

*Exxon Valdez* Oil Spill  
Restoration Project Annual Report

Barren Islands Seabird Studies, 1998

Restoration Project 98163J  
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, 1998

### Restoration Project 98163J Annual Report

**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), 1997 (Project 97163J; see Roseneau, *et al.* 1998), and 1998 (Project 98163J).

**Abstract:** We monitored breeding and foraging parameters of common murres, black-legged kittiwakes, and tufted puffins at the Barren Islands, Alaska, and compared the results with those from studies in 1995-1997. Breeding parameters included productivity, nesting chronology, and chick growth rate; foraging parameters were adult nest attendance, foraging trip duration, chick feeding frequency, and chick meal size. We monitored the prey base by examining chick diets and by beach seining.

During 1998 nesting was late and productivity declined for all three species. Many murres lost first eggs and some relaid. Kittiwakes produced few eggs. Nest attendance by murres during the incubation period was lower than during 1996-1997. Attendance during the nestling period by murres and kittiwakes was similar to that of other years, and kittiwake chicks grew at normal rates. Puffin chicks grew slowly.

The Gulf of Alaska warmed during the late winter-early spring of 1998 and many murres died in the gulf during this period. Foraging conditions may have been poor before the breeding season and during the early part of the nesting period.

Murre chicks were fed almost exclusively capelin, as in 1995-1997. Kittiwake chick diet was similar to that of 1996-1997; it was composed mainly of sand lance and capelin. The proportion of capelin in puffin chick diets increased during 1995-1998.

Results presented in this report are preliminary. Data will be analyzed in greater detail in the Final Report.

**Key Words:** Barren Islands, black-legged kittiwake, common murre, East Amatuli Island, *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 help determine 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 (*Rissa tridactyla*), common murre (*Uria aalge*), and tufted puffins (*Fratercula cirrhata*) 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; Manuwal 1978, 1980; Manuwal 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, 1998). 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 1998 we monitored murre, kittiwake, and puffin productivity and nesting chronology; type and amount of prey fed to chicks; 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. We also made 30 beach seine sets during the 1998 field season, using methods employed by the Gull and Chisik island studies (Project 98163M).

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 1995-1997 APEX Barren Islands seabird studies (see Roseneau *et al.* 1996a, 1997, 1998). Information was shared with other APEX investigators for among-colony comparisons (e.g., Projects 98163E, 98163M, and 98163G).

## **OBJECTIVES**

Objectives of the 1998 Barren Islands seabird studies were to:

1. Determine the productivity of common murres (fledglings/eggs laid), black-legged kittiwakes (fledglings/nests), 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 Project 97163M methods.
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 10 June-12 September by a team of 4-5 people. Team members 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 10 East Amatuli Island - Light Rock plots established for this purpose in 1993 (see Roseneau *et al.* 1995). Plots contained 19-42 nest sites (sites with eggs) each (1998 nest site total = 286) 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. Plot checks consisted of noting whether nests contained eggs, chicks, or adults in incubation or brooding posture, and counting adults. Plots were checked at least 35 times during 13 June - 4 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/nest sites. Hatching and fledging success were also calculated. Differences among 1993-1998 results were tested by Analysis of Variance (ANOVA). *Additional information on APEX murre monitoring methods is provided in Appendix 1 of Roseneau et al. 1997.*

**Kittiwakes:** Kittiwake productivity data were collected from 11 East Amatuli Island plots (5 were established 1993 and 6 in 1995) located on the headlands that contained the murre productivity plots. Plots contained 13-27 nests (1998 nest total = 210; 60 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. Plots were checked at least 35 times during 13 June - 4 September, from the start of egg-laying until most chicks had fledged. Plots were treated as sample units and productivity was calculated as fledglings/nests. Differences among 1993-1998 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<sup>2</sup> 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 30 July - 4 August, when most chicks were about 1 week old. A 35-cm-long flexible scoop was used to help search burrows for nestlings. After the initial visit, burrows containing chicks were checked every 5 days until 11 September. Active burrows, inactive burrows, and nestlings in the 4 transects were counted on 03 September, just prior to fledging.

Data from burrows in the plots and transects were pooled for analysis. Productivity was calculated as: (number of active burrows containing chicks just prior to fledging) / (number of active burrows). The differences among 1995-1998 results were compared with Pearson's Chi-square test.



Hatching success was measured in 5 plots that contained a total of 55 burrows with eggs. Burrows were checked 3 times during the nesting season: just before hatching, just after hatching, and just before most chicks fledged. We calculated hatching success for each plot and then calculated the mean among plots.

### **Nesting Chronology**

**Murres:** Median hatch date was the measure of murre nesting chronology (see Roseneau *et al.* 1995, 1996a,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-egg-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, 1996a,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 1993-1998 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). Because few nests had fledglings in 1998, we grouped some plots to increase the number of nests in the samples. The resulting 6 plots were treated as sample units for 1998; differences among 1994-1998 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 estimate the age at first wing measurement of each of 41 growth study chicks, and then calculated hatch dates. The chicks' mean hatch date was the index for the season; differences among 1994-1998 results were tested by ANOVA.

### **Chick Growth Rate**

**Murres:** During 1996 and 1997 we were able to dip-net and measure a sample of murre chicks as they left the cliffs. Because sea conditions were rough during most of the 1998 fledging period, we were able to capture only 3 chicks.

**Kittiwakes:** Fourteen kittiwake chicks from 13 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 at a younger age (6 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;  $n = 13$ ) and 'B' chicks (the second-hatched chicks in 2-chick nests;  $n = 1$ ). Using chicks as sample units, differences among 1995-1997 'A' chick growth rates were tested by ANOVA.

**Puffins:** Thirty-eight puffin chicks in the 3 growth study plots and the FWS transects (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. Among-year differences in growth rate during 1995-1998 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 1-10 meters from nest sites. On 9 days during 9 August - 8 September, 408 prey items were observed. Four hundred-four (99%) 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 (*Mallotus villosus*), Pacific sand lance (*Ammodytes hexapterus*), Cods (Gadidae), prowfish (*Zapora silenus*), pink salmon (*Oncorhynchus gorbuscha*), and squid (Cephalopoda).

**Kittiwakes:** Samples of prey brought to kittiwake nestlings were obtained from growth study chicks ( $n = 24$  samples), incubating adults ( $n = 10$ ), and adults with chicks ( $n = 14$ ) when they regurgitated while being handled. Chick regurgitations were obtained on 9 days during 18 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 (*Clupea harengus pallasii*), 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). Forty-one bill loads containing 77 prey items were obtained on 7 days at East Amatuli Island and 4 at West Amatuli Island during 13 August - 8 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, 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:** We used the weight of regurgitated samples (see Chick Diet, above) as the measure of kittiwake meal size. 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 ( $n = 7$ ). Using regurgitations as sample units, we tested differences among 1995-1998 results by ANOVA.

**Puffins:** We used the average weight of screen samples ( $n = 41$ ; see Chick Diet, above) as the index for puffin chick meal size. Using each screened bill-loads as sample units, differences among 1995-1998 results were tested by ANOVA.

### **Chick Provisioning Rate**

**Murres:** Murre chick provisioning rate data were collected on 8 days (9, 11, 14, 15, 20, 22, 27, and 30 Aug) from a plot of 9 nest sites near one of the productivity observation posts. Activities at the nests 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. 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. During tape playback it appeared that all recordings started before birds began delivering food to chicks 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 from the two methods did not differ for feeding frequency, attendance, and times of day when nest activities were first and last visible.

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 4 study years were 0700-1959 hr. Results from this interval were tested for among-year differences with ANOVA.

**Kittiwakes:** Data on kittiwake chick provisioning rate were collected on 28 July and 3, 11, and 14 August from nests containing 10- to 32-day-old chicks. A new plot of 5-7 nests was used each day. At least one adult from each nest was marked with a magic marker and/or leg-banded. Nests were observed with binoculars during 0600-2300 hr. We recorded adult arrival and departure times, and the times that chicks were fed.

Only the first regurgitation to a chick after a parent returned from a trip was scored as a 'feeding', and then only if it occurred within 30 min of an adult's return from a trip of at least 30 min duration. In accordance with Project 97163E protocol, we used the number of feedings per nest per day as the value for comparison among years and project sites. Because there were significant differences in feeding frequency between 1- and 2-chick nests ( $n = 17$  and  $5$ , respectively), we analyzed data from the 2 nest types separately.

In 1995 observations ended at 1959 hr and in 1996 observations began at 0700 hr (instead of encompassing all daylight hours as in 1997-1998). Results from the 4 study years were compared using the block of time common to all years: 0700-1959 hr. Differences among 1995-1998 results were tested with ANOVA.

**Puffins:** We collected data to measure provisioning rate of tufted puffin chicks by observing adults returning to 8 marked nest burrows in one of the chick growth rate study plots during 4 all-day watches (0600-2230 hr on 19, 23, and 24 Aug and 0600-2200 hr on 30 Aug). 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 20 m from the burrows. We recorded the times adult returned and departed, and whether returning adults carried bill loads. These observations and those made in 1996-1997 were intended as preliminary investigations of this parameter, and results will be discussed in the Final Report.

### **Activity Budgets of Adults**

**Murres:** Using data from the all-day observations during the nestling period (see Feeding Rates, above) and 9 days during the incubation period (9, 11, 13, 15, 18, 27, 29, and 31 July and 6 Aug), we calculated the amount of time adult murres spent at their nest sites. Bird-minutes/hour was used to measure 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 data from the incubation and nestling periods separately. Differences among 1995-1998 results were tested with ANOVA.

We also calculated the duration of foraging trips made by adults. Only trips that concluded with chick feedings were used in the analysis ( $n = 192$  trips). The average of all trips was used as the annual index. Differences among 1995-1998 indices were tested by ANOVA, and frequencies of trips in the first two 2-hr blocks of time (0-2 and 2-4 hr) were compared among years with Pearson's Chi-square test.

**Kittiwakes:** Using data from the all-day observations (see Feeding Rates, above), we calculated the amount of time 1, 2, and no adult kittiwakes attended each nest during the nestling period. Bird-minutes/hour was 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 were 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, each day (the 'nest-day'), and the annual index was the average of the nest-day values for the season. Differences among 1995-1998 results were tested with ANOVA.

We also calculated the duration of foraging trips made by adults. Only trips that concluded with chick feedings ( $n = 57$  trips) were used in the analysis. Mean trip time was used as the annual index. Differences among 1995-1998 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:** Murre adults were counted on the 10 productivity plots on 16 days between the peak of egg-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 1995-1997 Barren Islands APEX seabird projects (see Roseneau *et al.* 1996a, 1997). Differences among the 1993-1998 indices were tested with ANOVA.

**Kittiwakes:** Adult kittiwakes were counted on the 11 productivity plots on 21 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 1998 counts were most stable between the median hatch date and the first fledging of chicks. Because we counted kittiwakes on only 4 plots in 1993, we used these plots to compare 1993-1998 results. Differences among years were tested with ANOVA.

Individual kittiwakes and nests were counted repetitively on a larger set of plots from a boat. Results from these data and the larger set of productivity plots will be presented and discussed in the Final Report.

