MONITORING SEABIRD POPULATIONS IN AREAS OF OIL AND GAS DEVELOPMENT ON THE ALASKAN CONTINENTAL SHELF: CAPE LISBURNE AND CAPE THOMPSON SEABIRD STUDIES, 1995-1997

FINAL REPORT

(USGS Study USGS/BRD/CR-1999-0002)
(OCS Study MMS 99-0011)

by

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and G. Vernon Byrd

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DISCLAIMER

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Monitoring Seabird Populations in Areas of Oil and Gas Development on the Alaskan Continental Shelf: Cape Lisburne and Cape Thompson Seabird Studies, 1995-1997

Final Report

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Abstract: Black-legged kittiwakes *(Rissa tridactyla)* and common and thick-billed murres *(Uria aalge and U. lomvia)* were first studied at Cape Lisburne and Cape Thompson in the eastern Chukchi Sea in 1959-1961 and 1976, respectively. Cape Lisburne was last visited in 1993, and Cape Thompson in 1991. We collected data on murres and kittiwakes at both locations in 1995, and conducted additional work at the Cape Lisburne colony in 1996-1997.

Cape Lisburne — At Cape Lisburne, we found evidence that kittiwake and murre populations had increased since the mid-1970's, and that murre numbers had doubled since the mid-1980's. Kittiwake nesting schedules only varied by about 5 days in 1987, 1992-1993, 1995, and 1997, but less precise information suggested nesting occurred several days later in the late 1970's. Although kittiwakes failed to lay eggs at Cape Lisburne in 1996, productivity averaged about 0.45 chicks per nest start in 1995 and 1997. Kittiwakes also experienced near-complete breeding failures at Cape Lisburne in 1976 and 1984, and they only produced about 0.3 eggs or chicks per nest or less in 1985 and 1992. However, this relatively high incidence of poor reproductive performance in 5 (31%) of the 16 study years was apparently not sufficient to prevent the population from increasing over the 1977-1997 interval. Breeding failures and annual differences in timing of nesting events and productivity were probably related to annual variations in ice cover, ice breakup, weather events, and prey availability. Data from the late 1970's and early 1980's suggested that 1995 and 1997 kittiwake chick growth rates were about average, and the fact that these rates did not differ suggested that prey availability was similar during these years. Murres nested about 5 days later in 1996, compared to 1995 and 1997, and productivity was high in 1995 (0.85-0.88 fledglings per egg) suggesting that environmental conditions and food supplies were near-optimal for these diving birds. Significantly fewer murre chicks were produced in 1996-1997 (0.53-0.68 fledglings per egg); however, in both years, productivity was still higher than average 1976-1997 Pribilof Islands values (0.51-0.54 fledglings per egg). Prey taken by murres and kittiwakes varied over the years, and these annual differences are still poorly understood; however, they are probably due in part to annual variations in environmental conditions, including extent and breakup of ice cover, water temperatures and salinities, and development of Alaska Coastal Water.

Cape Thompson — At Cape Thompson, evidence suggested that kittiwakes increased during 1976-1990; however, evidence for the increase was not convincing because the positive trend was driven solely by the 1990 data and the 1995 count was made in a year of near-complete reproductive failure. Some evidence also suggested that murres declined at Cape Thompson during 1976-1988; however, 1990 and 1995 data suggested that numbers rebounded to near mid- and late 1970's levels by 1995. Kittiwakes nested on about the same schedule most years, but 1976-1977 first hatching dates were up to 2 weeks later than in 1995. In 1976 and 1995, kittiwakes experienced reproductive failures at Cape Thompson and productivity was less than 0.01 fledglings per nest. As at Cape Lisburne, breeding failures and annual differences in timing of nesting events were probably related to annual variations in ice cover, ice breakup, weather events, and prey availability. In 1995, murres nested about 1 week later than the Cape Lisburne birds, but productivity was high and nearly identical to the 1995 Cape Lisburne values (0.88-0.91 fledglings per egg *vs* 0.85-0.88 fledglings per egg). Also as at Cape Lisburne, prey taken by murres and kittiwakes varied over the years and these differences probably resulted from annual variations in environmental conditions.

Although the 1995-1997 results have been summarized in this report, and some of them have been pooled and compared with information from earlier studies (e.g., population counts), we are still in the time consuming process of achieving our ultimate in-house goal of locating, compiling, and verifying all pre-1995 Cape Lisburne and Cape Thompson data, and incorporating them into master data bases. We are also still in the process of obtaining pre-1995 ice cover and water temperature information from various types of satellite imagery and weather records from U.S. Air Force archives for inclusion in the data bases. More comprehensive analyses and discussions will be included in future reports after missing information becomes available and data sets have been finalized.

Key Words: Black-legged kittiwake, Cape Lisburne, Cape Thompson, common murre, population monitoring, *Rissa tridactyla*, thick-billed murre, *Uria aalge*, *Uria lomvia*.

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INTRODUCTION

The eastern Chukchi Sea supports 2 large seabird colonies at Cape Thompson and Cape Lisburne. These breeding concentrations are dominated by common and thick-billed murres *(Uria aalge* and *U. lomvia)* and black-legged kittiwakes *(Rissa tridactyla)*, 3 species that can help identify changes in marine environments. Because several potentially disruptive activities, including harbor and causeway construction and extraction of on- and off-shore natural resources (e.g., oil, gas, gravel, rock, coal, other minerals), were proposed in the region during the late 1950's – early 1990's, long-term records have accrued on nesting populations of these species at these important northwestern Alaska breeding colonies.

Seabirds were first studied in the eastern Chukchi Sea in 1959-1961, as part of a regional environmental assessment for Project Chariot, a U.S. Atomic Energy Commission (AEC) proposal to use nuclear energy to create a harbor in the lower Ogoturuk Creek valley, just south of the Cape Thompson breeding complex (Swartz 1966, 1967). Additional studies that included the Cape Thompson and Cape Lisburne nesting colonies were conducted under the National Oceanic and Atmospheric Administration Outer Continental Shelf Environmental Assessment Program (NOAA-OCSEAP) during 1976-1983 (Springer and Roseneau 1977, 1978; Springer *et al.* 1979, 1984; Murphy *et al.* 1980; Roseneau *et al.* 1985; Springer *et al.* 1985a, 1985b, 1985c, 1985d). Subsequent to these research projects, the Alaska Maritime National Wildlife Refuge (AMNWR) funded smaller scale monitoring efforts at Cape Lisburne in 1984-1986 under its seabird monitoring program (Byrd 1986a). During 1987-1993, the Minerals Management Service (MMS) periodically supported additional studies at these eastern Chukchi colonies to update information on seabirds and assess effects of proposed off-shore oil and gas exploration and development in the region (Fadely *et al.* 1989, Springer and Roseneau 1989, Roseneau *et al.* 1992, Sharp 1993, Denlinger *et al.* 1994, Nishimoto and Mendenhall 1994).

In 1995, we began a new round of Cape Lisburne and Cape Thompson seabird colony studies funded by the U.S. Geological Survey - Biological Resources Division (USGS-BRD). These full-season investigations, conducted at Cape Lisburne in 1995-1997 and Cape Thompson in 1995, were designed to collect new information on murre and kittiwake numbers, productivity, nesting chronology, and diets that could be used in conjunction with historical data to monitor long-term population trends, and help identify and measure impacts from off-shore and coastal resource development on the eastern Chukchi seabirds and their marine ecosystems.

The 1995-1997 results have summarized in this report, and some of them have been pooled and compared with information from earlier studies (e.g., population counts). However, we are still in the time consuming process of achieving our ultimate in-house goal of locating, compiling, and verifying all pre-1995 Cape Lisburne and Cape Thompson data, and incorporating them into master data bases. We are also still in the process of obtaining pre-1995 ice cover and water temperature information from various types of satellite imagery and weather records from U.S. Air Force (USAF) archives for inclusion in the data bases. More comprehensive analyses and discussions will be included in future reports after missing information becomes available and data sets have been finalized.

STUDY AREAS

Cape Lisburne

The Cape Lisburne seabird colony is located at about 68° 52' N, 166° 05' W, 62 km northeast of Point Hope (Fig. 1). Local physical and climatic conditions have been described in previous reports (e.g., Springer *et al.* 1977, 1978, 1979, 1985b; Roseneau *et al.* 1992; Denlinger *et al.* 1994).

Nesting habitat consists of about 7 km of precipitous, near-continuous 15-200 m-high sedimentary limestone and shale sea-cliffs that begin about 1 km south of Kay Creek and end 1.6 km west of the Cape Lisburne USAF Long Range Radar Site (LRRS) runway (Fig. 2; the USAF LRRS, established in the late 1950's, is still active). The most recent estimates, based on early 1992 data, suggest that the Cape Lisburne breeding population contained about 290,000-300,000 birds, including 260,000 murres (about 70-75% thick-bills and 25-30% commons), 20,000-30,000 black-legged kittiwakes, and a few thousand pelagic cormorants *(Phalacrocorax penicillatus)*, glaucous gulls *(Larus hyperboreus)*, black guillemots *(Cepphus grylle)*, parakeet auklets *(Cyclorrhynchus psittacula)*, and horned and tufted puffins *(Fratercula corniculata* and *F. cirrhata)* (Denlinger *et al.* 1994; D.G. Roseneau, unpubl. data). Subsistence hunters from Point Hope traditionally gather murre eggs at several places in the western and northern sectors of the colony during late June - early July (e.g., D.G. Roseneau, A.M. Springer, and A.L. Sowls, unpubl. data).

Cape Thompson

The Cape Thompson study area is situated at about 68° 08' N, 166° 21' W, 45 km southeast of Point Hope (Fig. 1). Local physical and climatic conditions have been described in previous reports and publications (e.g., Swartz 1966; Springer and Roseneau 1977, 1978; Springer *et al.* 1979; Murphy *et al.* 1980; Fadely *et al.* 1989). Five large, separate headlands provide nesting habitat for cliff- and crevice-nesting seabirds breeding at the Thompson complex (Colonies 1-5, Fig. 3). The precipitous sedimentary limestone and shale cliffs range from about 9 to 200 m high. Colonies 2 and 5 contain most of the habitat and support about 80% of the birds. In 1960, an estimated 421,000 birds, including 393,000 murres (about 60% thick-bills and 40% commons), 26,000 black-legged kittiwakes, and 2,300 pelagic cormorants, glaucous gulls, black guillemots, pigeon guillemots *(C. columba)*, and horned and tufted puffins, nested on these 5 eastern Chukchi Sea headlands (Swartz 1966). More recent information obtained in the mid-1970's - early 1980's indicated that populations of most species were similar to 1960 levels; however, murres (about 70-75% thick-bills and 25-30% commons) had apparently declined by about 50% (e.g., Springer and Roseneau 1977, 1978; Springer *et al.* 1979; Murphy *et al.* 1980; Springer *et al.* 1985c; Fadely 1989). Subsistence hunters from Kivalina and Point Hope traditionally harvest murre eggs at several places in colonies 2-5 during late June - early July (e.g., Swartz 1966; L.G. Swartz, unpubl. field notes; Springer and Roseneau 1977; D.G. Roseneau and A.M. Springer, unpubl. data).

The Eastern Chukchi Sea Environment

The Chukchi Sea is a shallow body of water overlying the broad continental shelf between northwestern Alaska and northeastern Siberia. Average depth is only about 50 m (Naidu and Gardner 1988, Weingartner and Proshutinsky 1998), and tides along the eastern side average less than 30 cm (Johnson 1988). Sea ice consisting of annually forming 1-3 m-thick first-year ice and thicker (up to 6 m), less saline multiyear ice that advances southward during winter covers most of the surface for about 8 months each year (Springer and Roseneau 1977, Lewbel 1984, Johnson 1988). Freeze-up usually begins in October, is well underway by early November, and open water becomes severely restricted by January-February. However, a combination of northward flowing currents and strong surface winds keeps a large dynamic lead system open between Bering Strait and the Point Barrow area all winter (Barry *et al.* 1977, Springer and Roseneau 1977, Roseneau and Herter 1984). This lead system, sometimes called the Chukchi Polynya, serves as an important spring migration route for large numbers of marine birds and mammals (Woodby and Divoky 1982, Stringer 1982, Lewbel 1984, Roseneau and Herter 1984). Relatively large polynyas also persist just south and west of Cape Lisburne and opposite Cape Thompson (Barry *et al.* 1977, Springer and Roseneau 1977). In most years, ice cover begins breaking up about mid-June and the region south of Point Lay becomes ice-free by mid-July; however, the dissipation and dissolution of the ice are dependent on currents, winds, and air temperatures, and can vary by as much as 6 weeks. In some years, extensive bands and patches of broken, melting shorefast ice persist along the Thompson and

Lisburne coasts well into late July, but in other years, waters south of Point Lay may be completely free of ice by mid-June (Springer and Roseneau 1977, 1978; Springer *et al.* 1979, 1984).

Timing of breakup and the dissipation and dissolution of the ice cover are important factors affecting prey availability for seabirds breeding at the Lisburne and Thompson colonies, particularly surface feeding kittiwakes. During spring, large dense schools of Arctic cod *(Boreogadus saida)* feed on zooplankton and invertebrates at the water-ice interface. When breakup occurs, these fish become accessible to kittiwakes and other seabirds foraging over the clear open leads and pools between the shifting pans and floes. In cool years, when large amounts of broken ice persist into late July, this abundant prey resource remains readily available to kittiwakes well into the early chick-rearing period. Conversely, in warm years when ice cover is gone by mid-June, kittiwakes lose access to this important energy source at about the same time they normally begin to lay eggs, because the cod rapidly leave the warming surface layers for cooler environments well below the plunging depths of the birds. Arctic cod are also less accessible to surface-feeding kittiwakes in years when shorefast ice persists in large, extensive, unbroken sheets that finally break loose from the land enmasse and are then quickly transported beyond the foraging range of the birds by northward flowing currents and strong easterly and southerly winds. In these years, foraging areas are first severely limited by the lingering near-solid ice cover, and then the cod move to deeper, inaccessible depths soon after the ice-sheets move offshore.

In addition to being ice-covered for most of the year, the Chukchi Sea is strongly influenced by Pacific Ocean waters (Springer *et al.* 1984, Weingartner and Proshutinsky 1998). Strong barotropic currents originating in the northern Bering Sea flow northward through Bering Strait year-around (Coachman *et al.* 1975, Coachman and Aagaard 1981, Weingartner *et al.* 1998). These currents reach velocities of up to 150 $cm{\cdot}s^{-1}$ and transport averages about 1×10^6 to $2 \times 10^6 \, m^3{\cdot}s^{-1}$. During summer, waters flowing into the Chukchi Sea through Bering Strait are composed of 3 distinct water masses: Bering Shelf Water; colder more saline Anadyr Water from the deep Anadyr basin; and warmer less saline Alaska Coastal Water, a combination of Bering Sea parent water diluted by melting sea ice and fresh water input primarily from the Yukon River drainage that develops annually over the shallow northeastern Bering Sea shelf during late spring - early summer. As Alaska Coastal Water forms, it is rapidly heated by insolation (Coachman *et al.* 1975), and as it flows northward through Bering Strait, temperatures along the eastern side of the strait increase by up to 10° C shortly after ice dissipation (Bloom 1964, Ingraham 1981).

North of Bering Strait, cold, nutrient-rich high-salinity Anadyr and Bering Shelf waters mix and flow northwestward and northward through the Hope and Herald valleys into the western Chukchi basin, and some Bering Shelf Water, mixed with warm lower salinity nutrient-poor Alaska Coastal Water, also flows northward through a depression toward the Herald Shoal vicinity. However, most of the warm Alaska Coastal Water is transported eastward toward Cape Thompson and Point Hope, and then northward and eastward along the eastern Chukchi Sea coast by the relatively swift Alaska Coastal Current.

Alaska Coastal Water begins to reach the Cape Thompson and Cape Lisburne vicinities by about mid-July, and it can be found as far north as Icy Cape by late July or early August (Fleming and Heggarty 1966, Hufford 1973, Coachman *et al.* 1975, Springer *et al.* 1984; annual development and northward transport of this water mass can be easily tracked using infrared and false-color satellite imagery). In relatively light ice-years, this warm, low-salinity plume of water often rounds Point Barrow and enters the Beaufort Sea by late August, but during years when thick multiyear ice persists south of Barrow and Wainwright well into August , it tends to dissipate in the Icy Cape - Wainwright region.

Although Alaska Coastal Water is inherently nutrient-poor, its seasonal development and arrival along the eastern shores of the Chukchi Sea strongly influence the diversity and richness of food

webs that the Cape Thompson and Cape Lisburne seabird colonies rely on (Springer *et al.* 1984). During spring and early summer, the eastern Chukchi is dominated by an Arctic benthic and demersal food web consisting primarily of Arctic cod, sculpin (primarily *Myoxocephalus* spp.), and flatfish (primarily Pleuronectidae). However, by about mid-summer, a rich boreal pelagic food web supporting Pacific sand lance *(Ammodytes hexapterus)* and capelin *(Mallotus villosus)* begins to develop as the warm northward flowing plumes of Alaska Coastal Water carry a variety of zooplankton endemic to the Bering Sea into the region, particularly large numbers of copepods (primarily *Eucalanus*, *Calanus*, and *Acartia* spp.) and euphausiids (primarily *Thysanoessa* spp.).

As Alaska Coastal Water begins to transport rich developing zooplankton stocks past the Thompson and Lisburne vicinities in mid-summer, physical changes are dramatic. Nearshore water temperatures often increase by as much as 10° C and salinity declines by several parts per thousand within only a few days time. This combination of rapidly warming nearshore environments and abundant zooplankton stocks appears to strongly influence the availability of sand lance, one of the primary forage fish that murres, kittiwakes, and other fish-eating seabirds depend on during the nesting season.

In most years, large dense schools of 0+ to 1+ age class sand lance begin to appear in the Lisburne and Thompson nearshore surface waters at about the same time kittiwake eggs begin to hatch at the colonies in mid-July. However, if seasonal development of Alaska Coastal Water is poor and nearshore environments remain cold, strong inshore and along-shore runs of these fish either fail to materialize or are delayed, and surface-feeding kittiwakes have difficult times provisioning and fledging chicks. Conversely, in years when Alaska Coastal Water development is strong and nearshore temperatures rise sufficiently, sand lance are usually abundant in surface waters during mid-July - mid-August and kittiwake productivity improves markedly. Some evidence suggests that nearshore environments can also become too warm to support strong coastal runs of sand lance near the eastern Chukchi Sea seabird colonies. In 1984, when sea-surface temperatures were at record highs, sand lance were scarce at Cape Lisburne and kittiwakes failed reproductively (D.G. Roseneau, A.M. Springer, and G.V. Byrd, unpubl. data).

METHODS

We conducted field work at Cape Lisburne during 24 June – 3 September 1995, 25 June – 1 September 1996, and 23 June – 4 September 1997, and at Cape Thompson during 2 July – 20 August 1995. Data were collected by teams of 2-3 experienced observers based at the USAF LRRS facility (Cape Lisburne, Fig. 2) and a temporary field camp located near the mouth of Ikijaktusak Creek (Cape Thompson, Fig. 3 and Fadely *et al.* 1989). Methods for monitoring populations and productivity were based on standard AMNWR protocols for ledge-nesting species and were comparable to those used during earlier studies (see AMNWR 2000).

Population Counts

Murres and kittiwakes were counted on previously established sets of boat- and land-based monitoring plots used to assess changes in population numbers at the nesting colonies. Cape Lisburne data were collected from 14 large plots first counted from boats in 1976 (CP 11, 12, 25, 26, 30, 32, 65, 66, 70, 72, and 73-76; see Springer and Roseneau 1977, Roseneau *et al.* 1992) and 2 smaller land-based plot sets created in 1987 and 1992, respectively (LP 1-8 and LP 9-14; see Roseneau *et al.* 1992, Denlinger *et al.* 1994). Cape Thompson data were obtained from 18 boat-based Colony 4 plots (C4 Plots 4A-4R, which include the entire colony) and 6 Colony 5 land-based plots first counted in 1960 (LGS Plots 5G, 5L, 5M, 5N, 5P, and 5Q; see Swartz 1966, L.G. Swartz, unpubl. data), and 14 plots set up at Colonies 3-5 in 1988 (BSF Plots 3-1A, 3-2B, 3-2C, 4-1A, 4-1B, 4-2C, 4-3D, 4-4E, 5-1A, 5-1B, 5-1C, 5-2F, 5-2G, and 5-7L; see Fadely *et al.* 1989).

Boat-based counts (Lisburne CP plots, Thompson plots 4A-4R) were made on calm days from drifting inflatable rafts with the aid of 7 x 42 binoculars and hand-held tally meters. Distances between observers and birds varied from about 50 to 200 m. Although distances varied depending on the height and configuration of the cliff-faces, they were kept as consistent as possible among counts, including those made during earlier studies. Kittiwakes and their nests were counted by 1's by single observers. In almost every case, murres were estimated by 10's by 2 people counting plots simultaneously. The only exceptions to this procedure occurred on a few sections of Lisburne plots CP 30 and 32, where densely packed birds were estimated by 50's and occasionally by 100's. During the counts, 1 census team member recorded plot scores without revealing his or her own counts to the other observer and compared them to see if they were within 10% of each other (i.e., within 5% of their average). If they were not, plots were recounted until scores fell within this range (initial counts rarely failed to meet the percentage rule; however, most plots were counted 2-3 times regardless of first counts meeting the criterion—several similar scores lent confidence to the data).

Land-based counts (Lisburne plots LP 1-14, Thompson LGS and BSF plots) were made by 1 or 2 people from previously established beach or cliff-top observation posts with the aid of 7 x 42 binoculars and hand-held tally meters (see Fadely *et al.* 1989 for examples of observation sites). Distances between birds and observers varied from about 20 to 100 m and were kept as consistent as possible among counts, including those made during previous studies. Kittiwakes and their nests were counted by 1's, and murres were counted by 1's (Lisburne plots LP 1-14, Thompson BSF plots), and 1's and 10's (Thompson LGS plots). When only 1 observer collected data, 1-2 additional counts were often made to check accuracy.

All counts were made during the part of the nesting season when murre and kittiwake attendance are the most stable. Murre and kittiwake census periods were defined as the intervals between peak laying and first sea-going of chicks (e.g., see Hatch and Hatch 1989, Byrd 1989), and peak laying and first fledging of chicks, respectively. Times of day for counting birds were based on information from earlier studies; all data were collected during 1200-2100 hrs Alaska Daylight Time (ADT). Plot boundaries were located using photographs in AMNWR files (e.g., see Fadely *et al.* 1989 and Roseneau *et al.* 1992 for examples of plot photographs).

Data were analyzed by first calculating average daily scores for each plot in the respective monitoring plot sets by averaging individual observer counts, and then averaging observers' scores, if more than 1 person counted plots. Results were summed to obtain respective 1-day totals for the plot sets, and the averages of these daily totals were used as the annual plot-set values, if plot sets were counted more than once per year. Final plot-set scores were pooled with corresponding data from earlier studies, and linear regressions were run to test for trends at the 0.1 significance level (0.1 was used to increase the power of the tests and reduce Type II error; the 0.9 confidence interval was adequate for our purposes). Average annual increases/decreases were based on the slopes of the regression lines and percentages derived from this information were rounded to the nearest half percent (e.g., slope = +64.9 birds per year or about +4.5% per year).

Nesting Chronology

Kittiwakes: Information on kittiwake nesting chronology was obtained from the same data sets used to measure productivity (see Productivity below). To compare Cape Lisburne data with information from earlier studies, we located, reviewed, and reanalyzed the 1987, 1992, and 1993 data sets, and calculated total numbers, percentages, and cumulative percentages of eggs hatched during 4- to 10-day intervals (dates when data were collected determined interval lengths). We also compiled first hatching dates, estimated peak hatching dates from the 66% hatch interval, and calculated median hatching dates from chick hatching ranges. To compare data from Cape Thompson with information from previous years, we reviewed reports and publications to determine what types of data were available. Based on the review, we compiled first and median hatching dates, and whenever

possible, identified intervals during which about 66% of the eggs had hatched. Peak hatching dates were estimated by subtracting 2-3 days from the last dates in these intervals.

Murres: Murre nesting chronology information was derived from the same sets of data used to measure productivity (see Productivity below). For common and thick-billed murres at Cape Thompson, and thick-billed murres at Cape Lisburne, we treated productivity plots as sample units, calculated median hatching dates for each plot, and then averaged the respective plot set dates to obtain final values for comparing timing of breeding among years. For Cape Lisburne common murres, nest sites were treated as sample units instead of plots, and mean hatching dates were used as annual indices, because all of the plots combined only contained 22-25 sites that could be used to calculate this variable (i.e., several plots only had 2-3 nest sites each, too few to treat plots as sample units).

To calculate hatching dates, we assumed chicks that were at least 15 days old before disappearing from nest sites survived and went to sea. Dates nest sites changed status from eggs to chicks (the hatching dates) were defined as the midpoints between the nearest pre- and post-event observation dates. Nest sites with data gaps of more than 7 days between observation dates or without sufficient information to satisfy the 15-day age criteria were excluded from the analyses. Also, if laying dates were known and the range of possible laying dates was smaller than the range of possible hatching dates, hatching dates were estimated by adding 32 days to laying dates (e.g., see Byrd 1986b, Roseneau *et al.* 1995).

We also calculated chick sea-going dates and ages at Cape Lisburne (the Cape Thompson field season was too short to obtain data on these variables). To compute sea-going dates, we assumed chicks that were at least 15 days old before they disappeared from nest sites, or that were 14 days old on last observation dates, survived and went to sea. Age calculations were restricted to sites with 15 day-old or older chicks. Sea-going dates were defined as the midpoints between the last day chicks were present and the first day they were absent, and sea-going ages were defined as the differences between chick hatching and sea-going dates.

Productivity

Kittiwakes: At Cape Lisburne, kittiwake productivity data were collected by checking 217 nests 9-10 times 7 July – 25 August 1995, 195 nests 3 times during 11 July – 11 August 1996, and 190 nests 8 times during 4 July - 28 August 1997 (only 3 checks were made in 1996 because birds failed to lay eggs). Nests were mapped and numbered in notebooks, and contents checked by having 1 person hold a moon-style, chromed metal hub cap attached to an extendible fiberglass pole above the nests while a second person looked at the hub cap surface with binoculars or the naked eye for reflected images of eggs and chicks (hub caps are superior to glass mirrors because they are unbreakable and the curved surfaces provide wider fields of view). We also checked 479 kittiwake nests at Cape Thompson 9-10 times during 11 July - 19 August 1995. Nests were mapped and numbered on photographs, and contents checked via binoculars from nearby vantage points.

Data were analyzed by totaling numbers of nests (A), nests with 1 or more eggs (B), eggs (C), nests with 1 or more chicks (D), chicks (E), nests with 1 or more chicks fledged (F), and chicks fledged (G) for each plot and all plots combined, and then calculating laying success (B/A), clutch size (C/B), nesting success (D/B), hatching success (E/C), chick success (G/E), egg success (G/C), fledging success (F/D), reproductive success (F/B), fledglings per nest start (G/A), and overall productivity (F/A) for each plot and all plots combined. To compare Lisburne data with information from earlier studies, we also calculated eggs or chicks per nest attempt (nest start) and successful nest (nests containing at least 1 egg), and estimated production per nest and per successful nest (maximum estimates based on the presence of live, healthy-appearing chicks) for visit dates nearest to 8 August, the last date data were obtained during several pre-1995 studies (dates used for the

1995-1997 calculations were 9, 11, and 8 August, respectively). Spearman's Rank Correlation tests were used to check for correlations between variables.

Murres: Murre productivity data were collected from a series of plots set up for this purpose. At Cape Lisburne, information on common and thick-billed murres was obtained from 5-7 and 10-13 plots, respectively. Thick-billed murre plots contained 9-37 nest sites each (total sites = 294 in 1995, 247 in 199, and 264 in 1997), and common murre plots supported 1-24 nest sites each (total sites = 44 in 1995, 33 in 1996, and 35 in 1997). Cape Thompson data were collected from 9 common murre and 14 thick-billed murre plots containing 3-57 and 16-72 nest sites each (total common and thick-billed sites = 294 and 639 in 1995, respectively).

The productivity plots were checked with 7 x 42 binoculars and 15-60 power spotting scopes from land-based observation posts as often as possible, weather permitting (usually every 2-4 days at Cape Lisburne and 3-5 days at Cape Thompson). Viewing distances varied from about 25 to 100 m, and observers were assigned to specific plots for the duration of the field season. Nest sites, defined as sites with eggs, were mapped in field notebooks or on photographs, and data were recorded using previously established codes. Plot checks included searching for eggs, chicks, and adults in incubation and brooding postures, and counting adults. Observations began shortly before egg-laying stopped and ended at about the time chicks started leaving the cliffs to go to sea (Cape Thompson), or after sea-going was almost complete (Cape Lisburne).

Postures of incubating and brooding adults were used to supplement direct observations of eggs and chicks (e.g., see Byrd 1989; Roseneau *et al.* 1995, 1996). Incubating birds sit forward with backs humped, tails held down, and wings slightly lowered with uncrossed wing-tips. Brooding individuals extend 1 wing and lower it to mantle (shelter) chicks after nestlings are about 1-3 days old. Birds observed in incubation postures on 3 consecutive occasions were assumed to have eggs, and individuals seen wing-mantling once were assumed to be brooding chicks.

During the analyses, we assumed that chicks reaching an age of at least 15 days old before they disappeared from nest sites survived and went to sea (see Hunt *et al.* 1981; Byrd 1986b, 1989; Roseneau *et al.* 1995), unless we had specific information indicating they died before leaving nesting ledges (e.g., from storms, avian predators, falling rocks). Chick ages were derived from hatching date calculations and direct observations of chicks. Nest sites where chick ages were uncertain were excluded from the analyses. Plots were treated as sample units, and the average fledglings per egg value was used as the primary variable for comparing productivity among years. Differences among years were checked with Pearson Chi-square tests.

Chick Growth Rates and Sea-going Weights

Kittiwakes: Information on growth rates of kittiwake chicks was not obtained at Cape Thompson because most pairs failed to produce nestlings and nest sites belonging to successful pairs were not accessible in 1995. However, we were able to collect these data at Cape Lisburne in 1995 and 1997 (no nestlings were produced there in 1996). Nests containing chicks that could be reached from a 24-foot-long aluminum ladder were mapped and numbered, and nestlings assigned identifying codes. Chicks were placed in small nylon bags and weighed (nearest whole g) 3-6 times during late July - late August at 3-10 day intervals. Data were analyzed by calculating average daily weight gains using information from the linear section of the growth curve (hatching to 350 g) and simple linear regressions (slope of regression = g/day), and then averaging the chick values to obtain final indices for comparing growth rates among years.

Murres: Information on murre chick growth rates were not obtained at the Lisburne and Thompson colonies because disturbing birds to weigh and measure nestlings would have caused egg loss and high levels of chick mortality. However, we were able to collect data on sea-going weights of common and thick-billed nestlings at Cape Lisburne each year. Chicks were captured and weighed

(nearest whole g) when they jumped from nesting ledges and ran across First and Kittiwake beaches to reach the sea. Nestlings were released at the edge of the water immediately after processing to minimize stress and predation by glaucous gulls and Arctic foxes *(Alopex lagopus)*. Weights were also obtained from several fresh, still-warm, intact chicks killed and cached by Arctic foxes in 1996, and from nestlings that died at sea and washed ashore shortly after leaving nesting ledges in 1995 and 1997 (most deaths resulted from internal injuries, including badly bruised and ruptured livers, that occurred when jumping chicks struck rocks below nesting ledges). Average chick weights were used as indices for comparing sea-going weights among years. Differences among years were checked with ANOVA and LSD Multiple Comparisons tests.

Food Habits

To obtain food habits information, we collected murres and kittiwakes with 12 gauge shotguns at Cape Lisburne during 11 July - 22 August 1995, 5-11 July 1996, and 30 June - 4 July 1997 (poor weather prevented collecting birds after mid-July in 1996-1997) for stomach content analysis. Most birds were shot about 0.8 - 1.6 km offshore of the USAF LRRS facility and the Igrarok Hills as they returned from feeding areas in Ledyard Bay east and northeast of the colony. The remainder were obtained as they foraged within about 3.2 km of the coast between the Igrarok Hills and the LRRS runway. Stomachs from adults and nestlings killed by falling rocks and murre chicks that died at sea and washed ashore or were killed and cached by Arctic foxes were also salvaged for analysis.

We also collected murres and kittiwakes at Cape Thompson during 6 July - 20 August 1995 to obtain dietary data. These birds were shot within about 1.0 km of the coast as they returned to Colonies 2-4 from offshore feeding areas.

Most of the stomachs were removed from the birds and preserved in 70% ethanol for later analysis; some birds were also frozen whole at the USAF LRRS facility. Stomach contents were analyzed by A.M. Springer, FALCO, Fairbanks. Prey items were identified with the aid of preserved reference material and taxonomic keys. Fish were identified from otoliths or a combination of otoliths and preopercular bones (sculpins, Cottidae). Otoliths were also used to age fish and help calculate wet weights. Weights were estimated using standard regression equations relating otolith lengths to fish lengths and fish lengths to wet weights (e.g., see Springer *et al.* 1984, 1986). Invertebrates were identified from hard parts (e.g., jaws, uropoda, rostra, eyes); weights were estimated by using average values from whole specimens, including those obtained during previous northern Bering and eastern Chukchi sea seabird studies (e.g., Springer *et al.* 1984, 1986). Data were analyzed by calculating percentages by number and weight of identifiable items in several basic prey categories, including capelin, cod (Gadidae, primarily Arctic cod), sand lance, sculpin (Cottidae, primarily *Myoxocephalus* spp.), flatfish (Pleuronectidae, probably primarily *Liopsetta* spp.), other fish, and invertebrates. More detailed analyses will be conducted for future reports, after 1977-1986 Cape Lisburne and 1976-1982 Cape Thompson data have been located, verified, and compiled in tables and spreadsheets.

We also obtained some information on prey items delivered to murre chicks at the Cape Lisburne colony. Data were obtained opportunistically during productivity plot work and by standing below the cliffs and waiting for foraging adults to return to their nest ledges. Fish were visually identified to species or family groups (e.g. Gadidae) on the basis of body color and body and fin shapes (e.g., caudal, anal, adipose fins) with the aid of binoculars and field guides. Body color and shape were also used to identify and classify invertebrates (e.g., shrimp).

Water Temperatures

In 1995, we collected water temperature data at Cape Lisburne and Cape Thompson by lowering hand-held thermometers into surface waters (< 1 m) from inflatable rafts drifting near shore, or

submerging them in buckets of water dipped from the surf near the USAF LRRS facility and Ikijaktusak Creek camp. Similar methods were used to obtain additional information at Cape Lisburne during 1996-1997 (these methods were also used during earlier studies).

In 1997, we also anchored an Onset Optic StowAway Temp data logger about 2-3 m above the bottom in 15 m of water 1.6 km offshore of the Selin Creek mouth, just east of the Cape Lisburne USAF LRRS facility. The data logger recorded water temperatures every 12 minutes during 6 July - 21 August. Data were downloaded into a computer, and hourly means were calculated and averaged for every 24 hr block of time in the data collection period.

To compare 1995-1997 Cape Lisburne hand-held temperature data with information from the 1987, 1992, and 1993 studies, we located, reviewed, and reanalyzed these earlier data sets to identify a common block of time that could be compared among years (23-28 July). Cape Thompson hand-held temperature data were archived for later analysis, because historical data were not readily available. These data will be compiled and included in a future report.

CAPE LISBURNE: RESULTS AND DISCUSSION

Population Counts

Kittiwakes: We compiled all available information on boat-based counts of kittiwakes and kittiwake nests at Cape Lisburne (Appendix 1) and selected 10 census plots with the best long-term records for trend analysis (Table 1). When these data were pooled and tested, increases were found in both parameters over the 20-year 1977-1997 interval (Fig 4; linear regression, $P < 0.05$ in both cases).

Boat-based count data were also divided into northern and western colony components and tested separately. These analyses revealed that the significant increases in birds and nests were limited to the census plots on the western side of the colony (Fig. 5; linear regression, $P < 0.01$ in both cases).

We also tabulated all land-based counts of birds and nests on land plots LP 1-8 and tested them for trends (Table 2). Results from this north-facing plot set were similar to the results from the boat-based counts on the northern side of the colony: trends were not present and numbers of birds and nests remained relatively stable during the 1987-1997 interval (Fig. 6; also see Fig 5a). Data collected on a second set of land plots (LP 9-14) were archived for later analysis (see Appendix 2). This plot set was established in 1992 as a backup LP 1-8 in case this primary plot set was damaged by rock falls. Numbers of birds and nests on LP 9-14 have generally tracked 1992-1997 LP 1-8 counts.

The fact that birds and nests only increased along the western side of the colony suggested that something was limiting population growth on the north-facing nesting cliffs. The most likely contributing factors appeared to be differences in availability of nesting habitat and local environmental conditions. Kittiwake nesting habitat is less abundant on the northern side of the colony, particularly east of Grizzly Bear Beach in census plots CP 65-76, and most birds nest along the western side in census plots CP 1-51 (Fig. 2). The north-facing cliffs also tend to experience the most extreme summer weather conditions. During July-August, they are commonly subjected to strong, cold 50-60 kt northerly winds carrying driving rain and spray, and dense, cold, moist banks of advective fog that form when light southerly breezes carry warm air across the adjoining hill and ridge-tops. They are also prone to violent, swirling 50-100+ kt downdrafts and microbursts during periods of moderately strong 20-40 kt southerly winds. Wind speeds of only 20-25 kts at the USAF LRRS radome about 485 m above the cliffs typically generate 50-60+ kt downdrafts that strike the beaches and water at their bases, and 40 kt winds can cause extreme events—e.g., in one case, a violent microburst swept over 100 murres, kittiwakes, and their chicks off a section of cliff and drove them straight down onto First Beach with more than enough force to kill them instantly.

These more adverse local weather conditions coupled with differences in availability of nesting habitat may help explain why kittiwakes have not increased on the northern side of the colony.

Murres: We compiled all available information on boat-based counts of murres at Cape Lisburne (Appendices 3 and 4) and selected 10 census plots with the best long-term records for analysis (see Table 3). When data were pooled and tested, positive trends were found over the 1976-1984 and 1984-1997 intervals (Fig. 7; linear regression, $P = 0.04$ and 0.2, respectively), and the rate of increase was highest after 1984 (about 6.0% per year *vs* 1.5% per year during 1976-1984).

We also tabulated all land-based counts of murres on land plots LP 1-7 and tested them for trends (see Table 4). Results from this plot set were similar to results from boat-based counts: numbers increased significantly at a rate of about 7.5% per year over the 1987-1997 interval (Fig. 8; linear regression, $P < 0.01$). Data collected on another set of land plots (LP 9-14) were reserved for later analysis (see Appendix 5). This plot set was established in 1992 to backup LP 1-7 in case this primary plot set was damaged by rock falls. Murre numbers have remained relatively stable on LP 9-14 since 1992.

The positive trends found on the boat- and land-based population monitoring plots were similar and suggested that murre numbers doubled at the Cape Lisburne colony since the mid-1980's. The increases in numbers and average rates of increase on the plot sets since the mid-1980's (6.3% and 7.0% per year, respectively; see above) also suggested that productivity and recruitment were relatively high and winter mortality of adults and chicks relatively low during the mid-1980's - late 1990's.

Nesting Chronology

Kittiwakes: In 1995, kittiwake eggs began to hatch at Cape Lisburne on 17 July, 68% hatched by 31 July, another 28% hatched by 4 August, and hatching was essentially complete by 9 August (99%, Appendix 6). Based on this information, peak and median dates were about 27-28 July and 26 July, respectively (Table 5). Data were not obtained in 1996 because of a colony-wide reproductive failure; birds only laid 2 eggs on the study plots and both of them failed to hatch (see Productivity below). In 1997, timing of nesting was similar to 1995: eggs began hatching on 17 July, 63% hatched by 29 July, another 25% hatched by 1 August, and hatching was nearly over by 8 August (95%, Appendix 6). This information suggested that peak and median dates were about 26-27 July and 25 July, respectively (Table 5).

Based on cumulative percentages of eggs hatched, timing of nesting was relatively consistent in 1987, 1992-1993, 1995, and 1997. Peak and median hatching dates only varied by about 5 days among years (peak range = 17-22 July, median range = 25-29 July; Table 5). Less precise information from 1977-1978 suggested that nesting may have occurred several days later in these years (most eggs probably hatched during about 2-15 August; see Springer *et al.* 1979). Kittiwake nesting chronology will be discussed in greater detail after the 1977-1986 observations have been compiled and added to the 1987-1997 data base.

Thick-billed Murres: In 1995-1997, thick-billed murre median hatching dates were 27 July (SD 2.4 days, range 22 days), 3 August (SD 2.2 days, range 22 days), and 28 July (SD 3.0 days, range 25 days, respectively (Table 6a, Appendices 7-8). The same chronological pattern was apparent when sea-going data were analyzed: respective median chick sea-going dates were 21 August (SD 2.0 days, minimum range 14 days), 25 August (SD 1.7 days, minimum range 22 days), and 20 August (SD 1.2 days, range 26 days).

These results suggested that thick-billed murres nested at about the same time in 1995 and 1997, and 5-6 days later in 1996. We suspect that the later 1996 chick hatching and sea-going dates were related to annual differences in environmental conditions and food supplies in the vicinity of Cape

Lisburne during the 2-month-long early May - late June prelaying period (murres typically begin frequenting the Cape Lisburne area in late April or early May, about 7-8 weeks before laying eggs; M. Husband, pers. comm.—also see Swartz 1966). Relationships between environmental factors and timing of thick-billed murre nesting events will be discussed in greater detail after historical data have been compiled and analyzed in conjunction with weather records and information on ice conditions and water temperatures retrieved from satellite imagery. Detailed data on the timing of thick-billed murre nesting events were not obtained at Cape Lisburne prior to 1995.

Common Murres: Common murre nesting chronology results followed the same general pattern found in the thick-billed murre data over the 3-year interval. Median chick hatching and sea-going dates were 31 July (SD 6.2 days, range 24 days) and 24 August, 5 August (SD 5.3 days, range 25 days) and 29 August, and 30 July (3.6 days, range 16 days) and 21 August in 1995, 1996, and 1997, respectively (Table 6b, Appendices 9 and 10).

These results suggested that common murres nested at about the same time in 1995 and 1997, and 4-6 days later in 1996. They also suggested that these birds nested about 3-5, 2-4, and 1-2 days later than thick-billed murres in 1995, 1996, and 1997, respectively. Again we suspect, as with thick-billed murres, that the later 1996 hatching and sea-going dates were related to annual differences in environmental conditions and food supplies near Cape Lisburne during the early May - late June prelaying period. Detailed data on timing of common murre nesting events were not obtained at Cape Lisburne prior to 1995.

During several previous Cape Lisburne studies, general observations suggested that common murres nested a few days later than thick-billed murres (D.G. Roseneau, pers. obs.); however, information on timing of nesting was insufficient to document this apparent difference between species. Given the consistent differences in nesting dates between common and thick-billed murres in 1995-1997, and the fact that common murres are a more southern species better adapted to warmer environments (e.g., see Tuck 1961), we suspect that slightly later common murre nesting schedules are the general rule, not the exception, at the eastern Chukchi Sea colonies.

Productivity

Kittiwakes: In 1995, kittiwake clutch size, hatching success, and fledglings per nest start were 1.71 eggs per nest (SD 0.12), 0.66 chicks per egg (SD 0.11), and 0.47 chicks per nest (SD 0.16), respectively (Table 7, Appendix 11). The following year was marked by a near-complete reproductive failure that began early in the nesting cycle. Most breeding activities stopped during the nest-building stage; only 2 pairs finally laid single eggs on the study plots, and both eggs failed to hatch (Table 7, Appendix 12). In 1997, breeding success rebounded and was similar to 1995: clutch size, hatching success, and fledglings per nest start were 1.25 eggs per nest (SD 0.11), 0.68 chicks per egg (SD 0.12), and 0.42 chicks per nest (SD 0.10), respectively (Table 7, Appendix 13).

The 9 August 1995 and 8 August 1997 productivity values of 0.9 and 0.6 eggs or chicks per nest attempt that were calculated for comparison with the 1976-1993 data fell slightly above and below the long-term average, respectively (average value 0.8 eggs or chicks per nest attempt, $n = 16$ years; see Table 8, Fig. 9, and Appendices 14-16). In contrast, the 11 August 1996 figure of < 0.1 eggs or chicks per nest attempt was similar to the lowest previously reported values (0.1 and < 0.1 eggs or chicks per nest attempt in 1976 and 1984, respectively—the only other occasions when near-complete reproductive failures occurred at the colony).

The number of eggs or chicks per nest was positively correlated with the number of eggs or chicks per successful nest (Spearman's Rank Correlation, $n = 16$, $P < 0.01$; Table 8 and Fig. 9). This suggested that in years when overall reproductive success rates were low, pairs also tended to have smaller broods.

Based on the long-term productivity estimates, kittiwakes only produced about 0.3 eggs or chicks per nest attempt or less in 5 (31%) of the 16 study years (1976, 1984-1985, 1992, and 1996; see Table 8 and Fig. 9). However, this relatively high incidence of poor reproductive performance was apparently not sufficient to prevent the population from increasing over the 1977-1997 interval (see Population Counts above and Fig. 9). The fact that the poor reproductive success incidents were spread out through time (i.e., in 1976, 1984-1985, 1992, and 1996) almost certainly helped ameliorate the potential effects of several years of poor productivity on overall population growth.

The near-complete reproductive failure in 1996 resulted from birds failing to lay eggs, the first time this phenomenon has been observed at Cape Lisburne since studies began in 1976 (D.G. Roseneau, A.L. Sowls, and A.M. Springer, unpubl. data). We suspect that the inability to produce eggs was related to unusual ice conditions that persisted in Ledyard Bay throughout the late May - late June prebreeding and early egg-laying periods. In most years, shorefast ice breaks up in Ledyard Bay before laying begins, allowing access to rich stocks of Arctic cod. However, in 1996, shorefast ice remained nearly intact until the first week of July, when it finally broke loose enmasse in several large sheets that were quickly transported northward by strong southerly winds. The presence of near solid ice cover well beyond the time kittiwakes normally begin to lay eggs (late June) almost certainly limited access to important early season food supplies that would have improved body condition and provided energy for forming eggs. The near-complete absence of subcutaneous and mesenteric fat in 7 adult kittiwakes collected on 11 July 1996, a few days after Ledyard Bay became ice-free, supported the hypothesis that persistent, near-solid ice cover restricted access to food during the critical prebreeding and early egg-laying periods.

Reproductive failures in 1976 and 1984, and low productivity in 1985 and 1992 were almost certainly associated with food supply and weather events that occurred after eggs were laid. For example, in 1992, a near-absence of sand lance during the late incubation and chick-rearing periods, and near-freezing temperatures in early August followed by persistent snow falls after 10 August resulted in steady losses of eggs and chicks (D.G. Roseneau and A.L. Sowls, unpubl. data). Relationships among environmental factors (e.g., ice cover, timing of shorefast ice breakup, air and water temperatures), food supplies (e.g., presence or absence of sand lance during critical nesting periods), and kittiwake productivity will be discussed in greater detail after historical data have been compiled and analyzed in conjunction with weather records and information on ice conditions and water temperatures retrieved from satellite imagery.

<u>Murres</u>: Productivity of thick-billed and common murres was high at Cape Lisburne in 1995 (0.88 and 0.85 fledglings per egg, respectively; Table 9, Fig. 10, Appendices 17 and 18). In 1996-1997, productivity of both species was significantly lower (Pearson Chi-square, $P < 0.03$ in both cases); however, in both of these years, it was still higher than the average 1976-1997 Pribilof Islands values (thick-billed murres 0.62 and 0.53 fledglings per egg in 1996 and 1997, respectively, compared to an average of 0.51 fledglings per egg, $n = 18$, range = 0.15-.072, SD = 0.13; and common murres 0.68 and 0.63 fledglings per egg in 1996 and 1997, respectively, compared to an average of 0.54 fledglings per egg, $n = 15$, range = 0.30-0.69, SD = 0.12—AMNWR unpubl. data). Common murre productivity was also well within the range of values reported for this species at Bluff in 1987-1990 (0.51-0.73 fledglings per egg; only a few pairs of thick-billed murres nest at this Norton Sound colony—see Murphy 1993).

The similar declines in common and thick-billed murre productivity after 1995, and similarities in productivity within species and years, suggested that these species responded to annual differences in local environmental conditions and food supplies in similar ways over the 3-year study interval. Detailed information on murre productivity was not collected at Cape Lisburne prior to 1995; however, the steady, on-going increase in population numbers that began in the mid-1980's (see Figs. 7 and 8) suggested that reproductive success, survivorship of chicks, and recruitment were well above average at this important eastern Chukchi Sea colony throughout most of the 1980's and 1990's.

Chick Growth Rates and Sea-going Weights

Kittiwakes: In 1995, growth rates of kittiwake chicks weighed during the linear phase of growth averaged 16.8 g per day (SD 5.3, $n = 9$; see Table 10). Data were not obtained in 1996 because of a colony-wide reproductive failure (birds only laid 2 eggs on the study plots and neither hatched; see Productivity above). In 1997, growth rates were similar to 1995 values, averaging 18.0 g per day (SD 3.5, $n = 8$; see Table 10).

Data obtained on kittiwake chick growth rates in 1977-1981, when average daily weight gains ranged from 14.3 to 19.7 g per day annually, suggested that the 1995 and 1997 rates were average and maximum values, respectively (see Springer *et al.* 1985c). The difference between the 1995 and 1997 values suggested that prey availability was higher during the 1997 chick-rearing period than in 1995.

Murres: Sea-going weights of common and thick-billed murre chicks declined over the 3-year study period. In 1995-1997, thick-billed nestlings averaged 226 g (SD 28, $n = 40$), 207 g (SD 24, $n = 58$), and 193 g (SD 31, $n = 10$), and common murre chicks averaged 236 g (SD 23, $n = 17$), 220 g (SD 19, $n = 12$), and 180 g (SD 10, $n = 5$), respectively (Fig. 11, Table 11). These among-years differences were significant for both species (ANOVA; common murres $P < 0.01$ and thick-billed murres $P < 0.02$ in all cases), and weights became significantly lower each year (LSD Multiple Comparisons; common murres $P < 0.04$ and thick-billed murres $P < 0.09$ in all cases).

