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THE POPULATION STATUS OF SEABIRDS ON ST. MATTHEW AND HALL ISLANDS, 1985 AND 1986

FINAL REPORT FOR MINERALS MANAGEMENT SERVICE

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June, 1987

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The opinions, findings, conclusions, and recommendations expressed in this report are those of the authors, and do not necessarily reflect the views of the U.S. Department of the Interior, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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ABSTRACT

Numbers, reproductive success and food habits of cliff-nesting seabirds were studied on St. Matthew and Hall Islands in 1985 and 1986. Murre numbers varied markedly within years; during the daylight hours the variability was unrelated to time of day or weather conditions except that numbers were reduced when wind speeds exceeded about 7m/sec. Significant between-year differences in numbers of murre on the cliffs were documented. Kittiwake numbers were progressively higher in 1985 and 1986 compared to 1983 and numbers of kittiwake nests were highest in 1986. Breeding chronology was most advanced and clutch sizes of kittiwakes were largest in 1986 but chick survival was poor. In all years of study murre and particularly kittiwakes had poor reproductive success. Walleye Pollock has been a major prey, particularly for murre, but the trophic relationships of murre and kittiwakes on St. Matthew and Hall Islands cannot be adequately understood until food habits during a year of successful reproduction can be documented. Data on both food habits and reproduction suggest that the north end of St. Matthew Island and Hall Island may be more suitable for breeding than the south end of St. Matthew Island. Using a new analytical technique to evaluate year-to-year changes in numbers, we found that differences of several percent could be detected statistically. Annual variations in baseline numbers are probably related primarily to annual differences in foraging conditions and reproductive performance; monitoring of numbers, reproduction and food habits during two years of good reproduction would complete the baseline, complementing the several years of data now available from years of poor reproductive performance.

INTRODUCTION

The Minerals Management Service (MMS) of the Department of the Interior is responsible for conducting environmental studies of the Outer Continental Shelf (OCS) lease areas that may be affected by oil and gas development. MMS is directing research efforts toward seabird colonies because they are major, conspicuous components of Alaska marine ecosystems and may be especially vulnerable to OCS activity. In addition, seabirds are protected by several international treaties.

Large seabird colonies are located on St. Matthew Island and neighboring Hall and Pinnacle Island in the Bering Sea. These colonies contain an estimated 1.5 million breeding birds (Sowls et al. 1978). Because St. Matthew Island is the land area nearest the Navarin Basin lease area, it has been the proposed site for a logistical base for offshore oil exploration. Due to potential for disturbance associated with building and operating a logistical base (e.g., helicopter traffic and support facility construction), MMS initiated a seabird-monitoring study for St. Matthew Island in 1985. Field work was conducted in 1985 and 1986 in the Cape Upright area at the southeast end of St. Matthew Island, at the northwest end of St. Matthew Island, and at the south end of Hall Island (hereafter, St. Matthew-S, St. Matthew-N, and Hall, respectively).

St. Matthew-S is the area most likely to be affected by the proposed development; St. Matthew-N and Hall were considered potential "control areas" for future comparison with possibly disturbed populations at St. Matthew-S.

The focus of the study was to establish a population monitoring protocol primarily for three species of cliff-nesting seabirds: Black-legged Kittiwakes (*Rissa tridactyla*), Common Murres (*Uria aalge*), and Thick-billed Murres (*Uria lomvia*) and to a lesser extent for Pelagic Cormorants (*Phalacrocorax pelagicus*) and Northern Fulmars (*Fulmarus glacialis*). Some permanent census plots for assessing population trends were established at St. Matthew and Hall islands prior to this study (DeGange and Sowls 1978, A. Sowls, pers. comm.; Springer et al. 1984; Springer et al. 1985a), and additional plots were established in this study. Census results from these plots can be used to determine overall population changes if it is assumed that these plots, which were chosen opportunistically on the basis of location and ease of observation, are representative of the colony as a whole.

In addition to population size, several aspects of reproductive biology were also of interest, including breeding chronology and various measures of reproductive success, such as number of active nests, clutch size, and hatching and fledging success. Descriptions of food habits and sources of natural disturbance (e.g., predation), also were sought.

To assess the effects of development on bird populations the natural variability in population parameters must be distinguished from changes induced by human activity. Although design of a monitoring protocol for population trends was of primary concern, pursuit of this goal demands consideration of all aspects of the study. Reproductive success and foraging conditions likely affect numbers of birds present on census plots. Factors known to influence colony attendance include stage of breeding, diurnal cycles, and weather. It is necessary to consider these factors, both in attempting to obtain a precise estimate of population numbers and in interpreting apparent changes in numbers.

A complete understanding of the natural sources of variability in seabird populations is unlikely to develop in the near future, nevertheless assessment of development impacts on birds may be feasible if an appropriate control site can be used for comparison with the area directly affected by development. St. Matthew-N and Hall are proposed as control areas for St. Matthew-S. Birds at St. Matthew-S and birds in the control area must be exposed to, and respond similarly to, natural influences in order to isolate impacts of development. **Pre-development** comparisons among areas are important in evaluating the appropriateness of these control areas.

METHODS

In 1985, we conducted field studies from 2 July to 20 August. The field crew was transported from Bethel to St. Matthew Island by an amphibious airplane (Grumman "Goose") on 2 July, and landed at Big Lake. Transportation to the two base camps (Bull Seal Point and Cape Upright) was provided by the U.S. Fish and Wildlife Service (USFWS)-chartered vessel, the M/V NorPac, on 7-8 July. Transportation from St. Matthew I. to Nome was provided by the R/V Alpha Helix, which picked up the field crew on 20 August.

In 1986 we conducted field studies from 7 July to 19 August. The field crew was transported to the three base camps (Cape Upright, Bull Seal Point, and Hall Island) by a chartered vessel, the M/V Maritime Maid. We departed Dutch Harbor at 2030 hours (ADT) on 5 July and arrived at Cape Upright at 1800 hours on 7 July. In 1986 fieldwork was terminated at St. Matthew-S on 10 August, Hall on 13 August and St. Matthew-N on 23 August. The principal investigator and a volunteer also visited the study area during 1986, from 2-10 August. Transportation for them was provided by the R/V Alpha Helix.

Field work consisted of three principal tasks:

- (1) replicate counts on well-defined census plots to monitor numbers of birds present;
- (2) intensive observations of nesting birds on selected plots to monitor breeding chronology and production of young; and
- (3) collection of adult birds near the colonies to examine food habits and body condition.

We used time-lapse photography to examine the temporal patterns of colony attendance by **murres** and used those data in interpreting censuses. The materials and methods employed in each task are described separately in the sections that follow.

Land-Based Counts: Field Methods

Land-based census plots, each consisting of a **well-defined** section of cliff face, were counted repeatedly **during** the census period (see below) during 1985 and 1986. There were 27 such plots at St. Matthew-S, 7 at St. Matthew-N, and 12 on Hall (Figures 1, 2, and 3). Some of these had been established, numbered, and **censused** at **least** once before by other researchers (in 1982 or 1983). To eliminate confusion we created a unified **re-numbering** scheme for all land-based census plots. Our new plot numbers are cross-referenced with 1982-83 plot names and numbers in Appendix 1. We photographed all land-based **plots**. These photographs were enlarged and plot boundaries were drawn in. A set of these photographs has been provided to the Alaska Maritime National Wildlife Refuge. The Refuge personnel **will** keep the set of photographs and **also** will send slides copies to the **VIREO** archiving systems at the Philadelphia Academy of Sciences. In 1986, we marked observation points with metal survey stakes to ensure exact relocation and identification of plots.

We defined the census period as **beginning-about** one week before initiation of hatching of **murre** eggs and ending when the first sea-going of murre chicks occurred. This period lasted approximately three weeks and was timed to coincide with the period when diurnal and day-to-day variation in colony attendance by **murres** would be least (**Birkhead** and

Nettleship 1980). The census period began on 20 July in 1985 and on 10 July in 1986. Each plot at St. Matthew-N and Hall was counted at least 10 times in 1985. At St. Matthew-S weather and scheduling difficulties in 1985 resulted in a smaller number of counts per **plot**, ranging from four to nine, with an average of about seven.

In 1986 the census period began on 10 July. Each plot was counted at least 10 times, except for several plots at St. Matthew-S that were located high on Cape Upright and were obscured by dense fog for most of the summer; that group of plots was counted three to **five** times,

Each observer was responsible for counting specific plots on successive visits. An effort was made to count each plot at about the same time of day on all visits, usually during mid-day. **All** field personnel set their watches to Alaska Daylight Time (ADT). Alaska Daylight Time in 1985 and 1986 equals Bering Daylight Time in 1983 plus two hours. Thus, our watches were approximately 3 hours ahead of "real" sun time. We used binoculars and hand-held counters to count all adult **murre**s, **kittiwake**s, and **fulmar**s on the census plots. We were able to distinguish Common **Murre**s from Thick-billed **Murre**s on all land-based census **plots**. We defined **kittiwake** nests as substantial platforms with evidence of activity in the current year (e.g., **Ramsdell** and **Drury** 1979). We counted **kittiwake** nests and **fulmar** pairs.

Land-based Counts: Statistical Methods

Assuming that the individual counts made on plots within and between years and between plots were independent, we calculated a measure of relative change of land-based counts between years and its standard error for each area.

We describe the technique as it applies to either a single area or **all** three **areas**. Let n = the number of **plots** on which counts were made in this area, \bar{y}_{ij} = average count on plot i in year j, and $S_{\bar{y}_{ij}}$ = estimated standard error of \bar{y}_{ij} . The estimated relative change and its standard error for an area from year 1 to year 2 was estimated following **Miller** (1986, Chapter 6) as:

$$\text{Relative change} = \hat{\theta} = \frac{\bar{y}_2 - \bar{y}_1}{\bar{y}_1}$$

The estimated standard error of relative change is:

$$\text{S.E. } \hat{\theta} = \left[\frac{1}{\bar{y}_1} (\text{Var} (\bar{y}_{i2}) + \hat{\theta}^2 \text{Var} (\bar{y}_{i1})) \right]^{1/2}$$

where $\bar{y}_j = \frac{1}{n} \sum_{i=1}^n \bar{y}_{ij}$ and

$$\text{Var} (\bar{y}_{ij}) = \frac{1}{n^2} \sum_{i=1}^n S_{\bar{y}_{ij}}^2$$

Their variance estimate $\text{Var}(\bar{y}_{ij})$ was chosen to allow for differences in the variability of counts between plots. Under the assumptions noted above, the **covariance** term $[-2\theta^2 \text{Cov}(\bar{y}_{i2}, \bar{y}_{i1})]$ is zero. This term could **not** be estimated well given the method of data collection.

In 1983 many of the land-based plots were counted only once, thus we did not **have** an estimated standard error of \bar{y}_{ij} . For those cases we made the assumption that $S_{\bar{y}_{ij}}$ in 1983 was equal to $S_{\bar{y}_{ij}}$ in 1985.

Boat-based Counts

In 1985 we established five boat-based census **plots** at St. Matthew-S and three at Hall (Figures 1-3). There are no comparable data for these plots from previous years. During 1985 we also **recensused** six plots at St. Matthew-N that had been **censused** previously in one or more of the years 1977, 1982, and 1983. During 1985 plots at St. Matthew-S were counted once (23 July); **plots** at St. Matthew-N and Hall were **censused** two or three times each. We were generally unable to distinguish the two species of **murre**s on boat-based plots. Inflatable boats were anchored or idled off the plots and two observers counted simultaneously, using binoculars and hand-held counters. Except for some initial counts when observers were becoming familiar with plots, counts were not compared until after returning to camp. All boat-based plots were photographed. These photographs were enlarged and plot boundaries were drawn on the photographs. A set of these photographs has been provided to the Alaska Maritime National **Wildlife** Refuge in Homer, Alaska; personnel in that office will keep the set of photographs and send slide copies to the **VIREO** archiving system at the Philadelphia **Academy** of Sciences. We did not conduct **any** boat-based counts during 1986 **because** of time constraints.

Time-Lapse Photography: Field Methods

In 1985 we selected one **plot** at each area (St. Matthew-S, St. Matthew-N, and Hall) for **time-lapse** camera monitoring of colony attendance by **murre**s. The plot at St. Matthew-N was occupied almost exclusively by Common **Murre**s; the plots at the other two areas were occupied **almost** exclusively by Thick-billed **Murre**s. We abandoned an additional site at St. Matthew-N because of equipment failure.

In 1986 we operated cameras **at** the three sites used in 1985, and three additional plots in each area so that we had one plot which was occupied predominantly by Thick-billed **murre**s and one plot occupied predominantly by **Common Murre**s in each area (Table 1). We were forced to abandon the Thick-billed **Murre** camera plot at St. Matthew-N because of equipment failure. At each camera plot a tripod-mounted 35-mm camera, equipped with a 65-200 mm zoom lens, data-back, motor drive, and remote control **intervalometer** was set to shoot one frame every hour, on the hour. The data-back printed the time on each frame. Film was changed every 24-36 hours. In 1985 we used black-and-white film, but in 1986 we used color slide film in order to facilitate counting birds on the photos once back from the field. Monitoring spanned from 20 July to 10 August during **1985** and from 15 July to 10 August during 1986, with some additional coverage at St. Matthew-N and **Hall** in both years. **Table 1** lists the species, mean numbers of birds and dates of operation for each camera site. Major gaps in various photo records occurred because of fog, because personnel were unavailable to change film and because of periodic equipment failure. Binocular counts were made for comparison

with counts from the photographs. We used a binocular dissecting microscope to count the birds on the black-and-white photograph negatives from 1985, and either a Bausch and Lomb (7-30X) dissecting microscope or a Kodak Caramate slide viewer to count birds on the color slides from 1986.

Time-Lapse Photography: Statistical Analyses

A qualitative assessment of the cyclic nature of time-series data may be obtained by modeling the time series with a periodic function, such as a sine wave. Figure 4 illustrates a **simple** example of a sine wave with a period of 24 hours and a peak at noon superimposed on a set of counts of birds. **This** particular **model** provides **only** a moderate fit to the data points shown; there is considerable scatter in the data points about the sine wave. More complex **models** could be specified that combine sine and cosine waves of various frequencies and amplitudes to improve the fit to the observed data. Spectral analysis (Dixon 1983) identifies component sine waves of a complex periodic function and assesses the relative contribution of each component sine wave of different frequency to the **total** variability in the time series. The many gaps in our time series data (due to fog, rain, darkness and equipment failure) preclude use of this powerful technique. However, we were able to assess the contribution of specific spectral frequencies to the **total** variability in the data by generating sinusoid waves of these frequencies and determining the correlation of the predicted counts with the actual counts of birds.

The predicted number of birds (Y) at time (X) can be specified by the equation:

$$Y = \alpha \cos \frac{2\pi X}{\lambda} + \beta \sin \frac{2\pi X}{\lambda}$$

where λ is the period (expressed in hours) of interest (e.g., "24" for a single daily cycle) (Davis 1973).

In combination, the coefficients α and β specify both the amplitude and phase of the sinusoid (Davis 1973). By entering the sine and cosine terms as variables in a multiple regression, we can determine the coefficients α and β , the correlation of a wave with **specified** frequency with the observed data on bird numbers, and multiple r^2 (representing the proportion of **total** variance in bird numbers explained by a **cycle** of that frequency).

We also examined the relationship of weather to our time-lapse counts. Weather data were available from a remote weather station near Cape Upright on St. Matthew Island, that is operated by the Brown and Caldwell engineering firm. We obtained temperature, barometric pressure, wind speed and wind direction data for every third hour during the census period, **and** we interpolated between adjacent readings to obtain estimates for the intervening hours. For **all** variables except those incorporating wind direction we made simple linear interpolations. We interpolated between values for wind direction using procedures outlined in Zar (1974) for circularly distributed variables. Temperature data were available only for 1985 and we incorporated barometric pressure into the analyses only for 1986.

We **also** determined 24-hour running means for each of the weather variables, i.e., the value associated with a particular date and time was the arithmetic mean of the value at that time and those recorded 21,

18, 15, 12, 9, 6, and 3 hours previously. To compute the mean wind vector, we used mean speed corrected for variability in wind direction. If wind direction did not vary during the 24-hour period the vector would equal the mean speed. For example, a northerly wind of 10 m/sec that shifted to a southerly wind of 10 m/sec halfway through the 24-hour period would have a mean vector of zero. Thus, higher values of the mean vector reflect both stronger and more directionally consistent winds. Analysis of weather effects was conducted only for those data between 0800h and 2200h ADT because all counts of plots were conducted during that period and because we were principally interested in the residual variability after minimizing the influence of diurnal cycles.

Reproduction Plots: Field Methods

We selected plots for intensive monitoring of the breeding chronology and success of **murre**s, kittiwakes, **fulmars**, and cormorants on the basis of ease of observation of individual nest sites. Some reproduction plots were identical to land-based census plots, or were portions of land-based plots, and some were on completely different sections of cliff. We monitored these plots from 16 July to 17 August 1985 and from 10 July to 19 August 1986. All reproduction plots were photographed, the photographs were enlarged and plot boundaries were drawn in. A set of these photographs has been provided to the Alaska Maritime National Wildlife Refuge in Homer, Alaska. Refuge personnel will keep the set of photographs and send **slide** copies to the VIREO archiving system at the Philadelphia Academy of Sciences.

As with land-based census plots, each reproduction plot was assigned to a particular observer who monitored the plot on successive visits. The observer prepared a sketch map of **all** sites (nests or roosts) on the initial visit in 1985, or marked sites **on** a photograph of the plot in 1986. Each site was assigned a unique number and on each visit the observer recorded the number and behavior of adults present and the nest contents on data forms (Appendix 2). Because **murre**s and **fulmars** do not build nests, we could only record data on adult numbers and presence or absence of eggs or chicks at each site for those species. We also classified kittiwake sites as nests, mud roosts or rock roosts according to the definitions in Appendix 3.

During 1985, we had difficulty distinguishing "mud roosts" from "incomplete nests" because many sites were maintained but improved only sporadically during the season. Kittiwakes brought fresh vegetation and mud to the sites up until we left in mid-August, but on any given day a maintained site might appear unused. Given these difficulties in distinguishing mud roosts from nests, we have defined an "improved site" as any site showing evidence of addition of fresh material (mud or vegetation) at any time during the season. Improved sites are considered equivalent to "nesting attempts". We attempted to classify complete and incomplete nests but were unable to discount among-observer differences in classification as a basis for any differences among plots in the ratio of incomplete to complete nests, so this distinction was not considered reliable.

Variable-power telescopes and binoculars were used to view eggs or chicks when incubating or brooding adults shifted their position enough to permit observation of the nest contents. We attempted to view the contents of each nest on each visit but that objective was rarely achieved. Instead, we gradually built on the knowledge of previous

visits to eventually obtain a data record on the status of all sites on each plot. We classified **murre** and kittiwake chicks by age class (Appendices 4 and 5) whenever possible.

Reproduction Plots: Analyses for Murres

In most cases the exact dates of hatch of **murre** chicks were unknown because the interval between successive visits to plots ranged from two to eight days (most were four or fewer days) and not **all** eggs/chicks were observed on each visit. Assigning exact hatching dates is inappropriate given this **level** of precision; instead, we assigned hatches to four-day periods. Our conventions adopted for assigning hatching dates are listed **below**.

1) Hatching date was assigned to the midpoint of the interval between the last observation of an egg and the first observation of a chick at that nest site, provided that interval did not exceed eight days. Most observations fell into this category.

2) If the interval described in (1) exceeded eight days and **age** class (see Appendix 4) was noted, or if the egg was not actually seen but the first observation of a chick was accompanied by an age-class designation, hatching date was assigned by back-dating. For Age Class 1 or 2, hatching date was assumed to be four days prior to the observation.

3) **If** the interval described in (1) exceeded eight days and the first observation of a chick was not accompanied by an age-class designation, the record was eliminated from the data summary.

4) For eggs still present at the end of the season, projected date of hatch was assigned by adding the incubation period (34 days for Thick-billed **Murres**, 31 days for Common **Murres**, [Hunt et al. 1981b]). **If** laying date was unknown (egg was present at the first visit to the plot), the last probable hatching date was determined by adding the incubation period to the date the egg was first observed. For each such case, one "hatch" was pro-rated over **all** possible hatch dates between the last visit to the plot and last probable hatch date.

Observers were absent from Hall during the peak of hatch in 1985, resulting in much uncertainty about the distribution of hatching dates during the periods 4-7 August and 8-11 August. Therefore these two periods have been lumped for **Hall** in 1985 and all analyses including these data combine these eight days in a single category.

Reproductive success of **murres** is frequently described in terms of a "k-ratio", which is the ratio of the number of breeding pairs (sites with eggs) to the average number of adults (**Birkhead**, 1978). To compare reproductive performance among areas the average k-ratio for each area was estimated according to the formula:

$$K = \frac{\sum y_i}{\sum x_i}$$

where y_i is the number of eggs in the i th **plot**, and x_i is the mean number of adults for that plot. This estimator is **most** precise when: (1) the relationship between the number of eggs and number of adults is a straight line through the origin, and (2) the variance of the number of eggs about the **line** in (1) is proportional to the number of adults

(Cochran 1963). These conditions were met reasonably well, based on visual inspection of a bivariate plot of these two variables, using data from all areas combined.

In order to test for differences among years in k-ratios, we used a "split plot over time" design on the ranks of plot k-ratios. Here the areas were treated as whole plots and time as the split plot. Ranks were used as a variance stabilizing transformation. Analysis of untransformed k-ratios yielded similar results.

Reproduction Plots: Analyses for Kittiwakes

Reproduction plots were usually visited every two or three days, but occasionally at longer intervals because of adverse weather conditions which precluded data collection. Also, observers could not **always** see the contents of each nest on each visit. These gaps in data collection lead to uncertainty in designating exact hatching dates, or in the case of lost eggs or chicks, uncertainties as to whether the egg hatched and was lost before it was recorded as a chick or if it disappeared as an egg. To deal with such problems and to standardize data interpretation, we developed the following method. To determine hatching dates we took the midpoint between the last date an egg was seen and the first date a chick was observed. Because we noted each chick's age class when possible (Appendix 5), we were able to refine this date in some cases so that it corresponded with the chick's age range. Similarly, we computed the chick's date of death using the midpoint between the last day the chick was observed alive and the day it was first recorded as missing from the nest or dead in the nest. If the interval between known presence and disappearance of an egg or chick was greater than eight days, we did not compute a date of hatch or death, and those cases were excluded from the summary of death dates, although they still contributed to the count of dead chicks. We could not identify the individual eggs or chicks in 2-egg clutches, so when we visited a one-chick nest that previously had an egg and a chick, we did not know if the surviving chick was the chick that hatched last, or if the second egg had disappeared before hatching. To deal with this problem, we made the following assumptions for the egg in a 2-egg clutch that hatched last: 1) **all** eggs not seen more than four days after hatch date of first egg were assumed to have hatched and died; 2) date of hatch of the second egg was assumed to be as close to hatch date of first egg as was consistent with the data; 3) if only one chick survived, it was assumed **to** be the first chick; 4) if the interval between known presence and disappearance of the second egg/ chick exceeded eight days, no date of death was assigned and the case was excluded from the summary of death dates and ages.

At the time of our departure from St. Matthew-S in **1985**, 6 out of 38 nests still contained unhatched eggs for which laying dates were unknown. We allocated hatch dates for those eggs equally among the possible intervals during which hatching of those eggs may have occurred. In **1985** we assumed that all eggs present when observers last visited the plots hatched. Because hatch occurred much earlier in 1986, and **all** eggs remaining **on** the plots were known to be > 28 days **old**, we assumed that eggs present when observers last visited plots in that year did not hatch.

Specimen Collection

Separate specimen collections were made at St. Matthew-S and St. Matthew-N. We shot **adult murre**s and **kittiwakes** from the inflatable boats offshore from the colonies. To increase the probability of obtaining **birds** that had fed recently, we attempted to collect only those individuals that appeared to be returning to the colony from foraging trips. During the chick-rearing period we selectively collected some **murre**s carrying fish in their **bills**. We processed specimens as soon as possible after returning to camp and recorded the following information: weight, diagonal tarsus length, wing chord, stage of brood **patch** development (six-category scale developed by Swartz [1966]), extent of subcutaneous and mesenteric fat deposits ("light", "moderate", or "heavy"), and gonad measurements (**left** testis length and width or diameter of largest ovarian follicle). We removed stomach contents and linings and preserved the material in 70% ethanol. Fish collected as bill-loads were measured and preserved in 5% formalin. Parasites were examined but not preserved.

Food Habits Analyses

Food items were sorted and identified in the laboratory under a Wild 6-50x stereomicroscope, using appropriate taxonomic keys and preserved reference material. Because food items were usually in an advanced stage of digestion, most invertebrates were identified from parts such as eyes, rostra, jaws, and **uropoda**. Fish were counted and identified on the basis of **otoliths**, dense bones of the inner ear that resist digestion and have species-specific configurations. **Sculpins** (**Cottidae**) were counted and identified using **preopercular** spines as well as **otoliths**.

Otoliths enlarge as fish grow, so they can be measured to estimate the fishes' size and weight, using regression equations relating **otolith** length to fish **length** and fish length to fish weight (Table 2).

Data relating **otolith** length to fish length were not available for Pacific cod (**Gadus macrocephalus**). Lengths and weights for this species, and any cod that could not be identified to species when the **otoliths** were too worn, were calculated using the **walleve pollock** (**Theragra chalcogramma**) equations.

Sculpins often were not identifiable to species or genus. For analytical purposes, equations for **Myoxocephalus quadricornis** were used to estimate their size. **M. quadricornis** is the only Bering Sea **sculpin** for which data are available.

The following length-weight estimates of **capelin** (**Mallotus villosus**) were obtained from K. Pahlke (unpubl. data):

- fish length < 80 mm, weight estimate = 5 g,
- 80 mm < fish length < 115 mm, weight estimate = 10 g,
- fish length > 115 mm, weight estimate = 20 g.

Flatfish (**Pleuronectidae**) were generally young-of-year fish and were assigned an average weight of 0.5 g. Young-of-year cods and unknown young-of-year fish were also assigned an average weight of 0.5 g (S-S. Lee, unpubl. data). Unknown fish older than one year were assigned an average weight of 2 g (Springer et al. 1984).

Many **otoliths** were broken. After as many fragments as possible were pieced together, the **otolith** size was measured or was estimated if all pieces were not present. Estimates were based on comparisons of the pieces with whole **otoliths**.

Because invertebrate prey are quickly ground into fine fragments after ingestion, we did not attempt to quantify numbers or weights of invertebrates. Presence-absence values were the only data used in our analyses.

We assumed that all invertebrates and fish found in bird stomachs were consumed directly by the birds, rather than by fish that the birds ate.

RESULTS

MURRES

Numbers: Land-based Counts

We compared 1983, 1985 and 1986 land-based murre censuses by computing the estimated relative change between each pair of years (1983-1985, 1983-1986, 1985-1986) with a 95% confidence interval. For each species we computed these values on four groups of land-based plots: St. Matthew-S, St. Matthew-N, Hall, and all areas combined (Table 3).

For Common Murres, counts were significantly higher in 1983 than in 1985 at St. Matthew-S and Hall, but not significantly different at St. Matthew-N (Table 3). When all areas were combined we found a 16-24% decrease in Common Murre counts from 1983 to 1985. Comparing 1983 - 1986 values, we found that counts were significantly lower in 1986 at St. Matthew-S and Hall, and significantly higher at St. Matthew-N. When all areas were combined, we found a 15-21% decrease in Common Murre counts from 1983 to 1986. Examining 1985 to 1986 values, we found no significant differences at St. Matthew-S or St. Matthew-N, and a 3-10% increase in counts at Hall. When all areas were combined, we found a 1-11% increase in Common Murre counts from 1985 to 1986.

Examining values of relative change for Thick-billed Murres, we found a 9-35% rise in counts from 1983 to 1985 at St. Matthew-S, but no significant changes in counts at St. Matthew-N or Hall (Table 3). When all areas were combined, we found a 6-23% increase in Thick-billed Murre counts from 1983 to 1985. Comparing 1983 to 1986 values, we found significant increases at all three areas. When all areas were combined, we found a 18-32% increase in Thick-billed Murre counts from 1983 to 1986. Examining 1985 to 1986 values, we found a 5-10% increase in counts at Hall, but no significant differences in counts at St. Matthew-S and St. Matthew-N. When all areas were combined, we found no significant differences in Thick-billed Murre counts from 1985 to 1986.

In summary, then, there were no clearcut trends in Common Murre counts, except perhaps a decrease in counts from 1983 to 1985 and 1986. Thick-billed Murre counts increased significantly from 1983 to 1986. However, all 1983 comparisons must be examined skeptically for the following reason: There are some fairly large among-year differences in average counts on some of the plots, especially in 1983 vs. 1985 and/or 1986. (Appendices 6 and 7). We found large day-to-day variation in colony attendance (see below), and in 1983 only one or two counts were made on most plots. If these one or two counts were made during periods of particularly high or low attendance, 1983 counts could be unreliable.

To determine whether murre numbers varied concurrently on land-based plots within or among areas (i.e. St. Matthew-S, St. Matthew-N, and Hall) from day-to-day, we computed Pearson's correlation coefficient for all possible pairwise combinations of plots, for all days on which counts were made of both plots (SAS 1984). To condense our findings, we computed means of all correlation coefficients for each area combination (e.g. St. Matthew-S/St. Matthew-S, St. Matthew-S/St. Matthew-N, etc.) using only those coefficients that were based on at least four counts (Table 4). Mean correlation values ranged from -0.16 to 0.84, and generally fell below 0.45. Means of the correlation coefficients within areas were not consistently higher than between-area means, except for Common Murres in 1986. For all values except the St.

Matthew-N/St. Matthew-N comparison, Common **Murre** plot correlations were closer to zero than Thick-billed **Murre** plot correlations. For both species, 1986 correlation values were closer to zero than 1985 values in all cases.

These data indicate that plot attendance patterns varied widely within each day both within an area and among areas. Also, there was less synchrony in day-to-day attendance among plots during 1986 than during 1985.

Numbers: Boat-based Counts

None of the boat-based plots at St. Matthew-S or Hall were **censused** prior to **1985**, so results from the 1985 censuses could serve as limited baselines for future comparison. These results are presented in Appendix 8. Seven plots in the Bull Seal Rock - Glory of Russia Cape area were censused in at least two years (DeGange and **Sowls 1977**; Springer et al. **1985a, b**; this study), and these data can be used to examine trends in numbers on the cliffs. The trends in annual average counts for these plots (Figure 5) are fairly consistent, with **murre** numbers generally changing in a similar fashion among **plots**. Average counts were generally low in 1982, with an increase in 1983; 1985 counts were similar to, or slightly lower than, 1983 counts.

The average annual counts used in Figure 5 represent a reduction in the data in several respects. For many censuses there were replicate counts by two observers counting simultaneously and for many plots there were replicate censuses (varying in number) conducted on different dates in a given year. Therefore, the **annual** mean includes components of variability due to differences among observers and among censuses (which includes variation over time, both among days and within days).

A nested analysis of variance (ANOVA) was used to partition the sources of variation due to years, censuses within a **year**, and observers within a census for each plot [**D1, D7, D8, D9(A, B, C, D)**]. Because the design was unbalanced, the regression approach was used (**Neter et al. 1985**). The mean squares for observers for various plots differed by several orders of magnitude, and inspection indicated that transformations would not remedy the problem. Replication of observers and/or censuses was not consistent across **plots** and years so a large ANOVA using all **plots** would have many empty cells. Therefore, the analysis was run separately for each plot.

Results of this analysis were mixed (Table 5). In three cases, among-census differences were significant (**$p < 0.02$**), and in two cases they were marginally significant ($0.10 < P < 0.13$). In the remaining two **cases**, either between-observer differences were so large as to obscure among-census variation, or among-census variation was small. In four of seven cases, **no** significant among-year variation could be detected against the background of high **variability** among censuses and/or between observers. These results indicate that, because the variability of censuses on successive days within a year is high, the apparent changes in numbers seen in Figure 5 **are** not statistically significant.

Because weather and sea conditions precluded adequate replication of boat-based counts, we discontinued these censuses in 1986. Instead, we concentrated our efforts on land-based plots. We have included boat-based census data for future reference, should other investigations find them useful.

Patterns of Colony Attendance by Murres Method-Related Sources of Error

A potential source of error in analyzing time-lapse counts is among-observer difference in performing counts from photographs. In 1985 we examined this variability by conducting "double-blind" counts, in which two observers examined six photographs independently. The percent difference between observer's counts ranged from 1.6% to 5%, with a mean of 3.2%. We considered this to be a negligible source of error and conducted no further tests.

A second possible source of error is that counts from photographs may not have reflected accurately the actual numbers of birds on the cliffs. To examine this possibility we compared field counts, made at the site by observers with binoculars with counts obtained from photographs. The mean percent departure of photo counts from binocular counts was calculated as follows:

$$\% \text{ Departure} = \sum_{i=1}^n \frac{\text{binocular count} - \text{camera count}}{\text{binocular count}} \times 100$$

This error was **small** for Thick-billed Murre photos (Table 6). For Common Murres, some of the departures were quite high, particularly for the plot at St. Matthew-S. The overall departures for Common Murres at St. Matthew-N and Hall were acceptable (4.5 - 0.8%), but **small subplots** consisting of **crowded** ledges (Hall subplots z-3 and St. Matthew-1 subplots 1-2) tended to have higher mean departures. The plot at St. Matthew-S consisted mainly of one crowded ledge, which may account for the inaccuracy of counts of **photographs** relative to **binocular** counts. For crowded ledges, it appears that birds that are partially obscured and can be detected by binocular counts may be sufficiently obscured that they are not detectable on the photographs; **M.P. Harris (pers. comm.)** also noted such **discrepancies** in photographic and **actual** counts of **crowded** ledges.

Synchrony of Attendance Patterns Among Plots

Correlations of counts among time-lapse plots within each year are presented in Table 7. Twelve of 18 **coefficients** were above 0.44, corresponding to a **value** of 19 percent (0.44²) for the variance in counts explained by synchronous variation with another plot. Of the six remaining correlations, five were for pairs including the Thick-billed Murre plot at St. Matthew-N in 1986. It is unclear why attendance patterns on **this plot** differed so much from those on other **plots**; however, the camera was only operated for ten days and this may have affected the correlations. No pattern of higher correlations was evident for plot pairs of the same species or at the same location. These low to **moderate correlations** indicate that the degree of synchrony in attendance patterns is not high. Either a great deal of random fluctuation exists, or the factors influencing colony attendance are not affecting all plots in the same way.

There is also considerable asynchrony on a smaller scale, at the level of adjacent subplots. Correlation coefficients for subplots generally are higher than those for plots, but even the highest

correlation coefficients do not exceed 0.79 (Table 8). Thus the greatest variance explained in murre numbers (r^2) was about 60% between adjacent subplots.

Diurnal Cycles

Many studies have noted that time of day influences the number of murre present at the breeding colony for at least part of the breeding season (e.g., Slater 1980, Johnson 1985), and previous studies at St. Matthew Island have attempted to correct for within-day variability (e.g., Springer et al. 1985a). Data from the time-lapse plots are summarized in "box plots", which show the median count and variability around the median on each plot for every hour of the day (Figures 6-10). Strong daily patterns had a periodicity evenly divisible into 24 and less than or equal to 24 hours. The general pattern in all these graphs was one of relatively little difference in median counts from approximately 0800h - 2200h ADT (seven hours to either side of solar noon, which was approximately 1500h ADT). An apparent drop in numbers during the hours of darkness was detected, as was a possible tendency toward bimodality, with two daytime peaks separated by eight to twelve hours, and an intervening, slight, mid-day low. A striking feature was the high degree of day-to-day variability, which is indicated by the high variability for every hour of the day in the box plots. Coefficients of variation (CVs) are provided in Table 9 for each hour between 0900h and 2200h ADT, for each plot in 1985 and 1986. No clear pattern emerges to indicate that counts at a particular time of day were less variable than others. Mean CVs ranged from 14% to 34%; these were higher than CVs reported from the British Isles which are normally around 10% (Harris et al. 1986). High counts exceeded low counts on the photo plots by a factor of three or four, except for the Common Murre plot at St. Matthew-S, where counts ranged from 2 to 109. The wide range of counts on that plot may have been a result of gull predation; a gull was present on the plot during many of the lowest counts.

Tables 10-11 list multiple r^2 and associated probabilities for cycles of varying lengths for each of the time-lapse plots. A 24-hour cycle accounted for 4-24% of the variance in counts with a mean of about 11%. In nearly all cases, eight or twelve-hour cycles produced a poorer fit, the exception being Common Murre counts at St. Matthew-N, which correlated best with a 12-hour cycle in both years of study.

The box plots indicate a general pattern of a nighttime low in numbers and a broad, indistinct daytime peak. When the analysis is restricted to the hours 0800-2200h ADT, the correlations decrease for all cases except Common Murre at St. Matthew-N. In general, the correlation with a 24-hour cycle is due principally to the nighttime drop in numbers; daytime counts do not correlate well with a 24-hour cyclic pattern.

A more complex model, including two or more frequencies, can improve the fit of the model. The suggestion of a bimodal peak separated by 8-12 hours led us to include cycles with those periodicities in the model. In general this improved the fit (Tables 10-11), but once again, restricting the analysis to daytime counts reduced the r^2 values to low levels. These results suggest that there is little cyclic pattern to fluctuations in numbers of murre during the daytime hours.

Influence of Weather Conditions on Colony Attendance

To determine if weather affected the time-lapse counts, we conducted stepwise **discriminant** analysis on low counts (all values within the first quartile) and high counts (all values within the fourth quartile) on time-lapse data, using a procedure similar to that was described by Darby (1980). For the 1985 data, on the basis of the single variable "**Vector24**" (mean wind vector for the 24 hours prior to the count), the **discriminant** function could correctly classify a count into the high or low category 73% of the time. Using three variables [**Vector24**, **Speed24** (mean windspeed for the 24 hours prior to the count), and **Current Windspeed** (at the time of the count)], the **discriminant** function could correctly classify 82% of low counts and 78% of high counts. For the 1986 data, the best discriminator was **Current Windspeed**, which alone could correctly classify 77% of high counts and 60% of low counts. **Vector24** and **Speed24** were too highly correlated with **Current Windspeed** to improve the discrimination. Including **Current Barometric Pressure** and **Barometric Pressure for 24 hours prior to the count** allowed the **discriminant** function to correctly **classify** 80% of high counts and 64% of low counts. These results provide reasonable evidence that counts are affected by weather conditions, and we felt justified in attempting to develop predictive models using stepwise multiple regression on weather variables using count as the dependent variable (Dixon 1983).

Our objective was to develop a single predictive model for counts on the basis of weather conditions that could **apply** to all census plots. Accordingly we combined data from all time-lapse plots, first standardizing time-lapse counts for each plot by the formula:

$$\text{standardized count} = \frac{\text{count} - \text{mean count}}{\text{standard deviation.}}$$

We used only those data for the hours 0800 - 2200 ADT.

Only variables related to windspeed were good predictors of **murre** numbers. Neither temperature (for 1985 data) nor barometric pressure (for 1986 data) significantly improved **the model's** predictive capability. The single best predictor in both years was **Current Windspeed**, although **Vector24** was a slightly better predictor for the 1985 counts. The relationship between windspeed and **murre** numbers for each **murre** species is depicted in Figures 11 and 12. Fitting a quadratic function to the data suggests that the effect of windspeed is more pronounced at moderate to high speeds. For example, if one divides the horizontal axis at 7 m/sec, this "threshold effect" is **clearly** shown (Figure 13). For low to moderate windspeeds, the r^2 values for **Thick-billed** and **Common murre**s are **0.006** and 0.04, respectively. For moderate to high windspeeds, the r^2 values are 0.26 and 0.52, respectively. Two possible approaches to correcting for **wind-related** variability are to (1) develop separate regression equations for low and high wind conditions, or (2) avoid **censusing** during high wind conditions. The second approach is appealing in that it avoids the necessity of developing a linear model that would be equally **applicable** to all plots in all-years. We have not attempted to **find** the "**best**" **cutpoint** for windspeed; we have used 7 m/sec (approximately 14 knots) as an example to illustrate the influence of high wind conditions on **murre** numbers.

In 1985, the most severe storm of the season occurred on 5-6 August. Winds averaged 35-45 km/h, with gusts to 60 km/h. Colony attendance during the storm was low, but on 7 August the seasonal high count for **murre**s and kittiwakes was obtained in 37 of 45 census plots; the remainder had numbers close to the maximum count. Two such storms occurred in **1986**, on 18-19 July and 1 August; however, no "rebound effect" was apparent after those storms.

