Exxon Valdez Oil Spill
APEX Project Annual Report

Using Predatory Fish to Sample Forage Fishes, 1995-1999

APEX Project 99163K
Final Report

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Study History: This project was initiated as part of the *Exxon Valdez* Oil Spill Trustee Council-sponsored Alaska Predator Experiment (APEX) in 1995 (Project 95163K). One annual report and one publication were written at the conclusion of the first year of work (see Roseneau and Byrd 1996, Using predatory fish to sample forage fishes, 1995; and Roseneau and Byrd 1997, Using Pacific halibut to sample the availability of forage fishes to seabirds). Additional data were collected in 1996-1998 with support from the Alaska Maritime National Wildlife Refuge and the Trustee Council, and this information was presented in two more annual reports [see Roseneau and Byrd 1998, Using predatory fish to sample forage fishes, 1997 (Project 97163K); and Roseneau and Byrd 1999, Using predatory fish to sample forage fishes, 1998 (Project 98163K). In 1999, the study continued as APEX Project 99163K, and the 1995-1999 data were analyzed for this final report.

Abstract: Evaluating the influence of fluctuating prey populations (e.g., forage fish) is critical to understanding the recovery of seabirds injured by the T/V *Exxon Valdez* oil spill; however, it is expensive to conduct annual hydroacoustic and trawl surveys to assess forage fish stocks over broad regions. As part of the 1995 *Exxon Valdez* Oil Spill Trustee Council-sponsored Alaska Predator Ecosystem Experiment (APEX), we began to test the feasibility and effectiveness of using stomach contents from sport-caught Pacific halibut *(Hippoglossus stenolepis)* to obtain spatial and temporal data on capelin *(Mallotus villosus)* and Pacific sand lance *(Ammodytes hexapterus)*, two forage fish important to piscivorous seabirds. Because initial efforts provided valuable information on both species of fish in Kachemak Bay - lower Cook Inlet, we collected additional data in 1996-1998 with support from the Alaska Maritime National Wildlife Refuge and Trustee Council. In 1999, we analyzed another 817 halibut stomachs from the study area. Results from these analyses suggest that this relatively simple sampling technique can supply important low-cost presence/absence and relative abundance data on Kachemak Bay - lower Cook Inlet forage fish populations that can be utilized to help monitor seasonal and interannual variations in forage fish stocks and seabird prey bases in Kachemak Bay - lower Cook Inlet and other regions that have sport charter fleets and subsistence fishieries targeting halibut and other predatory fish species (e.g., Pacific cod, *Gadus macrocephalus*; lingcod, *Ophiodon elongatus*).

Key Words: *Ammodytes hexapterus*, Barren Islands, capelin, Chisik Island, Cook Inlet, forage fish, Gull Island, halibut, *Hippoglossus stenolepis*, Kachemak Bay, *Mallotus villosus*, Pacific halibut, Pacific sand lance, sand eels, sand lance.

Project Data: Data are archived in Excel spreadsheets and are stored at the Alaska Maritime National Wildlife Refuge headquarters in Homer, Alaska. Copies of the data are also available from Scott Meyer, Alaska Department of Fish and Game, Homer, Alaska, and John Piatt, U.S. Geological Survey Biological Resources Division, Anchorage, Alaska.

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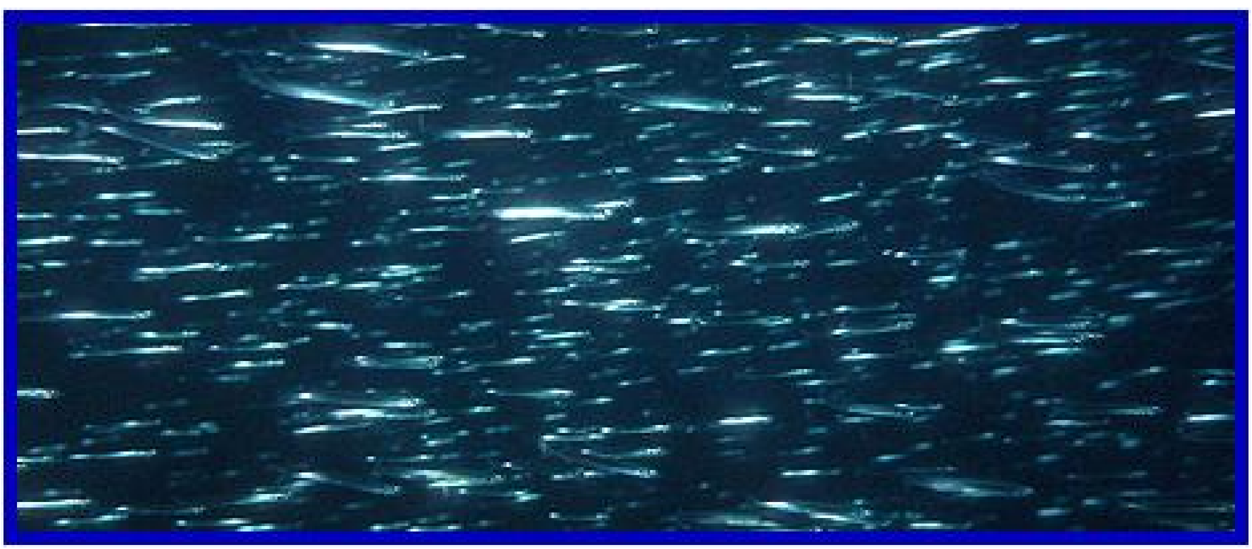

Underwater view of a dense Pacific sand lance *(Ammodytes hexapterus)* school (photograph by Bill Bechtol, Alaska Department of Fish & Game, Homer, Alaska).

INTRODUCTION

Evaluating the influence of fluctuating prey populations (e.g., forage fish) is critical to understanding the recovery of seabirds injured by the March 1989 T/V *Exxon Valdez* oil spill; however, it is expensive to conduct annual hydroacoustic and trawl surveys to assess forage fish stocks over broad regions. As part of the 1995 *Exxon Valdez* Oil Spill Trustee Council-sponsored Alaska Predator Ecosystem Experiment (APEX), we began testing the feasibility and effectiveness of using stomach contents from sport-caught Pacific halibut *(Hippoglossus stenolepis)* to obtain spatial and temporal data on capelin *(Mallotus villosus)* and Pacific sand lance *(Ammodytes hexapterus)*, two forage fish species important to piscivorous seabirds (APEX Project 95163K; see Roseneau and Byrd 1996, 1997). Because initial efforts provided valuable information on both species in Kachemak Bay - lower Cook Inlet, we continued the work in 1996-1998 with support from the Alaska Maritime National Wildlife Refuge and Trustee Council (see Roseneau and Byrd 1998, 1999), and in 1999, we completed the study after collecting one additional set of data. Results from the 5-year study indicated that this relatively simple sampling technique can supply low-cost relative abundance data on Kachemak Bay - lower Cook Inlet forage fish populations that can be utilized to help monitor seasonal and interannual variations in forage fish stocks and seabird prey bases.

OBJECTIVES

Objectives of the 5-year pilot project were to test the feasibility of using stomach contents from sport-caught halibut to sample forage fish stocks in the Kachemak Bay - lower Cook Inlet region, and evaluate the effectiveness of the technique in obtaining information useful to APEX seabird and forage fish studies in the northern Gulf of Alaska spill area (e.g., studies of common murres, *Uria aalge*; black-legged kittiwakes, *Rissa tridactyla*; sand lance and capelin).

METHODS

Halibut were chosen as potential samplers of forage fish populations because they opportunistically take a wide range of both fish and invertebrate prey, including sand lance and capelin (see Yang 1990; Roseneau and Byrd 1996, 1997, 1998, 1999). They were also selected as sampling tools because a large, 100-150 vessel sport charter boat fleet fishes for them in Kachemak Bay - lower Cook Inlet throughout May-August in several of same areas utilized by foraging seabirds (see Roseneau and Byrd 1996, 1997, 1998, 1999).

The Kachemak Bay - lower Cook Inlet study area was set up and divided into 12 sampling subunits in May 1995 (Fig. 1, Appendix 1; see Roseneau and Byrd 1996, 1997, 1998, 1999). During late May - early September 1995-1999, we obtained 585, 777, 1,432, 1,050 and 817 halibut stomachs from 6-7 of these areas, respectively (Appendix 2)[1]. Most stomachs were acquired when charter boat operators filleted fish for customers at public and private fish-cleaning facilities on the Homer Spit. However, Lake Clark National Park and Alaska Department of Fish and Game (ADF&G) biologists collected 182 stomachs from lodge owners and sport fishermen in Areas 1-2 in 1996, and ADF&G fisheries personnel obtained 323, 282, and 322 stomachs from these areas in 1997, 1998, and 1999, respectively.

Catch dates, locations, and fish lengths were usually obtained when stomachs were removed from carcasses; however, in some cases, these data were attached to bagged frozen samples saved for

[1] During 1995-1999, halibut lengths averaged 99 cm (n = 585, range = 71-213 cm), 111 cm (n = 777, range = 64-160 cm), 87 cm (n = 433, range = 57-141 cm), 88 cm (n = 280, range =45-147 cm), and 86 cm (n = 316, range = 55-152 cm), respectively.

the project by participating fishermen. Stomach contents were identified using taxonomic keys, photographs, and voucher specimens (see Roseneau and Byrd 1996, 1997, 1998, 1999). Whole and partly digested, but still recognizable fish and invertebrates were sorted into several categories, including capelin, sand lance, flatfish, sculpin, cod, crabs, shrimp, squid, octopus, mollusks, and other fish and invertebrate species. Most emptied stomachs were weighed to obtain estimates of content weight, and samples of undigested capelin and sand lance were weighed and measured to obtain size data for other investigators (e.g., J. Piatt, Project 98163M). Some whole capelin and sand lance were also frozen, or preserved in 10% buffered formaldehyde and 75% ethanol - 2% glycerin solutions for later analysis by other researchers.

Data were entered stomach-by-stomach into computer spreadsheets. Analyses consisted of eliminating all potential bait items from the data base (e.g., cod and salmon heads; cut or hook-punctured Pacific herring, *Clupea harengus pallasi*); sorting remaining information by dates, areas, and species; and calculating numbers and frequencies of occurrence of fish and invertebrates in stomachs from different geographic areas and time periods (see Roseneau and Byrd 1996, 1997, 1998, 1999). Relationships among sets of data were tested with Pearson Correlation Coefficient (numbers) and Spearman Rank Correlation (percentages) tests at the 0.1 significance level (the 0.1 significance level was used to increase the power of the tests and reduce Type II error; the 0.9 confidence interval was adequate for our purposes).

RESULTS

We limited multiyear analyses to Areas 1, 2, 4, 6, 8, and 10 (see Fig 1). Halibut stomachs were not obtained from Areas 3, 5, 7, 9, and 11, because these locations are rarely fished by the sport charter fleet. Also, samples were only obtained from Area 12 in 1995 and 1998, because vessels fishing this distant region usually stay overnight and filet their catch before returning to Homer.

