POPULATION AND TROPHICS STUDIES OF SEABIRDS IN THE NORTHERN BERING AND EASTERN CHUKCHI SEAS, 1981

by

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I. SUMMARY OF OBJECTIVES, CONCLUSIONS AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

A. Objectives

The general objectives of this research unit are to 1) describe relationships of seabird populations and seabird food webs to regional physical processes and environmental variation, and 2) to provide a data set which will ensure that future changes in numbers of thick-billed murres *(Uria lomvia)*, common murres *(Uria aalge)* and black-legged kittiwakes *(Rissa tridactyla)* at major breeding colonies in Alaska can be detected, and that the significance of the changes can be properly interpreted.

B. Conclusions

A major decline in numbers of murres occurred at Cape Thompson between 1960 and 1976, and numbers continued to steadily decline there between 1976 and 1979. A similar downward trend in numbers of murres has occurred at Bluff in Norton Sound since 1975. That trend was still apparent in 1981. Numbers of murres at Cape Lisburne and nearby Cape Lewis have not appeared to decline during recent years. The number of murres in one colony on St. Lawrence Island, the only colony for which we have more than one year of data, was considerably lower in 1976 than in 1972; but 1972 and 1981 numbers were comparable, suggesting a short-term fluctuation in the size of the breeding population in the mid-1970’s at a time when environmental conditions were unusually cold.

Environmental fluctuations during the 1970’s had important repercussions on the breeding biology of murres, black-legged kittiwakes and least auklets *(Aethia pusilla)* in northern Alaska by affecting supporting food webs. Breeding phenology and reproductive success of kittiwakes in the eastern Chukchi Sea, and of kittiwakes and common murres in Norton Sound, were strongly correlated with climatic conditions. Historical data indicate that the spring and summer periods during about two decades preceding the mid-1970's were relatively cold. After 1976 the spring-summer periods became warmer. Breeding phenology was later and reproductive success was lower in colder years when conditions were less favorable for some prey populations. Breeding phenology was earlier and reproductive success was higher in warmer years when prey availability was higher. Below average natality between 1959-1976, a relatively cold period in northern Alaska, could have led to declining numbers of murres in recent years. Kittiwake and murre reproductive success has been high since 1978 when spring-summer periods have been warm. A preliminary simulation analysis has predicted that murre numbers should increase over the next several years, beginning in 1982, if differential reproductive success is responsible for the numeric changes (see Springer et al. 1982). Regional differences in physical processes and food web stability appear to account for changes in kittiwake productivity and could account for differences in numeric trends of local breeding populations of murres in northern Alaska.

C. Implications with Respect to OCS Oil and Gas Development

Information of the kind we are obtaining on seabird biology will help us differentiate between future changes in seabird populations that might result from OCS oil and gas development, and changes resulting from environmental fluctuations unrelated to OCS activities.

II. INTRODUCTION

A. General Nature and Scope of Study

Seabirds occupy top positions in marine food webs and thereby integrate many elements of regional ecosystems. Among the many species of seabirds, murres and kittiwakes are easily studied and are sensitive to changes in the environment. Our studies take advantage of these characteristics to examine spatial and temporal differences in several marine food webs, and the relationships between these food webs, regional physical processes and seabird biology.

Substantial declines in murre populations during recent years in northern Alaska have demonstrated the need for a system that will permit future monitoring of colonies as resource exploration and development increases on Alaska's outer continental shelf. Therefore, our studies are designed to provide methods for reliably censusing murres, thus establishing useful indices of murre numbers at major breeding colonies in Alaska.

B. Specific Objectives

Our initial plans for the FY81 field season called for colony studies at St. Lawrence Island, Little Diomede Island and Cape Thompson. The *Surveyor* would have been used to transport people and equipment to those locations. The *Surveyor* was unavailable for that purpose, and it was necessary to modify our plans concerning field sites. We elected to retain our first priority of visiting St. Lawrence Island and to continue work at two more accessible locations, Bluff and Cape Lisburne/Cape Lewis. The specific objectives of the FY81 work remained unchanged and included:

1. Censusing murres and black-legged kittiwakes at each location.
2. Establishing as many permanent murre and kittiwake census plots as possible on St. Lawrence Island for future comparison.
3. Determining breeding phenologies and levels of reproductive success of kittiwakes and other seabirds at each location.
4. Determining growth rates of kittiwake chicks at each location.
5. Collecting specimens of seabirds, primarily murres, kittiwakes, crested auklets *(Aethia cristatella)* and least auklets, for food habits data and as a means of sampling local marine organisms for distribution and relative abundance.

6. Obtaining data on other species of seabirds that would provide useful information on local marine systems.

C. Relevance to Problems of Oil Development

The success of OCSEAP will depend in part on an ability to detect changes in marine biological systems and in part on an ability to separate naturally occurring changes from changes that might result from resource development in Alaskan waters. OCSEAP sponsored studies of seabirds in the Bering and Chukchi seas have shown that population parameters such as numbers, breeding phenology and reproductive success can vary considerably between years. Such marked natural variation could make it difficult to determine if developmental activities were involved in biological changes that might be detected in future years.

Our studies have shown that annual variability is not random, but is predictable from annual changes in the physical environment and in regional food webs. Information of this kind is relevant to problems of OCS development because it provides the means to more clearly differentiate between natural phenomena and changes resulting from resource development. This aspect of our work is acquiring added importance because of the recent declines in murre numbers that we have documented at two major colonies, one in the eastern Chukchi Sea and the other in the northeastern Bering Sea.

Seabirds are appropriate species to study not only because they are sensitive indicators of changes in the environment, but also because they are relatively easy to study, especially by comparison to other high profile marine vertebrates such as seals and whales. They also offer an excellent means of sampling lower trophic levels that often defy scientific sampling methodologies. Therefore, seabird studies can provide a great amount of relatively inexpensive information on marine ecosystem dynamics. The monitoring of seabird populations at strategic locations in Alaskan waters may be one of the most effective means of detecting significant changes resulting from OCS developments and activities.

III. CURRENT STATE OF KNOWLEDGE

Prior to OCSEAP-sponsored studies, seabird colonies at Cape Lisburne and nearby Cape Lewis in the eastern Chukchi Sea, and at Bluff in Norton Sound in the northeastern Bering Sea had not been investigated.[1] Field work in 1981 at Cape Lisburne and Cape Lewis extended OCSEAP studies conducted there between 1976-1979 and previously reported by Springer and Roseneau (1977, 1978), Springer et al. (1979) and Murphy et al. (1980). Field work in 1981 extended other OCSEAP studies conducted at that site in 1975-1978 and previously reported by Drury (1976), Steele and Drury (1977), Biderman et al. (1978), Ramsdell and Drury (1979), Murphy et al. (1980) and Drury et al. (1981).

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[1] Some general information on the relative sizes of these colonies was obtained by aerial surveys in 1970-1973 (see Bartonek and Scaly 1979).

Most previous seabird work on St. Lawrence Island has emphasized auklets (e.g., Scaly 1968, 1975, 1981; Bédard 1969a, 1969b; Scaly and Bédard 1973; Searing 1977). Reports on other species, particularly murres and kittiwakes, which are the next most abundant birds on the island, have tended to be general in nature (e.g., Murie 1936, Fay and Cade 1959, Thompson 1967, Johnson 1976,and Bartonek and Scaly 1979) , although one study provides considerable information on horned puffins *(Fratercula corn-ieuZata)* (Scaly 1973).

S. R. Johnson (unpubl. data) censused murres along a portion of the west coast of St. Lawrence Island in 1972. He reported data on growth rates, heat regulation and the timing of murre chick sea-going, and on metabolism in adult murres (Johnson and West 1975). Searing (1977) visited the island in 1976 and censused murres at the same location counted by Johnson. Searing also obtained data on murre and kittiwake breeding phenology and success in 1976. Aerial surveys were made at St. Lawrence Island in 1977 and 1978, and provided some information on seabird numbers, colony locations and offshore feeding areas (Ramsdell and Drury 1979, Drury et al. 1981). Offshore concentrations of birds in the vicinity of the island were also reported by Gould (1977), Harrison (1977), Biderman and Drury (1978) and Hunt et al. (1981). Sowls et al. (1978) reported colony locations and numbers of seabirds on St. Lawrence Island based on the above studies. In 1979, F. Fay (pers. comm.) made a rapid boat-based estimate of seabirds along a portion of the northeastern sector of the island. Data relevant to our studies on murres, kittiwakes and auklets from these earlier investigations are included in following sections of this report.

IV. STUDY AREAS

The locations of the 1981 study areas are shown in Figure 1. Details of the Cape Lisburne, Cape Lewis and Bluff study areas were reported previously by Steele and Drury (1977), Biderman et al. (1978), Springer and Roseneau (1977, 1978), Ramsdell and Drury (1979), Springer et al. (1979), Murphy et al. (1980) and Drury et al. (1981) and we refer readers to these reports for additional information on them.

St. Lawrence Island is shown in detail in Figures 2, 3 and 4. Fay and Cade (1959), Thompson (1967), Scaly (1968, 1973, 1975), Bedard (1969a, 1969b), Scaly and Bedard (1973), Searing (1977) and Drury *et al.* (1981) have provided various descriptions of the St. Lawrence Island study area. We have drawn on these accounts and other reports relevant to the region (e.g., Hood and Kelly 1974; Coachman et al. 1975; Brewer et al. 1977a, 1977b; Hood and Calder 1981) in preparing the following discussion.

St. Lawrence Island in the largest island in the Bering Sea. It is about 160 km long and varies between 18-40 km wide, with an approximate surface area of 5100^2 km. It lies north of the continental shelf break about 220 km south of Bering Strait, 60 km southeast of Chukotsk Peninsula (U.S.S.R.), and 200 km southwest of Seward Peninsula, Alaska (Figure 1).

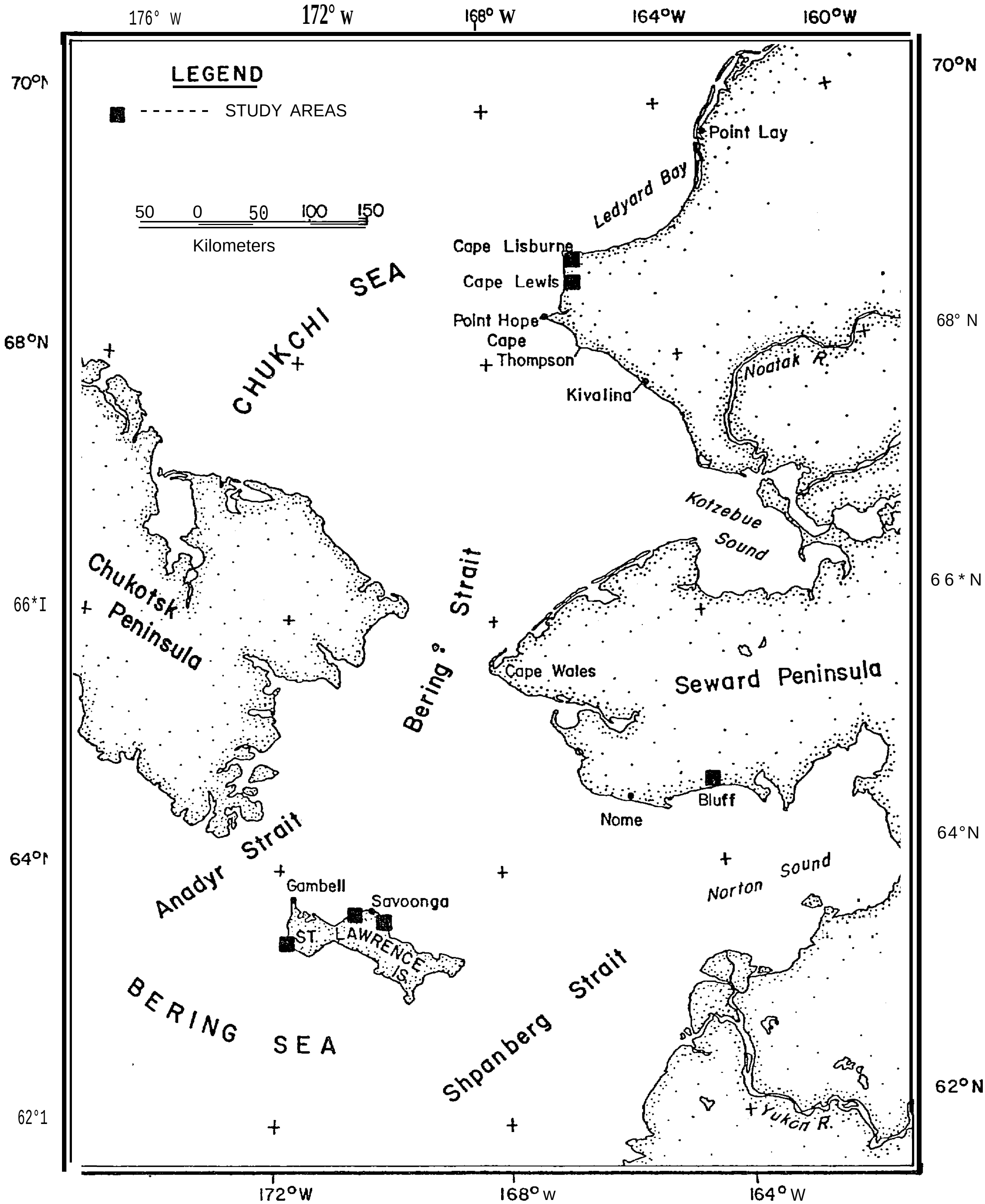

Figure 1. Study areas visited in 1981.

