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MONITORING OF POPULATIONS AND PRODUCTIVITY OF SEABIRDS AT CAPE PEIRCE, BLUFF, AND CAPE THOMPSON, ALASKA, 1990

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ABSTRACT

Populations and productivity of seabirds were monitored at two colonies in the Bering Sea, Cape Peirce and Bluff, and at Cape Thompson in the Chukchi Sea. Murres and kittiwakes were monitored at all three colonies to facilitate intercolony comparisons. These species were selected because they are relatively easy to study, numerous, sensitive to potential impacts of development, and widely distributed.

Monitoring methods were standardized among the three colonies to facilitate comparisons among colonies and years. Populations and productivity were monitored in a portion of each colony, on permanent plots that were delineated on photographs and viewed from the top of the cliff. Five to 10 replicate counts of adult-plumaged birds were made on population plots during the middle of the breeding season, when numbers of birds were least variable. We also counted birds from offshore at each colony for comparison with data from early years, and early plot counts from Cape Peirce were re-analyzed for comparison with new data. Observations of productivity began at the time nests were established and continued until most young had fledged. Kittiwake nests and murre breeding sites used for estimation of productivity were mapped on photographs or sketches and the fate of each was recorded.

Productivity of kittiwakes was much higher at all three colonies than in the most recent year studied (1989 at Bluff and Cape Peirce, 1988 at Cape Thompson), and murre productivity was slightly higher than recently. Productivity of kittiwakes was near the long-term mean at Bluff and Cape Thompson; it was the highest recorded at Cape Peirce, but still low in comparison with most other Alaskan colonies.

Populations of murres and kittiwakes continued the trends observed during the 1980's. Numbers of both species are stable at the three colonies, except that murres have declined gradually at Cape Peirce since 1985. Long-term trends at Bluff (since 1976) and Cape Thompson (since 1961) have been similar: kittiwakes have been stable or have increased slightly, whereas murre numbers declined until the late 1970's before stabilizing. We analyzed long-term trends at Cape Peirce for the first time from both plot data and offshore counts. There was no trend in murres on plots since 1976 and a slight increase in kittiwakes. We can draw no conclusions yet about long-term trends at Cape Peirce based on offshore counts. Offshore counts of colonies near Cape Peirce (Shaiak Rock, Cape Newenham, and Bird Rock) suggest that kittiwakes may have declined since 1973 at the latter two colonies and in the area as a whole.

Food habits were studied at all 3 colonies in 1990. Diet samples are being analyzed; results will be included in the final report.

CHAPTER 1. INTRODUCTION

The Bering and Chukchi Seas support a large and diverse seabird fauna, including some of the world's largest breeding colonies. Approximately 11,500,000 seabirds breed in the Bering Sea and 2,000,000 in the eastern Chukchi Sea. The marine ecosystem of this area is highly productive, owing to the upwelling of nutrient-rich water from the south onto the Bering Sea shelf, currents from the deep Gulf of Anadyr into the Bering Straits and Chukchi Sea, and the seasonal overturn of water masses (Kinder 1981, Springer et al. 1987).

The seabird populations of the Bering and Chukchi Seas have been censused and studied only in the past three decades, and monitoring of populations has been even more recent. The first survey to establish the location and approximate size of an Alaskan colony was done at Cape Thompson from 1959 through 1961 during pre-development studies for "Project Chariot" (Swartz 1966). Work on Alaskan seabirds expanded throughout the Bering Sea from 1976 with the Outer Continental Shelf Environmental Assessment Program funded by the Minerals Management Service. Permanent plots were established at a number of colonies for monitoring of populations and productivity; most studies also included breeding biology and feeding ecology. Field work in the Chukchi Sea was resumed at Cape Thompson and Cape Lisbume from 1976 through 1982 (Springer and Roseneau 1977, 1978, Murphy et al. 1980, Springer et al. 1985a, b, c). Newly censused colonies in the northern Bering Sea included St. Lawrence Island, St. Matthew Island, and Bluff on Norton Sound (DeGange and Sowls 1978, Drury et al. 1981, Roseneau et al. 1985, Springer et al. 1985a, 1985b, 1985c.) Colonies studied in the southern Bering sea included St. George and St. Paul Islands in the Pribilofs (Hickey and Craighead 1977, Hunt et al. 1981, Craighead and Oppenheim 1982) and Cape Peirce in northern Bristol Bay (Petersen and Sigman 1977). Descriptions of the offshore feeding areas of seabirds have been begun by Schneider and Hunt (1984), Piatt et al. (1988), and Fadely et al. (1989).

In recent years, although descriptive studies have continued, emphasis has increased on standardized monitoring of populations and productivity of seabirds. Commercial uses of the Continental Shelf of the Bering and Chukchi Seas, including oil and gas development, subsurface placer mining, and commercial fishing, carry the potential for adverse pressures on seabird populations. The U.S. Fish and Wildlife Service and Minerals Management Service have both supported monitoring of seabird populations at the Pribilofs (Johnson 1985, Byrd 1986, Byrd 1987), Bluff (Murphy et al. 1986) and Cape Peirce (Johnson 1985, O'Daniel 1988), St. Matthew Island, (Murphy et al. 1987), St. Lawrence Island (Piatt et al. 1988), and Cape Thompson (Fadely et al. 1989). In 1989 a joint project was initiated by the two agencies to monitor three colonies in the Bering Sea, St. George Island, Cape Peirce, and Bluff, simultaneously using the same methods (Mendenhall 1991).

In the present study, Minerals Management Service and the Fish and Wildlife Semite have cooperated in monitoring seabirds at two colonies in the Bering Sea--Cape Peirce, in Bristol Bay west of Dillingham, and Bluff, on the north shore of Norton Sound -- and at Cape Thompson in the Chukchi Sea. These three colonies were selected because of their size, location, exposure to risks that could affect many colonies, and relative accessibility. They are major seabird concentrations; Cape Peirce is considered to have approximately 64,000 seabirds, Bluff 65,000, and Cape Thompson 425,000 (U.S. Fish and Wildlife Service 1990.) The colonies are vulnerable to threats from commercial activities. Oil and gas exploration is in progress in the Chukchi Sea, tanker traffic increases the potential for oil spills near all of the colonies, and marine dredging for gold may take place near Bluff. The colonies in this study have the longest continuous baseline of monitoring data of any in the Bering Sea, which enables us to make maximum use of our results for 1990 in interpreting the status of the populations.

Common and thick-billed murres (Uris aalge and U. lomvia) and black-legged kittiwakes (Rissa tridactyla) have been selected as "index" species for monitoring in the Bering and Chukchi Seas, from among the eight to 12 species present at each colony, because they are important in the ecosystem, relatively easy to study, and sensitive to environmental changes. Murres and kittiwakes represent two major foraging guilds of subarctic seabirds, divers and surface-feeders that prey on fish. The species also are widespread, allowing trends to be compared among many colonies.

The protocol followed in this study was developed to provide sufficiently precise estimates of seabird population trends while being feasible at large and remote colonies. Methods were developed in both the North Atlantic and Alaska (Nettleship 1976, Birkhead and Nettleship 1980, Piatt et al. 1988, Byrd 1989). The whole colony is not censused each year; rather, an index of the population is obtained each year from replicate counts of permanent sample plots. It is also desirable to re-census entire colonies from off-shore in occasional years to provide a second data set for comparison with trends indicated by sample plots. In 1990, new offshore counts were made of murres and kittiwakes at Cape Peirce and Cape Thompson and of kittiwakes at Bluff. An estimate of populations at three large colonies near Cape Peirce--Cape Newenham, Bird Rock, and Shaiak Island--was also made to increase our information on the seabird community represented by monitoring at Cape Peirce. In addition to populations, production of young birds is monitored each year because environmental problems are often revealed more quickly by breeding failure than by population declines.

This study continues our effort to monitor seabirds simultaneously at several colonies in western Alaska, using standardized methods. Each colony has a long database that has been added to frequently. Comparison of trends between colonies should contribute to our understanding of population processes throughout the Bering Sea and improve our ability to assess impacts of environmental perturbations on seabirds.

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CHAPTER 2. GENERAL METHODS

By Vivian M. Mendenhall, Lisa Haggblom,
Edward C. Murphy, and Brian Sharp

INTRODUCTION

Methods common to the three colonies in this study are described in this chapter. Field methods used in the recent past were generally similar at these colonies. Additional standardization within this study was achieved by coordination of investigators' efforts at a pre-season meeting in May 1990. Some details of field methods used in 1990 differed between colonies because of idiosyncrasies in topography, weather, or the history of monitoring at each colony. Details of data analyses likewise varied. Methods specific to each colony are described in chapters 3, 4, and 5.

Monitoring at all three sites relied on experienced field camp leaders assisted by seasonal personnel who were inexperienced in seabird work. New observers were trained carefully before data were recorded.

POPULATIONS

Populations were assessed on sample plots designated within each colony. Each plot was a section of cliff face that was visible from the cliff top. Viewing points at the cliff top were marked with metal survey stakes to assist in locating plots and to ensure that plots were viewed similarly each year. Plots were outlined with felt-tip or drafting pen on a photograph taken from the observation point to ensure that a consistent area was censused. Plot photos were Carned in the field during all observations. Copies of the photographs are stored at the U.S. Fish and Wildlife Office in Anchorage and at national wildlife refuge offices (in Dillingham, for Cape Peirce; in Homer, for Cape Thompson). Plot documentation will be archived as slides at the VIREO archiving system at the Philadelphia Academy of Sciences.

Plot locations at each colony were selected on cliff faces that were visible from a safe viewpoint, were close enough to the observer to allow accurate counting of birds, and were feasible to approach without disturbing the birds. Some viewing points at Cape Peirce must be approached very carefully to avoid flushing birds. An effort was made to distribute plots throughout representative portions of the colony. However, the lower portions of cliffs are under-represented at Cape Thompson because they are difficult to see. It was not feasible to select plots randomly because we wanted to include most suitable cliff faces in the interests of an adequate and representative sample. A map showing locations of the plots is given in the chapter on each colony.

Population plots were censused between the end of egg-laying and the departure of the first chicks, the period when numbers of birds on the cliffs vary least (Birkhead and Nettleship 1980, Hunt et al. 1981a, Murphy et al. 1987, Hatch and Hatch 1988, Fadely et al. 1989). The exact census period differed somewhat between colonies. The time of day for censusing also was standardized within each colony to minimize between-day variation (Lloyd 1975, Biderman et al. 1978, Birkhead and Nettleship 1980, Murphy et al. 1980, Fadely et al. 1989). Replicate counts were made of the entire set of plots on a number of days during the sampling period to encompass day-to-day variation and to provide confidence limits for the population index (Birkhead and Nettleship 1980, Piatt et al. 1988, Byrd 1989). Sample sizes are given in the chapter for each colony. A replicate census of all plots could be done in a single day at Bluff and Cape Peirce, but Cape Thompson had to be censused over several days because of its size.

All adult kittiwakes and murres were counted on population plots. Numbers of kittiwake nests have been recorded in many population studies; however, nests were not used by us for estimating breeding populations because previous monitoring at our colonies has relied on numbers of birds, because numbers of birds provide a less variable index to populations than do nests (Hatch and Hatch 1988). Binoculars and spotting scopes were used for counts. Censuses were avoided if the wind exceeded approximately 20 knots, since high winds have been found to influence attendance by murres on cliffs (Birkhead 1978, Murphy et al. 1987).

Population trends on census plots at each colony were compared across years. Inter-year comparisons used only those plots that had been censused in every year. Population trends at colonies in this study have been analyzed by two methods. At Cape Peirce, and also at St. George in 1989 (Mendenhall et al. 1991), a population total was obtained for each year by summing across all plots within each replicate, then calculating the mean of replicates throughout the year. This population index for the colony was then compared with other years using the t test or regression analysis. In the second method, used for Bluff and Cape Thompson, the mean of replicate censuses was calculated for each plot, and pairwise inter-year comparisons were made between years for each plot. The trend for the colony across all years was inferred from the pattern of plot differences.

In 1990 we conducted a second census at each colony from a boat stationed offshore. Most early studies included complete censuses of colonies from offshore, in order to estimate their size (Swartz 1966, Drury et al. 1981, U.S. Fish and Wildlife Service 1990). In subsequent years, monitoring of population trends from offshore continued at Cape Thompson and Bluff for several years (Springer et al. 1985, Murphy et al. 1986). Yearly monitoring eventually shifted to plots viewed from the top of the cliff at all three colonies, since counts of land-based plots are more precise and can be replicated (Petersen and Sigman 1977, Fadely et al. 1989, Murphy 1991). However, offshore counts in occasional years are desirable for verifying trends that we see on the sample plots. Murres and kittiwakes were counted visually from a boat at Cape Thompson, using plots designated in the 1970's. Copies of original plot photographs were carried; only selected plots were counted at some subcolonies. At Bluff, kittiwakes but not murres were counted visually. Numbers of murres and kittiwakes

were estimated at Cape Peirce, using photographs made from a boat rather than direct visual counts because the roughness of the water made visual counts unreliable. Photographic methods at Cape Peirce were under development in 1990 and estimates of numbers were therefore approximate. Colonies near Cape Peirce, Shaiak Island, Cape Newenham, and Bird Rock, were also photographed and numbers were estimated.

DIETS

Diets of breeding seabirds were studied at all three colonies. Murres and kittiwakes were collected by shooting birds as they returned to the colony from offshore (Bluff, Cape Thompson) or from a nearby shallow bay (Cape Peirce). Proventriculus and gizzard were preserved in 70% isopropanol within 1 hour of collection. Contents of the samples were sorted and identified in the laboratory using appropriate taxonomic keys and reference material (by A.M. Springer, Institute of Marine Sciences, University of Alaska, Fairbanks). The sizes of most fish prey recovered were estimated from regressions of fish length on otolith length and from fish weight on fish length (details are in Springer et al. 1984).

Diet samples were still being analyzed during preparation of this draft report; results will be reported in the final report.

PRODUCTIVITY

Productivity was assessed by intensive observations of cliff plots (Birkhead and Nettleship 1980). Productivity plots were selected in the same manner as population plots. They were generally smaller than population plots and were closer to the observer, although some plots served both purposes.

Observations of productivity began at the time birds were establishing nest sites and continued until most young had departed. Each observer was assigned a set of productivity plots so that the same person monitored each plot throughout the season; familiarity with the plot improved the detection of eggs and chicks. Plots were observed every one to three days, except when bad weather prevented this. Each breeding site was mapped on a photograph of the plot, using a plastic overlay, or on a sketch. A murre breeding site was the position where an egg was laid; replacement eggs ("re-la ys"; B irkhead and Hudson 1977) were assigned to the same site when possible. A kittiwake breeding site ("nest start") was defined as any structure which contained fresh vegetation, whether or not the nest appeared to be completed. At each visit to a productivity plot the observer endeavored to record data for every breeding site on presence or absence of adults, eggs, and chicks, and for black-legged kittiwakes, the number of eggs or chicks. Two or three hours were sometimes required to determine the status of breeding sites. On a given day the status of murres could be ascertained for half or more of the sites with eggs (Gaston and Nettleship 1981, Gaston et al. 1983) and for up to three-quarters of sites with chicks (Schulmeister et al. 1991).

Successive observations provided cumulative records on each breeding site that greatly increased the accuracy of observations in comparison with the data that could be obtained on a single visit. Sites where the contents could not be seen on a given visit were flagged for special attention on the next occasion. Birds were disturbed as little as possible during observations; no birds were disturbed for the purpose of revealing nest contents, since disturbance may reduce productivity (Hunt et al. 1981b).

At Cape Peirce, the posture of murres was used to help indicate incubation of an egg or brooding of a chick (Byrd 1986). Incubation was recorded if a slightly hunched "incubating posture" was seen on three successive occasions. Brooding was recorded if the "brooding posture," with a distinctly hunched back and one drooping wing, was seen once. Murre postures were not considered reliable indicators of breeding status at Bluff and Cape Thompson because many birds there assume similar positions during warm weather. Observations of eggs and chicks were used to confirm incubating and brooding whenever possible.

Chronologies of first laying, hatching, chick deaths, and fledging were recorded for each rest site. Where nests were not observed daily, the timing of each event was estimated as the midpoint of the observation interval in which it occured. The chronology of laying was based on the first egg at each nest site. Chronologies did not include replacement eggs of murres (except at Cape Peirce) nor subsequent eggs in clutches of black-legged kittiwakes.

Productivity of kittiwakes at each colony was estimated as the sum of chicks fledged on all plots, divided by the sum of nest starts on all plots. Kittiwakes were assumed to have fledged if they departed from the nest at 36 days or later (30 days at Cape Thompson). Murre productivity was estimated as the sum of chicks that jumped off ledges on all plots at 15 days or older (14 days at Bluff), divided by the sum of breeding sites on all plots. The term "fledging" as used for murres in this report means jumping from the nest site. For chicks whose date of hatching was not known, but the laying date of whose egg could be estimated, the expected fledging date was determined by adding the incubation period (32 days for murres and 26 days for kittiwakes) to the rearing period. We believe that the number of eggs on plots was underestimated slightly because some eggs that were lost shortly after they were laid probably were never detected by observers. The number of murre breeding sites was probably estimated more accurately than the number of eggs, because an egg lost early in incubation is often replaced, and if either egg lasts several days or longer it is likely to be seen by the observer (Gaston et al. 1983).

Hatching success and fledging success also were estimated. When an egg disappeared near the expected hatching date and it was not known whether the loss occurred before or after hatching, it was arbitrarily assumed that the egg was lost before hatching. Hatching success probably is therefore underestimated slightly.

Statistics for productivity and other reproductive characteristics of each species were calculated using a ratio estimator method (Schaeffer et al. 1986, Byrd 1989). Calculations were performed using a program in a Lotus 1-2-3 spreadsheet (Ackerman and Garton 1987). The method estimates the variance for the overall productivity ratio (all chicks divided by all nest sites) based on the deviation of the productivity on each plot from the overall ratio. The plot was used as the sampling unit for estimating variance rather than the individual nest because success of nests within each plot probably is not independent (Byrd 1989). The estimate of overall productivity is

$$(r) = \frac{\sum y_i}{\sum x_i}$$

and the estimate of variance is

$$(s^2) = \frac{1}{n} \frac{1}{X^2} \frac{\sum (y_i - rx_i)^2}{n - 1}$$

where y_i is the number of chicks leaving the nest on plot i, xi is the number of breeding sites on plot i, and n is the number of plots observed. The standard error for the estimate of productivity, s^2r, was used to calculate confidence bounds.

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CHAPTER 3. CAPE PEIRCE

by Lisa Haggblom and Vivian M. Mendenhall

INTRODUCTION

In Bristol Bay, Cape Peirce seasonally supports up to 30,000 seabirds (Figures 3.1 and 3.2). Common murres (Uris aalge) and black-legged kittiwakes (Rissa tridactyla) are the most abundant breeding species. In moderate abundance are double-crested and pelagic cormorants (Phalacrocorax auritus and P. pelagicus), glaucous-winged gulls (Lams glaucescens), pigeon guillemots (Cepphus columba), and tufted puffins (Fratercula cirrhata). Red-faced cormorants (Phalacrocorax urile), homed puffins (Fratercula corniculata) and parakeet auklets (Cyclorrhyncus psittacula) are least abundant.

Studies have been conducted at Cape Peirce since 1971 (Dick and Dick 1971, Peterson and Sigman 1977, Lloyd 1985, Johnson and Baker 1985, Troy and Baker 1985, Herter and Higgins 1986, van Hulsteyn and Kavanaugh 1987, Haggblom and O'Neil 1987, O'Daniel 1988, Haggblom and Mendenhall, 1991). In 1988, O'Daniel (1988) standardized monitoring methods at Cape Peirce to be consistent with methods used at other seabird colonies in the Bering Sea.

Although population and productivity study methods have been consistent since 1988, the percentage of the total population we monitored was unknown. Our shore-based plot populations represent just a fraction of the total population which can be viewed from sea. In 1990, we estimated populations from sea, in addition to monitoring shore-based plots.

We are unsure whether population and productivity trends observed at Cape Peirce are representative of other colonies in this area. Shaiak Island, Cape Newenham, and Bird Rock are three large seabird colonies within 25 km of Cape Peirce (Figure 3.2). There may be more breeding seabirds at each of these colonies than at Cape Peirce, but few population estimates are available for them (Petersen and Sigman 1977, Sowls et al. 1978). To begin baseline data collection for these colonies in 1990, we estimated populations from sea at Shaiak Island, Cape Newenham, and Bird Rock.

Populations of seabirds were first estimated at Cape Peirce by Peterson and Sigman (1977), based on censuses from land of plots which they established. Most of these plots are still being monitored yearly, Populations estimated in 1976 have not been compared with censuses from 1985 to the present, however, because early data were analyzed differently from recent data. We wished to determine whether populations of common murres or black-legged kittiwakes have changed significantly since 1976, as has occurred for one or both

species at other colonies in western Alaska (Byrd 1986, 1989, Murphy et al. 1986, Fadely et al. 1989). We therefore re-analyzed Petersen's raw population data and compared them with our data for the same plots.

METHODS

The field camp at Cape Peirce (58° 35'N, 161° 45'W), was staffed from 25 April through 4 September, 1990, for seabird studies. A 14' Avon inflatable raft equipped with a 25-hp Johnson outboard motor was used for all boat-based work.

Populations, 1990

Shore-based counts -- Methods for monitoring populations are described in Chapter 2. To determine the appropriate census period at Cape Peirce, population counts of productivity plots were taken on every visit from 29 May to 21 August and graphed daily to observe attendance fluctuations. Recording dates of egg laying (see "Productivity") also assisted in determining the appropriate census period. Population counts were conducted from 21 June to 16 July, 1990; this time period encompassed the latter half of egg-laying to the early part of chick-rearing for kittiwakes, and the egg-laying period for murres. This is typically when adult attendance is the least variable on the plots. Counts were usually made between 10:00 and 20:00 hours.

Ten replicate counts of population plots were made on 34 kittiwake plots and 35 murre plots. Plot photos from 1976, 1984, 1987, and 1989 were used in determining locations and boundaries from previous years (Figure 3.3). One new population plot (plot 47) was added this year, and one plot censused only in 1976 was reestablished (plot 20-1). Standard surveyor's stakes, with identifying numbers engraved on the stake caps, were placed at the observation point for each plot.

Replicate counts of plots have been made each year since 1984 (Tables 3.1 and 3.2). Nineteen plots have been censused in every year since 1985, and we have used these for comparisons among years. Plots were included in comparisons only if three to twelve replicate counts were made in all years.

Boat-based counts -- Cape Peirce and Shaiak Island were photographed from the boat on 2 July, 12 July, and 10 August, 1990. Photos were taken with a Nikon F3 35-mm camera, with a Nikon 80-200 mm telephoto zoom lens; film was Kodachrome 64, Kodak Technical Pan, 1S0 25 (pushed to 1S0 100), and Ektachrome 100 on successive dates. Photographs were taken from approximately 200-300 meters from shore. On 2 July, boat-based observers counted kittiwakes and murres at both colonies as photographs were taken by boat, to compare counts between observers and between observers and photographs. On 12 July, a shore-based observer counted birds on plots 20-4a as the plots were photographed from the

boat, to compare shore-based and boat-based counts. Negatives and slides were enlarged to 8-inch by 12-inch prints for counting purposes. Only birds on cliffs were counted; flying birds and those sitting on the water were not.

The 10 August exposures provided small-scale photos of both Cape Peirce Peninsula and Shaiak Island for orientation purposes; the July exposures provided estimates of numbers.

We photographed the Cape Newenham peninsula from shore during the week of 11-17 June, 1990. The peninsula was photographed from the boat on 13 July (south side, with Kodak Technical Pan film) and on 3 August (north side and Bird Rock, with Ektachrome 100 film). The entire peninsula could not be photographed 13 July due to rough seas, hence the postponement to 3 August. The shore-based population counts at Cape Peirce concluded 16 July, therefore the 3 August exposures of Cape Newenham and Bird Rock are not representative of that census period. A series of aerial photographs of Cape Newenham and Bird Rock taken in September provided small-scale photos for orientation purposes; the July and August exposures provided estimates of numbers.

Budget constraints prevented enlargement of all the exposures. We enlarged those which most clearly defined kittiwakes and murres, and contained high numbers (greater than 100), for each colony. A transparent grid was placed over the 8 x 12 enlargements to facilitate counting of birds. After counting, the areas of enlargements were located on small-scale photographs (Cape Newenham, Bird Rock) and enlargements (Cape Peirce, Shaiak Island, and Bird Rock) of the entire colony. The percent of the total population that was counted was estimated, and numbers were extrapolated for the colony. The counts were rounded to the nearest 1,000, then averaged if counts were available from more than one day (as with Cape Peirce counts).

Populations, 1976

Unpublished counts of common murres and black-legged kittiwakes at Cape Peirce in 1976 were made available to us by Margaret R. Petersen. Of the 47 plots established and counted in 1976 (Tables 3.1 and 3.2), we selected 15 plots that were counted frequently in that year and also in 1985-1990.

Plots were counted throughout the season in 1976. We analyzed 1976 data only from the latter part of egg-laying to early chick-rearing, the interval used for censuses during our study at Cape Peirce. This period was determined for 1976 to be between 15 June through 26 July, based on breeding chronologies described by Petersen and Sigman (1977). Eleven days were selected on which replicate counts of all plots were made, except that a few missing counts had to be estimated (Appendix A-4). When plots were counted more than once in a day, we used the mean of all counts between 10:00 and 19:00 as the number for that day.

Data were analyzed by summing census totals for each day across plots. Our estimated population index for 1976 was the mean of the 11 daily totals. Because four plots used for analyses of trends from 1985 to 1990 were not counted in 1976, we re-analyzed data from the remaining 15 plots for comparison with 1976.

Productivity

Methods for monitoring productivity are described in Chapter 2. Eleven plots with a total of 237 nests were monitored for kittiwake productivity. Nest attempts per plot ranged from 13 to 25. Plots were typically visited at least every other day, except for 10-21 June, when they were visited one to three times. Nest maps drawn in 1989 were used wherever possible.

For chronology and nesting period durations, data were used if 7 or fewer days had elapsed between unequivocal observations of nest contents. If the interval at a given nest was 8 days or greater, the data were used only for productivity calculations. If the date of laying or hatching either was not adequately documented, but the other date could be estimated with sufficient precision, one date was estimated from the other, and both dates were used in chronology estimates.

Eight plots with a total of 145 "sites with eggs were monitored for murre productivity. The same protocol was followed as for kittiwakes.

Mean productivity parameters and 90% confidence intervals were calculated as described in Chapter 2.

Food Habits

A total of 45 kittiwakes were collected for stomach content analysis. Fifteen birds were collected during each of the following periods: pre-laying (20 May through 4 June), incubation (21 June through 10 July), and chick-rearing (22 July through 6 August). Throughout the breeding season, birds were observed in feeding flocks in shallow waters in the channel and lower regions of Nanvak Bay. They were collected as they flew over the beach on their flight back to their nest sites. Stomach contents were preserved in 70% alcohol in whirl-paks in the field, then transferred to glass jars in Dillingham for long-term storage.

Other observations

Predation on seabirds and disturbance by aircraft, boats, and people were observed opportunistically from 27 April through 4 September, 1990. 'Date, location, species, and descriptions of the observations were recorded.

Beached bird survey

Beginning August 17, the 1.2-km beach south of the entrance to Nanvak Bay was surveyed daily for seabird carcasses. If the carcass was in relatively good condition, the gizzard was preserved for diet analysis or the skin was removed for museum preparation. Many beached birds had already been scavenged by ravens, gulls, or foxes. Their wing tips were snipped, and the carcasses were tossed above the high tide mark to prevent re-counting.

RESULTS

Black-legged Kittiwakes

Populations, 1990 -- A summary of ten replicate counts of 34 plots is given in Table 3.3. This summary includes plots not consistently censused every year. An average of 2,407 adults were recorded for these plots. A summary of replicate counts for the 19 plots consistently censused since 1985 is given in Table 3.4 and Figure 3.4. Raw data for 1990 are in Appendix
A-1 through A-3.

A boat-based count was compared with a count from shore on 12 July, when an observer on shore recorded 266 kittiwakes on plot 20-4a, as compared with 433 counted on the photograph taken simultaneously from the boat. The shore-based count represented . approximate y 61% of the kittiwakes observed from the boat.

From boat-based photographs, roughly 8,000 kittiwakes were estimated at Cape Peirce (2 July and 12 July). On Shaiak Island (2 July) roughly 4,000 kittiwakes were estimated. At Cape Newenham (12 July) and Bird Rock (3 August), there were approximately 14,000 and 6,000 kittiwakes, respectively. The total number of kittiwakes for all four colonies was approximately 32,000.

Approximately 27'% of the total kittiwake population was counted from shore on our standard census plots in 1990, and approximately 14% of the total population was counted from our standard census plots shore in all years since 1985.

Populations. 1976 -- Black-legged kittiwake population data were re-analyzed for 15 plots that were censused regularly in both 1976 and subsequent years. A mean of 631 birds were counted on these plots (Table 3.5a).

In 1990 the mean number of kittiwakes counted on the same plots was 832 (Table 3.5b), or 31% higher. Since variances for 1976 and 1990 did not differ significantly ($F = 1.85$, $P > 0.05$), the means were compared. Black-legged kittiwake numbers on the plots were significantly higher in 1990 than 1976 ($t = 3.748$, $P < 0.01$).

Mean numbers of kittiwakes observed on each plot in 1976 are given in Table 3.6. Raw data are listed in Appendix A-4.

Breeding chronology -- Kittiwake incubation, brooding, and total chick-rearing durations in 1990 are given in Table 3.7. Kittiwakes incubated eggs an average of 26.3 days and brooded chicks an average of 36.0 days. The average chick-rearing period was 62.0 days. Since chicks could typically fledge at 36 days old, but often returned to the nest after fledging, actual fledging dates were sometimes difficult to obtain. Therefore, for chicks still observed in their nests longer than 40 days after hatching, 36 days was added to the chick-hatching date to estimate fledging dates.

The average egg laying date was 11 June, the average chick hatching date 7 July, and the average fledging date 11 August (Table 3.8). Egg, chick, and fledgling numbers per four-day interval are shown in Figure 3.5.

Reproductive performance -- Of a total of 237 kittiwake nests, 129 nests had eggs, for an overall laying success of 0.54. The average clutch size was 1.47 eggs per active nest. Out of 189 eggs, 93 chicks hatched, for an overall hatching success of 0.49 hatchlings per egg. Fifty survived to fledge for a fledging success of 0.55. Reproductive success (chicks fledged per nests with eggs) was 0.40, and productivity (chicks fledged per nest start) was 0.22 (Tables 3.9 and 3.10, Figure 3.6).

Food habits -- All birds collected were adults (22 females, 22 males), with the exception that the last individual collected was a second-year female. Twenty-nine percent of the total collected had empty stomachs. Stomach contents are awaiting analysis. Preliminary observations of contents suggest their prey included sandlance (*Ammodytes hexapterus*), crustaceans, and fish roe. Kittiwakes were consistently observed feeding in shallow (less than 2 meters) water along Nanvak channel, approximately 2.5 km from the closest nest sites, and along intertidal areas of lower Nanvak Bay. They were also observed in feeding flocks short distances (less than 2 km) offshore of the cliffs. These feeding flocks near the cliffs sometimes included other species, such as common murres, pelagic cormorants, and homed and tufted puffins.

Predation -- Common ravens (Corvus corax) preyed on kittiwakes of all ages, but most often they took eggs. On 27 April, 27 May, 12 June, and 24 June, ravens killed and ate immature (27 April) and adult kittiwakes, both on and away from kittiwake nest sites. At plot 31 on 12 June, a raven pulled an adult kittiwake off its nest, killed and ate it, then returned to the nest and took the kittiwake eggs. It appeared that the raven initially desired the eggs, and opportunistically ate the adult as the adult tried to defend its nest. There were sixteen sightings of ravens taking eggs or flying with eggs in their bills from 5 June through 27 June. Since ravens cache seabird eggs, it is difficult to quantify the predation on kittiwake eggs. Three active raven nests (located on plots 21 and 20-1, and under observation post 3) produced two, three, and two fledglings, respectively. The raven chicks all fledged by 14 July.

Glaucous-winged gulls (Lams glaucescens) were often observed circling plots in search of chicks, but were never seen taking chicks from nests. From 26 July to 28 August, there were seven sightings of glaucous-winged gulls eating kittiwake chicks and fledglings on the water and rocks below plots 20, 31, 43, and 46. A glaucous-winged gull nest on plot 19-5 contained three chicks, all of which fledged by August 11.

Disturbance -- Kittiwakes were most often flushed from their nest sites by low-flying (less than 1,000 feet above ground level) aircraft during the herring fishing season at Togiak and Security Cove from 3 May to 13 May. Of 34 sightings of low-flying aircraft during this time, a minimum of 13 resulted in flushing kittiwakes. After adults are flushed, predators may potentially take nest contents with ease, or nest contents may be displaced by birds as they leave the nests. However, there were no kittiwake eggs or chicks present in the nests during May 1990.

Vessels further than approximately one-half kilometer from the coastline typically did not disturb seabirds on the cliffs (Haggblom, pers. ohs.). Therefore, only boat sightings within one-half kilometer of shore, including boats entering or exiting Nanvak Bay, are reported here. There were a total of thirteen boat sightings from 28 April to 4 September. Of these, a minimum of three resulted in flushing kittiwakes (13 May, 1 July, and 3 July).

Beached bird survey -- During the beached bird survey, four adult kittiwakes and sixty-one fledgling kittwakes were found in various stages of decomposition (Table 3.11). The weather was severe during most of the survey; there was a storm on 16-17 August coupled with an unusually high tide and a second storm followed on 24-25 August, with winds reaching 60 mph; foul weather continued through September.

Common Murres

Populations -- A summary of ten replicate counts of 34 plots is given in Table 3.3. This summary includes plots not consistently censused every year. An average of 5,575 murres were recorded for these plots. A summary of replicate counts for the 19 plots consistently censused since 1985 is given in Table 3.12 and Figure 3.7. Raw counts of murres in 1990 are given in Appendix A1-A3.

Reliability of visual counts from the boat was assessed by three simultaneous estimates of murres on one rock face by three observers, Totals ranged from 430 to 1200. Approximately 700 murres were counted from the enlarged photograph of the rock face.

On 12 July, an observer on shore counted approximately 1,173 murres on plot 20-4a, compared with 761 counted from the photograph taken simultaneously from the boat.

Roughly 14,000 murres were estimated at Cape Peirce from photographs taken by boat (2 July and 12 July). At Cape Newenham (12 July) and Bird Rock (3 August), there were 66,000 and 41,000 murres estimated, respectively. On Shaiak Island (2 July) roughly 51,000 murres were estimated. The total number of murres estimated for all four colonies was approximately 170,000.

Approximately 40% of the total murre population was counted on plots from shore in 1990, and approximately 19% of the total population was counted from shore in all years since 1985.

Populations, 1976 -- Murre numbers in 1976 on 15 plots for which data were re-analyzed averaged 2,716 (Table 3.5a). In 1990, mean numbers on the same plots were 2,381. This was only 12% lower than in 1976, but the difference is significant (t = 2.371, P c 0,05).

Mean numbers of murres counted on each plot in 1976 are given in Table 3.6; raw data are in Appendix A-4.

Breeding chronology -- Murre incubation, brooding, and total chick-rearing durations are given in Table 3.6. Murres incubated eggs an average of 32.0 days and brooded chicks an average of 23.5 days, for a total chick-rearing period of 55.5 days. The average egg laying date for first eggs was 27 June; the average re-laying date was 11 July. The average chick hatching date was 30 July, and the average fledging date 21 August (Table 3.13). Egg, chick, and fledgling numbers per four-day interval are shown in Figure 3.8. There was overlap in time between nest initiation and chick hatching from 4 July to 28 July, possibly because observers mistook relaid eggs for first eggs. The majority of chicks fledged between 29 August and 6 September.

Reproductive performance -- Of a total of 145 murre sites with eggs, 89 produced chicks, for an overall hatching success of 0.61 hatchlings per egg. Eighty chicks survived to fledge, for a fledging success of 0.90 fledglings per hatchling. Reproductive success (chicks per nest site) was 0.55 (Tables 3.14 and 3.15, Figure 3.9).

Predation -- Ravens and foxes preyed on murre eggs and chicks. Both also cached eggs in shallow holes on the tundra, and were observed with eggs in August, well after eggs ceased to be available from the cliffs. There were five sightings of ravens taking murre eggs and eating chicks from 9 June to 5 August, and numerous sightings of ravens flushing murres from ledges during that time. On 28 July, a raven flushed approximately 50 murres from plot 22, then ate the fish dropped onto the ledges by the murres. Foxes (*Vulpes vulpes*) were observed with eggs on 27 June and 28 June, and with chicks on 20 July, 25 July, 27 July, and 29 July. On each of these days the fox carried one chick in its mouth, except for on 29 July, when the fox carried 3 chicks at once.

Glaucous-winged gulls were observed standing on the periphery of murre ledges, but were never observed taking eggs or chicks.

Disturbance -- Murres were flushed from nest sites by low-flying aircraft similarly to kittiwakes described above. There were no murre eggs or chicks present on the nest sites during May, when aircraft disturbance was greatest. Murres are more easily disturbed than kittiwakes by humans walking along cliff edges and bases (Haggblom and O'Neil 1987, Haggblom and Mendenhall 1991, this study). In 1990, researchers unintentionally flushed murres from plot 45 on June 16 by walking along the cliff base. Several eggs were knocked off the ledges when the adults were flushed.

Boats disturbed murres similarly to kittiwakes on 13 May, 1 July, and 3 July.

Beached Bird Survey -- During the beached bird survey, one adult murre was found on 18 August and one on 22 August (Table 3.11).

DISCUSSION

Populations

Black-legged kittiwake numbers censused in 1990 on plots at Cape Peirce were higher than numbers on the same plots in 1985, 1987, and 1989. However, they were lower than numbers recorded for 1986 and 1988. There has been a slight decline since 1986, although this trend has not been significant (regression coefficient = -123, $t = 2.229$, $P > 0.10$; Table 3.4, Figure 3.4). There has been no significant trend in kittiwake populations during the past six years (regression coefficient = 11.68, $t = 0.764$, $P > 0.10$).

Kittiwake populations at Cape Peirce have increased slightly since 1976, based on Petersen's data for 15 plots. Populations on the plots were significantly higher in 1990 than in 1976. However, the increase is not significant when the 1976 population is compared with data for the past 6 years on 15 plots (Figure 3.4; regression coefficient = 15.40, t = 2.220, P > O.1O). Common murre numbers censused in 1990 on plots at Cape Peirce were similar to numbers on "the same plots in 1988, and higher than those in 1989. However, they were lower than numbers recorded for 1985, 1986, and 1987 (Table 3.11, Figure 3.8). There has been a slight but significant decline since 1986 (regression coefficient = -123, t = 3.064, P < 0.05). The gradual downward trend from 1985 through 1989 was also significant (regression coefficient = -174., t = 4.199, P < 0.05; it was erroneously stated in Haggblom and Mendenhall (1991) that the 1985-1989 trend was not significant.) The recent decline in murres on Cape Peirce plots, and its reversal in 1990, may represent either normal fluctuation in a stable population or an overall decline that is still underway. Monitoring should be repeated at 1- to 3-year intervals in the future to elucidate the trend. Although common murre numbers were significantly lower in 1990 than in 1976, there was no significant trend over all years from 1976 through 1990 (Figure 3.7; regression coefficient = -32,55, t = -1.849, P > 0.10).

Our estimates of kittiwake and murre numbers on Cape Peirce plots in 1976 are more reliable than similar data for several other colonies in western Alaska during the mid-1970's. Petersen's plot censusus were replicated during the season, whereas at other colonies (e.g. St. George and Cape Thompson; Fadely et al. 1989, Dragoo et al. 1991) only one count was made in each year. We can therefore be confident of mean numbers estimated on plots in 1976 and of trends in numbers on the plots between 1976 and recent years.

Our methods for censusing total populations in colonies using photographs were under development in 1990, and our estimates were affected by uncertainties in the methods. Our single count of murres and kittiwakes from shore, made at the same time the cliff was photographed from the boat, gave different results for the two species. More kittiwakes were counted on photographs from the boat than from shore, whereas the reverse was true for murres. The observers felt that some portions of the plot probably were not visible from the observation point on land (which is on the cliff across a cove from the plot), which would explain the higher estimate of kittiwakes from the photograph. However, murres were difficult to count on black-and-white photographs because they nested in dense groups , and murres therefore apparently were undercounted. Since not all of the plot was visible from shore, the actual undercount of murres may have been even greater than suggested by comparison of the raw counts from shore and on the photograph. Replicated comparisons of land and boat-based counts of murres by Rodway (1990) yielded a ratio of 1.44 murres actually present on the cliff for each bird counted on an enlarged photograph. More "ground truth" counts are needed before we can estimate colony populations reliably from photographs.

Both species were difficult to count on black-and-white enlargements due to poor resolution. We suspected that both species were more seriously underestimated on black and white prints than on higher-quality color prints. Numbers of birds estimated from color exposures of 2

July (Shaiak Island and part of Cape Peirce) and 3 August (northern Cape Newenham and Bird Rock) were probably closer to actual numbers present than were estimates made from black-and-white prints of 12 and 13 July (part of Cape Peirce and the south side of Cape Newenham).
Because the 3 August exposures of Bird Rock and of northern Cape Newenham peninsula were taken approximately two weeks after the last Cape Peirce population counts, these numbers probably were not representative of numbers in the census period. Large numbers of murres were observed flying off Bird Rock before photographs were taken on 3 August, so numbers estimated from the exposures on that day seriously underestimated.

Comparisons of bird numbers among colonies in our study are tentative because of differences in the resolution of photographs and in the stage of the reproductive cycle at which they were made. However, kittiwake populations at Cape Peirce, Shaiak Island, and Bird Rock appear to be similar in size, whereas numbers are probably higher at Cape Newenham. The murre population appears to be smallest at Cape Peirce and several times larger at the other three colonies.

Comparisons of our 1990 estimates with those for previous years are also tentative.
J. Bartonek and G. Divoky surveyed all seabird colonies in the area in 1973 (Sowls et al, 1978). For these comparisons we have combined all colonies they designated on the south side of the Cape Newenham peninsula with totals for Cape Newenham. Our estimate for total murres in the 4 colonies (Bird Rock, Cape Newenham, Cape Peirce, and Shaiak Island) was similar to theirs (1973: 160,600; 1990: 172,000). Estimates for Shaiak Island and Cape Newenham changed little. Our estimate for Cape Peirce was lower (1973: 35,320; 1990: 14,000), whereas we estimated more murres at Bird Rock (1973: 10,000; 1990: 41,000). Apparent shifts in murre populations suggested by these comparisons are probably unreliable, given the approximate nature of our estimates. In contrast with murres, our estimates of kittiwakes for the four colonies were dramatically lower than previous ones. We estimated a total kittiwake population for the area of 32,000, whereas Bartonek and Divoky reported 350,000. Some colonies appear to have declined moderately (Cape Peirce, 26,500 to 8,000; Shaiak Island, 14,300 to 4,000). Other declines appear to have been more severe (Cape Newenham: 109,000 to 14,000; Bird Rock: 200,000 to 32,000).

The estimates by Petersen and Sigman (1977) for Shaiak Rock (50,000 murres and 20,000 kittiwakes) were similar to those of Bartonek and Divoky. However, Petersen and Sigman's estimates for Cape Peirce (500,000 murres and 200,000 kittiwakes) were probably serious overestimates.

A decline in kittiwakes at Cape Peirce and nearby colonies conflicts with our finding that populations on study plots have not changed since 1976. Two possible explanations for the discrepancy are (1) plot results are unreliable because plots are not representative of trends in the whole Cape Peirce population, or (2) counts of the whole colony are imprecise and may be unreliable for detecting moderate changes in numbers. Plots are most likely to be representative of the whole population in the colony if they cover a substantial fraction of the

colony and if they are randomly selected (Harris et al. 1983). Plots at Cape Peirce, like those at other Alaskan colonies, were not randomly selected because observers have preferred to census all visible plots. However, our plots encompass a large proportion of the population that we estimated from the boat: 27% for kittiwakes and 40% for murres (based on 1990 plot totals). Even if we have underestimated total populations, our plots represent a large sample of the colony, comparable with 31% in the study of Harris et al. (1983). Plots at Cape Peirce constitute a larger sample than at most Alaskan colonies. At Cape Thompson's Colony 4, 11% of kittiwakes and 19% of murres are censused on plots viewed from shore (data from Sharp 1991, this volume); plots at Bluff contain approximately 6 to 10% of kittiwakes in the colony (Murphy 1991, this volume, Figure 4.5); and plots at St. George contain 1% or less of each species (data from U.S. Fish and Wildlife Service 1990, Dragoo et al. 1991).

Plots' may also become unrepresentative of the colony over a period of years if the relative densities of nesting birds shift between sections of the cliffs (Harris et al. 1983). During change in seabird numbers, each section of the colony tends to remain at an optimal density (Nelson 1979) while fluctuating in the area of cliff it occupies. This problem cannot be avoided entirely, although it can be minimized with plots that cover a large proportion of the colony (as at Cape Peirce). Changes in occupation patterns on the cliff can be detected on photographs taken from offshore, however. Comparison of our 1990 photos with another set made 5 or 10 years hence could provide valuable information on changes in the location and density of nesting seabirds in each colony.

