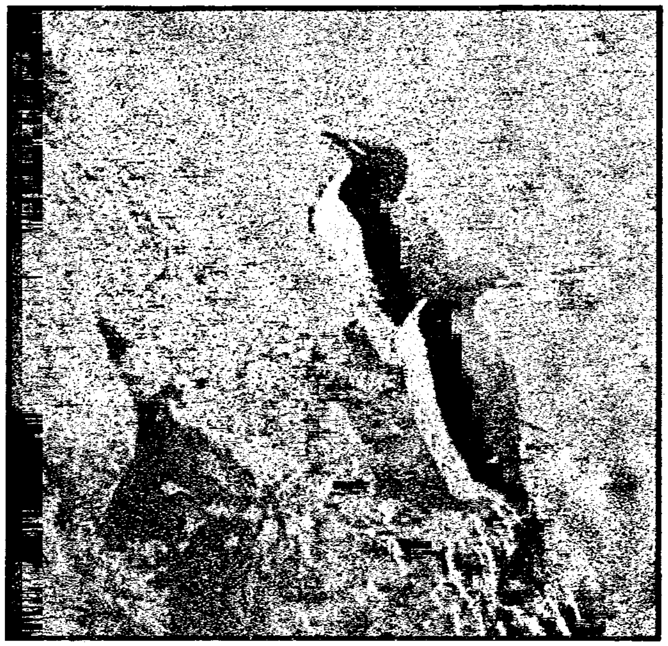
OCS Study
MMS 90-0049

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

MONITORING OF POPULATIONS AND PRODUCTIVITY OF SEABIRDS
AT ST. GEORGE ISLAND, CAPE PEIRCE, AND BLUFF, ALASKA, 1989



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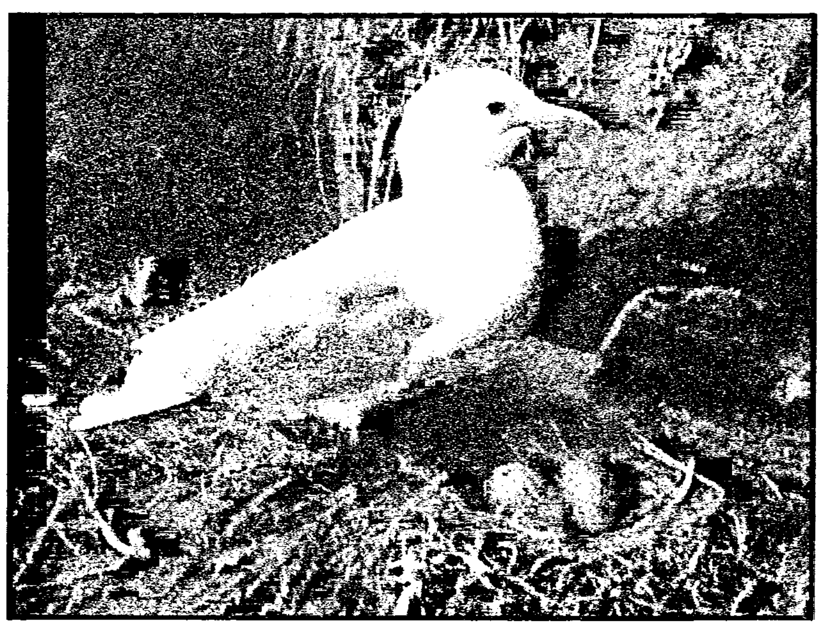

Edited by Vivian M. Mendenhall
U. S. Fish & Wildlife Service
Migratory Bird Management
Marine and Coastal Bird Project
Anchorage, Alaska

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ABSTRACT

Populations and productivity of seabirds were monitored in 1989 at three Bering Sea colonies: St. George, Cape Peirce, and Bluff. Murres and black-legged kittiwakes were monitored at all 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. Red-legged kittiwakes also were monitored at St. George because of concern for the world status of this species.

Monitoring crews were on St. George Island from 30 May to 5 September, at Cape Peirce from 26 April to 7 October, and at Bluff from 10 June until 9 September. Personnel stayed on St. George in staff quarters of the National Marine Fisheries Service, at Cape Peirce in an administrative cabin of Togiak National Wildlife Refuge, and at Bluff in a cabin by arrangement with private owners.

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. 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.

Populations of black-legged kittiwakes have been stable at all three colonies during the 1980's, although they probably declined during the 1970's at St. George and Bluff (early data for Cape Peirce have not been reanalyzed for comparison with ours). The red-legged kittiwake is still declining at St. George; numbers are now 25% below those of 1984 and probably are 50% below 1976 counts. This is of serious concern because the majority of the world population of red-legged kittiwakes breeds on St. George Island.

Breeding was initiated relatively late in spring of 1989 at the three colonies by both murres and kittiwakes, except that kittiwakes on St. George began breeding at a normal time. Productivity of murres was slightly low but was near normal levels. Kittiwake production was very poor at all three colonies. No young kittiwakes fledged at St. George or Bluff; no eggs were hatched at St. George, and hatching success was only 0.19 at Bluff. Clutch size and the proportion of nests in which clutches were initiated were also below normal at Bluff. Kittiwake production at Cape Peirce was only 0.06 fledglings per nest, but this was not significantly different from the mean for all years at the colony. Mean productivity of kittiwakes for all years studied has been highest at Bluff and has been extremely low at Cape Peirce. If low breeding success continues at Cape Peirce, the population may decline in the

near future, unless there is immigration from other colonies. Yearly breeding success at St. George and Bluff appears to be limited in some years by food; several factors may combine to depress productivity at Cape Peirce, but they have yet to be identified.

An abbreviated method for monitoring murres, which had been proposed in previous years, was compared with the "Type I" method used in this study. In the shortened "Type II" method, numbers of murre chicks were counted shortly before fledging, and productivity was estimated as the ratio of chicks to the numbers of adult birds counted in mid-season. Estimates of murre productivity by the Type II method were lower than Type I estimates. We concluded that the Type II index is unreliable; its relationship to the Type I estimate is highly variable due to uncertainty in counts of chicks because breeding sites were not mapped, and due to variability among years in the proportion of adult birds that occupy breeding sites. The Type II method for estimating kittiwake productivity that was proposed in earlier years was not tested by us, but other have concluded that it yields a reliable index of kittiwake productivity.

Productivity of kittiwakes at the three colonies in this study was not correlated among years for any pair of colonies. Productivity at Bluff was highly correlated with that at both Cape Thompson and Cape Lisburne, and productivity at St. George has been found by others to be correlated with that at St. Paul. We concluded that productivity at seabird colonies within a limited area is correlated, with the size of the area being determined by oceanographic factors. Productivity is not correlated among colonies in large areas such as the Bering Sea although there are occasional years when many colonies show similar extremes in success.

Monitoring data now available for the three colonies in this project are adequate in most respects, but additional data are needed at two colonies. Adequate baselines for future comparisons are provided by population and productivity data collected in at least three consecutive years, and analysis of trends usually requires at least five years' data. Data for all three colonies are adequate for analysis of population trends and for comparison of kittiwake productivity. Murre productivity has been monitored using standardized methods for a shorter time at Bluff (3 years) and Cape Peirce (2 years); additional years' data are essential at Cape Peirce to characterize murre success, and more data are needed at Bluff if trends in murre success are to be analyzed. Regular monitoring should be maintained at all three colonies.

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.

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. 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, the emphasis on population monitoring of seabirds has increased. 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 in the Bering Sea. Periodic or regular monitoring has been conducted 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), the latter three colonies with support from Minerals Management Service. Plots have also been established at Nunivak Island (Byrd et al. 1982, McCaffrey 1987). The state of Alaska has monitored kittiwake productivity in several years at Round Island (Walrus Islands, Bristol Bay; Sherburne and Lipchak 1988).

In the present study, Minerals Management Service and the Fish and Wildlife Service have cooperated in monitoring seabirds at three colonies in the Bering Sea: St. George Island in the Pribilofs group; Cape Peirce, in Bristol Bay west of Dillingham; and Bluff, on the north shore of Norton Sound. These three colonies were selected as representative of Bering Sea colonies because of their size, location, exposure to risks that could affect many colonies, and relative accessibility. They are major seabird concentrations; St. George Island has 2.5 million seabirds, Cape Peirce roughly 700,000, and Bluff 65,000 (Sowls et al. 1978). The colonies are vulnerable to threats from commercial activities. The Pribilof Islands group alone was the site of five vessel groundings from 1986 through 1989, four of which resulted in spilled oil and fuel (data from National Oceanic and Atmospheric Administration; courtesy J. Whitney, Anchorage). The leases in the North Aleutian Basin and future tanker traffic increase the potential for oil spills near any 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 1989 in interpreting the status of the populations.

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; rather, an index of the population is obtained each year from replicate counts of permanent sample plots. Production of young birds is also estimated each year because breeding failure often reveals environmental problems more quickly than population trends. Common and thick-billed murres (Uria aalge and U. lomvia) and black-legged kittiwakes (Rissa tridactyla) have been selected as "index" species for monitoring in the Bering Sea, 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. In addition, red-legged kittiwakes (R. brevirostris) were monitored at St. George because almost the entire species population breeds on that island.

This study is the first effort to monitor seabirds simultaneously at several colonies in the Bering Sea, using standardized methods. Consistent monitoring of each colony and 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, Donald E. Dragoo,
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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 1989. Some details of field methods used in 1989 differed between colonies because of idiosyncracies 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. Viewpoints overlooking the plots were marked with stakes (usually metal survey markers) to ensure each plot was viewed from a consistent place. 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 carried in the field during all observations. Copies of the photographs are stored at the U.S. Fish and Wildlife Office in Anchorage (for St. George, at the Service office in Homer) and 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. An effort was made to distribute plots throughout representative portions of the colony. However, the lower portions of cliffs are under-represented at St. George 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 (Hickey and Craighead 1977, Birkhead and Nettleship 1980, Hunt et al. 1981a, Murphy et al. 1987, Hatch and Hatch 1988, Byrd 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, Byrd 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 St. George 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 as the best index of the populations. Binoculars and spotting scopes were used for counts. Two counts were averaged for each plot observation at St. George and Cape Peirce; counts were repeated if necessary until they differed by 5% or less. 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).

The population index for 1989 for each species at a colony was obtained by summing the number of birds across plots within replicates, and then calculating the mean and standard error for the colony using the replicate sum as the sampling unit. A modification of this method was used at St. George because bad weather caused variations in the numbers of replicate counts obtained for plots (Chapter 3).

The population indices for 1989 were compared with numbers counted on the same plots in previous years to estimate population trends at each colony. Details of statistical analyses are given in each chapter.

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-lays"; Birkhead 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 (this study, Chapter 6). 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 St. George and 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 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 32 days or later (red-legged kittiwakes) or 36 days or later (black-legged kittiwakes). 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

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

and the estimate of variance is

$$(s^2) = \left(\frac{1}{n}\right)\left(\frac{1}{x^2}\right)\left[\frac{\Sigma(y_i - rx_i)^2}{n - 1}\right]$$

where y_i is the number of chicks leaving the nest on plot i, x_i 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, $\sqrt{s^2 r}$, was used to calculate confidence bounds.

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CHAPTER 3. ST. GEORGE ISLAND

by
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INTRODUCTION

Some of the largest seabird colonies in the North Pacific occur on the Pribilof Islands (Figure 3.1). About 2.5 million marine birds of eleven species nest there. The vast majority of the cliff-nesting seabirds in the Pribilofs breed on the immense cliffs of St. George Island. The estimated 1.5 million thick-billed murres on St. George make this the largest nesting concentration for this species in the Bering Sea. The 220,000 red-legged kittiwakes that nested on St. George Island (Hickey and Craighead 1977) constitute the largest breeding colony in the world. There are also significant populations of northern fulmars (Fulmarus glacialus), parakeet and least auklets (Cyclorrhynchus psittacula, Aethia pusilla), and both horned and tufted puffins (Fratercula corniculata, F. cirrhata) (Hickey and Craighead 1977).

The majority of the cliffs on St. George Island are part of the Alaska Maritime National Wildlife Refuge, while the rest of the island is privately owned. Private lands are being developed by the village of St. George for a harbor and a new airport, and the fishing and tourism industries are growing. Other potential threats to Pribilof Island seabirds occur offshore in the form of commercial fisheries operations, possible oil exploration, and development activities on the adjoining continental shelf. These activities can affect seabirds through disturbance of breeding sites, depletion of their prey fish, or oil pollution. St. George Island was selected as a major monitoring site for marine birds in the Bering Sea because of potential threats, the existence of historical data on breeding seabirds, and the relative ease of access to the island.

Monitoring of seabirds on St. George Island began in 1975 and continued through 1979 (Hickey and Craighead 1977, Hunt et al. 1981). Observations were repeated in 1982 (Craighead and Oppenheim 1982), 1983 (Lloyd 1985), and 1984 (Johnson and Baker 1985, Troy and Baker 1985). The Alaska Maritime National Wildlife Refuge began monitoring seabirds at the Pribilof Islands in 1985 and has continued this effort annually (Byrd et al. 1985, Byrd 1986a and b, 1987, Dragoo et al. 1989). In combination with this earlier work, the Pribilof Island seabird monitoring project represents one of the longest and most thorough attempts to monitor marine bird populations in Alaska.

This report summarizes the data that were collected pertaining to population trends and reproductive success of kittiwakes and murres during the 1989 breeding season at St. George Island. Comparisons were made with previously collected data.

METHODS

A crew of four arrived on St. George Island on 30 May 1989. Personnel stayed at staff quarters of the National Marine Fisheries Service in St. Geroge. The main crew made observations of reproductive performance and conducted population counts. Two additional people arrived in mid-July to help with the population counts. All personnel left the island on or before 5 September.

Populations

The collection of data for the population portion of the monitoring program involved counting birds on plots distributed in all areas of seabird concentration (Figures 3.2 and 3.3). General census methods were described in Chapter 2. Populations were censused on St. George in 1989 from 13 July, when the last eggs were laid, to 9 August, when the first chicks fledged. Census data were entered in the field into a computerized data base (dBase III+) on Zenith Supersport 286 laptop computers.

We planned to replicate the complete count of all population plots six times in 1989. However, the weather interfered with this. The summer of 1989 was the foggiest in the five years that refuge staff have been working there; island residents stated that the fog was the worst since 1978. Because of the frequent fog, crews on St. George Island were not able to make counts of the high-elevation population plots as often as desired. Only two counts were made of the High Bluffs Plots (plots 40-44 and 54-55), and only three counts were possible for the majority of the plots in the Red Bluffs-Cascade Point area (plots 24-38) (Figures 3.2 and 3).

The low number of replicate counts for some plots made it desirable to calculate colony population indices using a procedure for stratified sampling described by Byrd (1989). Plots were assigned to strata based on similarity of geographic location, other environmental factors such as elevation, and the number of replicate counts. For instance, all plots on High Bluffs were grouped together into one stratum because they are similar in geography, aspect and elevation, and number of replicates (Table 3.1). Locations of plot strata are shown in Figure 3.2.

A mean and combined variance for the colony-wide stratified population index were calculated according to the method described by Byrd (1989:10-11). This method is illustrated using the 1989 data for black-legged kittiwakes in Table 3.2.

1. The mean of the population plot counts for each stratum was calculated. Plot counts were totalled for each replicate and the mean of the replicate totals was calculated.

2. Stratum means were summed across all strata to obtain a colony-wide index of 514 black-legged kittiwakes for 1989.

3. The total number of replicate counts for all strata was 27; the mean number of replicates per stratum was 27 divided by 6 = 4.5.

4. The pooled variance (s^2_p), or average variance weighted by the proportion of samples from each stratum, was calculated by multiplying s^2 times n for each stratum, adding the products across strata, and dividing the total for all strata by the sum of all n's (13,907.5 divided by 27 = 515.093) (Zar 1984:124).

5. The combined variance for all strata was calculated by multiplying s^2_p times the number of strata (515.093 x 6 = 3090.5556).

6. The standard error for the mean population index for all strata was obtained by dividing the combined variance by the mean number of replicates in all strata (3090.556 divided by 4.5 = 686.79) and then taking the square root of that value (26.2067).

7. The 90% confidence bound around the mean population index was calculated as the standard error times t. Degrees of freedom for the t value were calculated using the average n for all strata rounded to the nearest whole number (4.5 rounds to 5; d.f.= 5-1= 4).

Table 3.1. Population plot strata used for calculating population parameters at St. George Island, Alaska.

Stratum Number	Area	Plots Included
1	First Bluff	1, 2, 39
2	High Bluffs	40-44, 54, 55
3	Rush Pt./Zapadni	3-20,75
4	Murie Cove	21-23
5	Red Bluffs/Cascade Pt.	24-38
6	Tolstoi Pt.	45-53
7[a]	Village Cliffs	58, 59, 81

[a]. Stratum 7 was not used in comparisons between years, since no counts were available for some years.

Table 3.2. Black-legged kittiwake populations on common census plots at St. George Island in 1989.

Stratum	Mean # of birds	Variance (s^2)	Replicates (n)	s^2*n
1	43	139	5	693.5
2	69	72	2	144.0
3	40	119	5	594.0
4	3	3	6	17.8
5	131	637	3	1,911.0
6	228	1,758	6	10,547.2
Totals	514		27	

The population indices estimated for St. George in 1989 were used in comparisons of population levels of the four study species between years. It should be noted that not every plot counted in 1989 was included in the index estimate for inter-year comparisons. Only plots that were counted in all years being compared (called "common plots") were used for this purpose. As a result, the entire Village Cliffs stratum (Table 3.1, Figure 3.2) was excluded from the calculations.

Stratified means and statistics were computed for population counts for 1985 through 1989. No statistics were estimated for 1976, 1982, and 1984. For 1976 and 1982, only a single count was made on each plot during the census period. Although replicate counts were made on some plots in 1984, many plots were counted only once during the designated count period, thus precluding the calculation of statistics. The population estimates from 1976, 1982 and 1984 are, therefore not included in Table 3.3.

It should also be noted that some of the numbers presented in various tables in this report do not coincide exactly with those reported in previous reports. This is due to the fact that Byrd (1989) recalculated some estimates using different assumptions or procedures where these changes were warranted. We have used the values reported in Byrd's thesis (1989) in place of those from earlier sources. This is the case for all study species, and estimates of both population and productivity trends.

Due to the fact that single counts, as opposed to replicate counts, were made of population plots in 1976 through 1984, it was not possible to calculate confidence bounds for all years. Comparisons between years were therefore made using both pairwise tests and overall trends were estimated with least squares regression.

Productivity

Four observers monitored the reproductive performance of kittiwakes and murres on St. George Island during the 1989 breeding season. Due to the incessant heavy fog, our monitoring of productivity was hampered to varying degrees; particularly where cliffs were high or observation distances were long, viewing of plots was prevented for several days at a time. Because of this, we were unable to maintain our proposed three-day observation intervals on these plots. Some lower-elevation plots were visited every day or every other day during this period.

Productivity was observed on specially selected plots as described in Chapter 2. Observations were made from 30 May to 5 September. The chronology of chick departure was not estimated for murres because observers left the island before all chicks had jumped from ledges. No hatching and fledging phenologies are given for kittiwakes because of the total reproductive failure that occurred in 1989 (see "Results"). For estimates of "fledging success" for murres, we omitted all sites where fledging could have occurred more than three days after the last observations were made.

Estimates of reproductive success were determined as described in Chapter 2. Because of low numbers of nests of certain species breeding on some plots, it was necessary to combine nests from two plots in some cases. Approximately 25 to 30 breeding sites on a plot are desirable (Byrd 1989). Plots whose nests were combined were as much alike as possible in such things as locality, elevation and aspect. For example, the 10 nests from plot 60 were combined with those from plot 61 to form one sampling unit for thick-billed murres. In some cases it was not feasible to combine plots because there were no similar ones nearby, so a few plots were used although they had fewer nests than was desired.

RESULTS

Kittiwakes

Populations--Because of fog, two counts were feasible on some high elevation plots. The mean count of red-legged kittiwakes on common plots in 1989 was 1,693. Black-legged kittiwakes, which are much less numerous on St. George, averaged 514 (Table 3.3, Figure 3.4). The counts for each plot and replicate in 1989 are presented in Appendix A, Tables A1 and A2.

Breeding Chronology--Both kittiwake species began building nests in early June and continued until late August in some cases. The first black-legged kittiwake eggs were observed on 27 June. Laying continued until 7 July. The mean laying date was 3 July (Table 3.4, Figure 3.5). The first eggs of the red-legged kittiwake were seen on 13 June and laying continued until 17 July. The mean date for egg laying was 22 June (Table 3.4, Figure 3.5).

Reproductive Performance--A total of 59 black-legged kittiwake pairs built nests in 1989 on productivity plots at St. George Island (Table 3.5). A total of 12 eggs were laid in nine nests. The average clutch size was, therefore, 1.33 eggs per nest in which at least one egg was laid. None of these eggs hatched, and only one live chick was seen on the island during our entire stay. Nests were built by 190 pairs of red-legged kittiwakes on St. George Island productivity plots this year (Table 3.5). Only 26 eggs were laid; clutch size was one egg per nest. No red-legged kittiwakes hatched. As was the case with its congener, only one live chick of this species was observed on any part of the island that was visited by observers.

Other observations--Since no kittiwake chicks hatched on our productivity plots, we do not have any observations pertaining to foods brought to chicks or feeding frequencies. The only food-related information that can be reported from this year is that there appeared to be far fewer feeding melees just offshore from St. George than there were in 1988 (a relatively high production year for kittiwakes; Dragoo et al. 1989). The few melees that were observed were of much shorter duration than those in 1988.

Murres

Populations--As with kittiwakes, there is a great disparity in the numbers of the two species of murres present on the St. George Island plots. The common murre, in spite of its name, is the less abundant of the two at the Pribilof Islands. A mean of 1,811 common murres were present on the census plots in 1989 (Table 3.2, Figure 3.6). The thick-billed murre averaged 15,117 on our census plots during the 1989 breeding season. This is by far the most prevalent cliff nesting seabird on the island (Table 3.2, Figure 3.6). The actual counts obtained for each replicate in 1989 are presented in Appendix A, Tables A3 (common murre) and A4 (thick-billed murre).

Breeding Chronology--Murres were first seen in attendance on the cliffs on 6 June. Most were still to be found in large rafts offshore until about the middle of the month when they began to lay their eggs.

Eggs of common murres were first observed on 21 June. Eggs were laid until 9 August. The mean laying date was 2 July (Table 3.4, Figure 3.7). The first chicks were seen on 23 July and hatching continued until 20 August. The mean hatching date for this species was 4 August (Table 3.4, Figure 3.8). The earliest fledged common murre chick was recorded on 14 August. Several chicks were still on the cliffs when observers left at the end of the season so we were not able to record the last day that a chick fledged or calculate a mean fledging date.

We saw the first thick-billed murre eggs on the plots on 14 June and the last new egg on 4 August. The mean laying date for thick-billed murres was 2 July (Table 3.4, Figure 3.7). The first chicks were observed on 21 July and hatching continued until 22 August. The mean hatching date was the same as for common murres, 4 August (Table 3.4, Figure 3.8). The first chick was observed to fledge on 10 August. As for common murres, several chicks still occupied their nest sites when we left.

Reproductive Performance--Eggs were laid at 114 common murre nest sites on 5 plots (Table 3.6). Of these, 65 hatched and 42 of the chicks fledged. The overall reproductive success of this species was 0.37 chick fledged for every nest site. In 1989, 326 thick-billed murre sites on 12 productivity plots contained eggs (Table 3.6). Out of this total, 208 chicks hatched and 171 fledged. This constitutes a productivity of 0.52 chick fledged per nest site where an egg was laid (Table 3.7).

Other Observation--No food samples were collected from murres this year. The only information in this regard is anecdotal in nature, consisting of observations of foods brought to chicks. There appeared to be no one species of prey that predominated in the few sightings of this type we made. Squid, sculpins and sand lance were the only prey items we identified. One thick-billed murre chick was fed four times during a 90-minute period. Murre chicks were typically fed less frequently than this.

DISCUSSION

Numbers of black-legged kittiwakes on census plots at St. George Island in 1989 were lower than those in 1988, and were the lowest there since 1986.

Visual inspection of data on black-legged kittiwake numbers on St. George (Figure 3.4) suggest that they declined from the time monitoring began in 1976 until 1984 and were relatively stable thereafter. The overall trend from 1976 through 1989 was not significant, based on a t-test of the least squares linear regression ($b = -29.4$, $p > 0.05$; Sokal and Rohlf 1981). The decline from 1982 through 1989 bordered on significance ($b = -15.0$, $0.10 > p > 0.05$). The decline was significant for the periods 1976 through 1986 and 1976 through 1987 (Byrd 1986b, 1989). Since 1984 there has been a slight but significant increase in numbers ($b = 10.5$, $p < 0.05$). However, r^2 for the regression for the past 5 years is very low (0.19), suggesting that most variation in numbers was not associated with a consistent change over time.

Data of seabird numbers for 1976 and 1982 on St. George are much less reliable than those collected in 1984 and later, because each plot was counted on only one day per season. Each single count represents one sample from a hypothical census mean, and that mean could have been considerably higher or lower than the single value actually obtained. If coefficients of variation for means of 1976 and 1982 had been similar to those for estimated census means on the plots from 1985 through 1989 (standard deviations for those years were up to 19% of the means), then there is a 68% probability that means estimated for 1976 or 1982 could have been as much as 19% higher or lower than the actual single counts. There is a 90% probability that means could have been as much as 40% different from the single count, and a small chance that mean numbers would have been even higher or lower than this.

Other evidence suggests that there probably was a decline in black-legged kittiwake numbers on St. George. Counts for both 1976 and 1982 were significantly higher than the mean for 1984-1989 (t-tests for single observations; $t = 4.037$ for 1976 and 3.751 for 1982; $p < 0.01$ for both; Sokal and Rohlf 1981). In addition, although each single count is unreliable by itself, their reliability is improved by the existence of two early data points and the consistent trend from 1976 to the mid-1980's. Although we can never be certain whether black-legged kittiwakes declined during the late 1970's, it is extremely likely that numbers in 1976 were well above those in the 1980's.

Numbers of red-legged kittiwakes on St. George are declining (Figure 3.4). The trend is significant for 1982 - 1989 ($b = -162.2$, $p < 0.02$, $r^2 = 0.82$) and for 1984-1989 ($b = -99.4$, $p < 0.02$, $r^2 = 0.74$). The decline borders on significance for the entire period covered by our study (1976-1989; $b = -151.4$, $0.10 > p > 0.05$, $r^2 = 0.93$). Previous analysis have found the decline to be significant for the periods 1976-1986 and 1976-1987 (Byrd 1986b, 1989). As for black-legged kittiwakes, the data from 1976 and 1982 were single counts and therefore were relatively unreliable, but they were significantly than the mean for 1984-1989 ($t = 3.251$

and 4.360, $p < 0.01$). The number of kittiwakes in St. George have declined 25% since 1984, and the trend is continuing. If the 1976 census were to be considered reliable the loss since then would have been 50%. We believe there has been a decline on St. George since at least 1976, as discussed for the black-legged kittiwake (above); however, we can not be certain of its magnitude over that time.

The 25% decline on St. George over the past 6 years is extremely serious, even without firm data on previous trends. Fully since 95% of the world population of red-legged kittiwakes breeds on St. George. There are only five other small colonies on St. Paul and Otter Islands in the Pribilof Islands, Bogoslof and Buldir Islands in the Aleutians, and the Komandorskiye Islands in the Eastern Soviet Union. The population of one small colony that is currently monitored, on Buldir Island, is increasing, although 1989 counts were slightly below those for 1988 (Byrd and Climo 1988, Byrd and Douglas 1989). The population on St. Paul has declined since 1976 (Byrd 1986), although numbers on plots increased in 1988 and 1989 (unpublished data, Alaska Maritime National Wildlife Refuge). In spite of improved numbers at other colonies, however, the status of the red-legged kittiwakes world population is determined by trends on St. George because of the overwhelming dominance of numbers there. There is an urgent need for intensive study of the red-legged kittiwake to determine whether management actions may exist that could reverse its decline.

The estimate of the common murre population on plots at St. George Island was the second highest on record, being 14.5% higher than the 1988 estimate (Table 3.3, Figure 3.6). There has been no trend in common murre numbers on St. George over the entire study period since 1976 ($b = 5.66$, $p > 0.10$). For the period 1984-1989 there has been a slight but significant increase in numbers on our plots ($b = 14.8$, $p < 0.05$). The low r^2 for 1984-1989 (0.12) suggests that most variation was not related to the trend over these years. The number of thick-billed murres on plots also increased from 1988 to 1989 (Table 3.3, Figure 3.6). There was a significant decline in thick-billed murres over the entire study period ($b = -421$, $p < 0.05$; $r^2 = 0.79$), but there has been no trend over the past 6 years ($b = -73.0$, $p > 0.10$, $r^2 = 0.03$). Murre populations on St. George Island appear to be stable.

The timing of breeding of black-legged kittiwakes at St. George Island in 1989 (Figure 3.5) was similar to other years (Table 3.3). Red-legged kittiwakes laid their eggs slightly earlier, on average (22 June), than they did during the two previous breeding seasons (Table 3.4; Dragoo et al. 1989). The mean laying date for 1989 (3 July) was similar to that in 1987 (Table 3.4). Laying was somewhat later than the probable date for 1988 (Dragoo et al. 1989). Although no data were obtained for phenology on St. George in 1988, observers believed that the timing of laying on St. George was similar to that recorded on St. Paul, where the mean laying date was 23 June (Dragoo et al. 1989). The mean laying date for both common and thick-billed murres at St. George Island (Figure 3.7) was 2 July (Table 3.4). This date falls near the late end of the range of laying dates observed in earlier years for both species. Both murre species also had a mean hatching date (4 August) that was near the late end of the range of yearly means (Table 3.4, Figure 3.8).

Kittiwakes in Alaska tend to vary considerably in their reproductive output from year to year (Hatch 1987), and this pattern holds true for both species that breed at St. George Island (Byrd 1989). Productivity of the two kittiwake species for 1976-1989 was highly correlated (Table 3.8; $r = 0.78$, $p < 0.01$). The years 1982 and 1983 were omitted from the regression because precise data were not available. Both species failed to raise any chicks in 1989, which was the first time in 14 years this has been observed for the red-legged kittiwake and the second time for the black-legged kittiwake. Springer and Byrd (1989) presented evidence that reproductive success in kittiwakes on the Pribilofs is correlated with abundance of forage fish and is ultimately linked to air or sea-surface temperature. Although the diets of black-legged and red-legged kittiwakes tend to be dominated by different families of fish (Hunt et al. 1981), the similarity of trends in their productivity (Springer and Byrd 1989; this study) suggest that the same factors have limited the reproductive success of both species in the Pribilofs during the past 14 years. Hatch (1987) and Byrd (1989) have noted that the reproductive output of both species of kittiwakes in the Pribilofs was generally higher during the period from 1976-1980 than since 1980. Springer and Byrd (1989) found a significant increase in the productivity of both species from 1983 through 1988, suggesting that they are recovering from the dismal production of the early 1980's. The failures of 1989 did not reverse this trend; for both species there was still a significant increase in productivity for 1983-1989 ($b = 0.0132$ for the black-legged kittiwake, $p < 0.02$; for the red-legged kittiwake, $b = 0.0304$, $p < 0.01$). The variability accounted for by the regression over 1983-1989 was extremely low, however ($r^2 = 0.035$ and 0.12 for the two species), in contrast to the earlier trend (Springer and Byrd 1989). Several more years' data will be necessary before it will be clear whether 1989 represented an anomaly in the improving productivity described by Springer and Byrd (1989) or whether another trend is developing.

Thick-billed murre productivity (Table 3.7) was lower in 1989 than in the previous two years, but was well within the range of values reported in the past (Table 3.9, Figure 3.9). The productivity of common murres on plots at St. George Island in 1989 (Table 3.7) was the lowest reported since 1981 (Table 3.8, Figure 3.9). However, the estimate of productivity for common murres on St. George in 1989 may have been biased by the small number of plots (5) used to observe their reproduction. Monitoring of common murre productivity on St. George is hampered because there are few birds of this species on the island, and most do not nest on portions of the cliff that are visible to observers. Bias may have been significant in 1989 because success varied greatly between plots in this year (Table 3.6). Plot 78 lost all chicks and 15 out of 19 eggs between 11 and 14 August. Since there were also two dead adults on the cliff, an avian predator is suspected as the cause of the failure. Observers felt that common murre production on St. George Island as a whole was higher than the estimate from plots (0.37 chicks per site). If Plot 78 was excluded, common murre production on plots for 1989 was estimated at 0.53, which is lower than usual but well above the 1981 minimum (Table 3.9).

Estimates of productivity for species other than common murres illustrate the value of observing a large enough number of plots to represent the population. Thick-billed murres on St. George also failed almost completely on one plot (Table 3.6), but 12 plots were observed for this species. The confidence bounds of the estimate for thick-billed murre production were much smaller than for common murres (Table 3.7), and the general impression of observers was that the estimated productivity for thick-billed murres (0.52 chicks per site) was representative of the colony as a whole. An effort will be made in the future to add new plots for common murres, and one was added in 1989. The number of productivity plots for thick-billed murres on St. George is nevertheless below the 25 to 30 recommended by Byrd (1989). Estimates of kittiwake productivity also appeared to be representative of the colony; confidence bounds for both species have been within 20-30% of the mean in years of good production (Table 3.7). The failure observed on plots in 1989 reflected performance throughout the colony, where observers were able to find only one hatched chick of each species and no fledglings. The number of plots for black-legged kittiwakes is, however, much lower than the 15 to 20 recommended by Byrd (1989). It would be preferable to add several plots for black-legged kittiwakes on St. George Island, if this was feasible in the small population of the species there.

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Table 3.3 Estimates of the number of murres and kittiwakes on population plots[a] at St. George Island, Alaska, 1985-1989[b].

Black-legged Kittiwake

Year	Mean	90% CB[c]	n[d]
1985	559	105 (18)	4.5
1986	482	30 (6)	4.5
1987	530	78 (15)	4.5
1988	585	71 (12)	5.0
1989	514	56 (11)	4.5

Red-legged Kittiwake

Year	Mean	90% CB	n
1985	2,423	189 (8)	4.3
1986	2,281	701 (31)	4.5
1987	2,412	334 (14)	4.7
1988	2,300	149 (6)	5.0
1989	1,963	122 (6)	4.5

Common Murre

Year	Mean	90% CB	n
1985	1,684	352 (21)	4.3
1986	1,627	281 (17)	4.3
1987	1,705	390 (23)	5.2
1988	1,582	91 (6)	5.0
1989	1,811	166 (9)	4.5

Thick-billed Murre

Year	Mean	90% CB	n
1985	15,347	1,616 (11)	4.3
1986	14,095	3,236 (23)	4.3
1987	13,374	3,972 (29)	4.8
1988	13,897	802 (6)	5.0
1989	15,117	801 (5)	4.5

[a] Includes only plots that were counted in all represented years. Data for all plots are presented in the appendix.

[b] Data from: 1985-1987, Byrd (1989); 1988, Dragoo et al. (1989).

[c] 90% confidence bound (percentage of the mean in parentheses).

[d] Sample size = the average number of days on which counts were made (replicates).

Table 3.4 Nesting chronology of kittiwakes and murres at St. George Island, Alaska, 1975-1989[a].

	Black-legged Kittiwake		Red-legged Kittiwake		Common Murre		Thick-billed Murre	
	Lay	Hatch	Lay	Hatch	Lay	Hatch	Lay	Hatch
Years								
1975	---	---	---	08/01[b]	---	---	---	---
1976	07/01	07/28	07/07	08/05	---	08/03	07/02	08/03
1977	06/30	07/27	07/04	07/31	07/03	08/04	06/29	08/05
1978	07/03	08/01	07/07	08/10	06/30	08/02	06/23	07/29
1979	---	---	07/09	---	---	---	---	---
1981	---	07/22	06/24	07/24	---	07/30	---	07/26
1985	07/08	07/31	07/11	08/07	---	---	---	08/03
1986	06/18	07/13	06/13	07/10	07/01	08/03	06/29	07/31
1987	07/04	08/02	06/26	07/29	07/01	07/31	07/01	07/31
1989	07/03	None Hatched	06/22	None Hatched	07/02	08/04	07/02	08/04

[a] References for information are: 1975-1979, Hunt et al. (1981); 1981, Lloyd (1985); 1985, Byrd et al. (1985); 1986, Byrd (1986) and Climo (1986); 1987, Byrd (1987); 1989, this study. Phenology data are not available for 1988 (see Dragoo et al. 1989).