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

### **Sea Temperature**

We recorded sea temperature at Amatuli Cove during 11 June-8 September and at Lonesome Cove during 15 June-14 July and 2 August-7 September with Onset Optic Stowaway Temp data loggers anchored about 5 m deep (the Lonesome Cove logger failed to self-start after an in-field download on 14 July; in 1999 we will use 2 loggers at each location). Temperatures were recorded every 12 minutes. These data were graphed and will be discussed in the Final Report.

## Other Data

**Kittiwake adult body condition:** We weighed (to 1 g) adult kittiwakes and measured the length of the head-bill (to 0.1 mm), tarsus (to 0.1 mm), wing chord (to 1 mm), and 10th primary feather (to 1 mm), using APEX protocol. We measured 25 incubating adults, 24 brooding adults, and 12 adults without chicks during the nestling period. We also measured adults in 1997. Results will be presented and discussed in the Final Report.

**Beach seine sets:** We made 30 beach seine sets and processed catches according to Appendix 1 and Project 98163M protocol. Similar methods were used during 1996-1997. Results will be presented and discussed in the Final Report.

## RESULTS

### Productivity

**Murres:** Murre productivity was 0.59 fledglings/nest sites [standard deviation ( $s$ ) = 0.31; (Fig. 3a)], hatching success was 0.74 chicks/eggs ( $s$  = 0.26), and fledging success was 0.71 fledglings/chicks ( $s$  = 0.34); productivity was not significantly different from 1993-1997 values (0.47, 0.72, 0.73, 0.74, and 0.81 fledglings/nest sites, respectively).

**Kittiwakes:** Productivity of kittiwakes was very low (0.04 fledglings/nests,  $s$  = 0.06; Fig. 3b) and significantly lower than 1994-1997 values (0.67, 0.81, 0.71, and 0.29;  $P$  <0.001, <0.001, <0.001, and = 0.008, respectively), but similar to 1993, when there were no eggs or chicks on study plots.

**Puffins:** Just before fledging 0.22 ( $s$  = 0.02; Fig. 4) tufted puffin chicks/occupied burrows were found in the 3 growth rate plots and group of 4 transects. This was lower than the 1997 and 1995 values (0.34 and 0.53;  $P$  = 0.30 and <0.001) and similar to the 1996 value (0.31). Hatching success in the 5 plots established to measure this parameter was 0.34 ( $s$  = 0.20) chicks/eggs.

### Nesting Chronology

**Murres:** The median hatch date of murre chicks was 7 August ( $s$  = 2.6; Fig. 5a), 5 days later than in 1997 [2 August; this difference was marginally significant ( $P$  = 0.087)]. The 1998 date was significantly earlier than in 1993 (16 August,  $P$  <0.001) but was not different from dates in 1994-1996 (10, 8, and 4 August).

**Kittiwakes:** The median hatch date for kittiwake chicks was 28 July ( $s$  = 5.9; Fig. 5b). This was significantly later than hatch dates in 1994-1997 (11, 7, 7, and 17 July;  $P$  <0.001 in each case).

**Puffins:** The mean hatch date for puffins was 31 July ( $s$  = 3.4; Fig. 6). This was significantly later than in 1995-1997 (22, 18, and 30 July,  $P$  <0.001 in each case).

## Chick Growth Rate

**Kittiwakes:** The average growth rate of kittiwake 'A' chicks (chicks in single-chick nests plus first chicks to hatch in 2-chick nests) was 17.3 g/day ( $s = 2.6$ ; Fig. 7a). This result was similar to 1995-1997 values (18.7, 17.6, and 16.7 g/day). There was only one 'B' chick.

**Puffins:** Puffin chicks in the 3 main study plots gained an average of 3.5 g/day ( $s = 2.51$ ; Fig. 7b). This was significantly slower than in 1995 and 1997 (11.5 and 6.7 g/day;  $P < 0.001$  in both cases) and similar to growth rates in 1996 (3.2 g/day).

## Chick Diet

**Murres:** Most prey items delivered to murre chick were capelin (94% by number, Fig. 8). Adults also fed nestlings Pacific sand lance (2%), Gadidae (2%), and salmonids (2%). Four fish (<1%) could not be identified to group or species. Results were similar in 1995-1997: capelin was the predominant prey fed to chicks (86%, 91%, and 91% in 1995-1997).

**Kittiwakes:** By weight, kittiwake chick regurgitation samples ( $n = 17$ ) were composed of 54% Pacific sand lance, 27% capelin, 16% salmonids, 3% herring, and 1% pollock (Fig. 9). Regurgitation samples from brooding adults ( $n = 15$ ) contained 42% Pacific sand lance, 37% capelin, 17% unidentified smelt, and 4% Pacific cod. Samples from incubating adults ( $n = 9$ ) contained 78% sand lance, 15 % capelin, and 6% greenling.

**Puffins:** By weight, puffin screen samples contained 60% capelin, 11% pollock, 11% pink salmon, 8% sand lance, 4% Pacific cod, 4% squid, and less than 1% each of euphausiids, octopus, and larval fish (Fig. 10). While the diversity and type of prey species in puffin chick diets remained fairly consistent during 1995-1998, the proportion of capelin gradually increased over the period.

## Amount Fed to Chicks

**Kittiwakes:** Kittiwake chick regurgitation samples collected from chicks 20 or more days old averaged 12.9 g ( $s = 10.4$ ,  $n = 7$ ). This value was significantly lower than that of 1995 (27.7 g,  $P < 0.001$ ) and did not differ from values in 1996-1997 (20.8 g and 14.1 g).

**Puffins:** The average weight of 41 screen samples collected during the nestling period was 8.2 g ( $s = 7.3$ ). This was not significantly different from values in 1995-1997 (10.6 g, 6.9 g, and 7.4 g).

## Chick Provisioning Rate

**Murres:** During the 8 all-day observation periods, murre chicks averaged 0.22 feedings/hr ( $s = 0.06$ ; Fig. 11a), and during 0700-1959 hr (the time period used for among-year comparisons), they averaged 0.23 feedings/hr ( $s = 0.06$ ). In 1995-1997, the averages for this time period were 0.29, 0.26, and 0.27 feedings/hr. Differences among years were not significant.

**Kittiwakes:** During the 4 all-day observation periods single-chick kittiwake nests averaged 0.19 feedings/hr ( $s = 0.09$ ,  $n = 17$  nest-days; Fig. 11b); nests containing 2 chicks averaged 0.25 feedings/hr ( $s = 0.09$ ,  $n = 5$  nest-days). During the block of time used for among-year comparisons (0700-1959 hr) single-chick nests averaged 0.18 feedings/hr ( $s = 0.11$ ) and 2-chick nests averaged 0.26 ( $s = 0.13$ ). Feeding rates in 1-chick nests in 1997 were significantly lower in 1997 than in 1995, 1996, and 1998 ( $P = 0.004$ , 0.01, and 0.002, respectively). There were no significant among-year differences in attendance of 2-chick nests.

**Puffins:** It is apparent from the 1996-1998 results (Fig. 12) that to measure provisioning rate in tufted puffins we must increase the number of days that we sample. In 1999 we will attempt to do so.

### **Activity Budgets of Adults**

**Murres:** (*Nest Attendance*) -- During the incubation period, at least 1 adult murre always attended each nest site, and both pair members were present an average of 12.7 min/hr (72.7 bird-min/hr,  $s = 4.2$ ,  $n = 12$  days; Fig. 13). During the 0700-1959 hr block of time the average was 73.7. This result was lower than the 1996 and 1997 values (80.3 and 83.8,  $P = 0.074$  and 0.003).

During the nestling period at least 1 adult always attended each site; both birds were present an average of 8.9 min/hr (68.9 bird-min/hr,  $s = 5.1$ ; Fig. 14a). During the 0700-1959 hr block of time, the result (69.2 bird-min/hr,  $s = 5.7$ ) was similar to the 1995-1997 values (65.8, 69.1, and 73.1 bird-min/hr).

(*Duration of Foraging Trips*) -- During the nestling period, murre foraging trips averaged 157.9 min ( $s = 119.5$ ; Fig. 15). This did not differ significantly from 1995-1997 values (157.7, 170.6, and 157.4 min). In 1998 the proportion of 0-to-2-hr trips to 2-to-4-hr trips in 1998 (94 trips vs. 83 trips, respectively) was significantly higher than in 1996 (22 vs. 51 trips,  $P < 0.001$ ) but similar to that of 1995 (39 vs. 29 trips) and 1997 (65 vs. 55 trips).

**Kittiwakes:** (*Nest Attendance*) -- Single kittiwake chicks were left alone an average of 1.5 min/hr (bird-min/hr = 58.5,  $s = 5.5$ ,  $n = 1$ ; Fig. 14b) and 2-chick broods were always attended by adults (60.3 bird-min/nest/hr,  $s = 0.3$ ,  $n = 5$ ). During the 0700-1959 hr block of time, results for 1- and 2-chick nests were 58.7 ( $s = 5.8$ ) and 60.3 ( $s = 0.4$ ) bird-min/nest/hr, respectively. Results for 1998 were not significantly different from those of 1995-1997 for 1-chick nests (57.1, 57.7, and 50.9 bird-min/hr) or for 2-chick nests (55.3, 54.6, and 43.6 bird-min/hr), although the 1997 value was lower than the 1998 value at a marginally significant level ( $P = 0.078$ ).

(*Duration of Foraging Trips*)-- Kittiwake foraging trips averaged 289.2 min ( $s = 176.0$  min; Fig. 16). This was not significantly different from 1995-1997 values (236.6, 325.9, and 332.1 min).



## Population Counts

**Murres:** Counts of murres on the productivity plots averaged 455 birds ( $s = 38.1$ ; Fig. 17a). This was significantly higher than the 1994-1996 counts (412, 392 and 406 birds;  $P = 0.002$ ,  $<0.001$ , and  $<0.001$ , respectively) but similar to the 1993 and 1997 values (429 and 436 birds, respectively).

**Kittiwakes:** Kittiwake counts on the 4 productivity plots that could be compared among the years 1993-1998 averaged 145 birds ( $s = 27.4$ ; Fig. 17b). This was similar to 1994-1997 averages (192, 201, 183, and 196). Counts in each of these years were higher than counts made in 1993 (average = 120 birds,  $P <0.001$  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 1995-1998 (125, 142, 127, and 93 burrows; Fig. 18).

## Sea Temperature

Sea temperature was warmer at the beginning of the 1998 season than at the start of the 1996-1997 seasons (Fig. 19). These data will be discussed in the Final Report.

## DISCUSSION

Results from the 1998 season will be discussed in the Final Report, which will be submitted in September 2000.