In 1997, the average weights of thick-billed and common chicks that went to sea were about 15% and 24% lower than they were in 1995, respectively. These low sea-going weights suggested that the nestlings left the colony with relatively poor lipid reserves, and as a result, chick mortality may have been relatively high during the first few days at sea, compared to 1995-1996. If this scenario is correct, the 1997 cohorts may not contribute many birds to the Cape Lisburne murre population in upcoming years (any marked reductions in recruitment resulting from increased mortality of the 1997 common and thick-billed chick cohorts may be detectable during 2000-2004, when surviving birds are 3-7 years old).

In contrast to chick sea-going weights, sea-going ages of nestlings were remarkably similar during 1995-1997, only varying by about 1 and 3 days for thick-billed and common chicks, respectively (Appendices 7 and 9). This information, coupled with the steady annual declines in the sea-going chick weights of both species over the 3-year interval, suggested that common and thick-billed murres responded to changing environmental conditions and food supplies in similar ways (just as productivity information did—see above). These results also suggested that prey availability declined markedly during the chick-rearing period over the 3-year study period.

Food Habits

Kittiwakes: (Adults) — In 1995-1996, food habits data were obtained from 34 and 9 adult kittiwakes collected during 11 July - 22 August and 5 July – 12 August, respectively (Tables 12-14; only 1 bird was obtained in 1997, because this species was difficult to collect on 30 June and 4 July, and inclement weather and sea conditions prevented making subsequent sampling trips). Thirty-three (91%) of the 1995 birds and 7 (78%) of the 1996 individuals contained prey.

Although invertebrates were the most numerous prey items found in the 1995-1996 stomach samples (77% and 80%, respectively), almost all of the biomass consisted of fish (94% and 95% by weight, respectively; Tables 12-14, Figs. 12-13). Cod clearly dominated the diets by weight both years (71% and 95% in 1995 and 1996, respectively); however, the 1995 samples also contained relatively high percentages of sculpin (primarily fourhorn sculpin, *Myoxocephalus quadricornis*; 16% by weight, see Fig. 12). The single stomach obtained in 1997 only contained 1 unidentified cod; these data were not graphed because of sample size (see Table 14 and Fig. 14).

Invertebrates were scarce in the 1987 and 1992-1993 stomach samples (0%, 15%, and 0% by number, respectively; Tables 15-17, Figs. 15-17). In all of these years, almost all of the biomass consisted of fish (100%, > 99%, and 100% by weight in 1987, 1992, and 1993 respectively), just as it did in 1995-1996; however, cod only dominated the diets by weight in 1992 (99%). In the other 2 years, the stomachs contained relatively large proportions of both sand lance and cod (sand lance 49% and 35%, and cod 39% and 45% by weight in 1987 and 1993, respectively; see Figs. 15 and 17).

Kittiwakes: (Chicks) — In 1995 and 1996, food habits data were obtained from 5 and 6 kittiwake chicks salvaged during 4-26 August and 20 July – 29 August, respectively (Tables 18-19; data were not obtained in 1996 because of a colony-wide reproductive failure—see Productivity above). Four (80%) of the 1995 chicks and 5 (83%) of the 1997 nestlings contained prey.

In 1995, prey items consisted of sand lance, sculpin, and invertebrates (hyperiidean amphipods and euphausiids). Almost all of the biomass consisted of fish (95%), and sand lance and sculpin accounted for 68% and 27% of the weight, respectively; Table 18, Fig. 18). Nineteen ninety-seven prey remains consisted solely of fish, including cod, sand lance, and sculpin; prey weights could not be calculated for these fish because the otoliths were too eroded to age (see Table 19 and Fig. 19).

Thick-billed Murres: (Adults) — In 1995-1997, food habits data were obtained from 35, 19, and 20 adult thick-billed murres collected during 11 July - 22 August, 5 July – 12 August, and 4 July, respectively (Tables 12-14). All (100%) of the 1995 birds, 18 (95%) of the 1996 individuals, and 18 (90%) of the 1997 specimens contained prey.

Although invertebrates were the most numerous prey items found in the 1995-1997 stomach samples (62%, 78% and 48%, respectively), almost all of the biomass consisted of fish (94%, 93%, and 91% by weight, respectively; Tables 12-14, Figs. 12-14). Cod were the primary prey item by weight in all 3 years (70%, 68%, and 45%, respectively); however, relatively high percentages of sculpin (primarily fourhorn sculpin) were also present in the 1996-1997 samples (23% and 31% by weight, respectively; see Figs. 13-14).

Invertebrates were not present in the 1987 and 1993 stomach samples; however, they dominated the 1992 samples by number (95%; Tables 15-17, Figs. 15-17). In all of these years, almost all of the biomass consisted of fish (100%, 82%, and 100% by weight in 1987, 1992, and 1993 respectively), just as it did in 1995-1996. In 1987, sand lance replaced cod as the primary prey item by weight (63% *vs* only 6% for cod); however, percentages of cod were relatively high in both 1992 and 1993 (46% and 51% by weight, respectively) and similar to the 1997 amount (45% by weight, see Fig. 14). The 1987 and 1992-1993 stomach samples also contained relatively large proportions of sculpin (22%, 36%, and 42% by weight, respectively) in amounts similar to those present in the 1996-1997 samples (23% and 31% by weight, respectively; see Figs. 13-14).

Thick-billed Murres: (Chicks) — In 1995-1997, food habits data were obtained from 22, 27, and 31 thick-billed murre chicks salvaged during 4-26 August, 15-27 August, and 20 July – 29 August, respectively (Tables 18-20). Nineteen (86%) of the 1995 chicks, 23 (85%) of the 1996 nestlings, and 9 (29%) of the 1997 specimens contained prey.

All of the prey items found in the 1995-1997 stomach samples consisted of fish (Tables 18-20, Figs. 18-20). Based on weight, cod (primarily Arctic cod) were clearly the primary prey fed to thick-billed chicks in 1995-1996 (86% and 80%, respectively). In 1997, prey weights could not be calculated because fish otoliths were too eroded to age; however, based on average weights of cod and sculpin fed to thick-billed murre chicks in 1995-1996 (16.9 g, $n = 41$, and 5.4 g, $n = 11$, respectively), sculpin probably played a larger role in the 1997 chick diets than cod (i.e., the 31 sculpin and 6 cod reported in Fig. 20 would have weighed about 167 g and 101 g, respectively). Thick-billed chicks were also fed a relatively high percentage of sculpin in 1995 (10% by weight;

second only to cod— see Fig. 18), and in 1996, they received a relatively substantial amount of sand lance (17% by weight; again, second only to cod—see Fig. 19).

In 1995-1997, some information was also obtained on prey delivered to thick-billed murre chicks by adults (Table 21a, Fig. 21). Thirty-three, 40, and 11 items were identified in 1995, 1996, and 1997, respectively. Sand lance were the most numerous prey brought to nestlings in 1995 (64%) and 1996 (75%); however, in 1997, when the sample size was relatively small (n = 11), Arctic cod outnumbered sand lance (55% *vs* 36%, respectively; see Fig. 21).

Common Murres: (Adults) — In 1995 and 1997, food habits data were obtained from 14 and 8 adult common murres collected during 11 July - 22 August and 4 July, respectively (Tables 12-14; data were not obtained in 1996, because common murres were difficult to see in the mixed flocks that flew by during the collecting trips). Thirteen (93%) of the 1995 birds and all (100%) of the 1997 individuals contained prey.

Although invertebrates were the most numerous prey items found in the 1995 and 1997 stomach samples (84% and 78%, respectively), almost all of the biomass consisted of fish (94% and 96% by weight, respectively; Tables 12-14, Figs. 12 and 14). Cod clearly dominated the diets by weight both years (73% and 80%, respectively); however, the 1995 and 1997 samples also contained relatively large amounts of sculpin and sand lance (18% and 12% by weight, respectively; see Figs. 12 and 14).

Invertebrates were not present in the 1987, 1992, and 1993 stomach samples, and all of the biomass consisted of fish (Tables 15-17, Figs. 15-17). Cod were the primary prey item by weight in all 3 years (51%, 97%, and 69%, respectively); however, the 1987 and 1993 stomach samples also contained relatively large proportions of sand lance (30% and 20% by weight, respectively; see Figs. 15 and 17). A relatively high percentage of capelin was also present in the 1987 samples (11% by weight; the largest amount of these important forage fish found in the murre and kittiwake diets during 1987-1997, see Figs. 12-17).

Common Murres: (Chicks) — In 1995-1997, food habits data were obtained from 3, 6, and 6 common murre chicks salvaged during 4-26 August, 15-27 August, and 20 July – 29 August, respectively (Tables 18-20). Two (66%) of the 1995 chicks, 5 (83%) of the 1996 nestlings, and 2 (33%) of the 1997 specimens contained prey.

All of the prey items found in the 1995-1997 stomach samples consisted of fish (Tables 18-20, Figs. 18-19). Nineteen ninety-seven data were not graphed because the samples only contained 2 unidentified fish. In 1995 and 1996, only 4 and 7 fish were present in the samples respectively, and in both cases, prey consisted of cod and sand lance. In both years, cod outweighed sand lance (89% and 73% *vs* 11% and 27%, respectively; see Figs. 18 and 19).

In 1995-1997, some information was also obtained on prey delivered to common murre chicks by adults (Table 21b, Fig. 21). Sixty-six, 38, and 6 items were identified in 1995, 1996, and 1997, respectively. Sand lance were the most numerous prey brought to the nestlings in 1995 (70%) and 1996 (55%); however, in 1997, when the sample size was relatively small (n = 6), Arctic cod were as numerous as sand lance (50% in both cases; see Fig. 21).

Cape Lisburne kittiwake and murre food habits will be discussed in greater detail after data from 1977-1986 have been compiled, verified, and compared with 1987-1997 information. During this more comprehensive analysis, 1977-1997 data will be plotted as a series of bar graphs illustrating both general prey categories (e.g., fish, invertebrates) and individual species, and compared among years. Data will also be divided into appropriate prey categories and early, mid-, and late season time blocks, and compared among years (e.g., see Fig. 5 in Springer *et al.* 1984). Results from this more detailed analysis will also be compared with historical information on kittiwake and murre

breeding parameters (e.g., timing of nesting events, clutch size, hatching and fledging success), environmental conditions (e.g., last ice dates and water temperatures, including those retrieved from satellite imagery; air temperatures retrieved from weather records), and observations of feeding-flight directions (e.g., see Springer and Roseneau 1977, 1978; Springer *et al.* 1979, Hatch *et al.* 2000). Making these types of comparisons using the full suite of information that will be compiled for the 21-year study interval will increase chances of identifying relationships between food supplies, environmental factors, and reproductive success of the birds.

Water Temperatures

Sea-surface temperature data collected with hand-held thermometers at Cape Lisburne in 1987, 1992, and 1993 were compiled and reviewed in context with 1995-1997 information, and a common block of time was identified that could be compared among years (23-28 July; Table 22, Appendix 19). Dates encompassed by the common block of time corresponded to the beginning of the kittiwake and murre chick-rearing periods in 1987-1997 and 1995-1997, respectively (see Nesting Chronology above). Temperatures were the highest in 1993 (10° C) and the lowest in 1995 (5.8° C), and 1996 was the median year.

In 1997, an Onset Optic StowAway Temp data logger was tested at Cape Lisburne. The test was successful: the submerged unit maintained its position about 12-13 m below the surface 1.6 km offshore despite 50-60 kt winds and high seas, and provided a continuous record of water temperatures during 6 July - 21 August (Fig. 22). These data indicated that temperatures averaged about 6.5° C (range 5.0-7.5° C, SD 0.8° C) until 23 July, then rose rapidly and averaged 8.6° C (range 8.4-8.7° C, SD 0.1° C) during 23-28 July, then dropped sharply to 6.6° C on 29 July before steadily increasing to 9.8° C by 5 August, and then averaged 10.1° C (range 9.5-10.7° C, SD 0.3° C) during 5-21 August. The data logger records confirmed that information collected with hand-held thermometers in the surf zone during 23-28 July 1997 were representative of nearshore temperatures during that time (average = 8.5° C *vs* 8.6° C from the data logger unit, see Table 22 and Fig. 22).

Based on the results of the 1997 data logger test, these devices will be used to collect water temperature information at the Cape Lisburne colony during all future studies lasting more than 2 weeks. Employing these devices during short field trips is not practical because of the limited amount of time available to successfully deploy and recover them (i.e., favorable sea conditions are needed for deployment and recovery; in all likelihood, arriving field teams will have to wait several days before deploying the device, and then take the chance that there will be an opportunity to recover it shortly before they leave the study area).

Sea-surface temperature data collected at Cape Lisburne during 1976-1986 will be compiled and analyzed in conjunction with 1987-1997 information in a future report. This more comprehensive multiyear analysis will also include data on sea-surface temperatures obtained from satellite imagery, and results will be compared with murre and kittiwake nesting chronology, productivity, and food habits data to determine if relationships exist among these variables.

CAPE THOMPSON: RESULTS AND DISCUSSION

Population Counts

Kittiwakes: We compiled all available boat-based Colony 4 kittiwake counts and tested them for trends (Table 23, Fig. 23). The high 1960 count of 6,264 birds was not included in the analysis because of the 16 year data gap between count records. When 1976-1995 data were pooled analyzed, no trend was apparent over the 20-year interval. However, we noticed a pattern in the

counts that suggested birds increased during 1976-1990, and when we tested these data separately. a positive trend was evident over the 15-year period (Fig 23; linear regression, $P = 0.04$).

We also tabulated land-based counts on several combinations of LGS and BSF plots at Colonies 3-5 (Tables 24-27). In 3 cases, only 3-4 years of information was available; as a result, we archived these data for future analysis (Tables 24-26). When the data set containing 5 years of information from LGS plots 5L, 5M, and 5Q was tested, no trend was apparent over the 17-year interval (Table 24, Fig. 24). Although counts on these plots did not show an overall increase, they suggested that numbers were higher in 1990-1991 than in 1979, 1988, and 1995. Patterns were similar on the plot sets containing 3-4 years of information: the 1979, 1988, and 1995 counts were relatively low, and bird numbers were highest during the early 1990's (see Tables 25-27).

The 1976 and 1995 Colony 4 kittiwake counts were lower than all other scores obtained on this nesting area (Table 23, Fig. 23). Both of these counts were made in years when kittiwakes experienced near-complete reproductive failures, and as a result, they may have been artificially low because of erratic attendance (see Productivity below). Because the counts may have under estimated bird numbers, and because the positive trend detected in the 1976-1990 data set was driven solely by inclusion of the unusually high 1990 score (5,566 individuals, 32% more than the next highest count) in the analysis, we were not convinced that kittiwakes increased at Colony 4 over the 1976-1990 interval. However, we also noted that the 1995 land-based counts may have been artificially low because of erratic attendance, and an average score of only 150 birds (the average of the 1990-1991 counts, only 42 birds more than the 1995 score of 108 individuals) on LGS plots 5L, 5M, and 5Q would have resulted in a positive trend on this plot set. Additional counts will have to be made at Cape Thompson when kittiwake productivity is average or better to help determine the true status of this species at this eastern Chukchi Sea nesting location.

<u>Murres</u>: We compiled all available boat-based counts of murres at Colony 4 and tested the 1976-1995 scores for trends (Table 28, Fig. 25; the 1960-1961 counts of 8,562 and 6,305 birds were not included in the analysis because of the 15 year data gap in count records). No trend was apparent over the 20-year period. However, we noticed a pattern in the counts that suggested birds decreased during 1976-1988, and when we tested these data separately, a negative trend was evident over the 13-year interval (Fig 25; linear regression, $P < 0.01$).

We also tabulated land-based counts on several combinations of LGS and BSF plots at Colonies 3-5 (Tables 29-32, Figs. 26-27). In 2 cases, only 3-4 years of information was available; as a result we archived these data for future analysis (BSF plots, Table 31 and 32). We also did not test the information listed in a third case (LGS plots, Table 32), because the data were essentially the same as those used in another an Table 30, Fig. 27; data reported in Table 30 are complete counts of the plot set made on the same day, whereas Table 32 data include all counts made on the plots regardless of the "same day" rule—Table 30 data are the preferred data set). When the LGS plot sets containing 5-6 years of information were pooled and tested, no trends were found over the 17-year 1979-1995 period (Tables 29-30, Figs. 26-27; 1960 data were not included in these analyses because of the 16 year data gap between count records).

The negative trend found on the Colony 4 population monitoring plot set suggested that murre numbers declined at Cape Thompson during 1976-1988. However, counts made on this set of plots in 1990 and 1995 also suggested that numbers may have rebounded to near mid- and late 1970's levels by 1995 (i.e., over the 7-year period after 1988; see Fig. 25). Additional field work scheduled for about 2001-2002 will help determine if the 1990 and 1995 Colony 4 counts actually reflect the initial stages of an increasing trend in the Cape Thompson murre population.

Nesting Chronology

Kittiwakes: Precise data on kittiwake hatching dates were not obtained at Cape Thompson in 1995, because hatching success was low (only 0.25 chicks per egg, Appendix 20). The first chick was observed on 21 July, and about 66% of the eggs hatched by 5 August (Table 33). Based on this information, hatching probably peaked about 2-3 August (i.e., when it was estimated to be about 50% complete), about 6 days behind the 1995 Cape Lisburne schedule (see above).

Based on historical information, the 1995 first hatching date (21 July) was 19 and 8 days earlier than the 1976-1977 dates (9 August and 29 July, respectively), and about average, compared to the 1959-1961, 1978-1979, 1982, 1988, and 1990-1991 dates (mean date 20 July, *n* = 9 years, range 17-25 July, SD 2.5 days; see Table 33). Hatch-interval and peak hatching information was only available from 1978-1979 and 1988. These data indicated that the 1995 and 1978-1979 nesting schedules varied by only a few days. They also suggested that hatching occurred over somewhat shorter intervals of time in 1978 and 1988, compared to 1979 and 1995 (66% of the eggs hatched in 9 and 10 days in 1978 and 1988, respectively, compared to 14, and 15 days in 1979 and 1995, respectively), and that it peaked several days earlier, compared to the other 3 years (on 25-26 July *vs* 31 July - 1 August, 29-30 July, and 2-3 August in 1978, 1979, and 1995, respectively; see Table 33).

Nesting chronology data from 1976-1995 suggested that kittiwakes nested at about the same time at Cape Thompson in most years. Late nesting in 1976-1977, as indicated by late first hatching dates (9 August and 29 July, respectively; Table 33) may have been related to heavy ice cover during the prebreeding and egg-laying periods that reduced access to local food supplies during these critical intervals; ice persisted throughout the Cape Thompson region well into the third and fourth weeks of July in 1977 and 1976, respectively (e.g., see Springer *et al.* 1984). Potential relationships between timing of kittiwake nesting events and environmental conditions will be explored in greater detail after remaining historical data have been located and reviewed, and analyzed in conjunction with ice-cover information retrieved from satellite imagery.

Murres: In 1995, common and thick-billed murre eggs started hatching at Cape Thompson on 25 July (Table 34). Based on cumulative percentages, hatching was about 70% complete by 7 August, and essentially over by 15 August for both species (99%-100%; see Appendix 21). Median common and thick-billed hatching dates were 6 and 5 August, respectively, and respective first sea-going dates were <19 August and 18 August (Table 34).

Based on 1959-1991 data, 1995 was a relatively early nesting year for murres breeding at Cape Thompson (first hatch 25 July in 1995, 1959-1991 range 21 July – 11 August; see Table 34). In 6 (50%) of the 12 study years, hatching began about 30 July (1960, 1961, 1977, 1988, 1991, and 1995; *n* = 9, range 25 July – 1 August, SD 2.8 days). During the other 6 breeding seasons, eggs started to hatch 6-12 days later in 3 (25%) cases (1959, 1976, and 1982; mean 9 August, *n* = 4, range 5-11 August, SD 2.9 days), and 7-9 days earlier on 3 (25%) occasions (1978, 1979, and 1990; mean 22 July, *n* = 3, range 21-23 July, SD 1.0 days). Variations in hatching dates over the years may have reflected differences in June-July ice cover. Potential relationships between timing of murre nesting events and environmental conditions will be explored in greater detail after weather records have been reviewed and ice cover information retrieved from satellite imagery.

In 1995, median hatching and first sea-going dates indicated that common murres nested slightly later than thick-billed murres; this pattern was also apparent in the 1960-1961 first hatching and sea-going dates (see Table 34). These data supported 1995-1997 Cape Lisburne findings (see above).

Productivity

Kittiwakes: Kittiwakes experienced a near-complete reproductive failure at Cape Thompson in 1995 (Table 35, Appendix 20). Pairs only laid eggs in 98 (21%) of the 479 study nests, and only 39 (37%) of the 105 eggs hatched. Only 3 (8%) of the 39 chicks were still alive on 19 August, when nests were last checked, and assuming they survived, productivity was less than 0.01 fledglings per nest (Table 35).

During 1976-1979, 1982, 1988, and 1990-1991, productivity varied from zero (1976) to 1.15 fledglings per nest (1982; Table 35, Fig 28). During 4 of these years, when data were also collected at Cape Lisburne (1976-1979), productivity followed the same basic pattern at both colonies (i.e., from zero or near zero in 1976, to moderate levels in 1977-1978, and then to the highest overall values in 1979; see Tables 8 and 35, and Figs. 9 and 28). The increase in productivity during the late 1970's appeared to be correlated with earlier dissipation of ice, increases in availability of fish, positive trends in the lengths of several important forage fish species (Arctic cod, capelin, sand lance), and increases in overall availability of sand lance during the chick-rearing periods (e.g., see Springer *et al.* 1984).

In 1995, when kittiwakes experienced a near-complete reproductive failure at Cape Thompson, productivity averaged about 0.47 fledglings per nest at Cape Lisburne (see Table 7 and Appendix 11). These data and the fact that ice cover dissipated several days earlier at Cape Thompson suggested that there were differences in prey availability between the colonies. Marked differences in laying, hatching, and chick success at the colonies also indicated that prey were scarce in Cape Thompson surface waters during the 1995 prelaying, incubation, and chick-rearing periods (laying, hatching, and chick success were only 0.19, 0.25, and 0.03 at Cape Thompson *vs* 0.84, 0.66, and 0.49 at Cape Lisburne, respectively; see Appendices 11 and 20).

Linkages between kittiwake productivity, prey availability, and environmental conditions are complex, and as yet poorly understood. Relationships among these parameters will be identified and described in greater detail after the remainder of the Cape Thompson and Cape Lisburne kittiwake data have been compiled and analyzed in conjunction with weather records and information on ice cover and water temperatures retrieved from satellite imagery (see Cape Lisburne above).

Murres: In contrast to kittiwakes, productivity of thick-billed and common murres was high at Cape Thompson in 1995: 0.88 and 0.91 fledglings per egg, respectively (Table 36). These results were nearly identical to the high 1995 Cape Lisburne values (0.88 and 0.85 fledglings per egg for thick-bills and commons, respectively; see Table 9 and Fig. 10).

Prior to 1995, detailed data on murre productivity were only collected at Cape Thompson in 1988, 1990, and 1991. During these earlier years, common murres produced 0.60, 0.86, and 0.37 fledglings per egg, and thick-billed murres 0.61, 0.76, and 0.51 fledglings per egg, respectively (Table 37, Fig. 29). Based on this information and 1995 data, success rates for both species were high in both 1990 and 1995. These data were encouraging because, barring unusual mortality events, the combination of the large 1990 and 1995 chick cohorts should start to bolster population numbers by about 2000, when birds from these age classes begin to enter the breeding population as 5- to 7-year-old individuals.

Food Habits

Kittiwakes: (Adults) — In 1995, food habits data were obtained from 14 adult kittiwakes collected during 13 July - 20 August (Table 38). Ten (81%) of the birds contained prey.

Invertebrates were not present in the 1995 stomach samples (Table 38, Fig. 30). All (100%) of the prey items consisted of fish, and cod clearly dominated the diets by weight (96%).

Invertebrates were scarce in the 1988 stomach samples (4% by number) and absent from the 1991 samples; however, they were the most numerous prey items found in the 1990 stomachs (52%; see Tables 39-41, Figs. 31-33). In all of these years, almost all of the prey items consisted of fish (<99%, 91%, and 100%, in 1988, 1990, and 1991, respectively), and cod clearly dominated the diets by weight (80%, 91%, and 60% in 1988, 1990, and 1991, respectively), just as in 1995. However, the 1988 samples also contained relatively high percentages of other fish, primarily Pacific herring (*Culpea harengus pallasi*, 19% by weight; see Fig. 31), and the 1991 samples contained substantial amounts of sculpin (35% by weight; see Fig. 33).

Thick-billed Murres: (Adults) — In 1995, food habits data were obtained from 10 adult thick-billed murres collected during 13 July - 20 August (Table 38). Seven (70%) of the specimens contained prey.

Invertebrates were not present in the 1995 stomach samples (Table 38, Fig. 30). All (100%) of the prey items consisted of fish, and cod clearly dominated the diets by weight (87%).

Small numbers of invertebrates were present in the 1988, 1990, and 1991 stomach samples (2%, 7%, and 7%, respectively; Tables 39-41, Figs. 31-33). However, almost all of the prey items consisted of fish (<99% in each case), and cod dominated the diets by weight in all 3 years (97% in 1988 and 1990, and 52% in 1991), just as in 1995. The 1991 samples also contained large amounts of sculpin (45% by weight, see Fig. 33). Based on these results, thick-billed murre diets were similar to kittiwake diets in 1988, 1990-1991, and 1995 (see above).

Common Murres: (Adults) — In 1995, food habits data were obtained from 17 adult common murres collected during 13 July - 20 August (Table 38). Ten (59%) of the individuals contained prey.

Invertebrates were not present in the 1995 stomach samples (Table 38, Fig. 30). All (100%) of the prey items consisted of fish, and cod clearly dominated the diets by weight (83%); however, the samples also contained relatively large proportions of sculpin (13% by weight).

Invertebrates were also not present in the 1987, 1992, and 1993 stomach samples (Tables 39-41, Figs. 31-33). In all of these years, all (100%) of the prey items consisted of fish, and cod clearly dominated the diets by weight (98%, 95%, and 100%, in 1988, 1990, and 1991, respectively), just as in 1995.

Cape Thompson kittiwake and murre food habits will be discussed in greater detail after 1976-1979 and 1982 data have been compiled, verified, and compared with the 1988-1995 information (data will be analyzed in the same manner as the 1977-1997 Cape Lisburne information and comparisons will be made with the same basic suite of variables—e.g., timing of nesting events, clutch size, hatching and fledging success, last ice dates and water temperatures, observations of feeding-flight directions—see above).

Water Temperatures

Water temperature data collected at Cape Thompson during 1976-1991 will be compiled and analyzed in conjunction with the 1995 information in a future report. This more comprehensive multiyear analysis will also include data on sea-surface temperatures retrieved from satellite imagery, and results will be compared with murre and kittiwake nesting chronology, productivity, and food habits information to help determine if relationships exist among these variables.

CONCLUSIONS

1. Black-legged kittiwakes and kittiwake nests increased at Cape Lisburne over the 20-year study interval; however, the increases were limited to the western side of the colony suggesting that a combination of habitat availability and local environment conditions (wind, fog, spray) may be locally influencing population growth at this northern nesting location.

2. Black-legged kittiwakes may have also increased at Cape Thompson during 1976-1990; however, evidence for the increase was not convincing because the positive trend was driven solely by the 1990 data and the 1995 count was made in a year of near-complete reproductive failure. Additional counts will have to be made at Cape Thompson when kittiwake productivity is average or better to help determine the true status of this species at this eastern Chukchi Sea colony.

3. Positive trends found on the Cape Lisburne boat- and land-based population monitoring plots indicated that the murre population doubled at this breeding colony since the mid-1980's. These increases also suggested that productivity and recruitment were relatively high and winter mortality of adults and chicks relatively low at this nesting location during the mid-1980's - late 1990's.

4. A negative trend found at Colony 4 at Cape Thompson suggested that murre numbers declined at this breeding location during 1976-1988. However, counts made at Colony 4 in 1990 and 1995 also suggested that numbers rebounded to near mid- and late 1970's levels by 1995. Additional field work will be required to help determine if the 1990 and 1995 counts actually reflect the initial stages of an increasing trend in the Cape Thompson murre population.

5. Black-legged kittiwake peak and median hatching dates only varied by about 5 days at Cape Lisburne in 1987, 1992-1993, 1995, and 1997, but less precise 1977-1978 information suggested that nesting occurred several days later in these years. Data from 1976-1995 also suggested that kittiwakes nested at Cape Thompson on about the same schedule most years, with the exception of 1976-1977, when first hatching dates were up to 2 weeks later than in 1995. Late nesting by Lisburne and Thompson kittiwakes was probably related to spring and early summer ice conditions that reduced access to food supplies during the prelaying and early egg-laying periods.

6. In 1996, Cape Lisburne murres nested about 5 days later than in 1995 and 1997, and in 1995, they also nested about 1 week later than murres at Cape Thompson. These differences in timing were probably related to differences in environmental conditions (e.g., ice cover) and food supplies during the prelaying period.

7. Murre nesting chronology data from both Cape Lisburne and Cape Thompson suggest that, as a general rule, common murres probably nest slightly later than thick-billed murres at these eastern Chukchi Sea colonies.

8. Black-legged kittiwakes experienced a near-complete breeding failure at Cape Thompson 1995, and failed to lay eggs at Cape Lisburne in 1996. In contrast, productivity averaged about 0.45 chicks per nest start at Cape Lisburne in 1995 and 1997. Near-complete reproductive failures also occurred at Cape Lisburne in 1976 and 1984, and at Cape Thompson in 1976. Breeding failures and annual differences in productivity at these northern nesting locations are probably related to annual variations in ice cover, ice breakup, weather events, and prey availability.

9. Black-legged kittiwakes only produced about 0.3 eggs or chicks per nest or less in 5 (31%) of the 16 study years at Cape Lisburne. However, this relatively high incidence of poor reproductive performance did not prevent the population from increasing over the 1977-1997 interval because these incidents were spread out through time.

10. Productivity of murres was high at Cape Lisburne and Cape Thompson in 1995, suggesting that environmental conditions and food supplies were near-optimal for these diving birds at both colonies.

11. The similar declines in common and thick-billed murre productivity at Cape Lisburne after 1995, and similarities in productivity within species and years, suggested that these species responded to annual differences in environmental conditions and food supplies in similar ways over the 3-year study interval.

12. Data obtained at Cape Lisburne in 1977-1981 suggested that the 1995 and 1997 kittiwake chick growth rates were about average, and the fact that these rates did not differ suggested that prey availability was similar during these years.

13. During 1995-1997, sea-going weights of thick-billed and common murre chicks declined by about 15% and 24%, respectively, at Cape Lisburne. As a result, chick mortality may have been higher during the first few days at sea in 1997 than in 1995-1996.

14. At Cape Lisburne, consistency in the 1995-1997 common and thick-billed murre chick sea-going ages coupled with steady annual declines in sea-going weights of both species during the same time suggested that these birds responded to changes in environmental conditions and food supplies in similar ways. The pattern in chick sea-going ages and weights also suggested that chick-rearing period prey availability declined markedly over the 3-year interval.

15. Prey taken by murres and kittiwakes have varied over the years at both eastern Chukchi Sea colonies. These annual differences are still poorly understood; however, they are probably due in part to annual variations in environmental conditions, including extent and breakup of ice cover, water temperatures and salinity's, and development of Alaska Coastal Water.

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Table 1. Average counts of black-legged kittiwakes and kittiwake nests on 10 census plots at Cape Lisburne, Alaska during 1977-1997 (birds and nests were counted by 1's; counts were made from boats unless noted otherwise below).

Census Plot	Year														
	1977[a]	1978[b]	1979[c]	1981[d]	1983[e]	1985[f]	1986[g]	1987[h]	1992[i]	1995[j]	1996[k]	1997[l]	$\bar{x}$[m]	SD[n]	CV (%)[o]
11	114[p] (112)[q]			202 (157)	260				259	387 (259)	409 (237)	494 (210)	304 (195)	132 (60)	43.5 (30.8)
12	75 (73)			179 (160)	207				128	395 (309)	422 (309)	457 (281)	266 (226)	155 (106)	58.2 (46.7)
25	54 (48)			45 (40)	77				58	93 (63)	107 (54)	110 (72)	78 (55)	26 (13)	33.9 (22.8)
26	265 (235)			246 (222)	322				230	321 (217)	325 (299)	368 (246)	297 (244)	50 (33)	16.9 (13.5)
30	126 (126)			139 (124)	216				201	158 (173)	197 (139)	206 (131)	178 (139)	36 (20)	20.2 (14.5)
32	33 (0)			43 (38)	22				173	286 (156)	375 (218)	272 (238)	172 (130)	143 (107)	83.1 (82.0)
Western Subtotal	*667 (594)*			*854 (741)*	*1,104*				*1,049*	*1,640 (1,177)*	*1,835 (1,256)*	*1,907 (1,178)*	*1,294 (989)*	*495 (300)*	*38.3 (30.3)*
65	247 (247)	340	371 (336)	310 (272)	460[r]	456 (266)	612 (322)	(233)	338[s]	332 (272)	342 (248)	397 (260)	347 (260)	67 (12)	19.3 (4.7)
66	50 (50)	47	51 (37)	43 (40)	50	61 (45)	83 (39)	(58)	44[t]	45 (46)	29 (30)	77 (28)	48 (39)	14 (10)	30.0 (24.8)
70	296 (291)	302	352 (172)	116 (113)	324[u]	419 (252)	273 (174)	(245)	262[v]	370 (336)	332 (270)	406 (236)	301 (249)	94 (84)	31.3 (33.9)
72	274 (259)	189	204 (183)	128 (118)	210	240 (144)	585 (364)	(117)	140[w]	240 (183)	217 (184)	217 (162)	204 (181)	52 (51)	25.7 (28.2)
Northern Subtotal	*867 (847)*	*878*	*978 (728)*	*597 (543)*	*1,044*	*1,176 (707)*	*1,553 (899)*	*(643)*	*784*	*987 (837)*	*920 (732)*	*1,097 (686)*	*989 (736)*	*244 (111)*	*24.7 (15.1)*
Total	1,534 (1,441)			1,451 (1,284)	2,148				1,833	2,627 (2,014)	2,755 (1,988)	3,004 (1,864)	2,193 (1,718)	616 (334)	28.1 (19.5)

[a] Census Plots 70 and 72 were counted on 11 August 1977; Census Plots 11 and 12 were counted on 12 August; Census Plot 30 was counted on 13 August; Census Plots 65 and 66 were counted on 16 August; and Census Plots 25, 26, and 32 were counted on 27 August. Data are from Springer and Roseneau (1978), Springer *et al.* (1979), and Springer *et al.* (unpubl. data).

Table 1 (Continued).

[b] All counts were made during late July and early August 1978. Data are from Springer *et al.* (1979).
[c] All counts were made on 19 July 1979. Data are from Springer *et al.* (unpubl. data) and Byrd (1986).
[d] Census Plots 11, 12, 25, 26, 30, and 32 were counted on 25 July and 2 August 1981; and Census Plots 65, 66, 70, and 72 were counted on 25 July. Data are from Roseneau *et al.* (1985) and Springer *et al.* (unpubl. data).
[e] Census Plots 11, 12, 25, 26, 30, and 32 were counted from a boat on 21 July 1983; Census Plots 66 and 72 were counted from a boat on 11 August; and Census Plots 65 and 70 were counted from the beach on 11 August. Data are from Springer *et al.* (1985d), Springer *et al.*, unpubl. data; and Byrd (1986).\
[f] All counts were made from the beach during late July and early August 1985. Data are from Springer *et al.* (unpubl. data) and Byrd (1986).
[g] All counts were made by from the beach during 28–31 July 1986. Data are from Springer *et al.* (unpubl. data) and Byrd (1986).
[h] The counts were made on 4 August 1987. Data are from Roseneau *et al.* (1992) and D.G. Roseneau and A.L. Sowls (unpubl. data).
[i] Census Plots 11, 12, 25, and 26 were counted on 25 July 1992; Census Plots 30 and 32 were counted on 27 July; and Census Plots 65, 66, 70, and 72 were counted on 31 July and 6 August. Data are from Denlinger *et al.* (1994).
[j] The count was made on 9 August 1995; data are from this study.
[k] The count was made on 18 August 1996; data are from this study.
[l] The count was made on 10 August 1997; data are from this study.
[m] $\bar{x}$ = mean.
[n] SD = standard deviation.
[o] CV = coefficient of variation [standard deviation (SD) divided by the mean and multiplied by 100].
[p] Numbers not enclosed by parentheses are numbers of birds.
[q] Numbers in parentheses are numbers of nests.
[r] In 1983 a boat-based count of Census Plot 65 made within 30 minutes of the land-based count of 460 birds totaled only 250 individuals (Springer *et al.*, unpubl. data).
[s] Average of two counts of Census Plot 65 in 1992: (31 July 1245 hrs) A.L. Sowls = 358; D.G. Roseneau = 348; mean = 353; (6 August 1348 hrs) A.L. Sowls = 324; D.G. Roseneau = 321; mean = 323.
[t] Average of two counts of Census Plot 66 in 1992: (31 July 1350 hrs) A.L. Sowls = 44; D.G. Roseneau = 47; mean = 46; (6 August 1438 hrs) A.L. Sowls = 44; D.G. Roseneau = 40; mean = 42.
[u] Byrd (1986) reported a total of 316 birds on Census Plot 70 in 1983, but the mean of two counts from the beach on 11 August 1983 (338 birds and 310 birds, respectively) is 324 individuals (Springer *et al.*, unpubl. data). Also, a boat-based count of Census Plot 70 made within 45 minutes of the land-based count of 324 birds totaled only 200 individuals (Springer *et al.*, unpubl. data).
[v] Average of two counts of Census Plot 70 in 1992: (31 July 1415 hrs) A.L. Sowls = 239; D.G. Roseneau = 244; mean = 242; (6 August 1455 hrs) A.L. Sowls = 268; D.G. Roseneau = 294; mean = 281.
[w] Average of two counts of Census Plot 72 in 1992: (31 July 1500 hrs) A.L. Sowls = 135; D.G. Roseneau = 130; mean = 133; (6 August 1545 hrs) A.L. Sowls = 142; D.G. Roseneau = 149; mean = 146.

Table 2. Counts of black-legged kittiwakes and kittiwake nests on land plots 1–8 at Cape Lisburne, Alaska during 1987-1997 (birds and nests were counted by 1's; counts were made from land).

1987[a]		1992[b]		1993[c]		1995[d]		1996[d]		1997[d]	
Date	Birds (Nests)	Date	Birds (Nests)	Date	Birds (Nests)	Date	Birds (Nests)	Date	Birds (Nests)	Date	Birds (Nests)
18 Jul	458 (361)	17 Jul	361 (334)	21 Jul	427 (383)	24 Jul	390 (397)	7 Jul	260 (290)	11 Jul	539
1 Aug	556 (370)	20 Jul	312 (331)	26 Jul	411 (393)	27 Jul	519	9 Jul	310	12 Jul	425 (394)
		23 Jul	331	28 Jul	510	28 Jul	484	10 Jul	414	21 Jul	531
		28 Jul	358	1 Aug	508	29 Jul	538	20 Jul	522	24 Jul	494
		30 Jul	366	2 Aug	454	30 Jul	491	31 Jul	449	30 Jul	515
		3 Aug	391			5 Aug	480	10 Aug	631	2 Aug	551
		8 Aug	569			13 Aug	440				
		10 Aug	532			19 Aug	458				
$\bar{x}$ [e]	507 (366)		403 (333)		462 (388)		475 (397)		431 (290)		509 (394)
SD[f]	69 (6)		95 (2)		46 (7)		46		136		46
n[g]	*2 (2)*		*8 (2)*		*5 (2)*		*8 (1)*		*6 (1)*		*6 (1)*

[a] Data are from Denlinger *et al.* (1994) and D.G Roseneau and A.L. Sowls (unpubl. data).
[b] Data are from Denlinger *et al.* (1994).
[c] Data are from A.L. Sowls (unpubl. data).
[d] Data are from this study.
[e] $\bar{x}$ = mean.
[f] SD = standard deviation.
[g] *n* = sample size (number of counts).

Table 3. Average counts of murres on census plots CP 11, 12, 25, 26, 30, 32, 65, 66, 70, and 72 at Cape Lisburne, Alaska during 1976-1997 (counts were made from boats unless noted otherwise below; birds were counted by 100's in 1976 and by 10's in all other years).

	Year													
Census Plot	1976[a]	1977[b]	1979[c]	1981[d]	1983[e]	1984[f]	1987[g]	1992[h]	1995[i]	1996[j]	1997[k]	$\bar{x}$[l]	SD[m]	CV (%)[n]
11	750	928	910	1,072	1,170	1,115	1,765	1,335	1,640	1,620	1,850	1,287	378	29.4
12	1,300	1,545	1,480	1,776	1,500	2,175	2,960	2,055	3,203	3,075	4,640	2,337	1,027	43.9
25	825	1,085	790	928	755	780	1,228	860	1,120	1,020	1,220	965	178	18.4
26	600	1,225	1,140	1,033	925	1,113	1,135	929	1,620	1,245	1,485	1,132	276	24.4
30	4,250	3,585	4,065	3,588	3,140	4,180	5,645	5,142	7,670	6,530	7,568	5,033	1,614	32.1
32	2,200	1,738	2,005	1,716	1,910	1,865	2,875	5,124	6,035	5,685	8,223	3,580	2,278	63.6
65[o]	1,275	2,010	1,915	2,208	2,232[p]	2,130	2,575	2,264[q]	2,800	3,060	2,410	2,262	472	20.9
66	1,250	1,335	1,568	1,450	1,820	1,325	2,260	2,098[r]	2,865	2,170	2,660	1,891	560	29.6
70[s]	900	1,205	1,290	1,135	1,953	1,240	1,805	1,531[t]	2,140	2,223	2,295	1,611	492	30.5
72	750	845	960	642	985	690	1,180	774[u]	1,320	1,138	1,065	941	220	23.4
Total	14,100	15,501	16,123	15,548	16,390	16,613	23,428	22,112	30,413	27,766	33,416	21,037	6,837	32.5

[a] The counts were made on 25–28 August 1976 after the census period and were probably too low. Data are from Springer and Roseneau (1978), Springer *et al.* (1979), and Murphy *et al.* (1980).

[b] The counts were made on 21–26 July 1977. Data are from Springer and Roseneau (1978), Springer *et al.* (1979), and Murphy *et al.* (1980).

[c] The counts were made on 15 August 1979. Data are from Murphy *et al.* (1980).

[d] The counts were made on 25 July and 2 August 1981. Data are from Roseneau *et al.* (1985).

[e] The counts were made on 21 July, and 6, 11, and 19 August 1983 (additional counts made on 27–28 August were not included in these calculations because they were made outside the census period). Data are from Springer *et al.* (1985).

[f] The counts were made on 4 August 1984. Data are from Byrd (1986); and A.M. Springer and G.V. Byrd, unpubl. data.

[g] The counts were made on 4 August 1987. Data are from Roseneau *et al.* (1992) and D.G. Roseneau and A.L. Sowls (unpubl. data).

[h] The counts of Census Plots 11, 12, 25, and 26 were made on 25 July 1992; Census Plots 30 and 32 were counted on 27 July; and Census Plots 65, 66, 70, and 72 were counted on 31 July and 6 August. Data are from Denlinger *et al.* (1994).

[i] The counts were made on 9 August 1995. Data are from this study.

[j] The counts were made on 28 July 1996. Data are from this study.

[k] The counts were made on 31 July 1997. Data are from this study.

[l] $\bar{x}$ = mean.

[m] SD = standard deviation.

[n] CV = coefficient of variation [standard deviation (SD) divided by the mean and multiplied by 100].

Table 3 (Continued).

[o] Census Plot 65 was counted from the beach in 1983 and 1984 and from boats in all other years.

[p] The raw mean of 2,236 for Census Plot 65 in 1983, reported by Springer *et al.* (1985d) on page 296 of OCSEAP Vol. 30, Final Report of Principal Investigators, is an error; the correct number is 2,232.

[q] Average of two counts for Census Plot 65 in 1992: (31 July 1245 hrs) A.L. Sowls = 2,375; D.G. Roseneau = 2,395; mean = 2,385; (6 August 1348 hrs) A.L. Sowls = 2,163; D.G. Roseneau = 2,120; mean = 2,142.

[r] Average of two counts for Census Plot 66 in 1992: (31 July 1350 hrs) A.L. Sowls = 1,895; D.G. Roseneau = 1,795; mean = 1,845; (6 August 1438 hrs) A.L. Sowls = 2,360; D.G. Roseneau = 2,340; mean = 2,350.

[s] Census Plot 70 was counted from the beach in 1983 and from boats in all other years.

[t] Average of two counts for Census Plot 70 in 1992: (31 July 1415 hrs) A.L. Sowls = 1,583; D.G. Roseneau = 1,610; mean = 1,597; (6 August 1455 hrs) A.L. Sowls = 1,410; D.G. Roseneau = 1,520; mean = 1,465.

[u] Average of two counts for Census Plot 72 in 1992: (31 July 1500 hrs) A.L. Sowls = 890; D.G. Roseneau = 875; mean = 883; (6 August 1545 hrs) A.L. Sowls = 640; D.G. Roseneau = 690; mean = 665.

Table 4. Counts of murres on land plots LP 1–7 at Cape Lisburne, Alaska during 1987-1997 (counts were made from land; birds were counted by 1's).

1987[a]		1992[b]		1993[c]		1995[d]		1996[d]		1997[d]	
Date	Birds	Date	Birds	Date	Birds	Date	Birds	Date	Birds	Date	Birds
14 Jul	1,399	17 Jul	2,091	21 Jul	2,102	17 Jul	2,260	10 Jul	2,589	11 Jul	3,103
16 Jul	1,408	20 Jul	2,401	26 Jul	1,915	19 Jul	2,747	14 Jul	1,954	12 Jul	2,801
18 Jul	1,488	25 Jul	1,540	28 Jul	2,965	24 Jul	2,675	20 Jul	2,483	17 Jul	2,826
21 Jul	1,278	28 Jul	2,147	1 Aug	2,468	27 Jul	2,424	27 Jul	2,498	21 Jul	3,439
28 Jul	1,723	30 Jul	2,094	2 Aug	2,028	28 Jul	2,557	31 Jul	2,168	22 Jul	2,641
30 Jul	2,205	3 Aug	1,922			29 Jul	2,658	1 Aug	1,930	24 Jul	3,268
1 Aug	2,025	4 Aug	1,927			30 Jul	2,926	8 Aug	2,834	25 Jul	2,219
4 Aug	1,868	8 Aug	1,997			5 Aug	2,786	10 Aug	3,243	30 Jul	2,747
		10 Aug	2,725			13 Aug	2,826			2 Aug	2,441
										5 Aug	3,966
$\bar{x}$[e]	1,674		2,094		2,296		2,651		2,462		2,945
SD[f]	334		330		428		208		446		512
(*n*)[g]	*(8)*		*(9)*		*(5)*		*(9)*		*(8)*		*(10)*

[a] Data are from Denlinger *et al.* (1994) and D.G Roseneau and A.L. Sowls (unpubl. data).
[b] Data are from Denlinger *et al.* (1994).
[c] Data are from A.L. Sowls (unpubl. data).
[d] Data are from this study.
[e] $\bar{x}$ = mean.
[f] SD = standard deviation.
[g] n = sample size (number of counts).

Table 5. Black-legged kittiwake hatching dates at Cape Lisburne, Alaska during 1987-1997.

Year[1]	First Hatching Date	66% Hatch Interval[2]	Estimated Peak Hatching Date[3]	Median Hatching Date
1987	22 Jul	22-31 Jul	ND[4]	29 Jul[5]
1992	~20 Jul	20 Jul - 1 Aug	ND	28 Jul
1993	ND	(by about 28 Jul)	ND	29 Jul[5]
1995	17 Jul	17-31 Jul	~27-28 Jul	26 Jul[5]
1996	(no eggs hatched)[6]	—	—	—
1997	17 Jul	17-30 Jul	~26-27 Jul	25 Jul[5]
Mean Date:	19 Jul[7]			

[1] Data are from: 1987 and 1992-1993, A.L. Sowls and D.G. Roseneau, unpubl. Data; 1995-1997, this study.

[2] The interval during which about 66% of the eggs hatched.

[3] Date when about 50% of the eggs were estimated to have hatched (estimates were based on the 66% hatch interval).

[4] ND = no data.

[5] These median dates were calculated using chick hatching ranges of more than 7 days. The hatching ranges for these years were: 1987, 10 days; 1993, 11 days; 1995, 10 days; and 1997, 8 days.

[6] In 1996, only 2 eggs were laid on the study plots, and both failed to hatch.

[7] Based on Julian dates for both leap and non-leap years.

Table 6a. Hatching and sea-going dates of thick-billed murre chicks at Cape Lisburne, Alaska, 1995-1997.[a]

Year	First Hatch Date	Median Hatch Date	First Sea-going Date	Median Sea-going Date
1995	19 Jul	27 Jul (SD = 2.4 days)[b]	14 Aug	21 Aug (SD = 2.0 days)
1996	22 Jul	3 Aug (SD = 2.2 days)	11 Aug	25 Aug (SD = 1.7 days)
1997	18 Jul	28 Jul (SD = 3.0 days)	8 Aug	20 Aug (SD = 1.2 days)

[a] All calculations were made using Julian dates that took leap years into account (1996 was a leap year). Data are from Appendices 6 and 7; plots were used as sample units.
[b] SD = standard deviation.

Table 6b. Hatching and sea-going dates of common murre chicks at Cape Lisburne, Alaska, 1995-1997.[a]

Year	First Hatch Date	Median Hatch Date	First Sea-going Date	Median Sea-going Date
1995	23 Jul	31 Jul (SD = 6.2 days)[b]	16 Aug	24 Aug
1996	27 Jul	5 Aug (SD = 5.3 days)	21 Aug	29 Aug
1997	23 Jul	30 Jul (SD = 3.6 days)	14 Aug	21 Aug

[a] All calculations were made using Julian dates that took leap years into account (1996 was a leap year). Data are from Appendices 8 and 9; nest sites were used as sample units.
[b] SD = standard deviation.

