Alaska Fish and Wildlife Research Center

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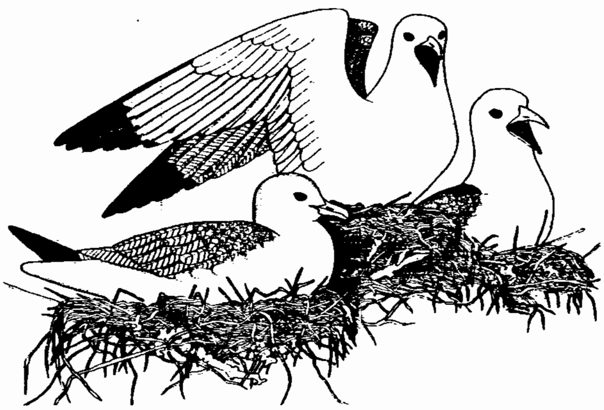
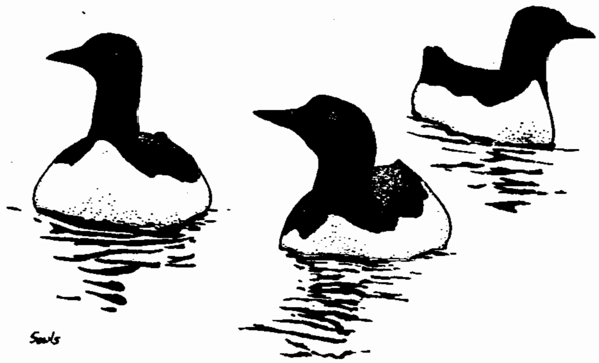
DEPARTMENT OF THE INTERIOR

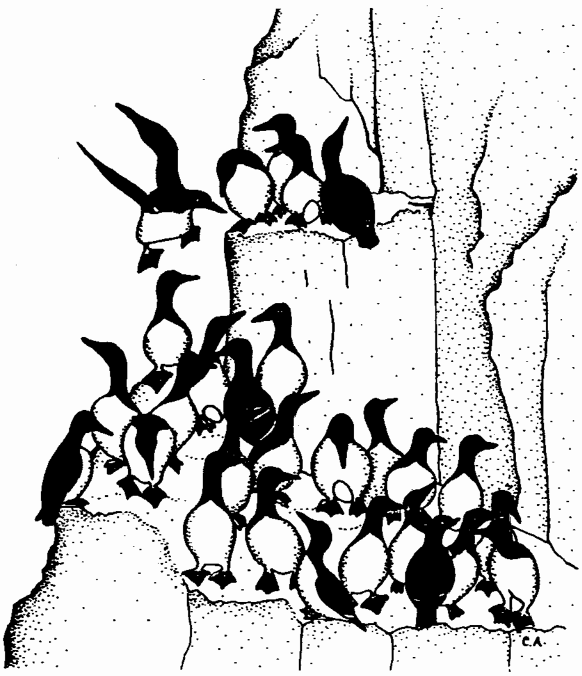
Monitoring Seabird Populations in Areas of Oil and Gas Development on the Alaskan Continental Shelf:

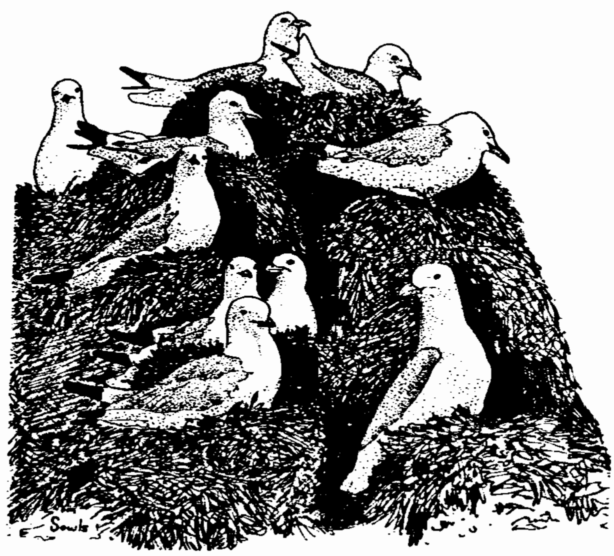
Populations, Productivity, and Feeding Habits of Seabirds at Cape Thompson, Alaska

Final Report









OCS Study
MMS 89-0014

POPULATIONS, PRODUCTIVITY, AND FEEDING HABITS OF SEABIRDS AT CAPE THOMPSON, ALASKA

Final Report

by

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ABSTRACT

Investigations of seabird population sizes and breeding biology were conducted at Cape Thompson from 1959 to 1961 during pre-development studies associated with the Atomic Energy Commission's "Project Chariot." From 1976 through 1982, the Alaskan Outer Continental Shelf Environmental Assessment Program (OCSEAP) supported efforts to recensus seabirds at Cape Thompson and determine whether changes had occurred since the 1959-61 period. Prior to the present study, it had been 6 years since the last efforts to census seabird colonies in this area.

We established a field camp at the mouth of Ikijaktusak Creek on 2 July and occupied it continuously until 31 August 1988. Permanent study plots were selected for cliff nesting species in four of the five discrete colonies comprising the Cape Thompson complex, and regular observations were made throughout the study to document attendance patterns, breeding phenology, and success of murres and kittiwakes. Periodic collections of adults offshore were used to determine the food habits of study species. Shore-based work was supplemented with offshore studies of seabird foraging from the USFWS vessel Eagle-Tiglax, 24-31 August (Fig. 2).

Correlation analysis revealed negative trends in murre attendance at all Cape Thompson colonies between 1960 and 1982 or 1988, significantly so for 3 of the 5 colonies. Based on apparent changes in species composition within the colonies, Common Murres declined at a more rapid rate than Thick-billed Murres between 1960 and 1988. Combining information from all colonies, it appears that murre populations have been relatively stable since about 1979. In contrast to murres, the kittiwake population showed no significant trends between 1960 and 1982 or between 1960 and 1988. All fluctuations in kittiwake numbers documented between years were within the variability expected within years. Breeding productivity of murres was about average during 1988 (0.47 young/pair), whereas the productivity of kittiwakes was very poor (0.15 young/pair).

Murres and kittiwakes fed mostly on arctic cod and sand lance distributed widely but in low concentrations (e.g., 0.1-10 g/m^3) up to 120 km north and

northwest of Cape Thompson. In the total area surveyed (225 km^2), only two major feeding aggregations were observed where fish school densities exceeded 15 g/m^3. Forage fish densities were higher in shallow Alaska Coastal Current waters than offshore in Bering Sea waters, and piscivorous seabirds like murres and kittiwakes fed mostly in coastal waters. Reduced numbers of fish in murre and kittiwake stomachs in August and low breeding success of kittiwakes suggested that forage fish densities observed around Cape Thompson in late August were sufficient to sustain murres but were insufficient for, or inaccessible to, kittiwakes.

The breeding failure of Black-legged Kittiwakes at Cape Thompson in 1988 was part of a pervasive syndrome of failure in this species observed throughout the Bering/Chukchi seas and Gulf of Alaska in recent years. The causes of recurrent widespread breeding failure need to be identified if kittiwakes are to have a role in area-wide population monitoring during the period of Alaskan OCS development by the oil and gas industry.

The system of land-based plots established in 1988 is recommended for future population monitoring of cliff-nesting birds at Cape Thompson. Based on the coefficients of variation among counts observed in this study, it is estimated that 10 replicate counts per year would detect an 8% change in numbers of Thick-billed Murres between years and a 12% change in Common Murres, with 75% certainty of statistical significance at the 0.05 level. Similarly, a 9% annual change in the population of Black-legged Kittiwakes should be detectable at the 0.05 significance level given samples of 10 replicate counts of the land-based plots.

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CHAPTER 1. INTRODUCTION

1.1 General Background

Seabird colonies in Alaska contain more than 40 million birds of 30 species, and some of the largest colonies are associated with the productive waters of the Bering and Chukchi seas. Although critical nesting and foraging habitat of these birds has so far remained mostly free from disturbance or alteration, there is a possibility of adverse effects on either or both components of the birds' environment from the exploration, production, or transport of oil and gas in the region.

The Outer Continental Shelf (OCS) Lands Act (43 U.S.C. 1331-1356) established federal jurisdiction over the submerged lands of the continental shelf seaward of state boudaries. The Act charges the Secretary of the Interior with the responsibility for administering mineral exploration and development of the OCS. It also empowers the Secretary to formulate regulations so that the provisions of the Act will be met. The OCS Lands Act Amendments of 1978 established policies and procedures for managing oil and natural gas resources of the OCS, including provisions for post-sale monitoring in the Minerals Management Service (MMS) program of environmental studies. Seabird colonies are part of the monitoring program because they are major components of Alaska marine ecosystems and because they may be especially vulnerable to OCS activity. Further, many of the seabirds occurring in the Bering Sea and Arctic Ocean migrate along Pacific coasts and are protected by conventions or treaties between the United States, Soviet Union, Canada, Japan, and Mexico.

In recent years, the MMS has sponsored efforts to monitor seabird populations through periodic visits to selected colonies in the Bering and Chukchi seas (Fig. 1.1). Colonies on the Pribilof Islands and Cape Peirce were studied in 1984 (Johnson 1985), followed by 2 years' work on St. Matthew and Hall Islands (Murphy et al. 1987). In 1987, studies at two locations on St. Lawrence Island were co-sponsored by MMS and the U.S. Fish and Wildlife Service (USFWS) (Piatt et al. 1988). The present report contains the results of studies conducted at Cape Thompson in 1988 by USFWS personnel under a continued inter-agency agreement with MMS.

Among all seabird colonies in Alaska, those at Cape Thompson are exceptional in having a relatively long history of previous investigations. Swartz (1966) censused seabirds at the cape and studied the breeding biology of several species. Swartz' studies were carried out between 1959 and 1961 and were the first detailed investigation of any seabird colony in Alaska. Beginning in 1976, the Outer Continental Shelf Environmental Assessment Program (OCSEAP) supported efforts to recensus the seabirds of Cape Thompson and determine whether changes had occurred since Swartz' work. Springer et al. (1985a,b) reported that the combined populations of Common and Thick-billed Murres (Uria aalge and U. lomvia) declined markedly between 1961 and 1976 and continued to decline through 1982 in some portions of the Cape Thompson complex. The numbers of Black-legged Kittiwakes (Rissa tridactyla) showed no consistent trend over the same period but varied markedly among years. When we revisited Cape Thompson in 1988, 6 years had passed since the last efforts to census seabirds at the colonies.

We made counts of murres and kittiwakes comparable to previous boat-based censuses at Cape Thompson, and instituted a new land-based system of study plots following guidelines in Piatt et al. (1988). We also collected information on the breeding productivity and food habits of murres and kittiwakes and quantified some sources of variation in attendance that can affect year-to-year trend analyses. Finally, with the support of the USFWS vessel M/V 'Tiglax', we conducted surveys of the distribution and abundance of foraging seabirds and their prey in the Cape Thompson region during late August.

This chapter describes the objectives and general methods employed, provides a description of the study area, summarizes previous studies at Cape Thompson and offers logistical information that may be useful to future investigators working in this area. Chapter 2 presents population census data for murres and kittiwakes obtained from newly established land-based plots. Chapter 3 provides information on breeding productivity; Chapter 4 summarizes trends in populations and discusses implications of murre and kittiwake census data spanning 28 years at Cape Thompson. Chapter 5 discusses adult foraging patterns and diets, as well as oceanographic characteristics of the eastern Chukchi Sea. Photodocumentation of study plots, observation points, travel routes, 1988 census data, and incidental observations of birds and mammals are presented in Appendices A-F. All previous census data from 1960-1982 are listed in Appendix G.

1.2 Objectives

The major objectives of this study were as follows:

1. Establish land-based study plots for monitoring murre and kittiwake numbers and permanently mark and photodocument them.

2. Conduct Type II censuses of Thick-billed Murres, Common Murres, and Black-legged Kittiwakes (i.e., as per Birkhead and Nettleship 1980).

3. Estimate the annual productivity of murres and kittiwakes.

4. Determine the diets of adult murres and kittiwakes foraging near Cape Thompson during July and August 1988.

5. Identify important feeding areas of seabirds in the vicinity of Cape Thompson.

1.3 Study Area

The Cape Thompson complex of seabird colonies (68° 08'N, 166° 21'W) consists of an 11-km stretch of cliffs where the Kemegrak Hills of the western Brooks Range meet the eastern Chukchi Sea, about 39 km southeast of Point Hope (Fig. 1.2). Tundra slopes and hills with plateaus and buttes characterize terrestrial habitat (Kachadoorian 1966). Biological and geological aspects of the area have been described by Campbell (1966), Johnson et al. (1966), Pruitt (1966), and Williamson et al. (1966). Although geographically part of the Arctic basin, oceanographic characteristics of the Cape Thompson region are dominated by a strong northward barotropic flow of

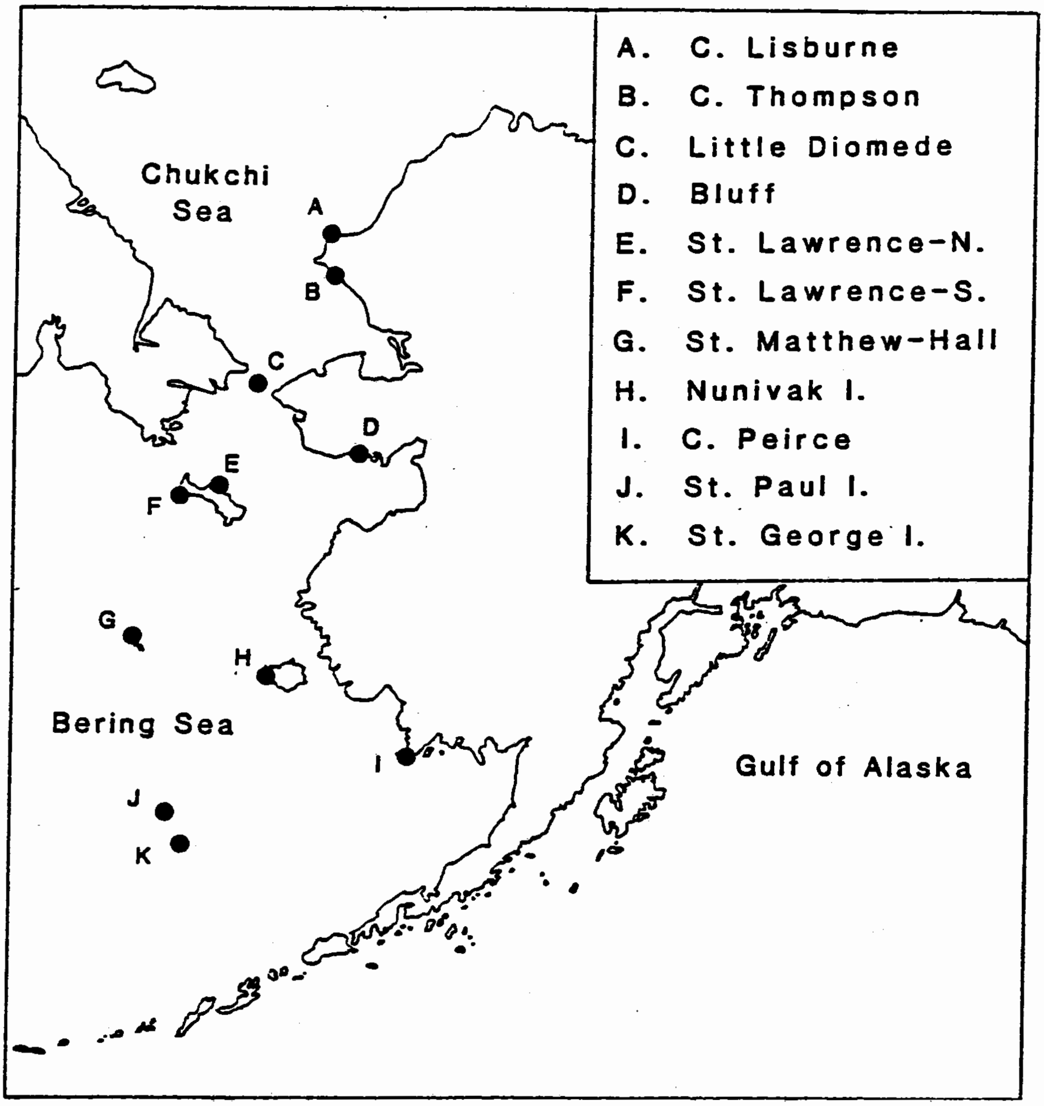

Figure 1.1. Locations of established and potential study sites for seabird monitoring in the Bering and Chukchi seas.

water from the Bering Sea (Fleming and Heggarty 1966, Coachman and Aagaard 1981).

Weather of the Cape Thompson region is quite variable, and can be extreme. Fog was frequent during the 1988 field season, especially during periods with southerly winds. Winds were light and variable in early July. After mid-July winds were nearly continuous and predominantly southerly until about 15 August, when they shifted to northerlies, a typical pattern reported for the area (Allen and Weedfall 1966). High velocity surface winds from northern quadrants have been reported for this region in other years (Allen and Weedfall 1966, Springer and Roseneau 1977). In 1988, these winds reached velocities of 90-190+ km/h, and lasted up to 3 days. Winds were sufficient to blow surface water into the air and create water-spouts up to 40 m high. The rainiest season is usually July through September (during which time, about 75% of the annual precipitation falls--see Allen and Weedfall 1966).

Sea ice typically breaks up in the region by mid-late June (Springer and Roseneau 1978), but even after the ice pack retreats north of Point Hope, a substantial amount (a band about 4-6 km wide in 1988) often remains along the coast between Point Hope and Kivalina until about the second or third week of July. This ice cover is maintained by southerly and westerly winds, as well as by discontinuities between offshore and coastal currents (Fleming and Haggerty 1966, Springer and Roseneau 1978). Once ice-free, the Cape Thompson region generally remains so until November (Springer and Roseneau 1978).

Swartz (1966) described five distinct cliff areas (colonies) varying from about 0.6-2.4 km long that are used by breeding seabirds (Fig. 1.2). Together these cliffs comprise some 6.8 km of the 11.4 km of coastline from Crowbill Point (Colony 1) to a point about 2.3 km northwest of Cape Thompson (Colony 4), where Imnapak Cliff (Colony 5) ends at the southern base of the Point Hope Peninsula. Cliff elevations range from about 9-200 m above sea level (Springer and Roseneau 1978, Murphy et al. 1980). Colonies 1 and 4 have the smallest areas and Colonies 2 and 5 the largest; Colony 3 is intermediate in size.

The rocks forming the cliffs of Cape Thompson are Mississippian

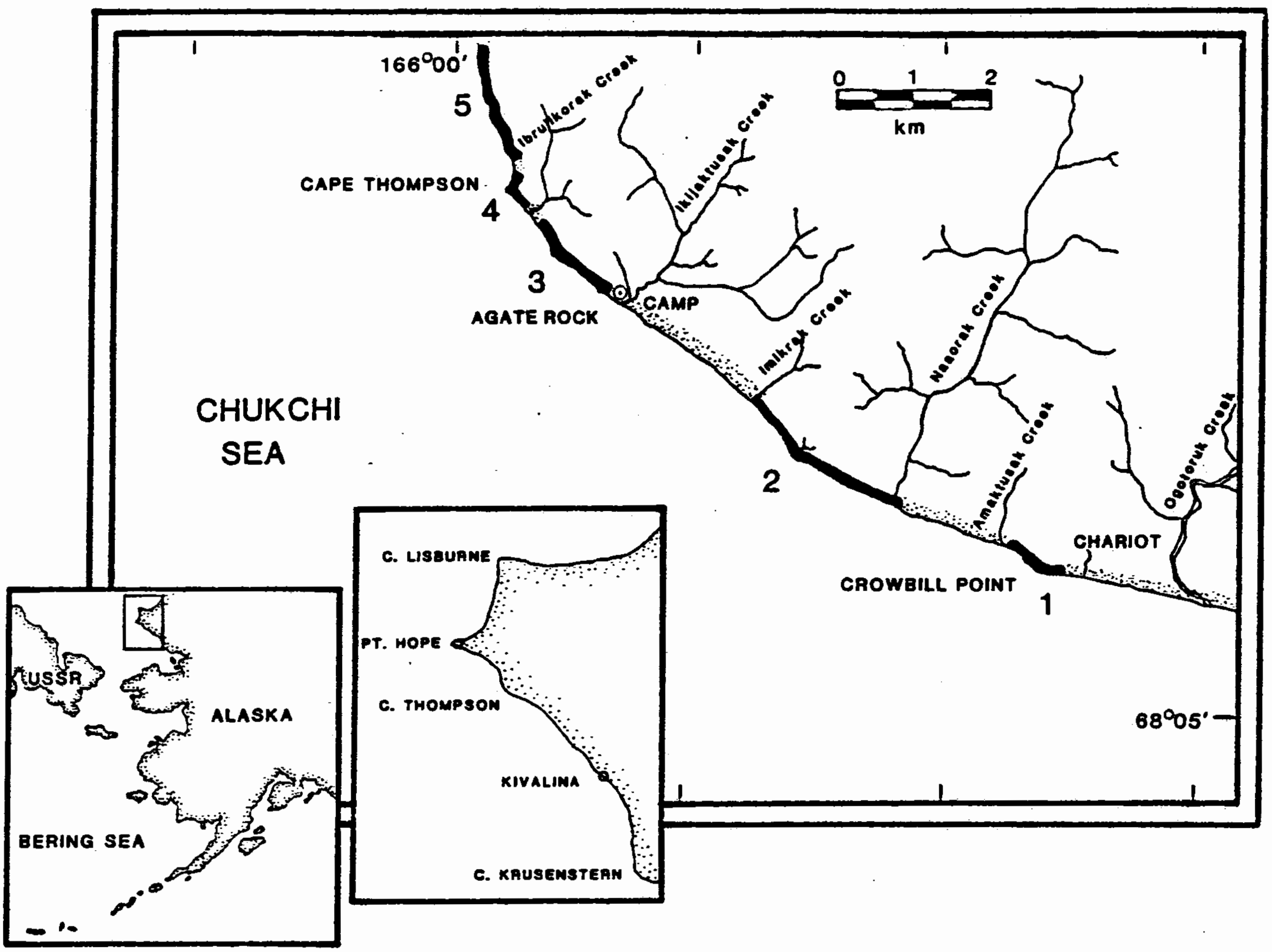

Figure 1.2. Location map of the study area showing the five cliffs in the Cape Thompson complex of seabird colonies. The position of the 1988 basecamp at the mouth of Ikijaktusak Creek is also indicated.

sedimentary limestones and shales that have been folded and shifted to varying degrees among the colonies (Campbell 1966). The rocks of Colony 1 (Crowbill Point to Amaktusak Creek) have been folded such that cracks run vertically, presenting few ledges that seabirds can use for breeding sites (Swartz 1966). The dolomitic formations of Colony 2 (between outlets of Nasorak and Imikrak Creeks) provide abundant broad ledges for cliff-nesting birds (Campbell 1966, Swartz 1966, Murphy et al. 1980). Colony 3, lying between Ikijaktusak Creek and Ibrulikorak Creek, has cliffs approaching 200 m above sea level. This colony and Colony 5 are composed of softer and more fragmented rocks than Colonies 1 and 2 (Campbell 1966, Murphy et al. 1980), contributing to frequent rockslides. Colony 4 (Cape Thompson), between Ibrulikorak Creek and Imnapak Cliff, has undergone noticeable habitat change as a result of a major rockfall that occurred sometime between September 1978 and June 1979 (D.G. Roseneau and A.M Springer, unpubl.). Colony 5 (Imnapak Cliff) is characterized by having the highest cliffs, up to about 200 m above sea level, and the most unstable strata. Rockfalls are common in Colony 5, and there was a nearly constant shower of small rocks and gravel along the cliffs in 1988.

Nine seabird species breed on the cliffs at the Cape Thompson colonies. In order of decreasing abundance (Swartz 1966) they include: Thick-billed Murres, Common Murres, Black-legged Kittiwakes, Horned Puffins (Fratercula coriculata), Glaucous Gulls (Larus hyperboreus), Tufted Puffins (Fratercula cirrhata), Pelagic Cormorants (Phalacrocorax pelagicus), Black Guillemots (Cepphus grylle), and Pigeon Guillemots (Cepphus columba). In 1960, about 93% of the birds present were murres, 6% were kittiwakes, and the remaining species accounted for 0.5% of an estimated 421,000 birds (Swartz 1966). Five terrestrial species have also been reported nesting on the cliffs: Common Ravens (Corvus corax), Gyrfalcons (Falco rusticolis), Peregrine Falcons (F. peregrinus), Snow Buntings (Plectrophenax nivalis), and Say's Phoebes (Sayornis saya). Evidence of breeding was noted in 1988 for all of the above species except Peregrine Falcons and Gyrfalcons. Other bird species observed during the study are listed in Appendix B.

1.4 Previous Studies

Prior to the first studies during 1959-1961 (Swartz 1966), little was known about the seabird colonies at Cape Thompson. Swartz (1966) cited several sources mentioning seabirds in the Cape Thompson vicinity. Hooper (1881, 1884) published notes from ship voyages in which he suggested that Cape Thompson was a favorite camping area of local residents because of an abundance of birds and eggs on the cliffs. Hudson (1957) observed large flocks of seabirds around cliffs a few miles south of Point Hope, most likely at Cape Thompson.

Swartz' 1959-1961 studies of seabirds at Cape Thompson were conducted as part of the Atomic Energy Commission's Project Chariot (Swartz 1966, 1967). In an attempt to determine the total populations of murres and kittiwakes in the area, Swartz established boat-based plots that provided complete coverage of each colony. Twelve plots along the top of Colony 5 were counted from land as well as from the water, and on some of the same plots observers were able to differentiate between Thick-billed and Common Murres. Birds on Colony 5 plots were counted by 100's, whereas others were counted by 10's. Numbers of Black-legged Kittiwakes were estimated from counts of nests at all colonies. Swartz also collected information on the breeding phenology and success of most species and on diurnal variation in attendance of murres. Finally, he collected morphometric and adult food habits data.

A variable set of Swartz's census plots have been used by observers in all subsequent studies. Springer and Roseneau (1977) censused murres and kittiwakes in 1976 on most of Swartz' boat-based plots. They counted kittiwake adults instead of nests because few nests were built that year. Murres were estimated by 100's on Colony 5 and by 10's elsewhere. Only total murres were counted because it is difficult to distinguish between the two species on many of the large boat-based plots. Observations were made of diurnal variation, breeding phenology, and murre foraging flight directions (from shore), and murres and kittiwakes were collected for dietary analyses.

Springer and Roseneau (1978) returned to Cape Thompson in 1977 to repeat censuses of adult murres and kittiwakes. All plots were counted from a boat. They also recorded murre foraging flight directions from shore and collected birds for dietary analyses.

In 1978, Cape Thompson was revisited briefly and adult kittiwakes and kittiwake nests were counted at Colony 4 and on two plots in Colony 2 (Springer et al. 1979). Both murres and kittiwakes were collected for dietary analyses, and flight directions were observed from shore and during aerial surveys offshore.

Murres and kittiwakes (adults and nests) were completely censused at all five colonies in 1979 (Murphy et al. 1980). Also, plots along the upper portion of Colony 5 were counted from both land and boats for comparison. Additional information was gathered on diurnal attendance of murres, chick growth rates and kittiwake breeding success. Murphy et al. (1980) also investigated the accuracy and precision of their counting methods and assessed patterns of population change within and between seabird colonies at Cape Thompson. Results from the 1976-1979 studies were summarized and compared to Swartz' (1966) data by Springer et al. (1985b), and Springer et al. (1984) reviewed murre prey composition and breeding phenology in light of oceanic, meteorological, and sea ice cover data.

The most recent census work prior to the present study was performed in 1982 (Springer et al. 1985a). Murres and kittiwakes were censused by boat, and several of Swartz' Colony 5 plots were also recounted from land to determine ratios of Thick-billed and Common Murres. Measurements of breeding phenology, egg volumes, and adult prey composition were also collected.

1.5 General Methods And Rationale

1.5.1 Colony Studies

Seabird population monitoring, including studies of numbers, productivity, food habits, and other aspects of breeding biology has proceeded in Alaska with a measure of continuity since the mid-1970's. Studies have been conducted by a large number of different investigators, with widely varying investments of time and effort at different colonies.

Inevitably, some loss of comparability among data sets has occurred because of different field schedules and methods.

A protocol for monitoring seabirds at colonies in the Bering and Chukchi seas was prepared during 1987, the first year of MMS/FWS collaboration on seabird monitoring (Piatt et al. 1988). The protocol calls for two visits annually to each of 6 or more colonies distributed throughout the region. The first visit (approximately 2 weeks mid-season) is timed such that 5-15 daily counts of birds on plots are made during a census period which is predetermined for each species and study site. Counts provide an annual index of population size and a standard measure of breeding effort. Productivity, the number of young surviving per unit of adult attendance on the plots, is determined on the second visit (1-4 days near the time of fledging). Proposed study species include Black-legged Kittiwakes, Thick-billed Murres, and Common Murres, with other species observed only a second-priority basis.

A primary objective of studies at Cape Thompson during 1988 was to meet or exceed the standards for monitoring seabird populations and productivity outlined in the Bering/Chukchi monitoring protocol. Because a suitable complement of study plots was not already in place at this site, we allowed more time for population assessment than the standard 2 weeks. We occupied the study site continuously from 1 July-31 August; systematic counts and most other data gathering began on 8 July, after an initial period for camp set-up and reconnaissance.

We established 25 land-based census plots in four of the five colonies in the Cape Thompson complex (plot distribution: 14 plots in Colony 5 [C5], 5 plots in C4, and 3 plots each in C3 and C2). Colony 1 did not prove feasible for land-based counts due to a lack of sites visible safely from land. During the census period 10 July through 15 August, plots in C4 and C5 were counted 10-12 times and plots in C2 were counted 6 times. Colony 3 plots were counted nearly daily. The combined total of all plots averaged 7769 murres and 1100 kittiwakes. With a base camp established at the south end of C3 on the Ikijaktusak Creek (see below), all plots in C2, C3, C4, and C5 could be visited and counted in 1 day by 2-3 people without boat transportation.

To compare our land-based counts with historical counts from Cape Thompson, we counted five of Swartz' (1966) land-based plots at least three times from land and all boat-based plots in C4 and C5 once from a boat during the census period. We also photographed the entire Cape Thompson complex from boat to update the 1960 photographs used for boat-based counting.

Additional studies of murre and kittiwake attendance patterns, breeding phenology, and productivity were conducted as described in Chapters 2 and 3.

1.5.2 Shipboard Studies

Whereas seabird populations are most efficiently monitored where they are concentrated in breeding colonies, the most serious of potential impacts from oil and gas development are likely to occur in pelagic habitats. Federal responsibility for regulatory management and impact assessment during OCS development clearly includes the marine habitats of seabirds, but pertinent studies to date are few in comparison with land-based work. Since bird studies generally have been possible only on an incidental basis during oceanographic cruises, many basic questions about seabird movements and habitat requirements at sea remain unanswered. Therefore, to complement the colony studies at Cape Thompson in 1988, we conducted bird transects and hydroacoustic surveys in adjacent waters over several days in late August. Several semi-circular surveys were conducted around the colonies at Cape Thompson and Cape Lisburne (Fig. 1.1) to determine flight directions of birds from the colonies. Inshore surveys running parallel to the coast were conducted from Cape Thompson to Point Hope, and from Point Hope to Cape Lisburne. Offshore surveys running perpendicular to the coast were conducted to the south and north of Cape Thompson. Hydroacoustic and bird data were obtained on all these surveys, and water temperature and salinity profiles of the water column were obtained on offshore surveys (Chapter 5).

1.6 Logistics and Basecamp

Cape Thompson is geographically isolated and boat or air travel is required to gain access. We ferried personnel and equipment in a chartered Cessna 206 from Kotzebue to an old airstrip at the abandoned Chariot site (Fig. 1.2). An approximately 340-m gravel strip in reasonably good condition is on the north side of a group of abandoned buildings, near the mouth of Ogotoruk Creek. There are longer airstrips across Ogotoruk Creek, but in 1988 they were in unusable condition. Use of these strips would also have created difficulties in transferring equipment to the beach.

A basecamp was established about 60 m from the beach on the north side of Ikijaktusak Creek (Fig. 1.2). Equipment was transported by inflatable boat (Zodiac Mark II, with Johnson 15 or 25 hp motors) between Chariot and the basecamp site. The basecamp location allowed relatively easy walking or boat access to Colonies 2-5, without requiring spike-camps (although spike-camps were set up for 24-hour plot counts, described in Part 2.1.1.2). Ikijaktusak Creek was used as a source of freshwater, with no ill effects reported from personnel this year, or in other years. A single sideband radio provided communications with the Selawik National Refuge Office in Kotzebue, the Selawik National Refuge Field Station, the Pribilof Islands, Adak, and several field camps in the Aleutian Islands. For emergency use, VHF aviation or Citizens Band (CB) radios are preferable to marine band radios in this region, because of regularly scheduled service between Kotzebue and Point Hope, and the use of CB radios by hunters from Point Hope and Kivalina.

As noted earlier, weather in the region can be variable and extreme. Tents should be pitched in areas that will not receive the full force of northerly or southerly winds, or at least be tied down to counteract high winds from those directions. Also, tents should not be pitched in frost boil areas, which become quagmires after rain. Ikijaktusak Creek floods during sustained rain storms, so camp sites in the valley should be located at least 2 m above the creek bed. After sea ice dissipates, boats must be hauled well away from the water's edge and secured, and the beach kept clear of equipment. Incoming swells from the S-SE typically cause topographical changes to gravel beaches along the 11 km of the study area. Large swells occasionally obliterate the entire beach at Ikijaktusak Creek, sending waves and driftwood up the narrow valley. Also, rockfalls are extremely common along all cliffs, and are especially common along the bases of Agate Rock

(Colony 3) and Imnapak Cliff (Colony 5).

Although we did not encounter problems with grizzly bears, they commonly frequent the area (Appendix A) and previous researchers have had rafts damaged by curious bears (E. C. Murphy and A. M. Springer, pers. comm.). Food should be sealed in containers, kept away from sleeping areas and camp sites should be kept clean. It is also advisable to carry firearms or bear repellant (such as Counter Assault™) capable of dissuading aggressive bears.

1.7 Acknowledgments

We would like to thank especially the volunteers who assisted with the field work at Cape Thompson: Jane Burger, Daniel Taylor, and Paul Rodewald. Thanks also go to Joel Hubbard (MMS) for assistance in the field during his visit. The unselfish assistance rendered by Lena Anungazuk and the Selawik National Wildlife Refuge staff was greatly appreciated, as was the expert flying and help in unloading gear by John Plaza of Baker Aviation.

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Stomach contents from murres and kittiwakes were analyzed by A.M. Springer, under a contract with FALCO, Fairbanks, AK.

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CHAPTER 2. ATTENDANCE PATTERNS AND POPULATION COUNTS OF MURRES AND KITTIWAKES

2.1 Introduction

Previous census work at Cape Thompson (Swartz 1966, Springer et al. 1985a) has been largely conducted by counting seabirds on plots from boats offshore. These plots covered all occupied cliff areas and therefore provided estimates of total numbers in some years. However, because of the time involved in counting these plots and the relatively few days conducive to boat counts, complete censuses of all colonies at Cape Thompson have not always been accomplished. Additionally, this method has generally produced only one annual count of the plots during the census period, limiting the application of statistical tests for detecting numerical changes.

Seabird numbers on breeding cliffs vary with time of day, stage of the breeding cycle, weather, nest or site attendance, and food availability (Gaston and Nettleship 1982; Tschanz 1983; Hatch and Hatch 1988, 1989). This variation can be great enough to obscure year-to-year changes in seabird numbers. By increasing the number of replicate counts within a census period, the probability of detecting yearly changes increases. To measure the status of seabird populations (i.e., direction and magnitude of population change), multiple counts of smaller land-based plots spread throughout the Cape Thompson colonies would provide greater statistical confidence in detecting changes than is possible using the established boat-based plot system (Lloyd 1975; Wanless et al. 1982; Hatch and Hatch 1988, 1989). One potential failure of this approach, of course, is the necessary assumption that sample plots are representative of the colony as a whole.

Here we describe the development and censusing of land-based plots at Cape Thompson. We also quantify behavioral and environmental sources of variation in attendance within years that affect the interpretation of population trend data.

2.2 Methods

2.2.1 Plot Counts and Attendance Patterns

2.2.1.1 Land-based Plots

Murres and kittiwakes were counted by establishing land-based census plots following Type II guidelines (Birkhead and Nettleship 1980), an approach that has been used successfully to monitor seabird populations in other areas (Gaston and Nettleship 1981; Wanless et al. 1982; Harris et al. 1983; Piatt and McLagan 1987; Hatch and Hatch 1988, 1989). We established 25 land-based plots in Colonies 2-5 (Table 2.1). Plots were not chosen randomly, but were instead based on their distribution within each colony, safe access for observers, natural features to facilitate counting, and the number of birds present. Plots 5-5J and 5-8N were equivalent to plots C5-L and C5-Q respectively, used by Swartz (1966) in 1960. All plots were photographed with a Polaroid 600 SE Professional Pack Film camera system, and plot boundaries were drawn on each instant photograph, which were then used by observers when counting the plots. Locator maps and photographs of plots, observation points, and approach routes are presented in Appendix C.

Between 8 July and 15 August, plots in Colonies 4 and 5 were counted 10-12 times and Colony 2 plots were counted 6 times. Plots in Colonies 4 and 5 were counted on the same days. Plots within Colony 2 were counted on same days also, but on different dates than Colonies 4 and 5. Counts of murres and kittiwakes present within plot boundaries were obtained by observers using binoculars and/or spotting scopes while in position at the observation points. After counting the total number of murres present, either Thick-billed or Common Murre numbers were determined. Kittiwakes were recorded as the numbers of single birds and pairs present, and the number of birds in a sitting posture (as an index of incubating birds) was also noted. Kittiwake nests were counted within plots on 8 or 10 July, and as chicks became evident the number of nests with chicks was recorded. Murres and kittiwakes that were transitory during counts (ie., landing or leaving) were not included. If birds flushed while counting, observers waited approximately 2-5 minutes before restarting.

Table 2.1. Distribution and designations of land-based census plots established at Cape Thompson, Alaska in 1988.

Colony	Plot Designation
1	None
2	2[a]-1[b]A[c], 2-2B, 2-3C
3	3-1A, 3-2B, 3-2C
4	4-1A, 4-1B, 4-2C, 4-3D, 4-4E
5	5-1A, 5-1B, 5-1C, 5-1D, 5-2E, 5-2F, 5-2G, 5-3H, 5-4I, 5-5J, 5-6K, 5-7L, 5-8M (kittiwakes only), 5-8N

[a] Denotes colony number.

[b] Observation point number within colony.

[c] Plot identifier.

2.1.1.2 Diurnal Variation in Attendance

Variation in murre counts attributable to diurnal attendance patterns was quantified by two methods, 24-hour plot counts and time-lapse photography. Murres on plot 4-1B were counted every 15 minutes for 24 hours on 22-23 July (during incubation) and on 16-17 August (during chick rearing). A 7 h interruption occurred during the second watch because of low light and poor weather conditions. All times reported are Alaska Daylight Time (ADT).

Two 8-mm format time lapse cameras (Minolta) in wood housings with plexiglass front plates were placed to view portions of plots 4-2C and 5-1D from 17 July to 28 August. Quartz driven wall clocks were positioned to be viewable in the frame, and intervalometers released the shutter and advanced the film every 4-5 minutes. Developed film was analyzed by counting the numbers of murres and kittiwakes in each countable frame.

2.1.1.3 Daily Attendance

Daily counts of murres and kittiwakes were performed on all plots in Colony 3, weather permitting, between 8 July and 28 August. Counts of these plots were shared among the four observers throughout the census period, providing a basis to test for any major differences among observers in census counts.

2.1.1.4 Individual Site Occupancy

The percentage of time that individuals spent at their breeding sites was calculated following Hatch and Hatch (1988, 1989). The occurrence of a single bird or pair was noted during each check of the individually monitored sites on phenology plots for murres and kittiwakes (see below). Maximum possible attendance was determined by multiplying the known number of nests or breeding sites by 2, and the percent attendance determined as a ratio of that total. These data provided estimates of site occupancy rates for both species of murres (breeders and nonbreeders combined) and for active and failed kittiwake breeders.

2.2.2 Breeding Phenology

Breeding phenology of murres and kittiwakes was monitored in selected areas of Colonies 4 and 5. Individual sites were marked on sketches or photographs and monitored throughout the study for clutch size, hatching and fledging dates, and chick or egg losses. Egg laying was nearly complete in all three species by the time we arrived, so monitoring began at late incubation or early chick-rearing stages. A chick was considered to have fledged if it survived to 15 days (murres) or 30 days (kittiwakes) before disappearing. Precise records of hatching and fledging dates were frequently prevented by poor weather conditions. Median hatching and fledging dates were calculated from dates known to within 48 h.

Murres and kittiwakes were collected by shotgun on their return to the cliffs from foraging trips. In addition to diet analysis and other measurements (Chapter 4), we assessed the birds' breeding condition by quantifying brood patch development following Swartz (1966). Swartz grouped brood patches into seven classes 0-6, with 0 and 6 being the complete absence of any patch and 3 the maximum development possible.

2.2.3 Environmental Data

Environmental conditions were recorded on most days during the study. Wind speed was estimated from sea surface conditions, and direction was estimated by general compass bearing. Ambient maximum and minimum temperatures were measured with a recording thermometer. The presence or absence of fog was noted, and cloud cover was estimated as the percent coverage of the sky. Sea surface temperatures were measured nearshore from boat, and swell height and direction were estimated.

2.2.4 Data Analysis

Results presented in the text are means ±1 SD unless otherwise specified. Simple statistical tests (i.e., some t-tests, Friedman's Test, runs tests, etc.) were done on a hand calculator following Sokal and Rohlf (1981). More complicated tests (ANOVA, multiple comparisons analysis, Spearman rank correlation coefficient) were performed using the SPSSx statistical package (SPSS, Inc. 1983). Unless specified otherwise, all correlations are Spearman rank correlation coefficients with two-tailed tests.

2.3 Results

2.3.1 Environmental Conditions

Weather conditions throughout the 1988 breeding season were variable, and days with fog, rain, or high winds were common (Fig. 2.1). Except for the first 2 weeks (1-13 July), which tended to be clear, the sky was frequently obscured (Fig. 2.2a). Prevailing winds were primarily southerly or northerly (Fig. 2.2b). Northerly winds occurred with significantly higher frequency in August (71%) than in July (34%) ($P<0.01$). Southerly winds were often associated with fog, rain storms, and high seas. Northerly winds tended to bring lower temperatures, and were sometimes of extremely high velocity (Fig. 2.2c). We recorded 6.4 cm of rainfall, but this was undoubtedly an underestimate, as most rainfall was associated with winds strong enough to prevent accurate collection by the rain gauge. We estimate that at least 15 cm fell during 13-26 July. These weather patterns were similar to those recorded by Allen and Weedfall (1966) between 1959-1961.

When we arrived in the area on 1 July, there was considerable sea ice up to 3 km offshore between Point Hope and Kivalina. This ice was pushed inshore on 14 July and was completely disintegrated by wave action by 17 July. This was the latest recorded occurrence of ice in the region since 1976 (Fig. 2.3). The mean surface seawater temperature was significantly lower when ice was present ($4.9 \pm 0.7°$ C, n=13) than after ($8.3 \pm 0.3°$ C, n=12) ($\underline{P}<0.001$) (Fig. 2.4).

2.3.2 Common and Thick-billed Murres

2.3.2.1 Breeding Phenology

We arrived at Cape Thompson during the mid-laying period of murres. Birds were still copulating during the first week of July, although many were

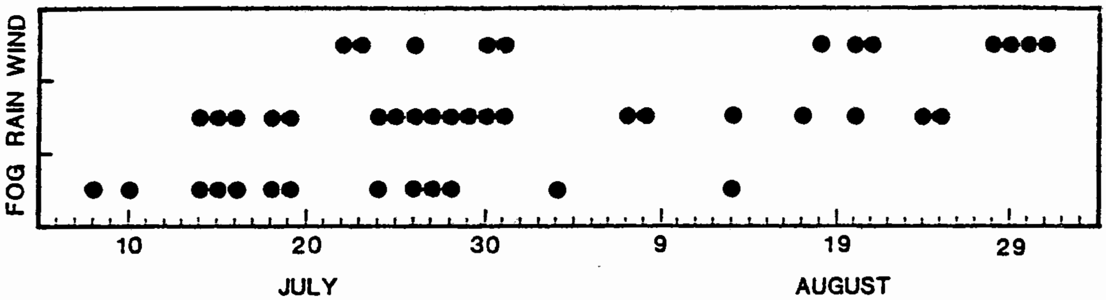

Figure 2.1. Daily occurrence of fog (reducing visibility to less than 0.25 km), measurable rainfall, and winds (above 50 km/h) at Cape Thompson from 8 July - 31 August 1988.

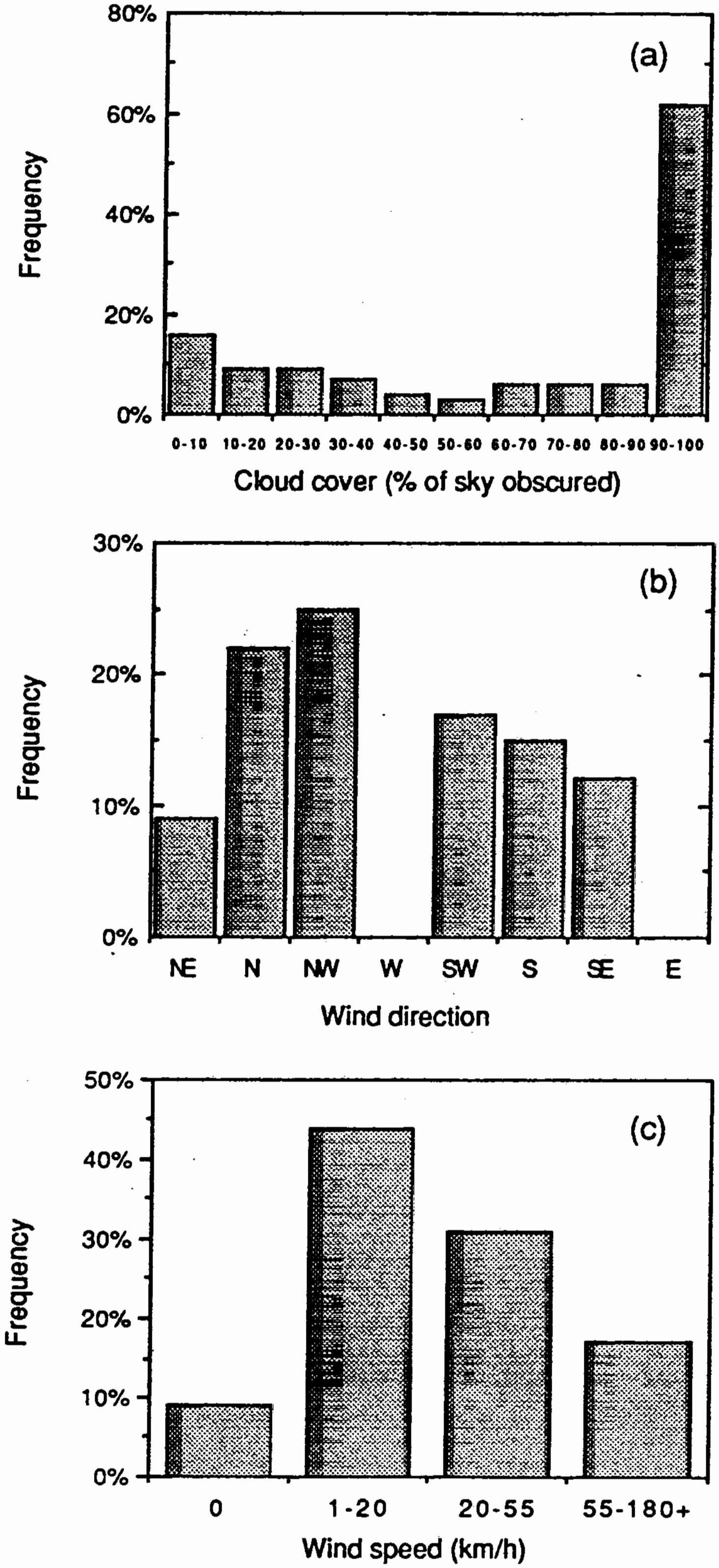

Figure 2.2. Weather patterns at Cape Thompson from 8 July - 31 August 1988. (a) Frequency of cloud cover. (b) Distribution of wind directions. (c) Distribution of wind speeds.

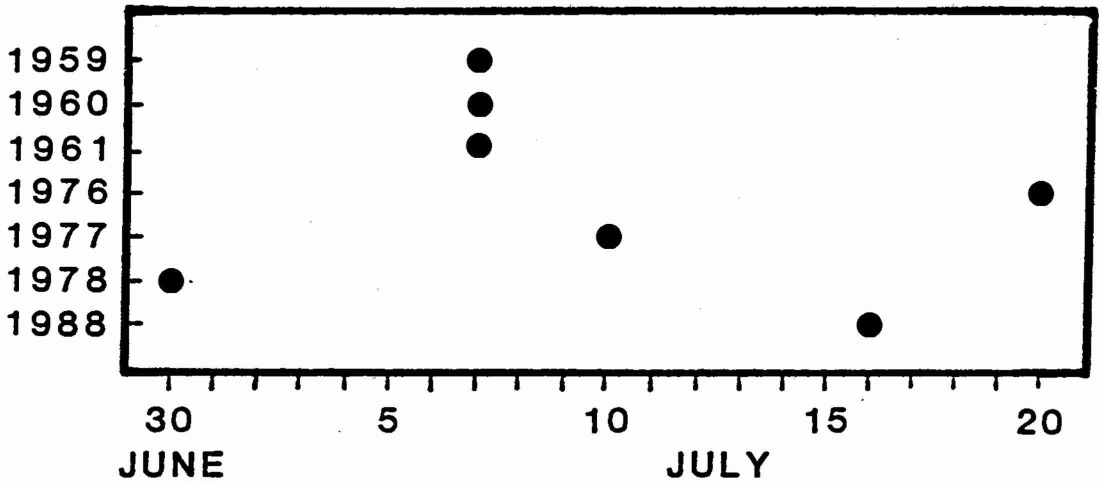

Figure 2.3. Dates of latest nearshore ice at Cape Thompson between 1959 and 1988 (1959-1961, Swartz; 1976-1977, Springer and Roseneau 1978).

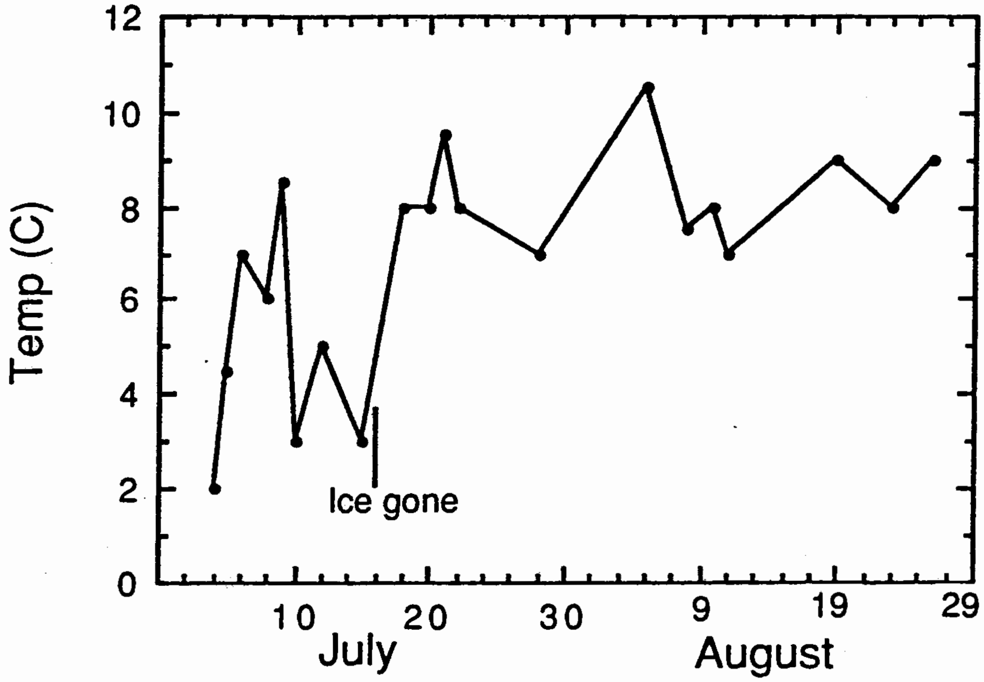

Figure 2.4. Surface seawater temperature measured at or near shore, Cape Thompson, 1988.

already sitting on eggs. On 8 July, a Common Murre was collected with a hard-shelled egg in the oviduct. The first Thick-billed Murre hatching was observed on 31 July, and a Common Murre chick was spotted on 4 August that had probably hatched between 1-2 August. Assuming a 33 d incubation period (Birkhead and Nettleship 1987; Piatt et al. 1988), first laying probably occurred about 29 June. Hatching was not highly synchronized; the overall hatching interval was at least 29 days (31 July - 28 August), and birds were still incubating on the day of our departure (31 August). We obtained 14 Common Murre hatching dates known to within 48 hours, about equally scattered throughout that hatching period. Thick-billed Murre hatching peaked between 7-9 August, and the median hatching date for both species combined was 10-12 August (Fig. 2.5a).

Sea-going chicks were first observed on 22 August (Thick-billed Murre) and 24 August (Common Murre), with a combined median fledging date of 24 August (Fig. 2.6b). This estimate may be somewhat earlier than the actual median fledging date, because many chicks we were monitoring were still alive on 31 August but had not yet fledged. However, a median fledging date of 24 August indicates a chick-rearing period of 25 days, similar to the duration observed at other colonies (21-25 days, Birkhead and Nettleship 1987; 24 days, Piatt et al. 1988)

Dates of first hatching and first fledging were near the midpoint of ranges described by data from 1959-1982 (Fig. 2.6). The timing of both events is positively correlated with the timing of the last presence of ice at Cape Thompson, but only the relationship for sea-going is significant (hatching dates: $r_s=0.47$, $P>0.1$, $n=9$; fledging dates: $r_s=0.83$, $P<0.01$, $n=8$).

Thick-billed Murres with fully developed brood patches were present throughout the sampling period, 6 July - 27 August, but average brood patch development regressed throughout the season (Fig. 2.7).

2.3.2.2 Attendance

There were no clear trends in daily attendance patterns of Thick-billed

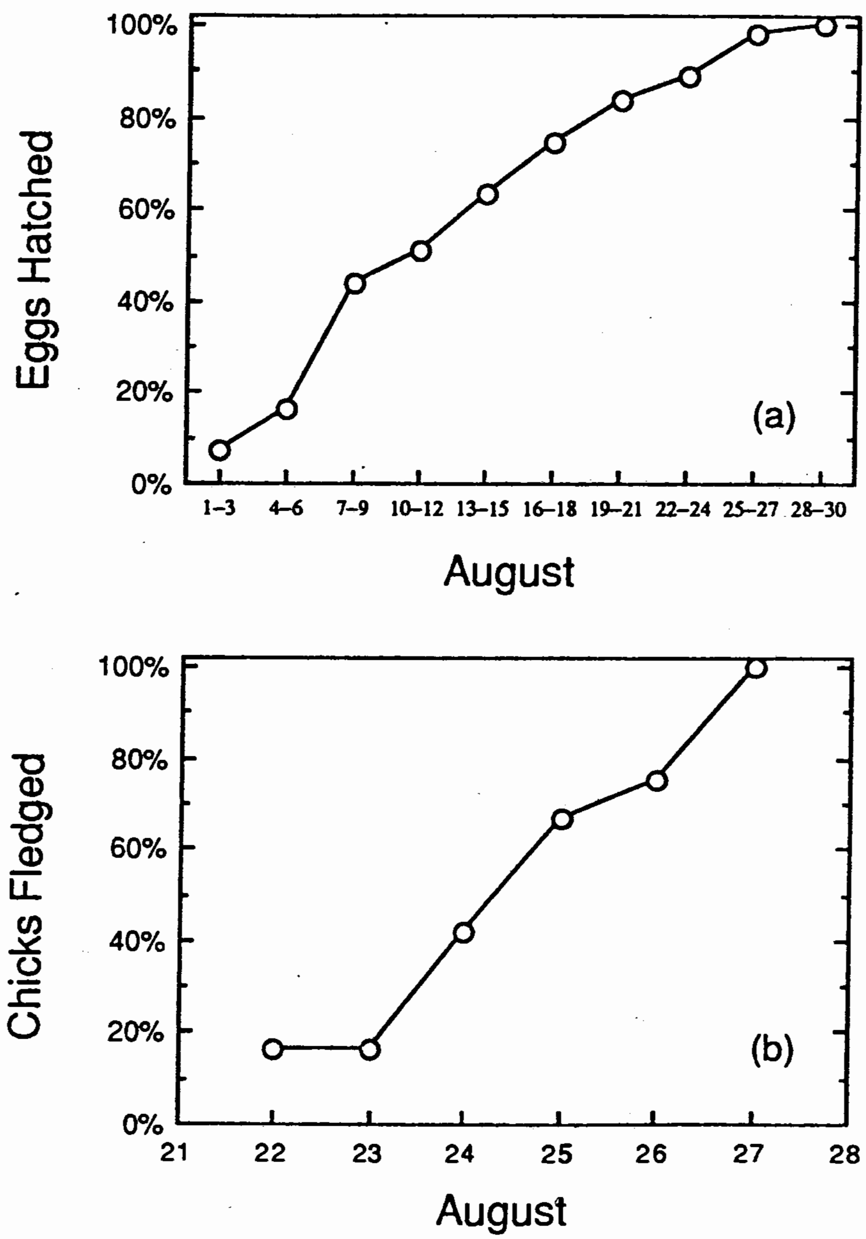

Figure 2.5. Breeding phenology of Thick-billed and Common Murres at Cape Thompson in 1988: (a) cumulative hatching frequency, (b) cumulative fledging frequency.

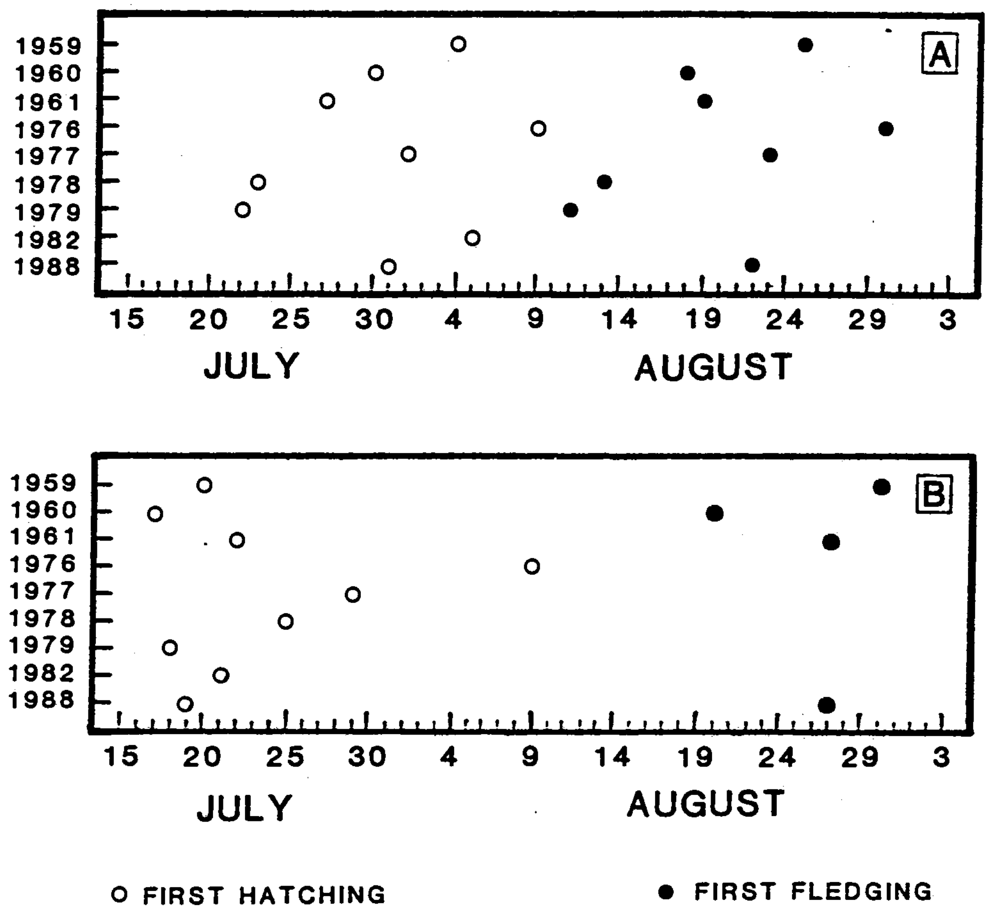

Figure 2.6. Dates of first observed hatching and fledging in (a) Common and Thick-billed Murres, and (b) Black-legged Kittiwakes at Cape Thompson (1959-1961, Swartz 1966; 1976-1982, Springer et al. 1985a).

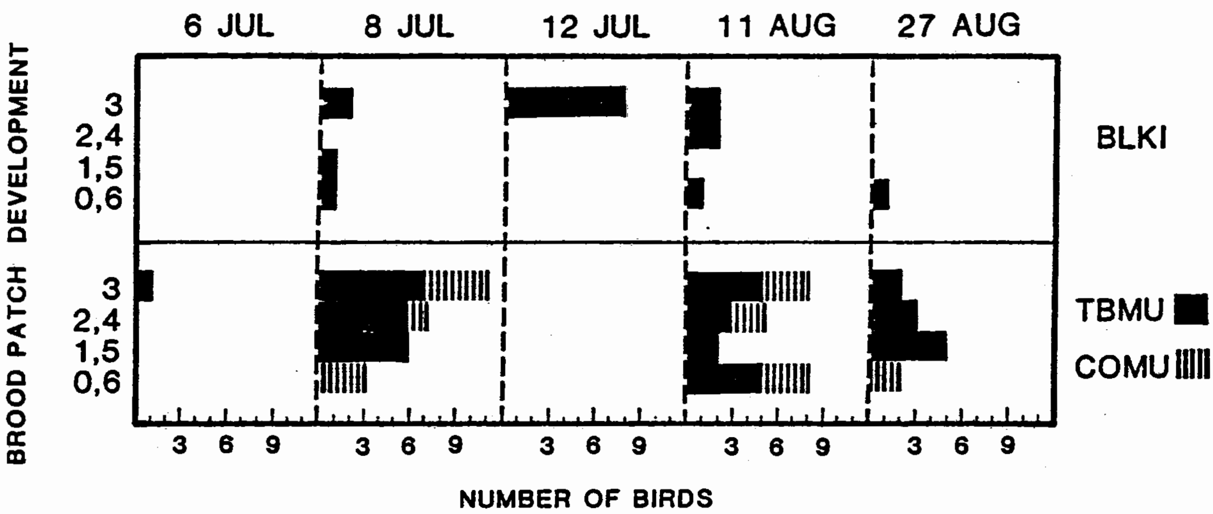

Figure 2.7. Brood patch development in murres and kittiwakes at Cape Thompson in 1988. Maximum development = 3, minimum = 0,6 (scale from Swartz 1966).

and Common Murres in Colony 3 through July and August (Fig. 2.8). The coefficient of variation (CV) in daily attendance was 18.8% until 22 August, and was 41.6% thereafter, coinciding with the beginning of chick fledging (Fig. 2.9). Thick-billed and Common Murre counts were significantly correlated (r_s=0.63, P<0.01, n=18). Variation in Common Murre attendance (CV=22%) was not significantly different than Thick-billed Murre variation (CV=19%; t_s=1.38, P>0.05), although variability in attendance in our C3 plots may not have been typical because of an apparently large proportion of non-breeders on the plots. Based on daily variation observed in Colony 3, census counts could have been conducted between 10 July-22 August, although censusing was completed this year on 15 August.

Diurnal attendance patterns from 24-hour counts exhibited peaks at about 2400 h and between 0900-1200 h on 22-23 July (mid-incubation), but only one apparent peak between 1100-1300 h on 15-16 Aug (mid-late chick-rearing) (Fig. 2.10). The CV's of incubation and chick-rearing period attendance patterns were similar, 6.1% and 6.9% respectively. Although absolute numbers attending were greater during the first count (incubation), the 19% difference between highest and lowest counts was slightly less than the difference during the chick-rearing stage (25%). Fluctuations in murre attendance during times when census plot counts were conducted (1330-2030) were relatively minor, with a CV of 4.5% in July and 3.7% in August.

The change of diurnal attendance to a single peak from a bimodal pattern was also evident in time-lapse film records of sections of plots 4-2C (Fig. 2.11) and 5-1D (Fig. 2.12). At both plots between 30 July and 3 August, however, there was essentially no variation in attendance during the day. Murre attendance was significantly correlated between the two plots between 10-15 August (Kendall's coefficient of concordance, X^2=4.57, P=0.033), but not between 17-22 July (X^2=1.47, P=0.23) or 30 July - 3 August (X^2=1.92, P=0.17).

Active breeders spent 50.3% of their time attending breeding sites (Table 2.2). There was no significant difference between the site occupancy rates of Thick-billed and Common Murres (t_s=0.596, P>0.05), nor did rates change throughout July or August.

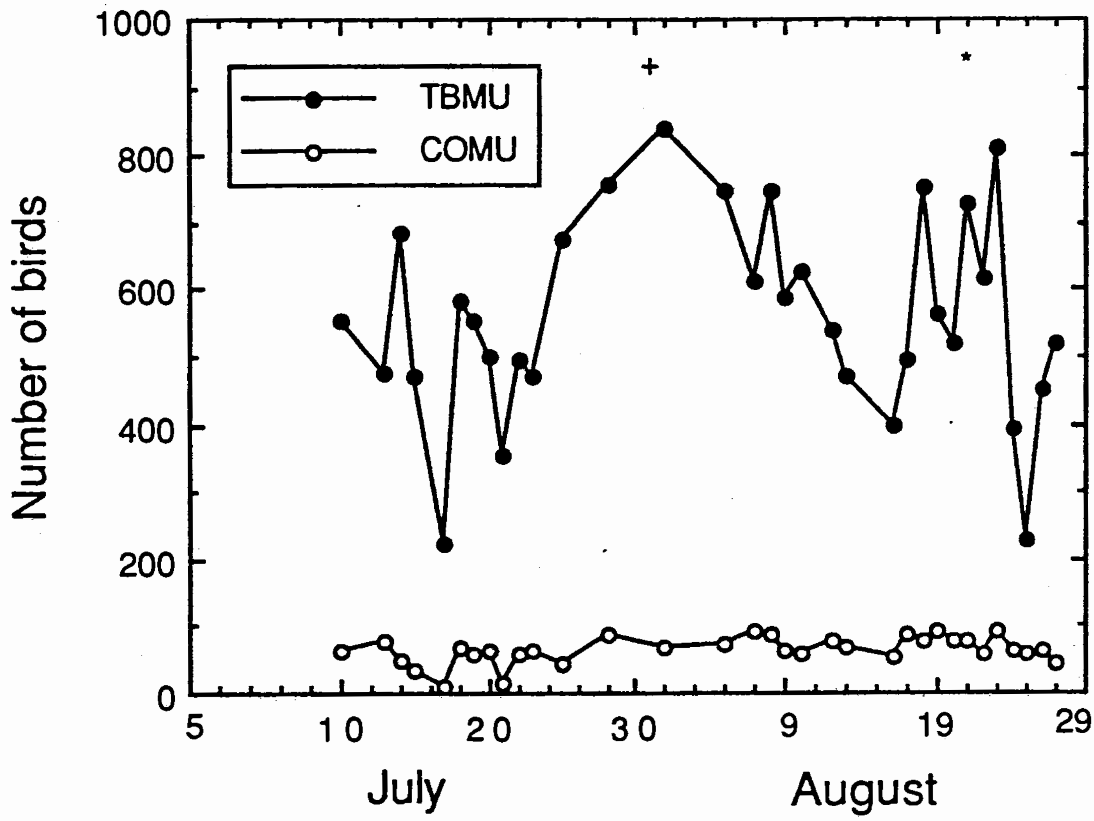

Figure 2.8. Daily murre attendance at Colony 3, Cape Thompson in 1988 (+ first hatching, * first fledging, TBMU = Thick-billed Murre, COMU = Common Murre).

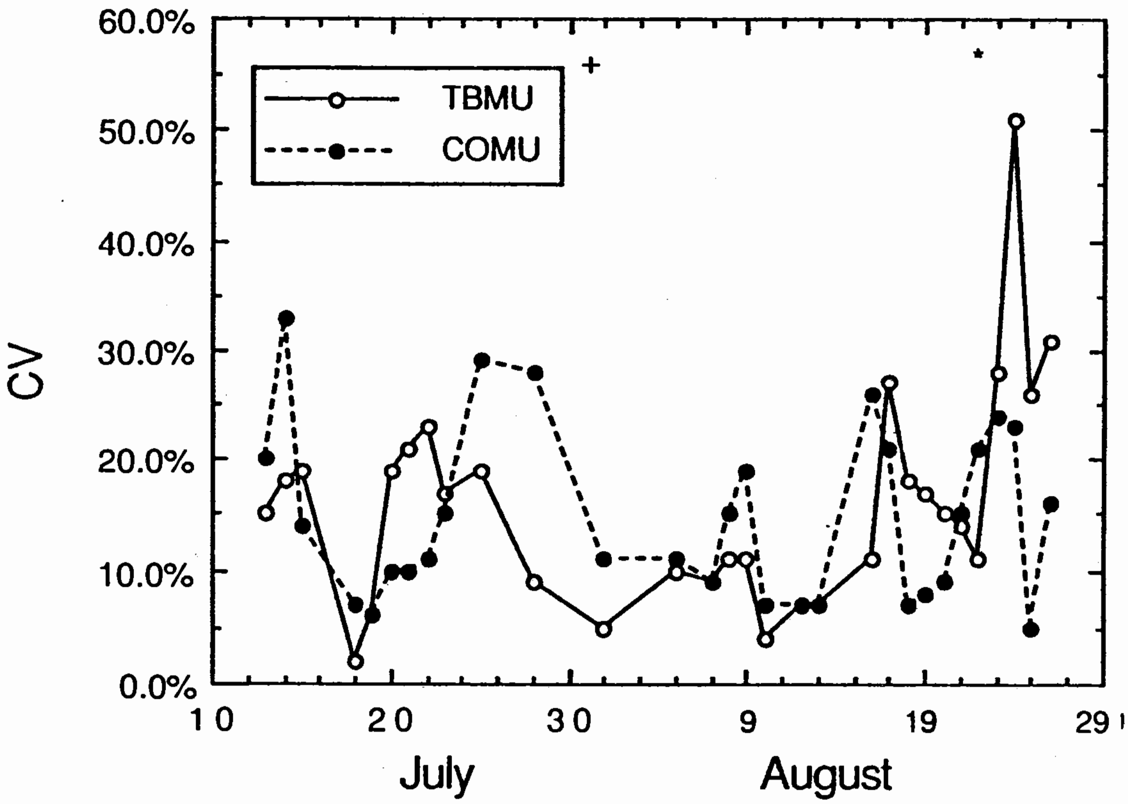

Figure 2.9. Coefficient of variation (CV) of daily murre attendance at Colony 3, Cape Thompson, calculated from 3-day running means (+ first hatching, * first fledging, TBMU = Thick-billed Murre, COMU = Common Murre).

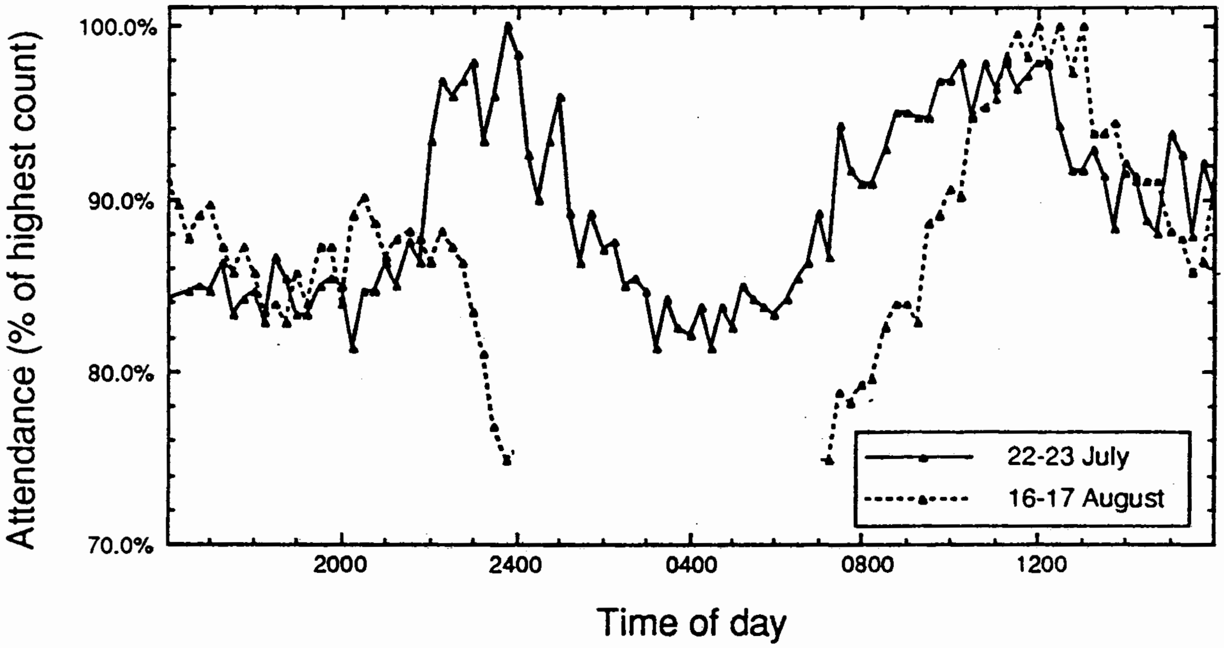

Figure 2.10. Diurnal attendance patterns of murres at plot 4-1B, Cape Thompson, 1988. No data for 2400-0700 on 16-17 August.

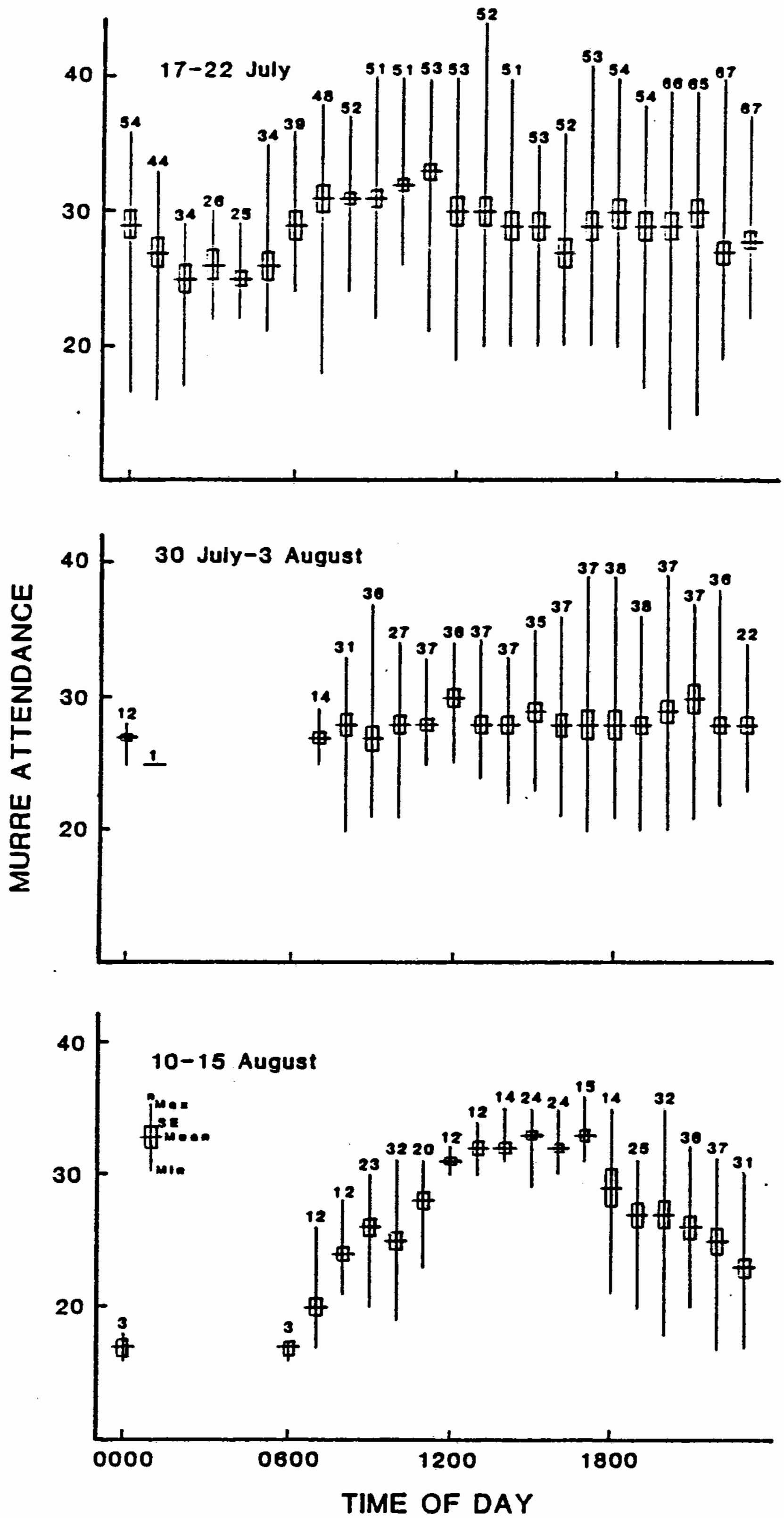

Figure 2.11. Diurnal patterns of murre attendance in a section of plot 4-2C, recorded by time-lapse photography.

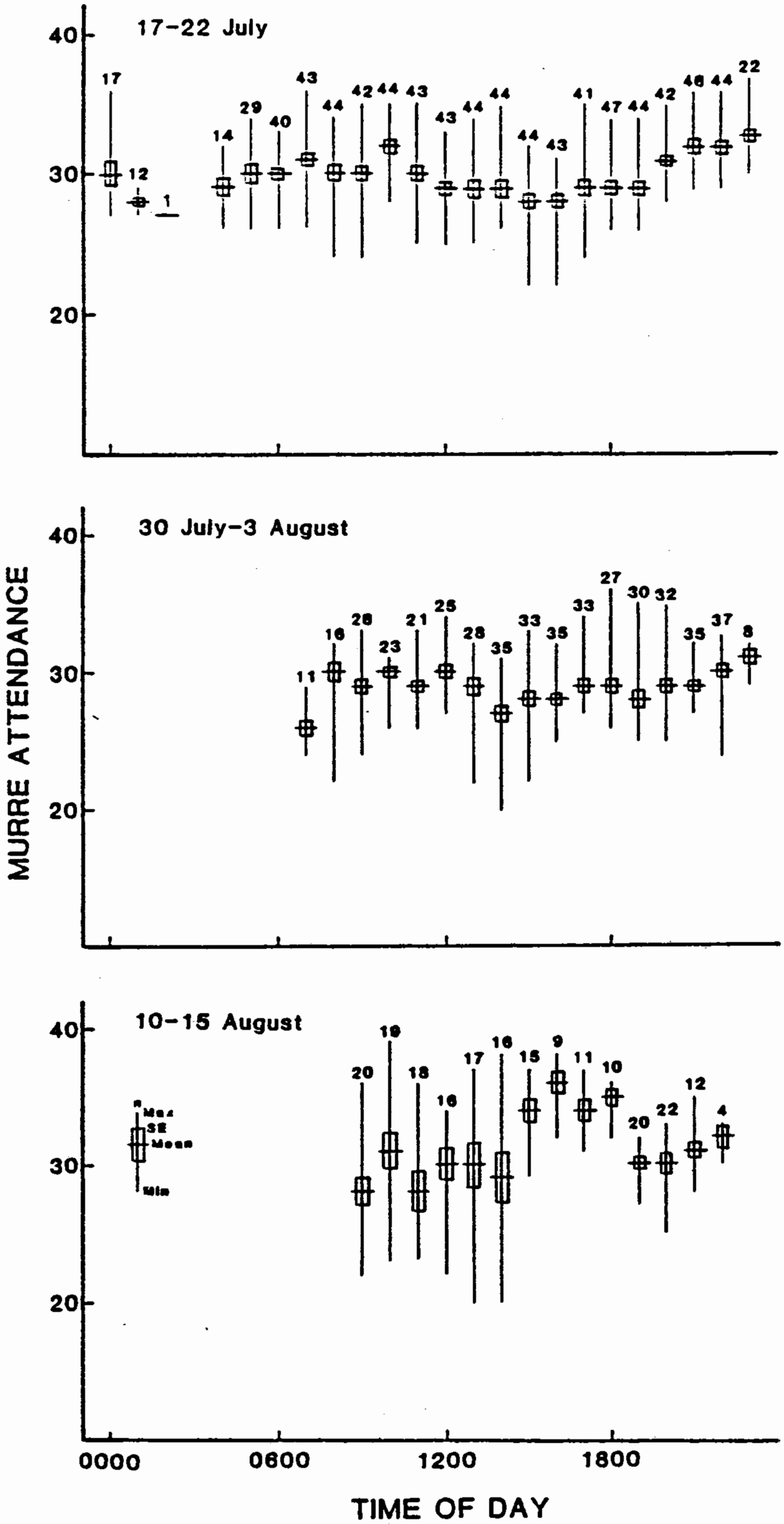

Figure 2.12. Diurnal patterns of murre attendance in a section of plot 5-1D, recorded by time-lapse photography.

Table 2.2. Mean site occupancy of Common (COMU) and Thick-billed (TBMU) murres at Cape Thompson during the 1988 census period.

Species	Attendance[a,b]	n[b]	%
COMU	198	384	51.6
TBMU	478	960	49.8
Both	676	1344	50.3

[a] Attendance of active breeders only (sites with an egg or chick).

[b] Attendance and n (sample size) expressed in bird-days.

There were no significant effects of wind direction, rain, fog, or maximum daily temperature on daily murre attendance in Colony 3. Attendance was significantly affected (ANOVA, $F_{2,8}$=9.574, P<0.01) by increasing wind speeds, which resulted in lower counts. Wind speed accounted for 44% of the variation in daily attendance.

2.3.2.3 Plot Counts for Population Monitoring

Newly established land-based plots for murres were counted between the late-laying/early incubation period and first chick-fledging (Fig. 2.13). Plots ranged in size from 25-1047 mean adult murres present (Tables 2.3-2.7). The mean daily total for all plots was 6099 Thick-billed and 709 Common Murres. Coefficients of variation of plot counts ranged from 6%-25%. Raw counts, dates, and times of each count are tabulated in Appendix D.

There was no serial dependence among census counts (runs test; Sokal and Rohlf 1981) except for plot 5-1C, and counts among plots in Colonies 4 and 5 fluctuated synchronously (Friedman's two-way ANOVA, X^2=148.7, P<0.001). Within Colony 4, 7 (70%) of 10 pairwise correlations of plot counts were significant (P<0.05) and correlations among plots were fairly strong (r_s=0.5882 ± 0.2100, n=10). However, there was no clear relationship between the degree of correlation and distance or degree of visual contact between plots (cf. Piatt and McLagan 1987, Hatch and Hatch 1989). For example, counts at two adjacent plots (4-1A, 4-1B) were not correlated (r_s=0.25, P>0.10, n=11), yet the two most distant plots in Colony 4, completely separated by cliffs and hills (4-2C, 4-4E), were significantly correlated (r_s=0.70, P<0.01, n=11). In Colony 5, daily attendance was significantly correlated in 48 (62%) of 78 pairwise plot comparisons, again with no apparent effects of distance or visual contact between plots. Correlations between plots within apparent visual range (r_s=0.55 ± 0.37, n=13) were not significantly different from plots without visual contact (r_s=0.58 ± 0.22, n=65). Also, as in Colony 4, there were significant correlations between distant plots (5-1A, 5-8N) separated by 0.5 km (r_s=0.55, P<0.05, n=11). Some adjacent plots were correlated (e.g., 5-2F and 5-2G; r_s=0.96, P<0.001, n=10) and others were not (e.g., 5-1A and 5-1B; r_s=0.35, P>0.10, n=11). Daily attendance was significantly correlated in

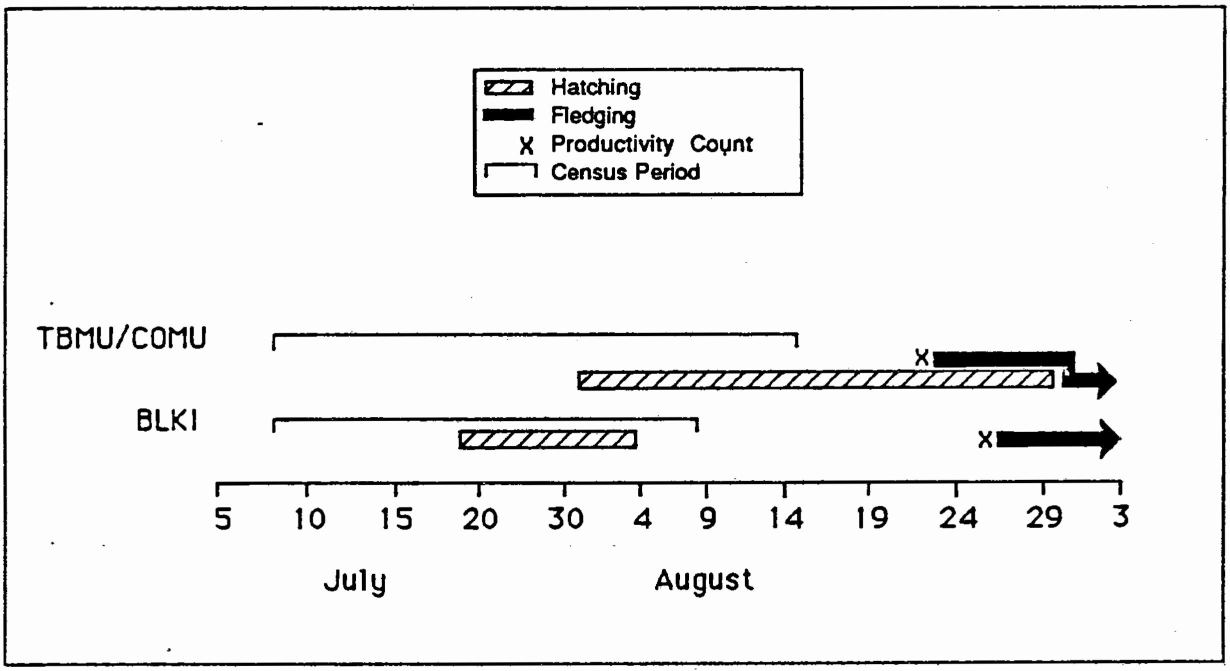

Figure 2.13. Breeding phenology and timing of census and productivity checks at Cape Thompson, 1988.

Table 2.3. Murre and kittiwake numbers on land-based plots at Colony 2, Cape Thompson, 12 July - 10 August 1988.

	Thick-billed Murre			Common Murre			Black-legged Kittiwake			
Plot	Mean	SD	n	Mean	SD	n	Mean	SD	n	Nests
2-1A	150	51	6	201	49	6	20	3	6	21
2-2B	36	15	6	265	47	6	9	1	5	8
2-3C	232	20	6	39	7	6	17	1	5	16

Table 2.4. Murre and kittiwake numbers on land-based plots at Colony 3, Cape Thompson, 10 July - 15 August (murres) and 10 July - 8 August (kittiwakes), 1988.

	Thick-billed Murre			Common Murre			Black-legged Kittiwake			
Plot	Mean	SD	n	Mean	SD	n	Mean	SD	n	Nests
3-1A	130	35	27	9	4	27	6	1	21	5
3-2B	413	101	20	55	17	20	53	8	18	50
3-2C	51	13	23	0	0	23	4	2	19	4

Table 2.5. Murre and kittiwake numbers on land-based plots at Colony 4, Cape Thompson, 8 July - 15 August (murres) and 8 July - 8 August (kittiwakes), 1988.

	Thick-billed Murre			Common Murre			Black-legged Kittiwake			
Plot	Mean	SD	n	Mean	SD	n	Mean	SD	n	Nests
4-1A	199	31	12	92	24	12	46	5	10	41
4-1B	146	34	12	82	17	12	34	12	10	30
4-2C	210	76	12	171	55	12	201	20	10	175
4-3D	103	27	11	43	15	11	44	6	9	41
4-4E	39	16	11	232	59	11	205	16	9	176

Table 2.6. Murre and kittiwake numbers on land-based plots at Colony 5, Cape Thompson, 11 July - 15 August (murres) and 11 July - 8 August (kittiwakes), 1988.

	Thick-billed Murre			Common Murre			Black-legged Kittiwake			
Plot	Mean	SD	n	Mean	SD	n	Mean	SD	n	Nests
5-1A	31	7	11	1	1	11	32	5	9	28
5-1B	211	28	11	219	46	11	152	11	9	136
5-1C	24	4	11	1	1	11	12	2	9	10
5-1D	183	23	11	7	2	11	0	0	9	0
5-2E	298	33	11	33	10	11	90	11	8	91
5-2F	403	54	11	1	2	11	3	1	9	4
5-2G	276	37	10	11	2	10	0	0	9	0
5-3H	245	31	11	0	1	11	0	0	9	0
5-4I	104	14	10	0	0	10	0	0	9	0
5-5J	898	141	10	23	13	10	91	6	8	88
5-6K	561	72	10	7	4	10	6	1	8	7
5-7L	319	33	10	93	16	10	2	2	8	0
5-8M	-	-	-	-	-	-	102	16	8	82
5-8N	837	110	10	19	11	10	31	4	9	32

Table 2.7. Murre numbers on productivity subplots at Colony 5, Cape Thompson, 20 July - 15 August 1988.

	Thick-billed Murre			Common Murre		
Plot	Mean	SD	n	Mean	SD	n
5-2F'	115	8	9	0	0	9
5-3H'	149	44	8	0	0	9
5-6K'	175	23	7	3	2	7
5-7L'	199	18	9	16	4	9
5-8N'	247	20	9	0	0	9

27 (42%) of 65 pairwise comparisons of plots from Colony 4 and Colony 5. The mean coefficient of correlation between attendance on C4 and C5 was 0.50 ± 0.19 (n=60).

The effect of plot size on the CV of murre counts was weakly negative and nonsignificant (Fig. 2.14). There were no significant differences among individual observer means for Colony 3 plots (ANOVA, $F_{3,26}$=0.169, P>0.05), although only large observer differences would be detected against the observed background of daily variation.

2.3.3 Black-legged Kittiwakes

2.3.3.1 Breeding Phenology

Bad weather prevented us knowing the date of first hatching precisely, but it occurred sometime between monitoring checks on 18 and 21 July. Hatching in kittiwakes was more synchronous than it was in murres; 47% hatched by 21 July, 91% by 28 July, and the last hatching was observed on 4 August, for a total hatching interval of 16 days. Assuming an incubation period of 26-27 days (Coulson and White 1958, Piatt et al. 1988), first laying occurred between 21-24 June. All kittiwakes collected on 12 July had fully developed brood patches.

Dates of first observed hatching at Cape Thompson have ranged from 17 July through 9 August (Fig. 2.6). Although the date of first hatching in 1988 was among the earliest of the years studied, the date of first fledging was near the middle of the range (Fig. 2.6). No fledged chicks were seen before 28 August. Bad weather prevented further observations until 31 August, when the first fledged chicks were observed. However, a fledged chick appeared on a frame of time-lapse film on 27 August, indicating an approximate chick-rearing period of 30-39 days, within the range (34-41 days) reported by Swartz (1966) for Cape Thompson between 1959-1961. First hatching and first fledging dates tend to be later in years with late ice at Cape Thompson, but neither correlation is significant (r_s=0.38, P>0.10, n=9 years; r_s=0.77, P>0.10, n=4 years, respectively).

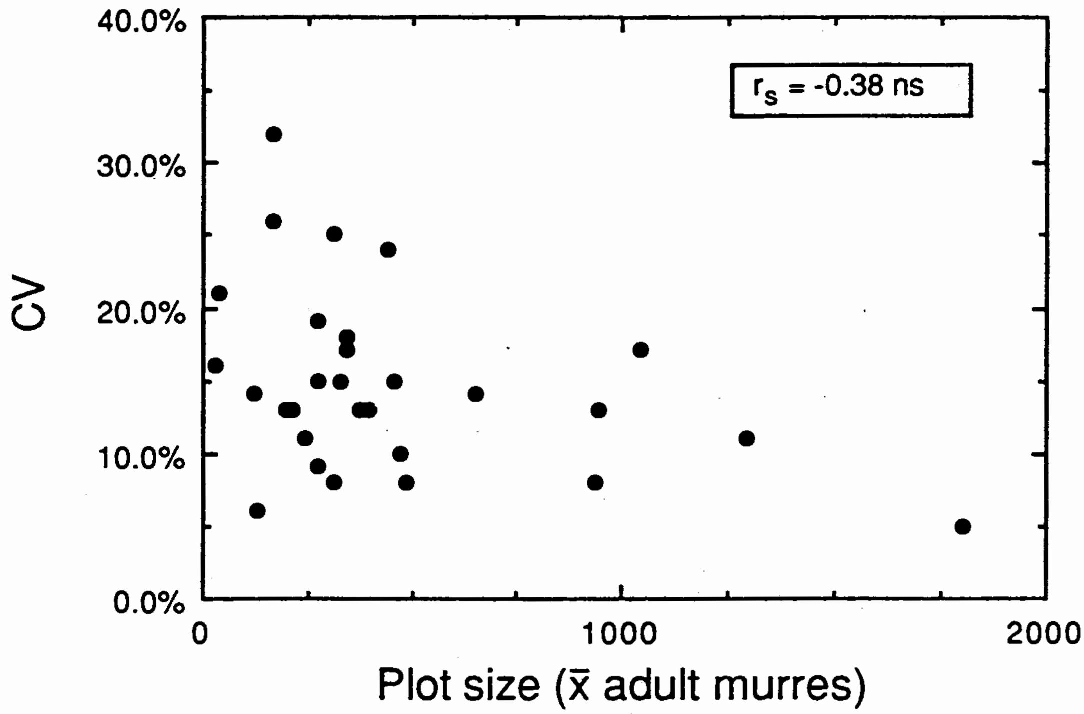

Figure 2.14. Relationship between plot size (based on census mean) and CV of murre census counts on land-based census plots, Cape Thompson, 1988.

The dates of first observed hatching in murres and kittiwakes are positively but nonsignificantly correlated in 9 years from 1959 through 1988 (r_s=0.42, P>0.05), as are the dates of first observed fledging in 4 years (r_s=0.80, P>0.05).

2.3.3.2 Attendance

Adult kittiwake attendance on Colony 3 plots averaged 62 ± 8 birds until 5 August, when numbers declined precipitously (Fig. 2.15a). This drop coincided with the decreasing proportion of sitters, and a decrease in nest site attendance (see below). The CV of daily counts in Colony 3 between 10 July and 8 August was 12.6%. It increased to 38.3% between 9-27 August (Fig. 2.15b). The number of adults in an incubating posture was highest from 11-16 July. Kittiwake attendance was not correlated with Thick-billed or Common Murre attendance (r_s=-0.09, P>0.05, n=18; r_s=-0.11, P>0.05, n=18, respectively).

Active breeders did not spend significantly more time on nests than failed breeders before the latest observed hatching date, 4 August (Table 2.8). However, attendance patterns changed through the breeding season (Fig. 2.16). Attendance by active breeders and failed breeders varied more, and there was an overall 32% decrease in nest attendance, after 4 August (Table 2.8). However, only breeders spent significantly less time on nests after 4 August (t_s=8.69, P<0.001). Breeders also spent significantly less time at nests than failed breeders. Attendance of breeders was negatively correlated with date after 4 August, decreasing at the rate of 1% per day (r=-0.76, P<0.01), but leveled off at 22% about 20 days after the first chick hatched (Fig. 2.17).

Diurnal attendance patterns of kittiwakes were not discernible from time-lapse films due to a small sample size of observable nests (n=7). None of the weather variables we measured had a significant effect on daily kittiwake attendance in Colony 3.

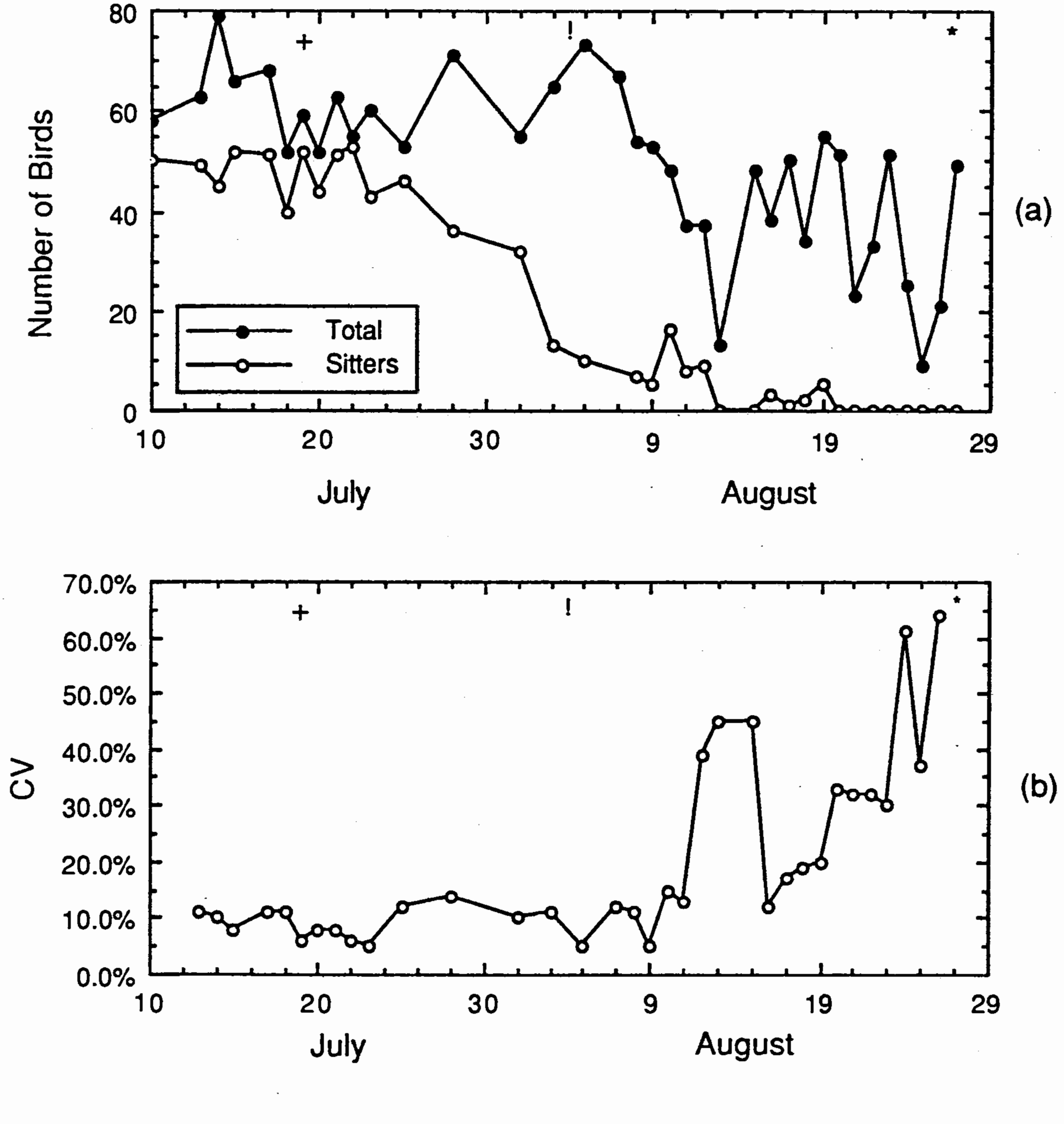

Figure 2.15. Counts of Black-legged Kittiwakes at Colony 3, Cape Thompson, 1988. (a) Daily attendance, 10 July - 28 August, (b) Coefficient of variation (CV) of daily attendance counts calculated from 3-day running means (+ first hatching; ! last hatching; * first fledging).

Table 2.8. Nest attendance of Black-legged Kittiwakes at Cape Thompson during the 1988 nesting season.

Status of pair	Before 4 August[a]				After 4 August				Overall		
	Attendance[b]	n	%	CV	Attendance	n	%	CV	Attendance	n	%
Active[c]	143	274	52.7	11.8	149	558	26.8	37.7	186	364	51.1
Failed[d]	36	80	44.7	1.3	79	136	38.6	45.7	44	100	44.0

[a] 4 August was end of hatching period.

[b] Attendance and n (sample size) expressed in bird-days.

[c] Pairs with nests containing eggs or chicks.

[d] Attendance after loss of eggs or chicks.

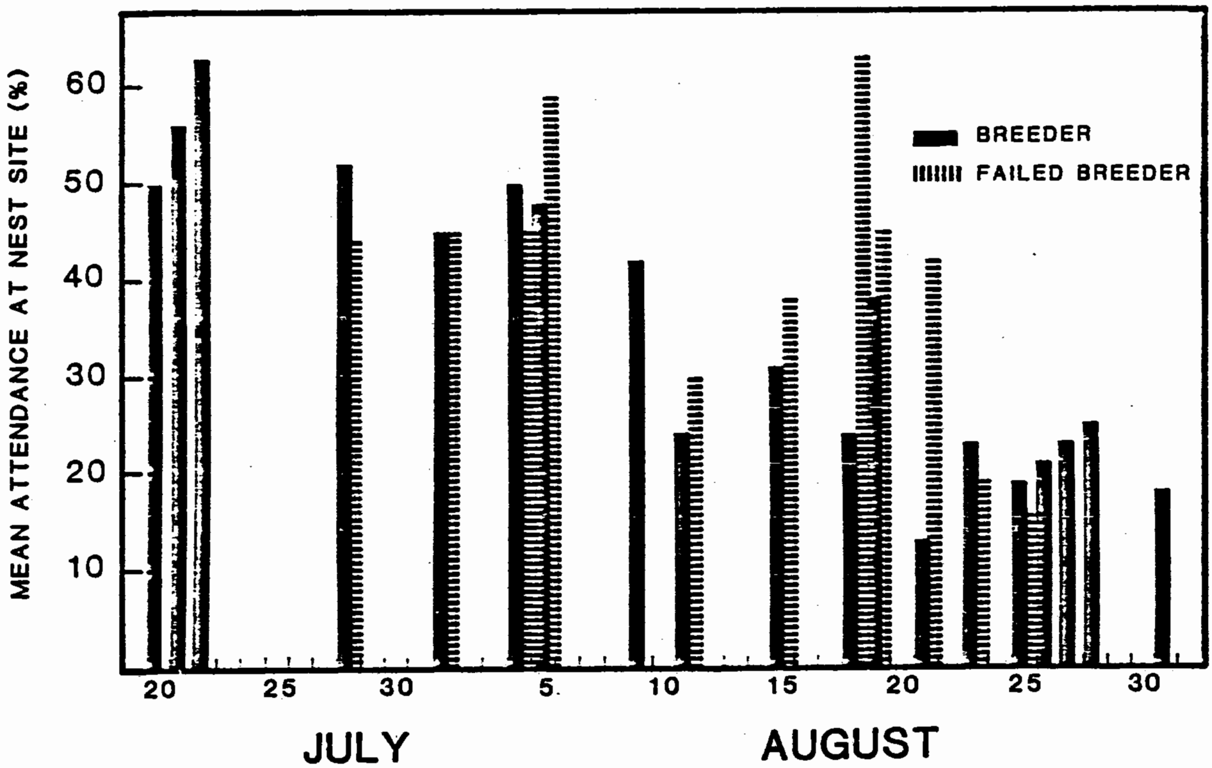

Figure 2.16. Kittiwake nest site attendance on phenology sites at Cape Thompson, 1988. Two birds in every site would constitute 100% attendance.

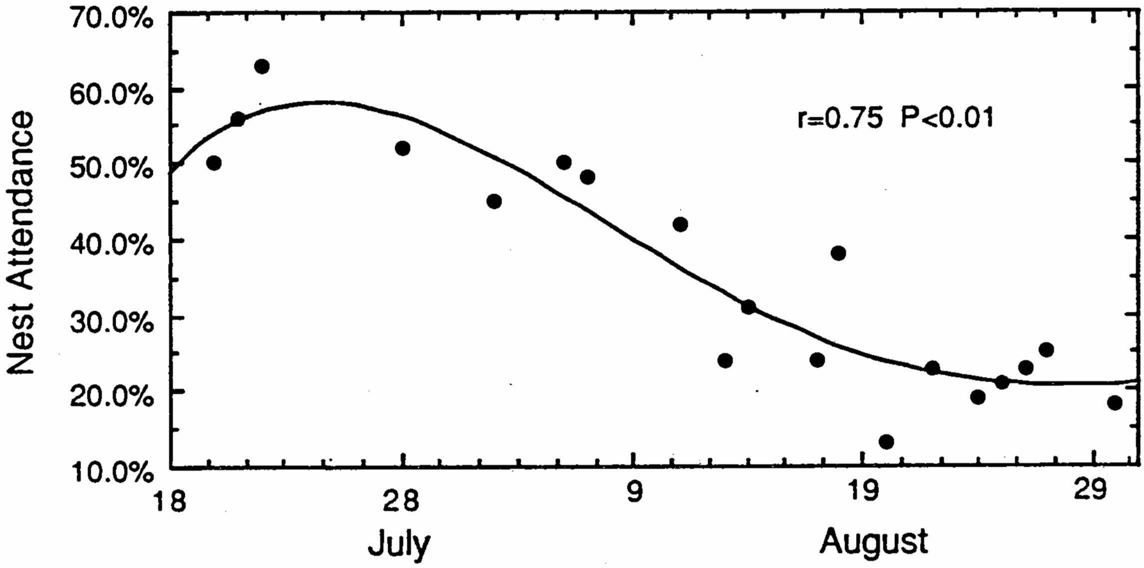

Figure 2.17. Nest site attendance of actively breeding kittiwakes at Cape Thompson, 1988. Two birds in every site would constitute 100% attendance.

2.3.3.3 Plot Counts for Population Monitoring

Adult kittiwakes were censused from late incubation until a few days after last hatching (Fig. 2.13). Census plots contained between 4-205 adult kittiwakes (Tables 2.3-2.7), with a mean total of 1160 individuals present. CV's for kittiwake plot counts ranged from 4%-42%. Raw count data are tabulated in Appendix E.

Counts of C4 and C5 plots varied synchronously during the census period (Friedman two-way ANOVA, X^2=80.81, P<0.001). However, attendance was significantly correlated in only 6 (15%) of 40 comparisons of C4 and C5 plots. Thirteen (33%) of the 40 coefficients were negative. Only 2 (20%) of 10 pairwise correlations of plot counts were significantly correlated within Colony 4, and only 3 (11%) of 28 correlations were significant within Colony 5. Within Colony 2, attendance was significantly correlated only between plots 2-2B and 2-3C (r_s=0.89, P<0.01, n=6).

A count of kittiwake nests made at the outset of the study was significantly correlated with the census mean of adults (Fig. 2.18). There were no significant differences between observer means of kittiwake counts on C3 plots (ANOVA, $F_{3,26}$=0.312, P>0.05).

2.4 Discussion

2.4.1 Common and Thick-billed Murres

2.4.1.1 Breeding Phenology

Although they may not always represent the breeding phenology of a colony adequately, dates of first hatching or first fledging have been observed in several years at Cape Thompson. Delays in breeding are evident during years of late ice, as was noted by Springer et al. (1985b). Correlations between late ice years and delayed breeding have also been reported from other murre colonies at high latitudes (Tuck 1961, Nettleship et al. 1984, Springer et al. 1984, Birkhead and Nettleship 1987).

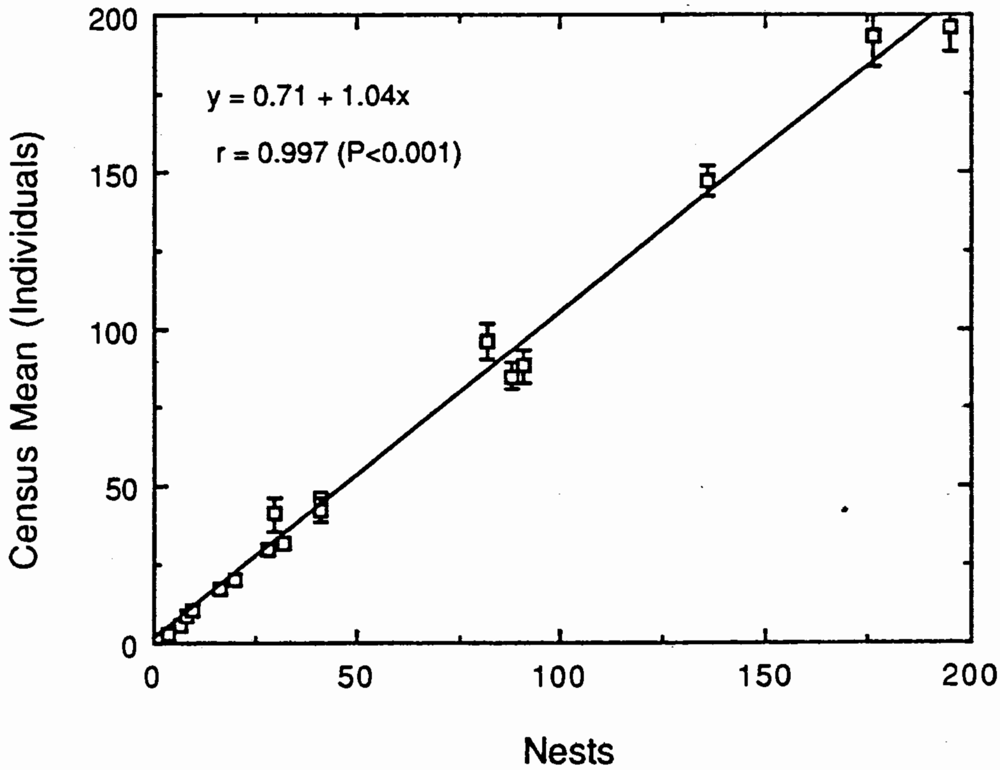

Figure 2.18. Relationship between kittiwake nest counts (8-10 July) and census mean of individuals for land-based census plots at Cape Thompson, 1988. Error bars are ± 1 SE if wider than symbol.

The influence of ice conditions or other environmental factors has resulted in an 18-day range of first hatching dates at Cape Thompson since 1960. Given a mean incubation period of 33 days (Harris and Birkhead 1985), the first laying date has ranged from 20 June to 8 July. However, because there is approximately a 40-day range of acceptable days for plot counts, this site can be readily incorporated into a Bering/Chukchi monitoring program such as proposed by Piatt et al. (1988). If more intensive studies were planned for Cape Thompson (such as Type I studies; Birkhead and Nettleship 1980), they would have to begin by about 15 June.

2.4.1.2 Diurnal Variation in Attendance

Diurnal attendance patterns for murres were fairly typical for Cape Thompson and other Alaskan colonies (Swartz 1966, Drury 1978, Springer and Roseneau 1978, Murphy et al. 1980, Piatt et al. 1988, Hatch and Hatch 1989). Diurnal attendance cycles observed by Swartz (1966) between 30 August - 1 September 1959 were generally similar to the pattern on 16-17 August 1988, but with a peak in attendance occurring between 0900-1100 h (time standard, if different from ADT, unknown). Activity patterns observed by Springer and Roseneau (1978) on 27 July 1976, 18 August 1976, and 26 July 1977 were bimodal, with a peak occurring between 0800-1300 h and another between 2300-0100 h (ADT). In a series of 24-hour counts throughout the census period in 1979, Murphy et al. (1980) found morning and evening peaks, but the hours at which they occurred shifted through the season. They also found that different colonies of the Cape Thompson complex were out of phase with respect to their diurnal cycles. A change of attendance patterns during the breeding season may account for differences between the two 24-hour watches conducted in 1988; seasonal shifts are also evident in our time-lapse data. Furthermore, attendance patterns were only correlated between the Colony 4 and Colony 5 plots between 10-15 August, not between 17-22 July or between 30 July - 3 August. Thus, as Murphy et al. (1980) suggest, it would be inappropriate to correct plot counts for diurnal variation based on only one or a few observations of the cycle. Rather, plot counts should be accomplished during periods of the day when numbers fluctuate least. Observed diurnal patterns at Cape Thompson indicate that variation in attendance is least from about 1300-2000 h.