## ACKNOWLEDGMENTS

We thank Stephanie Zuniga, Tammy Steeves, Gavin Brady, and Margaret Blanding for making the 1998 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 Mike Yourkowski, M/V *Kittiwake II*, for transporting us and the field camp to and from the Barren Islands. 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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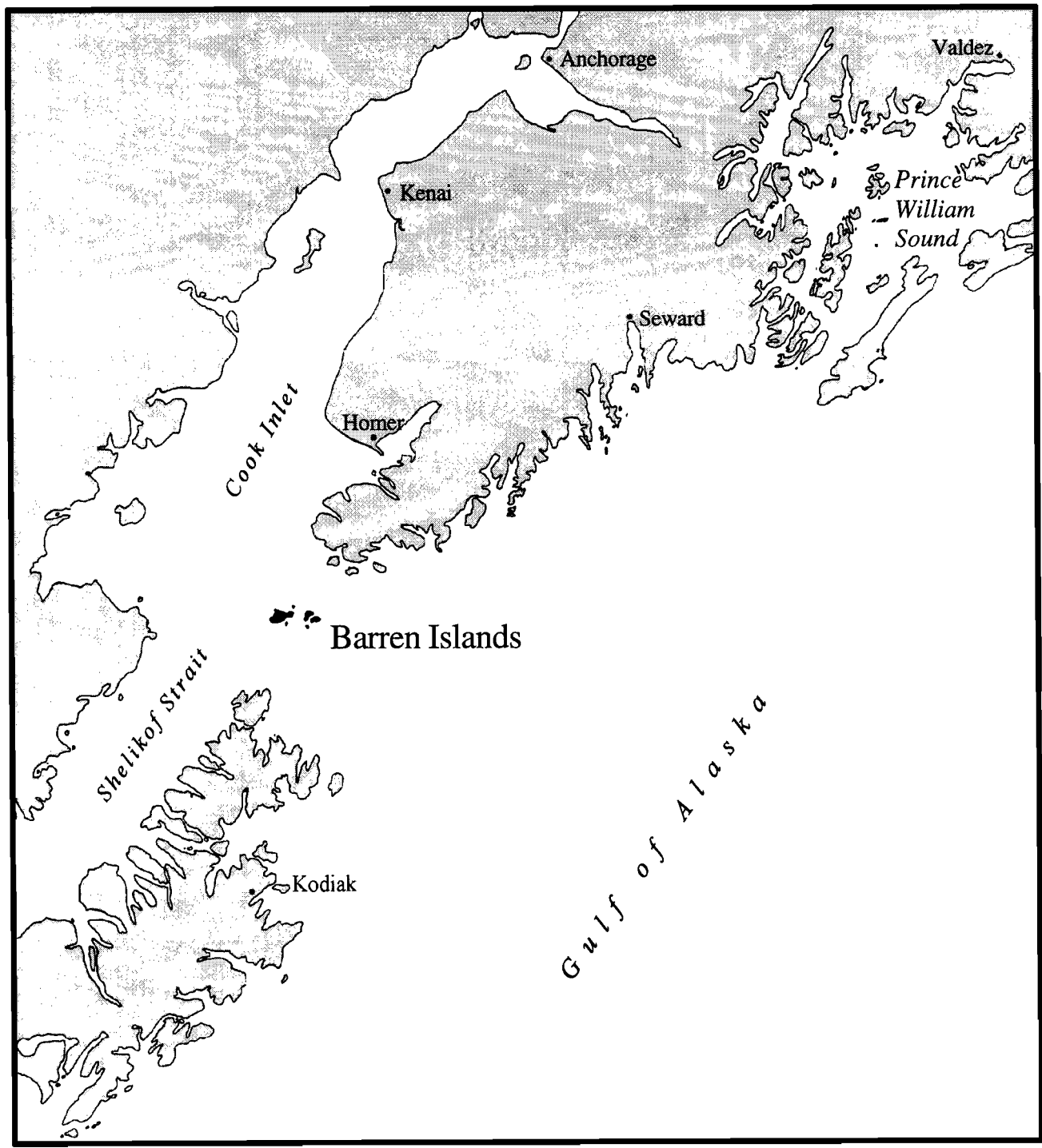


Figure 1. Location of the Barren Islands, Alaska.

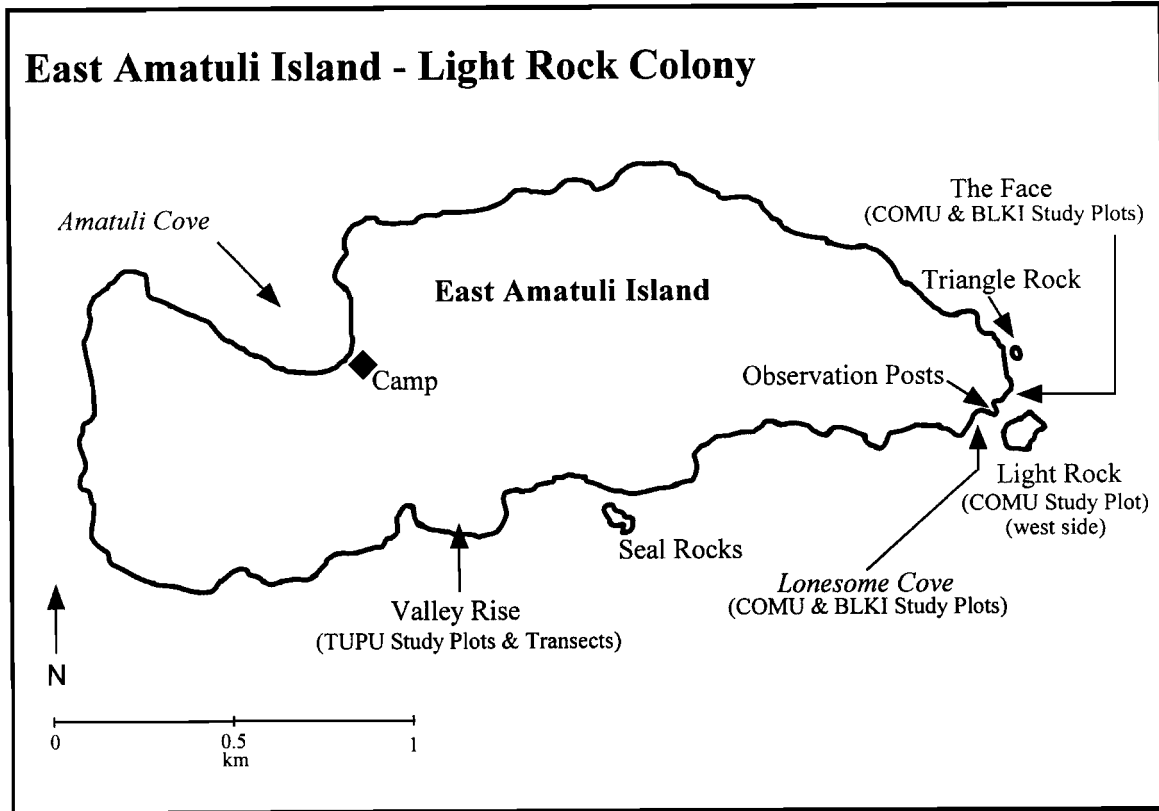


Figure 2. The East Amatuli Island study area, showing the general locations of common murre (COMU), black-legged kittiwake (BLKI), and tufted puffin (TUPU) study sites.

## Productivity

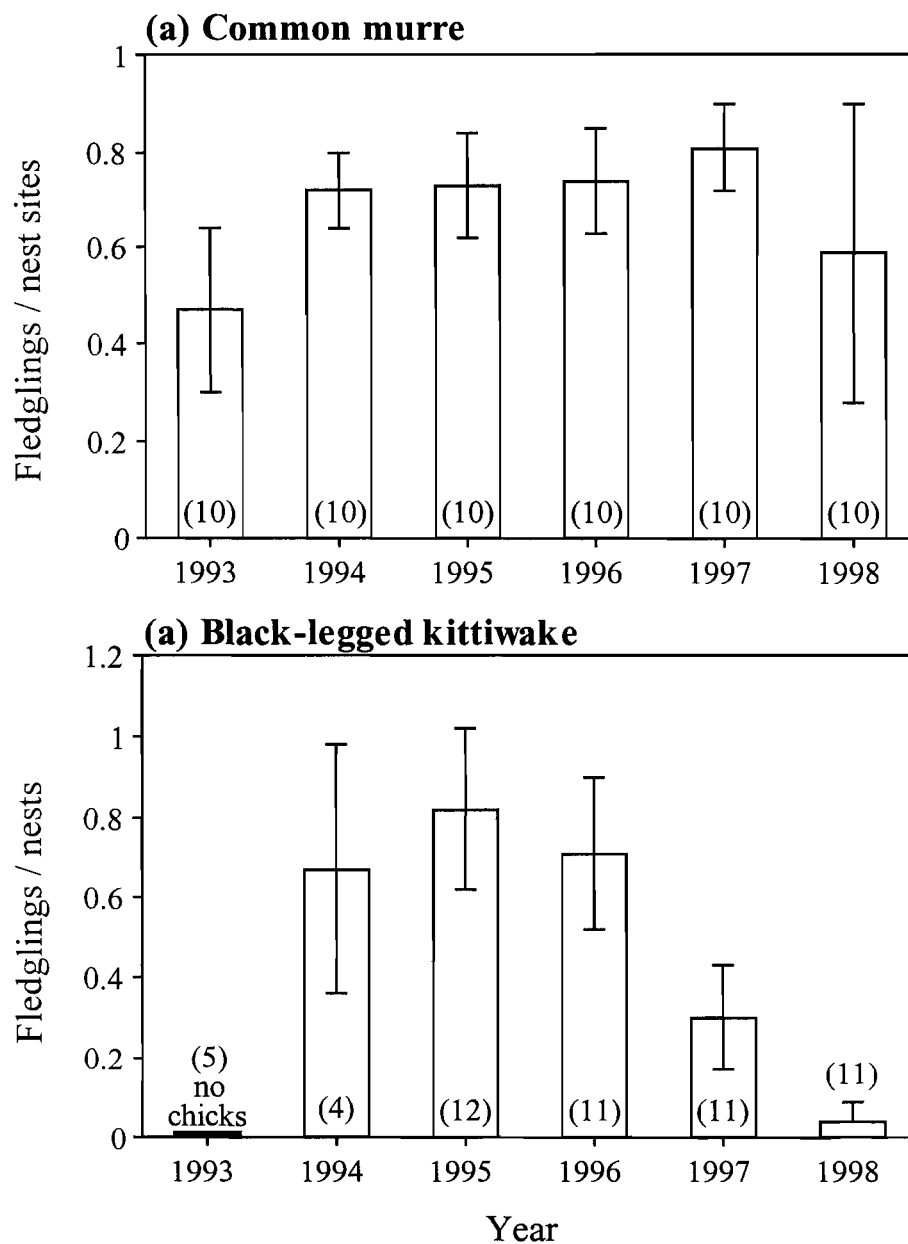


Figure 3. Productivity of (a) common murres (fledglings per nest site) and (b) black-legged kittiwakes (fledglings per nest) at East Amatuli Island, Barren Islands, Alaska, 1993-1998. Number of plots in parentheses; error bars = standard deviation.

