APPENDIX J

APEX: 95163 J

Exxon Valdez Oil Spill
APEX Project Annual Report

Barren Islands Seabird Studies, 1995

APEX Project 95163J
Annual Report

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__Study History__: This project has no study history. It is a new project that was implemented in 1995 as part of the *Exxon Valdez* Oil Spill Trustee Council-sponsored Alaska Predator Experiment (APEX).

__Abstract__: As part of the 1995 APEX seabird - forage fish project, we conducted a pilot study to collect data on common murres *(Uria aalge)*, black-legged kittiwakes *(Rissa tridactyla)*, and tufted puffins *(Fratercula cirrhata)* at the East Amatuli Island - Light Rock colony in the Barren Islands. The work was included in the APEX program because some information on these species were already available from the colony, and its offshore location provided opportunities to compare data from oceanic environments with information being collected in Prince William Sound and in other areas of lower Cook Inlet - Kachemak Bay. Also, capelin (*Mallotus villosus*), an important forage fish species scarce in the northern Gulf of Alaska since the late 1970's, were abundant near the Barren Islands in 1993-1994. The presence of large stocks of these fish and other forage fishes (e.g., sand lance, *Ammodytes hexapterus*; young walleye pollock, *Theragra chalcogramma*) in surrounding waters provided an opportunity to study seabird - forage fish relationships and natural ecological processes that might help explain why populations of some seabird species have not increased in the T/V Exxon Valdez oil spill area. During the study, data were collected on nesting chronology, productivity, growth and feeding rates of chicks, time budgets of adults, and types and amounts of prey fed to chicks. Although some data are still being analyzed, preliminary results indicate that sufficient types and amounts of information can be collected at this northern Gulf of Alaska colony to help test three APEX project hypotheses: (a) composition and amounts of prey in seabird diets reflect changes in relative abundance and distribution of forage fishes near the nesting colonies; (b) changes in seabird productivity reflect differences in forage fish abundance as measured by amounts of time adult birds spend foraging for food, amounts of food fed to chicks, and provisioning rates of chicks; and (c) seabird productivity is determined by differences in forage fish nutritional quality.

__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*, *Uria lomvia*.

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INTRODUCTION

As part of the 1995 *Exxon Valdez* Oil Spill Trustee Council-sponsored Alaska Predator Experiment (APEX), we conducted a pilot study to collect data on black-legged kittiwakes *(Rissa tridactyla)*, common murres *(Uria aalge)*, and tufted puffins *(Fratercula cirrhata)* at the East Amatuli Island - Light Rock colony in the Barren Islands. The Barren Islands study was included in the APEX seabird - forage fish project because some information on these species was already available from the colony (e.g., Bailey 1975a,b and 1976; Manuwal 1978, 1980; Manuwal and Boersma 1978; Nysewander and Dipple 1990, 1991; Dippel and Nysewander 1992; Nysewander *et al.* 1993; Dragoo *et al.* 1994; Boersma *et al.* 1995; Erikson 1995; Roseneau *et al.* 1995, 1996), and its offshore location provided opportunities to compare data from oceanic environments with information from APEX studies in Prince William Sound and Minerals Management Service (MMS) research in lower Cook Inlet - Kachemak Bay. Also, capelin *(Mallotus villosus)*, an important forage fish species scarce in the northern Gulf of Alaska since the late 1970's (Piatt and Anderson 1995; P. Anderson, unpubl. data), were abundant near the Barren Islands in 1993-1994 (Roseneau *et al.* 1995, 1996). Large stocks of these fish and the presence of other forage fishes, including sand lance *(Ammodytes hexapterus)* and young cods (e.g., 0-1+ age-class walleye pollock, *Theragra chalcogramma*, and Pacific cod, *Gadus macrocephalus)* in surrounding waters provided an opportunity to study seabird - forage fish relationships and natural ecological processes that might help explain why populations of some seabird species have not increased in the T/V *Exxon Valdez* oil spill area.

Data collected during the study will be used to help test three APEX hypotheses:

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

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

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

Because some types of information needed to test these hypotheses had not been obtained from the Barren Islands before, we evaluated the feasibility of collecting these data at the East Amatuli Island - Light Rock colony (e.g., for murres and kittiwakes, data on feeding frequencies and types of prey fed to chicks, time-activity budgets of adults; for kittiwakes, chick growth rates and amounts of food fed to chicks).

During the work, we collected data on kittiwake, murre, and puffin productivity and nesting chronology; types and amounts of prey fed to kittiwake, murre, and puffin chicks; growth rates of kittiwake and puffin chicks; feeding frequencies of kittiwake and murre chicks; and time-activity budgets of kittiwake and murre adults. Based on our pilot study results, we have concluded that sufficient amounts and types of information can be obtained at the Barren Islands to help test the APEX hypotheses.

Preliminary results from our pilot study are summarized below. Most of these results have already been shared with other APEX investigators to allow them to begin making comparisons between colonies (e.g., D. Irons, Project 95163E, and J. Piatt, Project 96163M; prey samples were also provided to D. Roby, Project 95163G, for energy content and density analyses). In several cases, we have compared our results with data from the 1993-1994 EVOS-sponsored Barren Islands common murre restoration monitoring projects (Projects 93049 and 94039; see Roseneau *et al.* 1995, 1996). After the 1996 field season has been completed, we will reanalyze these data sets and test them for trends (e.g., four years of murre, kittiwake, and puffin productivity data will be available for these types of analyses). We will also expand the comparisons to include relevant information from historical Barren Islands studies (e.g., kittiwake productivity data in Manuwal 1980) and other data sets that can be tested for between-years differences (e.g., two years of kittiwake and murre feeding frequency and time budget data will be available for testing after the 1996 field season).

OBJECTIVES

Our overall 1995 objective was to determine the feasibility of collecting the types of data at the Barren Islands that are needed for a multispecies, multicolony, multiyear analysis of seabird productivity and energetics in Prince William Sound and lower Cook Inlet. Specific objectives were to:

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

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

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

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

5. Determine the feeding frequencies of common murre and black-legged kittiwake chicks (feedings-per-hour and per-nest, respectively).

6. Determine amounts of food fed to black-legged kittiwake chicks (grams per regurgitation) and tufted puffin chicks (grams per screened sample).

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

METHODS

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 the East Amatuli Island - Light Rock colony, and personnel stayed at the Amatuli Cove camp (Fig 2). Four people occupied the camp during 15 June - 9 September. They commuted to murre and kittiwake study sites in outboard-powered, 4.8-m-long, ridged-hulled inflatable boats and hiked to puffin study areas near Valley Rise.

Productivity

Murres: Murre productivity data were collected at the 10 East Amatuli Island - Light Rock plots used for this purpose in 1993-1994 (MPP 1-10; see Roseneau *et al.* 1995, 1996) and one additional plot (MPP 11) set up during this study (Fig. 2). The plots, containing about 25-50 nest sites (sites with eggs) each (total = 342), were checked with 7 x 42 binoculars and 15-60 power spotting scopes from land-based observation posts as often as weather allowed (range = 1-6 days). Viewing distances varied from about 30 to 100 m, and observers were assigned specific plots for the duration of the field season. Nest sites were mapped using photographs and sketches, and data were recorded for each site using previously established codes. Plot checks consisted of searching for eggs and chicks and adults in incubation and brooding postures, and counting adults. Each plot was checked 25 times during 24 June - 3 September, from just before eggs were laid until after sea-going of chicks peaked. Data were analyzed by treating plots as sample units and calculating productivity as fledglings per egg (see Roseneau *et al.* 1995, 1996). Productivity data were also used to compute hatching and fledging success (see Roseneau *et al.* 1995, 1996). Differences among 1993-1995 results were tested with ANOVA.

Kittiwakes: Kittiwake productivity data were collected from 12 East Amatuli Island plots; five established in 1993 (KPP 1-4; D.G. Roseneau and A.B. Kettle, unpubl. data) and seven set up during this study (KPP 5-12; Fig. 2). The plots, located on the same headlands as the murre productivity plots, contained 25-50 nests each (total = 431; 391 with eggs). Methods for collecting and analyzing data were similar to those used for murres; methods were also compatible with Project 95163E PWS protocols. Nest checks consisted of searching for eggs and chicks, and counting adults (incubation and brooding postures were not used for kittiwakes). Each plot was checked 26 times during 22 June - 30 August, from just after egg-laying began until after fledging peaked. During data analysis, plots were treated as sample units and productivity was calculated as fledglings per egg. Data were also analyzed using nests as sample units to obtain a fledglings per nest value for direct comparison with Project 95163E PWS information. Laying, hatching, and fledging success were also computed from the productivity data. Differences among 1993-1995 results were tested with ANOVA.

Puffins: Puffin productivity data were obtained from five study plots (TPP 1-5) set up by UW personnel in 1990 to collect information on chick growth rates (see growth rates below), and four transects (TPT 1-4) totaling 270 m^2 established by FWS crews in 1986 to monitor numbers and occupancy rates of burrows (Nishimoto 1990; Fig 2). Burrows on the three UW plots were searched for signs of occupancy (trampled and cleared vegetation, guano from adults and chicks, fresh digging) and chicks during 29 July - 4 August, when most nestlings were about one week old. A 35-cm-long flexible scoop was used to help determine presence/absence of chicks. After the initial visit, all burrows containing nestlings were checked every five days until 6 September (most chicks had fledged by this date). Burrows on the FWS transects were checked once on 1 September, just prior to fledging, to count occupied burrows and nestlings. Using the transect information (numbers of occupied burrows and nestlings), productivity was calculated as the percentage of occupied burrows containing chicks. *[Data from the five study plots are still being analyzed; when complete, the same procedures will be used to calculate productivity for this data set. The study plot data will provide information on fledging success.]*

Nesting Chronology

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

Kittiwakes: Median hatch date, derived from productivity plot data, was used to measure kittiwake nesting chronology. The date was computed by the same methods described for murres, except that 27 days (instead of 32) were added to laying dates at sites where the range of possible laying dates was smaller than the range of possible hatching dates (see Byrd 1986, 1989). The difference between 1994 and 1995 results was checked with a two-tailed *t*-test (no eggs or chicks were present on the plots in 1993).

Puffins: Median hatch date was used to measure puffin nesting chronology. This information was derived from chick growth rate data rather than laying or hatching information, because the burrows were not visited until the chicks were about one week old (visiting them prior to this time can result in abandonment of eggs or chicks). The date was obtained by estimating the ages of 43 chicks from first wing measurements and a growth equation reported by Amaral (1977), and then calculating the median of the nestlings' estimated hatch dates.

Chick Growth Rates

Murres: Data on murre chick growth rates were not obtained during the study, because disturbing the birds to weigh and measure chicks could have caused high levels of chick mortality.

Kittiwakes: Kittiwake growth rate information was collected from 41 chicks that were weighed (to nearest g) and measured (e.g., wing chord, culmen, tarsus, and back of head to tip of bill to nearest 0.1 mm) 3-4 times, beginning shortly after they had attained weights of about 200 g (weights were not obtained prior to this time because time was needed to find accessible nests and set up ropes to reach study sites). Methods for calculating growth rates followed Project 95163E PWS protocol. Weights higher than 325 g were excluded from the data set (growth rates are linear until they reach this point), and the difference in weight between each chick's first and last measurements were divided by the number of days between these measurements (15 chicks were weighed at least twice before reaching 325 g). The resulting nestling values were then used to calculate mean growth rates for 'A' chicks (chicks in single-chick nests plus first chicks to hatch in 2-chick nests; n = 9), 'B' chicks (the second to hatch chicks in 2-chick nests; n = 6), and chicks in single-chick nests (n = 6). *[Exploratory work conducted during 1995 will allow sample sizes to be increased in 1996.]*

Puffins: Forty-three puffin chicks on three of the five UW growth rate plots (see productivity above) were weighed (to nearest g) and measured (culmen, wing chord, and tarsus to nearest 0.1 mm) every five days, from the time they were about one week old until they fledged (most nestlings were weighed seven times prior to fledging). Twenty-one additional nestlings were weighed and measured three times on the two other growth rate plots during the chick-rearing period to check for effects of disturbance on growth. Weight was chosen as the primary measurement of growth. Data were analyzed by fitting a simple liner model to the 150-450 g section of each chick's growth curve (the portion that is nearly linear), and then calculating the average daily weight gain by using the slope of the line and numbers of days between first and last measurements. The final grams per day rate was the mean of 34 chick values. *[Data from the 21 "control" nestlings are still being analyzed; when complete, the average growth rate of these chicks will be compared with the average value obtained from the 34 "experimental" nestlings.]*

Chick Food Types

Murres: Prey delivered to murre chicks were identified during feeding frequency and adult activity budget observations (see feeding frequency below). Food items brought to chicks on ledges adjacent to the feeding frequency plots were also recorded, as time allowed, to supplement plot observations. Prey were identified with 7 x 42 binoculars and field guides. In total, 460 prey items, all fish, were observed during 16 August - 3 September, when chicks were about one - three weeks old. Three hundred fifty-six (78%) of the fish were identifiable to species or family groups (e.g. gadidae) on the basis of color and body and fin shapes (e.g., caudal, anal, adipose fins). Data were analyzed by calculating percentages by number of identifiable items for five categories of prey (capelin, *Mallotus villosus*; sand lance, *Ammodytes hexapterus*; prowfish, *Zaprora silenus*; and cods, Gadidae).