In 1999, fish were present in 40% of the stomachs, compared to 49% in 1995, 55% in 1996, 32% in 1997, and 38% in 1998 (Fig. 2). Occurrence of fish also varied in stomachs containing prey over the 5-year interval (Fig. 3). The percentage of stomachs containing sand lance tended to increase from 1995 to 1999 (11%, 6%, 17%, 20%, and 20%, respectively). In contrast, the percentage containing capelin declined during 1995-1997 and then rose to near the 1995 level by 1999 (33%, 11%, 8%, 20%, and 26%, respectively). The proportions of other forage fish (17%, 29%, 27%, 5%, and 4%) and non-forage fish (25%, 29%, 34%, 24%, and 15%) species were lowest in 1995 and 1999, years when percentages of capelin were highest (29% and 26%, respectively; see Fig 3).

Numbers of fish in stomachs containing prey followed a pattern similar to occurrence of capelin: they declined markedly during 1995-1997 (79%, 44%, and 35%, respectively) and then increased in 1998 and 1999 (50% and 56%, respectively; Fig 4). Capelin numbers also followed this same overall pattern (59%, 45%, 18%, 43%, and 54%, respectively). In contrast, the change in numbers of sand lance appeared to almost be the reverse; they tended to increase between 1995 and 1997 (23% and 50%, respectively) and decline during 1998-1999 (44% and 39%, respectively).[2] Although capelin and sand lance dominated the fish component by number every year (82%, 53%, 68%, 87%, and 93% in 1995-1999, respectively), combined percentages of these fish were lowest in 1996-1997, when non-forage fish numbers were highest (22% and 25%, respectively; see Fig. 4).

[2] The 1996 sand lance value of 8% was almost certainly artificially low. One of the volunteers processing the halibut stomachs found many small fish in addition to capelin that were almost certainly sand lance; however, these fish were almost always recorded as "other small fish". Based on careful review of the field notes and discussions with the volunteer, we believe that, conservatively, the 1996 sand lance value was probably at least 20-25%.

When fish numbers were compared among areas and years, numbers of capelin were consistently lowest in Areas 1 (Fig. 5a; mean 7%, range 0-31%, SD 13.5) and 2 (mean 4%, range 0-11%, SD 4.7) and highest in Areas 6 (Fig. 5b; mean 63%, range 47-74%, SD 10.4) and 10 (Fig. 5c; mean 67%, range 28-93%, SD 24.7).[3] Combined data from Areas 4, 6, 8, and 10 also provided strong evidence that capelin stocks were relatively high and similar over a broad region in 1995-1996 and 1998, much lower in 1997, and highest in 1999 (Area 12 data were not sufficient to include in these comparisons; see Fig. 5d). For these four areas combined, this species averaged 56% and 55% in 1995-1996 (range 37-82%, SD 26.1 and 39-65%, SD 12.1, respectively), 21% in 1997 (range 2-47%, SD 20.7), 54% in 1998 (range 27-66%, SD 18.0), and 75% in 1999 (range 58-93%, SD 14.7). In contrast, evidence from these same four areas suggested that sand lance populations were relatively low over the same broad region in 1995-1996 and 1998, highest in 1997, and lowest in 1999 (mean 25%, 5%, 43%, 31%, and 19%; range 0-57%, 0-3%, 23-74%, 21-49%, and 5-39%; and SD 24.9, 5.6, 22.1, 12.8, and 14.8, respectively).[4] Indeed, throughout this broad region, there appeared to be a negative relationship between the apparent changes in sand lance and capelin stocks; however, the relationship was not quite significant, probably because of low sample size (Spearman Rank Correlation; r = -0.70, n = 5 years).

We graphed the numbers of capelin and sand lance found per halibut stomach in Area 6 (Point Adam) in 1995, the area and year with the best June-August data series (Fig. 6). It was apparent from this data set that the relative abundance of these species changed over time. Sand lance averaged about 1.2 fish per stomach in this area during June, but were nearly absent from the July - early August samples (< 0.1 individual per stomach). In contrast, numbers of capelin increased markedly after late June, rising from an average of only 0.9 fish per stomach that month, to 2.4 individuals during July and 7.7 fish by early August.

We analyzed capelin and sand lance data from halibut stomachs and black-legged kittiwake chick regurgitations collected at East Amatuli Island in the Barren Islands (see Roseneau *et al.* 1996b, 1997, 1998, 1999, 2000). The relationship between the numbers of capelin found in the stomachs from Areas 1, 2, 4, 6, 8, and 10 and the weights of these forage fish as percentages of total fish in the 1995-1999 Barren Islands chick diets was significant (Fig. 7; Spearman Rank Correlation, r = 0.98, $P < 0.01$). We also found a similar almost significant relationship between Area 10 (Barren Islands) capelin numbers and the weights of these fish in the 1995-1999 chick diets (Fig. 8; Spearman Rank Correlation, r = 0.87, $P = 0.11$).

Graphing the 1995-1999 Area 1, 2, 4, 6, 8, and 10 sand lance and Barren Islands kittiwake chick diet data also suggested that a relationship may have been present (Fig. 7). However, because the calculated 1996 halibut stomach sand lance value was quite low (8%), this relationship was not significant (Spearman Rank Correlation, r = 0.70; see footnote 2—the actual 1996 sand lance value was conservatively at least 20-25%, and at the 25% level, the relationship would have been significant—r = 0.90, $P = 0.1$). We also plotted and tested the 1995-1999 Area 10 halibut stomach sand lance values and weights of these fish in the Barren Islands kittiwake chick diets, but did not find a significant relationship (Fig. 8; Spearman Rank Correlation, r = 0.11).

We reviewed the 1995-1999 halibut stomach capelin and sand lance data in relation to numbers of fish fed to common murre chicks at the Barren Islands East Amatuli Island - Light Rock colony in 1995-1999. No relationships were present because the chick diets consisted of more than 85% capelin each year (see Roseneau *et al.* 1996b, 1997, 1998, 1999, 2000). A review of the 1995-1999 Area 1, 2, 4, 6, 8, and 10 halibut stomach capelin and sand lance data, and the murre and kittiwake chick diet data collected at Gull and Chisik islands during 1995-1999 that we had at hand also failed to reveal relationships (see USGS and USFWS 2000).

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[3] SD = standard deviation.

[4] Again, the 1996 sand lance value was almost certainly artificially low; see footnote 2.

Mid-water trawl data obtained near the Barren Islands during 1996-1999 (Appendix 3; also see USGS and USFWS 2000) were analyzed in conjunction with 1996-1999 Area 10 halibut stomach capelin and sand lance data. The relationship between the log-transformed mean number of capelin found per halibut stomach and per trawl was significant (Fig. 9; Pearson Correlation Coefficient, $r = 0.99$, $P < 0.02$). In contrast, the log-transformed mean number of sand lance found per halibut stomach and per trawl was not significant (Pearson Correlation Coefficient, $r = 0.66$). However, these data also suggested that a similar relationship might be found between these variables, if a few more years of information were available (see Fig. 9).

Only two capelin were caught in 40 beach seine sets at the Barren Islands in 1997-1999 (see Appendix 4). The extremely small catch indicated that this sampling method did not provide sufficient information on this forage fish species for comparison with halibut stomach and trawl data.

In contrast to capelin, relatively large numbers of sand lance were caught in the Barren Islands beach seine sets during 1997-1999 (see Appendix 4). However, the data time series was not sufficient for analysis (i.e., n = 3 years).

DISCUSSION

The small numbers of capelin found in halibut stomachs from Areas 1 and 2 were almost certainly related to the less saline, more turbid water conditions typically found north of Anchor Point, and the consistently high percentages of these forage fish found in the Area 6 and 10 samples were probably related to the cold water upwellings that are characteristic of the Point Adam and Barren Islands vicinities (see USGS and USFWS 2000; J. Piatt, pers. comm.).

Study results indicated that forage fish stocks were higher in 1995 and 1998-1999 than during 1996-1997. They also suggested that sand lance populations were highest in 1997, while capelin stocks declined through 1997 and then increased again by 1999. These changes were consistent with observations from other studies and charter boat skippers. For example, in 1993-1995, tens of thousands seabirds, including sooty shearwaters *(Puffinus griseus)*, black-legged kittiwakes, tufted puffins, murres, and cormorants *(Phalacrocorax* spp.*)*, and up to 200 humpback whales *(Megaptera novaeangliae)* were regularly observed feeding on large post-spawning schools of capelin in the Barren Islands area during late June - late August (see Roseneau *et al.* 1995, 1996a; Roseneau and Byrd 1996, 1997). Capelin schools and associated concentrations of feeding seabirds and whales were scarce in this area during mid-July - mid-August 1996, and almost entirely absent from it during the same interval in 1997 (seabirds primarily consisted of tufted puffins and kittiwakes in groups of fewer than 500 individuals in 1996, and fewer than 100 birds the following year, and the highest daily whale counts in these years were 12 and 4 individuals, respectively; D.G. Roseneau, pers. obs., Projects 96144 and 97144). In 1998, large schools of capelin that attracted as many as 40-100 humpback whales, 20-45 killer whales *(Orcinus orca)*, and thousands of seabirds were common in the Barren Islands, Kennedy Entrance, and Point Adam areas after mid-July (Capt. R. Swenson, Homer Ocean Charters, pers. comm.). The following year, large schools of capelin were abundant over a much broader region. During early July 1999, the U.S. Fish and Wildlife Service research vessel *Tiglax*, with several National Marine Fisheries Service researchers aboard, made a cruise along the eastern side of Kodiak Island past Marmot Island and then northward through the Barrens Islands to the Chugach Islands on the southern tip of the Kenai Peninsula, where it turned eastward and continued along the coast to the Chiswell Islands and Montague Island vicinities before reversing course and docking in Seward. The captain of the vessel reported that they had encountered "huge" schools of capelin associated with "hundreds" of humpback whales and large flocks of shearwaters in the Marmot Island area, in the passage between West Amatuli and Ushagat islands in the Barren Islands, and throughout the Chugach, Chiswell, and Montague islands vicinities (K. Bell, pers.

comm.). Shortly afterwards, a seabird biologist working on kittiwakes in Prince William Sound reported observing large flocks of seabirds feeding on capelin schools, particularly in the Cape Puget, Cape Cleare, and Hinchinbrook Entrance areas (R. M. Suryan, pers. comm.). Given this information and how well it appears to reflect the patterns seen in the halibut stomach data (see Figs. 4 and 5), we believe that the relatively low cost halibut stomach sampling method can provide important information on long-term changes in the relative abundance of northern Gulf of Alaska forage fish stocks, particularly sand lance and capelin

