Exxon Valdez Oil Spill
Restoration Project Annual Report

Barren Islands Seabird Studies, 1997

Restoration Project 97163J
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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Study History: Barren Islands APEX seabird studies began in 1995 (Project 95163J; see Roseneau *et al.* 1996a) and continued through 1996 (Project 96163J; see Roseneau, *et al.* 1997) and 1997 (Project 97163J).

Abstract: We measured breeding and foraging parameters of common murres (*Uria aalge*), black-legged kittiwakes (*Rissa tridactyla*), and tufted puffins (*Fratercula cirrhata*) at the Barren Islands, Alaska, and compared results with those from similar studies in 1995 and 1996.

Murre productivity was high in 1997, as it was in 1995 and 1996. The diet, feeding frequency, and nest attendance of murre chicks was similar among 1995-1997. Fledglings were heavier in 1997 than in 1996. Murres have nested progressively earlier each year (including 1997) since 1993.

In contrast to murres, kittiwakes laid eggs later, had lower productivity, attended nests for shorter time periods, and fed chicks less frequently in 1997 than in 1995-1996. Kittiwake chick diet composition was similar to that of 1996; in both 1996 and 1997 the proportion by weight of capelin (*Mallotus villosus*) was lower, and that of Pacific sand lance (*Ammodytes hexapterus*) higher, than in 1995. Growth rates of kittiwake chicks did not differ significantly during 1995-1997; it is possible that in years of low food availability, brood reduction boosts growth of surviving chicks.

Productivity of tufted puffins was lower in both 1997 and 1996 than in 1995. Puffin chicks grew faster than in 1996 but more slowly than in 1995. Chick diet composition was diverse and similar among years; the size of meals in 1996 and 1997 was smaller than in 1995.

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 16 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, seabird breeding parameters and the distribution, abundance, and energy content of forage fish are being compared among species, years, and study sites in Prince William Sound and lower Cook Inlet-Kachemak Bay to study how ecosystem processes affect populations of seabirds nesting in the spill area.

The Barren Islands support some of the largest nesting concentrations of black-legged kittiwakes, common murres, and tufted puffins in the spill area. Information on several productivity and population parameters for these species is available from past Barren Islands studies (e.g., Bailey 1975*a*,*b*, 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, 1996*a*,*b*, 1997). The islands' offshore location provides opportunities to compare data from an oceanic environment with results from APEX studies in Prince William Sound and with Minerals Management Service (MMS) and other APEX research in lower Cook Inlet-Kachemak Bay.

Data collected at the Barren Islands are being used to help test 3 APEX hypotheses:

Hypothesis 7: Composition and amount of prey in seabird diets reflect changes in the 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 the amount of time adult birds spend foraging for food, amount of food fed to chicks, and provisioning rates of chicks.

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

In 1997 we measured murre, kittiwake, and puffin productivity and nesting chronology; type and amount of prey fed to chicks; fledging size of murres and growth rate of kittiwake and puffin chicks; feeding frequency of chicks; and time-activity budgets of kittiwake and murre adults. We counted adults on productivity study plots as one index of population size for each of the 3 species (trends in Barren Islands murre numbers were studied in greater detail by Project 96144 and 97144. We also made 28 beach seine sets during the 1997 field season, using methods employed by the Gull and Chisik island studies (Project 97163M).

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, 1996b) and the 1995-1996 APEX Barren Islands seabird studies (see Roseneau *et al.* 1996a, 1997). Information was shared with other APEX investigators for among-colony comparisons (e.g., Projects 97163E, 97163M, and 97163G).

OBJECTIVES

Objectives of the 1997 Barren Islands seabird studies were to:

1. Determine the productivity of common murres (fledglings/egg laid), black-legged kittiwakes (fledglings/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 fledging size of murre chicks (grams) and growth rate of black-legged kittiwake and tufted puffin chicks (grams/day).

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

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

6. Obtain an index of the amount of food fed to black-legged kittiwake and tufted puffin chicks (grams/chick regurgitation and grams/nest screen, respectively).

7. Calculate activity budgets for common murre and black-legged kittiwake adults (time spent attending the nest, duration of foraging trips).

8. Measure body condition of adult kittiwakes.

9. Sample near-shore forage fish populations throughout the season with regular beach seine sets using methods of Project 97163M.

10. Collect forage fish samples from kittiwake regurgitations, tufted puffin burrow screens, and beach seines for proximate and isotope analyses by other investigators.

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 9

June-12 September by a team of 4-5 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 10 East Amatuli Island - Light Rock plots established for this purpose in 1993 (see Roseneau *et al.* 1995). Plots contained about 25-50 nest sites (sites with eggs) each (1997 nest site total = 311) and were viewed through 7 x 42 binoculars and 15-60 power spotting scopes from land-based observation posts as often as weather permitted (range = 1-5 days). Viewing distances varied from about 50 to 150 m, and each observer was assigned specific plots for the field season. Nest sites were mapped using photographs and sketches, and data were recorded for each site using previously established codes. A plot check consisted of noting for each nest whether it contained an egg, a chick, or an adult in incubation or brooding posture, and of counting all adults on the plot. Each plot was checked at least 35 times during 11 June - 3 September, from before eggs were laid until almost all chicks had gone to sea. Plots were treated as sample units and productivity was calculated as fledglings/egg. These data were also used to calculate hatching and fledging success. Differences among 1993-1997 results were tested by Analysis of Variance (ANOVA).

Kittiwakes: Kittiwake productivity data were collected from 11 East Amatuli Island plots (5 were established 1993 and 7 in 1995) located on the headlands that contained the murre productivity plots. Each plot contained 25-50 nests (1997 nest total = 304; 205 contained eggs). Methods for collecting and analyzing data were similar to those used for murres and for Projects 96163E and 96163M. Nest checks consisted of searching for eggs and chicks (adult postures were not used to determine the content of kittiwake nests) and counting adults. Each plot was checked at least 35 times during 11 June - 3 September, from before egg-laying began until most chicks had fledged. Plots were treated as sample units and productivity was calculated as fledglings/nest site. These data were used to also calculate hatching and fledging success. Differences among 1993-1997 results were tested by ANOVA.

Puffins: Puffin productivity data were obtained from 3 study plots established in 1990 by University of Washington personnel for measurement of chick growth rate (see Growth Rates below) and 4 transects totaling 270 m^2 established in 1986 by FWS crews for monitoring numbers and occupancy of burrows (see Nishimoto 1990). Burrows in the growth study plots were first searched for signs of activity (trampled and cleared vegetation, guano from adults and chicks, fresh digging) and nestlings during 28 July - 4 August, when most chicks were about 1 week old. A 35-cm-long flexible scoop was used in the burrows to help search for nestlings. After the initial visit, burrows containing chicks were checked every 5 days until 10 September. Active burrows, inactive burrows, and nestlings in the 4 transects were counted on 28 August, just prior to fledging.

Data from burrows in the plots and transects were pooled for analysis. Productivity was calculated as active burrows containing chicks just prior to fledging/active burrows. The differences among 1995-1997 results were compared with Pearson's Chi-square tests.

Hatching success was measured in a plot that contained 27 burrows with eggs. Burrows were checked 3 times during the nesting season: just before hatching, just after hatching, and just before most chicks fledged. To calculate hatching success we divided the number of burrows that produced a chick by the number that had contained eggs.

Nesting Chronology

Murres: Median hatch date was the measure of murre nesting chronology (see Roseneau *et al.* 1995, 1996*a*,*b*, 1997). The median date was calculated for each of the productivity plots, and the average of these median dates was the annual index for the 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. First, for nest sites with closer pre- and post-lay observations than pre- and post-hatch observations, the hatch date was calculated by adding 32 days to the lay date (32 days is the average incubation time—see Byrd 1986, 1989; Roseneau *et al.* 1995, 1996*a*,*b*, 1997). Second, nest sites with data gaps of more than 7 days surrounding both laying and hatching were excluded from the data set. Plots were treated as sample units and differences among 1993-1997 results were tested by ANOVA.

Kittiwakes: Median hatch date was also used to measure kittiwake nesting chronology (see Roseneau *et al.* 1996a, 1997). Methods were identical to those described above for murres, except that 27 days (rather than 32) were added when hatch dates were calculated from lay dates (see Byrd 1986, 1989). Plots were treated as sample units and differences among 1993-1997 results were tested by ANOVA.

Puffins: Mean hatch date was the measure of puffin nesting chronology. Because burrows were not visited until puffin chicks were about 1 week old (visiting burrows prior to this time can result in abandonment of eggs or chicks), hatch date was calculated from wing measurements rather than nest status observations. We used a growth equation reported by Amaral (1977) to estimated the age at first wing measurement of each of the 44 growth study chicks. With this chick age we calculated the hatch date for each chick. The mean hatch date among chicks was the index for the season; differences among 1994-1997 results were tested by ANOVA.

Chick Growth Rate

Murres: Because disturbing murres at nests could have caused high levels of chick mortality from predation by glaucous-winged gulls *(Larus glaucescens)*, we did not measure the growth rate of murre chicks. During 5 nights (19, 20, 24, 26, and 28 Aug), 96 nestlings were dip-netted from Lonesome Cove just after they left the cliffs; the chicks were weighed (to 1 g) and measured (culmen, tarsus, and wing chord to 1 mm). Chicks were captured, processed, and released quickly, 1-at-a-time. Average chick weight was used as the index of sea-going size; differences between 1996 and 1997 results were compared with a t-test.

Kittiwakes: Fifty-two kittiwake chicks from 39 broods were weighed (to 1 g) and measured (e.g., wing chord, culmen, tarsus, and back of head to tip of bill to 0.1 mm) every 4-7 days, from just after hatching until they were about 30 days old, unless they died younger (35 chicks reached 30 days). Growth rate calculations followed Project 95163E protocol: average daily increase in weight was calculated for each chick for the most linear section of the growth curve (60-300 g) by dividing the difference in weight between the first and last measurements within this range by the number of days between measurements. We averaged these results for 'A' chicks (chicks in single-chick nests plus first-to-hatch chicks in 2-chick nests; $n = 34$) and 'B' chicks (the second-hatched chicks in 2-chick nests; $n = 7$). Using the chick as the sample, differences among 1995-1997 'A' chick growth rates were tested by ANOVA.

Puffins: Fifty-two puffin chicks in the 3 growth study plots (see Productivity above) were weighed (to 1 g) and measured (culmen, wing chord, and tarsus to 0.1 mm) every 5 days, from the time they were about 1 week old until they fledged. Weight gain was used as the primary indicator of growth. The rate of increase was calculated for each chick by fitting a simple linear model to the 150-450 g section of the growth curve (the portion that is nearly linear); then the rates were averaged. Differences in growth among the years were tested by ANOVA.

Chick Diet

Murres: Prey items delivered to murre chicks were identified in parents' bills as they returned to nest sites. Observations were made with 7 x 42 binoculars from a blind located 1-20 meters from nest sites. On 10 days during 6 August - 3 September, 421 prey items were recorded; 408 (97%) of these were identified to species or family groups (e.g. Gadidae) using color and shape of the body and fins (e.g., caudal, anal, adipose fins). We calculated percentages of the total number for 6 categories of prey: capelin, Pacific sand lance, cods (Gadidae), Pacific herring (*Clupea harengus pallasi*), prowfish (*Zapora silenus*), and squid (Cephalopoda).

