	0.01	0.0	2.8	0.0001	1.7
Plot * day	49	2.2	0.0001	8.2	1.8	0.001	8.1
Error	508	--	—	34.3	--	--	43.7

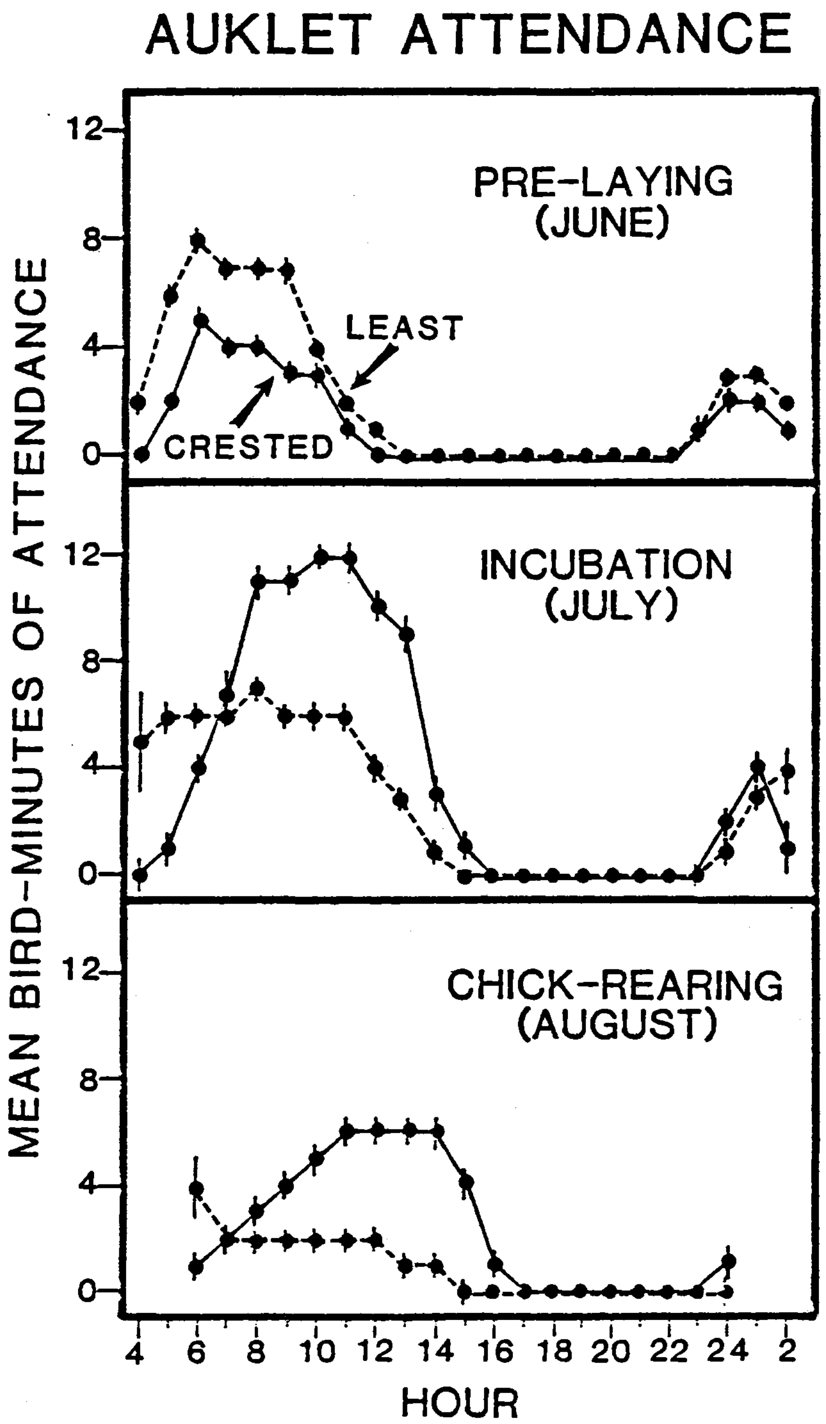

Figure 3.8. Diurnal attendance patterns of auklets during pre-laying, incubation, and chick-rearing as determined by time-lapse photography. Each data point is the mean (+ s.e. bars) attendance per hour per month.

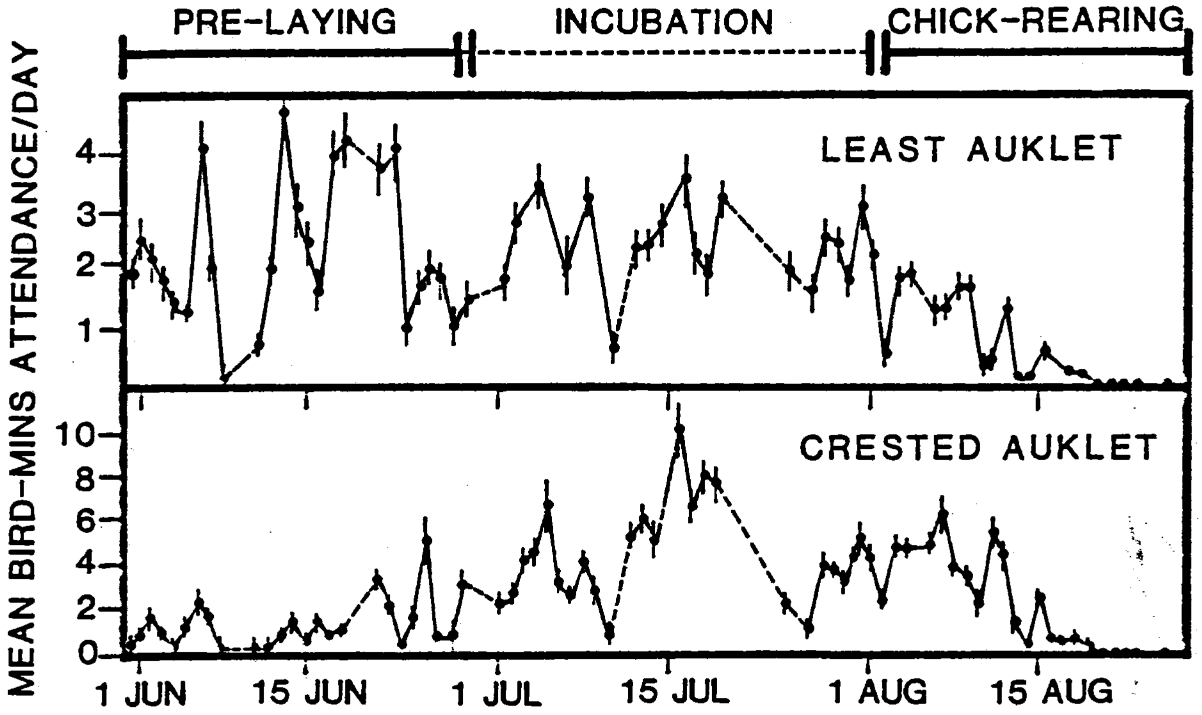

Figure 3.9. Seasonal attendance patterns of auklets as determined from time-lapse photography. Each data point is the mean (+ s.e. bars) attendance per day.

exhibit a quite different seasonal pattern of attendance than Least Auklets. Least Auklet attendance peaks during pre-laying whereas Crested Auklet attendance slowly builds to a peak during incubation.

The effects of the environment were assessed by measuring correlations between integrated daily attendance values (excluding the fledging period) and environmental variables (Table 3.7). Attendance of both species was negatively correlated with windspeed, which accounts for many days of low attendance we observed (Figs. 3.7, 3.9). Correlations with the daily range of tidal oscillations were also negative, and improved to much higher values when data were grouped over seven day intervals. Maximum tidal oscillations result in increased turbulence in the water column which may affect feeding conditions, and therefore time spent foraging (Piatt 1987). Crested Auklet attendance was also negatively correlated with barometric pressure, and positively correlated with air temperatures and rainfall.

As indicated in Fig. 3.9 and by analysis of variance components (Tables 3.5, 3.6), the degree of variation in attendance differed between each stage of the breeding season, particularly in Crested Auklets. Part of the reason for this is probably that environmental variables, especially windspeed, had a greater effect on attendance early in the breeding season when birds were not bound to breeding sites by incubation or chick-rearing responsibilities. For censusing purposes, it is desirable to know at which stage of breeding that daily variations are minimized. Coefficients of variation in auklet attendance integrated over two week intervals indicate that the best time to conduct censuses would be during late incubation or early chick-rearing (Table 3.8).

3.3.5 Population Trends

We censused auklets on Owalit Mountain and Kongkok Basin, and compared our counts to those of Searing (1977) and Bedard (1969a) where comparisons were appropriate (Table 3.9). At both colonies, Searing had counted higher numbers of Least and Crested Auklets in 1976 than Bedard in 1964. At Kongkok Basin, we counted much high numbers of Least Auklets, and about the same number of Crested Auklets in 1987 as Searing had in 1976. Considering the

Table 3.7. Spearman rank correlations between mean numbers of auklets attending time-lapse plots per day and environmental variables.

		Least		Crested	
Variable	n	r	P<	r	P<
Wind speed	55	-0.29	0.05	-0.31	0.05
Air pressure	55	-0.07	NS	-0.57	0.0001
Tide range	55	-0.07	NS	-0.28	0.05
Tide (7-d means)	9	-0.69	0.05	-0.54	NS
Max. Temp.	55	0.26	NS	0.48	0.05
Min. Temp.	55	0.11	NS	0.65	0.01
Fog	55	0.04	NS	0.41	NS
Rain	55	0.21	NS	0.52	0.05

Table 3.8. Variation in Least and Crested Auklet attendance during different periods in their breeding cycle at St. Lawrence Island (counts of auklets at 5-min intervals at time-lapse film plots throughout breeding).

			Least			Crested		
Period	Date	n	Mean	S.E.	C.V.	Mean	S.E.	C.V.
Pre-laying	JUN 1-15	1289	0.51	0.03	229	0.10	0.01	426
	JUN 16-30	2846	0.48	0.02	238	0.37	0.02	278
Incubation	JUL 1-15	3139	0.49	0.02	216	0.76	0.03	224
	JUL 16-31	2095	0.67	0.03	188	1.58	0.06	175
Chick-rearing	AUG 1-15	2171	0.49	0.02	199	1.43	0.05	166
	AUG 16-31	1470	0.05	0.01	549	0.07	0.01	526

Table 3.9. Mean densities of Least and Crested Auklets on Owalit Mountain and Kongkok Basin, St. Lawrence Island.*

	Least Auklet									Crested Auklet								
	1987				1976			1964		1987				1976			1964	
Location	n	Mean	S.E.		n	Mean	S.E.	n	Mean	n	Mean	S.E.		n	Mean	S.E.	n	Mean
Kongkok Basin																		
Grouped data	48	90	5.9	H	48	56	5.0	39	34	48	42	6.0	H	48	40	12.6	39	30
North side	24	58	3.9	L	21	76	8.1			24	62	3.3	L	21	85	23.7		
South side	24	122	6.8	H	27	40	3.6			24	21	1.6	H	27	5	1.4		
Owalit Mtn.**																		
Grouped data	24	53	3.0	L	24	64	4.9	?	36	24	32	4.4	H	24	13	1.7	?	19
Plots 1,2,8	9	44	2.0	L	0	56	4.0			9	25	5.2	H	9	10	1.8		
Plots 3,4,7	9	50	3.8	L	9	60	2.7			9	42	10.1	H	9	19	2.5		
Plot 6	3	80	1.5	L	3	120	4.1			3	33	1.0	H	3	20	1.8		
Plot 5	3	65	3.8	H	3	45	4.1			3	23	3.0	H	3	2	0.3		

* Counts from 1987 (our data) indicated to be higher (H) or lower (L) than counts in 1976 by Searing (1977). Counts in 1964 from Bedard (1969b). All counts of 200 m^2 auklet plots.

** Based on Searing's original field notes. We compared counts from plots located in similar areas (upper stratum: 3, 4, 2; and lower stratum: 1, 2, 8), and two plots (5 and 6) believed to be in exactly the same locations.

north and south side of Kongkok separately, there appeared to be a decrease in mean densities of both species on the north side, but a large increase in densities on the south side.

At Owalit Mountain, Searing observed an increase in auklet densities since Bedard's counts. We observed a small decrease in Least Auklet densities since Searing's counts, but a large increase in Crested Auklet densities. We believe that two of the plots (5, 6) we monitored in 1987 were identical to ones counted by Searing (we found Searing's wooden stakes). Least Auklet densities declined at one of these plots, but increased on the other. Crested Auklet densities increased at both plots. On the basis of Searing's report (1977) and original field notes, we stratified two sets of three plots by their locations on the talus slopes (lower: 1, 2, 8; upper: 3, 4, 7) and compared counts with Searing's plots which were in the same general area. Trends were consistent at both sets of plots: Least Auklets decreased whereas Crested Auklets increased.

We did not test the significance of these differences because, as demonstrated above (3.3.4 Attendance Patterns), there is so much variability in attendance between plots, within-days and between-days, that statistical comparison of these data would be meaningless. Nonetheless, plots were chosen in representative areas and were censused by the same methods over similar time periods. While the results may not allow statistical comparison, they may still be biologically valid. If so, our census suggests that i) birds increased in some colony areas but decreased in others, ii) Least Auklet densities have increased dramatically at Kongkok and declined very slightly at Owalit, and, iii) Crested Auklet densities increased dramatically at Owalit, but did not vary at Kongkok.

3.3.6 Diets

Least and Crested Auklets had markedly different diets for the period in which they were sampled (Table 3.10). Least Auklet diets, which were sampled over the entire period of 7 August - 1 September, were dominated entirely by calanoid copepods and in particular, by Neocalanus plumchrus, a zooplankton species typical of outer domain waters (Fig. 1.1). Least Auklets ate a great

Table 3.10. Composition of Least (n = 74) and Crested (n = 54) Auklet meals collected at St. Lawrence Island between 7 August - 1 September 1987.

	Least Auklet			Crested Auklet		
Prey species	n	% No.	% Wt.	n	% No.	% Wt.
Neocalanus cristatus	725	1.4	2.4	280	3.2	0.6
Neocalanus plumchrus	44,417	82.9	87.0	909	10.4	1.2
Calanus marshallae	5,646	10.5	5.5	285	3.3	0.2
Calanoid copepod	690	1.3	1.0	20	0.2	0.1
Metridia pacifica	40	0.1	0.1	0	0	0
Eucalanus bungii	286	1.5	0.3	0	0	0
Euchaeta elongata	2	0.1	0.1	0	0	0
Apherusa glacialis	1	0.1	0.1	0	0	0
Anisogammarus pugettensis	48	0.1	0.1	0	0	0
Parathemisto libellula	135	0.3	1.0	9	0.1	0.1
Parathemisto pacifica	571	1.1	0.7	24	0.3	0.1
Parathemisto spp.	28	0.1	0.1	27	0.3	0.1
Thysanoessa spp. adult	36	0.1	0.8	7,048	80.3	97.8
Thysanoessa spp. furcilia	413	0.8	0.1	165	1.9	0.1
Pandalus spp. zoea	525	1.0	1.0	13	0.1	0.1
Paguridae spp. zoea	23	0.1	0.1	0	0	0
Limacina helicina	3	0.1	0.1	0	0	0
Squid	1	0.1	0.1	0	0	0
Fish	1	0.1	0.1	0	0	0

variety of other prey in much smaller quantities, however, including amphipods (Parathemisto spp.), euphausiids (Thysanoessa spp.), and shrimp (Pandalus spp.) zoea. Most Crested Auklets were obtained on one day (30 August) so they probably do not adequately reveal diet breadth. Euphausiids (Thysanoessa spp.) totally dominated diets of Crested Auklets, with copepods and amphipods contributing only slightly to the total composition of diets.

3.4 Discussion

3.4.1 Phenology

The breeding schedules of Least and Crested Auklets in 1987 were apparently normal for St. Lawrence Island (Bedard 1969b, Sealy 1968, Searing 1977, Roseneau et al. 1982). In five of six previous years of study (1964-67, 1976, 1981), birds arrived nearshore in late May and egg-laying commenced in the last week of June; setting the schedule for peak hatching in late July/early August and fledging in late August/early September. Breeding phenology was ca. 10-14 d earlier in 1967, probably because of unusally mild weather conditions and an early snow-melt on breeding habitat (Sealy 1968, 1975).

Incubation and chick-rearing periods observed in this study were similar to those reported previously from St. Lawrence Island. Sealy (1968, 1981) estimated that Least Auklets incubated for ca. 31 d; just one d longer than our average of 30 d. Both these estimates are considerably shorter than Knudtson and Byrd's estimate from Buldir Island (35-36 d). Our estimate of the Least Auklet chick-rearing period (29 d) was the same as Sealy's from St. Lawrence Island and Roby and Brinks' from St. George Island. Similarly, our estimate of Crested Auklet incubation period (34 d) is slightly lower than Sealy's (36 d), and both these estimates are much lower than Knudtson and Byrd's (40-41 d) from Buldir Island.

Because of the difficulty in establishing the first occurrence of eggs (see Methods), we cannot be certain that all eggs used in our analysis of incubation times were seen on the first day of laying, and this may account for our estimates being slightly lower than Sealy's. On the other hand, there is some variation in incubation period between years (Sealy 1968) and incubation time may vary considerably depending on the degree of disturbance to incubating birds (Sealy 1968, 1984). The incubation periods reported by Knudtson and Byrd (1982) were probably over-estimated, possibly owing to disturbance, but also because breeding sites were not checked frequently enough to pinpoint laying and hatching dates (Sealy 1984).

Only four eggs were suspected as being re-lays, and if included in the analysis, would alter the assessment of phenology only slightly. The proportion of adult auklets that may lose and re-lay eggs is poorly known. Sealy (1968) observed only one positive case of re-laying in Parakeet Auklets, and suspected that only two re-lays by Least and Crested Auklets occurred during his period of study.

Breeding phenology of auklets at St. Lawrence Island (63° 24' N) is ca. 7-10 d later than at St. Matthew Island (60° 27' N, Springer et al. 1983, 1985), ca. 2-3 wk later than at St. George Island in the Pribilofs (56° 55' N, Roby and Brink 1986), and ca. 3-4 wk later than at Buldir Island in the western Aleutians (52° 21' N, Knudtson and Byrd 1982). This geographic difference in phenology is probably related to differences in the timing of prey availability (Sealy 1968, Birkhead and Harris 1985).

It appears that Least and Crested Auklets are usually quite synchronized in laying of eggs, but owing to different incubation and chick-rearing periods, hatching is out of phase by ca. 5 d, and fledging by ca. 9 d at the end of the breeding season. This represents only a modest reduction in temporal overlap at breeding colonies compared to other coexisting alcids; e.g., ca. one month difference in fledging between Common Murres (Uria aalge) and Atlantic Puffins (Fratercula arctica, Piatt 1987).

3.4.2 Breeding Success

All previous investigators have acknowledged that their estimates of hatching rates for auklets were probably high because searching for eggs continued throughout the laying/incubation period and eggs lost to predation or other causes were likely underestimated (Sealy 1968, Searing 1977, Knudtson and Byrd 1982, Roby and Brink 1986). Using the Mayfield (1961, 1975) method, which is a simple and robust (Johnson 1979) procedure for estimating hatching or fledging success rates, this source of error can be evaluated. In our case, hatching success was likely overestimated by 5-10%, leading to an overestimate of breeding success by ca. 2-7%. The magnitude of this error will depend on how early in the laying/incubation period observations begin, and should be evaluated in all auklet studies.

Our estimate of Least Auklet hatching success on Intensive plots (66-69%) was similar to that reported from Buldir Island (68%, Knudtson and Byrd 1982). Our estimate of Least Auklet hatching success at the relatively undisturbed Kongkok plots (80-86%) was close to success reported from St. George Island (87-90%, Roby and Brink 1986). By Searing's (1977) account, his disturbance of breeding sites was so great that his estimate of Least Auklet hatching success (47%) cannot be considered valid. The highest loss of eggs on our Intensive plots resulted from non-hatching/abandonment (22%); which occurred at much lower rates on the less disturbed Control (6.9%) and Kongkok (5.4%) plots. Knudtson and Byrd (1982) reported a similar rate of non-hatching/abandonment (29%), as did Searing (24.2%), but Roby and Brink (1986) did not report the fate of lost eggs (only 10-13% in total).

These results are ambiguous and difficult to interpret. Knudtson and Byrd's study was incidental to other work on Buldir Island, and breeding site checks were conducted much less frequently (ca. 3-7 d) than by Roby and Brink on St. George Island (ca. 1-2 d). If observer disturbance is as damaging as our results suggest, then Roby and Brink's estimates of hatching success should have been lower and at least around the level of other studies. Roby and Brink did not indicate whether most eggs were located just prior to hatching, but if so, this might account for their high estimates of hatching success. Alternatively, perhaps the habitat and birds on St. George Island are less vulnerable to disturbance. Application of the Mayfield method to their hatching data might have resolved this question.

Similarly, estimates of Crested Auklet eggs lost due to non-hatching/abandonment by Searing (50%), Knudtson and Byrd (22%) and us (14%) suggest that observer disturbance is the most important factor influencing hatching success estimates. Our overall estimate of Crested Auklet hatching success (66-76%) on Intensive plots was similar to Knudtson and Byrd's from Buldir Island (76%). Again, Searing's estimate can be disregarded owing to extreme disturbance (Searing 1977).

Disturbance effects may also seriously affect hatching success estimates of other alcid species. High egg losses owing to non-hatching/abandonment have been reported for Parakeet Auklets (20%, Sealy and Bedard 1973), Cassin's Auklet (Ptychoramphus aleuticus, 23-30%, Vermeer and Lemon 1986), and Xantu's Murrelet (Synthliboramphus hypoleucus, 14%, Murray et al. 1983).

Least Auklet fledging success rates also varied considerably between our different study plots (54%, 71%, 81%). Greatest chick losses were due to chick disappearance and death at the breeding site (37% of nestlings on Intensive plots), and most of these losses were probably caused by observer disturbance. High Least Auklet fledging success rates were also observed on St. George Island (76-82%, Roby and Brink 1986) and on Buldir Island (75%, Knudtson and Byrd 1982). Highest chick losses at these colonies were also due to death/disappearance (16-19% and 25% of nestlings, respectively). Crested Auklet fledging success at St. Lawrence Island (64%) was similar to that observed at Buldir Island (67%), and most losses at both colonies were due to death and disappearance of chicks (31% and 35%, respectively).

Overall Least Auklet breeding success (no. chicks fledged per egg laid) on the least disturbed Kongkok plots (66-70%) was considerably higher than at Buldir Island (51%) and a little lower than at St. George Island (67-73%). Given differences in methodology, it is impossible to say whether these breeding success estimates reflect real differences in the biology of Least Auklets between areas or years. The same is true for Crested Auklet breeding success, which was somewhat lower at St. Lawrence Island (42-49%) than at Buldir Island (51%).

It is likely that the breeding success rate observed at Kongkok is representative for Least Auklets, and that success of both auklets is higher than most studies would indicate because: i) Observer disturbance clearly reduces breeding success in study plots. Extrapolating from our study to account for disturbance effects, Least and Crested Auklet might have breeding success rates of ca. 82% and 90%, respectively; ii) The assessment of breeding success from breeding sites which are accessible to humans probably biases results. It is likely that optimal breeding sites for Least Auklets, and especially Crested Auklets, are those in deeper and/or less accessible crevices where the effects of human disturbance, predation, and weather are less pronounced (Bedard 1969b, Sealy 1968); and, iii) Auklets at Kongkok suffer from less predation (see below), and occur in much higher abundance and density than at Owalit Mountain (Bedard 1969b, Table 3.9). For many seabirds, breeding success is highest where densities are highest (Birkhead 1985), and thus, the production rates observed at Kongkok may be most typical for Least Auklets on St. Lawrence Island, and for the species as a whole. The same may be true for Crested Auklets.

In summary, our study suggests that the breeding biology of crevice-nesting auklets is best studied over a range of conditions. Intensive observation may artificially increase adult desertion and chick mortality, but the fate of eggs and chicks is more readily assessed. Conversely, less disturbed plots yield better estimates of breeding success. Finally, different colonies or colony areas may be subject to differing effects from predation, habitat type, and bird density. A more thorough study of auklets on St. Lawrence Island is required to address these issues.

3.4.3 Predation and Weather Effects

In our study, 2-3% of eggs and 2-9% of chicks were lost to predation by voles at Intensive plots. Although Tundra Voles (Microtus oeconomus) were observed in small numbers, Red-backed Voles (Clethrionomys rutilus) were by far the most abundant and widespread small mammal occuring on breeding slopes and were likely the source of most predation on auklets (Sealy 1982).

Sealy (1968, 1982) and Searing (1977) observed similar rates of predation on eggs (2-11%) and chicks (1-9%) of Least and Crested Auklets on St. Lawrence Island. Sealy and Bedard (1973) also reported similar rates of vole predation on Parakeet Auklet eggs (3.3%) and chicks (20%) on St. Lawrence Island. Predation on seabirds by microtine rodents is unusual (Sealy 1982).

In one extreme case, Murray et al. (1983) observed severe (44%) predation on Xantu's Murrelet eggs by deer mice (Peromyscus maniculatus) and suggested this was a serious problem for murrelets on Santa Barbara Island.

This does not appear to be the case for auklets on St. Lawrence Island. We observed no predation at the Kongkok Basin colony, possibly because we checked breeding sites less frequently there. Nonetheless, our impression was that unlike Owalit Mountain, where auklet densities were lower and vegetation abundant, few voles were observed in the dense talus scree at Kongkok where the majority of auklets breed. Indeed, the high density of birds and guano may inhibit growth of plants required by voles. Rates of predation at the relatively small (72,000) auklet colony on Sevuokuk Mountain studied by Sealy, and at Owalit, may therefore not be representative for the majority of the auklet population on St. Lawrence Island.

Some proportion of 'unknown' egg losses, and 'disappearance' of chicks was due to predation by Arctic Fox. Whereas voles left visible marks on eggs and chicks, allowing us to measure predation, foxes took whole eggs and chicks intact, and we can only speculate about their impact on breeding success. Arctic Foxes were seen carrying murre eggs more often than auklet eggs during incubation, but Crested Auklet adults and chicks were their main fare during chick-rearing. Foxes were seen almost daily on Owalit Mountain, and a den in which 8 pups were reared successfully was located near (ca. 200 m) the slopes where our plots were located. Prey parts scattered around the den were mostly from adult Crested Auklets. In mid-August, all 8 pups moved onto the slopes with their mother and were observed in the area until we left in September. Arctic Foxes were also observed frequently in Kongkok Basin.

Thus, it is possible that much of the 'unknown' losses of auklet eggs (ca. 4%) and chicks (ca. 13-23%) was due to predation by Arctic Foxes. Although Sealy (1968) suggested that fox predation on St. Lawrence Island was negligible, he was working at Sevuokuk Mountain near the Yupik Eskimo community of Gambell, and fox numbers there are probably limited by hunting and trapping (Lane Iyakitan, pers. comm.) The negative impact of fox predation on seabird and waterfowl populations in the Aleutians is well known, especially from cases where they were introduced to islands for farming (Jones and Byrd 1979). Arctic Fox predation on auklets at St. George Island may inhibit population growth there (Roby and Brink 1986). On the other hand, fox predation may be negligible on large islands with very large seabird colonies and where severe winters may limit populations (Sklepkovich 1986). Both these conditions apply to St. Lawrence Island.

At least one Red Fox was frequently seen foraging near Owalit, but it seemed to prey mostly on rodents. Nunivak Island is the only other island in Alaska where Red and Arctic foxes coexist naturally (Ed Bailey, pers. comm.). Other major auklet predators included Glaucous (Larus hyperboreus) and Herring (L. argentatus) Gulls. These were observed patrolling the breeding slopes and pursuing adults (mostly Least Auklets).

Another important factor influencing auklet breeding success on St. Lawrence Island in 1987 was weather. Breeding from boreal regions to the high Arctic, alcids regularly encounter extreme weather conditions and it is not unusual for chicks to die from exposure (Sealy 1968). Like Roby and Brink (1986), we found that adult incubation of Least and Crested Auklet chicks decreased with chick age up to ca. 10 d of age. Similarly, adult Cassin's Auklets attend chicks continuously for 1-2 d post-hatching, but attendance declines steadily for the next 12 d (Vermeer and Lemon 1986). As chicks do not become homeothermic until ca. 4-5 d of age (Sealy 1968), unattended chicks are particularly vulnerable to cold, wet weather during this stage. Thus, it was not surprising to observe increased chick mortality following two prolonged periods of rain in August which came immediately after median hatching of both species. This effect was probably exacerbated by our disturbance of nesting adults.

3.4.4 Chick Growth

Chick growth on St. Lawrence Island in 1987 appeared to be normal for Least and Crested Auklets. There was no indication that auklets had any unusual difficulty feeding and rearing chicks as median weights, maximum growth rates, and development times were similar to those found in other years or locations.

Sealy (1968, 1981) found that Least Auklet chick mass peaked at ca. 98% of adult mass and then declined by ca. 11% before fledging at ca. 88% of adult mass. On St. George Island, Roby and Brink (1986) found that Least Auklet chick mass did not decline significantly after reaching asymptotic mass, and chicks fledged at ca. 108% of adult mass. Like Sealy, we also observed a recession in weight (9.8%), but fledgling mass was ca. 103% of adult mass. This discrepency occurs only because Sealy compared chicks to adults collected throughout the breeding season rather than during the chick-rearing period. Bedard (1969a) showed that adult auklet mass declines through the season by ca. 11 % (93.4 to 83.4 g).

Similarly, adult Crested Auklets lose ca. 12% of their mass through the breeding season (300 to 265 g, Bedard 1969a). Thus, Sealy's observation that following a 12% recession from asymptotic mass, Crested Auklet chicks fledged at ca. 80% of adult mass is a slight underestimate because he took 287 g as adult mass, whereas data suggest that adult mass during chick-rearing is closer to 265 g (Bedard 1969a, this study), and thus chicks fledge at ca. 85-90% adult mass.

In any case, our data corroborate Sealy's findings that Least and Crested Auklet chicks exhibit a weight recession prior to fledging. Although pre-fledging weight recession is common in the Alcidae (Sealy 1968), the cause of this phenomenon is not clear. Sealy (1968, 1981) suggested it may occur because of increased physical activity by chicks prior to fledging. But if so, then Least Auklet chicks on St. George Island should have also exhibited some weight recession.

Alternatively, Sealy suggested that reduced chick feeding activity by adults at the end of chick-rearing may account for chick weight recession. There are no data on seasonal trends in chick feeding by auklets with which to test this hypothesis. However, chicks on St. George Island exhibited the fastest growth rates, shortest growth periods, and highest fledging weights of any study on Least Auklets to date. This suggests an abundance of food at St. George Island during the period of study; and this may explain the absence of a recession in chick weight.

Our data on attendance patterns revealed that adult attendance ends completely during the late chick-rearing period. This suggests that foraging becomes progressively more time-consuming as the chicks near fledging age, and would support Sealy's suggestion that chick weight recession results from reduced feeding activity.

3.4.5 Attendance Patterns and Population Monitoring

The general pattern of auklet attendance that we observed on St. Lawrence Island, i.e., pronounced diurnal peaks in morning and evening, have been observed there previously (Bedard 1969a), at Buldir Island in the western Aleutians (Byrd et al. 1983), and at the Pribilof Islands (Least Auklets only; Roby and Brink 1986). All investigators have noted a shift in attendance through the breeding season, with more birds attending later in the day as the season progresses.

Roby and Brink (1986) assessed attendance by monitoring the 'net movement' of adult and immature birds to and from breeding sites. They determined that the period of apparent non-attendance during midday of the chick-rearing period is deceptive as adult birds are actually coming and going with food for chicks; they just do not linger at breeding sites long enough to be observed 'attending'. Based on their observations of marked individuals at a small colony site, they concluded that the best time to census breeding adults was during evening hours of the mid to late chick-rearing periods because at that time, only adults with meal deliveries were observed arriving at the colony.

Similarly, Byrd et al. (1983) examined attendance of Least and Crested Auklets by measuring net movement at different plots, and also by counting attending birds in the manner described by Bedard (1969a). Like Roby and Brink (1983), they assumed that the net movement technique could be used to approximate the actual number of breeding pairs if: i) both members of the pair spend the night in the breeding crevice, ii) in the morning, one member of a pair leaves the crevice, sits around outside for a while, then flys out to sea to spend the day feeding, and, iii) that same evening, the feeding bird returns, sits outside the crevice for a while, then returns to its crevice and waiting mate. The pattern presumably repeats itself the next day when the other bird goes to sea.

Byrd et al. (1983) compared census estimates derived from the net movement of marked birds with estimates derived by observer counts of total birds attending (Bedard technique), and found that the net movement technique resulted in estimates about an order of magnitude greater than the Bedard technique. Estimates from both techniques were significantly correlated, although the correlation was much weaker in Least Auklets. Byrd et al. suggested this was because Crested Auklets, which are much bigger, intimidate Least Auklets and where the two co-occur, reduce the amount of time Least Auklets spend outside their crevices. Our observation of a negative correlation in attendance of these species over small spatial scales supports this conclusion.

There are pros and cons associated with both census techniques. Bedard's technique is favorable because: i) large numbers of attending birds may be counted in many plots by a single observer, ii) there does appear to be a direct relationship between the number of breeding adults standing around outside their crevices and breeding bird densities (Ian Jones, pers. comm.), and, iii) the technique is relatively simple to apply and interpret. On the negative side: i) counts are conducted during the pre-egglaying stage when attendance is most variable, ii) Least Auklet attendance may be reduced in the presence of high densities of Crested Auklets, iii) it assumes that all breeders are in attendance on talus slopes early in the mornings prior to laying, and, iv) count variability is handled by the dubious technique of arbitrarily taking a mean value of the second, third, and fourth highest counts as the total number of breeding birds.