Table 7. Reproductive performance of black-legged kittiwakes at Cape Lisburne, Alaska. 1995-1997.[1]

Parameter	1995	1996	1997
Laying Success[2]	0.84	0.01	0.63
Clutch Size[3]	1.71	1.00	1.25
Nesting Success[4]	0.74	0.00	0.72
Hatching Success[5]	0.66	0.00	0.68
Chick Success[6]	0.49	0.00	0.81
Egg Success[7]	0.33	0.00	0.56
Fledging Success[8]	0.73	0.00	0.94
Reproductive Success[9]	0.54	0.00	0.67
Fledglings per Nest Start[10]	0.47	0.00	0.42
Overall Productivity[11]	0.46	0.00	0.41
Total Eggs	309	2	157
Total Plots (*n*)	*(8)*	*(8)*	*(8)*

1 Data are from Appendices 10, 11, and 12 (results using plots as sample units; i.e., "All Plots" column).
2 Number of nests with 1 or more eggs divided by number of nests.
3 Number of eggs divided by number of nests with 1 or more eggs.
4 Number of nests with 1 or more chicks divided by number of nests with 1 or more eggs.
5 Number of chicks divided by number of eggs.
6 Number of chicks fledged divided by number of chicks.
7 Number of chicks fledged divided by number of eggs.
8 Number of nests with 1 or more chicks fledged divided by number of nests with 1 or more chicks.
9 Number of nests with 1 or more chicks fledged divided by number of nests with 1 or more eggs.
10 Number of chicks fledged divided by number of nests.
11 Number of nests with 1 or more chicks fledged divided by number of nests.

Table 8. Estimated productivity of black-legged kittiwakes at Cape Lisburne, Alaska during 1976-1997 (1976-1993 estimates were typically based on data collected during the first 2 weeks of August before hatching was complete; the average date that information was last obtained in those years was 8 August—to compare 1995-1997 data with information from 1976-1993, 1995-1997 estimates were calculated from observations made as near to that date as possible—9, 11, and 8 August, respectively; see Appendices 14-16).[a]

Year	Eggs or Chicks Nest Attempt^{-1}	Eggs or Chicks Successful Nest^{-1}
1976	0.1	1.0
1977	0.6	1.1
1978	0.8	1.2
1979	1.8	1.8
1980	1.5	1.6
1981	1.3	1.7
1983	1.6	1.7
1984	<0.1	1.3
1985	0.2	1.1
1986	0.9	1.4
1987	1.2	1.4
1992	0.3[b] (0.2)	1.0[b] (1.1)
1993	0.7[c] (0.7)	1.1[c] (1.0)
1995	0.9[d] (0.7)	1.2[d] (1.2)
1996	<0.1[e] (0.0)	1.0[e] (0.0)
1997	0.6[f] (0.5)	1.1[f] (1.1)
Mean	0.8	1.3

[a] Data for 1976–1987 are from Table 5 in Byrd (1986); data for 1987 are from Table 8 in Roseneau *et al.* (1992); data for 1992 are from Denlinger *et al.* (1994); data for 1993 are from A.L. Sowls (unpubl. data); and data for 1995–1997 are from this study. Productivity is expressed as eggs or chicks per successful nest (a complete nest structure containing an egg or chick, or both, when it was examined), and eggs or chicks per nesting attempt (a nest structure to which nesting material was added during the breeding season, which may have never contained eggs, or which may have lost eggs or chicks before the nest was examined).

Table 8 (Continued).

[b] Two 1992 data points are shown for each category. Numbers listed first (0.3 and 1.0) are total numbers of eggs/chicks found in nests checked on 8 August 1992. These data are comparable to data reported from previous years. Numbers listed in parentheses (0.2 and 1.1) indicate estimated actual production of chicks based on the number of live, healthy-appearing chicks present in the nests checked on 8 August 1992 (i.e., in this case, eggs remaining in the nests were not included in the calculations because most were unlikely to hatch).

[c] Two 1993 data points are shown for each category. Numbers listed first (0.7 and 1.1) are total numbers of eggs/chicks found in nests checked on 3 August 1993. These data are comparable to data reported from previous years. Numbers listed in parentheses (0.7 and 1.0) indicate estimated actual production of chicks based on the number of live, healthy-appearing chicks present in the nests checked on 3 August 1993 (i.e., in this case, eggs remaining in the nests were not included in the calculations because most were unlikely to hatch).

[d] Two 1995 data points are shown for each category. Numbers listed first (0.9 and 1.2) are total numbers of eggs/chicks found in nests checked on 9 August 1995. These data are comparable to data reported from previous years. Numbers listed in parentheses (0.7 and 1.2) indicate estimated actual production of chicks based on the number of live, healthy-appearing chicks present in the nests checked on 9 August 1995.

[e] Two 1996 data points are shown for each category. Numbers listed first (<0.1 and 1.0) are total numbers of eggs/chicks found in nests checked on 11 August 1996. These data are comparable to data reported from previous years. Numbers listed in parentheses (0.0 and 0.0) indicate estimated actual production of chicks. Only two eggs that were unlikely to hatch were present in two nests on 11 August 1996; all other nests were still empty and falling into disrepair. In late August, a few fledglings were finally observed on First and Kittiwake beaches and in other parts of the colony; however, total numbers were too small (<20 birds) to indicate anything other than a near-complete, colony-wide breeding failure.

[f] Two 1997 data points are shown for each category. Numbers listed first (0.6 and 1.1) are total numbers of eggs/chicks found in nests checked on 8 August 1997. These data are comparable to data reported from previous years. Numbers listed in parentheses (0.5 and 1.1) indicate estimated actual production of chicks based on the number of live, healthy-appearing chicks present in the nests checked on 8 August 1997.

Table 9. Reproductive performance of murres at Cape Lisburne, Alaska during 1995-1997.[1]

Parameter	1995		1996		1997	
	COMU[2]	TBMU[3]	COMU	TBMU	COMU	TBMU
Hatching Success[4]	0.95	0.91	0.75	0.59	0.75	0.73
Fledging Success[5]	0.93	0.93	0.82	0.90	0.91	0.87
Reproductive Success[6]	0.88	0.85	0.62	0.53	0.68	0.63
Total Eggs	44	294	33	247	35	264
Total Plots (*n*)	*(2)*	*(13)*	*(2)*	*(12)*	*(2)*	*(10)*

[1] Data are from Appendices 16 and 17 (results using plots as sample units).
[2] COMU = common murre.
[3] TBMU = thick-billed murre.
[4] Chicks per egg.
[5] Fleglings per chick hatched.
[6] Fledglings per egg.

Table 10. Growth rates of black-legged kittiwake chicks during the linear phase of growth at Cape Lisburne, Alaska in 1995 and 1997 (no chicks were produced at the colony in 1996).

Chick Number	1995						Slope[a] (grams/day)
	31 Jul	4 Aug	9 Aug	15 Aug	20 Aug	25 Aug	
21	105[b]	218	340	*375*[c]	*476*		26.0
22	48	115	200	264	270	*432*	11.5
23	40	86	150	255		*402*	14.3
33	138	224	285	*404*			16.2
34	105	185	290	*374*	*400*	*487*	20.6
35A	45	118	195				16.6
35B	82	136	230	219	297	*377*	9.9
36		50	115	244	261	337	13.6
38	80	140	280	*394*			22.5
Mean							16.8
Standard Deviation							5.3

Chick Number	1997						Slope (grams/day)
	29 Jul	30 Jul	1 Aug	8 Aug	18 Aug	28 Aug	
10	56		121	221		*397*	16.1
17		45	72	177	*377*	*472*	14.8
19		60	93	261	*442*		22.8
23			58	160	*387*		14.6
33a	112		172	318	*432*		20.6
33b	81		141	234	*402*		14.9
34	126		168	347	*494*		22.7
35			46	166	*372*	*482*	17.1
Mean							18.0
Standard Deviation							3.5

[a] Slope of simple linear regression; only weights of 350 g or less (the linear phase of growth) were used to calculate slopes.
[b] Weight in grams.
[c] Italicized weights (over 350 g) were excluded from calculations.

Table 11. Weights of sea-going murre chicks at Cape Lisburne, Alaska during 1995-1997.[a]

Parameter	Common Murres 1995[b]	Common Murres 1996[c]	Common Murres 1997[d]	Thick-billed Murres 1995[b]	Thick-billed Murres 1996[c]	Thick-billed Murres 1997[e]
Mean Weight	236	220	180	226	207	193
Standard Deviation	23	19	10	28	24	31
Minimum Weight	196	186	168	156	148	152
Maximum Weight	280	240	188	290	255	234
Sample Size *(n)*	*(17)*	*(12)*	*(5)*	*(40)*	*(58)*	*(10)*

[a] Weight in grams at the time chicks jumped from nesting ledges.

[b] Chicks were captured and weighed as they jumped from nesting ledges during 20–26 August 1995; some chicks that had jumped and died shortly afterward were also collected and weighed during the same time period.

[c] Chicks were captured and weighed as they jumped from nesting ledges during 20–28 August 1996; some chicks that had jumped and died shortly afterward were also collected and weighed during 16–26 August.

[d] No live common murre chicks were captured in 1997; chicks that had jumped and died shortly afterward were collected and weighed during 17–23 August.

[e] Thick-billed murre chicks were captured and weighed as they jumped from nesting ledges during 18–22 August 1997.

Table 12. Prey species found in the stomachs of thick-billed murre (TBMU), common murre (COMU), and black-legged kittiwake (BLKI) adults collected during 11 July - 22 August 1995 at Cape Lisburne, Alaska. Values in parentheses show frequency among total number of stomachs examined, and values not in parentheses show percent frequency, numbers, and weight among stomachs containing identifiable prey items.

	TBMU		COMU		BLKI	
	n	%	*n*	%	*n*	%
Number of stomachs examined	35	(100)	14	(100)	34	(100)
Number of empty stomachs	0	(0)	1	(7)	3	(9)
Number of stomachs containing prey	35	(100)	13	(93)	31	(91)
Frequency of fish (stomachs containing prey)	28	80	11	85	30	97
Frequency of invertebrates (stomachs containing prey)	23	66	10	77	26	84
A. Frequency of Occurrence						
Capelin *(Mallotus villosus)*	2	6	0	0	1	3
Arctic cod *(Boreogadus saida)*	18	51	5	38	16	52
Saffron cod *(Eleginus gracilis)*	5	14	1	8	1	3
Unidentified cod (Gadidae)[a]	3	9	0	0	0	0
Pacific sand lance *(Ammodytes hexapterus)*	11	31	5	38	5	16
YOY sculpin (Cottidae)[b,c]	12	34	1	8	17	55
Unidentified sculpin (Cottidae)[d]	9	26	2	15	0	0
YOY flatfish (Pleuronectidae)	11	31	1	8	9	29
Unidentified fish	2	6	0	0	0	0
Mussel *(Mytilus* spp.)	0	0	0	0	1	3
Polychaete *(Nereis* spp.)	0	0	0	0	1	3
Mysid *(Neomysis rayii)*	6	17	0	0	0	0
Gammaridean amphipod (Gammaridea)	1	3	0	0	1	3
Hyperiidean amphipod *(Parathemisto libellula)*	3	9	1	8	10	32
Euphausiid *(Thysanoessa* spp.)	4	11	4	31	20	65
Pandalid shrimp *(Pandalus* spp.)	2	6	0	0	1	3
Hippolytid shrimp *(Eualus* spp.)	3	9	0	0	1	3
Unidentified shrimp	2	6	0	0	0	0
Unidentified crab (Decapoda)	3	9	0	0	1	3
Unidentified crustacean	8	23	6	46	0	0
B. Numbers of Individuals						
Total countable prey items	887	100	249	100	2,815	100
Total countable fish	340	38	40	16	651	23
Total countable invertebrates	547	62	209	84	2,164	77
Capelin *(Mallotus villosus)*	2	<1	0	0	2	<1
Arctic cod *(Boreogadus saida)*	133	15	14	6	42	1
Saffron cod *(Eleginus gracilis)*	15	2	1	<1	2	<1
Unidentified cod (Gadidae)[a]	7	1	0	0	0	0
Pacific sand lance *(Ammodytes hexapterus)*	49	6	5	2	21	1
YOY sculpin (Cottidae)[b,c]	67	8	15	6	553	20
Unidentified sculpin (Cottidae)[d]	22	2	4	2	0	0
YOY flatfish (Pleuronectidae)	44	5	1	<1	31	1
Unidentified fish	1	<1	0	0	0	0
Mussel *(Mytilus* spp.)	0	0	0	0	1[e]	<1
Polychaete *(Nereis* spp.)	0	0	0	0	2	<1

Table 12 (Continued).

	TBMU		COMU		BLKI	
	n	%	*n*	%	*n*	%
B. Numbers of Individuals (continued)						
Mysid *(Neomysis rayii)*	227	26	0	0	0	0
Gammaridean amphipod (Gammaridea)	1	<1	0	0	1	<1
Hyperiidean amphipod *(Parathemisto libellula)*	36	4	1	<1	370	13
Euphausiid *(Thysanoessa* spp.)	271	31	202	81	1,787	64
Pandalid shrimp *(Pandalus* spp.)	1	<1	0	0	1	<1
Hippolytid shrimp *(Eualus* spp.)	1	<1	0	0	1	<1
Unidentified shrimp	2[f]	<1	0	0	0	0
Unidentified crab (Decapoda)	0	0	0	0	1	<1
Unidentified crustacean	8[g]	1	6[h]	2	0	0
C. Estimated Wet Weight (g)						
Total measurable items	1,791	100	269	100	1,455	100
Total measurable fish	1,681	94	252	94	1,370	94
Total measurable invertebrates	110	6	17	6	85	6
Capelin *(Mallotus villosus)*	9	<1	0	0	6	<1
Arctic cod *(Boreogadus saida)*	1,171	65	192	72	1,027	71
Saffron cod *(Eleginus gracilis)*	58	3	5	2	6	<1
Unidentified cod (Gadidae)[a]	33	2	0	0	0	0
Pacific sand lance *(Ammodytes hexapterus)*	144	8	5	2	76	5
YOY sculpin (Cottidae)[b,c]	27	2	6	2	226	16
Unidentified sculpin (Cottidae)[d]	192	11	44	16	0	0
YOY flatfish (Pleuronectidae)	42	2	<1	<1	29	2
Unidentified fish	5	<1	<1	<1	0	0
Mussel *(Mytilus* spp.)	0	0	0	0	0[e]	0
Polychaete *(Nereis* spp.)	0	0	0	0	2	<1
Mysid *(Neomysis rayii)*	82	5	0	0	0	0
Gammaridean amphipod (Gammaridea)	<1	<1	0	0	<1	<1
Hyperiidean amphipod *(Parathemisto libellula)*	2	<1	1	<1	32	2
Euphausiid *(Thysanoessa* spp.)	20	1	16	6	31	2
Pandalid shrimp *(Pandalus* spp.)	1	<1	0	0	5	<1
Hippolytid shrimp *(Eualus* spp.)	5	<1	0	0	10	<1
Unidentified shrimp	0[f]	0	0	0	0	0
Unidentified crab (Decapoda)	0	0	0	0	5	<1
Unidentified crustacean	0[g]	0	0[h]	0	0	0

a The unidentified cod were either Pacific tomcod *(Microgadus proximus)* or polar cod *(Arctogadus glacialis)*—definitely not Arctic cod, saffron cod, or Pacific cod *(Gadus macrocephalus).*

b YOY = young-of-the-year.

c Most (if not all) of the YOY sculpin were fourhorn sculpin *(Myoxocephalus quadricornis).*

d Most of these sculpin were fourhorn sculpin *(Myoxocephalus quadricornis)*; a few may have been *Icelus* spp.

e Unweighable trace representing at least one individual present in one BLKI stomach.

f Unweighable trace representing at least two individuals present in two TBMU stomachs.

g Unweighable trace representing at least eight individuals present in eight TBMU stomachs.

h Unweighable trace representing at least six individuals present in six COMU stomachs.

Table 13. Prey species found in the stomachs of thick-billed murre (TBMU) and black-legged kittiwake (BLKI) adults collected during 5 July - 12 August 1996 at Cape Lisburne, Alaska. Values in parentheses show frequency among total number of stomachs examined, and values not in parentheses show percent frequency, numbers, and weight among stomachs containing identifiable prey items.

	TBMU		COMU[a]		BLKI	
	n	%	*n*	%	*n*	%
Number of stomachs examined	19	(100)	0	0	9	(100)
Number of empty stomachs	1	(5)	0	0	2	(22)
Number of stomachs containing prey	18	(95)	0	0	7	(78)
Frequency of fish (stomachs containing prey)	17	94	0	0	6	86
Frequency of invertebrates (stomachs containing prey)	11	61	0	0	3	43
A. Frequency of Occurrence						
Arctic cod *(Boreogadus saida)*	8	44	0	0	1	14
Saffron cod *(Eleginus gracilis)*	5	28	0	0	0	0
Unidentified cod (Gadidae)	0	0	0	0	4	57
Pacific sand lance *(Ammodytes hexapterus)*	3	17	0	0	1	14
Unidentified sculpin (Cottidae)	13	72	0	0	0	0
Longhead dab *(Limanda proboscidea)*	2	11	0	0	0	0
Unidentified squid (Cephalopoda)	1	6	0	0	0	0
Polychaete *(Nereis* spp.*)*	0	0	0	0	1	14
Mysid *(Neomysis rayii)*	7	39	0	0	1	14
Gammaridean amphipod (Gammaridea)	1	6	0	0	0	0
Hyperiidean amphipod *(Parathemisto libellula)*	1	6	0	0	0	0
Euphausiid *(Thysanoessa* spp.*)*	2	11	0	0	0	0
Pandalid shrimp *(Pandalus* spp.*)*	2	11	0	0	0	0
Crangonid shrimp *(Sclerocrangon* spp.*)*	4	22	0	0	1	14
Unidentified crustacean	1	6	0	0	0	0
B. Numbers of Individuals						
Total countable prey items	349	100	0	0	43	100
Total countable fish	77	22	0	0	11	26
Total countable invertebrates	272	78	0	0	32	74
Arctic cod *(Boreogadus saida)*	26	7	0	0	4	9
Saffron cod *(Eleginus gracilis)*	11	3	0	0	0	0
Unidentified cod (Gadidae)	0	0	0	0	6	14
Pacific sand lance *(Ammodytes hexapterus)*	5	1	0	0	1	2
Unidentified sculpin (Cottidae)	33	9	0	0	0	0
Longhead dab *(Limanda proboscidea)*	2	1	0	0	0	0
Unidentified squid (Cephalopoda)	1	<1	0	0	0	0
Polychaete *(Nereis* spp.*)*	0	0	0	0	1	2
Mysid *(Neomysis rayii)*	130	37	0	0	30	70
Gammaridean amphipod (Gammaridea)	1	<1	0	0	0	0
Hyperiidean amphipod *(Parathemisto libellula)*	1	<1	0	0	0	0
Euphausiid *(Thysanoessa* spp.*)*	129	37	0	0	0	0
Pandalid shrimp *(Pandalus* spp.*)*	2	1	0	0	0	0
Crangonid shrimp *(Sclerocrangon* spp.*)*	7	2	0	0	1	2
Unidentified crustacean	1[b]	<1	0	0	0	0

Table 13 (Continued).

	TBMU		COMU[a]		BLKI	
	n	%	*n*	%	*n*	%
C. Estimated Wet Weight (g)						
Total measurable items	1,167	100	0	0	296	100
Total measurable fish	1,086	93	0	0	281	95
Total measurable invertebrates	81	7	0	0	15	5
Arctic cod *(Boreogadus saida)*	701	60	0	0	84	28
Saffron cod *(Eleginus gracilis)*	89	8	0	0	0	0
Unidentified cod (Gadidae)	0	0	0	0	196	66
Pacific sand lance *(Ammodytes hexapterus)*	11	1	0	0	1	<1
Unidentified sculpin (Cottidae)	274	23	0	0	0	0
Longhead dab *(Limanda proboscidea)*	10	1	0	0	0	0
Unidentified squid (Cephalopoda)	3	<1	0	0	0	0
Polychaete *(Nereis* spp.*)*	0	0	0	0	1	<1
Mysid *(Neomysis rayii)*	47	4	0	0	11	4
Gammaridean amphipod (Gammaridea)	<1	<1	0	0	0	0
Hyperiidean amphipod *(Parathemisto libellula)*	<1	<1	0	0	0	0
Euphausiid *(Thysanoessa* spp.*)*	6	1	0	0	0	0
Pandalid shrimp *(Pandalus* spp.*)*	1	<1	0	0	0	0
Crangonid shrimp *(Sclerocrangon* spp.*)*	23	2	0	0	3	1
Unidentified crustacean	0[b]	0	0	0	0	0

a No adult common murres (COMU) were collected at Cape Lisburne in 1996.
b Unweighable trace representing at least one individual present in one TBMU stomach.

Table 14. Prey species found in the stomachs of thick-billed murre (TBMU), common murre (COMU), and black-legged kittiwake (BLKI) adults collected on 30 June and 4 July 1997 at Cape Lisburne, Alaska. All of the murres were obtained on 4 July. Values in parentheses show frequency among total number of stomachs examined, and values not in parentheses show percent frequency, numbers, and weight among stomachs containing identifiable prey items.

	TBMU		COMU		BLKI	
	n	%	*n*	%	*n*	%
Number of stomachs examined	20	(100)	8	(100)	1	(100)
Number of empty stomachs	2	(10)	0	(0)	0	(0)
Number of stomachs containing prey	18	(90)	8	(100)	1	(100)
Frequency of fish (stomachs containing prey)	17	94	7	88	1	100
Frequency of invertebrates (stomachs containing prey)	12	67	7	88	0	0
A. Frequency of Occurrence						
Capelin *(Mallotus villosus)*	1	6	2	25	0	0
Pacific herring *(Clupea harengus pallasi)*	0	0	1	13	0	0
Arctic cod *(Boreogadus saida)*	4	22	5	63	0	0
Saffron cod *(Eleginus gracilis)*	2	11	2	25	0	0
Walleye pollock *(Theragra chalcogramma)*	0	0	1	13	0	0
Unidentifed cod (Gadidae)	0	0	0	0	1	100
Sand lance *(Ammodytes hexapterus)*	2	11	2	25	0	0
Sculpin (Cottidae) [a]	14	78	0	0	0	0
Flatfish (Pleuronectidae)	1	6	1	13	0	0
Unidentified fish	2	11	3	38	0	0
Polychaete *(Nereis* spp.*)*	1	6	0	0	0	0
Amphipod *(Orchomene spp.)*	1	6	0	0	0	0
Pandalid shrimp *(Pandalus* spp.*)*	1	6	0	0	0	0
Hippolytid shrimp *(Lebbeus groenlandicus)*	4	22	0	0	0	0
Hippolytid shrimp *(Heptacarpus moseri)*	1	6	0	0	0	0
Unidentified shrimp	1	6	0	0	0	0
Euphausiid *(Thysanoessa* spp.*)*	0	0	1	13	0	0
Mysid *(Neomysis rayii)*	5	28	2	25	0	0
Unidentified crustacean	4	22	4	50	0	0
B. Numbers of Individuals						
Total countable prey items	122	100	264	100	1	100
Total countable fish	63	52	57	22	1	100
Total countable invertebrates	59	48	207	78	0	0
Capelin *(Mallotus villosus)*	1	1	3	1	0	0
Pacific herring *(Clupea harengus pallasi)*	0	0	1	<1	0	0
Arctic cod *(Boreogadus saida)*	12	10	19	7	0	0
Saffron cod *(Eleginus gracilis)*	2	2	3	1	0	0
Walleye pollock *(Theragra chalcogramma)*	0	0	1	<1	0	0
Unidentifed cod (Gadidae)	0	0	0	0	1	100
Sand lance *(Ammodytes hexapterus)*	22	18	25	9	0	0
Sculpin (Cottidae) [a]	21	17	0	0	0	0
Flatfish (Pleuronectidae)	3	2	1	<1	0	0
Unidentified fish	2	2	4	2	0	0
Polychaete *(Nereis* spp.*)*	1	<1	0	0	0	0
Amphipod *(Orchomene spp.)*	1	<1	0	0	0	0

Table 14 (Continued).

	TBMU		COMU		BLKI	
	n	%	*n*	%	*n*	%
B. Numbers of Individuals (continued)						
Pandalid shrimp *(Pandalus* spp.*)*	6	5	0	0	0	0
Hippolytid shrimp *(Lebbeus groenlandicus)*	5	4	0	0	0	0
Hippolytid shrimp *(Heptacarpus moseri)*	3	2	0	0	0	0
Unidentified shrimp	1	<1	1	<1	0	0
Euphausiid *(Thysanoessa* spp.*)*	0	0	160	61	0	0
Mysid *(Neomysis rayii)*	38	31	42	16	0	0
Unidentified crustacean	4	3	4	2	0	0
C. Estimated Wet Weight (g)						
Total measurable items	215	100	412	100	50	100
Total measurable fish	195	91	394	96	50	100
Total measurable invertebrates	20	9	18	4	0	0
Capelin *(Mallotus villosus)*	4	2	8	2	0	0
Pacific herring *(Clupea harengus pallasi)*	0	0	1	<1	0	0
Arctic cod *(Boreogadus saida)*	88	41	301	73	0	0
Saffron cod *(Eleginus gracilis)*	9	4	22	5	0	0
Walleye pollock *(Theragra chalcogramma)*	0	0	7	2	0	0
Unidentifed cod (Gadidae)	0	0	0	0	50	100
Sand lance *(Ammodytes hexapterus)*	25	12	51	12	0	0
Sculpin (Cottidae) [a]	67	31	0	0	0	0
Flatfish (Pleuronectidae)	1	<1	<1	<1	0	0
Unidentified fish	1	<1	<1	<1	0	0
Polychaete *(Nereis* spp.*)*	<1	<1	0	0	0	0
Amphipod *(Orchomene spp.)*	<1	<1	0	0	0	0
Pandalid shrimp *(Pandalus* spp.*)*	4	2	0	0	0	0
Hippolytid shrimp *(Lebbeus groenlandicus)*	4	2	0	0	0	0
Hippolytid shrimp *(Heptacarpus moseri)*	4	2	0	0	0	0
Unidentified shrimp	0[b]	0	0	0	0	0
Euphausiid *(Thysanoessa* spp.*)*	0	0	10	2	0	0
Mysid *(Neomysis rayii)*	8	4	8	2	0	0
Unidentified crustacean	0[b]	0	0	0	0	0

[a] Most of these sculpin were fourhorn sculpin *(Myoxocephalus quadricornis)*; a few may have been *Icelus* spp.

[b] Unweighable trace representing at least one individual present in four TBMU stomachs.

Table 15. Prey species found in the stomachs of thick-billed murre (TBMU), common murre (COMU), and black-legged kittiwake (BLKI) adults collected on 22 July and 3 August 1987 at Cape Lisburne, Alaska. Values in parentheses show frequency among total number of stomachs examined, and values not in parentheses show percent frequency, numbers, and weight among stomachs containing identifiable prey items.

	TBMU		COMU		BLKI	
	n	%	*n*	%	*n*	%
Number of stomachs examined	11	(100)	5	(100)	13	(100)
Number of empty stomachs	0	(0)	0	(0)	0	(0)
Number of stomachs containing prey	11	(100)	5	(100)	13	(100)
Frequency of fish (stomachs containing prey)	11	100	5	100	12	100
Frequency of invertebrates (stomachs containing prey)	4	36	0	0	0	0
A. Frequency of Occurrence						
Capelin *(Mallotus villosus)*	2	18	2	40	0	0
Arctic cod *(Boreogadus saida)*	2	18	2	40	2	17
Saffron cod *(Eleginus gracilis)*	0	0	4	80	1	8
Unidentified prickleback (Stichaeidae)	0	0	1	20	0	0
Pacific sand lance *(Ammodytes hexapterus)*	7	64	4	80	5	42
YOY sculpin (Cottidae)[a]	4	36	2	40	3	25
Unidentified sculpin (Cottidae)	3	27	0	0	0	0
YOY flatfish (Pleuronectidae)	2	18	1	20	0	0
Unidentified fish	0	0	0	0	2	17
Unidentified euphausiid (Euphausiacea)	1	9	0	0	0	0
Unidentified shrimp	3	27	0	0	0	0
B. Numbers of Individuals						
Total countable prey items	395	100	78	100	80	100
Total countable fish	391	99	78	100	80	100
Total countable invertebrates	4	1	0	0	0	0
Capelin *(Mallotus villosus)*	14	4	5	6	0	0
Arctic cod *(Boreogadus saida)*	2	<1	10	13	6	8
Saffron cod *(Eleginus gracilis)*	0	0	12	15	1	1
Unidentified prickleback (Stichaeidae)	0	0	1	1	0	0
Pacific sand lance *(Ammodytes hexapterus)*	100	25	22	28	23	29
YOY sculpin (Cottidae)[a]	183	46	26	33	48	60
Unidentified sculpin (Cottidae)	7	2	0	0	0	0
YOY flatfish (Pleuronectidae)	85	22	2	3	0	0
Unidentified fish	0	0	0	0	2	3
Unidentified euphausiid (Euphausiacea)	1	<1	0	0	0	0
Unidentified shrimp	3	<1	0	0	0	0
C. Estimated Wet Weight (g)						
Total measurable items	595	100	310	100	208	100
Total measurable fish	593	>99	310	100	208	100
Total measurable invertebrates	2	<1	0	0	0	0
Capelin *(Mallotus villosus)*	7	1	35	11	0	0
Arctic cod *(Boreogadus saida)*	34	6	76	25	81	39
Saffron cod *(Eleginus gracilis)*	0	0	82	27	1	<1

Table 15 (Continued).

	TBMU		COMU		BLKI	
	n	%	*n*	%	*n*	%
C. Estimated Wet Weight (g) (continued)						
Unidentified prickleback (Stichaeidae)	0	0	8	3	0	0
Pacific sand lance *(Ammodytes hexapterus)*	376	63	93	30	102	49
YOY sculpin (Cottidae)[a]	92	15	13	4	24	12
Unidentified sculpin (Cottidae)	41	7	0	0	0	0
YOY flatfish (Pleuronectidae)	43	7	3	<1	0	0
Unidentified fish	0	0	0	0	<1	<1
Unidentified euphausiid (Euphausiacea)	1	<1	0	0	0	0
Unidentified shrimp	1	<1	0	0	0	0

a YOY = young-of-the-year.

Table 16. Prey species found in the stomachs of thick-billed murre (TBMU), common murre (COMU), and black-legged kittiwake (BLKI) adults collected on 22 and 24 July 1992 at Cape Lisburne, Alaska. Values in parentheses show frequency among total number of stomachs examined, and values not in parentheses show percent frequency, numbers, and weight among stomachs containing identifiable prey items.

	TBMU		COMU		BLKI	
	n	%	*n*	%	*n*	%
Number of stomachs examined	19	(100)	10	(100)	10	(100)
Number of empty stomachs	6	(32)	3	(30)	2	(20)
Number of stomachs containing prey	13	(68)	7	(70)	8	(80)
Frequency of fish (stomachs containing prey)	8	62	6	86	8	100
Frequency of invertebrates (stomachs containing prey)	6	46	1	14	2	25
A. Frequency of Occurrence						
Arctic cod *(Boreogadus saida)*	4	31	4	57	5	63
Pacific sand lance *(Ammodytes hexapterus)*	0	0	2	29	0	0
Unidentified sculpin (Cottidae)	1	8	0	0	0	0
YOY flatfish (Pleuronectidae)	0	0	1	14	0	0
Unidentified fish	3	23	1	14	3	38
Unidentified polychaete (Polychaeta)	0	0	0	0	1	13
Unidentified euphausiid (Euphausiacea)	6	46	1	14	1	13
Unidentified crab (Decapoda)	0	0	0	0	1	13
B. Numbers of Individuals						
Total countable prey items	272	100	47	100	20	100
Total countable fish	13	5	47	100	17	85
Total countable invertebrates	259	95	0	0	3	15
Arctic cod *(Boreogadus saida)*	6	2	35	74	14	70
Pacific sand lance *(Ammodytes hexapterus)*	0	0	2	4	0	0
Unidentified sculpin (Cottidae)	4	1	0	0	0	0
YOY flatfish (Pleuronectidae)	0	0	9	19	0	0
Unidentified fish	3[b]	1	1[c]	2	3[b]	15
Unidentified polychaete (Polychaeta)	0	0	0	0	1	5
Unidentified euphausiid (Euphausiacea)	259[d]	95	0	0	1[c]	5
Unidentified crab (Decapoda)	0	0	0	0	1	5
C. Estimated Wet Weight (g)						
Total measurable items	110	100	464	100	405	100
Total measurable fish	91	83	464	100	403	100
Total measurable invertebrates	19	17	0[c]	0	2	<1
Arctic cod *(Boreogadus saida)*	51	46	452	97	403	100
Pacific sand lance *(Ammodytes hexapterus)*	0	0	7	2	0	0
Unidentified sculpin (Cottidae)	40	36	0	0	0	0
YOY flatfish (Pleuronectidae)	0	0	5	1	0	0
Unidentified fish	0[b]	0	0[c]	0	0[b]	0

Table 16 (Continued).

	TBMU		COMU		BLKI	
	n	%	*n*	%	*n*	%
C. Estimated Wet Weight (g) (continued)						
Unidentified polychaete (Polychaeta)	0	0	0	0	0[c]	0
Unidentified euphausiid (Euphausiacea)	19	17	0[c]	0	1	<1
Unidentified crab (Decapoda)	0	0	0	0	1	<1

a YOY = young-of-the-year.
b Unweighable traces representing at least three individuals present in three TBMU and three BLKI stomachs.
c Unweighable traces representing at least two individuals present in one COMU and one BLKI stomach.
d The remains of 254 euphausiids were found in one TBMU stomach, and unweighable traces representing a total of at least five more euphausiids were present in five other TBMU stomachs.

Table 17. Prey species found in the stomachs of thick-billed murre (TBMU), common murre (COMU), and black-legged kittiwake (BLKI) adults collected on 28 July 1993 at Cape Lisburne, Alaska. Values in parentheses show frequency among total number of stomachs examined, and values not in parentheses show percent frequency, numbers, and weight, among stomachs containing identifiable prey items.

	TBMU		COMU		BLKI	
	n	%	*n*	%	*n*	%
Number of stomachs examined	4	(100)	3	(100)	10	(100)
Number of empty stomachs	0	(0)	0	(0)	0	(0)
Number of stomachs containing prey	4	(100)	3	(100)	10	(100)
Frequency of fish (stomachs containing prey)	4	100	3	100	10	100
Frequency of invertebrates (stomachs containing prey)	0	0	1	33	0	0
A. Frequency of Occurrence						
Rainbow smelt *(Osmerus mordax)*	0	0	1	33	0	0
Arctic cod *(Boreogadus saida)*	2	50	3	100	4	40
Saffron cod *(Eleginus gracilis)*	1	25	1	33	1	10
YOY cod (Gadidae)[a]	1	25	2	67	0	0
Unidentified cod (Gadidae)[b]	0	0	1	33	0	0
Prickleback *(Lumpenus* spp.*)*	1	25	0	0	0	0
Pacific sand lance *(Ammodytes hexapterus)*	0	0	2	67	5	50
YOY sculpin (Cottidae)	2	50	2	67	3	30
Unidentified sculpin (Cottidae)	2	50	0	0	0	0
YOY flatfish (Pleuronectidae)	1	25	2	67	0	0
Unidentified flatfish (Pleuronectidae)	1	25	1	33	1	10
Unidentified fish	1	25	1	33	2	20
Hippolytid shrimp *(Eualus* spp.*)*	0	0	1	33	0	0
B. Numbers of Individuals						
Total countable prey items	87	100	66	100	75	100
Total countable fish	87	100	65	98	75	100
Total countable invertebrates	0	0	1	2	0	0
Rainbow smelt *(Osmerus mordax)*	0	0	1	2	0	0
Arctic cod *(Boreogadus saida)*	8	9	18	27	32	43
Saffron cod *(Eleginus gracilis)*	1	1	2	3	2	3
YOY cod (Gadidae)[a]	9	10	2	3	0	0
Unidentified cod (Gadidae)[b]	0	0	1	2	0	0
Prickleback *(Lumpenus* spp.*)*	1	1	0	0	0	0
Pacific sand lance *(Ammodytes hexapterus)*	0	0	5	8	26	35
YOY sculpin (Cottidae)	13	15	17	26	11	15
Unidentified sculpin (Cottidae)	38	44	0	0	0	0
YOY flatfish (Pleuronectidae)	15	17	15	23	0	0
Unidentified flatfish (Pleuronectidae)	1	1	0	0	2	3
Unidentified fish	1	1	4	6	2[c]	3
Hippolytid shrimp *(Eualus* spp.*)*	0	0	1[d]	2	0	0

Table 17 (Continued).

	TBMU		COMU		BLKI	
	n	%	*n*	%	*n*	%
C. Estimated Wet Weight (g)						
Total measurable items	432	100	339	100	1,168	100
Total measurable fish	432	100	339	100	1,168	100
Total measurable invertebrates	0	0	0[d]	0	0	0
Rainbow smelt *(Osmerus mordax)*	0	0	2	1	0	0
Arctic cod *(Boreogadus saida)*	207	48	226	67	461	39
Saffron cod *(Eleginus gracilis)*	5	1	1	<1	1	<1
YOY cod (Gadidae)[a]	9	2	3	1	0	0
Unidentified cod (Gadidae)[b]	0	0	5	1	0	0
Prickleback *(Lumpenus* spp.)	3	1	0	0	0	0
Pacific sand lance *(Ammodytes hexapterus)*	0	0	68	20	683	58
YOY sculpin (Cottidae)	7	2	9	3	16	1
Unidentified sculpin (Cottidae)	174	40	0	0	0	0
YOY flatfish (Pleuronectidae)	8	2	8	2	0	0
Unidentified flatfish (Pleuronectidae)	15	3	0	0	7	1
Unidentified fish	5	1	20	6	0[c]	0
Hippolytid shrimp *(Eualus* spp.)	0	0	0[d]	0	0	0

a YOY = young-of-the-year.
b The unidentified cod were either Pacific tomcod *(Microgadus proximus)* or polar cod *(Arctogadus glacialis)*—definitely not Arctic cod, saffron cod, or Pacific cod *(Gadus macrocephalus)*.
c Unweighable trace representing at least two individuals present in two BLKI stomachs.
d Unweighable trace representing at least one individual present in one COMU stomach.

Table 18. Prey species found in the stomachs of thick-billed murre (TBMU), common murre (COMU), and black-legged kittiwake (BLKI) chicks salvaged during 4-26 August 1995 at Cape Lisburne, Alaska. Values in parentheses show frequency among total number of stomachs examined, and values not in parentheses show percent frequency, numbers, and weight, among stomachs containing identifiable prey items.

	TBMU		COMU		BLKI[1]	
	n	%	*n*	%	*n*	%
Number of stomachs examined	22	(100)	3	(100)	5	(100)
Number of empty stomachs	3	(14)	1	(33)	1	(20)
Number of stomachs containing prey	19	(86)	2	(67)	4	(80)
Frequency of fish (stomachs containing prey)	19	100	2	100	4	100
Frequency of invertebrates (stomachs containing prey)	0	0	0	0	1	25
A. Frequency of Occurrence						
Arctic cod *(Boreogadus saida)*	13	68	1	50	0	0
Unidentified cod (Gadidae)[2]	1	5	0	0	0	0
Unidentified prickleback (Stichaeidae)	1	5	0	0	0	0
Pacific sand lance *(Ammodytes hexapterus)*	4	21	2	100	3	75
YOY sculpin (Cottidae)[3,4]	0	0	0	0	1	25
Unidentified sculpin (Cottidae)[5]	7	37	0	0	0	0
YOY flatfish (Pleuronectidae)	1	5	0	0	0	0
Unidentified fish	1	5	0	0	0	0
Hyperiidean amphipod *(Parathemisto libellula)*	0	0	0	0	1	25
Euphausiid *(Thysanoessa* spp.*)*	0	0	0	0	1	25
B. Numbers of Individuals						
Total countable prey items	43	100	4	100	27	100
Total countable fish	43	100	4	100	21	78
Total countable invertebrates	0	0	0	0	6	22
Arctic cod *(Boreogadus saida)*	25	58	2	50	0	0
Unidentified cod (Gadidae)[2]	1	2	0	0	0	0
Unidentified prickleback (Stichaeidae)	2	5	0	0	0	0
Pacific sand lance *(Ammodytes hexapterus)*	4	9	2	50	6	22
YOY sculpin (Cottidae)[3,4]	0	0	0	0	15	56
Unidentified sculpin (Cottidae)[5]	9	21	0	0	0	0
YOY flatfish (Pleuronectidae)	1	2	0	0	0	0
Unidentified fish	1	2	0	0	0	0
Hyperiidean amphipod *(Parathemisto libellula)*	0	0	0	0	3	11
Euphausiid *(Thysanoessa* spp.*)*	0	0	0	0	3	11
C. Estimated Wet Weight (g)						
Total measurable items	548	100	37	100	21	100
Total measurable fish	548	100	37	100	21	100
Total measurable invertebrates	0	0	0	0	<1	<5
Arctic cod *(Boreogadus saida)*	453	83	33	89	0	0
Unidentified cod (Gadidae)[2]	5	1	0	0	0	0
Unidentified prickleback (Stichaeidae)	16	3	0	0	0	0
Pacific sand lance *(Ammodytes hexapterus)*	14	3	4	11	15	71

Table 18 (Continued).

	TBMU		COMU		BLKI[1]	
	n	%	*n*	%	*n*	%
C. Estimated Wet Weight (g) (continued)						
YOY sculpin (Cottidae)[3,4]	0	0	0	0	6	29
Unidentified sculpin (Cottidae)[5]	55	10	0	0	0	0
YOY flatfish (Pleuronectidae)	<1	<1	0	0	0	0
Unidentified fish	5	1	0	0	0	0
Hyperiidean amphipod *(Parathemisto libellula)*	0	0	0	0	<1	<5
Euphausiid *(Thysanoessa* spp.*)*	0	0	0	0	<1	<5

1 The five BLKI samples consisted of two stomachs from chicks that were found dead and regurgitations from three live chicks. One salvaged stomach was empty and the other contained three Pacific sand lance that weighed a total of 3 g.
2 The unidentified cod were either Pacific tomcod *(Microgadus proximus)* or polar cod *(Arctogadus glacialis)*—definitely not Arctic cod, saffron cod *(Eleginus gracilis)*, or Pacific cod *(Gadus macrocephalus)*.
3 YOY = young-of-the-year.
4 Most, if not all, YOY sculpin were fourhorn sculpin *(Myoxocephalus quadricornis)*.
5 Most of the sculpin were fourhorn sculpin *(Myoxocephalus quadricornis)*, but a few may have been *Icelus* spp.

Table 19. Prey species found in the stomachs of thick-billed murre (TBMU) and common murre (COMU) chicks salvaged during 15-27 August 1996 at Cape Lisburne, Alaska. Values in parentheses show frequency among total number of stomachs examined, and values not in parentheses show percent frequency, numbers, and weight among stomachs containing identifiable prey items.

	TBMU		COMU		BLKI[1]	
	n	%	*n*	%	*n*	%
Number of stomachs examined	27	(100)	6	(100)	0	0
Number of empty stomachs	4	(15)	1	(17)	0	0
Number of stomachs containing prey	23	(85)	5	(83)	0	0
Frequency of fish (stomachs containing prey)	23	100	5	100	0	0
Frequency of invertebrates (stomachs containing prey)	0	0	0	0	0	0
A. Frequency of Occurrence						
Arctic cod *(Boreogadus saida)*	8	35	0	0	0	0
Unidentified cod (Gadidae)	4	17	2	40	0	0
Pacific sand lance *(Ammodytes hexapterus)*	11	48	4	80	0	0
Unidentified sculpin (Cottidae)	2	9	0	0	0	0
Unidentified fish	3	13	0	0	0	0
B. Numbers of Individuals						
Total countable prey items	33	100	7	100	0	0
Total countable fish	33	100	7	100	0	0
Total countable invertebrates	0	0	0	0	0	0
Arctic cod *(Boreogadus saida)*	8	24	0	0	0	0
Unidentified cod (Gadidae)	5	15	2	29	0	0
Pacific sand lance *(Ammodytes hexapterus)*	15	45	5	71	0	0
Unidentified sculpin (Cottidae)	2	6	0	0	0	0
Unidentified fish	3	9	0	0	0	0
C. Estimated Wet Weight (g)						
Total measurable items	252	100	45	100	0	0
Total measurable fish	252	100	45	100	0	0
Total measurable invertebrates	0	0	0	0	0	0
Arctic cod *(Boreogadus saida)*	152	60	0	0	0	0
Unidentified cod (Gadidae)	50	20	33	73	0	0
Pacific sand lance *(Ammodytes hexapterus)*	44	17	12	27	0	0
Unidentified sculpin (Cottidae)	4	2	0	0	0	0
Unidentified fish	2	1	0	0	0	0

[1] No black-legged kittiwake (BLKI) chicks were salvaged at Cape Lisburne in 1996.

Table 20. Prey species found in the stomachs of thick-billed murre (TBMU), common murre (COMU), and black-legged kittiwake chicks salvaged during 20 July - 29 August 1997 at Cape Lisburne, Alaska. Values in parentheses show frequency among total number of stomachs examined, and values not in parentheses show percent frequency, numbers, and weight among stomachs containing identifiable prey items.

	TBMU		COMU		BLKI	
	n	%	*n*	%	*n*	%
Number of stomachs examined	31	(100)	6	(100)	6	100
Number of empty stomachs	22	(71)	4	(67)	1	17
Number of stomachs containing prey	9	(29)	2	(33)	5	(83)
Frequency of fish (stomachs containing prey)	8	89	2	100	5	100
Frequency of invertebrates (stomachs containing prey)	0	0	0	0	0	0
A. Frequency of Occurrence						
Arctic cod *(Boreogadus saida)*	2	22	0	0	2	40
Saffron cod *(Eleginus gracilis)*	0	0	0	0	1	20
Unidentified cod (Gadidae)	2	22	0	0	1	20
Pacific sand lance *(Ammodytes hexapterus)*	0	0	0	0	2	40
Unidentified sculpin (Cottidae)	1	11	0	0	0	0
Flatfish (Pleuronectidae)	1	11	0	0	0	0
Unidentified fish	4	44	2	100	0	0
B. Numbers of Individuals						
Total countable prey items	47	100	2	100	11	0
Total countable fish	47	100	2	100	11	0
Total countable invertebrates	0	0	0	0	0	0
Arctic cod *(Boreogadus saida)*	4	9	0	0	3	27
Saffron cod *(Eleginus gracilis)*	2	4	0	0	1	9
Unidentified cod (Gadidae)	0	0	0	0	1	9
Pacific sand lance *(Ammodytes hexapterus)*	0	0	0	0	4	36
Unidentified sculpin (Cottidae)	31	66	0	0	2	18
Flatfish (Pleuronectidae)	3	6	0	0	0	0
Unidentified fish	7	15	2	100	0	0
C. Estimated Wet Weight (g)[1]						
Total measurable items	3	100	0	0	0	0
Total measurable fish	3	100	0	0	0	0
Total measurable invertebrates	0	0	0	0	0	0
Arctic cod *(Boreogadus saida)*	0	0	0	0	0	0
Saffron cod *(Eleginus gracilis)*	0	0	0	0	0	0
Unidentified cod (Gadidae)	0	0	0	0	0	0
Pacific sand lance *(Ammodytes hexapterus)*	0	0	0	0	0	0
Unidentified sculpin (Cottidae)	0	0	0	0	0	0
Flatfish (Pleuronectidae)	2	100	0	0	0	0
Unidentified fish	0	0	0	0	0	0

[1] With the exception of three flatfish otoliths found in one TBMU chick stomach, otoliths were too eroded to age fish, and as a result, it was impossible to use regression equations to estimate fish weights (otoliths were eroded because almost all of the chicks remained alive for 2-3 days at sea or on the beaches before they died and were salvaged).

Table 21a. Prey species delivered to thick-billed murre (TBMU) chicks at Cape Lisburne, Alaska in 1995-1997.

	1995		1996		1997	
	n	%	*n*	%	*n*	%
Number of identifiable prey items	33	100	40	100	11	100
Number of fish	30	91	40	100	11	100
Number of invertebrates	3	9	0	0	0	0
Number of Individuals						
Capelin *(Mallotus villosus)*	0	0	2	5	0	0
Arctic cod *(Boreogadus saida)*	4	12	5	13	6	55
Unidentified cod (Gadidae)	0	0	1	3	0	0
Pacific sand lance *(Ammodytes hexapterus)*	21	64	30	75	4	36
Arctic shanny *(Stichaeus punctatus)*	0	0	2	5	1	9
Unidentified prickleback (Stichaeidae)	4	12	0	0	0	0
Unidentified sculpin (Cottidae)	1	3	0	0	0	0
Unidentified shrimp	3	9	0	0	0	0

Table 21b. Prey species delivered to common murre (COMU) chicks at Cape Lisburne, Alaska in 1995-1997.

	1995		1996		1997	
	n	%	*n*	%	*n*	%
Number of identifiable prey items	66	100	38	100	6	100
Number of fish	66	100	38	100	6	100
Number of invertebrates	0	0	0	0	0	0
Number of Individuals						
Capelin *(Mallotus villosus)*	0	0	3	8	0	0
Rainbow smelt *(Osmerus mordax)*	1	2	1	5	0	0
Arctic cod *(Boreogadus saida)*	9	14	9	24	3	50
Saffron cod *(Eleginus gracilis)*	0	0	2	5	0	0
Unidentified cod (Gadidae)	0	0	2	5	0	0
Pacific sand lance *(Ammodytes hexapterus)*	46	70	21	55	3	50
Unidentified prickleback (Stichaeidae)	10	15	0	0	0	0

Table 22. Daily mean sea-surface temperatures measured by hand-held thermometers during 23–28 July at Cape Lisburne, Alaska, 1987–1997 (data are from Appendix 18).