2.4.1.3 Daily Variation in Attendance

An appropriate census period based on the daily attendance patterns of murres extended at least from mid-egg-laying (ca. 13 July) to early fledging (ca. 22 August) at Cape Thompson in 1988. This censusing window has also been determined for the Semidi Islands (Hatch and Hatch 1989) and Saint Lawrence Island (Piatt et al. 1988), but is somewhat longer than that originally proposed by Birkhead and Nettleship (1980). The apparent decrease in murre attendance coinciding with fledging is typical for murre colonies in general (Gaston and Nettleship 1981, 1982; Piatt and McLagan 1987; Hatch and Hatch 1989).

2.4.1.4 Individual Site Occupancy

The time an adult murre allocates to attendance at its breeding site influences the results of plot counts. Thus, estimating site occupancy rates helps to interpret annual variation in numbers (Hatch and Hatch 1989). Site occupancy by actively breeding Common Murres (51.6%) was somewhat less at Cape Thompson in 1988 than in the Semidi Islands between 1979-1981 (58.4%-60.3%) (Hatch and Hatch 1989). Thick-billed Murres also spent less time attending breeding sites at Cape Thompson (49.8%) than at the Semidi Islands (55.3%-56.8%). It is likely that differences in food availability account for the differences in colony attendance. More work is needed to test this potentially useful index of foraging conditions, but whatever their cause, differences in site occupancy rates among years contribute to observed annual variation in mean plot counts.

2.4.1.5 Environmental Effects on Attendance

Murre attendance has been correlated with tidal cycles (Slater 1976) and various weather conditions (Gaston and Nettleship 1981, Piatt et al. 1988, Hatch and Hatch 1989). Both Piatt et al. (1988) and Hatch and Hatch (1989) found significant negative correlations between wind speed and murre counts, although on the Semidi Islands the effect was negligible during the census period (Hatch and Hatch 1989). Piatt and McLagan (1987) found no effect of wind speed at Cape St. Mary's, Newfoundland, and Gaston and Nettleship (1981) observed an effect only during extreme conditions. Wind effects at Cape Thompson may have been exaggerated because of the relatively large proportion of nonbreeders on Colony 3 plots where the effects were studied. At face value, our results suggest counts should be made when winds are below 15-20 kts, which was true about 80% of the time during the census period at Cape Thompson in 1988.

2.4.2 Black-legged Kittiwakes

2.4.3.1 Breeding Phenology

The wide spread of first hatching dates in kittiwakes (24 days) in the years since 1960 apparently is not a reflection of early and late ice years. Changes in breeding phenology are predictably associated with changes in breeding success, however (Chapter 3). The observed annual variation in breeding times should present no major problems in integrating Cape Thompson into a Bering/Chukchi regional monitoring program. An acceptable census period for kittiwakes begins as early as first laying and lasts about 50 days, or until the last eggs have hatched (Hatch and Hatch 1988). First laying has occurred between 20 June and 13 July in 9 years from 1960-1988 at Cape Thompson. The census period (first egg to final hatching) has generally lasted 46-50 days.

2.4.2.2 Daily Variation in Attendance

Once hatching was complete, abrupt changes in daily attendance patterns and a decrease in the average number of kittiwakes present signaled an end to the acceptable census period this year at Cape Thompson. During the census period, the CV of kittiwake attendance was less than that of both murre species, perhaps because nonbreeders and off-duty mates were apparently not loitering within our census plots. Kittiwakes were not responding to the same environmental cues as murres, because there was no correlation between kittiwake and murre attendance patterns.

2.4.2.3 Individual Site Occupancy

The decrease in time allocated to nest site attendance by kittiwakes completely explains the decrease in daily attendance counts after 4 August. The same numbers of individuals were still visiting the colony, but they were spending less time at their nest sites. Reduced site occupancy by breeders may be explained by their need to increase foraging time (assuming foraging success remained constant) to meet the energy requirements of the growing chick. After a kittiwake chick is about 20 days old, growth slows and its energy requirements maintain a relatively constant level (Coulson and Porter 1985). On average, breeding kittiwakes reduced the amount of time allocated to nest attendance to 22%, but no further, when the first chicks were about 20 days old (Fig. 2.17). This would imply either that chick feeding requirements were being met, or that adults will not reduce their parental attendance beyond this minimal level even when foraging conditions are poor. Since the male and female rarely spent time with the chick simultaneously, doubling the observed site occupancy rates provides an estimate of the percentage of time a chick was attended. Up to the age of 20 days, attendance at the nest by at least one parent was essentially 100%. Between chick ages 21-30 days it declined to 58% and was only 44% for chicks older than 30 days. Roberts (1988) also observed decreases in nest attendance throughout chick-rearing at Middleton Island in the Gulf of Alaska, but this pattern is not reported from some North Atlantic colonies, where kittiwakes normally maintain 100% nest attendance through most of the nestling period (Pearson 1968, Hodges 1969, Wooller 1979). Temporary abandonment of chicks presumably results from poor foraging conditions (Galbraith 1983, Roberts 1988) and is probably a good predictor of poor growth rates and survival of young (Barrett and Runde 1980).

2.4.2.4 Environmental Effects on Attendance

We found no effects of measured weather variables on kittiwake attendance, but other studies have reported effects of wind speed (Hatch and Hatch 1988, Piatt et al. 1988) and maximum daily temperatures (Piatt et al. 1988). Considering only the portion of the breeding cycle within the census period, however, those studies also found little or no influence of weather on attendance.

2.4.3 Population Monitoring of Murres and Kittiwakes

Seabirds at Cape Thompson have been censused mostly by boat counts over the last 28 years (Springer et al. 1985b). These counts have revealed broad scale changes in the murre population over the years (Chapter 4). However, to include Cape Thompson in a Bering/Chukchi monitoring program as proposed by Piatt et al. (1988), reliance on colony-wide boat counts becomes impractical. Boat counts are time consuming, often requiring a day or more for each colony at Cape Thompson, and good weather and sea conditions are necessary for acceptable precision. While this has the indirect advantage of limiting the variation of counting conditions, the small number of days conducive to boat counting at Cape Thompson during the census period severely limits the ability to replicate counts. In future years it should be possible for two persons to count all the plots we established in Colonies 4 and 5 in a single day. Because the plots are accessible on foot from the campsite at the mouth of Ikijaktusak Creek, the chances are good of obtaining 8-10 daily counts during a 2-week visit, despite the likelihood of bad weather during July and August.

The number of counts required to detect a given percentage change between years can be calculated from the variances we observed in counts of murres and kittiwakes in 1988 (following Sokal and Rohlf 1981: 262-264). Assuming the data from plots in Colonies 4 and 5 are representative, we estimate that 10 counts would detect an 8% change in numbers of Thick-billed Murres between years and a 12% change in Common Murres, with 75% certainty of the change being significant at the P=0.05 level (Fig. 2.19). A 9% annual change in the population of Black-legged Kittiwakes should be detectable at the P=0.05 significance level given samples of 10 replicate counts of the land-based plots (Fig. 2.20). Thus, the observed variation among murre and kittiwake plot counts at Cape Thompson allows detection of changes on the same scale as the in the Semidi Islands (Hatch and Hatch 1988, 1989) and on Saint Lawrence Island (Piatt et al. 1988).

The strong correlation between kittiwake nest sites and mean plot counts

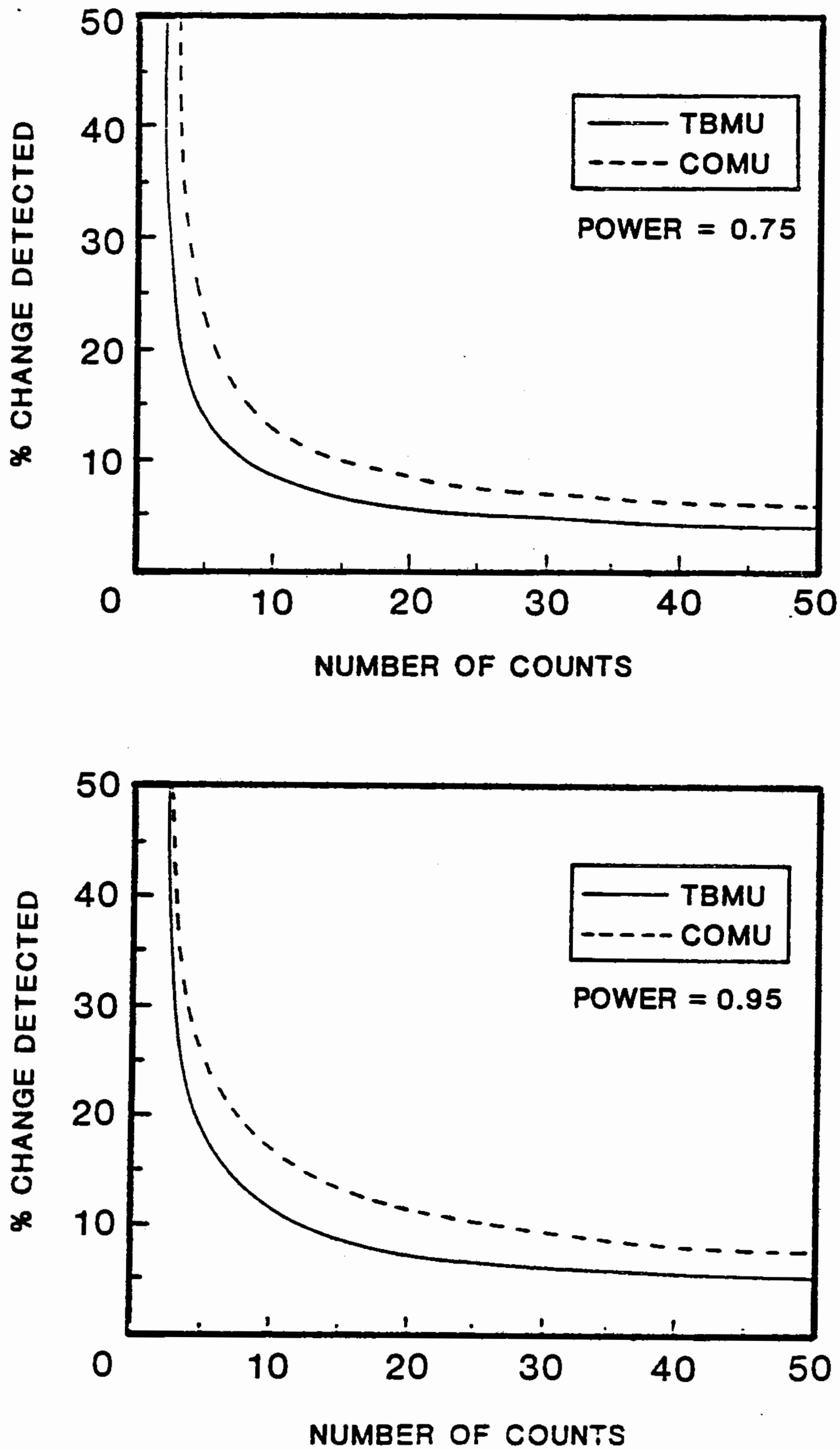

Figure 2.19. Relationship between sample size (number of daily counts made during the census period) and proportionate change in murre numbers detectable between years at Cape Thompson. Power is the degree of confidence that the difference would be significant at the 0.05 probability level. (TBMU = Thick-billed Murre, COMU = Common Murre).

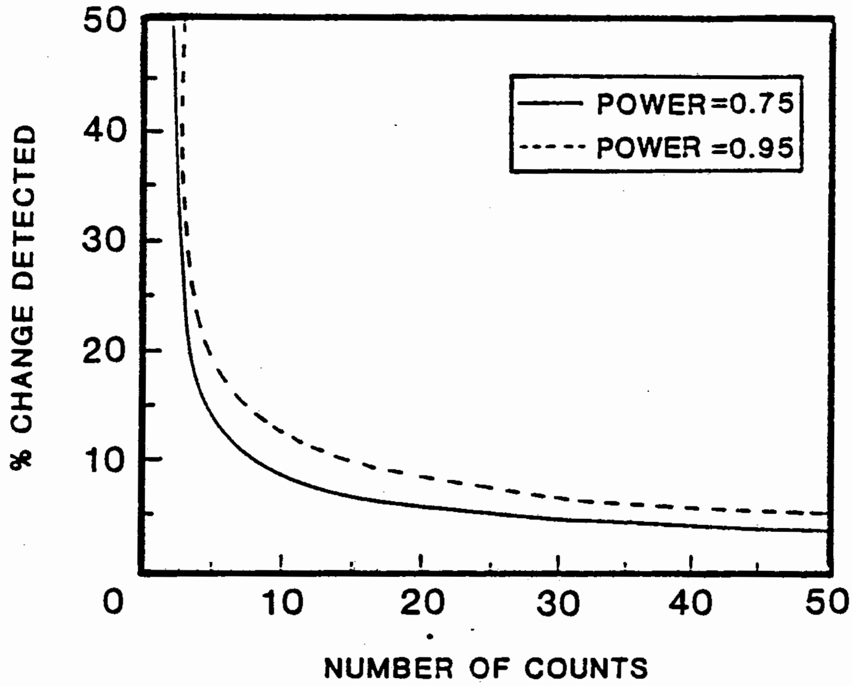

Figure 2.20. Relationships between sample size (number of daily counts made during the census period) and proportionate change in kittiwake numbers detectable between years. Power is the degree of confidence that the difference between sample means would be significant at the 0.05 probability level.

(Fig. 2.18) suggests that a well-timed count of nests might be as effective for monitoring as counts of individuals. However, Hatch and Hatch (1988) found that annual variation in kittiwake nest counts was greater than annual variation in counts of individuals because nest counts are greatly affected by variation in breeding effort between years.

Although a statistically significant change in murre or kittiwake numbers may occur between years, this may or may not reflect real change in population size. There are several alternative hypotheses to explain apparent changes (Birkhead and Nettleship 1980, Piatt et al. 1988): (1) changes in attendance or proportionate size of the nonbreeding population, (2) time allocated to attendance at the breeding site may change between years in response to food supply, (3) in poor years with low breeding success failed breeders may leave the colony early, or (4) immigration and emigration may occur among colonies. Therefore, conclusions about population change generally are premature unless the existence of a trend can be demonstrated in a series of counts over several years. In Chapter 4 we examine the evidence for trends in murre and kittiwake population data collected at Cape Thompson since 1960.

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CHAPTER 3. PRODUCTIVITY AND BREEDING SUCCESS

3.1 Introduction

The productivity of seabird colonies is a useful parameter to monitor because it is sensitive to changes in environmental conditions, particularly food resources (Birkhead and Nettleship 1988; Hunt et al. 1981a,b; Johnson and Baker 1985; LeCroy and Collins 1972; Piatt et al. 1988; Safina et al. 1988). If they are carried out annually for a sufficient number of years, productivity measurements may also aid the interpretation of population changes. This may prove to be especially important for Black-legged Kittiwakes, which have recently experienced total breeding failures at many colonies in the Bering and Chukchi seas (Hatch 1987).

There are several possible measures of productivity. The number of young produced in a colony or sample plot can be expressed as a ratio of eggs laid, breeding pairs present, number of occupied sites, or the average number of adults present during the study. Because eggs and and young chicks are difficult to observe, especially in murres, measures of other parameters such as clutch size, hatching success, and fledging success require substantial amounts of time invested at each colony, with observations beginning before egg-laying and continuing through chick fledging. Piatt et al. (1988) suggested a strategy for monitoring murre and kittiwake productivity that entails, for each colony monitored for population change, a second visit late in the season to count chicks surviving on census plots. Visits would be timed to be as late as possible, but before the first young have fledged. Since murres and kittiwakes have asynchronous patterns of fledging, it would in most instances be necessary to compromise the estimate of kittiwake productivity by making the chick counts well ahead of the first fledging date. Productivity would be expressed as the number of chicks surviving on study plots divided by the mean count of adults attending the plots during the census period (murres) or the count of nests obtained during the census period (kittiwakes).

We made the proposed measures of productivity for murres and kittiwakes, and since our studies encompassed a good portion of the incubation and chick-periods we also performed some preliminary assessments of factors that affect the quality of such estimates. We made limited observations on individual breeding sites within our study plots to characterize the timing and magnitude of egg and chick losses at Cape Thompson in 1988.

3.2 Methods

3.2.1 Common and Thick-billed Murres

3.2.1.1 Productivity Check

Murre productivity was estimated by counting chicks present in census plots 4-1B, 4-2C, 5-1A, 5-1C, and in subplots 5-2F', 5-3H', 5-6K', 5-7L' and 5-8N'. Subplots were used to sample portions of larger plots in which attempting to count all chicks present was impractical. Productivity checks were made from plot observation points (Appendix C) on 21 August, the day prior to first observed fledging (Chapter 2). Observers used spotting scopes to count chicks, which were identified as Thick-billed or Common whenever possible. Productivity was calculated as the number of chicks divided by the mean number of adults counted on the plot during the census period (Chapter 2).

The effect on productivity estimates of counting prior to and after the date of first fledging was assessed by completing productivity counts between 18-26 August. On 26 August, we counted chicks in two ways. The first count was of chicks actually observed that day, the second was of chicks estimated to be present, based on adult behavior and the observer's accumulated knowledge of a given plot. We also attempted to quantify the effect of time spent counting on numbers of chicks observed by recording numbers of chicks observed during 5-minute intervals for up to 35 minutes on a series of plots that varied in size from 115-381 adults.

3.2.2.2 Components of Productivity

Phenology sites (Part 2.2.2) were monitored for hatching and fledging success in both murre species until 31 August. Because sites observed were selected post-laying, the observations do not constitute a true Type I study (Birkhead and Nettleship 1980). We assume much of the egg mortality occurred before monitoring began. Also, due to frequent bad weather, the fate of some eggs and chicks was unknown.

3.2.3 Black-legged Kittiwakes

3.2.3.1 Productivity Check

All kittiwake nests in Colonies 3, 4 and 5 were used for the productivity check (n=973 nests). The number of nests present on each land-based plot was determined at the beginning of the census period on 8 or 10 July. Counts of kittiwake chicks present in each plot were made from plot observation points (Appendix C) using binoculars or spotting scopes on 26 August, the day prior to the first observed fledging. Productivity was calculated as the ratio of chicks present to the number of nests on a plot. Chick counts were also conducted daily, weather permitting, between 8-31 August to quantify the effect of timing on the results of such a productivity measurement. Considering the 26 August productivity estimate to be the "true" value, we calculated the percent error introduced by checking productivity later or earlier.

3.2.3.2 Components of Productivity

Components of productivity such as clutch size, hatching success, and fledging success were studied at phenology sites in Colonies 4 and 5 as described in Part 2.2.2. These sites were first observed during late incubation, when an unknown mortality of eggs had already occurred. Therefore, they cannot be considered Type I study plots (Birkhead and Nettleship 1980).

3.2.4 Chick Feeding Rates

Groups of nests (kittiwakes) or breeding sites (murres) on phenology study plots were observed with binoculars or spotting scopes to assess chick feeding rates. Observers monitored the behavior of chicks, the attendance of adults, and the delivery of food items in 2.0-4.5 h periods between 1300-1730 h on 9-11 August.

3.2.5 Statistical Analysis

Spearman rank correlations with two-tailed tests were used for all comparisons using the SPSSx statistical package (SPSS, Inc. 1983). Results expressed in the text are mean ±1 SD.

3.3 Results

3.3.1 Common and Thick-billed Murres

3.3.1.1 Productivity

Estimates of murre productivity on 21 August ranged from 0.000–0.104 chicks per adult on nine plots (Table 3.1), and these values apparently were independent of plot size (Fig. 3.1). No differences were evident between Thick-billed and Common Murre productivity using this method, but the species of chicks observed on mixed-species plots could not be determined in all cases. Mean productivity was 0.05 ± 0.042 on six plots containing only Thick-billed Murres and 0.05 ± 0.023 on three plots with both species.

Chicks became more observable as they grew, hence productivity estimates increased from the early to mid-fledging stage (Fig. 3.2). Our ability to observe chicks was also affected by weather. Wind speeds were 40-70 km/h on both 24 and 26 August, and productivity estimates from those days were well below the trend indicated by the other data (Fig. 3.2). On windy days chick visibility was reduced not only by adults sitting tighter over their young (lower frequency of shifting position), but also because the wind caused spotting scopes to vibrate, making it difficult to view the plots.

The behavioral posture of drooping one wing, as described by Gaston and Nettleship (1981), was effective for discriminating adults with chicks, although on clear days the sun warmed the cliff faces and many birds without

Table 3.1. Productivity of Thick-billed (TBMU) and Common (COMU) murres determined by chick counts on 21 August 1988 at Cape Thompson.

Plot	Mean adult attendance on plot[a] TBMU	COMU	Chicks	Productivity (chicks/adult)	Adjusted[b] Productivity (chicks/adult)
4-1B	146	82	17	0.075	0.101
4-2C	210	171	11	0.029	0.301
5-1A	31	1	3	0.094	0.125
5-1C	24	1	0	0.000	0.000
5-2F'	115	0	12	0.104	0.157
5-3H'	149	0	13	0.087	0.107
5-6K'	175	3	6	0.034	0.045
5-7L'	199	16	13	0.060	0.079
5-8N'	247	0	9	0.036	0.053
Mean				0.058	0.078
SD				0.035	0.050

[a] Determined from census counts (see Chapter 2).

[b] Productivity adjusted for discrepancies between observed chick numbers and chick numbers estimated to be present on 26 August 1988.

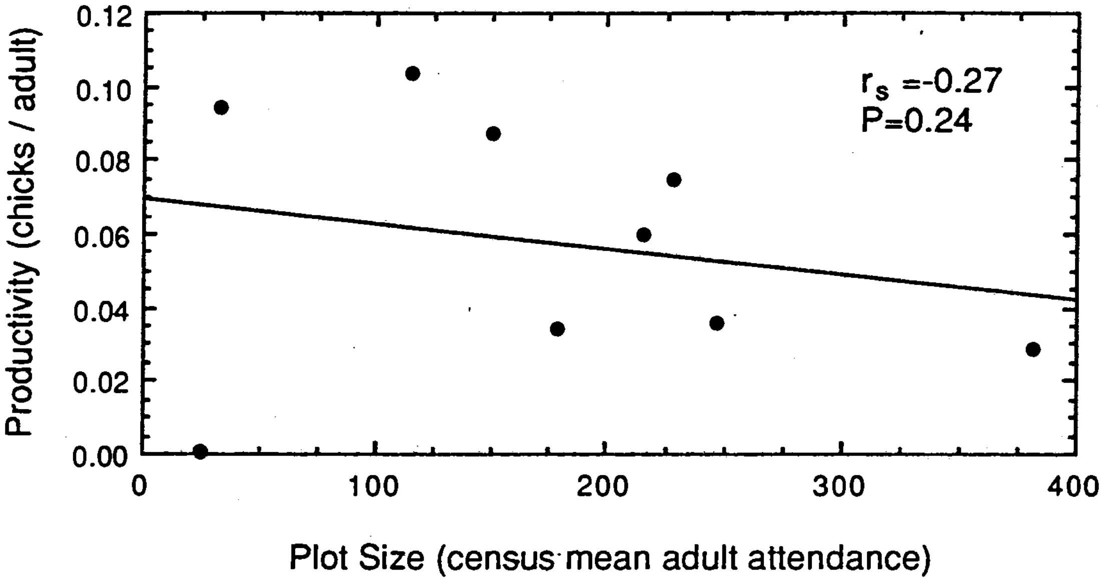

Figure 3.1. Murre productivity estimates in relation to plot size (as measured by mean number of adults on plot) at Cape Thompson, 1988.

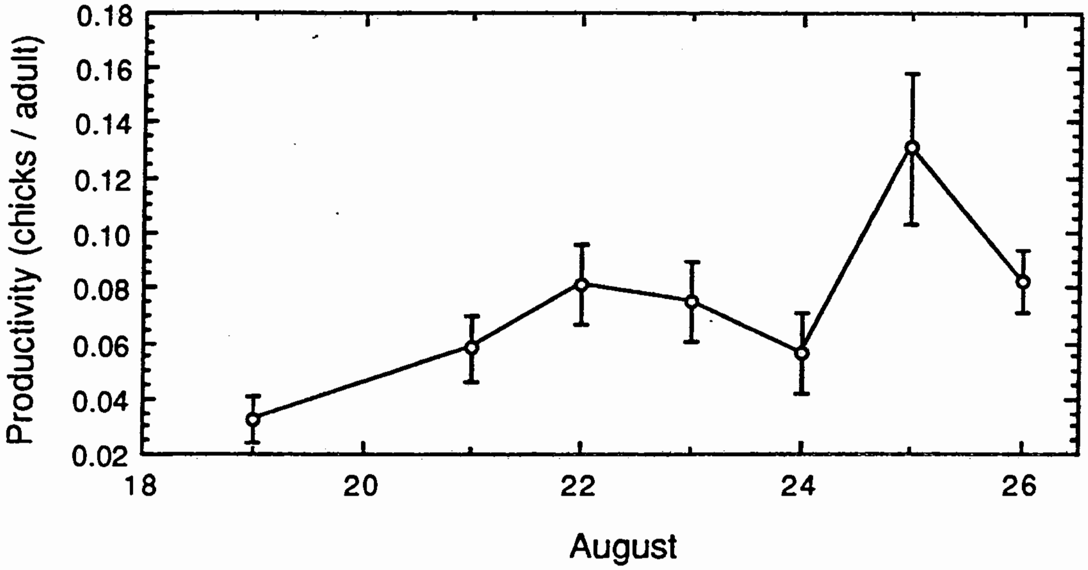

Figure 3.2. Changes of murre productivity estimates during the first half of the fledging period. Error bars are ± 1 SD.

chicks also displayed the posture. At the time of the productivity check on 21 August, most chicks were still well hidden by adults and it was not always evident from adult behavior whether a chick was present or not. After observing the plots for several days, observers had better knowledge of which adults had chicks, so on 26 August estimates of actual chick numbers were made to compare with counts of observed chicks. On that date, the ratio of observed chicks to estimated chicks (an indication of observation accuracy) decreased significantly with plot size; it was possible to detect larger proportions of chicks on smaller plots (Fig. 3.3). On average, 29.1 ± 14.3% (9 plots) fewer chicks were observed than were estimated to be present. This ratio should improve as chicks grow and become more observable, so there may have been an even larger discrepancy on 21 August. However, having no way to quantify the difference at any other stage, we used 26 August ratios to adjust our productivity estimates for 21 August (Table 3.1).

Numbers of chicks observed were dependent upon the time spent counting (Fig. 3.4). Ninety-six percent of observed chicks were spotted in the first 25 minutes, independent of plot size over the range of plot sizes studied. On 6 plots containing 115-381 adults, the number of "new" chicks spotted per unit time of observation time averaged 0.75 chicks/min over the first 25 minutes of effort. Because most of the plots required spotting scopes to observe chicks, we found that after 25 minutes it was difficult to discriminate between "new" chicks (previously unobserved) and "old" chicks (previously observed).

3.3.1.2 Components of Productivity

Breeding performance, as measured in the phenology sites, was essentially identical in the two murre species (Table 3.2). Because the monitoring of phenology sites began about 20 days after first egg-laying, unadjusted estimates of breeding success are undoubtedly too high. The estimates were adjusted using egg mortality data from the Semidi Islands (Hatch and Hatch 1989), which show that 22% of Thick-billed and 21% of Common Murre eggs had been lost by 20 days after laying. As egg mortality can be quite variable within a colony and over time (Gaston and Nettleship 1981), there is no reason to assume these values accurately represent Cape Thompson mortality,

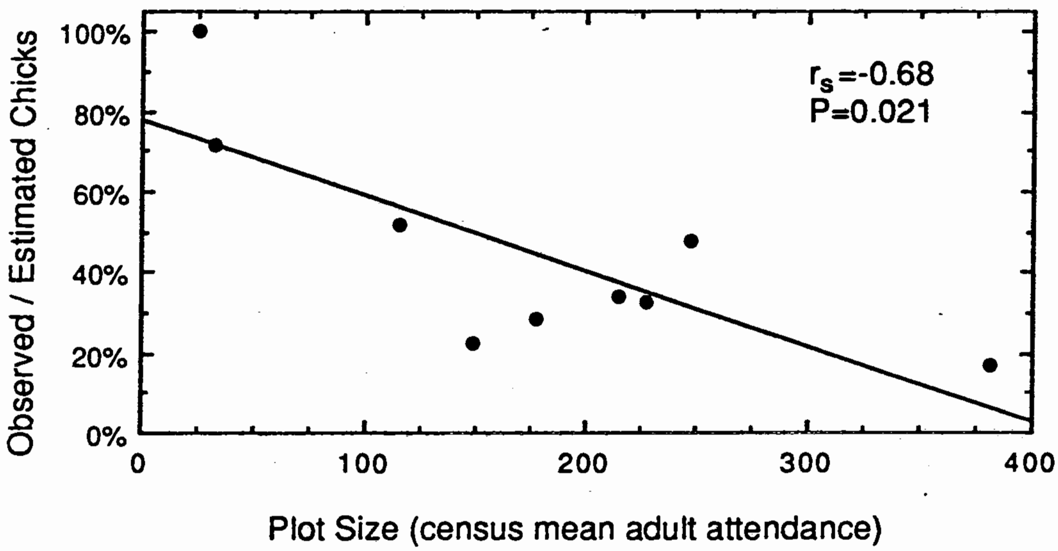

Figure 3.3. Percentage of murre chicks observed on productivity plots on 26 August, 1988.

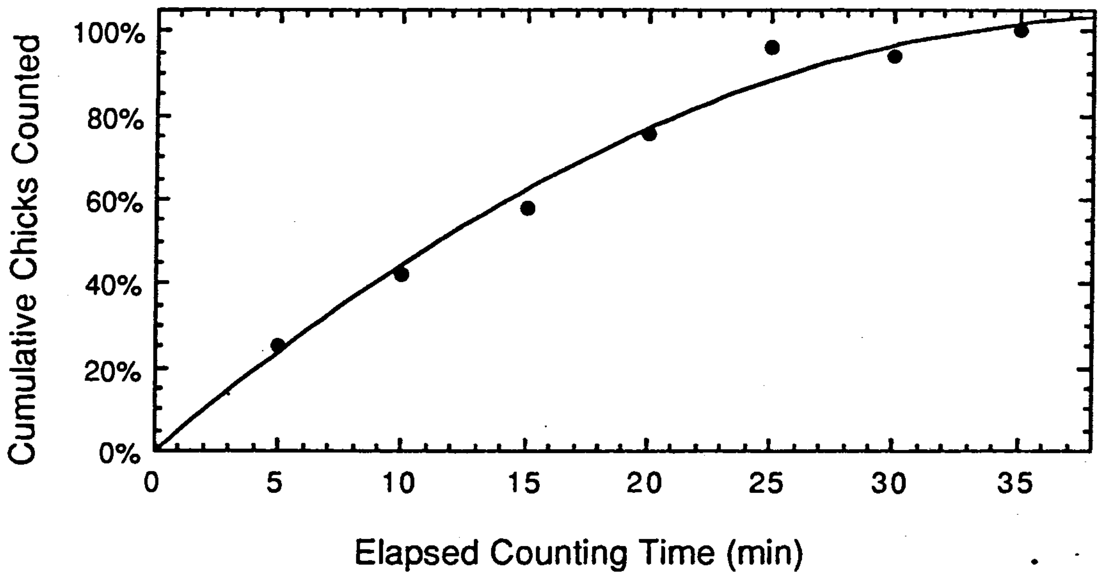

Figure 3.4. Effect of counting duration on numbers of murre chicks observed on 6 plots at Cape Thompson, 1988.

Table 3.2. Components of breeding productivity in Common and Thick-billed murres at Cape Thompson, 1988, based on eggs of known fate in phenology sites.

	Common Murre	Thick-billed Murre
Sites with eggs	25	84
No. eggs hatched (%) [%][a]	20 (80) [63]	66 (79) [61]
No. chicks fledged (%)	15 (76)	51 (77)
Breeding success [%]	60 [47]	61 [47]

[a] Adjusted for egg mortality assumed to occur prior to first observations (see text).

but they do provide a more reasonable estimate of breeding success. Adjusted overall breeding success was therefore close to 0.47 chicks fledged per breeding pair in both species (Table 3.2).

We observed but did not specifically quantify sources of egg and chick mortality. Eggs were frequently taken by Glaucous Gulls (Larus hyperboreus) and Common Ravens (Corvus corax). One observation was made of a kittiwake feeding on a murre egg on 9 August at plot 5-8N. Murre eggs were also taken by local residents from various areas in mid-July, but this seemed to be a relatively minor source of egg mortality. Eggs were occasionally observed to fall from cliffs as a result of murre-murre or murre-kittiwake fights, and from flushing due to rockfalls, predators, or other disturbances. Glaucous Gulls and short-tailed weasels (Mustella erminea) were seen taking murre chicks, and some murre chicks were observed dead on the cliffs for no readily apparent reason.

3.3.1.2 Chick Feeding Rates

Chick feeding rates observed at three Common and three Thick-billed Murre breeding sites at plot 4-2B on 10 August averaged 0.23 ± 0.15 feeds/chick/hour. This is equivalent to 5.5 ± 1.4 feeds/chick/day. These are possibly over- or underestimates of feeding rates if there was a diurnal periodicity in feeding rhythm, since observation times were short (2.0-4.5 hours). One fish observed being fed by a Common Murre was identified as a sand lance (Ammodytes hexapterus).

3.3.2 Black-legged Kittiwakes

3.3.2.1 Productivity

Kittiwake productivity averaged over all Colony 3-5 plots was 0.12 ± 0.34 chicks/nest (n=17 plots), or 0.15 chicks/nest for the pooled sample of 973 nests (Table 3.3). Productivities on separate plots ranged from 0.0-0.40 chicks/nest, but there were no significant effects of plot size on productivity estimates (Fig 3.5).

Table 3.3. Productivity of Black-legged Kittiwakes at Cape Thompson estimated on 26 August 1988.

Plot	Nests on Plot[a]	Observable Nests[b]	Chicks	Productivity (chicks/observable nest)
3-1A	5	5	0	0.00
3-2B	50	50	5	0.10
3-3C	4	4	0	0.00
4-1A	41	38	5	0.13
4-1B	30	16	2	0.13
4-2C	175	175	34	0.19
4-3D	41	41	1	0.02
4-4E	176	176	21	0.12
5-1A	28	28	7	0.25
5-1B	136	136	31	0.23
5-1C	10	10	4	0.40
5-2E	91	87	3	0.03
5-2F	4	4	0	0.00
5-5J	88	87	11	0.13
5-6K	7	7	0	0.00
5-8M	81	77	17	0.22
5-8N	32	32	1	0.03
All plots	999	973	142	0.15

[a] Numbers of nests counted on plots on 8 or 10 July.

[b] Observable nests were those that were not partially blocked from view and were counted at the time of initial nest counts.

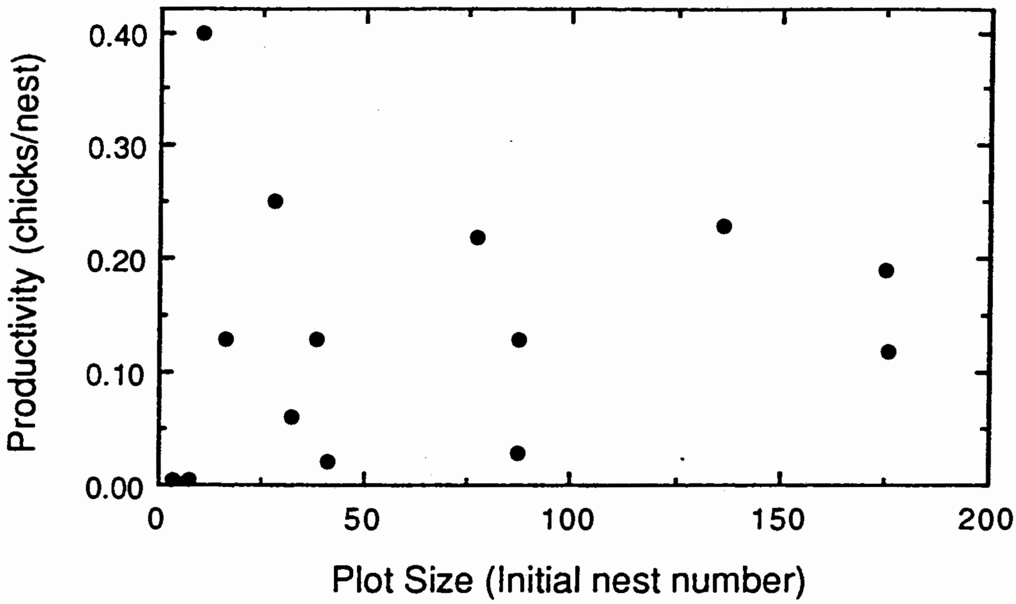

Figure 3.5. Effect of plot size (initial nest number) on kittiwake chick productivity estimates, 26 August 1988 at Cape Thompson.

Because of the shallow decline of chick numbers after 19 August (Fig. 3.6), productivity estimates would not have been substantially affected by completing checks between 19-31 August. There would have been at most a 0.03 chicks/nest over- or underestimate relative to the value for 26 August (Fig. 3.7). Specifically, if kittiwake productivity checks were timed to coincide with murre productivity checks (as envisioned by Piatt et al. (1988) for a comprehensive monitoring program), the estimate would have been only 0.03 chicks/nest higher than the value obtained at the optimum time for kittiwakes.

Kittiwake chick productivity in 1988 was the lowest measured in 28 years at Cape Thompson except for their total breeding failure in 1976 (Fig. 3.8, Table 3.4).

3.3.2.2 Components of Productivity

Mean clutch size and hatching success observed in the samples of individually monitored sites were generally similar to other years at Cape Thompson, but fledging success was relatively poor (Table 3.4). Since our observations began after kittiwakes had already laid, estimates of hatching success and of overall breeding success are undoubtedly overestimates. We made no attempt to adjust for early egg losses, which can be quite variable in kittiwakes.

Between 1959 and 1988, first hatching dates were strongly and negatively correlated with mean clutch sizes (r_s=-0.75, P<0.05, n=7), with fledging success (r_s=-0.77, P<0.05, n=6) and with breeding success (r_s=-0.69, P<0.05, n=8), but they were not correlated with hatching success (r_s=0.00, P>0.05, n=5) (Fig. 3.9a-d). Mean clutch sizes were positively correlated with breeding success (r_s=0.82, P<0.05, n=7; Fig. 3.9e). The date of last observed ice at Cape Thompson was significantly and negatively correlated with fledging success (r_s=-0.81, P<0.05, n=6) and breeding success (r_s=-0.70, P<0.05, n=8), but was less strongly correlated with dates of first hatching (r_s=0.38, P>0.05, n=9), hatching success (r_s=-0.15, P>0.05, n=5) and mean clutch size (r_s=-0.65, P>0.05, n=7) (Fig. 3.9f-h).

We observed several causes of egg and chick mortality but did not attempt

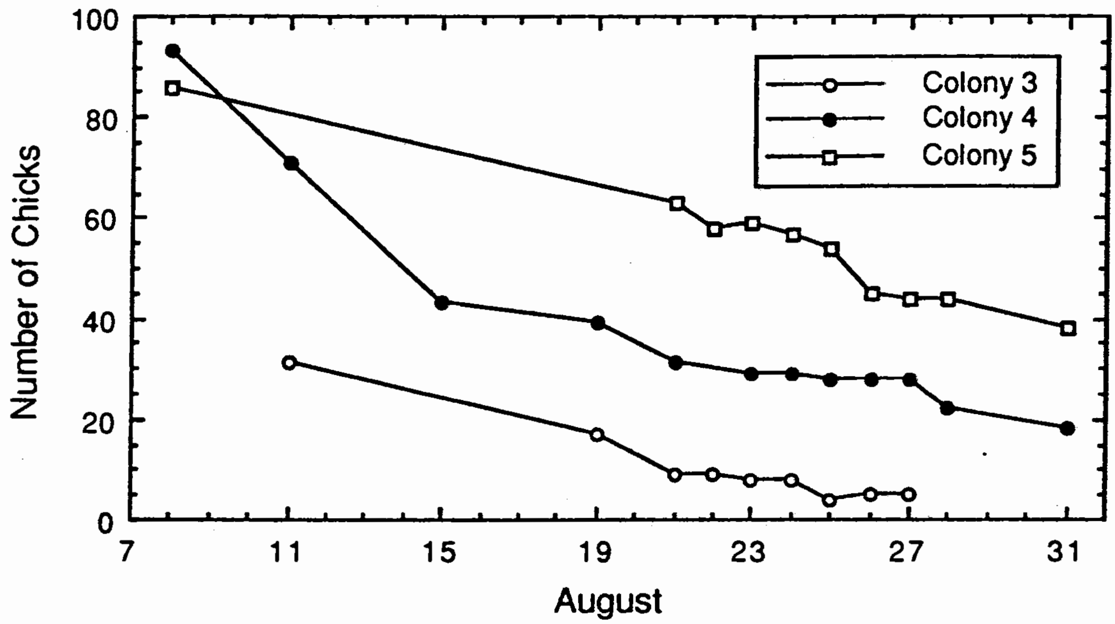

Figure 3.6. Changes in kittiwake chick numbers at the end of the chick-rearing period in 1988.

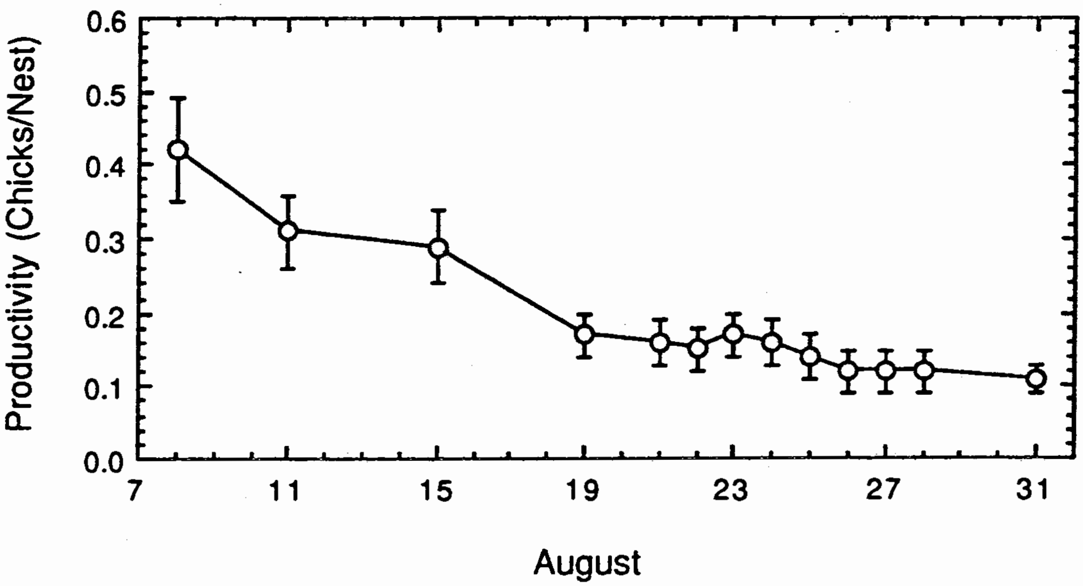

Figure 3.7. Effect of timing of chick counts on kittiwake productivity estimates during late chick-rearing and early fledging periods, Cape Thompson, 1988.

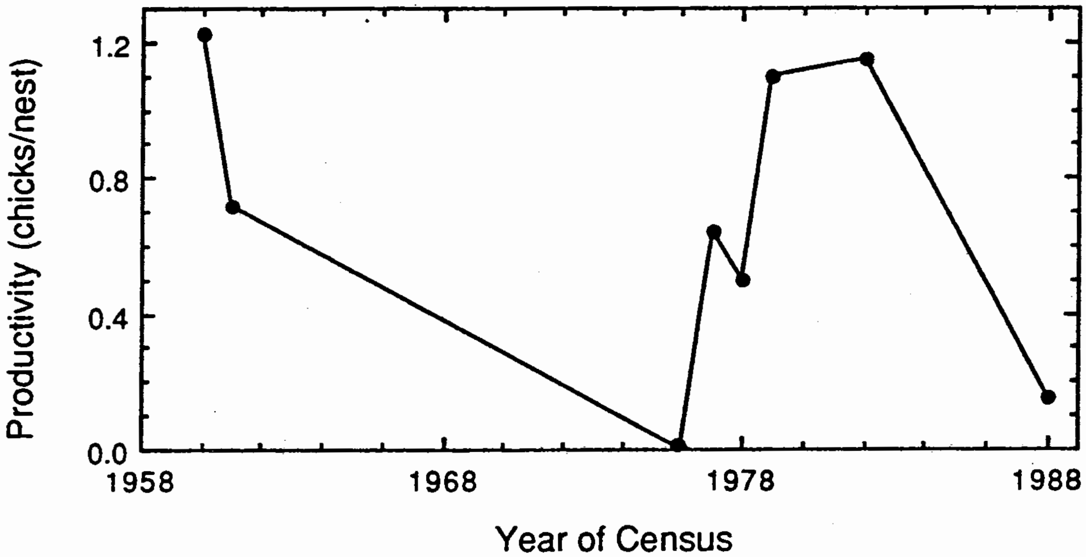

Figure 3.8. Black-legged Kittiwake chick productivity at Cape Thompson (1960-61, Swartz 1966; 1976, 1978-79, Murphy et al. 1980; 1977, Springer and Roseneau 1978; 1982, Springer et al. 1985a; 1988, this study).

Table 3.4. Components of breeding productivity in Black-legged Kittiwakes in 8 years at Cape Thompson.

	Year of study[a]							
Parameter	1960	1961	1976	1977	1978	1979	1982	1988
No. nest studied	60	29	200	73	236	374	-	70 (973)[b]
Mean clutch size	1.92	1.88	1.12	1.18	-	1.58	1.48	1.39
Hatching success (eggs hatched/ egg laid)	0.65	0.41	-	0.90	-	0.94	-	0.72
Fledging success (chicks fledged/ egg hatched	0.86	0.60	0.00	0.71	-	0.82	-	0.33
Productivity (chicks fledged/ nest)	1.22	0.72	0.00	0.64	0.50	1.10	1.15	0.31[c](0.15)

[a] 1960, 1961 data from Swartz (1966); 1976, 1978, 1979 data from Murphy et al. (1980); 1977 data from Springer and Roseneau (1978). Clutch sizes and some breeding success data from Springer et al. (1985a).

[b] Numbers in parantheses were from productivity checks of all nests on Colony 3, 4 and 5 land-based census plots.

[c] Does not include nests that failed prior to hatching, therefore figure is an overestimate of breeding success.

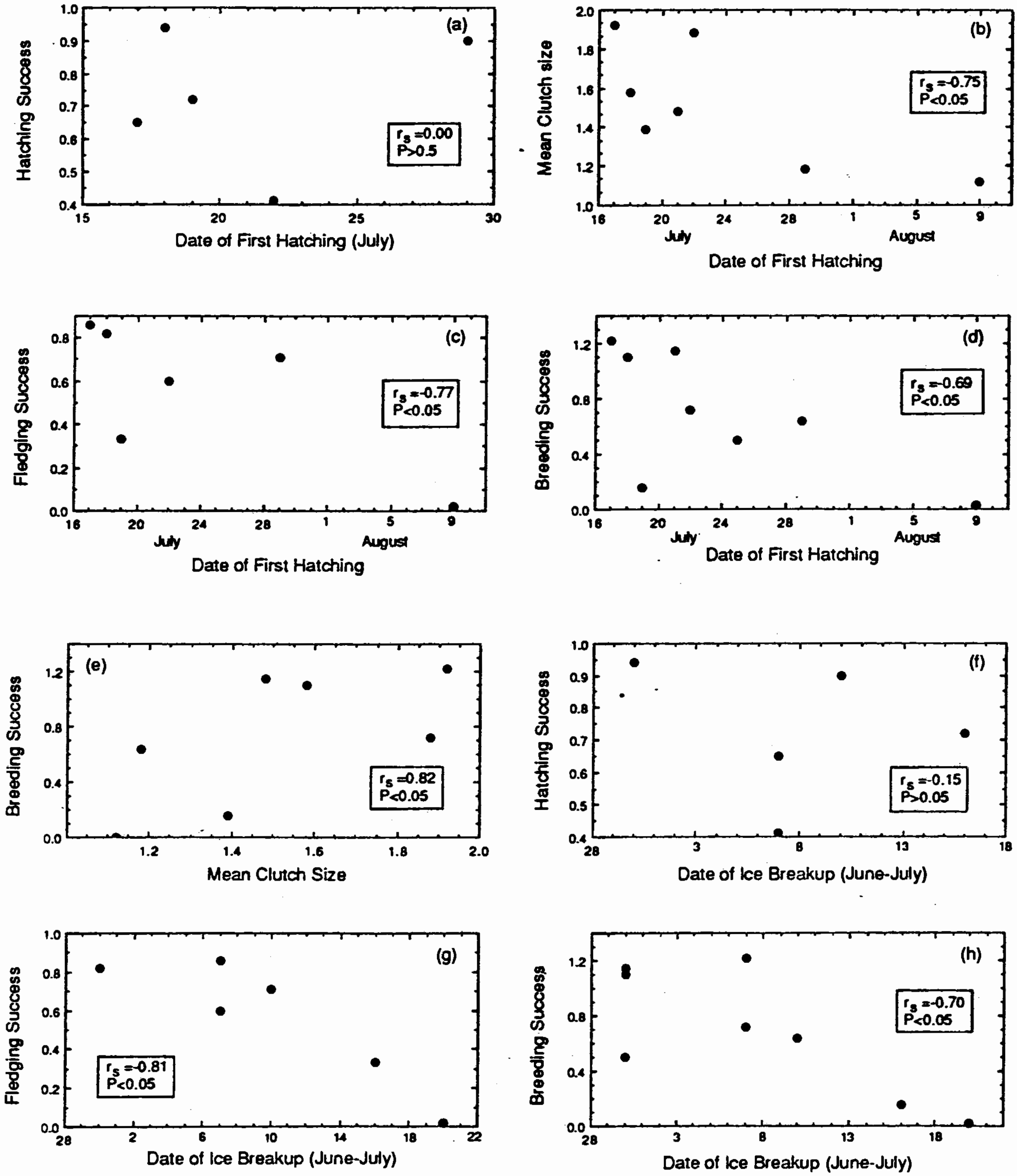

Figure 3.9. Correlates of kittiwake breeding performance at Cape Thompson. Data sources as in Fig. 3.8.

to quantify them. Many chicks apparently died from exposure or starvation, as we noticed several chicks that were left unattended eventually died in the nest. Common Ravens (Corvus corax) and Glaucous Gulls (Larus hyperboreus) were observed taking eggs and chicks. Although several nests contained 2-egg clutches, no kittiwakes succeeded in raising two chicks to fledging, and most chicks that hatched second died within 3-7 days. We were able to determine the age at death for 27 longer-lived chicks, most of which died between 11-30 days of age.

3.3.2.3 Chick Feeding Rates

The feeding rate of kittiwake chicks (aged 19-23 days) was 0.53 ± 0.22 feeds/h (n=7 chicks). This estimate may be biased if kittiwakes had diurnal periodicity in their chick feeding rates, because our watches were of short duration (2-4.5 hours).

3.4 Discussion

3.4.1 Common and Thick-billed Murres

3.4.1.1 Productivity Measurement

Estimating murre productivity from a well-timed chick count may be an effective monitoring technique if implemented by experienced personnel. However, estimates were affected by weather, timing, observer experience and position (distance from plot, orientation, etc.). For instance, winds above 40 km/h resulted in decreased estimates of productivity, because the chicks were more closely brooded and observations were especially difficult in the wind. Productivity estimated by this method was particularly sensitive to timing. 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. Practice increased the ability of observers to determine the presence or absence of chicks from adult behavior, and knowledge of chicks on a plot accumlated over several visits was an important factor. The use of observers already familiar with the method, or undertaking practice counts just prior to first fledging, should reduce variation. The distance of the observer from the plots and the number of birds on the plot also affected productivity estimates. Since observers had to use spotting scopes to see chicks, their reduced field of view caused difficulty in determining which chicks had already been observed during a given 25-minute period of observation. The chances of seeing a chick are improved by scanning the plot for adults that shift or move just prior to exposing their chicks (Gaston and Nettleship 1981), but time spent scrutinizing individuals through the spotting scope is still the limiting factor. Using photographs or sketches to record chick locations during a productivity check may alleviate some of these problems.

Productivity estimates from this method in 1988 were definitely underestimates of actual productivity. Although they fall within ranges previously observed at the Pribilof Islands, Cape Peirce, and Bluff (Drury et al. 1981, Johnson and Baker 1985), estimates as low as those found at Cape Thompson were associated with other low measures of productivity or breeding success. Our measurements of breeding success determined from phenology sites indicate that 1988 was a moderate year, which was not reflected in the productivity checks.

With experienced personnel, this technique may provide a suitable index for monitoring productivity, but its relation to actual productivity requires further study. Since it is based on the census mean of adults present, it is subject to sources of interannual variation not associated with actual population changes, just as are census counts. As with population changes, a trend established over a number of years would be acceptable evidence that productivity has changed.

3.4.1.2 Components of Productivity

Breeding success of both murre species was moderate (probably 0.4-0.5 fledged chicks per breeding pair) as compared with the range of breeding success reported from other Bering Sea colonies (Hunt et al. 1981b, Johnson and Baker 1985, Piatt et al. 1988). No comparable indices of breeding success have been gathered in other years at Cape Thompson. Birkhead and Nettleship (1981) presented evidence that late breeding was associated with lower breeding success in the Thick-billed Murres, and this pattern is also evident for kittiwakes at Cape Thompson. If the relationship holds for murres at Cape Thompson, breeding success in 1988 should have been moderate, as the date of first hatching was in the center of the range observed from 1960-1988 (Fig. 2.7a). As the date of first hatching was correlated with the timing of ice breakup at Cape Thompson, the lateness of ice may affect the breeding success of murres as well (cf. Birkhead and Nettleship 1981). Years with low productivity may also be associated with decreases in sea surface temperatures in the eastern Chukchi Sea (Springer et al. 1984).

At colonies where Common and Thick-billed Murres breed sympatrically, Common Murres often have higher breeding success, which has been related to breeding site characteristics (Birkhead and Nettleship 1987) and possibly food supplies and foraging behaviors (Piatt et al. 1988). We found no differences in breeding success between species this year at Cape Thompson, which may indicate a similarity of foraging conditions. Attendance at the breeding site was similar for both species (Chapter 2), which suggests that foraging times were approximately equal, and fish abundance in the diets of both murre species decreased similarly between July and August (Chapter 4).

3.4.2 Kittiwake Productivity and Breeding Success

Counting kittiwake chicks on plots just prior to first fledging is a simple and reliable method for estimating kittiwake productivity. There was no apparent effect of plot size on productivity estimates, and counts completed several days early to coincide with murre productivity checks resulted in minimal error. Although this estimate does not provide specific information on the sources of annual variation (i.e., clutch sizes, hatching success, fledging success) it provides easily obtainable data on overall productivity and should be routinely included in any population monitoring program.

Productivity of Black-legged Kittiwakes was extremely poor at Cape Thompson this year, supporting the hypothesis that productivity in this region is adversely affected by late sea ice coverage and low surface temperatures (Springer et al. 1984, 1985). Late ice and cooler water have been correlated with decreases in size classes and abundance of forage fishes in the eastern Chukchi Sea, especially stocks of capelin (Mallotus villosus) and sand lance (Ammodytes hexapterus), two important kittiwake food sources (Springer et al. 1984, 1985). In years with good kittiwake productivity, capelin and sand lance schools were abundant at Cape Thompson by 10-12 August, and large nearshore feeding flocks of kittiwakes were observed capitalizing on these resources (Springer and Roseneau 1978, Springer et al. 1985). We observed kittiwake flocks (300-1,000 individuals) feeding on Arctic cod (Boreogadus saida) and Pacific herring (Clupea harengus pacifica) schools among the ice floes within 3 km of shore between 5-10 July. After the ice breakup on 16 July, however, only two kittiwake feeding flocks (about 500 birds each) were observed, on 17 and 25 August, both about 500 m offshore from Colonies 4 and 5. Shipboard surveys from 23-28 August confirmed that foraging kittiwakes were widely dispersed in the region this year (Chapter 4). This contrasted with the larger size and frequency of occurrance of feeding flocks during years when capelin and sand lance were abundant at the surface (D.G. Roseneau, pers. obs.).

Sand lance were in the Cape Thompson region as early as 7 August, when Common Murres were observed with sand lance on census plots. Murres continued to return with sand lance throughout August, but sand lance were not found in kittiwakes collected on 8 July, 12 July, 11 August, or 27 August (Chapter 4). Thus it seems that although sand lance were in the area, they were not available at densities or depths readily exploitable by kittiwakes.

Adults were able to maintain body weight through the season (Chapter 4), but the apparent inaccessibility of prey in August caused extensive breeding failure during chick-rearing. All second-hatched chicks died soon after hatching, and we observed many chicks (up to 35 days old) that died in nests with no apparent injuries, presumably from starvation. Adult kittiwakes were making less than their typical allocation of time to nest attendance, presumably to increase foraging time (Chapter 2). However, although birds may have spent much time foraging, chick feeding rates indicated minimal success in returning with food. Chick feeding rates this year at Cape Thompson were about half the feeding rates of successful pairs on Middleton Island in 1984, and were similar to the feeding rates of unsuccessful pairs

(Roberts 1988).

Kittiwakes were apparently in good condition at the beginning of the breeding season, as clutch sizes and hatching success were no different than in prior years. Also, the date of first hatching was among the earliest since 1960. The evidence suggests that low kittiwake productivity in 1988 was due to inaccessible food resources during the mid- to late season, resulting in starvation for many chicks.

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CHAPTER 4. SEABIRD POPULATIONS AT CAPE THOMPSON, 1960-1988

4.1. Introduction

Populations of Thick-billed Murres (Uria lomvia), Common Murres (U. aalge), and Black-legged Kittiwakes (Rissa tridactyla) were censused at Cape Thompson at various intervals between 1959 and 1982 (Swartz 1966; Springer et al. 1985a). We made boat-based counts of some of the same census plots in 1988, which extended the period of census coverage at Cape Thompson to 28 years. This is the longest record of seabird censusing for any colony in Alaska; the data therefore provide a unique view of long-term variation in murre and kittiwake populations in this region. Here we compile and analyze all previous data along with our results from 1988 to ascertain whether murre or kittiwake population changes have occurred. We also consider whether changes in the murre population reflect changes in both or only one species. Finally, we discuss our findings in light of available reproductive and ecological data for the Cape Thompson region.

4.2. Methods

4.2.1. Study Area and Counting Methods

During most years of study, adult murres and kittiwakes have been censused along the 6.8 km of cliffs between Ogotoruk Creek and Imnapak Cliff (Fig. 1.2). In 1959, Swartz (1966) created census plots that covered all cliff surfaces. The 1959 plots were subdivided in 1960, and plot boundaries were recorded on photographs (reproduced in Appendix F). Swartz' plots have formed the basis for subsequent censusing, with the following exceptions. Observers were unable to locate all of Swartz' plots in 1976, and were required to estimate some of the plot positions. In 1977, field crews possessed all of Swartz' plot photographs, and found that some of the 1976 plots in colonies 3 and 5 were not equivalent to the 1960 plots. Springer and Roseneau (1978) created "special area" census plots to convert 1976 to 1960 plot designations (Appendix G). Census counts in later years, including 1988, followed Swartz' 1960 plot designations.

Census data from previous years were compiled by reviewing available original field notebooks and data summary sheets. Methods of compensating murre counts for diurnal variation in attendance have varied among years (Swartz 1966; Springer and Roseneau 1978; Springer et al. 1985b), and diurnal patterns may change within a census period (see section 2.4.1.2). Therefore, we tabulated only raw, uncompensated counts. The complete list of count data for 1960-1988 is provided in Appendix G. Count data from 1959 were unavailable in formats suitable for comparative use.

Counting methods have been similar but not identical in different years. All boat-based counts have been completed by observers using binoculars from inflatable boats either drifting or anchored offshore near the cliffs. If birds flushed during a count in 1960 or 1961, the number flushed was estimated as the birds departed, and that number was added to the plot total. In subsequent years, counts were stopped if birds flushed, and resumed several minutes later after birds had returned to the cliffs. In 1988, all boat-based counts were obtained by 2-3 observers following Swartz' 1960 plot designations, and if observer counts differed by >10%, the plot was recounted.

Murres have generally been counted by 1's or 10's, depending on plot size, but some of the largest plots have been estimated by mentally blocking off groups of 100 murres (such counts are identified by footnote in Appendix G). Counts of some colonies were completed in single days, while others required multiple days because of colony size or poor counting conditions (i.e., weather and sea-state). All murre counts (except colony 1 in 1979) have been completed within the preferred census period for these species (Table 4.1). The range of dates considered most suitable for censusing is based on attendance variation observed from land in 1988 (see section 2.3.2.2), and on results from other studies (Piatt et al. 1988; Hatch and Hatch 1989).

Swartz (1966) estimated kittiwake numbers in 1960 and 1961 by counting nests, but the details of how that was accomplished are unclear. Comments recorded in the original field notebooks suggest that kittiwake pairs may have been counted and used to estimate nest number (Appendix Table G.49, footnote e). It is unknown whether empty nests or nests with single birds were included in the counts. In all other boat-based kittiwake censuses, birds

Table 4.1. Murre breeding phenology and census dates at Cape Thompson.[a]

Event	1960	1961[b]	1976	1977	1979[c]	1982[b]	1988[d]
First Laying	27 Jun	24 Jun	7 Jul	29 Jun	19 Jun	3 Jul	29 Jun
First Hatching	30 Jul	27 Jul	9 Aug	1 Aug	22 Jul	5 Aug	31 Jul
First Fledging	18 Aug	19 Aug	>25 Aug[f]	23 Aug	11 Aug[g]	>10 Aug	22 Aug
Colony			**Census dates**				
C1	25 Jul	25 Jul 26 Jul 3 Aug	20 Jul 6 Aug	11 Aug	7 Jul 20 Jul 7 Aug 15 Aug 18 Aug	29 Jul 5 Aug 7 Aug	
C2	27 Jul 29 Jul 31 Jul 3 Aug	25 Jul	18 Aug	9 Aug	10 Jul 18 Jul 19 Jul 1,5 Aug 8,9 Aug 15 Aug 16 Aug 17 Aug	29 Jul 5 Aug	12 Jul 13 Jul 18 Jul
C3	21 Jul 22 Jul	25 Jul	23 Jul	10 Aug 12 Aug	10 Jul 18 Jul 1,7 Aug 11 Aug 15 Aug 16 Aug	3 Aug 5 Aug	
C4	15 Jul 17 Jul	22 Jul	9 Aug	12 Aug	7 Aug 11 Aug 14 Aug	28 Jul 3 Aug	10 Aug
C5	1,2 Aug 4 Aug 12 Aug		19 Aug	13 Aug 14 Aug 17 Aug	10 Jul 18 Jul 1,7 Aug 5 Aug 11 Aug 15 Aug 16 Aug	28 Jul 30 Jul 3,7 Aug	17 Jul 20 Jul 25 Jul 27 Jul 1,4 Aug 5,8 Aug 10 Aug 11 Aug 15 Aug

[a] Adapted from Springer et al. (1985a, Table 1).

[b] Data from Springer et al. (1985b).

Table 4.1. Continued.

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[c] Counts on 15, 16, 17, and 18 Aug were outside of census period.

[d] Data from present study.

[e] Estimated from hatching dates assuming 33 d incubation period (Harris and Birkhead 1985).

[f] No murre chicks had left the cliffs when field crews left the site on 25 August.

[g] One murre chick was seen on the water on 7 Aug; none were observed again until 11 Aug, when many were on the water.

were counted by 1's. Nests, including those which were apparently abandoned or only partially constructed, were also recorded by 1's; however, no nest count was obtained in some years. Many counts of kittiwakes occurred outside of the preferred census period (Table 4.2), which is based on daily variation observed from land at Cape Thompson in 1988 (section 2.3.3.2), and on observations from the Semidi Islands (Hatch and Hatch 1988).

Several of Swartz' 1960 plots were counted from land in some years. In 1960, land-based counts of murres and kittiwakes were made on two plots in colony 3 and on colony 5 plots 5A-5Z. In 1961, kittiwakes in colony 4 were counted from land only; in 1979, some plots were counted from both land and water. In 1988, five of the colony 5 plots created by Swartz in 1960 were counted by observers with binoculars during the appropriate census periods for murres and kittiwakes. Observers recorded the numbers of adult murres and kittiwakes present, and on 27 July, the number of kittiwake nests. Plots 5E, 5R and 5S were counted 3 times, and plots 5L and 5Q, incorporated into the new land-based plot system as plots 5-5J and 5-8N respectively, were counted 10 times each.

4.2.2. Analysis of Population Trend Data

4.2.2.1. Thick-billed and Common Murres

Raw count data were reduced for year-to-year comparisons using several criteria. Counts identified as being poor due to weather or sea-state conditions were not included in any part of the analysis. If plot counts were replicated on two or more different days within the census period, replicate counts were averaged to give a single plot total for that year. If in some years, a plot was counted in combination with others, such plot combinations were also calculated for other years to provide the greatest time span for comparisons. Comparisons were not made if they required mixing land-based and boat-based counts either within or between years, except for Colony 4 in 1960-1961. Before the collapse of certain cliff formations in recent years, plots in Colony 4 were about equally visible from land or boat positions, owing to the low elevations of the cliffs and the availability of good viewing areas from land. Thus, while comparing land and boat counts undoubtedly

Table 4.2. Kittiwake breeding phenology and census dates at Cape Thompson.

Event	1960[a]	1961[b]	1976	1977	1978[c]	1979	1982	1988[d]
First Laying[e]	20 Jun	25 Jun	13 Jul	2 Jul	28 Jun	21 Jun	24 Jun	22 Jun
First Hatching[f]	17 Jul	22 Jul	9 Aug	29 Jul	25 Jul	18 Jul	21 Jul	19 Jul
Last Hatching[g]	(2 Aug)	(7 Aug)	(25 Aug)	(14 Aug)	(10 Aug)	(3 Aug)	(6 Aug)	(4 Aug)
First Fledging	20 Aug	27 Aug						27 Aug
Colony				**Census dates**				
C2	27,28 Jul 29,31 Jul 3 Aug	10 Aug 11 Aug	18 Aug	17 Jul	20 Aug	11 Jul 18 Jul 19 Jul	5 Aug	18 Jul
C3	21,22 Jul	31 Jul 1,11 Aug	23 Jul	24 Jul 3 Aug		31 Jul 1 Aug		
C4	15 Jul	29 Jul 3 Aug	9 Aug	18 Jul 19 Jul	14 Aug	10 Jul 19 Jul	5 Aug	10 Aug
C5	1,2 Aug 4,12 Aug	12 Aug 13 Aug	19 Aug	19 Jul		5 Aug		11,17 Jul 20,25 Jul 27 Jul 1,4 Aug 5,8 Aug 10,11 Aug 15,18 Aug

[a] 12 Aug counts were outside of census period.

[b] 10, 11, 12, and 13 Aug counts were outside of census period.

[c] All counts were outside of census period.

[d] Counts after 8 Aug were outside of census period.

[e] Based on 27 d incubation period (Coulson and White 1958).

[f] 1960-1982 data from Springer et al. (1985b). Dates for 1977-1982 were estimated from chick growth rate. Data for 1988 from present study.

[g] Based on 16 d hatching period observed in 1988.

introduces some variation, we feel this error is probably minimal for colony 4 plots.

Having identified a single "best" measure of colony size for each colony and year censused, we used two statistical procedures to assess the patterns and significance of annual variation. In one approach, we tested for trends across years using Pearson product-moment correlations and Spearman rank correlations between murre or kittiwake numbers and year of census. Significance tests were two-tailed. The rationale here is that the sampling error, largely unknown, associated with each measure of population size becomes less important if there is convincing evidence of a long-term trend in a series of data.

Our second approach entailed estimating the component of daily variation among boat-based counts using all available information and asking whether the observed annual deviations from the 1960-1988 grand mean could have arisen from that source (daily variation) alone. First, we estimated the expected variation of murre attendance within years independently for every available set of replicated boat-based counts ($n \geq 2$ for a given plot) from 1961, 1976, 1979, and 1988). Standard deviations were converted to coefficients of variation (SD/mean) to adjust for differences in plot size. We pooled all such measures of daily variation using a weighted average:

$$\text{Pooled estimate CV for boat-based counts (within-years variability)} = \frac{\sum_{i=1}^{a} (n_i - 1)\, CV_i}{\sum_{i=1}^{a} n_i - a}$$

where CV_i = daily CV calculated for a given plot and year

n_i = number of replicate counts on which the calculation of CV_i is based

a = number of different measures of daily CV available to incorporate in the weighted mean.

This formula for a pooled-estimate CV is similar to the pooled variance commonly used in the demoninator of a t-test (Sokal and Rohlf 1981: 226). We also calculated a weighted sample size, n_o, associated with this overall estimate of daily variation (Sokal and Rohlf 1981: 214):

$$n_o = 1/(a-1)\ [\sum_{i=1}^{a} n_i - (\sum_{i=1}^{a} n_i^2 / \sum_{i=1}^{a} n_i)]$$

A conservative test for annual variation was then constructed by using this estimated within-years CV to put 95% confidence limits on the grand mean census total (usually a 6- or 7-year average) for each of the Cape Thompson colonies, C1-C5. We had to assume that our pooled-estimate CV accurately describes within season variability in different colonies and years, though it is in fact based on a relatively small subset of the data in 4 years. Confidence intervals for grand mean colony size (colonies C1-C5, respectively) were computed as follows:

$$95\%\ C.I. = \text{grand mean} \pm t_{0.05[n_o-1]}\ (s/\sqrt{n_o})$$

where s is the product of the grand mean for a colony and our pooled estimate CV. Note that we used the sample size n_o for estimating the standard error of the grand mean. That is, we used the sample size associated with the estimate of daily variation, rather than the number of years entering into the computation of the grand mean. Any of the several annual measures of colony size lying outside the 95% C.I. for the grand mean would exceed the deviation expected due to variability of boat-based counts within years.

Due to the hybrid character of this statistical procedure (i.e., using estimates of variance from one source to test the significance of differences obtained from other sources) the results must be interpreted cautiously. The method provides at least an approximate significance test, however, and a reasonable basis for assessing annual variation in population sizes at Cape Thompson in light of what is known about variation within years. We believe the tests are conservative because: (1) there was some averaging of $n \geq 2$ counts per plot in arriving at the single measures of colony size for each year studied, whereas the test assumes no replication, and (2) counts within a given colony sometimes required more than 1 day to complete, which would also reduce the effect of daily variation by an undetermined amount.

In 1960, Swartz' field crews separated the two murre species in their plot counts (Appendix G). Subsequent attempts to count both species from boats have not been successful. However, in 1988 we assessed Common and

Thick-billed Murre numbers separately at all land-based plots in Colonies 2-5. Assuming our plots provided a representative sample of habitat in each colony, we use these data to indicate the present species composition at Cape Thompson. We tested for significant changes in species composition by averaging the 1988 Thick-billed Murre ratios from each colony's replicate counts and comparing our mean to the single-estimate ratio from 1960 using the appropriate t-test (Sokal and Rohlf 1981). All ratio data were arcsine transformed initially.

Mean per annum percentage changes (r) in the murre population were calculated using an exponential model:

$$N_t = N_o e^{rt}$$

where N_o is the initial population size and N_t is population size at time t.

4.2.2.2. Black-legged Kittiwakes

Plot counts for between-year comparisons of kittiwakes were treated using the criteria already described for murre counts. In addition, we attempted to standardize all kittiwake counts as counts of individual birds, not pairs or nests. Previous studies (Springer et al. 1985b) have converted nest counts from 1960 and 1961 to estimates of bird numbers by doubling the nest count. We converted nest counts to an estimate of individual bird numbers by multiplying the nest count by 1.4, the mean ratio of individual birds to nest numbers during boat-based counts at colonies 2, 3, 4 and 5 in 1979, 1982, and 1988. As noted above, several kittiwake census counts have occurred outside of the census period. For the 1988 boat-based counts obtained after the census period, we multiplied the raw counts by 1.31, a correction factor determined by comparing the daily attendance counts of land-based plots at Colony 3 (Fig. 2.13a) on 10 August (the day of the boat-based census) to the census mean for those plots.

Yearly colony totals were evaluated for population trends using Spearman and Pearson correlations with two-tailed significance tests. Variation attributable to daily (within-season) patterns was estimated as described above for murres using replicate counts available from colonies 2 and 4 in 1979.

4.3. Results

4.3.1. Common and Thick-billed Murres

From count data presented in Appendix G, we obtained an estimated total of murres present in each colony during each year of study since 1960 (Tables 4.3-4.9). The specific plots and numbers of counts on which these totals are based are indicated. Column totals in Tables 4.3-4.9 are the basis of our analysis of population trends.

Correlation analysis revealed negative trends in murre attendance at all colonies between 1960 and 1982 or 1988, significantly so for colonies 1, 2 and 5 (Table 4.10). Declines were not uniform among colonies throughout this period, however: colonies 1 and 2 showed significant declines between 1960 and 1977 (Table 4.11), while colonies 4 and 5 were significant between 1976-1982/88 (Table 4.12). Colony 3 showed no significant trends over any time period. Colonies 1, 2, 3 and 5 exhibited the greatest apparent decrease in murre numbers between 1960-1976/77, but colony 4 did not begin to decline until after 1979 (Figs. 4.1-4.5). Considering all colonies except colony 1 (i.e., summing all plot totals from colonies 2, 3, 4 and 5) murre numbers declined significantly between 1960 and 1988 (r_s=-0.900, P=0.04; r=-0.9570, P=0.01) (Fig. 4.6). The trend was significant between 1960 and 1979 (r_s=-1.00, P<0.001; r=0.99, P=0.11), but nonsignificant from 1979 to 1988 (r_s=-0.500, P=0.67; r=-0.484, P=0.68).

The daily coefficient of variation of murre attendance based on replicate count data was 25.8% (n_o=3) for all data, and 27.1% (n_o=6) using only data that had >4 replicate counts (Table 4.13). We used the latter CV to compute a standard deviation and 95% C.I. for each colony grand mean. Most census counts fell within the 95% confidence intervals thus calculated (Figs. 4.1-4.6). However, the 1960 census count was outside the 95% C.I. for all colonies, as were the 1979 counts in colonies 1 and 5 and the 1988 count in

Table 4.3. Summary of boat-based census results from Cape Thompson - Colony 1 murres.[a]

	1960		1961		1976		1977		1979		1982	
Plot	x̄	n	x̄	n	x̄	n	x̄	n	x̄	n	x̄	n
1A	34	1	15	3	9	2	0	1	0 (0	3 5)[d]	0	3
1B,1C[b]	533	1	763	3	332	2	342	1	288 (301	3 5)	362	3
1D	721	1	678	7	282	2	390	1	392 (368	3 5)	338	3
1E	2089	1	2294	3	954	1	1152	1	914 (1046	3 5)	1117	3
1F,1G[c]	773	1	902	3	508	2	570	1	401 (499	2 4)	568	3
1H	36	1	30	3	34	2	16	1	0 (0	3 5)	19	3
1I	0	1	0	3	0	2	0	1	0 (0	3 5)	0	3
Total[e]	4186		4682		2119		2470		1995 (2214)		2404	

[a] No census counts were completed in 1978 or 1988.

[b] Plots 1B and 1C were counted separately, but observers had difficulty distinguishing plot boundaries between them, hence they were combined.

[c] These two plots were counted together in 1979, so are combined here in all years.

[d] The census period probably extended to 11 Aug. Numbers in parentheses include counts after that date.

[e]Total calculated using all plots.

Table 4.4. Summary of boat-based census results from Cape Thompson - Colony 2 murres.[a]

Plot	1960 x̄	1960 n	1961 x̄	1961 n	1976 x̄	1976 n	1977 x̄	1977 n	1979 x̄	1979 n	1982 x̄	1982 n	1988 x̄	1988 n
2A1	36	1	–[c]		5	1	9	1	8	1	14	2	28	1
2A2	50	1	–[c]		29	1	23	1	30	1	16	2		
2B	159	1	–[c]		145	1	125	1	154	1	129	2		
2C	1182	1			667	1	512	1	723	5	762	2		
									(740	7)[d]				
2D	83	1			75	1	152	1	156	1	225	1		
2E	2472	1			900	1	1677	1	1405	1	1635	1		
2F	780	1			430	1	847	1	580	1	505	1		
2G	3437	1			1295	1	2867	1	1740	1	1677	1		
2H	4113	1			2020	1	2500	1	2105	1	1935	1		
2I	2650	1			1025	1	1747	1	1125	1	1402	2		
2J	2870	1			1325	1	2415	1	1475	1	1720	1		
2K,2L[b]	3593	1			2037	1	3160	1	1910	1	2230	1		
2M	2802	1			2335	1	2000	1	1355	1	1700	1		
2N	2265	1			525	1	1642	1	1345	1	1615	1		
2O	2762	1			1025	1	1962	1	1238	6	1680	1		
									(1384	8)				
2P	1610	1			1255	1	1270	1	920	1	870	1		
2Q	4077	1			1525	1	3025	1	1925	1	1975	1		
2R	782	1			485	1	690	1	430	1	465	1		
2S,2T[b]	6836	1			6025	1	5630	1	3344	1	4090	1		
									(5724	2)[e]				
2U	3315	1			3420	1	2825	1	3225	1	2007	2	2165	2
2V	4575	1			3890	1	3347	1	3930	1	2405	1	2755	2
									(3205	2)				
2W	3355	1			2210	1	2215	1	1950	1	1860	1		
2X	2525	1			1880	1	1177	1	2030	1	1590	1		
2Y	3950	1			3465	1	3092	1	4195	1	2395	1		
2Z	2300	1			1530	1	1647	1	1145	2	1720	1		
2AA	1355	1			790	1	702	1	920	1	710	2		
2BB	2005	1			2035	1	990	1	1247	6	1200	2		
									(1233	9)				
2CC	1500	1			500	1	1162	1	1565	1	1220	1	990	1
2DD	5275	1			1647	1	1517	1	1800	1	1475	2		
2EE	1450	1			750	1	650	1	797	1	540	2		
									(698	2)				
2FF	817	1			445	1	440	1	615	1	465	2		
2GG	440	1	–[c]		545	1	360	1	395	1				
2HH,2II[b]	480	1	–[c]		485	1	434	1	518	1	702	2		
									(514	2)				
Total[f]	75461				46175		52451		45905		42934			
									(47606)					

Table 4.4. Continued.

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[a] No census counts were completed in 1978.

[b] These plots were occasionally counted together, so have been combined for all years here.

[c] These plots were counted from land in 1961.

[d] Counts in parentheses include those made after 11 Aug, the end of the census period.

[e] Replicate count for plot 2T only.

[f] Total calculated using all plots except 2GG.

Table 4.5. Summary of boat-based census results from Cape Thompson - Colony 3 murres.[a]

	1960		1961		1976		1977		1979		1982	
Plot	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n
3A	84	1	(234	1)	176	1	152	1	120	1	121	2
3B	900	1	(1072	1)	487	1	517	1	426	2	470	2
3C	100	1			550	1	480	1	305	1	195	1
3D	940	1	(1500[e]	1)	635	1	552	1	477	1	555	2
3E	620	1	(1200[e]	1)	530	1	564	1	395	1	502	2
3F	500	1			430	1	602	1	318	1	315	2
3G	–[c]	1			2300	1	1010	1	440	1	465	1[j]
3H	–[c]	1			700	1	565	1	478	1	485	1[j]
3I	400	1			1450	1	772	1	240	1	425	1[j]
3J	2900[d]	1			1275	1	2617	1	2920	1	1410	1[j]
3K	2600	1			1175	1	1585	1	317	1	790	1[j]
(3G+H+I+J+K)[j]					(6900	1)[j]	(4964	1)[j]	(4395	1)[j]	(3575	1)[j]
3L+M+N+O[b]	3710	1					2242	1	2459[f] (2569[g]	4 6)	2222	1[i]
3P	1400	1			1300	1	1332	1	1290	1	1297	2
3Q+R+S[b]	4660	1			2391	1	3649	1	2674	1	3260	1
3T+U[b]	4700	1			1877	1	3232	1	2917	2	3185	2
3V	900	1			862	1	835	1	755	1	872	2
3W	450	1	(833	1)	558	1	660	1	477 (502	4 6)[h]	457	2
Total[k]	15254				9796		12575		10154		11229	

[a] No counts were made in 1978 or 1988.

[b] These plots were combined in some counts for some years, so are combined for all years here.

[c] These plots were counted from land.

Table 4.5. Continued.

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[d] Observer estimated 2900 murres on plot, but noted he believed another 1000 to be present but hidden by ledges.

[e] Rough estimate counted by 100's; not an accurate count.

[f] Replicate counts for plot 3M only.

[g] Includes replicate counts for plot 3M from after census period (>11 Aug).

[h] Includes counts after 11 Aug.

[i] Plot 3P was counted twice.

[j] In 1982 Springer et. al. (1985a) had difficulty distinguishing boundaries between these plots and recommend combining them for interyear comparison.

[k] Totals calculated using plots 3A-3F, and 3P-3W.

Table 4.6. Summary of boat-based census results from Cape Thompson - Colony 4 murres.[a]

	1960		1961		1976		1977		1979		1982		1988	
Plot	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n
4A	133	1	73	1	137	1	157	1	152	2	110	2	64	1
4B	638	1	527	1	265	1	547	1	578	2	212	2	310	1
4C	834	1	369	1	910	1	975	1	251	2	432	2	195	1
4D	371	1	247	1	165	1	135	1	178	2	115	2	90	1
4E	1190	1	1030	1	880	1	985	1	875	3	670	2	595	1
4F	600	1	540	1	335	1	310	1	168	2	260	2	195	1
4G	1555	1	1115	1	912	1	1012	1	847	3	732	2	615	1
4H	348	1	351	1	375	1	346	1	343	2	277	2	247	1
4I	57	1	44	1	40	1	95	1	161	2	75	2	60	1
4J	424	2	199	1	804	1	560	1	531	2	490	2	545	1
4K	205	2			135	1	125	1	131	2	102	2	60	1
4L	171	1	164	1	125	1	420	1	288	2	325	2	215	1
4M	835[b]	2	485	1	569	1	487	1	394	3	362	2	307	1
4N	281[b]	2	184	1	327	1	324	1	348	2	295	2	230	1
4O	1	1	20	1	107	1	97	1	102	2	82	2	70	1
4P	614	1	498	1	490	1	657	1	581	3	517	2	255	1
4Q	172	1	154	1	260	1	165	1	144	2	257	2	245	1
4R	124	1	92	1	56	1	220	1	240	2	237	2	165	1
Total[c]	7232		5423		5861		6681		5439		4791		3866	

[a] No census was completed in 1978.

[b] Includes counts which were listed as being "estimated."

[c] Total calculated without plots 4K, 4M, and 4N.

Table 4.7. Summary of census results from Cape Thompson - Colony 5 murres, land-based counts.

	1960		1979		1982		1988	
Plot	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n
5A	947	1						
5B	2654	1			912	1		
5C	870	1						
5D	1700	1						
5E	3570	1			2015	3	1150	3
5F	990	1			446	3		
(5E+5F)[a]	(4560	1)[a]	(1277	1)[a]	(2461	3)[a]		
5G	4267	1	1835	1	1991	3		
5H	4275	1			1693	3		
5I	1350	1			640	1		
5J	2100	1						
5K	3687	1			1506	3		
5L	1850	1	490	1	748	3	930	10
5M	1700	1	702	1	835	1		
5N	3650	1	1400	1	2285	1		
5O	3050	1	835	1	826	2		
5P	3600	1	940	1	1191	2		
5Q	1762	1	900	1	744	2	833	11
5R	4350	1	1430	1	2023	2	1620	3
5S	1925	1			738	2	817	2
5T	1122	1			1073	2		
5U	875	1			440	1		
5V	110	1			417	2		
5W	70	1			568	2		
5X	1085	1						
5Y	2225	1						
5Z	475	1						

[a] 5E and 5F were combined for the 1979 count.

Table 4.8. Summary of boat-based census results from Cape Thompson - Colony 5 murres.[a]

	1960		1976[b]		1977		1978		1979		1982		1988	
Plot	x̄	n	x̄	n	x̄	n	x̄	n	x̄	n	x̄	n	x̄	n
5A+B+ C+X[c]			1400	1	952	1			1909	1[e]	965	1		
5D+Y+ Z[c]			3000	1	2472	1			1698	1	1215	1		
5E+F[c]					1477	1			825	1	160	1		
5G					1245	1			580	1	365	1		
5H+I[c]					1745	1			865	1	690	1		
5J					395	1			197	1	225	1		
5K					860	1			750	1				
5L					217	1			230	1	250	1		
5M					445	1			452	1	265	1		
5N					840	1			1040	1	890	1		
5O					375	1			380	1	180	1		
5P					700	1			520	1	530	1		
5Q					270	1			350	1	265	1		
5R					420	1					470	1		
5S					947	1			910	1	510	1		
5T					1025	1			650	1	455	1		
5U					170	1			230	1				
5V					172	1			57	1	120	1		
5W					145	1			140	1	110	1		
5AA	4866	1			2390	1			1316	6	1220	1	1735	1
									(1286	8)[f]				
5BB	1150	1			475	1					400	1		
5CC	1700	1			1010	1			770	1	230	1		
5DD	2950	1			1432	1					1115	2	1010	1
5EE	3100	1			2062	1			1720	1	1175	1		
5FF	4750	1			2710	1			2722	1				
5GG	7650	1			3697	1			984	5	2550	1	2560	1
5HH	12100	1			5235	1			2865	1	4947	1	4015	1
5II	7000	1			4885	1			2145	1	3230	1		
5JJ	7400	1			1612	1			1082	2	1480	1		
5KK	6175	1			2787	1			1920	1	2325	1		
5LL	1175	1			1010	1			687	2	935	2	960	1
5MM	6750	1			3512	1			2220	1	2450	1		
5NN	7350	1			4582	1			3135	1	2940	1		
5OO	6000	1			2352	1			1255	1	2257	2	1710	1
5PP	4050	1			2327	1			1265	1	2280	1		
5QQ	1425	1			1097	1			865	1	1140	1		
5RR	1725	1			1250	1			1375	1				

Table 4.8. Continued.

	1960		1976[b]		1977		1978		1979		1982		1988	
Plot	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n
5BB+DD[d]	4100	1			1907	1			1120	1	1515			
5U+RR[d]					1420	1			1605	1	1240	1		
5K+FF[d]					3750	1			3472	1	2410	1		
Total[g]	31791				14684				7107		11909		10980	

[a] No counts were completed in 1961 or 1978.

[b] 1976 plots were counted 1976 plot designations, with no "special area" conversion plots to convert them to Swartz' 1960 designations (see Table 4.9).

[c] These plots were counted together in some years, so all years were converted to match.

[d] These plots were counted together in 1982, and the combinations are listed here for other years.

[e] Plot 5X was counted twice.

[f] Includes counts after end of census period.

[g] Total calculated using plots 5AA, 5GG, 5HH, 5LL and 500.

Table 4.9. Summary of boat-based census results from Cape Thompson - Colony 5 murres using 1976 plot designations.

	1976		1977		1979		1982	
Plot	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n
5AA(1976)	1400	1	952		1909	1	965	1
5BB(1976)	3000	1	2472		1698	1	1215	1
5CC(1976)	14467	1	5395		2761	1[a]	2275	1
5DD(1976)	2933	1	6675		4665	1	3485	1
5FF(1976)	11117	1	5940				4525	1
5HH(1976)	10400	1	7730		3484	1[b]	6000	1
5KK(1976)	11533	1	9135		(4583[c])	1	7325	1
5LL(1976)	11267	1	8923		(5808[c])	1	6530	1
5NN(1976)	9300	1	7305		(4592[c])	1	5830	1
5QQ(1976)	2617	1	3055		(1928[c])	1	3420	1
5RR(1976)	1950	1	1737		1782	1	1470	1
Total[d]	79984		59319				43040	

[a] Part of plot was counted 6 times.

[b] Part of plot counted 5 times.

[c] Required use of estimates of special area attendance for conversion to these designations.

[d] Total calculated using all plots.

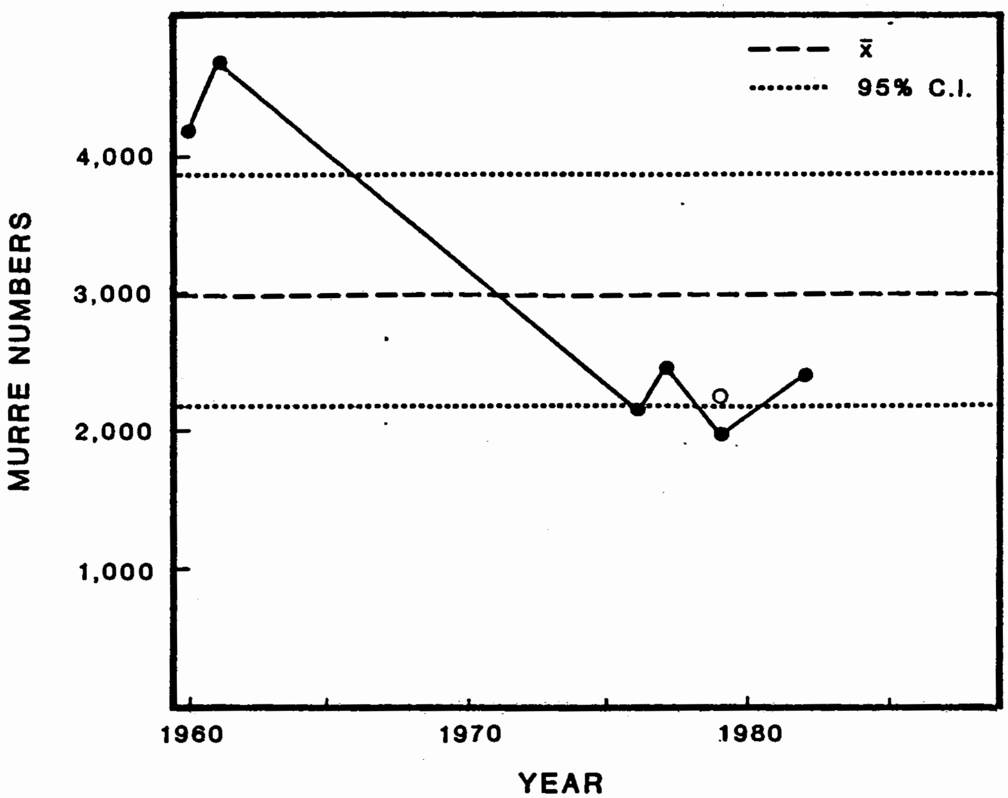

Figure 4.1. Murre population trends in Colony 1, Cape Thompson. Census totals for all plots. Open circle represents data obtained after standard census period.

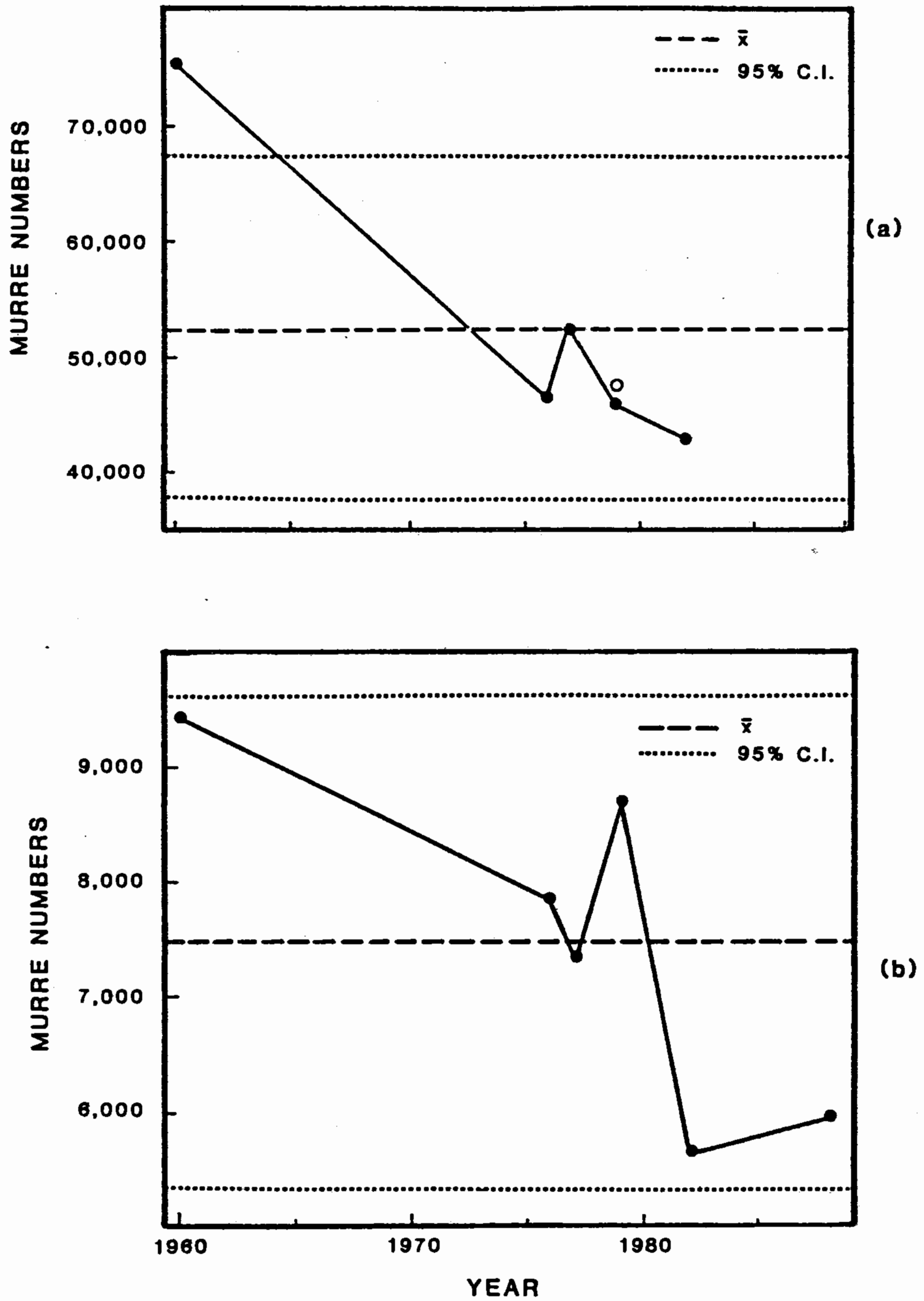

Figure 4.2. Murre population trends in Colony 2, Cape Thompson. (a) Census totals include all plots except 2GG. Open circle represents data obtained after standard census period. (b) Census totals for plots 2A1, 2U, 2V, and 2CC only.

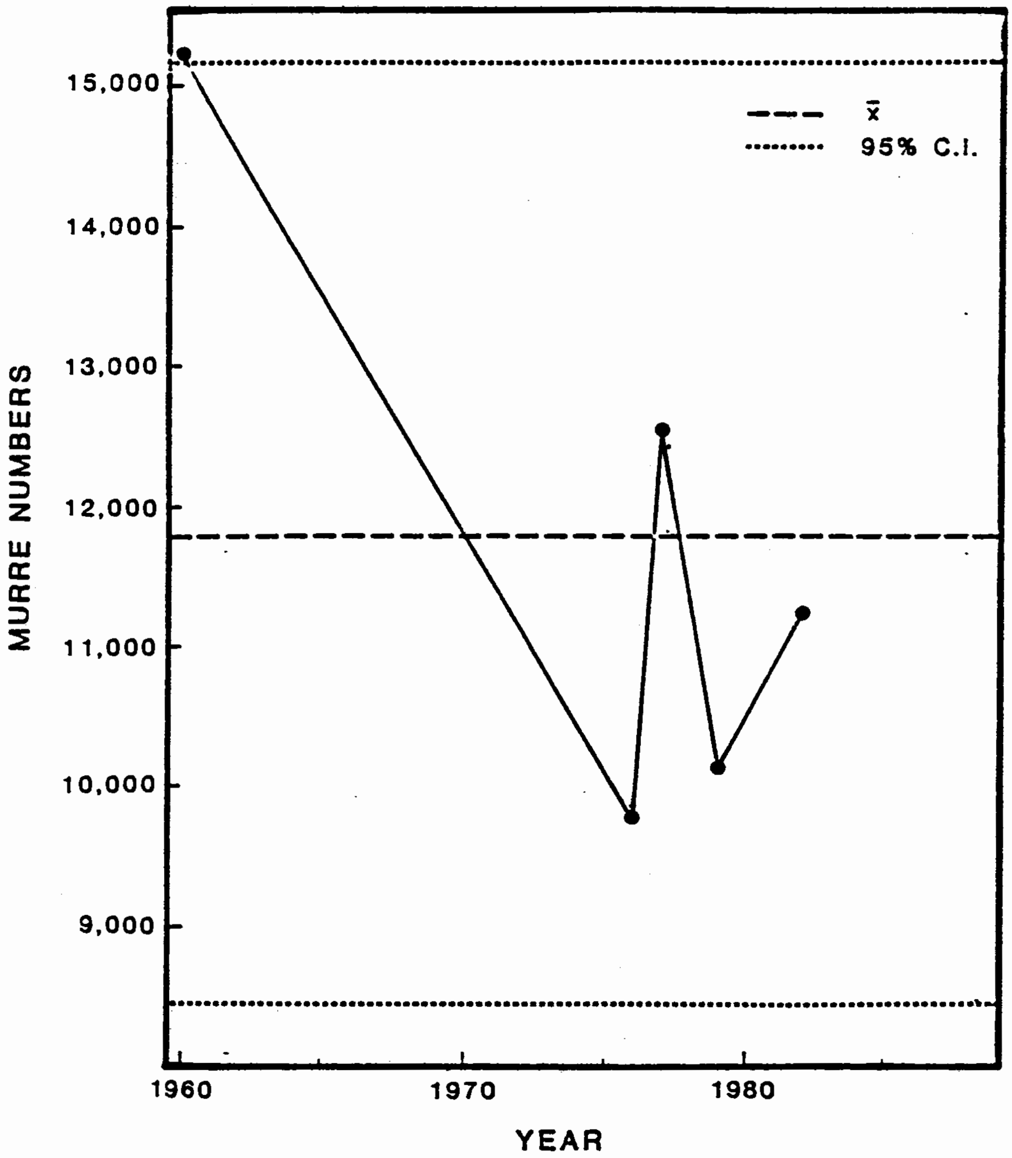

Figure 4.3. Murre population trends in Colony 3, Cape Thompson. Census totals for plots 3A-3F and 3P-3W.

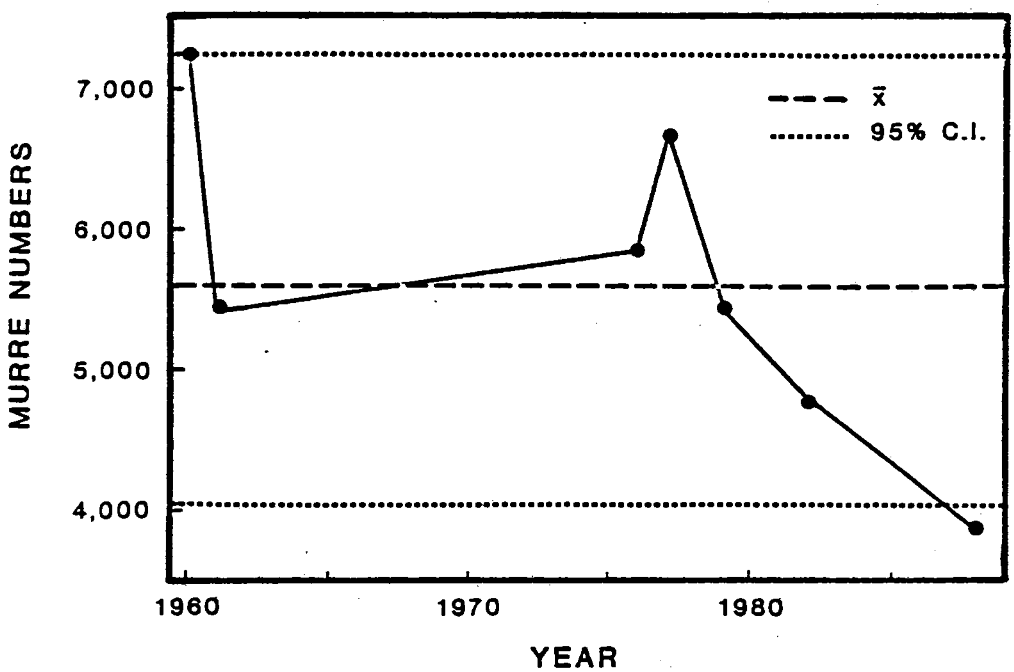

Figure 4.4. Murre population trends in Colony 4, Cape Thompson. Census totals include all plots except 4K, 4M, and 4N.

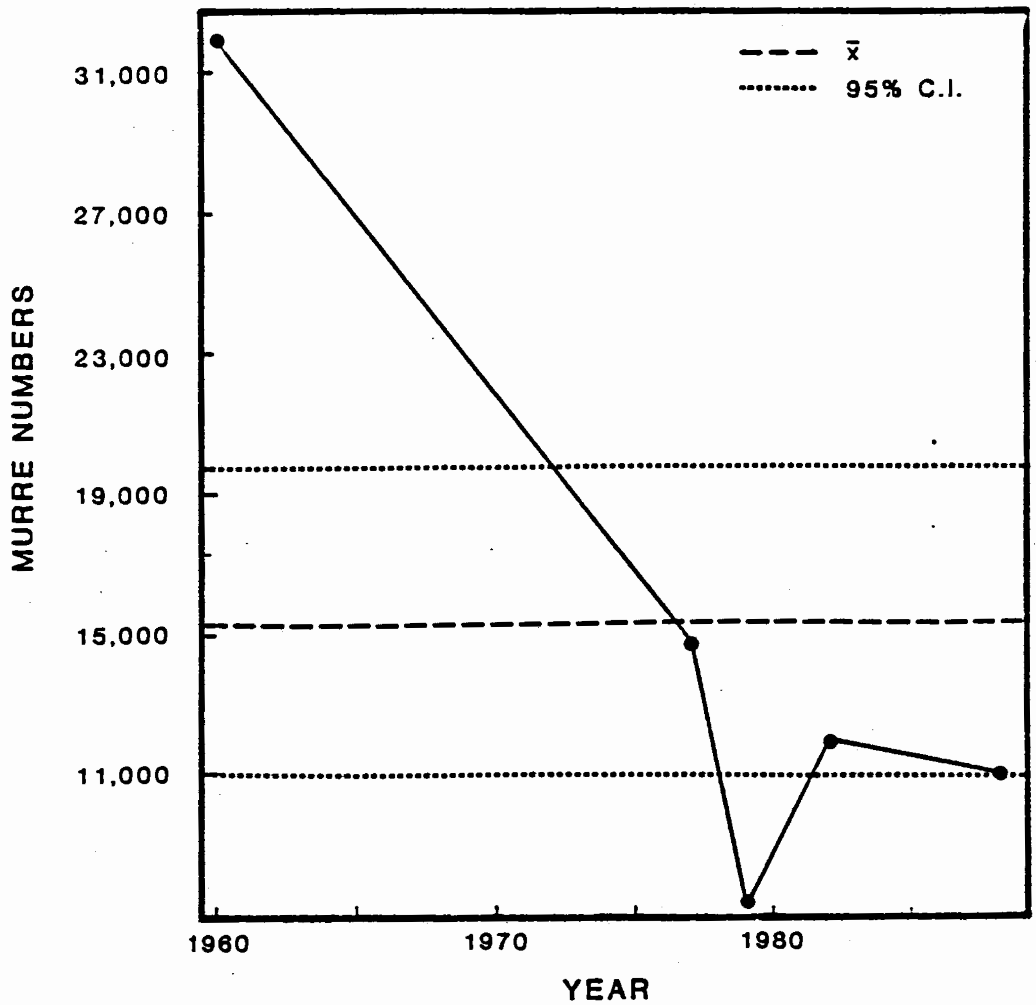

Figure 4.5. Murre population trends in Colony 5, Cape Thompson. Census totals for boat-based plots 5AA, 5GG, 5HH, 5LL, and 500.

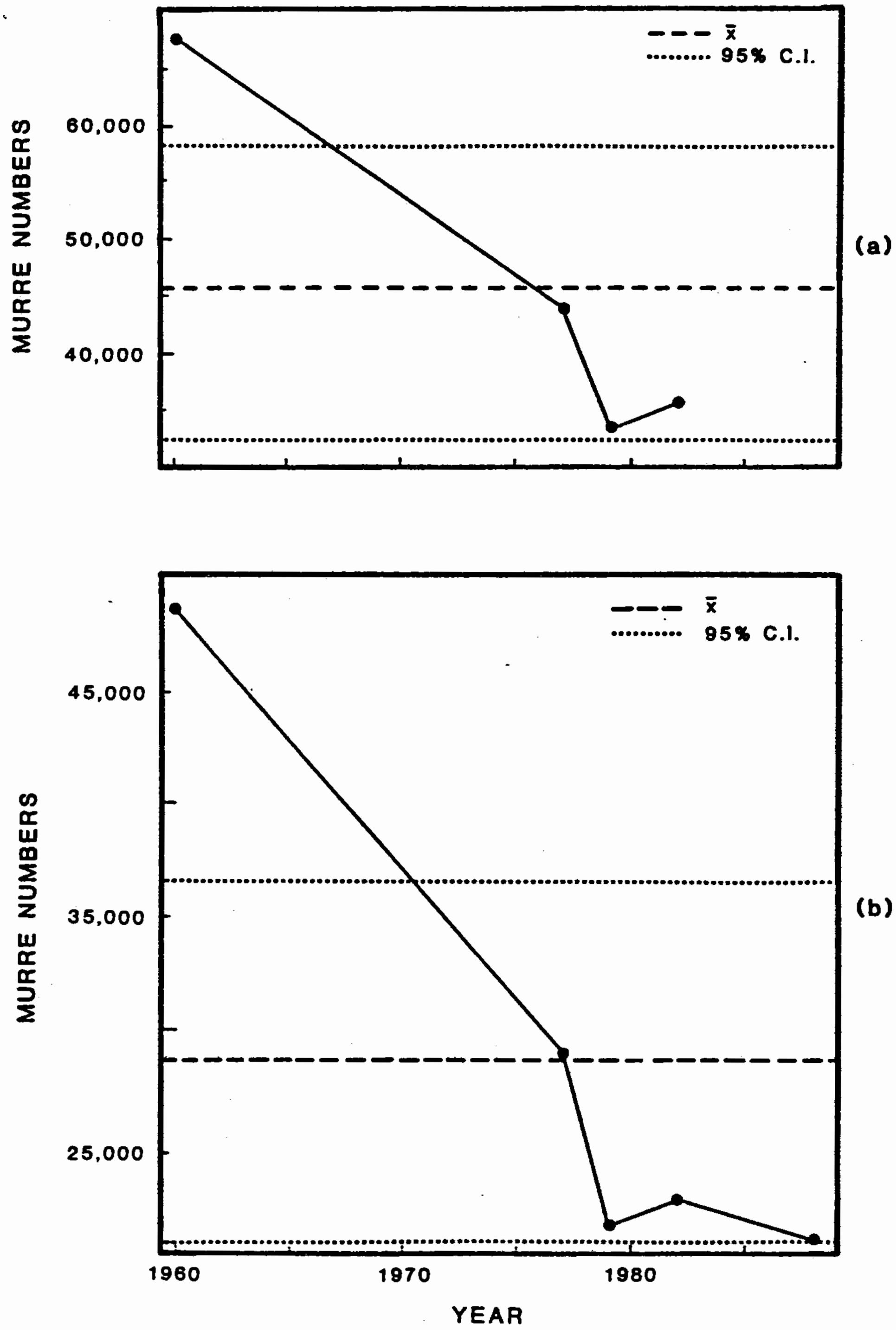

Figure 4.6. Combined murre population trends in: (a) Colonies 1-5, 1960-1982, and (b) Colonies 2, 4, and 5, 1960-1988.

Table 4.10. Correlations between year and murre attendance at Cape Thompson, 1960 through 1982 or 1988.

Statistic	Colony 1[a]	2[b]	3[c]	4[d]	5[e]	5[f]
Spearman r_s	-0.657	-0.771	-0.300	-0.750	-1.000	-0.700
P	0.156	0.072	0.624	0.052	0.0001	0.188
Pearson r	-0.944	-0.810	-0.827	-0.683	-0.995	-0.897
P	0.005	0.050	0.084	0.091	0.065	0.039

[a] All plots in 1960, 1961, 1976, 1977, 1979, and 1982.

[b] Plots 2A1, 2U, 2V, 2CC in 1960, 1976, 1977, 1979, 1982, and 1988.

[c] Plots 3A-3F, 3P-3W in 1960, 1976, 1977, 1979, and 1982.

[d] Plots 4A-4J, 4L, 4O-4R in 1960, 1961, 1976, 1977, 1979, 1982, and 1988.

[e] Land counts of plots 5E, 5L, 5Q, 5R, 5S in 1960, 1982, and 1988.

[f] Boat counts of 5AA, 5GG, 5HH, 5LL, 5OO in 1960, 1977, 1979, 1982, and 1988.

Table 4.11. Correlations between year and murre attendance at Cape Thompson, 1960-1977.

Statistic		Colony 1[a]	2[b]	3[c]	4[d]
Spearman	r_s	-0.600	-1.000	-0.500	-0.200
	P	0.400	0.0001	0.667	0.800
Pearson	r	-0.966	-0.980	-0.833	-0.062
	P	0.034	0.129	0.373	0.938

[a] All plots in 1960, 1961, 1976, 1977, 1979 and 1982.

[b] Plots 2A1, 2U, 2V, 2CC in 1960, 1976, 1977, 1979, 1982, and 1988.

[c] Plots 3A-3F, 3P-3W in 1960, 1976, 1977, 1979, and 1982.

[d] Plots 4A-4J, 4L, 4O-4R in 1960, 1961, 1976, 1977, 1979, 1982 and 1988.

Table 4.12. Correlations between year and murre attendance at Cape Thompson, 1976-1982/88.

Statistic		Colony				
		1[a]	2[b]	3[c]	4[d]	5[e]
Spearman	r_s	0.000	-0.600	0.400	-0.900	-1.000
	P	1.000	0.285	0.600	0.037	0.0001
Pearson	r	0.227	-0.686	0.104	-0.926	-0.907
	P	0.773	0.201	0.897	0.024	0.277

[a] All plots in 1960, 1961, 1976, 1977, 1979 and 1982.

[b] Plots 2A1, 2U, 2V, 2CC in 1960, 1976, 1977, 1979, 1982 and 1988.

[c] Plots 3A-3F, 3P-3W in 1960, 1976, 1977, 1979 and 1982.

[d] Plots 4A-4J, 4L, 4O-4R in 1960, 1961, 1976, 1977, 1979, 1982 and 1988.

[e] Boat counts of 1976 plot designations; all plots in 1976, 1977 and 1982.