The net movement technique is favorable because: i) it estimates actual numbers moving in and out of the talus slopes rather than static attendance, and thus provides a much more reliable indication of the total number of breeding birds, and, ii) it can be used at any stage of the breeding cycle; e.g., during incubation when attendance is more stable. On the negative side: i) a substantial banding effort is required to mark birds for net movement observations and population estimates, ii) counts are time-consuming and difficult to conduct in high density areas, iii) count variance is very high, iv) the general assumptions (see above) may not be reliable. For example, both adults may sometimes forage for chicks thereby doubling net movement estimates, and, v) interpretation of net movement estimates are not straightforward, and vary with the stage of breeding (Byrd et al. 1983).

Given all these problems associated with these census techniques, we recommend a new approach to censusing auklets based on time-lapse photography. Our data clearly indicate that: i) within-day, between-day, and between-period variability in attendance is extreme and cannot be adequately dealt with by observations over only a few days (as in the above techniques), ii) environmental perturbations add another component of variance that cannot be addressed with short-term counts, iii) attendance is least variable during late incubation and early chick-rearing, iv) Crested Auklets exhibit a markedly different seasonal pattern of attendance than Least Auklets, with peak attendance occurring during incubation and early chick-rearing.

Thus, we recommend that auklet censusing should be conducted by establishing permanently marked sites within auklet colonies where 35 mm time-lapse cameras can be mounted to photograph large plot areas (ca. 200 m^2) at regular intervals (e.g., 20 min) during a two week period in the late incubation - early chick-rearing period. Plot areas could be delineated with polypropelene rope to define plot boundaries in the photographs. Auklet counts made from these photographs could be integrated over the entire period to obtain a single measure, with a variance estimate, of auklet attendance in different years. We believe that two weeks would be adequate to deal with within-day and between-day variance, and weather effects.

There are many advantages to this approach: i) once established, data can be collected with little more effort than changing the camera film pack at appropriate intervals, ii) an index of populations can be obtained which allows for testing the significance of trends, iii) since we are counting total birds attending as an index of population size, the contribution of immatures to total counts is irrelevant, although investigators may assess this independently during the count period, iv) investigators are released from the time-consuming task of all-day counts, and may gather appropriate ancillary data on breeding success and feeding habits.

Clearly, this approach needs to be evaluated further at St. Lawrence Island and elsewhere. However, we believe it offers great potential for detecting population trends at auklet colonies. One additional approach, which we failed to undertake in 1987, would be to document by maps and photographs the total area occupied by breeding auklets at specific colonies. This would serve to monitor possible variations in breeding densities at the periphery of colonies where, in fact, population changes may be more evident or pronounced.

3.4.6 Population Trends

Given the above discussion, the limitations of our auklet censuses conducted using the Bedard technique should be evident. If we accept that the censuses conducted by Bedard (1969a), Searing (1977) and ourselves in 1987 are comparable, then it appears that i) Least Auklet densities have increased dramatically at Kongkok but declined very slightly at Owalit and, ii) Crested Auklet densities have increased dramatically at Owalit, but not at Kongkok. Overall, the densities of both species have increased since Bedard's study.

We can only speculate on the cause of this increase, if indeed it is real. If populations are limited by food, then it may be that food has become increasingly more abundant or available over the 23-year period examined. Pending assimilation of further information, there are few data with which to assess this hypothesis. Water temperatures in the northern Bering Sea showed a general warming trend in the mid-1960's, followed by a cooling trend from the late 1960's to mid-1970's, followed by another warming trend since about 1976 (Coachman et al. 1975, Springer et al. 1984). If zooplankton populations in the area of St. Lawrence Island have responded to these variations, this may have influenced breeding success of auklets over the years, but the absence of a consistent oceanographic trend does not explain the (apparent) consistent increase in auklet populations. Given the large number of other factors likely to affect zooplankton; e.g., food supplies, current movements, predation, etc., it is not likely that temperature fluctuations alone could explain the 'trend' in auklet populations.

A reduction in the amount of predation on auklets by foxes and humans may be partially responsible for increasing auklet numbers. Native trapping of foxes has taken place for many years on St. Lawrence Island, and with the arrival of modern, more efficient traps and snowmobiles in the 1960's, the population of foxes on St. Lawrence Island has been reduced (Lane Iyakitan, pers. comm.). In addition, the traditional Native method of capturing auklets in nets at their breeding sites has apparently fallen into disfavor at Kongkok, possibly because ample numbers are taken now by shooting at sea. We found numerous stone walls and blinds at both Owalit and Kongkok that were used in the past for hiding while netting birds, but these appeared not to have been used in recent years, and we observed no netting in 1987. Thus, the indirect negative effect of netting (disruption of adult attendance and chick-feeding) and direct effect (loss of breeding adults) has been reduced or eliminated since Bedard's time.

Finally, the different patterns of population increase at Kongkok and Owalit between auklet species may be due to competitive interactions and habitat differences between these sites. The habitat at Kongkok definitely favors Least Auklets, especially on the south side, because the talus is composed of a generally shallow layer of small boulders (Bedard 1969a, Searing 1977). The reverse is found on Owalit, where a deep layer of talus composed of large boulders would favor breeding by Crested Auklets (Bedard 1969a, Searing 1977). The fact that Crested Auklets did not decline in the face of a large increase in Least Auklets at Kongkok, but that Least Auklets declined when Crested Auklets increased at Owalit, supports the idea that there is assymetric interference competition between these species with Crested Auklets being superior because of their larger size and aggressive behavior (Bedard 1969a, Byrd et al. 1983, this study).

3.4.7 Auklet Diets

The diets of Least and Crested Auklets in August 1987 were similar to diets reported by Bedard (1969b) for the same time period: Least Auklets consumed almost entirely copepods, whereas Crested Auklets consumed almost entirely euphausiids. Although auklets take a greater variety of prey earlier in the breeding season, Bedard (1969b) observed in all three years (1964-1966) of his study that both auklets became nearly monophagic in late July, and maintained this trend through most of August. Based on a review of the biology of relevant zooplankton species, he suggested that zooplankton blooms in late summer result in a superabundance of these food items, leading to a predominance of the most abundant species in the diets of auklets. Subsequent investigations on Least Auklets by Searing (1977) and Springer and Roseneau (1985) in 1981 have revealed a similar pattern of monophagy during the chick-rearing period.

The species composition of diets that we observed was very similar to that reported by Bedard for Crested Auklets (i.e., predominantly *Thysanoessa* spp., with very small proportions of *Parathemisto* spp. and calenoid copepods), but was markedly different for Least Auklets. Whereas we, and other investigators (Searing 1977, Springer and Roseneau 1985), found that Least Auklets consumed predominantly *Neocalanus plumchrus*, and generally much lower proportions of *Calanus marshallae* and *N. cristatus*, Bedard reported that *C. finmarchicus* (now called *C. marshallae* in the Pacific) was the dominant calenoid copepod in diets and reported no observations of *C. plumchrus*. The remainder of prey identified by Bedard were similar in composition to those reported by all subsequent investigators.

This striking difference seems odd, especially since *C. marshallae* is most common in middle domain waters of the Bering Sea (Fig. 1.1), where it dominates the diet of Least Auklets on St. Matthew Island (Springer and Roseneau 1985). It seems unlikely that Bedard would not have seen at least a few *C. plumchrus* in three years of study, unless there has been some major change in zooplankton fauna since his time. However, the concordance in occurrence of all other species in diets between 1964 and 1987 argues against such an explanation. The simplest explanation may be that Bedard mis-identified *C. plumchrus* as *C. finmarchicus*, because as he noted (p. 1036, 1969b): "No detailed study of Calanus is available for the present study area and it is not certain that *C. finmarchicus*, *sensu stricto*, is the form present."

Like Bedard (1969b), we noted on several occasions a marked segregation in offshore feeding areas used by Least and Crested Auklets (Chapter 4), and where each species occurred they were grouped in large, high density aggregations. These birds may have been associated with dense swarms of zooplankton which were concentrated along the edge of fronts, or near the thermocline, in Anadyr water to the northwest of St. Lawrence Island. Similarly, dense feeding flocks were often observed nearshore when wind events results in nearshore upwelling and concentration of prey (Bedard 1969b, Springer and Roseneau 1985). The segregation of auklets suggests that prey were segregated also, and may explain why diet composition of individual birds was often totally dominated by only one species.

There is no indication that auklets had unusual difficulty in obtaining food in 1987. Meal composition was similar to that of previous years, chick meal loads were apparently normal, breeding success was quite high, and chick growth rates were average or better than in recent years. On the other hand, adult body weights during incubation were in the range described by Bedard (1969b) in 1966 as being possibly indicative of a 'poor' year for food. However, adult weights over the whole season were generally lower than those observed by Bedard, so that the lower weights we observed may only represent a long-term decline in average body mass.

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Chapter 4 - Foraging Areas and Time-dependent Habitat Use by Seabirds near the west end of St. Lawrence Island

4.1. Introduction

Previous surveys in Alaskan waters have located concentrations of foraging seabirds (e.g., Forsell and Gould 1981, Hunt et al. 1981, Gould et al. 1982), but there has been little replication of transects involved in this work. The persistence and recurrence of feeding "hot spots" has in most instances not been determined, and resource managers are therefore liable to make decisions without the benefit of realistic information on seabird habitat requirements. Primary objectives of the shipboard observations near St. Lawrence Island in 1987 were: (1) to identify major foraging areas used by seabirds breeding in colonies on the west end of the island, and (2) to determine whether offshore feeding aggregations are persistent and predictable. The present analysis concerns the focal species of colony studies conducted at Kongkok Bay: Common and Thick-billed Murres, Crested and Least Auklets, and Black-legged Kittiwakes.

4.2. Methods

Surveys were conducted aboard the M/V TIGLAX between 18 August and 3 September near colonies on the west end of St. Lawrence Island. Three transects were chosen for replication. One (WSW transect) was a polygonal cruise track that began and ended about 2 km offshore from the Kongkok colonies (63°22' N, 171°49' W) (Fig. 4.1). A second transect (NNW line) began about mid-way between Kongkok Bay and Gambell (63°32' N, 172°00' W) and proceeded across the Anadyr Strait to 64°00' N, 172°20' W. The third transect (NNE line) began at the northwest cape of St. Lawrence Island near Gambell (63°50' N, 171°45' W) and proceeded into the Chirikof Basin, ending near the international dateline at 64°43' N, 170°45' W. Nine replicates of transect 1 (WSW) were completed between 19 and 27 August, two replicates of transect 2 (NNW) were completed on 22 August and 26 August, and five replicates of transect 3 (NNE) were completed between 23 August and 1 September. Specific dates and times of these surveys are given in Tables 4.1-4.3.

Birds were counted continuously while the ship was underway. The census area consisted of a moving 300 x 300 m zone extending forward and abeam of the

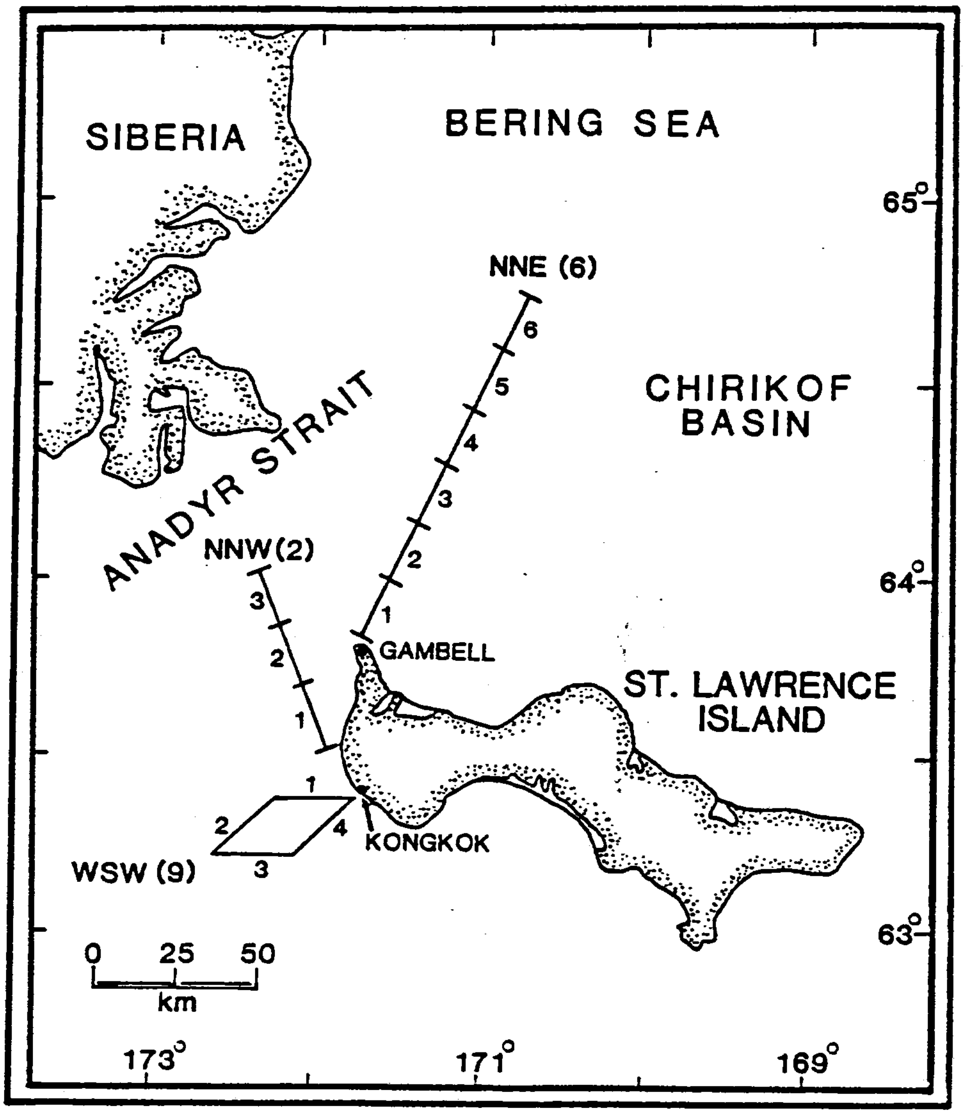

Figure 4.1. Orientation of transects used for shipboard surveys of seabirds near St. Lawrence Island in August-September, 1987. Tracks are numbered sequentially along the transect lines, and the number of replicates completed for each transect is indicated in parentheses.

vessel. Ship speed was maintained at approximately 10 knots. All birds were identified to species except murres, which generally could not be distinguished as either Thick-billed or Common Murres. The behavior (sitting on the water or flying) of all birds was recorded, as were the flight directions of birds observed in the air. Here we deal exclusively with counts of birds on the water in the case of auklets and murres, but include all data (sitting or flying) for kittiwakes. The reason for this is that alcid species tend to spend their time either swimming on the surface or diving when they are exploiting a feeding area (as opposed to moving between areas), whereas kittiwakes are known to engage in both surface activity and aerial searching behavior while foraging. We were primarily interested in documenting the distributional patterns of actively foraging birds.

The unit of observation used in the following analyses is the number of birds observed during each 10-minute time interval. In all, 473 10-minute counts were obtained during the study (excluding non-replicated cruise tracks). To facilitate the presentation and analysis of spatial patterns in bird distribution, we divided the three primary transect lines into a number of "tracks" defined by the turning points of the polygon (WSW transect) or the locations of hydrographic stations (NNW and NNE lines) (Fig. 1). Generally, seven 10-minute counts per track were completed during each replicate of the WSW transect line, and six 10-minute counts per track were conducted during each replicate of the NNW and NNE lines. Excluded from the analysis are counts cut short by the arrival of the ship on station or the presence of intermittent fog that reduced visibility to less than 300 m.

Analysis of the variation in bird densities per 10-minute count was performed using the SAS package of statistical programs (SAS Inc. 1985). The survey design described in Figure 4.1 and Tables 4.1-4.3 permitted us to assess the variability attributable to: (a) differences among major survey areas (SSW, NNW, and NNE transects), (b) differences among tracks within transect areas, (c) differences among days for a given track or transect area, and (d) temporal differences among replicates completed within the same day (WSW transect area only). Areas, tracks, days, hours, and interactions were all treated as random (as opposed to fixed) effects, and SAS procedures NESTED and VARCOMP were used to estimate the components of variance associated with

Table 4.1. Dates and times (Alaska Daylight Time) for replicated cruise tracks off Kongkok Bay (WSW transect), St. Lawrence Island, 1987.

	Date	Time
Day 1		
Replicate 1	19 August	0815 - 1335
Replicate 2	19 August	1340 - 1845
Replicate 3	19 August	1855 - 2350
Day 2		
Replicate 4	21 August	0836 - 1440
Replicate 5	21 August	1446 - 2035
Day 3		
Replicate 6	22 August	1720 - 2251
Day 4		
Replicate 7	26 August	0818 - 1316
Replicate 8	26 August	1323 - 1731
Day 5		
Replicate 9	27 August	1735 - 2244

Table 4.2. Dates and times (Alaska Daylight Time) for replicated NNW line in Anadyr Strait, St. Lawrence Island, 1987.

	Date	Time
Replicate 1	22 August	0848 - 1415
Replicate 2	26 August	1735 - 2220

Table 4.3. Dates and times (Alaska Daylight Time) for replicated NNE line, St. Lawrence Island, 1987.

	Date	Time
Replicate 1	23 August	1140 - 2146
Replicate 2	28 August	0855 - 1616
Replicate 3	29 August	0912 - 1948
Replicate 4	31 August	0911 - 1845
Replicate 5	1 September	0931 - 2024

each crossed or nested effect. We also report the significance levels of non-zero components of variance (from F-ratios of their mean squares), but we caution that such tests are inexact and possibly unreliable because of: (a) unbalanced cell frequencies in model II ANOVAs (Sokal and Rohlf 1981), and (b) the likely failure of transect data to meet the assumptions of normality and independence. In any case, our estimated variance components are useful for designing future surveys and for interpreting the results of past and future surveys that do not incorporate replication.

4.3. Results

The distributions of foraging auklets were extremely patchy, with few birds encountered for hours at a stretch, followed by periods when up to several hundred birds were seen per 10-minute count. Foraging concentrations of Least and Crested Auklets were largely non-overlapping. The only sizeable aggregations of either species occurring in the WSW transect area were of birds staging on the water immediately offshore from breeding colonies or flying in a north or northwesterly direction toward feeding grounds in Anadyr Strait or the Chirikof Basin. We found feeding concentrations of auklets primarily along the NNE line, and mean densities per track were correspondingly high in that area (Figs. 4.2. and 4.3). The considerable differences among tracks in mean auklet density along the NNE line are indicative of the clumped dispersion of these birds encountered on each of the several days we spent in the area.

Murres reached their highest densities along the NNE line, but they also occurred at moderate densities throughout the area southwest of large breeding colonies in Kongkok Bay and vicinity (Fig. 4.4). In contrast to both auklets and murres, Black-legged Kittiwakes occurred at relatively low densities throughout the study area, but appeared to be more abundant off Kongkok Bay than farther north (Fig. 4.5).

Using tracks within the transect lines as our spatial scale of resolution, we found that feeding concentrations typically were not located in the same places on different days. High densities (> 75 birds/10-minute count) of Least Auklets, for example, were found in most tracks along the NNE line at

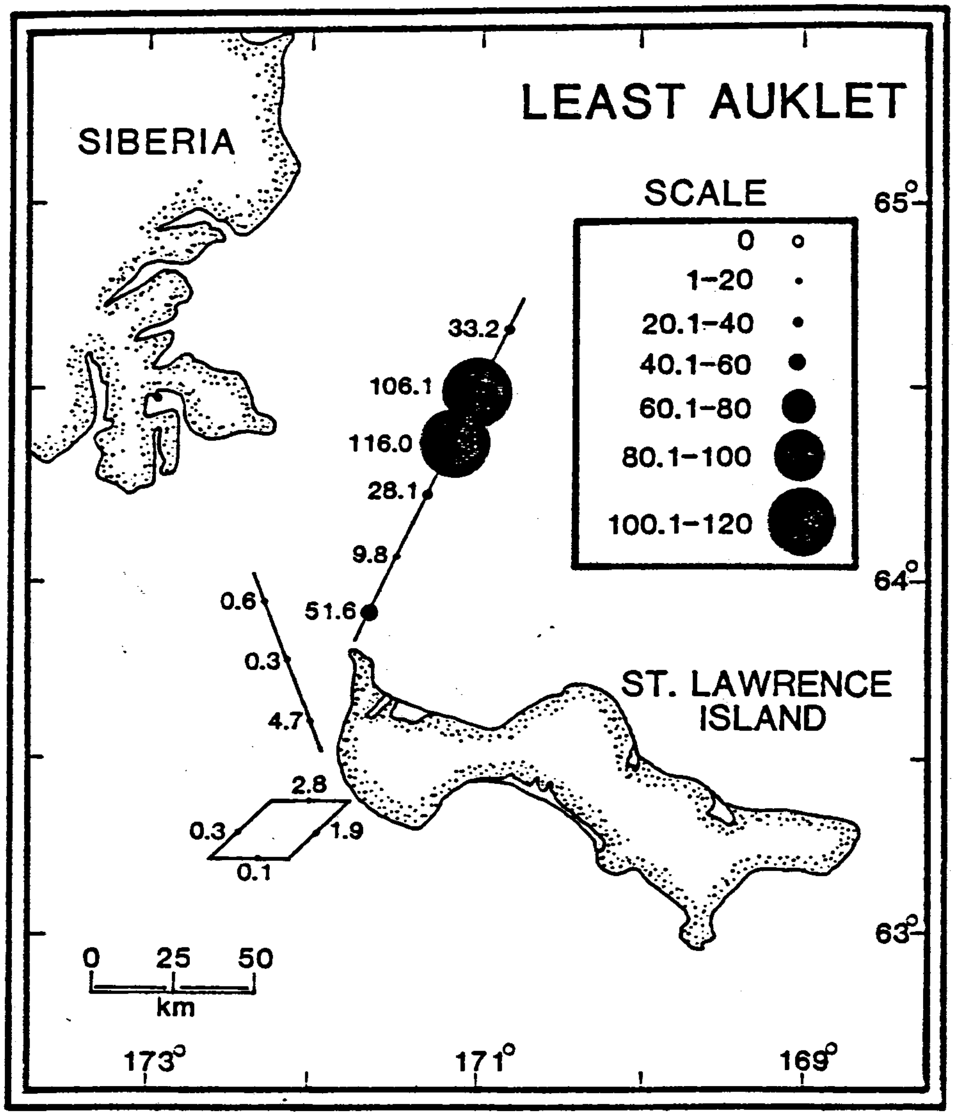

Figure 4.2. Overall mean densities within tracks (birds/10-minute count) of Least Auklets in WSW, NNW, and NNE transect areas from 18 August - 1 September, 1987.

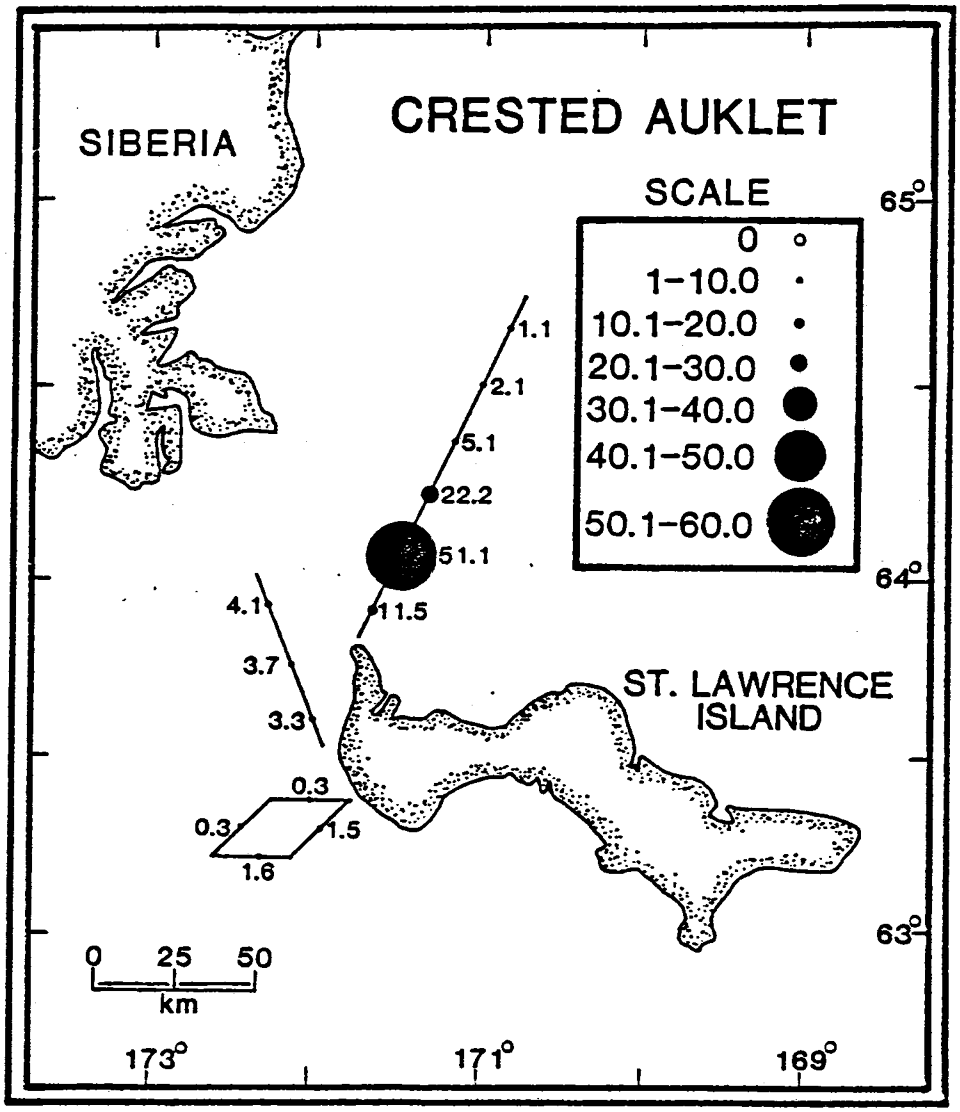

Figure 4.3. Overall mean densities within tracks (birds/10-minute count) of Crested Auklets in WSW, NNW, and NNE transect areas from 18 August - 1 September, 1987.

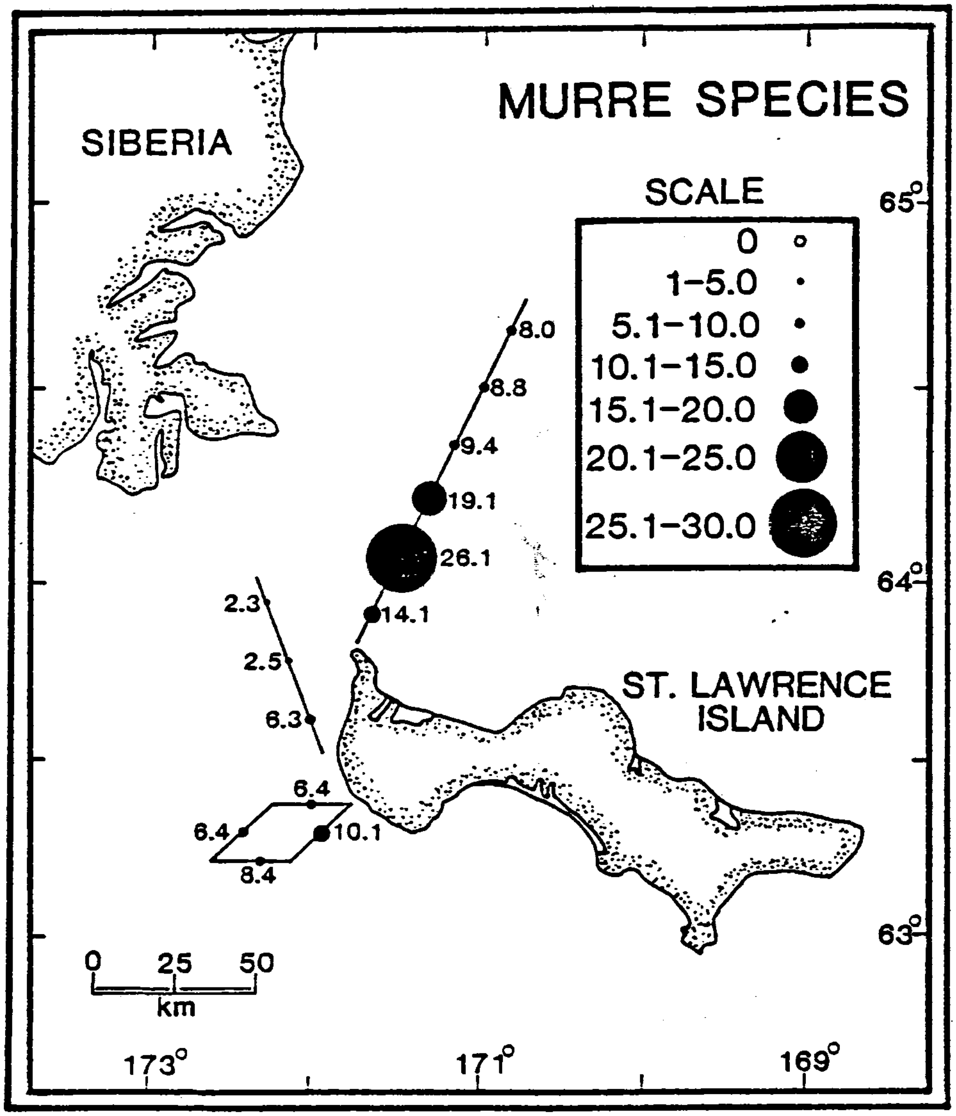

Figure 4.4. Overall mean densities within tracks (birds/10-minute count) of murre species in WSW, NNW, and NNE transect areas from 18 August - 1 September, 1987.

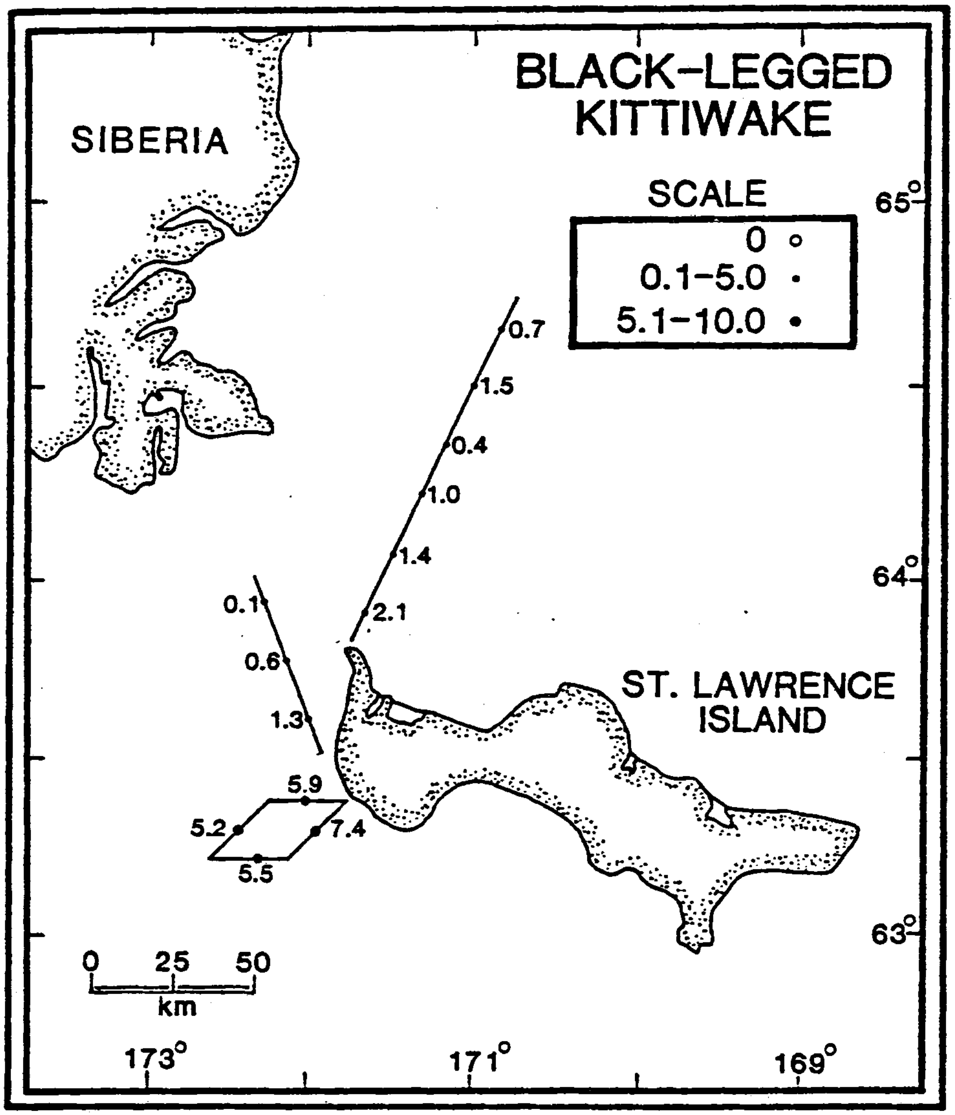

Figure 4.5. Overall mean densities within tracks (birds/10-minute count) of Black-legged Kittiwakes in WSW, NNW, and NNE transect areas from 18 August - 1 September, 1987.

least once, but densities in the same tracks were lower at other times by an order of magnitude (Fig. 4.6). Similar variability is evident in the data for Crested Auklets and murres (Figs. 4.7 and 4.8). Black-legged Kittiwake densities appeared to have smaller temporal fluctuations, at least in the NNE transect area (Fig. 4.9).

In a nested analysis of variance (days surveyed nested within WSW, NNW, and NNE transect areas), the seemingly large differences among areas illustrated in Figures 4.6–4.9 were found to be significant only for the Black-legged Kittiwake and, marginally, for the Least Auklet (Table 4.4). That is, after taking daily variation into account, there was little or no basis for inferring area differences in densities of murres or auklets. For comparison, we ran single classification ANOVAs (testing for area effects while ignoring temporal variation) and found highly significant differences among areas for all four species ($P < 0.0001$ in all cases).

