Exxon Valdez Oil Spill
APEX Project Annual Report

Using Predatory Fish to Sample Forage Fishes, 1997

APEX Project 97163K
Annual 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 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, with support from the Alaska Maritime National Wildlife Refuge (ANMWR). In 1997, the study continued as APEX Project 97163K.

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 a study 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 (APEX Project 95163K; see Roseneau and Byrd 1996, 1997). Because our initial efforts demonstrated that valuable information on target species could be obtained by this method, additional data were collected in 1996 with support from the Alaska Maritime National Wildlife Refuge. In 1997, we collected and analyzed over 1,400 halibut stomachs from the Kachemak Bay - lower Cook Inlet study area for the ongoing APEX ecological processes project. Results from the third year of work helped confirm that this relatively simple sampling technique can supply low-cost relative abundance data on forage fish populations in Kachemak Bay - lower Cook Inlet that are needed to help monitor and assess seasonal and interannual variations in forage fish stocks and seabird prey bases.

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

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

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Table of Contents

INTRODUCTION 1

OBJECTIVES 1

METHODS 1

RESULTS 2

DISCUSSION 2

CONCLUSIONS 3

RECOMMENDATIONS 3

ACKNOWLEDGMENTS 4

LITERATURE CITED 4

List of Figures

Figure 1. The Kachemak Bay - lower Cook Inlet study area 5

Figure 2. Frequency of occurrence of fish and invertebrates in halibut stomachs from Areas 2, 4, 6, 8, and 10 in Kachemak Bay - lower Cook Inlet, 1995-1997 6

Figure 3. Frequencies of occurrence of (a) fishes and (b) invertebrates in halibut stomachs from Areas 2, 4, 6, 8, and 10 in Kachemak Bay - lower Cook that contained prey, 1995-1997 7

Figure 4. Numbers of fish and invertebrates in halibut stomachs from Areas 2, 4, 6, 8, and 10 in Kachemak Bay - lower Cook Inlet that contained prey, 1995-1997 8

Figure 5a. Numbers of fish in halibut stomachs from Areas 2 and 4 in Kachemak Bay - lower Cook Inlet that contained prey, 1995-1997 9

Figure 5b. Numbers of fish in halibut stomachs from Areas 6 and 8 in Kachemak Bay - lower Cook Inlet that contained prey, 1995-1997 10

Figure 5c. Numbers of fish in halibut stomachs from Area 10 in Kachemak Bay - lower Cook Inlet that contained prey, 1995-1997 11

List of Appendices

Appendix 1. Boundaries of the 1995-1997 Kachemak Bay - lower Cook Inlet halibut stomach sampling areas 12

Appendix 2. Summary of 1995-1997 Kachemak Bay - lower Cook Inlet halibut stomach collections by sample area 13

INTRODUCTION

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 a study 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 (APEX Project 95163K; see Roseneau and Byrd 1996, 1997). Because our initial efforts demonstrated that valuable information on target species could be obtained by this method, additional data were collected in 1996 with support from the Alaska Maritime National Wildlife Refuge. In 1997, we collected and analyzed over 1,400 halibut stomachs from the Kachemak Bay - lower Cook Inlet study area for the ongoing APEX ecological processes project. Results from the third year of work helped confirm that this relatively simple sampling technique can supply low-cost relative abundance data on forage fish populations in Kachemak Bay - lower Cook Inlet that are needed to help monitor and assess seasonal and interannual variations in forage fish stocks and seabird prey bases.

OBJECTIVES

Project objectives were to test the feasibility of using stomach contents from sport-caught halibut to sample forage fish stocks in the northern Gulf of Alaska and evaluate the effectiveness of the method in obtaining information useful to APEX seabird and forage fish studies in the spill area (e.g., studies of common murres, *Uria aalge*; black-legged kittiwakes, *Rissa tridactyla*; Pacific sand lance, 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). They were also selected as sampling tools because a large 100-150 vessel charter boat fleet sport fishes for them in Kachemak Bay - lower Cook Inlet throughout May-August in several of same general areas frequented by foraging seabirds from the Barren Islands and Gull and Chisik islands breeding colonies (see Roseneau and Byrd 1996, 1997).

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). During late May - early September 1995-1997, we obtained 586, 778, and 1,433 halibut stomachs from 7-8 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, in 1996, Lake Clark National Park and Alaska Department of Fish and Game biologists collected 173 stomachs for the project from lodge owners and sport fishermen in Areas 1 and 2 during resource monitoring activities. Alaska Department of Fish and Game fisheries personnel also obtained an additional 324 stomachs from Areas 1 and 2 in 1997, when they processed sport-caught fish for age-sex-weight data in the Deep Creek and Ninilchik vicinities.