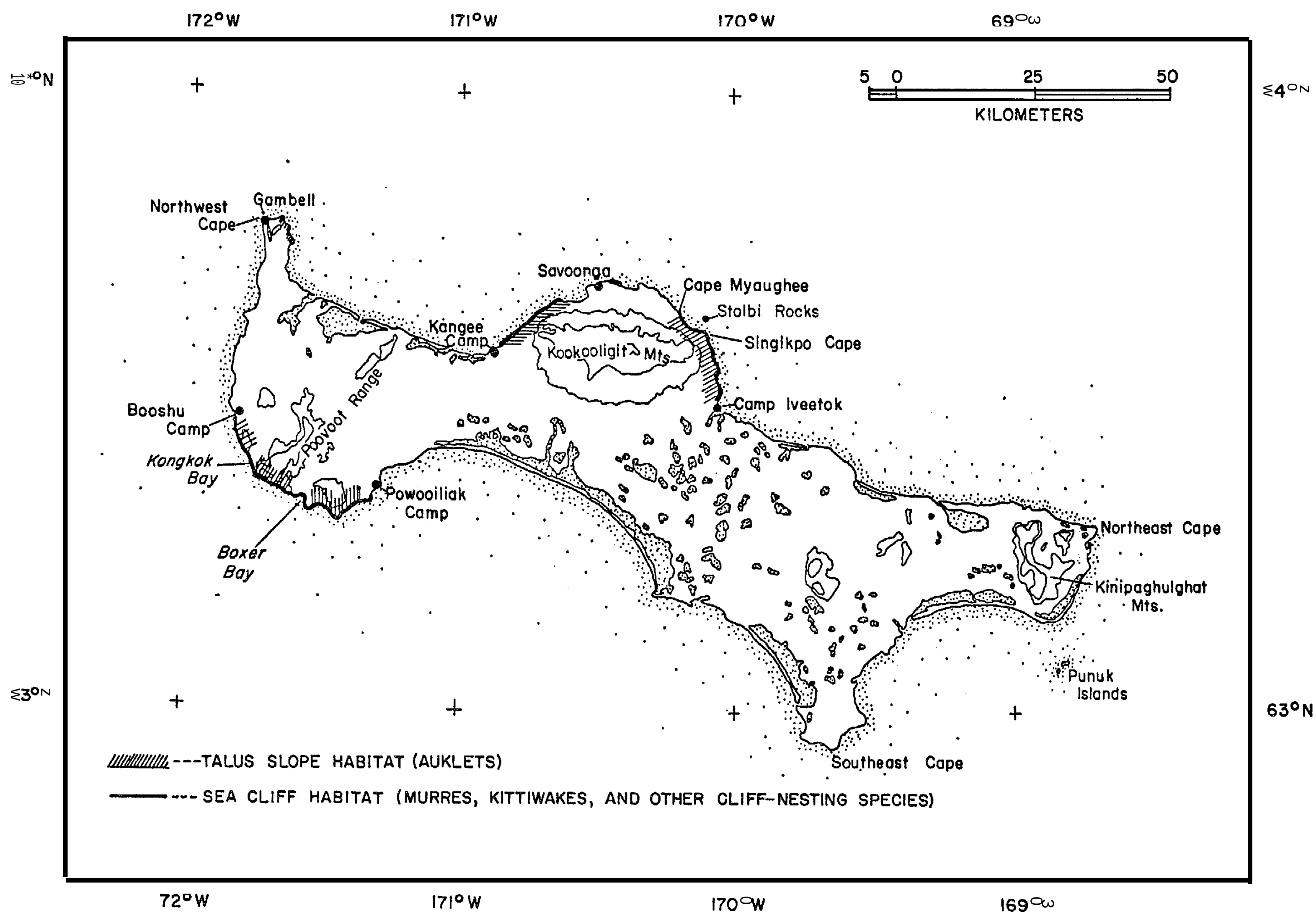

Figure 2. The St. Lawrence Island study area and locations of principal seabird nesting habitat.

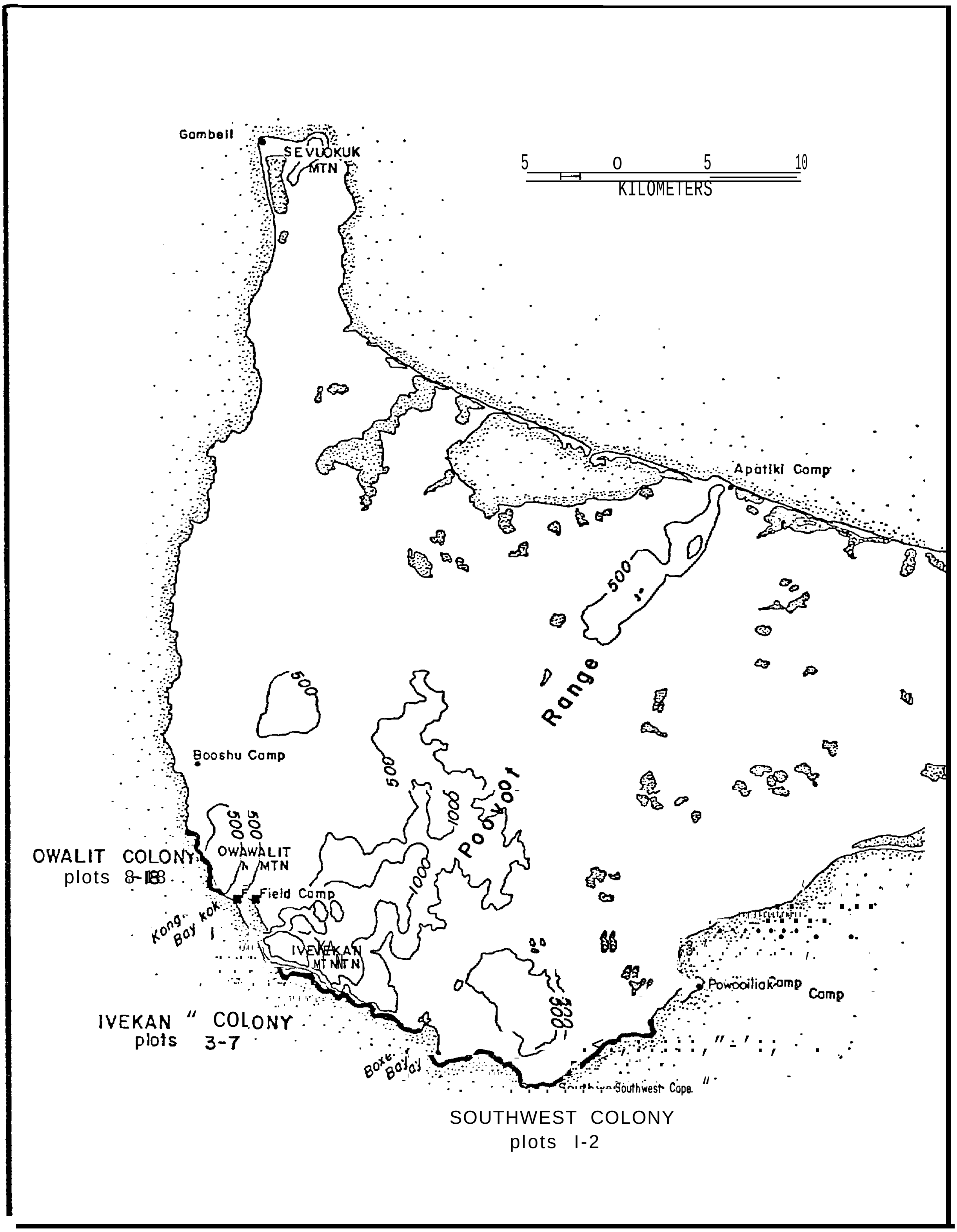

Figure 3. Murre and black-legged kittiwake colonies in the southwestern sector of St. Lawrence Island.

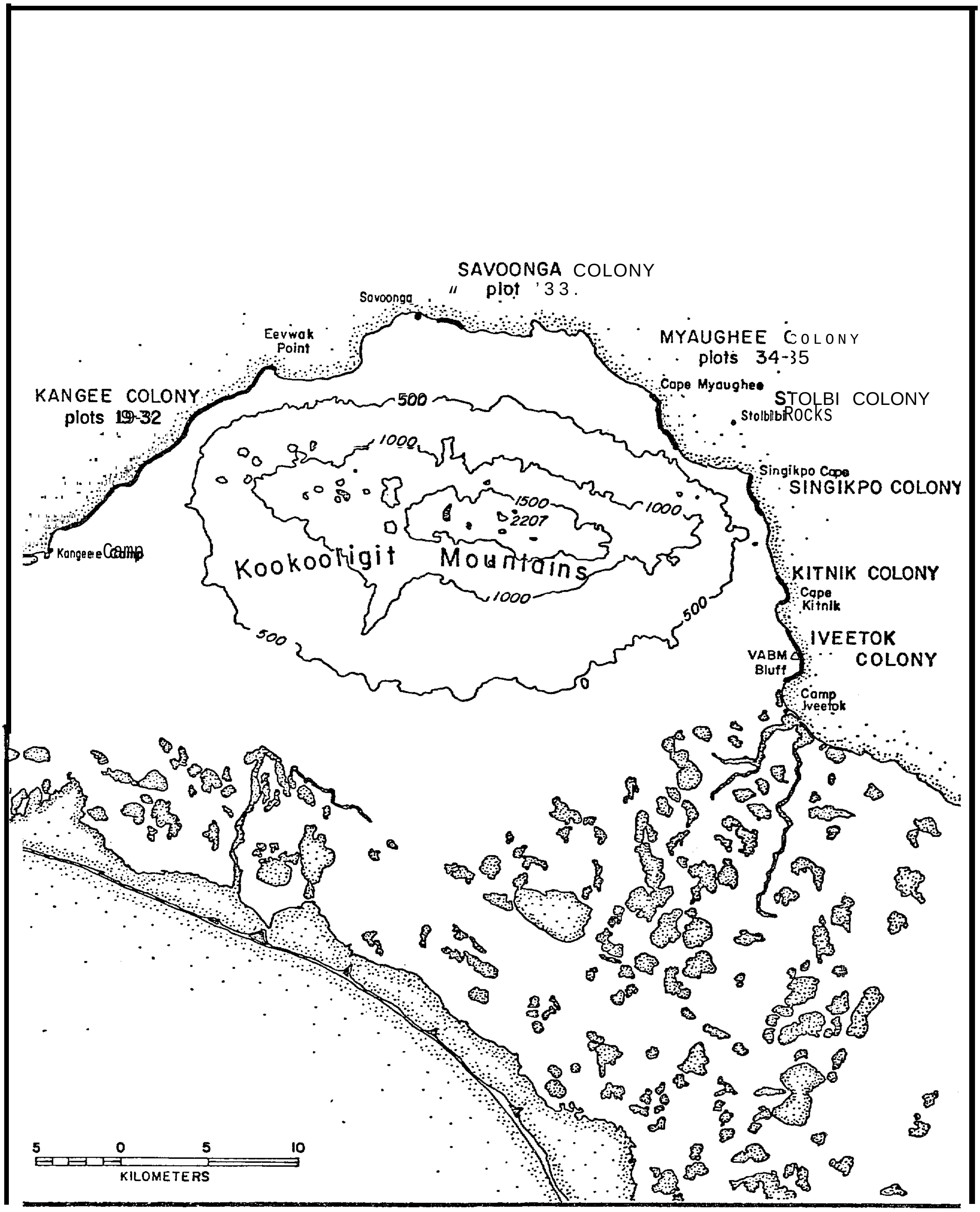

Figure 4. Murre and black-legged kittiwake colonies in the north-central sector of St. Lawrence Island.

The island has an arctic-maritime climate and seasonal weather typical of much of the northern Bering Sea region (see Brewer *et* al. 1977a, 1977b). Summers are short and tend to be cooler than in nearby continental areas. Mid-summer temperatures of 10-15°C, and occasionally 20°C, are typical, and moderate to strong winds from southern quadrants are especially common during June-August. Cloudy skies, fog, drizzle and rain are also common throughoutspring, summer and fall. Weather tends to be especially poor during late summer, fall and early winter when large, often violent storms track northward through the region. Winters are long, but somewhat milder than in nearby continental areas, and surrounding waters are ice-covered during much of the year. Snowfall is frequent and winds from northern quadrants are common. Blowing, drifting snow is typical of many winter days.

The highest point on St. Lawrence Island is about 670 m above mean sea level (msl); however, the majority of the island is low (60 m msl or less) and wet (Figure 2). Most of the upland areas are found in the southwestern, north-central and eastern sectors. The southwestern sector, dominated by the Poovoot Range, and the north-central sector, dominated by the Kookooligit Mountains, provide almost all of the 'rock-pile,' talus-slope and sea-cliff nesting habitat on the island (Figures 2-4; see also Fay and Cade 1959).

Sea-cliffs in the southwestern and north-central sectors of the island (Figures 3 and 4) are predominantly of volcanic origin and are relatively stable by comparison to cliffs at many of Alaska's northern mainland seabird colonies (e.g., Cape Lisburne, Cape Lewis and Cape Thompson in the eastern Chukchi Sea and Bluff in Norton Sound). They range in height from about 10 m msl to about 300 m msl and are typically highest in the southwestern sector between Booshu and Powooiliak camps where most cliffs rise about 50–200 m above the sea. In comparison, most sea-cliffs between Kangee Camp and Camp Iveetok in the north-central sector are about 10-30 m high, although some rise to heights of about 75 m msl in the central portion of Kangee Colony.

St. Lawrence Island's size, location and orientation relative to the Siberian and Alaskan landmasses and to prevailing ocean currents influence biota in the region, including seabirds. The western end of the island is separated from Chukotsk Peninsula by 60 km wide Anadyr Strait (Figure 1). Shpanberg Strait, 110 km wide, separates the eastern end of the island from the mainland of Alaska. The island's long axis (160 km), equivalent to about one-third of the 430 km distance between Chukotsk Peninsula and the delta of the Yukon River,is oriented perpendicularly to an ocean current flowing northward out of the Bering Sea through Bering Strait into the Chukchi Sea. Cold Bering Shelf Water and cold Anadyr Water pass through Anadyr Strait (see Coachman *et* al. 1975, Kinder and Schumacher 1981), and other elements of Bering Shelf Water, influenced by warmer, less saline Alaskan Coastal Water, pass through Shpanberg Strait (see Coachman *et* al. 1975, Ingraham 1981). The flow of water past the island affects sediment deposition, and long, linear shoals are present off its northeastern and northwestern flanks (Nelson *et* al. 1981). Currents are most pronounced through narrow Anadyr Strait, and an area of particularly intense bottom current activity is present north of the island's western end(Larsen *et* al. 1981).

The strong currents entering Anadyr Strait transport large seasonal populations of zooplankton, including a variety of endemic oceanic Bering Sea species dominated by copepods, such as *Eucalanus bungii, Calanus cristatus, C. plumchrus, Acartia longiremis* and *A. clausi* (see Cooney 1981), from the region of the shelf break past the western end of St. Lawrence Island during ice-free months. These currents, richly laden with zooplankton, and the turbulent mixing and upwelling northward of the island's western end create an annually important feeding area for large populations of seabirds breeding on the island and along the coast of Chukotsk Peninsula. The majority of seabirds from St. Lawrence Island, especially the alcids, forage north of Gambell (Northwest Cape) downstream in the current flow during most of the breeding season (Bédard 1969b, Searing 1977, Drury *et* al. 1981, Hunt *et* al. 1981). Many alcids favor this area well into fall, and during late summer some northern fulmars (*Fulmarus glacialis*) are also present there (Harrison 1977). Other large populations of transient seabirds, primarily shearwaters (*Puffinus* spp.), enter the northern Bering-eastern Chukchi region annually (Gould 1977). These birds may also feed heavily in the out-flow of Anadyr Strait when they are present in the area, but most of them have been observed downstream of the island's eastern end during late summer and fall (Harrison 1977, Hunt *et* al. 1981).