Table 4.13. Replicate counts of boat-based murre plots used to estimate daily attendance variation at Cape Thompson.[a]

	1961				1976				1979				1982				1988			
Plot	$\bar{x}$	SD	CV%	n	$\bar{x}$	SD	CV%	n	$\bar{x}$	SD	CV%	n	$\bar{x}$	SD	CV%	n	$\bar{x}$	SD	CV%	n
1A	14	8	55.6	2	9	4	47.1	2												
1B	248	112	45.2	2									138	10	7.5	3				
1C	451	158	35.0	2	333	11	3.2	2	301	94	31.3	5[b]	223	59	26.2	3				
1D	497	358	72.0	2	283	60	21.3	2	368	111	30.3	5	338	32	9.4	3				
1E	1997	1262	63.2	2					1046	316	30.2	5	1118	197	17.6	3				
1F	4	5	141.0	2									11	10	88.4	3				
1G	829	289	34.9	2	508	59	11.7	2	499	133	26.6	4[c]	557	50	9.0	3				
1H	23	32	141.0	2	34	30	87.3	2					19	11	57.3	3				
2A1													15	8	53.6	2				
2A2													16	6	35.3	2				
2B													129	9	6.6	2				
2C									740	96	13.0	7	763	4	0.5	2				
2I													1402	60	4.3	2				
2O									1384	338	24.4	8	1680	354	21.0	2				
2T									3723	1361	36.6	2								
2U													2008	506	25.2	2	2165	399	18.4	2
2V									3205	1025	32.0	2					2755	436	15.8	2
2Z									1145	665	58.1	2								
2AA													710	21	3.0	2				
2BB									1233	150	12.2	9	1200	212	17.7	2				
2EE									699	139	19.9	2								
2HH									313	10	3.2	2	510	219	43.0	2				
2II									201	16	7.7	2	193	4	1.8	2				
3A													122	97	79.7	2				
3B									426	58	13.6	2	470	155	33.1	2				
3D													555	14	2.6	2				
3E									395	28	7.2	2	503	11	2.1	2				
3F									319	23	7.3	2	315	50	15.7	2				
3H									478	95	19.8	2								
3M									975	285	29.3	6								
3N													973	81	8.4	2				
3P													1298	138	10.6	2				
3T									1525	495	32.5	2	1695	35	2.1	2				
3U									1393	555	39.9	2	1490	184	12.3	2				
3V													873	67	7.7	2				
3W									502	154	30.7	6	458	25	5.4	2				
4A									152	42	27.9	2	110	0	0.0	2				
4B									579	10	1.6	2	213	46	21.6	2				
4C									252	38	14.9	2	433	81	18.8	2				

Table 4.13. Continued.

	1961				1976				1979				1982				1988			
Plot	$\bar{x}$	SD	CV%	n	$\bar{x}$	SD	CV%	n	$\bar{x}$	SD	CV%	n	$\bar{x}$	SD	CV%	n	$\bar{x}$	SD	CV%	n
4D									179	16	9.1	2	115	21	18.4	2				
4E									875	131	15.0	3	670	7	1.1	2				
4F									168	81	48.0	2	260	14	5.4	2				
4G									847	206	24.3	3	733	251	34.3	2				
4H									344	38	10.9	2	278	152	54.8	2				
4I									61	20	32.5	2	75	14	18.9	2				
4J									531	136	25.6	2	490	0	0.0	2				
4K									131	41	31.3	2	103	11	10.3	2				
4L									289	9	3.2	2	325	113	34.8	2				
4M									394	96	24.2	3	363	39	10.7	2				
4N									349	19	5.5	2	295	141	47.9	2				
4O									103	4	3.5	2	83	11	12.9	2				
4P									581	104	18.0	3	518	202	38.9	2				
4Q									144	105	72.7	2	258	25	9.6	2				
4R									240	71	29.5	2	238	4	1.5	2				
5X									1125	21	1.8	2								
5AA									1286	695	54.0	8								
5DD													1115	219	19.7	2				
5GG									938	434	46.3	7								
5HH													4948	407	8.2	2				
5JJ									1083	513	47.4	2								
5LL									688	336	48.9	2	935	35	4.4	2				
5OO													2258	895	39.6	2				

[a] Raw data presented in Appendix G.

[b] Plots 1B and 1C combined.

[c] Plots 1F and 1G combined.

colony 4.

Murre numbers declined by an estimated 47% between 1960-1982 (data from colonies 1-5 combined), but the rate may have varied among colonies (C1=43%, C2=59%, C3=26%, C4=47%, and C5=63%). The per annum rate of decline in murres was 2.42% between 1960 and 1982, ranging from 1.85% in colony 4 to 3.89% in colony 5 (Table 4.14). There was no clear shift in per annum rates of decline between 1960-1977 and 1977-1988, but the smallest decrease (1.65% PA) occurred between 1982 and 1988 (Table 4.14).

Murre species composition differed significantly between 1960 and 1988 only in colony 5 (Table 4.15). Estimating species specific per annum population changes by applying the species ratios to the 1960 and 1988 boat-based counts suggests that Common Murres declined at a slightly higher rate (3.50% PA) than Thick-billed Murres (2.13% PA) (Table 4.16).

Annual changes in murre attendance were not significantly concordant among colony totals (Friedman Test; X^2=10.00, P=0.75, df=5), but tended to be concordant among plots within colonies (colony 1, X^2=34.28, P<0.001, df=6; colony 4, X^2=87.47, P<0.001, df=17). Patterns of change on individual plots are illustrated for colony 4 (Fig. 4.7).

4.3.2. Black-legged Kittiwakes

Our working totals for the number of kittiwakes present in each of the colonies C2-C5 during all years of study since 1960 are indicated in Tables 4.17-4.21 (see Appendix G for a complete list of plot counts by colony and year). No kittiwakes have nested in colony 1 during any year since 1960.

Kittiwake population changes showed no trends between 1960 and 1982 or 1960 and 1988, except in Colony 5, for which only 3 years' data are available (Table 4.22). The pooled-estimate CV for replicate boat-based counts in 1979 was 14.4% (n_o=2) (Table 4.23). Based on this measure of variation, all census totals were within the 95% C.I. of the grand mean for each colony (Figs. 4.8-4.11). Annual changes in kittiwake attendance were significantly concordant among plots within colony 4 (X^2=34.1, P<0.001, df=7) (Fig. 4.12).

Table 4.14. Murre population changes (% per annum)[a] at Cape Thompson.

	Colony								
Date Interval	1[b]	2	3[c]	4[d]	5[e]	5[f]	5[g]	x[h]	SD
1960-1982	-2.43	-2.53[i]	-1.38	-1.85	-3.41	-4.36		-2.42	0.95
1960-1988		-1.64[j]		-2.21	-3.24	-3.73		-2.71	0.95
1960-1976	-4.17	-3.02[i]	-2.73	-1.31				-2.81	1.18
1960-1977	-3.06	-2.12[i]	-1.13	-0.47		-4.44		-2.24	1.57
1976-1982	+2.13	-1.21[i]	+2.30	-3.30			-9.81	-1.98	4.97
1976-1988		-2.26[j]		-3.41				-2.84	0.81
1977-1982	-0.54	-3.93[i]	-2.24	-5.39		-4.10	-6.21	-3.45	2.05
1977-1988		-1.91[j]		-4.85		-2.61		-3.12	1.54
1982-1988		+0.84[j]		-3.51	-2.60	-1.34		-1.65	1.88

[a] Calculated using $N_t = N_o e^{rt}$; assumes uniform rates of decrease over years.

[b] All plots.

[c] Plots 3A-3F, 3P-3W.

[d] Plots 4A-4J, 4L, 4O-4R.

[e] Land-based plots 5E, 5L, 5Q, 5R, 5S.

[f] Boat-based plots 5AA, 5GG, 5HH, 5LL, 5OO.

[g] 1976 plot designations, all plots.

[h] Colony 5 estimates were pooled before calculating mean.

[i] All plots except 2GG.

[j] Plots 2A1, 2U, 2V, 2CC.

Table 4.15. Changes in murre species composition at Cape Thompson, 1960-1988.

	1960[a]			1988[b]			
Colony	%TBMU	%COMU	n[c]	%TBMU	%COMU	n[c]	t_s^d
1	81	19	4186				
2	49	51	76828[e]	44	56	923	0.45[ns]
3	90	10	984	88	12	658	0.38[ns]
4	42	58	8987	53	47	1317	0.59[ns]
5	80	20	139637	91	9	4805	2.30*

[a] Data from tables presented in Appendix H except for Colony 2.

[b] Data from 1988 land-based plots (Appendix D).

[c] Total number of birds on which ratios were based.

[d] T-tests comparing mean species ratios; degrees of freedom based on number of plots observed in each colony.

[e] Data from Swartz (1966). This n was reported as the total murre attendance on the Colony, and may or may not have been the actual n on which species ratios were based.

* $P<0.05$

ns non-significant ($P>0.05$).

Table 4.16. Species specific population decrease of murres (% per annum) between 1960-1988 at Cape Thompson.

Colony	TBMU	COMU
2[a]	1.94	1.37
4[b]	1.40	2.94
5[c]	3.04	6.20
Mean	2.13	3.50

[a] Calculated using species ratio data in Table 4.15 and murre attendance on plots 2A1, 2U, 2V, and 2CC.

[b] Calculated using species ratio data in Table 4.15 and murre attendance on plots 4A-4J, 4L, and 4O-4R.

[c] Calculated by using species ratio data in Table 4.15 for land and boat-based counts, and the attendance on land-based plots 5E, 5L, 5Q, 5R, and 5S; and boat-based plots 5AA, 5GG, 5HH, 5LL, and 5OO.

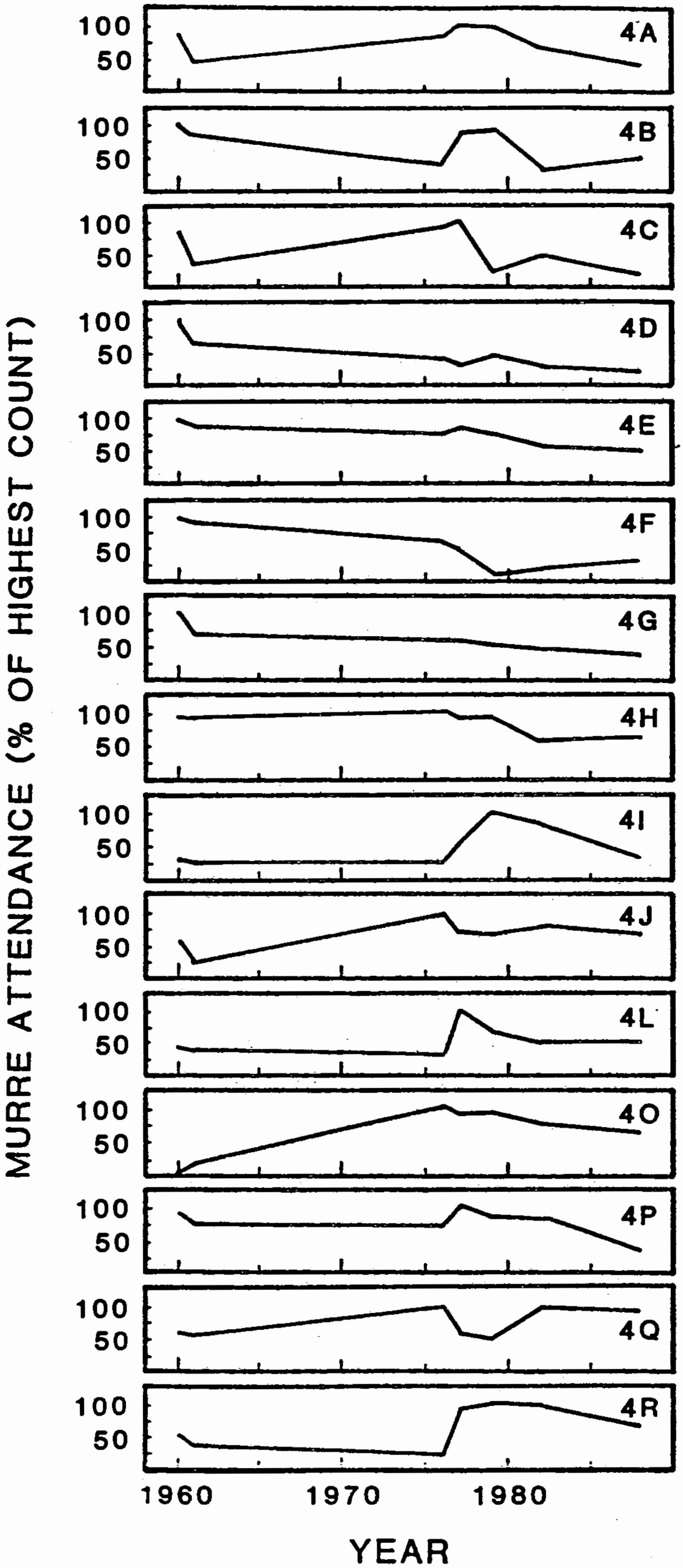

Figure 4.7. Comparison of murre population trends on Colony 4 plots, 1960-1988.

Table 4.17. Summary of boat-based census results from Cape Thompson - Colony 2 kittiwakes (birds).

	1960[a]		1961[a]		1976		1977[d]		1978[e]		1979		1982		1988[g]	
Plot	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n
2A1	0	1			0	1	0	1			0	1	0	1	0	1
2A2	0	1			0	1	0	1			0	1	0	1		
2B	0	1			0	1	0	1			0	1	0	1		
2C	0	1			0	1					0	1	0	1		
2D	0	1	0[b]	1	0	1					6	1				
2E	487	1	339[b]	1	261	1					325	1				
2F	381	1	351[b]	1	241	1					311	1				
2G	176	1			134	1					212	1				
2H	83	1	71[b]	1	36	1					78	1				
2I	188	1			110	1					206	1	216	1		
2J	231	1	218[b]	1	138	1					234	1				
2K	38	1			33	1										
2L	587	1			249	1					505[e]	1				
2M	676	1			513	1					544	1				
2N	587	1	554[b]	1	31	1					362	1				
2O	111	1			45	1					107	2	131	1		
2P	83	1	87[b]	1	43	1					56	2				
2Q	438	1			203	1					254	2				
2R	4	1	0[b]	1	8	1					12	1				
2S	126	1			85	1					114	1				
2T	417	1	440[b]	1	241	1					383	1				
2U	1036	1			345	1	501	1	1029[b]	1	475	1	703	1		
2V	449	1	434[b]	1	185	1			414[b]	1	372	1				
2W	301	1			148	1					211	1				
2X	105	1	132[b]	1	40	1					108	1				
2Y	196	1			84	1					187	1				
2Z	113	1	105[b]	1	28	1					78	1				
2AA	63	1			22	1					70	1	87	1		
2BB	8	1	7[b]	1	2	1					5	1				
2CC	20	1			11	1					18	1				
2DD	119	1	119[b]	1	79	1					153	1				
2EE	140	1			39	1					78	1				
2FF	13	1	11[b]	1							25	1				
2GG	4	1									4	1				
2HH+2II[c]	17	1	21[b]	1	18	1					56	1	75	1		
Using 1977 plot combinations:																
2C+2D+2E+2F	868	1	690	1	502	1	269	1			642	1				

Table 4.17. Continued.

	1960[a]		1961[b]		1976		1977[d]		1978		1979		1982		1988[g]	
Plot	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n
2G+2H+ 2I+2J	678	1			418	1	475	1			732	1				
2K+2L+ 2M+2N	1888	1			826	1	709	1								
2O+2P+ 2Q+2R	636	1			299	1	347	1			429	1				
2S+2T	543	1			326	1	290	1			497	1				
2U	1036	1			345	1	501	1	1029[b]	1	475	1	703	1		
2V+2W	750	1			333	1	373	1			583	1				
2X+2Y	301	1			124	1	53	1			295	1				
2Z+2AA	176	1			50	1	123	1			148	1				
2BB+2CC	28	1			13	1	84	1			23	1				
2DD+2EE+ 2FF	272	1					194	1			256	1				
2GG+2HH+ 2II	21	1					24	1			60	1				
Total[f]	1415		540								844		1212			
Total[g]	6904				3236		3224				5235					

[a] Swartz counted nests in 1960/1961. These have been converted to birds by multiplying nests by 1.4 (ratio of birds to nests determined from 1979, 1982, and 1988 data).

[b] Counts completed after the census period.

[c] These plots were combined in several years.

[d] 1977 plots were counted in combinations listed in bottom of table.

[e] Plots 2K and 2L were combined. This count was considered poor because the boat was rocking heavily.

Table 4.17. Continued.

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[f] Total calculated using plots 2A1, 2A2, 2B-2C, 2I, 2O, 2U, 2AA, 2HH, 2II.

[g] Total calculated using plots 2E, 2F, 2H, 2J, 2N, 2P, 2R, 2T, 2V, 2X, 2Z, 2BB, 2DD, 2HH, 2II.

Table 4.18. Summary of boat-based census results from Cape Thompson, Colony 3 kittiwakes (birds).[a]

	1960[b]		1961[b]		1976		1977		1979	
Plot[c]	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n
3A	0	1	0[d]	1	0	1	0	1	2	1
3B	0	1	0[d]	1	0	1	4	1	74[e]	1
3C	18	1	24[d]	1	20	1	35	1	52	1
3D+3E+3F	73	1	69[d]	1	109	1	73	1	113	1
3H			526[d]	1	275	1	328	1	510	1
3G+3I+ 3J+3K+3P					1875	1	1624	1	3004	1
3L+3M+3N+3O	322	1			250	1	219	1		
3Q+3R+3S	322	1			296	1	256	1	515	1
3T+3U	203	1			146	1	79	1	244	1
3V+3W	50	1	55[d]	1	97	1	36	1	58	1
Total[f]	666				660		483		1058	

[a] No plots were counted in 1978, 1982, or 1988.

[b] Swartz counted kittiwake nests. These were converted into "individuals" by multiplying nest counts by 1.4 (determined from 1979, 1982, and 1988 bird to nest ratios during census counts on Colonies 2, 3, 4, and 5).

[c] Plots were combined for counting like this in 1977, so all years here are converted for comparison.

[d] Plots counted after census period.

[e] Many birds were "loafers" sitting on the edge of the plot.

[f] Total calculated using plots 3A-3F, 3Q-3W.

Table 4.19. Summary of boat-based census results from Cape Thompson - Colony 4 kittiwakes (birds).

	1960[a]		1961[b]		1976		1977[d]		1978[e]		1979		1982		1988[g]	
Plot	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n
4A	330	1	(245)[c]	1	121	1			249	1	156	1	284	1	289	1
4B	430	1	(379)[c]	1	80	1			284	1	464	2	325	1	542	1
4C	525	1	(505)[c]	1	266	1	288	1	383	1	277[f]	2	405	1	164	1
4D	53	1	(52)[c]	1	15	1			22	1			55	1	18	1
4E	790	1	(560)[c]	1	265	1			479	1	481	2	511	1	732	1
4F			(312)[c]	1	79	1			175	1	169	1	245	1	255	1
4G			(658)[c]	1	155	1			380	1	375	1	406	1	576	1
4H	156	1	(148)[c]	1	107	1	283	1	177	1	144	1	134	1	170	1
4I	354	1	(419)[c]	1	146	1	102	1	324	1	345	1	394	1	373	1
4J	230	1	(183)[c]	1	96	1			101	1	116	1	134	1	100	1
4K	204	1	(197)[c]	1	87	1			105	1	185	1	166	1	160	1
4L	287	1	(223)[c]	1	69	1			198	1	185	1	232	1	191	1
4M	119	1	(113)[c]	1	50	1			125	1	116	1	123	1	85	1
4N	209	1	(217)[c]	1	75	1			174	1	176	1	219	1	183	1
4O	11	1	(14)[c]	1	11	1			28	1	50	1	47	1	32	1
4P	60	1	(56)[c]	1	27	1			80	1	89	1	109	1	109	1
4Q	0	1	(0)[c]	1	0	1			4	1	9	1	9	1	22	1
4R	0	1	(0)[c]	1	0	1			2	1	2	1	0	1	8	1
Using 1977 plot combinations:																
4A+4B	760		(624)[c]		201	1	429	1	533	1	620	1	609	1	831	1
4C	525		(505)[c]		266	1	288	1	383	1	277[f]	2	405	1	542	1
4D+4E	843		(612)[c]		280	1	404	1	501	1			566	1	182	1
4F+4G	>626[h]		(970)[c]		234	1	420	1	555	1	544	1	651	1	831	1
4H	156		(567)[c]		107	1	283	1	177	1	144	1	134	1	170	1
4I	354		(419)[c]		146	1	102	1	324	1	345	1	394	1	373	1
4J+4K+ 4L+4O	732		(617)[c]		263	1	283	1	432	1	536	1	579	1	483	1
4M+4N+ 4P+4Q+ 4R	388		(386)[c]		152	1	237	1	385	1	392	1	460	1	407	1
Total[i]	3541		4088		1369		2042		2789		2858		3232		3637	

[a] Counts were by pairs, which may have been an attempt to estimate nests. Values here are 1.4 times the original counts (the ratio of birds to nests

Table 4.19. Continued.

determined from census counts in 1979, 1982 and 1988 on Colonies 2, 3, 4, and 5).

[b] Swartz counted nests. These counts were converted to birds by multiplying by 1.4.

[c] Land-based counts.

[d] Plots were counted in combinations as listed in the second table.

[e] In 1978, plots were counted after the census period.

[f] The cliffs containing 4C and 4D collapsed sometime between 1978-1979.

[g] In 1988, plots were counted after the census period. The new counts have been multiplied by 1.31, based on daily attendance counts of land-based plots of Colony 3 (see Figure 2.13a).

[h] Listed in field notebook as not being all birds on plot. See Appendix Table G.54 (1960 Colony 4 kittiwake census).

[i] Total calculated using all plots except 4D and 4E.

Table 4.20. Summary of boat-based census results from Cape Thompson - Colony 5 kittiwakes (birds) using 1976 plot designations.[a]

	1976		1977		1979	
Plot	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n
5AA(1976)	33	1	48	1	69	1
5BB(1976)	103	1	118	1	127	1
5CC(1976)	859	1	567	1	229	1
5DD(1976)	48	1	47	1	-[b]	
5FF(1976)	452	1	342	1	-[b]	
5HH(1976)	490	1	335	1	606	1
5KK(1976)	347	1	182	1	411	1
5LL(1976)	78	1	21	1	80	1
5NN(1976)	12	1	0	1	0	1
5QQ(1976)	4	1	0	1	0	1
5RR(1976)	6	1	2	1	0	1
Total[c]	1932		1273		1522	

[a] 1960, 1961, and 1988 data do not exist in this format.

[b] Require mixing land and boat-based counts.

[c] Totals calculated using all plots except 5DD(1976) and 5EE(1976).

Table 4.21. Summary of boat-based census results from Cape Thompson - Colony 5 kittiwakes (birds).

	1960[a]		1961[a]		1979		1988	
Plot	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n
5A	1[b]	1			0	1		
5B	100[b]	1			0	1		
5C	0[b]	1			14	1		
5D	172[b]	1			12	1		
5E	283[b]	1			197[b]	1	221[b]	2
5F	11[b]	1			197[b]	1		
5G	23[b]	1			45[bd]	1		
5H	0[b]	1			1	1		
5I	42[b]	1			1	1		
5J	31[b]	1			14	1		
5K	19[b]	1			57	1		
5L	82[b]	1			68[b]	1	91[b]	8
5M	7[b]	1			9[b]	1		
5N	44[b]	1			84[b]	1		
5O	11[b]	1					7	1
5P	140[b]	1			128[be]	1		
5Q	18[b]	1			32[b]	1	31[b]	8
5R	239[b]	1			81[b]	1	124[b]	2
5S	58[b]	1					28[b]	1
5T	1[b]	1						
5U	5[b]	1			0	1		
5V	0[b]	1			0	1		
5W	0[b]	1			0	1		
5X	48[b]	1	67[g]	1	55	1		
5Y	164[b]	1			115	1		
5Z	1[b]	1			115	1		
5AA	147	1	123[g]	1	182	1	140[f]	1
5BB	175[c]	1			164	1		
5CC	462[c]	1	317[g]	1	282	1		
5DD	241[g]	1			152	1	170[f]	1
5EE	238[g]	1	231[g]	1	268	1		
5FF	343[g]				207	1		
5GG	357[g]	1	350[g]	1	379	1	347[f]	1
5HH	234[g]	1			212	1	236[f]	1
5II	175[g]	1	224[g]	1	238	1		
5JJ	27[g]	1			24	1		
5KK	280[g]	1			131	1		
5LL	1[g]	1	0[g]	1	0	1	0[f]	1
5MM	14[g]	1						
5NN	0[g]	1			0	1		

Table 4.21. Continued.

	1960[a]		1961[a]		1979		1988	
Plot	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n
5OO	0[g]	1	0[g]	1	0	1	0[f]	1
5PP	0[g]	1			0	1		
5QQ	0[g]	1			0	1		
5RR	0[g]	1			0	1		
Total[h]	680						495	
Total[i]	979				925		836	

[a] Swartz counted nests in 1960 and 1961. Those counts were multiplied by 1.2 (land-based counts) or 1.4 (boat-based) to estimate birds present. (Ratios determined from census counts in 1979, 1982, and 1988 at Colonies 3, 4, and 5).

[b] Counted from land.

[c] Observers reported having difficulty distinguishing the boundary between 5BB and 5CC.

[d] 5G boat count = 40.

[e] 5P boat count = 63.

[f] Counted after census period. Raw counts were multiplied by 1.31 to adjust the underestimate (based on daily attendance counts of land-based plots on Colony 3. See Figure 2.13.a.).

[g] Counted after census period.

[h] Total calculated using land-based counts of plots 5E, 5L, 5Q–5S.

[i] Total calculated using boat-based counts of plots 5AA, 5DD, 5GG, 5HH, 5LL, 5OO.

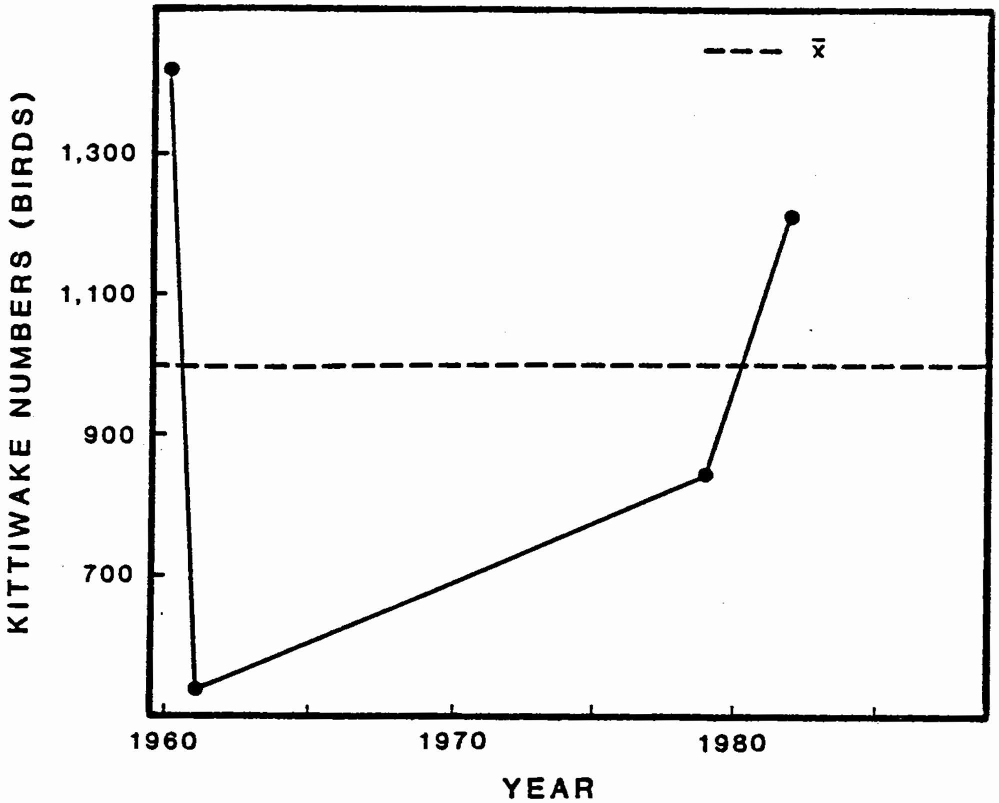

Figure 4.8. Kittiwake population trends in Colony 2, Cape Thompson. Census totals for plots 2I, 2O, 2U, 2AA, 2HH, and 2II. The 95% confidence interval is between -295 and 2301 birds.

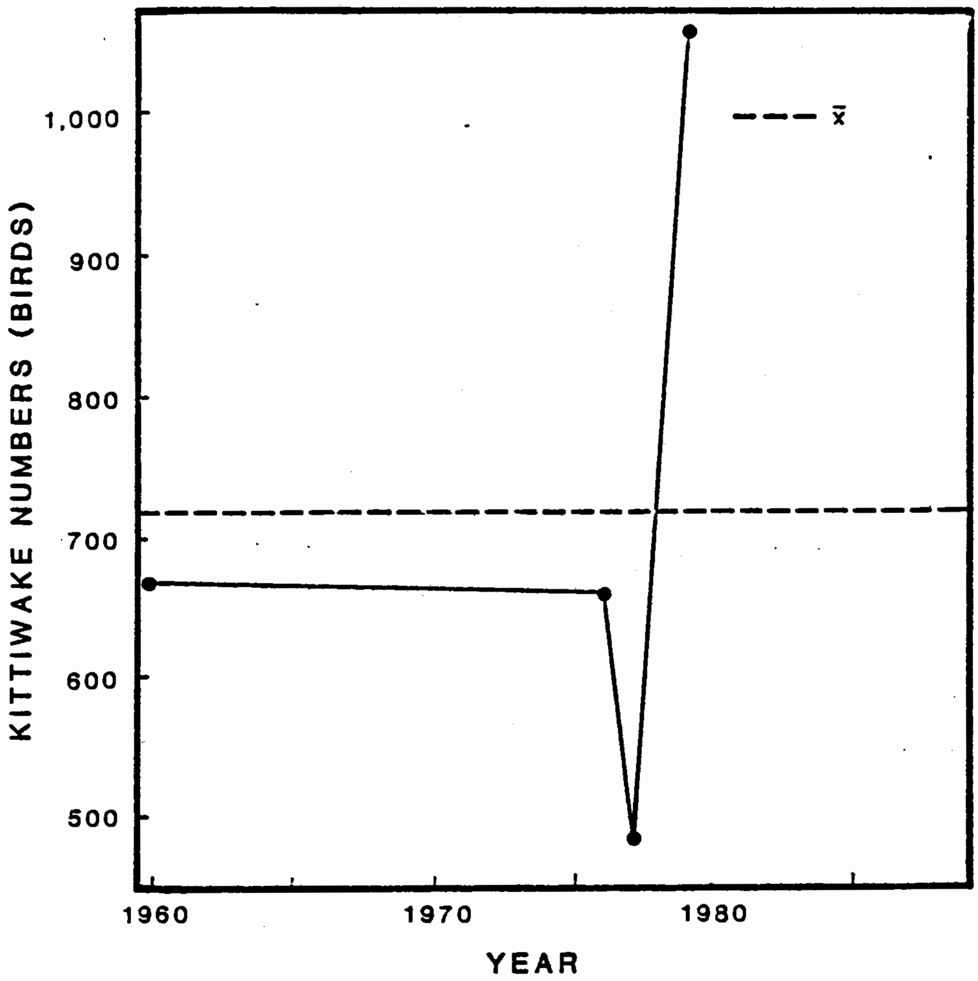

Figure 4.9. Kittiwake population trends in Colony 3, Cape Thompson. Census totals include plots 3A-3F and 3Q-3W. The 95% confidence interval is between -211 and 1645 birds.

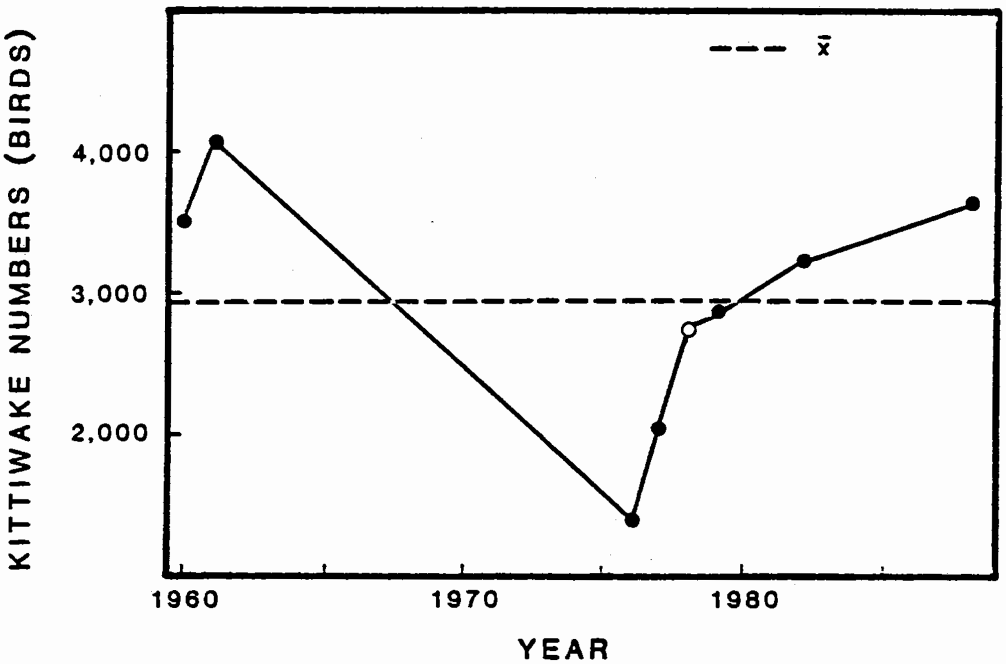

Figure 4.10. Kittiwake population trends in Colony 4, Cape Thompson. Census totals include all plots except 4D and 4E. The 95% confidence interval is between -865 and 6755 birds. Open circle represents data obtained after standard census period.

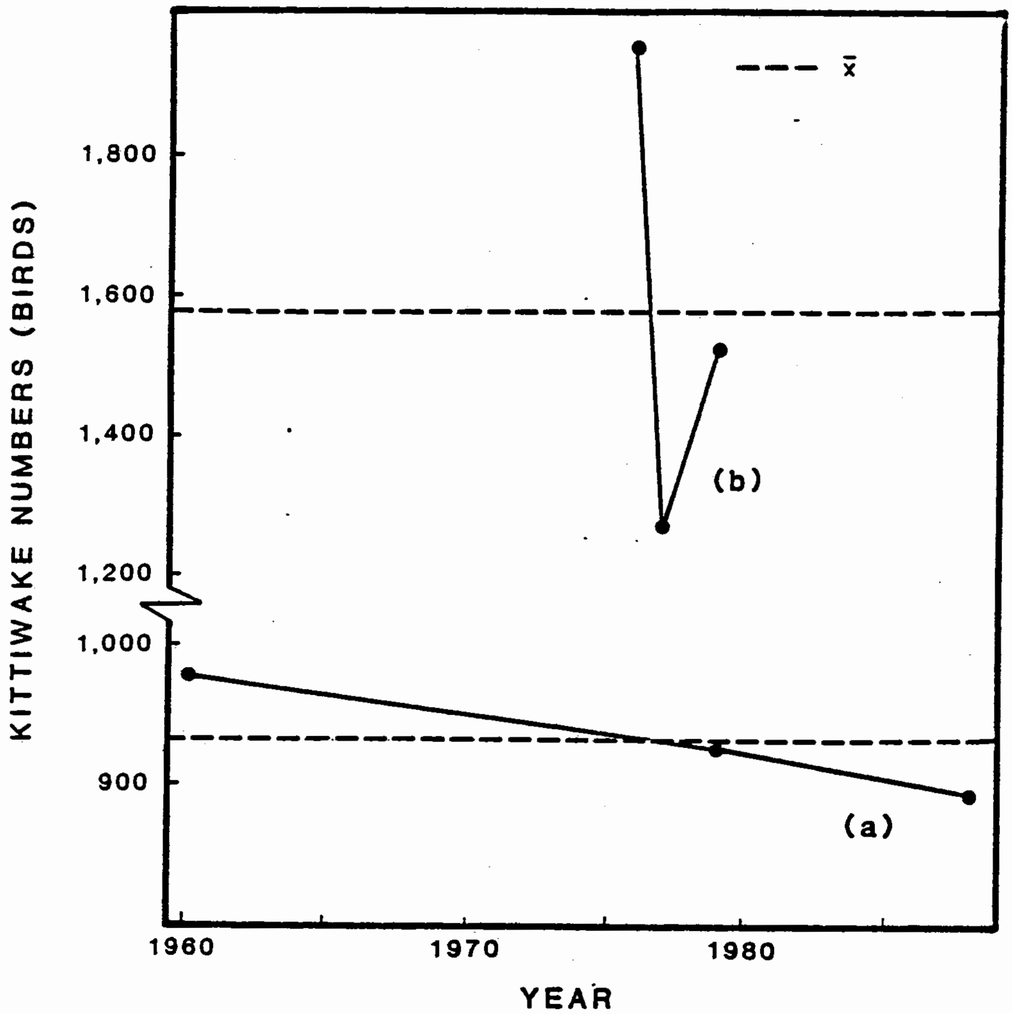

Figure 4.11. Kittiwake population trends in Colony 5, Cape Thompson. (a) Census totals for boat-based plots 5AA, 5DD, 5GG, 5HH, 5LL, and 500. The 95% confidence interval is between -274 and 2138 birds. (b) Census totals for boat-based plots (1976 designations) except 5DD (1976) and 5EE (1976). The 95% confidence interval is between -463 and 3615 birds.

Table 4.22. Correlations between year of census and kittiwakes (birds) at Cape Thompson.

Statistic		Colony				
		2[a]	3[b]	4[c]	5[d]	5[e]
Spearman	r_s	−0.200	0.200	0.024	−1.000	−0.500
	P	0.800	0.800	0.955	0.0001	0.667
Pearson	r	0.083	0.251	−0.298	−0.998	−0.455
	P	0.917	0.749	0.473	0.036	0.699

[a] Includes counts of plots 2I, 2O, 2U, 2AA, 2HH, and 2II in 1960, 1961, 1979 and 1982.

[b] Includes counts of plots 3A, 3B, 3C, 3D, 3E, 3F, 3Q, 3R, 3S, 3T, 3U, 3V, and 3W in 1960, 1976, 1977, 1979 and 1988.

[c] Includes counts of plots 4A, 4B, 4C, 4F, 4G, 4H, 4I, 4J, 4K, 4L, 4O, 4M, 4N, 4P, 4Q and 4R in 1960, 1961, 1976, 1977, 1978, 1979, 1982 and 1988.

[d] Includes plots 5AA, 5DD, 5GG and 5HH in 1960, 1979 and 1988.

[e] Includes plots 5AA(1976), 5BB(1976), 5CC(1976), 5HH(1976), 5KK(1976), 5LL(1976), 5NN(1976), 5QQ(1976) and 5RR(1976) in 1976, 1977 and 1979.

Table 4.23. Replicate counts of boat-based kittiwake plots used to estimate daily attendance variation at Cape Thompson.[a]

	1979			
Plot	$\bar{x}$	SD	CV%	n
2O	109	9	8.6	2
2P	57	1	1.3	2
2Q	255	5	1.9	2
2T	384	25	6.5	2
2Y	188	16	8.7	2
4B	464	136	29.3	2
4C	278	69	24.7	2
4E	482	163	33.9	2

[a] Raw data presented in Appendix G.

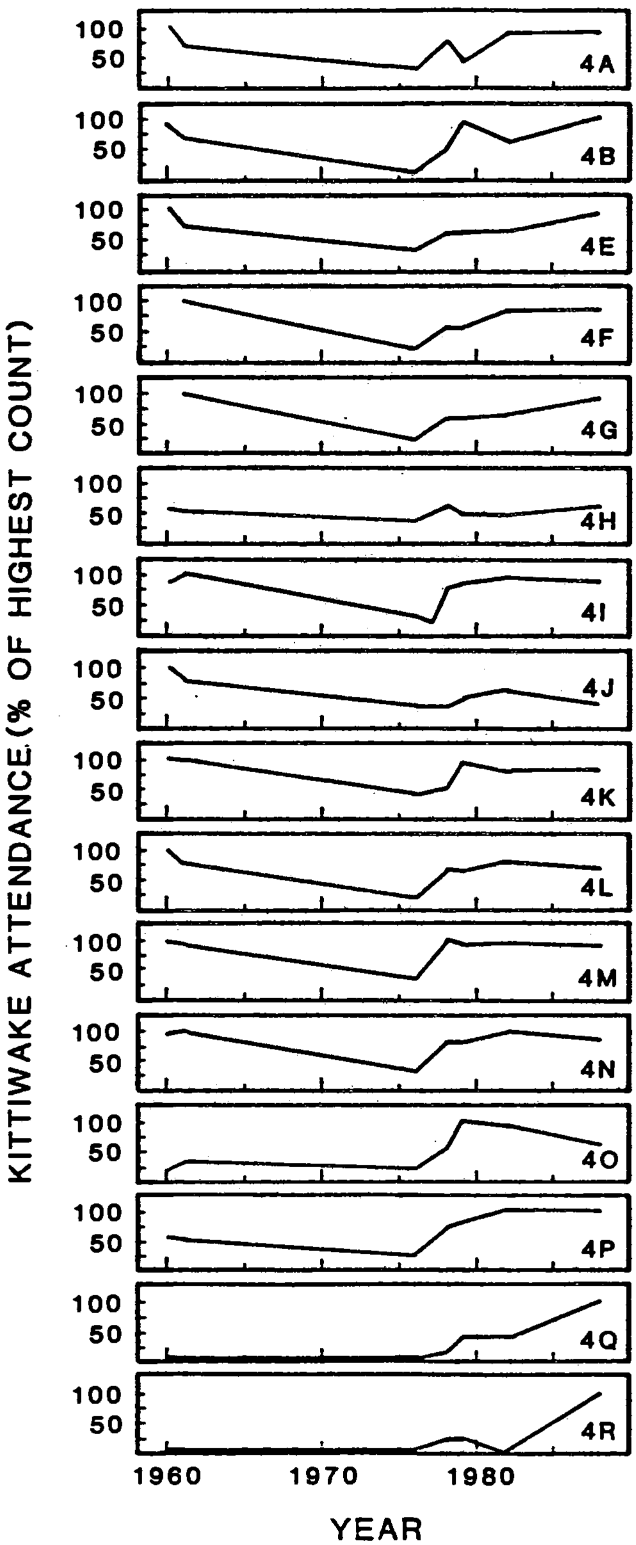

Figure 4.12. Comparison of kittiwake population trends on Colony 4 plots, 1960-1988.

4.4. Discussion

4.4.1. Common and Thick-billed Murres

Based on the evidence for trends in census totals and our analysis of within- and among-year variation, murre populations at Cape Thompson declined between 1960 and the mid-1970's. Our estimate of within-year variation in murre attendance for boat-based plots (CV=27.1%) was above the range observed on land-based plots (CV=6-25%, section 2.3.2.3), which presumably reflects the greater variability expected for boat-based counts. Against that background variation, the yearly changes in murre attendance in colonies 1, 2, and 5 between 1960 and the mid-1970's were greater than could be accounted for by within year variation alone, but the decline was not uniform among colonies. Colonies 1, 2, 3 and 5 all showed declines between 1960 and 1976, but colony 4 exhibited no clear trend until after 1979. Since 1976, changes in murre numbers at colony 3 have been well within the limits of within-year variation, and the overall decline in colony 3 was much lower than in the other four colonies. The decline appears to have been greater in colony 5 than in any other colony.

Combining information from all colonies, it seems that murre populations at Cape Thompson have been relatively stable since 1979. Based on apparent changes in species composition within the colonies, Common Murres declined at a more rapid rate than Thick-billed Murres between 1960 and 1988. In future, differential changes in the two murre species can and should be examined in greater detail using land-based plots.

Declines of murres at Cape Thompson parallel changes observed at Bluff, where murre numbers declined in the early 1970's, but have since been stable (Murphy et al. 1986). Populations at Cape Lisburne remained essentially unchanged between 1976 and 1981/83 (Springer et al. 1985c), whereas murres at Cape Thompson appeared to decline between 1976 and 1982. Studies of murre populations in the North Atlantic have found changes of between -28% and +12% per annum (Hudson 1985), with declines of 3-7 % per annum occurring in Common Murres over similar time periods to the Cape Thompson study [e.g., -3 % per annum between 1962-1970 at Handa Island, Scotland (Cramp et al. 1974); -7 %

per annum between 1950-1974 at Stora Karlso, Sweden (Hedgren 1975); both cited in Hudson (1985)]. Thus, population changes observed at Cape Thompson, Cape Lisburne, and Bluff are probably within the range of natural variation in murres.

If murres from Cape Thompson and Cape Lisburne winter in the same area of the southeastern Bering Sea (Shuntov 1972; Divoky 1978), mortality during the non-breeding season should be similar for these two populations. Thus, any difference in population trends between Cape Lisburne and Cape Thompson would arise from factors affecting mortality or reproductive success during the breeding season. Springer et al. (1985a) surmised that murres generally have higher breeding success at Cape Lisburne, but few quantitative data are available.

Murres from Cape Thompson and Cape Lisburne apparently track local prey sources throughout the breeding season. Cape Thompson murres feed S-SW of Cape Thompson throughout June-July, shifting to the NW in August, when they fly at least 60 km from the colonies to forage (Chapter 5; Springer et al. 1985a). Murres from Cape Lisburne feed NE of the colony in June-July, and tend to forage N-NW of Cape Lisburne in August (Springer et al. 1985a). If one or more of the following hypotheses is true, murres at Cape Lisburne would be expected to have greater productivity than murres from Cape Thompson: (1) the region NE of Cape Lisburne is more productive than Cape Thompson feeding grounds, (2) the region NE of Cape Lisburne provides shallower, more suitable habitat for sand lance than areas near Cape Thompson (Springer et al. 1985a), (3) the region NE of Cape Lisburne acts as a "prey trap" because of countercurrent eddies (Chapter 5), or (4) murres from Cape Lisburne are closer to their foraging grounds and therefore use less energy and spend less time away from their breeding sites while foraging. There are observations consistent with some of these ideas. Springer et al. (1985a) saw numerous foraging flocks of kittiwakes in the embayment NE of Cape Lisburne, suggesting an abundance of sand lance there. That area has a larger expanse of the coastal temperature regime associated with the primary prey species of murres than occurs near Cape Thompson (Chapter 5).

4.4.2. Black-legged Kittiwakes

The Black-legged Kittiwake population at Cape Thompson, in contrast to murres, remained relatively stable from 1960 through 1988, especially if counts from 1976 are excluded. In 1976, kittiwakes did not build nests, and their daily attendance was extremely variable (Springer and Roseneau 1977; Springer et al. 1985a). Thus, the low attendance in 1976 (and possibly 1977) was attributable to factors other than population change. All between-year fluctuations of kittiwake numbers were within the range expected within years, and our pooled-estimate CV for boat-based counts (14.4%) was within the range of CV's calculated for land-based plots in 1988 (4-42%). A significant trend in kittiwake numbers was found in colony 5, but the decline was small and possibly an artifact of small sample size (n=3 years).

4.5. Literature Cited

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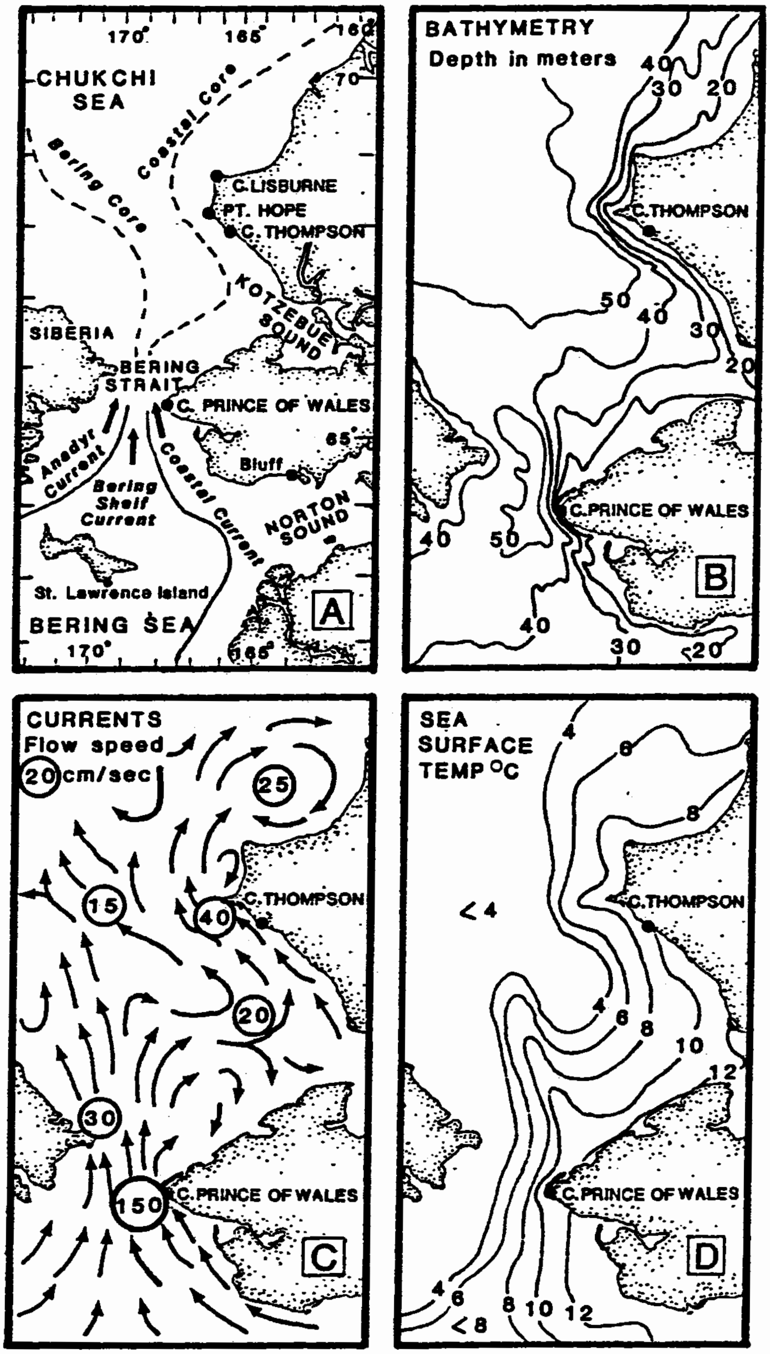
CHAPTER 5. THE DISTRIBUTION OF SEABIRDS AND THEIR PREY IN RELATION TO OCEAN CURRENTS IN THE SOUTHEAST CHUKCHI SEA

5.1 Introduction

The southeast Chukchi Sea (Fig. 5.1) harbors a large and diverse seabird fauna during summer months. In the Bering Strait, about one million planktivorous Least, Parakeet, and Crested Auklets (Aethia pusilla, A. psittacula, and A. cristatella) and five other members of the Alcidae breed on Little Diomede Island, foraging in locally productive waters and also north into the Chukchi Sea (Drury et al. 1981). At Cape Thompson and Cape Lisburne on the northwest Alaska mainland, about half a million piscivorous seabirds, mainly Thick-billed and Common Murres (Uria lomvia and U. aalge) and Black-legged Kittiwakes (Rissa tridactyla), breed and forage on pelagic schooling fishes around their colonies (Springer et al. 1984). Non-breeding migrants like Short-tailed Shearwaters (Puffinus tenuirostris) move through the Bering Strait into the Chukchi to take advantage of high production in summer, while some terrestrially breeding species like phalaropes and jaegers pass through the Chukchi Sea and forage en route to northern breeding grounds or southern wintering areas. In total, some 25 species of marine birds, including also Horned and Tufted Puffins (Fratercula corniculata and F. cirrhata), and Glaucous Gulls (Larus hyperboreus), regularly reside or forage in the southeast Chukchi Sea during summer (Swartz 1967, Drury et al. 1981, Appendix Table 5.1).

Productivity in the southeast Chukchi Sea is elevated during summer through several physical and biological mechanisms (Fleming and Heggarty 1966, Coachman et al. 1975, Springer et al. 1984). The dominant oceanographic feature of the region is the movement of three major currents north through the Bering Strait into the Chukchi Sea (Fig. 5.1). The Alaska Coastal Current, characterized by warm, low salinity waters, blankets the nearshore zone as it constricts and surges north past Cape Prince of Wales, winds back to the southeast and broadens into Kotzebue Sound, and constricts again along the Alaska coastline from south of Cape Thompson to Cape Lisburne. Bering Shelf and Anadyr Current waters converge at the Bering



5.1. Oceanography of the southeast Chukchi Sea (adapted from Fleming and Heggarty 1966, Coachman et al. 1975). (A) Place names mentioned in text and major currents. (B) Bathymetric contours. (C) Current directions and flow speeds. (D) Generalized pattern of sea surface temperatures (adjusted with data collected in this study).

Strait to form a well-mixed core of cold, nutrient-rich, high salinity Bering Sea water that dominates the south-central Chukchi, pushes eastward against the Alaska Coastal Current north of Kotzebue Sound to Pt. Hope, and traverses northwest towards the Arctic Ocean. Because of their differing origins and water types, each current carries a unique mixture of nutrients, plankton, and fish northward that add to, and stimulate, all levels of production in the Chukchi Sea. Production is also enhanced through local mechanisms. Retreating Arctic ice in June and July provides a broad band of ice-edge habitat for plankton growth and associated predators, particularly Arctic cod (Boreogadus saida), the most abundant fish in the southeastern Chukchi Sea (Alverson and Wilimovsky 1966). Sandy substrates deposited nearshore by the Alaska Coastal Current provide habitat for Pacific sand lance (Ammodytes hexapterus) and the warm nearshore waters stimulate growth and production of sandlance and other coastal fishes including saffron cod (Eleginus gracilis), herring (Clupea harengus), and sculpins (Cottidae). Where the Alaska Coastal and Bering Shelf Currents border, fronts may stimulate local production by bringing nutrients and plankton to the surface (Springer et al. 1984).

There have been several previous studies on the feeding ecology of seabirds and their foraging distributions in the southeast Chukchi Sea. Swartz (1966) examined the diets of seabirds breeding at Cape Thompson and summarized seabird censuses made from the MV 'Brown Bear' during the course of oceanographic studies of the southeast Chukchi Sea in 1960 (Swartz 1967). Three major aerial and ship-board surveys of the northern Bering and southeast Chukchi seas were conducted in the 1970's (Divoky 1978, Springer et al. 1979, Drury et al. 1981). More recent diet studies of seabirds at Cape Thompson and Cape Lisburne have been integrated with previous biological and oceanographic studies of the region to provide an overview of the dynamics of seabird interactions with their prey in the southeast Chukchi Sea (Springer et al. 1984).

As part of a study sponsored by the Minerals Management Service on the breeding biology of seabirds at Cape Thompson, we further investigated some aspects of seabird foraging ecology in the region. We collected murres and kittiwakes at Cape Thompson to examine their diets, and conducted surveys at sea to determine where birds were foraging in late August of 1988.

Hydroacoustic surveys were conducted simultaneously to assess the density and distribution of potential prey around the colonies, and seawater temperatures and salinities were monitored to characterize water masses and foraging habitats. Some data were also collected on seabird distributions around Cape Lisburne and the Diomede Islands. These data are included here to help assess the biological and oceanographic factors that are important in determining the foraging distribution of seabirds in the southeast Chukchi Sea.

5.2 Methods

Surveys for seabirds were conducted in the southeast Chukchi Sea from 23-28 August, 1988 from the U.S. Fish and Wildlife Service vessel MV 'Tiglax'. Initially, we planned to work in the area from 19 August to 3 September, but storms prevented us from passing through the Bering Strait until 23 August, and extreme winds (100+ km/h) prevented work from 29 August to 1 September, and prompted an early departure on 2 September. Moderate to strong winds prevailed throughout most of the study period and limited the collection and interpretation of some data (see below).

Except where noted otherwise, seabird censuses were conducted over 10-min intervals from the flying bridge of the MV 'Tiglax' using standard methods for recording species abundance and behavior (Gould and Forsell 1986). Exact protocols varied depending on the type of survey being conducted (Table 5.1). When hydroacoustic surveys for fish were conducted simultaneously with bird observations, all birds were counted in a 300 m wide strip directly in front of the vessel and the exact time within the census period that birds on the water were observed was noted (except for surveys 1 and 2 where the strip width was reduced to 150 m, birds were counted over 2-min intervals, and only birds on the water were recorded). Otherwise, all birds were counted in a 300 m wide strip to the left or right of ship's center depending on which side offered the best viewing conditions (Gould and Forsell 1986). Four of 11 surveys were conducted as arcs around the breeding colonies at Cape Thompson and Cape Lisburne (Table 1 and Fig. 5.2) to determine the directions taken by birds flying to foraging areas. Only flying murres were counted on the first of these arcs (survey 4) because of poor lighting conditions, and

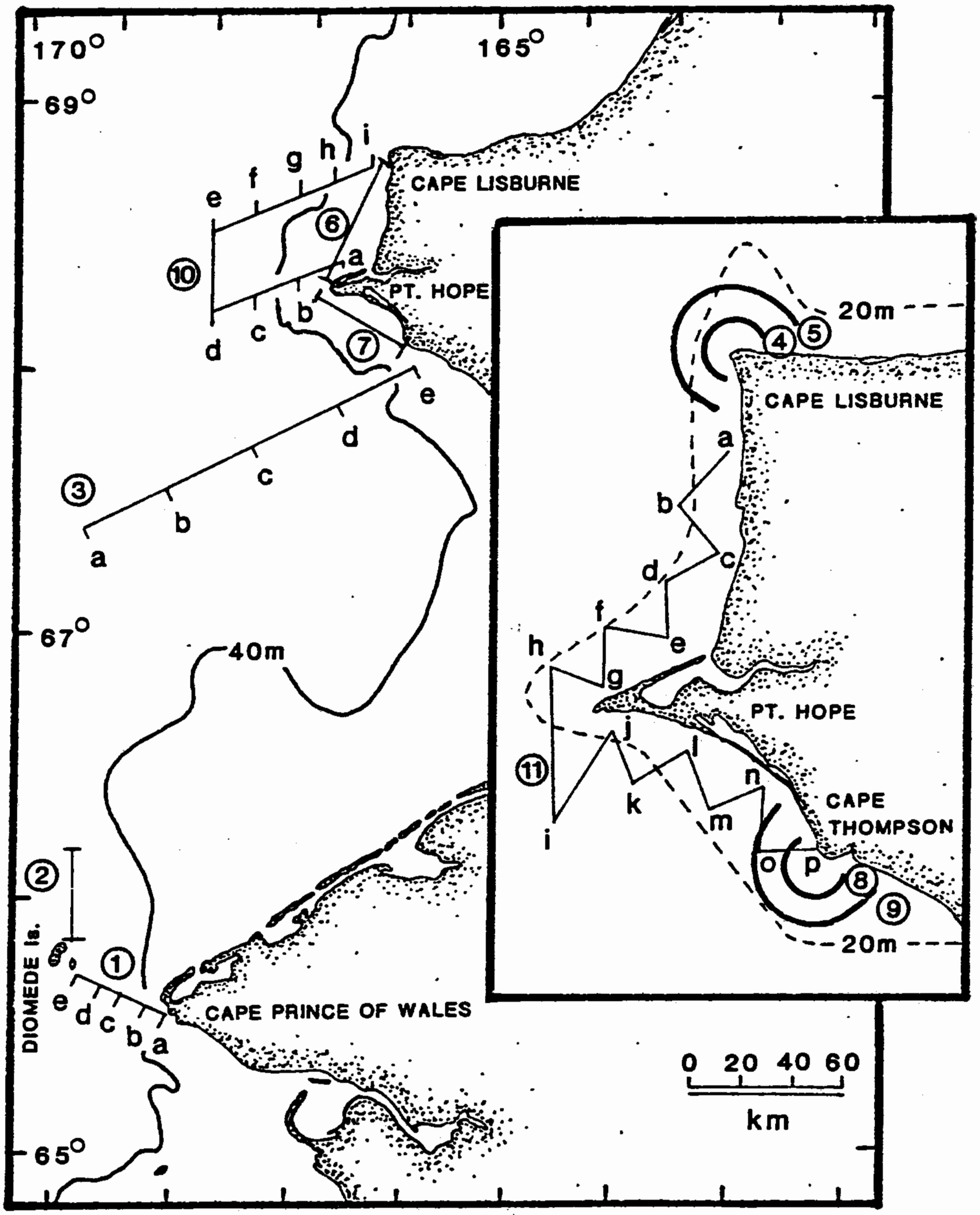


Figure 5.2. Surveys conducted in the southeast Chukchi Sea in August, 1988. Numbers in circles indicate survey number (see Table 5.1). Lower-case letters along surveys 1,3, and 10 indicate location of CTD stations, and along survey 11 (inset) indicate location of waypoints.

Table 5.1. Details of surveys, and numbers and densities of seabirds observed on surveys in the southeastern Chukchi Sea in August, 1988.

Survey no.	Date	Survey period	Area (km^2)	All birds no.	All birds no./km^2	On water no.	On water no./km^2	Survey type[a]
1	23 Aug.	1425-1845	8.0	-	-	58	7.3	I,H
2	23 Aug.	2140-2340	7.4	-	-	17	2.3	O,H
3	24 Aug.	0725-1555	42.6	452	10.6	27	0.63	O
4	24 Aug.	1025-1135	6.5	570	87.7	-	-	I,A
5	25 Aug.	0815-1020	11.6	2033	175.3	16	1.4	I,A
6	25 Aug.	1045-1315	13.9	675	48.6	55	4.0	I
7	25 Aug.	1915-2130	12.5	584	46.7	20	1.6	I
8	26 Aug.	1310-1425	6.9	695	100.7	11	1.6	I,A
9	26 Aug.	1505-1650	9.7	1394	143.7	24	2.5	I,A
10	27 Aug.	0830-1900	49.9	1450	29.1	77	1.5	O,H
11	28 Aug.	0840-1840	55.5	3874	69.8	650	11.7	I,H
Total or Mean			224.5	11802	53.7[b]	955	9.0	

[a] I-inshore, O-offshore, A-Arc around colony, H-Hydroacoustic survey conducted simultaneously.

[b] Arcs around colonies excluded from calculation.

censuses were conducted over 5-min intervals on the remaining arcs. Observations of murre flight directions were also made from the cliffs at Cape Thompson between 28 July and 21 August. The numbers of murres flying within 45 degree arcs of 360 degree compass bearings were recorded on one-hour watches in late afternoon.

On all surveys, sea surface (3 m) temperatures and salinities were monitored using a continuously recording thermosalinograph (Tsurumi Seiki Model 305861, Yokogawa Hokushin Electric Co.). On surveys 1, 3, and 10, water temperature profiles were obtained at the indicated stations (Fig. 5.2) using a conductivity - temperature - depth (CTD) recorder (Tsurumi Seiki Model 01930 In-situ Water Quality Monitor, Tsurumi Seiki Company Ltd., Yokohama, Japan). Additional information on wind speed and direction, sea state, observation conditions, and position were noted at the beginning of each census period (Gould and Forsell 1986).

Hydroacoustic surveys were conducted using a BIOSONICS Model 102 Echosounder and hull-mounted (at 5 m below the surface) 120 kHz dual-beam transducer. Transmit power was set at 217 dB, gain at -125.4 dB, bandwidth at 5 kHz, trigger interval at 0.5 sec, and pulse width at 0.5 msec for all surveys. Fish echo signals were integrated in real time over 2-min and 10-m depth intervals using a BIOSONICS Model 121 Digital Echo Integrator with 20 LogR amplification. Signals were integrated in relative voltage units, downloaded onto a microcomputer, and later analyzed to obtain absolute fish density and abundance estimates. Surveys were recorded on a BIOSONICS Model 111 Thermal Chart Recorder with a threshold setting of 200 mv. Acoustic signals were recorded using a BIOSONICS Model 171 Tape Recorder Interface and Sony Beta Digital Video Recorder on three channels at both 20 LogR and 40 LogR amplifications. Integrations of echo signals in the upper 10 m of the water column were not used to calculate fish densities because rough seas produced excessive surface noise.

Presuming that most of the fish targets observed were Arctic cod (see Results and Discussion), a target strength (TS) of -64 dB/g was calculated from regression equations for fish with swimbladders (Thorne 1983, Foote 1987). In situ measurements of Arctic cod TS's in Lancaster Sound, Canada, indicate this is a reasonable estimate (Rick Crawford, pers. comm., Dept. of Fisheries and Oceans, Winnipeg), and is very close to TS's determined in situ for capelin (Mallotus villosus) and Atlantic cod (Gadus morhua) in eastern Canada (Rose and Leggett 1988, Dan Miller, pers. comm., Dept. of Fisheries and Oceans, St. John's). The only other common forage fish likely to have been encountered in August was sand lance (Springer et al. 1984). There are no published estimates of sand lance TS's, but because they do not have swimbladders, it is likely that TS's are about 10 dB lower than those of Arctic cod (Rose and Leggett 1988). This would lead to an underestimate of sand lance densities on our surveys because we used Arctic cod target strengths for estimating fish densities, but this source of error probably occurred only inshore where sand lance reside around Cape Thompson (Springer et al. 1984).

Murres and kittiwakes were collected for diet studies by shooting birds as they flew in to the colony from offshore. Birds were weighed and the amount of subcutaneous and mesenteric fat was estimated visually (scale 0-3). Stomachs and gizzards were removed and stored in 50% ethanol solution for later examination. Stomach contents were sorted and identified in the laboratory using appropriate taxonomic keys and reference material (by Alan Springer, Institute of Marine Science, Univ. of Alaska, Fairbanks). The sizes of most fish prey recovered were reconstructed from regressions of fish length on otolith length and from fish weight on fish length (see Springer et al., 1984, for details).

The apparent size of fish and seabird aggregations can depend on the spatial scale at which they are measured, and correlations between birds and prey can also be scale-dependent (Schneider and Piatt 1986, Piatt 1989). Therefore in the following analyses, correlations were examined over a range of scales from the minimum scale of measurement (e.g., 2, 5, or 10 min, depending on the survey, where time is equivalent to distance traveled; e.g., 1 min = 0.3 km at a ship speed of 10 kts.) to larger scales (e.g., 10, 20, 40, or 80 min, depending on the total length of the survey and leaving at least four data points for measuring correlations). Similarly, correlations between fish or birds and gradients in sea surface temperature or salinity were examined at differing spatial scales. Gradients were calculated by lagging temperature or salinity measurements by one measurement interval (e.g., 10 min) and taking the absolute value of the difference between successive observations as the gradient. All correlations between birds, fish, and gradients were measured using Spearman rank correlation coefficients.

5.3 Results

5.3.1 Bering Strait

Two surveys were conducted in the Bering Strait area while en route to Cape Thompson (Table 5.1). The first survey (No. 1) crossed the strait from Cape Prince of Wales on the tip of the Seward Peninsula to Little Diomede Island (Fig. 5.2). Continuous records of sea surface temperature and salinity and periodic CTD profiles revealed a marked temperature-salinity gradient from east to west and a thermocline at a depth of about 30 m (Fig. 5.3). Zooplankton were concentrated just above the thermocline, and fish densities of up to about 2 g/m^3 were recorded in the 10-30 m layer (Figs. 5.3 and 5.4). The total abundance of fish in this layer was estimated at 21.8 mt/km^2.

The density of seabirds on the water was higher than observed on all subsequent surveys except for the coastal survey (No. 11) at Cape Thompson (Table 5.1). In decreasing order of abundance, Parakeet Auklets, Common Murres, Tufted Puffins, and Glaucous Gulls accounted for 74% of birds observed on the water. At the minimum measurement scale of 0.36 km, and over larger scales (up to 9 km) there were no strong correlations between total birds and fish densities in any depth strata. The surface layer (5-10 m) was excluded from this analysis because surface signals were due to turbulence rather than fish echos. The 'density' of signals in the uppermost stratum was significantly correlated with wind speed ($r=0.85$, $P<0.0001$) and sea state ($r=0.77$, $P<0.0001$). Correlations between Common Murres and fish increased with measurement scales up to 9 km, where murres were positively correlated with fish density in the 10-20 m stratum ($r=0.90$, $p=0.09$), and the 20-30 m stratum ($r=0.80$, $P=0.08$). At the same scale, Parakeet Auklets were negatively correlated with fish densities in the 10-20 m stratum ($r=-0.46$,

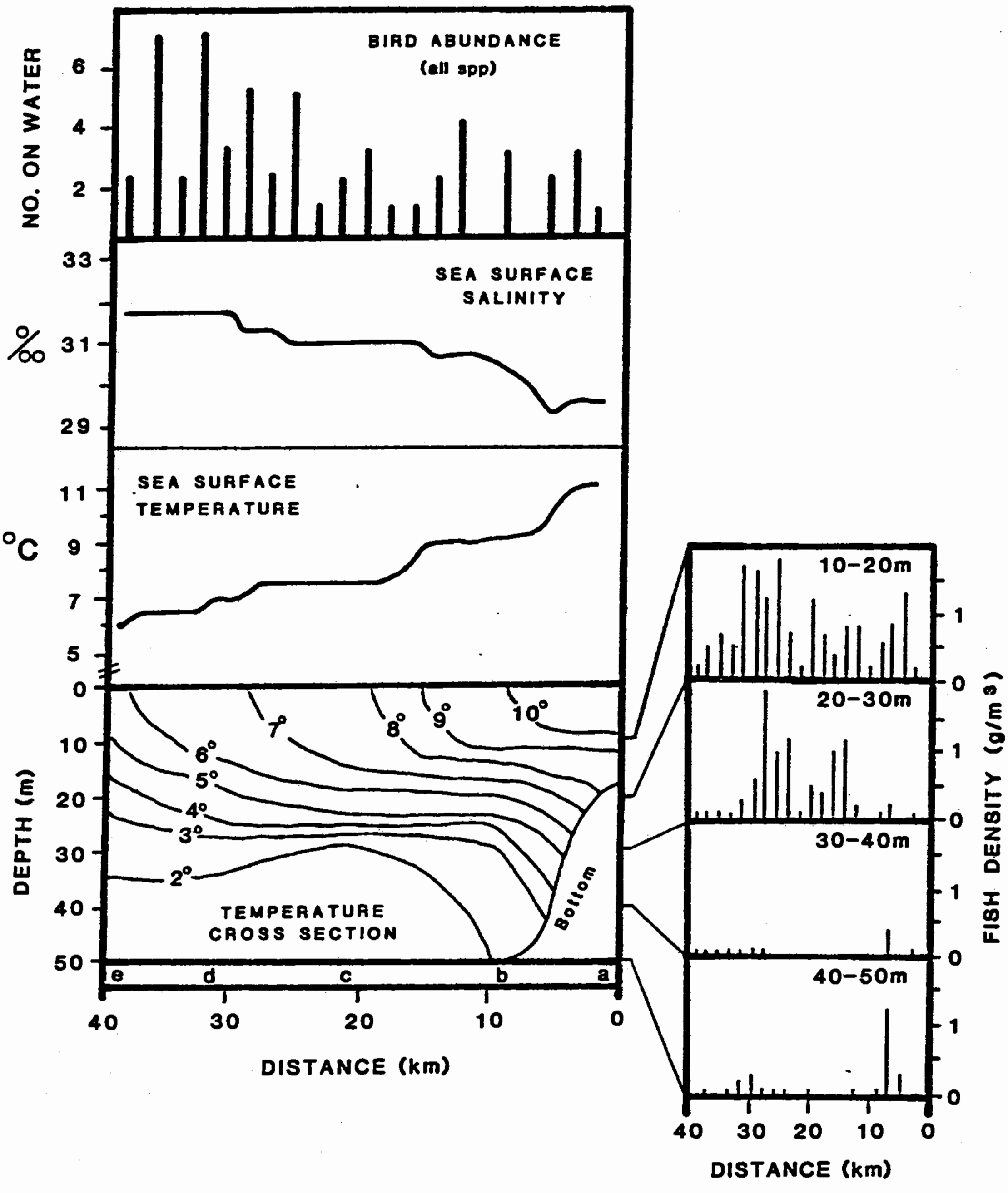


Figure 5.3. Observations of seabirds, fish, and hydrography on survey No. 1 across the Bering Strait. Lower-case letters at bottom correspond to CTD stations shown in Fig. 5.2. Histogram at lower right shows fish densities at different 10 m depth strata along the survey track.

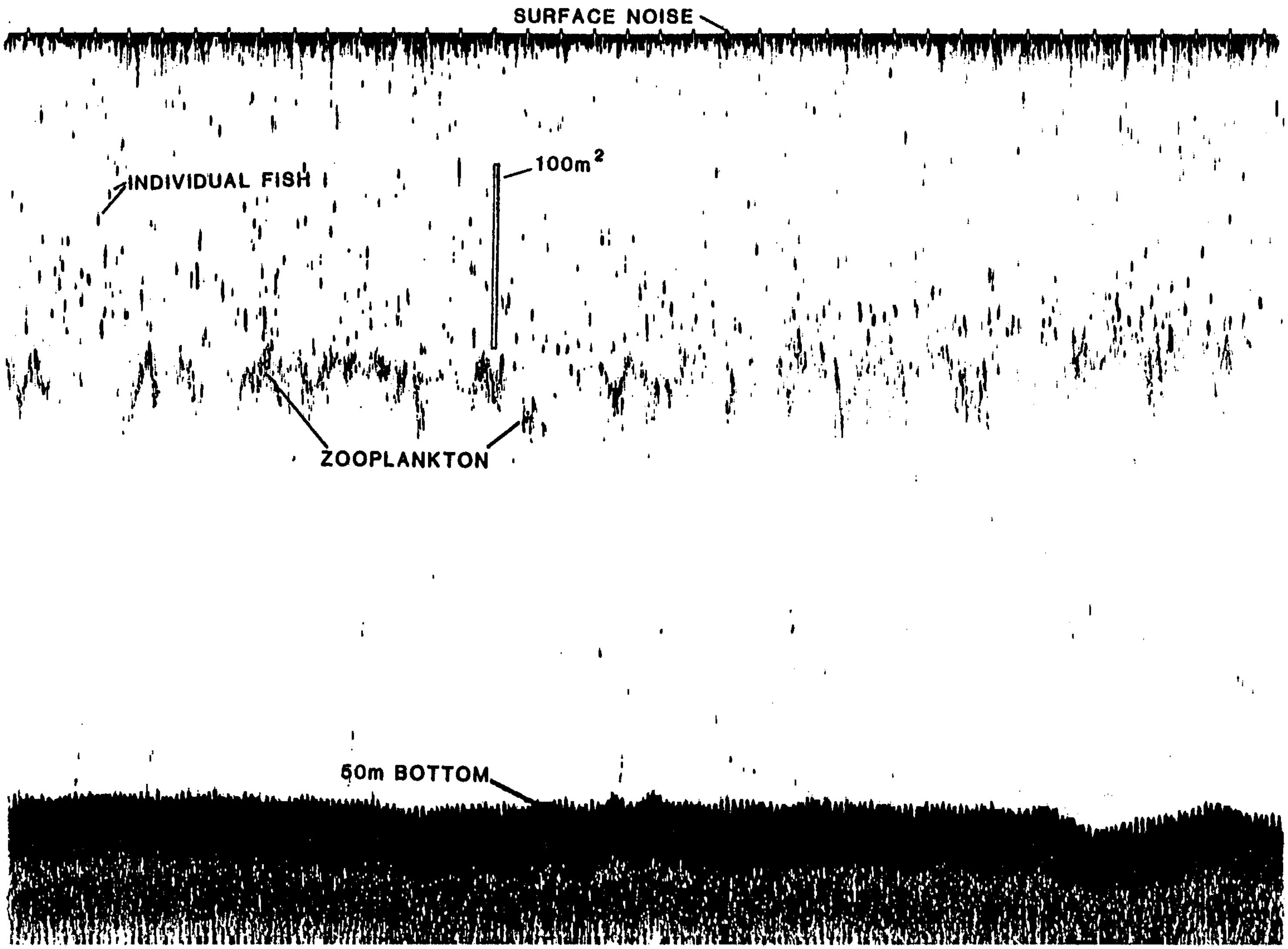


Figure 5.4. Hydroacoustic echogram recorded near station 'c' on survey No. 1 across the Bering Strait (see Fig. 5.3). Note the concentration of zooplankton and fish just above the thermocline at about 25 m.

P>0.10) and the 20-30 m stratum (r=-0.61, P>0.10). No strong correlations were observed for any other species.

On the survey north from Little Diomede (No. 2, Fig. 5.2), there was little variation in sea surface temperature (6-8° C) or salinity (30.6-31.3 ppt) from beginning to end. Average fish densities were between 0.04-0.15 g/m^3 in the 10-40 m depth stratum and total fish abundance was about 2.30 mt/km^2. Few birds were observed, of which 75% were Least, Parakeet, and Crested Auklets. Most auklets were observed within 10 km of Little Diomede Island.

5.3.2 Crossing the Southeast Chukchi

On August 24, we crossed the southeast Chukchi from about 150 km west-southwest to about 10 km south of Cape Thompson (Fig. 5.2). Sea surface temperature-salinity records and CTD profiles revealed that the survey started in the tongue of Alaska Coastal water that extends about 200 km north of Bering Strait (Fig. 5.1), crossed the broad band (ca. 80 km) of Bering Sea water that intrudes toward Kotzebue Sound, and ended in the Alaska Coastal Current (ca. 50 km wide). Hydroacoustic surveys were not conducted because of excessive turbulence. Only 6% of birds observed were on the water, and the density of flying birds was lower than on any other survey (Table 5.1). Nonetheless, some patterns were evident. Parakeet Auklets and phalaropes (of which 78% were identified as Red Phalaropes, Phalaropus fulicaria) were associated with a front between Alaska Coastal and Bering Sea Currents (Fig. 5.5). Least Auklets and Short-tailed Shearwaters occurred in low densities over Bering Sea waters and transitional waters between the Alaska Coastal and Bering Sea Currents. Murres, kittiwakes, and Horned Puffins were largely restricted to Alaska Coastal and transitional waters less than about 110 km from Cape Thompson, the nearest breeding colony. No significant correlations between birds and temperature-salinity gradients were found.

5.3.3 Radial Arcs around Cape Thompson and Cape Lisburne

Before attempting to locate seabird foraging aggregations near Cape Thompson, we conducted radial arc surveys around the colonies at Cape

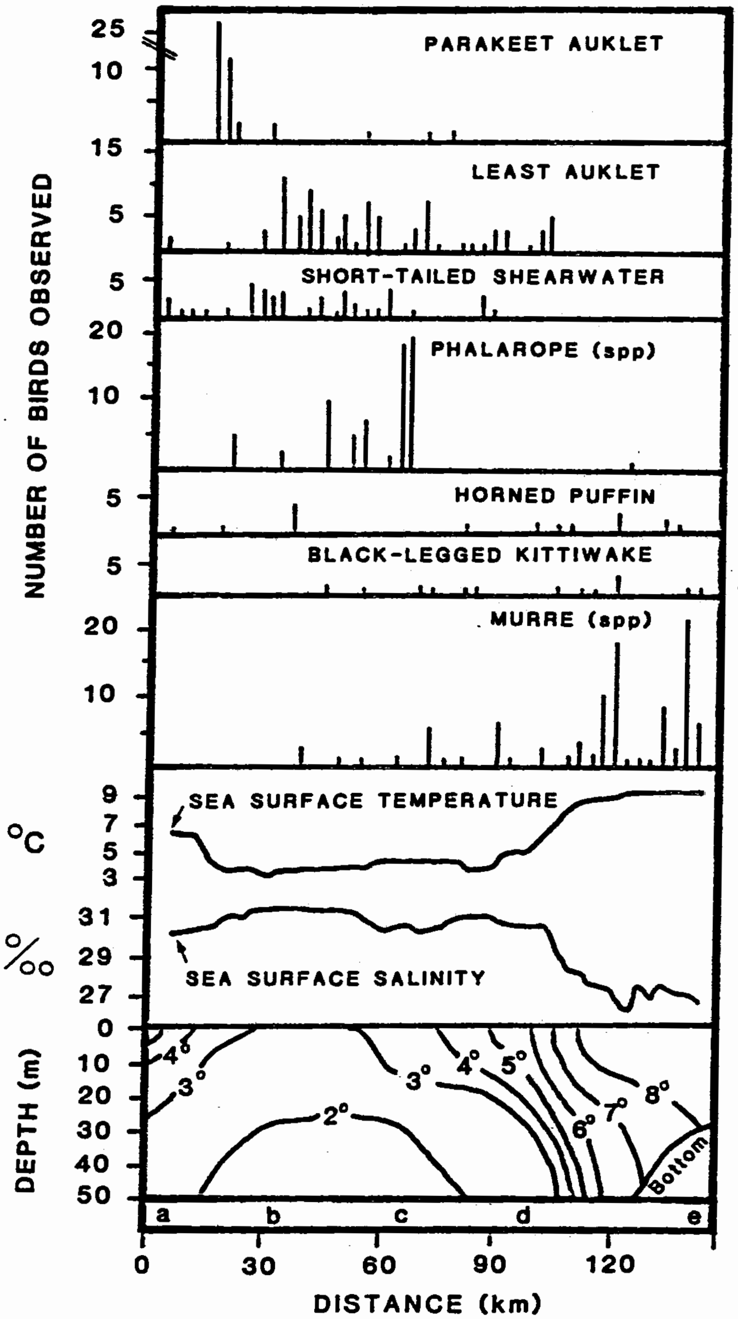


Figure 5.5. Observations of seabirds and hydrography on survey No. 3 across the southeast Chukchi Sea. Lower-case letters at bottom correspond to CTD stations shown in Fig. 5.2.

Thompson and Cape Lisburne to see where most birds were flying. Land-based surveys at Cape Thompson indicated that whereas murres had been foraging to the southeast and south of Cape Thompson in July and early August, a pronounced shift in foraging flight direction to the west had occurred by late August (Fig. 5.6). Radial surveys around Cape Thompson revealed that most murres and kittiwakes were flying to the northwest on 26 August, although a small proportion were flying southeast along the coast (Fig. 5.7). Horned Puffins flew mostly to the west and south of Cape Thompson. Surveys around Cape Lisburne revealed that most murres and kittiwakes flew to the northwest, north, and especially northeast. Again, Horned Puffins flew to different foraging areas than murres and kittiwakes.

5.3.4 Offshore from Pt. Hope to Cape Lisburne

With evidence from the radial arc surveys and two coastal surveys (Nos. 6 and 7) that most birds from Cape Thompson were flying to the west and north of Pt. Hope, we conducted a survey to encompass potential foraging areas up to about 90 km west and 110 km northwest of Cape Thompson (Fig. 5.2). Sea surface temperature-salinity records and CTD profiles revealed that the Alaska Coastal Current was constricted to a narrow band about 30 km wide off Pt. Hope (Fig. 5.8, CTD stations a-d), and was broader (ca. 40 km) off Cape Lisburne (Fig. 5.8, CTD stations e-i). Temperature-salinity gradients were stronger off Pt. Hope than off Cape Lisburne.

Fish densities and distributions varied markedly with hydrographic conditions (Fig. 5.8). In shallow Alaska Coastal waters at Pt. Hope, fish densities were relatively high (up to 23 g/m^3) and most fish were distributed near the bottom or in mid-water (Fig. 5.9). The average fish density was 1.6 g/m^3 and total fish abundance in the area averaged 35.5 mt/km^2. Moving offshore into the transitional zone between Alaska Coastal and Bering Sea waters (between ca. 25-50 km off Pt. Hope), fish were conspicuously absent at lower depths. Scattered zooplankton and very low densities of fish were present in the upper water layers (Fig. 5.10), presumably brought to the surface by strong upwelling. Further offshore in Bering Sea water, moderate fish densities (1-2 g/m^3) were again encountered between 20-40 m. Both fish and zooplankton were concentrated just above the

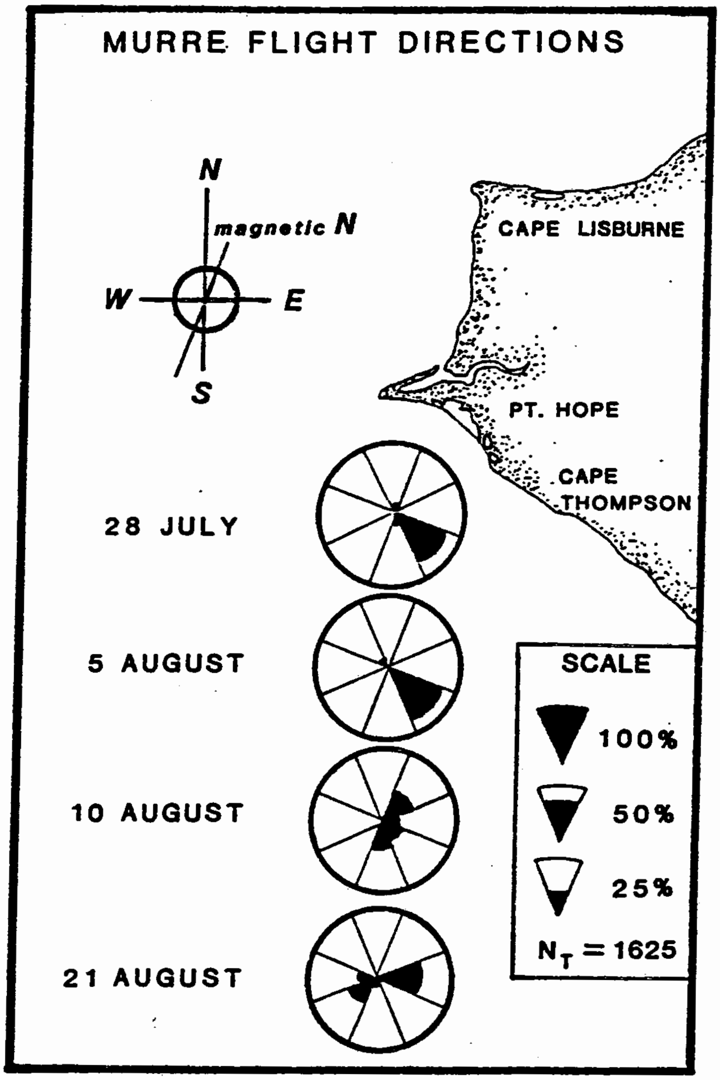


Figure 5.6. Murre flight directions as determined from colony-based surveys in July and August.

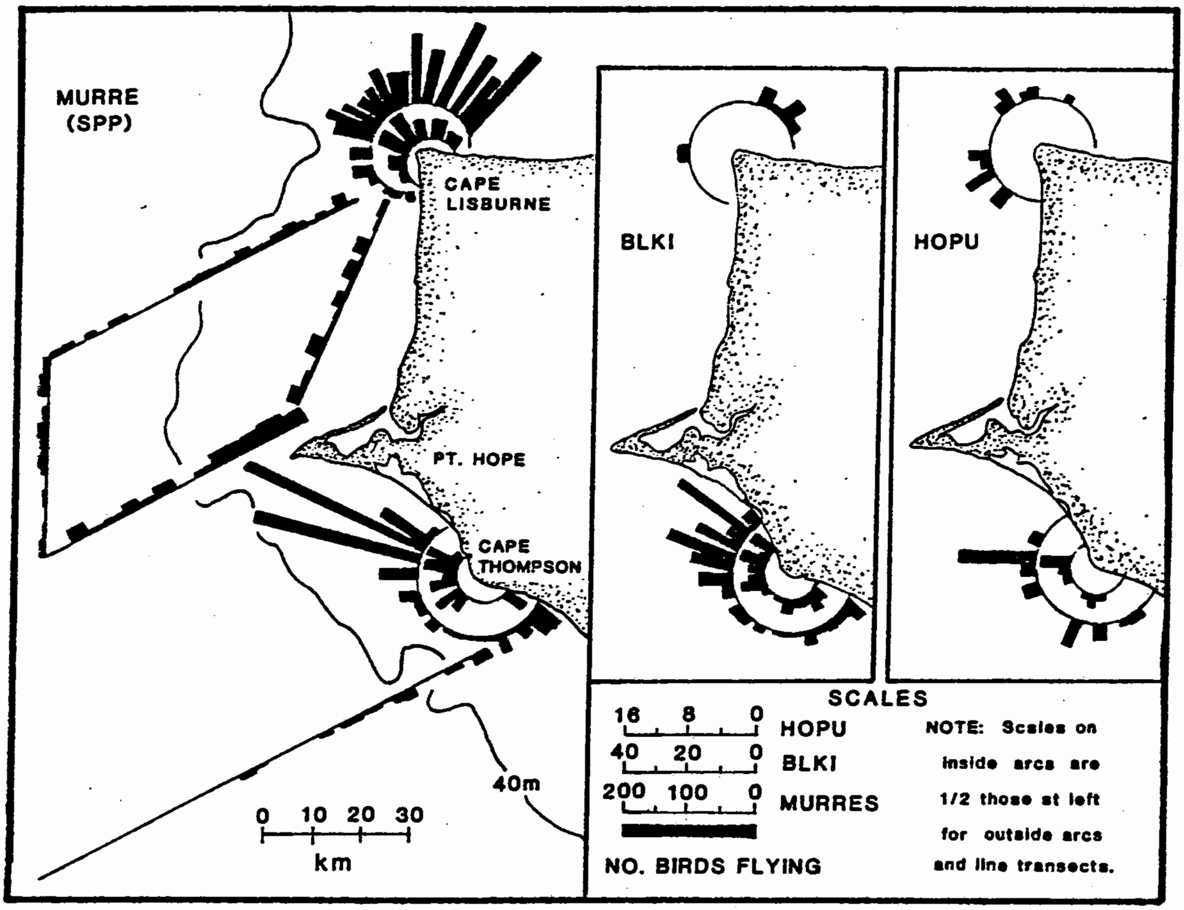


Figure 5.7. Murre, kittiwake, and Horned Puffin flight directions from Cape Thompson and Cape Lisburne as determined from arc surveys around the colonies. Numbers of murres flying on offshore surveys (Nos. 3 and 10) are also shown.

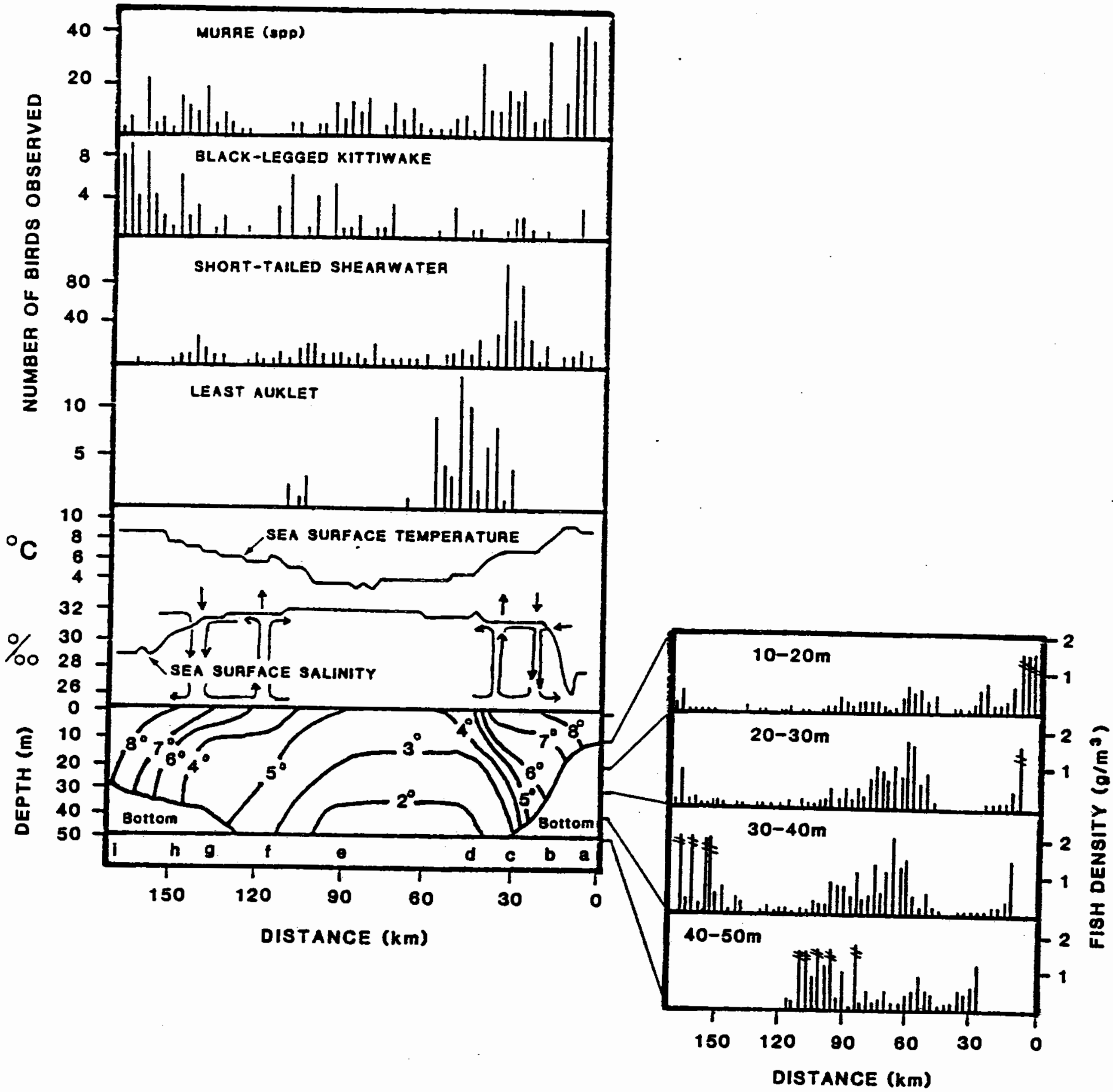


Figure 5.8. Observations of seabirds, fish and hydrography on survey No. 10 northwest of Cape Thompson. Lower-case letters at bottom correspond to CTD stations shown in Fig. 5.2. Histogram at lower right shows fish densities at different 10 m depth strata along the survey track.

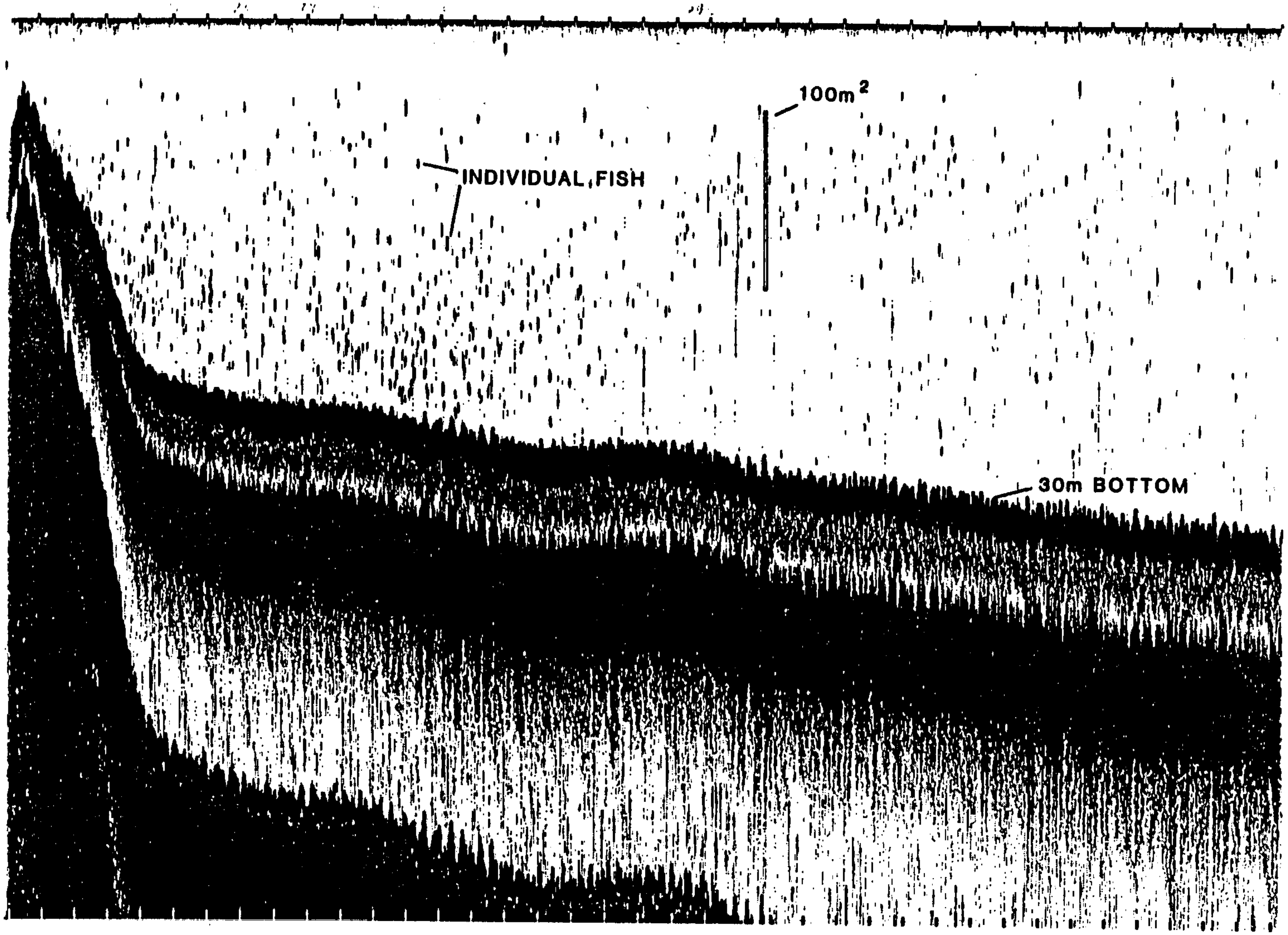


Figure 5.9. Hydroacoustic echogram recorded near station 'a' on survey No. 10 northwest of Cape Thompson (see Figs. 5.2 and 5.8). Fish densities near the bottom and in mid-water averaged 1.6 g/m^3.

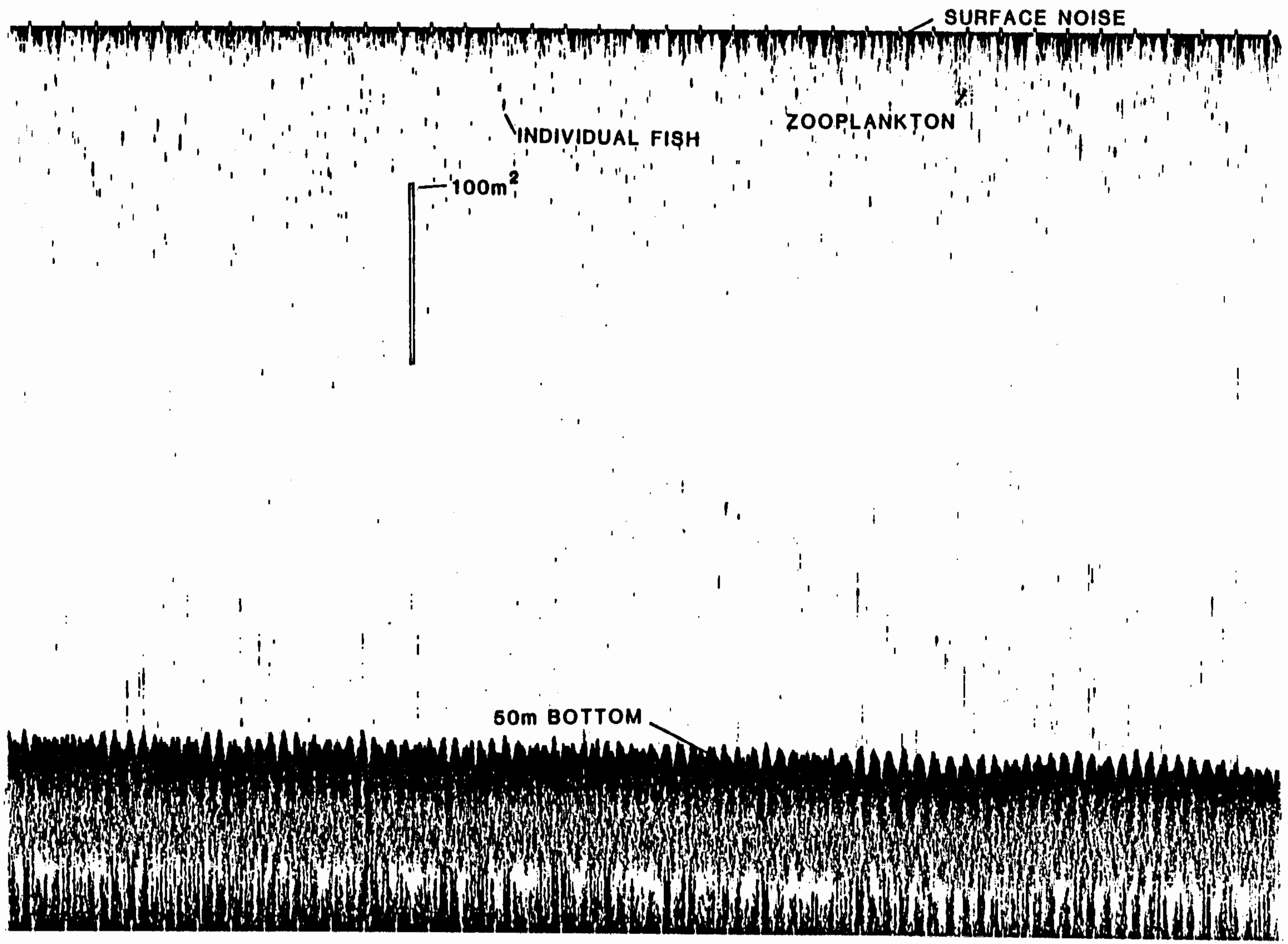


Figure 5.10. Hydroacoustic echogram recorded near station 'c' on survey No. 10 northwest of Cape Thompson (see Figs. 5.2 and 5.8). Note the concentrations of zooplankton and fish (<0.2 g/m^3 pushed towards the surface by upwelling in this convergent zone.

2^{o} C isotherm (Figs. 5.8 and 5.11). In transitional and Bering Sea waters, fish densities averaged 0.073 g/m^3 and fish abundance averaged 2.19 mt/km^2 in the 10-40 m stratum. Upon returning inshore to Cape Lisburne, fish densities declined again dramatically in the transition zone (ca. 40 km wide) before rising again to much higher levels (up to 249 g/m^3) near the bottom inshore (Fig. 5.8). Fish densities in this area averaged 1.26 g/m^3, and total abundance averaged 11.5 mt/km^2 in the 10-40 m strata.

At all spatial scales examined, fish density was negatively correlated with the strength of sea-surface temperature and salinity gradients, i.e., fish were scarce where Alaska Coastal and Bering Sea Currents diverged. At a 6 km spatial scale, negative correlations between fish density and temperature gradients were significant for two of four depth strata examined (10-20 m, r=-0.33, P=0.08; 20-30 m, r=-0.45, P<0.05; 30-40 m, r=-0.45, P<0.05; 40-50 m, r=-0.25, P>0.10). Negative correlations between fish density and salinity gradients were generally weaker and insignificant.

The distribution of some seabirds reflected patterns of fish and zooplankton distribution. The surface layer (<10 m) was excluded from this analysis because surface signals were due to turbulence rather than fish echos. The 'density' of signals in the uppermost stratum was significantly correlated with wind speed (r=0.53, P<0.0001) and sea state (r=0.69, P<0.0001). There were no significant correlations between numbers of murres observed and fish density in any depth strata at any scale examined. As in previous surveys, however, few (<3%) murres were observed on the water, and the abundance of murres near Pt. Hope (Fig. 5.8), for example, may only represent birds flying past Pt. Hope en route to other foraging areas rather than an association (or lack of association) between murres and fish at that location. However, murres on the water were strongly correlated at a spatial scale of 6 km with fish density in the 10-20 m stratum (r=0.82, P<0.001), 20-30 m stratum (r=0.51, P=0.10), and combination of these strata (10-30 m, r=0.60, P<0.05). Murres were poorly correlated with fish density at 30-40 m (r=0.37, P>0.10) and 40-50 m depths offshore (r=0.44, P>0.10). Reflecting the negative relationship between fish density and temperature salinity gradients, the number of murres on the water was also negatively correlated with the strength of sea-surface temperature (r=-0.79, P<0.05) and salinity

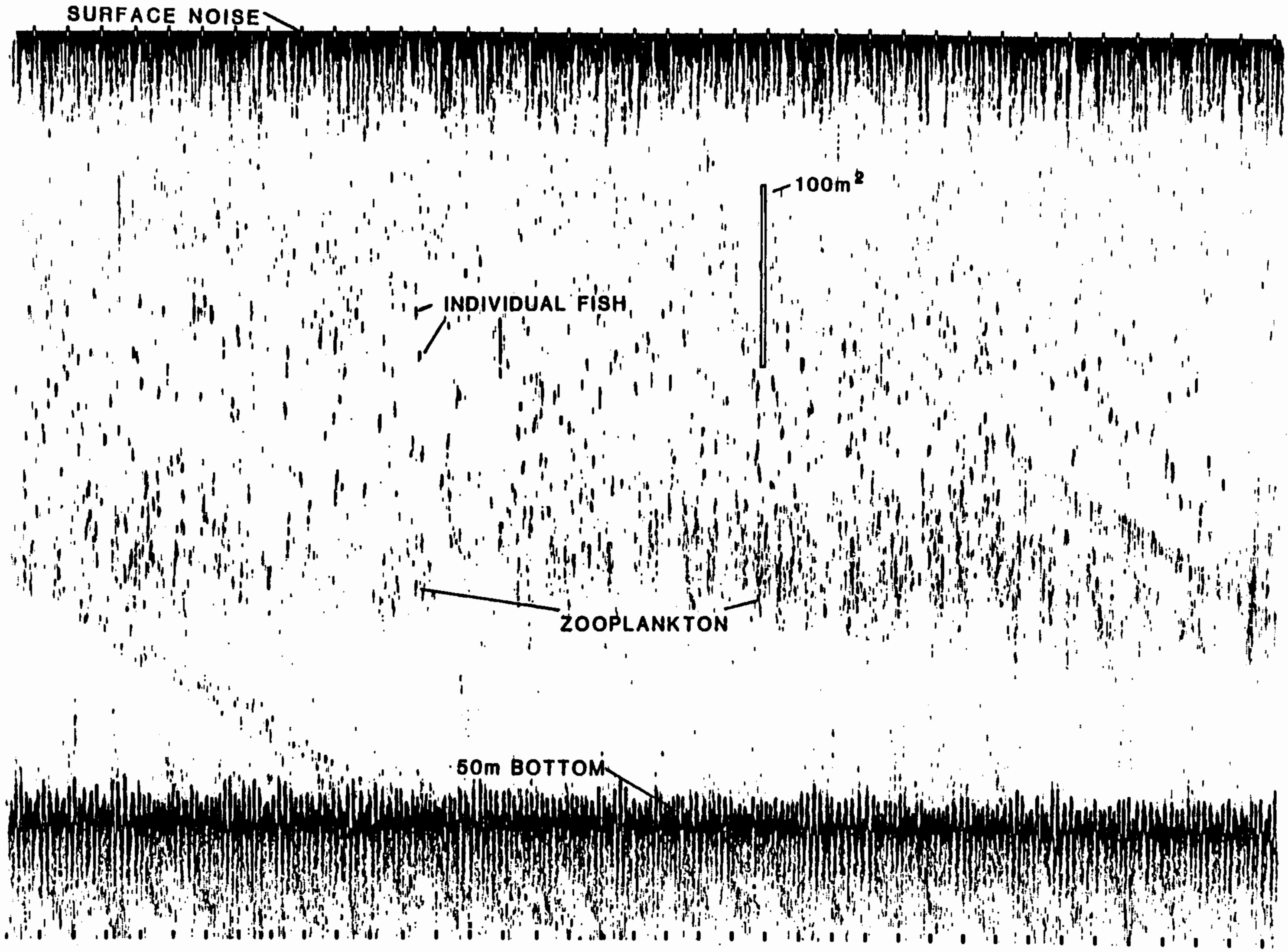


Figure 5.11. Hydroacoustic echogram recorded between stations 'd' and 'e' on survey No. 10 northwest of Cape Thompson (see Figs. 5.2 and 5.8). Note concentration of zooplankton and fish (1-2 g/m^3) just above the 2 C isotherm. The saw-tooth appearance of the bottom resulted from the violent motions of the ship, and the heavy traces at the surface resulted from turbulence and air bubbles trapped in the upper water column. The diagonal traces (at lower left and right) are false signals resulting from excessive electrical noise from the vessel.

($r=-0.52$, $P>0.10$) gradients at a 6 km spatial scale.

Kittiwakes were not strongly correlated with fish densities in any depth strata at any spatial scale. Unlike murres, which may spend much of their time swimming on the water in foraging areas, kittiwakes tend to fly most of the time (e.g., only one bird was observed on the water), and it was impossible to identify potential foraging birds for this analysis. However, kittiwakes were negatively correlated with sea-surface temperature-salinity gradients at both small (3 km, temp. $r=-0.38$, $P<0.05$; sal. $r=-0.13$, $P>0.10$) and large (18 km, temp. $r=-0.90$, $P<0.05$, sal. $r=-0.57$, $P>0.10$) spatial scales. Most kittiwakes were observed on approach to Cape Lisburne (Fig. 5.8), even though the arc surveys (Fig. 5.7) suggested that most kittiwakes from Cape Thompson fly toward Pt. Hope and few kittiwakes from Cape Lisburne fly south or southwest.

The only other seabirds seen in abundance were Short-tailed Shearwaters and Least Auklets. Both species were negatively correlated at the minimum spatial scale (3 km) with fish abundance in all depth strata, although correlations were generally weak (e.g., -0.04, ns, to -0.39, $P<0.01$). Most (81%) of the Least Auklets observed were swimming on the water in the middle of the convergence zone between the Alaska Coastal and Bering Sea Currents (Fig. 5.8) where upwelled waters brought plankton to the surface and fish were very scarce (Fig. 5.10). In contrast to murres and kittiwakes, Least Auklet numbers were positively correlated with sea surface temperature and salinity gradients (6 km scale, temp. $r=0.78$, $P<0.05$; sal. $r=0.83$, $P<0.05$). All the shearwaters observed were flying, and although they were dispersed over a wide area, most were concentrated on the Alaska Coastal Current side of the front (Fig. 5.8). Like auklets, Shearwaters were positively correlated with sea surface temperature and salinity gradients at all spatial scales, although correlations were significant for salinity gradients only at a measurement scale of 18 km (temp. $r=0.50$, $P>0.10$; sal. $r=0.78$, $P<0.05$).

5.3.5 Coastal Survey

On the evening of 27 August, we took shelter from strong northerly winds under coastal cliffs 80 km south of Cape Lisburne and encountered the first of two large murre and kittiwake feeding aggregations observed during the study. About 4 km from shore we passed over a small, dense school of fish (not quantified and suspected to be sand lance) on which about 500-700 murres, 25 kittiwakes, and 10 Glaucous Gulls were actively feeding. The following day, we surveyed the shallow nearshore zone in a zig-zag pattern from about 30 km south of Cape Lisburne to Cape Thompson (Fig. 5.2).

Sea surface temperature and salinity profiles suggested that north of Pt. Hope (waypoints a-h, Fig. 5.12), waters within the 20 m bathymetric contour (Fig. 5.2) were a non-homogeneous mix of mostly Alaska Coastal water with some transitional or Bering Sea water. 'Pure' Alaska Coastal water was observed at the start of the survey (waypoints a-b) and especially as we rounded Pt. Hope (waypoints h-i) where temperatures increased and salinities decreased rapidly. Immediately south of Pt. Hope, cold, high salinity transitional water predominated beyond the 20 m contour (waypoint i), and fronted (waypoints k, m, and o) with 'pure' Alaska Coastal waters inside the 20 m contour all the way to Cape Thompson.