Within transects, area differences can be evaluated with reference to tracks. Days were crossed (not nested) with tracks, because all tracks were surveyed on the same days. The interaction between track and day contributed substantially to the variances observed in NNE and NNW transect areas (Tables 4.5 and 4.6), which implies that any conclusions about spatial differences along the survey lines, however conspicuous they may appear by inspection of Figures 4.2–4.5, would be premature. The interaction of track and day reflects essentially the same pattern as the previous (nested) design—i.e., the density observed in a given sample area (track), depended greatly on the particular day on which it was surveyed.

Data from the WSW transect area include 3 days on which the entire cruise track was repeated during morning and afternoon time periods (Table 4.1). This enabled a crude assessment of diurnal variation in pelagic habitat use by two species. The component of variance among time periods within days was small but detectable in kittiwakes (6%) and relatively large in murres (22%) (Table 4.7). Auklet densities in the WSW transect area were probably too low to provide meaningful contrasts within days during this short-term study.

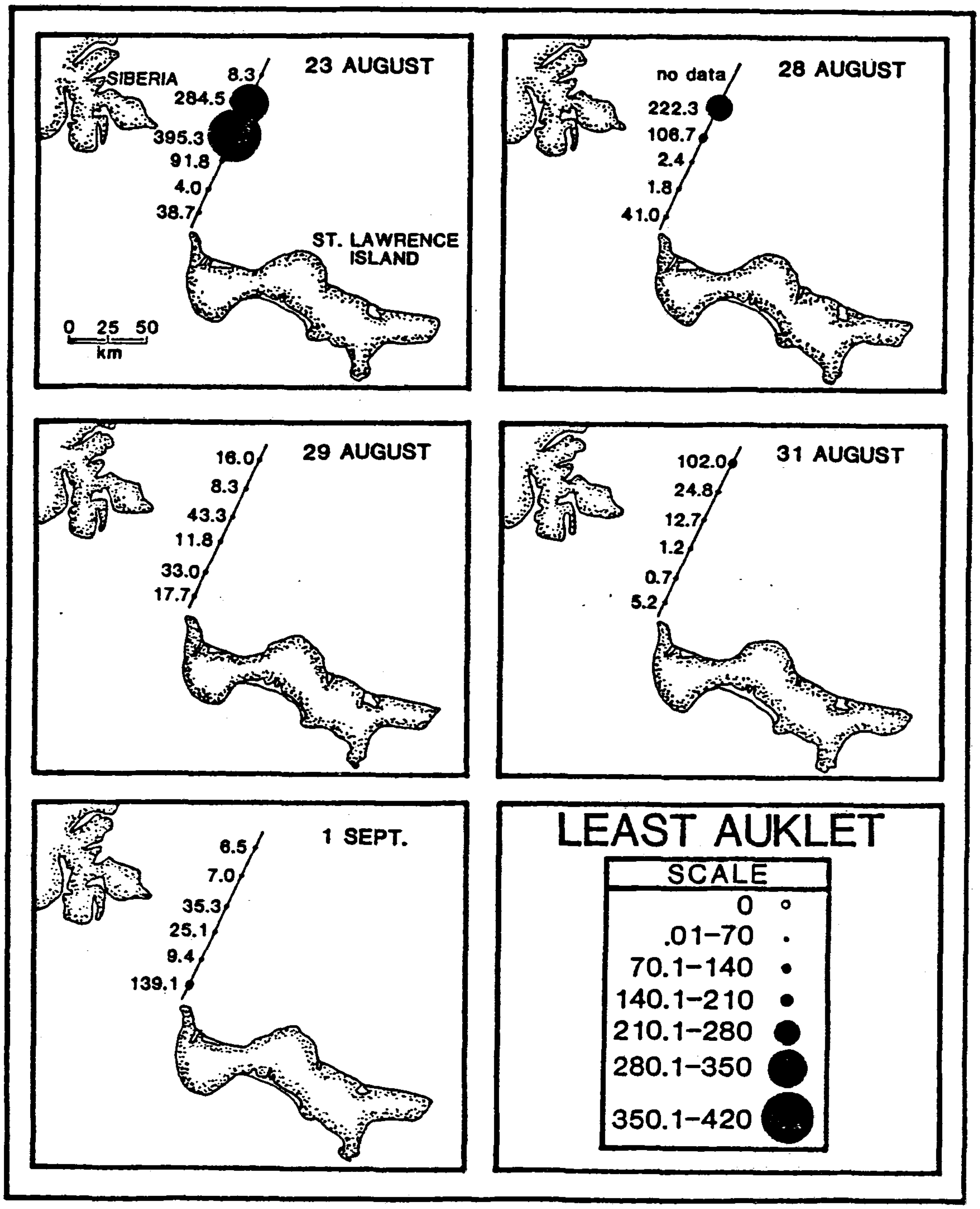

Figure 4.6. Mean densities of Least Auklets (birds/10-minute count) within tracks along the NNE transect line on five days in August and September, 1987.

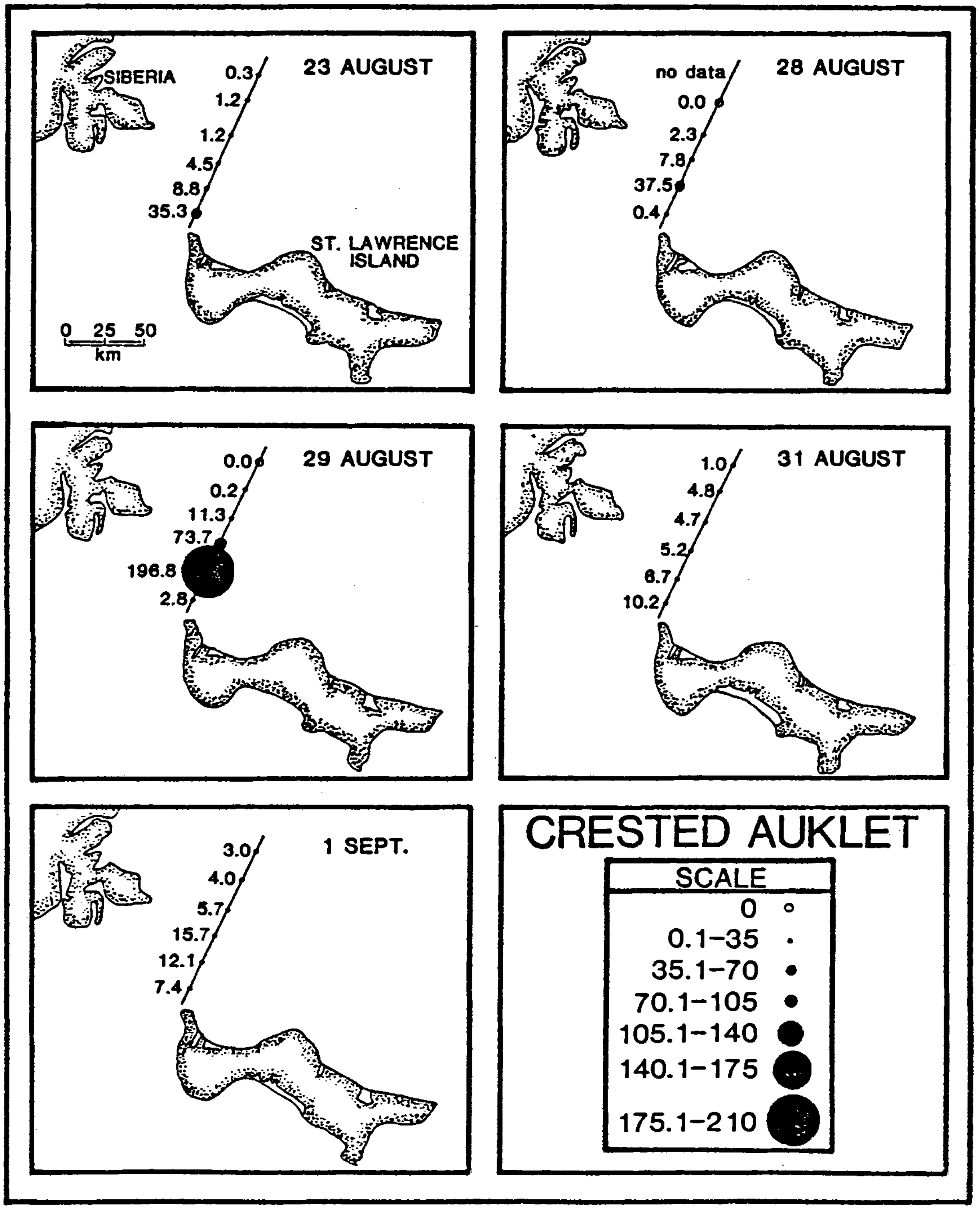

Figure 4.7. Mean densities of Crested Auklets (birds/10-minute count) within tracks along the NNE transect line on five days in August and September, 1987.

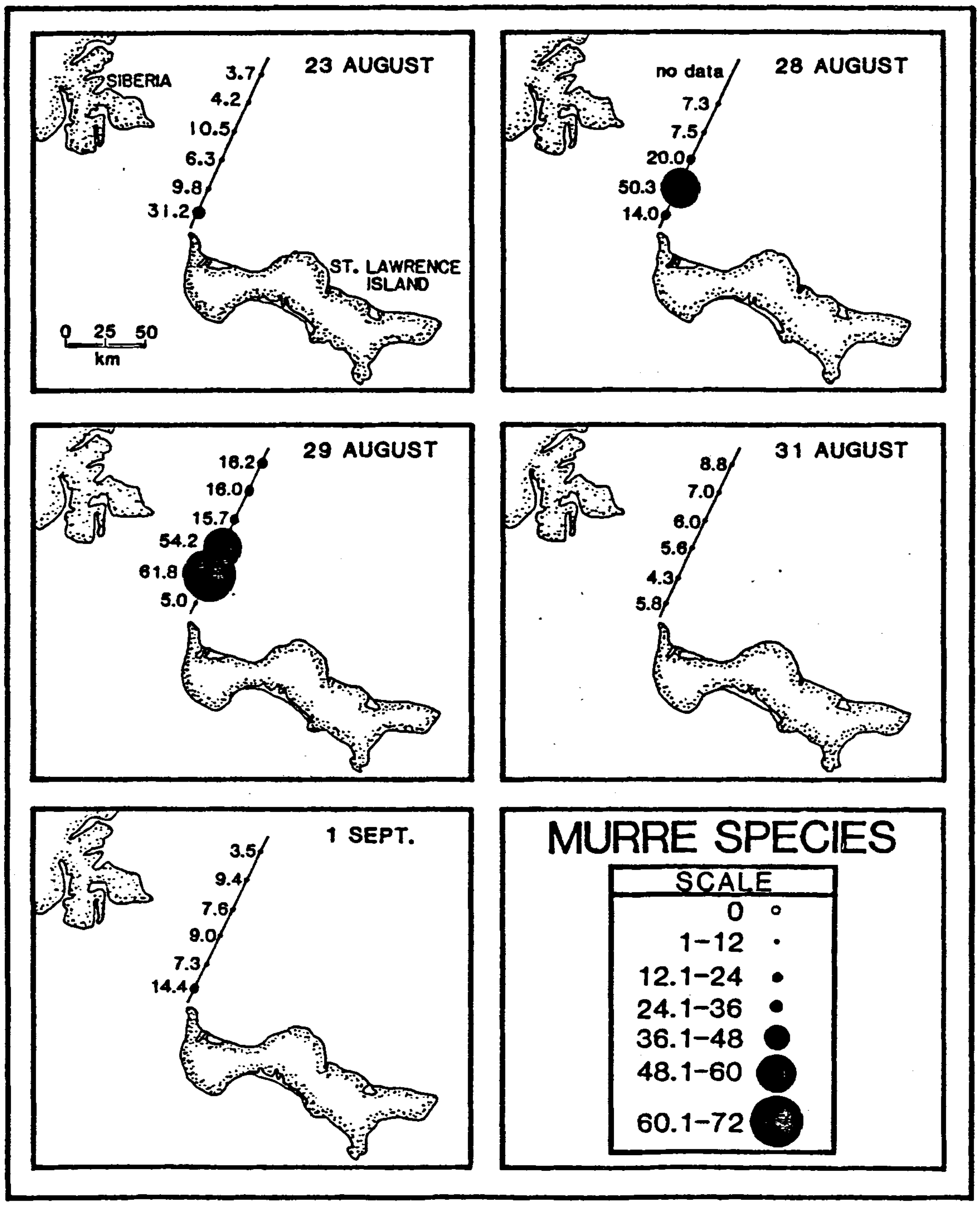

Figure 4.8. Mean densities of murre species (birds/10-minute count) within tracks along the NNE transect line on five days in August and September, 1987.

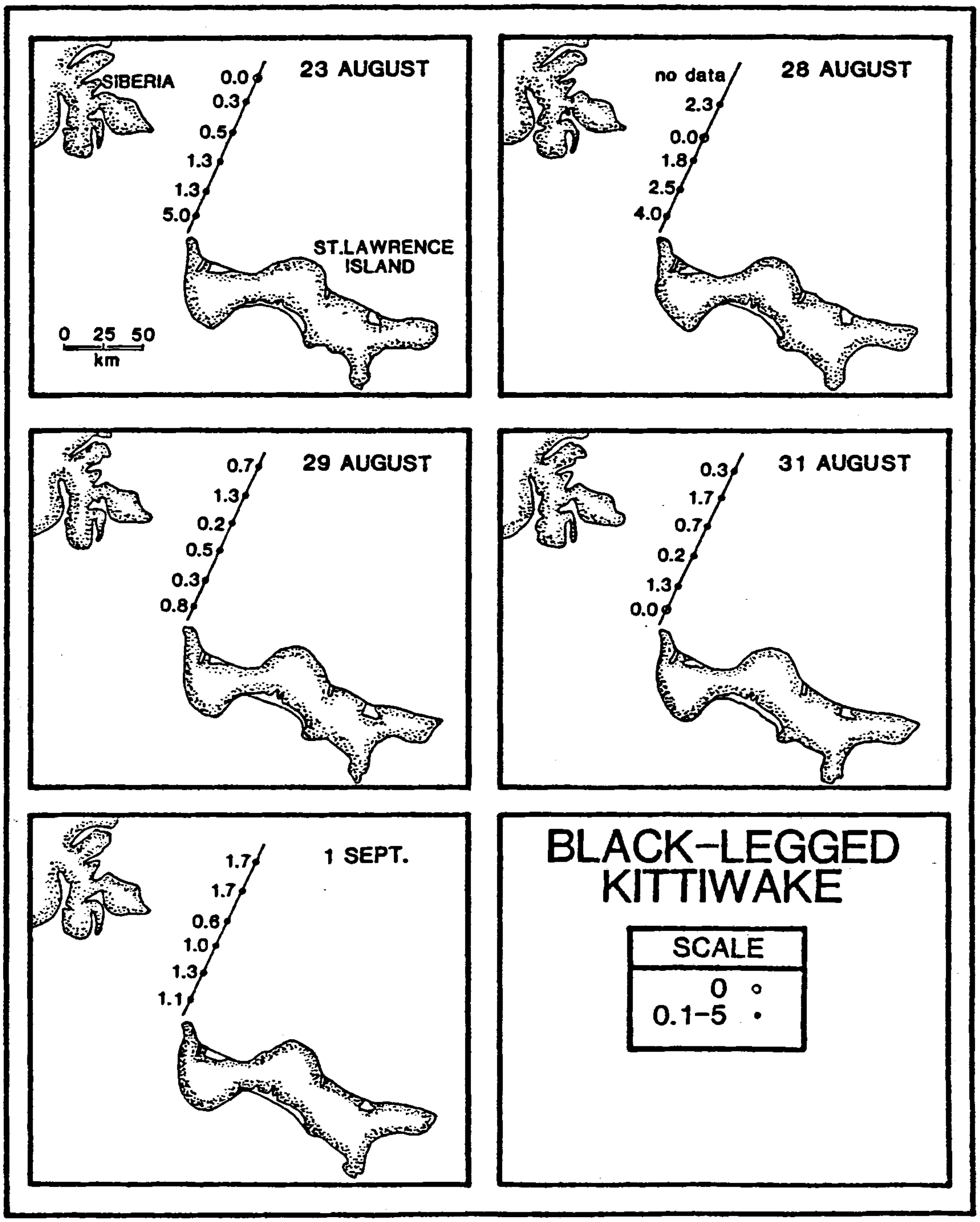

Figure 4.9. Mean densities of Black-legged Kittiwakes (birds/10-minute count) within tracks along the NNE transect line on five days in August and September, 1987.

Table 4.4. Components of variance in bird densities recorded during 10-minute counts in three transect areas (WSW, NNW, NNE) near St. Lawrence Island, 1987.

	Black-legged Kitiwake		Murre spp.		Crested Auklet		Least Auklet	
Source of variation	% of total variation	F-test[a]	% of total variation	F-test[a]	% of total variation	F-test[a]	% of total variation	F-test[a]
Among areas	38.9	**	3.6	ns	3.3	ns	13.7	*
Among days, within areas	8.4	**	7.5	**	4.6	**	9.2	**
Among 10-min. counts (Error)	52.7	--	88.9	--	92.1	--	77.1	--

[a] F-tests and significance levels are only approximate (see text). * $P < 0.05$; ** $P < 0.01$.

Table 4.5. Components of variance in bird densities recorded during 10-minute counts in the NNE transect area, St. Lawrence Island, 1987.

	Black-legged Kitiwake		Murre spp.		Crested Auklet		Least Auklet	
Source of variation	% of total variation	F-test[a]	% of total variation	F-test[a]	% of total variation	F-test[a]	% of total variation	F-test[a]
Among tracks	5.8	ns	1.6	ns	2.5	ns	2.1	ns
Among days	3.6	ns	5.8	ns	2.6	ns	5.7	ns
Track x day interaction	24.1	**	6.2	ns	12.2	*	27.9	**
Among 10-min. counts (Error)	66.6	--	86.4	--	82.6	--	64.3	--

[a] F-tests and significance levels are only approximate (see text). * $P < 0.05$; ** $P < 0.01$.

Table 4.6. Components of variance in bird densities recorded during 10-minute counts in the NNW transect area, St. Lawrence Island, 1987.

	Black-legged Kitiwake		Murre spp.		Crested Auklet		Least Auklet	
Source of variation	% of total variation	F-test[a]	% of total variation	F-test[a]	% of total variation	F-test[a]	% of total variation	F-test[a]
Among tracks	0.0	--	0.0	--	0.0	--	42.7	**
Among days	0.0	--	10.5	ns	0.0	--	0.0	--
Track x day interaction	46.5	**	33.9	**	0.0	--	0.0	--
Among 10-min. counts (Error)	53.5	--	55.6	--	100.0	--	57.3	--

[a] F-tests and significance levels are only approximate (see text). * $P < 0.05$; ** $P < 0.01$.

Table 4.7. Components of variance in bird densities recorded during 10-minute counts in the WSW transect area, St. Lawrence Island, 1987. [a]

	Black-legged Kitiwake		Murre spp.		Crested Auklet		Least Auklet	
Source of variation	% of total variation	F-test[b]	% of total variation	F-test[b]	% of total variation	F-test[b]	% of total variation	F-test[b]
Among tracks	0.6	ns	0.0	--	3.5	ns	1.4	ns
Among days	22.6	**	0.0	--	0.0	--	0.8	ns
Track x day interaction	0.7	ns	22.0	**	2.3	--	0.3	ns
Among hours, within days	5.8	*	21.7	**	0.4	ns	0.9	ns
Among 10-min. counts (Error)	70.3	--	56.3	--	93.8	--	96.5	--

[a] Included are data from the first two replicates (morning and mid-day) on 19 August, 21 August, and 26 August (see Table 4.1).

[b] F-tests and significance levels are only approximate (see text). * $P < 0.05$; ** $P < 0.01$.

4.4. Discussion

Results of this study indicate the importance of considering short-term temporal variation in attempting to assess seabird use of offshore habitats. The conclusions reached in a pelagic census may depend greatly on the number of days a particular region is surveyed, and possibly also on the times of day the surveys are conducted. While the indication so far is that auklets, and possibly also murres, that breed in colonies on the west end of St. Lawrence Island rely on foraging areas located north of Gambell, it is disconcerting that two weeks' effort to census birds by ship was inadequate to show conclusively any differences between potential feeding areas because of temporal variation within areas.

Most data on at-sea densities of birds in Alaska have, to date, been gathered during relatively brief, opportunistic surveys. Such information could conceivably result in ill-informed decisions by the unwary user. We suggest that where important land management decisions are concerned; for example, the protection of specific areas on the continental shelf for wildlife conservation, surveys should first be designed to assess temporal variation. Obviously, such surveys should investigate components that we could not address in this short-term study, including seasonal and annual changes in habitat use.

By far the largest component of variation in all our analyses of temporal and spatial effects was the error term, i.e., variation among the 10-minute counts. We recorded bird sightings continuously, and the choice of a 10-minute counting period as the basis for analysis, while following recent convention (Tasker et al. 1984), is arbitrary. It is possible that a more appropriate interval could be found for a given species that would optimize statistical analyses relative to a species' typical pattern of dispersion. Such questions depend on the scale of ecological phenomena and hypothesis testing (Schneider and Duffy 1985 and Schneider and Piatt 1986). We believe that further research in this area is desirable from a practical, as well as theoretical, standpoint.

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Chapter 5. Conclusions and Recommendations

5.1 Introduction

The objectives of our study on St. Lawrence Island were to i) collect baseline information on the biology of dominant seabirds, ii) establish and document permanent study plots which may be monitored again in the future, iii) assess whether populations or relevant breeding parameters have changed since previous studies, and iv) investigate new methods for monitoring auklet populations.

Although we achieved most of our objectives, much work remains to be done on St. Lawrence Island before we can be confident that future population fluctuations will be detectable. In this chapter, we present a few of our major findings that relate to population monitoring, and make recommendations for future consideration. Our conclusions are presented in point form and with little qualification. The reader is encouraged to read relevant sections in other chapters about the limitations of our conclusions and the basis of our recommendations.

5.2. Populations

5.2.1. Conclusions

1) Based on rather limited comparisons, it appears that populations of all study species have increased at Kongkok since the last study of seabirds there (murres 20%, kittiwakes 87%, Least Auklets 8%, Crested Auklets 44%).

2) Current methods for assessing population changes in cliff-nesting species are adequate, but more study plots need to be added to the 16 plots we documented, especially on the north side of St. Lawrence Island. Plots must be accessible and countable from land.

3) Current methods for assessing population changes in crevice-nesting species are inadequate because they cannot deal with the enormous daily and seasonal variations in attendance. Time-lapse photography offers great promise as a technique for monitoring auklet populations.

5.2.2. Recommendations

1) Future investigators should expand the number of study plots for cliff-nesting species, while they monitor the plots we established. All new study plots should be fully documented, marked, and described in reports for future investigators. Plot counts without complete documentation made publically available are virtually useless.

2) Pending further refinement of time-lapse monitoring techniques for auklets, future studies on St. Lawrence should undertake the establishment of permanent time-lapse study plots at Kongkok and at one or more large colonies on the north coast of St. Lawrence Island.

5.3 Productivity

5.3.1 Conclusions

1) Pelagic Cormorants, Common Murres, and Thick-billed Murres exhibited average, or above average, breeding success at Kongkok in 1987. Black-legged Kittiwakes exhibited near-total reproductive failure for unexplained reasons.

2) Crested and Least Auklets exhibited high levels of breeding success after the effects of observer disturbance were taken into account. Chick growth rates were average for these species. Predation by microtine rodents and foxes was a significant source of chick mortality.

5.3.2 Recommendations

1) Baseline data are now available on the breeding biology of all species studied in 1987 (except cormorants) for St. Lawrence Island. In the future, less intensive Type II monitoring with nest checks during chick-rearing will be adequate to obtain an index of productivity on cliff-nesting species. However, we still know very little about inter-annual variations in breeding success of auklets on St. Lawrence Island or elsewhere. A multi-year study of auklet breeding biology is essential before we can begin to say what is 'normal' for auklets.

2) The causes of kittiwake breeding failure need to be studied in more detail, if not at St. Lawrence Island, then at other colonies where failures are common. This will require intensive, long-term ecological, behavioral, and pelagic studies. The widespread and repeated failure of kittiwakes throughout the Bering Sea needs to be explained if we are to have any hope of assessing any kittiwake population fluctuations due to oil development or pollution.

3) The breeding biology of Least and Crested Auklets is still poorly known. To establish the 'normal' variability in auklet breeding success, more studies will have to be conducted over a wider geographic range. Our study indicates that least disturbed sites yield a better estimate of success than intensively studied sites. Thus, while more in-depth studies would be of interest, minimal disturbance and hence minimal effort studies would provide the information we require as long as they are standardized.

5.4 Feeding Habits

5.4.1 Conclusions

1) Diets of all species studied were apparently normal, and there was no evidence of problems in obtaining food. Kittiwakes were the major exception to this conclusion, but we obtained none of these birds for diet analysis owing to their very low densities in the study area.

2) We found feeding concentrations of murres and auklets primarily north of Gambell in the Anadyr Strait or western Chirikof Basin. Kittiwakes were dispersed widely over the study area.

3) Temporal variability of feeding aggregations was so great that conclusions about spatial patterns of habitat use are tenuous. Our study indicates that more detailed and longer-term surveys are required to measure temporal and spatial persistence of feeding aggregations.

5.4.2 Recommendations

1) Because seabirds are most vulnerable to oil pollution while they are at sea, pelagic studies should receive at least as much emphasis as colony work in the MMS environmental studies program. Although much can be learned by "piggy-backing" bird observations on cruises directed toward other objectives, dedicated vessel surveys are required to adequately measure seabird movements, habitat use, and spatial relationships between seabirds and their prey.

2) In light of the continuing kittiwake problem and point 1) above, an effort should be directed at studying kittiwake feeding behavior at sea in relation to prey aggregations.

3) Development and employment of alternate techniques for monitoring seabird behavior at sea (e.g., satellite telemetry) should be encouraged for the future. 'High-tech' methods may be able to address many of the same questions as shipboard or aerial surveys, but at a much lower cost and with greater resolution.

Chapter 6 - A Seabird Monitoring Protocol for the Bering and Chukchi Seas

Page

6.1. General Considerations and Rationale for a Seabird Monitoring Program in the Bering and Chukchi Seas

6.1.1. Introductory Remarks

In deciding whether or how to implement a seabird monitoring program in Alaska, it is important to be clear about what the activity can reasonably accomplish. A general concept that is frequently entertained is the possibility that seabirds can serve as useful indicators of the "health" of marine ecosystems (e.g., NOAA 1982). The idea is that because seabirds are top level consumers which sample large tracts of the ocean environment, their behavior and population parameters should integrate and reflect a broad range of conditions and processes in the sea. Seabirds are therefore seen to offer a relatively inexpensive alternative to monitoring fish, crustaceans, or other organisms that are relatively difficult to observe.

While the concept of seabirds as marine indicator species has not been critically evaluated or tested in practice, there is no doubt that seabirds are themselves a valued form of marine life which the public expects to be protected. It is therefore usually considered appropriate in the context of OCS development to monitor seabird populations for their own sake. Here again, it is best not to overstate the bounds of what can be achieved. To show how the size of a given population of vertebrates changes over time is reasonably straightforward. However, to ask also about the specific causes of such changes is to pose what is arguably the most comprehensive problem with which ecologists are concerned: the regulation of animal numbers. It is unrealistic to expect that a broad, yet affordable, program can be designed which will simultaneously track population changes and reveal the causes of those changes. The latter objective is the province of intensive, long-term population studies, and even among the best of those, the success rate cannot be considered particularly high.

6.1.2. The Four Levels of Sophistication in Population Monitoring

Assuming for the purpose of this discussion that our primary objective is to track population sizes over time, it is useful to consider each of the following questions: (1) If a change in the numbers or activity of birds on colonies occurs between two sampling periods, will we detect it with an acceptable degree of probability and precision? (2) If we detect a change in numbers or activity of birds on colonies, does that really reflect a change in the population of birds alive? (3) Of what magnitude and duration does a trend have to be before we would conclude that it is outside of the expected range of behavior for a population responding normally to natural variation in its environment? (4) If a trend is found to be unexpectedly steep or persistent, how will we establish the specific cause or causes contributing to it?

The answer to the first question entails a host of statistical considerations involved in sampling design. Put simply, one is required to make decisions about where to sample, when to sample, and how intensively to sample, and those decisions affect the probability of detecting a given magnitude of change in the parameter being measured. Temporal factors affecting population counts such as weather, breeding chronology, day-to-day variation, and diel patterns of colony attendance are all potentially important and are fairly well understood in some species. On the other hand, spatial variability within and between colonies, and its implications for sampling design, remain little understood and largely ignored. In Alaska, field efforts and discussions of seabird population monitoring have so far been largely stuck at the level of question 1, or have jumped ahead to conclusions about trends and causation before such basic issues of statistical confidence have been resolved.

Question 2 recognizes that although our sampling scheme may have the power to detect small annual differences in apparent population size, even large differences must be interpreted cautiously. Generally, we do not measure actual population size in seabird monitoring, but instead we measure the level of some kind of activity (e.g., nest site attendance) which we hope is strongly correlated with the number of birds comprising the colony. There are, however, factors that tend to weaken this correlation. For instance, Gaston and Nettleship (1982) noted that time spent foraging, and therefore counts of birds at colonies, may be determined principally by annual and seasonal variation in the birds' food supply. Thus, census results are partly a function of environmental conditions and behavior prevailing at the time the counts are made. The problem can be phrased in terms of two competing hypotheses to explain any apparent difference in colony size between years. The first hypothesis has several alternatives, or sub-hypotheses, as follows.

Observation: Mean plot counts during the census period differ between two years.

H_1: The population of birds alive was unchanged, but fewer birds were present at the colony during the census counts in one year.

H_{1a}: Breeding success was poor; some birds failed and left the colony before or during the census.

H_{1b}: Time budgets differed between years; birds spent less time at their nest sites in one year than the other.

H_{1c}: Fractions of the population (e.g., prebreeding age groups) stayed away from the colony altogether in one year.

H_{1d}: Fractions of the population emigrated to other colonies between sampling periods.

H_2: The population of birds alive actually changed between sampling periods.

We must have some basis for rejecting hypotheses 1a - 1d before we can confidently accept hypothesis 2. Unfortunately, the studies required to reject H_{1a} - H_{1d} are beyond the scope of a monitoring program as it is usually envisaged, and in some instances (especially H_{1c} and H_{1d}) beyond the scope of all but the most thorough of population studies.

One way around the dilemma posed by question 2 is to reserve judgment about population changes until a trend can be demonstrated in a series of annual counts. The longer and more consistent the trend, the more confident we are that it is really population change we are seeing. However, since the purpose of monitoring populations (aside from the inherent ecological interest of basic population dynamics) is to detect "unnatural" (anthropogenic) changes, we are next faced with the problem (question 3) of deciding when a trend has gone beyond what could be expected under natural conditions. There are two ways to establish these standards. The first is to conduct empirical studies over a long period of time. Given the long generation times of seabirds, a minimum study duration of 50-100 years is not an unreasonable requirement. The second way is to model the populations of interest mathematically and look at simulated population trajectories over time. Such a modelling exercise would incorporate the effects on population growth of variability in birth and death rates. The objective would be to predict the frequency of trends of a given duration and magnitude, given realistic estimates of means and annual variation in reproduction and survival. Because of the uncertainty of continued funding for seabird population monitoring over the next 100 years, and the need for usable information at the present time, we favor this second approach.

Finally, we suggest that the answer to question 4 (causation) will be the most difficult of all to obtain. Two methods of inquiry are accepted in the biological sciences to investigate cause and effect relationships. The first is an experimental approach in which factors are isolated and manipulated systematically, with suitable controls, to reveal their effects through a process of deductive reasoning. For a system as large and open as a seabird colony, and a question as comprehensive as the regulation of population size, this is obviously a difficult proposition. Lesser experiments, also difficult, might demonstrate some effects on bird behavior or physiology of various conditions associated with oil and gas development, but to extrapolate such results to the level of population dynamics would inevitably involve a number of untested assumptions.

The comparative approach is a second, largely inductive, method of assessing cause and effect relationships. Properly executed, this approach may permit at least a partial softening of our earlier statement that a simple monitoring program cannot reveal both the pattern and causes of change in population parameters. To illustrate the point, we offer the example of the widespread breeding failure observed in Black-legged Kittiwakes during recent years. One suggestion as to the cause of this failure in the southern Bering Sea is stock depletion of walleye pollock (Theragra chalcogramma) by commercial fisheries, resulting in reduced food availability to kittiwakes (Lloyd 1985). Though seemingly attractive in a limited regional context, this hypothesis suffers when we take a broader geographical perspective. We find essentially the same pattern of reproductive failure at kittiwake colonies throughout Alaska (Hatch 1987), including areas with no pollock harvest or other fisheries likely to have an effect on kittiwakes. Thus, the evidence suggests a different and more general explanation is needed. This type of reasoning will rarely lead to affirmative statements about cause, but it may allow us to reject one or more possibilities if there is a poor match-up, spatially, between purported causes and effects.

A monitoring program in which the effort is broadly distributed geographically is also advantageous because the local decline of a species, even if it is known to be caused by industrial activity, may be acceptable if the species is known to be secure throughout the majority of its range. For these reasons, we favor a seabird monitoring program in which many dispersed colonies are visited at frequent intervals, even at the expense of greater detail in the data obtained during each visit.

6.1.3. Choice of Parameters to Monitor

In principal, any of a large number of variables could be measured at intervals to reveal the effects on seabird populations of natural variability and human activities in the marine environment. A list of candidates is presented in Table 6.1. Most of the parameters can be placed into one or another of three categories dealing with: (a) population size, (b) breeding productivity, or (c) aspects of feeding ecology, physiology, or behavior.

Measures of population size (group A) are arguably the first priority in any monitoring effort because this is the feature of any species' biology we are ultimately trying to conserve. Because the accurate and repeated

Table 6.1. Parameters of seabird breeding or feeding biology that could be incorporated in a monitoring program.