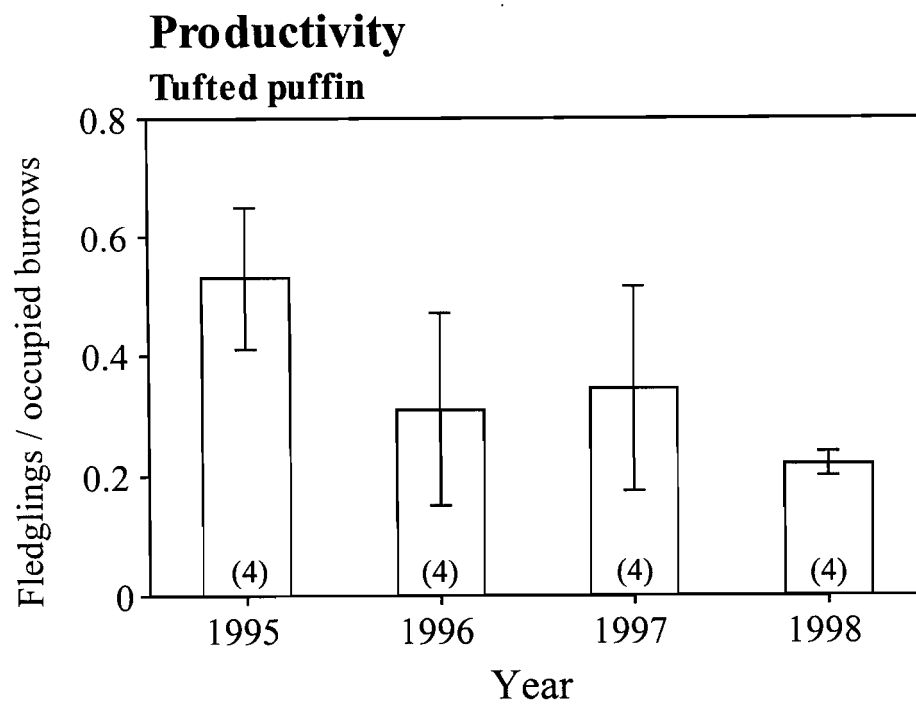


Figure 4. Productivity (fledglings per occupied burrow) of tufted puffins at East Amatuli Island, Barren Islands, Alaska, 1995-1998. Number of plots in parentheses; error bars = standard deviation.

## Nesting chronology

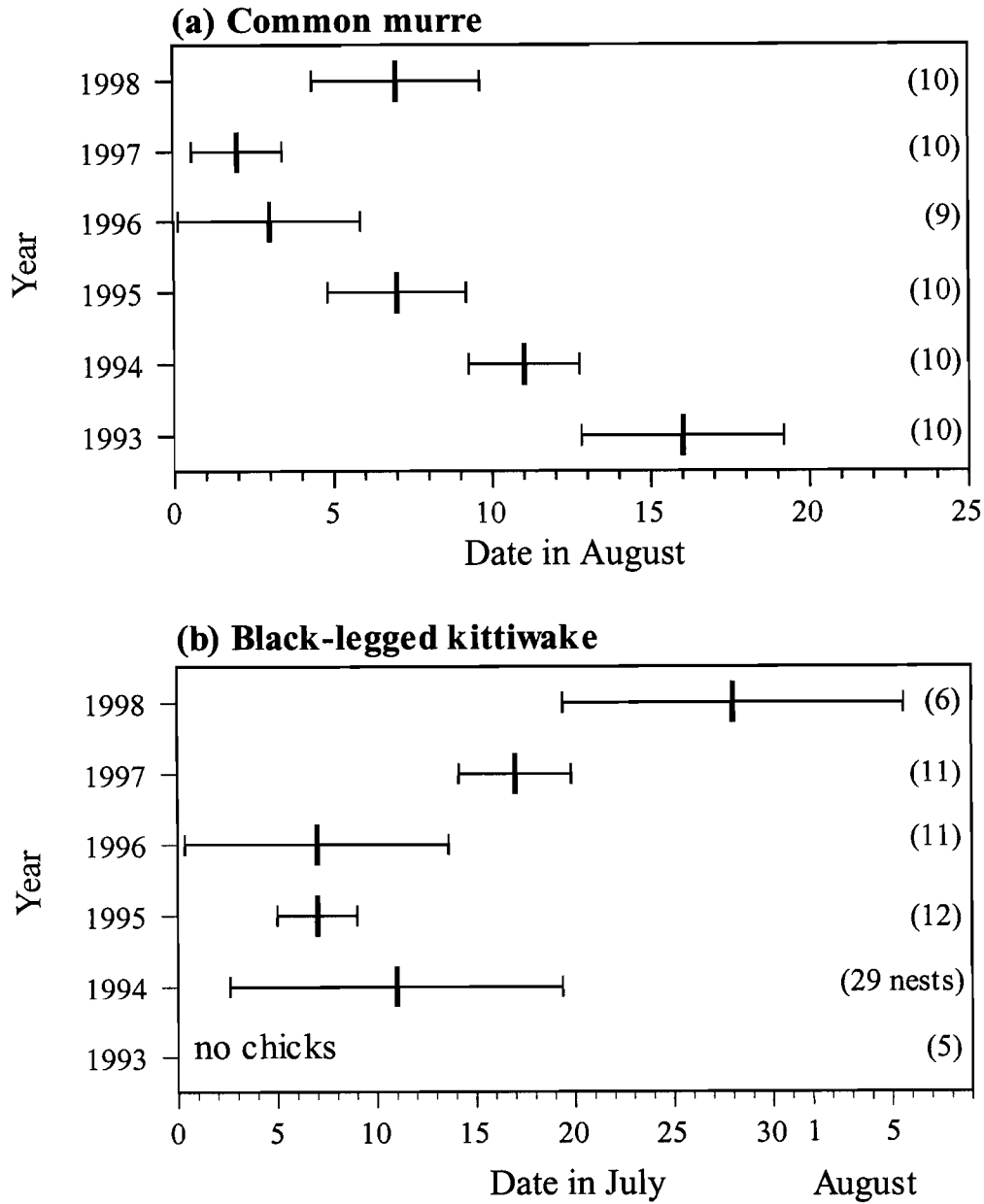


Figure 5. Nesting chronology (median hatch date) of (a) common murre and (b) black-legged kittiwakes at East Amatuli Island, Alaska, 1993-1998. Number of plots in parentheses; error bars = standard deviation.



## Nesting chronology

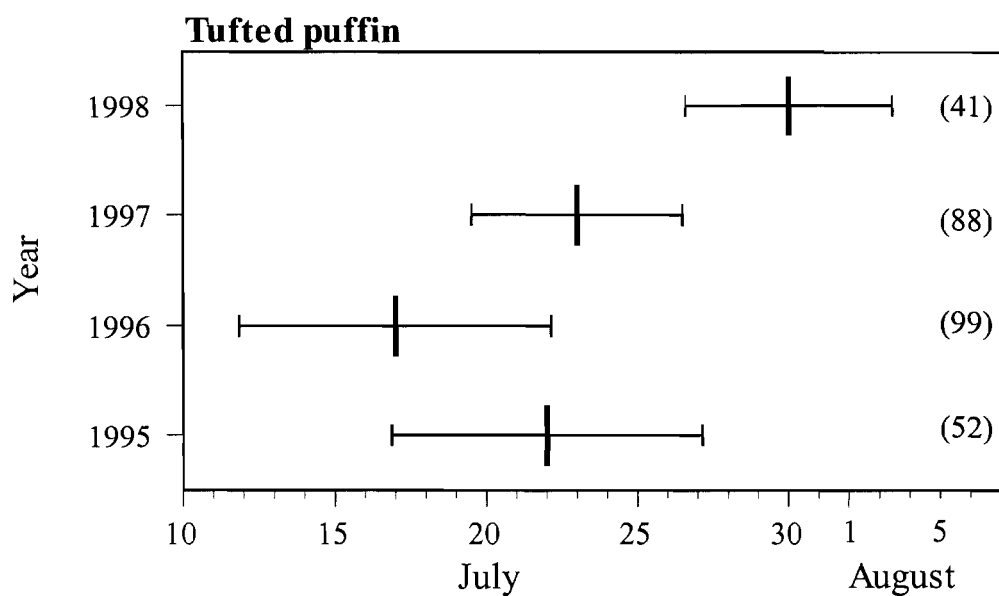


Figure 6. Nesting chronology (mean hatch date) of tufted puffins at East Amatuli Island, Alaska, 1994-1998. Number of chicks in parentheses; error bars = standard deviation.

## Chick growth rate

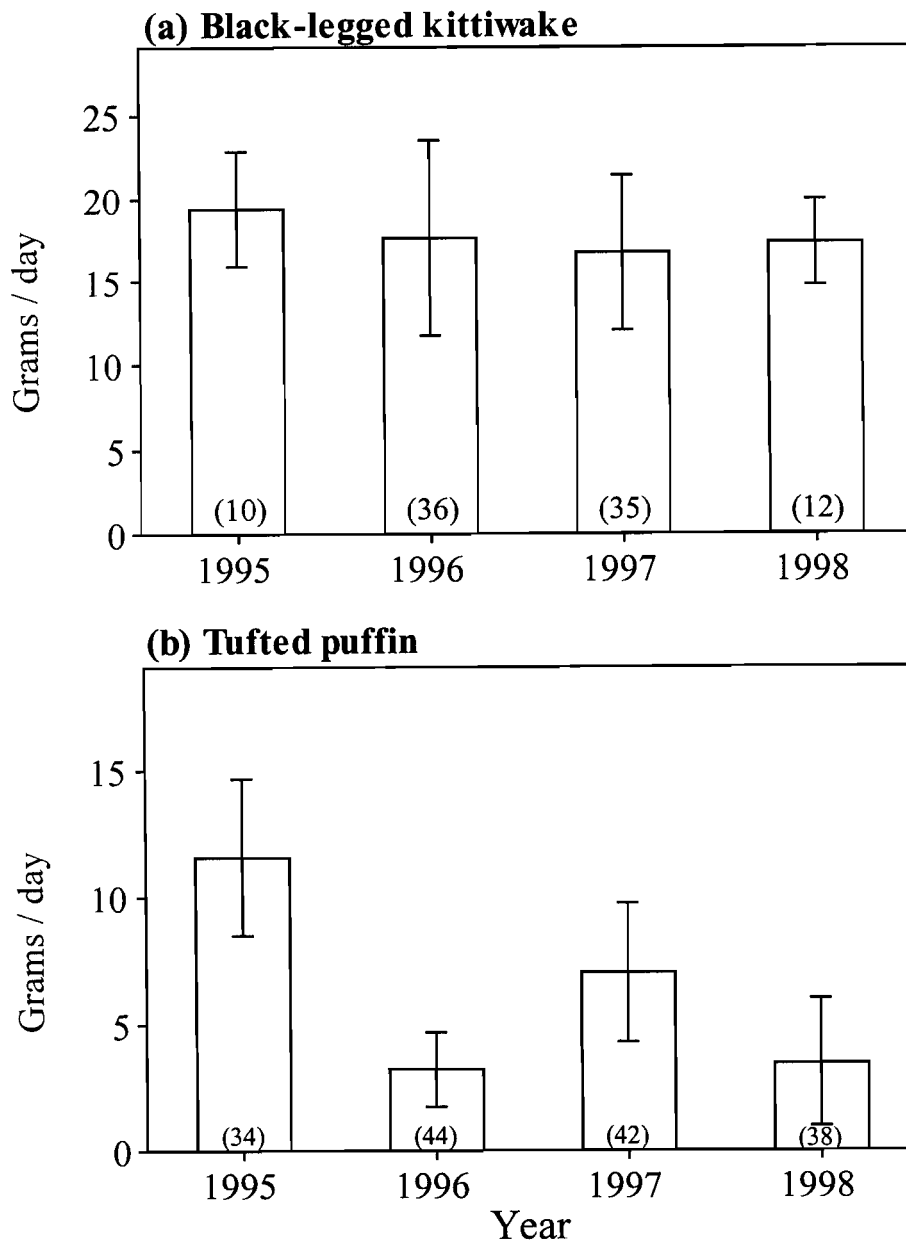


Figure 7. Growth rate of (a) black-legged kittiwake chicks and (b) tufted puffin chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1998. Number of chicks in parentheses; error bars = standard deviation.