Have the declines in kittiwakes indicated by comparison of 1990 and 1973 censuses really occurred? There were uncertainties in our counts, as discussed above, which probably resulted in underestimation of numbers. Our techniques did not yield a precise estimate of kittiwake population. There probably was also uncertainty in Bartonek and Divoky's figures, which were estimates rather than precise counts and were considered reliable only for detecting large changes (US. Fish and Wildlife Service 1990). It is urgent that our photographic censuses be repeated to verify our estimates of current populations. However, it appears likely that black-legged kittiwakes have declined dramatically at one or more colonies on the north shore of Bristol Bay since the early 1970's.

We plan to repeat offshore photography of all four colonies in 1991. Improvements should include (1) standardization of photographic methods to ensure that all counts are comparable; (2) a correction factor for actual numbers of birds on cliffs, based on replicated counts from shore and from simultaneously exposed photographs; (3) replication of photography of selected cliff areas to provide confidence limits on offshore counts; and (4) quantification of colony areas on prints and random selection of sample areas for counting. Shore-based monitoring should include plots at Cape Newenham, as well as at Cape Peirce, to determine representative trends for that colony. Boat-based plots may also be established. In the event that censuses of boat-based plots cannot be replicated due to poor weather, shore-based plots can provide indices to trends. Several years of monitoring will allow us to evaluate whether trends at Cape Peirce are representative of all four colonies, in which case we would consider monitoring only Cape Peirce plots again.

If future work confirms that common murres have remained approximately stable in northern Bristol Bay over the past 2 decades, this would contrast with trends at several other colonies in western Alaska. Murres declined in the late 1970's at St. George and St. Paul Islands (based on plot censuses; Byrd 1986, 1989), and at Bluff and Cape Thompson (based on offshore counts of whole colonies; Murphy et al. 1986, Fadely et al. 1989). Two other colonies at Cape Lisbume and on St. Lawrence Island may have been stable, based on offshore counts in a small number of years (Springer et al. 1985b, Piatt et al. 1988). Black-legged kittiwakes' populations have declined elsewhere in the southern Bering Sea on the Pribilof Islands (Byrd 1986, 1989, Dragoo et al. 1991) but have been stable farther north (Fadely et al. 1989, Murphy et al. 1991).

With a minimum of 170,000 kittiwakes and murres in this area, complex of colonies at Cape Peirce, Shaiak Island, Cape Newenham, and Bird Rock comprises the largest mainland seabird population in the Bering Sea. Obtaining accurate baseline data for these populations now is critical in case of future oil and gas exploration in Bristol Bay.

Productivity

Black-legged kittiwakes -- Productivity of black-legged kittiwakes (0.22) was higher at Cape Peirce in 1990 than in any year since 1981 for which productivity has been recorded (Table 3.10, Figures 3.6 and 3.10). There does not appear to be a consistent trend in breeding success through the years. Four relatively good years at Cape Peirce (1970, 1976, 1981, 1988), with approximately 0.15 chick fledged per nest, were scattered among 12 years of observations during the two decades prior to 1990.

Black-legged kittiwakes started their reproductive season at Cape Peirce earlier than in 1989. The mean egg-laying date was 11 June compared with 23 June in 1989. The mean chick-hatching date was 7 July, compared to 20 July in 1989, and the mean fledgling date was 11 August, compared to 30 August in 1989 (Table 3.16). Years with early hatching dates (1981, 1988, 1986, and 1990) appear to be correlated with relatively good productivity. However, weather can decrease productivity even in years with early hatching dates. In 1986, the majority of chicks on productivity plots disappeared during a mid-July storm, and no fledglings were produced (van Hulsteyn and Kavanaugh 1987).

Although productivity of black-legged kittiwakes in 1990 was the highest ever recorded at Cape Peirce, it was still relatively low for kittiwakes in Alaska. productivity in the southern Bering Sea has been as high as 0.54 fledged per nest at Round Island, 0.62 at St. George, and 0.54 at St. Paul (summarized in Hatch et al. in press). However, the most important question concerning a species' productivity is whether mean numbers of young fledged per pair are sufficient to maintain the population over the long term. Mean productivity of kittiwakes at Cape Peirce over the 12 years for which we have data was 0.086. This is the lowest mean productivity reported at the 14 Alaskan colonies which have been studied for 5 or more years; the range was 0.09 to 0.78 (data in Hatch et al. in press). It is noteworthy that the only other

colony whose mean productivity is almost as low as Cape Peirce's was Round Island, which is also in northern Bristol Bay. The low mean productivity at both Cape Peirce and Round Island suggests that kittwake populations there cannot sustain their numbers and must be maintained by immigration. Hatch et al. (in press) estimated that a long-term mean of approximately 0.31 fledglings per pair are needed statewide to maintain the Alaskan black-legged kittiwake population. The decline in black-legged kittiwakes that we suspect has occurred at 4 colonies in the Cape Newenham-Cape Peirce area would be consistent with the low productivity at Cape Peirce. Productivity data from Cape Newenham or another colony in the region could give valuable insight into this ecosystem.

Reasons for the low productivity of kittiwakes at Cape Peirce have not been studied sufficiently. Predation pressure by ravens, gulls, and foxes seems high. Our observation of ravens killing adult kittiwakes is unusual, although it has been reported before on a roosting area at Cape Peirce (Parmelee and Parmelee 1988). Predation by gulls, ravens, or other avian predators is thought to cause a large proportion of egg and chick losses at some colonies and may be worse in years of low food availability (Nysewander 1986, Hatch et al. in press). The number of kittiwake eggs and chicks taken by predators each year and the proportion of mortality that they account for have not been estimated. A study of specific causes of predation on the kittiwake population is needed.

Predation is not the only cause of low productivity in kittiwakes at Cape Peirce, however. The proportion of nests in which eggs are laid and the mean clutch size are both low in comparison with other colonies in Alaska, even in relatively good years (data in Nysewander 1986, Mendenhall 1991, Hatch et al. in press, Table 3.10); these components of productivity presumably are not affected by predation. Causes of low egg production by kittiwakes can include poor food resources. Breeding success of kittiwakes at other colonies has been found to vary with availability of the primary prey fish during the season (Springer et al. 1985a and b, Baird and Gould 1986, Fadely et al. 1989, Springer and Byrd 1989). Kittiwakes may be unable to find adequate secondary prey items if their primary prey items are not available. Preliminary results of the diet study suggest that sand lance predominated in kittiwake diets at Cape Peirce in 1990. Food habit studies should continue for kittiwakes.

Another potential cause of poor egg production is chronic low-level disease (Hatch et al. in press). Three adult kittiwakes died on their nests in 1989 (Haggblom and Mendenhall 1991), an unusual event that has not been reported in conjunction with most breeding failures (e.g. Dragoo et al. 1991, Murphy 1991). Investigation of disease should be considered at Cape Peirce.

Kittiwake productivity at Cape Peirce may also be affected by disturbance. The impacts of disturbance prior to the egg-laying period are difficult to assess, since kittiwakes attend nest sites sporadically during this period (Haggblom and Mendenhall 1991, this study). During incubation and chick-rearing periods, however, nest contents can be monitored when adults are flushed. Since kittiwakes at Cape Peirce do not lay a second clutch if the first clutch fails, loss of the clutch results in reproductive failure for the season. When boats flushed

kittiwakes on 1 July and 3 July, at the start of the chick-hatching period, the nest contents were not being monitored. More information is needed of the effects of disturbance on kittiwake productivity at Cape Peirce.

Bad weather may have contributed to post-fledging mortality of kittiwakes in 1990. Surveys began on the beach at the mouth of Nanvak Bay on 17 August at the end of a severe storm, and two days later a large number of dead fledglings washed onto the beach (Table 3.11). A total of 61 fledglings were recovered on the beach over 36 days in 1990, compared with 11 fledglings in 49 days during 1989 (Haggblom and Mendenhall 1991). The majority of dead juveniles appeared on the beach just after the peak of fledging in both years. More kittiwakes fledged at Cape Peirce in 1990 than 1989 (0.22 and 0.06 per nest), which accounts for part of the 5.5-times increase in beached juveniles. In both 1989 and 1990, as frequently occurs, there were storms from the middle of August through September. We need beach survey data from a year with relatively good late-summer weather before we can draw conclusions about the contribution of storms to postfledging mortality.

Reproductive success of kittiwakes is unknown for Shaiak Island, Cape Newenham, and Bird Rock. Productivity plots should be monitored at one or more of these three colonies to determine whether Cape Peirce trends are representative of the area.

Common murres -- Common murres started their reproductive season at Cape Peirce slightly earlier in 1990 than in 1989. The mean egg-laying date for first eggs was 27 June, compared to 1 July in 1989; mean chick-hatching date was 30 July, compared to 7 August in 1989; mean fledging date was 21 August, compared to 27 August in 1989 (Table 3.16).

Reproductive success of common murres was relatively good again in 1990, 0.55 fledglings per breeding site (Table 3.13, Figure 3.10). This was similar to reproductive success in previous years for which we have comparable data, 1988 (0.58; O'Daniel 1988) and 1989 (0.47; Haggblom and Mendenhall 1991). Several more years of data will be needed before we can draw conclusions about productivity of Cape Peirce murres. As with kittiwakes, we need better information on predation pressure and food requirements.

The effects of disturbance on murre reproductive success throughout the breeding season are unknown. Murres frequently lay a second egg should their first egg be lost; loss of the first egg therefore does not always result in reproductive failure.

Reproductive success of murres is unknown for Shaiak Island, Cape Newenham, and Bird Rock. As with populations, murre success at these colonies may be different than success at Cape Peirce. Productivity plots should be monitored at one or more of the other three colonies to determine whether Cape Peirce trends are representative of the area.

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Table 3.1, Population and productivity plot sampling schedule, Cape Peirce, Alaska, 1976-1990, plots 1 through 20-5. Includes all plots, whether or not censuses were replicated.

	Year								
Plot	1976	1981	1984	1985	1986	1987	1988	1989	1990
1	x			x	x			x	
2	x			x		x		x	
3	x			x	x	x		x	
4	x								
5	x			x	x	x		x	x
6	x			x	x	x		x	x
7	x		x	x	x	x		x	x
8	x		x	x	x	x		x	x
9	x								
10	x				x	x		x	x
11	x				x	x		x	
12	x			x	x	x		x	
13	x								
14	x								
15	x								
16	x								
17	x			x	x	x			
18	x			x	x	x		x	
19-1	x				x	x	x	x	x
19-2	x				x	x	x	x	x
19-3	x	x	x	x	x	x	x	x	x
19-4	x			x	x	x	x	x	x
19-4a									x
19-5	x					x	x	x	x
19-6							x	x	x
19-7								x	x
20-1	x		x						x
20-2	x		x	x	x	x	x	x	x
20-3	x		x	x	x	x	x	x	x
20-4	x		x	x	x	x	x	x	x
20-5	x		x	x	x	x	x	x	x

Table 3.2. Population and productivity plot sampling schedule, Cape Peirce, Alaska, 1976-1990, plots 21-47. Includes all plots, whether or not censuses were replicated.

	Year								
Plot	1976	1981	1984	1985	1986	1987	1988	1989	1990
21	x			x	x	x	x	x	x
22	x		x	x	x	x	x	x	x
23	x		x	x	x	x	x	x	x
24	x			x	x	x	x	x	x
25	x			x	x	x	x	x	x
26	x	x	x	x	x	x	x	x	x
27	x	x	x	x	x				
28	x			x	x	x	x	x	x
29-1	x		x	x	x	x		x	x
29-2	x		x	x	x	x		x	x
30	x								
31	x		x	x	x	x	x	x	x
32	x								x
32-1									x
33	x								
34	x								
35	x								
36	x								
37	x								
38	x								
39		x	x	x	x	x	x	x	x
40			x	x	x	x	x	x	x
41				x	x	x	x		
42				x	x	x		x	x
43			x	x	x	x	x	x	x
44								x	x
45								x	x
46								x	x
47									x

Table 3.3. Black-legged kittiwake and common murre population counts for Cape Peirce, Alaska, 1991 (38 plots). Includes some plots not used in comparisons between years.

		No. birds	
Replicate	Date	Kittiwakes	Murres
1	21 Jun	2,541	5,012
2	24 Jun	2,746	5,044
3	27 Jun	2,543	5,620
4	29 Jun	1,811	4,367
5	1 Jul	2,924	5,466
6	6 Jul	2,253	6,081
7	9 Jul	2,088	5,120
8	11 Jul	2,850	6,566
9	14 Jul	1,887	5,992
10	16 Jul	2,427	6,480
Mean		2,407	5,575
90% confidence bounds		± 714	±1,294

Table 3.4. Black-legged kittiwake counts for population plots on which replicate counts were made, Cape Peirce, Alaska, 1985 -1990.2

	Year					
Plot	1985	1986	1987	1988	1989	1990
19-4[1]	19	12	43	30	17	37
20-2	50	14	13	1	0	0
20-3	71	67	59	52	41	47
20-4[2]	417	541	508	558	524	594
20-5	103	112	104	175	97	107
21	11	36	18	17	5	8
22	24	34	33	59	37	44
23	14	18	10	31	9	7
24	4	2	2	2	0	0
26	13	16	11	22	13	9
28	1	3	4	1	1	0
31	105	143	102	132	109	141
39	14	18	16	27	22	28
40	33	44	26	29	6	10
43	58	83	52	53	54	74
SUM	937	1,143	1,001	1,189	935	1,106

[1] Black-legged kittiwakes were erroneously reported as being present on plot 19-3 in 1988 and 1989 (Haggblom and Mendenhall 1991, Table 4.8) No kittiwakes have been recorded on plot 19-3 in any year. The erroneous data were not included in totals for the 2 years, which are the same here and in Haggblom and Mendenhall (1991).

[2] Plots 20-4a, 20-4b, and 20-4c have been combined because they were reported as one plot in some years.

Table 3.5. Populations of black-legged kittiwakes and common murres on plots censused regularly in 1976 and 1990. Includes only plots used in comparison between the two years.[1]

a. 1976[2]

		Number of birds	
Replicate	Date	Kittiwakes	Murres
1	15 June	685	3,065
2	18 June	771	2,778
3	23 June	780	2,999
4	27 June	718	2,487
5	30 June	672	2,524
6	6 July	433	2,068
7	9 July	439	2,840
8	13 July	411	2,857
9	21 July	734	3,050
10	23 July	691	2,256
11	26 July	6 0 9	2,947
Mean		631	2,716
90% confidence bounds		± 57	± 139

Table 3.5. Continued

b. 1990[2]

Replicate	Date	Number of birds	
		Kittiwakes	Murres
1	21 June	853	2,239
2	24 June	975	1,958
3	27 June	772	2,391
4	30 June	668	1,900
5	1 July	806	2,382
6	6 July	785	2,447
7	9 July	773	2,353
8	11 July	961	2,684
9	14 July	768	2,729
10	16 July	955	2,730
Mean		832	2,381
90% confidence bounds		± 45	± 128

[1] Plots 19-3, 19-4, 20-2, 20-3, 20-4, 20-5, 21, 22, 23, 24, 25, 26, and 28.
[2] Source of data: 1976, M.R. Petersen (pers. comm.); 1990, this study.

Table 3.6. Mean numbers of black-legged kittiwakes and common murres in 1976 on plots used for comparison with other years. Data from M.R. Petersen (pers. comm.).

Plot	Black-legged kittiwake	Common murre
19-3	0	390
19-4	43	40
20-2	18	0
20-3	179	603
20-4	130	646
20-5	101	503
21	73	97
22	26	75
23	25	270
24	3	0
25	0	36
26	39	0
28	2	49

Table 3.7. Duration of incubation, chick rearing, and total nesting period (in days) for productivity plots, Cape Peirce, Alaska, 1990.

Stage	Variable	Kittiwakes	Murres
Incubation	Range, all eggs	1-44	1-51
	Range, hatched eggs	26-29	32-34
	Mean, hatched eggs	26.3 + 0.7[1] (8)	32.0 + 0.0 (7)
Chick rearing	Range, all chicks	1-58	7-42
	Range, fledged chicks	32-38	15-41
	Mean, fledged chicks	36.0 + 0.8 (7)	23.5 + 5.0 (6)
Total nesting period	Range, all eggs/chicks	1-85	1-82
	Range, fledged chicks	61-64	47-73
	Mean, fledged chicks	62.0 + 0.8 (7)	55.5 + 4.8 (6)

[1] Data expressed as mean + standard deviation (sample size), where sample size is the number of productivity plots where data were collected. Each plot contained 1-21 active nests or sites.

Table 3.8. Breeding chronology of black-legged kittiwakes at Cape Peirce, Alaska, 1990. Data are mean date and range of dates.

	Lay		Hatch		
PIot	Egg 1	Egg 2	Chick 1	Chick 2	Fledge, chick 1
39	11 Jun 6/09-6/20	13 Jun ·	5 Jul 7/05-7/06	8 Jul	11 Aug 8/10-8/12
26	9 Jun		7 Jul	·	
22	11 Jun 6/09-6/ 13	13 Jun			
40	13 Jun				-
19-1	8 Jun 6/06-6/09				
19-5	11 Jun 6/08-6/16	13 Jun	7 Jul 7/05-7/12		13 Aug 8/10-8/18
19-2	12 Jun 6/08-6/19	11 Jun 6/09-7/13	8 Jul 7/05-7/15		13 Aug 8/10-8/20
46	9 Jun 6/06-6/17	13 Jun 6/07-7/03	6 Jul 7/03-7/16	5 Jul	10 Aug 8/08-8/13
43	14 Jun 6/05-6/21	12 Jun 6110-6/14	11 Jul 7/05-7/17	10 Jul	13 Aug 8/11-8/17
31	9 Jun 6/06-6/16	11 Jun 6/09-6/16	5 Jul 7/02-7/2	5 Jul 7/05-7/08	8 Aug 8/07-8/09
10	9 Jun 6/05-6/16	10 Jun 6/08-6/16	4 Jul 7/02-7/10	5 Jul 7/04-7/05	9 Aug 8/06-8/13
Mean, all plots	11 Jun	12 Jun	7 Jul	7 Jul	11 Aug
Range, all plots	6/05-6/21	6/08-7/16	7/02-7/17	7/04-7/10	8/06-8/20

Table 3.9. Reproductive performance of black-legged kittiwakes on productivity plots at Cape Peirce, Alaska, 1990.

Plot	Nest starts[1]	Nests with eggs	Total eggs	Chicks hatched	Chicks fledged
39	20	8	11	5	4
26	15	2	2	1	0
22	18	2	3	0	0
40	13	1	1	0	0
19-1	25	2	2	0	0
19-5	24	15	19	8	5
19-2	24	20	27	17	11
46	25	19	30	14	10
43	24	17	23	11	3
31	24	19	31	17	3
10	25	24	40	20	14
Total	237	129	189	93	50

[1] Site where new vegetation was added this season.

Table 3.10. Productivity parameters of black-legged kittiwakes at Cape Peirce, Alaska, 1970-1990. Ratios are followed by 90% confidence bounds where data permitted.[1]

Year[1]	No. plots	Nest starts	Clutch size	Hatching Success*	Fledging success[3]	Reprod. success[4]	Product-ivity[5]
1970	1	60	-				0.15[6]
1973		190	-				0.09
1976[7]		1,986			0.55		0.16
1977		136		-	-	0.0	0.0
1981	9	308	1.64 ±0.13	0.59 ±0.09	0.24 ±0.01	0.23 ±0.16	0.16 ±0.13
1984	7	275	1.35 ±0.12	0.01 ±0.03	0.50 ±0.25	0.01 ±0.02	0.0
1985	7	260			-		0.01
1986	7	305	1.41 ±0.09	0.43 ±0.18	0.0	0.0	0.0
1987	4	110	1.32 ±0.14	0.51 ±0.08	0.07 ±0.07	0.05 ±0.04	0.02 ±0.02
1988	5	109	1.52 ±0.18	0.64 ±0.11	0.39 ±0.13	0.39 ±0.21	0.16 ±0.17
1989	6	124	1.31 ±0.11	0.42 ±0.09	0.29 ±0.21	0.16 ±0.13	0.06 ±0.06
1990	11	237	1.47 ±0.11	0.49 ±0.05	0.55 ±0.14	0,40 ±0.11	0.22 ±0.11

1 Sources of data; 1970, Dick and Dick 1971;1976 and 1977, M.A.Petersen, pers. comm; 1973 and 1981, Lloyd 1985; 1984, Johnson and Baker 1985; 1985, Herter and Higgins 1986; 1986, van Hulsteyn and Kavanaugh 1987; 1987, Haggblom and O'Neil 1987; 1988, O'Daniel 1988; 1989, Haggblom and Mendenhall 1991; 1991, this study.

2 Total chicks hatched/total eggs

3 Chicks fledged/chicks hatched

4 Chicks fledged/nests with eggs

5 Chicks fledged/total nest starts

6 No confidence limits calculated because data on individual plots not available.

7 Data for 1976 supersede those reported by Petersen and Sigman (1977). Data recalculated by Petersen using larger sample of plots ('MA. Petersen, pers. comm.).

Table 3.11. Beached birds on beach south of Nanvak Bay, Cape Peirce, 1990.

	Species[1]								
Date	BLKI	COMU	GWGU	LESP	Loon	PECO	SOSH	STSH	Total
17 Aug	f 4[2]								4
18 Aug	f 5	a1				f1			7
19 Aug	f16								16
20 Aug	f 5								
	a 1								6
21 Aug	f 1								1
22 Aug	f 2	a1							3
23 Aug							a1		1
26 Aug	f 4					f2			6
28 Aug	f 2								
	a 1								3
29 Aug	f 4								
	a 1								5
30 Aug	f 2						a1		3
31 Aug			s1			f1			2
3 Sep	f 2					f2			4
5 Sep	f 1					f2			3
8 Sep			s1						1
12 Sep	f 1								1
18 Sep	f 1								1
19 Sep	f 2			a1					
	a 1								4
22 Sep	f 9		S2		a1	a2	a2	a1	17
Total-f	61					8			69
Total-a	4	2		1	1	2	4	1	15
Total-s			4						4
Total	65	2	4	1	1	10	4	1	88

Table 3.12. Common murre counts for population plots on which replicate counts were made, Cape Peirce, Alaska, 1985-1990.

	Year					
Plot	1985	1986	1987	1988	1989	1990
19-3	261	121	206	197	159	159
19-4	112	0	29	0	0	17
20-3	136	79	91	89	64	79
20-4[1]	1,776	2,093	1,716	1,509	1,491	1,728
20-5	365	309	366	412	298	357
21	9	36	41	35	28	13
22	43	59	50	63	41	19
23	17	29	23	39	31	9
25	13	17	4	0	0	0
28	0	6	17	0	12	3
31	257	264	201	239	213	237
39	24	20	11	15	5	3
40	14	119	89	48	49	34
43	54	52	61	81	59	51
Sum	3,081	3,204	2,905	2,727	2,450	2,709

[1] Plots 20-4a, 20-4b, and 20-4c have been combined because they were reported as one plot in some years.

Table 3.13. Breeding chronology of common murres at Cape Peirce, Alaska, 1990. Data are mean date and range of dates.

	Lay			
Plot	Egg 1	Egg 2	Hatch	Fledge
39				
22	21 Jul 7/06-8/09		7 Aug	
40	17 Jun 6/07-6/25		18 Jul 7/12-7/23	5 Aug 8/04-8/06
19-6	18 Jun 6/10-6/30		19 Jul 7/13-7/29	15 Aug 8/06-8/24
19-7	27 Jun 6/17-7/25		25 Jul 7/19-8/04	22 Aug 8/10-8/29
19-3	26 Jun 6/17-7/18	10 Jul 7/05-7/20	9 Aug 8/06-8/22	5 Sep 8/31-9/06
43	2 Jul 6/15-7/26	15 Jul 7/12-7/18	16 Aug 8/13-8/17	5 Sep 8/30-9/06
31	20 Jun 6/18-7/08	9 Jul 7/12-7/12	21 Jul 7/15-7/26	12 Aug 7/31-8/18
Mean, all plots	27 Jun	11 Jul	30 Jul	21 Aug
Range, all plots	6/07-8/09	7/05-7/20	7/12-8/22	7/31-9/06

Table 3.14. Reproductive performance of common murres on productivity plots at Cape Peirce, Alaska, 1990.

Plot	Nest sites[1]	Chiecks hatched	Chicks fledged
39	0	0	0
22	7	1	0
40	11	9	6
19-7	24	21	21
19-6	16	14	1
19-3	21	11	11
43	32	16	15
31	34	17	13
Total	1 4 5	89	80

[1] Site where an egg was laid.

Table 3.15. Productivity parameters of common murres at Cape Peirce, Alaska, 1988-1990. Ratios are followed by 90% confidence bounds.

Year[1]	No. Plots	Nest starts[2]	Hatching success[3]	Fledgling success[4]	Reprod. Success[5]
1988	5	80	0.69 ±0.09	0.84 ±0.12	0.58 ±0.14
1989	4	78	0.51 ±0.04	0.93 ±0.11	0.47 ±0.07
1990	8	145	0.61 ±0.13	0.90 ±0.09	0.55 ±0.15

[1] Sources of data; 1988, O'Daniel 1988; 1989, Haggblom and Mendenhall 1990; 1990, this study.
[2] Nest sites at which an egg was laid.
[3] Chicks hatched/eggs laid.
[4] Chicks fledged/chicks hatched.
[5] Chicks fledged/nest sites.

Table 3.16. Breeding chronology of black-legged kittiwakes and common murres at Cape Peirce, Alaska, 1990.

	Species						
	Black-legged Kittiwake			Common murre			
				Lay			
Year	Lay[1]	Hatch	Fledge	Egg 1	Egg 2	Hatch	Fledge
1989	6/23	7/20	8/30	7/01[2]		8/07	8/27
1990	6/11	7/07	8/1 1	6/27	7/1 1	7/30	8/21

[1] First egg of clutch.
[2] Relays not included.

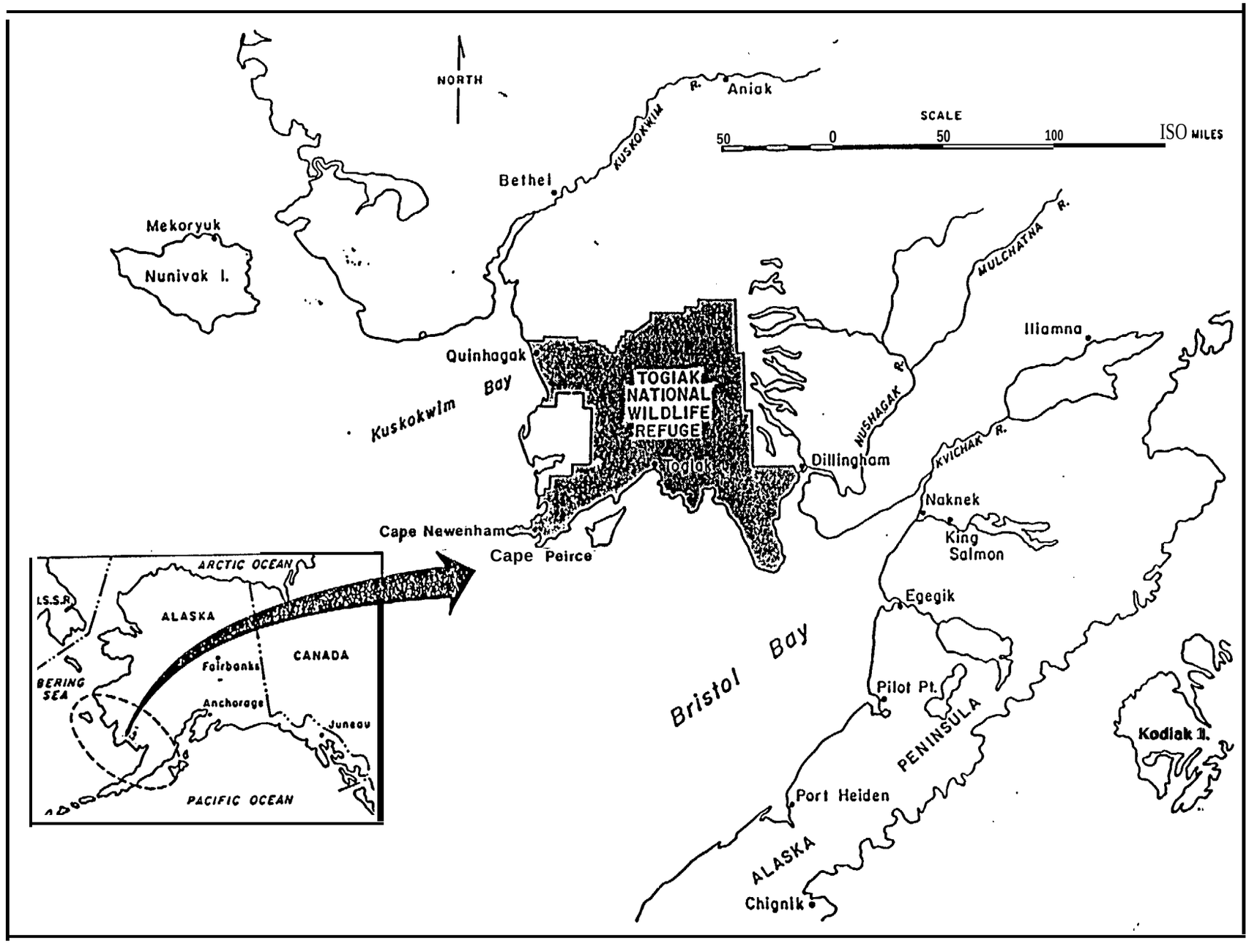

Figure 31. Location of Capes Peirce and Newenham, Togiak National Wildlife Refuge, Alaska.

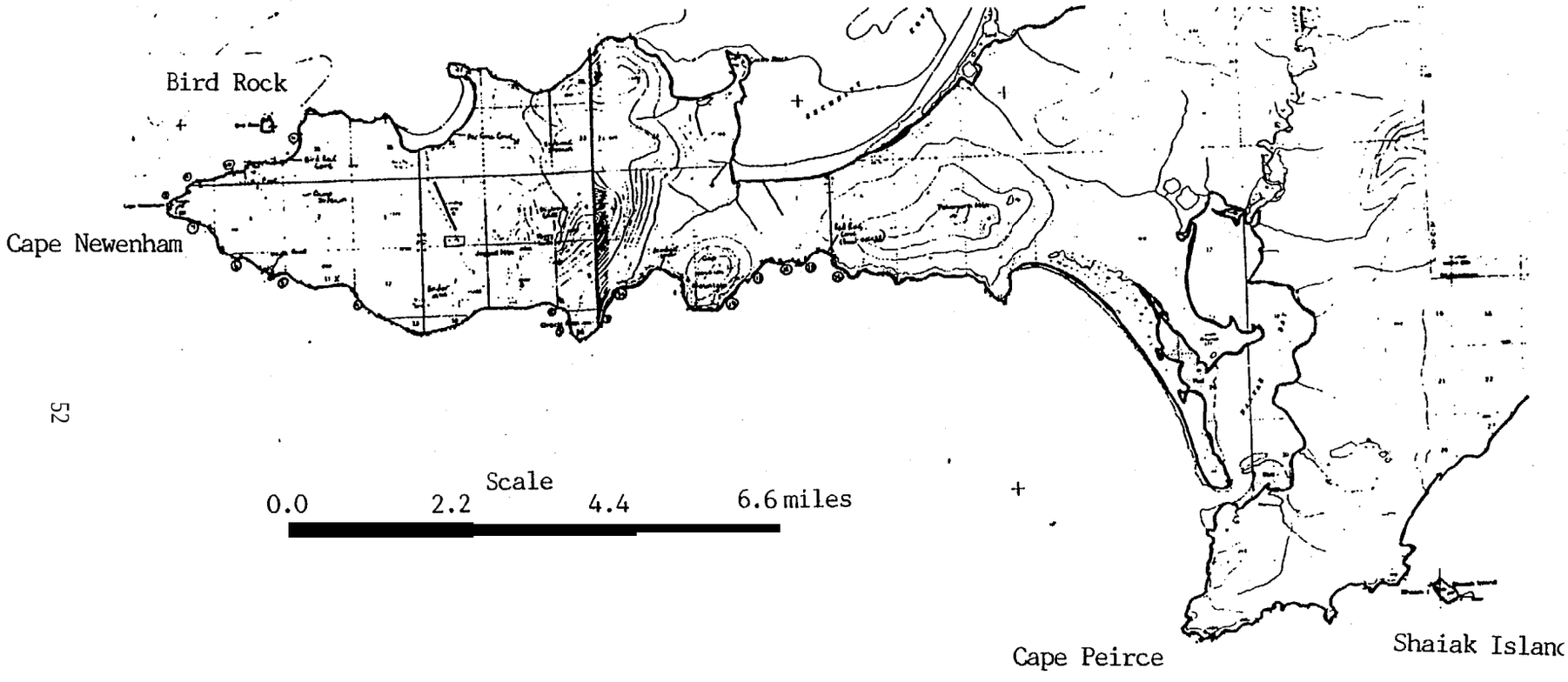

Figure 32. Location of Capes Peirce and Newenham, Shaiak Island, and Bird Rock, Togiak National Wildlife Refuge, Alaska.

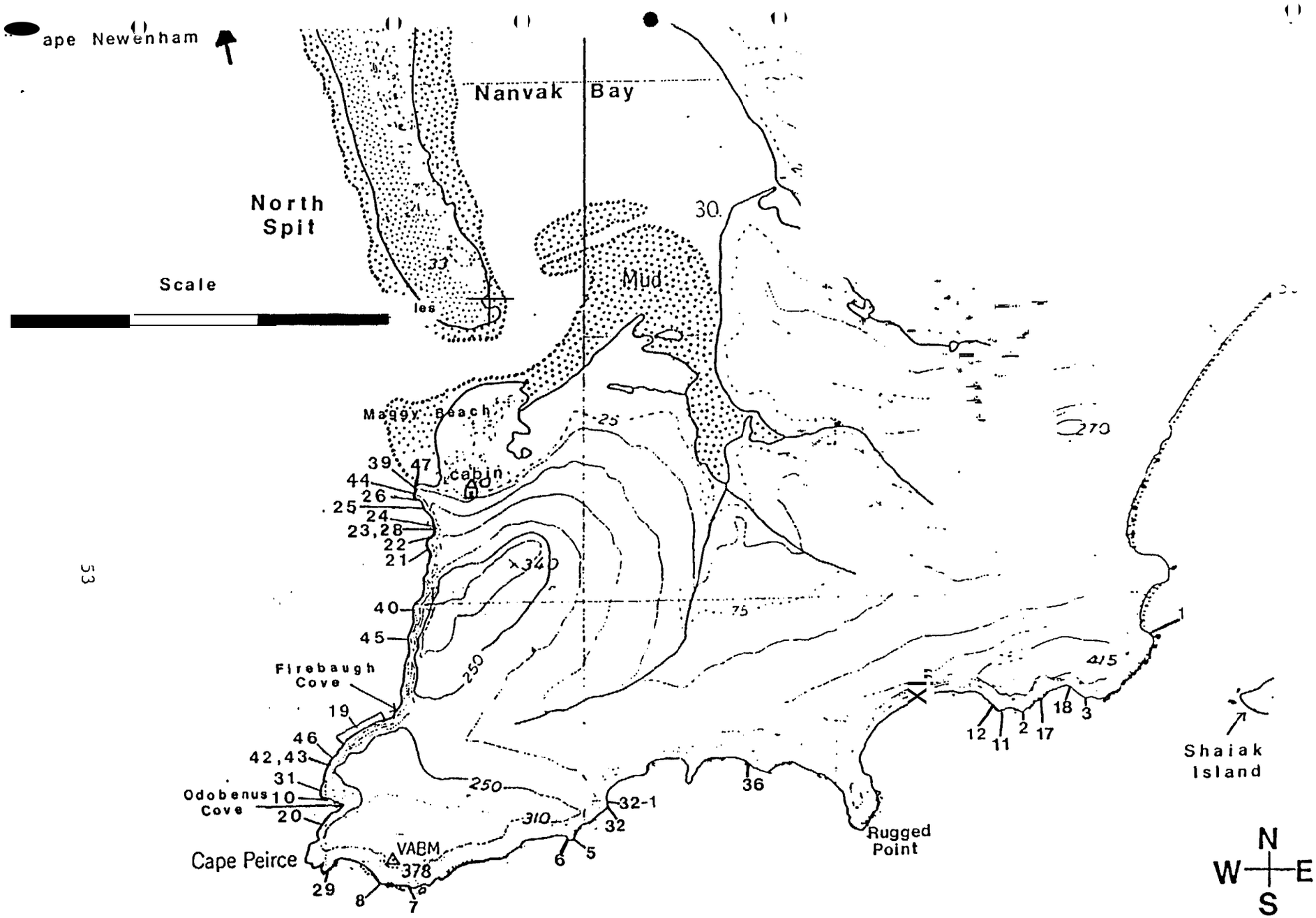

Figure 33. Location of seabird study plots at Cape Peirce, Alaska.

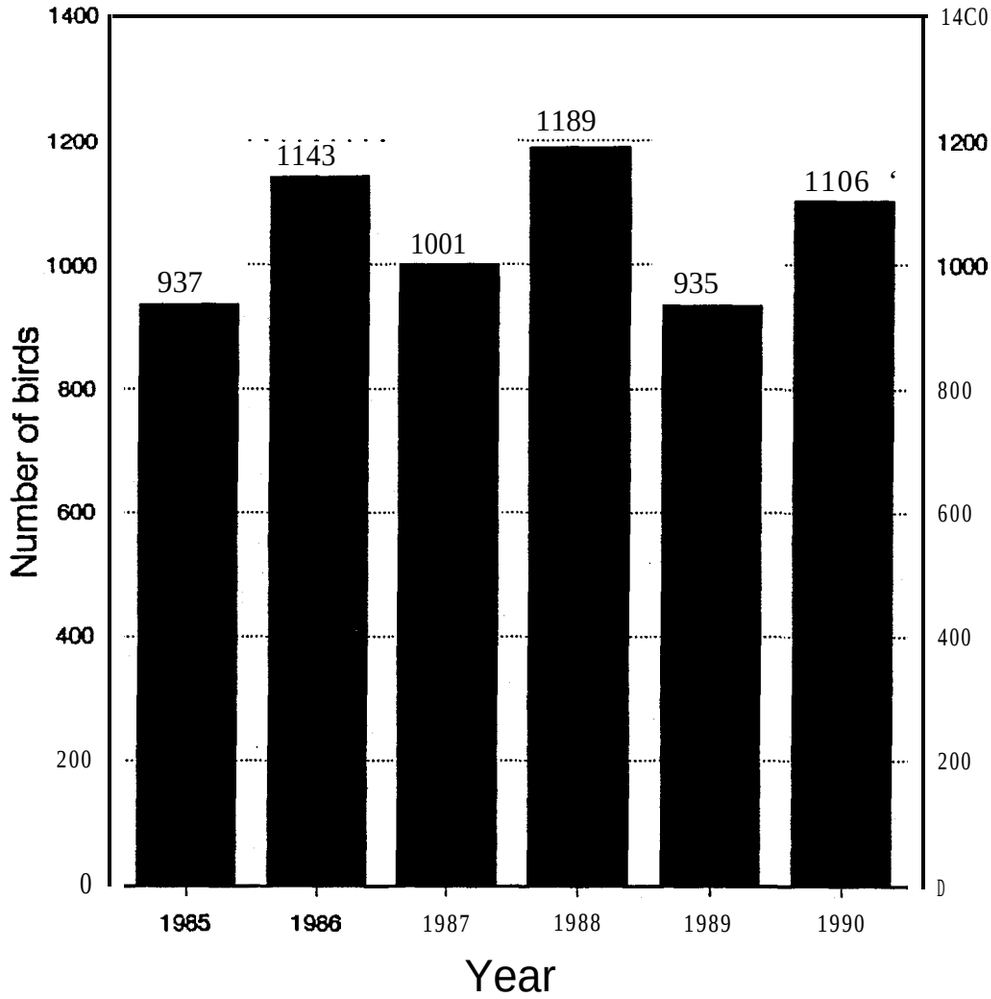

Figure 34. Population counts of black-legged kittiwakes on corm-non plots at Cape Peirce, AK, 1985-1990.

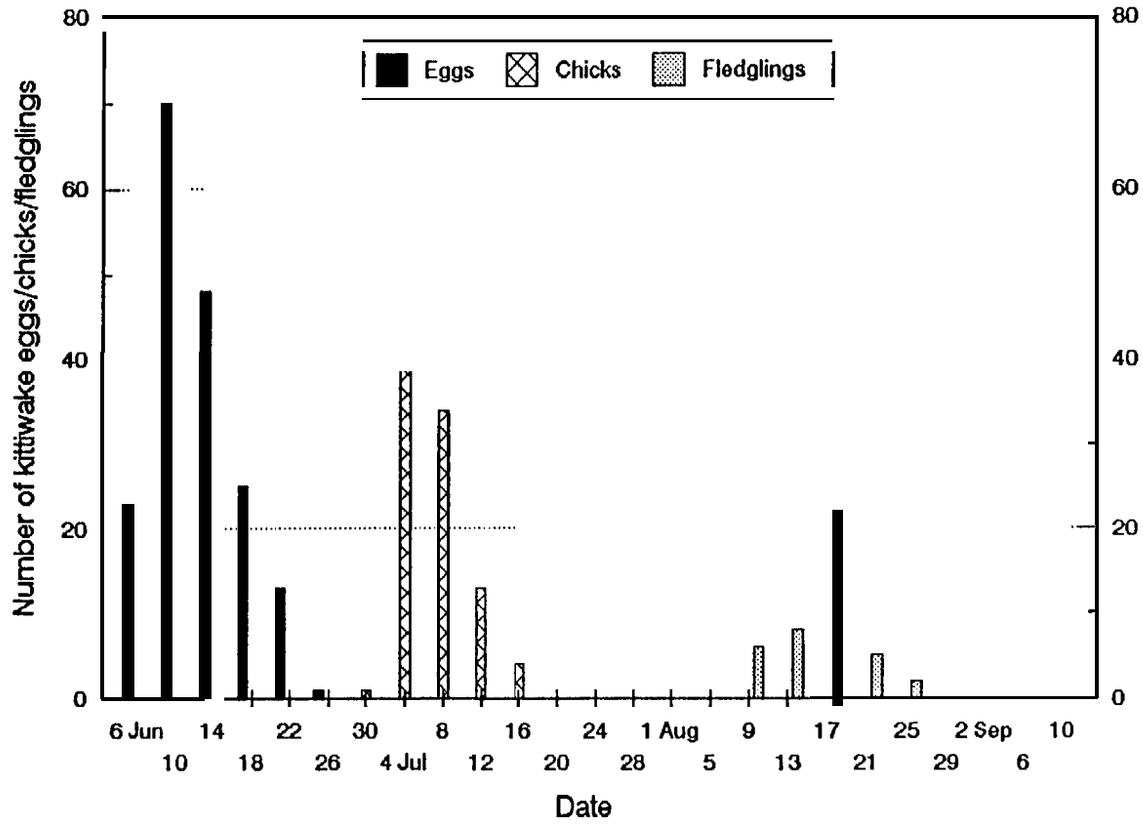

Figure 35. Black-legged kittiwake laying, hatching, and fledging dates at Cape Peirce, AK, 1990.

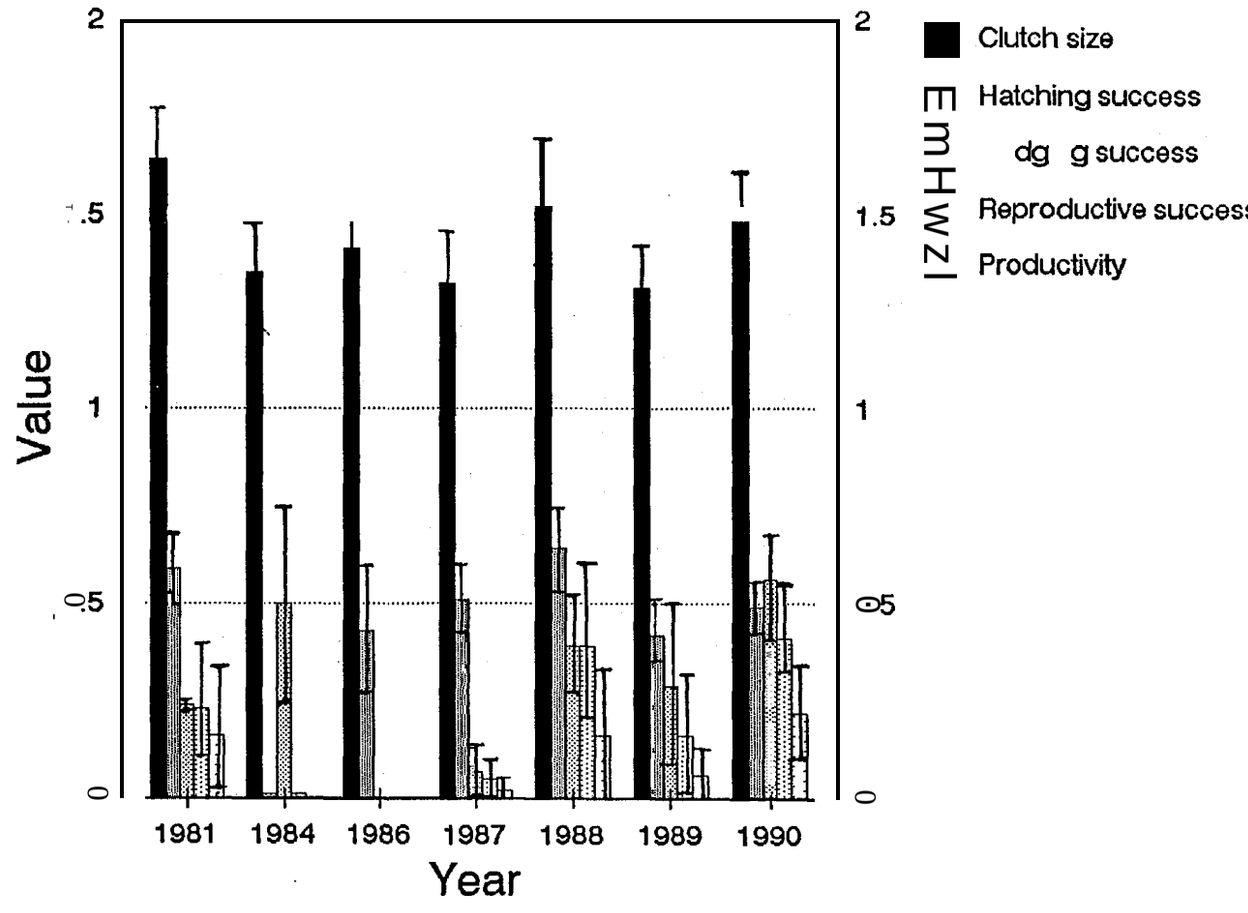

Figure 36. Black-legged kittiwake productivity parameters and confidence intervals (90%) at Cape Peirce, AK, 1981-1990.