[1] During 1995-1997, halibut lengths averaged 39 cm (n = 586, range = 71-213 cm), 111 cm (n = 778, range = 64-160 cm), and 87 cm (n = 433, range = 57-141 cm), 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 the project by participating fishermen. Stomach contents were identified using taxonomic keys, photographs, and voucher specimens (see Roseneau and Byrd 1996, 1997). 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. Empty stomachs were weighed to obtain estimates of content weight, and undigested capelin and sand lance were weighed and measured to obtain size data for other investigators (e.g., J. Piatt, Project 97163M). Samples of 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. Analysis consisted of eliminating all potential bait items from the data base (e.g., cod and salmon heads; 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 different geographic areas and time periods (see Roseneau and Byrd 1996, 1997).

RESULTS

We limited preliminary multiyear analyses to Areas 2, 4, 6, 8, and 10 (see Fig 1). Data from Areas 1 and 12 will be incorporated into the FY 98 report. *[Samples were not obtained from Areas 3, 5, 7, 9, and 11 during 1995-1997, because these areas are rarely fished by the sport charter fleet].*

In 1997, fish were only present in about 32% of the stomachs, compared to 49% in 1995 and 55% in 1996 (Fig. 2). Changes were also apparent in stomachs containing prey: occurrence of sand lance, other forage fishes, and non-forage fish species tended to rise over the 3-year interval (sand lance 11%, 6%, and 17%; other forage fishes 17%, 30%, and 28%; and non-forage fish species 24%, 31%, and 34% in 1995-1997, respectively), but only about 11% of the stomachs contained capelin in 1996 and 8% in 1997, compared with 33% in 1995 (Fig. 3).

Numbers of fish also declined markedly in stomachs containing prey over the 3-year period (from a high of 79% in 1995, to 45% in 1996 and only 36% in 1997; see Fig 4). Also, although capelin and sand lance dominated the annual fish component by number (83%, 56%, and 68% in 1995-1997, respectively), these species clearly switched roles between 1995 and 1997 (capelin and sand lance 60% and 23% in 1995 *vs* 19% and 49% in 1997; see Fig. 4).

When fish numbers were compared among areas and years, numbers of capelin were consistently lowest in Area 2 (Fig. 5a; mean 2%, range 0-7%) and highest in Areas 6 (Fig. 5b; mean 62%, range 47-74%) and 10 (Fig. 5c; mean 58%, range 28-82%). Data from these 3 areas and Areas 4 and 8 also provided additional evidence that capelin stocks declined and sand lance populations increased between 1995 and 1997; for the five areas combined, capelin averaged 44% (range 0-82%) and 18% (range 2-47%, and sand lance averaged 23% (range 0-12%) and 47% (range 33-74%), respectively (see Figs. 5a, 5b, and 5c).

DISCUSSION

The consistently smaller numbers of capelin found in halibut stomachs from Area 2 (see Fig. 1) may have been related to the less saline, more turbid water conditions often found north of Anchor Point, and the consistently larger numbers of these forage fish present in Area 6 and 10 stomachs may have been associated with cold water upwellings that occur the Point Adam and Barren Islands vicinities (J. Piatt, pers. comm.).

Study results indicated that forage fish stocks declined in Kachemak Bay - lower Cook Inlet between 1995 and 1997. They also suggested that sand lance populations increased and capelin stocks declined during this interval. These changes were supported by information from other studies. For example, in 1993-1995, tens of thousands seabirds, including sooty shearwaters *(Puffinus griseus)*, black-legged kittiwakes, tufted puffins *(Fratercula cirrhata),* 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, 1996; Roseneau and Byrd 1996, 1997). In contrast, capelin schools and associated feeding concentrations of seabirds and whales were scarce in this area during mid-July - mid-August 1996, and nearly 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).

The apparent shift from a capelin dominated food web in 1995 to one containing large numbers of sand lance in 1997 suggested by the multiyear halibut stomach data paralleled 1995-1997 changes in Barren Islands kittiwake chick diets. During these years, kittiwake chicks reared at the East Amatuli Island - Light Rock colony were fed about 64%, 28%, and 14% capelin, and 13%, 53%, and 63% sand lance by weight, respectively (see Roseneau *et al.* 1998).

Preliminary analysis of beach seine data collected by APEX Projects 96163J, 97163J, 96163M, and 97163M also indicated that sand lance were more numerous than capelin in the Kachemak Bay - lower Cook Inlet region in 1997 (M. Robards, pers. comm.). More comprehensive analyses that incorporate halibut stomach information from Areas 1 and 2, and beach seine and seabird chick diet data from the Barren Islands and Gull and Chisik islands colonies will be included in the FY 98 annual report.

CONCLUSIONS

1. Results from the third year of study helped confirm that analyzing stomach contents from sport-caught halibut can supply low-cost relative abundance data on forage fish populations in Kachemak Bay - lower Cook Inlet that are needed to help monitor and assess seasonal and interannual variations in forage fish stocks and seabird prey bases.