At depths of 10-20 m, where most fish north of Pt. Hope were distributed, fish density was negatively correlated with sea surface temperature and salinity gradients at most scales examined, but correlations were generally weak and nonsignificant (e.g., -0.13 to -0.35, ns). In the 20-30 m stratum, where the densest fish aggregations were found both north and south of Pt. Hope, fish density was positively correlated with gradients at all spatial scales, but was significantly correlated with temperature gradients only at the minimum scale of measurement (3 km, temp. $r=0.36$, $P<0.01$; sal. $r=0.17$, $P>0.10$). In the 30-40 m stratum, recorded only southwest of Pt. Hope (waypoint i), fish density was positively and significantly correlated with temperature gradients at all spatial scales, but reached a maximum at a scale of 12 km (temp. $r=0.69$, $P<0.01$; sal. $r=0.78$, $P<0.001$). This strong correlation corroborates the visual impression from Fig. 5.12 that few fish were found in the core of cold, high salinity transitional water south of Pt. Hope, but fish were abundant on the coastal side of the core where temperatures and salinities changed rapidly. Similar results at waypoints b, e-f, h, and k (Fig. 5.12) account for the positive correlation between fish density at 20-30 m and temperature gradients, and suggests that fish avoided

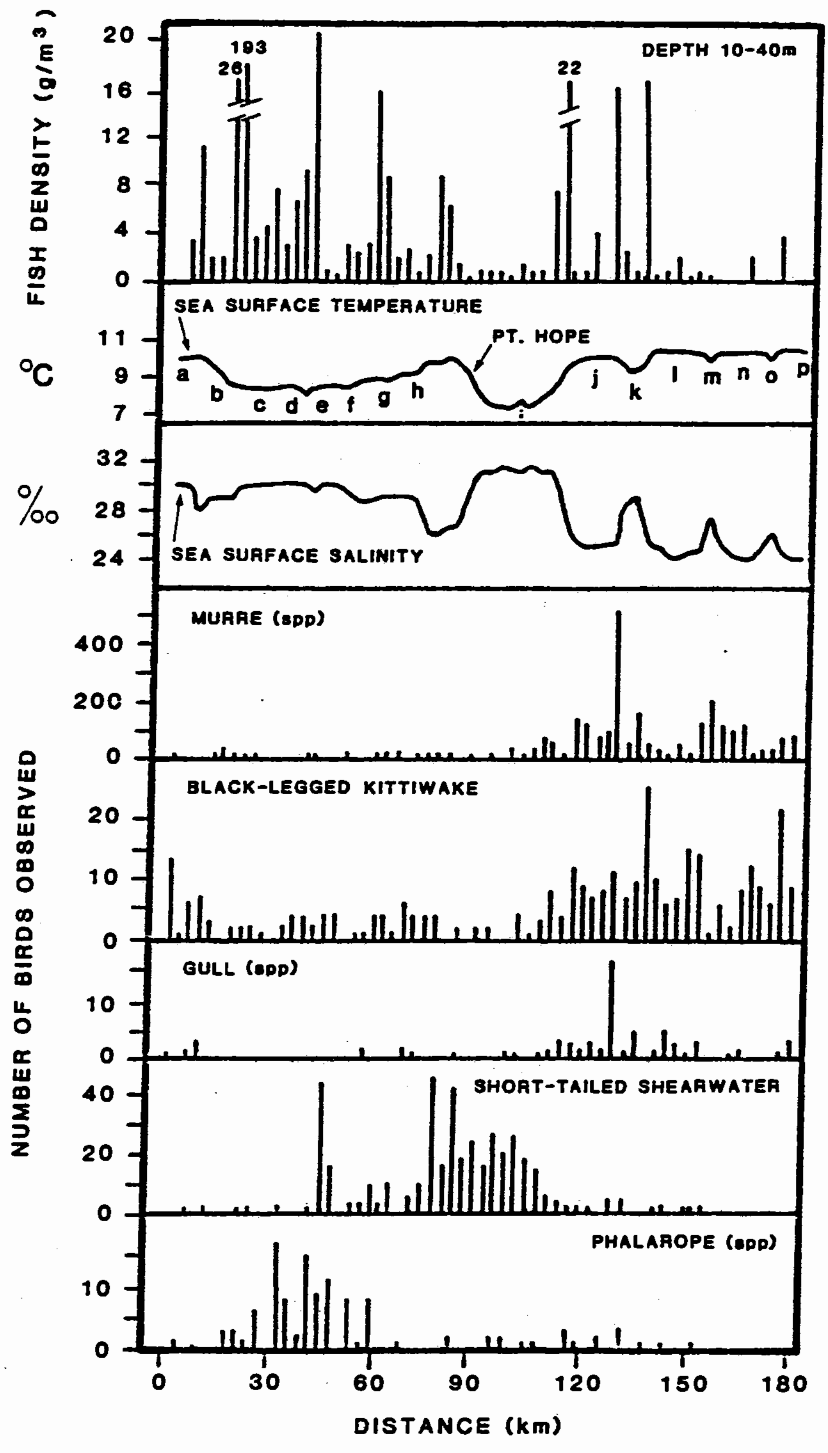


Figure 5.12. Observations of seabirds, fish and hydrography on coastal survey No. 11 north of Cape Thompson. Lower-case letters along sea surface temperature profile correspond to waypoints shown in Fig. 5.2. Histogram at top shows fish densities summed over 10-40 m depth strata. Asterisks indicate location of seabird feeding aggregations.

the center of upwelled waters, but aggregated on the coastal edge of the upwelling.

Over the whole survey area, fish densities averaged 0.59 g/m^3 and abundance averaged 5.3 mt/km^2 in the 10-30 m stratum. However, fish densities north of Pt. Hope were generally higher over a larger area (average density 1.3 g/m^3, total abundance 10.1 mt/km^2) than densities south of Pt. Hope (average density 0.18 g/m^3, total abundance 0.70 mt/km^2). North of Pt. Hope, at least five aggregations with densities greater than 10 g/m^3 and one school with a density of 193 g/m^3 were encountered (Figs. 5.12 and 5.13). No significant seabird feeding aggregations (i.e., >5 birds in a flock on the water) were found north of Pt. Hope. South of Pt. Hope, however, one large aggregation of murres (466), kittiwakes (10), and Glaucous Gulls (15) was found actively feeding on a school of fish that ranged from the surface to the bottom and had a maximum density of 14.3 g/m^3 in the 20-30 m stratum (Figs. 5.12 and 5.14). This school appeared qualitatively different from what we believed to be Arctic cod aggregations encountered elsewhere, and may have been a school of sand lance. If so, calculated densities would be higher (e.g., 140 g/m^3) because sand lance have a lower target strength than cod (see Methods). Another small seabird aggregation (41 murres, 3 kittiwakes, 3 gulls) was observed on the water above a similar school with densities of 16.5 g/m^3 (Fig. 5.12). No other seabird feeding aggregations were observed south of Pt. Hope.

It appeared that, with the exceptions noted above, most dense fish aggregations were not exploited by foraging seabirds (Fig. 5.12). Nonetheless, murres on the water (20% of 2,922 birds) were significantly correlated with fish density in the 20-30 m stratum (i.e., mostly south of Pt. Hope) at intermediate spatial scales (12 km scale, $r=0.54$, $P<0.05$). Fish were most widely distributed in the 10-20 m stratum north of Pt. Hope, and murres on the water were negatively correlated with fish in that stratum (12 km scale, $r=-0.36$, $P>0.10$). Similarly, kittiwakes on the water (6% of 326) were positively correlated with fish at the same scale in the 20-30 m stratum ($r=0.71$, $P<0.01$) but negatively correlated with fish in the 10-20 m stratum ($r=-0.31$, $P>0.10$). Murres were not strongly correlated with temperature or salinity gradients at any spatial scale, and kittiwakes were weakly

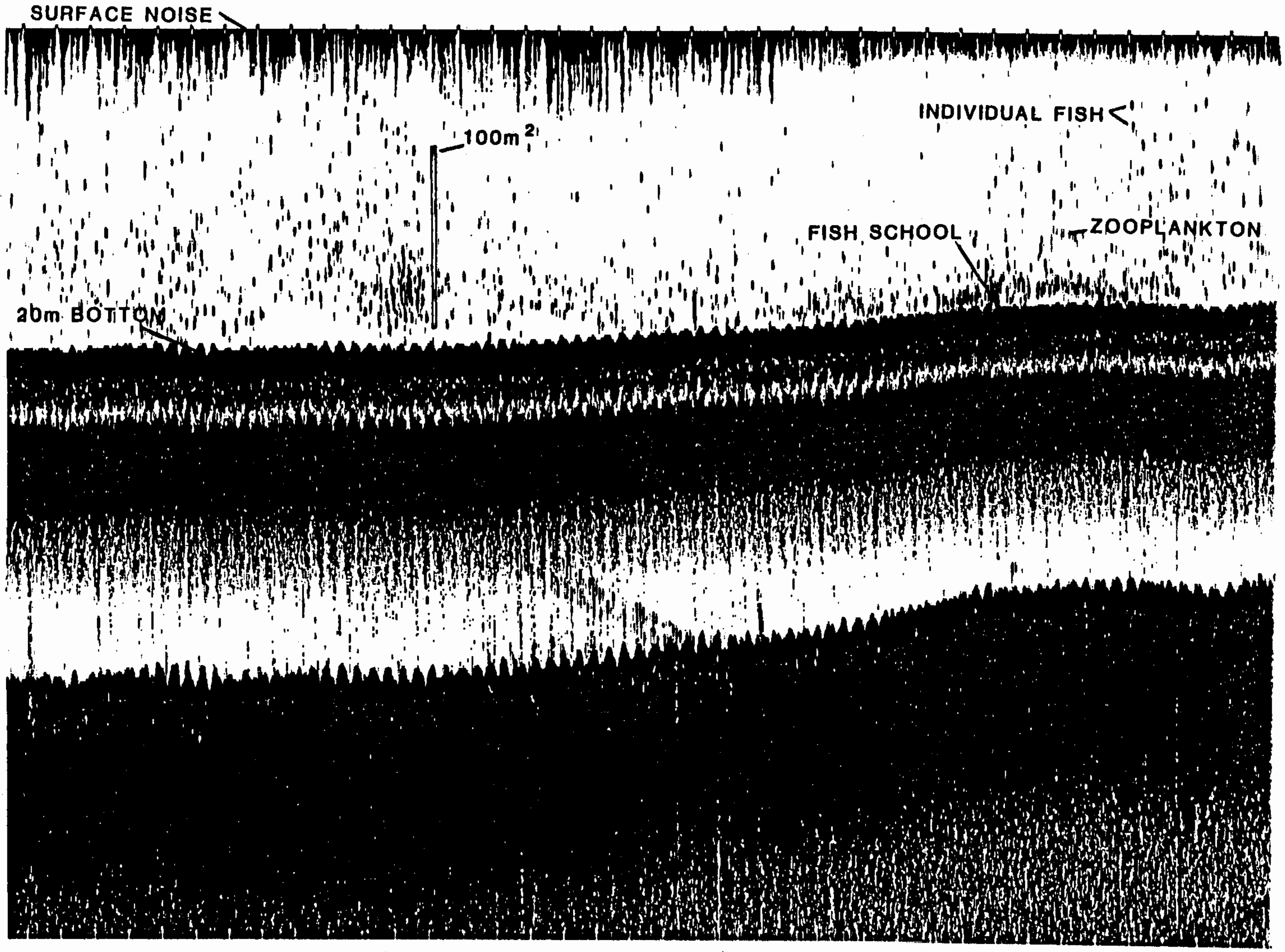


Figure 5.13. Hydroacoustic echogram recorded between waypoints 'b' and 'c' on coastal survey No. 11 (see Figs. 5.2 and 5.12). Fish densities at the indicated school were 193 g/m^3.

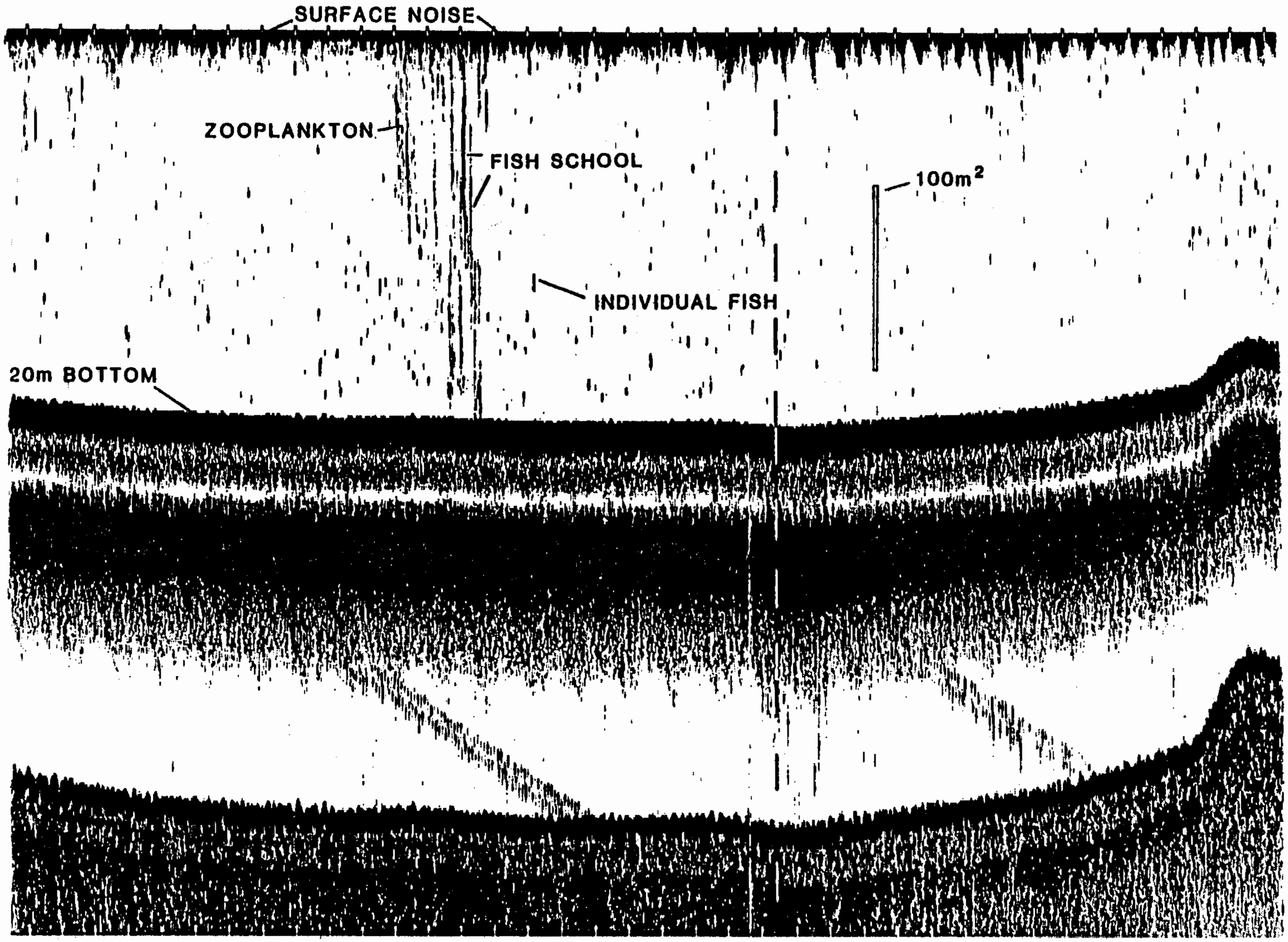


Figure 5.14. Hydroacoustic echogram recorded between waypoints 'j' and 'k' on coastal survey No. 11 (see Figs. 5.2 and 5.12). Fish (sand lance?) densities at the indicated school were probably >100 g/m^3. A large feeding aggregation of seabirds (>500) was associated with this school.

correlated with temperature gradients at small scales only (3 km, temp. r=0.27, P<0.05; sal. r=0.18, P>0.10).

Most identified gulls were Glaucous Gulls, and their numbers were poorly correlated with fish densities, although largest numbers were recorded over the previously described schools south of Pt. Hope (Fig. 5.12). However, like kittiwakes, gulls on the water (32% of 72 birds) were weakly correlated with temperature (r=0.27, P<0.05) and salinity (r=0.34, P<0.01) gradients at the minimum spatial scale of 3 km. As expected from their distributions, neither shearwaters or phalaropes were correlated with fish, although both were positively correlated with temperature gradients at moderate spatial scales (12 km, r=0.53, P<0.05; r=0.34, P>0.10, respectively). Shearwaters were concentrated in upwelled transitional waters off Pt. Hope. Phalaropes (only P. fulicaria identified) were concentrated north of Pt. Hope where transitional water fronted with Alaska Coastal water (waypoints e-f), fish densities were reduced, and some shearwaters were also present.

5.3.6 Summary: Seabird Affinities with Water Types

Considering all species and surveys, it appears that seabird densities were low in the southern and central Chukchi Sea, but high in the coastal and offshore zones northwest of Cape Thompson in late August (Fig. 5.15). However, different species were not distributed evenly between and within these areas. The affinity of different seabird species for different water types is clearly demonstrated (Figs. 5.16 and 5.17) by grouping seabird observations from all surveys according to whether they occurred in 'pure' Bering Sea water (surface temp. <7.5° C, surface sal. >31 ppt), transitional water (temp. >=7.5° C, sal. >30 ppt), or 'pure' Alaska Coastal water (sal. <30 ppt). Flying birds from arc and inshore surveys were excluded for this analysis. Least and Parakeet Auklets exhibited a strong affinity for 'pure' Bering Sea water, and Parakeet Auklets showed a slight preference over Least Auklets for coastal water (X^2=9.1, P<0.05). Common Murres were more strongly associated with Coastal water than any other species, but Horned Puffins, kittiwakes, gulls, and phalaropes also foraged mostly in Coastal water. Thick-billed Murres also prefered Coastal water, but a significantly higher proportion of Thick-billed than Common Murres

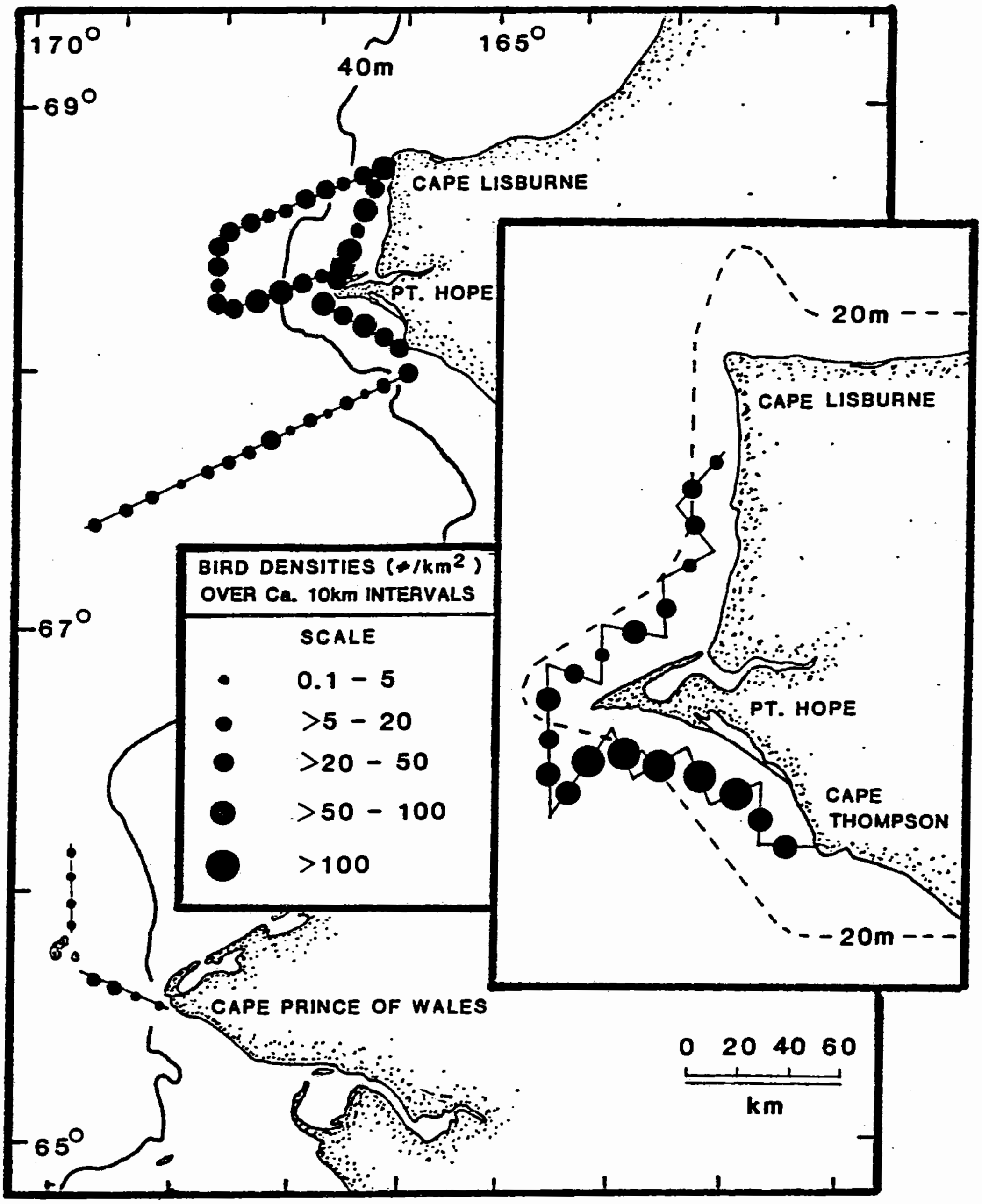


Figure 5.15. Densities of all seabirds observed on surveys in the southeast Chukchi Sea. Note that surveys west of Cape Prince of Wales (Nos. 1 and 2) included only birds on the water.

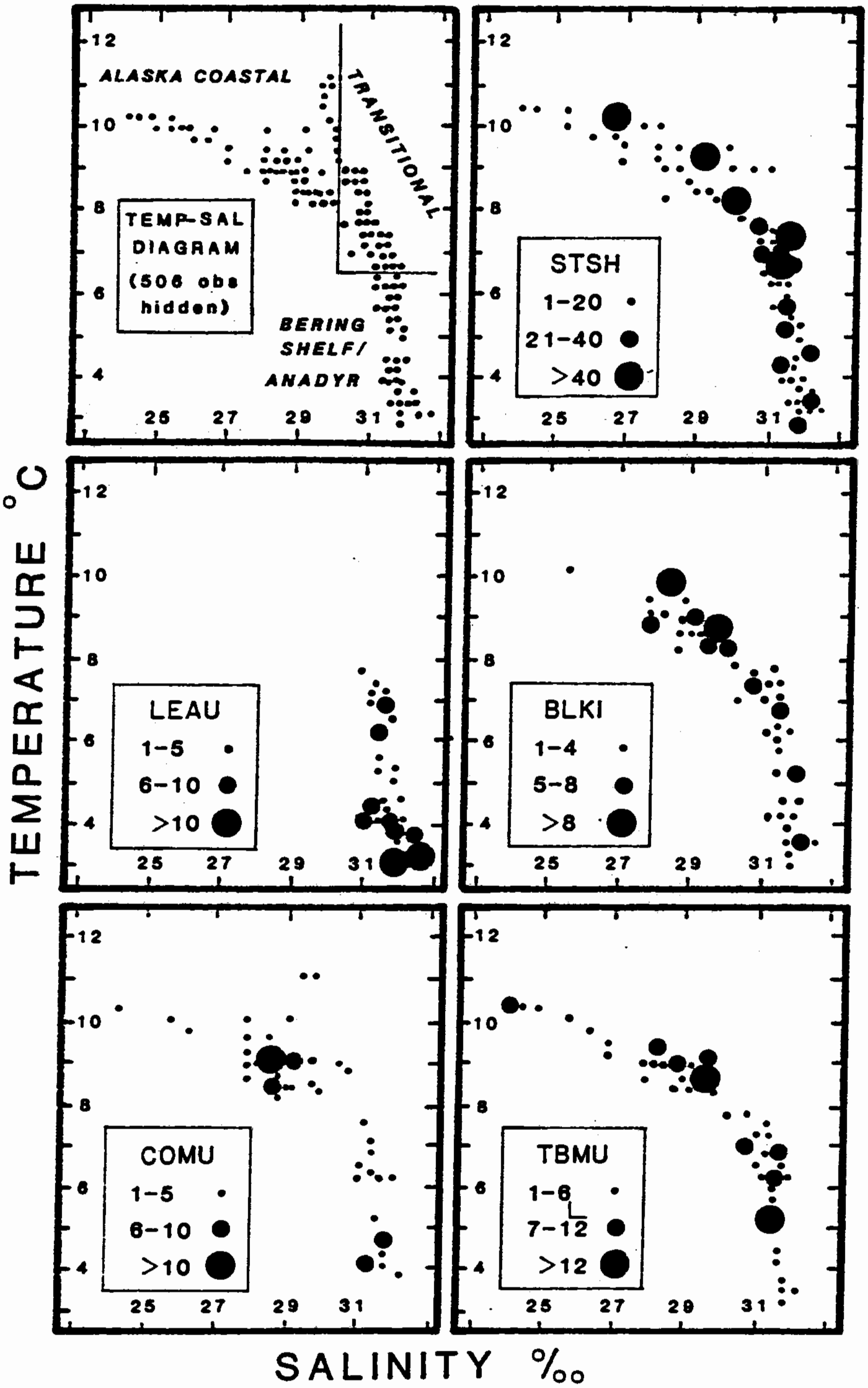


Figure 5.16. Temperature-salinity diagram of all waters sampled on surveys in the southeastern Chukchi Sea, and the abundance of selected seabird species within different water types.

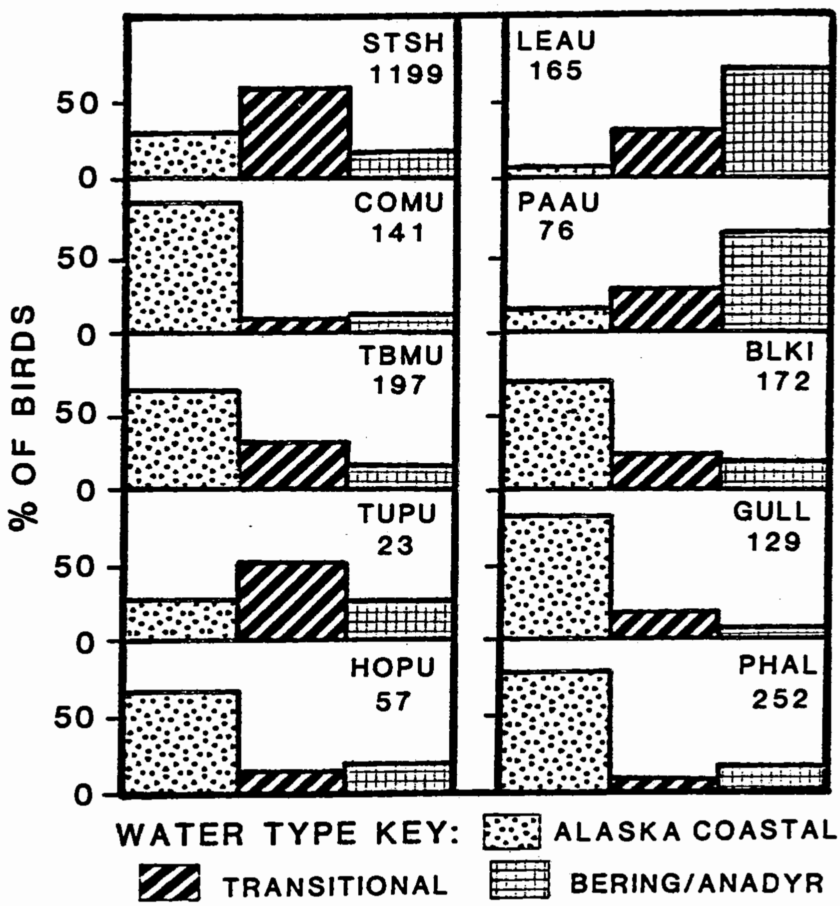


Figure 5.17. The proportion of seabirds observed in different water types in the southeastern Chukchi Sea (proportions weighted by the total area surveyed in each water type).

foraged in transitional water (X^2=17.7, P<0.001). Short-tailed Shearwaters and Tufted Puffins showed marked preferences for transitional water.

5.3.7 Diets and Condition of Seabirds at Cape Thompson

Murres and kittiwakes collected at Cape Thompson in July and August fed predominantly on schooling fishes, of which Arctic cod was most important by frequency of occurrence or percentage wet weight (Table 5.2). The average length of Arctic cod taken by all species was 157 ± 38 mm (n=202), with an extrapolated average weight of about 31 g. Thick-billed and Common Murres also fed frequently on sand lance, saffron cod, and sculpins, but these contributed little to the total mass of food consumed because of their low numbers or relatively small average masses (about 6.7, 23, and 4.8 g, respectively). Thick-billed Murres also fed on invertebrates, although they are probably under-represented here because of their rapid digestion (Springer et al. 1984). Only kittiwakes consumed herring, which were abundant nearshore in July and early August (pers. observation). Herring consumed by kittiwakes were estimated to be about 200 mm in length and 100 g in weight (Whitmore and Bergstrom 1983), and kittiwakes had obvious difficulty swallowing such large fish. Herring were apparently too large for murres to handle or swallow, and murres ignored herring schools around Cape Thompson (pers. observation).

The numbers of fish (or otoliths) found in bird stomachs varied markedly through the seabird breeding season (Table 5.3). In early to mid-July, all species were apparently successful in foraging, and Arctic cod predominated in their diets. Numbers of Arctic cod in stomachs declined markedly by mid- to late August, and even though sand lance, saffron cod, and herring were also consumed, birds apparently could not make up for the lack of Arctic cod. Most of the empty stomachs (Table 5.2) we observed were from birds collected in August.

Murre and kittiwake body masses declined between July and August, although the difference was significant only for male Thick-billed Murres and Kittiwakes (Table 5.4). The body mass of Common Murres declined by only 4%, Thick-billed Murres by 8%, and kittiwakes (male only) by 11%. Fat deposits

Table 5.2. Occurrence of major taxa in diets of Thick-billed Murres (TBMU), Common Murres (COMU), and Black-legged Kittiwakes (BLKI) at Cape Thompson in summer, 1988. Values not in parentheses represent the percent number or weight among birds with identifiable prey remains.

	TBMU		COMU		BLKI	
	n	%	n	%	n	%
Number examined	46	(100)	14	(100)	18	(100)
Number empty	15	(33)	1	(7)	2	(11)
Frequency of invertebrates	5	16	0	0	3	19
Frequency of fish	30	97	13	100	14	88
A. Number of individuals						
Arctic cod	125	78	58	89	22	71
Saffron cod	5	3	2	3	0	0
Sculpins	4	2	1	2	0	0
Herring	0	0	0	0	5	16
Sand lance	18	11	1	2	0	0
Unidentified fish	3	2	2	3	1	3
Shrimps	2	1	0	0	0	0
Amphipods	3	2	0	0	0	0
Gastropods	1	1	0	0	3	10
B. Estimated wet weight						
Arctic cod	4527	94	1429	94	524	51
Saffron cod	99	2	62	4	0	0
Sculpins	16	<1	8	<1	0	0
Herring	0	0	0	0	500	48
Sand lance	126	3	2	<1	0	0
Unidentified fish	30	<1	20	1	10	1
Shrimps	<1	<1	0	0	0	0
Amphipods	<1	<1	0	0	0	0
Gastropods	1	<1	0	0	3	<1

Table 5.3. Mean (± SE) numbers of fishes in the diets of murres and kittiwakes at Cape Thompson.

Species	Date		
	6-12 July	11 August	27 August
Thick-billed Murre (n)	(19)	(15)	(12)
Fish	6.3 ± 1.2	0.73 ± 0.28	1.9 ± 0.72
Arctic cod	6.1 ± 2.0	0.53 ± 0.27	0.17 ± 0.11
Saffron cod	0.21 ± 0.12	0	0
Sand lance	0	0	1.5 ± 0.71
Common Murre (n)	(8)	(6)*	
Fish	6.5 ± 0.65	2.2 ± 0.79	
Arctic cod	6.4 ± 0.75	1.2 ± 0.83	
Saffron cod	0.13 ± 0.13	0.17 ± 0.17	
Sand lance	0	0.17 ± 0.17	
Black-legged Kittiwake (n)	(12)	(6)[a]	
Fish	1.8 ± 0.43	1.0 ± 0.52	
Arctic cod	1.4 ± 0.47	0.83 ± 0.54	
Herring	0.33 ± 0.14	0.17 ± 0.17	

[a] Includes one bird collected on 27 August.

Table 5.4. Body weight (g) and mean indices of subcutaneous (Sub-fat) and mesenteric (Mes-fat) body fat content of Thick-billed Murres (TBMU), Common Murres (COMU) and Black-legged Kittiwakes (BLKI) collected at Cape Thompson.

		M+F			Male			Female			Sub-fat		Mes-fat	
Spp.	Date	Wt.	SE	n	Wt.	SE	n	Wt.	SE	n	mean	SE	mean	SE
TBMU	6-8 Jul	1037	15	19	1051	16	16	963	14	3	1.5	0.1	0.9	0.1
TBMU	11 Aug	952	15	15	972	18	9	921	21	6	2.2	0.1	1.3	0.1
TBMU	27 Aug	946	15	12	949	22	8	941	9	4	2.1	0.2	1.3	0.1
COMU	8 Jul	1030	24	8	1007	28	3	1044	32	5	2.0	0.0	1.0	0.0
COMU	11 Aug[a]	985	28	6	990	55	3	980	9	3	2.2	0.2	1.0	0.0
BLKI	8-12 Aug	508	18	11	545	20	6	452	18	6	2.3	0.2	2.1	0.2
BLKI	11 Aug[a]	485	16	4	485	16	4	-	-	-	1.4	0.2	1.6	0.2
Overall means[b]														
TBMU		985	11	46	1005	13	33	937	12	13				
COMU		1011	19	14	998	31	6	1020	23	8				
BLKI		495	15	16	521	16	10	452	18	6				

[a] Includes one bird collected on 27 August.

[b] Thick-billed Murre males significantly heavier than females on 6-8 July ($P<0.01$), and over all dates combined ($P<0.01$). Male kittiwakes heavier than females ($P<0.01$). Male Thick-billed Murres ($P<0.001$) and kittiwakes ($P<0.05$) significantly lighter between July and August. Significant increase in fat content of Thick-billed Murres (Sub-fat $P<0.001$, Mes-fat $P<0.001$), and decrease in fat content of kittiwakes (Sub-fat $P<0.01$, Mes-fat $P>0.05$) between July and August. All other comparisons non-significant using two-tailed t-test.

in both murre species increased or remained stable between July and August, whereas kittiwake fat deposits decreased significantly.

On the evening of 26 August, we captured a small number of murre chicks on the water below breeding cliffs at Cape Thompson. One Common Murre chick weighed 140 g, and 6 Thick-billed Murre chicks weighed an average (± SE) of 130 ± 3.3 g.

5.4 Discussion

5.4.1 Oceanography

Two oceanographic features of the southeast Chukchi in 1988 figured prominently in our study of the distribution and abundance of seabirds and their prey. First, sea ice disappeared from the area later in 1988 than in any previous year of study (Chapter 1), and sea-surface temperatures were about 1-2 degrees colder than those reported by Fleming and Heggarty (1966) and Coachman et al. (1975). Second, we found that the Alaska Coastal Current surged more than 200 km north of the Bering Strait before winding around to the south again, leaving a broad band of cold Bering Sea water in the south-central Chukchi between the northern tongue of Coastal water in the west and the Alaska Coastal Current core in the east.

On the basis of the oceanographic data collected, and on the observed distribution of seabirds (see below), we hypothesize that fronts between coastal and Bering currents resulted in three distinct water masses and foraging habitats for seabirds (Fig. 5.8). On approaching the border of coastal water from offshore, a divergent front resulted in strong upwelling. In the middle of this front, waters were unstratified vertically, but there were strong horizontal gradients in sea-surface temperatures and salinities. Proceeding another 10-20 km inshore, over which transitional sea-surface temperatures and salinities were relatively stable, a convergent front resulted in downwelling of transitional and 'pure' coastal waters, again characterized by strong gradients in sea-surface temperatures and salinities. If this model for tidally induced fronts (Simpson 1981, Schneider et al. 1989) is applicable to this study, then it appears that the core of Bering Sea water was separated from the coastal core by a cell of transitional water with intermediate hydrographic characteristics. Hunt and Harrison (1989) have observed similar oceanographic conditions at the border of Bering Shelf and Alaska Coastal currents in the northern Bering Sea.

5.4.2 Fish Abundance and Distribution

We believe that most of the prey recorded on hydroacoustic surveys were Arctic cod, although a few of the schools detected inshore may have been sand lance. On fishing surveys concentrated in the study area off Cape Thompson in late August, Arctic cod were the most abundant and widely distributed fish caught in bottom trawls and numbers caught exceeded those of other common fishes by at least 1-2 orders of magnitude (Alverson and Wilimovsky 1966). A variety of flatfishes and sculpins are common in the area, but most of these bottom-dwelling fishes would not have been detected or integrated on our hydroacoustic surveys. However, other common pelagic species like capelin (offshore) and saffron cod (inshore) may have contributed to our estimates of fish density. As those species are also consumed by seabirds, are similar in size to Arctic cod, and probably have similar target strengths (Foote 1987, Rose and Leggett 1988), our conclusions regarding fish densities should not be compromised by assuming that most of the fish detected were Arctic cod, or at least potential forage fish for seabirds. Herring is another pelagic species that could have been detected inshore, but observations from Cape Thompson and at sea suggest that herring had migrated out of the area by late August. Sand lance are a relatively minor component of the fish fauna in August (Alverson and Wilimovsky 1966), but in most years constitute an important part of piscivorous seabird diets in late August (Springer et al. 1978, 1984). Springer and Roseneau (1979) have documented how abundant sand lance schools can be in late August, and how obvious schools and seabird feeding aggregations are when they occur locally. Our observations at sea and from the colony at Cape Thompson, and the relative scarcity of sand lance in seabird diets, suggest that sand lance schools were uncommon in 1988, possibly because of the colder than normal water temperatures (Springer et al. 1984). The scarcity of capelin in diets may have also been related to cold water temperatures (Springer et al. 1984, Piatt 1987).

Despite their overwhelming importance in the ecology of breeding seabirds in the southeast Chukchi, little is known about the habits of Arctic cod. The following scenario is inferred from a few local studies and from studies on Arctic cod and various predators in other regions of the Arctic (Alverson and Wilimovsky 1966, Swartz 1966, Lowry and Frost 1981, Frost and Lowry 1984, Springer et al. 1984, Bradstreet et al. 1986). It appears that in June, Arctic cod are associated with the retreating ice-edge, and are concentrated in cracks in the ice where primary and secondary production is elevated. In July, Arctic cod form large, dense schools which may be especially common nearshore, particulary around convergent fronts where high salinity waters downwell under low salinity inshore waters. Spawning by Arctic cod occurs in winter, and it is not clear why they form dense schools in July. Schooling may be a response to food dispersion (Bradstreet et al. 1986). The pronounced schooling behavior in July must account for the marked increase in frequency of Arctic cod in diets of seabirds and marine mammals at that time. Schools disperse in August, and although Arctic cod remain abundant in the region, they generally do not form the dense schools observed in July.

In accord with the above scenario, we found that Arctic cod were widely dispersed in low densities on our surveys in late August. The average biomass densities calculated from integration of hydroacoustic signals inshore (0.73 g/m^3) and offshore (0.073 g/m^3) suggested average fish densities of less than about 1 fish/100 m^3. Even in areas of concentration, fish densities were only about 30-300 fish/100 m^3 (or 0.3-3 fish/m^3). Examination of fish target densities on corresponding echograms suggests that these calculated estimates are reasonable. Because of their higher densities inshore, the total biomass (6200 mt) of cod inshore (in the 1170 km^2 area in which survey 11 was conducted) was higher than the total biomass (5080 mt) offshore (in the 2320 km^2 area offshore circumscribed by survey 10). Similarly, Alverson and Wilimovsky (1966) found Arctic cod to be widely dispersed and abundant in August both inshore (i.e., within the 30 m bathymetric contour) and offshore. Bottom trawls (about 30 min in duration) conducted offshore caught fewer cod (mean $\pm$ SE, 58 $\pm$ 12, n=28) than trawls conducted inshore (217 $\pm$ 144, n=7). As indicated by variance/mean ratios (I'), Arctic cod were more highly aggregated inshore (I'=669) than offshore (I'=76).

The distribution of Arctic cod was clearly influenced by the fronts observed at the border of Bering Sea and Alaska Coastal currents. In the strongly upwelled divergent zone between Bering and transitional water, and in the cell of transitional water itself, fish were conspicuously absent throughout the water column except for low densities associated with zooplankton at the surface. We hypothesize that fish avoid the upwelling zone to escape predation by seabirds and marine mammals. Densities of zooplankton and fish at the surface could have been much higher than we detected because surface turbulence limited our ability to detect organisms in that layer, and the ship's transducer was located below the top 5 m layer of water. The abundance of planktivorous seabirds above the divergence (see below) supports this suggestion. Low densities of fish were found concentrated in mid-water above the 2^{o} C isotherm in the stratified, Bering Sea side of the divergence. Fish densities were highest on the stratified, coastal side of the downwelling convergence between transitional and Alaska Coastal waters. We hypothesize that fish (Arctic and saffron cod, sand lance, etc.) aggregate near the bottom on the coastal side of the convergence to feed on plankton entrained in the downwelled current.

On the survey which crossed all three water types (No. 10), fish densities throughout the water column were negatively correlated with gradients in sea-surface temperature and salinity at all spatial scales. This negative relationship existed because of the strong avoidance by fish of upwelled water at the divergence. On the coastal survey (No. 11), conducted largely inside the convergence, fish densities in the lower water column were positively correlated with gradients in sea-surface temperature and salinity and correlations were strongest at small spatial scales. This supports the hypothesis that fish aggregated in the immediate vicinity of downwelled water on the coastal side of the convergence. Differences between surveys in the direction and scale of fish-gradient correlations indicate that caution is required before interpreting associations between seabirds and gradients in the absence of data on prey distributions (e.g., Schneider 1982, Kinder et al. 1983).

5.4.3 Foraging Ecology of Seabirds

Like previous investigators, (Swartz 1967, Divoky 1978, Drury et al. 1981) we found that murres, shearwaters, and kittiwakes were the most abundant seabirds in the southeast Chukchi in late summer. Our total list of species (Appendix 5.1) closely resembles previous lists in terms of species composition and relative abundances. Swartz (1966, 1967) and Springer et al. (1984) noted the importance of the frontal zone between Bering Sea and Alaska Coastal currents in determining the distribution of seabirds, and our study has revealed some of the mechanisms by which marine habitats are partitioned by frontal processes. On the basis of previous studies, and our own findings, we have reached the following conclusions about seabird foraging behavior in the southeast Chukchi Sea.

All of the dominant seabirds breeding at Cape Thompson can be classified as piscivorous Coastal species, and most were found within Coastal waters where fish densities were highest, even though this sometimes meant foraging along the coast more than 100 km from the colony (e.g., kittiwakes). Most birds appeared to forage within 60 km of Cape Thompson. However, foraging ranges for all species change through the breeding season (Swartz 1966, Springer and Roseneau 1979). Because our study was conducted at the end of the summer when Arctic cod schools had dispersed and some birds had left breeding colonies, the ranges we observed were probably extreme, but normal for that time of year.

The relative distribution of breeding seabirds between Alaska Coastal, transitional, and Bering Sea waters was consistent with known dietary habits of these species. Murres (spp.) were positively correlated with fish densities inshore and offshore, and enough positive identifications of the two species were made to detect a significant difference between them in use of foraging habitats. Common Murres feed almost exclusively on pelagic, schooling fishes (Springer et al. 1984, Piatt et al. 1988), and they showed a greater affinity for Coastal water than any other species. Smaller numbers occurred offshore in Bering Sea water, but Common Murres, like fish, were rare in transitional waters. Because Common Murres prefer to forage on dense schools of fish (Piatt 1989), the aggregation of fish along the coastal side of the convergent front may be an important biophysical factor influencing the foraging distribution of Common Murres at Cape Thompson. Thick-billed Murres also feed heavily on fish, but consistently consume a substantial number of invertebrates as well (Springer et al. 1984, Piatt et al. 1988). Accordingly, a higher proportion of Thick-billed than Common murres foraged in transitional waters where fronts presumably concentrated invertebrates near the surface in 'slicks' (Brown 1980, Brown and Gaskin 1986). Whereas they also feed heavily on fish, Horned Puffins, kittiwakes, and Glaucous Gulls have more diverse diets than Common Murres (Swartz 1966, Springer et al. 1984) and accordingly, those species were often encountered in transitional waters. Hunt et al. (1989a) and Schneider et al. (1989) have also observed concentrations of murres (spp.) and kittiwakes feeding on euphausiids along convergent slicks off St. Matthew and St. George islands.

All evidence suggests that by the end of the breeding season, the density of fish around Cape Thompson was barely sufficient to support murres, and fish were largely inaccessible to kittiwakes. Except for a few schools inshore where densities reached 10-100's g/m^3, fish densities were low (0.1-10's g/m^3) throughout the study area and especially near Cape Thompson, compared to those in extended capelin aggregations exploited by Common Murres, Atlantic Puffins (Fratercula arctica), and baleen whales in Witless Bay, Newfoundland (Piatt 1989, Piatt et al. 1989), or to those of euphausid, pollock (Theragra chalcogramma) and herring schools exploited by Humpback Whales (Megaptera novaeangliae) in Alaska (10-100's g/m^3, Krieger and Wing 1986, Dolphin 1987). However, murres and kittiwakes at Cape Thompson were well-fed in July when Arctic cod were presumably schooling nearby, and reduced prey abundance at the end of the breeding season was not unexpected (Safina and Burger 1985, Piatt 1989). Nonetheless, the numbers of fish in murre and kittiwake stomachs in August, 1988, were much lower than in several previous 'normal' years (Springer et al. 1984).

Murres (spp.) seemed capable of dealing with the relatively low densities of prey in August. Body fat stores were normal, breeding success (ca. 50%, Chapter 3) was typical for these species in Alaska (Piatt et al. 1988), and although chick weights at fledging seemed low for murres (Hatch 1983), they were not significantly different from chick weights observed by Swartz

(1966). In contrast, kittiwakes lost fat stores in August and experienced the second lowest level of breeding success (ca. 12%, Chapter 3) recorded for Cape Thompson in 8 years. The difference between murres and kittiwakes in breeding success may be due to the inability of kittiwakes to exploit Arctic cod, which were common at depths of 20-40 m, and the scarcity of sand lance, which often comprise the bulk of kittiwake diets in August (Springer et al. 1984). The inaccessibility of Arctic cod to kittiwakes in August may be normal in most years, whereas the availability of sand lance in any given year appears less predictable and probably related to water temperatures (Springer et al. 1984).

Five other common seabirds were observed on our surveys, and all appeared to choose foraging habitats according to their dietary preferences and foraging capabilities. Least Auklets foraged widely over stratified Bering Sea waters, but were sometimes concentrated on the Bering Sea side of the upwelling divergence between Bering Sea and transitional waters. Least Auklets have a strong preference for the copepods typically found in Bering Sea waters (e.g., Neocalanus plumchrus, Bedard 1969, Hunt and Harrison 1989), and zooplankton volumes are much higher in Bering Sea waters off Cape Thompson than in adjacent Coastal waters (English 1966). Presumably, Bering Sea copepods were not found in transitional water on the coastal side of the divergence, or Least Auklets would have been observed there as well. Vertical stratification and upwelling may be the most important mechanisms for concentrating zooplankton exploited by Least Auklets (Hunt et al. 1989b, Hunt and Harrison 1989). Parakeet Auklets have more diverse diets than Least Auklets (Bedard 1969), and most were found in upwelled Bering Sea water where presumably amphipods, copepods, Pteropods, and a variety of other invertebrates were concentrated in the upper water column.

The dietary habits of Short-tailed Shearwaters and Tufted Puffins in the Chukchi sea are poorly known, but judging from diets in other areas (Hunt et al. 1981), it is reasonable to assume that these species feed on a great variety of prey including fishes, euphausiids, shrimp, squid, and other invertebrates. Shearwaters and Tufted Puffins exhibited a stronger affinity for transitional waters than any other species. Transitional waters are likely to have a greater diversity of prey types than adjacent Bering Sea or

Coastal waters because both water masses contribute to the composition of transitional waters. Whereas the foraging behavior of Tufted Puffins is poorly known, shearwaters (including also P. griseus and Calonectris diomedea) are often associated with divergent and convergent fronts (Schneider 1982, Haney and McGillivary 1985, Briggs et al. 1987).

Phalaropes (of which 91% were identified as Red Phalaropes) were one of the most abundant seabirds we encountered, and most were found on the Coastal side of the convergence between transitional and Coastal waters. The association of phalaropes with convergent fronts has been well documented, and it is clear that phalaropes are attracted to planktonic prey which accumulate in surface slicks near convergent waters (Brown and Gaskin 1988).

5.4.4 Summary and Conclusions

The distribution and density of seabirds in the southeast Chukchi Sea appeared to be strongly influenced by the distribution and density of potential prey, which in turn depended on ocean temperatures, currents, and fronts between those currents. There were four main habitats used by seabirds: (1) Offshore in Bering Sea water, fish and zooplankton were concentrated in mid-water above the 2^{o} C isotherm. These prey are generally accessible to diving alcids, and possibly accessible to surface foragers through the mechansim of localized fronts induced by bathymetric gradients (e.g., Brown 1980, Kinder et al. 1983). (2) At the divergent front between Bering Sea and transitional waters, fish and piscivorous seabirds were scarce, but planktivorous auklets fed on zooplankton upwelled on the Bering Sea side of the front. (3) In transitional waters between the divergent and convergent fronts, omnivorous species like shearwaters and Tufted Puffins aggregated to feed on prey brought to the surface or concentrated at slicks. A significant proportion of predominantly fish-eating species (murres, kittiwakes) also used this habitat. (4) In Coastal waters, fish apparently aggregated near the wall of downwelled water at the convergence of transitional and Coastal waters, and piscivorous species foraged mostly in Coastal waters. Within the Coastal habitat, Arctic cod and sand lance are the most important prey for piscivorous seabirds, and the absolute density and vertical distribution of these fish species may strongly influence foraging success by seabirds.

Like other investigators, we found that seabird communities were segregated by oceanographic processes that could be characterized by gradients in water temperature and salinity (e.g., Haney 1986, Briggs et al. 1987). However, apparent associations between seabirds, gradients, and potential prey may be scale-dependent (Schneider and Piatt 1986) and may vary within and between habitats. The use of hydroacoustics to study the density and distribution of potential seabird prey below the ocean surface offers great promise for elucidating mechanisms by which marine habitats are created and exploited by different seabird species. This is particularly true for Arctic and sub-Arctic waters where sub-surface foragers dominate seabird communities.

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Appendix Table 5.1. Species and numbers of marine birds and mammals observed on all surveys in the southeast Chukchi Sea (in order of abundance).

Common name	Scientific name	No.
Murre spp.		8237
Thick-billed Murre	Uria lomvia	680
Common Murre	Uria aalge	198
Short-tailed Shearwater	Puffinus tenuirostris	1292
Black-legged Kittiwake	Rissa tridactyla	684
Eider spp.		647
King Eider	Somateria spectabilis	2
Phalarope spp.		271
Red Phalarope	Phalaropus fulicaria	91
Red-necked Phalarope	Phalaropus lobatus	8
Least Auklet	Aethia pusilla	165
Glaucous Gull	Larus hyperboreus	131
Horned Puffin	Fratercula corniculata	101
Parakeet Auklet	Aethia psittacula	76
Tufted Puffin	Fratercula cirrhata	23
Brant	Branta bernicla	20
Northern Fulmar	Fulmarus glacialis	14
Jaeger spp.		15
Pomarine Jaeger	Stercorarius pomarinus	11
Parasitic Jaeger	Stercorarius parasiticus	3
Arctic Tern	Sterna paradisaea	9
Pacific Loon	Gavia pacifica	3
Sabine's Gull	Xema sabini	2
Oldsquaw	Clangula hyemalis	2
Herring Gull	Larus argentatus	2
Crested Auklet	Aethia cristatella	2
Pigeon Guillemot	Cepphus columba	1
Pelagic Cormorant	Phalacrocorax pelagicus	1
Common Loon	Gavia immer	1
Gray Whale	Eschrichtius robustus	24
Humpback Whale	Megaptera noveangliae	1
Spotted Seal	Phoca largha	1

APPENDIX A. MARINE AND TERRESTRIAL MAMMAL SIGHTINGS IN THE CAPE THOMPSON AREA, 1988

Observations on land were limited to the area between Chariot and Imnapak Cliff, and about 2 km inland, though the majority of our time was spent between Colony 2 and Colony 5. Marine observations include Chariot through 2 km north of Imnapak Cliff, to about 2 km offshore.

TERRESTRIAL MAMMALS

Grizzly bear (Ursus horribilis)

This region has been noted for its abundant population of grizzly bears (Pruitt 1966; Selkregg 1974), but our interactions with them were few. We often spotted tracks on the beaches in front of camp and Colonies 2 and 4, and we occasionally found excavated ground squirrel burrows. An apparently disused den was located on a hillcrest at the north end of C3 about 120 m above the Ibrulikorak Creek. Grizzly feces examined (n=3) contained bones from the Arctic ground squirrel (Spermophilus parryii). Our sightings were: (1) 13 Aug (06:30); at camp across the Ikijaktusak Creek. This bear ran up the creek valley upon seeing one of our party. (2) 19 Aug (03:30); heard running through camp. (3) 30 Aug (22:00); on Agate Rock hillside above camp. When initially observed, the bear was digging a ground squirrel burrow. Shouts gained its attention, but it returned to digging. Shotgun blasts into the air gained the bear's attention again, but resulted in little or no reaction. Eventually the bear wandered up the hill and over the crest to the north.

The scarcity of bears near camp may have been due to a lack of beached marine mammals on the camp beach. In contrast to our experience, two kayakers travelling from Kotzebue had been having serious problems from bears while camping on beaches to the south. Marine mammal carcasses were common (especially walrus) along the kayakers route, and we observed several walrus carcasses on beaches north of C5 and on beaches south of C1 at Chariot. Local currents were apparently unfavorable for depositing dead marine mammals on the beaches near camp.

Wolf (*Canis lupus*)

We observed one set of wolf tracks on the Ikijaktusak Creek (Camp) beach upon our arrival 5 July. Wolf records from the Cape Thompson region have previously been rare (Pruitt 1966).

Red fox (*Vulpes fulva*)

We found one den with a mother and 5 pups in an abandoned shed at Chariot on Ogotoruk Creek. No evidence of foxes was observed in the camp or seabird colony areas.

Shorttail weasel (*Mustela erminea*)

This weasel was observed on 23 and 25 August. Sightings were on the bluffs over Colonies 4 and 5, and in both instances the weasel was very curious, to the point of climbing onto the leg of one observer. On 25 August, we observed the weasel capture and return to its hole with an approximately 7 day old murre chick. It was not possible to determine if both sightings were of the same or different weasels.

Arctic ground squirrel (*Spermophilus parryii*)

Abundant throughout the study period and the Cape Thompson area. Became a pest species after burrowing into the Weatherport and other tents, and eating our food.

Tundra vole (*Microtus oeconomus*)

Abundant throughout the study period and the Cape Thompson region.

Moose (*Alces alces*)

One female and her calf was observed on 18 July approximately 50 m upstream of camp on the Ikijaktusak Creek.

Barren ground caribou (*Rangifer articus*)

One bull was sighted on 17 July above Ikijaktusak Creek. approximately 1 km from camp. Individual bull sightings have been reported (Pruitt 1966) from this area, with most movements of the Arctic herd occurring farther inland.

Muskox (*Ovibos moschatus*)

One herd of up to 30 muskoxen (including 2 young and 2 radio-collared animals) was sighted frequently between 25 July and 22 August. During this period, the animals were observed foraging, travelling, or resting in the Ikijaktusak Creek valley. These muskoxen derive from transplants to the Cape Thompson region in 1970 (36 animals) and 1977 (35 animals) (Grauvogel 1984). Aerial surveys in 1983 reported a herd of only 9 muskoxen (plus several scattered individuals) in the Cape Thompson area (Grauvogel 1984), but land observations indicated 14-16 muskoxen may have been present in 1982 (D.G. Roseneau, pers. comm., cited in Jinfors and Klein 1982).

MARINE MAMMALS

Polar bear (*Ursus maritimus*)

A lone bear was observed on 8 July about 1.6 km offshore of camp on the drift ice. The drift ice pack at that time was dense to about 3 km offshore, extending north to Point Hope and south to Chariot.

Walrus (*Odobenus rosmarus divergens*)

Walrus were sighted throughout the study period: (1) 10 July; single animal within 1 km of camp shoreline among the drift ice. (2) 28 July; single juvenile (no tusks) observed swimming below Colony 4. (3) 12 August; large individual swimming southeast along shoreline. (4) 19-20 August; small (yearling?) individual hauled out on rocks at Colony 1. The health of this animal was questionable; it paid no attention to our approach, and seemed lethargic.

Ringed seal (*Phoca hispida*)

This was the most commonly observed of 3 seal species, spotted daily 5-15 July while drift ice was present. Ringed seals were often close to shore where they may have been attracted by runs of char (*Salvelinus alpinus*) and Arctic cod (*Boreogadus saida*). Ringed seals are abundant in the Chukchi Sea (Johnson et al. 1966; Kelly 1988).

Spotted seal (*Phoca largha*)

Common between 5-15 July, spotted seals were often observed swimming inverted at the surface before diving. They were also frequently seen along the shoreline feeding on schools of herring (Clupea harengus) and Arctic cod. Typically, two or three seals herded the schools into the shallows at the water's edge, then dart into the schools to capture fish. Individual seals were also observed feeding on herring schools clustered under ice floes.

Bearded seal (Erignathus barbatus)

Uncommon among the drift ice 5-15 July.

Harbor porpoise (Phocoena phocoena)

Observed on 4 occasions within 0.25 km of shore at camp and at Colony 4; 21 Aug (1), 23 Aug (2), 25 Aug (1), and 26 Aug (1). Although harbor porpoises have been reported in the Chukchi Sea (Tomilin 1957; cited in Johnson et al. 1966), Johnson et al. (1966) did not observe any in the Cape Thompson vicinity.

Beluga (Delphinapterus leucas)

Beluga were observed twice: (1) 14 July; solitary animal heading E-SE 0.25 km off Colony 4, when ice was still present but becoming scarce. (2) 20 July; solitary animal heading E-SE approximately 2 m offshore of camp beach (Ikijaktusak Creek mouth).

Gray whale (Eschrichtius robustus)

One 25' whale was feeding within 0.75 km of Colony 4-5 shoreline from 12:00-18:40 on 22 July. A circular travel path brought it within 0.25 km of shore, trailing mud plumes behind. A second feeding whale was observed on 30 July, foraging between 0.03-0.5 km offshore from camp. Mud plumes and mud issuing from the mouth were observed, as well as one spy hop.

Humpback whale (Megaptera noveangliae)

A single whale was sighted approximately 1.5 km offshore between camp and Colony 2 on 21 August. It displayed 10 breaches within 20 min, apparently swimming in circles in a specific location.

Unknown Baleen Whale

On 10 July we observed from boat a large gray-black whale, lacking a dorsal fin, but with barnacle callosities on the lower jaw and upper head, and a large rostrum. This animal was a northern right whale (Eubalaena glacialis), a bowhead whale, or a melinistic gray whale (Eschrichtius robustus). It was approximately 0.5 km offshore of camp, and swimming rapidly to the north, but in reviewing photographs, it appears as if it may have been feeding as well (the photos show the mouth open with body slightly tilted to the right side at the surface).

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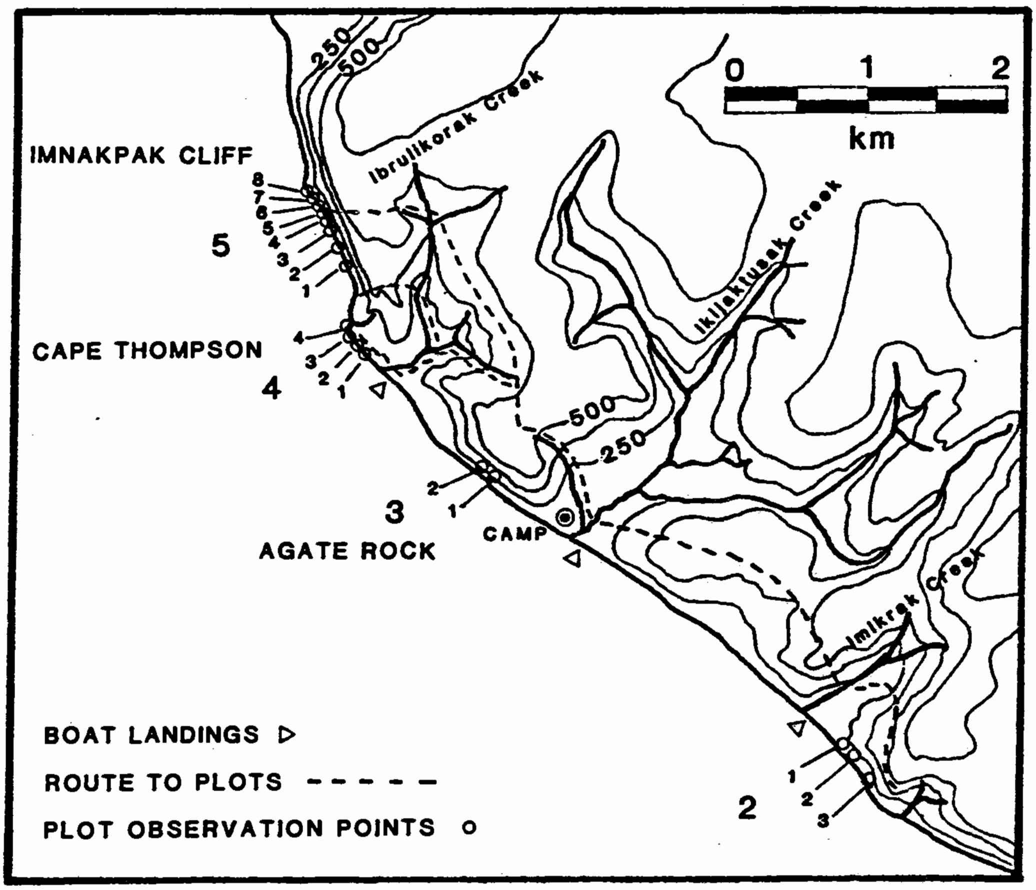
APPENDIX B. BIRD LIST FOR CAPE THOMPSON AND VICINITY 1 JULY - 31 AUGUST, 1988

Red-throated Loon (*Gavia stellata*)
Pacific Loon (*Gavia*
Yellow-billed Loon (*Gavia adamsii*)
Northern Fulmar (*Fulmarus glacialis*)
Short-tailed Shearwater (*Puffinus tenuirostris*)
Pelagic Cormorant (*Phalacrocorax pelagicus*)
Greater White-fronted Goose (*Anser albifrons*)
Brant (*Branta bernicla*)
Northern Pintail (*Anas acuta*)
Greater Scaup (*Aythya marila*)
Common Eider (*Somateria mollissima*)
King Eider (*Somateria spectabilis*)
Spectacled Eider (*Somateria fischeri*)
Steller's Eider (*Somateria stelleri*)
Harlequin Duck (*Histrionicus histrionicus*)
Oldsquaw (*Clangula hyemalis*)
Black Scoter (*Melanitta nigra*)
Red-breasted Merganser (*Mergus serrator*)
Northern Harrier (*Circus cyaneus*)
Rough-legged Hawk (*Buteo lagopus*)
Golden Eagle (*Aquila chrysaetos*)
Merlin (*Falco columbarius*)
Peregrine Falcon (*Falco peregrinus*)
Gyrfalcon (*Falco rusticolus*)
Willow Ptarmigan (*Lagopus lagopus*)
Rock Ptarmigan (*Lagopus mutus*)
Sandhill Crane (*Grus canadensis*)
American Golden Plover (*Pluvialis dominica*)
Semipalmated Plover (*Charadrius semipalmatus*)
Lesser Yellowlegs (*Tringa flavipes*)
Wandering Tattler (*Heteroscelus incanus*)
Whimbrel (*Numenius phaeopus*)

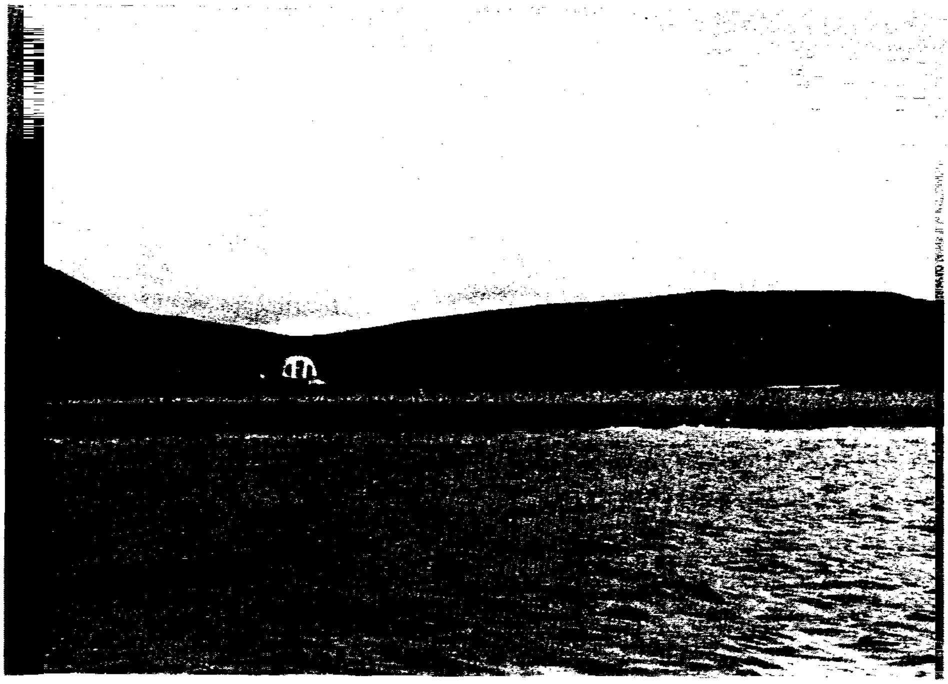
Bar-tailed Godwit (*Limosa limosa*)
Ruddy Turnstone (*Arenaria interpres*)
Red Knot (*Calidris canutus*)
Semipalmated Sandpiper (*Calidris pusilla*)
Western Sandpiper (*Calidris mauri*)
Least Sandpiper (*Calidris minutilla*)
Baird's Sandpiper (*Calidris bairdii*)
Pectoral Sandpiper (*Calidris melanotos*)
Dunlin (*Calidris alpina*)
Long-billed Dowitcher (*Limnodromus scolopaceus*)
Red-necked Phalarope (*Phalaropus*
Red Phalarope (*Phalaropus fulicarius*)
Pomarine Jaeger (*Stercorarius pomarinus*)
Parasitic Jaeger (*Stercorarius parasiticus*)
Long-tailed Jaeger (*Stercorarius longicaudus*)
Herring Gull (*Larus argentatus*)
Slaty-backed Gull (*Larus schistisagus*)
Glaucous Gull (*Larus hyperboreus*)
Black-legged Kittiwake (*Rissa tridactyla*)
Sabine's Gull (*Xema sabini*)
Arctic Tern (*Sterna paradisaea*)
Common Murre (*Uria aalge*)
Thick-billed Murre (*Uria lomvia*)
Black Guillemot (*Cepphus grylle*)
Pigeon Guillemot (*Cepphus columba*)
Parakeet Auklet (*Cyclorrhynchus psittacula*)
Crested Auklet (*Aethia cristatella*)
Horned Puffin (*Fratercula corniculata*)
Tufted Puffin (*Fratercula cirrhata*)
Short-eared Owl (*Asio flammeus*)
Alder Flycatcher (*Empidonax alnorum*)
Say's Phoebe (*Sayornis saya*)
Horned Lark (*Eremophila alpestris*)
Tree Swallow (*Iridoprocne bicolor*)
Violet-green Swallow (*Tachycineta thalassina*)
Bank Swallow (*Riparia riparia*)

Barn Swallow (*Hirundo rustica*)
Common Raven (*Corvus corax*)
Red-breasted Nuthatch (*Sitta canadensis*)
Arctic Warbler (*Phylloscopus borealis*)
Ruby-crowned Kinglet (*Regulus calendula*)
Bluethroat (*Luscinia svecica*)
Northern Wheatear (*Oenanthe oenanthe*)
Gray-cheeked Thrush (*Catharus minimus*)
American Robin (*Turdus migratorius*)
Varied Thrush (*Ixoreus naevius*)
Yellow Wagtail (*Motacilla flava*)
Water Pipit (*Anthus spinoletta*)
Bohemian Waxwing (*Bombycilla garrulus*)
Northern Shrike (*Lanius excubitor*)
Orange-crowned Warbler (*Vermivora celata*)
?Yellow-rumped Warbler (*Dendroica coronata*)
Common Yellowthroat (*Geothlypis trichas*)
Wilson's Warbler (*Wilsonia pusilla*)
American Tree Sparrow (*Speizella arborea*)
Savannah Sparrow (*Passerculus sandwichensis*)
Fox Sparrow (*Passerella iliaca*)
Golden-crowned Sparrow (*Zonotrichia atricapilla*)
White-crowned Sparrow (*Zonotrichia leucophrys*)
?Harris' Sparrow (*Zonotrichia querula*)
Dark-eyed Junco (*Junco hyemalis*)
Lapland Longspur (*Calcarius lapponicus*)
Snow Bunting (*Plectrophenax nivalis*)
Gray-crowned Rosy Finch (*Leucosticte tephrocotis*)
Common Redpoll (*Carduelis flammea*)
Hoary Redpoll (*Carduelis hornemanni*)

APPENDIX C. PHOTODOCUMENTATION OF STUDY PLOTS ESTABLISHED IN 1988

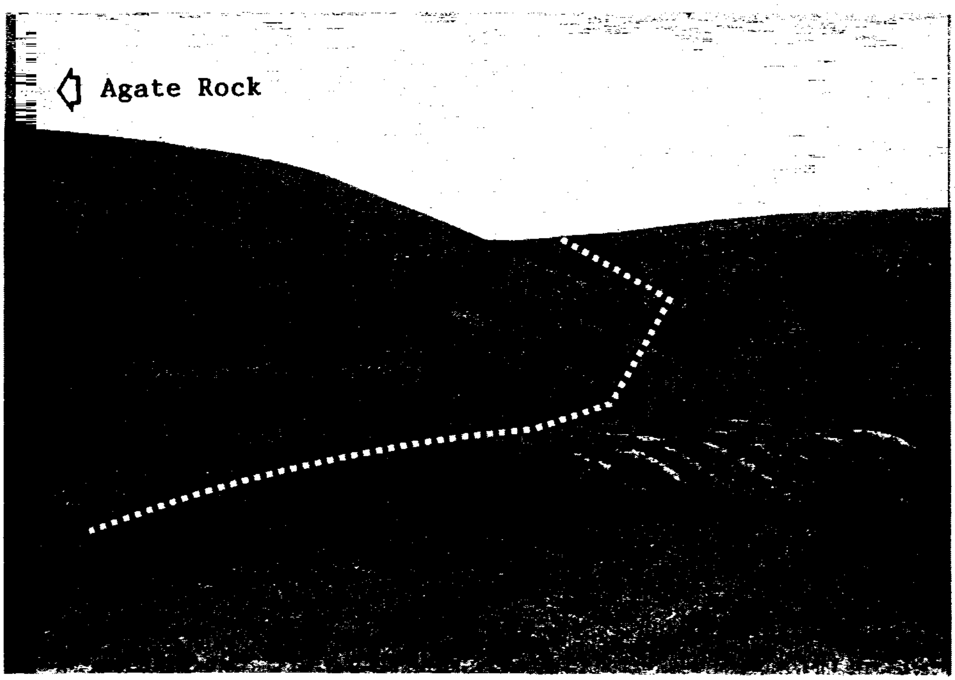


Routes to newly established land-based plots, and general plot locations at Cape Thompson, Alaska.

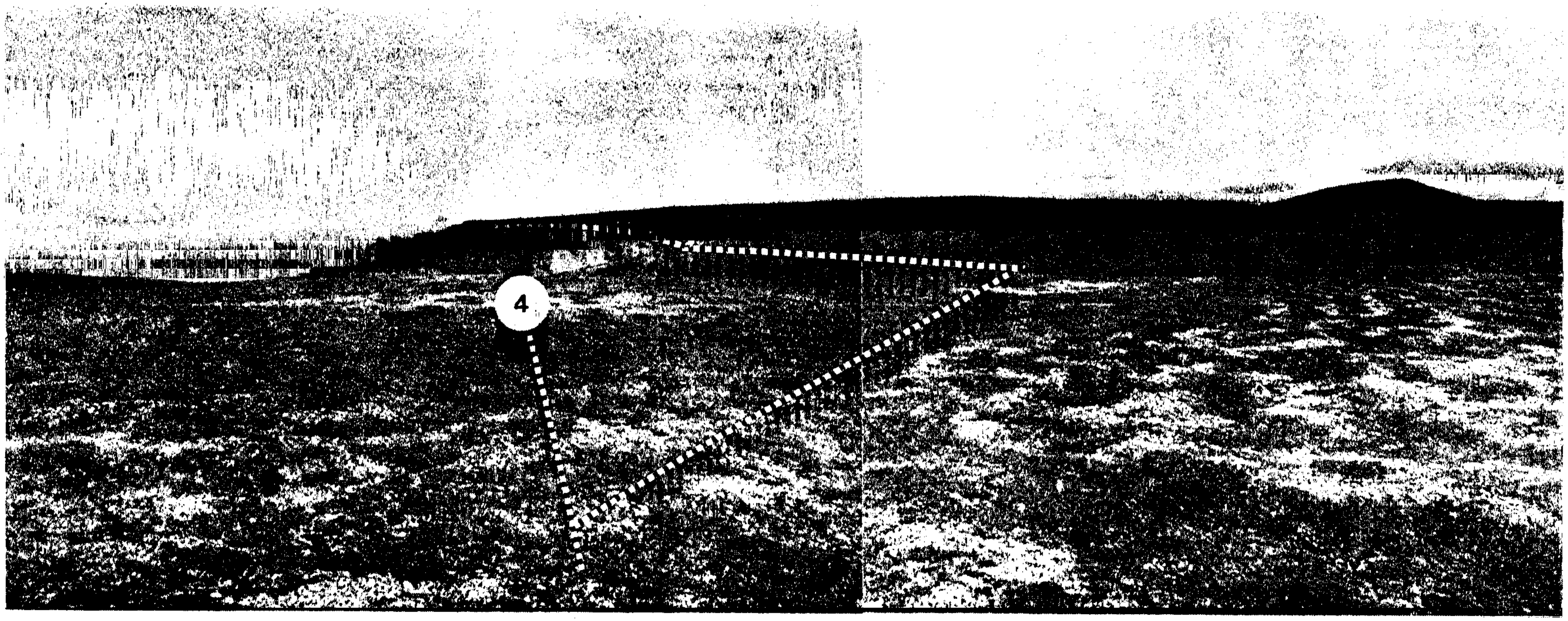


(1) Base camp at Ikijaktusak Creek.

LAND ROUTES TO COLONIES 4 AND 5

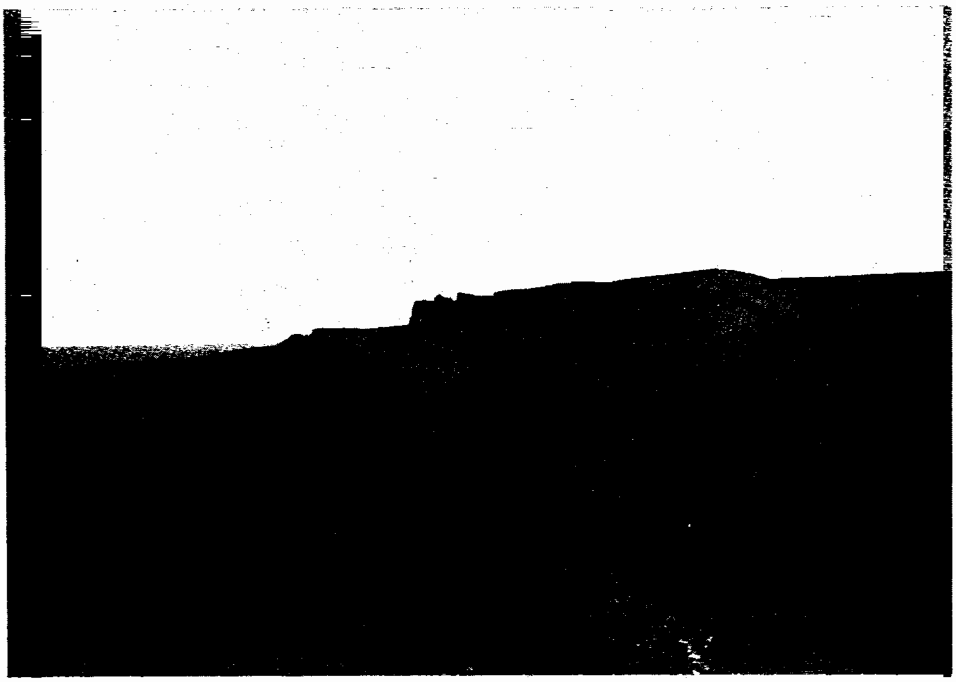


(2) Looking N-NW. From camp, proceed up ravine around Agate Rock hill.

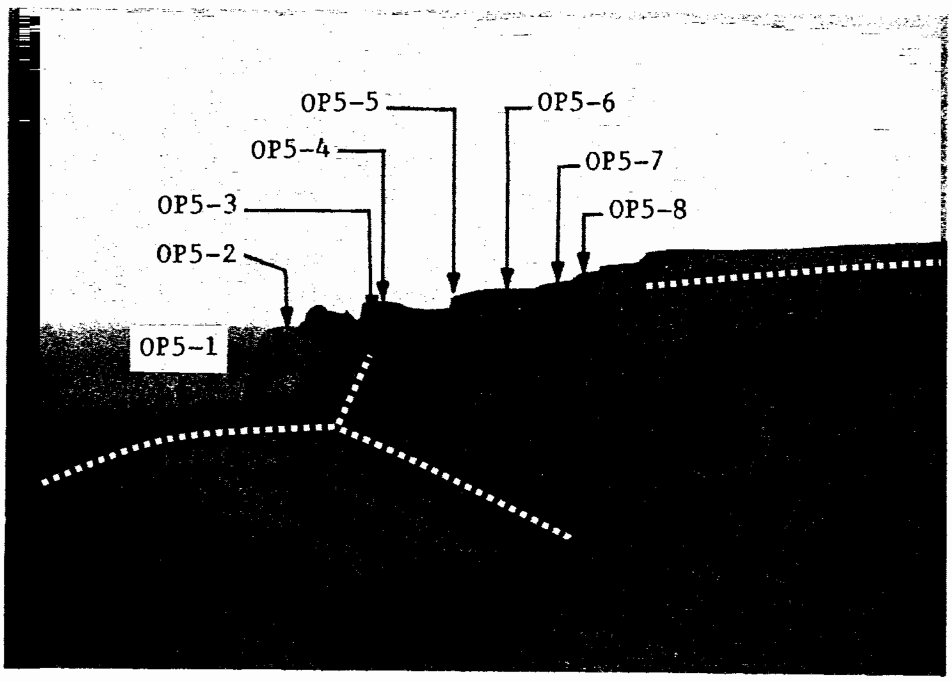


(3) NW view from summit plateau atop Agate Rock hill. Several routes access Colonies 4 and 5 from here.

(Numbers in circles denote location from which the photograph with that number was taken).

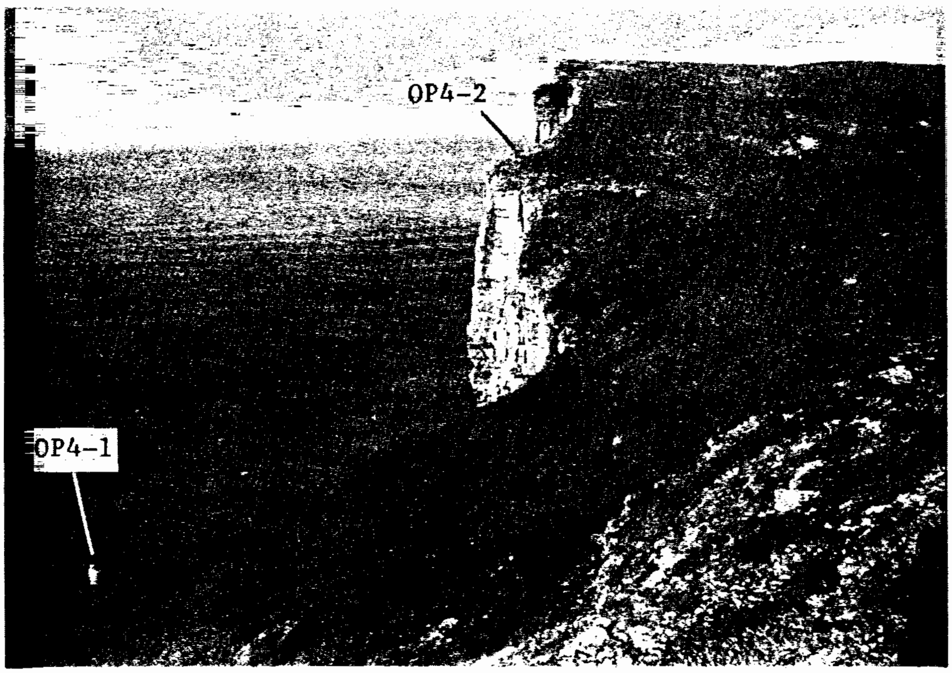


(4) NW view behind Colony 5 and part of Colony 4. One route proceeds down the creek bed, the other around the ridge tops, off the picture to the right.

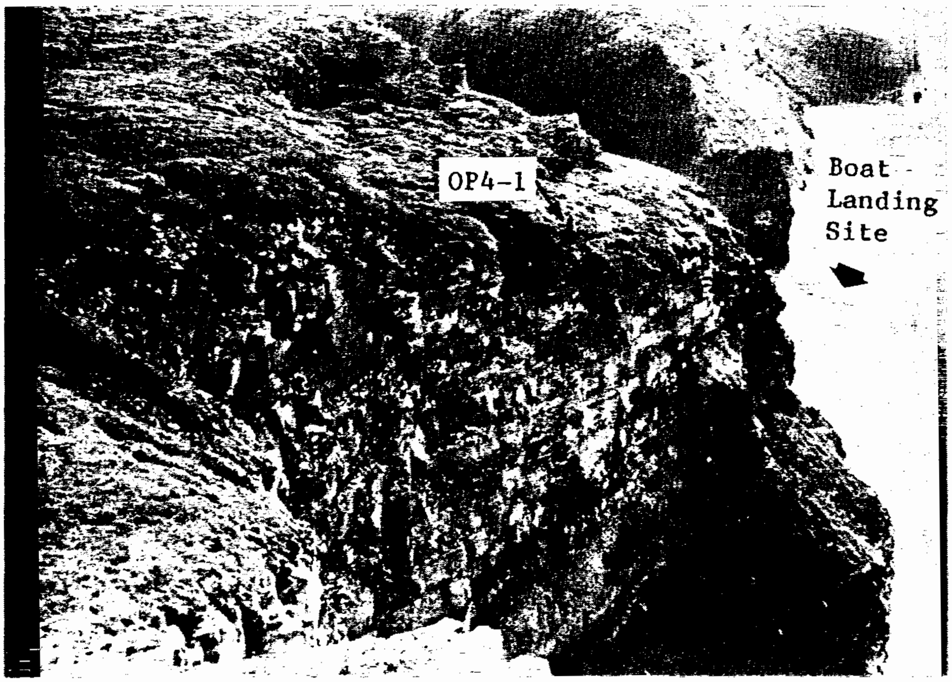


(5) Close-up of area behind Colony 5, showing general locations of observation points along the cliffs.

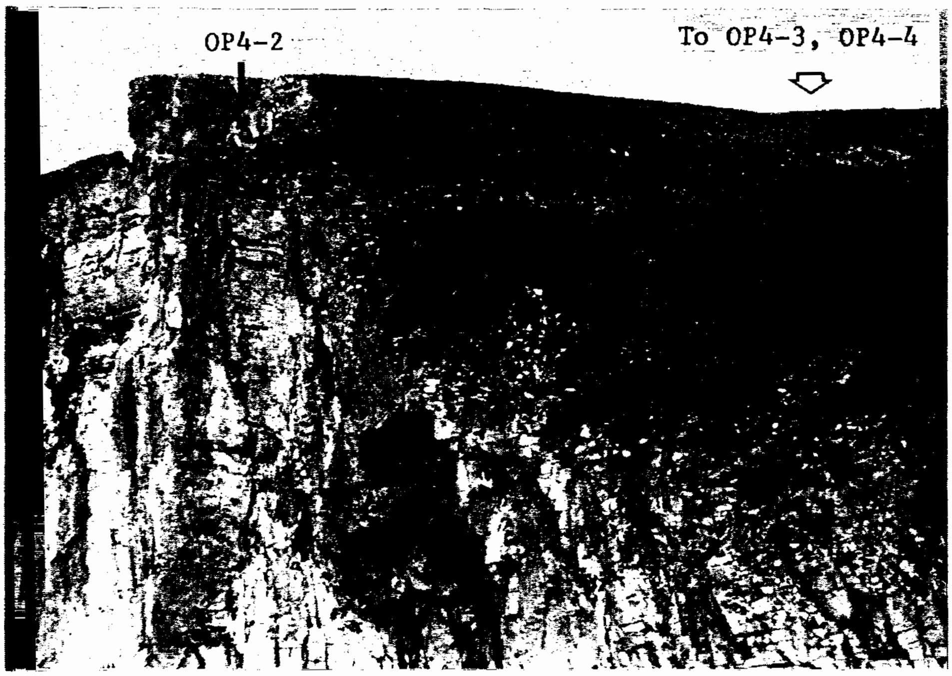
(6) Suggested boat landing area, just SE of Colony 4.



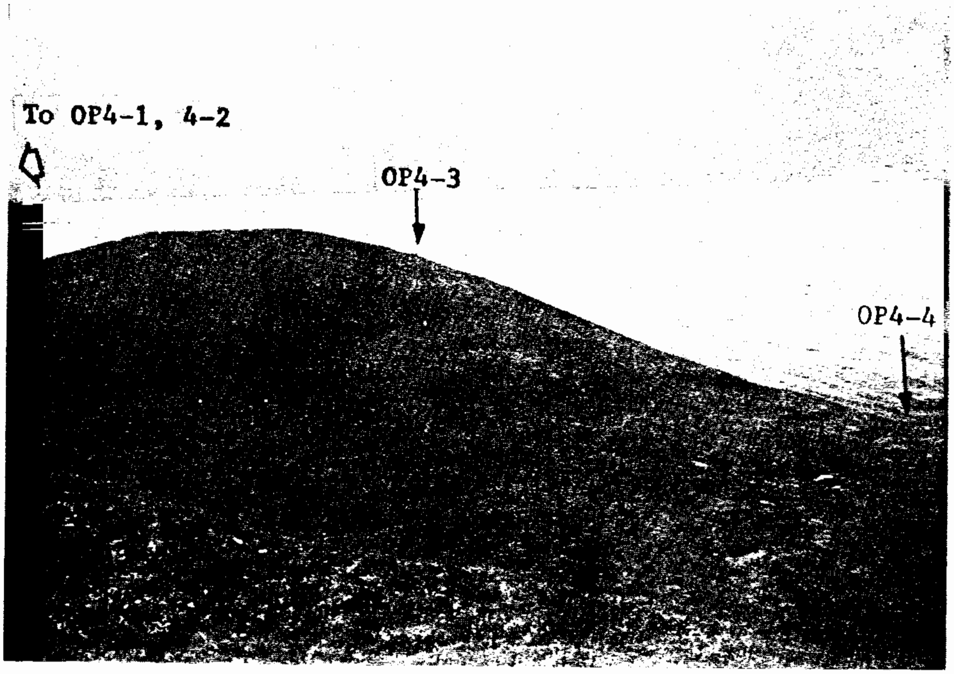
(7) Colony 4. Observers at OP4-1 and OP4-2.



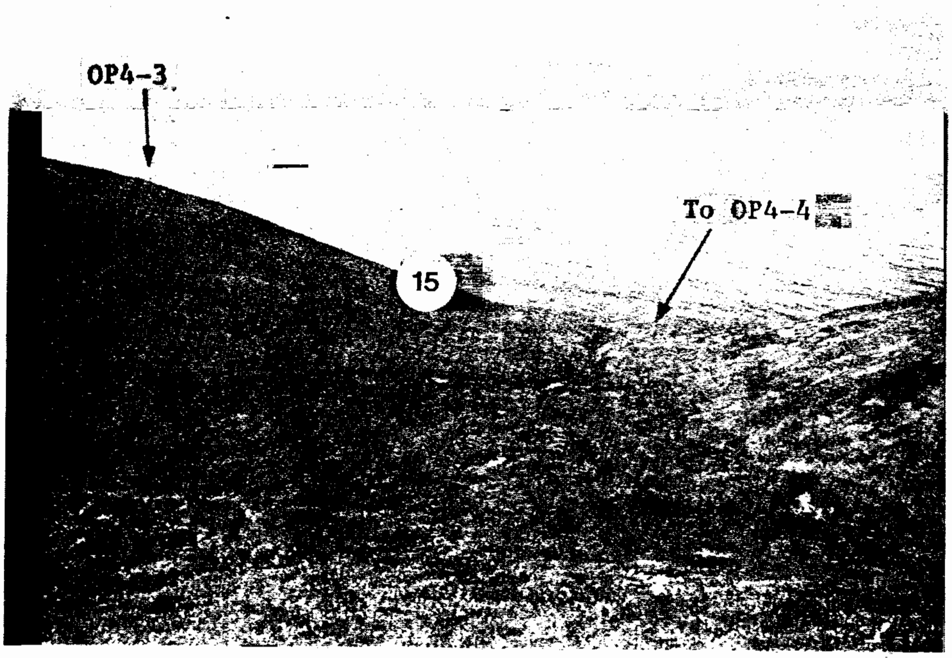
(8) Colony 4. Observer in place at OP4-1 (view from OP4-2).



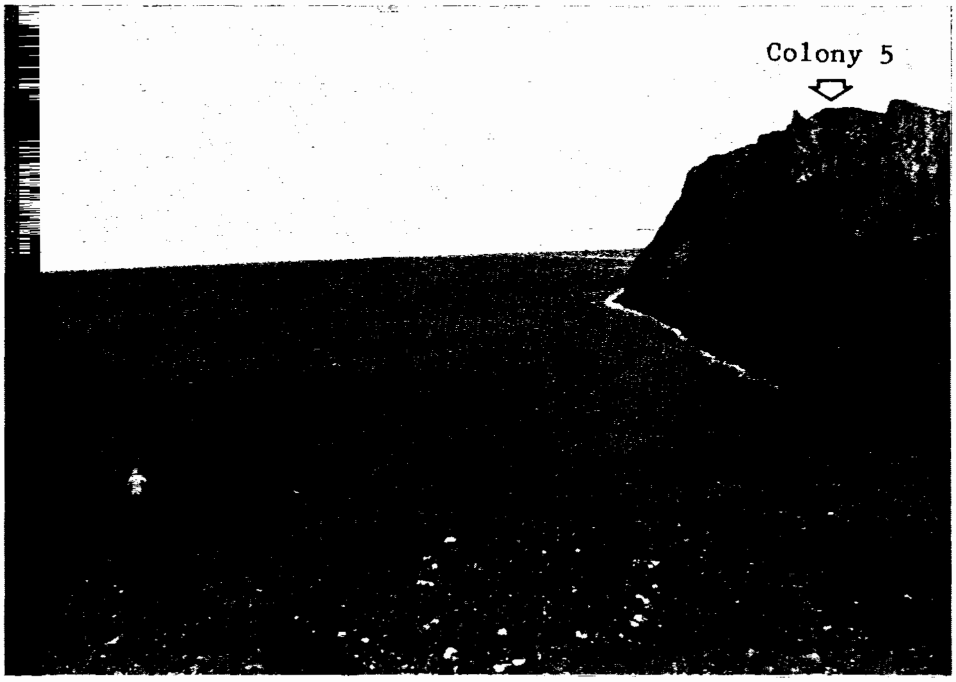
(9) Colony 4. Observer at OP4-2 (view from OP4-1).



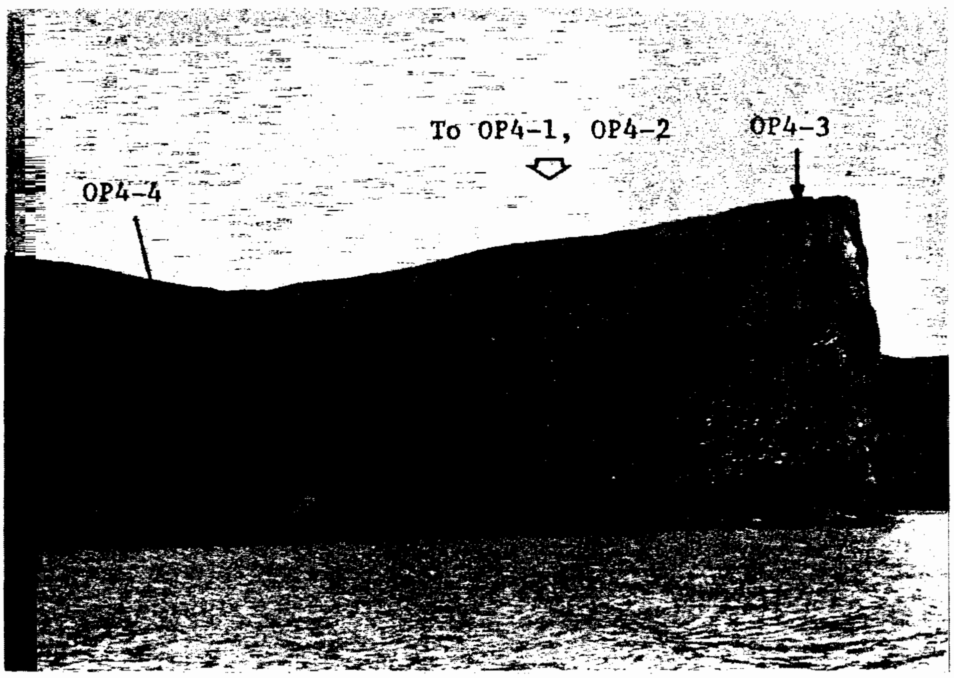
(10) Colony 4, Observer at OP4-3.



(11) Colony 4. Observer at OP4-3, other observer enroute to OP4-4.

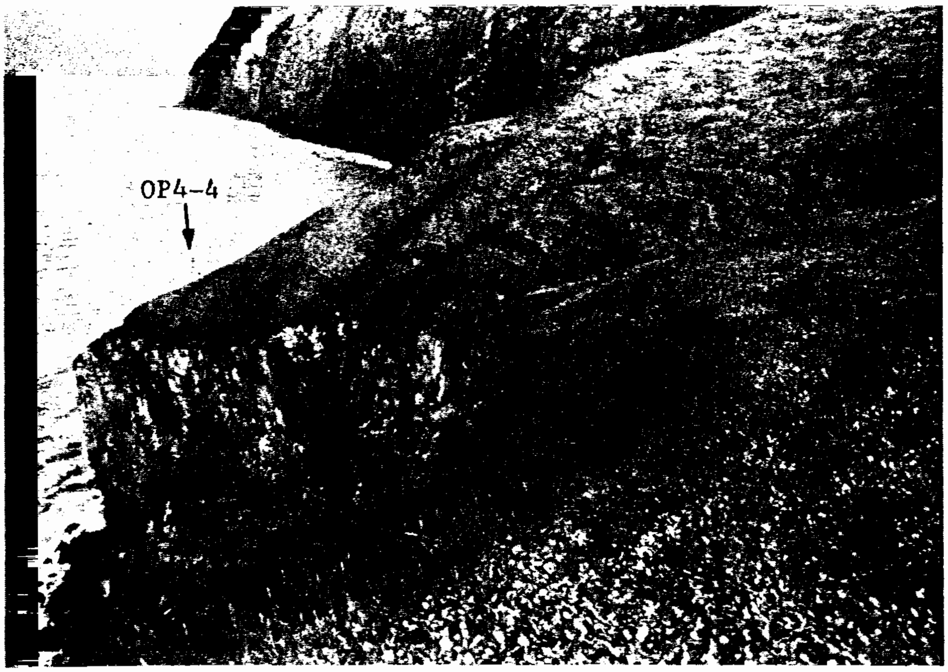


(12) Colony 4. Climbing down to OP4-4.

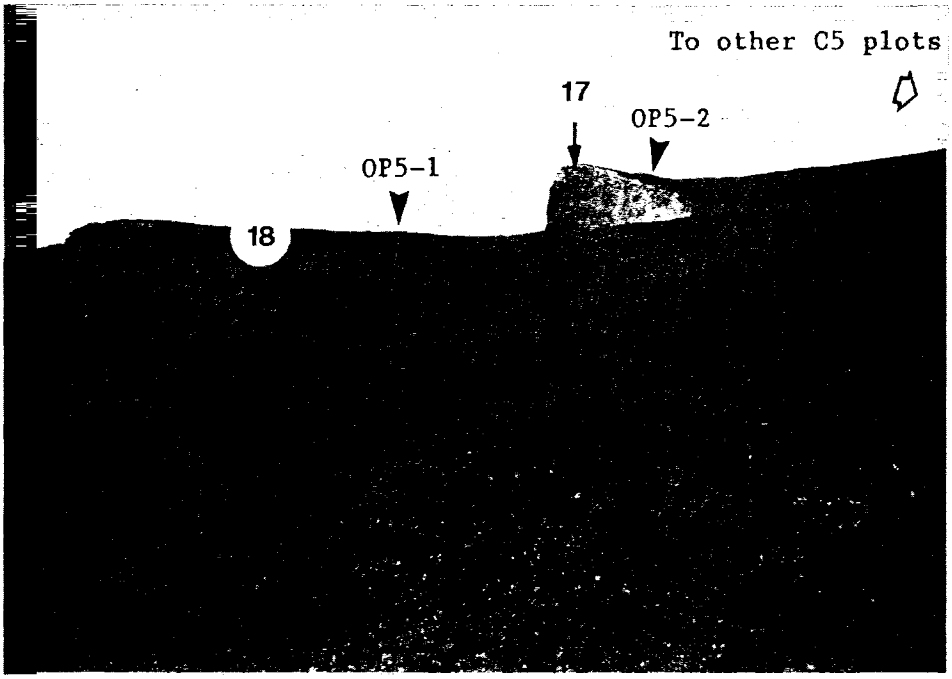


(13) Colony 4. View from sea of OP4-3 and OP4-4.

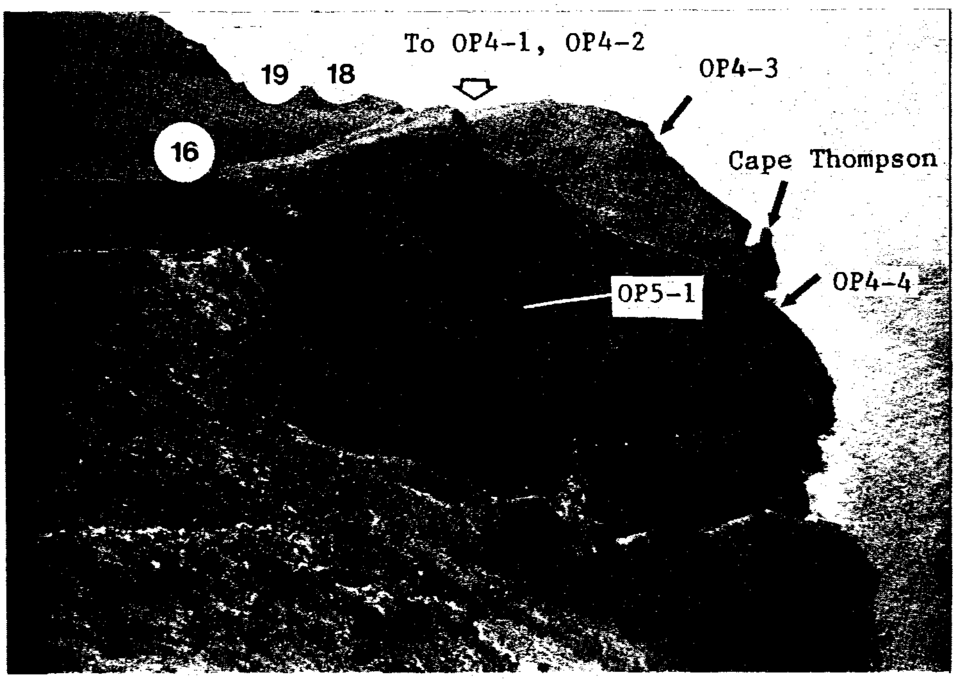
(14) Colony 4. Observer in place at OP4-4.



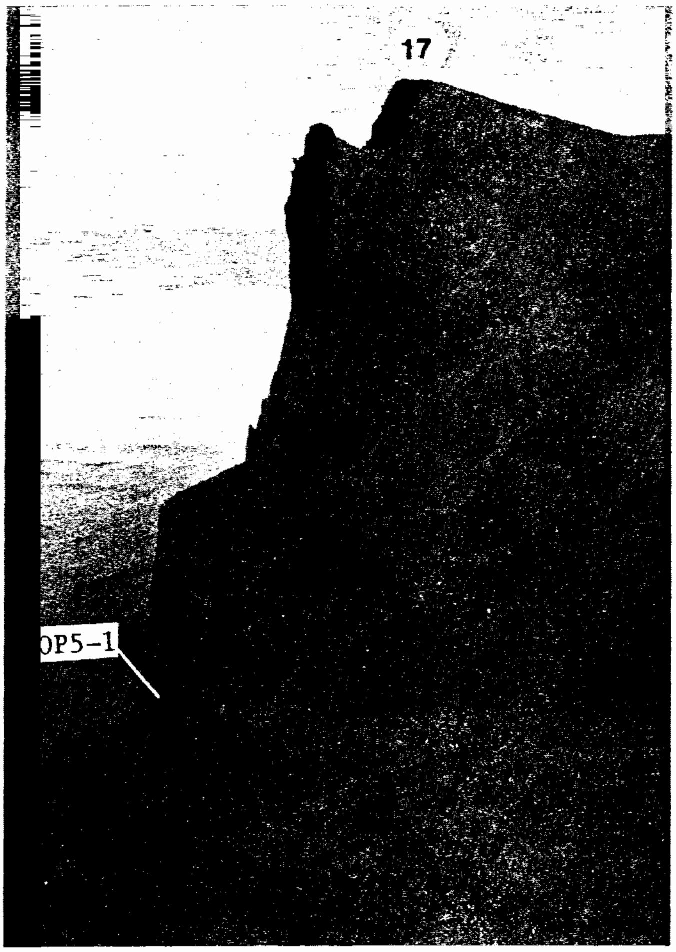
(15) Colony 4. Observer in place at OP4-4. View from over plot 4-4E.



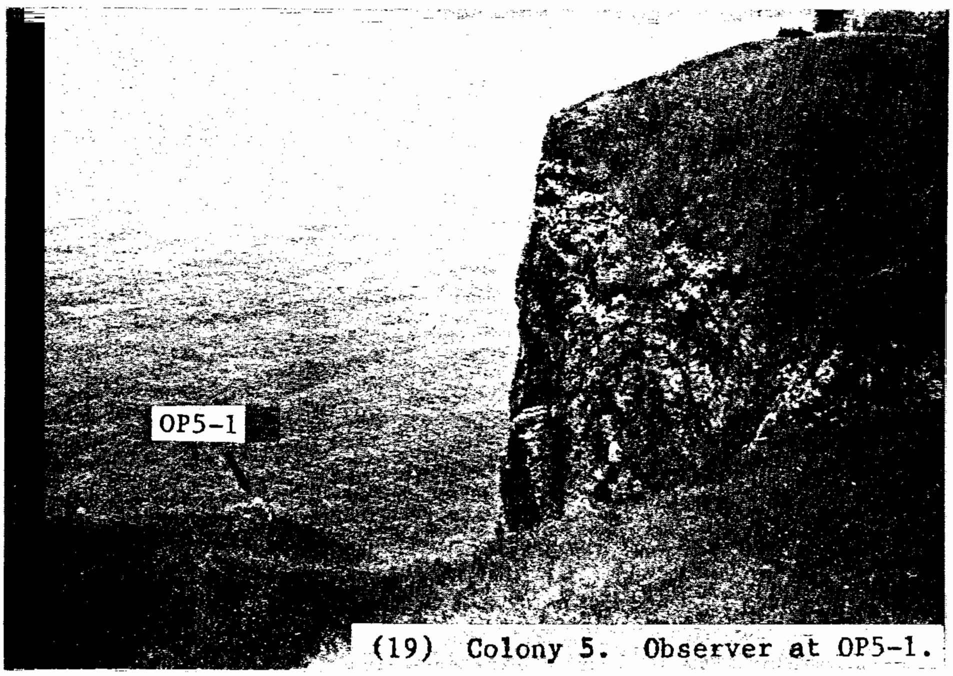
(16) Colony 5. Looking NW toward Colony 5 from Colony 4. OP5-1 is down other side of hill.



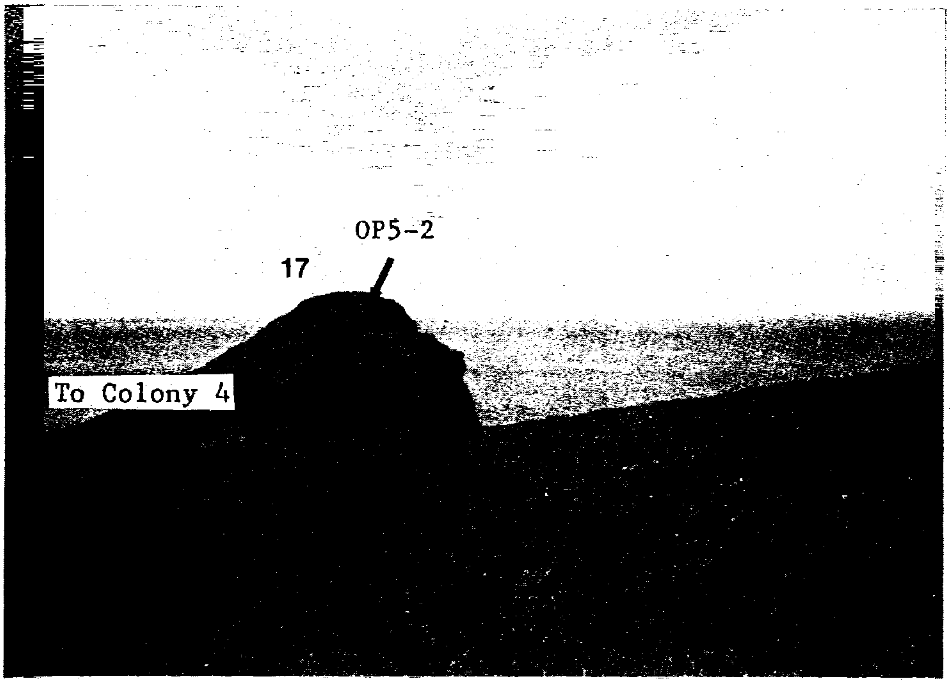
(17) Colony 5. Observer at OP5-1, view from above OP5-2.



(18) Colony 5. Observer in place at OP5-1.

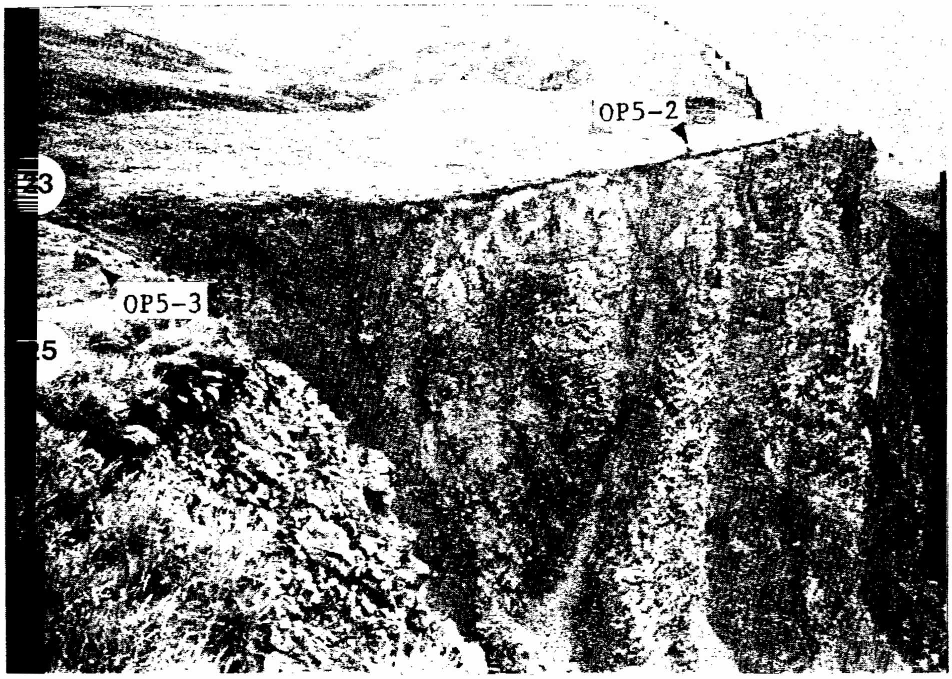


(19) Colony 5. Observer at OP5-1.

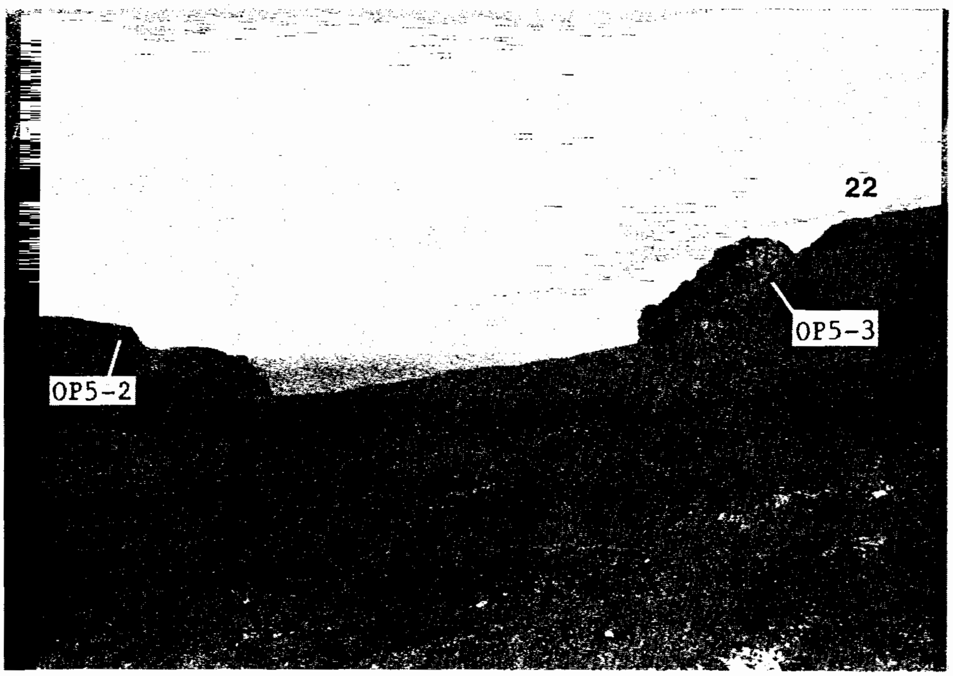


(20) Colony 5. Observer at OP5-2.

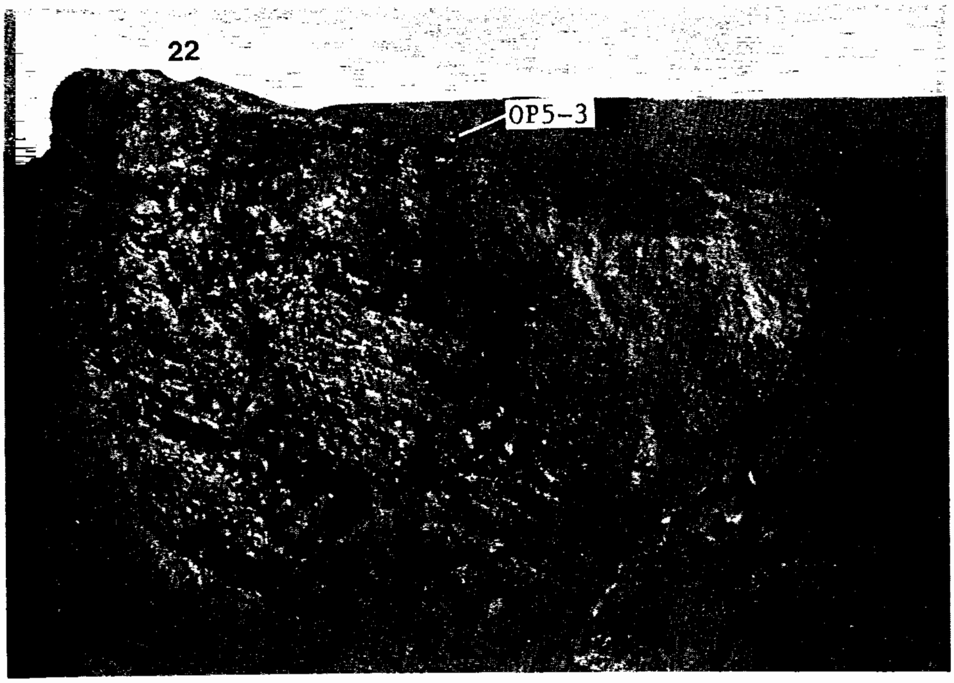
(21) Colony 5. Observer in place at OP5-2, viewed from OP-3.