Date	Year					
	1987	1992	1993	1995	1996	1997
23 Jul	8.0°	ND	8.9°	5.0°	8.0°	8.4°
24 Jul	ND	5.1°	ND	5.5°	8.0°	8.1°
25 Jul	ND	7.0°	11.7°	6.5°	7.3°	8.5°
26 Jul	9.0°	ND	7.8°	6.5°	7.3°	8.7°
27 Jul	9.0°	6.5°	11.1°	5.5°	7.5°	8.3°
28 Jul	ND	6.3°	10.6°	5.5°	7.1°	8.9°
Mean	8.7°	6.2°	10.0°	5.8°	7.5°	8.5°
Standard Deviation	0.6°	0.8°	1.6°	0.6°	0.4°	0.3°
Minimum Daily Temperature	8.0°	5.1°	7.8°	5.0°	7.1°	8.1°
Maximum Daily Temperature	9.0°	7.0°	11.7°	6.5°	8.0°	8.9°
Sample Size (*n*)[1]	*(3)*	*(4)*	*(5)*	*(6)*	*(6)*	*(6)*

[1] Number of days sea-surface temperature measurements were taken.

Table 23. Counts of black-legged kittiwakes at Colony 4, Cape Thompson, Alaska during 1960-1995 (counts were made from boats; most birds were counted by 1's).

	Year												
	1960[a]	1976[b]	1977[c]	1978[d]	1979[e]	1982[f]	1988[g]	1990[h]		1995[i]			
Plot	Cnt 1[l]	Cnt 1	Cnt 1	Cnt 1	Cnt 1	Cnt 1	Cnt 1	Cnt 1	Cnt 2	Cnt 1	$\bar{x}$	SD[j]	CV (%)[k]
4A	472	121		249	156	285	219	516	492	118	292	161	55
4B	614	80		284	368	325	414	397	396	237	346	145	42
4A+4B			430								430	—	—
4C	750	266	289	383	326[m]	405	125	449	742	164	390	213	55
4D	76	15		22	0[n]	56	14	71	85		42	33	77
4E	1,128	265		479	366	512	559	750	799		607	276	45
4D+4E			404							299	352	74	21
4F		79		175	170	245	195		315	154	190	74	39
4G		155		380	375	406	440		734	236	389	183	47
4F+4G	894[o]		421					1,049			788	327	42
4H	224	107	284	177	144	134	130	270	291	112	187	73	39
4I	506	146	102	324	345	395	285	508	437	213	326	141	43
4J	328	96		101	116	134	76	153	131	81	135	77	57
4K	292	87		105	185	166	122	224	186	135	167	64	38
4L	410	69		198	185	233	146	324	284	152	222	104	47
4J+4K+ 4L+4O			293								293	—	—
4M	170	50		125	116	123	65	165	129	72	113	42	37
4N	298	75		174	176	219	140	292	316	146	204	83	41
4O	16	11		28	50	48	25	90	116	24	45	36	80
4P	86	27		80	89	109	83	173	132	76	95	41	43
4Q	0	0		4	9	10	17	60	41	16	17	20	118
4R	0	0		2	2	0	6	7	2	2	2	3	150
4M+4N+ 4P+4R			238								238	—	—
Total	6,264	1,649	2,461	3,290	3,178	3,805	3,061	5,503	5,628	2,237			
								(mean = 5,566)					

[a] The count was made on 15 July. Data are from Fadely *et al.* (1989) and L.G. Swartz's original field notes.

Table 23 (Continued).

[b] The count was made on 9 August. Data are from Springer and Roseneau (1977), Fadely *et al.* (1989), and A.M. Springer's and D.G. Roseneau's original field data summary sheets.

[c] The count was made on 18-19 August. Data are from Springer and Roseneau et al. (1978), Fadely *et al.* (1989), and D.G. Roseneau's original field notebook [numbers reported here differ slightly from those reported in Fadely *et al.* (1989) because of differences in rounding methods].

[d] The count was made on 14 August. Data are from Springer *et al.* (1979); Fadely *et al.* (1989); A.M. Springer's and D.G. Roseneau's original field notes; and E.C. Murphy's original field data summary sheets.

[e] The count was made on 10 July. Data are from Fadely *et al.* (1989); and A.M. Springer's, D.G. Roseneau's, M.I. Johnson's, and E.C. Murphy's original field notes and E.C. Murphy's data summary sheet.

[f] The count was made on 5 August. Data are from Springer *et al.* (1985), Fadely *et al.* (1989), and E.C. Murphy's original field data summary sheets [numbers reported here differ slightly from those reported in Fadely *et al.* (1989) because of differences in rounding methods].

[g] The count was made on 10 August. Data are from Fadely *et al.* (1989).

[h] The counts were made on 25 July and 3 August. Data are from Sharp (1993) and B. Sharp (unpubl. data) [numbers reported here differ slightly from those reported in Sharp (1993) because of differences in rounding methods].

[i] The count was made on 28 July. Data are from this study.

[j] SD = standard deviation.

[k] CV = coefficient of variation [standard deviation (SD) divided by the mean and multiplied by 100].

[l] Cnt = Count.

[m] The entire face of census plot 4C collapsed into the sea sometime during September 1978 - June 1979; the 326 birds that were counted on the plot were perched on a few remaining nest ledges and on the rubble pile at the base the fresh cliff-face—a few partial nests were present, but recolonization of the plot was just beginning.

[n] Almost all of census plot 4D collapsed into the sea sometime during September 1978 - June 1979; no birds were perching on the remains of the plot at the time of the count.

[o] L.G. Swartz stated that this plot contained more than 894 birds on his data summary sheet.

Table 24. Counts of black-legged kittiwakes on LGS plots 5L, 5M, and 5Q at Cape Thompson, Alaska during 1979-1995 (counts were made from land; birds were counted by 1's).

1979[a]		1988[b]		1990[c]		1991[d]		1995[e]	
Date	Birds	Date	Birds	Date	Birds	Date	Birds	Date	Birds
5 Aug	109	17 Jul	126	21 Jul	154	26 Jul	139	15 Jul	90
		25 Jul	117	28 Jul	158	28 Jul	118	22 Jul	58
		27 Aug	119			31 Jul	143	24 Jul	106
		1 Aug	118			2 Aug	155	26 Jul	151
		4 Aug	110			4 Aug	167	29 Jul	93
		5 Aug	118					31 Jul	108
		8 Aug	135					1 Aug	87
								2 Aug	111
								4 Aug	135
								9 Aug	76
								11 Aug	120
								12 Aug	102
								14 Aug	116
								15 Aug	164
$\bar{x}$[f]	109		120		156		144		108
SD[g]	—		8		3		18		28
(n)[h]	*(1)*		*(7)*		*(2)*		*(5)*		*(14)*

[a] Data for 1979 are from Murphy *et al.* (1980); also see Fadely *et al.* (1989).
[b] Data for 1988 are from Fadely *et al.* (1989).
[c] Data for 1990 are from Sharp (1993).
[d] Data for 1991 are from Nishimoto and Mendenhall (1994).
[e] Data for 1995 are from this study.
[f] $\bar{x}$ = mean.
[g] SD = standard deviation.
[h] n = sample size (number of counts).

Table 25. Counts of black-legged kittiwakes on LGS plots 5G, 5L, 5M, 5N, 5P, and 5Q at Cape Thompson, Alaska during 1979-1995 (counts were made from land; birds were counted by 1's).

	1979[a]		1990[b]		1991[c]		1995[d]
Date	Birds	Date	Birds	Date	Birds	Date	Birds
5 Aug	366	21 Jul	492	31 Jul	433	15 Jul	304
		28 Jul	499			24 Jul	347
						29 Jul	358
						1 Aug	304
						4 Aug	406
						11 Aug	405
						14 Aug	424
$\bar{x}$[e]	366		496		433		364
SD[f]	—		5		—		49
(*n*)[g]	*(1)*		*(2)*		*(1)*		*(7)*

[a] Data for 1979 are from Murphy *et al.* (1980); also see Fadely *et al.* (1989).
[b] Data for 1990 are from Sharp (1993).
[c] Data for 1991 are from Nishimoto and Mendenhall (1994).
[d] Data for 1995 are from this study.
[e] $\bar{x}$ = mean.
[f] SD = standard deviation.
[g] *n* = sample size (number of counts).

Table 26. Counts of black-legged kittiwakes on BSF land plots 3-1A, 3-2B, 3-2C, 4-1A, 4-1B, 4-2C, 4-3D, 4-4E, 5-1A, 5-1B, 5-1C, 5-1D, 5-2E, 5-2F, 5-2G, 5-3H, and 5-7L at Cape Thompson, Alaska during 1988-1995 (counts were made from land; birds were counted by 1's).

1988[a]		1991[b]		1995[c]	
Date	Birds	Date	Birds	Date	Birds
17 Jul	941	2 Aug	1,068	22 Jul	431
25 Jul	922	4 Aug	1,198	26 Jul	902
1 Aug	843			31 Jul	735
5 Aug	861			2 Aug	745
8 Aug	922			9 Aug	636
				12 Aug	601
				15 Aug	953
$\bar{x}$[d]	898		1,133		715
SD[e]	43		92		179
(n)[f]	*(5)*		*(2)*		*(7)*

[a] Data for 1988 are from Fadely *et al.* (1989).
[b] Data for 1991 are from Nishimoto and Mendenhall (1994).
[c] Data for 1995 are from this study.
[d] $\bar{x}$ = mean.
[e] SD = standard deviation.
[f] *n* = sample size (number of counts).

Table 27. Average counts of black-legged kittiwakes on 6 LGS and 14 BSF plots at Cape Thompson, Alaska during 1979-1995 (counts were made from land; birds were counted by 1's).

LGS Plot	Year 1979[a]	1990[b]	1991[c]	1995[d]	$\bar{x}$[e]	SD[f]	CV (%)[g]
5G	45	53	52	53	51	4	7.6
5L	68	111	99	71	87	21	24.2
5M	9	10	8	6	8	2	20.7
5N	84	97	89	62	83	15	18.1
5P	128	190	173	142	158	28	17.9
5Q	32	36	41	32	35	4	12.1
Total	366	497	462	366	423	67	15.9

BSF Plot	Year 1988[h]	1990	1991	1995	$\bar{x}$	SD	CV (%)
3-1A	6	8	7	7	7	1	11.7
3-2B	53	59	57	36	51	10	20.4
3-2C	3	5	5	4	4	1	22.5
4-1A	46	101	82	47	69	27	39.3
4-1B	37	22	35	20	29	9	30.7
4-2C	201	200	250	178	207	30	14.7
4-3D	44	66	47	29	47	15	32.7
4-4E	205	228	181	134	187	40	21.5
5-1A	32	50	32	30	36	9	26.1
5-1B	152	206	170	108	159	41	25.6
5-1C	12	18	12	9	13	4	29.6
5-2F	3	7	4	0	4	3	82.5
5-2G	90	80	96	99	91	8	9.2
5-7L	2	18	17	13	13	7	58.6
Total	886	1,068	995	714	916	154	16.8

[a] Data for 1979 are from Murphy *et al.* (1980); also see Fadely *et al.* (1989).
[b] Data for 1990 are from Sharp (1993).
[c] Data for 1991 are from Nishimoto and Mendenhall (1994).
[d] Data for 1995 are from this study.
[e] $\bar{x}$ = mean.
[f] SD = standard deviation.
[g] CV = coefficient of variation [standard deviation (SD) divided by the mean and multiplied by 100].
[h] Data for 1988 are from Fadely *et al.* (1989).

Table 28. Average counts of murres at Colony 4, Cape Thompson, Alaska during 1960-1995 (counts were made from boats; birds were counted by 1's and 10's).

	Year															
	1960[a]	1961[b]	1976[c]	1977[d]	1979[e]		1982[f]		1988[g]	1990[h]		1995[i]				
Plot	Cnt 1[l]	Cnt 1	Cnt 1	Cnt 1	Cnt 1	Cnt 2	Cnt 1	Cnt 2	Cnt 1	Cnt 1	Cnt 2	Cnt 1	Cnt 2	$\bar{x}$	SD[j]	CV (%)[k]
4A	133	73	138	158	123	182	110	110	64	82	82	68	60	108	38	35
4B	639	527	265	548	585	572	245	180	310	109	182	285	330	392	181	46
4C	835	369	910	975	225	278	375	490	195	315	315	365	260	511	306	60
4D+E	1,562	1,402	1,045	1,120	986	973	765	805	685	564	780	895	625	1,001	317	32
4F+G	2,156	1,656	1,248	1,323	757	1,282	1,180	805	810	840	841	1,073	1,040	1,234	434	35
4H	348	351	375	347	370	317	385	170	247	331	330	450	375	336	50	15
4I	58	45	40	95	48	75	65	85	60	53	45	15	22	56	22	39
4J	425	199	804	560	435	627	490	490	545	407	739	780	595	535	168	31
4K	206	(206)[m]	135	125	160	102	95	110	60	69	124	47	115	127	51	40
4L	171	165	125	420	295	282	405	245	215	312	251	227	295	250	92	37
4M	836	485	569	488	301	492	390	335	307	163	360	495	355	459	170	37
4N	281	184	327	324	335	362	395	195	230	277	292	655	450	314	103	33
4O	1	20	108	98	101	105	90	75	70	100	80	110	98	75	39	52
4P	614	499	490	658	485	692	660	375	255	402	553	750	560	528	124	23
4Q	172	155	260	165	70	218	240	275	245	258	367	260	240	217	59	27
4R	124	92	57	220	190	290	240	235	165	252	304	350	200	188	81	43
Total	8,562	6,305	6,896	7,624	5,466	6,849	6,130	4,980	4,463	4,534	5,645	6,825	5,620			
					(mean = 6,158)		(mean = 5,555)			(mean = 5,090)		(mean = 6,223)				

[a] Plots 4A-4I and 4L were counted on 15 July, plots 4O-4P were counted on 17 July, and plots 4J, 4K, 4M, and 4N were counted on both 15 and 17 July—the plot values listed here for 4J, 4K, 4M, and 4N are the averages of the 15 and 17 July scores [numbers reported here differ slightly from those reported in Fadely *et al.* (1989) because of differences in rounding methods]. Data are from Fadely *et al.* (1989) and L.G. Swartz's original field notes.

[b] The count was made on 22 July. Data are from Fadely *et al.* (1989) and L.G. Swartz's original field notes and data summary sheets [numbers reported here differ slightly from those reported in Fadely *et al.* (1989) because of differences in rounding methods].

[c] The count was made on 9 August. Data are from Springer and Roseneau (1977); Fadely *et al.* (1989); and A.M. Springer's and D.G. Roseneau's original field data summary sheets [numbers reported here differ slightly from those reported in Fadely *et al.* (1989) because of differences in rounding methods].

[d] The count was made on 12 August 1977. Data are from Springer and Roseneau (1978); Fadely *et al.* (1989); and A.M. Springer's, D.G. Roseneau's, and E.C. Murphy's original field data summary sheets [numbers reported here differ slightly from those reported in Fadely *et al.* (1989) because of differences in rounding methods].

Table 28 (Continued).

[e] The counts were made on 7 and 14 August. Data are from Fadely *et al.* (1989); and A.M. Springer's, D.G. Roseneau's, M.I. Johnson's, and E.C. Murphy's original field notebooks and E.C. Murphy's field data summary sheets [numbers reported here differ slightly from those reported in Fadely *et al.* (1989) because of differences in rounding methods and because we did not use the data obtained during an incomplete count on 11 August; also, a typographical error in Fadely (1989) added 100 birds to the average of the two counts made on plot 4I].

[f] The counts were made on 28 July and 3 August. Data are from Springer *et al.* (1985c); Fadely *et al.* (1989); and E.C. Murphy's original field data summary sheets [numbers reported here differ from those reported in Fadely *et al.* (1989) because of differences in rounding methods].

[g] The count was made on 25 July and 3 August. Data are from Fadely *et al.* (1989).

[h] The counts were made on 25 July and 3 August. Data are from Sharp (1993) and B. Sharp (unpubl. data) [numbers reported here differ slightly from those reported by Sharp (1993) because of differences in rounding methods and because we only used the counts made by J. Evanich; Evanich counted almost all of the plots twice on both days, and in most cases, his scores were consistently within 10-15% of each other—in contrast, Sharp only counted about 65% of the plots per day and some of his scores were 2-3 times higher than Evanich's counts, suggesting that he may have been having problems locating plot boundaries.

[i] The counts were made on 28 July and 10 August. Data are from this study.

[j] SD = standard deviation.

[k] CV = coefficient of variation [standard deviation (SD) divided by the mean and multiplied by 100].

[l] Cnt = Count.

[m] Plot 4K was not counted in 1961. We used the 1960 score of 206 birds for plot 4K to allow comparisons to be made among years.

Table 29. Counts of murres on LGS plots 5L, 5M, and 5Q at Cape Thompson, Alaska during 1960-1995 (counts were made from land; birds were counted by 1's and 10's).

1960[a]		1979[b]		1982[c]		1988[d]		1990[e]		1991[f]		1995[g]	
Date	Birds	Date	Birds	Date	Birds	Date	Birds	Date	Birds	Date	Birds	Date	Birds
1 Aug	5,312	7 Aug	2,092	3 Aug	2,224	17 Jul	2,554	21 Jul	2,673	28 Jul	1,912	15 Jul	1,898
						25 Jul	1,988	28 Jul	1,985	31 Jul	1,959	22 Jul	1,987
						27 Aug	2,597			2 Aug	2,214	24 Jul	2,910
						1 Aug	2,323			4 Aug	2,481	26 Jul	2,967
						4 Aug	1,997					29 Jul	2,288
						5 Aug	2,242					31 Jul	2,641
						8 Aug	2,590					1 Aug	2,178
						11 Aug	2,250					2 Aug	2,568
						15 Aug	2,731					4 Aug	2,680
												9 Aug	2,501
												11 Aug	2,390
												12 Aug	2,421
												14 Aug	2,440
												15 Aug	2,433
$\bar{x}$[h]	5,312		2,092		2,224		2,364		2,329		2,142		2,450
SD[i]	—		—		—		270		486		262		305
(n)[j]	*(1)*		*(1)*		*(1)*		*(9)*		*(2)*		*(4)*		*(14)*

[a] Data for 1960 are from Swartz (1966); also see Fadely *et al.* (1989).
[b] Data for 1979 are from Murphy *et al.* (1980); also see Fadely *et al.* (1989).
[c] Data for 1982 are from Springer *et al.* (1985); also see Fadely *et al.* (1989).
[d] Data for 1988 are from Fadely *et al.* (1989).
[e] Data for 1990 are from Sharp (1993).
[f] Data for 1991 are from Nishimoto and Mendenhall (1994).
[g] Data for 1995 are from this study.
[h] $\bar{x}$ = mean.
[i] SD = standard deviation.
[j] *n* = sample size (number of counts).

Table 30. Counts of murres on LGS plots 5G, 5L, 5M, 5N, 5O, 5P, and 5Q at Cape Thompson, Alaska during 1960-1995 (counts were made from land; birds were counted by 1's and 10's).

	1960[a]		1979[b]		1982[c]		1990[d]		1991[e]		1995[f]	
	Date	Birds	Date	Birds	Date	Birds	Date	Birds	Date	Birds	Date	Birds
	1 Aug	19,879	7 Aug	7,102	3 Aug	8,557	21 Jul	8,524	31 Jul	7,302	15 Jul	6,777
							28 Jul	7,252			24 Jul	9,477
											29 Jul	7,605
											1 Aug	7,288
											4 Aug	8,885
											11 Aug	8,920
											14 Aug	8,620
$\bar{x}$[g]		19,879		7,102		8,557		7,888		7,302		8,225
SD[h]		—		—		—		899		—		1,000
(n)[i]		*(1)*		*(1)*		*(1)*		*(2)*		*(1)*		*(7)*

[a] Data for 1960 are from Swartz (1966); also see Fadely *et al.* (1989).
[b] Data for 1979 are from Murphy *et al.* (1980); also see Fadely *et al.* (1989).
[c] Data for 1982 are from Springer *et al.* (1985); also see Fadely *et al.* (1989).
[d] Data for 1990 are from Sharp (1993).
[e] Data for 1991 are from Nishimoto and Mendenhall (1994).
[f] Data for 1995 are from this study.
[g] $\bar{x}$ = mean.
[h] SD = standard deviation.
[i] n = sample size (number of counts).

Table 31. Counts of murres on BSF plots 3-1A, 3-2B, 3-2C, 4-1A, 4-1B, 4-2C, 4-3D, 4-4E, 5-1A, 5-1B, 5-1C, 5-1D, 5-2E, 5-2F, 5-2G, 5-3H, and 5-7L at Cape Thompson, Alaska during 1988-1995 (counts were made from land; birds were counted by 1's).

	1988[a]		1991[b]		1995[c]
Date	Birds	Date	Birds	Date	Birds
17 Jul	4,395	2 Aug	5,348	22 Jul	4,530
25 Jul	4,270	4 Aug	5,789	26 Jul	5,799
1 Aug	4,917			31 Jul	5,045
5 Aug	4,481			2 Aug	4,723
8 Aug	4,872			9 Aug	5,065
11 Aug	4,333			12 Aug	4,807
15 Aug	5,293			15 Aug	4,992
$\bar{x}$[d]	4,652		5,569		4,994
SD[e]	381		312		404
(n)[f]	*(7)*		*(2)*		*(7)*

[a] Data for 1988 are from Fadely *et al.* (1989).
[b] Data for 1991 are from Nishimoto and Mendenhall (1994).
[c] Data for 1995 are from this study.
[d] $\bar{x}$ = mean.
[e] SD = standard deviation.
[f] n = sample size (number of counts).

Table 32. Average counts of murres on 7 LGS and 17 BSF plots at Cape Thompson, Alaska during 1960-1995 (counts were made from land; birds were counted by 1's and 10's on the LGS plots, and by 1's on the BSF plots).

LGS Plot	Year						$\bar{x}$[g]	SD[h]	CV (%)[i]
	1960[a]	1979[b]	1982[c]	1990[d]	1991[e]	1995[f]			
5G	4,267	1,835	1,991	1,638	1,693	2,014	2,240	1,005	44.9
5L	1,850	490	765	904	708	843	927	474	51.2
5M	1,700	702	835	555	566	728	848	431	50.8
5N	3,650	1,400	2,285	1,367	1,435	1,121	1,876	955	50.9
5O	3,050	835	826	832	993	935	1,245	887	71.2
5P	3,600	940	1,191	1,371	1,568	1,757	1,738	956	55.0
5Q	1,762	900	745	812	893	880	999	379	37.9
Total	19,879	7,102	8,638[j]	7,479[j]	7,856[j]	8,278[j]	9,872	4,933	50.0

BSF Plot	Year				$\bar{x}$	SD	CV (%)[i]
	1988[k]	1990	1991	1995			
3-1A	140	168	204	206	180	32	17.6
3-2B	477	491	587	403	490	76	15.4
3-2C	52	66	69	67	64	8	12.2
4-1A	292	272	296	248	277	22	7.9
4-1B	228	161	179	148	179	35	19.6
4-2C	381	335	538	657	478	148	30.9
4-3D	146	145	142	153	147	5	3.2
4-4E	270	183	240	309	251	53	21.2
5-1A	32	116	39	36	56	40	72.2
5-1B	430	729	814	637	653	165	25.3
5-1C	25	59	27	29	35	16	46.0
5-1D	190	195	195	176	189	9	4.8
5-2E	331	293	272	297	298	24	8.2
5-2F	405	403	506	481	449	53	11.7
5-2G	286	351	305	346	322	32	9.8
5-3H	245	302	236	304	272	36	13.4
5-7L	412	482	466	497	464	37	8.0
Total	4,342	4,751	5,115	4,994	4,801	341	7.1

[a] Data for 1960 are from Swartz (1966); also see Fadely *et al.* (1989).
[b] Data for 1979 are from Murphy *et al.* (1980); also see Fadely *et al.* (1989).
[c] Data for 1982 are from Springer *et al.* (1985); also see Fadely *et al.* (1989).
[d] Data for 1990 are from Sharp (1993).
[e] Data for 1991 are from Nishimoto and Mendenhall (1994).
[f] Data for 1995 are from this study.
[g] $\bar{x}$ = mean.
[h] SD = standard deviation.
[i] CV = coefficient of variation [standard deviation (SD) divided by the mean and multiplied by 100].
[j] These totals differ from the totals shown in Table 29, because they use all of the counts made on the plots, not just the complete counts made on one day.
[k] Data for 1988 are from Fadely *et al.* (1989).

Table 33. Black-legged kittiwake hatching dates at Cape Thompson, Alaska during 1959-1995.

Year[1]	First Hatching Date	66% Hatch Interval[2]	Estimated Peak Hatching Date[3]	Median Hatching Date
1959	20 Jul	ND[4]	ND	ND
1960	17 Jul	ND	ND	ND
1961	22 Jul	ND	ND	ND
1976	9 Aug	ND	ND	ND
1977	29 Jul	ND	ND	ND
1978	25 Jul	25 Jul - 3 Aug	31 Jul - 1 Aug	ND
1979	18 Jul	18 Jul - 1 Aug	29-30 Jul	ND
1982	21 Jul	ND	ND	ND
1988	19 Jul	19-28 Jul	25-26 Jul	ND
1990	18 Jul	ND	ND	21 Jul
1991	19 Jul	ND	ND	25 Jul
1995	21 Jul	21 Jul - 5 Aug	2-3 Aug	ND
Mean Date:	23 Jul[5]			

[1] Data are from: 1959-1961, Swartz (1966); 1976-1979, Murphy *et al.* (1980); 1982, Springer *et al.* (1985c); 1988, Fadely *et al.* (1989); 1990, Sharp (1993); 1991, Nishimoto (1994); 1995, this study.

[2] The interval during which about 66% of the eggs hatched.

[3] Date when about 50% of the eggs were estimated to have hatched (estimates were based on the 66% hatch interval).

[4] ND = no data.

[5] Based on Julian dates for both leap and non-leap years.

Table 34. Murre hatching and sea-going dates at Cape Thompson, Alaska during 1959-1995.

Year[1]	Species	First Hatch Date	Median Hatch Date	First Sea-going Date
1959	COMU[2]	11 Aug	ND[3]	ND
	TBMU[4]	11 Aug	ND	25 Aug
1960	COMU	1 Aug	ND	>26 Aug[5]
	TBMU	30 Jul	ND	18 Aug
1961	COMU	~31 Jul	ND	>24 Aug[6]
	TBMU	27 Jul	ND	19 Aug
1976	UNMU[7]	9 Aug	ND	~30 Aug
1977	UNMU	1 Aug	ND	23 Aug
1978	UNMU	~23 Jul	ND	13 Aug
1979	UNMU	22 Jul	ND	11 Aug
1982	UNMU	5 Aug	ND	ND
1988	UNMU	31 Jul		22 Aug
1990	UNMU	21 Jul	28 Jul	14 Aug
1991	UNMU	27 Jul	6 Aug	11 Aug
1995	COMU	25 Jul	6 Aug	<19 Aug[8]
	TBMU	25 Jul	5 Aug	18 Aug

[1] Data are from: 1959-1961, Swartz (1966); 1976-1979, Murphy *et al.* (1980); 1982, Springer *et al.* (1983); 1988, Fadely *et al.* (1989); 1990, Sharp (1993); 1991, Nishimoto (1994); 1995, this study.

[2] COMU = common murre.

[3] ND = no data.

[4] TBMU = thick-billed murre.

[5] Swartz (1966) reported that the first departure was observed on 26 August, but he also noted that departures probably occurred before that date.

[6] Swartz (1966) reported that the first departure was observed on 24 August, but he also noted that departures probably occurred before that date.

[7] UNMU = unidentified murre species; data on individual species were not available for 1976-1991 (we are continuing to search for original notes that may provide specific information for these years.

[8] No chicks had departed as of 19 August, but they were almost ready to go (it is likely that first sea-going occurred only 1-2 days later—i.e., on 20 or 21 August).

Table 35. Reproductive performance of black-legged kittiwakes at Cape Thompson, Alaska during 1960-1995.

Year[1]	Total Nests	Nests w/Eggs	Mean Clutch	Hatching Success[2]	Fledging Success[3]	Reproductive Success[4]	Productivity[5]
1960	ND[6]	60	1.92	0.65	0.86	1.22	ND
1961	ND	29	1.88	0.41	0.60	0.72	ND
1976	200	ND	1.12	ND	0.00	0.00	0.00
1977	220	73	1.18	0.90	0.71	0.64	0.48
1978	236	ND	ND	ND	ND	ND	0.42
1979	381	357	1.58	0.94	0.82	ND	1.12
1982	ND	ND	1.48	ND	ND	ND	1.15
1988	70	ND	1.39	0.72	0.33	ND	0.31
1990	102	97	1.61	ND	ND	1.10	1.00
1991	ND	ND	1.44	ND	ND	0.57	0.39
1995	479	98	1.07	0.36	0.08	ND	< 0.01

[1] Data are from: 1960-1961, Swartz (1966); 1976-1979, Murphy *et al.* (1980); 1982, Springer *et al.* (1985c); 1988, Fadley *et al.* (1989); 1990, Sharp (1993); 1991, Nishimoto and Mendenhall (1994); 1995, this study.

[2] Chicks per egg.

[3] Fledglings per nest w/eggs.

[4] Fledglings per nest start.

[5] Fledglings per nest.

[6] ND = no data.

Table 36. Reproductive performance of murres at Cape Thompson, Alaska in 1995.

	1995	
Parameter	COMU[1]	TBMU[2]
Hatching Success[3]	0.93	0.91
Fledging Success[4]	0.98	0.96
Reproductive Success[5]	0.91	0.88
Total Eggs	229	552
Total Plots *(n)*	*(8)*	*(14)*

[1] COMU = common murre
[2] TBMU = thick-billed murre.
[3] Chicks per egg.
[4] Fledglings per chicks hatched.
[5] Fledglings per egg.

Table 37. Reproductive performance of murres at Cape Thompson, Alaska during 1988-1995.

Year [1]	Total Sites	Hatching Success [2]	Fledging Success [3]	Reproductive Success [4]
Common Murre				
1988	25	0.80	0.76	0.60
1990	22	ND[5]	ND	0.86
1991	119	0.96	0.39	0.37
1995	229	0.93	0.98	0.91
Thick-billed Murre				
1988	84	0.79	0.77	0.61
1990	168	ND	ND	0.76
1991	211	0.95	0.53	0.51
1995	552	0.91	0.96	0.88

[1] Data are from: 1988, Fadley *et al.* (1989); 1990, Sharp (1993); 1991, Nishimoto and Mendenhall (1994); 1995, this study.
[2] Chicks per egg.
[3] Fledglings per chick hatched.
[4] Fledglings per egg.
[5] ND = no data.

Table 38. Prey species found in the stomachs of thick-billed murre (TBMU), common murre (COMU), and black-legged kittiwake (BLKI) adults collected during 13 July - 20 August 1995 at Cape Thompson, Alaska. Values in parentheses show frequency among total number of stomachs examined, and values not in parentheses show percent frequency, numbers, and weight among stomachs containing identifiable prey items.

	TBMU		COMU		BLKI	
	n	%	*n*	%	*n*	%
Number of stomachs examined	10	(100)	17	(100)	14	(100)
Number of empty stomachs	3	(30)	7	(41)	4	(29)
Number of stomachs containing prey	7	(70)	10	(59)	10	(71)
Frequency of fish (stomachs containing prey)	7	100	10	100	10	100
Frequency of invertebrates (stomachs containing prey)	1	14	0	0	0	0
A. Frequency of Occurrence						
Arctic cod *(Boreogadus saida)*	4	57	8	80	4	40
Saffron cod *(Eleginus gracilis)*	1	14	2	20	0	0
Unidentified cod (Gadidae)	0	0	0	0	1	10
Pacific sand lance *(Ammodytes hexapterus)*	0	0	1	10	0	0
Unidentified sculpin (Cottidae)	2	29	4	40	2	20
Unidentified flatfish (Pleuronectidae)	2	29	4	40	2	20
YOY unidentified fish[a]	1	14	1	10	3	30
Pandalid shrimp *(Pandalus* spp.*)*	1	14	0	0	0	0
B. Numbers of Individuals						
Total countable prey items	101	100	69	100	20	100
Total countable fish	99	98	69	100	20	100
Total countable invertebrates	2	2	0	0	0	0
Arctic cod *(Boreogadus saida)*	66	65	40	58	9	45
Saffron cod *(Eleginus gracilis)*	6	6	7	10	0	0
Unidentified cod (Gadidae)	0	0	0	0	1	5
Pacific sand lance *(Ammodytes hexapterus)*	0	0	1	1	0	0
Unidentified sculpin (Cottidae)	5	5	7	10	4	20
Unidentified flatfish (Pleuronectidae)	21	21	13	19	3	15
YOY unidentified fish[a]	1[b]	1	1[b]	1	3[c]	15
Pandalid shrimp *(Pandalus* spp.*)*	2	2	0	0	0	0
C. Estimated Wet Weight (g)						
Total measurable items	208	100	859	100	145	100
Total measurable fish	206	99	859	100	145	100
Total measurable invertebrates	2	1	0	0	0	0
Arctic cod *(Boreogadus saida)*	177	85	673	78	135	93
Saffron cod *(Eleginus gracilis)*	6	3	40	5	0	0
Unidentified cod (Gadidae)	0	0	0	0	5	3
Pacific sand lance *(Ammodytes hexapterus)*	0	0	23	3	0	0
Unidentified sculpin (Cottidae)	13	6	112	13	2	1
Unidentified flatfish (Pleuronectidae)	11	5	11	1	2	1
YOY unidentified fish[a]	1[b]	<1	1[b]	<1	2[c]	1

Table 38 (Continued).

	TBMU		COMU		BLKI	
	n	%	*n*	%	*n*	%
C. Estimated Wet Weight (g) (continued)						
Pandalid shrimp *(Pandalus* spp.)	2	1	0	0	0	0

[a] YOY = young-of-the-year.
[b] 0.5-gram trace representing at least one individual found in one TBMU and one COMU stomach.
[c] 0.5-gram traces representing at least one individual each found in three BLKI stomachs.

Table 39. Prey species found in the stomachs of thick-billed murre (TBMU), common murre (COMU), and black-legged kittiwake (BLKI) adults collected during 6 July - 27 August 1988 at Cape Thompson, Alaska. Values in parentheses show frequency among total number of stomachs examined, and values not in parentheses show percent frequency, numbers, and weight among stomachs containing identifiable prey items.

	TBMU		COMU		BLKI	
	n	%	*n*	%	*n*	%
Number of stomachs examined	47	(100)	13	(100)	18	(100)
Number of empty stomachs	15	(32)	2	(15	4	(22)
Number of stomachs containing prey	32	(68)	11	(85)	14	(78)
Frequency of fish (stomachs containing prey)	32	100	11	100	14	100
Frequency of invertebrates (stomachs containing prey)	3	9	0	0	1	7
A. Frequency of Occurrence						
Pacific herring *(Clupea harengus pallasi)*	0	0	0	0	5	36
Arctic cod *(Boreogadus saida)*	25	78	9	82	9	64
Saffron cod *(Eleginus gracilis)*	4	13	1	9	0	0
Pacific sand lance *(Ammodytes hexapterus)*	4	13	1	9	0	0
Unidentified sculpin (Cottidae)	3	9	1	9	0	0
Unidentified fish	3	9	2	18	1	7
Unidentified snail (Gastropoda)	0	0	0	0	1	7
Unidentified amphipod	2	6	0	0	0	0
Pandalid shrimp *(Pandalus* spp.*)*	1	3	0	0	0	0
Unidentified decapod	1	3	0	0	0	0
B. Numbers of Individuals						
Total countable prey items	162	100	61	100	29	100
Total countable fish	158	98	61	100	28	97
Total countable invertebrates	4	2	0	0	1	3
Pacific herring *(Clupea harengus pallasi)*	0	0	0	0	5	17
Arctic cod *(Boreogadus saida)*	127	78	56	92	22	76
Saffron cod *(Eleginus gracilis)*	5	3	1	2	0	0
Pacific sand lance *(Ammodytes hexapterus)*	18	11	1	2	0	0
Unidentified sculpin (Cottidae)	5	3	1	2	0	0
Unidentified fish	3	2	2	3	1	3
Unidentified snail (Gastropoda)	0	0	0	0	1[a]	3
Unidentified amphipod	2	1	0	0	0	0
Pandalid shrimp *(Pandalus* spp.*)*	1	1	0	0	0	0
Unidentified decapod	1[a]	1	0	0	0	0
C. Estimated Wet Weight (g)						
Total measurable items	4,504	100	1,591	100	653	100
Total measurable fish	4,503	100	1,591	100	653	100
Total measurable invertebrates	1	<1	0	0	0[a]	0
Pacific herring *(Clupea harengus pallasi)*	0	0	0	0	128	20
Arctic cod *(Boreogadus saida)*	4,257	95	1,499	94	524	80
Saffron cod *(Eleginus gracilis)*	99	2	62	4	0	0
Pacific sand lance *(Ammodytes hexapterus)*	126	3	2	<1	0	0
Unidentified sculpin (Cottidae)	16	<1	24	2	0	0

Table 39 (Continued).

	TBMU		COMU		BLKI	
	n	%	*n*	%	*n*	%
C. Estimated Wet Weight (g) (continued)						
Unidentified fish	5	<1	4	<1	1	<1
Unidentified snail (Gastropoda)	0	0	0	0	0[a]	0
Unidentified amphipod	<1	<1	0	0	0	0
Pandalid shrimp *(Pandalus* spp.*)*	1	<1	0	0	0	0
Unidentified decapod	0[a]	0	0	0	0	0

[a] Unweighable trace representing at least one individual found in one BLKI stomach.

Table 40. Prey species found in the stomachs of thick-billed murre (TBMU), common murre (COMU), and black-legged kittiwake (BLKI) adults collected during 10 July - 27 August 1990 at Cape Thompson, Alaska. Values in parentheses show frequency among total number of stomachs examined, and values not in parentheses show percent frequency, numbers, and weight among stomachs containing identifiable prey items.

	TBMU		COMU		BLKI	
	n	%	*n*	%	*n*	%
Number of stomachs examined	18	(100)	8	(100)	18	(100)
Number of empty stomachs	9	(50)	2	(25)	5	(28)
Number of stomachs containing prey	9	(50)	6	(75)	13	(72)
Frequency of fish (stomachs containing prey)	8	89	6	100	9	69
Frequency of invertebrates (stomachs containing prey)	1	11	0	0	5	38
A. Frequency of Occurrence						
Arctic cod *(Boreogadus saida)*	3	33	5	83	6	46
Saffron cod *(Eleginus gracilis)*	5	55	2	33	2	15
Unidentified cod (Gadidae)	0	0	0	0	1	8
Pacific sand lance *(Ammodytes hexapterus)*	0	0	1	17	0	0
Unidentified sculpin (Cottidae)	1	11	1	17	0	0
Unidentified fish	1	11	0	0	0	0
Unidentified polychaete (Polychaeta)	1	11	0	0	5	38
B. Numbers of Individuals						
Total countable prey items	59	100	44	100	100	100
Total countable fish	55	93	44	100	48	48
Total countable invertebrates	4	7	0	0	52	52
Arctic cod *(Boreogadus saida)*	34	58	33	75	41	41
Saffron cod *(Eleginus gracilis)*	8	14	5	11	6	6
Unidentified cod (Gadidae)	0	0	0	0	1	1
Pacific sand lance *(Ammodytes hexapterus)*	0	0	5	11	0	0
Unidentified sculpin (Cottidae)	12	20	1	2	0	0
Unidentified fish	1[a]	2	0	0	0	0
Unidentified polychaete (Polychaeta)	4	7	0	0	52	52
C. Estimated Wet Weight (g)						
Total measurable items	490	100	694	100	557	100
Total measurable fish	486	99	694	100	505	91
Total measurable invertebrates	4	1	0	0	52	9
Arctic cod *(Boreogadus saida)*	451	92	652	94	483	87
Saffron cod *(Eleginus gracilis)*	24	5	7	1	10	2
Unidentified cod (Gadidae)	0	0	0	0	12	2
Pacific sand lance *(Ammodytes hexapterus)*	0	0	33	5	0	0
Unidentified sculpin (Cottidae)	11	2	2	<1	0	0
Unidentified fish	0[a]	0	0	0	0	0
Unidentified polychaete (Polychaeta)	4	1	0	0	52	9

[a] Unweighable trace representing at least one individual found in one TBMU stomach.

Table 41. Prey species found in the stomachs of thick-billed murre (TBMU), common murre (COMU), and black-legged kittiwake (BLKI) adults collected during 5 July - 19 August 1991 at Cape Thompson, Alaska. Values in parentheses show frequency among total number of stomachs examined, and values not in parentheses show percent frequency, numbers, and weight among stomachs containing identifiable prey items.

	TBMU		COMU		BLKI	
	n	%	*n*	%	*n*	%
Number of stomachs examined	16	(100)	3	(100)	8	(100)
Number of empty stomachs	7	(44)	1	(33)	5	(63)
Number of stomachs containing prey	9	(56)	2	(67)	3	(38)
Frequency of fish (stomachs containing prey)	8	89	2	100	3	100
Frequency of invertebrates (stomachs containing prey)	1	11	0	0	0	0
A. Frequency of Occurrence						
Capelin *(Mallotus villosus)*	0	0	0	0	1	33
Arctic cod *(Boreogadus saida)*	1	11	0	0	1	33
Saffron cod *(Eleginus gracilis)*	2	22	2	100	1	33
Unidentified cod (Gadidae)[a]	1	11	0	0	0	0
Unidentified sculpin (Cottidae)[b]	4	44	0	0	1	33
Unidentified fish	2	22	0	0	0	0
Unidentified crab (Decapoda)	1	11	0	0	0	0
B. Numbers of Individuals						
Total countable prey items	14	100	9	100	9	100
Total countable fish	13	93	9	100	9	100
Total countable invertebrates	1	7	0	0	0	0
Capelin *(Mallotus villosus)*	0	0	0	0	2	22
Arctic cod *(Boreogadus saida)*	1	7	0	0	1	11
Saffron cod *(Eleginus gracilis)*	5	36	9	100	5	56
Unidentified cod (Gadidae)[a]	1	7	0	0	0	0
Unidentified sculpin (Cottidae)[b]	4	29	0	0	1	11
Unidentified fish	2[c]	14	0	0	0	0
Unidentified crab (Decapoda)	1[d]	7	0	0	0	0
C. Estimated Wet Weight (g)						
Total measurable items	264	100	192	100	119	100
Total measurable fish	264	100	192	100	119	100
Total measurable invertebrates	0[d]	0	0	0	0	0
Capelin *(Mallotus villosus)*	0	0	0	0	6	5
Arctic cod *(Boreogadus saida)*	87	33	0	0	21	18
Saffron cod *(Eleginus gracilis)*	51	19	192	100	50	42
Unidentified cod (Gadidae)[a]	7	3	0	0	0	0
Unidentified sculpin (Cottidae)[b]	119	45	0	0	42	35
Unidentified fish	0[c]	0	0	0	0	0
Unidentified crab (Decapoda)	0[d]	0	0	0	0	0

[a] Probably Arctic or saffron cod.

Table 41 (Continued).

[b] Most unidentifiable sculpin parts were probably from *Myoxocephalus* spp., probably fourhorn sculpin (*M. quadricornis*), the most common sculpin species found in the eastern Chukchi Sea.
[c] Unweighable traces representing at least two individuals present in two TBMU stomachs.
[d] Unweighable trace representing at least one individual present in one TBMU stomach.

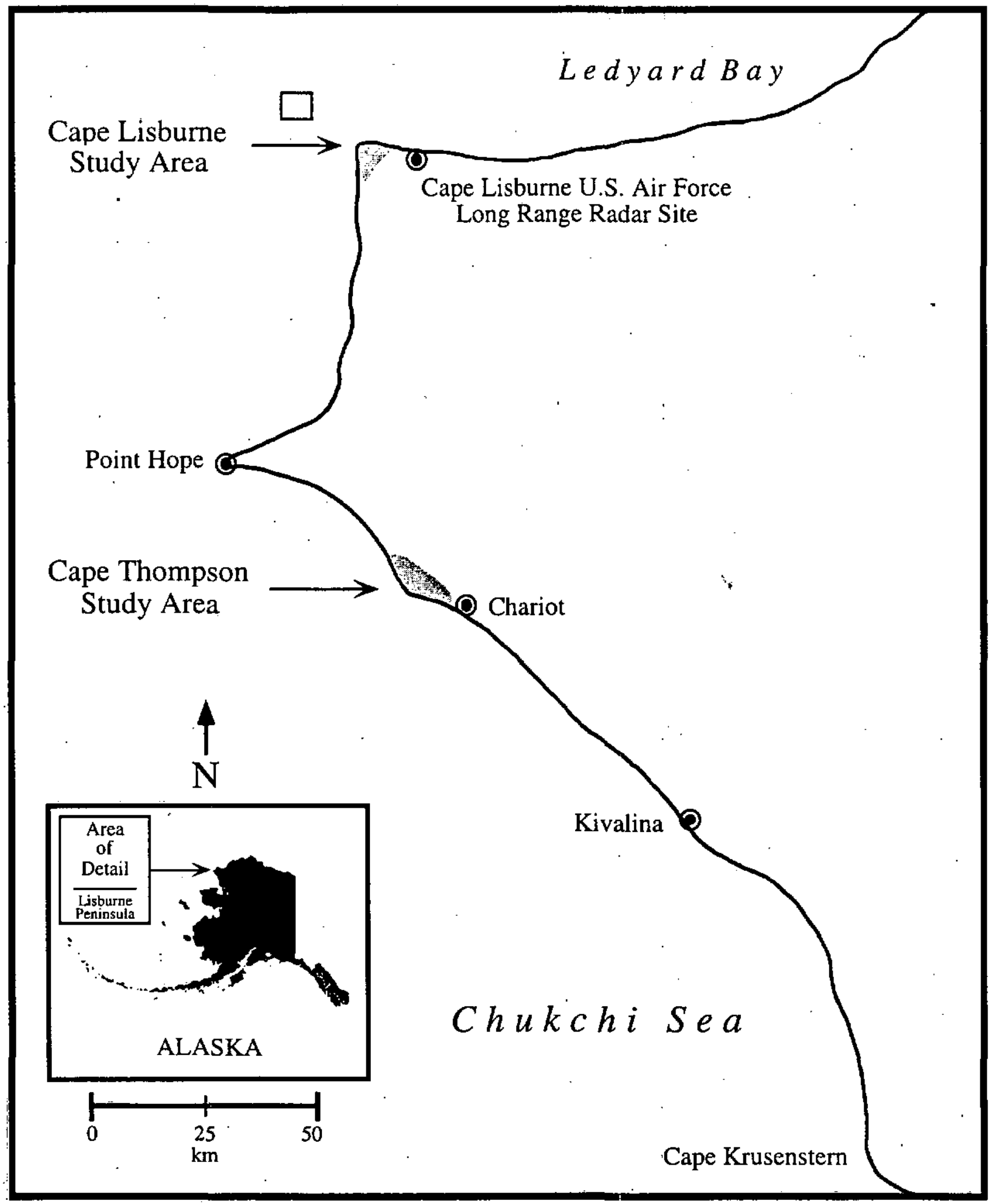


Figure 1. Locations of the Cape Lisburne and Cape Thompson study areas in the eastern Chukchi Sea, Alaska.

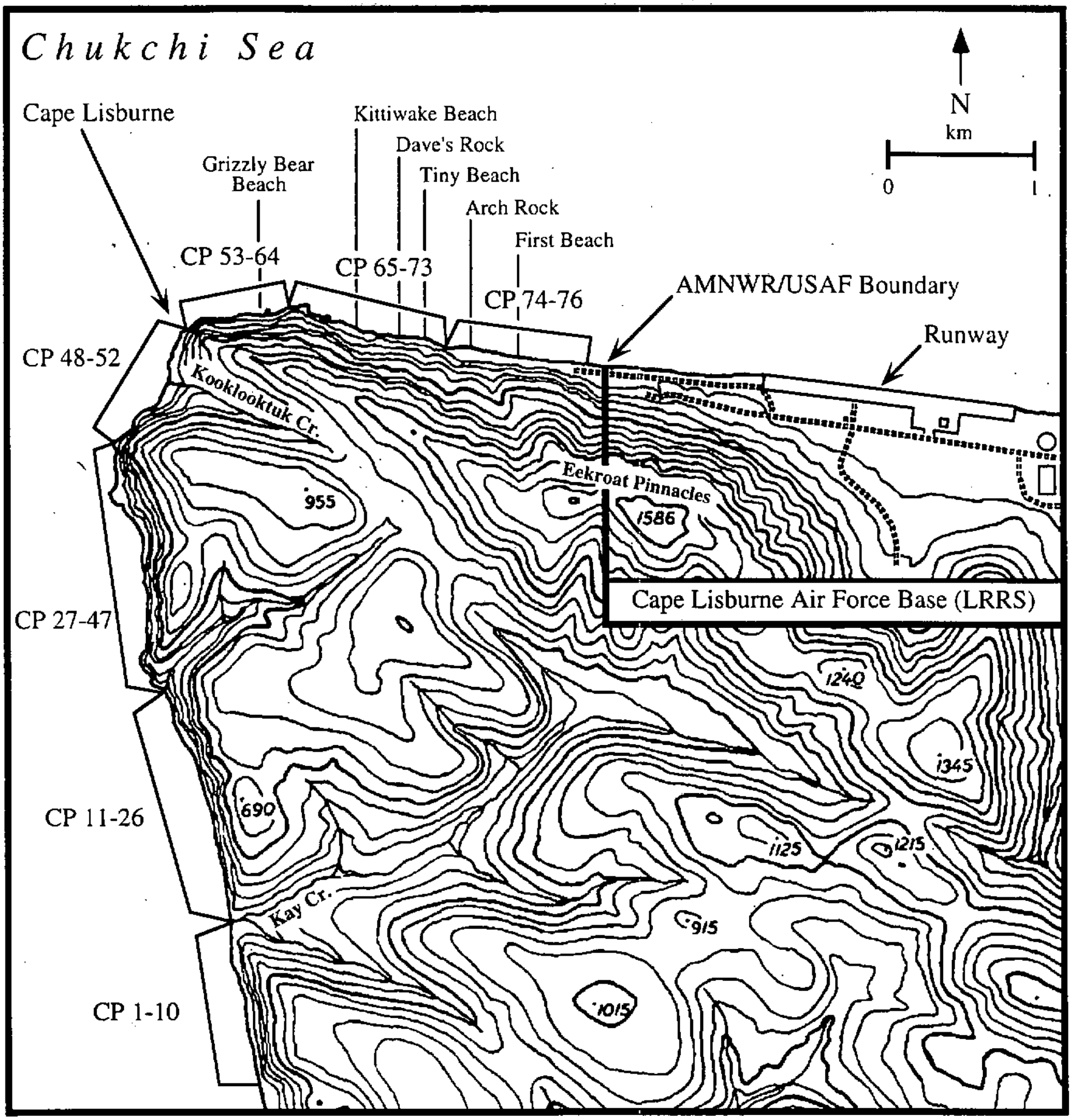


Figure 2. The Cape Lisburne study area showing the 76 census plots used for boat-based population counts and the locations of First, Tiny, Kittiwake and Grizzly Bear beaches; Arch and Dave's rocks; the Cape Lisburne U.S. Air Force (USAF) Long Range Radar Site (LRRS) lands and runway; and the Alaska Maritime National Wildlife Refuge (AMNWR) - U.S. Air Force boundary.