Kittiwakes: Samples of prey brought to kittiwake chicks were obtained by visiting nests and gently inducing nestlings to regurgitate food. A total of 69 samples was obtained on eight different dates during 17 July - 5 August, when chicks were about 9-28 days old. Samples were fixed in 10% buffered formaldehyde for 24 hrs before being stored in 50% ethanol (weights were obtained after samples were decanted in the lab). Prey items were analyzed by A.M. Springer, Institute of Marine Sciences, University of Alaska-Fairbanks. Fish were identified, counted, and aged from otoliths, and otoliths were also used to help calculate wet weights. Wet weights (to nearest g) were estimated by using standard regression equations relating otolith lengths to fish lengths and fish lengths to wet weights of fish (e.g., see Springer *et al.* 1984, 1986). For unidentified cods (probably Pacific cod, *Gadus macrocephalus*), average weights of similar-size Pacific cod collected during the puffin burrow screening work (this study, see below) were used to estimate wet weight. Invertebrates were identified and counted from whole specimens and hard parts (e.g., jaws, rostra). Wet weights were estimated by weighing whole specimens, or in some cases by using average weights from specimens collected during the work (for small euphausiids and squid; this study, see below). Data were analyzed by calculating percentages by number and weight of identifiable items (n = 629) for five categories of prey (capelin; sand lance; walleye pollock, *Theragra chalcogramma*; cods, Gadidae; and invertebrates).

Puffins: Samples of prey brought to puffin chicks were collected by temporarily blocking burrows with small squares of hardware cloth (screens). One hundred thirty-nine samples containing 346 identifiable items were obtained during six days of screening at East Amatuli Island and four at West Amatuli Island during 31 July - 8 September. Samples were weighed (to nearest g) and prey items were measured (length, to nearest mm) before being frozen (28 August and 2 September) or fixed in 10% buffered formaldehyde for 24 hrs and stored in 50% ethanol. Most specimens were identified in the field using field guides and taxonomic keys; however, some items (e.g., larval fishes) were sent to UAF and NOAA personnel for identification. Frozen prey items were thawed and weighed (to nearest g) in the lab. These data and the measurements made in the field were used to estimate wet weights of preserved specimens. Data were analyzed by calculating percentages by number and weight of identifiable prey items for eight categories of prey (capelin; sand lance; walleye pollock; prowfish; Pacific cod; larval daubed shannies, *Lumpenus maculatus*; squids, Cephalopoda; and euphausiids, *Thysanoessa* spp.).

Chick Feeding Frequencies

Murres: Murre chick feeding frequency data were obtained from two plots set up in different types of nesting habitat near the productivity plot observation posts (see productivity above). One plot (The Cliff) consisted of a narrow ledge on a steep cliff-face about 15 m below an observation post; this plot contained 12 nest sites with chicks. The second plot (Rubble), containing 16 nest sites with chicks, was located in a flat rock-strewn area about 35 m from another observation post. Food deliveries were recorded on the plots during two 13-hr-long dawn-to-dusk watches on 24 and 26 August, and during shorter blocks of time (2.5-7.5 hrs) on 16, 17, 18, 21, 22, and 23 August. Data analyses consisted of calculating the average number of feedings per hour for the 0630-2000 hr dawn-to-dusk watches, two 0630-1030 hr blocks of time (24 and 26 August), and three 0800-1200 hr blocks of time (22, 24, and 26 August) using hours and chicks as sample units. Hours were treated as sample units to check temporal variation and help identify the most active part of the day, and chicks were used as sample units to measure variation among nests and provide an average feeding rate for comparison with data from other lower Cook Inlet studies (e.g., 1995 data collected by J. Piatt at Gull and Chisik islands). Differences in feeding rates between the two dawn-to-dusk watches and between the two 0630-1030 blocks of time were checked with two-tailed t-tests, and differences among the four 0800-1200 blocks of time were tested by ANOVA. *[Data from the Rubble plot and shorter blocks of time on other days are still being analyzed to help refine protocols for collecting this type of information (data can be analyzed in several ways—e.g., for blocks of time encompassing the most active times of the day, or for blocks of time that best represent an average rate for the entire day). Methods for collecting and analyzing these data will be finalized in cooperation with J. Piatt, Project 96163M, before the 1996 field season begins.]*

Kittiwakes: Kittiwake chick feeding frequency data were obtained from 11 nests in one of the kittiwake productivity plots (see productivity above). The nests contained 18 chicks. Most of the information was collected by watching the nests with 7 x 42 binoculars from about 20 m away and recording times of begging and feeding events. Some data were also obtained by recording these activities on video tape (using an 8-mm Sony HandyCam) and reviewing tapes in camp (no differences were found between data collected simultaneously by the video and direct observation methods). Observations began when the nestlings were about 20 days old (chicks ages were known because of the productivity work). Because chicks may be fed several times after foraging adults return to nests, and because birds sometimes leave their nests for short periods of time without foraging at sea, only first feedings after trips lasting 30 minutes or more were counted as feeding events. Two 13-hr-long dawn-to-dusk watches were conducted on 26 and 27 July to help identify the most active 4-hr part of the day, and data were collected on two additional dates (5 and 6 August) during that period (0800-1200 hrs). Data analysis consisted of dividing the data into 1- and 2-chick nests, and calculating the average number of feedings per hour for the dawn-to-dusk watches and for the four 0800-1200 hr blocks of time using hours and nests as sample units. Hours were treated as sample units to check temporal variation, and nests were used as sample units to measure variation among nests and provide an average feeding rate for comparison with data from other lower Cook Inlet colonies and studies in Prince William Sound (e.g., 1995 data collected by J. Piatt at Gull and Chisik islands, and D. Irons at Shoup Bay and Eleanor Island, respectively). Differences in feeding rates between the two dawn-to-dusk watches were checked with two-tailed t-tests, and differences among the four 0800-1200 blocks of time were tested by ANOVA. *[These data and some additional information collected during shorter times on three other dates are still being analyzed to help refine protocols for this parameter. Methods for collecting and analyzing these data will be finalized in cooperation with D. Irons, Project 96163E; D. Roby, Project 96163G; and J. Piatt, Project 96163M, before the 1996 field season begins.]*

Puffins: Data on feeding frequencies of puffin chicks were not obtained during 1995; however, a potential study site was located near the East Amatuli Island observation posts. Plans are being made to set up a blind and assess the feasibility of collecting these data. *[If these data can be obtained during August 1996, they will be compared among years and discussed in context with murre and kittiwake results.]*

Amounts of Food fed to Chicks

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

Kittiwakes: Information on amounts of food fed to kittiwake chicks was obtained from regurgitated samples (see chick food types above). Because the amount of food fed to nestlings increased until they were about 20 day old, the average weight of 44 samples collected from chicks that were that age or older was used as the seasonal index for this variable.

Puffins: Information on amounts of food fed to puffin chicks was obtained from burrow screening samples (see chick food types above). Because it was obvious that some screened samples were only partial bill-loads (e.g., only tails of fish were present; adults were seen flying off with some prey items still in their bills), the average weight of 110 samples was used as the seasonal index for this variable.

Activity Budgets of Adults

Murres: Murre activity budget information was obtained during chick feeding frequency observations (see chick feeding frequencies above). Adult arrival and departure times, and times when members of pairs exchanged duties (i.e., incubating eggs or brooding chicks) were recorded at each nest site. Average trip time was obtained by treating trips as sample units and calculating the mean duration of all trips made by birds during the two dawn-to-dusk watches (i.e., during the combined 26 hrs of observations). Nest sites were used as sample units to calculate the average numbers of minutes per hour that no adults and two adults were present at the nests during the same 26 hr period of time. Differences in attendance between the two days were tested with two-tailed t-tests.

Kittiwakes: Kittiwake activity budget information was obtained during chick feeding frequency observations (see chick feeding frequencies above). Adult arrival and departure times, and times when members of pairs exchanged duties (i.e., incubating eggs or brooding chicks) were recorded at each nest. Data were analyzed by treating nests as sample units and calculating the average number of minutes per hour that no adults and two adults were present at 1- and 2-chick nests during the two dawn-to-dusk watches (i.e., during the combined 26 hrs of observations). Differences in attendance between the two days were tested with two-tailed t-tests. *[Data are still being analyzed to obtain an average trip duration value using the same procedures described for murres—see above.]*

Puffins: Information on puffin activity budgets was not obtained in 1995. *[However, this information will be collected in 1996, if feasibility tests to obtain puffin feeding frequency data are successful.]*

Population Counts

Population counts of birds were not included in the 1995 APEX Barren Islands study plan. However, some counts were made when time was available.

Murres: Murres were counted five times on the 8 East Amatuli Island - Light Rock multicount plots censused in 1993-1994 (plots BMP 1-8; see Roseneau *et al.* 1995, 1996), and they were also counted on the productivity plots every time the plots were checked (25 times; these counts were also made in 1993-1994). Methods for collecting and analyzing these data were the same as those used during the 1993-1994 Barren Islands restoration monitoring studies (see Roseneau *et al.* 1995, 1996).

Kittiwakes: Kittiwakes were counted at the productivity plots every time the plots were checked (26 times). These counts were made and analyzed by the same procedures used during 1993-1994 (D.G. Roseneau and A.B. Kettle, unpubl. data).

Puffins: During the puffin work, about 200 burrows on the five UW growth rate plots and 63 burrows on the FWS transects were checked for occupancy. This information is being analyzed to provide an index of occupied burrows per m^2 that can be used to help monitor changes in population size during coming years.

RESULTS

Productivity

Murres: Common murre productivity was high in 1995 (0.77 fledglings per egg, SD = 0.09; Table 1, Fig. 3a) and similar to the 1994 results (0.73 fledglings per egg; Roseneau *et al.* 1995); values from both of these years were significantly higher than in 1993 (0.55 fledglings per egg, $P = 0.001$ and 0.007, respectively; Roseneau *et al.* 1996). Fledging success was also high (0.91 chicks per egg, SD = 0.006; see Byrd *et al.* 1993) and nearly identical to the 1994 level (0.93), and results from both years were higher than the 1993 value (0.79; $P = 0.004$ and 0.011, respectively). Hatching success exhibited a different pattern: while the 1995 and 1994 figures (0.85 chicks per egg, SD = 0.07, and 0.79, respectively; also high values, see Byrd *et al.* 1993) were similar each other, only the 1995 value was significantly higher than the 1993 figure (0.70; $P = 0.017$).

Kittiwakes: Productivity of kittiwakes was high in 1995 (0.81 fledglings per nest, SD = 0.20; Table 1, Fig. 3b—also see Hatch *et al.* 1993) and similar to the 1994 level (0.64 fledglings per nest; D.G. Roseneau and A.B. Kettle, unpubl. data). These results were in sharp contrast to 1993, when nesting pairs failed early in the nesting season and reproductive success was zero (no eggs or chicks were present on the five East Amatuli Island plots; however, a few fledglings were observed at the colony at the end of the breeding season—Roseneau *et al.* 1995). Hatching success (0.73 chicks per egg, SD = 0.11) was higher than it was in 1994 (0.50, SD = 0.21; $P = 0.012$), but fledging success (0.61, SD = 0.15) was lower than the 1994 value (0.87, SD = 0.05; $P = 0.005$).

Puffins: Based on the information obtained from transects TPT 1-4, productivity of puffins (0.52 chicks per occupied burrow; Table 1 and 2, Fig. 4) fell between the 1993 and 1994 values (60% and 47%, respectively). *[Data from the growth rate study plots are being analyzed to obtain productivity values for 1993-1995; the plots sample a much larger area then the transects.]*

Nesting Chronology

Murres: Based on the median hatch date (9 August, SD = 2.9 days; Table 1), hatching occurred two days earlier than in 1994 (11 August; Roseneau *et al.* 1995) and seven days earlier than in 1993 (16 August; Roseneau *et al.* 1996). Although no difference was found between the 1994 and 1995 estimates, the 1993 date was significantly later than the 1994-1995 dates (ANOVA, $P = 0.001$ in both cases).

Kittiwakes: The median hatch date was 8 July (SD = 1.7 days; Table 1). *[1994 nesting chronology data are still being analyzed.]*

Puffins: The median hatch date was 22 July (SD = 5.1 days; Table 1). *[1993-1994 nesting chronology data are still being analyzed.]*

Chick Growth Rates

Kittiwakes: The average growth rate of kittiwake chicks, based on all chicks combined (n = 15), was 19.0 grams per day (SD = 4.2 days; Table 1). "A" chicks (chicks in single-chick nests plus first chicks to hatch in 2-chick nests; n = 9) gained about 18.7 grams per day (SD = 3.8 days), while "B" chicks (the second to hatch chicks in 2-chick nests; n = 6) grew at a rate of about 19.6 grams per day (SD = 5.0 days). The average daily weight gain for chicks in single-chick nests (n = 6) was about 18.6 grams per day (SD = 4.3 days). No significant differences were found among these values.

Puffins: Based on a preliminary analysis of 34 nestlings in three study plots, puffin chicks grew at an average rate of 11.5 grams per day (SD = 3.3 grams; Table 1). *[Data from the 21 nestlings that were weighed and measured only three times during the nestling period, and information obtained during the 1993-1994 field seasons are still being analyzed.]*

Chick Food Types

Murres: Prey items delivered to murre chicks consisted solely of small fish (n = 460), most of which were capelin (86%, n= 356; Fig. 5). Adults also fed nestlings unidentified cods (Gadidae, probably primarily walleye pollock and Pacific cod), prowfish, and sand lance, but in much lower numbers (7%, 6%, and 1%, respectively). Based on the general sizes of fish brought to the chicks and the large numbers of capelin fed them, this forage fish species must have also dominated the diets by weight.