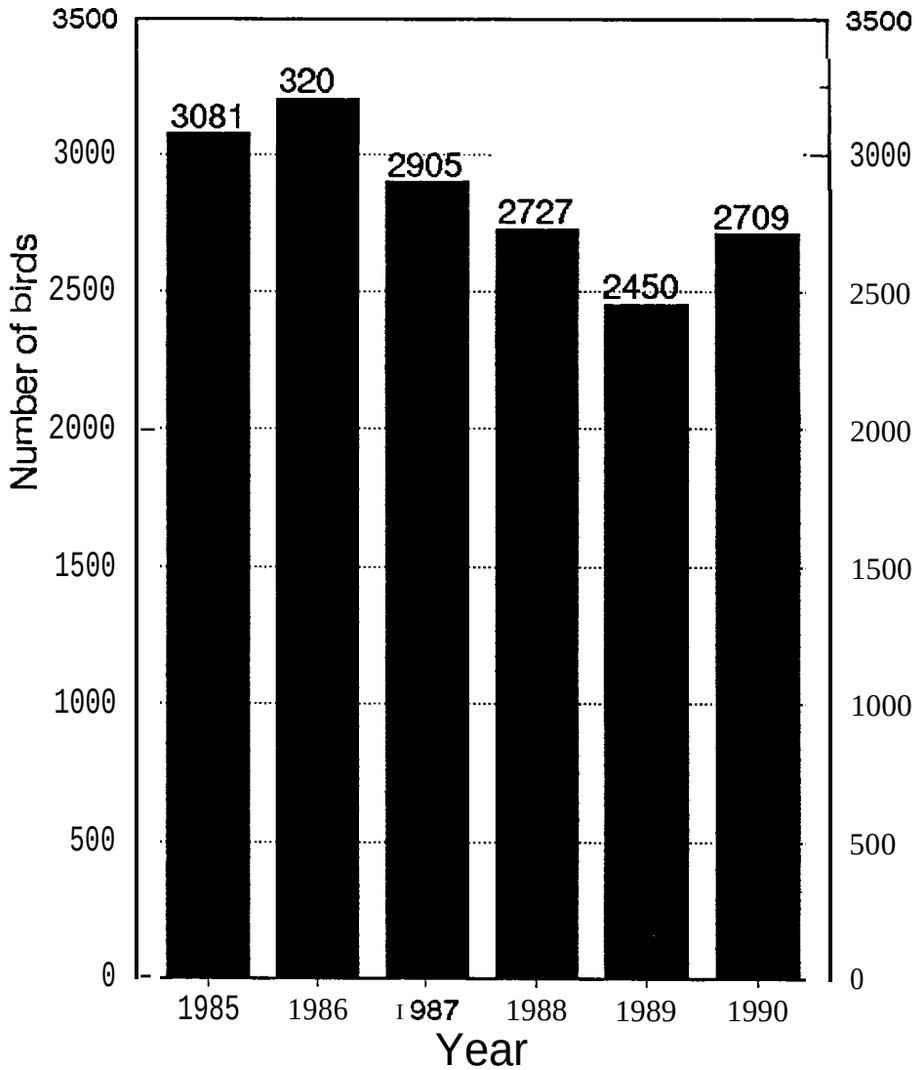

Figure3.7. Population counts of common murres on common plots at Cape Peirce, AK, 1985-1990.

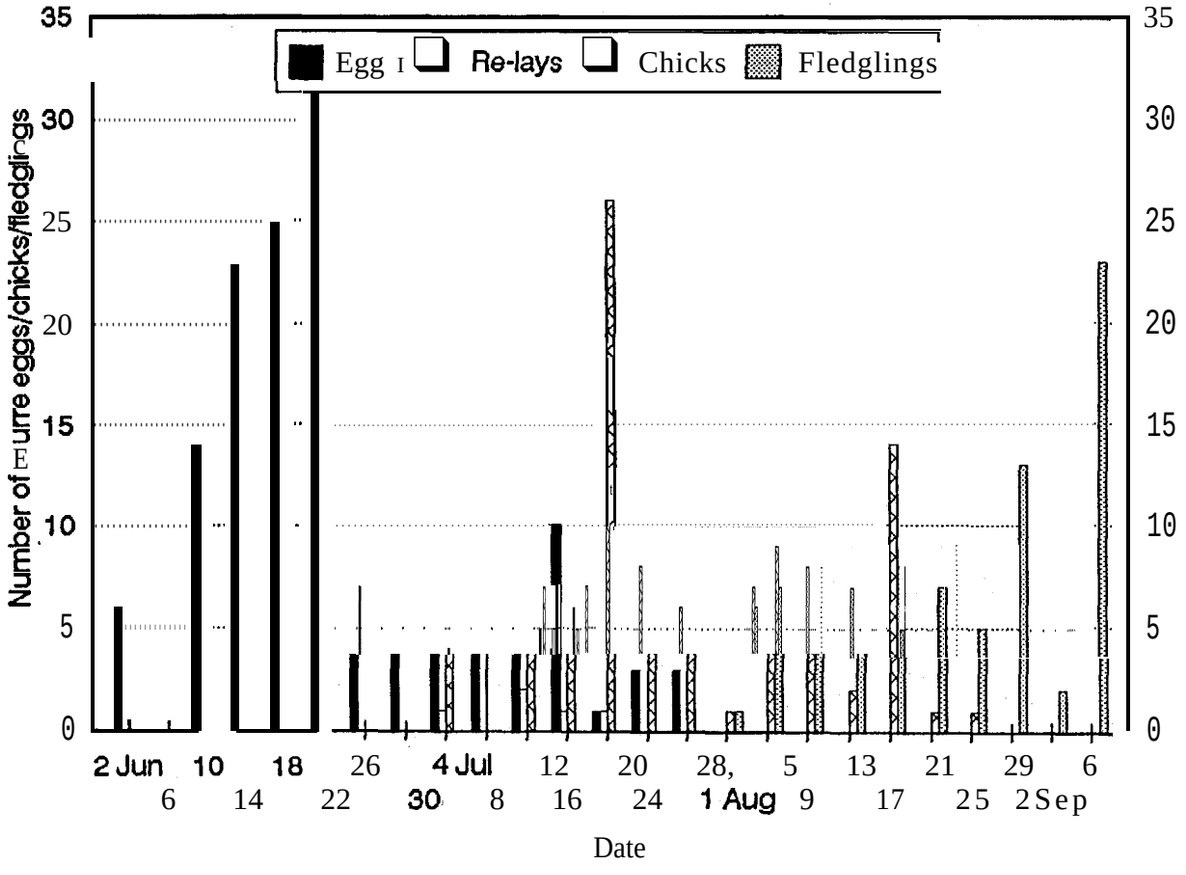

Figure 38. Common murre laying, hatching, and fledging dates at Cape Peirce, AK, 1990.

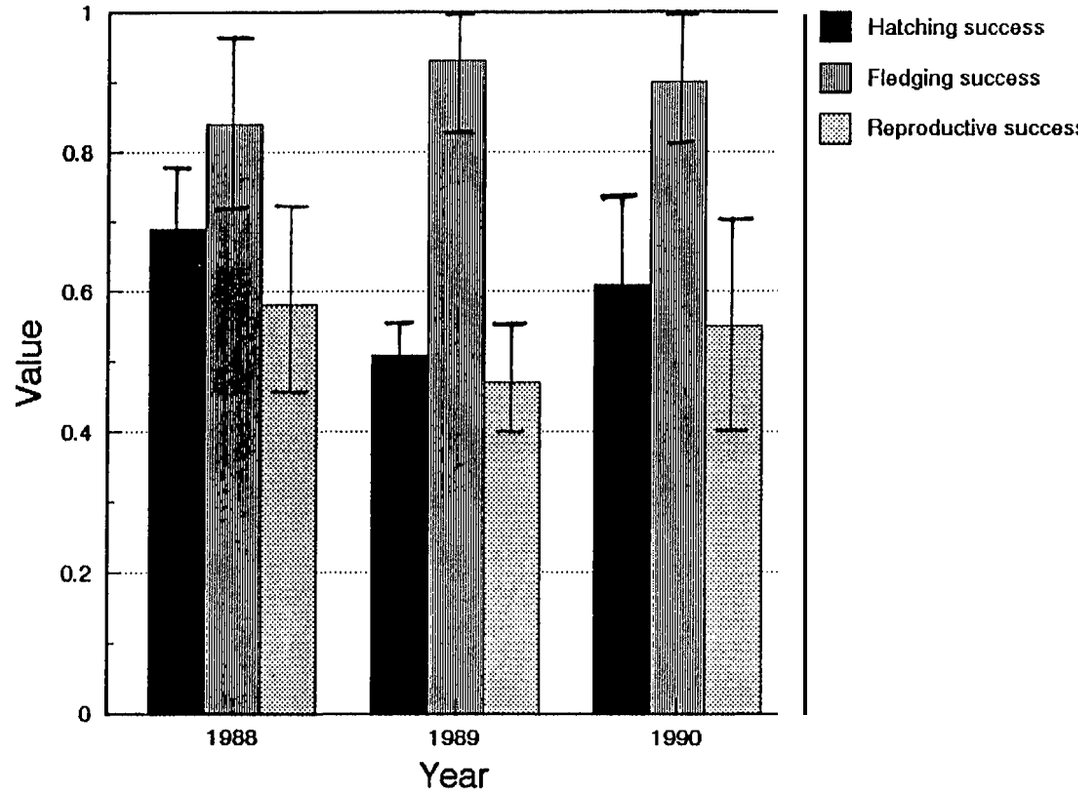

Figure 39. Common murre reproductive success parameters and confidence intervals (90%) at Cape Peirce, AK, 1988-1990.

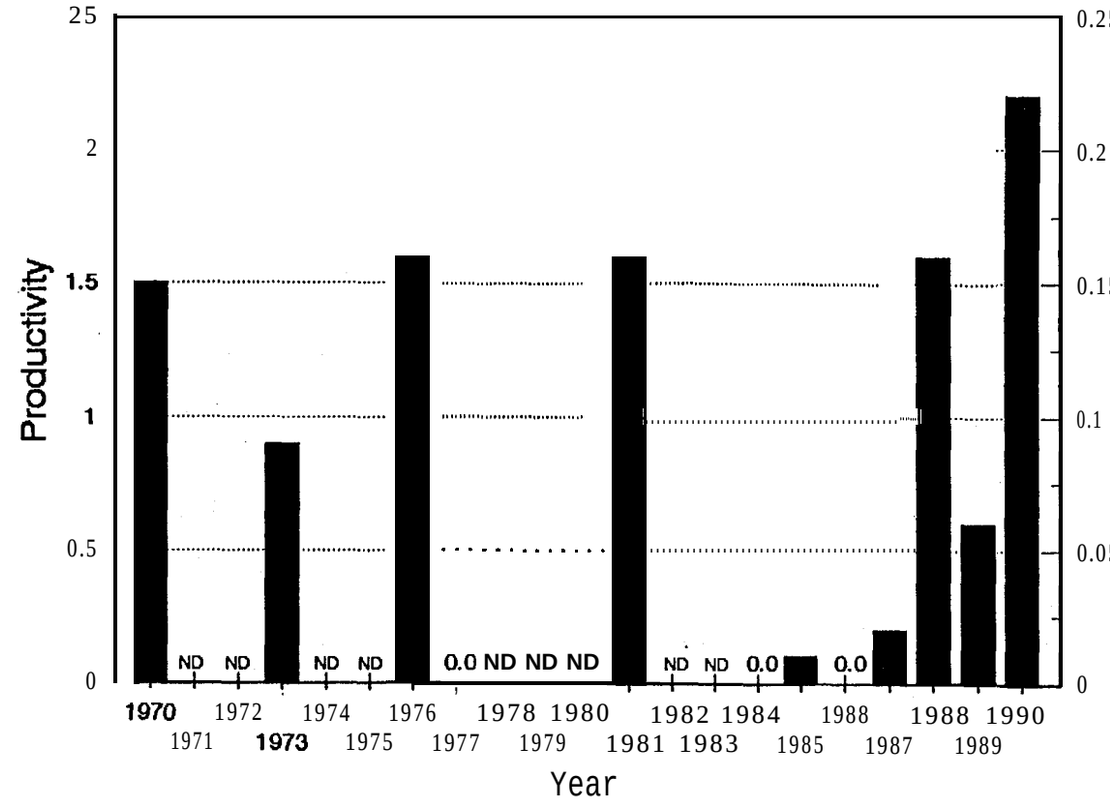

Figure 10. Black-legged kittiwake productivity at Cape Peirce, AK, 1970-1990.

CHAPTER 4. POPULATION STATUS OF MURRES AND KITTIWAKES AT BLUFF, ALASKA, IN 1990

By Edward C. Murphy

INTRODUCTION

Monitoring of numbers and reproduction of murres (Una spp., predominantly common murres, Uris aalge) and black-legged kittiwakes (Rissa tridactyla) at Bluff, Alaska began in July 1975 (Drury 1976). In 1976, field methods were refined, and boundaries of most murre and kittiwake reproductive plots used in subsequent years were first defined (Steele and Drury 1977). In 1976-1978 the colony was studied for the entire breeding season (e.g., Ramsdell and Drury 1979). In 1979-1986 fieldwork covered only part of the breeding season; studies in 1987-1990 spanned the entire breeding season. .

In 1979 repeated land-based counts of two cliff faces (census plots 10 and 15) at 1900h ADT were first made (Murphy et al. 1980). In the mid- 1980's the evening counts were expanded to include the reproductive plots, and morning counts of large census plots throughout the colony were initiated. In 1990 we expanded the evening counts of murres and kittiwakes, including several more census plots.

Numbers of kittiwakes on the cliffs and the reproductive performance of kittiwakes have varied markedly among years at Bluff. Detecting impact-related departures from natural patterns of variability in such systems will be a difficult challenge. Murphy et al. (in press) analyzed annual variation in kittiwake numbers and reproduction in 1975-1989 in relation to environmental variability and developed a series of regression equations that accounted for much of the annual variability in the breeding biology of kittiwakes. In this report, I compare observed values of kittiwake numbers and reproduction in 1990 to those that would be predicted by the regression models developed for the 1975-1989 data base. This permits evaluation of the predictive, as well as explanatory, value of those models. It also provides an analytical framework that can be used to evaluate current data in relation to past data. Such a procedure would be appropriate in the assessment of impacts of future development near Bluff, e.g., offshore gold dredging, because post-development impacts could result in significant departures from pre-development patterns.

STUDY AREA AND METHODS

The seabird colony at Bluff (64°34'N, 163°45'W), which is located on the north shore of Norton Sound, Alaska, has been described in detail elsewhere (Drury and Ramsdell 1985, Murphy etal.1986, inpress; see Figure 4.1). Drury et al. (1981) and Drury and Ramsdell (1985) summarized their 1975-1978 studies. I first participated in the fieldwork in 1978 and conducted fieldwork there in 1979-1990, assisted by one or more co-workers. In 1990 P. Cotter and T. Lowy conducted fieldwork for the entire breeding season. They arrived on 7 June. Cotter remained until 30 August and Lowy departed on 4 September. I trained them in field methods in the first week and returned on 21-27 July.

The census techniques for murres in 1975-1983 were first presented in Murphy et al. (1986). One or more mid-season boat-based censuses were conducted in 1975-1985 (see Murphy et al. 1986); none have been conducted since, and therefore they are not considered in this report. Beginning in 1979 field workers counted murres and kittiwakes on two large census plots (Plot AA = Stake 10, Plot GG = Stake 15) at 1900h ADT (as currently defined) on one or more days between the end of egg-laying and the initiation of "fledging" of murre chicks. In the mid-1980's we expanded the evening (1900h ADT) counts to include the reproductive plots and initiated extensive morning counts on large census plots throughout the colony. We initiated the morning counts of murres as well as continuing the late afternoon counts to obtain data during daily periods of high (morning) and low (late afternoon) attendance. Based on similarities of morning and evening counts (Murphy 1991) we reduced the frequency of the morning counts and included several more census plots in the series of evening counts in 1990. All new plots in the evening counts (5B, 6, 8b, 9, 13a, 14, and 16) are east of VABM Bluff (see Figure 4.1).

Methods for obtaining reproductive data of murres follow those outlined in Murphy et al. (1986). Plot boundaries- of all plots but 13 are identical to those shown by Drury and Ramsdell (1985). In 1987 and 1989, respectively, subplots 22-23 and 34-35 were added to the original subplots (1-21). In all years adults on the reproductive plots were mapped on drawings in notebooks using photographs for reference. Occupied sites were monitored for eggs and chicks in all years. In 1987-1990 field workers visited reproductive plots daily to quantify reproduction better than was possible in previous years when plots were visited every few days.

We classified laying, hatching, and "fledging" dates as known, estimated, or unknown. If we could not estimate laying, hatching, or fledging dates to within 1 day, we classified them as unknown. If an egg was observed the first day that a murre consistently maintained an incubating posture we considered that date the known laying date. If an egg was first observed one or more days following our first observation of a consistently incubating adult, the date the adult was first observed in an incubating posture was considered the estimated laying date. Laying dates were classified as unknown if an egg was observed after a series of daily observations of adults in various postures (e.g., standing, incubating). Hatching dates were classified as "known" if a chick was observed the first day an adult adopted a brooding

posture. Estimated hatch dates are defined as the first day an adult consistently adopted a brooding posture if a chick was later seen. If adult postures vacillated back and forth between brooding and incubating and a chick was later seen, we classified the hatching date as unknown. If a chick was two weeks old or older when last observed on the nest site, we classified the attempt as successful and defined the fledging date as the first day the chick was no longer present. If the chick had been observed the previous day, we classified the fledging date as "known"; if its presence the previous day was not determined, we classified the fledging date as "estimated".

Evening counts of kittiwakes generally have been conducted concurrently with those of murres; no morning counts of kittiwakes have been made. In most years, including 1990, one or more boat-based counts of kittiwakes were made (see Murphy et al., in press). Several reproductive plots (8, 10, 13a, 14 and 17), documented on photographs, were established for kittiwakes in 1976 (Drury and Ramsdell 1985) and were studied in 1976-1990. In addition, we established one new reproductive plot (13c) in 1990 and obtained photographs for 2 others (4, 16) for possible use in the future. On all of these plots virtually all nest-sites can be viewed well, but none of them are accessible for handling of eggs and chicks. Nests have been defined as substantial platforms with evidence of activity in the current year (see Drury and Ramsdell 1985). Each year nests were counted on each reproductive plot. Whenever possible, the number of eggs and the number and age class (see Ramsdell and Drury 1979) of chicks were recorded.

In 1979-1988 and 1990 nests of kittiwakes in three additional areas, Castle, Thumb Stack, and Golden Eagle Beach, were mapped and their contents recorded every several days. In 1989 repeated storms precluded regular visits to these areas and no data could be collected for comparisons to other years. In 1990 these areas were visited twice before hatching on 24 June and 5 July, and 4 times after hatching (23 July, 26 July, 3 August, 8 August). At accessible nests in these areas the length and breadth of each newly found egg (1981-1983, 1987-1988, 1990) and the weight of each chick (1979-1981, 1983, 1987-1988, 1990) were measured.

The timing of the fieldwork and the areas of study of reproduction are listed in Table 4.1. As noted above, in 1975 and 1979-1986 the fieldwork did not encompass the entire breeding season. In most of those years visits were during the chick periods. In 1982 the fieldwork ended shortly after hatching began, and we therefore obtained no data on the chick growth rates and fledging success in that year. In the years that the fieldwork was of short duration relative to the breeding season, our counts of nests and eggs were underestimates to the extent of nest loss and egg loss before our arrival, and our counts of fledglings were overestimates to the extent that chick loss occurred after our departure. Because most chick mortality generally occurs in the first several days of life (e.g. Ramsdell and Drury 1979), the latter bias probably is small. Due to the great magnitude of variation in reproductive performance among years (see below) none of these biases are sufficiently large to alter the overall interannual pattern of reproductive performance.

In preliminary analyses we found that growth rates of surviving chicks were approximately linear from the time chicks weighed less than 75 g until they weighed over 325 g (also see Coulson and Porter 1985). Therefore, we calculated a regression equation of weight vs. date for each surviving chick surviving through our last visit that was weighed two or more times between 75 g and 325 g. The regression coefficient, i.e., slope of the line, is an estimate of growth rate (g/day). We also calculated the date on which the chick would have weighed 35 g, the typical hatching weight, and used this value as the estimated hatching date. This value has been within one day of the hatching date for all known-age chicks measured since 1979 at Bluff. Except for 1975-1977 and 1989, when data on growth rates were not collected, our reporting of breeding chronology of kittiwakes is based on analyses" of weighed chicks.

Data on food habits were obtained from collections of adults returning to the colony in 1978, 1979-1982, 1984-1990. In 1984 we also obtained a sample of 5 adult kittiwakes that had been found dead near Unalakleet, a coastal village in eastern Norton Sound about 160 km from Bluff. In 1983 no adults were collected, but the stomach contents of 16 chicks that had been collected for analyses of heavy metal content were analyzed. We removed stomachs from the specimens within 2 h after collection and preserved them in 70 percent ethanol. Once back from the field we identified fish prey on the basis of their otoliths (dense bones of inner ear which resist digestion and have species-specific configurations) using an otolith reference collection for all fish prey of seabirds in the Bering Sea region. We identified the few invertebrates on the basis of any identifiable fragments of exoskeletons found in the stomach samples. Because the samples for 1987-1990 have not been analyzed, we do not report results on food habits here.

RESULTS

Murres

Morning counts--Table 4.2 summarizes the morning counts that have been conducted on the 19 census plots at Bluff. Numbers increased significantly ($P<0.05$, Tukey's pairwise comparisons on ranked data, Table 4.3) on half of the plots between 1985 and 1987 and 1985 and 1988. No significant changes occurred on any plot between 1987 and 1988. On about half of the plots, numbers were significantly lower in 1989 than either 1987 or 1988. On 6 plots numbers were higher in 1990, but on 3 plots they were lower than in 1985. On about half the plots, and overall, numbers were lower in 1990 than in either 1987 or 1988. However, counts were significantly higher in 1990 on 5 plots and overall than in 1989. These results suggest generally that numbers were higher in 1987-1988 than in 1985 or 1989-1990.

Evening counts--Data for evening (1900 ADT) counts of murres are available annually since 1979 for two cliff faces, census plots 10 and 15 (Table 4.4, Figure 4.2). Since 1984, numbers also have been counted at reproductive plots 8, 10, 12c, 12i, El 3b, 14 and 15 (Table 4.5). To

examine the 1990 counts relative to those in previous years, I first conducted a Kruskal-Wallis test for differences among years and then Tukey's pairwise comparisons for differences between each pair of years; here I report only those differences for census plots 10 and 15 combined and all reproductive plots combined. The 1990 counts on census plots 10 and 15 were significantly lower than the 1981 and 1987 counts but did not differ significantly from those in any other year (1979-1980, 1982-1986, 1988-1989). For the reproductive plots data were available only for 1984-1985 and 1987-1990. Counts were significant y lower in 1984 than in any subsequent year, including 1990. In general, numbers at 1900h ADT were relatively high in the late 1970's and early 1980's, low in the mid-1980's and again high in the late 1980's and 1990.

Reproduction--On the 7 reproductive plots the first murre egg was laid on 11 June in 1990, and the mean laying dates of first eggs at nest sites on the reproductive plots was 25 June (Table 4.6, Figure 4.3). Laying was somewhat delayed relative to 1987 (mean date = 22 June) and 1988 (mean date = 18 June) but slightly earlier than in 1989 (mean date = 30 June). The mean date of sea-going ("fledging") of chicks from first eggs was 18 August in 1990, a week earlier than in 1989 (Murphy 1991). Because hatching success of first eggs was high in 1990 (see below), relatively few replacement eggs were laid compared to 1987-1989, and we obtained few data on chronology of replacement eggs (see Table 4.6, Figure 4.3).

Table 4.7 summarizes murre reproduction in 1990 at Bluff. For all seven reproductive plots eggs were laid at 349 sites. Combining the data for all plots and considering both original eggs and eggs that were relaid after loss of an egg, 84 percent of the nest sites produced a hatched egg and 66-74 percent of the sites produced a sea-going chick. On a per egg basis, 79 percent of the eggs hatched and 62-69 percent of the eggs resulted in sea-going chicks. Table 4.8 compares reproductive data at Bluff for all phases of reproduction in 1987-1990 and for hatching in all years. Compared to 1987-1989, about 50 fewer active sites were documented in 1990, but hatching success was relatively high. Approximately equal total numbers hatched and fledged in 1987-1988 and 1990, and reproductive success was relatively low only in 1989.

In 1979-1986 murre reproduction was studied only in mid-season, Only estimates of numbers hatching were consistently obtained in those years. The total number of eggs hatching on the 7 reproductive plots was similar in 1987-1988 and 1990 (Figure 4.4). These values were intermediate compared to those in previous years. Values in 1987-1990 were higher than those in 1984-1986, lower than those in 1979-1981 and 1983, and similar to those in 1977 and 1981 (Table 4.8b).

Numbers and reproduction--l%e annual variation in numbers of adults on the cliffs could be due to actual differences in adult population size or variability in attendance due to other factors. There is a strong correlation ($r = 0.808$, $n = 11$, $P < 0.01$) between the 1900h counts on plots 10 and 15 and the estimated total number of eggs hatching on the reproductive plots. This relationship suggests that the number of murres on the cliffs is high in years when

reproductive performance is high. Consequently, the annual variation in numbers in 1979-1990 in mid-season may be related to annual variations in reproductive performance rather than changes in population size per se. Similar relationships between annual differences in numbers and reproductive success were noted for St. Matthew Island (Murphy et al. 1987).

Kittiwakes

Numbers--In 1990, evening (1900h) counts of adult kittiwakes on census plots 10 and 15 and the 5 reproductive plots averaged 629 and 275, respectively (Tables 4,9, 4.10; Figure 4,5). The counts in 1990 on the Census Plots were significantly (P c 0.05) higher than in 1979 or 1984, significantly lower than in 1988, but not significantly different from those in any other years. Similarly, the counts of the reproductive plots were significantly higher in 1990 than in 1984.

On 24 July two of us simultaneously conducted boat-based counts of kittiwakes throughout the colony. The two counts (10, 833 by ECM and 10,459 by PAC) averaged 10,646. This value was intermediate in relation to mean values of colony counts of kittiwakes in previous years (Murphy et al. in press).

Reproduction--Based on measurements of 14 chicks, estimated hatching dates in 1990 ranged from 13 July to 28 July (mean = 19 July, standard deviation = 4 days). Statistically, hatching chronology in 1990 was comparable to that in 1978 and 1988, earlier than hatching in 1987 and later than hatching in 1979-81 and 1983 (Tukey's pairwise comparisons on ranked data (P c 0.05)).

The earliest hatching date actually observed on the Bluff study plots was 11 July on reproductive plot 10, and the latest was between 3 and 8 August (Thumb Stack, Nest 43). Few chicks had fledged when plots were last visited in late August to early September.

Table 4.11 summarizes the data on reproductive output of kittiwakes on the reproductive plots in 1990. Counts of nests were higher than in any year except 1988, but counts of active nests (nests found to contain eggs or chicks, at least temporarily) were lower than in 7 other years (Table 4.12). Numbers of eggs laid, eggs hatching and chicks fledging also were intermediate in comparison to 1975-1989 (Table 4.12, Figure 4.6).

Clutch size (number of eggs laid/active nest) in 1990 was lower (P <0.05, Tukey's pairwise comparisons) than in 1978, 1981, 1983, and 1987-1988 (see Table 4.13); as in 1975-1977, 1982, 1984-1985, and 1989, one-egg clutches predominated. However, both hatching success and fledging success (85% and 74%, respectively) were high in comparison to most previous years (see Table 4.13). The number of fledglings/active nest was lower (P<0.05, Tukey's

pairwise comparisons) than in 1978-1981, higher than in 1976-1977, 1983-1985, and 1989 and not significantly different than in 1975 and 1986-1988. In summary, reproductive performance from laying through fledging was intermediate in relation to 1975-1989.

Preliminary analyses (Murphy, unpubl.) of egg volume indices showed that first eggs were significantly larger than second eggs in 2-egg clutches ($F_{1,81}$ = 14.53, P = 0.003), but in 1987 and 1988 there were no significant differences in volumes of second eggs in 2-egg clutches and the eggs of l-egg clutches ($F_{1,115}$ = 1.14, P = 0.29). Therefore, I compared egg volumes among years using second (or smaller, if position was unknown) eggs of 2-egg clutches and eggs of l-egg clutches. There were no significant differences in volumes among years (Table 4.14, $F_{5,212}$ = 2.17, P = 0.059).

Coulson (1963) calculated a shape index (breadth x 100/length) for kittiwake eggs and noted that as female kittiwakes age their eggs become shorter and broader, i.e., the shape index increases. He suggested that the shape index could be used as a measure of the age composition of a colony. At Bluff, the shape index did differ significantly among years ($F_{5,212}$ = 3.25, P = 0.0075) but was intermediate in 1990 (Table 4.14).

Growth rates of chicks that survived through the last visits of the field crew to the reproductive areas averaged 18.6g/day in 1990 (Table 4.13). Statistically, the growth rates in 1990 were indistinguishable (P >0.05, Tukey's pairwise comparisons on ranked data) from those in all previous years.

DISCUSSION

Murre numbers and reproduction

Earlier analyses, based on boat-based censuses and limited land-based counts, suggested that murre numbers declined in the mid-1970's (Murphy et al. 1986). Analyses of land-based counts in 1979-1990 reported here suggest that numbers have not increased or decreased overall in the last decade and that fluctuations among years have been positively associated with differences in reproductive success.

In 1990 we expanded the evening counts of census plots to include 7 plots in addition to census plots 10 and 15. All of these plots are in the eastern half of the colony (east of VABM Bluff, see Figure 4.1). Inclusion of plots in the western half of the colony is logistically unfeasible because neither member of a 2-person field crew would be able to travel quickly enough between those plots and either census plot 10 or 15, which must be counted at 1900h ADT for comparisons to previous years. The new plots do provide broad spatial coverage of the eastern half of the colony.

In 1987-1990 we classified murre eggs as first eggs, first relays, and second relays on the basis of observations of egg presence and loss at each active site. There are two difficulties that may bias these data. First, Schauer (in prep.) observed that most egg loss in 1987 and 1988 occurred soon after laying and some eggs were lost within several minutes of laying. Even though plots were observed daily during egg laying in 1987-1990, eggs could have been lost before they were observed. Consequently some eggs laid relatively late that were classified as first eggs probably were relays. Secondly, some apparent relays occurred within several days (minimum = 4 days) of loss of an egg at a site. Such observations suggest that either multiple sites were erroneously classified as single sites or literature estimates of relaying intervals of about two weeks are erroneous (see Harris and Wanless 1988). Extremely long intervals (maximum = 29 days) between loss of an egg and observation of a new egg are suggestive of lack of detection of an intermediate relay that was lost soon after laying.

In comparison to 1987-1989, relatively few first eggs apparently were lost after laying, and hatching success was high in 1990. In all 4 years field personnel made daily, or nearly daily, visits to each murre reproductive plot, and field protocols in 1990 were nearly identical to those in 1987-1989. At the present time reasons for these differences are unclear. Common ravens (Corvus corax) are the primary predators of murre eggs at Bluff, actively displacing incubating murres. In 1990 three, and possibly four, pairs of ravens nested on the cliffs. Their numbers were as high as or higher than in previous years, suggesting that losses of first eggs should have been high also.

In 1990 the field crew was relatively inexperienced compared to those in 1987-1989. At many nest sites murres were seen in incubating postures for one to several days where no eggs were documented. It seems likely that eggs perhaps were laid and lost at many of those sites. If such undocumented losses occurred more often in 1990 than in 1987-1989, then both the number of active sites and the number of replacement eggs would have been underestimated, and hatching success of first eggs overestimated, in 1990 relative to 1987-1989. Such observer bias would explain the differences noted between 1987-1988 and 1990.

Kittiwake numbers and reproduction

Kittiwake numbers on Census Plots 10 and 15 have fluctuated markedly among years and generally have been highest in years of good reproduction (e.g., 1978-1981, 1987-1988). Although data on annual variability in the abundance of forage fishes are lacking, it appears that numbers and reproduction are both depressed if sand lance (Ammodytes hexapterus) abundance near the cliffs is low. It would be possible to conduct systematic counts of foraging flocks of kittiwakes near the colony from one or more vantage points at the tops of the cliffs, Comparisons among years could be made to assess the hypothesis that kittiwakes can be observed feeding near the colony more frequently in good reproductive years than in

poor reproductive years. Boat-based studies of foraging kittiwakes and their fish prey could be designed to establish the causes of the annual variability in kittiwake numbers and reproduction.

Evaluating current data using past relationships

Using the regression equations generated using the 1975-1989 data base for kittiwakes, I compared predicted and observed values in 1990. For some variables differences between observed and expected values were pronounced (Table 4.15).

More nests were counted on the reproductive plots than predicted. However, the percentage of those nests that was active was much lower than predicted. Clutch size also was much lower than predicted, but fledging success was higher than predicted. The regression equations of numbers on environmental variables were poor predictors of numbers in 1990, but the regression of numbers of adults on the census plots vs. the total number of nests on the reproductive plots was a good predictor of adult numbers in 1990.

Discrepancies between observed and predicted values may indicate lack of robustness in particular regression models, a change in the approach to data collection, or an actual change in the relationship between predictor (independent) variables and the dependent variable. The results shown in Table 4.15 may represent a combination of these factors.

The percentage of active nests in 1990 was significantly lower than predicted by the regression equations. There also were far fewer active nests (123) than predicted (198) by a quadratic regression on May temperature, indicating that fewer kittiwakes initiated breeding attempts in 1990 than would be expected based on air temperature in May. These results indicate that additional data are needed to establish a baseline that adequately measures the relationship between the number of breeding kittiwakes and spring climatic conditions.

It is also possible that more inactive nest-sites were classified as nests, resulting in a higher count of nests but a lower percentage of active nests, in 1990 than in previous years. In our study, and studies of kittiwakes elsewhere in Alaska, nest sites have been classified as nests as soon as there is evidence of nest-building in the current year. Nest-building typically is extensive at sites where breeding is documented, i.e., at "active" sites. However, nest-building may be ephemeral at inactive sites. For example, I have observed (unpubl.) nonbreeding kittiwakes obtain grasses from debris floating near the colony and deposit it at nest-sites on a single day, but not on other days during the same season when such debris was not readily available. When such ephemeral events are observed many more sites may be classified as nests than in years when those events do not occur or are not observed. Counts of active nests are probably subject to much less of this type of apparently random variability than counts of all nests.

In 1990 observed clutch size was significantly lower than the value predicted by the 1975-1989 data. This discrepancy could have occurred if observers in 1990 more often missed one of the eggs in 2-egg clutches than in other years when nest contents were viewed on the reproductive plots. Comparisons between the reproductive plots, where no nests are accessible and all of the nests must be viewed from distant vantage points, and reproductive areas, where nests are either accessible or can be approached sufficiently close to cause the tending adult to flush, suggest that such a bias may have occurred in 1990. On the reproductive areas clutch size averaged 1.46 eggs (n = 28 nests), a value similar to the predicted value of 1.52 eggs based on the 1975-1989 data. On the reproductive plots, clutch size averaged 1.23 eggs; this difference is significant (^{2}= 6.308, d.f. = 1, 0.01 <P <0.025).

The number of chicks fledged/active nest (i.e., the number chicks near fledging age) probably can be measured accurately by both experienced and inexperienced observers. In 1990 the observed value (0.70) was more than one standard deviation below the value (0.95) predicted by a quadratic regression on May temperature using the 1975-1989 data. This discrepancy again demonstrates that the data base is not yet sufficient to adequately account for baseline variability in kittiwake reproduction at Bluff.

The regression models used to predict adult numbers from environmental variables provided poor predictions of numbers in 1990. However, kittiwake numbers in mid-season were predicted well from counts of nests. This relationship suggests that counts of kittiwakes at the colony are highly sensitive to conditions for breeding as well as numbers in the population. Therefore, it is possible that changes in population numbers, per se, could go undetected. In the regression analyses I included year as possible independent variable for inclusion in the models but it did not enter any model, suggesting that there have been no clear monotonic temporal trends in numbers or reproduction of kittiwakes since 1975.

Future directions

J. H. Schauer is now completing his M.Sc. thesis on the breeding biology of murres at Bluff using the 1987-1988 data. This summer and fall he and I will prepare two manuscripts for publication in refereed journals, incorporating the 1989-1990 data. Analyses for those manuscripts will provide an analytical framework for assessing future data on numbers and reproduction of murres, comparable to that I am now using for kittiwakes.

Although the high annual variability in numbers and reproduction of murres and kittiwakes at Bluff makes it difficult to establish a baseline for assessment of future impacts, each year of additional study will permit testing and refinement of predictive models that will be indispensable in impact analysis. Because such high variability also characterizes all other colonies that have been studied in the Bering-Chukchi Seas region, it will be possible to assess impact of development adequately only at those colonies, such as Bluff, that have an extensive data base that is increased each year.

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Table 4. Timing and duration of fieldwork and areas of data collection for reproduction of kittiwakes and murres at Bluff, Alaska, 1975-1990,

Year	Time of Fieldwork: Arrival	Time of Fieldwork: Departure	Areas studied: Kittiwake reproduction	Areas studied: Murre reproduction	Reference
1975	3 Jul	22 Sep	1,3,4,4b,10	unique plots	Drury 1976
1976	29 May	10 Ott	8-17[a]	8-15[b]	Steele and Drury 1977
1977	21 May	12 Sep	8-17	8-15	Biderman et al. 1978
1978	27 May	20 Aug	8-17, CA, TS, GE	8-15	Ramsdell & Drury 1979
1979	19 Jul	10 Aug	8-17, CA, TS, GE	8-15	Murphy et al. 1980
1980	19 Jul	25 Jul	10, 13a, 14, CA, TS, GE	8,10	Murphy et al. in press
1981	10 Jul	23 Jul	10, 14, CA, TS, GE	8,10	Murphy et al. in press
1982	12 Jul	21 Jul	8-17, CA, TS, GE	--	Murphy et al. in press
1983~	8 Jul	27 Jul	8, 10, 14, 17, CA, TS, GE	8,1O,12C,14,15	Murphy et al. in press
1984	6 Jul	20 Jul	8-17, CA, TS, GE	8,10,14	Murphy et al. in press
1985[d]	9 Jul	27 Jul	8-17, CA, TS, GE	8,10,12c,12i,14,15	Murphy et al. in press
1986e	8 Aug	14 Aug	8, 10, 13a, 14	10,13b,15	Murphy et al. in press
1987	1 June	27 Aug	8-17, CATS, GE	8-15	Murphy et al. in press
1988	24 May	1 Sept	8-17, CA, TS, GE	8-15	Murphy et al. in press
1939	10 June	9 Sept	8-17	8-15	Murphy et al. in press
1990	7 June	4 Sept	8-17, CA, TS, GE	8-15	This Report

[a] "8-17" refers to plots 8, 10, 13, 14, and 17 (see Drury and Ramsdell 1985). CA, TS, and GE are acronyms for Castle, Thumb Stack and Golden Eagle Beach (see Murphy et al. 1986). In all years after 1975 nests were counted on plots 8, 10, 13, 14 and 17, but numbers of eggs and chicks were documented for all nests only on plots that are listed for a particular year.

b "8- 15" refers to plots 8, 10, 12c,12i,13b, 14, and 15 (see Drury and Ramsdell 1985).

c Plots 10, CA, TS, and GE also were studied on 17 August.

(i Fieldwork on all listed plots also was conducted on 16-18 August.

e Fieldwork also was conducted on 10-17 June,

Table 12. Morning counts of murres at Bluff, 1985-1990.

	Year				
Plots	1985	1987	1988	1989	1990
1	497±18(3)[b]	680±71(5)	658±30(5)	586±63(8)	671±77(7)
3a	271A1O(3)	318±30(5)	324±21(5)	291±33(8)	303±49(7)
3b	1392*97(3)	2036±248(5)	1897±123(5)	1733±199(8)	1756±148(7)
4b	727±28(3)	1083±105(5)	1108±40(5)	856±117(8)	886±1 lo(7)
4C	793±27(3)	1433*175(5)	1397*93(5)	1058±174(8)	1218±133(7)
4d	2131*148(3)	3060±282(5)	3042±241(5)	2560±250(8)	341 O*353(7)
4e(Ax)	869±145(3)	1160±84(5)	1229±74(5)	953±117(8)	11782131(7)
4f(Hatchet)	872±35(3)	1327±155(5)	1 347*75(5)	1025±121(8)	1196±74(7)
5a-1	670±6(2)	651±39(5)	672±60(5)	550±24(8)	511±72(7)
5b	ND	1127173(5)	1195*111(5)	986±119(8)	1056A8O(7)
6(Castle)	248±53(3)	352±43(5)	313±40(5)	300±25(8)	381±25(7)
8a	679±59(2)	797*70(5)	778±79(5)	657±68(8)	596±36(7)
8b(Thumbstack)	483±41(3)	503±26(5)	444*44(5)	362±20(8)	358±24(7)
9	998±60(2)	1222*45(5)	1236±81(5)	891±73(8)	1039A89(7)
10	1513±112(13)	1638*84(5)	1573±80(5)	1188±65(8)	1342±118(7)
12	ND	329±15(5)	331±35(5)	256±82(8)	230±21(7)
13	330±86(2)	413±26(5)	382±28(5)	342±47(8)	332±22(7)
14(Ropestack)	481(1)	550±124(5)	557*51(5)	518±56(8)	480±140(7)
15	767±67(13)	1OO3A52(5)	988±33(5)	829±108(8)	869±7 1 (7)
Total	ND	19682±1 126(5)	19455*71 1(5)	15939*1463(8)	17811±641(7)

[a] The plots are coded by the observer's location when making the counts. All plot boundaries are marked onphotographs.
[b] Mean + standard deviation (sample size).

Table 3. Results of pairwise comparisons[a] of morning counts of murres at Bluff.

Plot	1985-1987	1985-1988	1985-1989	1985-1990	1987-1988	1987-1989	1987-1990	1988-1989	1988-1990	1989-1990
1	+[b]	+		+						
3a										
3b	+	+								
4b	+	+				[c]	-	-	-	
4c	+	+		+		-	-	-		
4d	+	+		+		-		-		+
4e		+		+		-		-		+
4f	+	+		+		-		-		+
5a			-	-		-		-	-	
5b	NA[d]	NA	NA	NA				-		
6	+			+					+	+
8a							-	-	-	
8b				-					-	
9	+	+						-	-	+
10			-	-					-	
12	NA	NA	NA	NA		-	-	-	-	
13										
14	+	+				-		-		
15										
Sum of +'s	9	9	0	6	0	0	0	0	1	5
Sum of -'s	0	0	3	3	0	3	7	13	7	0
All	NA	NA	NA	NA		-	-	-		+

[a]Tukey's test on ranked values.

[b]+: significant (P<0.05) increase.

[c]-: significant (P<0.05) decrease.

[d]NA: not applicable (plot not counted in 1985).

Table 4. Evening counts of murres on Census Plots at Bluff, 1979-1990a.

