APPENDIX J

APEX: 96163J

Exxon Valdez Oil Spill
Restoration Project Annual Report

Barren Islands Seabird Studies, 1996

Restoration Project 96163J
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

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Barren Islands Seabird Studies, 1996

Restoration Project 96163J
Annual Report

Study History: Barren Islands APEX seabird studies were initiated in 1995 (Project 95163J; see Roseneau *et al.* 1996a, Barren Islands seabird studies, 1995). In 1996, these studies became Project 96163J (see the APEX FY 96 detailed project description).

Abstract: Data on breeding and foraging parameters of common murres *(Uria aalge)*, black-legged kittiwakes *(Rissa tridactyla)*, and tufted puffins *(Fratercula cirrhata)* were obtained by the same collection and analysis methods used at the Barren Islands in 1995. Murre and kittiwake productivity was high and normal, respectively, and similar to 1994-1995. Although Pacific sand lance *(Ammodytes hexapterus)* replaced capelin *(Mallotus villosus)* as the dominant prey fed to kittiwake chicks, and chick regurgitation weights were lower, nestling growth rates were normal and similar to 1995. Murre and puffin chick diets were similar to 1995: murres received about 90% capelin (*Mallotus villosus*), and puffins were primarily fed capelin, Pacific sand lance *(Ammodytes hexapterus)*, and walleye pollock (*Theragra chalcogramma*). However, puffin bill-load weights and chick growth rates were lower, and fewer puffin chicks fledged than in 1995. Murre and kittiwake chick feeding rates were similar among days and to 1995 levels, but puffin chick rates (a variable not obtained in 1995) differed between 1996 observation dates. Although murre attendance varied between days both within and between years, kittiwake attendance was similar to 1995. Kittiwake foraging trips lasted longer, and murres made fewer 2-4 hour-long trips, compared to the previous year. Nesting chronology of kittiwakes was similar to 1994-1995, but murres nested earlier than in all previous postspill years. The trend toward earlier timing in murre nesting chronology since 1993 may have resulted from changing environmental conditions and/or the increasing age and experience of the breeding birds.

Key Words: Barren Islands, black-legged kittiwake, common murre, East Amatuli Island, East Amatuli Light Rock, *Exxon Valdez*, forage fish, *Fratercula cirrhata*, oil spill, Prince William Sound, *Rissa tridactyla*, tufted puffin, *Uria aalge*.

Project Data: (To be addressed in the final report)

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INTRODUCTION

This study is a component of the Alaska Predator Ecosystem Experiment (APEX). The APEX project, initiated in 1995, is composed of 15 related studies designed to determine whether forage fish availability and quality are limiting the recovery of seabird populations injured by the T/V *Exxon Valdez* oil spill. Over the course of the 5-year project, data on a variety of seabird breeding parameters and distribution, abundance, and energy content of forage fish will be compared among species, years, and study sites in Prince William Sound and lower Cook Inlet-Kachemak Bay to provide insight into how ecosystem processes may be affecting populations of seabirds nesting in the spill area.

The Barren Islands were included in the APEX seabird-forage fish project for several reasons. The islands support some of the largest concentrations of black-legged kittiwakes *(Rissa tridactyla)*, common murres *(Uria aalge)*, and tufted puffins *(Fratercula cirrhata)* nesting in the spill area, and some information on these species was available from past studies (e.g., Bailey 1975a,b and 1976; Manual 1978, 1980; Manual and Boersma 1978; Nysewander and Dippel 1990, 1991; Dippel and Nysewander 1992; Nysewander *et al.* 1993; Dragoo *et al.* 1995; Boersma *et al.* 1995; Erikson 1995; Roseneau *et al.* 1995, 1996a,b). Also, the offshore location of the islands provided opportunities to compare data from an oceanic environment with results from APEX studies in Prince William Sound and Minerals Management Service (MMS) and other APEX research in lower Cook Inlet-Kachemak Bay. Furthermore, capelin *(Mallotus villosus)*, an important forage fish species scarce in the northern Gulf of Alaska since the late 1970's (Piatt and Anderson 1995), were abundant near the islands during 1993-1994 (Roseneau *et al.* 1995, 1996b). Large stocks of these fish and the presence of other forage species, including Pacific sand lance *(Ammodytes hexapterus)* and young cods (e.g., 0-1 age-class walleye pollock, *Theragra chalcogramma*, and Pacific cod, *Gadus macrocephalus*) in surrounding waters provided an opportunity to explore seabird - forage fish relationships that might help explain why populations of some seabird species have not increased in the spill area.

Data collected at the Barren Islands are being used to help test three APEX hypotheses:[1]

Hypothesis 7: Composition and amounts of prey in seabird diets reflect changes in relative abundance and distribution of forage fish near nesting colonies.

Hypothesis 8: Changes in seabird productivity reflect differences in forage fish abundance as measured by amounts of time adult birds spend foraging for food, amounts of food fed to chicks, and provisioning rates of chicks.

Hypothesis 9: Seabird productivity is determined by differences in forage fish nutritional quality.

In 1996, we collected data on kittiwake, murre, and puffin productivity and nesting chronology; types and amounts of prey fed to kittiwake, murre, and puffin chicks; growth rates of kittiwake and puffin chicks and fledging size of murres; feeding frequencies of kittiwake, murre, and puffin chicks; and time-activity budgets of kittiwake and murre adults. We also obtained information that can be used to help track trends in population size of the these species (trends in Barren Islands murre numbers are being studied in greater detail by Projects 96144 and 97144; see the FY 96 and FY 97 common murre population monitoring project descriptions).

Data were compared with results from the 1993-1994 EVOS-sponsored Barren Islands common murre restoration monitoring projects (Projects 93049 and 94039; see Roseneau *et al.* 1995,

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[1] APEX hypotheses are currently undergoing review; they may be modified to better address questions raised by the T/V *Exxon Valdez* oil spill.

1996b) and the 1995 APEX Barren Islands seabird studies (see Roseneau *et al.* 1996a). Information was also shared with other APEX investigators to allow comparisons to be made among colonies (e.g., D. Irons, Project 96163E; J. Piatt, Project 96163M; D. Roby, Project 96163G). Prey samples were sent to D. Roby for energy content and density analyses, to D. Schell (University of Alaska-Fairbanks) for isotope analysis, and to M. Sturdevant (Project 96163C) for studies of fish diets. Also, 40 beach-seine sets were made during the 1996 field season using the same methods employed at Gull and Chisik islands (Project 96163M). Data from these activities were sent to J. Piatt to allow comparisons to be made among study sites (see Robards and Piatt, in press).

OBJECTIVES

Objectives of the 1996 Barren Islands seabird studies were to:

1. Determine the productivity of common murres (fledglings per egg laid), black-legged kittiwakes (fledglings per nest), and tufted puffins (percent of occupied burrows containing chicks).

2. Determine the nesting chronology of common murres, black-legged kittiwakes, and tufted puffins (median hatch date).

3. Determine the growth rates of black-legged kittiwake and tufted puffin chicks (grams per day).

4. Determine the types of prey fed to common murre chicks (composition by number), and black-legged kittiwake and tufted puffin chicks (composition by number and weight).

5. Determine provisioning rates for common murre and black-legged kittiwake chicks (feedings per hour), and tufted puffin chicks (feedings per day).

6. Determine the amounts of food fed to black-legged kittiwake and tufted puffin chicks (grams per chick regurgitation and grams per nest screen, respectively).

7. Determine adult activity budgets for common murre and black-legged kittiwake adults (foraging trip duration, minutes per hour both adults were present at nests, minutes per hour both adults were absent from nests).

8. Sample near-shore forage fish populations throughout the season by making regular beach seine sets using Project 96163M methods.

9. Collect forage fish samples from kittiwake regurgitations and tufted puffin burrow screenings.

METHODS

Study Area

The Barren Islands are located at about 58° 55' N, 152° 10' W, between the Kodiak archipelago and the Kenai Peninsula (Fig. 1). The study was conducted at East and West Amatuli islands, and Amatuli Cove camp served as base of operations (Fig. 2). Data were collected during 18 June - 13 September by a team of four to five people. Team members commuted to murre and kittiwakes study sites in outboard-powered, 4.8-m-long, rigid-hulled inflatable boats, and to puffin study areas by boating and hiking.

Productivity

Murres: Murre productivity data were collected at 9 of the 10 East Amatuli Island - Light Rock plots established for this purpose in 1993-1995 (see Roseneau *et al.* 1995, 1996a,b) and one plot set up to replace another that had become difficult to see. The plots, containing about 25-50 nest sites (sites with eggs) each (1996 nest site total = 266), were viewed through 7 x 42 binoculars and 15-60 power spotting scopes from land-based observation posts as often as weather permitted (range = 1-6 days). Viewing distances varied from about 30 to 100 m, and observers were assigned specific plots for the duration of the field season. Nest sites were mapped using photographs and sketches, and data were recorded for each site using previously established codes. Plot checks consisted of searching for eggs and chicks and adults in incubation and brooding postures, and counting adults. Each plot was checked about 28 times during 23 June - 4 September, from before eggs were laid until most chicks had gone to sea. Plots were treated as sample units and productivity was calculated as fledglings per egg laid. These data were also used to calculate hatching and fledging success (see Roseneau *et al.* 1995, 1996a,b). Differences among 1993-1996 results were tested by ANOVA.

Kittiwakes: Data on kittiwake productivity were collected from 11 East Amatuli Island plots, including four established 1993 and seven set up in 1995 (see Roseneau *et al.* 1995, 1996a,b). The plots, located on the same headlands as the murre productivity plots, contained 25-50 nests each (1996 nest total = 312; 285 contained eggs). Methods for collecting and analyzing data were similar to those used for murres, and were compatible with methods used by Projects 96163E and 96163M. Nest checks consisted of searching for eggs and chicks, and counting adults (adult postures were not used to determine kittiwake nest content). Each plot was checked about 28 times during 23 June - 4 September, from just after laying began until most chicks had fledged. Plots were treated as sample units and productivity was calculated as fledglings per nest site. Information on hatching and fledging success was not obtained in 1996, because poor weather conditions made it impossible to collect sufficient data during the hatching period. Differences among 1993-1996 results were tested by ANOVA.

Puffins: Puffin productivity data were obtained from four study plots established by University of Washington personnel in 1990 to collect information on chick growth rates (see growth rates below), and four transects totaling 270 m^2 established by FWS crews in 1986 to monitor numbers and occupancy of burrows (see Nishimoto 1990). Burrows in the plots were searched for signs of activity (trampled and cleared vegetation, guano from adults and chicks, fresh digging) and nestlings during 23 July - 25 July, when most chicks were about one week old. A 35-cm-long flexible scoop was used to help determine presence/absence of nestlings. After the initial visit, burrows containing chicks were checked every five days until 8 September. Active and inactive burrows and nestlings were also counted once on the transects on 28 August, just prior to fledging. Burrows were treated as sample units and productivity was calculated as the percentage of active burrows containing chicks just prior to fledging. The difference between 1995-1996 results was checked with Pearson's Chi-square test. Data on hatching success were obtained from a plot containing 36 burrows marked for this purpose. Burrows were checked three times during the nesting season: once just before and once just after hatching, and once just before most chicks fledged.

Nesting Chronology

Murres: Median hatch date, derived from productivity plot data, was used as the primary measurement of murre nesting chronology (see Roseneau *et al.* 1995, 1996b). Median dates were calculated for the plots and values were averaged to describe timing of nesting events. Because laying and hatching of eggs and fledging of chicks were rarely observed, the date that nest sites changed status (i.e., from eggs to chicks) was estimated to be the midpoint between the closest pre- and post-event observation dates. Two methods were used to maintain precision during analysis. Nest sites with data gaps of more than seven days between pre- and post-event laying and hatching observation dates were excluded from the data set. Also, for nest sites where the range of possible laying dates was smaller than the range of possible hatching dates, hatching dates were calculated by adding 32 days to laying dates (32 days is the average incubation time—see Byrd 1986, 1989; Roseneau *et al.* 1995, 1996a,b). Plots were treated as sample units and differences among 1993-1996 results were tested by ANOVA.

Kittiwakes: Median hatch date, derived from productivity plot data, was used to measure kittiwake nesting chronology (see Roseneau *et al.* 1996a). Methods for calculating this variable were the same as those described for murres, except that 27 days (rather than 32) were added to laying dates at sites where the range of possible laying dates was smaller than the range of possible hatching dates (see Byrd 1986, 1989). Plots were treated as sample units and differences among 1993-1996 results were tested by ANOVA.

Puffins: Median hatch date was used to measure puffin nesting chronology. The date was derived from wing measurements of chicks instead of laying or hatching information, because burrows were not visited until the chicks were about one week old (visiting burrows prior to this time can result in abandonment of eggs or chicks). Chicks were treated as sample units and the date was obtained by estimating the ages of 44 chicks from first wing measurements and a growth equation reported by Amaral (1977), and then calculating the median of the nestlings' estimated hatch dates. The difference between 1995-1996 results was checked with a two-tailed *t*-test.

Chick Growth Rates

Murres: Data on murre chick growth rates were not obtained during the study, because disturbing birds to weigh and measure chicks could have caused high levels of chick mortality. However, 46 nestlings were dip-netted from the water and weighed (to nearest whole g) and measured (culmen, tarsus, and wing chord to nearest whole mm) just after they left the cliffs and went to sea (captured chicks were released immediately after data were collected). Chicks were captured at night to prevent predation by glaucous-winged gulls *(Larus glaucescens).* Average chick weight provided an index of sea-going size.

Kittiwakes: To obtain information on kittiwake chick growth rates, 40 chicks from 38 broods were weighed (to nearest whole g) and measured (e.g., wing chord, culmen, tarsus, and back of head to tip of bill to nearest 0.1 mm) every 5-7 days, from shortly after hatching until they were about 32 days old. Growth rate calculations followed Project 95163E protocol. Average daily increases in weight were calculated for each chick from the most linear section of the growth curve (from 60 to 300 g) by dividing the difference in weight between the first and last measurements by the number of days between measurements. Resulting values were then used to calculate average growth rates for 'A' chicks (chicks in single-chick nests plus first to hatch chicks in 2-chick nests; n = 33) and 'B' chicks (the second-hatched chicks in 2-chick nests; n = 2). The difference between 1995-1996 'A' chick growth rates was checked with a two-tailed *t*-test.

Puffins: Thirty-three puffin chicks on three of the five study plots (see productivity above) were weighed (to nearest whole g) and measured (culmen, wing chord, and tarsus to nearest 0.1 mm) every five days, from the time they were about one week old until they were almost ready to fledge. To check the effects of more frequent visits on growth, 12 additional nestlings were weighed and measured three times on the remaining study plots. Weight was used as the primary indicator of growth. Data were analyzed by fitting a simple linear model to the 150-450 g section of each chick's growth curve (the portion that is nearly linear), and then calculating the average daily weight gain for each chick by using the slope of the line and numbers of days between first and last measurements. The final grams per day rate was the mean of the 33 chick values. The difference between 1995-1996 growth rates was checked with a two-tailed *t*-test.

Chick Diets

Murres: Prey items delivered to murre chicks were observed on seven different days during 12 August-1 September. Identifications were made using 7 x 42 binoculars and field guides. In total, 236 prey items, all fish, were recorded during deliveries, and 226 (96%) fish were identified to species or family groups (e.g. Gadidae) on the basis of color and body and fin shapes (e.g., caudal, anal, adipose fins). Data were analyzed by calculating percentages by number for five categories of prey: capelin, Pacific sand lance, cods (Gadidae), salmonids *(Oncorhynchus* spp.*)*, and unidentifiable fish species.

Kittiwakes: Samples of prey brought to kittiwake nestlings were obtained when growth study chicks regurgitated before, during, and after measurements. A total of 84 regurgitations were obtained on 15 days during 14 July - 9 August, when nestlings were about 1-4 weeks old. Samples were frozen shortly after collection and weighed (to nearest whole g) in the Homer lab. Individual prey items were weighed and identified by K.R. Turco at the University of Alaska-Fairbanks. Data were analyzed by calculating percentages by number and weight for seven categories of prey: capelin, Pacific sand lance, Pacific herring *(Clupea harengus pallasi)*, walleye pollock, salmonids, euphausiids *(Thyssanoessa* spp.*)*, and unidentifiable items.

Puffins: Samples of prey brought to puffin chicks were collected by temporarily blocking nesting burrows with squares of hardware cloth (screens). One hundred thirty-nine potential chick meals containing 446 prey items were obtained on six screening days at East Amatuli Island and four at West Amatuli Island during 23 July - 7 September. Prey were identified in the field using taxonomic keys and field guides, and then frozen. Preserved items were thawed, cleaned, and weighed (to nearest whole g) in the Homer lab. Data were analyzed by calculating percentages by number and weight for nine categories of prey: capelin, Pacific sand lance, walleye pollock, Pacific cod, prowfish *(Zaprora silenus)*, larval daubed shannies *(Lumpenus maculatus)*, pink salmon *(Oncorhynchus gorbuscha)*, squids (Cephalopoda), and other species.

Chick Provisioning Rates

Murres: Data on murre chick provisioning rates were collected from a plot containing 10 nest sites near one of the productivity plot observation posts. The plot was located in a flat rock-strewn area near the top of a cliff containing some of the productivity plots. Food deliveries were recorded during three 14-hr-long (0700-2100) watches on 12, 17, and 24 August. Data were analyzed by calculating the average number of feedings per hour for the three observation periods. Nest-days were used as sample units and differences among the five 1995-1996 observation dates were checked by ANOVA.

Kittiwakes: Kittiwake chick provisioning rate data were obtained from 12 chicks in eight nests that were located in one of the kittiwake productivity plots (see productivity above). Most information was collected by viewing nests through 7 x 42 binoculars from about 20 m away and recording times of feeding events during three 14-hr-long (0700-2100) watches on 16, 26, and 30 July. Some data were also obtained by recording activities on video tape (using two modified 8-mm Sony HandyCam camera/recorders) and reviewing the tapes in camp (in 1995, no differences were found between data collected simultaneously by the two methods). Observations began when nestlings were about nine days old and ended when they were about 23 days old. Because chicks are often fed several times after foraging adults return to their nests, and because adults sometimes leave their nests for short periods of time without foraging at sea, only first feedings after trips lasting 30 minutes or more were counted as feeding events. Data were analyzed by dividing the data into 1- and 2-chick nests, and calculating the average number of feedings per hour for the three observation periods. Differences between 1- and 2-chick nests on the five 1995-1996 observation dates were checked with two-tailed *t*-tests (if nest-types differed, annual indices were calculated for each type). Differences among the five observation dates were tested by ANOVA.

Puffins: Data on puffin chick provisioning rates were collected by observing adults returning to 10 marked burrows in one of the chick growth rate study plots during two 16-hr-long dawn-to-dusk watches (0600-2200) on 31 August and 2 September. Observations were made with 7 x 42 binoculars from a blind located about 50 m from the nesting burrows. Data consisted of adult departure and return times, and notes on activities in the vicinity of the burrows that might have affected the behavior of returning and departing birds (e.g., visits by aerial predators). Days were treated as sample units and the difference between observation dates was checked with a paired-sample *t*-test.

Amounts of Food Fed to Chicks

Murres: Data on amounts of food fed to murre chicks were not collected during the study, because disturbing the birds to collect and weigh fish could have caused high levels of chick mortality.

Kittiwakes: Information on amounts of food fed to kittiwake chicks was obtained from regurgitated samples (see chick food types above). Because amounts of food fed to nestlings increased until they were about 20 days old, the average weight of 33 samples collected from 20-day-old or older chicks were used to calculate meal-size. The difference between 1995-1996 results was checked with a two-tailed *t*-test.

Puffins: Data on amounts of food fed to puffin chicks were obtained from burrow screening samples (see chick food types above). Weights of the screened samples were averaged to obtain the meal-size index for this variable, and the difference between 1995-1996 results was checked with a two-tailed *t*-test.

Activity Budgets of Adults

Murres: Data on murre activity budgets were obtained during the three 14-hr-long observation periods used to collect chick feeding frequency information (0700-2100 hrs) on 12, 17, and 24 August; see chick provisioning rates above) and three additional 14-hr-long watches made during the incubation period (0700-2100 hrs on 15, 21, and 31 July). Adult arrival and departure times, and times when members of pairs exchanged duties (i.e., incubating eggs or brooding chicks), were recorded for each nest site. Bird-minutes per hour were used to measure the amount of time nest sites were attended by one or two adults. For example, if one adult was present at its nest site for 60 minutes and the second adult was present for 30 minutes during the same hour-long block of time, the nest was assigned 90-bird-minutes of attendance for that hour. Nest-days were used as sample units and differences among the five 1995-1996 observation dates were checked by ANOVA. Average foraging trip time was obtained by treating trips made during the nestling period as sample units and calculating the mean trip duration during the three dawn-to-dusk watches that ended in chick feedings (n = 85 trips). Nest-days were used as sample units and the difference between 1995-1996 results was checked with a two-tailed *t*-test. The frequency of trips in 2-hr blocks of time (0-2, 2-4, 4-6 and 6-8 hrs) was also computed and between-years differences were checked with a Chi-square test.

Kittiwakes: Kittiwake activity budget information was obtained during chick feeding frequency observations at eight nests (see chick provisioning rates above) and one incubation period watch. Adult arrival and departure times, and times when members of pairs exchanged duties (i.e., incubating eggs or brooding chicks) were recorded for each nest. Bird-minutes per hour were used to measure the amount of time adults spent at their nests each day (see murres, above). Nest-days were used as sample units and differences among the five 1995-1996 observation dates were checked by ANOVA. Average foraging trip time was obtained by treating trips made during the nestling period as sample units and calculating the mean duration of trips that ended in chick feedings and left another adult at the nest (because adults were not marked; n = 23 trips). Nest-days were used as sample units and the difference between 1995-1996 results was checked by a two-tailed *t*-test.