A. Numbers
    1. Total colony size
    2. Population index

B. Productivity
    3. Overall productivity (young fledged per unit of population)
    4. Percent nest site occupancy (burrowing species only)
    5. Proportion of birds in colony that breed
    6. Clutch size
    7. Hatching success
    8. Hatchability
    9. Fledging success

C. Time budgets and nutrition (breeding biology)
    10. Breeding chronology
    11. Time allocation (proportions of time on land and at sea)
    12. Adult body weights and composition
    13. Egg weights
    14. Egg neglect
    15. Chick feeding rates
    16. Chick growth
    17. Adult diet composition
    18. Foraging distributions

D. Other
    19. Adult survival
    20. Tissue burden of contaminants

estimation of total colony size is fraught with practical and statistical difficulties, the method of choice will generally be to quantify, on permanent study plots, some kind of activity that serves as an index of population size (item 2).

Measures of breeding productivity (group B) are of interest because they reflect the condition of the environment a given species experiences during the spring and summer months. Although a number of different components of productivity (items 4-9) are commonly measured in ecological studies, the single measure of overall annual productivity is the parameter of choice for monitoring purposes because it subsumes all the rest and has direct application to the analysis of life tables.

Items in group C all relate to the foraging ecology and nutrition of birds during the breeding season. They are useful to varying degrees in addressing the question of why breeding success is higher in some years than others, but measurements tend to be difficult to standardize and hard to obtain in brief visits to colonies. We suggest that group C parameters should be de-emphasized in a geographically broad program so that population size and productivity can be monitored at a large number of sites. Studies focusing on items 10-18 are appropriate when population declines or reproductive failures are identified in particular colonies or species.

The last two items on the list are of special interest. Unlike all parameters in groups B and C, adult survival rates convey information about conditions outside of the breeding season, when most of a species' annual mortality occurs. Unfortunately, survival data are obtained only at the colonies, and the wintering areas of birds from particular colonies are largely unknown. Further, although population growth is sensitive to minor changes in the adult survival of long-lived species, these changes are especially difficult to detect. Studies involving marked birds are time- and labor-intensive, and it is unlikely that monitoring of adult survival, within suitable bounds of accuracy, can be sustained given realistic levels of funding and manpower.

Tissue burdens of contaminants are of particular relevance to the issue of possible effects from oil and gas development. Although there is a substantial literature on the physiological effects of ingested hydrocarbons, we are unaware of any studies directly linking population declines to chronic hydrocarbon pollution. Nevertheless, we support the idea of contaminants monitoring, and suggest the Minerals Management Service should continue and possibly expand its present program in this area for marine birds. Laboratory analyses are expensive, but frequent sampling may be unnecessary. For the present, a thorough sample of pre-development material should be obtained, possibly employing the tissue bank approach.

With the primary objective of broad geographic coverage in mind, we recommend that measures of population size (indices) and breeding productivity should be obtained for selected species on an annual or near-annual basis at a large number of colonies in the Bering and Chukchi Seas.

6.1.4. Choice of Species to Monitor

In deciding which species to monitor, it is again necessary to consider what it is we are trying to accomplish. If we wish to monitor the health of the marine environment, conventional logic suggests we would want to select species that sample this environment in a variety of ways. For instance we might categorize species as surface feeders or divers, fish or plankton feeders, nearshore or offshore in respect to foraging habitat, then select one or more species from each group. On the other hand, there may be species that are specially valued, rare, or vulnerable, which we would choose to monitor without regard to how representative they may be. Other considerations include ease of study (generally better for open- than crevice- or burrow-nesting birds) and geographic representation throughout the area of interest (related to the above discussion on hypothesis testing using a comparative approach).

Based mainly on the last two criteria, a list of candidate species for population monitoring in the Bering and Chukchi Seas includes: Northern Fulmar, Red-faced and Pelagic Cormorants, Black-legged and Red-legged Kittiwakes, Common and Thick-billed Murres, and Least and Crested Auklets.

Considerable latitude with respect to prey types and foraging styles is also present in this selection. Ultimately, however, the scope of a monitoring program will be determined by time and money constraints, and it is clear the list of species is still too long. We feel that if good information were obtained consistently on two or three species in a large number of colonies, the primary objectives of an area-wide monitoring program would be well-served.

The Northern Fulmar is an offshore surface feeder, omnivorous, and easy to study. However, it occurs at only two colonies in the Bering Sea, one of which (St. Matthew Island) is relatively inaccessible. Cormorants are inshore divers that occur throughout the study region. As cliff-nesting species they are easy to observe, but at least on some islands they have the habit of moving their colonies from place to place between years (Hunt 1977, Hatch and Hatch 1983). This feature is incompatible with the use of permanent study plots. Least and Crested Auklets are numerically important elements of the Bering Sea avifauna and are the only plankton-feeding specialists on the list. The productivity of auklets is extremely difficult to assess, however, and suitable methods for monitoring their population sizes have yet to be worked out (see Methods below). If counting techniques can be standardized and applied regularly in several Bering Sea colonies, then auklets should be included in the monitoring program for the study of numbers only (not productivity).

Murres and kittiwakes are present at every major seabird colony in the Bering and Chukchi Seas. They are open-nesting species for which methods of observation are well developed and easy to apply. A program including only these species, while compromising ecological variety, would at least include surface feeding and diving species and would offer maximum geographic coverage and overlap. Therefore, we suggest that resources available for seabird monitoring in this region should be allocated to maximize information on numbers and productivity of murres and kittiwakes, with the other species (except auklets) included only on a not-to-interfere basis. Provisionally, auklet numbers might also be monitored on a regular basis, since we envision this would be best accomplished by automated data-gathering techniques.

6.1.5. Methods

In Chapter 1, we referred to Type I and Type II methods for monitoring seabird populations on colonies (see also Birkhead and Nettleship 1980). Type I methods require that observations be made from pre-laying through fledging stages of the breeding cycle. A relatively complete description of breeding activity and success, including the timing as well as magnitude of reproductive failures, is obtained using this approach. Type II methods entail a series of daily counts of birds on permanent study plots during a pre-defined "census period." The census period is chosen to fall within that portion of the breeding cycle that has minimal daily variation in attendance at the colony. By itself, a Type II data set is adequate for documenting annual changes in populations, but not for assessing the means or variability of annual productivity. Consistent with our preference for geopraphic coverage at the expense of detail, we recommend Type II methods for monitoring numbers of murres and kittiwakes, with the addition of a secondary visit to each colony late in the season to assess productivity. Procedures for monitoring auklet numbers, described below, have not been implemented in any study to date.

Requirements for conducting a Type II census of cliff-nesting birds at any given study site include the following:

(1) A set of well-defined, permanent study plots, adequately marked and documented so that observers new to the study site would have no trouble relocating the counting areas.

(2) Plots are observed from land and are of manageable size, say 50-500 birds, depending on the species and habitat.

(3) Plots are of a sufficient number (not fewer than 5) to support analyses that treat the plot as the sampling unit for detecting population change (see Murphy et al. 1987), but not so numerous or far-flung that they cannot all be visited by two observers in a single day.

(4) Plots should be selected to be representative of the range of habitat types—e.g., center vs. edge, densely vs. sparsely populated, etc. A random selection of plots is desirable (Harris et al. 1983) but in most instances this will be impractical. It may be possible to use a random sample of the "viewable" population.

(5) Where possible, plots should initially include unoccupied surrounding habitat available for expansion in numbers at original densities.

(6) At least 5 daily counts per plot should be made each season. Ten counts is a better target; more than 10 is useful, but there are diminishing returns from larger numbers of counts in terms of the relative change in numbers that can be detected statistically (Fig. 6.1). Counts should be made during a specified census period when daily variation in attendance is known to be low. For instance, in Black-legged Kittiwakes this period extends from first egg-laying through final hatching (about 50 days); in murres it last from the middle of egg-laying through final hatching (about 40 days) (Hatch and Hatch in press, MS).

In most instances, the required number of plot counts will be completed before the season has advanced far enough for a valid measure of breeding productivity to be made. The strategy for monitoring productivity would be to visit each study area again near the end of the season to count the number of young surviving on the census plots. These visits should be timed to be as late as possible, but before the first young have fledged. Since murres and kittiwakes have asynchronous patterns of fledging, it will in most instances be necessary to compromise the estimate of kittiwake success by making the chick counts well ahead of the first fledging date. As most losses occur before the mid-chick stage in kittiwakes, this procedure is probably satisfactory. Productivity of kittiwakes could be expressed as the number of young surviving on the second visit divided by the number of nests on plots during the initial census period. For all species, however, productivity should also be expressed as the number of surviving young divided by the mean count of adults present on the first visit.

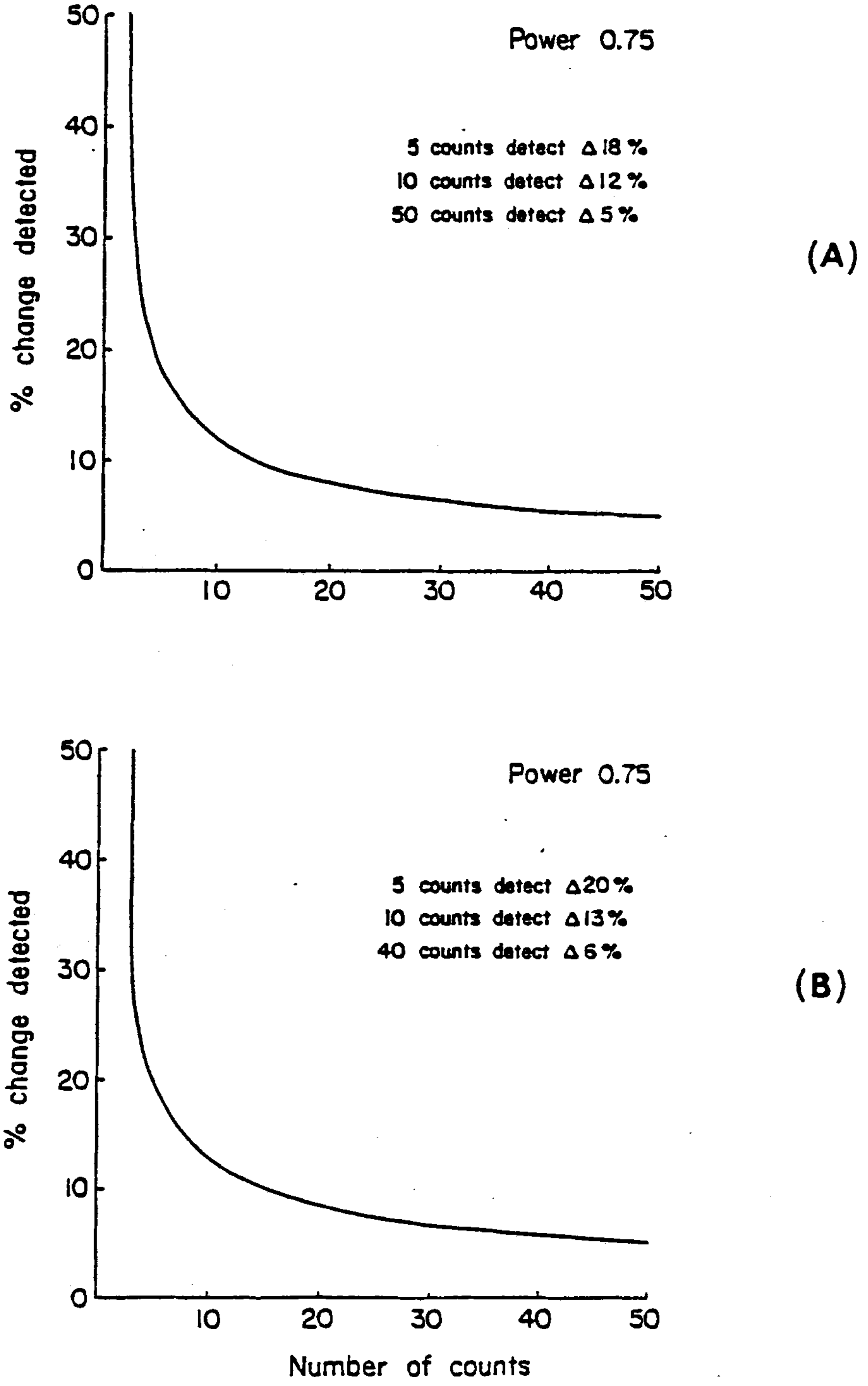

Figure 6.1. Relationships between sample size (number of daily counts made during the census period in two or more years) and the proportionate change in numbers detectable in a t-test or analysis of variance for: (a) Black-legged Kittiwakes, and (b) Common and Thick-billed Murres. Power is the degree of confidence that the difference between sample means would be significant at the 0.05 level.

The goal of monitoring numbers of Least and Crested Auklets presents special problems. Unlike murres or kittiwakes, these species have strong diurnal fluctuations in attendance and are also prone to frequent panic flights during the hours of the day they spend on the surface of their talus nesting slopes. A large number of counts within each day must be averaged to overcome this short-term variability in numbers. Furthermore, there is considerable variation among different observers in counting ability at the distances from which the plots must be viewed. The precise demarkation of plot boundaries is another problem.

We suggest the use of time-lapse photography as an alternative to human observers making the counts in the field. Our experience suggests that a 35 mm format will be necessary to give consistently usable products and that some means of elevating the cameras 8-10 feet above the ground surface will be needed in most situations. This could be done, for example, by mounting camera boxes on steel towers which are designed to be erected and dismantled seasonally. Towers would have concrete footings placed permanently in the talus slopes. The boundaries of the plot or plots (quadrats) within each camera's field of view should be delineated by taut lengths of brightly colored polypropylene line. Metal corner pins for securing the lines should also be permanently cemented in place. The use of a bulk film magazine and programmed timers should permit a camera to operate unattended for 10 days, exposing 2-4 frames per hour during periods of auklet attendance. In the future, it may be cheaper and more efficient to use a video recording system in place of conventional photography.

In the lab, the numbers of birds within each quadrat would be counted and summed over all photographs for each day to give an integrated value for auklet attendance over one diurnal cycle. The average of 10 or so of these integrated daily totals would be the annual index of auklet numbers on the study plots, with a standard error based on the sample size of 10 days.

While the proposed scheme would relieve personnel of the tedious and imprecise task of making repeated counts in the field, the set-up and maintenance of such equipment would not be a trivial matter. It may be desirable to conduct such operations at less than annual intervals. In any event, until a rigorous set of procedures such as we have described is put into practice, we question the value of any efforts to monitor auklet populations in Bering Sea colonies.

6.1.6. Selection of Study Sites

The selection of study sites for the proposed monitoring program should be based upon: (a) the goal of maximizing geographic coverage, (b) the presence of species chosen to monitor, (c) accessibility, and (d) the existence of an established system of study plots and historical data base. Based on these criteria we identified 11 priority study sites in the Bering and Chukchi Seas (Fig. 6.2). Previous studies have been conducted at most of these sites with funding provided by the Outer Continental Shelf Environmental Assessment Program (OCSEAP), Minerals Management Service (MMS), or Fish and Wildlife Service (FWS). One site which has not received previous attention (Little Diomede Island) is included because of the importance of its seabird colonies, its strategic location in the Bering Strait, and recent interest in this area expressed by the MMS. A synopsis of earlier efforts at other sites relevant to the proposed monitoring scheme is presented in Table 6.2. A selected list of publications and reports pertaining to these areas is provided in Appendix 6.1.

It is noteworthy (Table 6.2) that although several of the prominent seabird colonies in the Bering/Chukchi region have been visited regularly since the mid-1970's, Type II censusing of murres and kittiwakes, including 5 or more replicate counts in a season, has been completed only recently or not at all in most colonies. Thus the data base for assessing population trends with an acceptable degree of statistical confidence is poor, and this situation will improve only if a concerted effort using standardized methods is implemented and faithfully executed over a number of years.

Without first-hand knowledge of each study site, it is difficult to evaluate the suitability of existing study plots for uniform Type II methods. Probably a subset of the large number of plots established in some study areas could be chosen which would serve the purpose. There is no plot system in place at any study site to support the photographic Type II

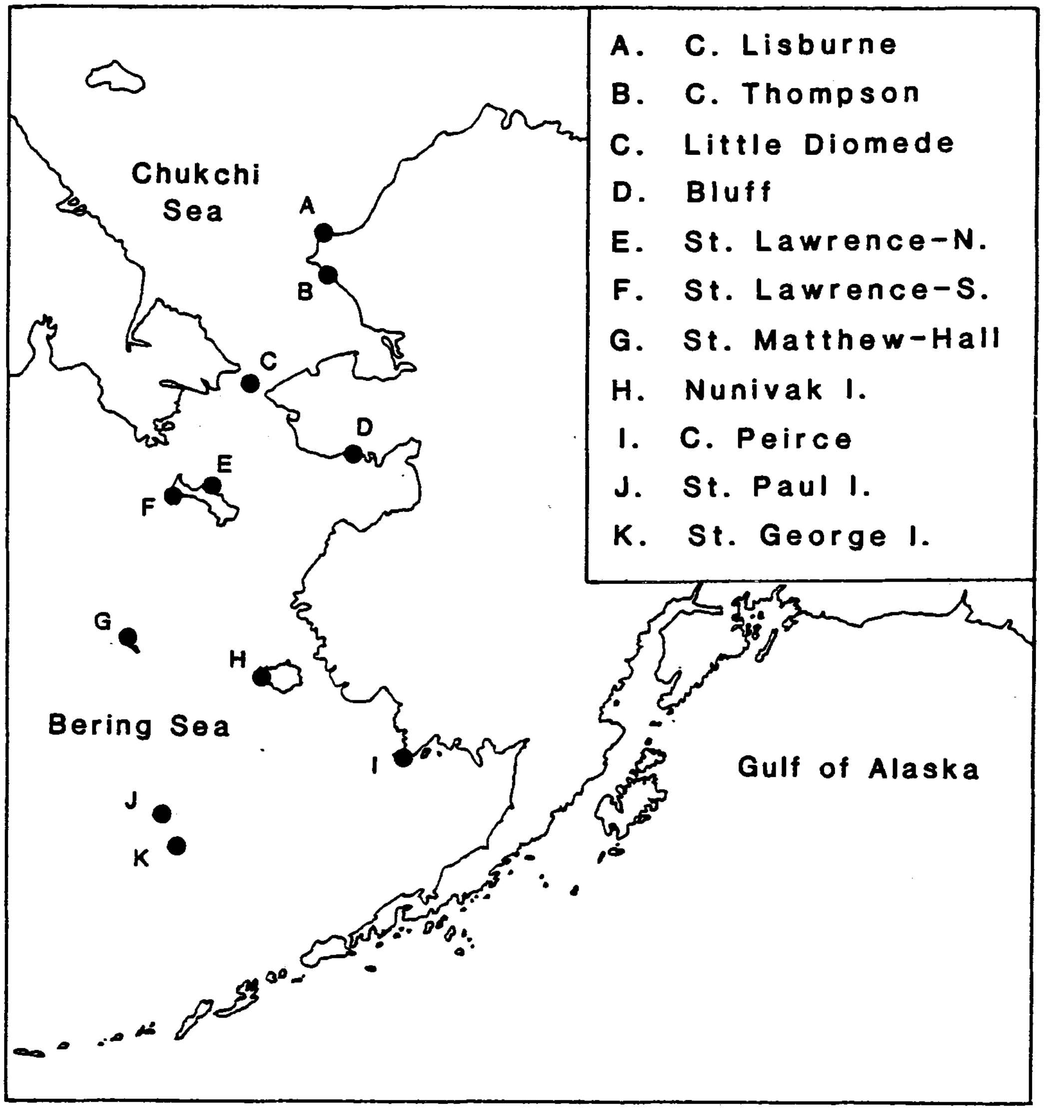

Figure 6.2. Locations of proposed study sites for a seabird monitoring program in the Bering and Chukchi Seas.

Table 6.2. Status of seabird observations at 11 sites proposed for inclusion in an area-wide monitoring program for the Bering and Chukchi Seas.

	Colony										
Status	St. George	St. Paul	Cape Peirce	Nunivak Island	St. Matthew-Hall	St. Lawrence-South	St. Lawrence-North	Bluff	Little Diomede	Cape Thompson	Cape Lisburne
Type II plot system in place, documented?											
Murres	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes
No. plots	57	35	17	35	44	7	9	11	-	137	75
Kittiwakes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes
No. plots	57	35	24	35	44	7	9	11	-	137	75
Auklets[a]	no	-	-	-	no	no	-	-	no	-	-
Annual visits[b]											
Earliest	'76	'76	'76	'87	'77	'76	'87	'75	-	'60	'76
No. to date	9	9	5	1	5	2	1	13	0	5	9
Type II minimum criteria met? (≥ 5 counts/plot)											
Murres											
No. years	4[c]	3[c]	4	0	2	2	1	0	0	0	0
Earliest	'84	'85	'76	-	'85	'76	'87	-	-	-	-
Kittiwakes											
No. years	4[c]	3[c]	4	0	2	2	1	0	0	0	0
Earliest	'84	'85	'76	-	'85	'76	'87	-	-	-	-
No. years productivity estimates available											
Murres	5	6	6	0	2	2	0	8	0	0	0
Kittiwakes	13	13	7	0	4	3	0	11	0	5	10

Table 6.2. (Continued)

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[a] Plots for visual attendance counts of auklets exist on St. George, Hall Island, and St. Lawrence-South.

[b] Includes observations that used the current plot system, or parts of it.

[c] Sample size less than 5 counts for some plots in all years.

methods for auklets described earlier. Colonies where this approach could be applied are located on St. George Island, Hall Island, St. Lawrence-South (Kongkok Bay), and Little Diomede Island.

It may be unnecessary or infeasible to visit all of the proposed sites in all years. From a purely geographical point of view, there may be redundancy in including both of the main islands in the Pribilofs or both sites on St. Lawrence Island. Similarly, although plot systems for murres and kittiwakes exist at both ends of St. Matthew Island (Murphy et al. 1987), we recommend trying to maintain only one in this relatively inaccessible area. The northern site, including Hall Island, may be appropriate because of the abundance of auklets also breeding in that area. However, southeastern plots on St. Matthew may have more relevance to potential oil and gas industry support activities.

6.2. Details of a Bering/Chukchi Seabird Monitoring Program: Breeding Chronologies and Field Schedule

Obviously, the objective of getting information on seabird populations and productivity from a large number of colonies annually imposes logistic difficulties and the need for coordinated field activity. The purpose of this section is to show how the work could be accomplished through the efficient timing of visits to colonies. The information on seabird breeding schedules incorporated in this discussion was extracted from reports listed in Appendix 6.1. Data summaries are intended for general planning purposes only, since we had to take considerable liberty with the fragmentary information available.

The typical census period for Type II counts of individual species lasts 40 to 50 days (i.e., early to mid-laying until late hatching). If we assume that a field party would need about 2 weeks at a given study site to make the desired number of counts (about 10), it is clear that one crew would be unable to visit all the proposed colonies in a season. Some advantage is derived from the fact that breeding schedules are not completely overlapping in different colonies. For example, the breeding schedules of murres and kittiwakes are earlier in the Southern Bering Sea and Norton Sound than they are farther north or seaward, but there is still much synchrony of breeding throughout the region (Fig. 6.3). Moreover, the inclusion of two or more species in the study design reduces the number of days available for counting at a given colony. This is illustrated for the Pribilof Islands in Figure 6.4. If Type II counts are desired for all seven candidate species on the Pribilofs, there is only one 14-day period during which these counts could be made in a single visit to the islands. Similar analyses for six additional study sites are presented in Figures 6.5-6.9. Clearly, one result of emphasizing species diversity over geographic coverage in the overall monitoring program is to reduce flexibility in the timing of visits to colonies.

The alternative we suggest is to optimize the effort for murres and kittiwakes and to settle for only as much information on other species as can then be taken opportunistically. Estimated census periods for murres and kittiwakes at seven colonies are listed in Table 6.3. Despite the overlap in dates available for counting in these areas, two crews could cover all the colonies, spending an average of 2 weeks in each area (Fig. 6.10). Little time is available for travel between colonies, but the 14-day period allocated to each area should allow for additional travel time as required, camp set-up, poor weather, and 8-10 days of counting. A third crew would be needed to work additional colonies (e.g., Nunivak Island and Little Diomede) and also to assist with productivity checks at several colonies in August. Two options for a follow-up visit are shown for each colony, one that allows the measurement of murre productivity, and a later visit that is better timed for kittiwakes but too late for murres. Although productivity checks should require only 1-2 days of observations per site, it would be necessary under either option for crews to visit two or more sites in quick succession.

Though the schedules depicted in Figure 6.10 are designed to optimize for murres and Black-legged Kittiwakes, the opportunity exists to count other species during their respective census periods at most colonies. These additional species include Red-legged Kittiwakes, fulmars, cormorants, and auklets, depending on the colony (Table 6.4). Similarly, the productivity of additional species besides murres and kittiwakes could be

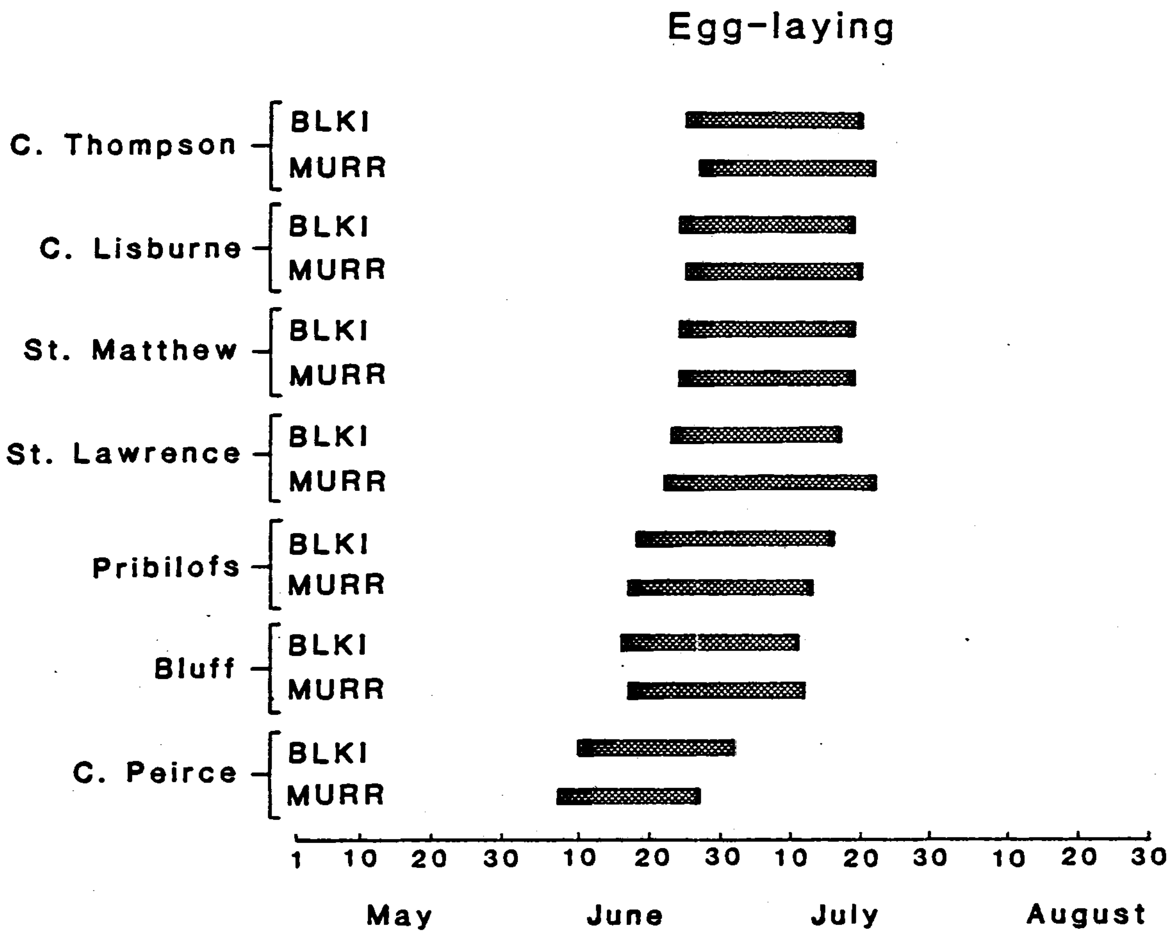

Figure 6.3. Mean span of egg-laying in murres (MURR) and Black-legged Kittiwakes (BLKI) at seven colonies in the Bering and Chukchi Seas.

▩	Laying
▨	Hatching
➡	Fledging
↑___↑	Census period
X	Productivity check
↔	Common Type II census period for target species

NOFU - Northern Fulmar
RFCO - Red-faced Cormorant
PECO - Pelagic Cormorant
BLKI - Black-legged Kittiwake
Red-legged Kittiwake
TBMU - Thick-billed Murre
COMU - Common Murre
LEAU - Least Auklet
CRAU - Crested Auklet

Legend to Figures 6.4 - 6.9

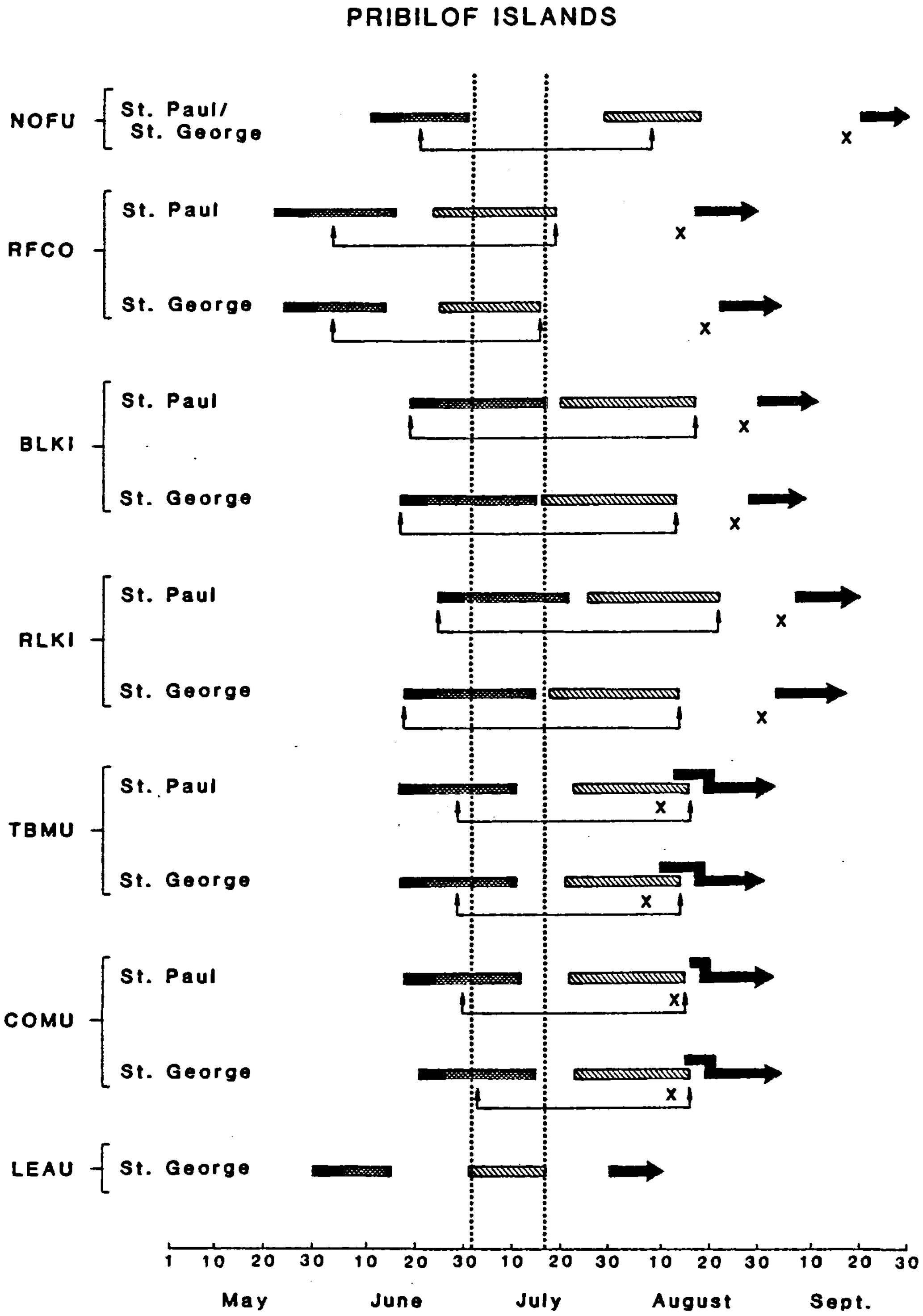

Figure 6.4. Breeding chronologies of seabirds on the Pribilof Islands and the timing of visits for Type II census counts and productivity checks. For definitions of symbols see legend on page 166.