Table 3.5 Reproductive performance of kittiwakes on productivity plots at St. George Island, Alaska, 1989.

Plot	Red-legged kittiwake Nest[a] starts	Red-legged kittiwake Eggs[b] laid	Red-legged kittiwake Eggs hatched	Black-legged kittiwake Nest starts	Black-legged kittiwake Eggs[c] laid	Black-legged kittiwake Eggs hatched
56	4	0	0	6	3	0
57	1	0	0	5	0	0
60	2	0	0	20	3	0
61	5	0	0	10	2	0
62	-	-	-	13	4	0
64	13	0	0	3	0	0
65	-	-	-	-	-	-
66	22	5	0	-	-	-
67	35	4	0	-	-	-
68	18	3	0	-	-	-
69	49	6	0	-	-	-
70	20	5	0	-	-	-
71	-	-	-	-	-	-
72	-	-	-	-	-	-
73	-	-	-	-	-	-
74	-	-	-	-	-	-
78	21	3	0	-	-	-
79	-	-	-	-	-	-
82	-	-	-	2	0	0
83	-	-	-	-	-	-
84	-	-	-	-	-	-
Total	190	26	0	59	12	0

[a] Site where new vegetationwas added during the current season.

[b] Clutch size for red-legged kittiwakes was one egg/nest for all nests.

[c] Clutch size for black-legged kittiwakes was one egg/nest except for one nest each in plots 56, 61, and 62 in which two eggs were laid (mean=1.33).

Table 3.6 Reproductive performance of murres on productivity plots at St. George Island, Alaska, 1989.

	Common Murre			Thick-billed murre		
Plot	Nest[a] starts	Chicks hatched	Chicks fledged	Nest[a] starts	Chicks hatched	Chicks fledged
56	-	-	-	26	15	9
57	-	-	-	27	18	16
60	-	-	-	10	5	3
61	16	7	7	34	15	13
62	-	-	-	28	16	13
64	-	-	-	24	9	5
65	-	-	-	33	22	21
66	-	-	-	14	5	1
67	-	-	-	-	-	-
68	-	-	-	20	17	16
69	-	-	-	-	-	-
70	-	-	-	-	-	-
71	-	-	-	13	11	10
72	-	-	-	13	12	9
73	-	-	-	15	10	10
74	-	-	-	30	27	24
78	34	16	0	-	-	-
79	42	35	29	5	4	4
82	11	3	3	8	3	1
83	-	-	-	22	16	13
84	11	4	3	4	3	3
Total	114	65	42	326	208	171

[a] Site where an egg was laid.

Table 3.7 Productivity estimates for murres and kittiwakes at St. George Island, Alaska, 1985-1989.

Species	Year	Nest[b] starts	No. fledged	No. plots	Prod.[c]	90%CB[d]
BLKI	1985	153	19	9	0.12	0.08
BLKI	1986	154	40	9	0.26	0.10
BLKI	1987	126	0	9	0.00	--
BLKI	1988	85	34	6	0.40	0.11
BLKI	1989	59	0	7	0.00	--
RLKI	1985	269	20	11	0.07	0.03
RLKI	1986	256	75	11	0.29	0.07
RLKI	1987	250	32	11	0.13	0.05
RLKI	1988	230	125	8	0.54	0.08
RLKI	1989	190	0	11	0.00	--
COMU	1985	51	39	3	0.76	0.27
COMU	1986	66	38	4	0.58	0.33
COMU	1987	113	85	5	0.75	0.23
COMU	1988	83	59	4	0.71	0.13
COMU	1989	114	42	5	0.37	0.39
TBMU	1985	316	228	11	0.72	0.07
TBMU	1986	386	147	13	0.38	0.12
TBMU	1987	377	252	15	0.67	0.06
TBMU	1989	326	171	12	0.52	0.10

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

[b] Site where new vegetation was added (kittiwakes) or where an egg was laid (murres) during the specified season. This value indicates the number of nest sites monitored in any given year and may not be representative of the actual nesting effort exhibited by the species in question during that season.

[c] Prod. = productivity (estimated proportion of nest starts where a chick fledged).

[d] 90% confidence bounds were calculated with the variances of ratios, using plots as sample units. 1985-1987 data from Byrd (1989).

Table 3.8 Reproductive performance of kittiwakes on plots at St. George Island, Alaska, 1976-1989.

Year	Nest Starts[a]	Mean Clutch[b]	Hatching Success[c]	Fledging Success[d]	Reproductive Success[e]	Productivity[f]
Black-legged Kittiwake:						
1976	34	1.42	0.82	0.80	0.79	0.62
1977	110	1.46	0.84	0.47	0.56	0.45
1978	229	1.20	0.67	0.62	0.48	0.22
1979	146	--	--	--	--	0.40
1980	106	--	--	--	--	0.38
1981	102	1.37	0.58	0.17	0.12	0.07
1982	?[g]		--	--	0.01	0.01
1983	?	--		--	0.01	0.01
1984	57	1.31	0.24	0.56	0.19	0.14
1985	153	1.18	--	--	0.18	0.12
1986	154	1.70	--	--	0.30	0.26
1987	126	1.04	0.08	0.0	0.0	0.0
1988	85	1.40	0.45	0.85	0.54	0.40
1989	59	1.33	0.0	--	0.0	0.0
Red-legged Kittiwake:						
1976	88	1.00	0.83	0.80	0.67	0.38
1977	240	1.00	0.82	0.83	0.68	0.54
1978	235	1.00	0.69	0.65	0.43	0.13
1979	52	1.00	--	--	--	0.18
1980	123	1.00	--	--	--	0.27
1981	79	1.00	0.66	0.49	0.29	0.11
1982	?	1.00	--	--	--	0.01
1983	?	1.00	--	--	--	0.01
1984	149	1.00	0.22	0.93	--	0.13
1985	259	1.00	0.56	0.21	0.10	0.07
1986	256	1.00	0.53	0.67	0.36	0.29
1987	250	1.00	0.49	0.49	0.29	0.13
1988	230	1.00	0.81	0.87	0.70	0.54
1989	190	1.00	0.0	0.0	0.0	0.0

[a] Nest sites to which new vegetation was added.

[b] Expressed as mean clutch = (eggs laid/nests with $\geq$ 1 egg).

[c] Hatching success = (chicks hatched/egg laid).

[d] Fledging success = (chicks fledged/chicks hatched).

[e] Reproductive success (chicks fledged/nest with $\geq$ 1 egg).

[f] Productivity (chicks fledged/nest started).

[g] Question marks indicate unknown sample sizes; reproductive success and productivity values are based on general impressions by Craighead and Oppenheim (1982) and local residents (1983)--values assigned by Lloyd (1985).

Table 3.9 Productivity of murres on plots at St. George Island, Alaska, 1977-1989.

Year	Nest starts[a]	Hatching success[b]	Fledging success[c]	Reproductive success[d]
Common Murre:				
1978	10	0.80	0.87	0.70
1981	64	0.82	0.37	0.30
1985	47	0.72	0.93	0.76
1986	66	0.73	0.79	0.58
1987	113	0.80	0.94	0.75
1988	83	0.83	0.86	0.71
1989	114	0.57	0.65	0.37
Thick-billed Murre:				
1977	51	0.72	0.66	0.43
1978	90	0.66	0.78	0.51
1981	88	0.77	0.20	0.15
1984	126	0.73	0.88	0.51
1985	297	0.79	0.92	0.72
1986	388	0.65	0.59	0.38
1987	377	0.75	0.87	0.67
1988	195	0.75	0.86	0.65
1989	326	0.64	0.82	0.52

[a] Nest sites at which an egg was laid.

[b] Hatching success = (chicks hatched/egg laid).

[c] Fledging success = (chicks fledged/chicks hatched).

[d] Reproductive success = (chicks fledged/nest started [this value is equal to "prod." given in Table 7]).

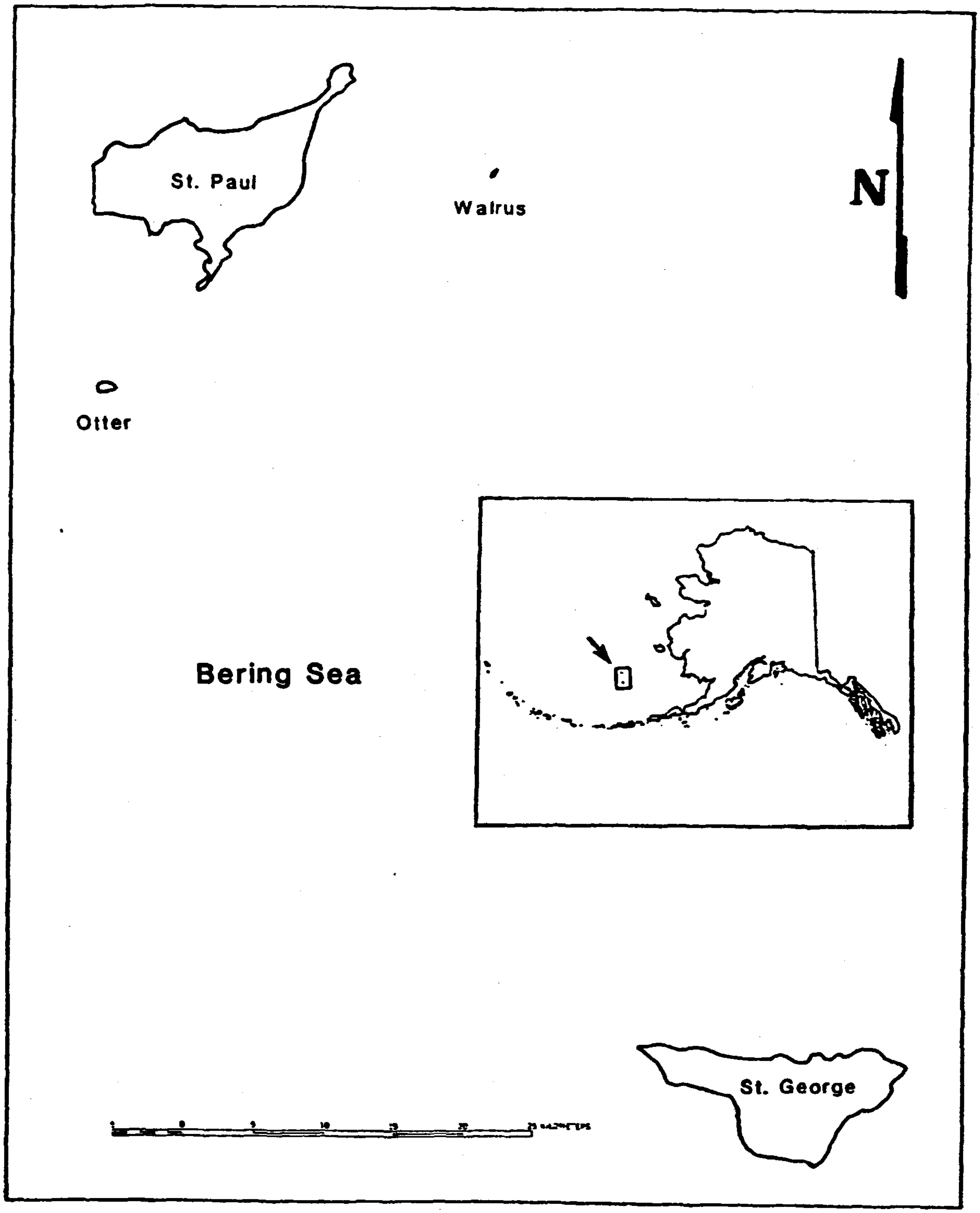


Figure 3.1. Location of the Pribilof Islands, Alaska.

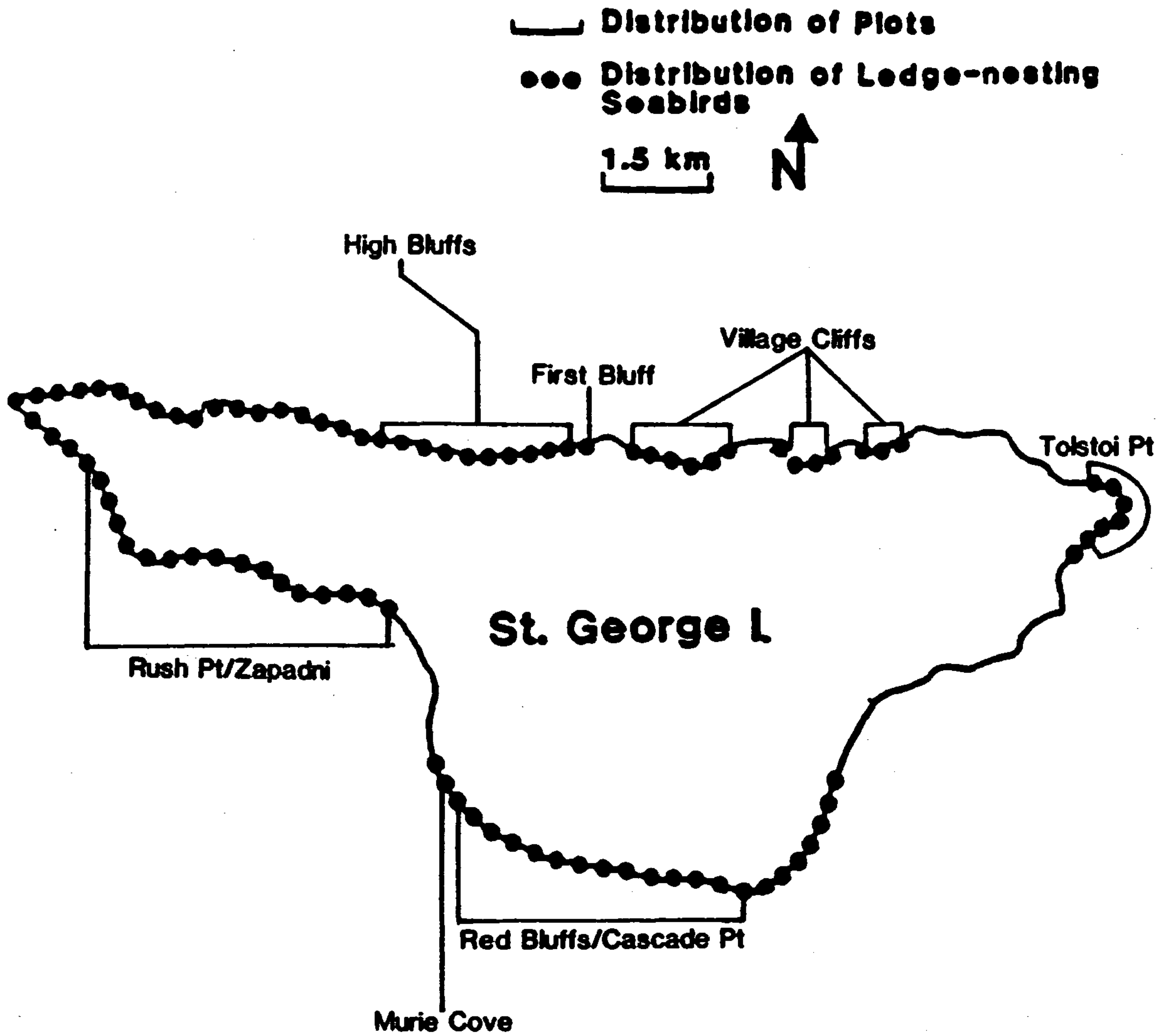


Figure 3.2. Location of seabird study areas (strata) at St. George Island, Alaska (after Byrd 1989).

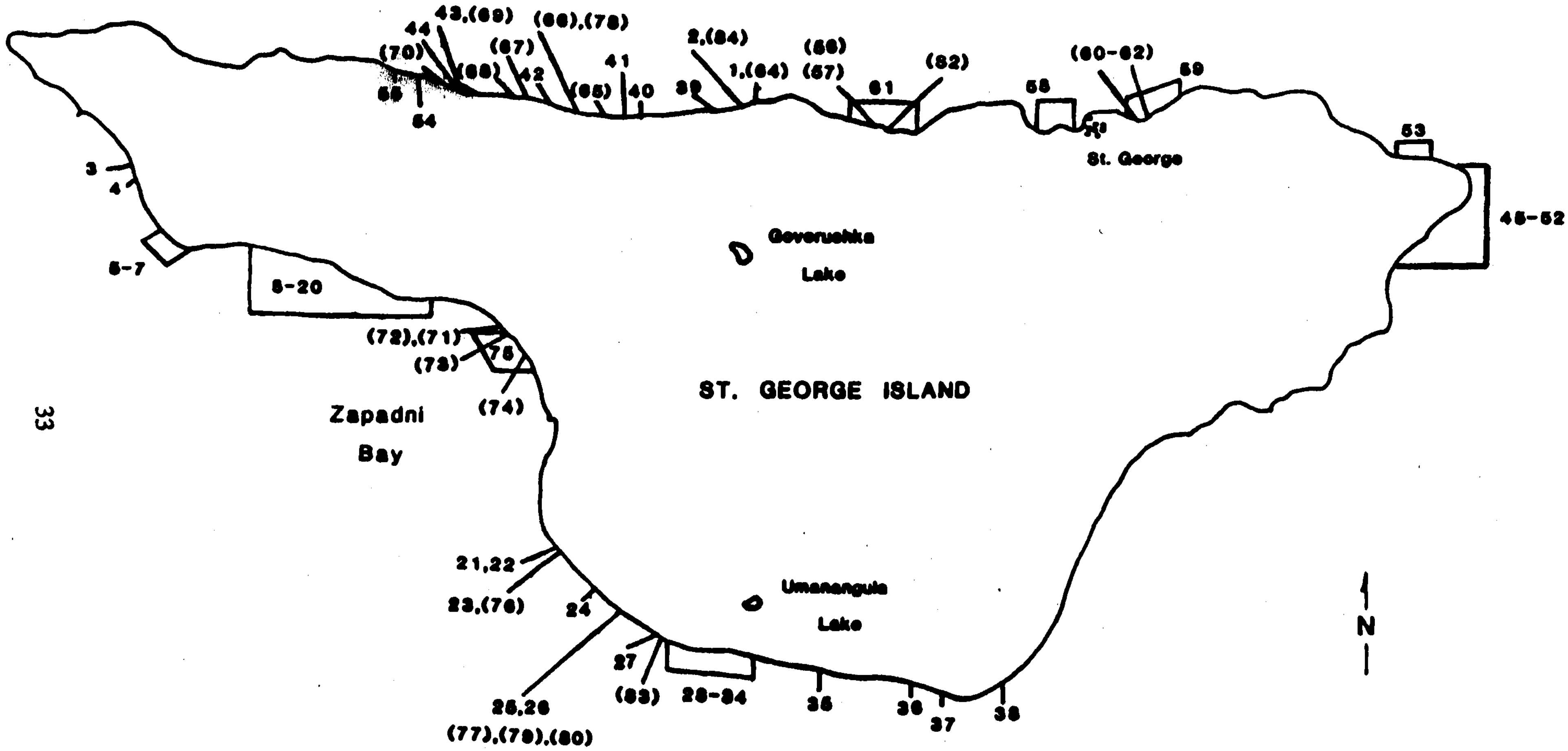


Figure 3.3. Location of seabird study plots at St. George Island, Alaska.

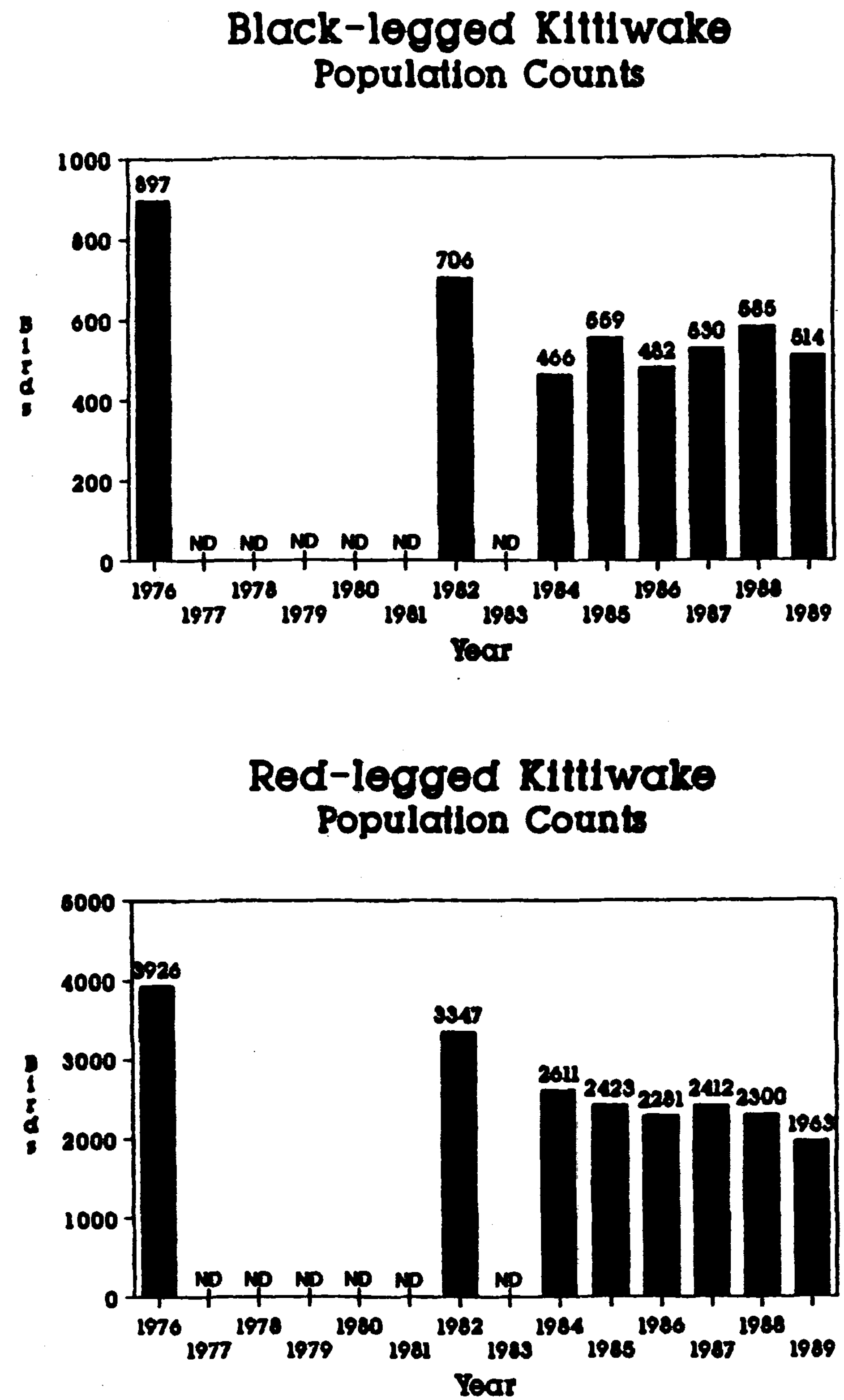
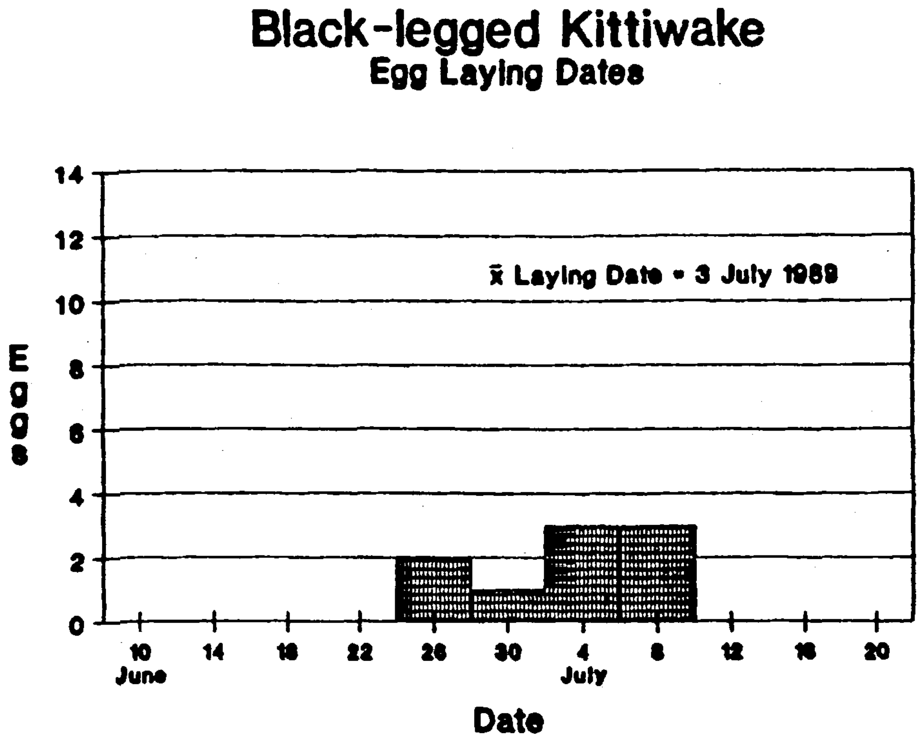


Figure 3.4. Population counts of kittiwakes on common plots at St. George Island, Alaska. ND = No data.



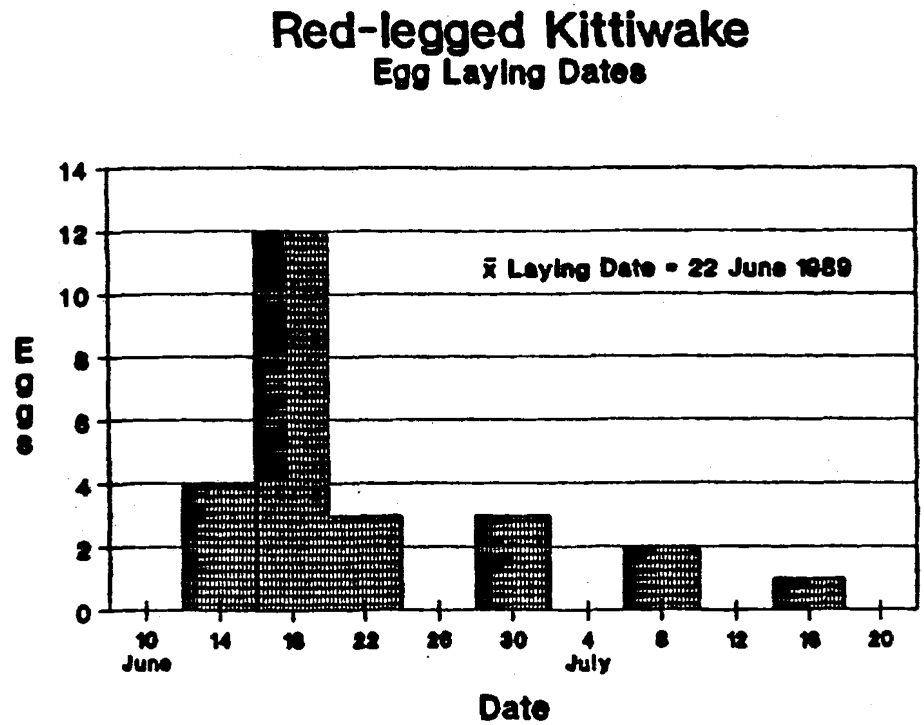
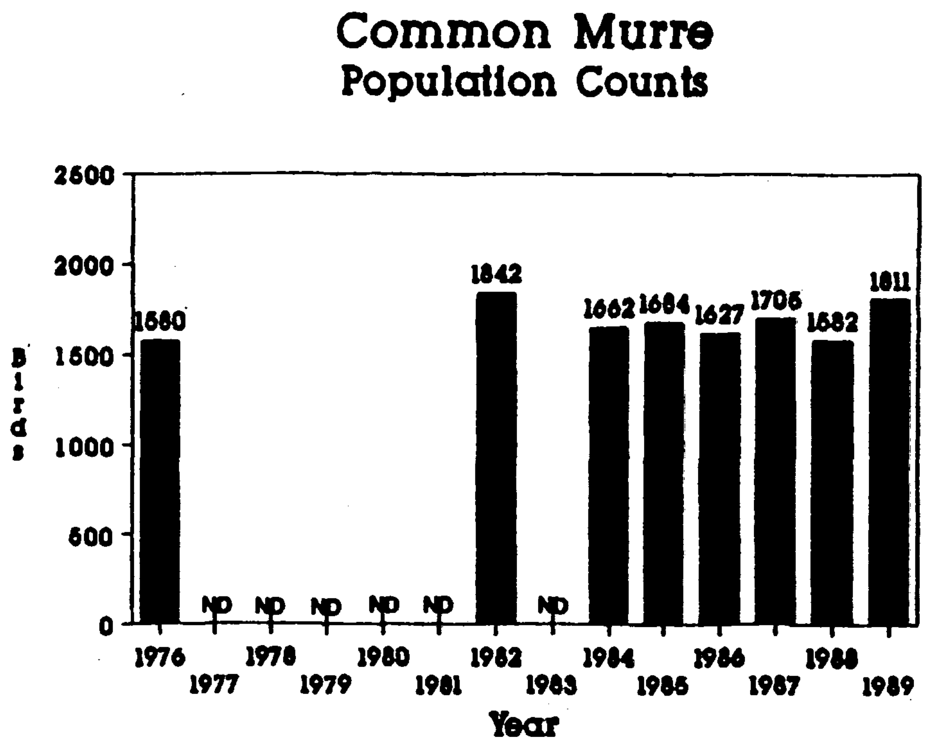


Figure 3.5. Laying dates of kittiwake eggs at St. George Island, Alaska in 1989.



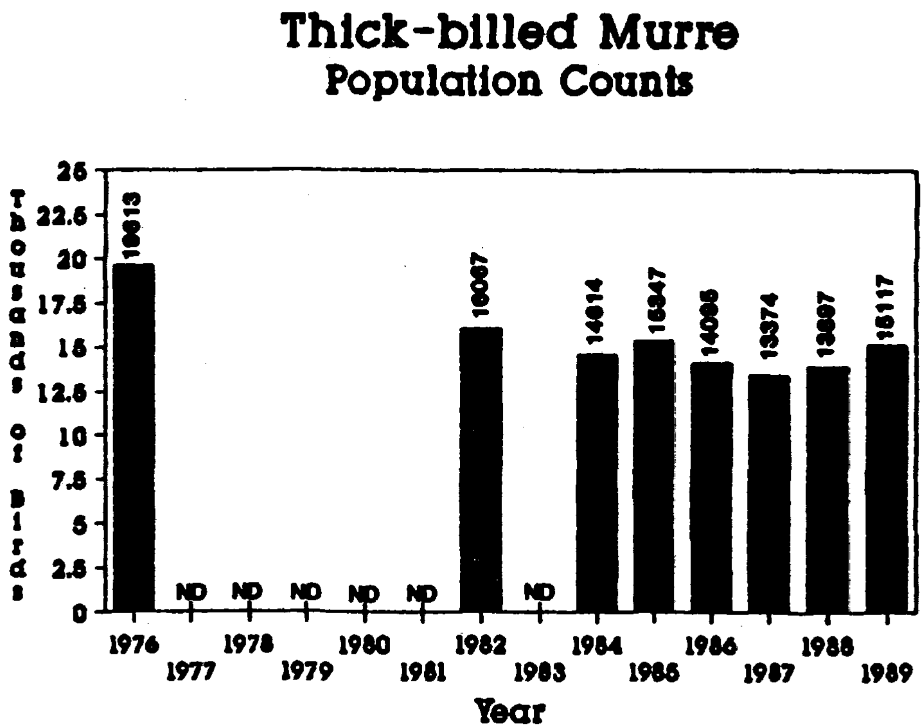


Figure 3.6. Population counts of murres on common plots at St. George Island, Alaska. ND = No data.

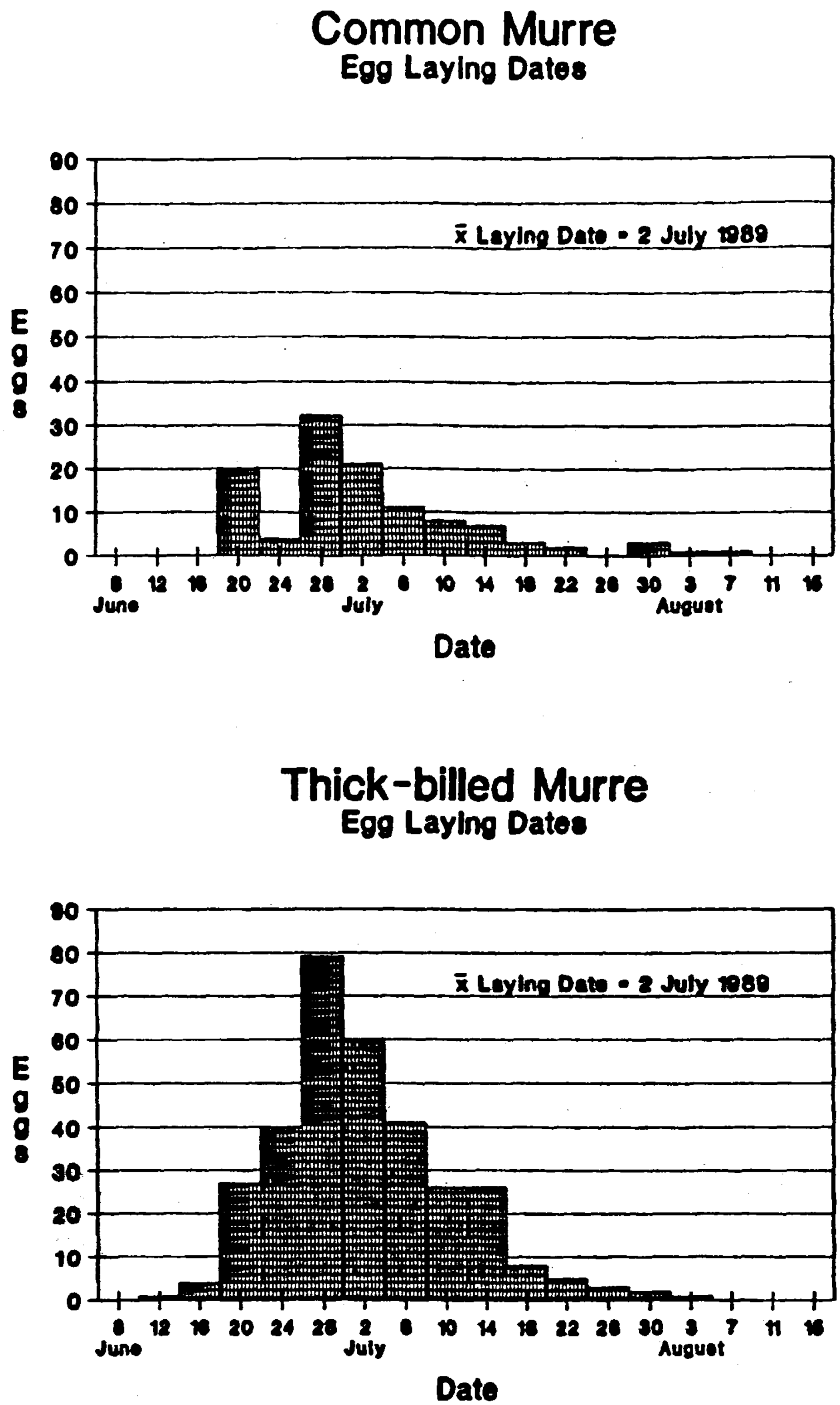


Figure 3.7. Laying dates of murre eggs at St. George Island, Alaska in 1989.