Puffins: During the two dawn-to-dusk watches made to obtain chick provisioning rate data, adult puffins stayed at their nesting burrows about 30 seconds or less to deliver fish to chicks. Because adults left the burrows unattended and were not marked, it was not possible to determine the duration of the foraging trips made by individual birds.

Population Counts

Murres: Murres were counted 16 times on the productivity plots on 16 different dates between the peak of laying and the first sea-going of chicks. Methods for collecting and analyzing data were the same as those used during the 1993-1994 Barren Islands murre restoration monitoring studies (see Roseneau *et al.* 1995, 1996b) and the 1995 Barren Islands APEX seabird project (see Roseneau *et al.* 1996a). Counts were averaged to obtain an annual estimate of birds on the plots and differences among the 1993-1996 scores were tested by ANOVA. *Note: Trends in Barren Islands murre numbers are being studied in greater detail by Project s96144 and 97144.*

Kittiwakes: Kittiwakes were counted 12 times on the productivity plots on 12 different dates before numbers began declining near the onset of fledging. Methods for collecting and analyzing data were the same as those used during 1993-1995 (D.G. Roseneau and A.B. Kettle, unpubl. data). Counts were averaged to obtain an annual estimate of birds on the plots and differences among the 1993-1996 scores were tested by ANOVA.

Puffins: The number of active puffin burrows on the three chick growth rate study plots and four transects were calculated to provide an annual index of population size. Plots and transects were treated as sample units and the difference between 1995-1996 results was checked with a Wilcoxon signed-ranks test.

RESULTS

Productivity

Murres: Murre productivity was high (0.77 fledglings per egg, SD = 0.14; Table 1, Fig. 3a; see Byrd *et al.* 1993) and similar to 1994-1995 levels (0.73 and 0.77 fledglings per egg, respectively; Roseneau *et al.* 1995, 1996a,b); however, all of these values were higher than the 1993 results (0.55 fledglings per egg; $P = 0.011$, 0.001, and 0.002, respectively). Fledging success followed an identical pattern: it was high (0.90 chicks per egg, SD = 0.12; see Byrd *et al.* 1993) and similar to 1994-1995 levels (0.93 and 0.91 chicks per egg, respectively), and results from all three years were higher than the 1993 value (0.79 chicks per egg; $P = 0.014$, 0.035, and 0.063, respectively). Hatching success exhibited a slightly different pattern: although it was also high (0.85 chicks per egg, SD = 0.10; see Byrd *et al.* 1993) and similar to 1994-1995 levels (0.85 and 0.79 chicks per egg, respectively), only 1995-1996 values were higher than the 1993 results (0.70; $P = 0.023$ and 0.022, respectively).

Kittiwakes: Productivity of kittiwakes was high (0.71 fledglings per nest, SD = 0.19; Table 1, Fig. 3b; see Hatch *et al.* 1993) and similar to 1994 and 1995 levels (0.64 and 0.81 fledglings per nest, respectively; see Roseneau *et al.* 1996a). These values differed sharply from 1993, when nesting pairs failed early in the nesting season and reproductive success was zero (no eggs or chicks were present on the four East Amatuli Island plots, Roseneau *et al.* 1995).

Puffins: Just prior to fledging, 0.31 (SD = 0.16) chicks were found per occupied burrow on the three growth rate plots and group of four transects (Table 1). This was a significantly lower (P <

0.001) than in 1995 (0.53 chicks per occupied burrow; see Roseneau *et al.* 1996a). Hatching success, obtained from a plot established for this purpose, was 0.5 chicks per egg. This figure was lower than most values reported from other Alaskan colonies (see Byrd *et al.* 1993).

Nesting Chronology

Murres: Based on the median hatch date (4 August, SD = 4; Table 1), hatching occurred 5, 7, and 12 days earlier than in 1995, 1994, and 1993, respectively. These dates differed significantly from one another, with the exception the 1994-1995 dates. Also, the 1993 hatch date was earlier than the reported 1992 Nord Island and 1991 East Amatuli Light Rock dates (see Dragoo *et al.* 1995 and Boersma *et al.* 1995, respectively).

Kittiwakes: The median hatch date was 7 July (SD = 7; Table 1); this was similar to 1994-1995 results (10 and 8 July, respectively).

Puffins: The median hatch date for puffins was 16 July (SD = 5; Table 1). This was significantly earlier than in 1995 (21 July, $P<0.001$).

Chick Growth Rates

Murres: The average weight of the 46 murre chicks dip-netted from the sea was 240 grams (SD = 24; Table 1).

Kittiwakes: The average growth rate of kittiwake chicks, for all chicks combined (n = 35), was 17.5 grams per day (SD = 5.8; Table 1). 'A' chicks (chicks in single-chick nests plus first chicks to hatch in 2-chick nests; n = 33) gained 17.6 grams per day (SD = 5.9), while 'B' chicks (the second-hatched chicks in 2-chick nests; n = 2) grew at a rate of about 14.9 grams per day (SD = 1.6). The 'A' chick rate was similar to the 1995 value (19.4 g per day).

Puffins: Puffin chicks in the three main study plots gained an average of 3.3 grams per day (SD = 1.6 g, n = 32; Table 1), while chicks visited only three times during the same period gained 3.1 grams per day (SD = 1.3, n = 12). The difference between these rates was not significant. The combined growth rate for all chicks was 3.2 grams per day (SD = 1.5; n = 44), a rate that was low for puffins, and considerably lower than the 1995 value of 11.4 grams per day ($P < 0.001$).

Chick Diets

Murres: Prey items delivered to murre chicks consisted solely of small fish (n = 236), most of which were capelin (91% by number; Fig. 4a). Adults also fed nestlings a few unidentified cods (Gadidae, probably walleye pollock and Pacific cod) and Pacific sand lance, and one unidentified salmonid (3%, 2%, and <1% by number, respectively). Ten fish (4%) could not be identified to group or species. Results were similar to 1995: capelin were clearly the primary component in chick diets.

Kittiwakes: By weight, 29% of the contents in the 84 kittiwake chick regurgitation samples could not be identified (Fig. 4b). However, Pacific sand lance (40%) and capelin (21%) were apparently the primary sources of food, while other prey types, including Pacific herring (6%), walleye pollock (1%), salmon (1%), and euphasiids (1%) were less important. Based on these data, chicks were apparently fed a larger proportion of sand lance and a smaller proportion of capelin, compared to 1995. However, methods used to identify the contents of the regurgitation samples differed somewhat from the previous year (otoliths recovered from the samples were saved, but not identified as they had been in 1995). This difference is being resolved, and a more detailed comparison between 1995-1996 results will be made in the next annual report.

Puffins: Prey deliveries (n = 139 screen samples) to puffin chicks contained 446 items (Fig. 5). By weight, capelin (37%), Pacific sand lance (27%), and walleye pollock (18%) were clearly the primary sources of food, while other types of prey, including pink salmon 6 (%), larval daubed shannies (4%), Pacific cod (2%), prowfish (2%), squid (2%), and other fish and invertebrates (2%), were less important. Based on this information, chicks received larger amounts of capelin and sand lance, and much smaller amounts of prowfish, compared to 1995. Chicks were also fed somewhat smaller amounts of pollock, compared to the previous year; however, this decrease (6%) was equivalent to the new pink salmon component (6%), which was not present in 1995.

Chick Provisioning Rates

Murres: During the three all-day observation periods, chicks averaged 0.26 feedings per hour (SD = 0.05, n = 3 d; Table 1, Fig 7a), a figure similar to the overall 1995 value (0.29 feedings per hour). No differences were found among the five 1995-1996 all-day watches.

Kittiwakes: During the three all-day observation periods, single-chick nests averaged 0.19 feedings per hour (SD = 0.03, n = 3 d; Table 1, Fig. 7b), and nests containing two chicks averaged 0.24 feedings per hour (SD = 0.08, n = 3 d). Although this difference was not significant, the difference between 1- and 2-chick nests was significant in 1995 (1- and 2-chick nests = 0.21 and 0.40 feedings per hour, respectively; $P = 0.015$). As a result, the 1995-1996 1- and 2-chick nest values were compared separately; however, no significant differences occurred among the five 1995-1996 all-day observation periods.

Puffins: All puffins returning to burrows were carrying fish. The number of feedings per burrow differed between the two all-day watches (31 Aug = 7.20, SD = 2.25; 2 Sep = 3.80, SD = 1.55; $P < 0.001$; Table 1), and there was a pronounced diurnal pattern on both dates: chicks were fed more often in the early morning hours than during other parts of the day (see Fig. 8).

Amounts of Food Fed to Chicks

Kittiwakes: Kittiwake chick regurgitation weights increased with nestling age (based on median hatch date). Weights averaged 10.1 grams (SD = 5.7, n = 18), 16.6 grams (SD = 11.0, n = 32), and 20.8 grams (SD = 13.3, n = 33) when chicks were less than 10 days old, 10-20 days old, and 20 days old or older, respectively. Only data from the 20-day-old and older chicks were used to compute this index. The average meal-size of 20.8 grams (SD = 13.3; Table 1) was lower than 1995 results (27.7 g, SD 11.5, n = 37; $P = 0.2$).

Puffins: The average weight of 109 screen samples collected during the nestling period was 6.9 grams (SD = 6.8, Table 1). This was significantly lower than the average weight of 110 samples obtained in 1995 (10.3 g; SD = 12.8; n = 110).

Activity Budgets of Adults

Murres: *(Nest Attendance)* -- During the incubation period, at least one adult murre always attended each nest site, and both pair members were present an average of 19.5 minutes per hour (79.5 bird-min/hr; SD = 6.0; n = 3 d; Table 1, Fig. 9a). During the nestling period, at least one adult was also always attended each site, and both birds were present an average of 9.6 minutes per hour (69.6 bird-minutes/hr; SD = 4.1; n = 3 d); this was similar to the 1995 figure (66.4 bird-min/hr). Testing by ANOVA showed that there was a significant difference among observation dates, and a Tukey post-hoc test indicated that two days were marginally different in 1996 (12 and 17 August; $P = 0.055$), as were one in 1995 (24 August) and one in 1996 (15 August; $P = 0.069$). These results indicated that differences between days were as great as differences between years.

(Duration of Foraging Trips) -- During the nestling period, murre foraging trips averaged 150 minutes (SD = 78, n = 85 trips; Table 1), a figure similar to 1995 results (158 minutes). However, the frequency of trips between 0-2 and 2-4 hrs differed between years (see Figs. 10 and 11; $\chi^2 = 17.14$, $P = 0.001$); shorter trips were more common in 1995.

Kittiwakes: *(Nest Attendance)* -- Adult kittiwakes rarely left eggs unattended during the incubation period, and during the same interval, it was even rarer for members of pairs to tend nests together. During the nestling period, as in 1995, members of pairs also rarely attended nests together. In 1996, chicks were occasionally left alone: both adults left 1- and 2-chick nests for an average of 1.0 minutes per hour (SD = 1.4, n = 3 d; Table 1, Fig. 9b) and 5.4 minutes per hour (SD =4.5). respectively. Although within day differences between 1- and 2-chick nests were not significant, 2-chick nests were consistently left alone more often than 1-chick nests (1-chick nests, 59.0 bird-min/hr/nest, SD = 1.43; 2-chick nests, 54.6 bird-min/hr/nest, SD = 4.48). As a result, data were analyzed separately; however, no differences in attendance were detected among days at 1- and 2-chick nests.

(Duration of Foraging Trips)-- Kittiwake foraging trips averaged 326 minutes during the nestling period (SD = 91 min, n = 23 trips; Table 1). This was significantly longer than in 1995 (237 min; $P = 0.01$).

Population Counts

Murres: Murre counts on the productivity plots averaged 407 birds (SD = 24.3; Table 1). This estimate was similar to the 1993, 1994, and 1995 scores of 435, 404, and 392 individuals, respectively (see Roseneau *et al.* 1995, 1996a,b).

Kittiwakes: Kittiwake counts on the four productivity plots that could be compared among years averaged 183 individuals (SD = 8.2, n = 12; Table 1). This estimate was similar to the 1994 and 1995 scores of 192 (SD = 10.3) and 201 (SD = 8.7) birds, respectively, but higher than the 1993 count of 120 individuals (SD = 50.3; $P < 0.001$).

Puffins: The number of occupied puffin burrows on the three growth rate study plots and group of four transects were similar between years (142 active burrows in 1996, Table 1; and 125 active burrows in 1995).

DISCUSSION

In 1995-1996, availability of forage fish to black-legged kittiwakes and common murres was apparently high enough in the vicinity of the Barren Islands to allow these species to reproduce at average and above average levels, respectively. In contrast, tufted puffin productivity was normal in 1995, but quite low in 1996. The lack of concordance between murres and puffins, both diving species, may in part, reflect differences in chick-rearing strategies. Puffin chicks remain in nesting burrows about twice as long as murre chicks stay at nest sites, and prey, including forage fish, need to be available to adult puffins for longer periods of time to ensure continued growth and survival of nestlings to fledging age. Foraging behavior also differs between puffins and murres: puffins tend to forage in flocks less often than murres; this trait might help explain why puffin chick diets were much more diverse than diets of murre chicks in 1995-1996.

During 1995-1996, growth rates of kittiwake and puffin chicks mirrored productivity (murre growth rates were not obtained during the study). However, while growth rates of kittiwake chicks were normal and similar between years, puffin chick growth rates were normal in 1995, but quite low in 1996. Again, differences in chick-rearing strategies and foraging behaviors might partially explain this difference. However, the low growth rate of puffin chicks in 1996 also suggested that these seabirds were having a harder time finding food during the chick-rearing period than in the previous year.

Capelin, generally considered to be relatively high quality prey, were by far the most common item fed to murre chicks in 1995-1996, and nestling diets were similar between years. Murres also reproduced at similar above average levels in 1995-1996. Capelin, in combination with Pacific sand lance, another high quality prey species, also played an important role in the diets of kittiwake and puffin chicks; however, by weight, percentages varied between years and were higher in 1995 than in 1996. Sand lance use followed an opposite pattern: percentages by weight in the chick diets of both species varied between years, but were higher in 1996 than in 1995. However, despite these dietary differences, kittiwake chick growth rates and productivity were normal and similar between years.

Puffin chick diets were the most diverse among the three seabird species. The percentage of prowfish fed to nestling puffins was relatively high in 1995, but markedly lower in 1996, when larger percentages of capelin and sand lance were delivered to burrows, compared to the previous year. Prowfish are generally considered to be poorer-quality prey than sand lance or capelin; however, nestling growth rates and productivity were normal in 1995, but quite low in 1996, when chicks received higher percentages of higher quality prey species. This difference suggested that a change in prey availability, rather than a change in food type, was responsible for the lower chick growth rates and productivity of puffins in 1996.

Seabird productivity and chick growth rates can be altered by availability of prey. The size of meals delivered to nestling kittiwakes was lower in 1996 than in 1995, and the duration of foraging trips was longer, compared to the previous year. These differences suggested that food was more difficult to acquire, and more effort was needed to feed chicks in 1996. However, by working harder, kittiwakes were apparently able to compensate for changes in prey availability and provide food to their nestlings at a frequency similar to the previous year—thereby preventing growth rates and productivity from dropping below 1995 levels.

Murres may have also worked harder to obtain food for chicks in 1996: fewer short foraging trips were made, compared to the previous year, although average trip duration was similar to 1995, and nest attendance and chick provisioning rates did not differ between years. Because murres are capable of diving and foraging throughout the water column, they are less susceptible to changes in oceanographic conditions that can affect surface-feeding kittiwakes by causing prey to remain below this specie's feeding depths.

Puffins delivered significantly smaller meals to chicks in 1996, compared to 1995. Again, this difference suggested these birds were having a more difficult time finding food than in the previous year. Changes in prey availability and amounts of food fed to chicks, rather than changes in types of prey, probably accounted for the lower chick growth rate and productivity of puffins in 1996.

Murre nesting chronology has been getting steadily earlier in the Barren Islands since 1993 (and also apparently since 1991). While the possibility exists that changes in food supplies and environmental conditions may be involved in this in timing change, the pattern is typical for populations undergoing increases in age and experience of breeding individuals— something that might be expected after a major mortality event, such as the *Exxon Valdez* oil spill (see Nysewander *et al.* 1993). Factors that may be responsible for the change in timing of murre nesting events may be identified by continuing to explore relationships among breeding parameters and food supplies of murres and other seabirds at the Barren Islands colonies.

CONCLUSIONS (To be addressed in the final report)

ACKNOWLEDGMENTS

We would like to thank Stephanie Zuniga, Margaret Blanding, Carrie Alley, and Jonathan Maletta for making the 1996 APEX Barren Islands seabird project a success. Their constant dedication to the work allowed us to safely collect data in spite of sometimes hostile weather and sea conditions. We also extend our thanks to Captain John Rogers, M/V *Waters*, for transporting us to the Barren Islands in June, and Captain Kevin Bell, FWS R/V *Tiglax*, for transporting us back to Homer in September. Trina Fellows and Carol Hagglund, Alaska Maritime NWR, monitored our radio calls on a daily basis and cheerfully helped us with many logistical needs. This study was funded by the *Exxon Valdez* Oil Spill Trustee Council.

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Table 1. Results from Barren Islands Seabird Studies, 1996.

Variable	Common murre		Black-legged kittiwake		Tufted puffin	
Productivity	Eggs hatched / eggs laid	0.85 (0.10)[1]	Chicks fledged / nests built:	0.71 (0.19)	Chicks / occupied burrow	0.31(0.16)
	Chicks fledged / eggs hatched	0.90 (0.12)				
	Chicks fledged / eggs laid	0.77 (0.14)				
Nesting chronology	Median hatch date:	4 Aug (4)	Median hatch date:	7 Jul (7)	Median hatch date:	16 Jul (5)
Chick growth rate	Fledging weight (g):	240 (24)	Grams / day (all chicks):	17.5 (5.8)	Grams / day:	3.3 (1.6)
			("A" chicks):	17.6 (5.9)		
			("B" chicks):	14.9 (1.6)		
Chick feeding freq.	Feedings / chick / hr (0700-2100):	0.26 (0.05)	Feedings/nest/hr (0700-2100) (1 ch):	0.19 (0.03)	Feedings/nest/d (0600-2200):	7.2 (2.2) - 3.8 (1.5)
			(2 ch):	0.24 (0.08)		
Adult trip duration	Minutes / trip:	150 (78)	Minutes / trip:	326 (91)	*No data*	
Time no ad. on nest	Minutes / hour:	0.0	Minutes / hour (1 chick):	1.0 (1.4)	*Not yet analyzed*	
			(2 chicks):	5.4 (4.5)		
Time 2 ad. on nest:	Minutes / hour (incubation):	19.5 (6.0)	Minutes / hour (1 chick):	0.0	*Not yet analyzed*	
	(nestling period):	9.6 (4.1)	(2 chicks):	0.0		
Chick meal size	*no data*		Regurgitant weight (g):	20.8 (13.3)	Screen samp. wt. (g):	6.9 (6.8)
Population size	Productivity plots (no. of birds):	407 (24)	Productivity plots (no. of birds):	183 (8.2)	Number of burrows:	142