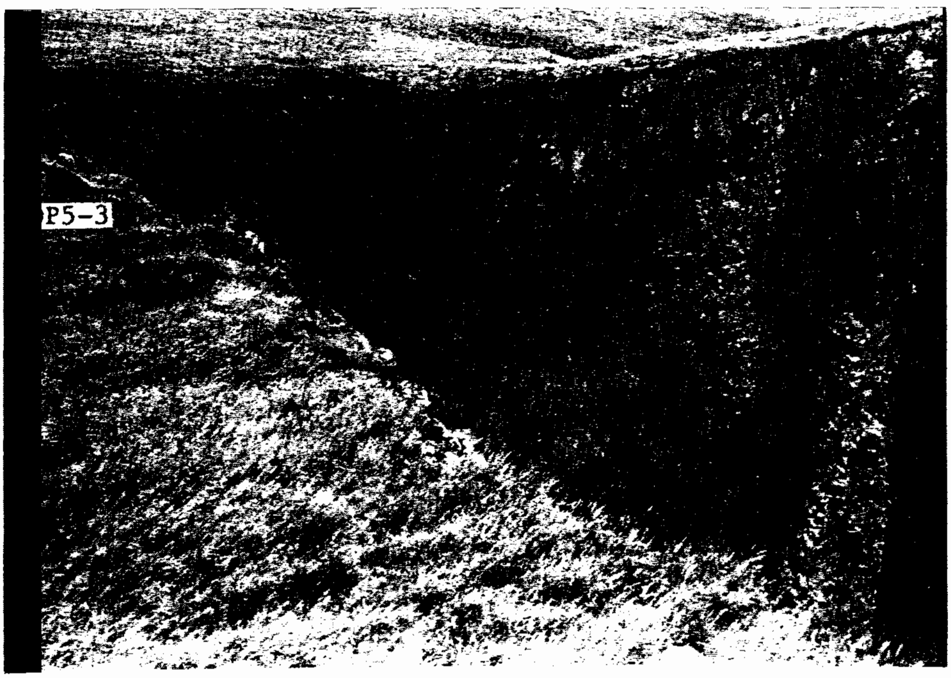
(22) Colony 5. Observers at OP5-2 and OP5-3.



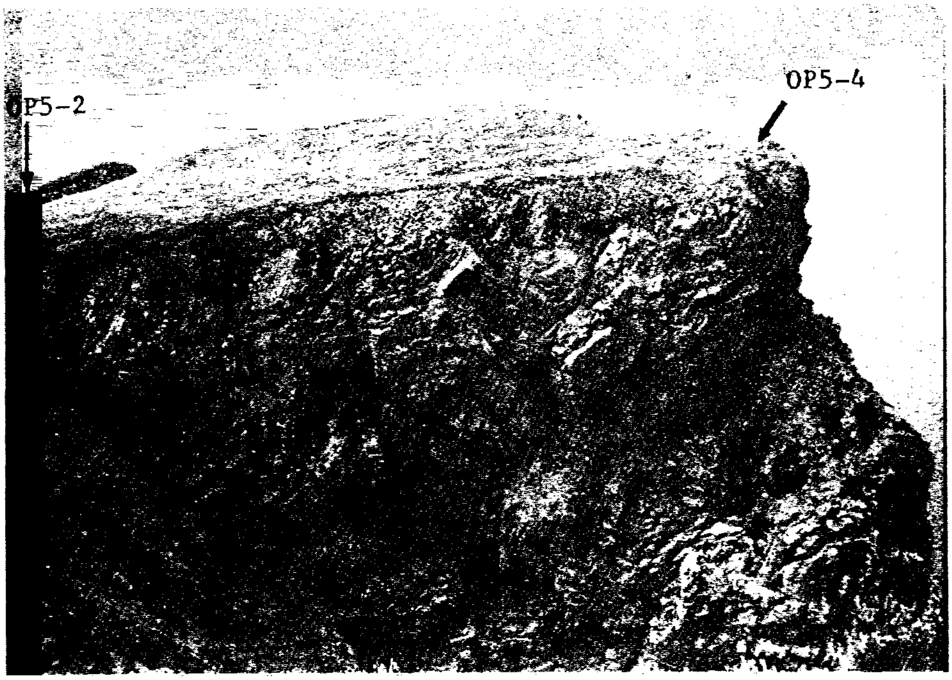
(23) Colony 5. Observers in place at OP5-2 and OP5-3.



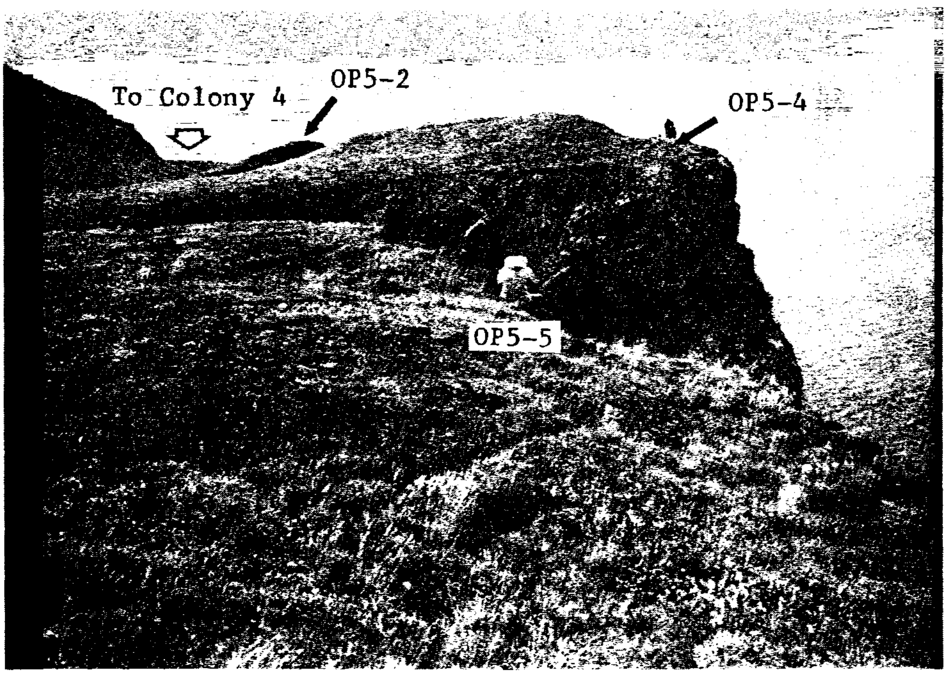
(24) Colony 5. Observer at OP5-3, viewed from OP5-2.



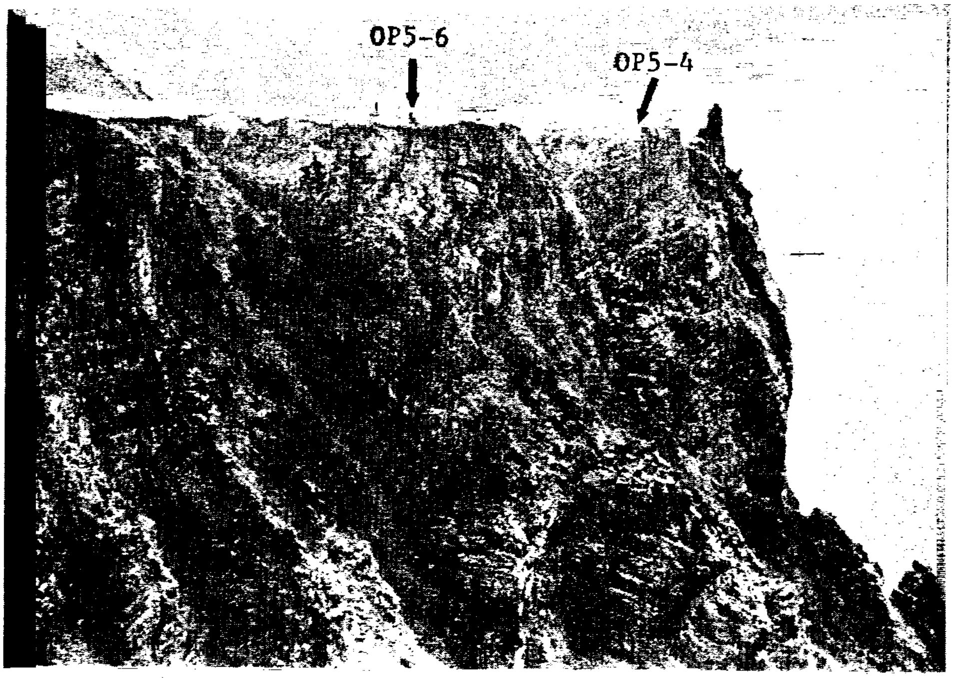
(25) Colony 5. Observer at OP5-3.



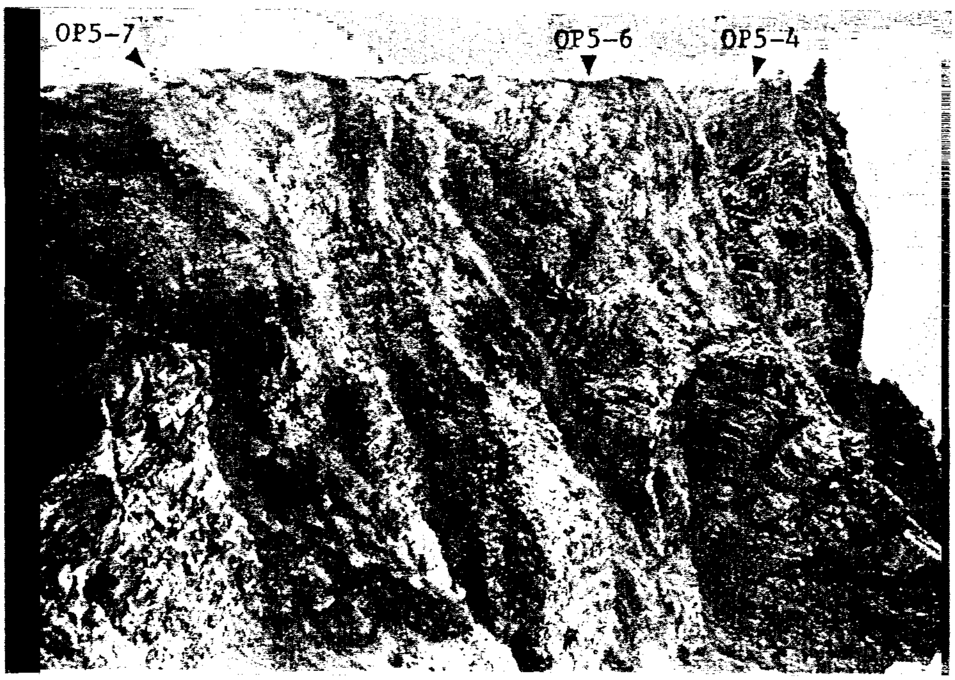
(26) Colony 5. Observer at OP5-4, viewed from OP5-5.



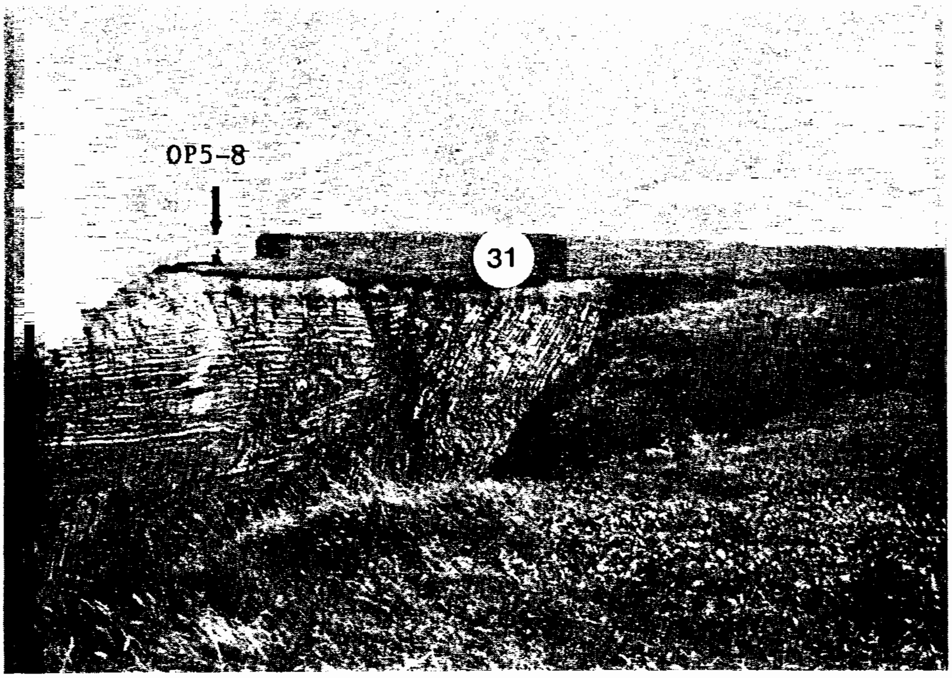
(27) Colony 5. Observer in place at OP5-5; other observer is standing by OP5-4.



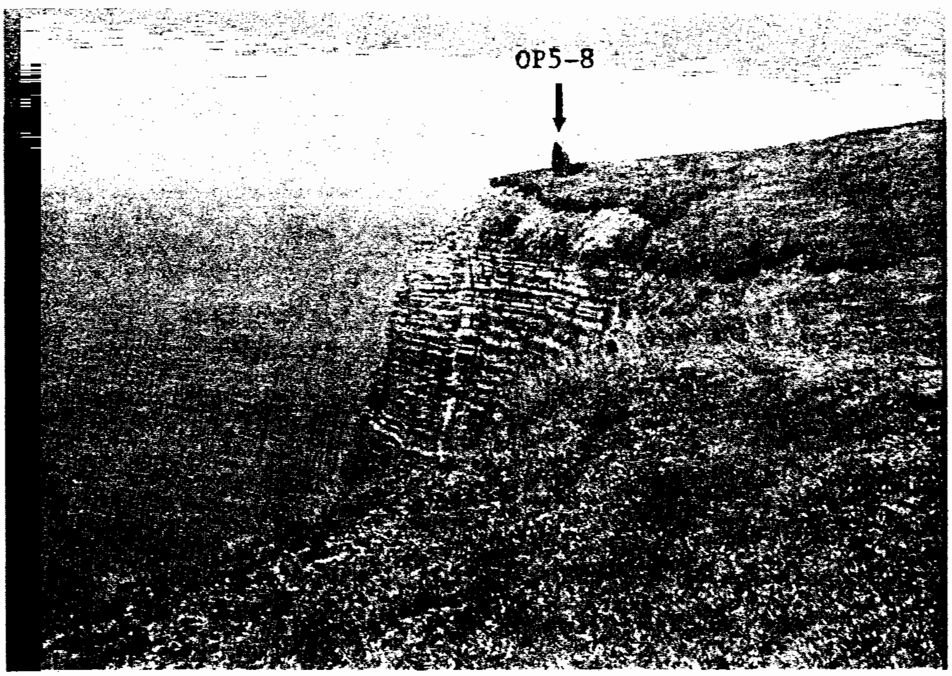
(28) Colony 5. Observer in place at OP5-6, viewed from OP5-8.



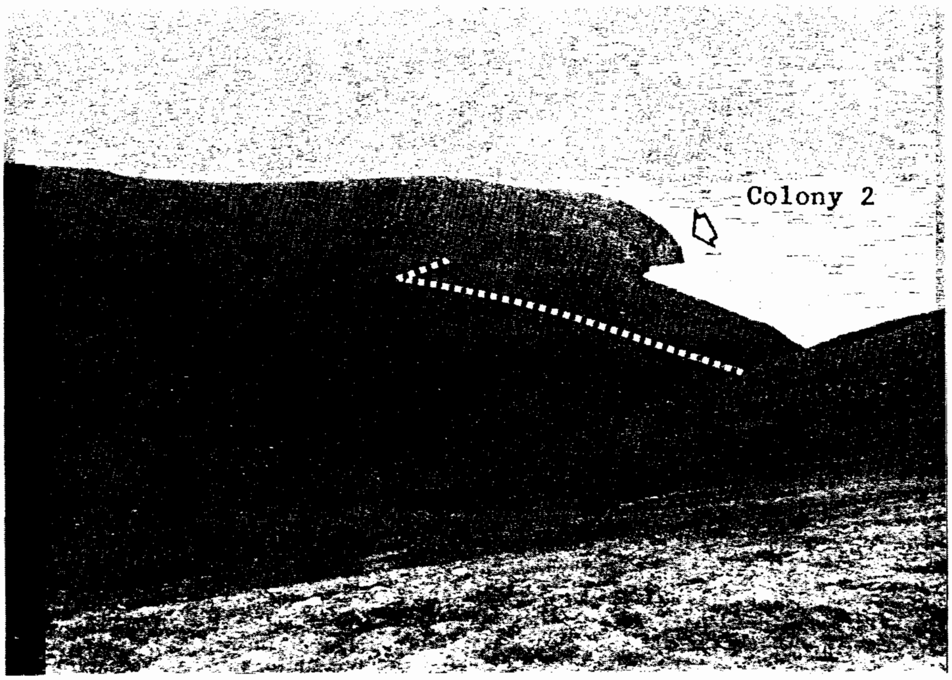
(29) Colony 5. Observer in place at OP5-7, viewed from OP5-8.



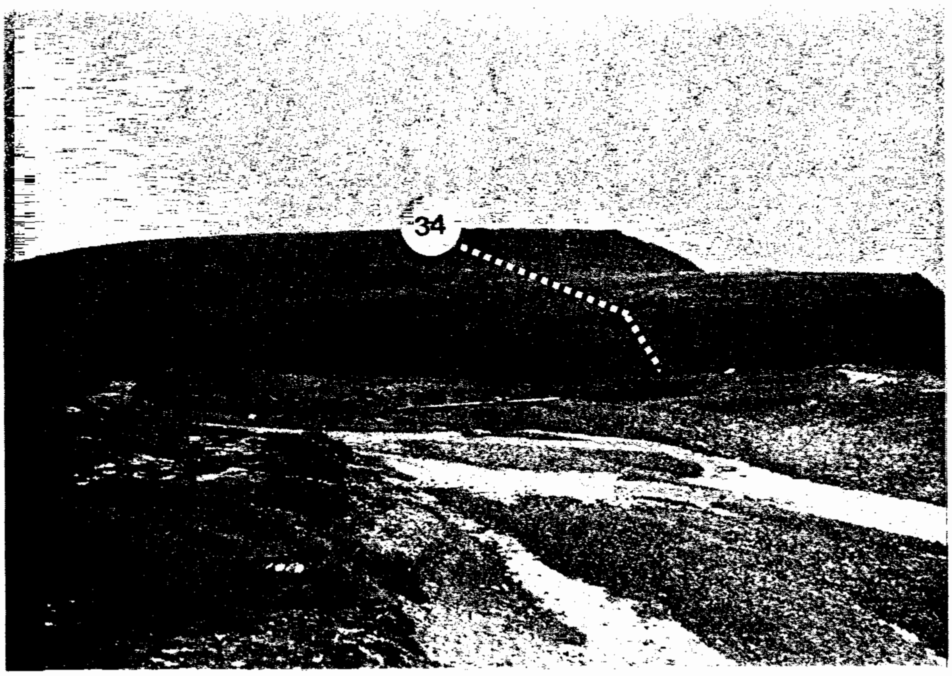
(30) Colony 5. Observer in place at OP5-8.



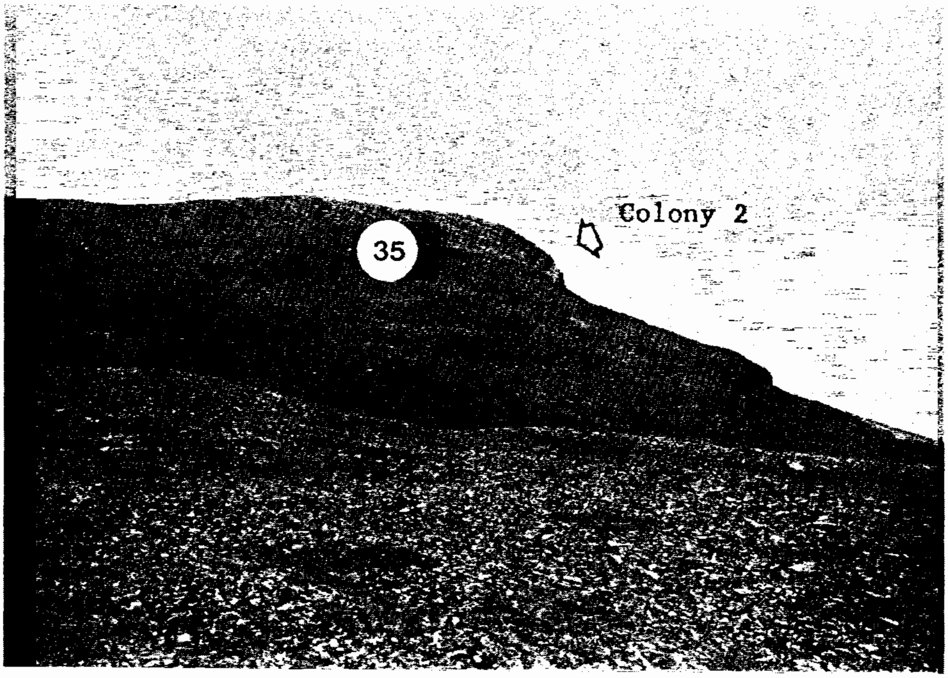
(31) Colony 5. Observer in place at OP5-8.



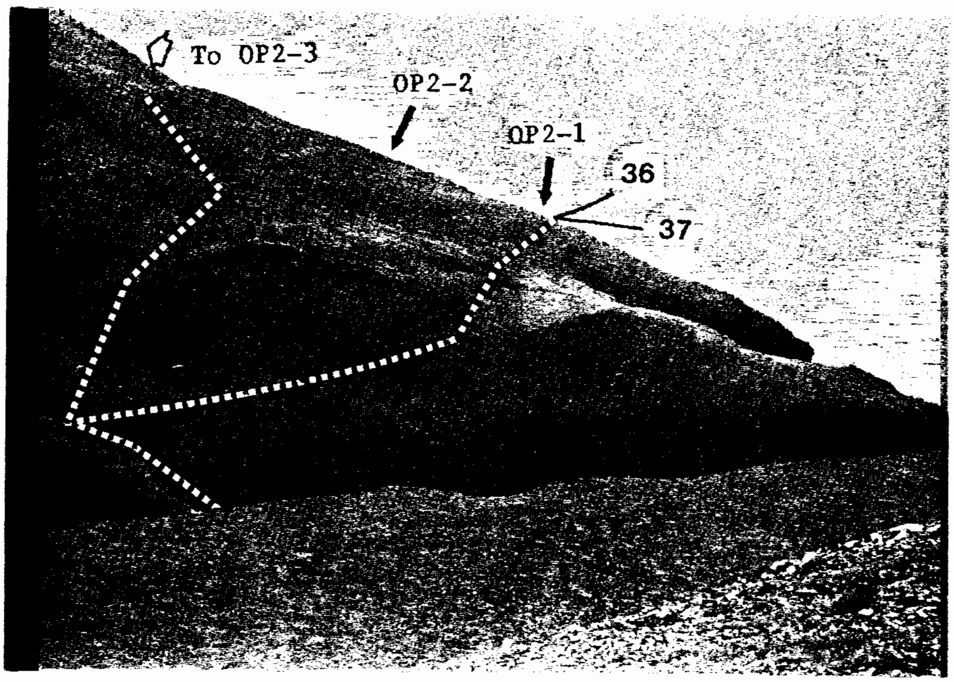
(32) View looking SE from above camp on Agate Rock Hill.



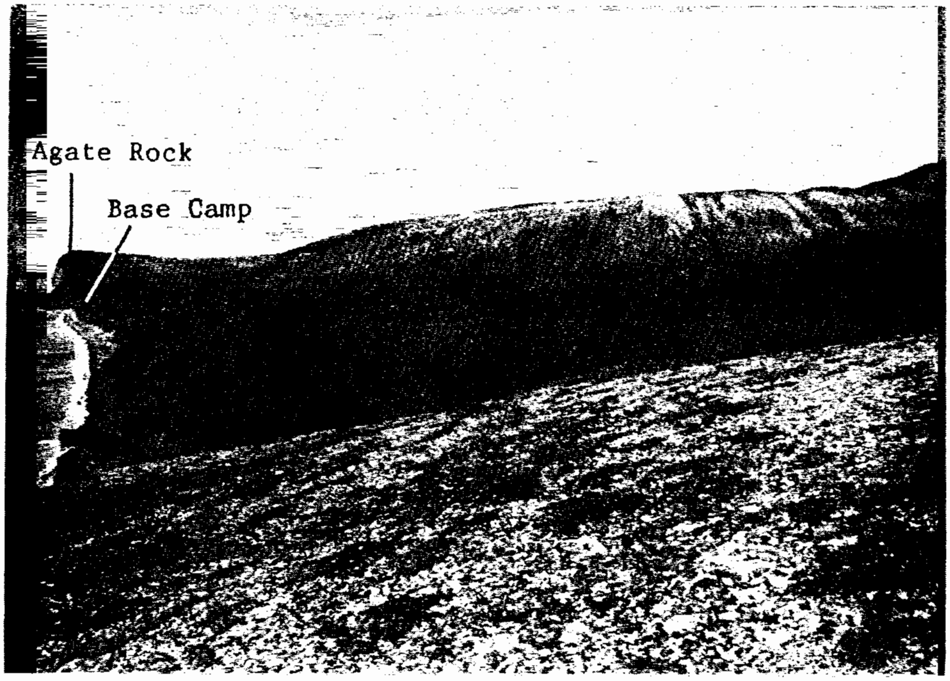
(33) View looking SE from Ikijaktusak Creek at camp.



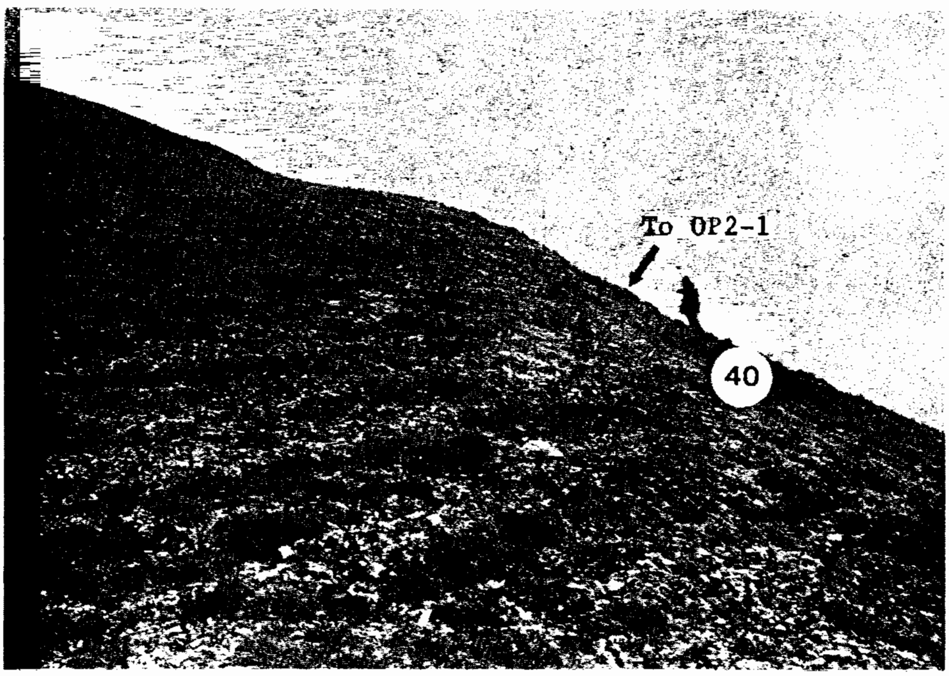
(34) Enroute to Colony 2, looking SE.



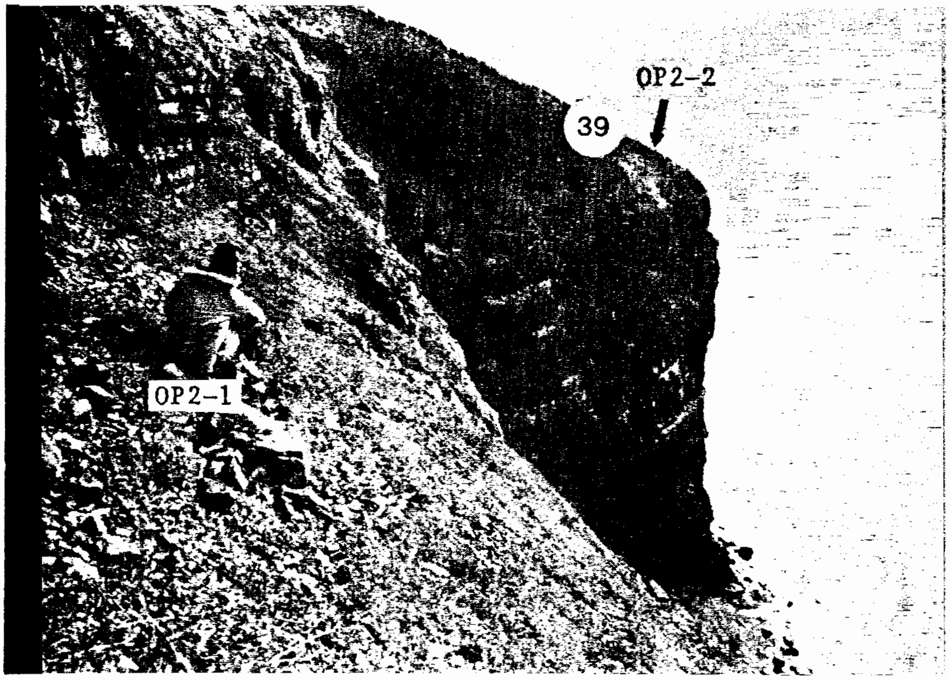
(35) Colony 2. View towards Colony 2, looking SE. Route is down through the canyon and up the creek bed.



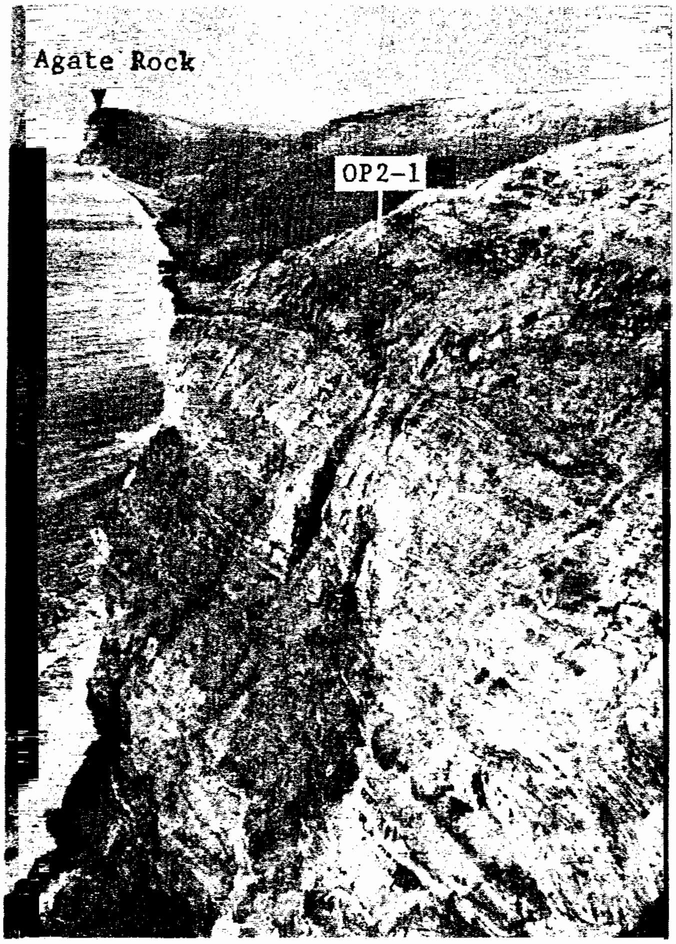
(36) Colony 2. Looking NW from Colony 2 towards camp.



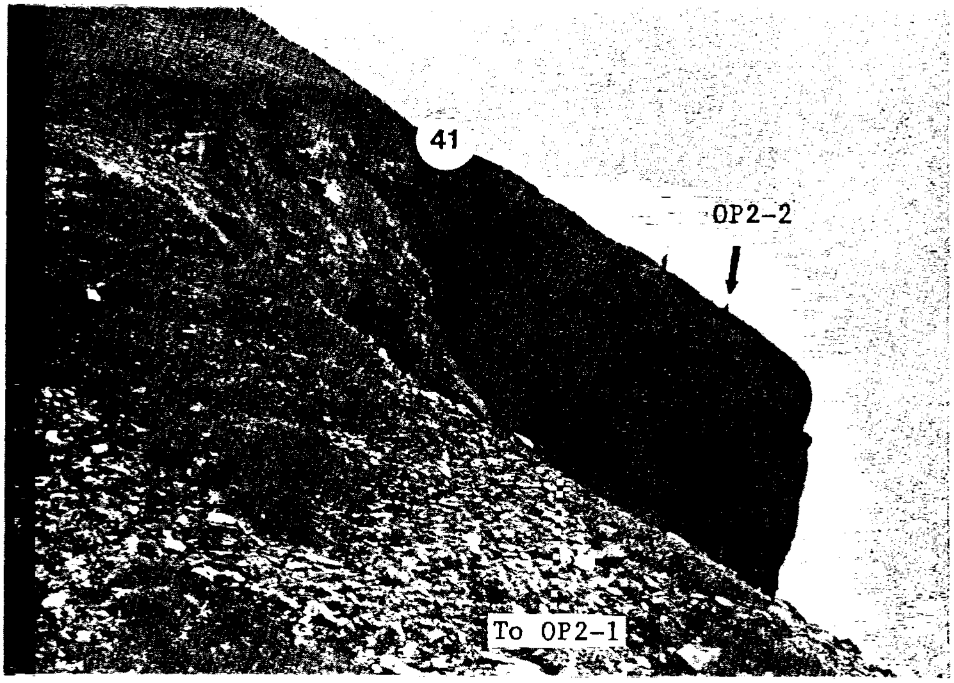
(37) Enroute to OP2-1, which is down below the hill. View looking SE.



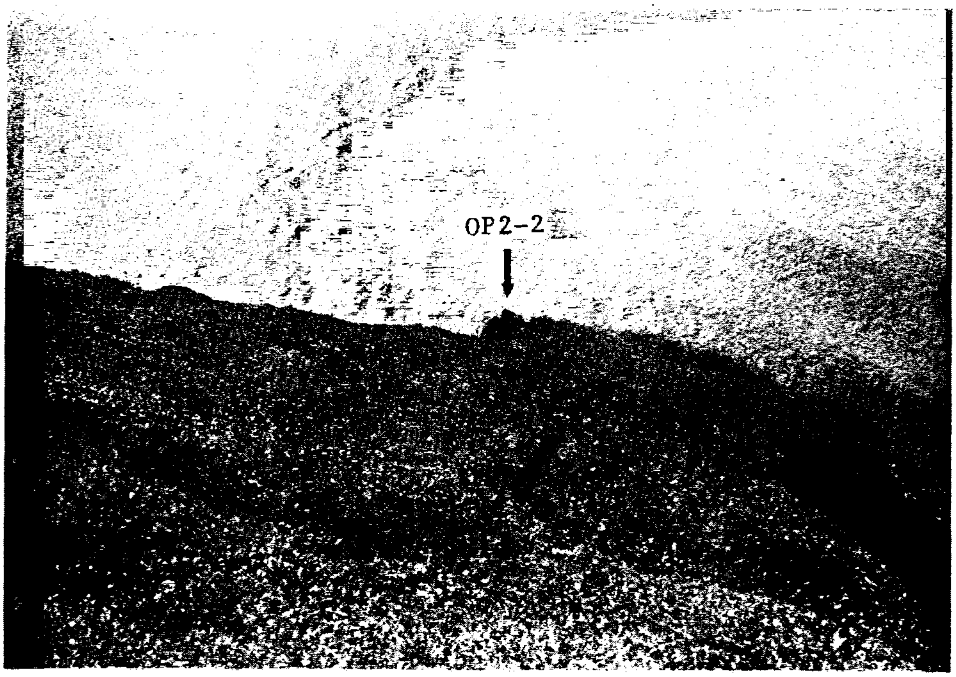
(38) Colony 2. Observer at OP2-1.



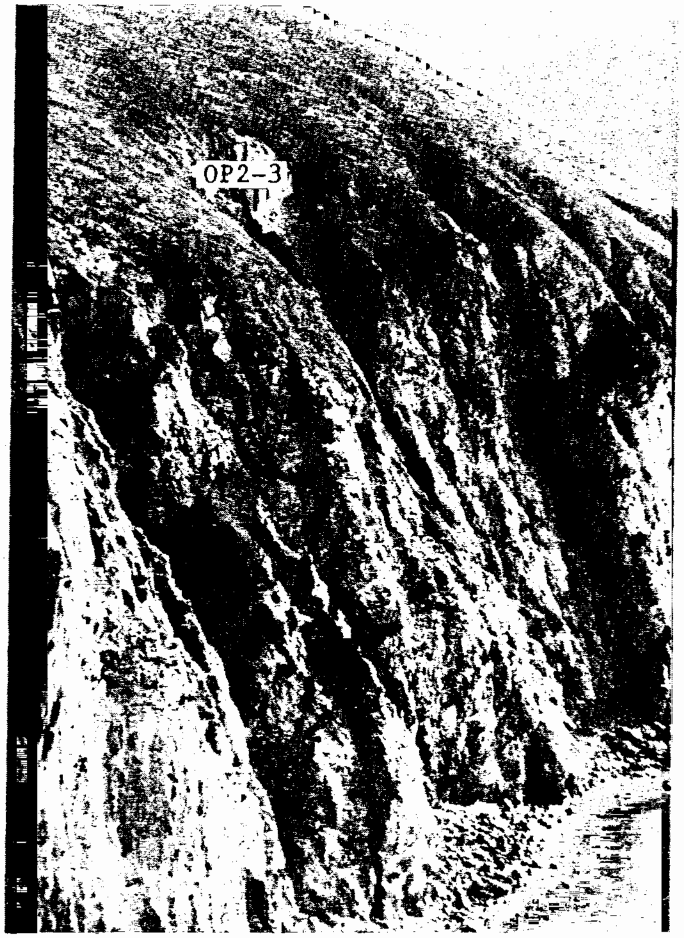
(39) Colony 2. View of OP2-1 from OP2-2.



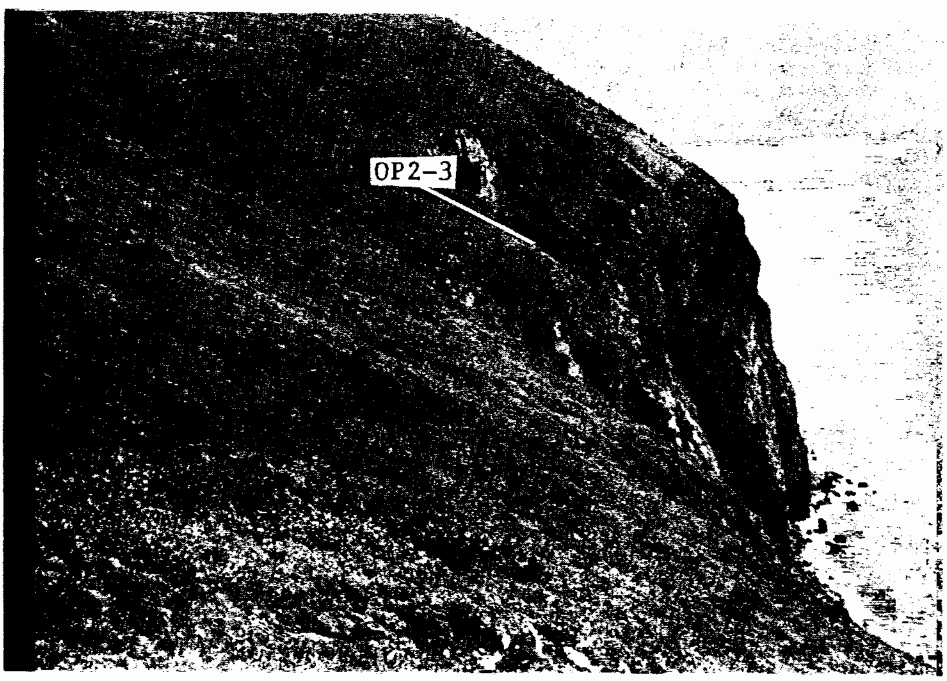
(40) Colony 2. Observer at OP2-2 viewed from just above OP2-1.



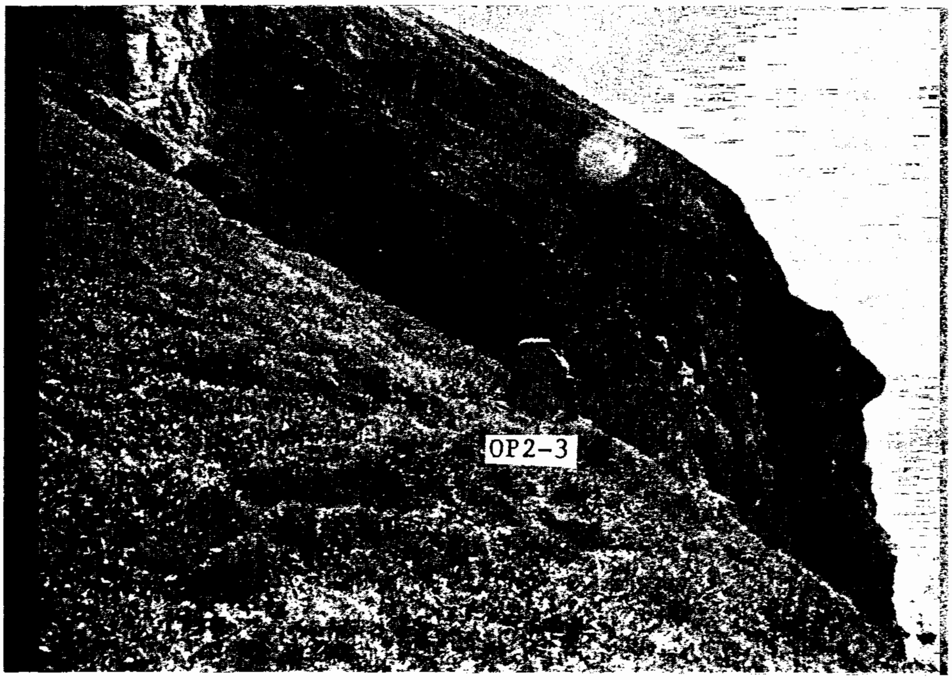
(41) Colony 2. Observer in place at OP2-2.



(42) Colony 2. View of OP2-3 from OP2-2.



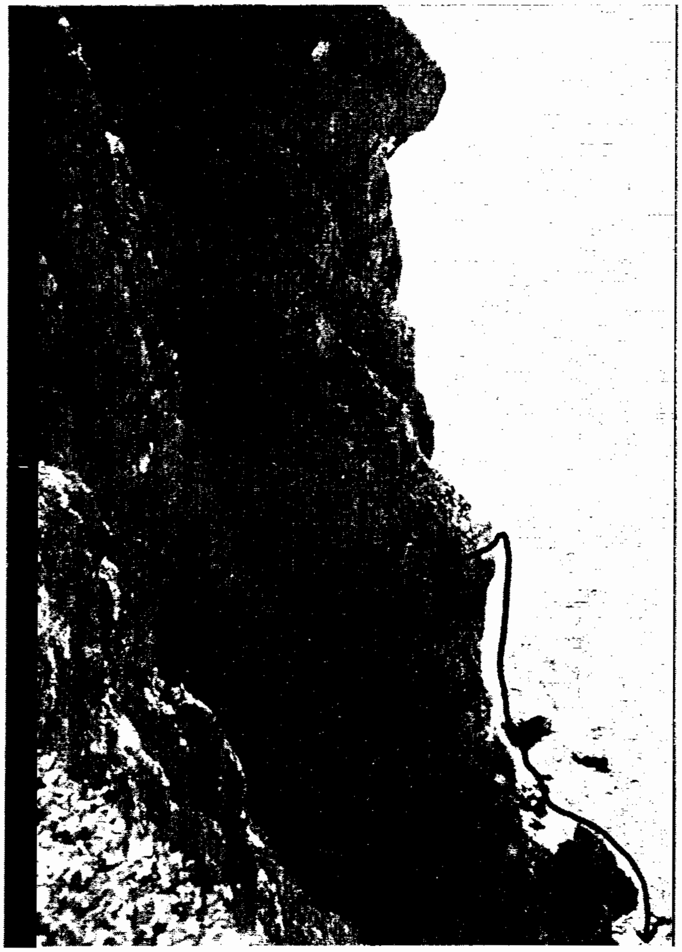
(43) Colony 2. Observer in place at OP2-3.



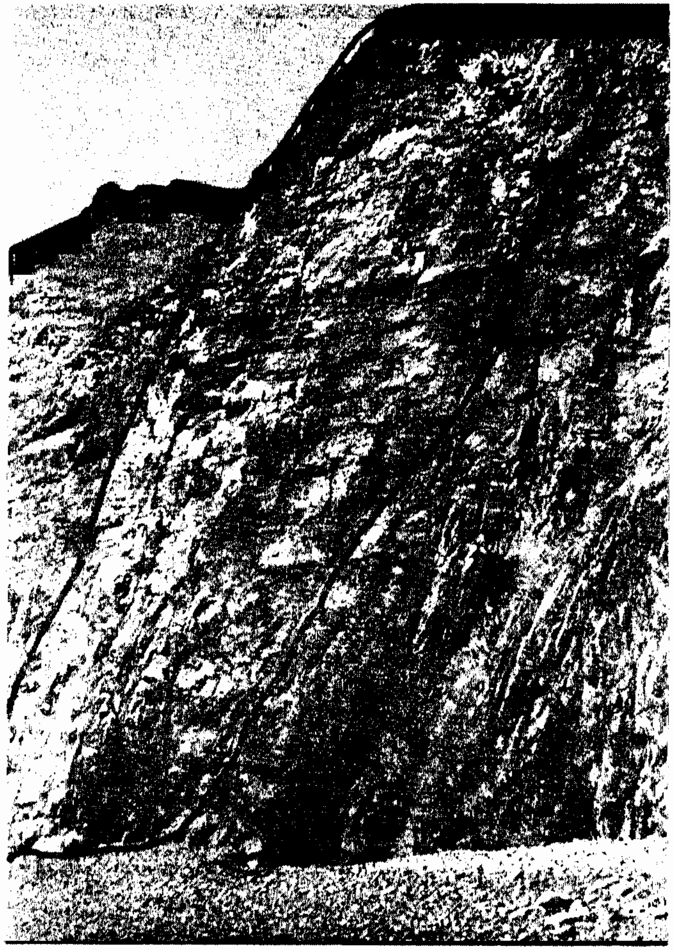
(44) Colony 2. Observer in place at OP2-3.

COLONY 2, PLOT 2-1A

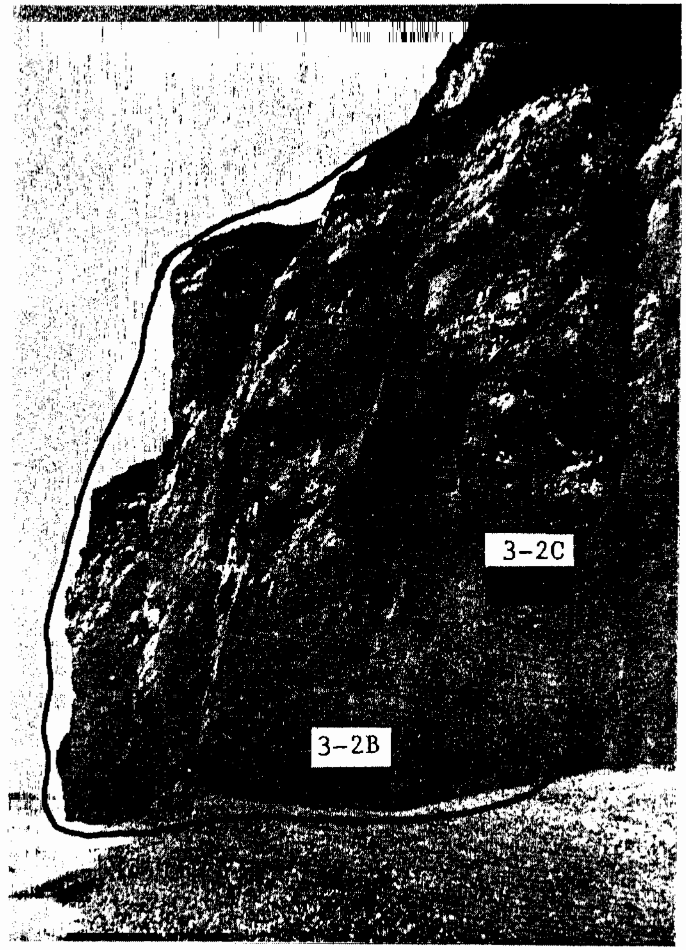
COLONY 2, PLOT 2-2B



COLONY 2, PLOT 2-3C



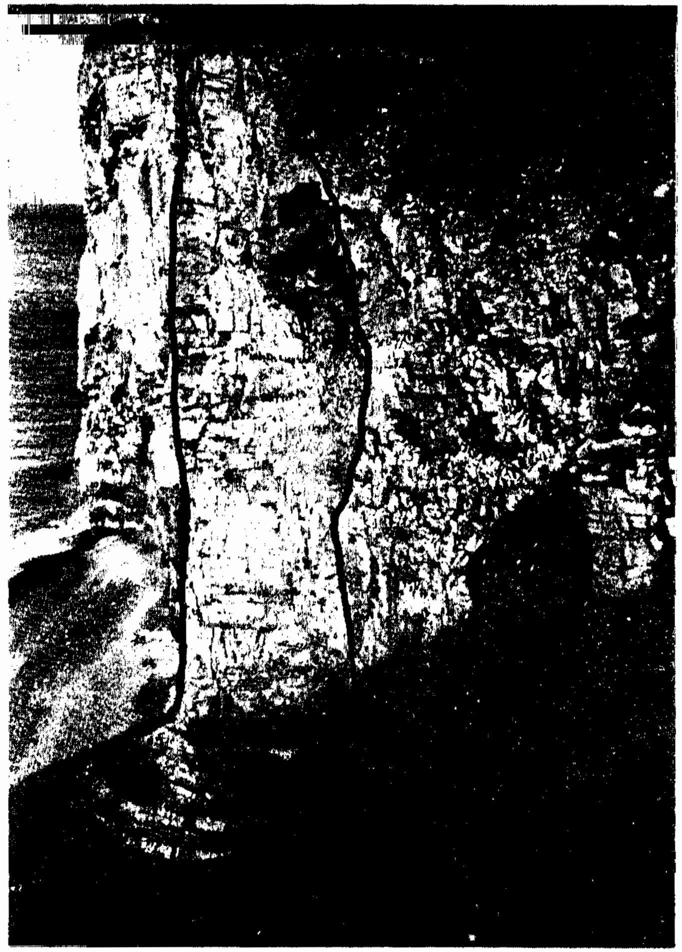
COLONY 3, PLOT 3-1A



COLONY 3, PLOT 3-2B, 3-2C

Colony 3 plots are accessed by walking NW along the beach from base camp.

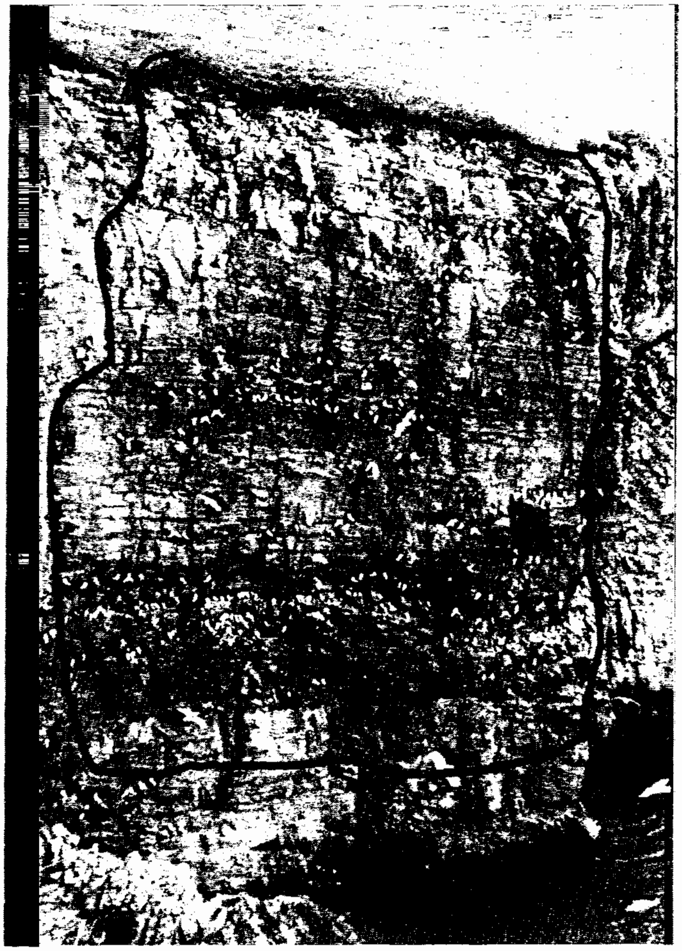
COLONY 4, PLOT 4-1A



COLONY 4, PLOT 4-1B

COLONY 4, PLOT 4-2C

COLONY 4, PLOT 4-3D



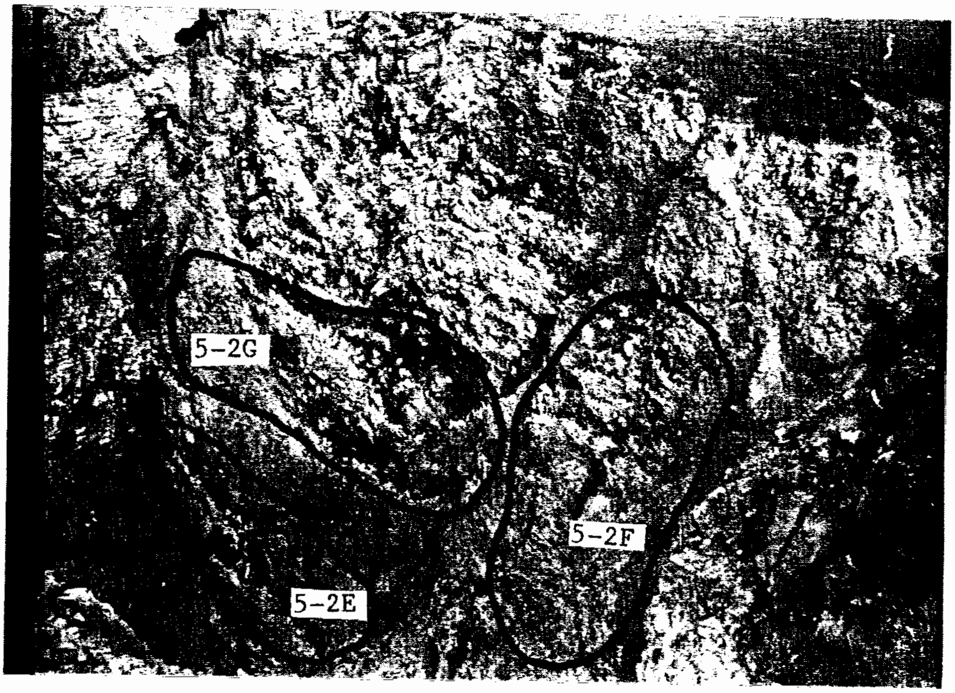
COLONY 4, PLOT 4-4E

COLONY 5, GENERAL VIEW OF PLOTS 5-1A,B,C

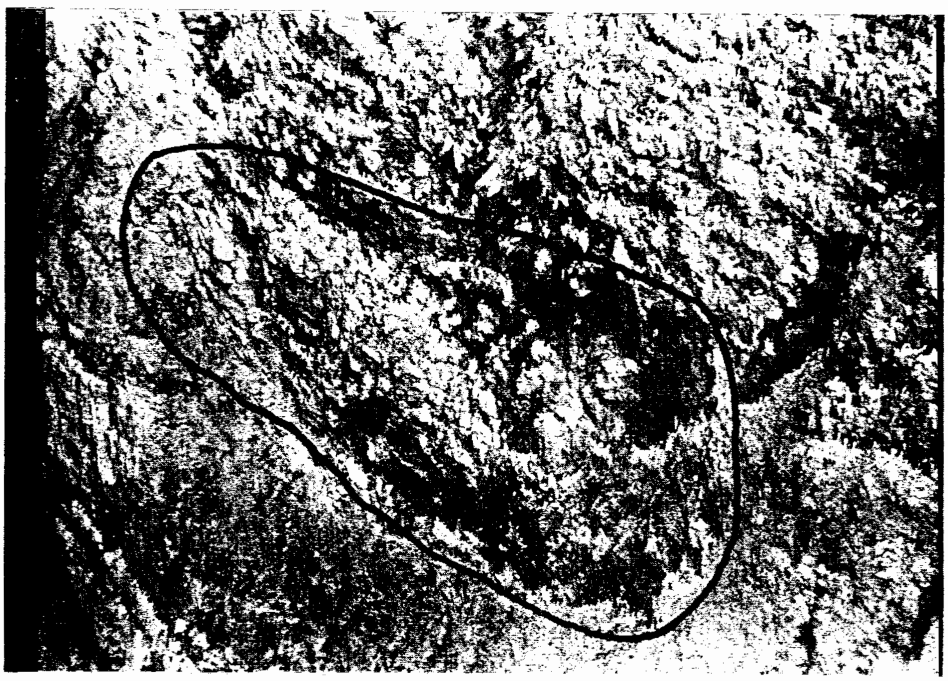
COLONY 5, PLOT 5-1A

COLONY 5, PLOT 5-1C

COLONY 5, PLOT 5-1D

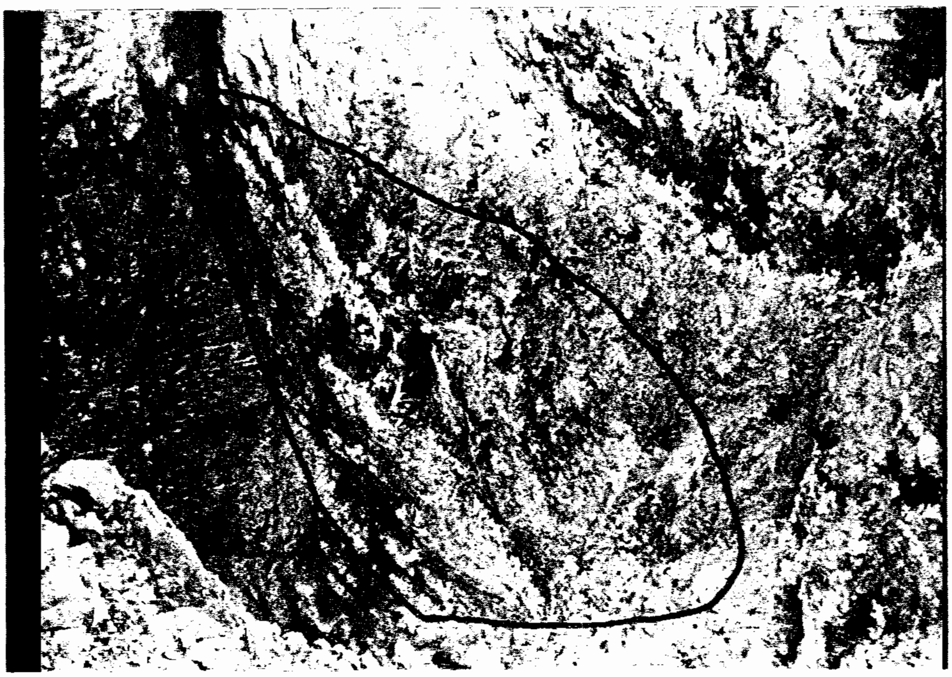


COLONY 5, GENERAL VIEW OF PLOTS 5-2E,F,G

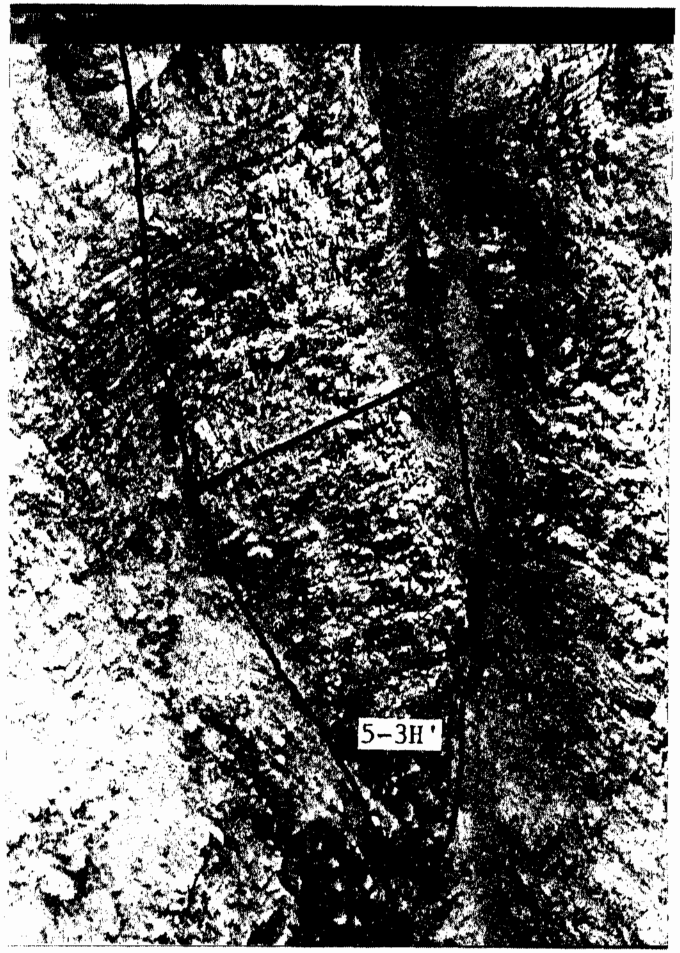


COLONY 5, PLOT 5-2E

COLONY 5, PLOTS 5-2F, 5-2F'



COLONY 5, PLOT 5-2G

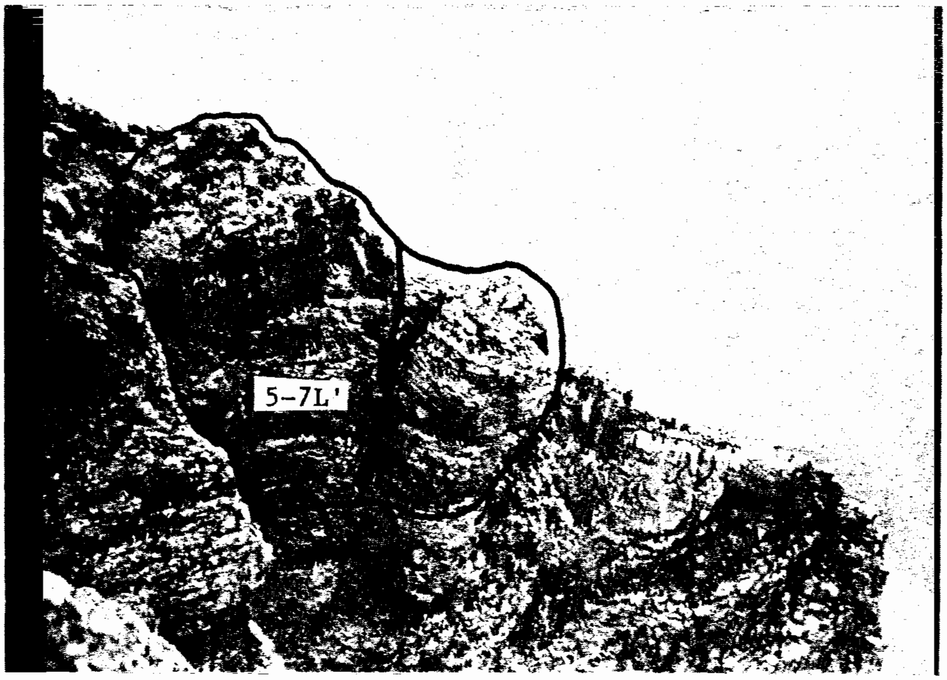


COLONY 5, PLOTS 5-3H, 5-3H'

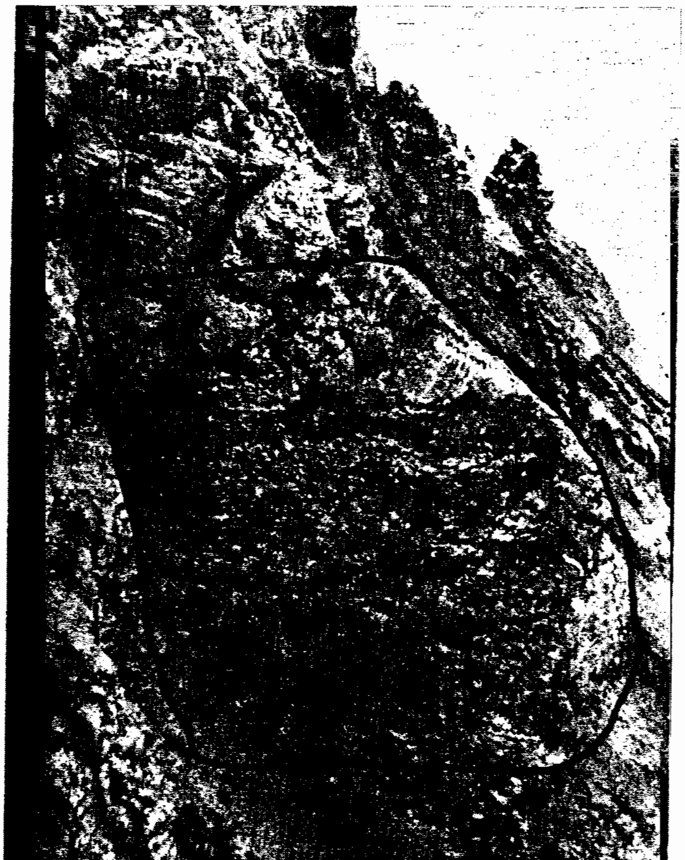

COLONY 5, PLOT 5-4I

COLONY 5, PLOT 5-5J

COLONY 5, PLOTS 5-6K, 5-6K'



COLONY 5, PLOTS 5-7L, 5-7L'



COLONY 5, PLOT 5-8M

COLONY 5, PLOTS 5-8N, 5-8N'

APPENDIX D. CENSUS DATA FOR COMMON AND THICK-BILLED MURRES, 1988 RAW COUNTS

This appendix contains all original murre counts from Cape Thompson land-based plots during the census period in 1988. Observers were:

JB Jane Burger
BF Brian Fadely
SH Scott Hatch
DR Dave Roseneau
DT Daniel Taylor
PR Paul Rodewald

Plot	Date	Time	Total	TBMU	COMU	Observer
2-1A	12 Jul	1323	335	170	165	BF/SH/DT
	16 Jul	1551	275	100	175	BF/JB/DT/PR
	18 Jul	1340	356	227	129	DT/PR
	26 Jul	1730	408	188	220	DT
	7 Aug	1721	347	80	267	BF
	10 Aug	1200	386	136	250	DT
2-2B	12 Jul	1424	193	21	172	BF/DT
	16 Jul	1630	275	23	252	BF/JB/DT/PR
	18 Jul	1415	327	65	262	PR
	26 Jul	1722	338	25	313	BF
	7 Aug	1720	342	41	301	JB
	10 Aug	1300	335	43	292	DT
2-3C	12 Jul	1540	291	245	46	BF/DT
	16 Jul	1702	248	220	28	BF/JB/DT/PR
	18 Jul	1430	292	258	34	DT
	26 Jul	1725	290	248	42	PR
	7 Aug	1730	239	201	38	PR
	10 Aug	1330	264	217	47	DT
3-1A	10 Jul	1548	105	103	2	JB/BF
	13 Jul	1530	97	88	9	JB
	14 Jul	1830	154	150	4	JB/BF
	15 Jul	1241	117	112	5	DT/JB
	17 Jul	2020	172	161	11	PR
	18 Jul	1548	142	136	6	JB/BF

Plot	Date	Time	Total	TBMU	COMU	Observer
3-1A	19 Jul	1749	133	121	12	BF
	20 Jul	1910	103	94	9	JB/PR
	21 Jul	2038	152	144	8	JB/PR
	22 Jul	1130	89	81	8	DT
	23 Jul	1553	82	71	11	BF
	25 Jul	1915	132	129	3	JB
	26 Jul	1615	160	149	11	DT
	27 Jul	2334	193	-	-	BF
	28 Jul	1900	154	140	14	PR
	30 Jul	2040	148	142	6	JB
	1 Aug	1905	202	193	9	PR
	2 Aug	1945	185	181	4	JB
	3 Aug	1600	84	73	11	DT
	5 Aug	1145	174	160	14	PR
	7 Aug	1600	96	83	13	DT
	8 Aug	1645	203	192	11	BF
	9 Aug	1730	153	141	12	PR
	10 Aug	0945	121	112	9	DT
	11 Aug	-	148	137	11	DT
	12 Aug	1831	144	143	1	BF
	13 Aug	1730	113	99	14	PR
	15 Aug	2010	172	168	4	DT
3-2B	10 Jul	1600	486	424	62	JB
	13 Jul	1600	424	356	68	JB
	14 Jul	1844	510	466	44	JB/BF
	15 Jul	1300	348	320	28	DT/JB
	17 Jul	2040	582	-	-	PR
	18 Jul	1602	453	391	62	JB/BF
	19 Jul	1809	426	379	47	BF
	20 Jul	1922	412	358	54	JB/PR
	21 Jul	2045	152	144	8	JB/PR
	22 Jul	1200	417	367	50	DT
	23 Jul	1610	402	351	51	BF
	25 Jul	1930	531	491	40	JB
	28 Jul	1915	628	554	74	DT
	1 Aug	1920	645	584	61	PR
	2 Aug	2000	622	-	-	JB
	3 Aug	1615	342	-	-	DT
	5 Aug	1200	602	541	61	PR
	7 Aug	1615	564	483	81	DT
	8 Aug	1649	569	493	76	BF
	9 Aug	1740	453	400	53	PR
	10 Aug	1015	517	470	47	DT
	11 Aug	-	486	-	-	DT
	12 Aug	1841	425	349	76	BF
	13 Aug	1800	394	340	54	PR

Plot	Date	Time	Total	TBMU	COMU	Observer
3-2B	15 Aug	2030	538	-	-	DT
3-2C	10 Jul	1615	25	25	0	JB
	13 Jul	1615	35	33	2	JB
	14 Jul	1920	69	69	0	JB/BF
	15 Jul	1315	42	39	3	DT/JB
	17 Jul	2115	63	63	0	PR
	18 Jul	1617	55	55	0	JB/BF
	19 Jul	1826	54	54	0	BF
	20 Jul	1935	49	49	0	JB/PR
	21 Jul	2100	68	68	0	JB/PR
	22 Jul	1220	46	46	0	DT
	23 Jul	1641	50	50	0	BF
	25 Jul	1930	56	56	0	JB
	28 Jul	1945	62	62	0	PR
	1 Aug	1950	65	65	0	PR
	2 Aug	2015	48	-	-	JB
	3 Aug	1630	39	39	0	DT
	5 Aug	1215	48	48	0	PR
	7 Aug	1630	45	45	0	DT
	8 Aug	1730	65	65	0	BF
	9 Aug	1755	44	44	0	PR
	10 Aug	1030	46	46	0	DT
	11 Aug	-	63	-	-	DT
	12 Aug	1905	46	45	1	BF
	13 Aug	1830	31	31	0	PR
	15 Aug	2045	74	74	0	DT
4-1A	8 Jul	1815	218	159	59	JB/PR
	11 Jul	1645	205	149	56	PR/DT/DR
	17 Jul	1545	315	200	115	PR
	20 Jul	1450	272	189	83	DT
	25 Jul	1635	316	210	106	PR
	27 Jul	1745	328	212	116	PR
	1 Aug	1638	341	237	104	BF
	4 Aug	2118	266	190	76	BF
	5 Aug	1825	308	191	117	PR
	8 Aug	1730	243	187	56	PR
	11 Aug	1455	304	196	108	PR
	15 Aug	1800	382	272	110	PR
4-1B	8 Jul	1800	167	117	50	JB/PR
	11 Jul	1630	181	120	61	PR/DT/DR
	17 Jul	1545	223	135	88	DT
	20 Jul	1450	193	117	76	PR
	25 Jul	1615	194	118	76	PR
	27 Jul	1730	220	130	90	PR
	1 Aug	1651	240	160	80	BF

Plot	Date	Time	Total	TBMU	COMU	Observer
4-1B	4 Aug	2110	227	164	63	BF
	5 Aug	1840	245	142	103	PR
	8 Aug	1730	346	241	105	PR
	11 Aug	1510	236	136	100	PR
	15 Aug	1810	264	171	93	PR
4-2C	8 Jul	1545	238	104	134	JB/PR
	11 Jul	1500	259	168	91	PR/DT/DR
	17 Jul	1505	328	170	158	PR
	20 Jul	1510	306	176	130	PR
	25 Jul	1600	376	214	162	DT
	27 Jul	-	467	284	183	DT
	1 Aug	-	407	230	177	DT
	4 Aug	2133	435	113	322	BF
	5 Aug	1900	357	182	175	DT
	8 Aug	1720	471	254	217	DT
	11 Aug	-	396	232	164	DT
	15 Aug	1756	534	397	137	BF
4-3D	8 Jul	1427	117	85	32	JB/PR
	11 Jul	1730	65	49	16	PR/DT/DR
	17 Jul	1450	111	82	29	PR/DT/DR
	20 Jul	-	-	-	-	
	25 Jul	1600	132	99	33	DT
	27 Jul	-	181	132	49	DT
	1 Aug	-	174	122	52	DT
	4 Aug	2153	152	85	67	BF
	5 Aug	-	166	103	63	DT
	8 Aug	1640	156	108	48	DT
	11 Aug	-	148	114	34	DT
	15 Aug	1830	201	156	45	BF
4-4E	8 Jul	-	-	-	-	
	11 Jul	1300	131	20	111	PR/DT/DR
	17 Jul	1410	180	22	158	PR/DT
	20 Jul	2211	218	64	154	BF
	25 Jul	1632	274	56	218	BF/JB
	27 Jul	1800	312	52	260	JB
	1 Aug	1725	307	35	272	BF
	4 Aug	2212	288	17	271	BF
	5 Aug	2012	318	31	287	BF
	8 Aug	1700	347	56	291	PR
	11 Aug	1625	292	26	266	BF
	15 Aug	2201	306	47	259	BF
5-1A	11 Jul	1959	29	28	1	BF/SH
	17 Jul	1352	29	28	1	JB
	20 Jul	1410	26	24	2	JB
	25 Jul	1510	30	29	1	JB

Plot	Date	Time	Total	TBMU	COMU	Observer
5-1A	27 Jul	1634	35	30	5	JB
	1 Aug	1510	33	33	0	JB
	4 Aug	2030	26	26	0	JB
	5 Aug	1800	29	28	1	JB
	8 Aug	1535	29	28	1	PR
	11 Aug	1400	39	38	1	JB
	15 Aug	1700	52	49	3	JB
5-1B	11 Jul	2007	340	231	109	BF/SH
	17 Jul	1356	415	260	155	JB
	20 Jul	1412	438	234	234	JB
	25 Jul	1510	458	184	274	JB
	27 Jul	1634	465	193	272	JB
	1 Aug	1510	429	199	230	JB
	4 Aug	2030	422	175	247	JB
	5 Aug	1800	422	198	224	JB
	8 Aug	1555	443	221	222	PR
	11 Aug	1415	414	192	222	JB
	15 Aug	1700	484	263	221	JB
5-1C	11 Jul	2027	25	24	1	BF/SH
	17 Jul	1400	33	32	1	JB
	20 Jul	1437	27	26	1	JB
	25 Jul	1510	19	19	0	JB
	27 Jul	1701	23	22	1	JB
	1 Aug	1525	22	22	0	JB
	4 Aug	2040	23	21	2	JB
	5 Aug	1830	22	22	0	JB
	8 Aug	1615	24	21	3	PR
	11 Aug	1420	23	22	1	JB
	15 Aug	1700	31	31	0	JB
5-1D	11 Jul	2027	171	168	3	BF/SH
	17 Jul	1402	190	185	5	JB
	20 Jul	1440	170	164	6	JB
	25 Jul	1510	164	155	9	JB
	27 Jul	1705	222	214	8	JB
	1 Aug	1530	223	216	7	JB
	4 Aug	2045	165	162	3	JB
	5 Aug	1835	181	172	9	PR
	8 Aug	1625	206	198	8	JB
	11 Aug	1425	170	164	6	JB
	15 Aug	1700	228	219	9	JB
5-2E	11 Jul	1416	269	244	25	BF/SH
	17 Jul	1645	353	314	39	DT
	20 Jul	1340	300	294	6	PR
	25 Jul	1630	310	275	35	PR
	27 Jul	1615	344	304	40	PR
	1 Aug	1420	358	323	35	PR

Plot	Date	Time	Total	TBMU	COMU	Observer
5-2E	4 Aug	1800	292	258	34	PR
	5 Aug	1515	327	295	32	PR
	8 Aug	1455	344	300	44	PR
	11 Aug	1225	328	292	36	PR
	15 Aug	1515	416	377	39	PR
5-2F	11 Jul	1334	308	308	0	BF/SH
	17 Jul	1645	430	424	6	PR
	20 Jul	1320	430	429	1	PR
	25 Jul	1450	393	392	1	PR
	27 Jul	1630	427	426	1	PR
	1 Aug	1440	450	449	1	PR
	4 Aug	1815	316	315	1	PR
	5 Aug	1530	374	374	0	PR
	8 Aug	1510	426	425	1	PR
	11 Aug	1230	393	392	1	PR
	15 Aug	1530	503	502	1	PR
5-2G	11 Jul	1454	225	219	6	BF/SH
	17 Jul	1700	317	306	11	PR/DT
	20 Jul	-	-	-	-	
	25 Jul	1510	272	259	13	PR
	27 Jul	1650	289	279	10	PR
	1 Aug	1455	310	300	10	PR
	4 Aug	1825	256	243	13	PR
	5 Aug	1540	249	236	13	PR
	8 Aug	1520	303	292	11	PR
	11 Aug	1240	283	273	10	PR
	15 Aug	1545	359	350	9	PR
5-3H	11 Jul	1534	178	178	0	BF/SH
	17 Jul	1740	259	259	0	PR
	20 Jul	1330	240	240	0	JB
	25 Jul	1500	227	227	0	DT
	27 Jul	-	283	283	0	DT
	1 Aug	-	265	263	3	DT
	4 Aug	-	235	235	0	DT
	5 Aug	1700	231	231	0	DT
	8 Aug	1600	256	256	0	DT
	11 Aug	-	223	223	0	DT
	15 Aug	-	297	297	0	DT
5-4I	11 Jul	1615	81	81	0	BF/SH
	17 Jul	1751	115	115	0	BF
	20 Jul	-	-	-	-	
	25 Jul	1500	101	101	0	DT
	27 Jul	-	105	105	0	DT
	1 Aug	-	101	101	0	DT
	4 Aug	-	89	89	0	DT
	5 Aug	1700	98	98	0	DT

Plot	Date	Time	Total	TBMU	COMU	Observer
5-4I	8 Aug	1530	110	110	0	DT
	11 Aug	-	104	104	0	DT
	15 Aug	-	134	134	0	DT
5-5J	11 Jul	-	-	-	-	
	17 Jul	1812	1136	1106	30	JB
	20 Jul	1332	955	927	28	BF
	25 Jul	1525	638	627	11	BF
	27 Jul	1530	1005	979	26	PR
	1 Aug	1510	944	890	54	BF
	4 Aug	2028	745	731	14	BF
	5 Aug	1724	934	924	10	BF
	8 Aug	1500	1047	1016	31	DT
	11 Aug	1334	779	768	11	BF
	15 Aug	1931	1027	1016	11	BF
5-6K	11 Jul	1739	405	405	0	BF/SH
	17 Jul	1750	554	546	8	DT
	20 Jul	-	-	-	-	
	25 Jul	1430	628	616	12	JB
	27 Jul	1617	616	608	8	JB
	1 Aug	1421	626	619	7	JB
	4 Aug	1936	534	520	14	JB
	5 Aug	1720	497	493	4	JB
	8 Aug	1440	575	571	4	PR
	11 Aug	1300	570	562	8	JB
	15 Aug	1547	676	672	4	JB
5-7L	11 Jul	1810	335	264	71	BF/SH
	17 Jul	1755	395	297	98	PR
	20 Jul	-	-	-	-	
	25 Jul	1500	386	318	68	DT
	27 Jul	-	454	353	101	DT
	1 Aug	-	446	345	101	DT
	4 Aug	-	397	309	88	DT
	5 Aug	1700	428	309	119	DT
	8 Aug	-	441	335	106	DT
	11 Aug	-	387	283	104	DT
	15 Aug	-	452	378	74	DT
5-8N	11 Jul	1849	609	-	-	BF/SH
	17 Jul	1805	864	850	14	BF/DT
	20 Jul	1235	818	801	17	PR
	25 Jul	1447	722	690	32	BF
	27 Jul	-	976	969	7	DT
	1 Aug	1440	753	703	45	BF
	4 Aug	1942	718	710	8	BF
	5 Aug	1618	811	798	13	BF
	8 Aug	1430	968	949	19	DT
	11 Aug	1233	901	886	15	BF

Plot	Date	Time	Total	TBMU	COMU	Observer
5-8N	15 Aug	2023	1028	1013	15	BF
5-2F'	20 Jul	1428	111	111	0	BF
	25 Jul	1505	113	113	0	PR
	27 Jul	1645	107	107	0	PR
	1 Aug	1450	130	130	0	PR
	4 Aug	1820	105	105	0	PR
	5 Aug	1535	110	110	0	PR
	8 Aug	1515	118	118	0	PR
	11 Aug	1235	123	123	0	PR
	15 Aug	1540	121	121	0	PR
5-3H'	20 Jul	1410	81	81	0	BF
	25 Jul	1500	75	75	0	DT
	27 Jul	-	-	-	-	
	1 Aug	-	187	187	0	DT
	4 Aug	-	165	165	0	DT
	5 Aug	1700	150	150	0	DT
	8 Aug	1600	175	175	0	DT
	11 Aug	-	152	152	0	DT
	15 Aug	-	203	203	0	DT
5-6K'	20 Jul	1325	145	145	0	BF
	25 Jul	1430	192	192	2	JB
	27 Jul	-	-	-	-	
	1 Aug	1421	206	202	4	JB
	4 Aug	1950	165	157	8	JB
	5 Aug	1720	158	155	3	JB
	8 Aug	-	-	-	-	
	11 Aug	1310	170	167	3	JB
	15 Aug	1600	212	208	4	JB
5-7L'	20 Jul	1310	187	176	11	BF
	25 Jul	1500	208	195	13	DT
	27 Jul	-	242	229	13	DT
	1 Aug	-	242	221	21	DT
	4 Aug	-	198	182	16	DT
	5 Aug	1700	211	190	21	DT
	8 Aug	-	218	198	20	DT
	11 Aug	-	203	186	17	DT
	15 Aug	-	230	216	14	DT
5-8N'	20 Jul	1240	254	254	0	BF
	25 Jul	1508	258	258	0	BF
	27 Jul	-	264	263	0	DT
	1 Aug	1455	221	221	0	BF
	4 Aug	2002	216	216	0	BF
	5 Aug	1647	255	255	0	BF
	8 Aug	1430	259	259	0	DT
	11 Aug	1314	223	223	0	BF
	15 Aug	2023	272	272	0	BF

APPENDIX E. CENSUS DATA FOR BLACK-LEGGED KITTIWAKES, 1988 RAW COUNTS

This appendix contains the original kittiwake counts from Cape Thompson land-based plots during the census period in 1988. Observers were:

JB Jane Burger
BF Brian Fadely
SH Scott Hatch
DR Dave Roseneau
DT Daniel Taylor
PR Paul Rodewald

Plot	Date	Time	Singles	Pairs	Total	Nests	Observers
2-1A	12 Jul	1323	23	0	23	20	BF/SH/DT
	16 Jul	1551	19	0	19		BF/JB/DT/PR
	18 Jul	1340	21	0	21	21	DT/PR
	26 Jul	1730	22	1	24		DT
	7 Aug	1721	10	3	16		BF
	10 Aug	1200	15	1	17		DT
2-2B	12 Jul	1424	9	0	9	8	BF/DT
	16 Jul	1630	8	0	8		BF/JB/DT/PR
	18 Jul	1415	9	0	9		PR
	26 Jul	1722	8	0	8		BF
	7 Aug	1720	11	0	11		JB
	10 Aug	1300	6	0	6		DT
2-3C	12 Jul	1540	18	0	18	16	BF/DT
	16 Jul	1702	16	0	16		BF/JB/DT/PR
	18 Jul	1430	17	0	17		DT
	26 Jul	1725	17	0	17		PR
	7 Aug	1730	16	1	18		PR
	10 Aug	1330	13	0	13		DT
3-1A	10 Jul	1548	5	0	5	5	JB/BF
	13 Jul	1530	5	0	5		JB
	14 Jul	1830	6	0	6		JB/BF
	15 Jul	1241	6	0	6		DT/JB
	17 Jul	2020	6	0	6	5	PR
	18 Jul	1548	6	0	6		JB/BF

Plot	Date	Time	Singles	Pairs	Total	Nests	Observers
3-1A	19 Jul	1749	6	0	6		BF
	20 Jul	1910	6	0	6		JB/PR
	21 Jul	2038	6	1	8		JB/PR
	22 Jul	1130	6	0	6		DT
	23 Jul	1553	5	0	5		BF
	25 Jul	1915	5	0	5		JB
	26 Jul	1615	5	0	5		DT
	27 Jul	2334	6	0	6		BF
	28 Jul	1900	6	0	6		PR
	30 Jul	2040	5	0	5		JB
	1 Aug	1905	5	0	5		PR
	2 Aug	1945	5	0	5		JB
	3 Aug	1600	0	0	0		DT
	5 Aug	1145	5	0	5		PR
	7 Aug	1600	4	0	4		DT
	8 Aug	1645	6	0	6		BF
3-2B	10 Jul	1600	46	5	56	50	JB
	13 Jul	1600	48	4	56		JB
	14 Jul	1844	58	6	70		JB/BF
	15 Jul	1300	53	2	57		DT/JB
	17 Jul	2040	53	1	55		PR
	18 Jul	1602	40	1	42		JB/BF
	19 Jul	1809	50	0	50		BF
	20 Jul	1922	43	0	43		JB/PR
	21 Jul	2045	52	0	52		JB/PR
	22 Jul	1200	46	0	46		DT
	23 Jul	1610	53	0	53		BF
	25 Jul	1930	41	1	45		JB
	28 Jul	1915	54	2	58		DT
	1 Aug	1920	44	2	48		PR
	2 Aug	2000	–	–	–		JB
	3 Aug	1615	61	0	61		DT
	5 Aug	1200	58	3	64		PR
	7 Aug	1615	59	1	61		DT
	8 Aug	1649	44	0	44		BF
3-2C	10 Jul	1615	2	0	2	3	JB
	13 Jul	1615	2	0	2		JB
	14 Jul	1920	3	0	3		JB/BF
	15 Jul	1315	3	0	3		DT/JB
	17 Jul	2115	5	1	7		PR
	18 Jul	1617	4	0	4		JB/BF
	19 Jul	1826	3	0	3		BF
	20 Jul	1935	3	0	3		JB/PR
	21 Jul	2100	3	0	3		JB/PR
	22 Jul	1220	3	0	3		DT
	23 Jul	1641	2	0	2		BF

Plot	Date	Time	Singles	Pairs	Total	Nests	Observers
3-2C	25 Jul	1930	3	0	3		JB
	28 Jul	1945	5	1	7		PR
	1 Aug	1950	2	0	2		PR
	2 Aug	2015	3	1	5		JB
	3 Aug	1630	4	0	4		DT
	5 Aug	1215	4	0	4		PR
	7 Aug	1630	2	0	2		DT
	8 Aug	1730	4	0	4		BF
4-1A	8 Jul	1815	46	0	46	41	JB/PR
	11 Jul	1645	43	0	43		PR/DT/DR
	17 Jul	1545	50	1	52		PR
	20 Jul	1450	43	0	43		DT
	25 Jul	1635	51	1	53		PR
	27 Jul	1745	51	1	53		PR
	1 Aug	1638	43	1	45		BF
	4 Aug	2118	33	4	41		BF
	5 Aug	1825	41	0	41		PR
	8 Aug	1730	39	2	43		PR
4-1B	8 Jul	1800	32	2	36	30	JB/PR
	11 Jul	1630	35	0	35	30	PR/DT/DR
	17 Jul	1545	50	1	52		DT
	20 Jul	1450	33	0	33		PR
	25 Jul	1615	28	0	28		PR
	27 Jul	1730	29	10	49		PR
	1 Aug	1651	33	0	33		BF
	4 Aug	2110	33	0	33		BF
	5 Aug	1840	40	3	46		PR
	8 Aug	1730	41	1	43		PR
4-2C	8 Jul	1545	209	3	215	168	JB/PR
	11 Jul	1500	216	2	220	175	PR/DT/DR
	17 Jul	1505	219	1	221	195	PR
	20 Jul	1510	194	2	198		PR
	25 Jul	1600	229	2	233		DT
	27 Jul	-	176	1	178		DT
	1 Aug	-	174	4	182		DT
	4 Aug	2133	158	11	180		BF
	5 Aug	1900	185	5	195		DT
	8 Aug	1720	187	2	191		DT
4-3D	8 Jul	1427	47	0	47	41	JB/PR
	11 Jul	1730	46	1	48	41	PR/DT/DR
	17 Jul	1450	38	0	38		PR/DT/DR
	20 Jul	-	-	-	-	-	
	25 Jul	1600	48	0	48		DT
	27 Jul	-	47	0	47		DT
	1 Aug	-	45	3	51		DT

Plot	Date	Time	Singles	Pairs	Total	Nests	Observers
4-3D	4 Aug	2153	35	0	35		BF
	5 Aug	-	42	2	46		DT
	8 Aug	1640	35	1	37		DT
4-4E	8 Jul	-	-	-	-		
	11 Jul	1300	207	2	211	176	PR/DT/DR
	17 Jul	1410	211	2	215		PR/DT
	20 Jul	2211	211	0	211		BF
	25 Jul	1632	211	5	221		BF/JB
	27 Jul	1800	205	2	209		JB
	1 Aug	1725	171	7	185		BF
	4 Aug	2212	167	7	181		BF
	5 Aug	2012	156	18	192		BF
	8 Aug	1700	212	6	224		PR
5-1A	11 Jul	1959	36	0	36	28	BF/SH
	17 Jul	1352	27	2	27		JB
	20 Jul	1410	30	0	30		JB
	25 Jul	1510	26	1	28		JB
	27 Jul	1634	27	0	27		JB
	1 Aug	1510	29	1	31		JB
	4 Aug	2030	29	1	31		JB
	5 Aug	1800	29	1	31		JB
	8 Aug	1535	41	2	45		PR
5-1B	11 Jul	2007	153	6	165	136	BF/SH
	17 Jul	1356	156	4	164		JB
	20 Jul	1412	139	5	149		JB
	25 Jul	1510	149	3	155		JB
	27 Jul	1634	139	5	149		JB
	1 Aug	1510	139	8	155		JB
	4 Aug	2030	123	6	135		JB
	5 Aug	1800	123	8	139		JB
	8 Aug	1555	151	5	161		PR
5-1C	11 Jul	2027	10	1	12	10	BF/SH
	17 Jul	1400	11	1	13		JB
	20 Jul	1437	10	0	10		JB
	25 Jul	1510	9	0	9		JB
	27 Jul	1701	11	1	13		JB
	1 Aug	1525	10	0	10		JB
	4 Aug	2040	10	0	10		JB
	5 Aug	1830	9	3	15		JB
	8 Aug	1615	11	1	13		PR
5-1D	11 Jul	2027	0	0	0	0	BF/SH
	17 Jul	1402	0	0	0		JB
	20 Jul	1440	0	0	0		JB
	25 Jul	1510	0	0	0		JB
	27 Jul	1705	0	0	0		JB

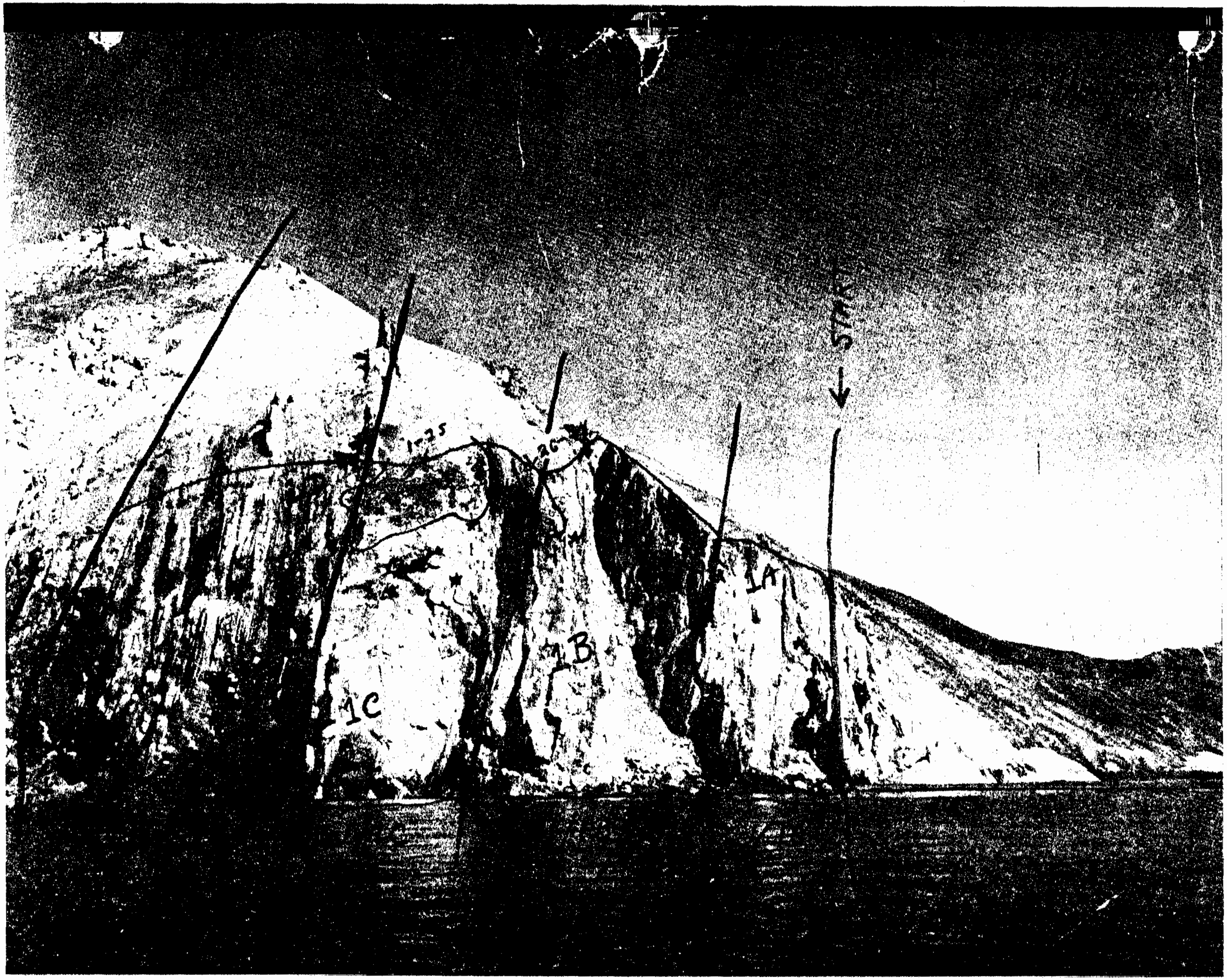
Plot	Date	Time	Singles	Pairs	Total	Nests	Observers
5-1D	1 Aug	1530	0	0	0		JB
	4 Aug	2045	0	0	0		JB
	5 Aug	1835	0	0	0		PR
	8 Aug	1625	0	0	0		JB
5-2E	11 Jul	1416	85	1	87	89	BF/SH
	17 Jul	1645	103	0	103	91	DT
	20 Jul	1340	-	-	-		
	25 Jul	1630	88	1	90		PR
	27 Jul	1615	87	0	87		PR
	1 Aug	1420	89	2	93		PR
	4 Aug	1800	72	3	78		PR
	5 Aug	1515	75	0	75		PR
	8 Aug	1455	98	4	106		PR
5-2F	11 Jul	1334	4	0	4	4	BF/SH
	17 Jul	1645	4	0	4	4	PR
	20 Jul	1320	3	0	3	4	PR
	25 Jul	1450	3	0	3		PR
	27 Jul	1630	4	0	4		PR
	1 Aug	1440	3	0	3		PR
	4 Aug	1815	2	0	2		PR
	5 Aug	1530	3	0	3		PR
	8 Aug	1510	2	1	4		PR
5-2G	11 Jul	1454	0	0	0	0	BF/SH
	17 Jul	1700	0	0	0		PR/DT
	20 Jul	-	-	-	-		
	25 Jul	1510	0	0	0		PR
	27 Jul	1650	0	0	0		PR
	1 Aug	1455	0	0	0		PR
	4 Aug	1825	0	0	0		PR
	5 Aug	1540	0	0	0		PR
	8 Aug	1520	0	0	0		PR
5-3H	11 Jul	1534	0	0	0	0	BF/SH
	17 Jul	1740	0	0	0		PR
	20 Jul	1330	0	0	0		JB
	25 Jul	1500	0	0	0		DT
	27 Jul	-	-	-	-		
	1 Aug	-	-	-	-		
	4 Aug	-	-	-	-		
	5 Aug	1700	0	0	0		DT
	8 Aug	1600	0	0	0		DT
5-4I	11 Jul	1615	0	0	0	0	BF/SH
	17 Jul	1751	0	0	0		BF
	20 Jul	-	-	-	-		
	25 Jul	1500	0	0	0		DT
	27 Jul	-	0	0	0		DT
	1 Aug	-	0	0	0		DT

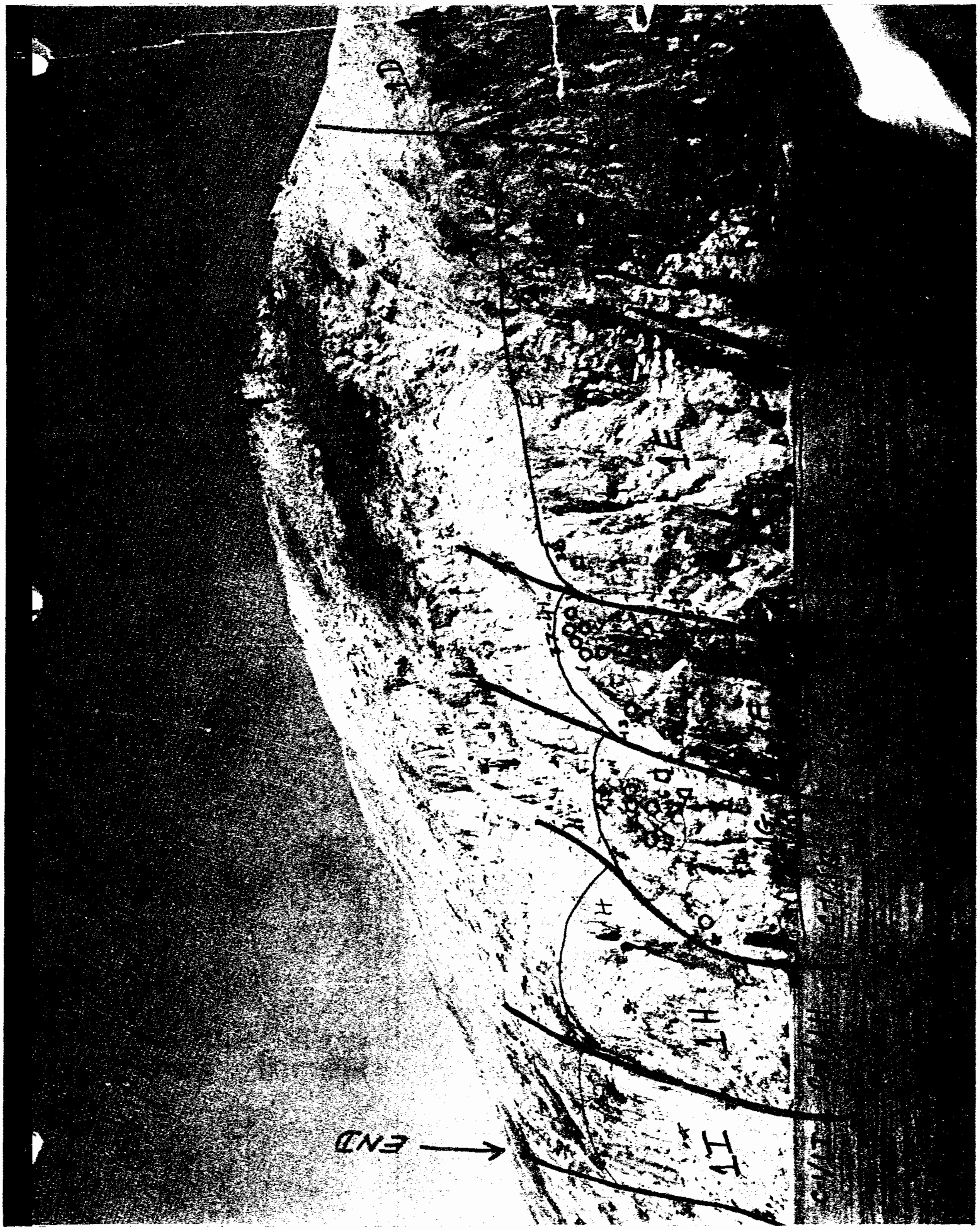
Plot	Date	Time	Singles	Pairs	Total	Nests	Observers
5-4I	4 Aug	-	0	0	0		DT
	5 Aug	1700	0	0	0		DT
	8 Aug	1530	0	0	0		DT
5-5J	11 Jul	-	-	-	-		
	17 Jul	1812	82	3	88	77	JB
	20 Jul	1332	93	3	99		BF
	25 Jul	1525	81	2	85		BF
	27 Jul	1530	90	0	90		PR
	1 Aug	1510	87	1	89		BF
	4 Aug	2028	85	1	87		BF
	5 Aug	1724	77	5	87		BF
	8 Aug	1500	94	3	100		DT
5-6K	11 Jul	1739	7	0	7	7	BF/SH
	17 Jul	1750	6	0	6		DT
	20 Jul	-	-	-	-		
	25 Jul	1430	6	0	6		JB
	27 Jul	1617	7	0	7		JB
	1 Aug	1421	6	0	6		JB
	4 Aug	1936	5	0	5		JB
	5 Aug	1720	4	0	4		JB
	8 Aug	1440	7	1	9		PR
5-7L	11 Jul	1810	0	0	0	0	BF/SH
	17 Jul	1755	1	0	1		PR
	20 Jul	-	-	-	-		
	25 Jul	1500	1	0	1		DT
	27 Jul	-	0	0	0		DT
	1 Aug	-	0	0	0		DT
	4 Aug	-	4	0	4		DT
	5 Aug	1700	5	0	5		DT
	8 Aug	-	1	0	1		DT
5-8M	11 Jul	1816	83	4	91	82	BF/SH
	17 Jul	1805	99	1	101		PR
	20 Jul	-	-	-	-		
	25 Jul	1512	96	2	100		BF
	27 Jul	-	88	0	88		DT
	1 Aug	1508	104	2	108		BF
	4 Aug	2005	82	4	90		BF
	5 Aug	1650	88	6	100		BF
	8 Aug	1450	126	6	138		DT
5-8N	11 Jul	1849	33	1	35	32	BF/SH
	17 Jul	1805	32	0	32	32	BF/DT
	20 Jul	1235	36	1	38		PR
	25 Jul	1447	30	1	32		BF
	27 Jul	-	29	0	29		DT
	1 Aug	1440	29	0	29		BF
	4 Aug	1942	21	1	23		BF

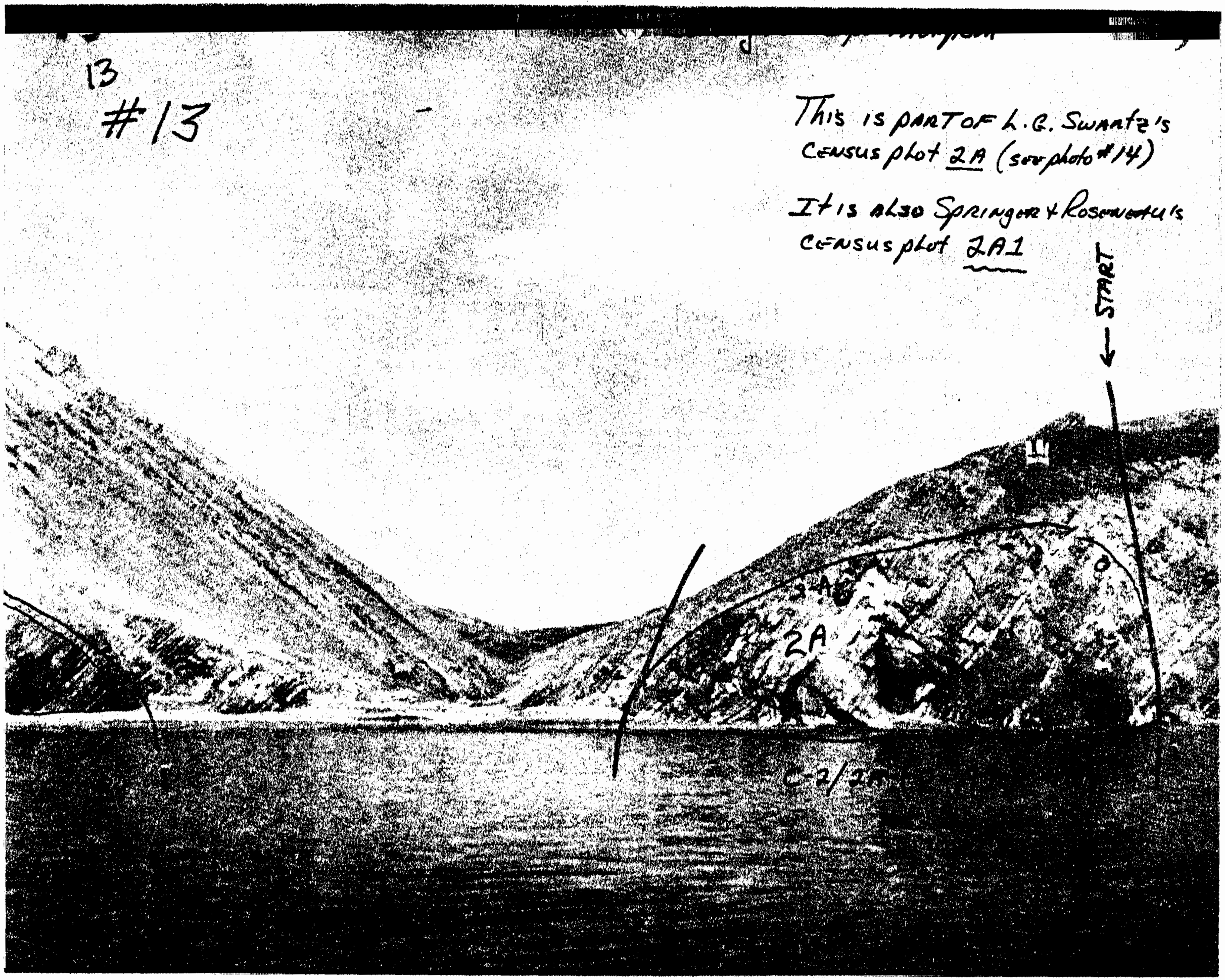
Plot	Date	Time	Singles	Pairs	Total	Nests	Observers
5-8N	5 Aug	1618	27	2	31		BF
	8 Aug	1430	34	0	34		DT

APPENDIX F. PHOTODOCUMENTATION OF BOAT-BASED CENSUS PLOTS AT CAPE THOMPSON

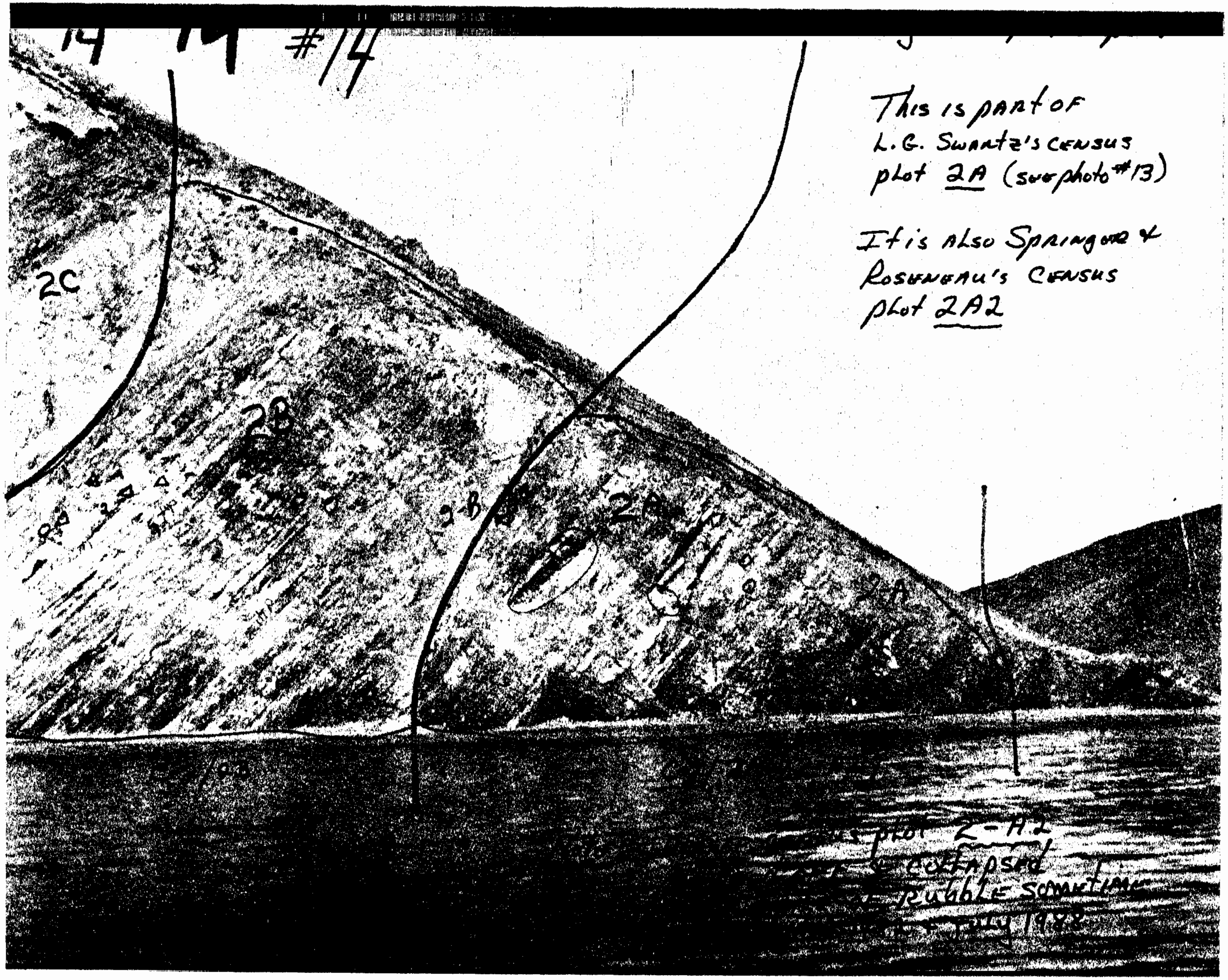
Following are 45 annotated photographs idicating the boundaries of L.G. Swartz' original (1959-1961) census plots. The series is sequential from south (Colony 1, Crowbill Point) to north (Colony 5, Imnapak Cliff). Also included (pp. 306-310) are photographs of 5 land-based plots established in Colony 5 prior to 1988.