Kittiwakes: Samples of prey brought to kittiwake nestlings were obtained from growth study chicks and brooding adults when they regurgitated while being handled. Eighty-two regurgitations were obtained on 18 days during 15 July - 21 August, when nestlings were about 1-4 weeks old. Samples were weighed (to 0.01 g) and frozen in the field. Prey items were identified, measured, and weighed by K. R. Turco and A. M. Springer, FALCO. Percent composition of the total number and weight were calculated for 11 categories of prey: capelin, Pacific sand lance, Pacific cod (*Gadus macrocephalus*), walleye pollock (Theragra chalcogramma), Pacific herring, salmonids (*Onchorynchus* spp.), greenlings (*Hexagrammos* spp.), unidentified smelt (Osmeridae), euphausiids *(Thyssanoessa* spp.*)*, squid, and unidentified.

Puffins: Samples of prey brought to puffin chicks by adults were collected by blocking nesting burrows for 3 hours with squares of hardware cloth. When bill loads were collected, they were replaced with freshly-thawed fish caught during beach seining operations; these replacement meals were placed inside the burrows, close to the nest bowl (Wehle 1983 supplemented the diet of tufted puffin chicks with this method). One hundred fifty-two bill loads containing 551 prey items were obtained on 9 days at East Amatuli Island and 1 at West Amatuli Island during 11 August - 9 September. Prey items were identified in the field using taxonomic keys and field guides and then cleaned, weighed (to 0.01 g), measured (fork length to 0.1 mm), and frozen. Percentages of the total number and weight were calculated for 9 categories of prey: capelin, Pacific sand lance, Pacific cod, walleye pollock, prowfish, pink salmon *(Oncorhynchus gorbuscha)*, larval fish, squid, and euphausiids.

Amount Fed to Chicks

Murres: Because it would have caused high levels of disturbance to many birds we did not weigh or measure prey brought to murre chicks.

Kittiwakes: To measure meal size we used the weight of regurgitated samples (see Chick Diet, above). Because mean meal size increased with the age of chicks until they were about 20 days old, we used as the annual index the average weight of regurgitations collected from chicks 20 days or more of age ($n = 25$). Using each regurgitation as a sample, we tested differences among 1995-1997 results by ANOVA.

Puffins: We used the average weight of screen samples (see Chick Diet, above) as the index for puffin chick meal size. We excluded bill loads that because of their condition could not be accurately weighed; 115 remained. Using each screened bill-load as a sample, differences among 1995-1997 results were tested by ANOVA.

Chick Provisioning Rate

Murres: Murre chick provisioning rate data were collected on 6 days (14, 17, 20, 22, 26, and 28 Aug) from a plot of 9 nest sites near one of the productivity observation posts. Activities on the plots were recorded with a video camera and a time-lapse recorder set at 5 frames/sec. Frames were labeled with dates and times. Each day's record began before dawn and ended after dusk (start and stop times varied with cloud cover and day length but all days started at or before 0600 hr and ended at or after 2200 hr). Tapes were viewed with a variable-speed player; times of all adult arrivals, chick feedings, departures, and exchanges of brooding duties were entered on a spreadsheet for later analysis. It appeared that each day's recordings started before birds began food deliveries and ended after deliveries had stopped.

During several occasions in 1996-1997, we recorded events on video tape while simultaneously collecting these data by hand with binoculars. Results for feeding frequency, attendance, and times of day when nest activities were first and last visible were similar between the 2 methods.

To analyze the data, for each observation day we calculated the average number of feedings/hr for each of the 9 nests, and then averaged the 9 nest-day values. This daily mean was the value used for among-year and among-site comparisons. Data collection times common to the 3 study years were 0700-1959 hr (in 1997 there was no significant difference between feeding frequency averaged over the entire day and that measured during 0700-1959 hr). Results limited to these times were tested for among-year differences with ANOVA. In 1998 we will compare among-day differences and among-nest differences to determine the best sample unit for among-year analyses.

Kittiwakes: Data on kittiwake chick provisioning rate were collected from nests containing 10- to 32-day-old chicks located in and near one of the kittiwake productivity plots. Data were collected with a time-lapse video system (see Murres, above), and results from playback analysis were similar to those obtained during simultaneous manual observations. Only the first regurgitation to a chick after a parent returned from a trip was scored as a 'feeding', and only if it occurred within 30 min of an adult's return from a trip of at least 30 min duration. Because at times both parents were gone from the nest, bands and marks applied during body condition measurements were used to identify adults.

In accordance with Project 97163E protocol, we used the nest-day as the value for comparison among years and project sites. There were significant differences in feeding frequency between 1- and 2-chick nests, so we analyzed separately data from the 2 nest types. We recorded activities of 3-6 nests during each of the 6 all-day (16-hr) observations (21 and 26 Jul; 4, 7, 15, and 16 Aug). Different nests were used each day; there were 27 samples for 1-chick nests and 7 samples for 2-chick nests. We tested differences among 1995-1997 results with ANOVA.

Rather than covering all daylight hours (as in 1997), in 1995 observations ended at 1959 hr and in 1996 observations began at 0700 hr. To compare among the 3 study years we used the block of time common to all years: 0700-1959 hr. (in 1997 there was no significant difference between feeding frequency averaged over the entire day and that measured during 0700-1959 hr).

Puffins: Provisioning rate of tufted puffin chicks was measured by observing adults returning to 7-10 marked nest burrows in one of the chick growth rate study plots during 16- or 17-hr-long watches on 4 days (0600-2259 hr on 9 Aug and 0600-2159 hr on 19 and 29 Aug, and 2 Sep). Observations began at first light, before adults returned with bill loads, and ended after dusk, when deliveries had ceased. Observations were made with 7 x 42 binoculars from a blind located about 25 m from the burrows. We recorded the times adult returned and departed, and whether returning adults carried bill loads.

We also calculated the number of meals delivered to each nest, each day. The value used for comparison among years was the average among nests for the day. Because only 2 observation days were available from 1996 (and none from 1995) we did not statistically compare results between years.

Activity Budgets of Adults

Murres: Using data from the all-day observations during the nestling period (see Feeding Rates, above) and 4 days during the incubation period (15, 23, and 26 July; 2 Aug), we calculated the amount of time adults spent at their nests. We used the unit 'bird-minutes'/hour as the measure of nest attendance. For example, if 1 adult was present for the entire hour and its mate was present for 30 min, nest attendance was 90 bird-min for that nest, that hour. For each observation day we averaged bird-minutes-per-hour values for each nest. The average among nests for the day was the value used for comparisons among years and project sites. We analyzed separately data from the incubation and nestling periods. Differences among 1995-1997 results were compared with ANOVA.

We also calculated the duration of foraging trips from the nest by adults. Only trips that concluded with chick feedings were used in the analysis (n = 145 trips). The average of all trips was used as the annual index. Differences among 1995-1997 indices were tested by ANOVA, and the frequencies of trips in 2-hr blocks of time (0-2, 2-4, 4-6, and 6-8 hr) were compared among years with Pearson's Chi-square tests.

Kittiwakes: Using data from the all-day observations (see Feeding Rates, above), we calculated the amount of time 1, 2, and no adults attended each nest during the nestling period. Bird-minutes/hour were used to measure nest attendance. Since adults rarely attended the nest together, bird-minutes/hour rarely exceeded 60; fewer than 60 bird-minutes indicated that the nest was unattended for some portion of the hour. The average number of bird-minutes/hour for all hours of the day was calculated for each nest, for each day (the 'nest-day'). The annual index was the average of all the nest-day values for that season. Differences among 1995-1997 results were tested with ANOVA.

We also calculated the duration of foraging trips from the nest by adults. Only trips that concluded with chick feedings were used (n = 30 trips). Average time among trips was used as the annual index. Differences among 1995-1997 results were tested with ANOVA.

Puffins: Adult puffins did not stay at their nests during the 4 all-day observation periods; they usually spent less than 15 seconds in the burrow to deliver bill loads to chicks before flying off. Because both adults were gone at the same time and were unmarked, it was not possible to determine the duration of foraging trips made by individual birds.

Population Counts

Murres: Murres were counted on the 10 productivity plots on 18 days between the peak of laying and the first sea-going of chicks. Methods for collecting and analyzing data were the same as those used by the 1993-1994 and 1996 Barren Islands murre population monitoring studies (see Roseneau *et al.* 1995, 1996b, 1997) and the 1995 and 1996 Barren Islands APEX seabird projects (see Roseneau *et al.* 1996a, 1997). Differences among the 1993-1997 indices were tested by ANOVA. *Trends on sets of larger plots were studied in greater detail by Project 97144.*

Kittiwakes: Kittiwakes were counted on the 11 productivity plots on 31 days. Counts from the 11 plots were summed for each day, then sums were averaged for the portion of the nesting season with stable counts. In 1997, counts began to decline earlier in the season than during 1994-1996 (but not earlier than 1993, the year of nesting failure) and were most stable between median lay and median hatch dates. Therefore, we used the average of these counts as an annual index of population size. Since in 1995 we counted kittiwakes on only 4 plots, daily subtotals of these plots were used for comparison among the years 1993-1997. These differences were tested with ANOVA.

Puffins: The number of active puffin burrows on the 3 chick growth rate study plots and 4 transects was used as the annual index of population size. Differences among 1995-1997 results were compared with the Friedman test.

Sea Temperature

During the 1996-1997 field seasons we recorded sea temperature at Lonesome Cove during the 1996 and 1997 field seasons with an Onset Optic Stowaway Temp data logger, anchored about 5 m deep. In 1996 temperature was recorded every 10 min from 4 July to 4 September; in 1997 data were recorded every 12 min from 16 June to 8 September. These data will be analyzed and compared in the final report.

RESULTS

Productivity

Murres: Murre productivity was high (0.81 fledglings/egg, standard deviation (SD) = 0.09; Fig. 3a; see Byrd *et al.* 1993 for comparisons among Pacific colonies of murre productivity measures) and similar to 1994-1996 levels (0.72, 0.73, 0.74 fledglings/egg, respectively; Roseneau *et al.* 1995, 1996*a*,*b*); all of these values were higher than 1993 results (0.47; $P < 0.001$ for each of the years 1994-1997). Hatching and fledging success followed the same pattern. Hatching success was high (0.90 chicks/egg; SD = 0.09) and similar to 1994-1996 levels (0.67, 0.84, and 0.84) and results from all 4 years were higher than the 1993 value (0.80; for 1994-1996, $P = 0.049$, $= 0.003$, $= 0.003$, and < 0.001). Fledging success was high (0.90 fledglings/chick; SD = 0.07), similar to that of 1994-1996 (0.91, 0.87, 0.88), and results from these 4 years were higher than in 1993 (0.69; for 1994-1996, $P < 0.001$, $= 0.002$, $= 0.001$, and < 0.001). *Data analysis methods have been refined; some numbers reported here differ slightly from those listed in previous reports.*

Kittiwakes: Productivity of kittiwakes was low (0.30 fledglings/nest; SD = 0.13; Fig. 3b; see Hatch *et al.* 1993 for comparisons among Pacific colonies) and significantly lower than 1994-1996 values (0.67, 0.81, and 0.71; $P = 0.011$, < 0.001, and < 0.001, respectively). Productivity during each of the years 1994-1997 was higher than in 1993 ($P < 0.001$ for 1994-1996; $P = 0.038$ for 1997), when no eggs were laid in the plots.

Puffins: Just before fledging 0.34 (SD = 0.17; Fig. 4) tufted puffin chicks/occupied burrow were found in the 3 growth rate plots and group of 4 transects. This was similar to the 1996 value (0.31 chicks/burrow); results from 1996 and 1997 were lower than in 1995 (0.53 chicks/occupied burrow; $P < 0.001$ and $= 0.10$, respectively). Hatching success in the plot established for this parameter was 0.48 chicks/egg. This figure was similar to that of 1996 (0.50 chicks/egg) and lower than most values reported from other Alaskan colonies (see Byrd *et al.* 1993).