Year	Plot							
	10a	10b	10c	10a-c	15a	15b	15a-b	10 and 15
1979	249±19[b]	604±45	595±46	1448±106(15)[c]	247±52	547±74	794±1 17(14)	2251*213(14)
1980.	228±12	491±33	628±34	1348*66(5)	350±38	472±18	821±27(4)	2167*95(4)
1981	254±11	527±22	666±45	1447±72(11)	461±21	531±40	991±60(8)	2541±76(8)
1982	217±29	456±43	559±34	1233±100(8)	349±49	367±69	716±116(7)	1970*179(7)
1983	243±13	517±31	616±49	1375A86(10)	439±28	476±37	9 1 5 * 5 7 (9)	2293±97(9)
1984	131±37	215±89	420±45	766±162(13)	198±61	193±64	391±120(14)	1166±277(13)
1985	206±39	400±107	568±83	1173±223(18)	295±66	325±66	6201120(18)	1793±342(18)
1986	--	. .	--	1413*98(2)	--	--	814±220(2)	2278*245(2)
1987	273±22	518±45	680±43	1471±102(12)	420±39	498±52	917±88(12)	2388*181(12)
1988	251±28	491±49	666±43	1407±110(12)	407±27	447±36	854±60(12)	2261*159(12)
1989	219±48	460±85	620±45	1299±154(10)	361±34	450±72	811±95(10)	211O*235(10)
1990	222±18	435L21	603±33	1261~60(11)	361±30	437±57	798±78(11)	2059±125(1 1)

a Census plots 10 and 15 arethe same faces designated asPlots AA and GG in some previous reports. These two plots have been counted al900h ADT inall years. In 1990 we also initiatedcounts 01 Census Plots 5B (335 ± 13(9)), 6(141 ± 11(9)), 8b(217 ± 17(9)), 9(1064 ± 137(9)), 13a(178 ± 9(9)), 14(339 ± 20(10)), and 16(212 ± 18(9)).

b Mean ± standard deviation.

c The number of counts is listed in parentheses.

Table 5. Counts of murres on Reproductive Plots, 1900h ADT.

Year	Plot 8	10	12C	12i	13a	14	15	Total
1978[b]	71	166	49	52	81	131	71	621
1979	--	167±9(13)[c]	--	--	--	--	--	--
1980	--	147±7(5)	--	--	--	--	--	--
1981	--	170±11(11)	--	--	--	--	--	--
1982	--	147±17(8)	--	--	--	--	--	--
1983	--	163±8(I o)	--	--	--	--	--	--
1984	40±6(1 3)	83±33(14)	6±10(13)	7±10(13)	36±16(13)	15ix)(14)	46±9(13)	220±72(12)
1985	48±10(18)	118±38(18)	26±10(18)	33±7(18)	71±16(12)	97113(18)	50±7(18)	441±89(12)
1986		136±8(2)	--	--	91±1(2)	--	--	--
1987	63±6(12)	151±8(12)	41±4(12)	36±6(12)	65±4(12)	105±4(12)	64 ±6(12)	526±22(12)
1988	58±3(12)	140±11(12)	44±2(12)	32i2(12)	63±3(12)	103±7(12)	62±7(12)	503±24(1 2)
1989	57±9(10)	158±16(10)	42±8(10)	39±9(10)	65±8(10)	107±7(1 o)	69±7(10)	536±55(10)
1990	48±5(1 1)	131110(9)	40±3(11)	37±3(11)	60±4(1 I)	111±7(12)	60±7(12)	491±25(9)

[a] In 1979-1986, counts were made of subplots 1-21. In 1987, subplots 22-33 were added and counts were made of subplots 1-33 in 1987-1989. In 1990 separate counts of subplots 1-21 and 22-33 were made irnd used to convert the 1987-1989 totals 10 values comparable to counts based on subplots 1-21 in earlier years.

[b] Ramsdell and Drury (1979:679) reported mean values of all counts during 16 July -6 August; these counts were not standardized by time of day.

[c] Mean ± standard deviation (sample size).

Table 4. Breeding chronology of murres at Bluff, 1990a.

A. First Attempts

Plot	Laying Date	Hatching Date	Sea-going Date
8	28 June ± 9 (33)[b]	31 July&9 (27)	19 Aug ± 8 (18)
10	23 June ± 8 (82)	28 July ± 7 (65)	17 Aug ± 6 (64)
12C	28 June ± 19 (24)	1 Aug ± 6 (17)	19 Aug ± 5 (19)
12i	23 June& 5 (27)	28 July ± 5 (20)	17 Aug ± 2 (17)
13b	28 June ± 11 (57)	31 July ± 12 (40)	20 Aug ± 9 (41)
14	27 June ± 8 (51)	30 July ± 7 (52)	19 Aug ± 6 (60)
15	23 June ± 4 (44)	27 July ± 3 (30)	17 Aug ± 4 (33)
TOTAL	25 June ± 8(3 18)	29 July ± 8 (251)	18 Aug ± 6 (252)

B. Replacement Attempts[b]

Plot	Laying Date	Hatching Date	Sea-going Date
TOTAL	6 July ± 10 (23)	8 Aug ± 12 (15)	25 Aug ± 8 (12)

[a] For all variables, both known and estimated dates are used (see methods).

[b] Mean+-standard deviation (sample size).

[c] Few data on chronology for replacement eggs were available for any of the 7 plots; therefore, data are reported for all plots combined.

Table 7. Summary of reproduction of murres on 7 Reproductive Plots at Bluff, 1990.

Variable	PLOT							
	8	10	12C	12i	13b	14	15	Total
First Attempts	36	87	26	28	59	69	44	349
eggs hatching	28	66	20	21	46	62	34	277
sea-going chicks	13-19[a]	54-58	18-19	17	32-41	56-59	32	222-245
eggs lost	8	15	4	7	11	5	9	59
chicks lost	9	8	1	4	5	3	2	32
eggs failing to hatch	o	6	2	0	2	2	1	13
chicks still on cliffs	6	4	1	0	9	3	0	23
Second Attempts	4	8	1	3	6	2	2	26
egg hatching	3	7	1	2	3	2	0	18
sea-going chicks	2-3	4-6	1	0	1-3	2	0	10-15
eggs lost	1	1	0	1	2	0	2	7
chicks lost	0	1	0	2	0	0	0	3
eggs failing to hatch	o	0	0	0	1	0	0	1
chicks still on cliffs	1	2	0	0	2	0	0	5

[a] Upper value includes chicks still alive when the plots were last studied; lower value includes only those chicks that had departed before the plots were last studied.

[b] Includes one replacement egg that had not yet hatched.

Table 8. Murre reproduction.

a. Summary of reproduction in 1987-1990.

Year	Numbers		First Eggs		First Replacement Eggs				PROD[a]	K-ratio[b]
	Plots[c]	Active Sites	HS(%)[d]	FS(%)[e]	n	% Replaced[f]	HS(%)	FS(%)		
1987	7	400	60	87-95	64	43	75	32-92	68	0.72
1988	7	397	57	92-94	82	52	68	73-84	65	0.74
1989	7	366	47	84-86	79	46	54	70-77	51	0.64
1990	7	340	79	80-89	20	34	65	38-77	73	0.65
AVERAGES[g]	7	376±28	61±13	91±4	67±32	44±8	66±9	83±7	64±9	0.69±0.05

[a] PROD: Productivity (number of chicks, "fledging" or still alive when field crew departed/number of active sites).

[b] K-Ratio: Number of active sites/mean number of adults during mid-season counts at 1900h ADT (see Table 5).

[c] On plot 13, data are based on subplots 1-33, which were studied in all 4 years.

[d] HS: Hatching success (numbers of eggs hatching/number of eggs laid).

[e] FS: Fledging success (number of chicks "fledging"/number of eggs hatching). Lower value assumes that chicks still alive when fieldcrews departed did not fledge; upper value assumes that those chicks did fledge.

[f] Based on number of first eggs lost during incubation.

[g] Mean ± standard deviation. For fledging success the value assumes that chicks were alive when fieldcrews departed did fledge.

Table 4.8 (continued).

b. Number of eggs hatching.

	PLOT							
Year	8	10	12C	12i	13ba	14	15	Total
1977	--	71	--	--	--	--	--	(258)[b]
1978	26	89	29	28	44[b]	73	30	319
1979	--	≥88	--	--	--	--	--	(≥320)
1980	≥26	≥88	--	--	--	--	--	(≥298)
1981	33	66	--	--	--	--	--	(259)
1982	--	--	--	--	--	--	--	ND
1983	36	88	--	38	--	--	33	(342)
1984	≥16	≥26	0	0	--	≥1	--	(≥57)
1985	≥16	≥40	≥4	≥14	--	≥30	≥28	(≥151)
1986	--	≥57	--	--	≥20	..	--	(≥191)
1987	34	74	16	18	39	55	35	271
1988	33	76	16	16	37	57	29	264
1989	20	54	3	6	27	68	29	207
1990	29	72	21	23	22	63	34	264

[a] Only subplots 1-21 were designated and studied before 1987; values reported here are for subplots 1-21 only.

[b] Totals in parentheses are estimates based on numbers hatching on plots that were studied, relative to numbers hatching on all plots in 1978 and 1987-1990.

Table 9. Counts of kittiwakes on Census Plots 10 and 15, 1900h ADT[a].

	PLOT							
Year	10a	10b	10C	10a-c	15a	15b	15a-b	10 and 15
1979	138±11[b]	107±8	90±8	335±25(15)[c]	61~2	118A5	179±6(14)	515±29(14)
1980	143±2	57±3	147±5	346±8(5)	67±8	118±12	186±20(5)	532±18(5)
1981	148±8	65±4	157±11	37O*15(10)	78±6	136±6	213±12(8)	587±17(8)
1982	171±17	75±6	172±27	419±46(8)	94±14	153±12	248±26(7)	677±83(9)
1983	154±22	66±13	160±33	380±66(10)	95±20	142±15	237±33(9)	630±83(9)
1984	16±22	6±9	24±22	46±53(13)	13±10	27±21	41±31(11)	92±86(10)
1985	136±38	51±17	163±32	350±83(18)	78±23	143±31	221~53(1 8)	571±131(18)
1986	--	--	--	526(1)	106	134	240(1)	766(1)
1987	167±17	60±6	210±14	437±30(11)	11 8±9	169±14	288±23(11)	725±47(11)
1988	168±15	64*7	215±18	448~36(11)	128±13	172±19	301*31(11)	748~66(11)
1989	106±58	41±21	128±60	275±137(10)	64±30	117t43	181±72(11)	456±209(11)
1990	134±8	49±5	185±12	369±20(1 1)	101±18	159±29	261~38(11)	6~9~49(11)

[a]In 1990 we initiated counts on Census Plots 5b(67 ± 6(9)), 6(no kittiwakes observed in 9 counts). 8b(93 ± 7(9)), 9(25 1 ± 16(9)), 13c(48 ± 7(10)), 16(1 50 ± 27(9))

[b]Mean ± standard deviation.

[c]Nun-her of counts.

Table 4. Counts of kittiwakes on reproductive plots, 1900h ADT.

Year	Plot					
	8	10	13a	14	17	Total
1984	7±6(13)[a]	8±10(13)	14±13(12)	4~8(14)	10±8(10)	29±28(7)
1985	36±9(18)	64±20(18)	62±14(18)	33±88(8)	60~5(18)	254±44(18)
1986	--	--	.-	--	--	--
1987	40±3(11)	87±5(11)	66±4(1)	39±3(1)	61±9(11)	291±15(1)
1988	39±1(11)	87~6(11)	67±7(1)	40±3(11)	65±3(11)	298±16(1)
1989	--	--	.-	--	--	--
1990	33±2(11)	81±6(9)	57~4(11)	35~2(11)	67±6(11)	275±1O(9)

[a]Mean+ standard deviation (sample size).

Table 11. Reproductive performance of kittiwakes at Bluff, 1990.

Plot	Nests	Active Nests	Eggs	Eggs Hatching		Chicks Fledging
				Maximum	Minimum	
8	2	7	17	19	18	15
10	63	40	52	51	41	31
13a	42	16	19	18	15	13
14	36	17	23	19	17	12
17	59	29	33	28	24	16
SUBTOTAL	227	123	148	134	112	85
13c[a]	32		--	--	--	9
TOTAL	259	--	--	--	--	94

[a]Plot newly established in 1990.

Table 12. Reproductive performance of Kittiwakes on five Reproductive Plots (8,10,13% 14, and 17) at Bluff, 1975-1990.

	Numbers						
		Active[a]	Eggs	Eggs Hatching			Chicks
Year	Nests	Nests	Laid	Maximum	Actual	Minimum	Fledging
1975	(169)[b]	116C	145[c]	116C	--	97C	68[c]
1976	131	42	47	--	7	--	5
1977	98	37	44	--	15	--	11
1978	201	183	312	--	234	--	164
1979	207	z184d	ND	(≥269)	--	(≥239)	222
1980	196	≥175	ND	(≥240)	--	(≥222)	(≤185)
1981	204	(≥161)	(299)	(≥221)	--	(177)	(≤142)
1982	152	71	79	ND	--	ND	h[T]D
1983	188	175	(308)	(255)	--	(217)	(50)
1984	58	8	10	--	0	--	0
1985	44	3	3	--	0	--	0
1986	(160)	(≥88)	ND	(≥91)	--	(≥83)	(≤61)
1987	209	183	258	229	--	168	136
1988	239	211	341	312	--	212	146
1989	64	24	26	--	5	--	0
1990	227	123	148	134		112	85

[a] Active Nests: Nests known to contain eggs, at least temporarily.
[b] Values in parentheses are estimates based on totals for four or fewer plots. In 1975 counts of nests were obtained on plot 10 and 4 plots not studied in later years; in 1980, 1981, 1983, and 1986 data on some or all of the other variables were not obtained at one or more of the five plots (Table 1). To estimate totals for all 5 plots in those years, we first calculated proportions on each of the 5 plots in all years combined when data were Obtained on all 5 plots and used those values as correction factors.
[c] Estimate based on ratios of counts of each variable to number of nests at Stake 3 (Drury 1976).
[d] ND: no data: Fieldwork was not timed appropriately to collect data.
[e] Inequality signs are used for hatching values obtained when hatching had commenced before our arrival and for fledging values when we left while chicks were still downy.

Table 4. 13. Reproductive performance of Black-legged Kittiwakes at Bluff, 1975-1990[a].

Year	Hatching Chronology First	Hatching Chronology Median	Number/Active Nest[b] Clutch Size	Eggs Hatching Maximum	Eggs Hatching Actual	Eggs Hatching Minimum	Chicks Fledging	HS[c] (%)	FS[d] (%)	Growth Rate of Chicks
1975	18 July	29 July	1.25±0.44(24)[e]	1.08±0.65(24)		0.92±0.50(24)	0.58±0.58(24)	80	58	ND
1976	19 July	30 July	1.12±0.33(42)		0.17±ND(42)		0.12±0.33(42)	15	71	ND
1977	18 July	2 Aug.	1.19±0.40(37)		0.41±ND(37)		0.30±0.46(37)	34	73	ND
1978	10 July	23 July	1.70±0.46(183)		1.28±0.74(183)		0.90±0.49(183)	75	70	18.0±4.3(18)[c]
1979	7 July	14 July	ND	ND		≥1.27±0.56(226)	1.16±0.54(226)	ND	≤91	19.7±4.4(39)
1980	6 July	15 July	ND	ND		≥1.35±0.60(179)	≤1.15±0.58(180)	ND	ND	17.1±2.1(30)
1981	8 July	13 July	1.70±0.52(192)	1.53±0.58(174)		1.34±0.58(174)	≤1.03±0.47(172)	85	≤72	17.6±5.5(20)
1982	18 July	ND	1.10±0.29(105)	ND		ND	ND	ND	ND	ND
1983	9 July	10 July	1.69±0.50(211)	1.48±0.61(211)		1.08±0.71(217)	0.30±0.46(123)	76	24	12.4*5.3(10)
1984	>20 July[f]	ND	1.12±0.33(17)		0.00±0.00(17)		0.00±0.00(17)	0	NA	NA
1985	1 Aug.[g]	ND	1.00±0(8)		0.00±0.00(8)		0.00±0.00(8)	0	NA	NA
1986	1 Aug.[h]	ND	ND	ND		≥0.99±0.32(70)	4.7330.45(70)	ND	ND	ND
1987	20 July	26 July	1.45@.5q251)	1.30±0.60(251)		0.97±0.61(251)	0.72±0.48(251)	78	64	16.7±3.5(47)
1988	11 July	19 July	1.66±0.48(265)	1.52±0.60(265)		1.08±0.60(265)	0.74±0.47(265)	78	57	16.3±3.2(41)
1989	25 July	29 July	1.04±0.20(25)		0.20±0.41(25)		0.00±0.00(25)	19	0	N D
1990	11 July	19 July	1.24±0.45(119)	1.16±0.54(151)		0.93±0.53(164)	0.70±0.49(160)	85	74	18.6±4.3(14)

ND: No data available. NA: Not applicable.

[a] Sources are listed in Table 1. Values are based on all nests on Reproductive Plots and in Reproductive Areas for which data for a particular variable were available.

[b] Three values are reported for number hatching/active nest. "Maximum" assumes all eggs disappearing during hatching hatched before they disappeared. "Minimum" assumes that none of those eggs hatched. Actual values are provided if the number hatching was determined precisely. Inequality signs for hatching indicate that field observations started after hatching began; those for fledging indicate that observations ended before chicks were about 3 weeks old or older.

[c] HS: Hatching success (number of eggs hatching/number of eggs laid), based on actual values or the mean of maximum and minimum values of eggs hatching/active nest.

[d] FS: Fledging success (number of chicks fledging/number of eggs hatching, based on actual values or the mean of maximum and minimum values of eggs hatching/active nest).

[e] Mean ± standard deviation (sample size: number of active nests).

[f] No eggs hatched on study plots; however eggs were still being incubated in one or more nests elsewhere in the colony when we departed.

[g] No eggs hatched by 27 July, but 3 chicks seen on 17 August were 2-3 weeks old.

[h] No eggs hatched by 16 July, but many had hatched by 7 August; Ibis estimate is based on the weight of the largest chick found on 11 August and the average growth rate of chicks of 17.2 g. (all years combined).

Table 14. Volume and shape indices of kittiwake eggs at Bluff[a].

Year	Volume[b]	Shape Index[c]
1981	48.5 ± 2.9 (37)	71.8 ± 3.4 (37)
1982	45.4 ± 3.3 (13)	72.2 ± 3.7 (13)
1983	47.3 ± 3.8 (35)	69.9 ± 3.4 (35)
1984-1986	no data	no data
1987	47.3 ± 4.6 (77)	70.3 ± 2.9 (77)
1988	48.3 ± 4.1 (44)	69.5 ± 2.7 (44)
1989	no data	no data
1990	49.8 ± 4.1 (12)	70.4 ± 3.2 (12)

[a] Second eggs of 2-egg clutches and eggs of 1-egg clutches only. If laying position was unknown for 2-egg clutches, the smaller egg of the clutch was used in the analysis.

[b] Volume = 0.4866 * breadth^2 * length (Coulson 1963).

[c] Shape index = 100* breadth/length (Coulson 1963).

Table 15. Regression of reproductive and count variables on wearher variables.

Variable	Number of Years	Variance Explained[a]	Equations	1990 Ohs.	1990 Pred.	1990 Diff.[c]
Number of nests	15	0.70	103.7 + 18.3*MAYTEMP[c]	227	185	42*
		0.92	85.3 + 70.3* MAYTEMP - 8.3*MAYTEMP^2	227	166	61*
		0.89	7549.8 + 13.6*MAYTEMP - 3.6* MAYSNOW - 7.3*JUNBARO	227	204	23*
Active Nests (%)	11	0.77	0.331 + O.1O3*MAYTEMP	54.2%	78.9%	-24.7%*
		0.86	0.278 + 0.280*MAYTEMP - 0.029*MAYTEMP^2	54.2%	95.8%	-41.6%***
		0.98	1.465 + 0.075 *MAYTEMP - 0.024* MAYSNOW - 0.229*JULWIND - 0.021 *JULPPT	54.2%	101.8%	47.6%**"*
Hatching Date	12	0.86	21.3- 2.09* MAYTEMP	11 July	12 July	-1 day
		0.88	35.2- 1.87* MAYTEMP - 3.44*JUNWIND	11 July	13 July	-2 days
Clutch Size	12	0.95	1.097 + 0.098 *MAYTEMP	1.24	1.53	-0.29***
Hatching Success	11	0.66	0.238 + 0.098* MAYTEMP	85.0%	67.5%	17.5%
		0.81	0.182 + 0.340*MAYTEMP - 0.039*MAYTEMP^2	85.0%	91.6%	-6.6%
Fledging Success	8	0.67	0.733- 0.045 *MAYSNOW	74.()%	64.2%	9.8%
		0.78	0.923- 0.058*MAYSNOW - 0.044* MAYTEMP	74.0%	60.7%	13.3%*
Chick Growth Rate	7	0.52	31.99- 1.32*JULTEMP	18.5 g/d	14.4 g/d	4.1 g/d
Number of Adults at Colony	13	0.51	29646- 4965*JULWIND	10,646	8,339	2,307
		0.82	26347- 4116*JULWIND + 589*MAYTEMP - 51O*JULPPT	10,646	5.262	5.384***
Number of Adults on Census Plots	11	0.31	756.7- 32.4*JULPPT	629	373	256*
		0.62	309.6 + 1.68* NESTCNT	629	690	-61

[a]For single term equations this value is simply the square of the correlation coefficient. For multiple term equations the "adjusted r^2" is reported (see Dixon 1990).

[b]The best single variable equation is listed first. Polynomial equations with all significant ($P < 0.05$) terms are then listed if significant. The multiple regression equation incorporating all significant ($P < 0.05$) terms is then listed, if two or more terms were significant In multiple term equations the variables are listed according to the absolute values of their partial regression coefficients in descending order.

[c]Difference between observed and predicted; number of asterisks equals the number of standard deviations of observed value from predicted value.

'Acronyms: MAYTEMP: Average temperature in May, MAYSNOW Total snowfall in May, JUNBARO: Average barometric pressure in June. JULWIND: Average wind speed in July, JULPPT: Total precipitation in July, JUNWIND: Average wind speed in June, JULTEMP: Average temperature in July, and NESTCNT: number of nests on Reproductive Plots.

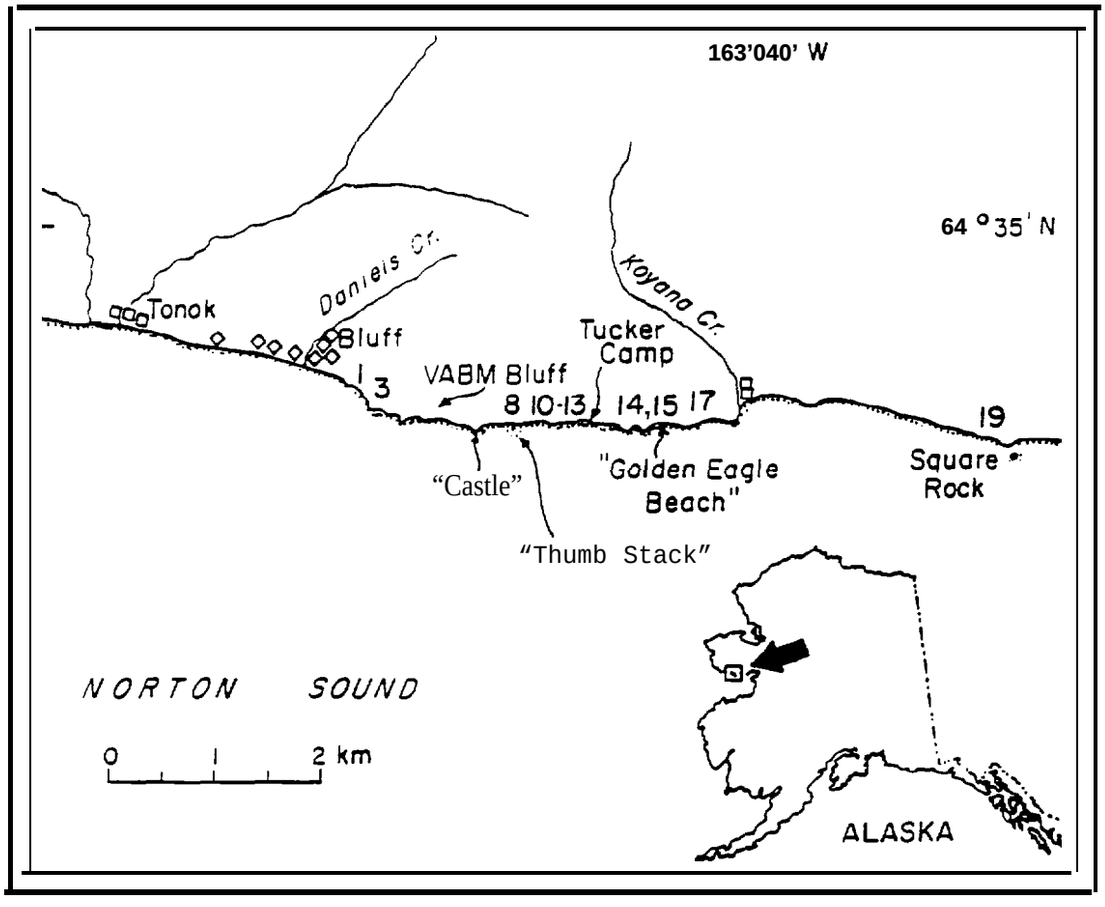

Figure 41. Bluff and vicinity. Locations of all Census Stakes (location of observer when making a count) except 4b-4f, 5a, 5b, 6, and 16 are shown; stakes 4b-6 are located sequentially from west to east between stakes 3 and 8, and stake 16 is between stakes 15 and 17.

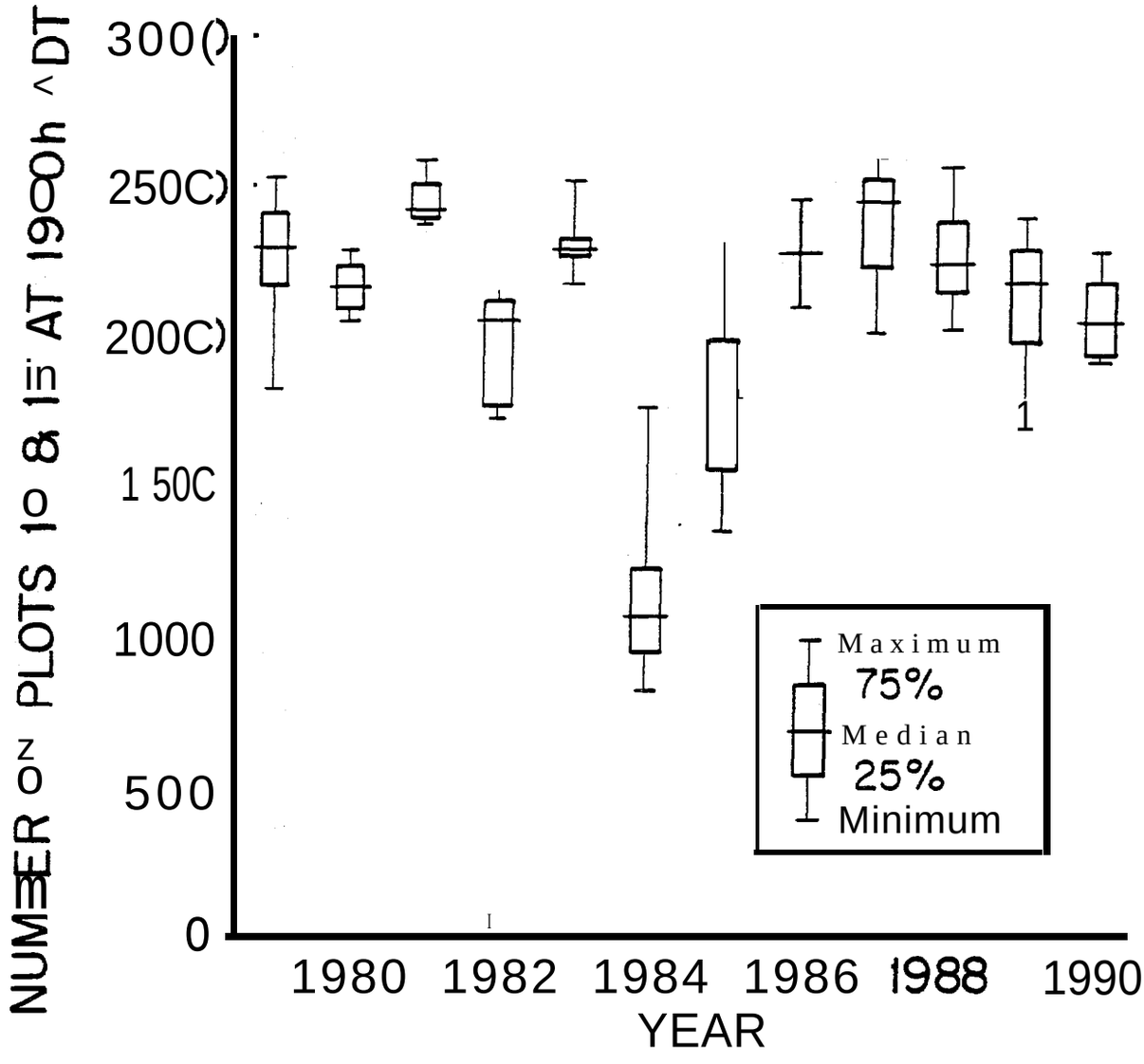

Figure 42. Counts of murres at mid-season (between the end of egg-laying and beginning of "fledging") at Census Plots 10 and 15. All counts were made at 1900h ADT.

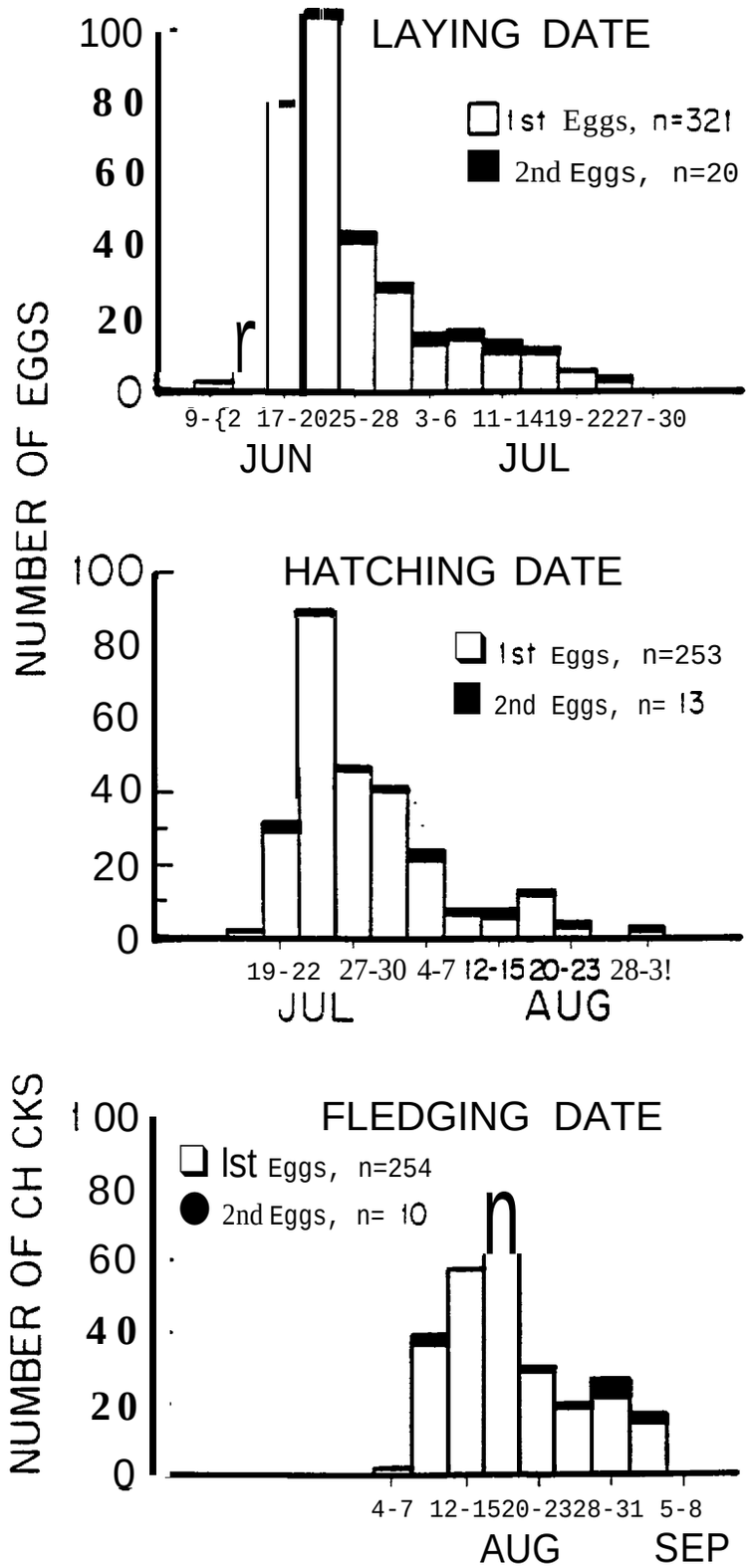

Figure43. Laying, hatching, and fledging chronology of murres on Reproductive Plots at Bluff in" 1990.

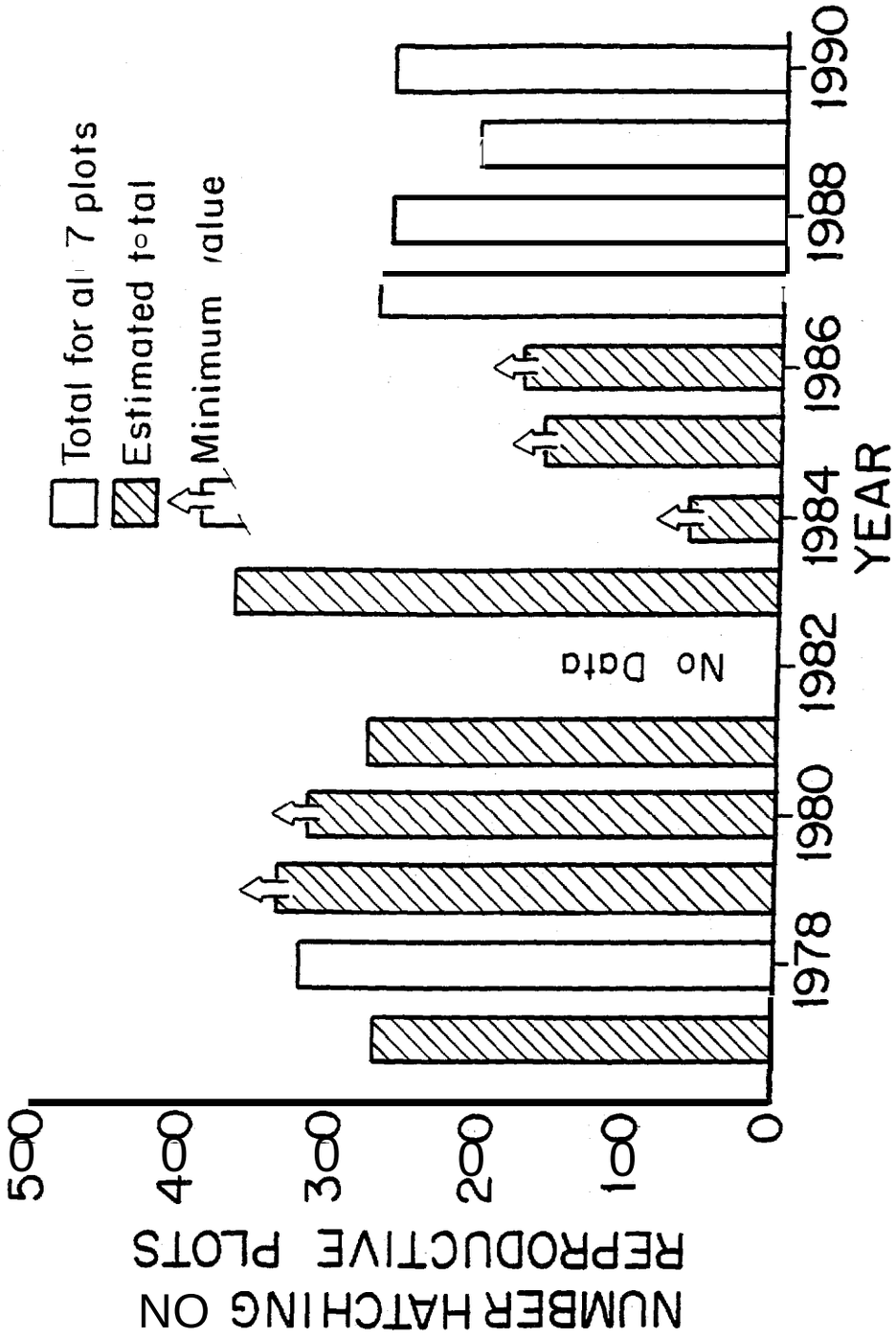

Figure 44. Number of murre eggs hatching on 7 Reproductive Plots at Bluff. Estimates were calculated if complete data were available for 6 or fewer subplots. Values are reported as minima if fieldwork was initiated after hatching began.

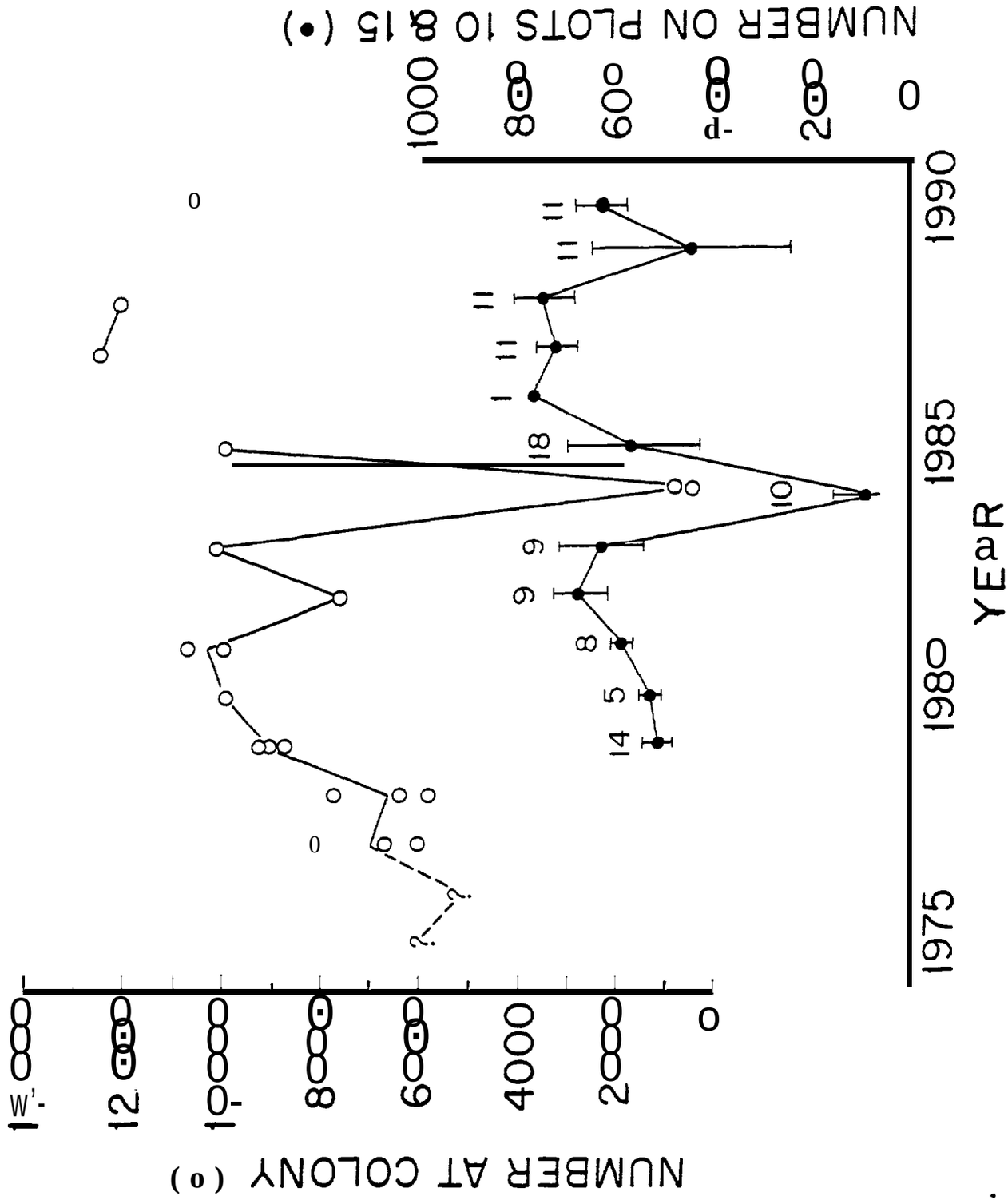

Figure 45. Number of Kittiwakes in adult plumage counted in the entire colony at mid-day (open symbols) and on plots IO and 15 at 1900h ADT (closed symbols). Each entire colony count between the end of egg-laying and the onset of fledging is shown, and the line connects mean values. Values for 1975 and 1976 were estimated (see text). For the counts on plots 10 and 15 the circles correspond to the mean values and the bars encompass one standard deviation above and below the mean. The number above each bar is the sample size, i.e., the number of days that counts were made.

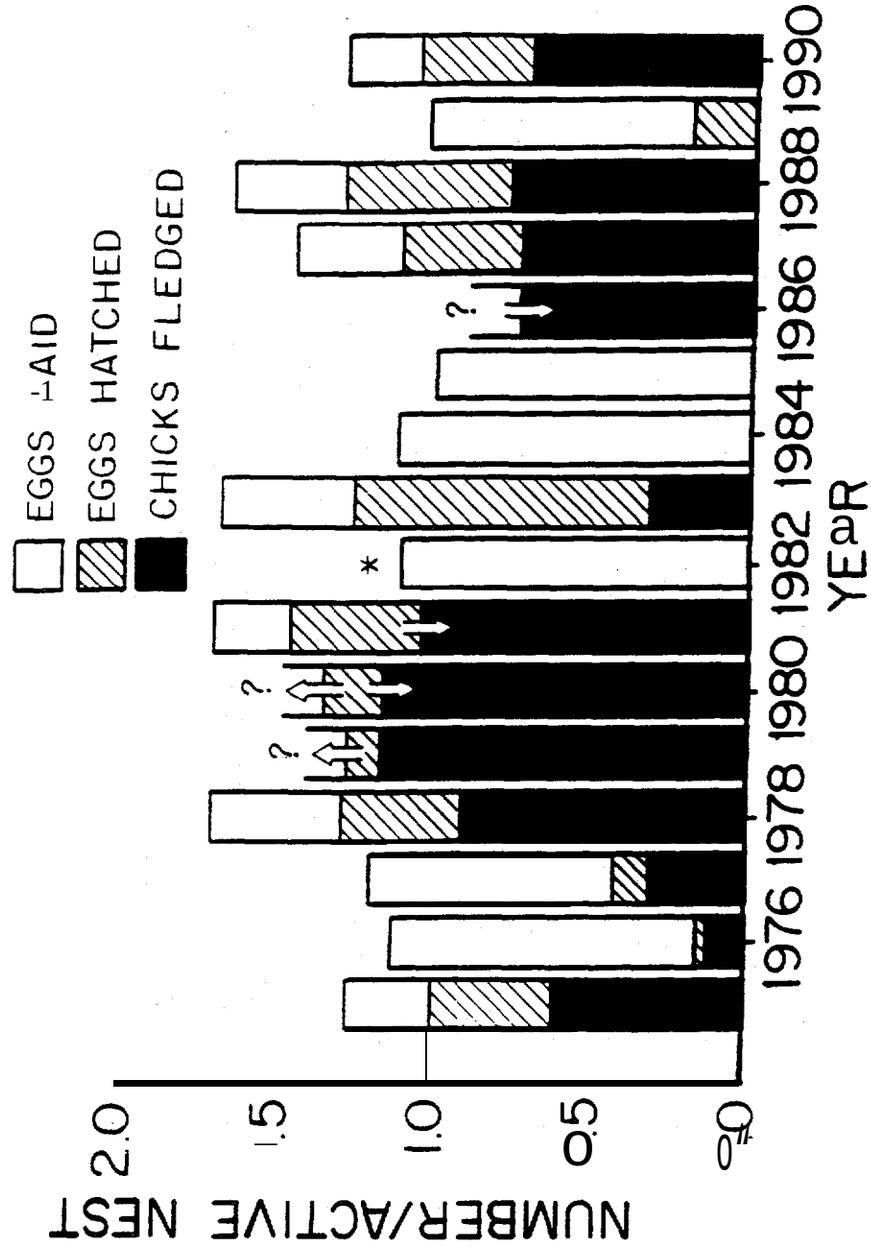

Figure 46. Clutch size, number of eggs hatching/active nest, and number of chicks fledging/active nest, 1975-1990. Within bars, upward arrows denote minimum values, and downward arrows denote maximum values. Question marks indicate that values were not determined. In 1982 (asterisk) information was obtained only for clutch size.