The apparent shift from a capelin dominated food web in 1995 to one containing large numbers of sand lance in 1997 that was suggested by the multiyear halibut stomach data paralleled 1995-1997 changes in Barren Islands kittiwake chick diets. During these three years, kittiwake chicks reared at the East Amatuli Island - Light Rock colony were fed about 68%, 32%, and 16% capelin, and 14%, 60%, and 68% sand lance by total weight of fish, respectively (see Fig. 7). In 1998, when halibut stomachs contained high percentages of both forage fish species, chick diets reflected this change: regurgitations from nestlings contained about 32% capelin and 65% sand lance, and regurgitation's from adult kittiwakes delivering food to chicks consisted of about 29% capelin and 38% sand lance (Roseneau *et al.*, unpubl. data).[5] In 1999, when capelin and sand lance percentages rose and fell in the halibut stomachs, respectively, chick diets followed suit: nestling regurgitations contained 37% capelin and 57% sand lance (see Fig. 7). The significant and near-significant relationships between the amounts of capelin and sand lance fed to kittiwake chicks at the Barren Islands and the numbers of these important prey species in the halibut stomachs indicate that the relatively low cost halibut stomach sampling method can provide valuable information on forage fish stocks that will be useful during future seabird monitoring studies at this important northern Gulf of Alaska nesting location

The fact that capelin constituted more than 85% of the prey fed to common murre chicks each year at the Barren Islands East Amatuli Island - Light Rock colony indicated that these deep-diving seabirds have strong preferences for this forage fish. Based on this information, we suspect that major declines in capelin stocks would have to occur before murres begin feeding their nestlings other prey species. As a consequence, it appears unlikely that strong relationships will be detected between halibut stomach and murre chick diet data unless capelin stocks decline to low levels—a piece of information that would be useful to any ongoing murre monitoring studies at the Barren Islands nesting colonies. Future murre monitoring work at this breeding location may also benefit from information obtained from comparisons between halibut stomach and kittiwake chick diet data, because adult murres take a wider range of prey and less extreme changes in capelin stocks might be reflected in other variables (e.g., body condition, foraging trip duration).

Few halibut stomachs were obtained from locations that appear to be commonly used by foraging Gull and Chisik island kittiwakes (in upper Kachemak Bay, near Gull Island, along the coast between the Homer Spit and Bluff Point, and on the western side of Cook Inlet; USGS and USFWS 2000; D.G. Roseneau, pers. obs.). As a result, it was not particularly surprising that relationships were not apparent between chick diets at these colonies and numbers of capelin and sand lance in halibut stomachs. It may be possible to increase the amount of data obtained from some of these locations by expanding efforts to include local subistence fishermen operating their own boats.

The strong relationship between numbers of capelin per mid-water trawl and per halibut stomach in the vicinity of the Barren Islands suggests that the relatively low cost halibut stomach sampling technique may be as effective as trawling for monitoring long-term changes in capelin and sand

[5] In 1998, chick and adult regurgitation's also contained about 5% and 33% unidentified smelt, respectively, and most of these fish were probably capelin.

lance stocks in the northern Gulf of Alaska. Indeed, we suspect that using stomach contents from several large, opportunistic predatory fish species such as halibut and other right-eye flounders (Pleuronectidae), Pacific cod *(Gadus macrocephalus)*, lingcod *(Ophiodon elongatus)*, and rockfish *(Sebastes spp.)* to track changes in forage fish populations may be more effective than using mid-water trawls because samples can be collected steadily over a much longer period of time each year at a considerably cheaper cost (i.e., every 1-2 weeks during May-August, a sampling schedule that would require many days of expensive vessel time).

Aside from the fact that only three years of data were available, the lack of relationships between the Barren Islands halibut stomach data and the capelin and sand lance beach seine data was not surprising. Capelin do not appear to frequent waters close to beaches except during spawning periods, and few halibut feed right along shorelines where younger age class sand lance tend to congregate (e.g., 0, 0+, and 1-year-olds, the age classes typically caught next to shore by seining).

CONCLUSIONS

1. Results from the 5-year study confirmed that analyzing stomach contents from sport- and subsistence-caught halibut can supply low-cost relative abundance data on capelin and sand lance stocks that can be used to monitor long-term changes in prey bases important to seabird and marine mammal populations. If data are collected at regular intervals, within-season variation can also be detected by this relatively simple technique (see Fig. 6).

2. The strong relationships that were detected between the halibut stomach data and the kittiwake chick diet and mid-water trawl data sets indicate that changes observed in halibut stomach data can provide a variety of valuable information on forage fish stocks that will be useful to long-term seabird monitoring studies in areas where seabird foraging areas and sport and subsistence fishing activities regularly overlap (e.g., Barren Islands).

RECOMMENDATIONS

Based on the overall results of the 1995-1999 halibut stomach - forage fish study, we recommend establishing a community-based program to use the stomach contents of sport- and subsistence-caught predatory fish (e.g., particularly halibut, but also other right-eye flounders, cod, lingcod, and rockfish) to monitor long-term changes in capelin and sand lance populations in Kachemak Bay - lower Cook and the northern Gulf of Alaska during the Gulf Ecosystem Monitoring (GEM) program. The study should be closely coordinated with local fishing communities, and it should be designed to include the use of students and other local residents to help collect data.

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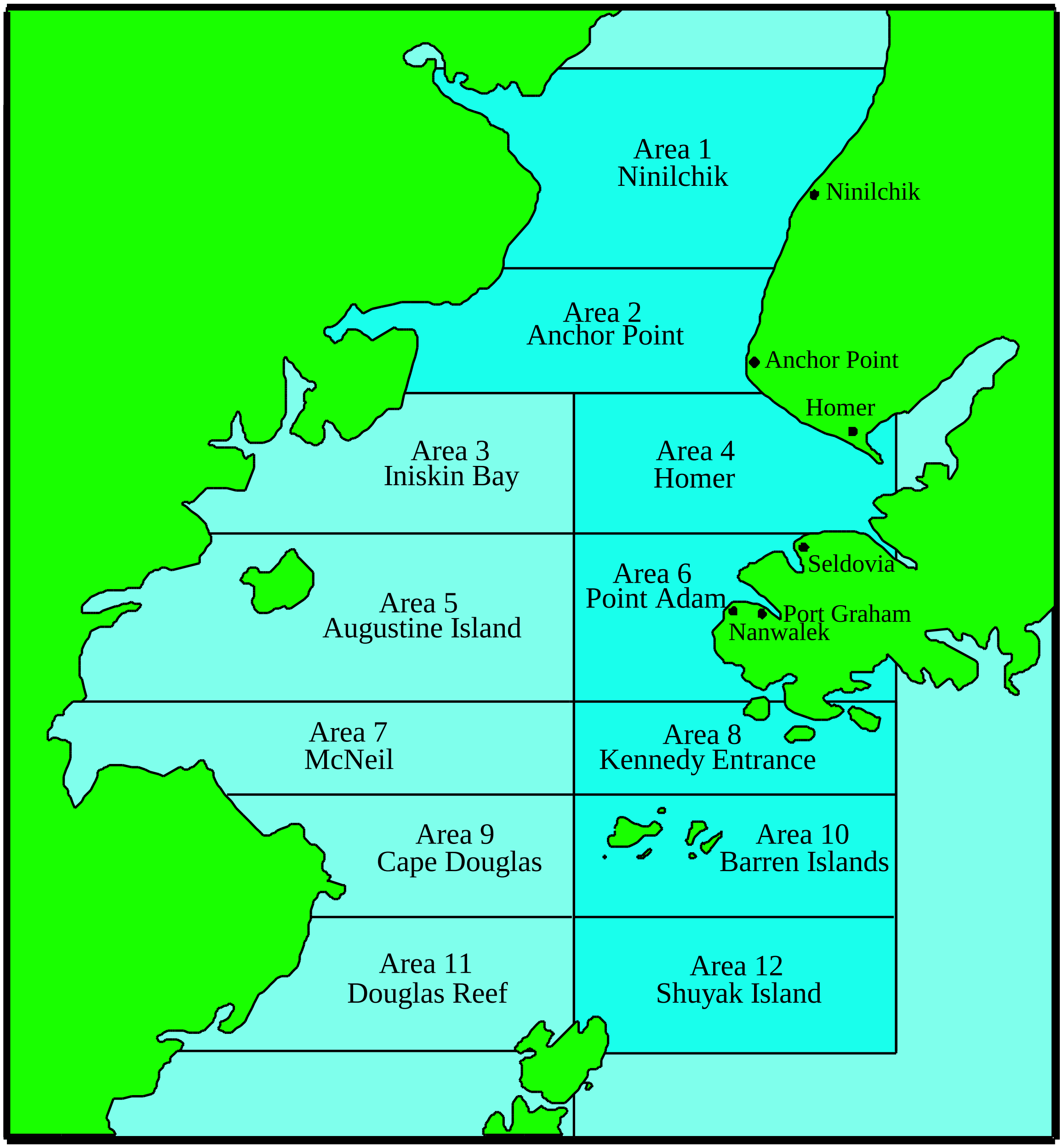

Figure 1. The 1995-1999 Kachemak Bay – lower Cook Inlet study area (samples were collected in the shaded areas).

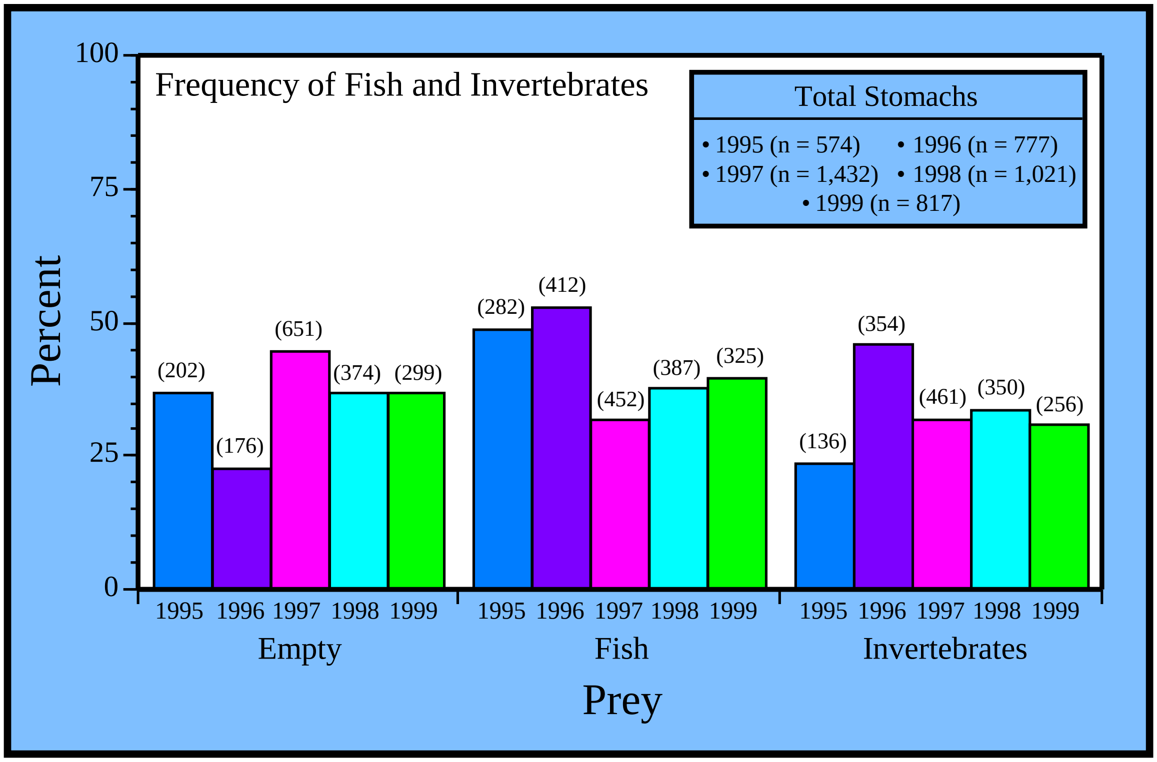

Figure 2. Frequency of occurrence of fish and invertebrates in halibut stomachs from Areas 1, 2, 4, 6, 8, and 10 in Kachemak Bay - lower Cook Inlet, 1995-1999 (numbers of stomachs shown in parentheses).