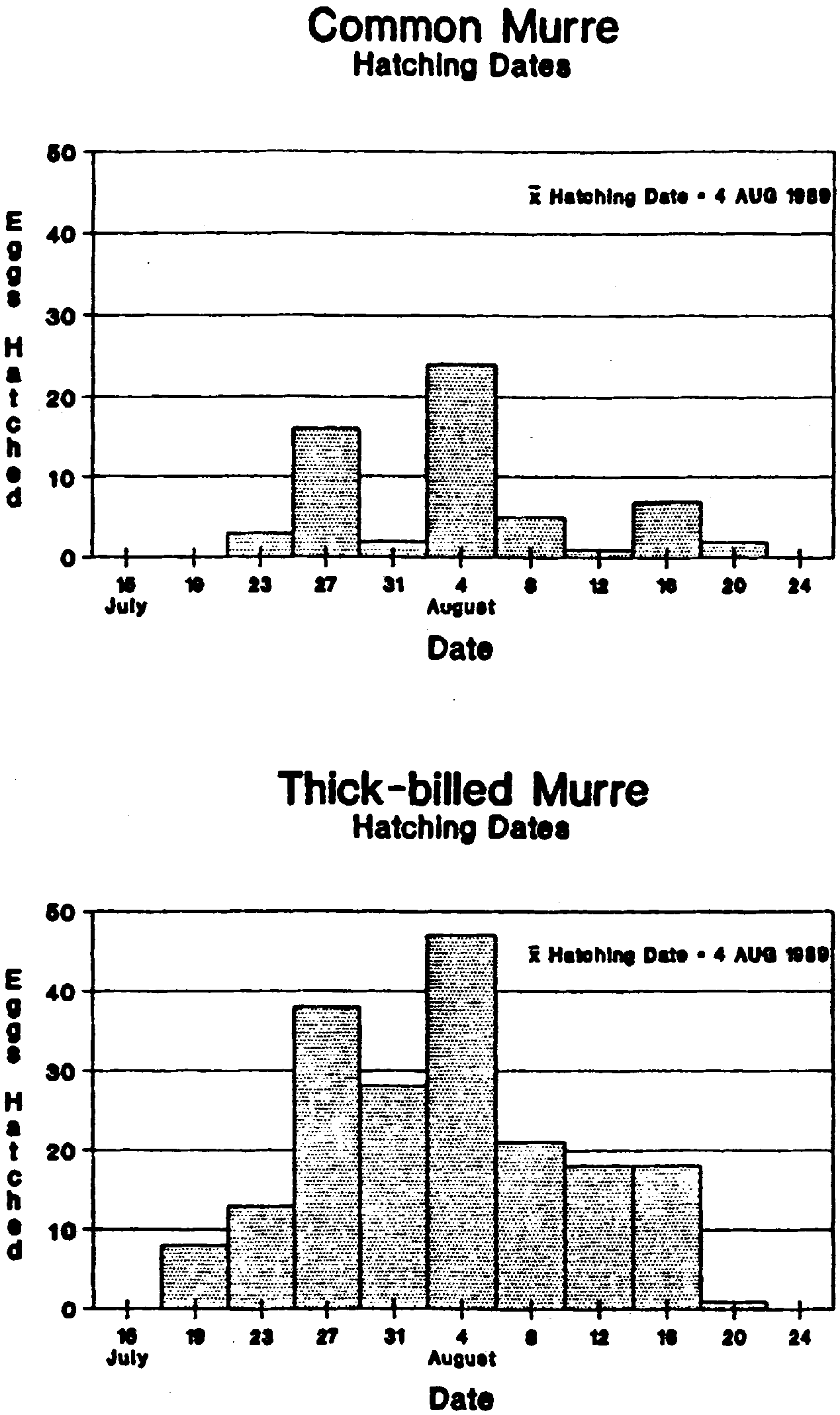
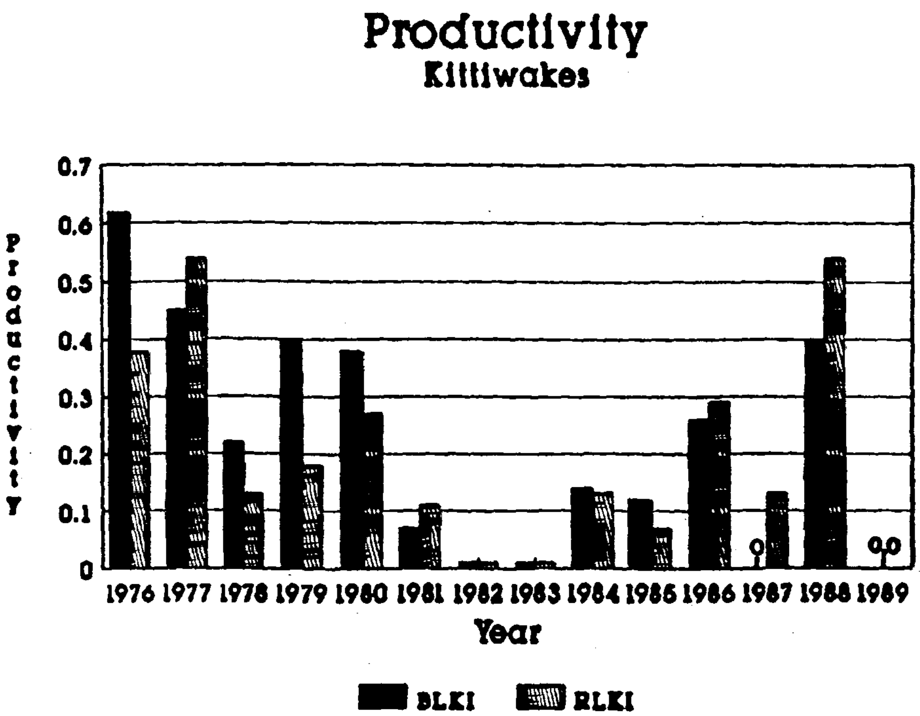


Figure 3.8. Hatching dates of murre chicks at St. George Island, Alaska in 1989.



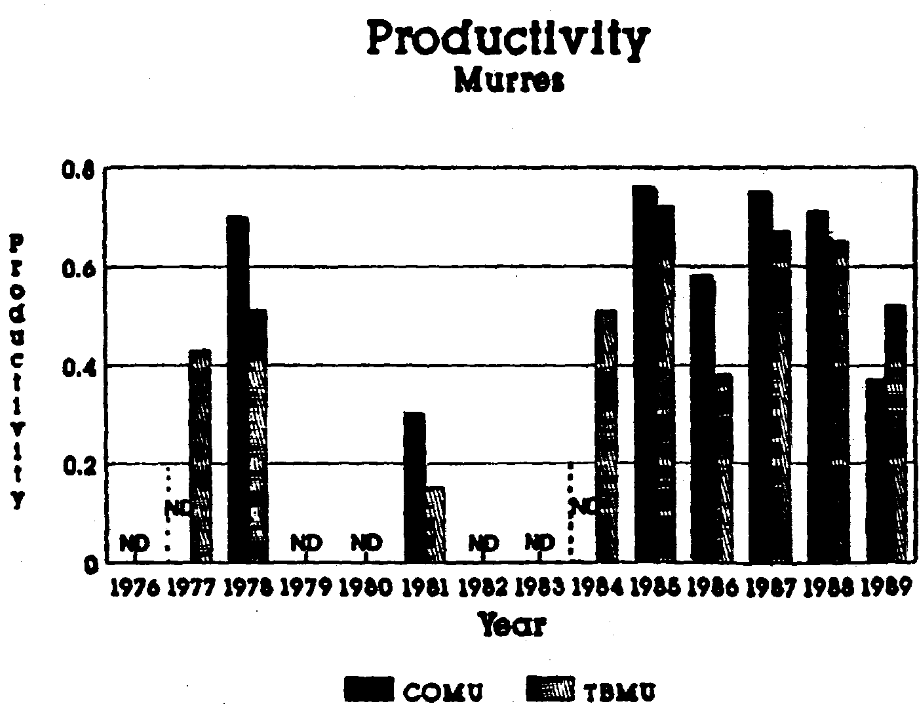


Figure 3.9. Productivity estimates (chicks fledged/nest start) of kittiwakes and murres at St. George Island, Alaska. ND = no data.

CHAPTER 4. CAPE PEIRCE

By Lisa Haggblom and Vivian M. Mendenhall

INTRODUCTION

Cape Peirce (58°35'N, 161°45'W) in Bristol Bay supports large populations of breeding seabirds during the summer months (Figure 4.1). The most abundant species are black-legged kittiwakes (Rissa tridactyla), glaucous-winged gulls (Larus glaucescens), common murres (Uria aalge), pelagic cormorants (Phalacrocorax pelagicus), and horned and tufted puffins (Fratercula corniculata and Fratercula cirrhata). Pigeon guillemots (Cepphus columba), parakeet auklets (Cyclorrhyncus psittacula, and double-crested cormorants (Phalacrocorax auritus) are less abundant. Common murres are the most numerous species at Cape Peirce. As a mainland colony, Cape Peirce provides seabird population and productivity data which can be compared with other mainland colonies as well as offshore island colonies in the Bering Sea. It may also serve as an index to populations at nearby major colonies at Cape Newenham, Shaiak Island, and Round Island.

The Cape Peirce coastline is dominated by cliffs as high as 150 m, which terminate on the north at a sandy beach at the entrance to Nanvak Bay (Figure 4.2). Nanvak Bay is approximately 8 km long. The bay is shallow; extensive mudflats are exposed at low tides. Cliff-nesting seabirds such as kittiwakes gather most of their nest material from the mudflats and eelgrass (Zostera sp.) beds in the bay. Kittiwakes also gather nest material from small brackish ponds in the area, and roost in the bay in large flocks towards the end of the breeding season.

Studies have been conducted at Cape Peirce since 1971. Observations began in the early 1970's (Dick and Dick 1971, Lloyd 1985). Petersen and Sigman (1977) established population plots in 1976. These plots have been censused periodically since then, and additional plots have been established since 1984 (Lloyd 1985, Herter and Higgins 1986, Higgins 1985, Troy and Baker 1985, Johnson and Baker 1985). Togiak National Wildlife Refuge staffed Cape Peirce with volunteers from 1985 through 1988 in order to monitor seabird populations and productivity (van Hulsteyn and Kavanaugh 1987, Haggblom and O'Neil 1987, O'Daniel 1988). Until 1988, methods were standardized concerning plot locations and boundaries, but timing of censuses, amount of time spent at productivity plots, and final data analysis varied from year to year. In 1988, O'Daniel (1988) standardized methods at Cape Peirce so as to be consistent with those used at other seabird colonies in the southeastern Bering Sea.

Data on black-legged kittiwakes and common murres are presented in this report. Another report (Haggblom 1989) summarizes monitoring data for these species and pelagic cormorants (Phalacrocorax pelagicus).

METHODS

The field camp at Cape Peirce (Figure 4.1) was set up on 26 April 1989 using a Cessna 185 equipped with skis. The camp was serviced by a Cessna 185 on floats or a Grumman Widgeon which landed on Nanvak Bay. Field personnel stayed at a small Fish and Wildlife Service cabin that is approximately 1/2 km inland from both Nanvak Bay and the outer coast. The clifftops above seabird study plots were readily accessible from the camp by foot. Many cliff faces were still covered in ice and snow when camp was established. The camp was closed on 7 October.

Populations

Methods for monitoring productivity are described in Chapter 2. Population counts were conducted from 28 June to 4 August, 1989, the period which encompassed the latter half of egg-laying to the early part of chick-rearing for kittiwakes and murres. This is typically when adult attendance is the least variable at the plots, if not necessarily the highest. To determine the appropriate census period at Cape Peirce, population counts of productivity plots were taken every visit from 28 April to 9 September 1989 and graphed daily to observe attendance fluctuations. Murre attendance increased as chicks matured, potentially due to failed breeders being replaced with higher numbers of non-breeders. Recording dates of egg laying (see "Productivity") also assisted in determining the appropriate census period. Counts were usually made between 10:00 and 20:00 hours.

Eight replicate counts of population plots were made on 22 kittiwake plots and 19 murre plots (Appendix Table B-1). Additional plots were counted one or a few times but were not used in inter-year comparisons. Most of the seldom-counted plots were small ones on the south side of the Cape Peirce peninsula. Table 4.1 shows which plots have been counted in every year since 1976. Plot photos from 1976, 1984, and 1987 were used in determining locations and boundaries from previous years (Figure 4.2). Three new population plots were added this year, and plots viewed from observation points 1 through 10 (Appendix Table B-2) were re-photographed at the end of July. Most of the metal stakes from previous years had been destroyed or had disappeared over the winter, so new stakes were installed at the majority of the observation points. Stakes that disappeared between years have contributed to inconsistencies in plot censusing between years, causing plots to be overlooked or misidentified.

Replicate counts of plots have been made each year since 1984. Nineteen plots have been censused in every year since 1985, and we have used these for inter-year comparisons. In 1984 few plots were censused, but we hope to analyze these data in the future for comparison with ours. The census period used in various years has not been consistent. Populations on plots were calculated before 1988 by using replicate counts from the entire breeding season (pre-laying through fledging). We recalculated population indices for 1985 through 1987 by selecting data only from the latter part of egg-laying through early chick-rearing periods. Comparisons between years were based only on plots for which 3 to 12 replicate counts were made in all years. Totals used in this paper are therefore different from those reported for most other years. An adjustment was made in plot totals when they were reported for 1985 through 1987. In reports for those years the plot counts were doubled in an effort to approximate total populations on the Cape Peirce Peninsula. Here we report only populations censused on plots. Census data for 1984 (Troy and Baker 1985) could not be compared with other years because the system of numbering plots used in 1984 does not correspond with numbers used before and since. We also have not compared our counts with 1976 data because that census has not yet been reported as separate plot counts. We hope to include comparisons with 1976 and 1984 counts in future reports.

Total populations were estimated for all years by summing across plots within each replicate and calculating the mean of replicate counts for the year. For 1989 only, 90% confidence bounds were calculated.

Productivity

Methods for monitoring productivity are described in Chapter 2. Six plots with a total of 124 nests were monitored for kittiwake productivity. Nest attempts per plot ranged from 15 to 24. Plots were visited at least every other day, except on a few occasions when weather limited visibility and two days elapsed before the next visit. Nest maps drawn in 1988 were used wherever possible.

Four plots with a total of 78 breeding sites were monitored for murre productivity. The same protocol was followed as for kittiwakes.

Methods used in this study for monitoring productivity (Chapter 2) have not been used consistently at Cape Peirce. Breeding sites of kittiwakes have been mapped for each plot since 1981, and plots have been observed frequently throughout the breeding season since 1986. Data on kittiwake productivity for 1971, 1973, 1977, and 1985 came from surveys of unmapped nests. Data for 1973, 1977, and 1984 came from only two observation periods throughout the season. These studies probably gave a good indication of the general level of breeding success, although they are not directly comparable with our results. The methods we used to study murre productivity were implemented at Cape Peirce only in 1988 (O'Daniel 1988). Except in 1984, individual murre breeding sites were not mapped, and adult posture was not used as a clue to breeding status. Murre breeding sites were mapped in 1984, but observations were limited to two one-week periods near laying and hatching. Hatching success in 1984 may have been estimated with reasonable accuracy, but fledging success could not have been. Disturbance of breeding murres by observers also was frequent in some earlier years (Van Hulsteyn and Kavanaugh 1987). We therefore compared our estimate of murre productivity with that for 1988 but not with those for earlier years.

Mean productivity parameters and 90% confidence intervals were calculated as described in Chapter 2. Confidence intervals were generated for past years' data as well when data were available for individual plots.

Beached birds were surveyed approximately twice a week throughout the season on a sandy beach approximately 1.2 km long just south of the entrance to Nanvak Bay. Birds counted on each occasion were tossed above the high tide mark to prevent their being re-counted. Counts provided a minimum estimate of dead birds washed up on the beach because carcasses were scavenged by ravens, gulls, and foxes.

RESULTS

Black-legged Kittiwakes

Populations--An average of 1,172 adults and 1,209 kittiwake nests were recorded for 8 plots on which replicate counts were made (Table 4.2a). An additional 746 adults and 742 nests were recorded on plots that were counted fewer than eight times.

Breeding chronology--Kittiwakes incubated eggs an average of 27 days and brooded chicks an average of 47 days, for a total chick-rearing period of 74 days (Table 4.3). The average egg laying date was 22 June, the average chick hatching date 19 July, and the average fledging date 31 August (Table 4.4, Figure 4.3). Egg, chick, and fledgling numbers per day are given in Appendix Table B-3. There was no overlap between egg laying and chick hatching nor between hatching and fledging.

Reproductive performance--Kittiwakes had poor reproductive success at Cape Peirce (Table 4.5a, Figure 4.4). Of the 124 nests on reproductive plots, 41% contained at least one egg; the average clutch size was 1.31. The 67 eggs produced 28 chicks, for a hatching success of 0.42. Eight chicks survived to fledge, giving fledging success of 0.29 and an overall productivity of 0.06 young per nest.

Mortality--A total of 40 eggs and 20 chicks were known to have died (Table 4.6 and Figure 4.5). Loss of eggs primarily occurred shortly after laying. A few eggs apparently were infertile or contained dead embryos, since adults incubated 7 eggs up to 12 days after the maximum incubation period for eggs that hatched (Tables 4.3 and 4.6). The majority of kittiwake chicks died at the age of 13-16 days, but a few died as old as 33-36 days. The last remaining chick on plot 43 had barely started to show primary feather development at the age of 34 days, and it disappeared from the nest 2 days later. (Kittiwake chicks are typically ready to fledge as early as 36 days old.)

Common ravens (Corvus corax) preyed heavily on kittiwake eggs but little on the chicks. On 1 July, one pair of ravens took four kittiwake eggs within thirty minutes from four nests on plot 19-1. This was the last day eggs were seen on this productivity plot. One raven nest with four chicks was located at plot 21. The small seabird plots surrounding this nest had erratic attendance patterns throughout the census period, most likely due to frequent disturbance. Red fox (Vulpes vulpes) also reached some of the more accessible nest sites to steal eggs and chicks. While the senior author was censusing plot 20-4 on 3 July a red fox and a common raven were observed in the plot competing for a kittiwake egg that one had apparently removed from a nest. The fox took the egg; the raven then turned its attention to another nest, but the incubating kittiwake adult managed to fend the raven off by lunging at it from the nest.

Glaucous-winged gulls were often observed circling plots in search of chicks. Several unattended kittiwake chicks were observed being snatched from their nests by gulls. The gull would then land on the water nearby and feed its young. An adult gull was seen eating a kittiwake chick which had fairly well-developed flight feathers. The glaucous-winged gull nest on plot 19-5 contained 3 chicks, 2 of which fledged.

Three dead adult kittiwakes were observed in their nests on three different plots. The cause of death was not known, but the deaths occurred prior to the mid chick-hatching period. The three mates abandoned the nests.

Beached birds were recorded from the Maggy Beach area between 3 August and 28 September. Four adult kittiwakes and twelve fledgling kittiwakes were found in various stages of decomposition (Table 4.7). High seas and foul weather dominated most of August and September and may have contributed to these deaths.

Common Murres

Populations--A summary of 8 replicate counts of 19 plots is given in Table 4.2b. An average of 2,651 murres were recorded for these plots. An additional 2,389 murres were counted on plots that were censused one to a few times.

Breeding chronology--Murres began laying at Cape Peirce on 8 June. The average date for laying was 29 June, for hatching was 19 July, and for fledging was 27 August (Table 4.4; dates were calculated without relays). Murres incubated eggs an average of 35 days and brooded chicks an average of 20 days, for a total chick-rearing period of 55 days (Table 4.3). Egg, chick, and fledgling numbers per day are given in Appendix Table B-3. There was some overlap between egg laying and chick hatching from 13 July to 24 July, as well as overlap between chick hatching and fledging from 10 August to 21 August. As for kittiwakes, the majority of chicks fledged from 3 September to 6 September.

Reproductive performance--Murres had higher reproductive success than kittiwakes at Cape Peirce. Out of a total of 78 sites with eggs, 40 sites had chicks, with an overall hatching success of 0.51; 37 chicks survived to fledge, with an overall fledging success of 0.93. Reproductive success was 0.47 (Table 4.5b, Figure 4.6).

Mortality

A total of 44 eggs and 3 chicks were known to have died (Table 4.6). The majority of murre chicks died at the age of 9-12 days.

Common ravens (Corvus corax) preyed heavily on murre eggs but little on the chicks. The small seabird plots around plot 21, which contained a raven nest, had erratic attendance patterns throughout the census period, most likely due to disturbance by the ravens. One pair of ravens was observed stealing a murre egg by yanking the attending murre adult off the egg by its wing. One of the ravens then grabbed the egg while the second raven was still holding onto the murre as both birds flew downwards. Murre eggs in the mouths of ravens were a common observation in June and July. Ravens and foxes cached eggs in shallow holes on the tundra, and both species were observed with eggs in August, well after eggs were available from the cliffs.

Beginning 3 August and ending 12 September, two adult murres, each consisting only of a pair of wings, were found on Maggy Beach (Table 4.7). High seas and foul weather may have contributed to these deaths.

Weather observations

The weather was typically cool, wet, and windy during the summer of 1989, with the exception of a few calm sunny days in mid-June and early July. We recorded a low temperature of -8°C on 27 July and a high of 18° on 3 July. The period from mid-August through September was consistently stormy, with frequent winds of 15 knots and several days of 30 to 35 knots, and high seas.

DISCUSSION

Black-legged kittiwake numbers censused in 1989 on plots at Cape Peirce were lower than numbers on the same plots during the past three years (Table 4.8, Figure 4.7). However, there has been no significant decrease in kittiwake numbers at Cape Peirce during the past five years ($b = -12.0$, $p > 0.10$). In the light of recent poor productivity, populations of kittiwakes at Cape Peirce should be monitored closely.

Common murre numbers on plots we censused in 1989 were lower than during the previous five years (Table 4.8, Figure 4.8). There appears to have been a slight decline in murres on census plots during the late 1980's (Figure 4.8), but this was not significant ($b = -173.9$, $p > 0.10$). Productivity has been good for the past two years. Several additional years of monitoring murre productivity at Cape Peirce are needed in order to establish a baseline for future comparison.

Black-legged kittiwakes started their reproductive season at Cape Peirce relatively late in 1989. We compared dates for hatching rather than egg-laying because in several past years observers arrived after egg-laying had begun. The first hatching of 1989 was seen on 9 July; in 1986 through 1988 dates were 3 July, 9 July, and 4 July (van Hulsteyn and Kavanaugh 1987, Haggblom and O'Neil 1987, O'Daniel 1988). The modal date of hatching in 1989, 18 July, was later than that reported for 1976 (15 July; Petersen and Sigman 1977); the mean date of hatching in 1989, 20 July, was later than the mean date in 1981 (26 June; Lloyd 1985). There is a clear pattern of earlier hatching in years when productivity was good (1976, 1981, and 1988). The exception to this pattern is the relatively early start of hatching in 1986, a year when no fledglings were produced. This reflects the fact that breeding success can be influenced by changes in the factors that influence it during the season. Weather in 1986 began warm but became very stormy in July (van Hulsteyn and Kavanaugh 1987).

Productivity of black-legged kittiwakes was very low at Cape Peirce in 1989. Even with only 0.06 chick fledged per nest, however, the birds did slightly better than in 4 of the 9 previous years for which we have data (Table 4.9, Figure 4.9). There does not appear to be a consistent trend in breeding success through the years. Four "good" years at Cape Peirce, with approximately 0.15 chick fledged per nest, were scattered throughout two decades (Figure 4.9). Our data are not adequate to test whether there has been any consistent trend in kittiwake reproduction at Cape Peirce. Breeding success in this species is extremely variable between years (Hatch 1987), and we need a number of consecutive years' data in order to characterize the pattern of variations at Cape Peirce.

The reasons for poor productivity of kittiwakes at Cape Peirce are only partly known. Predation by ravens on eggs is high (Petersen and Sigman 1977, van Hulsteyn and Kavanaugh 1987, Haggblom and O'Neil 1987, this study). Predation by ravens apparently was less on kittiwakes in 1988, a year of relatively good success (O'Daniel 1988). Glaucous-winged gulls preyed on chicks; red foxes took at least small numbers from accessible ledges, but foxes seem unlikely to have reached many nests on cliffs at Cape Peirce. Seabirds are disturbed periodically at Cape Peirce by low-flying aircraft and by boats passing nearby (Haggblom and O'Neil 1987, unpubl. obs.), which may increase the impact of predators. The number of kittiwake eggs and chicks that may actually be taken by predators each year, and the proportion of mortality that they cause, have not been estimated. A study is needed of predation pressure on the Cape Peirce kittiwake population and the reasons for its variation between years.

Breeding success of kittiwakes at other colonies has been found to vary with availability of the primary prey fish during the season (Baird and Gould 1983, Springer et al. 1985a and b, Fadely et al. 1989, Springer and Byrd 1989). We have no information on the prey utilized by Cape Peirce seabirds nor on their correlation with breeding success. Our unusual observation of dead adults in the colony and the widespread abandonment of nests seem consistent with scarcity of food. Although we have no data on growth rates of chicks, the bird whose remiges had barely appeared at the age of 34 days may have grown very slowly. Plumage development is delayed in some groups of birds when growth is severely retarded (e.g., waterfowl; Dzubin 1959). Slow growth of chicks would have been consistent with a poor food supply. Data should be collected in the future on diets of breeding kittiwakes, growth rates, and evidence of feeding activity near the colony. Mortality of adults also suggests that disease should be investigated as a possible factor.

Post-fledging mortality is an important component of population dynamics, and we obtained evidence of mortality of black-legged kittiwake fledglings in storms during August and September. The beach should be re-surveyed in future years to provide inter-year comparisons of mortality indices.

Productivity of murres at Cape Peirce was relatively good. We have only one other year of data that is comparable to ours; chicks fledged from 0.58 of nest sites in 1988 (Table 4.10), which was better than productivity in 1989, although the difference is not quite significant ($t = 1.94$, $0.10 > p > 0.05$).

Several more years of data will be needed on the productivity of murres at Cape Peirce before we can draw conclusions about baseline mean productivity levels there. Standardized methods for estimating productivity of murres were not adopted at Cape Peirce until 1988 because of infrequent visits to the colony (1984) and lack of trained personnel (1985-1987). As with kittiwakes, we also need better information on predation pressure and food requirements.

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Table 4.1. Population and productivity plot monitoring at Cape Peirce, by year.

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

x Indicates that plot was counted in that year.

Table 4.1, continued. Population and productivity plot monitoring at Cape Peirce.

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

x Indicates that plot was counted in that year.

Table 4.2 Population counts for black-legged kittiwake and common murre at Cape Peirce, 1989.

4.2a. Black-legged kittiwake. There were 22 plots; counts by plot are given in Appendix. Includes some plots not used in comparisons between years.

Replicate	Date	No. Birds	90% confidence bounds
1	7 July	1,364	
2	9 July	1,242	
3	17 July	1,427	
4	20 July	973	
5	22 July	1,059	
6	24 July	1,041	
7	27 July	1,077	
8	31 July	1,189	
Mean		1,172	±109.2

4.2b. Common murre. 19 plots are included; counts by plot are given in Appendix. Includes some plots not used in comparisons between years.

Replicate	Date	No. Birds	90% confidence bounds
1	7 July	2,916	
2	9 July	2,439	
3	17 July	3,039	
4	20 July	2,513	
5	22 July	2,678	
6	24 July	2,815	
7	27 July	2,068	
8	31 July	2,739	
Mean		2,651	±210.9

Table 4.3 Duration of incubation, chick rearing, and total nesting period in days for black-legged kittiwakes and common murres, Cape Peirce, 1989. Data are listed by nest site in Appendix B-4.

Stage	Variable	Black-legged kittiwake	Common murre
Incubation	Range, all eggs	1-44	1-55
	Range, eggs that hatched	25-32	31-55
	Mean, eggs that hatched	27.1[1] ±1.50 (28)	34.9 ±4.34 (40)
Chick-rearing	Range, all chicks	9-52	1-26
	Range, chicks that fledged	42-52	15-26
	Mean, chicks that fledged	46.8 ±3.69 (8)	20.0 ±3.28 (37)
Total nesting period	Range, all nests or sites	1-79	1-76
	Range, nests or sites fledging chicks	69-79	46-76
	Mean, nests or sites fledging chicks	74.1 ±3.72 (8)	55.0 ±5.54 (37)

[1] Data under "mean" are mean ± standard deviation (sample size).

Table 4.4 Reproductive chronology of black-legged kittiwakes and common murres at Cape Peirce, 1989.

		Laying	Hatching	Fledging
Black-legged kittiwake	Mean date	22 June[1]	19 July	31 August
	S.D.	5.52	6.03	5.96
	N	52[1]	28	8
Common murre	Mean date	29 June	19 July	27 August
	S.D.	11.5	6.96	9.20
	N	75	39	36

[1] Includes both first and second eggs of clutch.

[2] Relays excluded.

Table 4.5 Productivity parameters for black-legged kittiwakes and common murres at Cape Peirce, 1989.

A. Black-legged kittiwake

Plot	Nest starts	Nests with eggs	Total eggs	Chicks hatched	Chicks fledged
19-1	24	0	0	-	-
26	20	13	18	5	0
31	15	8	11	4	1
39	19	13	17	8	3
43	24	8	8	5	0
46	22	9	13	6	4

B. Common murre

Plot	Nest sites	Chicks hatched	Chicks fledged
19-6	17	9	9
31	30	16	13
39	3	0	-
43	28	15	15

Table 4.6 Age-specific frequencies of egg loss and chick mortality for black-legged kittiwakes and common murres, Cape Peirce, 1989.

Age (days)	Black-legged Kittiwake Eggs 1st	Black-legged Kittiwake Eggs 2nd	Black-legged Kittiwake Chicks	Common Murre Eggs	Common Murre Chicks
1	4	0	0	5	1
2	0	0	0	1	0
3	1	1	0	3	0
4	3	0	0	1	0
5	0	1	0	1	0
6	3	0	0	3	0
7	0	0	0	2	0
8	0	0	0	3	0
9	0	1	2	2	1
10	4	1	0	0	0
11	0	0	0	2	0
12	1	0	0	1	1
13	1	0	1	2	0
14	0	0	1	0	0
15	0	0	1	1	0
16	0	1	3	1	0
17	1	0	1	0	5
18	0	0	0	1	0
19	1	0	2	0	0
20	1	0	1	0	0
22	1	0	2	1	0
24	1	0	2	4	0
25	0	1	2	1	0
26	0	0	0	0	0
27	0	0	0	1	0
29	0	1	1	1	0
30	0	2	0	4	0
31	0	0	0	1	0
32	0	1	0	2	0
33	0	1	0	0	0
34	0	1	0	0	0
35	1	1	1	0	0
37	0	1	0	0	0
38	0	0	0	1	0
40	0	1	0	0	0
42	0	0	0	0	0
43	0	1	0	1	0
48	0	0	0	1	0
Sum	24	16	20	44	3

Table 4.7 Birds recorded on beach south of Nanvak Bay near Cape Peirce, 1989.

Species	Date	Age	State of decomposition*
Bald Eagle	28 Apr	adult	2
Black-legged Kittiwake	3 Aug	adult	5
	3 Aug	adult	5
	3 Aug	adult	2
	12 Aug	adult	3
	5 Sep	fledgling	1
	11 Sep	fledgling	4
	12 Sep	fledgling	1
	14 Sep	fledgling	4
	14 Sep	fledgling	4
	18 Sep	fledgling	4
	18 Sep	fledgling	4
	18 Sep	fledgling	4
	18 Sep	fledgling	4
	18 Sep	fledgling	4
	18 Sep	fledgling	1
Common Murre	3 Aug	adult	4
	12 Sep	adult	4
Common Raven	31 Jul	adult	2
	6 Aug	adult	2
Golden-crowned sparrow	6 Sep	fledgling	1
Glaucous-winged gull	6 Aug	immature	1
	11 Aug	adult	3
	14 Aug	immature	
	30 Aug	immature	1
	2 Sep	immature	2
	5 Sep	immature	?
	10 Sep	immature	2
	12 Sep	fledgling	4
	12 Sep	immature	3
	14 Sep	immature	4
	14 Sep	immature	4
	18 Sep	immature	4
	18 Sep	immature	5
	21 Sep	fledgling	2
	1 Oct	fledgling	2
	1 Oct	fledgling	2
	1 Oct	fledgling	2
Pelagic cormorant	5 Sep	fledgling	1
	11 Sep	fledgling	2
	18 Sep	fledgling	2
	18 Sep	fledgling	1
	18 Sep	fledgling	1
Sooty shearwater (?)	2 Oct	adult	4
Short-tailed shearwater	1 Aug	adult	1
	3 Aug	adult	2
Total			47

* Decomposition coded as: 1, whole carcass; 2, entrails missing; 3, head and entrails missing, 4, pair of wings; 5, 1 wing

Table 4.8 Black-legged kittiwakes and common murres counted on population plots for which replicate counts were made, Cape Peirce 1985-1989.

	Black-legged kittiwake					Common murre				
Plot	1985	1986	1987	1988	1989	1985	1986	1987	1988	1989
19-3	0	0	0	206	197	159	121	206	197	159
19-4	19	12	43	30	17	112	0	29	0	0
20-2	50	14	13	1	0	0	0	0	0	0
20-3	71	67	59	52	42	136	79	91	89	63
20-4a	*[a]	*[a]	261	*[a]	283	*[a]	*[a]	1,086	*[a]	985
20-4b	417	541	163	558	146	1,776	2,093	279	1,509	213
20-4c	*[a]	*[a]	84	*[a]	81	*[a]	*[a]	351	*[a]	294
20-5	103	112	104	175	97	365	309	366	412	298
21	11	36	18	17	5	9	36	41	35	28
22	24	34	33	59	37	43	59	50	63	41
23	14	18	10	31	9	17	29	23	39	31
24	4	2	2	2	0	0	0	0	0	0
25	0	0	0	0	0	13	17	4	0	0
26	13	16	11	22	13	0	0	0	0	0
28	1	3	4	1	1	0	6	17	0	12
31	105	143	102	132	109	257	264	201	239	213
39	14	18	16	27	22	24	20	11	15	5
40	33	44	26	29	6	14	119	89	48	49
43	58	83	52	53	54	54	52	61	81	59
sum	937	1,143	1,001	1,189	935	3,081	3,204	2,904	2,727	2,450

a) In 1985, 1986, and 1988, plots 20-4a through 20-4c were grouped into plot 20-4, listed in the 20-4b row.

Table 4.9. Productivity of black-legged kittiwakes at Cape Peirce, 1970-1989. Ratios are followed by 90% confidence bounds where data permitted. Nests were mapped and were followed individually through hatching in 1984, and were mapped and followed through fledging in 1986-1989[1].

Year	No. Plots	Nest Starts	Nest w/eggs[2]	Clutch size	Hatching success[3]	Fledging success[4]	Productivity[5]
1970	1	60	-[6]	-	-	-	0.15[7]
1973	-	190	-	-	-	-	0.09
1976	-	2631[8]	-	-	-	0.55[8]	0.16[8]
1977	-	136	-	-	-	-	0.0
1981	9	308	209	1.64 ±0.13	0.59 ±0.09	0.24 ±0.01	0.16 ±0.13
1984	7	275	99	1.35 ±0.12	0.01 ±0.03	0.50 ±0.25	0.004 ±0.007
1985	7	260	74	-	-	-	0.01
1986	7	305	185	1.41 ±0.09	0.43 ±0.18	0.0	0.0
1987	4	110	40	1.32 ±0.14	0.51 ±0.08	0.07 ±0.07	0.02 ±0.02
1988	5	109	44	1.52 ±0.18	0.64 ±0.11	0.39 ±0.13	0.16 ±0.17
1989	6	124	51	1.13 ±0.11	0.42 ±0.09	0.29 ±0.21	0.06 ±0.06

[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 Huylsteyn and Kavanaugh 1987; 1987, Haggblom and O'Neil 1987; 1988, O'Daniel 1988; 1989, this study.

[2] Nests with ≥ 1 egg.

[3] Total chicks hatched/total eggs.

[4] Chicks fledged/chicks hatched.

[5] Chicks fledged/total nest starts.

[6] Data not available.

[7] No confidence limits calculated because data on individual plots not available.