St. Lawrence Island is also a dominant geographic feature affecting regional patterns of winter ice cover. North winds are prevalent in winter, and as the ice front advances southward into the Bering Sea, ice converges against the island's northern shore and a large, persistent polynya forms off its southern shore (Shapiro and Burns 1975a, 1975b, McNutt 1981). Dynamic zones of fractured, divergent ice are also created on either side of the island (McNutt 1981). The polynya south of St. Lawrence Island is important to wintering oldsquaws (*Clangula hyemalis*) and eiders (*Somateria* spp.) (Fay and Cade 1959, Divoky 1981). Murres (presumably thick-billed murres), pelagic cormorants (*Phalacrocorax pelagicus*) and some large gulls (*Larus* spp.) also frequently winter there (L. Iyakitan pers. comm.) . Large numbers of sea ducks (especially oldsquaws) and murres have also been observed in the zone of divergent ice south and west of the island (F. Fay pers. comm.).

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Field efforts during 1981 began on 10 July and continued until 15 August . One two-man team visited Bluff from 10 July to 22 July, Cape Lisburne from 25 July to 5 August, and made a short trip to Cape Lewis (18 km south of Cape Lisburne) on 2 August. A second two-man team visited St. Lawrence Island from 14 July to 15 August. Boat trips were made along the north coast of St. Lawrence Island between Gambell and Cape Myaughee on 18-19 July, and between Gambell and Kaghkusalik Point on 12 August. Most effort was concentrated in the southwestern sector of the island between Booshu Camp and Powooiliak Camp; a field camp at Kongkok Bay served as base of operations from 21 July to 10 August.

A total of 65 thick-billed murres, 42 common murres and 72 black-legged kittiwakes was collected at varying intervals at St. Lawrence Island, Bluff and Cape Lisburne. Ten least and 12 crested auklets were also collected at St. Lawrence Island, and the regurgitated contents from gular pouches of other least and crested auklets were obtained by flushing perching adults after they returned from foraging at sea. Data on weight, breeding condition and fat condition were taken from all birds within two hours of collection and stomach contents and gular pouch contents were preserved in 70% ethanol for future identification.

Complete censuses of murres and kittiwakes were made at Bluff and Cape Lewis using previously established plot boundaries (see Springer and Roseneau 1978, Murphy *et* al. 1980). Murres and kittiwakes were also censused on 10 of 75 plots previously established at Cape Lisburne (see Springer and Roseneau 1977). Six of the 10 plots were counted on two separate occasions. Six of 10 colonies (see Figures 2-4) of murres were completely censused at St. Lawrence Island. The six colonies were divided into 35 plots at the time of census, and include all murre breeding areas on the island except those between Ataaka's Camp and Camp Iveetok, and one offshore location on Stolbi Rocks. The boundaries of these plots were photographed for future reference.

The censuses of murres at all sites followed previously established methods, and all counts were timed to occur between mid-incubation and first sea-going of chicks, dates comparable to those of previous censuses (see Murphy *et* al. 1980). In all but one case, two observers counted murres simultaneously on each plot with the aid of binoculars from a small boat stationed offshore. The exception occurred at Bluff, where only one observer was able to count murres. Each observer estimated the number of murres by 10's at all census plots except plots 1-5 on St. Lawrence Island. These five large plots at Southwest Colony and Ivekan Colony between Powooiliak Camp and Bunnell Cape were counted by 100's. Estimation by 100's at these particularly lengthy sections of cliff allowed the observers to complete the census of murres in the southwestern sector of the island before a major storm system arrived. During each census observers intermittently counted 10 or 100 individual birds in areas of varying densities to maintain accuracy and precision. The scores of individual observers were not compared until after all counts of murres were complete at each colony.

The censuses of kittiwakes at Cape Lisburne, Cape Lewis and Bluff also followed previously established methods. These censuses were conducted in the same manner as the murre censuses; however, both individual birds and nests were counted, and all counts were by 1's.

To allow later evaluation of differences in counts of murres and kittiwakes between observers, we have adhered to and extended the notation for observers used in earlier annual reports (e.g., Murphy *et* al. 1980). As used in this report and applied to the field crews in 1981, the notations are:

Code	Name
C	A. M. Springer
E	D. G. Roseneau
F	E. C. Murphy
K	R. Mulé

Four of six small study plots established by Searing (1977) were successfully located at Owalit Colony, St. Lawrence Island. Murres, kittiwakes and kittiwake nests were counted by 1's by either one or two observers from the same approximate land or sea position used by Searing. Additional kittiwake nesting areas were also photographed for future reference.

Kittiwake nests were examined at varying intervals at Cape Lisburne, Bluff and in the southwestern sector of St. Lawrence Island. On 12 August we also had an opportunity to examine a large number of kittiwake nests near Kangee Camp in the north-central sector of St. Lawrence Island. Visits to kittiwake nests at varying intervals provided data from the time of hatching through the period of maximum growth of chicks., Ratios of empty/occupied nest were obtained at each location, and clutch size, hatching success and weights of chicks were recorded at each nest. All chicks were encouraged to regurgitate food prior to weighing. In the few instances when chicks had food in their crops and did not readily regurgitate it, the weight of the retained food was estimated on the basis of known weights of similar volumes of food. Regurgitated food from chicks was collected and preserved in 70% ethanol to supplement other food habits samples.

Kittiwake chicks were weighed on Pesola spring balances. Growth rates were calculated for each chick by determining the slope of the regression equation relating all of the respective weights taken between the first weighing and the highest weight recorded that was less than. or equal to 300 g. A preliminary analysis indicated that growth rates of most chicks remained linear through 300 g (also see Coulson and White 1958, Maunder and Threlfall 1972).

Because we visited nests every several days, we frequently did not know the exact hatching date of particular chicks. In such instances we estimated the hatching date if the chick was weighed two or more times before attaining 300 g. Using the regression equation for daily growth rate, we calculated the date on which the chick would have weighed 35 g and used that value as the estimated hatching date for that chick. In some instances chicks were first weighed more than ten days later than the estimated hatching date, and we eliminated such individuals from the data base on hatching phenology. This method is unbiased if the growth rate is linear, or approximately so, between hatching and 300 g. Various studies (e.g., Coulson and White 1958, Maunder and Threlfall 1972) indicate that the growth rate of kittiwakes is linear from the time of hatching until about three weeks of age.

We located several least auklet nests in Kongkok Basin at Ivekan Mountain, St. Lawrence Island. These nests were found just prior to hatching or within a few days after hatching, and chicks were subsequently weighed and measured on several occasions for growth rate information.

Observations of flight directions of murres, kittiwakes and auklets departing and returning to their colonies were made regularly during offshore collecting trips, boat trips along the coast, and from the beaches and cliff-tops at all colonies.

VI. & VII. RESULTS AND DISCUSSION

A. Murres

Census

Results of murre censuses taken at St. Lawrence Island, Cape Lisburne, Cape Lewis and Bluff in 1981 are presented in Tables 1-4. Table 5 summarizes all censuses taken at all four locations and at Cape Thompson since 1960.

St. Lawrence Island

All previous estimates of the size of the murre population of St. Lawrence Island have been general approximations. The estimates include an average of about 200,006 individuals during the 1950's (Fay and Cade 1959); a range of about 102,000-360,000 individuals obtained during aerial surveys in 1977-1978 (Biderman and Drury 1978, Ramsdell and Drury 1979, Drury *et al.* 1981); and an estimate of about 300,000 individuals derived from the aerial estimates and from Searing's (1977) census of one colony and general observations at others in the southwestern sector of the island in 1976 (Sowls *et al.* 1978).

We conducted censuses of murres at six of the 10 breeding colonies at St. Lawrence Island[1] (Table 1). We were unable to visit the four remaining colonies at Singikpo Cape, Cape Kitnik, VABM Bluff near Iveetok Camp and Stolbi Rocks, offshore of Singikpo Cape (see Figure 4). Some recent observations at those colonies and the results of our censuses at the other six colonies suggest that the total population of murres on St. Lawrence Island is larger than was previously thought.

Aerial estimates of numbers of all species of birds at Singikpo, Kitnik and Iveetok colonies in 1977-1978 included 10,000-50,000 murres. F. Fay (unpubl. data) tried to quickly estimate numbers of all species of birds

[1]Sowls et at. (1978) reported the presence of murres at an eleventh location, the Punuk Islands, based on Thompson's (1967) observations of a few individuals; however, even though a few murres are occasionally present, they do not breed there (B. Kelly, L. Iyakitan, V. Slwooko pers. comm.).

at these same colonies from a passing boat in early July 1979. His estimates of murres, including birds in the air, on the water and on the cliffs, totaled 76,000 (±50%). Stolbi Rocks also provide habitat for at least a few thousand murres (Drury *et* al. 1981).

The attempts to determine the number of murres at Singikpo, Kitnik, Iveetok and Stolbi colonies were not plot-by-plot censuses. Furthermore, the estimates were made quickly and were directed simultaneously toward all species present, including hundreds of thousands of auklets. Still, the estimates clearly suggest that a complete census of the four colonies would have increased our raw score (uncompensated for daily or diurnal differences in numbers, see Springer *et* al. 1982) of about 329,000 murres by several tens of thousands of individuals.

Owalit Colony (Figure 3) is the only location on St. Lawrence Island for which good historical data on numbers of murres are available. The colony was censused in 1972 by S.R. Johnson (unpubl. data) and in 1976 by Searing (1977). The uncompensated results of these censuses, which were conducted similarly to ours, were about 32,000 and 16,000 individuals, respectively (Table 5). Our count in 1981 totaled 34,000 murres. Searing (1977) reported the results of Johnson's census as about 60,000 individuals. That number is incorrect, and an explanation of the problem is presented in the Appendix.

We believe that the differences in numbers of murres between 1976 and the other two census years were real because the colony is not difficult to count, and because the observed changes in. numbers there were large in both cases. Some of the difference between 1972 and 1976 may be explained in part by a rock-fall that occurred in a densely occupied portion of the colony after 1972, but before 1976 (Johnson per.comm.). However., our observations of the cliffs suggest that rock-falls could not account for most of the apparent change between those years. The similarity in numbers of murres present in 1972 and 1981 also suggests that other factors were responsible for the changes.

We believe that most of the differences in numbers of murres at Owalit Colony between 1972 and 1976, and between 1976 and 1981, are best explained by the unusually cold environmental conditions that prevailed in the Bering-Chukchi region in the mid-1970's (see Niebauer 1980, 1981a, 1981b) . The unusually cold environment may have affected the presence of breeding murres at Owalit Colony in several ways. Local conditions may have made it physically difficult for murres to nest. Searing (1977) noted that snow cover persisted on the breeding ledges at Owalit Colony in spring 1976, and he described how the presence of snow might have affected the presence of murres on the cliffs. Also, the annually cooling climatic conditions preceding the unusually cold year of 1976 may have influenced seabird food webs. Searing (1977) noted a high usage of invertebrate prey by murres at Owalit Colony in 1976, a phenomenon that also occurred at Cape Thompson during the same year (Springer *et al.* 1982). Because murres feed predominantly on fish during the breeding season, the higher incidence of invertebrates in murre diets in 1976 indicates that fish biomass was relatively low that year. Such changes in food webs may have influenced the number of murres attempting to breed at Owalit Colony in the mid-1970's.

The effect may have been especially great on common murres, which depend even more on fish than do thick-billed murres (Swartz 1966, Springer *et al.* 1982).

Regardless of the specific reasons for the presence of fewer murres at Owalit Colony in 1976, the number of murres present on the cliffs in 1981 was about the same as a decade ago. The similarity in numbers between 1972 and 1981, both climatically mild years, and the cold environmental conditions that coincided with the 1976 breeding season suggest that the 1976 population decrease was a short-lived event rather than an actual decline-in the population.

Cape Lisburne and Cape Lewis

Results of our censuses at Cape Lisburne and Cape Lewis (Tables 2 and 3) suggest that numbers of murres have remained relatively stable at these two colonies since the mid-1970's (Table 5). In contrast, murres declined at Cape Thompson between 1960 and 1976, and between 1976 and 1979 (see Murphy *et al.* 1980). The apparent stability of populations of murres at Cape Lisburne and Cape Lewis compared to decreasing numbers at Cape Thompson are discussed by Springer *et al.* 1982.

Bluff

Our earlier analysis of pre-1980 census data indicated that the number of murres declined at Bluff during 1975-1979 (see Murphy *et* al. 1980). Data we obtained in 1981 indicate that the murre population is still decreasing (Table 5).

The rate of decline of murres at Bluff was fairly steady during 1975-1981, and nearly the same as the rate of decline previously documented for murres at Cape Thompson during 1976-1979 (Murphy *et* al. 1980). We are presently examining two possible reasons for these decreases, which involve effects of a changing environment on: (1) natality of murres and (2) winter mortality of murres. A thorough discussion of these possibilities is presented in Springer *et al.* 1982.

Phenology

Dates of first hatching of murre eggs and first sea-going of murre chicks at St. Lawrence Island, Cape Lisburne, Bluff and Cape Thompson since 1959 are summarized in Table 6. Based on hatching dates, murres at St. Lawrence Island bred about one week earlier in 1981 than did murres at Cape Lisburne, but about one and a half weeks later than murres at Bluff.

Hatching of thick-billed murre eggs at Owalit Colony, St. Lawrence Island commenced about 20 July. On 23 July, a ledge used predominantly by common murres contained 21 unpipped eggs, 1 pipping egg and 2 small chicks estimated to be about two days old. Several other chicks, approximately 2-5 days old, were seen on ledges where thick-billed murres predominated. Chicks were numerous on many ledges by 30 July and hatching appeared to peak about 1-2 August, but was still occurring on 10 August. Some of the earliest chicks seen were well-developed and appeared ready to go to sea on 10 August. Sea-going may have commenced as early as the evenings of 10-11 August, but probably did not peak until about 15-16 August .

The first common murre chick was seen at Bluff on 11 July. Most chicks hatched between 14 July and 22 July. Our early departure prevented us from determining the full extent of the hatching period at Bluff in 1981.