Effects of **Windspeed** on Land-based **Murre** Counts

After finding the strong negative correlation between windspeeds > 7 m/s and **murre** numbers on the time-lapse plots, we examined the effect of deleting **all** land-based census counts made during 1985 or 1986 when windspeeds at the St. Matthew weather station exceeded 7 m/s on year-to-year comparisons of relative numbers. This resulted in exclusion of 11.8% of the censuses from our data set for land-based censuses.

Excluding the censuses conducted during high wind conditions, when bird attendance was usually low, resulted in reduced variance of the estimated relative change in most, but not all, cases (Table 12).

After eliminating censuses conducted **while** windspeed was > 7 m/s, we found that murre counts showed the same general trends as when counts during **all** windspeeds were considered (see Table 4), with a few discrepancies. We found that Common **Murre** counts changed significantly from 1985 to 1986 only at St. Matthew-S (a **1-15%** increase). When **all** areas were combined, we found that Common **Murre** counts increased from **0.2** to **7%** from **1985** to **1986**. Thick-billed Murre counts dropped significantly from **1985** to 1986 at **Hall**, rose significantly at St. Matthew-S, and did not change significantly at St. Matthew-N. When **all** areas were combined, we found a **5-15%** increase in counts of Thick-billed **Murres** from **1985** to 1986.

Effects of Wind Direction on Land-based Counts

Using the time-lapse data we determined that there was a negative relationship between **murre** counts and windspeed (see above). Here we examine the possibility that wind direction **also** was a factor affecting plot attendance. We hypothesized that nonbreeders, failed breeders, and off-duty mates would be less **likely** to remain on a plot during periods when wind blew directly toward the plot (within 90° of plot aspect) than when the plot was sheltered from the wind. **Murres**, especially **thick-billed**s, seem to have difficulty maintaining their position on the narrow ledges they typically occupy under strong wind conditions (**pers. obs.**), possibly making them susceptible to wind blowing toward the plots.

To examine this hypothesis, **we** first standardized the land-based counts of murres (see above). We then made a comparison of correlations between standardized land-based **murre** counts and windspeed for those counts when wind direction was within 90° of plot aspect, versus those counts when wind direction deviated more than 90° from plot aspect. We ran the analysis twice: once including all cases and once for cases where wind speed was > 7 m/s. Wind direction had no effect upon plot attendance for either Common or Thick-billed **murre**s (Table 13). If wind direction was important, correlation coefficients would have been more

negative for cases where wind was within 90° of plot aspect. Instead, we found correlation coefficients that were more positive in 3 of 4 cases where plots were sheltered from the wind. A test comparing pairs of correlation coefficients (Zar, 1974) showed that none of the pairs were significantly different ($p > 0.05$).

Influence of Reproductive Performance on Colony Attendance

The minimum count of adults on a plot must generally equal the number of eggs incubated and/or chicks brooded. This observation leads to the hypothesis that favorable breeding conditions should be accompanied by less variability in repeated counts of a given plot, because a higher and relatively constant number of adult birds would be constrained to attend their egg or chick. In addition, attendance patterns of **subadults** might be less variable in such instances. Thus, for a group of **plots**, k-ratios (a measure of the proportion of adults engaged in successful breeding attempts, see below) should be inversely correlated with the coefficients of variation of **daily** counts. This hypothesis was tested using the set of all reproduction plots for which the mean number of adults was 10 or more and for which there were at least five counts. Thick-billed **Murres** showed no correlation between the k-ratio and the coefficient of variation in either year (Figure 14). A significant negative correlation between CV and k-ratio was found for Common **Murres** in both years (Figure 15), with r^2 values of 0.65 in 1985 and 0.45 in 1986. We have no biological explanation for this apparent difference between the species.

In years of poor reproduction fewer birds may be regularly present at nest sites (e.g., Gaston and Nettleship 1982), thus, numbers may be depressed as well as more variable. For Common **Murres**, therefore, we examined the relationship between mean numbers and coefficient of variation in numbers by plotting the net change between 1985 and 1986 in mean numbers and in coefficients of variation (Figure 16). A significant, but weak, negative relationship was found ($r = -0.392$, $p < 0.05$). A negative relationship indicates that mean numbers tend to be depressed when variability in attendance is higher.

Breeding Chronology: Thick-billed **Murres**

The first Thick-billed **Murre** chicks were observed on 29 July 1985 and 28 July 1986. Distributions of hatching dates for Thick-billed **Murres** are presented in Figure 17.

Differences in chronology among plots within each year and within each of the three areas (except for St. Matthew-S in 1985, for which there are too few data) were examined using a **Kruskal-Wallis** test and procedure for pairwise comparisons (Conover 1980). In some of the tests, adjacent subplots and/or plots were combined into plot groups to yield reasonable sample sizes (Tables 14 and 15). Of five tests, three showed no difference in timing of hatching between plots. In 1985, timing of hatching differed at the two plots at St. Matthew-N ($0.025 < p < 0.05$) and in 1986 five of six **pairwise** comparisons indicated significant among-plot variability at Hall.

These results indicate that there may be fine-scale spatial variability in breeding chronology within an area. An analysis of variance approach would be necessary to partition the variability in

chronology among ledges, plots and locations. However, the approach is inappropriate given the form of our data, in which hatching dates are grouped into four-day blocks rather than appearing as a continuous variable. To test for location differences, we lumped plots within a location, implicitly adopting the assumption that within-location differences were unimportant. Breeding chronology differences among locations within each year were examined with a Kruskal-Wallis test (Table 16). Pairwise comparisons showed that breeding chronology at St. Matthew-S was delayed relative to the other two locations in both years. St. Matthew-N and Hall did not differ with respect to breeding chronology.

Location and year effects on breeding chronology were examined using a log-linear models approach to analysis of multiway contingency tables (see Fienberg 1970). In this context, distribution of hatching dates is viewed as a dependent variable potentially influenced by the independent variables "year" and "location". The results (Table 17) indicate that year, location and date are not mutually independent. The introduction of a date-location interaction term (i.e., a location effect on hatching date distribution) improves the model significantly. Introduction of a date-year interaction does not significantly improve the fit of the model, suggesting that while there may be year-to-year variation in breeding chronology, the most important contribution to variance was location; in addition, chronology of each area relative to the others was similar in both years.

Year-to-year variation within an area was not significant at St. Matthew-S (contingency χ^2 , $v=2$, $p=0.52$) or St. Matthew-N (contingency χ^2 , $v=2$, $p=0.46$) but a significant result (contingency χ^2 , $v=2$, $p=0.04$) was obtained for Hall. Hatching dates at Hall averaged earlier in 1986 than 1985 (Table 18).

Breeding Chronology: Common Murres

The first Common Murre chicks were observed 27 July 1985 and 22 July 1986. In 1985, the median hatch date for St. Matthew-N and Hall was in the period 4-7 August. In 1986, the median hatch date was in the period 4-7 August at St. Matthew-N but 31 July - 3 August at Hall. The distribution of hatching dates for Common Murres is presented in Figure 18.

Sufficient sample sizes for evaluation of among-plot (within-location) variability in hatching chronology existed only for Hall in 1986. Based on the data in Table 19, there was no difference in chronology among plots at Hall in 1986. (Kruskal Wallis $H=2.157$, $v=3$, $0.50 < p < 0.75$).

Differences between St. Matthew-N and Hall were examined for both years separately (Table 20). No difference was found in 1985 (Kruskal-Wallis $H=0.04$, $v=1$, $0.75 < p < 0.90$), but there was significant difference in the timing of hatch in 1986 (Kruskal-Wallis $H=7.90$, $v=1$, $0.001 < p < 0.005$): there were relatively more late hatches at St. Matthew-N.

Multiway contingency analysis on year and area effects did not reveal the relative importance of these factors in contributing to variability in the timing of breeding in Common Murres. Models with all combinations of simple effects of year, area and interaction terms produced expected distributions significantly different from observed. These results were corroborated with a two-way analysis of variance on

hatching dates, with dates ranked according to date category (all hatching within a specified period received the same rank). The ANOVA indicated a significant area effect ($F_{1, 200} = 4.31$, $p = 0.039$). The year effect was not significant ($F_{1, 200} = 2.19$, $p = 0.076$) but probably also had an important influence on breeding chronology,

Reproductive Performance

Assessments of **murre** reproductive performance and success are complicated by the fact that **murre**s do not construct nests and it can be difficult to determine which birds are actually incubating eggs. Appendices 9 - 12 summarize reproductive performance of murre for each reproductive monitoring plot. The number of eggs laid is very likely an underestimate because of eggs that were laid and lost before we could document their presence after our arrival at the study area. Because of less intensive coverage for St. Matthew-S in 1986, a range is provided for the estimated number of eggs laid, to include cases where the presence of eggs was not confirmed but strongly suspected on the basis of repeated (at least three) observations of **adults** in incubating postures. The higher end of the range is probably closer to the true number of eggs laid, and this figure is used for comparative purposes.

Because of the difficulties in assessing the actual number of breeding pairs on a plot, we present k-ratios (**Birkhead** 1978) as a means of comparing reproductive performance among locations. The k-ratio is the ratio of eggs laid to the average number of **adults** counted at the reproduction plot at the beginning of each visit. The k-ratios for each plot are presented in Appendices 9 - 12. The k-ratios for St. Matthew-S plots are based on suspected as well as known eggs. Mean k-ratios and standard errors of k-ratios (**Cochran** 1963) for each area are included in Table 21.

Based on k-ratios, reproductive performance of Thick-billed **Murre**s improved in 1986 relative to 1985. Figure 19 compares the k-ratios for all three areas in both years of study. We tested for differences between years and among areas with an ANOVA (split plot over time) on the ranks of plot k-ratios (only those plots with ten or more adults). The areas were treated as whole **plots** and time as the split plot. Ranks were used to stabilize variance, though an analysis of untransformed k-ratios yielded similar results. Results from this test indicate a significant year effect ($p = 0.003$) and area effect ($p < 0.001$) and no significant location by year interaction. ($p = 0.483$). Thus, k-ratios appear to have increased in 1986 and there is no evidence that birds in the three locations responded differently to improved conditions in **1986**. However, St. Matthew-S evidently had a significantly higher proportion of birds without eggs in both years, when compared with Hall. These tests assume that the correlation between k-ratios (or their ranks) on the same plots across years is not high (see for example **Anderson and McLean** (1974, p. 167)). This assumption may not be valid; 1985 and 1986 k-ratios (all areas combined) were positively correlated ($n = 19$, $r = 0.70$, $p < 0.001$) suggesting that certain plots tend to have more successful breeders than others in successive year.

The use of permanent monitoring plots also allows us to compare egg production of Thick-billed **Murre**s among years. We used the **Wilcoxon** signed ranks test (**Conover** 1971) to compare egg production on plots monitored in both years of study. Although a trend toward increased egg

production occurred in all three locations, only Hall showed a significant ($p=0.018$) difference in egg production between years. The sample size for St. Matthew-S ($n=5$) and St. Matthew-N ($n=6$) was less than for Hall ($n=8$) so that the sensitivity of the test is not as great for these areas. Egg production may have differed between years for St. Matthew-S and St. Matthew-N combined, ($p= 0.062$). This exceeds the usual α level of 0.05, but suggests an inter-year trend that might have been detected with a larger sample size.

Sample size was insufficient to test for area differences among Common Murre k-ratios. Only three Common Murre egg sites were located on study plots at St. Matthew-S in 1985, and none in 1986. Only one Common Murre reproduction monitoring plot was studied at St. Matthew-N. When this plot is combined with the Hall plots, a significant ($p=0.012$) between-year difference in k-ratios is evident (Wilcoxon signed ranks test). Thus, it appears that for both species of murre, k-ratios increased in 1986 relative to 1985.

For Common Murres, numbers of eggs on plots monitored in both years also clearly increased in 1986. The differences between years were significant for the plots on St. Matthew-N and Hall (Wilcoxon signed ranks test, $p < 0.001$).

Summaries of reproductive performance, including hatching success, are provided for each area in Table 22, based on the proportion of known-fate eggs that hatched. These figures may be overestimates of actual overall hatching success for the following reasons: (1) small numbers of the chicks were seen at sites where no eggs were actually recorded, (2) some undetected eggs could have hatched and been lost without being recorded, and (3) it is assumed that eggs unhatched at the end of the study would hatch in the same proportion, which is unlikely to be true since all infertile eggs would be included in the group of as yet unhatched eggs. Hatching success varied widely among locations and between years. For instance, Common Murres at Hall apparently suffered much higher egg losses in 1985 than in 1986. Several plots were decimated by predation by arctic foxes (*Alopex lagopus*) in 1985 but not in 1986. It is unclear whether the results reflect a true easing of fox predation in 1986; certainly the small number of reproduction monitoring plots at each location means that even a few predation events can greatly influence the estimates of hatching success. This caution notwithstanding, there was a trend toward improved hatching success for Thick-billed Murres in 1986.

"Fledging" success is unknown because our studies were terminated in both years prior to sea-going by most murre chicks from the study plots. Chick losses ranged from 0-33% but are difficult to interpret because the values reported are not corrected for the age of chicks at the time studies were ended. Estimating chick production on the basis of these data does not seem warranted. Table 23 provides maximum possible breeding success (chicks produced per egg laid) under the unreasonable assumption of no further chick or egg loss as after the conclusion of our field studies. These represent an upper bound to fledging success, not the most probable estimate.

Food Habits: Thick-billed Murres

The food samples of Thick-billed Murres collected at St. Matthew in 1985 and 1986 were similar to those collected there in 1982 and 1983 (Table 24). Walleye pollock, primarily age 0 (young-of-year) and age 1

fish, was the prey species consumed most frequently in all four years, and it contributed the greatest number and estimated biomass of all fishes in our samples. Age 0 flatfishes (*Pleuronectidae*) were generally the second most important taxon of fishes in the samples. Although older age classes of flatfishes are primarily benthic, the age 0 fish are often abundant in the water column (T. Nishiyama, pers. comm.), where apparently they are more available to seabirds.

Sand lance (*Ammodytes hexapterus*) were present in the samples collected at St. Matthew-N in 1985 and 1986, but were not encountered at St. Matthew-S in either year, or in 1982 or 1983. Although they occurred in relatively large numbers only in mid-July, sand lance were probably seasonally important to the birds in 1985, judging from the frequency with which they were eaten and the estimated biomass they contributed. These fish were large; the mean length of 24 individuals was 165 mm (SD = 19 mm), and the mean weight was 19 g (SD = 6 g). Bradstreet (in Johnson 1985) also found large sand lance in food samples from seabirds at the Pribilof Island in 1984, but they were generally less important to seabirds there than were pollock (Hunt et al. 1981; Bradstreet in Johnson 1985). Sand lance eaten by seabirds in coastal areas of the Bering and Chukchi seas, where they are much more important to the birds than at the offshore islands, are usually smaller, averaging about 80 - 120 mm in length and weighing about 2 - 5 g (Springer et al. 1984; Springer, unpubl. data).

Sculpins (*Cottidae*) were relatively common in the diets in most years but did not contribute much to total biomass of fishes in the samples. Sculpins are common, and generally more important, in diets of Thick-billed Murres at colonies on St. Lawrence I. and in the eastern Chukchi Sea (Springer et al. 1984). Pacific herring (*Clupea harengus*), capelin (*Mallotus villosus*), Pacific cod (*Gadus macrocephalus*) and pricklebacks (*Lumpenus* spp.) were eaten infrequently and contributed little to the overall diets.

Thick-billed Murres fed on a rather large variety of invertebrates in both years, as they did in 1982 and 1983 (Table 24). Polychaetes and crustaceans, particularly shrimp, gammaridean amphipods, and the hyperiid amphipods (*Parathemisto* spp.), were the most common taxa. Invertebrates are characteristic in diets of this species elsewhere (Hunt et al. 1981a; Springer et al. 1984; Bradstreet in Johnson 1985).

Because invertebrates in stomach contents are generally too fragmented to count accurately, and because they pass from the stomach more rapidly than do fish otoliths, it is difficult to assess their importance accurately, relative to that of fishes, in the diets of the birds. In general, the importance of invertebrates in diets is probably underestimated. On the basis on their frequency of occurrence, invertebrates were of similar importance to fishes overall (Table 24). Their relative frequency declined seasonally (Figure. 20), a pattern reported at other colonies (Hunt et al. 1981a; Springer et al. 1984; Bradstreet in Johnson 1985). Their absolute importance, in terms of biomass, is less certain. For example, two of the three Thick-billed Murres from the northwest end of St. Matthew I. in 1986 that had identifiable euphausiids (*Thysanoessa*) in their stomachs contained at least 98 and 119 individuals, respectively, with no-remains of fish. On the other hand, three other murres with at least 229 *Parathemisto* and 9 and 18 polychaetes, respectively, also contained a calculated biomass of 30 g, 69 g, and 268 g, respectively, of fish prey. The invertebrates

were probably important in the first case, but much less so in the second case.

The average estimated weight of fishes represented in the stomach contents of Thick-billed **Murres** on St. Matthew I. tended to increase during summer, and was higher by a factor of about 2-10 in the samples collected in all intervals in 1983 and 1985 at St. Matthew-N (Fig. 21). The higher values in 1983 and 1985 correspond to the higher estimates of recruitment of age 1 **pollock** in those years made by the National Marine Fisheries Service (Table 25).

The average weights of the 1983 and 1985 samples, although considerably higher than those of the other **samples**, were nevertheless below the average weights of samples collected at two other colonies (Cape **Lisburne** and St. Lawrence I.) during the same intervals in several years (Table 26). Two factors **could** explain the generally low values from St. Matthew I.: either prey availability is **low** around St. Matthew I. compared to Cape **Lisburne** and St. Lawrence I., or the birds from St. Matthew I. must **fly** much farther to feed, resulting in greater digestion and hence fewer prey remains in their **stomachs** by the time they return. In either case it appears that feeding conditions around **St. Matthew I.** were less suitable than **at** the other colonies during the years studied.

Age 0 **pollock** contributed a variable proportion of the total **pollock** biomass in all years (Table 27). Their importance at St. Matthew-N was lowest in 1983 and 1985, the years of the highest estimates of recruitment of age 1 fish (Table 25). This pattern apparently is inconsistent with the data from St. Matthew-S in 1985, when age 0 fish accounted for 100% of the **pollock** biomass.

We obtained information on prey fed to Thick-billed **Murre** chicks **only** in 1986. Five adults that we collected were carrying fish; four carried **pricklebacks** and one carried a **sculpin**.

Food Habits: Common Murres

Pollock also was the most important prey species in the diets of Common **Murres** on St. Matthew I., predominating in all three categories of importance (Table 28). Age 0 **flatfishes** were the next most important of the fish **prey**, but contributed generally less biomass to the diets of Common Murres ($\bar{x} = 7$ g/bird, $n = 6$ sample-years) than they did to those of Thick-billed **Murres** ($\bar{x} = 11$ g/bird, $n = 6$ sample-years). **Common Murres** consumed fewer **sculpins**, but more **capelin**, than did Thick-billed **Murres**; this pattern has been noted at St. Lawrence I. (Springer et al. in press) and in the eastern **Chukchi** Sea (Springer et al. 1984). Sand lance were present but uncommon in **samples only** at St. Matthew-N in 1985 and 1986, while **pricklebacks** were present **only** in 1986, as for the diets of Thick-billed **Murres**.

Common **Murres** fed on fewer taxa of **invertebrates**, particularly **polychaetes**, shrimp and crabs (Table 28), than did Thick-billed **Murres**. Invertebrates are **less** frequent in diets of Common **Murres** elsewhere, as well (Hunt et al. 1981a; Springer et al. 1984). **Euphausiids** generally were the invertebrates most frequently identified, although they were not found in samples from St. **Matthew-S.** At St. Matthew-N they were more common and abundant in Common **Murre** diets than in Thick-billed **Murre** diets. As an example of their abundance, in 1985 six Common **Murres** contained an average of at least 180 (range = 25 - 382) individuals. Hunt et al. (1981a) also **found euphausiids** to be more

abundant in diets of Common **Murres** than in those of Thick-billed **Murres** on the **Pribilof** Islands.

Invertebrates tended to be more frequent in the diets of Common **Murres** earlier in the summer than later, as they were in diets of Thick-billed **Murres** (Figure 20). The opposite pattern was exhibited in the frequency (Figure 20) and abundance (Figure 21) of fishes.

The estimated biomass of fish represented among the prey remains of Common **Murres** tended to be greater than in Thick-billed **Murres** (Figure 21). Such a difference would be expected if Common **Murres** feed closer to the island than do Thick-billed **Murres**, or if they are better able to capture prey that is primarily pelagic. Also, fish biomass was greater in 1983 and 1985 than in 1982 or 1986, as it was for Thick-billed **Murres** (Figure 21). Overall, the estimated biomass of fish in Common **Murre** diets was within the range of values documented at other colonies (Table 26).

Age 0 **pollock** apparently were less important to Common **Murres** than to Thick-billed **Murres** in all years (Table 27). Annual differences in their importance to Common **Murres** followed a pattern similar to that of Thick-billed **Murres**, with the lowest contribution relative to age 1 **pollock** occurring in 1983 and 1985, the years of the highest recruitment estimates of age 1 **pollock**.

Common **Murre** eggs usually hatched before those of Thick-billed **Murres**, and we consequently have more information on prey fed to Common **Murre** chicks. **Pollock** were fed to chicks in all years, **capelin** in three years, and **pricklebacks** in only one year (Table 29). The use of **pricklebacks** only in 1986 is consistent with the observations **pricklebacks** in adult samples in that year only.

Predation

The two principal predators of **murre** eggs and chicks on St. Matthew and **Hall** islands were the arctic fox (**Alopex lagopus**) and Glaucous **Gull** (**Larus hyperboreus**). It is difficult to quantify the impact of these predators without intensive study, but anecdotal evidence suggests that foxes and Glaucous Gulls may have substantial impacts on nesting success, at least locally.

Arctic foxes constantly patrolled the cliff tops and beaches and were frequently seen carrying eggs. The remains of eggs likely eaten by foxes were common on the edges of **cliffs** inhabited by **murres**. On 13 **July** 1986 we removed all broken egg shells within a band approximately 15m wide parallel to the cliff edge from the observation point for plots 4, 5, and 7 south to the crest of the rise near plot 13. This section of cliff contained the majority of nesting Thick-billed and Common **murres** on the southeast end of **Hall** Island. We counted 92 eggs which we believe were taken in that year, based upon **color**, lack of algal growth, and weathering of **shell** fragments. On 13 August 1986, we walked the same area and counted an additional 150 eggshells. Most of these eggs were probably eaten by arctic foxes, judging from the shape and size of openings in egg shells. Tooth marks were sometimes evident. Also, many of the eggshells were found along fox paths and well away from cliff edges, where it is unlikely a gull would stand to eat an egg. Gulls often swallow eggs whole and regurgitate the shell fragments later as pellets. A **small** portion were probably eaten by Glaucous Gulls.

The 242 eggs found on the cliff edge do not represent the total number of eggs lost to predators in the transect area. Foxes often

cache their eggs on the tundra and those with pups to feed carry eggs back to the den. Gulls do not always carry eggs to the cliff edge, but sometimes carry them to the beach, nest site, or other roost where they consume the egg, or consume them in the air (whole). Regurgitated pellets of Glaucous Gulls containing **murre** eggshells were common on the **beaches**. We cannot estimate the **intensity** of predation because the number of eggs present on the sampled portion of **cliff** was unknown.

The susceptibility of **murre** eggs to fox predation may depend on the topography of the cliffs. Where nest ledges are accessible to foxes, **murre**s may suffer variable predation losses, as illustrated by two examples from Hall Island. At reproduction **plots H-26A1-4**, the entire complement of 30 eggs on a series of **ledges** disappeared between 26 July and 2 August 1985. A fox was seen on these ledges on 2 August. On the following day, nests on adjacent ledges also appeared to have been depredated. In 1986, 38 of 46 eggs on these same ledges hatched successfully, with only three known eggs **lost** and five eggs remaining when the study ceased. In 1985 a fox was seen twice on plot H-32A. By 26 July 1985 there were no egg sites left on that plot although counts of Thick-billed **Murre**s averaged over 199 birds. Foxes were seen again on this plot in 1986. In these instances, local losses of eggs were severe, **while** eggs at other nest-sites nearby (apparently equally accessible) were not molested. Based on the similarity between the above cases and episodes of **local**, heavy egg losses on plots N-9 and H-6 in 1985, we suspect fox predation was responsible for losses in these latter instances, as well.

An indirect measure of the impact of fox predation may be provided by a comparison of Common **Murre** egg **loss** at St. Matthew-N with that at **Hall**. The Common **Murre** reproduction plot at St. Matthew-N was located on an offshore **islet** inaccessible to foxes, although Glaucous Gulls inhabited the rock. During 1985, Common **Murre** egg loss was only 11% at that plot, whereas at **Hall** it was over 50%. During 1986 Common **Murre** egg **loss** was 17% at that **plot**, whereas at **Hall** it was 30%.

Glaucous Gulls were seen scavenging unattended eggs and also actively seeking incubated eggs by harassing incubating **murre**s. **Gulls** often were seen soaring along nesting cliffs or perched near nesting ledges of **murre**s. Piles of **murre** eggshells were evident at Glaucous Gull nests, and gulls were also observed feeding on **murre** chicks. As previously mentioned, large numbers of regurgitated **gull** pellets containing **murre** eggshells were found on various beaches.

We recorded substantial egg **losses** in our reproduction plots but were **unable** to quantify the causes. It is possible that many of our **plots** that were easy to monitor **were** also atypically susceptible to fox predation, since they tended to be near the edge of the cliff faces. Further investigation on the impact of predators would probably best be accomplished by intensive observation of the predators themselves.

Other Sources of Mortality

Not **all** losses of eggs and chicks could be attributed to predation. On several occasions we observed eggs being displaced and knocked off ledges. On one occasion, an egg was displaced during a fight between the incubating adult and a neighboring adult. On another occasion, an egg was knocked off by an adult **murre** during a brief period when the incubating adult was absent. Occasionally, birds would flush off reproduction **plots** because of presence of observers at close range, and

an egg would be knocked off the cliff face in the process. This was a rare occurrence, however, as we attempted to minimize observer disturbance by approaching plots slowly and quietly.

Many of the cliffs on St. Matthew Island and Hall Island appear to be unstable. The following anecdotes from Hall and St. Matthew-N illustrate the potential importance of rock-slides and mud-slides in egg and chick loss, and even mortality of adults.

On one occasion, we heard a **rumble** about 300m away and then a rush of wings as thousands of **murres** and kittiwakes left the cliffs near **plots** H-9 and 10 simultaneously. A relatively small portion in the lower left corner of the plot (from viewpoint) where 10-15 Thick-billed **Murres** often sat had given way. We saw an injured murre in the water evidently with broken wings. A few other birds may have been buried. This section of cliff was reused later by about five **murres**.

On 31 July 1986, a small **slab** of rock broke loose on Plot H-12. We saw it moments after it crumbled; it did not create as much noise or flush many birds as the previous slide did. However, we counted 12 injured Thick-billed **Murres** in the water, apparently unable to fly; another three Thick-billed **Murres** had been **killed** immediately. Another **murre** was pinned down by rocks and was killed by a fox.

On 3 August 1986 we noticed that a section of plot H-6 was covered with **loose** dirt and 6 **murres** with chicks and eggs were missing. We suspect an overhanging clump of earth and tundra sod broke loose and knocked the eggs and chicks off the cliff.

On **8 August** 1986 at plot H-10F, we noticed that two Thick-billed **murre** eggs and one chick were lost about 15 minutes after a previous observation. It appeared that a small dirt slide had occurred. A mud-slide also occurred on plot N-9 in 1986, destroying at least one nest site.

BLACK-LEGGED KITTIWAKES

Numbers: Land-Based Counts

We compared 1983, 1985, and 1986 land-based kittiwake adult and nest censuses by computing the estimated relative change between each pair of years with a 95% confidence interval, as we did for **murres**. We computed these **values** on four groups of land-based plots for counts of adults and counts of nests: St. Matthew-S, St. Matthew-N, Hall, and all areas combined (Table 3). Summaries of land-based censuses of **kittiwakes** and kittiwake nests are presented in Appendices 15 and 16.

Counts of kittiwake adults increased significantly for all groups of plots from 1983 to 1985 and from 1983 to 1986 (Table 3). When all areas **were combined**, we found a 25-35% increase in counts from 1983 to 1985, **and** a 27-37% increase in counts from 1983 to **1986**. We found that 1985 and 1986 counts were significantly different only at Hall, where counts were 5-10% higher in 1986. When all three areas were combined, we found no significant differences in counts from **1985** to 1986.

From 1983 to 1985 counts of kittiwake nests decreased significantly from 1983 to 1985 at St. Matthew-S and St. Matthew-N, but increased significantly at **Hall** (Table 3). When **all** areas were combined, we found a 10-16% drop in counts of kittiwake nests from 1983 to 1985. Counts increased significantly in all three areas from 1983 to 1986. When all areas **were** combined, we found a 19-25% increase in nests from 1983 to 1986. **Counts** of kittiwake nests also rose significantly in all three

areas from 1985 to 1986. When all areas were combined, we found a 41-45% increase in kittiwake nest counts from 1985 to 1986.

We calculated mean correlation coefficients for land-based counts of kittiwakes using the same methods as for murrelets (see above). Mean correlation **values** had a range of 0.29 to 0.73 and within-area coefficients were not consistently higher than between-area coefficients. Thus, plot attendance patterns varied widely from day-to-day within an area, and factors affecting changes in kittiwake numbers were probably similar among St. Matthew-S, St. Matthew-N, and Hall (*i.e.*, plots may be treated as independent units, regardless of proximity). Mean correlation **values** were not consistently higher or lower in 1986, suggesting equal levels of synchrony in day-to-day attendance among **plots** during the two years.

Numbers: Boat-based Counts

We conducted boat-based counts of kittiwakes only during 1985. We concentrated our efforts on analysis of land-based counts in both 1985 and 1986 and present results of our boat-based counts in 1985 only for future reference, should other investigators find them useful.

Comparisons between 1983 and 1985 boat-based counts of kittiwakes were only possible for St. Matthew-N (Appendix 13). A sign test showed no significant differences ($P > 0.05$) in numbers of adults or nests between 1983 and 1985 on boat-based plots. Results of our 1985 boat-based censuses are presented in Appendix 14.

Influence of Reproductive Performance on Colony Attendance

In 1985 there were few complete nests **built** or eggs laid by kittiwakes on St. Matthew and Hall islands. As a result there was a large proportion of nonbreeding birds or failed breeders at the **colony** for the entire census period. In 1986 many kittiwakes **built** nests and laid eggs, but chicks died soon after hatching. **Thus**, the proportion of **nonbreeders** and **failed** breeders was **small** before hatching (which corresponded with the first **half** of the census period) and was large after hatching (the second half of the census period). **It** seemed reasonable to suspect that counts of adults and variability in those counts might change with the proportion of nonbreeders or failed breeders, thus affecting the results of our land-based counts and inter-year comparisons.

To test this hypothesis, we compared **pre-hatching** counts with post-hatching counts; for 1986 we compared the counts made on or before 23 **July** (median hatching dates) with those made later. In 1985, when the median hatch date occurred after the census period we **split** the count groups at 2 August (early counts: those made on **or** before 2 August). In 1985 the average of mean counts was 75.6 and 80.3 for counts made before 1 August and those made after and including 1 August, respectively. The mean coefficients of variation in 1985 were **0.184** and **0.161** for **early** and late counts. In 1986 the average of mean counts was 79.7 and 77.5 for early and late counts. The corresponding mean coefficients of variation in 1986 were **0.117** for early counts and **0.134** for late counts. These results show no consistent differences in numbers or variability between the two periods in either year, suggesting that variable proportions of nonbreeders or **failed** breeders did not influence count results.

Breeding Chronology

Kittiwake eggs hatched about 3 weeks earlier in 1986 than in 1985. In 1985 the first chicks hatched on 29 July and the median hatching date was in the period 10-13 August. In 1986 the first kittiwake eggs hatched on 13 July and the median hatch date was in the period 21-24 July. Hatching in 1985 was asynchronous, with a poorly defined peak, whereas hatching in 1986 was more synchronous, at least within areas (Figures 22 and 23). Based on an incubation period of 28 days (Swartz 1966) laying began on 1 July in 1985 and 15 June in 1986. Springer et al. (1985a, b) reported initiation of egg-laying on 26 June in 1982 and 21 June in 1983.

In 1985, kittiwakes continued to lay eggs very late into July. At St. Matthew-S, 14 of 41 eggs (34%) that were monitored were laid after 16 July. At St. Matthew-N, 18 of the monitored 59 eggs (31%) were laid after 16 July, and several eggs were laid as late as 28-31 July. The late eggs were laid after eggs were lost (presumably to Glaucous Gull predation). In three cases we documented egg production within two to six days of the initial loss this period is considerably shorter than that of 14 days reported by Maunder and Threlfall (1972) for true replacement eggs. Based on known dates of egg laying, hatching would have occurred up until 26-29 August (Figure 22).

In 1986, only five kittiwake eggs were laid after we began observations, all between 14 and 19 July. All of these eggs were lost or did not hatch. It is not surprising that we did not observe more egg laying in 1986, because our first observations of reproduction plots were made from 10-17 July, which was well after the peak of laying.

We compared distributions of hatching dates using a Kruskal-Wallis test (Conover 1980). We only compared the three areas (St. Matthew-S, St. Matthew-N, and Hall) for 1985 because of small sample sizes, but for 1986 could compare hatching dates among subplots within plots, among plots within areas, and among areas. We also examined hatching distribution for year and location effects using a multiway contingency analysis (Fienberg 1970).

Our 1986 comparisons of hatching date among plots within an area showed some variability. At St. Matthew-S we found that the hatch dates on plot S-19 were different from those on plots S-21 and S-23 ($H = 12.31$, $V = 2$, $0.001 < P < 0.005$). We could not make interplot comparisons at St. Matthew-N, since we monitored only one reproductive plot there, but did find some differences among the four plots at Hall ($H = 19.55$, $V=3$, $p < 0.001$).

These interplot differences in distribution of hatching dates led us to consider a smaller scale of variability in hatching chronology, and we compared the distribution of hatching dates among subplots within plot N-2, and in plots H-26 and 27. Since plots H-26 and H-27 are adjacent we felt justified in using their subplots for one set of subplot comparisons. At St. Matthew-N, subplot N-2A had a significantly different distribution of hatch dates than subplots N-2B and N-2C ($p < 0.05$). At Hall we compared the hatching distribution of six subplots; here there were significant differences among subplots overall ($H=11.39$, $v=5$, $0.025 < p < 0.05$) and significant ($P < 0.05$) pairwise differences between 3 of the 15 possible subplot combinations.

The results from the Kruskal-Wallis tests for plot and subplot differences indicate that there may be fine-scale variability in hatching chronology within an area. An analysis of variance approach

would be necessary to partition the variability among nests, subplots, plots, and areas, but was not used for reasons outlined in the section on **murre**s. To test for differences among areas we made the assumption that within-area differences were unimportant and lumped all plots within an area. We found no significant difference among hatching dates in 1985 among the three areas ($H=4.01$, $v=2$, $0.1 < p < 0.25$). In 1986 we did find significant differences in hatching dates among areas ($H=12.83$, $v=2$, $0.001 < p < 0.005$), with a higher proportion of late hatches at St. Matthew-S, and a higher proportion of early hatches at St. Matthew-N and Hall. St. Matthew-N and Hall had similar hatching distributions ($p > 0.05$).

We examined between-year differences in hatching distributions using a **multiway** contingency analysis. For this analysis we pooled hatching distributions, creating 4 date categories based on the median hatch dates of 1985 and 1986, and the midpoint between those dates (i.e., 12-22 July, 23 July - 1 August, 2-13 August, and 14-29 August). The best **fit** model incorporates interactions between date and location and between date and year; the location-year interaction term is not important, i.e., the differences among locations were similar in both years (St. Matthew-S was latest and St. Matthew-N and Hall were similar); hatching chronology was advanced in 1986 vs. 1985 (the date-year interaction contributed substantially to the **model** ($G=494$, $V=7$, $p < 0.001$)).

Reproductive Performance

Kittiwake reproductive data for each **plot** are presented in **Appendix 17**, while summaries by area and year are presented in Tables 31 and 32, and Figure 24. Where a range of values is reported below, the lower **value** is based on observed contents and the higher value represents inclusion of nests where we observed adults in brooding postures but could not observe nest contents for several visits but where we later found **no** eggs or chicks. For the upper value we assumed that one egg had been laid in each of those nests. Few **kittiwakes** laid eggs at any of the sites monitored in 1985, resulting in a generally poor reproductive season. The proportion of nesting attempts resulting in an egg laid in 1985 was 25% at St. Matthew-S, 26% at St. Matthew-N, and 19% at Hall (Table 31). All clutches observed consisted of **single** eggs, thus average clutch size was one egg and the numbers of eggs per nest for each area are equivalent to the above figures. In 1986 the proportion of nesting attempts resulting in at least one egg laid was much higher; 69-70% at St. Matthew-S, 71% at St. Matthew-N, and 84% at Hall (Table 31). We did observe 2-egg clutches in 1986, in contrast to 1985. For nests **with** eggs, average **clutch** size in 1986 was 1.13 - 1.17 at St. Matthew-S, **1.53** at St. Matthew-N, and 1.56 at **Hall**. When all nesting attempts are included, average **clutch size** in 1986 was 0.79 to 0.80 at St. Matthew-S, **1.08** at St. Matthew-N, and **1.31** at **Hall**.

In 1985, relatively few kittiwakes laid eggs, but chick survivorship was high, at least until the time of our departure. Chick mortality was 8%, and approximately 80% of the eggs found at all these sites were still present as eggs or chicks at the **last** visits to plots (13-17 August). In 1986 many more eggs were laid, but chick mortality was 59-92% and only 18-19% of the eggs or chicks found at all three areas were still present as chicks on the last visits to plots (9-19 August). This is probably a minimal estimate of chick mortality, since large numbers of chicks were still dying when we ended observations of

some of the reproductive plots, Maximal possible reproductive success (number of surviving chicks and eggs (eggs not included in 1986)/ number of nesting attempts) was very low in all three areas in both years (Table 31, Figure 24).

Comparative data from 1983 are available for plot N-2. In that year, there were 185 nests (17% fewer than in 1985 and 44% fewer than in 1986), with 97 one-egg clutches and 10 two-egg clutches. Thus, the average number of eggs/nest was 0.6 in 1983, falling between values from 1985 and 1986. However, chick survival was poor in 1983, with virtually no chicks surviving past the first few days after hatching (Springer et al. 1985a). Springer et al. (1985b) reported an average of 0.35 eggs/nest in 1982 and less than 0.1 young fledged/nest. Thus, in all four years reproductive success was very low, but during 1986 we saw fairly high clutch sizes, with heavy losses occurring during the chick-rearing period, and in 1985 few eggs were laid (Figure 24).

Spatial Variability in Clutch Size

We used a Kruskal-Wallis test to look for differences in distribution of the number of eggs/nest among subplots, among plots within an area, and among areas during 1985 and 1986. In 1985, we found no significant differences among subplots at St. Matthew-S ($H=2.69$, $v=2$, $0.24 < p < 0.5$) or Hall ($H=8.33$, $v=7$, $0.25 < p < 0.5$), but did find a difference among subplots at plot N-2 ($H=3.93$, $v=2$, $0.025 < p < 0.05$). On plot N-2 subplot C had a higher proportion of nests with no eggs than subplot A but not subplot B, and proportions of nests with zero vs. 1 egg were similar on subplots A and B ($p > 0.05$). In 1986, we found no significant differences among subplots at St. Matthew-S ($H=4.15$, $v=5$, $0.5 < p < 0.75$) or Hall ($H=8.40$, $v=8$, $0.25 < p < 0.5$), but again found a difference among subplots at N-2 ($H=23.60$, $v=2$, $p < 0.001$), where subplot C had a much higher proportion of nests with no eggs than subplots A or B ($p < 0.05$).

We found no significant differences in numbers of eggs/nest among plots at St. Matthew-S in 1985 ($H=2.69$, $v=2$, $0.25 < p < 0.5$) but did find differences among plots at Hall ($H=14.02$, $v=2$, $p < 0.001$), where H-9 had a greater proportion of nests with no eggs than H-26/27 or H-28 ($p < 0.05$). In 1986, we found no significant differences in the numbers of eggs/nest among plots at St. Matthew-S ($H=0.36$, $v=2$, $0.75 < p < 0.9$) or Hall ($H=6.94$, $v=3$, $0.05 < p < 0.1$).

