Appendix VIII

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The feeding ecology and Trophic Relationships of Key Species of Marine Birds in the Kodiak Island Area, May-September 1977

By

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INTRODUCTION

Studies of the feeding ecology and trophic relationships of marine birds have been a part of the NOAA BLM Outer Continental Shelf Environmental Assessment Program (OCSEAP) in Alaska since its inception. The general objectives, rationale, methods, and preliminary results of such studies by the U.S. Fish and Wildlife Service in 1975 and 1976 were described in previous annual reports (Sanger and Baird 1977; Lensink et al 1976). Included in these studies was pelagic work in the northwestern Gulf of Alaska on cruises aboard NOAA vessels. Birds were collected opportunistically for feeding habits studies on many of the cruises. Along with a few birds collected in the Chiniak Bay area of Kodiak Island in winter (Dick 1977), and collections of bill loads and regurgitations on nesting colonies, these samples number 153 specimens of 15 species (Sanger & Baird 1977). Data from these samples will be completed when our computer capabilities are in operation.

In 1977 we concentrated our efforts under this research unit in the Kodiak Island area. This was primarily because the leasing schedule for the Kodiak Basin had been moved up and the Kodiak archipelago and surrounding waters harbor large numbers of breeding and migrant marine birds. Commercial air transportation to and around Kodiak is readily available, so the area is logistically more feasible for long-term studies than many areas in Alaska. This work included intensive studies of breeding biology at a number of sites in Chiniak Bay (Nysewander and Hoberg 1978), in Sitkalidak Strait (Baird and Moe 1978), and studies of the birds' feeding ecology, distribution and abundance at sea.

This report focuses specifically on the feeding studies conducted at sea in 1977. Details of the pelagic distribution and abundance of the birds are reported by Gould et al (1978), but aspects pertinent to the feeding studies are summarized here. Baird and Moe (1978) discuss those specialized aspects of feeding ecology pertinent to breeding biology. An integration and synthesis of this information with the data reported here will be covered in subsequent reports.

CURRENT STATE OF KNOWLEDGE

Sanger and Baird (1977) discussed the general state of knowledge of the feeding ecology of marine birds in the eastern North Pacific Ocean and the Bering Sea. Investigations of the feeding ecology of marine birds in Alaska have continued in many areas (Hunt 1977; Drury 1977; Divoky 1977). Laboratory analyses of the backlog of stomach samples collected as part of RU-341 in 1975-76 has been completed for all but a few of the lower priority species, but a thorough analyses and synthesis of resulting data is still lacking. A major portion of our effort under this RU will be directed toward accomplishing this task.

Through this report and Baird and Moe (1978), we will just begin to understand feeding ecology of a few key species of birds present in the Kodiak Island area in spring and summer. Fall and winter data remains particularly lacking. However, Dick (1977), and a study in the Chiniak Bay area of Kodiak currently being conducted as part of this RU, will give a better idea of the winter feeding ecology of marine birds in the nearshore area of Kodiak.

Nothing is known about food web relationships among marine birds and the other biota in the ecosystem of the Kodiak area. The inter-disciplinary food web studies planned for this spring and summer will help rectify this situation. Further, it is unknown if there are annual variations in the feeding habits of marine birds, or if such variations reflect changes in prey availability. It is also unknown how productivity on the colonies may be affected by annual changes in prey availability or prey species composition. The longer that the integrated studies are continued, the better able we will be to understand annual variations and their affect on the ecosystem.

STUDY AREA

This study was conducted in the general area off northeastern Kodiak Island, from Marmot Bay south to the Geese Islands, and over the shelf to about 45 km offshore of the major headlands (Figure 1). Bird collections for feeding habits studies were concentrated in and offshore from Marmot and Chiniak Bays in the north, and in the area around Sitkalidak Island in the south. In the Sitkalidak area, the collections were mostly in two general areas: 1. Within and just offshore of the mouth of the northern end of Sitkalidak Strait and Kiliuda Bay, between Cape Barnabas and Dangerous Cape, and 2. Within and off the mouth of the southern end of Sitkalidak Strait, between Two Headed Island and Black Point. Further details about the study area in general are reported by Gould _et al_ (1978).