Nesting Chronology

Murres: The median hatch date of 2 August (SD = 1.4; Fig. 5a) was 14, 8, 6, and 2 days earlier, respectively, than during the years 1993-1996. Each year, hatching was significantly earlier than during the previous year, with the exception of the 1994-1995 and 1996-1997 pairs. Nesting chronology in 1993 was earlier than reported for 1992 at Nord Island and 1991 at East Amatuli Light Rock (see Dragoo *et al.* 1995 and Boersma *et al.* 1995, respectively).

Kittiwakes: The median hatch date for kittiwake chicks was 17 July (SD = 2.8 Fig. 5b). This was significantly later than in 1994-1996 (11, 7, and 7 July; $P = 0.023$, < 0.001, and < 0.001, respectively).

Puffins: The mean hatch date for puffins was 23 July (SD = 3.5; Fig. 6). This was significantly earlier than in 1996 (18 July, $P<0.001$) and similar to that of 1995 (22 July).

Chick Growth Rate

Murres: The average weight of sea-going murre chicks was 253 g (SD = 21.4; Fig. 7). Chicks were significantly heavier than in 1996 (240 g, $P = 0.001$).

Kittiwakes: The average growth rate of 'A' chicks (chicks in single-chick nests plus first chicks to hatch in 2-chick nests was 16.7 g/day (SD = 4.7; Fig. 8a). This result was similar to that of 1996 (17.6 g/day) and 1995 (18.7 g/day). There were few 'B' chicks (the second-hatched chick in 2-chick nests) and they grew more slowly (8.4 g/day) than 'A' chicks.

Puffins: Puffin chicks in the 3 main study plots gained an average of 6.75 g/day (SD = 3.28 g; Fig. 8b). This was significantly faster than in 1996 (3.3 g/day, SD = 1.6; $P < 0.001$); in both years chicks grew more slowly than during 1995 (11.5 g/day, SD = 3.3; $P < 0.001$ and < 0.001, respectively).

Chick Diet

Murres: Most prey items delivered to murre chick were capelin (91% by number; Fig. 9a). Adults also fed nestlings Pacific sand lance (4%), gadids (1%), and squid (0.2%). Thirteen fish (3%) could not be identified to group or species. Results were similar in 1995 and 1996: capelin was the predominant prey fed to chicks (86% and 91% in 1995 and 1996, respectively).

Kittiwakes: By weight, the kittiwake regurgitation samples were composed of 63% Pacific sand lance, 14% capelin, 7% smelt (unidentified smelt and non-capelin smelt), 6% Pacific herring, 6% euphausiids; the rest (about 4%) was composed of salmonids, greenling, and pollock (Fig. 9b). Results were generally similar to those of 1996, except that in 1996 the proportion of Pacific sand lance was slightly smaller (53%) and that of capelin higher (28%). In contrast, in 1995 the proportions of capelin and Pacific sand lance were the reverse of the 1997 results: 64% capelin and 13% Pacific sand lance.

Puffins: By weight, screen samples contained capelin (33%), Pacific sand lance (33%), and walleye pollock (21%). Chicks were also fed pink salmon (6%), squid (3%), and larval fish (2%); the remainder (about 2%) consisted of Pacific cod, euphausiids, octopus, flatfish, and unidentified species (Fig. 10). These results were remarkably similar to those of 1996, when the proportions of capelin, Pacific sand lance, walleye pollock, salmon, and squid were 37%, 27%, 18%, 6%, and 2%, respectively. Prey composition was also similar to that of 1995, with the exceptions of a 22% prowfish component, smaller proportion of Pacific sand lance, and lack of pink salmon in 1995.

Amount Fed to Chicks

Kittiwakes: Kittiwake chick regurgitation samples collected 20 or more days after the mean hatch date averaged 14.14 g (SD = 9.65). This value was significantly lower than the 1995 result (27.7 g; $P < 0.001$) and did not differ from that obtained in 1996 (20.8 g).

Puffins: The average weight of 115 screen samples collected during the nestling period was 6.6 g (SD = 6.0). This was significantly lower than the 1995 result (10.6 g; $P = 0.001$), but similar to the 1996 value (6.9 g).

Chick Provisioning Rate

Murres: During the 6 all-day observation periods chicks averaged 0.28 feedings/hr (SD = 0.04; Fig. 11a), and during 0700-1959 hr (the time period used for among-year comparisons), they averaged 0.27 (SD = 0.04). In 1995 and 1996 the averages for this time period were 0.26 and 0.29, respectively. These differences were not significant.

Kittiwakes: During the 6 all-day observation periods single-chick nests averaged 0.10 feedings/hr (SD = 0.06; Fig. 11b); nests containing 2 chicks averaged 0.19 feedings/hr (SD =

0.14). During the block of time used for among-year comparisons (0700-1959 hr; see Methods) single-chick nests averaged 0.10 feedings/hr (SD = 0.06) and 2-chick nests averaged 0.20 (SD = 0.12). Feeding rates in 1-chick nests in 1997 were significantly lower than in 1995 (0.21, SD = 0.11, $n = 10$ nest-days, $P = 0.001$) and 1996 (0.19, SD = 0.05, $n = 11$ nest-days, $P = 0.002$).

Puffins: During the 4 all-day observations of tufted puffin nest returns, the number of feedings/day/nest averaged 7.92 (SD = 2.64; Fig. 12).

Activity Budgets of Adults

Murres: *(Nest Attendance)* -- During the incubation period, at least 1 adult always attended each nest site, and both pair members were present an average of 21.9 min/hr (81.9 bird-min/hr; SD = 5.1). During the 0700-1959 hr block of time the average was 83.8 (SD = 5.4). This result was similar to that of 1996 (80.3, SD = 4.0).

During the nestling period at least 1 adult also always attended each site; both birds were present an average of 13.3 min/hr (73.3 bird-min/hr; SD = 4.2). During the 0700-1959 hr block of time, the result (73.1 bird-min/hr, SD = 4.1) was similar to the 1995-1996 values (65.8 and 69.1 bird-min/hr, respectively).

(Duration of Foraging Trips) -- During the nestling period, murre foraging trips averaged 157.4 min (SD = 118.7; Fig. 14). This result was not significantly different from the 1995 and 1996 values (157.7 and 170.6 min, respectively). The frequency of trips between 0-2 hr and 2-4 hr did differ; there were fewer shorter trips in 1996 than in 1995 ($X^2 = 9.02$, $P = 0.003$) and 1997 ($X^2 = 11.17$, $P = 0.001$).

Kittiwakes: *(Nest Attendance)* -- Single chicks were left alone an average of 9.0 min/hr (bird-min/hr = 50.6; SD = 15.3; Fig. 13b) and 2-chick nests were unattended for 17.2 min/nest/hr (42.8 bird-min/nest/hr; SD = 22.3). During the 0700-1959 hr block of time, results for 1- and 2-chick nests were 50.9 (SD = 14.9) and 43.6 (SD = 21.4) bird-min/nest/hr, respectively. Results for 1-chick nests were significantly lower than 1995 and 1996 values (57.1 and 57.7, respectively; $P = 0.039$ and 0.01). Two-chick nest results followed a similar among-year pattern (1995: 55.3 bird-min; 1996: 54.6; 1997: 43.6, SD = 4.8) but these differences were not significant.

(Duration of Foraging Trips)-- Kittiwake foraging trips averaged 332.1 min (SD = 159.3 min, Fig. 15). This result was similar to the 1996 value (325.9 min) and significantly longer than the 1995 results (236.6 min; $P = 0.045$).

Population Counts

Murres: Counts of murres on the productivity plots averaged 436 birds (SD = 20.9). This was significantly higher than the 1995 and 1996 counts (392 and 406 birds, $P < 0.001$ and = 0.016, respectively) but similar to the 1993 and 1994 values (411 and 429 birds, respectively).

Kittiwakes: Kittiwake counts on the 4 productivity plots that could be compared among all years averaged 196 birds (SD = 11.2). This was similar to 1994-1996 averages (192, 201, and 183, respectively. Counts in each of these years were higher than counts made in 1993 (average = 120; $P < 0.001$ in each case).

Puffins: The number of occupied puffin burrows on the 3 growth rate study plots and group of 4 transects was similar during 1995-1997 (125, 142, and 127, respectively).

Sea Temperature

During each of the 1996-1997 fields seasons, sea temperature gradually warmed and exhibited warm pulses that lasted about 5 days-1 month (Fig. 16). While the baseline temperature was similar between years, pulses in 1997 were warmer and of longer duration than in 1996. These data will be analyzed in the final report.

DISCUSSION

During the first 3 years of this Project there was a lack of concordance among the 3 study species in several breeding parameters. Results differed not only between the diving and surface feeding species but also between the 2 divers.

Productivity: Murres maintained high productivity annually, but kittiwake productivity was relatively low in 1997 and puffin productivity was relatively low in 1996-1997.

Nesting Chronology: While mean hatch dates of puffins varied by only about 5 days during 1994-1997, kittiwake nesting was about 10 days later in 1997 than in the previous year. Kittiwake chronology appeared to be correlated with productivity: when productivity was low, nesting was late.

Since 1993, murres have hatched 2-5 days earlier each year, and the timing of nesting in 1993 was earlier than during 1991-1992 studies. Because this annual progression has been remarkably regular, changes in food supply may not explain the pattern. Another possible explanation is increasing age and experience of the breeding birds. De Forest and Gaston (1996) showed that within breeding seasons, pairs of thick-billed murres that included 1 or 2 young birds laid eggs later than pairs of older birds. Gradual colony-wide increases in age and experience would follow a large mortality event, such as the *Exxon Valdez* oil spill or a starvation event.

Chick Growth Rate: Sea-going murre chicks were about 5% heavier in 1997 than in 1996, a difference that was significant because of the large sample of chicks. We did not find similar significant differences in some of the other murre parameters, possibly because of smaller sample sizes, particularly before 1997.

Despite a drop in kittiwake productivity from 1995-1996 to 1997, chick growth rate did not significantly change. Two possible explanations for the lack of association between chick growth and productivity are: (1) low productivity in 1997 may have been caused by lack of food only early in the season, before chick measurements began, so that growth of the surviving chicks was not affected; and (2) brood reduction in 1997 may have boosted growth rates of surviving chicks.

Puffin chick growth rate varied significantly among years. These changes generally followed productivity and meal size results.

Chick Diet: Capelin and Pacific sand lance were the largest component of chick diets in all 3 species during all 3 years. Murre chicks were fed capelin almost exclusively. The diet of kittiwake chicks varied among years; in 1995 chicks were fed mainly capelin but in 1996-1997 they were fed mainly Pacific sand lance. The diet of tufted puffin chicks did not have a dominant component; they were fed near-equal shares of capelin, Pacific sand lance, and pollock in 1996-1997. This combination made up about 80% of the diet. The 1995 diet was similar to that of the other years, except that the proportion of Pacific sand lance was lower and prowfish made up about a quarter of the diet. Prowfish are low in energy content (Anthony 1997) and are unlikely to have supported growth rates as high as Pacific sand lance would have; rather, it is likely that the greater meal size in 1995, or more frequent chick feeding (this parameter was not measured in 1995) supported the higher growth rate that year.

Chick Provisioning Rate: Chick feeding frequency in murres was similar among the 3 years. For kittiwakes, feeding rates in 2-chick nests were higher than at 1-chick nests during all 3 years. Feeding rates in 1-chick nests followed the pattern of productivity: in 1997 rates were lower than in 1995 and 1996. Puffin feeding frequency was highly variable among days; therefore the sample of 2 days in 1996 was probably inadequate to represent conditions that year. In 1998 we will attempt to use a time-lapse video system to increase the sample size for puffin chick-feeding rates.