Kittiwakes: Kittiwakes fed their nestlings both fish and invertebrates, and on the basis of numbers alone (n = 629; Fig. 6a), invertebrates outranked fish (438 items = 70% vs. 191 items = 30%, respectively). However, invertebrates were present in only six (9%) regurgitations, and most of them (424 small euphausiids totaling 97% of all invertebrate prey) were found in two samples. When the samples were analyzed by weight (Fig. 6b), it was clear that fish dominated the diets (94% vs. 6% invertebrates) and capelin (65% by weight) outranked other species.

Puffins: Prey deliveries (screen samples; n = 139) to puffin chicks contained 346 items, most of which were fishes (87% by number vs. 13% invertebrates; Fig. 7a). By number, walleye pollock (26%), larval daubed shannies (21%), capelin (14%), and sand lance (12%) were the most common prey fed to nestlings (73% of the total). By weight, fishes were also clearly the most important prey (93%; Fig. 7b). However, in this analysis, capelin (28%), walleye pollock (24%), prowfish (22%), and sand lance (13%) made up the bulk of the chicks' diets (87% of the total).

Chick Feeding Frequencies

Murres: During the two all-day watches, chicks on the Cliff plot averaged 0.31 feedings per hour (SD = 0.11, n = 12; Table 1, Figs. 8 and 9). Feeding rates during the two 0630-1030 and three 0800-1200 hr morning blocks of time averaged 0.39 (SD = 0.22, n = 12) and 0.24 (SD = 0.16, n = 12) per-hour, respectively. No differences were found between the two 13-hr average values (0.35/hr, SD = 0.16 and 0.27/hr, SD = 0.11 on 24 and 26 August, respectively), or between the 0630-1030 average rates (0.42/hr, SD = 0.34 and 0.35/hr, SD = 0.23 on 24 and 26 August, respectively), or among the 0800-1200 average values (0.23/hr, SD = 0.21; 0.31/hr, SD = 0.28; and 0.19/hr, SD = 0.19 on 22, 23, and 26 August, respectively).

Kittiwakes: During the two all-day watches, single-chick nests averaged 0.28 feedings per hour (SD = 0.11, n = 11; Table 1, Figs. 10 and 11), and nests containing two chicks averaged 0.47 feedings per hour (SD = 0.19, n = 11). This difference was almost significant (two-tailed *t*-test, $P = 0.07$). Feeding rates during the four 0800-1200 hr blocks of time averaged 0.39 (SD = 0.18, n = 5) and 0.72 feedings per hour (SD = 0.50, n = 6) at 1-chick and 2-chick nests, respectively. This difference was barely significant (two-tailed *t*-test, $P = 0.05$). No differences were found between the two 13-hr average values (0.33/hr, SD = 0.19, and 0.44/hr, SD = 0.18 on 26 and 27 July, respectively), or among the four 0800-1200 average rates (0.39/hr, SD = 0.23; 0.48/hr, SD = 0.21; and 0.59/hr, SD = 0.34; and 0.82/hr, SD = 0.20 on 26 and 27 July, and 5 and 6 August, respectively).

Amounts of Food fed to Chicks

Kittiwakes: The weight of kittiwake chick regurgitations increased with collection date, until the nestlings were about 20 days old (from 10.9 g, SD = 5.1 on 17 July to 26.6 g, SD = 9.5 on 30 July). The average weight of the 44 regurgitation samples obtained from chicks that were about 20 days of age or older was 27.7 g (SD = 11.5; Table 1).

Puffins: The average weight of 110 screen samples collected during the nestling period was 10.3 g (SD = 12.8; Table 1).

Activity Budgets of Adults

Murres: *(Duration of Trips from Nest)* -- The average duration of murre foraging trips during the two dawn-to-dusk watches at the Cliff plot was 157.7 minutes (Table 1, Fig. 12); however, variation was high (SD = 131.3; Table 1, Fig. 13). *(Time Spent at Nest)* -- At least one adult was always present at each site, and both birds were present an average of 5.6 minutes per hour (SD = 4.4; Fig. 13). *[The duration of foraging trips at the Rubble plot are still being analyzed.]*

Kittiwakes: *(Duration of Trips from Nest)* -- Kittiwake foraging trip data are still being analyzed. *(Time Spent at Nest)* -- Average times spent at nests by adults were as follows: at 1- and 2-chick nests, both adults were present 0.3 minutes per hour (SD = 0.0, n = 11; Table 1, Fig. 15) and 0.3 minutes per hour (SD = 0.2, n = 11), respectively, and neither adult was present 1.1 minutes per hour (SD = 0.9) and 5.1 minutes per hour (SD = 5.0), respectively. No differences were found between days for amounts of time two adults spent at nests (26 and 27 July, 4.3 min/hr, SD = 7.1 and 2.2 min/hr, SD = 3.3, respectively), or for times both adults were absent from nests (26 and 27 July; 0.3 min/hr, SD = 0.1, and 0.4 min/hr, SD = 0.3, respectively).

Population Counts

Murres: The average number of murres counted on multicount plots BMP 1-8 was 5,224 individuals (SD = 583; Table 1, Fig 16a). In 1993 and 1994, these plots averaged 5,808 and 5,599 birds, respectively (Roseneau *et al.* 1995, 1996). Counts on productivity plots MPP 1-10 averaged 439 (SD = 32) murres (Fig. 16b), and in 1993 and 1994 scores were 481 and 456 birds, respectively. The multicount and productivity plot estimates will be tested for trends after 1996 data become available. [These data will be analyzed in conjunction with recently approved restoration monitoring Project 96144.]

Kittiwakes: Counts on kittiwake productivity plots KPP 1-12 averaged 199 birds (SD = 15). The 1993-1996 estimates will be tested for trends after completion of the 1996 field season.

Puffins: *[Data on burrow occupancy rates are still being analyzed.]*

DISCUSSION

Eventually, we will be able to compare all of our Barren Islands results among years and make both among- and within-year comparisons with information from other lower Cook Inlet - Kachemak Bay and Prince William Sound colonies to help test APEX hypotheses 7-9. However, at this point during the multiyear study, detailed discussions are premature. Data from previous Barren Islands studies were available for comparison with some of the parameters we measured in 1995 (e.g., reproductive success of all three species, puffin chick growth rates and prey samples), but for other variables (e.g., time-activity budgets of murres and kittiwakes), 1995 was the first year data were collected at the study site. Because some data analyses are still underway, the preliminary discussion provided here is limited to the analyses that have been completed to date.

Productivity

As suggested by APEX hypothesis 8, seabird productivity may reflect shifts in prey abundance near breeding colonies. During 1994 and 1995, murre and kittiwake productivity were high at East Amatuli Island - Light Rock, compared with values reported from 10 North Pacific common murre colonies (see Table 3 in Byrd *et al.* 1993) and 162 estimates from 28 North Pacific black-legged kittiwake colonies (see Table 2 in Hatch *et al.* 1993). In 1993, productivity of murres was within normal bounds; however, it was lower, and the variation among plots higher, than during 1994-1995. Most of the difference in productivity between 1993 and 1994-1995 was caused by the loss of chicks on two exposed study plots during a late August 1993 storm (Roseneau *et al.* 1995).

In contrast to murres, kittiwakes experienced an early, near-complete reproductive failure in 1993: no eggs were laid on the East Amatuli and Nord island study plots (FWS, unpubl. data), and only a few fledglings were seen at the colonies (Roseneau *et al.* 1995). Kittiwake failures have been relatively common events at Alaskan colonies in recent years, and no correlation's appear to exist between these failures and the productivity of diving species (e.g., murres, puffins, cormorants; see Hatch *et al.* 1993). This lack of concordance and the fact that productivity of diving birds has often been within normal ranges in years when surface-feeding kittiwakes fail to reproduce, suggest that the vertical distribution of prey, rather than overall prey abundance, has been responsible for these events (Hatch *et al.* 1993). Available evidence suggests that this was probably the case at the Barren Islands in 1993: although large schools of small fish were present at depth that year, kittiwake feeding melees were rare (Roseneau *et al.* 1995; D.G. Roseneau, pers. obs.)

APEX hypothesis 9 suggests that seabird productivity can be affected by the quality of prey. It is possible that the 1993 kittiwake breeding failure was related to only poor-quality prey being available to these birds, while murres had access to higher-quality food items.

There is some evidence that the frequency of kittiwake reproductive failures has increased recently in the Gulf of Alaska, and that if the current trend continues, colonies may not be able to sustain themselves (Hatch *et al.* 1993). As more data are obtained on seabird reproductive and feeding parameters among species, colonies, and years, and on the distribution and abundance of forage fishes near colonies, specific causes of these events may become more apparent.

In 1995, puffin productivity (defined in this report as the percent of occupied burrows containing chicks just before fledging) fell between the 1993 and 1995 levels, and appeared to be within normal limits, compared to information from other colonies (see Table 6 in Byrd *et al.* 1993; this table uses fledglings per egg as the measurement of productivity).

Nesting chronology

Although nesting chronology was not specifically mentioned in APEX hypotheses 7-9, this variable may be an indicator of changes in environmental conditions that might affect forage fish populations. The average laying dates of most seabird species tend to be timed so that their chick-rearing periods coincide with times when food is most abundant (e.g., Lack 1954). However, the timing of breeding also appears to respond to broad-scale water temperature changes that may alter the distribution, abundance and types of prey available to the nesting birds (e.g., see Boekelheide *et al.* 1990).

Murre nesting chronology often varies by up to 6-10 days among years within colonies (Harris and Birkhead 1985). Based on this information, the 1-week difference between the 1993 and 1994-1995 East Amatuli Island - Light Rock hatch dates was within the normal range of variability. As data are gathered over the next few years, we may be able to use the timing of murre, kittiwake, and puffin nesting events to help detect large-scale changes in environmental conditions.

Chick Growth Rates

Growth rates of seabird chicks may vary with adult foraging conditions, particularly when food abundance is low (Cairns 1987). Data on chick growth rates can be used to help address APEX hypotheses 7 and 8, because this variable can supply indirect information on the types and amounts of prey available to the breeding birds. Because growth rates of chicks can also affect their survival, this parameter may also apply to hypotheses 8 and 9, as a component of seabird productivity. During the course of our studies, we will compare chick growth rates with direct measurements of fish abundance and quality, and with data on feeding frequencies and meal sizes of chicks, types of prey fed to chicks, and adult time budgets. After these comparisons have been made over a few years among species and among colonies, they may help identify relationships between food availability and chick growth rates.

Variation in kittiwake chick growth rates was high. As a result, only large differences in growth rates between "A", "B", and single chicks, and between chicks at the East Amatuli Island and Prince William Sound colonies would have been statistically significant. Because study plots for collecting kittiwake growth rate data were set up in 1995, we will be able to begin making measurements earlier in 1996, and increase our sample size.

In 1995, puffin chicks at East Amatuli Island apparently grew more slowly than at Seal Island in Prince William Sound. This difference may have been caused by differences in the quantity, quality, and types of prey available to foraging adults. Although weights of screen-sampled chick meals were highly variable at the Barren Islands, the mean weight was similar to the Seal Island mean weight. However, the type of food fed to chicks was clearly different between the two locations: a high proportion of Pacific herring *(Clupea harengus pallasi)* was fed to chicks at Seal Island, but herring were absent from the Barren Islands samples. While the data were insufficient to rule out differences in abundance of food as the cause of the growth rate differences, it is possible that the availability of herring helped chicks grow more quickly at Seal Island.

Chick Food Types

As suggested in hypothesis 7, the type of food delivered to chicks may reflect the types of forage fish available in the water column. Because energy content varies among species and age classes of fishes, changes in types of fish available to foraging adults may affect the abilities of adults to perform breeding activities. Changes in prey types may also affect growth and survival of chicks, which may in turn affect the overall productivity of nesting populations, as stated in hypothesis 9.

The degree to which types of prey fed to chicks reflect the composition of forage fishes in surrounding waters probably varies among seabird species. Capelin, by both number and weight, were, by far, the largest components in the murre and kittiwake chick diets. In contrast, capelin, pollock, and prowfish were found in about equal proportions by weight in the puffin burrow screen samples. It is possible that puffin foraging areas differed from the foraging areas used by murres and kittiwakes, and that capelin were less abundant there. Other possibilities were that murres and kittiwakes selected capelin, while puffins did not discriminate among types of prey, or that when large numbers of capelin were present, puffins selected a variety of prey, while murres and kittiwakes took whatever was most abundant.

However, puffin-bill loads collected at East Amatuli Island during 1976 and 1979 were heavily dominated by capelin, and those obtained during 1977-1978 contained mostly capelin and sand lance (Manuwal 1980). Pollock was absent from the 1970's samples, and Pacific cod and prowfish were rare. These changes in prey types agree with results from shrimp trawl surveys conducted in the Gulf of Alaska that show that the abundance of capelin declined after the late 1970's, while the abundance of gadids increased (Piatt and Anderson 1995). This information suggests that the contents of puffin bill-loads may reflect the abundance and availability forage fish.

During the study, we plan to compare the types of prey fed to chicks with data from hydroacoustic and trawl surveys. Comparing these data will help clarify and quantify relationships between chick diets and the distribution and abundance of forage fishes near nesting colonies. We will also make comparisons between chick food types, productivity measurements, amounts of food fed to chicks, adult activity budgets, and chick growth rates, to help quantify the effects that chick food types may have on seabird breeding success.

Chick Feeding Frequencies

Hypothesis 8 suggests that chick feeding frequencies may be useful indicators of forage fish abundance, that may in turn be related to seabird productivity. Nineteen ninety-five was the first year murre and kittiwake chick feeding frequency data were collected at East Amatuli Island. After the 1996 field season is complete, we will compare changes in this variable with changes in productivity and other parameters among colonies and years.