[1] Standard deviation in parentheses

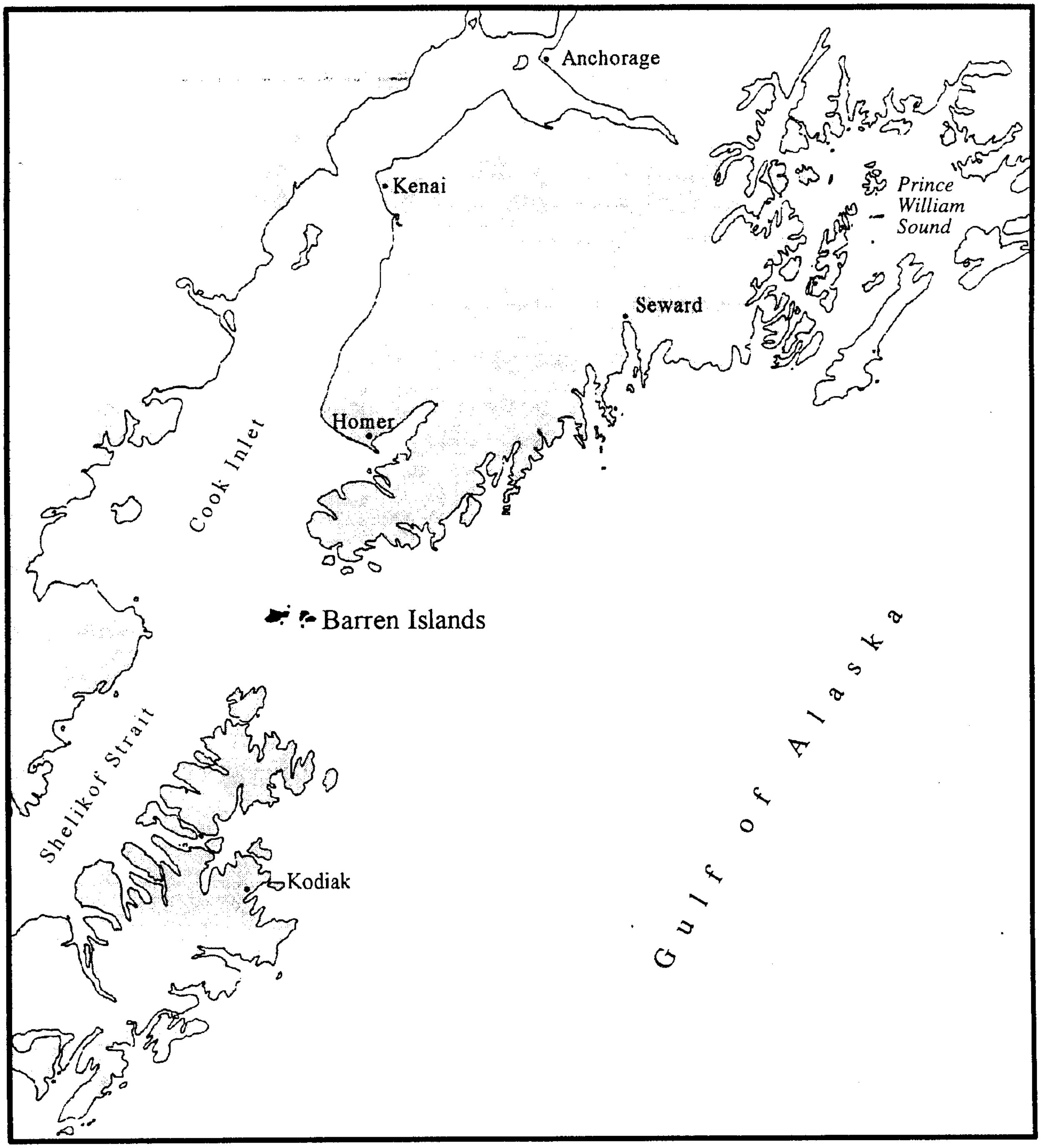

Figure 1. Location of the Barren Islands, Alaska

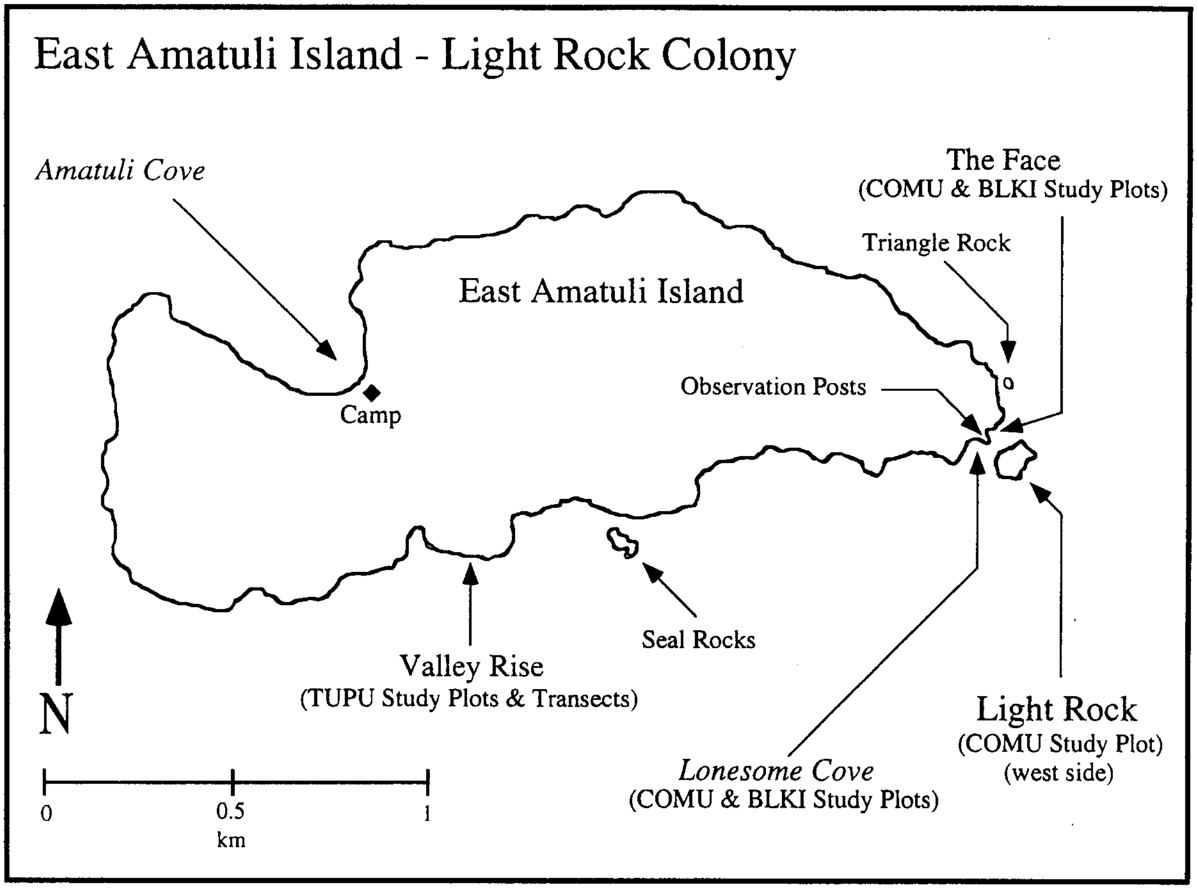

Figure 2. The East Amatuli Island study area showing the general locations of the common murre (COMU), black-legged kittiwake (BLKI), and tufted puffin (TUPU) study sites.

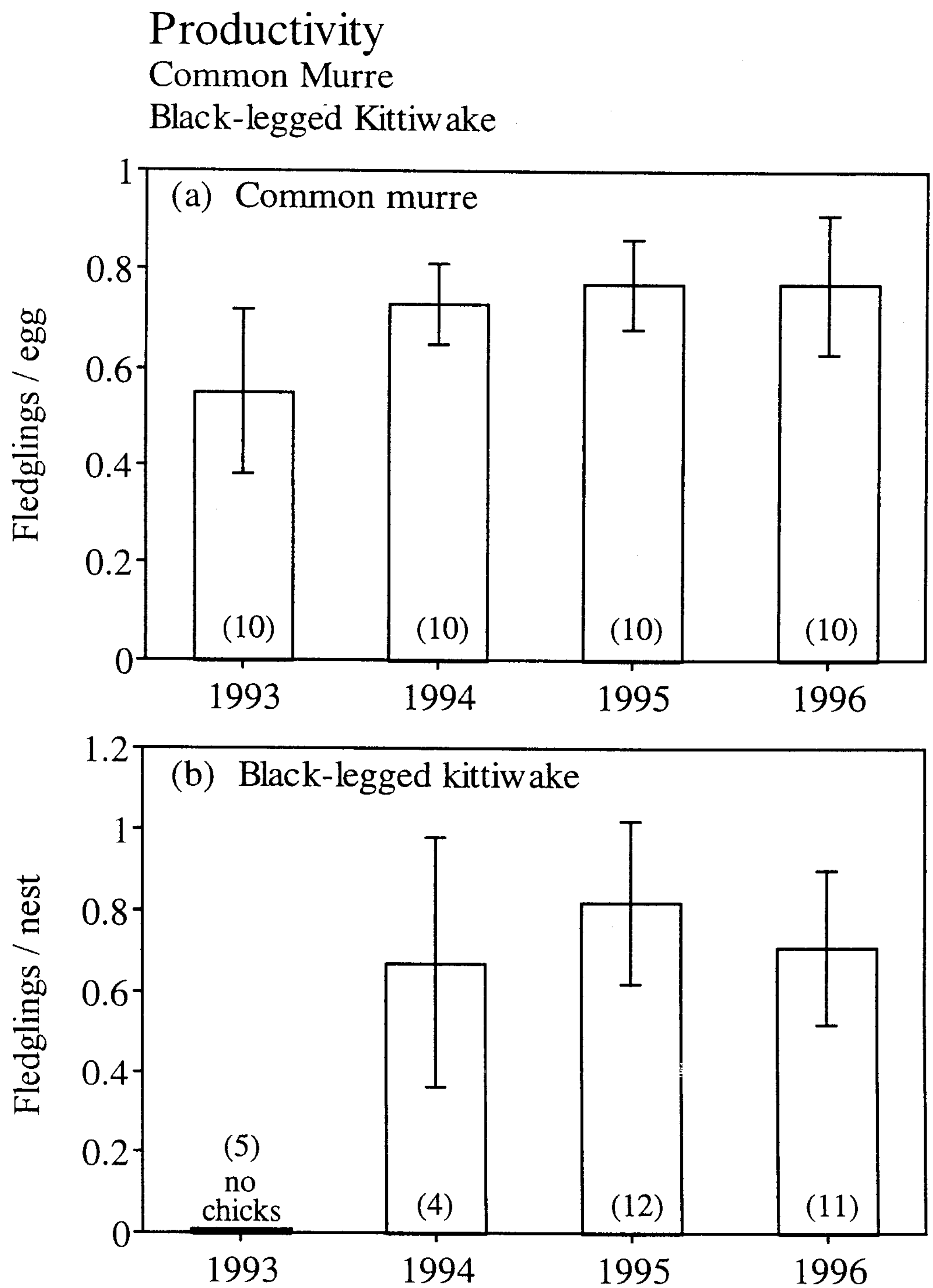

Figure 3. Productivity of (a) common murres and (b) black-legged kittiwakes at East Amatuli Island, Barren Islands, Alaska, 1993-1996 (number of plots shown in parentheses; error bars = standard deviation).

Chick diet

Common murre
Black-legged kittiwake

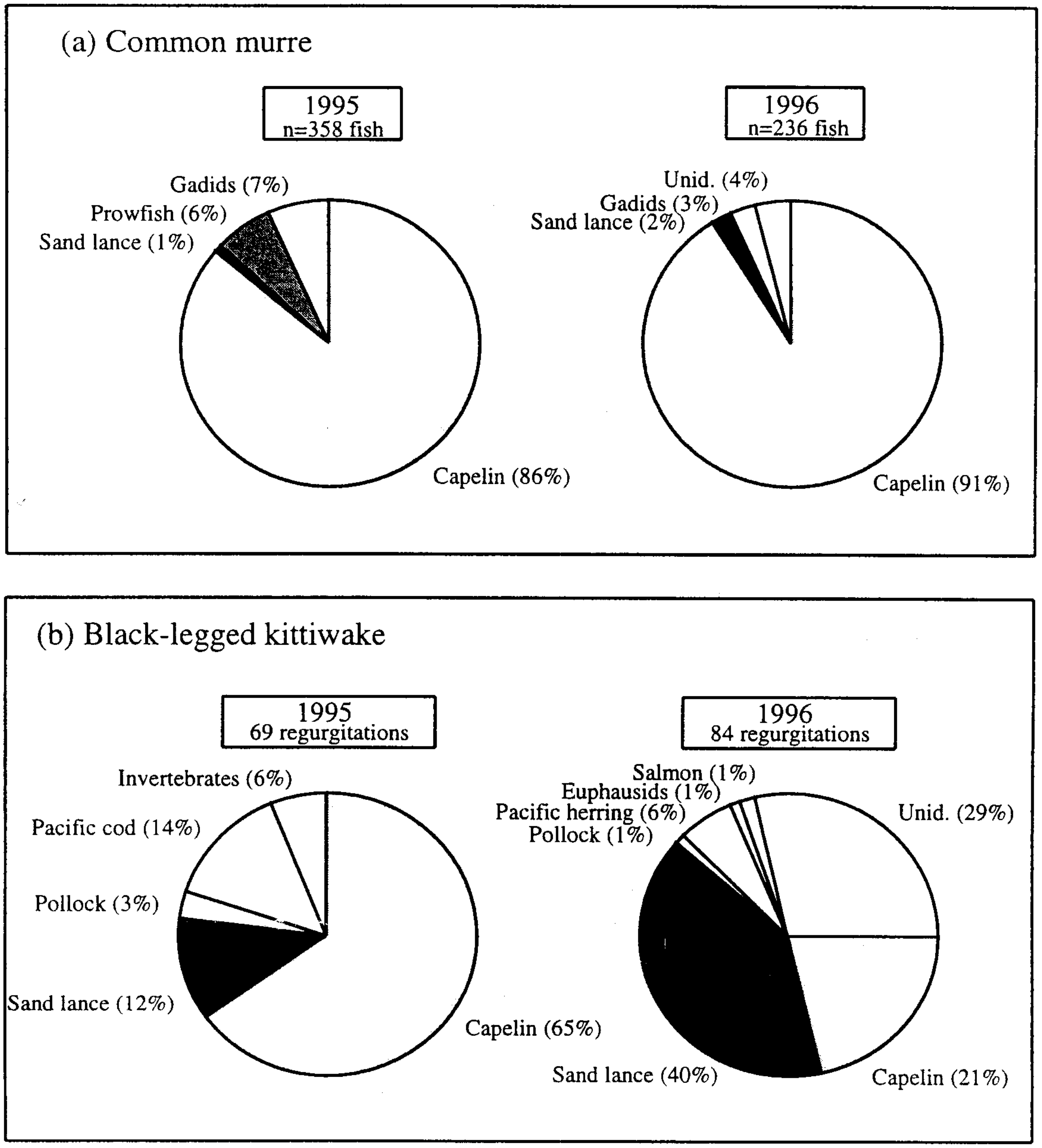

Figure 4. Types of prey fed to (a) common murre and (b) black-legged kittiwake chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1996: Composition of prey by (a) number and (b) weight.

Chick diet

Tufted puffin

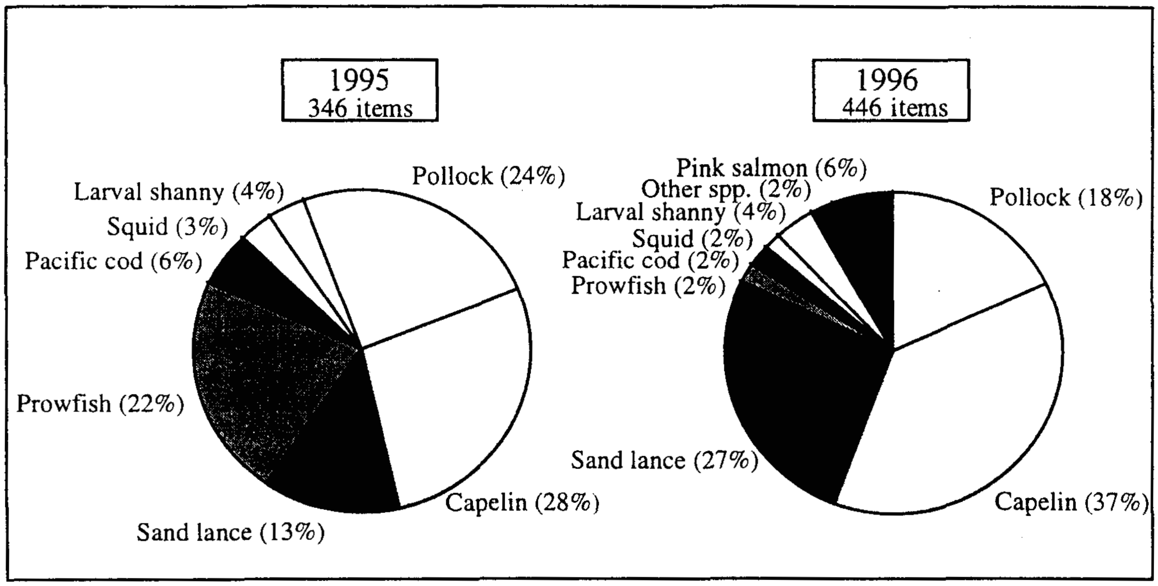

Figure 5. Types of prey fed to tufted puffin chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1996 (composition by weight).

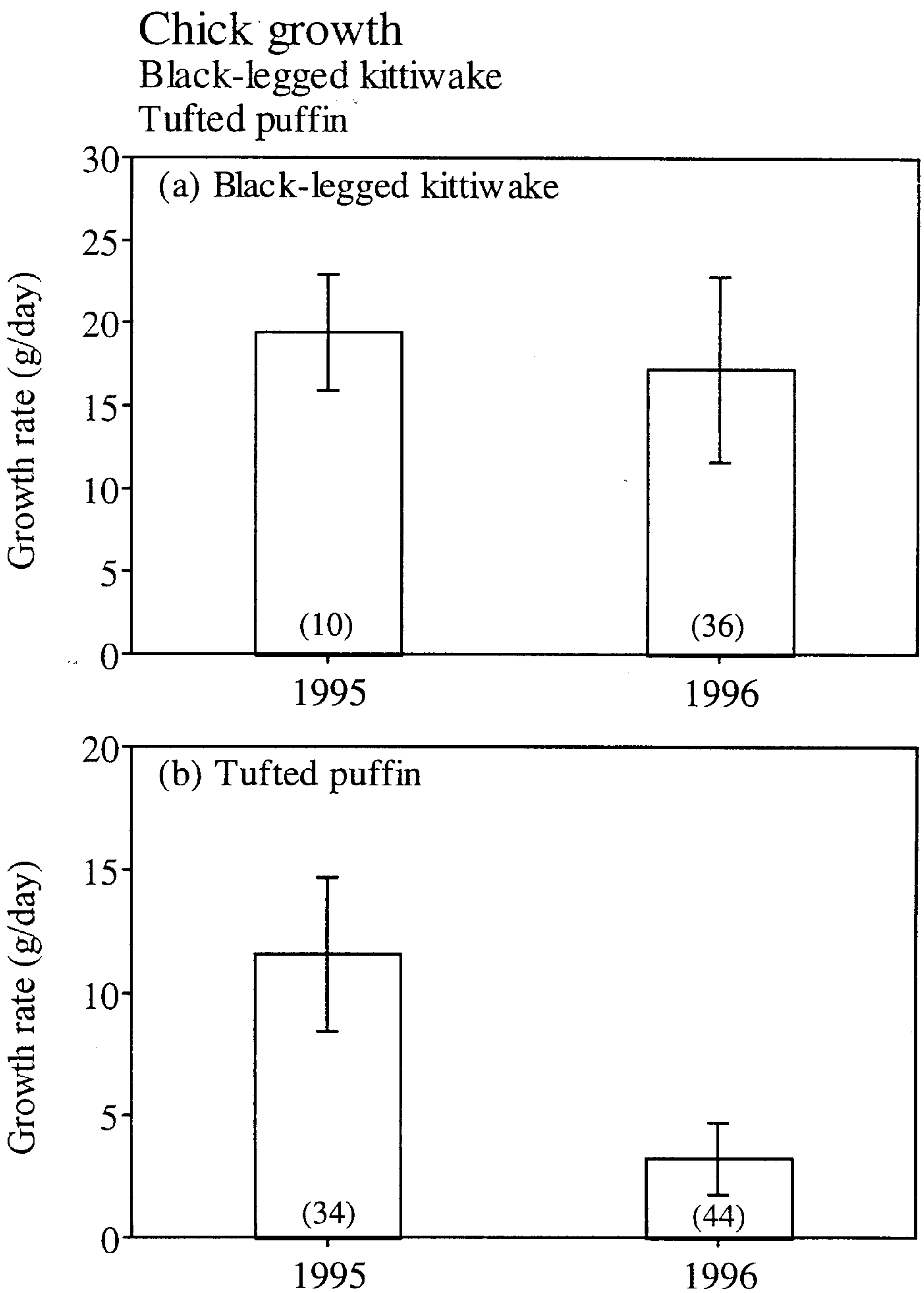

Figure 6. Growth rates of (a) black-legged kittiwake and (b) tufted puffin chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1996 (number of chicks shown in parentheses; error bars = standard deviation).

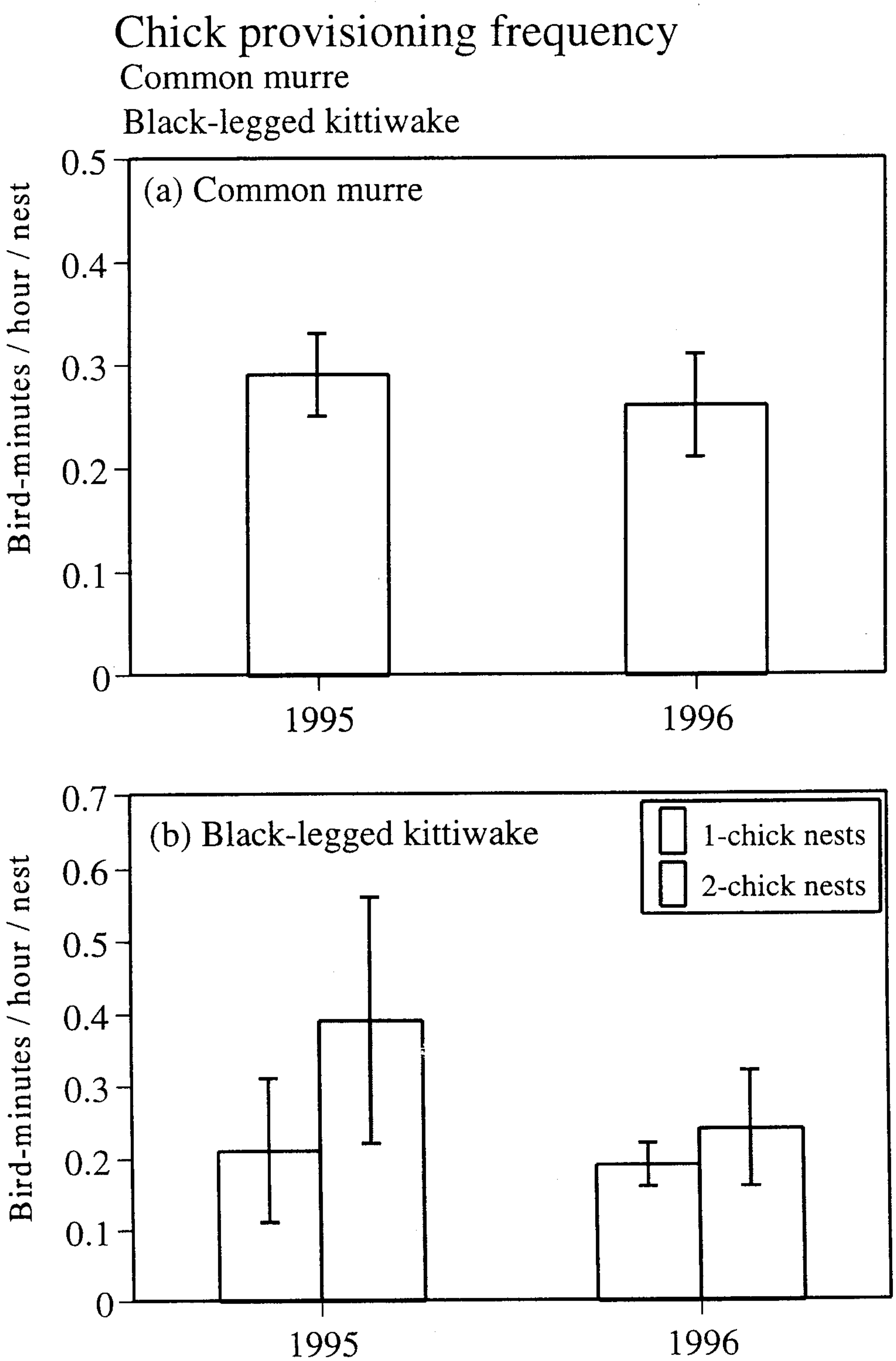

Figure 7. Provisioning rates of (a) common murre and (b) black-legged kittiwake chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1996 (n = 2 days in 1995 and 3 days in 1996; error bars = standard deviation).