Nest Attendance: For murres, mean nest attendance during both the incubation and nestling periods was similar in 1995-1997. A larger sample, or a large change in food supply, may cause this parameter to change in accordance with other parameters.

Kittiwake attendance during the nestling period was lower at 1-chick nests than at 2-chick nests, each year, as was feeding frequency. Attendance was lower and more variable in the year of low productivity (1997) than during 1995-1996.

Foraging Trip Duration: The frequency distribution of the duration of foraging trips has differed among years while mean trip duration (the annual index) has not. An improved annual index that accounts for frequency distribution would be a more sensitive measure.

We have not been able to compare the frequency distribution of kittiwake foraging trips because the data are more sparse and spread across more blocks of time. We are investigating ways to increase the sampling size of kittiwake nesting activities.

ACKNOWLEDGMENTS

We thank Stephanie Zuniga, Lena Wilensky, John Hoover, and Margaret Blanding for making the 1997 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 Kevin Bell, FWS R/V *Tiglax*, for transporting us to the Barren Islands in June, and Captain Roark Brown, M/V *Sourdough* for transporting us back to Homer in September. Trina Fellows and Kris Thorsrud, 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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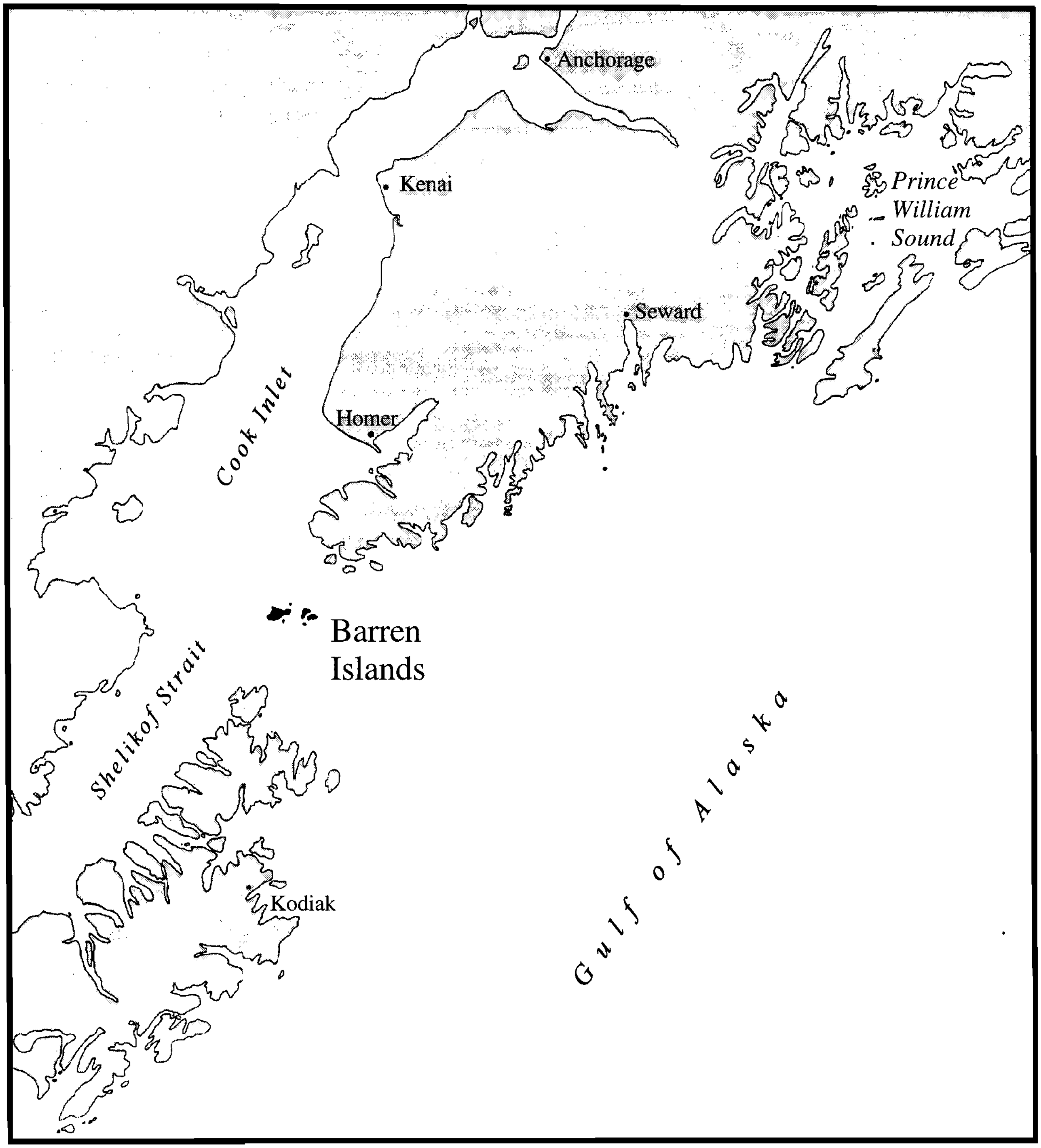


Figure 1. Location of the Barren Islands, Alaska.

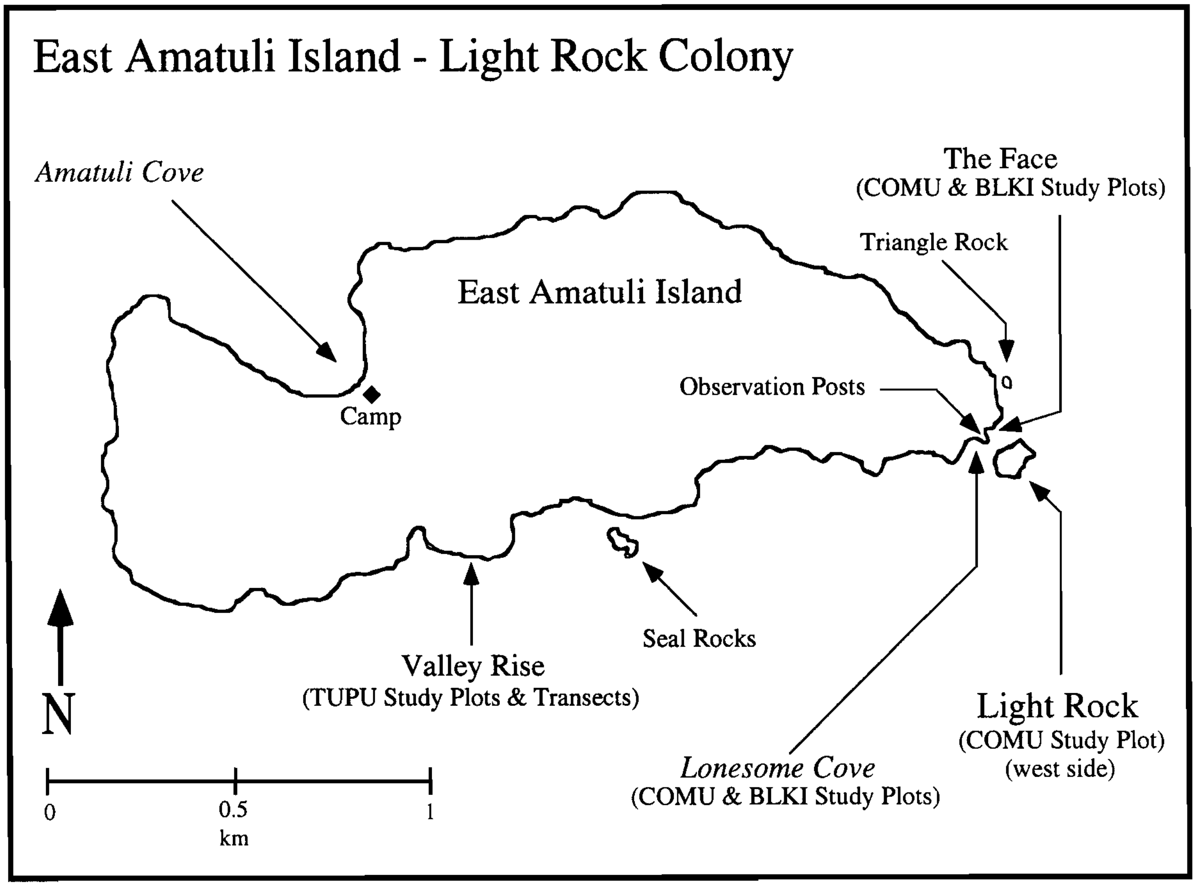


Figure 2. The East Amatuli Island study area showing the general locations of the common murre (COMU), black-legged kittiwake (BLKI), and tufted puffin (TUPU) study sites.

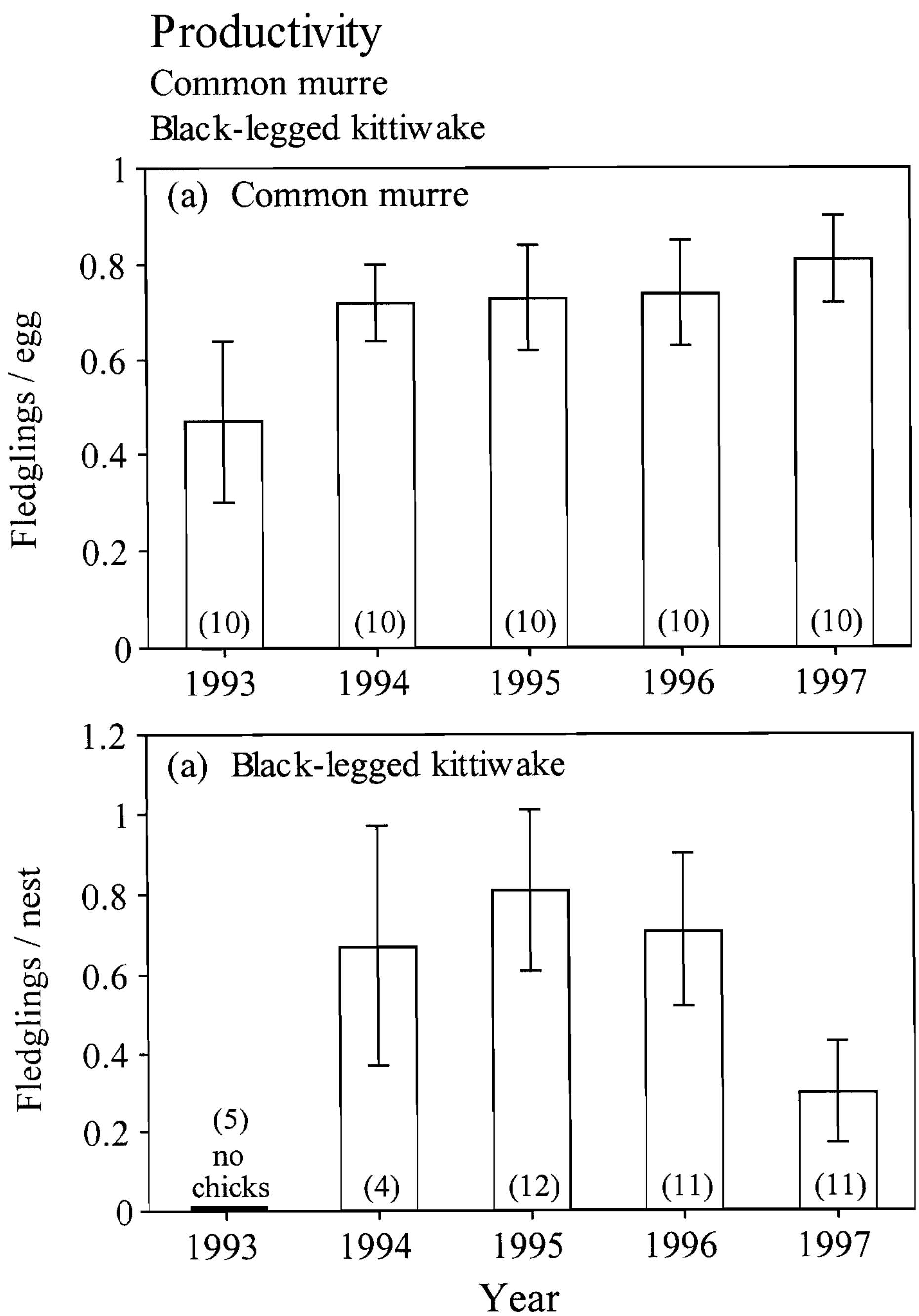


Figure 3. Productivity of (a) common murres and (b) black-legged kittiwakes at East Amatuli Island, Barren Islands, Alaska, 1993-1997. Number of plots in parentheses; error bars = standard deviation.