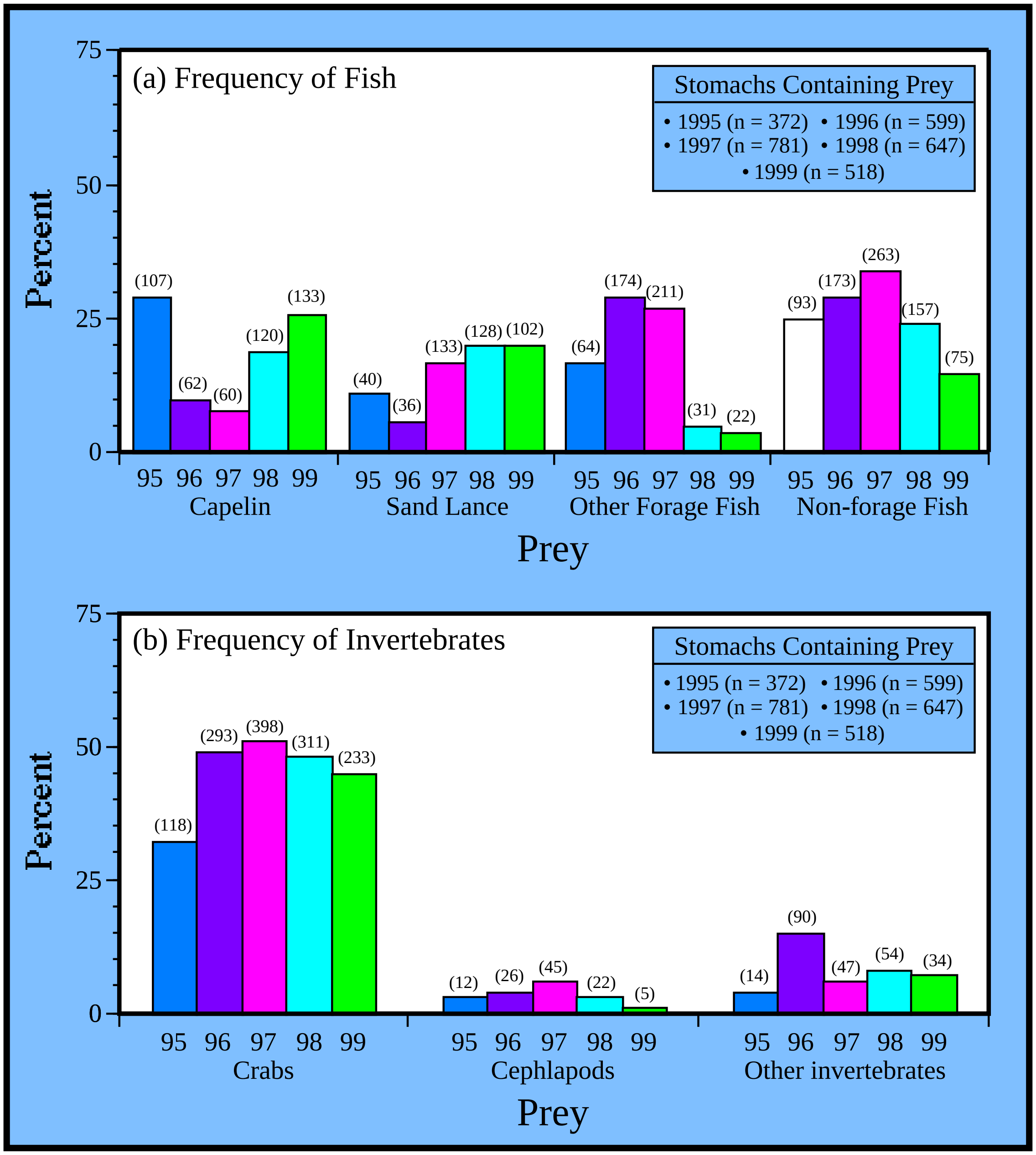

Figure 3. Frequencies of occurrence of (a) fishes and (b) invertebrates in halibut stomachs from Areas 1, 2, 4, 6, 8, and 10 in Kachemak Bay - lower Cook Inlet that contained prey, 1995-1999 (numbers of stomachs shown in parentheses).

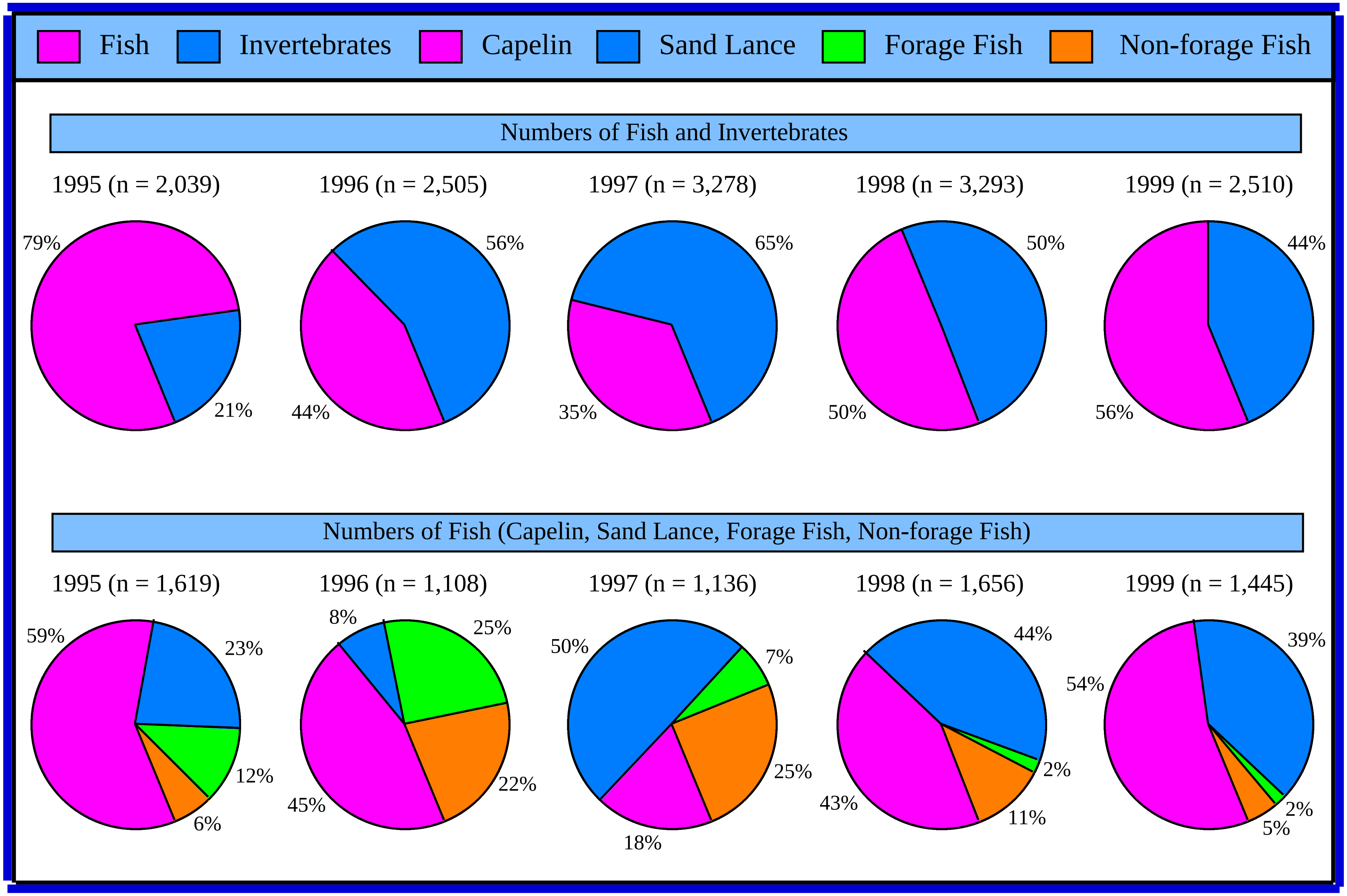

Figure 4. Numbers of fish and invertebrates in halibut stomachs from Areas 1, 2, 4, 6, 8, and 10 in Kachemak Bay - lower Cook Inlet that contained prey, 1995-1999.