Comparing areas, in 1985, we found significant differences only between St. Matthew-N and Hall in numbers of eggs/nest ($p < 0.05$). In 1985 Hall had the lowest proportion of 1-egg clutches, followed by St. Matthew-S and St. Matthew-N, respectively. We did find significant differences among all three areas in 1986 ($H=54.45$, $v=22$, $p < 0.001$), with St. Matthew-S having a predominance of nests with one egg, St. Matthew-N having a fairly equal distribution of nests with 0, 1, and 2 eggs, and Hall having relatively high numbers of 1- and 2-egg nests ($p < 0.05$). We made the same comparison on numbers of nests with eggs only and found significant differences ($H=66.2$, $v=2$, $p < 0.001$). St. Matthew-S had a significantly higher proportion of nests with 1 egg than the other 2 areas ($p < 0.05$). St. Matthew-N and Hall were significantly different ($p < 0.005$).

We used a two-way analysis of variance to examine between-year differences in the distribution of 0-, 1- and 2-egg clutches. The ANOVA indicated that there was a significant year effect ($p < 0.0001$), as well

as significant area ($p=0.001$) and area-year effects ($p=0.0001$). Thus, clutch size differed between years and among areas, and the relationships among the areas were different in each year.

Survivorship of Chicks

We used the **Kruskal-Wallis** test to compare distributions of date and age of chick death in 1986 among subplots, among plots within areas, and among areas. These tests were not run on our 1985 data because **sample** sizes were too small.

The only subplot comparisons of date and age of chick death were made for plot N-2 (3 subplots). No significant differences were found for age at death ($H=1.17$, $v=2$, $0.25 < p < 0.5$), but we did find significant differences in date of death ($H=8.47$, $v=2$, $0.01 < p < 0.025$), in which subplots B and C differed significantly from A, but not from each other ($p < 0.05$). This difference in date, but not age, of death is probably related to significantly later hatching dates on subplot A reported previously."

At St. Matthew-S we found significant among-plot differences ($H=8.38$, $v=2$, $0.01 < p < 0.025$) in chick age at death, where plots S-19 and S-21 differed ($p < 0.05$). We found no significant differences among plots at St. Matthew-S for date of death ($H=0.72$, $v=2$, $0.5 < p < 0.75$). At Hall (4 plots) we found significant differences for age at death ($H=8.50$, $v=3$, $0.025 < p < 0.05$), where plots H-9 and H-23/24 differed ($p < 0.05$). Again, since plots H-23 and H-24 were adjacent, they were treated as a single unit. No significant differences were found among any of the **four** plots on Hall Island for date of death ($H=6.44$, $v=3$, $0.05 < p < 0.1$).

Comparing areas, we found significant differences in age and date at death ($H=20.9$, $v=2$, $p < 0.001$; $H=48$, $v=2$, $p < 0.001$; respectively). Chicks at St. Matthew-S died at an older age ($p < 0.05$) and at a later date ($p < 0.05$) than St. Matthew-N or Hall, which did not differ from one another in these respects.

We produced survivorship curves for kittiwake chicks **during** 1986. The curves **for** St. Matthew-N and **Hall** were similar, showing high mortality within the first week of life, after which the curve flattened out and dropped more slowly (Figure 25). The curve for St. Matthew-S showed a steady decline in numbers. Thus, chicks died there at a later age on the average, but the end result was that survivorship was poor in **all** three areas.

Survivorship of eggs and chicks was not significantly different among the three areas in either 1985 or 1986, in terms of hatching success (eggs **hatched/eggs** laid) and fledging success (chicks surviving/eggs hatched) (**Kruskal-Wallis** test, $p > 0.05$). To test for differences between years, we ran a two-way analysis of variance using a general **linear model** procedure. The rationale for this procedure and the assumptions we made are presented in the section on reproductive performance of **murres**. Hatching success was significantly different between years ($P=0.0054$), being higher in 1986, but we found no area or area-year effects. Fledging success was significantly different between 1985 and 1986 ($p=0.0001$), being higher during 1986, and again we found no area or area-year effects. Maximum possible reproductive success (number of surviving chicks and eggs on last visit to plot (eggs not included in 1986)/number of nesting attempts) was significantly different between 1985 and 1986 ($p=0.0107$), but we found no area or

area-year effects. Maximum reproductive success was low for both years, ranging from 15% to 22%.

Food Habits

Unlike the case for **murre**s, **pollock** was not always the dominant item in the diet samples of Black-legged **Kittiwakes** (Table 32). **Pollock** generally occurred the most frequently among the fish prey, but it contributed the greatest biomass in only 3 of the 6 collections. Four other taxa, **capelin**, **pricklebacks**, sand lance and **flatfish**, also were present in relatively large quantities in 4 of 6 collections. Sand **lance** occurred only in the samples of kittiwakes from St. Matthew-N, as was the case for **murre**s.

The diet samples of kittiwakes also contrasted with those of **murre**s in that invertebrates generally occurred much more frequently than fishes (Table 32, Figure 20). Polychaetes, pteropods and crustaceans, particularly **isopods**, **gammaridean amphipods** and *Parathemisto* spp., were the most common. Such a high use of invertebrates also contrasts with the diets of kittiwakes at other colonies in the Bering and **Chukchi** seas, where invertebrates have generally constituted a much small proportion of the diet (Figure 26).

Crabs and crab offal were eaten by many kittiwakes, particularly in 1986 when several commercial crab processor ships were working near the colonies at St. Matthew-N. **Kittiwakes** were numerous around the ships and fed on discarded crab parts, particularly the gills. Nearly half of the kittiwakes we collected in 1986 at St. Matthew-N contained crab gills.

The proportion of age 0 **pollock** among **all pollock** in kittiwake diets was highly variable during the four years, ranging from 0 to 100% (Table 27). These year-to-year changes in the proportion of age 0 **pollock** in **kittiwake** diets did not parallel those changes in **murre** diets. If differences in general abundance of age 0 **pollock** in the environment were responsible for differences in use by predators, we would expect the patterns to be more similar between kittiwakes and **murre**s. This suggests that factors such as variable vertical distributions of the fish might account for the interannual differences in use by kittiwakes, since **kittiwakes** are limited to feeding on prey near the surface of the ocean.

Predation

We have no direct evidence of predation on Kittiwake eggs, but saw two instances during 1986 at plot N-2 where a Glaucous **Gull** harassed **kittiwakes** into leaving their nests. In the first instances one chick was eaten by a **gull** and the other **fell** down to another nest where it was pecked to death by an adult kittiwake. In the second instance, a chick was knocked from its nest following harassment of the **adult** by a Glaucous **Gull**. The chick's fate was unknown, but presumably it died.

Kittiwake nests are generally inaccessible to foxes and we did not witness any instances of predation on chicks or eggs by foxes. Twice we observed a fox carrying an **adult** kittiwake away from the base of plot N-2, however. We do not know if these birds were injured or dead before the fox took them.

NORTHERN FULMARS

Numbers: Land-based Plots

Comparisons of counts of **fulmar** adults on land-based plots on St. Matthew-S indicated a significant decline between 1985 and 1986, but the differences between 1983 and 1985 and between 1983 and 1986 were not in both parameters significant (Table 3). At St. Matthew-N there was no significant difference between 1985 and 1986. A summary of land-based counts of **fulmars** and **fulmar** sites is presented in Appendix 18.

Counts of occupied sites (derived by subtracting the number of **pairs** counted from the number of **adults** counted) also were compared between 1985 and 1986. There was a mean decrease in the number of adults counted of 13.0% from 1985 to 1986, and a mean decrease of 9.8% in the number of sites (Table 3). Even though the 95% confidence intervals are relatively broad, significant decreases were detected in both parameters for St. Matthew-S. There was no significant difference between 1985 and 1986 in the number of occupied sites at St. Matthew-N.

Within plots, **fulmar** numbers varied substantially among days, with coefficients of variation averaging 37-38% for adult counts and 31-36% for site counts (Table 33). Even with approximately twice as many counts per plot in 1986 than in 1985, the coefficients of variation remained high. This variation was caused by fluctuations in the numbers of off-duty mates, failed breeders, non-breeding site-holders, and non-breeding "floaters" (prospecting birds) attending the cliffs.

Examination of correlation coefficients for all pairwise combinations of plots **also** counted on the same days indicates that variation in **daily** attendance among **plots** was substantial. We computed mean correlation coefficients among St. Matthew-S **plots only** (Table 34); other comparisons were precluded by small **sample** sizes. As for **murre**s and **kittiwakes**, these mean coefficients for **all plots** combined were relatively low ($r=0.54-0.58$ for adults, $r=0.46$ for occupied sites) and had high variances. Only about 30%-40% of the correlations were significant (Table 34), indicating a weak positive correlation.

To investigate whether the distance between plots had an effect on the degree of correlation, we examined two relatively discrete groups of plots at St. Matthew-S: one group of eight plots at **Vibrissae** Gap (plots **S-13** through S-20) and one group of six **plots** at Little Gap (plots S-22 through S-27). The relatively high mean correlation coefficients and high proportions of significant correlations among **Vibrissae** Gap plots (Table 34), especially in 1986, suggested a strong positive tendency for numbers to vary in concert among plots located near one another. However, no such tendency was evident among the Little Gap plots (Table 34), where mean correlation coefficients were low in both years and few correlations were significant.

Correlations were consistently higher for counts of adults than for **counts** of sites, although the difference was **usually small**. The magnitude of the site count **on** a given day depended on the proportion of pairs present, which varied among days. The overall mean proportion of pairs **on** occupied sites was 20.1% ($SD=5.8%$) in 1985 and 16.0% ($SD=9.4%$) in 1986 for plots at St. Matthew-S. As Hatch -(1985) found at the **Semidi** Islands, the proportion increased late in the season as pairs spent more time together at the nests when their chicks were **large**.

To examine seasonal trends in attendance, we divided each year's count period approximately in half and compared the mean site counts on plots using the procedure previously described for estimating relative change. In each year the division point of the count period immediately

preceded peak hatching. In 1985, site counts after 1 August averaged 25.1% (95% C.I. of $\pm 12.7\%$) higher than those before. In 1986, the mean increase was 25.5% (95% C.I. of $\pm 14.3\%$) higher after 24 July. Because the magnitude of the seasonal increase was virtually identical between years, we did not attempt to compensate for this source of variation in comparing the 1985 and 1986 counts.

We did not undertake a detailed analysis of **fulmar** attendance patterns in relation to weather conditions. Daily counts of birds are required for a comprehensive time-series analysis, and our counts were made at intervals of several days. Nevertheless, we did note a tendency for large departures of non-nesting birds from the cliffs during periods of stormy weather. In 1986, the two lowest daily count totals occurred on the days immediately following the onset of the two worst storms, with sea conditions corresponding to Beaufort Force 6-7, of the count period. No counts were made during the worst weather in 1985. On the other count days in both years, substantial variation in numbers occurred among days on which weather conditions were similar to one another.

Breeding Chronology and Reproductive Success

A relatively small sample of **fulmar** sites was monitored in each year to examine the timing and success of reproductive attempts. Because the species was of secondary importance in the overall study, less observation time was available than would be necessary to fully document reproduction. In addition, because of the long breeding season of the species and the probability of relatively high egg loss prior to our field work in both years, standard estimates of hatching success and breeding success (expressed as chicks hatched per egg laid and as chicks fledged per egg laid, respectively) cannot be calculated. These drawbacks notwithstanding, we obtained several measures of reproduction that are useful for comparisons with other (including future) studies.

In 1985, the first **fulmar** chicks were observed on 26 July at St. Matthew-N and on 27 July at St. Matthew-S. In 1986, the first chicks were seen on 21 July at St. Matthew-S and on 26 July at St. Matthew-N. In both years hatching began earlier than those dates given, however, because the first chicks seen were several days old. In addition, our first sightings of unattended chicks indicated that hatching may have begun as early as 16-18 July in each year; **fulmar** chicks are first left unattended by parents at about 2 weeks of age ($\bar{x}=16$ days), although chicks as young as 4-9 days are sometimes left unattended (Hatch 1979).

Based on a **sample** of 18 chicks in 1985 at St. Matthew-S, peak hatching occurred early in the first week of August. In 1986, **only** 12 chicks were available for this determination, but the peak appeared to occur during the **last** week of July. Using a mean incubation period of 48 days (Hatch 1979), peak egg-laying occurred about mid-June in 1985 and was slightly earlier in 1986. In each year, the last eggs probably hatched during the second week of August. Based on an estimated fledging age of about 7-8 weeks (Mougin 1967 [in Hatch 1979]), most **fulmar** chicks would have fledged in the last two weeks of September and the first week of October.

Our best information on reproductive success of **fulmars** is from St. Matthew-S (Table 35). We monitored 40 "active" sites (in use on 50% or more of **plot** visits) on 5 plots in 1985 and 27 active sites on 4 plots in 1986. A small sample (**n=35**) of sites in 1985 indicated that 46% of the sites were "active". Because of the difficulty in detecting eggs

without a great deal of observation, and because substantial egg losses may have occurred before our arrival, we express reproductive success as the number of young likely to fledge per active site. Hatch (1979, 1985) found that survival of chicks older than two weeks of age was high, so we assumed that chicks reaching that age were likely to fledge. In **1985**, 45% (18 of 40) of the active sites contained chicks at our last visits; in **1986**, the proportion was 37% (**10** of 27). No mortality of chicks was detected in 1985, whereas 23% (3 of **13**) of chicks that were known to have hatched disappeared in **1986**. Of 19 **sites** (presumably occupied by the same nesting pairs in both years) from which chicks fledged in **1985** and/or 1986, 53% (**10**) had chicks fledge in both years of study.

Another way in which we measured reproductive success was to count the number of chicks visible on land-based plots at **our** last visits (Table 36). These counts were undoubtedly low, although most chicks were relatively large and conspicuous at the time we conducted the counts. We originally intended to use the ratio of the number of chicks to the mean number of sites counted on the plots as an index of success. However, that index is unreliable because there is evidence that failed breeders vacate sites more readily following failure, and that the number of sites occupied in a given year depends largely on the reproductive success in that year (**Dott** 1973, **Dunnet** et al. 1979, Hatch **1985**). Thus, it is conceivable that the same ratio of chicks to sites could be obtained for different years in which overall breeding success was very different. Accordingly, we compared only the actual number of chicks counted in both years on the same plots. In 1986, 57 chicks were counted on six plots (**S-21**, S-22, S-24, S-25, S-26, S-27) that had 65 chicks in **1985**. This index of reproductive success corroborates the results from the percentages of chicks on active sites, with both measures indicating that reproductive success in 1986 was slightly lower than in 1985. The possibility **thus** arises that the decreases in counts of **adults** and sites from 1985 to **1986** may have been due **simply** to lower reproductive success in the **latter** year.

In both years of study, we documented predation by foxes on both eggs and **adult fulmars**, although we were unable to make any quantitative estimates of predation losses. Our impression was that the magnitude of such losses was relatively small. Gull predation on **fulmar** eggs is a problem only at unattended nest sites separated from neighboring sites; **fulmars** actively defend their sites against gulls (Hatch 1985).

PELAGIC CORMORANTS

Breeding Chronology and Reproductive Performance

Plots containing 56 Pelagic Cormorant nests were established on Hall Island in **1985**. Of these, 52 were known nest attempts (contained eggs or chicks sometime during observation), including one nest which was built 4 August 1985 but did not contain eggs that season. **Plots** were visited every three to eight days. Thirty-two nests were observed from 16 July to **17** August, whereas the remaining 20 nests were discovered at various times during that period. As of 16 July (the first day of observation), 58% (**15** of 26) of nests with known contents contained eggs or eggs and chicks (henceforth, **late** nests and late chicks), and the remainder contained chicks (early nests and early

chicks). All but one egg had been lost or hatched by 3 August. Relaying was not observed although some clutches may have been lost before initial observation followed by laying of a second clutch as observed in British Columbia (Drent et al. 1964). Of 41 eggs observed, 15 were known to hatch and 26 were presumed lost although they may have hatched and been lost as very young chicks. Therefore, hatching success is a minimum estimate (Table 37). Chick mortality is a minimum estimate based on chicks known to have hatched. Chick mortality was 0.2 among late chicks and 0.17 for early chicks. Chick production by 17 August (last observation) was 0.55 chicks/late **nest** and **2.2 chicks/early nest**.

Observations on most nests were made from a distance with binoculars. However, 23 nests in 1985 and 20 nests in 1986 were approached closely, and the adults of these nests sometimes flushed. Although we were careful not to approach too suddenly, the adults were occasionally disturbed. In one instance a flushing adult dislodged an egg and, in another instance, a chick. In addition, a clutch of one to three eggs disappeared after an adult flushed from its nest. These known losses were not included in the data presented; however, other disturbance-related losses may have occurred without our knowledge.

Cormorant nests were visited on 17 August 1985 at St. Matthew-N. We have no information on hatching success or chick mortality. St. Matthew-N produced slightly fewer chicks per known nest attempt than did Hall at last observation (Table 37). However, known nest attempts were probably underestimated and chicks per known nest attempt were overestimated for St. Matthew-N because empty nests can be difficult to see and **unmaintained** nests may have eroded by that time of year.

During 1986, the plots on Hall contained 50 known nest attempts. We visited plots between 10 July and 10 August. Breeding chronology on Hall Island was apparently the same during 1985 and 1986. As of 15 July, 54% (26 of 48 nests) still contained eggs. No empty nests were attended by adults. All but three eggs were hatched or lost by 4 August. There was no significant difference in number of known nest attempts on plots between 1985 and 1986 ($P > 0.05$, **Wilcoxon** matched-pair test). Eighty-four eggs were observed, of which 40 were known to hatch and 44 were assumed lost. Minimum hatching success was somewhat higher and chick mortality was much higher on Hall in 1986 than in 1985 (Table 37). Chick mortality was at least 0.38 for late chicks and 0.42 for early chicks. The number of chicks per known nest attempt on 10 August (last observation) was 1.42 for early nests and 0.86 for late nests. The number of **chicks** surviving on each plot was significantly lower in 1986 than in 1985 (Table 38, $P < 0.02$, **Wilcoxon** matched-pair test).

During 1986, we visited permanent plots between 10 July and 16 August at St. Matthew-N where 25 known nest attempts nests were observed. Breeding chronology did not differ greatly from chronology at Hall in 1985 or 1986. As of 16 **July**, 48% of 23 nests contained eggs. All eggs had hatched or had been lost by 28 July. Of 32 eggs observed, at least 16 hatched and 16 were assumed lost. Minimum hatching success was nearly the same for St. Matthew-N and Hall in **1986** (Table 37). We recorded higher chick mortality (all nests) and **lower** chick production (**at** final observation) at St. Matthew-N in **1986** than at **Hall** in 1985 or 1986. Mortality of early and late chicks at St. Matthew-N was 0.64 and 0.37, respectively. Chicks surviving per known nest attempt on 16 August (last observation) was 0.90 for early nests and 0.67 for late nests.

Data from this study can be compared with data collected during **1982** and **1983** assuming breeding chronology was similar among years. For purposes of comparison we used nest status during the period 26-31 **July** for the 1985 and 1986 data (Table 39). During 1982 and 1983 no observations were made prior to late July, therefore nesting attempts are probably underestimated and chicks per nest attempt overestimated for reasons stated earlier. Nonetheless, chick production per nest was much **lower** for **1986** than other years. Because the number of chicks per active nest (nests active at time of observation) did not differ substantially, it appears that there was greater loss of whole broods in **1986** than other years (Tables 37 and 39).

The apparent cause of lower productivity in **1986** was mortality related to bad weather and storms. Two storms were recorded with high winds and surf in **1986** (**18 - 19 July** and **1 - 3 August**), whereas storms during 1985 were not as severe. These storms corresponded with peaks in chick and egg **losses** at **Hall** (Table 40) and may have caused the high proportion of brood losses observed in 1986 (**Table 38**). Most chick mortality occurs in the first two weeks after hatching of cormorants (Robertson **1971**) and within four days after hatching of the shag (*Phalacrocorax aristotelis*) (Snow **1959**). Although observed chick mortality occurred **early** in 1985, chick mortality was high as late as August in 1986 (Table 40).

Further evidence suggestive of storm associated mortality is provided **by** data on chick age at time of loss. Age categories were based on relative sizes of chicks and feather growth (**Table 41**), which could be observed from a distance with binoculars. Durations of age categories were computed from records of chicks which were observed through consecutive age categories. Chronological ages corresponding to each category are necessarily ranges limited in precision by the length of the intervals between observations. A high proportion of chicks in **age class 3 (16-34 days)** and two chicks in age class 4 (35-48 days) were lost **at Hall** in 1986 (Table 42). Also mortality rates were higher for **early** chicks than **late** chicks at both **Hall** and St. Matthew-N in 1986 suggesting older chicks were at some disadvantage.

One possible disadvantage is that **older** chicks (≥ 16 days) are not covered by adults as often or as completely as young chicks and, therefore, are relatively more exposed to inclement weather. Our observations indicate that there is an inverse relationship between the amount of time an adult spends on the nest and the ages of its chicks. Potts (1969) reported that Shags suffered high mortality after long periods of high onshore winds and may not have fed effectively. Nysewander (**1983**) and Hatch (**1978**) observed Pelagic Cormorant nests in the **Gulf of Alaska** washed away and high chick loss due to heavy rains. **It** seems improbable that **older** chicks should be more vulnerable than younger chicks to food limitations and inclement weather, given equal exposure.

In 1986, chick mortality at **St. Matthew-N** did not exhibit such a strong association with storms as chick mortality did at **Hall**. **Hall** cormorant plots faced south and southeast, while the cormorant plots at **St. Matthew-N** were generally west-facing. Our observations indicate that wind direction during storms and aspect of nests influenced nestling survival. Three nests containing five eggs and six chicks with a south-southwest aspect were completely washed out during a southwesterly storm. Five of these chicks were 16 to 34 days old. Two

Large chicks (35-48 days old) died in their northeast facing nest during a northeasterly storm during which a time-lapse photo shows wave splash surrounded the nest. It is unclear whether chick mortality during storms was a direct result of exposure or an indirect result (or interaction with) reduced food delivery to the chicks as hypothesized for Shags by Potts (1969). However, Potts et al. (1980) reported that weather caused the greatest nesting losses of Shags in the Fame Islands.

Other sources of chick mortality were losses due to disturbance and predation. Cormorant adults were disturbed by close approach of people. We recorded losses of three eggs and one chick to disturbance, as mentioned earlier. Two nests were apparently preyed upon by gulls (Larus spp.) resulting in loss of at least two eggs. We did not observe arctic foxes preying upon cormorants chicks or eggs. However, disturbance by foxes may result in chick or egg loss as resulted from disturbance by river otters (Lutra canadensis) at cormorant colonies on Kodiak (Nysewander 1983).

Cormorant productivity varies greatly among years and locations (this study, Nysewander 1983). Although most chick losses ordinarily may occur soon after hatching, inclement weather can lead to mortality of chicks that are near fledging. Single to several visits by observers to a cormorant colony results in incomplete productivity data. Nesting attempts may not be as observable when adults are no longer at nests, and nests can wash out. There are many stages at which nests can fail and each may indicate a different casual relationship between Pelagic Cormorants and factors affecting reproduction. In order to fully assess factors affecting productivity of Pelagic Cormorants, surveys of nests must be conducted throughout the breeding season.

DISCUSSION

The goal of this study has been to develop field and analytical protocols and collect data that will facilitate future evaluation of impacts of oil exploration and development on the population status and breeding biology of the seabirds on St. Matthew and Hall islands. Variables that (1) can be measured precisely, (2) show little variation that cannot be explained by other easily measured variables, and (3) would be affected by such activities would be most suitable for study. This study has focused primarily on numbers and reproductive success of murre and kittiwakes, and secondarily on numbers and reproductive success of Northern Fulmars and Pelagic Cormorants. Data on food habits of murre and kittiwakes also have been gathered. Below we evaluate the utility of these data for the future monitoring of the population ecology of these species at St. Matthew and Hall islands.

Population numbers

In 1985 we counted kittiwakes and murre on boat-based plots and land-based plots. Although counts of these taxa also had been conducted on those boat-based plots in one or more previous years (1977, 1982, 1983), typically only one count had been conducted in any one year. The data on within-day and among-day variation in numbers collected in 1985 and 1986 on the time-lapse camera plots indicate that numerous counts of plots are necessary within years if changes in numbers between years are

to be detected. Repeated counts of boat-based plots in 1985 were extremely time-consuming compared to counts of land-based plots and certainly were less precise because it is considerably more difficult to count from a boat anchored offshore than from a promontory on land. Because boat-based counts can be conducted only when seas are calm or **nearly** so and such conditions occur infrequently in St. Matthew Island waters, we chose to suspend boat-based counts for the 1986 field season and concentrate instead on land-based counts.

On the land-based plots, numbers of **murre**s and kittiwakes varied markedly within years, and we **could** account for only a **small** portion of within-year variability in the **murre** counts when we examined models of within-day cycles of **attendance and the relationship** of the counts to weather variables that were measured at the weather station or at observation sites where the land-based counts were made. Such high unexplained variability within years would seem to preclude detection of changes in numbers from year to year. However, the analytical technique we used to assess changes in numbers between years was sensitive to changes of several percent and appears to be extremely promising.

Numbers of Black-legged Kittiwakes on the land-based plots were significantly higher **in 1985** and 1986 than in 1983, but the numbers of kittiwake nests were significantly lower in **1985** than in 1983 and significantly higher in 1986 than in either of those years (Table 3). Numbers of Common **Murre**s were highest in 1983, lowest **in 1985**, and intermediate in 1986. In contrast, numbers of Thick-billed **Murre**s were higher in 1985 and 1986 than in 1983. Numbers of Northern **Fulmar**s and numbers of occupied **fulmar** sites were significantly lower in 1986 than in 1985. These contrasting results for the different species indicate that numbers of each species do not vary among years in parallel, and that the causal factors of the variability among years apparently varied from species to species.

Spatial patterns of population changes

To assess the geographic extent of these differences among years, we examined the data for St. Paul Island and St. George Island, **i.e.**, the **Pribilof** Islands. Unfortunately, seabirds were not counted in 1983 on the **Pribilof** Islands, and consequently only differences between 1985 and 1986 can be used to evaluate the similarity of changes at St. Matthew and Hall islands to St. George and St. **Paul** Island. On the **Pribilof** Islands **kittiwake** numbers were lower in 1986 than in 1985 (**V. Byrd, pers. comm.**); no trend occurred at St. Matthew and **Hall** islands. Common **Murre** numbers were lower in 1986 than in 1985 on the **Pribilofs**, in contrast to St. Matthew and Hall islands. Numbers of Thick-billed **Murre**s increased between **1985** and 1986 **on St. Paul Island** but decreased **on St. George Island**; we found no differences between years on St. Matthew Island, but did find a 7 percent increase at **Hall** Island. **Fulmar** numbers were lower on St. **Paul Island** but higher on St. George Island in 1986 than in **1985**. With only two years of data in common to these two study areas, it is not yet possible to evaluate the hypotheses that numbers of one or more species fluctuate in parallel at the two areas. The results for St. Matthew and Hall islands seem to be more similar to those for **St. Paul** Island than for St. George Island, but there is no close correspondence overall. Such comparisons suggest that there is regional variation in the factors influencing annual changes in

numbers, and the discrepancies between St. Paul and St. George Island, as well as those among study areas on St. Matthew and Hall islands (see Table 3) suggest that such factors vary on a local scale as well.

Factors affecting changes in numbers

There is a general consensus among seabird biologists that food availability is the primary factor influencing both fecundity and survivorship of seabirds, and consequently variation in food availability should be the first factor examined in an effort to explain annual differences in numbers within areas and differences among areas in annual changes. Few data are available on the winter diet of any of these species and no comparative data have been collected to evaluate annual differences in diet that could influence overwinter survivorship and thus population numbers at the beginning of the breeding season.

We do not yet understand the dynamics of the interaction between food availability and initiation of nesting or the effect of this relationship on numbers of birds on the cliffs later in the breeding period. In years of poor reproduction, it seems likely that fewer adults would be present at the colony or that adults would spend less time on the cliffs during periods of food stress. However, if adults do not initiate nesting attempts but conditions near the colony are favorable later in the season, perhaps more birds would spend more time on the cliffs, thus elevating counts later in the season. This pattern occurred at Bluff in 1985 (Murphy et al. MS)--very few kittiwakes built nests, but mid-season counts were very high and reflected the presence of both mates at many inactive nest-sites. In contrast, in 1984 numbers of adults were extremely low during the counting period-- the colony was abandoned during the second week of July and food was unavailable near the colony (Murphy et al. submitted). Thus, counts at mid-season during poor reproductive years may be high if conditions at that particular time are good, but they may be low if conditions are poor. At St. Matthew and Hall islands, the apparent discrepancy between the increase in kittiwake nests in 1986 and the lack of a change in counts of adults late in the incubation period and early in the chick period could be explained by high suitability of conditions during the nest-building and egg-laying stages (clutch sizes were high in comparison to other years) followed by poor conditions by mid-season (fledging success was extremely low). These results suggest that numbers of adults on the cliffs cannot be used as a reliable index of population size, because counts apparently vary in relation to conditions during the counting period, i.e., counts vary in relation to changes in attendance patterns as well as changes in population size.

We examined numerous factors that might account for variation within days and among days in counts of murrelets on the time-lapse photo plots. No factor that we examined accounted for much of the variation in numbers, with the exception of high winds, which depressed numbers. The relationship of the counts to wind speed has little applicability to the variability among counts on the land-based census plots, however, because counts of those plots typically were made when winds were about 7 m/sec or slower, i.e., at wind speeds that had no discernible effect on numbers. Thus we have not yet accounted for much of the within-year variability in counts, and understanding of that variability is fundamental to interpreting between-year differences in counts. At the

present time we cannot differentiate between changes in **levels** of attendance during the counting period and actual changes in population numbers among years.

The magnitude of year-to-year changes in numbers that would be expected in the absence of human activities has not been quantified for **any** seabird species. The life histories of seabirds are characterized by low fecundity, delayed maturity, and high **survivorship**, consequently numbers of **adults** probably do not fluctuate markedly from year to year. However, one problem in establishing a baseline for St. Matthew and Hall islands is that the cliff-nesting seabirds there eat young age classes of walleye **pollock**. The substantial commercial fishery on **pollock** in the southern Bering Sea could be affecting the numbers and distribution of young **pollock**, and thus their availability to the seabirds, particularly to kittiwakes, who cannot feed at depth.

Long-term changes in numbers of kittiwakes at colonies in the north Atlantic are related to changes in prey availability that are influenced by various commercial fisheries (e.g., **Coulson** 1983). The commercial fishery for **pollock** in the Bering Sea **could** be influencing the numbers and distribution of young **pollock**, which are major components of the diet of both kittiwakes and **murres**. **Murre** declines at Bluff in Norton Sound (Murphy et al. 1986) and Cape Thompson on the **Chukchi** Sea coast (Springer et al. 1985b) are not well-understood but also could be related to the **pollock** fishery, **i.e.**, **pollock** occur in the diet of murres wintering in the southern Bering Sea and the fishery could be adversely affecting numbers and availability of young **pollock** on which **the murres** feed. Thus long-term changes in numbers of murres already may be occurring at some colonies in the region and the causes are not well-understood at this time. If no further **pre-development** studies of population numbers of **murres** and kittiwakes at **St. Matthew** and **Hall** islands are conducted and differences are detected after activities begin, inferring cause-effect relationships may be impossible.

On **the** other hand, logistics of studies **on** **St. Matthew** and **Hall** islands are considerably more difficult than **at** other colonies in the region (and the price **tag** correspondingly higher), and some inferences could be made if long-term studies elsewhere in the region are continued. Studies have been conducted annually at Bluff in Norton Sound since 1975 and in most years on the **Pribilof** Islands since 1975; a less detailed long-term data base has been established for Cape **Lisburne** on the **Chukchi** Sea coast. Investigation of the reproductive ecology of seabirds at those colonies is necessary to gain a reasonable understanding of the population status and factors that influence population numbers of murres and kittiwakes. At present, it is difficult to evaluate whether the reproductive ecology of seabirds on **St. Matthew** and **Hall** **islands** is more closely aligned to that on the **Pribilof** Islands or at **the** coastal colonies to the north. Definitive statements are not yet possible because reproductive failures in all years of study at **St. Matthew** and **Hall** islands preclude any understanding of which prey species are critical to reproductive success.

Because the area just north of the cliffs at the southeast end of **St. Matthew** Island was the proposed site for staging facilities for **oil** exploration and development, we conducted studies at **St. Matthew-S** to accumulate baseline data there and conducted parallel studies at **St. Matthew-N** and **Hall** **Island** to evaluate their suitability as controls for

future evaluation of impacts at St. Matthew-S. This approach is necessary because **annual** variation in numbers of various species at St. Matthew-S is marked, precluding simple **pre- and** post-development comparisons there. On the other hand, reproductive performance may vary among the three **areas** independently of any human activities. For example, **tidal current flow** through Sarichef Strait results in different physical oceanographic conditions and apparently food availability (T. Cooney, **unpubl.** data; G. Hunt, **unpubl.** data) than flow to the east of St. Matthew Island and west of Hall Island. Local differences in food availability and other factors **could** result in differences among areas in their suitability to breeding seabirds and thus in the population dynamics of those species (see **Fretwell** 1972).

In general, numbers of kittiwake individuals and nests varied in parallel in all three areas among the years, **1983**, 1985, and 1986. At Hall Island, however, numbers of adults were higher in 1986 than in 1985, and there were no differences between St. Matthew-S and St. Matthew-N between 1985 and 1986. The biggest discrepancy among areas was a significant increase in numbers of kittiwake nests at Hall and significant decreases at St. Matthew-S and St. Matthew-N between 1983 and 1985. Numbers of Common **Murres** and Thick-billed **Murres** fluctuated similarly but not identically among years in the three areas. In contrast, numbers of **fulmars** decreased at St. Matthew-S and showed an insignificant increase at St. Matthew-N. These results indicate that annual changes in numbers of **kittiwakes** and murres generally, but not always, occurred in parallel in the three study areas. Therefore, St. Matthew-N and Hall probably would be suitable controls for evaluation of major, but not minor, post-development impacts on numbers at St. Matthew-S. Although they would not be ideal as controls, there is no other sampling method that would permit evaluation of local impacts at St. Matthew-S.

Reproduction

We found no consistent relationships between numbers and reproductive performance; for example, there was higher variance in counts of Common **Murres** but not Thick-billed **Murres** on plots where k-ratios (breeder:nonbreeder ratios) were lower. However, numbers of adults on the cliffs might be lower and more variable if reproduction is poor. If counts are made during a period of food stress, for example, it seems likely that fewer nonbreeders and off-duty mates would be present on the cliffs. If food stress is sufficient to depress reproductive performance but **pre-dates** the count period, counts may be more variable because there would be relatively more failed breeders. For example, our counts of **murres** and **kittiwakes** at Bluff in 1984 occurred when kittiwakes deserted the colony and many **murres** abandoned their eggs; counts at plots were low and variable. In contrast virtually no kittiwakes nested at Bluff in 1985 but mid-season counts were extremely high and variable compared to 1979-1983 (Murphy, **unpubl.** data). Several more years of data on both numbers and reproduction would be necessary before quantification of effects of **reproduction** on numbers would be possible at St. Matthew and Hall islands.

Data on breeding chronology of kittiwakes were available for 1985 and 1986, and, on average, chronology was advanced in **1986**. The number of eggs/nest was markedly higher in 1986 than in 1982, 1983, or 1985,

suggesting that conditions early in the breeding season were much better in 1986 than in earlier years. In 1986, performance was very poor during the chick period, however, and the maximum possible number of chicks fledged/nest was similar to that of 1985, indicating that conditions for breeding deteriorated at mid-season.

No reproductive data could be collected at St. Matthew-S for Common Murres. Average k-ratios were higher in 1986 than in 1985 at both St. Matthew-N and Hall. The maximum potential values for fledging success were similar overall in the two years. Data were collected for Thick-billed Murres in **all** three areas; k-ratios were higher in 1986 than in 1985 and the maximum potential fledging success also averaged higher in 1986 than in **1985**.

The overall patterns of annual differences in reproduction are not based on similar results among areas, however. For kittiwakes, breeding chronology was delayed at St. Matthew-S in 1986 relative to other two areas, although all were advanced relative to 1985. Proportions of chicks lost were similar at all three areas in both 1985 and 1986, but the age-related patterns of chick mortality varied among the areas in 1986: relatively more older-aged chicks died at St. Matthew-S than at the other two areas. Common Murres breeding at St. Matthew-N had higher success than those at Hall, particularly in fledging success in 1985. For Thick-billed Murres, breeding chronology was delayed at St. Matthew-S compared to St. Matthew-N in both years. Mean k-ratios were lowest at St. Matthew-S, intermediate at St. Matthew-N, and highest at **Hall** in both 1985 and 1986. However, fledging success averaged higher at St. Matthew-S than at the other two **areas**.

For an **overall** comparison of the three areas in terms of reproduction, we assigned ranks (1 - latest chronology or lowest value, to, **3** - advanced chronology or highest value) for chronology, number of eggs/nest and survivorship of chicks of kittiwakes and chronology, k-ratios, and fledging success of Thick-billed Murres in both 1985 and 1986. We assigned tied ranks in **all** instances in which we had found no significant differences. We then summed the ranks for all parameters **for** each of the areas. The overall rank was lowest for St. Matthew-S (20), intermediate at St. Matthew-N (23.5) and highest at **Hall** (28.5), suggesting that suitability for breeding may not be equal for the three areas.

Comparisons of the food habits at St. Matthew-S and St. Matthew-N suggested that there was lower diversity and abundance of food for kittiwakes at St. Matthew-S in 1985, e.g., **sand lance** were not found in the diet there, 1986 patterns appeared similar but the results for St. Matthew-N were confounded by the presence of crab offal generated by the processors stationed at that end of the island.

Examination of data on kittiwake reproduction elsewhere in the region suggests that some colonies consistently outperform others (e.g., Cape **Lisburne vs. Bluff**) but that performance at northern coastal colonies and the **Pribilofs** varies independently among years, and performance has been higher at the **Pribilofs** in some years, e.g., 1976 and 1977 but higher at the coastal colonies in others (**Roseneau et al.** in prep.). We cannot predict at this time whether consistent differences among areas within the St. Matthew region are likely to be found or if relative performance at the study areas varies from year to year. The reproductive failures of kittiwakes at St. Matthew I. in 1982, 1983, 1985, and 1986 have coincided with failures or poor success

at both Bluff and the **Pribilofs**, but as noted above the longer-term data sets for those colonies suggest that reproductive performance varies independently at Bluff and the **Pribilofs**. Consequently, we cannot yet say whether the food webs that are keys to reproductive success in St. Matthew Island waters (mid-shelf) are likely to be similar to those at **the Pribilofs** (shelf-break), those at Bluff (coastal waters) or intermediate.

RECOMMENDATIONS FOR FUTURE STUDY

Monitoring Protocols

Boat-based censuses permit extensive coverage of the nesting cliffs, including coverage of areas where there are no suitable vantage points for land-based counts from the top of the cliffs. However, boat-based counts are difficult to conduct in the St. Matthew Island area because only rarely are seas sufficiently calm to count the birds on the cliffs accurately from a boat anchored below the **cliffs**. It is impractical to plan repeated boat-based counts within a year, but detection of changes in numbers between years is possible only if within-year variation can be quantified by such replication. Consequently, future boat-based censuses should be conducted on plots counted in previous years only if censuses of land-based plots suggest that major changes in numbers have occurred.

The time lapse camera results showed that numbers of **murre**s demonstrated no consistent pattern of variation during daylight hours, suggesting that counts of land-based census plots can be made at any time of day between about **0800h** and **2200h ADT**. Counts of **murre**s should not be conducted during periods when wind speeds are faster than about 7 m/sec (see Figs. 11, 12).

The variability in annual differences in numbers, reproduction and food habits among the study areas (St. Matthew-S, St. Matthew-N, and Hall) suggests that St. Matthew-N and Hall may not be adequate controls for evaluation of impacts of proposed developments near St. Matthew-S. However, St. Matthew-N and Hall probably can be considered as controls in a general sense and further evaluation of impacts would be possible if more distant plots within St. Matthew-S also are used as controls to assess impacts on areas nearest to any development. Comparing the St. Matthew-N and Hall Study areas, we would recommend concentration of future effort on Hall Island because many more plots that **can** be viewed from close range are available therefor all of the **cliff-nesting** species. Because the breeding cliffs at St. Matthew-S **occur** in two major units and we collected data on plots in each of **those** units, subareas within St. Matthew-S at different distances from any development also could be compared for impact analysis.