Amounts of Food fed to Chicks

Hypothesis 7 indicates that the amount of food fed to chicks may reflect the abundance and distribution of forage fishes, and hypothesis 8 suggests that the amounts of food fed to chicks may affect seabird productivity.

It was not surprising to find that kittiwake chick regurgitation weights increased over time, because stomach capacities of younger chicks are smaller than stomach capacities of older chicks. However, because this variable does change over time, sampling protocols must be designed to ensure that regurgitation weights are comparable between years and study sites. One approach might be to collect samples during one or more specified age intervals (e.g., from nestlings that are known to be 20-30 days old, or from 5-10, 15-20, and 25-30 day-old chicks, respectively). Another approach may be to evenly distributing samples throughout the entire chick-rearing period. If samples can only be obtained from chicks with unknown hatch dates, estimating ages based on plumage development might improve the quality of comparisons made among years and sites.

Because variation in the Barren Islands puffin screen sample weights was high, only large differences between the mean weights of these samples and the Seal Island samples would have been significant. The mean weight of the Barren Islands samples was lower than the mean weights reported for puffin bill-loads collected at East Amatuli Island during 1976 (14.9 g) and 1977 (20.4 g). However, it is possible that the method used to collect bill-loads during those years (mist-netting adults returning to the colony) may have been more effective in obtaining higher proportions of complete loads. *[On occasion, we have see puffins drop partial bill-loads near their burrows and then fly off with some prey items after they encounter the screens.]*

By estimating the sizes of fish delivered to murre chicks, it may be possible to estimate the amount of food fed to nestlings. Although the size estimates may not be precise, the number of fish delivered to the chicks can be measured precisely. Therefore, the estimates of what nestlings are actually fed may be relatively accurate over periods of time.

Activity Budgets of Adults

At this point in the study, we cannot make correlation's between adult time budgets and productivity (as required to test hypothesis 8), because 1995 was the first year both parameters were measured simultaneously. After additional data have been collected at the Barren islands and other study sites, we will be able to begin exploring the relationship between these parameters.

As indicated in hypothesis 8, adult time budgets may reflect changes in food supplies. Cairns (1987) stated: "Most animals typically have a reserve of spare time which can be used for feeding as necessity demands (Herbers 1981), and direct measurements of foraging activity are probably linked more tightly to food availability than are other measurable seabird parameters." As data are obtained on the distribution and abundance of forage fishes (e.g., during hydroacoustic and trawl surveys), and on parameters that may respond to changes in food supplies among years and colonies, we will begin to explore the relationships between adult time budgets and food supplies in greater detail.

Population Counts

During 1993-1995, the murre multicount and productivity plot counts followed the same pattern. This similarity lends confidence to both sets of population numbers data. The count pattern suggests that murre numbers may be decreasing on both sets of plots. If this pattern persists, it may result in a negative trend. Counts made at the Barren Islands colonies in 1996 under Project 96144 (common murre population monitoring) will provide a fourth year of data that will allow us to test these count sets for trends.

Other Comparisons

During the course of the study, data (e.g., productivity, nesting chronology, chick growth rates and prey types) will be compared with pre-1995 information from the Barren Islands [e.g. Amaral (1977), Manuwal (1978, 1980), Manuwal and Boersma (1978), Boersma, *et al.* (1995), Dragoo, *et al.* (1994), Nysewander, *et al.* (1993)] and other colonies in the Gulf of Alaska (e.g., Puale Bay—Dewhurst 1991, Dewhurst and Moore 1992, McCarthy and Dewhurst 1993; Semidi Islands—Baggot *et al.* 1989, Dragoo *et al.* 1991a,b), whenever appropriate. Within- and among-years comparisons will also be made with information being collected by other APEX investigators at colonies in Prince William Sound (D. Irons, Project 96163E, Shoup Bay and Eleanor Island) and lower Cook Inlet - Kachemak Bay (J. Piatt, Project 96163M, Gull and Chisik Islands).

CONCLUSIONS

1. Sufficient quantities of the types of data that are needed to help test APEX hypotheses 7-9 can be obtained from the East Amatuli Island - Light Rock colony in a cost-effective manner.

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Table 1. Preliminary results from Barren Islands Seabird Studies, 1995.

Variable	Common murre		Black-legged kittiwake		Tufted puffin	
Productivity	Eggs hatched / eggs laid	0.85 (0.07)[1]	Clutches / nests built:	0.95 (0.06)	Chicks / occupied burrow	0.52
	Chicks fledged / eggs hatched	0.91 (0.09)	Clutch size:	1.93 (0.16)		
	Chicks fledged / eggs laid	0.77 (0.09)	Eggs hatched / eggs laid	0.73 (0.10)		
			Chicks fledged / eggs hatched:	0.61 (0.14)		
			Chicks fledged / nests built:	0.82 (0.20)		
Nesting chronology	Median hatch date:	9 Aug (2.9)	Median hatch date:	8 Jul (1.7)	Median hatch date:	22 Jul (5.1)
Chick growth rate	*No data*		Grams/day (all chicks):	19.0 (4.2)	Grams per day:	11.5 (3.3)
			("A" chicks):	18.7 (3.8)		
			("B" chicks):	19.6 (5.0)		
			(single chicks):	18.6 (4.3)		
Chick feeding freq.	Feedings / chick / hr (0630-1930):	0.31 (0.11)	Feedings/nest/hr (0700-2000) (1 ch):	0.28 (0.11)	*No data*	
	(0630-1030):	0.39 (0.22)	(2 ch):	0.47 (0.19)		
	(0800-1200):	0.24 (0.16)	(0800-1200) (1 ch):	0.39 (0.18)		
			(2 ch):	0.72 (0.30)		
Adult trip duration	Minutes / trip:	157.7 (131.3)	*Analysis incomplete*		*No data*	
Time no ad. on nest	Minutes / hour:	0.0	Minutes / hour (1 chick):	1.1 (0.9)	*No data*	
			(2 chicks):	5.1 (5.0)		
Time 2 ad. on nest:	Minutes / hour:	5.6 (4.4)	Minutes / hour (1 chick):	0.3 (0.0)	*No data*	
			(2 chicks):	0.3 (0.2)		
Chick meal size	*no data*		Regurgitant weight (g):	27.7 (11.5)	Screen samp. wt. (g):	10.3 (12.8)
Population size	Multicount plots (no. of birds):	5224 (583)	Productivity plots (no. of birds):	198 (15)	*Analysis incomplete*	
	Productivity plots (no. of birds):	439 (32)				

[1] Standard deviation in parentheses

Table 2. Results from searches of four tufted puffin transects at East Amatuli Island, Barren Islands, Alaska, 1993-1995. Total area = 270 m^2

Year	Burrows	Occupied burrows	Occupied / total burrows	Chicks	Chicks / occupied burrows
1993	58	25	43	15	0.60
1994	44	17	39	8	0.47
1995	63	25	40	13	0.52
Average	60	23	40.7	12.0	0.58
St. Dev.	16	3	2.1	4.0	0.15

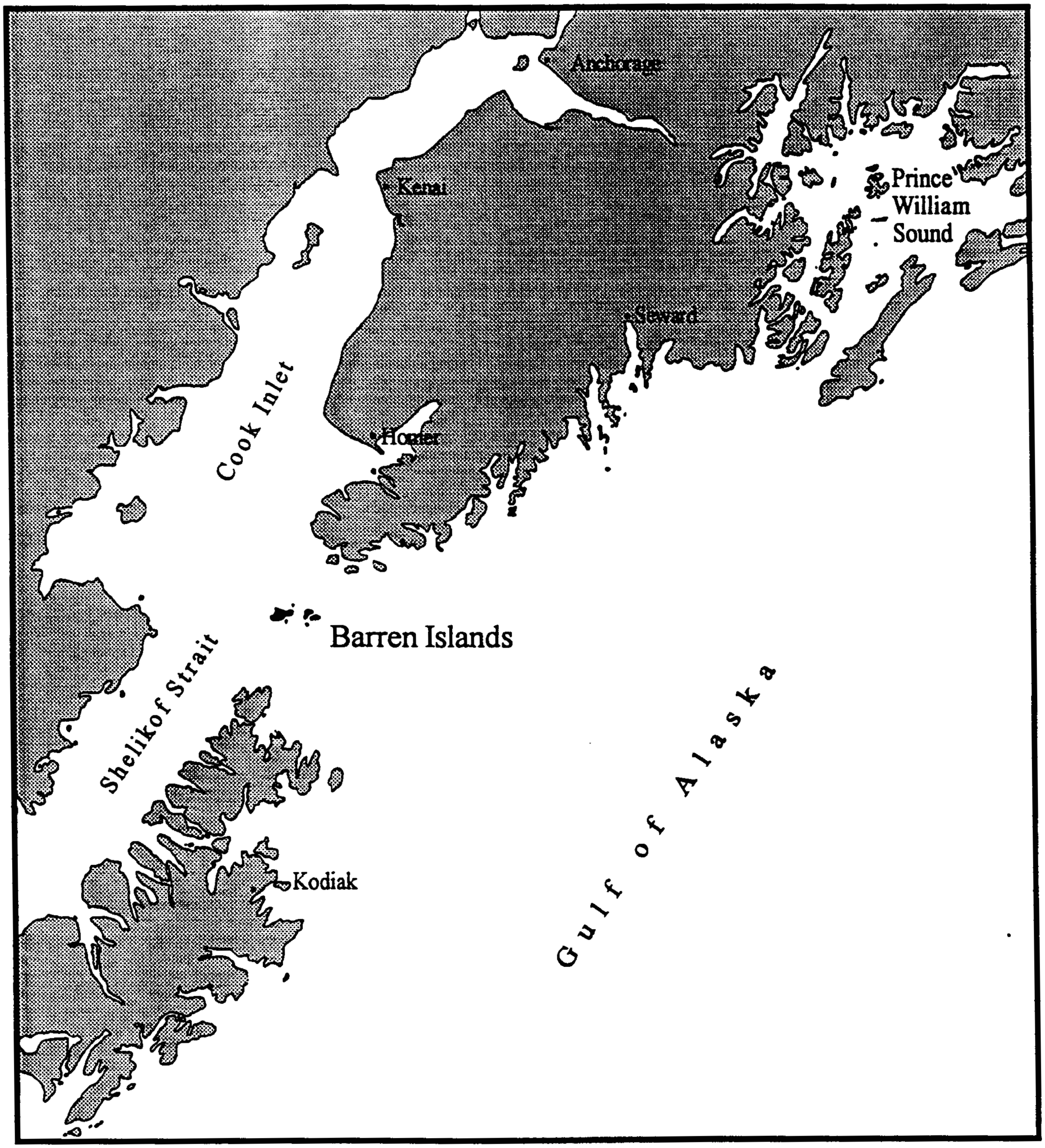

Figure 1. Location of the Barren Islands, Alaska.

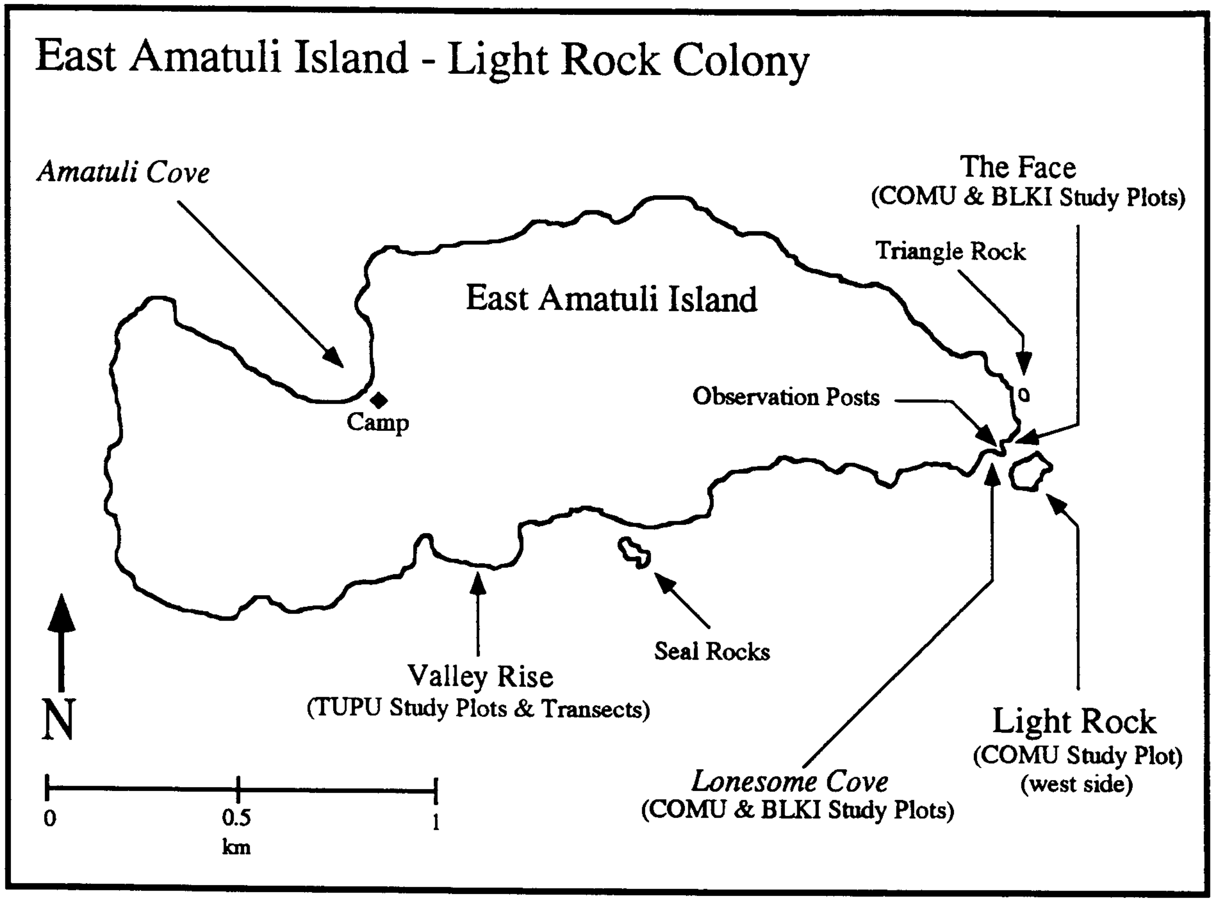

Figure 2. The 1995 Barren Islands study area showing the general locations of the common murre (COMU), black-legged kittiwake (BLKI), and tufted puffin (TUPU) study sites.