[8] Data for 1976 supersede those reported by Petersen and Sigman (1977). Data recalculated by Petersen using larger sample of plots (M.A. Petersen, pers. comm.).

Table 4.10 Productivity of common murres at Cape Peirce in 1988 and 1989. Ratios are followed by 90% confidence bounds.

Year	No. plots	No breeding sites[1]	Hatching success[2]	Fledging success[3]	Productivity[4]
1988[5]	5	80	0.69 ±0.09	0.84 ±0.12	0.58 ±0.14
1988	4	78	0.51 ±0.05	0.93 ±0.11	0.47 ±0.07

[1]Sites where an egg was laid (replacement eggs were assigned to same site)

[2]Total chicks hatched/total eggs

[3]Total chicks fledging (leaving cliff after 15 days of age) total chicks hatched

[4]Total chicks fledging/total breeding sites

[5]Data from O'Daniel 1988

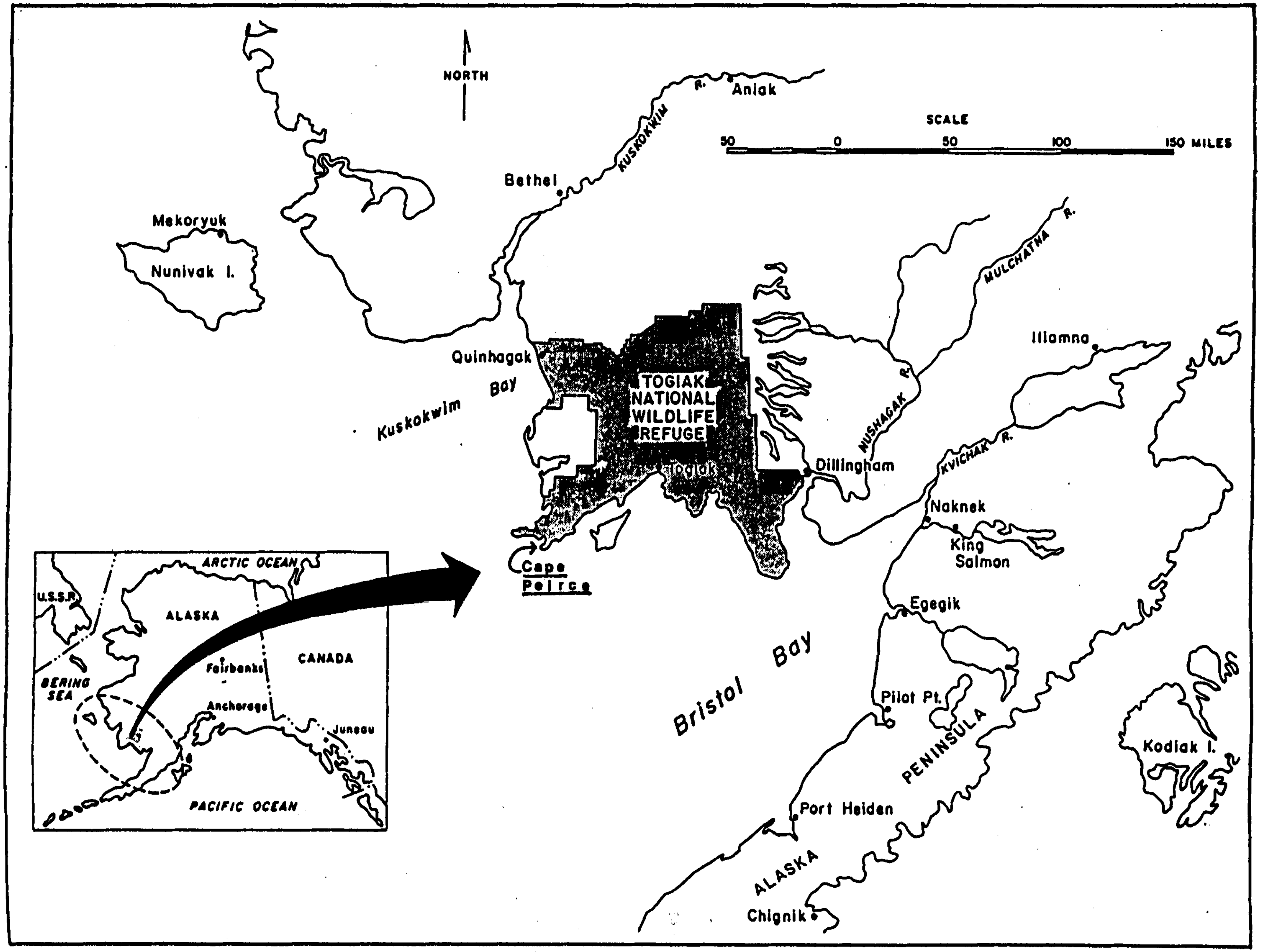
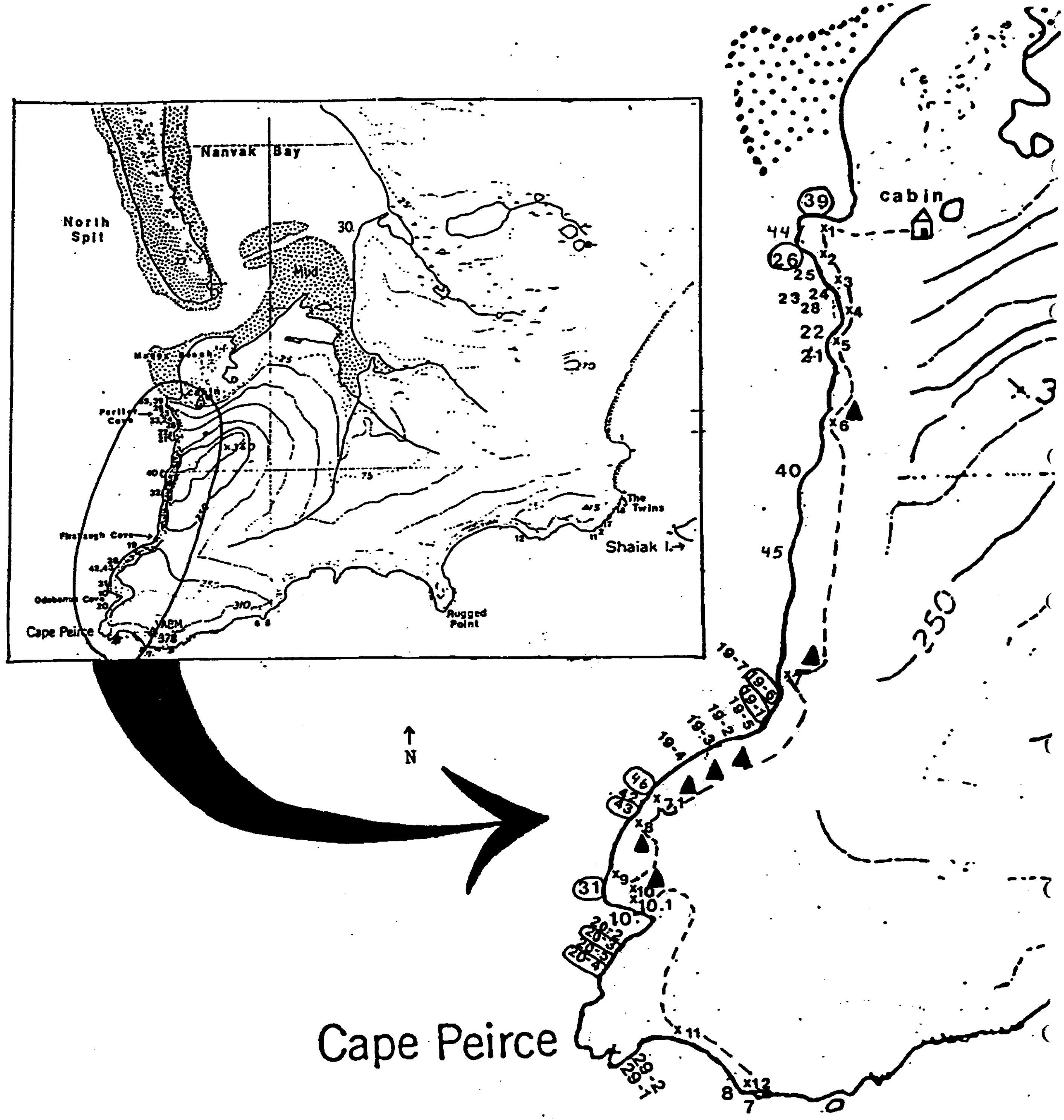


Figure 4.1. Location of Cape Peirce and Togiak National Wildlife Refuge.



KEY:

x =observation point #n (marked with stake)
eg 39=seabird plot number
---=footpath
▲ =large rock outcropping
eg (39)=productivity plots, 1989

Figure 4.2. Location of Cape Peirce population and productivity plots, and observation points (1-12), 1989.

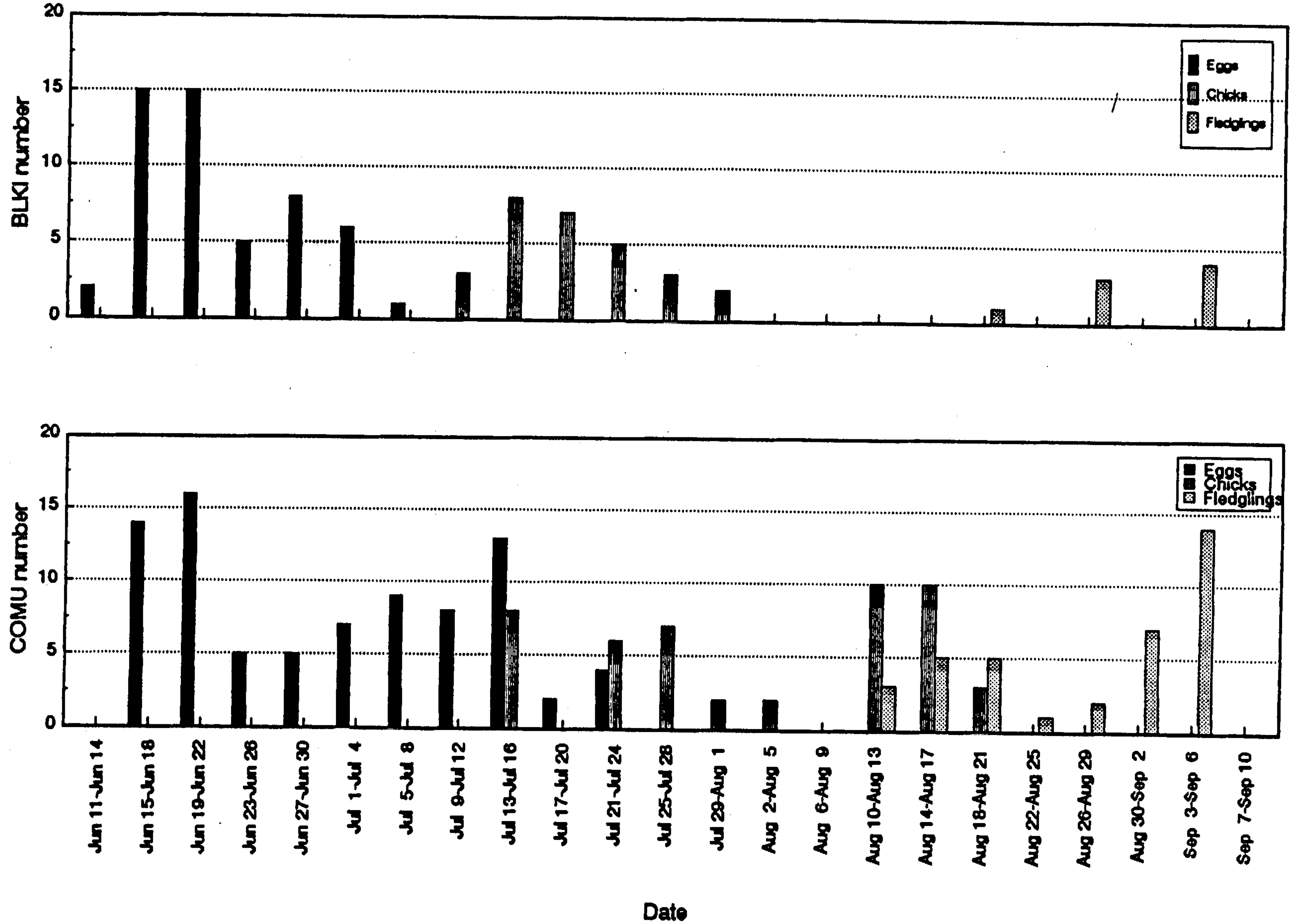


Figure 4.3. Black-legged kittiwake (BLKI) and Common Murre (COMU) laying, hatching, and fledging frequencies by four-day intervals, Cape Peirce, 1989.

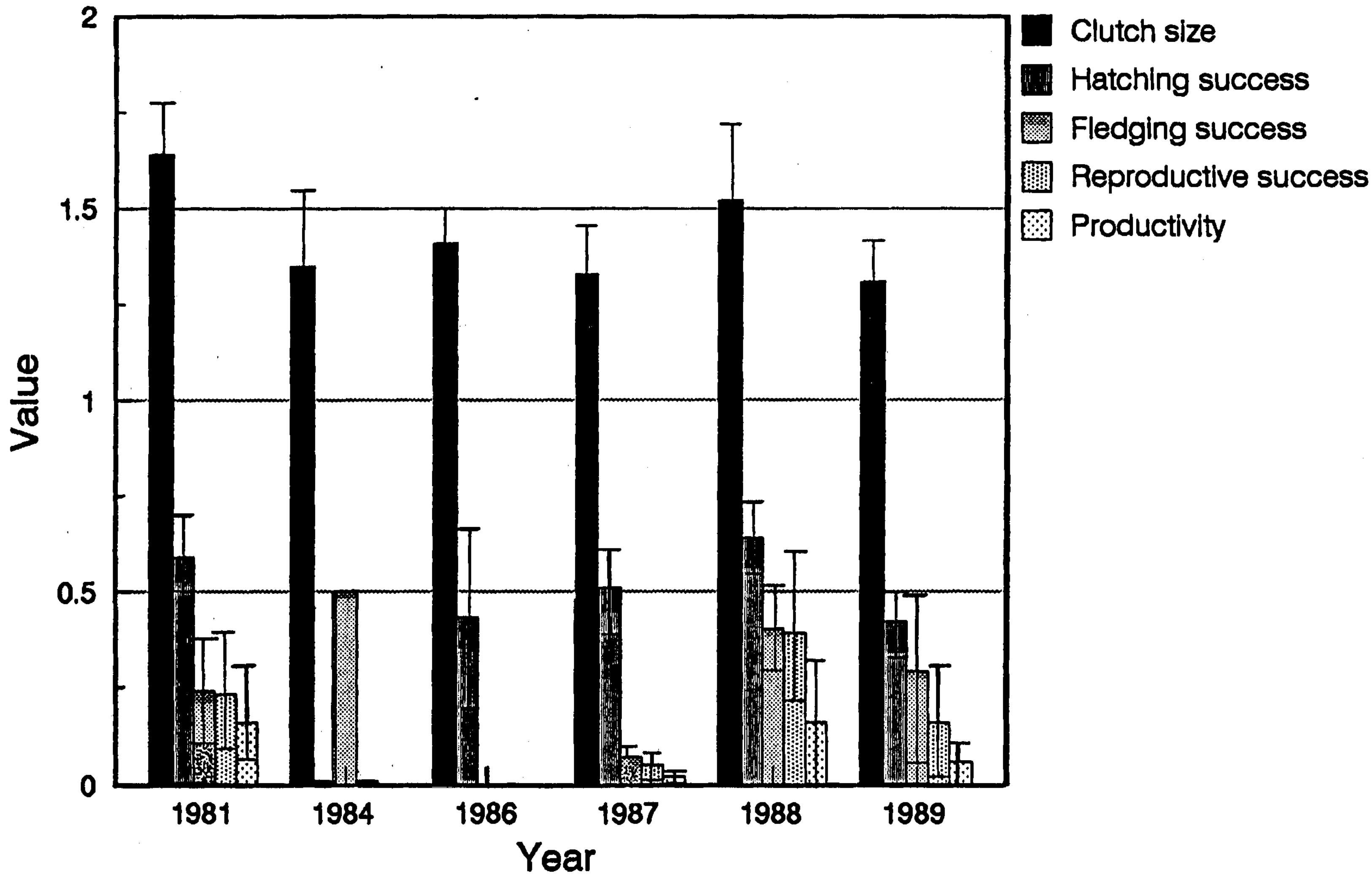


Figure 4.4. Black-legged kittiwake productivity parameters and confidence intervals (90%) at Cape Peirce, 1981-1989.

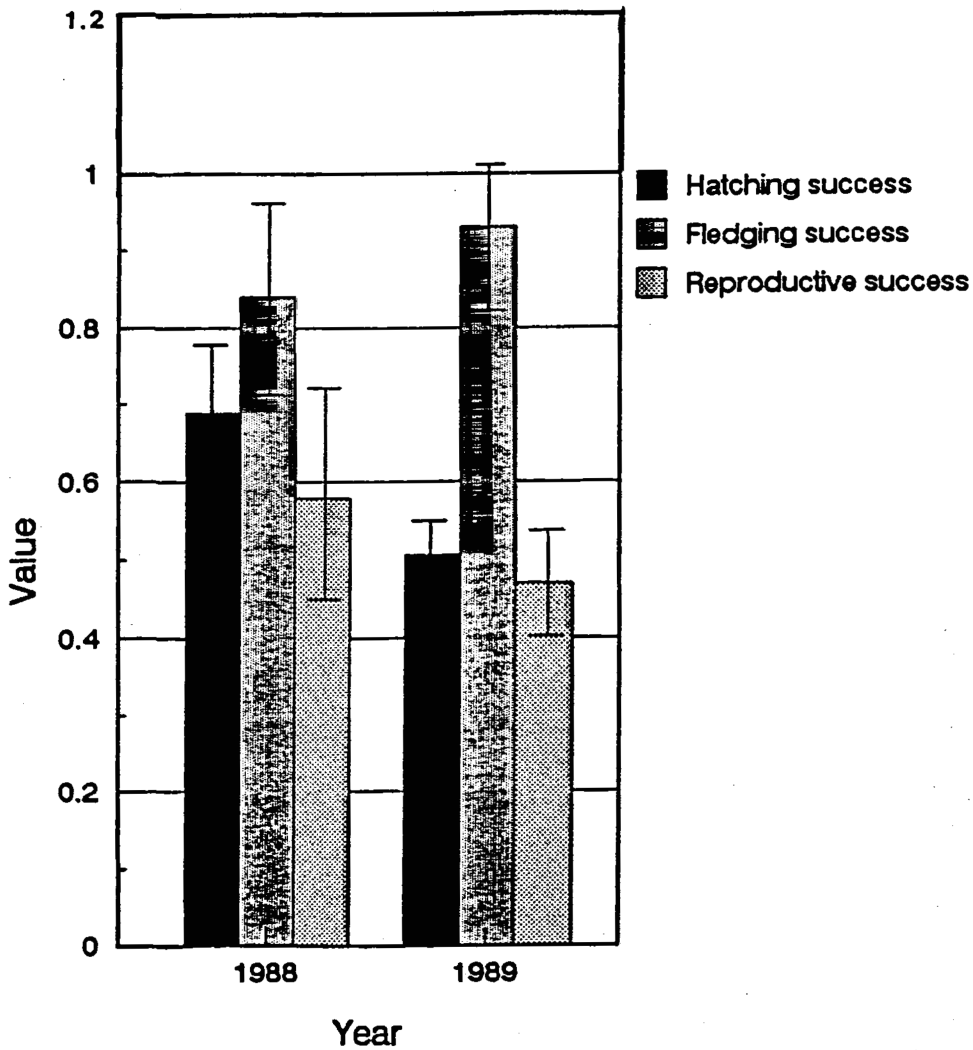


Figure 4.5. Common murre reproductive success parameters and confidence intervals (90%) at Cape Peirce, 1984-1989.

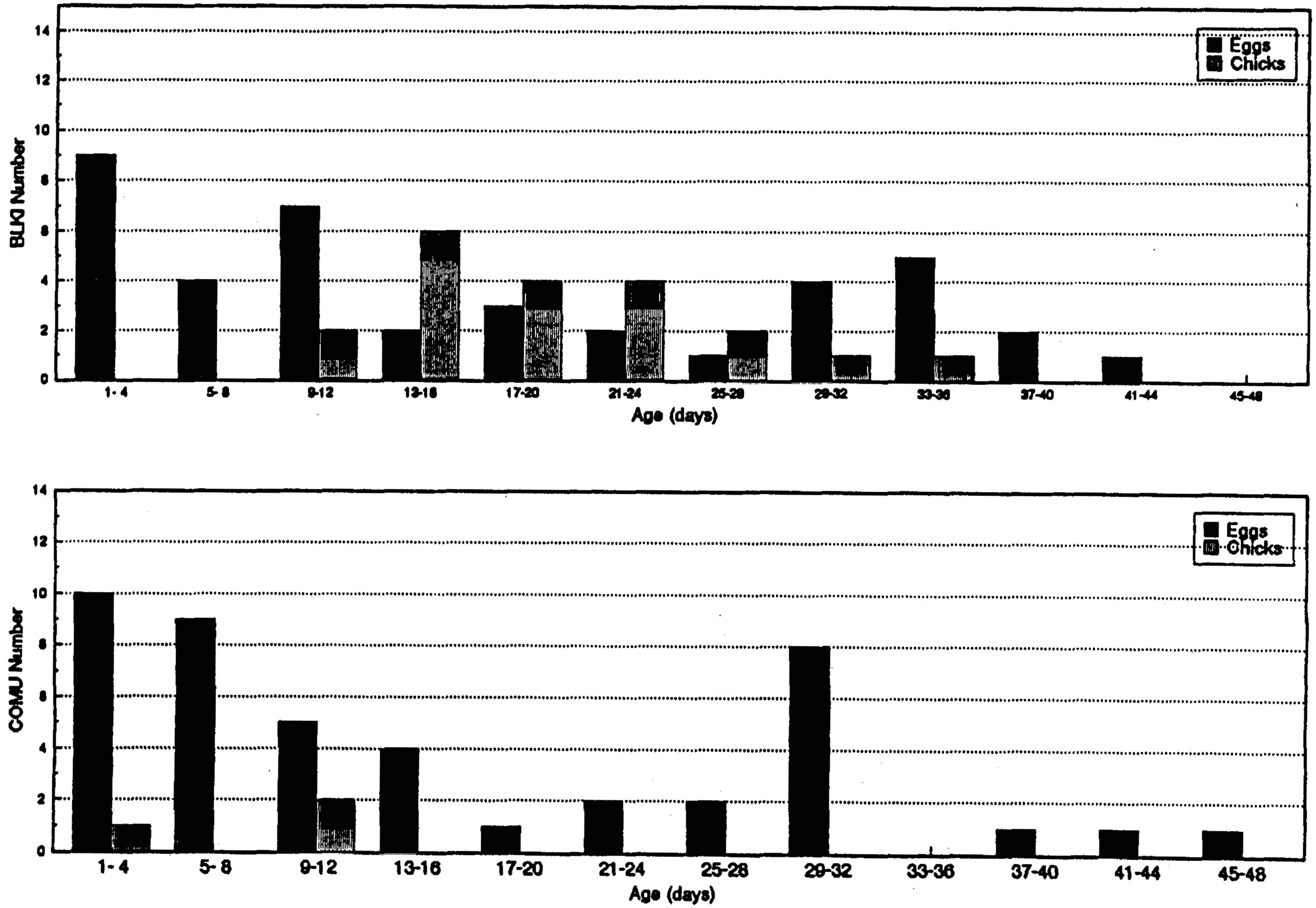


Figure 4.6. Black-legged kittiwake (BLKI) and common murre (COMU) egg and chick mortality frequency, in four-day intervals, Cape Peirce, 1989.

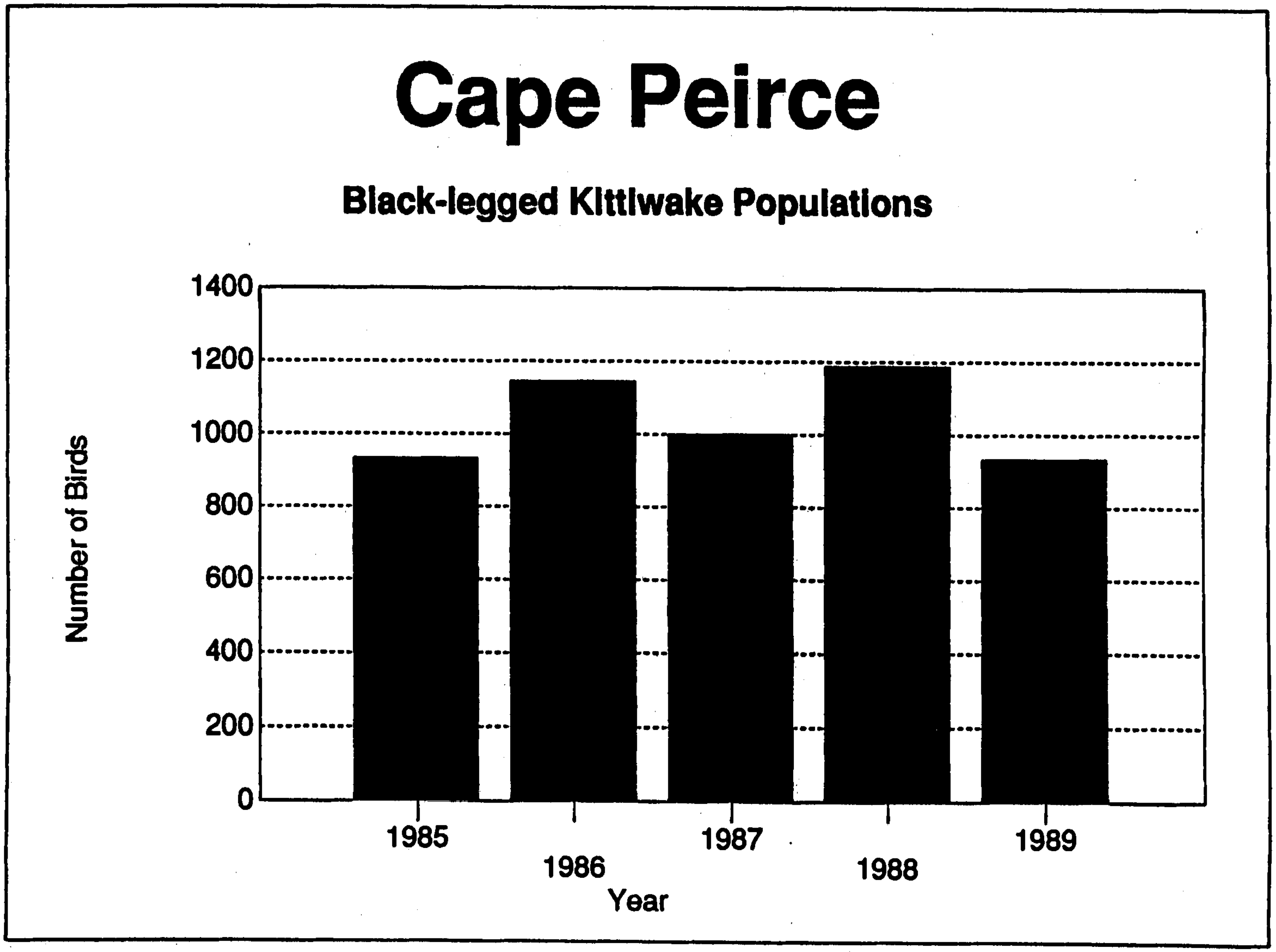


Figure 4.7. Black-legged kittiwake populations on monitoring plots at Cape Peirce, 1985-1989.

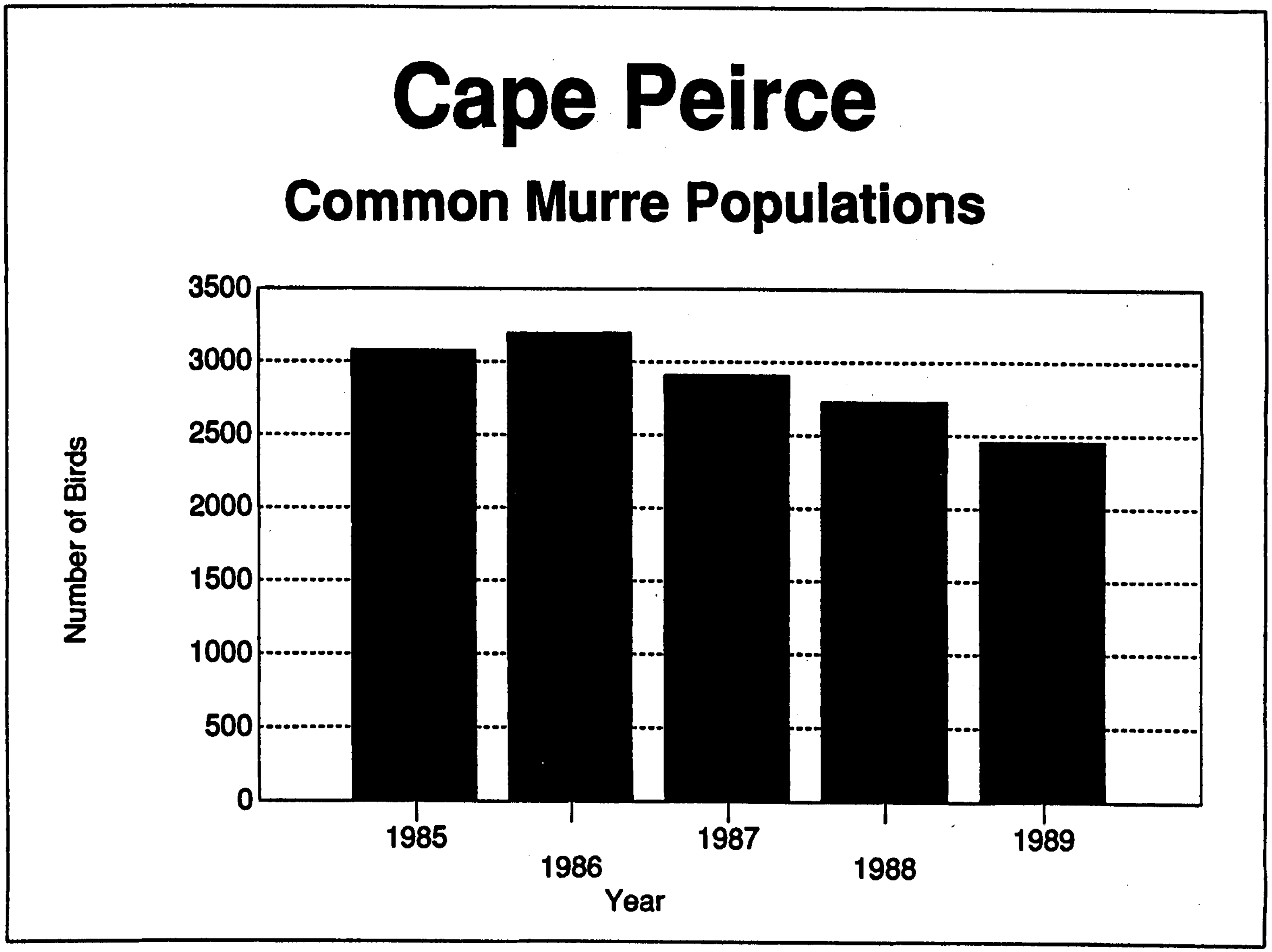


Figure 4.8. Common murre populations on monitoring plots at Cape Peirce, 1985-1989.

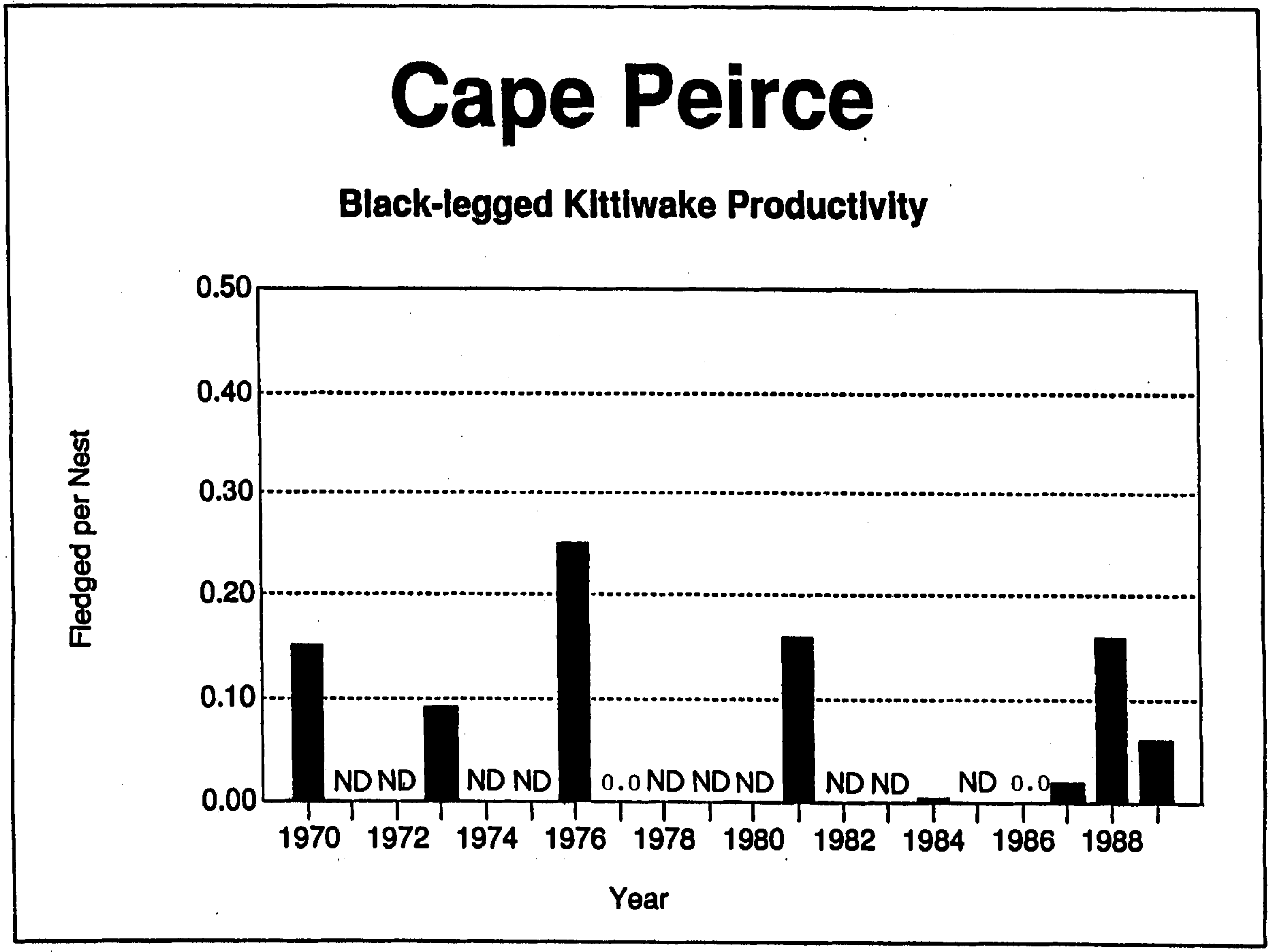


Figure 4.9. Productivity of black-legged kittiwakes at Cape Peirce, 1970-1989.

CHAPTER 5. BLUFF

by Edward C. Murphy

INTRODUCTION

Monitoring of numbers and reproduction of murres (Uria spp.) and black-legged kittiwakes (Rissa tridactyla) at Bluff, Alaska began in July 1975 (Drury 1976). In 1976 field methods were refined; boundaries of most murre and kittiwake reproductive plots used in subsequent years were first defined in 1976 (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 1987-1989 spanned the entire breeding season. In 1979 repeated land-based counts of two cliff faces (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 plots throughout the colony were initiated.

Here we report only those data on numbers and reproduction that were collected in 1989. No boat-based censuses (e.g., see Murphy et al. 1986) were conducted, and no eggs or chicks of kittiwakes were measured. Although we collected food samples of kittiwakes and made zooplankton tows, laboratory analyses of those samples have not been made.