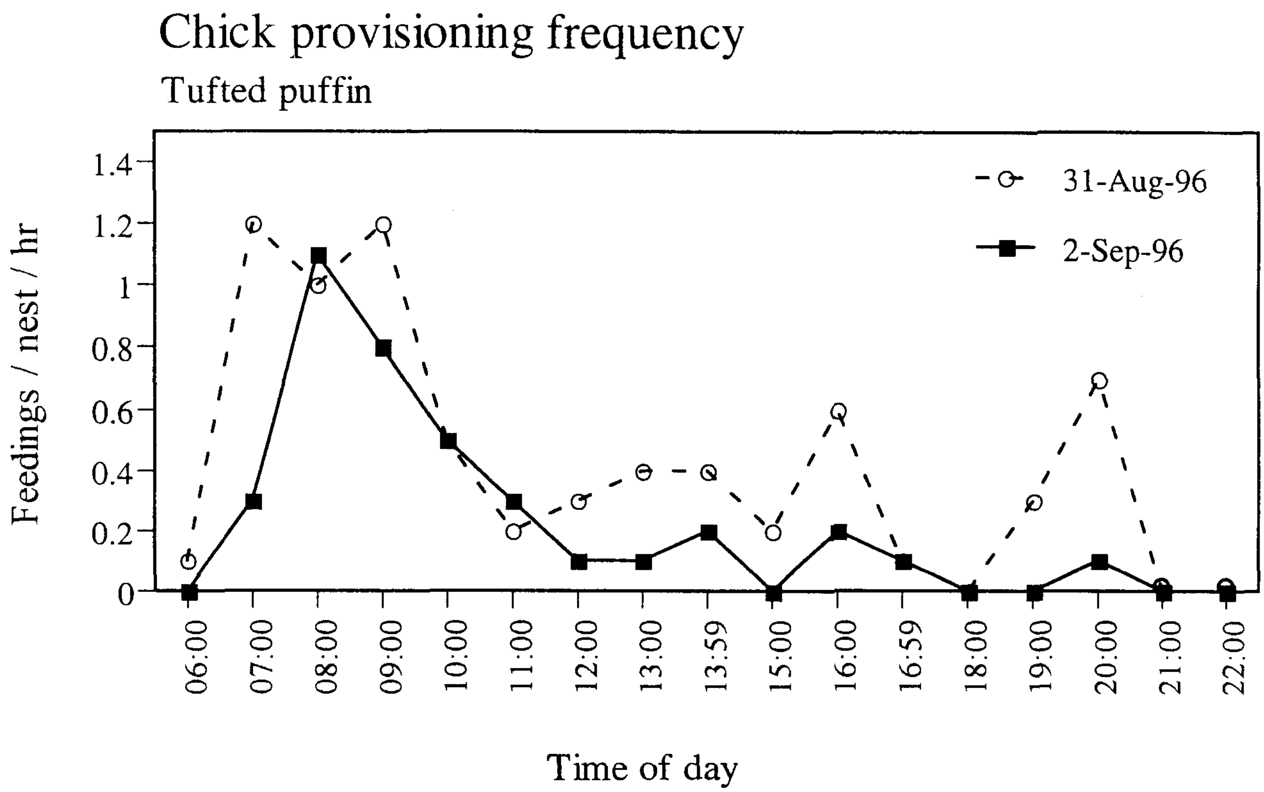

Figure 8. Number of times adult puffins brought prey to burrows at East Amatuli Island, Barren Islands, Alaska during two dawn-to-dusk observation periods in 1996 (calculated as returns per nest per hour, for a sample of 10 nests with chicks; hours are start times for corresponding data points).

Nest attendance -- nestling period
Common murre
Black-legged kittiwake

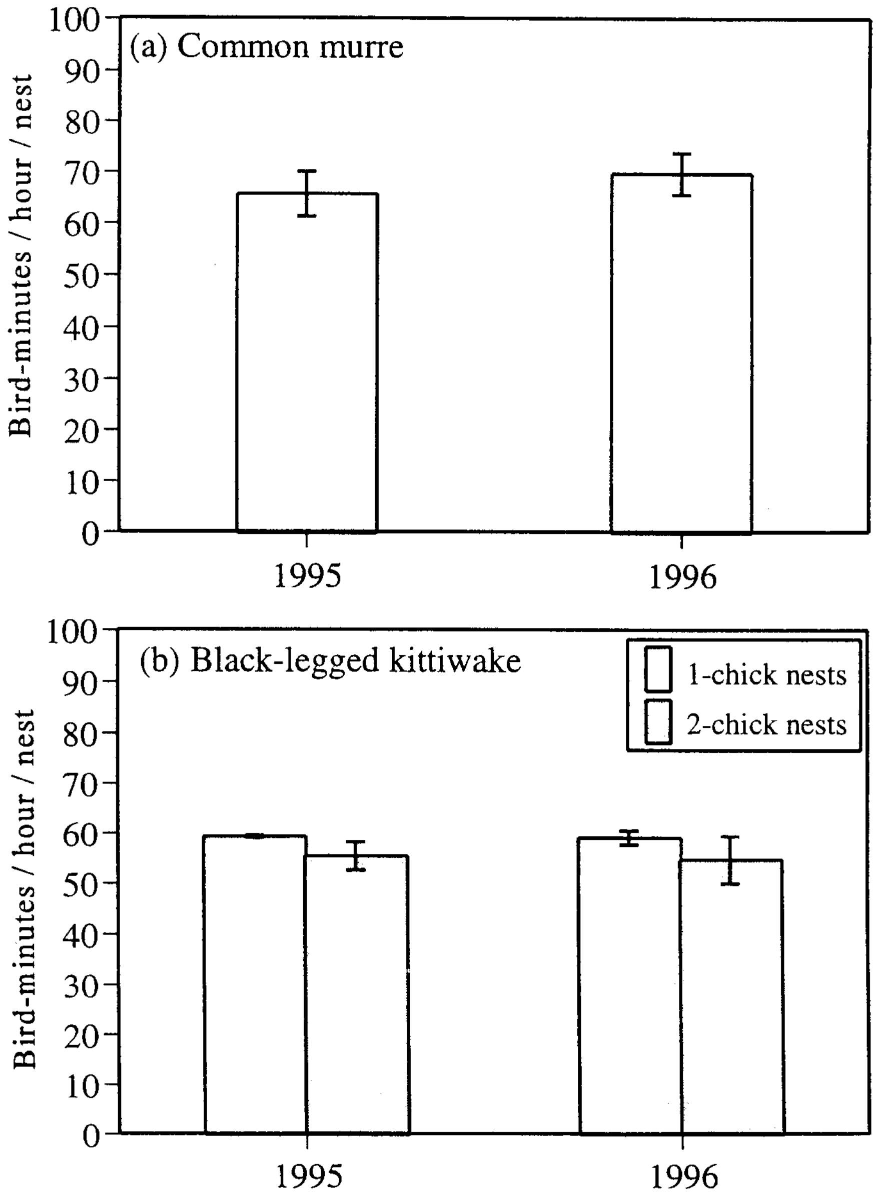

Figure 9. Number of minutes per hour spent at nests by (a) common murre and (b) black-legged kittiwake adults during the chick rearing period at East Amatuli Island, Barren Islands, Alaska, 1995-1996 (n = 2 days in 1995 and 3 days in 1996; error bars = standard deviation).

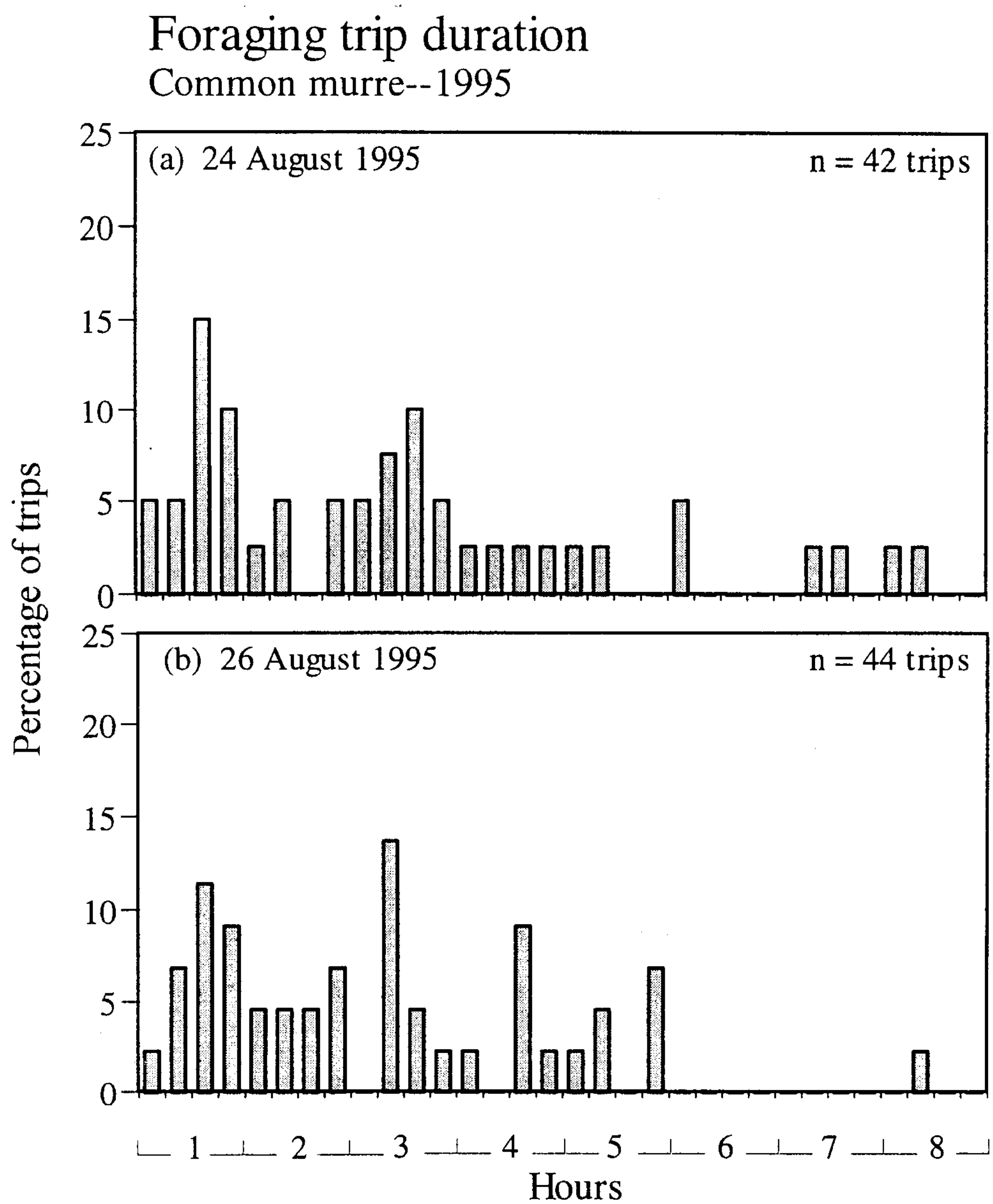

Figure 10. Duration of foraging trips by common murres from 12 nest sites at East Amatuli Island, Barren Islands, Alaska during two days in 1995: (a) 24 August and (b) 26 August.

Appendix 1

Protocol for APEX Common Murre Studies

Protocol for APEX Common Murre Studies

Barren Islands
Gull Island
Chisik Island

Arthur Kettle, John Piatt, Dave Roseneau, and Stephani Zador
17 April 1997

Productivity and Hatch Dates

Murre productivity and hatch dates are calculated from data recorded during regular observations of nest sites grouped into plots.

Field work: Generally, clusters of 20-40 nest sites (sites with eggs) on cliff faces or sections of flat-topped offshore rock are considered plots. At least 7 plots are subjectively selected (to include different habitat types) at each study location (E. Amatuli, Gull, Duck). Plot boundaries are defined by recognizable, permanent features of the substrate.

If possible, the same plots are used each year. When it is possible to identify nest sites used in previous years, nest site numbers are retained. New nest sites receive new numbers (or the number of an adjacent site plus a letter). Observations of each plot are made from a marked point that is used each year. Plot boundaries are clearly marked on photographs taken from the observation point, and on hand-drawn maps that show recognizable features of the terrain.

Plots are checked about every 3 days, from before eggs are laid until nest fates can be determined. During each check, codes are used to describe for each nest site the status of adults and, if visible, the nest content. Since it is often difficult to see underneath a murre to determine whether an egg or chick is present, distinct adult postures are used as indicators of the presence of eggs or chicks (see "Data analysis"). Codes for these data follow:

Adult codes

S Standing and not in incubation or brooding posture.

L Laying down and not in incubation or brooding posture.

IP Incubation posture. A distinct posture assumed by most murres when incubating eggs. Adult sits forward with back humped, tail held down, and wings slightly dropped with tips uncrossed.

BP Brooding posture. A distinct posture assumed by most murres when brooding chicks. Characterized by wing-mantling--the wing sheltering the chick is dropped.

P Adult present. Can't classify posture as any of the above.

N No adult present.

Example: "2S" means that 2 adults were standing

<u>Nest content codes</u>

E An egg is seen

C A chick is seen

Ø There is no egg or chick

U Undetermined nest content

Examples: "SLØ" means that one adult stood, another lay, and there was no egg or chick.

"NC" is an unattended chick

"NØ" is an empty nest site

<u>Data analysis</u>: For each plot we calculate productivity (chicks fledged[1] per nest site), hatching success (chicks hatched per nest site), fledging success (chicks fledged per chick), and median hatch date. The mean and standard deviations of plot values provide the point estimate for a study location for each year. Data are analyzed according to the procedures in appendices 1 and 2.

Plot estimates (n >= 7 per site) are the sample for comparison among sites and years with ANOVA and Tukey pairwise mean comparison. Trends among years are tested with Kendall's tau rank correlation analysis.

Chick Growth

Gull and Chisik islands

<u>Field work</u>: On Gull and Chisik islands, fifteen to thirty unmarked murre chicks of unknown age are weighed and measured three times. Personnel visit the colonies before dawn or after sunset during early, mid, and late chick-rearing periods and attempt to measure a sample that represents

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[1]The term "fledge" in this protocol refers to the departure of a chick from its nest site, rather than the ability of flight or independence from parental care.

chicks of varying ages. Data recorded are mass (to 1 g), flattened wing chord (to 1 mm), and culmen (to 0.1 mm). Personnel time in the colony is limited to 30 min.

Data analysis: Mean mass as a function of wing length is plotted for all data, and the linear phase of mass increase is determined. For all measurements within this linear phase, mass is divided by wing length to derive an index of body condition. These values are then averaged for each island.

East Amatuli Island

Field work: At East Amatuli Island, if sea conditions allow it (as they did in 1996), fledglings will be weighed and measured just after they jump from the nesting cliffs. Fledglings are scooped from the water, weighed, measured, and released one at a time. A dip net is used to capture the chicks. Wing chord is measured to 1 mm, culmen to 0.1 mm, and mass to 1 g. Wing chord is measured on a flattened wing. If the weighing platform is a boat, a 500-g Pesola scale, rather than a 300-g scale, will be used to minimize bounce. To maintain boating safety and precision of weights, this parameter will be measured only in very calm sea conditions.

Data analysis: Mean mass, wing chord, and culmen are averaged as annual indices. Differences among years are tested with ANOVA and Tukey pairwise mean comparison.

In 1997, personnel at Gull and Chisik will assess the feasibility of measuring murre fledgling size, and the crew at East Amatuli Island will assess the feasibility of measuring more pre-fledging samples (one sample of 33 chicks was measured late in the nestling period in 1996).

Chick Food Types

Field work: We identify prey items brought to chicks by observing, with binoculars, prey in the bills of adults as they return to the nest. Identification is based on the color and shape of the item, and of the caudal, anal, adipose fins of fish. "A field guide to common murre bill loads" (John Piatt) and other keys is used to identify prey.

Observation periods can occur at any time of day and be of any specified length of time, but the time is set aside specifically for this purpose. We do not include fish haphazardly observed during productivity checks; this practice may skew observations toward large fish. At least 50 positive identifications will be obtained during each week of the nestling period. When possible, days of observations will be synchronized among Gull, Chisik, and East Amatuli islands. Only prey fed to chicks are recorded (not fish brought in for "display"). Each observation is recorded as one of the following three categories: (1) "Not Seen" (a feeding occurred, but because the return was too fast or was obscured, no identification was possible), (2) "Unknown" (a view sufficient for identification was obtained, but positive identification was not made) and the reason why identification was not made (e.g., not enough of the fish was available for identification), or (3) the fish is identified to the lowest practical taxonomic level.

When nest sites are visited for chick measurements, the area is searched for dropped prey items;

any found are collected.

Data analysis: Percentage of occurrence will be calculated for "unknown" and for each taxon of prey. The "not seen" category will be excluded.

Adult Time Budgets
Chick Provisioning Frequency
Nest Attendance by Adults
Foraging Trip Duration

Field work: Adult time budgets are calculated from day-long observations of a plot of 10 nest sites at each study location. So that variation among both nest sites and days can be calculated, the same nest sites are used for all observation-days within a year, if possible (although some nests for attendance observations will be different from nests used for the nesting period, if eggs fail to produce chicks). The observation post provides a view of chick feeding for each nest site. The time of all adult arrivals, deliveries of prey to chicks, exchanges of incubation or brooding duty, and adult departures are recorded. Each observation-day begins as close to first light as possible and ends as close to dark as possible. Because at East Amatuli Island a commute by boat is necessary, early-morning and late-night observations are recorded by video and later analyzed at camp. At least three observation-days occur during incubation and three during the nestling period. The observations sample the early, middle, and late parts of the incubation and nestling periods. When possible observation days are synchronized among study locations. If observation nests must change between years we will choose nests near the previous ones, to minimize the possibility of confounding among-plot effects with among-year effects.

In 1997 we will attempt to color-mark with a squirt gun and dye one adult at each nest site.

Data analysis: Nest attendance is measured as bird-minutes per nest per hour (e.g., a nest with one bird attending for a full hour and its mate attending for half of the hour has 90 bird-minutes that hour), and we calculate separately nest attendance during incubation and during the nestling period. Adult provisioning frequency is measured as feedings per nest per hour. Adult duty exchange frequency is calculated as exchanges per nest per hour. A trip from the nest begins when an adult leaves the nest and ends when it returns. Values are calculated separately for trips made during incubation, trips during the nestling period, and trips that ended with chick provisioning. Only complete trips are counted--not trips that were in progress when the observation period started or ended.

Within each year, among-nest and among-day differences in attendance, and in provisioning and exchange frequency are analyzed using the nest-day value as the sample. For example, to test differences among nests, the number of feedings for Nest 1 on the first, second, and third observation-day are compared with the three values for Nest 2, etc. To test differences among days, the number of feedings for nests 1-10 on Day 1 are compared with the ten values on Day 2, etc. Differences are tested with repeated-measures ANOVA and Tukey pairwise mean comparison.

Because there are not enough complete trips from each nest each day for us to obtain an average daily trip duration that is representative of each nest, the sample for comparisons among days is the individual trip; trips from all nests are pooled. Differences among days are tested with ANOVA and Tukey pairwise mean comparison.

For among-year comparisons of attendance, and of provisioning and exchange frequency, the sample is the mean among nests for an observation-day. For trip duration, the sample is the per-day mean of all trips. The annual index of each parameter is the mean and standard deviation of the per-day values. Comparisons among years are tested with ANOVA and Tukey pairwise mean comparisons; trends among years are tested with Kendall's tau rank correlation test.

Population Counts

Field work: Murres are counted on all productivity plots each day that they are checked. Murres on an additional set of larger attendance plots are counted 5-10 times during the season.

Counts are made between 1100 and 2000 hours on East Amatuli (the time during daylight hours when attendance is most stable [see Birkhead and Nettleship 1980; D.E. Dragoo, unpubl. data; Boersma *et al.* 1995; Roseneau *et al.* 1995]), and between 1000 and 1600 hours on Chisik and Gull Islands.

Data analysis: The sample for obtaining the annual mean for each type of plot set is the daily total count of all the plots. The annual index for comparing population size among years is the mean and standard deviation of the samples for all days between the peak of egg-laying and the start of fledging. If plots are added or subtracted between years, we will maintain a sample of plots for which counts can be compared among all the years of the study.

Differences among years and sites are tested with ANOVA followed by Tukey pairwise mean comparison. Trends are tested with Kendall's tau rank correlation analysis.

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Appendix 1. Rules used for analysis of APEX common murre productivity and nesting chronology data

1. Sites without observations of eggs and postures that indicate the presence of an egg (see [3.], below) are excluded from all productivity analyses, whether or not a chick is seen.