2. Results also indicated that the sampling method can be used to monitor seasonal changes in relative abundance of capelin and sand lance in certain circumstances. When data were sufficient to be divided into two-week time blocks, we were able to detect within-season variation in these species (e.g., Area 6 in 1995; see Roseneau and Byrd 1996, 1997). Based on these data, we believe that this relatively simple cost-effective technique can provide a variety of useful information on forage fish stocks in areas where seabird foraging areas and regular sport fishing activities overlap (e.g., Barren Islands, Gull and Chisik island vicinities).

RECOMMENDATIONS

Based on 1995-1997 results, including similarities identified between halibut stomach contents and seabird chick diets, we recommend continuing this relatively inexpensive Kachemak Bay - lower Cook Inlet forage fish sampling project in FY 98 - FY 99 (or until the conclusion of the APEX ecological processes study).

ACKNOWLEDGMENTS

We would like to thank our volunteers, Jill Aho, Daniel Boone, and Martin Robards, for their help during the study. Jill and Daniel made arrangements to obtain samples from halibut charter boat operators, met returning vessels, recorded catch dates and locations, and processed stomach contents. Martin single-handedly identified the contents of over 1,600 stomachs at the Kasitsna Bay Laboratory during 1996-1997. We also thank Scott Meyer and Willy Dunn of the Alaska Department of Fish & Game Homer office for collecting stomachs from fishermen in the Ninilchik -Deep Creek vicinities in 1996-1997; Alan Bennet, Lake Clark National Park and Preserve, for providing data from stomachs collected by his crew along the western side of Cook Inlet in 1996; Captain Rick Swenson, Homer Ocean Charters, for letting us sample carcasses at his facilities on the Homer Spit in 1995-1996; and all of the other charter boat operators and vessel captains who participated in the study. Bruce Wright, National Marine Fisheries Service, and John Piatt, U.S.Geological Survey Biological Resources Division (APEX Project 97163M), provided helpful suggestions and support during the work. The study was funded by the *Exxon Valdez* Oil Spill Trustee Council, as part of the ongoing Alaska Predator Ecosystem Experiment (APEX Project 97163); additional support was obtained from the Alaska Maritime National Wildlife Refuge.

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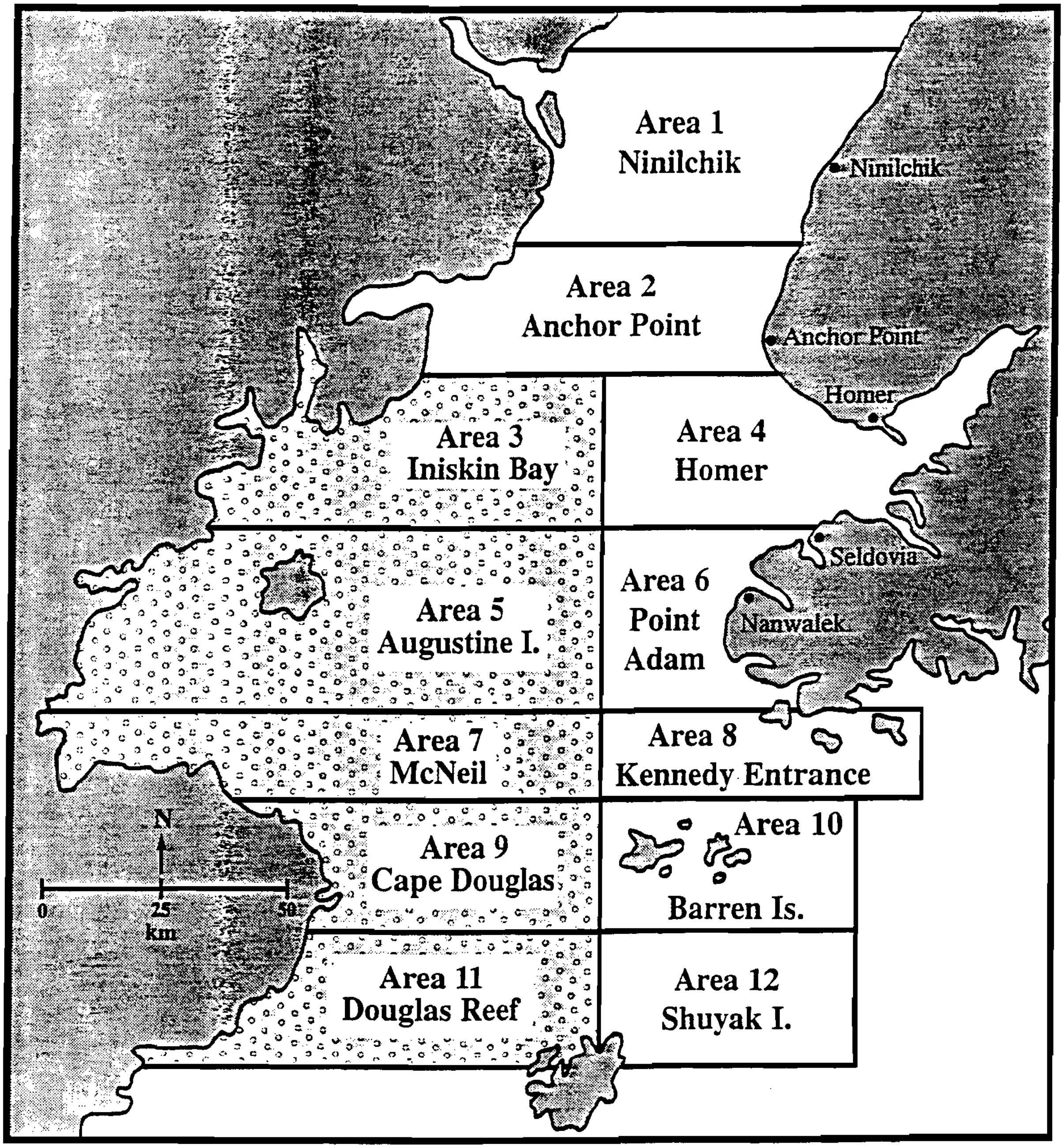