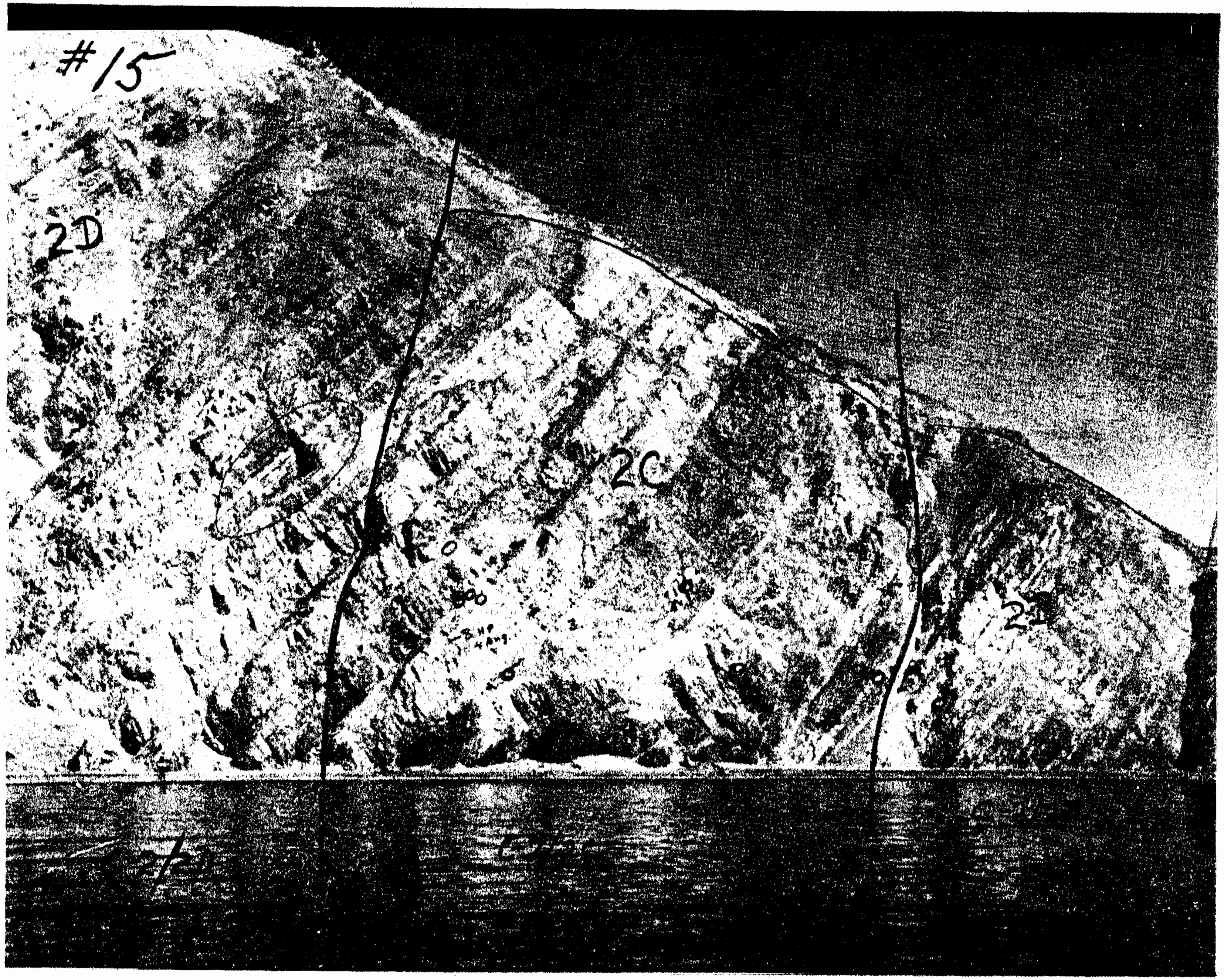

START
1A
1B
1C

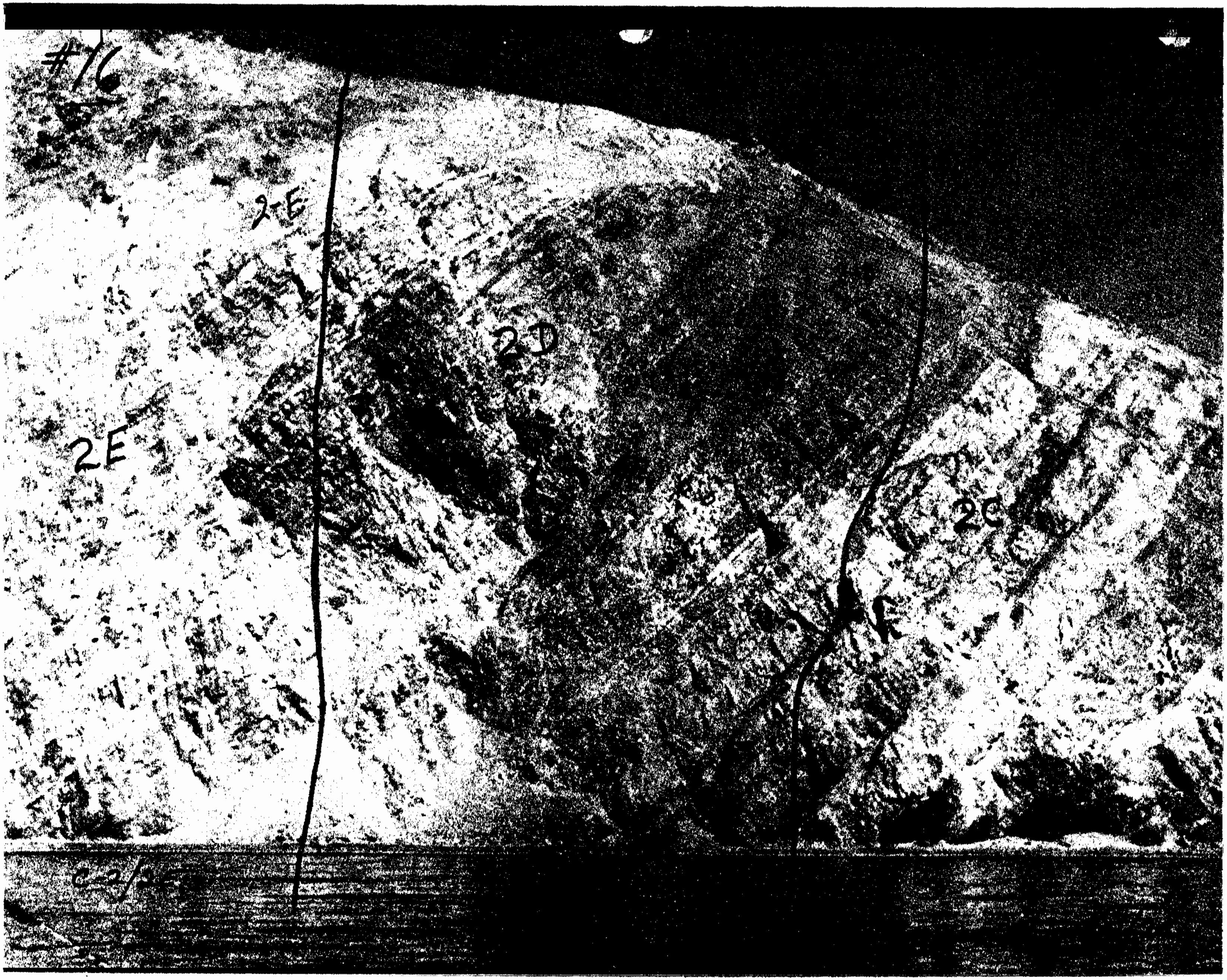

END
1I
1H
1G
1E
1D

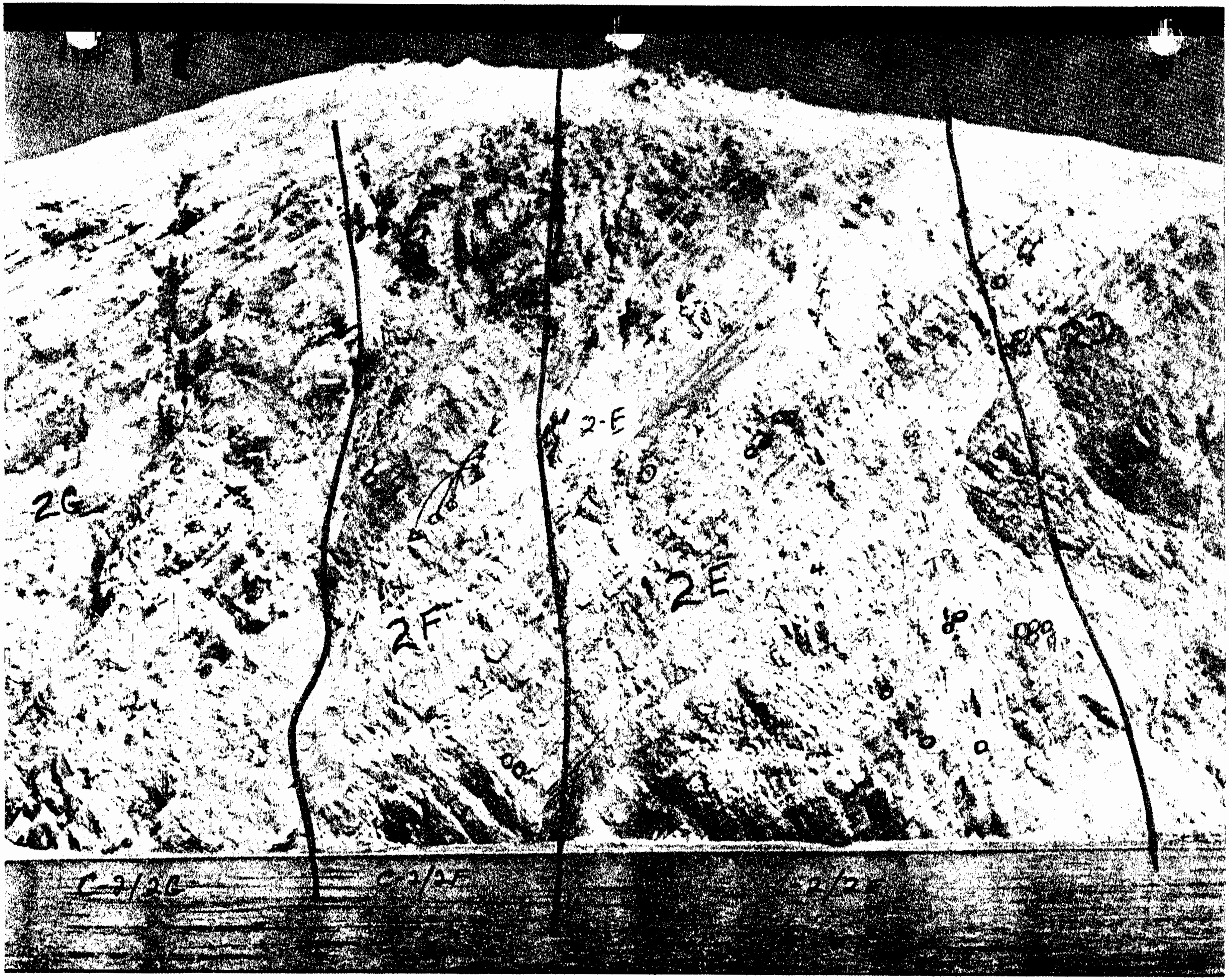


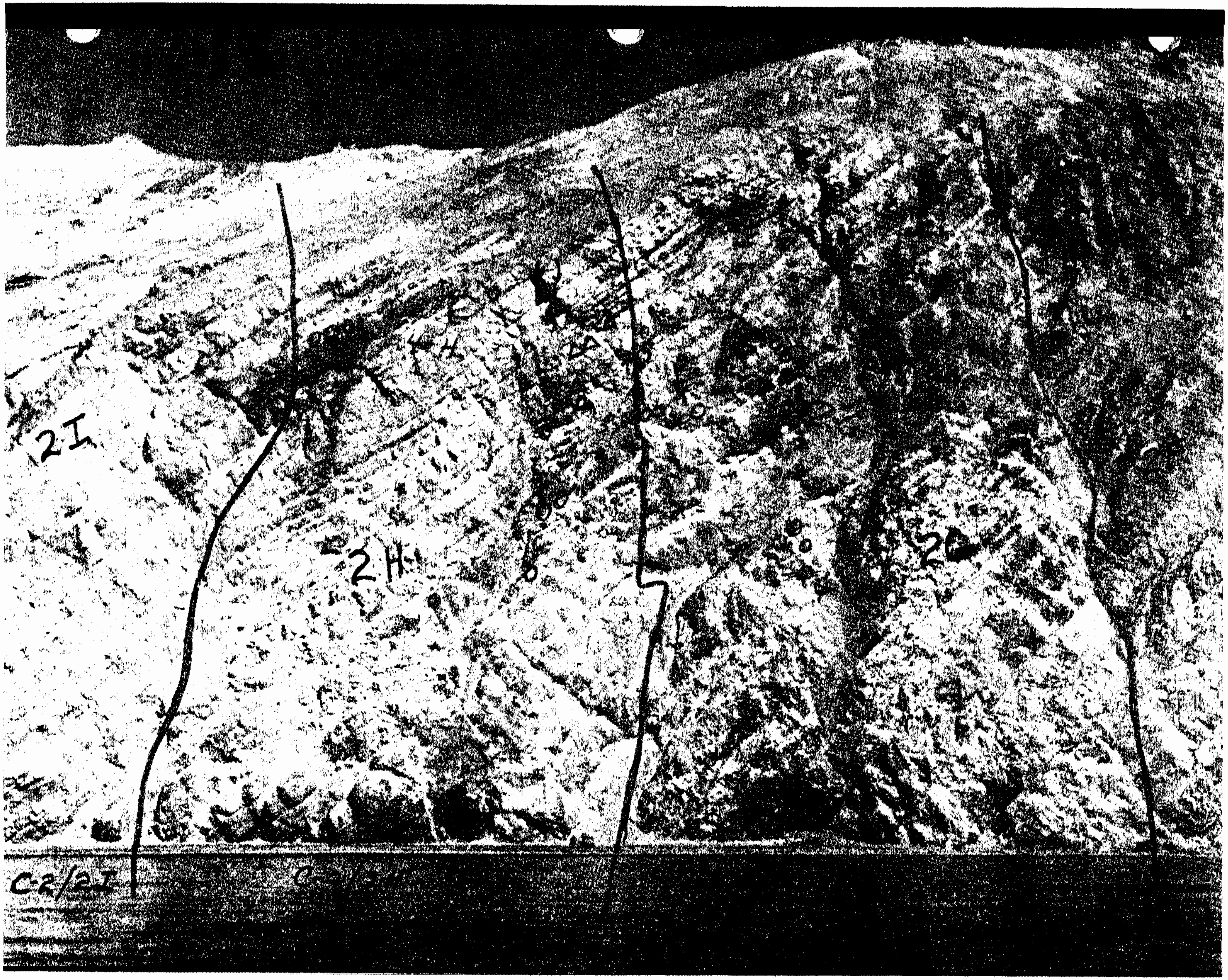
13
#13
This is part of L.G. Swartz's census plot 2A (see photo #14)
It is also Springer & Rosenthal's census plot 2A1
START
2A

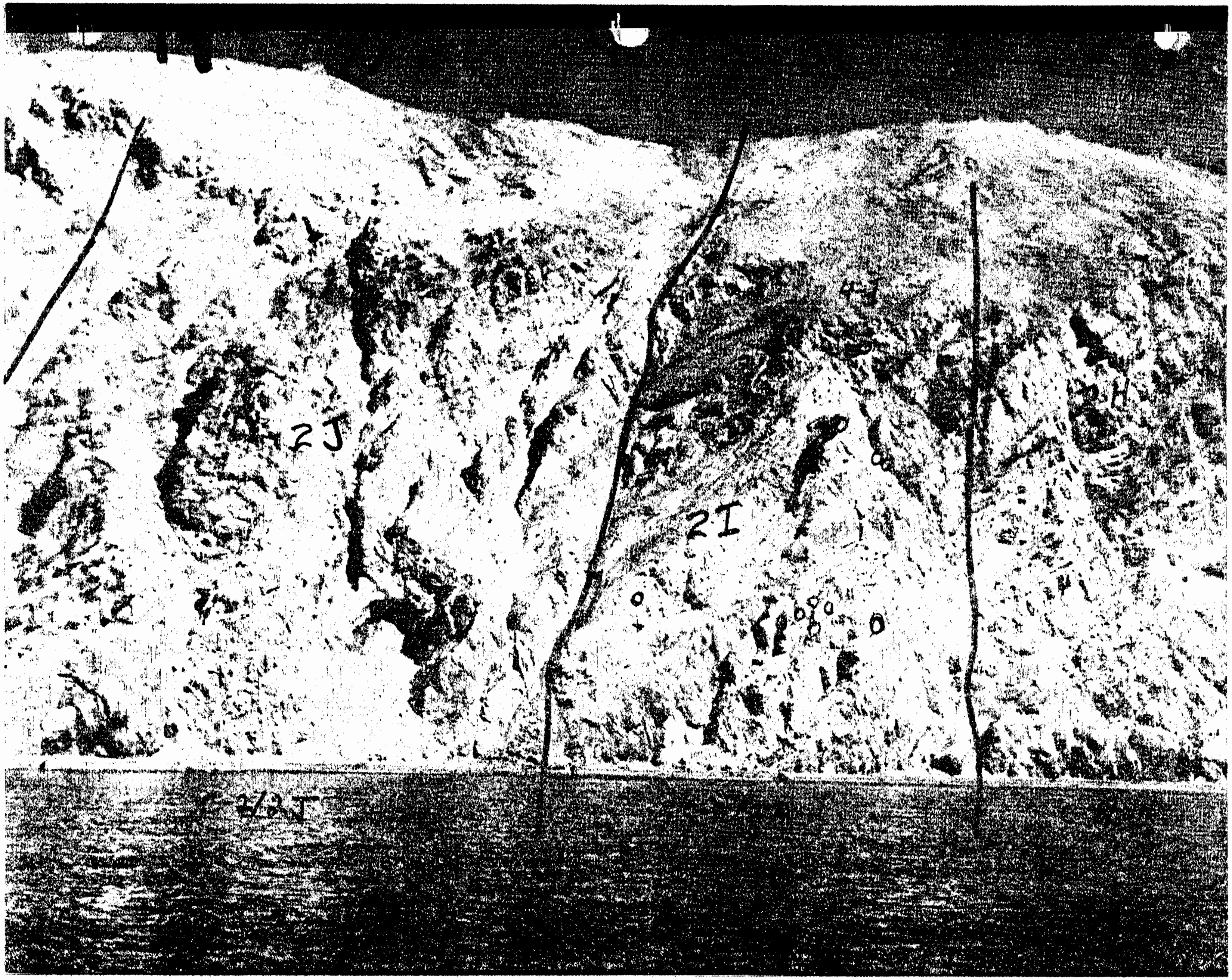

#14
This is part of
L.G. Swartz's census
plot 2A (see photo #13)
It is also Springer &
Rosenau's census
plot 2A2
2C
2B
2B
2A

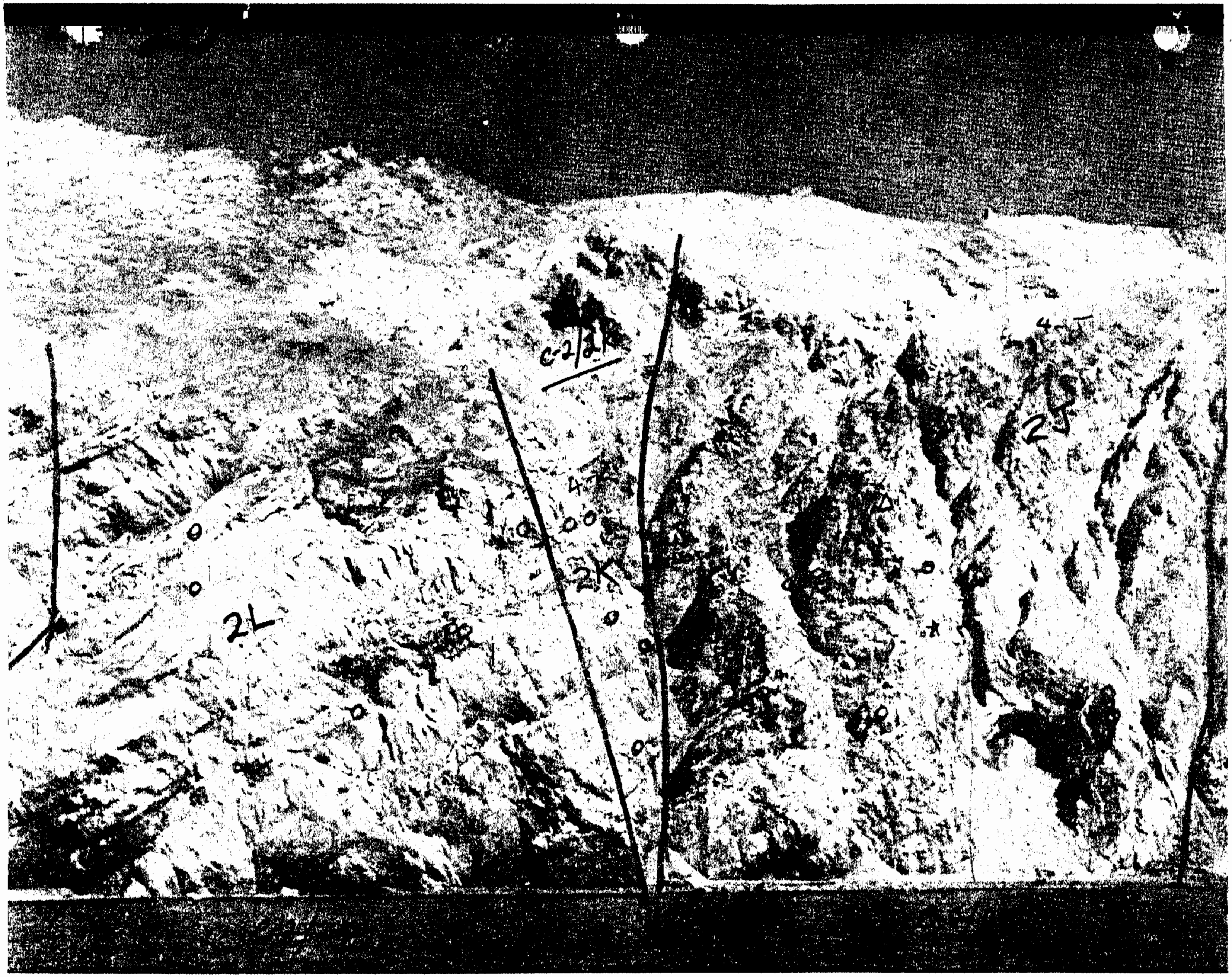

#15
2D
2C

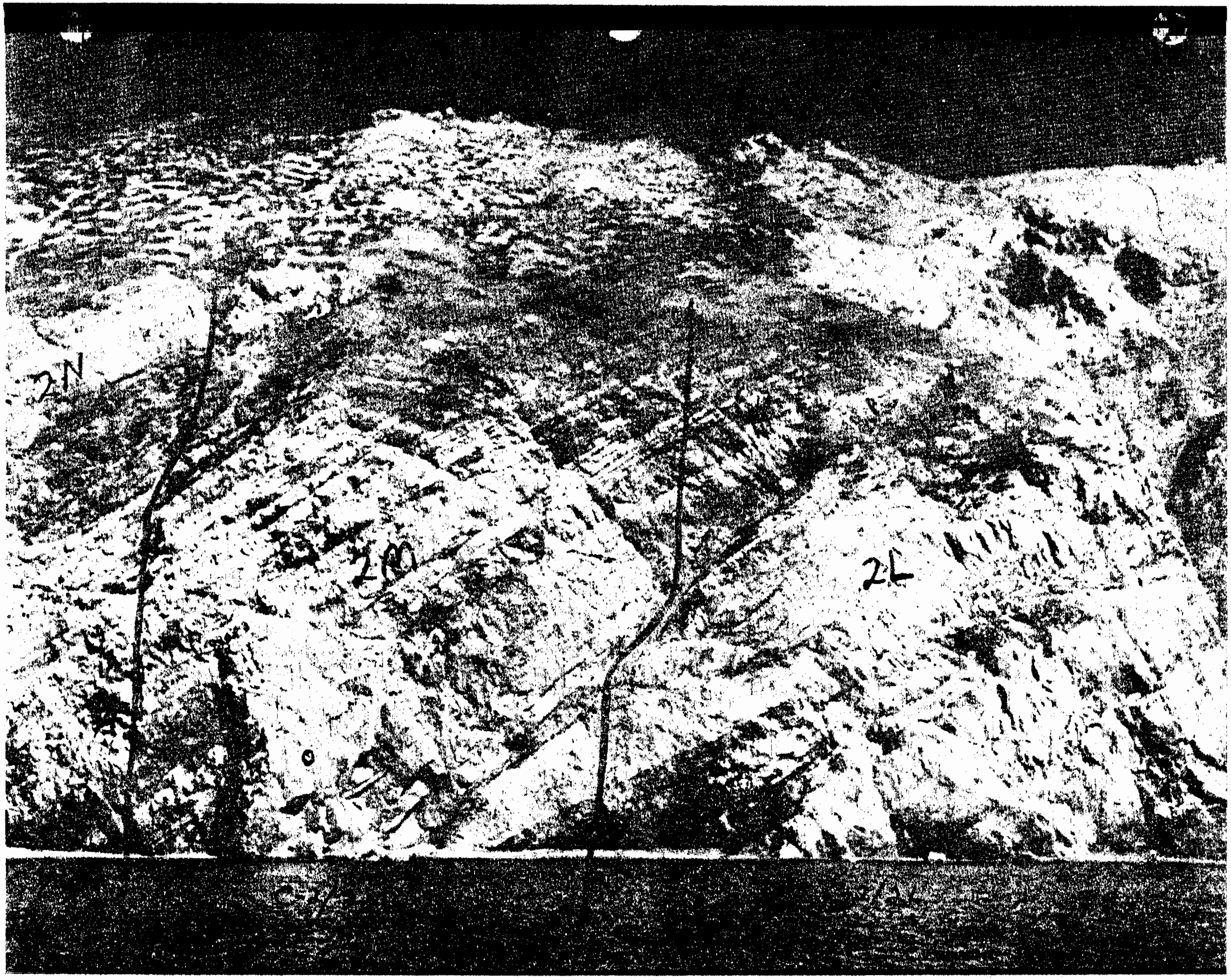

#16
2E
2E
2D
2C


2G
2F
2-E
2E

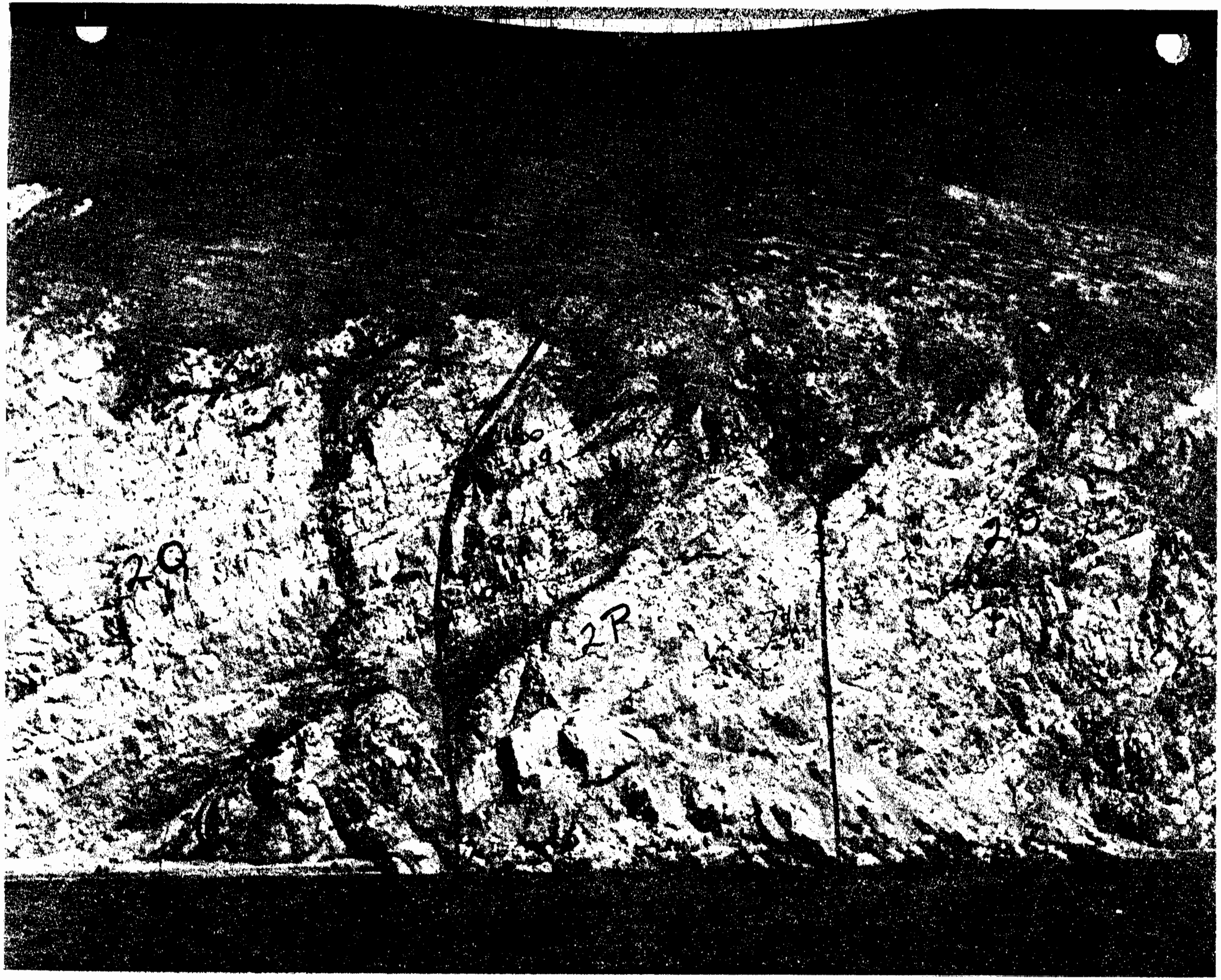

2I
2H
2G
C-2/2I

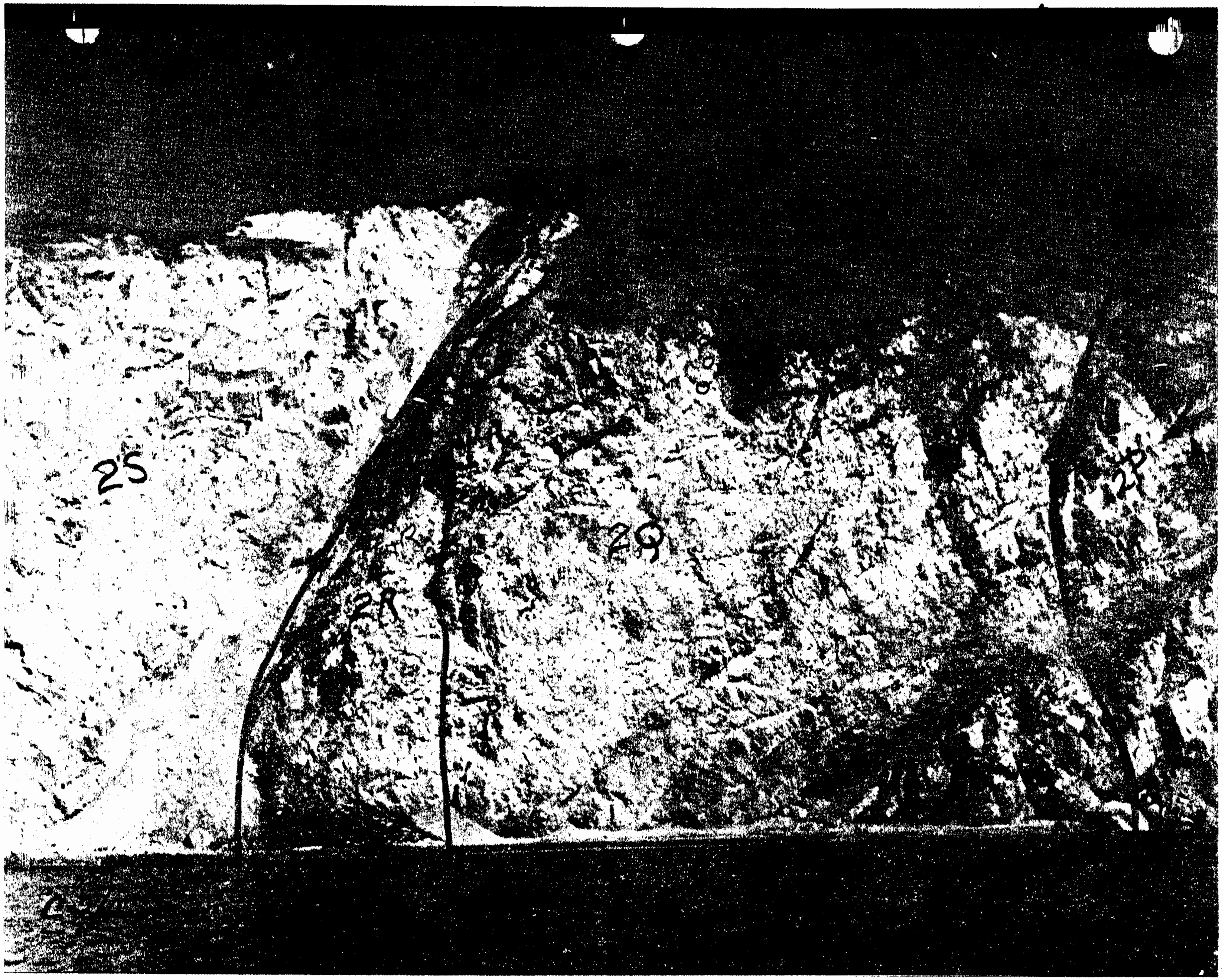

2J
2I
H

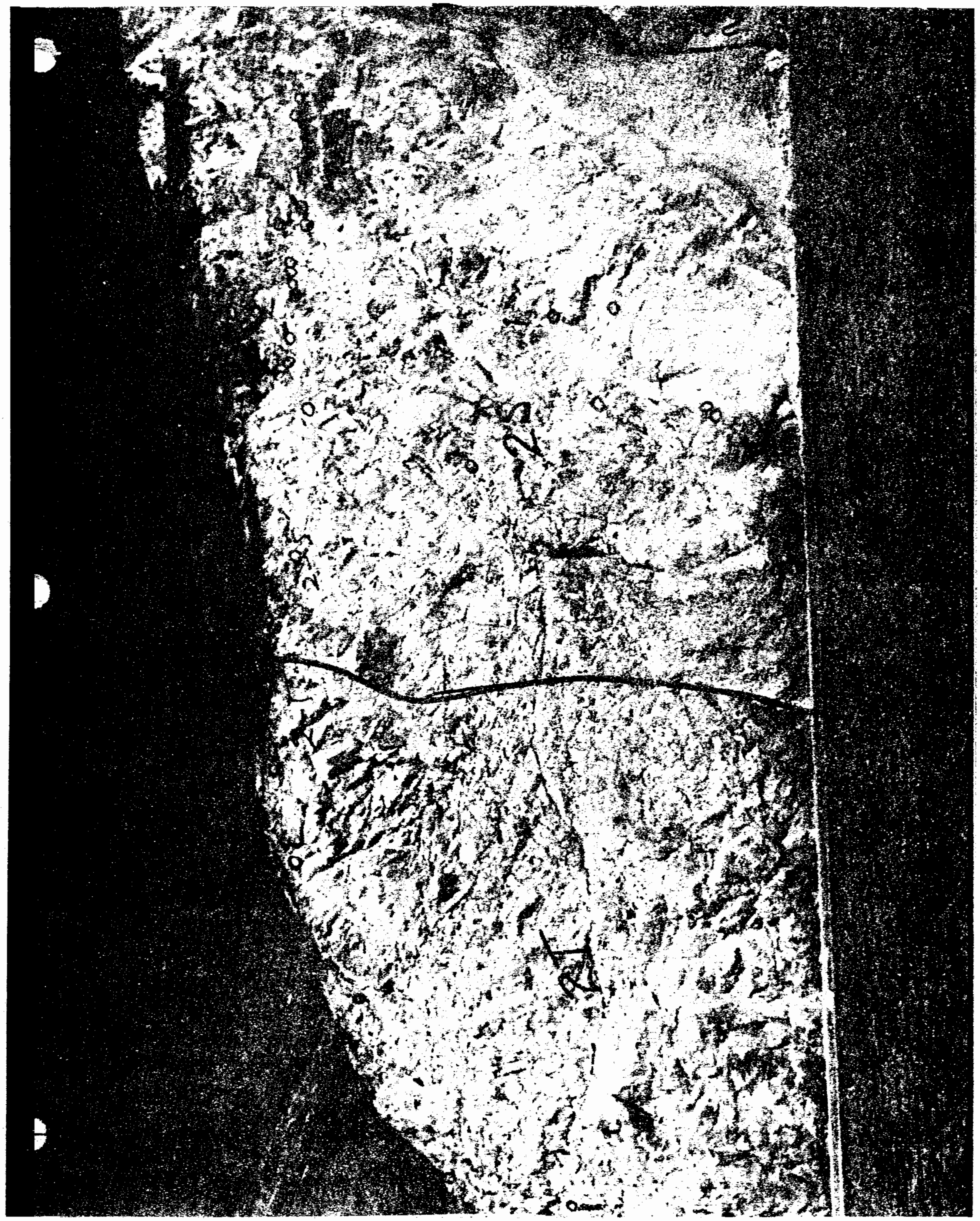

2L
2K

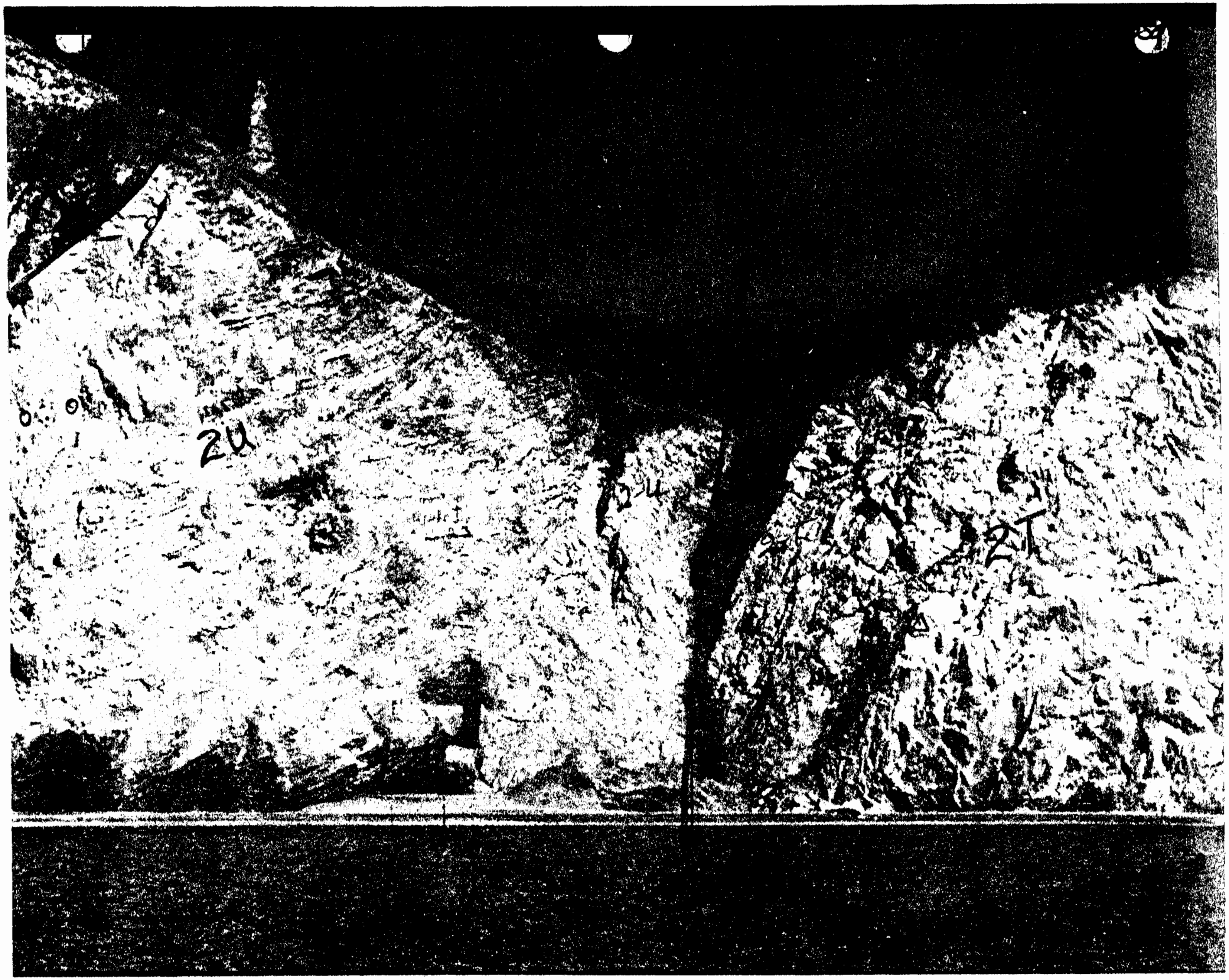

2N
2L

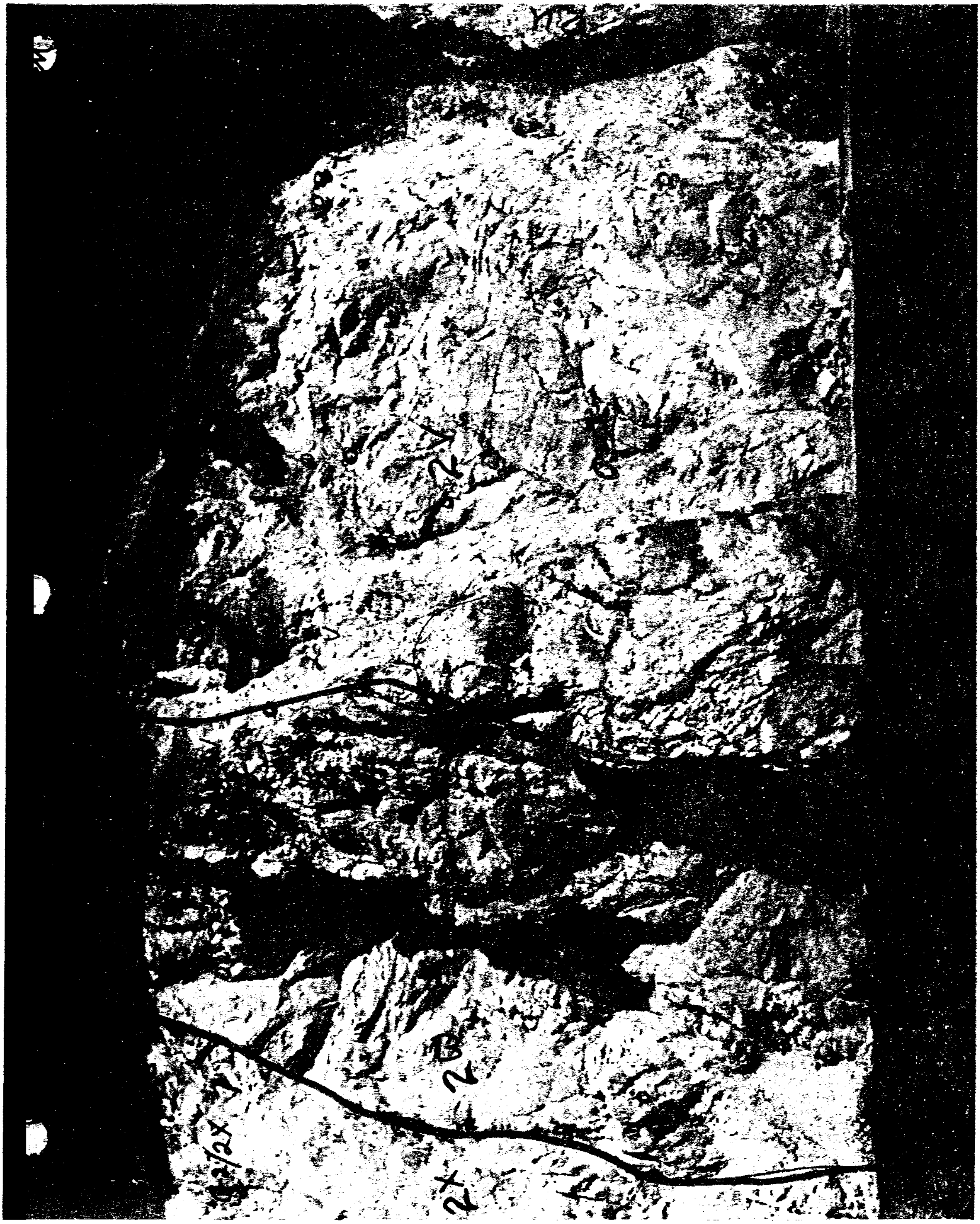

2P
2O
2N

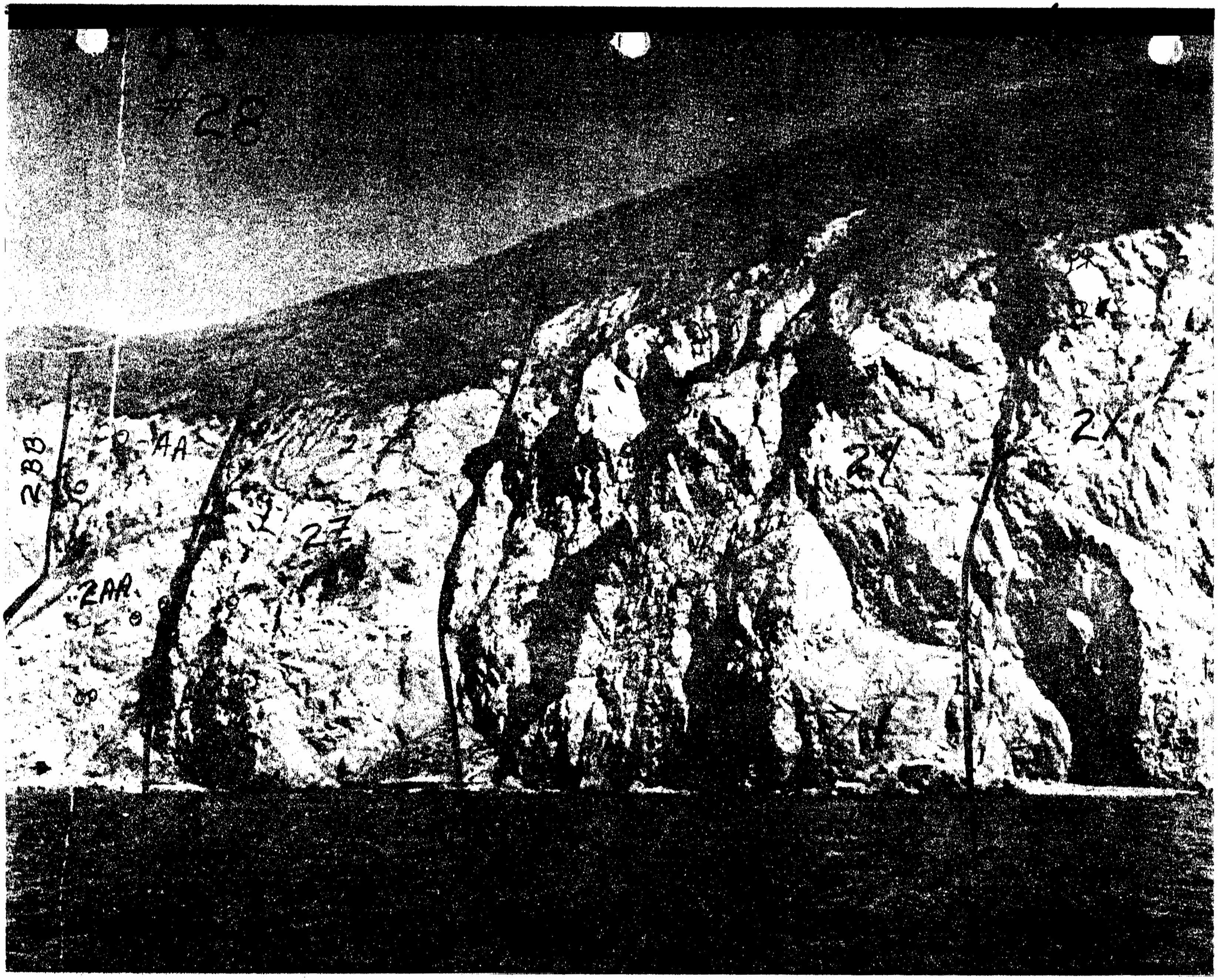

2Q
2R

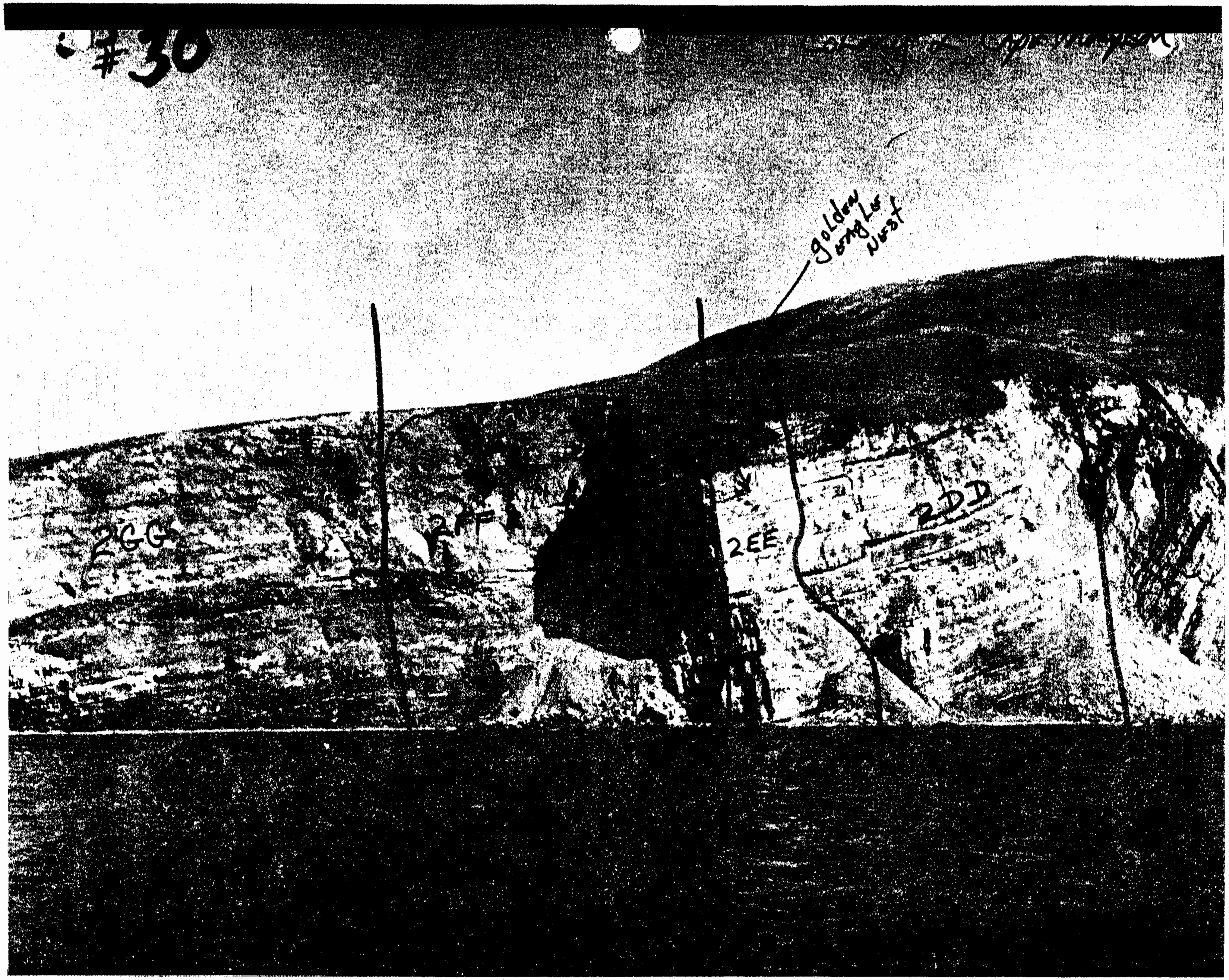

25
29



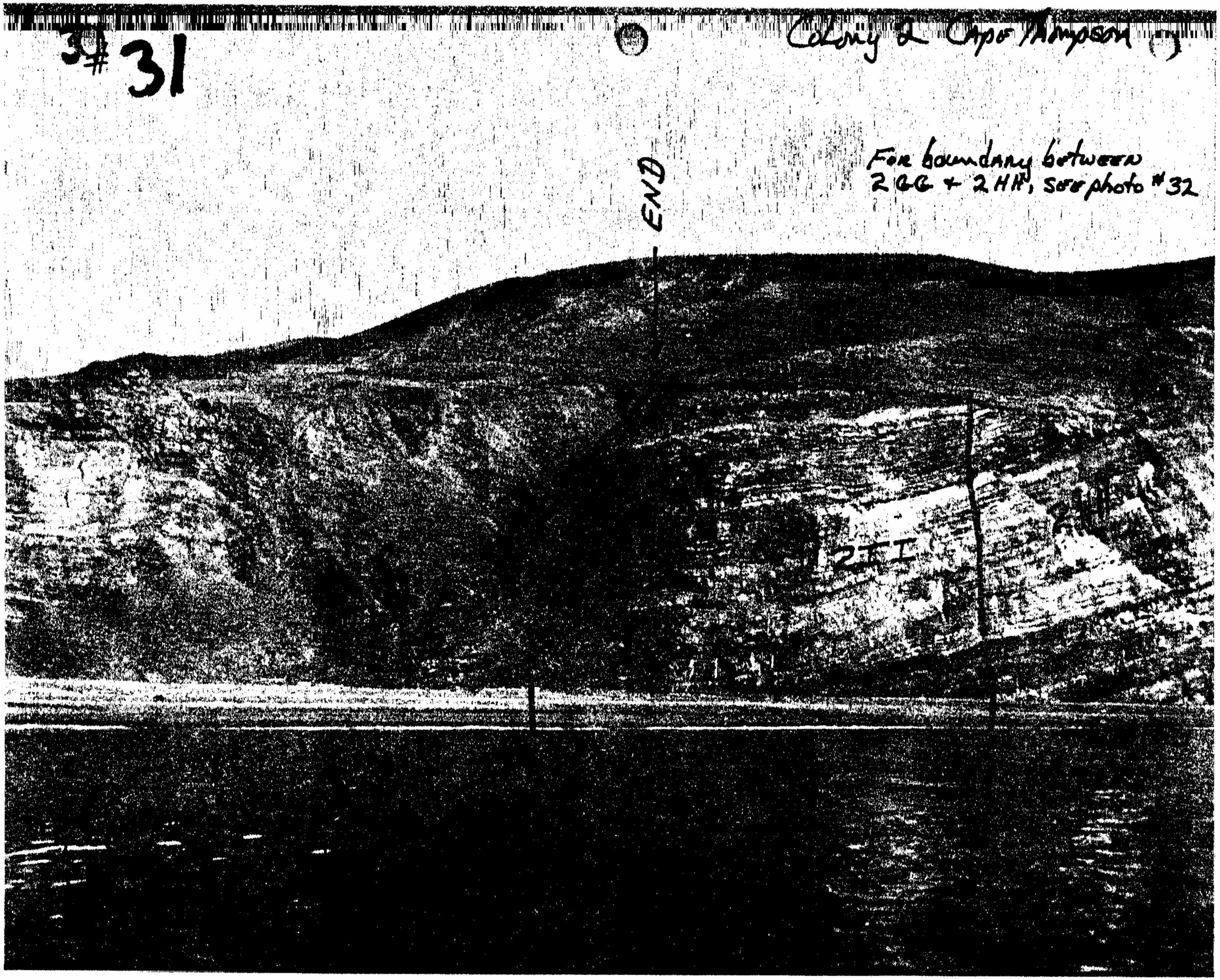

2U
2T

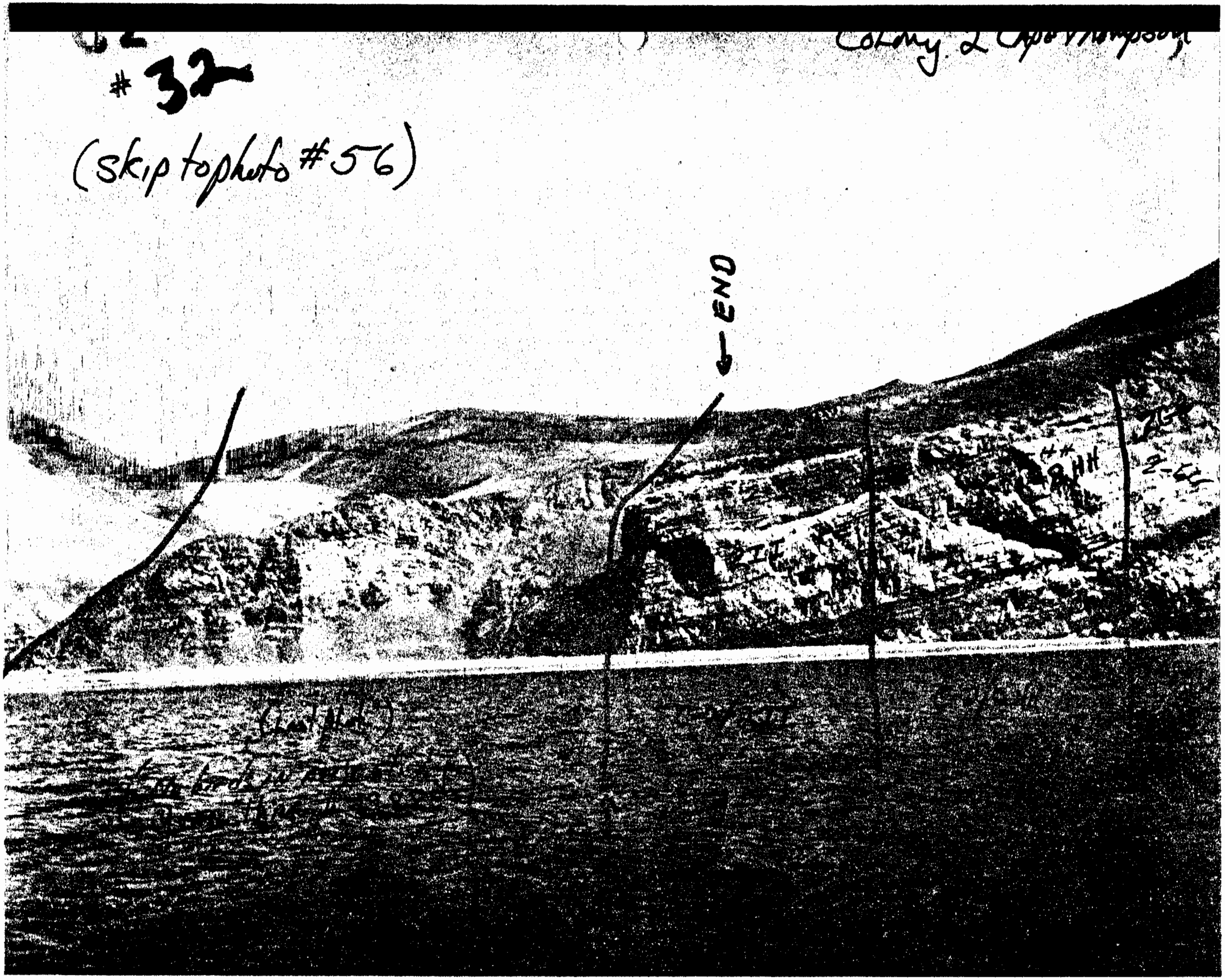

2X
2V

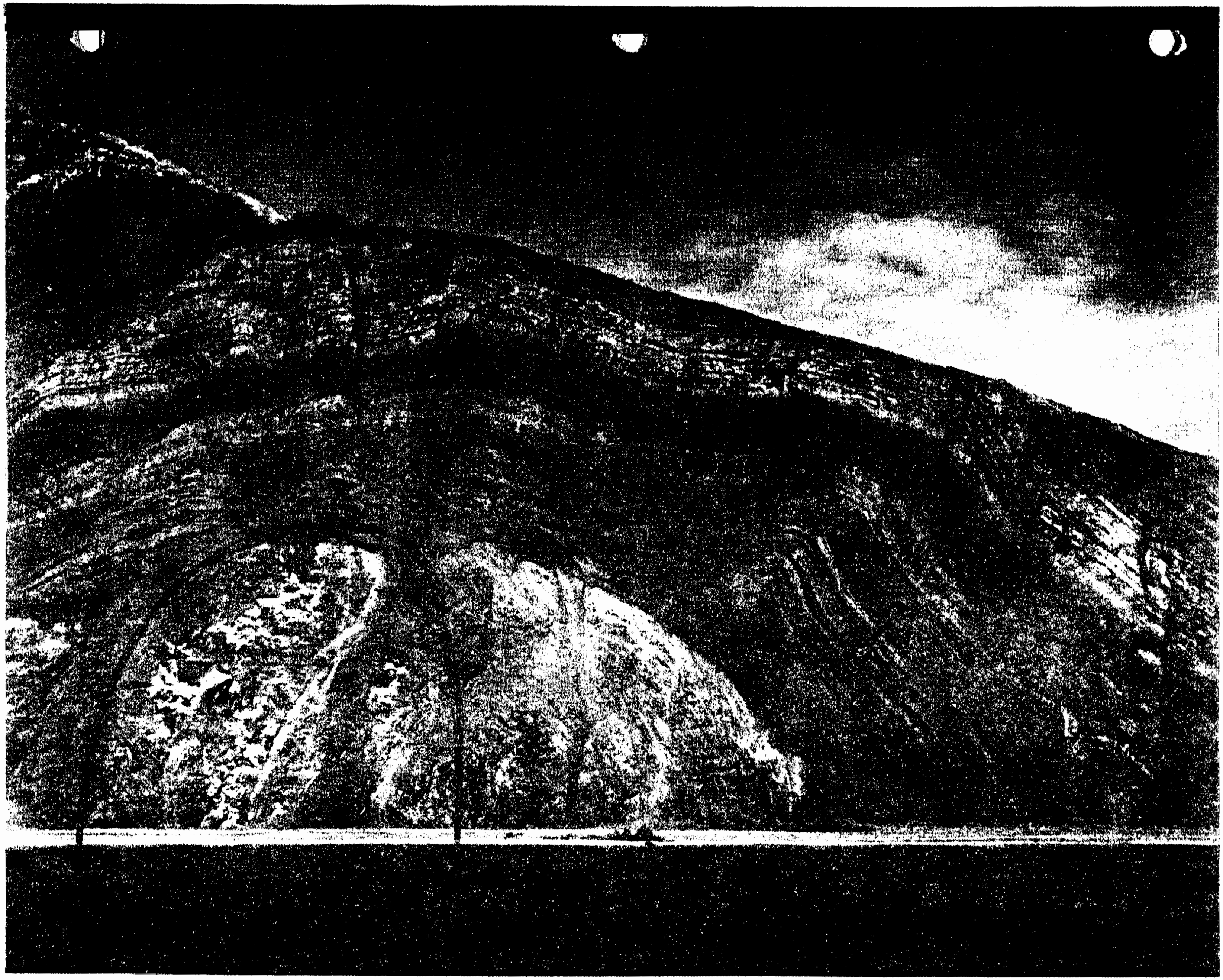

#28
2BB
AA
2AA
2Z
2Y
2X

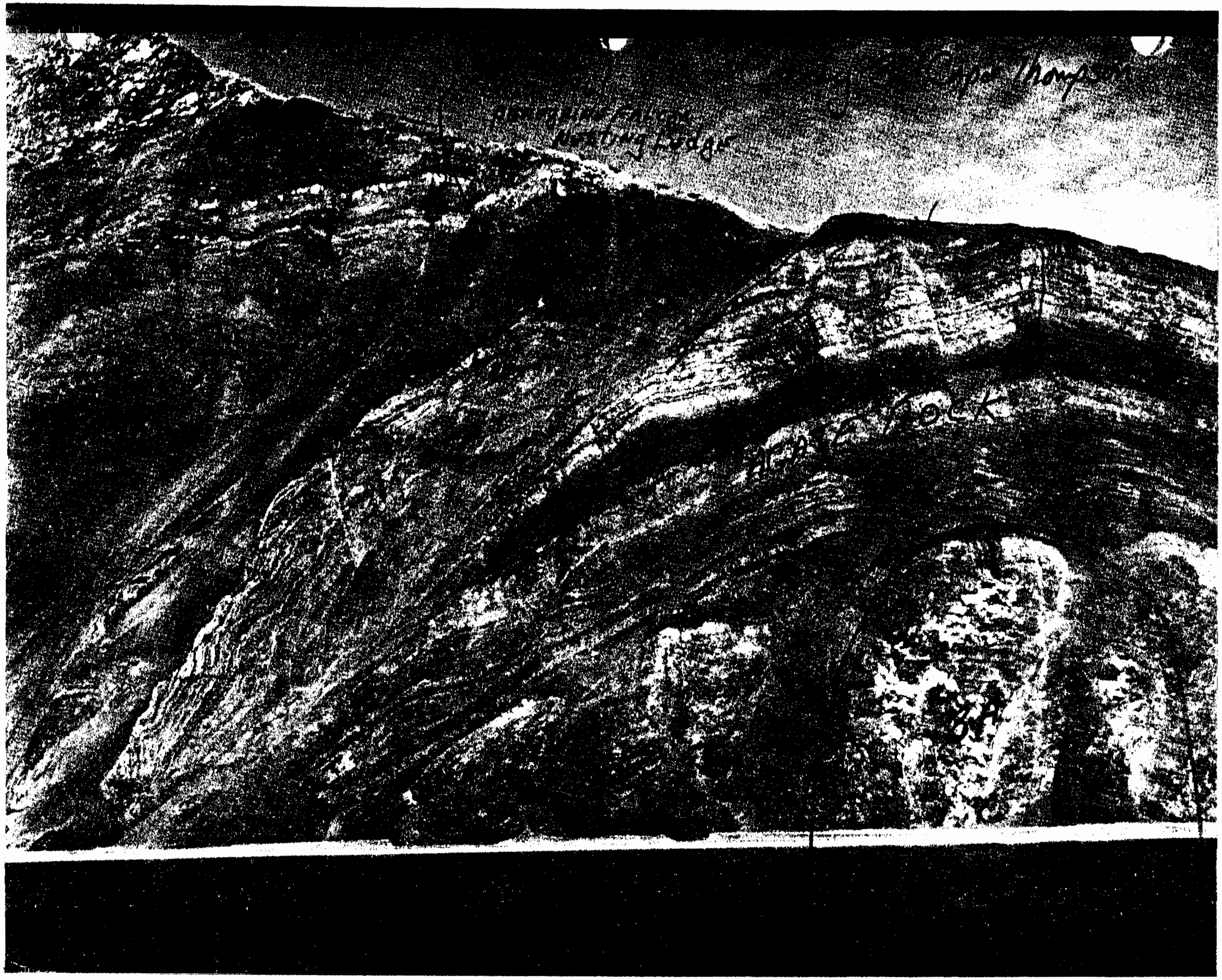


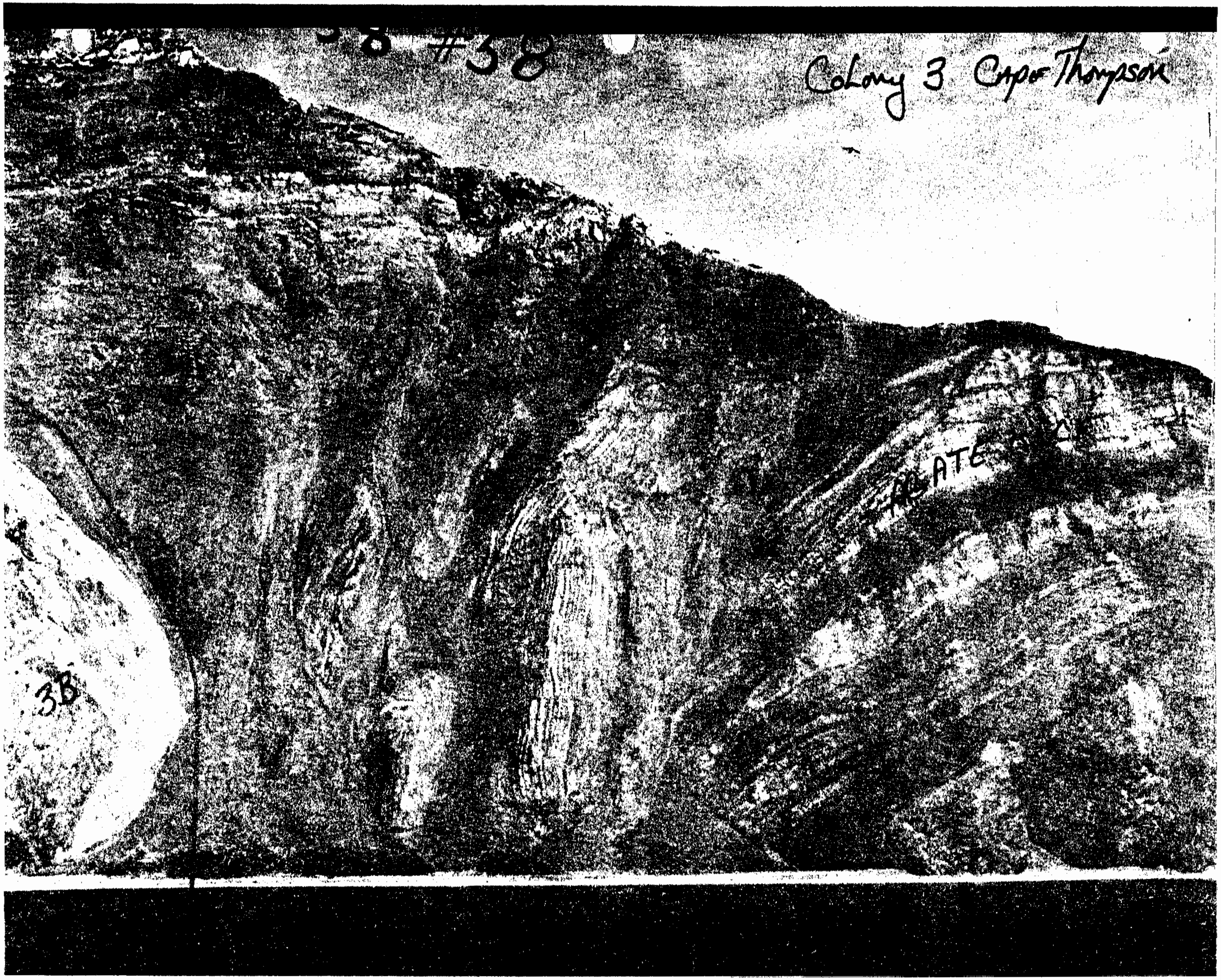
#30
golden eagle Nest
2GG
2FF
2EE
2DD

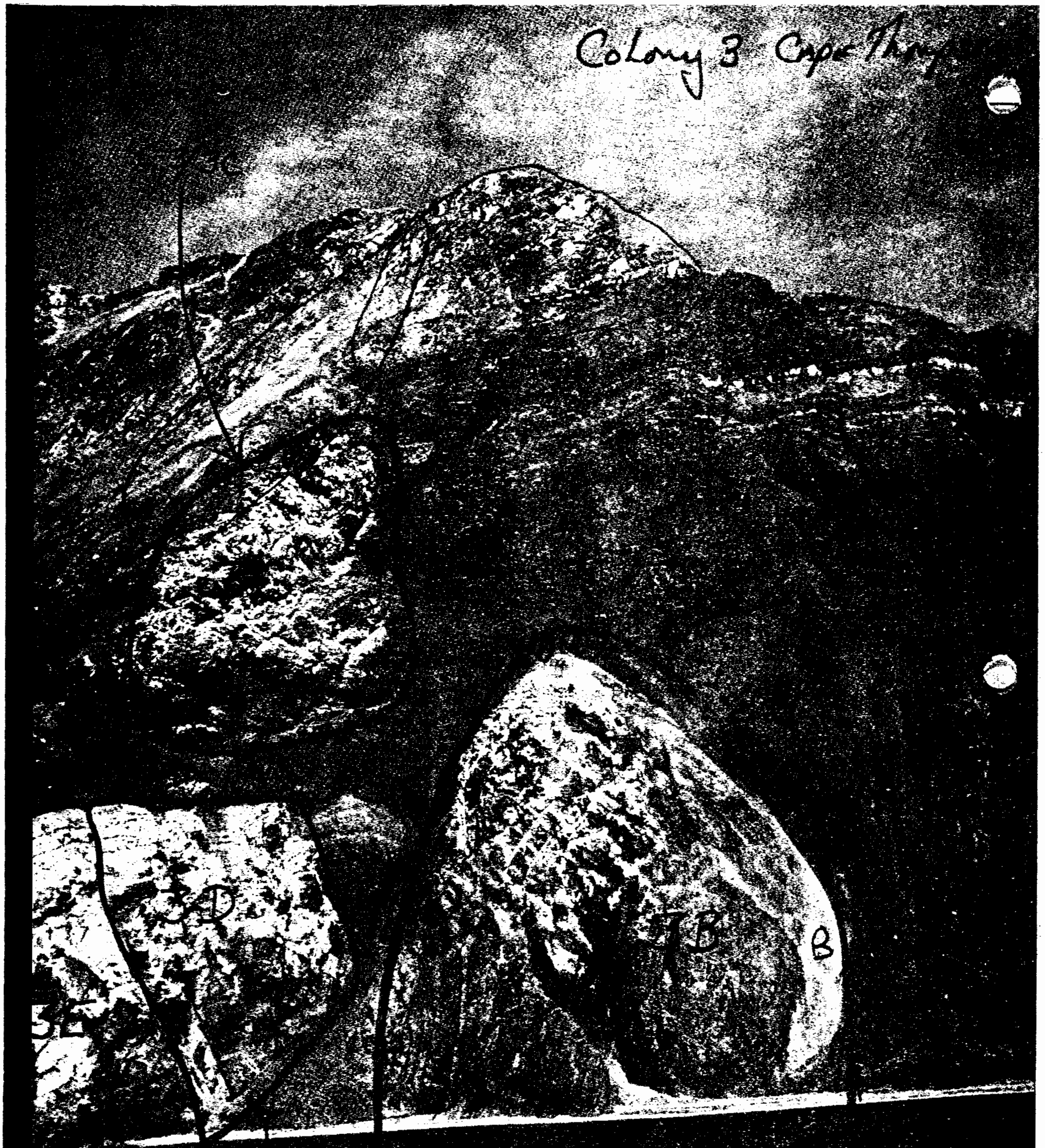

#31
Colony 2 Cape Thompson
For boundary between
2GG + 2HH, see photo #32
END
2II


#32
(skip to photo #56)
END

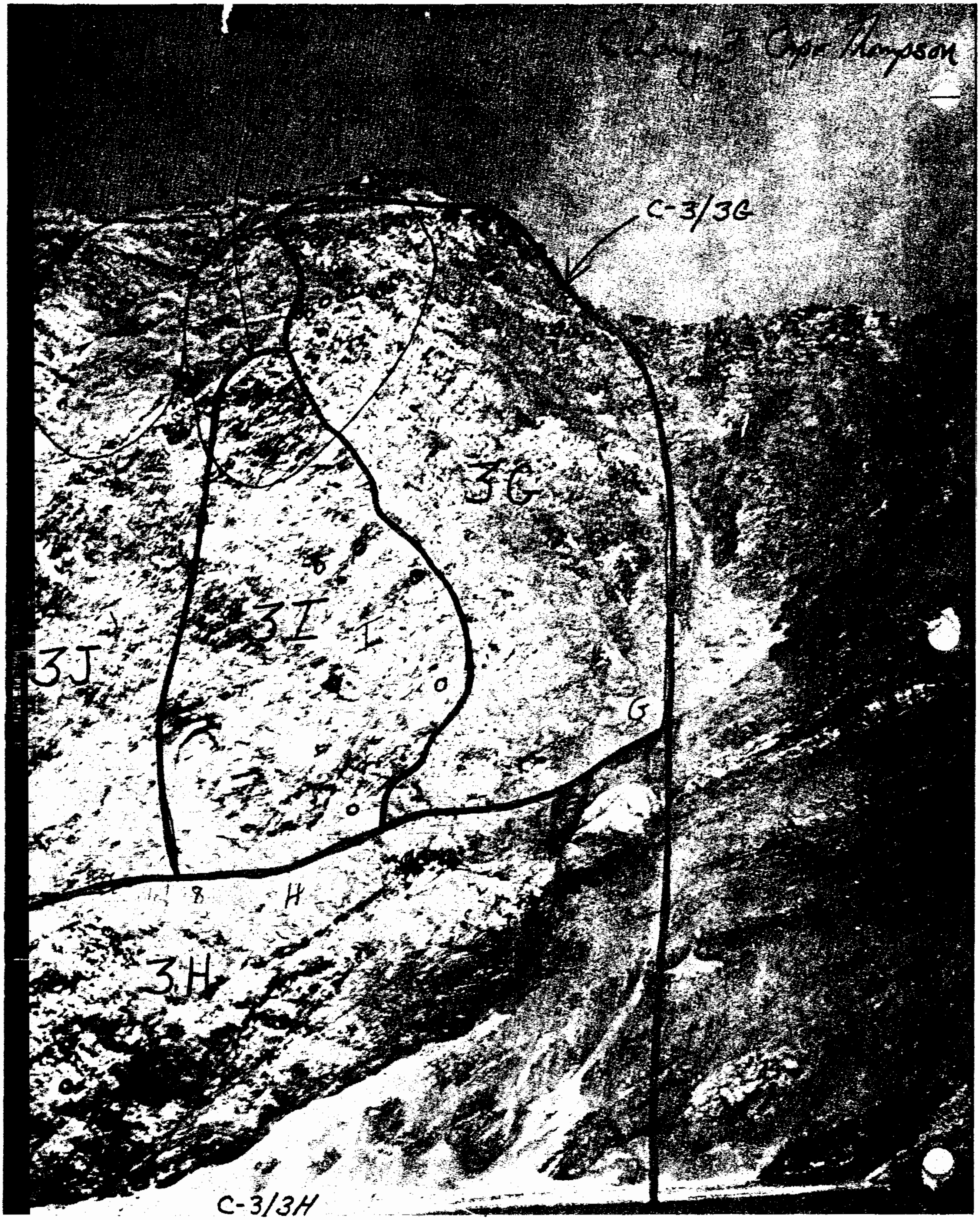


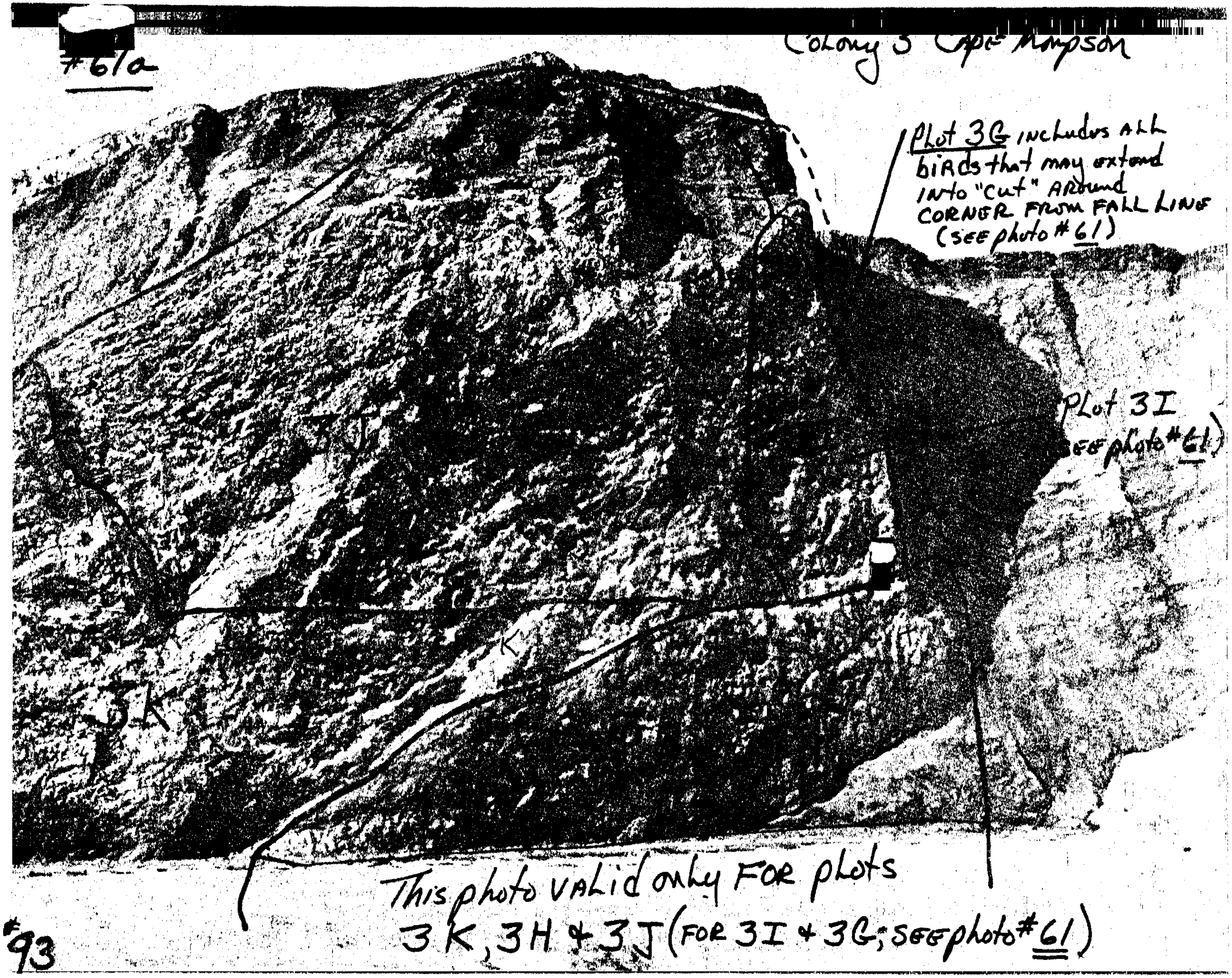

Nesting Ledge
Cape Thompson

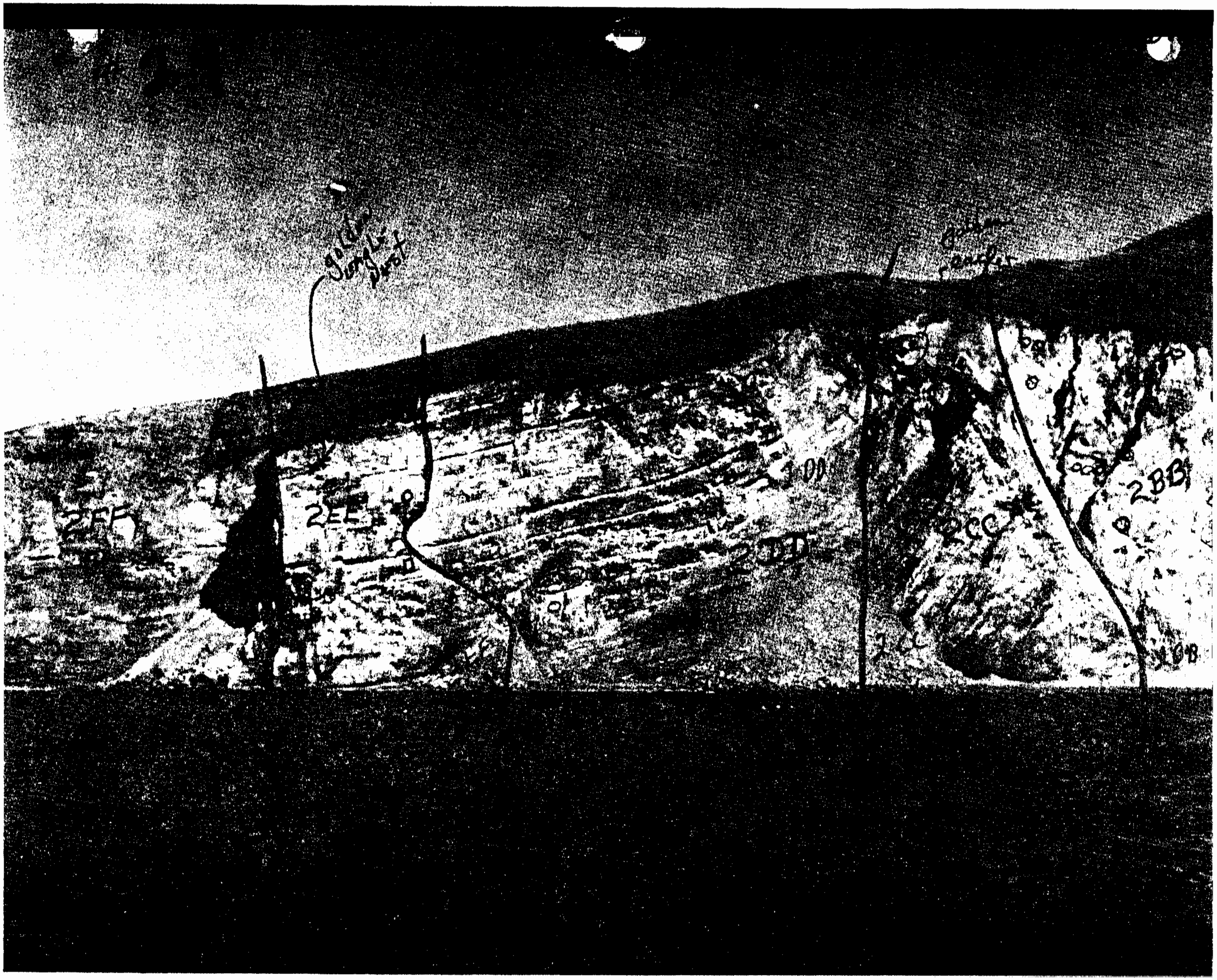

#38
Colony 3 Cape Thompson
ATE
3B

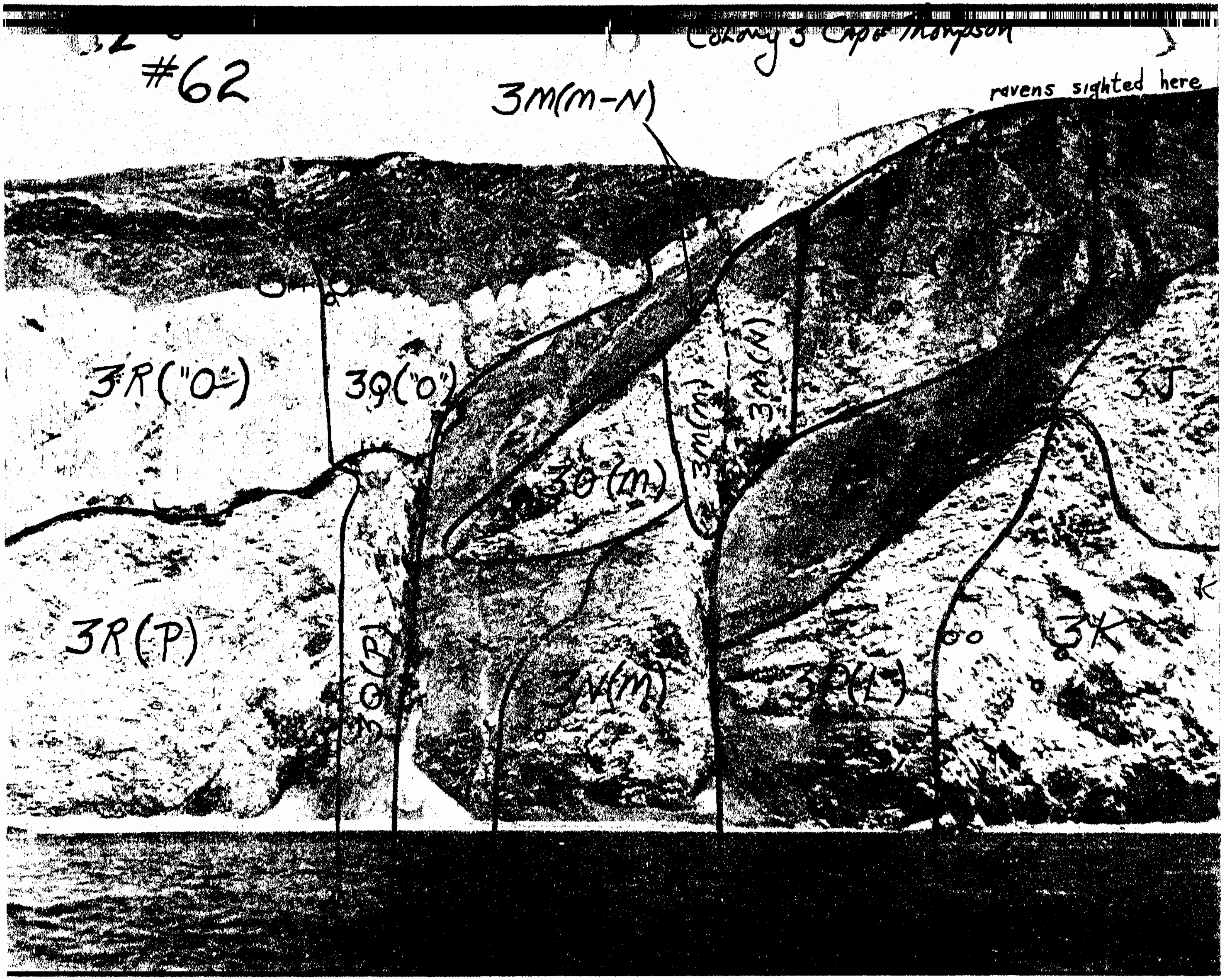

Colony 3
D
B
B

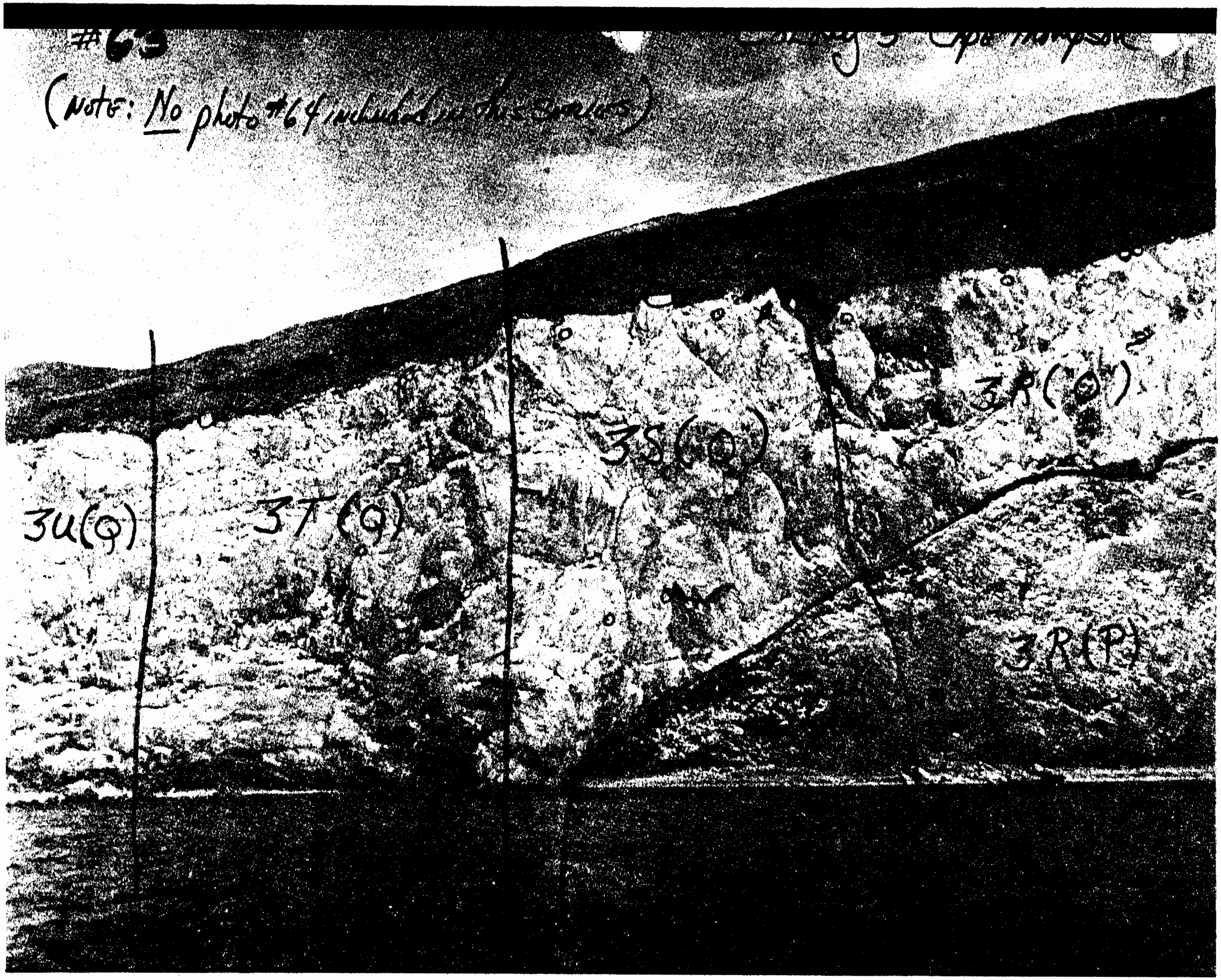

Colony 3 Cape Thompson
3D
3E
3F

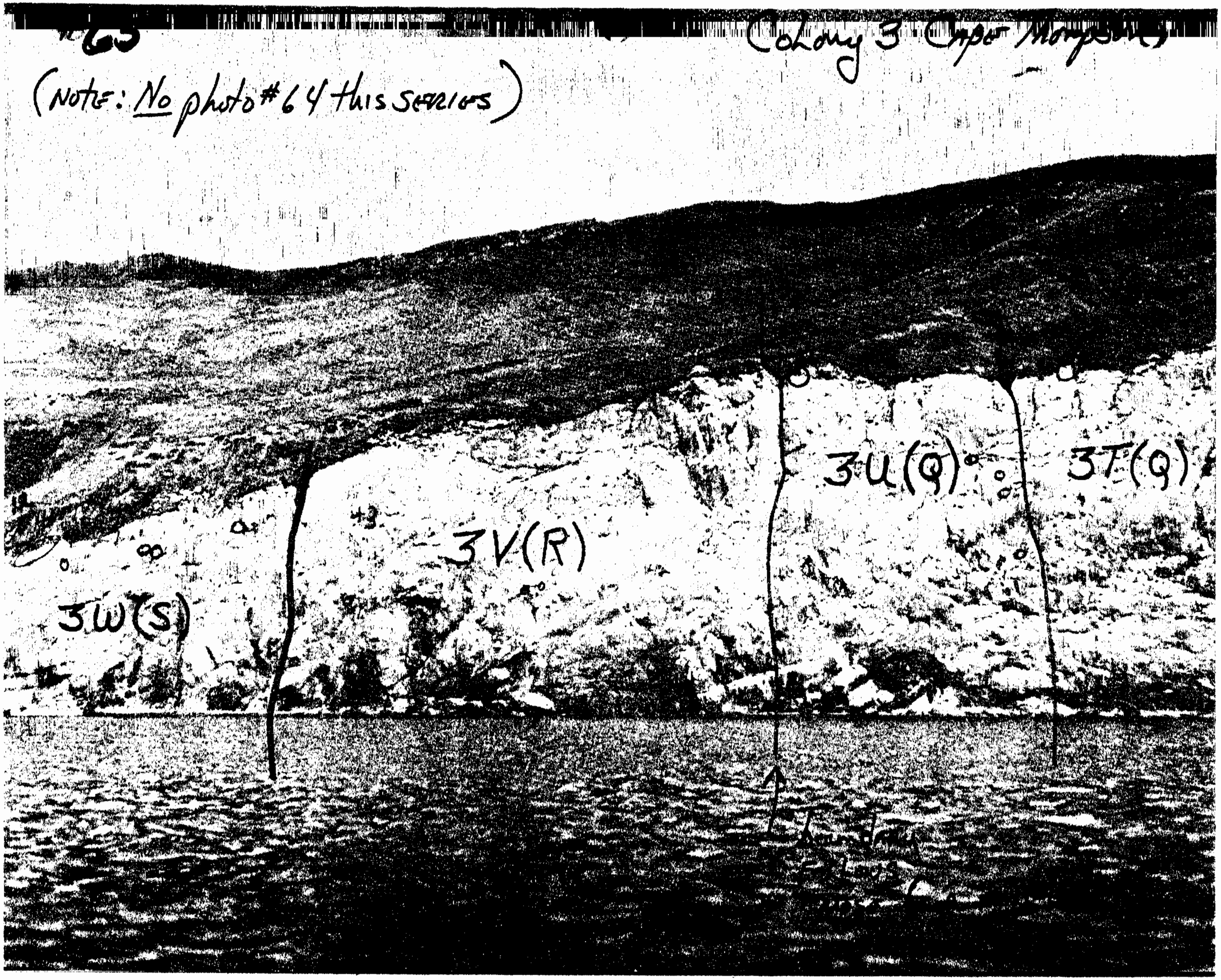

C-3/3G
3G
3I
3J
G
H
3H
C-3/3H


#61a
Colony 3 Cape Thompson
Plot 3G includes ALL birds that may extend into "cut" AROUND CORNER FROM FALL LINE (see photo #61)
Plot 3I (see photo #61)
3J
3K
This photo valid only FOR plots 3K, 3H + 3J (FOR 3I + 3G; see photo #61)
#93

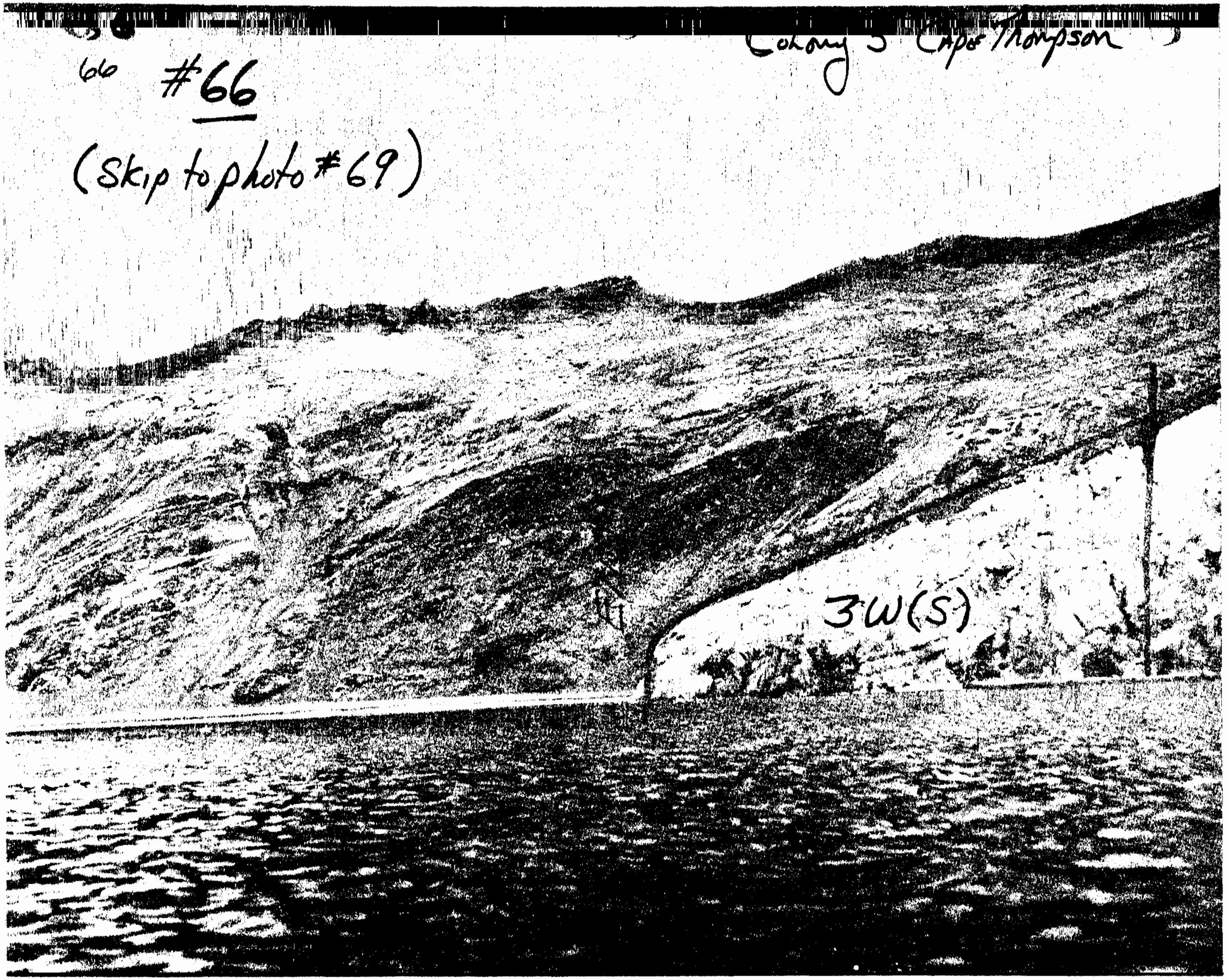

2FF
2EE
2CC
2BB

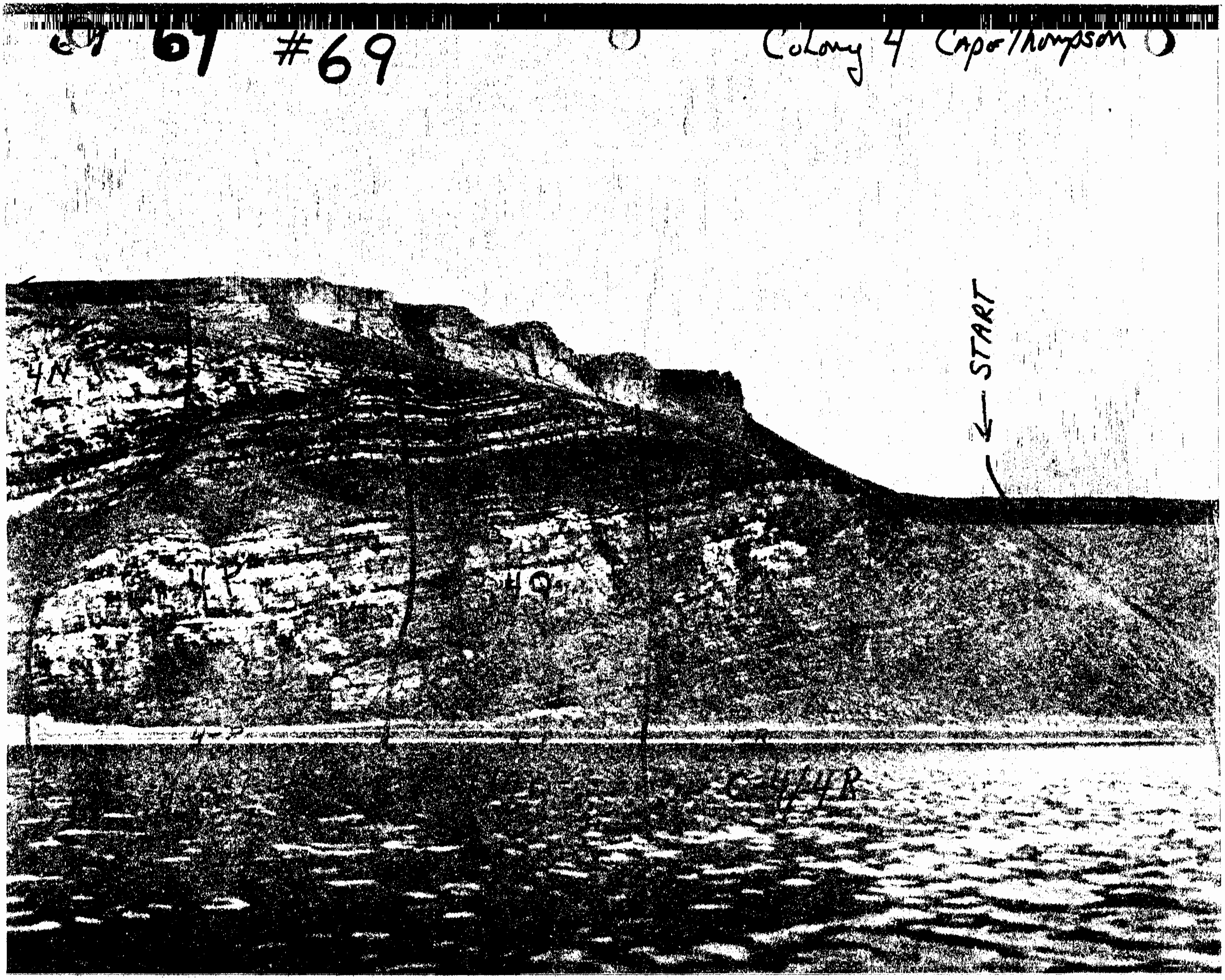

#62
3M(M-N)
ravens sighted here
3R("O")
3Q("O")
3O(M)
3M(M)
3M(N)
3J
3R(P)
3N(M)
3P(L)
3K

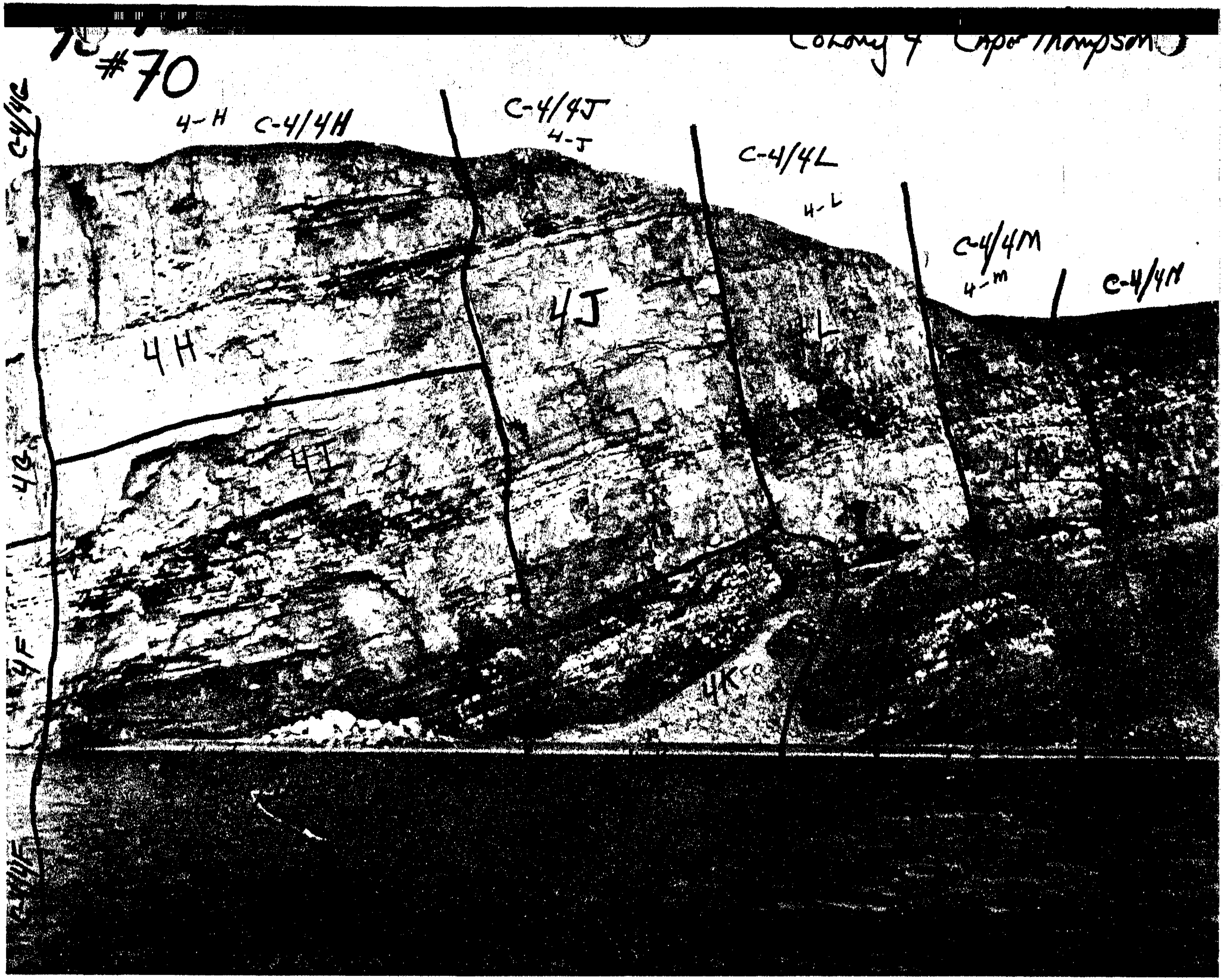

(Note: No photo #64 included in this series)
3U(Q)
3T(Q)
3S(Q)
3R(Q)
3R(P)