Reproductive performance may vary dramatically within a season, as shown in 1986 for kittiwakes, when increased numbers of nests were built (vs. 1983 and 1985), chronology was advanced, and clutch sizes were high but fledging success was very low. Thorough monitoring **of reproduction** throughout **the** reproductive period can indicate periods of physiological stress, particularly on kittiwakes, that are sufficient **to disrupt** the reproductive attempt. At Bluff we and previous investigators have documented failures at the **pre-egg** stage, during incubation, and during the chick period in different years. Cliff-nesting **seabirds** may be more

vulnerable to disturbance at some reproductive stages than others. For example, **murres** that are incubating eggs or brooding chicks do not tend to flush in response to low-flying fixed-wing aircraft and helicopters at Bluff (Murphy, **unpubl.** data); Bluff is on a frequently used corridor for small planes and perhaps the seabirds there have habituated to the frequent overflights. However, **murres** there do flush easily during the pre-egg period of attendance and perhaps when first on eggs. Unfortunately few systematic observations or experiments have been conducted on cliff-nesting seabirds (see **Dunnet** 1977).

Any stipulations restricting aircraft and other human activity should be very conservative until suitable studies have been conducted to provide a scientific rationale for changes and refinements. If there is short-term abandonment of nests in response to disturbance, reproduction would be an excellent parameter to monitor, particularly in experimental vs. control areas.

The technique that we have used to calculate a confidence interval for percent change is considerably more sensitive than any others that have been used previously by seabird researchers. There are assumptions of independence in the use of this test **that** do not seem to be violated by this data set. First, plots (sampling units for inter-year comparisons) must be independent units. We were particularly concerned that numbers might tend to fluctuate in parallel on nearby plots, which would mean that such plots could not be considered as independent units. However, correlations did not show any pattern with respect to proximity of the plots (correlations did not average higher between plots within **areas** than between plots in different areas). A second assumption is that counts at a plot are independent, i.e., a particular count should be no more strongly correlated with temporally neighboring counts than with counts more separated in time. For example, the great day to day variation in counts at a specific hour could result from a pattern of "high days" when many birds tend to be present throughout the day and "low days" when relatively few are present. **If** this is the typical pattern, then counts **early** in the day should be good predictors of counts later in the day. For the six camera **plots** in 1986, the mean correlation coefficient between counts at 1000 h versus counts at 1200 h was 0.78. The correlation falls to 0.57 for pairs of counts at 1000 h and 1400 h, and 0.47 for pairs of counts at 1000 h and 1800 h. Thus there is no indication of a pattern of high versus **low** day, suggesting also that any **autocorrelation** among days would be low. A third assumption, which is an outcome of the first **two** assumptions, is that counts are made independently on the various **census** plots. In one sense this assumption was violated, particularly within areas, because most or **all** plots generally were counted on the same set of days. However, counts were made on most days during the census period and thus constitute a rather thorough sample of days on which counts **could** have been made.

To most effectively use this technique to analyze changes in numbers between years, a large sample size for plots, as well as of counts within plots, is desirable. It may not **be** feasible logistically to both increase the area coverage of counts and maintain a schedule of repeated counts on all census plots; an alternative may be to subdivide the existing **plots**, as long as the resultant **plots** are not so small that numbers on adjacent plots are more highly **correlated** than those on more distant plots. We are not yet **able** to recommend minimal **plot** sizes from

this perspective, but our graphic analyses of the percent change in numbers of **murre**s between 1985 and 1986 vs. the mean number in 1985 suggested that percent change varies markedly on plots with fewer than about 50 **murre**s; i. e., plots with only small numbers of **murre**s give relatively imprecise results compared with plots of about 50 or more **murre**s (Figure 27). Consequently, maximizing the number of plots consistent with a mean number of **murre**s/plot of 50-100 probably would result in the most effective sampling design for detecting changes in numbers of **murre**s.

The time-lapse cameras provided detailed records of numbers on a limited number of plots. We feel that the cameras were extremely useful for documentation of within-season variation in numbers. However, they would not be particularly suitable for general censusing because (1) fog and rain can adversely affect the quality of the photographic images and impair camera function without precluding accurate counts by field personnel except in extreme conditions, and (2) the number of plots would necessarily be limited by the number of cameras that are available and functioning properly.

General Recommendations

Poor reproduction of **murre**s and kittiwakes in all years of study to date precludes any detailed interpretation of data on their numbers and food habits. Data on numbers, reproduction, and food habits in one or more years of good reproduction would be very instructive and will be necessary prior to development for detailed analysis of any impacts.

EXECUTIVE SUMMARY

This report presents the results of a study of the cliff-nesting seabirds on St. Matthew and Hall islands in the eastern Bering Sea in the summers of 1985 and 1986. The study was funded by the Minerals Management Service (MMS) in anticipation of possible oil-related activity in the **Navarin** Basin and on St. Matthew I. Of particular concern to MMS was a plan to construct an airstrip at the southeast end of the island.

The primary goal of the study was to assess variability in numbers of seabirds on these islands, and in so doing, to further develop field and analytical protocols for the monitoring of the population status of seabirds in very large colonies. Information on the reproductive success and food habits of certain species was gathered in order to help evaluate the biological significance of numerical fluctuations.

The islands were divided into three study areas, St. Matthew I. - south, St. Matthew I. - north, and Hall I. Within each area, census plots were established or relocated from earlier studies. The plots included ones visible from above on land, and ones visible only from below at sea. Counts of the land-based plots were emphasized both because of the greater accuracy and precision that can be obtained when counting from above on a stable platform and because repeated counts of land-based plots could be conducted easily. Three species of seabirds were chosen for intensive study - Common **Murre**s, Thick-billed **Murre**s and Black-legged Kittiwakes. Data also were collected on Northern **Fulmar**s and Pelagic Cormorants.

The census plots were counted by individuals using binoculars or telescopes at standard times on several days. Additional data on numbers were obtained by the use of time-lapse photograph, which was useful in assessing the levels of daily and day-to-day variability. The boat-based plots were counted less frequently and **only in 1985**. On certain plots, the numbers of pairs, nests, eggs and chicks of various species were mapped and counted to determine breeding chronology and performance. To assess **food habits** and **trophic** relationships, **murre**s and **kittiwakes** were collected at intervals during both summers as they returned to the colonies from feeding.

In analyzing the census data for the land-based **plots**, we first assumed that the individual counts were independent both within **plots** (within and between years) and among plots and then calculated a measure of the mean percentage change in counts between years and its standard error for each study area and for **all** study areas combined.

The time-series data from the cameras were **analysed** by assessing the contribution of specific spectral frequencies to the total variability in the data. This was done by generating sinusoid waves of given **periodicities** (e.g., 12-hour and 24-hour cycles) and determining the correlation of the predicted counts with the actual counts of birds.

The numbers of **murre**s and **kittiwakes** varied markedly within years, and we could account for only a small proportion of that variability. When analyses of the time lapse data were restricted to counts of photographs taken between **0800h** and **2200h** ADT there was no diurnal pattern of variation in the counts. In general, various weather variables accounted for **little** of the variation in the time lapse counts but numbers on the cliffs were low when wind speeds were high (>7m/sec). Because land-based counts were conducted during the daylight hours on days when winds were calm to moderate, analyses of the time lapse data suggested that variation in time of day and in weather conditions when land-based counts were made contributed little to within-year variation in those counts.

In general, numbers of **murre**s and **kittiwakes** increased between 1985 and 1986 by about **2-7%**. The numbers of **kittiwakes** and Thick-billed **Murre**s were about 10 - 30% higher and Common **Murre**s about 20% lower on census plots overall in 1985 than in 1983. Numbers of kittiwake nests increased much more, by about 40%, between 1985 and 1986, but were generally lower in 1985 than in 1983.

Other elements of the breeding biology of murre and **kittiwakes** **also** showed a positive response between 1985 and 1986. In 1986, egg-laying by **all** species was advanced, kittiwake clutch sizes were much larger, and a greater proportion of **murre**s laid eggs. For an overall comparison of the breeding performance of birds in the three areas we assigned ranks of from 1 to 3 for chronology, clutch size, and proportion of adults with chicks and chick survival. The overall rank was lowest for St. Matthew I. - south, intermediate at St. Matthew I. - north and highest at Hall I., suggesting that suitability for breeding might not be equal for these three areas.

Murres fed on a variety of fishes and invertebrates, particularly young age classes of walleye **pollock**. Sand lance were taken in both years at the north end of St. Matthew I., but not the south end, and were possibly important in early summer. Sand lance were not present among prey remains of **murre**s collected in 1982 or 1983 at the north end. **Pricklebacks** were caught by some adult murre and were fed to chicks in

1986 but not in any previous year. Besides **pricklebacks**, **pollock** were apparently the other important food given to chicks. **Pollock** did not dominate the diets of kittiwakes as they apparently did with murre. **Kittiwakes** took relatively more invertebrates than murre, including crab offal discarded by commercial processors operating near the island in 1986. A comparison of the food habits for all three species at the two ends of the island suggested that prey diversity and abundance were both higher at the north end, which could account for generally earlier and more successful breeding at St. Matthew I. - north and at Hall I. than at St. Matthew I. - south.

The increased numbers of eggs laid by kittiwakes in 1986 did not lead to proportionally higher production, as chick mortality was extremely high. In both 1985 and 1986, as well as in 1982 and 1983, the reproductive success of kittiwakes was poor, either because few eggs were laid, or because chicks died before they were old enough to leave the nests. The cause of death has apparently been starvation. Black-legged Kittiwakes and Red-legged Kittiwakes on the **Pribilof I.** also have had generally poor reproductive success in recent years. **Pollock** are important prey of kittiwakes and murre on the **Pribilof I.**, as they are on St. Matthew I., and a low availability of **pollock** is likely the cause of the low success rates of the **kittiwakes** in producing young.

The analytical techniques we used to census **murre** and **kittiwakes** were sensitive to changes of a few percent and appear to be very promising by comparison to methods used in previous other seabird studies. To most effectively use this technique to monitor changes in numbers between years, a large sample size of plots and of plot counts is desirable, with a mean number of birds per plot of 50 - 100. The use of time-lapse cameras was extremely useful in determining the level of within-season variability in numbers, and should be a part of any monitoring study.

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Table 1. Locations, species, mean number of birds, and dates of operation of time-lapse cameras.

Location	Plot	Species	Year	Mean#	Dates of Operation ¹
St. Matthew-S	S-28	Common Murre	1986	53	15JL - 10AU
St. Matthew-S	S-28	Thick billed Murre	1985	373	20 JL - 8 AU
			1986	338	15 JL - 10AU
St. Matthew-N	N-2	Common Murre	1985	135	18JL - 18 AU
			1986	152	13 - 18 JL , 29 JL - 15AU
St. Matthew-N	N-9	Thick-billed Murre	1986	75	14- 24JL, 26 - 27JL
Hal 1	H-7	Common Murre	1986	168	11 JL - 12AU
Hall	H-10F1	Thick-billed Murre	1985	180	17 -18 JL, 22 - 29 JL, 1 - 9 AU, 12 - 15 AU
			1986	179	11 -14 JL, 17 J1 - 7 AU, 9 - 12 AU

¹Gaps in coverage longer than one day noted below, shorter gaps exist within the periods listed.

Table 2. Regression equations for estimating lengths and weights of fish identified in prey remains found in murre and kittiwake from St. Matthew Island, 1985.

Species	Equation	Sample Size	Correction Coefficient	Source
Walleye pollock (<i>Theragra chalcogramma</i>)	Otoliths > 10.0 mm			
	Fish length (cm) = 3.175 x otolith length (mm) - 9.770	98	0.968	Frost and Lowry (1981)
	> 1 year old, otoliths ≤ 10.0 mm			
	Fish length (cm) = 2.246 x otolith length (mm) - 0.510	158	0.981	Frost and Lowry (1981)
	Fish weight (g) = 0.0075 fish length (cm) ^{2.977}			Pererya et al. (1976) in Smith (1979)
Sculpin ^a (<i>Cottidae</i>)	Fish length (cm) = 4.009 x otolith length (mm) - 4.364			K.J. Frost and L.F. Lowry, unpubl. data
	Log weight (g) = -6.016 + 3.46 log length (mm)	272	0.98	Craig and Haldorson (1981)
Sandlance (<i>Ammodytes hexapterus</i>)	Fish length (mm) = 4.01 x otolith length (units) ^b - 19.0	31	0.91	Springer et al. (1984)
	Log weight (g) = -6.45 + 3.47 x log length (mm)	143	0.919	D. Schmidt and P. Craig, unpubl. data
Capelin (<i>Mallotus villosus</i>)	Fish length (mm) = 3.42 x otolith length (units) ^b + 29.22	12	0.99	Springer et al. (1984)

^aEquations were derived from specimens of *Moxocephalus quadricornis*.

^b 12.5 units x mm⁻¹.

Table 3. The estimated relative change (with a 95% confidence interval) of seabird numbers on land-based plots at St. Matthew and Hall island from 1983 to 1985, 1983 to 1986, and 1985 to 1986. An asterisk appears when the estimated relative change is significant ($p < 0.05$). ND = no data.

Species	Area	Comparison					
		1983-1985	(n)	1983-1986	(n)	1985-1986	(n)
Black-legged Kittiwake	St. Matthew-S	0.1095±0.0812*	7	0.0851±0.0599*	7	-0.0293±0.039	10
	St. Matthew-N	1-J.4490±0.110*	3	0.4933±0.127*	3	0.0315±0.051	6
	Hall	0.3723±0.1408*	6	0.4434±0.1271*	7	0.0749±0.024*	8
	All areas combined	0.2980±0.047*	16	0.3191±0.047*	17	0.0187±0.021	24
Black-legged Kittiwake Nests	St. Matthew-S	-0.2552±0.0813*	6	0.3326±0.0630*	6	0.7488±0.055*	10
	St. Matthew-N	-0.1272±0.055*	3	0.0216±0.045	3	0.1483±0.036*	6
	Hall	0.1786±0.1178*	5	0.7838±0.3975*	6	0.5450±0.033*	8
	All areas combined	-0.1322±0.030*	14	0.2216±0.030*	15	0.4254±0.021*	24
Common Murre	St. Matthew-S	-0.168±0.1075*	5	-0.1618±0.1388*	5	0.0692±0.098	16
	St. Matthew-N	0.0667±0.1855	3	0.1735±0.159*	3	-0.0048±0.096	5
	Hall	-0.2419±0.0621*	5	-0.2149±0.0364*	6	0.0675±0.032*	10
	All areas combined	-0.2027±0.037*	13	-0.1748±0.030*	14	0.0636±0.046*	31

Table 3. Continued.

Species	Area	Comparison					
		1983-1985	(n)	1983-1986	(n)	1985-1986	(n)
Thick-billed Murre	St. Matthew-S	0.2206±0.1271*	13	0.3238±0.1510*	13	0.0864±0.108	28
	St. Matthew-N	0.0404±0.191	3	0.2415±0.240*	3	-0.097±0.107	7
	Hall	0.0351±0.1800	6	0.1624±0.0734*	7	0.0725±0.060*	10
	All areas combined	0.1484±0.083*	22	0.2471±0.072*	23	0.0681±0.076	45
Northern Fulmar	St. Matthew-S	0.0712±0.1582	13	0.0131±0.1444	12	-0.1299±0.094*	19
	St. Matthew-N	ND		ND		0.0783±0.121	5
	Hall	ND		ND		ND	
	All areas combined	0.0048±0.1496	14	0.0136±0.1360	13	-0.0912±0.078*	24
Northern Fulmar Occupied Sites	St. Matthew-S	ND		NO		-0.0980±0.088*	19
	St. Matthew-N	ND		ND		ND	
	Hall	ND		NO		ND	
	All areas combined	NO		ND		ND	

Table 4. Mean correlation coefficients of daily murre, kittiwake, and fulmar counts among groups of land-based census plots at St. Matthew and Hall Island, 1985 and 1986 (S = St. Matthew-S, N = St. Matthew-N, H = Hall; values given = mean \pm SD, n).

	ARFA		
	S	N	H
Common Murre			
S 1985	0.29 \pm 0.51 n=34	--	--
1986	0.24 \pm 0.60 n=140		
N 1985	-0.16 \pm 0.61 n=6	0.43 \pm 0.34 n=6	--
1986	-0.01 \pm 0.47 n=46	0.08 \pm 0.52 n=9	
H 1985	0.56 \pm 0.29 n=10	0.42 \pm 0.43 n=37	0.46 \pm 0.42 n=45
1986	-0.08 \pm 0.52 n=98	0.06 \pm 0.32 n=48	0.21 \pm 0.36 n=65
Thick-billed Murre			
S 1985	0.55 \pm 0.38 n=94	--	--
1986	0.41 \pm 0.50 n=356		
N 1985	0.42 \pm 0.49 n=29	0.28 \pm 0.52 n=10	--
1986	0.05 \pm 0.57 n=109	0.01 \pm 0.55 n=18	
H 1985	0.69 \pm 0.24 n=35	0.52 \pm 0.37 n=48	0.84 \pm 0.11 n=45
1986	0.36 \pm 0.38 n=202	0.32 \pm 0.38 n=48	0.71 \pm 0.20 n=66
Black-legged Kittiwake			
S 1985	0.62 \pm 0.16 n=10	--	--
1986	0.30 \pm 0.46 n=70		
N 1985	0.29 \pm 0.51 n=16	0.73 \pm 0.09 n=7	--
1986	0.34 \pm 0.38 n=45	0.51 \pm 0.26 n=15	
H 1985	0.73 \pm 0.21 n=7	0.35 \pm 0.40 n=32	0.34 \pm 0.33 n=36
1986	0.34 \pm 0.37 n=81	0.36 \pm 0.36 n=54	0.42 \pm 0.33 n=36
Northern Fulmar			
S 1985	0.58 \pm 0.29 n=47	--	--
1986	0.54 \pm 0.32 n=47		
N 1985	--	--	--
1986			
H 1985	--	--	--
1986			
Northern Fulmar Sites			
S 1985	--	--	--
1986	0.46 \pm 0.37 n=149		
N 1985	--	--	--
1986	--	--	--
H 1985	--	--	--
1986			

Table 5. Results of nested ANOVA on boat-based counts of murrees at St. Matthew-N, 1977-1985. P-values marked with an asterisk are significant at $p = 0.05$.

Plot	Among-Census, Within-Year		Among-Year	
	df	P	df	P
D1/D2	3	0.017*	3	0.681
D7	1	0.770	3	0.049*
D8	2	0.250	3	0.015*
D9A	3	0.116	2	0.016*
D9B	8	0.000*	2	0.715
D9C	4	0.000*	2	0.853
D9D	3	0.123	1	0.296

Table 6. Comparison of counts obtained from time-lapse photos with counts made at the site by observer with binoculars.

Species	Plot Location	Subplot	Mean Binocular Count		% Departure	
			1985	1986	1985	1986
Common Murre	St. Matthew-S			86		15.0
	St. Matthew-N	1	24	21	9.2	9.6
	St. Matthew-N	2	43	41	6.4	7.0
	St. Matthew-N	3	84	82	6.7	4.7
	St. Matthew-N	all	154	144	6.4	4.8
	Hall	1		126		4.4
	Hall	2		24		10.0
	Hall	3		32		9.0
	Hall	all		183		4.5
	Thick-billed Murre	St. Matthew-S	-	439	-	5.0
St. Matthew-N		-		63	-	0.2
Hall				177	-	2.1

Table 7. Correlations (Pearson's r) among time-lapse plots, 1985 and 1986. Correlation coefficients marked with an asterisk are significant, $p < 0.05$. COMU = Common Murre, TBMU = Thick-billed Murre.

Year	Species	Location	Common Murre			Thick-billed Murre	
			St. Matthew-S	St. Matthew-N	Hall	St. Matthew-S	St. Matthew-N
1985	COMU	St. Matthew-N					
	TBMU	St. Matthew-S		0.36*			
	TBMU	Hall		0.50*		(-).63*	
1986	COMU	St. Matthew-S					
	COMU	St. Matthew-N	0.49*				
	COMU	Hall	0.50*	0.64*			
	TBMU	St. Matthew-S	0.65*	0.61*	0.74*		
	TBMU	St. Matthew-N	0.38*	0.44*	0.31*	-0.08	
	TBMU	Hall	0.54*	0.52*	0.75*	0.65*	0.26*

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Table 8. Correlations (Pearson's r) among subplots of Common Murre time-lapse plots, 1985 and 1986. Correlation coefficients marked with an asterisk are significant, $p < 0.05$.

Year	Location	Subplot	Subplot 1	Subplot 2	Subplot 3
1985	St. Matthew-N	1			
		2	0.73*		
		3	0.68*	0.60*	
1986	St. Matthew-N	1			
		2	0.77*		
		3	0.79*	0.79*	
	Hal 1	1			
		2	0.73*		
		3	0.68*	0.61*	

Table 9. Coefficients of variation (%) of counts of murrees for each hour between 0800-2200 ADT on time-lapse plots.

Hour	Common Murre				Thick-billed Murre				
	St. Matthew-S	St. Matthew-N		Hall	St. Matthew-S	St. Matthew-N		Hall	
	1985	1985	1986	1986	1985	1986	1986	1985	1986
0800	38	18	20	17	40	33	9	21	14
0900	38	12	17	15	30	35	10	21	14
1000	31	18	9	15	32	32	13	19	13
1100	32	9	11	11	30	32	18	18	17
1200	31	14	12	12	29	34	18	19	14
1300	31	10	11	14	30	38	16	20	14
1400	41	21	16	16	27	31	17	18	14
1500	39	17	17	16	23	39	25	16	15
1600	48	22	12	15	23	39	30	15	16
1700	42	20	17	16	29	32	31	13	17
1800	40	21	16	17	30	33	29	11	19
1900	32	21	18	19	28	35	24	11	20
2000	25	16	15	18	29	33	28	10	19
2100	22	5	11	14	32	30	27	12	19
2200	26	11	15	14	28	33	23	14	19
Mean	34	16	14	15	29	34	21	16	16

Table 10. Correlations of observed numbers of Common Murres time-lapse plots with numbers protected by sinusoid functions with various periods. "Daytime counts" include only those made between 0800h and 2200h ADT.

Year	Cycle Period (hr)	St. Matthew - S.				St. Matthew - N				Hall						
		r ²	F	df	v ² , v?	P	r ²	F	df	v ² , v?	P	r ²	F	df	v ² , v?	P
1985	8	--	--	--	--	--	0.01	0.56	2, 136	>0.75	--	--	--	--	--	--
	12	--	--	--	--	0.10	7.78	2, 136	<0.001	--	--	--	--	--	--	--
	24	--	--	--	--	0.05	3.54	2, 136	<0.05	--	--	--	--	--	--	--
	Daytime 24	--	--	--	--	0.10	8.03	2, 131	<0.001	--	--	--	--	--	--	--
1986	8 + 12 + 24	--	--	--	--	0.26	9.13	5, 133	<0.001	--	--	--	--	--	--	--
	Daytime 8 + 12 + 24	--	--	--	--	0.15	3.77	6, 127	<0.005	--	--	--	--	--	--	--
1986	8	0.07	7.07	2, 183	<0.01	0.04	6.10	2, 271	<0.025	0.06	12.69	2, 408	<0.001			
	12	0.04	3.93	2, 183	<0.025	0.12	18.56	2, 271	<0.001	0.02	5.36	2, 408	<0.025			
	24	0.14	15.27	2, 183	<0.001	0.04	5.40	2, 271	<0.075	0.10	22.40	2, 408	<0.001			
	Daytime 8 + 12 + 24	0.06	4.52	2, 150	<0.05	0.10	12.25	2, 213	<0.001	0.01	1.70	2, 332	>0.10			
1986	8 + 12 + 24	0.32	14.25	6, 179	<0.001	0.32	20.65	6, 267	<0.001	0.24	21.43	6, 404	<0.001			
	Daytime 8 + 12 + 24	0.07	1.97	6, 146	>0.10	0.16	6.76	6, 209	<0.001	0.05	2.83	6, 328	<0.05			

Table 11. Correlations of observed numbers of Thick-billed Murres on time-lapse plots with numbers predicted by sinusoid functions with various periods. "Daytime counts" include only those made between 0800h and 2200h AOT.

Year	Cycle Period (hr)	St. Matthew-S				St. Matthew-N				Hall			
		r ²	F	df _{v1,v?}	P	r ²	F	df _{v1,v?}	P	r ²	F	df _{v1,v?}	P
1985	8	0.10	11.11	?, 706	0.001	--	--	--	--	0.08	12.43	2, 306	0.001
	12	0.00	0.56	2, 206	0.75	--	--	--	--	0.00	0.95	2, 306	0.75
	24	0.24	12.43	2, 706	0.001	--	--	--	--	0.12	22.79	2, 306	0.001
	Daytime 24	0.02	2.12	2, 180	0.75	--	--	--	--	0.06	2.37	?, 256	0.75
	8 + 12 + 24	0.35	21.44	5, 703	0.001	--	--	--	--	0.24	15.87	6, 302	0.001
	Daytime 8 + 12 + 24	0.06	1.98	6, 174	0.10	--	--	--	--	0.06	2.44	6, 249	0.10
1986	8	0.04	3.87	2, 169	0.05	0.06	4.74	7, 150	0.05	0.04	9.37	%, 424	0.10
	12	0.01	0.44	2, 169	0.75	0.05	3.8	2, 150	0.10	0.02	6.94	2, 424	0.01
	24	0.07	6.25	2, 169	0.025	0.13	12.14	2, 150	0.001	0.09	20.63	2, 424	0.001
	Daytime 24	0.00	0.16	2, 146	0.75	0.01	0.55	2, 114	0.75	0.06	10.90	2, 350	0.001
	8 + 12 + 24	0.14	5.52	5, 166	0.001	0.35	13.08	6, 146	0.001	0.19	16.06	6, 420	0.001
	Daytime 8 + 12 + 24	0.03	0.73	6, 142	0.75	0.04	1.70	3, 113	0.20	0.08	4.76	6, 346	0.001

Table 12. The estimated relative change (with a 95% confidence interval) of murre numbers on land-based plots at St. Matthew and Hall Island from 1985 to 1986, where counts have been corrected for windspeed. All counts where windspeed >7 m/sec were excluded from this analysis. An asterisk (*) appears when the estimated relative change is significant ($P < 0.05$).

Species	Area	1985 vs. 1986	(n)
Common Murres	St. Matthew-S	0.0784±0.074*	16
	St. Matthew-N	-0.0281±0.104	5
	Hall	0.0102±0.032	10
	All areas combined	0.0371±0.035*	31
Thick-billed Murres	St. Matthew-S	0.1912±0.074*	28
	St. Matthew-N	-0.0889±0.089	7
	Hall	-0.0790±0.055*	10
	All areas combined	0.1055±0.049*	45

Table 13. A comparison of correlations between standardized land-based murre counts and windspeed when wind direction was within 90° of plot aspect versus when wind direction was deviated more than 90° from plot aspect, for all cases and for those cases where windspeed was > 7 m/sec.

Species	ALL CASES						CASES WHERE WINDSPEED > 7m/s					
	wind direction within 90° of plot aspect			wind direction deviates more than 90° of plot aspect			wind direction within 90° of plot aspect			wind direction deviates more than 90° of plot aspect		
	<u>r</u>	<u>p</u>	<u>(n)</u>	<u>r</u>	<u>p</u>	<u>(n)</u>	<u>r</u>	<u>p</u>	<u>(n)</u>	<u>r</u>	<u>p</u>	<u>(n)</u>
Common Murre	0.076	0.429	(112)	0.097	0.391	(80)	-0.004	0.982	(36)	0.210	0.286	(28)
Thick-billed Murre	0.032	0.676	(175)	-0.097	0.289	(121)	0.190	0.157	(57)	-0.061	0.693	(45)

Table 14. Hatching dates of Thick-billed Murres in 1985, by plot, and results of Kruskal-Wallis test for differences among plots.

St. Matthew -N

Date	Plot	
	N-9	N-10
31 JL - 3 AU	12	4
4 AU - 7 AU	2	7
8 AU - 31 AU	3	5

Kruskal-Wallis H=4.86, v=1, 0.025<p<0.05

Hall

Date	Plot		
	H-6	H-23	H-26/H-27
27 JL - 30 JL	5	2	4
31 JL - 3 AU	7	10	1
4 AU - 11 AU	9	8	15
12 AU - 31 AU	2	4	3

Kruskal-Wallis H=2.63, v=2, 0.75<p<0.90

Table 15. Hatching dates of Thick-billed Murres in 1986, by plot, and results of Kruskal-Wallis tests for differences among plots

Date	Plot			
	S-14	S-18	S-21	S-23
31 JL - 3 AU	4	1	1	0
4 JL - 7 AU	4	3	2	2
8 AU - 31 AU	14	2	3	1

Kruskal-Wallis $H=1.44$, $v=3$, $0.50 < p < 0.75$

Date	Plot	
	N-9	N-10
27 JL - 30 JL	1	10
31 JL - 3 AU	3	6
4 AU - 7 AU	5	13
8 AU - 31 AU	1	9

Kruskal-Wallis $H=0.00$, $v=1$, $p > 0.99$

Date	Plot			
	H-6	H-10F1	H-23	H-26/H-27
23 JL - 26 JL	5	0	0	0
27 JL - 30 JL	13	2	0	4
31 JL - 3 AU	12	13	1	10
4 AU - 11 AU	5	8	13	6
8 AU - 11 AU	0	4	7	0
12 AU - 31 AU	2	4	7	1

Kruskal-Wallis $H=43.86$, $v=3$, $p < 0.001$

Table 16. Hatching dates of Thick-billed Murres, and results of Kruskal-Wallis tests for differences among locations.

1985			
Location			
Date	St. Matthew-S	St. Matthew-N	Hal 1
27 JL - 30 JL	0	0	11
31 JL - 3 AU	2	16	11
4 AU - 11 AU	9	11	36
12 AU - 31 AU	13	6	13
Kruskal-Wallis H=14.61, v=2, p<0.001			
1986			
Location			
Date	St. Matthew-S	St. Matthew-N	Hal 1
23 JL - 26 JL	0	0	5
27 JL - 30 JL	0	11	20
31 JL - 3 AU	6	9	41
4 AU - 7AU	11	18	36
8 AU - 11 AU	4	3	12
12 AU - 15 AU	4	1	8
16 AU - 31 AU	11	4	13
Kruskal-Wallis H= 19.44, v=2, p<0.001			

Table 17. Tests of fit of three log-linear models with data on chronology of hatch of Thick-billed Murres. Year and Location are independent variables.

Model Parameters	d.f.	Log-likelihood ratio statistic	P
1) year, date, location	12	44.2	0.000
difference, model 1 and 2	4	33.2	0.000
2) year, date X location	8	10.89	0.2081
difference, model 2 and 3	2	4.58	0.1013
3) date X location, date X year	6	6.31	0.3895

Table 18. Distribution of Thick-billed Murre hatch dates by year and contingency test for differences in hatching chronology between years for each location.

Location	Year	Dates			χ^2	p
		23 JL-3 AU	4 AU-11 AU	12 AU-31 AU		
St. Matthew-S	1985	2	8	13	1.30	0.52
	1986	6	15	15		
St. Matthew-N	1985	16	11	6	1.56	0.46
	1986	20	21	5		
Hall	1985	22	36	13	6.3?	0.04
	1986	66	48	21		

Table 19. Frequency of Common Murre hatch dates, on a subset of plots on Hall Island 1986.

Date	Plots			
	10A	26A1-A	26B1-4	27H4
23 JL - 30 JL	2	3	4	1
31 JL - 7 AU	4	29	9	10
8 AU - 11 AU	2	3	1	0

Table 20. Hatch frequency of Common **Murres** at St. Matthew-N and Hall Island (all plots combined within area) in 1985 and 1986.

1985			1986		
Date	St. Matthew-N	Hall	Date	St. Matthew-N	Hall
			19 JL - 26 JL	0	5
27 JL - 30 JL	2	4	17 JL - 30 JL	7	10
31 JL - 3 AU	9	14	31 JL - 3 AU	5	43
			4 AU - 7 AU	10	26
4 AU - 11 AU	7	8	8 AU - 11 AU	3	6
12 AU - 15 AU	1	4	12 AU - 15 AU	8	8
16 AU - 28 AU	6	11	16 AU - 28 AU	5	2

Table 21. "Summary of reproductive performance of murre, St. Matthew Island 1985 and 1986.
TBMU = Thick-billed Murre, **COMU** = Common Murre.

Area	Year	Species	Egg Sites	Range of K-ratio ^a	Mean K-ratio ^a	Standard Error of K-ratio ^a	Sample size for K.-ratio ^b
St. Matthew-S	1985	TBMU COMU	47 3	0.12-0.79 0	0.22 0	0.025 --	5 --
	1986	TBMU COMU	56 0	0.13-0.40 --	(.) .78 --	0.047 --	5 --
St. Matthew-ii	1985	TBMU COMU	65 27	0.14-0.60 --	0.28 0.41	0.092 --	6 1
	1986	TBMU COMU	94 46	0.32-9.60 --	0.52 0.65	0.021 --	6 1
Hall	1985	TBMU COMU	104 87	0.40-0.64 0.08-0.53	0.55 0.31	0.074 0.065	6 7
	1986	TBMU COMU	199 152	0.14-0.74 0.35-0.68	0.59 0.56	0.075, 0.034	8 10

^a Includes only plots for which mean number of adults was ten or more.
^b Number of plots sampled meeting criterion in (a).

Table 22. Summary of reproductive performance of murre, St. Matthew Island 1985 and 1986. TBMU = Thick-billed Murre, COMU = Common Murre.

Area	Year	Species	Egg Sites	Status at Last Observation ^a						Mean % Hatching Success	Mean % Chick Survival ^c
				Eggs				Chicks			
				Hatched	Failed	Unhatched	Unknown	Survived	Failed		
St. Matthew-S	1985	TBMU	47	14	22	11	0	13	1	39	93
		COMU	3	1	1	1	0	1	0	--	--
St. Matthew-S	1986	TBMU	56	18	13	18	7	17	1	58	94
		COMU	0	--	--	--	--	--	--	--	--
St. Matthew-N	1985	TBMU	65	25	32	6	0	19	6	44	76
		COMU	27	21	3	3	0	21	0	88	100
St. Matthew-N	1986	TBMU	94	43	47	4	0	29	14	48	67
		COMU	46	28	8	10	0	23	5	78	82
Hall	1985	TBMU	104	50	43	11	0	34	16	54	68
		COMU	87	28	46	11	0	23	5	38	82
Hall	1986	TBMU	199	116	60	23	0	94	22	66	81
		COMU	152	96	41	11	4	86	10	70	90

^aLast observation in 1985 was 14-17 AU for St. Matthew-S, 17 AU for St. Matthew-N and Hall .
Last observation in 1986 was 6-8 AU for St. Matthew-S, 15-18 AU for St. Matthew-N, 11-12 AU for Hall .

^bEggs hatched per eggs laid, for known fate eggs only, summed for all plots within location.

^cChicks surviving until last observation, per eggs hatched, summed for all plots within location.

Table 23. Maximum possible fledging success (% chicks produced to sea-going age per egg hatched) for **murres** at St. Matthew Island^a.

Location	1985		1986	
	Thick-billed Murre	Common Murre	Thick-billed Murre	Common Murre
St. Matthew-S	51	--	75	--
St. Matthew-N	38	88	35	72
Hall	43	39	59	64

^a Assuming no chick or egg mortality occurred after field studies ended.

Table 24. Occurrence of major taxa in diets of Thick-billed Murres on St. Matthew Island. Years followed by N are from the northwest end of the island, years followed by S are from the southeast end.

	1982 N ^a		1983 N ^a		1985 N		1985 S		1986 N		1986 S	
	<u>15 JL - 8 AU</u>		<u>7 J N - 9 A U</u>		<u>10 JL - 15 AU</u>		<u>15 ,11 - 11 AU</u>		<u>11 JL - 11 AU</u>		<u>1 O J L - 9 A U</u>	
	n	% ^b	n	% ^b	n	% ^b	n	% ^b	n	% ^b	n	% ^b
Number examined	34	(100)	57	(100)	40	(100)	11	(100)	41	(100)	42	(100)
Number empty	10	(30)	5	(9)	1	(3)	1	(9)	3	(7)	?	(5)
Frequency of invertebrates	17	35	39	75	21	54	7	70	31	82	38	95
Frequency of fishes	21	62	37	71	39	100	6	60	37	84	29	73
A. Frequency of occurrence												
<u>Clupea harengus</u>	0	0	1	?	0	0	0	11	0	0	0	0
<u>Mallotus villosus</u>	0	0	1	2	1	3	0	0	0	0	1	3
Gadidae	0	0	0	0	5	13	1	10	0	0	0	0
<u>Gadus macrocephalus</u>	0	0	0	0	6	15	0	0	0	0	0	0
<u>Theragra chalcogramma</u>	13	54	34	65	31	79	6	60	27	71	27	68
Cottidae	7	29	2	4	7	18	0	0	4	11	2	5
<u>Lumpenus sp.</u>	0	0	0	0	0	0	0	0	1	3	0	0
<u>Ammodytes hexapterus</u>	0	0	0	0	8	71	0	0	1	3	0	0
Pleuronectidae	6	25	15	29	21	54	4	40	70	53	10	25
Unidentified fishes	3	13	n	0	4	10	0	0	6	16	2	5
Polychaetes	8	33	8	15	14	36	0	0	9	24	12	30
Gastropod	7	8	0	0	1	3	0	0	0	0	0	0
Unidentified crustaceans	0	0	15	29	9	23	6	60	70	53	18	45

Table 24. Continued.

	1982 N ^c		1983 N ^a		1985 N		1985 s		1986 N		1986 S	
	<u>15 JL - 8 Au</u>		<u>7 J N - 9 A U</u>		<u>10 JL - 15 AU</u>		<u>15 JL - 11 AU</u>		<u>11 JL - 11 AU</u>		<u>10 JL - 9 A U</u>	
	n	%'	n	% ^b	n	%'	n	% ^b	n	%'	n	% ^b
Mysidae	1	2	1	2	0	0	1	10	0	0	0	0
Isopoda	0	0	3	6	0	0	0	0	0	0	0	0
Gammaridea	5	21	10	19	2	5	1	10	1	3	4	10
<u>Parthemisto spp.</u>	3	13	6	12	2	5	1	10	7	18	11	28
Shrimp	6	25	1	2	1	3	0	0	6	16	a	20
Crabs	1	4	1	2	1	3	0	0	0	0	o	0

8. Numbers of individuals

<u>Clupea harengus</u>	0	0	1	<1	0	0	0	0	0	0	0	0
<u>Mallotus villosus</u>	0	0	2	<1	1	<1	0	0	0	0	1	<1
Gadidae	0	0	0	0	5	<1	1	<1	0	0	0	0
<u>Gadus macrocephalus</u>	0	0	0	0	9	1	0	0	0	0	0	0
<u>Theragra chalcogramma</u>	640	68	317	84	527	65	78	70	760	63	207	84
Cottidae	31	3	15	4	14	2	0	0	33	3	4	2
<u>Lumpenus spp.</u>	0	0	0	0	0	0	0	0	2	<1	0	0
<u>Ammodytes hexapterus</u>	0	0	o	0	24	3	0	0	1	<1	0	0

Table 24. Continued.

	198? N ^a		1983 N ^a		1985 N		1985 S		1986 N		1986 S	
	<u>15 JL - 8 AU</u>		<u>7 JN - 9 AU</u>		<u>10 JL - 15 All</u>		<u>15 JL - 11 AU</u>		<u>11 JL - 11 AU</u>		<u>10 JL - 9 AU</u>	
	n	% ^b	n	% ^b	n	% ^b	n	% ^b	n	% ^c	n	% ^b
Pleuronectidae	266	28	43	11	209	26	34	30	393	33	32	13
Unidentified fishes	3	<1	0	0	25	3	0	0	11	<1	3	1

c. Estimated wet weight (g)

<u>Clupea harengus</u>	0	0	30	?	0	0	0	0	0	0	0	0
<u>Mallotus villosus</u>	0	0	40	2	1	<1	0	0	0	0	?	<1
Gadidae	0	0	0	0	5	<1	37	40	0	0	0	0
<u>Gadus macrocephalus</u>	0	0	0	0	9	1	0	0	0	0	0	0
<u>Theragra chalcogramma</u>	536	63	1553	90	527	65	38	41	465	66	260	89
Cottidae	170	20	75	4	14	?	0	0	20	3	7	?
<u>Lumpenus spp.</u>	0	0	0	0	0	0	0	0	16	7	0	0
<u>Ammodytes hexapterus</u>	0	0	0	0	24	3	0	0	1	<1	0	0
Pleuronectidae	133	16	??	1	209	26	17	18	197	79	21	7
Unidentified fishes	6	<1	0	0	25	3	0	0	9	1	2	<1

^aData from Springer et al. 1986.^bValues in parentheses represent the frequency among the total number of birds examined. Values not in parentheses are the percent frequency, numbers, or weight, respectively, among birds with identifiable prey remains.^cTentative identification.