Figure 1. The Kachemak Bay - lower Cook Inlet study area (samples were analyzed from Areas 2, 4, 6, 8, and 10; no samples were obtained from shaded areas).

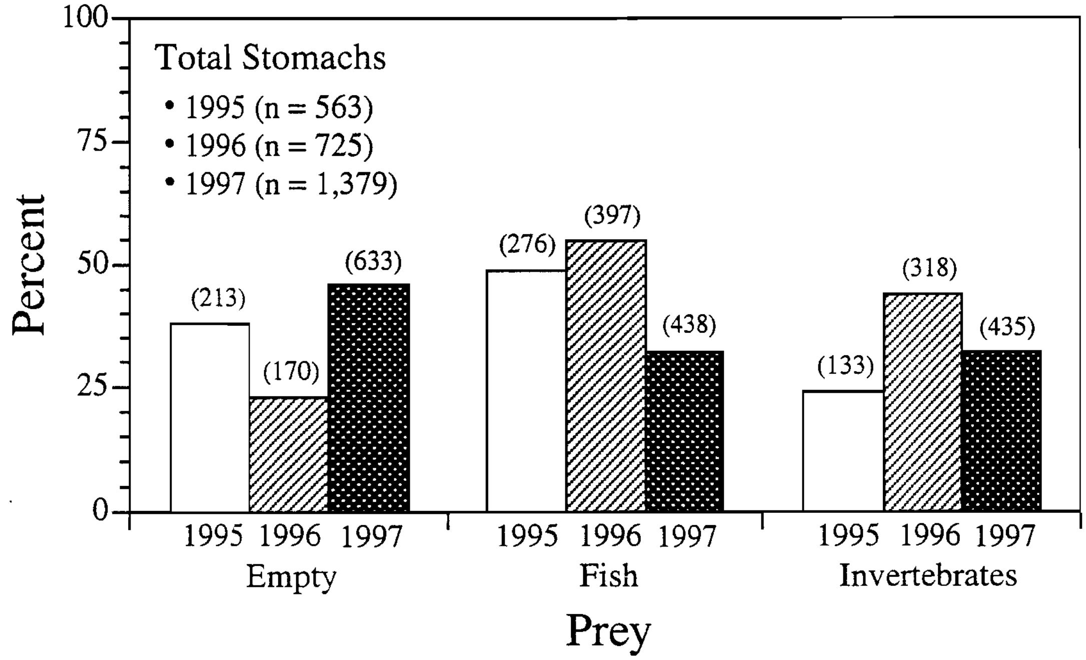

Figure 2. Frequency of occurrence of fish and invertebrates in halibut stomachs from Areas 2, 4, 6, 8, and 10 in Kachemak Bay - lower Cook Inlet, 1995-1997 (numbers of stomachs shown in parentheses).