STUDY AREA AND METHODS

The seabird colony at Bluff (64°134'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 et al. 1986; see Figure 5.1). Drury et al. (1981) and Drury and Ramsdell (1985) summarized their 1975-1978 studies. One of us (ECM) first participated in the fieldwork in 1978 and conducted fieldwork there in 1979-1989, assisted by one or more co-workers.

In 1989 M. Matsuki and C. Sullivan conducted fieldwork for the entire breeding season. They arrived on 10 June. Sullivan remained until 31 August and Matsuki departed on 9 September. E. Murphy trained them in field methods on 10-21 June and returned for a week in mid-July with A. Kondratiev and V. Mendenhall. Personnel stayed at a private cabin on Koyana Creek (0.5 km north of the Bluff colony) by special arrangement with the owner. Transportation was by a chartered Cessna 185 which landed on the tundra approximately 1 km inland from the cabin.

Methods used in 1987 through 1989 followed those described in Chapter 2. Methods differed in earlier years and are summarized below.

The census techniques for murres in 1975-1983 are 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 were conducted in 1989 and therefore they are not considered in this report. Beginning in 1979 field workers counted murres and kittiwakes on two large census plots viewed from the cliff top at 1900h ADT on one or more days between the end of egg-laying and the initiation of fledging of murre chicks. Terminology for these plots has varied over the years; Plot AA is the same as Plot 10 of this study, and Plot GG is Plot 15. In the mid-1980's we expanded the evening (1900h ADT) counts to include the reproductive plots and initiated extensive morning counts on large 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. Morning counts of kittiwakes were made only in 1989.

Methods for obtaining murre reproductive data follow those outlined in Murphy et al. (1986). 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 1987-1989 field workers visited reproductive plots daily to better quantify reproduction than in previous years when plots were visited every few days.

Several reproductive plots (8, 10, 13, 14 and 17), documented on photographs, were established for kittiwakes in 1976 (Drury and Ramsdell 1985), and were studied in 1976-1989 Plot 10 was also studied in 1975. On those 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), except in 1977, when nests were defined as structures capable of holding an egg (Biderman et al. 1978). These differences in definitions of a nest apparently are trivial in accounting for annual differences in numbers of nests (Ramsdell and Drury 1979). Each year nests were counted on each reproductive plot. Whenever possible, the number of eggs and the number and age class of chicks were recorded (see Ramsdell and Drury 1979).

In 1979-1988 nests of kittiwakes in three additional areas, Castle, Thumb Stack, and Golden Eagle Beach, were mapped and their contents recorded every several days. At accessible nests in these areas the length and breadth of each newly found egg (1981-1983, 1987-1988) and the weight of each chick (1979-1981, 1983, 1987-1988) were measured. In 1986 and 1989 repeated storms precluded regular visits to these areas and no data could be collected for comparisons to other years.

The timing of the fieldwork and the areas of study are listed in Table 5.1. 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 have no data on the chick growth rates and fledging success for 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 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 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. On average this value equalled the hatching date, and it always was within one day of the hatching date for known-age chicks. Except for 1975-1977, and 1989, when data on growth rates were not collected, our reporting of average hatching dates is based on analyses of weighed chicks. Drury et al. (1981) reported "peak" hatch dates for 1975-1977. In 1989, actual hatch dates were determined for all eggs on reproductive plots.

Data on food habits were obtained in 1989 and in previous years by collecting adult kittiwakes as they returned to the colony. Because the samples for 1989 (and two other years) have not been analyzed, no information on food habits is given in this report.

RESULTS

Murres

<u>Morning Counts</u>--Table 5.2 summarizes the morning counts of census plots that have been conducted at Bluff. All counts are listed in the Appendix (Table C-1).

Numbers increased significantly (Table 5.3) on about half of the plots between 1985 and 1987 and 1985 and 1988, based on pairwise comparisons (Conover 1980:300). No significant changes occurred on any plot between 1987 and 1988 except numbers declined significantly on Thumb Stack. On about half of the plots, numbers were significantly lower in 1989 than either 1987 or 1988. These results suggest generally that numbers were higher in 1987-1988 than in 1985 or 1989. Results of a Friedman test, using plots as blocks and years as treatments, demonstrated significant ($P<0.001$) differences among years. Pairwise comparisons (Conover 1980) showed that 1987 and 1988 counts were significantly ($P<0.05$) higher than the 1985 and 1989 counts.

Evening Counts--Data for evening (1900 ADT) counts of murres are available annually since 1979 for two faces, plots 10 and 15 (Table 5.4; Figure 5.2; Appendix, Table C-2). Since 1984, numbers were also counted at reproductive plots 8, 10, 12C, 12I, E13, 14 and 15 (Table 5.5; Appendix, Table C-2). To examine the 1989 counts relative to those in previous years, I first conducted a Kruskal-Wallis Test for differences among years and then Scheffe's pairwise comparisons for differences between each pair of years; here I report only those differences that were significant between 1989 and any previous year. In 1989 numbers were significantly higher ($P<0.05$) than in 1984 on both plots 10 and 15, significantly lower than in 1987 on plot 10, and significantly lower than in 1981 on plot 15. For the combined counts for plots 10 and 15, the 1989 counts were significantly lower than the 1981 counts and significantly higher than the 1984 counts. The total counts on the reproductive plots were significantly higher in 1989 than in 1984 and 1985. In general, numbers at 1900h ADT were relatively high in 1979-1981, low in the mid-1980's, and again high in 1987-1988.

Reproduction--Breeding chronology of murres at Bluff in 1989 was delayed relative to 1987 and 1988. The median laying date for all observed eggs was 30 June; Table 5.6 and Figure 5.3 summarize the 1989 data on breeding chronology.

Table 5.7 summarizes murre reproduction in 1989 at Bluff. For all seven reproductive plots eggs were laid at 382 sites. Combining the data for all plots and considering both original eggs and eggs that were relaid after loss of an egg, 60 percent of the nest sites produced a hatched egg and 47-49 percent of the sites produced a sea-going chick. On a per egg basis 48 percent of the eggs hatched and 39-40 percent of the eggs resulted in sea-going chicks. Table 5.8 compares reproductive data at Bluff for all phases of reproduction in 1987-1989, and for hatching in all years (Figure 5.4). The 1989 value of numbers hatching exceeded only the 1984-1986 values. In all aspects, reproduction in 1989 was poorer than in either 1987 or 1988.

Numbers and Reproduction--The annual variations in numbers of adults on the cliffs could be due to actual differences in adult population size or to variability in attendance due to other factors. There is a strong correlation ($r=0.79$, $n=10$, $P<0.01$) 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 1979-1989 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--Evening (1900h) counts of kittiwakes on plots 10 and 15 were lower in 1989 than in any other year but 1984 (Table 5.9; Figure 5.5; Appendix, Table C-3); no evening counts of the kittiwake reproductive plots were made in 1989 (Table 5.10). The low counts on plots 10 and 15 in 1989 contrast with high counts in 1988 and 1987 (Table 5.9).

Reproduction--Few kittiwake eggs were laid at Bluff in 1989. Estimated laying dates were obtained for 29 eggs; the median date was 5 July (range: 23 June - 14 July; Figure 5.6). Hatching dates were determined for only 5 eggs. The median hatching date was 29 July (range: 25 July - 1 August). No chicks fledged from the study plots.

There were 25 clutches in 64 kittiwake nests in 1989, and only one of them was a 2-egg clutch (Table 5.11). Most eggs were lost before hatching; only 5 hatched, and no chicks fledged.

Tables 5.12 and 5.13 and Figure 5.7 summarize data on kittiwake reproduction for 1976-1989. As can be seen readily, kittiwakes failed to reproduce successfully in 1984-1985 and 1989.

DISCUSSION

Murre Numbers

Earlier analyses, based on boat-based censuses and limited land-based counts, suggested that murre numbers declined in the mid-1970s (Murphy et al. 1986). Analyses of land-based counts in 1979-1989 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.

Earlier analyses of within-day changes in numbers on the cliffs showed two daily peaks in the early morning and late evening (e.g., Murphy et al. 1980). At Bluff, local clock time in summer is approximately 3 hours ahead of sun time, e.g., the sun is due south at about 1500h ADT. Our 1900h ADT counts coincide with a low phase in the daily cycle of numbers. In the mid-1980s it appeared that daily fluctuations were amplified in poor reproductive years (Murphy, pers. obs.), and I therefore initiated early morning counts of murres as well as continuing the 1900h counts. At the time, I felt that early morning and late afternoon counts might be more disparate in poor reproductive years than in good reproductive years and that comparisons of the two sets of counts might permit discrimination between the population of murres using the cliffs and changes in attendance patterns that are related to reproduction. Our analyses of the morning counts in 1985 and 1987-1989 suggest that numbers are depressed not only in the late afternoon but also in the early morning in poor reproductive years such as 1985 and 1989. Consequently, the early morning and late afternoon counts seem to be supplying redundant information about numbers. Because the morning counts are more disruptive to the work schedules of field personnel, requiring departure for the cliffs at 0500h-0600h ADT (0200-0300h sun time), I recommend concentration of counting efforts in future years in the late afternoon period.

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 1987-1989, 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 unsuccessful.

Heavy losses of eggs and high frequencies of replacement laying were documented in 1987-1989, when daily checks of reproductive plots were made. Less frequent plot visits or delaying fieldwork until the completion of the egg-laying period could result in a very erroneous depiction of the chronology and extent of egg-laying. I hope that future studies at Bluff can focus on the quantification of egg loss to accidents and predation. Several pairs of common ravens (Corvus corax) nest either within or near the colony and seem to take large numbers of murre eggs, actively displacing incubating murres.

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 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.

ACKNOWLEDGMENTS

Many people have contributed to the data base that is now available for Bluff. W.H. Drury and his family and students initiated the studies there in 1975 and continued them through 1978. In 1979 G.J. Murphy and A. Watson assisted me in the fieldwork. A.D. MacGuire and M.I. Springer aided me in the fieldwork and data analysis in 1980. In 1981 R.S. Mule assisted me, and we were aided in 1982 by G.J. Murphy and S. Mule. R.H. Day participated in 1983. J.A. Stroebele and A.M. Springer helped conduct the fieldwork in 1984. In 1985 G.J. Murphy, M.P. Harris, S. Wanless and B.A. Cooper aided in the fieldwork; B.A. Cooper also analyzed food habits specimens. In 1986 G.J. Murphy, A.M. Springer, M.I. Springer, W. Walker and B. Tritell assisted in the field. In 1987 and 1988 J.H. Schauer and D. Kildaw conducted fieldwork for the entire breeding season. C. Sullivan and M. Matsuki aided in data analysis and summarization for this report as well as conducting the fieldwork in 1989. Through the many years I have been travelling to Bluff numerous people in Nome have provided invaluable assistance. B. Hahn has always offered her cabins at Koyana Creek to house the field crews. T. Smith, D. Anderson, and R. Nelson of the Alaska Department of Fish and Game have repeatedly helped us in Nome. M.O. Olsen not only has flown personnel and supplies between Nome and Koyana Creek but also has checked with field crews frequently to insure our safety. All of these people have my sincere thanks.

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Table 5.1. Timing and duration of field work and areas of data collection for reproduction of kittiwakes and murres at Bluff, Alaska, 1975-1989.

Year	Time of Fieldwork		Areas Studied		Reference
	Arrival	Departure	Kittiwake reproduction	Murre reproduction	
1975	3 Jul	22 Sep	1,3,4,4b,10	unique plots	Drury 1976
1976	29 May	10 Oct	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	10,13,17,CA,TS,GE	8,10	Murphy, unpubl. data
1981	10 Jul	23 Jul	10,14,CA,TS,GE	8,10	Murphy, unpubl. data
1982	12 Jul	21 Jul	8-17,CA,TS,GE	--	Murphy, unpubl. data
1983[c]	8 Jul	27 Jul	8,10,14,17,CA,TS,GE	8,10,12c,14,15	Murphy, unpubl. data
1984	6 Jul	20 Jul	8-17,CA,TS,GE	8,10,14	Murphy, unpubl. data
1985[d]	9 Jul	27 Jul	8-17,CA,TS,GE	8,10,12c,12i,14,15	Murphy, unpubl. data
1986[e]	8 Aug	14 Aug	8,10,13,14	10,13,15	Murphy, unpubl. data
1987	1 Jun	27 Aug	8-17,CA,TS,GE	8-15	Murphy, unpubl. data
1988	24 May	1 Sep	8-17,CA,TS,GE	8-15	Murphy, unpubl. data
1989	10 Jun	9 Sep	8-17	8-15	Murphy, unpubl. data

[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, 13, 14, and 15 (see Drury and Ramsdell 1985).

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

[d] Fieldwork on all listed plots also was conducted on 16-18 August.

[e] Fieldwork also was conducted on 10-17 June.

Table 5.2. Morning counts of murres at Bluff. 1985-1989.

Stake[a]	Year 1985	1987	1988	1989
1	497±18(3)[b]	680±71(5)	658±30(5)	586±63(8)
3a	271±10(3)	318±30(5)	324±21(5)	291±33(8)
3b	1392±97(3)	2036±248(5)	1897±123(5)	1733±199(8)
4b	727±28(3)	1083±105(5)	1108±40(5)	853±117(8)
4c	793±27(3)	1433±175(5)	1397±93(5)	1058±174(8)
4d	2131±148(3)	3060±282(5)	3042±241(5)	2560±250(8)
4e(Ax)	869±145(3)	1160±84(5)	1229±74(5)	953±117(8)
4f(Hatchet)	872±35(3)	1327±155(5)	1347±75(5)	1025±121(8)
5a	2116±(1)	2798±139(5)	3043±263(5)	1761±352(8)
5b	ND	1127±73(5)	1195±111(5)	986±119(8)
6	248±53(3)	352±43(5)	313±40(5)	300±25(8)
8a	679±59(2)	797±70(5)	778±79(5)	657±68(8)
8b	483±41(3)	503±26(5)	444±44(5)	362±20(8)
9	998±60(2)	1222±45(5)	1236±81(5)	891±73(8)
10	1513±112(13)	1638±84(5)	1573±80(5)	1188±65(8)
12	ND	329±15(5)	331±35(5)	256±82(8)
13	330±86(2)	413±26(5)	382±28(5)	342±47(8)
14	481±(1)	550±124(5)	557±51(5)	518±56(8)
15	767±67(13)	1003±52(5)	988±33(5)	829±108(8)

[a] The plots are coded by the observer's location when making the counts. All plot boundaries are marked on photographs.

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

Table 5.3. Results of pairwise comparisons of morning counts of murres at Bluff.

Plot	1985-1987	1985-1988	1985-1989	1987-1988	1987-1989	1988-1989
1	+[a]	+				
3a						
3b	+	+				
4b	+	+			-[b]	-
4c	+	+			-	-
4d	+	+			-	-
4e	+	+			-	-
4f	+	+			-	-
5a					-	-
5b	NA[c]	NA	NA			-
6						
8a					-	
8b			-	-	-	-
9		+			-	-
10			-		-	-
12	NA	NA	NA			-
13						
15	+	+			-	-
14						

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

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

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

Table 5.4. Counts of murres on census plots 10 and 15 at Bluff, 1900h ADT[a], 1979-1989.

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±117(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	1375±86(10)	439±28	476±37	915±57(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	620±120(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)	2110±235(10)

[a] Census plots 10 and 15 are the same faces designed as Plots AA and GG in some previous reports.

[b] Mean ± standard deviation.

[c] The number of counts is listed in parentheses.

Table 5.5. Counts of murres on reproductive plots at Bluff, 1900h ADT, 1979-1989.

Year	Plot 8	10	12c	121	13	14	25	Total
1979	--	167± 9(13)	--	--	--	--	--	--
1980	--	147± 7 (5)	--	--	--	--	--	--
1981	--	170±11(11)	--	--	--	--	--	--
1982	--	147±17 (8)	--	--	--	--	--	--
1983	--	163± 8(10)	--	--	--	--	--	--
1984	40± 6(13)	83±33(14)	6±10(13)	7±10(13)	36±16(13)	15±20(14)	46±9(13)	220±72(12)
1985	48±10(18)	118±38(18)	26±10(18)	33± 7(18)	71±16(12)	97±13(18)	50±7(18)	441±89(12)
1986	--	136±(2)	--	--	91±(2)	--	94(1)	--
1987	63± 6(12)	151± 8(12)	41± 4(12)	36± 6(12)	98± 6(12)	105± 4(12)	64±4(12)	559±23(12)
1988	58± 3(12)	140± 1(12)	44± 2(12)	32± 2(12)	96± 5(12)	103± 7(12)	62±7(12)	535±24(12)
1989	57± 9(10)	158±16(10)	42± 8(10)	39± 9(10)	98±12(10)	107± 7(10)	69±7(10)	569±59(12)

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

Table 5.6. Breeding chronology of murres at Bluff, 1989.

A. First Attempts

Plot	Laying Date	Hatching Date	Sea-going Date
8	28 Jun ± 6 (34)[a]	1 Aug ± 6 (17)	23 Aug ± 6 (14)
10	30 Jun ± 6 (94)	3 Aug ± 6 (43)	23 Aug ± 5 (34)
12c	3 Jul ± 10 (17)	15 Aug ± 1 (2)	3 Sep ± 1 (2)
12i	3 Jul ± 10 (19)	28 Aug (1)	ND[b]
13	4 Jul ± 9 (63)	10 Aug ± 8 (24)	28 Aug ± 8 (20)
14	29 Jun ± 7 (92)	2 Aug ± 8 (52)	24 Aug ± 6 (46)
15	29 Jun ± 7 (52)	2 Aug ± 6 (27)	22 Aug ± 4 (18)
Total	30 Jun ± 8 (376)	4 Aug ± 8 (166)	24 Aug ± 6 (139)

B. All Attempts

Plot	Laying Date	Hatching Date	Sea-going Date
8	1 Jul ± 9 (47)	3 Aug ± 9 (20)	24 Aug ± 6 (16)
10	1 Jul ± 8 (110)	5 Aug ± 8 (52)	24 Aug ± 5 (45)
12c	6 Jul ± 10 (23)	18 Aug ± 5 (3)	3 Sep ± 1 (2)
12i	7 Jul ± 11 (29)	19 Aug ± 6 (5)	2 Sep ± 3 (3)
13	6 Jul ± 9 (83)	11 Aug ± 8 (43)	29 Aug ± 7 (34)
14	1 Jul ± 8 (114)	5 Aug ± 9 (68)	26 Aug ± 6 (60)
15	1 Jul ± 9 (59)	3 Aug ± 7 (30)	22 Aug ± 4 (20)
Total	3 Jul ± 9 (465)	6 Aug ± 9 (221)	26 Aug ± 6 (180)

[a] mean ± standard deviation (sample size)

[b] ND: No Data

Table 5.7. Summary of reproduction of murres on 7 reproductive plots at Bluff, 1989.

	Plot							
Variable	8	10	12-inside	12-crack	13	14	15	Total
Active sites	39	94	17	19	69	92	52	382
Eggs laid	47	110	23	29	89	113	59	470
Eggs hatching	20	54	3	5	43	69	30	224
Seagoing chicks	16	46	2	3	33	61	20	181
Eggs lost	26	44	20	22	41	37	25	215
Chicks lost	4	8	1	2	9	6	8	38
Eggs failing to hatch	1	12	0	1	5	7	4	30
Chicks still on cliffs	0	0	0	0	1	2	2	5

Table 5.7. (continued).

b. Numbers of eggs hatching, 1977-1989.

	Plot							
Year	8	10	12c	12i	13	14	15	Total
1977	--	71	--	--	--	--	--	(271)[a]
1978	26	89	28	29	44	73	30	319
1979	--	≤88	--	--	--	--	--	(≤336)
1980	≤26	≤88	--	--	--	--	--	(≤314)
1981	33	66	--	--	--	--	--	(273)
1982	--	--	--	--	--	--	--	ND
1983	36	88	--	38	--	--	33	(364)
1984	≤16	≤26	0	0	--	≤1	--	(≤61)
1985	≤16	≤40	≤4	≤14	--	≤30	≤28	(≤160)
1986	--	≤57	--	--	≤20	--	--	(≤175)
1987	34	73	15	18	55	56	37	288
1988	33	76	16	16	55	57	30	283
1989	20	54	5	3	43	69	30	224

[a] Totals in parentheses are estimates based on numbers hatching on plots that were studied, relative to numbers hatching on all plots in 1978 and 1987-1989.

Table 5.8. Murre reproduction at Bluff, 1977-1989.

a. Summary of reproduction in 1987-1989, laying through fledging.

	Numbers		First Eggs		Replacement Eggs					
	Plots	Active Sites	HS(%)[a]	FS(%)[b]	n	Replaced	HS(%)	FS(%)	Prod(%)[c]	K-ratio[d]
1987	7	404	59	95	64	39	75	92	67	0.72
1988	7	407	55	94	92	51	63	85	64	0.76
1989	7	382	45	83	88	39	57	72	48	0.67
Averages	7	382-407	53±7[e]	91±7	64-92	43±7	65±9	83±10	60±10	0.72±0.05

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

[b] FS: Fledging success (number of chicks "fledging"/number of eggs hatching).

[c] Prod: Productivity (number of chicks "fledging"/number of active sites).

[d] K-ratio: Number of active sites/mean number of adults (see Table 5).

[e] Mean ± standard deviation.

Table 5.8 (continued).

b. Numbers of eggs hatching, 1977-1989.

Year	Plot							
	8	10	12c	12i	13	14	15	Total
1977	--	71	--	--	--	--	--	(271)[a]
1978	26	89	28	29	44	73	30	319
1979	--	≤88	--	--	--	--	--	(≤336)
1980	≤26	≤88	--	--	--	--	--	(≤314)
1981	33	66	--	--	--	--	--	(273)
1982	--	--	--	--	--	--	--	ND
1983	36	88	--	38	--	--	33	(364)
1984	≤16	≤26	0	0	--	≤1	--	(≤61)
1985	≤16	≤40	≤4	≤14	--	≤30	≤28	(≤160)
1986	--	≤57	--	--	≤20	--	--	(≤175)
1987	34	73	15	18	55	56	37	288
1988	33	76	16	16	55	57	30	283
1989	20	54	5	3	43	69	30	224

[a] Totals in parentheses are estimates based on numbers hatching on plots that were studied, relative to numbers hatching on all plots in 1978 and 1987-1989.

Table 5.9. Counts of kittiwakes on census plots 10 and 15 at Bluff, 1900h ADT[a], 1979-1989.

	Plot							
Year	10a	10b	10c	10a-c	15a	15b	15a-b	10 and 15
1979	138±11[a]	107±8	90±8	335±25(15)[b]	61±2	118±5	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	370±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(18)	571±131(18)
1986	--	--	--	526±(1)	106	134	240±(1)	766(1)
1987	167±17	60±6	210±14	437±30(11)	118±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±16(11)
1989	106±58	41±21	128±60	275±137(10)	64±30	117±43	181±72(11)	456±209(11)

[a] Mean ± standard deviation.

[b] Number of counts.

Table 5.10. Counts of kittiwakes on reproductive plots at Bluff, 1900h ADT, 1984-1989.

	Plot					
Year	8	10	13	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(18)	60±5(18)	254±44(18)
1986	--	--	--	--	--	--
1987	40±3(11)	87±5(11)	66±4(11)	39±3(11)	61±9(11)	291±15(11)
1988	39±1(11)	87±6(11)	67±7(11)	40±3(11)	65±3(11)	298±16(11)
1989	--	--	--	--	--	--

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

Table 5.11. Reproductive performance of kittiwakes at Bluff, 1989.

Plots	Nests	Eggs	Eggs Hatching	Chicks Fledging
8	7	1	0	0
10	6	8	2	0
13	20	8	1	0
14	17	7	2	0
17	14	2	0	0
TOTAL	64	26	5	0

Table 5.12 Reproductive performance of kittiwakes on five reproductive plots at Bluff 1975-1989.

				Numbers			
					Eggs Hatching		
Year	Nests	Active[a] Nests	Eggs	Maximum	Actual	Minimum	Chicks Fledging
1975	(169)[b]	116[c]	145[c]	116[c]	-	97[c]	68[c]
1976	131	42	47	-	7	-	5
1977	98	37	44	-	15	-	11
1978	201	183	312	-	234	-	164
1979	207	≥184[d]	ND[e]	(≥269)	-	(≥239)	222
1980	196	≥175	ND	(≥240)	-	(≥222)	(≥185)
1981	204	(≥161)	(299)	(≥221)	-	(177)	(≥142)
1982	152	71	79	ND	-	ND	ND
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

[a]Active Nests: Nests known to contain eggs.

[b]Values in parentheses are estimates based on totals for four or fewer plots. In 1975 data obtained on plot 10 and on 4 plots not studied in later years; in 1980, 1981, 1983, and 1986 data or 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 factor.

[c]Estimate based on ratios of counts of each variable to number of nests at Stake 3 (Drury 1976).

[d]Inequality signs were used for hatching values obtained when hatching had commenced before our arrival and for fledging values when we left while chicks were still downy.

[e]ND: no data.

Table 5.13. Summary of reproductive performance of black-legged kittiwakes at Bluff, 1975-1989[a].

Year	Hatching chronology: First	Hatching chronology: Median	Clutch size	Eggs hatching/Active nest[b]: Maximum	Eggs hatching/Active nest[b]: Actual	Eggs hatching/Active nest[b]: Minimum	Chicks fledging/ Active nest	HS[c] (%)	FS[d] (%)	Growth rate of chicks
1975	18 Jul	29 Jul	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 Jul	30 Jul	1.12±0.33(42)		0.17±ND(42)		0.12±0.33(42)	15	71	ND
1977	18 Jul	2 Aug	1.19±0.40(37)		0.41±ND(37)		0.30±0.46(37)	34	73	ND
1978	10 Jul	23 Jul	1.70±0.46(183)		1.28±0.74(183)		0.90±0.49(183)	75	70	18.0±4.3(18)[e]
1979	7 Jul	14 Jul	ND	ND		≥1.27±0.56(226)	1.16±0.54(226)	ND	≤91	19.7±4.4(39)
1980	6 Jul	15 Jul	ND	ND		≥1.35±0.60(179)	≤1.15±0.58(180)	ND	ND	17.1±2.1(30)
1981	8 Jul	13 Jul	1.70±0.57(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 Jul	ND	1.10±0.29(105)	ND		ND	ND	ND	ND	ND
1983	9 Jul	10 Jul	1.69±0.50(211)	1.49±0.62(212)		1.08±0.71(217)	0.30±0.46(123)	76	24	12.4±5.3(10)
1984	>20 Jul[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)	≤0.73±0.45(70)	ND	ND	ND
1987	20 Jul	26 Jul	1.45±0.50(251)	1.30±0.60(251)		0.97±0.61(251)	0.72±0.48(251)	78	64	16.7±3.5(47)
1988	11 Jul	19 Jul	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 Jul	29 Jul	1.04±0.20(25)		0.20±0.41(25)		0.00±0.00(25)	19	0	ND

ND: No data available. NA: Not applicable.

[a] Sources are listed in Table 1.

[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 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; this estimate is based on the weight of the largest chick found on 11 August and the average growth rate chicks of 17.2g (all years combined).

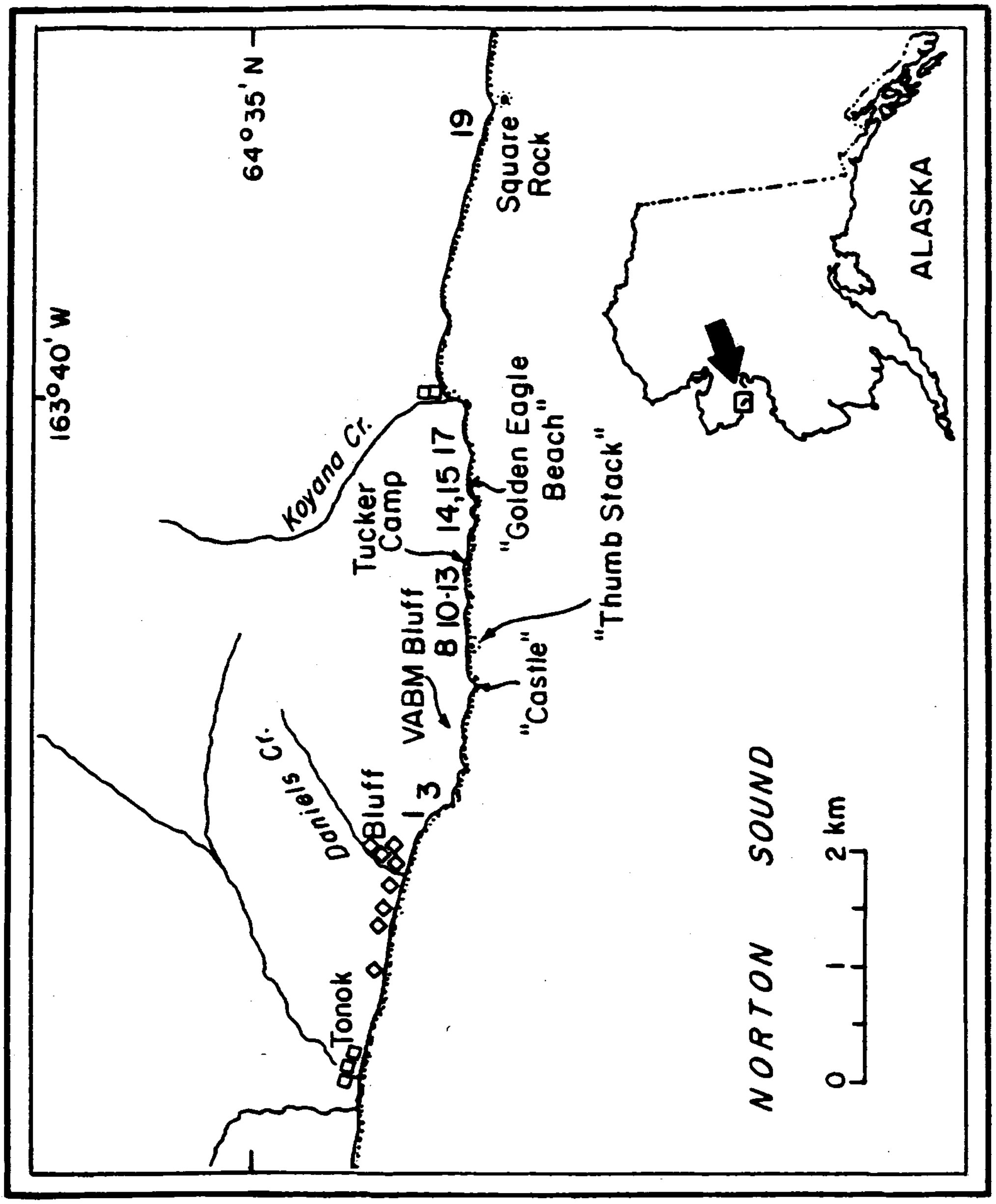

Figure 5.1. Location of the Bluff seabird colony, and of census states (location of observer when counting birds on a plot). All stakes except 4b-4f, 5a, 5b, and 6 are shown; stakes 4b-6 are located sequentially from west to east between stakes 3 and 8. Open squares denote structures.

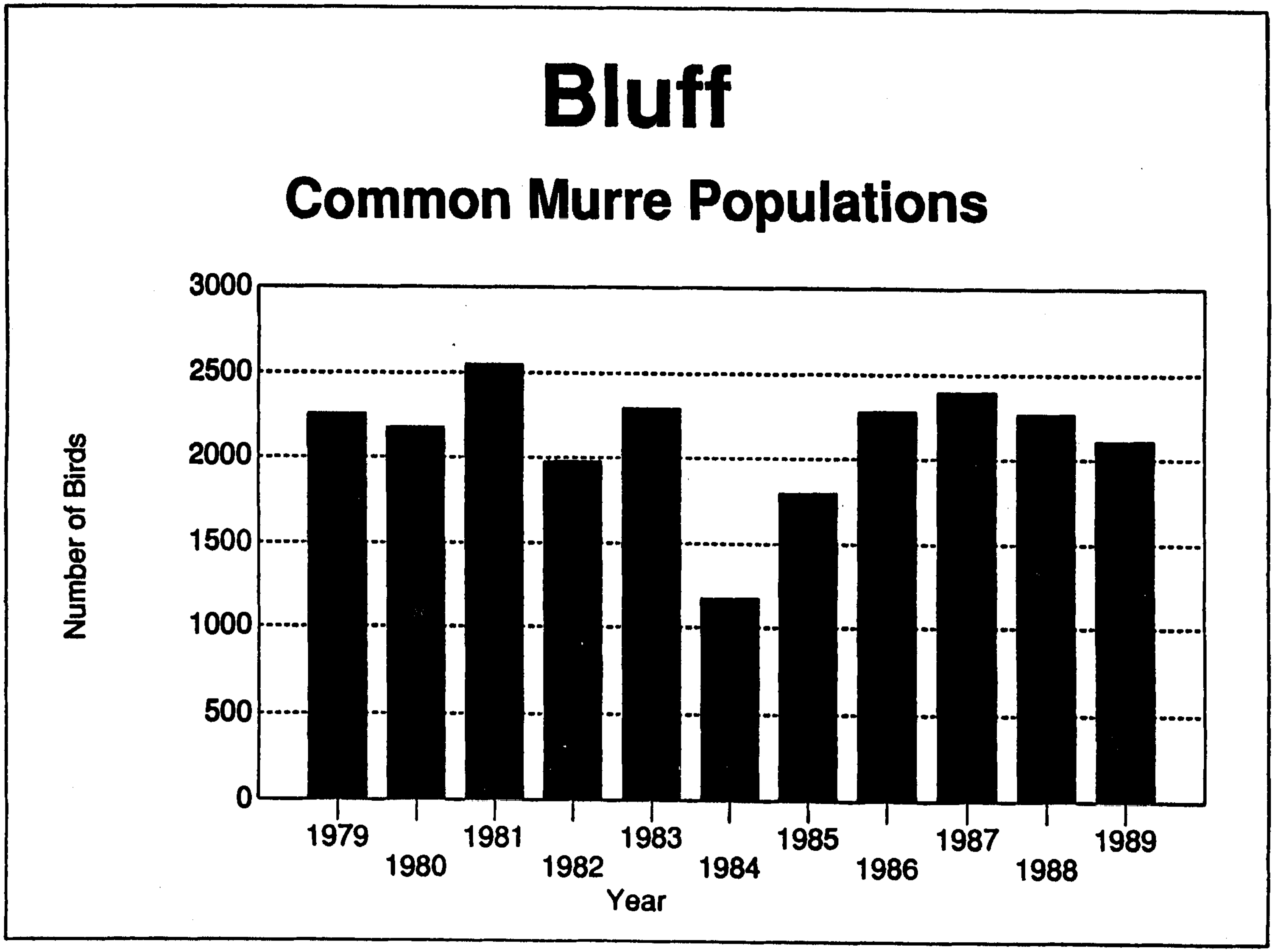

Figure 5.2. Evening counts of common murres at Bluff, 1979-1989.