Table 25. Population estimates of age 1 pollock from bottom trawl surveys in the eastern Bering Sea. From Bakkaia et al. (1986).

Year	Year-Class	Population number estimates (billions)
1979	1978	8.2
1981	1980	1.0
1982	1981	0.8
1983	1982	3.7
1984	1983	0.3
1985	1984	4.0
1986	1985	2.2

Table 26. Average estimated weight (**g**) of fishes in diets of **murres** at three northern colonies. Geometric mean, range (number of interval - years).

Colony	Years	Species	JN	1-20 JL	21 JL-10 AU	11-31 AU
C. Lisburne^a	1977-84	TBMU	31, 19-50(2)	29 , 8-110(4)	25, 12-110(5)	23, 7-41(5)
St. Lawrence I ^a	1981	TBMU	nd	38	46	nd
Bluff ^b	1978-84	COMU	nd	28 , 11-78(3)	34, 24-48(3)	nd
C. Lisburne^a	1978-84	COMU	147(1)	72 , 23-224(2)	43, 16-182(4)	119(1)
St. Lawrence I ^a	1981	COMU	nd	nd	92	nd

^a Springer et al. (**unpubl.** data).

^b Springer et al. in press.

Table 27. Relative proportion (%) of age 0 pollock among all pollock in diets of murre and kittiwakes from St.

Matthew I. during the intervals 15 JL - 8 AU 1982, 7 JN - 9 AU 1983, 10 JL - 15 AU 1985, and 9 JU - 11 AU 1986.

	Thi ck-bi 11 ed Murre						Common Murre						Black-legged Kittiwake						
	1982		1983		1985		1986		1982		1983		1985		1986				
	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S			
Frequency of occurrence	69	37	85	100	100	93	82	45	84	73	74	86	0	0	100	100	75	75	
Number	99	68	89	100	99	96	88	21	57	73	97	97	0	0	9	8	100	86	66
Biomass	59	8	35	100	81	49	16	1	6	13	48	48	0	0	40	100	60	2	

Table 28. Occurrence of major taxa in diets of Common Murres on St. Matthew Island. Years followed by N are from the northwest end of the Island, years followed by S are from the southeast end.

	1982 N ^a		1983 N ^a		1985 N		1985 s		1986 N		1986 S	
	15 JL - 8 AU		7 JN - 9 AU		10 JL - 15 AU		15 JL - 11 All		11 JL - 11 AU		10 JL - 9 AU	
	n	% ^b	n	% ^b	n	% ^b	n	% ^b	n	% ^b	n	% ^b
Number examined	42	(100)	79	(100)	32	(100)	12	(100)	45	(100)	18	(100)
Number empty	9	(21)	4	(5)	0	0	0	0	3	17)	3	(17)
Frequency of invertebrates	19	45	18	24	5	16	1	8	24	57	3	20
Frequency of fishes	31	74	71	95	32	100	12	100	36	86	14	93
A. Frequency of occurrence												
<u>Clupea harengus</u>	0	n	1	1	0	0	0	0	0	0	n	0
<u>Mallotus villosus</u>	?	6	1	1	7	6	7	17	?	5	1	7
Gadidae	0	0	0	0	2	6	1	8	n	0	0	0
<u>Gadus macrocephalus</u>	1	3	0	0	4	13	0	0	0	0	0	0
<u>Theragra chalcogramma</u>	28	85	63	84	28	88	12	100	35	83	14	93
Cottidae	7	21	2	4	5	16	2	17	0	0	0	0
<u>Lumpenus</u> spp.	0	0	0	0	0	0	0	0	6	14	0	0
<u>Ammodytes hexapterus</u>	0	0	0	0	4	13	0	0	2	5	0	0
Pleuronectidae	20	61	15	29	22	69	8	75	25	60	7	47
Unidentified fishes	2	6	0	0	4	13	?	17	5	12	3	20

Table 28. Continued.

	1982 N ^a		1983 N'		1985 N		1985 s		1986 N		1986 S	
	15 JL - 8 AU		7 JN - 9 AU		10 JL - 15 AU		15 JL - 11 AU		11 JL - 11 AU		10 JL - 9 AU	
	n	% ^b	n	% ^b	n	% ^b	n	% ^b	n	% ^b	n	% ^b
Polychaetes	4	12	1	1	0	0	0	0	4	10	1	7
Unidentified crustaceans	7	21	9	12	4	13	1	8	12	79	2	14
Mysidae	1	1	1	1	0	n	0	0	0	0	0	0
Gammaridea	1	3	0	0	0	0	0	0	0	0	0	0
<u>Parathemisto</u> spp.	5	15	2	3	0	0	0	0	5	12	0	0
<u>Thysanoessa</u> spp.	2	6	7	9	2	6	0	0	7	17	0	0
Shrimps	0	0	2	3	0	0	0	0	4	10	0	0
Crabs	2	6	0	0	0	0	0	0	0	0	0	0
8. Numbers of individuals												
<u>Clupea harengus</u>	0	0	2	<1	0	n	0	0	0	0	0	0
<u>Mallotus villosus</u>	3	<1	52	4	7	1	7	1	5	<1	?	<1
Gadidae	0	0	0	0	3	<1	1	<1	0	0	0	0
<u>Gadus macrocephalus</u>	1	<1	0	0	4	<1	0	0	0	0	0	0
<u>Theragra chalcogramma</u>	464	71	786	64	46?	72	368	74	1804	69	531	62
Cottidae	8	1	4	<1	17	3	4	<1	10	<1	0	0
<u>Lumpenus</u> spp.	0	0	0	0	0	n	0	0	2	<1	0	0
<u>Ammodytes hexapterus</u>	0	0	0	0	8	1	0	0	?	<1	0	0

Table 28. Continued.

	1982 N ^a		1983 N ^a		1985 N		1985 s		1986 N		1986 S	
	15 JL - 8 AU		7 JN - 9 AU		10 JL - 15 AU		15 JL - 11 AU		11 JL - 11 AU		11 JL - 9 AU	
	n	% ^b	n	% ^b	n	% ^b	n	% ^{a, b}	n	% ^b	n	% ^b
Pleuronectidae	169	96	378	31	137	21	115	23	790	30	313	37
Unidentified fishes	4	<1	0	0	7	1	4	<1	11	<1	6	1
r. Estimated wet weight(g)												
<u>Clupea harengus</u>	0	0	60	<1	0	0	0	0	0	0	0	0
<u>Mallotus villosus</u>	35	3	0	0	23	1	19	7	5	<1	2	<1
Gadidae	0	0	955	14	33	1	19	7	0	0	0	0
<u>Gadus macrocephalus</u>	5	<1	0	0	107	4	0	0	0	0	0	0
<u>Theragra chalcogramma</u>	1247	90	5773	83	2167	86	1070	91	872	64	535	77
Cottidae	0	0	7	<1	75	1	?	<1	0	0	0	0
<u>Lumpenus</u> spp.	0	0	0	0	0	0	0	0	80	6	0	0
<u>Ammodytes hexapterus</u>	0	0	0	0	174	3	0	0	6	<1	0	0
Pleuronectidae	85	6	189	3	69	3	5a	5	395	29	156	2?
Unidentified fishes	8	<1	0	0	14	<1	R	<1	13	<1	5	1

^aData from Springer et al. 1986.

^b Values in parentheses represent the frequency among the total number of birds examined. Values not in parentheses are the percent frequency, number, or weight, respectively, among birds with identifiable prey remains.

^cTentative identification.

Table 29. Fishes carried by adult Common Murres returning to St. Matthew I. during the chick period.

Prey	1982 ^a	1983 ^a	1985	1986
<u>Theragra chalcogramma</u>	3	5	5	3
<u>Mallotus villosus</u>	4	5	2	0
<u>Lumpenus</u> spp.	0	0	0	3

^a From Springer et al. (unpubl. data).

Table 30. Summary of reproductive performance of Black-legged Kittiwakes, St. Matthew I., 1985 and 1986.

Location	Year	Total Improved Sites (nesting attempts)	Complete Nests			Survivorship			At Last Visit	
			Nests w/0 eggs	Nests w/1 egg	Nests w/2 eggs	Eggs Lost	Eggs Hatched	Chicks Lost	Eggs Left	Chicks Left
St. Matthew-S	1985	171	74	41	0	5	16	1	20	15
	1986	214	55	125-128	22	12-30	126-156	77-98	4-14	47-56
St. Matthew-N	1985	223	71	59	0	11	40	4	8	36
	1986	279	92	100	97	56-89	205-238	158-191	8	47
Hall	1985	175	88	34	0	6	18	1	10	17
	1986	235	25	86	111	47-107	192-252	148-195	9	43
Total	1985	569	233	134	0	22	74	6	38	68
	1986	728	172	311-314	230	115-226	523-646	383-484	21-31	137-146

Table 31. **Summary of** reproductive performance of Black-legged Kittiwakes, St. Matthew I., 1985 and 1986.

	Year	St. Matthew-S	St. Matthew-N	Hal 1
Proportion of nesting attempts resulting in ≥ 1 egg laid	1985	24% (41/171)	26% (59/223)	19% (34/175)
	1986	*69-70% (147-150/214)	71% (197/279)	84% (197/235)
Average Clutch Size (No. eggs/no. nesting attempts)	1985	0.24 (41/171)	0.26 (59/223)	0.19 (34/175)
	1986	*0.79-0.80 (169-172/214)	1.08 (302/279)	1.31 (308/235)
Hatching success (No. eggs hatched/ no. eggs laid x 100)	1985	39% (16/41)	68% (40/59)	53% (18/34)
	1986	*73-91% (47-56/125-156]	*68-79% (205 -238/302)	*62-82% (192-252/308)
Fledging success (no. chicks surviving /no. chicks hatched x 100)	1985	94% (15/16)	90% (36/40)	94% (17/18)
	1986	*30.44% (47-56/126-156)	*20-23% (47/205-238)	*17-22% (43/192-252)
Maximum possible reproductive success (no. chicks and eggs at last visit /no. nesting attempts x 100)	1985	20% (35/171)	20% (44/223)	15% (27/175)
	1986	**22% (47-56/214)	**17% (47/279)	**18% (43/235)

* Ranges reflect data gaps due to adverse weather conditions which precluded timely visits to **plots and/or** the fact that contents of a given nest were not necessarily observed **on each visit**; see methods for a more detailed discussion of the problem.

****Eggs at last visit not included in 1986, for reasons mentioned in text.**

Table 32. Occurrence of major taxa in diets of Black-legged Kittiwakes on St. Matthew Island. Years followed by N are from the northwest end of the island, years followed by S are from the southeast end.

	1982 N ^r		1983 N ^a		1985 N		1985 s		1986 N		1986 S	
	15 JL - 8 AU		7 JN - 9 Au		10 JL - 15 AU		15 JL - 11 AU		11 JL - 11 AU		10 J L - 9 A U	
	n	% ^b	n	% ^b	n	% ^b	n	% ^b	n	% ^b	n	% ^c
Number examined	16	(100)	53	100)	43	(100)	8	(100)	39	(100)	35	100)
Number empty	2	(13)	3	(6)	9	(21)	?	(25)	5	(13)	9	(26)
Frequency of invertebrates	12	75	35	70	26	76	5	93	33	97	23	88
Frequency of fishes	1	6	21	42	20	59	2	33	11	32	8	31
A. Frequency of occurrence												
<u>Mallotus villosus</u>	0	0	3	6	0	0	0	0	7	6	0	0
Gadidae	0	0	0	0	1	3	1	17	0	0	0	0
<u>Theragra chalcogramma</u>	0	0	17	36	10	29	1	17	4	12	4	15
Cottidae	0	0	0	0	1	3	0	0	0	0	0	0
<u>Lumpenus</u> spp.	0	0	0	0	0	0	0	0	2	6	1	4
<u>Ammodytes hexapterus</u>	0	0	0	0	7	21	0	0	1	3	0	0
Pleuronectidae	1	7	0	0	5	15	1	17	2	6	0	0
Unidentified fishes	0	0	0	0	3	9	0	0	4	12	5	19
Polychaetes	8	57	17	26	15	44	?	33	13	38	15	58
Squids	1	7	3	6	0	0	0	0	0	0	0	0
Pteropods	7	50	8	17	1	3	0	0	3	9	3	12

Table 32. Continued.

	1982 N ^a		1983 N ^a		1985 N		1985 S		1986 N		1986 S	
	15 JL - 8 AU		7 JN - 9 AU		10 JL - 15 AU		15 JL - 11 AU		11 JL - 11 AU		1 O J L - 9 A U	
	n	% ^b	n	% ^b	n	% ^b	n	% ^b	n	% ^b	n	% ^b
Unidentified crustaceans	1	7	5	11	10	29	1	17	5	15	3	12
I sopoda	0	0	2	4	1	3	0	0	7	21	0	0
Gammaridea	1	7	4	9	6	18	3	50	3	9	2	8
<u>Parathemisto</u> spp.	1	7	3	6	2	6	1	17	1	6	0	0
<u>Thysanoessa</u> spp.	2	14	1	2	1	3	0	0	0	0	1	4
Shrimps	1	7	1	2	1	3	0	0	1	6	0	0
Crabs ^d	2	14	0	0	5	15	1	17	16	47	2	8

B. Numbers of individuals

<u>Mallotus villosus</u>	0	0	4	9	0	0	0	0	2	9	0	0
Gadidae	0	0	0	0	1	<1	1	11	0	0	0	0
<u>Theragra chalcogramma</u>	0	0	41	91	43	34	3	33	7	30	6	46
Cottidae	0	0	0	0	1	<1	0	0	0	0	0	0
<u>Lumpenus</u> spp.	0	0	0	0	0	0	0	0	3	13	2	15
<u>Amodytes hexapterus</u>	0	0	0	0	1?	10	0	0	2	9	0	0
Pleuronectidae	1	100	0	0	24	19	5	56	4	17	0	0
Unidentified fishes	0	0	0	0	44	35	0	0	5	22	5	38

Table 32. Continued.

	1982 N ^a		1983 N ^a		1985 N		1985 S		1986 N		1986 S	
	<u>15 JL - 8 AU</u>		<u>7 JN - 9 AU</u>		<u>10 JL - 15 AU</u>		<u>15 JL - 11 AU</u>		<u>11 JL - 11 AU</u>		<u>1 O J L - 9 A U</u>	
	n	% ^c	n	% ^b	n	% ^b	n	% ^b	n	% ^b	n ^d	% ^b
c. Estimated wet weight (g)												
<u>Mallotus villosus</u>	0	0	100	20	0	0	0	0	11	14	0	0
Gadidae	0	0	0	0	37	8	5	50	0	0	0	0
<u>Theragra chalcogramma</u>	o	0	388	80	43	9	7	20	6	8	120	85
Cottidae	o	0	0	0	23	5	0	0	0	0	0	0
<u>Lumpenus</u> spp.	o	0	0	0	0	0	0	0	24	32	16	11
<u>Ammodytes hexapterus</u>	o	0	0	0	250	55	0	0	21	28	0	0
Pleuronectidae	<1	100	0	0	12	4	3	30	?	3	0	0
Unidentified fishes	o	0	0	0	88	19	0	0	12	16	6	4

^a Data from Springer et al. 1986.

^b Values in parentheses represent the frequency among the total number of birds examined. Values not in parentheses are the percent frequency, numbers, or weight, respectively, among birds with identifiable prev remains.

^c Tentative identification.

^d Includes offal.

Table 33. Mean coefficients of variation for land-based counts of Northern **Fulmar** adults and occupied **fulmar** sites at St. Matthew-S during 1985 and 1986. Plots with mean counts ≤ 5 were excluded from this analysis.

	<u>Year</u>	<u>CV (%)</u>	<u>SD</u>	<u>Range</u>	n
Adults	1985	37	13	15-59	18
	1986	38	8	29-52	17
Sites	1985	36	15	9-66	18
	1986	31	8	22-51	17

Table 34. Mean correlation coefficients of daily counts of Northern Fulmar adults and Fulmar sites among selected groups of land-based census plots at St. Matthew-S, 1985-1986.

Area	Census	Year	Mean Correlation Coefficient	S.D.	% Significant (P < 0.05)	n
St. Matthew-S	Adults	1985	0.58	0.29	30	47
		1986	0.54	0.32	40	149
	Sites	1986	0.46	0.37	29	149
Vibrissae Gap	Adults	1985	0.64	0.23	39	28
		1986	0.74	0.17	86	28
	Sites	1986	0.71	0.18	82	28
Little Gap	Adults	1985	0.50	0.36	13	15
		1986	0.47	0.26	27	15
	Sites	1986	0.37	0.28	70	15

Table 35. Summary of data from Northern Fulmar reproduction plots at St. Matthew-S, 1985-1986. Values in parentheses are maximum possible numbers of eggs or chicks, assuming that some were lost before they were detected.

Plot	subplot	No. Sites Monitored		No. Eggs Observed		No. Chicks Observed		Eggs or Chicks on Final Visit	
		1985	1986	1985	1986	1985	1986	1985	1986
S-14	B	9	8	6 (7)	6	6	6	6	4
S-18	B/C	5	14	3 (5)	5 (7)	2 (3)	5 (7)	3	4
S-19	B	3	4	1 (2)	1	1	1	1	1
S-21	-	1	1	1	1	1	1	1	1
S-23	A,C,E,/F	22	-	8 (14)		7	-	7	-
Total		40	27	19 (29)	13 (ii)	18 (19)	13 (15)	18 (19)	10

Table 36. Summary of reproductive success of Northern Fulmars on selected census **plots** at St. Matthew-S, 1985-1986.

Plot	Subplot	No. chicks At Last Visit		
		1985	1986	
S-12	B+C	6	-	
S-13			13	
S-14			17	
S-15			10	
S-16			10	
S-17			3	
S-18			-	5
S-21			1	1
s-22	A	22	21	
S-23	A-G	7	-	
S-24		33	20	
S-25	-	0	4	
S-26	A-C	9	7	
S-27	A-D	0	2	
Total		78	113	

Table 37. Reproductive values for pelagic **Comorants** from **Hall** and **St. Matthew Islands**, Alaska.

	Hall		St. Matthew-N	
	1985 ^a	1986 ^b	1985 ^c	1986 ^d
Late nest s ^e	20	29		15
Eggs/late nest	2.05	2.90		2.13
Minimum hatching success ^f	0.37	0.48		0.50
Chicks surviving/late nest ^g	0.55	0.86	-	0.67
Known nest attempts ^h	52	50	31	25
Eggs or chicks/ known nest attempt ⁱ	2.38	2.70	-	2.28
Chicks' surviving/ known nest attempt	1.59	1.10	1.52	0.76
Proportion of clutches lost	0.25	0.28		0.13
Proportion of broods lost	0.09	0.21		0.41
Chicks lost/ chicks observed	0.17	0.40		0.54
Proportion of chick loss due to loss of brood	0.35	0.44		0.45

^a Observed between 16 July and 17 August.

^b Observed between 9 July and 10 August.

^c Observed once 17 August.

^d Observed between 10 July and 16 August.

^e Nests containing at least one egg (including nests with chicks and eggs) during the observation period.

^f Number of eggs observed hatched/number of eggs laid.

^g Number of **chicks** alive 10 August which were observed from egg stage.

^h **Nests containing eggs** or chicks during observation period.

ⁱ Eggs plus chicks which were present during observation period.

Table 38. Numbers of Pelagic Cormorant nests and chicks on Hall Island, 1983, 1985, and 1986. (Fashed lines indicate data not available.

Plot	1983 ^a		1985		1986	
	Nests	Chicks (28-30 JL)	Nests ^b	Chicks ^c (17 AU)	Nests ^d	Chicks ^e (10 AU)
H-1A	--	--	4	5	4	4
15	--	--	2	4	1	0
H-4	5	--	5	9	5	8
H-7A	--	--	2	6	2	2
H-n	0	--	3	7	7	4 (3 eggs)
H-15A	--	--	3	6	4	2
H-16A	--	--	2	2	1	0
16B	--	--	2	1	0	0
H-17A	--	--	4	7	4	5
17B	--	--	1	0	0	0
H-18A	--	--	3	5	4	8
18B	--	--	2	5	3	4
H-19A	2	5	2	1	2	3
19B	3	5	1	3	0	0
H-20	7	5	0	0	0	0
H-21A	--	--	2	3	1	0
21B	--	--	2	3	0	0
21C	--	--	3	0	0	0
21D	4	12	2	4	5	10
21E	--	--	1	2	1	2
H-22A	--	--	2	5	0	0
H-29	--	--	0	0	3	0
H-30	17	34	5	3	7	3

- ^a A. SOWLS, unpubl. data of known nest attempts and chicks observed 28-30 July.
^b Known nest attempts (containing eggs or chicks) observed between 16 July and 17 August.
^c Number of chicks alive on 17 August.
^d Known nest attempts (containing eggs or chicks) observed between 9 July and 10 August.
^e Number of chicks alive on 10 August.

Table 39. Summary of breeding success data for Pelagic Cormorants from St. Matthew-N and Hall.

	St. Matthew-N			Hall	
	1982 ^a	1983 ^b	1986 ^c	1985 ^d	1986 ^e
No. chicks	132	40	26	87	68
No. active nests ^f	74	19	17	43	34
No. chicks/ active nest	1.78	2.11	1.53	2.02	2.00
No. known nesting attempts ^g	82	22	25	52	50
No. of chicks/ nest attempt	1.61	1.82	1.04	1.67	1.36

^a D.G. Roseneau, unpubl. data from plot E5, 4 and 5 August.

^b D.G. Roseneau, unpubl. data from plots D1 and D9B, 27 July and 1 August.

^c 28 July.

^d 26 and 27 July.

^e 31 July.

^f Nests containing eggs or chicks on observation date.

^g Estimated for 1982 and 1983 from empty nests.

Table 40. Cormorant **egg** and chick **loss** by date on St. Matthew and Hall Islands, 1985 and 1986. Number in parentheses is percentage of eggs or chicks observed.

Hall 1985							
Date	16-21 JL	22-24 JL	25-26 JL	27 JL-2 AU	3-6 AU	7-12 AU	13-17 AU
Eggs lost	10(24)	3(7)	2(5)	3(7)	0(0)	0(0)	1(2)
Chicks lost ^a	6(11)	0(0)	1(2)	3(6)	0(0)	2(4)	1(2)

Hall 1986						
Date	9-14 JL	15-20 JL	21-25 JL	26-30 JL	31 JL-3 AU	4-9 AU
Eggs lost	2(2)	18(12)	9(11)	7(8)	1(1)	0(0)
Chicks lost	3(3)	13(14)	4(4)	4(4)	11(12)	1(1)

St. Matthew-N 1986						
Date	10-15 JL	16-22 JL	23-27 JL	28 JL-1 AU	2-7 AU	8-16 AU
Eggs lost	7(22)	6(19)	3(9)	0(0)	0(0)	0(0)
Chicks lost	5(12)	4(10)	5(12)	5(12)	3(7)	0(0)

^a Calculated for only those chicks with known dates of loss and those observed by 16 July. One chick was lost between 25 July and 13 August, and one chick was lost between 3 and 17 August. Percentages are calculated from 56 chicks observed from 16 June.

Table 41. Identifiable **stages** of pelagic Cormorant chick development.

<u>Class</u>	<u>Age (days)</u>	<u>Characteristics</u>
1	1 - 6	Chick unable to hold up its head; eyes closed; skin pink to gray colored, with shiny appearance, and without down.
2	7 - 15	Chick can hold up head for short periods but cannot stand; skin dark gray to black colored with dull appearance; down appears; eyes open; body 1/8 - 1/4 adult size.
3	16 -34	Chick able to stand; entirely down-covered with emerging primaries and rectrices growing to \geq 1/2 adult length; body 1/4 - 3/4 adult size.
4	35 -45	Development of scapulars occurs; rectrices and primaries are half to full adult size; body is 3/4 to adult-size.
5	46 to fledging	Chicks have lost all downy contour feathers, except on the neck and head; body is adult-size.

Table 42. Age-specific losses of Pelagic Cormorant chicks on Hall and St. Matthew Islands, Alaska, 1986.

Days old	0-6	7-15	16-34	35-48
Hall	13	5	16	?
St. Matthew	6	9	2	0

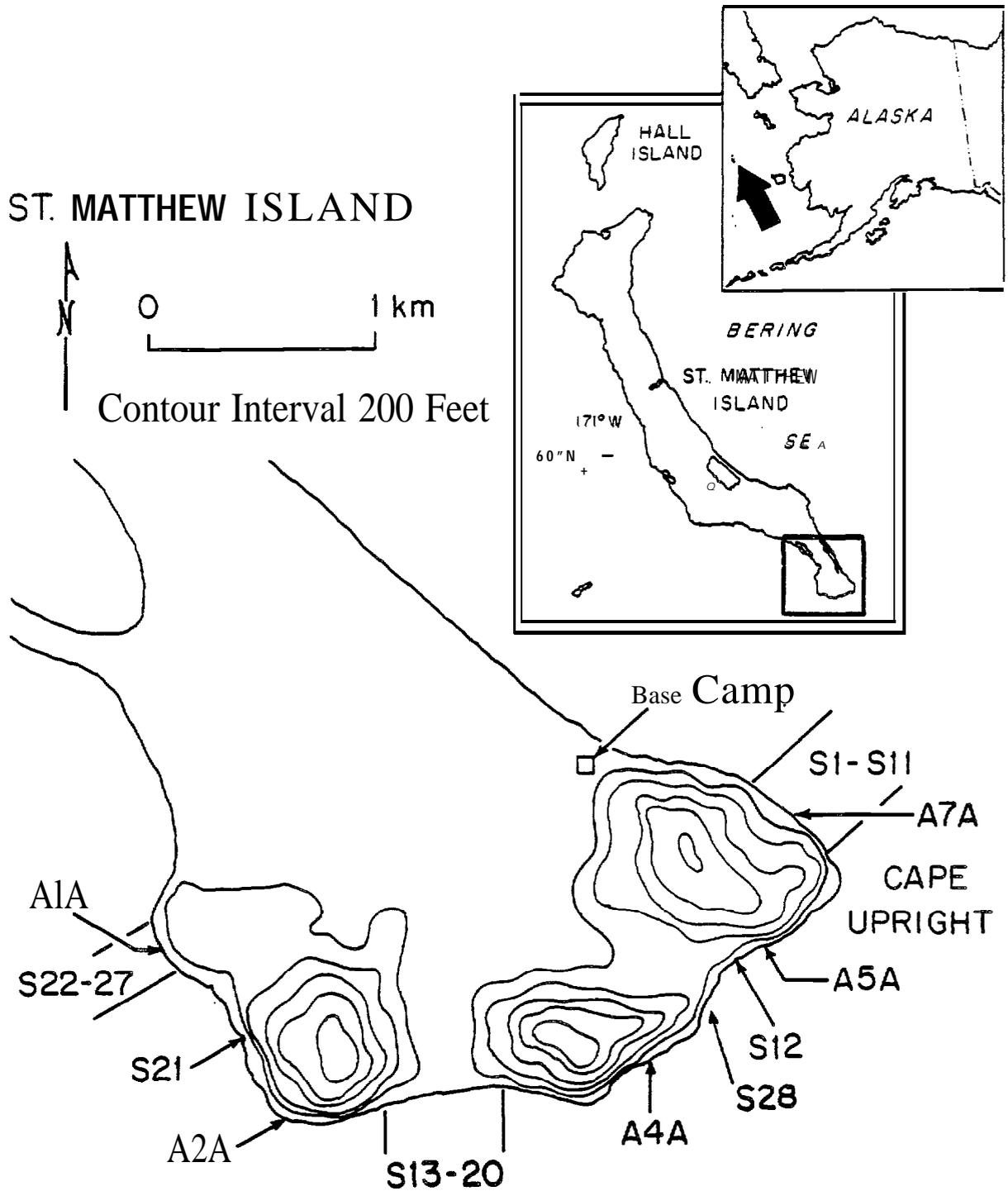


Figure 1. Camp and study plot locations at the southeast end of St. Matthew Island (St. Matthew-S). Land-based plots denoted by prefix "S"; others are boat-based plots.

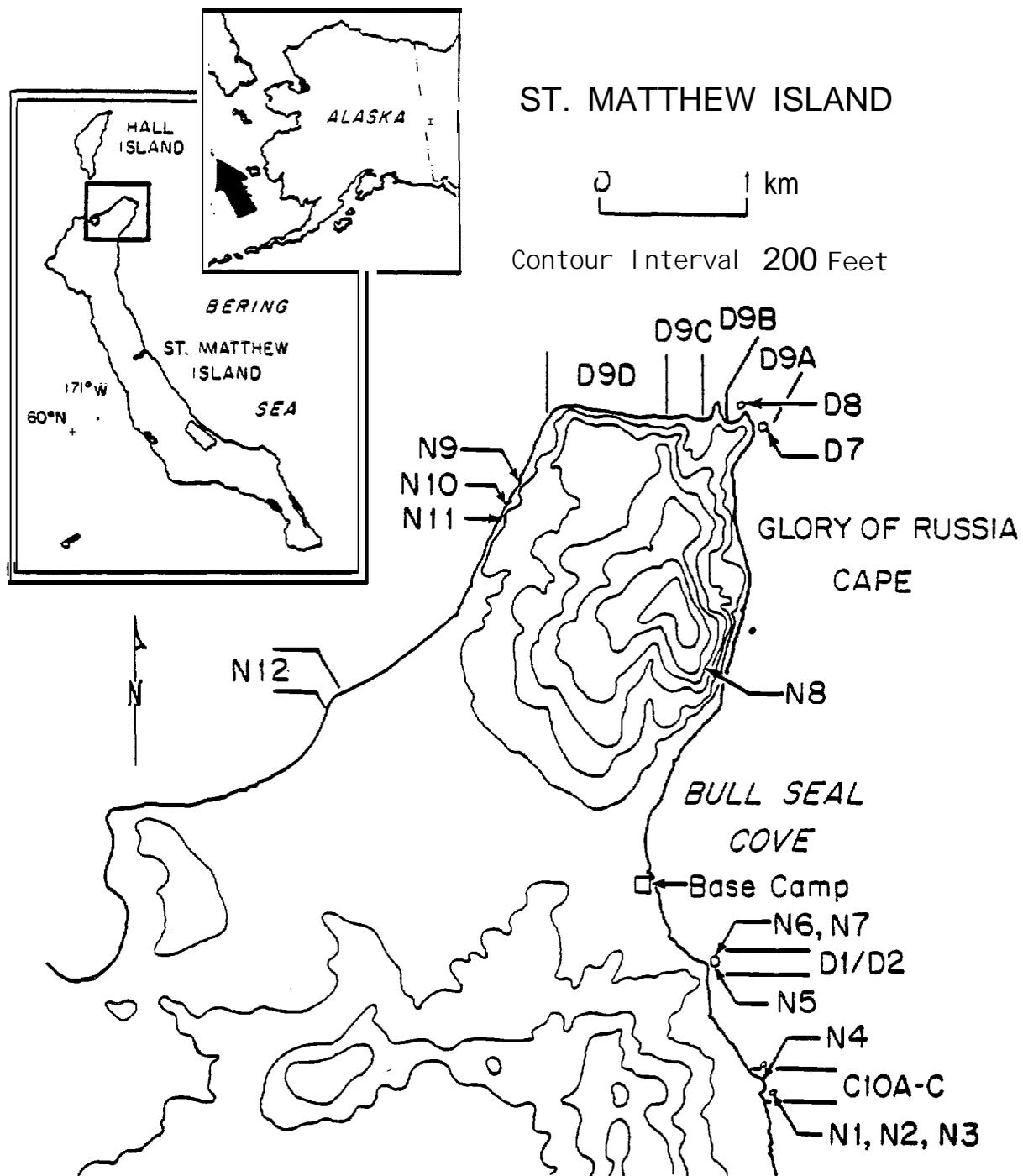


Figure 2. Camp and study plot locations at the northwest end of St. Matthew Island (St. Matthew-N]. Land-based plots are denoted by prefix "N"; others are boat-based plots.

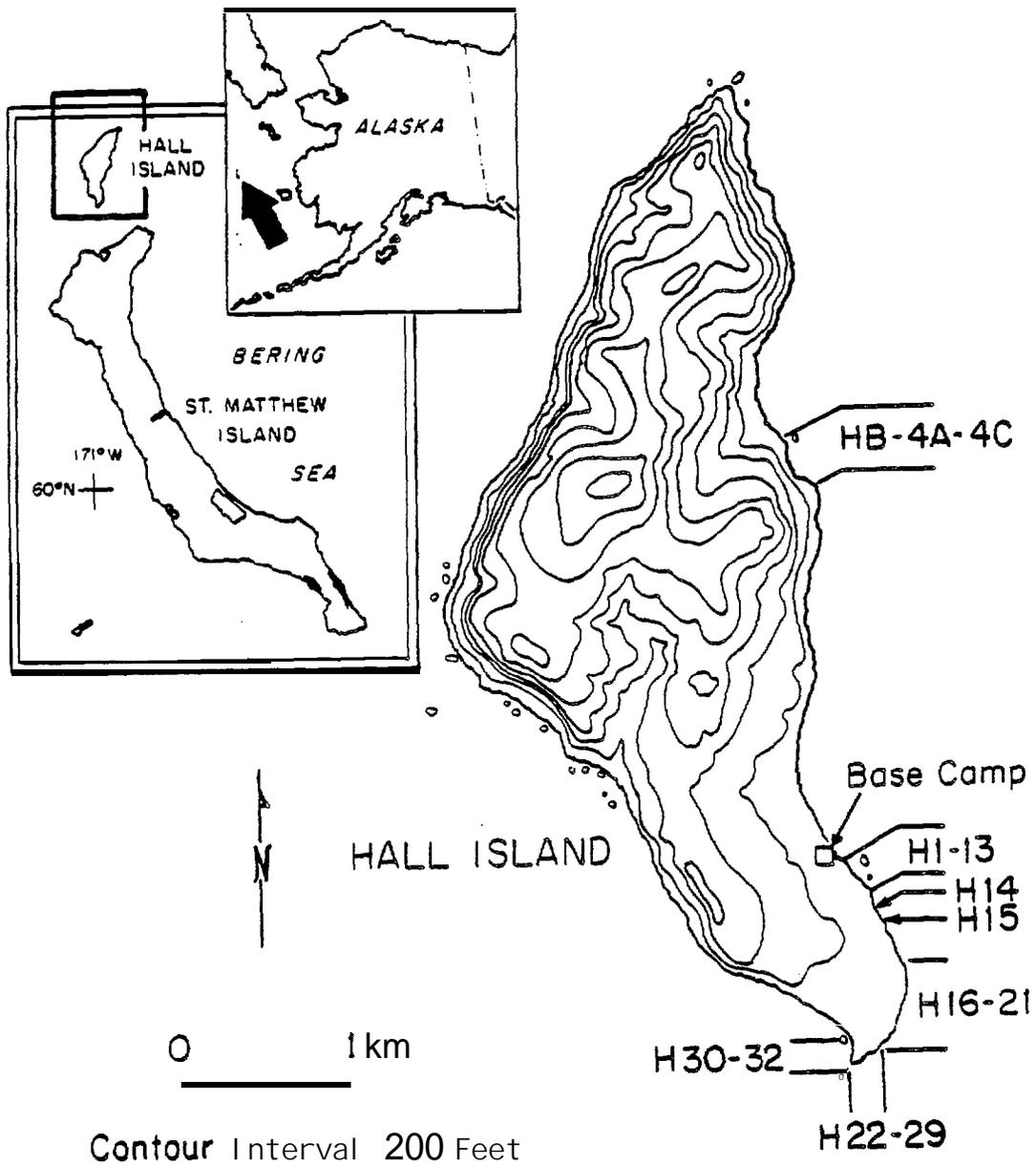


Figure 3. Camp and study locations on Hall Island (Hall). Land-based plots denoted by Prefix "H"; others are boat-based plots.

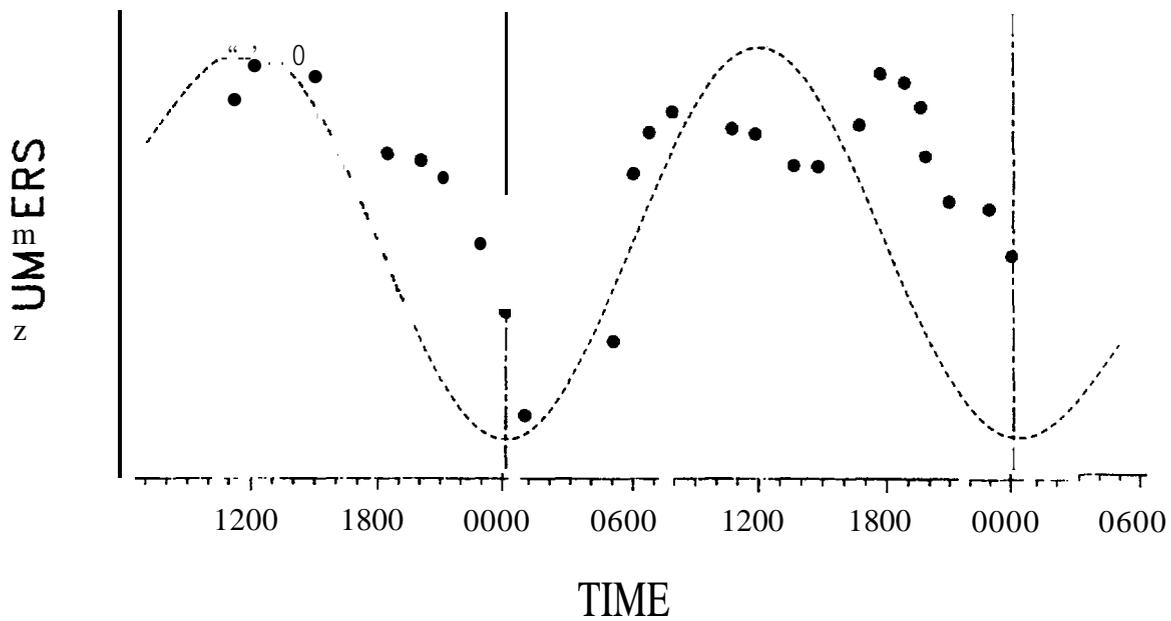


Figure 4. Hypothetical example of a time series of **counts** of birds superimposed on a periodic function (sine wave with period of 24 hours and peak at noon). Points form a series showing strong diurnal cycle would deviate little from the expected value (dashed line).