CHAPTER 5. POPULATIONS AND PRODUCTIVITY OF SEABIRDS AT CAPE THOMPSON IN 1990

By Brian Sharp

INTRODUCTION

The Chukchi Sea supports large breeding colonies of seabirds, including 2,000,000 in the eastern (North American, or northwestern Alaskan) portion of the Sea. These seabird populations are significant biological resources per se, and are also important in the subsistence economy of the Inupiat inhabitants of the region. There are proposals to lease and develop offshore oil and gas deposits in the Chukchi Sea. A large seabird colony consisting of approximately 420,000 birds of nine species nests on the cliffs at Cape Thompson (Swartz 1966) and forages in the eastern Chukchi Sea (Springer et al. 1984). Exploration, development, and transportation of oil and gas have the potential to impact seabird populations adversely, either by causing direct mortality, or by reducing their productivity via food supply effects. The subsistence utilization of the seabird resource by the native people could also be affected. Arctic Ocean food webs are relatively simple and are vulnerable to disturbance (McKnight and Knoder 1979). Arctic seabird populations may also respond adversely to natural and other man-induced changes--climate, ozone depletion, and global warming, for example.

Data on population size and productivity of seabirds in the Chukchi Sea are basic to understanding seabird population dynamics. Long-term monitoring of status and productivity is necessary to determine the magnitude of variations in those parameters, long-term population trends, and the impacts of resource development, oil spills, or other environmental changes. Data are available on the seabird populations of Cape Thompson beginning in 1959-61 (Swartz 1966), continuing intermittently through the 1970's and 1980's (summarized by Fadely et al. 1989). The objectives of the present study were to obtain current data on the Cape Thompson seabird colony by monitoring the populations and annual productivity of three species: thick-billed murres (Uris lomvia), common murres (Uris aalge), and black-legged kittiwakes (Rissa tridactyla). Data were also collected on foraging success. This paper presents the results of data gathered in 1990, and compares the results of this year's work with data gathered in previous years.

Cape Thompson is a series of cliffs on an 1 l-km coastline in the southeastern Chukchi Sea (68° 08'N, 166°21' W). Seabirds are loosely grouped in five colonies, which were numbered from southeast to northwest by Swartz (1966). The surrounding terrain consists of rolling hills intersected by deep narrow stream valleys, including Ikijaktusak Creek where the base camp was established. Vegetation is tundra, with willow scrub along permanent streams.

The broad valley of Oguturuk Creek southeast of Colony 1 was the site of the Project research project in the 1960's. The gravel airstrip at this site provides the closest air access to the Cape Thompson camp.

METHODS

Methods utilized in 1990 are summarized in Chapter.2. These procedures were derived from methods developed in earlier studies at Cape Thompson and elsewhere in Alaska, Canada, and Great Britain (see Lloyd 1975; Gaston et al. 1983; Slater 1980; and in particular Birkhead and Nettleship 1980). In addition, we added other procedures to supplement the standardized data in order to increase comparability with previous years' work at Cape Thompson,

Personnel and equipment were flown to Chariot, 8 km south of the camp site, on 3 July (see "Logistics and Operations," below). The camp site was reached by inflatable raft. Field work began on 6 July, and the camp was evacuated on 30 August.

Populations

"Fadely plots" -- Populations of both murres and kittiwakes were monitored by replicate counts of birds at permanent sample plots established in 1988 (Fadely et al., 1989) and referred to hereafter as "Fadely plots." These plots were monitored from land-based observation points at the edges of cliffs. Observation points were marked by us in 1990 with numbered iron stakes (iron rebar with numbered aluminum caps), using the numbering system developed in 1988. One, 3, 5, and 13 plots were monitored at colonies 2, 3, 4, and 5, respectively. Three of the land-based plots established in 1988 were not monitored in 1990; these were plots 2-1A and 2-2B at Colony 2, which, along with Observation Point 2 ("OP-2"), had collapsed into the sea, and plot 5-41, which seemed to require the observer's placing himself or herself in danger. The single remaining plot at colony 2 (2-3C) was not monitored regularly in 1990 since it was an inefficient use of time and energy to walk to Colony 2 to count one plot. It seemed doubtful that even the full complement of three plots established in 1988 would have been sufficient to sample Colony 2, which is a large colony almost a mile in length. Colony 2 was therefore inadequately monitored from land in 1990.

Each population plot count was replicated 6-10 times. Counts were performed during the time of day and during the period of the breeding cycle when numbers vary least, i.e, from 1000 to 2000 hours during incubation (Birkhead 1978; Fadely et al. 1989). Population counts were carried out between 8 July and 9 August, except for one plot which was last counted on 13 August, at the very end of the "census period." These 1990 land-based counts would be compared to the 1988 counts obtained by Fadely et al. (1989).

Duplicate counts of some land-based plots were made by different observers to test for observer differences early in the field season. Differences between some observers were large at first, but with experience became more comparable.

"Swartz Plots" -- Between 1959 and 1961 Swartz (1966) conducted land-based counts of parts of colony 5 visible from the cliff-tops. Some of these (hereafter termed "Swartz plots") were also counted in the last 1970's and early 1980's (A.M. Springer, pers. comm.). Only three Swartz plots were among the land-based monitoring plots established in 1988. In 1990 an attempt was made to locate and count Swartz plots in order to continue a comparable and possibly valuable database going back thirty years, Therefore, 6 additional land-based plots at colony 5 were added to the population monitoring effort, making a total of 9 Swartz plots. Swartz plots were replicate-counted in the same manner as the population plots established in 1988, i.e., 6-9 times during the "stable period." Photographic documentation of all plots, including both Fadely plots and Swartz plots, is filed with the Marine Bird Section of the FWS in Anchorage for reference. All Swartz plots were censused from marked observation points as described in Appendix Cl.

Boat Plots -- Sampling of some colonies, especially colonies 2 and 3, by the land-based plots established in 1988 seemed inadequate, given the unrepresentative distribution of the population plots within the colonies and the small number of plots in some colonies. Colony 3, for example, is an extensive colony, much of it inaccessible from shore; only its southeastern periphery is sampled by the three land-based Fadely plots. Similarly, Colony 2, also an extensive colony, was represented by only three land-based Fade] y plots in 1988, all of them at the northern end of the colony, and 2 of the 3 had collapsed into the sea in 1990. Colony 5 was well represented by 14 Fadely plots, but none of these were at the northern end of the colony.

All parts of the five colonies are equally visible from a boat in good weather. The colonies have been counted from offshore by boat since 1960, using plots established by Swartz (1966). Plots counted from offshore are referred to here as "boat plots". Subsequent modifications of some boat plots are summarized by Fadely et al. (1989). The data on boat plots provide a second basis for analyzing population changes at Cape Thompson over 31 years.

We wished to verify the reliability of boat-based counts to ensure against possible large counting errors. Therefore, colony 4 was first counted twice in its entirety (18 plots) to determine the variation between counts. The results of this test would determine whether boat counts would be extended to other colonies. Since the duplicate counts of Colony 4 gave comparable results (see Results section below), boat-based counts were extended to all of the other colonies. Selected plots were counted within the large colonies 2, 3, and 5, and colony 1 was counted in toto. At colonies 2, 3, and 5, plots at both the center and at the periphery of colonies were counted, and an attempt was made to select those plots most often counted in prior years (summarized by Fadel y et al. 1989). Photographs of Swartz' boat plot demarcations were used to identify plot boundaries.

Duplicate counts were made by different observers to identify and compensate for observer differences. If differences were large, plots were recounted. The means of all counts were used as the population count for the plot. Some large plots were counted by 5's or

(occasionally) 10's. Murres were not differentiated to species. Boat counts, except replicate 1 at Colony 4, were performed while the boat was at anchor. Colony 4 was first counted while moving slowly past the plot.

Boat-based plots thus extended the population counts to all parts of all colonies. The resulting data supplemented the more intensive, replicated land-based counts, and seined as an "additional source of information on trends against which to cross-check the trend data provided by the land-based counts of both Fadely plots and Swartz plots.

K-factor -- Population counts by themselves may not give a true picture of the status of a population. Variation between years in numbers of non-breeding birds may affect population counts (Lloyd 1975, Gaston and Nettleship 1982, Hatch and Hatch 1989). The proportion of breeding pairs (sites with eggs) to total birds in adult plumage, referred to as the k-factor, may be used to correct the total population counts at plots or colonies to determine the total number of breeding sites. This index can also be compared with k-factors obtained in other years to obtain a better understanding of some of the dynamics underlying observed population levels and changes, e.g., the possibly differing proportion of non-breeding birds between years. It was also thought that the k-factor might be useful in comparing estimates of productivity when Type I method (this study) and Type II method (Fadely et al. 1989) are used.

In 1990, therefore, those portions of productivity plots in which the breeding status of most or all birds was known were examined for the presence of non-breeding birds. Counts were made of the proportion of non-breeding birds on "control ledges" (see Nettleship 1976) if necessary to eliminate portions of plots where the status of birds was unknown. The number of breeding sites was divided by the total number of birds on the plot. K-factor data were collected at the same time of day and during the same stage of the nesting cycle in which " population counts were made, i.e., during the stable period. K-factors were obtained for murres only.

Productivity

Productivity was monitored according to the procedures outlined in Chapter 2. The method utilizes the so-called "Type I Method" of Birkhead and Nettleship (1980). It was not possible to determine the breeding status of all birds on productivity plots throughout the breeding season, due to the large number of birds on most plots and the amount of observation time necessary before breeding status of each bird could be determined. Therefore, a subsample of birds within the productivity plots were monitored for productivity on a regular basis throughout the season. An attempt was made to obtain a "fix" on every bird being monitored within the productivity plot on every other visit to the plot. Since productivity monitoring usually alternated with population plot counts on every other day, determination of reproductive status was thus obtained every fourth day. Depending on the ability of the observer, the relative difficulty of observing birds on a given plot, etc., it was not possible to monitor more than 20-60 birds on a given productivity plot.

The subsample of birds within productivity plots that were monitored through the breeding season were selected on the basis of observability. In practice this translated into nesting sites being selected if eggs were observed early in the breeding season. Birds being tracked that showed no evidence of incubating an egg or eggs were eventually excluded from further consideration. Therefore, there is an obvious bias toward selecting pairs that had not lost eggs, and against non-breeding pairs. Breeding success was related only to the number of pairs attempting to breed rather than the total number of birds on the productivity plot, as in 1988 (Fadely et al. 1989).

In 1988 a modified method of estimating productivity was tested (Fadely et al. 1989). This method relied on limited monitoring visits to the breeding colony--one early in the breeding season (during egg-laying) to obtain a count of the number of birds present at the colony, and another towards the end of the breeding season to count the number of chicks close to fledging. Since this method differed from the method used in 1990, it was thought that the k-factor, once obtained (see above), because it includes an estimate of the proportion of non-breeding birds, could be used to derive an estimate of productivity similar to the Type II method for the sake of comparing productivity between years. It was thought that the Type I estimate of productivity, based on the number of chicks successfully fledged per breeding attempt, could simply be recalculated to include the known proportion of non-breeding birds.

In 1988 the criterion for fledging was survival to 15 days for murres and survival to 30 days for kittiwakes (Fadely et al. 1989: 21). In 1990, productivity calculations were based on these same criteria to ensure comparability between years. However, more complete histories of many chicks were obtained in 1990 using the "Type I" method. In 1990 kittiwake fledging was observed in a few nests, for example, and mortality of murre chicks was observed between age 15 days and fledging (thick-billed murres begin to fledge at 15 days--Gaston and Nettleship 1982). It was possible to calculate murre productivity in 1990 to account for known chick losses between age 15 days and fledging using the following criteria for deciding whether a disappeared chick fledged or died:
(a) chick close to median fledging age (circa 21-22 days for thick-billed murres); (b) size of chick when last observed if chick age was unknown; and (c) behavior of adults, i.e., presence of paired adults at a nesting site after chick disappearance was assumed to indicate a lost chick. It should be noted, however, that chick histories at many murre breeding sites were still incomplete when observers left the colony in 1990, and some chick disappearances were assigned to mortality or fledgling categories with difficulty, and perhaps wrongly in some cases.

Kittiwake chicks were assigned to the fledging category if it was observed that they had left the nest and subsequently returned, or if the chicks were large and apparently fully grown at the time of our last observation on 29 August. The median age of kittiwake chicks on 29 August would have been approximately 35-37 days.

Survival rates of eggs and chicks were also estimated by the Mayfield method (May field 1975), which provides estimates of daily egg or chick mortality based on the intervals between actual observations of eggs and chicks. The method may give a more accurate estimate of productivity than the Type I method if observations are not made from the start of egg-laying until the end of fledging, as at Cape Thompson. It assumes that survival is constant during the interval considered. If it is suspected that survival varies during the breeding cycle, rates can be estimated separately for several interals. For kittiwakes, for example, significant chick mortality can occur in the first few days after hatching due to sibling rivalry. This interval can be considered separately, if desired.

The boundaries of productivity plots as outlined on the photographs were sometimes modified in order either to choose birds that were more observable (e.g., that presented lateral rather than dorsal views of the incubating adults), or to increase the sample sizes of species that were under-represented on the established plots (common murres and kittiwakes). Specific details pertaining to modifications of the individual plots are given in Appendix C.1 and on plot photos taken in 1990 filed with the Marine Bird Section of the FWS in Anchorage.

Food habits

Adult murres and kittiwakes were collected on 10 July by A.M. Springer, in the middle of August (15-16) at sea, and toward the end of August (26-27) from land to investigate food abundance and prey selection. An attempt was made to differentiate and collect those birds returning to the colony with food. Contents of the proventriculus and gizzard were preserved in isopropyl alcohol for future examination. Food samples have not yet been analyzed.

Since seabird reproductive success is related to foraging success, which in turn is related to prey abundance and/or availability, and since the study was not designed to obtain observations on prey abundance directly, we obtained an indirect measurement of foraging success and prey abundance (or availability) by quantifying the rate of delivery of food to common and thick-billed murre chicks. Survival of chicks is a function of food delivery rate (Ford et al. 1982). Where possible, groups of birds known to have chicks were observed simultaneously to increase the number of “chick-hours” observed and thus sample sizes. We did not measure food deliveries (regurgitations) to kittiwake chicks. Delivery rates provide an indirect measure of foraging success not provided by collecting adult birds, and potentially provide adequate sample sizes without the attendant mortality of adults or chicks.

Weather

Maximum and minimum temperature, wind speed, and the occurrence of precipitation, sunshine, and fog or smoke were recorded on a daily basis. Wind speed was measured in late afternoon or evening with a wind gauge held at a height of approximately 1.5 meters. Both temperatures and wind speed were measured at sea level at our base camp at Ikijaktusak Creek. Sea temperature near the surface was measured periodically, either in the surf or at sea during boat censuses.

LOGISTICS AND OPERATIONS

Equipment and Supplies

Approximately 6,700 lbs of equipment, fuel, and supplies, including personal gear, were transported to base camp at Ikijaktusak Creek. Moving that amount of material was time-consuming and physically demanding. Air transportation of personnel and equipment to the field by Baker Aviation of Kotzebue required a 12-hour day. Five trips were made by Cessna 402 from Kotzebue to Kivalina, and 10 trips were made by Cessna 206 from Kivalina to the airstrip at Chariot, 8 km southeast of base camp. Transportation of supplies from the Chariot airstrip to the beach required approximately 14 raft-loads from Chariot over parts of two days. An additional 15 12-hour person-days were required to transport supplies from airstrip to beach and from beach to campsite. Good weather and calm seas during establishment of the camp were welcome.

Backup equipment was included and it enabled the field project leader and crew to deal with foreseeable contingencies and to replace lost or damaged items. An extra tent enabled us to replace wind-and bear-damaged parts of other tents. A second inflatable boat was insurance against bear damage. Complete repair kits for weatherport, tents, and boats were an absolute necessity. A wheelbarrow or wheeled cart might have reduced the considerable physical effort of carrying our more than three tons of equipment and supplies to and from the beaches.

Approximately 1900 lbs ($2900 worth) of food were taken into the field. A reserve of bulk items, mostly rice, beans and canned goods, would have been sufficient for another two to three weeks in case of a weather-enforced stay, but most of the food was consumed.

At the end of the summer, the evacuation of the field camp to Chariot, even with maximum consolidation of equipment and supplies, required 6 boat-loads. Some leftover food and the plywood floor of the weatherport were discarded to reduce the number of boat trips to a minimum, since the weather, fair in the morning, deteriorated by late afternoon, with increasing wind and high seas. Evacuation of field camp from Ikijaktusak to Chariot took 14 hours, or 56 person-hours, with an additional 2-3 person-days to carry supplies from the beach to the landing strip.

Boats

Both boats (new Achilles 14-foot rafts) and motors (new Johnson 30-hp) performed reliably in 1990. Gear oil was changed in the bottom ends of both motors after the break-in period. At the end of the summer during evacuation, one motor quit within a mile of Chariot on the last trip, possibly due to water in the gas. We also had difficulty starting one of the backup Johnson 15-hp motors.

Food

The field team ate mainly a vegetarian diet.

Two crates each of apples and fresh oranges lasted the whole summer and were worth the labor of transporting them. Potatoes and onions were also relatively non-perishable. Cheeses deteriorated before the whole supply could be consumed, except for cream cheese. A block of mozzarella cheese discovered in a spring, presumably left by the 1988 field crew, was in good condition and edible in 1990!

Fresh vegetables were in short supply, but the tundra provides several easily recognizable species of edible plants that can be used as greens: sourdock (Rumex sp.), which is cooked like spinach, Oxria digyna, which is eaten raw like a salad, and wild onion (Allium sp.) green leaves of which can be eaten raw. In July the tundra hillsides produced an abundance of unidentified, tan-colored mushrooms, growing singly, that some team members elected to test for edibility, and Boletus edulis appeared in small numbers in August.

Liquid food items such as fruit juices should be minimized for this camp because of air travel.

Fuel

125 gallons of gasoline in 5-gallon cans were taken to Cape Thompson. 75 gallons were consumed during field operations, including transportation to the' field camp, boat surveys, and collecting. The amount of gasoline taken in 1990 was excessive and could be reduced in the future. However, a generous margin of safety is needed, including enough gasoline to reach Point Hope in an emergency (60 miles round trip).

Ten gallons of kerosene was taken as fuel for the tent heater. Because of the good weather experienced in 1990, not all of this was used. Fifteen gallons may have been needed in a more typical year. The tent heater appeared to consume about a gallon in about 8 hours of operation.

Most of approximately 80 lbs of propane in 4 20-lb containers was used for operation of the camp cookstove. However, there was extra propane left over in case of a weather-extended stay.

Local concerns

Since seabird populations of the Chukchi Sea have social and cultural consequences for area communities, it would be valuable to involve the Eskimos of Point Hope, Kivalina, or Kotzebue in the field study in the future. The local people we met invariably expressed lively interest in our methods and results.

Communications

We were equipped with a single-sideband radio (upper sideband only), powered by a 100 amp-hour deep-cycle battery which was charged by a 14 l/2-volt, 3-ampere solar panel. This system worked satisfactorily, providing good contact on 5907 mHz with Anchorage and with Selawik National Wildlife Refuge in Kotzebue. About 12 August, radio contact was lost for the rest of the summer. That the reason was probably atmospheric is indicated by the fact that despite additional charging by the backup gasoline powered generator, no further contact was obtained, and the battery was fully charged when checked in Kotzebue. An acquaintance reported similar radio difficulties in Greenland in 1990; greater than normal sunspot activity in 1990 was thought to be responsible for the radio interference.

We carried an aviation-frequency air-to-ground radio for emergency backup. Cape Thompson is not altogether isolated; it is on the daily flight path to Point Hope, and sometimes several planes per day pass overhead or just offshore. Unfortunately, radio contact was unavailable when we needed to make evacuation arrangements at the end of the summer and the backup air-to-ground radio had been damaged by salt-water. At our request, residents of Point Hope whom we met in the field relayed evacuation instructions to Baker Aviation. Point Hope is three hours from Cape Thompson by boat (weather permitting), and as a last resort could have been reached overland on foot. Lack of any radio communication was an inconvenience when we needed to arrange our return from the field, and it would have been of more serious concern if anyone in the crew had required medical attention.

Hazards

Most conditions at Cape Thompson are similar to those at other remote field camps. Several potential hazards that were unusually frequent at Cape Thompson, at least in the summer of 1990, are described below.

Bears -- The section of coast near Cape Thompson may have the highest population of grizzly bears in northwest Alaska (Baker Aviation pilot, pers. comm.). In 1988, the only previous year when a Service camp was at Ikijaktusak Creek, sightings of bears were infrequent and no bears entered the camp (Fadely et al. 1989). Up to four different adult or subadult bears and two cubs inhabited the Ikijaktusak area in 1990 and regularly patrolled the creek drainage, beach, and hills. On the night of July 27, 1990, an adult bear tore apart the end of the weatherport, and also pushed on the side of the project leader's " Bombshelter" tent, causing it to collapse.

The bear was apparently attracted by two days' accumulation of "garbage''--mostly tin cans, packaging, and paper--which it strewed about; it did not touch the food stored in the weatherport. No food was kept in the sleeping tents. The repair of the weatherport required 27 person-hours to sew up 57 feet of tears. The poles of the Bombshelter tent were bent; we replaced them with a spare set. After this incident, garbage was burned on a daily basis to eliminate food odors, As a further precaution, the door of the weatherport was left open at

night to allow any future ursine breakers and enterers access weatherport without destroying it. (Ground squirrels were prevented from entering by a plywood barrier across the doorway.) There were no further problems with bears insofar as the weatherport and our food were concerned. At camps with a bear hazard, firearms and bear repellent spray should be within easy reach of people in sleeping tents; in this case they were stored elsewhere.

Another nocturnal visit by a female bear with two cubs resulted in damage to one of the Achilles rafts on the beach. Apparently a bear bit the front end of the raft. The punctures and tears were repaired by extensive gluing and sewing of patches. Repairs had to be made on the inside of the inflatable chamber because of the hard rubber bumper strip on the outside of the damaged area. During the last night before our departure at the end of the field season, two unaccompanied bear cubs inflicted a small puncture on one boat; this damage was within a flat surface and was easily repaired.

Later in the summer, a hunter sleeping inside a tent 100 miles north of Kotzebue was critically injured by a bear while in his sleeping bag.

Other wildlife -- Arctic ground squirrels (*Spermophilus parryi*) were locally numerous in 1990 and were more of a problem than bears insofar as our food supply was concerned. During camp establishment, cardboard boxes containing food were temporarily stored outside and were vulnerable to squirrel pilfering.
A number of items, especially cereals, dried fruits and nuts, were consumed, carried off, or spoiled. Food was safe inside the weatherport for a time. Later, the weatherport had to be protected by an exterior skirting of scrap plywood on the outside to prevent squirrels from chewing their way through the vinyl. This barrier was effective until almost the end of the summer. Ground squirrels are endearing, and it is tempting to feed them, but it is advisable to prevent their associating the weatherport with food.

Tundra voles (*Microtus oeconomus*) were impossible to exclude from the weatherport. They did minor damage to cereals stored in boxes on the floor. Damage to some vulnerable high energy foodstuffs such as dried fruit and nuts was prevented by storing these off the floor. Both voles and ground squirrels were inclined to chew their way into sleeping tents looking for food; no food should be kept in the tents.

Cliffs -- Grass and soil often overhang the rock substrate at observation points at the top of the cliff, and gusty winds are common at the cliff-top, especially at the upper reaches of Colony 5. Caution is needed in approaching cliff edges, and potential overhangs should be checked from one side. Observation point 5-4 required the observer to hang over the edge to obtain a clear view of the birds below. This was judged too hazardous by the project leader, and plot 5-41 therefore was not monitored in 1990.

The cliffs at Cape Thompson consist of fractured sedimentary rocks (limestone, siltstone, etc.) which are unstable and prone to collapse. The entire headland on which Observation Point 2-2 was located collapsed into the sea between 1988 and July 1990. On 18 August 1990, a

section of cliff 8-10 feet from Observation Point 5-6 collapsed and fell onto the beach 600 feet below while an observer watched from Observation Point 5-8. Two hours earlier the observer had been sitting at OP 5-6!

Boat Safety -- Census, collections, moving of equipment and supplies required boat operation. Strong offshore winds (20 to 40 mph) are not unusual at Cape Thompson and could present a serious hazard in case of motor problems. On about 7 July, four men from Point Hope were blown out to sea for three days by offshore winds when their engine failed in the vicinity of Cape Thompson. It was our practice not to use boats during strong offshore winds, to take a backup 15 hp motor in the boat, and to carry a hand-held marine radio to contact base camp at Ikijaktusak in case of emergency.

RESULTS

Environmental conditions

The summer of 1990 in northwest Alaska was unusually warm. Sea ice was last seen on the evening of 6 July, after several days when the temperature was 75-80° F. This date of latest nearshore ice was somewhat earlier than the mean of July 9 (Fadely et al., 1989). Sea temperature reached a maximum of 15° C or 4° C higher than in 1988 (Fadely et al. 1989). The weather was sunny and warm, skies were clear, and there were no strong winds for 23 days from 21 July to 12 August. There were periods of rain, fog, and wind before and after these dates. On 26 August, a violent storm with winds above 80 km/hr struck the northwest coast and generated seas with 4-m waves (flooding Kotzebue). Daily weather data are summarized in Appendix C.2. Rain and fog precluded seabird observations on a few days in early July.

Populations

hind-based plots--In 1990, replicate counts were made of common murre, thick-billed murre, and black-legged kittiwake numbers, and kittiwake nests on 22 of the 25 land-based plots established in 1988. Counts were made during the time of day and stage of breeding cycle when the coefficients of variation of replicate counts were lowest (Lloyd 1975, Fadely et al. 1989). Counts were replicated 6-10 times (mean 8.6), except for the single plot at Colony 2, which was counted twice. Colony 3, a large colony, was not represented well by the land-based plots, since the plots were small and all at the southern end of the colony. Plots at Colony 4 were well-distributed. Colony 5 was monitored by the largest number of plots, which were fairly well distributed, but the southern end of the colony was more heavily sampled. Approximately 7,445 thick-billed murres, 1,260 common murres, 1,350 kittiwakes, and 860 kittiwake nests were counted at 2-3 day intervals. Daily count data are given in Appendix C.3. (Note: in a few cases, murres were not identified to species. Except at Swartz plots 50 and 5P, these totals for murre species were partitioned to thick-billed and

common murres on the basis of the proportions of each species on all other replicate counts for that plot. Raw totals for murre species are still presented in the "Murre spp." column, but figures for thick-billed and common murres include partitioned numbers).

Means of population counts for each Fadely plot, summed across days, and their sample sizes, standard deviations, and coefficients of variation are presented for murres and kittiwakes in Appendices C.2 and C.3. Population counts were summed for each plot across days, rather than across plots for each day. " This was done so that analyses would be comparable to the treatment of population data in 1988 (Fadely et al. 1989), and also because not all plots were counted an equal number of times or on the same days.

Coefficients of variation tended to be lower for kittiwakes than for murres, lower for thick-billed than for common murres, and lowest for counts of kittiwake nests. After an initial break-in period, differences between observers at land-based counts seemed to be insignificant and less than daily variations.

From a non-rigorous review of the data, rain and wind did not appear to be correlated with lower replicate counts (cf. Harris et al. 1983).

Data from all 1990 land-based counts were used to estimate the relative numbers of common and thick-billed murres. Thick-billed murres comprised 86% of the murres overall in 1990 (Table 5.1). The percentage of thick-billed murres was lowest in Colony 4 (46%) and was consistently high, between 85% and 96%, at Colonies 2, 3, and 5. An increase in the proportion of thick-billed murres seems to have occurred both since 1960 and since 1988.

In 1990 nine of the land-based plots counted by Swartz in 1960 were counted in the same manner as the land-based plots established in 1988. Counts were replicated 6-9 times (mean 7.3). Swartz plot data collected in 1990 are summarized in Appendix C.5. A mean total of 9,560 murres, 842 kittiwakes, and 567 kittiwake nests were counted in 1990. Almost all Swartz plots are larger in terms of numbers of birds than Fadely population plots. Three of the Fadely plots are the same as three Swartz plots and were also counted in 1988. Although murre species were differentiated in 1990, the data are summarized as combined murre species for the sake of comparisons with prior years (see Discussion).

Boat-based Riots -- In order to obtain a second independent measure of differences between 1990 and prior years, boat-based counts of at least parts of each colony were made in 1990, using Swartz's 1960 plot demarcations.

Colony 4 was counted twice in its entirety from a boat to determine whether boat counts would provide replicable results. Summations of plot count means were 5,927 and 5,892 for murre species, and 5,506 and 5,627 for kittiwakes (Appendix C.6a-d). These summations of count means varied by less than 2%. At some boat-based plots, however, differences between observers were noticeable. At large plots with 1,000-5,000 murres, counts by BES were consistently higher than counts by JE. When differences between observers were large, plots

were counted again. However, when differences persisted, the counts were incorporated into the means for those plots. Errors causing differences between observers may have been magnified on plots with large numbers of birds.

Since the two boat counts of Colony 4 were comparable, a single boat-based count was made of Colony 1 and of some plots in Colonies 2, 3, and 5. Results of these counts are presented in Appendices C.6-C.9. Approximately 40,200 murres and 10,700 kittiwakes were counted at Colonies 1-5 during the boat counts in 1990.

One plot was counted from both boat and land (land-based plot 3-1A and Swartz boat plot 3A). Kittiwake count means were identical (= 8). Means for murres (both species combined) were 208 from boat versus 177 from land, an indication either that the boat-based count did not underestimate the number of birds present, or that more of the cliff was visible from offshore.

K-factor -- For murres, estimates of the proportion of breeding pairs with eggs to total birds on selected plots, or within selected portions of plots, are presented in Table 5.2. This proportion, the "k-factor", averaged 0.59 $\pm$ 0.035 for both murre species. K-factors from other colonies have varied between 0.28 and 0.79 (Birkhead 1978; Slater 1980; Schulmeister and Mendenhall 1991). On some plots, the proportion of breeding pairs was underestimated in 1990 because of inadequate data on the breeding status of many individuals on the plot: these unknowns were included with non-breeders. Data from such plots were therefore excluded from the calculation of the mean k-factor given above. On some plots, however, the low k-factor was apparently real, i.e., some plots had a lower proportion of non-breeding birds than others. On plot 5-3H', for example, where the breeding status of almost all birds was known, the k-factor was only 0.18. The proportion of breeding birds varied between different cliffs of Colony 5.

K-factors were not obtained for black-legged kittiwakes.

K-factor results could be used to adjust means of raw counts of birds at plots to approximate the number of breeding birds at colonies. If K-factor data were recorded annually, differences between years might be compared using the number of breeding birds at cliffs rather than the total number of birds, or the differing proportions of non-breeders could be ascertained in different years.

Productivity

Type I Method -- Table 5.3 summarizes productivity data for murres on a per plot basis. I used only data on nests for which monitoring began before 26 July, because most sites added to the sample after that date could have been initiated some time before. Overall productivity of thick-billed and common murres on all plots in 1990 was 0.76$\pm$ 0.06 and 0.86$\pm$ 0.15 young per nesting attempt, respectively. As mentioned above in the section on Methods, in order for 1990 productivity data to be comparable to data collected in 1988, a murre nestling was

presumed to have fledged if it survived until age 15 days. However, the more complete histories of some nests in 1990 indicated some loss between age 15 days and expected fledging, so productivity is overestimated using the 1988 criterion for fledging. If the data are corrected for known chick mortalities after age 15 days, productivity is closer to 0.71. Nest histories were detailed enough for only a few nest sites in 1990 to allow detection of chick mortality after age 15 days, however.

The 1990 data for murre incubation periods are incomplete and do not permit a calculation of hatching success using the Type I method.

For kittiwakes, components of productivity for kittiwakes are presented in Table 5.4. The mean percentage of successful nests was 87± 7%, mean clutch size was 1.61, hatching success was 88%, fledging success was 75%, and overall productivity y was 1.1 chicks fledged per active nest and 1.0 (± 0.1) chicks fledged per total nests.

Adjusted Type I Method -- The Type II method of calculating productivity in 1988 included the non-breeding birds on a productivity plot in the denominator of the calculation (chicks observed/number of birds). The Type I estimates of productivity presented above were adjusted to include non-breeding birds using the observed mean k-factor for murres from Table 5.2 to see if an estimate of productivity could be derived that was similar to the Type II estimate of Fadely et al. (1989). Estimates of productivity for 1990 adjusted by this method were 0.43 and 0.51 chicks/adult for thick-billed and common murres, respectively.

Mayfield Method -- The May field method (Mayfield, 1975) utilizes the interval between observations of eggs and/or chicks to provide an estimate of daily mortality of eggs or chicks. The interval between observations, in days, times the number of eggs or chicks exposed to risk, is termed "exposure day" (May field 1975). One egg or chick exposed for one day is one exposure-day, two eggs exposed for five days equals 10 exposure-days, etc. The method assumes that the time of disappearance of an egg or chick is in the interval between the last observation of the egg/chick and the observation when it was determined that the egg or chick was no longer present. For convenience the midpoint of the interval was used here. The principal advantage of the method is that all available observations of eggs and/or chicks are utilizable as long as a time interval is obtained, even if the data are otherwise incomplete. For example, nest sites added later in the season (after 26 July) to the sample of birds to be followed for productivity estimation, which could not be used by the Type I method, were used to estimate daily survival using the May field method. It also assumes that survival rate over the interval is constant.

The daily mortality rates of thick-billed murres, common murres, and black-legged kittiwakes calculated by the Mayfield method are presented by plot in Appendices C.1O-C.2, and survival rates are summarized in Table 5.5. The survival rates of thick-billed murre eggs and chicks in 1990 were 0.9917 and 0.989, respectively (based on 1,681 and 3,360 exposure-days) (Appendix C.1O). The probability of survival of thick-billed murre eggs over a 34-day

incubation period was 0.75, the probability of survival of chicks over a 22-day nestling period was 0.78, and the overall survival of eggs and chicks over the entire reproductive period was thus (0.75) (0.78) = 0.59 (Table 5.5).

Sample sizes for common murres were smaller. Based on 246 and 658 exposure-days, common murre survival rates were 0.996 and 0.995 for eggs and chicks, respectively (Appendix C.11). The probability of survival of eggs over the incubation period was 0.86, of chicks through the nestling stage was 0.89, and overall survival of eggs and chicks over the nesting period was (0.86) (0.88) = 0.76 (Table 5.5). Survival of common murre eggs and chicks was apparently greater than that of thick-billed murres.

Exposure-days for kittiwakes were calculated on a per-egg or per-chick rather than on a per-nest basis. Based on 629 and 4,515 exposure-days, daily survival rates were 0.9714 and 0.9918 for eggs and chicks, respectively (Appendix C.12). The probability of survival of eggs thorough the incubation period was 0.44, of chicks through the nestling period was 0.75, and the overall survival of eggs and chicks over the nesting period was (0.44) (0.75) = 0.33 (Table 5.5).

There did not appear to be great differences in daily mortality rates of eggs and chicks between plots for any species (Appendices C.1O-C.12).

Mortality -- The observed distribution of egg and chick disappearances in July and August (note: uncorrected for effort, i.e., the number of eggs or chicks under observation varied through the breeding season) is shown in Table 5.6. There did not appear to be any pattern in the losses of eggs and chicks of murres, except for 10 disappearances on or about 11 August. It is possible that some of these may have represented earliest fledging rather than chick losses. Most of the identifiable murre egg and chick mortality observed in 1990 was due to rockfalls and predation. Glaucous gulls (*Larus hyperboreus*) and ravens (*Corvus corax*) were observed taking and eating murre eggs, and a glaucous gull was observed to swallow whole a large murre chick that was apparently almost ready to fledge on 29 August. (This took place adjacent to a productivity plot; the chick was of unknown age.)

Weather was not observed to have an adverse influence on reproductive success in 1990. A violent windstorm late in the season on August 26-27, with winds 80-90 km/hr, had little apparent effect: almost all murre and kittiwake chicks were still present at monitored cliff nesting sites after the storm. It is possible, however, that the 4-m waves generated by that storm had an effect on murre chicks that had gone to sea.

There was a pattern of losses of kittiwake eggs and chicks. Most of the egg losses occurred during the hatching stage, and most chick losses occurred in a 9-day interval 7 days after hatching began (Table 5.6). Most kittiwake losses were thus of eggs or small young.

A resident of Point Hope (pers. comm.) estimated that Inupiat of Point Hope and Kivalina take about 2,000 murre eggs annually from the Cape Thompson colonies for personal use. Gathering of eggs is carried out under the exemption for subsistence harvest granted to Alaska Natives by the Migratory Bird Treaty Act. This collecting is something of a tradition near the Fourth of July. No data were gathered to verify independently the extent of this mortality factor.

Food Habits and Feeding

Collections -- Ten black-legged kittiwakes, 6 common murres, and 12 thick-billed murres were collected on 10 July. In August a total of 16 murres and kittiwakes were collected (Appendix C.13). A minimum of 9 birds were hit and not retrieved; approximately 250 shells were expended, for an average of approximately 16 shots per bird collected. Most of the shells "fired were #3 steel shot, which were unsuitable for collecting due to their tight shot pattern. Better success was obtained with #6 steel shot,

Digestive tracts were preserved in alcohol and are undergoing analysis. Data on birds collected in August are given in Appendix C. 13.

Feeding rates -- A total of 108 chick-hours of observations on thick-billed and common murres were made in the middle of August, when chicks were approximately 2-3 weeks old, to determine food delivery rates to chicks (Appendix C. 14). Feeding rate data are summarized in Table 5.7. Chick feeding rates averaged 0.26 $\pm$ 0.066, 0.17$\pm$ 0.059, and 0.19$\pm$ 0.027 per hour for. thick-billed murres, common murres, and murre species combined, respectively.

Foraging observations -- No pattern of feeding flight direction could be determined from incidental observations of birds leaving cliffs at Colony 5 in July. At Ikijaktusak Creek most feeding flights appeared to be in a southeasterly direction from colonies on 4 and 5 July; however, observations were non-random. On
20 July kittiwakes were observed in foraging flocks within 250 meters of the mouth of Ikijaktusak Creek. On 5 August while at sea 8-15 km NW of Cape Thompson, we observed flocks of murres flying NW and WNW, apparently to foraging areas even further to the NW. On that trip, a flock of kittiwakes, along with a few glaucous gulls and 5 marauding pomarine jaegers (Stercorarius pomarinus), were observed feeding among a surfacing school of small fish approximately 8 km NW of Cape Thompson. Later in the summer (19 August) foraging flocks of kittiwakes were observed within 0.7 km of Colony 2 (8/19). On the same day a red-throated loon (Gavia stellata) was observed foraging at or near the breaker line 0.6 km southeast of the mouth of Ikijaktusak Creek. Seven of 11 dives within the space of 5 to 10 minutes were successful, suggesting an abundance of fish inshore.

Phenology

Due to the timing of field operations, data on incubation periods were incomplete in 1990 for all species. The longest incubation period observed for thick-billed murres which resulted in a hatched chick was 32 days. Two thick-billed murres incubated eggs for at least 32 and 42 days before those nesting attempts failed.

Cumulative hatching and fledging frequencies of the three species studied are summarized in Table 5.8. Hatching occurred over a two week period for kittiwakes versus a four week period for thick-billed murres. Thirty common murre chicks, 90 kittiwake chicks and only 19 thick-billed murre chicks (12 of the latter at one plot 5-1Z--a plot that received little sun) were still present on ledges at the time of last observation on 29 August; fledging frequencies shown for kittiwakes and common murres are, therefore, unreliable. First fledging of thick-billed murres occurred on 14 August (or earlier) and chicks were first observed at sea on 15 August. Though hatching frequencies for common murres overlapped those of thick-billed murres, the mean fledging date of common murres was later than that of thick-billed murres at Cape Thompson, and relatively few common murres had fledged by the end of August. First fledgling kittiwakes were noticed at sea on 16 August, fledglings were commonly seen near shore by 24 August, and most chicks on productivity plots were near fledging at the end of August.

Nestling periods were estimated in three ways, using data from productivity plots only, not incidental observations of fledglings at sea. (1) The midpoints of the interval between the last observation of an egg and the first observation of chicks and chick on the nesting site, and the midpoint between the last observation of a chick and the first observation that a chick had disappeared (if this was 15 days or more after hatching), were determined from raw field data for a sample of 17 nests of thick-billed murres and 4 nests of common murres. The interval between the midpoints was the estimated nestling period. (2) The interval between first hatching and first fledging was calculated from Table 5.15. (3) The interval between cumulative median hatching and cumulative median fledging was calculated from Table 5.8.

At the time of departure of the field team in late August, a large proportion of common murres and kittiwakes were still in the nest. Cumulative median fledging percentages are thus too incomplete for calculations of nestling period for common murres. The best data sets for thick-billed and common murres were selected nest sites and interval between first hatching and first fledging, respectively. Mean nestling periods for thick-billed murre, common murre, and black-legged kittiwakes were 22, 24, and 36-37 days, respectively, in 1990 (Appendices C. 15a, C. 15b). Some thick-billed murre chicks seem to have fledged as early as 18 days, and few brooded chicks as long as 26 days. Mean nestling periods for murres were not different from those observed by Swartz (1966). The mean kittiwake nestling period seemed shorter than the nestling period observed at Cape Thompson in 1960 (44 days; Swartz, 1966) and at Cape Peirce in 1989 (46 days; Haggblom and Mendenhall, 1990), though the nestling period for kittiwake chicks is very variable (Swartz, 1966).

A southward movement of small flocks (9-32 birds) of mostly adult-plumaged kittiwakes which did not appear to be foraging was noted at Chariot on 1 September.

DISCUSSION

"Population counts--comparison between 1990 and previous years

Land-based Counts -- Means and standard deviations of land-based counts in 1990 and 1988 are compared in Tables 5.9-5.12. The standard deviations within plots between years were similar. Sample means within plots were thus compared assuming equal variances using a t-test applied to the differences between the means (Steel and Torrie 1960: 73-74). Within plots, numbers of thick-billed murres increased significantly between 1988 and 1990 on 6 plots, decreased on 3 plots, and on 11 plots there were no significant differences (Table 5.9). Common murres decreased significantly on 10 plots, increased on 4 plots, and on 8 plots there was no change (Table 5.10). Black-legged kittiwakes increased on significantly on 15 plots, decreased on 2 plots, and on two plots there was no change (Table 5.11). Chi-square tests were not significant for these frequencies of increases and decreases. Between-year differences for kittiwake nests were not tested on an individual plot basis.

Overall colony differences (across plots) were compared using the Wilcoxon signed rank test (Tables 5.9-5.12). For thick-billed and common murres, differences between 1988 and 1990 were not significant. Black-legged kittiwake numbers increased significantly between 1988 and 1990 at Colony 5 ($p < 0.05$) and at all colonies ($p < 0.01$), but differences for nests were not significant using the Wilcoxon test.

Differences between colony means were converted to percentages and also compared using a t-test for paired observations (Steel and Torrie 1960: 78-79). Black-legged kittiwake nests for all plots at all colonies combined were significantly higher in 1988 to 1990 (Table 5.12), but t-test differences between colonies for other species were not significant. Tests of log-transformed data may be better able to detect differences (Wanless et al. 1982).

Land-based counts of Swartz Plots -- Means of population counts on Swartz plots for all available years are summarized in Table 5.13. Statistical comparison between 1990 and 1988 was prevented by small sample size in 1988, but populations did not appear to have changed substantially since 1988. Other between-year differences were tested by the Wilcoxon signed rank test (Table 5.14). Two plots that were counted by boat in 1979 (5B and 5H) were omitted from the comparison. Murre counts on Swartz plots were not significantly different in 1990 when compared to 1979 and 1982, but were lower than in 1960 ($p < 0.01$). Murre populations thus appear to have remained stable since 1979, but were still only 36% of 1960 levels. A precipitous, unexplained decline apparently occurred between 1960 and 1977. According to Murphy et al. (1986) a series of years of low reproductive success and increased fishing pressure on pollock, an important winter food source for murres wintering in the

southwestern Bering Sea, are possible explanations for observed population declines at Bluff in Norton Sound in the 1960's and 1970's. Birkhead and Hudson (1977) found that population trends at colonies were correlated with juvenile survival.

In contrast, numbers of nests of kittiwakes increased on Swartz plots between 1960 and 1990. Increases in kittiwake numbers between 1990 and other years were non-significant (Table 5.14). Kittiwake numbers were apparently at their highest recorded levels at Cape Thompson in 1990, and were 2.6 times 1960 levels.

Boat-based Counts -- Boat count data from previous years, compiled by Fadely et al. (1989) (see their Appendix G), are presented for comparison with 1990 boat count data on selected plots in Tables 5.15-5.17. The data are also summarized by colony in Tables 5.18a and 5. 18b. Regressions, correlation coefficients, and Spearman rank correlation coefficients were calculated to detect trends (Tables 5.19a, 5. 19b).

Murre numbers have shown consistently negative regressions on year of census at individual colonies and at all colonies combined in the time period 1960 to 1990, but regressions were all non-significant. Regressions for murres at Colony 5 and kittiwakes at Colony 3 approached significance at the 0.05 level. Spearman rank correlations for murres were all negative, and correlations were significant at Colonies 1, 4, and at Colony 2, which exhibited the strongest declines. If the high population figures from 1960-61 are excluded from the analysis, correlations are still negative but insignificantly so, except at Colony 2. Murre numbers at Colonies 3, 4, and 5 appear to have been more stable since 1976-77. At all colonies combined, murre population levels in 1990 were comparable to other counts over the past 14 years. Pearson correlation analyses likewise show consistently negative trends, with significant negative correlations at Colonies 1 and 2 ($p < 0.01$) and at Colony 5 and all colonies combined ($p < 0.05$).