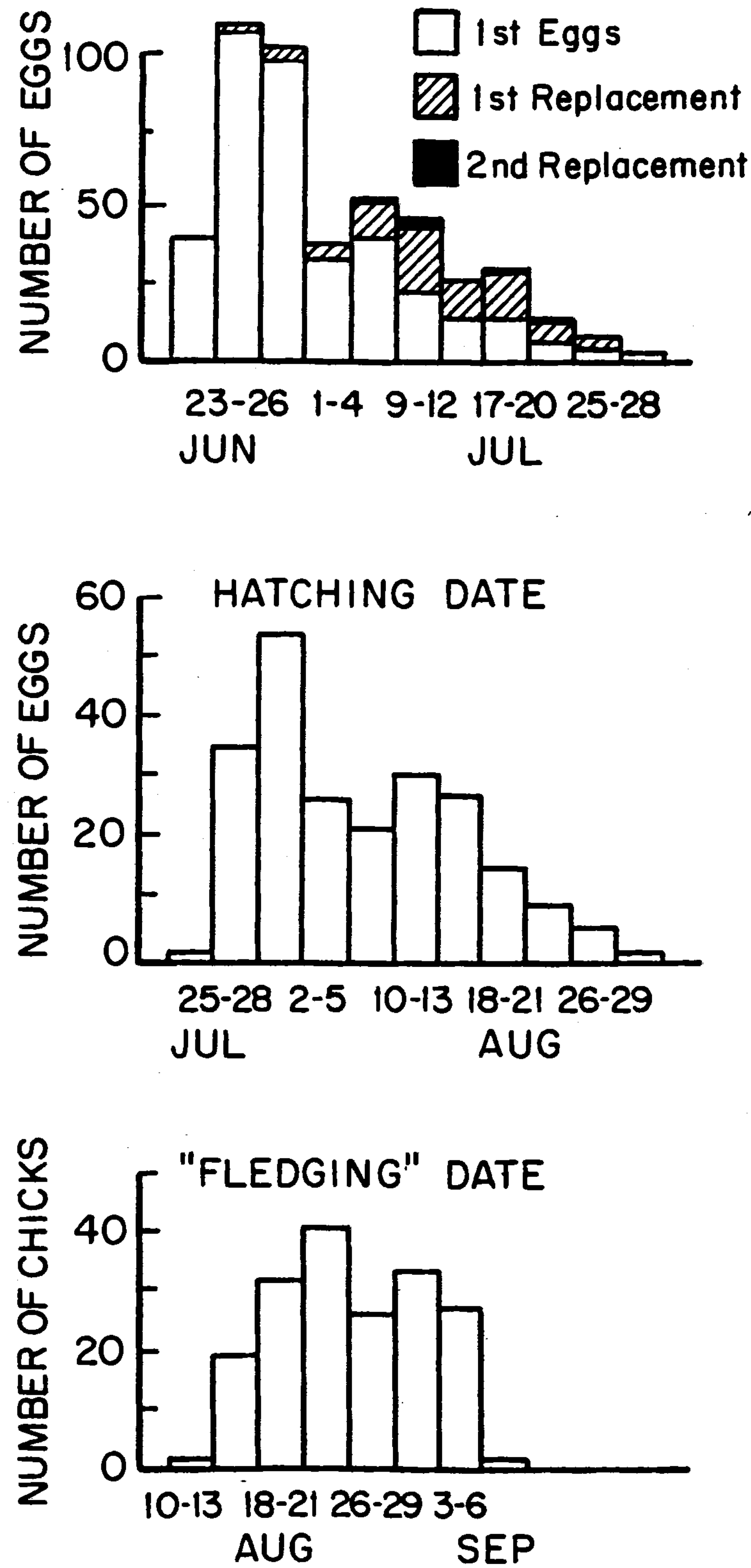

Figure 5.3. Breeding chronology of Common Murres at Bluff in 1989.

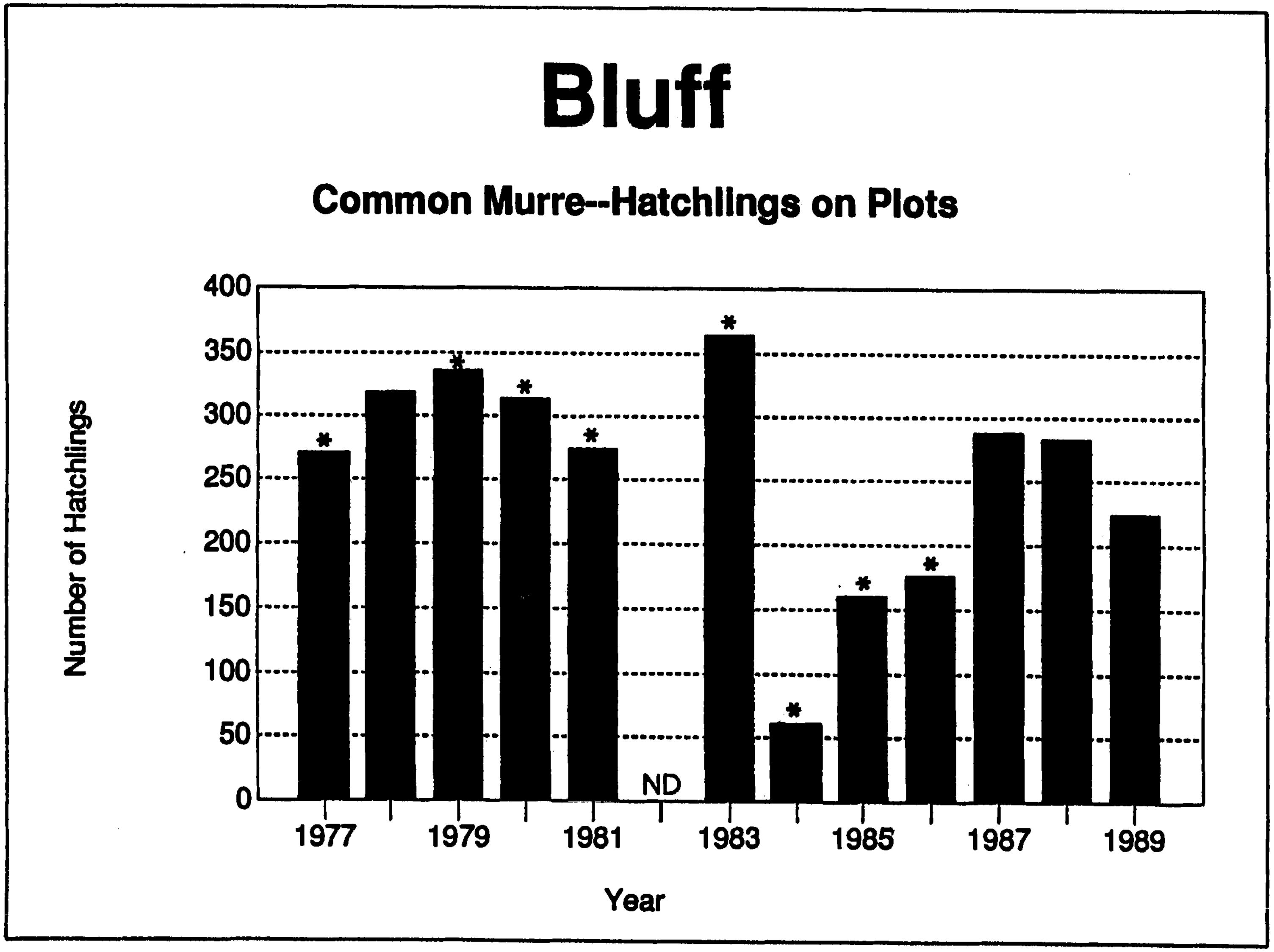

Figure 5.4. Common murre hatchlings on reproductive plots at Bluff, 1979-1989.

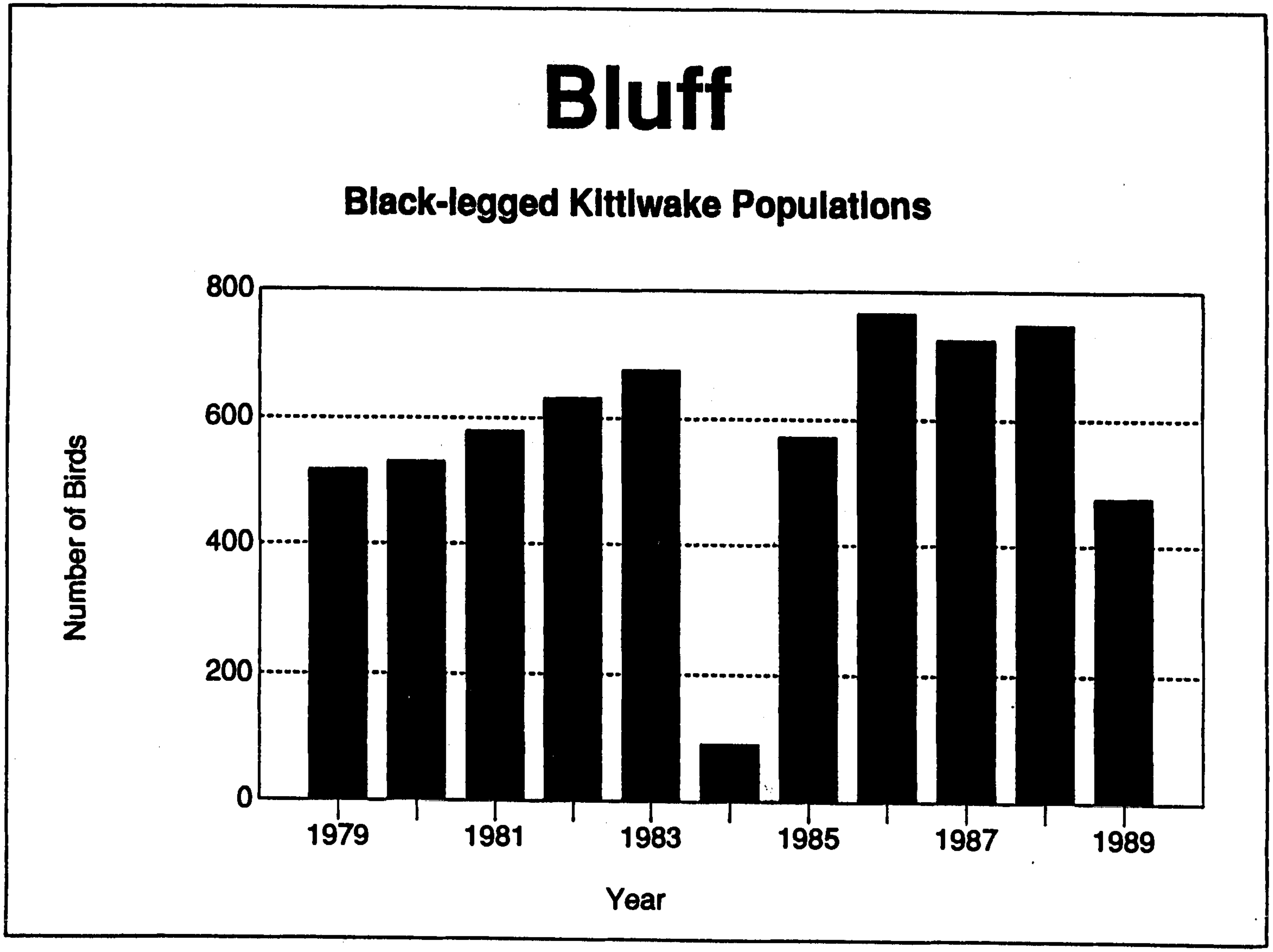

Figure 5.5. Counts of black-legged kittiwakes at Bluff, 1979-1989.

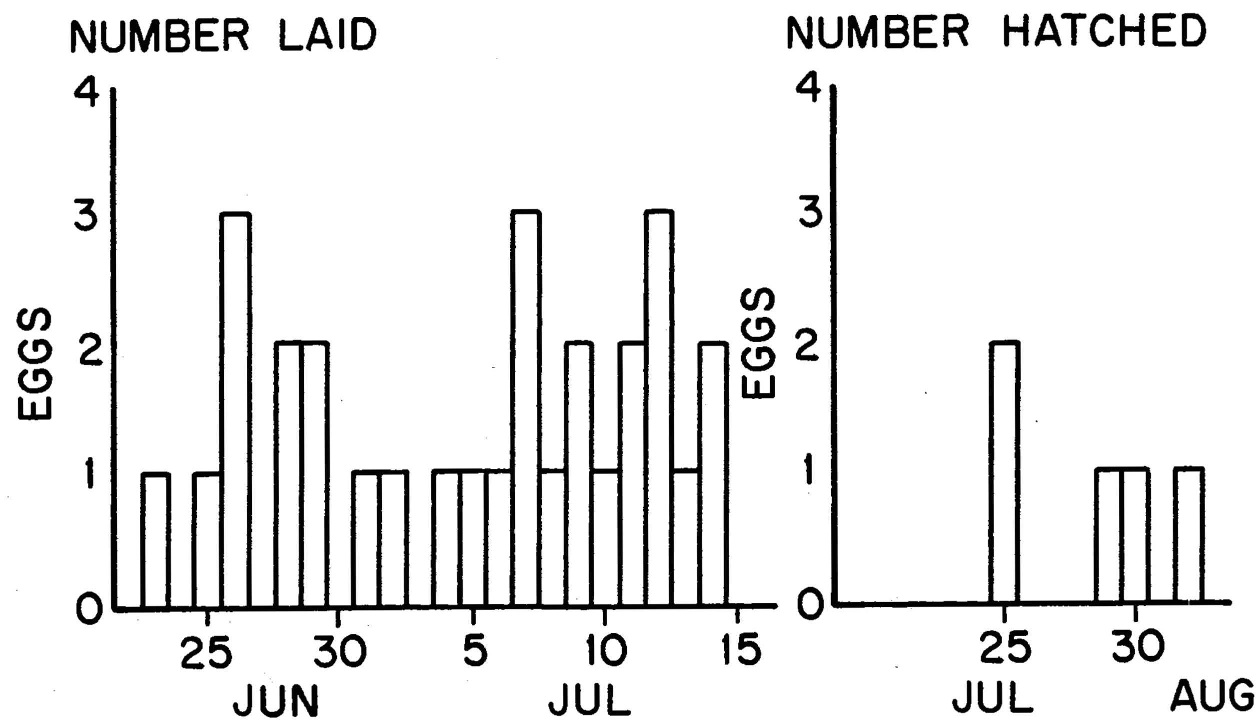

Figure 5.6. **Breeding chronology of black-legged kittiwakes at Bluff in 1989.**

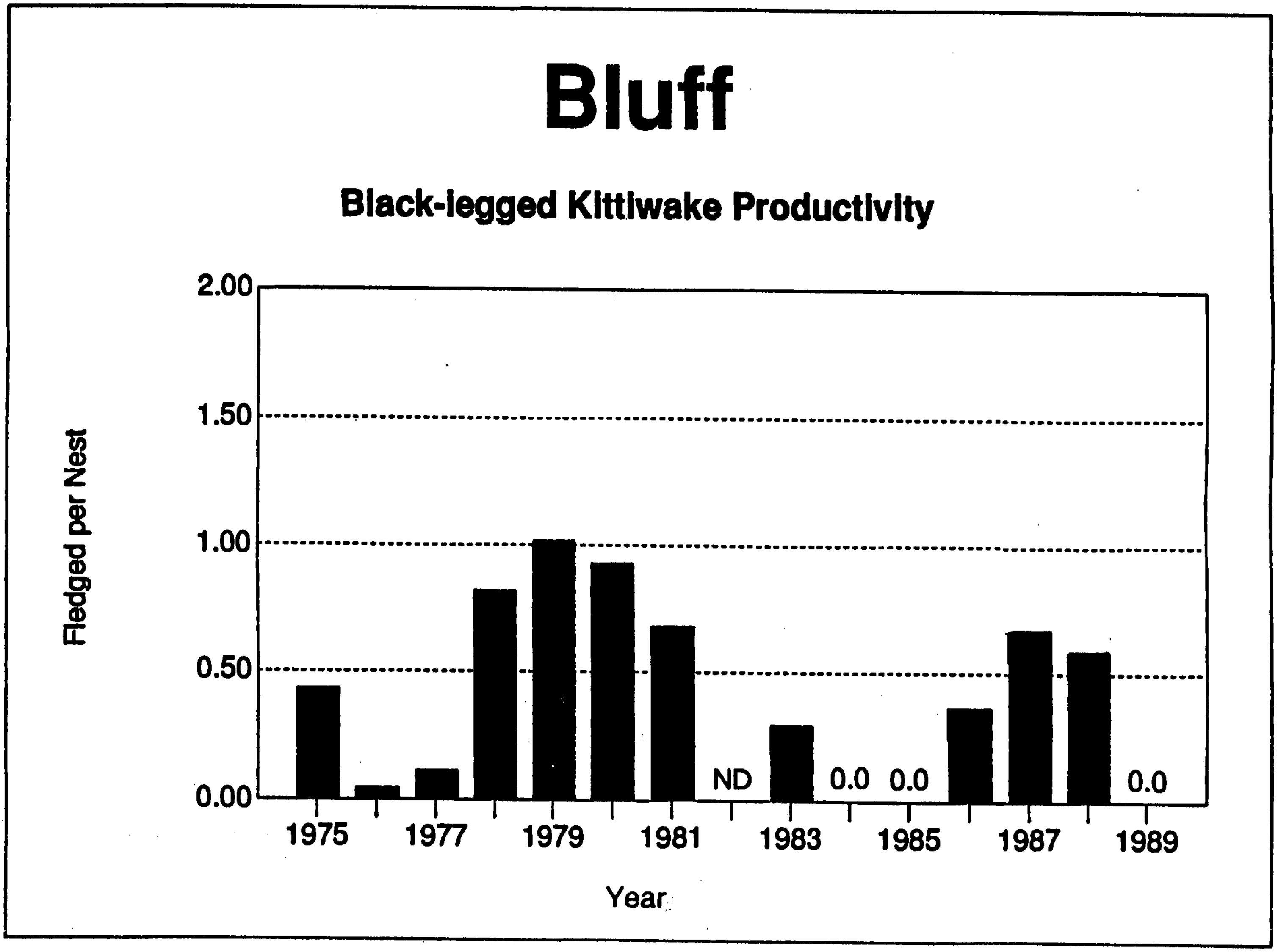

Figure 5.7. Productivity (fledglings/nest) of black-legged kittiwakes at Bluff.

CHAPTER 6. EVALUATION OF AN ALTERNATE METHOD FOR ESTIMATING SEABIRD PRODUCTIVITY

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INTRODUCTION

Seabird productivity is monitored each year that populations are censused at colonies in the Bering and Chukchi Seas. Comparison of breeding success among years can be important in understanding processes that affect seabird populations, and in assessing whether changes in populations are natural or caused by human activities such as oil development.

The methods used in this study to estimate productivity of murres and kittiwakes were intensive. Productivity plots were observed every one to three days, requiring 2 to 4 observers per colony for 10 to 13 weeks (Chapter 2). This method was termed "Type I" by Birkhead and Nettleship (1980). The prolonged and detailed observations of the Type I method produce an accurate record of the number of pairs of birds that initiated breeding on each plot and of the number of chicks fledged. Productivity (chicks fledged per breeding pair) can then be estimated.

Estimates of productivity may be biased due to observer error such as overlooking breeding sites (e.g., failing to notice an egg hidden beneath a murre, or failing to recognize a new kittiwake nest that has been improved briefly and then abandoned), or overlooking chicks that have fledged successfully (e.g., failing to notice chicks being brooded by parents), or failing to examine plots until some chicks have departed). Murre productivity estimated by Type I methods has a bias due to observer error of less than 5% if observations are conducted daily (Gaston et al. 1983). We have not evaluated observer error for our 2- to 3-day observation intervals but we believe it to be less than 10%. Estimates for kittiwakes have not been evaluated but are probably negligible because breeding sites and chicks are much easier to see than those of murres.

The advantage of relatively precise estimates of productivity is that they can be compared with confidence that differences between years can be detected. The magnitude of change among years that we need to assess is determined by our objectives. It has been suggested that if productivity or populations are to be used as indicators of problems that may be affecting Alaskan seabirds, methods should allow detection of changes of approximately 20% or less (Lawrence Johnson and Associates 1985). Downward trends in numbers over several years should then be detectable in time for managers to attempt identification and mitigation of problems. Methods used to estimate seabird productivity in the Pribilofs would usually reveal changes of 20% (Byrd 1989). The Type I method also provides information such as chronology, clutch size (for kittiwakes), hatching success, and the timing of egg and chick losses. These data may help in interpreting changes in productivity.

The Type I method has the disadvantage of being labor-intensive. Several observers must be at each colony throughout the breeding season. Alternate methods have therefore been proposed by which observers would make a few short visits to the colony during the essential periods for estimating the number of breeding sites and successful chicks. Harris (1987) observed kittiwakes on one-day visits during the nest-initiation, incubation, and fledging periods. Estimates of productivity from brief observations were 13% higher than results from observations every 3 days, but this bias was considered acceptable for judging the health of kittiwake populations. Similar abbreviated observations of murre productivity have been used at some colonies in Alaska. Drury et al. (1981) and Murphy et al. (1986) estimated murre productivity at Bluff as the number of chicks that left ledges on the productivity plots divided by the number of adult murres counted on the same plots during population censuses.

Piatt et al. (1988; Chapter 5) proposed that estimates of seabird productivity throughout the Bering-Chukchi Sea study area be based on two visits to each colony yearly. During a first visit of 2 weeks when birds were incubating or hatching eggs, adult murres and kittiwakes would be counted on plots. On a second visit of 1 to 2 days, shortly before the first murres fledge and near the middle of the chick-rearing period for kittiwakes, chicks of both species would be counted. Productivity for both species would be expressed as chicks per adult. This method of estimating productivity was termed the "Type II method" (Piatt et al. 1988). A suggested advantage of the method was that several colonies could be monitored by the same field crew (Piatt et al. 1988).

The Type II method was tested in the field at Cape Thompson in 1988 by Fadely et al. (1989). Observers were present throughout the season, but most productivity plots were visited for only two brief periods. Adult kittiwakes and murres were censused at mid-season, and chicks were counted on the same plots just before fledging. Observations of chicks were designed both to provide a one-time count and assess the influence of several variables on accuracy of the estimate. Several additional plots were observed frequently throughout the season to obtain data on phenology. Type I estimates of productivity were calculated for all species on these plots for comparison with the Type II estimates.

In this study we carried out a limited test of the Type II method by reanalyzing data from plots that we observed by the Type I method. Our test does not simulate some of the conditions in a true Type II count, in which observers would be unfamiliar with plots and the locations of breeding sites. Nevertheless, this test complements the evaluation of Fadely et al. (1989) by providing a maximum estimate of the chicks that could be counted on each plot during one visit near fledging.

METHODS

We simulated a Type II estimate of thick-billed murre productivity using data from 12 productivity plots (Chapter 3). Common murre productivity was not reanalyzed because of small sample sizes for this species. Breeding of both black-legged and red-legged kittiwakes failed completely at St. George in 1989, so we were unable to assess kittiwake productivity using the Type II method.

We calculated the mean number of adult murres present on each of our productivity monitoring plots between 13 July and 9 August, using 5 to 9 replicate counts. Methods for population counts are given in Chapter 2, and statistical analysis is described in Chapter 3.

In order to simulate a Type II count of chicks on productivity plots, we selected data from one visit to each plot just before the first fledging of thick-billed murres was observed on 10 August. Piatt et al. (1988) recommended that the count of chicks should be timed as late as possible, but before the first fledging date. Not all of our productivity plots were visited on a single day; therefore dates for the pre-fledging chick count ranged from 7 to 9 August.

A second Type II chick count was simulated to determine how the results would be affected by timing of the visit. Fadely et al. (1988:85) found that "Chicks became more observable as they grew, and productivity estimates increased after the date of first fledging, despite the fact that some young had already left the breeding ledges." Data for the second count were selected from productivity observations made on 17 and 18 August, one week after the first fledging of thick-billed murres.

Methods for counting chicks on each visit were those used during intensive Type I observations (Chapter 2), since the "Type II" data were selected from those records. All sites where a chick was present had been mapped on large-scale photographs of each plot during the egg-laying period. Our detection of chicks was helped by use of the maps and by our prior knowledge of the location of chicks based on frequent observations since eggs were laid. Presence of chicks was determined by actually seeing the chick or by the adult bird's brooding posture (described in Chapter 2). Since some chicks were difficult to see, use of brooding posture improved the estimate of total chicks present. Type II productivity estimates were calculated as the ratio of chicks recorded on all plots during "Type II" visits to the mean number of adults counted earlier on the same plots.

RESULTS

The mean count of adult thick-billed murres on productivity plots in July and early August was 598 (Table 6.1). This was 1.8 times the number of breeding sites (sites where at least one egg was laid) recorded on the plots (Table 3.6).

The number of thick-billed murre chicks that were counted on productivity plots during the first simulated Type II count on 7-9 August was 131 (Table 6.1). At this time 80 eggs were still being incubated on the plots (the last egg was laid on 9 August; Chapter 3). The number of chicks counted during the second simulated Type II count on 17-18 August was 148. At this time 29 unhatched eggs remained on the plots, and some chicks that had been present during the first count had fledged.

The total chicks that eventually fledged on productivity plots according to our Type I observations was 171 (Table 3.6). The two Type II estimates of numbers fledging therefore were 77% and 86% of our best (Type I) estimate. The mean number of adult-plumaged thick-billed murres counted on productivity plots was 598 (Table 6.1). The Type II estimate of productivity (chicks per adult) therefore was 0.22 for the first count and 0.25 for the second count.

DISCUSSION

Should the Type II method of monitoring seabird productivity be used instead of the time-consuming Type II method? The adequacy of the Type II method needs to be assessed in terms of the goals of our monitoring program. The criterion suggested for the design of Alaskan seabird monitoring funded by Minerals Management Service, whose purpose is to identify impacts of development on seabird populations, was that a difference of 20% between colonies or years should be detectable. Less rigorous criteria suitable for some management purposes might be to collect data that would permit detection of a significant trend over 3 to 5 years, or even simply to classify productivity in a given year as reasonably good or very poor. All these criteria for monitoring share one requirement: that the index of productivity bear a predictable relationship to the "true" productivity in the colony.

Type II estimates of murre productivity, expressed as chicks per adult, are influenced by three major sources of variation. (1) Counts of birds in adult plumage may not bear a predictable relationship to the numbers of breeding birds on study plots. The proportion of breeding to nonbreeding birds on plots probably varies between years, but breeders and nonbreeders cannot be distinguished during censuses. Therefore, observed differences in Type II estimates of productivity could result either from differences in the proportion of nonbreeders or real differences in chick production. (2) Counts of chicks on productivity plots during 1 or 2 visits may not give reliable estimates of actual numbers. Some chicks may not be present on the day of the count because eggs have not yet hatched or the first young have fledged. (3) Counts of chicks also may be biased if observers fail to see chicks that are present; young birds are often hidden beneath their parents, and it is difficult to keep an accurate count of chicks that are seen only briefly.

Variation in the proportion of breeding birds to total murres censused on study plots can be examined using the "k ratio," the ratio of sites where one or more eggs were laid to the number of adult-plumaged birds (Birkhead 1978). If Type II estimates are to yield consistent indices of breeding success, the k ratio must be similar between years and colonies. However, the ratio of murres to breeding sites has not been consistent among years at Bering Sea colonies. The k-ratio for thick-billed murres on St. George Island was 0.72 in 1986, 0.78 in 1987 (Byrd 1989), and 0.55 in 1989 (this study). Reproductive success as determined by Type I methods was lower on St. George in 1989 than in 1986-1987, but the decrease was much less than would have been concluded based on counts of adults. An even larger change in k-ratios of thick-billed murre was observed at the north end of St. Matthew Island by Murphy et al. (1987). There were 0.28 breeding sites per adult in 1985 and 0.52 in 1986. Breeding success was similar in the two years (Murphy et al. 1987), but the Type II estimate 1986 would have been twice as high in 1986 as in 1985. Comparisons of Type II estimates among years at these colonies would have been very misleading.

Numbers of adults at breeding sites also differ greatly between colonies within the same year (Gaston and Nettleship 1980). K-ratios for thick-billed murres in 1986 were 0.72 for St. George Island, 0.56 for St. Paul (Byrd 1989), 0.28 for the south end of St. Matthew Island, 0.52 for the north end of St. Matthew, and 0.59 for Hall Island near St. Matthew (Murphy et al. 1987). Comparisons of Type II productivity estimates between these colonies for 1986 would have been meaningless. At colonies in some areas, k ratios have been found to change little over periods up to 3 years (Birkhead 1978, Hatch and Hatch 1989). Numbers of murres in adult plumage may be a useful basis for yearly productivity estimates at such colonies.

Counts of murres on cliffs may vary because of current conditions or the history of the colony. Attendance can decline when food is less available and birds must spend more time foraging (Gaston and Nettleship 1982). Numbers of nonbreeding birds are likely also to vary in part due to reproduction success and survival in the previous few years.

Numbers of murres used in Type II productivity estimates are intended to represent the adult population of the colony (i.e., birds capable of breeding). However, counts of murres at a colony may be quite different from numbers of breeding adults. Census results depend both on numbers actually visiting the colony in that year, and on attendance at the colony, which determines the likelihood that individuals will be counted during a census. Furthermore, some of the adult-plumaged murres at a colony are subadult birds 2 to 4 years old, most of which have never bred (Hudson 1986). There is evidence that much of the variation in numbers during censuses is due to changes in attendance by nonbreeding birds (Gatson and Nettleship 1981, Hatch and Hatch 1989). It is not possible to distinguish breeding from nonbreeding birds at a colony (Harris and Wanless 1990) or adults from subadults. Therefore census data, although valuable as an index of population numbers for analyzing trends over several years, are not a precise enough index of adult numbers for use in estimates of productivity.

Our counts of murre chicks near the date of first fledging tested one source of variation in a Type II estimate: the proportion of total fledglings that were present on the plots during a single count. Our simulated Type II counts of murre chicks on August 7-9 yielded 77% of the number that actually fledged, and 86% one week later. During the second count a larger proportion of total fledglings were recorded, even though some chicks had fledged by this time, because additional eggs had hatched since the first count. The reliability of our simulated Type II chick count on St. George appeared to be relatively good; the two estimates differed by 13%, which might be sufficiently precise for many monitoring purposes. However, we did not test a major potential bias in one-day chick counts in the field: the ability of observers to detect chicks on the plots during brief visits. Because our "Type II" counts followed an entire season's observations of each breeding site, we were confident that all chicks were recorded. But observers who visit murre productivity plots for the first time just before fledging may fail to see many chicks that are present. At any one time, most chicks are concealed by adults; they are brooded continuously until 10 days of age and intermittently thereafter (Harris and Birkhead 1986). At some Alaskan colonies a brooding parent can be identified by its posture (Chapter 2), but at other colonies this is not reliable (Fadely et al. 1989; E.C. Murphy, pers. comm.). In order to detect and count murre chicks, each productivity plot must be observed until every site has been checked for presence of a chick. On St. George we were able to detect all chicks because we had become familiar with each plot during the past 2 months, breeding sites were mapped on a photograph and numbered, and the record of recent observations indicated where chicks were likely to be. For a one-time Type II count of chicks, in contrast, observers would be unfamiliar with breeding sites, and there would be no map to help in recording chick locations.

Fadely et al. (1989) evaluated the accuracy of their Type II chick count and rejected it as unreliable. On their first count on 21 August, observers had difficulty in determining how many chicks were hidden beneath adults. Subsequent observations were made over the next week. The total estimate of chicks 5 days after the first count was 35% higher; better familiarity with the plots improved the chick counts, as did growth of the chicks. However, there was still difficulty in arriving at a total count because observers tended to lose track during each observation of chicks that had already been seen (Fadely et al. 1989:72). The Type II estimate of thick-billed murre productivity at Cape Thompson for 1988 was 0.078 chicks per adult (Fadely et al. 1989:69). The authors believed that actual productivity was much higher, based on other observations of the birds' behavior (Fadely et al. 1989:86). The Type I estimate obtained at Cape Thompson from phenology plots studied intensively throughout the season, using methods similar to our Type I procedures, was 0.47 fledglings per breeding site (Fadely et al. 1989:76). The Type II estimate of productivity obtained at Cape Thompson under actual field conditions was therefore only 16% of the Type I estimate for the same colony. The Type II estimate suggested that murres suffered very poor reproductive success at Cape Thompson in 1988, whereas to the Type I estimate, for productivity was moderately good. Fadely et al. (1989:86) concluded cautiously that "with experienced personnel, this technique may provide a suitable index for monitoring productivity." However, the authors quoted the Type I estimate of 0.47 fledglings per pair exclusively throughout the rest of the report, rather than the Type II estimate.

Type II productivity estimates of murres are influenced by variability in numbers of breeding and nonbreeding adult plumaged birds on plots, numbers of chicks present at the time of the count, and the observer's difficulty of detecting and keeping track of the closely-brooded chicks. Our simulated Type II estimate was influenced by the first two types of variability; the test conducted by Fadely et al. (1989) was influenced by all three. Type II estimates of murre productivity were unreliable when compared with Type I estimates for the same colonies, which ensured that almost all breeding sites and chicks were detected (biases are discussed in Chapter 2). We conclude that the Type II method is not suitable for estimating murre productivity, either for detection of 20% changes or for distinguishing between moderate and poor success.

There would appear to be more reliable alternatives to Type I studies of murre productivity than the Type II method. A rough "boom or bust" index to that would be useful for some purposes is simply the number of chicks, compared between years on a standard series of plots. This index would be affected by the uncertainties of chick counts, but it would not also be biased by changes in adult attendance. Chick counts near the hatching period, conducting with mapping of all sites, have been used as an index of murre productivity at Bluff (this study, Chapter 5). Counts of hatchlings would not allow intercolony comparisons of productivity, since the data would depend on plot sizes in each colony; trends could be compared, however. Another alternative to annual Type I monitoring might be to estimate productivity only once every 2 or 3 years. Productivity of murres at Alaskan colonies is relatively stable, and the value of yearly information on breeding success may sometimes be offset by the cost and effort of obtaining it at some colonies. However, it is important to begin new monitoring at any murre colony with full Type I monitoring of productivity. It is necessary to obtain reliable baseline data on productivity for future comparisons,success of murres studied at Alaskan colonies has varied two-fold (Murphy et al. 1987, Piatt et al. 1988, this study) and in a few colonies elsewhere has been as low as 0.17 chicks per site (Harris and Wanless 1990). Furthermore, correct timing of population censuses depends on determining phenology and activity patterns during initial Type I studies (Gaston and Nettleship 1980).

Kittiwake productivity could not be assessed by us because of complete breeding failure at St. George in 1989. Fadely et al. (1989) estimated chick numbers using Type II counts in late August. Productivity was expressed in terms of nests counted in July rather than of numbers of adults. Type II estimates of kittiwake productivity were not compared with Type I counts from phenology plots, but repeat counts of chicks indicated that estimates were consistent (Fadely et al. 1989: 79). Similar methods have been used elsewhere for estimating kittiwake productivity. Harris (1987) compared methods for kittiwake estimates similar to our Type I and II methods and concluded that Type II estimates were 13% high. Bias was due both to missing some nests built after the early-season visit and to overestimating the numbers of chicks that would fledge after the chick count. Harris (1987) pointed out that the bias in a Type II count might be considerably worse in a year of low productivity, when abandonment of nests and their complete disappearance may begin before the Type II nest count is made. Irons et al. (1987) used similar methods in southcentral Alaska. Type II estimates of kittiwake success appear reliable for distinguishing between good, moderate, and poor productivity, especially if numbers of nests are used in the ratio rather than adults.

Implementing a Type II method for productivity would require preliminary observations in each season to ensure that timing was accurately coordinated with phenology of the birds. Phenology of kittiwakes in western Alaska varies between years by as much as three weeks (Chapters 3, 4, and 5). Breeding is also very asynchronous in some years. It is desirable to minimize variability between Type II and Type I estimates by counting kittiwake nests within two weeks, and fledglings within one week, of the optimal (Harris 1987). Accurate timing of Type II counts (and of population counts) require being at the colony before data must be collected, or reliable correlations between breeding phenology and local meteorological data, which are not available for most colonies.

An advantage of Type I observations is information on the stage of the breeding cycle at which failure occurred, e.g. whether no eggs were laid, eggs did not hatch, or chicks died on the ledges. This can be especially important in interpretation of total breeding failure. According to Hunt et al. (1981), "Knowledge of when and why normal stress in the breeding cycle occur facilitates predictions of the effects of oil spills or other perturbations of these systems." Little information on the chronology of breeding failure can be obtained with Type II observations.

A major advantage of Type II estimates as proposed by Piatt et al. (1988) would be a reduction in the number of field crews, because one crew could move between several colonies each summer. However, rotation of a crew between several sites is not practical in western Alaska due to large distances, primitive transportation, and bad weather. Travel to St. George, Cape Peirce, Bluff, and Cape Thompson must originate in Anchorage and involves both large commercial carriers and small aircraft. Travel between any two colonies therefore requires four flights and at least two days. Delays of up to a week due to fog or high winds are common when flying to or from colonies. The only attempt to move a field crew between colonies included in this study was from St. Paul to St. George (a distance of 45 miles) in 1988. This resulted in a week's delay and loss of important data (Dragoo et al. 1989). Field crews must be at colonies in western Alaska throughout the period of data collection, and no field crew should expect to visit more than one colony in each year. The exception may be in areas where a crew could travel reliably between colonies over short distances by land or boat. Colonies around St. Matthew Island, Bluff, and Cape Peirce are in this category.