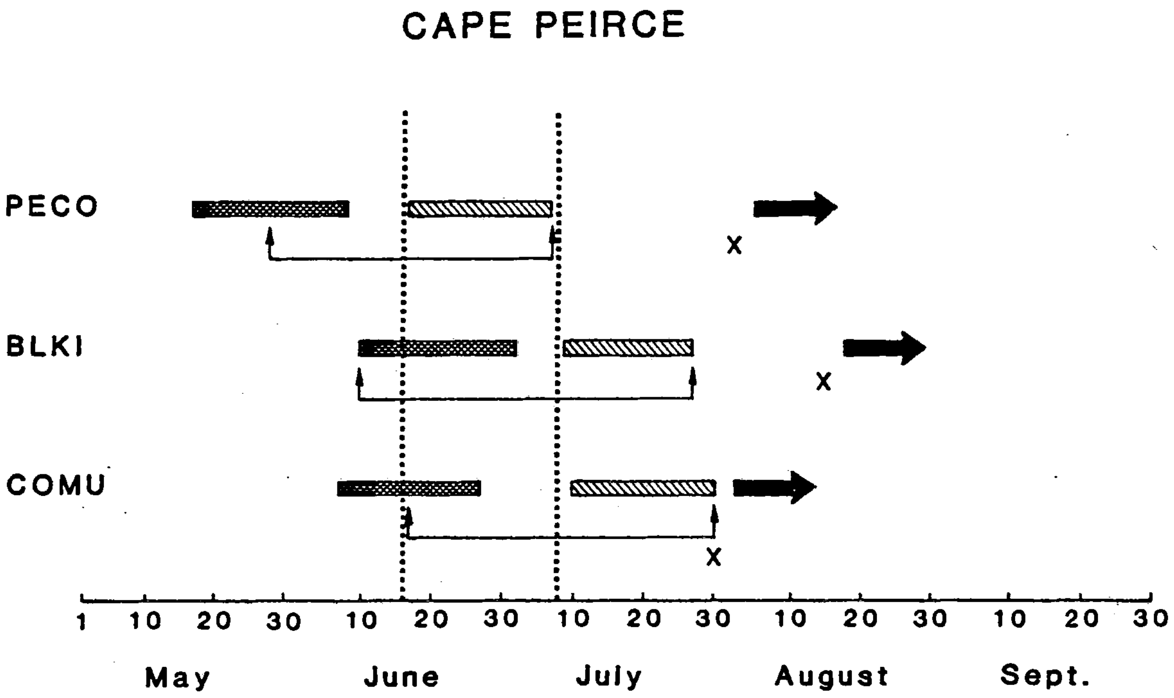

Figure 6.5. Breeding chronologies of seabirds at Cape Peirce and the timing of visits for Type II census counts and productivity checks. For definitions of symbols see legend on page 166.

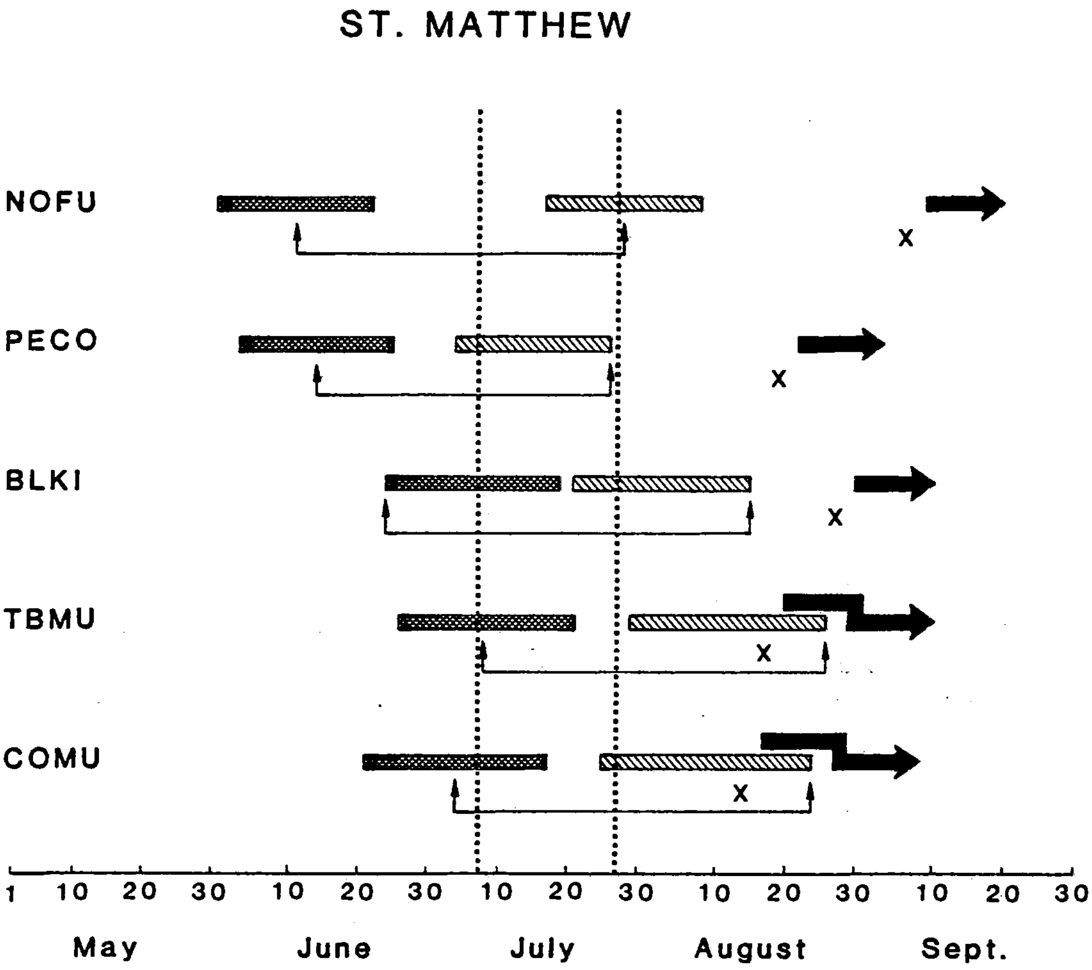

Figure 6.6. Breeding chronologies of seabirds on St. Matthew Island and the timing of visits for Type II census counts and productivity checks. For definitions of symbols see legend on page 166.

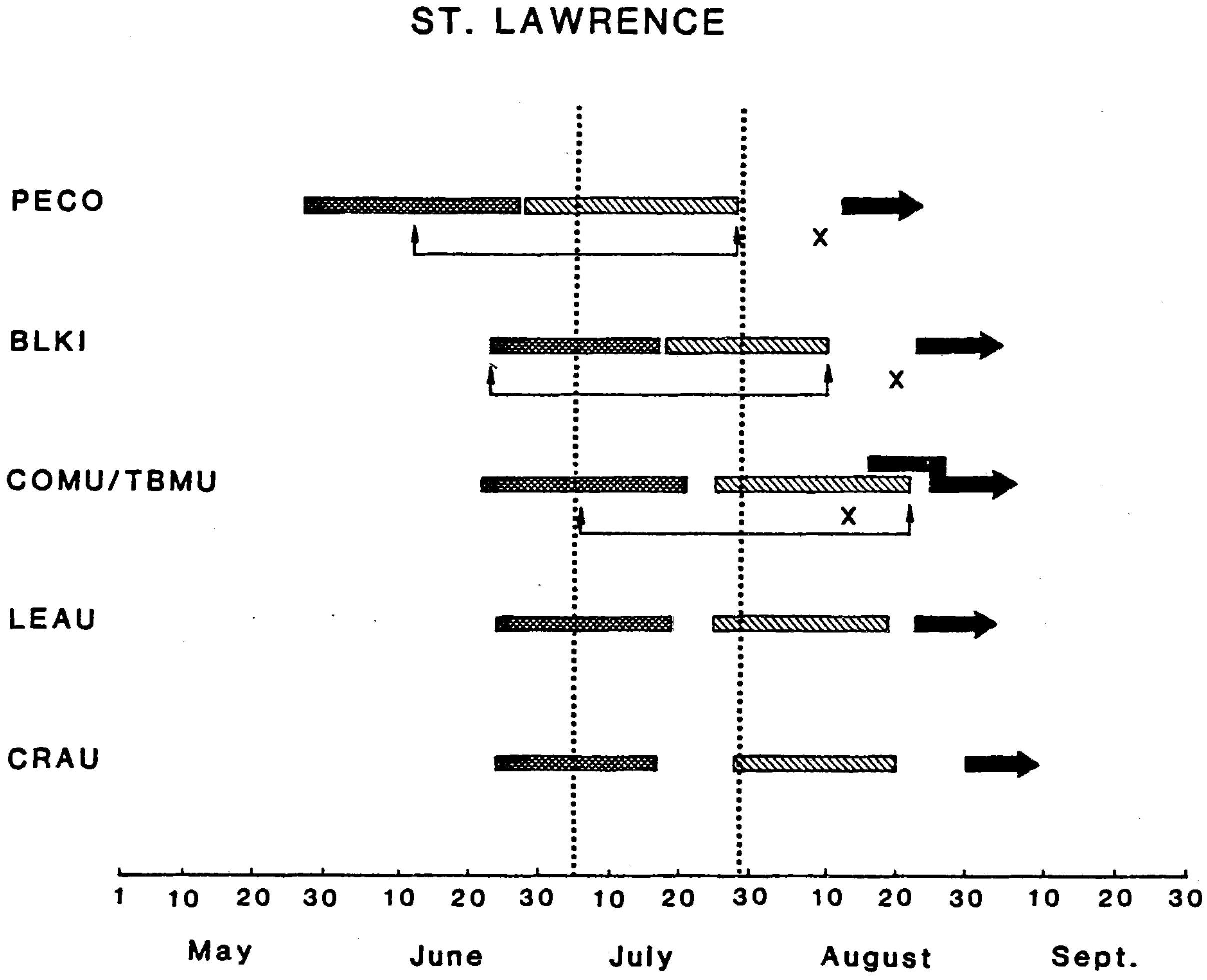

Figure 6.7. Breeding chronologies of seabirds on St. Lawrence Island and the timing of visits for Type II census counts and productivity checks. For definitions of symbols see legend on page 166.

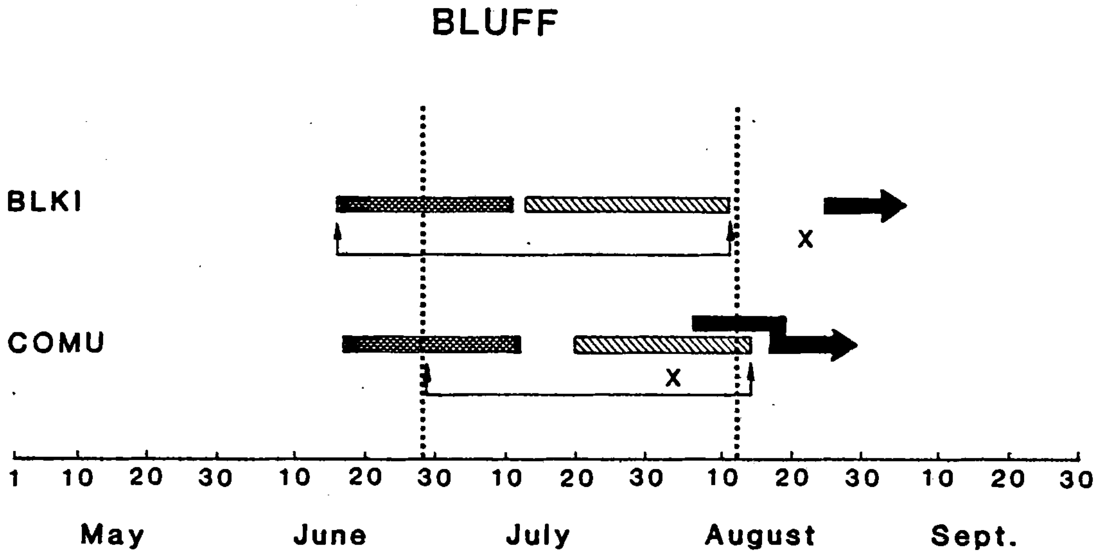

Figure 6.8. Breeding chronologies of seabirds at Bluff and the timing of visits for Type II census counts and productivity checks. For definitions of symbols see legend on page 166.

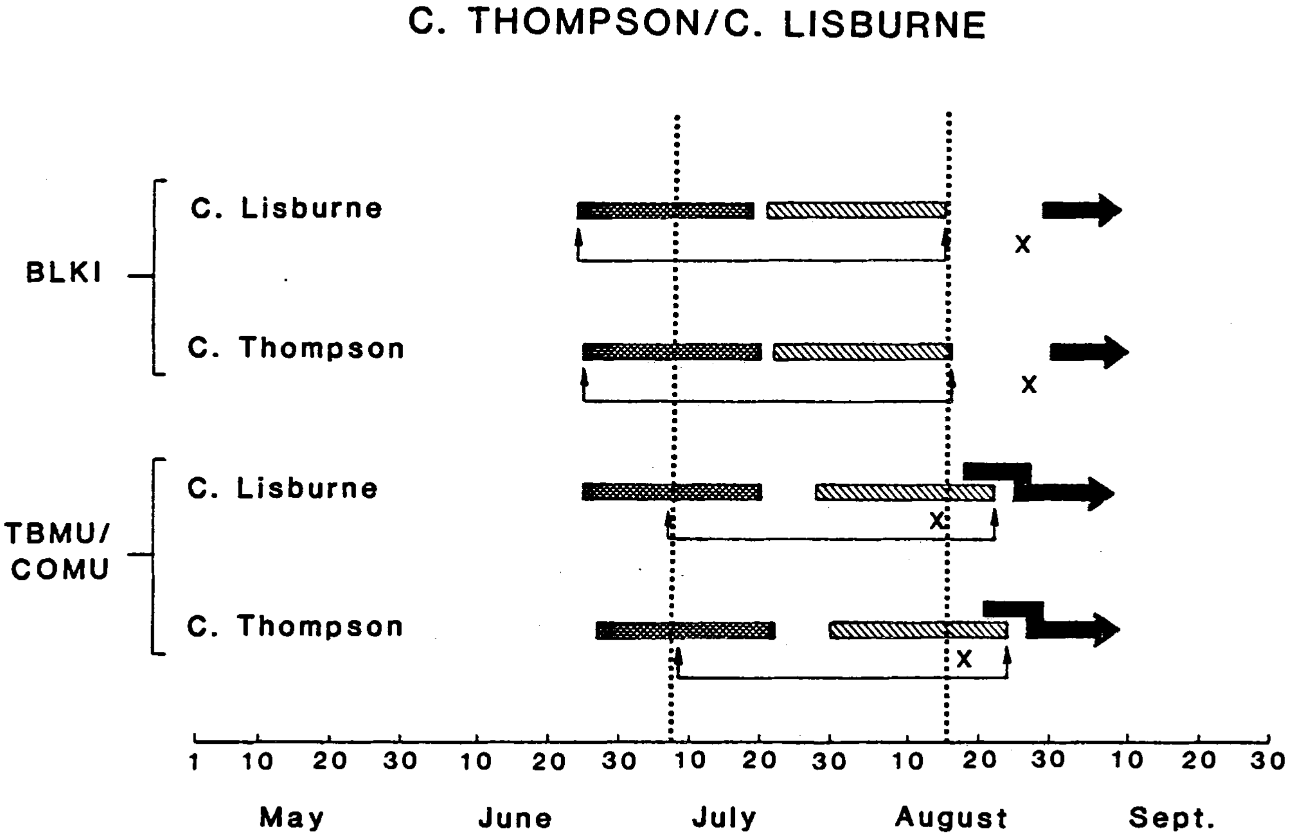

Figure 6.9. Breeding chronologies of seabirds at Cape Thompson and Cape Lisburne and the timing of visits for Type II census counts and productivity checks. For definitions of symbols see legend on page 166.

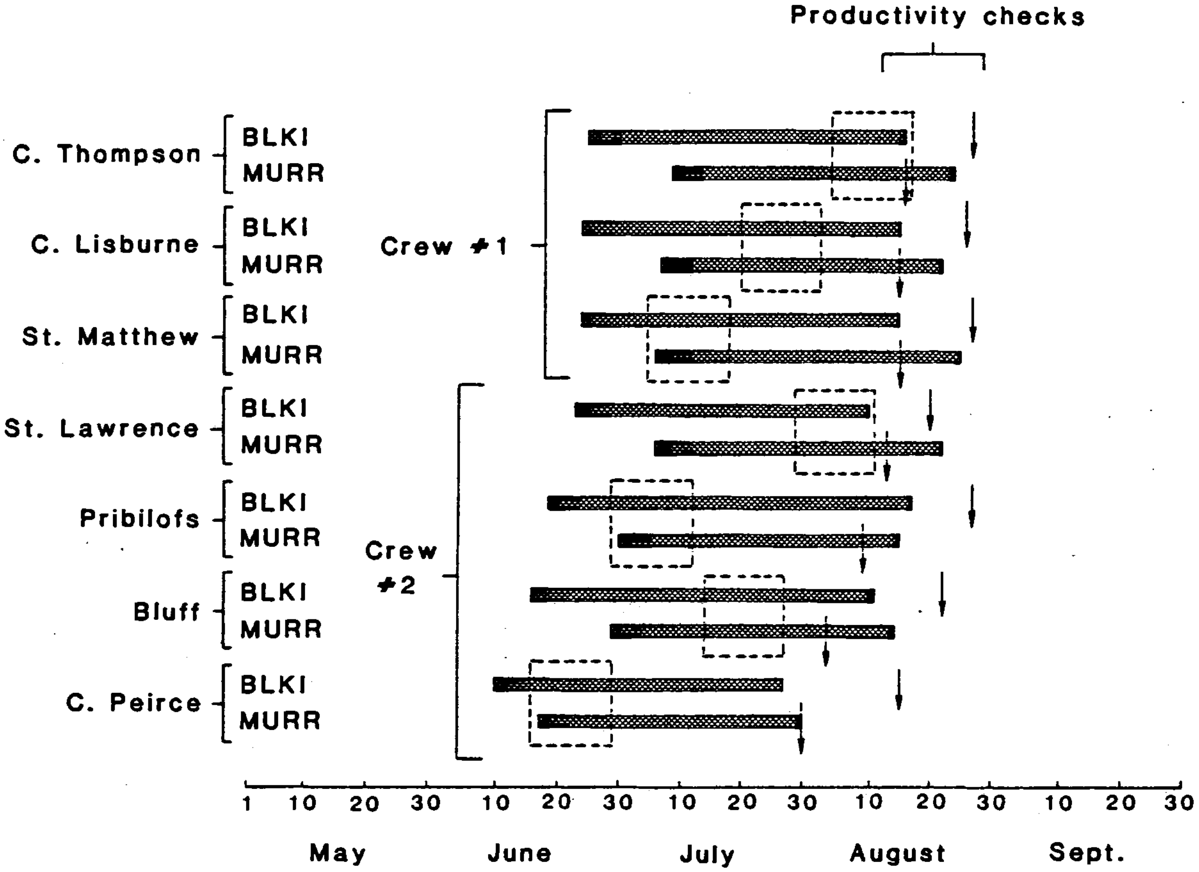

Figure 6.10. Census periods of murres and Black-legged Kittiwakes at seven colonies and the timing of visits for Type II counts (dashed boxes) and productivity checks (arrows).

Table 6.3. Estimated census periods for Type II counts of murres and Black-legged Kittiwakes at seven colonies in the Bering and Chukchi Seas.

	Census Period	
Colony	Black-legged Kittiwake	Thick-billed and Common Murres
Cape Thompson	25 June - 16 August	9 July - 24 August
Cape Lisburne	24 June - 15 August	7 July - 22 August
St. Matthew-Hall	24 June - 15 August	6 July - 25 August
St. Lawrence	23 June - 10 August	6 July - 22 August
Pribilofs	19 June - 17 August	30 June - 15 August
Bluff	16 June - 11 August	29 June - 14 August
Cape Peirce	10 June - 27 July	17 June - 30 July

Table 6.4. Scheduled visits to Bering and Chukchi seabird colonies and species other than murres and kittiwakes whose census periods coincide with those visits.

Colony	Dates in area	Ancillary species to census (no. census days available)
Cape Peirce	17 June - 28 June	PECO (14)
Pribilofs	30 June - 11 July	RLKI (14), RFCO (14), NOFU (14), LEAU (14)
Bluff	15 July - 26 July	-
St. Lawrence	30 July - 10 August	LEAU (14?), CRAU (14?)
St. Matthew-Hall	6 July - 17 July	NOFU (14), PECO (14), LEAU (14), CRAU (14)
Cape Lisburne	21 July - 1 August	-
Cape Thompson	5 Aug. - 16 August	-

Table 6.5. Scheduled visits to assess breeding productivity of murres and kittiwakes at Bering and Chukchi colonies and other species whose productivity could be assessed during the same visits.

Colony	Visit timed for Kittiwakes	Other spp. available	Visit timed for Murres	Other spp. available
Cape Peirce	15 August	-	30 July	BLKI, PECO
Pribilofs	27 August	NOFU, RLKI	9 August	BLKI, RLKI, RFCO, NOFU
Bluff	22 August	-	3 August	BLKI
St. Lawrence	20 August	-	13 August	BLKI, PECO
St. Matthew	27 August	NOFU	15 August	NOFU, BLKI, PECO
Cape Thompson	27 August	-	15 August	BLKI
Cape Lisburne	27 August	-	16 August	BLKI

checked during August visits, particularly if the early option is elected (Table 6.5).

The success of this type of field operation would depend on careful planning and the experience of the field crews. Success at a given study site is unlikely unless at least one member of the field party has personal experience in the area.

6.3. Complementary Studies

6.3.1. At-Sea Distribution and Movements

Although seabird populations are most efficiently monitored where they are concentrated in breeding colonies, the most serious of potential impacts from oil and gas activity, commercial fisheries, and other developments, will likely occur in pelagic habitats. We have little information, however, on the offshore distribution and movements of birds in relation to particular colonies, and our understanding of environmental features that might be used to recognize and classify key habitats is crude at best. We suspect that feeding activity is spatially concentrated in areas of abundant food supplies near colonies, but it is unknown whether these areas are fixed over time, or ephemeral. Thus, though we may detect population declines in the future, and may even have some general indications of their cause, we are in no position to recommend specific management actions that could mitigate or reverse any adverse trends. Models for predicting the impact of oil spills on marine birds (Ford et al. 1982, Samuels and Lanfear 1982) are also limited by the scarcity of information on at-sea distribution and movements of birds from colonies. Therefore, complementing the land-based seabird monitoring program, studies should be initiated to:

(1) Document the breeding season distribution and abundance of foraging seabirds in relation to specific colonies and characterize the habitats being used. (Can marine habitats used by seabirds be defined in such a manner that we can accurately predict where feeding concentrations will occur?)

(2) Document the winter distribution and abundance of seabirds and characterize the habitats being used. (Are the locations of wintering concentrations constant or do they vary over time? Do birds from specific colonies tend to migrate to and winter in specific areas, or do wintering concentrations include birds from scattered colonies?)

The answers to these questions will help determine the relative vulnerability of birds at sea and will ensure that effective mitigation strategies are employed. We anticipate that 6-8 weeks of dedicated ship time (M/V Tiglax, NOAA vessels, or other) would be needed annually over 4-5 years to conduct these studies.

6.3.2. Population Modelling

As noted earlier, the usefulness of tracking population changes in Alaskan seabirds is limited by our lack of understanding of natural variation. Since annual productivity, and possibly also adult survival, tends to be highly variable in some species, the potential exists for considerable fluctuation of population sizes around long-term means. Models are available for projecting population growth given age-specific rates of fecundity and survival (Leslie 1945, 1948). As they are usually applied, however, such models incorporate mean values for birth and death rates, with no allowance for the annual variation in these parameters that is characteristic of Alaskan seabirds. Preliminary results from computer simulations that incorporate this variability (Hatch, unpubl.) suggest that population sizes may fluctuate as much as 50-100% over 10-15 years, simply because of the concatenation of several years of high or low productivity and high or low over-winter survival. We believe that further work in this area is desirable so that managers might avoid the mistake of reacting to population declines that are entirely natural and ultimately transient.

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APPENDIX 6.1 - List of References for Proposed Bering/Chukchi Study Sites

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APPENDICES

APPENDIX A. STUDY PLOTS FOR CLIFF-NESTING SEABIRDS AT THE KONGKOK STUDY AREA, ST. LAWRENCE ISLAND, ALASKA

Seven study plots were monitored in the Kongkok area for Black-legged Kittiwakes, Common Murres, Thick-billed Murres and Pelagic Cormorants. The following written descriptions, photographs and figures show how to locate these plots.

Table A-1 indicates which plots were counted, the types of observations conducted, species counted, whether our counts were comparable to Searing's (1977), and the plot marker designations (e.g. Area A). Markers are permanently placed, circular brass surveyor's markers inscribed with the letters "USFWS SLI PLR AREA ___". A map (Fig. A-1) showing the location of all plots, the route to all plots, and plot marker locations is provided. Finally, a sketch map and photograph of each plot (except no. 4) is provided (plots 1-7, Owalit Mountain).

LOCATING THE STUDY PLOTS

Plots 1 and 2: Plots 1 and 2 can both be found by traversing along the lower slopes of Owalit Mountain (Fig. A-1). From camp, at the western shore of Kongkok lake, the observer walks west along the shoreline, climbing up the talus slopes of Owalit Mountain far enough to avoid the steep cliffs along the water's edge. Once above these cliffs, the observer traverses around the side of the mountain.

Plot 1 is located on a steep NW facing cliff and is the first large aggregation of murres and kittiwakes encountered on the traverse W/NW from camp. A jagged pinnacle of rock surrounded by water at the base of this cliff is also included in the plot. The observation point (OP) is approximately 13 m west of the plot on a grassy hillside and must be approached slowly so as not to flush the birds. A permanent brass surveyor's marker (inscribed "area B") can be found on top of a large flat rock about 3 m above the OP.

Plot 2 is .25 km NW of plot 1. It is located on some cliffs which form the base of a large SE facing ridge. The OP is 90 m SE of the plot on a grassy sloping hillside. A permanent marker ("area D") was placed on top of a boulder approximately 25 m above the OP.

Plots 3, 5, 6, and 7: These four plots all can be found by climbing to the top of Owalit Mountain and then following along the steep cliff edge in a NW direction (Fig. A-1).

Plots 3 and 6 are encountered first on the walk from camp. These plots are both located on a ridge forming the NW side of a steep gulley and are viewed from the same OP. This OP is marked by a permanent marker ("area C") placed on top of a flat rock at the top of the cliff's edge. Plot 3 encompasses the cliff area furthest from the OP and closest to the ocean. Plot 6 is the cliff system closer to the observer.

To find plots 5 and 7, continue walking N/NW along the cliff edge, about .5 km past the OP for plots 3 and 6. Plot 5 can not be seen from the top of the cliff. A permanent marker ("area R") placed on top of a large boulder marks the descent route to the plot. The observer must climb down the side of a steep hillside until a south facing cliff system above the water's edge can be seen. The OP for plot 5 is located south of the plot, as far down the side of a steep hillside as it is safe to go. It should be emphasized that the descent to this plot can be slippery in early June, when there is still plenty of snow remaining on the hillside.

To locate plot 7, continue 15 to 20 m past the permanent marker for plot 5, heading W/NW along the cliff edge. A large triangular rock island situated next to the shoreline can be seen by looking down from a small promontory. The protected east face of the rock island and the south facing cliff next to it are both included in plot 7. Permanent marker ("area J") can be found on top of one of the large boulders where the OP is located.

Plot 4: Plot 4 is the only plot located SE of camp and can only be counted by boat. It is a 2.5 km boat trip from the beach at Kongkok Bay to the NW side of Tatik Point where the plot is located (Fig. A-1). This plot was only censused three times in 1987. We recommend that plot 4 be discontinued from future monitoring because inclement sea conditions frequently prevent counts from being made of Tatik Point where the plot is located.

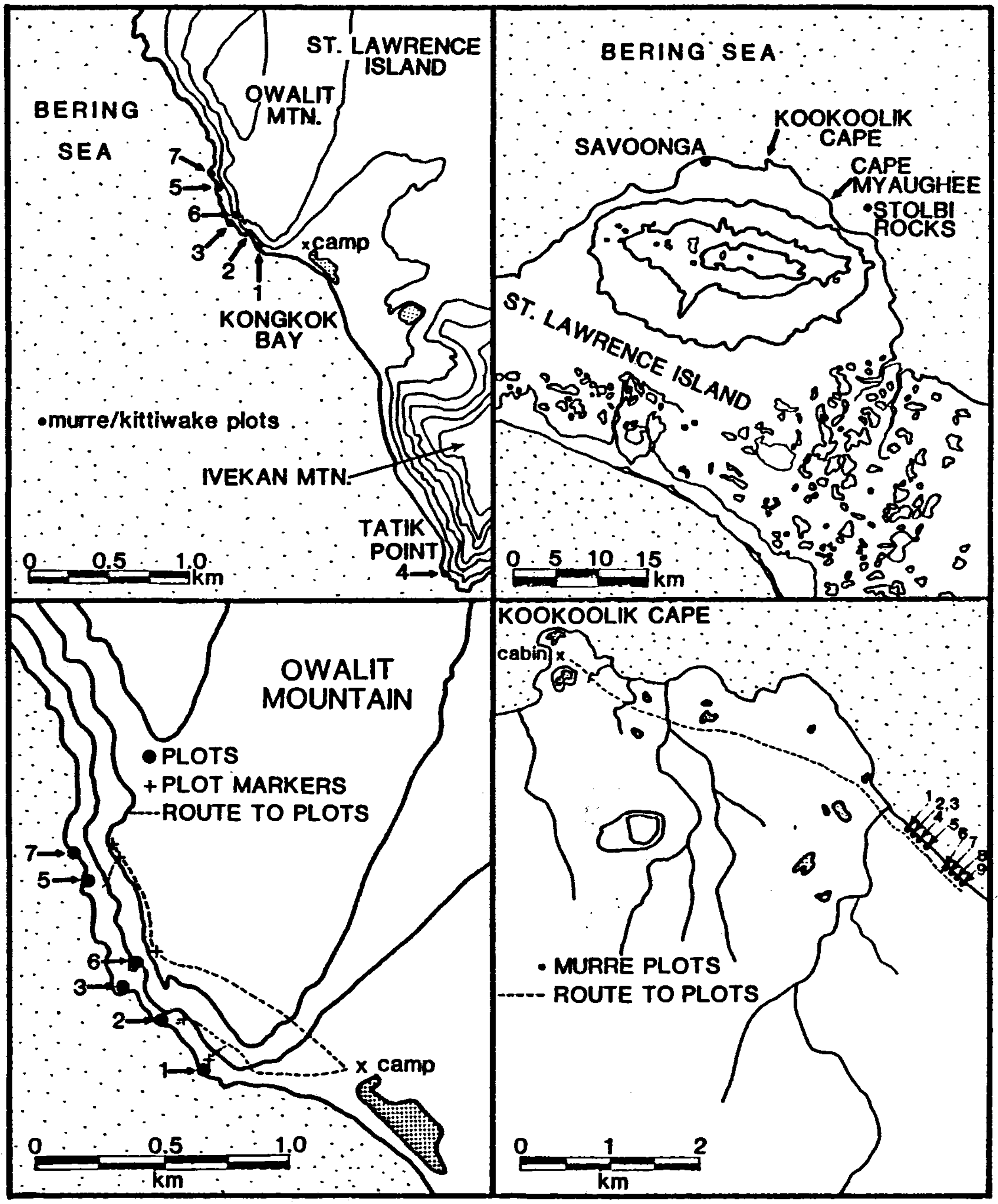
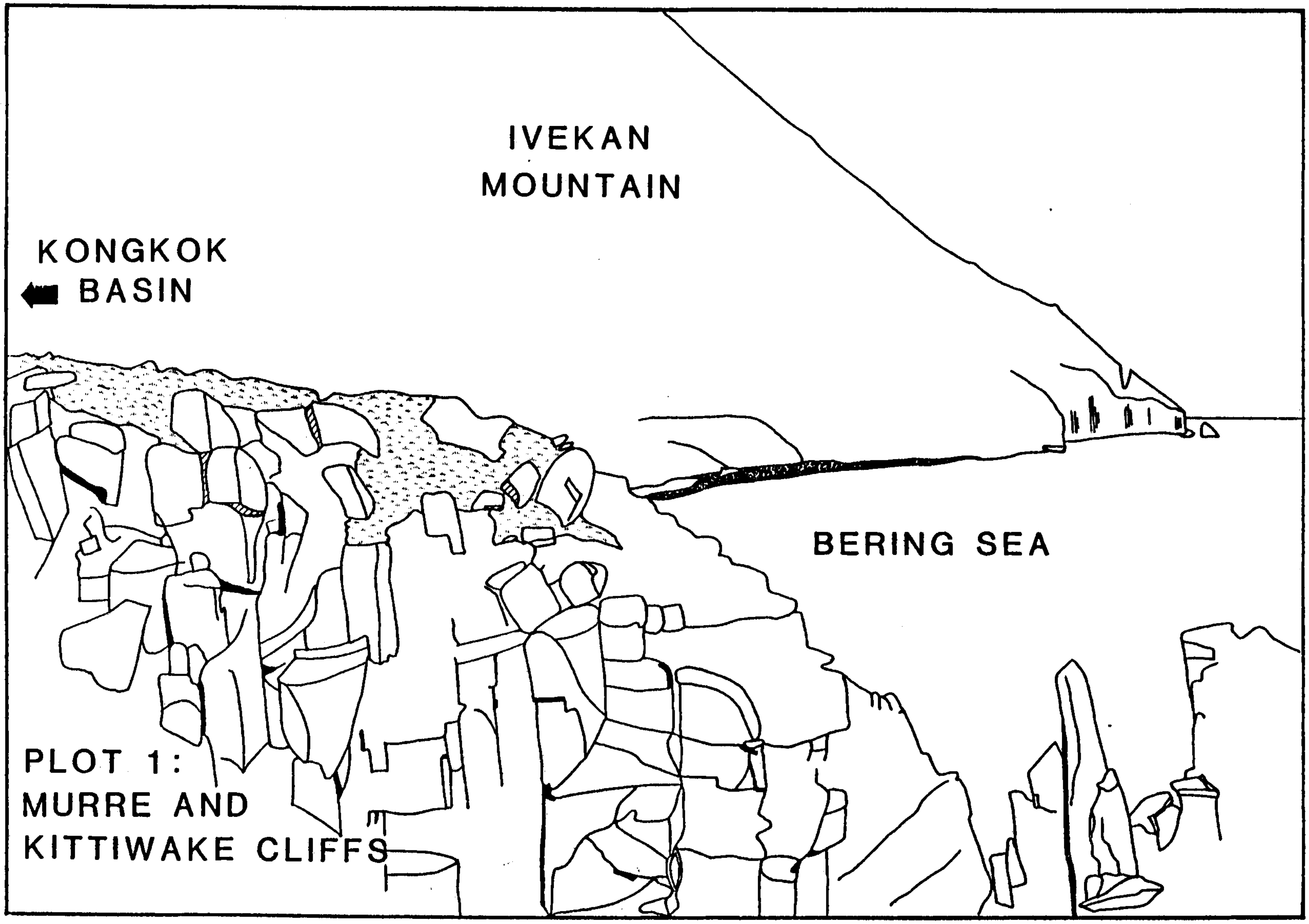


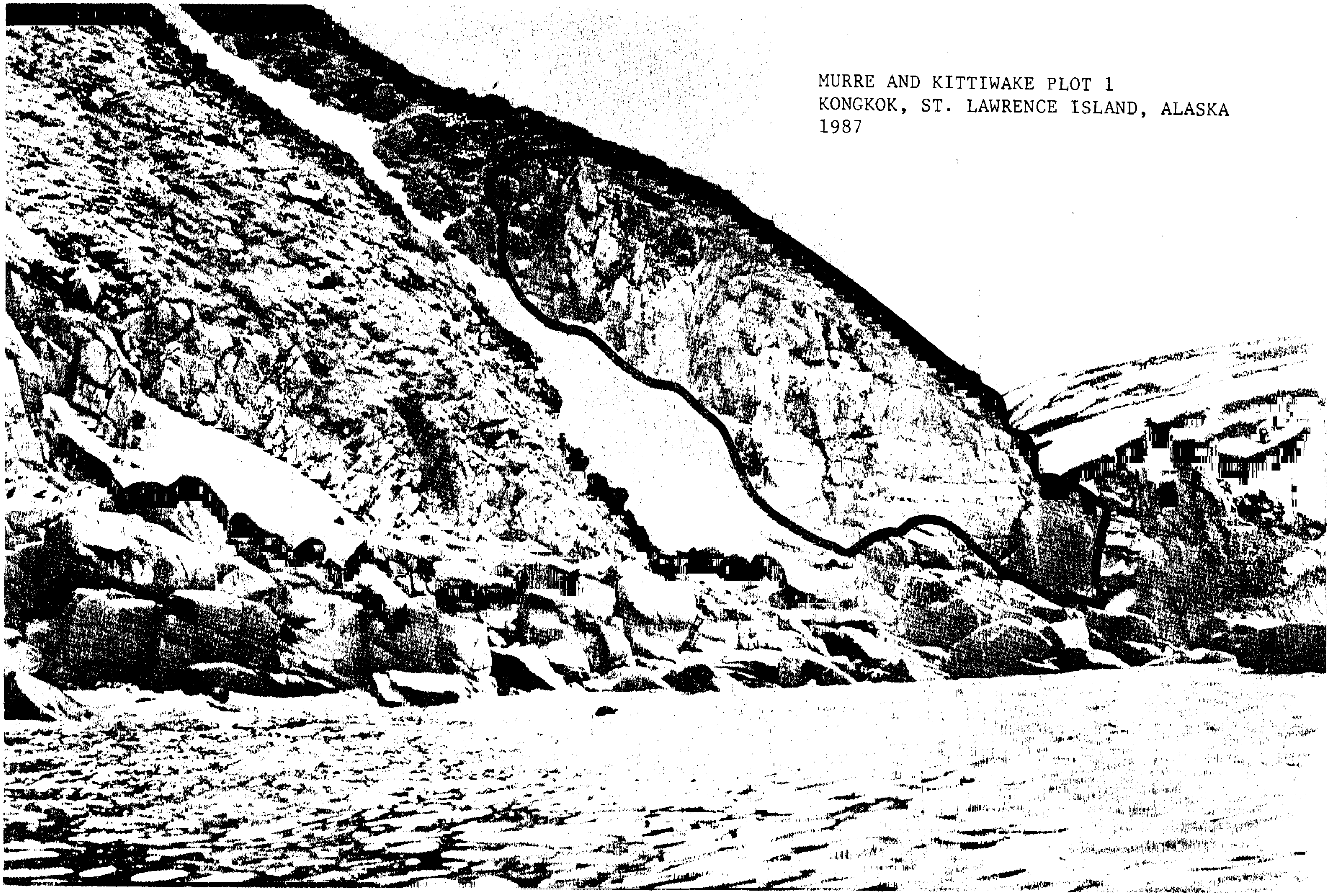
Figure A-1. Locations of murre and kittiwake study plots at Kongkok (Owalit Mountain) and east of Savoonga.