Except at Colony 5, regressions of kittiwake numbers on year were all positive but not significant. Spearman rank correlation coefficients were significant at Colonies 3 and 5, whereas Pearson correlation coefficients were all non-significant. In 1990 kittiwake populations were at their highest recorded levels at colonies 2, 3, and 4, and at all colonies combined. Populations seemed to be stable at Colony 2, increasing significantly at Colony 3, stable at Colony 4, and declining slightly at Colony 5.

Extrapolating from boat counts on our selected plots (Table 5.18a), murre populations at all Cape Thompson colonies in 1990 were 50.5% of 1960 levels. Using the 393,000 figure for total murres of both species at Cape Thompson in 1960 (Swartz, 1966) (instead of the figures in Springer et al. 1985, Table 5.4), the murre population in 1990 was approximately 199,000. Kittiwake populations in 1990, extrapolated from our boat counts (Table 5. 18b), were 142% of 1960 levels. Using the 26,000 figure for total kittiwakes at Cape Thompson in 1960 (Swartz, 1966), the kittiwake population this year was thus approximately 37,000.

Data from Fadely's land-based population plots established in 1988, Swartz's land-based plots, and boat-based counts appear to provide consistent estimates of murre population levels and trends. Boat-based and Swartz plots both show stable murre numbers since the mid- or late-1970's, and 1990 murre populations that are 50% and 36% of 1960 levels. Swartz and Fadely plots show no change in murre numbers since 1988. Data for kittiwakes are also complementary for the most part in that counts from boat, Swartz, and Fadely plots show increased numbers overall in 1990, with the exception that boat counts indicate a downward trend at
Colony 5.

Productivity

Within-year comparisons, 1990 -- Two estimates of productivity were obtained in 1990. Estimates derived 'from the Type I method (Tables 5.3 and 5.4) are significantly higher for all three species studied than those calculated by the May field method (Table 5.5). For thick-billed murres, common murres, and black-legged kittiwakes, Type I and May field estimates of productivity are 0.76 and 0.59, 0.86 vs 0.76, and 1.0 vs 0.33, respectively. The Type I method as used at Cape Thompson may have overestimated productivity in 1990 by about 29% for thick-billed murres, 13% for common murres, and 200% for kittiwakes on a per egg basis. The undetected loss of nests, eggs and/or chicks early in the season before regular monitoring was established was probably the major reason for the overestimate of productivity provided by the Type I method. Fadely et al. (1989) dealt with this problem for murres by assuming that 22% of eggs were lost before observations started, using data derived from the Semidi Islands. If the 22% correction is applied to Type I productivity estimate obtained for murres in 1990, estimates of thick-billed murre and common murre productivity in 1990 become 0.59 and 0.67, respectively, which are comparable with the estimates derived by the May field method.

The Mayfield method gives unbiased estimates of daily mortality when nest checks are frequent (Johnson 1979). Nests were checked at two-day intervals in 1990, and a concerted effort was made to obtain a "fix" on the reproductive status of nests on at least every second visit, i.e., every four days. The May field method also assumes that daily mortality rates of nests are homogeneous, i.e., remain constant throughout the period of observation and among nests. In the case of murres in 1990, the frequency of egg or chick losses did not appear to be concentrated in any particular period of the breeding cycle (Table 5.6), and May field method-derived estimates of mortality for murres appear unbiased. For kittiwakes, most chick mortality occurred in the first few days of nestling life, during the period July 25-30 in 1990 (Table 5.6). Therefore, average daily mortality for kittiwake chicks is probably biased upward to a certain extent, by the inclusion of early chick losses in the overall mean. Because of the high incidence of chick losses typical of kittiwakes in the first few days post-hatch, it would be more accurate to calculate survival for the first week of nestling life separately from the rest of the nestling period.

The May field method also assumes homogeneity among the nests observed, whereas survival rates of nests of novice and experienced breeders may differ. Without marked birds no information can be obtained on the possibly different reproductive performance of breeders of different ages.

Fadely et al. (1989:29) summarized dates of first hatching and first fledging for seabirds at Cape Thompson. Dates of first hatching of thick-billed murres in 1990 (21 July) and black-legged kittiwakes (18 July) were respectively the earliest and second earliest recorded in 9 years at Cape Thompson. First fledging dates--l3 July for thick-billed murres and 16 July for kittiwakes--were the second earliest and the earliest recorded in 8 and 4 years, respectively. The breeding season was therefore early in 1990. Early fledging was probably due to early egg laying before the arrival of the field team on July 4; growth rates of kittiwake chicks may also be higher in warm years when food is abundant or is available earlier inshore (Springer et al. 1987).

Food shortage and starvation did not appear to be a mortality factor for either murres or kittiwakes in 1990. The feeding rates obtained for murres in 1990 were comparable to those observed in 1988. In 1988 murre feeding rates on August 10 averaged 0.23 $\pm$ 0.15 feeds/chick/hour (Fadely et al. 1989), not significantly different from the overall rate of 0.19 $\pm$ 0.027 feeds/chick/hour in 1990. Our ability to detect differences was limited by the smaller sample size and relatively large standard error in 1988, however. At Copinsa y, Scotland, Slater (1980) observed common murres to feed chicks at the rate of 0.21 feeds per chick per hour.

That food supplies were favorable or adequate for nestling growth is indicated by the nestling periods observed in 1990, which were average for murres and relatively short for kittiwakes (Appendix C.15), by the early fledging dates for both murres and kittiwakes, and by the relatively high productivity rates (Table 5.5).

Sea temperatures were warm in the summer of 1990, as high as 15° C (Table 5.1), which is higher than the maxima of 10-11° C recorded in 1988 (Fadely et al., 1989). Prey fish populations may have been affected favorably by warm sea temperatures in 1990. Springer et al. (1987) found an abundance of sandlance (Ammodytes sp.) close to shore at St. Matthew Island during 1981, a "warm year".

Murre nest sites were chosen for monitoring productivity on the basis that eggs were observed. The bias against selecting failed murre nesting sites is real and problematical for the Type I method. The problem might at first have been minimal due to egg-laying being still in progress in early July (see Table 5.8 to back-date hatching frequencies). However, inclement weather during the second week in July, which precluded observations during the latter part of egg-laying, resulted in a very small initial sample of murre sites under observation. It was necessary to add to the sample of murres being monitored through much of July when an egg or chick was observed at a site for the first time. This may have

contributed to underestimation of early egg or chick losses resulting in too high an estimate of productivity. We attempted to minimize this bias by rejecting sites that were first observed after 26 July.

On the other hand, the exclusion of surviving murre chicks still in the nest at the end of the field season can exaggerate mortality when the Type I method is used. This compensatory effect did not greatly influence Type I method calculations for thick-billed murres, because relatively few (19 of 101) chicks under observation remained on the ledges on 29 August, or for kittiwake nests because most chicks had survived to 36 days or older, and nests were therefore assumed to have been successful. A large number and proportion of common murre chicks were still unfledged at the end of our field season, however.

An additional bias derives from the necessity of choosing birds that are observable for productivity monitoring. For visibility reasons, common murres especially were not selected for monitoring in 1990 if they were part of large groups. Sowl (1979) reported that eggs and chicks of birds not on crowded ledges suffer a higher mortality. In 1990, two instances of predation by glaucous gulls were observed to be directed at murres nesting singly, which did not enjoy the benefits of the common defence observed when gulls approached groups of murres.

Between-year comparisons--murres -- In 1988, productivity for murres was estimated by the Type 11 method as 0.058 chicks per adult censused on the plots (Fadely et al. 1989). In 1990, it was hypothesized that the Type I estimate of 1990 (chicks fledged per breeding site) might be adjusted using the k-factor obtained in this study to compare with the Type II estimate for 1988. Our k-factor was 0.59 breeding sites per adult, which results in adjusted estimates for 1980 of 0.43 chicks per adult for thick-billed murres and 0.53 for common murres. This is still an order of magnitude higher than the Type II estimate for 1988. The Type II method greatly underestimated productivity of murres not only because non-breeding birds were included in the denominator, but also because observers failed to detect many chicks that were being brooded and any that had just fledged (Mendenhall 1991).
A more reasonable estimate of murre productivity in 1988 was derived from "phenology plots" (presumably akin to the Type I method used in 1990). After a 22% correction for early chick loss in each year, both murre species had an overall breeding success of 0.47 chicks per breeding pair in 1988 (Fadely 1989:76), compared to 0.59 and 0.67 chicks per breeding pair of thick-billed and common murres, respectively, in 1990. Productivity in 1990 was therefore higher than in 1988. Murre productivity was not monitored at Cape Thompson before 1988.

Between-year comparisons--black-le~~ed kittiwakes -- Assuming that kittiwake productivity was estimated using similar methodology in previous years, the Type I method provided a comparable estimate of productivity. Table 5.20 compares components of productivity for black-legged kittiwakes in 9 years for which data are available at Cape Thompson. Kittiwake productivity was relatively high in 1990 for all components measured. Eighty-seven per cent of active nests fledged at least one young, and 1.0 young were fledged per nest (Table 5.4).

Productivity has equalled or exceeded 1.0 young per nest in 4 of nine years for which there are data, including in 1990. Productivity in Chukchi Sea colonies is consistently higher than elsewhere in Alaska (Hatch et al. in press).

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Table 5.1. Murre species ratios, Cape Thompson.

Colony	1990 land-based plots			1988 land-based plots			1960		
	TBMU[1]	COMU[2]	%TBMU	TBMU	COMU	%TBMU	TBMU	COMU	%TBMU
1							3,41(?	776[3]	81
2	233	40	85	418	505	45			
3	680	31	96	594	64	90	889	95	90
4	504	595	46	697	620	53	3,814[3]	5,173[3]	42
5	6,028	595	91	4,286	415	91	111,235[4]	28,402[4]	20
All	7,445	1,261	86	5,995	1,604	79	119,348	34,446	78

[1] Thick-billed murre.
[2] Common murre.
[3] Boat-based counts.
[4] Combination of land- and boat-based counts.

Table 5.2. K-factor calculations for murres, Cape Thompson, 1990. K-factor is number of breeding pairs (sites with egg) divided by total birds on plot.

Species	Plot	Date	Time	No. of breeders	Total birds	K-factor	Observer
TBMU[1]	5-6K'	8/6	1430	12	20	0.60	BES[2]
TBMU	5-8N '	8/6	1600	12	16	0.75	BES
TBMU	5-6K'	8/9	1606	15	18	0.83	BES
TBMU	5-2F'	8/2	1415	62	104	0.60	JE[2]
TBMU	5-3H'	8/2	1501	14	78	0.18	JE
TBMU	5-7L'	8/2	1520	29	79	0.37[3]	JE
TBMU	5-2F'	8/13	1410	70	131	0.53	JE
TBMU	5-3H'	8/13	1455	18	78	0.23	JE
TBMU	5-7L'	8/13	1520	23	60	0.38[3]	JE
TBMU	5-1Z	8/5	1220	14	47	0.30[3]	AMM[2]
COMU[1]	5-1Z	8/5	1300	5	20	0.25[3]	AMM
TBMU	5-1A	8/5	1400	9	30	0.30[3]	AMM
COMU	5-1A	8/5	1430	14	167	0.08[3]	AMM
TBMU	5-1C	8/5	1600	15	53	0.28[3]	AMM
TBMU	5-1A	8/7	1200	4	11	0.36	AMM
TBMU	5-1Z	8/5	1220	30	41	0.73	AMM
COMU	5-1Z	8/5	1300	14	18	0.78	AMM
TBMU	5-1A	8/5	1400	23	30	0.77	AMM
COMU	5-1A	8/5	1430	90	157	0.57	AMM
TBMU	5-1C	8/5	1600	39	53	0.74	AMM

Summary:

	Murre Spp.	TBMU	COMU
Mean	0.59	0.57	0.68
Standard deviation	0.21	0.22	0.15
n	13	11	2
Standard error	0.016	0.021	0.074
95% conf. int.	±0.035	±0.046	±0.32

[1] TBMU = Thick-billed murre, COMU = common murre.
[2] Observers: BES = Brian E. Sharp, JE = Joe Evanich, AMM = Alan M. Mcready.
[3] Bird of unknown breeding status included in the denominator, Data excluded from summary.

Table 5,3. Productivity of thick-billed and common murres at Cape Thompson in 1990.

	Thick-billed murre			Common murre		
Plot	No. pairs	No. fledged	Fledged/ pair	No. pairs	No. fledged	Fledged/ pair
4-1A'	5	4	0.80	2	2	1.0
4-1B'	17	10	0.59			
4-2C'	2	2	1.0			
4-4E'	2	0	0.0			
5-1A'	8	7	0.87	14	13	0.93
5-1C'	14	11	0.79			
5-12'	13	12	0.92	4	3	0.75
5-2F'	23	17	0.74			
5-3H'	7	6	0.86			
5-6K'	38	33	0.87	1	0	0.0
5-7L'	21	15	0.71	1	1	1.0
Mean	168	127	0.76[1]	22	19	0.86

[1] 0.7 if known losses between age 15 days and fledging are subtracted.

Table 5.4. Components of productively for black-legged kittiwakes, Cape Thompson, 1990.

Plot	Nests	Active Nests	No. Eggs'	Clutch Size[1,2]	Eggs hatched	Hatching success[3]	successful clutches[4]	Chicks fledged	Fledging success[5]	successful broods'	Productivity (chicks fledged/nest)	Chicks fledged per active nest
4-1A'	11	11	16	1.45	15	0.94	10	12	0.80	9	1.1	1.1
4-2C'	12	11	13	1.18	11	0.85	10	11	1.0	10	0.92	1.0
4-4E'	14	13	15	1.15	12	0.80	10	10	0.83	9	0.71	0.77
5-1A'	21	19	32	1.68	29	0.91	19	23	0.79	18	1.1	1.2
5-1C'	11	11	21	1.91	20	0.95	11	14	0.70	10	1.3	1.3
5-6K'	19	19	35	1.84	30	0.86	18	20	0.67	17	1.1	1.1
5-8N'	14	13	24	1.85	21	0.88	12	14	0.67	11	1.0	1.1
Total	102	97	156		138		90	104		84		
Overall'				1.61		0.88			0.75		1.0	1.1

[1] Figures are minima.
[2] Clutch size = eggs laid divided by active nests.
[3] Hatching success = eggs hatching divided by eggs laid.
[4] Clutches hatching at least one egg.
[5] Fledging succes = chicks fledged divided by eggs laid.
[6] Broods fledging at least one young.
[7] Numerator and denominator are totals across plots.

Table 5.5. Mayfield method-derived survival rates of eggs and chicks of thick-billed murres, common murres, and black-legged kittiwakes at Cape Thompson in 1990, estimated by the May field method.[1] Data in Appendix 12.

	Thick-billed murre	Common murre	Black-legged kittiwake
Daily survival rate of eggs	0,992	0,996	0.97
Daily survival rate of chicks	0.989	0.995 "	0,992
Incubation period[2] (days)	34	36	28
Survival rate over incubation period	0.75	0.86	0.44
Nestling period[3] (days)	22	24	36.5
Survival rate over nestling period	0.78	0.89	0.75
Survival rate over entire nesting period	0.59	0.76	0.33

[1] May field 1975.
[2] From Swartz.
[3] This study.

Table 5.6. Frequencies of observed egg and chick losses of murres and black-legged kittiwakes at Cape Thompson in 1990.[1]

	Egg Losses			Chick Losses		
Date	Thick-balled murre	Common murre	Black-legged kittiwake	Thick-billed murre	Common murre	Black-legged kittiwake
Jul 15-16	1					
17	1		2	6		
19			1			
21			2			
23			1			
25			5			7
27	3		1	1		4
29	1		1	1		5
31						1
Aug 1-2	2		1	1		3
4	2			1		
6	1					1
8				1		1
10				1		2
12				10		2
14			1	3	1	
16						1
18		1	1	2	2	
20						
22	1		1	1		
24	1					1
26						
28						2

[1] Some dates are actual; some dates are approximations (midpoints of internals).

Table 5.7. Feeding rates (food deliveries to chicks per hour) of murres, at Cape Thompson, August 1990. Data are given in Appendix 14.

Statistic	Common murre	Thick-billed murre	Murre spp.
Mean	0.17	0.26	0.19
Standard deviation	0.20	0.36	0.27
n	8	12	20
Standard error	0.025	0.030	0.013

Table 5.8. Cumulative hatching and fledging frequencies (%) of thick-billed murres, common murres, and black-legged kittiwakes at Cape Thompson in 1990.

	Hatching			Fledging		
Date	TBMU[1]	COMU[1]	BLKI[1]	TBMU[2]	COMU	BLKI[3]
Jul 18-19			20			
21	1		37			
23	11		77			
25	21	7	82			
27	42	14	91			
29	59	28	93			
31	72					
Aug 1-2	80		98			
4	87	36	100			
6	88	43				
8	92					
10						
12	95	50				
14	96	64		11		
16	98	79		26		
18		86		54	33	
20	99	100		76	67	
22	100			92		
24				97	100[4]	6
26						
28				99		56
30				100[4]		100[4]
n	95	14	65	101	3	16
Unfledged chicks				19	30	90

[1] TBMU = Thick-billed murre, COMU = Common murre, BLKI = Black-legged kittiwake.
[2] Fledgling murres first seen at sea on 8/15.
[3] Fledgling kittiwakes first seen at sea on 8/16.
[4] Fledging was not complete by our last observations on August 29, so frequencies calculated for fledging represent proportions of observations rather than of all fledglings in colony.

Table 5.9. Comparison of 1988 and 1990 means for counts of thick-billed murres on Fadely population plots at Cape Thompson.

			Difference between years		
Plot	1988 Mean	1990 Mean	Change	t-test	Wilcoxon test
2-3C	232	233	+1	ns[1]	
3-1A	130	171	+41	P<0.01	
3-2B	413	444	+31	ns	
3-2C	51	65	+14	ns	
4-1A	199	169	-30	P<0.05	
4-1B	146	103	-43	P<0.01	
4-2C	210	86	-124	P<0.01	
4-3D	103	110	+7	ns	
4-4E	39	36	-3	ns	
5-1A	31	31	0	ns	
5-1B	211	481	+270	P<0.01	
5-1C	24	54	+30	P<0.01	
5-1D	183	179	-4	ns	
5-2E	298	293	-5	ns	
5-2F	403	403	0	ns	
5-2G	276	351	+75	P<0.01	
5-3H	245	302	+57	P<0.01	
5-5J	898	907	+9	ns	
5-6K	561	555	-6	ns	
5-7L	319	413	+94	P<0.1	
5-8M	-[2]	1,249	.	-	
5-8N	837	810	-27	ns	
Colony 3			+22%[3]	ns	
Colony 4			-21%	ns	
Colony 5			+27%	ns	ns
All colonies (2-5)			+13%	ns	ns

[1] ns = not significant.
[2] No data in 1988.
[3] Percentage is mean of percentage changes on all individual plots, not ratio of pooled yearly means.

Table 5.10. Comparison of 1988 and 1990 means for counts of common murres on Fadely population plot Cape Thompson.

			Difference between years		
Plot	1988 Mean	1990 Mean	Change	t-test	Wilcoxon test
2-3C	39	40	+1	ns[1]	
3-1A	9	6	-3	P<0.05	
3-2B	55	25	-30	P<0.01	
3-2C	0	0	0	ns	
4-1A	92	106	+14	ns	
4-1B	82	58	-24	P<0.01	
4-2C	171	249	-78	P<0.01	
4-3D	43	35	-8	ns	
4-4E	232	147	-85	P<0.01	
5-1A	1	85	+84	P<0.01	
5-1B	219	248	+29	ns	
5-1C	1	5	+4	P<0.01	
5-1D	7	17	+10	P<0.01	
5-2E	33	0	-33	P<0.01	
5-2F	1	0	-1	ns	
5-2G	11	0	-11	P<0.01	
5-3H	0	0	0	ns	
5-5J	23	9	-14	P<0.01	
5-6K	7	4	-3	ns	
5-7L	93	68	-25	P<0.01	
5-8M	-[2]	157			
5-8N	19	-[2]	-17	P<0.01	
Colony 3			-29%[3]	ns	
Colony 4			-4%	ns	
Colony 5			+703%	ns	ns
All Colonies (2-5)			+396%	ns	ns

[1] ns = not significant.
[2] No data in 1988.
[3] Percentage is mean of percentage changes on all individual plots, not ratio of pooled yearly means.

Table 5.11. Comparison of 1988 and 1990 means for counts of black-legged kittiwakes on Fadely population plots at Cape Thompson.

			Difference between years		
Plot	1988 Mean	1990 Mean	Change	t-test	Wilcoxon test
2-3C	17	20	+3	P<0.05	
3-1A	6	8	+2	P<0.01	
3-2B	53	59	+6	P<0.05	
3-2C	4	5	+1	P<0.05	
4-1A	46	101	+55	P<0.01	
4-1B	34	22	-12	P<0.01	
4-2C	201	200	-1	ns[1]	
4-3D	44	66	+22	P<0.01	
4-4E	205	225	+20	P<0.01	
5-1A	32	50	+18	P<0.01	
5-1B	152	206	+54	P<0.01	
5-1C	12	18	+6	P<0.01	
5-ID	0	o	o	ns	
5-2E	90	o	-90	P<0.01	
5-2F	3	7	+4	P<0.01	
5-2G	0	80	+80	P<0.01	
5-3H	0	0	o	ns	
5-5J	91	111	+20	P<0.01	
5-6K	6	10	+4	ns	
5-7C	2	18	+16	P<0.01	
5-8M	102	110	+8	ns	
5-8N	31	36	+5	P<0.01	
Colony 3			+112%[2]	ns	
Colony 4			+33%	ns	
Colony 5			+699%	ns	P<0.05
All Colonies (2-5)			+423%	ns	P=0.01

[1] ns = not significant.
[2] Percentage is mean of percentage changes on all individual plots, not ratio of pooled yearly means.

Table 5.12. Comparison of 1988 and 1990 means for counts of black-legged kittiwake nests on Fadely population plots at Cape Thompson.

			Difference between years		
Plot	1988 Mean	1990 Mean	Mean	t-test	Wilcoxon test
2-3C	16	15	-1	.[1]	
3-1A	5	6	+1		
3-2B	50	38	-12		
3-2C	3	3	0		
4-1A	41	68	+27		
4-1B	30	11	-19		
4-2C	179	117	-62		
4-3D	41	38	-3		
4-4E	176	132	-44		
5-1A	28	33	+5	-	
5-1B	136	140	+40		
5-1C	10	13	+3	-	
5-1D	0	0	o	-	
5-2E	90	0	-90		
5-2F	4	3	-1		
5-2G	0	50	+50		
5-3H	0	0	o		
5-5J	77	78	+1		
5-6K	7	6	-1		
5-7L	0	12	+12		
5-5M	82	76	-6		
5-8N	32	25	-7		
Colony 5					ns
All Colonies (2-5)			+273%[2]	P<0.05	ns[3]

[1] Individual plot differences not tested.
[2] Percentage is mean of percentage changes on all individual plots, not ratio of pooled yearly means.
[3] ns = not significant.

Table 5.13. Means of population counts on Swartz plots counted from land at Colony 5, 1960-1990. Data for 1960-1988 from Fadely et al. (1989).

Species	Plot	1960	1979	1982	1988	1990
Murre spp.	5B	2,654	110[1]	912		1,795
	5G	4,267	1,835	1,991		1,638
	5H	4,275	580[1]	1,693		471
	5L	1,850	490	765	921	915
	5M	1,700	702	835	568	558
	5N	3,650	1,400	2,285		1,200
	5 0	3,050	835	826		818
	5P	3,600	940	1,191		1,353
	Total	26,808	7,792	11,243		9,675
Black-legged kittiwakes (birds)	5B		0[1]			287
	5C		45			53
	5H		6[1]			40
	5L		68		91	9
	5M		9		6	4
	5N		84			97
	5 0		7[1]			18
	5P		128			190
	5Q		32		31	36
	Total		379			742
Black-legged kittiwakes (nests)	5B	83	0[1]			196
	5G	19	24			24
	5H	0	5[1]			21
	5L	68	58		77	78
	5M	6	7		7	6
	5N	37	58			81
	5 0	9	5[1]			11
	5P	117	102			125
	5Q	15	29		32	25
	Total	354	288			915

[1] Boat based count; excluded from comparison between 1979 and 1990 (Table 14).

Table 5.14. Comparisons between means of land-based population counts on Swartz plots for murres and black-legged kittiwakes at Cape Thompson (Wilcoxon signed rank test).[1]

	Probability		
		Black-legged kittiwake	
Comparison	Murre spp	Birds	Nests
1990 VS 1982	n.s.[2]		
1990 Vs 1979	n.s.	n.s.	n.s.
1990 vs 1960	Decrease**[2]		Increase**

[1] Data from Table 13, except 1990 vs 1979 comparison excludes boat-based counts of plots 5B and 5H.

[2] n.s. = no significant change, ** = $p < .01$.

Table 5.15a. Boat counts of murres on selected plots at Colony 2, Cape Thompson, 1960-1990. Data for 1960-1982 from Fadely et al. (1989), Appendix G.

Plot	1960	1976	1977	1979	1982	1990
2F	780	430	847	580	505	642
2K	421	715		268		364
2L	3,172	1,322		1,645		1,937
2K+ 2L[1]			3,160		2,230	
2U	3,315	3,420	2,825	3,225	2,007	2,335
2V	4,575	3,890	3,347	3,930	2,405	2,503
2CC	1,500	500	1,162	1,565	1,220	1,110
2HH	320		277	306	510	112
21 I	160		157	212	192	317
2HH+ 2111		485				
Total	14,243	10,762	11,775	11,728	9,069	9,310

Table 5.15b. Boat counts of black-legged kittiwakes on selected plots at colony 2, 1960-1990. Data sources as Table 15a.

Plot	1960	1976	1979	1990
2F	381	241	311	389
2K	38	33		73
2L	587	249		614
2K+ 2L[1]			505	
2U	1,036	345	475	1,125
2V	449	185	372	686
2CC	20	11	18	92
2HH	17		48	152
21 I	0		8	48
2HH+ 2111		18		
Total	2,528	1,082	1,737	3,179

[1] Note: Plots were combined in some years; totals of columns are comparable.

Table 5.16a. Boat counts of murre spp. on selected plots at Colony 3, Cape Thompson, 1960-1990. Data for 1960-1982 from Fadely et al. (1989), Appendix G.

Plot	1960	1976	1977	1979	1982	1990
3A	84	176	152	120	121	208
3B	900	487	517	426	470	397
3C	100	550	480	305	195	188
3D	940	635	552	477	555	626
3E	620	530	564	395	502	531
3F	500	430	602	318	315	75
3P	1,400	1,300	1,332	1,290	1,297	1,270
3Q, 3R, 3S[1]	4,660	2,391	3,649	2,674	3,260	3,364
3V, 3W[1]	1,350	1,420	1,495	1,231	1,330	1,478
Total	10,354	7,919	9,343	7,236	8,045	8,137

Table 5.16b. Boat counts of black-legged kittiwakes on selected plots at Colony 3, 1960-1990. Data sources as Table 16a.

Plot	1960[2]	1961[2]	1976	1977	1979	1990
3A	o	0	0	0	2	8
3B	0	0	0	4	74	29
3C	18	24	20	35	52	80
3D	0	0	2		6	32
3E	73	56	90	73[3]	86	105
3F	0	13	17		21	38
3P	3	20	0	(-)[4]	29	50
3Q, 3R, 3S'	322	(-)[5]	296	256	515	623
3V, 3W[1]	50	55	97	115	58	105
Total	466	490	522	496	543	1,070

[1] Plots counted separately in 1960-1982; data combined by me for comparison with 1990.
[2] Nests x 1.4.
[3] In 1977 counts of plots D, E, F were lumped.
[4] Missing data point; mean of 1960-1979 (13) substituted in calculations.
[5] Missing data point; mean of 1960 (322) substituted in calculations.

Table 5.17a. Boat counts of murres unselected plots at Colony 5, Cape Thompson, 1960-1990. Data from prior years from Fadelyet al. (1989), Appending.

Plot	1960	1977	1979	1982	1988	1990
5AA	4,866	2,390	1,022	1,220	1,735	2,145
5DD	2,950	1,432	(645)[1]	1,115	1,010	1,938
5GG	7,650	3,697	984	2,550	2,560	3,245
5HH	12,100	5,235	2,865	4,947	4,015	4,625
5JJ	7,400	1,612	1,082	1,480	(1,300)[2]	1,029
5LL	1,175	1,010	687	935	960	945
5 0 0	6,000	2,352	1,255	2,257	1,710	1,826
Total	42,141	17,728	8,540	14,504	13,290	15,753

[1] Missing data point; plot 5DD was lumped with plot 5BB. 1977 count for BB subtracted.
[2] Missing data point; average of 1977-90 means substituted.

Table 5.17b. Boat counts of black-legged kittiwakes unselected plots at Colony 5, 1960-1990. Data source as Table 17a.

Plot	1960	1979	1988	1990
5AA	147	182	140	162
5DD	241	152	170	211
5GG	357	379	347	283
5HH	234	212	236	182
5JJ	27	24	(22)[1]	14
5LL	1	0	0	0
5 0 0	0	0	0	4
Total	1,007	949	915	856

[1] Missing data point; mean of 1960, 1979, and 1990 means substituted.

Table 5.18a. Summary of boat counts of murres, Cape Thompson, 1960-1990.

Colony	1960	1961	1976	1977	1979	1982	1988	1990
1[1]	4,186	4,061	2,175	2,470	2,441	2,402	-	1,559
2[2]	14,243		10,762	11,775	11,728	9,069	-	8,834
3[3]	10,354	·	7,919	9,343	7,236	8,045	-	8,137
4[1]	8,554	6,297	6,892	7,617	6,312	5,550	4,463	5,910
54	42,141		·	17,728	8,540	14,504	13,290	15,753
Total	79,478		-	48,933	36,257	39,570	-	40,193

Table 5. 18b. Summary of boat counts of black-legged kittiwakes, Cape Thompson, 1960-1990.

Colony	1960	1961	1976	1977	1978	1979	1982	1988	1990
1[1]									o
2[2]	2,528		1,082	-	-	1,737	-	-	3,179
3[3]	466	490	522	496	-	843	-	-	1,070
4[1]	3,541	4,088	1,369	2,042	2,789	2,858	3,232	3,637	5,567
54	1,007		·			949	-	915	856
Total	7,542					6,387			10,672

[1] Entire colony.
[2] Plots 2F, 2K, 2L, 2U, 2V, 2CC, 2HH, and 21 I (Table 15a).
[3] Plots 3A-3F, 3P, 3Q, 3R, 3S, 3V, and 3W (Table 16a).
[4] Plots 5AA, 5DD, 5GG, 5HH, 5JJ, 5LL, and 500 (Table 17a).

Table 5.19. Coefficients of regression, Pearson correlation, and Spearman rank correlation between year of census and boat counts of murres and kittiwakes at Cape Thompson.[1]

Species	Colony 1	2	3	4	5	Colonies 1-5
Kittiwakes						
Regression		15.5	17.6	1.9	-4.3	86.2
Correlation		0.21	0.81	0.17	-0.93	0.59
Rank correlation		0.40	0.94***	0.12	1.0**	-
Murre spp.						
Regression -	-87.4	-191.5	-83.0	-78.0	-933	-1453
Correlation	-0.97**	-0.94[8]”	-0.72	-0.69	-0.84”	-0.90”
Rank correlation	-0.79’	-0.94”	-0.31	-0.76”	-0.49	-0.60
Murre spp. (excluding 1960-61)						
Rank correlation	-0.40	-1.0″	0.51	-0.64	-0.10	- 0 . 2 0

[1] Data from Tables 18a and 18b.
[2] * P<0.05; ** P<0.01.

Table 5.20. Components of productivity in black-legged kittiwakes during 9 years at Cape Thompson.*

Colony	1960	1961	1976	1977	1978	1979	1982	1988	1990
No. nests	60	29	200	73	236	374		70	97
Clutch size	1.92	1.88	1.12	1.18	-	1.58	1.48	1.39	1.61
Hatching success[2]	0.65	0.41	-	0.90	-	0.94	-	0.72	0.88
Fledging success[3]	0.86	0.60	0.0	0.71	-	0.82	-	().33	0.75
Productivity	1.22	0.72	0.0	().64	0.50	1.1	1.15	0.31	1.0

[1] Data prior to 1990 summarized by Fadely et al. (1989).
[2] Eggs hatched/eggs laid.
[3] Chicks fledged/eggs hatched.
[4] Chicks fledged/nest.

CHAPTER 6. GENERAL DISCUSSION AND COMPARISON OF COLONIES

By Vivian Mendenhall

POPULATIONS

Population of murres and black-legged kittiwakes at Cape Peirce, Bluff, and Cape Thompson continued trends observed during the 1980's. Black-legged kittiwake numbers have been stable at all three colonies during the decade. More kittiwakes were present on plots at Cape Peirce and Cape Thompson in 1990 than in the most recent previous monitoring year Haggblom and Mendenhall 1991, this study--Fadely et al. 1989, Sharp, this study). There was no change in kittiwake numbers on plots at Bluff from 1989 to 1990 (Murphy 1991, this study). These increases were associated with higher breeding success at all three colonies in 1990 than in the most recent previous year. Inter-year fluctuations in breeding populations are typical of the variability that characterizes kittiwake numbers in Alaska, including populations whose overall trend is stable (Hatch et al. in press, Murphy et al. 1991, in press).

Populations of murres exhibited no significant trend at Bluff and Cape Thompson during the past decade. Common murre populations at Cape Peirce have declined significantly since 1985, with a 25% decrease in murres on plots between 1986 and 1989. Murre numbers increased again at Cape Peirce between 1989 and 1990, but it is too soon to tell whether this represents a reversal of the decline. It is important to continue monitoring murre populations at Cape Peirce in the near future.

Long-term trends in murre populations at the three colonies have differed. At both Cape Thompson and Bluff, murre populations monitored from offshore declined sharply before 1979 (Springer et al. 1985, Murphy et al. 1986). At Cape Peirce we are able for the first time to compare population estimates with those for the 1970's, both on land-based plots and from offshore. Murre numbers on land-based plots were slightly but significantly lower in 1990 than in 1976, but the trend across all years (1976 and 1985-1990) was not significant. Estimates of the size of the Cape Peirce population from offshore suggest that murres may have decreased at Cape Peirce from 1973 to 1990. However, numbers were estimated only approximately in both years; estimates in 1973 were made by units of several thousand, and precision of our estimate in 1990 was reduced by poor quality of photographs and lack of "ground-truth" correction factors. Conclusions about trends at Cape Peirce should therefore be deferred until we obtain reliable estimates with confidence limits.

There has been little long-term trend in black-legged kittiwake populations at Cape Thompson and Bluff. The principal change appears to have been a localized increase in the breeding population of Colony 2 at Cape Thompson. Similar shifts in the relative occupation of separate cliff areas appeared to have accompanied the decline in murres at Cape Thompson (Springer et al. 1985, Fadely et al. 1989).

Our evidence for long-term trends in kittiwake numbers at Cape Peirce is equivocal. Populations monitored on land-based plots increased moderately but significantly between 1976 and 1990, whereas numbers estimated from offshore declined between 1973 and 1990. At present we cannot say whether the discrepancy between trends on land-based plots and in offshore counts is due to plots that are unrepresentative of numbers in the colony as a whole, or to unreliable offshore counts. Plot censuses at Cape Peirce seem likely to be representative of trends in the colony as a whole. Plots cover a relatively large proportion of this colony, approximately 30%. Coverage of 8 to 30% was recommended by Harris et al. (1983) and Rothery et al. (1988). Plots also are well distributed throughout the colony. Kittiwake numbers on plots at Bluff, which comprise a smaller proportion of the total population, have "tracked" closely to numbers estimated for the colony as a whole (Figure 4.5). The possibility cannot be eliminated that population declines have occurred exclusively in areas outside the study plots, but this seems unlikely. It is more likley that offshore counts in 1973 and 1990 are unreliable for detection of moderate trends. Our current estimates of total kittiwake numbers at Cape Peirce are less precise than plot censuses and are subject to the uncertainties discussed above for murre counts. Analysis of trends in both species at Cape Peirce should be deferred until we obtain better estimates of colony size. The U.S. Fish and Wildlife Service is supporting continued development of offshore census methods at Cape Peirce in 1991.

In addition to censuses at Cape Peirce, we undertook the first counts in 15 years at major nearby colonies on the north shore of Bristol Bay: Cape Newenham, Bird Rock, and Shaiak Island. We estimated approximately 170,000 murres and 30,000 kittiwakes at the four colonies combined. Murre numbers over all colonies were similar to those estimated in 1973 (160,000), but black-legged kittiwakes in 1973 were estimated at less than 10% of the 1973 population (350,000). Most of the apparent decline took place at Cape Newenham and Bird Rock. Our estimates are least reliable for Bird Rock, but such a large difference between the two years suggests that a real decline has occurred, even though we are uncertain of its magnitude.

PRODUCTIVITY

Productivity of black-legged kittiwakes was higher at all three colonies than in the most recent year studied previously. At Cape Peirce the number of young fledged per nest (0.22) was the highest recorded in the 12 years studied. However, mean productivity at Cape Peirce is the lowest for any colony in Alaska that has been studied for 5 or more years (data in Hatch et al. in press). At Bluff and Cape Thompson the productivity in 1990 (0,37 and 1.0

chicks per nest respectively) was intermediate between the worst and best years; 1990 production was close to the long-term mean at Bluff and exceeded the mean at Cape Thompson (data from Hatch et al. in press). Condition at all three colonies were apparently better in 1990 than recently.

Productivity of murres at all three colonies was slightly higher than in the previous year studied. Murres apparently responded to the same improvement in conditions that benefitted kittiwakes. Inter-year variability in breeding success of murres in Alaska is moderate, whereas kittiwakes' productivity is highly variable at all colonies that have been studied (Springer et al. 1985, Baird 1986, Hatch and Hatch 1990, Hatchet al. in press, Murphy et al. in press).

Inter-year variations in breeding success of seabirds are strongly associated with fluctuations in the availability of food resources (Springer et al. 1984, 1985, Fadely et al. 1989, Springer and Byrd 1989, Hatch and Hatch 1990, Baird 1990). Successful breeding by cliff-nesting seabirds at Bluff and Cape Thompson has been associated with warm air temperatures in spring and early summer, early breakup of sea ice, and warm water temperatures (Springer et al. 1984, 1985, Murphy et al. 1986, in press). Apparently warm surface temperatures in these areas favor availability of preferred prey such as sand lance (Ammodytes hexapterus) in August when densities of other fish decline near the surface (Springer et al. 1984, Piatt et al. in press). Sea-surface temperatures measured offshore of Cape Thompson were 2°C warmer in summer of 1990 than in the less successful year of 1988 (Fadely et al. 1989; Sharp, this study). Feeding flocks of kittiwakes and other seabirds were seen frequently near Cape Peirce and Cape Thompson in 1990, in contrast with Cape Thompson in 1988 and Cape Peirce in 1989 (Fadely et al. 1989; Piatt et al. in press; Haggblom and Mendenhall, this study; Sharp, this study; Mendenhall, pers. ohs,). Conditions in 1990 apparently favored availability of fish prey that are needed by kittiwakes to rear young successfully. However, the moderate success of kittiwakes at Bluff, which was lower than predicted from warm spring weather in 1990, suggests that factors other than sea temperature may influence breeding success of northern Alaska seabirds in some years.

Predation on both kittiwakes and murres has been reported by various observers at the three colonies in this study. Common ravens (Corvus corax) exert the highest predation pressure on cliff-nesting seabirds in western Alaska, followed by large gulls (glaucous-winged gulls Lams glaucescens at Cape Peirce and Bluff, glaucous gulls L. hyperboreus at Cape Thompson). Predation pressure differs between murres and kittiwakes, between stages in reproduction, and among the three colonies. Loss of black-legged kittiwake eggs and chicks to ravens was continuous throughout the season at Cape Peirce in all years studied, and gulls also preyed on kittiwake chicks in some years. Murre eggs at Cape Peirce were taken by both predators, but only a few murre chicks were taken by ravens (Petersen and Sigman 1977; van Hulsteyn and Kavanaugh 1987; O'Daniel 1988; Haggblom and Mendenhall 1991, this study). Kittiwake adults also have been killed and eaten by ravens at Cape Peirce on two occasions (Parmelee and Parmelee 1988; Haggblom and Mendenhall, this study). At Bluff, ravens were the principal predators on murre eggs and chicks, and gulls took lesser numbers;

ravens preyed on kittiwake eggs and gulls on both eggs and chicks (Biderman et al. 1978; Murphy 1991, this study). At Cape Thompson the only predation reported on kittiwakes has been taking of eggs by gulls (Swartz 1966), but both ravens and gulls take eggs and chicks of murres (Swartz 1966; Springer and Roseneau 1978; Sharp, this study).

Mammalian predators also accounted for some losses of seabirds. Red foxes V. vulpes took eggs and chicks of both species at Cape Peirce (Haggblom and Mendenhall 1991, this study). Murre nests at Cape Thompson have been raided by short-tailed weasels (Mustela ermines; Fadel y et al. 1989) and even by an acrobatic grizzly bear (Ursus arctos; Springer and Roseneau 1978). Mammals appear to exert less predation pressure at these colonies than avian predators, however (in contrast to severe impacts of mammals on seabirds when they have been introduced to islands; Jones and Byrd 1979, Petersen 1982).

Is predation an important limiting factor of seabird reproductive success in western Alaska? A conclusive answer needs to start with quantification of predation pressure, but this has been done in only a few cases. Biderman et al. (1978) estimated that ravens preying on common murres took only 5% to 6% of all eggs and a smaller number of chicks, based on remains of prey found near raven nests. Glaucous gull predation on thick-billed murres was estimated to account for a similar proportion (4%) of murre eggs laid at Prince Leopold Island in the Canadian Arctic, and 3% of murre chicks (Gaston and Nettleship 1981), based on both prey remains and rates of attack. However, predation represented the most important source of reproductive failure at Prince Leopold Island (Gaston and Nettleship 1981). Gulls caused 46% and 87% of kittiwake chick losses at Middleton Island in two years (Roberts 1988). Predation pressure on various other seabird colonies in Alaska and elsewhere has been qualitatively estimated to range from slight (Cullen 1957, Hatch and Hatch 1990) to major, although severe impacts may be restricted to localized areas (Maunder and Threlfall 1972; Barrett and Runde 1980; Nysewander 1986; Irons 1988; Irons, pers. comm.).

Factors that determine predation pressure and its role in reproductive success at a seabird colony may include availability of prey (for either seabird or predator), species of predator present, densities of nesting birds and predators, and characteristics of the cliff habitat. These factors probably interact with each other in complex ways.

Differences in intensity of predation and in species of predators may be explained in part by cliff habitats. In several colonies, predation on kittiwakes by gulls was most severe where broad ledges or gentle terrain provided adequate landing sites nearby (Barrett and Runde 1980, Galbraith 1983, Bonfield 1986). Some steep cliffs are almost free of avian predation (Cullen 1957). In other places gulls are capable of attacking nests on cliffs while in flight (Gaston and Nettleship 1981, Bonfield 1986), although this strategy may be confined to a few specialist individuals (Gaston and Nettleship 1981). Ravens in eastern Canada attacked kittiwakes on steep cliffs from the air (Montevecchi 1979), and ravens appeared to be more agile than gulls at out-maneuvering murres on narrow ledges at Bluff (Biderman et al. 1978). The apparent predominance of predation by ravens over that of gulls at Cape Peirce and Bluff may be due to the relatively steep cliffs occupied by seabirds in both places.

It has been suggested that steep cliffs and narrow ledges can prevent avian predation on kittiwakes (Cullen 1957, Roberts 1988). However, steepness may be effective only against some gull species. Ravens are rare or absent in eastern England (Peterson et al. 1967) and on Middleton Island (Bonfield 1986), where kittiwakes were protected by steep cliff, whereas ravens easily attacked kittiwakes and murres on steep cliffs at Bluff (Biderman et al. 1978). Even glaucous gulls attacked murres on the steepest cliffs of Prince Leopold Island (Gaston and Nettleship 1981). Predation pressure on murres was lower in parts of a colony where birds were densely grouped than in looser clusters, because the combined threats of several murres were capable of repelling gulls (Birkhead 1977, Gaston and Nettleship 1981). Common murres were better protected on wide ledges than on narrow ledges that on accommodated only a single row of birds (Birkhead 1977). The steepness and structure of cliff habitat that provide optimal protection from avian predators probably differ among species of cliff-nesting seabirds.

Predation pressure probably varies with the number of predators present, at least at relatively low densities of predators. Cliff-nesting seabirds on the Pribilof Islands have been subject to little or no avian predation. A few pairs of glaucous-winged gulls nest there, but ravens have been absent for most years of seabird studies. One or two pairs of ravens were seen on both St. George and St. Paul in 1990 and 1991 and were seen carrying seabird chicks in 1991; however, predation pressure was still very low (L. Fairchild, pers. comm.). Both ravens and glaucous-winged gulls have been reported to defend portions of seabird colonies as territories, (Biderman et al. 1978, Roberts 1988), and this would limit numbers of predators in the colony.