METHODS

Field Methods

The work was conducted aboard a chartered boat, the M/V _Yankee Clipper_, a 58' vessel with a Westport, semi-planing hull. Navagtion and position fixes were usually determined by radar and fathometer, and sometimes by dead reckoning. The vessel offered excellent visibility forward and abeam from the pilot house.

Bird collections for feeding habits studies, and transect counts of the birds for density estimates, were conducted from 26 May through 19 September, on cruises of 11 to 24 days duration during the five time intervals listed in Table 1. The nominal track followed for transect censuses during the cruises is indicated in Figure 1; Gould _et al_ (1978) indicate the departures from this nominal track. The weather dictated to a large extent the order in which the track was transited.

Gould _et al_ (1978) give details of the methods used in transect observations. A knowledge of the densities of birds in an area, determined at the same time the birds are sampled for stomach contents analyses, is important in studies of their feeding ecology.

The density data (number of birds per km^2 of sea surface) provide a means of estimating total numbers of birds in a given area on the same time basis that their feeding habits are studied. These estimates are important if estimates of the total consumption of prey for a given area are to be made, and are essential information for ecosystem modeling.

During the transect counts, feeding behavior and the size and species composition of feeding flocks was noted and recorded. The behavior of the birds was observed in some detail before actual collection; these observations lasted from a few minutes to as long as an hour and a half depending on the circumstances. On two instances, one of our biologists (Forsell) SCUBA dived beneath large flocks of Short-tailed Shearwaters to observe their underwater swimming and feeding behavior.

Most of the birds were collected when they were encountered during the transect counts in feeding situations, or when they were otherwise concentrated enough to collect several at the same time and place. Most of the time collections were accomplished by putting the vessel's skiff (a 17' Smokercraft with a 25 hp outboard engine) over the side with two or three biologists aboard and motoring a km or more away from the vessel to collect with a shotgun. Less frequently, specimens were collected from the Yankee Clipper herself.

Usually within five minutes of collection, the specimens were weighed with a small spring scale to the nearest ten g, and their stomachs were injected with 10% buffered formalin through 5 mm tygon tubing inserted through their bill. They were tagged with a label indicating weight and time of collection. The specimens were processed within an hour or two by making standard measurements on each bird, and the digestive tract was removed and preserved in 10% buffered formalin in a plastic "whirlpak". Among the measurements made which are particularly pertinent to feeding ecology studies are body weight, bill width and fat index. The fat index is a numerical but subjective expression of the amount body fat. The bill width is defined as the distance at the angle of the commissure from one inside edge of the bill to the other, with the bill held open at an angle of 30° to 45°.

The general rationale was to collect birds only if they appeared to be actively feeding. Attempts were made to collect a series of at least five birds of each species in each situation. Attempts were made to sample such series of each of the five key species as closely as possible in time and space so as to determine trophic interactions as closely as possible. For the most part, collections were obtained immediately preceding, during and immediately following the transect counts; this was generally between 0800 and 1800, but there were exceptions. Due to the small vessel crew (two, only one of whom could operate the vessel), our work was limited to about 12 to 15 hours in the middle of the day. A series of birds was collected at the same location at two hour intervals, from 0600 until 2100 hours once in September.

Closely associated with the work aboard the Yankee Clipper was the work at Sitkalidak Strait on nesting colonies on Cathedral Island and other colonies nearby. This is described in detail by Baird and Moe (1978). The work was focused on the Tufted Puffin, Black-legged Kittiwake, Glaucous-winged Gull, and Arctic and Aleutian Terns. Included were intensive observations on the feeding behavior and frequency, collections of adult birds for stomach analyses, and collection of bill loads and regurgitations of food carried by parent birds to chicks on the nests. Feeding studies were less intensive in the Chiniak Bay colony studies (Nysewander and Hoberg 1978), but they too will be helpful in understanding the feeding ecology of birds in the Kodiak area.

Laboratory Methods

We continued to use the basic laboratory methods described by Sanger and Baird (1977). A continuing effort was made to strengthen our prey and prey part reference collection. Standard taxonomic keys were used. Each time we encountered a prey species new to us, or of questionable identity, it was sent to a specialist for identification.