These data and consistent differences among the locations in previous years (Table 6) probably reflect the typically warmer, earlier spring conditions at the more southern latitudes of Bluff (~64°30'N) and St. Lawrence Island (~63°30'N) compared to the later, cooler spring conditions at the more northern latitudes of Cape Lisburne (~68°50'N) and Cape Thompson (~68°10'N) (see Brewer *et* al. 1977a, 1977b).

Phonological changes among years at each location also follow a consistent trend (Table 6). Murres nested latest in the mid-1970's and earliest in the late 1970's. Changes in phenology at all murre colonies occurred concomitantly with changes in regional physical conditions (Figure 5). Relationships between phonological changes, reproductive changes and physical conditions are discussed in greater detail in Springer *et* al. (1982).

Foraging Areas

Observations of the flight directions taken by murres as they commuted between offshore foraging areas and nesting areas at St. Lawrence Island, Cape Lisburne and Bluff in 1981 are summarized below.

St. Lawrence Island

The majority of murres nesting at Owalit, Ivekan and Southwest colonies clearly fed in Anadyr Strait and its out-flow north of Northwest Cape, where Anadyr Water mixes with Bering Shelf Water and where strong currents result in turbulence and upwelling in the vicinity of shoals (see Nelson *et* al. 1981). Throughout the day, flocks departing from colonies in the southwestern sector paralleled the coast between Boxer Bay and Booshu Camp, where they tended to disperse toward Anadyr Strait (Figure 6). Departing flocks, typically small (often only 5-30 individuals), fanned out toward the north and north.west; some flew within sight of the coast as far as Gambell, where they were lost from sight as they continued northward. Inbound flocks were typically much larger (often hundreds of individuals), and nearly unbroken strings of murres returned to the vicinity of Sevuokuk Mountain at Northwest Cape from north and northeast of the island during evening hours[1] (Figure 6). Flocks of murres flew past Northwest Cape and paralled the island's western coast as they returned to Owalit, Ivekan and Southwest Colonies.

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[1]These returning flights of murres were accompanied by large numbers of least and crested auklets and small numbers of parakeet auklets (*Cyclorrhynchus psittacula*), horned puffins, tufted puffins (*Lunda cirrhata*), *some* kittiwakes and occasional pelagic cormorants and pigeon guillemots (*Cepphus columba*).

Table 1. Murre census results from St. Lawrence Island, 1981 .[a]

Colony	Plot	Date	Time[b]	Observer C	Observer E	$\bar{x}$
South side of island						
Southwest Cape	1	1 August	17:45	56,000	58,950	57,475
	2	1 August	19:25	16,200	14,100	15,150
Subtotals				72,200	73,050	72,625
Ivekan Mtn.	3	2 August	14:25	17,000	19,600	18,300
	4	2 August	13:40	33,800	33,200	33,500
	5	2 August	10:40	59,500	67,500	63,500
	6	24 July	17:58	11,400	11,240	11,320
	7	24 July	17:37	4,520	4,180	4,350
Subtotals				126,220	135,720	130,970
Owalit Mtn.	8	24 July	17:30	500	500	500
	9	24 July		372	361	367
	10	24 July		253	257	255
	11	24 July	16:00	8,280	10,050	9,165
	12	24 July	15:10	8,920	9,630	9,275
	13	24 July	14:47	6,120	7,220	6,670
	14	24 July	14:25	5,080	3,570	4,325
	15	24 July	14:04	880	870	875
	16	24 July	13:52	1,710	1,815	1,763
	17	24 July	13:42	150	175	163
	18	24 July	13:25	590	607	599
Subtotals				32,855	35,055	33,957
North side of island						
Kangee	19	19 July	14:20	5,390	5,420	5,405
	20	19 July	14:15	1,580	2,040	1,810
	21	19 July	13:45	4,030	6,860	5,445
	22	19 July	13:40	4,300	2,410	3,355
	23	19 July	13:20	3,230	2,840	3,035
	24	19 July	13:05	3,280	3,060	3,170
	25	19 July	12:46	7,080	7,170	7,125
	26	19 July	12:10	12,580	17,110	14,845
	27	19 July	11:40	6,960	10,540	8,750
	28	19 July	11:15	4,760	5,930	5,345
	29	18 July	21:25	150	130	140
	30	18 July	21:15	2,470	2,870	2,670
	31	18 July	20:30	9,080	10,910	9,995
	32	18 July	20:10	1.310	1,220	1,265
Subtotals				66,200	78,510	72,355
Savoonga	33	18 July	19:30	4,080	4,310	4,195
Subtotals				4,080	4,310	4,195
Cape Myaughee	34	18 July	18:50	5,080	6,350	5,715
	35	18 July	17:50	7,170	10.880	9,025
Subtotals				12,250	17,230	14,740
TOTALS				313,805	343,875	328,840

[a] Estimates are by 10's of birds except: plots 1-5 by 100's; plots 9 and 10 by 1's on several dates at varying times and numbers given here are averages of those counts.

[b] Times are times at start of count, Bering Daylight Time.

Table 2. Murre census results from Cape Lisburne, 1981.[a]

	25 July				2 August			
Plot	Time[b]	Observer F	Observer K	x̄	Time[b]	Observer F	Observer K	x̄
11	1815	950	737	844	2000	1,340	1,260	1,300
12	1840	1,550	1,624	1,587	2015	1,950	1,980	1,965
25	1910	695	624	660	2030	1,170	1,220	1,195
26	1920	1,010	769	890	2045	1,240	1,110	1,175
30	1935	3,130	2,850	2,990	2100	3,930	4,430	4,185
32	1950	1,890	1,773	1,832	2140	1,530	1,670	1,600
65	2020	2,140	2,276	2,208				
66	2045	1,450	1,450	1,450				
70	2100	1,070	1,200	1,135				
72	2110	700	583	642				
Total		14,585	13,886	14,238		11,160	11,670	11,420

[a] Estimates are by 10's.

[b] Times are Bering Daylight Time.

Table 3. Murre census results from Cape Lewis, 1981.[a]

Plot	Time	2 August Observer F	2 August Observer K	x
1	1055	580	640	610
2	1115	2,050	1,610	1,830
3	1140	700	720	710
4	1150	1,030	960	995
5	1200	1,960	1,320	1,640
6	1220	1,260	1,060	1,160
7	1230	1,800	1,510	1,655
8	1255	2,480	2,890	2,685
9	1315	3,370	3,090	3,230
10	1330	200	290	245
11	1345	1,120	990	1,055
12	1355	1,070	1,200	1,135
13	1410	1,850	2,120	1,985
14	1430	1,540	1,720	1,630
Total		21,010	20,120	20,565

[a]Estimates are by 10's.

[b]Times are Bering Daylight Time.

Table 4. Murre census results from Bluff, 1981.[a]

Section	15 July Observer F	19 July Observer F
End-C	7,410	5,080
C-D	8,485	8,415
D-E	3,900	3,820
E-F	3,750	3,990
F-G	1,520	1,280
G-H	1,230	1,430
H-I	3,400	3,630
I-J	280	200
Total	29,975	27,845
Time at end (Bering Daylight Time)	1010	1110
Time at J (Bering Daylight Time)	1935	1900

[a]Estimates are by 10's.

TABLE 5 Summary of census results of murres in northern Alaska.

Year	Cape Lisburne Raw	Cape Lisburne Standardized	Cape Lewis Raw	Cape Thompson[1] Raw	Cape Thompson[1] Standardized	Bluff Average[4]	St. Lawrence Is.[2] Raw
1960				251,000	357,000		
1972							32,000
1975						70,000	
1976	130,000	184,000		157,000	199,000	50,000	16,000
1977	131,000	184,000	19,000	143,000	171,000	38,000	
1978[5]	126,000	172,000				40,000	
1979[5]	142,000	246,000		114,000	149,000	35,000	
1980[5]	173,000	174,000				31,000	
1981[5]	149,000	153,000	21,000			29,000	34,000

[1]Data for 1960 are from L.G. Swartz (unpubl. data).

[2]Owalit Mtn. study area only: data for 1972 are from S.R. Johnson (unpubl. data); data for 1976 are from Searing (1977).

[3]Data have been standardized for differences in counting times during the day (see Springer and Roseneau 1978 and Murphy *et al.* 1980).

[4]Average of two or three complete counts (See Murphy et al. 1980): data for 1975-1979 are from Drury *et al.* 1981.

[5]Estimate based on partial census.

Table 6, Murre breeding phenology: dates of first hatching and first sea-going at colonies in the northern Bering Sea and eastern Chukchi Sea.[a]

A. First Hatching

Year	Cape Lisburne[b]	Cape Thompson[b]	St. Lawrence Island[d]	Bluff[c]
1959	---	~4 Aug[e]	---	---
1960	---	30 Jul.	---	---
1961	---	27 Jul	---	---
1972	---	---	30 Jul.	---
1975	---	---	---	~24 Jul
1976	~6 Aug	9 Aug	31 Jul	~27 Jul
1977	1 Aug	1 Aug	---	3 Aug
1978	21 Jul	~23 Jul	---	15 Jul
1979	22 Jul	22 Jul	---	~15 Jul
1980	1 Aug	---	---	<19 Jul
1981	26 Jul	---	20 Jul	11 Jul

B. First Sea-going

Year	Cape Lisburne[b]	Cape Thompson[b]	St. Lawrence Island[d]	Bluff[c]
1959	---	25 Aug	---	
1960	---	18 Aug	---	---
1961	---	19 Aug	---	
1972		---	18 Aug	
1975	---	---	---	~10 Aug
1976	28 Aug	~30 Aug	21 Aug	~14 Aug
1977	20 Aug	23 Aug	---	20 Aug
1978	11 Aug	13 Aug	---	31 Jul
1979	14 Aug	11 Aug	---	2 Aug
1980	~2 Aug	---	---	≥24 Jul
1981	~16 Aug	---	~11 Aug	~29 Jul

[a] Data for 1959-1961 at Cape Thompson are from Swartz (1966 and unpubl. data); data for 1972 at St. Lawrence Island are from Johnson and West (1975) and S. R. Johnson (unpubl. data); data for 1975 at Bluff are from Drury (1976): data for 1976 at St. Lawrence Island are from Searing (1977); data for 1976 at Bluff are from Steele and Drury (1977); data for 1977 at Bluff are from Biderman *et al.* (1978); data for 1978 at Bluff are from Ramsdell and Drury (1979);

[b] Data for Capé Thompson and Cape Lisburne are for thick-billed murrea. Approximate dates were calculated from first hatching or sea-going using an average chick age of 22 days.

[c] Data for Bluff are for common murres. Approximate dates were calculated from first hatching or sea-going dates using an average chick age of 19 days (see Ramsdell and Drury 1979). Wherever approximate dates are given for both hatching and sea-going in the same year, dates were estimated from whatever information the authors provided.

[d] Data for St. Lawrence Island in 1981 are for thick-billed murres, and data for 1972 and 1976 are assumed to be representative of this species. Johnson and West' e (1975) data indicate that the phenologies of both species were similar in 1972, and Searing (1977) did not note any major cliff erences between the two species in 1976. Since both studies reported first dates of both events, any bias would probably favor thick-billed murres as they may hatch and go to sea slightly earlier then common murres (e. g., Fay and Cade 1959, Swartz 1966).

[e] Swartz (1966) reported 11 August ae ehe date thick-billed murre chicks were first eeen in 1959. We adjusted chic date on the basis of a chick age of 22 days and the date of first sea-going (25 Aug) to better reflect the date of hatching that yeas.

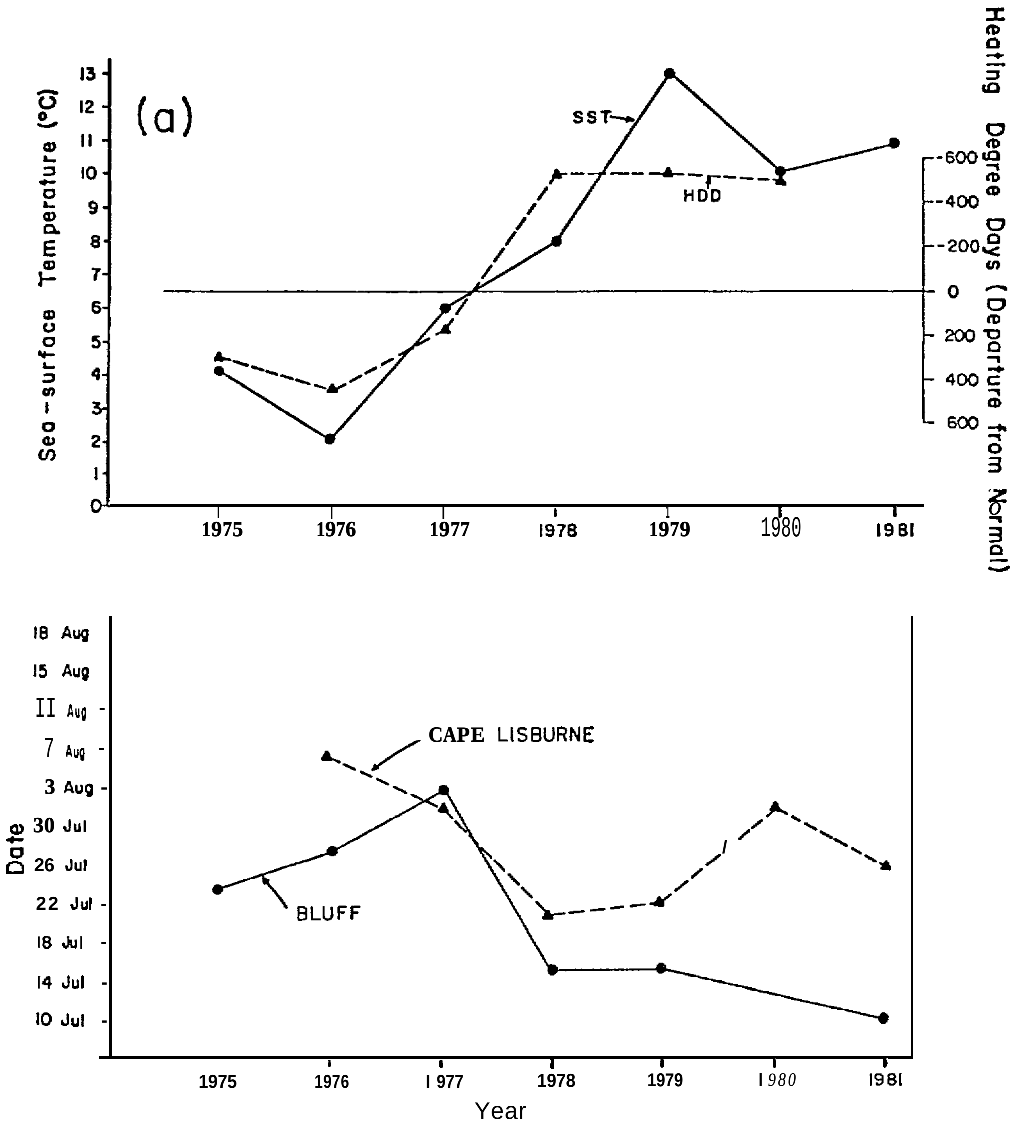

Figure 5. Relationships between environmental change and murre breeding phenology. (a) Sea-surface temperature near Cape Lisburne (mean date = 16 July, s = 3 days), and departure from normal heating degree days in April-July at Nome. (b) Date of first hatching of murre eggs.