## Chick Diet Common murre

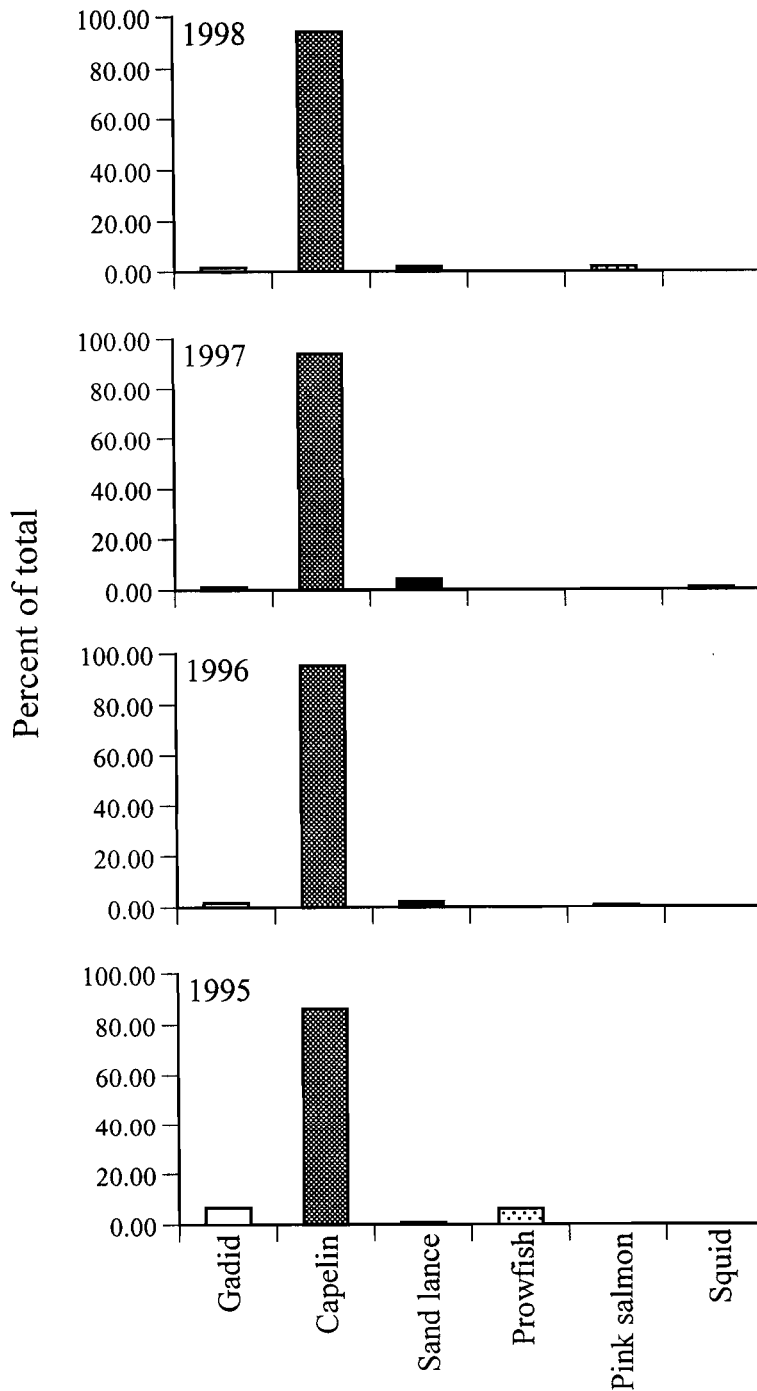


Figure 8. Types of prey fed to common murre chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1998. Percent of total, by number of prey items, of each prey type.

# Chick Diet

## Black-legged kittiwake

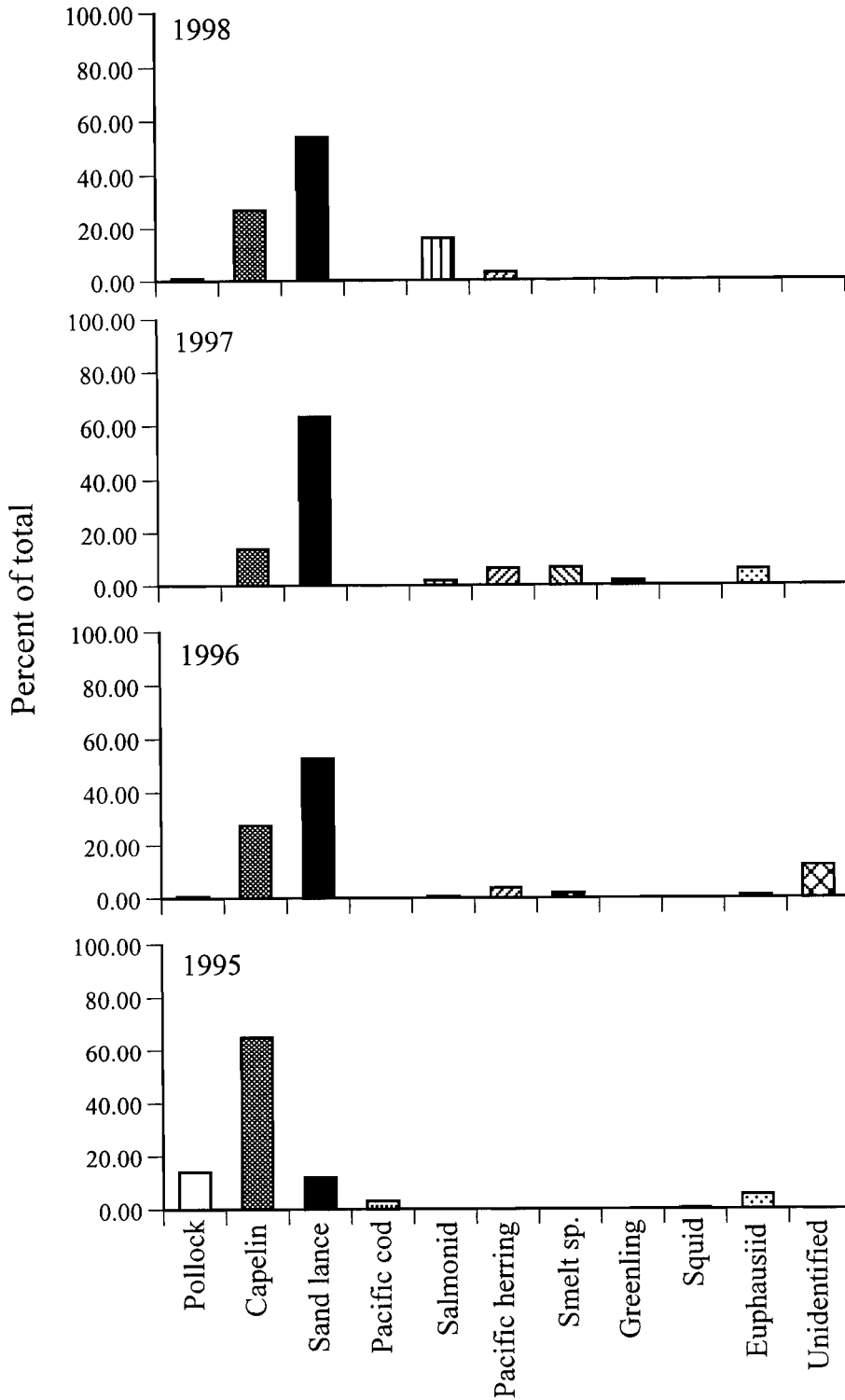


Figure 9. Types of prey fed to black-legged kittiwake chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1998. Percent of total, by weight, of each prey type.

# Chick Diet

## Tufted puffin

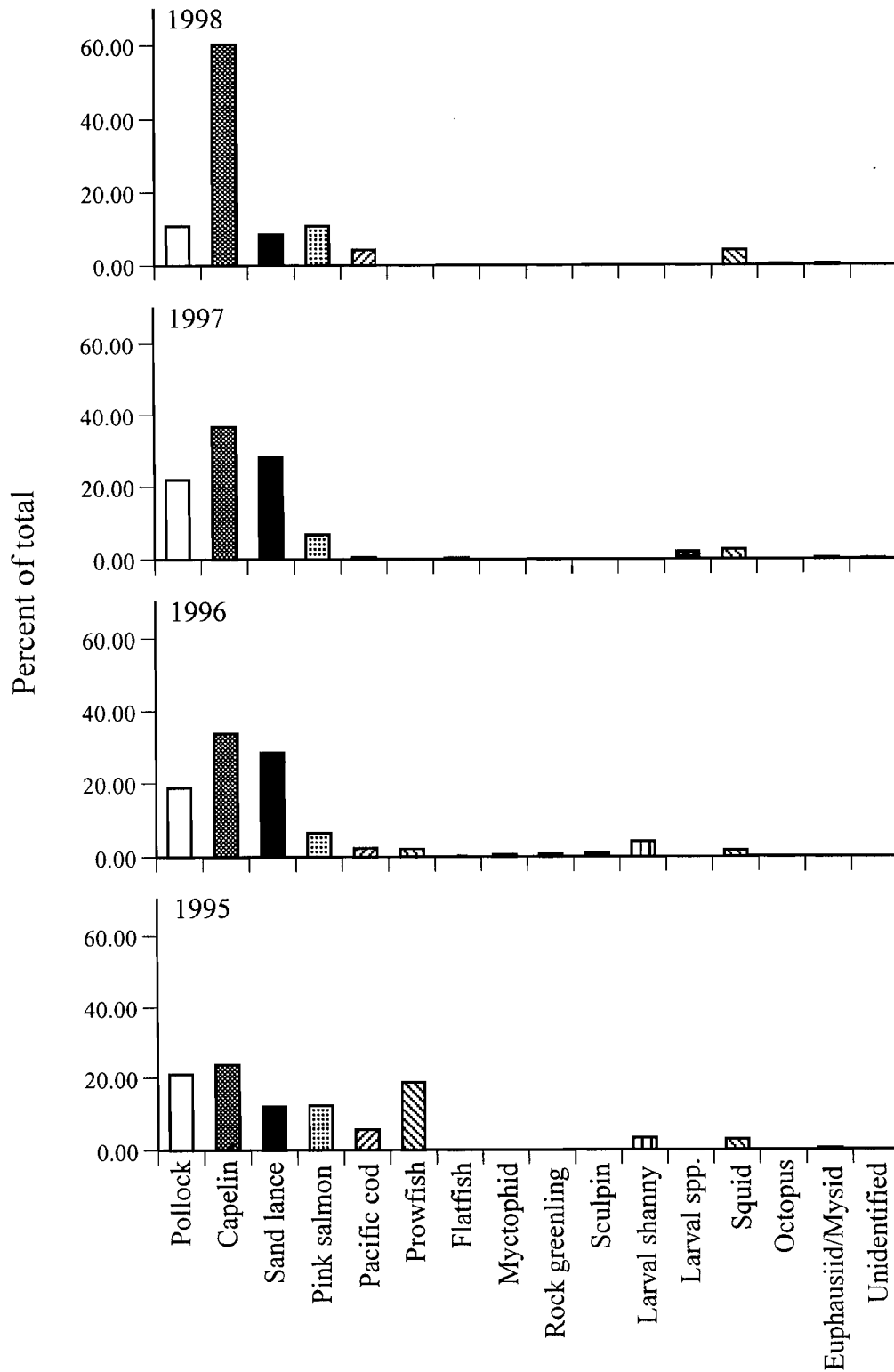


Figure 10. Types of prey fed to tufted puffin chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1998. Percent of total, by weight, of each prey type.