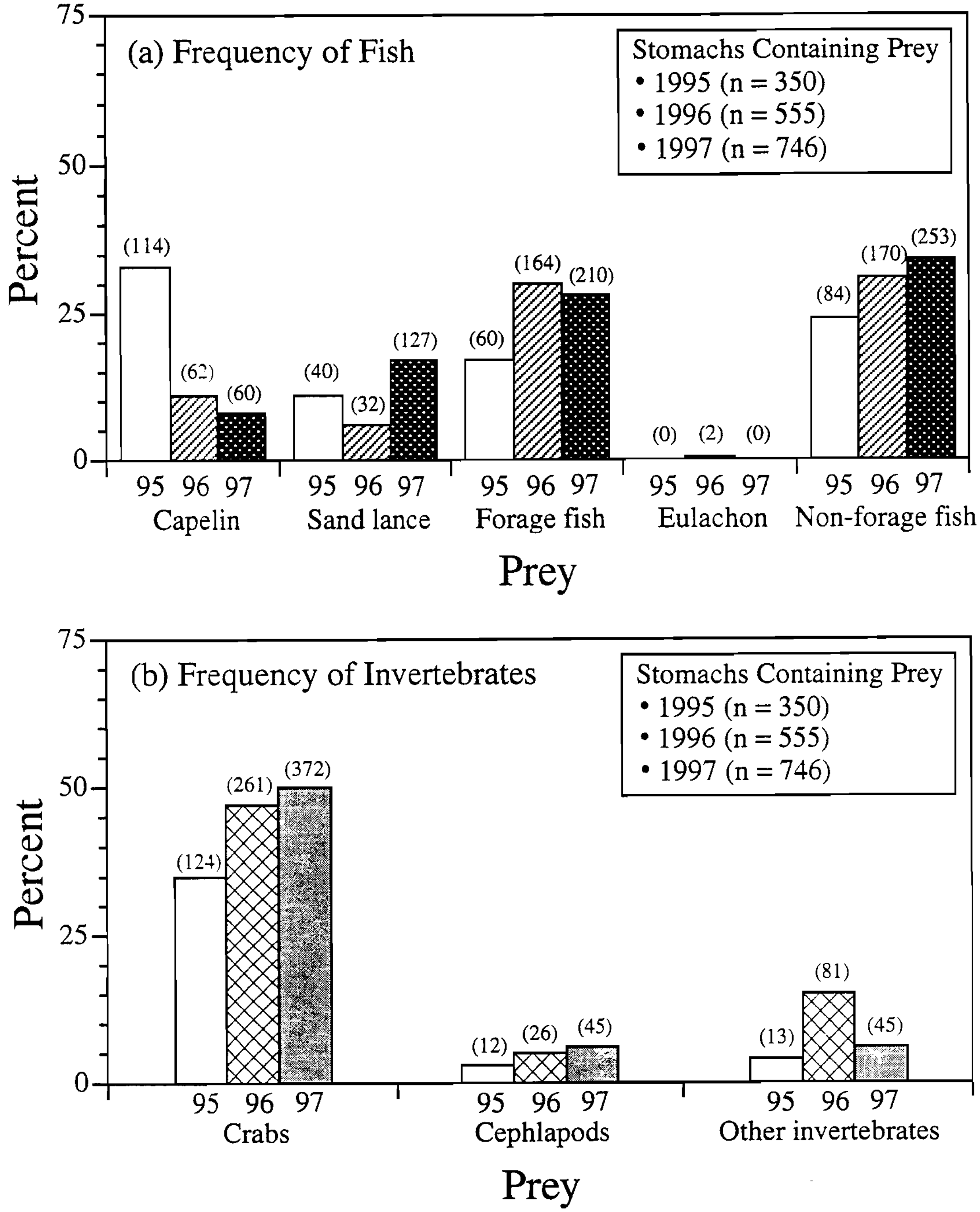

Figure 3. Frequencies of occurrence of (a) fishes and (b) invertebrates in halibut stomachs from Areas 2, 4, 6, 8, and 10 in Kachemak Bay - lower Cook Inlet that contained prey, 1995-1997 (numbers of stomachs shown in parentheses).