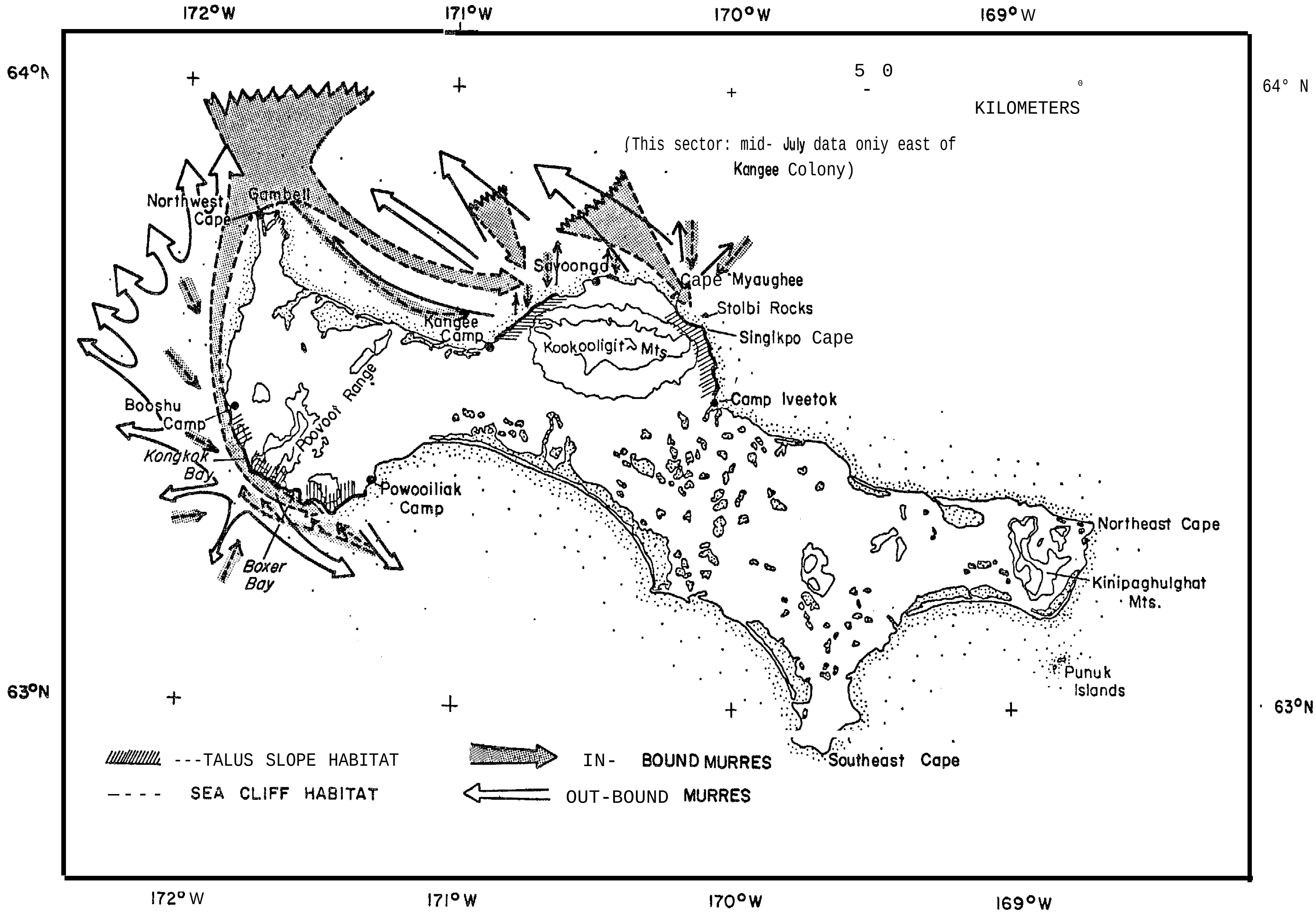

Figure 6. Flight directions followed by murres at St. Lawrence Island, mid-July through mid-August 1981.

Smaller numbers of murres nesting at Owalit, Ivekan and Southwest colonies departed to and returned from a southeasterly direction (Figure 6). This flight pattern was most evident at Boxer Bay and Southwest Cape, where some inbound birds carrying fish turned into Southwest Colony and others continued past Boxer Bay toward Kongkok Bay. Smaller numbers of murres also occasionally fed directly offshore of all three colonies.

Flight patterns of murres nesting in the southwestern sector of the island did not change substantially during mid-July through mid-August, but murres spent more time in front of the colonies after the first week of August. Activity, including some feeding in front of the cliffs, increased as the chicks neared sea-going age. Drury *et* al. (1981) observed concentrations of murres near the southwestern sector colonies after mid-August in 1978. We believe that these concentrations were also primarily the result of sea-going activities.

We also observed the inbound and outbound flight directions taken by murres commuting between breeding colonies in the north-central sector of the island and offshore feeding areas on 18-19 July and 12 August. Most murres nesting at Kangee, Savoonga and Myaughee colonies departed to and returned from the north and northwest (Figure 6). The flight pattern indicated that these birds shared the same general foraging area used by murres nesting in the southwestern sector of the island.

Movements of murres to and from the north-central sector colonies occurred on a broad front. Many murres returned from the north and northeast to the vicinity of Sevuokuk Mountain, where they turned eastward after separating from the flocks traveling toward the southwestern sector of the island. Murres that turned eastward at Sevuokuk Mountain rarely intercepted the coast west of Kangee Colony; instead, the majority remained several kilometers or more offshore as they flew directly across the large embayment between Sevuokuk Mountain and Savoonga toward Kangee Colony. Many other flocks of murres apparently turned southeastward toward Kangee, Savoonga and Myaughee colonies at greater distances offshore. These flocks intercepted the southeasterly flow of birds at various points along the northwestern coast of the island. Some murres at Myaughee Colony also departed toward and returned from north and northeasterly directions. We have no information on flight directions taken by murres nesting southeast of Cape Myaughee at Singikpo, Kitnik or Iveetok colonies, except that some murres appeared to be flying past Myaughee Colony without stopping there.

Flight patterns of murres at St. Lawrence Island indicate that the majority travel long distances to feed during most of the breeding season. Murres from the southwestern sector colonies may regularly fly in excess of 70 km each way to forage north of Northwest Cape. Many murres from colonies in the north-central sector of the island may commute similar distances each way to feed in the same area. Flight patterns between the primary foraging area and the colonies change little from year to year. In 1981, murres from the southwestern sector of the island followed the same basic flight pattern used in 1972 (Johnson unpubl. data) and 1976 (Searing 1977), and indeed, as used in almost all years (L. Iyakitan pers. comm.). These observations demonstrate the annual importance of food-rich Anadyr Strait and its out-flow to foraging seabirds.

Cape Lisburne

The majority of murres nesting at Cape Lisburne in the eastern Chukchi Sea fed north and northeast of the colony during our late July-early August visit. Murres regularly forage northeast of the colony in Ledyard Bay during early and mid-summer, and northto northwest of the Cape after early August (see Springer and Roseneau 1977, 1978; Springer *et al.* 1979; Springer *et* al. 1982).

Bluff

The majority of murres nesting at Bluff dispersed widely to feed off-shore in Norton Sound during mid-July through mid-August in 1980 and during our mid-July visit in 1981, a pattern typical of past years (see Drury *et al.* 1981).

B. Black-legged Kittiwakes

Census

Results of our 1981 censuses of black-legged kittiwakes at colonies in the northern Bering and eastern Chukchi seas are presented in Tables 7-9. All censuses of kittiwakes at these colonies, and at Cape Thompson, since 1976 are summarized in Table 10.

St. Lawrence island

Photographs were taken of several census plots to provide a basis for comparisons of numbers in future years. Numbers of birds and nests have not yet been counted from these photographs.

Cape Lisburne

We counted kittiwakes on 10 of the 75 census plots, and recounted kittiwakes on 6 of those 10 plots at Cape Lisburne in 1981 (Table 7). These data were used to estimate the total number of birds present on the cliffs, and the resulting estimate of approximately 14,000 individuals was nearly identical to our previous estimates at this colony (Table 10). These data suggest that little change has occurred in the size of the kittiwake population during the last five years.

Cape *Lewis*

We first censused kittiwakes at Cape Lewis in 1977 (Springer and Roseneau 1978). Plots 1-7, half of all plots, were censused in 1978. That count indicated an increase of over 100% in the number of kittiwakes between 1977 and 1978 (Table 10). We were unable to census the colony in either 1979 or 1980; however, brief observations of it in both years also suggested that many more kittiwakes were present than in 1977. Our 1981 census of 5,228 individuals (Table 8) confirms our previous impressions - over twice as many kittiwakes were present at Cape Lewis in 1981 than in 1977.

Table 7. Black-legged kittiwake census results from Cape Lisburne, 1981.[a]

		25 July						2 August						
		Observer F		Observer K					Observer F		Observer K			
Plot	time[b]	birds	nests	birds	nests	x̄(birds)	x̄(nests)	time	birds	nests	birds	nests	x̄(birds)	x̄(nests)
11	1815	201	159	196	156	199	158	2000	193	153	216	158	205	156
12	1840	164	140	227	207	196	174	2015	161	148	161	142	161	145
25	1910	41	34	40	33	41	34	2030	42	40	54	50	48	45
26	1920	281	243	205	180	243	212	2045	258	241	238	223	248	232
30	1935	112	99	137	118	125	109	2100	142	132	161	146	152	139
32	1950	48	43	41	36	45	40	2140	37	32	43	37	40	35
SUBTOTAL		847	718	846	730	847	724		833	746	873	756	S54	752
65	2020	309	281	310	262	310	272							
66	2045	45	42	41	38	43	40							
70	2100	110	109	121	117	116	113							
72	2110	129	119	127	116	128	118							
TOTAL		1,440	1,269	1,445	1,263	1,446	1,270							

[a]Counts are by 1's.

[b]Times are Bering Daylight Time.

Table 8. Black-legged kittiwake census results from Cape Lewis, 2 August 1981.[a]

Plot	time[b]	Observer F		Observer K		$\bar{x}$ (birds)	$\bar{x}$ (nests)
		birds	nests	birds	nests		
1	1055	120	90	121	81	121	86
2	1115	339	269	342	250	341	260
3	1140	80	65	75	59	78	62
4	1150	218	181	202	151	210	166
5	1200	686	592	538	454	612	523
6	1220	259	225	263	215	261	220
7	1230	513	464	584	458	549	461
8	1255	607	543	440	363	524	453
9	1315	799	729	513	473	656	601
10	1330	74	64	68	55	71	60
11	1345	493	443	406	370	450	407
12	1355	520	478	552	508	536	493
13	1410	659	575	556	497	608	536
14	1430	198	178	224	191	211	185
Total		5,565	4,896	4,884	4,125	5,228	4,513

[a] Counts are by 1's.

[b] Times are Bering Daylight Time.

Table 9. Black-legged kittiwake census results from Bluff, 1981.[a]

	15 July						19 July					
	Observer F		Observer K				Observer F		Observer K			
Section	birds	nests	birds	nests	$\bar{x}$(birds)	$\bar{x}$(nests)	birds	nests	birds	nests	$\bar{x}$(birds)	$\bar{x}$(nests)
End-C	2,056	1,787	2,141	1,573	2,099	1,680	2,138	1,931	2,473	2,238	2,306	2,085
C-D	2,037	1,716	2,107	1,809	2,072	1,763	2,341	1,975	2,384	2,049	2,363	2,012
D-E	963	852	1,033	893	998	873	1,502	1,260	1,419	1,243	1,461	1,252
SUBTOTAL	5,056	4,355	5,281	4,275	5,169	4,316	5,981	5,166	6,276	5,530	6,130	5,349
E-F	ND[b]	ND	1,101	996	ND	ND	1,316	1,178	1,389	1,205	1,353	1,192
F-G	ND	ND	830	705	ND	ND	923	780	1,006	847	965	814
G-H	ND	ND	381	325	ND	ND	416	332	623	450	520	391
H-I	ND	ND	1,209	971	ND	ND	1,364	1,088	1,310	1,053	1,337	1,071
I-J	353	275	394	260	374	268	352	281	460	297	406	289
TOTAL			9,196	7,532			10,352	8,825	11,064	9,382	10,711	9,106
Time at A	11:10 Bering Daylight Time						10:08 Bering Daylight Time					
Time at J	19:00 "						19:35 "					

[a]Counts are by 1's.

[b]ND = No data (not counted or counts not completed).

TABLE 10. Black-legged kittiwake census summaries for colonies in northern Alaska, 1975-1981.

Colony	1975	1976	1977	1978	1979	1980	1981
Bluff[a]	7,250	7,000	7,400	6,600	9,000	9,900	10,700
Cape Thompson	ND[b]	10,500	10,200	15,200[c]	16,800	ND	ND
Cape Lewis	ND	ND	2,300	5,800[d]	ND	ND	5,200
Cape Lisburne	ND	ND	14,700	15,400[e]	17,300[e]	ND	16,300[e]

[a]Data for 1975-1976 are from Steele and Drury (1977); data for 1977 are from Biderman et al. (1978); data for 1978 are from Ramsdell and Drury (1979).

[b]ND = no data.

[c]Estimate derived from the count of Colony 4 only. The value is the mean (S=1900) of three estimates of the 1978 colony total. The estimates were derived by using each of the other three years as bases for extrapolating the colony total from counts at Colony 4 in 1978.

[d]Estimate derived from a count of 50% of the census plots. The value is the mean (S=380) of two estimates of the 1978 colony total. The estimates were derived by using each of the other two years as bases for extrapolating the colony total from partial counts in 1978.

[e]Estimate derived from counts of selected census plots within the colony.

Bluff

We completely censused kittiwakes at Bluff in 1981 (Table 9). The total number of individuals counted, 10,711, was nearly identical to the total number of individuals counted in 1980, but the population clearly increased after 1977-1978 (Table 10).