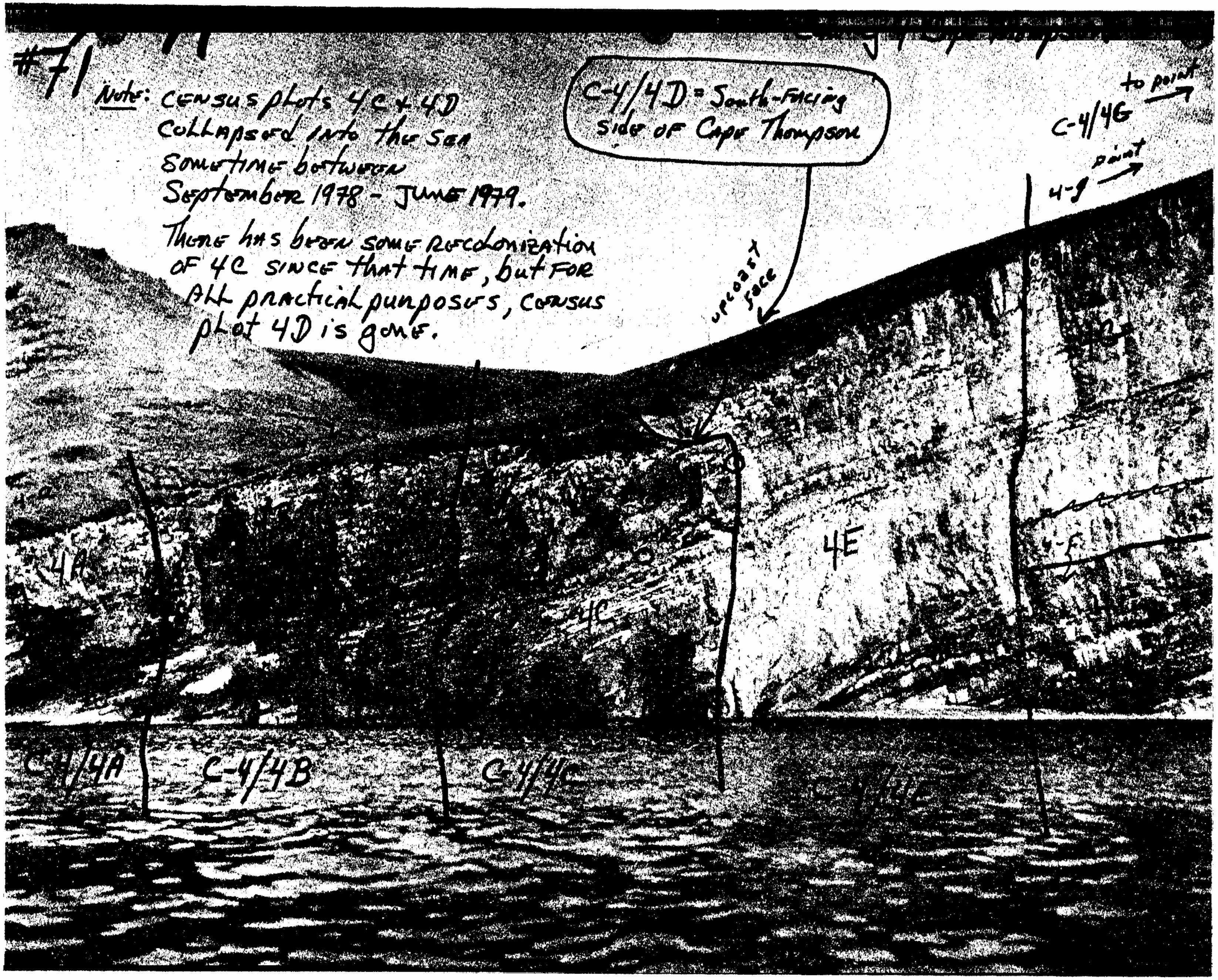


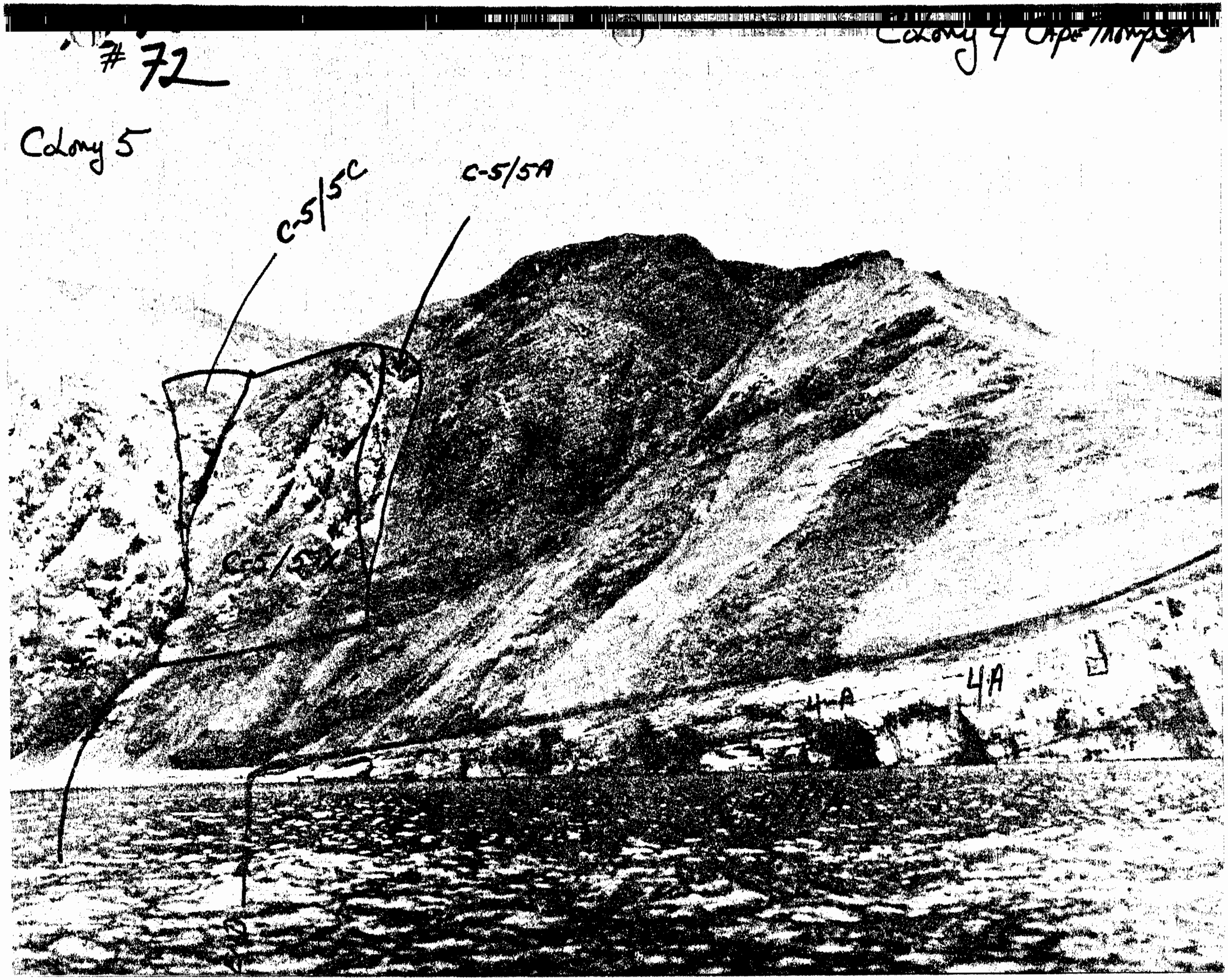
63
Colony 3 Cape Thompson
(Note: No photo #64 this series)
3W(S)
3V(R)
3U(Q)
3T(Q)

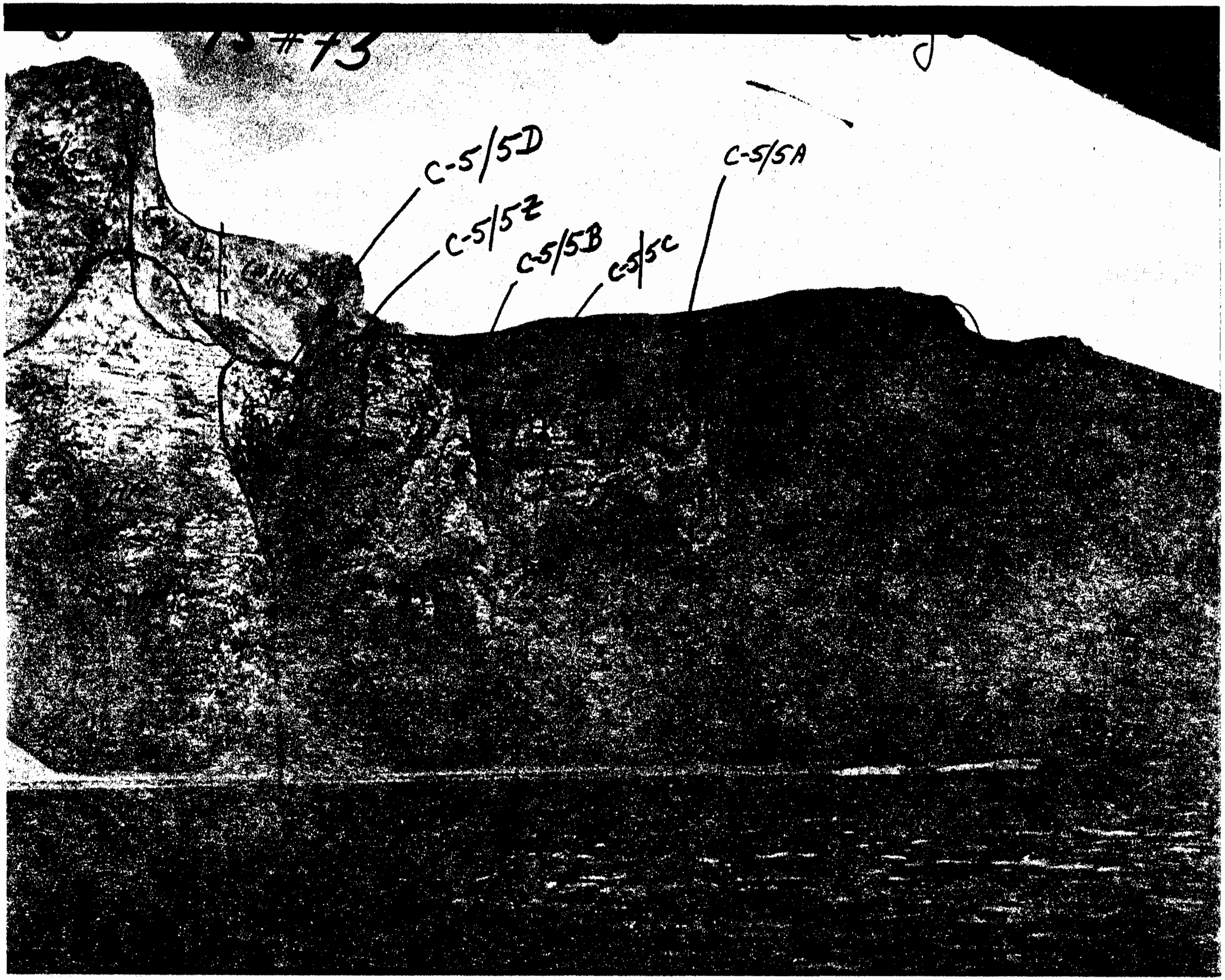

66
#66
(Skip to photo #69)
Colony 3 Cape Thompson
3W(S)


#69
Colony 4 Cape Thompson
START
4N
4Q

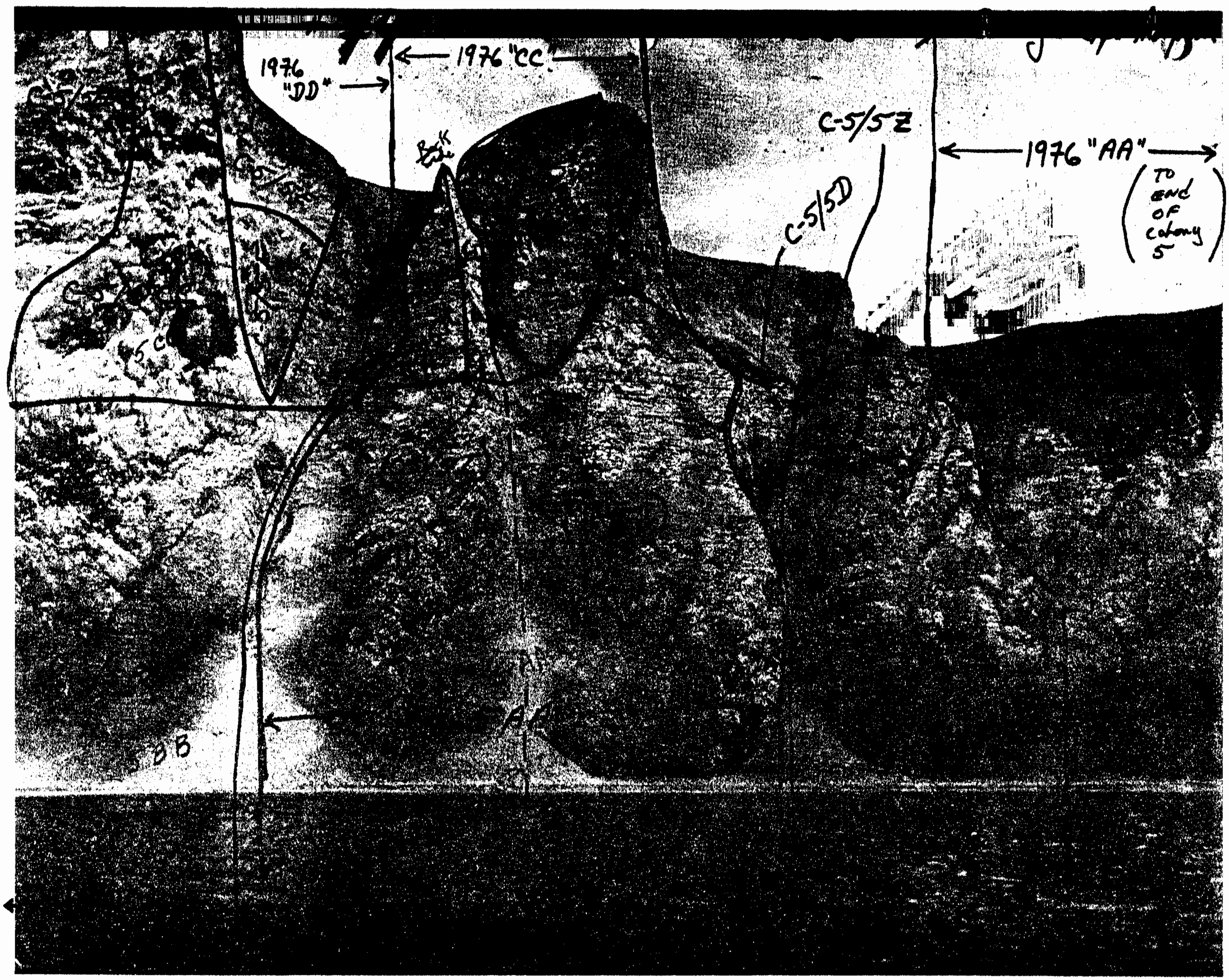

#70
Colony 4 Cape Thompson
4-H
C-4/4H
C-4/4J
4-J
C-4/4L
4-L
C-4/4M
4-m
C-4/4N
4H
4J
4K

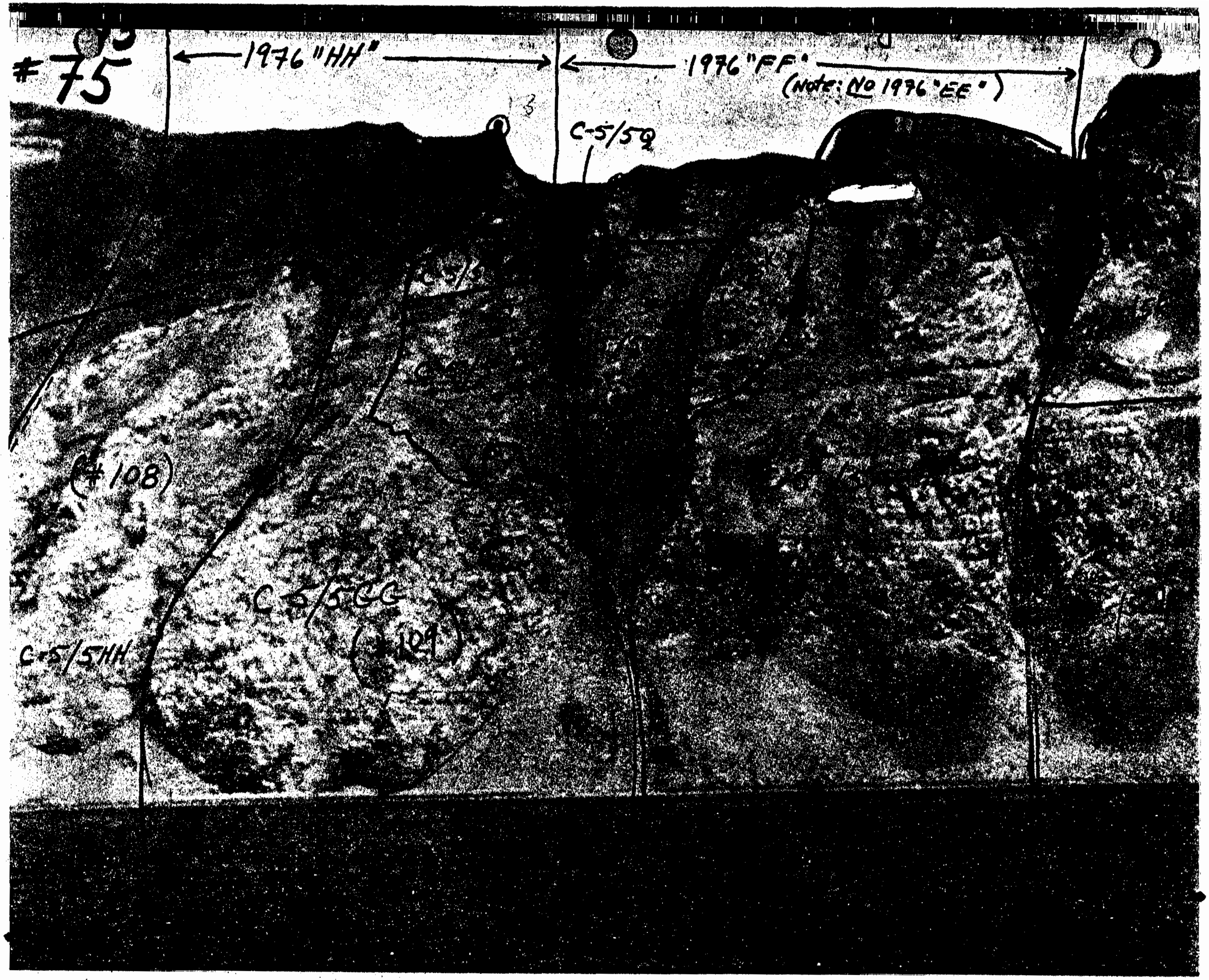

#71
Note: Census plots 4C + 4D collapsed into the sea sometime between September 1978 - June 1979.
There has been some recolonization of 4C since that time, but for all practical purposes, census plot 4D is gone.
C-4/4D = South-facing side of Cape Thompson
upcoast face
to point
C-4/4G
point
4-8
4A
4C
4E
C-4/4A
C-4/4B
C-4/4C

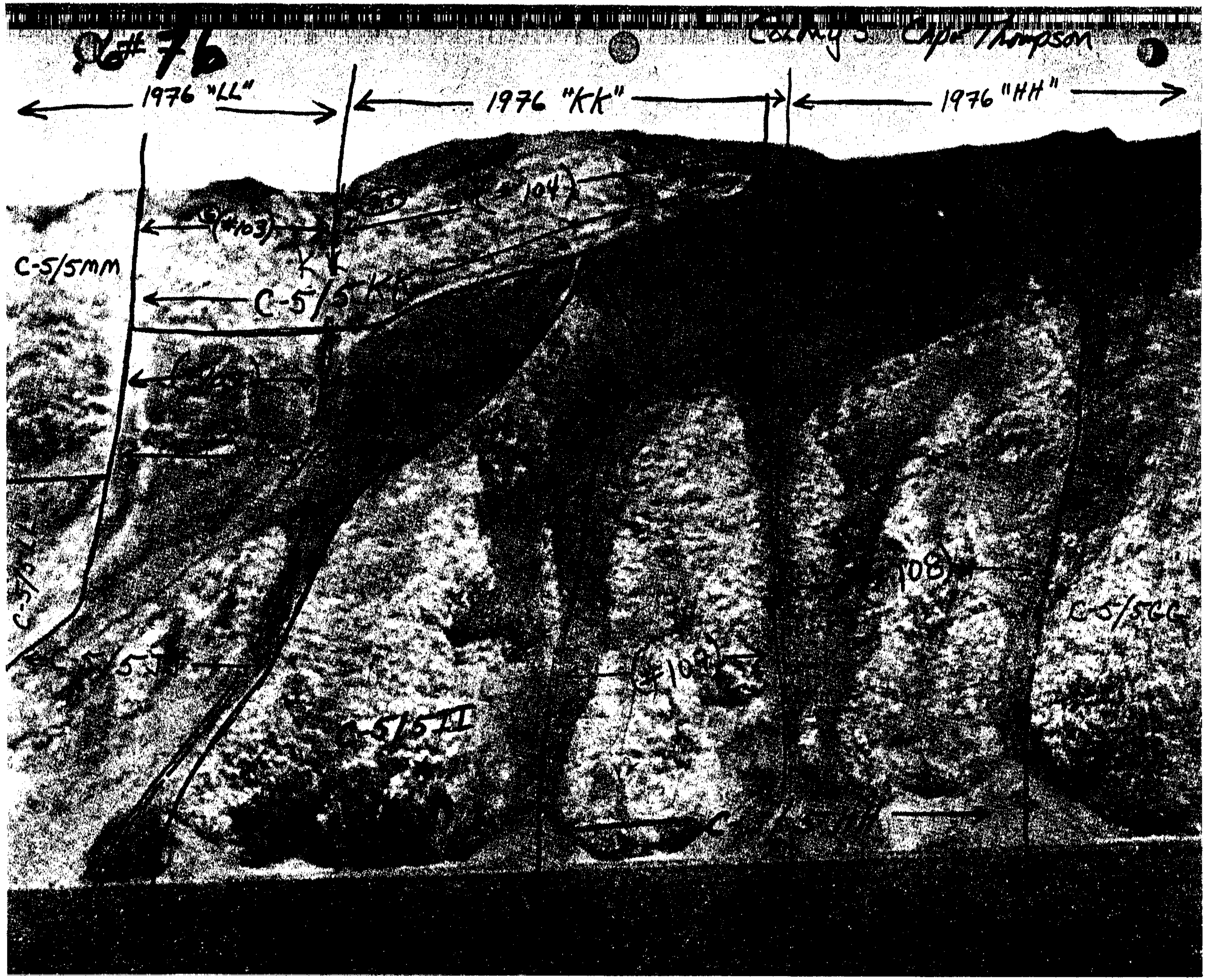

#72
Colony 4 Cape Thompson
Colony 5
C-5/5C
C-5/5A
4A
4A

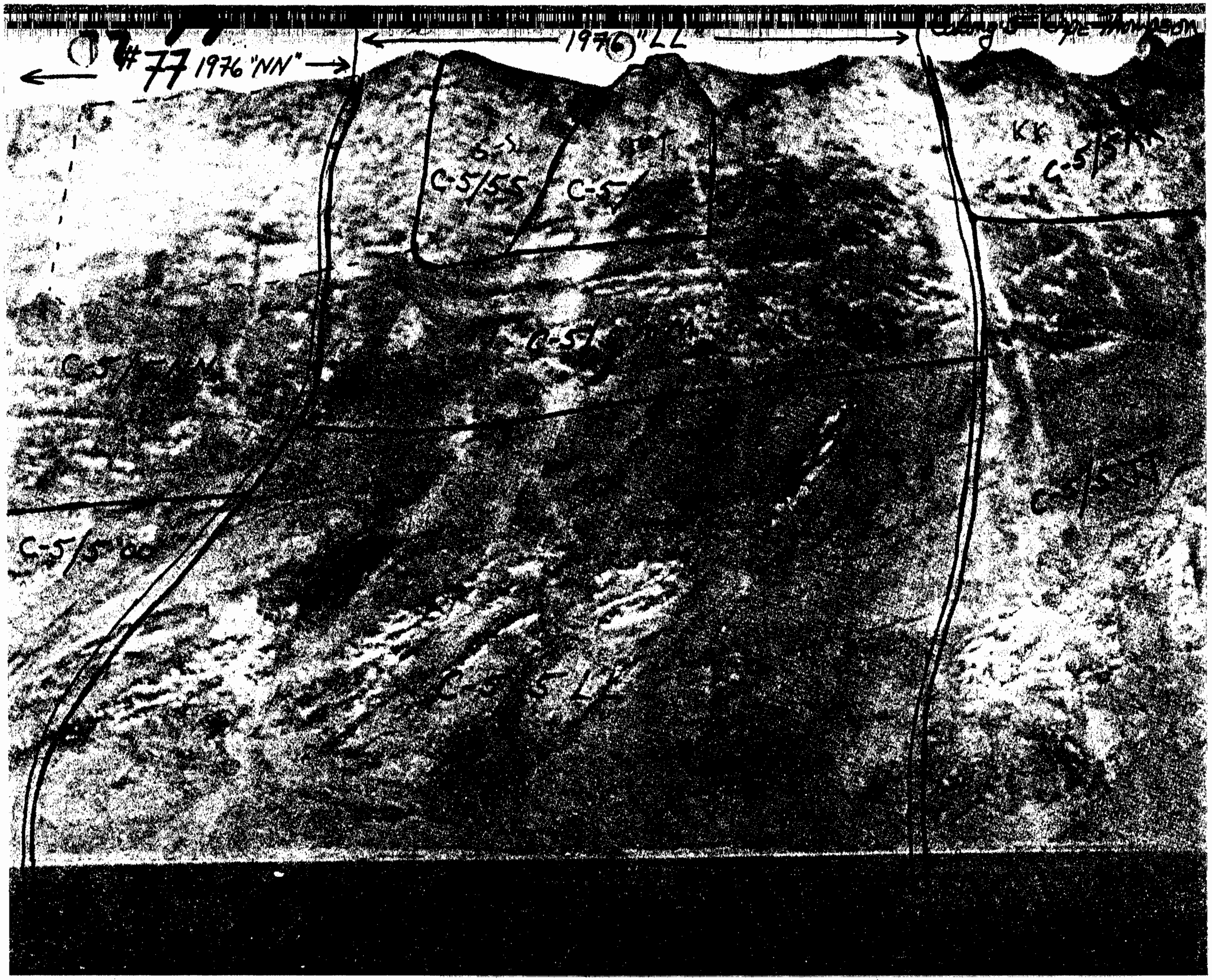


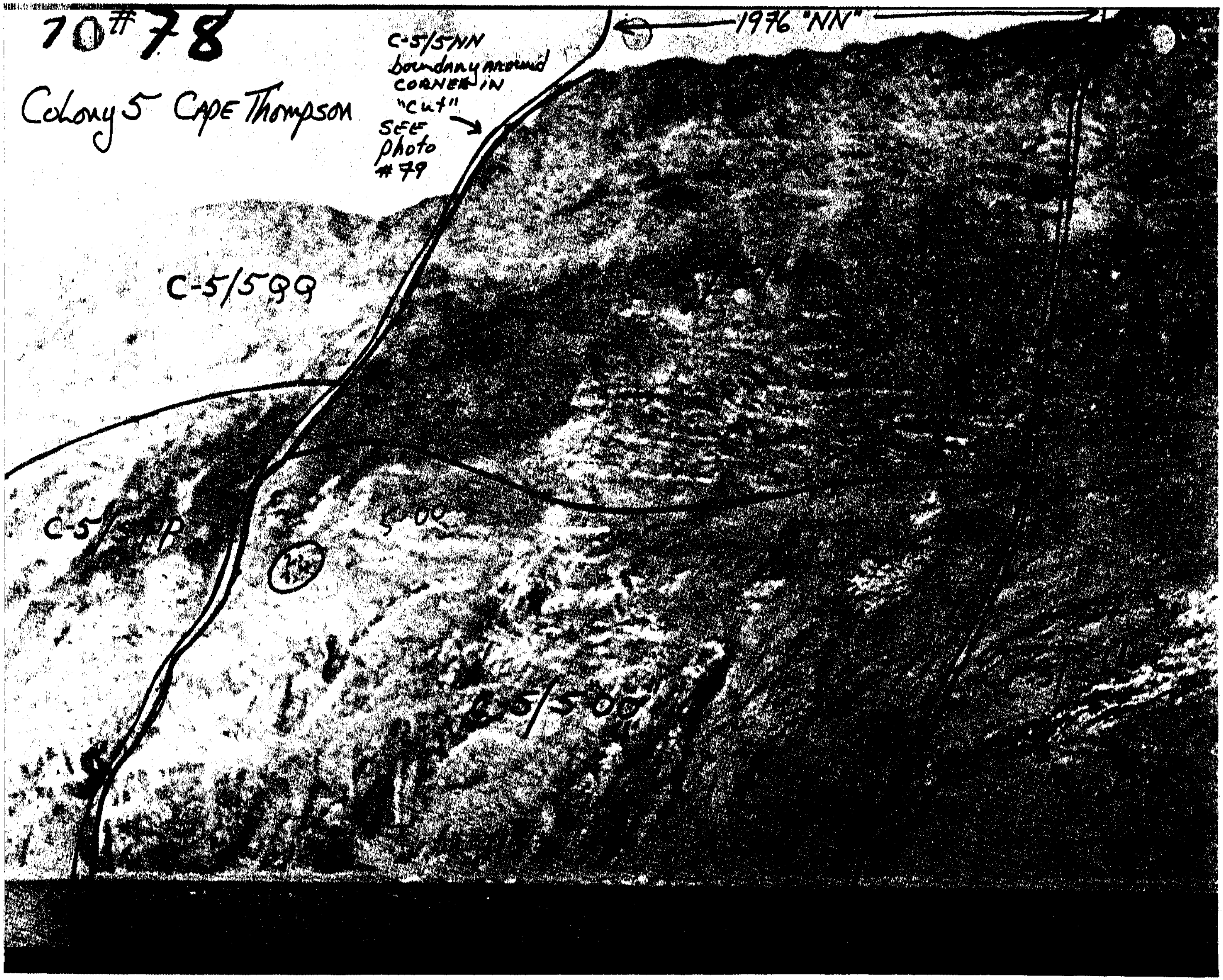
C-5/5D
C-5/5Z
C-5/5B
C-5/5C
C-5/5A

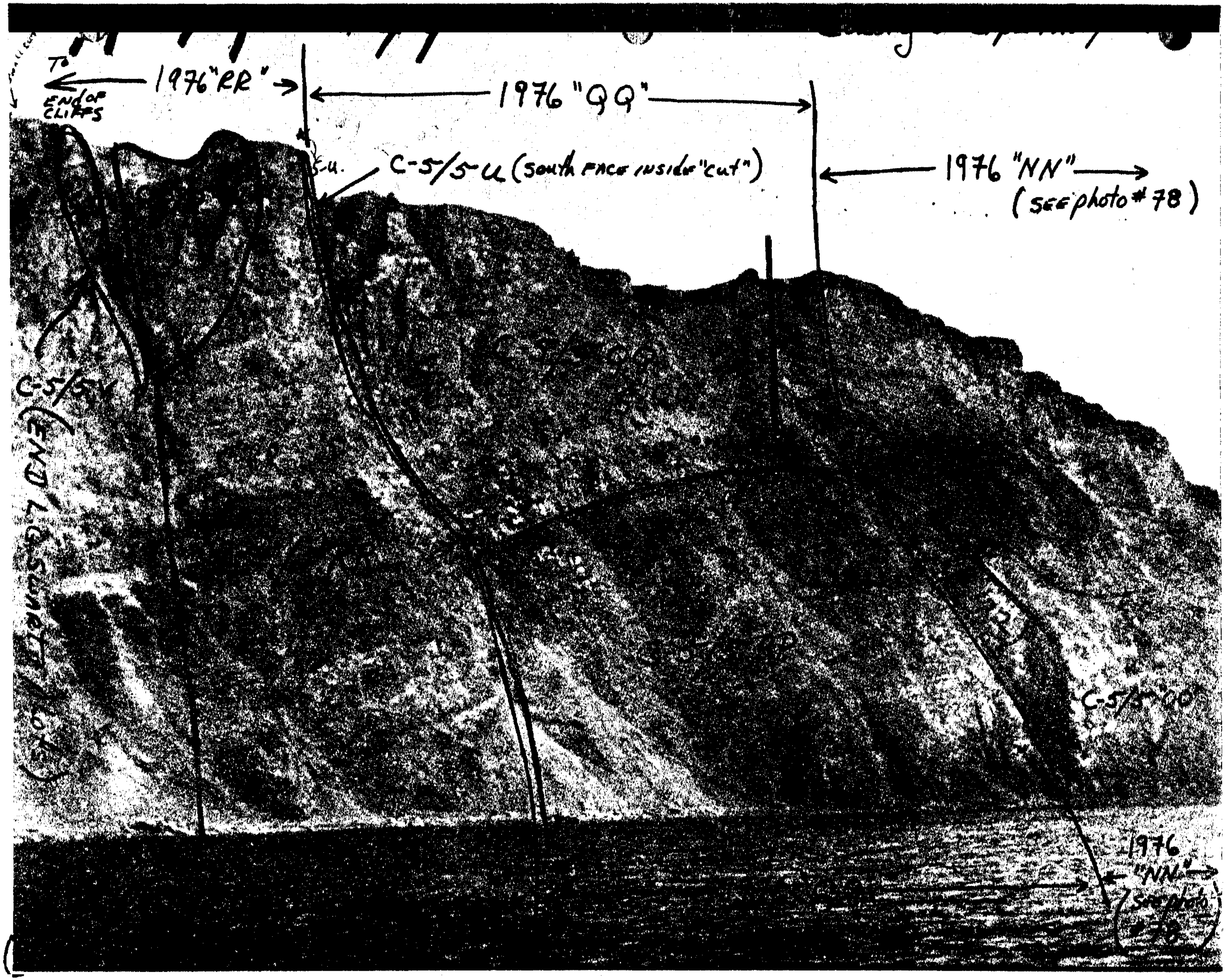

1976 "DD"
1976 "CC"
C-5/5Z
1976 "AA"
TO END OF colony 5
C-5/5D


#75
1976 "HH"
1976 "FF"
(Note: No 1976 "EE")
C-5/5Q
(#108)
C-5/5GG
C-5/5HH

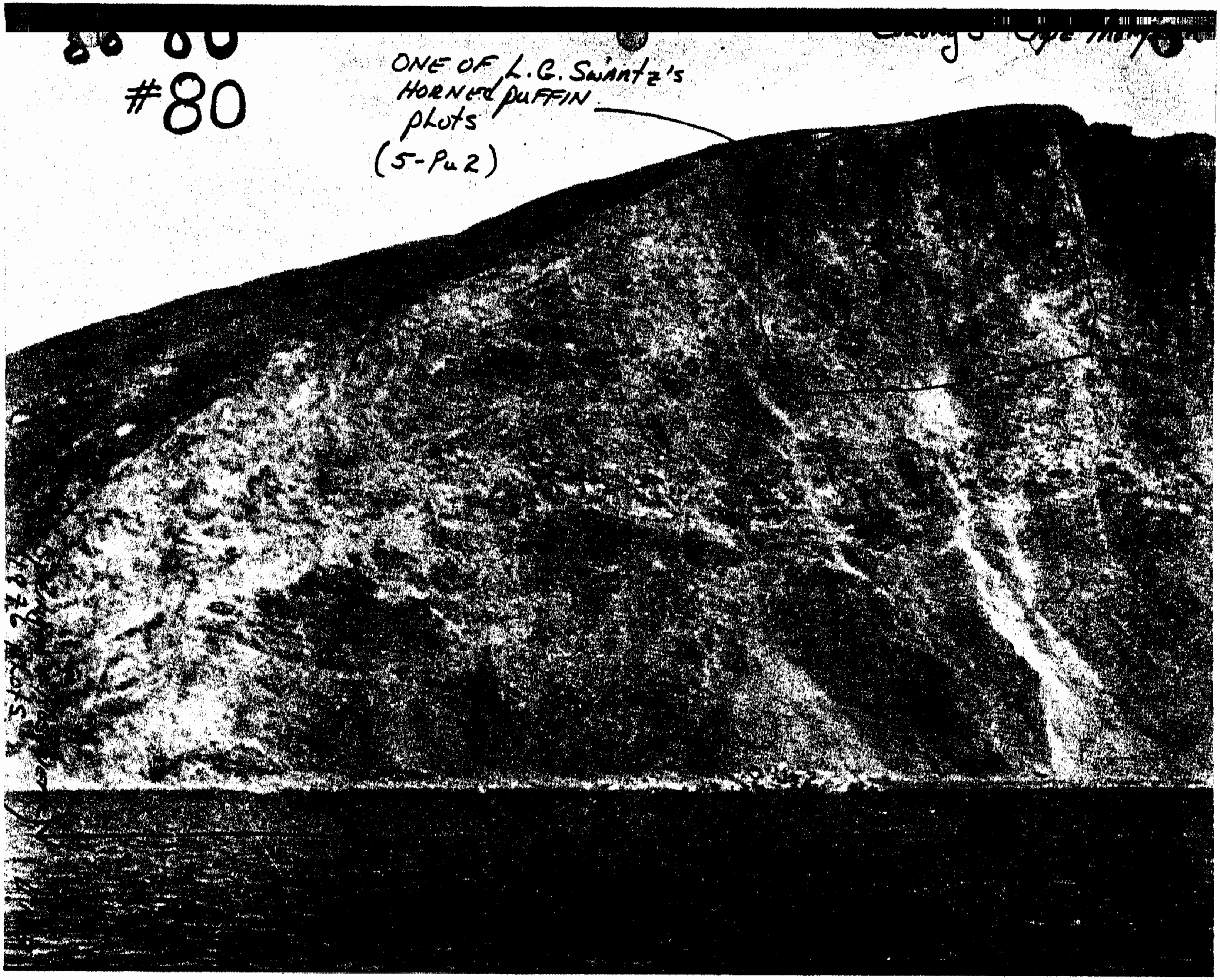

#76
1976 "LL"
1976 "KK"
1976 "HH"
(#103)
(#104)
C-5/5MM
C-5/5II
108
C-5/5GG

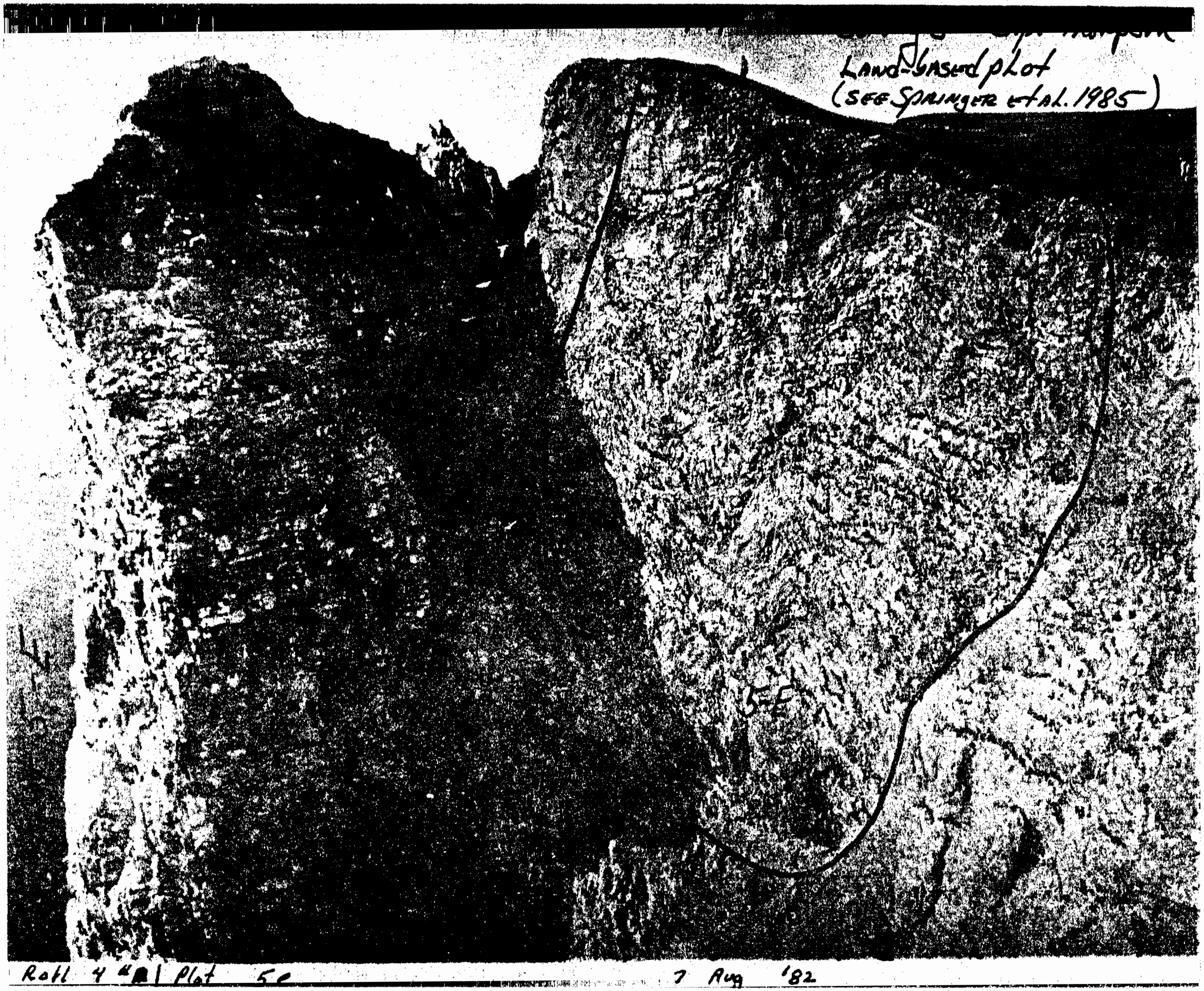

#77 1976 "NN"

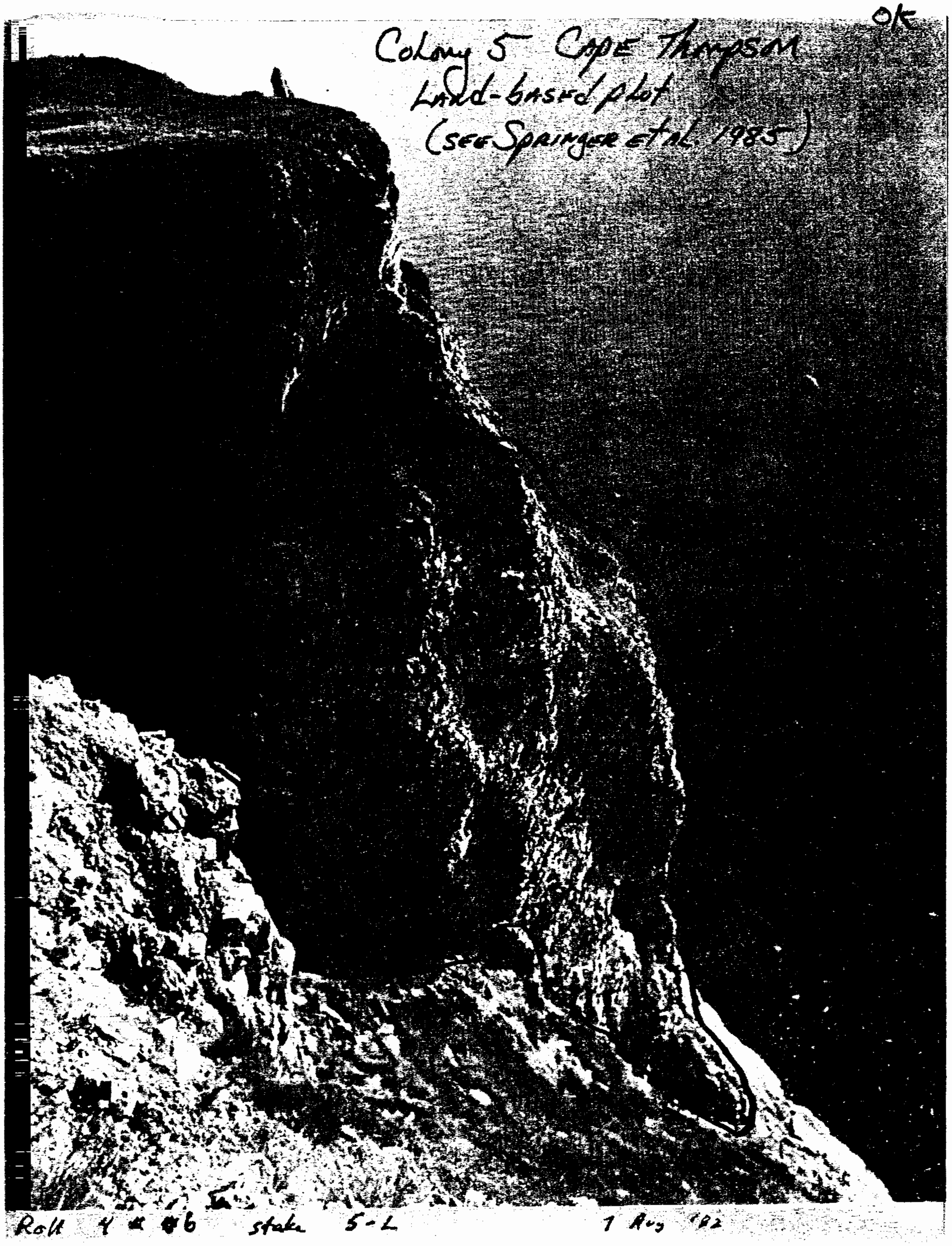

70 #78
Colony 5 Cape Thompson
C-5/5NN boundary around CORNER IN "cut" SEE photo #79
1976 "NN"
C-5/5QQ
C-5/5PP
5OO
C-5/5OO

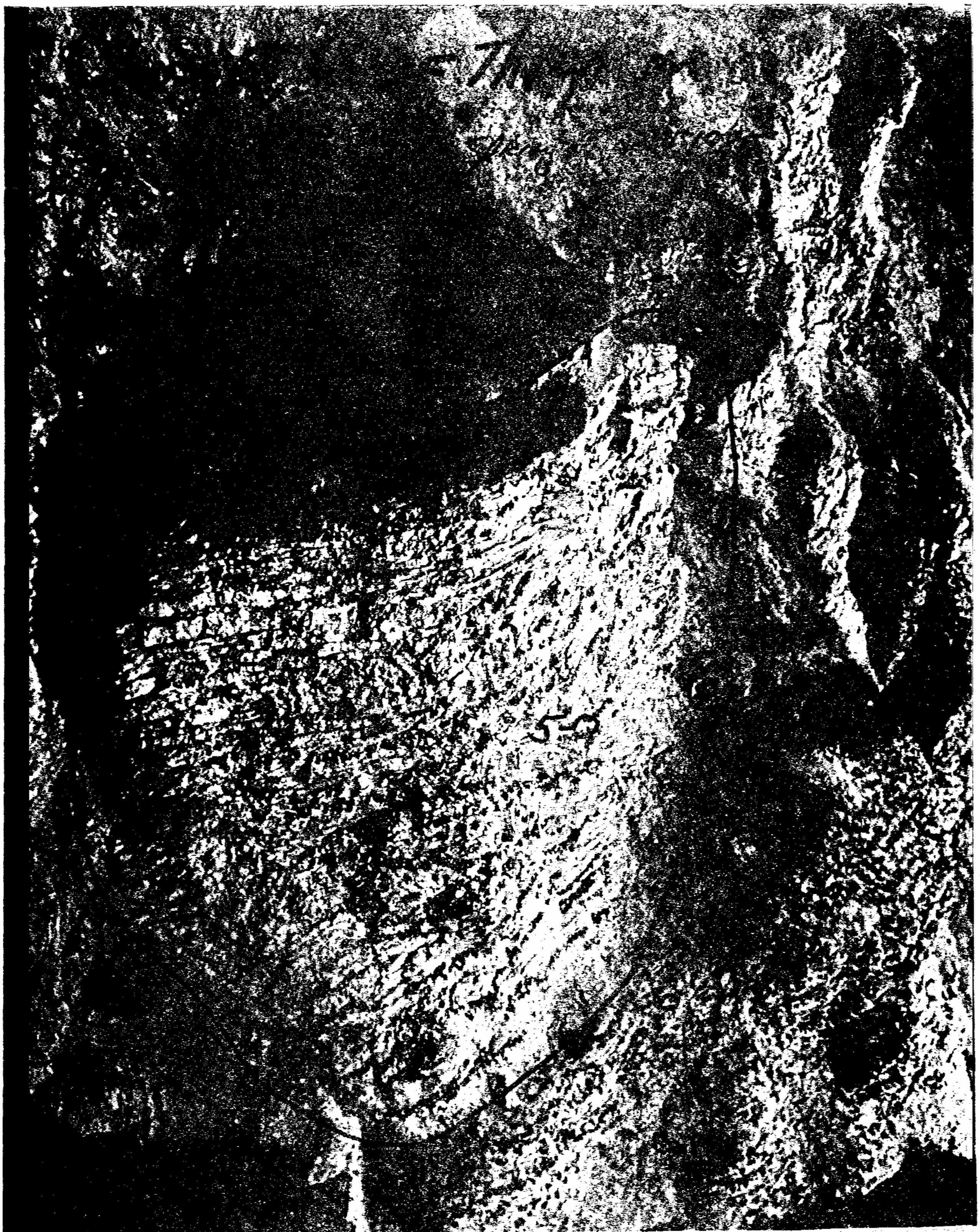


To END OF CLIFFS
1976 "RR"
1976 "QQ"
C-5/5-U (south face inside "cut")
1976 "NN"
(see photo #78)
C-5/5-V
1976 "NN"

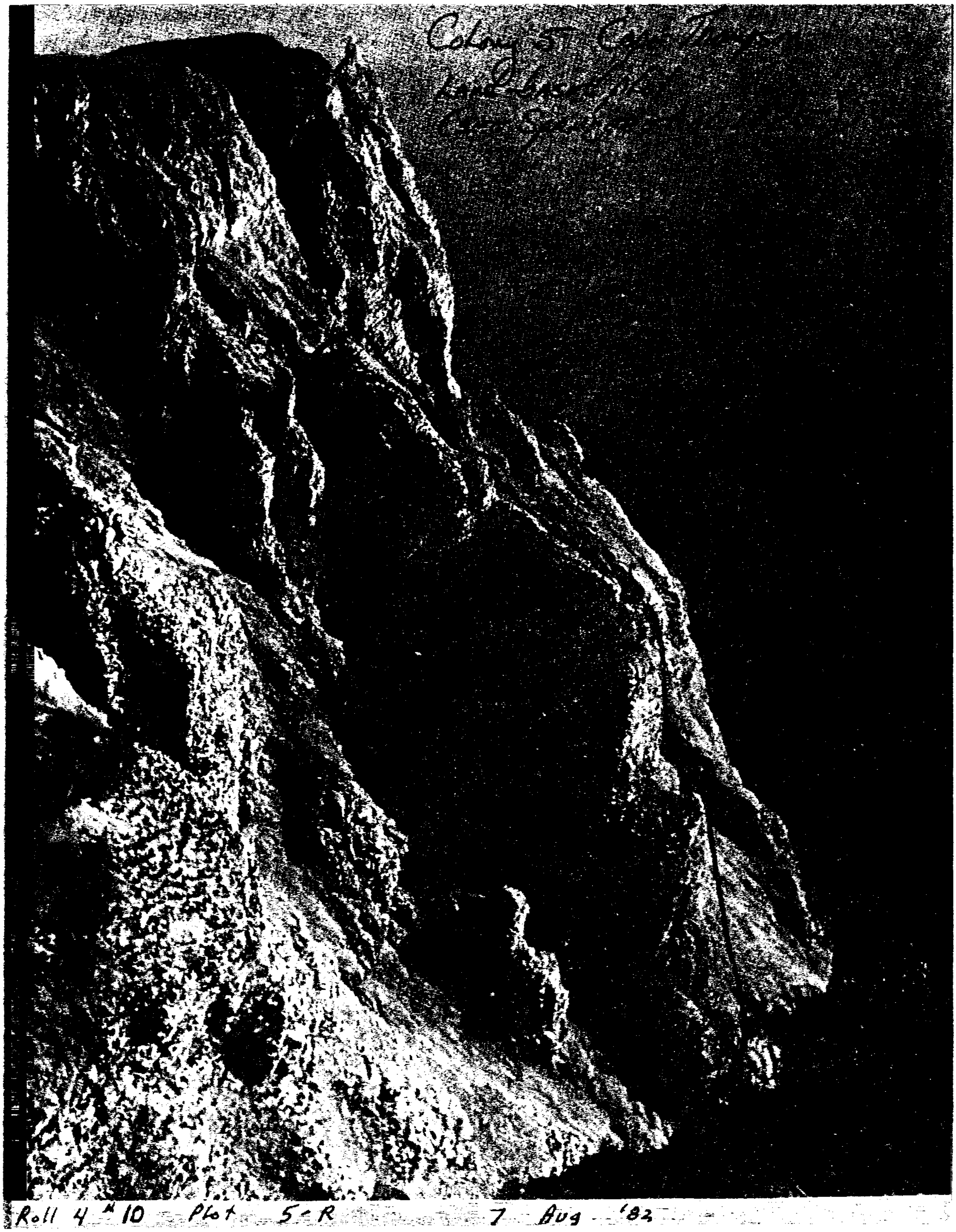

#80
ONE OF L.G. Swartz's
HORNED PUFFIN
plots
(5-Pu2)

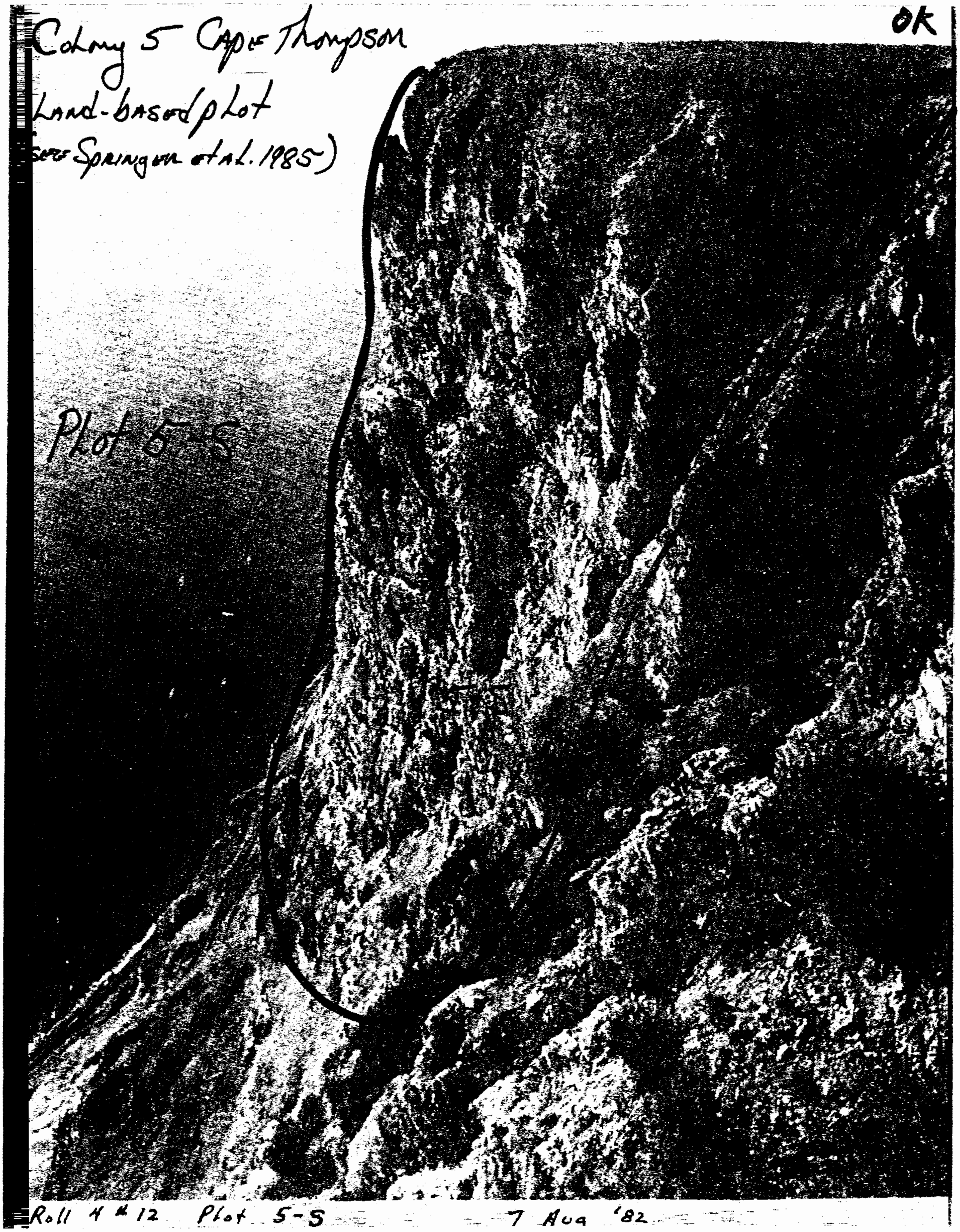

Land-based plot
(see Springer et al. 1985)
5E
Roll 4 Plot 5e 7 Aug '82


OK
Colony 5 Cape Thompson
Land-based plot
(see Springer et al. 1985)
Roll 4 # 6 stake 5-L 1 Aug '82



Roll 4 #9 Plot 5-Q 7 Aug '82


Roll 4 # 10 Plot 5-R 7 Aug '82


Colony 5 Cape Thompson
Land-based plot
(see Springer et al. 1985)
OK
Plot 5-S
Roll 4 # 12 Plot 5-S 7 Aug '82

APPENDIX G. MURRE AND KITTIWAKE CENSUS DATA FROM BOAT-BASED PLOTS AT CAPE THOMPSON, 1960-1988

Census counts at Cape Thompson have been recorded using Bering Standard Time (BST), Bering Daylight Time (BDT) and Alaska Daylight Time (ADT). BDT is 2 h earlier than present ADT times. Count means were rounded down to the next whole integer if the fraction was less than or equal to 0.5, and rounded up if it was equal to or greater than 0.51. All counts presented in the appendices are raw scores uncompensated for diurnal or other sources of variation. Colony totals are not presented if some plots were uncounted, or if it required summing plots counted from land and boat. All plots are listed using L.G. Swartz' 1960 plot designations unless otherwise specified (see further information for Colonies 3 and 5 immediately following). The following list contains the names of the observers who have participated in counts at Cape Thompson. The right-hand column lists the observer codes used by A.M. Springer, D.G. Roseneau and E.C. Murphy in their reports. In this report, the initials of the observers are used to identify personnel making the counts.

Belson, L.M.	(LMB)	
Burger, J.L.	(JLB)	
Cox, G.W.	(GWC)	
Dillard, M.A.	(MAD)	A
Fadely, B.S.	(BSF)	
Hatch, S.A.	(SAH)	
Hawkings, J.	(JH)	
Johnson, D.	(DJ)	B
Jones, K.	(KJ)	R
MacDonald, D.	(DM)	
Mule', R.S.	(RSM)	K
Murphy, E.C.	(ECM)	F
Norton, D.	(DN)	
Powers, A.	(AP)	
Rodewald, P.	(PR)	
Roseneau. D.G.	(DGR)	E
Schene, L.	(LS)	
Springer, A.M.	(AMS)	C
Springer (Johnson), M.I.	(MIJ)	H

Stern, J.	(JS)	G
Swartz, L.G.	(LGS)	D
Taylor, D.	(DT)	
Tritel, B.	(BT)	
Troy, D.	(DT)	
Walker II, W.	(WW)	I
Watson, A.	(AW)	J
Willoughby, E.J.	(EJW)	

COLONY 3 CENSUS PLOT CONVERSION GUIDE

This guide provides conversions to allow direct comparisons to be made between: 1) L.G. Swartz' 1960-61 data; 2) A.M. Springer and D.G. Roseneau 1976-1977 data as reported in Springer and Roseneau (1977) Table 4, and Springer and Roseneau (1978) Table 4; 3) A.M. Springer, D.G.Roseneau, E.C. Murphy and M.I. Springer's 1982 data as reported in Springer et al. (1985) Table 5. Colony 3 census plots were not counted in 1988.

TABLE G.1. COLONY 3 CENSUS PLOT DESIGNATIONS

(L.G. Swartz) Field Seasons		(Springer and Roseneau 1977, 1978) Field Seasons		(Springer et al. 1985) Field Season
1960	1961	1976	1977	1982
A	A	A	A	A
B	B	B	B	B
C	C	C	C	C
D	D	D	D	D
E	E	E	E	E
F	F	F	F	F
G	G	G	G	G
H	H	H	H	H
I	I	I	I	I
J	J	J	J	J
K	K	K	K	K
L	L			L
M	M			M
N	N	M+N	M+N	N
O	O			O
P	P	L	L	P
Q	Q			Q-O + Q-P
R	R	O+P	O+P	R-O + R-P
S	S			S-O + S-P
T	T	Q	Q	T
U	U			U
V	V	R	R	V
W	W	S	S	W

Note that on Colony 3 photographs (Appendix F), census plots designated by only one letter (i.e., plots 3A-3K) are L.G. Swartz' original plots. Also note that the remainder of the census plots are labelled with more complex designations. These designations are interpreted as follows:

3Q(0)

Colony 3 — LGS 1960 plot Q — Springer and Roseneau 1976 and 1977 plot 0

Further note that designations such as "Q-0", "Q-P", "R-0", "R-P", "S-0" and "S-P" as used in some reports (e.g., Springer et al. 1985) are equal to 3Q(0), 3Q(P), 3R(0), 3R(P), 3S(0) and 3S(P), respectively.

Swartz' 1960 plots L, M, N and 0 must be lumped to be equivalent to Springer and Roseneau's 1976 and 1977 plot M+N because:

1) 1976 and 1977 plot M is equal to Swartz' plots N plus 0 plus about one half of Swartz' plot M (or about one half of the plot "M-N" shown on the Colony 3 photographs).

2) 1976 and 1977 plot N is equal to about one half of Swartz' plot M plus Swartz' plot L [i.e., 3M(N) + 3L(N)].

The individual 1976-1977 plots "M" and "N" can be directly compared only between these two years. To compare these two plots with any other years (i.e., Swartz' 1960 and 1961 data, or the 1979 and 1982 data), they must be added together. They are then equivalent to Swartz' plots L+M+N+0, which were counted correctly as plots L, M, N, and 0 in 1979 and 1982.

COLONY 5 - SPECIAL AREA DESCRIPTIONS

A.M. Springer, D.G. Roseneau and E.C. Murphy established 15 special areas at Colony 5 in 1977 to allow comparisons between their 1976 data and data collected by L.G. Swartz in 1960-1961. The 15 special areas were numbered 101-115. Later, it was confirmed that area #109 corresponded directly to Swartz' 1960 plot 5GG, #111-112 corresponded directly to Swartz' 1960 plot 5AA, and area #115 corresponded directly to Swartz' 1960 plots 5Y+5Z. It was also confirmed that areas #110, #113, and #114 were in an area falling outside of Swartz' census plots and that these areas did not historically contain either murres or kittiwakes. As a consequence, only special areas #101-108 are important in converting data for comparisons between years.

#101: The extreme left end of 1960 census plot 5NN, bounded on the bottom by 1960 plot 5PP. It faces northwest and its upper boundaries are the right and left points on the skyline forming a "notch". This plot has never had any birds in it.

#102: The right end of 1960 census plot 5PP, which is right of a big natural vertical "cut" or "draw" to the left boundary of 1960 plot 5OO (the big natural vertical cut appears to most observers as the "natural" place to have made the boundary between 5OO and 5PP).

#103+104: Equals 1960 census plot 5KK.

#103: The left third of 1960 plot 5KK. Its right boundary is a natural vertical "cut" or "draw" in 5KK, about one third of the way to the right of the left boundary of 5KK.

#104: The right two thirds of 1960 plot 5KK. Its left boundary is a natural vertical "cut" or "draw" in 5KK, about one third of the way to the right of the left boundary of 5KK.

#105+106: 1960 census plot 5JJ.

#105: The left two thirds of 1960 plot 5JJ. It contains 95%+ of the birds in 5JJ, and includes all of the lower "white" area and the upper "black" area left of the vertical "blackline".

#106: The right one third of 1960 plot 5JJ. It contains less than 5% of the birds in 5JJ, which are those in the center of the lower "cut" between 1960 plot 5II and the lower white rock complex in 5JJ, as well as the birds in a small "black" hole near the center of "black" area above the "cut" and below the right one third of 1960 plot 5KK.

#107+108: 1960 census plot 5HH.

#107: Left half of 1960 plot 5HH.

#108: Right half of 1960 plot 5HH.

#109: 1960 plot 5GG.

#110: A small triangle below 1960 plot 5N, just to the left of 1960 plot 5FF and just to the right of 1960 plots 5GG and the lower one third of 5P.

#111+112: 1960 census plot 5AA.

#113 and #114: Cliff areas south and east of census plot 5G and above census plots 5AA, 5D, 5Y, and 5Z that have not supported either murres or kittiwakes in any study year.

#115. 1960 plot 5Y.

TABLE G.2. PLOT CONVERSION GUIDE FOR COLONY 5 (ALL YEARS)

Original census plot designations assigned to Colony 5 by L.G. Swartz in 1960	Census plot designations created by A.M. Springer and D.G. Roseneau in 1976	Census plot designations as listed in Springer and Roseneau (1977) (Table 7)	Census plot designations as listed in Springer and Roseneau (1978) (Table 6)
5A,5B,5C,5X	5AA(1976)	A	A
5D,5Y,5Z	5BB(1976)	B	B
5G,5H,5I,5AA	5CC(1976)	C,E	C,E
5E,5F,5L,5BB,5CC, 5DD,5EE	5DD(1976)	D	D
5J,5K,5M,5N,5Q, 5R,5FF	5FF(1976)	F	F
5O,5P,5GG[a],5HH(part)[a]	5HH(1976)	G	G
5HH(part)[b],5II, 5JJ(part)[b],5KK(part)[b]	5KK(1976)	H	H
5S,5T,5JJ(part)[c], 5KK(part)[c],5LL,5MM	5LL(1976)	I	I
5NN(part)[d],5OO, 5PP(part)[d]	5NN(1976)	J	J
5NN(part)[e], 5PP(part)[e],5QQ	5QQ(1976)	K	K
5U,5V,5W,5RR	5RR(1976)	L	L

[a] Only that part of 1960 plot 5HH that was designated as special area #108 by A.M. Springer, D.G. Roseneau and E.C. Murphy in 1977 (see above). Plot 5GG is also equal to special area #109.

[b] Only those parts of 1960 plots 5HH, 5JJ, and 5KK that were designated special areas #107, #106, and #104, respectively, by A.M. Springer, D.G. Roseneau and E.C. Murphy in 1977 (see above).

[c] Only those parts of 1960 plots 5JJ and 5KK that were designated as special areas #105 and #103, respectively, by A.M. Springer, D.G. Roseneau, and E.C. Murphy in 1977 (see above).

[d] All of 1960 census plot 5NN excluding that part designated by special area #101 by A.M. Springer, D.G. Roseneau, and E.C. Murphy in 1977; and only that part of 1960 plot 5PP that was designated special area #102 (see above).

[e] Only that part of 1960 plot 5NN that was designated as special area #101, and all of 1960 plot 5PP excluding that part designated special area #102 by A.M. Springer, D.G. Roseneau and E.C. Murphy in 1977 (see above).

Note: Census plot CC(1976) includes special area #113 (see above), but area #113 is not included in any of L.G. Swartz 1960 census plots. Therefore, to correctly compare data collected by A.M. Springer, D.G. Roseneau, and E.C. Murphy in 1976, 1977,1979 and 1982, special area #113 must be included (or entirely excluded) in the total for census plot CC(1976) or its equivalent [i.e., C+E in 1976 (Table 7 in Springer and Roseneau 1977) and 1977 (Table 6 in Springer and Roseneau 1978)]. However, to compare data collected by A.M. Springer, D.G. Roseneau and E.C. Murphy in 1976,1977,1979, and 1982 with data following Swartz 1960 plot designations, special area #113 must be subtracted from the totals for plot CC(1976) or its equivalents in 1976, 1977, 1979 and 1982 Data from special area #113 could not be located for 1979 and 1982. However, it has historically contained 10-20 birds.

TABLE G.3. COLONY 1 MURRE CENSUS, 1960[a]

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (GWC)	Obs. 2 (EJW)	Mean
1A	25 Jul	1320	34	34	34
1B[c]	25 Jul	1340	203	191	197
1C[c]	25 Jul	1405	351	321	336
1D	25 Jul	1435	735	707	721
1E	25 Jul	1515	2157	2022	2089
1F	25 Jul	1620	5	5	5
1G	25 Jul	1622	832	705	768
1H	25 Jul	1700	36	–[d]	36
1I	25 Jul	1700	0	0	0
Total			4353		4186

[a] Data from L.G. Swartz' collection of original field notes; specific sources include C.W. Cox Notebook No. 2 and E.J. Willoughby Notebook No. 1. Boat-based census, counts by 1's and 10's.

[b] Bering Standard Time (BST).

[c] Observers in 1960-1961 and 1976-1977 had difficulty in ascertaining boundaries between plots 1B and 1C. Therefore, plots 1B and 1C should be combined for interyear comparisons.

[d] No data.

TABLE G.4. COLONY 1 MURRE CENSUS, 1961[a]

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (KJ)	Obs. 2 (EJW)	Mean
1A	25 Jul	2255	7	10	8
1A	3 Aug	1405	24	22	23
1A	3 Aug	1625	15	16	15
1B[d]	25 Jul	–[c]	177	162	169
1B	3 Aug	1410	329	270	299
1B	3 Aug	1645	328	384	356
1C[d]	25 Jul	–	319	359	339
1C	3 Aug	1420	520	513	516
1C	3 Aug	1655	778	441	609
1D	25 Jul	–	265	223	244
1D	3 Aug	1430	796	597	696
1D	3 Aug	1720	890	1029	959
1D	3 Aug	1930	787	871	829
1D	3 Aug	2030	749	663	706
1D	3 Aug	2100	622	727	674
1D	3 Aug	2130	594	678	636
1E	25 Jul	2330	1088	1120	1104
1E	3 Aug	1450	2620	3225	2922
1E	3 Aug	1720	3202	2511	2856
1F	25 Jul	2350	0	0	0
1F	3 Aug	1525	5	25	15
1F	3 Aug	1810	0	0	0
1G	25 Jul	2350	567	682	624
1G	3 Aug	1530	1014	916	965
1G	3 Aug	1810	1119	1084	1101
1H	26 Jul	0010	0	0	0
1H	3 Aug	1545	32	53	42
1H	3 Aug	1830	49	48	48
1I	26 Jul	0010	0	0	0
1I	3 Aug	1545	0	0	0
1I	3 Aug	1830	0	0	0
Total	26 Jul		2423	2556	2488[e]
Total	3 Aug		5340	5621	5478[f]
Total	3 Aug		6381	5513	5944[g]
Total					4061[h]

[a] Data are from L.G. Swartz' collection of original field notes; specific source was K. Jones Notebook No. 2. All counts were boat-based, and murres were counted by 1's and 10's.

[b] Bering Standard Time (BST).

[c] No data.

[d] Observers indicated difficulties discerning the boundaries of this plot during the count. Because of problems with discerning boundaries between 1B and 1C in 1960-1961 and 1976-1977, plots 1B and 1C should be combined for interyear comparisons.

[e] Springer and Roseneau (1977) reported this value as 3589, which was a typographical error. The correct value is 2488.

[f] Springer and Roseneau (1977) reported this value as 5464, a typographical error. Correcting the error and using our rounding method gives 5478.

[g] Springer and Roseneau (1977) reported this value as 5796, resulting from a typographical error in the mean value of plot 1C (459 instead of 609). Correcting the error and using our rounding method gives 5944.

[h] Total calculated by averaging 3 August means, then averaging those with 25 or 26 July mean counts, and summing.

TABLE G.5. COLONY 1 MURRE CENSUS, 1976[a]

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (MAD)	Obs. 2 (DJ)	Mean
1A	20 Jul	1830[c]	12		12
1A	6 Aug	1000[d]	6	6	6
1B[e]	20 Jul	-	0		0
1B[e]	6 Aug	-	0	0	0
1C[e]	20 Jul	-	340		340
1C[e]	6 Aug	-	370	281	325
1D	20 Jul	-	240		240
1D	6 Aug	-	298	352	325
1E	20 Jul	-	(1006)[f]		(1006)[f]
1E	6 Aug	-	980	929	954
1F	20 Jul	-	0		0
1F	6 Aug	-	0	0	0
1G	20 Jul	-	550		550
1G	6 Aug	-	540	392	466
1H	20 Jul	-	55		55
1H	6 Aug	-	13	13	13
1I	20 Jul	1930	0		0
1I	6 Aug	1300	0	0	0
Total	20 Jul		2203		2203
Total	6 Aug		2207	1973	2089
Total					2145[g]

[a] Data from Springer and Roseneau (1977), and A.M. Springer and D.G Roseneau original field data summary sheets. Boat-based counts, murres counted by 1's and 10's.

[b] Bering Daylight Time (BDT).

[c] Plots were counted between 1830-1930 h, but specific times were not recorded.

[d] Plots were counted between 1000-1300 h, but specific times were not recorded.

[e] Because of problems with discerning boundaries between 1B and 1C in 1960-1961 and 1976-1977, plots 1B and 1C should be combined for interyear comparisons.

[f] Plot 1E was not counted; Springer and Roseneau (1977) and A.M. Springer and D.G. Roseneau (unpubl. data) estimated 1006 birds present on the basis of percent differences between counts on 20 July and 6 August at census plots A-D and F-I.

[g] Total calculated from sum of averaging 20 July and 6 August mean values.

TABLE G.6. COLONY 1 MURRE CENSUS, 1977[a]

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (DGR)	Mean
1A	11 Aug	2123	0	0	0
1B,1C	11 Aug	2117	330	355	342
1D	11 Aug	2108	395	385	390
1E	11 Aug	2052	1125	1180	1152
1F	11 Aug	2045	0	0	0
1G	11 Aug	2038	580	560	570
1H	11 Aug	2031	16	16	16
1I	11 Aug	2030	0	0	0
Total			2446	2496	2470

[a] Data are from Springer and Roseneau (1978), and A.M. Springer and D.G. Roseneau original field data summary sheets. Boat-based counts, murres counted by 1's and 10's.

[b] Bering Daylight Time (BDT).

TABLE G.7. COLONY 1 MURRE CENSUS, 1979[a]

			Murres (birds)								
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (WW)	Obs. 3 (AP)	Obs. 4 (DM)	Obs. 5 (BT)	Obs. 6 (MIJ)	Obs. 7 (AMS)	Obs. 8 (DGR)	Mean
1A	7 Jul	2245	0								0
1A	20 Jul	2220		0	0	0	0				0
1A	7 Aug	2225						0	0	0	0
1A	15 Aug	2125	0							0	0
1A	18 Aug	1940	0							0	0
1B,1C	7 Jul	–[c]	220								220
1B,1C	20 Jul	–[d]		431	435	425	467				439
1B,1C	7 Aug	2220						210	200		205
1B,1C	15 Aug	2120	340							300	320
1B,1C	18 Aug	1940	340							300	320
1D	7 Jul	–[c]	265								265
1D	20 Jul	–[d]		587	539	510	597				558
1D	7 Aug	2235		323						385	354
1D	15 Aug	2117	320							340	330
1D	18 Aug	1935	320							345	332
1E	7 Jul	–[c]	560								560
1E	20 Jul	–[d]		1260		1280					1270
1E	7 Aug	2220		1015						810	912
1E	15 Aug	2107	1175							1490	1332
1E	18 Aug	1925	1215							1100	1157
1F,1G	7 Jul	2215	320								320
1F,1G	7 Aug	2145		450				420	515	545	482
1F,1G	15 Aug	2100	667							573	620
1F,1G	18 Aug	1915	570							580	575
1H	7 Jul	2215	1								1
1H	20 Jul	2122		0	0	0	0				0
1H	7 Aug	2145						0	0		0
1H	15 Aug	2100	0							0	0
1H	18 Aug	1915[e]	0							0	0
1I	7 Jul	2215[e]	0								0
1I	20 Jul	2122[e]		0	0	0	0				0
1I	7 Aug	2145[e]		0						0	0
1I	15 Aug	2100[e]	0							0	0
1I	18 Aug	1915[e]	0							0	0

TABLE G.7. COLONY 1 MURRE CENSUS, 1979 (cont.)

			Murres (birds)								
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (WW)	Obs. 3 (AP)	Obs. 4 (DM)	Obs. 5 (BT)	Obs. 6 (MIJ)	Obs. 7 (AMS)	Obs. 8 (DGR)	Mean
Total	7 Jul										1366
Total	20 Jul										-
Total	7 Aug										1953
Total	15 Aug										2602
Total	18 Aug										2384
Total											2441[f]

[a] Data are from Murphy et al. (1980), and Murphy et al. original data field note books and field data summary sheets. Boat-based counts, murres counted by 1's and 10's.

[b] Bering Daylight Time (BDT).

[c] Between 2215-2245 h.

[d] Between 2122-2220 h.

[e] Estimated times.

[f] Total calculated by summing averages of 20 July-18 August mean counts.

TABLE G.8. COLONY 1 MURRE CENSUS, 1982[a]

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (RSM)	Mean
1A	29 Jul	2040	0	0	0
1A	5 Aug	2110	0	0	0
1A	7 Aug	2230	0	0	0
1A	7 Aug	2310	0	0	0
1B[c]	29 Jul	2035	130	130	130
1B[c]	5 Aug	2106	150	150	150
1B[c]	7 Aug	2230	140	130	135
1B[c]	7 Aug	2310	140	130	135
1C[c]	29 Jul	2032	220	180	200
1C[c]	5 Aug	2105	280	300	290
1C[c]	7 Aug	2225	150	190	170
1C[c]	7 Aug	2305	180	200	190
1D	29 Jul	2028	360	370	365
1D	5 Aug	2052	350	340	345
1D	7 Aug	2215	280	330	305
1D	7 Aug	2258	320	285	302
1E	29 Jul	2020	1070	940	1005
1E	5 Aug	2040	1270	1420	1345
1E	7 Aug	2210	1110	880	995
1E	7 Aug	2252	1140	880	1010
1F	29 Jul	2015	0	0	0
1F	5 Aug	2038	16	15	15
1F	7 Aug	2102	16	15	15
1F	7 Aug	2247	24	23	23
1G	29 Jul	2010	540	560	550
1G	5 Aug	2030	620	600	610
1G	7 Aug	2159	500	530	515
1G	7 Aug	2245	525	490	507
1H	29 Jul	2009	13	12	12
1H	5 Aug	2025	28	35	31
1H	7 Aug	2155	13	16	14
1H	7 Aug	2243	13	11	12
1I	29 Jul	2005	0	0	0
1I	5 Aug	2020	0	0	0
1I	7 Aug	2155	0	0	0
1I	7 Aug	2243	0	0	0

TABLE G.8. COLONY 1 MURRE CENSUS, 1982 (cont.)

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (RSM)	Mean
Total	29 Jul		2333	2192	2262
Total	5 Aug		2714	2860	2786
Total	7 Aug	(first)	2209	2091	2149
Total	7 Aug	(second)	2342	2019	2179
Total					2402[d]

[a] Data from Springer et al. (1985), and A.M. Springer, D.G. Roseneau, and E.C. Murphy unpublished data (specific source, E.C. Murphy original field data summary sheets).

[b] Bering Daylight Time (BDT).

[c] Because of problems with discerning boundaries between 1B and 1C in 1960-1961 and 1976-1977, plots 1B and 1C should be combined for interyear comparisons.

[d] Total calculated from sums of averages of mean plot counts between 29 July-7 August.

TABLE G.9. COLONY 2 MURRE CENSUS, 1960[a]

			Murres (birds)			
Plot	Date	Time[b]	Obs. 1 (GWC)	Obs. 2 (EJW)	Obs. 3 (LS)	Mean
2A1	27 Jul	1415	37		36	36
2A2	27 Jul	1425	50		50	50
2B	27 Jul	1435	154		165	159
2C	27 Jul	1440	1251		1114	1182
2D	27 Jul	1445	84		82	83
2E	27 Jul	1520	2300		2645	2472
2F	27 Jul	1545	770		790	780
2G	27 Jul	1620	3525		3200/3500 ($\bar{x}$=3350)	3437
2H	27 Jul	1700	3990		4225/4250 ($\bar{x}$=4237)	4113
2I	27 Jul	1730	2900		2400	2650
2J	27 Jul	1815	2970		2770	2870
2K	29 Jul	1355	405/421 ($\bar{x}$=413)	429		421
2L	28 Jul	1510	2950	3395		3172
2M	29 Jul	–[cd]	2903	2702		2802
2N	29 Jul	1545	2810	1720		2265
2O	29 Jul	1635	2510	3015		2762
2P	29 Jul	1705	1840	1380		1610
2Q	31 Jul	1215	4055		4100	4077
2R	31 Jul	1240	765		800	782
2S	31 Jul	1300	2380		2040	2210
2T	31 Jul	1340	4870		4050/4200/4900 ($\bar{x}$=4383)	4626
2U	31 Jul	1515	3270		3360	3315
2V	31 Jul	1535	4620		4530	4575
2W	31 Jul	1630	3240		3470	3355
2X	31 Jul	1645	2750		2300	2525
2Y	31 Jul	1730	4200		3700	3950
2Z	3 Aug	1400	2300		2300	2300
2AA	3 Aug	–[e]	1250		1460	1355
2BB	3 Aug	1410	2050		1960	2005
2CC	3 Aug	1420	1600		1400	1500
2DD	3 Aug	–[f]	5250		5300	5275
2EE	3 Aug	–[f]	1500		1400	1450
2FF	3 Aug	–[f]	700/790 ($\bar{x}$=745)		820/960 ($\bar{x}$=890)	817
2GG	3 Aug	1540	450		430	440
2HH	3 Aug	–[g]	340/350 ($\bar{x}$=345)		270/320 ($\bar{x}$=295)	320
2II	3 Aug	–[g]	150		163/180 ($\bar{x}$=171)	160

TABLE G.9. COLONY 2 MURRE CENSUS, 1960 (cont.)

			Murres (birds)			
Plot	Date	Time[b]	Obs. 1 (GWC)	Obs. 2 (EJW)	Obs. 3 (LS)	Mean
Total			77247		74569	75901

[a] Data are from L.G. Swartz's collection of original field notes. Specific sources for the counts include: G.W. Cox Notebook No. 2 and L. Schene Notebook No. 2 (census plots 2A1-2J and 2Q-2II); G.W. Cox Notebook No. 2 (census plot 2L); G.W. Cox Notebook No. 2 and E.J. Willoughby Notebook No. 1 (census plots 2K and 2M-2P). Boat-based census; counts of murres by 10's.

[b] Bering Standard Time (BST).

[c] No data.

[d] Probably about 1500 h.

[e] Probably about 1405 h.

[f] Probably between about 1425-1540 h.

[g] Probably between about 1545-1600 h.

TABLE G.10. COLONY 2 MURRE CENSUS, 1961[a]

Plot	Date	Time[b]	Murres (birds) Obs. 1 (LGS)	Obs. 2 (KJ)	Mean
2A1	25 Jul	2115	3	3	3
2A2	25 Jul	2115	26	25	25
2B	25 Jul	2115	155	150	152
2C	25 Jul	2120	1091	955	1023
2GG	25 Jul	2155	600[c]	383	383
2HH	25 Jul	2215	315	297	306
2II	25 Jul	2215	141	164	152

[a] Data are from L.G. Swartz's collection of original field notes; specific sources include L.G. Swartz and K. Jones' field notebooks. Land-based census; counts of murres by 1's and 10's.

[b] Bering Standard Time (BST).

[c] Not an accurate count; reported to be only a rough estimate.

TABLE G.11. COLONY 2 MURRE CENSUS, 1976[a]

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (MAD)	Obs. 2 (AMS)	Mean
2A1	18 Aug	0910	5	5	5
2A2	18 Aug	0910	29	29	29
2B	18 Aug	0910	157	134	145
2C	18 Aug	0910	675	660	667
2D	18 Aug	0910	70	80	75
2E	18 Aug	1020	1020	780	900
2F	18 Aug	1320	430	430	430
2G	18 Aug	1320	1350	1240	1295
2H	18 Aug	1350	1870	2170	2020
2I	18 Aug	1400	1070	980	1025
2J	18 Aug	1035	1480	1170	1325
2K	18 Aug	1035	720	710	715
2L	18 Aug	1100	1515	1130	1322
2M	18 Aug	1100	2510	2160	2335
2N	18 Aug	1150	540	510	525
2O	18 Aug	1215	1200	850	1025
2P	18 Aug	1215	1350	1160	1255
2Q	18 Aug	1215	1470	1580	1525
2R	18 Aug	1300	440	530	485
2S	18 Aug	2110	2230	1750	1990
2T	18 Aug	2045	4440	3630	4035
2U	18 Aug	2015	3400	3440	3420
2V	18 Aug	2015	4180	3600	3890
2W	18 Aug	1830	1960	2460	2210
2X	18 Aug	1830	1730	2030	1880
2Y	18 Aug	1705	4220	2710	3465
2Z	18 Aug	1700	1860	1200	1530
2AA	18 Aug	1645	830	750	790
2BB	18 Aug	1700	2550	1520	2035
2CC	18 Aug	1710	500	500	500
2DD	18 Aug	1725	1645	1650	1647
2EE	18 Aug	1730	900	600	750
2FF	18 Aug	1730	500	390	445
2GG	18 Aug	1730	590	500	545
2HH,2II[c]	18 Aug	1740	530	440	485
Total			49966	43478	46720

TABLE G.11. COLONY 2 MURRE CENSUS, 1976 (cont.)

[a] Data are from Springer and Roseneau (1977), and A.M. Springer and D.G. Roseneau's original data summary sheets. Boat-based census; counts of murres by 10's.

[b] Bering Daylight Time (BDT).

[c] Census plots 2HH and 2II were combined during the counts.

TABLE G.12. COLONY 2 MURRE CENSUS, 1977[a]

Plot	Date	Time[b]	Murres (birds) Obs. 1 (ECM)	Obs. 2 (DGR)	Mean
2A1	9 Aug	1510	9	9	9
2A2	9 Aug	1512	23	23	23
2B	9 Aug	1517	130	120	125
2C	9 Aug	1525	490	535	512
2D	9 Aug	1535	150	155	152
2E	9 Aug	1540	1410	1945	1677
2F	9 Aug	1608	920	775	847
2G	9 Aug	1620	3445	2290	2867
2H	9 Aug	1715	2840	2160	2500
2I	9 Aug	1735	1860	1635	1747
2J	9 Aug	1755	2525	2305	2415
2K,2L[c]	9 Aug	1818	3220	3100	3160
2M	9 Aug	1850	2055	1945	2000
2N	9 Aug	1935	1645	1640	1642
2O	9 Aug	1940	1910	2015	1962
2P	9 Aug	2000	1275	1265	1270
2Q	9 Aug	2015	3110	2940	3025
2R	9 Aug	2035	710	670	690
2S	9 Aug	2045	2260	2490	2375
2T	9 Aug	2105	2960	3550	3255
2U	9 Aug	2130	2750	2900	2825
2V	9 Aug	2150	3395	3300	3347
2W	9 Aug	1740	2170	2260	2215
2X	9 Aug	1715	1135	1220	1177
2Y	9 Aug	1635	3075	3110	3092
2Z	9 Aug	1615	1780	1515	1647
2AA	9 Aug	1600	685	720	702
2BB	9 Aug	1540	1000	980	990
2CC	9 Aug	1530	1090	1235	1162
2DD	9 Aug	1505	1485	1550	1517
2EE	9 Aug	1455	710	590	650
2FF	9 Aug	1445	435	445	440
2GG	9 Aug	1436	370	350	360
2HH	9 Aug	1425	285	270	277
2II	9 Aug	1420	155	160	157
Total			53467	52172	52811

[a] Data are from Springer and Roseneau (1978), and A.M. Springer and D.G. Roseneau's original data summary sheets. Boat-based census; counts of murres by 10's.

[b] Bering Daylight Time (BDT).

[c] Census plots 2K and 2L were combined during the counts.

TABLE G.13. COLONY 2 MURRE CENSUS, 1979[a]

			Murres (birds)								
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (WW)	Obs. 3 (AP)	Obs. 4 (DM)	Obs. 5 (BT)	Obs. 6 (MIJ)	Obs. 7 (AMS)	Obs. 8 (DGR)	Mean
2A1	9 Aug	1100	9	9							
		1230	–[c]	4							
		2030	–	9							
				($\bar{x}$=7)							8
2A2	8 Aug	1625			30	30					30
2B	8 Aug	1625			150	158					154
2C	10 Jul	2027	580/ 570 ($\bar{x}$=575)		670/ 695 ($\bar{x}$=682)		730/ 640 ($\bar{x}$=685)				647
2C	18 Jul	1835	680/ 720 ($\bar{x}$=700)					709		596/ 680 ($\bar{x}$=638)	682
2C	1 Aug	2158						865	880	912	886
2C	5 Aug	1845			580	650					615
2C	8 Aug	1630			725	850					787
2C	15 Aug	–	760				850				805
2C	16 Aug	1930		765			750				757
2D	8 Aug	1720			152	160					156
2E	8 Aug	1725			1480	1330					1405
2F	8 Aug	1740			580	580					580
2G	8 Aug	1745			1800	1680					1740
2H	8 Aug	1805			2010	2200					2105
2I	8 Aug	1820			1070	1180					1125
2J	8 Aug	1830			1440	1510					1475
2K	8 Aug	1840			240	290					265
2L	8 Aug	1845			1740	1550					1645
2M	8 Aug	1900			1470	1240					1355
2N	8 Aug	1910			1280	1410					1345
20	10 Jul	2110	1350		1110/ 1250 ($\bar{x}$=1180)		1410/ 1390 ($\bar{x}$=1400)				1310
20	18 Jul	1904	1030					1300		1820	1383
20	19 Jul	1910	1300					1420		1220	1313
20	1 Aug	2123						1387	1280	1846	1504
20	5 Aug	1855			830	875					852
20	8 Aug	1920			1130	1000					1065
20	15 Aug	2032	1810				1940				1875
20	16 Aug	1940		1650			1885				1767

TABLE G.13. COLONY 2 MURRE CENSUS, 1979 (cont.)

			Murres (birds)								
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (WW)	Obs. 3 (AP)	Obs. 4 (DM)	Obs. 5 (BT)	Obs. 6 (MIJ)	Obs. 7 (AMS)	Obs. 8 (DGR)	Mean
2P	8 Aug	1930			920	920					920
2Q	8 Aug	1940			1900	1950					1925
2R	8 Aug	1955			410/ 430 ($\bar{x}$=420)	450/ 430 ($\bar{x}$=440)					430
2S[d]	8 Aug	2010			2115	1890					2002
2T	8 Aug	1955	4840	4530							4685
2T	17 Aug	1520		2760							2760
2U	8 Aug	1940	3470	2980							3225
2V	8 Aug	1915	3920	3940							3930
2V	17 Aug	1505		2480							2480
2W	8 Aug	1910	2000	1900							1950
2X	8 Aug	1900	2210	1850							2030
2Y	8 Aug	1815	4290	4100							4195
2Z	8 Aug	1805	1510	1720							1615
2Z	11 Aug	2239	780	805/ 820 ($\bar{x}$=812)							796
2Z	11 Aug	2240			510/ 580 ($\bar{x}$=545)	560					553
2AA	8 Aug	1755	850/ 870 ($\bar{x}$=860)	980							920
2BB	10 Jul	2145	910/ 1060 ($\bar{x}$=985)		1080		1110/ 1020 ($\bar{x}$=1065)				1043
2BB	18 Jul	1926	1310					1230		1150	1230
2BB	1 Aug	2036						1552		1536	1544
2BB	5 Aug	1905			1065	1260					1162
2BB	8 Aug	1745	1220	1350							1285
2BB	11 Aug	2222	1360	1530							1445
2BB	11 Aug	2225			960	980/ 1050 ($\bar{x}$=1015)					987
2BB	15 Aug	1954	1340	1230			1305				1292

TABLE G.13. COLONY 2 MURRE CENSUS, 1979 (cont.)

			Murres (birds)								
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (WW)	Obs. 3 (AP)	Obs. 4 (DM)	Obs. 5 (BT)	Obs. 6 (MIJ)	Obs. 7 (AMS)	Obs. 8 (DGR)	Mean
2BB	16 Aug	1950		1330			1220				1275
2BB	17 Aug	1445		1050							1050
2CC	8 Aug	1735	1550	1580							1565
2DD	8 Aug	1725	1630	1970							1800
2EE	8 Aug	1715	940/ 860 ($\bar{x}$=900)	690/ 700 ($\bar{x}$=695)							797
2EE	17 Aug	1435		600							600
2FF	8 Aug	1705	640	590							615
2GG	8 Aug	1655	390	400/ 400 ($\bar{x}$=400)							395
2HH	8 Aug	1645	320	300/ 290/ 290 ($\bar{x}$=293)							306
2HH	17 Aug	1420		320							320
2II	8 Aug	1640	214	210							212
2II	17 Aug	1415		190							190
Total											50042[e]
Total											51926[f]

[a] Data are from A.M. Springer, D.G. Rosenesu and E.C. Murphy (unpubl. data); specific source, original field census notebook. Boat-based census; counts of murres by 10's.

[b] Bering Daylight Time (BDT).

[c] No data.

[d] Census plot 2S was counted as follows: the right portion was counted twice by M.I. Johnson (scores=870 and 760; x=815) and A.M. Springer (scores=700 and 760; x=730), and the left portion was counted by W. Walker (score=1300) and D.G. Roseneau (score=1160). M.I. Johnson's mean score (815) was added to W. Walker's score (1300) for a total of 2115 birds, A.M. Springer's mean score (730) was added to D.G. Roseneau's score (1160) for a total of 1890 birds, and those two totals (2115 and 1890) were averaged.

[e] Total calculated from counts on 8 Aug (2A2-2II) and 9 Aug (2A1).

TABLE G.13. COLONY 2 MURRE CENSUS, 1979 (cont.)

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[f] Total calculated using averages of replicate mean counts, when available.

TABLE G.14. COLONY 2 MURRE CENSUS, 1982[a]

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (RSM)	Mean
2A1	29 Jul	1446	9	10	9
2A1	5 Aug	1525	20	20	20
2A2	29 Jul	1448	15	10	12
2A2	5 Aug	1530	19	20	20
2B	29 Jul	1453	136	110	123
2B	5 Aug	1531	140	130	135
2C	29 Jul	1458	750	770	760
2C	5 Aug	1540	770	760	765
2D	29 Jul	1506	210	240	225
2E	29 Jul	1509	1560	1710	1635
2F	29 Jul	1516	470	540	505
2G	29 Jul	1525	1525	1830	1677
2H	29 Jul	1533	1870	2000	1935
2I	29 Jul	1540	1280	1610	1445
2I	5 Aug	1550	1270	1450	1360
2J	29 Jul	1550	1690	1750	1720
2K,2L[c]	29 Jul	1602	2330	2130	2230
2M	29 Jul	1610	1430	1970	1700
2N	29 Jul	1625	1540	1690	1615
2O	29 Jul	1634	1610	2250	1930
2O	5 Aug	1620	1480	1380	1430
2P	29 Jul	1641	840	900	870
2Q	29 Jul	1649	1930	2020	1975
2R	29 Jul	1657	430	500	465
2S,2T[d]	29 Jul	1705	4180	4000	4090
2U	29 Jul	1720	2610	2120	2365
2U	5 Aug	1645	1660	1640	1650
2V	29 Jul	1736	2250	2560	2405
2W	29 Jul	1822	1850	1870	1860
2X	29 Jul	1829	1630	1550	1590
2Y	29 Jul	1836	2730	2060	2395
2Z	29 Jul	1848	1850	1590	1720

TABLE G.14. COLONY 2 MURRE CENSUS, 1982 (cont.)

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (RSM)	Mean
2AA	29 Jul	1853	690	760	725
2AA	5 Aug	1709	690	700	695
2BB	29 Jul	1900	1340	1360	1350
2BB	5 Aug	1717	1010	1090	1050
2CC	29 Jul	1908	1240	1200	1220
2DD	29 Jul	1915	1590	1360	1475
2EE	29 Jul	1922	580	500	540
2FF	29 Jul	1930	460	470	465
2GG	29 Jul	-	-	-	-
2HH	29 Jul	1935	700	630	665
2HH	5 Aug	1725	370	340	355
2II	29 Jul	1940	190	200	195
2II	5 Aug	1732	190	190	190
Total			43515[e]	44270[e]	43891[e]

[a] Data are from Springer et al. (1985) and A.M. Springer, D.G. Roseneau, and E.C. Murphy (unpubl. data; specific source, E.C. Murphy original field data summary sheets). Boat-based census; counts of murres by 10's.

[b] Bering Daylight Time (BDT).

[c] Census plots 2K and 2L were combined during the counts.

[d] Census plots 2S and 2T were combined during the counts.

[e] Springer et al. (1985) totals of 43780 and 44370 were typographical errors. Totals were calculated from 29 July data. Total does not include plot 2GG.

TABLE G.15. COLONY 2 MURRE CENSUS, 1988[a]

			Murres (birds)					
Plot	Date	Time[b]	Obs. 1 (JLB)	Obs. 2 (BSF)	Obs. 3 (DT)	Obs. 4 (DGR)	Obs. 5 (PR)	Mean
2A1	18 Jul	1337	27	29				28
2CC	12 Jul	1905	890			1100	980	990
2U	12 Jul	1340	1870			1800/1900 ($\bar{x}$=1850)	1930	1883
2U	13 Jul	2140		2550	2240	2550		2447
2V	12 Jul	1310	2360			2650/2510 ($\bar{x}$=2580)	2400	2447
2V	13 Jul	2100[c]		2600	2610	3740		2983
2V	13 Jul	2125[c]		3230	2740	3220		3063

[a] Data are from this study. Boat-based census; counts of murres by 10's.

[b] Alaska Daylight Time (ADT).

[c] 2100 h was a rapid count; use 2125 h count for comparisons.

TABLE G.16. COLONY 3 MURRE CENSUS, 1960[a]

			Murres (birds)	
Plot	Date	Time[b]	Obs. 1 (LS)[c]	Mean
3A	21 Jul	1145	84	84
3B	21 Jul	1215	700/1100 ($\bar{x}$=900)	900
3C	21 Jul	1250	75/125 ($\bar{x}$=100)	100
3D	21 Jul	1325	940	940
3E	21 Jul	1340	620	620
3F	21 Jul	1415	500	500
3G[d]	21 Jul	1445	1550	1550
3H[d]	21 Jul	1500	400	400
3I	21 Jul	1630	400	400
3J	21 Jul	1715	1350[e]	1350[e]
3J	22 Jul	1300	3900[f]	3900[f]
3K	22 Jul	–[g]	2600	2600
3L	22 Jul	–[g]	280	280
3M	22 Jul	1450	650	650
3N	22 Jul	1510	1930	1930
3O	22 Jul	1610	850	850
3P	22 Jul	1530	1400	1400
3Q	22 Jul	1630	1600	1600
3R	22 Jul	1705	2260	2260
3S	22 Jul	1715	800	800
3T	22 Jul	–[h]	2500	2500
3U	22 Jul	–[h]	2200	2200
3V	22 Jul	1830	900	900
3W	22 Jul	1830	450	450
Total				27814[i]

[a] Data are from L.G. Swartz' collection of original field data; specific source, L. Schene's Notebook No. 2. Boat-based counts (except where noted), counts of murres by 10's, some larger plots by 100's.

[b] Bering Standard Time (BST).

[c] G.W. Cox also counted census plots 3A-3W on 21-22 July, recording his data in his Notebook No. 1. However, he lost this notebook before L.G. Swartz could recopy it.

[d] Counted from land.

[e] This count of 3J was made under deteriorating sea conditions, and according to L. Schene, birds were "...in shadow of rocks and difficult to make out." The count was disregarded in favor of the recount on 22 July.

[f] L. Schene estimated 2900 murres on census plot 3J during this count, and then noted that he believed at least another 1000 murres were present, but hidden by ledges.

[g] Between 1300–1450 h.

[h] Between 1715–1830 h.

[i] Total excludes the count made on census plot 3J on 21 July.

TABLE G.17. COLONY 3 MURRE CENSUS, 1961[a]

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (LGS)	Obs. 2 (KJ)	Mean
3A	25 Jul	1415	230	238	234
3B	25 Jul	1430	1312	833	1072
3D	25 Jul	1445	1500[c]	1500[c]	1500[c]
3E	25 Jul	1445	1200[c]	1200[c]	1200[c]
3W[d]	25 Jul	1500	827	840	833

[a] Data are from L.G. Swartz'collection of original field notes; specific sources include L.G. Swartz and K. Jones field notebooks. Land-based counts; murres counted by 1's and 10's.

[b] Bering Standard Time (BST).

[c] Reported to be a rough estimate, counted by 100's; not an accurate count.

[d] L.G. Swartz 1960 plot 3W is equivalent to Springer and Roseneau (1977, 1978) 1976 and 1977 census plot 3S.

TABLE G.18. COLONY 3 MURRE CENSUS, 1976[a]

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (LGS)	Obs. 2 (DGR)	Mean
3A	23 Jul	2117	183	170	176
3B	23 Jul	–[c]	400	575	487
3C	23 Jul	–[c]	500	600	550
3D	23 Jul	–[c]	720	550	635
3E	23 Jul	–[c]	610	450	530
3F	23 Jul	2050	430	430	430
3G	23 Jul	–[d]	2100	2500	2300
3H	23 Jul	2010	750	650	700
3I	23 Jul	1955	1500	1400	1450
3J	23 Jul	–[e]	1400	1150	1275
3K	23 Jul	1920	1200	1150	1175
3L,3M, 3N,30	23 Jul	–[f]	1850[g]	1950[g]	1900[g]
3P	23 Jul	1900	1250	1350	1300
3Q,3R,3S	23 Jul	1615	2271	2512	2391
3T,3U	23 Jul	2150	1795	1960	1877
3V	23 Jul	2140	703	1021	862
3W	23 Jul	2115	531	585	558

[a] Data are from Springer and Roseneau (1977), and A.M. Springer and D.G. Roseneau original field data summary sheets. Boat-based counts, murres counted by 1's and 10's.

[b] Bering Daylight Time (BDT).

[c] Between 2050–2117 h.

[d] Between 2010–2050 h.

[e] Between 1920–1955 h.

[f] Between 1600–1900 h.

[g] Counts are a few hundred too low because 1960 census plot 3L, which was most of 1976 and 1977 census plot 3N (see Springer and Roseneau 1977) was not counted.

TABLE G.19. COLONY 3 MURRE CENSUS, 1977[a]

			Murres (birds)		
Plot[b]	Date	Time[c]	Obs. 1 (ECM)	Obs. 2 (DGR)	Mean
3A	10 Aug	1810	150	155	152
3B	10 Aug	1817	540	495	517
3C	10 Aug	1835	460	500	480
3D	10 Aug	1323	525	580	552
3E	10 Aug	1828	545	583	564
3F	10 Aug	1841	605	600	602
3G	12 Aug	2005	1120	900	1010
3H	10 Aug	1850	580	550	565
3I	12 Aug	1855	595	950	772
3J	12 Aug	1745	2570	2665	2617
3K	10 Aug	1912	1590	1580	1585
3L[d]	12 Aug	1728	1205	1460	1332
3M[e]	12 Aug	1705	1435	1780	1607
3N[e]	12 Aug	1656	600	670	635
3O[f]	12 Aug	1613	1685	1800	1742
3P[f]	12 Aug	1640	1990	1825	1907
3Q[g]	10 Aug	1940	3265	3200	3232
3R[h]	10 Aug	2013	805	865	835
3S[i]	10 Aug	2020	650	670	660
Total			20915	21828[j]	21366

[a] Data are from Springer et al. (1978), and A.M. Springer and D.G. Roseneau original field data summary sheets. Boat-based counts, counts by 10's.

[b] These are 1977 plot designations. To compare with L.G. Swartz 1960 census plot designations, convert by using the table given in the general introduction to Appendix G (3A-3K are equivalent to the L.G. Swartz 1960 designations).

[c] Bering Daylight Time (BDT).

[d] 1977 3L = Swartz' 1960 plot 3P.

[e] 1977 3M + 3N = Swartz' 1960 plots 3L + 3M + 3N + 30.

[f] 1977 30 + 3P = Swartz' 1960 plots 3Q + 3R + 3S.

[g] 1977 3Q = Swartz' 1960 plots 3T + 3U.

[h] 1977 3R = Swartz' 1960 plot 3V.

[i] 1977 3S = Swartz' 1960 plot 3W.

[j] Springer and Roseneau (1978) reported the total as 21904, an error that resulted from a mistake in addition.

TABLE G.20. COLONY 3 MURRE CENSUS, 1979[a]

			Murres (birds)								
Plot	Date	Time[b]	Obs. 1 (MIJ)	Obs. 2 (AMS)	Obs. 3 (WW)	Obs. 4 (DGR)	Obs. 5 (ECM)	Obs. 6 (DM)	Obs. 7 (AP)	Obs. 8 (BT)	Mean
3A	7 Aug	1920	120	120							120
3B	7 Aug	1925	380	390							385
3B	11 Aug	2205	460	460/490							
				($\bar{x}$=475)							467
3C	7 Aug	1930	300	310							305
3D	7 Aug	1935	490	450/480							
				($\bar{x}$=465)							477
3E	7 Aug	1940	380	370							375
3E	11 Aug	2200	400	430							415
3F	7 Aug	1950	340	330							335
3F	11 Aug	2154	260/290	320/340							
			($\bar{x}$=275)	($\bar{x}$=330)							302
3G	7 Aug	1945	450	430							440
3H	7 Aug	1955	400/430	390/415/420							
			($\bar{x}$=415)	($\bar{x}$=408)							411
3H	11 Aug	2145	560	530							545
3I	7 Aug	2000	240	240							240
3J	7 Aug	2025			2660	3180					2920
3K	7 Aug	2000			310	300/350					
						($\bar{x}$=325)					317
3L	7 Aug	1930			160/200	180/230					
					($\bar{x}$=180)	($\bar{x}$=205)					192
3M	10 Jul	2200	620/730		680/840		780/800				
			($\bar{x}$=675)		($\bar{x}$=760)		($\bar{x}$=790)				742
3M	18 Jul	2016			650			785	730		722
3M	1 Aug	1947						1233	1330		1281
3M	7 Aug	1945			680	750					715
3M	15 Aug	1930			850	1390	970				1070
3M	16 Aug	2025				1370	1270				1320

TABLE G.20. COLONY 3 MURRE CENSUS, 1979 (cont.)

Plot	Date	Time[b]	Obs. 1 (MIJ)	Obs. 2 (AMS)	Obs. 3 (WW)	Obs. 4 (DGR)	Obs. 5 (ECM)	Obs. 6 (DM)	Obs. 7 (AP)	Obs. 8 (BT)	Mean
			Murres (birds)								
3N	7 Aug	1910			810/820 ($\bar{x}$=815)	800					807
3O	7 Aug	1920			660	530					595
3P	7 Aug	1925			1380	1200					1290
3Q	7 Aug	1935			540	575					557
3R	7 Aug	1847			1455	1650					1552
3S	7 Aug	1840			580	550					565
3T	7 Aug	1900	1180	1170							1175
3T	11 Aug	2154			1800	1950					1875
3U	7 Aug	1855	910	1090							1000
3U	11 Aug	2145			1950	1620					1785
3V	7 Aug	1845	730	780							755
3W	10 Jul	2240	330/340 ($\bar{x}$=335)		330/360 ($\bar{x}$=345)		330/360 ($\bar{x}$=345)				342
3W	18 Jul	2035			600/620 ($\bar{x}$=610)			585	625		607
3W	1 Aug	1926						671	670		670
3W	7 Aug	1840	290	280/300 ($\bar{x}$=290)							290
3W	15 Aug	1920			420	560	540				507
3W	16 Aug	2035				605	590				597
Total	7 Aug		15485	16458							15818
Total											17008[c]

[a] Data are from A.M. Springer, D.G. Roseneau, E.C. Murphy and M.I. Johnsons original field notebooks, and E.C. Murphy's field data summary sheets. Boat-based counts, counts by 10's.

[b] Bering Daylight Time (BDT).

[c] Total calculated using averages of 10, 18 July and 1, 7, and 11 August counts when available.

TABLE G.21. COLONY 3 MURRE CENSUS, 1982[a]

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (RSM)	Mean
3A	3 Aug	0852	180	200	190
3A	5 Aug	1148	56	50	53
3B	3 Aug	0905	380	340	360
3B	5 Aug	1040	580	580	580
3C	3 Aug	0908	200	190	195
3D	3 Aug	0909	570	560	565
3D	5 Aug	1030	560	530	545
3E	3 Aug	0912	510	510	510
3E	5 Aug	1034	480	510	495
3F	3 Aug	0915	310	250	280
3F	5 Aug	1051	370	330	350
3G[c]	3 Aug	0922	460	470	465
3H[c]	3 Aug	0940	600	370	485
3I[c]	3 Aug	0935	460	390	425
3J[c]	3 Aug	0951	1540	1280	1410
3K[c]	3 Aug	0955	660	920	790
3L	3 Aug	1009	180	270	225
3M	3 Aug	1011	760	750	755
3N	3 Aug	1017	1000	1060	1030
3N	5 Aug	1058	880	950	915
30	3 Aug	1014	250	290	270
3P	3 Aug	1021	1150	1250	1200
3P	5 Aug	1102	1360	1430	1395
3Q[d]	3 Aug	1032	700	830	765
3R[e]	3 Aug	1040	1650	1750	1750

TABLE G.21. COLONY 3 MURRE CENSUS, 1982 (cont.)

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (RSM)	Mean
3S[f]	3 Aug	1050	680	810	745
3T	3 Aug	1105	1740	1700	1720
3T	5 Aug	1113	1670	1670	1670
3U	3 Aug	1110	1600	1640	1620
3U	5 Aug	1120	1330	1390	1360
3V	3 Aug	1130	1040	800	920
3V	5 Aug	1131	840	810	825
3W	3 Aug	1135	450	500	475
3W	5 Aug	1148	420	460	440
Total			17070	17130	17100[g]
Total					16831[h]

[a] Data are from Springer et al. (1985), and A.M. Springer's, D.G. Roseneau's, and E.C. Murphy's original field notes and field data summary sheets. Boat-based counts, murres counted by 10's. In Springer et al. (1985), Colony 3 plots listed in Table 5 using hyphens are equivalent to the parenthetical designations shown on the photographs, ie, Q-O = 3Q(O); Q-P = 3Q(P), etc.

[b] Bering Daylight Time (BDT).

[c] Census plots 3G, 3H, 3I, 3J, and 3K were combined by Springer et al. (1985) because the two observers reported having difficulties locating and agreeing on the plot boundaries. Because of these difficulties the scores reported here for these 5 plots should not necessarily be used for direct comparisons of these individual plots between years (ie., to compare 1982 data with data from preceding and following years, these 5 plots should be combined).

[d] L.G. Swartz' census plot 3Q, as listed here, is the equivalent of plots "Q-O" plus "Q-P" listed in Table 5 of Springer et al. (1985).

[e] L.G. Swartz' census plot 3R, as listed here is the equivalent of plots "R-O" plus "R-P", listed in Table 5 in Springer et al. (1985).

[f] L.G. Swartz' census plot 3S, as listed here, is the equivalent of the two plots "S-O" plus "S-P" listed in Table 5 of Springer et al. (1985).

[g] Census total from 3 August counts.

[h] Calculated using averages of 3 and 5 August counts, when available.

TABLE G.22. COLONY 4 MURRE CENSUS, 1960[a]

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (LGS)	Obs. 2 (GWC)	Mean
4A	15 Jul	1257	127	139	133[c]
4B	15 Jul	1325	629	648	638[c]
4C	15 Jul	1348	867	802	834[c]
4D	15 Jul	1600	363	380	371[c]
4E	15 Jul	1425	1131	1249	1190[c]
4F	15 Jul	1510	575	626	600[c]
4G	15 Jul	1525	1550[d]	1560	1555[c]
4H	15 Jul	1610	303	393	348[c]
4I	15 Jul	1700	59	56	57[c]
4J	15 Jul	1725	291	275	283
4J	17 Jul	1315	555	577	566[c]
4K	15 Jul	1745	–[e]	203	203
4K	17 Jul	1340	200	215	207[c]
4L	15 Jul	1750	154	188	171[c]
4M	15 Jul	1805	730[d]	589[f]	659
4M	17 Jul	1335	925[d]	1100[g]	1012[c]
4N	15 Jul	1845	261	313	287
4N	17 Jul	1345[h]	275[d]	275[g]	275[c]
4O	17 Jul	1400	1	1	1[c]
4P	17 Jul	1405	559	670	614[c]
4Q	17 Jul	1455	172	–	172[c]
4R	17 Jul	1455	–	124	124[c]
Total					8868[i]
Total					8554[j]

[a] Data are from L.G. Swartz' collection of original field notes; specific sources include L.G. Swartz and G.W. Cox field notebooks. Presumably all plots were counted from boat, and murres estimated by 1's and 10's except where noted.

[b] Bering Standard Time (BST).

[c] Counts used for census total of the colony by Swartz (1966).

[d] Listed by L.G. Swartz as being "estimated", rather than "counted". Counts may have been made by 100's.

[e] No data.

[f] Listed by G.W. Cox as including "100 from hole".

[g] Listed by G.W. Cox as being "estimated", rather than "counted". Possibly was counted by 100's.

[h] L.G. Swartz lists this time as 1445 h, but is probably an error; the correct time was probably 1345 h.

[i] This total differs from that reported by Springer and Roseneau (1977) because they reported compensated rather than raw values for the census plots.

[j] Total calculated by using averaged count values for plots counted on 15 and 17 July.

TABLE G.23. COLONY 4 MURRE CENSUS, 1961[a]

			Murres (birds)		
Plot[b]	Date	Time[c]	Obs. 1 (KJ)	Obs. 2 (LGS)	Mean
4A	22 Jul	1141	68	78	73
4B	22 Jul	1150	479	575	527
4C	22 Jul	1200	363	375	369
4D	22 Jul	1224	274/303 ($\bar{x}$=288)	196/218 ($\bar{x}$=207)	247
4E	22 Jul	1215	1130	931	1030
4F	22 Jul	1320	578	503	540
4G	22 Jul	1330	1065	1165	1115
4H	22 Jul	1615	372	330	351
4I	22 Jul	1415	45	44	44
4J	22 Jul	1430	206	192	199
4K[d]	22 Jul	–[e]	–	–	–
4L	22 Jul	1500	173	156	164
4M	22 Jul	1530	519	451	485
4N	22 Jul	1545	179	189	184
4O	22 Jul	1515	21	19	20
4P	22 Jul	1520	483	514	498
4Q	22 Jul	1600	157	152	154
4R	22 Jul	1600	89	95	92

[a] Data are from L.G. Swartz' collection of original field notes and data summary sheets; specific sources include K. Jones' and L.G. Swartz' field notebooks. Apparently all were boat-based counts; estimates by 1's and 10's.

[b] L.G. Swartz used different designations for Colony 4 census plots in 1960 and 1961. Designations shown here follow the 1960 system, and were converted as follows:

1960	1961
A	A,B
B	C
C	D
D	E
E	F,G
F	H
G	I
H	J
I	L
J	M
K	K
L	N
M	P
N	Q
O	O

TABLE G.23. COLONY 4 MURRE CENSUS, 1961 (cont.)