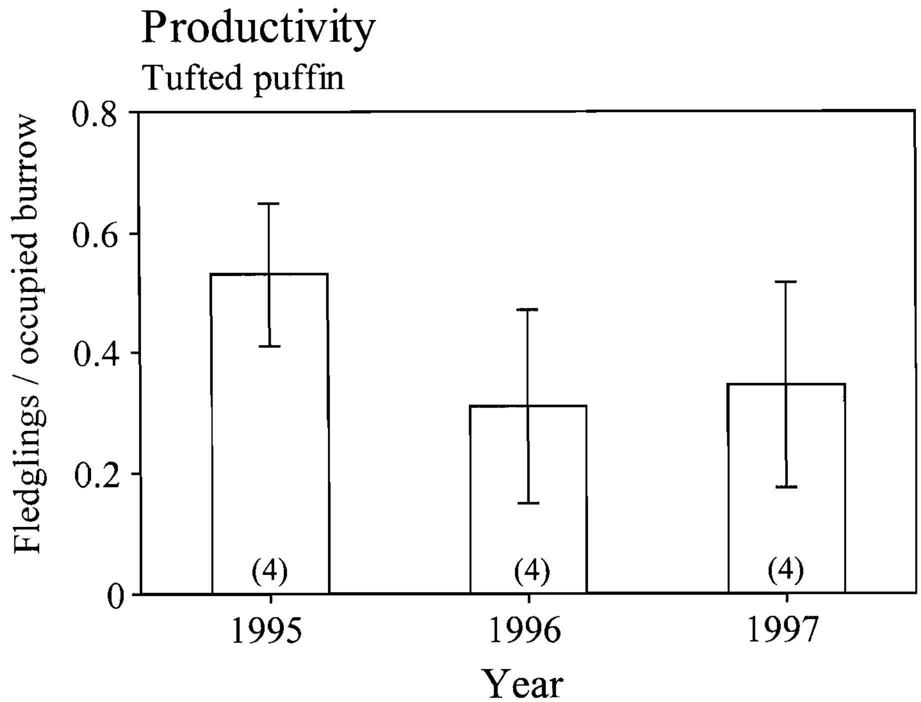
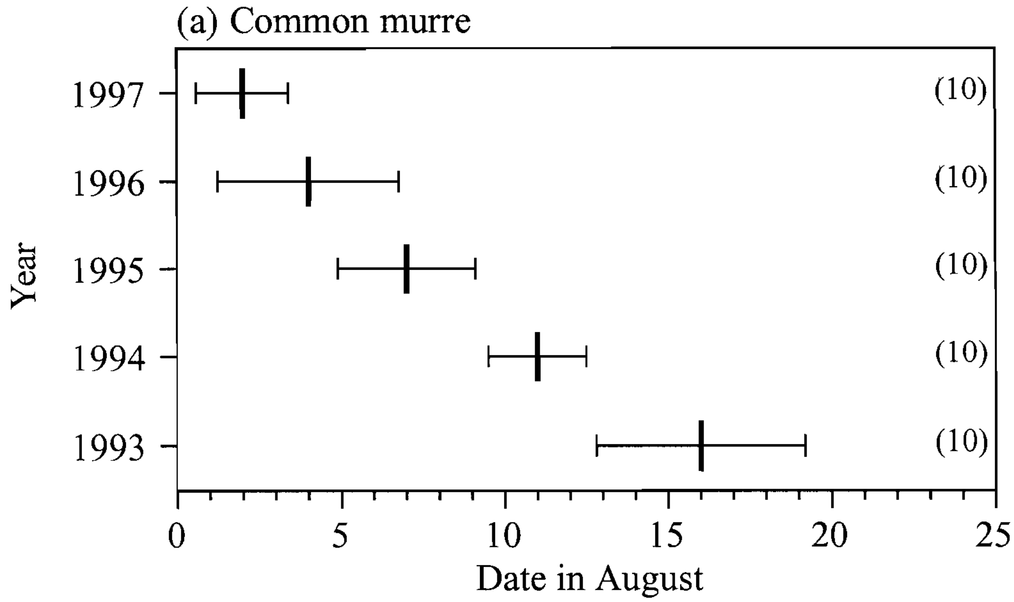


Figure 4. Productivity of tufted puffins at East Amatuli Island, Barren Islands, Alaska, 1993-1997. Number of plots in parentheses; error bars = standard deviation.

Nesting chronology



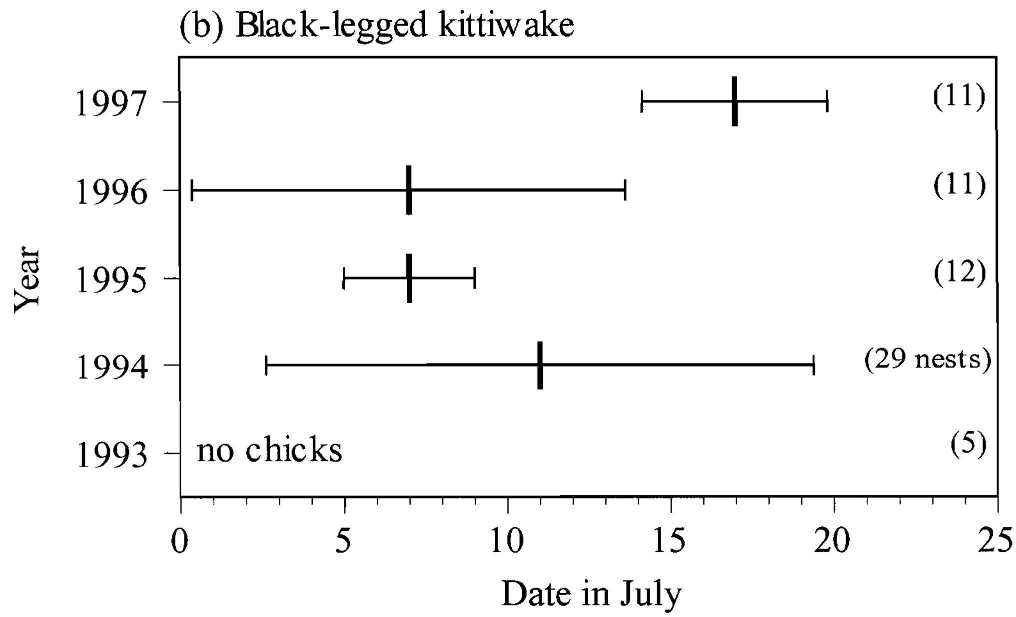


Figure 5. Nesting chronology of (a) common murres and (b) black-legged kittiwakes at East Amatuli Island, Alaska, 1993-1997. Number of plots in parentheses; error bars = standard deviation.

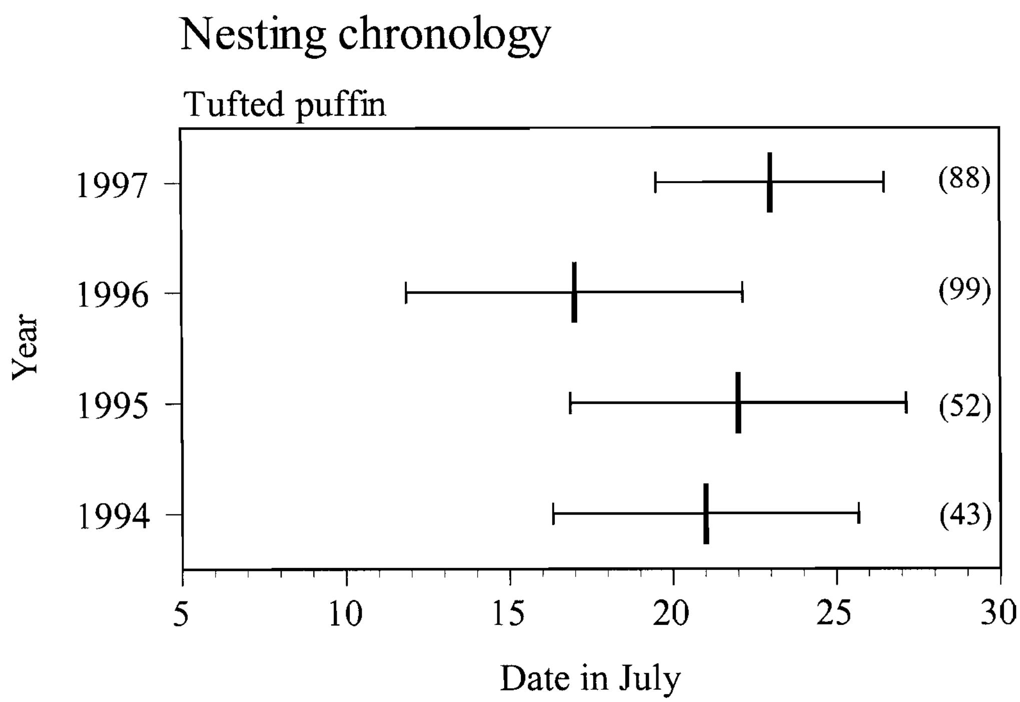


Figure 6. Nesting chronology of tufted puffins at East Amatuli Island, Alaska, 1994-1997. Number of chicks in parentheses; error bars = standard deviation.

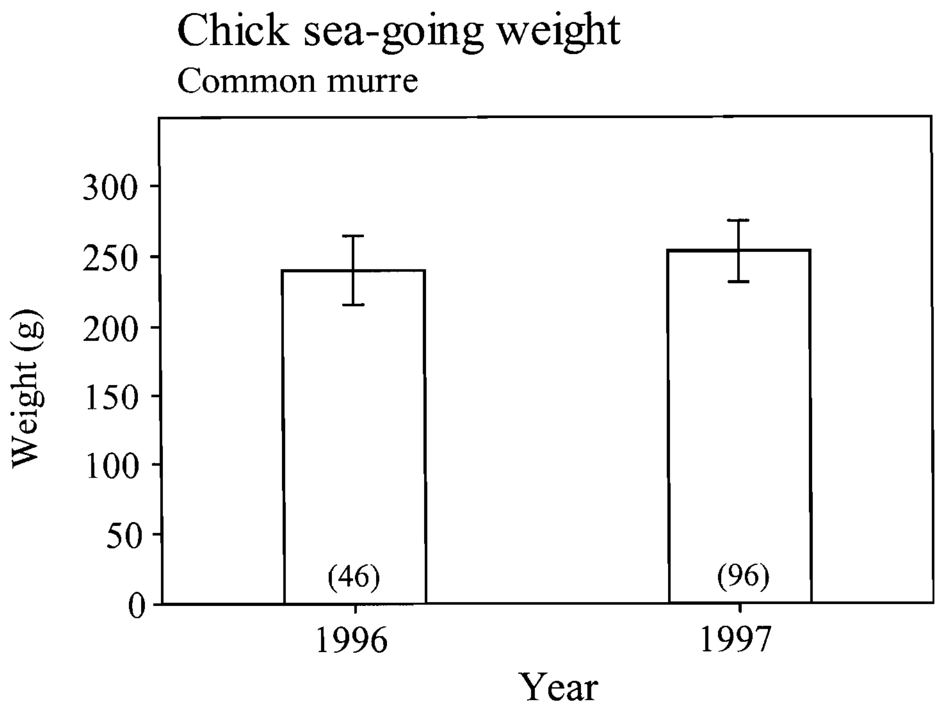


Figure 7. Sea-going weight of murre chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1997. Number of chicks in parentheses; error bars = standard deviation.