2. Sites with data that are not logical (e.g., an observation of "no nest content" between sightings of a chick) are excluded from analyses.

3. Observation of an incubation posture (IP) during three nest checks without an intervening observation of (1) no nest content; or (2) one adult, standing, without an egg sighting; or (3) two adults, standing, without an egg sighting, constitutes an egg at that sight first "seen" on the day of the first IP. For this rule, an egg sighting is equivalent to an IP after the first IP (e.g., if there are sightings of "IP, E, E" then the egg was first "seen" on the date of the IP).

   a. This rule is also used to determine the last day that an egg is present.

4. An observation of a brooding posture (BP) constitutes a chick first "seen" on that day.

   a. This rule is also used to determine the last day that a chick is present.

5. Because laying and hatching of eggs and fledging of chicks are rarely observed during plot checks, the date that a nest site changes status (i.e. "no egg" to "egg," "egg" to "chick," or "chick" to "no chick") is estimated to be the midpoint between the closest pre- and post-event observation dates. If the number of days between the two visits is even or is zero, the even Julian date closest to the midpoint is used in place of the midpoint.

   a. On the day that a nest's status changes from "egg" to "chick," the chick's age is zero. The day that the status changes from "chick" to "no chick" is included in the chick's age. Simply subtracting of the hatch date from the "disappeared" date will age the chick according to these rules.

6. In nests with relaid eggs, only the first egg is used for hatch date calculations and only the second for determination of breeding success.

7. Two methods are used to improve hatch date calculation precision.

   a. Each nest site with a "data gap" of more than seven days between pre- and post-event observations for both laying and hatching is excluded from calculations involving hatch dates or chick ages. Since this rule acts only on nests that produce chicks, it has the potential to artificially reduce the chicks-to-eggs ratio. For analyses that involve the proportion of eggs that produced chicks, the number of egg-only nests should be reduced by the proportion of chick-nests that were excluded (e.g., if 15 percent of the nests with chicks were excluded, the number of egg-only nests is reduced by 15 percent).

b. If the data gap for laying is smaller than the gap for hatching, we calculate the hatch date by adding 32 days (the incubation period) to the laying date.

8. Nests with more than 7 days between the last sighting of the chick and the first sighting of no chick are excluded from calculations involving the number of fledglings.

9. Chicks that disappeared at age 15 days[2] or older are considered fledged. Nests with data insufficient for determination of whether chicks died or fledged are excluded from fledging analyses.

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[2]Other studies have used similar conventions for fledging age:

Study	Observation interval (days)	Midpoints used for fledge date?	Minimum chick age for fledging (days)
Hunt, *et al.* 1981	3-4	no	16
Byrd 1989	3-5	no	15
Hatch and Hatch 1990	2	no	16
Dragoo and Dragoo 1994	3	yes	15
Roseneau *et al.* 1995	1-7	yes	15

Appendix 2. Information included on forms for collection and analysis of APEX murre productivity and nesting chronology data

Data collection form

Each page of the field data collection forms is labeled with the island name and the year, species, and plot. Data fields (columns) are the nest site and the plot check dates; data records (rows) are listed by nest site. Observation codes are entered for each date, by nest site. Forms are printed on waterproof paper.

Data analysis form

Each page of the form used for analysis of nest status change dates is labeled with the island name and the year, species, and plot. Each record in the form contains the calculations for one nest site. Suggested data fields are:

Parameter abbreviation	Short for:	Data needed for calculation:
1. Nest site		
2. ENL	"Egg No Last":	the last "no egg" observation date
3. EY1	"Egg Yes 1st":	the first "yes egg" observation date
4. EYL	"Egg Yes Last":	the last "yes egg" observation date
5. CY1	"Chick Yes 1st":	the first "chick yes" observation date
6. CYL	"Chick Yes Last":	the last "chick yes" observation date
7. CN1	"Chick No 1st":	the first "chick no" observation date
8. #E	"# Eggs"	the number of eggs produced on the plot
9. #C	"# Chicks"	for murres, a "0" or a "1."
10. ELR	"Egg Lay Range"	EY1 minus ENL
11. CHR	"Chick Hatch Range"	CY1 minus EYL
12. BHR	"Best Hatch Range"	Lowest of ELR and CHR
13. BHD	"Best Hatch Date"	EYL + (CY1 minus EYL) / 2, unless ELR < CHR; then BHD = ENL + 32 + (EY1 minus ENL) / 2
14. CGR	"Chick Gone Range"	CN1 minus CYL
15. CGD	"Chick Gone Date"	if CGR =< 8: CYL + (CN1 minus CYL) / 2; otherwise leave blank
15. CGA	"Chick Gone Age"	if CGR =< 8: CGD minus BHD; otherwise leave blank
16. FA	"Fledge Age"	CGA if CGA >= 15; otherwise leave blank
17. DA	"Dead Age"	CGA if CGA < 15; otherwise leave blank

Exxon Valdez Oil Spill
Restoration Project Annual Report

Barren Islands Seabird Studies, 1996

Restoration Project 96163J
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

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March, 1997

Barren Islands Seabird Studies, 1996

Restoration Project 96163J
Annual Report

Study History: Most of the monitoring methods used in this project were also employed during 1995, at the same study sites, by Project 95163J. A report of that study was appended to the 1995 annual report for APEX Project 95163.

Much of the information generated from both the 1995 and 1996 studies is directly comparable with information gathered at the same study site in 1993-1994 during Restoration Projects 93049 and 94039 (see Roseneau *et al.* 1995, 1996).

Abstract: This 1996 APEX component continued methods of Project 95163J (1995) for monitoring the breeding and foraging parameters of common murres (*Uria aalge*), black-legged kittiwakes (*Rissa tridactyla*), and tufted puffins (*Fratercula cirrhata*) at the Barren Islands, Alaska. Many of the results are directly comparable with results from 1993-1994 restoration studies at the Barren Islands, and some are comparable with results from earlier studies. Breeding productivity (the number of chicks fledged per nest) of murres and kittiwakes was relatively high and normal, respectively, at East Amatuli Island in 1996; these results were similar to those of the previous two years. Growth rates of kittiwake chicks were normal and not significantly different from those of 1995, although the mass of chick regurgitant samples was lower in 1996. Kittiwake chick diet had a greater proportion of sand lance and a lower proportion of capelin in 1996 than in the previous year. The composition of murre and puffin chick diets in 1996 was similar to that of 1995: murre chicks were fed about 90% capelin (*Mallotus villosus*), and puffin chicks received mainly capelin, walleye pollock (*Theragra chalcogramma*), and Pacific sand lance (*Ammodytes hexapterus*). However, puffins fledged fewer chicks in 1996 than in 1995, and the growth rate of puffin chicks was very low. The mean mass of puffin bill-load samples was lower in 1996 than in 1995. Further analysis of the data may indicate whether the food shortage occurred during all or just part of the nesting season, and why the reproductive success of only puffins and not that of murres and kittiwakes was affected.

There were no significant differences among days in 1995 and 1996 in the frequency that murre and kittiwake chicks were fed. There was a significant difference in puffin provisioning frequency between the two days we observed this in 1996. We found differences in nest attendance for murres between days both within and between years, but found no differences for kittiwakes.

Mean foraging trip duration was longer for kittiwakes in 1996 than in 1995. For murres, there were fewer short trips of 2-4 hours of duration in 1996 than in 1995.

Common murres on East Amatuli Island have laid and hatched their eggs earlier each year since 1993. Breeding chronology in 1993 was, in turn, earlier than during previous post spill years (Dragoo *et al.* 1994; Boersma *et al.* 1995). This trend may be caused by environmental conditions or by increasing age and experience of breeding murres. Further analysis, including examination of other species' breeding chronology, will explore these and other possible factors.

Key Words: Barren Islands, black-legged kittiwake, common murre, East Amatuli Island, East Amatuli Light Rock, *Exxon Valdez*, forage fish, *Fratercula cirrhata*, oil spill, Prince William Sound, *Rissa tridactyla*, tufted puffin, *Uria aalge*.

Project Data: (will be addressed in the final report)

Citation: Roseneau, D.G., A.B. Kettle, and G.V. Byrd. 1997. Barren Islands seabird studies, 1996. Unpub. annual rept. by the Alaska Maritime National Wildlife Refuge, Homer, Alaska for the *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska (APEX Project 96163J). __ pp.

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INTRODUCTION

This study is a component of the Alaska Predator Ecosystem Experiment (APEX). APEX began in 1995 and is an association of 18 study components designed to determine whether low prey quality or abundance is limiting the recovery of populations of seabirds that were damaged in the *Exxon Valdez* oil spill. By comparing measurements of seabird activity among years, species, and sites, and with results from studies of forage fish distribution, abundance, and energy content, we hope to learn more about how ecosystem processes affect the population dynamics of seabird colonies.

The Barren Islands study was included in the APEX seabird-forage fish project for several reasons. First, the Barrens provide nest sites for the largest groups of common murres (*Uria aalge*)[1] and tufted puffins in the oil spill area. The majority of dead seabirds were found near or downstream from the Barrens. Common murres are being monitored for recovery. Second, some information on these species was already available from the colony (E.G. Bailey 1975a, b and 1976; Manual 1978, 1980; Manual and Boersma 1978; Nysewander and Dippel 1990, 1991; Dippel and Nysewander 1992; Nysewander *et al.* 1993; Dragoo *et al.* 1994; Boersma *et al.* 1995; Erikson 1995; Roseneau *et al.* 1995, 1996). Third, the island group's offshore location provided opportunities to compare data from an oceanic environment with results from APEX studies in Prince William Sound and Minerals Management Service (MMS) and other APEX research in lower Cook Inlet-Kachemak Bay. Finally, capelin (*Mallotus villosus*), an important forage fish species scarce in the northern Gulf of Alaska since the late 1970's (Piatt and Anderson 1995), were abundant near the islands during 1993-1994 (Roseneau *et al.* 1995, 1996). Large stocks of these fish and the presence of other forage species, including sand lance (*Ammodytes hexapterus*) and young cods (e.g., 0-1 age-class walleye pollock [*Theregra chalcogramma*] and Pacific cod [*Gadus macrocephalus*]) in surrounding waters provided an opportunity to study seabird - forage fish relationships that might help explain why populations of some seabird species have not increased in the T/V *Exxon Valdez* oil spill area.

Data collected during the study are being used to test three APEX hypotheses:

> Hypothesis 7: Composition and amounts of prey in seabird diets reflect changes in relative abundance and distribution of forage fish near nesting colonies.
>
> Hypothesis 8: Changes in seabird productivity reflect differences in forage fish abundance as measured by amounts of time adult birds spend foraging for food, amounts of food fed to chicks, and provisioning rates of chicks.
>
> Hypothesis 9: Seabird productivity is determined by differences in forage fish nutritional quality.

---

[1]Although a few thick-billed murres (*Uria lomvia*) breed in the Barren Islands, In this report, "murre" refers to the common murre.

We collected data on kittiwake, murre, and puffin productivity and nesting chronology; types and amounts of prey fed to kittiwake, murre, and puffin chicks; growth rates of kittiwake and puffin chicks and fledging size of murres; feeding frequencies of kittiwake, murre, and puffin chicks; and time-activity budgets of kittiwake and murre adults. We also collected information for analysis of population trends of the three species. The status of murre population size at both East Amatuli and Nord Islands are covered more broadly by *Exxon Valdez* Oil Spill Trustee Council Project 96144, Common Murre Population Monitoring .

We have compared our results with data from the 1993-1994 EVOS-sponsored Barren Islands common murre restoration monitoring projects (Projects 93049 and 94039; see Roseneau *et al.* 1995, 1996). Results from this study have been shared with other APEX investigators for comparisons among colonies (e.g., D. Irons, Project 96163E, and J. Piatt, Project 96163M; D. Roby, Project 96163G). Prey samples have been provided to D. Roby for energy content and density analyses, to D. Schell (Project ____) for isotope analysis, and to M. Sturdevant (Project 96163C) for studies of fish diets. The Barrens field crew made 40 beach-seine sets during the season; protocol and methods were the same as for crews on Gull and Chisik islands. The results of this activity were sent to J. Piatt, who reported comparisons among sites (Robards and Piatt, submitted).

OBJECTIVES

Objectives for this 1996 study at the Barren Islands were (units of measure are in parentheses):

1. Determine the breeding productivity of the common murre (fledglings per egg-site), black-legged kittiwake (fledglings per nest), and tufted puffin (percent of occupied burrows containing chicks).

2. Determine the nesting chronology of the common murre, black-legged kittiwake, and tufted puffins (median hatch date).

3. Determine the growth rates of black-legged kittiwake and tufted puffin chicks (grams per day).

4. Determine the types of prey fed to chicks of the common murre (species composition by number), black-legged kittiwake (species composition by number and weight), and tufted puffin (species composition by number and weight).

5. Determine chick provisioning frequencies of common murres, black-legged kittiwakes, and tufted puffins (feedings per hour).

6. Determine the amounts of food fed to chicks of the black-legged kittiwake (grams per chick regurgitation) and tufted puffin (grams per nest screen).

7. Determine adult activity budgets for the common murre and black-legged kittiwake (foraging trip duration, minutes per hour both adults were present at nests, minutes per hour both adults were absent from nests).

8. Sample near-shore forage fish by regularly setting a beach seine, using methods shared with Project 96163M. Measure samples of each species caught, throughout the season.

9. Collect samples of forage fish from tufted puffin burrows, kittiwake regurgitant, and beach seines.

METHODS

Study Area

The Barren Islands are located at about 58° 55' N, 152° 10' W, between the Kodiak archipelago and the Kenai Peninsula (Fig 1). The study was conducted at East Amatuli and West Amatuli islands, and personnel stayed at the Amatuli Cove camp (Fig 2). Four to five people occupied the camp during 18 June - 13 September. They commuted to murre and kittiwake study sites in outboard-powered, 4.8-m-long, rigid-hulled inflatable boats, and to puffin study areas by boating and hiking.

Productivity

Murres: Murre productivity data were collected at 9 of the 10 East Amatuli Island - Light Rock plots used for this purpose in 1993-1995 (see Roseneau *et al.* 1995, 1996b) and one plot established to replace another that had been difficult to see. The plots, containing about 25-50 nest sites (sites with eggs) each (1996 nest site total = 266), were inspected with 7 x 42 binoculars and 15-60 power spotting scopes from land-based observation posts as often as weather allowed (range = 1-6 days). Viewing distances varied from about 30 to 100 m, and observers were assigned specific plots for the duration of the field season. Nest sites were mapped using photographs and sketches, and data were recorded for each site using previously established codes. Plot checks consisted of searching for eggs and chicks and adults in incubation and brooding postures, and counting adults. Each plot was checked about 28 times during 23 June - 4 September, from before eggs were laid until most chicks had left the cliffs. Using the plot as the sample unit, breeding productivity was calculated as fledglings per nest site; we also calculated hatching and fledging success (see Roseneau *et al.* 1995, 1996b). Differences among 1993-1996 results were tested with ANOVA.

Kittiwakes: Kittiwake productivity data were collected from 11 East Amatuli Island plots; four have been used in studies since 1993, and the other seven since 1995. The plots, located on the same headlands as the murre productivity plots, contained 25-50 nests each (1996 nest total = 312; 285 contained eggs). Methods for collecting and analyzing data were similar to those used for murres; methods were also compatible with those used in other APEX studies in Cook Inlet, and those in Prince William Sound . Nest checks consisted of searching for eggs and chicks, and counting adults (adult postures were not used to determine kittiwake nest content). Each plot was checked approximately 28 times during 23 June - 4 September, from just after egg-laying began until most chicks had fledged. Using the plot as the sample unit, breeding productivity was calculated as fledglings per nest site. Hatching and fledging success were not calculated for 1996 because weather prevented us from obtaining enough data during the egg-hatching period. Differences in productivity among 1993-1996 results were tested with ANOVA, with the plot as the sample unit.

Puffins: Puffin productivity data were obtained from four study plots established by University of Washington personnel in 1990 to collect information on chick growth rates (see "Growth Rates" below), and four transects totaling 270 m^2 established by FWS crews in 1986 to monitor numbers and occupancy of burrows (Nishimoto 1990; Table 2). Burrows in the growth rate plots were searched for signs of activity (trampled and cleared vegetation, guano from adults and chicks, fresh digging) and chicks during 23 July - 25 July, when most nestlings were about one week old. A 35-cm-long flexible scoop was used to help determine presence/absence of chicks. After the initial visit, all burrows containing nestlings were checked every five days until 8 September. Burrows in the transects were checked once on 28 August, just prior to chick fledging, to count all burrows, active burrows, and nestlings. Productivity for both the growth rate plots and the transects was calculated as the proportion of active burrows containing chicks just prior to fledging. Using the burrow as the sample unit, a productivity index (i.e., pre-fledging chicks per active burrow) was calculated and compared between years with Pearson Chi-square.

We measured tufted puffin hatching success in a plot of 36 burrows marked for this purpose. We checked this plot once just before eggs hatched, again just after they hatched, and a third time just before chicks fledged.

Nesting Chronology

Murres: From the productivity plot data, we calculated median hatch date to measure murre nesting chronology (see Roseneau *et al.* 1995, 1996b). The median hatch date was calculated for each plot. These dates were then averaged. Because laying and hatching of eggs and fledging of chicks were rarely observed on the productivity plots, the date that nest sites changed status (i.e., from eggs to chicks) was estimated to be the midpoint between the closest pre- and post-event observation dates. Two methods were used to maintain precision during data analysis. First, each nest site with a "data gap" of more than seven days between pre- and post-event observations for both laying and hatching was excluded from the data set. Second, at each nest site with a smaller data gap for laying than for hatching, we calculated the hatch date by adding 32 days (the incubation period) to laying the date (see Byrd 1986, 1989; Roseneau *et al.* 1995, 1996b). Using the plot as the sample unit, we tested for differences among the years 1993-1996 with ANOVA.

Kittiwakes: Median hatch date was used to measure kittiwake nesting chronology. Data analysis methods were the same as described above for murres, except that an incubation period of 27 days (rather than 32) was added to laying dates when the laying date calculation was more precise than the hatch date calculation (see Byrd 1986, 1989). Using the plot as the sample unit, we tested for differences among the years 1993-1996 with ANOVA.

Puffins: Median hatch date was used to measure puffin nesting chronology. Wing measurements, rather than laying or hatching information, were used to determine the hatch date for each chick, because burrows were not visited until the chicks were about one week old (visiting them prior to this time can result in abandonment of eggs or chicks). The hatch date was calculated for each chick in the growth study by estimating the age of the chick at the first wing measurement with a growth equation reported by Amaral (1977). The median hatch date among the chicks was then determined. The difference between 1995 and 1996 results were compared with a t-test, using the hatch date of each chick as the sample unit.

Chick Growth Rate

Murres: We weighed and measured 33 chicks on Light Rock just before the start of fledging. This was performed at night to prevent predation of the chicks by glaucous-winged gulls (*Larus glaucescens*). We also weighed and measured 46 fledging murre chicks by dipnetting them from the water as they jumped from cliffs. Murre chick measurements included culmen, tarsus, and wing chord (to 1 mm), and mass (to 1 g). As an index of fledgling size for 1996, we calculated the mean fledging weight.

Kittiwakes: We weighed (to 1 g) and measured (e.g. wing chord, culmen, tarsus, and back of head to tip of bill, all to 0.1 mm) 40 kittiwake chicks from 38 broods every 5-7 days, from near hatching until they were about 32 days old. Methods for calculating growth rates followed the protocol for APEX Project 96163E in Prince William Sound. The daily increase in mass was calculated for each chick for the most linear section of the growth curve (from 60 to 300 g), by first calculating the difference in mass between the first and last measurements within the "linear phase" and then dividing the result by the number of days between those measurements. These values were then used to calculate the mean growth rates for "A" chicks (chicks in single-chick nests plus chicks first to hatch in 2-chick nests; n = 33) and "B" chicks (the second-hatched chicks in 2-chick nests; n = 2). Differences between 1995 and 1996 growth slopes were compared with a t-test, using each "A" chick's growth slope as the sample unit.

Puffins: Thirty-three puffin chicks in three of the five study plots (see productivity above) were weighed (to 1 g) and measured (culmen, wing chord, and tarsus, all to 0.1 mm) every five days, from the time they were about one week old until we left the island, when most chicks were old enough to fledge. To check for the effect on growth of more frequent measurement, 12 additional nestlings were weighed and measured only 3 times on the two other study plots. Average daily mass change was chosen as the primary measurement of growth. Data were analyzed by fitting a simple linear model to the 150-450 g section of each chick's growth curve (the portion that is nearly linear), using the slope of the line as the measure of average daily mass change, and then averaging the slopes among the chicks to represent the annual index and to calculate variation. Differences in the slopes between 1995 and 1996 were compared with a t-test.

Chick Diet

Murres: Prey items delivered to murre chicks were identified during observation periods on 7 days. Prey were identified with 7 x 42 binoculars and field guides. In total, 236 prey items, all fish, were observed during 12 August-1 September. Two hundred twenty-six (96%) of the fish were identifiable to species or family groups (e.g. *Gadidae*) on the basis of color and body and fin shapes (e.g., caudal, anal, adipose fins). Data were analyzed by calculating percentages by number of items for five categories of prey: capelin (*Mallotus villosus*); sand lance, (*Ammodytes hexapterus*); salmonids, (*Oncorhynchus*); and cods, (*Gadidae*).

Kittiwakes: Samples of prey brought to kittiwake chicks were obtained when growth study chicks regurgitated before, during, and after measurements. A total of 84 samples was obtained on 15 days during 14 July - 9 August, when chicks were about 1-4 weeks old. Samples were frozen the same day they were collected and weighed (to 1 g) when we returned to Homer.