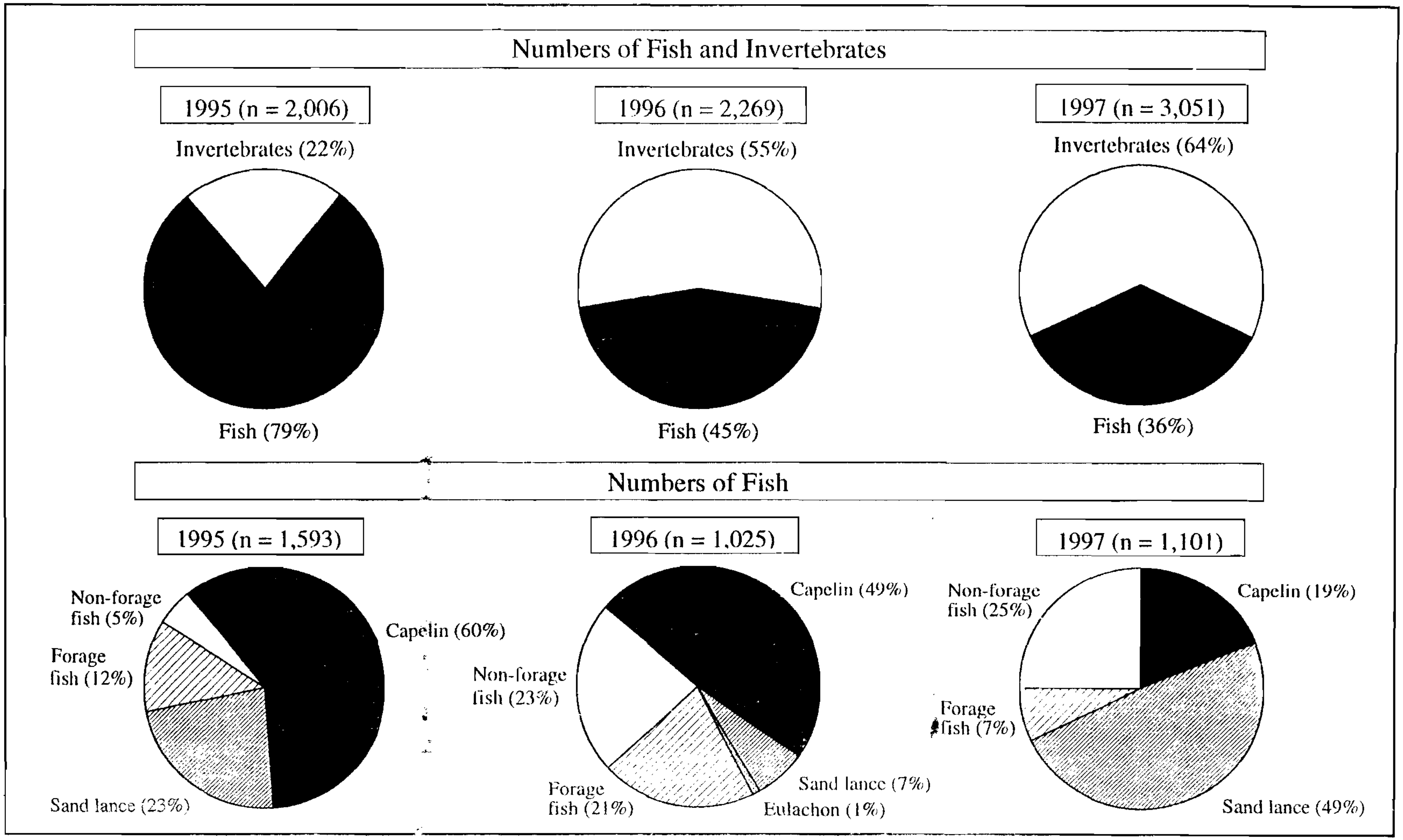

Figure 4. Numbers of fish and invertebrates in halibut stomachs from Areas 2, 4, 6, 8, and 10 in Kachemak Bay - lower Cook Inlet that contained prey, 1995-1997.