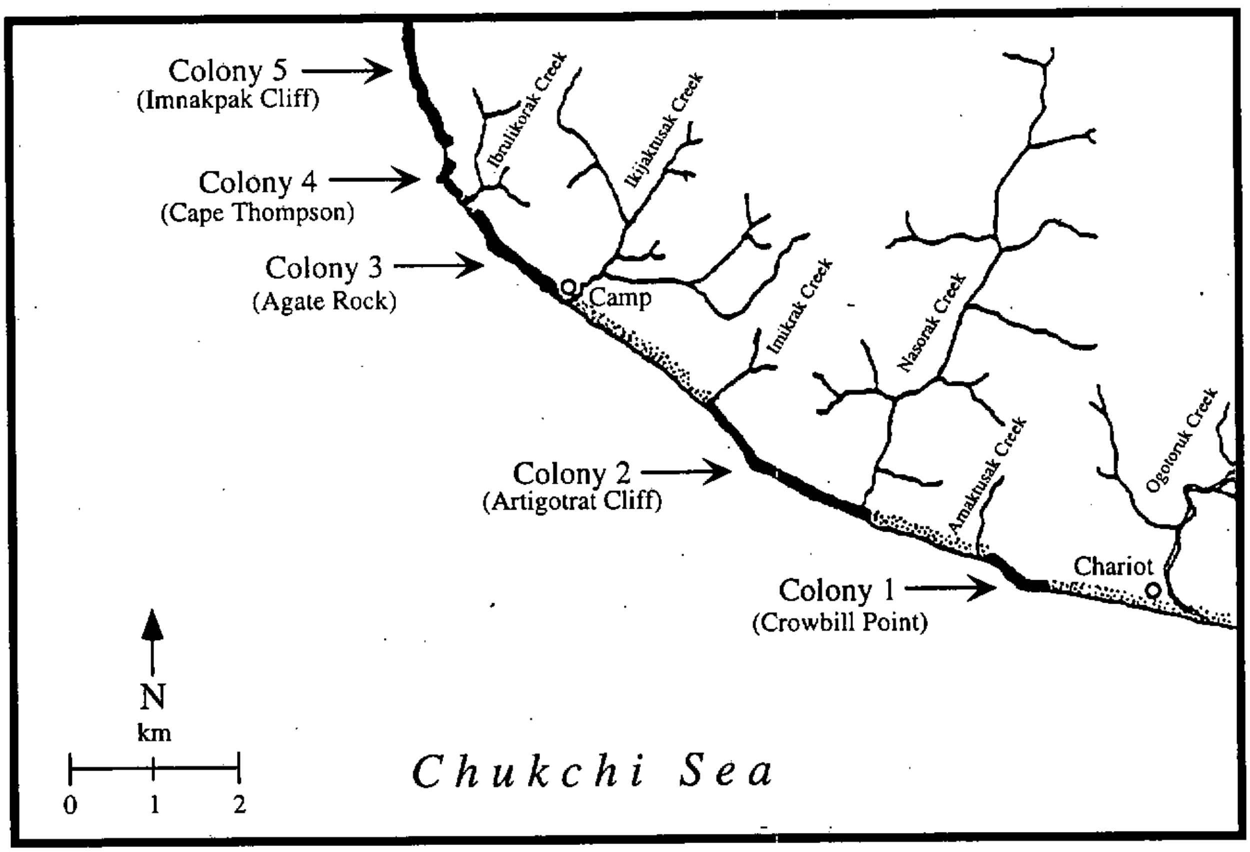


Figure 3. The Cape Thompson study area showing the locations of Colonies 1-5, the Chariot site and landing strip, and the field camp site.

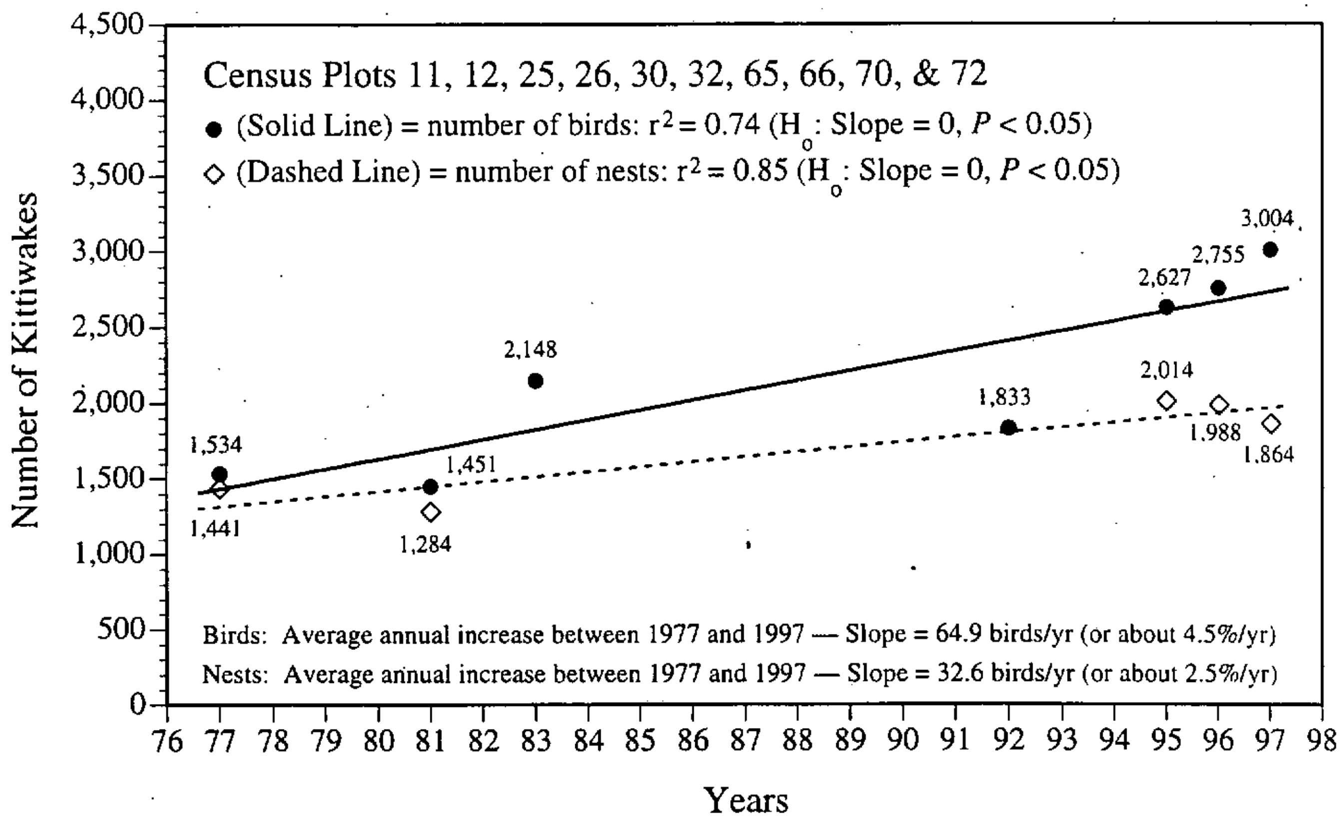


Figure 4. Counts of black-legged kittiwakes on census plots 11, 12, 25, 26, 30, 32, 65, 66, 70, and 72 at Cape Lisburne, Alaska during 1977-1997 (all counts were single counts without measures of variability; average annual increases based on slopes of the lines and percentages rounded to nearest half percent; data are from Table 1).

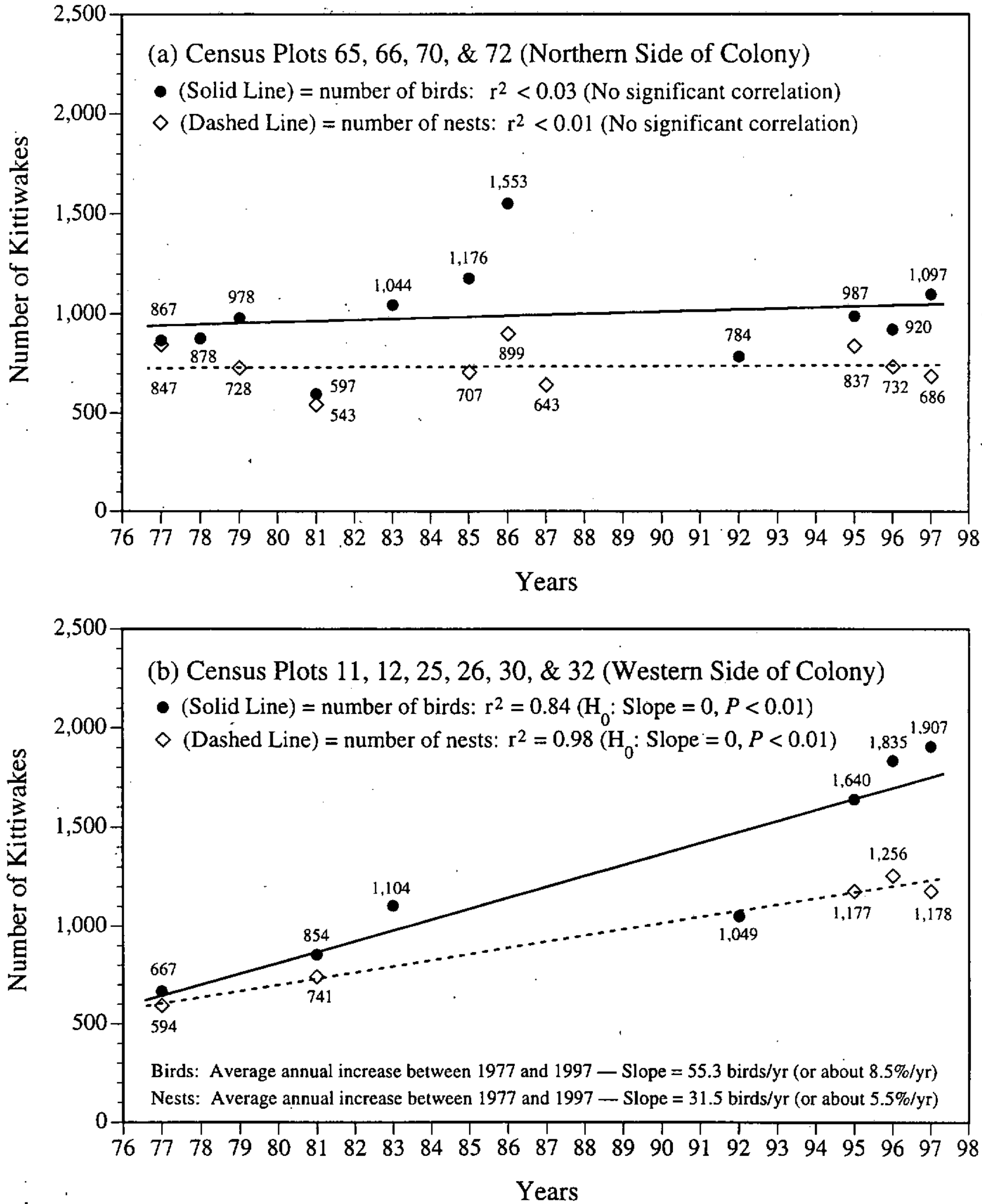
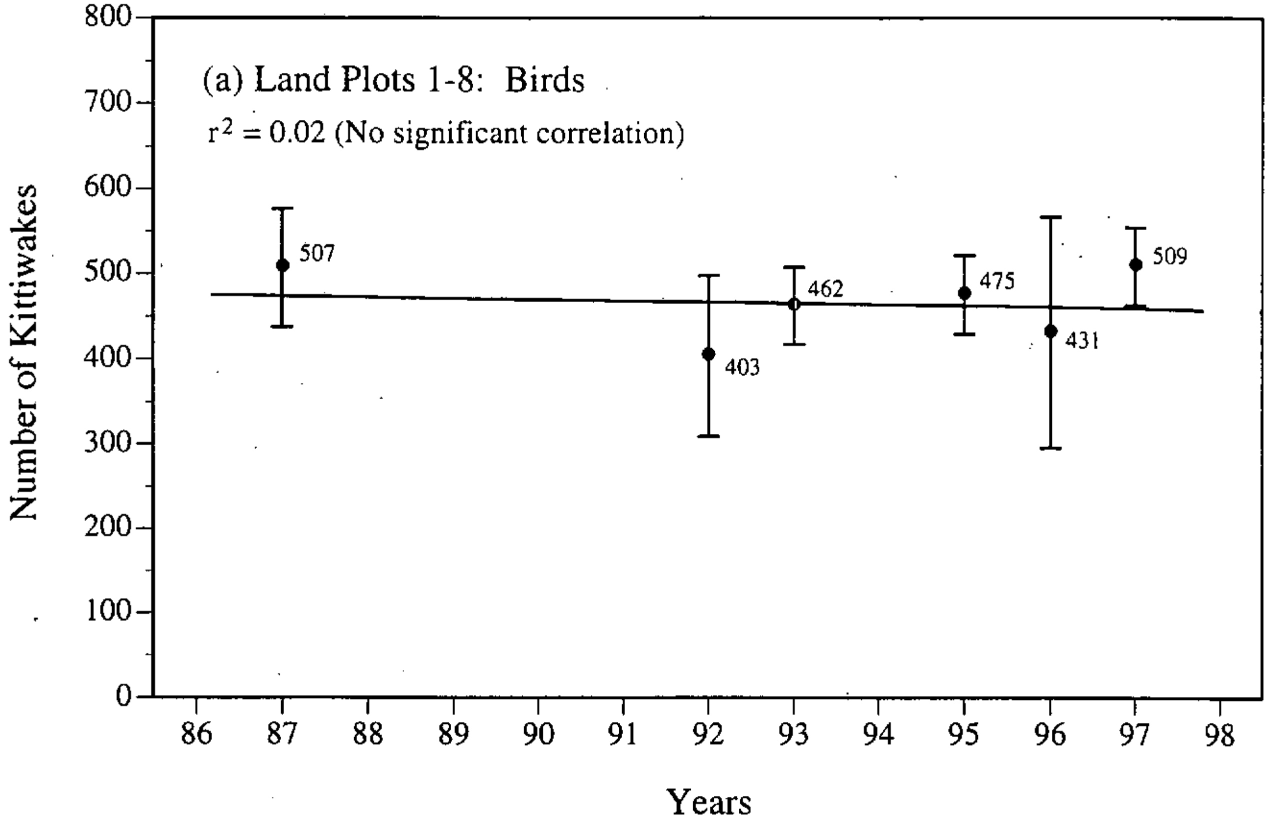


Figure 5. Counts of black-legged kittiwakes on (a) north-facing census plots 65, 66, 70, and 72, and (b) west-facing census plots 11, 12, 25, 26, 30, and 32 at Cape Lisburne, Alaska during 1977-1997 (all counts were single counts without measures of variability; average annual increases based on slopes of the lines and percentages rounded to nearest half percent; data are from Table 1).



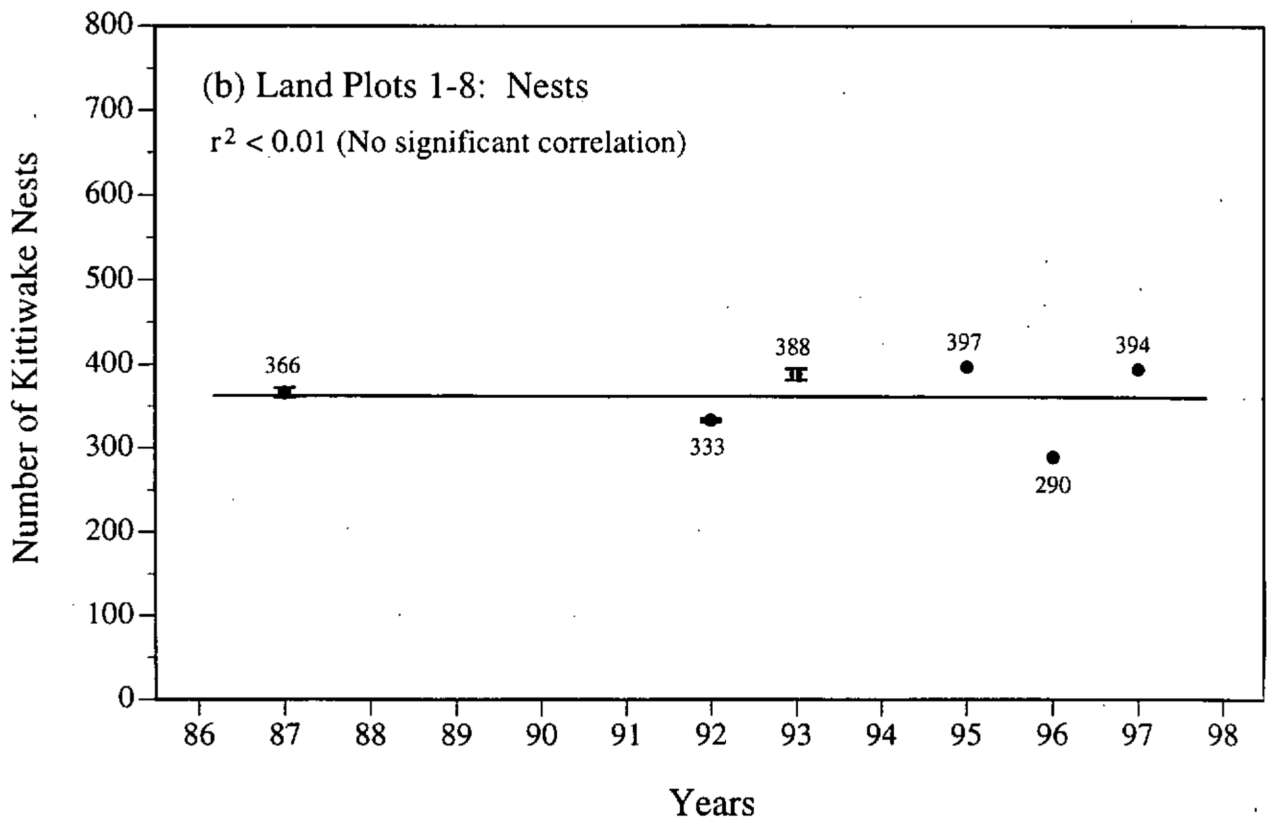


Figure 6. Counts of (a) black-legged kittiwakes and (b) black-legged kittiwake nests on north-facing land plots LP 1-8 at Cape Lisburne, Alaska during1987-1997 (most counts were multiple counts with measures of variability; data are from Table 2).

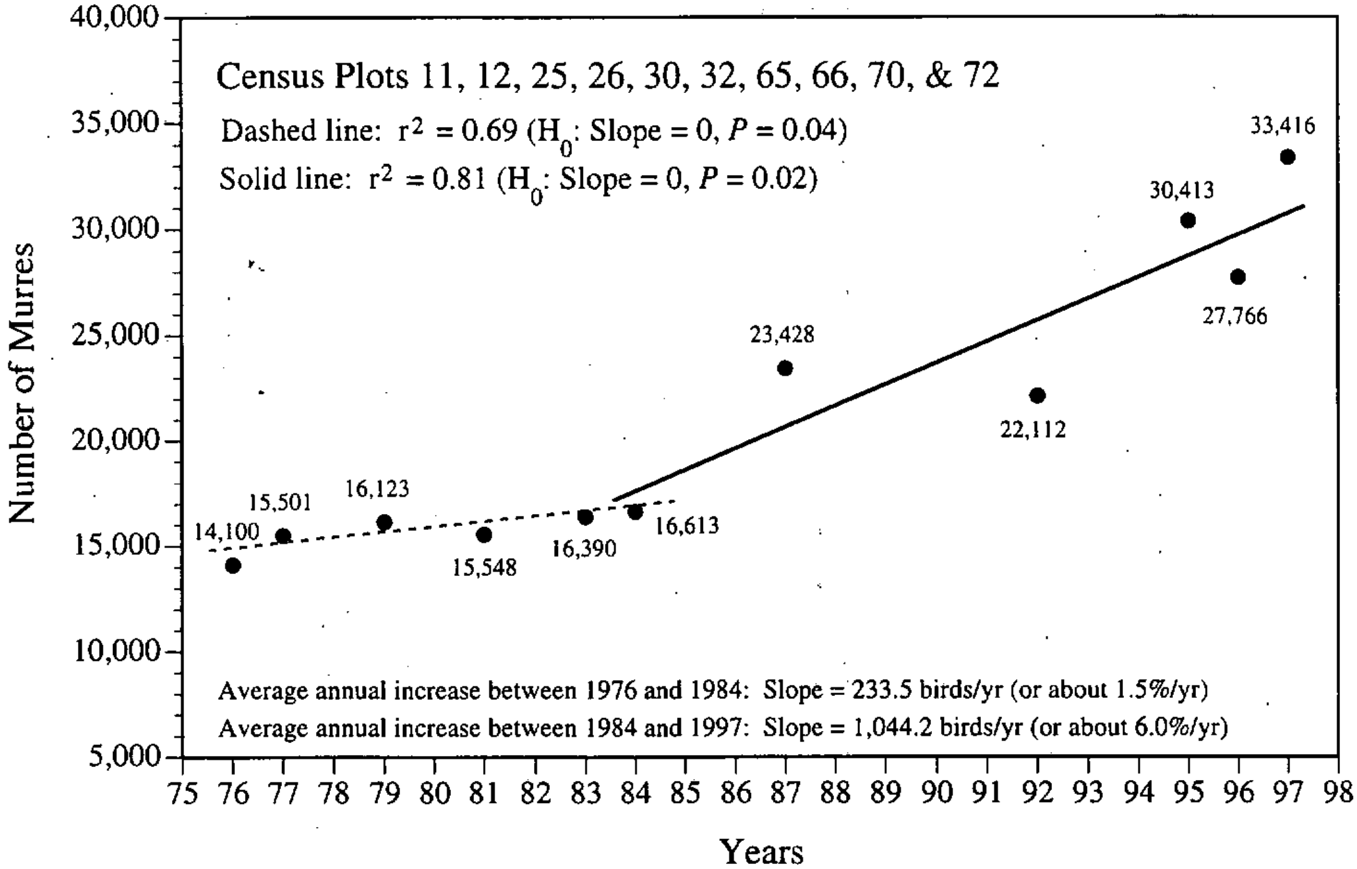


Figure 7. Counts of murres on census plots 11, 12, 25, 26, 30, 32, 65, 66, 70, and 72 at Cape Lisburne, Alaska during 1976-1997 (all counts were single counts without measures of variability; average annual increases based on slopes of the lines and percentages rounded to neared half percent; data are from Table 3).

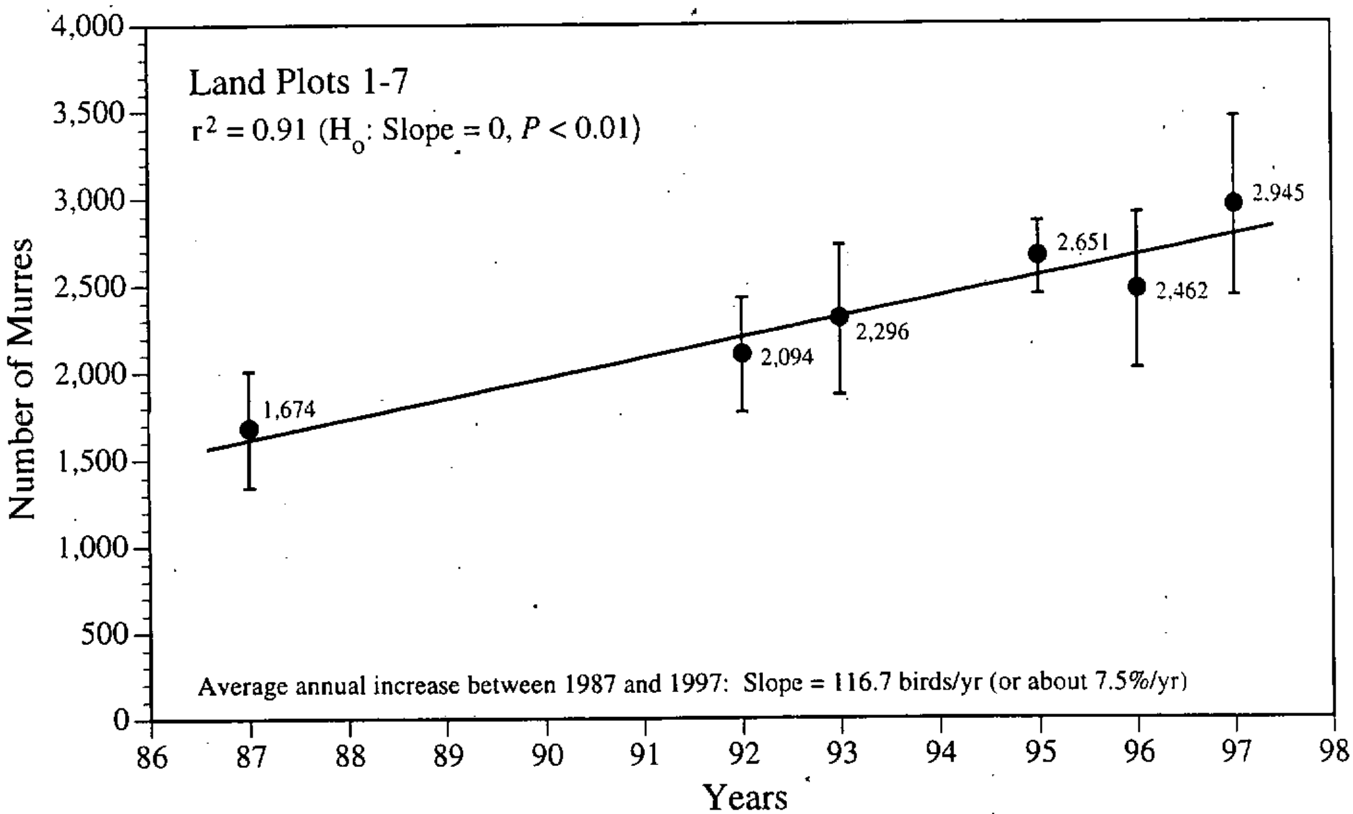


Figure 8. Counts of murres on land plots LP 1-7 at Cape Lisburne, Alaska during 1987-1997 (all counts were multiple counts with measures of variability; average annual increase based on slope of the line and percentage rounded to nearest half percent; data are from Table 4).

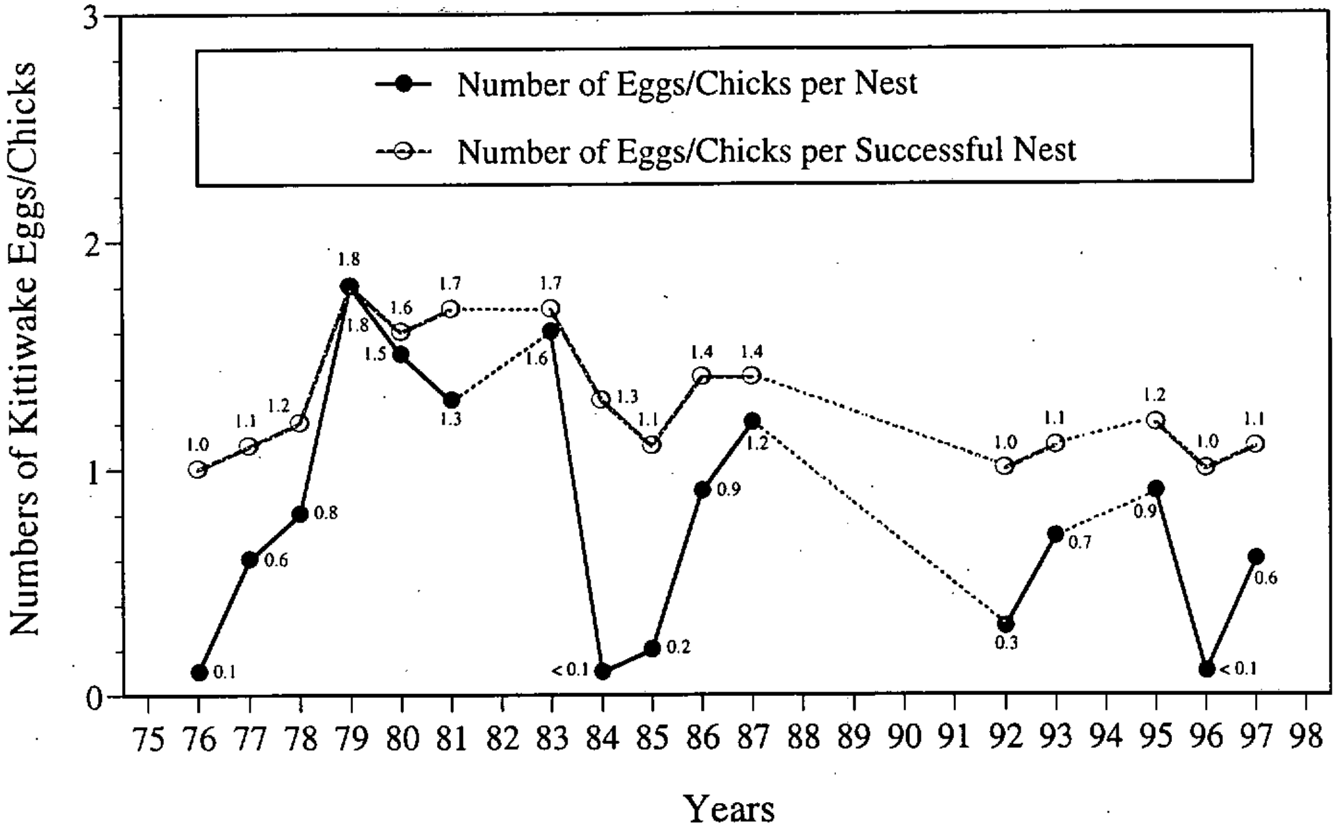


Figure 9. Estimated productivity of black-legged kittiwakes at Cape Lisburne, Alaska during 1976-1997 (a successful nest was a nest that contained at least one egg or live chick; to compare 1995-1997 data with 1976-1993 information, 1995-1997 values were calculated from data collected on or as close to 8 August as possible—see Table 8).

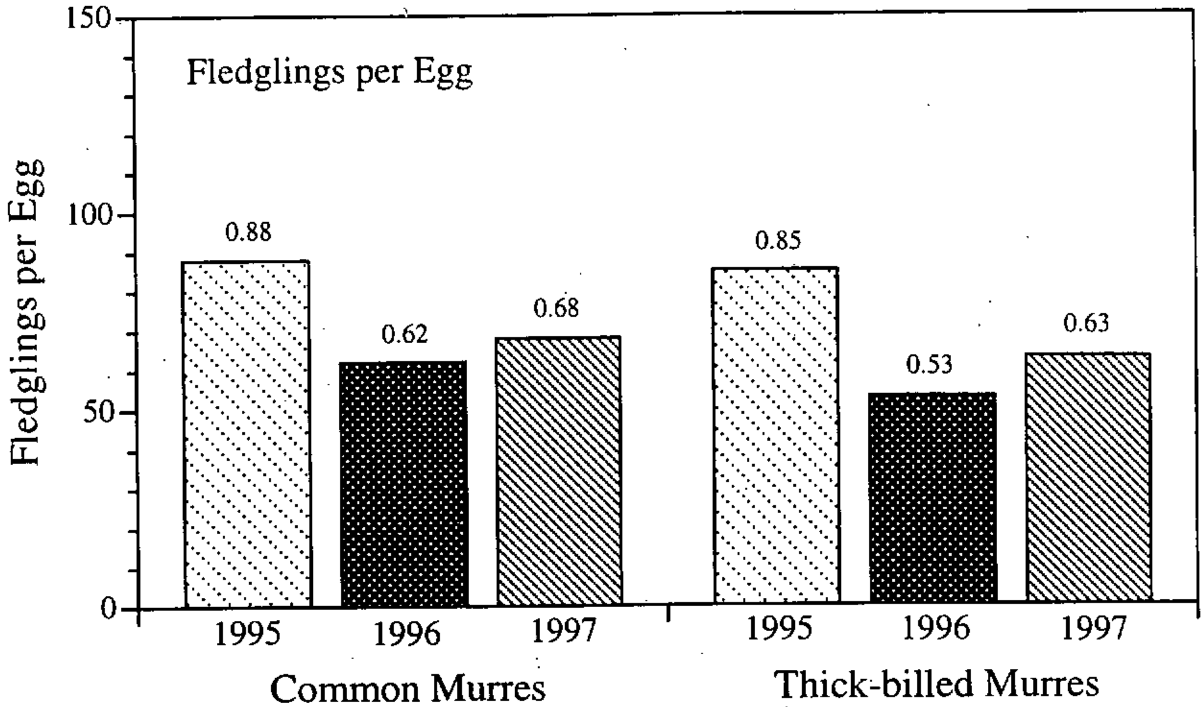


Figure 10. Productivity (fledglings per egg) of common and thick-billed murres at Cape Lisburne, Alaska during 1995-1997 (data are from Table 9).

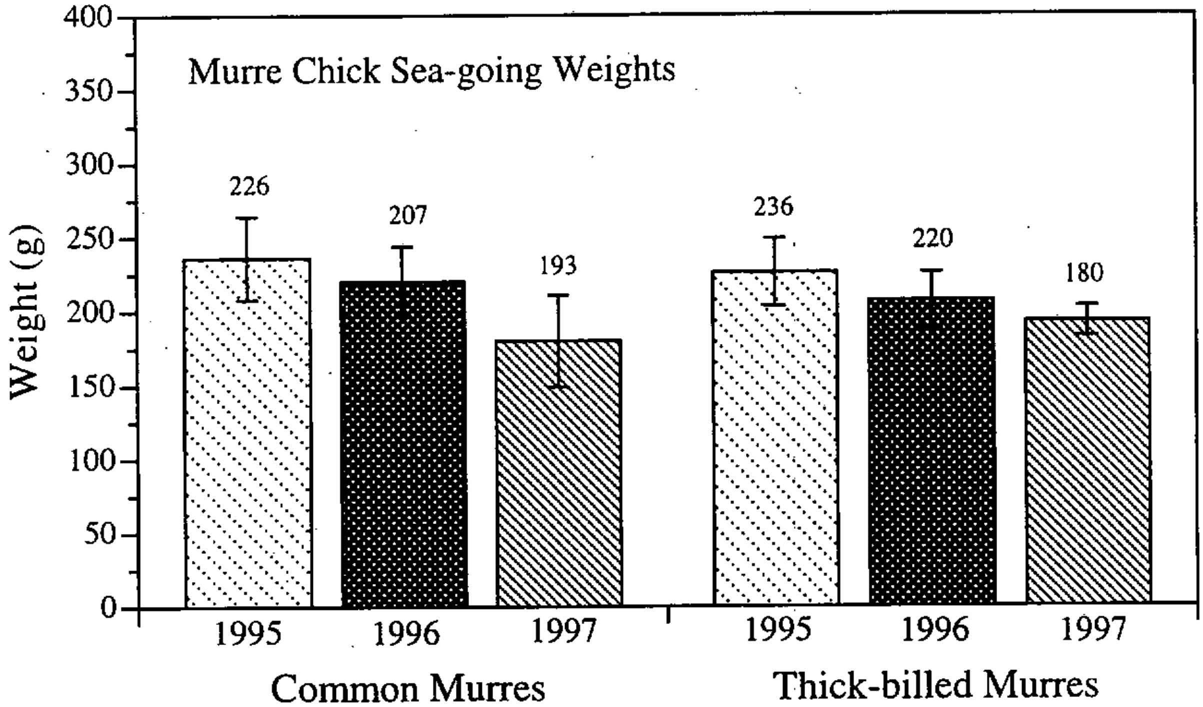


Figure 11. Sea-going weights (g) of common and thick-billed murre chicks at Cape Lisburne, Alaska during 1995-1997 (error bars show standard deviation; data are from Table 11).

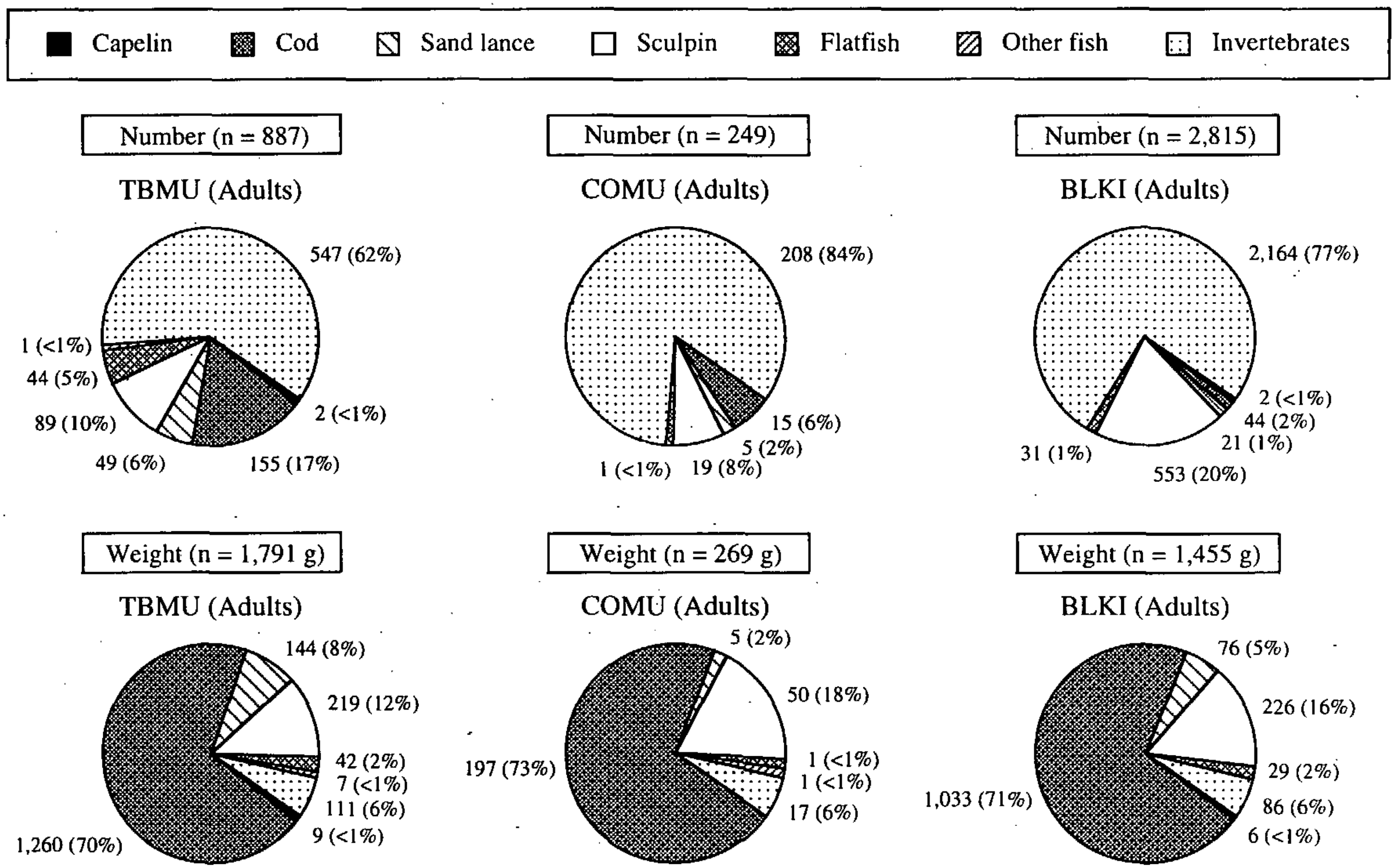


Figure 12. Number and estimated wet weight (g) of prey found in the stomachs of 35 thick-billed murre (TBMU), 13 common murre (COMU), and 31 black-legged kittiwake (BLKI) adults collected at Cape Lisburne, Alaska during 11 July - 22 August 1995 (data are from Table 12).

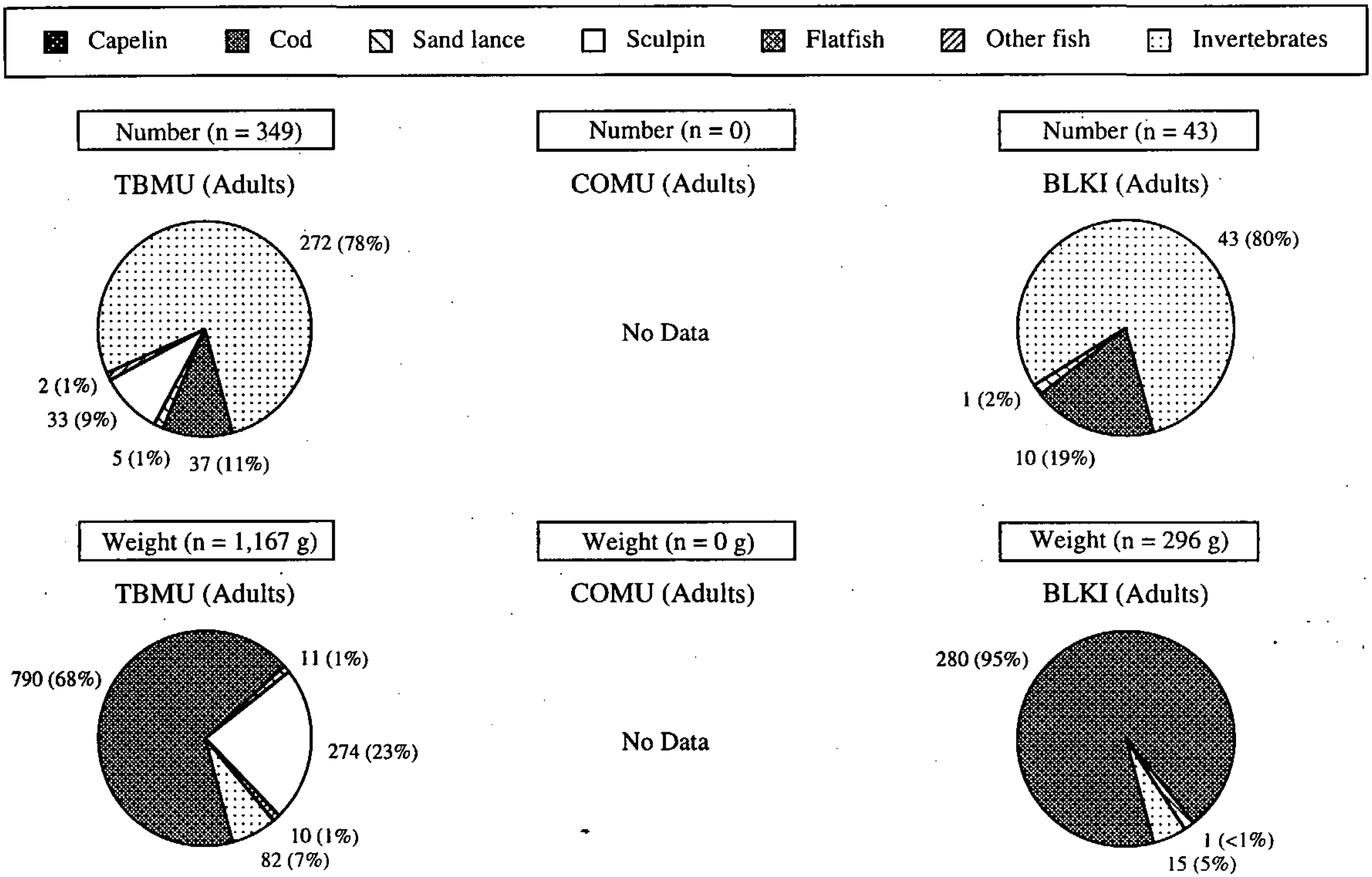


Figure 13. Number and estimated wet weight (g) of prey found in the stomachs of 18 thick-billed murre (TBMU) and 7 black-legged kittiwake (BLKI) adults collected at Cape Lisburne, Alaska during 5 July - 12 August 1996 (data are from Table 13).

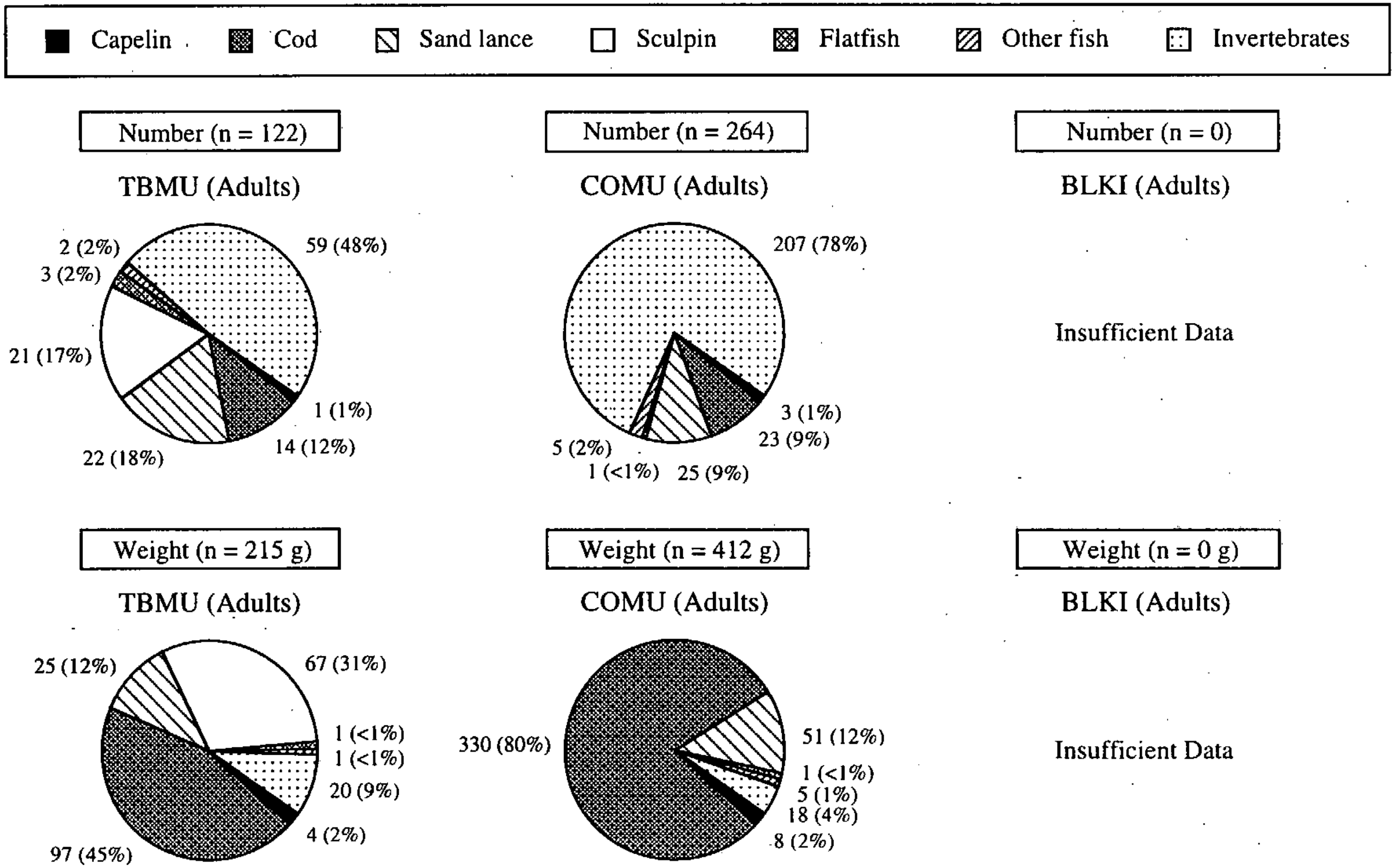


Figure 14. Number and estimated wet weight (g) of prey found in the stomachs of 18 thick-billed murre (TBMU) and 8 common murre (COMU) adults collected at Cape Lisburne, Alaska on 4 July 1997 (data are from Table 14).