## Chick provisioning rate

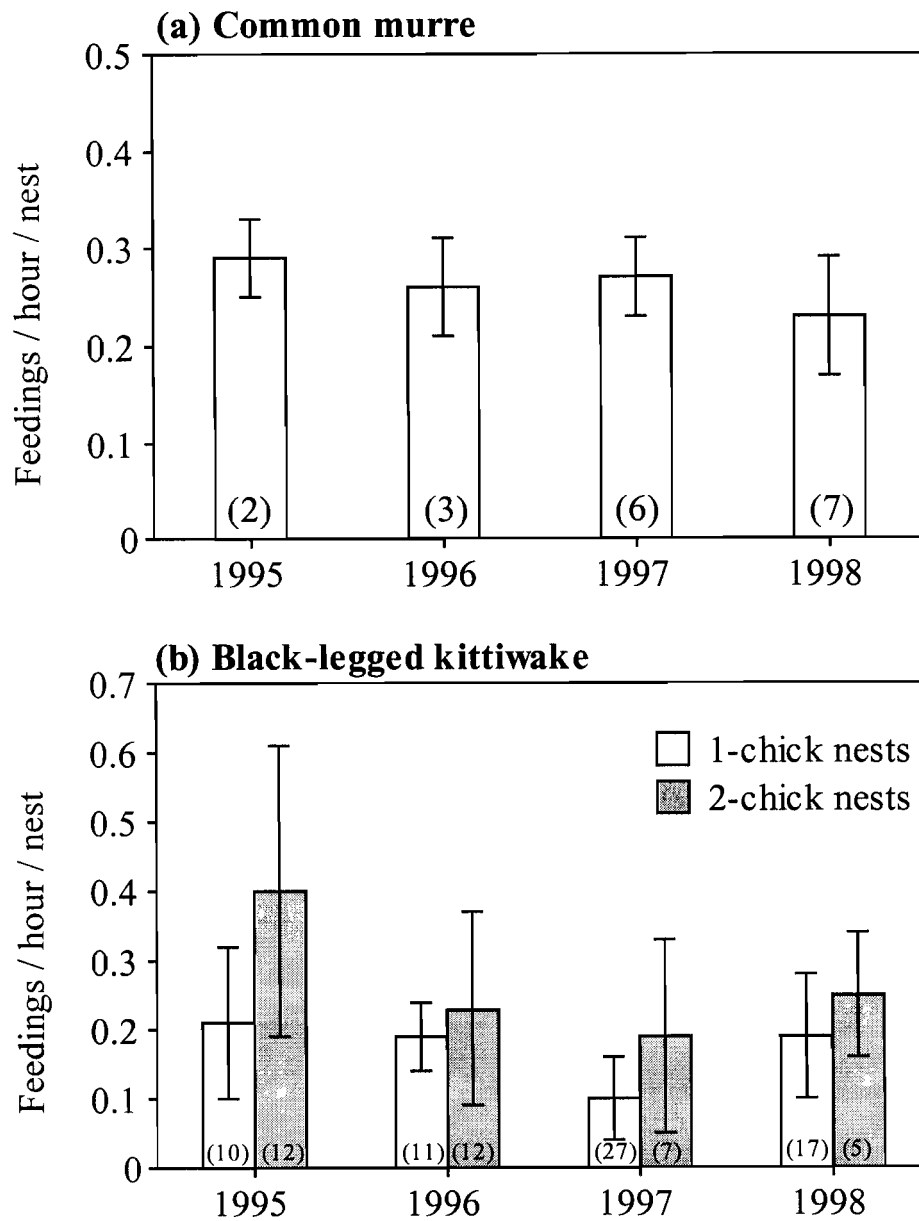


Figure 11. Provisioning rate of (a) common murre (number of days in parentheses) and (b) black-legged kittiwake (number of nest-days in parentheses) chicks at East Amatuli Island, Barren Islands, Alaska, 1995-1998. Error bars = standard deviation.

## Chick provisioning rate

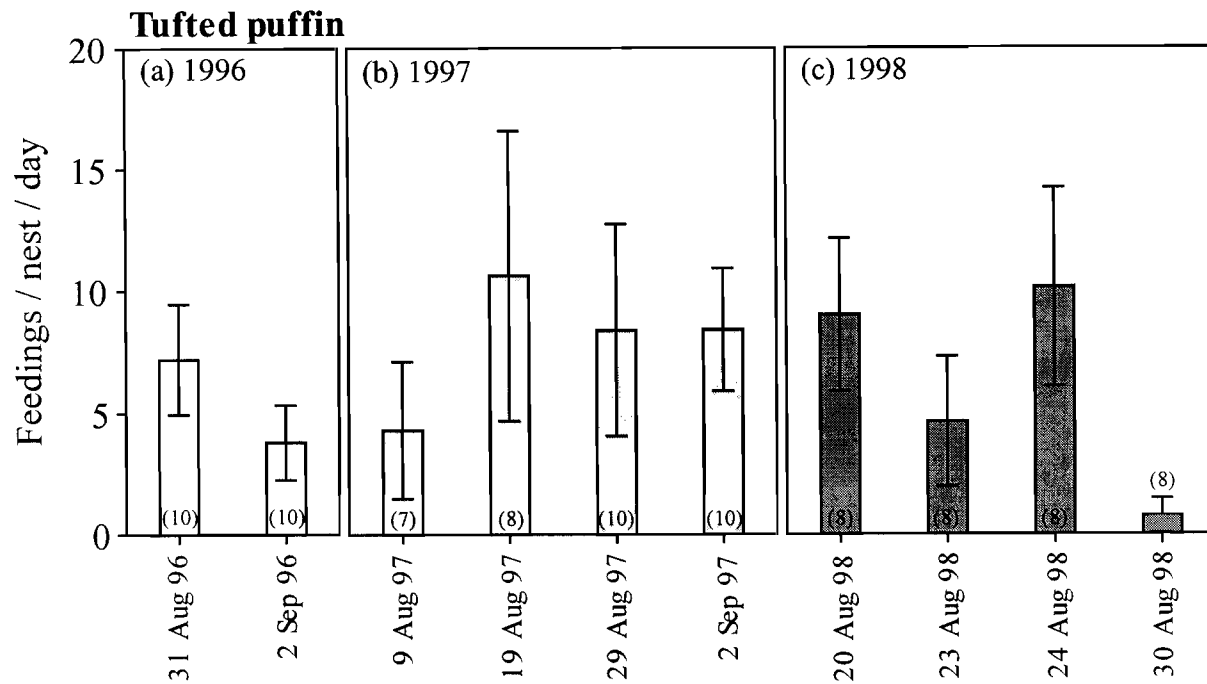


Figure 12. Provisioning rate of tufted puffin chicks at East Amatuli Island, Barren Islands, Alaska during (a) 1996, (b) 1997, and (c) 1998. Number of nests in parentheses; error bars = standard deviation.

## Nest attendance--incubation period

### Common murre

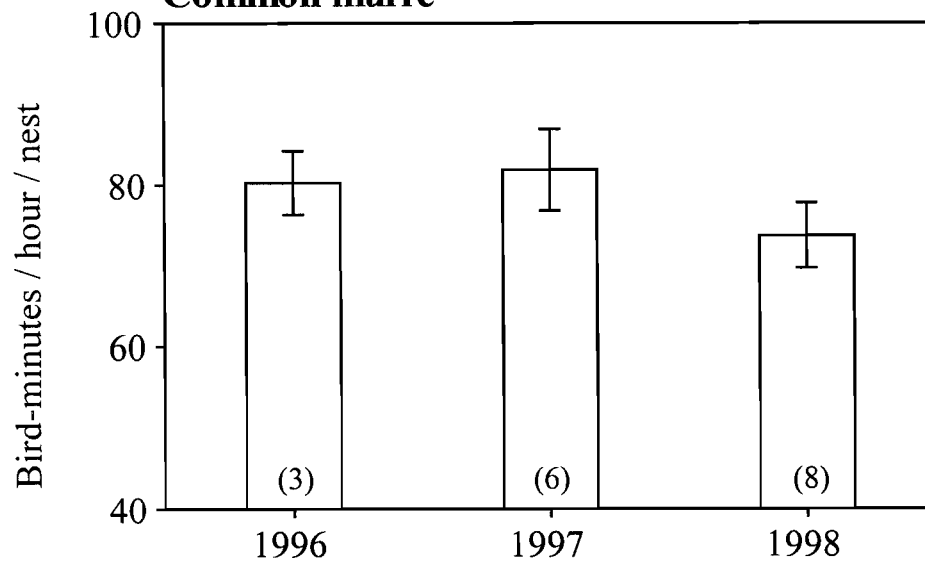


Figure 13. Number of minutes per hour spent at nests by common murre (number of days in parentheses) during the incubation period at East Amatuli Island, Barren Islands, Alaska, 1995-1998. Error bars = standard deviation.