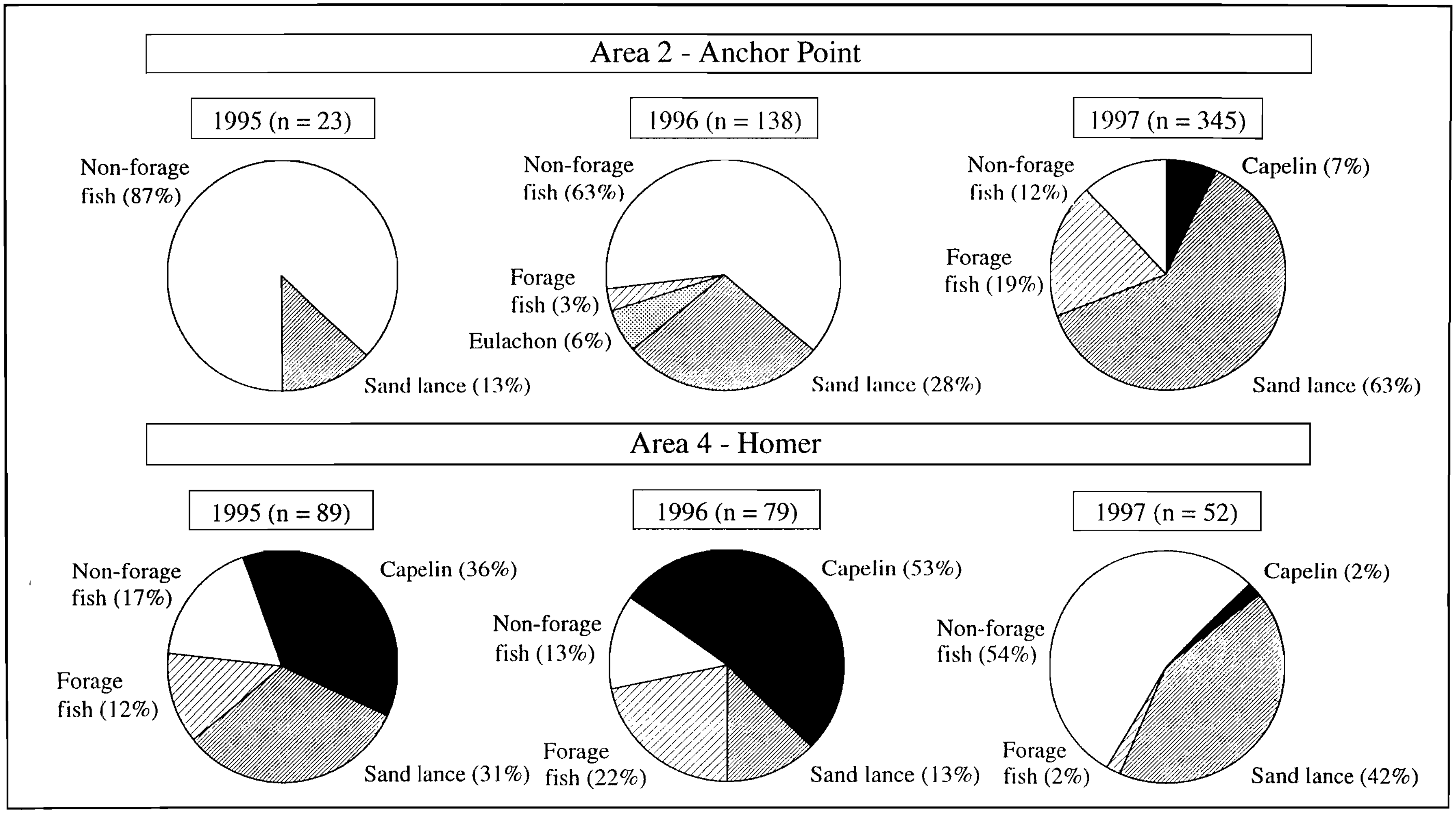

Figure 5a. Numbers of fish in halibut stomachs from Areas 2 and 4 in Kachemak Bay - lower Cook Inlet that contained prey, 1995-1997.

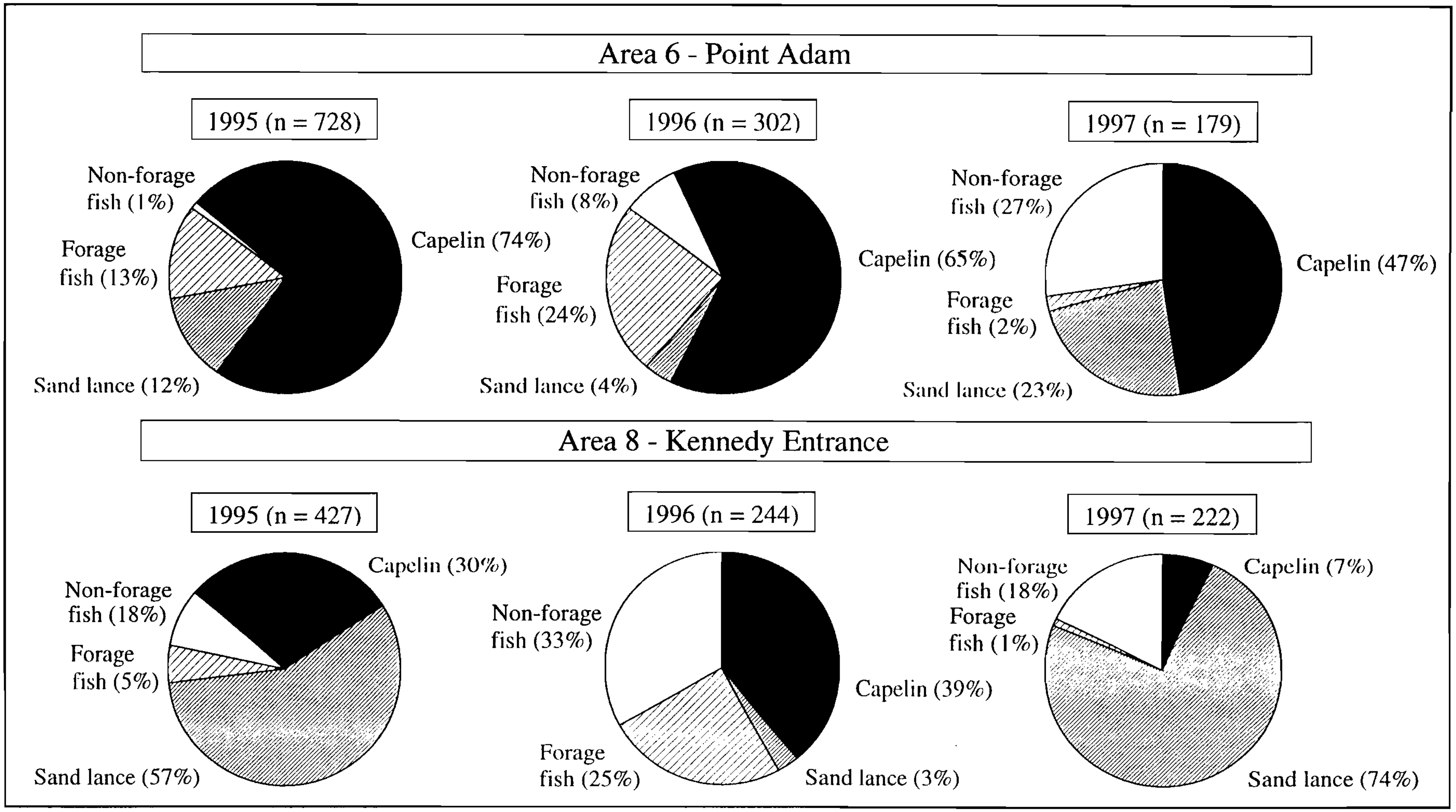

Figure 5b. Numbers of fish in halibut stomachs from Areas 6 and 8 in Kachemak Bay - lower Cook Inlet that contained prey, 1995-1997.