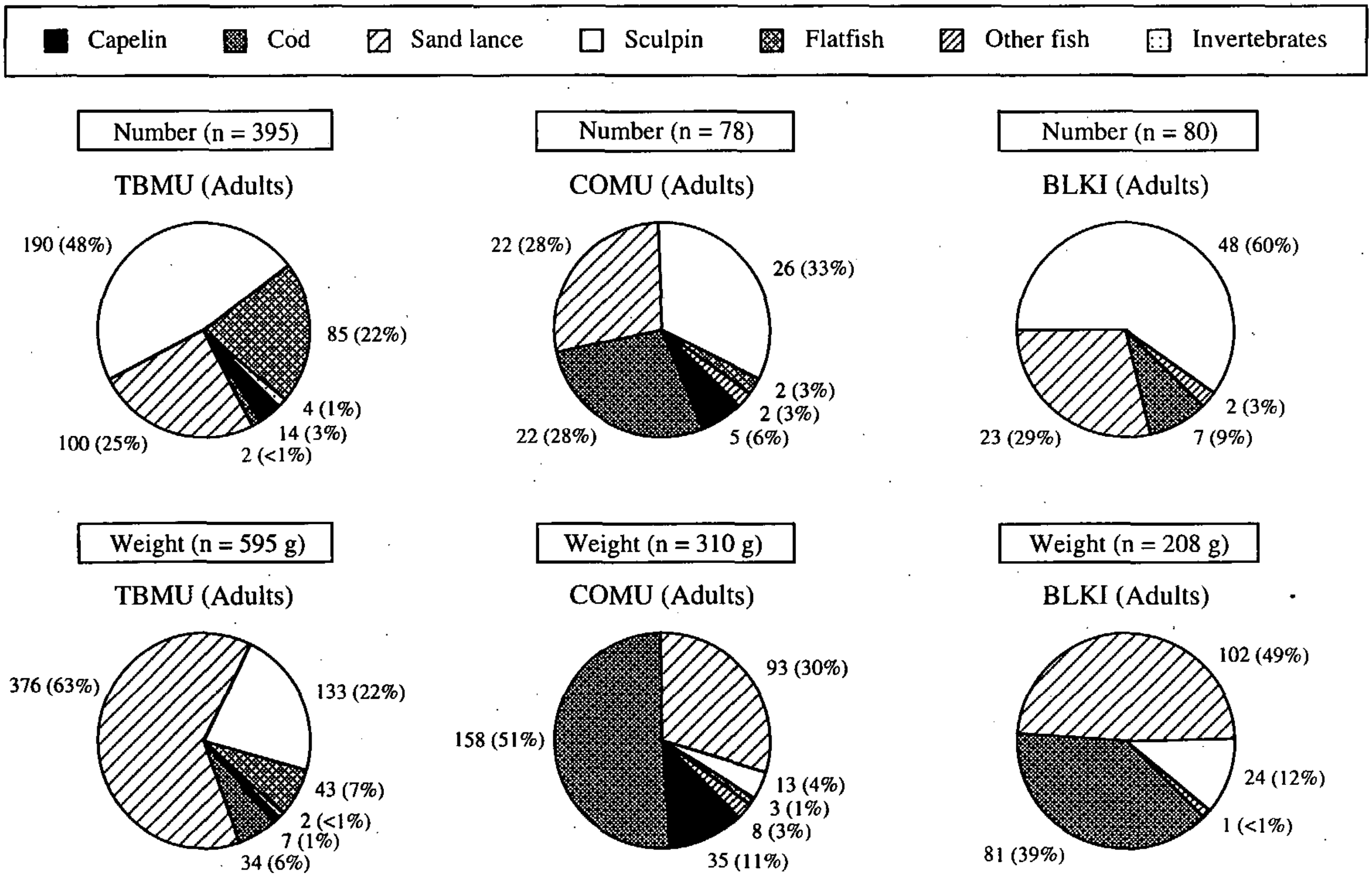


Figure 15. Number and estimated wet weight (g) of prey found in the stomachs of 11 thick-billed murre (TBMU), 5 common murre (COMU), and 13 black-legged kittiwake (BLKI) adults collected at Cape Lisburne, Alaska on 22 July and 3 August 1987 (data are from Table 15).

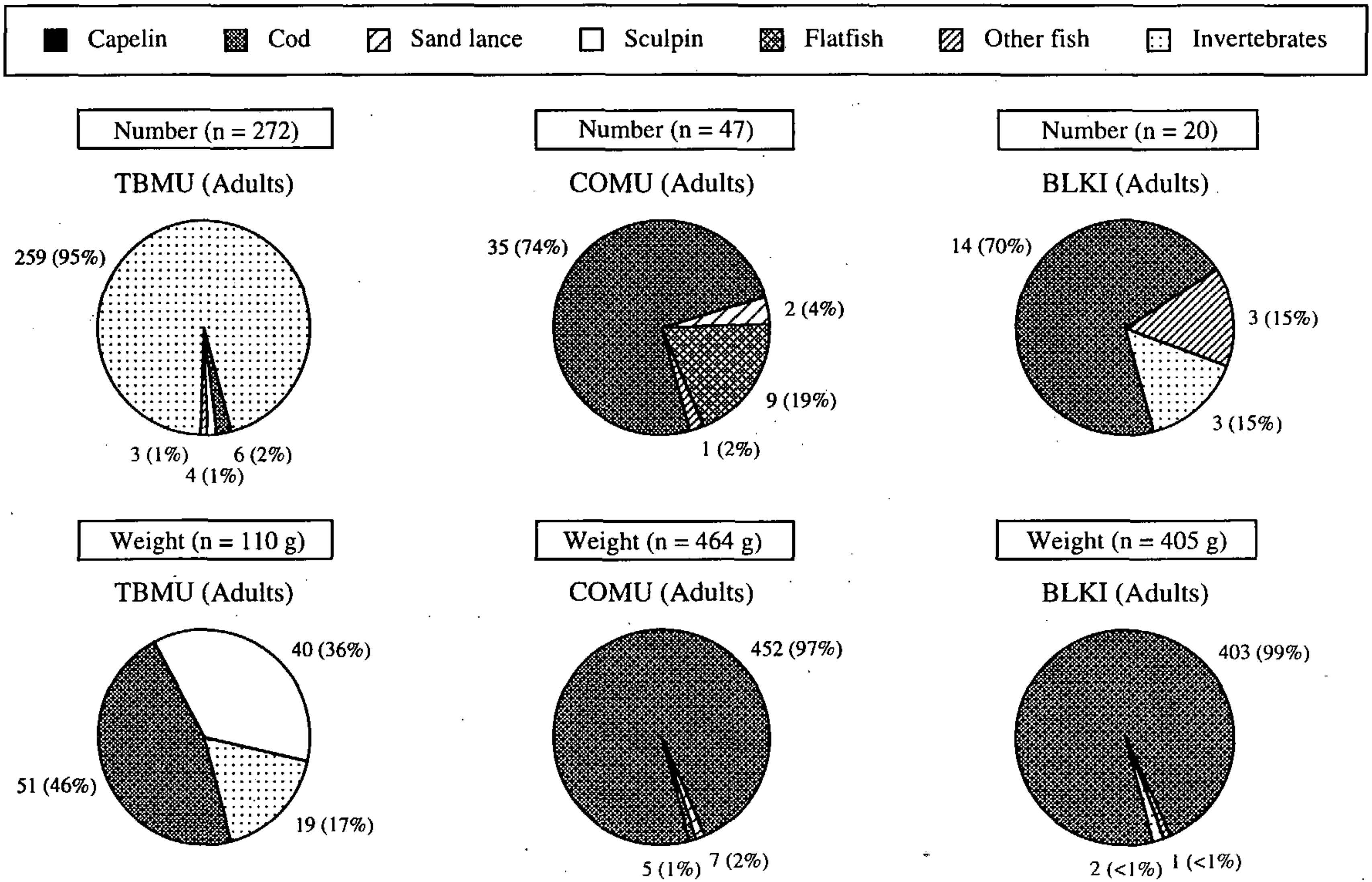


Figure 16. Number and estimated wet weight (g) of prey found in the stomachs of 13 thick-billed murre (TBMU), 7 common murre (COMU), and 8 black-legged kittiwake (BLKI) adults collected at Cape Lisburne, Alaska on 22 and 24 July 1992 (data are from Table 16).

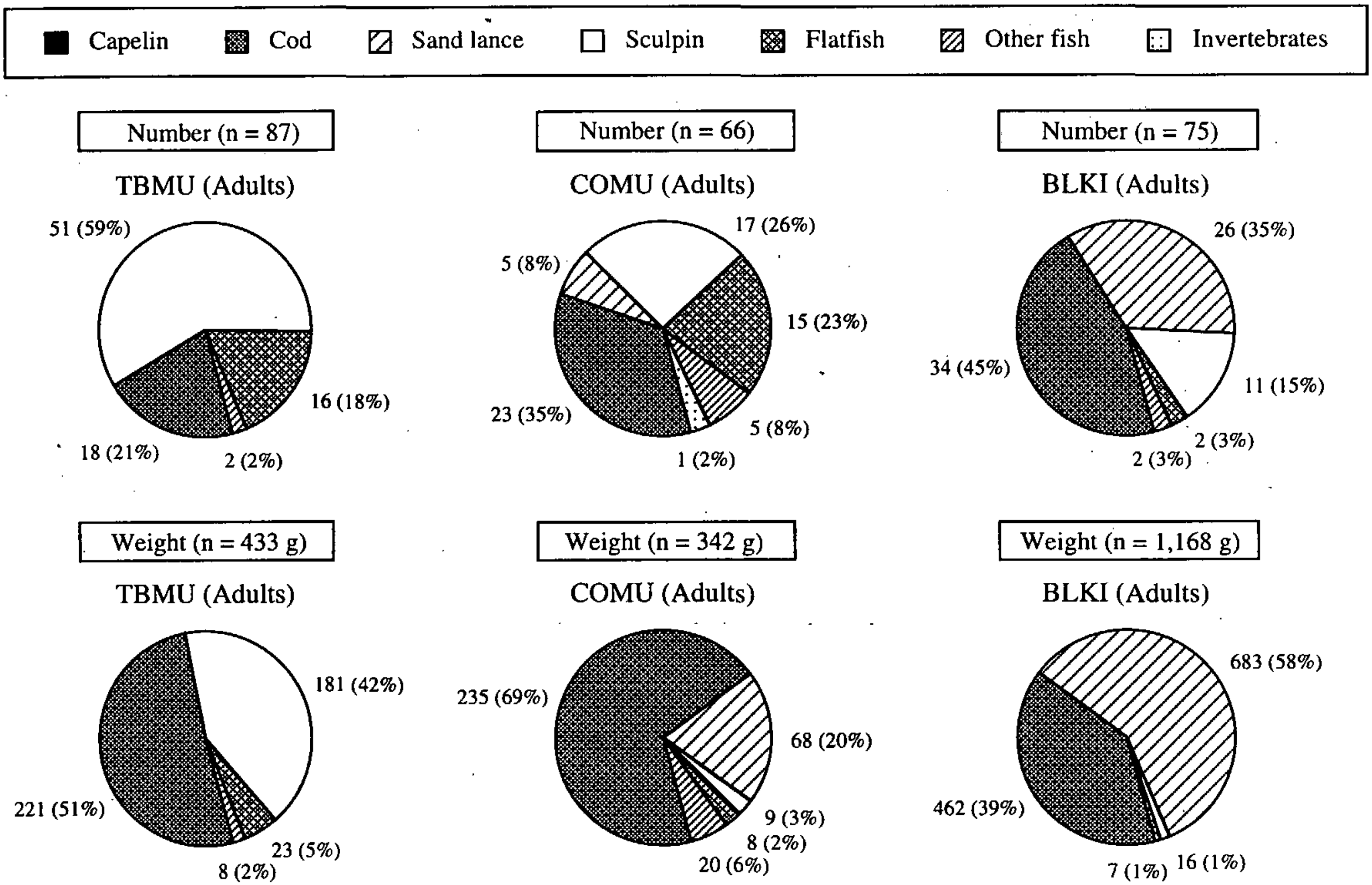


Figure 17. Number and estimated wet weight (g) of prey found in the stomachs of 4 thick-billed murre (TBMU), 3 common murre (COMU), and 10 black-legged kittiwake (BLKI) adults collected at Cape Lisburne, Alaska on 28 July 1993 (data are from Table 17).

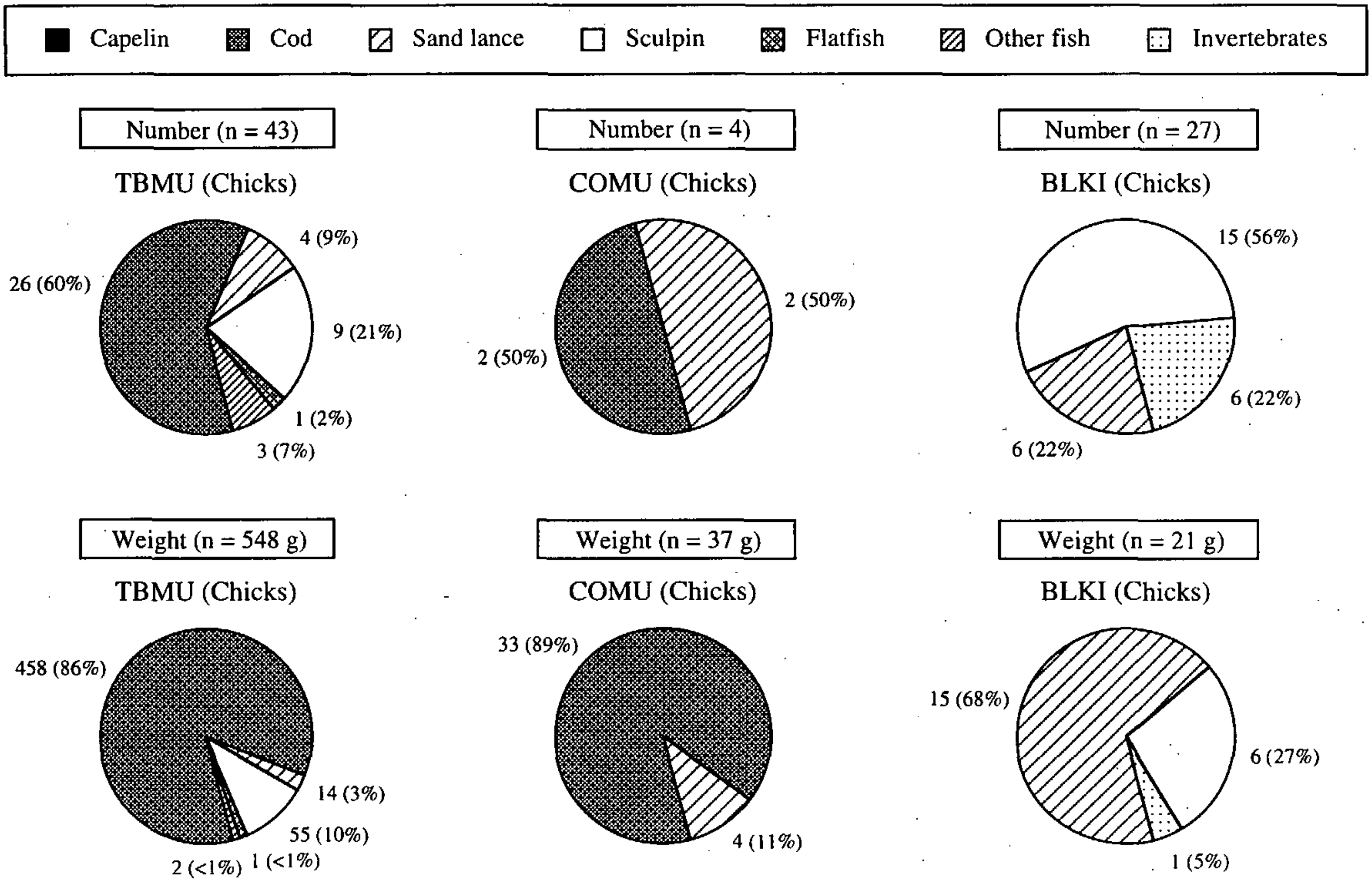


Figure 18. Number and estimated wet weight (g) of prey found in the stomachs of 19 thick-billed murre (TBMU), 2 common murre (COMU), and 4 black-legged kittiwake (BLKI) chicks collected at Cape Lisburne, Alaska during 4-26 August 1995 (data are from Table 18).

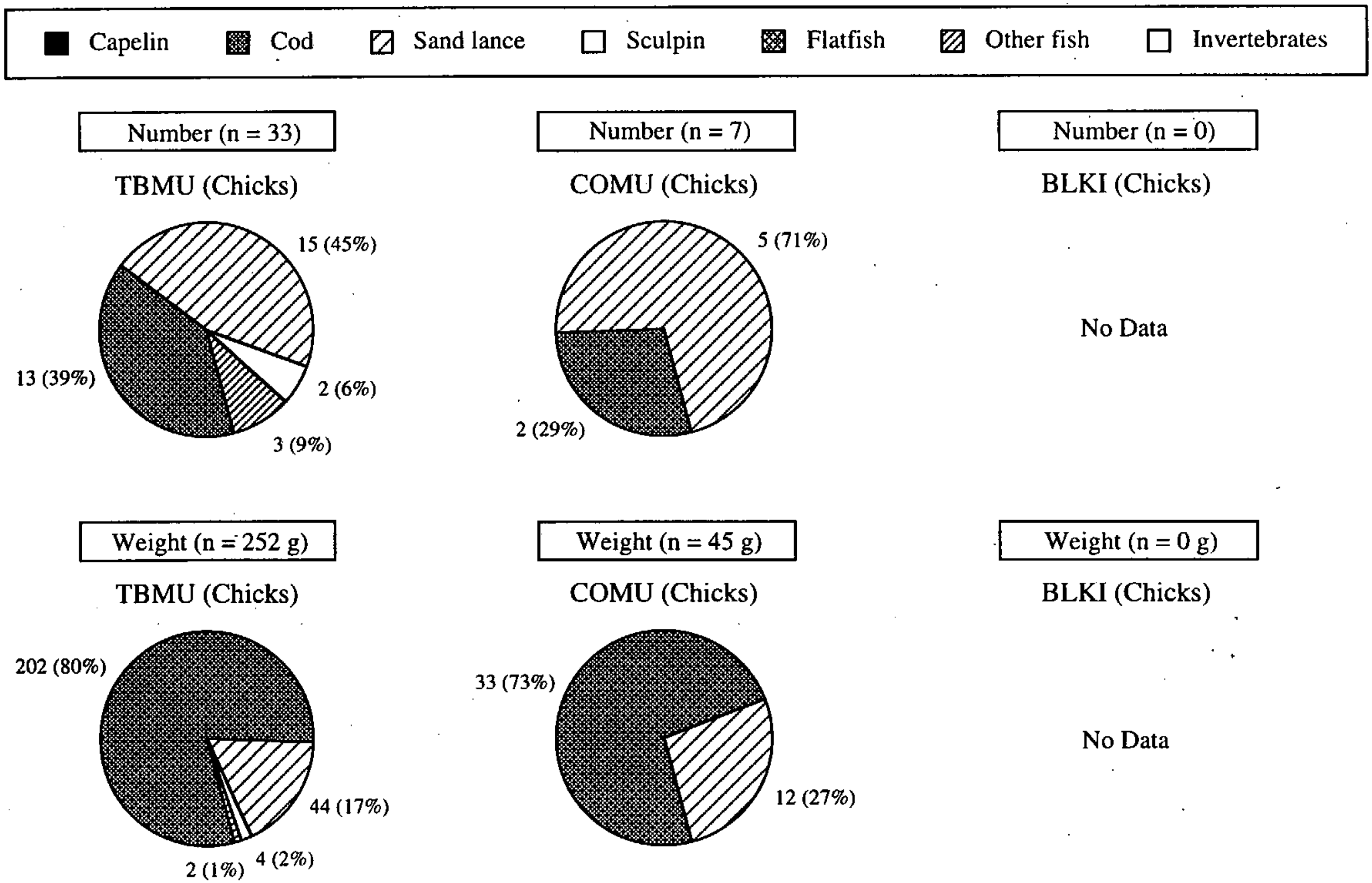


Figure 19. Number and estimated wet weight (g) of prey found in the stomachs of 23 thick-billed murre (TBMU) and 5 common murre (COMU) chicks collected at Cape Lisburne, Alaska during 15-27 August 1996 (data are from Table 19).

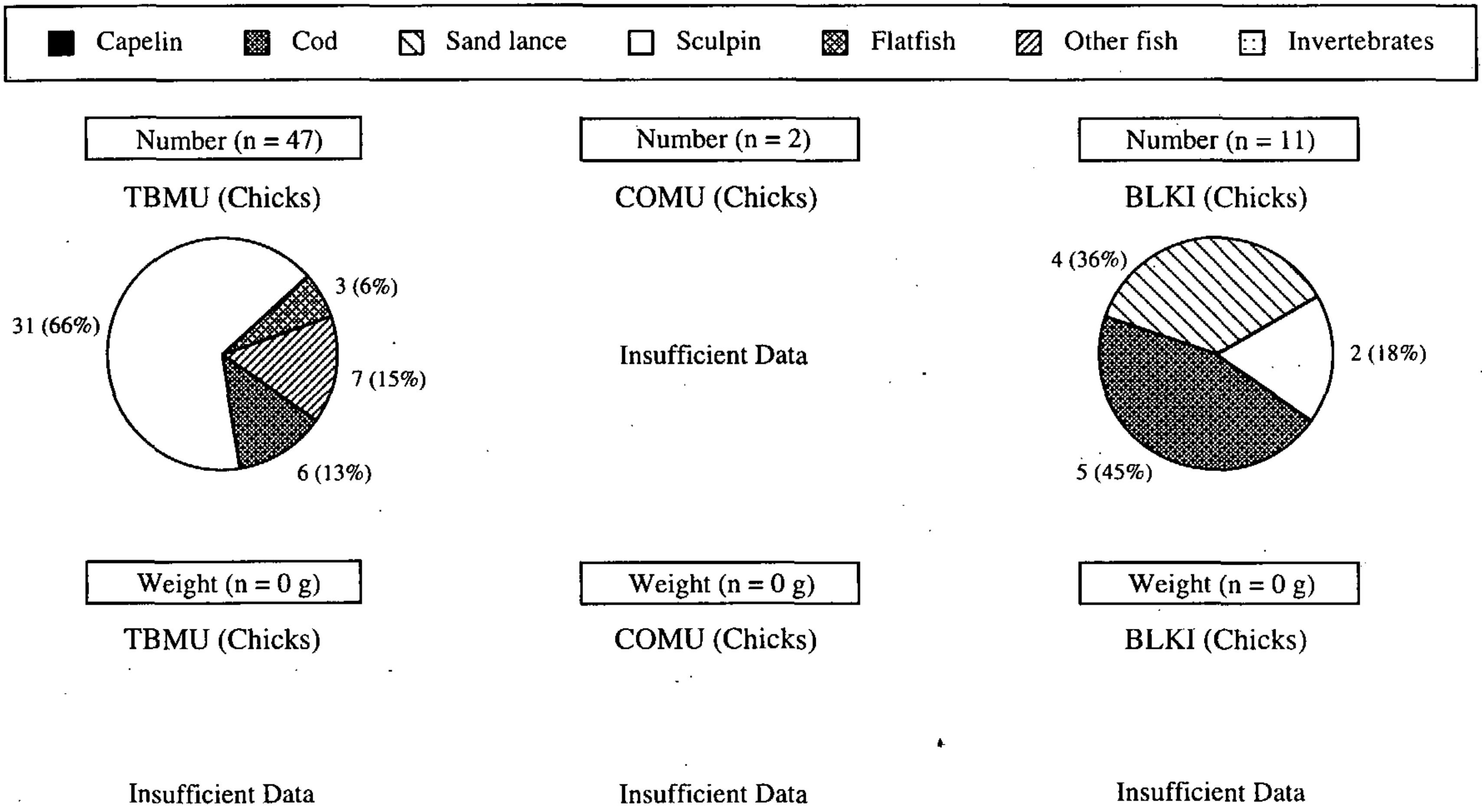


Figure 20. Number and estimated wet weight (g) of prey found in the stomachs of 9 thick-billed murre (TBMU) and 5 black-legged kittiwake chicks salvaged at Cape Lisburne, Alaska during 20 July - 29 August 1997 (prey weights could not be calculated because otoliths were too eroded to age; data are from Table 20).

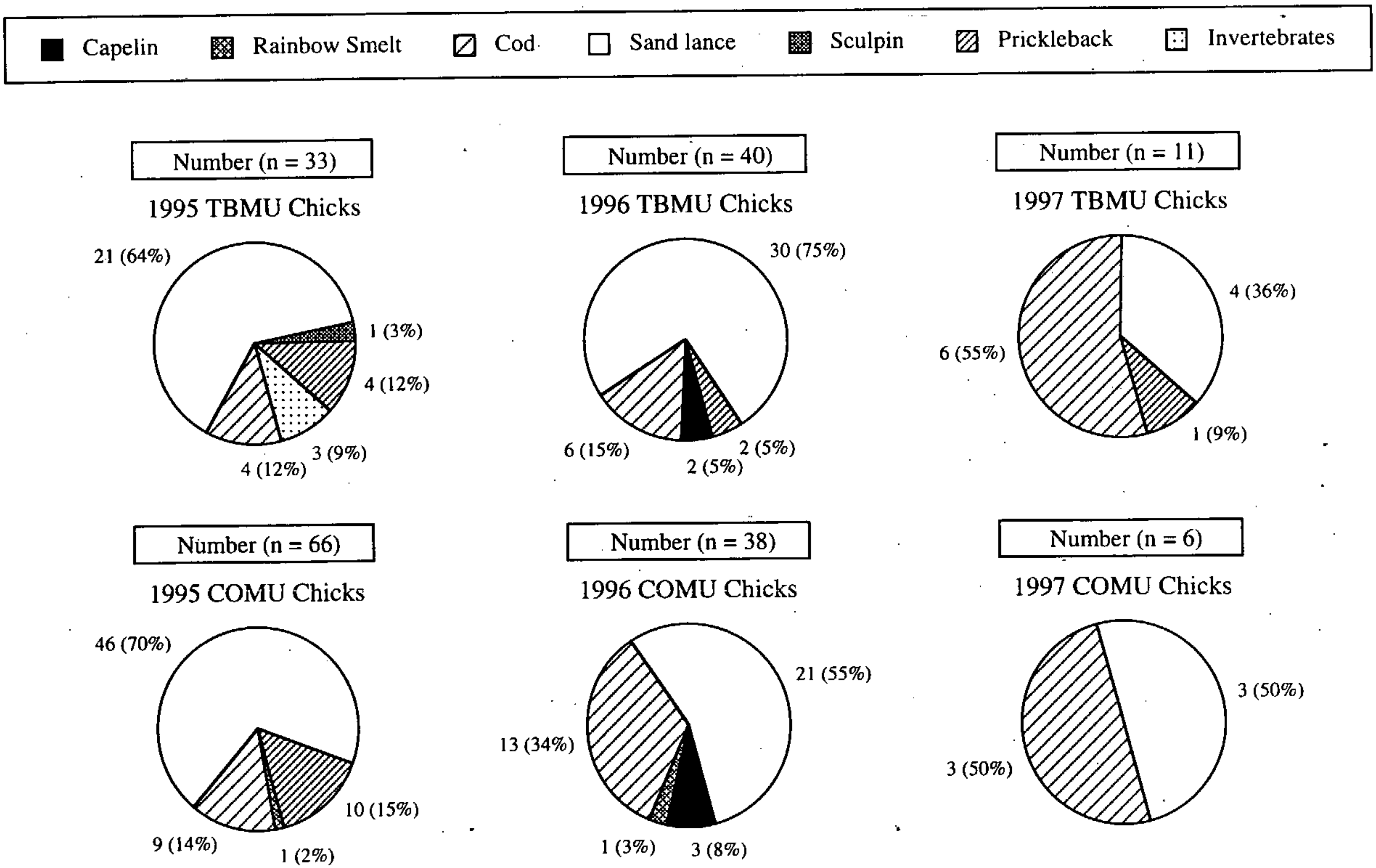


Figure 21. Prey species delivered to thick-billed murre (TBMU) and common murre (COMU) chicks at Cape Lisburne, Alaska in 1995-1997 (data are from Tables 21a and 21b).

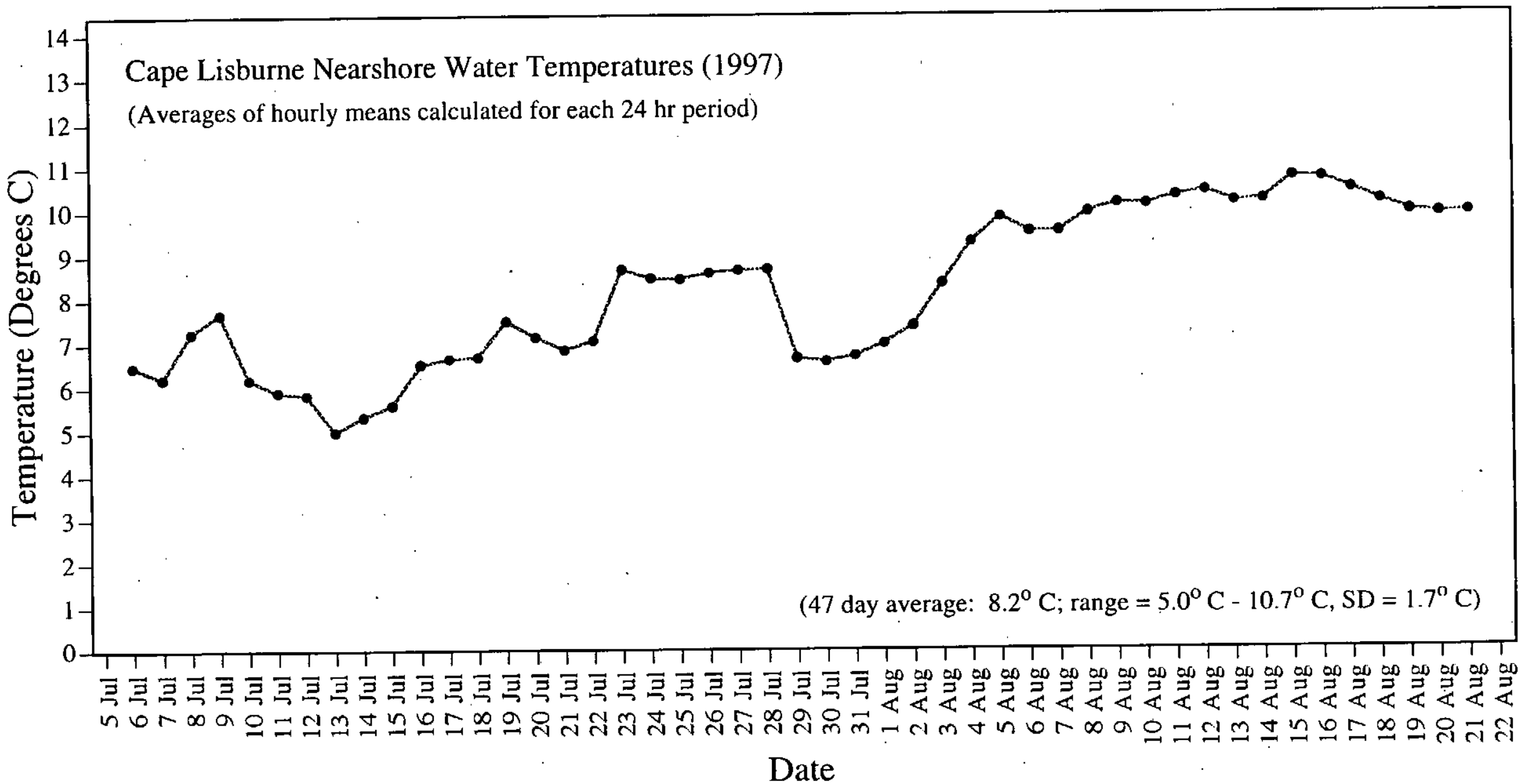


Figure 22. Daily nearshore water temperatures at Cape Lisburne, Alaska during 6 July - 21 August 1997. Data were recorded every 12 minutes by an Onset Optic StowAway Temp data logger anchored 2-3 m above the bottom in 15 m of water 1.6 km offshore of the Selin Creek mouth, about 3.5 km east-northeast of the eastern end of the Cape Lisburne seabird colony (SD = standard deviation).

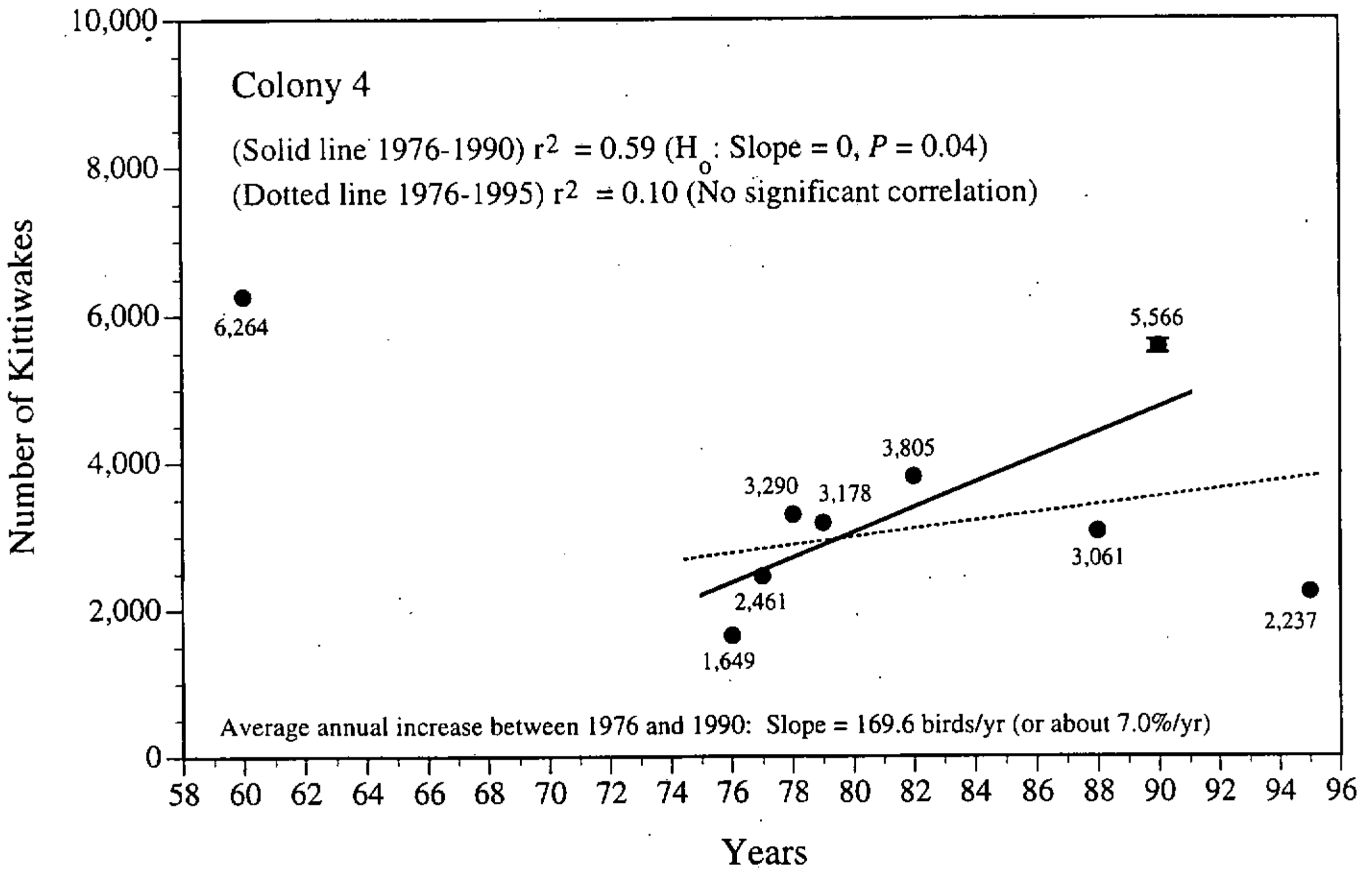


Figure 23. Counts of black-legged kittiwakes at Colony 4, Cape Thompson, Alaska during 1960-1995 (all counts were single counts without measures of variability, except $n = 2$ in 1990; average annual increase based on slope of the line and percentage rounded to nearest half percent; data are from Table 23).

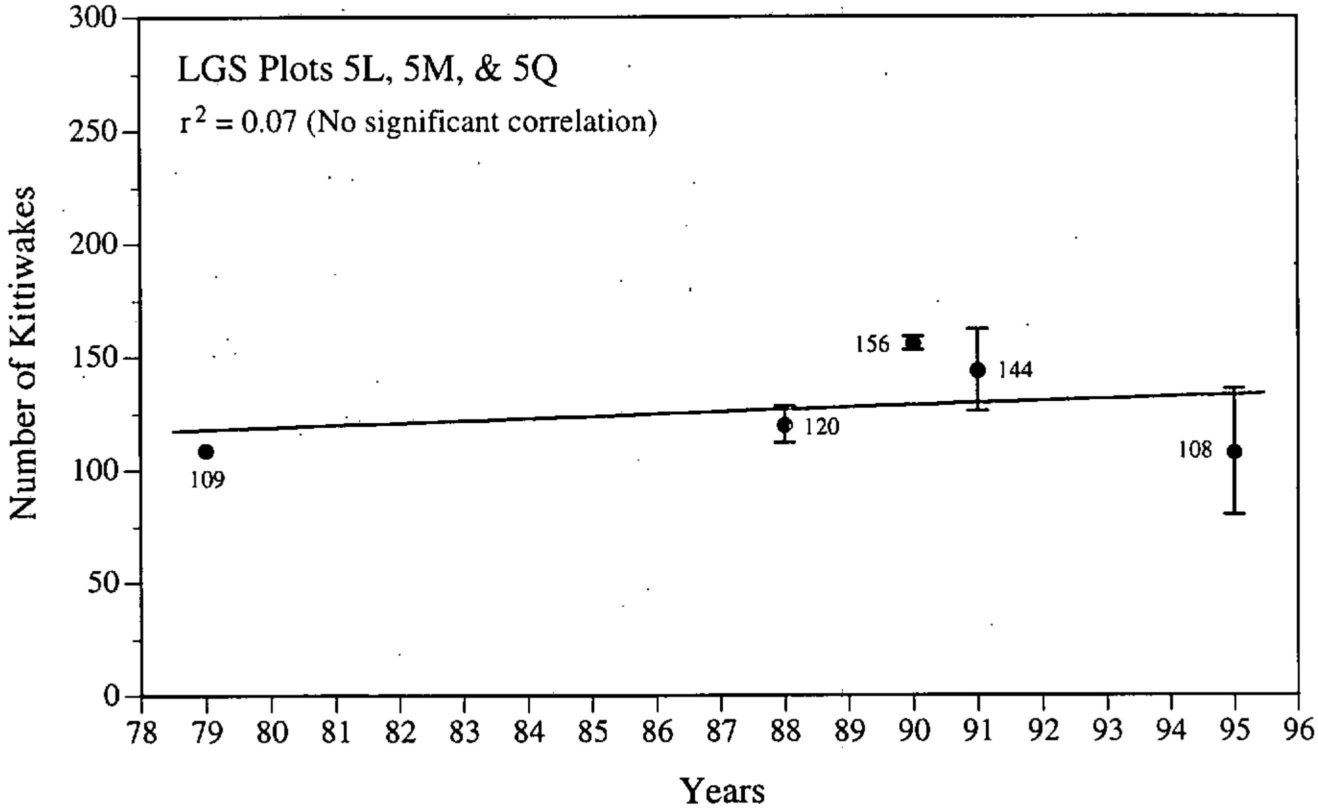


Figure 24. Counts of black-legged kittiwakes on LGS plots 5L, 5M, and 5Q at Cape Thompson, Alaska during 1979-1995 (the 1979 count was a single count without any measure of variability; however, in 1988, 1990, 1991, and 1995, n = 7, 2, 5, and 14, respectively—data are from Table 24).

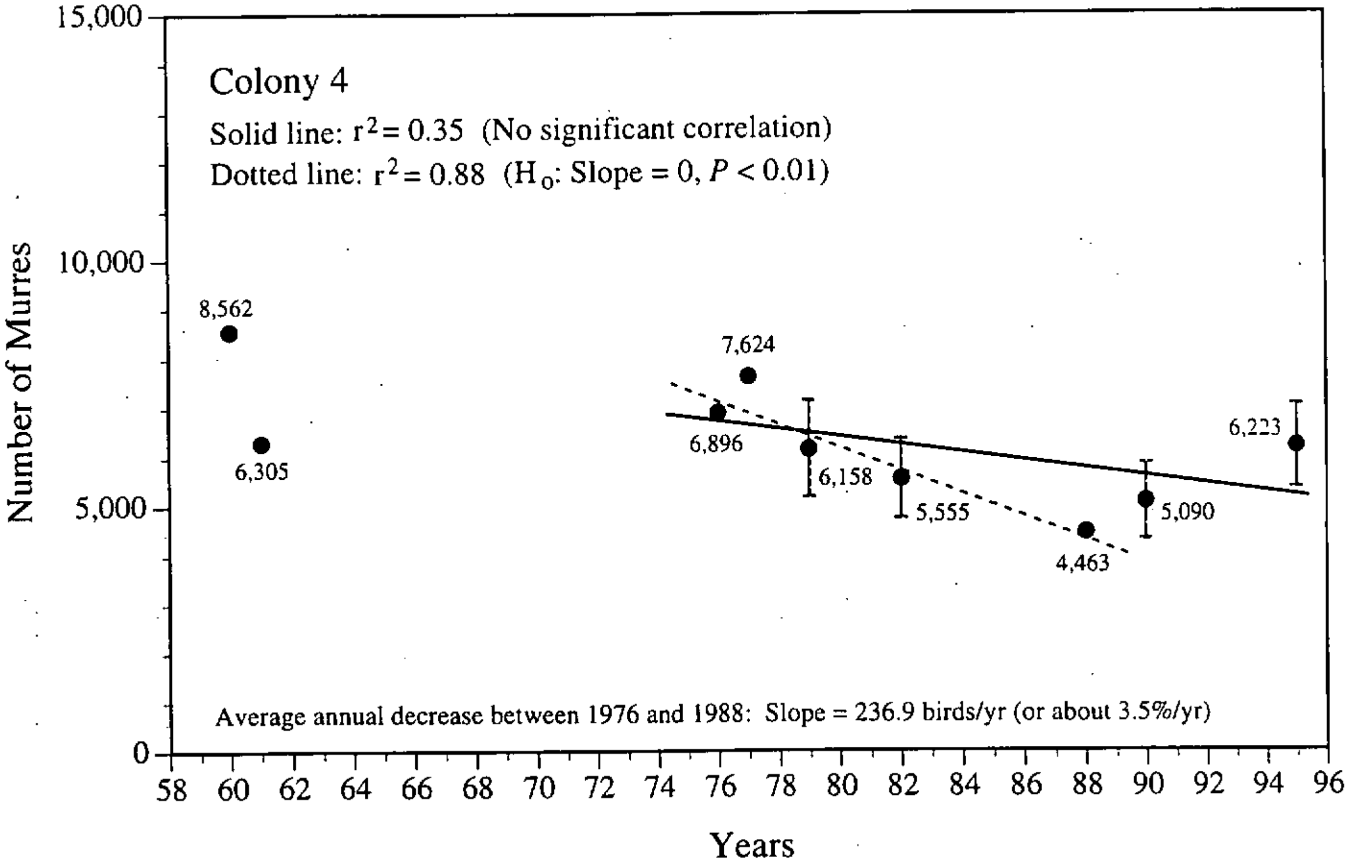


Figure 25. Average counts of murres at Colony 4, Cape Thompson, Alaska during 1960-1995 (some counts were single counts without any measures of variability, but n = 2 in 1979, 1982, 1990, and 1995; average annual decrease based on slope of the line and percentage rounded to nearest half percent; data are from Table 28).

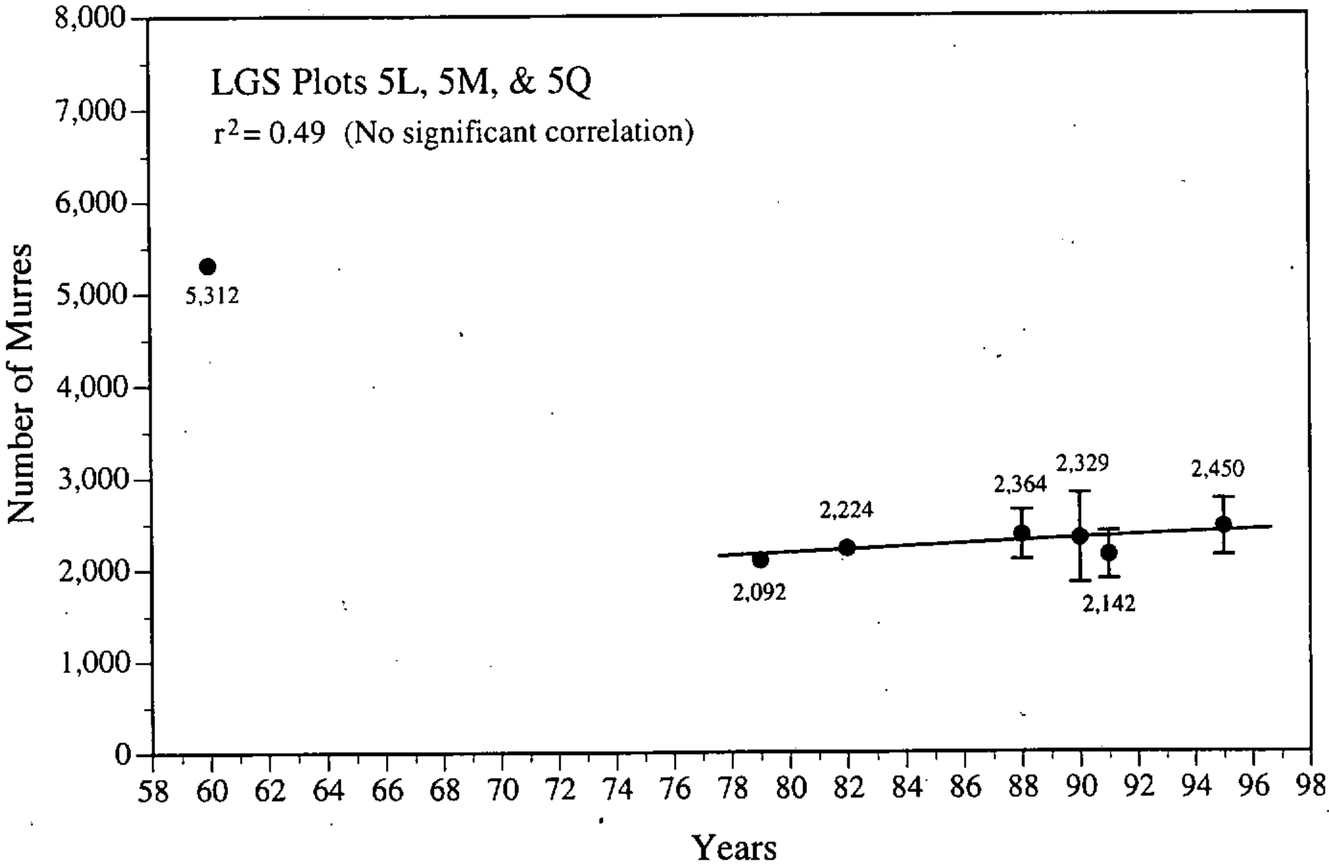


Figure 26. Counts of murres on LGS plots 5L, 5M, and 5Q at Cape Thompson, Alaska during 1960-1995 (some counts were single counts without any measures of variability, but n = 9, 2, 4, and 14 in 1988, 1990, 1991, and 1995, respectively; data are from Table 29).

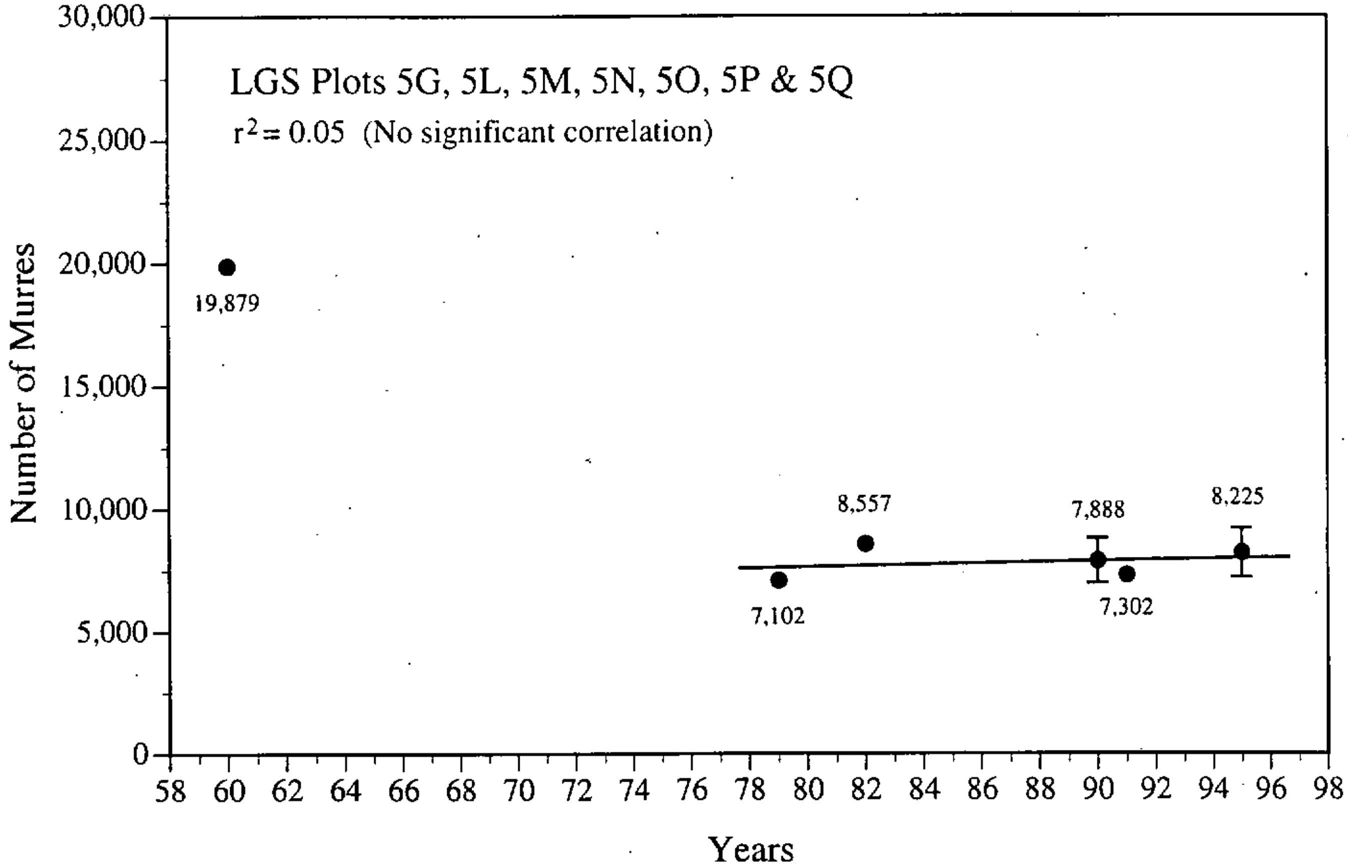


Figure 27. Counts of murres on LGS plots 5G, 5L, 5M, 5N, 5O, 5P, and 5Q at Cape Thompson, Alaska during 1960-1995 (some counts were single counts without any measures of variability, but n = 9, 2, 4, and 14 in 1988, 1990, 1991, and 1995, respectively; data are from Table 30).