Phenology

Mean hatch dates of black-legged kittiwake eggs at St. Lawrence Island, Cape Lisburne, Bluff and Cape Thompson are summarized in Table 11.

Kittiwakes at St. Lawrence Island bred a few days earlier in 1981 than kittiwakes at Cape Lisburne, but about one week later than kittiwakes at Bluff. Hatching of kittiwake eggs at Owalit and Ivekan colonies at St. Lawrence Island began about 18 July, based on weights of chicks on 21 and 23 July. The peak of hatching occurred about 22 July. Of 16 eggs checked on 21 July, 7 had hatched, 4 were pipping and 5 were unpipped. Eighteen eggs were checked on 23 July at two other plots: 11 were hatched, 3 were pipping and 4 were unpipped. Three of the 4 unpipped eggs proved to be addled and only 1 of them hatched at a later date. Hatching was essentially complete by 1 August.

Kittiwake eggs at Cape Lisburne began hatching about 21 July, based on weights of chicks on 25 July. The peak of hatching occurred about 26 July, based on chick growth rates, but actually may have occurred a few days later, based on direct observations. Sixty-seven of 237 eggs had hatched by 25 July, and by 31 July 103 of 188 eggs had hatched. Hatching was still occurring when we departed on 5 August and may not have been complete until several days later.

Weights taken of kittiwake chicks at Bluff indicated that hatching commenced about 7 July, the date of our arrival. Hatching peaked about 15 July, based on chick growth rates, but may have occurred about two days later, based on chick observations. Sixteen of 152 eggs had hatched by 10 July, and 64 of 141 eggs had hatched by 16 July. Hatching was nearly complete by 22 July.

Phonological data on kittiwakes at colonies in the northern Bering Sea and the eastern Chukchi Sea (Table 11) have followed the same pattern demonstrated for murres (Table 6). Breeding schedules at Cape Lisburne and Cape Thompson have been similar, but consistently later than breeding schedules at St. Lawrence Island and Bluff. Kittiwakes have always bred earlier at Bluff than at any of the other colonies.

Phonological changes among years at each colony have also followed a consistent trend. Kittiwakes bred latest in the mid-1970's and earliest in the late 1970's and early 1980's.

Differences between kittiwake breeding schedules at St. Lawrence Island, Bluff and Cape Thompson/Cape Lisburne are probably associated with latitudinal climatic differences, as with murres. Average spring and early summer conditions at St. Lawrence Island are somewhat warmer than at Cape Lisburne

Table 11. Black-legged kittiwake breeding phenology: dates of peak hatching at colonies in the northern Bering Sea and the eastern Chukchi Sea.[1]

Year	Cape Lisburne	Cape Thompson	St. Lawrence I	Bluff
1975	----	----	----	29 Jul[2]
1976	15 Aug[3]	12 Aug[4]	27 Jul[5]	30 Jul[2]
1977	14 Aug	3 Aug	----	1 Aug[2]
1978	6 Aug	----	----	22 Jul
1979	25 Jul	29 Jul	----	16 Jul
1980	26 Jul	----	----	15 Jul
1981	26 Jul	----	23 Jul	15 Jul

[1]Dates are estimated from weights of chicks when first found and from subsequent growth rates, unless otherwise noted. We have standardized our method of calculating hatching dates from chick weights and growth rates, and this has resulted in some minor adjustments between dates reported here and dates reported by Murphy *et* al. (1980).

[2]Data are from Drury *et al.* (1981).

[3]Chicks were not weighed; estimate is based on sizes of chicks relative to those at Cape Thompson.

[4]Chicks were not weighed; estimate is based on direct observation.

[5]Data are from Searing (1977); estimate is based on date the first of two total eggs was found and an incubation period of 28 days (see Swartz 1966).

and Cape Thompson, but all three of these locations, aligned with Bering Strait, share typically cooler regional climates than that which occurs to the east at Bluff, in relatively well-protected Norton Sound (Brewer *et* al. 1977a, 1977b).

Changes in breeding schedules of kittiwakes between the mid-1970's and the early 1980's are clearly related to regional physical conditions (Figure 7) (see Springer *et* al. 1982). Unusually cold conditions prevailed in the mid-1970's, but after 1976 conditions became warmer and kittiwakes nested progressively earlier each year during 1977-1979. Changes in breeding schedules after 1979 continued to reflect changes in environmental conditions; sea-surface temperatures were somewhat cooler in the northern Bering-eastern Chukchi region in 1980, but somewhat warmer again in 1981.

Productivity and Growth Rates

Productivity data on black-legged kittiwakes at St. Lawrence Island, Bluff and Cape Lisburne are presented in Tables 12-14 and are summarized in Figure 8. Growth rates of kittiwake chicks at these colonies and at Cape Thompson since 1977 are summarized in Table 15.

The pattern of productivity between kittiwakes nesting at colonies in the northern Bering Sea and the eastern Chukchi Sea followed the same pattern as phenology. Productivity of kittiwakes at St. Lawrence Island was perhaps slightly higher than productivity at Cape Lisburne, but apparently lower than productivity at Bluff. Productivity at St. Lawrence Island was not especially high or low in 1981, although it was considerably better than in 1976 when a reproductive failure occurred there (Searing 1977). Similar changes in productivity of kittiwakes occurred at Cape Lisburne, Cape Thompson and Bluff during the same years (Drury *et* al. 1981, Springer *et* al. 1982) .

Differences in productivity of kittiwakes between the mid-1970's and the early 1980's are clearly related to regional physical conditions, just as are differences in phenology (Figure 7). Although our measurements of the physical environment are not strictly the same, they are comparable to other measurements that have been shown to be significantly correlated in the Bering Sea (Niebauer 1980, 1981a, 1981b). Air temperature affects water temperature, which is in turn related to the abundance of important prey populations for kittiwakes (Springer et al. 1982).

The average growth rate of kittiwake chicks at St. Lawrence Island was about 47% higher than at Cape Lisburne, and about 35% higher than at Bluff (Table 15). Also, growth rates at St. Lawrence Island were significantly higher during the second week of the weighing interval (22.5 g day^{-1}, s=5) than during the first weekof theweighing interval (16.5 g day^{-1}, s=3) (Wilcoxon Rank Sum Test, $P<0.05$). These data suggest that food availability to kittiwakes during the second weighing interval was higher than during the first weighing interval, and was higher during both intervals at St. Lawrence Island than at either Bluff or Cape Lisburne.

The average growth rate of kittiwake chicks at Cape Lisburne was about

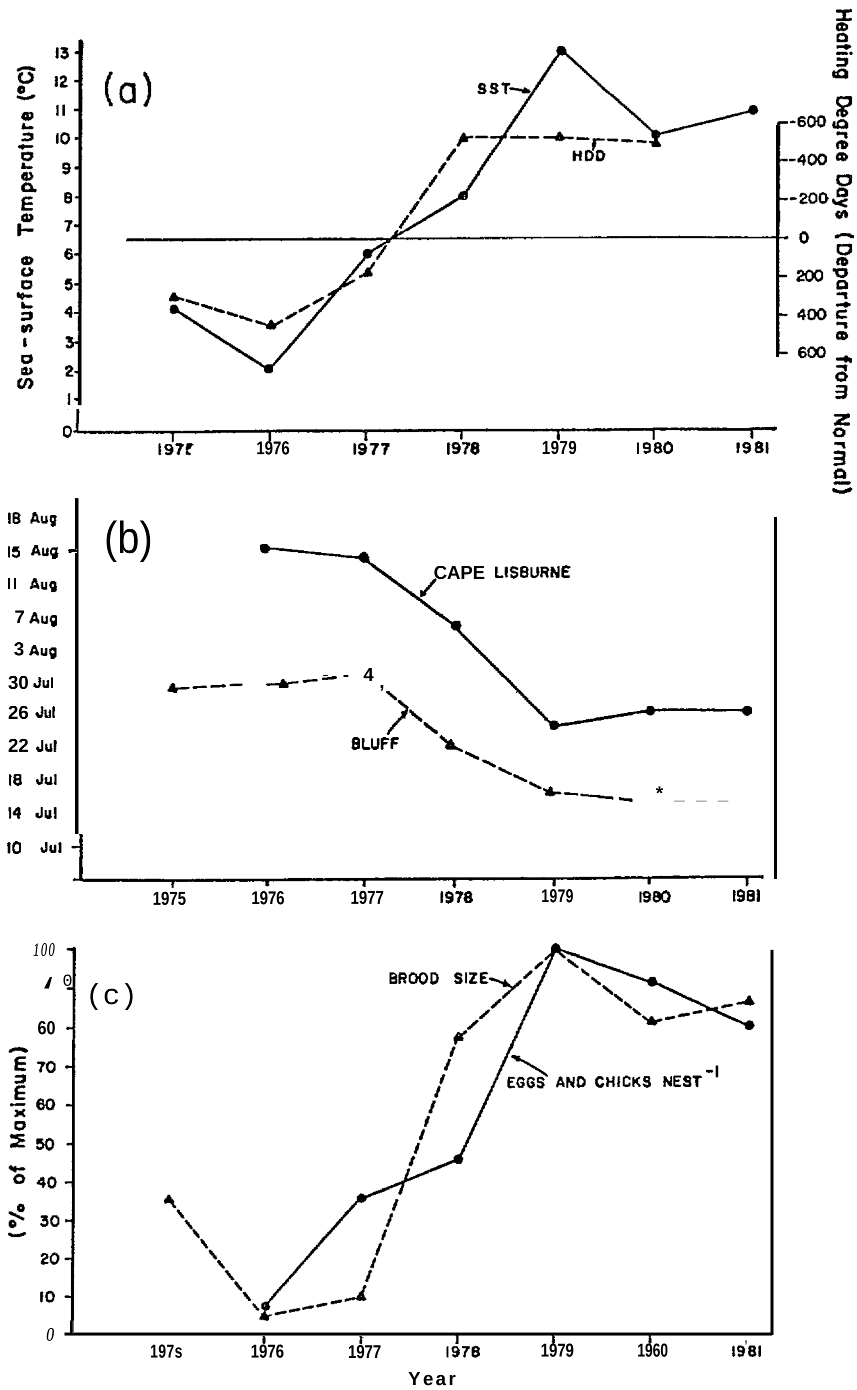

Figure 7. Relationships between environmental change, kittiwake nesting phenology and estimates of kittiwake reproductive success at Cape Lisburne and Bluff. (a) Sea-surface temperature near Cape Lisburne (mean date = 16 July, s = 3 days), and departure from normal heating degree days in April-July at Nome. (b) Mean date of hatch of kittiwake chicks. (c) Numbers of kittiwake eggs and chicks nest^{-1} in first week of hatch at Cape Lisburne (as a percentage of maximum = 1.7 eggs and chicks nest^{-1}), and kittiwake brood size in the late chick period at Bluff (as a percentage of maximum = 1.03 chicks nest-l). Data for 1980 and 1981 at Bluff are from the early chick period; data for 1975-1978 at Bluff are from Drury *et* al. 1981.

Table 12. Black-legged kittiwake nest contents at St. Lawrence Island, 1981.

Date	Empty	1 egg	2 eggs	3 eggs	1 chick	2 chicks	1 egg & 1 chick
21-23 July	3	4	9	0	11	9	5
30 July-1 August	4	3	2	0	28	5	1
8-9 August	9	0	0	0	31	3	0

Table 13. Black-legged kittiwake nest contents at Bluff, 1981.

Date	Empty	1 egg	2 eggs	3 eggs	1 chick	2 chicks	1 egg & 1 chick
10 July	6	18	53	2	2	4	6
16 July	8	15	23	2	16	19	10
20 July	9	11	5	0	46	14	6
22 July	11	8	0	0	53	10	9

Table 14. Black-legged kittiwake nest contents at Cape Lisburne, 1981.

Date	Empty	1 egg	2 eggs	3 eggs	1 chick	2 chicks	1 egg & 1 chick
25 July	36	39	59	1	9	24	10
31 July	51	22	24	0	42	23	15
3 August	69	13	10	0	67	15	10

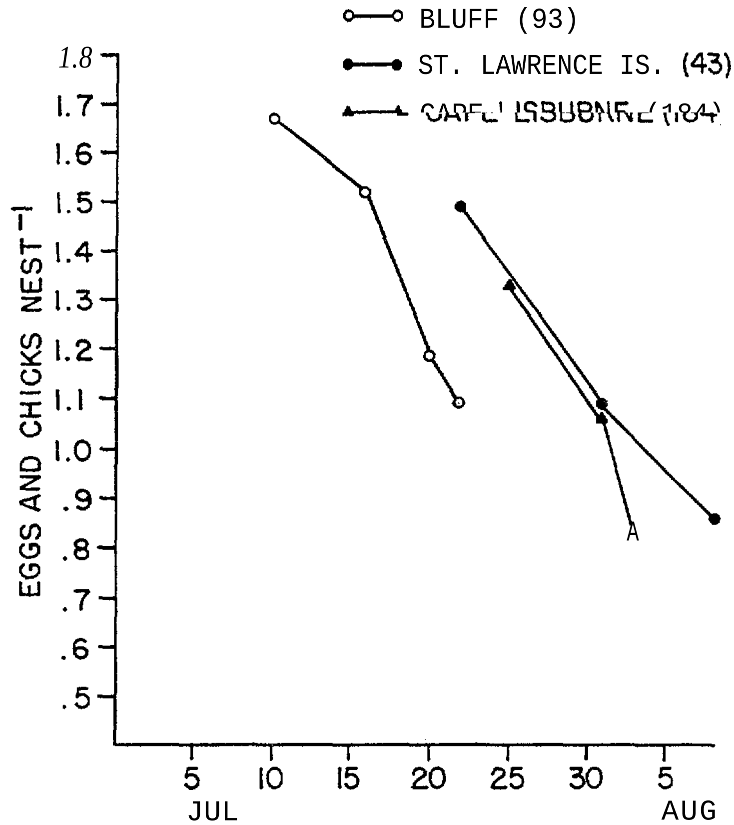

Figure 8. Contents of black-legged kittiwake nests at Bluff, St. Lawrence Island and Cape Lisburne, 1981.

20% lower in 1981 than in 1980, and about 25% lower than growth rates in 1977-1979 (Table 15).[1] A similar trend was apparent at Bluff, where the average growth rate of chicks was about 11% lower in 1981 than in 1978 and 1980, and about 24% lower in 1981 than in 1979. These data suggest that mid-season food availability declined in the eastern Chukchi Sea and Norton Sound in the cooler years following the exceptionally warm year of 1979. The differences in chick growth rates between Cape Lisburne and St. Lawrence Island, and between Bluff and St. Lawrence Island in 1981 indicate that less food was available to kittiwakes in the eastern Chukchi Sea and Norton Sound than in the waters near Anadyr Strait that year. Changes in food availability between years are related to changing environmental conditions (Springer *et* al. 1982), and differences in food availability between colonies in a single year are also probably related to annual, local differences in regional physical conditions.