Productivity

Common Murre

Black-legged Kittiwake

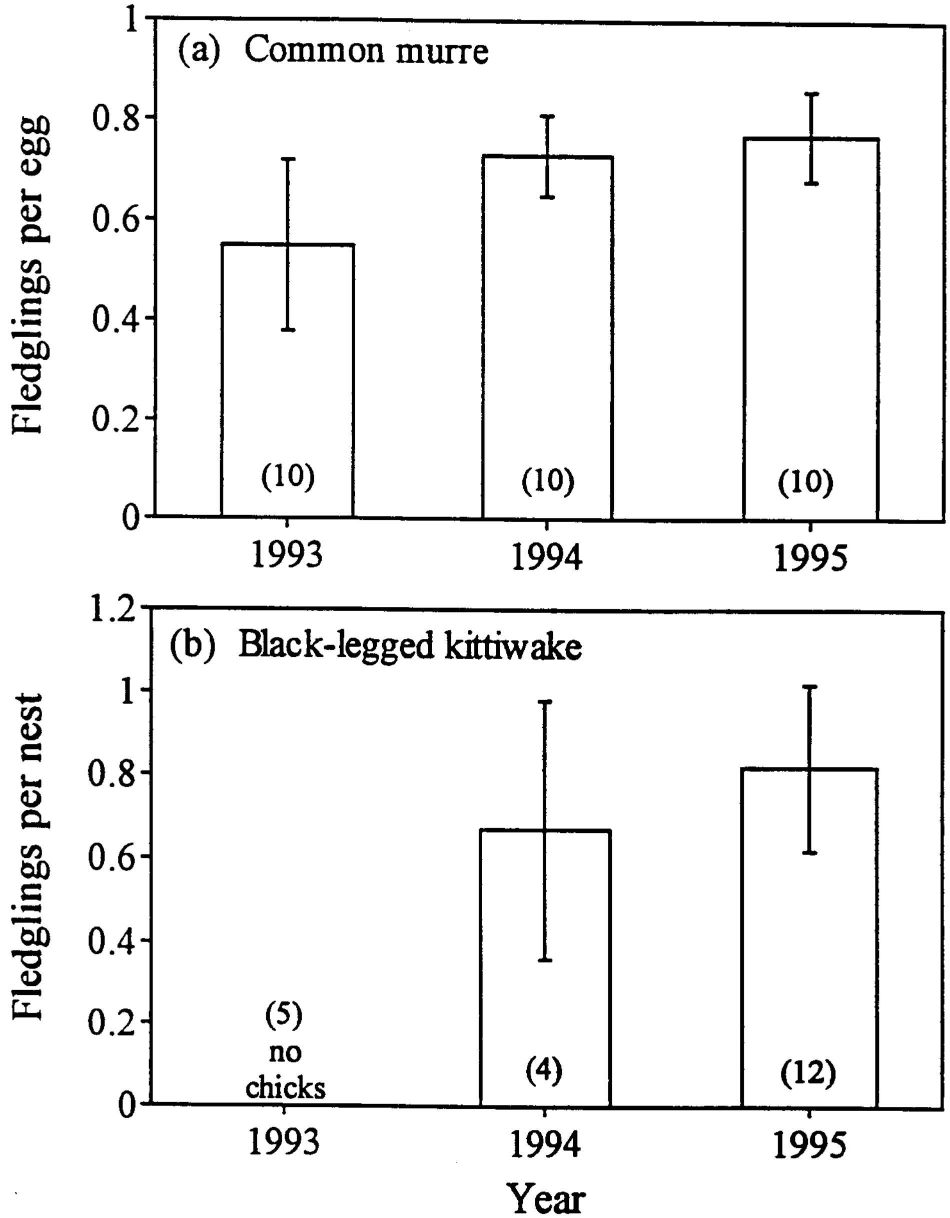

Figure 3. Productivity of (a) common murres and (b) black-legged kittiwakes at East Amatuli Island, Barren Islands, Alaska, 1993-1995. Number of plots in parentheses.

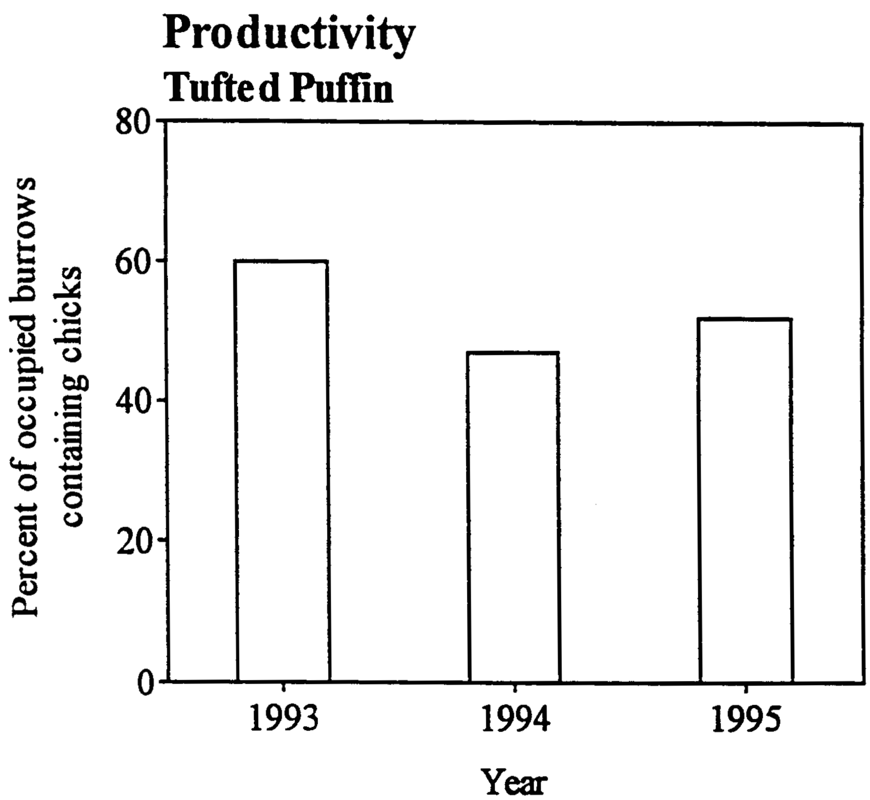

Figure 4. Percent of occupied tufted puffin burrows containing chicks in four transects totaling 270 m^2 at East Amatuli Island, Barren Islands, Alaska during late August-early September, 1993-1995.

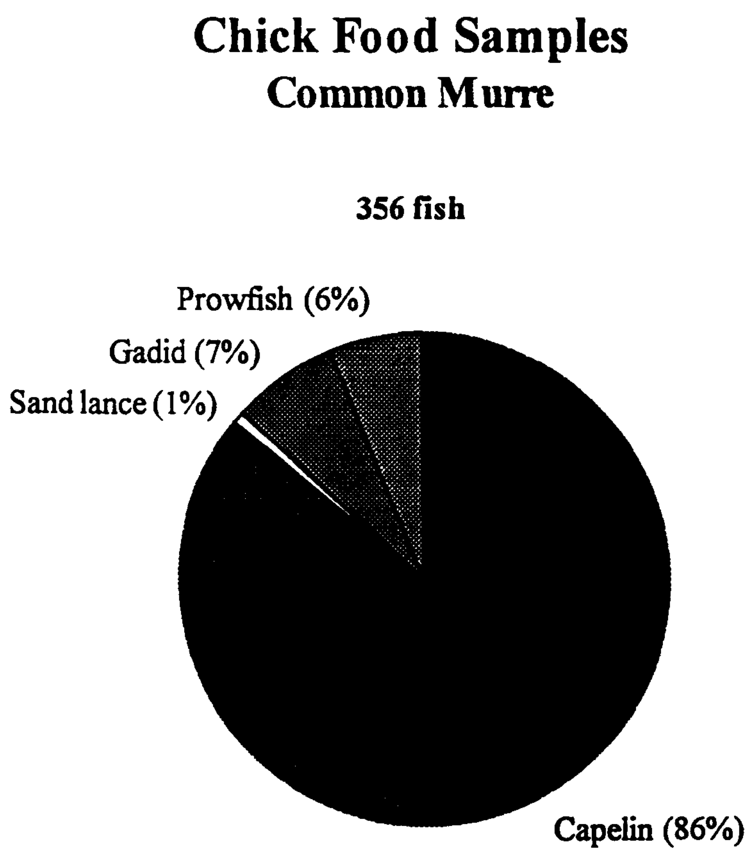

Figure 5. Types of prey fed to common murre chicks at East Amatuli Island, Barren Islands, Alaska, 1995.

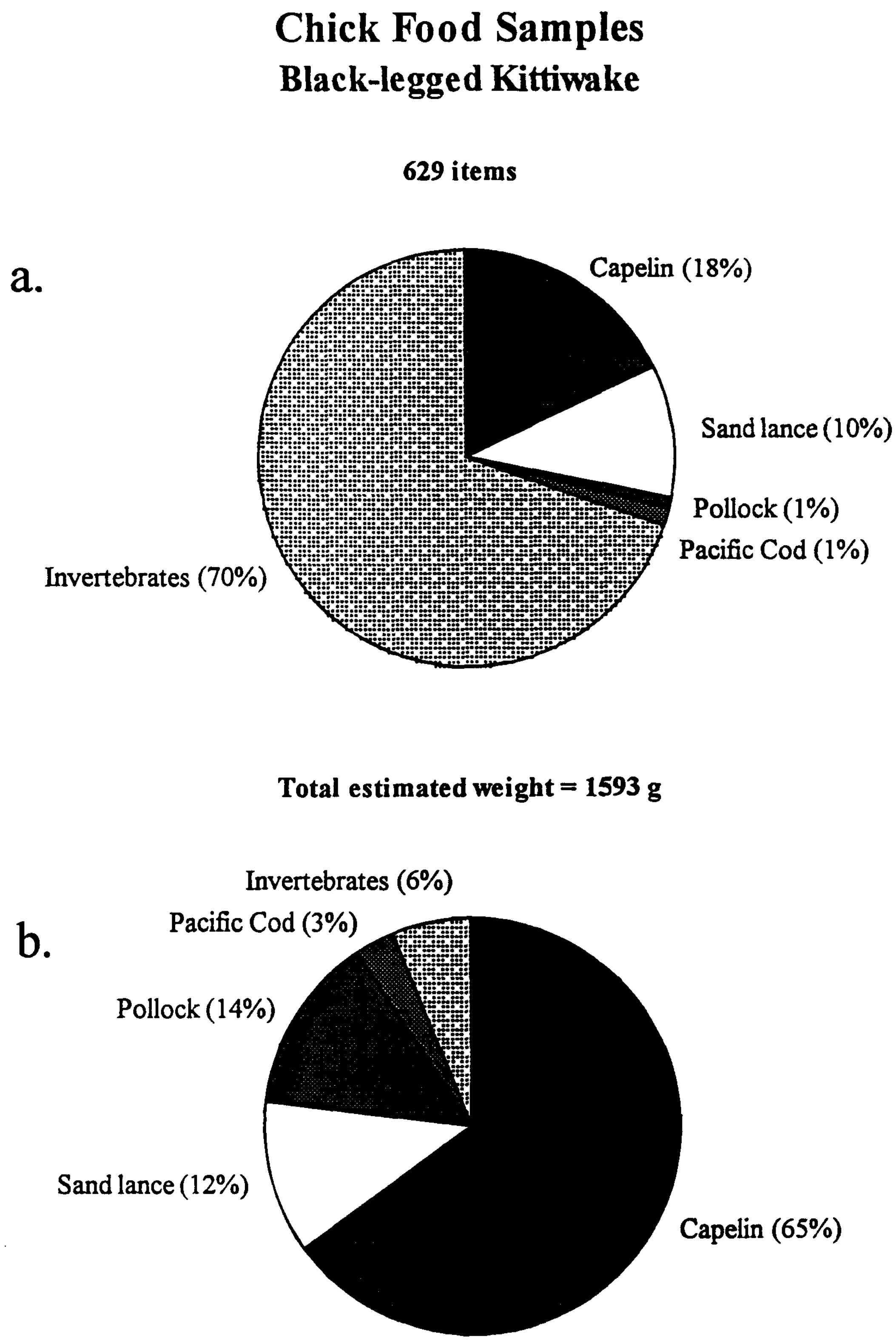

Figure 6. Types of prey fed to black-legged kittiwake chicks at East Amatuli Island, Barren Islands, Alaska, 1995. (a) Percent by number; (b) percent by weight.