Table A-1. Summary of census techniques for cliff-nesting birds at Kongkok study area, St. Lawrence Island, Alaska, 1987.

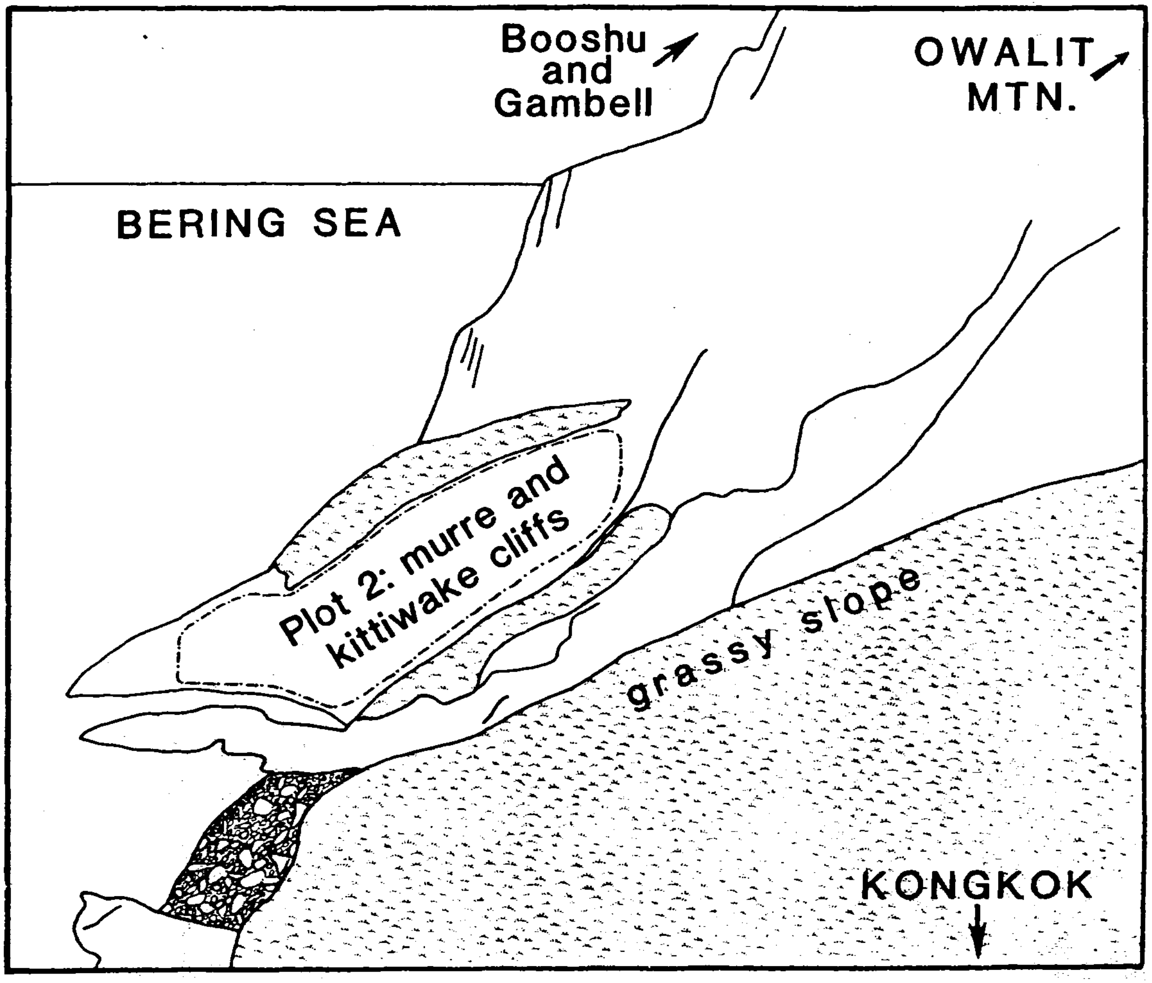
Plot No.	Permanent Marker	Type of Counts Made	Species Counted	1987 Counts Comparable w/Searings?	Land/Boat Counts
1	Area B	1 and 2	Murre BLKI	Yes	Land
2	Area D	1 and 2	Murre BLKI Corm	Yes	Land
3	Area C	2	Murre BLKI	No	Land
4	-	2	Murre	No	Boat
5	Area R	1 (For Corm & BLKI only) 2	Murre BLKI Corm	No	Land
6	Area C	2	Murre	Yes	Land
7	Area J	2	Murre BLKI	-	Land



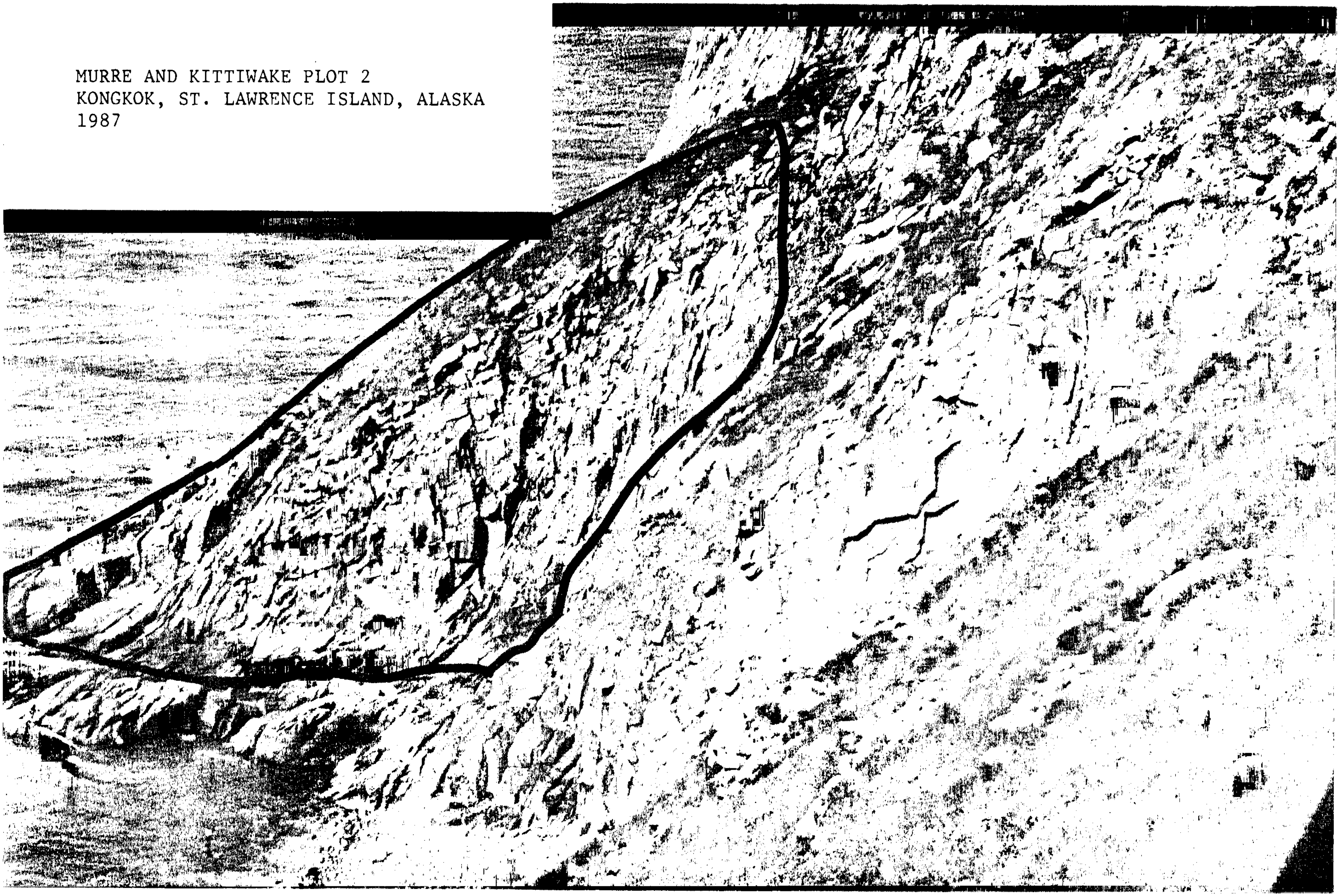
PLOT 1: MURRE AND KITTIWAKE CLIFFS

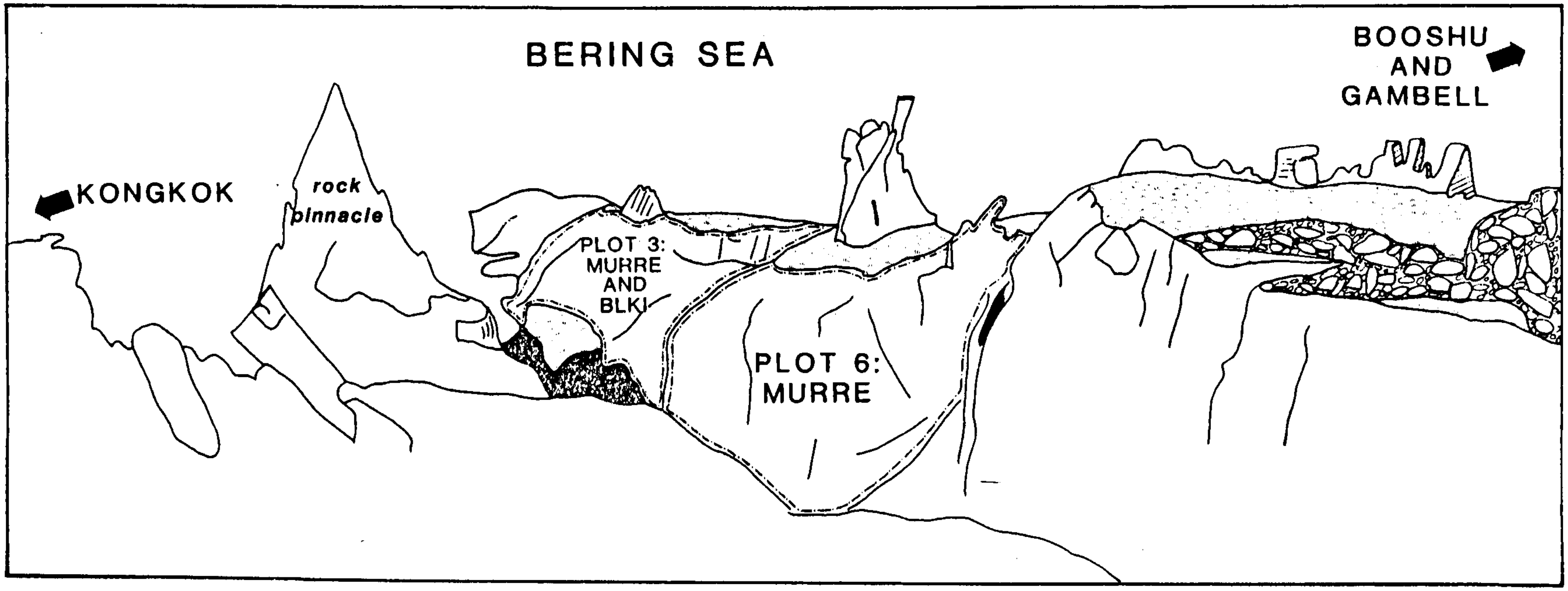


MURRE AND KITTIWAKE PLOT 1
KONGKOK, ST. LAWRENCE ISLAND, ALASKA
1987

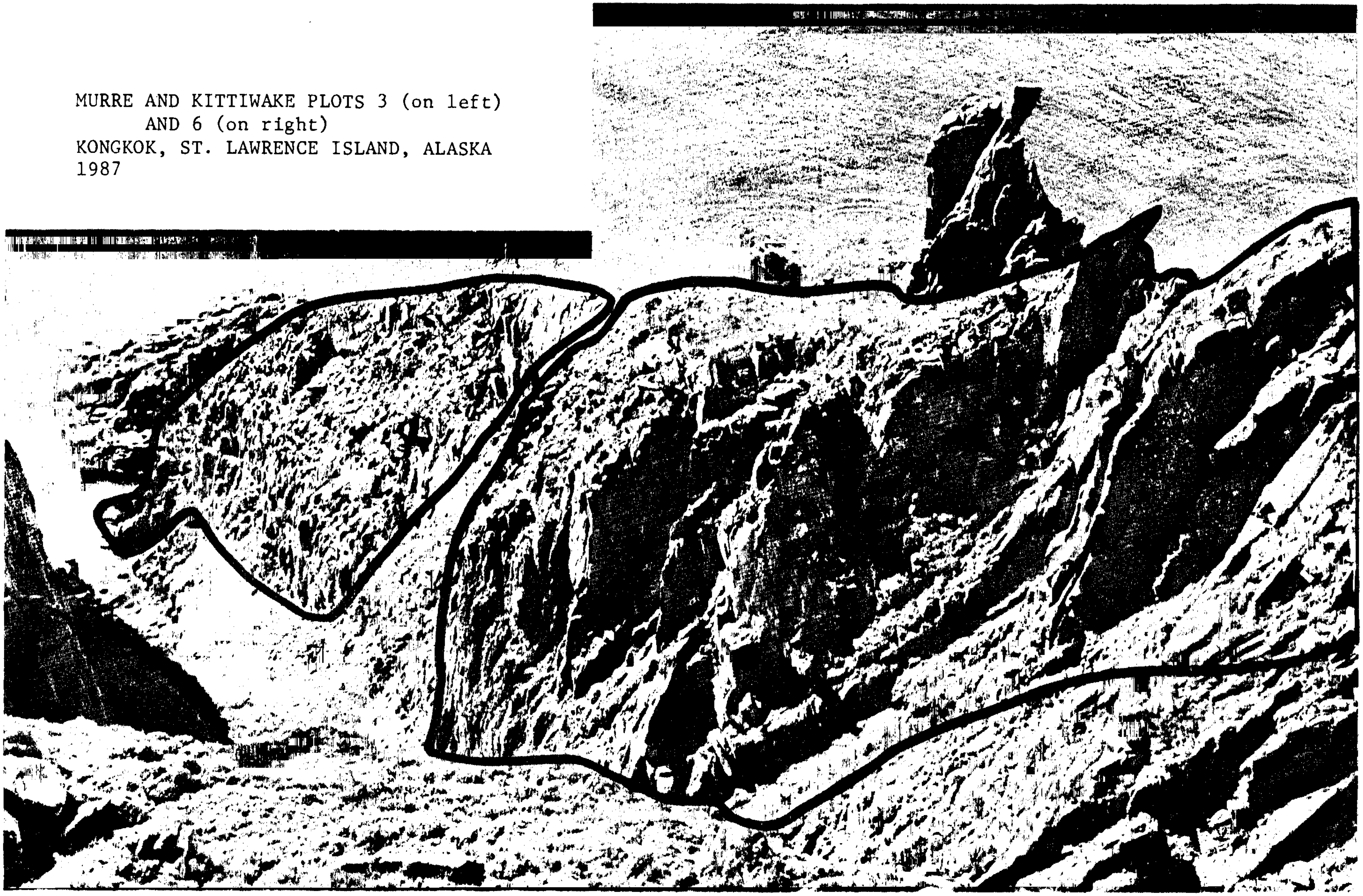

Booshu and Gambell
OWALIT MTN.
BERING SEA
Plot 2: murre and kittiwake cliffs
grassy slope
KONGKOK

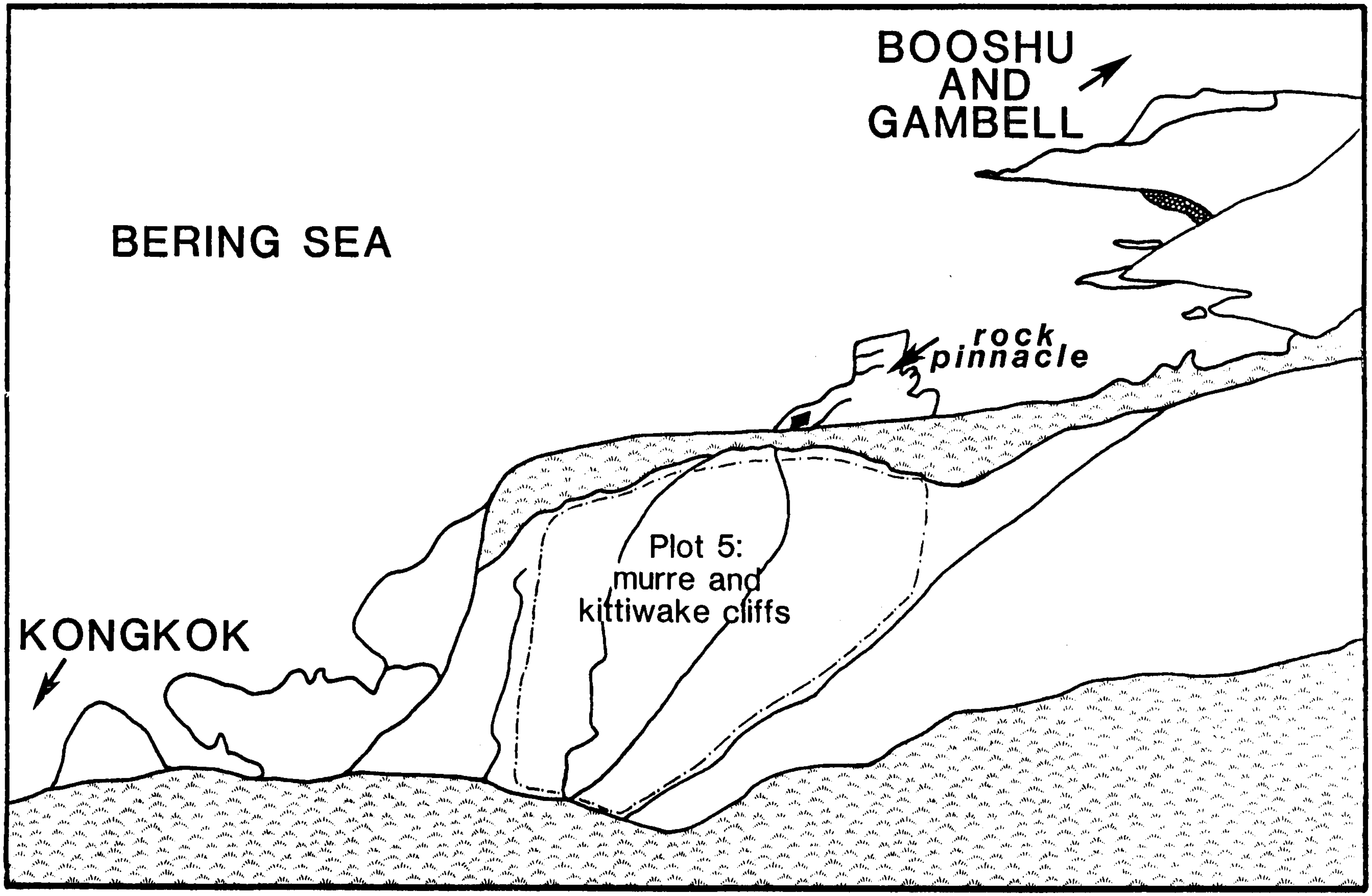
MURRE AND KITTIWAKE PLOT 2
KONGKOK, ST. LAWRENCE ISLAND, ALASKA
1987



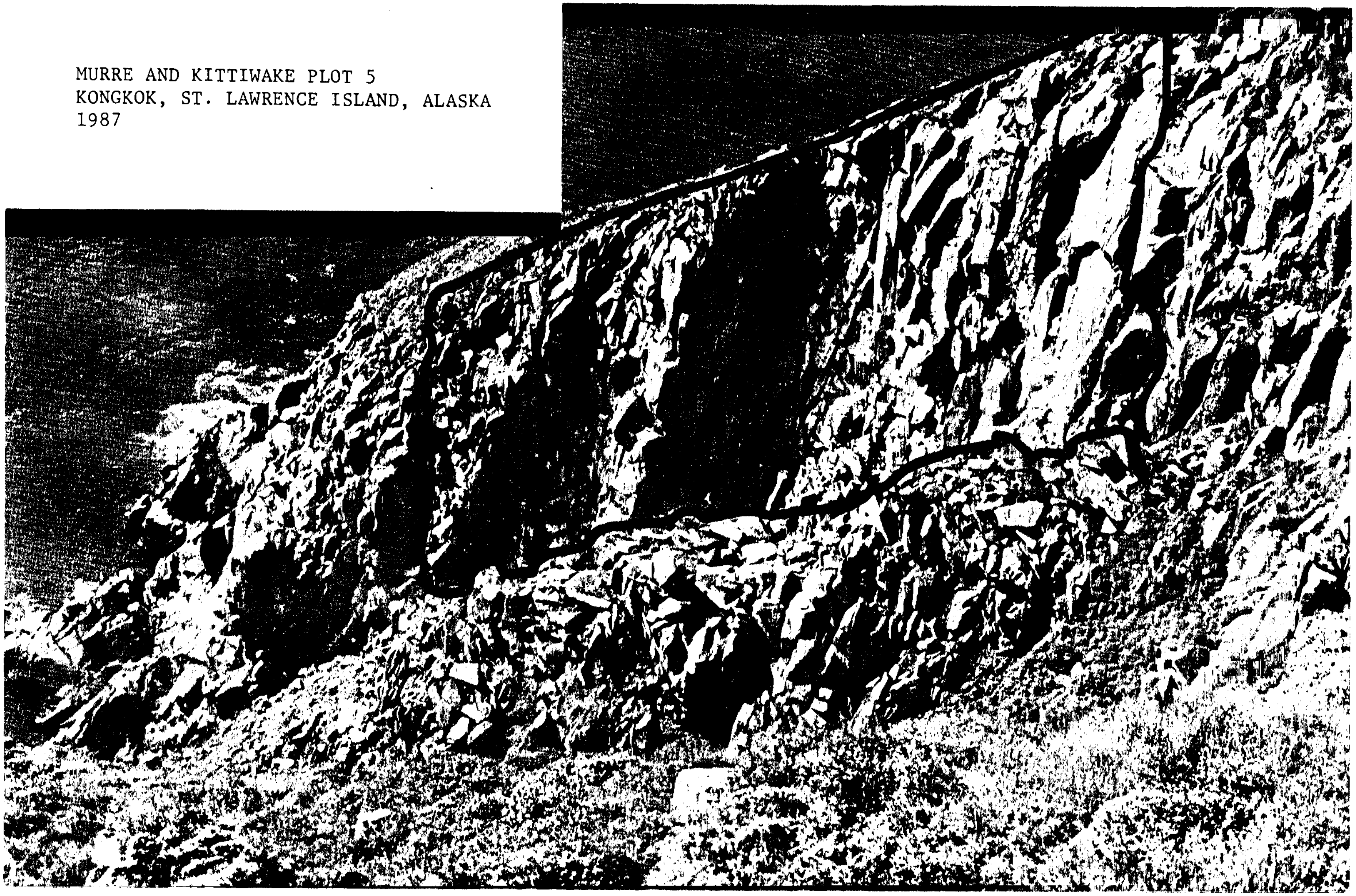

BERING SEA
BOOSHU
AND
GAMBELL
KONGKOK
rock
pinnacle
PLOT 3:
MURRE
AND
BLKI
PLOT 6:
MURRE

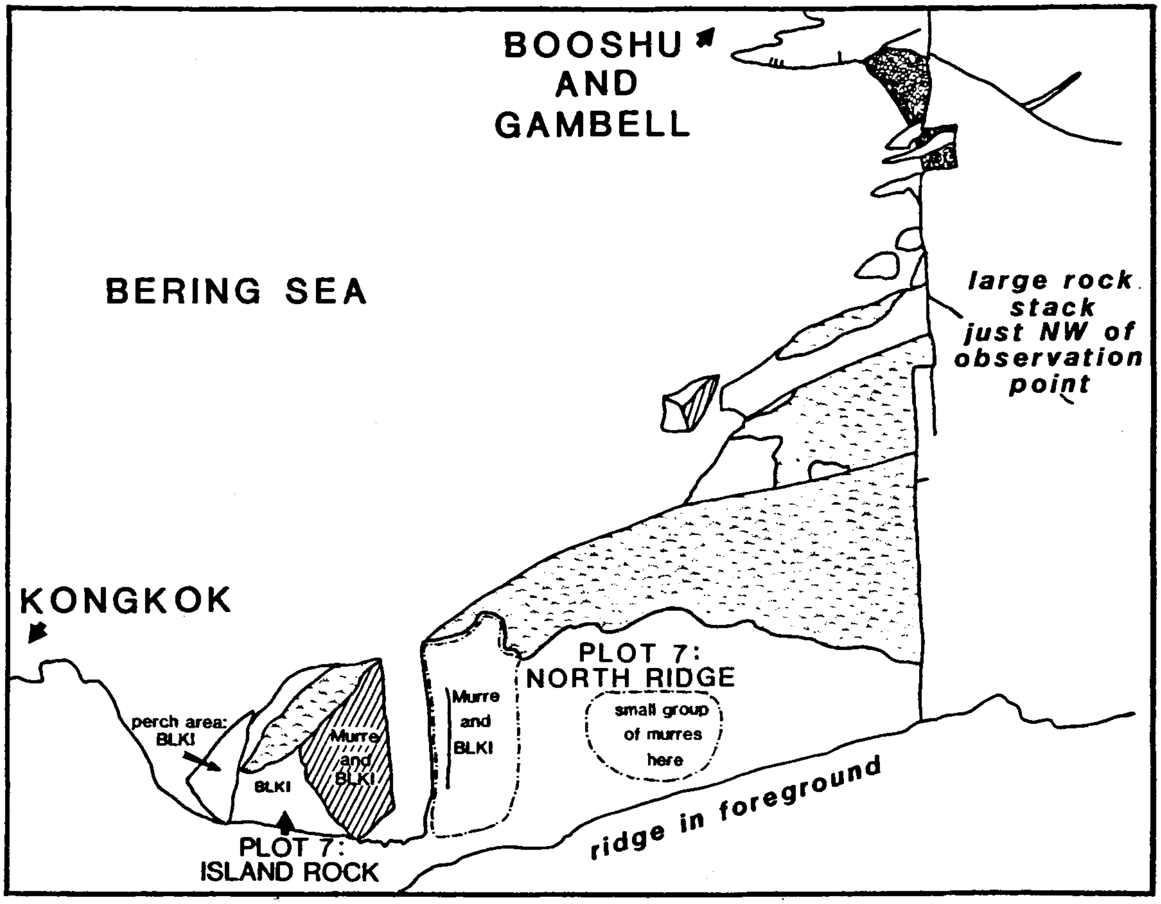
MURRE AND KITTIWAKE PLOTS 3 (on left)
AND 6 (on right)
KONGKOK, ST. LAWRENCE ISLAND, ALASKA
1987



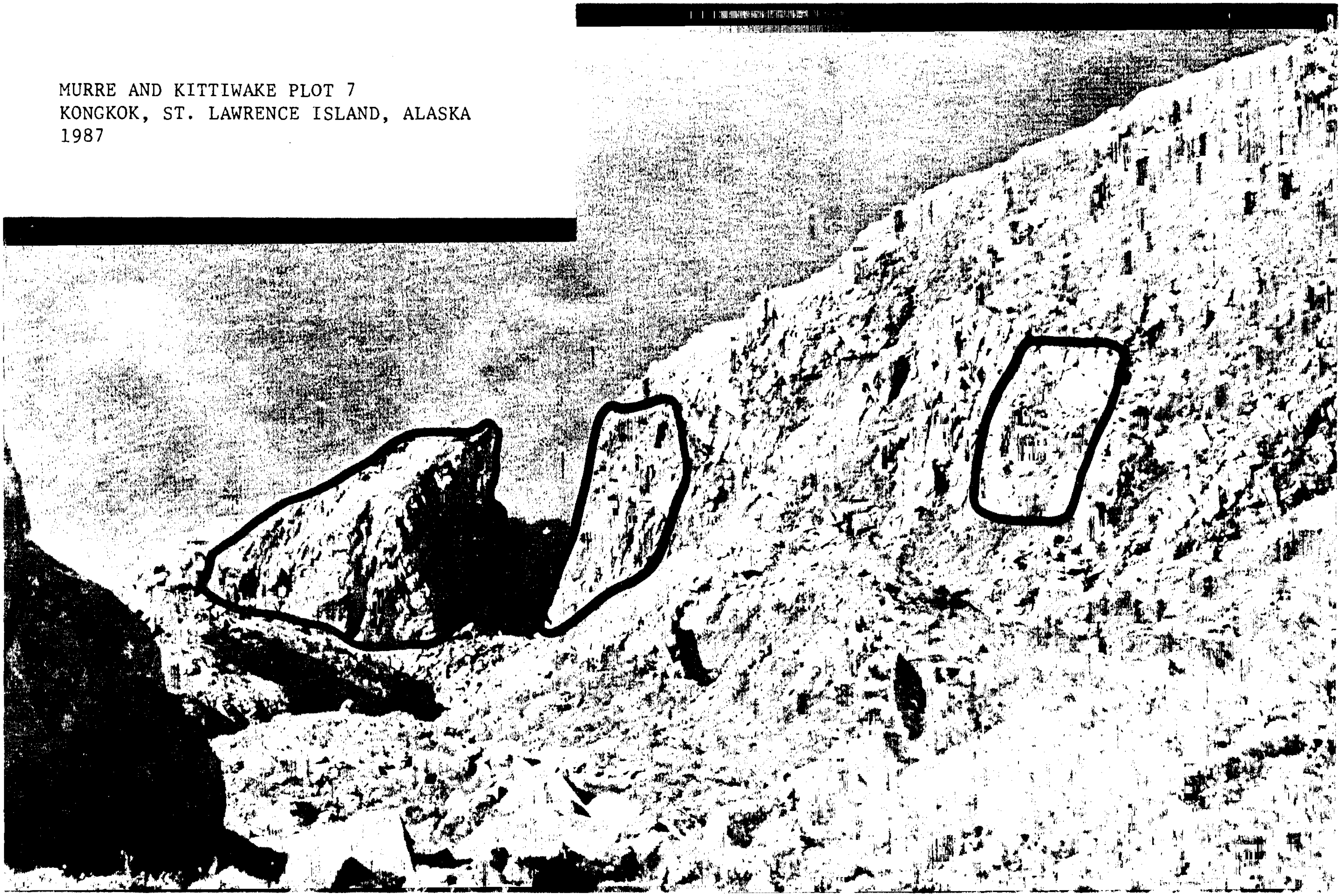

BOOSHU AND GAMBELL
BERING SEA
rock pinnacle
Plot 5: murre and kittiwake cliffs
KONGKOK

MURRE AND KITTIWAKE PLOT 5
KONGKOK, ST. LAWRENCE ISLAND, ALASKA
1987




BOOSHU AND GAMBELL
BERING SEA
large rock stack just NW of observation point
KONGKOK
perch area: BLKI
BLKI
Murre and BLKI
Murre and BLKI
PLOT 7: NORTH RIDGE
small group of murres here
PLOT 7: ISLAND ROCK
ridge in foreground

MURRE AND KITTIWAKE PLOT 7
KONGKOK, ST. LAWRENCE ISLAND, ALASKA
1987



APPENDIX B. STUDY PLOTS FOR CLIFF-NESTING SEABIRDS EAST OF SAVOONGA, ST. LAWRENCE ISLAND

Nine study plots were established for Black-legged Kittiwakes, Common Murres, and Thick-billed Murres along a 1/2 mile stretch of sea cliffs, approximately 6-1/2 miles east-southeast of the town of Savoonga (Fig. A-1). In the following, we provide written descriptions of how to locate the plots, and photographs with plot areas delineated on them.