Prey items were analyzed by K.R. Turco and A.M. Springer, Institute of Marine Sciences, University of Alaska-Fairbanks. Samples were thawed, then separated into identified and unidentified portions. Identified prey were separated by species or lowest possible taxon. All component groups were weighed. Composition of the diet was summarized by listing the proportion of the total mass represented by the mass of each component group.

Puffins: Samples of prey brought to puffin chicks were collected by temporarily blocking burrows with squares of hardware cloth (screens). One hundred thirty-nine chick meals containing 446 items were obtained during six screening days at East Amatuli Island and four at West Amatuli Island during 23 July - 7 September. Samples were frozen. Specimens were identified in the field using field guides and taxonomic keys. Frozen prey items were cleaned and weighed (to 1 g) in the lab when we returned to Homer. Data were analyzed by calculating percentages by number and weight of identifiable prey items.

Chick Provisioning Frequency

Murres: We collected murre chick provisioning frequency data from a plot of 10 nest sites near one of the productivity plot observation posts. The plot was located in a flat rock-strewn area near the top of a cliff that contained some of the productivity plots. Food deliveries were recorded on the plots during three 14-hr-long (0700-2100) watches during the nestling period (12, 17, and 24 August). We tested for differences among these three days in 1996 and the two observation-days in 1995, using the nest-day as the sample unit, with ANOVA.

Kittiwakes: Kittiwake chick provisioning frequency data were obtained from eight nests in one of the kittiwake productivity plots (see Productivity, above). The nests contained 12 chicks. Most of the data were collected by watching the nests with 7 x 42 binoculars from about 20 m away and recording times of feeding events. Some data were also obtained by recording these activities on video tape (using two modified 8-mm Sony HandyCam camera/recorders) and reviewing the tapes in camp (during analysis in 1995, no differences were found between data collected simultaneously by the video and direct observation methods). Observations began when the nestlings were about nine days old. Because chicks may be fed several times after a foraging adult returns to the nest, and because adults sometimes leave their nests for short periods of time without foraging at sea, only first feedings after trips lasting 30 minutes or more were counted as "provisioning" events. Food deliveries were recorded on the plots during three 14-hr-long (0700-2100) watches during the nestling period (16, 26, and 30 July).

We compared the difference between in feeding rates between 1-chick and 2-chick nests for each of the five observation days during the two years. We used t-tests, with the nest-day as the sample unit. If we found a difference between the two types of nest, we would calculate an annual index for each type of nest, rather than combining them. We tested for differences among days, using the nest-day as the sample unit, with ANOVA.

Puffins: During 31 August and 2 September we measured the provisioning frequency of tufted puffin chicks by observing adults returning to 10 nests in one of the tufted puffin chick growth study plots. Observations were made from a blind located about 50 m from the nests. Nests were marked with numbered flags. We made two dawn-to-dark watches (0600-2200), from before the adults were flying until after they had stopped. Binoculars were used to observe whether returning adults were carrying fish. We noted the time of each adult's return and departure, and any activities in the vicinity that may have been affecting the return or departure behaviors and times (e.g., visits by aerial predators). Using the nest-day as the sample unit, we compared the chick provisioning frequencies of the two days with a paired-sample t-test.

Amount Fed to Chicks

Murres: We did not collect data on the size of murre chick meals.

Kittiwakes: An annual index of the size of meals fed to kittiwake chicks was obtained from regurgitated samples (see Chick Food Types, above). Because the amount of food fed to nestlings increased until they were about 20 days old, we used as the annual index the average mass of 33 samples collected from chicks that were about 20 or more days old. Using the regurgitant sample as the sample unit, we compared the masses in 1996 with those in 1995, with a t-test.

Puffins: An annual index of the size of meals fed to puffin chicks was obtained by averaging the masses of burrow screening samples (see chick food types above). The 1996 samples were compared with those of 1995 with a t-test.

Activity Budgets of Adults (Nest attendance, Foraging trip duration)

Murres: Data to describe adult murre activity budgets were recorded during the 14-hr observations used for feeding frequency (see above) and three 14-hr periods during the incubation period (15, 21, and 31 July; 0700-2100 hrs). Adult arrival and departure times, and times when members of pairs exchanged duties (i.e., incubating eggs or brooding chicks) were recorded at each nest site.

We used "bird-minutes per hour" to measure the proportion of time that the nest was attended by one or two adults. If during one hour a nest was attended by one adult for the entire hour and the second adult for half the hour, the nest had 90 bird-minutes of attendance that hour. The sample unit for comparisons among years was the nest-day. We compared among the five nest-days over the two years, with ANOVA.

Average foraging trip time was obtained by treating trips as sample units and calculating the mean duration of all trips made by birds during the three dawn-to-dusk watches during the nestling period, that ended with a chick feeding ($n = 85$ trips). Using the trip as the sample unit, we compared the duration of trips in 1996 with trips in 1995, with a t-test. We also calculated the frequency of trips in 2-hr blocks of time (0-2, 2-4, 4-6 and 6-8 hr), and compared these frequencies in 1996 with those in 1995, with a Chi-square test.

Kittiwakes: Kittiwake activity budget information was obtained during chick feeding frequency observations of 10 nests (see Chick Provisioning Frequencies, above) and one incubation watch. Adult arrival and departure times, and times when members of pairs exchanged duties (i.e., incubating eggs or brooding chicks) were recorded at each nest. We calculated the amount of time spent by adults at each nest, for each day (using "bird-minutes," as with murres, above). Using the nest-day as the sample unit, we compared differences among the observation days of 1995-1996 with ANOVA.

We calculated mean foraging trip duration for kittiwakes, during the nestling period. Only trips that resulted in a chick-feeding, and only trips that left another adult attending the nest were used (because adults were unmarked). As for murres, the sample for obtaining an index of the season was the individual trip. We compared trips in 1996 with those in 1995, with a t-test.

Puffins: During the two days of observations, puffin adults did not stay at the study nests longer than the approximately 30 seconds used to deliver fish to the chicks. Because adults left the nests unattended and adults were unmarked, we could not determine the duration of foraging trips of individual birds.

Population Counts

Murres: Murres were counted on the productivity plots almost every time the plots were checked (19 counts). To calculate an annual index we averaged the 16 counts made between median lay date and the start of fledging. Methods for collecting and analyzing these data were the same as those used during the 1993-1995 Barren Islands restoration monitoring studies (see Roseneau *et al.* 1995, 1996b). Using the plot-set count as the sample unit, we compared the annual means of 1993-1996 with ANOVA. More extensive counts of murres in the Barren Islands were made by Project 96144.

Kittiwakes: Kittiwakes were counted on the productivity plots almost every time the plots were checked (23 counts). To obtain an annual index for the year we first graphed the data and marked visually the date when adult counts began to decline near the start of fledging. We then averaged the daily plot-set counts made before that date (we used 12 counts for the 1996 average).

These counts were made and analyzed by the same procedures used during 1993-1995 (D.G. Roseneau and A.B. Kettle, unpubl. data). Counts were compared among years with ANOVA, using the daily plot-set count as the sample unit.

Puffins: We used the number of active burrows in the three tufted puffin chick growth plots and the four transects as an index of the population size for each year. We compared the number of active burrows between the two years with a Wilcoxon signed rank test, using the plots and transects as sample units.

RESULTS

Productivity

Murres: Common murre productivity was high in 1996 (0.77 fledglings per egg, SD = 0.14; Table 1, Fig. 3a) and similar to the 1994-1995 results (0.73 and 0.77 fledglings per egg, respectively; Roseneau *et al.* 1995, 1996b). Values from 1994, 1995, and 1996 were significantly higher than in 1993 (0.55 fledglings per egg, P = 0.011, 0.001, and 0.002, respectively; Roseneau *et al.* 1996).

Fledging success was also high (0.90 chicks per egg, SD = 0.12; see Byrd *et al.* 1993 for comparisons) and similar to the 1994-1995 levels (0.93 and 0.91, respectively). Results from 1994, 1995, and 1996 were higher than the 1993 value (0.79; P = 0.014, 0.035, and 0.063, respectively).

Hatching success exhibited a slightly different pattern; the 1996, 1995 and 1994 figures (0.85 (SD = 0.10), 0.85, and 0.79 chicks per egg, respectively) were similar to each other (and were also high values, see Byrd *et al.* 1993), but only the 1995 and 1996 values were significantly higher than the 1993 figure (0.70; P = 0.023 and 0.022, respectively).

Kittiwakes: Productivity of kittiwakes was high in 1996 (0.71 fledglings per nest, SD = 0.19; Table 1, Fig. 3b; see Hatch *et al.* 1993 for comparisons in the Gulf of Alaska) and similar to the 1994 and 1995 levels (0.64 and 0.81 fledglings per nest, Roseneau *et al.* 1995). These results were in sharp contrast to 1993, when nesting pairs failed early in the nesting season and reproductive success was zero (no eggs or chicks were present on the four East Amatuli Island plots, Roseneau *et al.* 1995).

Puffins: Just prior to fledging in 1996, 0.31 (SD = 0.16) chicks per active burrow were found in the 3 growth plots and the group of 4 transects. This was a significantly lower ($P < 0.001$) result than in 1995 (0.53, SD = 0.12).

Hatching success, from data obtained in the plot established for this purpose, was 0.5 chicks per egg. This was lower than reported for most years in other colonies of Alaska (Byrd *et al.* 1993).

Nesting Chronology

Murres: Based on the median hatch date (4 August, SD = 4; Table 1), hatching in 1996 occurred five days earlier than in 1995, seven days earlier than in 1994, and 12 days earlier than in 1993. Each of the years 1993-1996 were significantly different from the others, except for the 1994-1995 comparison. Hatching in 1993, in turn, occurred earlier than during 1992 at nearby Nord Island (Dragoo *et al.* 1994) and 1991 on East Amatuli Light Rock (Boersma *et al.* 1995).

Kittiwakes: The average median hatch date was 7 July (SD = 7; Table 1); this was similar to that of 1995 (8 July) and 1994 (10 July).

Puffins: The median chick hatch date for tufted puffins in the study plots was 16 July (SD = 5). This was significantly earlier than for 1995 (21 July, $P<0.001$).

Chick Growth Rate

Murres: The average weight of the 46 fledging murre chicks was 240 g (SD = 24).

Kittiwakes: The average growth rate of kittiwake chicks, for all chicks combined (n = 35), was 17.5 g per day (SD = 5.8; Table 1). "A" chicks (chicks in single-chick nests plus first chicks to hatch in 2-chick nests; n = 33) gained 17.6 g per day (SD = 5.9), while "B" chicks (the second-hatched chicks in 2-chick nests; n = 2) grew at a rate of about 14.9 g per day (SD = 1.6). The mean growth rate for "A" chicks in 1996 was not significantly different from the 1995 mean (19.4 g per day).

Puffins: Puffin chicks in the three main study plots gained an average of 3.3 g per day (SD = 1.6 g, n = 32; Table 1). In the "control" plots (where chicks were measured only 3 times during the same period), they gained 3.1 g per day (SD = 1.3, n = 12). The difference between the two groups was not significant. The growth rate for the two groups combined was 3.2 g per day (SD

= 1.5; n = 44). This rate was very low for puffins in general, and was much lower than last year's rate of 11.4 g per day (P<0.001).

Chick Diet

Murres: Prey items delivered to murre chicks consisted solely of small fish (n = 236), most of which were capelin (91%; Fig. 4a). Adults also fed nestlings unidentified cods (*Gadidae*, probably primarily walleye pollock and Pacific cod), sand lance, and an unidentified salmonid, but in much lower numbers (3%, 2%, and <1%, respectively). We were unable to identify 10 fish (4%) of those observed. These results were similar to last year's (see Fig. 4a).

Kittiwakes: The unidentified portion of the samples made up 29 percent of the total mass, and 29 of the 84 samples were unidentified. One and one-half percent of the identified portion was classified as euphausid shrimp (euphausids were present in two of the samples). The remainder was composed of forage fish. Of the identified portion, sand lance made up 40 percent of the total; capelin 21 percent; pacific herring 6 percent, salmon 1.6 percent; and walleye pollock 1.6 percent.

It appears that there was a higher proportion of sand lance and lower proportion of capelin in the diet of kittiwake chicks than in 1995. Differences between this and last year's methods of analyzing the regurgitant samples are being resolved before more detailed comparisons in diet are made.

Puffins: Prey deliveries (n = 139 screen samples) to puffin chicks contained 446 items (Fig. 5). Capelin, sand lance, and pollock were by weight the largest components of the samples (37%, 27%, and 18% of the total, respectively), followed by pink salmon (*Oncorhynchus gorbuscha*), pacific cod, squid, and larval fish (probably daubed shanny [*Lumpenus maculatus*]). By number, the larval fish were the largest component (44%), followed by walleye pollock, sand lance, capelin (23%, 15%, and 13%, respectively) and in lower proportions: squid, pink salmon, sculpin, greenling, prowfish, pacific cod, octopus, and larval flatfish. The main difference in prey deliveries between 1995 and 1996 was that in 1995 prowfish were the third most important species by weight; this year there was only one prowfish found.

Chick Provisioning Frequency

Murres: During the three observation-days of the 1996 nestling period, chicks averaged 0.26 feedings per hour (SD = 0.05, n = 3 d; Table 1, Fig 7a). There were no significant differences among the results from the five observation days in 1995-1996 (the 1995 mean was 0.29).

Kittiwakes: During the three observation days of the nestling period, single-chick nests averaged 0.19 feedings per hour (SD = 0.03, n = 3 d; Table 1, Fig. 7b), and nests containing two chicks averaged 0.25 feedings per hour (SD = 0.09, n = 3 d). This difference was not significant; however, the difference between 1- and 2-chick nests in 1995 was significant (1-chick nests =

0.21 feedings/nest/hour; 2-chick nests = 0.40; P = 0.015). Therefore, in comparing feeding rates between 1995 and 1996, we chose to compare 1-chick nests and 2-chick nests separately.

The number of feedings per nest per hour for 1-chick nests and for 2-chick nests were not significantly different among any of the five observation days during 1995 and 1996.

Puffins: All returning adults were carrying fish. The number of feedings per nest was different between the two days (P < 0.001; 31 Aug = 7.20, SD = 2.25; 02 Sep = 3.80, SD = 1.55).

There was a pronounced diurnal pattern of feeding on both days--there were more feedings early in the morning than during the rest of the day (Fig. 8).

Amount Fed to Chicks

Kittiwakes: The mass of kittiwake chick regurgitations increased with collection date. When (according to the median hatch date) chicks were less than 10 days old, the mean regurgitant mass was 10.1 g (SD = 5.7, n = 18); when 10 -20 days old, the mass was 16.6 g (SD = 11.0, n = 32); when older than 20 d: 20.8 g (SD = 13.3; n = 33). The latter mass was used as the annual index in 1996 and 1995. The 1996 masses were significantly lower (P = 0.02) than those of 1995 (27.7 g; SD 11.5, n = 37).

Puffins: The average weight of the 109 screen samples collected during the nestling period was 6.9 g (SD = 6.8, Table 1). This was significantly lower than the mean of the 110 samples collected in 1995 (10.3 g; SD = 12.8; n = 110).

Activity Budgets of Adults

Murres: *Nest attendance* -- During the incubation period, at least one adult was always present at each site, and both birds were present an average of 19.5 minutes per hour per nest (79.5 "bird-min/hr;" SD = 6.0; n = 3 d; Fig. 9a). During the nestling period, at least one adult was always present at each site, and both birds were present an average of 9.6 minutes per hour per nest (69.6 bird-minutes/hr; SD = 4.1; n = 3 d); this was similar to the 1995 figure (66.4 bird-min/hr). The ANOVA showed a significant difference among the observation days; the Tukey post-hoc test showed that two of the days in 1996 were marginally different (12 and 17 August; P = 0.055), as were one day in 1995 (24 August) and one in 1996 (15 August; P = 0.069). These results show that differences between days were as great as differences between the two years, for the given sample size.

Foraging trip duration -- The average duration of murre foraging trips during the nestling period was 150 minutes (SD = 78 min.; n = 85 trips). This was similar to the 1995 mean of 158 minutes. However, the frequency of trips between 0-2 hour and 2-4 hour were different (Fig.11 and 11; $\chi^2 = 17.14$, P = 0.001); the shorter trips were more common in 1995.

Kittiwakes: *Nest attendance* -- Incubated eggs were very rarely left unattended, and it was even rarer for two adults to tend the nest together during incubation. During the nestling period, as in 1995, there were very rarely two adults on a nest. Chicks were occasionally left unattended in 1996; both adults were absent from 1-chick nests for an average of 1.0 minutes per hour per nest (SD = 1.4, n = 3 d; Fig. 9b); from 2-chick nests: 5.4 minutes per hour per nest (SD =4.5). Although within each day, the differences between 1- and 2-chick nests were not significant, 2-chick nests were consistently abandoned more often than were 1-chick nests (1-chick nests: 59.0 bird-min/hr/nest, SD = 1.43; 2-ch nests: 54.59 bird-min/hr/nest; SD = 4.48), so we analyzed the data separately, when looking for among-day differences.

There were no differences among days, for 1-chick nests or 2-chick nests.

Foraging Trip Duration -- We calculated a mean foraging trip duration for kittiwakes of 326 minutes(SD = 91 min, n = 23 trips). This was significantly longer than the mean duration in 1995 (237 min; P = 0.01).

Population Counts

Murres: The average number of murres counted on the productivity plot sample was 407 (SD = 24.3). In 1993, 1994, and 1995, the average counts were 435, 404, and 392, respectively. While there were no significant differences among years in these counts, the general pattern of the counts across years agreed with the counts of larger plots counted at East Amatuli Island in other projects in previous years, and in Project 96144.

Kittiwakes: Counts on the sample of four kittiwake plots for which we can compare for the years 1993-1996 averaged 183 in 1996 (SD = 8.2; n = 12). This average was similar to that for 1995 (201; SD = 8.7) and 1994 (192; SD = 10.3); the results for all three of these years were higher than those for 1993 (120; SD = 50.3; P<0.001).

Puffins: There was no significant difference in the number of active tufted puffin burrows in the seven productivity plots between 1996 (total = 142 active burrows) and 1995 (125 active burrows).

DISCUSSION

Forage fish near the Barren Islands in 1995 and 1996 apparently provided adequate prey to support average or higher productivity for kittiwakes and murres. Tufted puffins produced normally in 1995, but had reduced success in 1996. The lack of concordance between murres and puffins, both divers, may reflect their different chick-rearing strategies. Puffin chicks are fed approximately twice as long at nest sites as are murre chicks, so forage fish would have to be available at adequate densities for a longer period. There also are differences in feeding behavior between puffins and murres. Puffins tend to feed less often in flocks; this may have resulted in puffins collecting more diverse prey than did murres in 1995 and 1996.

Chick growth rates of kittiwakes and puffins in 1995 and 1996 mirrored their productivity (we had no 1995 growth data for murres). Growth rates for kittiwake chicks in 1995 and 1996 were similar (they were slightly, but not significantly, lower in 1996) and normal. Puffin chicks grew normally in 1995 but had very low growth rates in 1996.

Capelin was the most important prey item for murres in 1995 and 1996 in the Barren Islands. This forage fish, along with sand lance, was also important to kittiwakes and puffins. The proportion of sand lance brought to kittiwake chicks was higher in 1996 than in 1995. Puffin chick diets were the most diverse of the three species. There was a substantial reduction in the amount of prowfish in the puffin diets from 1995 to 1996. Capelin and sand lance are relatively high in lipid content and are generally considered high-quality prey for seabirds. In contrast, prowfish are low in lipids and would not be considered high-quality prey.

Productivity and chick growth are affected by factors other than prey type. The size of meals delivered to kittiwake chicks was lower in 1996 than in 1995, and the duration of forage trips was longer in 1996. Although these results indicate that adult kittiwakes were working harder in 1996 than in 1995, they managed to feed chicks at relatively similar frequencies in the two years, thus keeping growth rates and productivity from being significantly reduced in 1996. Murres also may have worked harder in 1996. They made fewer short foraging trips in 1996 than in 1995, although mean trip durations were similar. There were no significant differences between years in murre nest attendance or chick provisioning frequency. Murres have access to prey throughout the water column, so they are likely to obtain food more easily than are surface-feeding kittiwakes. Puffins delivered significantly smaller meals to chicks in 1996 than in 1995. This reduction in meal size, rather than a change in prey type, probably accounted for reduced chick growth and productivity of puffins in 1996.

The timing of the onset of nesting has been gradually getting earlier for murres in the Barren Islands since at least 1993. While it is possible that changes in food supply could be involved, this pattern would be expected for a population undergoing an increase in the age or experience of breeders, as would occur after a mortality event, such as the *Exxon Valdez* oil spill (see Nysewander et al. 1992). By more closely examining the timing of breeding of murres and other species on the Barren Islands, and by continuing our examination of the effects of changes in food supply on these species, we will explore the potential causes of this pattern in breeding chronology.

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Table 1. Results from Barren Islands Seabird Studies, 1996.