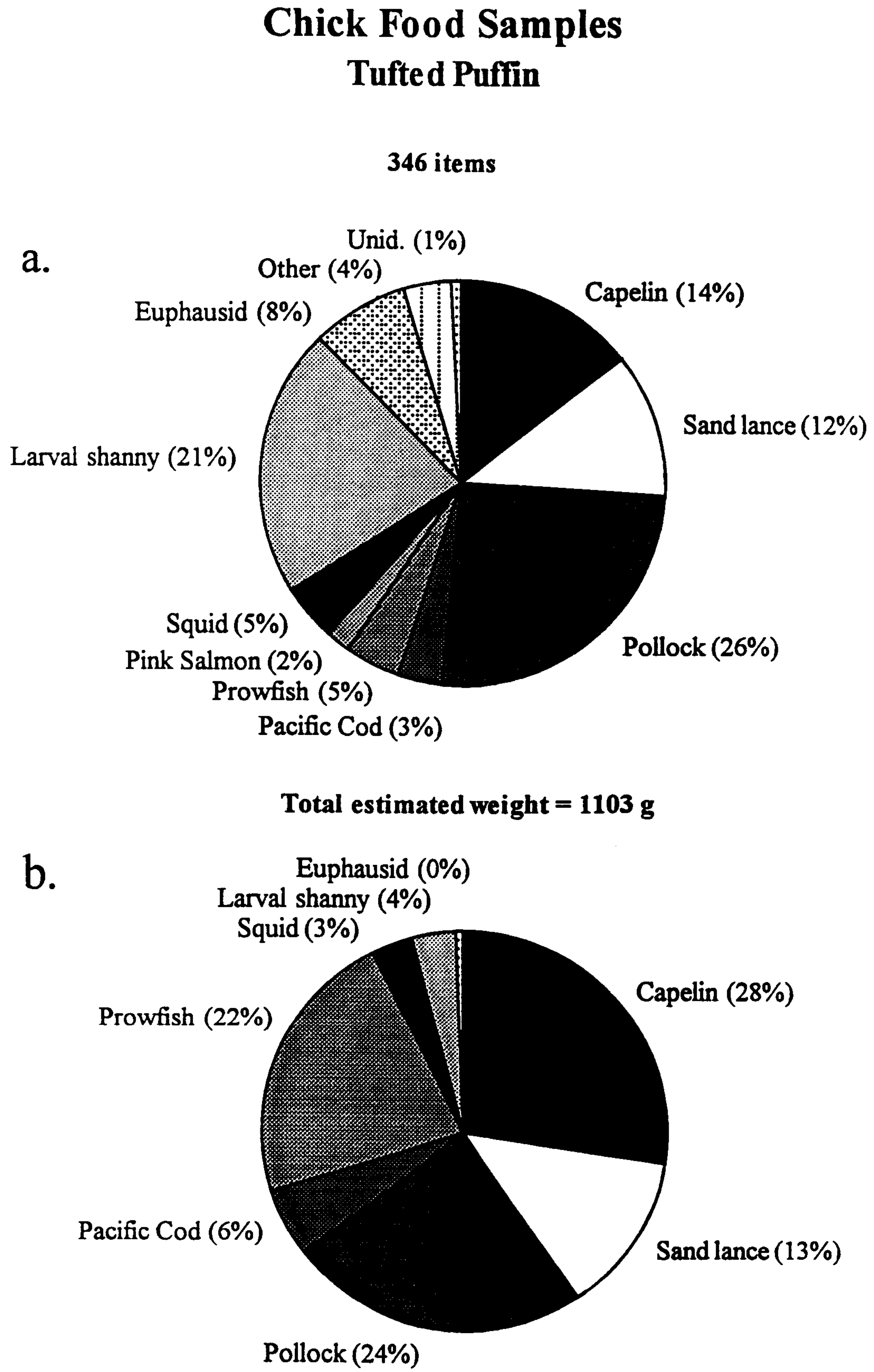

Figure 7. Types of prey brought to tufted puffin chicks at East Amatuli Island, Barren Islands, Alaska, 1995. (a) Percent by number; (b) percent by weight.

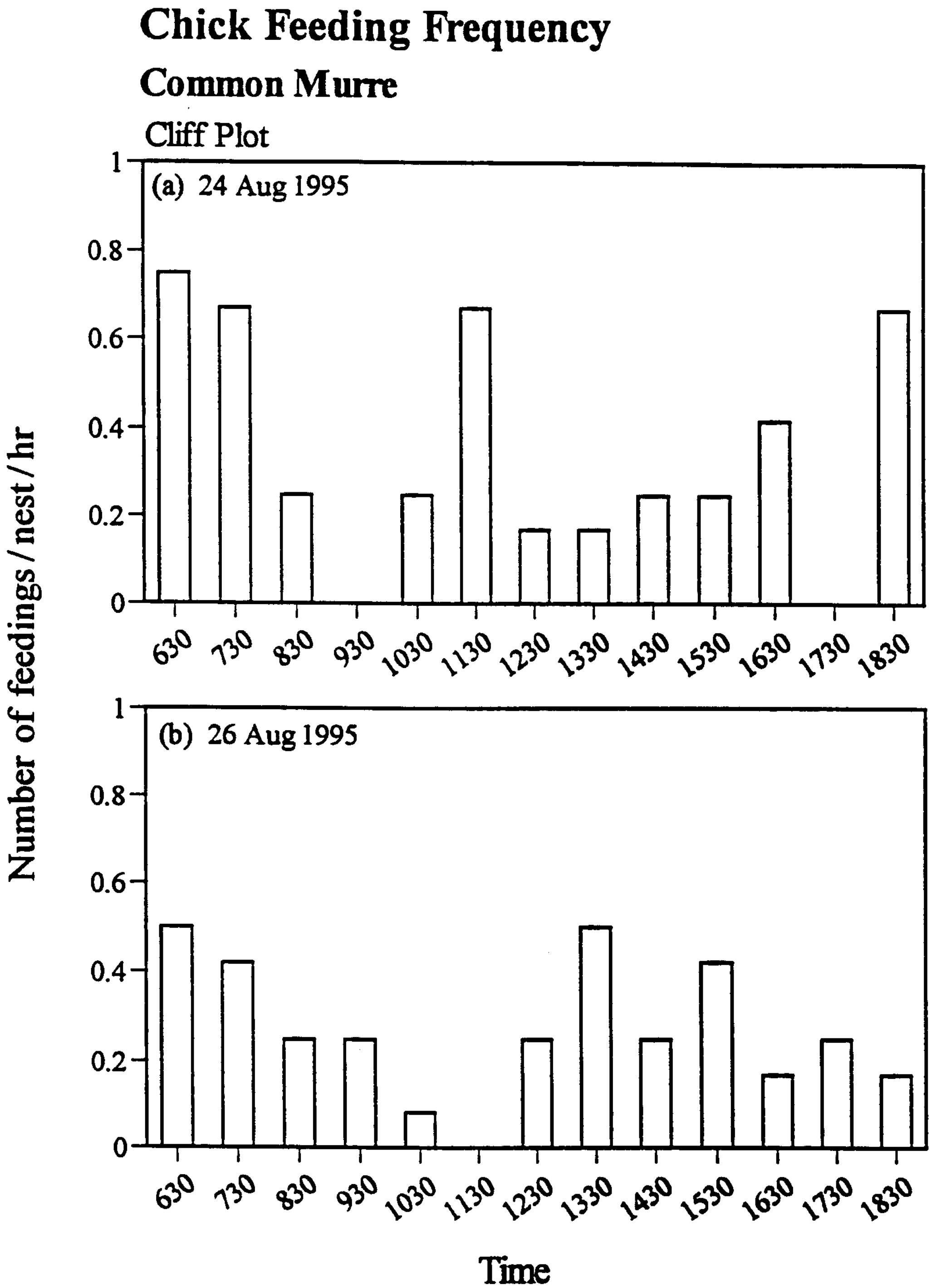

Figure 8. Number of feedings per nest per hour, by hour, during two dawn-to-dusk watches of common murres at East Amatuli Island, Barren Islands, Alaska, 1995: (a) 24 August; (b) 26 August.

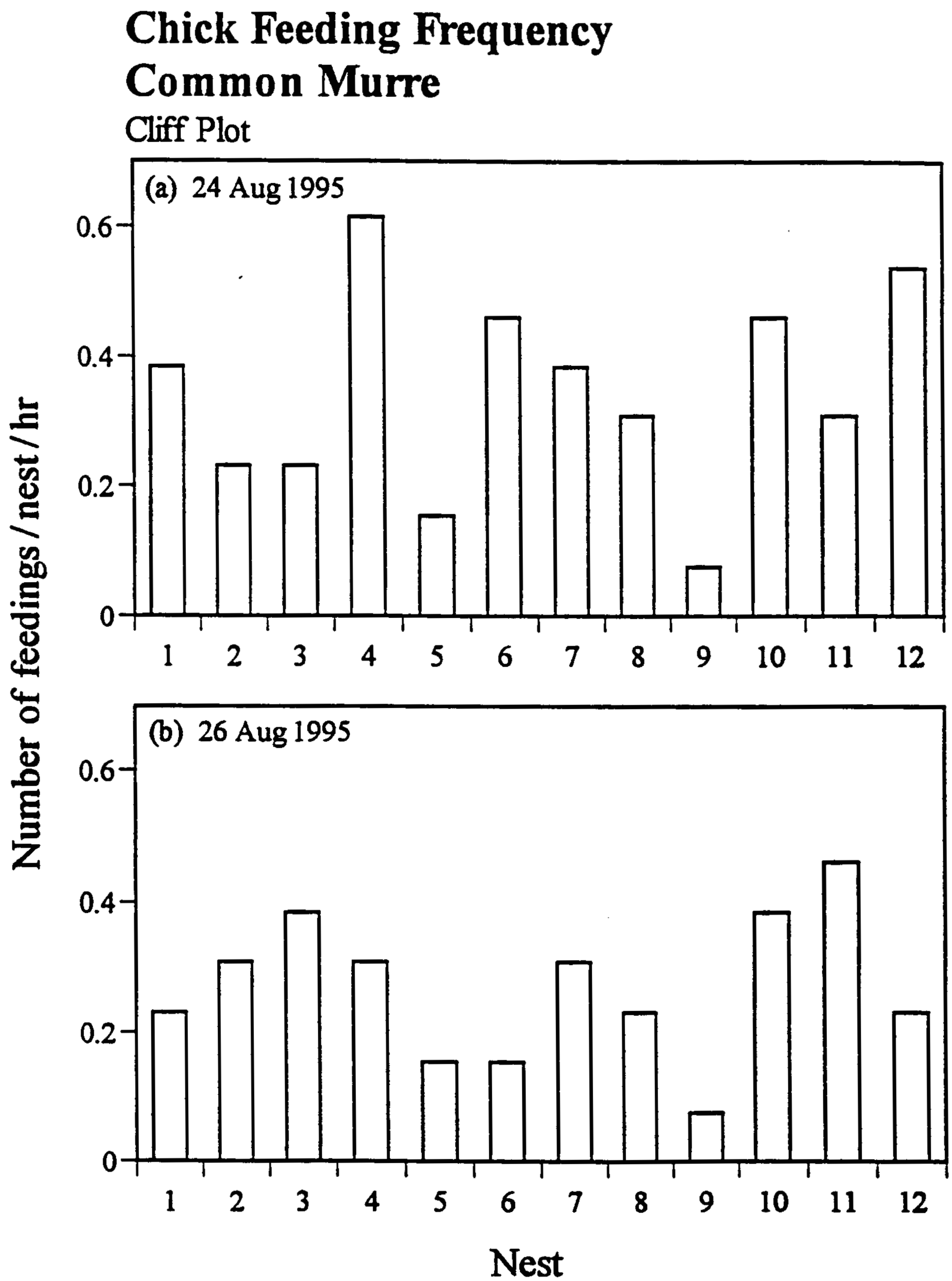

Figure 9. Number of feedings per nest per hour, by nest, during two dawn-to-dusk watches of common murres at East Amatuli Island, Barren Islands, Alaska, 1995: (a) 24 August; (b) 26 August.