C. Auklets

All data on auklets are from St. Lawrence Island, the only study area visited in 1981 where auklets breed.

[1]Values reported in Table 15 differ somewhat from those reported by Springer and Roseneau (1978), Springer *et* al. (1979) and Murphy *et* al. (1980) because we have revised our method of calculation (see Methods).

TABLE 15. Growth rates of black-legged kittiwake chicks in northern Alaska.

	Colony			
Year	Bluff	Cape Thompson	Cape Lisburne	St. Lawrence I.
1977	ND[a]	12.6 ± 3.6 (16)[b]	19.3 ± 2.9 (18)	ND
1978	17.9 ± 4.1 (22)	ND	19.7 ± 6.7 (21)	ND
1979	20.4 ± 4.4 (35)	20.2 ± 4.7 (111)	18.3 *1.4 (24)	ND
1980	17.6 *7.4 (30)	ND	17.9 *3.7 (43)	ND
1981	15.6 ± 4.5 (31)	ND	14.3 ± 3.0 (30)	21.0 ± 7.1 (15)

[a]ND = no data.

[b]Mean growth rate (g day-l) ± standard deviation (sample size).

Phenology

In 1981, hatching of least auklet eggs in Kongkok Basin on Ivekan Mountain commenced about 24-25 July. On 25 July, when 11 nests were checked, 9 contained single eggs and 2 contained tiny chicks estimated to be about one day old. Seventeen nests were checked-on 28 July. Thirteen of these contained single chicks (mean weight = 17.3g ± 5.0g) and four contained single eggs. By 5 August, hatching appeared essentially complete. The only eggs found on and after that date were addled.

Searing (1977) summarized phonological data on least auklets breeding at St. Lawrence Island. Previous dates when chicks were first found include 28 July 1964, 30 July 1965, about 27 July 1966, about 15 July 1967 and 25 July 1976. These dates correspond closely with our findings, with the exception of that given for 1967, a year when warm spring air temperatures caused an early snow melt (see Scaly 1975).

Productivity

Searing (1977) reported the fate of 16 of 34 least auklet chicks which hatched successfully at Kongkok Bay in 1976. Seven (44%) died or were killed by predators and nine (56%) survived to the age of fledging (about 32 days). The fate of 11 least auklet chicks to an age of about 15-16 days is known for 1981 at Ivekan Mountain. Four (36%) died or were killed by predators and 7 (64%) were still alive and healthy on 8 August, by which time they ranged in weight from 52g to 82g ($\bar{x}$ = 73.3g).

Growth Rates

Mensural data for least auklet chicks at Ivekan Mountain in 1981 are presented in Table 16. The average rate of weight gain of seven chicks during the interval 28 July-8 August was 4.7 g day^{-1} (s=0.82). That rate is 27% greater than the average growth rate of 10 chicks (3.7 g day^{-1}) during the period of maximum growth in 1976 (Searing 1977), but is similar to growth rates of least auklet chicks in 1966 (Scaly 1981).

These data are the first to suggest that important oceanic food webs might have been adversely affected by the unusually cold water temperatures and late springs of 1975 and 1976, as were neritic food webs in Norton Sound and the eastern Chukchi Sea (Springer *et* al. 1982). Food brought to least auklet chicks in 1976 was predominantly *Calanus plumchrus*. A preliminary examination of food brought to chicks in 1981 indicated that C. *cristatus* was the main item in diets that year. If we assume that adult auklets feed on the species of copepod which is most abundant in terms of biomass, without being too small to be taken efficiently (see Bédard 1969b), then we would conclude that C. *cristatus* was probably in low abundance compared to C. *plumchrus* in 1976, since the former is much larger than the latter and might well be selected for if numbers of the two species were equal. Although we cannot necessarily conclude that C. *plumchrus* was uncommon in 1981, or that C. *cristatus* was uncommon in 1976, we can be reasonably certain that the overall biomass of copepods was lower in 1976 than in 1981, as indicated by differences in chick growth rates between the two years.

Growth rates of least auklet chicks during the interval 5-8 August (6.7 g day^{-1}) were significantly greater than during the interval 28 July-5 August (4.6 g day^{-1}) (Wilcoxon Rank Sum Test, $P<0.05$). During the later interval, when north winds prevailed, adult least auklets from the Owalit Mountain and Ivekan Mountain colonies fed in large numbers along the coast near Kongkok Bay. During the earlier period they regularly traveled long distances northward to feed in Anadyr Strait north of Northwest Cape. It was not clear whether shorter commuting distances, greater copepod biomass, or both were responsible for the greater growth rates of chicks during the second interval.

Foraging Areas

We collected some information of foraging flight directions of least and crested auklets at St. Lawrence Island in 1981. These data supplement observations provided by Fay and Cade (1959), Bédard (1969b), Searing (1977) and Drury *et al.* (1981).

Owalit Colony and Ivekan Colony

The majority of least and crested auklets and many parakeet auklets nesting at Owalit and Ivekan colonies foraged in Anadyr Strait and its outflow between mid-July and early August. The flight pattern to and from this important feeding area is shown in Figure 9. Most flocks (typically 50 or more birds flock-l) departed northwestward toward Cape Chukotskiy and northward toward Northwest Cape. Huge numbers of least and crested auklets and some parakeet auklets, accompanied by large numbers of murres and small numbers of horned and tufted puffins, some kittiwakes, and occasional pelagic cormorants and pigeon guillemots, returned from the north and northeast toward Sevuokuk Mountain during the evening. The inbound flights

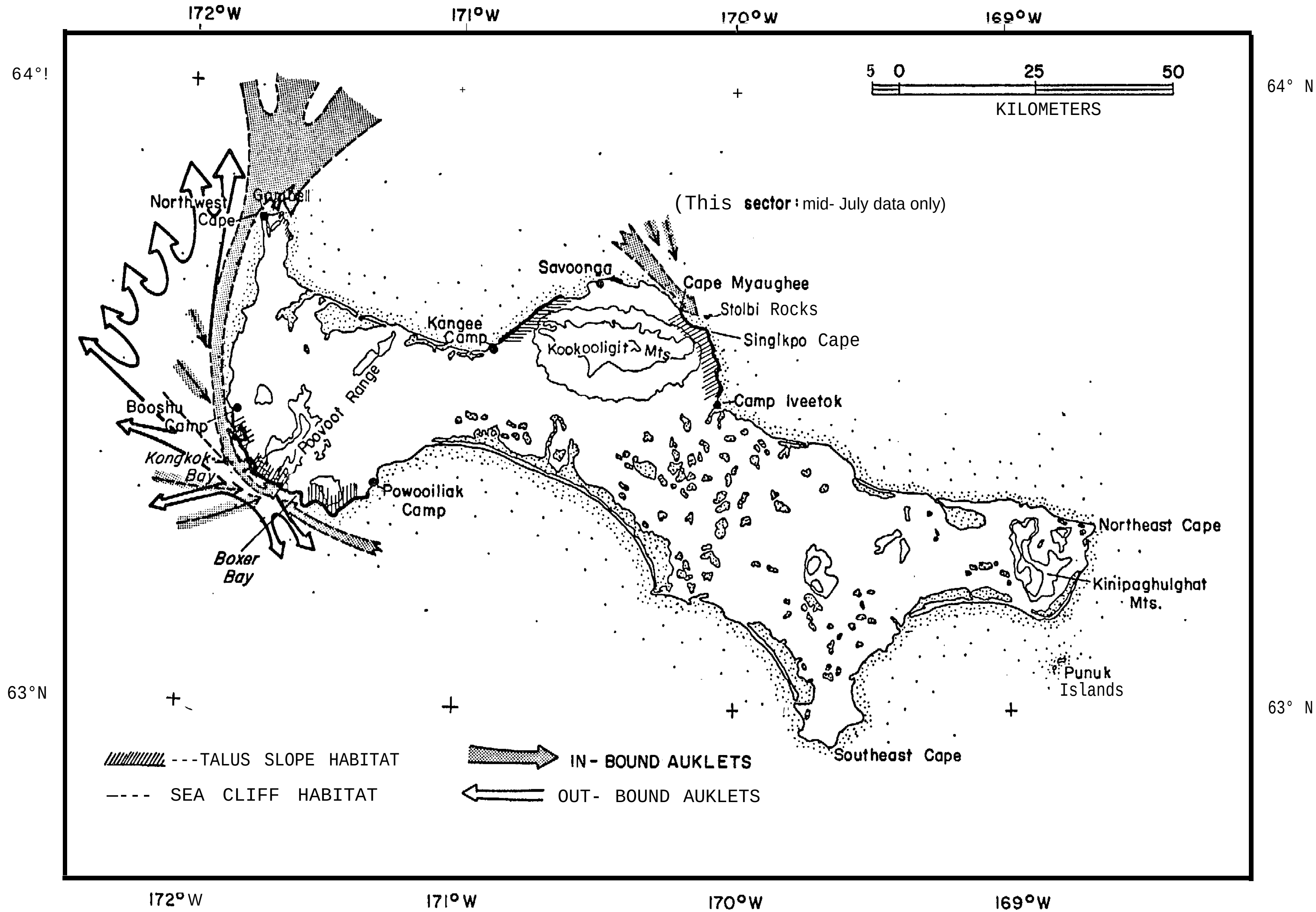

Figure 9. Flight directions followed by least and crested auklets at St. Lawrence Island, mid-July through mid-August 1981.

TABLE 16. Mensural data on least auklet chicks at St. Lawrence Island, 1981: T= tarsus length (mm); C= culmen length (mm); WT= weight (g).

Chick Number	28 July 1981			5 August 1981			8 August 1981		
	T	C	WT	T	C	WT	T	C	WT
1	16.0	6.0	19.5	17.5	6.5	44.0	17.8	7.0	52.0
2	16.5	6.5	22.5	17.8	8.3	60.0	18.7	8.2	79.0
3	16.0	6.5	22.5	18.3	6.8	56.0	18.7	7.5	73.0
3a				15.5	6.5	27.0	16.7	6.7	47.0
4	14.5	6.0	15.5	18.5	8.5	55.0	18.0	7.2	68.0
4a							19.0	8.4	78.0
5	17.0	6.7	26.0	18.5	7.4	60.0	19.4	7.5	80.0
6	14.3	5.5	13.0						
10	15.0	6.0	19.5	17.2	7.2	49.0	18.3	7.5	79.0
11	14.5	5.5	10.0						
12	14.5	5.5	13.5						
13	14.5	5.5	13.0	17.0	8.0	55.0			
14	16.0	6.5	22.5	19.0	8.5	54.0	18.8	7.6	82.0
14a							18.2	7.4	75.0
15	14.0	5.5	13.5						
17	14.5	5.5	14.0						

of auklets, consisting of near-constant strings of large flocks (typically hundreds of birds flock-l), usually commenced about 1930 h, peaked between about 2030 h and 2300 h, and decreased noticeably by about 2330-2400 h. The majority of flocks in the flights approaching Sevuokuk Mountain turned westward to round Northwest Cape and then streamed southward along the island's western coast.

Our best estimate of the magnitude of the southbound flights passing Gambell was obtained during a generally fog-free evening period on 17 July (Table 17). Subsequent boat trips between Gambell and Ivekan Mountain, and between Ivekan Mountain and Booshu Camp provided additional information. The returning flocks, forming a continuous stream of birds along the island's entire western coast, generally maintained a flight corridor several kilometers offshore of the island after passing Northwest Cape, and usually began to intercept and parallel the coast more closely near Booshu Camp before rounding Owalit Mountain and landing at the Owalit and Ivekan colonies.

The arrival of auklet flocks at Owalit and Ivekan colonies usually commenced about 2100 h and ended about 2400 h. On 23 July, for example, flocks began rounding Owalit Mountain and landing at the colonies at 2100 h, and by 2200 h tens of thousands of birds streamed in from the north to join those milling about in the air over the colonies. Arriving birds declined in number to about 1,000 per five-minute count by 2330 h and few birds appeared to arrive after about 0030 h. During the evening arrival period, some auklets also appeared to depart from the colonies.

A second period of intense activity occurred in the morning, usually between about 0400 h and 0800 h. Some flocks arrived at the colonies during this period, but many small flocks appeared to depart from them, dispersing northwestward, seaward of the route used by inbound flights. Many small flocks also appeared to depart throughout the remainder of the morning, and some occasionally departed or returned in the afternoon.

Although the majority of auklets nesting at Owalit and Ivekan colonies clearly fed in a major foraging area north and northwest of St. Lawrence Island's western end during mid-July through early August, small numbers also fed to the west. Several thousands of least and crested auklets, accompanied by some parakeet auklets, also fed southeast of Kongkok Bay. Flights returning from the southeast intercepted the coast near Southwest Cape, and flocks of birds with food-filled gular pouches paralleled the island's shoreline between Boxer Bay and Kongkok Bay.

Foraging flight patterns of auklets nesting at Owalit and Ivekan colonies changed in early August (Figure 10). After about 2-3 August, the majority of crested auklets ceased flying to and from the north and began departing to and returning from the west. This flight pattern was still evident at Gambell during 10-14 August; few outbound or inbound crested auklets passed Northwest Cape on those dates.