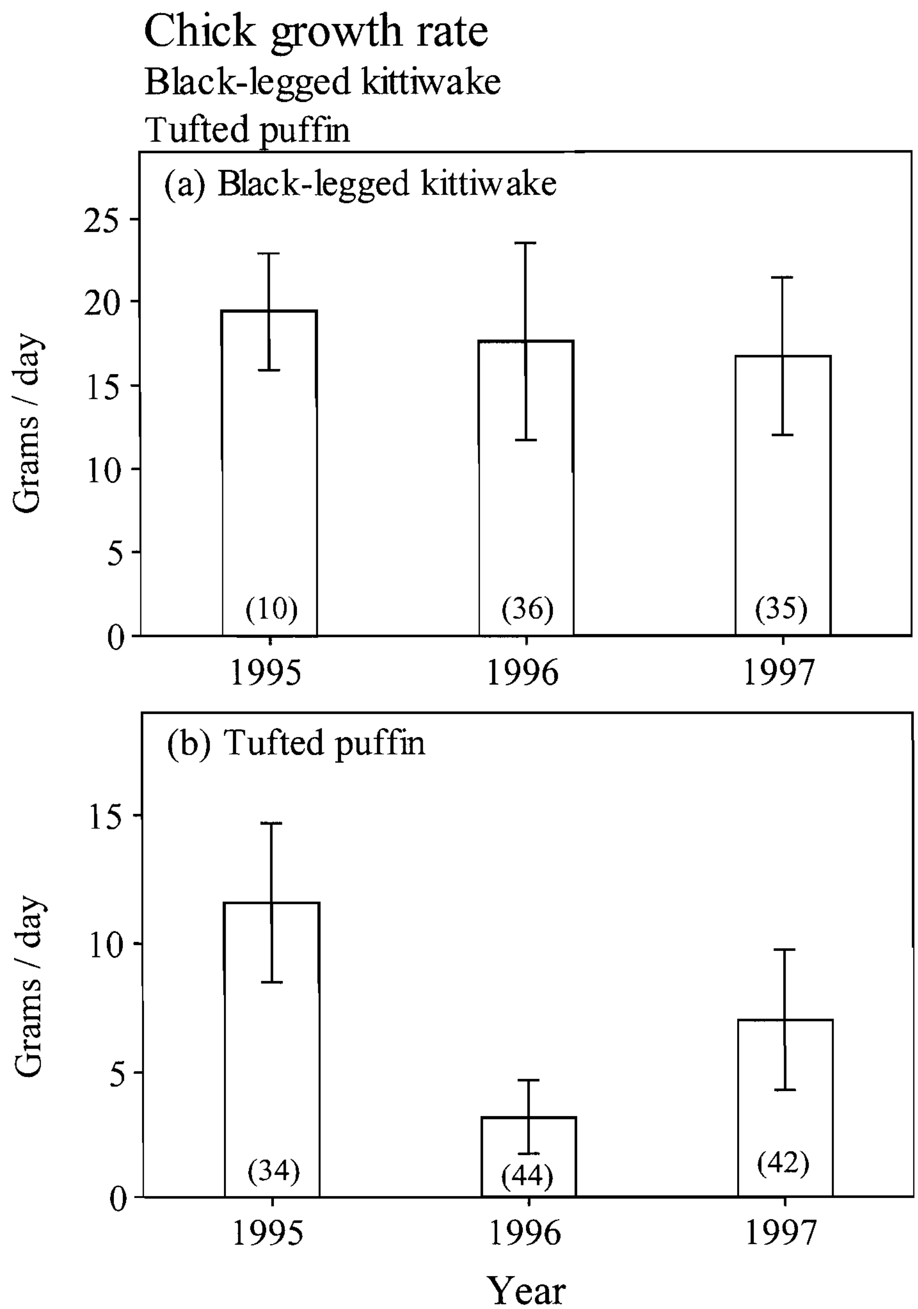
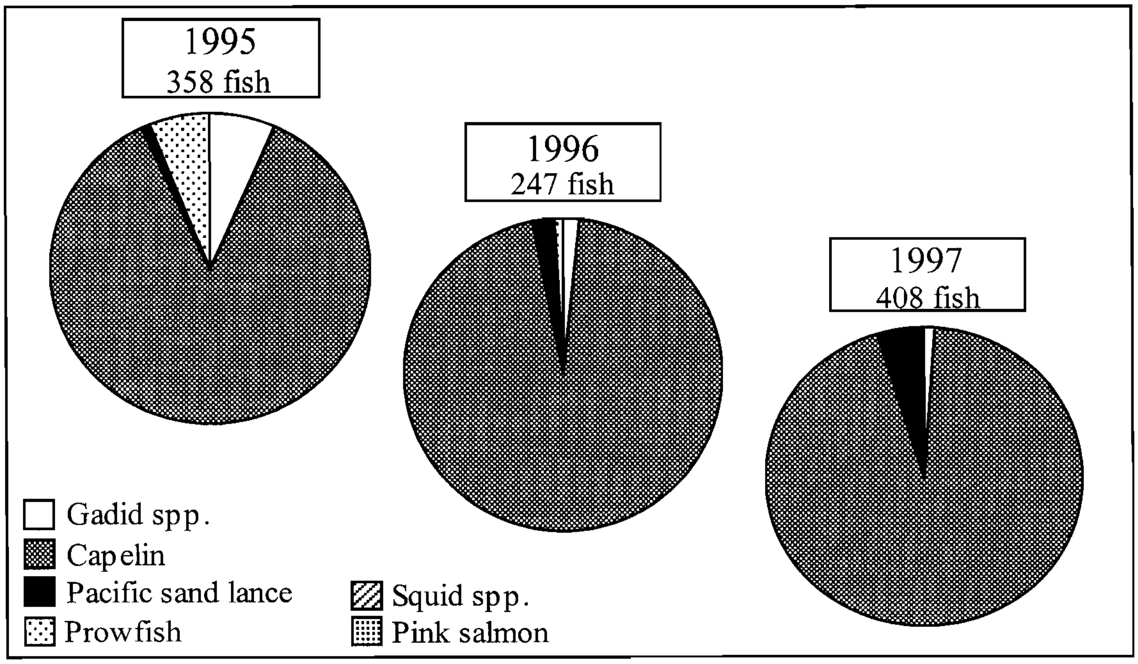


Figure 8. Growth rate of (a) black-legged kittiwake chicks and (b) tufted puffin chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1997. Number of chicks in parentheses; error bars = standard deviation.

Chick diet

(a) Common murre



(a) Black-legged kittiwake

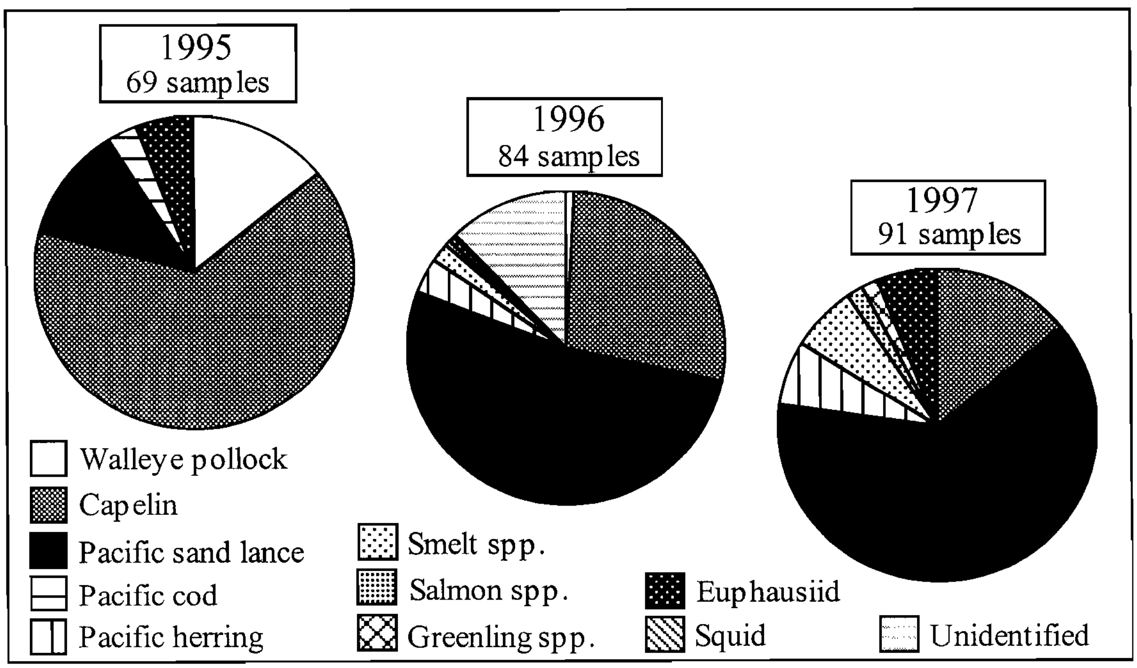


Figure 9. Types of prey fed to (a) common murre and (b) black-legged kittiwake chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1997. Composition of prey by (a) number and (b) weight.

Chick diet

Tufted puffin

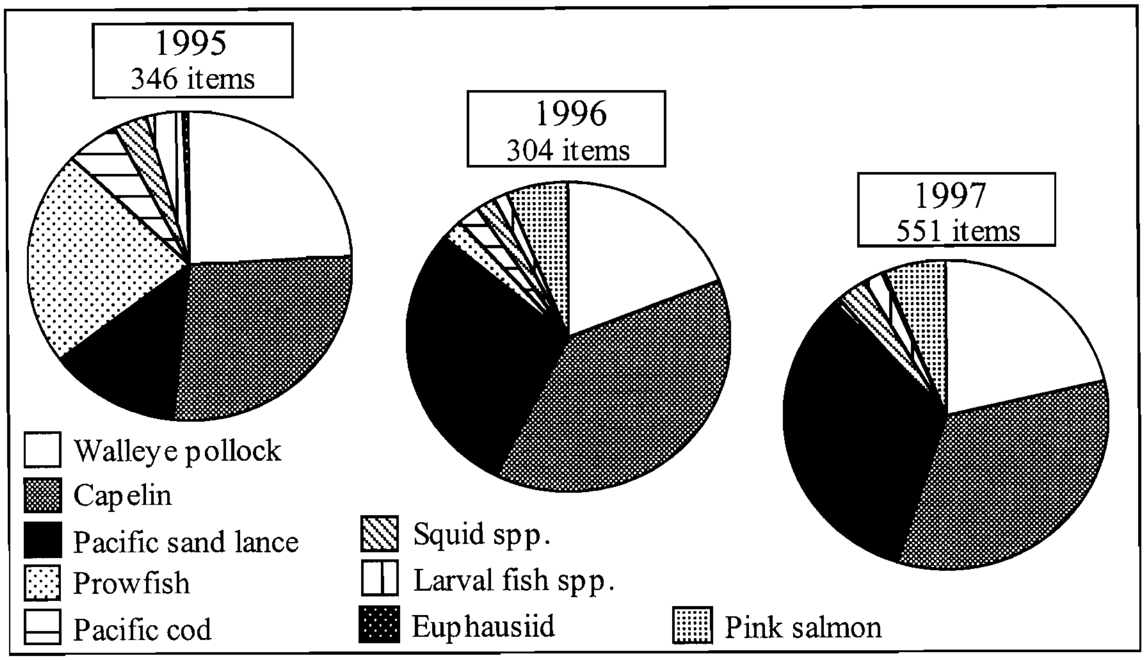


Figure 10. Types of prey fed to tufted puffin chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1997. Composition of prey by weight.