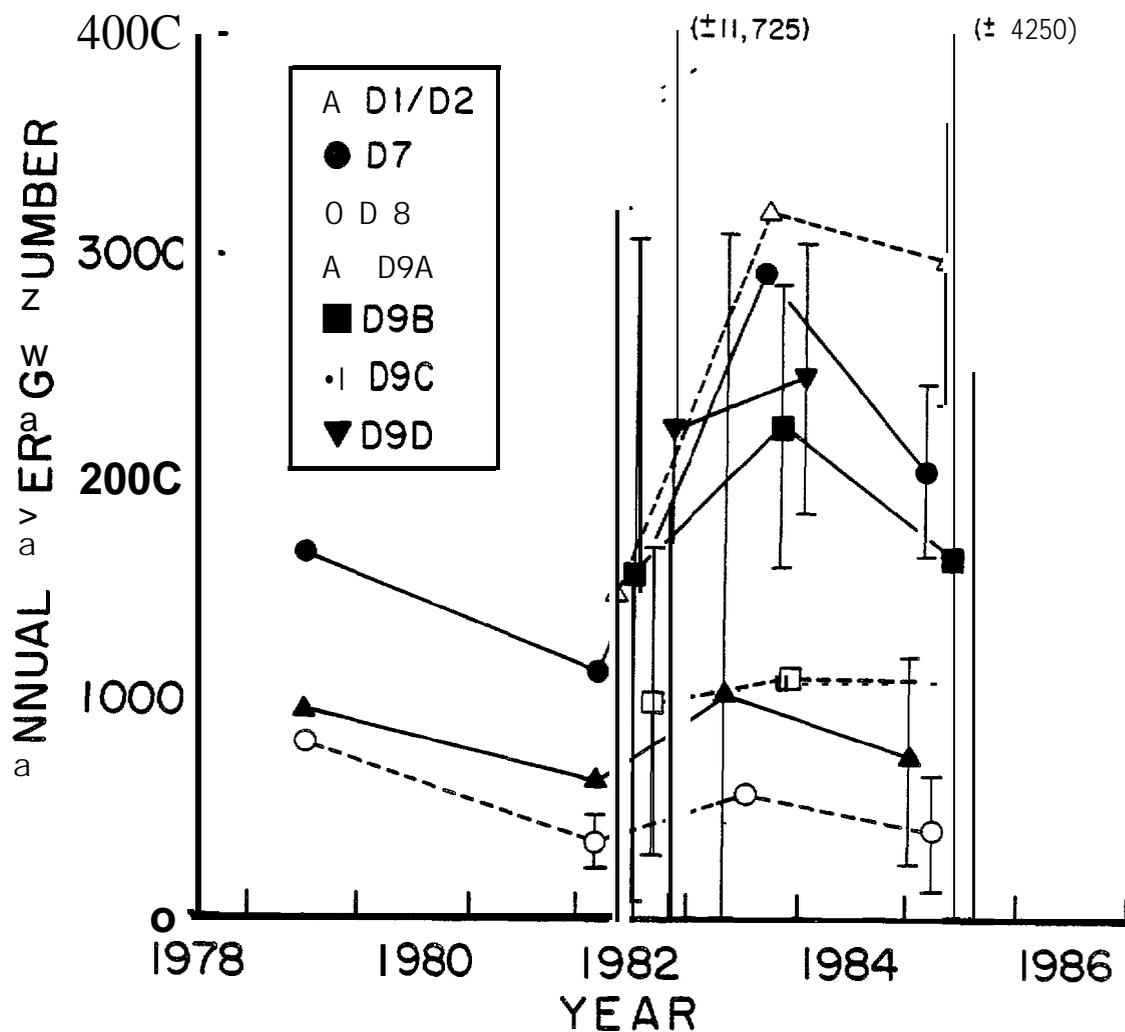


Figure 5. Annual average number of murrelets on boat-based plots at St. Matthew-N (± 1 SD) for which there are two or more years' data. No error bars are shown when only 1 count was made on a plot during a particular year. Two to four counts were made on the plots where an error bar is shown.

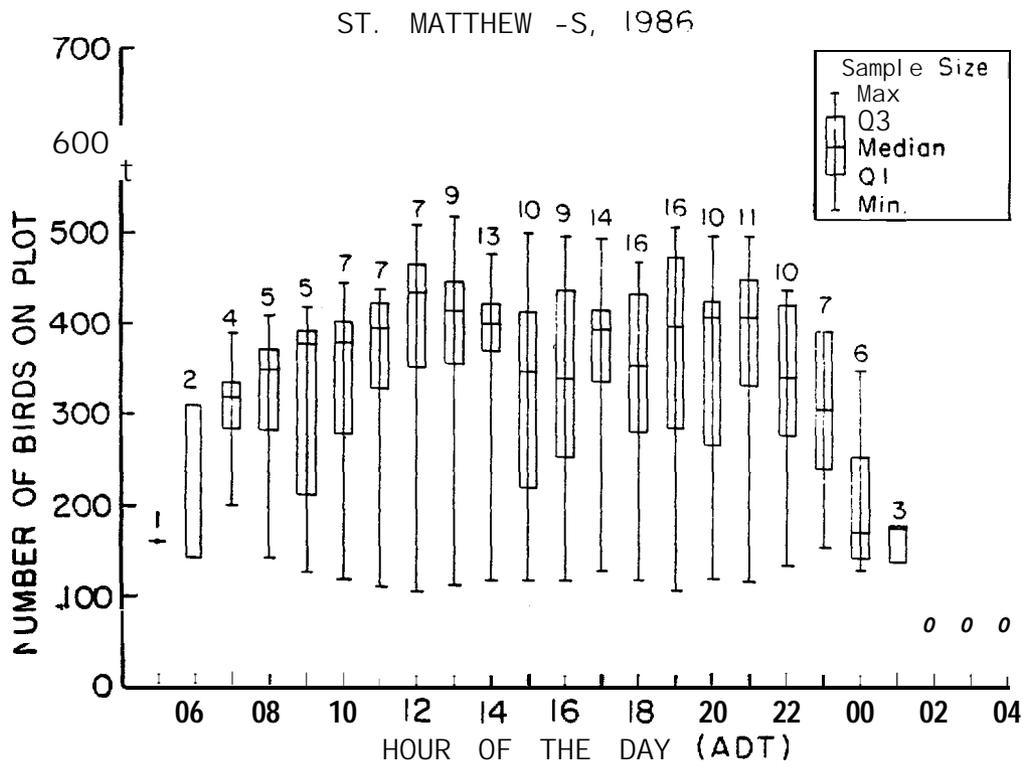
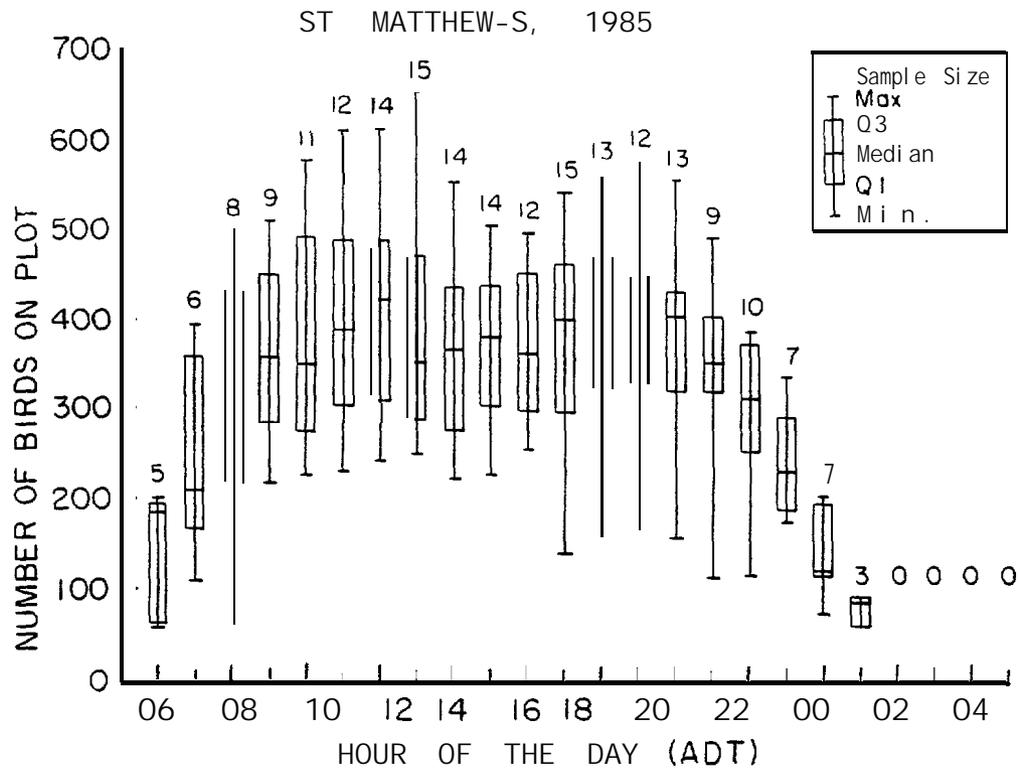


Figure 6. Summary of time-lapse counts for St. Matthew-S Thick-billed Murres, 1985 and 1986 (Min. = minimum count, Max. = maximum count, Q1 = first quartile, Q3=third quartile). Note that solar noon is approximately 1500h ADT.

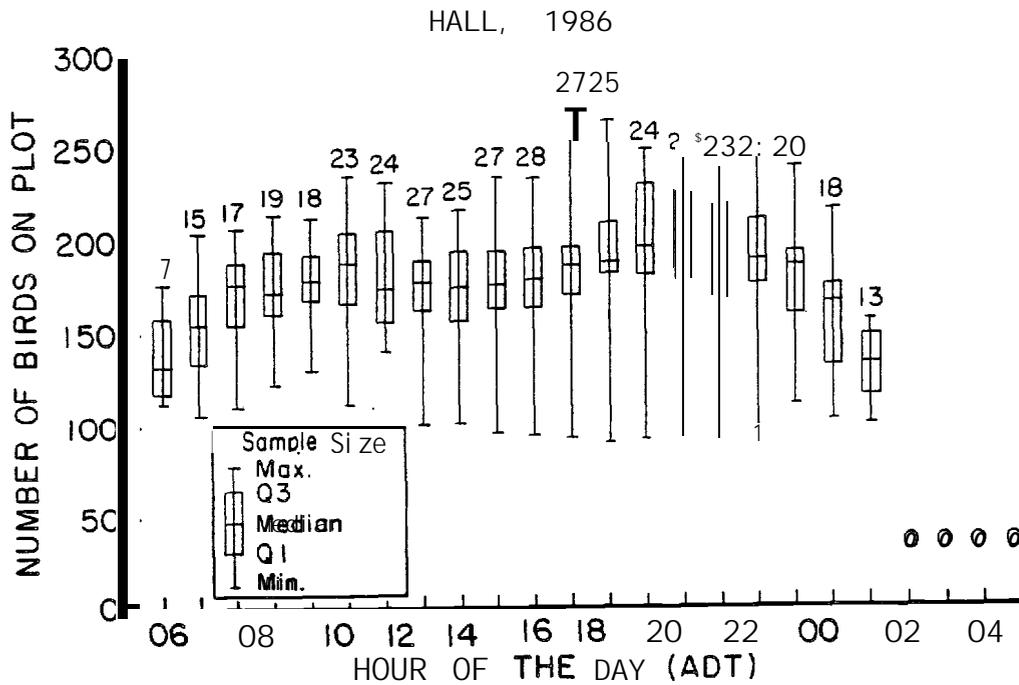
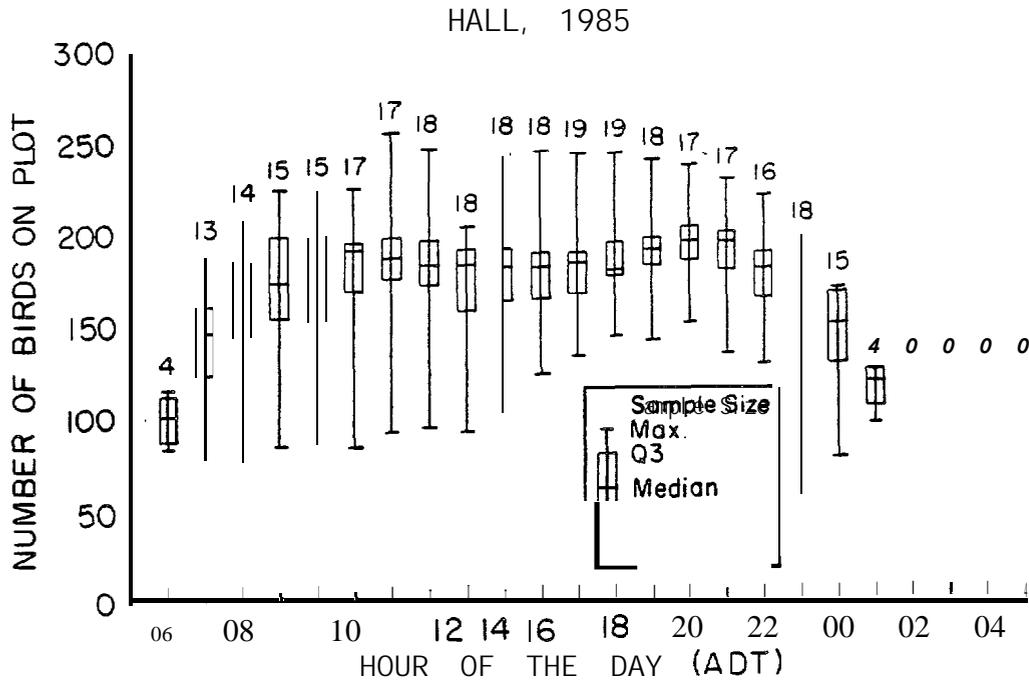


Figure 7. Summary of time-lapse counts for Hall Thick-billed Murres, 1985 and 1986 (Min. = minimum count, Max. = maximum count, Q1 = first quartile, Q3 = third quartile). Note that solar noon is approximately 1500h ADT.

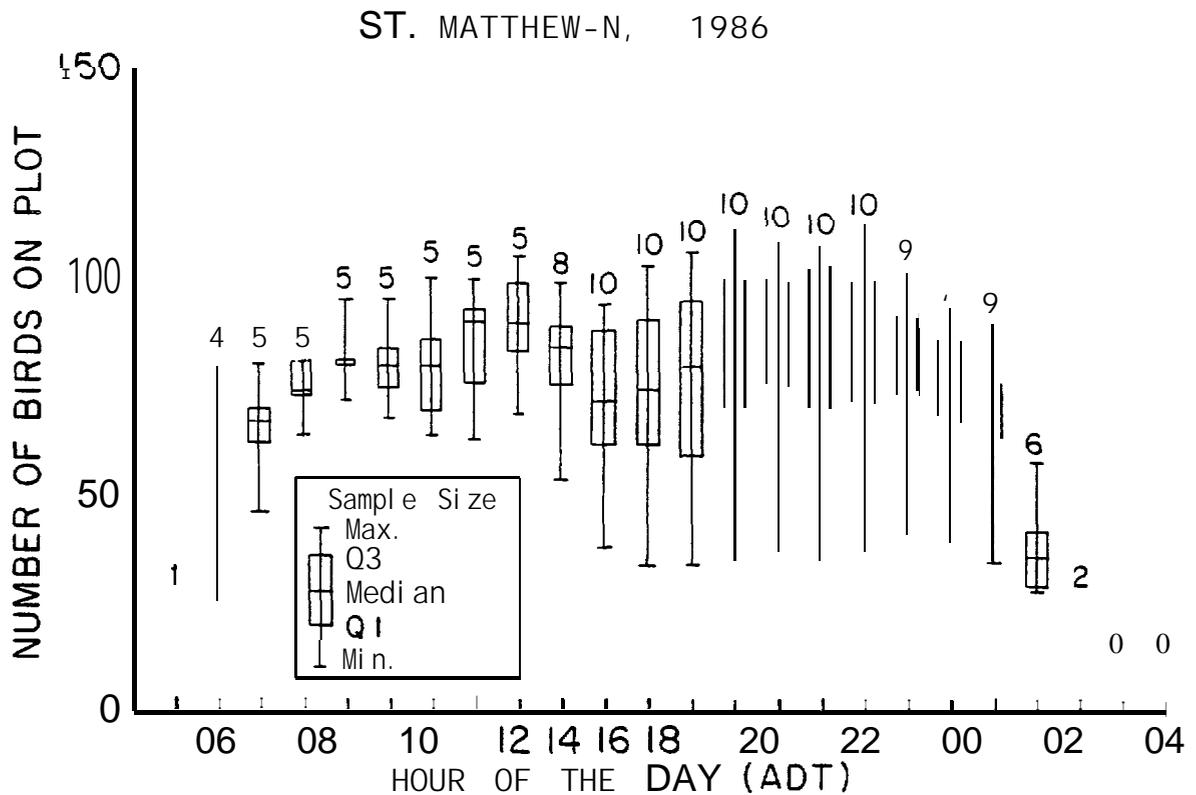
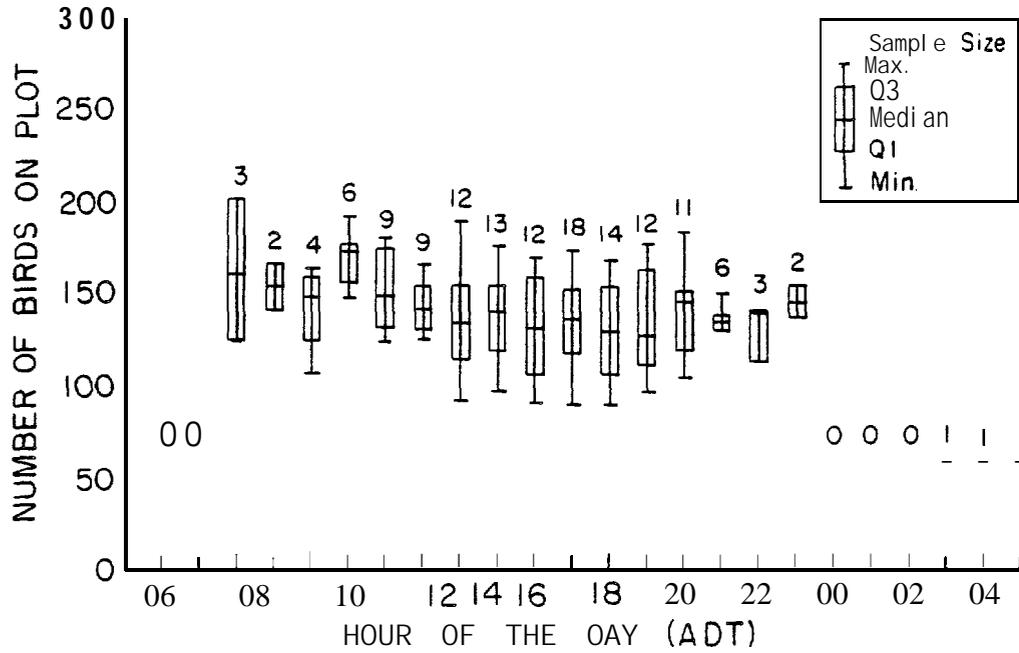


Figure 8. Summary of time-lapse counts for St. Matthew-N Thick-billed Murre, 1986 (Min. = minimum count, Max. = maximum count, Q1 = first quartile, Q3 = third quartile). Note that solar noon is approximately 1500h ADT.

ST. MATTHEW -N , 1985



ST MATTHEW-N, 1986

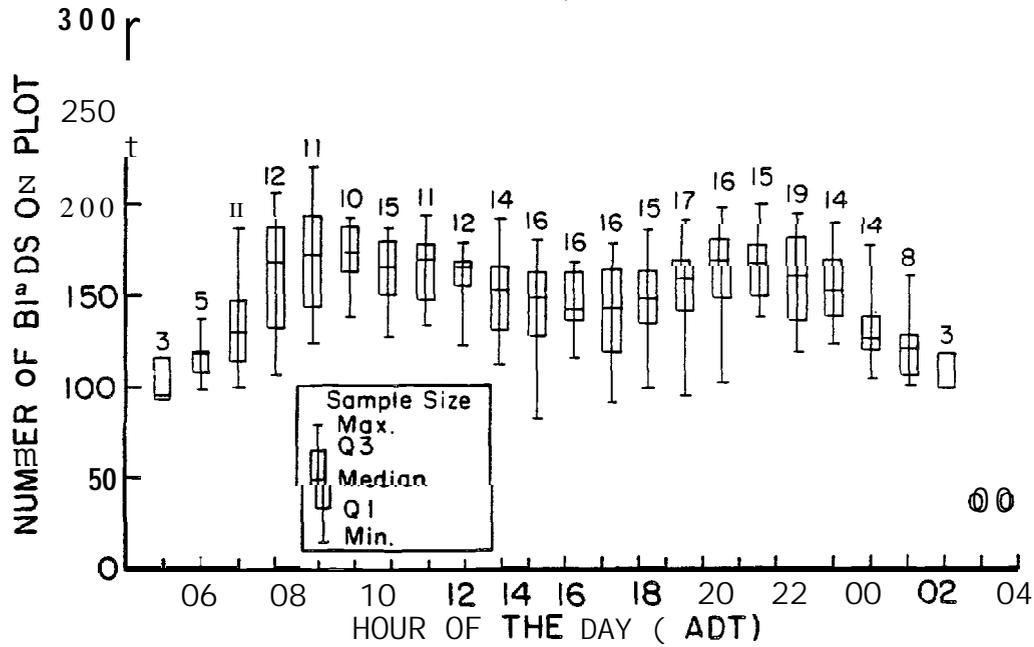


Figure 9. Summary of time-lapse counts for St. Matthew-N Common Murres, 1985 and 1986 (Min. = minimum count, Max. = maximum count, Q1 = first quartile, Q3 = third quartile). Note that solar noon is approximately 1500h ADT.

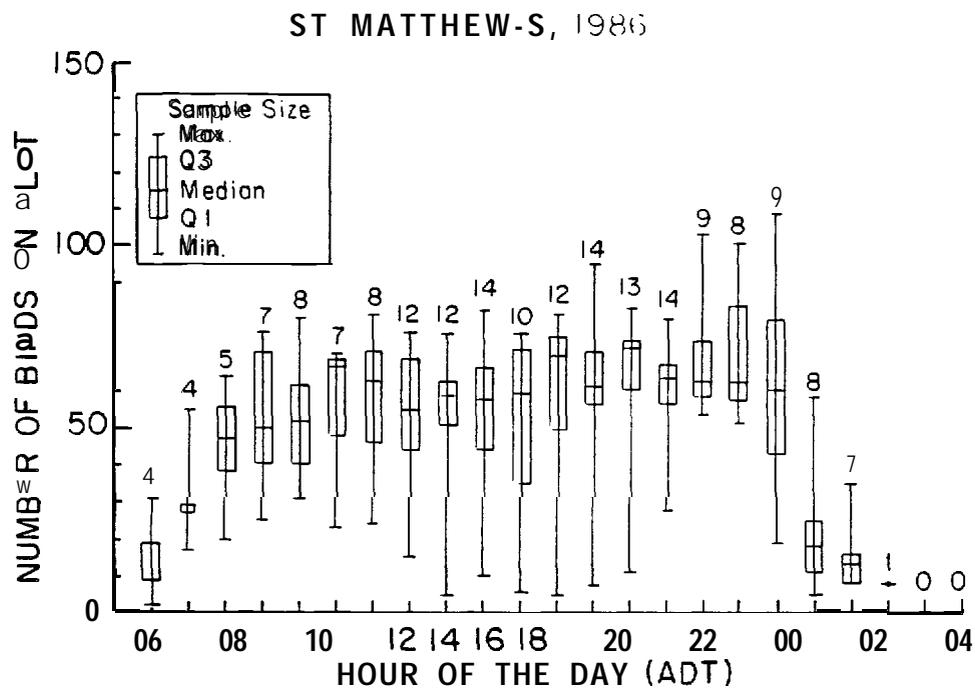
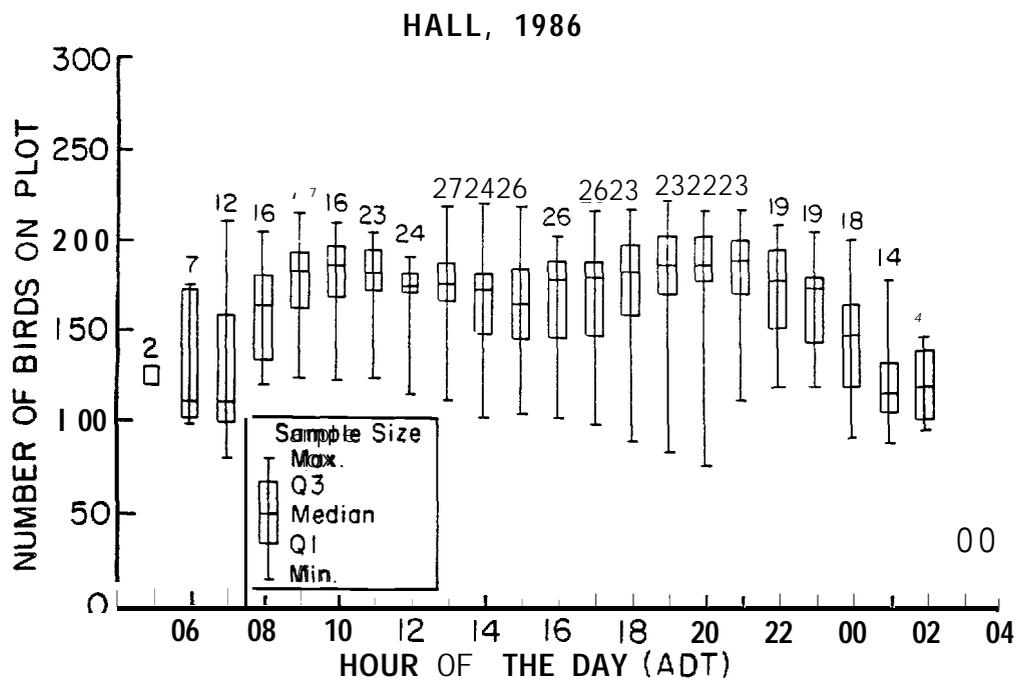
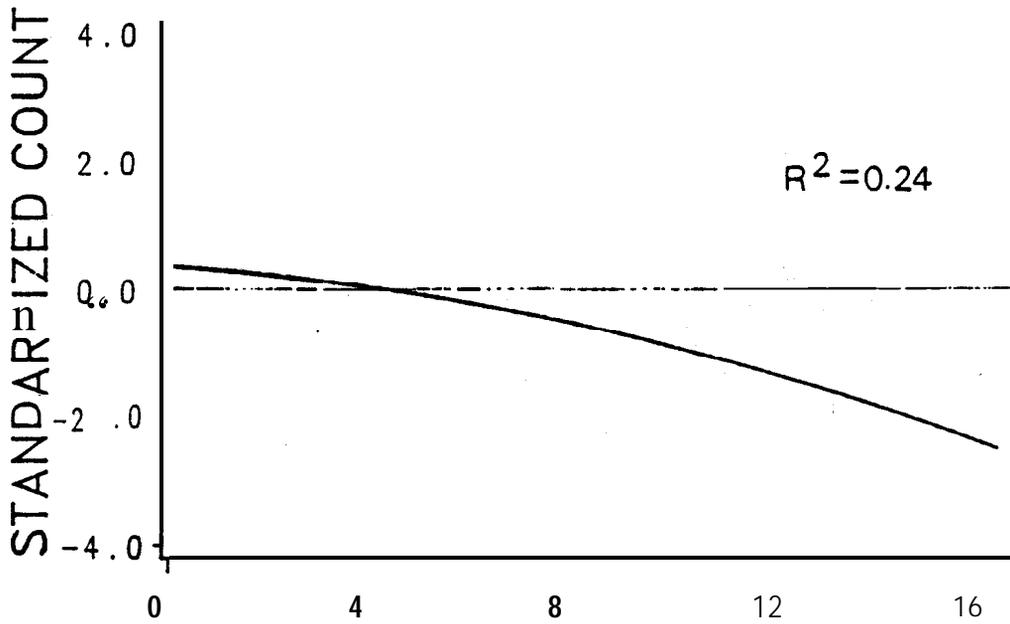
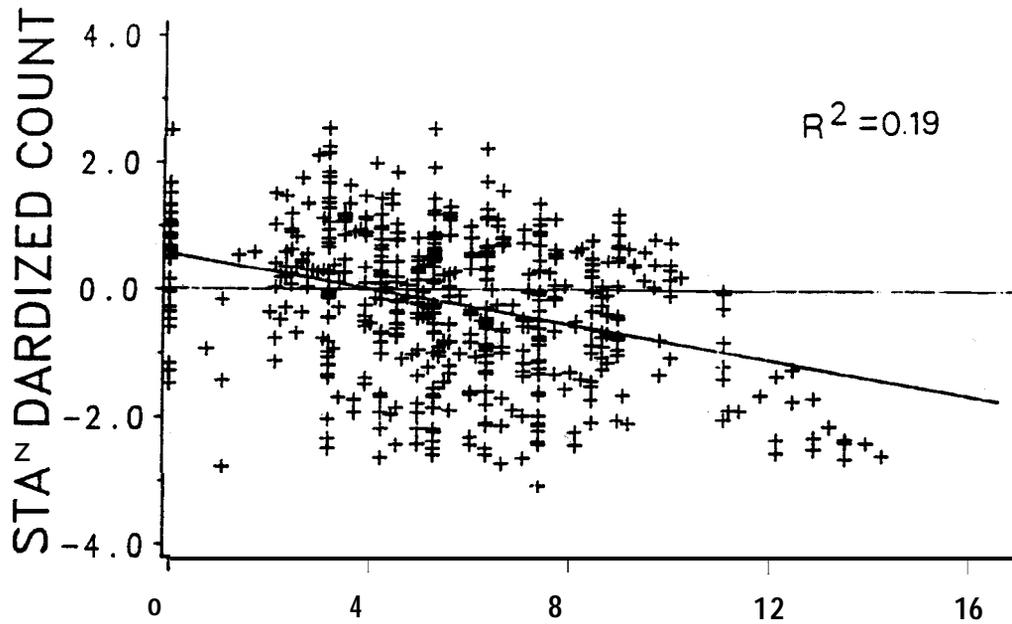


Figure 10. Summary of time-lapse counts for Hall and St. Matthew-S Common Murres, 1986 (Min. = minimum count, Max. = maximum count, Q1 = first quartile, Q3 = third quartile). Note that solar noon is approximately 1500h ADT.

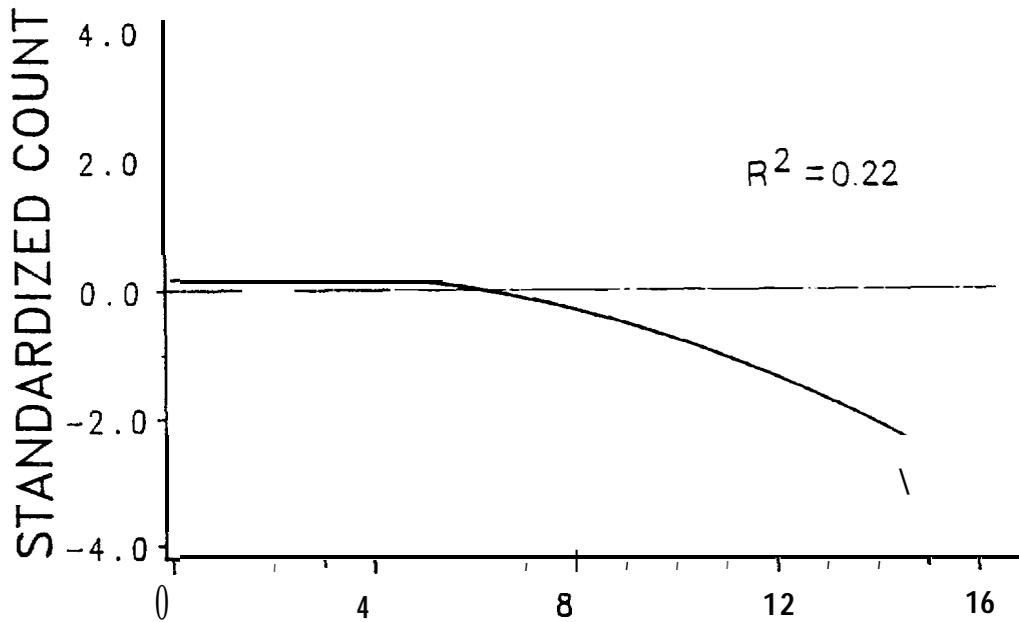
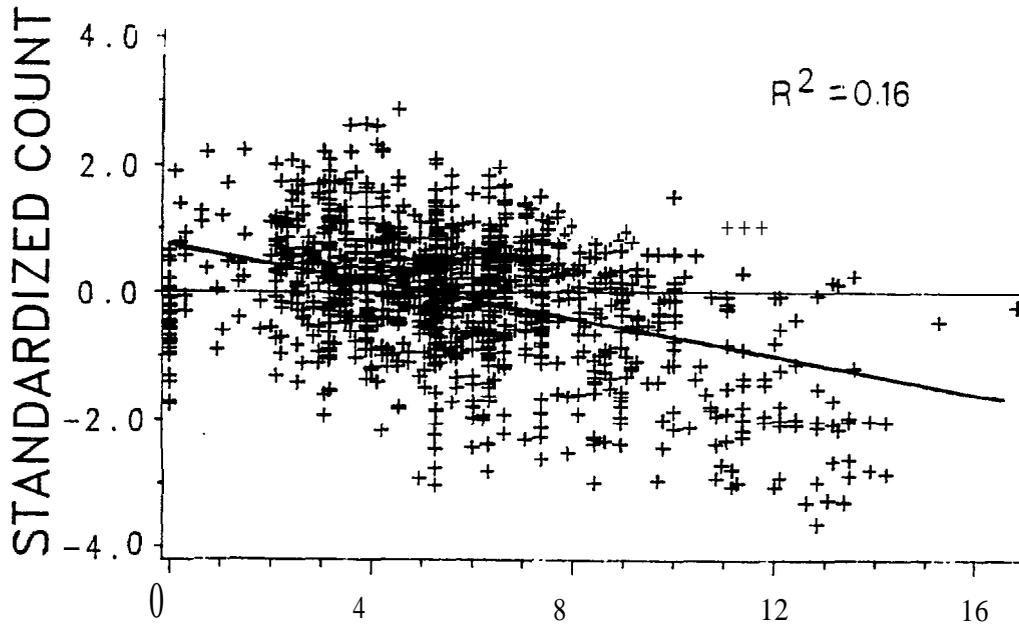
COMMON MURRE



WIND SPEED (M/SEC)

Figure 11. Relationship of Common Murre counts to windspeed, based on counts from all time-lapse plots, 1985 and 1986. Upper graph shows linear regression, lower graph shows quadratic regression.

THICK-BILLED MURRE



WIND SPEED (M/SEC)

Figure 12. Relationship of Thick-billed Murre counts to windspeed, based on counts from all time-lapse plots, 1985 and 1986. Upper graph shows linear regression, lower graph shows quadratic regression.

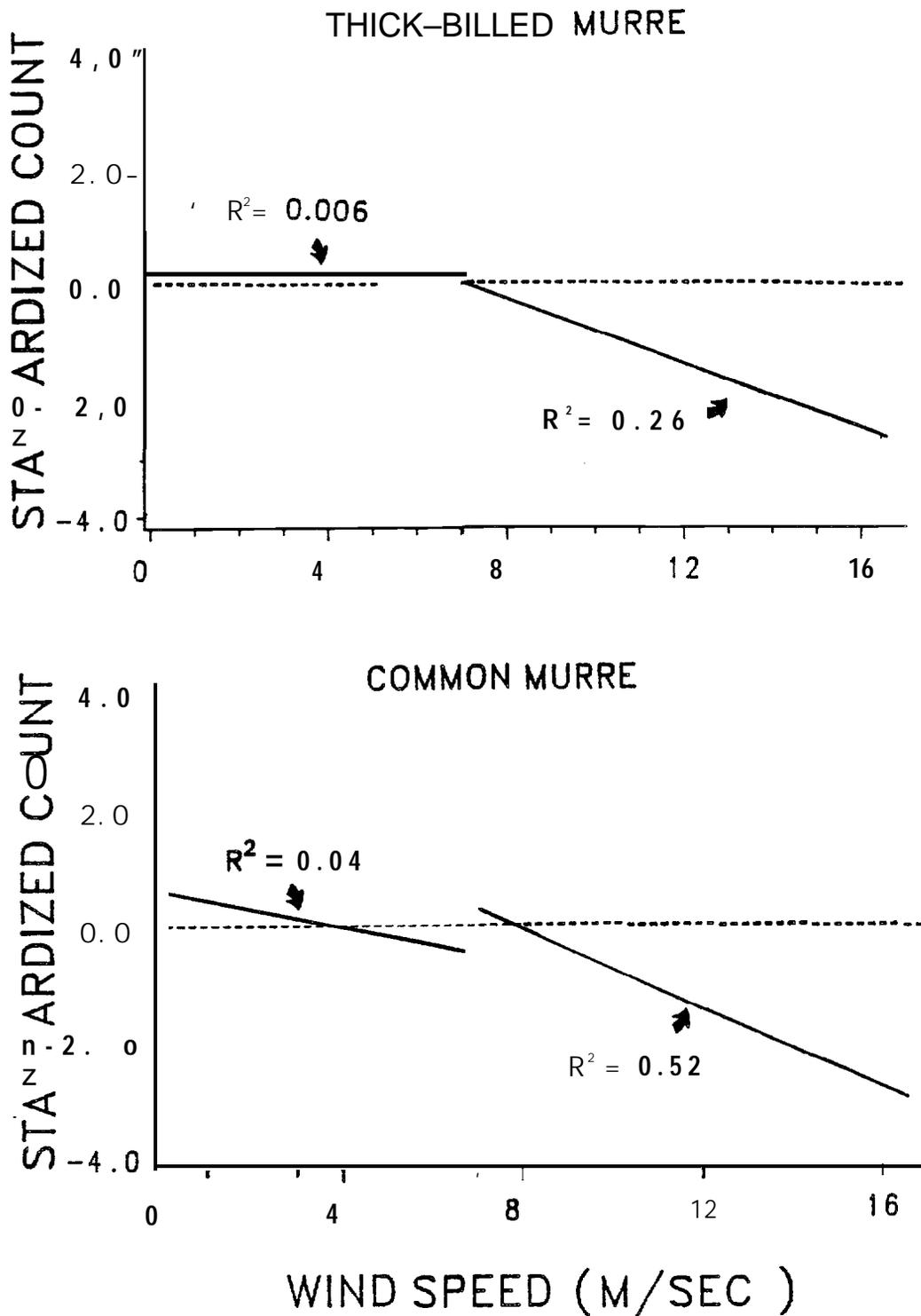
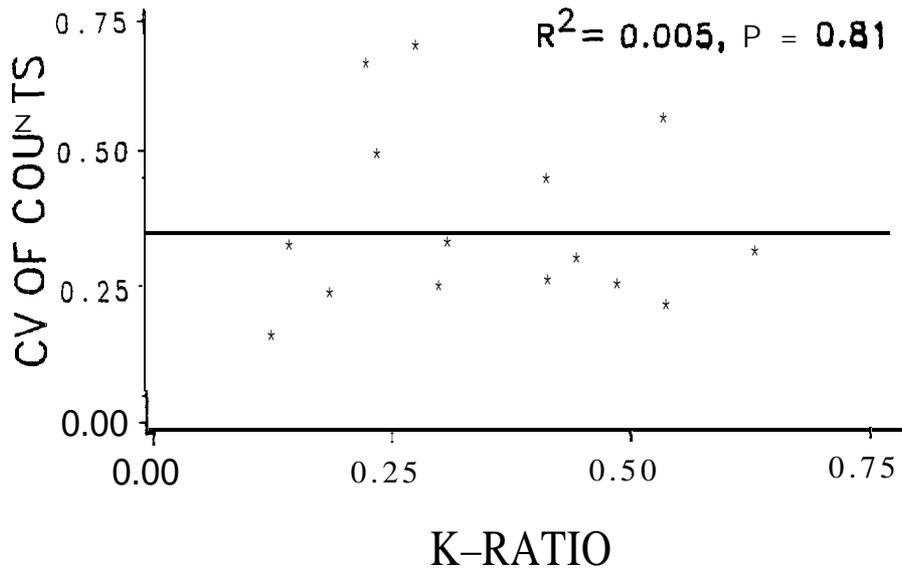


Figure 13. Relationship of murre counts to windspeeds above and below 7 m/sec. For both species, a much stronger effect is evident at moderate to high wind speeds.