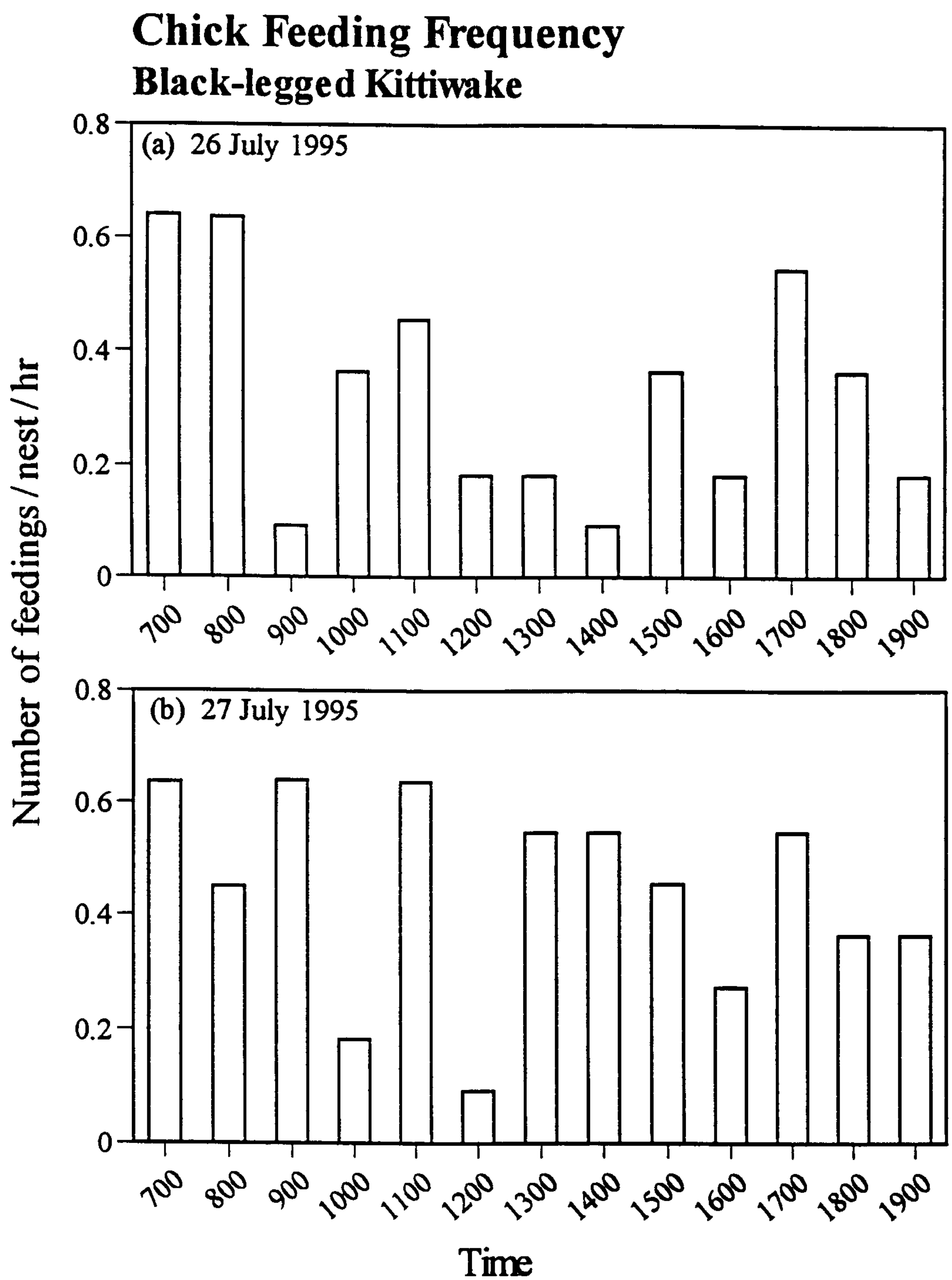

Figure 10. Number of feedings per nest per hour, by hour, during two dawn-to-dusk watches of black-legged kittiwakes at East Amatuli Island, Barren Islands, Alaska, 1995: (a) 26 July; (b) 27 July.

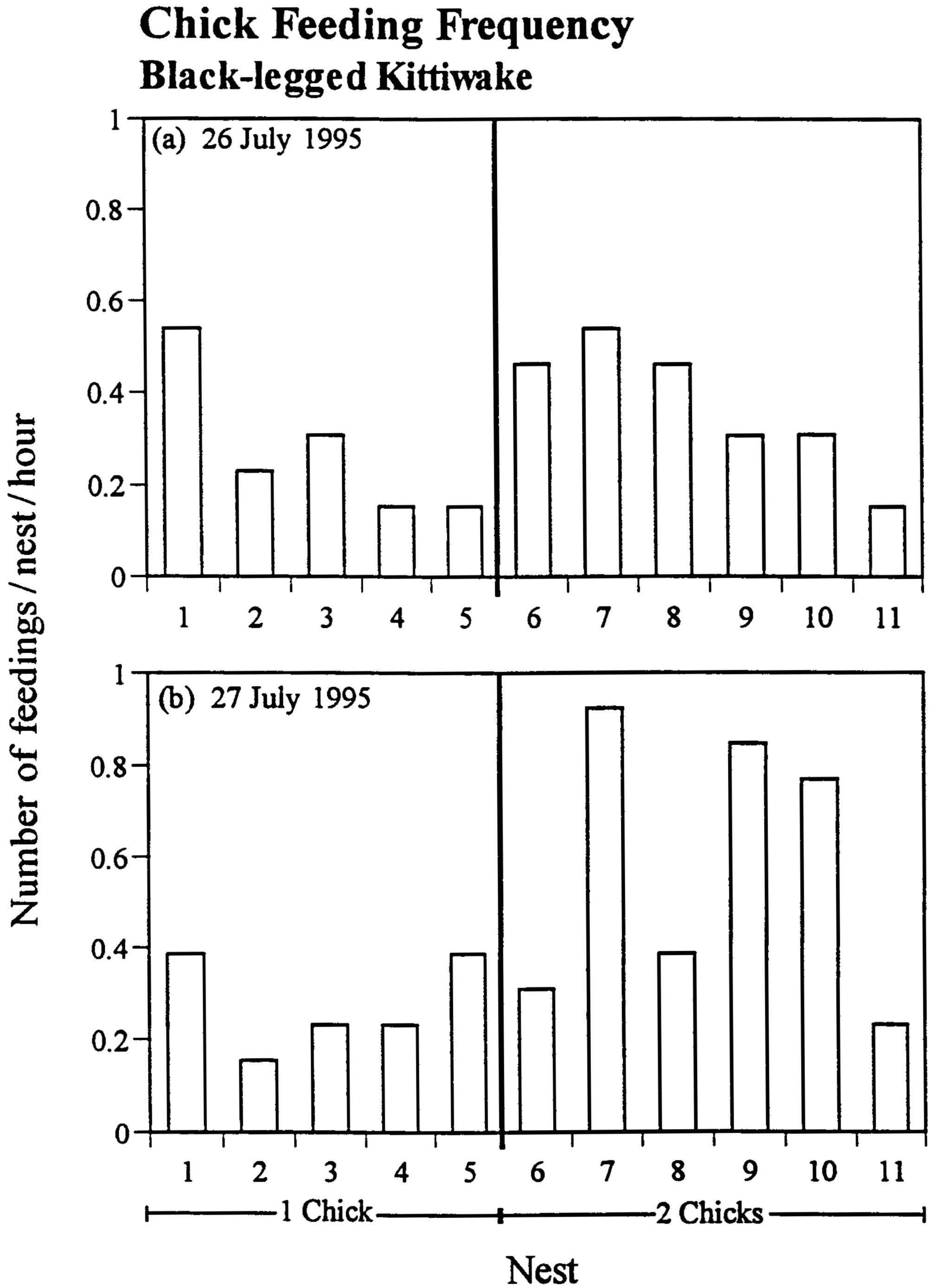

Figure 11. Number of feedings per nest per hour, by nest, during two dawn-to-dusk watches of black-legged kittiwakes at East Amatuli Island, Barren Islands, Alaska, 1995: (a) 26 July; (b) 27 July. One- and 2-chick nests are indicated.

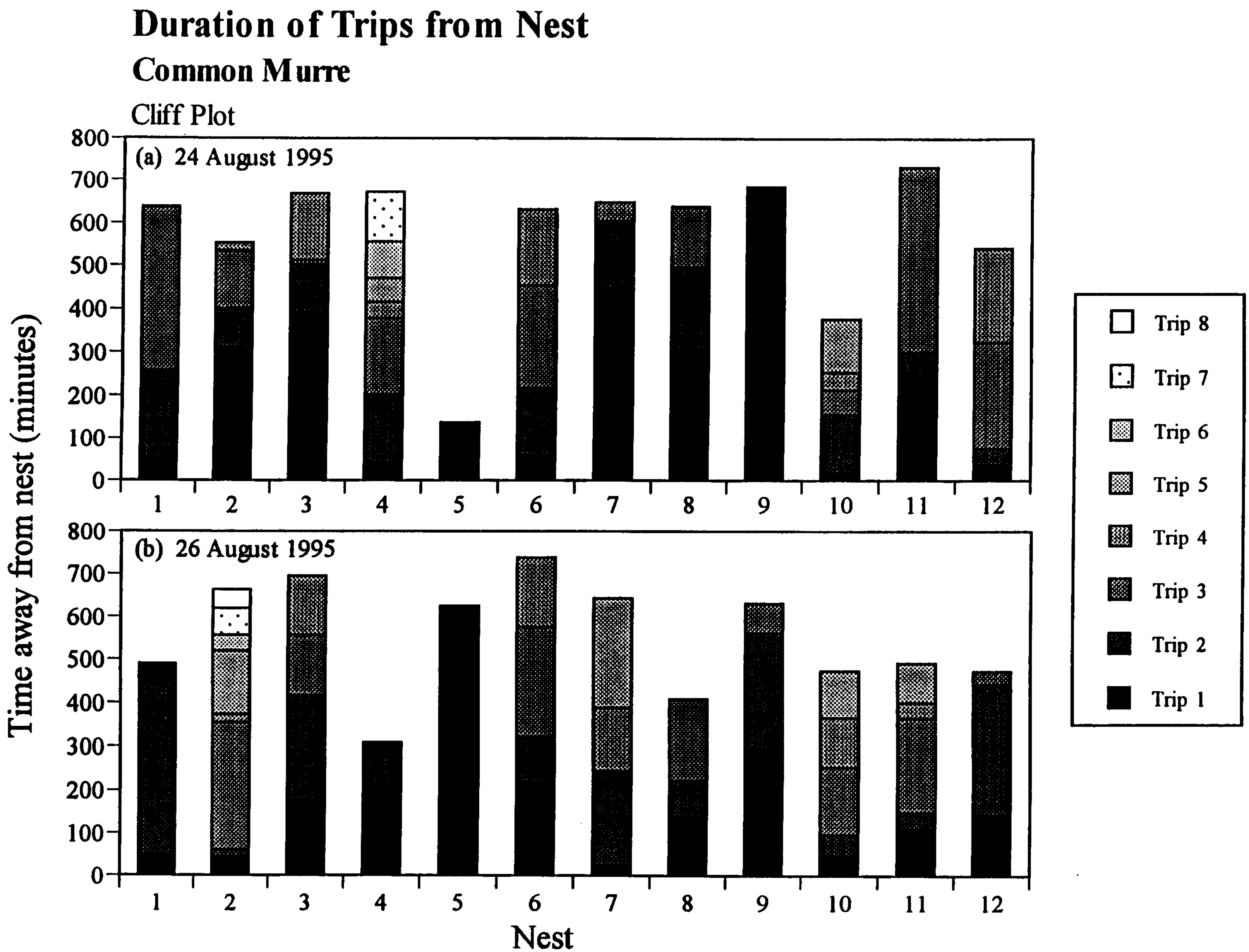

Figure 12. Duration of trips by common murres, by nest, during two dawn-to-dusk watches at East Amatuli Island, Barren Islands, Alaska, 1995: (a) 24 August; (b) 26 August.

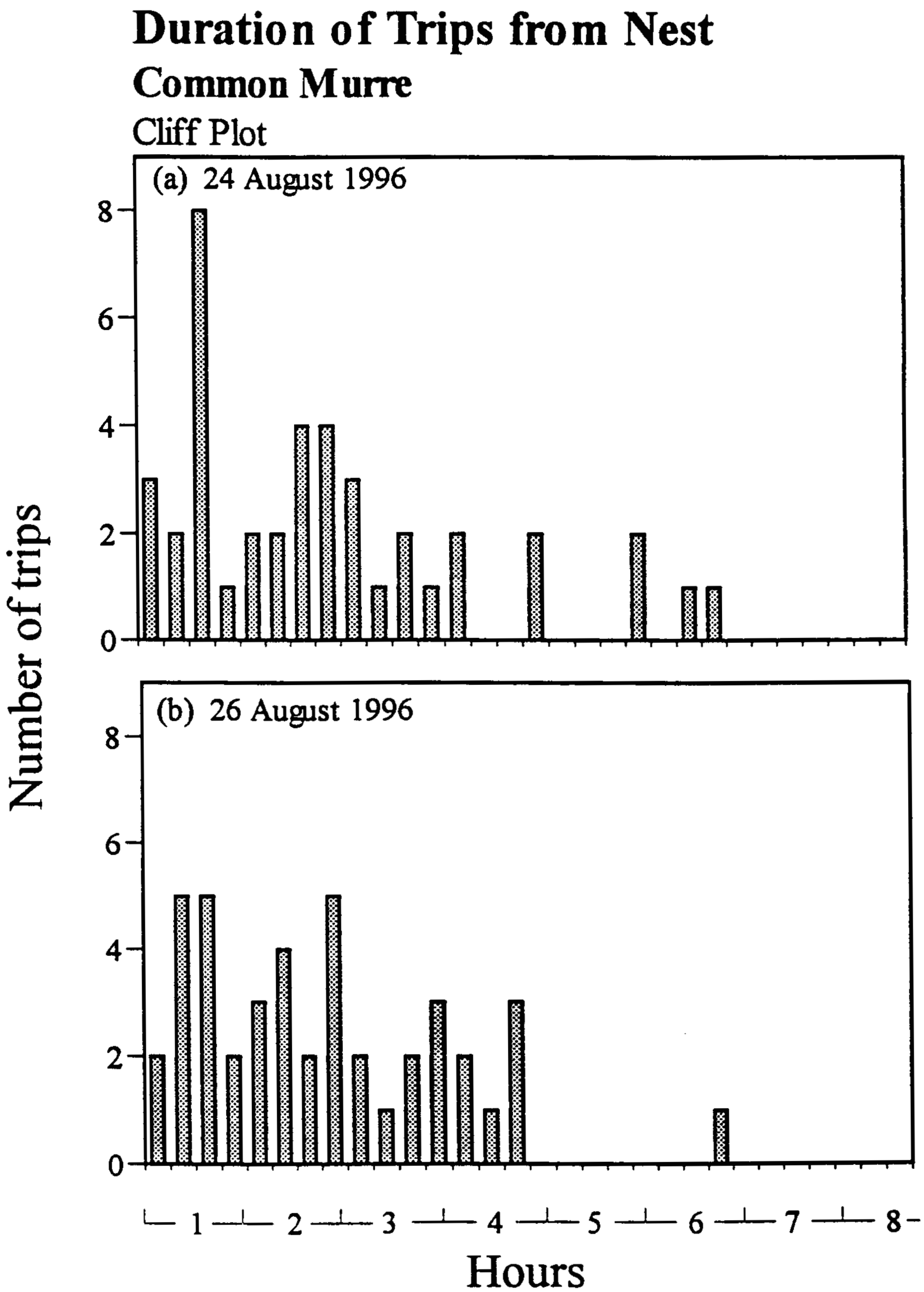

Figure 13. Duration of trips by common murres, by frequency of occurrence, from 12 nests at East Amatuli Island, Barren Islands, Alaska, 1995: (a) 24 August and (b) 26 August, 1995.