1960	1961
P	R
Q	S
R	T

[c] Bering Standard Time (BST).

[d] Census plot 4K contained 205 murres in 1960.

[e] No data.

TABLE G.24. COLONY 4 MURRE CENSUS, 1976[a]

Plot	Date	Time[b]	Murres (birds) Obs. 1 (MAD)	Obs. 2 (DGR)	Mean
4A	9 Aug	1846	140	135	137
4B	9 Aug	1846	260	270	265
4C	9 Aug	1900	840	980	910
4D	9 Aug	1930	180	150	165
4E	9 Aug	1910	860	900	880
4F	9 Aug	1917	310	360	335
4G	9 Aug	1917	990	835	912
4H	9 Aug	1917	390	360	375
4I	9 Aug	1917	50	30	40
4J	9 Aug	1917	820	788	804
4K	9 Aug	1917	130	140	135
4L	9 Aug	2000	130	120	125
4M	9 Aug	2000	570	568	569
4N	9 Aug	2000	310	344	327
4O	9 Aug	2000	90	125	107
4P	9 Aug	2000	460	520	490
4Q	9 Aug	2000	280	240	260
4R	9 Aug	2045	55	58	56
Total			6865	6923	6892

[a] Data are from Springer and Roseneau (1977), and A.M. Springer and D.G. Roseneau's original field data summary sheets. Boat-based counts; murres counted by 10's.

[b] Bering Daylight Time (BDT).

TABLE G.25. COLONY 4 MURRE CENSUS, 1977[a]

Plot	Date	Time[b]	Murres (birds) Obs. 1 (ECM)	Obs. 2 (DGR)	Mean
4A	12 Aug	1356	160	155	157
4B	12 Aug	1358	535	560	547
4C	12 Aug	1408	990	960	975
4D	12 Aug	1505	140	130	135
4E	12 Aug	1420	980	990	985
4F	12 Aug	1445	320	300	310
4G	12 Aug	1455	1075	950	1012
4H	12 Aug	1507	355	338	346
4I	12 Aug	1515	100	90	95
4J	12 Aug	1518	580	540	560
4K	12 Aug	1522	120	130	125
4L	12 Aug	1528	415	425	420
4M	12 Aug	1535	480	495	487
4N	12 Aug	1558	348	300	324
4O	12 Aug	1530	100	95	97
4P	12 Aug	1547	690	625	657
4Q	12 Aug	1539	160	170	165
4R	12 Aug	1540	220	220	220
Total			7768	7473	7617[c]

[a] Data are from Springer and Roseneau (1978) and A.M. Springer, D.G. Roseneau and E.C. Murphy original field data summary sheets. Boat-based counts, murres counted by 10's.

[b] Bering Daylight Time (BDT).

[c] Total differs slightly from that reported by Springer and Roseneau (1978) because of different methods of rounding numbers.

TABLE G.26. COLONY 4 MURRE CENSUS, 1979[a]

			Murres (birds)					
Plot	Date	Time[b]	Obs. 1 (WW)	Obs. 2 (DGR)	Obs. 3 (MIJ)	Obs. 4 (AMS)	Obs. 5 (ECM)	Mean
4A	7 Aug	1655	125	120				122
4A	14 Aug	2045	197	190			160	182
4B	7 Aug	1700	570	600				585
4B	14 Aug	2040	570	575			540/600 ($\bar{x}$=570)	572
4C[c]	7 Aug	1705	210	240				225
4C[c]	14 Aug	2038	295	270			270	278
4D[d]	7 Aug	1720	170	165				167
4D[d]	14 Aug	2030	190	190			–[e]	190
4E	7 Aug	1725	780	855				817
4E	11 Aug	2123	1120	930				1025
4E	14 Aug	2027	920	720			700/720 ($\bar{x}$=710)	783
4F	7 Aug	1735	113	110				111
4F	14 Aug	2025	250/260 ($\bar{x}$=255)	220			200	225
4G	7 Aug	1745[f]	620	670				645
4G	11 Aug	2130	820	860				840
4G	14 Aug	2020	1250	1100			820	1057
4H	7 Aug	1755	400	340				370
4H	14 Aug	2010	270	350			330	317
4I	7 Aug	1800	50	45				47
4I	14 Aug	2013	85	80			60	75
4J	7 Aug	1815	400	470				435
4J	14 Aug	2004	820	550			510	627
4K	7 Aug	1812	160	160				160
4K	14 Aug	2002	110	80			115	102
4L	7 Aug	1810	280/310 ($\bar{x}$=295)	290/300 ($\bar{x}$=295)				295
4L	14 Aug	2000	360	270			215	282
4M	7 Aug	1815			290/300/ 330 ($\bar{x}$=307)	280/310 ($\bar{x}$=295)		301

TABLE G.26. COLONY 4 MURRE CENSUS, 1979 (cont.)

			Murres (birds)					
Plot	Date	Time[b]	Obs. 1 (WW)	Obs. 2 (DGR)	Obs. 3 (MIJ)	Obs. 4 (AMS)	Obs. 5 (ECM)	Mean
4M	11 Aug	2135			380/380 ($\bar{x}$=380)	370/430 ($\bar{x}$=400)		390
4M	14 Aug	1957	560/570 ($\bar{x}$=565)	500			410	492
4N	7 Aug	1800			340	330		335
4N	14 Aug	1955	390	350			345	362
4O	7 Aug	1750			85/90/94 ($\bar{x}$=90)	106/116 ($\bar{x}$=111)		100
4O	14 Aug	1953	100	105			110	105
4P	7 Aug	1745			470	500		485
4P	11 Aug	2125			500/570 ($\bar{x}$=535)	560/630 ($\bar{x}$=595)		565
4P	14 Aug	1947	760	720			595	692
4Q	7 Aug	1755			65	75		70
4Q	14 Aug	1942	240	210			205	218
4R	7 Aug	1755			180	200		190
4R	14 Aug	1935	280	290			300	290
Total	7 Aug							5460
Total	14 Aug							6849
Total								6312[g]

[a] Data are from A.M. Springer, D.G. Roseneau, E.C. Murphy and M.I. Johnson's original field notebooks and E.C. Murphy's field data summary sheets. Boat-based count; counts by 10's.

[b] Bering Daylight Time (BDT).

[c] The entire face of census plot 4C collapsed into the sea sometime during September 1978 - June 1979. Murres were perching on a few ledges and on the rubble pile below the fresh cliff-face, and recolonization of this plot was just beginning.

[d] Census plot 4D consisted of all of the backside of the Cape Thompson arch that was also part of census plot 4C. Almost all of census plot 4D was gone; it collapsed into the sea sometime during September 1978 - June 1979 (see footnote c above).

TABLE G.26. COLONY 4 MURRE CENSUS, 1979 (cont.)

[e] No data.

[f] Estimated time.

[g] Total calculated using averages of plot counts from 7, 11 (if available), and 14 August.

TABLE G.27. COLONY 4 MURRE CENSUS, 1982[a]

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (RSM)	Mean
4A	28 Jul	2030	100	120	110
4A	3 Aug	1425	110	110	110
4B	28 Jul	2028	200	290	245
4B	3 Aug	1423	180	180	180
4C[c]	28 Jul	2025	430	320	375
4C[c]	3 Aug	1417	480	500	490
4D[d]	28 Jul	2007	130	70	100
4D[d]	3 Aug	1400	140	120	130
4E	28 Jul	2014	670	660	665
4E	3 Aug	1405	720	630	675
4F	28 Jul	2013	240	300	270
4F	3 Aug	1358	240	260	250
4G	28 Jul	2010	820	1000	910
4G	3 Aug	1356	570	540	555
4H	28 Jul	2000	410	360	385
4H	3 Aug	1346	170	170	170
4I	28 Jul	1958	90	40	65
4I	3 Aug	1344	90	80	85
4J	28 Jul	1953	460	520	490
4J	3 Aug	1341	480	500	490
4K	28 Jul	1950	90	100	95
4K	3 Aug	1339	110	110	110
4L	28 Aug	1945	360	450	405
4L	3 Aug	1333	240	250	245
4M	28 Jul	1936	370	410	390
4M	3 Aug	1330	320	350	335
4N	28 Jul	1940	370	420	395
4N	3 Aug	1328	190	200	195
4O	28 Jul	1942	90	90	90
4O	3 Aug	1325	70	80	75

TABLE G.27. COLONY 4 MURRE CENSUS, 1982 (cont.)

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (RSM)	Mean
4P	28 Jul	1933	610	710	660
4P	3 Aug	1320	360	390	375
4Q	28 Jul	1930	230	250	240
4Q	3 Aug	1314	260	290	275
4R	28 Jul	1928	260	220	240
4R	3 Aug	1308	240	230	235
Total	28 Jul		5930	6330	6130
Total	3 Aug		4970	4990	4980
Total					5550[e]

[a] Data from Springer et al. (1985) and A.M. Springer, D.G. Roseneau, and E.C. Murphy (unpubl. data; specific source, E.C. Murphy original field data summary sheets). Boat-based counts; counts of murres by 10's.

[b] Bering Daylight Time (BDT).

[c] The entire face of census plot 4C collapsed into the sea sometime during September 1978 - June 1979; numbers reported here represent a recolonization attempt. This must be taken into account in any comparison between these numbers and pre-1979 censuses.

[d] Almost all of census plot 4D collapsed into the sea sometime during September 1978 - June 1979; numbers reported here represent a recolonization attempt. This must be taken into account in any comparison between these numbers and pre-1979 censuses.

[e] Total calculated using mean counts for plots determined by averaging 28 July and 3 August values.

TABLE G.28. COLONY 4 MURRE CENSUS, 1988[a]

			Murres (birds)			
Plot	Date	Time[b]	Obs. 1 (JLB)	Obs. 2 (BSF)	Obs. 3 (PR)	Mean
4A	10 Aug	1500	60		68	64
4B	10 Aug	1527	320	300		310
4C[c]	10 Aug	1544	200	190		195
4D[d]	10 Aug	1559	90		90	90
4E	10 Aug	1617		590	600	595
4F	10 Aug	1628	190	200		195
4G	10 Aug	1636	600	630		615
4H	10 Aug	1710	250	250	240	247
4I	10 Aug	1708	60		60	60
4J	10 Aug	1720		550	540	545
4K	10 Aug	1715	60		60	60
4L	10 Aug	1733	210		220	215
4M	10 Aug	1743	310	290	320	307
4N	10 Aug	1749	230		230	230
4O	10 Aug	1724	70		70	70
4P	10 Aug	1831	250	260		255
4Q	10 Aug	1845	240	250		245
4R	10 Aug	1855	160	170		165
Total						4463

[a] Data from present study. Boat-based counts, murres counted by 1's and 10's.

[b] Alaska Daylight Time (ADT).

[c] The entire face of census plot 4C collapsed into the sea sometime during September 1978 - June 1979; numbers reported here represent a recolonization attempt. This must be taken into account in any comparison between these numbers and pre-1979 censuses.

[d] Almost all of census plot 4D collapsed into the sea sometime during September 1978 - June 1979; numbers reported here represent a recolonization attempt. This must be taken into account in any comparison between these numbers and pre-1979 censuses.

TABLE G.29. COLONY 5 MURRE CENSUS, 1960[a]

			Murres (birds)			
Plot	Date	Time[b]	Obs. 1 (GWC)	Obs. 2 (LMB)	Obs. 3 (LS)	Mean
5A[c]	2 Aug	1615	1020	875		947
5B[c]	2 Aug	1635	2654	-[d]		2654
5C[c]	2 Aug	1705	870	-		870
5D[c]	2 Aug	1725	1700	-		1700
5E[c]	1 Aug	1300[e]	3400		3740	3570
5F[c]	1 Aug	1300[e]	960		1020	990
5G[c]	1 Aug	1340	4500		3670/4400 (x̄=4035)	4267
5H[c]	1 Aug	1340[f]	4400		4000/4300 (x̄=4150)	4275
5I[c]	1 Aug	1420	1200		1500	1350
5J[c]	1 Aug	1645[g]	2000		2200	2100
5K[c]	1 Aug	1645[h]	3900		3150/3800 (x̄=3475)	3687
5L[ci]	1 Aug	1515	1800		1900	1850
5M[c]	1 Aug	-	1400		2000	1700
5N[c]	1 Aug	1615	3500		3800	3650
5O[c]	1 Aug	1615	2800		3300	3050
5P[c]	1 Aug	1615	3500		3700	3600
5Q[ci]	2 Aug	1320	1900	1625		1762
5R[c]	2 Aug	1320	4300	4400		4350
5S[c]	2 Aug	1420	1900	1950		1925
5T[c]	2 Aug	1440	1170	1075		1122
5U[c]	2 Aug	1500	900	850		875
5V[c]	2 Aug	1510	110	110		110
5W[c]	2 Aug	1515	70	70		70
5X[c]	4 Aug	1320	1200		970	1085
5Y[c]	4 Aug	1340	2250		2200	2225
5Z[c]	4 Aug	1400	450		500	475
5AA[j]	4 Aug	1400[k]	4300/4500/4800 (x̄=4533)		5200	4866
5BB[j]	4 Aug	1435[k]	1100		1200	1150
5CC[j]	4 Aug	1435[k]	1600		1800	1700
5DD[j]	12 Aug	1405[k]	3100		2800	2950
5EE[j]	12 Aug	1415[k]	3300		2900	3100
5FF[j]	12 Aug	1440[k]	4400		5100	4750
5GG[j]	12 Aug	1500[k]	7500		7800	7650
5HH[j]	12 Aug	1525[k]	1500		12700	12100
5II[j]	12 Aug	1540[k]	7400		6200/7000 (x̄=6600)	7000
5JJ[j]	12 Aug	1610[k]	7200		7600	7400
5KK[j]	12 Aug	1630[k]	6500		5400/6300 (x̄=5850)	6175
5LL[j]	12 Aug	1645[k]	1250		1000/1200 (x̄=1100)	1175

TABLE G.29. COLONY 5 MURRE CENSUS, 1960 (cont.)

			Murres (birds)			
Plot	Date	Time[b]	Obs. 1 (GWC)	Obs. 2 (LMB)	Obs. 3 (LS)	Mean
5MM[j]	12 Aug	1655[k]	6500		6800/7200 ($\bar{x}$=7000)	6750
5NN[j]	12 Aug	1720[k]	7300		7400	7350
5OO[j]	12 Aug	1730[k]	5900		6100	6000
5PP[j]	12 Aug	1745[k]	4250		3700/4000 ($\bar{x}$=3850)	4050
5QQ[j]	12 Aug	1755[k]	1650		1200/1200 ($\bar{x}$=1200)	1425
5RR[j]	12 Aug	–[k]	1800		1500/1800 ($\bar{x}$=1650)	1725

[a] Data are from L.G. Swartz' collection of original field notes. Specific sources include: G.W. Cox Notebook No. 2 and L.M. Belson Notebook No. 2 (Census plots 5A–5D and 5Q–5W); G.W. Cox Notebook No. 2 and L. Schene Notebook No. 2 (Census plots 5E–5P, 5X–5Z, and 5AA–5RR). Birds were counted by 10's and 100's.

[b] Bering Standard Time (BST).

[c] Land-based counts.

[d] No data.

[e] Time is approximate. G.W. Cox lists 1300 h and L. Schene lists 1315 h.

[f] Time is approximate. G.W. Cox lists 1340 h and L. Schene lists 1415 h.

[g] Time is approximate. G.W. Cox lists 1645 h and L. Schene lists 1445 h.

[h] Time is approximate. G.W. Cox lists 1645 h and L. Schene does not list a time.

[i] Plot 5L is equivalent to 5-5J, and 5Q is equivalent to 5-8N of the new land-based plot system.

[j] Counted from boat.

[k] Times are approximate. Times listed here are from G.W. Cox field notes, but L. Schene also recorded times that were 5–20 min later than those listed by Cox.

TABLE G.30. COLONY 5 MURRE CENSUS, 1976[a]

			Murres (birds)			
Plot[b]	Date	Time[c]	Obs. 1 (MAD)	Obs. 2 (DGR)	Obs. 3 (AMS)	Mean
5AA(1976)	19 Aug	1810	1500	1000	1700	1400
5BB(1976)	19 Aug	-[d]	3200	2200	3600	3000
5CC(1976)	19 Aug	1800	16300	10600	16500	14467
5DD(1976)	19 Aug	-[d]	4100	2000	2700	2933
5FF(1976)	19 Aug	1740	12400	10650	10300	11117
5HH(1976)	19 Aug	-[e]	11300	9200	10700	10400
5KK(1976)	19 Aug	1715	11500	13500	9600	11533
5LL(1976)	19 Aug	1655	12700	12400	8700	11267
5NN(1976)	19 Aug	-[f]	8100	13000	6800	9300
5QQ(1976)	19 Aug	-[f]	3100	2450	2300	2617
5RR(1976)	19 Aug	1615	1700	2750	1400	1950
Total			85900	79750	74300	79984

[a] Data are from Springer et al. (1977) and A.M. Springer and D.G. Roseneau original field data summary sheets. Boat-based counts, murres counted by 10's and 100's.

[b] These plot designations were developed in 1976, and match tables presented in Murphy et al. (1980) and Springer et al. (1985).

[c] Bering Daylight Time (BDT).

[d] Between 1800-1810.

[e] Between 1715-1740.

[f] Between 1615-1655.

TABLE G.31. COLONY 5 MURRE CENSUS, 1977[a]

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (DGR)	Mean
5A	17 Aug	1705	0	0	0
5B,C,X	17 Aug	1705	850	1055	952
5D,Y,Z	17 Aug	1645	2480	2465	2472
5E,F	17 Aug	1558	1550	1405	1477
5G	17 Aug	1522	1280	1210	1245
5H,I	17 Aug	1607	1720	1770	1745
5J	17 Aug	1500	390	400	395
5K	17 Aug	1435	840	880	860
5L	17 Aug	1507	210	225	217
5M	14 Aug	1950	460	430	445
5N	14 Aug	1955	810	870	840
5O	14 Aug	2000	390	360	375
5P	14 Aug	2005	770	630	700
5Q	14 Aug	1945	250	290	270
5R	17 Aug	1420	420	420	420
5S	14 Aug	1420	980	915	947
5T	14 Aug	1433	990	1060	1025
5U	13 Aug	1850	180	160	170
5V	13 Aug	1840	160	185	172
5W	13 Aug	1840	150	140	145
5AA	17 Aug	1602	2470	2310	2390
5BB	17 Aug	1555	440	510	475
5CC	17 Aug	1548	960	1060	1010
5DD	17 Aug	1527	1580	1285	1432
5EE	17 Aug	1510	1940	2185	2062
5FF	17 Aug	1445	2740	2680	2710
5GG[c]	14 Aug	1915	3510	3885	3697
5HH[d]	14 Aug	1800	5100	5370	5235
5II	14 Aug	1655	4840	4930	4885
5JJ[e]	14 Aug	1630	1675	1550	1612
5KK[f]	14 Aug	1600	2470	3105	2787
5LL	14 Aug	1513	1080	940	1010
5MM	14 Aug	1443	3705	3320	3512
5NN[g]	14 Aug	1330	4260	4905	4582
5OO	14 Aug	1310	2265	2440	2352
5PP[h]	13 Aug	1958	2255	2400	2327
5QQ	13 Aug	1915	1050	1145	1097
5RR	13 Aug	1840	1275	1225	1250
Total			58495	60115	59297

TABLE G.31. COLONY 5 MURRE CENSUS, 1977 (cont.)

[a] Data are from A.M. Springer, D.G. Roseneau and E.C. Murphy (unpubl. data; specific source was original field data summary sheets). All were boat-based counts, murres estimated by 10's. All plots follow Swartz 1960 designations.

[b] Bering Daylight Time (BDT).

[c] Counts are equivalent to counts of special area #109.

[d] Counts are equivalent to sum of special areas #107 and #108.

[e] Counts are equivalent to the sum of special areas #105 and #106.

[f] Counts are equivalent to the sum of special areas #103 and #104.

[g] Counts include counts of special area #101.

[h] Counts include counts of special area #102.

TABLE G.32. COLONY 5 MURRE CENSUS, 1977
USING 1976 PLOT DESIGNATIONS[a]

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (DGR)	Mean
5AA(1976)	17 Aug	1705	850	1055	952
5BB(1976)	17 Aug	1645	2480	2465	2472
5CC(1976)	17 Aug	1612	5480	5310	5395
5DD(1976)	17 Aug	1510	6680	6670	6675
5FF(1976)	17 Aug	1420	5910	5970	5940
5HH(1976)	14 Aug	1807	7640	7820	7730
5KK(1976)	14 Aug	1630	8800	9470	9135
5LL(1976)	14 Aug	1420	9070	8775	8923
5NN(1976)	14 Aug	1310	6910	7700	7305
5QQ(1976)	13 Aug	1915	2920	3190	3055
5RR(1976)	13 Aug	1840	1765	1710	1737
Total			58505	60135	59319[c]

[a] Data from Springer and Roseneau (1978) and A.M. Springer, D.G. Roseneau and E.C. Murphy original field data summary sheets. Boat-based counts, murres counted by 10's and 100's.

[b] Bering Daylight Time (BDT).

[c] Totals include 10 birds in Obs. 1 and 20 birds in Obs. 2 total of 5CC(1976) that were counted in Special Area #113.

TABLE G.33. COLONY 5 MURRE CENSUS, 1977
SPECIAL AREAS[a]

Plot	Date	Time[b]	Murres (birds) Obs. 1 (ECM)	Obs. 2 (DGR)	Mean
#101	13 Aug	1915	0	0	0
#102	13 Aug	1958	385	355	370
#103	17 Aug	1530	890	1230	1060
#104	17 Aug	1630	1580	1875	1727
#105	17 Aug	–[c]	1425	1310	1367
#106	17 Aug	1630	250	240	245
#107	17 Aug	1750	2130	2425	2277
#108	17 Aug	1807	2970	2945	2957
#109	17 Aug	1915	3510	3885	3697
#110	14 Aug	1445	0	0	0
#111	17 Aug	1602	720	750	735
#112	17 Aug	1612	1750	1560	1655
#113	17 Aug	1620	10	20	15

[a] Data are from A.M. Springer, D.G. Roseneau and E.C. Murphy original field data summary sheets. Refer to APX#.# for special area descriptions.

[b] Bering Daylight Time (BDT).

[c] No data.

TABLE G.34. COLONY 5 MURRE CENSUS, 1979[a]

Plot	Date	Time[b]	Obs.1 (DGR)	Obs.2 (WW)	Obs.3 (MIJ)	Obs.4 (AMS)	Obs.5 (AP)	Obs.6 (DM)	Obs.7 (ECM)	Obs.8 (BT)	Mean
			Murres (birds)								
5A	7 Aug	1150	0	0							0
5B	7 Aug	1330	100	120							110
5C	7 Aug	1332	650	700							675
5D	7 Aug	1215	350	346							348
5E	7 Aug	1300	450/470 ($\bar{x}$=460)	470							465
5F	7 Aug	1250	410/420 ($\bar{x}$=415)	304/309 ($\bar{x}$=306)							360
5E,5F[c]	7 Aug	1655			1390/ 1390 ($\bar{x}$=1390)	1228[d]/ 1100 ($\bar{x}$=1164)					1277
5G	7 Aug	1421	580	580							580
5G[c]	7 Aug	1650						1780/ 1890 ($\bar{x}$=1835)			1835
5H	7 Aug	1406	560	600							580
5I	7 Aug	1225	320	250							285
5J	7 Aug	1455	200	195							197
5K	7 Aug	1530	830	670							750
5L	7 Aug	1510	230	230							230
5L[c]	7 Aug	1640			470/480 ($\bar{x}$=475)	506[d]					490
5M	7 Aug	1602	450/460/ 510 ($\bar{x}$=473)	425/ 440 ($\bar{x}$=432)							452
5M[c]	7 Aug	1605					702[e]				
702											
5N	7 Aug	1611	1070	1010							1040
5N[c]	7 Aug	1605				1400					1400
5O	7 Aug	1615	380	380							380
5O[c]	7 Aug	1605			690/830 ($\bar{x}$=760)		910				835
5P	7 Aug	1618	520/570 ($\bar{x}$=545)	480/510 ($\bar{x}$=495)							520
5P[c]	7 Aug	1615			940						940

TABLE G.34. COLONY 5 MURRE CENSUS, 1979 (cont.)

			Murres (birds)								
Plot	Date	Time[b]	Obs.1 (DGR)	Obs.2 (WW)	Obs.3 (MIJ)	Obs.4 (AMS)	Obs.5 (AP)	Obs.6 (DM)	Obs.7 (ECM)	Obs.8 (BT)	Mean
5Q	7 Aug	1630	370/400/ 410 ($\bar{x}$=393)	300/310/ 310 ($\bar{x}$=307)							350
5Q[c]	7 Aug	1615				900					900
5R[c]	7 Aug	1620				1430					1430
5S	7 Aug	1320			810/830 ($\bar{x}$=820)	900/ 1100 ($\bar{x}$=1000)					910
5T	7 Aug	1330			650	650					650
5U	7 Aug	1155			210	250					230
5V	7 Aug	1130			60	55					57
5W	7 Aug	1130			130	150					140
5X	7 Aug	1150	1120	1159							1139
5X	11 Aug	2112	1150	1070							1110
5Y	7 Aug	1200	930	1050							990
5Z	7 Aug	1200	360	360							360
5AA	10 Jul	2300			740				855		797
5AA	18 Jul	2048		535			590	740			622
5AA	1 Aug	1900					967	1012			989
5AA	5 Aug	2005			945	940					942
5AA	7 Aug	1411	1825	1698							1761
5AA	11 Aug	2055	2590	2980							2785
5AA	15 Aug	1855	1130	1170							1150
5AA	16 Aug	2100	1310						1170		1240
5BB,DD	7 Aug	1430	1120	1120							1120
5CC	7 Aug	1310	710	830							770
5EE	7 Aug	1447	1700	1740							1720
5FF	7 Aug	1516	2520	2925							2722
5GG	10 Jul	2300		710	570				660		647
5GG	18 Jul	2105		825			850	870			848
5GG	1 Aug	1832					903	915		870	896
5GG	5 Aug	2010			620	650					635
5GG	7 Aug	1500			1770	2020					1895
5GG	15 Aug	1840	1080	623							851
5GG	16 Aug	2110	775						800/820 ($\bar{x}$=810)		792
5HH	7 Aug	1445			2800	2930					2865

TABLE G.34. COLONY 5 MURRE CENSUS, 1979 (cont.)

			Murres (birds)								
Plot	Date	Time[b]	Obs.1 (DGR)	Obs.2 (WW)	Obs.3 (MIJ)	Obs.4 (AMS)	Obs.5 (AP)	Obs.6 (DM)	Obs.7 (ECM)	Obs.8 (BT)	Mean
5II	7 Aug	1430			1950	2340					2145
5JJ	7 Aug	1425			740	700					720
5JJ	11 Aug	2100			1360	1530					1445
5KK	7 Aug	1415			1700	2140					1920
5LL	7 Aug	1355			440	460					450
5LL	11 Aug	2110			860	990					925
5MM	7 Aug	1340			2000	2440					2220
5NN	7 Aug	1225			3040	3230					3135
5OO	7 Aug	1305			1400	1110					1255
5PP	7 Aug	1210			1240	1290					1265
5QQ	7 Aug	1205			870	860					865
5RR	7 Aug	1140			1350	1400					1375

[a] Data are from A.M. Springer, D.G. Roseneau, and E.C. Murphy's original field notebooks and E.C. Murphy's field data summary sheets. Boat-based counts; counts of murres by 10's, except where land-based (see footnote d).

[b] Bering Daylight Time (BDT).

[c] Land-based counts; counts of murres by 1's, 2's, and 10's.

[d] Count by 2's.

[e] Counts by 1's.

TABLE G.35. COLONY 5 MURRE CENSUS, 1979 SPECIAL AREAS[a]

Special Area	Date	Time[b]	Murres (birds) Obs. 1 (MIJ)	Obs. 2 (AMS)	Mean
#101	7 Aug	1225	0	0	0
#102	7 Aug	1210	–[c] (198)[d]	– (206)[d]	– (202)[d]
#103	7 Aug	1415	– (646)[d]	– (813)[d]	– (729)[d]
#104	7 Aug	1415	– (1054)[d]	– (1327)[d]	– (1190)[d]
#105	7 Aug	1425	– (629)[d]	– (595)[d]	– (612)[d]
#106	7 Aug	1425	– (111)[d]	– (105)[d]	– (108)[d]
#107	7 Aug	1445	1140 (1176)[d]	– (1230)[d]	1140 (1203)[d]
#108	7 Aug	1445	1660 (1624)[d]	– (1700)[d]	1600 (1662)[d]
#109	7 Aug	1500	1770	2020	1895
#110	7 Aug	1618	0	0	0

[a] Data are from A.M. Springer, D.G. Roseneau, M.I. Johnson, and E.C. Murphy's field notebooks, and E.C. Murphy's field summary sheets. See introduction to Appendix G for descriptions of special areas.

[b] Bering Daylight Time (BDT).

[c] No data.

[d] Estimates based on the proportion of birds in special areas relative to census plot counts in 1977.

TABLE G.36. COLONY 5 MURRE CENSUS, 1982
BOAT-BASED COUNTS[a]

			Murres (birds)		
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (RSM)	Mean
5A,5B	28 Jul	1402	120	90	105
5C	28 Jul	1348	110	270	190
5D	28 Jul	1355	160	200	180
5E	28 Jul	1417	40	40	40
5F	28 Jul	1418	130	110	120
5G	28 Jul	1425	450	280	365
5H	28 Jul	1424	310	580	445
5I	28 Jul	1411	270	220	245
5J	28 Jul	1456	210	240	225
5K,5FF	28 Jul	1505	2320	2500	2410
5L	28 Jul	1540	210	290	250
5M	28 Jul	1545	230	300	265
5N	28 Jul	1550	880	900	890
5O	28 Jul	1515	180	180	180
5P	28 Jul	1519	410	650	530
5Q	28 Jul	1544	230	300	265
5R	28 Jul	1630	410	530	470
5S	28 Jul	1706	420	600	510
5T	28 Jul	1704	390	520	455
5U,5RR	28 Jul	1757	1270	1210	1240
5V	28 Jul	1805	110	130	120
5W	28 Jul	1808	100	120	110
5X	28 Jul	1350	700	640	670
5Y,5Z[d]	28 Jul	1352	1070	1000	1035
5AA	28 Jul	1405	1290	1150	1220
5BB	28 Jul	1434	560	240	400
5CC	28 Jul	1431	280	180	230
5DD	28 Jul	1440	1290	1250	1270
5DD	3 Aug	1446	920	1000	960
5EE	28 Jul	1449	1160	1190	1175
5GG	28 Jul	1552	2290	2810	2550
5HH	28 Jul	1605	5190	5280	5235
5HH	3 Aug	1456	4570	4750	4660
5II	28 Jul	1625	3300	3160	3230
5JJ	28 Jul	1640	1300	1660	1480
5KK	28 Jul	1635	1770	2880	2325
5LL	28 Jul	1714	870	950	910
5LL	3 Aug	1515	940	980	960
5MM	28 Jul	1708	2620	2280	2450
5NN	28 Jul	1735	3000	2880	2940
5OO	28 Jul	1729	2620	3160	2890
5OO	3 Aug	1522	1600	1650	1625
5PP	28 Jul	1746	2170	2390	2280
5QQ	28 Jul	1751	1040	1240	1140

TABLE G.36. COLONY 5 MURRE CENSUS, 1982
BOAT-BASED COUNTS (cont.)

Total	41480	44600	43040[e]
Total			41989[f]

[a] Data are from Springer et al. (1985) and A.M. Springer, D.G. Roseneau and E.C. Murphy (unpubl. data; specific source E.C. Murphy's original field data summary sheets). All murres counted from boat by 10's and 100's.

[b] Bering Daylight Time (BDT).

[c] No data.

[d] Census plot 5Y, as reported by Springer et al. (1985), is now known to also contain census plot 5Z.

[e] Totals are of 28 July counts

[f] Total calculated using averages of replicated plot counts, when available.

TABLE G.37. COLONY 5 MURRE CENSUS, 1982 - LAND-BASED COUNTS[a]

Plot	Date	Time[b]	Murres (birds) Obs. 1 (ECM)	Obs. 2 (RSM)	Obs. 3 (JSH)	Obs. 4 (DWN)	Mean
5B	30 Jul	1600	950	875			912
5E	30 Jul	1515	2300	2201	1820		2107
5E	3 Aug	1818			2540	1818	2179[c]
5E	7 Aug	1557	1780	1740			1760[d]
5F	30 Jul	1510	450	464	452		455
5F	3 Aug	1816			490	455	472
5F	7 Aug	1615	440	380			410[d]
5G	30 Jul	1640	1900	2428	1920		2083
5G	3 Aug	1738			2170	1677	1923[e]
5G	7 Aug	1625	1940	1880	2160	1890	1967[d]
5H	30 Jul	1700[f]	1480	1780			1630
5H	3 Aug	1750			1990	1520	1755
5H	7 Aug	1640	1650	1600	1690	1840	1695[d]
5I	3 Aug	2124	630	650			640
5K[g]	3 Aug	1848			1880	1509	1694
5K[g]	3 Aug	2103	1550	1550			1550
5K	7 Aug	1655	1200	1350	1570	980	1275[d]
5L[g]	3 Aug	1240				866	866
5L[g]	3 Aug	1918			710	603	656
5L	7 Aug	1725	830	850	770	640	772[d]
5M	3 Aug	2025	860	810			835
5N	3 Aug	2015	2170	2400			2285
5O	3 Aug	1938			910	950	930
5O	7 Aug	1732	780	760	820	730	722[d]
5P	3 Aug	1950			1140	1250	1195
5P	7 Aug	1737	1270	1110	1330	1040	1187[d]
5Q	3 Aug	2005	890	820	600	623	733
5Q	7 Aug	1752	835	750	680	760	756[d]
5R	3 Aug	1952[h]	1790	1790	1960	1890	1857
5R	7 Aug	1758	2120	2180	2250	2210	2190[d]
5S	3 Aug	1931[i]	730	650			690
5S	7 Aug	1824	820	820	790	720	787[d]

TABLE G.37. COLONY 5 MURRE CENSUS, 1982 - LAND-BASED COUNTS (cont.)

			Murres (birds)				
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (RSM)	Obs. 3 (JSH)	Obs. 4 (DWN)	Mean
5T	3 Aug	1910	1290	1200			1245
5T	7 Aug	1835	800	870	830	1110	902[d]
5U	3 Aug	1900	420	460			440
5V	3 Aug	1836	530	500			515
5V	7 Aug	1855	320	310	357	290	319[d]
5W	3 Aug	1825[j]	770	750			760
5W	7 Aug	1900	385	365	380	380	377[d]

[a] Data from Springer et al. (1985), and A.M. Springer, D.G. Roseneau and E.C. Murphy (unpubl. data; specific source E.C. Murphy's original field data summary sheets).

[b] Bering Daylight Time (BDT).

[c] Springer et al. (1985) reported a mean score of 2134 for census plot 5E on 5 August; however, 2134 was a typographical error and the correct value as listed on E.C. Murphy's original field data summary sheets is 2179.

[d] Springer et al. (1985) inadvertantly reported a time-compensated mean value instead of an uncompensated raw score for this plot on 7 August. The correct, uncompensated mean value as listed on E.C. Murphy's original field data summary sheets is shown here.

[e] Springer et al. (1985) reported a mean score of 1924 for census plot 5G on 3 August, but the correctly rounded value is 1923.

[f] Springer et al. (1985) reported this time as 1800 h, however the correct time as listed on E.C. Murphy's original field data summary sheets is 1700.

[g] These data were not reported by Springer et al. (1985).

[h] Springer et al. (1985) reported this time to be 1932 h, a typographical error. The correct time as listed on E.C. Murphy's original data summary sheets is 1952.

[i] Springer et al. (1985) reported this time to be 1937 h, a typographical error. The correct time as listed on E.C. Murphy's original data summary sheets is 1931.

[j] Springer et al. (1985) reported this time to be 1820 h, a typographical error. The correct time as listed on E.C. Murphy's original data summary sheets is 1825.

TABLE G.38. COLONY 5 MURRE CENSUS, 1982 USING 1976 PLOT DESIGNATIONS[a]

Plot	Date	Murres (birds) Obs. 1 (ECM)	Obs. 2 (RSM)	Mean
5AA(1976)[b]	28 Jul	930	1000	965
5BB(1976)[b]	28 Jul	1230	1200	1215
5CC(1976)	28 Jul	2320	2230	2275
5DD(1976)	28 Jul	3670	3300	3485
5FF(1976)	28 Jul	4280	4770	4525
5HH(1976)	28 Jul	5700	6300	6000
5KK(1976)	28 Jul	6930	7720	7325
5LL(1976)	28 Jul	6110	6950	6530
5NN(1976)	28 Jul	5620	6040	5830
5QQ(1976)	28 Jul	3210	3630	3420
5RR(1976)	28 Jul	1480	1460	1470
Total		41480	44600	43040

[a] Data from Springer et al. (1985) and A.M. Springer, D.G. Roseneau and E.C. Murphy original field data summary sheets.

[b] Incorrect values for these plots were reported in Springer et al. (1985; Table 8). In that table, only Swartz 1960 plots 5A, 5C and 5X were added to get 5AA(1976) (reported scores of 810 and 910), and Swartz' 1960 plot 5B was included in scores for 5BB(1976). The correct values presented here were calculated by including 1960 plot 5B into the total for 5AA(1976), and subtracting it from plot 5BB(1976).

TABLE G.39. COLONY 5 MURRE CENSUS, 1982
SPECIAL AREAS[a]

			Murres (birds)		
Special Area	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (RSM)	Mean
#101	28 Jul	1735	0	0	0
#102	28 Jul	1729	(347)[c]	(382)[c]	(364)[c]
#103	28 Jul	1635	510	940	725
#104	28 Jul	1632	1260	1940	1600
#105	28 Jul	1640	(1105)[d]	(1411)[d]	(1258)[d]
#106	28 Jul	1640	(195)[d]	(249)[d]	(222)[d]
#107	28 Jul	1608	2370	2620	2495
#108	28 Jul	1601	2820	2660	2740
#109	28 Jul	1522	2290	2810	2550
#110	28 Jul	1550	0	0	0

[a] Data are from A.M. Springer, D.G. Roseneau and E.C. Murphy's field notebooks and field data summary sheets. Boat-based counts, counts by 10's and 100's. See introduction to Appendix G for special area descriptions.

[b] Bering Daylight Time (BDT).

[c] Estimates based on counts of census plot 5PP and the proportion of birds in special area #102 in 1977.

[d] Estimates based on counts of census plot 5JJ and the proportion of birds in special areas #105 and #106 in 1977.

TABLE G.40. COLONY 5 MURRE CENSUS, 1988[a]

Plot	Date	Time[b]	Murres (birds) Obs. 1 (PR)	Obs. 2 (JLB)	Obs. 3 (BSF)	Obs. 4 (DT)	Mean
5E[c]	27 Jul	1700	940				940
5E[c]	5 Aug	1545	1157				1157
5E[c]	18 Aug	1330	1354				1354
5L[c]	17 Jul	1812		1136			1136
5L[c]	20 Jul	1332			995		995
5L[c]	25 Jul	1525			638		638
5L[c]	27 Jul	1530	1005				1005
5L[c]	1 Aug	1510			994		994
5L[c]	4 Aug	2028			745		745
5L[c]	5 Aug	1724			934		934
5L[c]	8 Aug	1500				1047	1047
5L[c]	11 Aug	1334			779		779
5L[c]	15 Aug	1931			1027		1027
5Q[c]	11 Jul	1849			609		609
5Q[c]	17 Jul	1805			864		864
5Q[c]	20 Jul	1235	818				818
5Q[c]	25 Jul	1447			722		722
5Q[c]	27 Jul	–[d]				976	976
5Q[c]	1 Aug	1440			753		753
5Q[c]	4 Aug	1942			718		718
5Q[c]	5 Aug	1618			811		811
5Q[c]	8 Aug	1430				968	968
5Q[c]	11 Aug	1233			901		901
5Q[c]	15 Aug	2023			1028		1028
5R[c]	27 Jul	1540			1430		1430
5R[c]	5 Aug	1658			1650		1650
5R[c]	18 Aug	1350			1780		1780
5S[c]	5 Aug	1630		731			731
5S[c]	18 Aug	1350		904			904
5AA[e]	10 Aug	1410		1750	1720		1735
5DD[e]	10 Aug	1352		1030	990		1010
5GG[e]	10 Aug	1250		2440	2680		2560
5HH[e]	10 Aug	1150		3710	4320		4015
5LL[e]	10 Aug	1122	920	1030	930		960
5OO[e]	10 Aug	1105		1730	1690		1710

TABLE G.40. COLONY 5 MURRE CENSUS, 1988[a]

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[a] Data from the present study. Murres counted by 1's and 10's. Plot designations follow Swartz 1960 census plot designations.

[b] Alaska Daylight Time (ADT).

[c] Land-based counts. Plot 5L is equivalent to plot 5-5J, and plot 5Q is equivalent to 5-8N of the new land-based system (Chapter 2). All plot designations follow Swartz 1960 system. 5L and 5Q counted by 1's, others counted by 10's.

[d] No data.

[e] Boat-based counts. Plots follow Swartz 1960 designations. Counts by 10's.

TABLE G.41. COLONY 2 KITTIWAKE CENSUS, 1960[a]

			Kittiwakes (nests)			
Plot	Date	Time[b]	Obs. 1 (GWC)	Obs. 2 (LS)	Obs. 3 (EJW)	Mean
2A1	27 Jul	1415	0	0		0
2A2	27 Jul	1425	0	0		0
2B	27 Jul	1435	0	0		0
2C	27 Jul	1440	0	0		0
2D	27 Jul	1445	0	0		0
2E	27 Jul	1520	301[d]	400/390 ($\bar{x}$=395)		348
2F	27 Jul	1545	265/265 ($\bar{x}$=265)	270/290 ($\bar{x}$=280)		272
2G	27 Jul	1620	128	118/132 ($\bar{x}$=125)		126
2H	27 Jul	1700	61	57		59
2I	27 Jul	1730	149	120		134
2J	27 Jul	1815	180	139/161 ($\bar{x}$=150)		165
2K	29 Jul	1355	26		28	27
2L	28 Jul	1510	454		385	419
2M	29 Jul	–[ef]	472		494[g]	483
2N	29 Jul	1545	429		410	419
2O	29 Jul	1635	84		75	79
2P	29 Jul	1705	70		48	59
2Q	31 Jul	1215	306	320		313
2R	31 Jul	1240	3	3		3
2S	31 Jul	1300	84	88/107 ($\bar{x}$=97)		90
2T	31 Jul	1340	314	267/285/295 ($\bar{x}$=282)		298
2U	31 Jul	1515	771	660/760 ($\bar{x}$=710)		740
2V	31 Jul	1535	318	325		321
2W	31 Jul	1630	235	160/230 ($\bar{x}$=195)		215
2X	31 Jul	1645	76	75		75
2Y	31 Jul	1730	156	124		140
2Z	3 Aug	1400	74	84/95 ($\bar{x}$=89)		81
2AA	3 Aug	–[h]	41	49		45
2BB	3 Aug	1410	6	6		6
2CC	3 Aug	1420	15	13		14
2DD	3 Aug	–[i]	85	86		85
2EE	3 Aug	–[i]	105	88/102 ($\bar{x}$=95)		100
2FF	3 Aug	–[i]	9	9		9
2GG	3 Aug	1540	3	3		3

TABLE G.41. COLONY 2 KITTIWAKE CENSUS, 1960 (cont.)

			Kittiwakes (nests)			
Plot	Date	Time[b]	Obs. 1 (GWC)	Obs. 2 (LS)	Obs. 3 (EJW)	Mean
2HH	3 Aug	-[j]	14	11		12
2II	3 Aug	-[j]	0	0		0
Total						5140

[a] Data are from L.G Swartz' collection of original field notes. Specific sources for the counts include: G.W. Cox Notebook No. 2 and L. Schene Notebook No. 2 (census plots 2A1-2J and 2Q-2II); G.W. Cox Notebook No. 2 (census plot 2L); G.W. Cox Notebook No. 2 and E.J. Willoughby Notebook No. 1 (census plots 2K and 2M-2P). Whenever observers made two or more counts on the same plot, L.G. Swartz only used the count that most closely matched that of the other observer. Boat-based census; counts of nests by 1's.

[b] Only nests were counted. For comparative purposes, Springer and Roseneau (1977) multiplied numbers of nests by 2. Differences between doubling values reported here and doubled scores reported by Springer and Roseneau (1977) for census plots 2E, 2F, 2G, 2I, 2J, 2K, 2M, 2S, 2T, 2U, 2W, 2Y, 2EE, and 2HH/2II result from different methods of rounding and the fact that several recently discovered repeat counts of these plots are included here.

[c] Bering Standard Time (BST).

[d] G.W. Cox commented that this count "...may be too low."

[e] No data.

[f] Probably about 1500 h.

[g] The total score reported by E.J. Willoughby was 486, but an error was made in addition and the actual total was 494.

[h] Probably about 1405 h.

[i] Probably between about 1425-1540 h.

[j] Probably between about 1545-1600 h.

TABLE G.42. COLONY 2 KITTIWAKE CENSUS, 1961[a]

Plot	Date	Time[b]	Kittiwakes (nests) Obs. 1 (KJ)	Obs. 2 (EJW)	Mean
2D	10 Aug	–[c]	0	0	0
2E	10 Aug	–	235	249	242
2F	10 Aug	–	239	264	251
2H	10 Aug	–	54	48	51
2J	10 Aug	–	153	160	156
2N	10 Aug	–	372	420	396
2P	11 Aug	–	65	60	62
2R	11 Aug	–	0	0	0
2T	11 Aug	–	312	317	314
2V	11 Aug	–	324	296	310
2X	11 Aug	–	94	95	94
2Z	11 Aug	–	77	73	75
2BB	11 Aug	–	5	5	5
2DD	11 Aug	–	87	84	85
2FF	11 Aug	–	8	8	8
2HH	11 Aug	–	16	15	15
2II	11 Aug	–	0	0	0

[a] Data are from L.G. Swartz' collection of original field notes, specificsource, K. Jones' Notebook No. 2, E.J. Willoughby's Notebook No. 3, and E.C. Murphy's summary sheets of data extracted from other sources. Boat-based census; counts of nests by 1's.

[b] Bering Standard Time (BST).

[c] No data.

TABLE G.43. COLONY 2 KITTIWAKE CENSUS, 1976[a]

			Kittiwakes (birds)			
Plot	Date	Time[b]	Obs. 1 (DGR)	Obs. 2 (MAD)	Obs. 3 (DJ)	Mean
2A1	18 Aug	–[c]	0	0	0	0
2A2	18 Aug	–	0	0	0	0
2B	18 Aug	–	0	0	0	0
2C	18 Aug	–	0	0	0	0
2D	18 Aug	–	0	0	0	0
2E	18 Aug	–	235	238	310	261
2F	18 Aug	–	230	218	275	241
2G	18 Aug	–	133	135	134	134
2H	18 Aug	–	36	30	42	36
2I	18 Aug	–	126	92	111	110
2J	18 Aug	–	133	144	136	138
2K	18 Aug	–	38	27	35	33
2L	18 Aug	–	242	242	263	249
2M	18 Aug	–	467	533	538	513
2N	18 Aug	–	31	31	31	31
2O	18 Aug	–	46	51	38	45
2P	18 Aug	–	41	47	41	43
2Q	18 Aug	–	206	207	195	203
2R	18 Aug	–	8	7	8	8
2S	18 Aug	–	93	71	92	85
2T	18 Aug	–	239	243	241	241
2U	18 Aug	–	345	345	345	345
2V	18 Aug	–	188	170	196	185
2W	18 Aug	–	158	147	139	148
2X	18 Aug	–	38	42	115[d]	40
2Y	18 Aug	–	87	80	84	84
2Z	18 Aug	–	28	28	27	28
2AA	18 Aug	–	22	21	24	22
2BB	18 Aug	–	2	2	2	2
2CC	18 Aug	–	11	10	11	11
2DD	18 Aug	–	104	59	75	79
2EE	18 Aug	–	39	39	39	39
2FF[e]	18 Aug	–	–[f]	–[f]	–[f]	–[e]
2GG[g]	18 Aug	–	–[g]	–[g]	–[g]	–[g]
2HH,2II	18 Aug	–	18	18	17	18
Total			3344	3277	3564[h]	3372[i]

[a] Data are from Springer and Roseneau (1977) and A.M. Springer and D.G. Roseneau's original field data summary sheets. Boat-based census; counts of kittiwakes by 1's.

[b] Bering Daylight Time (BDT).

[c] No data. Times were recorded during the census; however, Springer and Roseneau (1977) did not report them and the original data were lost during an arson-caused fire in their office building on 2 August 1978.

[d] This score was omitted from Table 15 in Springer and Roseneau (1977) because it was considered to be a bad count. It is reported here for purposes of completeness but should be deleted from any between years comparisons of numbers of birds on this census plot.

[e] Kittiwakes were not counted on census plot 2FF in 1976; however, this plot has typically supported only about 10-20 birds during past years.

[f] No data.

[g] Kittiwakes were not counted on census plot 2GG in 1976; however, this plot has typically supported fewer than 10 birds during past years.

[h] This total differs from the total reported for the observer by Springer and Roseneau (1977) because it includes a score for census plot 2X (also see footnote d above).

[i] This total differs from the mean total reported by Springer and Roseneau (1977) because of a few minor differences in rounding numbers and differences in mean values for census plot 2X (also see footnotes d and h above).

TABLE G.44. COLONY 2 KITTIWAKE CENSUS, 1977[a]

			Kittiwakes (birds)		
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (JS)	Mean
2A	17 Jul	2240	0	0	0
2B	17 Jul	–[c]	0	0	0
2C,2D,2E,2F[d]	17 Jul	–	263	275	269
2G,2H,2I,2J[d]	17 Jul	–	473	478	475
2K,2L,2M,2N[d]	17 Jul	–	713	705	709
2O,2P,2Q,2R[d]	17 Jul	–	364	330	347
2S,2T[d]	17 Jul	–	307	273	290
2U	17 Jul	–	496	506	501
2V,2W[d]	17 Jul	–	377	369	373
2X,2Y[d]	17 Jul	–	63	43	53
2Z,2AA[d]	17 Jul	–	121	126	123
2BB,2CC[d]	17 Jul	0130	87	82	84
2DD,2EE,2FF[d]	17 Jul	1900	191	197	194
2GG,2HH,2II[d]	17 Jul	1915	24	24	24
Total			3479	3408	3442

[a] Data are from Springer and Roseneau (1978) and A.M. Springer and D.G. Roseneau's original data summary sheets. Boat-based census; counts of kittiwakes by 1's.

[b] Bering Daylight Time (BDT).

[c] Census plots 2B-2AA were counted between about 1920-0130 h.

[d] Census plots were combined.

TABLE G.45. COLONY 2 KITTIWAKE CENSUS, 1978[a]

			Obs. 1 (DGR)	
Plot	Date	Time[b]	Birds	Nests
2U	20 Aug	1420	1029	582
2V	20 Aug	1530	414	247
Total			1443	829

[a] Data are from D.G. Roseneau's original field notebook. Boat-based census; counts of kittiwakes and nests by 1's.

[b] Bering Daylight Time (BDT).

TABLE G.46. COLONY 2 KITTIWAKE CENSUS, 1979[a]

			Kittiwakes (birds)							
Plot	Date	Time[b]	Obs.1 (DT)	Obs.2 (ECM)	Obs.3 (WW)	Obs.4 (AMS)	Obs.5 (MIJ)	Obs.6 (AP)	Obs.7 (DM)	Mean
2A1	11 Jul	1939	0	0						0
2A2	11 Jul	1941	0	0						0
2B	11 Jul	1942	0	0						0
2C	11 Jul	1943	0	0						0
2D	11 Jul	1947	6	6						6
2E	11 Jul	1952	335	316						325
2F	11 Jul	2010	273	350						311
2G	11 Jul	2025	221	202						212
2H	11 Jul	2040	71	85						78
2I	11 Jul	2100	224	188						206
2J	11 Jul	2115	235	233						234
2K,2L[c,d]	11 Jul	2150	470	540						505
2M[d,e]	11 Jul	2220	336	363						349
2M	18 Jul	1717			497/591					
					($\bar{x}$=544)					544
2N[d,e]	11 Jul	2240	235	293						264
2N	18 Jul	1737			362					362
2O[e]	11 Jul	2253	96	107						101
2O	18 Jul	1754						114		114
2P[e]	11 Jul	2300	58	57						57
2P	18 Jul	1801			60			52/53		
								($\bar{x}$=52)		56
2Q[e]	11 Jul	2300			220		296			258
2Q	18 Jul	1810						309	178/208[f]	
									($\bar{x}$=193)	251
2R	11 Jul	2250			12	13	10			12
2S	11 Jul	2240			110		119			114
2T[g]	11 Jul	2220			320/320		413			
					($\bar{x}$=320)					366
2T	19 Jul	1930			364			438		401
2U	11 Jul	2205			460/490					
					($\bar{x}$=475)					475
2V	11 Jul	2145			370/391	386	340/360			
					($\bar{x}$=380)		($\bar{x}$=350)			372
2W	11 Jul	2125			160/170	254	214			
					($\bar{x}$=165)					211

TABLE G.46. COLONY 2 KITTIWAKE CENSUS, 1979 (cont.)

			Kittiwakes (birds)							
Plot	Date	Time[b]	Obs.1 (DT)	Obs.2 (ECM)	Obs.3 (WW)	Obs.4 (AMS)	Obs.5 (MIJ)	Obs.6 (AP)	Obs.7 (DM)	Mean
2X	11 Jul	2115			106	111	106			108
2Y[g]	11 Jul	2050			190/197 ($\bar{x}$=193)	163	173			176
2Y	19 Jul	2022			215			183		199
2Z	11 Jul	2040			66	88	80		78	
2AA	11 Jul	2035			73	77	60		70	
2BB	11 Jul	2030			4	7	5		5	
2CC	11 Jul	2020			15	19	20		18	
2DD	11 Jul	–[hi]			152	169	138		153	
2EE	11 Jul	–[i]			76	80	78		78	
2FF	11 Jul	–[i]			25	26	24		25	
2GG	11 Jul	–[i]			4	4	4		4	
2HH	11 Jul	–[i]			46	47	52		48	
2II	11 Jul	1945			7/8 ($\bar{x}$=7)	11	6/7 ($\bar{x}$=6)			8
Total										5227[j]
Total										5482[k]

			Kittiwakes (nests)							
Plot	Date	Time[b]	Obs.1 (DT)	Obs.2 (ECM)	Obs.3 (WW)	Obs.4 (AMS)	Obs.5 (MIJ)	Obs.6 (AP)	Obs.7 (DM)	Mean
2A1	11 Jul	1939	0	0						0
2A2	11 Jul	1941	0	0						0
2B	11 Jul	1942	0	0						0
2C	11 Jul	1943	0	0						0
2D	11 Jul	1947	6	6						6
2E	11 Jul	1952	270	257					263	
2F	11 Jul	2010	240	289						264
2G	11 Jul	2025	191	174						182
2H	11 Jul	2040	70	76						73
2I	11 Jul	2100	185	155						170
2J	11 Jul	2115	164	165						164
2K,2L[cd]	11 Jul	2150	427	412						419
2M[de]	11 Jul	2220	242	224						233
2M	18 Jul	1717			280				227/312[f] ($\bar{x}$=269)	274

TABLE G.46. COLONY 2 KITTIWAKE CENSUS, 1979 (cont.)

			Kittiwakes (nests)							
Plot	Date	Time[b]	Obs.1 (DT)	Obs.2 (ECM)	Obs.3 (WW)	Obs.4 (AMS)	Obs.5 (MIJ)	Obs.6 (AP)	Obs.7 (DM)	Mean
2N[de]	11 Jul	2240		209						209
2N	18 Jul	1737						237	317[f]	277
2O[e]	11 Jul	2253	67	59						63
2O	18 Jul	1754			75/77 ($\bar{x}$=76)					76
2P[e]	11 Jul	2300	50							50
2P	18 Jul	1801			47				51	49
2Q[e]	11 Jul	2300				263				263
2Q	18 Jul	1810			236			237	187[f]	220
2R	11 Jul	2250				4	5			4
2S	11 Jul	2240				109				109
2T[g]	11 Jul	2220				375				375
2T	19 Jul	1930			295				261	278
2U	11 Jul	2205				513				513
2V	11 Jul	2145				357				357
2W	11 Jul	2125				229				229
2X	11 Jul	2115				93				93
2Y[g]	11 Jul	2050				163/166 ($\bar{x}$=165)	169			166
2Y	19 Jul	2022			147/151 ($\bar{x}$=149)				144	146
2Z	11 Jul	2040			56	69	66			64
2AA	11 Jul	2035			56	55	46			52
2BB	11 Jul	2030			3	7	4			5
2CC	11 Jul	2020			13	19	17			16
2DD	11 Jul	_[hi]			125	150	130			135
2EE	11 Jul	_[hi]			68	70	64			67
2FF	11 Jul	_[hi]			19	21	18			19
2GG	11 Jul	_[hi]			2	2	2			2
2HH	11 Jul	_[hi]			36	39	37			37
2II	11 Jul	1945			8	8	5			7
Total										4609[j]
Total										4642[k]

[a] Data are from A.M. Springer, D.G. Roseneau, E.C. Murphy and M.I. Johnson original field notebooks, and E.C. Murphy's field data summary sheets. Boat-based census; counts of kittiwakes and nests by 1's.

[b] Bering Daylight Time (BDT).

[c] Census plots 2K and 2L were combined.

[d] Counts were considered "poor" because the boat was rocking heavily.

[e] Plot was recounted on 18 July.

[f] These scores were not used in calculations by Murphy et al. (1980).

[g] Plot was recounted on 19 July.

[h] No data.

[i] Counted in sequence during 1945 - 2020 h.

[j] Totals calculated from 11 July data.

[k] Total calculated by excluding suspect counts made in rough weather,and by averaging replicate mean counts when available.

TABLE G.47. COLONY 2 KITTIWAKE CENSUS, 1982[a]

			Kittiwakes					
			Birds			Nests		
Plot	Date	Time[b]	Obs.1 (ECM)	Obs.2 (RSM)	Mean	Obs.1 (ECM)	Obs.2 (RSM)	Mean
2A1	5 Aug	1525	0	0	0	0	0	0
2A2	5 Aug	1530	0	0	0	0	0	0
2B	5 Aug	1535	0	0	0	0	0	0
2C	5 Aug	1540	0	0	0	0	0	0
2I	5 Aug	1550	222	211	216	162	166[c]	164
2O	5 Aug	1620	124	138	131	97	102[d]	99
2U	5 Aug	1645	727	680	703	633	598[e]	615
2AA	5 Aug	1709	83	92	87	51	68[f]	59
2HH	5 Aug	1725	68	71	69	42	46[g]	44
2II	5 Aug	1732	6	6	6	5	4	4

[a] Data are from Springer et al. (1985) and A.M. Springer, D.G. Roseneau, and E.C. Murphy (unpubl. data; specific source, E.C. Murphy's original field data summary sheets). Boat-based census; counts of kittiwakes and nests by 1's.

[b] Bering Daylight Time (BDT).

[c] Springer et al. (1985) reported this score as 164; however, the correct value as recorded on E.C. Murphy's original field data summary sheets is 166.

[d] Springer et al. (1985) reported this score as 100; however, the correct value as recorded on E.C. Murphy's original field data summary sheets is 102.

[e] Springer et al. (1985) did not report a score for this column and row but on E.C. Murphy's original field data sheets, R.S. Mule'is listed as counting nests on census plot 2U and his score was 598.

[f] Springer et al. (1985) did not report a score for this column and row but on E.C. Murphy's original field data sheets, R.S. Mule'is listed as counting nests on census plot 2AA and his score was 68.

[g] Springer et al. (1985) reported this score as 44; however, the correct value as recorded on E.C. Murphy's original field data sheets is 46.

TABLE G.48. COLONY 2 KITTIWAKE CENSUS, 1988[a]

			Kittiwakes					
			Birds			Nests		
Plot	Date	Time[b]	Obs.1 (JLB)	Obs.2 (BSF)	Mean	Obs.1 (JLB)	Obs.2 (BSF)	Mean
2A1	18 Jul	1337	0	0	0	0	0	0

[a] All data are from this study. Boat-based census; counts of kittiwakes and nests by 1's.

[b] Alaska Daylight Time (ADT).

TABLE G.49. COLONY 3 KITTIWAKE CENSUS, 1960[a]

			Kittiwakes (nests)		
Plot	Date	Time[b]	Obs. 1 (GWC)[c]	Obs. 2 (LS)	Mean
3A	21 Jul	1145		0	0
3B	21 Jul	1215		0	0
3C	21 Jul	1250		12/15 ($\bar{x}$=13)	13
3D	21 Jul	1325		0	0
3E	21 Jul	1340		52	52
3F	21 Jul	1415		0	0
3G[d]	21 Jul	1445		15	15
3H[d]	21 Jul	1500		208[e]/280	280
3I	21 Jul	1630		110/118 ($\bar{x}$=114)	114
3J	21 Jul	1715		410	410[f]
3J	22 Jul	1300		690	690
3K	22 Jul	–[g]		790	790
3L	22 Jul	–[g]		10	10
3M	22 Jul	1450		150	150
3N	22 Jul	1510		0	0
3O	22 Jul	1610		70	70
3P	22 Jul	1530		2	2
3Q	22 Jul	1630		50	50
3R	22 Jul	1705		50	50
3S	22 Jul	1715		130	130
3T	22 Jul	–[h]		75	75
3U	22 Jul	–[h]		70	70
3V	22 Jul	1830		26	26
3W	22 Jul	1830		10	10

[a] Data are from L.G. Swartz' collection of original field data; specific source, L. Schene's Notebook No. 2. Boat-based counts (except where noted otherwise), nests counted by 1's.

[b] Bering Standard Time (BST).

[c] G.W. Cox also counted census plots 3A-3W on 21-22 July, but his Notebook No. 1 containing the recorded data was lost before L.G. Swartz could recopy it.

[d] Land-based count.

[e] According to L. Schene, the first count of 208 "...did not include standing kittiwakes--kittiwakes observed standing had chicks in nest and were not incubating--next count of nests with standing kittiwakes [was] 280."

[f] This count of plot 3J was made under deteriorating sea conditions, and according to L. Schene, birds (and presumably nests in the case of kittiwakes) were "...in the shadow and difficult to make out." The count was discarded in favor of the recount of nests on this plot on 22 July.

[g] Between 1300-1450.

[h] Between 1715-1830.

TABLE G.50. COLONY 3 KITTIWAKE CENSUS, 1961[a]

			Kittiwakes (nests)		
Plot	Date	Time[b]	Obs. 1 (EJW)	Obs. 2 (KJ)	Mean
3A	11 Aug	–[c]	0	0	0
3B	11 Aug	–	0	0	0
3C	11 Aug	–	17	–	17
3D	11 Aug	–	0	0	0
3E	11 Aug	–	38	43	40
3F	11 Aug	–	9	9	9
3G	11 Aug	–	–	–	–
3H	11 Aug	–	380	373	376
3I	11 Aug	–	–	–	–
3J	11 Aug	–	1181	1030	1105
3K	11 Aug	–	–	–	–
3L	11 Aug	–	14	11	12
3M	11 Aug	–	–	–	–
3N	11 Aug	–	0	0	0
3O	11 Aug	–	–	–	–
3P	11 Aug	–	14	15	14
3Q	11 Aug	–	–	–	–
3R	11 Aug	–	115	105	110
3S	11 Aug	–	–	–	–
3T	11 Aug	–	75	73	74
3U	11 Aug	–	–	–	–
3V	11 Aug	–	26	27	26
3W	11 Aug	–	14	13	13

[a] Data are from L.G. Swartz' collection of oringinal field notes; specific sources include K. Jones' Notebook No. 2, E.J. Willoughby's Notebook No. 3, and E.C. Murphy's summary sheets of data extracted from the above sources.

[b] Bering Standard Time (BST).

[c] No data.

TABLE G.51. COLONY 3 KITTIWAKE CENSUS, 1976[a]

			Kittiwakes (birds)	
Plot[b]	Date	Time[c]	Obs. 1 (---)[d]	Mean
3A	23 Jul	-[e]	0	0
3B	23 Jul	-	0	0
3C	23 Jul	-	20	20
3D	23 Jul	-	2	2
3E	23 Jul	-	90	90
3F	23 Jul	-	17	17
3G	23 Jul	-	550	550
3H	23 Jul	-	275	275
3I	23 Jul	-	375	375
3J	23 Jul	-	300	300
3K	23 Jul	-	650	650
3L,M,N,O	23 Jul	-	250	250
3P	23 Jul	-	0	0
3Q,R,S	23 Jul	-	296	296
3T,U	23 Jul	-	146	146
3V	23 Jul	-	28	28
3W	23 Jul	-	69	69
Total				3068[f]

[a] Data are from Springer and Roseneau (1977), A.M. Springer's and D.G. Roseneau's original field data summary sheets, and E.C. Murphy's revised summary sheet. Boat-based counts, kittiwakes counted by 1's.

[b] Census plot designations shown here follow those devised by L.G. Swartz in 1960. A different system was used by Springer and Roseneau (1977) in 1976, which are related to Swartz' plots by: 1976 plots A-K equal 1960 plots A-K; 1976 plot L equals 1960 plot P; 1976 plots M+N equal 1960 plots L+M+N+O; 1976 plots O+P equal 1960 plots Q+R+S; 1976 plot Q equals 1960 plots T+U; 1976 plot R equals 1960 plot V, and 1976 plot S equals 1960 plot W.

[c] Bering Daylight Time (BDT).

[d] The name of the observer that performed the counts is unknown because Springer and Roseneau (1977) did not report it, and the original field notebooks containing this information were lost in an arson-caused fire in their office building on 2 August, 1978.

[e] Times were recorded but the original data are lost (see footnote d).

[f] Springer and Roseneau (1977) reported this total to be 3086, a typographical error. The correct total is 3068.

TABLE G.52. COLONY 3 KITTIWAKE CENSUS, 1977[a]

Plot[b]	Date	Time[c]	Kittiwakes (birds) Obs. 1 (ECM)	Obs. 2 (JS)	Mean
3A	24 Jul	2105	0	0	0
3B	24 Jul	2105[d]	4	4	4
3C	24 Jul	2105[d]	36	34	35
3D,E,F	24 Jul	-[e]	73	73	73
3H	24 Jul	-	331	325	328
3G,I,J, K,P	24 Jul	-	1591	1657	1624
3L,M,N,O	3 Aug	2200	207	232	219
3Q,R,S	3 Aug	2225[f]	263	249	256
3T,U	3 Aug	2250[g]	83	76	79
3V,W	3 Aug	-	36	36	36
Total			2624	2686	2654[h]

[a] Data are from Springer and Roseneau (1978); A.M. Springer's and D.G. Roseneau's original field data summary sheets; and E.C. Murphy's revised summary sheet.

[b] Census plot designations shown here follow those of L.G. Swartz in 1960. A different system was used by Springer and Roseneau (1978) in 1977, and their plot designations equate to 1960 plots by: 1976 plots A-C and H equal 1960 plots A-C and H, respectively; 1976 plots D+E+F equal 1960 plots D+E+F; 1976 plots G+I+J+K+L equal 1960 plots G+I+J+K+P; 1976 plots M+N equal 1960 plots L+M+N+O; 1976 plots O+P equal 1960 plots Q+R+S; 1976 plot Q equals 1960 plot T+U; 1976 plots R+S equal 1960 plots V+W.

[c] Bering Daylight Time (BDT).

[d] Estimated times.

[e] No data.

[f] Time not reported by Springer and Roseneau (1978) in their Table 27, but it was listed on E.C. Murphy's data summary sheets.

[g] Springer and Roseneau (1978) reported this time to be 2230 h, a typographical error. The correct time listed on E.C. Murphy's data summary sheet is 2250 h.

[h] This total differs slightly from that reported by Springer and Roseneau (1978) due to different methods of rounding numbers.

TABLE G.53. COLONY 3 KITTIWAKE CENSUS, 1979[a]

			Kittiwakes					
			Birds			Nests		
Plot	Date	Time[b]	Obs. 1 (MIJ)	Obs. 2 (DGR)	Mean	Obs. 1 (MIJ)	Obs. 2 (DGR)	Mean
3A	31 Jul	1710	2	2	2	1	1	1
3B	31 Jul	1705	69[c]	80[c]	74[c]	7	7	7
3C	1 Aug	1640	51	54	52	33	41	37
3D	31 Jul	1700	6	6	6	4	4	4
3E	31 Jul	1655	86	87	86	61	63	62
3F	31 Jul	1650	21	21	21	15	14	14
3G	1 Aug	1620	71	77	74	41	56	48
3H	1 Aug	1700	519	502	510	317	361	339
3I	1 Aug	1925	303	395	349	-[d]	310	310
3J	1 Aug	1748[e]	2040	2102	2071	-	1528	1528
3K	1 Aug	1520	443	519	481	312	412	362
3L	1 Aug	1436	14	12	13	10	11	10
3P	1 Aug	1442	25	33	29	12	12	12
3Q	31 Jul	1630[f]	30	30	30	5	5	5
3R	31 Jul	1610[f]	209	224	216	121	151	136
3S	31 Jul	1615	269	-[g]	269	-[h]	197	197
3T	31 Jul	1515	138/143 ($\bar{x}$=140)	154/177 ($\bar{x}$=165)	152	85/95 ($\bar{x}$=90)	114	102
3U	31 Jul	1455[f]	96	88	92	68	67	67
3V	31 Jul	1450[f]	46	-	46	38	-	38
3W	31 Jul	1445	12	-	12	8	-	8

[a] Data from A.M. Springer, D.G. Roseneau, E.C. Murphy and M.I. Johnson's original field notebooks, and E.C. Murphy's field data summary sheets.

[b] Bering Daylight Time.

[c] Many of the birds were "loafers" sitting on the edge of the plot.

[d] No data.

[e] From 1748 to 1915 h.

[f] Estimated.

[g] Census plot 3S is composed of two subplots, 3S(O) and 3S(P). D.G. Roseneau did not count birds on subplot 3S(O), but he did count birds on 3S(P); his total was 57 birds.

[h] Census plot 3S is composed of two subplots, 3S(O) and 3S(P). M.I. Johnson did not count nests on subplot 3S(O), but she did count nests on 3S(P); her total was 39 nests.

TABLE G.54. COLONY 4 KITTIWAKE CENSUS, 1960[a]

			Kittiwakes (birds)[b]
Plot	Date	Time[c]	Obs. 1 (---)[d]
4A	15 Jul	1257	472
4B	15 Jul	1325	614
4C	15 Jul	1348	750
4D	15 Jul	1600	76
4E	15 Jul	1425	1128
4F,4G	15 Jul	1510	>894[e]
4H	15 Jul	1610	224
4I	15 Jul	1700	506
4J	15 Jul	1725	328
4K	15 Jul	1750	292
4L	15 Jul	1805	410
4M	15 Jul	1845	170
4N	15 Jul	-[f]	298[g]
4O	15 Jul	-	16
4P	15 Jul	-	86
4Q	15 Jul	-	0
4R	15 Jul	-	0
Total			6264[h]

[a] Data are from Springer and Roseneau (1977), and L.G. Swartz' collection of original field data; specific sources include W. Henson's Notebook No. 1 and a summary sheet of 1959-1961 data found in L.G. Swartz' files. Boat-based count.

[b] Counts were by pairs, which may have been an attempt to tally the number of nests; values reported here have been converted to total birds (i.e., 2 x no. pairs). Swartz (1966) stated counts were by nests.

[c] Bering Standard Time (BST).

[d] The name of the observer was not listed on L.G. Swartz' summary sheets. However, based on murre census data collected at the colony on the same date, it the person was probably either L.G. Swartz or G.W. Cox.

[e] This count was listed as totaling more than 447 pairs (i.e., more than 894 total birds) on L.G. Swartz' data summary sheet.

[f] No data.

[g] Incorrectly reported to be 296 birds by Springer and Roseneau (1977); the correct total is 149 pairs x 2 = 298 birds.

[h] Total reported here is two birds more than the total reported by Springer and Roseneau (1977) because of an error in the number of birds on Census Plot 4N (see footnote g above).

TABLE G.55. COLONY 4 KITTIWAKE CENSUS, 1961[a]

			Kittiwakes (nests)		
Plot[b]	Date	Time[c]	Obs. 1 (EJB)	Obs. 2 (KJ)	Mean
4A	29 Jul[d]	–[e]	173	178	175
4B	3 Aug	–	296	247	271
4C	3 Aug	–	318	404	361
4D	29 Jul	–	37	37	37
4E	29 Jul	–	348	452	400
4F	29 Jul	–	217	229	223
4G	29 Jul	–	496	445	470
4H	3 Aug	–	107	106	106
4I	29 Jul	–	291	308	299
4J	29 Jul	–	128	135	131
4K	29 Jul	–	142	141	141
4L	29 Jul	–	156	163	159
4M	29 Jul	–	81	81	81
4N	29 Jul	–	158	153	155
4O	29 Jul	–	10	10	10
4P	29 Jul	–	40	40	40
4Q	29 Jul	–	0	0	0
4R	29 Jul	–	0	0	0
Total			2998	3129	3059

[a] Data are from L.G. Swartz collection of original field notes and data summary sheets; specific sources include E.J. Willoughby's Notebook #2 and K. Jones' Notebook #2. Land-based counts, nests counted by 1's.

[b] Swartz used different plot designators between 1960 and 1961 Colony 4 plots. Those listed here were converted to follow the 1960 scheme. Conversions are listed in APX#.2, footnote b.

[c] Bering Standard Time (BST).

[d] Counts of plot 4A were split between two dates; the part representing 1961 plot A was counted on 3 August, and the part representing 1961 plot B was counted on 29 July.

[e] No data.

TABLE G.56. COLONY 4 KITTIWAKE CENSUS, 1976[a]

			Kittiwakes (birds)
Plot	Date	Time[b]	Obs. 1 (DJ)
4A	9 Aug	–[c]	121
4B	9 Aug	–	80
4C	9 Aug	–	266
4D	9 Aug	–	15
4E	9 Aug	–	265
4F	9 Aug	–	79
4G	9 Aug	–	155
4H	9 Aug	–	107
4I	9 Aug	–	146
4J	9 Aug	–	96
4K	9 Aug	–	87
4L	9 Aug	–	69
4M	9 Aug	–	50
4N	9 Aug	–	75
4O	9 Aug	–	11
4P	9 Aug	–	27
4Q	9 Aug	–	0
4R	9 Aug	2045[d]	0
Total			1649

[a] Data are from Springer and Roseneau (1977) and A.M. Springer and D.G. Roseneau's original field data summary sheets.

[b] Bering Daylight Time (BDT).

[c] No data. Times were recorded during the counts of Census Plots 4A–4Q, but Springer and Roseneau (1977) did not report them or record them on the field data summary sheets, and the original field notebooks containing the data were lost during an arson-caused fire in Springer and Roseneau's office building on 2 August 1978.

[d] Time at end of census as recorded on E.C. Murphy's field data summary sheet.

TABLE G.57. COLONY 4 KITTIWAKE CENSUS, 1977[a]

			Kittiwakes (birds)		
Plot	Date[b]	Time[c]	Obs. 1 (ECM)	Obs. 2 (JS)	Mean
4A,4B	19 Jul	0130[d]	410	449	429
4C	19 Jul	-	287	290	288
4D,4E	18 Jul	-	423	385	404
4F,4G	18 Jul	-	435	406	420
4H	18 Jul	-	283	284	283
4I	18 Jul	-	97	107	102
4J,4K, 4L,40	18 Jul	-	309	277	293
4M,4N, 4P,4R	18 Jul	2200[d]	241	234	237
Total			2485	2432	2456

[a] Data are from Springer and Roseneau (1978), and A.M. Springer and D.G. Roseneau's field data summary sheets. Boat-based count, counts by 1's.

[b] Springer and Roseneau (1978; Table 28) listed the date of the counts as 18 July. However, the counts of census plots 3A, 3B and 3C were actually made in the early morning hours of 19 July.

[c] Bering Daylight Time (BDT).

[d] Springer and Roseneau (1978; Table 28) inadvertantly reversed the order of the count times. The counts started at the north end of the colony at census plot 3R at 2200 h on 18 July, and ended at the south end of the colony at plot 3A at 0130 h on 19 July.

TABLE G.58. COLONY 4 KITTIWAKE CENSUS, 1978[a]

			Kittiwakes	
			Obs. 1 (DGR)	
Plot	Date	Time[b]	Birds	Nests
4A	14 Aug	1410	249	111
4B	14 Aug	1420	284	97
4C	14 Aug	1430	383	136
4D	14 Aug	1448	22	10
4E	14 Aug	1450	479	306
4F	14 Aug	1508	175	120
4G	14 Aug	1520	380	207
4H	14 Aug	1535	177	84
4I	14 Aug	1550	324	112
4J	14 Aug	1605	101	55
4K	14 Aug	1610	105	62
4L	14 Aug	1625	198	71
4M	14 Aug	1640	125	53
4N	14 Aug	1630	174	132
4O	14 Aug	1620	28	18
4P	14 Aug	1646	80	53
4Q	14 Aug	1650	4	2
4R	14 Aug	1652	2	2
Total			3290	1630

[a] Data are from Springer et al. (1979), and D.G. Roseneau's original field notebook. Boat-based counts, birds and nests counted by 1's.

[b] Bering Daylight Time (BDT).

TABLE G.59. COLONY 4 KITTIWAKE CENSUS, 1979[a]

			Kittiwakes (birds)				Kittiwakes (nests)			
Plot	Date	Time[b]	Singles Obs. 1 (DT)	Pairs Obs. 2 (BT)	Singles Obs. 3 (AP)	Total	Obs. 1 (AMS)	Obs. 2 (WW)	Obs. 3 (DT)	Mean
4A	10 Jul	2315[c]	156	–[d]		156	104[e]			104
4B	10 Jul	–[c]	368	–		368	240[f]			240
4B	19 Jul	1738		618[g]	487/520[g] ($\bar{x}$=503)	560[h]		366/380 ($\bar{x}$=376)	377	376
4C[i]	10 Jul	–[c]	326	–		326	0			0
4C[i]	19 Jul	1810		243[g]	216[g]	229[h]		163/167 ($\bar{x}$=165)	137/140 ($\bar{x}$=138)	151
4D[j]	10 Jul	–[c]	–	–		–	–			–
4E	10 Jul	–[c]	366	–		366	360[k]			360
4E	19 Jul	1825		525[g]	670[g]	597[h]		454/465 ($\bar{x}$=459)	540	499
4F	10 Jul	–[c]	163/176 ($\bar{x}$=169)	9		169	110/142 ($\bar{x}$=126)[l]			126
4G	10 Jul	2230	375	5		375	391[m]			391
4H	10 Jul	–[n]	144	–		144	102[o]			102
4I	10 Jul	–[n]	345	35		345	263[p]			263
4J	10 Jul	2210	116	5		116	85[q]			85
4K	10 Jul	–[r]	185	17		185	128[s]			128
4L	10 Jul	–[r]	185	11		185	160[t]			160
4M	10 Jul	2145	116	6		116	82[u]			82
4N	10 Jul	2130[v]	176	4		176	161[e]			161
4O	10 Jul	2150[v]	50	8		50	24[e]			24
4P	10 Jul	2120[v]	89	4		89	70[e]			70
4Q	10 Jul	–[w]	9	0		9	7			7
4R	10 Jul	2110	2	0		2	1			1
Total						3177[x]				2304[y]

[a] Data are from A.M. Springer, D.G. Roseneau, E.C. Murphy, and M.I. Johnson's original field notebooks and E.C. Murphy's field data summary sheets. Boat-based counts; counts of nests by 1's, birds by singles and pairs. Singles counts represent all birds present; pairs counts are only the number of pairs present.

[b] Bering Daylight Time (BDT).

[c] Plots 4A - 4G were counted between 2230 h and 2315 h.

[d] No data.

[e] Plus 6 partial nests.

[f] Plus 20 partial nests.

[g] Birds counted as singles on 19 July.

[h] Means of observer counts.

[i] The entire face of census plot 4C collapsed into the sea sometime during September 1978 - June 1979. Kittiwakes were perching on a few new ledges and on the rubble pile below the fresh cliff-face and a few partial nests were evident, but recolonization of this plot was just beginning.

[j] Census plot 4D consisted of all of the backside of the Cape Thompson arch that was also part of census plot 4C. Almost all of census plot 4D was gone; it had collapsed into the sea sometime during September 1978 - June 1979 (see footnote i above).

[k] Plus 40 partial nests.

[l] Plus 9 partial nests.

[m] Plus 31 partial nests.

[n] Plots 4G - 4J were counted bewteen 2210 h and 2230 h.

[o] Plus 5 partial nests.

[p] Plus 19 partial nests.

[q] Plus 8 partial nests.

[r] Plots 4J - 4M were counted between 2145 h and 2210 h.

[s] Plus 11 partial nests.

[t] Plus 16 partial nests.

[u] Plus 7 partial nests.

[v] Estimated time.

[w] Counted between 2110 h and 2120 h.

[x] Total calculated from 10 July data.

[y] Total calculated from 10 July data. Plus 172 partial nests.

TABLE G.60. COLONY 4 KITTIWAKE CENSUS, 1982[a]

			Kittiwakes					
			Birds			Nests		
Plot	Date	Time[b]	Obs. 1 (ECM)	Obs. 2 (RSM)	Mean	Obs. 1 (ECM)	Obs. 2 (RSM)	Mean
4A	5 Aug	1410	299	270	284	193	177	185
4B	5 Aug	1405	376	274	325	240	192	216
4C[c]	5 Aug	1355	424	386	405	303	270	286
4D[d]	5 Aug	1350	42	69	55	23	38	30
4E	5 Aug	1338	623	400	511	430	323	376
4F	5 Aug	1332	280	210	245	205	169	187
4G	5 Aug	1317	450	362	406	326	284	305
4H	5 Aug	1306	143	125	134	98	84	91
4I	5 Aug	1254	449	340	394	289	240	264
4J	5 Aug	1246	132	136	134	66	87	76
4K	5 Aug	1241	176	156	166	115	108	111
4L	5 Aug	1234	266	199	232	156	147	151
4M	5 Aug	1228	122	124	123	84	78	81
4N	5 Aug	1223	217	221	219	141	156	148
4O	5 Aug	1221	45	50	47	28	26	27
4P	5 Aug	1217	108	110	109	62	64	63
4Q	5 Aug	1214	8	11	9	4	4	4
4R	5 Aug	1213	0	0	0	0	0	0
Total			4160	3443	3798	2763[e]	2447[f]	2601

[a] Data from Springer et al. (1985), and A.M. Springer, D.G. Roseneau and E.C. Murphy (unpubl. data; specific source, E.C. Murphy's original field data summary sheets). Boat-based counts, counted by 1's.

[b] Bering Daylight Time (BDT).

[c] The entire face of census plot 4C collapsed into the sea sometime during September 1978 - June 1979; numbers reported here represent a recolonization attempt. This must be taken into account in any comparison between these numbers and pre-1979 censuses.

[d] Almost all of census plot 4D collapsed into the sea sometime during September 1978 - June 1979; numbers reported here represent a recolonization attempt. This must be taken into account in any comparison between these numbers and pre-1979 censuses.

[e] Springer et al. (1985) reported this total as 2723, incorrect because of an error made in addition.

[f] Springer et al. (1985) reported this total as 2437, incorrect because of an addition error.

TABLE G.61. COLONY 4 KITTIWAKE CENSUS, 1988[a]

			Kittiwakes							
			Birds				Nests			
Plot	Date	Time[b]	Obs. 1 (JLB)	Obs. 2 (BSF)	Obs. 3 (PR)	Mean	Obs. 1 (JLB)	Obs. 2 (BSF)	Obs. 3 (PR)	Mean
4A	10 Aug	1500		219		219		192		192
4B	10 Aug	1527			414	414			370	370
4C[c]	10 Aug	1544			125	125			129	129
4D[d]	10 Aug	1559		14		14		16		16
4E	10 Aug	1617	559			559	367			367
4F	10 Aug	1628			195	195			158	158
4G	10 Aug	1636			440	440			317	317
4H	10 Aug	1710			130	130			102	102
4I	10 Aug	1708		285		285		247		247
4J	10 Aug	1720	76			76	56			56
4K	10 Aug	1715		122		122		117		117
4L	10 Aug	1733		146		146		118		118
4M	10 Aug	1743			65	65			60	60
4N	10 Aug	1749		140		140		150		150
4O	10 Aug	1724		25		25		24		24
4P	10 Aug	1831			83	83			78	78
4Q	10 Aug	1845			17	17			20	20
4R	10 Aug	1855			6	6			8	8
Total						3061				2529

[a] Data from the present study. Boat-based counts, kittiwake individuals and nests counted by 1's.

[b] Alaska Daylight Time (ADT).

[c] The entire face of census plot 4C collapsed into the sea sometime during September 1978 - June 1979; numbers reported here represent a recolonization attempt. This must be taken into account in any comparison between these numbers and pre-1979 censuses.

[d] Almost all of census plot 4D collapsed into the sea sometime during September 1978 - June 1979; numbers reported here represent a recolonization attempt. This must be taken into account in any comparison between these numbers and pre-1979 censuses.

TABLE G.62. COLONY 5 KITTIWAKE CENSUS, 1960[a]

Plot	Date	Time[b]	Kittiwakes (nests) Obs. 1 (GWC)	Obs. 2 (LMB)	Obs. 3 (LS)	Mean
5A[c]	2 Aug	1615	1	1		1
5B[c]	2 Aug	1635	84	83		83
5C[c]	2 Aug	1705	0			0
5D[c]	2 Aug	1725	143			143
5E[c]	1 Aug	1300[d]	253		220	236
5F[c]	1 Aug	1300[d]	11		8	9
5G[c]	1 Aug	1340	18		20	19
5H[c]	1 Aug	1340[e]	0			0
5I[c]	1 Aug	1420	36		35	35
5J[c]	1 Aug	1645[f]	25		27	26
5K[c]	1 Aug	1645[g]	15		17	16
5L[c]	1 Aug	1515	70		66	68
5M[c]	1 Aug	–[h]	7		5	6
5N[c]	1 Aug	1615	40		34	37
5O[c]	1 Aug	1615	8		10	9
5P[c]	1 Aug	1615	110		124	117
5Q[c]	2 Aug	1320	15			15
5R[c]	2 Aug	1320	209	190		199
5S[c]	2 Aug	1420	46	50		48
5T[c]	2 Aug	1440	1	1		1
5U[c]	2 Aug	1500	4	4		4
5V[c]	2 Aug	1510	–	0		0
5W[c]	2 Aug	1515	–	0		0
5X[c]	4 Aug	1320	39		41/42 ($\bar{x}$=41)	40
5Y[c]	4 Aug	1340	150		125	137
5Z[c]	4 Aug	1400	1		1	1
5AA[i]	4 Aug	1400[j]	105		105	105
5BB[i]	4 Aug	1435[j]	125[k]		125[k]	125[k]
5CC[i]	4 Aug	1435[j]	340[k]		320[k]	330[k]
5DD[i]	12 Aug	1405[j]	195		150	172
5EE[i]	12 Aug	1415[j]	190		150	170
5FF[i]	12 Aug	1440[j]	230		260	245
5GG[i]	12 Aug	1500[j]	250		260	255
5HH[i]	12 Aug	1525[j]	185		150	167
5II[i]	12 Aug	1540[j]	125		125	125
5JJ[i]	12 Aug	1610[j]	16		20/25 ($\bar{x}$=22)	19
5KK[i]	12 Aug	1630[j]	210		190	200
5LL[i]	12 Aug	1645[j]	3		0	1
5MM[i]	12 Aug	1655[j]	10		10	10
5NN[i]	12 Aug	1720[j]	0		0	0
5OO[i]	12 Aug	1730[j]	0		0	0
5PP[i]	12 Aug	1745[j]	–[h]		0	0
5QQ[i]	12 Aug	1755[j]	–[h]		0	0

TABLE G.62. COLONY 5 KITTIWAKE CENSUS, 1960 (cont.)

			Kittiwakes (nests)			
Plot	Date	Time[b]	Obs. 1 (GWC)	Obs. 2 (LMB)	Obs. 3 (LS)	Mean
5RR[i]	12 Aug	–[j]	0		0/0	0

[a] Data are from L.G. Swartz' collection of original field notes. Specific sources include: G.W. Cox Notebook #2 and L.M. Belson Notebook #2 (census plots 5A-5D and 5Q-5W); and G.W. Cox Notebook #2 and L. Schene Notebook #2 (census plots 5E-5P, 5X-5Z, and 5AA-5RR).

[b] Bering Standard Time (BST).

[c] Land-based counts, nests counted by 1's.

[d] Time is approximate. G.W. Cox lists 1300 h and L. Schene lists 1315 h.

[e] Time is approximate. G.W. Cox lists 1340 h and L. Schene lists 1415 h.

[f] Time is approximate. G.W. Cox lists 1645 h and L. Schene lists 1445 h.

[g] Time is approximate. G.W. Cox lists 1645 h and L. Schene does not list a time.

[h] No data.

[i] Boat-based counts, nests counted by 1's.

[j] Times are approximate, Times listed here are from G.W. Cox's field notes, but L. Schene also recorded times that were 5-20 min later than those listed by Cox.

[k] L. Schene states that both observers encountered boundary problems between census plots 5BB and 5CC; some kittiwake nests counted in 5BB may have been in 5CC, and vice versa.

TABLE G.63. COLONY 5 KITTIWAKE CENSUS, 1961[a]

Plot	Date	Time[b]	Kittiwakes (nests) Obs. 1 (KJ)	Obs. 2 (EJW)	Mean
5X	12 Aug	–[c]	47	50	48
5AA	12 Aug	–	89	88	88
5CC	12 Aug	–	269	260	264
5EE	13 Aug	–	238	224	231
5GG	13 Aug	–	240	260	250
5II	13 Aug	–	164	156	160
5LL	13 Aug	–	–	0	0
5OO	13 Aug	–	–	0	0

[a] Data are from L.G. Swartz' collection of original field notes; specific sources include K. Jones' Notebook No. 2 and E.J. Willoughby's Notebook No. 3. Boat-based counts, nests counted by 1's.

[b] Bering Standard Time (BST).

[c] No data.

TABLE G.64. COLONY 5 KITTIWAKE CENSUS, 1976[a]

			Kittiwakes (birds)		
Plot	Date	Time[b]	Singles Obs. 1 (MAD)	Pairs Obs. 2 (AMS)	Total[c]
5AA(1976)	19 Aug	–[d]	33	0	33
5BB(1976)	19 Aug	–	75	14	103
5CC(1976)	19 Aug	–	677	91	859
5DD(1976)	19 Aug	–	32	8	48
5FF(1976)	19 Aug	–	396	28	452
5HH(1976)	19 Aug	–	430	30	490
5KK(1976)	19 Aug	–	293	27	347
5LL(1976)	19 Aug	–	60	9	78
5NN(1976)	19 Aug	–	8	2	12
5QQ(1976)	19 Aug	–	4	0	4
5RR(1976)	19 Aug	–	4	1	6
Total			2012	210	2432

[a] Data are from Springer and Roseneau (1977), and A.M. Springer and D.G. Roseneau's original field data summary sheets. Boat-based counts; counts by 1's. These plot designations were developed in 1976, and match tables presented in Murphy et al. (1980) and Springer et al. (1985).

[b] Bering Daylight Time (BDT).

[c] Total is equal to number of singles plus 2 times the number of pairs.

[d] No data. Times were recorded during counts of all plots, but Springer and Roseneau (1977) did not report them or record them on the field data summary sheets, and the original field notebooks containing the data were lost during an arson-caused fire in Springer and Roseneau's office building on 2 August 1978.

TABLE G.65. COLONY 5 KITTIWAKE CENSUS, 1977[a]

Plot[b]	Date	Time[c]	Kittiwakes (birds) Obs. 1 (ECM)	Obs. 2 (JS)	Mean
5AA(1976)	19 Jul	0130	46	51	48
5BB(1976)	19 Jul	0130	121	115	118
5CC(1976)	19 Jul	0130	581	554	567
5DD(1976)	19 Jul	0130	46	48	47
5FF(1976)	19 Jul	0330	369	315	342
5HH(1976)	19 Jul	1700	311	359	335
5KK(1976)	19 Jul	1700	182	183	182
5LL(1976)	19 Jul	1700	21	22	21
5NN(1976)	19 Jul	1700	0	0	0
5QQ(1976)	19 Jul	1800	0	0	0
5RR(1976)	19 Jul	1820	2	3	2
Total			1679	1650	1662

[a] Data are from Springer and Roseneau (1978).

[b] These plot designations were developed in 1976, and match tables presented in Murphy et al. (1980) and Springer et al. (1985). They are comparable to Springer and Roseneau (1978) Table 29 as follows: 5AA(1976) = A; 5BB(1976) = B; 5CC(1976) = C + E; 5DD(1976) = D; 5FF(1976) = F; 5HH(1976) = G; 5KK(1976) = H; 5LL(1976) = I; 5NN(1976) = J; 5QQ(1976) = K; 5RR(1976) = L. The special area counts necessary to compare these plots directly to Swartz' 1960 plot designations (see APX#.#) were destroyed in a fire.

c Bering Daylight Time.

TABLE G.66. COLONY 5 KITTIWAKE CENSUS, 1979[a]

			Kittiwakes (birds)				
Plot	Date	Time[b]	Obs. 1 (MIJ)	Obs. 2 (AMS)	Obs. 3 (DGR)	Obs. 4 (WW)	Mean
5A	5 Aug	1335	0	0			0
5B	5 Aug	1335	0	0			0
5C	5 Aug	1315	12	16			14
5D	5 Aug	1330	13	12			12
5E,5F[c]	5 Aug	1635	171/211 ($\bar{x}$=191)	204			197
5G	5 Aug	1405	39	42			40
5G[c]	5 Aug	1745	45	46			45
5H	5 Aug	1420	6	6			6
5I	5 Aug	1415	1	1			1
5J	5 Aug	1555			14	15	14
5K	5 Aug	1545	58/59 ($\bar{x}$=58)	56			57
5L[c]	5 Aug	1740	70	67			68
5M[c]	5 Aug	1700	9	9			9
5N[c]	5 Aug	1705	88	81			84
5O	5 Aug	1520			5	9	7
5P	5 Aug	1525			63	63	63
5P[c]	5 Aug	1710	128	128			128
5Q[c]	5 Aug	1700	31/33 ($\bar{x}$=32)	32			32
5R[c]	5 Aug	1730	81	82			81
5S,5T, 5MM	5 Aug	1420			46/47 ($\bar{x}$=46)	42	44
5U	5 Aug	–[d]			0	0	0
5V	5 Aug	–			0	0	0
5W	5 Aug	–			0	0	0
5X	5 Aug	1310	50	60			55
5Y,5Z	5 Aug	1320	123	108			115
5AA	5 Aug	1335	194	170			182
5BB	5 Aug	1425	159	170			164
5CC	5 Aug	1450	263/289 ($\bar{x}$=276)	288[e]			282
5DD	5 Aug	1510	123/186 ($\bar{x}$=154)	146/156 ($\bar{x}$=151)			152
5EE	5 Aug	1525	259	278			268
5FF	5 Aug	1556			208	207	207
5GG	5 Aug	1530			379	380	379
5HH	5 Aug	1505			205	219	212

TABLE G.66. COLONY 5 KITTIWAKE CENSUS, 1979 (cont.)

Plot	Date	Time[b]	Kittiwakes (birds) Obs. 1 (MIJ)	Obs. 2 (AMS)	Obs. 3 (DGR)	Obs. 4 (WW)	Mean
5II	5 Aug	1450			248	228	238
5JJ	5 Aug	1435			23	25	24
5KK	5 Aug	1435			132	130	
5LL	5 Aug	1430[f]			0	0	0
5NN	5 Aug	1410			0	0	0
5OO	5 Aug	1410			0	0	0
5PP	5 Aug	1410			0	0	0
5QQ	5 Aug	1405			0	0	0
5RR	5 Aug	1400			0	0	0

Plot	Date	Time[b]	Kittiwakes (nests) Obs. 1 (MIJ)	Obs. 2 (AMS)	Obs. 3 (DGR)	Obs. 4 (WW)	Mean
5A	5 Aug	1335	0	0			0
5B	5 Aug	1335	0	0			0
5C	5 Aug	1315	12	15			13
5D	5 Aug	1330	7	10			8
5E,5F[c]	5 Aug	1635	159	190/167 ($\bar{x}$=178)			168
5G	5 Aug	1405	-	28			28
5G[c]	5 Aug	1745	20	29			24
5H	5 Aug	1420	4	6			5
5I	5 Aug	1415	1	1			1
5J	5 Aug	1555			8		8
5K	5 Aug	1545	-	61			61
5L[c]	5 Aug	1740	58	59			58
5M[c]	5 Aug	1700	7	7			7
5N[c]	5 Aug	1705	58	59			58
5O	5 Aug	1520			5		5
5P	5 Aug	1525			51	55	53
5P[c]	5 Aug	1710	101	104			102
5Q[c]	5 Aug	1700	28	30			29
5R[c]	5 Aug	1730	60	64			62
5S,5T, 5MM	5 Aug	1420			38/39		38
5U	5 Aug	-			0	0	0
5V	5 Aug	-			0	0	0

TABLE G.66. COLONY 5 KITTIWAKE CENSUS, 1979 (cont.)

			Kittiwakes (nests)				
Plot	Date	Time[b]	Obs. 1 (MIJ)	Obs. 2 (AMS)	Obs. 3 (DGR)	Obs. 4 (WW)	Mean
5W	5 Aug	-			0	0	0
5X	5 Aug	1310	-	41/47			44
5Y,5Z	5 Aug	1320	-	98			98
5AA	5 Aug	1335	152	127/142 ($\bar{x}$=134)			143
5BB	5 Aug	1425	97	98			97
5CC	5 Aug	1450	-	179			179
5DD	5 Aug	1510	122	131			126
5EE	5 Aug	1525	-	219			219
5FF	5 Aug	1556			164	175	169
5GG	5 Aug	1530			298	318	308
5HH	5 Aug	1505			161	174	167
5II	5 Aug	1450			175	153	164
5JJ	5 Aug	1435			18	19	18
5KK	5 Aug	1435			103	-	103
5LL	5 Aug	1430[f]			0	0	0
5NN	5 Aug	1410			0	0	0
5OO	5 Aug	1410			0	0	0
5PP	5 Aug	1410			0	0	0
5QQ	5 Aug	1405			0	0	0
5RR	5 Aug	1400			0	0	0

[a] Data are from A.M. Springer, D.G. Roseneau and E.C. Murphy's original field notebooks, and E.C. Murphy's field data summary sheet. Boat-based counts (except where noted otherwise), counts by 1's.

[b] Bering Daylight Time (BDT).

[c] Land-based counts, counts by 1's.

[d] No data.

[e] Estimated by 10's.

[f] Estimated time.

TABLE G.67. COLONY 5 KITTIWAKE CENSUS, 1979 - SPECIAL AREAS[a]

			Kittiwakes					
			Birds			Nests		
Special Area	Date	Time[b]	Obs. 1 (DGR)	Obs. 2 (WW)	Mean	Obs. 1 (DGR)	Obs. 2 (WW)	Mean
#101	5 Aug	1410	0	0	0	0	0	0
#102	5 Aug	1410	0	0	0	0	0	0
#103	5 Aug	1435	12	13	12	9	–[c]	9
#104	5 Aug	1440	120	117	118	94	–	94
#105	5 Aug	1435	23	25	24	18	19	18
#106	5 Aug	1435	0	0	0	0	0	0
#107	5 Aug	1515	54	56	55	44	46	45
#108	5 Aug	1505	151	163	157	117	128	122
#109	5 Aug	1530	379	380	379	298	318	308
#110	5 Aug	1530	0	0	0	0	0	0

[a] Data are from A.M. Springer, D.G. Roseneau and E.C. Murphy's original field notebooks, and E.C. Murphy's field data summary sheet. Boat-based counts, counts by 1's. These allow comparisons of 1976 plots with 1960 plots, see introduction to Appendix G.

[b] Bering Daylight Time (BDT).

[c] No data.

TABLE G.68. COLONY 5 KITTIWAKE CENSUS, 1988[a]

			Kittiwakes									
			Birds					Nests				
Plot	Date	Time[b]	Obs.1 (PR)	Obs.2 (JLB)	Obs.3 (BSF)	Obs.4 (DT)	Mean	Obs.1 (PR)	Obs.2 (JLB)	Obs.3 (BSF)	Obs.4 (DT)	Mean
5E[c]	27 Jul	1700	211				211	201				201
5E[c]	5 Aug	1545	231				231	–[d]				
–												
5E[c]	18 Aug	1330	137				137	–				–
5L[c]	17 Jul	1812		88			88	88[e]				
88[e]												
5L[c]	20 Jul	1332			99		99			–		–
5L[c]	25 Jul	1525			85		85			–		–
5L[c]	27 Jul	1530	90				90	–				–
5L[c]	1 Aug	1510			89		89			–		–
5L[c]	4 Aug	2028	87				87	–				–
5L[c]	5 Aug	1724	87				87	–				–
5L[c]	8 Aug	1500				100	100				–	–
5L[c]	11 Aug	1334			55		55			–		–
5L[c]	15 Aug	1931			72		72			–		–
5Q[c]	11 Jul	1849			35		35			32		32
5Q[c]	17 Jul	1805			32		32			32		32
5Q[c]	20 Jul	1235	38				38	–				–
5Q[c]	25 Jul	1447			32		32			–		–
5Q[c]	27 Jul	–				29	29				–	–
5Q[c]	1 Aug	1440			29		29			–		–
5Q[c]	4 Aug	1942			23		23			–		–
5Q[c]	5 Aug	1618			31		31			–		–
5Q[c]	8 Aug	1430				34	34				–	–
5Q[c]	11 Aug	1233			25		25			–		–
5Q[c]	15 Aug	2023			40		40			–		–
5R[c]	27 Jul	1540			131		131			109		109
5R[c]	5 Aug	1658			117		117			–		–
5R[c]	18 Aug	1350			75		75			–		–
5S[c]	5 Aug	1630		28			28		29			29
5S[c]	18 Aug	1350		14			14		–			–
5AA[f]	10 Aug	1410	107				107	76				76
5DD[f]	10 Aug	1352	130				130	127				127
5GG[f]	10 Aug	1250	265				265	231				231

TABLE G.68. COLONY 5 KITTIWAKE CENSUS, 1988 (cont.)

			Kittiwakes									
			Birds					Nests				
Plot	Date	Time[b]	Obs.1 (PR)	Obs.2 (JLB)	Obs.3 (BSF)	Obs.4 (DT)	Mean	Obs.1 (PR)	Obs.2 (JLB)	Obs.3 (BSF)	Obs.4 (DT)	Mean
5HH[f]	10 Aug	1150	180				180	144				144
5LL[f]	10 Aug	1122	0				0	0				0
5OO[f]	10 Aug	1105	0				0	0				0

[a] Data are from the present study. Kittiwake nests and individuals counted by ones. All plot designations follow Swartz 1960 census plots.

[b] Alaska Daylight Time (ADT).

[c] Land-based counts. Plot 5L is equivalent to plot 5-5J, and plot 5Q is equivalent to 5-8N of the new land-based system.

[d] No data.

[e] Approximately.

[f] Boat-based counts.

APPENDIX H. MURRE SPECIES RATIOS, CAPE THOMPSON, 1960

Table H.1. Colony 1, 25 July, 1960.[a]

Plot	Time	Obs. 1 (GWC) TBMU	Obs. 1 (GWC) COMU	Obs. 2 (EJW) TBMU	Obs. 2 (EJW) COMU	$\bar{x}$ TBMU	(%)	$\bar{x}$ COMU	(%)
1A	1320	34	0	34	0	34	(100)	0	(0)
1B	1340	158	45	157	34	158	(80)	40	(20)
1C	1405	344	7	317	4	331	(99)	6	(1)
1D	1435	548	187	517	190	533	(74)	89	(26)
1E	1515	1883	274	1688	334	1786	(85)	304	(15)
1F	1620	5	0	5	0	5	(100)	0	(0)
1G	1622	585	247	472	233	529	(69)	240	(31)
1H	1700	34	2	–	–	34	(94)	2	(6)
						3410	(81)	776	(19)

[a] Data from E.J. Willoughby Notebook #1, and G.W. Cox Notebook #2.

Table H.2. Colony 1, 1960.[a]

Time	TBMU (%)	COMU (%)	Total
1320	86 (91)	9 (9)	95
1345	101 (91)	10 (9)	111
1400	106 (91)	10 (9)	116
1415	110 (92)	10 (8)	120
1430	122 (90)	13 (10)	135
1445	-	-	134
1500	124 (89)	15 (11)	139
1515	126 (90)	14 (10)	140
1530	(Rock fell:	10 birds	flew)
1535	-	-	134
1545	-	-	135
1600	-	-	145
1615	-	-	138
1630	-	-	140
1645	-	-	138
1700	-	-	136

[a] Consecutive ratio counts for an unknown plot at north end of Colony 1, Crowbill Point. Data from Lou Schene's 1960 Book #2.

Table H.3. Colony 3, 21 July, 1960.[a]

Plot	Time	TBMU (%)	COMU (%)	
3A	1145	79 (94)	5 (6)	
3B	1215	810 (90)	90 (10)	(Est.)
		889 (90)	95 (10)	

[a] Data from Lou Schene's 1960 Book #2. Murre counts by ones.

Table H.4. Colony 4, 15 July 1960.[a]

Plot	Time	TBMU (%)	COMU (%)
4A	1257	107 (77)	32 (23)
4B	1325	266 (41)	382 (59)
4C	1348	216 (27)	586 (73)
4D	1400	356 (94)	24 (6)
4E	1425	211 (17)	1038 (83)
4F	1510	80 (13)	546 (87)
4G	1525	323 (21)	1237 (79)
4H	1610	270 (69)	123 (31)
4I	1700	25 (45)	31 (55)
4J	1725	80 (29)	195 (71)
4K	1745	139 (68)	64 (32)
4L	1750	127 (68)	61 (32)
4M	-	-	-
4N	1845	283 (90)	30 (10)
		2483 (36.3)	4349 (63.7)

[a] Data from Wayne Hanson's 1960 notebook (4 June-18 July). All counts completed by George W. Cox (GWC), from boat. Murres counted by 1's and 10's. These counts are identical to the Colony 4 census counts on 15 July, 1960, and represent the total birds on the plots.

Table H.5. Colony 4, 17 July 1960.[a,b]

Plot	Time	TBMU	(%)	COMU	(%)
4J	1315	194	(34)	383	(66)
4K	1340	135	(63)	80	(37)
4M	1335	775	(70)	325	(30)
4N	1445	200	(73)	75	(27)
4O	1400	1	(100)	0	(0)
4P	1405	406	(61)	264	(39)
4Q	1455	155	(90)	17	(10)[c]
4R	1455	94	(76)	30	(24)
		1960	(62.5)	1174	(37.5)

[a] Data from Wayne Hanson's 1960 Notebook (4 June–18 July). All counts by George W. Cox (GWC) from boat, unless otherwise noted. Murres counted by 1's and 10's. This was part of 17 July census, and all counts represent total murres present on the plots.

[b] Combining the best counts from the two sets of data for Colony 4 (15 July for plots 4A–4I, and 17 July data for plots 4J–4R) gives:

	TBMU	COMU	TOTAL
4A–4I	1854	3999	5853
4J–4R	1960	1174	3134
	3814 (42.4)	5173 (57.6)	8987

[c] Counted by LGS.

Table H.6. Colony 4, plot 4-2, 1960.[a]

Date	Time	TBMU (%)	COMU (%)
22 Jul	0800	94 (82)	20 (18)
23 Jul	0030	168 (84)	33 (16)
23 Jul	2000	139 (85)	24 (15)
24 Jul	0030	117 (81)	28 (19)
25 Jul	0145	149 (88)	21 (12)
26 Jul	0130	126 (85)	22 (15)
26 Jul	0700	160 (89)	20 (11)
26 Jul	2200	196 (92)	18 (8)
28 Jul	1400	143 (88)	20 (12)
29 Jul	1000	168 (85)	29 (15)
29 Jul	1100	149 (86)	25 (14)
29 Jul	1400	147 (87)	22 (13)
31 Jul	0230	128 (86)	20 (14)
2 Aug	1300	170 (83)	35 (19)
2 Aug	1700	177 (80)	45 (20)
2 Aug	0200	139 (89)	18 (11)
6 Aug	1400	180 (85)	31 (15)
7 Aug	1000	196 (87)	30 (13)
11 Aug	1300	181 (88)	25 (12)
14 Aug	0900	126 (86)	20 (14)
15 Aug	1100	87 (89)	11 (11)
16 Aug	1000	139 (87)	20 (13)
17 Aug	2000	154 (90)	18 (10)
18 Aug	0900	144 (89)	18 (11)
18 Aug	2045	146 (88)	20 (12)
19 Aug	1900	146 (87)	22 (13)
20 Aug	2100	154 (89)	20 (11)
21 Aug	1000	144 (87)	21 (13)
21 Aug	2000	156 (90)	18 (10)
22 Aug	0930	158 (89)	20 (11)
23 Aug	2045	156 (90)	18 (10)
26 Aug	1230	159 (89)	20 (11)
27 Aug	1800	123 (89)	15 (11)
28 Aug	0700	111 (86)	18 (14)
28 Aug	2000	96 (86)	16 (14)
29 Aug	1500	106 (87)	16 (13)
30 Aug	0900	131 (90)	15 (10)
31 Aug	0900	110 (89)	13 (11)
1 Sep	0900	62 (82)	14 (18)

[a] Plot 4-2 was counted for Thick-billed and Common Murres several times in 1960. Data is from Lou Schene 1960 Book #2; murres were counted by ones.

Table H.7. Colony 4, miscellaneous plots, 1960.[a]

Plot	Date	Time	TBMU (%)	COMU (%)
4SF1	8 Aug	1300	514 (74)	178 (26)
	11 Aug	1315	193 (71)	77 (29)
	14 Aug	0930[b]	226 (80)	56 (20)
	16 Aug	1030[b]	238 (70)	102 (30)
	29 Aug	1800	135 (77)	40 (23)
4-1	29 Aug	–[c]	52 (41)	75 (59)
4SF2	29 Aug	1815[b]	234 (65)	126 (35)
4-NF-GG1	29 Aug	1830	114 (73)	42 (27)

[a] Data from Lou Schene's 1960 Book #2.

[b] Estimated.

[c] Between 1500–1700 h.

Table H.8. Colony 5, 1960.[a]

Plot	TBMU	(%)	COMU	(%)
5A	970	(95)	50	(5)
5B	1698	(64)	956	(36)
5C	870	(100)	0	(0)
5D	1600	(94)	100	(6)
5E	2950	(87)	450	(13)
5F	900	(94)	60	(6)
5G	4000	(89)	500	(11)
5H	3300	(75)	1100	(25)
5I	1100	(92)	100	(8)
5J	1800	(90)	200	(10)
5K	3000	(77)	900	(23)
5L	1700	(94)	100	(6)
5M	1200	(86)	200	(14)
5N	3000	(86)	500	(14)
5O	2300	(82)	500	(18)
5P	2900	(83)	600	(17)
5Q	1800	(95)	100	(5)
5R	4000	(93)	300	(7)
5S	800	(42)	1100	(58)
5T	1050	(90)	120	(10)
5U	800	(89)	100	(11)
5V	110	(100)	0	(0)
5W	70	(100)	0	(0)
5X	1200	(100)	0	(0)
5Y	1850	(82)	400	(18)
5Z	450	(100)	0	(0)
5AA	3467	(76)	1066	(24)
5BB	1100	(100)	0	(0)
5CC	1600	(100)	0	(0)
5DD	2100	(68)	1000	(32)
5EE	2800	(85)	500	(15)
5FF	3600	(82)	800	(18)
5GG	5000	(67)	2500	(33)
5HH	8500	(74)	3000	(26)
5II	4000	(54)	3400	(46)
5JJ	4000	(56)	3200	(44)
5KK	5500	(85)	1000	(15)
5LL	1150	(92)	100	(8)
5MM	5600	(86)	900	(14)
5NN	7000	(96)	300	(4)
5OO	3500	(71)	1400	(29)
5PP	3650	(86)	600	(14)
5QQ	1650	(100)	0	(0)
5RR	1600	(89)	200	(11)
	111,235	(79.7)	28,402	(20.3)

[a]Data from L.G. Swartz' collection of original field notes, specifically from G.W. Cox' Notebook #2. Dates and times were the same as in Colony 5 murre census table for 1960. All estimates by GWC counting by 10's and 100's.