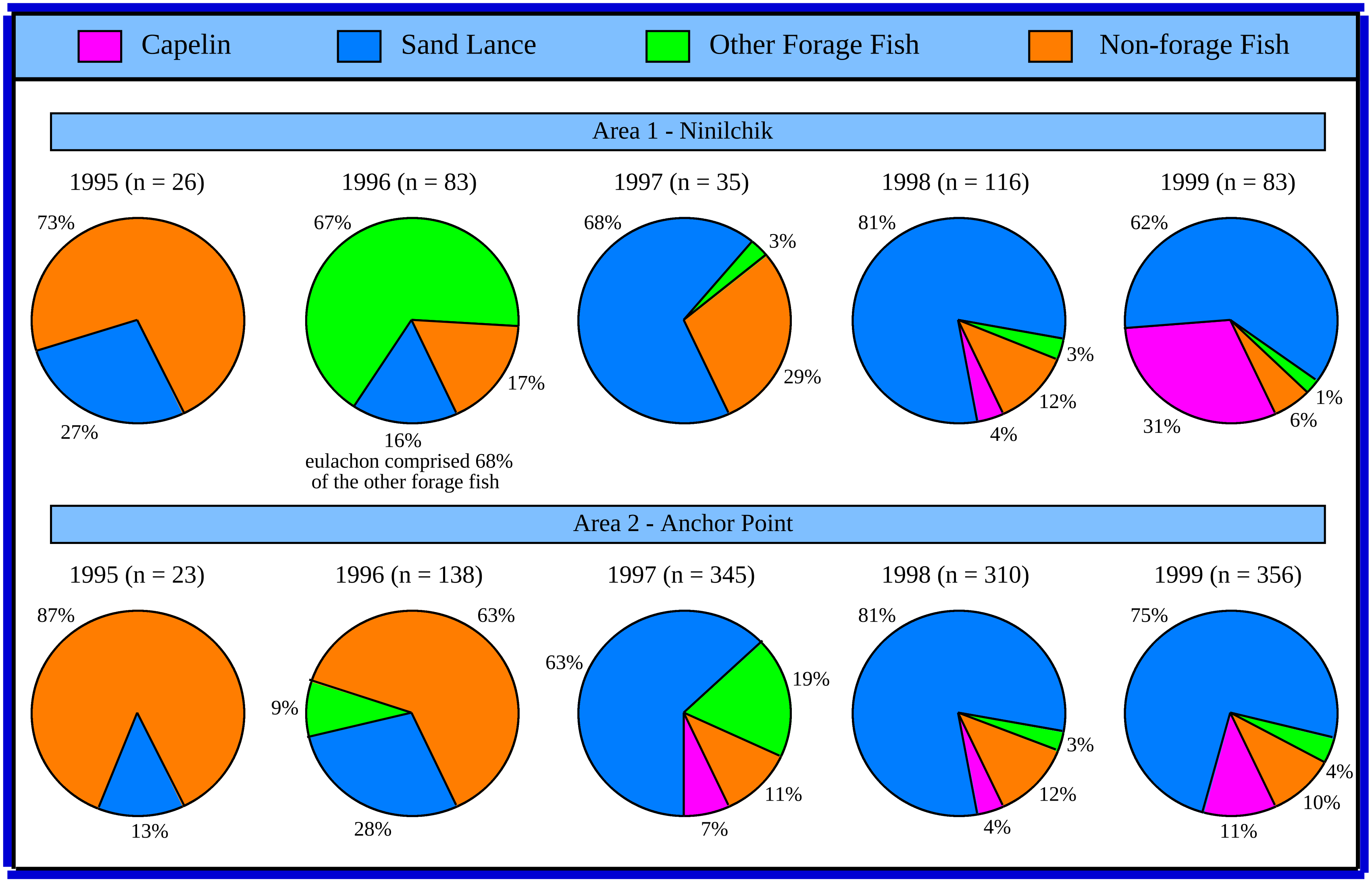

Figure 5a. Numbers of fish in halibut stomachs from Areas 1 and 2 in Kachemak Bay - lower Cook Inlet that contained prey, 1995-1999.

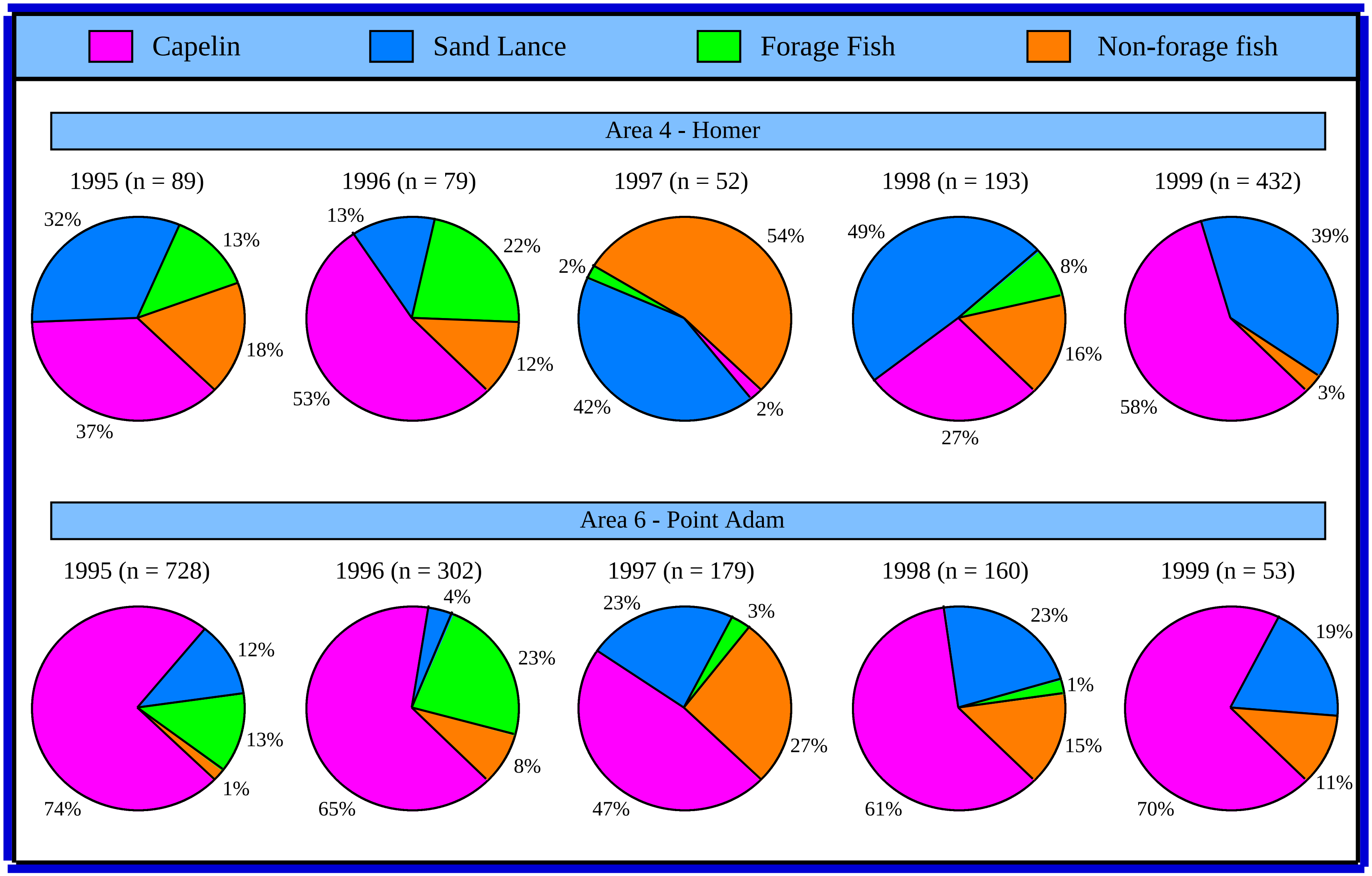

Figure 5b. Numbers of fish in halibut stomachs from Areas 4 and 6 in Kachemak Bay - lower Cook Inlet that contained prey, 1995-1999.

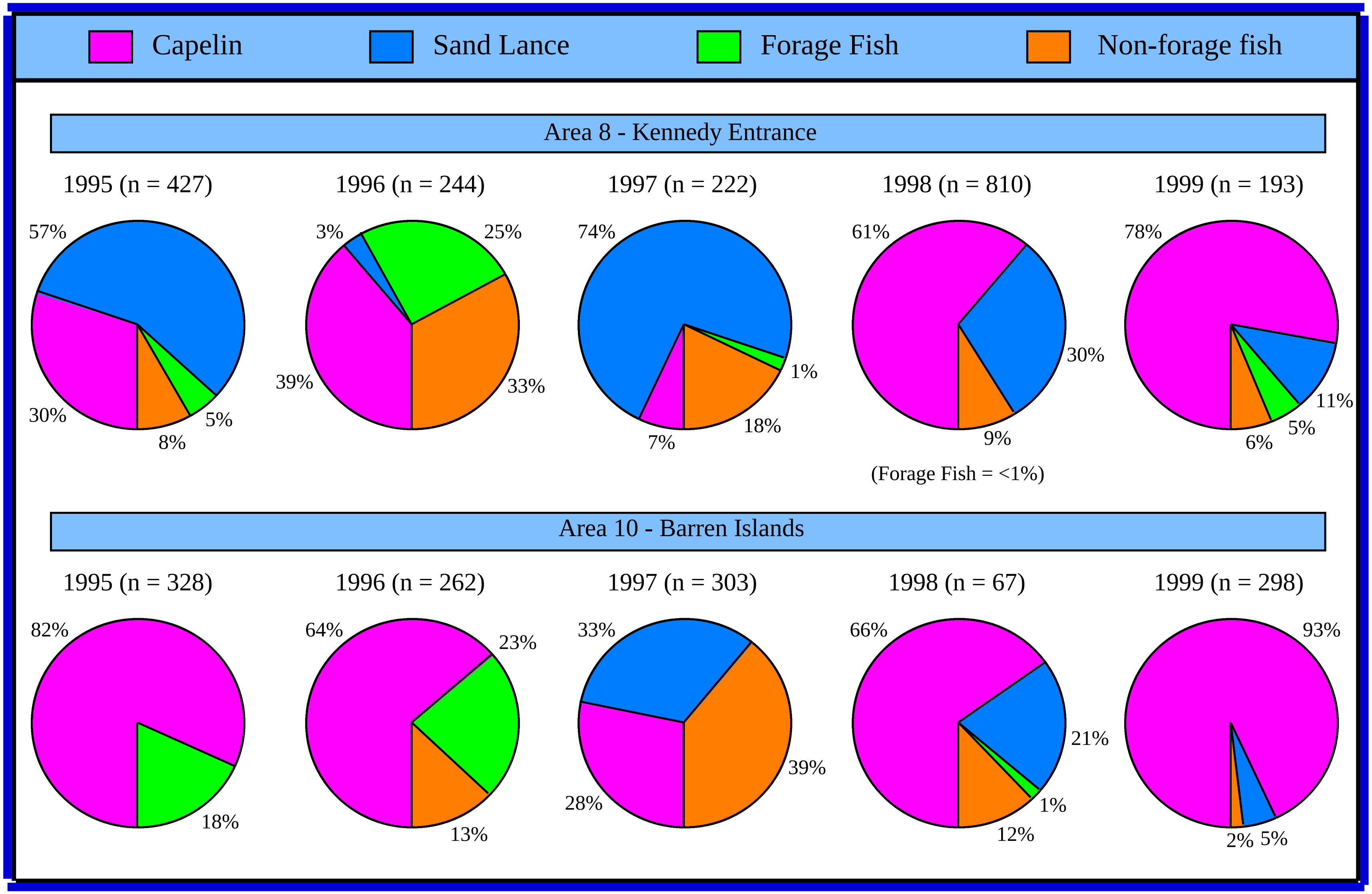

Figure 5c. Numbers of fish in halibut stomachs from Areas 8 and 10 in Kachemak Bay - lower Cook Inlet that contained prey, 1995-1999.