## Nest attendance--nestling period

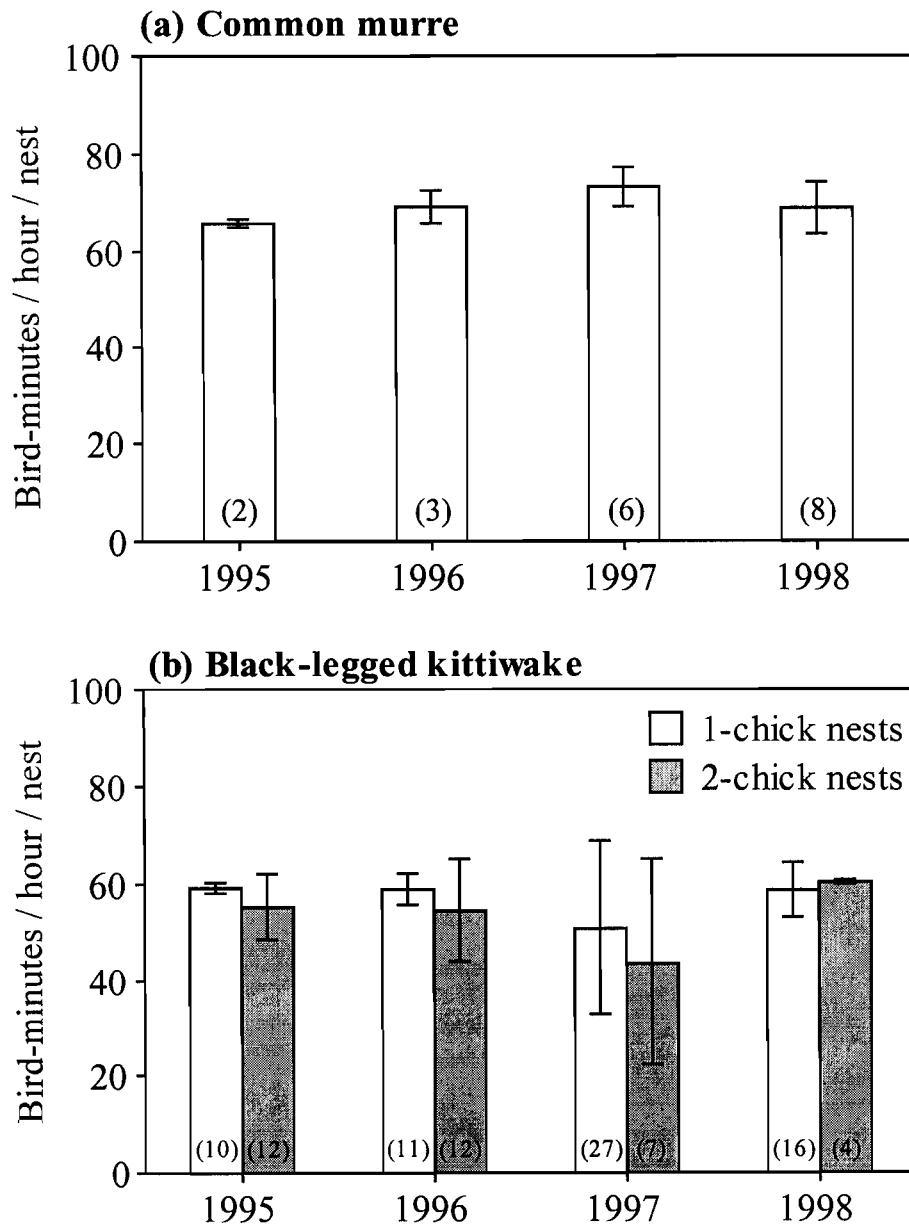


Figure 14. Number of minutes per hour spent at nests by (a) common murre (number of days in parentheses) and (b) black-legged kittiwake (number of nest-days in parentheses) parents during the chick-rearing period at East Amatuli Island, Barren Islands, Alaska, 1995-1998. Error bars = standard deviation.

# Foraging trip duration

## Common murre

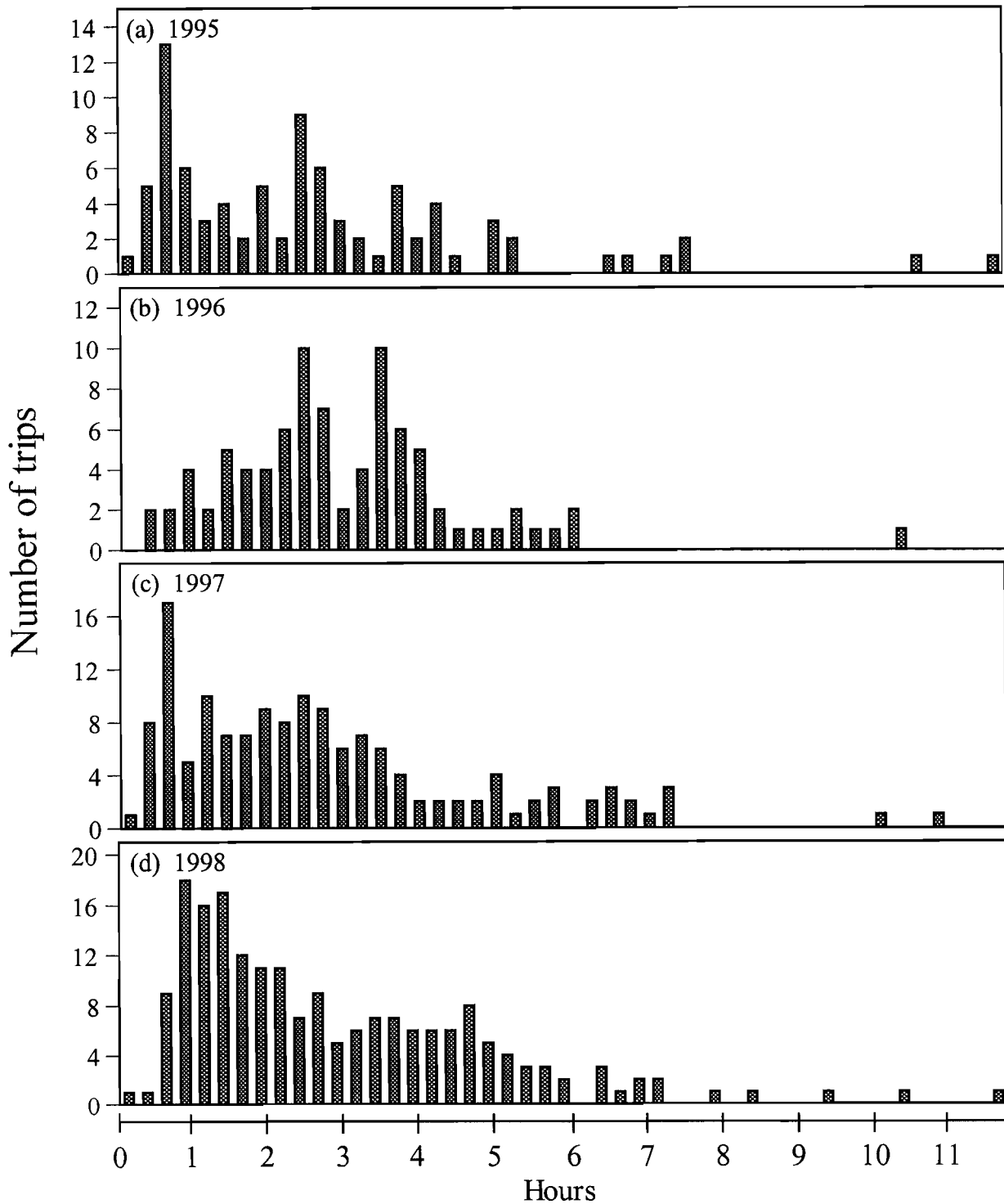


Figure 15. Duration of foraging trips by common murre at East Amatuli Island, Barren Islands, Alaska during (a) 1995, (b) 1996, (c) 1997, and (d) 1998.

# Foraging trip duration

## Black-legged kittiwake

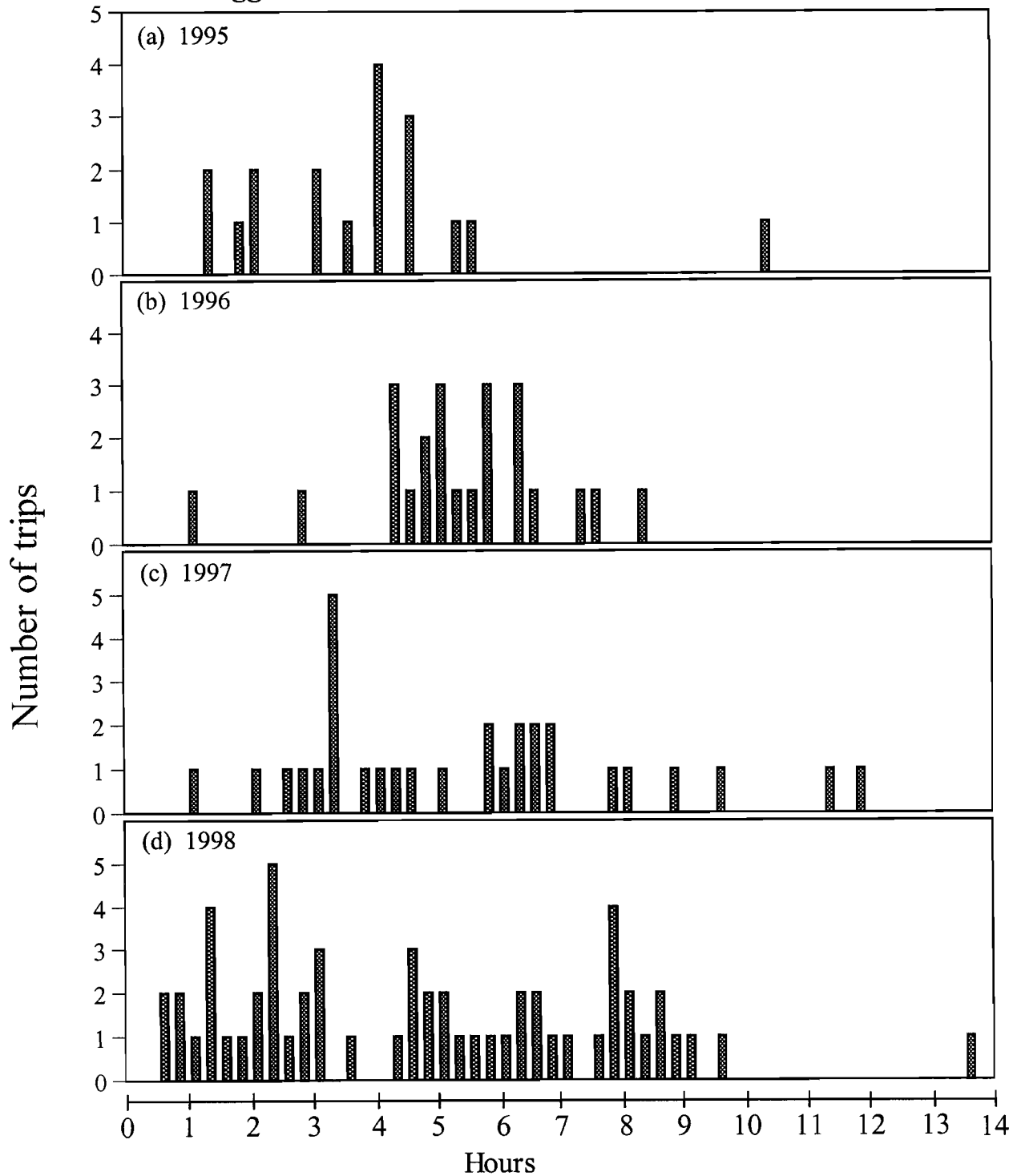


Figure 16. Duration of foraging trips by black-legged kittiwakes at East Amatuli Island, Barren Islands, Alaska during (a) 1995, (b) 1996, (c) 1997, and (d) 1998.