We conclude that the Type II method of estimating productivity of kittiwakes (Piatt et al. 1988) gives a reliable estimate of breeding success. However, the Type II method proposed for murres by Piatt et al. (1988) cannot be relied on to indicate productivity of a colony. The method underestimated the true productivity of murres severely, and it was rendered unreliable by several major biases. The Type II method for murres does not meet the criteria adopted by this and other studies for an index of productivity that allows statistically reliable detection of trends. Although non-intensive methods for monitoring murre productivity would be an advantage in various studies, much more work is needed to develop such methods.

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Table 6.1 Productivity estimates of thick-billed murres at St. George Island, Alaska, using the Type II method.

Plot	Adult TBMU[a]	Chicks 7-9 Aug.	Chicks 17-18 Aug.
56	52	5	8
57 + 82	63	13	16
60 + 61	85	9	17
62	48	5	12
64 + 84	59	8	7
65	53	15	20
66	46	5	0
68	26	14	13
71 + 72	50	14	15
73	27	6	8
74	51	23	15
79 + 83	38	14	17
Total	598	131	148
Chicks/Mean No. Adults		0.22	0.25

[a] Mean number of adults present. Calculated from replicate counts (n = 5-9) between 13 July and 9 August, 1989.

CHAPTER 7.

GENERAL DISCUSSION AND COMPARISON OF COLONIES

By Vivian M. Mendenhall

POPULATIONS

Black-legged kittiwake populations at our three study colonies have been stable during the past five years (Figures 3.4, 4.7, and 5.5). At Bluff there has been no significant change since 1976; numbers have also been stable since the 1960's at Cape Thompson, the other northern Alaska colony with a long baseline of data (Fadely et al. 1989). Black-legged kittiwakes at St. George, in contrast, declined from the first monitoring in 1976 through the early 1980's. Their present stability may represent equilibration of numbers at a new limit imposed by current conditions, possibly available food resources.

The black-legged kittiwake population at Cape Peirce also shows no significant trend over the last five years. This stability is difficult to explain. Productivity in the colony appears to have been consistently very poor (as discussed below), and it seems unlikely that the population is capable of maintaining its numbers. It is possible that current trends are being influenced by productivity during the early 1980's, when we have data for only 2 of 6 years. If mean productivity was higher in the early 1980's but has since declined, a downward trend in the population should become evident within the next five years, since the age of first breeding is approximately four to five years (Wooler and Coulson 1977). A second possibility is that the Cape Peirce population is being maintained by immigration from nearby colonies. Kittiwakes rarely move between colonies once they have established a breeding site (Coulson and Wooler 1985), but young birds disperse between colonies (Wooler and Coulson 1977, Coulson 1983). We have no information on the numbers of young kittiwakes produced at colonies near Cape Peirce. Kittiwake colonies in the Gulf of Alaska and Britain often fluctuate in size, and population trends and recruitment rates can vary between colonies within small areas (Coulson 1983, Irons et al. 1987). We hope to expand our analysis of kittiwake population trends at Cape Peirce by comparing present numbers with those counted in 1976 on the same plots. Continued population monitoring in future years is clearly important.

The red-legged kittiwake population on St. George is declining severely (Figure 3.4). This has serious implications for the world population, since 95% of the species breeds on St. George. The reasons for the decline are unknown; intensive work on diet is now being analyzed (D. Dragoo, pers. comm.).

Populations of common and thick-billed murres are currently stable on St. George, and common murres are stable at Bluff and Cape Peirce (Figures 3.6, 4.8, and 5.2). Murres at St. George and Bluff declined significantly in the late 1970's, however. Murres at Cape Thompson showed the same trend of a decrease until about 1979 and stable populations thereafter (Fadely et al. 1989). Two other western Alaska murre populations may have been stable or increased slightly from the 1970's to the 1980's, based on more limited monitoring data: Cape Lisburne (Springer et al. 1985b) and the Kongkok colony on St. Lawrence Island (Piatt et al. 1988). The early decline of murres at Bluff may have been due to adult mortality on the wintering grounds, possibly due to food shortage, since productivity seemed adequate to maintain the population (Murphy et al. 1986). The widespread pattern of decline in murre populations, followed by stability, suggests that populations in several areas were affected by similar factors; however, there is no clear correlation with location of the breeding colony, which is not inconsistent with winter mortality. We hope to re-analyze Cape Peirce census data for 1976 for comparison with ours.

PRODUCTIVITY

Productivity of murres at the three colonies in this study was slightly lower in 1989 than in previous years but was within the range normally observed. Productivity of kittiwakes at all three colonies was extremely low in 1989. It was also lower than usual at other Bering Sea colonies monitored in 1989: St. Paul (D. Dragoo, pers. comm.) and Nunivak Islands (B. McCaffery, pers. comm). This pattern of reproductive failure in several parts of the Bering Sea suggests that unfavorable conditions were widespread. Although we have no data on possible causes of the 1989 failure, kittiwake productivity in several areas has been shown to vary with availability of a locally preferred prey fish (e.g. Baird and Gould 1983, Springer et al. 1985a and c, Fadely et al. 1989).

The relatively long baseline of data on productivity of black-legged kittiwakes at our three study colonies (Figures 3.9, 4.9, and 5.7) allows us to place the lower success of 1989 in regional perspective. Breeding performance has been compared between colonies for past years when monitoring was conducted year at more than one place (e.g. Johnson and Baker 1985, Springer et al. 1985a, Murphy et al. 1987). For instance, black-legged kittiwakes produced poorly in 1984 at four Bering Sea colonies, and also at Bluff, St. Lawrence Island, and in the Chukchi Sea; but in 1983 at Bluff and Cape Lisburne, the only colonies studied in that year, kittiwakes did well (Johnson and Baker 1985). Such comparisons within one or two years offer tantalizing suggestions of regional patterns in reproductive success, but comparisons of longer data sets are necessary to evaluate them.

Productivity was correlated between the islands of St. George and St. Paul for both murres and kittiwakes (Byrd 1989). I compared black-legged kittiwake productivity for all available years between the three colonies in our study. There was no correlation for any pair of colonies (Table 7.1a). Hatch (1987) summarized data on breeding success of black-legged kittiwakes throughout Alaska from 1976 through 1985 and showed that, although reproductive failures frequently occur at all colonies, they tend not to coincide in the same years over large areas such as the entire Bering Sea. There are occasional years when most colonies fail (Hatch 1987), but even then a few colonies are almost always relatively successful. This lack of similarity between widely separated areas is not surprising. The oceanographic conditions in the vicinity of colonies that appear to favor nearby prey abundance vary between regions, with warm temperatures being favorable at Bluff (Murphy et al. 1986) but cool water at St. George (Lloyd 1985, Springer and Byrd 1989). Weather conditions also influence reproduction, with stormy weather reducing prey populations or feeding rates and sometimes causing direct mortality (Byrd and Tobish 1978, Hunt et al. 1981, Lloyd 1985). A bout of stormy weather reduced kittiwake productivity at the widely separated colonies of St. Matthew and Cape Peirce in 1986; however, although a severe storm reduced kittiwake productivity in the Aleutian Islands in 1976 (Byrd and Tobish 1978), success was good at St. George and Cape Peirce in the same year (Chapters 3 and 4). The relationships between weather and seabird productivity over large areas are likely to differ in many cases.

Reproductive success may be closely correlated between seabird colonies within an area. Productivity was correlated between the islands of St. George and St. Paul for both murres and kittiwakes (Byrd, 1989). These colonies are only 60 km apart, and although their seabird feeding areas differ somewhat (Schneider and Hunt 1984), variations in prey distribution may affect both similarly. Productivity is also highly correlated between Cape Thompson and Cape Lisburne, although the sample is small, and success at Bluff is correlated with that at both Cape Thompson and Cape Lisburne (Table 7.1b). Water temperatures and probably prey abundance at these three colonies are affected by the same oceanographic variables (Springer et al. 1984).

Our baseline data for kittiwakes at the three study colonies allow us to compare productivity for 1989 at each colony with historical performance there. Mean productivity over 14 years at Bluff is 0.43 (Table 7.2), and that for 11 years at St. George is 0.22. Mean productivity estimated for 11 years at Cape Peirce, however (Table 7.2) is only 0.07 young fledged per nest. (All estimates are based on total nests started each season, whether or not eggs were laid.) Differences in mean productivity between St. George and the other two colonies are significant (t tests, $p < 0.05$), and between Cape Peirce and Bluff ($p < 0.01$), are highly significant).

Productivity in 1989 at St. George and Bluff was clearly far below the inter-year means for those colonies. At Cape Peirce, however, productivity for 1989, although very low (0.06 young per nest), was only slightly below the 11-year mean, and the difference is not significant ($p > 0.10$; t-test for single observations; (Sokal and Rohlf 1981). Thus, unlike St. George and Bluff, Cape Peirce does not appear to have had worse conditions than usual in 1989.

The low productivity of kittiwakes at St. George and especially at Cape Peirce raises the question of the ability of these populations to maintain themselves. Kittiwakes in eastern Britain fledged an average of 1.2 young per nest with eggs (not per nest started, as in our study) over 17 years (Coulson and Thomas 1985). This is much higher than the mean of 0.57 young per nest with eggs at Bluff and 0.43 fledged per nest started (Chapter 5); productivity was lower yet at our other colonies. Data on adult and post-fledging survival and other demographic parameters in Alaska are needed before we can estimate the minimum average production of young needed to maintain populations. However, the Cape Peirce colony undoubtedly falls far below that value, and it seems that the population should be declining. Regular monitoring of productivity at Cape Peirce is recent, and several more years' data are needed to ensure that we are describing productivity adequately there. It is possible that nearby colonies such as those at Cape Newenham and Shaiak Island are supplying immigrants to the Cape Peirce colony; examination of kittiwake production at these colonies could shed much light on seabird population dynamics in northern Bristol Bay.

What are the reasons for the large differences in mean productivity between colonies? Definitive answers will come only with intensive study of major environmental influences on each colony, such as food, seasonal temperatures, weather, predation, and possibly disease. Food has been studied at St. George (Hunt et al. 1981; Dragoo, in prep.), seasonal temperatures at St. George and Bluff (above), and weather at St. George and Cape Peirce (Lloyd 1985). The aerial predators that are responsible for most predation on nesting kittiwakes appear have negligible impact at St. George; no ravens and few glaucous-winged gulls breed there. At Bluff, where predation by ravens and gulls appears heavy, Steel and Drury (1977) estimated that fewer than 10% of murre and kittiwake eggs may be taken by ravens; no intensive study has been done predation there, however. Predation on seabirds is also heavy at Cape Peirce (Chapter 4); however, no factors that potentially affect reproduction, other than weather, have been quantified at Cape Peirce.

Some indication of factors that affect productivity may be obtained by considering at what stage in the breeding season the success or failure of the breeding effort has the most influence on the number of young that ultimately fledge. Productivity can be divided into four components: (a) the proportion of nests in which eggs are laid, (b) clutch size, (c) hatching success of the eggs, and (d) fledging success of the young. The productivity of the population presumably is also affected by the proportion of adults that initially attempt to breed (that construct a nest), but it is not feasible to obtain data on this, since precise counts would be required both of nests and of adults that visit the colony briefly or remain at sea throughout the season.

I tested the correlation of black-legged kittiwake productivity with each of the four components for which we have data (Table 7.3). Data were used only from years in which breeding kittiwakes were observed for the full season (from nest initiation through fledging), which reduced the sample size but ensured reliable data for each component. At Bluff, productivity varied strongly with the proportion of nests in which eggs were laid, clutch size, and hatching success. For St. George there was a strong correlation of productivity with clutch size, hatching success, and fledging success. The lack of correlation at St. George with the proportion of nests that received eggs is surprising. I estimated these data for St. George

(Table 7.2, footnote), and I could not do this for the two years in which productivity was zero; however, the correlation is so low that addition of two more years probably would not render it significant.

It seems likely that at both Bluff and St. George, kittiwake productivity is usually affected by a single environmental factor (or two or more closely correlated ones). Influence of the factor probably begins some time before breeding (if condition of the females determines clutch size; Coulson and Porter 1985) and continues to affect the birds until late in the season. Several factors might operate in this way, but the most likely one would seem to be food availability. Reproductive failure has been observed in various years at all stages of the season (Chapters 3 and 5), but there is a tendency for consistent effects throughout the season.

At Cape Peirce, in contrast, productivity was not significantly correlated with any component of reproduction. Apparently, whatever limits reproductive success at Cape Peirce affects the birds at various stages of the season in different years. There may be two or more important but unrelated factors. The mean values for reproductive components at Cape Peirce suggest this also (Table 7.2). Mean nest occupancy, clutch size, and hatching success are no lower than at other colonies, although clutch size was reduced at Cape Peirce in 1989. This suggests that poor availability of food early in the season affected Cape Peirce kittiwakes in 1989 (the late initiation of breeding is also evidence of an early food shortage), but that food limitation is not the cause of low productivity at Cape Peirce in most years. Mean fledging success is much lower than at the other colonies, however. Factors which might affect chick survival but not earlier success include late-summer weather, predation, and possibly unpredictable food in late summer only. Gulls have been observed to prey on chicks at Cape Peirce (Chapter 4). Breeding studies of kittiwakes at Cape Peirce should include efforts to quantify predation pressure and other possible causes of chick mortality.

Mean productivity of common murres was similar among our three colonies (Table 7.4). There was no significant difference in productivity among the three places (Kruskal-Wallis test, $p > 0.10$). At least one additional year of data is needed for Cape Peirce to ensure that our estimate represents productivity there accurately.

Trends in murre productivity cannot be compared between colonies in our study because only at St. George do we have adequate data for analysis of trends. At Bluff we have data for 3 years, and at Cape Peirce 2 years, in which productivity was estimated by methods comparable to ours (mapping of breeding sites and records on hatching and fledging success for each site). Standardized methods were not adopted earlier at these sites because trained personnel were not available earlier for full field seasons. A longer series of data at Bluff and Cape Peirce would allow us to analyze trends in murre productivity there in the future.

RECOMMENDATIONS

Our monitoring program is adequate at present for assessing impacts of oil and gas development or other human-caused problems on some of the seabird populations we are studying. We have an excellent baseline against which to evaluate possible impacts on both productivity and populations of all four species we studied on St. George, on productivity and populations of kittiwakes at Bluff, and on murre populations at Bluff. Our baseline of regularly collected, reliable data on murre and kittiwake populations at Cape Peirce seems sufficient for evaluating short-term impacts (those that might cause a marked decline in one year), but we do not have a long enough database to evaluate impacts causing a gradual decline over several years.

Our data on productivity of murres at Bluff and on murres and kittiwakes at Cape Peirce have been collected over too short a time to permit any evaluation of impacts yet, and these baselines should be extended for several consecutive years. A baseline of 3 to 5 consecutive years' data is needed for populations or productivity of a seabird species at an Alaskan colony in order to estimate a mean and confidence interval. A series of data 3 to 10 years long is probably needed to detect any underlying trend, depending on variability among years. Our ability to compare trends between colonies and to monitor for possible impacts of future threats will be improved with the addition of 2 to 3 additional years' baseline data at these colonies. Black-legged kittiwakes at Cape Peirce and red-legged kittiwakes at St. George need careful monitoring because of apparent threats to their health.

Monitoring of productivity by the "Type I" method used in this study is time-consuming. An abbreviated procedure for determining numbers of kittiwakes fledged per nest, as proposed by Piatt et al. (1988) and others, would give a satisfactory estimate of productivity for many purposes, although no data would be obtained on the chronology of breeding failures. However, there is no reliable substitute at present for the "Type I" method of estimating the productivity of murres from the initiation of breeding through fledging. Further work is needed to explore ways of estimating murre productivity.

The differences in population trends and productivity demonstrated for the colonies in this study show the importance of identifying the characteristic population trends and reproductive behavior at each colony before monitoring can be relied upon for impact assessment. For instance, a season in which reproduction was average or better through hatching but in which fledging success was very low would not be unusual at Cape Peirce but might suggest that abnormal conditions should be considered at Bluff or St. George. A significant drop in a population that was not previously declining, especially if successful reproduction suggests that a large proportion of the population should have been at the breeding colony, could indicate unusually high adult mortality.

The utility of monitoring populations and productivity for assessing effects of development would be improved if monitoring were expanded to include data on food habits, sea-surface temperature, and possibly chick growth. At colonies where productivity, particularly of kittiwakes, is found to vary with food availability and/or water temperatures, these parameters could then be used in the future to help assess whether breeding failure in a given year was due to natural causes or to human interference. Where factors other than food may contribute significantly to limiting reproductive success, as seems possible at Cape Peirce, these also should be studied and then monitored yearly.

Evaluation of industrial impacts on seabird populations should include the ability to identify critical feeding areas near the colony. Offshore studies should continue to be conducted in conjunction with colony monitoring for one or more years at each site (e.g. Piatt et al. 1988, Fadely et al. 1989). Data should be collected on seabird distributions, and also on diets, oceanographic variables, and prey stock, to allow prediction of seabird distributions in the future.

How frequently do we need to monitor seabird colonies in order to be confident that we can detect impacts of development? Our analyses of changes in populations and especially of productivity have emphasized the need for regular monitoring. Monitoring studies that are repeated only once every few years make analysis of baseline trends uncertain at best, as for productivity of kittiwakes at Cape Peirce (this study) and for murre populations at St. Lawrence Island (Piatt et al. 1988). Baseline studies must be conducted yearly until we have an adequate sample of years with both successful and unsuccessful reproduction (Murphy et al. 1987) and until population trends are clear. Factors that could help predict reproductive success under natural conditions should also be established (above). Thereafter, monitoring every two or possibly every three years may be sufficient, at least at colonies with stable populations. Monitoring at irregular or lengthy intervals destroys the value of the baseline, however. Valuable data can of course be obtained from studies that last only a few years, as for analysis of ecosystems and for the preparation of environmental impact statements. In a program that is to be considered population monitoring, however, an adequate baseline must be collected and maintained.

Is our selection of sites and species appropriate for a coordinated monitoring program? It is feasible to monitor only a few sites in western Alaska because of the area's remoteness and the expense of travel in the field, so colonies must be carefully selected. One colony should be chosen from several within the same area whose productviity and population trends are correlated; our selection mets this criterion. Widely separated colonies and differing ecological areas should be represented; we have not yet achieved this objective. The area of monitoring should be extended to include the Chukchi Sea. Cape Thompson offers the best chance of obtaining data on population and productivity of both murres and kittiwakes, and a reasonably good baseline of data has been established there. A second major gap in our program is the absence of a monitoring site in the Bering Straits area and lack of data on the planktivorous seabirds that dominate that ecosystem. Monitoring techniques should be developed for auklets (_Aethia_ spp.), probably by building on the techniques explored by Piatt et al. (1988). Equal priority should, however, be given to maintaining monitoring at the three existing sites, where known or threatened hazards of oil spills and disturbance may need to be assessed in the foreseeable future. Continued consistent monitoring at these sites will also permit us to expand the comparisons of trends in productivity and populations within regions of the Bering and Chukchi Seas, which will add to our understanding of those ecosystems and our ability to evaluate changes in them.

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Table 7.1 Spearman rank correlation coefficients for black-legged kittiwake productivity at colonies in the Bering and Chukchi Seas. Data in parentheses are numbers of years for which estimates are available for both colonies in pair.

a. Colonies in this study.

	Cape Peirce	Bluff
St. George	0.47 (8)	0.02 (13)
Cape Peirce		-0.09 (8)

b. Bluff and other colonies in the northern Bering and Chukchi Seas. Data for Cape Thompson and Cape Lisburne from Hatch (1987).

	Cape Thompson	Cape Lisburne
Bluff	0.93*** (10)	0.98*** (5)
Cape Thompson		0.98* (4)

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 7.2. Productivity and components of productivity for black-legged kittiwakes at colonies monitored in 1989. Data are mean for all years, standard deviation, range, and number of years. Data were used only from years in which productivity was studied using the same methods as in 1989.

Colony	Nests with eggs	Clutch size	Hatching success	Fledging success	Productivity
St. George[1]	0.51[2]	1.34	0.46	0.43	0.22
	±0.069	±0.18	±0.32	±0.34	±0.20
	0.38 - 0.56	1.04 - 1.46	0 - 0.84	0 - 0.85	0 - 0.62
	(8)	(10)	(8)	(8)	(14)
Cape Peirce[3]	0.46	1.44	0.52	0.20	0.07
	±0.15	±0.19	±0.097	±0.16	±0.072
	0.28 - 0.68	1.17 - 1.68	0.42 - 0.64	0 - 0.39	0 - 0.16
	(6)	(5)	(5)	(5)	(11)
Bluff[4]	0.62	1.35	0.41[5]	0.57[6]	0.43
	±0.29	±0.28	±0.32	±0.24	±0.37
	0.32 - 0.91	1.00 - 1.70	0 - 0.75	0 - 0.82	0 - 1.07
	(6)	(12)	(11)	(10)	(14)

[1] Data from Table 3.8.

[2] Nests with eggs estimated from data in Table 3.8, as (productivity) divided by (reproductive success times clutch size).

[3] Data from Table 4.9.

[4] Data calculated from Table 5.12.

[5] Where range given in Table 5.12 for numbers of eggs hatched, minimum value used in ratio of eggs hatched/eggs laid.

[6] Where range given in Table 5.12 for numbers of eggs hatched, maximum value used in ratio of chicks fledged/eggs hatched.

Table 7.3 Correlations of productivity with its components for black-legged kittiwakes at colonies monitored in 1989. Data are Spearman rank correlation coefficients and sample sizes. Sources of data as in Table 7.2.

	Nests with eggs	Clutch size	Hatching success	Fledging success
St. George	0.07 (8)	0.70*[1] (10)	0.85** (8)	0.81* (8)
Cape Peirce	0.30 (6)	0.31 (5)	0.51 (5)	0.77 (5)
Bluff	0.85* (6)	0.94* (6)	0.97* (6)	0.37 (6)

[1]* $p<0.05$; ** $p<0.01$.

Table 7.4. Productivity and components of productivity for common murres at colonies monitored in 1989. Conventions as in Table 7.2.

Colony	Hatching success	Fledging success	Productivity[1]
St. George[2]	0.75 ±0.09 0.57 - 0.83 (7)	0.77 ±0.20 0.37 - 0.94 (7)	0.60 ±0.19 0.30 - 0.76 (7)
Cape Peirce[3]	0.60 ±0.12 0.51 - 0.69 (2)	0.89 ±0.064 0.84 - 0.93 (2)	0.53 ±0.078 0.47 - 0.58 (2)
Bluff[4]	0.55 ±0.051 0.48 - 0.59 (3)	0.89 0.073 0.81 - 0.95 (3)	0.60 ±0.10 0.48 - 0.67 (3)

[1] Productivity = chicks fledged/breeding sites where at least one egg laid.
[2] Data from Table 3.9.
[3] Data from Table 4.10.
[4] Data from Table 5.8. Hatching success and fledging success recalculated for all eggs (first eggs and replacement eggs pooled).

APPENDICES

Table A1. Summary of black-legged kittiwake population counts at plots in 1989 at St. George Island, Alaska.

	Replicate Number[a]						
Plot #	1	2	3	4	5	6	Nests[b]
01A	6	8	4	2	8	--	3
01B	0	0	7	0	2	--	0
02	1	0	0	0	0	--	0
*03FL	0	0	1	0	0	--	0
*03FU	13	12	28	7	12	--	7
*03N	0	0	0	2	0	--	0
*04L	0	0	0	0	0	--	0
*05	3	2	1	1	3	--	2
*06A	5	4	6	3	6	--	3
*06B	0	0	0	0	0	--	0
*07	6	2	1	0	5	--	2
08	3	3	3	5	0	--	1
09	6	11	0	6	6	--	6
10	3	0	1	2	0	--	2
11	3	2	0	0	2	--	1
12	2	1	0	2	2	--	0
*13N	0	0	0	0	0	--	0
13O	0	1	1	2	1	--	1
14	1	2	0	0	0	--	0
15	0	1	0	0	0	--	1
16	6	3	1	2	0	--	2
17	3	3	0	0	2	--	1
18	0	0	0	0	0	--	0
19	5	6	3	10	8	--	5
20	1	0	0	0	0	--	0
21	0	1	1	1	1	0	1
22	0	0	0	0	0	0	0
23	2	2	2	3	5	1	1
24M	0	0	0	--	--	--	0
24T	21	11	14	--	--	--	5
25	15	10	7	--	--	--	7
26	0	0	2	--	--	--	0
27B	3	0	1	--	--	--	0
27T	17	21	16	--	--	--	3
28L	12	16	20	--	--	--	2
28M	6	2	4	--	--	--	1
29	3	8	8	--	--	--	2
30L	0	0	0	--	--	--	0
30R	11	8	4	--	--	--	5
31	3	1	1	--	--	--	0
32B	3	11	2	--	--	--	0
32T	7	3	1	--	--	--	1
33A	2	0	1	--	--	--	0
33B	10	2	2	--	--	--	2

Table A1. Black-legged kittiwakes at St. George in 1989 (continued).

Plot #	Replicate Number[a] 1	2	3	4	5	6	Nests[b]
33C	0	0	0	--	--	--	0
33D	5	0	0	--	--	--	0
34	1	0	1	--	--	--	0
35B	6	5	4	--	--	--	0
35T	14	6	11	--	--	--	3
36	1	0	4	--	--	--	0
37B	6	1	9	--	--	--	2
37T	3	0	8	--	--	--	2
38B	5	3	3	--	--	--	2
38M	2	0	1	--	--	--	0
38T	3	2	0	--	--	--	0
39	40	32	44	22	38	--	20
40	10	3	--	--	--	--	4
41B	25	23	--	--	--	--	14
41T	7	3	--	--	--	--	4
42	0	0	--	--	--	--	0
43	0	0	--	--	--	--	0
44	13	16	--	--	--	--	5
45	14	11	18	19	11	14	10
46	24	23	33	40	20	24	11
47	11	7	9	10	20	5	4
48	5	5	6	7	8	5	1
49	4	1	3	2	1	5	1
50	0	0	0	0	1	0	0
51	23	24	16	20	17	21	7
52	43	44	39	59	32	32	8
53	83	102	152	127	70	100	58
54A	0	8	--	--	--	--	0
54B	0	5	--	--	--	--	0
54C	0	12	--	--	--	--	0
55	8	5	--	--	--	--	2
*58	131	263	195	210	314	205	150
*59A	1	1	0	0	0	0	0
*59B	24	20	14	16	24	9	7
*59C	66	69	64	51	83	52	33
*59D	70	59	67	66	59	56	30
75	17	15	17	15	9	--	10
*81A	49	71	58	89	53	48	33
*81B	5	22	32	18	14	7	14
*81C	12	20	18	20	17	14	16
*81D	44	68	75	63	16	52	40

[a]The number of times each plot was counted varied.
[b]Best estimate of the number of nests present on the plot.
*Plots not used in calculations of values used in inter-year comparisons.

Table A2. Summary of red-legged kittiwake population counts at plots in 1989 at St. George Island, Alaska.

	Replicate Number[a]						
Plot #	1	2	3	4	5	6	Nests[b]
01A	30	35	20	14	44	--	10
01B	33	20	34	13	32	--	7
02	13	21	11	14	12	--	3
*03FL	34	25	27	41	37	--	20
*03FU	51	28	6	48	53	--	23
*03N	2	2	1	0	1	--	1
*04	47	28	35	37	39	--	9
*05	0	0	0	0	0	--	0
*06A	0	2	0	1	2	--	1
*06B	0	0	0	0	0	--	0
*07	8	12	6	8	5	--	2
08	1	2	2	3	0	--	1
09	3	4	0	4	6	--	2
10	4	3	2	0	0	--	2
11	0	0	0	0	0	--	0
12	0	0	0	0	0	--	0
*13N	0	0	0	0	0	--	0
13O	0	0	0	0	0	--	0
14	0	0	0	1	0	--	0
15	2	1	2	2	4	--	1
16	1	0	1	0	0	--	0
17	0	0	0	2	2	--	0
18	0	0	0	0	0	--	0
19	0	0	2	0	7	--	0
20	0	0	0	0	4	--	0
21	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0
23	16	4	23	12	12	4	3
24M	0	0	1	--	--	--	0
24T	1	0	2	--	--	--	0
25	0	0	2	--	--	--	0
26	0	0	0	--	--	--	0
27B	16	1	8	--	--	--	3
27T	42	16	30	--	--	--	8
28L	7	3	5	--	--	--	1
28M	0	3	0	--	--	--	1
29	1	1	1	--	--	--	0
30L	0	0	0	--	--	--	0
30R	12	6	15	--	--	--	4
31	0	0	0	--	--	--	0
32B	10	5	10	--	--	--	2
32T	0	0	0	--	--	--	0
33A	173	57	92	--	--	--	21
33B	22	9	12	--	--	--	2

Table A2. Red-legged kittiwakes at St. George in 1989 (continued).

	Replicate Number[a]						
Plot #	1	2	3	4	5	6	Nests[b]
33C	0	0	0	--	--	--	0
33D	75	57	92	--	--	--	14
34	34	19	24	--	--	--	9
35B	7	5	8	--	--	--	1
35T	1	2	3	--	--	--	1
36	1	1	2	--	--	--	0
37B	9	5	5	--	--	--	3
37T	9	8	11	--	--	--	4
38B	1	1	1	--	--	--	0
38M	25	19	16	--	--	--	6
38T	56	28	44	--	--	--	9
39	42	45	27	42	43	--	22
40	105	71	--	--	--	--	41
41B	147	130	--	--	--	--	62
41T	99	124	--	--	--	--	58
42	46	109	--	--	--	--	52
43	375	296	--	--	--	--	192
44	373	202	--	--	--	--	189
45	7	8	16	8	10	3	4
46	0	1	3	1	3	0	0
47	12	13	15	9	5	10	6
48	0	1	1	1	0	0	0
49	0	0	0	0	0	0	0
50	2	0	2	1	0	0	0
51	11	7	9	8	12	10	3
52	8	8	12	4	13	14	0
53	44	58	95	58	71	85	31
54A	23	34	--	--	--	--	13
54B	25	51	--	--	--	--	15
54C	38	76	--	--	--	--	24
55	152	192	--	--	--	--	49
*58	10	70	93	69	67	52	8
*59A	1	1	0	0	0	1	1
*59B	1	0	2	1	0	1	0
*59C	21	15	18	16	17	20	9
*59D	48	44	68	65	73	65	19
75	2	1	7	13	18	--	0
*81A	9	0	33	29	36	25	10
*81B	7	14	18	29	32	5	6
*81C	2	5	11	6	3	2	0
*81D	15	37	78	104	70	120	19

[a]The number of times each plot was counted varied.
[b]Best estimate of the number of nests present on the plot.
*Plots not used in calculations of values used in inter-year comparisons.

Table A3. Summary of common murre population counts at plots in 1989 at St. George Island, Alaska.

	Replicate Number[a]					
Plot #	1	2	3	4	5	6
01A	0	0	0	0	0	--
01B	0	0	0	0	0	--
02	67	67	69	66	82	--
*03FL	0	0	0	0	0	--
*03FU	78	73	98	47	63	--
*03N	455	434	452	467	453	--
*04L	0	0	1	0	1	--
*04U	0	0	0	0	0	--
*05	0	0	0	0	0	--
*06A	0	0	0	0	0	--
*06B	19	17	8	32	14	--
*07	4	4	10	0	5	--
08	3	0	5	14	8	--
09	41	21	39	16	22	--
10	8	7	6	12	2	--
11	51	79	105	57	64	--
12	26	10	6	32	6	--
*13N	0	0	2	0	1	--
13O	6	1	1	4	0	--
14	7	0	9	0	7	--
15	0	0	0	0	0	--
16	7	12	10	11	16	--
17	1	0	0	0	0	--
18	0	0	0	0	2	--
19	16	10	59	5	5	--
20	0	0	0	0	6	--
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	1	2	1	1	0
24M	6	32	9	--	--	--
24T	88	102	116	--	--	--
25	93	113	109	--	--	--
26	597	605	776	--	--	--
27B	7	1	0	--	--	--
27T	31	20	10	--	--	--
28L	13	16	77	--	--	--
28M	46	46	65	--	--	--
29	23	47	35	--	--	--
30L	43	58	67	--	--	--
30R	82	66	88	--	--	--
31	28	30	33	--	--	--
32B	0	0	0	--	--	--
32T	83	29	105	--	--	--
33A	14	0	34	--	--	--
33B	0	0	1	--	--	--

Table A3. Common murres at St. George in 1989 (continued).

Plot #	Replicate Number[a] 1	2	3	4	5	6
33C	0	0	0	--	--	--
33D	0	0	0	--	--	--
34	0	0	0	--	--	--
35B	17	32	0	--	--	--
35T	43	0	0	--	--	--
36	13	10	12	--	--	--
37B	10	15	14	--	--	--
37T	0	6	6	--	--	--
38B	16	18	31	--	--	--
38M	25	19	21	--	--	--
38T	0	3	0	--	--	--
39	129	109	147	141	163	--
40	0	0	--	--	--	--
*41B	4	0	--	--	--	--
*41T	250	389	--	--	--	--
42A	0	0	--	--	--	--
42B	7	2	--	--	--	--
43	0	0	--	--	--	--
44	0	0	--	--	--	--
45	0	1	0	1	0	2
46	21	2	4	11	0	0
47	6	11	6	0	4	9
48	0	0	0	0	0	0
49	0	0	0	0	0	0
50	0	0	0	0	0	0
51	0	0	0	0	0	0
52	0	0	0	0	1	0
53	9	9	11	12	9	13
54A	0	0	--	--	--	--
54B	0	0	--	--	--	--
54C	0	0	--	--	--	--
*55	149	152	--	--	--	--
*58	77	47	67	61	43	82
*59A	40	35	36	46	55	45
*59B	42	35	37	52	44	42
*59C	7	10	12	8	13	7
*59D	84	35	56	61	51	42
75	24	23	7	27	22	--
*81A	0	0	0	0	0	0
*81B	21	21	5	38	55	36
*81C	13	15	19	19	18	16
*81D	71	72	57	76	55	60

[a]The number of times each plot was counted varied.
*Plots not used in calculations of values used in inter-year comparisons.

Table A4. Summary of thick-billed murre population counts at plots in 1989 at St. George Island, Alaska.

Plot #	Replicate Number[a]					
	1	2	3	4	5	6
01A	88	84	54	70	91	--
01B	162	153	156	144	163	--
02	318	309	313	327	364	--
*03FL	233	319	314	338	362	--
*03FU	592	571	474	623	560	--
*03N	570	643	566	551	501	--
*04	140	198	217	178	187	--
*05	182	158	158	98	198	--
*06A	176	149	197	153	161	--
*06B	112	99	91	67	96	--
*07	234	259	298	276	289	--
08	237	135	215	180	129	--
09	189	375	322	326	375	--
10	265	264	301	151	134	--
11	50	109	57	63	95	--
12	256	113	104	202	70	--
*13N	184	177	127	153	161	--
13O	93	140	112	76	68	--
14	110	142	122	110	121	--
15	131	100	59	62	78	--
16	129	140	138	127	61	--
17	155	159	29	67	124	--
18	94	91	73	63	74	--
19	180	171	92	127	156	--
20	85	75	61	42	66	--
21	126	96	80	75	93	118
22	164	111	148	100	123	167
23	287	184	276	217	239	374
24M	589	290	567	--	--	--
24T	572	590	607	--	--	--
25	463	516	569	--	--	--
26	191	237	187	--	--	--
27B	414	317	468	--	--	--
27T	513	465	594	--	--	--
28L	585	307	521	--	--	--
28M	213	169	258	--	--	--
29	636	550	653	--	--	--
30L	414	272	327	--	--	--
30R	348	204	357	--	--	--
31	186	131	121	--	--	--
32B	172	169	101	--	--	--
32T	202	134	148	--	--	--
33A	487	254	448	--	--	--
33B	413	290	319	--	--	--

Table A4. Thick-billed murres at St. George in 1989 (continued).