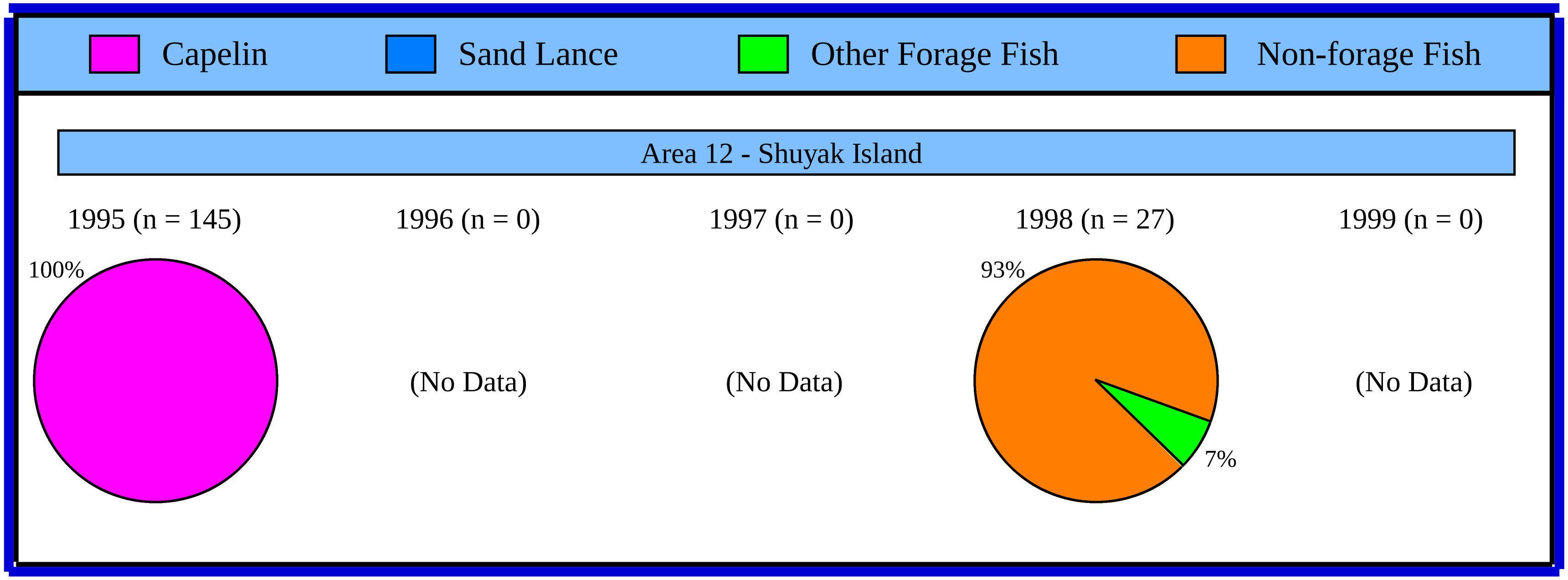

Figure 5d. Numbers of fish in halibut stomachs from Area 12 in Kachemak Bay - lower Cook Inlet that contained prey, 1995-1999.

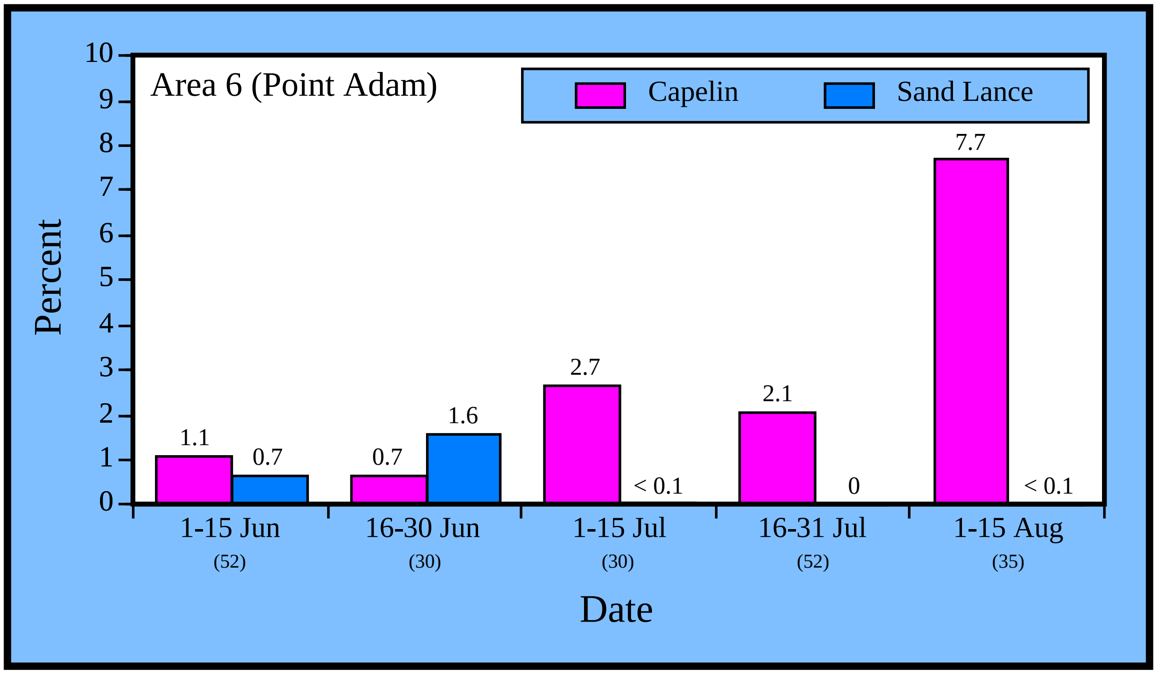

Figure 6. Average numbers of capelin and sand lance in halibut stomachs collected during two week intervals in Area 6 (Point Adam) in 1995 (numbers of stomachs shown in parentheses below time intervals).

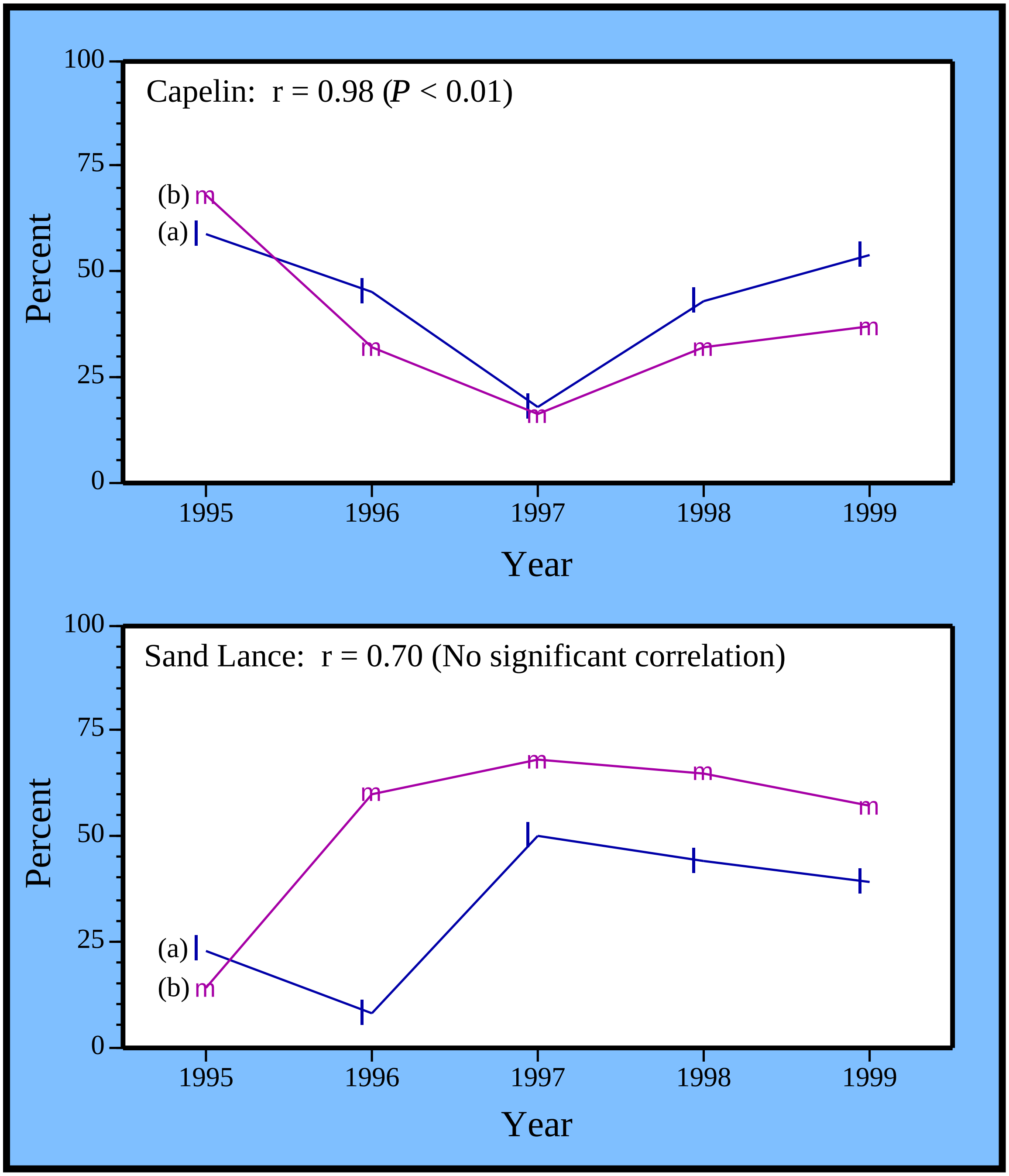

Figure 7. Numbers of capelin and sand lance in (a) halibut stomachs from Areas 1, 2, 4, 6, 8, and 10, and (b) weights of these forage fish species as percentages of total fish in black-legged kittiwake chick diets at the Barren Islands East Amatuli Island colony, 1995-1999 (the 1996 sand lance value of 8% was almost certainly artificially low—see footnote 2 in the text; kittiwake diet data are from Project 99163J).