The area in which the study plots were located is known to local residents as "Mahok". In 1987, John Wells established a field camp at a small cabin at Kookoolik, an old village about 4 1/2 miles east of Savoonga (Fig. A-1). The cabin was rented from its owner, Ivan Pungowiyi of Savoonga, for $25 per day. Trips to and from the study area were made on foot.

LOCATING THE STUDY PLOTS

The coast is low-lying for just over two miles on the walk east from the camp at Kookoolik. The cliffs begin just past a small pond near the shoreline and continue for several miles past Cape Myaughee. Note that the small pond appears in the background of the photograph of Plot 1. Walking along the cliff edge, in a southeasterly direction from the small pond, one encounters a steep-sided stream valley after about 1/4 mile. Climbing out of this valley, the land gradually levels out and, in clear weather, the Stolbi Rocks and the west side of Cape Myaughee appear in the background. Just at the point where Cape Myaughee becomes fully visible, the observer should cut towards the cliff edge. Plot 1 should now be visible to the west. Once Plot 1 has been found, the remaining study plots should be relatively easy to locate as the observer continues along the cliff edge in a southeasterly direction.

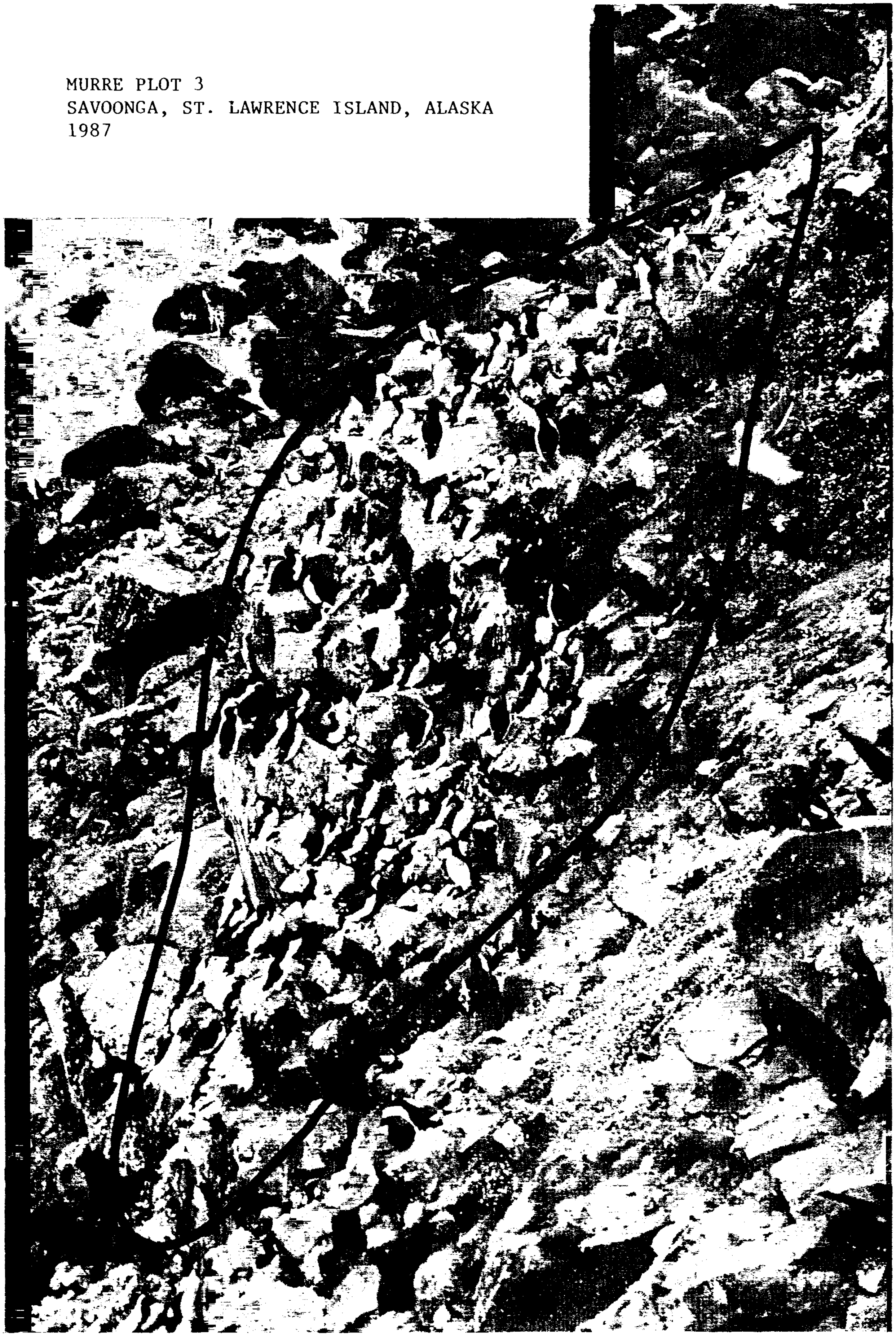
Plot 1	A natural corner in the cliff-edge configuration is the viewing point for Plot 1. Observer looks to the west.
Plot 2-3	These are counted from the same viewing point. The viewing point is a corner in the cliff-edge about 50 feet beyond the Plot 1 viewing point.

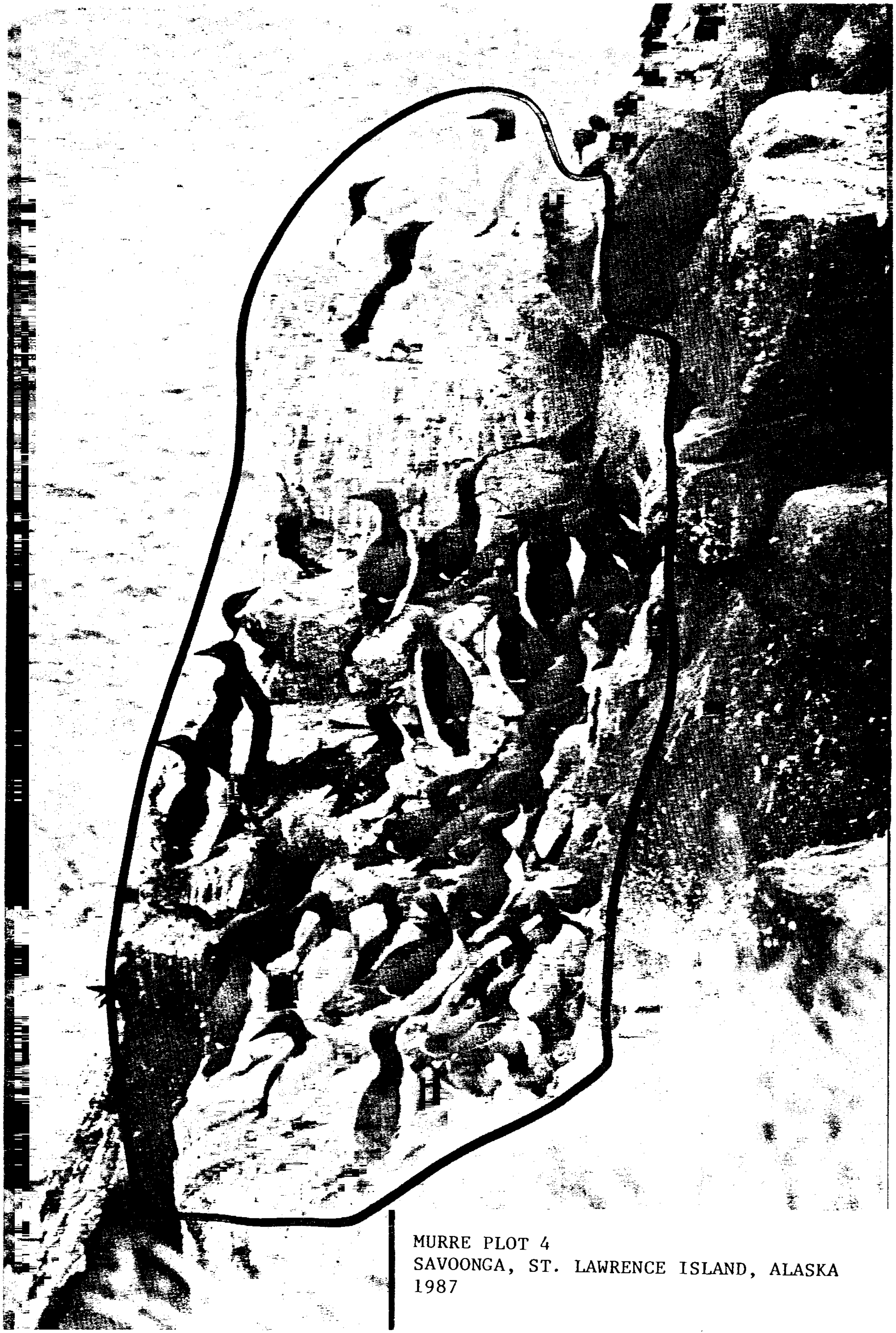
Plot 4	Continue past the viewing point for Plots 2 and 3 for about 100 feet. Plot 4 is near the top of the cliffs and must be approached slowly to avoid flushing the birds. Observer looks to the east.
Plot 5	Continue past Plot 4 for 50-70 m. A loose pile of boulders just inland from the viewing point may be of use in locating this plot. Observer looks down and to the east at this plot.
Plot 6	A rather long walk (about 350-700 m) is required to get from Plot 5 to Plot 6. Plot 6 should be easily recognized by the rock stack on the outer edge (see photograph). It is visible for some distance before the observer reaches the cliff-edge corner which is the viewing point. Observer looks to the east.
Plot 7	Continue past Plot 6 for 120-135 m. Observer looks to the west from a cliff-edge corner.
Plot 8	Immediately past Plot 7. Observer looks down and somewhat to the east of this plot.
Plot 9	Continue past Plot 8 until a large area of vertical, rocky cliff is visible to the immediate east. Plot 9 is counted looking to the east from the cliff-edge.

MURRE PLOT 1
SAVOONGA, ST. LAWRENCE ISLAND, ALASKA
1987

MURRE PLOT 2
SAVOONGA, ST. LAWRENCE ISLAND, ALASKA
1987

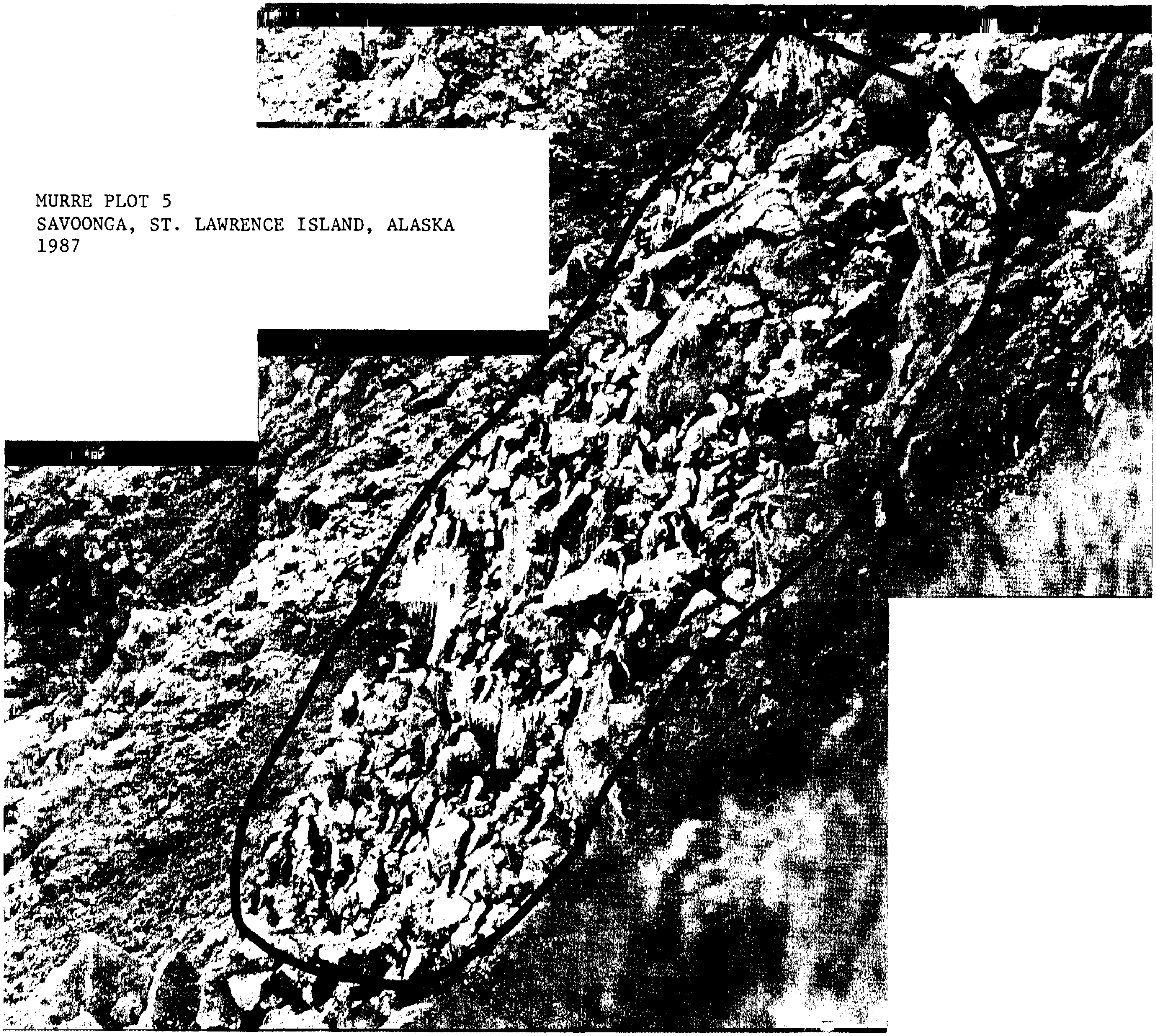
MURRE PLOT 3
SAVOONGA, ST. LAWRENCE ISLAND, ALASKA
1987

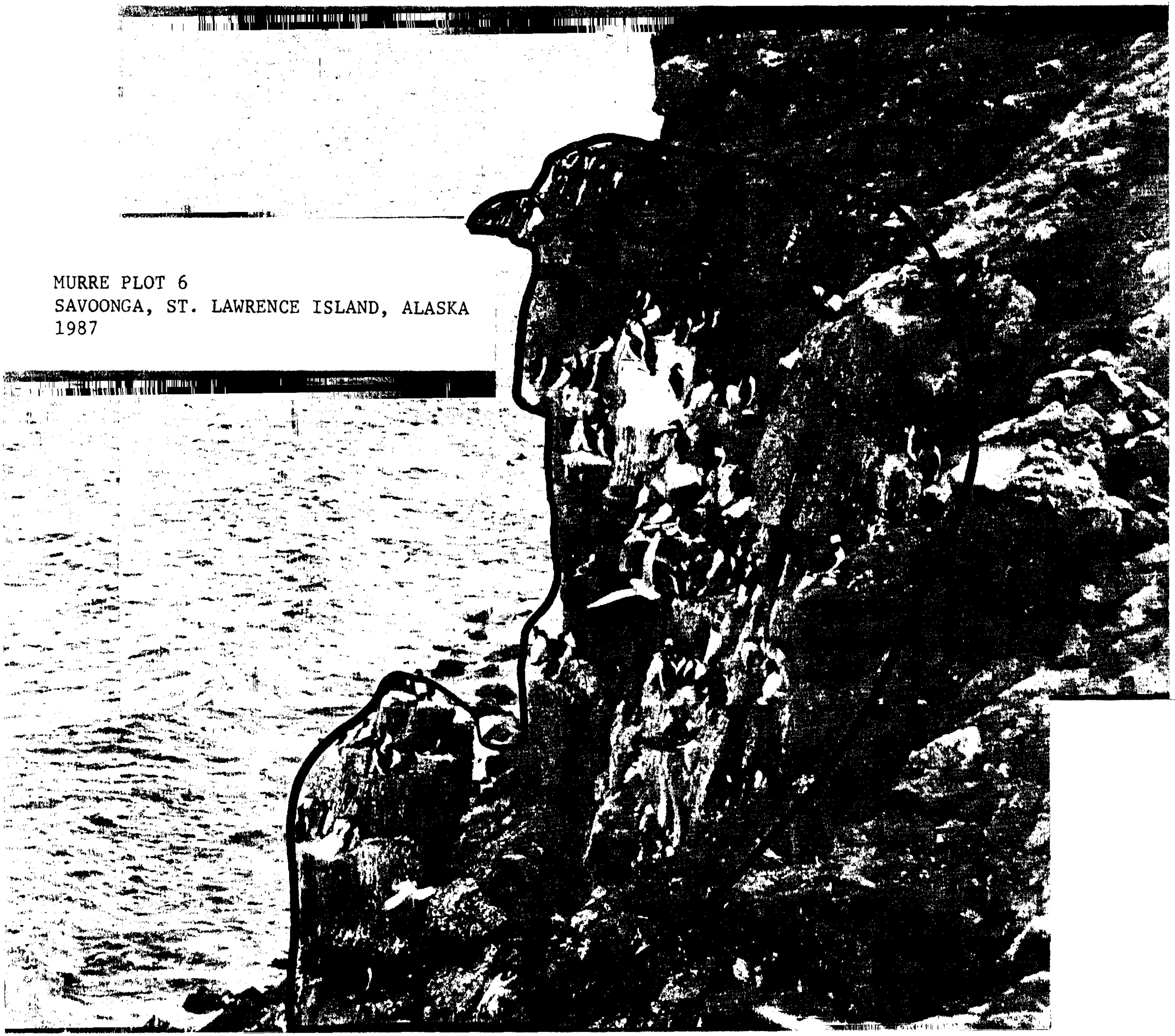




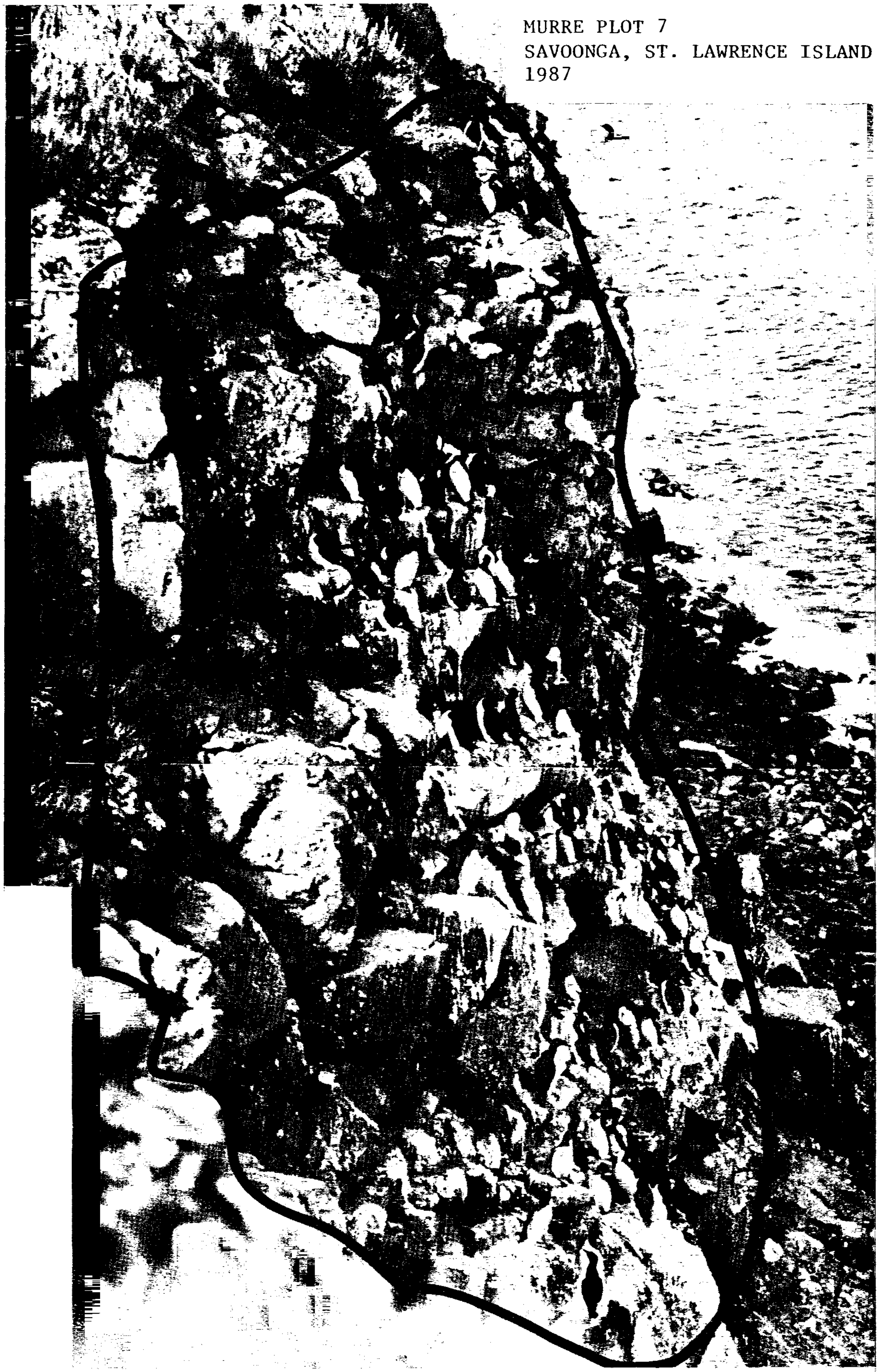
MURRE PLOT 4
SAVOONGA, ST. LAWRENCE ISLAND, ALASKA
1987

MURRE PLOT 5
SAVOONGA, ST. LAWRENCE ISLAND, ALASKA
1987



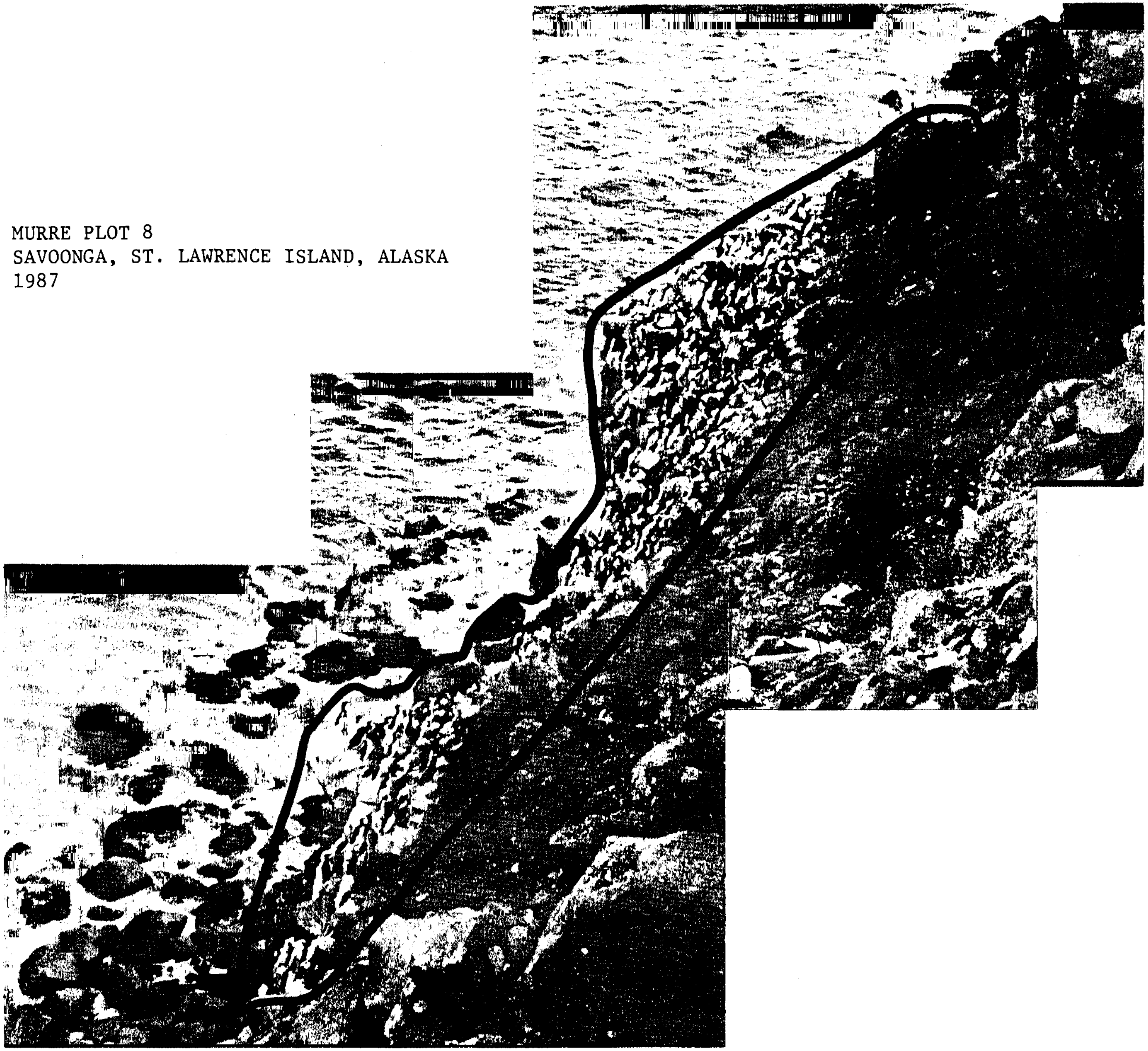


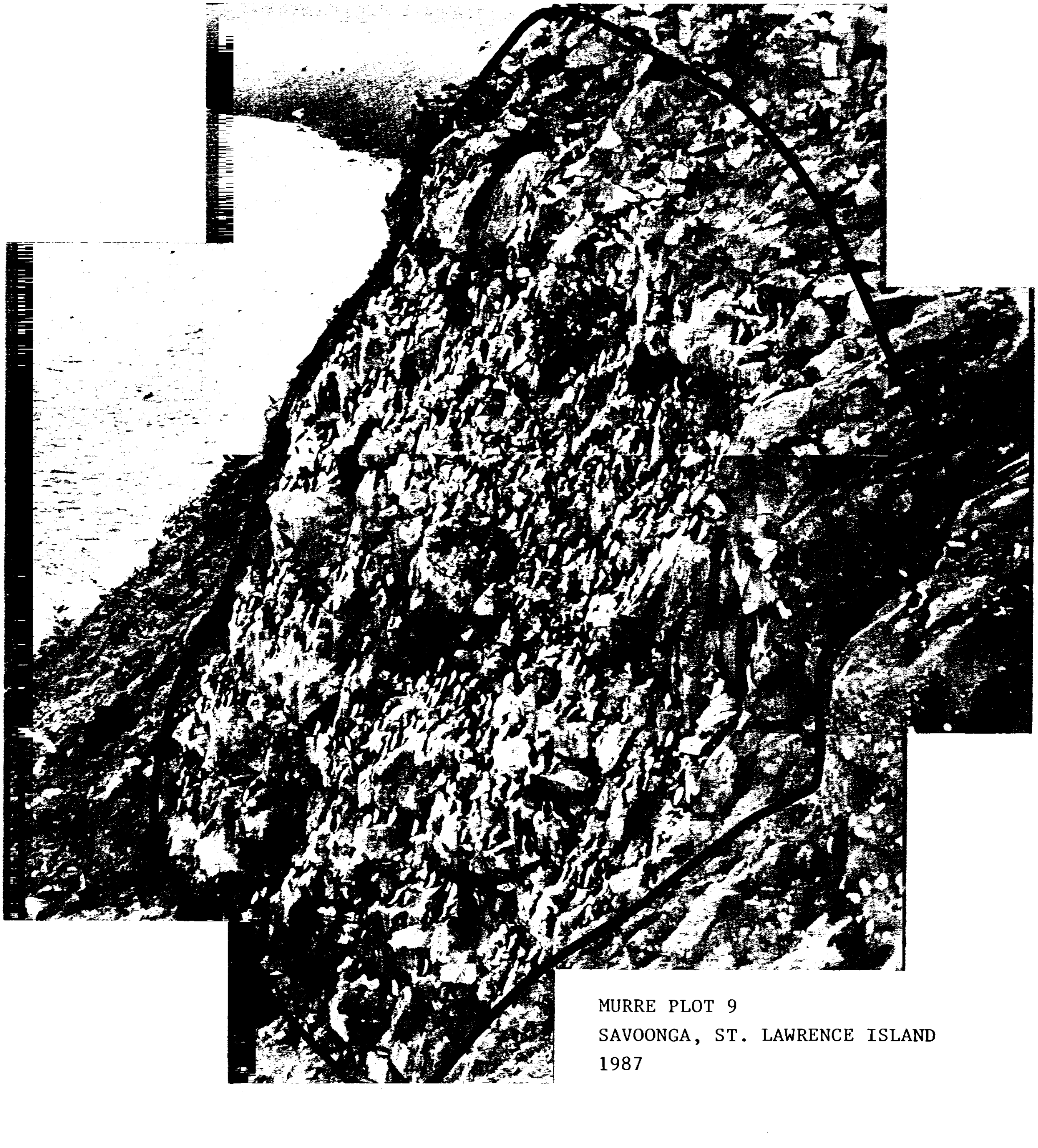
MURRE PLOT 6
SAVOONGA, ST. LAWRENCE ISLAND, ALASKA
1987



MURRE PLOT 7
SAVOONGA, ST. LAWRENCE ISLAND
1987

MURRE PLOT 8
SAVOONGA, ST. LAWRENCE ISLAND, ALASKA
1987





MURRE PLOT 9
SAVOONGA, ST. LAWRENCE ISLAND
1987

APPENDIX C. CRESTED AND LEAST AUKLET STUDY PLOTS AT KONGKOK STUDY AREA ST. LAWRENCE ISALND, ALASKA

A total of 32 auklet study plots were established on the talus slopes of Owalit Mountain (n=16) and Kongkok Basin (n=16). Each plot was 14.2 m on a side or 200 m^2. At Owalit Mountain, all day counts were made at eight of the plots (numbered 1 through 8) and all 16 plots were used for productivity monitoring (Fig. C-1). At Kongkok Basin, all 16 plots were censused but productivity checks were made only at the eight plots located at the south side of the basin (Figs. C-2 and C-3). Permanent brass surveyor's markers (labeled: USFWS SLI PLR Area ___), were placed at plots 1 through 8 at Owalit Mountain so that they could be exactly relocated in the future. The following pages describe the location of the marker within each plot and the compass bearings from the marker to the four corners of the plot. Sketch maps (Figs. C-1, C-2, C-3) indicate the location of all plots, and the locations from which census counts were made.

LOCATIONS OF PERMANENT MARKERS AT AUKLET PLOTS NO. 1-8 AT OWALIT MOUNTAIN

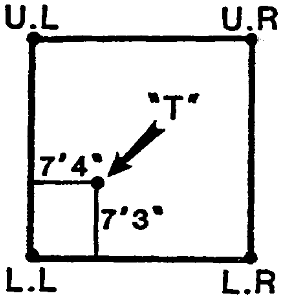
ST. LAWRENCE ISLAND, ALASKA

Note: U = Upper, L = Lower, L = Left, R = Right

Plot 1, Marker "T":

The marker is near the bottom L.L. corner, as the observer faces Owalit Mountain. It is 7'4" from the marker directly left to the left-hand border of the plot and 7'3" from the marker straight down to the bottom edge of the plot.

Bearings taken after compass adjusted for 12° from true north.

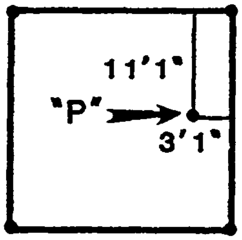


Bearings from marker to:

L.R. corner: 52°
L.L. corner: 180°
U.R. corner: 21°
U.L. corner: 311°

Plot 2, Marker "P":

The marker is near U.R. edge of plot, 3'1" from right-hand plot edge and 11'1" below upper plot edge.

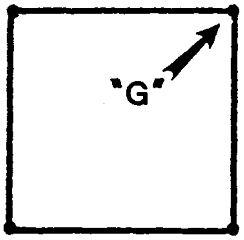


Bearings from marker to:

L.R. corner: 144°
L.L. corner: 189°
U.R. corner: 336°
U.L. corner: 253°

Plot 3, Marker "G":

The marker is located exactly in U.R. corner of the plot.

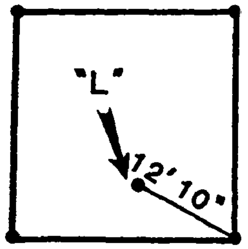


Bearings from marker to:

L.R. corner: 140°
L.L. corner: 190°
U.R. corner: 232°

Plot 4, Marker "L":

The marker is located 12'10" from L.R. corner, at bearing E. 82.