It is important to know whether predation pressure on murres and kittiwakes, even where it accounts for large losses of eggs or young, is ultimately dependent on other factors such as availability of food (Hatch et al. in press). Predation pressure by ravens or gulls appeared lower at several colonies in years when food for kittiwakes apparently was abundant (Nysewander 1986, O'Daniel 1988, Fadely pers. comm.). Kittiwakes may be more susceptible to predation on their eggs or chicks in years of food scarcity, when they more frequently desert the eggs or chicks for varying periods of time, allowing predators better access to the nest (Hatch et al. in press). At some colonies predators are not able to dislodge seabirds from their nests and can only rob pairs that leave their eggs unattended (gulls at Bluff and Cape Peirce -- Biderman and Drury 1978, Haggblom and Mendenhall, this study; gulls and ravens on the Semidi Islands -- Hatch and Hatch 1990). However, predators routinely pull kittiwakes or murres off their eggs or chicks at other colonies. Ravens forced birds off their nests frequently at Bluff and Cape Peirce (Biderman and Drury 1978; Haggblom and Mendenhall 1991, this study; Murphy 1991, this study), and gulls did the same at Middleton Island (Bonfield 1986, Roberts 1988), Skomer in Britain (Birkhead 1977) and Prince Leopold Island (Gaston and Nettleship 1981). In colonies where predators are able to force seabirds off their nests, predation may reduce reproductive success even in years when food is abundant. It is possible that even forcible predation is modified by food resources; kittiwakes on Middleton Island seemed more successful in defending their nests against gull attacks in a year when food was abundant (B.S. Fadely, pers. comm.). It should be

distinguished, however, whether predation pressure changed due to behavior of the prey or the predator. Kittiwakes may have become more tenacious on their nests because of improvement in their foraging success, or the gulls may have been less persistent because they benefitted from the same prey (which are shared by both species at some colonies in the Gulf of Alaska; Baird 1986, Nysewander 1986).

The factor responsible for most variation in reproductive success of seabirds in western Alaska is probably the food resource, as has been found in other areas. Predation probably also limits reproductive success in most years at colonies such as Cape Peirce and Bluff, where avian predators are numerous and are able to force seabirds off their nests. The roles of food, predation, and other factors should be studied further at Bluff and Cape Peirce, where predator behavior is similar but kittiwake productivity is very different. Better understanding of factors that limit seabird productivity in western Alaska is needed if we are to identify impacts that development or environmental change may have on populations of seabirds.

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APPENDICES

Appendix A-1. Replicate population counts of black-legged kittiwakes (nests and numbers) and common murres (numbers), plots 47 through 19-2, Cape Peirce, AK, 1990.

Species	Date (1990)	Plot number 47 nests	47 numbr	30 nests	30 numbr	26 nests	26 numbr	25 nests	25 numbr	24 nests	24 numbr	23 nests	23 numbr	22 nests	22 numbr	82 nests	82 numbr
Black-legged kittiwakes	21 Jun	9	6	21	26	12	13	0	0	0	0	8	8	26	32	2	2
	24 Jun	9	12	21	32	13	8	0	0	0	0	8	7	26	58	0	0
	27 Jun	11	11	20	40	10	14	0	0	0	0	8	11	27	67	0	0
	29 Jun	11	11	20	14	8	2	0	0	0	0	0	0	22	8	0	0
	1 Jul	10	6	20	33	9	15	0	0	0	1	8	15	28	77	0	1
	6 Jul	9	2	20	21	8	6	0	0	0	0	8	4	23	22	0	0
	9 Jul	8	7	25	26	9	3	0	0	0	0	8	6	29	30	0	0
	11 Jul	9	5	20	20	9	3	0	0	0	0	8	5	25	35	0	0
	14 Jul	9	9	20	25	7	3	0	0	0	0	0	0	23	28	0	0
	16 Jul	9	11	20	40	7	14	0	0	0	0	0	13	20	83	0	0
Common murres	21 Jun		0		3		0		0		0		21		31		4
	24 Jun		0		0		0		0		0		0		0		0
	27 Jun		0		0		0		0		0		0		11		0
	29 Jun		0		0		0		0		0		0		0		0
	1 Jul		0		0		0		0		0		0		13		0
	6 Jul		0		0		0		0		0		0		16		0
	9 Jul		0		0		0		0		0		2		8		0
	11 Jul		0		9		0		0		0		13		23		0
	14 Jul		0		10		0		0		0		15		46		2
	16 Jul		0		5		0		0		0		37		45		26

Species	Date (1990)	44 nests	44 numbr	21 nests	21 numbr	40 nests	40 numbr	19-7 nests	19-7 numbr	19-6 nests	19-6 numbr	19-1 nests	19-1 numbr	19-5 nests	19-5 numbr	19-2 nests	19-2 numbr
Black-legged kittiwakes	21 Jun	28	35	4	6	10	7	0	0	0	0	26	24	31	35	90	110
	24 Jun	39	50	3	7	10	8	0	0	0	0	26	21	34	35	87	89
	27 Jun	38	49	4	15	11	17	0	0	0	0	23	8	31	23	77	60
	29 Jun	30	5	4	0	8	4	0	0	0	0	26	14	30	17	71	66
	1 Jul	36	52	4	14	10	17	0	0	0	0	26	20	34	27	90	87
	6 Jul	32	19	4	6	10	8	0	0	0	0	26	15	36	29	79	79
	9 Jul	37	27	4	2	10	10	0	0	0	0	26	24	32	34	94	93
	11 Jul	35	34	5	8	9	7	0	0	0	0	24	13	34	37	81	84
	14 Jul	31	21	0	1	5	2	0	0	0	0	23	13	32	26	78	82
	16 Jul	38	58	0	23	5	17	0	0	0	0	25	0	25	21	58	56
Common murres	21 Jun		2		20		43		23		20		0		0		71
	24 Jun		0		0		22		40		16		0		1		44
	27 Jun		0		0		28		30		23		0		0		54
	29 Jun		0		0		27		30		17		2		1		57
	1 Jul		0		0		34		30		21		1		0		61
	6 Jul		0		13		34		46		23		2		1		89
	9 Jul		0		5		26		37		22		2		1		70
	11 Jul		0		21		39		45		27		3		1		82
	14 Jul		0		29		40		33		21		1		0		119
	16 Jul		0		39		50		39		18		0		0		69

Appendix A-2. Replicate population counts of black-legged kittiwakes (nests and numbers) and common murres (numbers), plots 19-3 through 29-1, Cape Peirce, AK, 1990.

Species	Date (1990)	19-3 nests	19-3 numbr	19-4 nests	19-4 numbr	42 nests	42 numbr	45 nests	45 numbr	46 nests	46 numbr	43 nests	43 numbr	31 nests	31 numbr	10 nests	10 numbr
		Plot number															
Black-legged kittiwakes	21 Jun	0	0	43	48	45	62	443	493	54	60	77	85	135	143	60	58
	24 Jun	0	0	32	33	105	55	370	389	54	80	74	85	132	148	59	57
	27 Jun	0	0	30	29	90	41	449	464	62	61	85	85	136	160	59	66
	29 Jun	0	0	33	32	93	44	242	243	62	54	68	66	127	123	56	52
	1 Jul	0	0	35	35	119	55	404	410	64	61	83	80	130	168	59	68
	6 Jul	0	0	38	41	105	46	372	349	61	54	88	72	131	123	56	56
	9 Jul	0	0	45	42	94	37	348	293	67	63	78	70	125	116	56	52
	11 Jul	0	0	38	42	113	52	484	473	65	66	84	86	125	133	56	57
	14 Jul	0	0	34	35	91	44	315	263	58	50	68	56	125	125	54	51
	16 Jul	0	0	32	30	100	39	260	153	55	48	77	57	120	174	55	63
Common murres	21 Jun		164		15		157		1310		0		69		264		0
	24 Jun		107		15		169		1491		0		54		211		0
	27 Jun		93		16		146		1617		0		0		242		0
	29 Jun		116		14		115		1180		0		4		192		0
	1 Jul		178		19		124		1407		0		46		254		0
	6 Jul		190		23		181		1925		0		71		227		0
	9 Jul		182		18		96		1311		0		57		225		0
	11 Jul		201		16		145		1904		0		65		264		0
	14 Jul		180		23		142		1701		0		68		217		0
	16 Jul		180		8		136		1870		0		76		272		0

Species	Date (1990)	20-1 nests	20-1 numbr	20-2 nests	20-2 numbr	20-3 nests	20-3 numbr	20-4a nests	20-4a numbr	20-4b nests	20-4b numbr	20-4c nests	20-4c numbr	20-5 nests	20-5 numbr	29-1 nests	29-1 numbr
Black-legged kittiwakes	21 Jun	45	49	0	1	122	135	245	258	161	164	81	84	100	102	3	7
	24 Jun	05	114	0	0	132	143	267	310	166	201	80	89	109	119	19	23
	27 Jun	90	65	0	0	117	112	235	232	142	143	80	78	89	86	26	43
	29 Jun	93	63	0	0	120	113	214	212	138	137	76	75	88	88	26	24
	1 Jul	119	132	0	0	138	148	268	286	146	168	78	85	103	110	32	140
	6 Jul	105	95	0	0	130	125	261	262	160	160	88	89	110	111	30	30
	9 Jul	94	92	0	0	141	131	231	221	158	155	85	83	102	100	31	25
	11 Jul	113	121	0	0	144	149	270	294	175	197	91	104	116	124	30	53
	14 Jul	91	77	0	0	129	117	233	232	158	158	85	85	108	109	30	23
	16 Jul	100	98	0	0	127	125	261	274	190	186	85	87	121	120	25	35
Common murres	21 Jun		212		0		332		820		240		335		278		20
	24 Jun		218		0		227		765		180		374		290		102
	27 Jun		270		0		290		962		249		403		367		144
	29 Jun		209		0		231		762		167		313		297		116
	1 Jul		123		0		270		924		237		374		367		164
	6 Jul		266		0		284		951		227		402		341		138
	9 Jul		251		0		255		873		246		384		380		139
	11 Jul		254		0		283		1033		258		452		383		161
	14 Jul		227		0		285		1034		258		419		438		148
	16 Jul		280		0		289		978		268		435		425		178
									Murres		9,102		2,331		3,891		
									BLKi		2,581		1,469		859		

Appendix A-3 Replicate population counts of black-legged kittiwakes (nests and numbers) and common murres (numbers), plots 29-2 through 32-1, Cape Peirce, AK, 1990.

Species	Date (1990)	Plot number 29-2 nests	29-2 numbr	8 nests	8 numbr	7 nests	7 numbr	6 nests	6 numbr	5 nests	5 numbr	32 nests	32 numbr	32-1 nests	32-1 numbr
Black-legged kittiwakes	21 Jun	112	115	104	121	51	56	30	32	133	164	0	0	0	0
	24 Jun	118	149	110	140	55	68	25	26	137	180	0	0	0	0
	27 Jun	120	162	107	145	57	67	25	26	119	163	0	0	0	0
	29 Jun	96	54	92	67	55	65	22	6	120	152	0	0	0	0
	1 Jul	118	194	106	138	51	73	24	32	122	176	0	0	0	0
	6 Jul	112	111	102	95	54	60	22	12	120	151	0	0	0	0
	9 Jul	126	100	96	99	57	59	24	2	131	86	0	0	0	0
	11 Jul	120	194	99	124	55	73	22	41	120	216	0	0	0	0
	14 Jul	100	13	95	97	53	52	20	6	100	84	0	0	0	0
	16 Jul	100	141	99	178	54	71	22	34	120	178	0	0	0	0
Common murres	21 Jun		177		223		105		0		53		0		0
	24 Jun		170		220		138		0		190		0		0
	27 Jun		220		191		144		0		120		0		0
	29 Jun		157		172		124		0		64		0		0
	1 Jul		324		242		161		0		92		0		0
	6 Jul		167		217		142		0		105		0		0
	9 Jul		196		180		105		0		59		0		0
	11 Jul		281		277		181		1		143		0		0
	14 Jul		147		208		145		0		75		0		0
	16 Jul		206		243		183		2		123				

Appendix A-4. Population counts at Cape Peirce, 1976: data selected for comparison with 1990 counts. On days when more than one count was made between 1000 and 1900, their mean was used as estimate for day. (Source: M.R. Petersen, unpublished.)

	Plot																	
	19-3			19-4			20-2			20-3			20-4a			20-4b		
Date	Time[1]	BLKI[2]	COMU[2]	Time	BLKI	COMU	Time	BLKJ	COMU	Time	BLKI	COMU	Time	BLKJ	COMU	Time	BLKI	COMU
15 Jun	10IXJ	o	492	1000	73	201	1200	15	4	12m	202	662	1200	33	188	1200	58	152
18 Jun	1200	o	437	12(XJ	57	18	1300	26	0	1400	177	723	13al	75	83	1300	33	172
23 Jun	1100	o	425	1100	38	8	1200	13	0	1200	202	717	12rNJ	41	407	1200	72	160
27 Jun	1100	0	366	1100	38	41	1300	33	0	13m	178	577	1300	65	69	1300	56	178
30 Jun	11(XI	o	311	1100	82	73	1200	11	2	1200	181	509	12CHI	25	322	1200	76	148
6 Jul	1100	o	283	1100	17	22	1200	10	3	1200	152	502	1200	17	231	1200	41	111
9 Jul	1100	0	363	11(KI	14	13	1200	8	0	1200	.146	588	I 2(KI	25	398	1200	63	142
13 Jul	1200	0	402	1200	28	19	1200	8	0	1200	142	684	1300	22	383	1300	35	184
21 Jul	1100	0	473	1100	50	26	1200	48	0	1200	186	612	1200	16	451	1200	72	160
23 Jul	1700	o	306[3]	1700	45	19	1800	13	0	1800	228	418	1800	53	117	1800	46	205
26 Jul	1100	0	431	1100	28	6	1200	18	28	1200	176	641	1200	18	481	12(XJ	69	153

Appendix A-4. Continued.

	Plot																	
	20-4c			20-5			21			22			23			24		
Date	Time	BLKI	COMU	Time	BLKI	COMU	Time	BLKI	COMU	Time	BLKI	COMU	Time	BLKI	COMU	Time	BLKI	COMU
15 Jun	1200	45	186	1200	106	606	1000	29	133	1000	28	100	1000	38	345	1000	2	0
										1900	28	57	1900	33	229	1900	2	0
18 Jun	1300	55	213	1300	139	527	1100	113	119	1100	29	19	1100	25	235	1100	9	0
										1600	31	82	1600	27	286			
23 Jun	1200	68	211	1200	119	543	1000	105	109	1100	31	83	1000	23,24[7]	313,256[7]	1000	5	0
										1800	32	87	00	25,37[7]	248,206[7]			
													00					
27 Jun	1300	35	214	1300	113	477	1000	100	107	1000	34	84	1000	28	251	1000	3	0
										1600	24	78	1391	21	342	1600	2	0
30 Jun	1200	41	190	1200	106	503	1000	55	100	1000	32	69	1000	28	266	1000	8	0
										1600	23	70	1600	18	211	1600	1	0
6 Jul	1200	25	105	1200	91	361	1000	17[4]	62[4]	1100	20	53	1000	19	251	1600	1	0
										1700	22	72	00	23	255			
9 Jul	1300	25	182	1300	72	278	1011	24.5[5]	130	1000	19	93	1000	20	301	1600, 1000	1,4[8]	0,0[8]
13 Jul	1300	29	180	1300	58	537	1100	32	65	1000	17	75	1000	20	244	1000	4[9]	0[9]
										1600	15	71	1600	19	246			
21 Jul	1200	19	269	1200	75	488	1000	109	139	1000	34	104	1000	30	305	1000	4	0
										1600	30	91	1600	28	263	1600	3	0
23 Jul	1800	19	323	1800	137	439	1700	65	38[6]	1000	29	19	1000	30	273	1000	4	0
										1600	29	49	1700	21	281	1700	1	0
26 Jul	1200	43	184	1200	92	521	1000	68	71	1000	26	50	1000	32	252	1000	5	0
										1600	29	86	1600	26	293	1600	3	0

Appendix A-4. Continued.

	Plot								
	25			26			28		
Date	Time	BLKf	COW	Time	BLKf	COMU	Time	BLKI	COMU
15 Jun	1000	o	56	1000	56	6	1900	2	36
	1900	0	22	00	56	2			
18 Jun	1100	0	44	1100	50	3	1100	2	60
	1600	0	33	1500	47	0	1700	2	51
23 Jun	1000	0	56	1000	55	4	1100	1	46
	1800	0	25	1800	58	0	1800	2	35
27 Jun	1000	0	42	000	41	0	1000	2	29
				1100	36	0			
	1600	0	26	1600	48	0	1600	2	43
30 Jun	1000	0	46	1100	37[10]	0[10]	1000	2	53
	1600	0	29	1600	39[10]	3[10]	1600	2	47
6 Jul	1000	0	33	1000	14	0	1100	2	41
	1600	0	25	1600	29	0	1700	2	46
9 Jul	1000	0	51	10XI	14	0	1000	2.2”	63
	1600	0	28	16(Q	21	0			
13 Jul	1000	0	49	1000	20	3	1000	2	53
	1100	0	24	1200	8	0	1600	3	44
				1600	18	0			
21 Jul	1000	0	39	1000	59	0	1000	3	62
	1600	0	20	1600	40	0	1600	3	59
23 Jul	1000	0	43	1000	40	0	1000	2	57
	1700	0	21	1700	32	0	1600	2	39
26 Jul	1000	0	46	1000	40	1	1000	3	57
	1600	0	24	1600	27	0	1600	2	49

[1] Count was made during the hour following the time listed.
[2] BLKf = black-legged kittiwake, COMU = common murre.
[3] Plot 19-3, 23 July no counts for subplots 1 and 2; used counts for 22 July.
[4] Plot 21,6 July: no count; used count for 7 July.
[5] Plot 21, 9 July: no count for kittiwakes; used mean of counts for 6 and 13 July.
[6] Plot 21, 23 July: no count; used count for 22 July.
[7] Plot 23, 23 June: no count; used mean of counts for 22 and 24 July.
[8] Plot 24, 9 July: no count; used mean of counts for 6 and 12 July.
[9] Plot 24, 13 July: no count; used count for 12 July.
[10] Plot 26, 30 June: no count; used count for 29 June.
[11] Plot 28 9 July: no count for BLKI; used mean of counts for 6 and 13 July.

Appendix C, A.1. Location of Swartz population plots.

5B: All of cliff face visible from OP 5-1. In 1990 included the

Appendix C.2. Cape Thompson weather, 1990.

Date	Air temperature (°F) Min	Air temperature (°F) Max	Sea temperature (°C)	Wind (gusts) (mph)	Rain	Sky condition
July 4	[1]	75-80		0-5	0	Clear, sun
5		75-80		0-5	0	Clear, sun
6		75-80		0-5	0	Clear, sun
7	43	58			+	Cloud
8	36	67		18(25)	o	Clear
9	40	71		0-3	0	Fog-clear
10	35	66		5-8	0	
11		50		SE 15-18		
12	44	48		S 15	+	Fog
13				S 20	+	Fog
14	41	51		W 10	o	Clear
15	40	50	9	S 20	+	Cloud, fog
16					+	Clear, cloud
17	44	50		s 6-8	+	Cloud
18	41	57			+	Cloud
19	50	52		5-20	+	Fog
20	48	49		S 8-10	+	Fog
21	48	62	9.5	S 2-5	0	Clear, sun
22	41	67		NW 5	0	Clear, sun
23	48	72		NW 5-10	0	Clear, sun
24	64	69		N 15-20	0	Clear, sun
25	50	69		N 5-10	0	Clear, sun
26	50	50	9.5	N 20-30 (40)	0	Clear, sun
27	58	59		N 20-30	0	Clear, sun
28	58	79		N 10	0	Clear, sun
29	44	74		0-5	0	Clear, sun
30	54	74		0-5	0	Clear, sun
31	48	78		N 0-5	0	Clear, sun

Appendix C.2. Continued.

Date	Air temperature (°F) Min	Max	Sea temperature (“c)	Wind (gusts) (mph)	Rain	Sky conditon
Aug 1	45	71	15	0-5	0	Clear, sun
2	48	68		0-1o	0	Clear, sun
3	46	66		N 0-10	0	Clear, sun
4	52	64		N 0-10	0	Clear, sun
5	43	76	12	NE 0-10	0	Clear, sun
6	53	74		NE O-5	0	Haze, sun
7	53	70	10	NE 5-10	0	Smoke, sun
8	46	69	13	NE 5-10	0	Clear, sun
9	50	64		NE 10-15	0	Clear, sun
10	45	70		0-2	0	Clear, sun
11	48	81	12	NE O-5	0	Clear, sun
12	60	72		SE 5-9	+	Cloud, smoke
13	55	65		SE 5-10	0	Smoke, cloud, sun
14	52	60		s 5-1o	+	Smoke
15	48	58	14.5	SE 0-2	+	Cloud
16	50	63		SE 0-10	0	Cloud
17	54	68		SE 0-5	0	Cloud, smoke, clear
18	49	64		Sw o-5	0	Cloud 40%
19	49	60		E 10-20 (30)	0	Clear, sun
20	44	60	(14,5)	NW O-5	0	Cloud 85%
21	46	61	13	NE O-5	+	Cloud
22	57	64		E O-5	+	Cloud
23	50	57		s o-5	0	Cloud
24	50	58		SE 5-8	0	Cloud 70%
25	48	62		E 10-15 (40)	+	Cloud
26	46	52		W 25-30	+	Cloud
27	40	44		NW 15-20 (30)	+	Cloud
28	41	54		5-1o	+	Cloud
29		51		NE 10-15	+	Cloud
30	40				0	Clear
31					0	Clear

[1] Blank = no data.

APPENDIX 3A . CENSUS DATA FOR BLACK-LEGGED KITTIWAKES, 1990

Plot	Date	Time	Birds	Nests
2-3C	12 Jul	1300	13	12
	8 Aug	1710	26	18
2-3D	8 Aug	1743	35	17
3-1A	8 Jul	1430	6	6
	11 Jul	1425	6	6
	17 Jul	1650	7	6
	17 Jul	1707	7	6
	18 Jul	1530	7	6
	20 Jul	2315	10	6
	23 Jul	1320	8	6
	26 Jul	1845	5	5
	29 Jul	1610	12	6
	5 Aug	2105	8	6
3-2B	8 Jul	1415	71	65
	11 Jul	1443	54	43
	17 Jul	1743	55	40
	17 Jul	1717	51	40
	18 Jul	1540	43	42
	20 Jul	2335	59	29
	23 Jul	1330	48	29
	26 Jul	1810	61	31
	29 Jul	1635	71	28
	5 Aug	2125	73	32
3-2C	8 Jul	1400	3	3
	11 Jul	1425	4	3
	17 Jul	1730	5	3
	17 Jul	1710	5	3
	18 Jul	1538	6	3
	20 Jul	2340	6	3
	23 Jul	1320	4	3
	26 Jul	1835	6	4
	29 Jul	1645	8	3
	5 Aug	2150	6	3

Plot	Date	Time	Birds	Nests
4-1A	9 Jul	1620	110	78
	21 Jul	1355	81	64
	22 Jul	1510	101	64
	23 Jul	1335	100	66
	26 Jul	1350	115	66
	28 Jul	1615	108	65
	30 Jul	1325	92	71
	1 Aug	1635	102	70
	,6 Aug	1645	98	70
4-l B	7 Jul	2035	14	10
	9 Jul	1550	40	27
	21 Jul	1345	21	9
	22 Jul	1500	19	9
	23 Jul	1330	17	9
	26 Jul	1330	21	9
	28 Jul	1550	19	9
	30 Jul	1310	22	9
	1 Aug	1625	25	9
	6 Aug	1640	26	9
4-2C	9 Jul	1810	214	168
	16 Jul	1400	1 9 2	88
	21 Jul	2030	199	101
	22 Jul	1535	191	101
	23 Jul	1455	164	124
	26 Jul	1730	201	98
	30 Jul	1615	204	110
	1 Aug	1545	197	143
	6 Aug	1350	240	121
4-3D	9 Jul	1905	50	38
	21 Jul	1430	73	46
	22 Jul	1600	82	45
	23 Jul	1555	56	36
	27 Jul	1625	65	36
	28 Jul	1810	56	35
	30 Jul	1730	62	35
	1 Aug	1415	73	33
	6 Aug	1520	73	35

Plot	Date	Time	Birds	Nests
4-4E	9 Jul	1930	249	190
	21 Jul	1455	272	129
	22 Jul	1615	193	123
	23 Jul	1615	209	136
	27 Jul	1640	240	139
	28 Jul	1830	187	133
	30 Jul	1600	230	132
	1 Aug	1430	227	135
	6 Aug	1535	245	132
5-1A	9 Jul	1550	40	30
	16 Jul	1450	41	29
	21 Jul	1542	56	32
	23 Jul	1730	65	34
	28 Jul	1520	50	35
	31 Jul	1530	53	36
	4 Aug	1550	48	35
	7 Aug	1420	46	36
5-l B	23 Jul	1740	199	133
	28 Jul	1535	212	134
	29 Jul	1530	228	140
	30 Jul	1540	203	148
	31 Jul	1450	203	129
	1 Aug	1600	212	135
	4 Aug	1605	200	145
	7 Aug	1430	193	152
5-l C	9 Jul	1626	14	12
	16 Jul	1545	19	15
	21 Jul	1620	16	13
	23 Jul	1810	19	13
	28 Jul	1610	16	13
	31 Jul	1550	22	15
	4 Aug	1650	16	14
	7 Aug	1505	18	12

Plot	Date	Time	Birds	Nests
5-ID	9 Jul	1645	1	0
	16 Jul	1550	0	0
	21 Jul	1632	0	0
	23 Jul	1820	0	0
	28 Jul	1620	0	0
	31 Jul	1600	0	0
	4 Aug	1705	0	0
	7 Aug	1505	0	0
5-lx	21 Jul	1710	1	1
	23 Jul	1900	0	0
	28 Jul	1700	1	0
	31 Jul	1630	1	1
	4 Aug	1745	0	0
	7 Aug	1545	0	0
5-l Y	21 Jul	1655	10	8
	23 Jul	1840	14	9
	28 Jul	1640	15	9
	31 Jul	1610	15	11
	4 Aug	1725	14	10
	7 Aug	1545	15	10
5-2F	16 Jul	1658	5	3
	21 Jul	1445	6	3
	22 Jul	1528	7	3
	26 Jul	1505	8	3
	28 Jul	1310	7	3
	31 Jul	1425	8	3
	6 Aug	--	5	3
	9 Aug	1355	8	3
5-2G	16 Jul	1720	71	44
	21 Jul	1510	87	54
	22 Jul	1552	75	54
	26 Jul	1516	87	53
	28 Jul	1349	71	49
	31 Jul	1435	81	48
	6 Aug	.-	93	48
	9 Aug	1320	72	49

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Plot	Date	Time	Birds	Nests
5-G	9 Jul	1745	34	12
	16 Jul	2015	39	17
	21 Jul	1655	52	17
	22 Jul	1625	40	26
	26 Jul	1659	68	19
	28 Jul	1439	60	34
	31 Jul	1455	78	33
	6 Aug	.-	48	29
	9 Aug	1440	55	31
5-H	9 Jul	1745	28	17
	16 Jul	2000	42	21
	21 Jul	1710	42	19
	22 Jul	1625	31	22
	26 Jul	1718	45	21
	28 Jul	1455	42	23
	31 Jul	1455	58	2 3
	6 Aug	--	34	19
	9 Aug	1455	34	21
5-5J	21 Jul	1938	107	70
	23 Jul	1515	98	67
	28 Jul	1520	118	66
	6 Aug	1809	117	86
	8 Aug	1300	118	86
	11 Aug	0920	106	83
	13 Aug	1050	114	88
5-6K	9 Jul	2000	8	5
	21 Jul	1455	9	6
	22 Jul	1831	11	6
	28 Jul	1700	10	6
	30 Jul	1535	9	6
	1 Aug	1508	12	6
	29 Aug	1530	10	6

Plot	Date	Time	Birds	Nests
5-7L	9 Jul	1900	20	15
	22 Jul	1641	18	12
	2a Jul	1535	20	12
	30 Jul	1345	6	4
	31 Jul	1625	24	12
	6 Aug	.-	21	15
	9 Aug	1538	20	13
5-8M	16 Jul	1548	99	81
	21 Jul	1819	110	67
	23 Jul	1831	115	76
	28 Jul	1748	103	68
	30 Jul	1325	108	77
	1 Aug	1737	106	76
	2 Aug	1641	126	84
5-8N	9 Jul	1800	24	20
	16 Jul	1630	39	25
	21 Jul	1845	38	25
	23 Jul	1915	30	24
	28 Jul	1820	30	22
	30 Jul	1355	34	24
	2 Aug	1510	45	30
	29 Aug	1500	48	27
5-N	9 Jul	2000	87	80
	21 Jul	1530	92	72
	23 Jul	1731	88	77
	28 Jul	1720	104	86
	30 Jul	1547	108	85
	1 Aug	1622	103	85
5-o	9 Jul	1930	13	11
	21 Jul	1430	14	9
	22 Jul	1854	18	9
	28 Jul	1444	17	11
	28 Jul	1550	21	12
	30 Jul	1610	20	15
	1 Aug	1530	20	10

Plot	Date	Time	Birds	Nests
5-P	9 Jul	1940	172	142
	21 Jul	1549	194	120
	23 Jul	1720	192	122
	28 Jul	1605	177	109
	30 Jul	1625	208	130
	1 Aug	1550	196	128

APPENDIX C. 3B. CENSUS DATA FOR MURRES, 1990

Plot	Date	Time	TBMU	COMU	Murre Sp.
2-3C	12 Jul	1300	235	6	
	8 Aug	1710	231	74	
2-3D	8 Aug	1743	690	230	
3-1A	8 Jul	1430	157	6	
	11 Jul	1425	161	12	91
	17 Jul	1707	207		
	18 Jul	1530	124	13	
	20 Jul	2315	207	18	
	23 Jul	1320	132	0	
	26 Jul	1845	127	0	
	29 Jul	1610	182	0	
	5 Aug	2105	206	0	
	8 Aug	1540	208		
3-2B	8 Jul	1415	381	35	
	11 Jul	1443	470	44	390
	17 Jul	1717	340	5	
	17 Jul	1743	468	21	
	18 Jul	1535	399		408
	20 Jul	2335	384		
	23 Jul	1320	421	13	
	26 Jul	1810	495	34	
	29 Jul	1615	434	21	
	5 Aug	2125	643	27	
3-2C	8 Jul	1400	66		
	11 Jul	1425	49		
	11 Jul	1443			21
	17 Jul	1730	67		
	17 Jul	1710	58		
	18 Jul	1538	65		
	20 Jul	2340	83		
	23 Jul	1320	48		
	26 Jul	1835	61		
	29 Jul	1640	72		
	5 Aug	2150	84		

Plot	Date	Time	TBMU	COMU	Murre Sp.
4-1A	7 Jul	2100		69	
	9 Jul	1620	201	116	
	21 Jul	1355	173	95	
	22 Jul	1510	150	76	
	23 Jul	1335	163	94	
	26 Jul	1350	188	111	
	28 Jul	1615	148	135	
	30 Jul	1325	172	88	
	1 Aug	1635	154	114	
	6 Aug	1645		158	
4-l B	7 Jul	2035	88	40	
	9 Jul	1550	172	61	
	21 Jul	1345	106	48	
	22 Jul	1500	85	71	
	23 Jul	1330	110	64	
	26 Jul	1330	97	49	
	28 Jul	1550	90	74	
	30 Jul	1310	98	70	
	1 Aug	1625	98	59	
	6 Aug	1640	85	43	
4-2C	9 Jul	1810	148	136	
	16 Jul	1400	134	203	
	21 Jul	2030	94	368	
	22 Jul	1535	48	274	
	23 Jul	1455	88	254	
	26 Jul	1730	15	244	
	30 Jul	1615	60	276	
	1 Aug	1545	134	139	
	6 Aug	1350	57	343	
4-3D	9 Jul	1905	88	51	
	21 Jul	1430	139	32	
	22 Jul	1600	80	43	
	23 Jul	1555	121	22	
	27 Jul	1625	121	28	
	28 Jul	1810	84	56	
	30 Jul	1730	105	39	
	1 Aug	1415	113	19	
	6 Aug	1520	136	24	

Plot	Date	Time	TBMU	COMU	Murre Sp.
4-4E	9 Jul	1930	30	159	
	21 Jul	1455	31	146	
	22 Jul	1615	32	121	
	23 Jul	1615	28	142	
	27 Jul	1640	62	185	
	28 Jul	1830	31	131	
	30 Jul	1600	34	148	
	1 Aug	1430	30	149	
	6 Aug	1535	49	143	
5-1A	9 Jul	1550	17	65	27
	16 Jul	1450	31	38	
	21 Jul	1542	37	95	
	23 Jul	1730	36	95	
	28 Jul	1520	26	109	
	31 Jul	1530	35	88-	
	4 Aug	1550	27	96 "	
	7 Aug	1420	35	95	
5-1B	23 Jul	1740	335	172	
	28 Jul	1535	447	208	
	29 Jul	1530	573	289	
	30 Jul	1540	442	329	
	31 Jul	1450	553	221	
	1 Aug	1600	428	231	
	4 Aug	1605	548	258	
	7 Aug	1430	520	274	
5-1C	9 Jul	1626	37	11	19
	16 Jul	1545	45	3	
	21 Jul	1620	56	1	
	23 Jul	1810	59	19	
	28 Jul	1610	56	1	
	31 Jul	1550	67	1	
	4 Aug	1650	57	2	
	7 Aug	1505	54	1	

Plot	Date	Time	TBMU	COMU	Murre Sp.
5-ID	9 Jul	1645	263	38	199
	16 Jul	1550	189	11	
	21 Jul	1632	197	10	
	23 Jul	1820	167	16	
	28 Jul	1620	171	14	
	31 Jul	1600	185	13	
	4 Aug	1705	180	15	
	7 Aug	1505	178	16	
5-lx	9 Jul	1728	190	79	155
	16 Jul	1625	269	22	
	21 Jul	1710	363	43	
	23 Jul	1900	388	66	
	28 Jul	1700	300	78	
	31 Jul	1630	314	75	
	4 Aug	1745	298	86	
	7 Aug	1545	271	56	
5-l Y	21 Jul	1655	265	80	
	23 Jul	1840	312	149	
	28 Jul	1640	316	108	
	31 Jul	1610	295	148	
	4 Aug	1725	312	205	
	7 Aug	1525	294	194	
5-l Z	9 Jul	1705	38	26	
	16 Jul	1555	62	28	
	21 Jul	1645	78	25	
	23 Jul	1840	60	25	
	28 Jul	1715	64	25	
	31 Jul	1640	68	24	
	4 Aug	1805	62	22	
	7 Aug	1605	66	21	
5-2E	16 Jul	1708	264		
	21 Jul	1500	286		
	22 Jul	1545	270		
	26 Jul	1525	281		
	28 Jul	1340	305		
	31 Jul	1440	336		
	6 Aug		275		
	9 Aug	1355	325		

Plot	Date	Time	TBMU	COMU	Murre Sp.
5-2F	16 Jul	1658	403		
	21 Jul	1445	360		
	22 Jul	1528	385		
	26 Jul	1505	404		
	28 Jul	1310	434		
	31 Jul	1425	458		
	6 Aug		404		
	9 Aug	1355	372		
5-2G	16 Jul	1720	330		
	21 Jul	1510	322		
	22 Jul	1552	2	8	7
	26 Jul	1516	298		
	28 Jul	1349	351		
	31 Jul	1435	384		
	6 Aug		426		
	9 Aug	1355	406		
5-3H	9 Jul	1700	318		
	16 Jul	1940	306		
	21 Jul	1630	301		
	22 Jul	1610	311		
	26 Jul	1650	276		
	28 Jul	1430	296		
	31 Jul	1455	324		
	6 Aug		302		
	9 Aug	1435	281		
5-G	9 Jul	1700	1652		
	16 Jul	1955	1654		
	21 Jul	1650	1634		
	22 Jul	1625	1506		
	26 Jul	1659	1358		
	28 Jul	1439	1732		
	31 Jul	1455	1904		
	6 Aug		1794		
	9 Aug	1440	1508		

Plot	Date	Time	TBMU	COMU	Murre Sp.
5-H	9 Jul	1730	581		
	16 Jul	2020	613		
	21 Jul	1710	448		
	22 Jul	1625	325		
	26 Jul	1718	301		
	28 Jul	1455	417		
	31 Jul	1455	492		
	6 Aug		640		
	9 Aug	1455	421		
5-5J	21 Jul	1938	1022	8	
	23 Jul	1515	984	1	
	28 Jul	1520	747	7	
	6 Aug	1809	1072	20	
	6 Aug		892	13	
	8 Aug	1300	865	7	
	11 Aug	0920	843	9	
	13 Aug	1050	828	5	
5-6K	9 Jul	2000	417		
	21 Jul	1455	637		
	22 Jul	1831	563		
	28 Jul	1700	533		
	30 Jul	1535	566		
	1 Aug	1508	614		
	29 Aug	1530	132		
5-7L	9 Jul	1900	467	57	
	21 Jul	1750	500	23	
	22 Jul	1641	379	51	
	26 Jul	1800	320	72	
	28 Jul	1535	438	66	
	30 Jul	1345	395	103	
	31 Jul	1625	492	78	
	6 Aug		340	81	
	9 Aug	1538	390	83	

Plot	Date	Time	TBMU	COMU	Murre Sp.
5-8M	9 Jul	1800	1172	146	
	16 Jul	1548	1180	130	
	21 Jul	1819	1450	180	
	23 Jul	1831	1259	158	
	28 Jul	1748	1222	153	
	30 Jul	1325	1053	132	
	1 Aug	1737	1350	195	
	2 Aug	1641	1308	160	
5-8N	9 Jul	1800	702	15	
	16 Jul	1630	890	0	
	21 Jul	1845	1006	0	
	23 Jul	1915	663	1	
	28 Jul	1820	698	0	
	30 Jul	1355	820	0	
	2 Aug	1510	888	0	
	29 Aug	1500	42		
5-N	9 Jul	2000	1 055	77	
	21 Jul	1530	1585	40	
	23 Jul	1731	1382	167	
	28 Jul	1720	1093	80	
	30 Jul	1547	1233	125	
	1 Aug	1622	1265	100	
5-o	9 Jul	1930			778
	21 Jul	1430			887
	22 Jul	1854			945
	28 Jul	1444			802
	28 Jul	1550			667
	30 Jul	1610			815
	1 Aug	1530			834
5-P	9 Jul	1940			1008
	21 Jul	1549	1545	160	1605
	23 Jul	1720	1023	140	1163
	28 Jul	1605			1627
	30 Jul	1625			1235
	1 Aug	1550			1485

Appendix C.4a. Thick-billed and common murre numbers on Fadely plots at colonies 2-5, Cape Thompson, 1990.

	Thick-billed murre				Common murre			
Plot	Mean	SD	n	CV	Mean	SD	n	CV
2-3C	233	2.8	2	1.2	40	48	2	120
3-1A	171	35	10	21	6	6.8	9	113
3-2B	444	85	10	19	25	13	8	51
3-2C	65	12	10	19	0		10	
4-1A	169	19	8	11	106	27	10	26
4-1B	103	26	10	25	58	12	10	21
4-2C	86	45	9	53	249	80	9	32
4-3D	110	22	9	20	35	13	9	37
4-4E	36	12	9	32	147	18	9	12
5-1A	31	6.9	8	22	85	23	8	27
5-1B	481	82	8	17	248	50	8	20
5-1C	54	9.1	8	17	5	6.6	8	133
5-1D	179	12	8	6.4	17	8.9	8	52
5-2E	293	27	8	9.0	0	0	9	0
5-2F	403	32	8	7.9	0	0	8	0
5-2G	351	51	8	14	0	0	8	0
5-3H	302	16	9	5.2	0	0	9	0
5-5J	907	110	8	12	9	5.7	8	63
5-6K	555	77	6	14	3	3.5	6	140
5-7L	413	65	9	16	68	23	9	34
5-8M	1,249	122	8	9.8	157	22	8	14
5-8N	810	127	7	16	2	5.7	7	285
Total	7,445				1,260			

Appendix C.4b. Black-legged kittiwake numbers on Fadely plots at colonies 2-5, Cape Thompson, 1990.

	Birds				Nests			
Plot	Mean	SD	n	CV	Mean	SD	n	C v
2-3C	20	9.2	2	46	15	4.2	2	28
3-1A	8	2.1	10	26	6	0.32	10	5.3
3-2B	59	10	10	18	38	11	10	29
3-2C	5	1.4	10	28	3	0.32	10	11
4-1A	101	10	9	10	68	4.6	9	6.7
4-1B	22	7.1	10	32	11	5.7	10	51
4-2C	200	20	9	10	117	25	9	22
4-3D	66	11	9	16	38	4.6	9	12
4-4E	225	28	8	13	132	4.8	8	3.7
5-1A	50	8.2	8	16	33	2.7	8	8.2
5-1B	206	11	8	5.3	140	8.1	8	5.8
5-1C	18	2.5	8	14	13	1.2	8	9.2
5-ID	0	0	8	0	0	0	8	0
5-1D	0	0	8	0	0	0	8	0
5-2E	0	0	8	0	0	0	8	0
5-2F	7	1.3	8	18	3	0.0	8	0
5-2G	80	8.6	8	11	50	3.5	8	7.0
5-3H	0	0	9	0	0	0	9	0
5-5J	111	7.7	7	6.9	78	9.9	7	13
5-6K	10	1.4	7	14	6	0.38	7	6.3
5-7L	18	5.8	7	32	12	3.7	7	31
5-8M	110	8.9	7	8.0	76	6.2	7	8.2
5-8N	36	8.1	8	22	25	3.0	8	12
Total	1,352				864			

Appendix C.5. Murre and kittiwake numbers on land-based "Swartz plots" at Colony 5, Cape Thomspon, 1990.

					Black-1egged kittiwake							
	Murre spp.				Birds				Nests			
Plot	Mean	SD	n	C v	Mean	SD	n	C v	Mean	SD	n	CV
5B	1,795	252	8	14	287	10	8	3.6	196	8.1	8	4.1
5G	1,638	165	9	10	53	14	9	27	24	8.1	9	34
5H	471	121	9	26	40	9.1	9	23	21	2.0	9	9.5
5L[1]	915	112	8	12	111	7.7	7	6.9	78	9.9	7	13
5M[2]	558	78	6	14	10	1.4	7	14	6	0.38	7	6.3
5N	1,200	532	6	44	97	9.1	6	9.3	81	5.6	6	6.8
5 0	818	87	7	11	18	3.1	7	17	11	2.1	7	19
5P	1,353	255	6	19	190	13	6	6.9	125	11	6	8.9
5Q[3]	812	125	7	15	36	8.1	8	22	25	3.0	8	12

[1] 5L (Swartz) = 5-5J (Fadely).
[2] 5M (Swartz) = 5-6K (Fadely).
[3] 5Q (Swartz) = 5-8N (Fadely).

Appendix C.6a. Boat counts of murres at Colony 4, Cape Thompson. Replicate 1, 25 July 1990.

		BES[1]		JE[1]		
Plot	Time	counts	Mean	Counts	Mean	Mean of Observers
4A	1200	90	90	77, 86	82	86
4B	1220			103, 114	109	109
4C	1240	390	390	315	315	352
4D	1249			70, 73	72	72
4E	1255	1010[2]	1010	510, 473	497	753
4F + G	1300	2410[2]	2410	757, 923	840	1,625
4H	1411	·		289, 372	331	331
41	1400	-		51, 54	53	53
4J	1418	730	730	396, 418	407	569
4K	1420	75	75	64, 73	69	72
4L	1444			291, 332	312	312
4M	1440			147, 179	163	163
4N	1500	280	280	265, 289	277	279
40	1434	120	120	93, 106	100	110
4P	1506	520, 595	557	405, 398	401	479
4Q	1519	265	265	266, 249	257	261
4R	1522	375, 325	350	239, 265	252	301
Total						5,927

[1] BES = Brian Sharp, JE = Joe Evanich.
[2] Mostly common murres.

Appendix C.6b. Boat counts of murres at Colony 4, Cape Thompson. Replicate 2, 3 August 1990.

Plot	BES[1]	JE[1] Counts	JE[1] Mean	Mean of Observers
4A		77, 86	82	82
4B		171, 192	182	182
4C		307, 323	315	315
4D		204, 232	218	218
4E	680	531, 592	562	621
4F	310	603, 635	619	464
4G	890	229, 216	222	556
4H	-	315, 344	330	330
41	50	40, 50	45	48
4J	875	712, 765	739	807
4K	120	127, 121	124	122
4L		235, 266	251	251
4M		377, 342	360	360
4N	245	284, 299	292	274
40	100	82, 77	80	90
4P	600	505, 600	553	577
4Q	200	367	367	284
4R	315	304	304	310
Total				5892

[1] JE = Joe Evanich, BES = Brian Sharp.

Appendix C.6c. Boat counts of black-legged kittiwakes at Colony 4, Cape Thompson. Replicate 1, 25 July 1990.