## Counts of birds on productivity plots

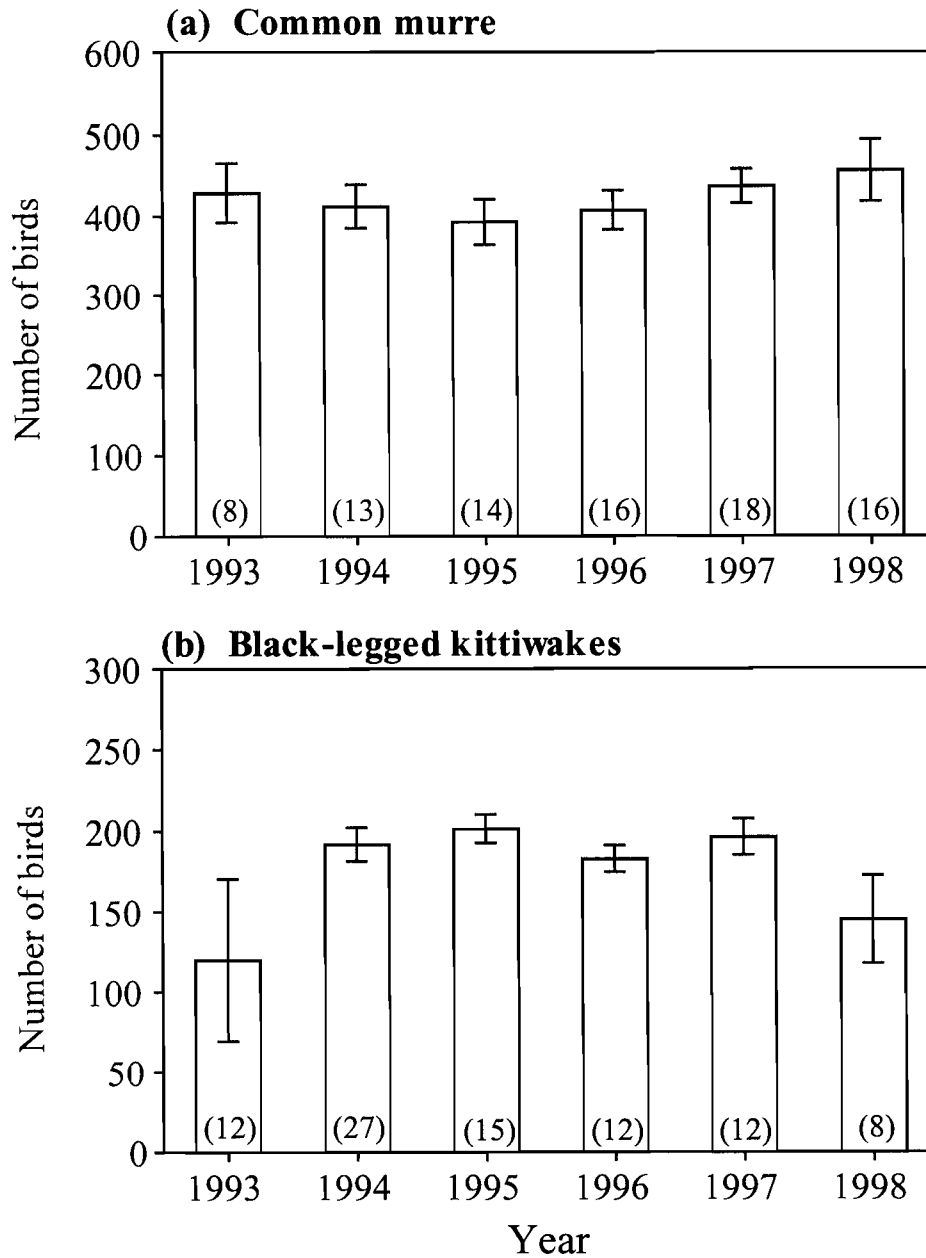


Figure 17. Counts of adult birds on productivity plots of (a) common murre and (b) black-legged kittiwakes at East Amatuli Island, Barren Islands, Alaska, 1993-1998. Number of counts in parentheses; error bars = standard deviation.

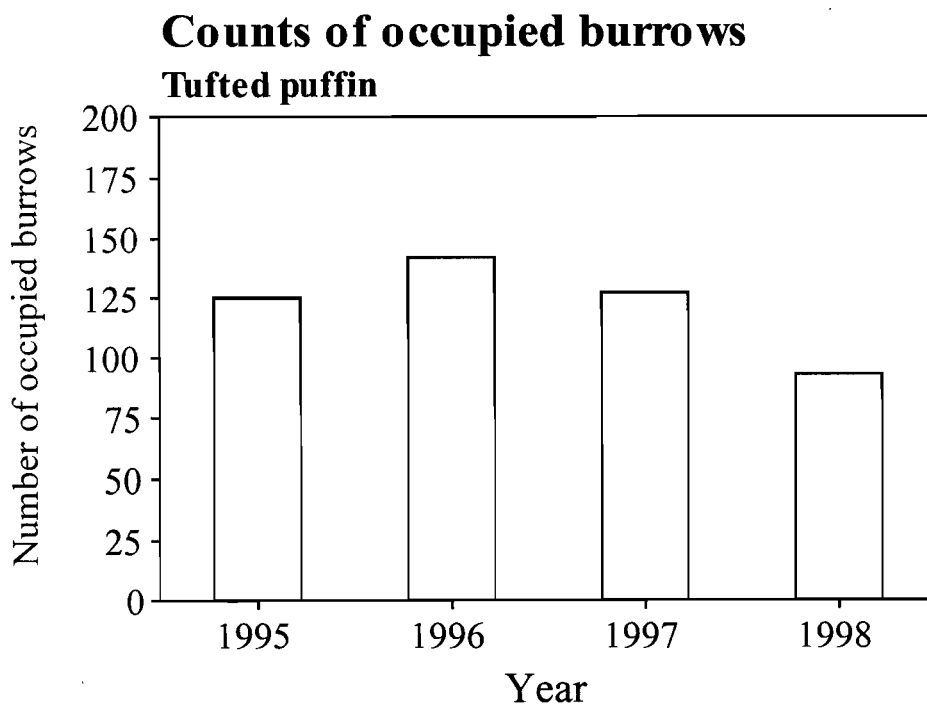


Figure 18. Number of occupied tufted puffin burrows in 7 plots at East Amatuli Island, Barren Islands, Alaska, 1995-1998.

## Sea temperature

### Lonesome Cove

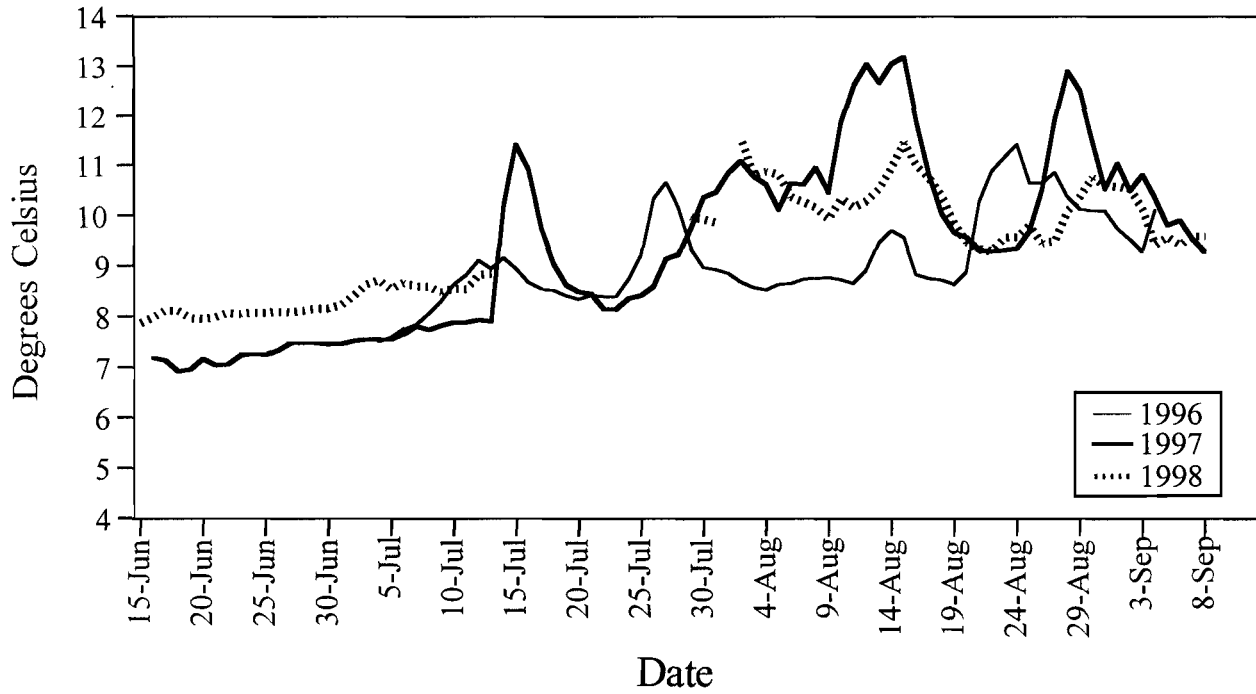


Figure 19. Sea temperature at Lonesome Cove, East Amatuli Island, Barren Islands, Alaska in 1996-1998. Daily averages of measurements taken at 12-minute intervals.

Appendix 1. Schedule for small-mesh beach seine sets at the Barren Islands, Alaska, 1998.

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Locations: --Amatuli Cove at East Amatuli Island  
--Cove at NW side of West Amatuli Island (1 day only)

Duration: 16 June - 8 September

Frequency: Every two weeks, during maximum tidal range: two adjacent sets during low tide and two during high tide.

Disposition: When catches were small (less than about 2 liters of fish) we sampled the entire catch. Larger catches were subsampled and the remainder was returned to the sea as quickly as possible. Fish longer than 150 mm were measured and returned to the sea. Samples were processed and those not collected and frozen were dumped into nearby deep water.

Processing of samples: Every set:  
--All individuals were identified.  
--Individuals were grouped by species. Each group was weighed and individuals were counted. When sets were subsampled, whole-set weights and counts for each species were extrapolated.

Every two weeks:  
--100 randomly-chosen sand lance of each age class were weighed to 0.01 g with an electronic balance and measured to 0.1 mm with vernier calipers.  
  
--50 randomly-chosen individuals of each age class of each other species were weighed (to 0.01 g) and measured (to 0.1 mm).

Every month:  
We collected and froze in individually-labeled bags:  
--50 sand lance 100 mm or less  
--50 sand lance >100 mm  
--50 of each other forage fish species  
--50 larval spp. individuals

Per season:  
We collected and froze 50 individuals of each other (non forage-fish) species caught.