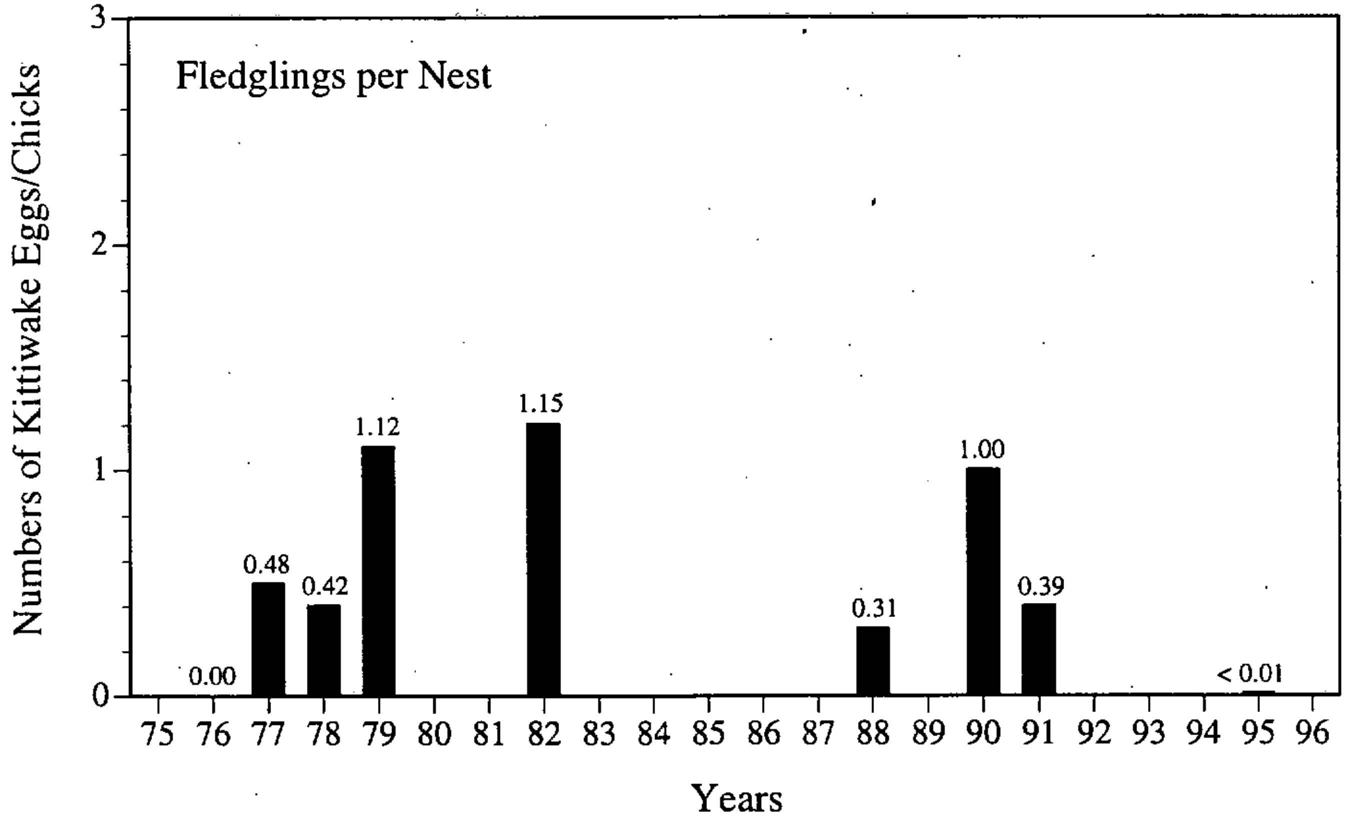


Figure 28. Productivity of black-legged kittiwakes at Cape Thompson, Alaska during 1976-1995 (data are from Table 35).

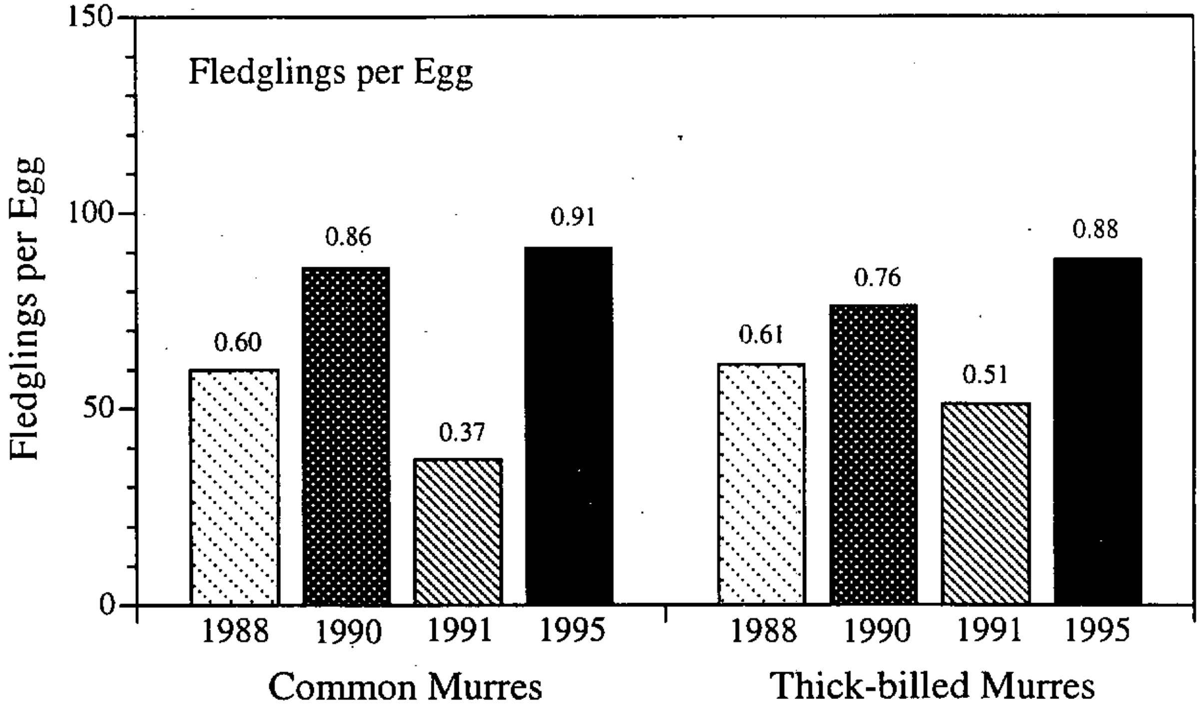


Figure 29. Productivity of common and thick-billed murres at Cape Thompson, Alaska during 1988-1995 (data are from Table 37).

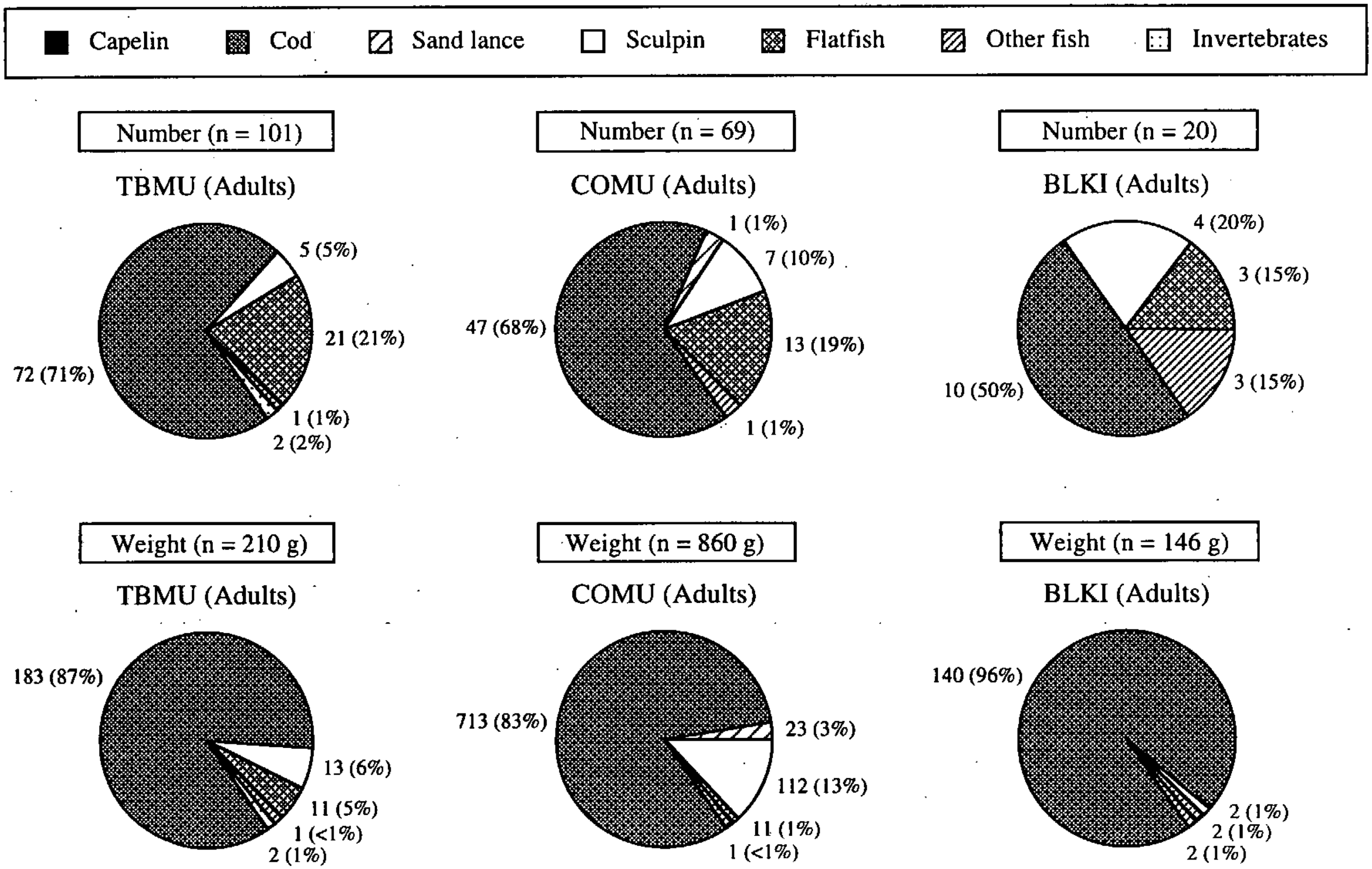


Figure 30. Number and estimated wet weight (g) of prey found in the stomachs of 7 thick-billed murre (TBMU), 10 common murre (COMU), and 10 black-legged kittiwake (BLKI) adults collected at Cape Thompson, Alaska during 13 July - 20 August 1995 (data are from Table 38).

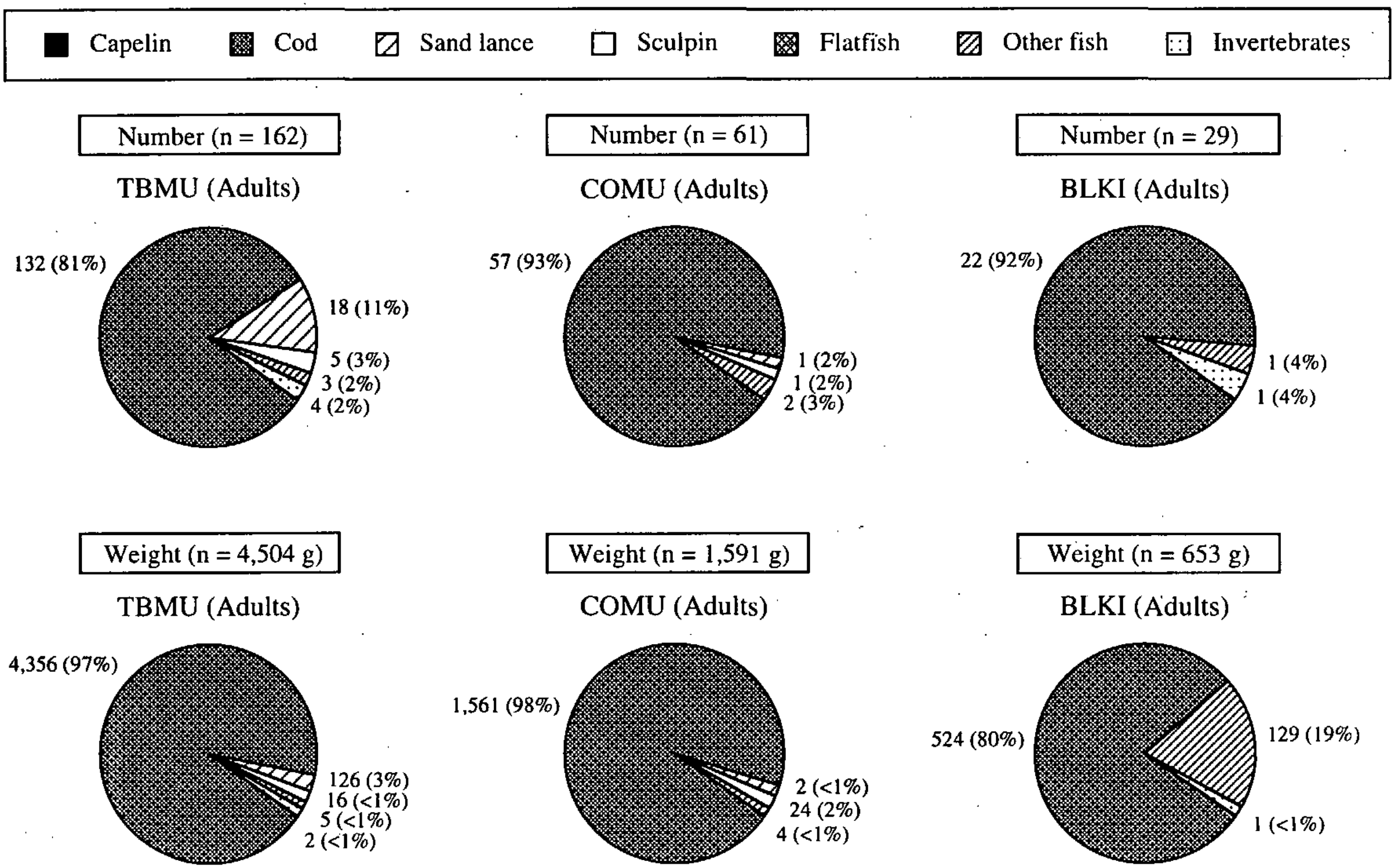


Figure 31. Number and estimated wet weight (g) of prey found in the stomachs of 32 thick-billed murre (TBMU), 11 common murre (COMU), and 14 black-legged kittiwake (BLKI) adults collected at Cape Thompson, Alaska during 6 July - 27 August 1988 (data are from Table 39).

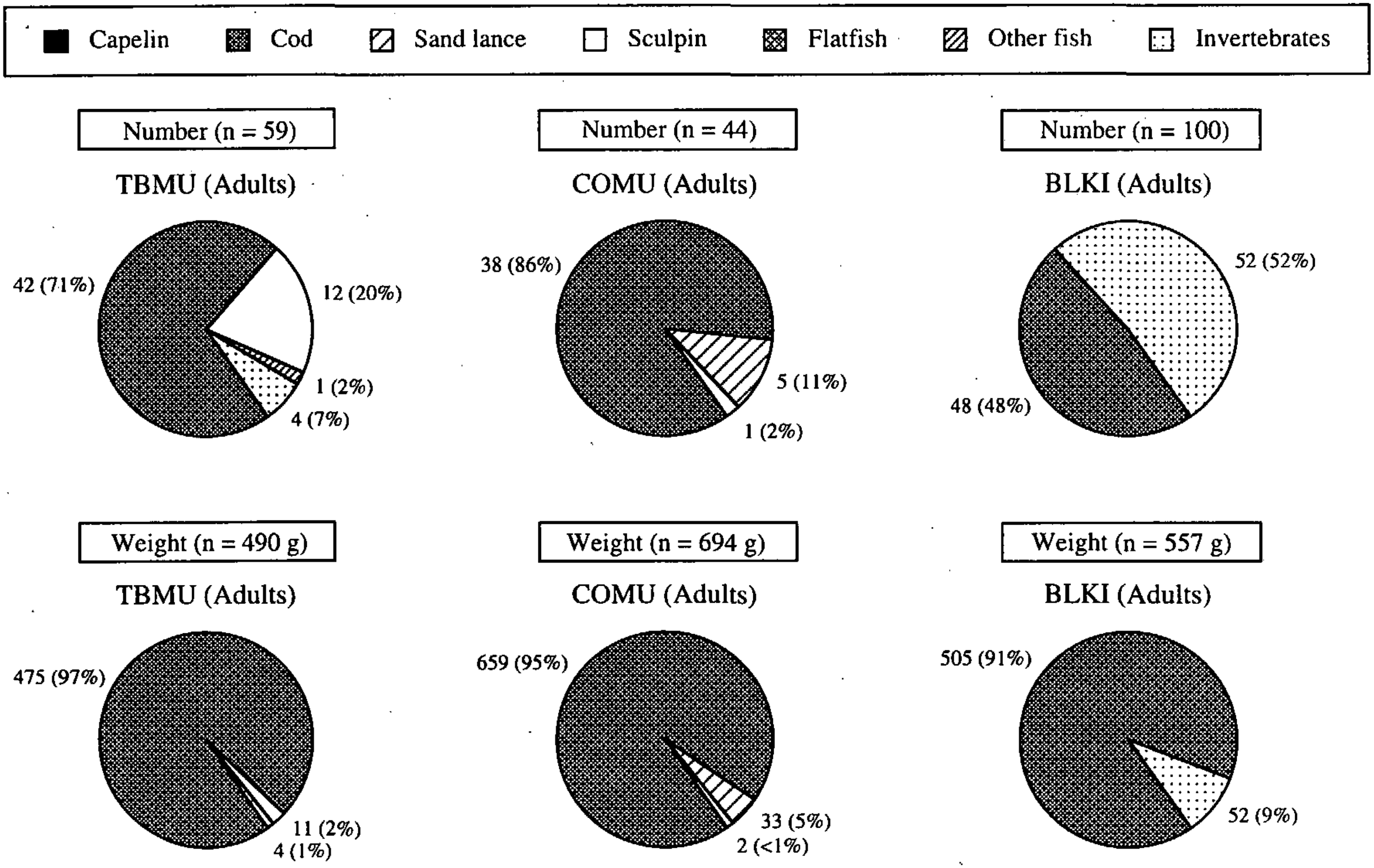


Figure 32. Number and estimated wet weight (g) of prey found in the stomachs of 9 thick-billed murre (TBMU), 6 common murre (COMU), and 13 black-legged kittiwake (BLKI) adults collected at Cape Thompson, Alaska during 13 July - 27 August 1990 (data are from Table 40).

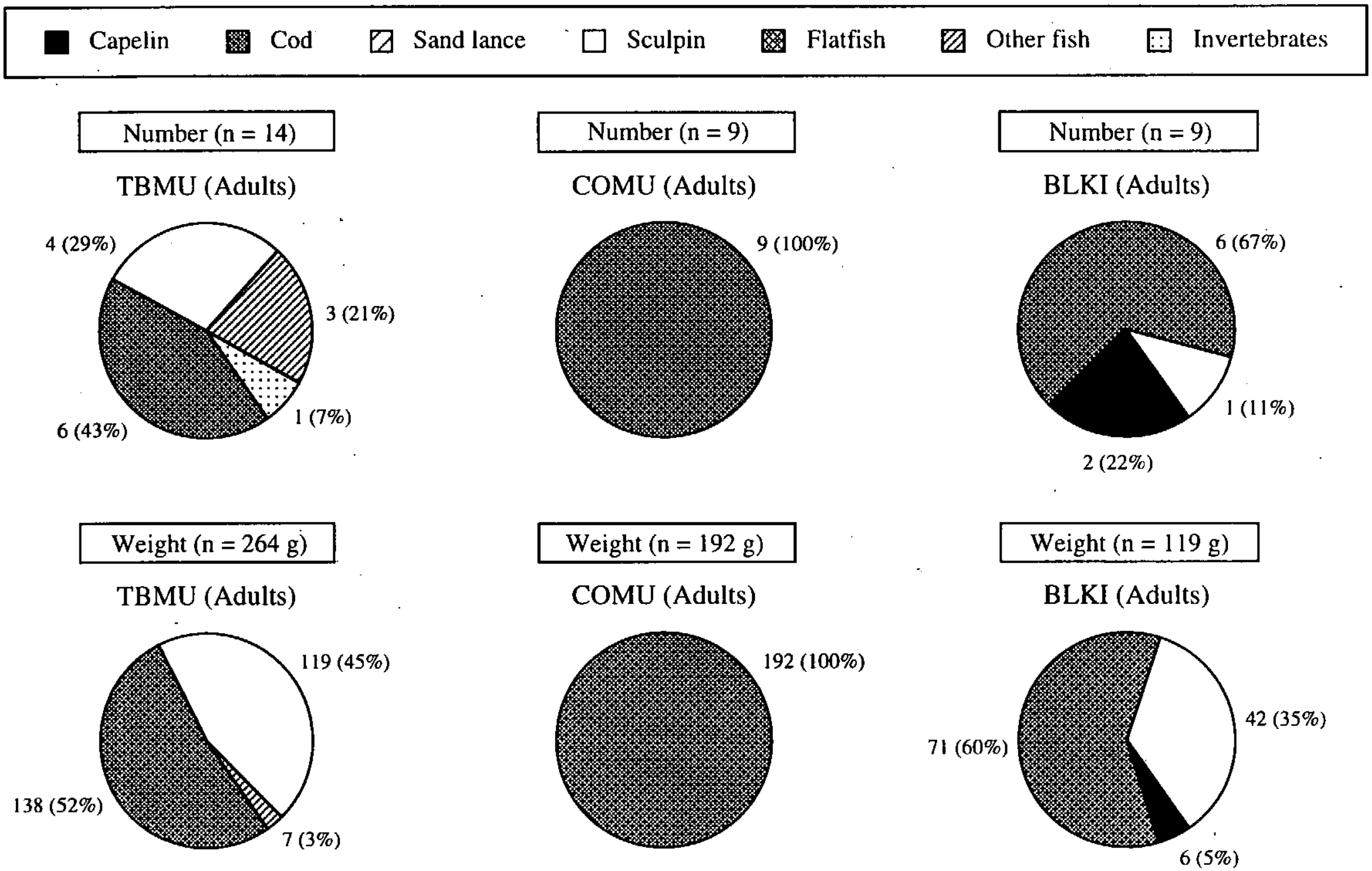


Figure 33. Number and estimated wet weight (g) of prey found in the stomachs of 11 thick-billed murre (TBMU), 2 common murre (COMU), and 3 black-legged kittiwake (BLKI) adults collected at Cape Thompson, Alaska during 5 July - 19 August 1991 (data are from Table 41).

Appendix 1. Average counts of black-legged kittiwakes and kittiwake nests on 18 of the 76 census plots at Cape Lisburne, Alaska during 1977–1997 (counts were made from boats, except as noted below; birds and nests were counted by 1's, and counts of nests are shown in parentheses).

Census Plot Number	Year											
	1977[a]	1978[b]	1979[c]	1981[d]	1983[e]	1985[f]	1986[g]	1987[h]	1992[i]	1995[j]	1996[k]	1997[l]
11	114 (112)	192 (ND)	ND[m] (ND)	202 (157)	260 (ND)	ND (ND)	ND (ND)	ND (215)	259 (ND)	387 (259)	409 (237)	494 (210)
12	75 (73)	ND (ND)	ND (ND)	179 (160)	207 (ND)	ND (ND)	ND (ND)	ND (215)	128 (ND)	395 (309)[n]	422 (309)	457 (281)
25	54 (48)	ND (ND)	ND (ND)	45 (40)	77 (ND)	ND (ND)	ND (ND)	ND (78)	58 (ND)	93 (63)	107 (54)	110 (72)
26	265 (235)	305 (ND)	ND (ND)	246 (222)	322 (ND)	ND (ND)	ND (ND)	ND (19)	230 (ND)	321 (217)	325 (299)	368 (246)
30	126 (126)	ND (ND)	ND (ND)	139 (124)	216 (ND)	ND (ND)	ND (ND)	ND (152)	201 (ND)	158 (173)	197 (139)	206 (131)
32	ND (33)	ND (ND)	ND (ND)	43 (38)	22 (ND)	ND (ND)	ND (ND)	ND (6)	173 (ND)	286 (156)	375 (218)	272 (238)
65	247 (247)	340 (ND)	371 (336)	310 (272)	460[o] (ND)	456 (266)	612 (322)	ND (223)	338[p] (ND)	332 (272)	342 (248)	397 (260)
66	50 (50)	47 (ND)	51 (37)	43 (40)	50 (ND)	61 (45)	83 (39)	ND (58)	44[q] (ND)	45 (46)	29 (30)	77 (28)
67 & 68[r]	323 (ND)	376 (ND)	319 (259)	ND (ND)	ND (ND)	ND (ND)	ND (ND)	ND (ND)	ND (ND)	ND (ND)	ND (ND)	ND (ND)
68	182 (176)	118 (ND)	ND (ND)	ND (ND)	ND (ND)	ND (ND)	ND (265)	ND (ND)	ND (ND)	ND (ND)	ND (ND)	ND (ND)
69	28 (ND)	27 (ND)	17 (16)	ND (ND)	ND (ND)	ND (ND)	57 (42)	ND (ND)	ND (ND)	ND (ND)	ND (ND)	ND (ND)
70	296 (291)	302 (ND)	352 (172)	116 (113)	324[s] (ND)	419 (252)	273 (174)	ND (245)	262[t] (ND)	370 (336)	332 (270)	406 (236)
71	177 (172)	342 (ND)	308 (261)	ND (ND)	ND (ND)	ND (ND)	ND (ND)	ND (ND)	ND (ND)	ND (ND)	ND (ND)	ND (ND)
72	274 (259)	189 (ND)	204 (183)	128 (118)	210 (ND)	240 (144)	585 (364)	ND (117)	140[u] (ND)	240 (183)	217 (184)	217 (162)
73	349 (337)	357 (ND)	335 (338)	ND (ND)	430 (ND)	ND (ND)	ND (ND)	ND (237)	334 (ND)	353 (310)	305 (316)	438 (336)

Appendix 1 (Continued).

Census Plot	Year											
	1977[a]	1978[b]	1979[c]	1981[d]	1983[e]	1985[f]	1986[g]	1987[h]	1992[i]	1995[j]	1996[k]	1997[l]
74[v]	ND	ND	ND	ND	ND	ND	488[w]	471[x,y]	390[z,aa]	500	448	550
	(174)	(ND)	(ND)	(ND)	(ND)	(ND)	(325)	(354)[x,y]	(334)[z,aa]	(444)	(379)	(421)
75	0	ND	ND	ND	ND	ND	2	0[ab]	0[ab]	0	0	0
	(0)	(ND)	(ND)	(ND)	(ND)	(ND)	(1)	(0)[ab]	(0)[ab]	(0)	(0)	(0)
76	0	ND	ND	ND	ND	ND	0	0[ac]	0[ac]	0	0	0
	(0)	(ND)	(ND)	(ND)	(ND)	(ND)	(0)	(0)[ac]	(0)[ac]	(0)	(0)	(0)

[a] Census Plots 70, 72, and 73 were counted on 11 August 1977; Census Plots 11 and 12 were counted on 12 August; Census Plots 30 and 68 were counted on 13 August; Census Plots 65, 66, 67–68, and 69 were counted on 16 August; and Census Plots 25, 26, 32, 74, 75, and 76 were counted on 27 August. Data are from Springer and Roseneau (1978), Springer *et al.* (1979), and Springer *et al.* (unpubl. data).

[b] All counts were made during late July and early August. 1978 Data are from Springer *et al.* (1979) and Springer *et al.* (unpubl. data).

[c] All counts were made on 19 July 1979. Data are from Byrd (1986) and Springer *et al.* (unpubl. data).

[d] Census Plots 11, 12, 25, 26, 30, and 32 were counted on 25 July and 2 August 1981; and Census Plots 65, 66, 70, and 72 were counted on 25 July. Data are from Roseneau *et al.* (1982) and Springer *et al.* (unpubl. data).

[e] Census Plots 11, 12, 25, 26, 30, and 32 were counted from a boat on 21 July 1983; Census Plots 66, 72, and 73 were counted from a boat on 11 August; and Census Plots 65 and 70 were counted from the beach on 11 August. Data are from Springer *et al.* (unpubl. data) and Byrd (1986).

[f] All counts were made from the beach during late July–early August 1985. Data are from Byrd (1986) and Springer *et al.* (unpubl. data).

[g] All counts were made from the beach during 28–31 July 1986. Data are from Byrd (1986) and Springer *et al.* (unpubl. data).

[h] Census Plots 11, 12, 25, 26, 30, 32, 65, 66, 70, 72, and 73 were counted from a boat on 4 August 1987; Census Plot 74 was counted from the beach (the Land Plots 3–7 section) and a boat (the "CP73/CP74 Nose" section) during 12 July–4 August (the CP73/CP74 Nose boat counts were made on 26 July and 4 August); and Census Plots 75 and 76 were counted from the beach during 12 July–4 August. Data are from Roseneau *et al.* (1992) and D.G. Roseneau and A.L. Sowls (unpubl. data).

[i] Census Plots 11, 12, 25, and 26 were counted from a boat on 25 July 1992; Census Plots 30 and 32 were counted from a boat on 27 July; Census Plots 65, 66, 70, and 72 were counted from a boat on 31 July and 6 August; and Census Plot 73 was counted from a boat on 6 August. Census Plot 74 was counted from the beach (the Land Plots 3–7 section) and a boat (the "CP73/CP74 Nose" section) during 17 July 10 August (the CP73/CP74 Nose boat count was made on 6 August); and Census Plots 75 and 76 were counted from the beach during 17 July–10 August. Data are from Denlinger *et al.* (1994).

[j] All bird counts were made on 9 August 1995. Counts of nests on Census Plots 11, 12, 25, 26, 30, and 32 were made on 28 July; counts of nests on Census Plots 65, 66, 70, 72, 73, and 74 were made on 8 August. Data are from this study.

[k] All counts were made on 18 August 1996. Data are from this study.

[l] All counts were made on 10 August 1997. Data are from this study.

[m] ND = no data.

[n] In 1995 nests on some sections of Census Plot 12 were not counted. To allow comparisons of total nest numbers, the 1996 count of 309 nests has been included as a 1995 count. (Because little or no nest-building occurred in 1996, the actual number of nests on Census Plot 12 in 1995 should have been at least as large as the 1996 count.)

[o] In 1983 a boat-based count of Census Plot 65 made within 30 minutes of the land-based count of 460 birds totaled only 250 individuals (Springer *et al.*, unpubl. data).

Appendix 1 (Continued).

[p] Average of two counts of Census Plot 65 in 1992: (31 July 1245 hrs) A.L. Sowls = 358, D.G. Roseneau = 348, mean = 353; (6 August 1348 hrs) A.L. Sowls = 324, D.G. Roseneau = 321, mean = 323; overall mean = 338.

[q] Average of two counts of Census Plot 66 in 1992: (31 July 1350 hrs) A.L. Sowls = 44, D.G. Roseneau = 47, mean = 46; (6 August 1438 hrs) A.L. Sowls = 44, D.G. Roseneau = 40, mean = 42; overall mean = 44.

[r] Census Plots 67 and 68 were counted together in 1979 (Springer *et al.*, unpubl. data) and are summed here to allow comparison among years.

[s] Byrd (1986) reported a total of 316 birds on Census Plot 70 in 1983, but the mean of the two counts made from the beach on 11 August 1983 (338 and 310 birds) is 324 individuals (Springer *et al.*, unpubl. data). Also, a boat-based count of Census Plot 70 made within 45 minutes of the land-based count of 324 birds totaled only 200 individuals (Springer *et al.*, unpubl. data).

[t] Average of two counts of Census Plot 70 in 1992: (31 July 1415 hrs) A.L. Sowls = 239, D.G. Roseneau = 244, mean = 242; (6 August 1455 hrs) A.L. Sowls = 268, D.G. Roseneau = 294, mean = 281; overall mean = 262.

[u] Average of two counts of Census Plot 72 in 1992: (31 July 1500 hrs) A.L. Sowls = 135, D.G. Roseneau = 130, mean = 133; (6 August 1545 hrs) A.L. Sowls = 142, D.G. Roseneau = 149, mean = 146; overall mean = 140.

[v] Census Plot 74 consists of Land Plots 3–7 and a hidden section lying just west of First Beach near the boundary between Census Plots 73 and 74 that can only be seen from offshore (the "CP73/CP74 Nose"). Census Plot 74 was counted from a boat in 1976 and 1977, and from the beach in 1987 and 1992, with the exception to the "CP73/CP74 Nose" portion, which was counted from a boat in 1987 and 1992.

[w] In 1987, we noted that one section of Census Plot 74 (the "CP73/CP74 Nose" lying just west of First Beach near the boundary between Census Plots 73 and 74) could only be seen from offshore. In 1987, we counted 200 kittiwakes and 0 nests on this portion of the plot and added these numbers to Byrd's (1986) beach-based counts of 488 birds and 325 nests, but here we do not include the 1987 "CP73/CP74 Nose" section count of 200 individuals and only report Byrd's beach-based score of 488 birds in 1986 to allow direct comparison with 1987 and 1992 data.

[x] Census Plot 74 includes Land Plots 3–7, and counts of these plots were used to determine the average number of kittiwakes and kittiwake nests present in 1987. Based on these data, the mean numbers of birds and nests present were 471 and 354, respectively.

[y] In 1987, we noted that one section of Census Plot 74 (the "CP73/CP74 Nose" lying just west of First Beach near the boundary between Census Plots 73 and 74) could only be seen from offshore. In 1987, we counted 200 birds and 0 nests on this portion of the plot and added these numbers to our beach-based counts, but here we do not include the 1987 "CP73/CP74 Nose" section count of 200 individuals and only report our beach-based score of 471 birds in 1987 to allow direct comparison with 1986 and 1992 data.

[z] In 1987, we noted that one section of Census Plot 74 (the "CP73/CP74 Nose" lying just west of First Beach near the boundary between Census Plots 73 and 74) could only be seen from offshore. In 1992, we counted 37 birds and 0 nests on this portion of the plot, but here we do not include the 1992 "CP73/CP74 Nose" section count of 37 individuals and only report our beach-based score of 390 birds in 1992 to allow direct comparison with 1986 and 1987 data.

[aa] Census Plot 74 includes Land Plots 3–7, and counts of these plots were used to determine the average number of kittiwakes and kittiwake nests present in 1992. Based on these data, the mean numbers of birds and nests present were 390 and 334, respectively.

[ab] Census Plot 75 consists of Land Plots 2 and 8, and counts of these plots were used to determine the average number of kittiwakes and kittiwake nests present in 1987 and 1992. Based on these data, the mean numbers of birds and nests present in both years were 0 and 0, respectively.

[ac] Census Plot 76 consists of Land Plot 1, and counts of these plots were used to determine the average number of kittiwakes and kittiwake nests present in 1987 and 1992. Based on these data, the mean numbers of birds and nests present in both years were 0 and 0, respectively.

Appendix 2. Counts of black-legged kittiwakes and kittiwake nests on land plots LP 9-14 at Cape Lisburne, Alaska during 1992-1997 (counts were made from land; birds were counted by 1's).

1992[a]		1993[b]		1995[c]		1996[c]		1997[c]	
Date	Birds (Nests)	Date	Birds (Nests)	Date	Birds (Nests)	Date	Birds (Nests)	Date	Birds (Nests)
21 Jul	288 (340)	22 Jul	498 (373)	15 Jul	432 (385)	11 Jul	275 (265)	16 Jul	387 (306)
25 Jul	404	25 Jul	479 (390)	20 Jul	353	11 Aug	603	18 Jul	482
28 Jul	364	28 Jul	520 (379)	31 Jul	385	12 Aug	618	30 Jul	444
29 Jul	365	1 Aug	527 (391)	11 Aug	378	15 Aug	643		
2 Aug	357	3 Aug	487						
6 Aug	377								
8 Aug	586								
$\bar{x}$ [d]	392 (340)		502 (383)		387 (385)		535 (265)		438 (306)
SD[e]	93		21 (9)		33		174		48
n[f]	*7 (1)*		*5 (4)*		*4 (1)*		*4 (1)*		*3 (1)*

[a] Data are from Denlinger *et al.* (1994).
[b] Data are from A.L. Sowls (unpubl. data).
[c] Data are from this study.
[d] $\bar{x}$ = mean.
[e] SD = standard deviation.
[f] *n* = sample size (number of counts).

Appendix 3. Average counts of murres on 14 of the 76 census plots at Cape Lisburne, Alaska during 1976–1997 (counts were made from boats, except as noted below; birds were counted by 100's in 1976 and by 10's during 1977–1997, with the following exceptions—census plots CP 74-75 and census plot CP 76 were counted by 1's in 1986-1992 and 1986–1997, respectively).

	Year														
Census Plot	1976[a]	1977[b]	1978[c]	1979[d]	1980[e]	1981[f]	1983[g]	1984[h]	1985[i]	1986[j]	1987[k]	1992[l]	1995[m]	1996[n]	1997[o]
11	750	928	779	910	1,195	1,072	1,170	1,115	ND[p]	ND	1,765	1,335	1,640	1,620	1,850
12	1,300	1,545	1,310	1,480	1,640	1,776	1,500	2,175	ND	ND	2,960	2,055	3,203	3,075	4,640
25	825	1,085	1,015	790	ND	928	755	780	ND	ND	1,228	860	1,120	1,020	1,220
26	600	1,225	1,275	1,140	ND	1,033	925	1,113	ND	ND	1,135	929	1,620	1,245	1,485
30	4,250	3,585	3,150	4,065	ND	3,588	3,140	4,180	ND	ND	5,645	5,142	7,670	6,530	7,568
32	2,200	1,738	1,995	2,005	ND	1,716	1,910	1,865	ND	ND	2,875	5,124	6,035	5,685	8,223
65[q]	1,275	2,010	ND	1,915	2,160	2,208	2,332[r]	2,130	2,139	1,976	2,575	2,264[s]	2,800	3,060	2,410
66	1,250	1,335	ND	1,568	1,750	1,450	1,820	1,325	1,723	1,533	2,260	2,098[t]	2,865	2,170	2,660
70[u]	900	1,205	ND	1,290	1,580	1,135	1,953	1,240	2,014	1,466	1,805	1,531[v]	2,140	2,223	2,295
72	750	845	ND	960	930	642	985	690	1,024	1,253	1,180	774[w]	1,320	1,138	1,065
73	950	1,035	ND	ND	ND	ND	ND	ND	ND	ND	645	615	970	705	580
74[x]	625	1,340	ND	ND	ND	ND	ND	ND	ND	1,502[y] (1,967) [2,066]	1,320[z] (1,785)	1,593[aa] (2,157)	3,090	3,720	2,755
75[ab]	ND	260	ND	ND	ND	ND	ND	ND	ND	288	377[ac]	472[ad]	955	920	910
76[ae]	ND	"few"	ND	ND	ND	ND	ND	ND	ND	53	58[af]	66[ag]	102	84	102

[a] The counts were made on 25–28 August 1976 after the census period and are probably too low. Data are from Springer and Roseneau (1978), Springer *et al.* (1979), and Murphy *et al.* (1980).

[b] The counts were made on 21–26 July 1977. Data are from Springer and Roseneau (1978), Springer *et al.* (1979), and Murphy *et al.* (1980).

[c] The counts were made on 3 August 1978. Data are from Springer and Roseneau (1978), Springer *et al.* (1979), and Murphy *et al.* (1980).

[d] The counts were made on 15 August 1979. Data are from Murphy *et al.* (1980).

[e] The counts were made on 1 and 3 August 1980. Data are from Springer *et al.* (unpubl. data).

[f] The counts were made on 25 July and 2 August 1981. Data are from Roseneau *et al.* (1982).

[g] The counts were made on 21 July 1983, and 6, 11, and 19 August (additional counts made on 27–28 August are not included in these calculations because they were made after the census period). Data are from Springer *et al.* (1985).

[h] The counts were made from a boat and the beach on 4 August 1984. Data are from A.M. Springer and G.V. Byrd (unpubl. data) and Byrd (1986).

Appendix 3 (Continued).

i The counts were made from the beach on 30 July 1985. Data are from A.M. Springer and G.V. Byrd (unpubl. data) and Byrd (1986).

j The counts were made from the beach on 30–31 July 1986. Data are from A.M. Springer and G.V. Byrd (unpubl. data) and Byrd (1986).

k Census Plots 11, 12, 25, 26, 30, 32, 65, 66, 70, 72, and 73 were counted from a boat on 4 August 1987; Census Plot 74 was counted from the beach (the Land Plots 3–7 section) and a boat (the "CP73/CP74 Nose" section) during 12 July–4 August (the CP73/CP74 Nose boat counts were made on 26 July and 4 August); and Census Plots 75 and 76 were counted from the beach during 12 July–4 August. Data are from Roseneau *et al.* (1992) and D.G. Roseneau and A.L. Sowls (unpubl. data).

l Census Plots 11, 12, 25, and 26 were counted from a boat on 25 July 1992; Census Plots 30 and 32 were counted from a boat on 27 July; Census Plots 65, 66, 70, and 72 were counted from a boat on 31 July and 6 August; and Census Plot 73 was counted from a boat on 6 August. Census Plot 74 was counted from the beach (the Land Plots 3–7 section) and a boat (the "CP73/CP74 Nose" section) during 17 July 10 August (the CP73/CP74 Nose boat count was made on 6 August); and Census Plots 75 and 76 were counted from the beach during 17 July 10 August. Data are from Denlinger *et al.* (1994).

m The counts were made on 9 August 1995. Data are from this study.

n The counts were made on 28 July 1996. Data are from this study.

o The counts were made on 31 July 1997. Data are from this study.

p ND = no data.

q Census Plot 65 was counted from the beach in 1983, 1984, 1985, and 1986, and from boats in all other years. In 1986, Byrd (1986) noted 330 murres that could only be seen from offshore and added them to the 1984, 1985, and 1986 beach-based mean scores of 1,800, 1,809, and 1,646, respectively, to allow comparisons with boat-based years.

r The raw mean of 2,236 for Census Plot 65 in 1983, reported by Springer *et al.* (1985) on page 296 of OCSEAP Vol. 30, Final Reports of Principal Investigators, is an error; the correct number is 2,232.

s Average of two counts of Census Plot 65 in 1992: (31 July 1245 hrs) A.L. Sowls = 2,375; D.G. Roseneau = 2,395; mean = 2,385; (6 August 1348 hrs) A.L. Sowls = 2,163; D.G. Roseneau = 2,120; mean = 2,142.

t Average of two counts of Census Plot 66 in 1992: (31 July 1350 hrs) A.L. Sowls = 1,895; D.G. Roseneau = 1,795; mean = 1,845; (6 August 1438 hrs) A.L. Sowls = 2,360; D.G. Roseneau = 2,340; mean = 2,350.

u Census Plot 70 was counted from the beach in 1983 and from boats in all other years.

v Average of two counts of Census Plot 70 in 1992: (31 July 1415 hrs) A.L. Sowls = 1,583; D.G. Roseneau = 1,610; mean = 1,597; (6 August 1455 hrs) A.L. Sowls = 1,410; D.G. Roseneau = 1,520; mean = 1,465.

w Average of two counts of Census Plot 72 in 1992: (31 July 1500 hrs) A.L. Sowls = 890; D.G. Roseneau = 875; mean = 883; (6 August 1545 hrs) A.L. Sowls = 640; D.G. Roseneau = 690; mean = 665.

x Census Plot 74 consists of Land Plots 3–7 and a hidden section lying just west of First Beach near the boundary between Census Plots 73 and 74 that can only be seen from offshore (the "CP73/CP74 Nose"). Census Plot 74 was counted from a boat in 1976 and 1977, and from the beach in 1987 and 1992, with the exception to the "CP73/CP74 Nose" portion, which was counted from a boat in 1987 and 1992.

y In 1987, we noted that one section of Census Plot 74 (the "CP73/CP74 Nose" lying just west of First Beach near the boundary between Census Plots 73 and 74) could only be seen from offshore. In 1987, we counted 465 murres on this portion of the plot and added this number to Byrd's (1986) beach-based count of 1,502 birds for comparative purposes (sum = 1,967), but here we first report Byrd's beach-based score of 1,502 individuals, then a second number in parentheses (1,967) derived by adding 465 birds (the 1987 mean count on the CP73/CP74 Nose) to the 1986 beach-based score of 1,502 individuals, and a third number in brackets [2,066] derived adding 564 birds (the 1992 mean count on the CP73/CP74 Nose) to the 1987 beach-based score of 1,502 individuals to allow more complete comparison with 1987 and 1992 data.

z In 1987, we noted that one section of Census Plot 74 (the "CP73/CP74 Nose" lying just west of First Beach near the boundary between Census Plots 73 and 74) could only be seen from offshore. In 1987, we counted 465 murres on this portion of the plot and added this number to our beach-based count of 1,320 birds (sum = 1,785), but here we first report our beach-based score of 1,320 individuals and a second number in parentheses (1,785) derived by adding 465 birds (the 1987 mean count on the CP73/CP74 Nose) to the 1987 beach-based score of 1,320 individuals to allow more complete comparison with 1986 and 1992 data. Also, this census plot consists of

Appendix 3 (Continued).

Land Plots 3–7 and the CP73/CP74 Nose, and counts of these plots were used to determine the average number of murres present in 1987. Based on these data, the mean number of birds present in 1987 was 1,320, and the 465 murres on the CP73/CP74 Nose that could only be seen from offshore were added to it (the 465 birds resulted from two counts by two observers: 26 July 1850 hrs, A.L. Sowls = 490, D.G. Roseneau = 510, mean = 500; and 4 August 1550 hrs, A.L. Sowls = 410, D.G. Roseneau = 450, mean = 430).

[aa] In 1987, we noted that one section of Census Plot 74 (the "CP73/CP74 Nose" lying just west of First Beach near the boundary between Census Plots 73 and 74) could only be seen from offshore. In 1992, our beach-based counts averaged 1,593 murres and our count of the hidden CP73/CP74 Nose averaged 564 additional birds. Here we first report the beach-based score of 1,593 individuals and then the sum of beach-based and CP73/CP74 Nose counts in parentheses (2,157) to allow more complete comparison with 1986 and 1987 data. Also, this census plot consists of Land Plots 3–7 and the CP73/CP74 Nose, and counts of these plots were used to determine the average number of murres present in 1992. Based on these data, the mean number of birds present in 1992 was 1,593, and the 564 murres on the CP73/CP74 Nose that could only be seen from offshore were added to it (the 564 birds resulted from one count by two observers: 6 August 1300 hrs, A.L. Sowls = 587, D.G. Roseneau = 540, mean = 564).

[ab] Census Plot 75 was counted from a boat in 1977, 1995, and 1996; it was counted from the beach in 1986, 1987, and 1992.

[ac] Census Plot 75 consists of Land Plots 2 and 8, and counts of these plots were used to determine the average number of murres present in 1987. Based on these data, the mean number of birds present in 1987 was 377.

[ad] Census Plot 75 consists of Land Plots 2 and 8, and counts of these plots were used to determine the average number of murres present in 1992. Based on these data, the mean number of birds present in 1992 was 472.

[ae] Census Plot 76 was counted from the beach in 1986, 1987, and 1992. In 1976, murres were not noted on this plot, and only a few individuals were seen on it in 1977 (A.M. Springer, pers. comm.).

[af] Census Plot 76 consists of Land Plot 1, and counts of this plot were used to determine the average number of murres present in 1987. Based on these data, the mean number of birds present in 1987 was 58.

[ag] Census Plot 76 consists of Land Plot 1, and counts of this plot were used to determine the average number of murres present in 1992. Based on these data, the mean number of birds present in 1992 was 66.

Appendix 4. Average counts of murres on census plots CP 11, 12, 25, 26, 30, 32, 65, 66, 70, 72, 73, and 74 at Cape Lisburne, Alaska during 1976-1997 (counts were made from boats, except as noted below; birds were counted by 100's in 1976 and by 10's in all other years, except for census plot CP 74, which was counted by 1's in 1987 and 1992).

Census Plot	Year									
	1976[a]	1977[b]	1987[c]	1992[d]	1995[e]	1996[f]	1997[g]	$\bar{x}$	SD[h]	CV[i]
11	750	928	1,765	1,335	1,640	1,620	1,850	1,413	426	30.2
12	1,300	1,545	2,960	2,055	3,203	3,075	4,640	2,683	1,150	42.9
25	825	1,085	1,228	860	1,120	1,020	1,220	1,051	160	15.3
26	600	1,225	1,135	929	1,620	1,245	1,485	1,177	340	28.9
30	4,250	3,585	5,645	5,142	7,670	6,530	7;568	5,770	1,577	27.3
32	2,200	1,738	2,875	5,124	6,035	5,685	8,223	4,554	2,365	51.9
65	1,275	2,010	2,575	2,264[j]	2,800	3,060	2,410	2,342	583	24.9
66	1,250	1,335	2,260	2,098[k]	2,865	2,170	2,660	2,091	611	29.2
70	900	1,205	1,805	1,531[l]	2,140	2,223	2,295	1,728	539	31.2
72	750	845	1,180	774[m]	1,320	1,138	1,065	1,010	222	21.9
73	950	1,035	645	615	970	705	580	786	192	24.4
74[n]	625	1,340	1,785[o]	2,157[p]	3,090	3,720	2,755	2,210	1,065	48.2
Total	15,675	17,876	25,858	24,884	34,473	32,191	36,751	26,815	8,113	30.3

[a] The counts were made on 25–28 August 1976. Data are from Springer and Roseneau (1978), Springer *et al.* (1979), and Murphy *et al.* (1980).

[b] The counts were made on 21–26 July 1977. Data are from Springer and Roseneau (1978), Springer *et al.* (1979), and Murphy *et al.* (1980).