THICK-BILLED MURRE

1985



1986

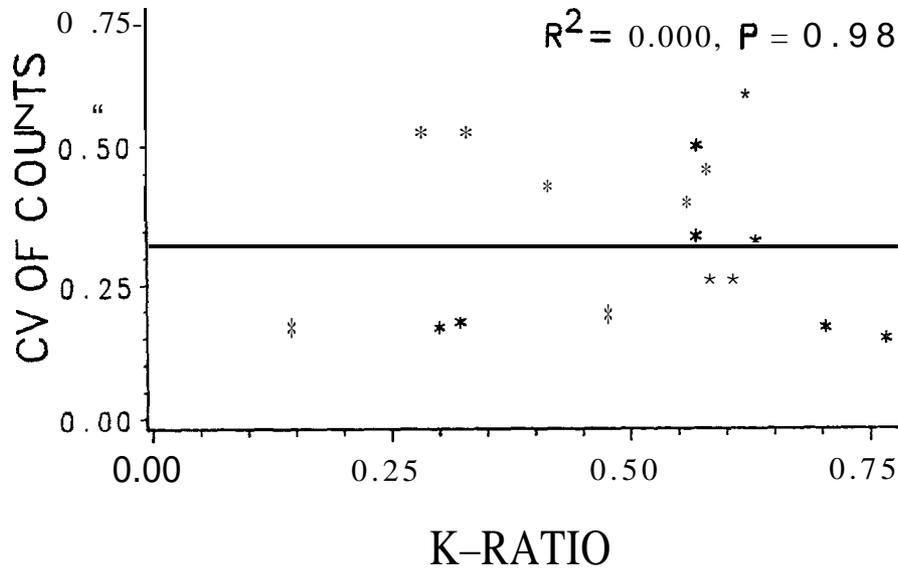
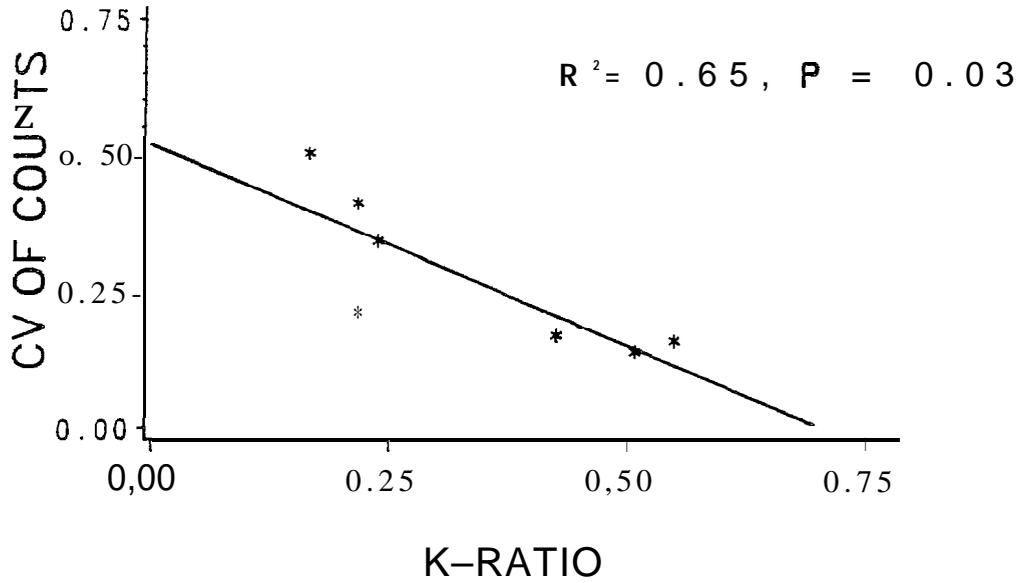


Figure 14. Relationship between k-ratio and coefficient of variation of daily counts on Thick-billed Murre reproduction plots.

COMMON MURRE

1985



1986

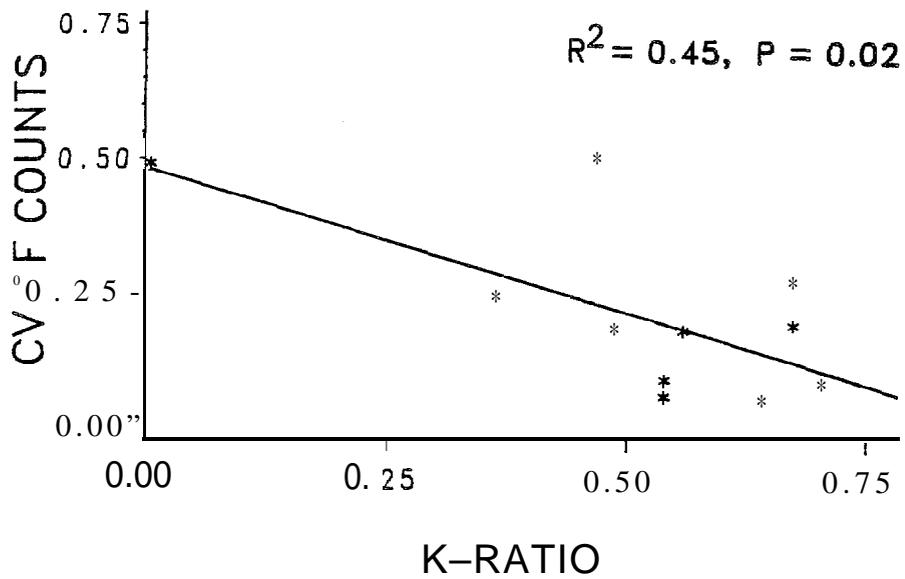


Figure 15. Relationship between k-ratio and coefficient of variation of daily counts on Common Murre reproduction plots.

COMMON MURRE

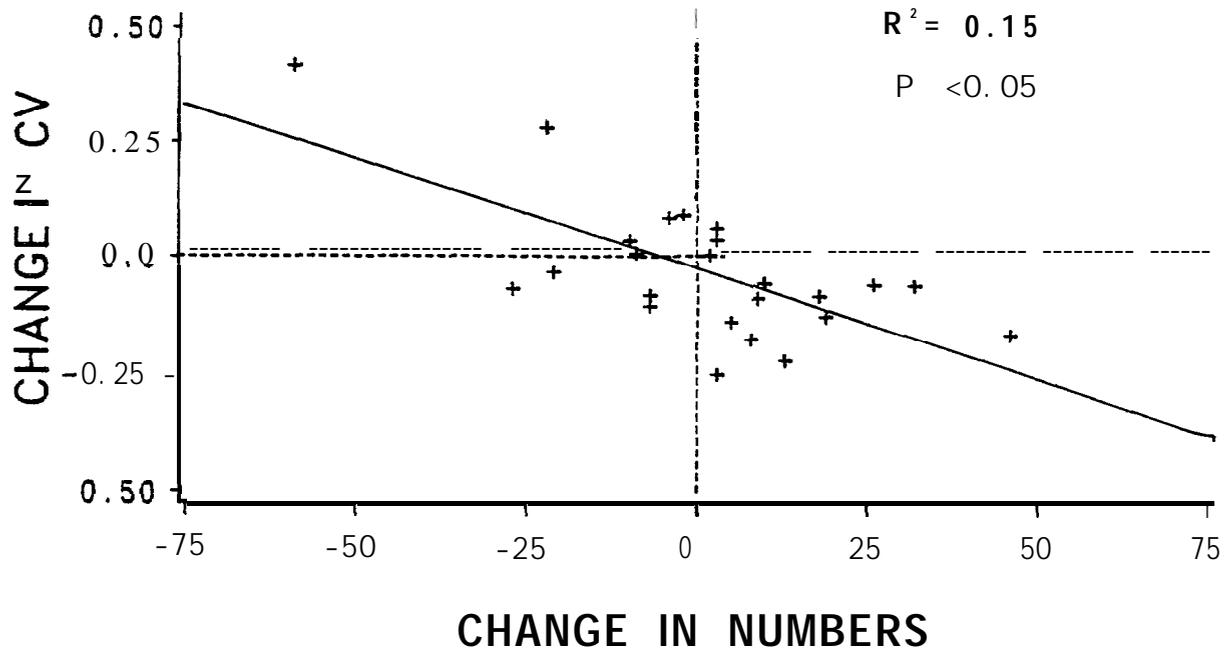


Figure 16. Relationship between numbers of birds and variability in counts. Each point represents the net change between 1985 and 1986 in mean numbers and in coefficients of variation, for each census plot (all areas combined).

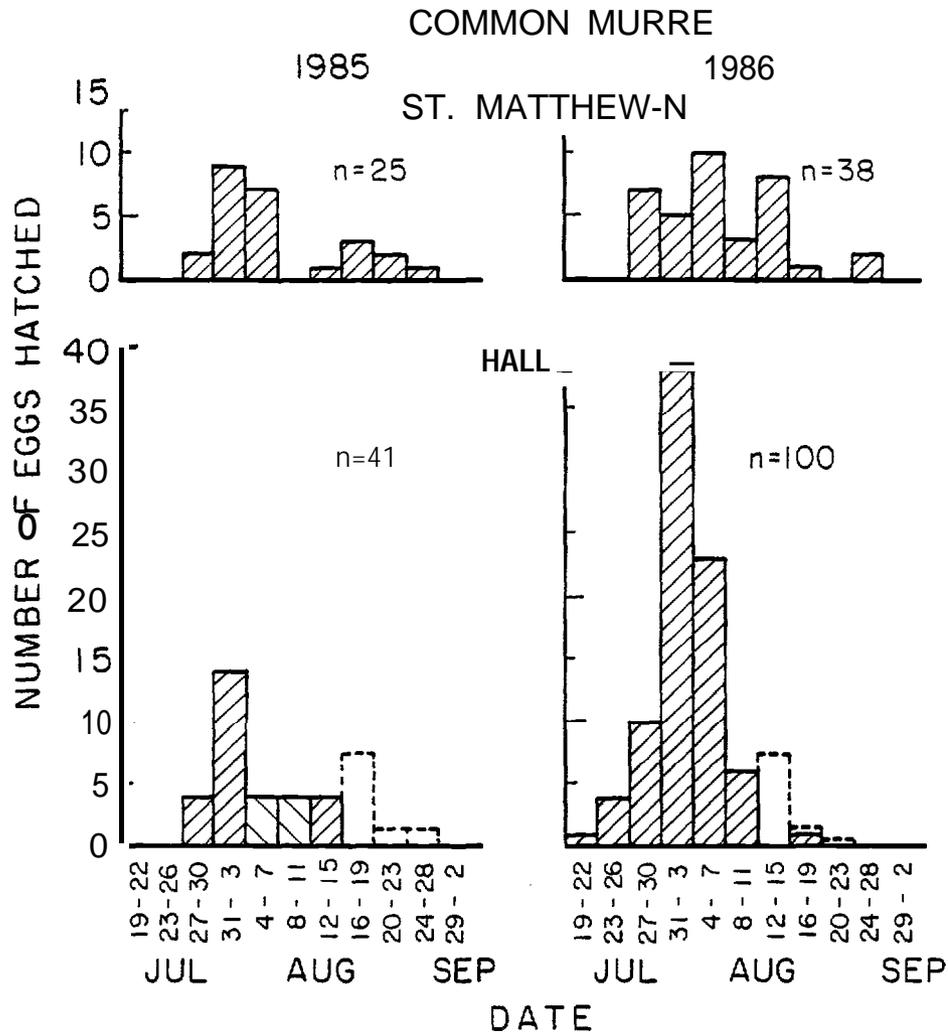


Figure 18. Hatching chronology of Common Murres, 1985 and 1986. Dashed lines indicate eggs with unknown hatching dates after field studies terminated, averaged over the possible intervals during which hatching may have occurred (see text). Eggs that hatched between 4-11 August 1985 on Hall have been averaged over the two time periods (note reversed shading).

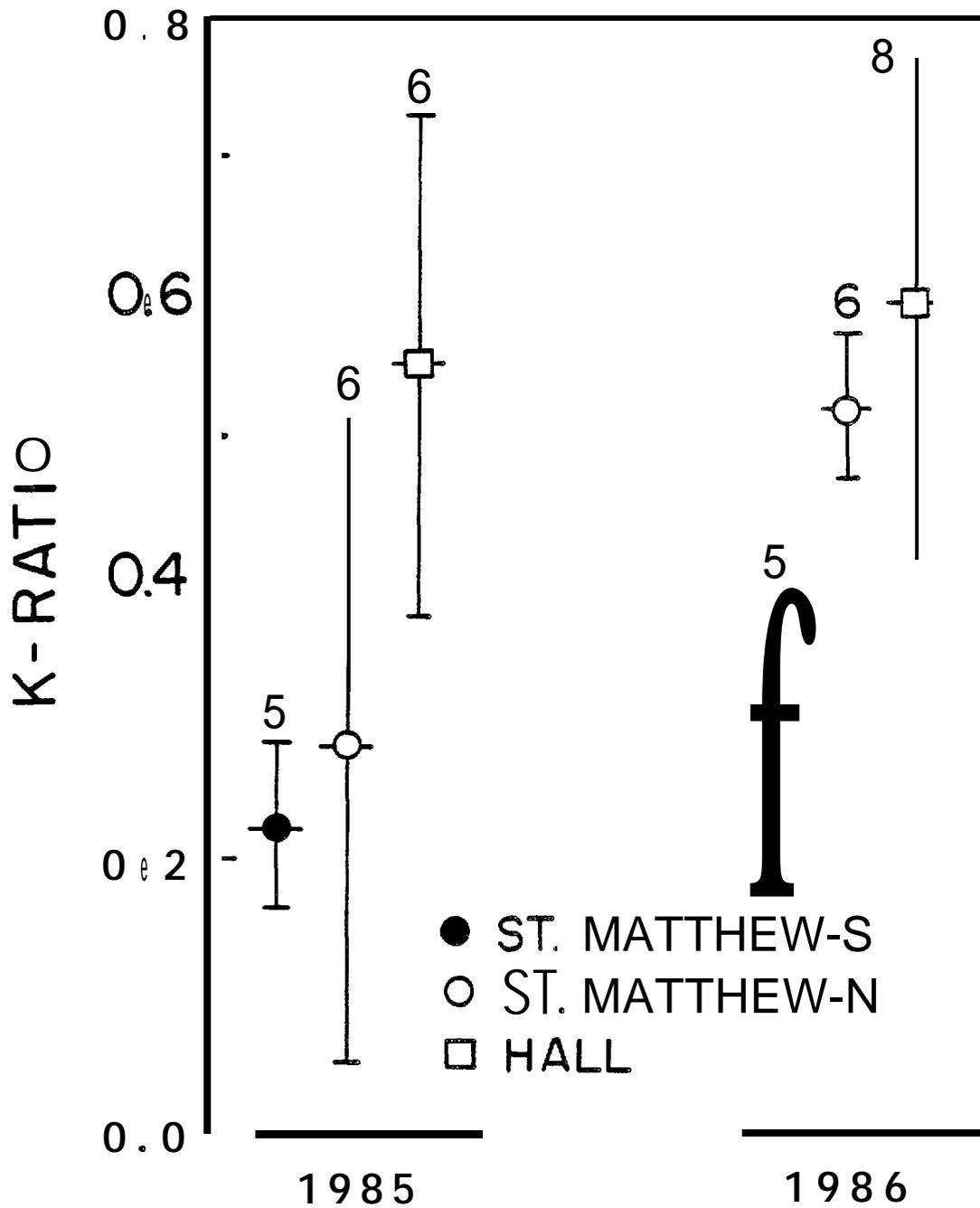


Figure 19. Mean k-ratios (and 95% confidence interval) by area for 1985 and 1986.

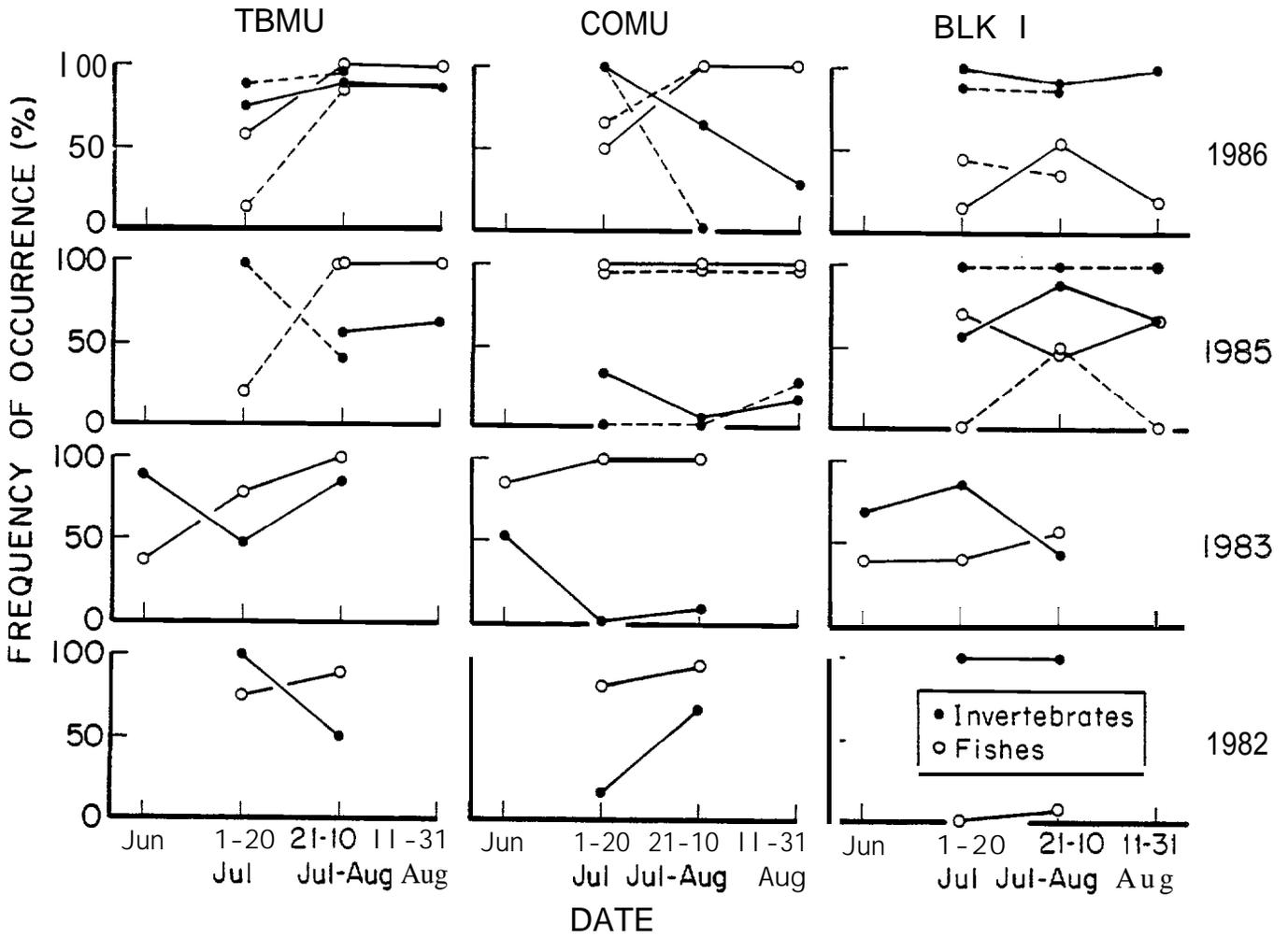


Figure 20. Seasonal frequency of occurrence of invertebrates and fishes in stomach samples of Thick-billed Murres (TBMU), Common Murres (COMU) and Black-legged Kittiwakes (BLKI) collected near St. Matthew Island in 1982, 1983, 1985 and 1986. Data from 1982 and 1983 are from Springer et al. (1985a, b).

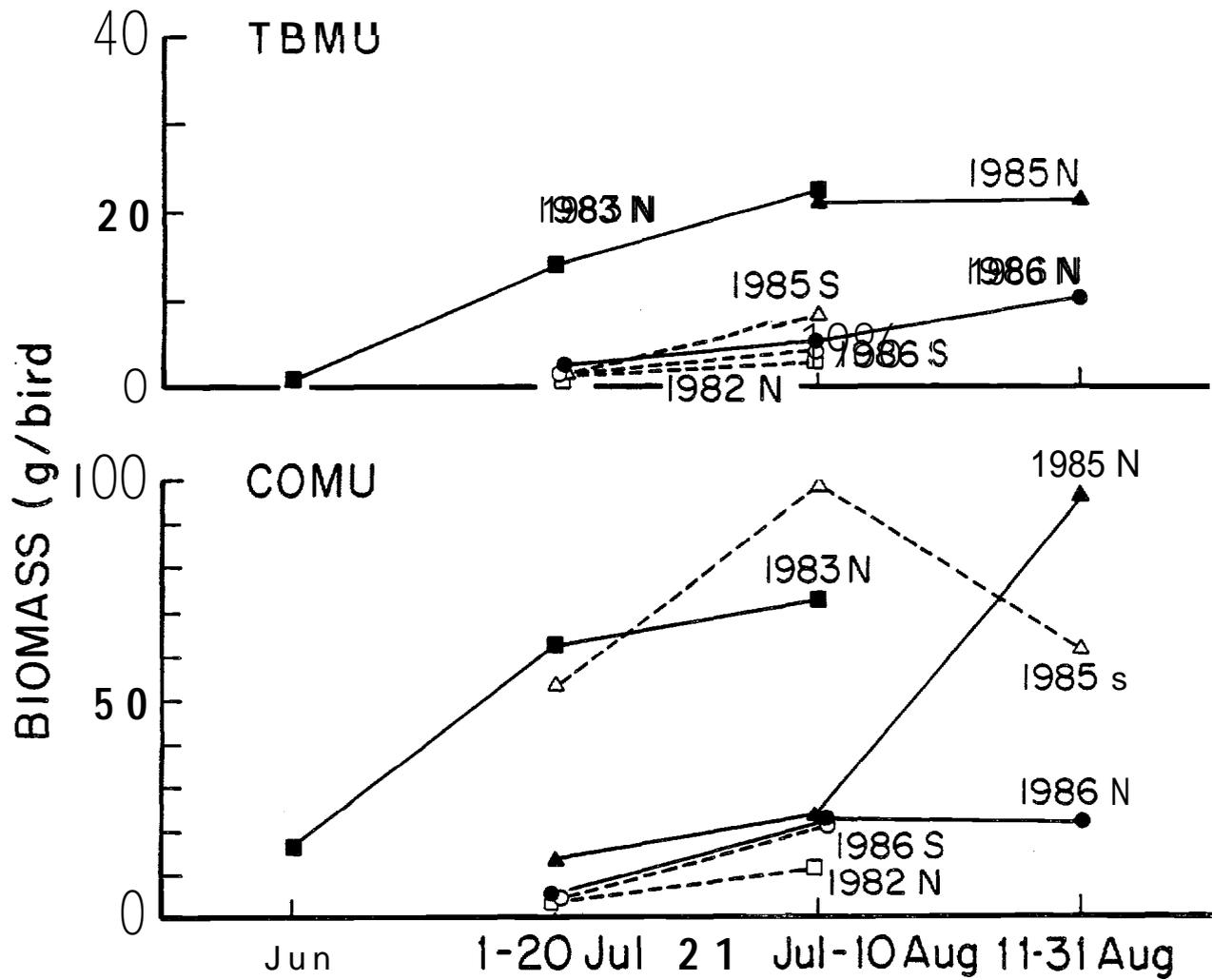


Figure 21. Estimated biomass (geometric mean wet weight) of fishes in diets of Thick-billed Murres (TBMU) and Common Murres (COMU) at St. Matthew-S (S) and St. Matthew-N (N) during 1982, 1983, 1985 and 1986. Data from 1982 and 1983 are from Springer et al. (1985a, b).

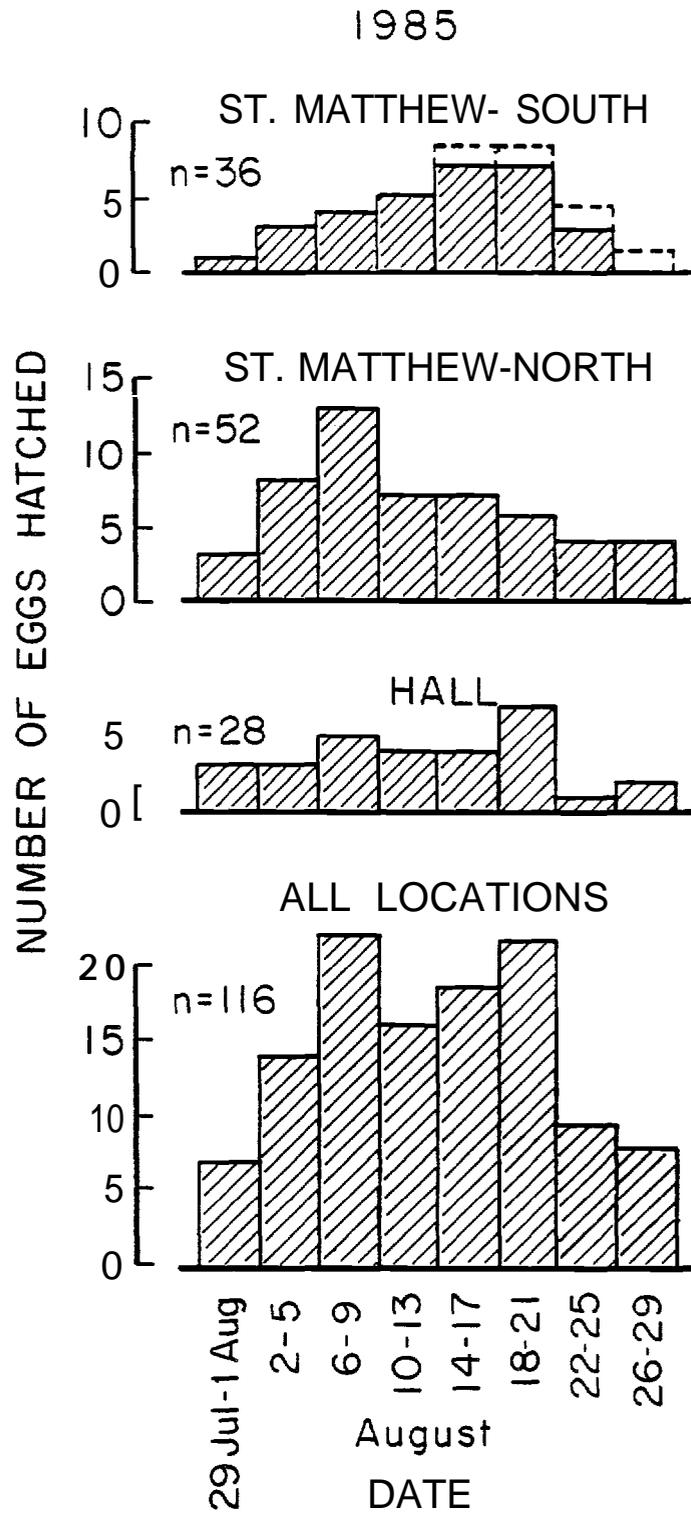


Figure 22. Hatching chronology of Black-legged Kittiwakes at St. Matthew Island during 1985. Area enclosed by dashed line represents eggs with unknown hatching dates; these were averaged over the possible intervals during which hatch may have occurred. All eggs present at last observation are presumed to have hatched.

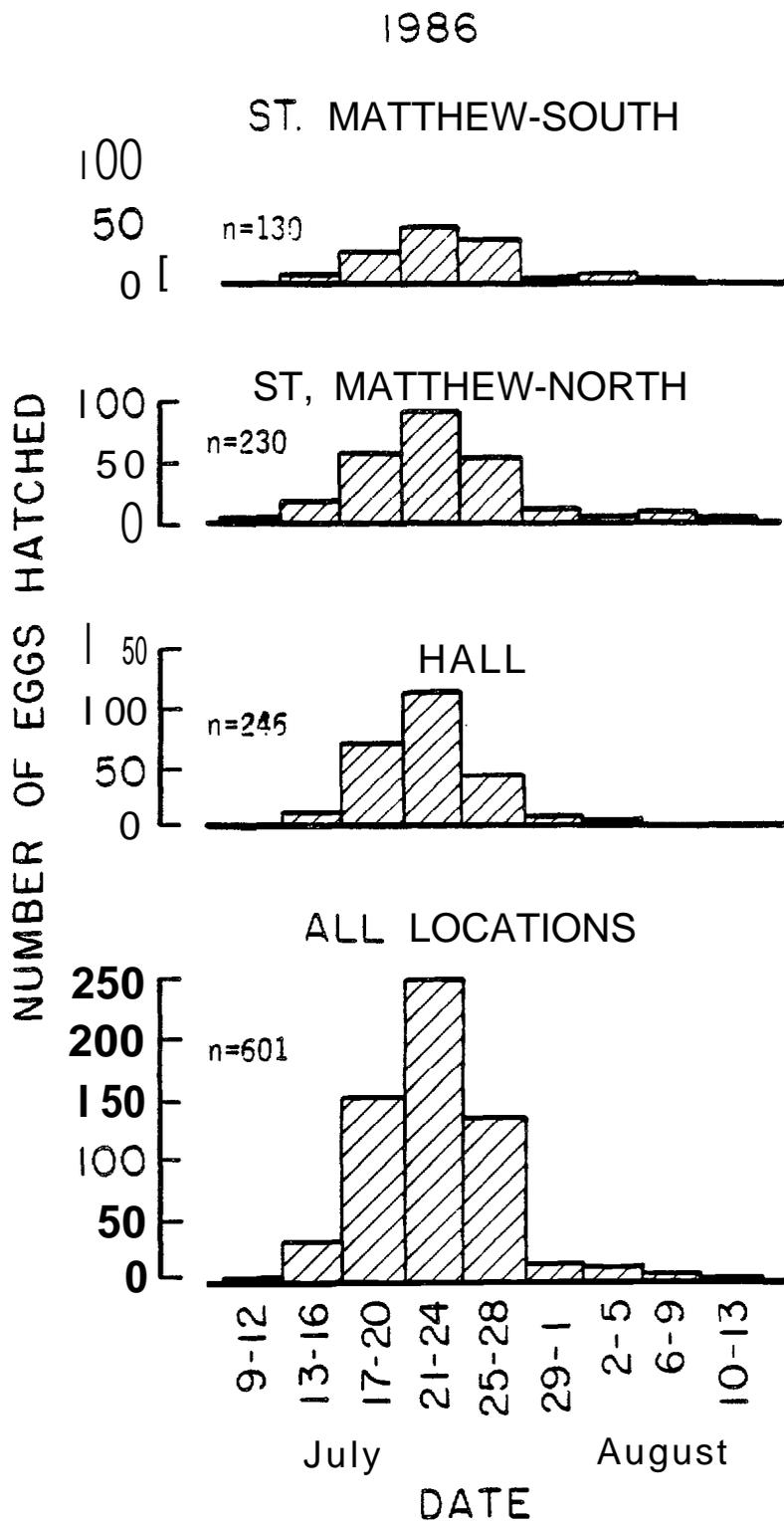


Figure 23. Hatching chronology of Black-legged Kittiwakes at St. Matthew island during 1986.

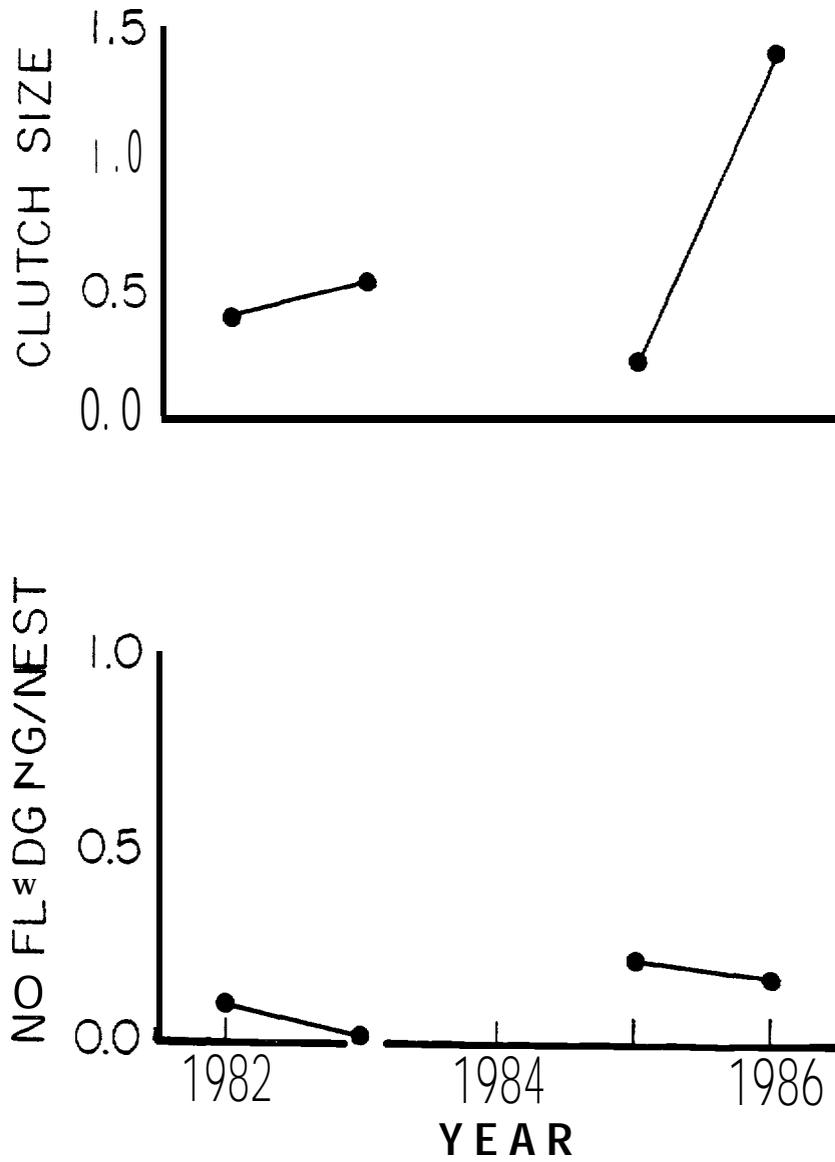


Figure 24. A summary of reproductive performance of Black-legged Kittiwakes on St. Matthew and Hall Islands, 1982-1986. Data from 1982 and 1983 are from Springer et al. (1985a, b).

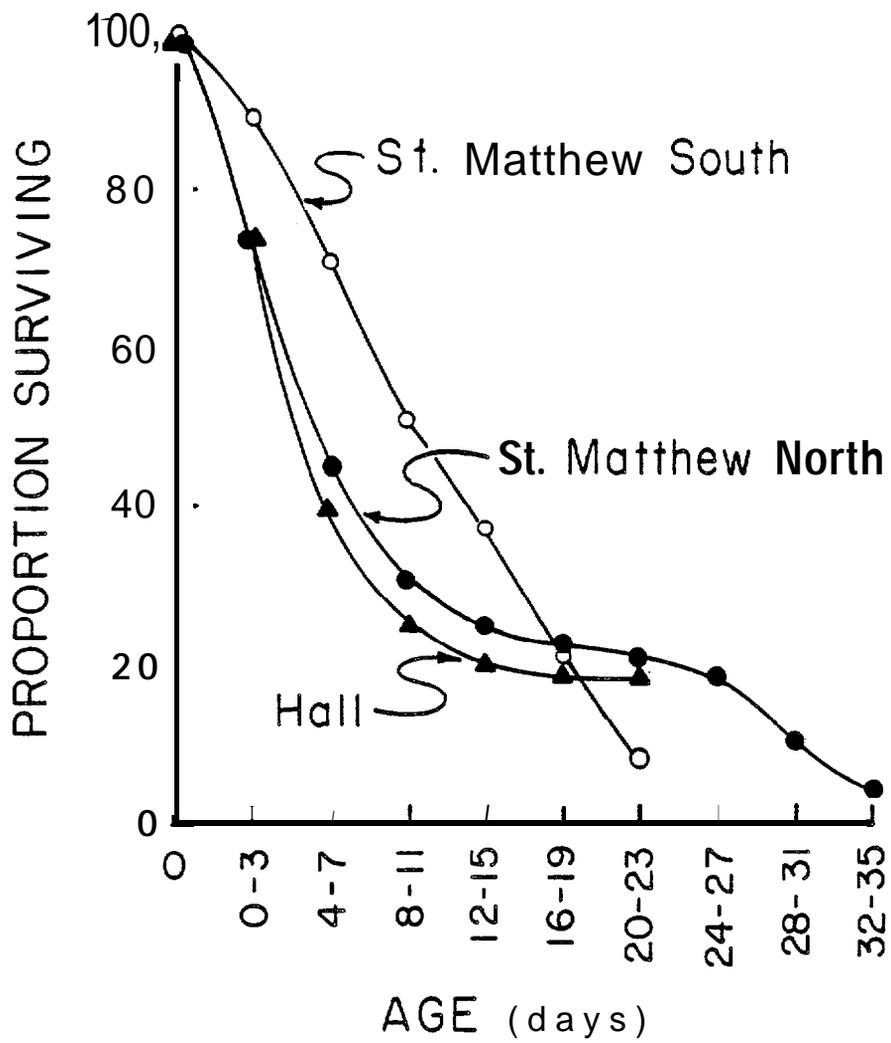


Figure 25. Survivorship curve for Black-legged Kittiwake chicks at St. Matthew Island during 1986.

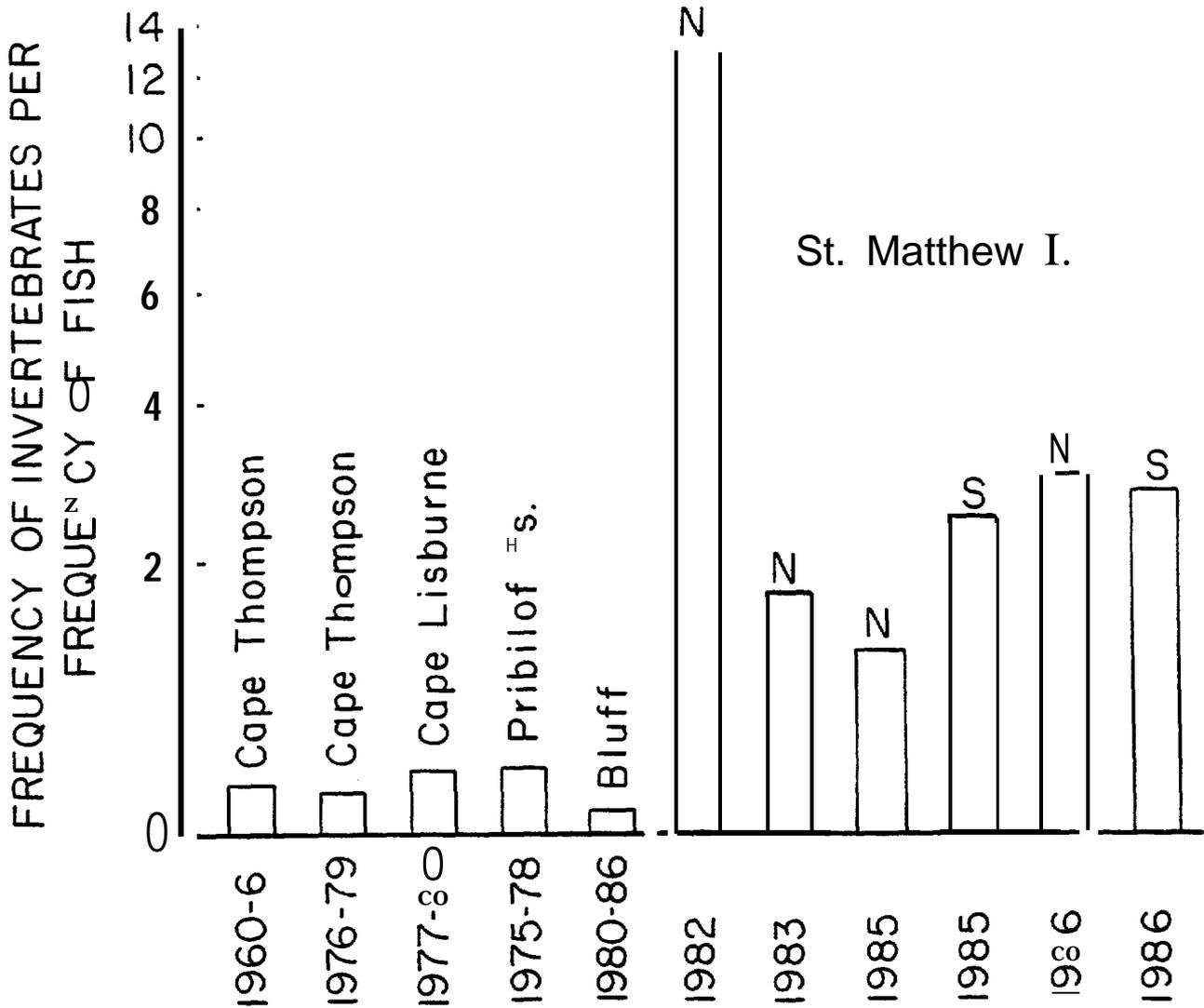


Figure 26. Relative proportion of invertebrates present in food samples from **Black-legged** Kittiwakes collected at St. Matthew-S (S) and St. Matthew-N (N) compared to samples collected at other colonies in the Bering and **Chukchi Seas**. Data from Capes Thompson and **Lisburne** are from Springer et al. (1984); **Pribilof** data are from Hunt et al. (1981); Bluff data are from **Murphy** et al. (1987, submitted); St. Matthew 1982-83 data are from Springer et al. (1985a, b).