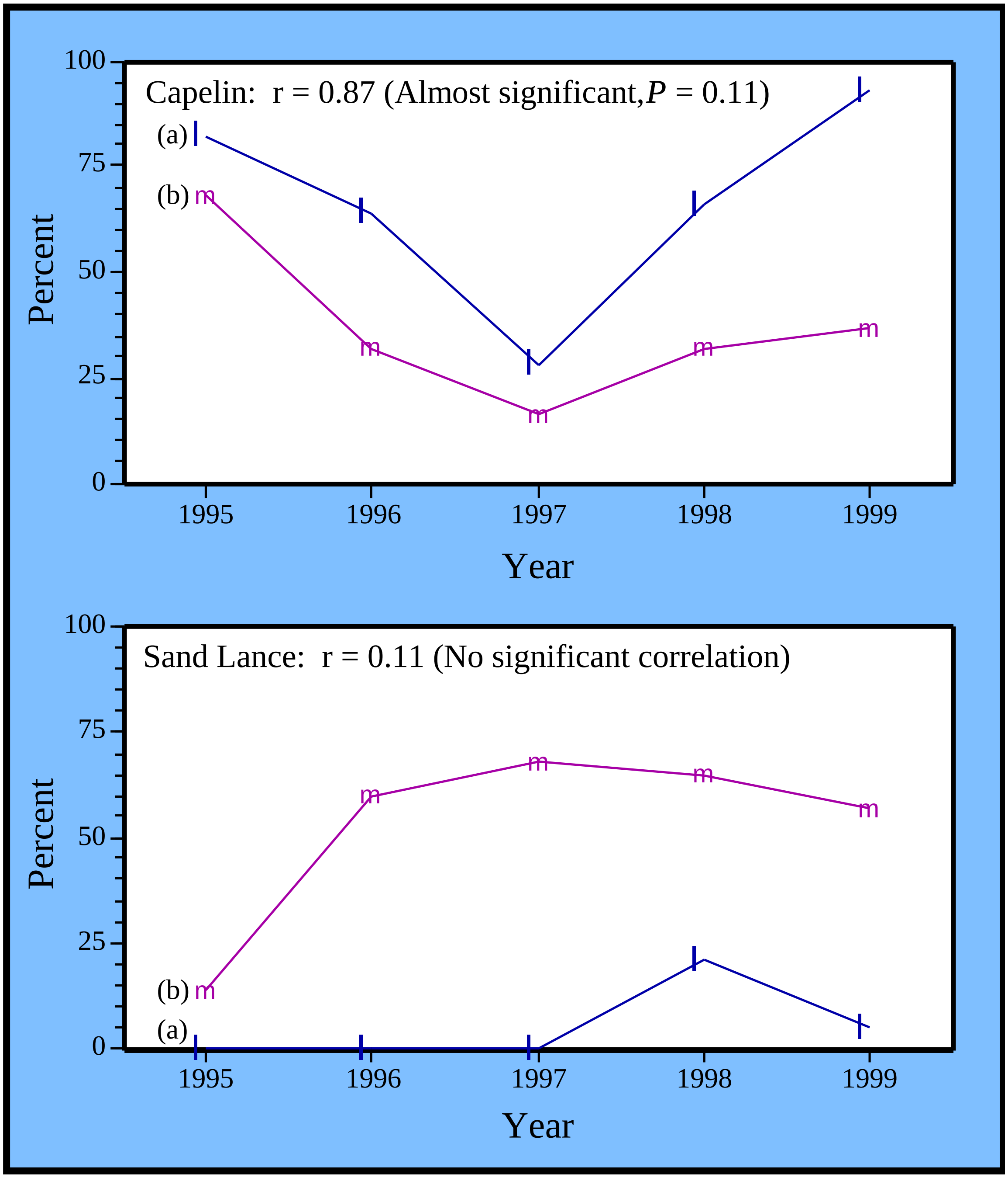

Figure 8. Numbers of capelin and sand lance in (a) halibut stomachs from Area 10, Barren Islands, and (b) weights of these forage fish species as percentages of total fish in black-legged kittiwake chick diets at the Barren Islands East Amatuli Island colony, 1995-1999 (kittiwake diet data are from Project 99163J).

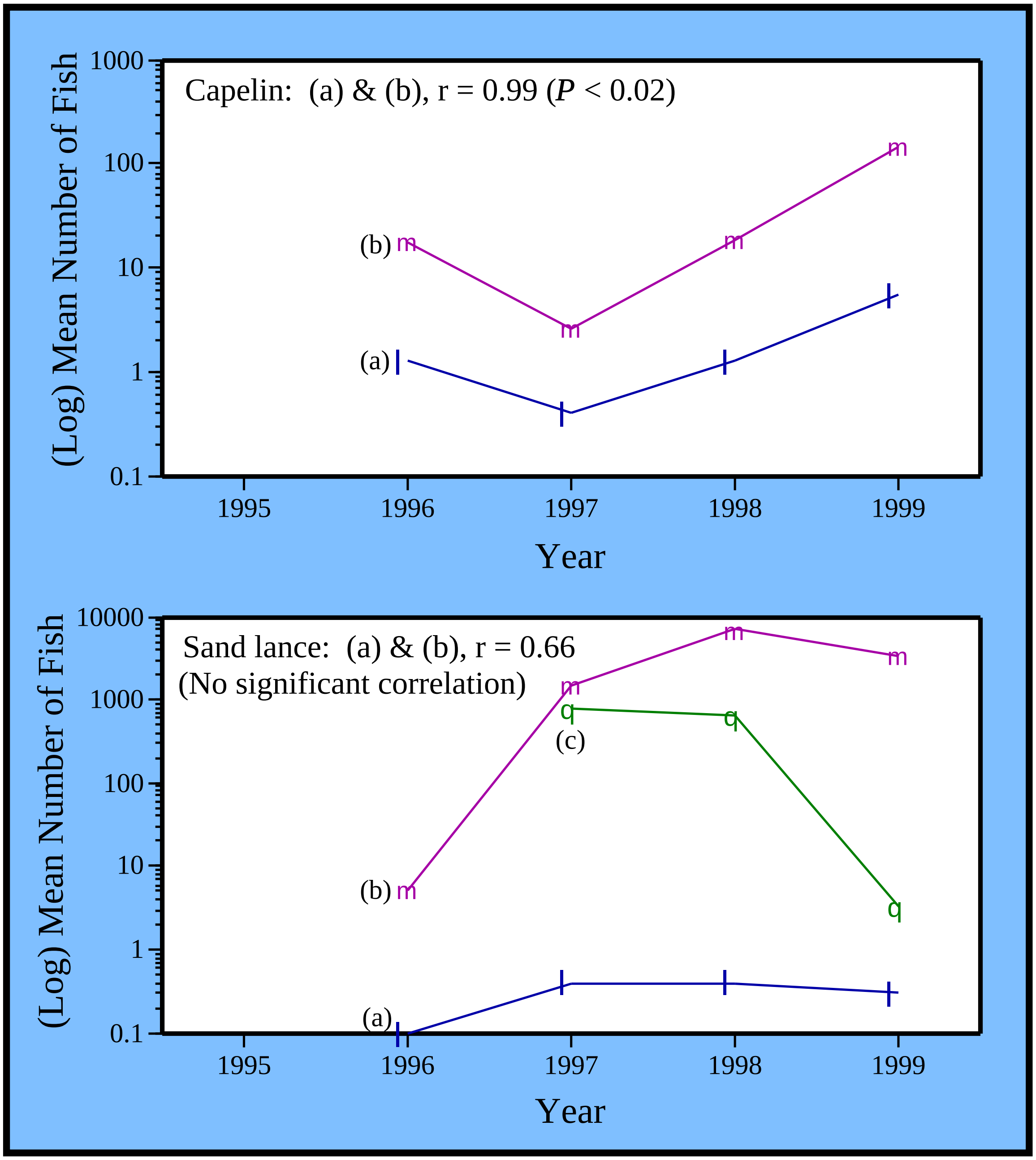

Figure 9. Mean numbers of capelin and sand lance found per (a) halibut stomach in Area 10, Barren Islands; (b) mid-water trawl near the Barren Islands; and (c) beach seine in Amatuli Cove, Barren Islands, 1996-1999 (only two capelin were caught in beach seines at the Barren Islands during 1996-1999; trawl data are from J. Piatt, Project 99163M, and beach seine data are from Project 99163J).

Appendix 1. Boundaries of the 1995-1999 Kachemak Bay - lower Cook Inlet halibut stomach sampling areas (latitudes and longitudes in hundredths of minutes and degrees and minutes).

Area 1 (Ninilchik): The northern boundary is 60.23 N (60˚ 14' N), the southern boundary is 59.92 N (59˚ 55' N), and the western and eastern boundaries are the shorelines of Cook Inlet.

Area 2 (Anchor Point): The northern boundary is 59.92 N (59˚ 55' N), the southern boundary is 59.72 N (59˚ 43' N), and the western and eastern boundaries are the shorelines of Cook Inlet.

Area 3 (Iniskin Bay): The northern boundary is 59.72 N (59˚ 43' N), the southern boundary is 59.45 N (59˚ 27' N), the western boundary is the shoreline of Cook Inlet, and the eastern boundary is 152.50 W (152˚ 30' W).

Area 4 (Homer): The northern boundary is 59.72 N (59˚ 43' N), the southern boundary is 59.45 N (59˚ 27' N), the western boundary is 152.50 W (152˚ 30' W), and the eastern boundary is 151.42 W (152˚ 25' W).

Area 5 (Augustine): The northern boundary is 59.45 N (59˚ 27' N), the southern boundary is 59.17 N (59˚ 10' N), the western boundary is the shoreline of Cook Inlet, and the eastern boundary is 152.50 W (152˚ 30' W).

Area 6 (Point Adam): The northern boundary is 59.45 N (59˚ 27' N), the southern boundary is 59.17 N (59˚ 10' N), the western boundary is 152.50 W (152˚ 30' W), and the eastern boundary is 151.42 W (152˚ 25' W).

Area 7 (McNeil): The northern boundary is 59.17 N (59˚ 10' N), the southern boundary is 59.02 N (59˚ 01' N), the western boundary is the shoreline of Cook Inlet, and the eastern boundary is 152.50 W (152˚ 30' W).

Area 8 (Kennedy Entrance): The northern boundary is 59.17 N (59˚ 10' N), the southern boundary is 59.02 N (59˚ 01' N), the western boundary is 152.50 W (152˚ 30' W), and the eastern boundary is 151.42 W (152˚ 25' W).

Area 9 (Cape Douglas): The northern boundary is 59.02 N (59˚ 01' N), the southern boundary is 58.80 N (58˚ 48' N), the western boundary is the shoreline of Cook Inlet, and the eastern boundary is 152.50 W (152˚ 30' W).

Area 10 (Barren Islands): The northern boundary is 59.02 N (59˚ 01' N), the southern boundary is 58.80 N (58˚ 48' N), the western boundary is 152.50 W (152˚ 30' W), and the eastern boundary is 151.58 W (151˚ 35' W).

Area 11 (Douglas Reef): The northern boundary is 58.80 N (58˚ 48' N), the southern boundary is 58.58 N (58˚ 35' N), the western boundary is the shoreline of Cook Inlet, and the eastern boundary is 152.50 W (152˚ 30' W).

Area 12 (Shuyak Island): The northern boundary is 58.80 N (58˚ 48' N), the southern boundary is 58.58 N (58˚ 35' N), the western boundary is 152.50 W (152˚ 30' W), and the eastern boundary is 151.58 W (151˚ 35' W).

Appendix 2. Summary of 1995-1999 Kachemak Bay - lower Cook Inlet halibut stomach collections by sample area (samples were not obtained from Areas 3, 5, 7, 9, and 11; see Fig. 1 and Appendix 1).

Area 1 (Ninilchik)

Total stomachs sampled: (1995) n = 10, number empty = 1 (10%), number with prey = 9 (90%); (1996) n = 52, number empty = 7 (13%), number with prey = 45 (87%); (1997) n = 53, number empty = 18 (34%), number with prey = 35 (66%); (1998) n = 70, number empty = 18, number with prey = 52; (1999) n = 66, number empty = 21(32%), number with prey = 45 (68%).