[c] Census Plots 11, 12, 25, 26, 30, 32, 65, 66, 70, 72, and 73 were counted from a boat on 4 August 1987; and Census Plot 74 was counted from the beach (the Land Plots 3–7 section) and a boat (the"CP73/CP74 Nose" section) during 12 July–4 August (the CP73/CP74 Nose boat counts were made on 26 July and 4 August). Data are from Roseneau *et al.* (1992) and D.G. Roseneau and A.L. Sowls (unpubl. data).

[d] Census Plots 11, 12, 25, and 26 were counted from a boat on 25 July 1992; Census Plots 30 and 32 were counted from a boat on 27 July; Census Plots 65, 66, 70, and 72 were counted from a boat on 31 July and 6 August; Census Plot 73 was counted from a boat on 6 August; and Census Plot 74 was counted from the beach (the Land Plots 3–7 section) and a boat (the"CP73/CP74 Nose" section) during 17 July 10 August (the CP73/CP74 Nose boat count was made on 6 August). Data are from Denlinger *et al.* (1994).

[e] The counts were made on 9 August 1995. Data are from this study.

[f] The counts were made on 28 July 1996. Data are from this study.

[g] The counts were made on 31 July 1997. Data are from this study.

[h] SD = standard deviation.

[i] CV = coefficient of variation.

[j] Average of two counts of Census Plot 65 in 1992: (31 July 1245 hrs) A.L. Sowls = 2,375; D.G. Roseneau = 2,395; mean = 2,385; (6 August 1348 hrs) A.L. Sowls = 2,163; D.G. Roseneau = 2,120; mean = 2,142.

[k] Average of two counts of Census Plot 66 in 1992: (31 July 1350 hrs) A.L. Sowls = 1,895; D.G. Roseneau = 1,795; mean = 1,845; (6 August 1438 hrs) A.L. Sowls = 2,360; D.G. Roseneau = 2,340; mean = 2,350.

[l] Average of two counts of Census Plot 70 in 1992: (31 July 1415 hrs) A.L. Sowls = 1,583; D.G. Roseneau = 1,610; mean = 1,597; (6 August 1455 hrs) A.L. Sowls = 1,410; D.G. Roseneau = 1,520; mean = 1,465.

[m] Average of two counts of Census Plot 72 in 1992: (31 July 1500 hrs) A.L. Sowls = 890; D.G. Roseneau = 875; mean = 883; (6 August 1545 hrs) A.L. Sowls = 640; D.G. Roseneau = 690; mean = 665.

[n] Census Plot 74 consists of Land Plots 3–7 and a section between Census Plot 73 and Census Plot 74 just west of First Beach that can only be seen from offshore called the "CP73/CP74 Nose." Census Plot 74 was counted from a boat in 1976 and 1977, and from the beach in 1987 and 1992, with the exception to the "CP73/CP74 Nose" section, which was counted from a boat in 1987 and 1992.

Appendix 4 (Continued).

o Census Plot 74 includes Land Plots 3–7, and counts of these plots were used to determine the average number of murres present in 1987. Based on these data, the mean number of birds present was 1,320, and another 465 murres that could only be seen from offshore were added to it (the 465 birds were the average of two counts by two observers: 26 July 1850 hrs, A.L. Sowls = 490, D.G. Roseneau = 510, mean = 500; and 4 August 1550 hrs, A.L. Sowls = 410, D.G. Roseneau = 450, mean = 430).

p Census Plot 74 includes Land Plots 3–7, and counts of these plots were used to determine the average number of murres present in 1992. Based on these data, the mean number of birds present was 1,593, and another 564 murres that could only be seen from offshore were added to it (the 564 birds resulted from one count by two observers: 6 August 1300 hrs, A.L. Sowls = 587, D.G. Roseneau = 540, mean = 564).

Appendix 5. Counts of murres on land plots LP 9-14 at Cape Lisburne, Alaska during 1992-1997 (counts were made from land; birds were counted by 1's).

1992[a]		1993[b]		1995[c]		1996[c]		1997[c]	
Date	Birds	Date	Birds	Date	Birds	Date	Birds	Date	Birds
21 Jul	2,034	22 Jul	2,819	15 Jul	2,000	11 Jul	2,272	16 Jul	3,090
25 Jul	2,245	25 Jul	2,872	19 Jul	2,136	17 Jul	2,915	18 Jul	2,203
28 Jul	2,381	28 Jul	2,971	20 Jul	1,835	11 Aug	2,681	30 Jul	1,940
29 Jul	2,347	1 Aug	2,486	31 Jul	2,212	12 Aug	2,748	5 Aug	3,390
2 Aug	2,923	3 Aug	2,642	4 Aug	2,715	15 Aug	3,184	8 Aug	2,824
6 Aug	2,503			11 Aug	2,677				
8 Aug	2,761								
$\bar{x}$[d]	2,456		2,758		2,263		2,760		2,689
SD[e]	304		193		360		335		606
(n)[f]	*(7)*		*(5)*		*(6)*		*(5)*		*(5)*

[a] Data are from Denlinger *et al.* (1994).
[b] Data are from A.L. Sowls (unpubl. data).
[c] Data are from this study.
[d] $\bar{x}$ = mean.
[e] SD = standard deviation.
[f] n = sample size (number of counts).

Appendix 6. Hatching chronology of black-legged kittiwakes at Cape Lisburne, Alaska during 1987-1997.[a]

Parameter	1987[b]			
	<22 Jul	22–23 Jul	24 Jul – 3 Aug	>3 Aug[c]
Number of Eggs Hatched	0	2	45	9
Percent Hatched	0	4	80	16
Cumulative Percent Hatched	0	4	84	100

	1992[d]				
	<21 Jul	21–25 Jul	26 Jul – 1 Aug	2–8 Aug	>8 Aug[c]
Number of Eggs Hatched	3	33	20	8	20
Percent Hatched	4	39	24	10	24
Cumulative Percent Hatched	4	43	67	76	100

	1993[e]		
	<23 Jul	23 Jul – 3 Aug	>3 Aug[c]
Number of Eggs Hatched	41	57	3
Percent Hatched	41	56	3
Cumulative Percent Hatched	41	97	100

	1995[f]							
	1–16 Jul	17–20 Jul	21–31 Jul	1–4 Aug	5–9 Aug	10–15 Aug	16–25 Aug	>25 Aug[c]
Number of Eggs Hatched	0	1	86	36	4	1	0	0
Percent Hatched	0	1	67	28	3	1	0	0
Cumulative Percent Hatched	0	1	68	96	99	100	100	100

Appendix 6 (Continued).

Parameter	1996[f,g]							
	1–13 Jul	14–20 Jul	21–31 Jul	1–4 Aug	5–9 Aug	10–15 Aug	16–25 Aug	>25 Aug[c]
Number of Eggs Hatched	0	0	0	0	0	0	0	0
Percent Hatched	0	0	0	0	0	0	0	0
Cumulative Percent Hatched	0	0	0	0	0	0	0	0

	1997[f]								
	<5 Jul	5–16 Jul	17–20 Jul	21–29 Jul	30 Jul–1 Aug	2–8 Aug	9–18 Aug	19–28 Aug	>28 Aug[c]
Number of Eggs Hatched	0	0	3	47	20	6	4	0	0
Percent Hatched	0	0	4	59	25	8	5	0	0
Cumulative Percent Hatched	0	0	4	63	88	95	100	100	100

[a] Only dates that first eggs hatched were used for nests containing more than one egg.
[b] Data are from Roseneau *et al.* (1992) and D.G. Roseneau and A.L. Sowls, unpubl. data.
[c] The date in the right-most column is the last date visits were made to the study plots in each respective year. If the eggs that were still present on the last visit hatched at all, they must have hatched *after* that date.
[d] Data are from Denlinger *et al.* (1994) and D.G. Roseneau and A.L. Sowls, unpubl. data.
[e] Data are from A.L. Sowls, unpubl. data.
[f] Data are from this study.
[g] In 1996, only two nests contained eggs, and neither of these single-egg clutches hatched.

Appendix 7. Hatching and sea-going dates and sea-going ages of thick-billed murre chicks at Cape Lisburne, Alaska, 1995-1997.

Parameter	Statistic[a]	Year 1995	Year 1996	Year 1997	Mean	SD[b]
Julian Hatch Date[c]	Average of plot medians (day no.)	208.1	214.6	208.5	210.4[d]	3.6 days
	SD of plot medians	2.4 days	2.2 days	3.0 days		
	Average of plot means (day no.)	208.9	214.3	208.3	210.5	3.3 days
	SD of plot means	1.2 days	1.5 days	2.4 days		
	Sample size (*n*)	6 plots	8 plots	10 plots		
	First hatch date (day no.)	200	204	199		
	Last hatch date (day no.)	222	226	224		
	Range	22 days	22 days	25 days		
	Number of nest sites[e]	122	143	184		
Julian Chick Sea-going Date[f]	Average of plot medians (day)	233.0	238.4	232.3	234.6[g]	3.3 days
	SD of plot medians	2.0 days	1.7 days	1.2 days		
	Sample size (*n*)	11 plots	7 plots	10 plots		
	First sea-going date (day)	226	224	220		
	Last sea-going date (day)[h]	240	246	246		
	Range	14 days	22 days	26 days		
	Number of nest sites	240	133	160		
Chick Sea-going Age[i]	Average of plot means	25.1 days	23.5 days	23.9 days	24.2 days	0.8 days
	SD of plot means	0.8 days	0.9 days	2.2 days		
	Sample size (*n*)	6 plots	7 plots	10 plots		
	Number of nest sites	103	113	160		

[a] Plots were treated as sample units; they contained at least 10 valid nest sites each. Sites with relaid eggs or data gaps of more than seven days between observation dates were excluded from analyses.

[b] SD = standard deviation in days.

[c] Hatch dates were defined as the midpoints between the last day eggs were present and the first day chicks were evident. Sites containing chicks less than 15 days old were excluded from analyses.

Appendix 7 (Continued).

[d] Julian day 210, the three-year average of the plot-by-plot median hatch dates, was 29 July in 1995 and 1997, and 28 July in 1996 (a leap year).

[e] Total number of nest sites on plot sets used in the analyses.

[f] Sea-going dates were defined as the midpoints between the last day chicks were present and the first day chicks were absent. Sites containing chicks less than 15 days old were excluded from the analyses unless chicks were 14 days old on the last observation date.

[g] Julian day 235, the three-year average of the plot-by-plot median sea-going dates, was 23 August in 1995 and 1997, and 22 August in 1996 (a leap year).

[h] In 1995 and 1996, plots respectively contained 34 and 18 chicks that were 14 days old or older on the last observation dates. In 1997, all chicks had left the plots by the last observation date.

[i] Sea-going ages were defined as the differences between chick hatch and sea-going dates. Sites used for age calculations contained chicks that were 15 days old or older.

Appendix 8. Hatching chronology of thick-billed murres at Cape Lisburne, Alaska, 1995-1997.

Parameter	Date							
	18 Jul	19-22 Jul	23-26 Jul	27-30 Jul	31 Jul - 3 Aug	4-7 Aug	8-11 Aug	12–15 Aug
1995 (*n* = 123)[a]								
Number of Eggs Hatched	0	1	74	15	20	9	3	0
Percent Hatched	0	1	61	12	16	7	2	0
Cumulative Percent Hatched	0	1	61	74	90	98	100	100
1996 (*n* = 143)								
Number of Eggs Hatched	0	2	8	37	57	22	16	1
Percent Hatched	0	1	6	26	40	15	11	1
Cumulative Hercent Hatched	0	1	7	33	73	88	99	100
1997 (*n* = 186)								
Number of Eggs Hatched	2	29	31	95	13	6	7	3
Percent Hatched	1	16	17	51	7	3	4	2
Cumulative Hercent Hatched	1	17	33	84	91	95	98	100

[a] Sample size (*n*) = number of eggs.

Appendix 9. Hatching and sea-going dates and sea-going ages of common murre chicks at Cape Lisburne, Alaska, 1995-1997.

Parameter	Statistic[a]	Year 1995	1996	1997	Mean	SD[b]
Julian Hatch Date[c]	Median of nest sites (day no.)	212	218	211	213.7[d]	3.8 days
	Mean of nest sites (day no.)	211.7	218.8	210.5	213.7	4.5 days
	SD of nest sites	6.2 days	5.3 days	3.6 days		
	Sample size (*n*)	19 sites	22 sites	25 sites		
	First hatch date (day no.)	204	209	204		
	Last hatch date (day no.)	228	234	220		
	Range	24 days	25 days	16 days		
Julian Chick Sea-going Date[e]	Median of nest sites (day no.)	236.0	242.0	233.0	237.0[f]	4.6 days
	Sample size (*n*)	37 sites	22 sites	22 sites		
	First sea-going date (day)	228	234	226		
	Last sea-going date (day)[g]	240	246	242		
	Range	12 days	12 days	16 days		
Chick Sea-going Age[h]	Mean of nest sites (day no.)	25.0 days	23.1 days	22.2 days	24.2 days	0.8 days
	SD of nest sites	3.7 days	3.9 days	4.7 days		
	Sample size (*n*)	15 sites	14 sites	21 sites		

[a] Plots were treated as sample units; they contained at least 10 valid nest sites each. Sites with relaid eggs or data gaps of more than seven days between observation dates were excluded from analyses.

[b] SD = standard deviation in days.

[c] Hatch dates were defined as the midpoints between the last day eggs were present and the first day chicks were evident. Sites containing chicks less than 15 days old were excluded from analyses.

[d] Julian day 214, the three-year average of the plot-by-plot median hatch dates, was 2 August in 1995 and 1997, and 1 August in 1996 (a leap year).

[e] Sea-going dates were defined as the midpoints between the last day chicks were present and the first day chicks were absent. Sites containing chicks less than 15 days old were excluded from the analyses unless chicks were 14 days old on the last observation date.

[f] Julian day 237, the three-year average of the plot-by-plot median sea-going dates, was 25 August in 1995 and 1997, and 24 August in 1996 (a leap year).

[g] In 1995 and 1996, plots respectively contained 11 and 6 chicks that were 14 days old or older on the last observation dates. In 1997, all chicks had left the plots by the last observation date.

Appendix 9 (Continued).

[i] Sea-going ages were defined as the differences between chick hatch and sea-going dates. Sites used for age calculations contained chicks that were 15 days old or older.

Appendix 10. Hatching chronology of common murres at Cape Lisburne, Alaska, 1995-1997.

Parameter	Date							
	23–26 Jul	27–30 Jul	31 Jul – 3 Aug	4–7 Aug	8–11 Aug	12–15 Aug	16–19 Aug	20–23 Aug
1995 (*n* = 19)[a]								
Number of Eggs Hatched	7	2	8	0	0	1	1	0
Percent Hatched	37	11	42	0	0	5	5	0
Cumulative Percent Hatched	37	47	89	89	89	95	100	100
1996 (*n* = 23)								
Number of eggs hatched	0	3	3	9	6	1	0	1
Percent Hatched	0	13	13	39	26	4	0	4
Cumulative Percent Hatched	0	13	26	65	91	96	96	100
1997 (*n* = 25)								
Number of Eggs Hatched	2	18	4	0	1	0	0	0
Percent Hatched	8	72	16	0	4	0	0	0
Cumulative Percent Hatched	8	80	96	96	100	100	100	100

[a] Sample size (*n*) = number of eggs.

Appendix 11. Reproductive performance of black-legged kittiwakes at Cape Lisburne, Alaska, 1995.[a]

Areas and Census Plots (CP)	Productivity Plots: Tiny Beach (CP73)				Kittiwake Beach East (CP71)			Dave's Rock (CP70)			Kittiwake Beach West (CP68)		Grand Totals
Plot Numbers and Totals	TB1	TB2	TB3	Total	KE1	KE2	Total	DR1	DR2	Total	KW1	Total	
Number of Nests (A)	44	27	11	82	24	19	43	14	52	66	26	26	Total Nests (A): 217
Nests w/1 or more Eggs (B)	39	22	10	71	14	16	30	13	43	56	25	25	Nests w/1 or more Eggs (B): 182
Number of Eggs (C)	62	38	18	118	24	28	52	20	71	91	48	48	Total Eggs (C): 309
Nests w/1 or more Chicks (D)	26	18	9	53	10	12	22	7	34	41	18	18	Nests w/1 or more Chicks (D): 134
Number of Chicks (E)	38	27	16	81	15	18	33	10	50	60	28	28	Total Chicks (E): 202
Nests w/1 or more Chicks Fledged (F)	20	16	7	43	7	8	15	4	28	32	11	11	Nests w/1 or more Chicks Fledged (F): 101
Number of Chicks Fledged (G)	20	17	8	45	7	8	15	4	29	33	11	11	Total Chicks Fledged (G): 104

Productivity Parameters	Tiny Beach (CP73)				Kittiwake Beach East (CP71)			Dave's Rock (CP70)			Kittiwake Beach West (CP68)		All Plots ($n = 8$)		Census Plots ($n = 4$)		Performance of all 217 Nests
	TB1	TB2	TB3	Total	KE1	KE2	Total	DR1	DR2	Total	KW1	Total	$\bar{x}$[b]	SD[c]	$\bar{x}$	SD	
Laying Success (B/A)	0.89	0.81	0.91	0.87	0.58	0.84	0.70	0.93	0.83	0.85	0.96	0.96	0.84	0.12	0.84	0.11	B/A: 0.84
Clutch Size (C/B)	1.59	1.73	1.80	1.66	1.71	1.75	1.73	1.54	1.65	1.63	1.92	1.92	1.71	0.12	1.74	0.13	C/B: 1.70
Nesting Success (D/B)	0.67	0.82	0.90	0.75	0.71	0.75	0.73	0.54	0.79	0.73	0.72	0.72	0.74	0.11	0.73	0.01	D/B: 0.74
Hatching Success (E/C)	0.61	0.71	0.89	0.69	0.63	0.64	0.63	0.50	0.70	0.66	0.58	0.58	0.66	0.11	0.64	0.04	E/C: 0.65
Chick Success (G/E)	0.53	0.63	0.50	0.56	0.47	0.44	0.45	0.40	0.58	0.55	0.39	0.39	0.49	0.08	0.49	0.08	G/E: 0.51
Egg Success (G/C)	0.32	0.45	0.44	0.38	0.29	0.29	0.29	0.20	0.41	0.36	0.23	0.23	0.33	0.10	0.32	0.07	G/C: 0.34
Fledging Success (F/D)	0.77	0.89	0.78	0.81	0.70	0.67	0.68	0.57	0.82	0.78	0.61	0.61	0.73	0.11	0.72	0.09	F/D: 0.75
Reproductive Success (F/B)	0.51	0.73	0.70	0.61	0.50	0.50	0.50	0.31	0.65	0.57	0.44	0.44	0.54	0.14	0.53	0.07	F/B: 0.55
Fledglings/nest Start (G/A)	0.45	0.63	0.73	0.55	0.29	0.42	0.35	0.29	0.56	0.50	0.42	0.42	0.47	0.16	0.46	0.09	G/A: 0.48
Overall Productivity (F/A)	0.45	0.59	0.64	0.52	0.29	0.42	0.35	0.29	0.54	0.48	0.42	0.42	0.46	0.13	0.45	0.08	F/A: 0.47

[a] Tiny Beach nests were checked 10 times during 7 July - 25 August, Kittiwake Beach East and Dave's Rock nests were checked 9 times during 7 July - 25 August, and Kittiwake Beach West nests were checked 10 times during 10 July - 25 August; nests with chicks less than 21 days old on the last visit were not included in the analyses.

[b] $\bar{x}$ = mean.

[c] SD = standard deviation.

Appendix 12. Reproductive performance of black-legged kittiwakes at Cape Lisburne, Alaska, 1996.[a]

Areas and Census Plots (CP)	Productivity Plots: Tiny Beach (CP73)				Kittiwake Beach East (CP71)			Dave's Rock (CP70)			Kittiwake Beach West (CP68)		Grand Totals
Plot Numbers and Totals	TB1	TB2	TB3	Total	KE1	KE2	Total	DR1	DR2	Total	KW1	Total	
Number of Nests (A)	40	19	9	68	23	20	43	11	51	62	22	22	Total Nests (A): 195
Nests w/1 or more Eggs (B)	2	0	0	2	0	0	0	0	0	0	0	0	Nests w/1 or more Eggs (B): 2
Number of Eggs (C)	2	0	0	2	0	0	0	0	0	0	0	0	Total Eggs (C): 2
Nests w/1 or more Chicks (D)	0	0	0	0	0	0	0	0	0	0	0	0	Nests w/1 or more Chicks (D): 0
Number of Chicks (E)	0	0	0	0	0	0	0	0	0	0	0	0	Total Chicks (E): 0
Nests w/1 or more Chicks Fledged (F)	0	0	0	0	0	0	0	0	0	0	0	0	Nests w/1 or more Chicks Fledged (F): 0
Number of Chicks Fledged (G)	0	0	0	0	0	0	0	0	0	0	0	0	Total Chicks Fledged (G): 0

Productivity Parameters	Tiny Beach (CP73)				Kittiwake Beach East (CP71)			Dave's Rock (CP70)			Kittiwake Beach West (CP68)		All Plots (*n = 8*)		Census Plots (*n = 4*)		Performance of all 195 Nests
	TB1	TB2	TB3	Total	KE1	KE2	Total	DR1	DR2	Total	KW1	Total	$\bar{x}$[b]	SD[c]	$\bar{x}$	SD	
Laying Success (B/A)	0.05	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.01	B/A: 0.01
Clutch Size (C/B)	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	—	1.00	—	C/B: 1.00
Nesting Success (D/B)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	—	0.00	—	D/B: 0.00
Hatching Success (E/C)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	—	0.00	—	E/C: 0.00
Chick Success (G/E)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	—	0.00	—	G/E: 0.00
Egg Success (G/C)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	—	0.00	—	G/C: 0.00
Fledging Success (F/D)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	—	0.00	—	F/D: 0.00
Reproductive Success (F/B)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	—	0.00	—	F/B: 0.00
Fledglings/nest Start (G/A)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	—	0.00	—	G/A: 0.00
Overall Productivity (F/Å)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	—	0.00	—	F/A: 0.00

[a] Nests were checked three times during 11 July - 11 August.
[b] $\bar{x}$ = mean.
[c] SD = standard deviation.

Appendix 13. Reproductive performance of black-legged kittiwakes at Cape Lisburne, Alaska, 1997.[a]

Areas and Census Plots (CP)	Tiny Beach (CP73)				Kittiwake Beach East (CP71)			Dave's Rock (CP70)			Kittiwake Beach West (CP68)		Overall Totals
Plot Numbers and Totals	TB1	TB2	TB3	Total	KE1	KE2	Total	DR1	DR2	Total	KW1	Total	
Number of Nests (A)	37	21	10	68	18	21	39	12	54	66	17	17	Total Nests (A): 190
Nests w/1 or more Eggs (B)	26	15	7	48	13	14	27	6	35	41	6	6	Nests w/1 or more Eggs (B): 122
Number of Eggs (C)	34	22	8	64	15	18	33	7	46	53	7	7	Total Eggs (C): 157
Nests w/1 or more Chicks (D)	18	11	6	35	8	9	17	3	24	27	6	6	Nests w/1 or more Chicks (D): 85
Number of Chicks (E)	21	16	7	44	9	11	20	4	28	32	6	6	Total Chicks (E): 102
Nests w/1 or more Chicks Fledged (F)	15	11	5	31	8	8	16	3	23	26	6	6	Nests w/1 or more Chicks Fledged (F): 79
Number of Chicks Fledged (G)	16	12	5	33	8	8	16	3	25	28	6	6	Total Chicks Fledged (G): 83

	Tiny Beach (CP73)				Kittiwake Beach East (CP71)			Dave's Rock (CP70)			Kittiwake Beach West (CP68)		All Plots (*n* = 8)		Census Plots (*n* = 4)		Performance of all 190 Nests
Productivity Parameters	TB1	TB2	TB3	Total	KE1	KE2	Total	DR1	DR2	Total	KW1	Total	$\bar{x}$ [b]	SD[c]	$\bar{x}$	SD	
Laying Success (B/A)	0.70	0.71	0.70	0.71	0.72	0.67	0.69	0.50	0.65	0.62	0.35	0.35	0.63	0.13	0.59	0.16	B/A: 0.64
Clutch Size (C/B)	1.31	1.47	1.14	1.33	1.15	1.29	1.22	1.17	1.31	1.29	1.17	1.17	1.25	0.11	1.25	0.07	C/B: 1.29
Nesting Success (D/B)	0.69	0.73	0.86	0.73	0.62	0.64	0.63	0.50	0.69	0.66	1.00	1.00	0.72	0.15	0.75	0.17	D/B: 0.70
Hatching Success (E/C)	0.62	0.73	0.88	0.69	0.60	0.61	0.61	0.57	0.61	0.60	0.86	0.86	0.68	0.12	0.69	0.12	E/C: 0.65
Chick Success (G/E)	0.76	0.75	0.71	0.75	0.89	0.73	0.80	0.75	0.89	0.88	1.00	1.00	0.81	0.10	0.86	0.11	G/E: 0.81
Egg Success (G/C)	0.47	0.55	0.63	0.52	0.53	0.44	0.48	0.43	0.54	0.53	0.86	0.86	0.56	0.14	0.60	0.17	G/C: 0.53
Fledging Success (F/D)	0.83	1.00	0.83	0.89	1.00	0.89	0.94	1.00	0.96	0.96	1.00	1.00	0.94	0.08	0.95	0.05	F/D: 0.93
Reproductive Success (F/B)	0.58	0.73	0.71	0.65	0.62	0.57	0.59	0.50	0.66	0.63	1.00	1.00	0.67	0.15	0.72	0.19	F/B: 0.65
Fledglings/nest Start (G/A)	0.43	0.57	0.50	0.49	0.44	0.38	0.41	0.25	0.46	0.42	0.35	0.35	0.42	0.10	0.42	0.05	G/A: 0.44
Overall Productivity (F/A)	0.41	0.52	0.50	0.46	0.44	0.38	0.41	0.25	0.43	0.39	0.35	0.35	0.41	0.09	0.40	0.04	F/A: 0.42

[a] All nests were checked 8 times during 4 July–28 August; nests with chicks less than 21 days old on the last visit were not included in the analyses.
[b] $\bar{x}$ = mean.
[c] SD = standard deviation.

Appendix 14. Reproductive success at 205 black-legged kittiwake nests checked on 9 August 1995 at Cape Lisburne, Alaska.

	Sample Areas									
Nest Status	Tiny Beach (CP-73)[a]		Kittiwake East (CP-71)		Dave's Rock (CP-70)		Kittiwake West (CP-68)		Total	
Empty	21	(28)[b]	16	(39)	15	(23)	4	(17)	56	(27)
1 Egg	4	(5)	1	(2)	12	(18)	1	(4)	18	(9)
2 Eggs	2	(3)	2	(5)	0	(0)	0	(0)	4	(2)
1 Egg & 1 Chick	1	(1)	3	(7)	2	(3)	1	(4)	7	(3)
1 Chick	36	(47)	18	(44)	30	(46)	15	(65)	99	(48)
2 Chicks	12	(16)	1	(2)	6	(9)	2	(9)	21	(10)
Total Nests	76	(100)	41	(100)	65	(100)	23	(100)	205	(100)
Eggs/Chicks Nest^{-1}	0.92 *(n = 76)*[c]		0.76 *(n = 41)*		0.89 *(n = 65)*		0.96 *(n = 23)*		0.88 *(n = 205)*	
Eggs/Chicks Successful Nest^{-1}[d]	1.27 *(n = 55)*		1.24 *(n = 25)*		1.16 *(n = 50)*		1.16 *(n = 19)*		1.21 *(n = 149)*	
Estimated Production Nest^{-1}[e]	0.80 *(n = 76)*		0.56 *(n = 41)*		0.68 *(n = 65)*		0.87 *(n = 23)*		0.72 *(n = 205)*	
Estimated Production Successful Nest^{-1}[e]	1.24 *(n = 49)*		1.05 *(n = 22)*		1.16 *(n = 38)*		1.11 *(n = 18)*		1.17 *(n = 127)*	

Number of nests containing eggs or chicks = 149 (73%)

[a] CP = census plot.
[b] Numbers in parentheses are percentages unless noted otherwise.
[c] *n* = sample size.
[d] A successful nest was a nest that contained at least one egg (i.e., 149 of the 205 nests).
[e] Maximum estimates based on the presence of live, healthy-appearing chicks on 9 August.

Appendix 15. Reproductive success at 195 black-legged kittiwake nests checked on 11 August 1996 at Cape Lisburne, Alaska.

Nest Status	Sample Areas: Tiny Beach (CP-73)[a]	Kittiwake East (CP-71)	Dave's Rock (CP-70)	Kittiwake West (CP-68)	Total
Empty	66 (97)[b]	43 (100)	62 (100)	22 (100)	193 (100)
1 Egg	2 (3)	0 (0)	0 (0)	0 (0)	2 (1)
2 Eggs	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
1 Egg & 1 Chick	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
1 Chick	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
2 Chicks	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Total Nests	68 (100)	43 (100)	62 (100)	22 (100)	195 (100)
Eggs/Chicks Nest^{-1}	0.03 (*n = 68*)[c]	0.00 (*n = 43*)	0.00 (*n = 62*)	0.00 (*n = 22*)	<0.01 (*n = 195*)
Eggs/Chicks Successful Nest^{-1}[d]	1.00 (*n = 2*)	0.00 (*n = 0*)	0.00 (*n = 0*)	0.00 (*n = 0*)	1.00 (*n = 2*)
Estimated Production Nest^{-1}[e]	0.00 (*n = 68*)	0.00 (*n = 43*)	0.00 (*n = 62*)	0.00 (*n = 22*)	0.00 (*n = 195*)
Estimated Production Successful Nest^{-1}[e]	0.00 (*n = 0*)	0.00 (*n = 0*)	0.00 (*n = 0*)	0.00 (*n = 0*)	0.00 (*n = 0*)

Number of nests containing eggs or chicks = 2 (1%)

[a] CP = census plot.
[b] Numbers in parentheses are percentages unless noted otherwise.
[c] *n* = sample size.
[d] A successful nest was a nest that contained at least one egg (i.e., 2 of the 195 nests).
[e] Maximum estimates based on the presence of live, healthy-appearing chicks on 11 August.

Appendix 16. Reproductive success at 173 black-legged kittiwake nests checked on 8 August 1997 at Cape Lisburne, Alaska.

Nest Status	Sample Areas: Tiny Beach (CP-73)[a]		Kittiwake East (CP-71)		Dave's Rock (CP-70)		Kittiwake West (CP-68)		Total	
Empty	26	(42)[b]	17	(50)	27	(45)	11	(65)	81	(47)
1 Egg	4	(6)	1	(3)	7	(12)	0	(0)	12	(7)
2 Eggs	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
1 Egg & 1 Chick	0	(0)	0	(0)	1	(2)	0	(0)	1	(1)
1 Chick	30	(48)	16	(47)	23	(38)	6	(35)	75	(43)
2 Chicks	2	(3)	0	(0)	2	(3)	0	(0)	4	(2)
Total Nests	62	(100)	34	(100)	60	(100)	17	(100)	173	(100)
Eggs/Chicks Nest-1	0.61 *(n = 62)*[c]		0.50 *(n = 34)*		0.60 *(n = 60)*		0.35 *(n = 17)*		0.56 *(n = 173)*	
Eggs/Chicks Successful Nest-1[d]	1.06 *(n = 36)*		1.00 *(n = 17)*		1.09 *(n = 33)*		1.00 *(n = 6)*		1.05 *(n = 92)*	
Estimated Production Nest-1[e]	0.55 *(n = 62)*		0.47 *(n = 34)*		0.47 *(n = 60)*		0.35 *(n = 17)*		0.49 *(n = 173)*	
Estimated Production Successful Nest-1[e]	1.06 *(n = 32)*		1.00 *(n = 16)*		1.08 *(n = 26)*		1.00 *(n = 6)*		1.05 *(n = 80)*	

Number of nests containing eggs or chicks = 92 (53%)

[a] CP = census plot.
[b] Numbers in parentheses are percentages unless noted otherwise.
[c] *n* = sample size.
[d] A successful nest was a nest that contained at least one egg (i.e., 92 of the 173 nests).
[e] Maximum estimates based on the presence of live, healthy-appearing chicks on 8 August.

Appendix 17. Reproductive performance of thick-billed murres at Cape Lisburne, Alaska during 1995-1997.

1995 Plot Numbers	F3.1	F3.2	F4.1	F5.1	F6.1	F6.2	F7.1	DR1	DR2	DR3	DR4	DR5	DR6	First Beach (F) (*n = 7*) $\bar{x}$	SD[a]	Dave's Rock (DR) (*n = 6*) $\bar{x}$ [b]	SD	All Plots (*n = 13*) $\bar{x}$	SD	Grand Totals
Sites w/Egg (A)	20	18	24	9	28	21	18	22	34	22	32	37	9							Total Eggs (A): 294
Sites w/Chick (B)	16	17	23	7	26	18	17	19	34	21	31	37	8							Total Chicks (B): 274
Sites w/Fledged Chick (C)	15	17	23	7	23	17	16	19	32	20	27	33	6							Total Chicks Fledged (C): 255
Productivity Parameters																				**Performance of all 294 Sites**
Hatching Success (B/A)	0.80	0.94	0.96	0.78	0.93	0.86	0.94	0.86	1.00	0.95	0.97	1.00	0.89	0.89	0.08	0.95	0.06	0.91	0.07	B/A: 0.93
Fledging Success (C/B)	0.94	1.00	1.00	1.00	0.88	0.94	0.94	1.00	0.94	0.95	0.87	0.89	0.75	0.96	0.04	0.90	0.09	0.93	0.07	C/B: 0.93
Reproductive Success (C/A)	0.75	0.94	0.96	0.78	0.82	0.81	0.89	0.86	0.94	0.91	0.84	0.89	0.67	0.85	0.08	0.85	0.10	0.85	0.09	C/A: 0.87

1996 Plot Numbers	F1.1	F1.2	F2.1	F2.2	F2.3	F3.1	F3.2	F4.1	F5.1	F6.2	F7.1	F7.2	First Beach (F) (*n = 12*) $\bar{x}$	SD	Grand Totals
Sites w/Egg (A)	23	20	31	13	11	25	32	22	12	19	16	23			Total Eggs (A): 247
Sites w/Chick (B)	15	9	25	10	6	15	22	16	6	10	4	12			Total Chicks (B): 150
Sites w/Fledged Chick (C)	13	8	24	9	6	12	22	15	6	9	3	9			Total Chicks Fledged (C): 136
Productivity Parameters															**Performance of all 247 Sites**
Hatching Success (B/A)	0.65	0.45	0.81	0.77	0.55	0.60	0.69	0.73	0.50	0.53	0.25	0.52	0.59	0.16	B/A: 0.61
Fledging Success (C/B)	0.87	0.89	0.96	0.90	1.00	0.80	1.00	0.94	1.00	0.90	0.75	0.75	0.90	0.09	C/B: 0.91
Reproductive Success (C/A)	0.57	0.40	0.77	0.69	0.55	0.48	0.69	0.68	0.50	0.47	0.19	0.39	0.53	0.16	C/A: 0.55

Appendix 17 (Continued).

1997 Plot Numbers	Thick-billed Murre Plots F1.1	F1.2	F2.2 + 2.3	F3.1	F3.2	F4.1 + 5.1	F6.1	F6.2	F7.1	F7.2	Grand Totals	
Sites w/Egg (A)	26	27	15	29	34	33	28	25	19	28	Total Eggs (A): 264	
Sites w/Chick (B)	20	19	14	12	20	27	24	17	15	20	Total Chicks (B): 188	
Sites w/Fledged Chick (C)	19	15	11	12	15	24	22	13	13	20	Total Chicks Fledged (C): 164	
Productivity Parameters											First Beach (F) (*n = 12*) $\bar{x}$	SD	Performance of all 264 Sites
Hatching Success (B/A)	0.77	0.70	0.93	0.41	0.59	0.82	0.86	0.68	0.79	0.71	0.73	0.15	B/A: 0.71
Fledging Success (C/B)	0.95	0.79	0.79	1.00	0.75	0.89	0.92	0.76	0.87	1.0	0.87	0.10	C/B: 0.87
Reproductive Success (C/A)	0.73	0.56	0.73	0.41	0.44	0.73	0.79	0.52	0.68	0.71	0.63	0.14	C/A: 0.62

[a] SD = standard deviation.
[b] $\bar{x}$ = mean.

Appendix 18. Reproductive performance of common murres at Cape Lisburne, Alaska during 1995-1997.

1995 Plot Numbers	Common Murre Plots FB3.2	FB5.1	FB6.1	FB7.1	DR.6	First Beach (FB) Totals	Dave's Rock (DR) Totals	Grand Totals		
Sites w/Egg (A)	1	10	2	7	24	20	24	Total Eggs (A): 44		
Sites w/Chick (B)	1	8	2	7	24	18	24	Total Chicks (B): 42		
Sites w/Fledged Chick (C)	1	8	1	6	23	16	23	Total Chicks Fledged (C): 39		
Productivity Parameters								FB & DR Plots ($n = 2$) $\bar{x}$[a]	SD[b]	Performance of all 44 Sites
Hatching Success (B/A)	1.00	0.80	1.00	1.00	1.00	0.90	1.00	0.95	0.07	B/A: 0.95
Fledging Success (C/B)	1.00	1.00	0.50	0.86	0.96	0.89	0.96	0.93	0.05	C/B: 0.93
Reproductive Success (C/A)	1.00	0.80	0.50	0.86	0.96	0.80	0.96	0.88	0.11	C/A: 0.89

1996 Plot Numbers	Common Murre Plots FB2.1	FB2.2	FB2.3	FB3.1	FB3.2	FB5.1	FB7.1	LP1-2[c] Totals	LP3-7[d] Totals	Grand Totals		
Sites w/Egg (A)	6	4	9	1	1	8	4	19	14	Total Eggs (A): 33		
Sites w/Chick (B)	6	3	6	1	1	7	1	15	10	Total Chicks (B): 25		
Sites w/Fledged Chick (C)	6	2	6	0	1	6	0	14	7	Total Chicks Fledged (C): 21		
Productivity Parameters										FB Plots LP1-2 & LP-3-7 ($n = 2$) $\bar{x}$	SD	Performance of all 33 Sites
Hatching Success (B/A)	1.00	0.75	0.67	1.00	1.00	0.88	0.25	0.79	0.71	0.75	0.06	B/A: 0.76
Fledging Success (C/B)	1.00	0.67	1.00	0.00	1.00	0.86	0.00	0.93	0.70	0.82	0.16	C/B: 0.84
Reproductive Success (C/A)	1.00	0.50	0.67	0.00	1.00	0.75	0.00	0.74	0.50	0.62	0.17	C/A: 0.64

Appendix 18 (Continued).

1997 Plot Numbers	Common Murre Plots FB2.2	FB2.3	FB3.1	FB3.2	FB5.1	FB6.1	FB7.1	LP1-2 Totals	LP3-7 Totals	Grand Totals		
Sites w/Egg (A)	8	5	1	1	12	1	7	13	22			Total Eggs (A): 35
Sites w/Chick (B)	6	4	0	1	10	1	4	10	16			Total Chicks (B): 26
Sites w/Fledged Chick (C)	6	4	0	1	8	1	3	10	13			Total Chicks Fledged (C): 23
Productivity Parameters										FB Plots LP1-2 & LP-3-7 (*n* = 2) $\bar{x}$	SD	Performance of all 35 Sites
Hatching Success (B/A)	0.75	0.80	0.00	1.00	0.83	1.00	0.57	0.77	0.73	0.75	0.03	B/A: 0.74
Fledging Success (C/B)	1.00	1.00	0.00	1.00	0.80	1.00	0.75	1.00	0.81	0.91	0.13	C/B: 0.88
Reproductive Success (C/A)	0.75	0.80	0.00	1.00	0.67	1.00	0.43	0.77	0.59	0.68	0.13	C/A: 0.66

[a] $\bar{x}$ = mean.
[b] SD = standard deviation.
[c] Land plots 1-2 on First Beach.
[d] Land plots 3-7 on First Beach.

Appendix 19. Sea-surface temperatures during 23–28 July at Cape Lisburne, Alaska, 1987–1997.[a] All temperatures were taken with hand-held thermometers east of the cape between the tip of the cape and the western Igrarok Hills. During this period in 1995 (and also probably in 1987), readings were estimated to the nearest 0.5° C; in other years, readings were estimated to the nearest 0.1° C. Locations in parentheses also show approximate distances offshore in meters (m) or kilometers (km); locations not enclosed by parentheses indicate that temperatures were taken in the surf, usually with the aid of a bucket.[b] Times are Alaska Daylight Time.

	23 July			24 July			25 July			26 July			27 July			28 July		
Year	Location	Time	° C	Location	Time	° C	Location	Time	° C	Location	Time	° C	Location	Time	° C	Location	Time	° C
1987	(KB 15 m)	1157	8.0°			ND[c]			ND	RW	1400	10.0°	(RW 30 m)	11:30	9.0°			ND
			—			—			—	GB	1714	8.5°			—			—
			8.0°			ND			ND	(KB 30 m)	1830	8.5°			9.0°			ND
										(RW 45 m)	1900	9.0°						
												—						
												9.0°						

Average of all temperature readings: 8.8° (range = 8.0°-10.0°, SD = 0.7°, $n = 6$)[d]
Average of daily mean temperatures: 8.7° (range = 8.0°-9.0°, SD = 0.6°, $n = 3$)

Year	Location	Time	° C	Location	Time	° C	Location	Time	° C	Location	Time	° C	Location	Time	° C	Location	Time	° C
1992			ND	(IH 0.8 km)	2200	5.0°	(KB 1 m)	1530	7.0°			ND	(CL 200 m)	1930	7.9°	(LP1 50 m)	1410	6.0°
			—	(RW 100 m)	2350	5.2°			—			—	(RW 50 m)	2300	5.0°	(RW 50 m)	1435	6.5°
			ND			—			7.0°			ND			—			—
						5.1°									6.5°			6.3°

Average of all temperature readings: 6.1° (range = 5.0°-7.9°, SD = 1.1°, $n = 7$)
Average of daily mean temperatures: 6.2° (range = 5.1°-7.0°, SD = 0.8°, $n = 4$)

Year	Location	Time	° C	Location	Time	° C	Location	Time	° C	Location	Time	° C	Location	Time	° C	Location	Time	° C
1993	(RW 200 m)	0900	8.9°			ND	(GB 500 m)	?	11.7°	(CL 500m)	1640	7.8°	(RW 500 m)	1700	11.1°	(RW 1 km)	1900	10.6°
			—			—			—			—			—			—
			8.9°			ND			11.7°			7.8°			11.1°			10.6°

Average of all temperature readings: 10.0° (range = 7.8°-11.7°, SD = 1.6°, $n = 5$)
Average of all temperature readings: 10.0° (range = 7.8°-11.7°, SD = 1.6°, $n = 5$)

Appendix 19 (Continued).

Year	23 July			24 July			25 July			26 July			27 July			28 July		
Year	Location	Time	°C	Location	Time	°C	Location	Time	°C	Location	Time	°C	Location	Time	°C	Location	Time	°C
1995	RW	1902	5.0°	RW	2328	5.5°	RW	2353	6.5°	RW	2318	6.5°	RW	2210	5.5°	RW	2244	5.5°
			5.0°			5.5°			6.5°			6.5°			5.5°			5.5°

Average of all temperature readings: 5.8° (range = 5.0°-6.5°, SD = 0.6°, *n* = 6)
Average of all temperature readings: 5.8° (range = 5.0°-6.5°, SD = 0.6°, *n* = 6)

Year	Location	Time	°C	Location	Time	°C	Location	Time	°C	Location	Time	°C	Location	Time	°C	Location	Time	°C
1996	RW	1156	7.9°	RW	1208	7.9°	RW	1150	7.4°	RW	1147	7.4°	RW	1145	7.4°	RW	1155	7.1°
	RW	1837	8.0°	RW	2003	8.0°	RW	2136	7.1°	RW	2246	7.2°	RW	2140	7.5°	RW	2346	7.1°
				IH	2050	8.0°				LP7	2307	7.3°						
			8.0°			8.0°			7.3°			7.3°			7.5°			7.1°

Average of all temperature readings: 7.5° (range = 7.1°-8.0°, SD = 0.4°, *n* = 14)
Average of all temperature readings: 7.5° (range = 7.1°-8.0°, SD = 0.4°, *n* = 6)

Year	Location	Time	°C	Location	Time	°C	Location	Time	°C	Location	Time	°C	Location	Time	°C	Location	Time	°C
1997	RW	1555	8.5°	RW	1430	8.3°	RW	1041	8.4°	RW	1354	8.9°	RW	1147	8.3°	RW	1337	8.4°
	RW	2337	8.3°	RW	2243	7.9°	RW	2354	8.6°	RW	2254	8.4°	RW	2254	8.3°	RW	2127	9.4°
			8.4°			8.1°			8.5°			8.7°			8.3°			8.9°

Average of all temperature readings: 8.5° (range = 7.9°-9.4°, SD = 0.4°, *n* = 12)
Average of all temperature readings: 8.5° (range = 8.1°-8.9°, SD = 0.3°, *n* = 6)

[a] Data for 1987 and 1992 are from Denlinger *et al.* (1994); data for 1993 are from A.L. Sowls (unpubl. data); data for 1995–97 are from this study.
[b] RW is the conventional place for taking local sea-surface temperatures; it is located at the edge of the beach about 60 m east of the eastern end of the Cape Lisburne LRRS runway. KB = Kittiwake Beach, GB = Grizzly Bear Beach, CL = Cape Lisburne, IH = western Igrarok Hills, and LP = land plot (with plot number). A 9.5 liter plastic bucket tied to a rope was used to collect water from the surf; temperatures were taken immediately after the filled bucket was pulled ashore.
[c] ND = no data.
[d] SD = standard deviation, *n* = sample size.

Appendix 20. Reproductive performance of black-legged kittiwakes at Cape Thompson, Alaska in 1995.[a]

	Productivity Plots															
Colony Number	Colony 4								Colony 5							Grand Totals
Plot Numbers and Totals	4-1A	4X[b]	4-1B	4Y[c]	4-2C	4-3D	4-4E	Total	5-1A	5-1B	5-1C	5-2G	5-5J	5-6K	Total	
Number of Nests (A)	32	56	9	30	103	21	79	330	19	37	8	43	37	5	149	Total Nests (A): 479
Nests w/1 or more Eggs (B)[d,e]	7	13	1 (1)	5 (1)	17	10 (2)	20 (2)	73 (6)	5	9 (1)	1	5	5	0	25 (1)	Nests w/1 or more Eggs (B): 98
Number of Eggs (C)	7	13	2	6	17	12	22	79	5	10	1	5	5	0	26	Total Eggs (C): 105
Nests w/1 or more Chicks (D)	3	7	0	3	9	4	7	33	0	5 (1)	0	0	0	0	5 (1)	Nests w/1 or more Chicks (D): 38
Number of Chicks (E)	3	7	0	3	9	4	7	33	0	6	0	0	0	0	6	Total Chicks (E): 39
Nests w/1 or more Chicks Fledged (F)	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	Nests w/1 or more Chicks Fledged (F): 3
Number of Chicks Fledged (G)	0	0	0	0	0	0	3[f]	3	0	0	0	0	0	0	0	Total Chicks Fledged (G): 3

	Colony 4								Colony 5							All Plots ($n = 11$)		Performance of all
Productivity Parameters	4-1A	4X[a]	4-1B	4Y[b]	4-2C	4-3D	4-4E	Total	5-1A	5-1B	5-1C	5-2G	5-5J	5-6K	Total	$\bar{x}$[g]	SD[h]	479 Nests
Laying Success (B/A)	0.22	0.23	0.11	0.17	0.17	0.48	0.25	0.22	0.26	0.24	0.13	0.12	0.14	0.00	0.17	0.19	0.11	B/A: 0.20
Clutch Size (C/B)	1.00	1.00	2.00	1.20	1.00	1.20	1.10	1.08	1.00	1.11	1.00	1.00	1.00	0.00	1.04	1.05	0.42	C/B: 1.07
Nesting Success (D/B)	0.43	0.54	0.00	0.60	0.53	0.40	0.35	0.45	0.00	0.56	0.00	0.00	0.00	0.00	0.20	0.26	0.26	D/B: 0.39
Hatching Success (E/C)	0.43	0.54	0.00	0.50	0.53	0.33	0.32	0.42	0.00	0.60	0.00	0.00	0.00	0.00	0.23	0.25	0.25	E/C: 0.37
Chick Success (G/E)	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	—	G/E: 0.08
Egg Success (G/C)	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	—	G/C: 0.03
Fledging Success (F/D)	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	—	F/D: 0.08
Reproductive Success (F/B)	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	—	F/B: 0.03
Fledglings/nest Start (G/A)	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.01	—	G/A: 0.01
Overall Productivity (F/A)	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.01	—	F/A: 0.01

[a] Nests were checked 9-10 times during 11 July - 19 August.
[b] Plot 4X was named "Swartz Subplot A" in the 1995 field notebooks.
[c] Plot 4Y was named "Swartz Subplot B" in the 1995 field notebooks.
[d] This is a minimum value; some eggs may have been laid and lost before observations began.
[e] Number of 2-egg clutches shown in parentheses; all other clutches consisted of single eggs.
[f] These chicks were still alive when last checked on 19 August and were presumed to have fledged.
[g] $\bar{x}$ = mean.
[h] SD = standard deviation.

Appendix 21. Hatching chronology of murres at Cape Thompson, Alaska in 1995.

Parameter	Date								
	19–24 Jul	25–26 Jul	27–30 Jul	31 Jul – 3 Aug	4–7 Aug	8–11 Aug	12–15 Aug	16–19 Aug	20–23 Aug
Common Murres ($n = 257$)[a]									
Number of Eggs Hatched	0	4	5	75	96	55	20	2	0
Percent Hatched	0	2	2	29	37	21	8	1	0
Cumulative Percent Hatched	0	2	4	33	70	91	99	100	100
Thick-billed Murres ($n = 559$)[a]									
Number of Eggs Hatched	0	9	56	117	229	115	31	2	0
Percent Hatched	0	2	10	21	41	21	6	0	0
Cumulative Percent Hatched	0	2	12	33	74	94	100	100	100

[a] n = sample size (257 and 559 eggs for common and thick-billed murres, respectively).

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