A method of extrapolating whole fish lengths from measurements of their parasphonoid bone (Sanger and Baird 1977) was considerably improved. Whole Capelin (Mallotus villosus) and Pacific Sandlance (Ammodytes hexapterus) were measured to mm total length. They are the two most importnat prey species in summer for most of the marine bird community in the Kodiak area (see below). Their skeletons were fleshed out and the parasphenoid bones (P-bones) and vertebral columns were removed and measured to the nearest mm. The vertebral column was measured from the base of the skull to the end of the caudal bone assembly. Regression equations for the relationships between these measurements and total lengths were calculated, and used to extrapolate whole prey length whenever needed. A manuscript (Hironaka, Fukuyama and Sanger, in prep.) describing this method is being prepared for publication.

The P-bone, which lies in the skull along the roof of the mouth, seems to persist in good condition in bird stomachs. It is easily recognized and is of a highly characteristic shape, so it has been very useful for identification of fish species as well as for extrapolation of original lengths. We have photographs and reference examples of the P-bone of juvenile Walleye Pollock (Theragra chalcogramma), True Cod (Gadus macrocephalus), Pacific Herring (Clupea harengus) and Pacific Sandfish (Trichodon trichodon).

Otoliths were occasionally used to identify fishes (Morrow 1977), but these bones have been relatively rare in our stomach samples. When present they were often digested beyond taxonomic usefulness. The relatively small size of fishes eaten by the birds have accordingly small and delicate otoliths, making them not as useful a taxonomic tool as in pinniped feeding studies (Kajimura and Sanger 1975), for example.

Data Analyses

The basic data on prey used in this report are identity, aggregate percent volume and percent frequency of occurrence. Considered on the bird specimens themselves are preliminary analyses of the fat index, bill width, body weight, percent of net body weight comprised by the stomach contents (food percent of body weight), and the index of filling, i.e., the food percent of body weight expressed as the percent of the maximum observed such percent for that species (Skalkin 1963). Depending on bird species and other factors, these data are compared by time interval (cruise), time of day, and area. In the preliminary treatment in the report, the data are broadly grouped by "northern area" and "southern area" without regard to distance offshore or specific bay or other area of collection. The northern area includes all samples from the Chiniak/Marmot Bay region, i.e., everything north of latitude 57°20' North, and the southern area includes samples south of here, mostly from the area around Sitkalidak Island.

RESULTS

Numbers of Birds Sampled

A total of 428 specimens of the five key species was collected in this study. These are summarized by species, cruise period and general area of collection in Table 1. Of the total, 373 (87%) had food in their stomachs. There was a certain amount of inconsistency in the distribution of numbers of specimens by time and general area, due to vagaries in the distribution of the birds. About 25 specimens of nine other species were also collected; these will be discussed in subsequent reports. Included were one or more specimens of Northern Fulmar, Fork-tailed Storm Petrels, Glaucous-winged Gull, Sabine's Gull, Northern Phalarope, Parasitic Jaeger, Cassin's Auklet and Marbled and Kittlitz's Murrelet. The statistical adequacy of the numbers of birds sampled are discussed below.

Kinds of Major Prey Types Eaten

Figure 2 shows the aggregate percent volume of prey for each of the five key species averaged for the entire study period. Specific aspects of the prey eaten by each bird species will be discussed below. Figure 2 clearly shows that, by volume, fish are the most important type of prey in late spring and summer. Fish are relatively more important for the Alaskan breeding species than for the shearwaters, which are summer migrants from the southern hemisphere. Fish comprised 100% of the diet of Common Murres, 97.2% for Black-legged Kittiwakes and 93.3% for Tufted Puffins. In contrast, 76% of the diet of Sooty Shearwaters was fish, and only 41.9% of the Short-tailed Shearwater diet was fish. Euphausiids were quite important (47%) for Short-tailed Shearwaters, and gonatid squid was more important to the shearwaters than the Alaska breeders. The Sooty Shearwater diet was 24% squid; squid comprised only 4% of the diet of Tufted Puffins and Common Murres and kittiwakes had no squid in their stomachs.