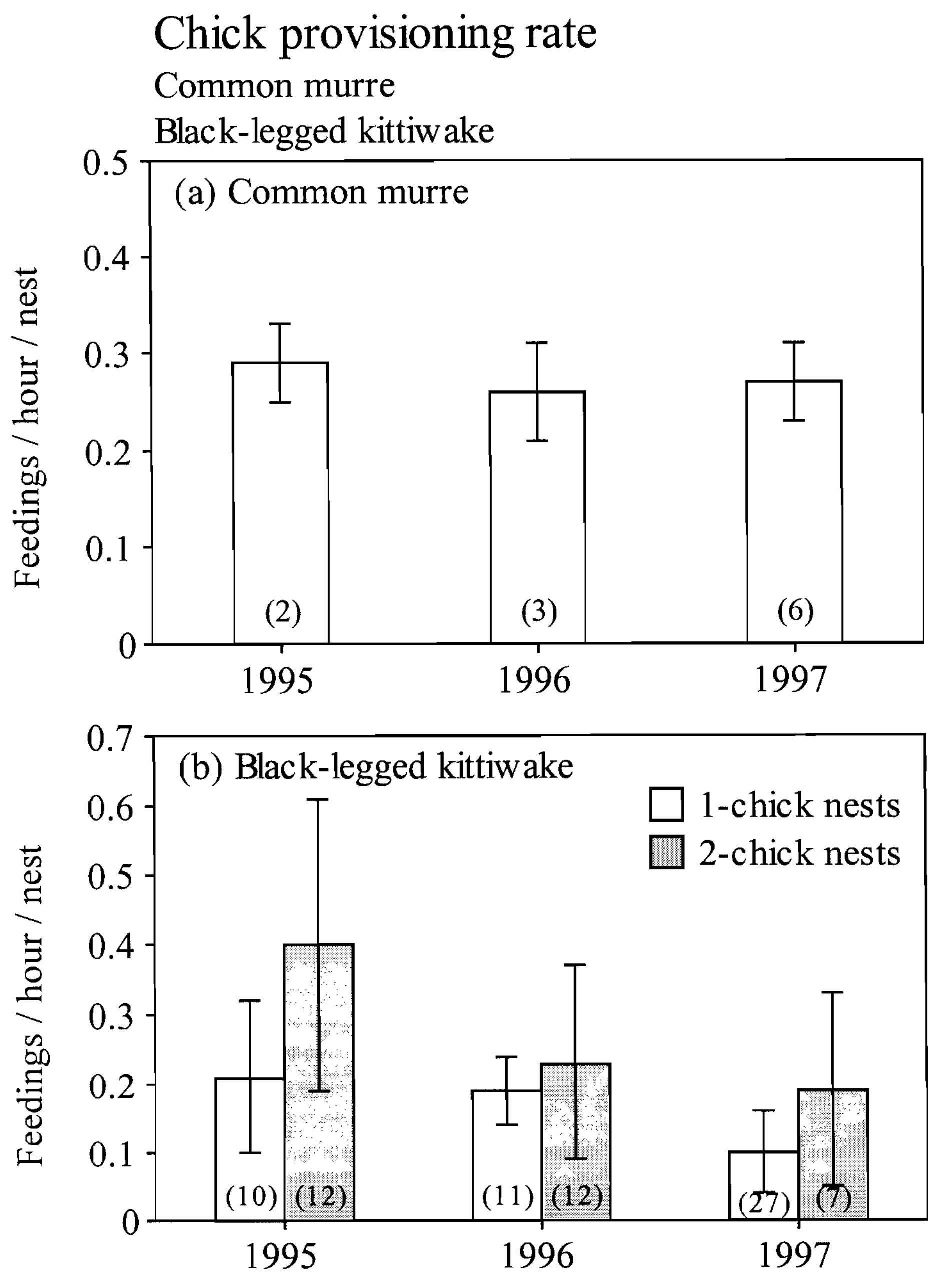


Figure 11. Provisioning rate of (a) common murre (number of days in parentheses) and (b) black-legged kittiwake (number of nest-days in parentheses) chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1997. Error bars = standard deviation.

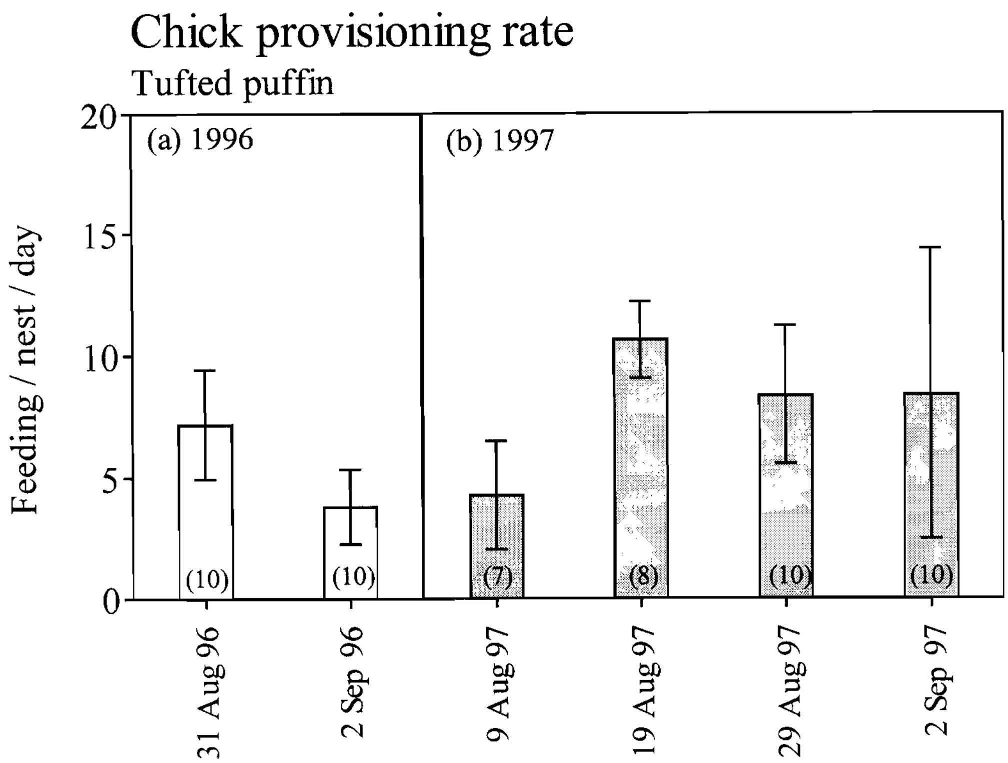


Figure 12. Provisioning rate of tufted puffin chicks at East Amatuli Island, Barren Islands, Alaska during (a) 1996 and (b) 1997. Number of nests in parentheses; error bars = standard deviation.

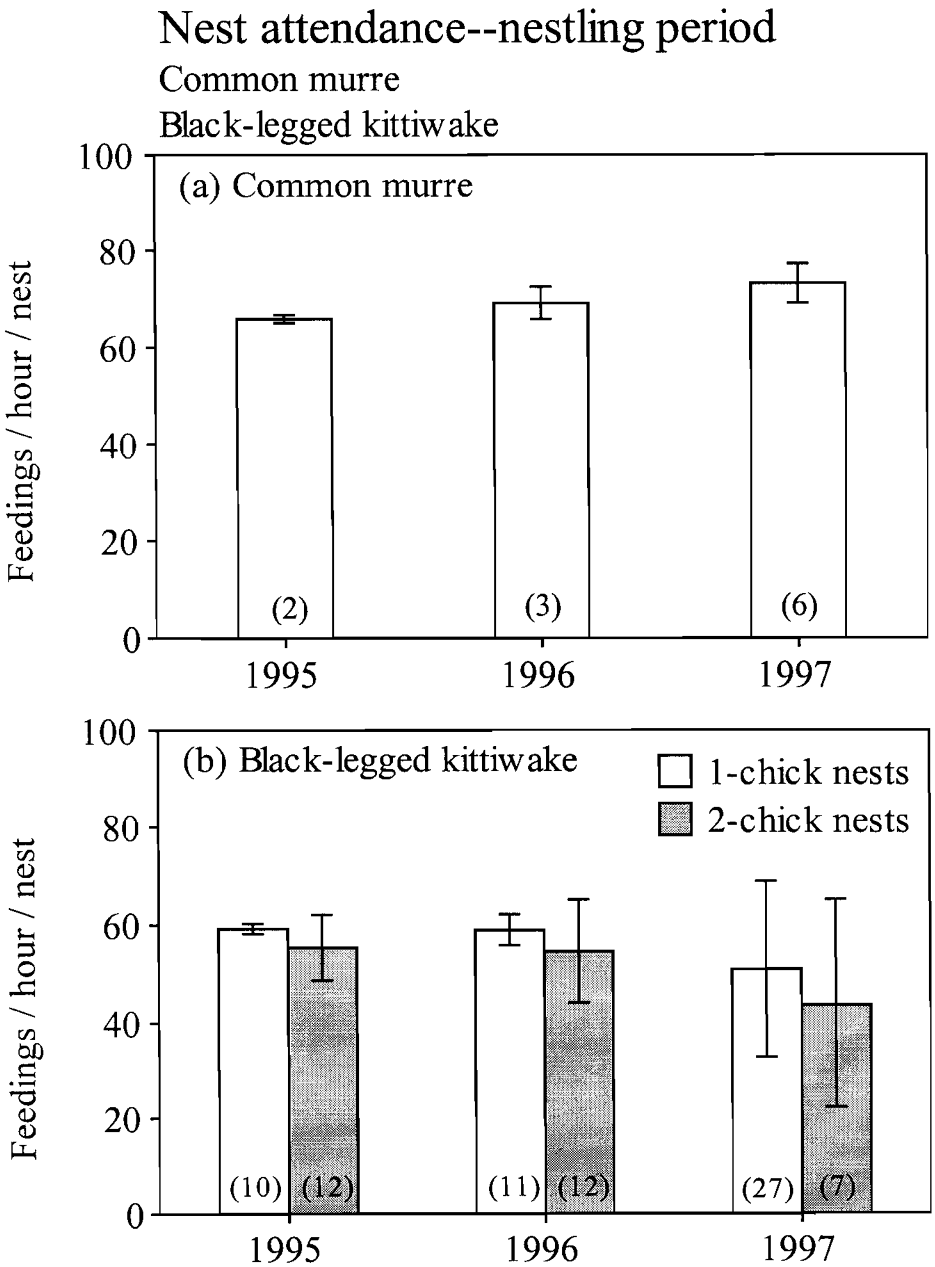


Figure 13. Number of minutes per hour spent at nests by (a) common murre (number of days in parentheses) and (b) black-legged kittiwake (number of nest-days in parentheses) adults during the chick-rearing period at East Amatuli Island, Barren Islands, Alaska, 1995-1997. Error bars = standard deviation.