Sample dates: (1995) 1 Jul; (1996) 1 Jun, 4 Jun, 5 Jun, 6 Jun, 8 Jun, 10 Jun, 18 Jun, 19 Jun, 20 Jun, 24 Jun, 26 Jun, 25 Jul, & 28 Jul; (1997) 12 Jun, 20 Jun, 21 Jun, 29 Jun, 2 Jul, 16 Jul, 27 Jul, & 28 Jul; (1998) 5 Jun, 8 Jun, 15 Jun, 19 Jun, 20 Jun, 22 Jun, 30 Jun, 8 Jul, 11 Jul, 19 Jul, 28 Jul, & 1 Aug; (1999) 23 May, 14 Jun, 6 Jul, 15 Jul, 18 Jul, 4 Aug, & 9 Aug.

Area 2 (Anchor Point)

Total stomachs sampled: (1995) n = 46, number empty = 10 (22%), number with prey = 36 (78%); (1996) n = 130, number empty = 21 (16%), number with prey = 109 (84%); (1997) n = 270, number empty = 67 (25%), number with prey = 203 (75%); (1998) n = 212, number empty = 45, number with prey = 167; (1999) n = 256, number empty = 68 (27%), number with prey = 188 (73%).

Sample dates: (1995) 27 May, 31 May, 28 Jun, 29 Jun, & 8 Jul; (1996) 1 Jun, 5 Jun,8 Jun, 9 Jun, 10 Jun, 11 Jun, 13 Jun, 20 Jun, 24 Jun, 27 Jun, 9 Jul, 15 Jul, 16 Jul, 21 Jul, 2 Jul, 14 Jul, 25 Jul, & 27 Jul; (1997) 5 Jun, 12 Jun, 14 Jun, 20 Jun, 21 Jun, 29 Jun, 2 Jul, 6 Jul, 8 Jul, 15 Jul, 16 Jul, 17 Jul, 19 Jul, 24 Jul, 28 Jul, 29 Jul, 2 Aug, 5 Aug, 6 Aug, 10 Aug, 17 Aug, 18 Aug, & 22 Aug; (1998) 5 Jun, 15 Jun, 20 Jun, 22 Jun, 28 Jun, 29 Jun, 30 Jun, 4 Jul, 8 Jul, 10 Jul, 11 Jul, 16 Jul, 18 Jul, 19 Jul, 25 Jul, 28 Jul, 1 Aug, & 9 Aug; (1999) 18 May, 23 May, 24 May, 4 Jun , 5 Jun, 7 Jun, 20 Jun, 23 Jun, 30 Jun, 2 Jul, 10 Jul, 15 Jul, 23 Jul, 1 Aug, 4 Aug, 10 Aug, 16 Aug, 19 Aug, & 26 Aug.

Area 4 (Homer)

Total stomachs sampled: (1995) n = 95, number empty = 42 (44%), number with prey = 53 (56%); (1996) n = 60, number empty = 12 (20%), number with prey = 48 (80%); (1997) n = 92, number empty = 42 (46%), number with prey = 50 (54%); (1998) n =153, number empty = 55, number with prey = 98; (1999) n = 163, number empty = 52 (32%), number with prey = 111 (68%).

Sample dates: (1995) 27 May, 9 Jun, 28 Jun, 7 Jul, 10 Jul, 17 Jul, 18 Jul, 12 Aug, 18 Aug, & 19 Aug; (1996) 24 Jun, 27 Jul, 19 Aug, & 20 Aug; (1997) 5 Jun, 13 Jun, 15 Jun, 14 Jul, 16 Jul, 2 Aug, 14 Aug, & 16 Aug; (1998) 17 Jun, 18 Jun, 19 Jun, 22 Jun, 23 Jun, 18 Jul, 31 Jul, & 14 Aug; (1999) 13 Jun, 15 Jun, 26 Jun, 28 Jun, 22 Jul, 28 Jul, 3 Aug, 10 Aug, & 22 Aug.

Area 6 (Point Adam)

Total stomachs sampled: (1995) n = 199, number empty = 55 (28%), number with prey = 144 (72%); (1996) n = 176, number empty = 33 (19%), number with prey = 143 (81%); (1997) n = 246, number empty = 93 (38%), number with prey = 153 (62%); (1998) n = 136, number empty = 50, number with prey = 86; (1999) n = 101, number empty = 55 (54%), number with prey = 46 (46%).

Appendix 2 (Continued).

Area 6 (Point Adam)

Sample dates: (1995) 1 Jun, 3 Jun, 8 Jun, 14 Jun, 16 Jun, 26 Jun, 27 Jun, 8 Jul, 11 Jul, 15 Jul, 21 Jul, 23 Jul, 27 Jul, 31 Jul, 5 Aug, 6 Aug, 9 Aug, & 14 Aug; (1996) 8 Jun, 13 Jun, 14 Jun, 15 Jun, 18 Jun, 19 Jun, 26 Jun, 30 Jun, 5 Jul, 6 Jul, 8 Jul, 9 Jul, 12 Jul, 22 Jul, 23 Jul, 10 Aug, & 11 Aug; (1997) 26 May, 5 Jun, 6 Jun, 14 Jun, 18 Jun, 1 Jul, 7 Jul, 16 Jul, 31 Jul, 10 Aug, 18 Aug, & 23 Aug; (1998) 20 Jun, 25 Jun, 3 Jul, 7 Jul, 20 Jul, 29 Jul, 7 Aug, & 14 Aug; (1999) 8 Jun, 7 Jul, 10 Jul, 11 Jul, & 20 Aug.

Area 8 (Kennedy Entrance)

Total stomachs sampled: (1995) n = 144, number empty = 60 (42%), number with prey = 84 (58%); (1996) n = 175, number empty = 52 (30%), number with prey = 123 (70%); (1997) n = 288, number empty = 173 (60%), number with prey = 115 (40%); (1998) n =374, number empty = 164, number with prey = 210; (1999) n = 153, number empty = 77 (50%), number with prey = 76 (50%).

Sample dates: (1995) 1 Jun, 2 Jun, 10 Jun, 14 Jun, 21 Jun, 22 Jun, 3 Jul, 5 Jul, 16 Jul, 20 Jul, 24 Jul, 3 Aug, 21 Aug, 1 Sep, & 3 Sep; (1996) 21 Jun, 22 Jun, 27 Jun, 7 Jul, 8 Jul, 16 Jul, 18 Jul, 23 Jul, 7 Aug, 8 Aug, 9 Aug, 13 Aug, 14 Aug, & 18 Aug; (1997) 1 Jun, 8 Jun, 15 Jun, 20 Jun, 21 Jun, 22 Jun, 28 Jun, 4 Jul, 5 Jul, 14 Jul, 21 Jul, 21 Jul, 26 Jul, 28 Jul, 12 Aug, 16 Aug, & 27 Aug; (1998) 17 Jun, 22 Jun, 4 Jul, 6 Jul, 8 Jul, 12 Jul, 17 Jul, 19 Jul, 22 Jul, 23 Jul, 25 Jul, 27 Jul, 30 Jul, 1 Aug, 3 Aug, 4 Aug, 10 Aug, 12 Aug, 17 Aug, 19 Aug, & 21 Aug; (1999) 7 Jun, 20 Jun, 1 Jul, 13 Jul, 4 Aug, 6 Aug, 18 Aug, & 27 Aug.

Area 10 (Barren Islands)

Total stomachs sampled: (1995) n = 80, number empty = 34 (43%), number with prey = 46 (58%); (1996) n = 184, number empty = 53 (29%), number with prey = 131 (71%); (1997) n = 483, number empty =258 (53%), number with prey = 225 (47%); (1998) n = 76, number empty = 42, number with prey = 34; (1999) n = 78, number empty = 26 (33%), number with prey = 52 (67%).

Sample dates: (1995) 17 Jun, 18 Jun, 23 Jun, 24 Jun, 25 Jun, 2 Jul, 26 Aug, & 30 Aug; (1996) 6 Jun, 7 Jun, 16 Jun, 21 Jun, 28 Jun, 29 Jun, 7 Jul, 14 Jul, 19 Jul, 22 Jul, 24 Jul, 26 Jul, 28 Jul, 3 3 Aug, & 8 Aug; (1997) 4 Jun, 8 Jun, 11 Jun, 15 Jun, 16 Jun, 20 Jun, 21 Jun, 26 Jun, 27 Jun, 28 Jun, 29 Jun, 7 Jul, 10 Jul, 12 Jul, 19 Jul, 27 Jul, 3 Aug, 4 Aug, 6 Aug, 7 Aug, 14 Aug, & 25 Aug; (1998) 26 Jun, 6 Jul, 9 Jul, & 10 Jul; (1999) 5 Jul, 9 Jul, 15 Jul, 19 Jul, 23 Jul, 25 Jul, & 26 Jul.

Area 12 (Shuyak Island)

Total stomachs sampled: (1995) n = 11, number empty = 2 (18%), number with prey = 9 (82%); (1996) n = 0, no data; (1997) n = 0, no data; (1998) n = 29, number empty = 6, number with prey = 23; (1999) n = 0, no data.

Sample dates: (1995) 20 Jun; (1996) none; (1997) none; (1998) 20 Jul & 25 Jul; (1999) none.

Appendix 3. Numbers of capelin and sand lance caught per mid-water trawl in Kachemak Bay - lower Cook Inlet, 1996-1999 (data are from J. Piatt, Project 00163M; number of trawls shown in parentheses).

Species	Kachemak Bay							
	1996 (16)		1997 (20)		1998 (18)		1999 (12)	
	mean	stdev	mean	stdev	mean	stdev	mean	stdev
Capelin *(Mallotus villosus)*	13.7	39.5	4.9	20.7	0.9	3.1	0.9	1.8
Pacific sand lance *(Ammodytes hexapterus)*	153.3	363.2	149.8	279.8	746.7	891.4	3724.4	6469.2
	Chisik Island							
	1996 (6)		1997 (11)		1998 (7)		1999 (14)	
	mean	stdev	mean	stdev	mean	stdev	mean	stdev
Capelin *(Mallotus villosus)*	15.8	24.1	0.3	0.6	0.2	0.4	147.3	533.2
Pacific sand lance *(Ammodytes hexapterus)*	13.4	25.5	236.3	599.5	231.3	367.9	78.9	218.2
	Barren Islands							
	1996 (19)		1997 (17)		1998 (8)		1999 (11)	
	mean	stdev	mean	stdev	mean	stdev	mean	stdev
Capelin *(Mallotus villosus)*	17.7	72.5	2.6	10.2	18.5	52.1	147.6	384.5
Pacific sand lance *(Ammodytes hexapterus)*	5.3	14.2	1503.8	3611.2	7108.8	10349.2	3415.3	5154.7

Appendix 4. Numbers of capelin and sand lance caught per beach seine at Amatuli Cove, Barren Islands, 1997-1999 (data are from Project 99163J; number of sets shown in parentheses).

Species	Year			
	1996	1997 (13)	1998 (14)	1999 (13)
Capelin *(Mallotus villosus)*	NA1	0	0	2
Pacific sand lance *(Ammodytes hexapterus)*	NA	10,062.00	9,265.00	44

1 NA = Not available.