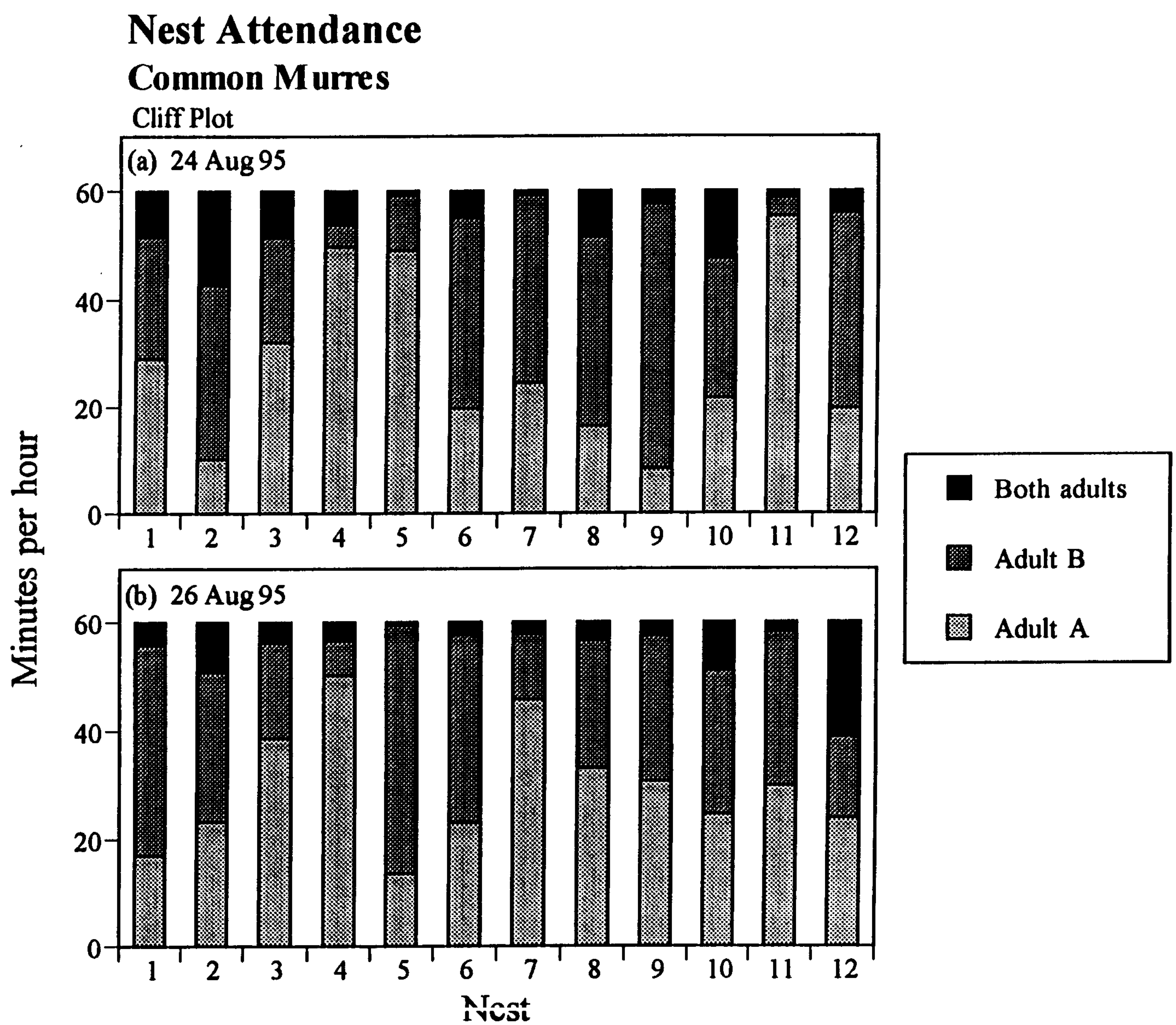

Figure 14. Minutes that one adult, two adults, and neither adult spent at the nest per hour of observation time, by nest, during two dawn-to-dusk watches of common murres at East Amatuli Island, Barren Islands, Alaska, 1995: (a) 24 August; (b) 26 August.

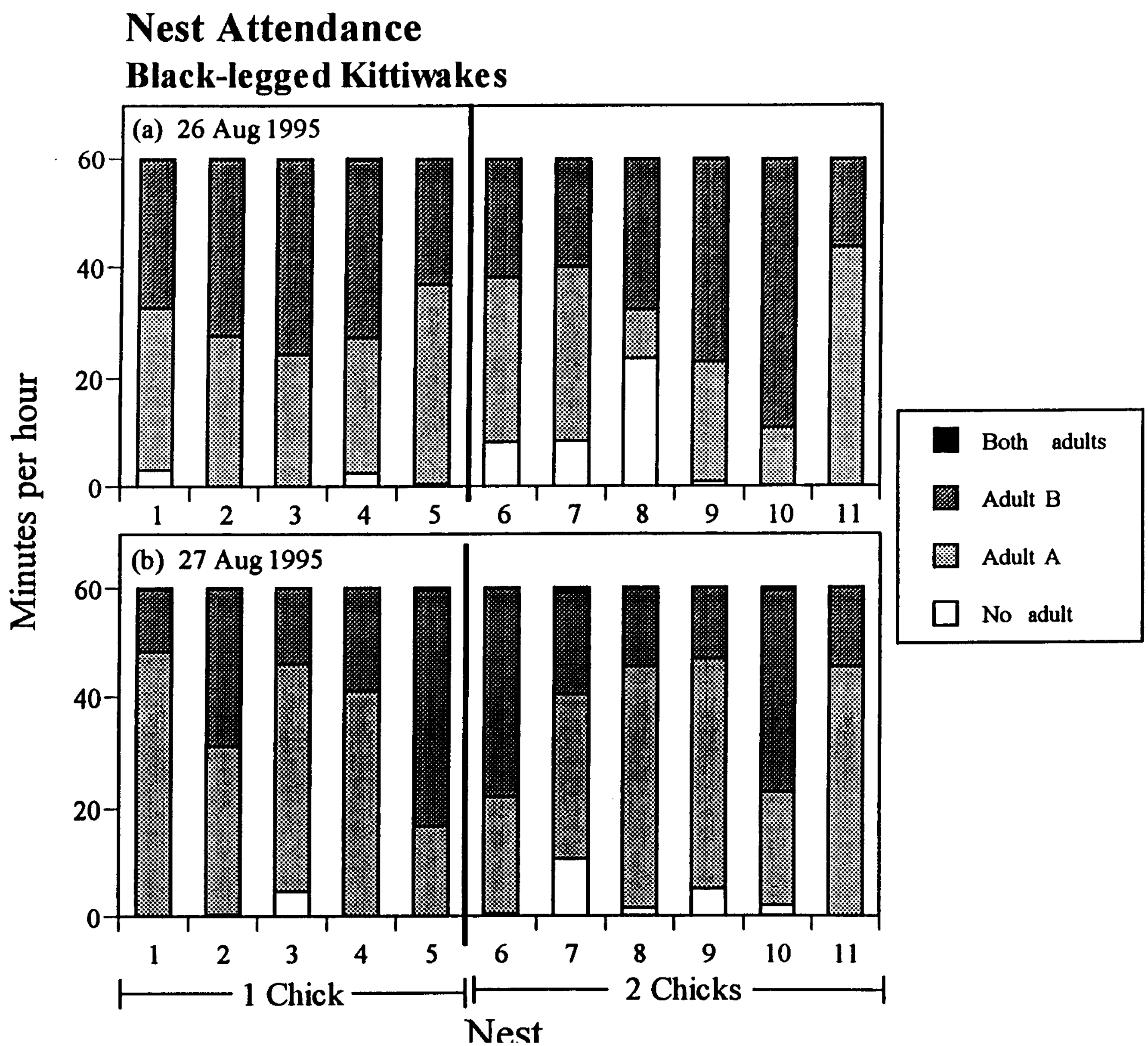

Figure 15. Minutes that one adult, two adults, and neither adult spent at the nest per hour of observation time, by nest, during two dawn-to-dusk observations of black-legged kittiwakes at East Amatuli Island, Barren Islands, Alaska, 1995: (a) 26 August; (b) 27 August. One- and 2-chick nests are indicated.

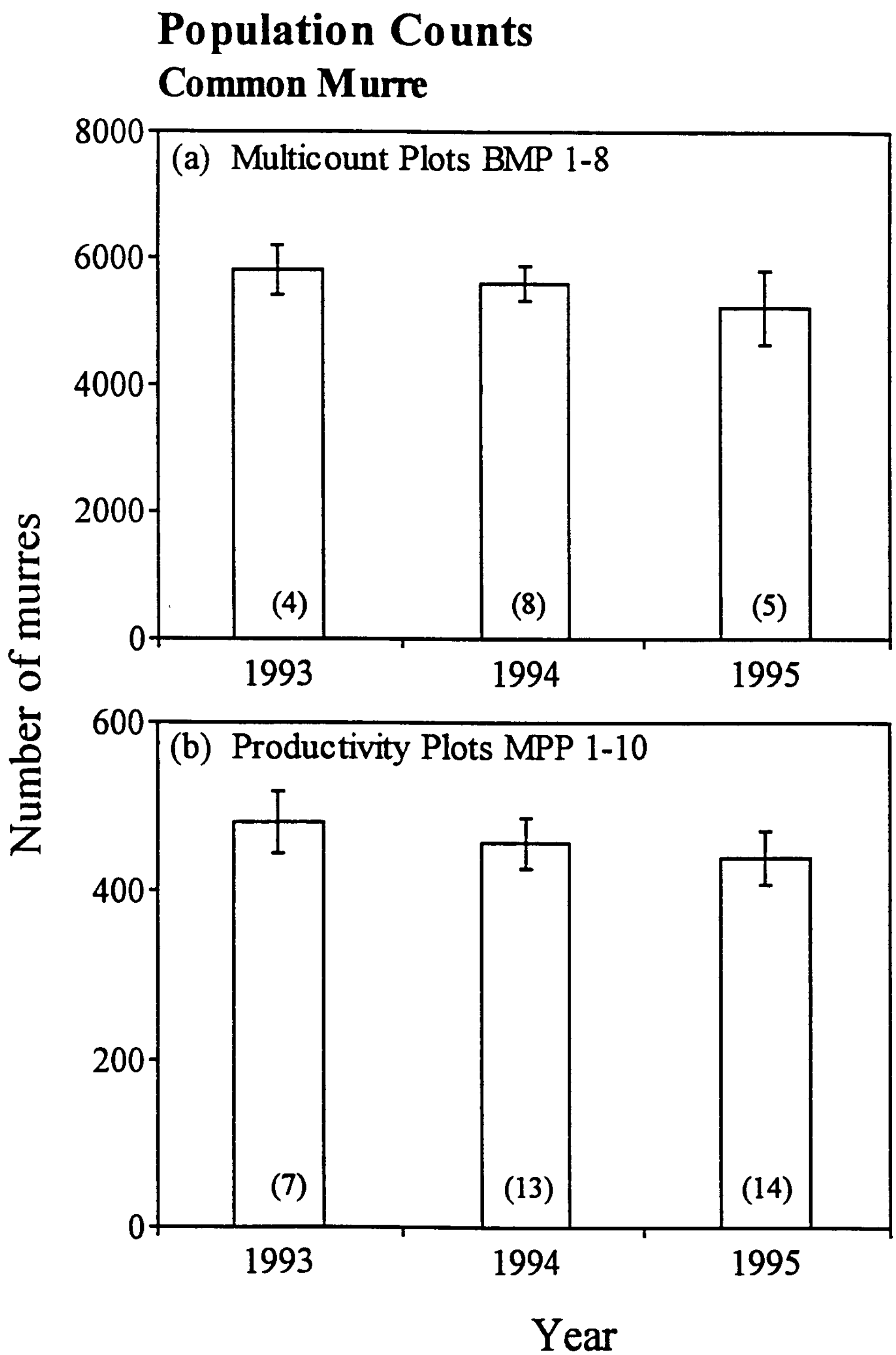

Figure 16. Number of murres on (a) multicount plots BMP 1-8 and productivity plots MPP 1-10 at East Amatuli Island, Barren Islands, Alaska, 1995. Number of counts in parentheses.