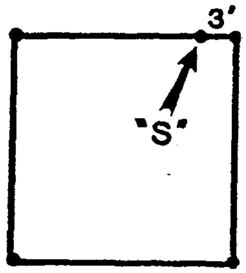


Bearings from marker to:

L.R. corner:	82°
L.L. corner:	236°
U.R. corner:	341°
U.L. corner:	277°

Plot 5, Marker "S":

The marker is located 3' left of U.R. corner, directly on plot boundary.



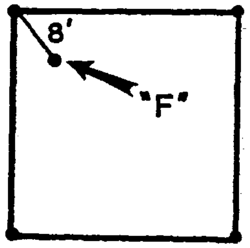
Bearings from marker to:

L.R. corner:	224°
L.L. corner:	180°
U.R. corner:	46°
U.L. corner:	220°

Plot 6, Marker "F":

The marker is located just inside U.L. corner of plot, 8'0" at 280° from marker to U.L. corner.

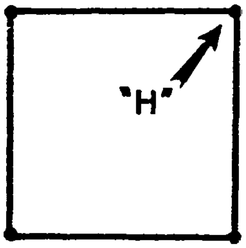
Bearings from marker to:



L.R. corner:	78°
L.L. corner:	144°
U.R. corner:	40°
U.L. corner:	280°

Plot 7, Marker "H":

The marker is located exactly in U.R. corner of plot.

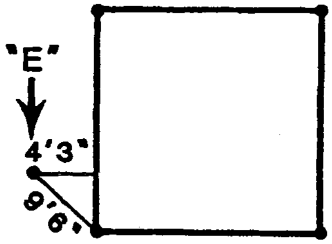


Bearings from marker to:

L.R. corner: 130°
L.L. corner: 190°
U.L. corner: 242°

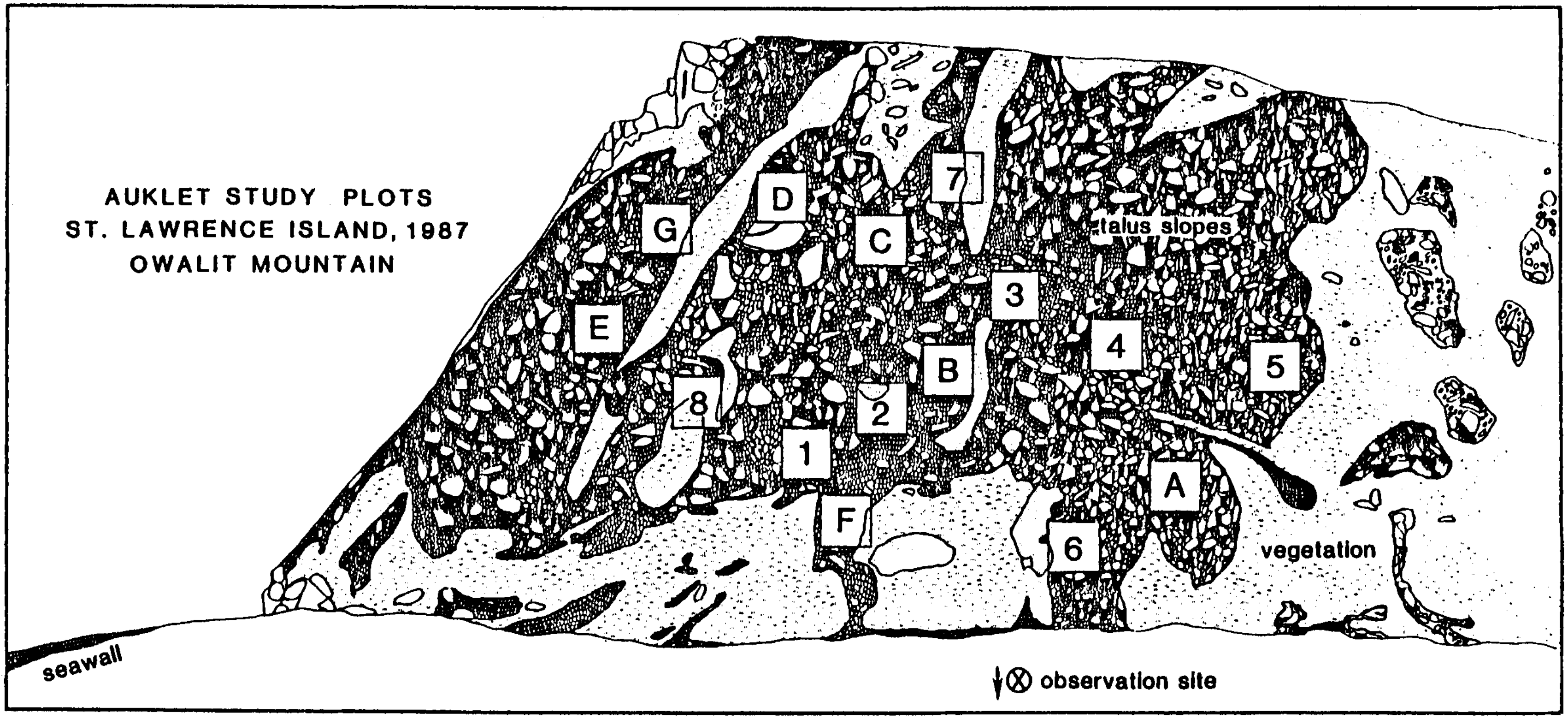
Plot 8, Marker "E":

The marker is located outside the plot. It is 4'3" from the marker directly right to left-hand border of the plot and 9'6" from the marker to the L.L. corner of the plot.

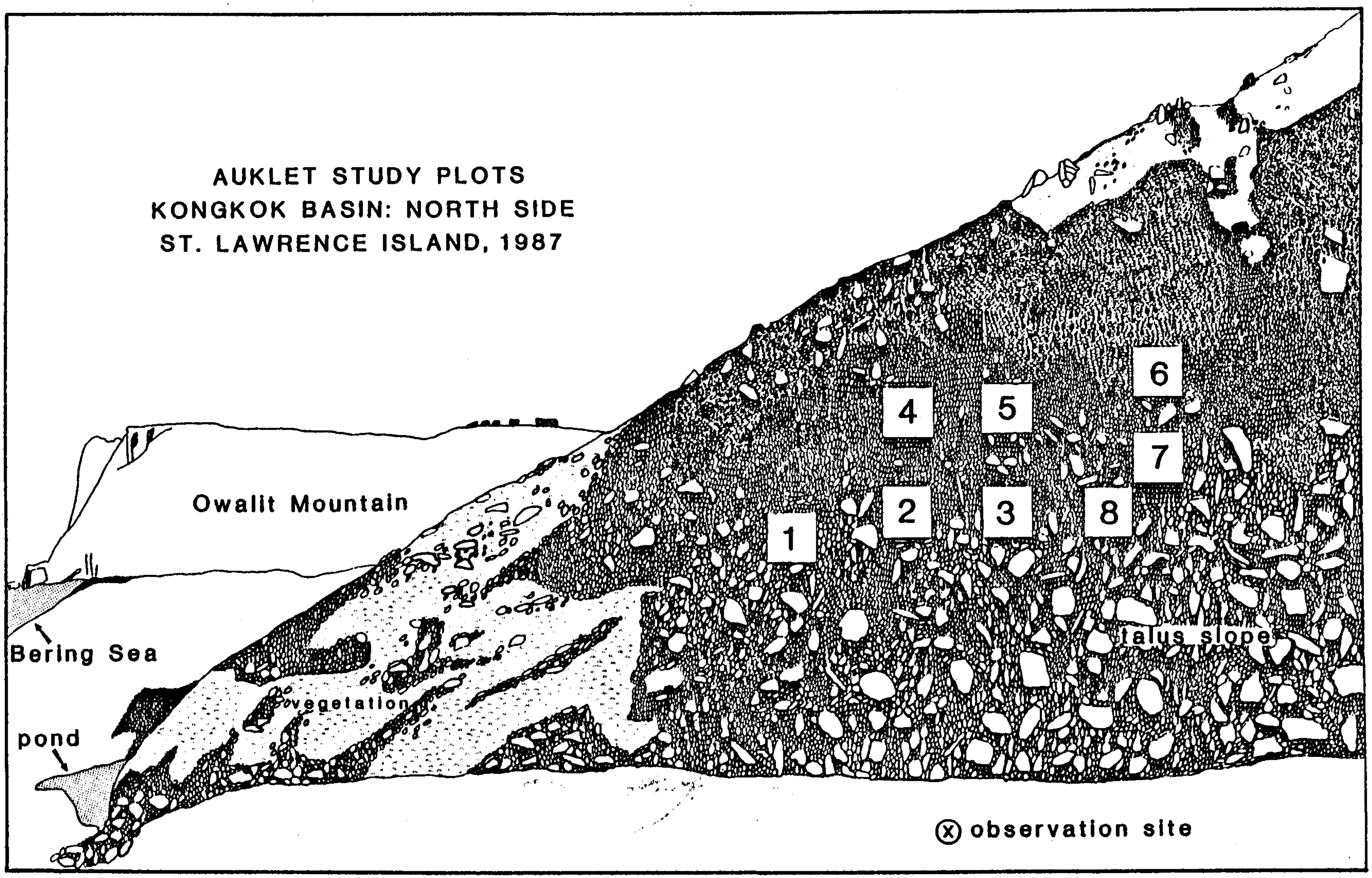


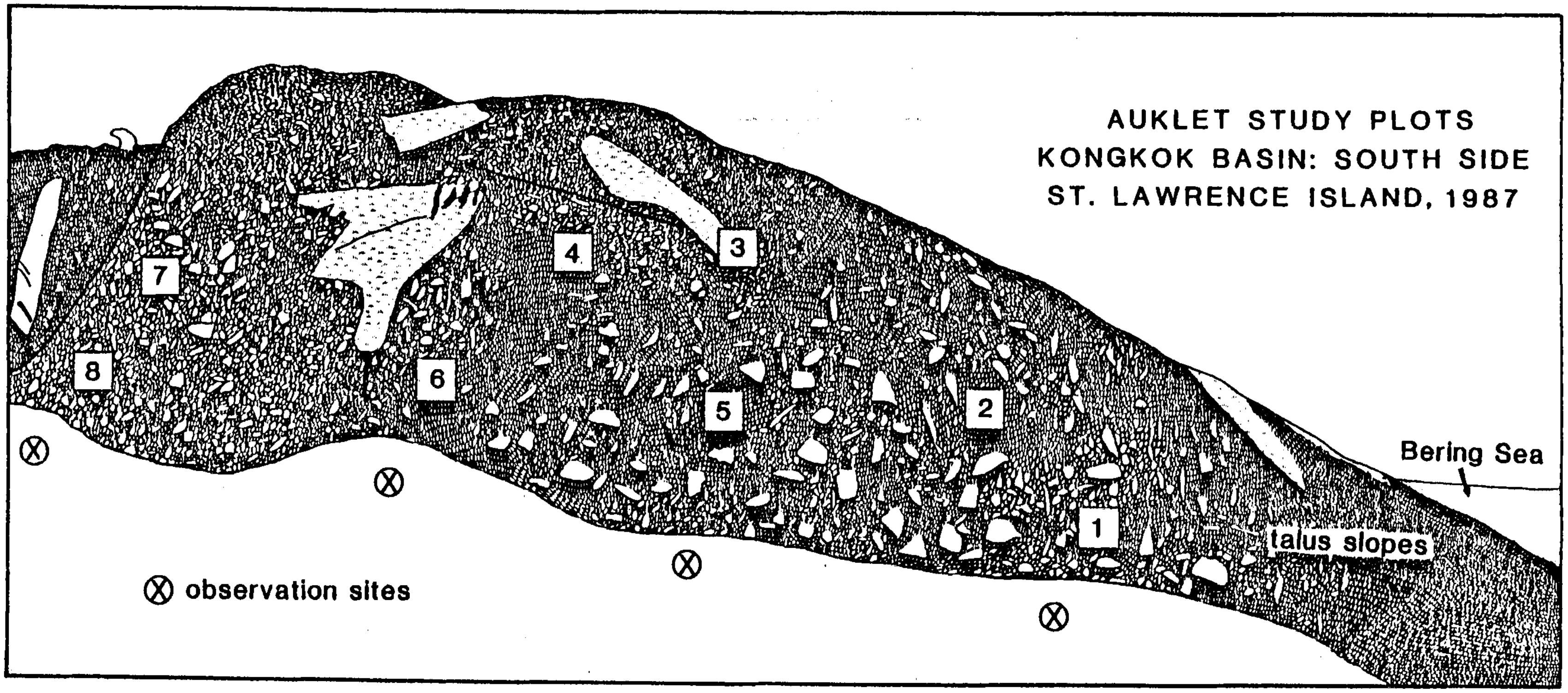
Bearings from marker to:

L.R. corner: 52°
L.L. corner: 101°
U.R. corner: 16°
U.L. corner: 328°



AUKLET STUDY PLOTS
ST. LAWRENCE ISLAND, 1987
OWALIT MOUNTAIN


AUKLET STUDY PLOTS
KONGKOK BASIN: NORTH SIDE
ST. LAWRENCE ISLAND, 1987
Owalit Mountain
Bering Sea
pond
vegetation
talus slope
1
2
3
4
5
6
7
8
ⓧ observation site



AUKLET STUDY PLOTS
KONGKOK BASIN: SOUTH SIDE
ST. LAWRENCE ISLAND, 1987

APPENDIX D. COUNTS OBTAINED ON MURRE PLOTS 1-7, BLACK-LEGGED KITTIWAKE PLOTS 1-7, AND ON THE AUKLET PLOTS ON OWALIT MOUNTAIN

(COUNTS FOR PLOTS 1-8 COMBINED)

COUNTS ON MURRE PLOTS, SLI, 1987

OBS	DATE	MUPLOT1	MUPLOT2	MUPLOT3	MUPLOT5	MUPLOT6	MUPLOT7
1	280587	.	.	550	400	.	.
2	310587	.	.	651	780	.	.
3	20687	.	.	1027	.	348	300
4	30687	.	.	289	.	197	62
5	60687	.	.	850	1009	.	397
6	80687	.	0	0	0	0	0
7	90687	.	178	718	664	487	307
8	100687	.	56	654	421	387	100
9	110687	.	267	734	467	306	121
10	120687	.	508	1208	840	597	446
11	130687	.	71	593	321	237	220
12	140687	.	441	.	.	211	286
13	150687	.	334	1035	750	379	226
14	160687	.	171	.	544	286	239
15	170687	.	436	1348	474	315	244
16	180687	.	311	.	.	.	.
17	190687	122	143	.	.	.	.
18	200687	.	311	561	512	242	146
19	210687	160	128	1054	745	373	221
20	220687	575	433	.	.	.	.
21	230687	104	.	.	266	84	45
22	240687	431	216	.	.	.	.
23	250687	174	.	.	.	.	.
24	260687	.	118	339	368	124	53
25	270687	187	127	.	.	.	.
26	280687	368	277	.	.	.	.
27	300687	441	.	.	.	.	.
28	10787	446	272	905	691	351	298
29	20787	463	265	739	783	434	232
30	30787	411	228	.	.	.	.
31	40787	.	249	.	.	.	.
32	50787	496	301	.	.	.	.
33	60787	356	203	765	691	257	227
34	70787	.	231	.	.	.	.
35	90787	383	276	.	.	.	.
36	110787	492	289	.	.	.	.
37	120787	501	301	1007	851	446	341
38	130787	372	263	.	.	.	.
39	150787	446	264	.	.	.	.
40	160787	.	.	.	.	.	.

COUNTS ON MURRE PLOTS, SLI, 1987

OBS	DATE	MUPLOT1	MUPLOT2	MUPLOT3	MUPLOT5	MUPLOT6	MUPLOT7
41	170787	459	311	1013	889	413	294
42	180787	402	.	.	.	.	.
43	200787	413	285	.	.	.	.
44	210787	436	278	.	.	.	.
45	220787	475	318	.	.	.	.
46	230787	.	274	.	.	.	.
47	240787	407	286	.	.	.	.
48	250787	412	212	554	741	212	203
49	260787	505	287	.	.	.	.
50	270787	471	330	.	.	.	.
51	280787	500	366	.	.	.	.
52	300787	444	254	1218	1062	393	226
53	310787	463	321	.	.	.	.
54	10887	494	.	.	.	.	.
55	30887	634	.	.	.	.	.
56	40887	450	324	.	.	.	.
57	50887	519	349	1208	972	328	348
58	60887	497	350	.	.	.	.
59	70887	468	.	.	.	.	.
60	80887	465	335	.	.	.	.
61	90887	401	286	.	.	.	.
62	110887	506	348	.	.	.	.
63	120887	.	.	.	.	.	.
64	130887	519	408	.	.	.	.
65	140887	.	419	.	.	.	.
66	170887	488	353	.	.	.	.
67	180887	428	363	.	.	.	.
68	190887	435	363	.	.	.	.
69	220887	470	386	.	.	.	.
70	230887	420	303	.	.	.	.
71	240887	415	.	.	.	.	.
72	260887	402	.	.	.	.	.
73	270887	371	244	775	454	175	237
74	280887	.	232	.	.	.	.
75	290887	192	178	.	.	.	.
76	300887	301	157	.	.	.	.
77	310887	71	39	.	.	.	.
78	10987	327	311	.	.	.	.
79	20987	168	171	.	.	.	.

COUNTS ON KITTIWAKE PLOTS, SLI, 1987

OBS	DATE	KWPLOT1	KWPLOT2	KWPLOT3	KWPLOT5	KWPLOT7
1	280587	.	.	230	280	.
2	310587	.	.	209	172	.
3	20687	.	.	204	.	233
4	30687	.	.	73	.	189
5	60687	.	.	98	178	346
6	80687	.	.	0	16	41
7	90687	.	64	85	211	231
8	100687	.	25	43	144	175
9	110687	.	47	38	96	125
10	120687	.	55	62	101	202
11	130687	.	34	41	150	220
12	140687	.	57	51	.	247
13	150687	.	61	107	144	304
14	160687	.	66	.	184	323
15	170687	.	76	91	183	259
16	180687	.	101	.	.	.
17	190687	.	.	.	.	.
18	200687	.	105	50	195	169
19	210687	84	159	94	184	246
20	220687	87	92	.	.	.
21	230687	39	.	.	88	131
22	240687	96	66	.	.	.
23	250687	72	.	.	.	.
24	260687	.	62	29	160	132
25	270687	48	84	.	.	.
26	280687	81	66	.	.	.
27	300687	95	.	.	.	.
28	10787	69	72	71	168	205
29	20787	89	75	52	148	193
30	30787	91	69	.	.	.
31	40787	.	75	.	.	.
32	50787	93	79	.	.	.
33	60787	77	68	28	161	188
34	70787	.	72	.	.	.
35	90787	69	55	.	.	.
36	110787	80	83	.	.	.
37	120787	99	92	94	179	344
38	130787	71	75	.	.	.
39	150787	83	76	.	.	.
40	160787	.	.	.	.	.

COUNTS ON KITTIWAKE PLOTS, SLI, 1987

OBS	DATE	KWPLOT1	KWPLOT2	KWPLOT3	KWPLOT5	KWPLOT7
41	170787	64	58	64	135	180
42	180787	64	.	.	.	.
43	200787	79	67	.	.	.
44	210787	90	79	.	.	.
45	220787	82	92	.	.	.
46	230787	.	79	.	.	.
47	240787	87	70	.	.	.
48	250787	74	45	40	127	194
49	260787	73	76	.	.	.
50	270787	53	67	.	.	.
51	280787	84	80	.	.	.
52	300787	67	68	78	176	201
53	310787	92	87	.	.	.
54	10887	75	.	.	.	.
55	30887	101	.	.	.	.
56	40887	98	89	.	.	.
57	50887	96	86	65	157	228
58	60887	101	87	.	.	.
59	70887	73	.	.	.	.
60	80887	84	74	.	.	.
61	90887	66	61	.	.	.
62	110887	91	87	.	.	.
63	120887	.	.	.	.	.
64	130887	88	79	.	.	.
65	140887	.	86	.	.	.
66	170887	69	65	.	.	.
67	180887	87	76	.	.	.
68	190887	72	57	.	.	.
69	220887	45	48	.	.	.
70	230887	53	34	.	.	.
71	240887	67	.	.	.	.
72	260887	62	.	.	.	.
73	270887	57	79	71	129	171
74	280887	.	46	.	.	.
75	290887	17	40	.	.	.
76	300887	57	35	.	.	.
77	310887	13	17	.	.	.
78	10987	85	87	.	.	.
79	20987	22	43	.	.	.

AUKLET COUNTS ON OWALIT MTN, SLI, 1987

OBS	DATE	TIME	CRESTED	LEAST
1	20687	500	108	192
2	20687	530	164	272
3	20687	600	214	310
4	20687	630	211	324
5	20687	700	159	412
6	20687	730	134	384
7	20687	800	137	323
8	20687	830	45	245
9	20687	900	33	172
10	20687	930	16	89
11	20687	1000	8	7
12	20687	1030	0	2
13	20687	1100	0	0
14	20687	1130	0	0
15	20687	1200	0	0
16	20687	1230	0	0
17	20687	1300	0	0
18	20687	1330	0	0
19	20687	1400	0	0
20	20687	1430	0	0
21	20687	1500	0	0
22	20687	1530	0	0
23	20687	1600	0	0
24	20687	1630	0	0
25	20687	1700	0	0
26	20687	1730	0	0
27	20687	1800	0	0
28	20687	1830	0	0
29	20687	1900	0	0
30	20687	1930	0	1
31	20687	2000	15	0
32	20687	2030	13	1
33	20687	2100	50	1
34	20687	2130	66	1
35	20687	2200	174	17
36	20687	2230	197	52
37	20687	2300	209	92
38	20687	2330	217	139
39	30687	0	117	176
40	30687	30	114	172

AUKLET COUNTS ON OWALIT MTN, SLI, 1987

OBS	DATE	TIME	CRESTED	LEAST
41	50687	500	113	270
42	50687	530	196	246
43	50687	600	227	333
44	50687	630	234	310
45	50687	700	211	391
46	50687	730	268	394
47	50687	800	238	440
48	50687	830	206	391
49	50687	930	69	81
50	50687	1000	27	3
51	50687	1030	12	0
52	50687	1100	0	0
53	50687	1130	0	0
54	50687	1200	0	0
55	50687	1230	0	0
56	50687	1300	0	0
57	50687	1330	0	0
58	50687	1400	0	0
59	50687	1430	0	0
60	50687	1500	0	0
61	50687	1530	0	0
62	50687	1600	0	0
63	50687	1630	0	0
64	50687	1700	0	0
65	50687	1730	0	0
66	50687	1800	0	0
67	50687	1830	0	0
68	50687	1900	0	0
69	50687	1930	1	0
70	50687	2000	4	0
71	50687	2030	11	0
72	50687	2100	15	0
73	50687	2130	26	0
74	50687	2200	55	6
75	50687	2230	114	30
76	50687	2300	186	50
77	50687	2330	202	84
78	60687	0	219	124
79	60687	30	151	182
80	80687	500	0	3

AUKLET COUNTS ON OWALIT MTN, SLI, 1987

OBS	DATE	TIME	CRESTED	LEAST
81	80687	530	0	14
82	80687	600	5	18
83	80687	630	15	39
84	80687	700	0	40
85	80687	730	2	18
86	80687	800	0	1
87	80687	830	0	5
88	80687	900	0	0
89	80687	930	0	0
90	80687	1000	0	0
91	80687	1030	0	0
92	80687	1100	0	0
93	80687	1130	0	0
94	80687	1200	0	0
95	80687	1230	0	0
96	80687	1300	0	0
97	80687	1330	0	0
98	80687	1400	0	0
99	80687	1430	0	0
100	80687	1500	0	0
101	80687	1530	0	0
102	80687	1600	0	0
103	80687	1630	0	0
104	80687	1700	0	0
105	80687	1730	0	0
106	80687	1800	0	0
107	80687	1830	0	0
108	80687	1900	0	0
109	80687	1930	0	0
110	80687	2000	2	0
111	80687	2030	3	0
112	80687	2100	12	1
113	80687	2130	16	3
114	80687	2200	30	4
115	80687	2230	35	6
116	80687	2300	28	9
117	80687	2330	20	12
118	90687	0	17	14
119	110687	500	4	12
120	110687	530	23	53

AUKLET COUNTS ON OWALIT MTN, SLI, 1987

OBS	DATE	TIME	CRESTED	LEAST
121	110687	600	12	58
122	110687	630	32	86
123	110687	700	25	79
124	110687	730	23	65
125	110687	800	9	45
126	110687	830	4	40
127	110687	900	0	1
128	110687	930	0	2
129	110687	1000	0	0
130	110687	1030	0	0
131	110687	1100	0	0
132	110687	1130	0	0
133	110687	1200	0	0
134	110687	1230	0	0
135	110687	1300	0	0
136	110687	1330	0	0
137	110687	1400	0	0
138	110687	1430	0	0
139	110687	1500	0	0
140	110687	1530	0	0
141	110687	1600	0	0
142	110687	1630	0	0
143	110687	1700	0	0
144	110687	1730	0	0
145	110687	1800	0	0
146	110687	1830	0	0
147	110687	1900	0	0
148	110687	1930	0	0
149	110687	2000	0	0
150	110687	2030	1	0
151	110687	2100	1	0
152	110687	2130	6	1
153	110687	2200	27	9
154	110687	2230	18	17
155	110687	2300	8	12
156	110687	2330	7	22
157	120687	0	32	43
158	120687	30	7	55
159	120687	100	1	36
160	260687	0	53	37

AUKLET COUNTS ON OWALIT MTN, SLI, 1987

OBS	DATE	TIME	CRESTED	LEAST
161	260687	30	119	135
162	260687	100	66	126
163	260687	130	48	92
164	250687	500	113	192
165	250687	530	200	186
166	250687	600	262	297
167	250687	630	242	259
168	250687	700	270	286
169	250687	730	230	222
170	250687	800	193	218
171	250687	830	153	176
172	250687	900	148	201
173	250687	930	145	195
174	250687	1000	96	153
175	250687	1030	65	110
176	250687	1100	54	153
177	250687	1130	34	141
178	250687	1200	11	70
179	250687	1230	10	53
180	250687	1300	0	5
181	250687	1330	0	0
182	250687	1400	0	0
183	250687	1430	0	0
184	250687	1500	0	0
185	250687	1530	0	0
186	250687	1600	0	0
187	250687	1630	0	0
188	250687	1700	0	0
189	250687	1730	0	0
190	250687	1800	0	0
191	250687	1830	0	0
192	250687	1900	0	1
193	250687	1930	0	0
194	250687	2000	0	0
195	250687	2030	0	2
196	250687	2100	0	0
197	250687	2130	1	0
198	250687	2200	2	2
199	250687	2230	12	2
200	250687	2300	24	2

AUKLET COUNTS ON OWALIT MTN, SLI, 1987

OBS	DATE	TIME	CRESTED	LEAST
201	250687	2330	41	11
202	20787	600	110	260
203	20787	630	188	357
204	20787	700	201	152
205	20787	730	229	296
206	20787	800	157	238
207	20787	830	230	247
208	20787	900	181	173
209	20787	930	176	193
210	20787	1000	150	162
211	20787	1030	153	125
212	20787	1100	153	129
213	20787	1130	142	144
214	20787	1200	65	138
215	20787	1230	74	98
216	20787	1300	30	91
217	20787	1330	9	31
218	20787	1400	4	11
219	20787	1430	0	0
220	20787	1500	0	0
221	20787	1530	0	0
222	20787	1600	0	0
223	20787	1630	0	0
224	20787	1700	0	0
225	20787	1730	0	0
226	20787	1800	0	0
227	20787	1830	0	0
228	20787	1900	0	0
229	20787	1930	0	0
230	20787	2000	0	0
231	20787	2030	2	0
232	20787	2100	2	0
233	20787	2130	0	0
234	20787	2200	0	0
235	20787	2230	0	0
236	20787	2300	21	3
237	20787	2330	37	6
238	30787	0	59	16
239	30787	30	100	49
240	30787	100	68	72

AUKLET COUNTS ON OWALIT MTN, SLI, 1987

OBS	DATE	TIME	CRESTED	LEAST
241	30787	130	114	187
242	30787	200	51	198
243	40787	500	5	133
244	40787	530	36	186
245	40787	600	118	265
246	40787	630	138	252
247	40787	700	112	234
248	40787	730	159	255
249	40787	800	212	305
250	40787	830	202	263
251	40787	900	129	168
252	40787	930	225	256
253	40787	1000	218	237
254	40787	1030	245	238
255	40787	1100	255	248
256	40787	1130	222	236
257	40787	1200	127	142
258	40787	1230	93	142
259	40787	1300	20	68
260	40787	1330	0	10
261	40787	1400	0	2
262	40787	1430	0	3
263	40787	1500	0	0
264	40787	1530	0	0
265	40787	1600	0	0
266	40787	1630	0	0
267	40787	1700	0	0
268	40787	1730	0	0
269	40787	1800	0	0
270	40787	1830	0	0
271	40787	1900	0	0
272	40787	1930	0	0
273	40787	2000	0	0
274	40787	2030	0	0
275	40787	2100	1	0
276	40787	2130	1	0
277	40787	2200	2	2
278	40787	2230	9	0
279	40787	2300	31	4
280	40787	2330	76	11

AUKLET COUNTS ON OWALIT MTN, SLI, 1987

OBS	DATE	TIME	CRESTED	LEAST
281	50787	0	113	103
282	50787	30	119	252
283	50787	100	124	261
284	50787	130	97	304
285	50787	200	32	267
286	130787	500	0	0
287	130787	530	1	37
288	130787	600	19	318
289	130787	630	192	354
290	130787	700	255	314
291	130787	730	357	348
292	130787	800	174	241
293	130787	830	339	264
294	130787	900	177	203
295	130787	930	368	228
296	130787	1000	255	211
297	130787	1030	391	228
298	130787	1100	311	211
299	130787	1130	293	208
300	130787	1200	230	173
301	130787	1230	244	132
302	130787	1300	219	166
303	130787	1330	135	89
304	130787	1400	18	67
305	130787	1430	2	10
306	130787	1500	0	3
307	130787	1530	0	0
308	130787	1600	0	0
309	130787	1630	0	0
310	130787	1700	0	0
311	130787	1730	0	0
312	130787	1800	0	0
313	130787	1830	0	0
314	130787	1900	0	0
315	130787	1930	0	0
316	130787	2000	0	0
317	130787	2030	0	0
318	130787	2100	0	0
319	130787	2130	0	0
320	130787	2200	0	1

AUKLET COUNTS ON OWALIT MTN, SLI, 1987

OBS	DATE	TIME	CRESTED	LEAST
321	130787	2230	0	0
322	130787	2300	3	2
323	130787	2330	3	0
324	140787	0	12	4
325	140787	30	34	39
326	140787	100	76	149
327	140787	130	71	197
328	260787	530	0	0
329	260787	600	0	4
330	260787	630	5	131
331	260787	700	94	165
332	260787	730	193	172
333	260787	800	342	175
334	260787	830	252	202
335	260787	900	363	206
336	260787	930	216	119
337	260787	1000	349	200
338	260787	1030	296	155
339	260787	1100	323	117
340	260787	1130	340	174
341	260787	1200	259	112
342	260787	1230	288	121
343	260787	1300	274	177
344	260787	1330	202	139
345	260787	1400	181	169
346	260787	1430	30	28
347	260787	1500	1	3
348	260787	1530	0	1
349	260787	1600	0	0
350	260787	1630	0	0
351	260787	1700	0	0
352	260787	1730	0	0
353	260787	1800	0	0
354	260787	1830	0	0
355	260787	1900	0	0
356	260787	1930	0	0
357	260787	2000	0	0
358	260787	2030	0	0
359	260787	2100	0	0
360	260787	2130	0	0

AUKLET COUNTS ON OWALIT MTN, SLI, 1987

OBS	DATE	TIME	CRESTED	LEAST
361	260787	2200	0	0
362	260787	2230	0	0
363	260787	2300	0	4
364	260787	2330	8	2
365	270787	0	7	2
366	270787	30	50	42
367	270787	100	183	109
368	100887	630	4	76
369	100887	700	18	175
370	100887	730	80	150
371	100887	800	152	99
372	100887	830	213	141
373	100887	900	214	109
374	100887	930	195	96
375	100887	1000	244	95
376	100887	1030	342	144
377	100887	1100	314	106
378	100887	1130	415	196
379	100887	1200	474	237
380	100887	1230	397	139
381	100887	1300	188	15
382	100887	1330	185	4
383	100887	1400	179	7
384	100887	1430	169	2
385	100887	1500	45	4
386	100887	1530	57	1
387	100887	1600	15	0
388	100887	1630	0	0
389	100887	1700	18	1
390	100887	1730	3	2
391	100887	1800	1	0
392	100887	1830	1	0
393	100887	2030	0	0
394	100887	2100	0	2
395	100887	2130	2	3
396	100887	2200	0	3
397	100887	2230	6	5
398	100887	2300	14	21
399	100887	2330	37	44
400	110887	0	43	65

AUKLET COUNTS ON OWALIT MTN, SLI, 1987

OBS	DATE	TIME	CRESTED	LEAST
401	230887	730	1	1
402	230887	800	1	1
403	230887	830	1	2
404	230887	900	2	1
405	230887	930	1	2
406	230887	1000	1	1
407	230887	1030	0	0
408	230887	1100	0	0
409	230887	1130	4	2
410	230887	1200	2	1
411	230887	1230	27	0
412	230887	1300	20	3
413	230887	1330	21	2
414	230887	1400	15	1
415	230887	1430	9	1
416	230887	1500	3	3
417	230887	1530	2	1
418	230887	1600	1	7
419	230887	1630	3	2
420	230887	1700	1	2
421	230887	1730	0	0
422	230887	1800	0	1
423	230887	1830	0	0
424	230887	1900	0	0
425	230887	1930	0	0
426	230887	2000	0	0
427	230887	2030	6	0
428	230887	2100	0	0
429	230887	2130	3	0