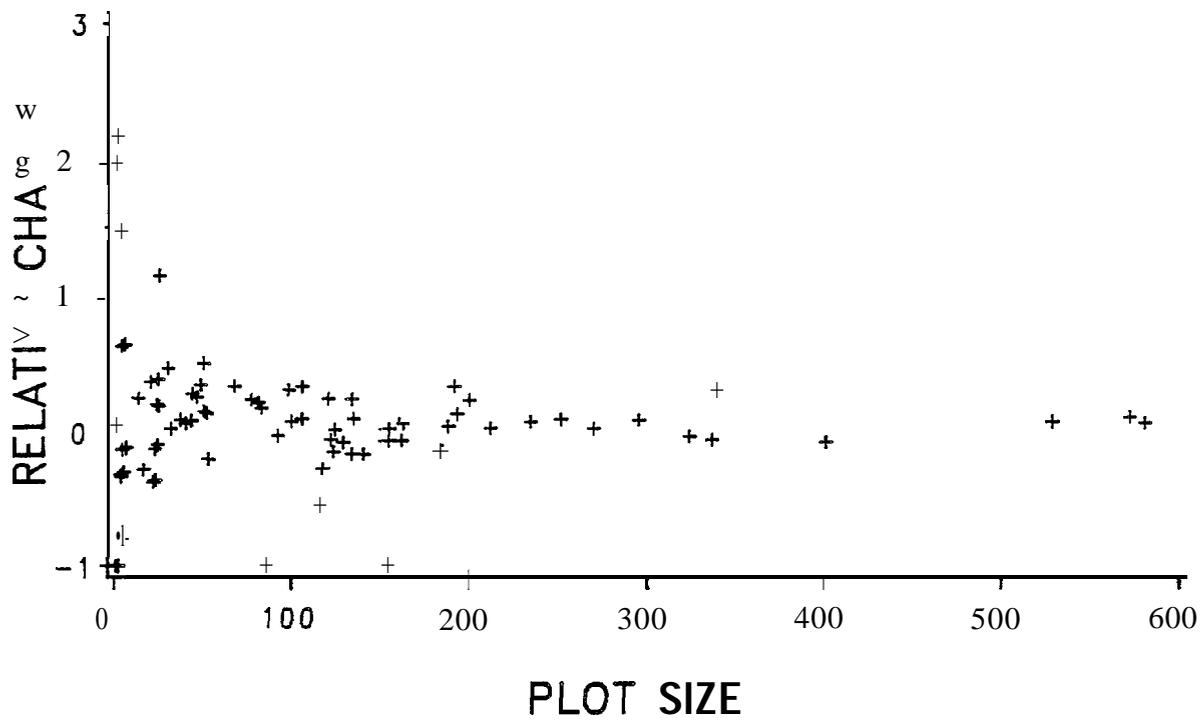


Figure 27. Relationship between plot size and relative change of Common and Thick-billed Murre counts from 1985 to 1986, where relative change = 1986 mean count of plot x - 1985 mean count of plot x / 1985 mean count of plot x, for all plots.

Appendix 1. A unified re-numbering scheme for land-based census plots on St. Matthew and Hall Islands.

1985 plot number ^a	1983 plot name/number ^b	1982 Plot name/number ^b
St. Matthew-S		
S-1	83-5	
S-2	83-6	
s-3	83-7	
s-4	83-8	
s-5	83-9	
S-6	83-10	
s-7	83-11	
S-8		
S-9		
S-10	83-12	
S-11		
S-12		
S-13	83-19	
S-14	83-20	VG-5 + VG-6 ^c
S-15	83-21	VG-4 ^c
S-16	83-22	VG-2
S-17	83-23	
S-18		VG-1^c
S-19	83-24	VG-3
S-20	83-25	
S-21		LG-1
s-22	83-18	
S-23	83-17	
S-24	83-16	
s-25	83-15	
S-26	83-14	
S-27	83-13	
S-28		
St. Matthew-N		
N-1	Tusk 4 ^d	
N-2	Tusk 2 ^d	
N-3	Tusk 3 ^d	
N-4	Tusk 1 ^d	
N-5	Bull Seal Rock (south side)	Bull Seal Rock (south side)
N-6	Bull Seal Rock (north side)	Bull Seal Rock (north side)
N-7	Bull Seal Rock (top)	Bull Seal Rock (top)
N-8	Bull Seal Fulmar Plot	Bull Seal Fulmar Plot
N-9	Arch	Slump Mountain ^d
N-10A	Waterfall 1-1:	North Camp Murre ^d
N-10B	Waterfall 1-2:	North Camp Murre ^d
N-10C	Waterfall 1-3:	North Camp Murre ^d
N-10D	Waterfall 1-4:	
N-10E		
N-11	North Camp Fulmar	North Camp Fulmar

Appendix 1. Continued.

1985 plot number ^a	1983 plot name/number ^b	1982 plot name/ number ^b
Hall Island		
H-1		
H-2	H-21	
H-3	H-20	
H-4	H-19 or Hall -1 ^d	
H-5	Hall 2 ^e	
H-6	Egg Plot 1 ^{c, e}	
H-7	Hall 3 ^e	
H-8	Hall 4 ^e	
H-9	Hall 5 ^e	
H-10	Hall 6 ^e	
H-11	H-18	
H-12A		
H-12B		
H-12C	H-1 ^c	
H-13A		
H-138		
H-13C	H-16	
H-14	H-15	
H-15	H-14	
H-16		
H-17		
H-18		
H-19	H-13	
H-20	H-12	
H-21A		
H-218		
H-21C	H-n	
H-22A		
H-228	H-10A	
H-22C	H-108	
H-23A	H-9C	
H-238	H-9A	
H-23C	H-98	
H-230		
H-23E		
H-24A	H-8B	
H-24B	H-8A	
H-25	H-7	
H-26	H-6	
H-27	H-5	
H-28A	H-4C	
H-28B	H-48	
H-28C	H-4A	
H-29	H-3	
H-30	H-2	
H-31	H-1	
H-32		

^a This study

^b A. SOWLS, pers. comm.; unless otherwise noted.

^c Cases where plot boundaries have some discrepancy with 1985 plot boundaries.

^d Springer et al. 1985a, 1985b.

^e D.G. ROSENEAU, pers. comm.

Appendix 3. Kittiwake nest/roost definitions.

Nest:

Substantial mud platform with evidence of building activity (e.g., **green** vegetation) in the current year. Note: If it **is** a poor reproductive year **also** note **which nests are complete (CN), i.e.,** have a well-formed cup of dry grasses.

Mud Roost:

Mud platform with no evidence of current building activity.

Rock Roost:

Guano-stained perch with no nest-building materials. Note: **We** distinguish between Active and Inactive Roosts when compiling the data. Active roosts are those occupied **by** at **least 1** bird **half** or more of the times **that** you record data **for** that roost.

Appendix 4. Identifiable stages of murre chick developments.

Age

1-8
days

1. Uniformly leaden color with speckles of white on the head and neck, chick does not raise its head.
2. Salt and **pepper** appearance, chick raises its head and stands up.

9-18
days

3. White chin, "cheeks" still "salt and pepper".
- 4* White chin, half-moon white cheeks, stands beside parent, peeps frequently when fed.
5. Gives ringing double note associated with jumping.

^a Source: **Bidermann et al. (1978:567)**

Appendix 5. Identifiable stages of kittiwake chick growths.

<u>Stage</u>	<u>Age</u>
1a	1-4 days. Chick downy with buff brown to red tint; small; lies or crouches in nest; egg tooth on bill; head and body of similar size.
1b	4-7 days. Defecates over edge of nest.
2	7-14 days. Downy, but increasingly gray; active - stands, walks in nest; loses egg tooth but bill tip is pale; body large relative to head.
3a	14-21 days. Downy, becoming feathered; black feathers erupting on elbows; silver back feathers emerge; dark pinfeathers visible on forearm and hand.
3b	17-26 days. Mixed down and feathers; can first clearly see black on tail feathers; pinfeathers have erupted into feathers on wing; down on collar; black ear patch and black smudge between eye and bill .
4a	21-30 days. As the bird perches on nest the tips of primaries extend to the tips of tail feathers; mostly feathered out; down still on back of head, flanks, rump; white at base of tail feathers.
4b	30-37 days; no down. 37-45 days; flying.

^a Source: Ramsdell and Drury (1979:651).

Appendix 6. Summary of 1982, 1983, 1985 and 1986 land-based censuses of Common Murres on St. Matthew and Hall Island.

Area	Plot	Subplot ^a	1982			1983			1985			1986		
			Mean	s.d.	(n)									
St. Matthew-S	S-01					148	-	1	153	26	7	143	30	5
	S-02													
	S-03					162	-	1	124	26	7	127	31	5
	S-04								40	8	7	43	11	5
	S-05													
	S-06								133	39	5	112	29	5
	S-07					33	-	1	32	3	5	34	3	5
	S-08	A							133	20	4	165	14	5
	S-08	B							339	32	4	439	71	5
	S-09								140	8	4	118	39	4
	s-10	A				9*		1*						
	s-10	B				*	*	*						
	s-10	C				*	*	*				4	2	5
	S-11								129	22	4	119	70	3
	S-12	A										10	4	10
	S-12	B										55	24	10
	S-12	C												
	S-13								1	1	8			
	S-14													
	S-15													
	S-16													
	S-17													
	S-18								23	9	8	21	10	14
	S-19			17	1	61	-	1	24	9	8	79	6	10
	S-20													
	S-21								1	2	6	1	0	11
	s-22													
	S-23								1	1	8	A	2	9
S-24								14	7	7	17	4	11	
S-25														
S-26						2	-	1	4	2	8	7	4	10
S-27								6	2	8	10	4	12	
S-28											80	19	11	
St. Matthew-N	N-01					12	2	8	20	9	17	28	7	9
	N-02	A				125*	29*	7*	23	10	19	16	5	11
	N-02	B							106	23	16	116	19	11
	N-02	C												
	N-03					10*	2*	8*	17	5	12	13	5	11
	N-04													
	N-09	A												
	N-09	B				12	5	17	22	8	12	15	4	13
	N-10													
	Hall	H-03					166	1	2	160	17	12	151	17
H-04						310	71	2	400	54	12	373	24	10
H-05									1	1	12	2	2	10
H-07		A				420	31	2	234	49	12	253	20	10
H-07		B							295	53	12	321	39	10
H-08						39	18	2				27	5	10
H-09									50	10	11	59	7	10
H-10												246	20	9
H-13														
H-15						61	21	2	44	16	7	57	8	10
H-25						412	30	2	200	56	12	246	27	10
H-32		A							2	1	10	6	3	8
H-32		B							77	19	10	95	16	8

^aIf subplot is not 1 listed, all subplots were pooled.

* All subplots combined for this particular year.

Appendix 7. Summary of 1982, 1983, 1985 and 1986 land-based censuses of Thick-billed Murre on St. Matthew and Hall Island.

Area	Plot	Subplot*	1982			1983			1985			1986		
			Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n
St. Matthew-S	S-01					319	-	1	323	105	7	315	101	5
	S-02				134	-	1	123	42	7	106	50	5	
	S-03				364	-	1	336	83	7	318	106	5	
	S-04							153	28	7	156	51	5	
	S-05													
	S-06							572	79	5	632	178	5	
	s-o?				48		1	30	6	5	44	8	5	
	s-oa	A						24	5	4	22	12	5	
	S-08	B						5	4	4	3	3	5	
	S-09							580	148	4	618	257	4	
	s-10	A				355*	-*	1*	161	33	7	171	35	5
	s-1o	B				*	*	*	43	15	7	47	15	5
	s-1o	C				*	*	*	212	65	7	218	50	5
	S-11							528	164	4	569	246	3	
	S-12	A						79	58	23	98		10	
	S-12	B									453	12	10	
	S-12	C									329	116	10	
	s-13					191		1	191	89	8	255	56	11
	S-14					41	-	1	81	32	9	98	16	13
	S-15								5	5	8	7	3	14
	S-16													
	S-17					58		1	67	45	8	90	20	14
	S-18								48	28	8	65	11	14
	S-19			23	1	25		1	50	35	8	75	17	10
	S-20					6		1	2	3	5	9	6	9
	S-21								38	8	7	42	14	13
	s-22					13		1	46	17	8	58	21	11
	S-23								98	17	8	129	22	13
S-24					39		1	118	25	7	87	26	11	
S-25								6	3	7	5	2	12	
S-26					65		1	193	34	8	219	39	10	
S-27					76		1	120	33	8	150	35	12	
S-28														
St. Matthew-N	N-01				23	13	8	25	8	17	34	13	9	
	N-02	A			25*	7*	7*	25	5	19	30	7	11	
	N-02	B			*	*	*	5	2	16	4	1	11	
	N-02	C						*						
	N-03				29*	10*	8	25	14	12	55	20	11	
	N-04													
	N-08	A			172*	76*	17*	116	54	12	52	29	13	
	N-08	B						185	58	12	161	53	13	
	N-08	C												
	N-08	O												
	N-09	A												
N-09	B													
N-10					116	25	5	122	35	11	116	43	13	
N-n														
Hall	H-03				132	79	2	135	46	12	148	32	10	
	H-04				18	5	2	53	11?	12	43	9	10	
	H-05				48	5	2	92	31	12	90	13	10	
	H-07	A						4	2	12	3	1	10	
	H-07	B						100	38	12	108	13	10	

Appendix 7. Continued.

Area	Plot	1982			1983			1985			1986			
		Subplot	Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n
	H-08													
	H-09		275	71	?	270	94	11	277	52	10	306	41	10
	H-10		266	-	1				378	59	9			
	H-12					155	111	6						
	H-13													
	H-15		195	18	2	188	87	7	196	33	10			
	H-25		302	21	2	251	110	12	275	53	10			
	H-32 A					105	52	10	141	46	8			
	H-32 B					52	23	10	59	17	8			

* If a subplot is not listed, all subplots were combined.

* All subplots were combined during this particular year.

Appendix 8. Results of 1985 boat-based murre censuses on St. Matthew Island; rep. = replicate count.
 Observer codes: Max K. Hoberg^a, Brian E. Lawhead^b, Peggy K. Klefn^c, Richard Rohleder^d, Philip D. Martin^e, Charles "Rick" Johnson^f.

Plot	23-24 July		28 July		9 August		11 August		12 August	
	Rep. 1	Rep. 2	Rep. 1 ^c	Rep. 2 ^d	Rep. 1 ^c	Rep. 2 ^d	Rep. 1 ^c	Rep. 2 ^f	Rep. 1 ^f	Rep. 2 ^c
St. Matthew-S										
A-1A	435 ^a	465 ^b								
A-2A	565 ^a	595 ^b								
A-4A	2450 ^a	1810 ^b								
A-5A	1385 ^a	1415 ^b								
A-7A	570 ^a	525 ^b								
St. Matthew-N										
C-10A	50 ^c	140 ^d			260	170	220	180		
C-10B	90 ^c	110 ^d			60	100	140	140		
C-1ot	80 ^c	60 ^d			140	150	160	150		
D-1/D2	490 ^c	641 ^d			64(I)	648	820	1040		
D-7	2220 ^c	1960 ^d	1880	2180						
D-8	470 ^c	450 ^d	480	520						
D-9-A	3130 ^c	2740 ^d	3080	3000						
D-9-B	1700 ^c	1600 ^d	2330	1790						
D-9-C	1150 ^c	850 ^d	1220	1220						
D-9-D										
Hal I										
HB-4A	830 ^e	810 ^e							1090	840
HB-4B	670 ^e	800 ^f							750	470
HB-4C	590 ^e	570 ^f							750	620

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Appendix 9. Summary of Thick-billed Murre reproductive success, by plot, St. Matthew Island, 1985.

Area and Plot	Subplot	Eggs			Chicks Lost	Count at Last Visit ^a		Mean No. of K Adults Patio ^b	
		Laid	Lost	Hatched		Eggs	Chicks	Adults	Patio ^b
St. Matthew-S									
S-14	B	17	8	7	0	2	7	74.1	0.23
S-18	B,C	9	7	1	0	1	1	33.8	0.27
S-19	B	5	3	0	0	2	0	23.0	0.22
S-21	F	5	2	1	0	2	1	40.6	0.12
S-23	A-C,E,F	11	2	5	1	4	4	38.6	0.29
St. Matthew-N									
N-2	B	0	-	-	-	-	-	-	-
N-9		37	21	13	2	3	11	79.0	0.47
N-10	A	5	1	4	1	0	3	37.0	0.14
N-10	B	10	5	4	2	1	2	25.0	0.40
N-10	C	3	3	0	0	0	0	48.5	0.06
N-10	D	4	0	0	0	2	0	22.1	0.18
N-10	E	6	2	4	1	0	3	19.7	0.30
Hall									
H-6		39	16	22	16	1	6	64.4	0.61
H-10	A	4	1	3	0	0	3	9.9	0.40
H-23	B-D,F	9	12	12	0	5	12	55.4	0.52
H-26	A1-4	0	-	-	-	-	-	-	-
H-26	A5	7	2	5	0	0	5	8.6	0.81
H-26	B1-4	6	2	2	0	2	7	13.8	0.43
H-77	H1	2	2	0	0	0	0	6.1	0.33
H-27	H3-4	2	1	1	0	0	1	29.7	0.07
H-27	H5	3	0	3	0	0	3	6.7	0.45
H-27	I1	13	1	11	1	1	10	20.3	0.64
H-28	B	0	-	-	-	-	-	-	-
H-28	c	8	5	1	0	2	1	15.5	0.52

^aLast visit was 14-17 AU for St. Matthew-S, 17 AU for St. Matthew-N, and 17 AU for Hall.

^bNo. of eggs/mean no. of adults.

Appendix 10. Summary of Thick-billed Murre reproductive performance, by plot, St. Matthew Island, 1986.

Area and Plot	Sub-plot	Eggs		Hatched	Chicks Lost	Count at Last Visit ^a		Mean No. of K Adults Ratio ^b	
		Laid	Lost			Eggs	Chicks	Adults	Ratio
St. Matthew-S									
S-14	B	26-28	2-5	8-11	0-3	14-17	8-11	90.8	0.31
S-18	B-C	10-1?	4-6	4-10	0	2-9	4-11	65.3	0.29
S-19	B	0-4	0-2	0-2	0	0-2	0-2	14.8	0.27
S-21		13-14	4-8	3-9	1-2	2-6	2-6	37.3	0.40
S-23	A-C,E,F	6-8	2-4	3	0	1-3	3	58.1	0.14
St. Matthew-N									
N-2	B	0	-	-	-	-	-	-	-
N-9		27	17	9	3	1	6	49.2	0.55
N-10	A	9	8	1	0	0	1	28.0	0.32
N-10	B	12	8	4	1	0	3	21.4	0.56
N-10	C	22	4	16	4	2	12	39.7	0.55
N-10	D	16	6	9	5	1	4	29.8	0.54
N-10	E	8	4	4	1	0	3	13.3	0.60
Hall									
H-6		57	19	36	8	2	28	74.8	0.68
H-10	A	7	5	2	0	0	2	11.5	0.61
H-10	F-1	40	8	27	6	5	21	86.9	0.46
H-23	B-D,F	48	19	21	3	8	18	68.7	0.70
H-24	A	4	1	3	0	0	3	27.6	0.63
H-26	A1-4	0	-	-	-	-	-	-	-
H-26	A5	9	0	8	2	1	6	9.8	0.91
H-26	B1-4	8	1	4	0	3	4	14.3	0.56
H-27	H1	2	0	1	0	1	1	6.7	0.30
H-27	H4	0	-	-	-	-	-	-	-
H-27	I1	14	4	9	1	1	8	19	0.74
H-28	B	0	-	-	-	-	-	-	-
H-28	C	10	3	5	2	2	3	16.9	0.5;

^a Last visit was 6-8 AU for St. Matthew-S, 15-18 AU for St. Matthew-N, 11-12 AU for Hall.

^b No. of eggs/mean no. adults; maximum number of eggs assumed for St. Matthew-S.

Appendix 11. Summary of Common Murre reproductive success, by plot, St. Matthew Island, 1985.

Area and Plot	Sub-plot	Eggs		Hatched	Chicks Lost	Count at Last Visit ^a		Mean No. of Adults	Ratio ^b
		Laid	Lost			Eggs	Chicks		
St. Matthew-S									
S-14	B	-	-		-	-	-		-
S-18	B,C	3	1	1	0	1	1	18.9	0.16
S-19	B	0				-	-		
S-21	F	0				-	-		
S-23	A-C,E,F	0				-	-		
St. Matthew-N									
N-2	B	27	3	21	0	3	21	65.8	0.41
N-9		0				-	-		
N-10	A	0				-	-		
N-10	B	0				-	-		
N-10	C	0				-	-		
N-10	D	0				-	-		
N-10	E	0				-	-		
Hall									
H-6		0	-			-	-		
H-10	A	15	6	6	0	3	6	30.4	0.49
H-23	B-D,F	0	-			-	-		
H-26	A1-4	30	30	0	0	0	0	72.0	0.42
H-26	A5	1	0	1	0	0	1	1.7	0.59
H-26	B1-4	17	2	12	4	3	8	32.1	0.53
H-27	H1	5	1	2	1	2	1	73.7	0.21
H-27	H-4	4	3	0	0	0	0	39.0	0.08
H-27	H-5	0	-			-	-		
H-27	11	4	0	4	1	0	3	11.4	0.35
H-28	B	8	0	5	0	3	5	38.8	0.21
H-28	c	5	2	3	0	0	3	22.2	0.23

^a Last visit was 14-17 AU for St. Matthew-S, 17 AU for St. Matthew-N, and 17 AU for Hall.

^b No. of eggs/mean no. of adults.

Appendix 12. Summary of Common Murre reproductive performance, by plot, St. Matthew Island, 1986.

Area and Plot	Sub-plot	Eggs		Hatched	Chicks Lost	Count at Last Visit ^a		Mean No. of K Adults Ratio ^b	
		Laid	Lost			Eggs	Chicks		
St. Matthew-S									
S-14	B	0			-	-	-	20.6	0
S-18	B,C	0			-	-	-	17.2	0
S-19	B	0			-	-	-		
S-21		0			-	-	-		
S-23	A-C,E,F	0			-	-	-		
St. Matthew-N									
N-2	B	46	8	28	5	10	23	70.4	0.65
N-9		0			-	-	-		
N-10	A	0			-	-	-		
N-10	B	0			-	-	-		
N-10	c	0			-	-	-		
N-10	D	0			-	-	-		
N-10	E	0			-	-	-		
Hall									
H-6		6	5	1	0	0	1	13.4	0.45
H-10	A	15	5	8	0	2	8	28.0	0.54
H-10	F-1	0			-	-	-		
H-23	B-D,F	0			-	-	-		
H-24	A	0	-	-	-	-	-	-	-
H-26	A1-4	46	3	38-39	1	4-5	37-38	67.8	0.68
H-26	A5	3	0	3	0	0	3	3.0	1.00
H-27	H1	12	5-7	4-6	0-2	1	4	23.0	0.52
H-26	B1-4	20	2-3	15-16	3-4	2	12	32.1	0.62
H-27	H4	19	7	11	1	1	10	29.0	0.65
H-27	11	4	2	1	0	1	0	11.4	0*35
H-28	B	15	7	8	2	0	6	28.7	0.5?
H-28	C	12	5	7	3	0	4	25.7	0.47

^aLast visit was 6-9 AU for St. Matthew-S, 15-18 AU for St. Matthew-N, 11-12 AU for Hall.

^bNo. of eggs/mean no. adults.

Appendix 13. Summary of 1985 and comparable 1977, 1982, and 1983 boat-based ki tiwake censuses on St. Matthew Island.

Plot	1977		1982		1983		1985a	
	Adults	Nests	Adults	Nests	Adults	Nests	Adults	Nests
	\bar{x} (s. d.) n							
St. Matthew-S								
A-1A							181 (--) 1	6? (--) 1
A-2A							39 (--) 1	9 (--) 1
A-4A							107 (--) 1	37 (--) 1
A-5A							654 (--) 1	222 (--) 1
A-7A							273 (--) 1	91 (--) 1
St. Matthew-N								
C-10A							452 (178) 3	154 (--) 1
C-10B							124 (19) 3	59 (--) 1
C-II-SC							228 (36) 3	120 (--) 1
C-iO (all)				545 (--) 1	335 (--) 1	805 (1,8?) 3	333 (--) 1	
D-1/D-2	-- (--)	770 (--) 1	434 (--) 1	284 (--) 1	679 (--) 1	376 (--) 1	689 (153) 3	346 (--)
D-7	-- (--)	50 (--) 1	211 (--) 1	126 (--) 1	248 (--) 1	115 (--) 1	270 (29) 3	83 (--)
o-8	-- (--)	10 (--) 1	8 (--) 1	1 (--) 1	0 (--) 1	0 (--) 1	7 (1) 3	0 (--)
O-9A					714 (--) 1	344 (--) 1	552 (90) 3	228 (--)
O-9B					337 (--) 1	178 (--) 1	339 (103) ?	149 (--)
D-9C					403 (--) 1	161 (--) 1	688 (265) 7	230 (--)
O-9D					2 (--) 1	0 (--) 1	0 (--) 1	0 (--)
O-9 (all)	-- (--)	857 (--) 1	1077 (--)	746 (--) 1				
Hal 1								
HB-4A							84 (13) 2	45 (14) 2
HB-4B							175 (16) 2	68 (14) 2
HB-4C							101 (38) 2	35 (4) 2

*In 1985 most counts of adults (and at St. Matthew-S, counts of nests as well) were conducted simultaneously by two observers. Values given here are derived from mean counts for each census date; see Appendix 10 for 1985 data, by observer.

Appendix 14, Results of 1985 boat-based censuses of Black-legged Kittiwakes on St. Matthew Island:
 rep = replicate count. Observer codes: Brian E. Lawhead^a, Max K. Hoberg^a, Peggy K. Klein^c,
 Richard Rohleder^a, Charles "Rick" Johnson^e, Phillip O. Martin^e.

Plot	23-24 July				28 July				9 August			11-13 August		
	Rep. 1		Rep. 2		Rep. 1 ^d		Rep. 2 ^c		Rep. 1 ^c		Rep. 2 ^d		Rep. 1	
	Adults	Nests	Adults	Nests	Adults	Nests	Adults	Nests	Adults	Nests	Adults	Nests	Adults	Nests
St. Matthew-S														
A-1A	189 ^a	79 ^a	173 ^b	44 ^b										
A-2A	40 ^a	10 ^a	37 ^b	8 ^b										
A-4A	98 ^a	36 ^a	115 ^b	37 ^b										
A-5A	722 ^a	264 ^a	586 ^b	180 ^b										
A-7A	296 ^a	112 ^a	250 ^b	70 ^b										
St. Matthew-N														
C-10A	534 ^c	--	663 ^d	--					417	--	370	--	154 ^f	
C-10B	172 ^c	--	120 ^d	--					108	--	125	--	59 ^f	
C-1ot	291 ^c	--	244 ^d	--					249	--	194	--	120 ^f	
D-1/D-2	863 ^c	--	857 ^d	--					598	--	682	--	346 ^c	
D-7					217	--	250	--					83 ^c	
O-8					7	--	6	--					0 ^c	
O-9A					620	--	587	--					228 ^c	
O-9B					391	--	431	--					149 ^c	
D-9C					934	--	818	--					230 ^c	
D-9D					0	0	--	--					0 ^c	
Hall														
HB-4A	93 ^e	55 ^e	-- ^f	-- ^f									74 ^f	35 ^f
HB-4B	183 ^e	81 ^e	189 ^f	74 ^f									164 ^f	58 ^f
HB-4C	128 ^e	37 ^e	128 ^f	37 ^f									74	32 ^f

Appendix 15. Summary of 1982, 1983, 1985 and 1986 band-based censuses of Black-legged Kittiwakes on St. Matthew and Hall Island.

Area	Plot	Subplot ^a	1982			1983			1985			1986			
			Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n	
St. Matthew-S	S-01					8	-	1	6	3	7	5	1	5	
	S-02														
	S-03														
	S-04														
	S-05														
	S-06								70	15	5	68	10	5	
	s-or						105	-	1	102	14	5	102	13	5
	S-08	A											4	3	3
	S-08	B											4	3	3
	S-09														
	s-10	A													
	s-10	B													
	s-10	C													
	S-11														
	S-12	A													
	S-12	B													
	S-12	C													
	S-13						16	-	1	18	4	7	13	3	10
	S-14									9	3	8	7	2	11
	S-15														
	S-16														
	S-17														
	S-18														
	S-19			172	-	1	171	-	1	179	30	8	188	23	11
	S-20														
	S-21			24	-	1				49	5	6	48	6	13
	s-22						5	-	1	21	4	8	14	4	11
	S-23						95	-	1	131	16	8	128	13	13
s-24															
S-25															
S-26						44	-	1	45	8	8	38	4	10	
S-27															
S-28															
St. Matthew-N	N-01					94	19	8	148	20	18	169	23	9	
	N-02	A				246*	59*	7*	-86	13	19	91	8	11	
	N-02	B				*	.	*	105	13	16	112	9	11	
	N-02	C						*	130	23	16	177	20	11	
	N-03					77*	24*	8	132	21	17	118	29	12	
	N-04					61	10	8	92	13	18	96	14	12	
	N-08	A													
	N-08	B													
	N-08	C													
	N-08	O													
	N-09	A													
	N-09	B													
	N-10														
	N-n														
Hall	H-03					34	10	2	47	9	12	53	5	10	
	H-04					17	4	2	28	7	12	26	5	10	
	H-05								26	5	12	37	3	10	
	H-07	A													
	H-07	B													

Appendix 15. Continued.

Area	Plot	Subplot	1982			1983			1985			1986		
			Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n
	H-08					12	-	1				10	1	9
	H-09					53	21	2	75	8	11	77	5	10
	H-10					26	-	1	37	5	9	4	4	?
	H-12													
	H-13								144	12	8	143	10	9
	H-15					2	1	2	2	3	7	5	1	10
	H-25					22	-	1	21	5	12	25	2	10
	H-32	A												
	H-32	B												

^aIf a subplot is not listed, all subplots were combined.

* All subplots were combined during this particular year.

Appendix 16. Summary of 1982, 1983, 1985 and 1986 land-based censuses of Black-legged Kittiwake nests on St. Matthew and Hall Island.

Area	Plot	Subplot	1982			1983			1985			1986				
			Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n		
St. Matthew-S	S-01							3	1	7	3	1	5			
	S-02															
	S-03															
	S-04															
	S-05															
	S-06							30	4	4	55	3	5			
	S-07							6	6	8	8	7	5			
	S-08	A				7	7	-	1	6	8	5	4	5		
	S-08	B										2	1	3		
	s-09											0	1	3		
	s-10	A														
	s-10	B														
	s-10	C														
	S-11															
	S-12	A														
	S-12	B														
	S-12	C							6	2	7	9	1	10		
	S-13								7	-	1	4	1	11		
	S-14															
	S-15															
	S-16															
	S-17															
	S-18															
	S-19			106	-	1	98	-	1	54	11	7	130	6	11	
	S-20															
	s-21			25	-	1				26	5	6	39	1	13	
	s-22						1		1	4	1	8	9	1	11	
	S-23						71	-	1	54	12	8	108	2	13	
S-24																
S-25																
S-26						25	-	1	26	4	8	33	1	10		
S-27																
S-28																
St. Matthew-N	N-01					75		8	4	87	11	17	121	10	9	
	N-0?	A				290*		*	-*	I*	54	6	19	65	3	11
	N-02	B							75	8	16	85		3	11	
	N-02	C						*	*	88	8	16	70		8	11
	N-03					55*		5	4	62	14	17	74	14	12	
	N-04					47		5	4	50	9	18	62	7	12	
	N-08	A														
	N-08	B														
	N-08	C														
	N-08	D														
	N-09	A														
	N-09	B														
	N-10															
	N-n															
Hall	H-03					12	-	1	21	3	12	44	4	10		
	H-04					8	-	1	15	2	12	19	2	10		
	H-05								16	3	12	31	2	10		
	H-07	A														
	H-07	B														

Appendix 16. Continued.

Area	Plot	Subplot*	1982			1983			1985			1986						
			Mean	s.d.	n													
	H-08					8	-	1										
	H-09					46	6	2										
	H-10					22	-	1										
	H-12																	
	H-13																	
	H-15																	
	H-25																	
	H-32	A				15	-	1										
	H-32	B																

*If a subplot is not listed, all subplots were combined.
 * All subplots were combined during this particular year.

Appendix 17. Kittiwake reproduction data by plot, St. Matthew and Hall Island, 1985 and 1986.

Plot	Subplot	Year	Total Sites	Roosts		Improved Sites	Complete Nests			Survivorship			Count at Last Visit		
				Active	Inactive		0 Egg	1 Egg	? Egg	Total Eggs	Eggs Lost	Chicks Hatched	Chicks Lost	Egg(s)	Chick(s)
St. Matthew-S															
S-19	R	1985		8	9	63	3?	17	0	12	1	?	0	9	2
	B	1986	132	27	22	83	28	45	10	65	6-13	42-58	31-40	0-8	11-19
S-21		1985		31	21	34	18	10	0	10	1	6	1	3	5
		1986	57	4	13	40	12	26	2	30	6-9	18-21	10-12	3	8
S-23	A	1985		9	13	6	3	1	0	1	1	0	0	0	0
	A	1986	20	0	5	15	4	9	2	13	0	13	6	0	7
S-23	B	1985		3	1	4	3	0	0	0	0	0	0	0	0
	B	1986	6	0	0	6	2	2	2	6	0-2	4-6	3	0	1
S-23	c	1985		?	3	7	5	1	0	1	0	0	0	1	0
	C	1986	11	1	3	7	1	6	0	6	0-1	5-6	4-5	0	1
S-23	D	1985		0	1	12	1	4	0	4	0	3	0	1	0
	D	1986	14	0	1	13	2	8	3	14	0	13-14	7-8	0-1	6-7
s-73	E	1985		3	4	17	5	4	0	4	7	0	0	2	0
	E	1986	21	7	4	15	5	9	1	11	0-1	9-11	4-7	0	4-5
S-23	F	1985		10	6	28	7	9	0	9	0	5	0	4	5
	F	1986	41	4	2	35	13	211-23	?	24-27	0-4	22-27	12-17	0-1	10-11

Appendix 17. Continued,

Plot	Subplot	Year	Total Sites	Roosts		Improved Sites	Complete Nests			Survivorship			Count at Last Visit			
				Active	Inactive		0	1	?	Total	Eggs	Chicks	Lost	Egg(s)	Chick(s)	
							Egg	Egg	Egg	Eggs	Lost	Hatched				Lost
St. Matthew-N																
	N-2	A	1985	12	1	69	15	21	0	?	1	2	14	1	5	13
		A	1986	89	7	9	73	9	38	76	90	11-17	7?-78	51-57	1	21
	N-2	B	1985		11	4	61	22	18	0	18	7	13	0	3	13
		B	1986	87	10	7	70	14	23	33	97	16-30	63-77	50-64	4	13
	N-2	c	1985		10	15	93	34	20	0	20	7	13	3	0	10
		c	1986	146	4	13	136	69	39	38	115	29-42	70-83	57-70	3	13
Hall																
	H-23		1985		7	2	57	45	5	0	5	1	4	0	0	4
			1986	73	5	1	67	13	28	26	80	6-25	52-71	39-58	3	13
	H-23	B	1985	*ND	NO	ND	NO	ND	ND	NO	NO	NO	ND	ND	ND	ND
		B		6	0	0	6	1	5	0	5	4	1	1	0	0
	H-24	A	1985	ND	Nil	ND	ND	ND	ND	NO	NO	NO	NO	NO	NO	ND
		B	1986	1?	0	0	12	3	5	4	13	1	11	11	1	n
	H-26	A	1985		9	3	12	3	5	0	5	3	2	0	0	?
		A	1986	26	?	6	18	4	6	8	22	6-9	13-16	12-15	0	1
	H-26	R	1985		2	3	7	0	1	0	1	0	1	0	0	1
		R	1906	20	0	7	18	4	4	10	24	3-7	17-21	13-18	0	4
	H-26	c	1985		1	3	17	8	3	0	3	0	2	0	1	7
		c	1986	11	0	3	8	0	2	6	14	2-6	8-1?	7-11	0	1

Appendix 17. Continued.

Plot	Subplot	Year	Total Sites	Roosts		Improved Sites	Complete Nests			Survivorship			Count at Last Visit		
				Active	Inactive		0 Egg	1 Egg	2 Egg	Total Eggs	Eggs		Chicks		
											Lost	Hatched	Lost	Egg(s)	Chick(s)
H-27	B,C,E	1985		0	1	13	5	3	0	3	1	0	0	2	0
	B,C E	1986	19	0	3	16	0	8	8	24	4-10	14-20	8-13	0	6
H-77	F	1985		1	?	7	1	0	0	0	0	0	0	0	0
	F	1986	6	0	0	6	3	0	3	6	1-?	4-5	4-5	0	0
H-27	G	1985		3	4	1?	5	0	0	0	0	0	0	0	0
	G	1986	31	0	7	24	3	10	11	37	5-10	19-24	13-18	3	6
H-27	H	1985		2	5	18	5	5	0	5	0	3	0	2	3
	H	1986	22	4	1	16	4	8	4	16	?-4	10-12	8-10	2	2
H-27	I	1985		?	2	25	10	6	0	6	1	3	1	2	2
	I	1986	41	1	0	40	5	13	22	5?	9-18	38-47	37-41	1	6
H-28	B	1985		1	1	9	3	3	0	3	0	0	0	0	0
	B	1986	13	0	1	12	1	4	7	18	9-12	6-9	4-7	0	?
H-28	c	1985		0	0	8	3	3	0	3	0	3	0	0	3
	c	1986	1?	1	1	10	1	3	6	15	0-4	11-15	8-12	0	3

ND = No data.

Appendix 18. Summary of 1982, 1983, 1985 and 1986 land-based censuses of Northern Fulmars and occupied fulmar sites on St. Matthew and Hal 1 Island.

Area	Plot	Subplot	Counts of fulmar adults												Counts of occupied sites					
			1982			1983			1985			1986			1985		1986			
			Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n
St. Matthew-S	S-01																			
	S-02																			
	S-03					5	-	1	1	2	7	0	0	5	1	1	7	0	0	5
	S-04					3	-	1	2	1	7	1	1	5	2	1	7	1	1	5
	S-05																			
	S-06								110	47	5	75	24	5	94	33	5	72	20	5
	S-07																			
	S-08	A																		
	S-08	B																		
	S-09								8	4	4	3	2	4	7	3	4	3	2	4
	S-10	A																		
	S-10	B																		
	S-10	C																		
	S-11											9	3	3	16	2	3	8	2	3
	S-12	A																		
	S-12	B							18	10	7	11	5	10	14	6	7	8	4	10
	S-12	C							26	6	7	21	7	10	21	3	7	18	5	10
	S-13					84	-	1	104	35	8	87	37	11	88	28	7	77	28	11
	S-14								62	19	8	86	22	13	51	14	7	49	15	13
	S-15					45	-	1	54	24	8	51	22	14	42	18	7	43	16	14
	S-16	29	-	1	42	-	1	35	9	7	33	10	15	30	7	7	29	7	15	
	S-17								11	4	8	7	3	14	8	3	8	7	2	14
	S-18					8	-	1	30	11	8	30	15	14	21	11	8	25	10	14
	S-19	2	-	1	15	-	1	11	6	7	12	4	11	9	4	7	11	3	11	
	S-20				245	-	1	188	95	5	233	118	9	145	67	5	188	84	9	
	S-21								2	1	5	1	0	13	2	1	5	1	0	13
	S-22					72	-	1	92	34	8	75	22	11	81	30	6	69	16	10
	S-23								36	14	8	28	10	13	26	13	7	24	7	12
	S-24					64	-	1	101	20	7	81	25	11	89	14	7	71	16	10
	S-25					22	-	1	21	7	7	21	9	12	17	5	7	18	6	11
	S-26					62	-	1	74	11	8	44	15	10	59	7	7	35	12	9
	S-27					27	-	1	28	15	8	9	5	12	21	14	7	7	4	12
	S-28											2	2	9						
St. Matthew-N	N-01																			
	N-02	A																		
	N-02	B																		
	N-02	C																		
	N-03																			
	N-04																			
	N-08	A							15	4	4	28	2	2			2	1	4	2
	N-08	B							37	4	4	33	10	7			26	6	2	

Appendix 18. Continued.

Area	Plot	Subplot	Counts of fulmar adults											Counts of occupied sites							
			1982			1983			1985			1986		1985			1986				
			Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n	Mean	s.d.	n	
	N-08	c							76	17	4	78	6	2				6	2	1	2
	N-08	D						50	1	2	69	-	1				6	5	-	1	
	N-09	A				8*	2*	17*													
	N-09	B																			
	N-10																				
	N-n		38	13	3	39	14	3	52	11	1?	40	?	14			33	13		14	
Hall	H-03																				
	H-04											6	1	10			6		1	9	
	H-05											3	1	8			?	1		7	
	H-07	A																			
	H-07	B																			
	H-08																				
	H-09											1	0	9			1	0		6	
	H-10																				
	H-12																				
	H-13																				
	H-15																				
	H-25																				
	H-32	A																			
	H-32	B																			

*If a subplot is not listed, all subplots were combined.
 * All subplots were combined during this particular year.