Variable	Common murre		Black-legged kittiwake		Tufted puffin	
Productivity	Eggs hatched / eggs laid	0.85 (0.10)[1]	Chicks fledged / nests built:	0.71 (0.19)	Chicks / occupied burrow	0.31
	Chicks fledged / eggs hatched	0.90 (0.12)				
	Chicks fledged / eggs laid	0.77 (0.14)				
Nesting chronology	Median hatch date:	4 Aug (4)	Median hatch date:	7 Jul (7)	Median hatch date:	16 Jul (5.1)
Chick growth rate	Fledging weight (g):	240 (24)	Grams / day (all chicks):	17.5 (5.8)	Grams / day:	3.3 (1.6)
			("A" chicks):	17.6 (5.9)		
			("B" chicks):	14.9 (1.6)		
Chick feeding freq.	Feedings / chick / hr (0700-2100):	0.26 (0.05)	Feedings/nest/hr (0700-2100) (1 ch):	0.19 (0.03)	Feedings/nest/hr (0600-2200):	7.2 (2.2) - 3.8 (1.5)
			(2 ch):	0.25 (0.09)		
Adult trip duration	Minutes / trip:	150 (78)	Minutes / trip:	326 (91)	*No data*	
Time no ad. on nest	Minutes / hour:	0.0	Minutes / hour (1 chick):	1.0 (1.4)	*Not yet analyzed*	
			(2 chicks):	5.4 (4.5)		
Time 2 ad. on nest:	Minutes / hour (incubation):	19.5 (6.0)	Minutes / hour (1 chick):	0.0	*Not yet analyzed*	
	(nestling period):	9.6 (4.1)	(2 chicks):	0.0		
Chick meal size	*no data*		Regurgitant weight (g):	20.8 (13.3)	Screen samp. wt. (g):	6.9 (6.8)
Population size	Productivity plots (no. of birds):	407 (24)	Productivity plots (no. of birds):	183 (8.2)	Number of burrows:	142

[1] Standard deviation in parentheses

Table 2. Results from searches of four tufted puffin transects at East Amatuli Island, Barren Islands, Alaska, 1993-1996. Total area = 270 m^2

Year	Burrows	Active burrows	Active / total burrows	Chicks	Chicks / active burrows
1993	58	25	0.43	15	0.60
1994	44	17	0.39	8	0.47
1995	63	25	0.40	13	0.52
1996	61	24	0.39	4	0.17
Average	57	23	0.40	10	0.44
St. Dev.	9	4	0.02	5	0.19

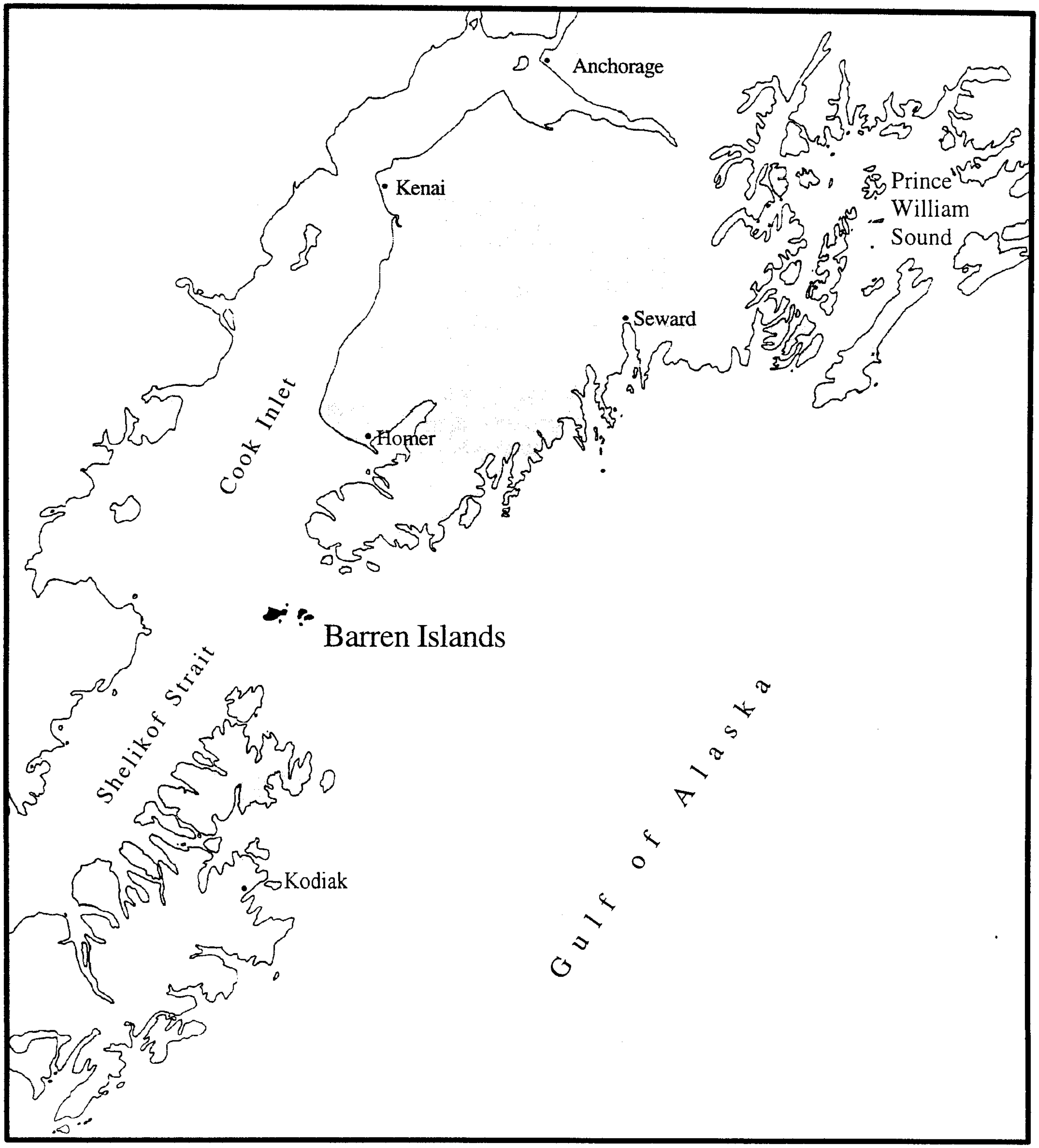


Figure 1. Location of the Barren Islands, Alaska.

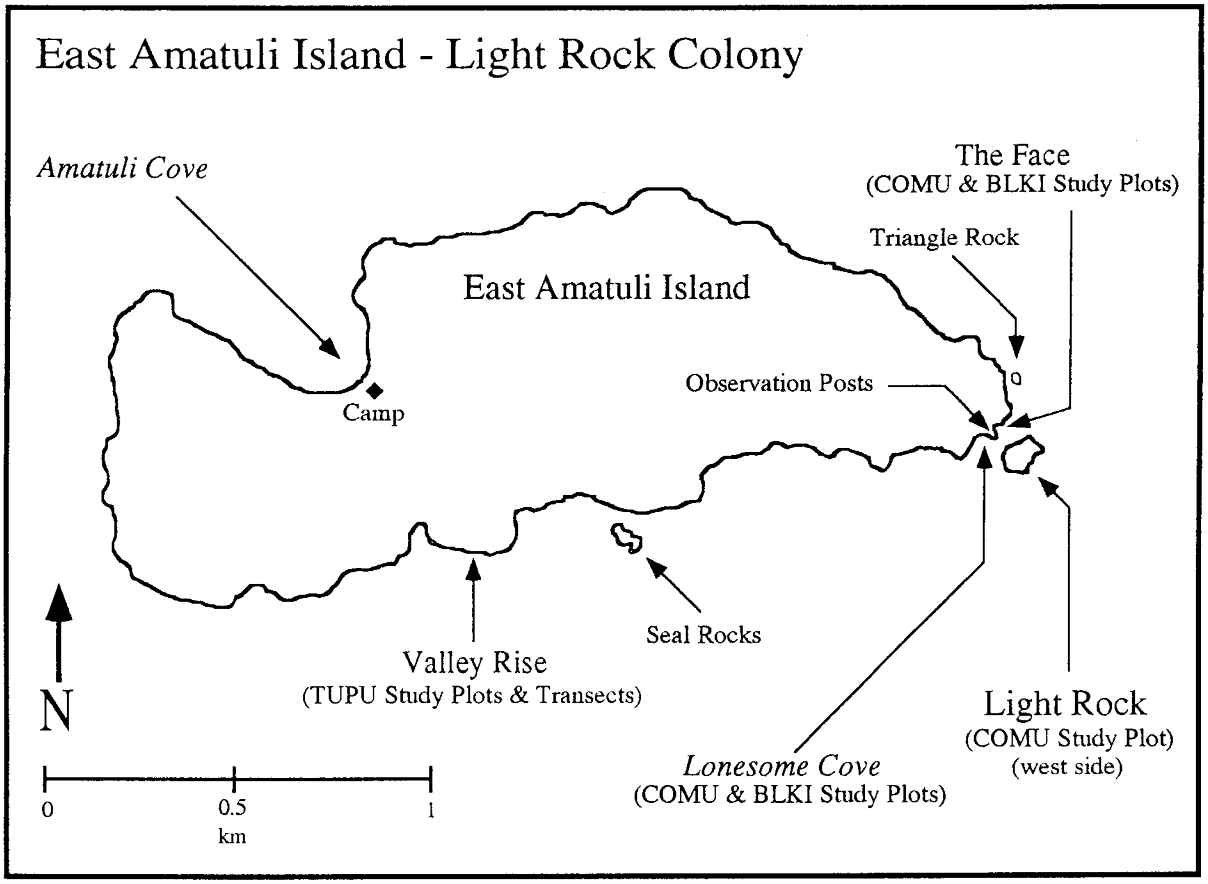


Figure 2. The East Amatuli Island study area showing the general locations of the common murre (COMU), black-legged kittiwake (BLKI), and tufted puffin (TUPU) study sites.

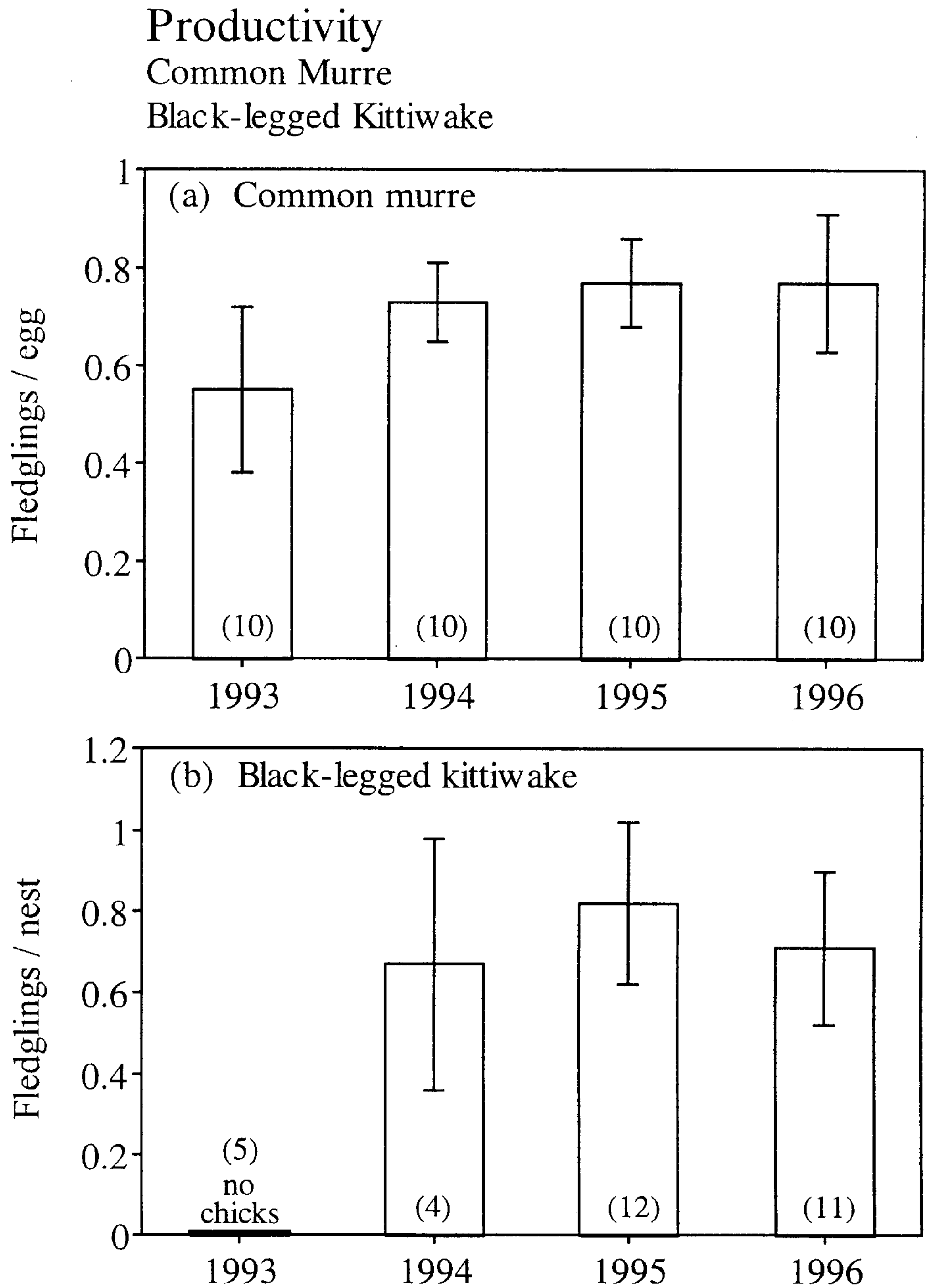
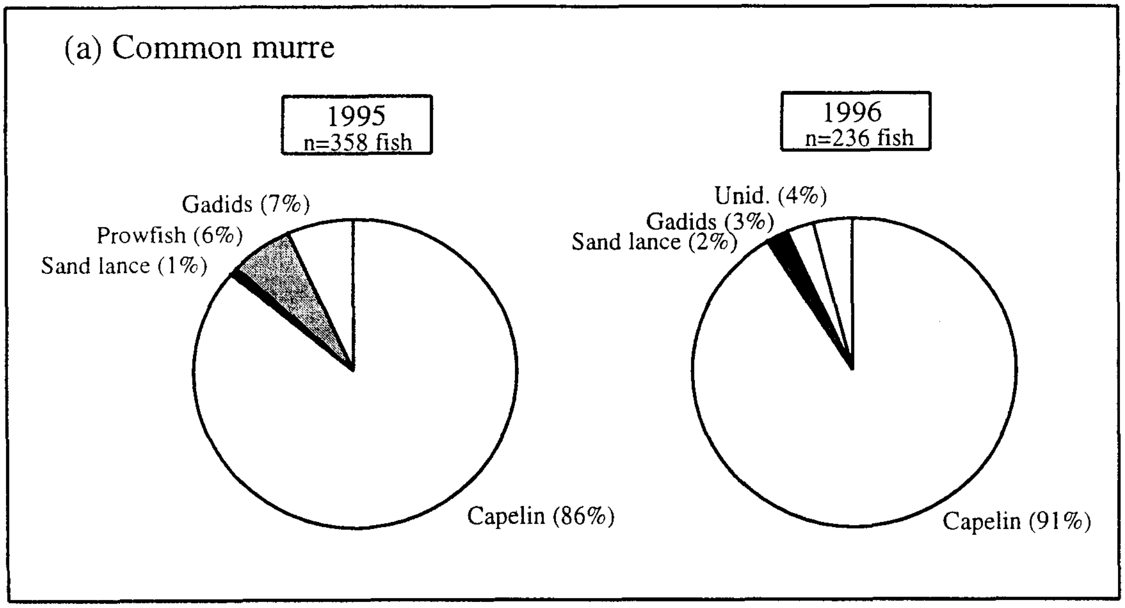


Figure 3. Productivity of (a) common murres and (b) black-legged kittiwakes at East Amatuli Island, Barren Islands, Alaska, 1993-1996. Number of plots in parentheses; error bars = standard deviation.

Chick diet

Common murre

Black-legged kittiwake



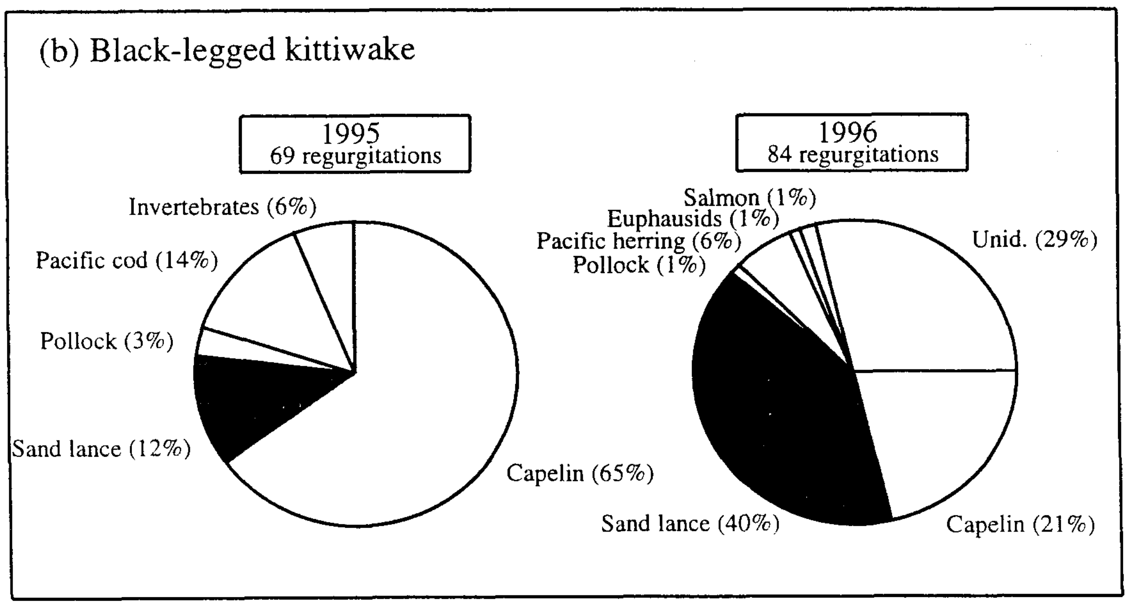


Figure 4. Types of prey fed to (a) common murre and (b) black-legged kittiwake chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1996. Composition of prey by (a) number of fish and (b) mass.

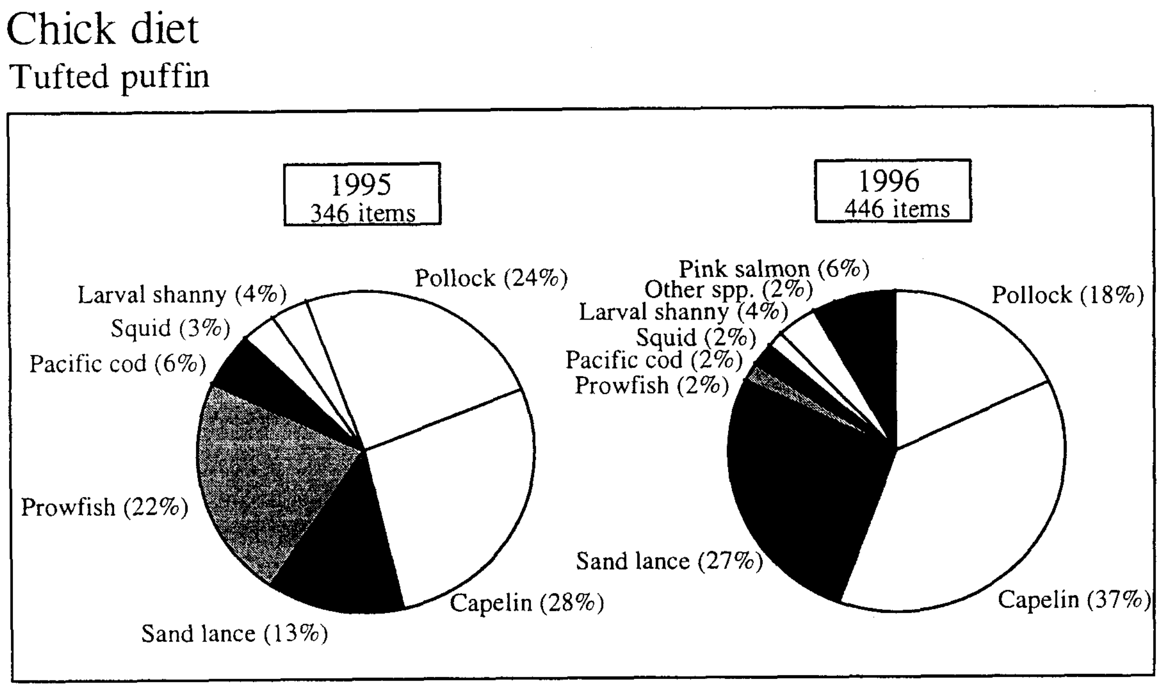


Figure 5. Types of prey fed to tufted puffin chicks at East Amatuli Island, Barren Islands, Alaska, 1995 and 1996. Composition of prey by mass.