The majority of least auklets, accompanied by some parakeet auklets, continued to travel to and from the north until 6 August, by which time strong northeasterly winds had developed. The winds, varying between 30-80 km h^{-1} and often gusting to 80-120 km h^{-1}, prevailed between the evenings

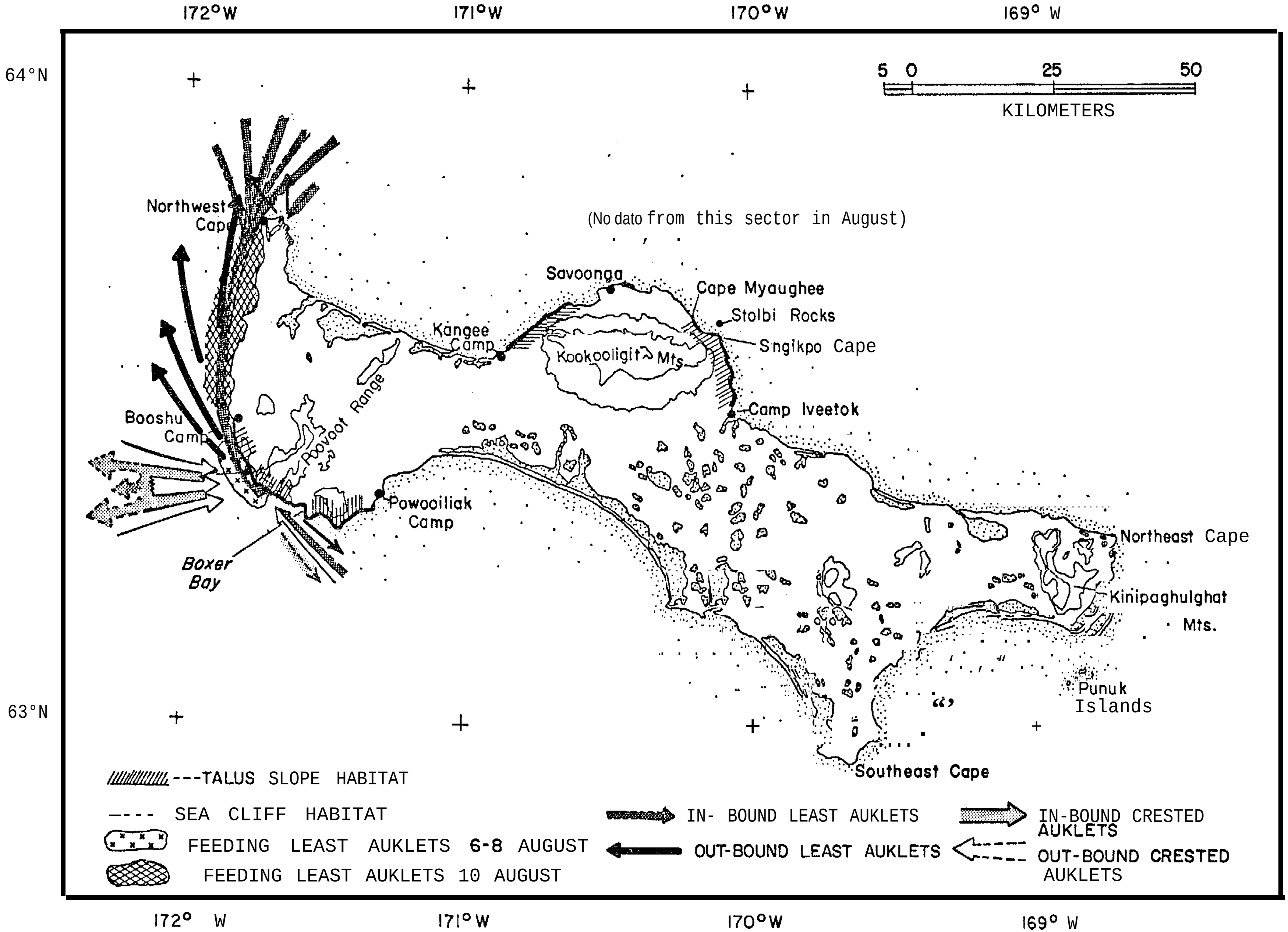

Figure 10. Flight directions followed by least and crested auklets at St. Lawrence Island, mid-August 1981.

of 5 and 8 August. During 6-8 August, large concentrations of least auklets fed in and near Kongkok Bay between the surf zone and a few kilometers offshore. Most least auklets resumed travel to and from the north with the advent of calmer conditions on 9 August, but many fed along the island's western coast in a zone of current slicks visible from the top of Owalit Mountain. On the evening of 10 August, large numbers of feeding least auklets were dispersed over a calm sea among these north-south oriented slicks about 0.5-5.0 km offshore along the entire coast between Booshu Camp and Gambell. Surface waters in and near the slicks were richly laden with pteropods, medusae, ctenophores and other small invertebrates. Although many flocks of least auklets with distended gular pouches were flying southward past Northwest Cape, numbers were smaller than during previous weeks. Large numbers of southbound least auklets, accompanied by small numbers of parakeet auklets, passed Gambell during the evening of 11 August, but the magnitude of the evening flights appeared to decrease again during 12-14 August with the advent of increasing northerly winds.

Sevuokuk Colony

The majority of auklets nesting on Sevuokuk Mountain also foraged in Anadyr Strait and its out-flow during mid-July. Small flocks of departing least and crested auklets generally dispersed northwestward and northward from the colony, and returned from northerly and northeasterly directions. As large inbound flights approached Sevuokuk Mountain, flocks returning there separated from the streams of southbound auklets. Foraging flight patterns of Sevuokuk Mountain auklets appeared little changed in mid-August. Flocks of least and crested auklets were returning to the colony from northwesterly through northeasterly directions as we boated past Sevuokuk Mountain during the evening of 12 August.

Table 17. Five-minute counts of least and crested auklets flying southwestward past Gambell, St. Lawrence Island, on 17 July 1981.[a]

Time[b]	Observer C[c]	Observer E[d]	$\bar{x}$
2130-2135	20,000	18,100	19,050
2200-2205	30,000	25,000	27,500

[a]These estimates were obtained only from the eastern margin of the movement. Many other low-flying flocks were occasionally visible at much greater distances offshore.

[b]Bering Daylight Time.

[c]Observer C estimated by 500's using 10x40 binoculars.

[d]Observer E estimated by 100's using 7x50 binoculars.

Singikpo Colony

Our observations of foraging flight patterns of auklets nesting along St. Lawrence Island's northern coast, predominantly in the Singikpo Cape area, are limited to 18-19 July. On 18 July between 1600 h and 1900 h in the Cape Myaughee vicinity, we saw numerous small flocks of least and crested auklets flying southeastward. The flocks were arriving from northwesterly directions and were headed toward Singikpo Cape, the third major auklet nesting area on St. Lawrence Island. West of Kookoolik Cape, nearer Savoonga, few auklets appeared to intercept the island's coastline. Between Kookoolik Cape *and* Kangee Camp, small flocks of eastward traveling crested auklets were occasionally encountered between 1930 h and 2300 h. We saw only a few small flocks of crested auklets between Savoonga and Sevuokuk Mountain during the morning and afternoon of 19 July, and between Kangee Camp and Sevuokuk Mountain during the evening of 12 August. The major auklet flight corridor leading toward Singikpo Cape apparently remained well offshore.

Our observations of the foraging flight patterns of auklets nesting at St. Lawrence Island's western end corroborate other observations made there by Bédard (1969b), Searing (1977) and Drury *et* al. (1981). Observations in the north-central sector of the island provide additional evidence that auklets from all three primary nesting areas on the island feed predominantly in the same area in Anadyr Strait and its out-flow during much of the breeding season (see Bédard 1969b).

The basic flight patterns followed by auklets nesting at colonies in the western sector of the island were typical of annual patterns that have occurred regularly for many years (L. Iyakitan pers. comm.). The change in auklet foraging patterns observed after early August may also be a fairly regular event.

VIII. CONCLUSIONS

1. Numbers of murres have declined at Cape Thompson in the eastern Chukchi Sea, and a similar decline is continuing at Bluff in Norton Sound. We are currently investigating two possible reasons for these decreases, which involve effects of a changing environment on (a) natality of murres and (b) winter mortality of murres.

2. Numbers of murres have not appeared to change at Cape Lisburne or Cape Lewis as they have at Cape Thompson and Bluff. This difference could be explained by the movement of birds, particularly prospecting subadults, between colonies during a regional decline. Local differences in food availability could lead to intercolony movements by murres.

3. At Owalit Colony on St. Lawrence Island, numbers of murres were markedly lower in 1976 than in 1972 or 1981. Similarity in numbers of murres between 1972 and 1981, both climatically mild years, and the cold environmental conditions that coincided with the 1976 breeding season suggest that the 1976 decrease was a short-lived event rather than an actual decline in the population as has occurred at Cape Thompson and Bluff.

4. Environmental fluctuations during the 1970's had important repercussions on the breeding biology of murres, black-legged kittiwakes and least auklets in northern Alaska by affecting supporting food webs. Year-to-year differences in breeding phenology and reproductive success were strongly correlated with changing climatic conditions. Differences in breeding phenology and reproductive success between colonies in the same year were probably related to local differences in regional climates. Variations in food availability between locations in a given year are also probably related to local regional climatic conditions.

5. The current data base on relationships between seabird population parameters, physical conditions and food webs indicates the value of long-term, low-level monitoring efforts. The results of these integrated studies can provide the means to separate natural changes from changes that may occur as a result of resource development. The degree to which such changes can be separated will clearly measure the success of future programs that may attempt to detect and monitor effects of resource exploration and extraction.

IX. NEEDS FOR FURTHER STUDY

The data base on northern Bering-eastern Chukchi seabirds justifies the continuation of studies to monitor numbers, reproductive success and food habits of murres, black-legged kittiwakes and auklets in northern Alaska. These studies can effectively explore relationships between annual variability in population parameters of seabirds, physical environmental changes and changes in seabird food webs. Earlier OCSEAP-sponsored studies of seabirds in Alaska indicated that marked annual variability occurred in several population parameters. The current longer-term data clearly show that annual variability in seabird populations is not random, but is related to and predictable from annual changes in the physical environment and regional food webs (see also Springer *et* al. 1982). Moderate levels of additionalresearch in the coming years would provide a firm basis with which to more clearly differentiate between natural phenomena and changes resulting from resource development. Such an ability to separate natural phenomena from other changes is important to any monitoring effort.

Our studies have made progress toward identifying the causes of declines in murre numbers *at* Cape Thompson and Bluff. Additional research is necessary to refine and test our hypothesis (see Springer *et* al. 1982). We especially recommend an effort that will allow us to expand and test our population model at Bluff. Also, we have not ruled out the possibility that similar declines are occurring *at* other murre colonies in northern Alaska. Colonies that have been censused at least once in previous years, such as St. Matthew Island and the Pribilof Islands, should be checked again soon.

A program of studies to fulfill the above needs does not have to be especially costly; however, it needs to be well organized and designed to run for several years. Study sites would be selected on the basis of location and past history of investigation. They should range from northern latitudes (i.e. , the Chukchi Sea) to southern latitudes (i.e. , the southern Bering Sea and Gulf of Alaska), and should include offshore and coastal locations. Within this framework, colonies at Cape Lisburne, Cape Thompson and Bluff would serve as 'home-base' study sites because of the long histories of study at them, their northern latitudes and their location relative to regional climatic and oceanographic conditions. Bluff has a much warmer climate than Cape Lisburne and Cape Thompson, and it lies in Norton Sound well removed from the more dynamic oceanographic conditions of Bering Strait. Cooler conditions prevail in the eastern Chukchi Sea, and Cape Lisburne in particular lies on the edge of major currents flowing through that region. Colonies such as St. Lawrence Island, St. Matthew Island and the Pribilof Islands would serve as offshore study sites, and colonies in northern Bristol Bay would serve as southern coastal locations.

Within this large region it would be preferable to visit three or four study sites each year for several years; however, home-base study sites at Bluff and either Cape Thompson or Cape Lisburne would. be visited every study year. Only one field team is required to accomplish the work at home-base sites because logistics are relatively simple and costs are minimal compared to many of the other colonies. One or two field teams would also work at one or two other colonies each year. These teams would alternate annually among the suite of selected study locations. Such a study design could:

1. Help clarify relationships between physical conditions, several seabird population parameters and food webs.

2. Establish a repeatable numeric monitoring system.

3. Monitor changes in seabird populations that might occur as a result of resource development.

There is a special need to resume work at St. Matthew Island as soon as possible because of strong industry interest to use part of the island as a staging area and support base for offshore exploration and development in the Navarin Basin. Development of support facilities, including a landing field for large transport aircraft, helicopter pads and fuel depots, has been proposed to begin as early as 1982. Although industry use of the island, currently designated a wilderness area, is being contested by the U.S. Fish and Wildlife Service (E. Baily pers. comm.), development may proceed in the near future. Murres have not been censused at St. Matthew Island since the first census there in 1977 (see DeGange and Sowls 1978). By the summer of FY 1982 it will have been five years since counts were made, an interval sufficiently long to allow significant changes in numbers to become apparent. A recensus of murres on St. Matthew Island would be an important precautionary measure, and would increase our understanding of declines in murres at more northern colonies. It would also increase our understanding of relationships between physical parameters, seabird food webs and seabird productivity. With little doubt, a recensus of murres would have the greatest value as an aid to understanding these changes if it were conducted before development and potential associated disturbance occurred. A recensus of murres at St. Matthew Island immediately prior to development would provide a firmer basis from which to detect effects of human actions, and to more clearly separate them from natural changes.

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APPENDIX

The estimate given by Searing (1977) of 60,000 murres at Owalit Mountain was derived from the unpublished data of S.R. Johnson, who censused this colony on 12 and 14 August 1972. Searing (1977) was not able to carefully examine Johnson's data; only raw scores for various sections of the colony were transmitted from Johnson to Searing (Johnson pers. comm.). Some details of the counting procedures were apparently omitted or unclear. Recently, we were able to examine Johnson's original field notes. Table 18 shows Johnson's 1972 censuses of Owalit Mountain. The 12 August census of the cliffs was incomplete; at least one large 'gully' and some other similar features which contained murres in plot D were not counted. A complete re-census of the cliffs was made on 14 August, when plot D was split into seven smaller areas (plots D-I, and K). Some areas counted during both censuses represented portions of adjacent air space or sea surface (area C, 12 and 14 August; areas J and L, 14 August). Searing's (1977) estimate of about 60,000 murres present in 1972 was incorrectly derived from the total of all murres counted in all habitats on both dates. The corrected estimate of approximately 32,000 murres[1] was derived from the total of all murres counted on the cliffs on 14 August 1972.

[1]The 25,000 murres reported in Johnson and West (1975) refers only to the densest part of the Owalit Mountain Colony.

Table 18. Census data for Owalit Mountain, St. Lawrence Island, 12 and 14 August 1972.[a]

	Number of Murres			
	12 August		14 August	
Plot (Area)	Flying	On Cliffs	Flying or on Water	On Cliffs
A		4,000		4,500
B		8,000		6,000
(C)	400-500[b]		480[b]	
D		9,500[c]		2,500
E				6,500
F				4,500
G				6,350
H				245
I				860
(J)			1,250[d]	
K				375
(L)			2,000[e]	
Total	400-500	21,500	3,730	31,830

[a]Data are from unpublished field notes of S.R. Johnson, 1972.

[b]This number is an estimate of birds flying to and from plots A and B at the time of census.

[c]This number is an incomplete estimate of the cliff areas D-I, and K.

[d]This number is an estimate of birds on the water between areas I and K at the time of census.

[e]This number is an estimate of birds in the air offshore of plots D-I, and K at the time of census.