		CB[1]		BES[1]		
Plot	Time	Counts	Mean	Counts	Mean	Mean of observers
4A	1200	426		605		526
4B	1220	386, 322	354	430, 450	440	397
4C	1240	449				449
4D	1249	66		85		71
4E	1255	660, 819	739	760		749
4F, 4G	1300	1057		1040		1048
4H	1411	264		275		270
41	1400	“410		605		508
4J	1418	155		150		153
4K	1420	238		210		224
4L	1444	322		325		324
4M	1440	189		140		165
4N	1500	335, 353	344	240		292
40	1434	69		110		90
4P	1506	170		175		173
4Q	1519	60				60
4R	1522	7 , 7		-		7
Total						5506

[1] CB = Chris Berkman, BES = Brian Sharp.

Appendix C.6d. Boat counts of black-legged kittiwake at Colony 4, Cape Thompson. Replicate 2, 3 August 1990.[1]

Plot	Mean	BES[2]	CB[2]	Mean
4A	1230	450	534	492
4B	1235	401	390	396
4C	1250	765	719	742
4D	1305	85	84	85
4E	1310	895	703	799
4F	1325	300	329	315
4G	1330	780	688	734
4H	1350	335	247	291
41	1336	440	433	437
4J	1402	145	117	131
4K	1408	155	217	186
4L	1420	335	232	283
4M	1435	125	133	129
4N	1440	285	347	316
40	1424	115	117	116
4P	1450	135	129	132
4Q	1500		41	41
4R	1505		2	2
Total				5,627

[1] Wind NW at 10 mph; visibility 2 (bright, no contrast between birds and cliff).
[2] BES = Brian Sharp, CB = Chris Berkman.

Appendix C.7. Boat-based counts of Colony 1 (all) and Colony 2 (selected plots[1]), Cape Thompson, 7-8 August 1990.

			Black-legged kittiwake[2]		Murre spp.				
Colony	Plot	Time	Counts	Mean	BES[3]	Mean	JE[3]	Mean	Overall mean
1	All	1746	0	0	1710		1408[2]		1559
2	2F	1603	429, 349	389	675, 700	688	596	596	642
	2L	1540	617,611	614	2315	2315	1558	1558	1937
	2U	1505	1246, 1004	1125	2250, 2495	2378	2292	2292	2335
	2V	1432	689, 683	686	2805	2805	2200	2200	2503
	2CC	1403	100, 84	92	1460, 1490	1475	707, 740	724	1100
	21 I	1340	43, 52	48	315	315	319	319	317
	2HH	1645	150, 154	152			114, 110	112	112
	2K	1705	88, 78	73			346, 382	364	364
Total				3179				9310	

[1] 4 plots were located in the middle of the Colony, others at the ends. Plots 2DD, 2EE, 2FF had collapsed into the sea.
[2] Black-legged kittiwakes and murres at Colony 1 were counted by Chris Berkman.
[3] BES = Brian Sharp, JE = Joe Evanich.

Appendix C.8. Boat counts of murres and kittiwakes at Colony 3, Cape Thompson, 8 August 1990.

		Black-legged kittiwake		Murre spp.			
Plot	Time	CB[1]	Mean	JE[1]	BES[1]	CB[1]	Mean
3Q, 3R, 3S	1350	639, 606	623	3313	3415		3364
3V, 3W	1430	97, 112	105	1551	1405		1478
3P	1450	54, 46	50	1194	1345		1270
3F	1505	36, 39	38		75		75
3C	1515	80, 79	80	188			188
3D	1525	33, 30	32	612	640		626
3E	1530	104, 105	105	526	535		531
3B	1535	28, 29	29	388	405		397
3A	1540	8, 8	8	207	201	217	208
Total			1070				8137

[1] CB = Chris Berkman, JE = Joe Evanich, BES = Brian Sharp.

Appendix C.9a. Boat counts of murres on selected plots at Colony 5, Cape Thompson, 4 August 1990.[1]

		BES[2]		JE[2]		
Plot	Time	Counts	Mean	Counts	Mean	Mean of observers
5DD	1653	1380, 1410	1395	2481	2481	1938
5GG	1529	4510, 3360	3935	2460, 2650	2555	3245
5HH	1426	4340, 5240	4790	4 4 6 0	4460	4625
5JJ	1552	1090, 1590	1340	611, 824	718	1029
5LL	1615	1240	1240	650	650	945
5 0 0	1625	1770, 1760	1765	1889	1889	1826
5AA	1718	2240	2240	2050	2050	2145
Total						15753

[1] Murres counted by 10's.
[2] BES= Brian Sharp, JE = Joe Evanich.

Appendix C.9b. Boat counts of black-legged kittiwakes unselected plots at Colony 5, 4 August 19900

		CB[1]			
Plot	Time	Counts	Mean	BES[1]	Mean of observers
5AA	1718	154, 170	162		162
5DD	1653	200, 206	203	219	211
5GG	1529	304, 261	283		283
5HH	1426	175 , 188	182		182
5JJ	1552	13, 15	14		14
5LL	1615	0 , 0	0		0
5 0 0	1625	4 , 3	4		4
Total					856

[1] CB = Chris Berkrnan, BES = Brian Sharp.

Appendix C. 10. Daily mortality rates of eggs and chicks at Cape Thompson in 1990 estimated by Mayfield method[1]: thick-billed murres.

	Exposure (days)		Lasses		Daily Mortality	
Plot	Eggs	Chicks	Eggs	Chicks	Eggs	Chicks
4-1A	10	77	0	0	0.0	0.0
4-1B	168.5	241.5	2	3	0.012	0.012
4-2	10	39.5	0	0	0.0	0.0
4-4	26	7	0	0	0.0	0.0
5-1A	30	144.5	1	4	0.033	0.028
5-1C	28	249.5	3	2	0.11	0.008
5-1Z	202.5	247.5	2	0	0.89	0.0
5-2F	277.5	552	1	10	0.0036	0.018
5-3H	94.5	175.5	0	0	0.0	0.0
5-6K	437	691	1	7	0.0023	0.010
5-7L	128.5	344.5	3	“ 3	0.023	0.0087
5-8N	268.5	590.5	1	9	0.0037	0.015
Total	1,681	3,360	14	38		
Overall daily mortality[2]					0.0083	0.011
Daily survival[3]					0.9917	0.989

[1] Mayfield (1975).
[2] Calculated by dividing pooled numerator by pooled denominator.
[3] 1- (overall daily mortality).

Appendix C.11. Daily mortality rates of eggs and chicks at Cape Thompson in 1990 estimated by May field method[1]: common murres.

	Exposure (days)		Losses		Daily Mortality	
Plot	Eggs	Chicks	Eggs	Chicks	Eggs	Chicks
4-1A	8	34	0	0	0.0	0.0
4-2	23	29	0	0	0.0	0.0
4-4	121.5	50.5	0	0	0.0	0.0
5-1A	10	433	0	1	0.0	0.0023
5-1Z	61	81.5	1	0	0.16	0.0
5-6K	11.5	10	0	1	0,0	0.10
5-7L	11.5	20	0	1	0.0	0.05
Total	246,5	658	1	3		
Overall daily mortality					0.0041	0.0046
Daily survival[3]					0.9959	0.995

[1] Mayfield (1975).
[2] Calculated by dividing pooled numerator by pooled denominator.
[3] 1 - (overall daily mortality).

Appendix C. 12. Daily mortality rates of eggs and chicks at Cape Thompson in 1990 estimated by May field method[1]: black-legged kittiwakes.

	Exposure (days)		Losses		Daily Mortality	
Plot	Eggs	Chicks	Eggs	Chicks	Eggs	Chicks
4-1A	24.5	473.5	1	1	0.041	0.0021
4-2	58	460	2	1	0.034	0.0022
4-4	38	367.5	4	2	0.11	0.0054
5-1A	111.5	1,103	2	10	0.018	0.0091
5-1C	8.5	591	2	5	0.025	0.0085
5-6K	156.5	880.5	5	10	0.032	0.011
5-8N	159.5	639.5	2	8	0.013	0.013
Total	629.5	4,515	18	37		
Overall daily mortality[2]					0.0286	0.00819
Daily survival[3]					0.9714	0.9918

[1] Mayfield (1975).
[2] Calculated by dividing pooled numerator by pooled denominator.
[3] 1 - (overall daily mortality).

Appendix C.13. Seabirds collected for diet study, Cape Thompson, August 1990.

Date	Species[1]	Specimen number	Sex	Wing (mm)	Weight (g)	Brood patch[2]	Fat[3]	Largest testis or follicle (mm)
8/15	TBMU	1	F	206		4	3	
8/15	TBMU	2	F	214		4	2	
8/16	TBMU	3	M	221		0	2	
8/16	TBMU	4	F	213		4	1	
8/16	COMU	5	M	210		4	1	
8/16	COMU	6	F	214		3/4	2	5.7
8/16	TBMU	7	M	220		4	3"	
8/16	TBMU	8	F	215		4	1	3.2
8/26	BLKI	1	M	324		6	1	10.0
8/26	BLKI	2	F	308		5	2	
8/26	BLKI	3	F	322		4	1	
8/26	BLKI	4	F	321		5	1	
8/26	BLKI	5	M	330		6	2	5.9' '
8/26	BLKI	6	F	342		4	2	
8/27	BLKI	7	M	327	473	0	1	7.7
8/27	BLKI	8	M	324	485	4	1	5.3

[1] TBMU = thick-billed murre, COMU = common murre, BLKI = black-legged kittiwake.

[2] 0 and 6 = no brood patch; 3 = maximum development, vascularized in murres; 4 = brood patch regressing, down and contour feather sheaths around edges; 5 = patch regressing, mostly down-covered, contour feathers emerging from sheaths.

[3] 1 = light, 2 = moderate, 3 = heavy.

Appendix C.14. Murre food deliveries to chicks, August 1990.

Species	Date	Plot No.	Time start	Time End	Hours Observed	No. chicks Observed	No. deliveries	No. deliveries per chick-hours
TBMU	8/18	5-6K'	1325	1525	2.0	7	1	0.071
TBMU	8/18	5-6K'	1425	1525	1.0	7	0	0.()
TBMU	8/2	5-1Z	1535	1715	1.7	4	1	0.42
TBMU	8/10	5-1Z	1525	1700	1.4	8	1	0.088
COMU	8/13	5-1Z	1515	1630	1.25	3	2	0.53
TBMU	8/18	5-1Z	1530	1635	1.1	11	1	0.84
TBMU	8/20	5-6K'	1519	1537	0.3	7	0	0.0
TBMU	8/20	5-6K'	1538	1552	0.2	4	1	1.07
TBMU	8/20	5-6K'	1626	1656	0.5	9	2	0.44
TBMU	8/20	5-l Z	1645	1745	1.0	12	1	0.083
COMU	8/20	5-1Z	1645	1745	1.0	6	0	0.0
TBMU	8/20	5-2F'	1500	1600	1.0	8	1	0.125
TBMU	8/22	5-6K'	1357	1405	0.1	4	0	0.0
COMU	8/18	4-2	1330	1430	1.0	1	0	0.0
COMU	8/18	4-4	1445	1545	1.0	3	0	().0
COMU	8/20	4-4	1600	1700	1.0	4	1	0.25
COMU	8/20	4-2	1445	1545	1.0	3	1	0.33
COMU	8/22	4-2	1400	1500	1.0	3	0	0.0
COMU	8/22	4-4	1530	1630	1.0	4	1	0.25
TBMU	8/22	4-4	1530	1630	1.0	1	0	0.0

[1] TBMU = thick-billed murre, COMU = common murre.

Appendix C.15a. Length of nestling period[1] for murres at Cape Thompson, 1990, based on selected nests.

Thick-billed murre			Common murre		
Plot	Site	Nestling period	Plot	Site	Nestling period
5-6K'	T1	20.5	4-1A	4	23
	T3	22	5-1Z	4	32.5
	T4	21.5		5	25.5
	T9	28.5	5-1A	36	22
	T14	18			
	T28	20.5			
	T34	24.5			
5-8N'	T9	21.5			
	T18	21			
	T22	20.5			
5-2F'	1	22.5			
	3	22.5			
	7	24.5			
	8	20.5			
	12	26.5			
	14	22.5			
Mean		21.9	Mean		25.75
n		17	n		4
SD		39.66	SD		4.100

[1] Nestling period defined as the interval between hatching and fledging. Hatching is the midpoint of the interval between last observation of an egg and first observation of a chick; fledging is the midpoint of the interval between last observation of a chick and first record of its disappearance due to presumed fledging.

Appendix C.15b. Estimation of nestling period from first and median hatching and fledging dates, Cape Thompson, 1990.[1]

Species	Hatching date	Fledging date	Nestling period
Black-legged kittiwake			
First	Jul 18-19	Aug 23-24	36
Median	Jul 21-22	Aug 27-28	37
Thick-billed murre			
First	Jul 21	Aug 14	24
Median	Jul 28	Aug 18	21
Common murre			
First	Jul 25	Aug 18	24

[1] Data from Table 8.

Appendix #6. Comments and Recommendations Regarding Population and Productivity Plots.

2-1A and 2-2B: Cliffs upon which both of these population plots were located had collapsed into the sea. Colony 2 was therefore represented by only 1 population plot in 1990. A cliff face is visible from OP-2 looking north, which could be added as a replacement plot in the future. However, it is somewhat too far to distinguish murre species without at least 10 x magnification. A sketch (no photograph) was made of this cliff face.

4-1A: Excellent visibility, though birds somewhat in a line, screening each other. Sheltered from wind. Recommend increasing the productivity sample here in the future. A rockslide reduced the number of nests being monitored.

4-1B: Excellent visibility, add to sample here.

4-2C: Good visibility, good angle, good lighting; most exposed to wind of all Colony 4 plots; difficulty distinguishing individual birds within clusters of birds, so productivity sample size not increased at this plot.

4-4E: Not a very useful plot for monitoring productivity in thick-billed murres, due to bad angle (looking upwards) and back-lighting. Good plot for observing larger number of kittiwakes. A larger number of common murres on a lower ledge could have been monitored easily.

5-1A: Poor visibility due to limited sunlight, bad angle, distance. A large proportion of common murres on the plot unfledged at the end of the field season.

5-1B: Plot closer to the observer than 1A. It is strongly recommended that this plot be used for productivity monitoring rather than 1A. For productivity purposes, a few observable common murres on plot 1B were added to those on plot 1A, to increase the sample size for this species.

5-1C: Almost meaningless as a population plot due to its smallness. There is also a question as to the independence of plots 5-1A and' 5-1C, due to their proximity.

5-1D: A few more easily observable common murres on plot 1D were added to those on plot 1A, to increase sample size for this species for productivity purposes.

5-1X and 5-1Y: Counts from these extra plots were combined with counts from plots 1A-1D to correspond with Swartz plot 5B.

5-1Z: An extra, experimental productivity plot established in 1990, located behind the observer as he faces plots 1A-ID. The

birds are very close to the observer, within several feet. Despite the closeness, productivity data were disappointingly difficult to obtain. The angle of observation (looking down) made it difficult to see eggs and chicks under the birds, and the birds also sat tight in the constant shade. Recommendation is not to bother monitoring this plot in the future.

OP 5-1: This observation point, along with OP 4-1, is the most sheltered and comfortable insofar as the wind is concerned. It is also the most complicated Observation Point because of the number of things going on there: 4 population plots, 2 extra population plots (all six combined equalling 1 Swartz plot), two standard productivity plots, and 1 experimental productivity plot.

Note: All remaining observation points (5-2 to 5-8) are exposed to winds from almost any direction, and the winds are stronger with the increase in elevation. Forty-mile-per-hour winds were encountered several times at these upper observation points.

5-2: Plots at OP 5-2 did not seem to be independent of one another.

5-2E: No comment.

5-2F: Birds close, good visibility, good angle. Opportunity to include some kittiwake nests for productivity monitoring to the left of and off the plot. Recommend changing the boundary of the plot for productivity purposes.

5-3H: Distance too far for easy observation, plot almost constantly in the shade, back-lighting a problem, resulting in difficulty seeing under birds. Low proportion of breeders results in small number of birds followed for estimating reproductive performance. Mobility of non-breeders within the plot also results in confusion. Recommendation: discard as productivity plot. Small plot good for k-factor, however: could ascertain breeding status of most of the birds with some degree of assurance, though k-factor low and perhaps atypical on this plot.

5-3: From OP 5-3 views are obtained of Swartz plots 5G (cliff face including 5-3H), and 5H (the spire not including the "lump" to the left of the spire). (Note: I was not very confident that the boundary of Swartz plot 5H did not include the base of the spire. Counts in 1990 were much lower than Swartz' count in 1960.)

5-41: This plot required an extremely close approach to the edge of the cliff, including even overhanging the edge, and was judged too hazardous at the beginning of the 1990 field season. At the end of the season, after gaining a measure of confidence working at the cliff edge all summer, the plot was judged "do-able."

5-5 J:' This was the most difficult and confusing of all the plots to count due to scarcity of features in the rock face that could be used to divide groups of birds. Obtaining an adquate view of the cliff face was also difficult. The observation point from which counts were taken was 4.5 to 7.5 paces southeast of the stake (1 pace = 5.5 feet).

5-6K: Fourteen kittiwake nests outside the boundaries marked on the plot photograph were added to the number of kittiwakes (6) being monitored on the plot. These were located below the productivity plot but within the population plot.

5-6: From OP 5-6 views are obtained of Swartz plots 5N (the rest of the cliff face below 5-6K), 50 (the upper half of the distant cliff face opposite), and 5P (the lower half of the cliff face opposite, including the dividing ledge). The bottom part of 5N is anxiety-producing to count, since the observer has to look down at an almost vertical angle . The distance of plots 50 and 5P from the observer make them somewhat difficult to count.

5-7L: Note the boundary discrepancy as marked on the plot-photograph.

5-8M: A large and difficult plot to count, and the distance of birds from the observer makes it difficult to differentiate murre species.

5-8N: Hazardous: to count birds at the bottom of the population plot requires close approach to edge overhang, and the resulting angle of view is near vertical. Birds to the right of and outside the marked productivity plot boundary were chosen for productivity monitoring in order to obtain oblique views of incubating/brooding birds, rather than perpendicular views of the backs of the birds, which are unproductive of results.

Appendix 17. observations of mammals in the Cape Thompson area, 1990

The area covered is the same as that described in Fadely et al. (1989), except for the addition of observations from Saligvik Ridge and Ilikrak Creek up to 32 km inland on August 10-12, and incidental observations from Akoviknak and Kemegrak Lagoons northwest of Colony 5 on July 25..

Grizzly bear (Ursus horribilis)

Grizzly bears were encountered several times in 1990. It appeared from the size of tracks and observations that perhaps 4 adult bears inhabited the Cape Thompson area. The bears apppeared to be subsisting on ground squirrels. Sign, including diggings for ground squirrels, was widespread.

On Jul 21, 4 a.m., a bear stumbled into the tent stays of one of the volunteers (JE), and pulled out two tent stakes. It ran up Agate Rock when an air horn was sounded. On Jul 27, 2 a.m., a bear tore into the weatherport, scattered garbage about, then pushed in the side of the project leader's tent. Ran up over Agate Rock pass. Later the same day, a bear was seen about a mile east of camp near Ikijaktusak Creek; it ran when it saw the observer. On Jul 29 a bear was observed on a hillside 1-1.2 miles east of camp. On Aug 1, a bear ran down into the willows in the creek bed close to camp. On Aug 14, early a.m., the presence of a bear was sensed in camp. Next morning, it was discovered that a bear had bitten and punctured the front end of one of the rubber rafts on the beach. Fresh tracks of an adult and cubs were found on the beach coming and going in the direction of Colony 2. On Aug 18 a young bear seen foraging on dry ridge north of Agate Rock saddle was approached to within 100 yards. On Aug 23, a large bear was observed for 1/4 hour lolling on hillside above the right branch of Ikijaktusak Creek 1.1 miles northeast of camp. The same day a freshly dug den was discovered 1.2 miles inland. (The den was located 170 yards east of main branch of Ikijaktusak Creek, along the second mini-ravine northeast of the confluence of the right branch and main branch of Ikijaktusak Creek.) On Aug 29, one of rubber rafts was punctured with a single toothmark, and tracks of two bear cubs were found on the beach.

Muskox (Ovibos moschatus)

On Jul 14, 5 animals were seen on the ridge 0.5 mi. behind (northeast of) camp. On Aug 10, a herd of 9 on Saligvik Ridge 4.5 mi. northeast of camp (T32N, R31W, sect. 20, s. 1/2) was approached closely from downwind, unseen at first. The smell of the herd similar to that of cattle. The largest bull snorted, approached, bared its teeth. A herd of 12 was-seen from Saligvik Ridge in lush bottomland in Saligvik Valley (T33N, R30W, sect 21). On Aug 12, a herd of 19 was seen on a rocky hillside in T33N, R31W, sect. 24. On Aug 23, 2 females and 2 calves were feeding in lush bottomland along the right branch of Ikijaktusak Creek 1.5 mi. north of camp.

Wolf (Canis lupus)

On July 26 fresh tracks of 4 or more animals were seen on the shore of Kemegrak Lagoon. On Aug 12, tracks of a single individual were noted along the Kukpuk River and lower Ilikrak Creek. Eskimos from Point Hope have observed a higher than usual number of sightings this year, hypothesizing fires in interior Alaska as the cause.

Dan **sheep** (Ovis dalli)

On Jul 31, one female was seen on the saddle of Agate Rock north of camp, heading south. On Aug 1, one animal seen on hill above left fork. of Ikijaktusak Creek. Eskimos have observed an unusual number of sightings this year in Point Hope area, perhaps related to widespread fire elsewhere in interior Alaska. Dan sheep were locally extirpated from the Chariot area prior to 1960 (Pruitt, Jr., 1966).

Red fox (Vulpes fulva)

On July 25, a large female was seen 3/4 mi. inland from Colony 3. On Aug 12, a fox was surprised in the act of digging a den in the bank of Ilikrak Creek. Another fox den identified by its smell was found on the same day in upper Ikijaktusak Creek 1.3 mi. northeast of camp.

Moose (Alces alces)

Jul 4, one was at Ogoturuk Creek, Chariot, on Jul 15, three in camp at Ikijaktusak, and on July 29, a moose was disturbed from its bed in willows, left branch of Ikijaktusak Creek, 0.75 mi. from camp.

Barren ground caribou (Rangifer arcticus)

On Jul 7 four animals were seen at a distance of 1.5 mi. inland from top of hill behind camp. On Jul 9, 8 caribou were seen in approximately the same location. On Aug 10, 1 antlered caribou was seen near the confluence of Ilikrak Creek and Kukpuk River. On Aug 16, there was the scent of caribou on a northeast breeze--a sizeable herd migrating inland?

Short-tailed weasel (Mustela ermines)

Weasels were observed on several occasions: Jul 22 underneath the weatherport; July 25 at OP 5-6 (Colony 5); Aug 2 in camp; Aug 9 at the weatherport; Aug 10 along Ilikrak Creek 1.5 mi. from Kukpuk River; Aug 16 near the weatherport at midnight; and Aug 21 in willows and grassy area along Ikijaktusak Creek 0.3 miles inland.

Tundra vole (Microtus oeconomus)

Ubiquitous.

Alaska (Singing) vole (Microtus miurus)

Jul 29 and Aug 29 in camp; Aug 7, three sightings at OP 5-1; and Aug 24, one at the mouth of a burrow at OP 4-1.

Arctic ground squirrel (Citellus parryi)

Common and widespread except on rocky ridges (only 2 observed the whole length of Saligvik Ridge, a distance of 18 mi., to Kukpuk River). There was a dense population in 1990 in the deeper soils near camp, fighting was frequently observed, and a high proportion of the animals bore scars. Ground squirrel feces with tapeworms observed on Aug 24.

Porcupine (Erethizon dorsatum)

On Aug 20, an extremely blond porcupine was browsing on willows in camp.

Harbor porpoise (Phocoena vomerina)

On Aug 24, a porpoise was swimming southeast past OP 4-1, submerging for intervals of 1-1.5 minutes.

Walrus (Odobenus rosmarus)

Eskimos from Kivalina and Kiana, the latter camped at Chariot hunting walrus, reported lack of walrus this year. On Jul 26, there was a beheaded carcass on shore at Akoviknak Lagoon, and 8 old carcasses and skeletons at Kemegrak Lagoon. On Aug 15, a bloated carcass with two tusks was floating approximately 1.5 miles offshore from ColNorthern sea lion (Eumetopias jubata)

On Aug 15 a single animals was hauled out about 15 feet above water level, below plot 4-4.

Ringed seal (Phoca hispida)

On Jul 3, 5-8 seals among sea ice at Chariot were probably this species. On Jul 6, a freshly shot young ringed seal was found on shore at south end of Colony 3.

Bearded seal (Erignathus barbatus)

On Aug 20 a whitish seal seen 150 m. off OP 5-1 was identified as a bearded seal by Warren Nashookpuk of Point Hope.

C.

Appendix #8. Annotated list of the birds of the Cape Thompson area, summer, 1990.

The purpose of the Cape Thompson study was the monitoring of cliff-nesting murres and kittiwakes, but an effort was made to document the occurrence and relative abundance of all species of birds encountered. Observations were not obtained systematically or in any standardized way. Incidental observations of birds were obtained daily during walks to and from the plots, a one-way distance of approximately 3 km.; in the vicinity of camp; on frequent (almost daily) bird walks along the tundra-riparian interface along Ikijaktusak Creek (one-way distance approximately 0.8 km.); and offshore during boat counts. occasional longer nature walks were taken inland. A visit to Akoviknak and Kemegrak Lagoons was made on Jul 25, and to Aiautak Lagoon on Aug 5. A three day expedition was also made to the Kukpuk River via Saligvik Ridge and Ilikrak Creek (approximately 32 km one-way) by BES and CB on August 10-12. Birds were also observed at Chariot along lower Ogoturuk Creek at the beginning and at the end of the study period, which extended from July 3 to September 3.

Habitat types searched for birds and approximate effort spent in each included open ocean (5%), cliffs and rocky shoreline (20%), creek beds (5%), riparian growth (mainly thickets of Salix alaskensis) (20%), wet tundra (characterized by tussocks of Eriophorum, Carex, and low shrubs, including Betula nana and Salix spp.) (20%), and rocky upland tundra (characterized by Dryas octopetala) (30%).

Names of birds in the following list follow the AOU Checklist Sixth Edition (1983) and supplements in The Auk.

Pacific loon (Gavia pacifica)

One bird was noted flying north along the coast at Chariot on Jul 3.

Red-throated loon (G. stellata)

Two birds were noted among sea ice at Chariot on Jul 3, and a pair was fishing offshore near camp on Aug 19. Fish were caught in 7 of 11 dives, attesting to the apparent abundance of food inshore in August.

Short-tailed shearwater (Puffinus tenuirostris)

One bird was observed at the mouth of Ikijaktusak Creek Aug 29, and another, perhaps the same bird 0.8 km farther south on Aug 30. The latter bird allowed the raft to approach within 2 m. as it rested on the water.

Pelagic cormorant (Phalacrocorax pelagicus)

Approximately 10-15 pairs of nesting birds (an underestimate) were noted throughout all five colonies. Small numbers (l-5 birds) were observed almost daily as they flew to and from feeding areas. Production of 2-3 young was 'noted in some nests.

Brant (Branta bernicla)

Flocks of migrating brant passed northward at Chariot on Jul 3 (6 birds), at Crowbill Pt. on Jul 9 (30 birds), and at sea near camp Jul 10.

Common eider (Somateria mollissima)

Four northward-bound flocks of 5-30 birds were noted at Crowbill Pt. on Jul 3, and another northward movement of 50-75 birds was noted at Ikijaktusak Creek Jul 10-11. One eider spp. was in the ocean near Colony 3, Aug 15. Dozens of old eider carcasses consisting of feathers and skeletons were found scattered singly all over the tundra, in creek bottoms, etc. Most were female plumaged. No explanation for this was discovered.

King eider (S. spectabilis)

Two flocks totalling approximately 18 birds were noted during the above-mentioned common eider movement on Jul 10. Five non-breeding female-plumaged birds were observed on the ocean below Colony 5 on Jul 16 and 22, and another 5 birds were at Crowbill Pt. on Sep 3.

Spectacle eider (S. fischeri)

One adult male wqs observed on the ocean at Colony 2 on Aug 11.

Harlequin duck (Histrionics histrionics)

Regular but uncommon in the surfline esp. off rocky shores throughout the summer, with a high count of 20 birds off Colony 2 Aug 11. Individuals were also noted on Ikijaktusak Cr. on Jul 17 and 22. Most birds observed were females or immatures. Nesting perhaps occurred farther inland.

Surf scoter (Melanitta perspicillata)

An adult male was on the ocean below Colony 5 on Jul 21.

Golden eagle (Aquila chrysaetos)

At least one immature and one adult were noted occasionally at various sites throughout the area, e.g., on Jul 6, 16, 17, 23, 28, and Aug 11. On Jul 18 a golden eagle flew along the cliffs at Colony 5 flushing tens of thousands of murres from the ledges. An agonistic interaction between a golden eagle and a white-tailed (bald?) eagle was noted in late Aug. from a distance of 2 km., too far for positive identification.

Rough-legged hawk (Buteo lagopus)

Two birds were seen on bluffs along the Kukpuk R. on Aug 11.

Peregrine falcon (Falco peregrinus)
A rare visitor to the Cape Thompson area. An immature was observed near OP 5-1 Aug "6-8, another. 1.6 km inland on Aug 23. There was no evidence of breeding in 1990 as in past years.

Gyrfalcon (F. rusticolus)
Nesting not uncommonly on coastal cliffs and inland along the Kukpuk River. A pair, 'including a white-phase bird was at Crowbill Pt., and a grey-phased pair, with immatures or young of the year were at Agate Rock all summer. Gyrfalcons were last noted on Aug 24.

Willow ptarmigan (Lagopus lagopus)
Uncommon resident in wide flat creek bottoms. Fifteen birds were observed in the Ogoturuk Valley Jul 3-4. Only 4 birds were seen during a 60 km hike to the Kukpuk R. Aug 10-12, at two locations along Ilikrak Cr. ca. 25 km inland.

Rock ptarmigan (L. mutus)
Common in h a b i t a t , nearby-open tundra, and rocky upland. A covey of 15-20 birds including chicks was resident in the willow thickets 0.5 km inland from camp. Some indication of movement upslope in mid-Aug. Several-hundred rock ptarmigan were encountered in a 60 km hike inland to the Kukpuk R. Aug 10-12, in rocky upland along Saligvik Ridge. and along Ilikrak Cr. A flock of 80 ptarmigan were already in winter plumage at on a hillside south of Ogoturuk Cr. on Sep 1.

Sandhill crane (Grus canadensis)
A lone crane was seen in marsh north of Kemegrak Lagoon on Jul 25. A family group of 5 birds was seen in an area of extensive Carex-Eriophorum tundra approximately 3.5 km inland on Jul 27.

Lesser golden-plover (Pluvialis dominica)
A common breeding species, frequently encountered in pairs in available habitat of wet sedge-dominated tundra. All birds identified to race were P. d. dominica, the American golden-plover. Began to leave the breeding grounds in early Aug; most had left by Aug 6, and was last noted on Aug 12.

Semipalmated plover (Charadrius semipalmatus)
Noted only at the mouth of Ogoturuk Cr. on Jul 3-5, with a high count of 30 birds on Jul 3. Observed on mudflats, gravel and sand bars, and barren ground.

Wandering tattler (Heteroscelus incanus)
Individuals were encountered along Ibrulikorak, Ikijaktusak, and Imikrak Creeks throughout Jul and early Aug. Breeding not confirmed. Last seen Aug 23.

Whimbrel (Numenius phaeopus)

An adult displaying defensive behavior was seen in wet sedge tundra 3 km east of camp on Jul 14, and two juveniles were seen there on Jul 27. Small flocks gathering in wet meadows near the coast and inland, or heading south, were observed almost daily from Aug 5 to 17. The largest daily count was a flock of 12 on Aug 12.

Bar-tailed godwit (Limosa lapponica)

Approximately 4 pairs of adults displaying defensive behavior in wet sedge tundra 3 km east of camp on Jul.. Two adults and 3 juveniles were noted there Jul 27. A single hatching year bird appeared near Ikijaktusak Cr. near camp Aug 7, and a small flock was seen approximately 20 km inland on a grassy slope of Saligvik Ridge.

Ruddy turnstone (Arenaria interpres)

One adult was seen 3 km inland in sedge meadow Jul 14 (breeding not confirmed). Two adults were seen on Ikijaktusak beach Jul 25 and again Jul 30.

Red knot (Calidris canutus)

A small mixed group of whimbrels, godwits, and red knots, including 1 hatching year bird, was seen approximately 20 km inland on a slope of Saligvik Ridge. Four hatching year birds observed in sedge meadow 3 km inland on Jul 27. A hatching year bird was seen associating with golden-plovers on rocky tundra near Ibrulikorak Cr. from Jul 28 to Aug 1.

Semipalmated sandpiper (C. pusilla)

A rare migrant: immature birds were noted near camp on Jul 8 (1 bird) and Jul 27 (3 birds).

Western sandpiper (C. mauri)

A common, sometimes abundant migrant, seen almost daily from Jul 7 to Aug 11 along creeks and beaches; no evidence of nesting observed. After Jul 25 most birds seen were hatching year. Highest counts were 45 birds on Jul 28, and several hundred birds at Kemegrak Lagoon on Jul 25.

Baird's sandpiper (C. bairdii)

A not uncommon nesting species, sightings in Jul and early Aug. both in creek drainages and on high, rocky tundra. Sightings usually consisted of individual birds or family groups during Jul and early Aug. A flock of ca. 14 birds was engaged in pre-migratory orientation flight in helical patterns over the tundra in early Aug. Last sighting of an adult and young along Ikijaktusak Creek near camp after Aug 13.

Pectoral sandpiper (C. melanotos)

An uncommon visitor: Individuals were noted in grassy meadows and in rocky uplands on Jul 9 and Aug 9, 10, and 12. A migrant flock of 20 birds was noted over camp on Aug 20.

Dunlin (C. alpina)

An uncommon migrant in the area: individuals (adults molting into non-breeding plumage) were noted near camp on Aug 5, 19, and 23, and at Kemegrak Lagoon on Jul 25.

Common snipe (Gallinago gallinago)
A common nesting species in the lower Ogoturuk Valley with approximately 10 birds seen/heard in display flight on Jul 3 and 4. A single bird was flushed from willow thickets along Ikijaktusak Cr. near camp on Aug 7.

Red-necked phalarope (Phalaropus lobatus)
A common migrant along creeks and ocean shores. up to 15 birds per day, mostly hatching year birds, were noted from Jul 25 to Aug 10. Common on coastal lagoons on Jul 25 and Aug 5.

Red phalarope (P. fulicaria)
More numerous than the preceding (up to 20 birds per day), in similar habitats, also at sea, between Jul 24 and Aug 11. Common on coastal lagoons on Jul 25 and Aug 5, and at sea near Pt. Hope on Aug 5. On Ilikrak Cr. inland on Aug 12, chased by a parasitic jaeger.

Parasitic jaeger (Stercorarius parasiticus)
Uncommon. Sightings of adult birds in Carex tundra inland on Jul 25 and 27, and Aug 1 and 12. Two sight-were of dark-phased birds.

Pomarine jaeger (S. pomarinus)
Four birds, one dark-phased, harrassed a feeding flock of kittiwakes at sea approximately 10 km nw of Cape Thompson on Aug 5.

-Long-tailed jaeger (S. longicaudus)
A common nesting species in wet sedge tundra. Remarkably tame: one walked up to within 1 m. of BES and CB on Saligvik Ridge on Aug 10. A pair of dark-phased adults were seen 1.5 km inland on Jul 28. Two nests were located with hatched young. Fledged young were seen along Ilikrak Creek on Aug 12. Small (family?) groups (3-4 birds) playing/performing aerial acrobatics Aug 6 and 12. The species was observed almost daily up to Aug 19; last seen Aug 23.

Glaucous gull (Larus hyperboreus)
A common nesting species on grass-covered cliff slopes. Observed daily, with numbers increasing in lat July and early Aug with the addition of fledged young. High count of ca. 130 birds on Aug 4. Along with common ravens and golden eagle, glaucous gulls were the major predators on cliff-nesting seabirds.

Black-legged kittiwake (Rissa tridactyla)
One of the three most abundant nesting seabirds at Cape Thompson, with a population of approximately 37,000 birds. Small flocks (19-32) of possibly migrating adults were observed flying south at Chariot on Sep 1, though many pairs still had young in _

the nest at the time.

Common murre (Uris aalge)
An abundant cliff-nesting species at Cape Thompson; 14% of approximately 199,000 murres were this species.

Thick-billed murre (U. lomvia)
The most abundant seabird nesting at Cape Thompson; approximately 171,000 birds were present at cliff ledges in 1990.

Black guillemot (Cepphus gryhe)
First noted on the ocean near Colony 5 on Jul 22; approximately 8 birds total were observed at all colonies to Aug 25.

Pigeon guillemot (C. columba)
Approximately 5 birds total were observed in the vicinity of all five colonies in 1990.

It is interesting to note that the nesting ranges of C. grylle and C. columba overlap at Cape Thompson. On Aug 3 a possible mixed pair was noted at the north end of Colony 4. They were observed roosting side by side on a low ledge, and when flushed flew out to sea remained in close contact as long as they were visible. A return to the site on Aug 4 found a single C. columba on the ledge. On Jul 23, a single C. grylle had been seen at this same ledge. No eggs or young were observed in crevices; high wind tides may have flooded these ledges earlier.

Crested auklet (Aethia cristatella)
One adult was sighted with horned puffins on the ocean below Colony 5 on Jul 9.

Tufted puffin (Fratercula cirrhata)
Single birds or pairs were infrequently encountered at Cape Thompson, with sightings at all five colonies, and most records from Colony 2. Uncommon and greatly outnumbered by the horned puffin.

Horned puffin (F. corniculata)
The third most abundant nesting alcid at Cape Thompson, encountered daily. Highest count 82 birds at "Cape Thompson" itself, at midnight, Aug 5, when feeding activity was at a low.

Short-eared owl (Asio flammeus)
An uncommon nesting species. Sightings occurred near camp on Jul 25, 31, and Aug 5 and 17. Two hatching year birds and an extremely pale, almost unmarked adult in sedge meadow 3 km inland on Aug 12.

Snowy owl (Nyctea scandiaca)
Three separate snowy owls were sitting on grassy slopes bordering Aiautak Lagoon on our return trip from Pt. Hope on Aug 5.

Alder flycatcher (Empidonax alnorum)
A single migrant was observed in willows along Ikijaktusak Cr. near camp on Aug 2.

Say's phoebe (Sayornis saya)
One bird was observed at Chariot on Jul 4, and another in camp during a wave of passerine migrants on Aug 3.

Horned lark (Eremophila alpestris)
Uncommon but probably breeding locally. No singing, but young of the year were noted on Aug 17 and 19. Small numbers (2-5 birds) were observed in open habitats on Jul 27, 28 and Aug 14, 17, 19, and 20.

Tree swallow (Tachycineta bicolor)
Ten migrants were seen flying over camp on Jul 25 and 2 birds on Aug 1.

Bank swallow (Riparia riparia)
Three migrants were seen over Ikijaktusak Cr. on Aug 9, 1 Aug 10, 5 over cliffs 1 km south of camp Aug 19.

Common raven (Corvus corax)
An uncommon but conspicuous nesting species, regularly seen in the vicinity of cliffs. Most were encountered as individuals or family groups, sometimes in larger groups of 8-12 birds. An egg predator of cliff-nesting seabirds.

Arctic warbler (Phylloscopus borealis)
A common migrant in willow thickets, first encountered 0.5 km upstream from camp on Aug 4, thereafter increasingly common until the end of Aug. Daily totals 2-5 birds, largest number 15 on Aug 10. Songs heard occasionally first two weeks in Aug.

Bluethroat (Luscinia svecica)
A common migrant in willow thickets, sometimes in open grassy situations; first encountered 0.5 km upstream from camp on Aug 7, and increasingly common thereafter, even in camp, until Aug 29. Daily totals 2-4 birds, highest count 15 on Aug 12. Encountered commonly inland to Kukpuk River Aug 10-12.

Northern wheatear (Oenanthe oenanthe)
Probable uncommon local breeder, and abundant migrant. Preferred dry, rocky tundra. On Jul 16 a breeding-plumaged adult male was observed feeding a hatching year bird on Agate Rock. An influx of birds occurred on Jul 31, and numbers increased dramatically after Aug 3, when wheatears appeared in camp. The species was then found in virtually all terrestrial habitats, including beaches, from the coast to the Kukpuk R. Wheatears were very curious about humans, often approaching closely to investigate. Highest count was 35 birds on Aug 11. Nearly all birds were in non-breeding plumage in Aug. One lengthy song was heard on Aug 2 given by a male in non-breeding plumage.

Wheatears still fairly common in camp Aug 29.

Northern shrike (Lanius excubitor)
One shrike was seen on sandbars and in willows along the Kukpuk R. on Aug 11.

Gray-cheeked thrush (Catharus minimus)
A locally uncommon nesting species in willow thickets, limited by restricted availability of preferred habitat. Two-three pairs apparently resided near camp, never more than 4 birds encountered per day. Last seen Aug 24.

American robin (Turdus migratorius)
A rare visitor. Single birds seen in willow thickets near camp on Jul 17, Aug 10 and Aug 20.

Yellow wagtail (Motacilla flava)
A common migrant, encountered as individuals or in flocks in both open tundra and in willow thickets. First noted Jul 29, last on Aug 23, highest daily total 60 Aug 10. Large numbers of hatching year and adult birds.

White wagtail (M. alba)
A singing male was observed: Jul 3 at Chariot using a building as a song perch. A single bird was observed at Ikijaktusak on Jul 4.

American pipit (Anthus rubescens)
A common nesting species, and abundant migrant after Jul 15. Preferred higher open tundra for nesting; as a-migrant frequently encountered also on beaches, in creek bottoms, and in riparian growth. Most birds were molting out of breeding plumage by Jul 20. Highest daily count was 80 birds on Aug 9; only a few pipits were seen by Aug 29. Both pink- and black-legged adults were seen, both apparently breeding in the area (feeding flying young). Several scores of pipits were examined closely for occurrence of red-throated pipits (A. cervinus), but none were found between the coast and the Kukpuk R.

Yellow warbler (Dendroica petechia)
An immature bird was observed in willow thickets in camp on Aug 6 and 8, and an immature male was singing in camp Aug 15.

Wilson's warbler (Wilsonia pusilla)
An uncommon visitor in willow thickets, with sightings roughly every other day from Jul 9 to Aug 15; may have nested locally. High count 6 birds on Aug 2.

American tree sparrow (Spizella arborea)
An uncommon visitor in willow thickets *or* grassy areas nearby. All sightings involved hatching year birds with or without a pair of adults. The species was first noted Aug 2 and last reported Aug 22. Nesting probably occurred inland. High count was 6 birds Aug 10.

Savannah sparrow (Passerculus sandwichensis)
Nested commonly in flat sedge meadow at Chariot Jul 3, but apparently only a migrant at Ikijaktusak. An influx of migrants at camp Aug 10. Highest count 35 birds on Aug 17.

Fox sparrow (Passerella iliaca)
Probable uncommon nesting species in the Ogoturuk Valley. A single bird seen in willows near camp on Aug 3.

White-crowned sparrow (Zonotrichia leucophrys)
A common nesting passerine in willows at Cape Thompson. Two nests with nearly fledged young were found during the last week of July, and birds of the year were common after Aug 1. The highest daily count was 35 birds on Aug 5 and 12.

Lapland longspur (Calcarius lapponicus)
With redpolls and pipits, probably the most abundant nesting passerine in the Cape Thompson area, found in all open or semi-open terrestrial habitats. Nesting behavior noted in tall sedge tussocks, but only occasional short songs were heard in early Jul and any aerial singing was finished by Jul 3. Birds in post-breeding molt were noted as early as Jul 3, and most had molted all traces of breeding plumage by Jul 20. Hatching year birds were reported from mid-July to the end of Aug. Numbers increased after Aug 5 with an influx of migrants. Flocks of longspurs were noted as early as Aug 8 (50 birds). Abundant in flocks inland Aug 10-12. Highest daily count was 150 on Aug 16. Numbers diminished by end of Aug.

Snow bunting (Plectrophenax nivalis)
A common nesting species, preferring cliff faces, rocky creek beds, talus slopes, and snow banks. Like the lapland longspur an. early nesting species: few songs, including only one aerial song, were heard in early July. Birds were noted in post-breeding molt as early as Jul 6, and young of the year were first observed Jul 11. Reproduction was apparently successful in 1990: many young were in evidence, with brood sizes 2-3 common. Largest daily counts 15 on Jul 28 and Aug 4 at Cape Thompson, and 45-50 at Chariot on Sep 1.

Rosy finch (Leucosticte arctoa)
An uncommon nesting species, infrequently but most often seen along cliffs, near snow banks, near streams, and on rocky hillsides. Largest daily count a family group of 8 birds on Aug 10.

Redpoll (Carduelis spp.)
One of the most common breeding passerine at Cape Thompson, observed almost daily; frequented mostly willow thickets, but also open tundra with scattered shrubs. High count was 70 birds at Chariot on Aug 26.

Both the hoary repoll (C. hornemanni) and common redpoll (C.

f lammea) were observed, but only very white, unmarked, small-billed birds were identified as hoary redpolls, and only those with extensive red on the breast, heavy markings on the underparts, and dark rumps were labelled common redpolls. 80% were intermediate in plumage and could not be identified to species.