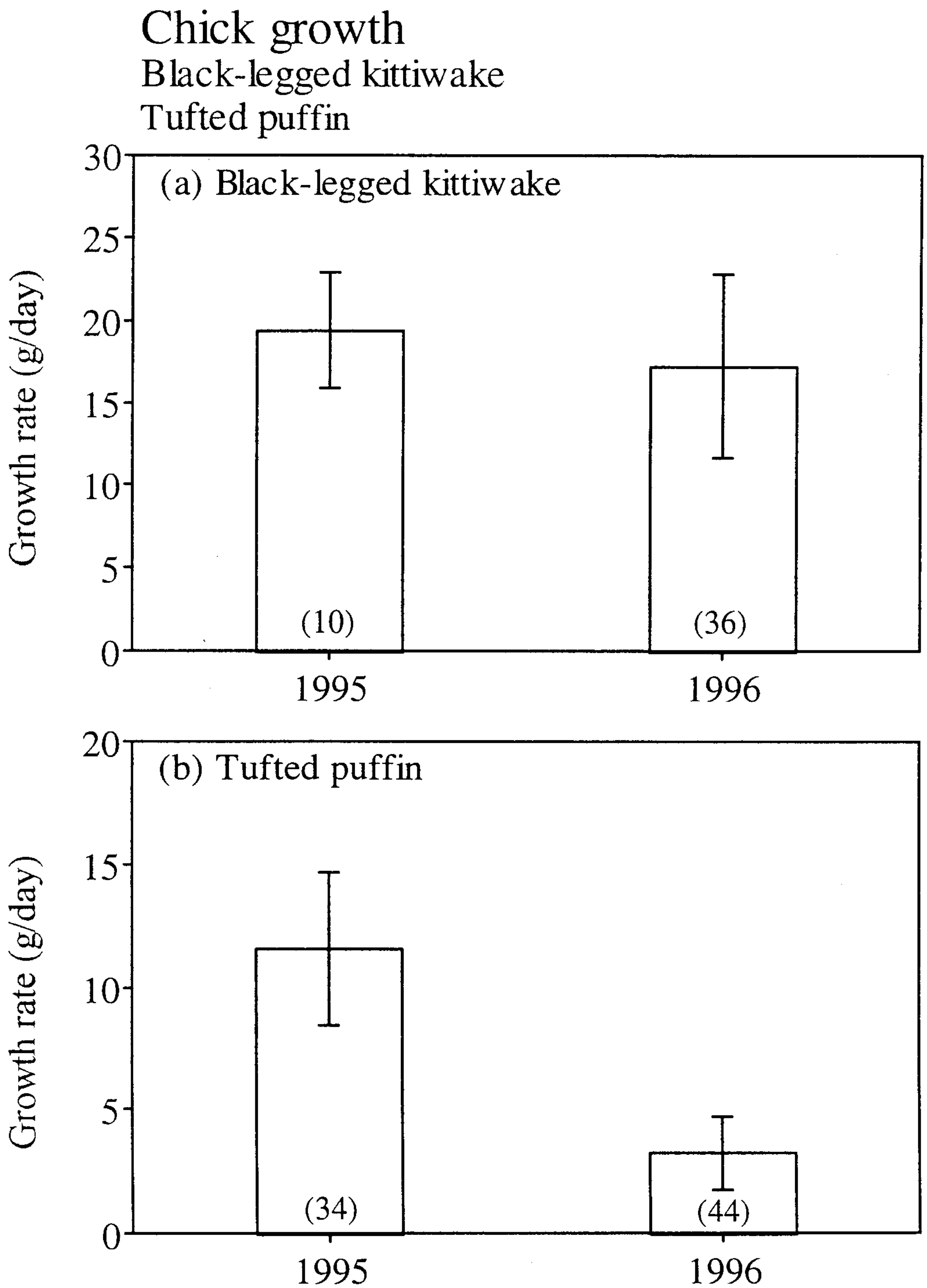


Figure 6. Growth rate of (a) black-legged kittiwake chicks and (b) tufted puffin chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1996. Number of chicks on parentheses, error bars = standard deviation.

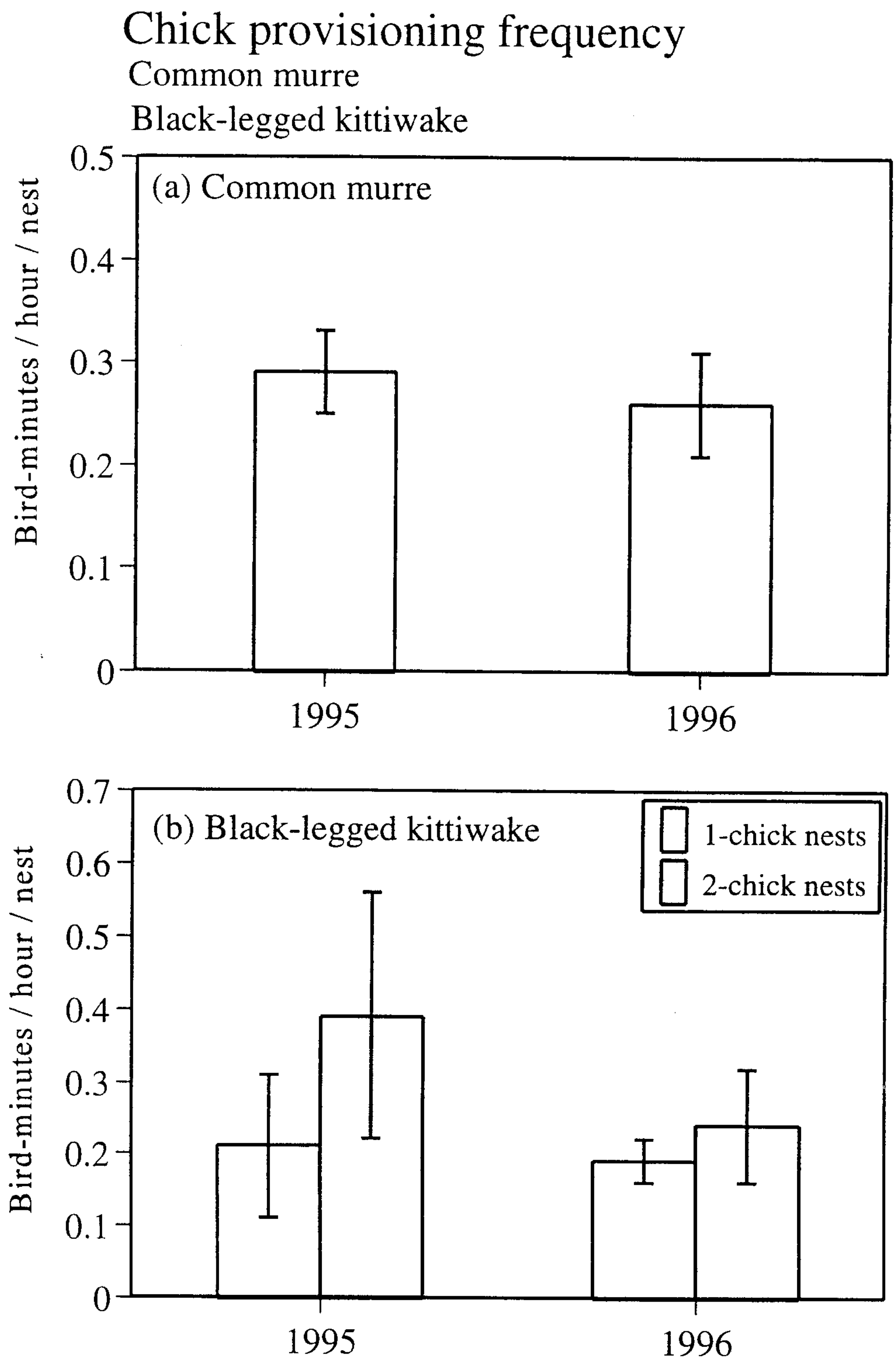


Figure 7. Chick provisioning frequency of (a) common murres and (b) black-legged kittiwakes at East Amatuli Island, Barren Islands, Alaska, 1995-1996. Sample size = 2 days in 1995 and 3 days in 1996; error bars = standard deviation.

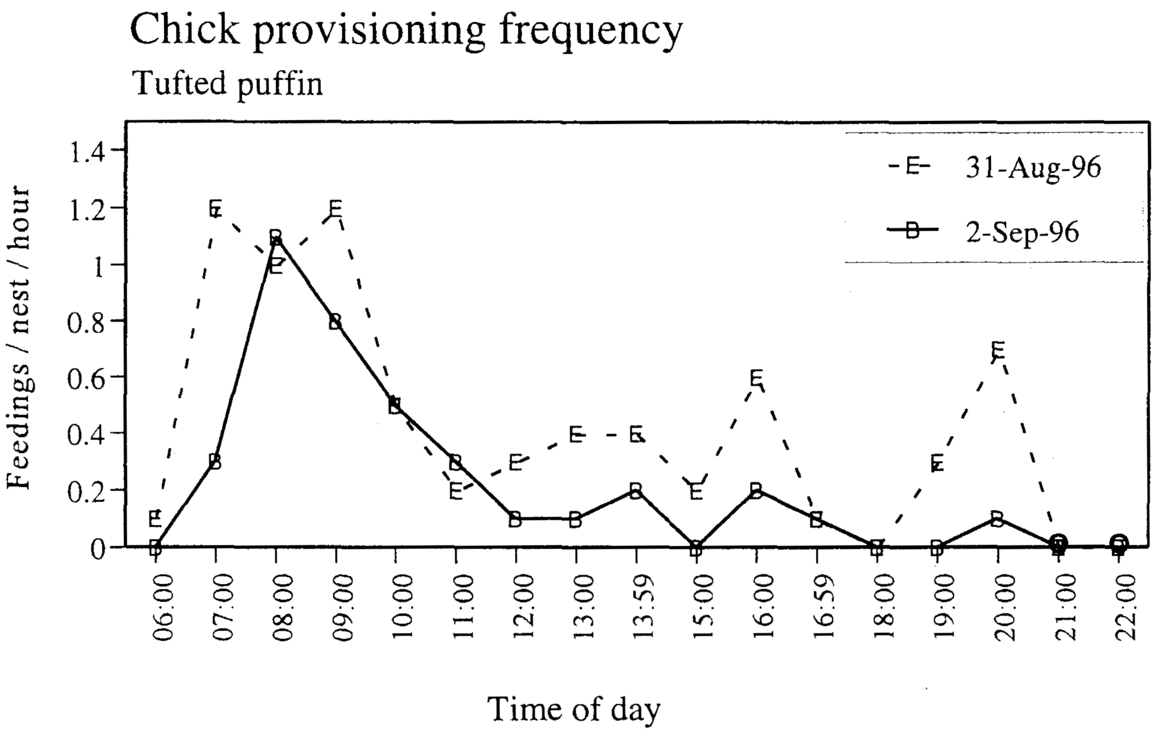


Figure 8. Number of times adult puffins returned to nests with fish at East Amatuli Island, Barren Islands, Alaska during two dawn-to-dusk observation periods in 1996. Calculated as returns per nest per hour, for a sample of 10 nests with chicks. Hours listed are start times for the corresponding data points.

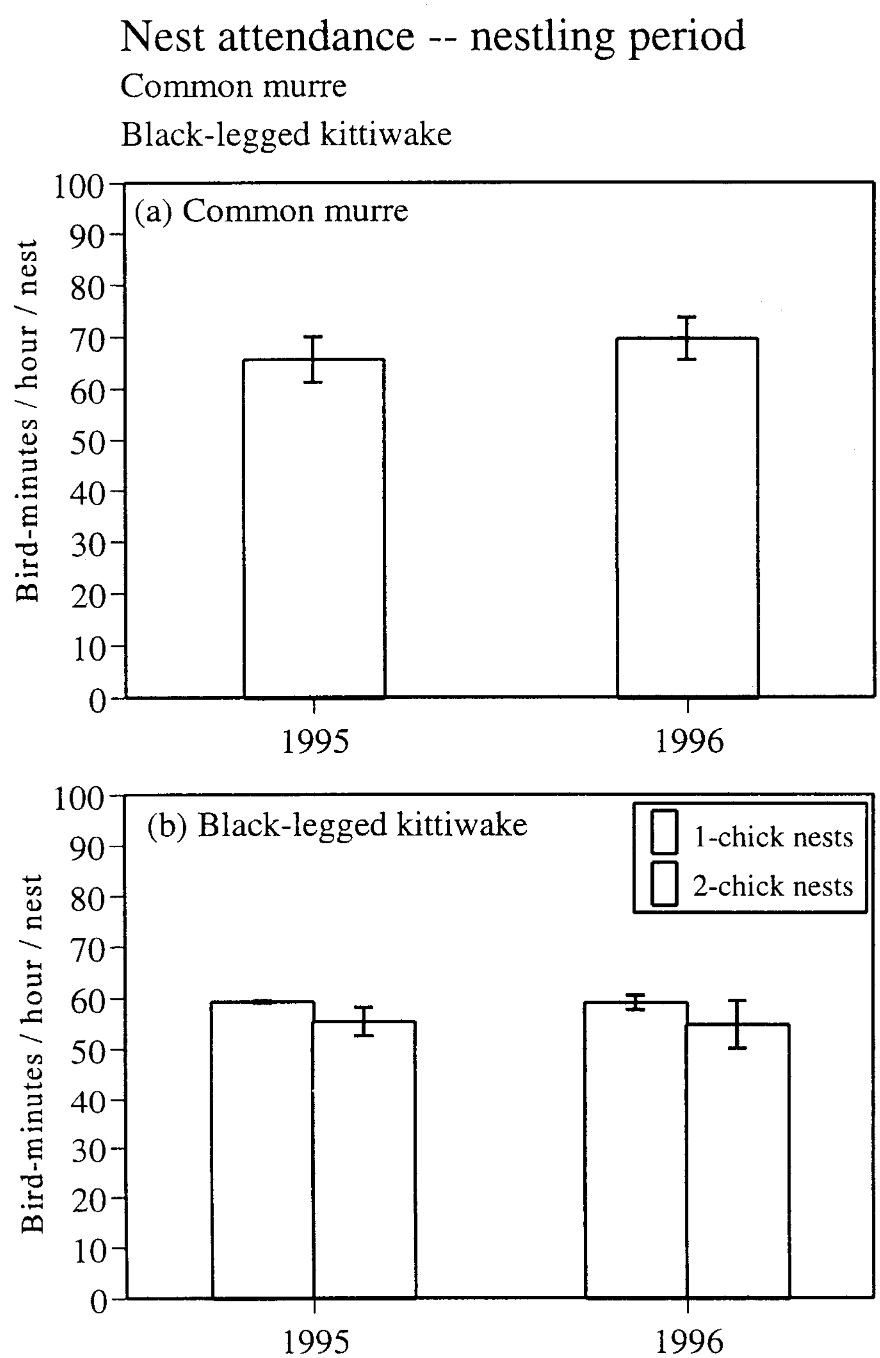


Figure 9. Number of minutes per hour spent at the nest by adults (e.g., 2 adults with full attendance = 120 bird-minutes per hour) of (a) common murre, and (b) black-legged kittiwake, during chick rearing at East Amatuli Island, Barren Islands, Alaska, 1995-1996. Sample size = 2 days in 1995 and 3 days in 1996; error bars = standard deviation.

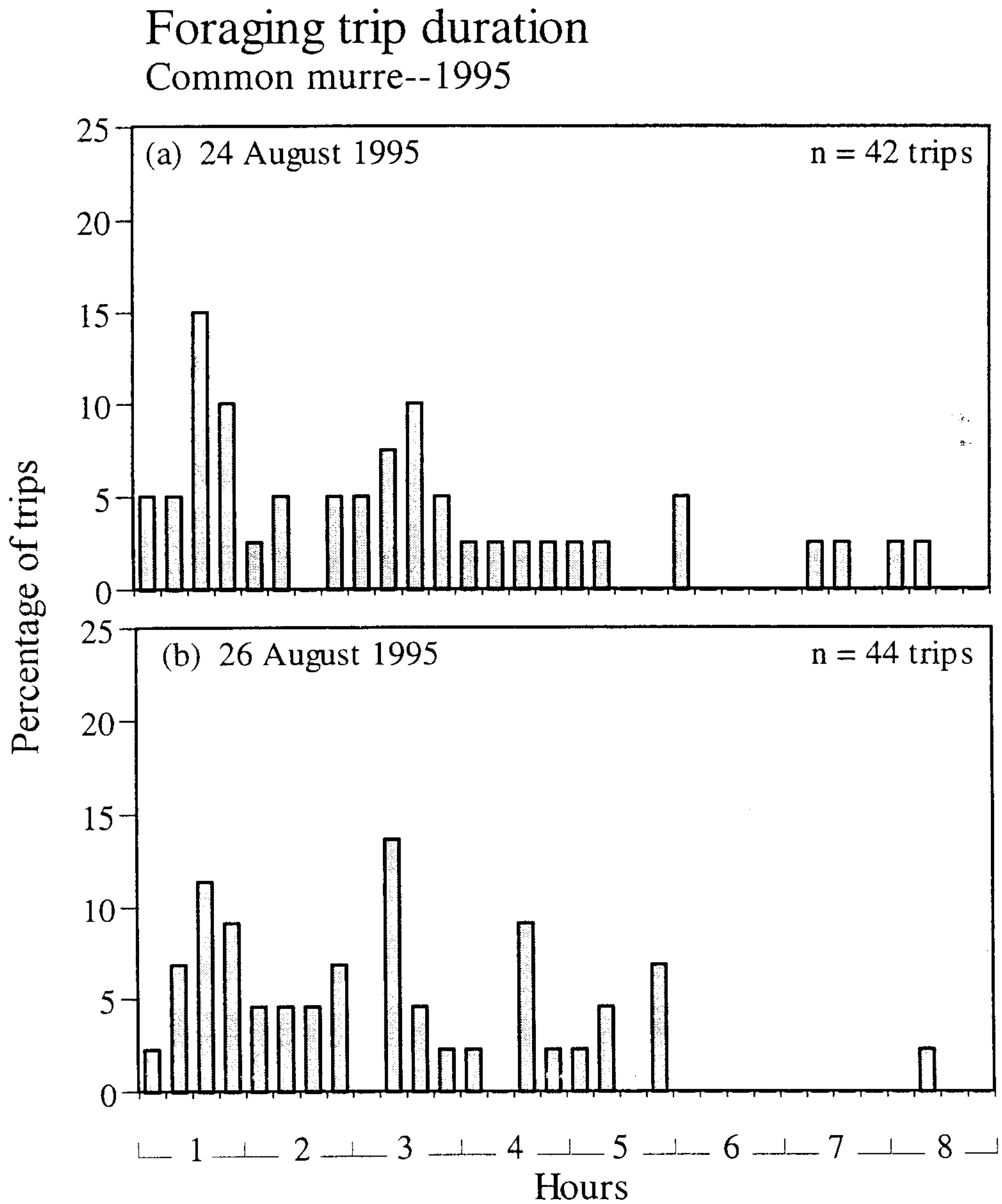


Figure 10. Duration of trips by common murres, by frequency of occurrence, from 12 nests at East Amatuli Island, Barren Islands, Alaska, 1995: (a) 24 August and (b) 26 August, 1995.

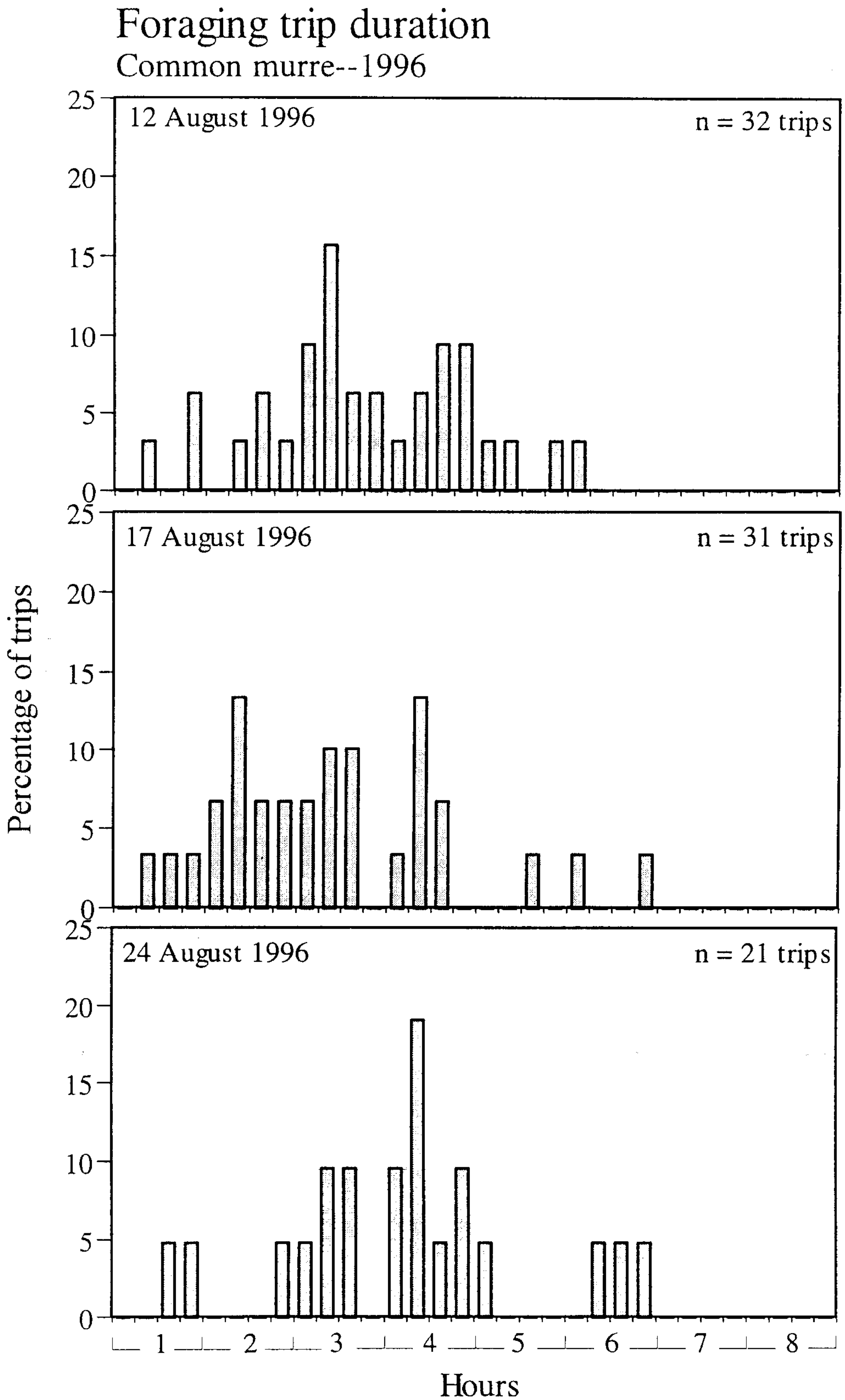


Figure 11. Duration of trips by common murres, by frequency of occurrence, from 10 nests at East Amatuli Island, Barren Islands, Alaska, during three days in 1996.