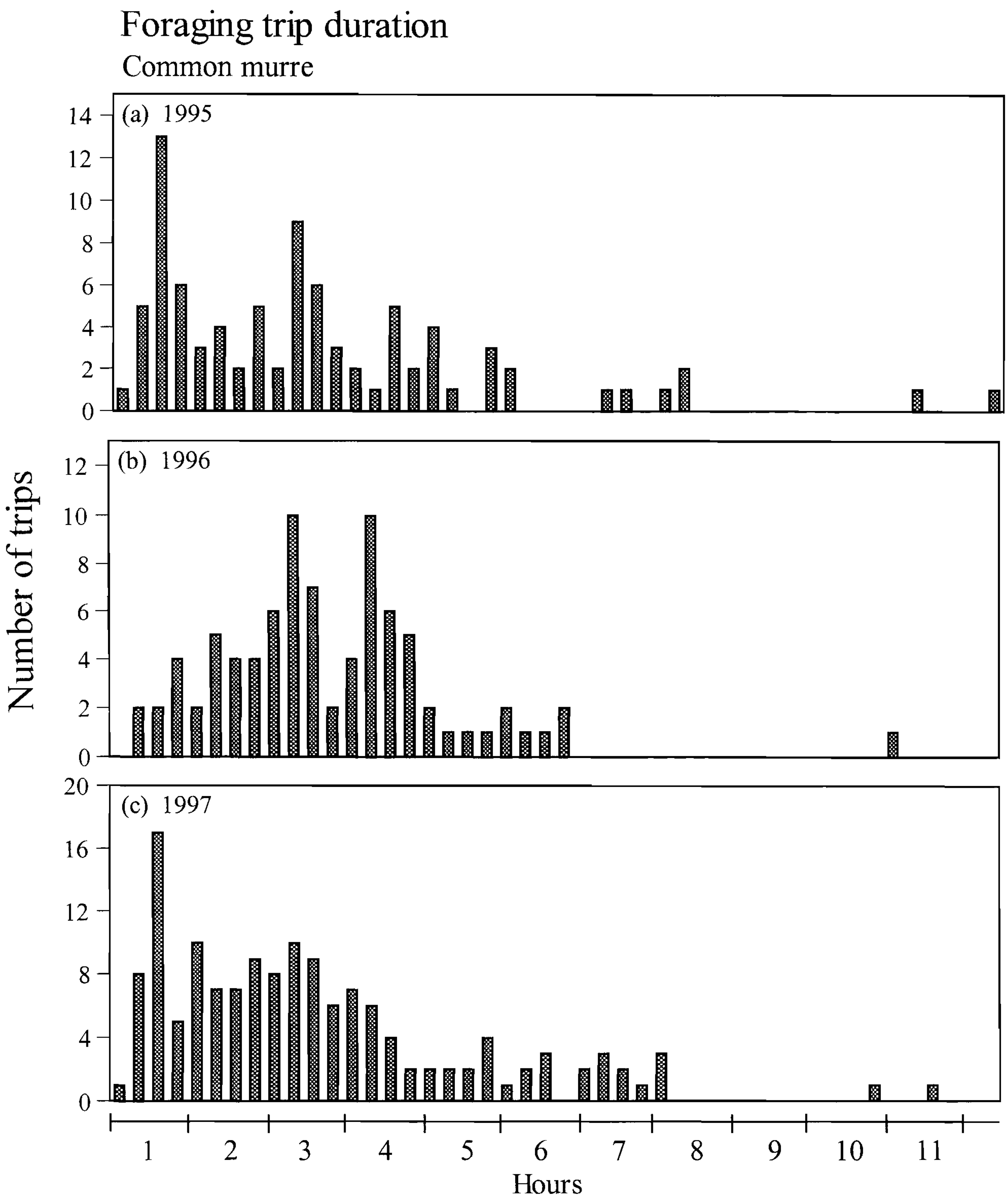


Figure 14. Duration of foraging trips by common murres at East Amatuli Island, Barren Islands, Alaska during (a) 1995, (b) 1996, and (c) 1997.

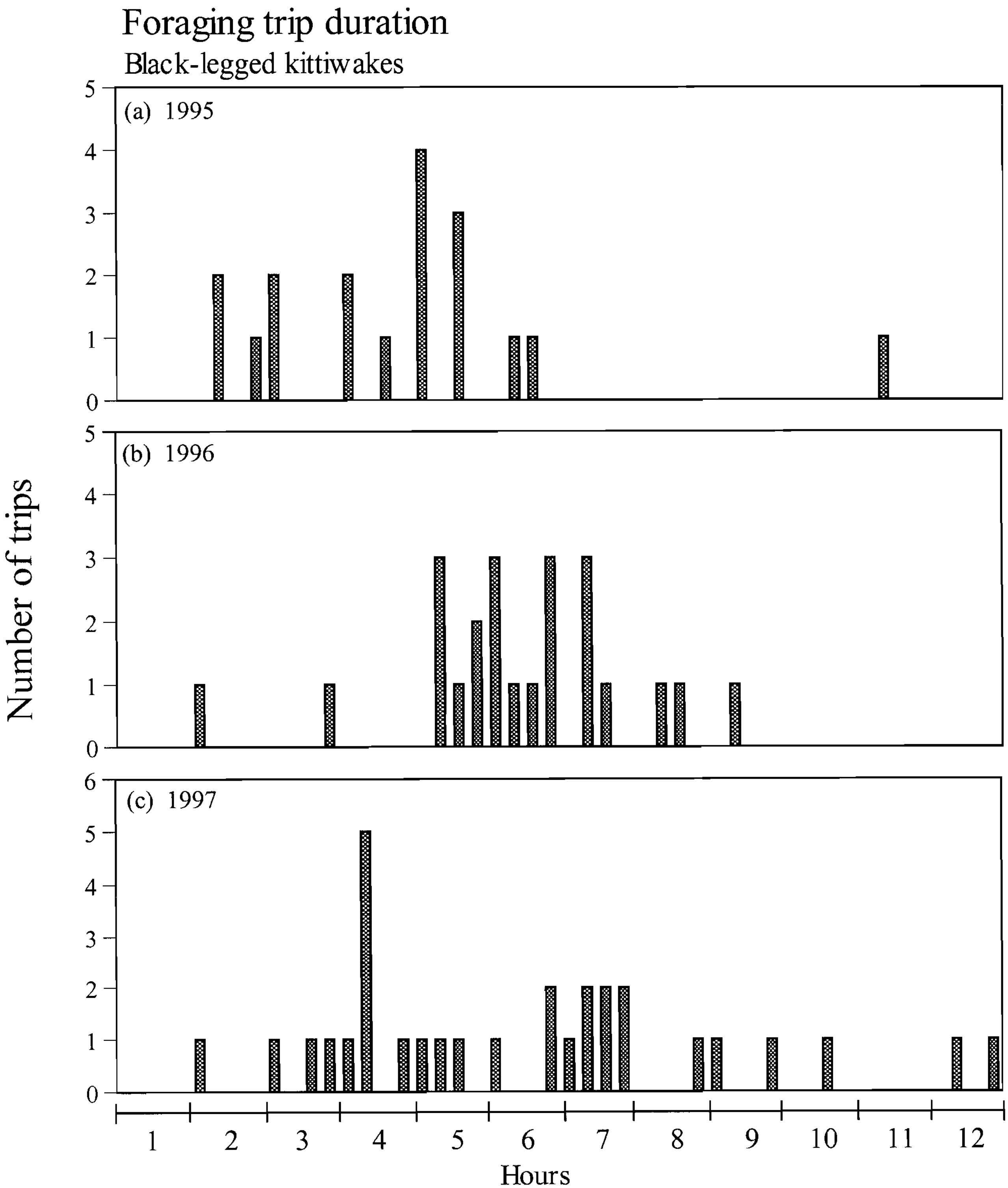


Figure 15. Duration of foraging trips by black-legged kittiwakes at East Amatuli Island, Barren Islands, Alaska during (a) 1995, (b) 1996, and (c) 1997.

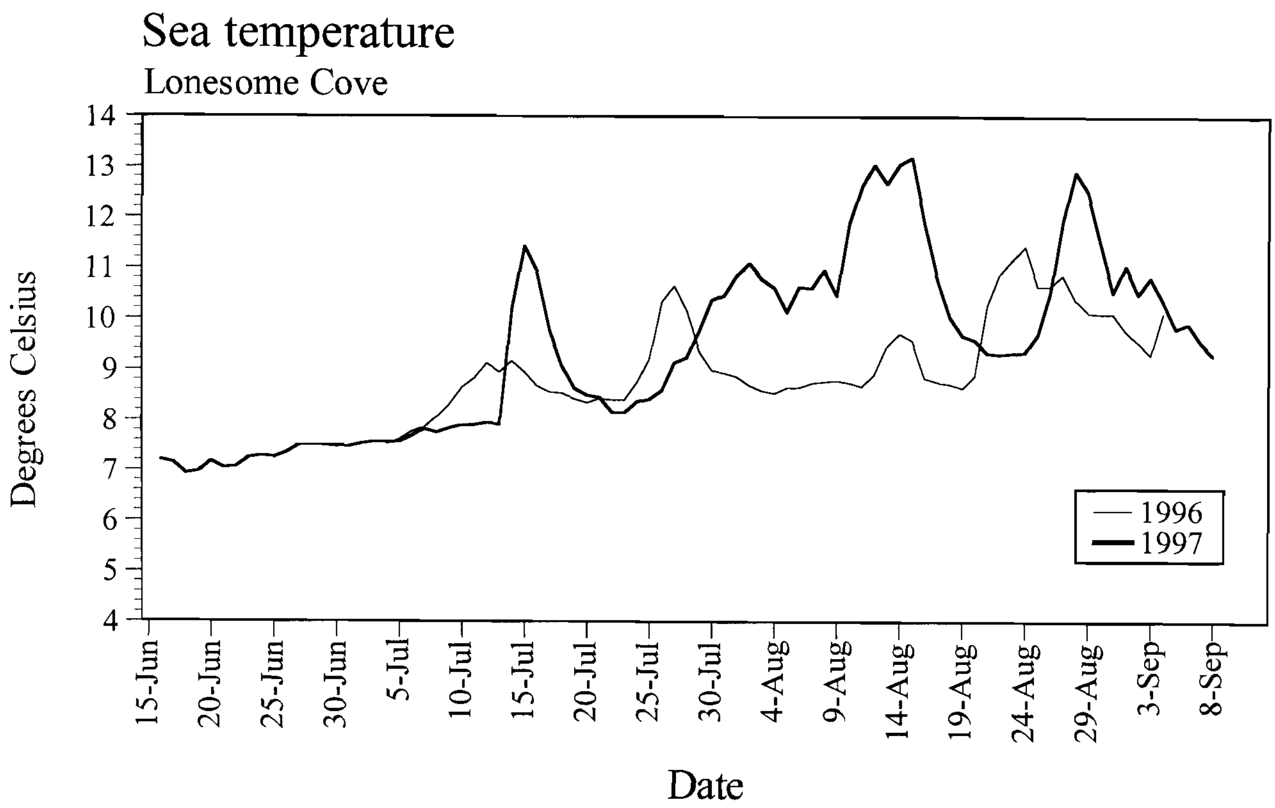


Figure 16. Sea temperature at Lonesome Cove, East Amatuli Island, Barren Islands, Alaska during 1996-1997 field seasons. Daily averages of measurments taken at 12-minute intervals.