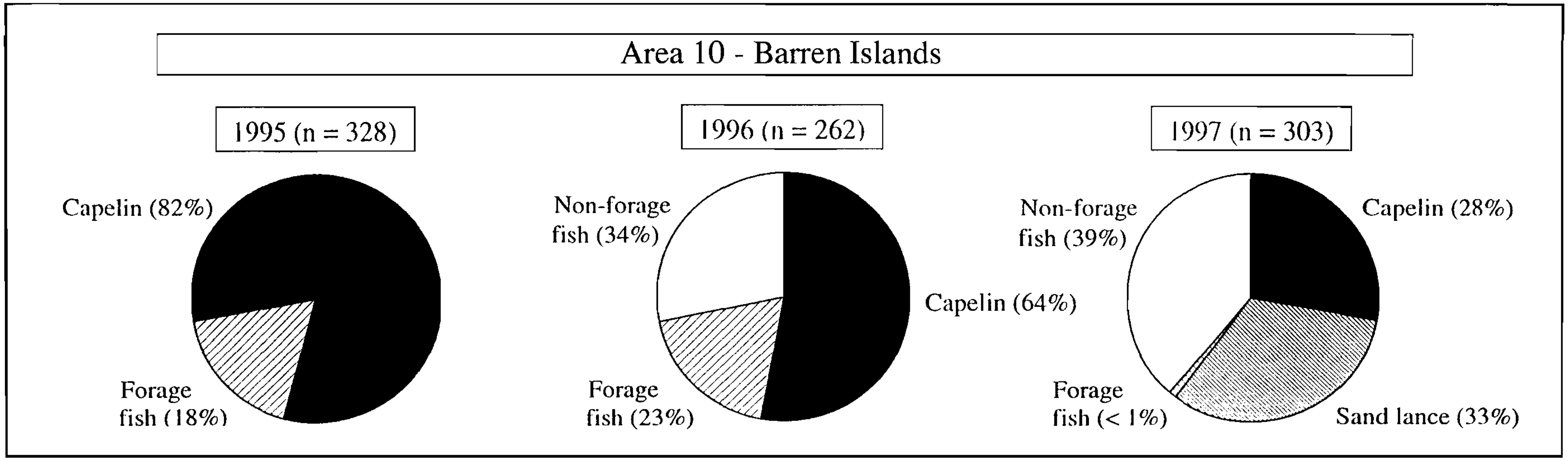

Figure 5c. Numbers of fish in halibut stomachs from Area 10 in Kachemak Bay - lower Cook Inlet that contained prey, 1995-1997.

Appendix 1. Boundaries of the 1995-1997 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 1995-1997 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 = 5 (50%), number with prey = 5 (50%); (1996) n = 52, number empty = 7 (13%), number with prey = 45 (87%); (1997) n = 53, number empty = 18 (34%), number with prey = 35 (66%).

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.

Area 2 (Anchor Point)

Total stomachs sampled: (1995) n = 45, number empty = 10 (22%), number with prey = 35 (78%); (1996) n = 130, number empty = 29 (22%), number with prey = 101 (78%); (1997) n = 270, number empty = 67 (25%), number with prey = 203 (75%).

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.

Area 4 (Homer)

Total stomachs sampled: (1995) n = 96, number empty = 41 (43%), number with prey = 55 (57%); (1996) n = 60, number empty = 11 (18%), number with prey = 49 (82%); (1997) n = 92, number empty = 42 (46%), number with prey = 50 (54%).

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.

Area 6 (Point Adam)

Total stomachs sampled: (1995) n = 199, number empty = 54 (27%), number with prey = 145 (73%); (1996) n = 177, number empty = 30 (17%), number with prey = 147 (83%); (1997) n = 246, number empty = 93 (38%), number with prey = 153 (62%).

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.

Area 8 (Kennedy Entrance)

Total stomachs sampled: (1995) n = 145, number empty = 61 (42%), number with prey = 84 (58%); (1996) n = 175, number empty = 50 (29%), number with prey = 125 (71%); (1997) n = 288, number empty = 173 (60%), number with prey = 115 (40%).

Appendix 2 (Continued).

Area 8 (Kennedy Entrance)

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.

Area 10 (Barren Islands)

Total stomachs sampled: (1995) n = 80, number empty = 33 (41%), number with prey = 47 (59%); (1996) n = 184, number empty = 49 (27%), number with prey = 135 (73%); (1997) n = 483, number empty =258 (53%), number with prey = 225 (47%).

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.

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.

Sample dates: (1995) 20 Jun; (1996) none; (1997) none.