	Replicate Number[a]					
Plot #	1	2	3	4	5	6
33C	213	232	279	--	--	--
33D	110	158	111	--	--	--
34	74	46	58	--	--	--
35B	205	227	125	--	--	--
35T	70	111	87	--	--	--
36	88	164	164	--	--	--
37B	166	129	140	--	--	--
37T	191	139	178	--	--	--
38B	252	386	371	--	--	--
38M	412	407	408	--	--	--
38T	217	121	136	--	--	--
39	351	394	359	350	481	--
40	55	142	--	--	--	--
41B	530	609	--	--	--	--
41T	754	1248	--	--	--	--
42	47	55	--	--	--	--
43	146	137	--	--	--	--
44	273	191	--	--	--	--
45	96	160	170	178	87	190
46	22	69	75	180	27	78
47	93	117	138	121	109	98
48	19	105	147	158	78	68
49	27	25	24	19	14	25
50	42	55	44	49	37	38
51	72	72	78	74	59	66
52	73	57	54	56	49	68
53	167	304	259	236	185	272
54A	16	11	--	--	--	--
54B	79	66	--	--	--	--
54C	76	83	--	--	--	--
55	327	475	--	--	--	--
*58	705	355	651	459	418	624
*59A	228	169	206	200	161	115
*59B	446	210	306	224	283	231
*59C	488	367	344	288	277	333
*59D	571	330	479	303	235	220
*81A	184	74	115	92	63	92
*81B	310	145	175	143	158	253
*81C	195	201	171	183	169	199
*81D	318	212	241	291	296	237

[a]The number of times each plot was counted varied.
*Plots not used in calculations of values used in inter-year comparisons.

Table B.1. Population counts of nesting seabirds at Cape Peirce, 1989: plots used for comparison with other years (1985-1988). Plot 39. BLKI = black-legged kittiwake, COMU = Common murre, PECO = pelagic cormorant, HOPU = horned puffin, TUPU = tufted puffin. Data for kittiwakes and cormorants are (numbers of nests/numbers of birds).

		Species				
Date	Time	BLKI	COMU	PECO	HOPU	TUPU
Jul 7	1124	24/23	0	4/4	1	0
Jul 9	1302	23/19	0	4/5	0	0
Jul 17	1021	23/22	12	4/3	2	0
Jul 20	1032	23/20	3	4/1	0	0
Jul 22	1216	22/21	0	4/1	0	0
Jul 24	1107	22/26	4	4/4	0	0
Jul 27	1146	22/25	11	4/3	0	0
Jul 31	1259	22/17	13	4/0	0	0

Table B.1., continued. Plot 19-1.

Date	Time	BLKI	COMU	PECO	HOPU	TUPU
				Species		
Jul 7	1408	26/15	8	0	0	0
Jul 9	1438	27/19	2	0	0	0
Jul 17	1225	28/24	5	0	0	0
Jul 20	1143	28/ 7	4	0	0	0
Jul 22	1340	26/ 8	1	0	0	0
Jul 24	1225	26/21	6	0	0	0
Jul 27	1315	26/23	0	0	0	0
Jul 31	1426	26/11	5	0	0	0

Table B.1., continued. Plot 19-2.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1337	73/ 70	93	1/1	2	1
Jul 9	1420	75/ 73	68	1/3	0	2
Jul 17	1151	86/106	100	1/1	0	2
Jul 20	1151	80/ 64	40	1/1	0	0
Jul 22	1347	62/ 62	57	1/1	0	2
Jul 24	1235	71/ 76	72	1/1	0	2
Jul 27	1327	68/ 71	51	1/2	0	0
Jul 31	1435	80/ 75	70	1/1	0	1

Table B.1., continued. Plot 19-3.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1345	0	210	0	2	0
Jul 9	1427	0	148	0	3	2
Jul 17	1201	0	209	0	3	0
Jul 20	1154	0	105	0	0	0
Jul 22	1355	0	155	0	1	0
Jul 24	1241	0	184	0	1	0
Jul 27	1332	0	110	0	0	0
Jul 31	1441	0	147	0	1	0

Table B.1, continued. Plot 19-4.

Date	Time	BLKI	COMU	PECO	HOPU	TUPU
Jul 7	1351	21/16	1	1/2	0	0
Jul 9	1432	18/18	0	1/0	0	0
Jul 17	1207	22/33	0	1/1	0	0
Jul 20	1156	20/ 8	0	1/1	0	0
Jul 22	1400	16/10	0	1/1	0	0
Jul 24	1245	14/13	0	1/1	0	0
Jul 27	1336	21/20	0	1/1	0	0
Jul 31	1444	15/16	0	1/1	0	0

Table B.1., continued. Plot 20-2.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1630	0	0	0	0	0
Jul 9	1615	0	0	0	0	0
Jul 17	1432	0	0	0	0	0
Jul 20	1322	0	0	0	0	0
Jul 22	1633	0	0	0	0	0
Jul 24	1522	0	0	0	0	0
Jul 27	1549	0	0	0	0	0
Jul 31	1707	0	0	0	0	0

Table B.1., continued. Plot 20-3.

Date	Time	Species				
		BLKI	COMU	PECO	HOPU	TUPU
Jul 7	1633	116/118	220	9/13	0	0
Jul 9	1634	113/113	192	10/12	0	0
Jul 17	1432	125/135	249	7/11	0	1
Jul 20	1341	112/104	204	7/ 9	0	0
Jul 22	1650	121/121	210	7/13	0	0
Jul 24	1523	107/104	229	7/ 8	0	1
Jul 27	1552	105/99	165	7/ 9	0	0
Jul 31	1707	124/107	239	7/ 8	0	0

Table B.1., continued. Plot 20-4a.

Date	Time	BLKI	COMU	PECO	HOPU	TUPU
				Species		
Jul 7	1651	243/295	940	10/11	1	0
Jul 9	1645	229/272	820	10/ 9	0	0
Jul 17	1454	212/248	915	10/ 6	0	0
Jul 20	1349	206/210	880	10/ 4	0	0
Jul 22	1701	202/204	835	10/ 8	0	0
Jul 24	1535	179/169	800	10/ 6	1	0
Jul 27	1605	186/167	605	10/ 4	0	0
Jul 31	1736	217/238	880	10/ 5	0	0

Table B.1., continued. Plot 20-4b.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1718	156/212	218	5/5	1	0
Jul 9	1714	133/166	223	5/6	0	0
Jul 17	1522	128/150	248	5/5	0	0
Jul 20	1406	122/115	172	5/6	0	0
Jul 22	1720	123/143	240	5/6	0	0
Jul 24	1553	119/112	233	5/6	1	0
Jul 27	1624	118/106	162	5/4	0	0
Jul 31	1804	159/165	210	5/5	0	0

Table B.1., continued. Plot 20-4c.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1750	88/107	313	6/5	0	0
Jul 9	1723	84/ 92	235	6/5	0	0
Jul 17	1534	75/ 92	275	6/5	0	0
Jul 20	1414	71/ 69	325	6/5	0	0
Jul 22	1729	76/ 80	338	6/4	0	0
Jul 24	1600	68/ 63	295	6/4	0	0
Jul 27	1637	69/ 57	241	6/3	0	0
Jul 31	1812	92/ 89	330	6/7	0	0

Table B.1., continued. Plot 20-5.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1759	114/131	313	0/0	0	0
Jul 9	1730	95/112	278	0/0	0	2
Jul 17	1543	96/109	318	0/0	0	0
Jul 20	1423	96/ 89	291	0/0	0	0
Jul 22	1736	97/90	310	0/1	1	4
Jul 24	1609	89/79	328	0/0	0	0
Jul 27	1650	88/75	268	0/0	0	0
Jul 31	1821	93/92	278	0/0	1	2

Table B.1., continued. Plot 21.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1259	5/ 0	16	1/2	5	0
Jul 9	1346	5/ 1	35	1/1	0	1
Jul 17	1115	11/19	40	1/4	1	2
Jul 20	1118	9/ 2	32	1/1	0	0
Jul 22	1304	8/ 1	25	1/2	1	0
Jul 24	1157	9/ 5	50	1/1	0	0
Jul 27	1245	9/ 6	8	1/2	0	0
Jul 31	1355	8/ 9	18	1/1	0	0

Table B.1., continued. Plot 22.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1203	25/28	38	4/3	2	0
Jul 9	1321	34/26	42	4/4	2	0
Jul 17	1040	39/60	66	3/3	2	0
Jul 20	1051	30/17	45	3/3	0	0
Jul 22	1234	25/28	21	3/3	2	0
Jul 24	1133	28/55	63	3/3	2	0
Jul 27	1215	32/44	12	3/3	0	0
Jul 31	1322	36/37	43	3/3	0	0

Table B.1., continued. Plot 23.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1154	13/ 7	41	0	1	0
Jul 9	1314	13/ 2	19	0	0	0
Jul 17	1029	13/15	35	0	0	2
Jul 20	1044	9/ 0	24	0	2	1
Jul 22	1228	9/11	41	0	0	0
Jul 24	1126	11/13	40	0	0	0
Jul 27	1203	14/17	14	0	0	0
Jul 31	1314	14/ 3	35	0	0	0

Table B.1., continued. Plot 24.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1158	0/0	0	1/1	0	0
Jul 9	1314	0/0	0	1/2	0	0
Jul 17	1029	0/0	0	1/2	0	0
Jul 20	1047	0/0	0	1/1	0	0
Jul 22	1230	0/0	0	1/1	0	0
Jul 24	1128	0/0	0	1/1	0	0
Jul 27	1206	0/0	0	1/1	0	0
Jul 31	1316	0/0	0	1/1	0	0

Table B.1., continued. Plot 25.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1151	0	0	0	0	0
Jul 9	1312	0	0	0	0	0
Jul 17	1027	0	0	0	0	0
Jul 20	1042	0	0	0	0	0
Jul 22	1226	0	0	0	0	0
Jul 24	1115	0	0	0	0	0
Jul 27	1200	0	0	0	0	0
Jul 31	1310	0	0	0	4	0

Table B.1., continued. Plot 26.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1148	18/14	0	0	0	0
Jul 9	1310	18/12	0	0	0	0
Jul 17	1025	15/17	0	0	0	0
Jul 20	1040	15/ 8	0	0	0	0
Jul 22	1224	13/10	0	0	0	0
Jul 24	1113	13/20	0	0	0	0
Jul 27	1158	13/ 9	0	0	0	0
Jul 31	1307	13/13	0	0	0	0

Table B.1., continued. Plot 28.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1224	3/0	17	0	0	0
Jul 9	1331	3/0	4	0	0	0
Jul 17	1053	3/2	20	0	0	0
Jul 20	1109	1/1	10	0	0	0
Jul 22	1251	1/0	17	0	0	0
Jul 24	1142	1/2	17	0	0	0
Jul 27	1226	0/0	0	0	0	0
Jul 31	1336	0/1	12	0	0	0

Table B.1., continued. Plot 31.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1552	113/119	221	0	0	0
Jul 9	1548	114/108	183	0	0	0
Jul 17	1404	138/141	243	0	3	0
Jul 20	1308	120/ 96	203	0	1	0
Jul 22	1557	112/105	205	0	1	0
Jul 24	1427	100/ 84	222	0	0	0
Jul 27	1441	113/110	183	0	0	0
Jul 31	1624	127/112	240	0	2	0

Table B.1., continued. Plot 40.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1252	12/ 6	59	0	2	0
Jul 9	1350	11/ 1	43	0	1	1
Jul 17	1122	14/12	61	0	0	2
Jul 20	1124	9/ 0	43	0	0	0
Jul 22	1312	14/ 3	44	0	0	3
Jul 24	1204	10/ 8	58	0	0	0
Jul 27	1248	16/17	30	0	0	0
Jul 31	1401	14/ 1	52	0	1	2

Table B.1., continued. Plot 43.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1512	73/55	44	0	0	0
Jul 9	1520	65/50	57	0	0	0
Jul 17	1328	73/66	73	0	0	0
Jul 20	1234	68/46	63	0	1	0
Jul 22	1523	67/49	52	0	0	0
Jul 24	1359	70/52	65	1	0	0
Jul 27	1416	73/57	55	0	0	0
Jul 31	1543	78/57	65	0	0	0

Table B.2. Population counts of nesting seabirds at Cape Peirce, 1989: plots not used for comparison with other years (not counted in all years, 1985-1989). Plot 44. Conventions as in Table B.1.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1228	44/37	2	3/3	0	0
Jul 9	1333	41/36	0	3/4	0	0
Jul 17	1055	43/46	0	1/3	0	0
Jul 20	1105	38/21	0	1/2	0	0
Jul 22	1252	35/27	0	1/2	0	0
Jul 24	1145	34/39	0	1/2	0	0
Jul 27	1227	48/54	0	1/1	0	0
Jul 31	1338	33/25	0	1/1	0	0

Table B.2., continued. Plot 19-5.

Date	Time	BLKI	COMU	PECO	HOPU	TUPU
				Species		
Jul 7	1334	20/21	1	0/0	0	0
Jul 9	1415	24/22	1	0/1	0	0
Jul 17	1147	19/29	2	0/0	0	0
Jul 20	1146	21/18	1	0/0	0	0
Jul 22	1343	19/13	0	0/0	0	0
Jul 24	1228	19/25	2	0/0	0	0
Jul 27	1319	20/30	0	0/0	0	0
Jul 31	1431	24/18	0	0/0	0	0

Table B.2., continued. Plot 19-6.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1405	0	16	0	0	0
Jul 9	1449	0	17	0	0	0
Jul 17	1223	0	23	0	0	0
Jul 20	1140	0	18	0	0	0
Jul 22	1337	0	16	0	0	0
Jul 24	1222	0	15	0	0	0
Jul 27	1312	0	17	0	0	0
Jul 31	1425	0	21	0	0	0

Table B.2., continued. Plot 19-7.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1403	0	27	0	0	0
Jul 10	1534	0	13	0	0	0
Jul 17	1355	0	41	0	0	0
Jul 20	1145	0	31	0	0	0
Jul 22	1343	0	24	0	0	0
Jul 24	1227	0	33	0	0	0
Jul 27	1318	0	30	0	0	0
Jul 31	1430	0	32	0	0	0

Table B.2., continued. Plot 42.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1354	46/47	148	0	0	0
Jul 9	1434	46/49	72	0	1	0
Jul 17	1210	49/50	145	0	0	0
Jul 20	1157	47/47	50	0	0	0
Jul 22	1402	37/39	111	0	2	0
Jul 24	1248	47/45	132	0	0	0
Jul 27	1339	40/42	136	0	0	0
Jul 31	1445	66/64	81	0	0	0

Table B.2., continued. Plot 46.

Date	Time	BLKI	COMU	Species PECO	HOPU	TUPU
Jul 7	1435	60/43	0	0	0	0
Jul 9	1502	64/51	0	1	0	0
Jul 17	1313	62/51	0	1	0	0
Jul 20	1221	56/31	0	0	0	0
Jul 22	1512	57/34	0	0	0	0
Jul 24	1339	58/30	0	0	0	0
Jul 27	1406	64/48	0	0	0	0
Jul 31	1527	66/39	0	0	0	0

Table B.3. Population counts of nesting seabirds at Cape Peirce, 1989: plots not used for comparison with other years (counted infrequently in 1989). Conventions as in Table B.1.

Date Aug 6

Colony	Time	BLKI	COMU	Species PECO	HOPU	TUPU
1	1200	0/0	0	0/0	0	0
2	1240	17/16	0	0/0	0	0
3	1241	0/0	0	0/0	0	0
5	1715	90/65	415	13/14	0	0
6	1717	0/0	0	0/0	0	0
7	1737	51/44	115	3/6	0	0
8	1754	80/81	170	4/3	0	0
(Aug 5) 10	1740	48/22	0	0/0	0	0
11	1250	0/0	0	0/0	1	0
12	1254	0/0	0	0/0	0	0
18	1241	0/0	0	0/0	0	0
29-1	1741	26/19	115	0/0	0	0
29-2	1746	127/108	75	0/0	0	0

Table B.3, continued. Plot 45.

Date	Time	BLKI	COMU	PECO	HOPU	TUPU
		Species				
Jul 17	1250	--/343	1640	1/1	1	1
Jul 24	1317	302/296	1300	1/2	0	0

Table C.1. Morning counts of murres at Bluff, 1985-1989.

YEAR	JDAT	STAKE LOCATION																		
		1	3A	3B	4B	4C	4D	4E	4F	5A	5B	6	8A	8B	9	10	12	13	15	14
1985	195	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	1526	-9	-9	756	-9
1985	198	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	1434	-9	-9	674	-9
1985	199	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	1629	-9	-9	856	-9
1985	200	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	1477	-9	-9	849	-9
1985	202	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	1627	-9	-9	876	-9
1985	203	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	1475	-9	-9	782	-9
1985	204	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	1705	-9	-9	818	-9
1985	205	518	273	1495	722	763	2269	887	832	-9	-9	207	-9	479	955	1553	-9	-9	755	-9
1985	206	487	260	1379	701	799	1974	716	898	2116	-9	230	637	444	-9	1497	-9	269	762	-9
1985	207	486	280	1303	757	817	2149	1005	887	-9	-9	308	720	526	1040	1570	-9	390	718	481
1985	208	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	1515	-9	-9	742	-9
1985	229	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	1385	-9	-9	726	-9
1985	230	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	1274	-9	-9	660	-9
1987	198	728	298	2148	1103	1496	3381	1247	1419	2789	1034	403	837	537	1214	1655	343	388	1075	622
1987	201	624	322	2080	998	1418	2990	1229	1471	2782	1075	389	787	489	1220	1606	331	437	982	642
1987	202	662	298	1950	1136	1290	2835	1094	1140	2995	1188	328	839	524	1264	1702	334	444	1036	337
1987	205	611	303	1669	958	1265	2763	1054	1180	2603	1207	298	679	477	1152	1718	303	399	942	552
1987	210	777	368	2334	1218	1698	3329	1174	1426	2820	1131	342	843	489	1261	1509	334	397	979	597
1988	188	647	344	1867	1140	1218	2683	1243	1310	3100	1276	379	744	467	1236	1621	303	404	1004	647
1988	190	619	336	2080	1112	1459	3312	1330	1454	3468	1326	291	882	472	1303	1678	352	414	973	533
1988	194	695	297	1830	1069	1392	3188	1259	1380	2963	1127	316	717	370	1242	1503	355	369	1018	532
1988	201	681	307	1759	1066	1401	2951	1158	1338	2898	1199	274	841	472	1298	1574	360	379	1007	547
1988	210	649	335	1951	1152	1423	3077	1154	1255	2787	1049	307	707	441	1103	1489	284	343	938	525
1989	197	543	311	1835	862	1236	2807	945	994	2195	1155	330	702	355	923	1244	448	302	938	589
1989	201	651	316	1884	923	1146	2682	1108	1132	1926	1062	321	736	360	940	1132	265	445	977	543
1989	205	517	275	1936	964	1042	2730	916	1043	2084	890	295	643	387	884	1224	206	328	679	512
1989	207	516	242	1334	603	786	2050	829	852	2118	818	261	522	328	797	1084	221	290	691	403
1989	209	542	248	1553	773	821	2414	795	876	1369	857	286	612	346	778	1162	205	337	791	515
1989	212	615	296	1736	895	1134	2591	933	1057	1422	1069	327	710	355	967	1149	197	353	898	555
1989	213	663	318	1746	894	1045	2448	977	1031	1463	994	274	647	376	868	1242	259	333	811	487
1989	214	643	325	1837	937	1250	2756	1124	1214	1514	1046	302	684	386	971	1267	245	347	844	536

-9: No count made.

Table C.2. Counts of murres at Bluff at 1900h, ADT, 1979-1989.

YEAR	JDAT	CENSUS PLOTS					REPRODUCTIVE PLOTS						
		10a	10b	10c	15a	15b	8	10	12c	12i	13	14	15
1979	202	211	519	516	138	440	-9	-9	-9	-9	-9	-9	-9
1979	203	244	567	603	237	509	-9	-9	-9	-9	-9	-9	-9
1979	204	236	554	546	-9	-9	-9	158	-9	-9	-9	-9	-9
1979	205	275	657	659	218	605	-9	165	-9	-9	-9	-9	-9
1979	206	276	650	615	344	635	-9	171	-9	-9	-9	-9	-9
1979	207	246	621	637	262	587	-9	170	-9	-9	-9	-9	-9
1979	208	279	670	632	305	622	-9	181	-9	-9	-9	-9	-9
1979	209	251	616	600	263	546	-9	163	-9	-9	-9	-9	-9
1979	210	253	590	605	265	562	-9	176	-9	-9	-9	-9	-9
1979	211	259	657	664	237	593	-9	179	-9	-9	-9	-9	-9
1979	212	256	625	616	243	555	-9	166	-9	-9	-9	-9	-9
1979	213	236	607	576	208	555	-9	162	-9	-9	-9	-9	-9
1979	214	231	570	588	231	504	-9	152	-9	-9	-9	-9	-9
1979	217	226	546	512	193	363	-9	154	-9	-9	-9	-9	-9
1979	218	261	609	560	311	586	-9	174	-9	-9	-9	-9	-9
1980	199	221	527	606	-9	-9	-9	146	-9	-9	-9	-9	-9
1980	200	232	510	653	344	463	-9	154	-9	-9	-9	-9	-9
1980	201	232	475	613	344	464	-9	145	-9	-9	-9	-9	-9
1980	202	213	442	595	310	499	-9	138	-9	-9	-9	-9	-9
1980	204	244	501	674	401	460	-9	154	-9	-9	-9	-9	-9
1981	191	232	494	581	-9	-9	-9	146	-9	-9	-9	-9	-9
1981	192	249	518	654	455	559	-9	165	-9	-9	-9	-9	-9
1981	193	251	505	696	450	511	-9	161	-9	-9	-9	-9	-9
1981	195	240	518	658	486	575	-9	172	-9	-9	-9	-9	-9
1981	196	265	529	647	-9	-9	-9	179	-9	-9	-9	-9	-9
1981	197	260	530	687	484	579	-9	176	-9	-9	-9	-9	-9
1981	199	244	520	628	463	520	-9	162	-9	-9	-9	-9	-9
1981	200	268	577	750	457	532	-9	183	-9	-9	-9	-9	-9
1981	201	261	545	699	419	457	-9	174	-9	-9	-9	-9	-9
1981	202	259	534	632	470	511	-9	178	-9	-9	-9	-9	-9
1981	203	263	530	693	-9	-9	-9	172	-9	-9	-9	-9	-9
1982	194	180	416	524	317	299	-9	123	-9	-9	-9	-9	-9
1982	195	213	451	548	396	442	-9	139	-9	-9	-9	-9	-9
1982	196	183	412	511	362	361	-9	130	-9	-9	-9	-9	-9
1982	197	222	443	580	254	265	-9	149	-9	-9	-9	-9	-9
1982	199	199	414	544	-9	-9	-9	143	-9	-9	-9	-9	-9
1982	200	260	519	567	390	436	-9	171	-9	-9	-9	-9	-9
1982	201	248	493	593	363	418	-9	167	-9	-9	-9	-9	-9
1982	202	233	503	608	363	348	-9	157	-9	-9	-9	-9	-9
1983	190	227	465	560	465	560	-9	154	-9	-9	-9	-9	-9
1983	191	236	559	615	434	485	-9	167	-9	-9	-9	-9	-9
1983	192	239	518	584	465	463	-9	165	-9	-9	-9	-9	-9
1983	193	225	482	558	450	463	-9	154	-9	-9	-9	-9	-9

Table C.2, continued. Counts of murres at 1900h.

YEAR	JDAT	CENSUS PLOTS					REPRODUCTIVE PLOTS						
		10a	10b	10c	15a	15b	8	10	12c	12i	13	14	15
1983	196	254	536	609	459	461	-9	162	-9	-9	-9	-9	-9
1983	200	247	516	627	416	456	-9	167	-9	-9	-9	-9	-9
1983	201	247	506	622	378	440	-9	151	-9	-9	-9	-9	-9
1983	203	251	523	643	428	454	-9	165	-9	-9	-9	-9	-9
1983	204	265	563	730	452	504	-9	176	-9	-9	-9	-9	-9
1983	205	234	497	613	-9	-9	-9	166	-9	-9	-9	-9	-9
1984	188	-9	-9	-9	163	105	-9	96	-9	-9	14	32	-9
1984	189	132	216	384	225	231	43	69	8	0	13	35	40
1984	190	77	169	416	101	175	32	40	1	4	3	38	39
1984	191	94	144	377	178	160	32	57	1	0	3	41	29
1984	192	88	122	355	147	130	38	46	0	1	2	44	19
1984	193	105	155	378	157	150	32	48	0	0	5	46	18
1984	194	154	185	456	207	232	46	78	0	4	10	56	25
1984	195	114	184	412	195	159	36	62	0	2	6	52	30
1984	196	124	163	402	212	168	43	80	0	1	4	49	13
1984	197	118	176	440	158	156	37	71	1	12	26	56	37
1984	198	135	219	401	155	183	48	108	0	0	11	41	61
1984	199	195	384	455	294	304	51	139	26	21	79	-9	39
1984	200	180	412	514	330	330	46	134	10	24	29	58	60
1984	201	181	269	476	248	216	38	129	26	25	10	54	62
1985	190	271	524	659	396	450	59	173	28	36	117	67	-9
1985	191	218	442	622	288	356	35	138	30	33	101	55	-9
1985	192	237	477	622	299	355	49	134	25	37	101	53	-9
1985	193	216	409	608	263	327	59	121	24	30	93	50	-9
1985	194	173	294	469	250	246	32	80	7	22	86	41	-9
1985	195	197	318	489	269	305	61	95	22	29	80	49	-9
1985	196	181	315	564	230	268	35	83	14	30	94	49	55
1985	197	158	305	562	258	276	33	67	17	31	69	51	66
1985	198	219	441	612	284	349	49	127	24	41	97	56	67
1985	199	147	255	447	259	267	43	73	21	27	106	50	42
1985	201	161	263	437	239	259	43	70	26	23	82	46	57
1985	202	158	272	427	231	261	41	83	19	27	87	43	76
1985	203	183	337	548	254	269	45	101	23	31	96	39	78
1985	204	200	414	580	282	313	42	134	22	41	108	45	76
1985	205	210	471	580	281	291	58	134	38	30	110	41	70
1985	206	252	559	684	352	421	59	181	45	42	111	54	103
1985	228	260	545	687	431	398	57	161	32	51	97	52	86
1985	229	264	552	620	444	434	57	173	45	38	116	54	77
1986	220	1351	0	0	355	400	-9	130	-9	-9	90	-9	-9
1986	221	1482	0	0	443	526	-9	142	-9	-9	91	-9	94
1987	194	228	464	581	357	378	57	136	40	31	109	64	86

Table C.2, continued. Counts of murres at 1900h.

YEAR	JDAT	CENSUS PLOTS					REPRODUCTIVE PLOTS						
		10a	10b	10c	15a	15b	8	10	12c	12i	13	14	15
1987	195	243	456	661	404	474	55	141	45	29	107	54	102
1987	196	269	526	669	368	476	58	153	38	38	112	64	100
1987	197	272	467	668	387	434	62	150	40	30	96	61	96
1987	201	265	566	700	420	492	71	150	48	43	107	60	97
1987	202	291	529	702	469	543	60	165	39	39	105	72	98
1987	204	293	537	691	416	512	61	156	40	33	100	63	100
1987	205	281	512	703	432	551	62	146	45	40	103	71	94
1987	206	288	586	717	470	527	64	163	41	43	104	63	103
1987	207	275	536	699	463	551	74	154	36	37	103	59	105
1987	208	265	468	625	392	496	63	145	38	29	107	64	90
1987	210	308	566	740	456	538	74	156	46	43	104	73	104
1988	188	250	438	629	399	473	56	138	40	36	100	60	89
1988	191	265	494	659	393	419	54	141	45	30	109	52	93
1988	194	275	492	709	400	432	60	144	45	33	116	57	92
1988	195	222	457	599	369	404	61	127	45	30	97	64	91
1988	201	229	462	644	407	424	55	132	43	29	102	51	104
1988	203	232	486	725	395	444	61	142	44	31	114	60	103
1988	205	197	404	605	373	442	54	120	44	31	94	56	94
1988	206	261	518	696	422	464	60	142	41	34	95	68	97
1988	208	274	533	705	427	468	60	146	43	29	101	70	100
1988	209	300	583	698	465	522	63	164	45	34	106	71	99
1988	210	265	543	684	434	479	61	145	48	35	106	70	96
1988	211	245	476	633	397	395	53	140	45	33	101	62	93
1989	195	173	357	597	366	488	59	142	31	37	99	78	92
1989	196	148	343	597	301	305	36	121	26	15	100	54	77
1989	197	149	347	565	318	388	61	150	45	35	103	64	80
1989	200	196	440	693	413	447	68	178	50	44	112	71	107
1989	204	280	559	593	353	503	60	172	51	41	115	79	111
1989	208	235	507	587	365	384	48	157	38	38	110	62	107
1989	210	252	467	615	363	480	56	164	47	41	108	71	98
1989	211	247	499	600	372	452	54	164	43	40	117	66	100
1989	212	262	534	685	354	551	66	161	43	51	99	70	106
1989	214	246	550	669	404	499	58	167	50	43	110	70	102

-9: No count made.

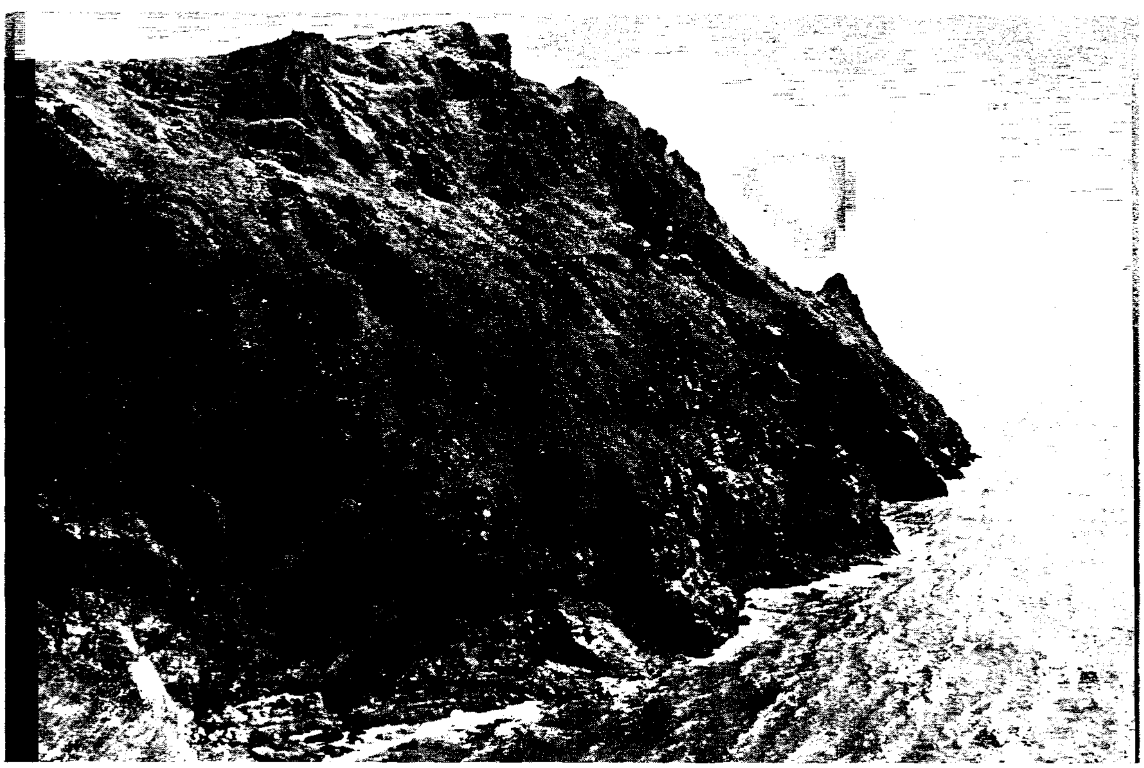

Figure D.1. Seabird colonies on St. George Island (above) and at Cape Peirce (below).

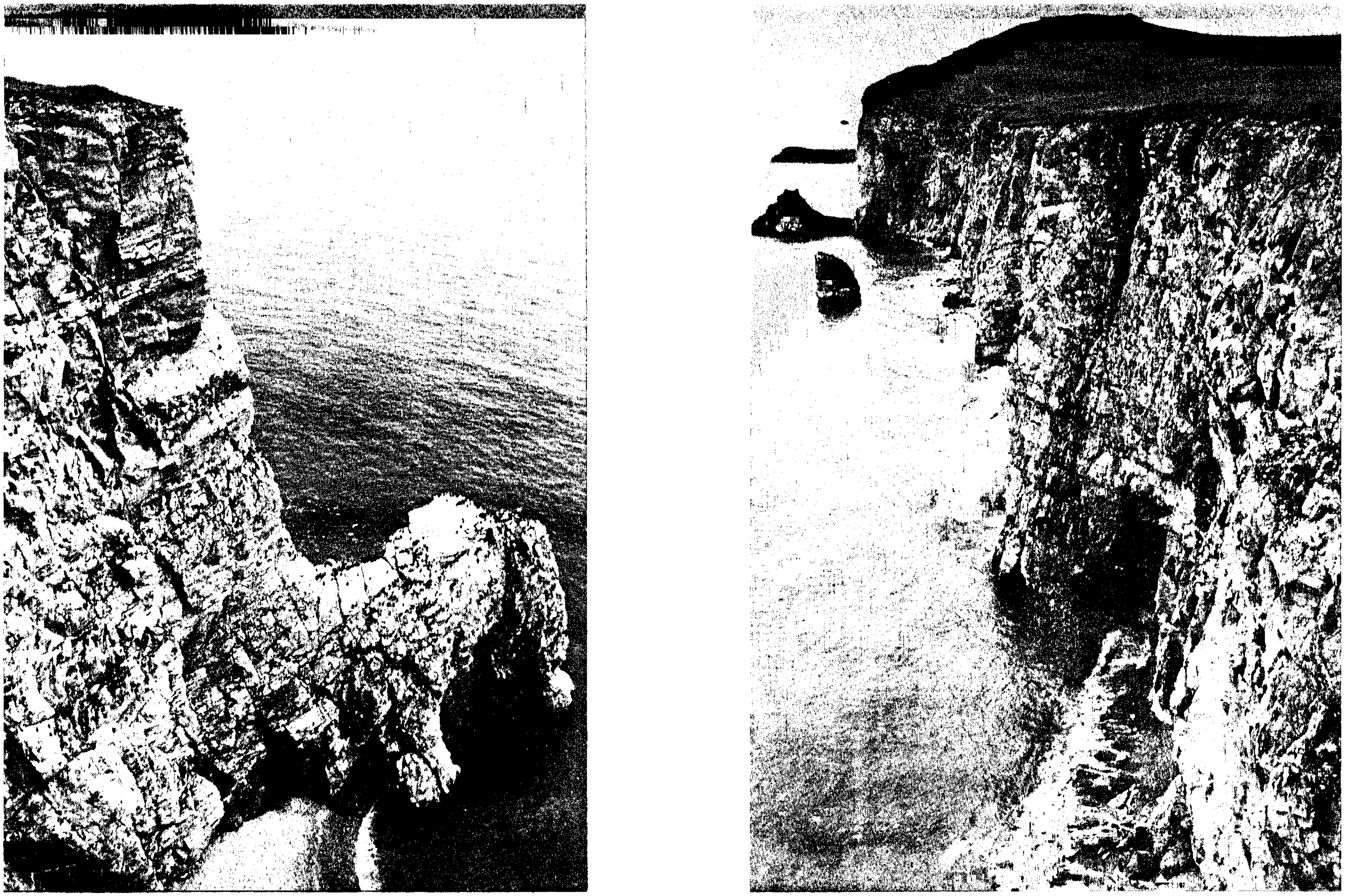

Figure D.2. Seabird colony at Bluff, Alaska.