Capelin dominated the volume of fish eaten by a large degree. The importance of this prey species becomes even more apparent when one considers that the unidentifiable osmeridae and some of the "unidentifiable fish" were likely Capelin as well; no whole osmerids other than capelin were present in the stomachs. Other fish species present in the stomachs were Pacific Sandlance, which formed 11% of the diet of Common Murres, and Walleye Pollock, which formed 6% of the diet of Tufted Puffins and 11% of the diet of Common Murres (if one assumes that the unidentifiable gadidae in the murres were pollock).

Species Accounts

Following are aspects of a preliminary analysis of feeding ecology of each of the five key species. General highlights of the pelagic distribution and densities are included, but the reader is directed to Gould et al (1978) for details about distribution and abundance in specific bays and other areas. General remarks on the distribution of feeding flocks are included where appropriate. The species accounts include selected aspects of the pelagic distribution and feeding behavior (in the broad sense), feeding habits (species composition and sizes of prey) and aspects of the birds' biological or physiological condition pertinent to an understanding of their feeding ecology.

Sooty Shearwater (*Puffinus griseus*)

General Background and Pelagic Biology. Sooty Shearwaters were scattered in relatively low densities. None of the shearwaters seen in late May-early June were positively identified as sooties. A few were seen mixed with the much more abundant Short-tailed Shearwater flocks by mid-June, and relatively small flocks (up to a few thousand birds at once) were seen from June through September. They seemed to be more prevalent in the northern part of the study area than the south. They occurred in Marmot Bay in July off Pillar Cape, but they were otherwise noted only over the shelf. Their presence among the large (up to 60 thousand birds) flocks of short-tails did not become evident until we were able to observe several at close range from the skiff. They were much more wary of the *Yankee Clipper* than the Short-tailed Shearwaters, and they were actually observed feeding on only three occasions. One large mixed-species feeding flock seen off southern Sitkalidak Island in August included several hundred sooties, a few hundred Short-tailed Shearwaters, 1,000 Black-legged Kittiwakes, and up to about 100 each of Parasitic and Pomarine Jaegers, Fork-tailed Storm Petrels, Northern Fulmars and Tufted Puffins. The larger of these species had fresh Capelin in their stomachs.

Feeding Habits. Thirty-five Sooty Shearwaters were collected, of which 33 (94.3%) had food in their stomachs (Table 1). Except for a sample of 16 birds taken in September, six or seven birds were collected each cruise. This species generally ate fish (76% of their diet) with most of this being Capelin and unidentifiable osmerids (67%) (Figure 2). Capelin were present in 71% of the sooties collected (Table 2). Polychaete worms were present in one bird each taken in August and September.

Percent volume of squid and fish in the sooties' diet changed in inverse proportion from June through September (Figure 3). Squid comprised most (55%) of their diet in June. Squid were present in no less than 65% of the birds taken in a given cruise (Figure 4), showing that this prey was consistently important to Sooty Shearwaters. Fish, again mostly Capelin or unidentifiable osmerids, increased from 45% to 95% occurrence in the sooties from June through September. No other fish species besides Capelin was identified in the stomachs.

Sixteen of the 35 birds (45.7%) had measurable Capelin in their stomachs. Figure 5 indicates the length frequency distribution of the measurable capelin from the Sooty Shearwaters. The Capelin lengths in the Sooty Shearwaters ranged from 55 mm to nearly 140 mm, with a modal length of about 85 mm.

Amount of Food Eaten The most, and greatest proportion of body weight of food found in any one of the birds was 102 g, or 11.7% of the body weight. The food percent of the body weight was generally low (Figure 6). In nearly 80% of the birds it was 3% or less and in only two birds was it 10% or greater. The frequency histogram of the filling index (Figure 7) reflects the same trend; 85% of the birds had a filling index of 40% or less. A plot of the filling indices on a graph of time of day and date (not included here) was inconclusive. Only five birds were collected earlier than 1200 in the day; none were collected earlier than 0930 nor later than 1745.

Biological Data Figure 8 shows the bill width data for the five key species, separated by sex. The mean, range and 95% confidence interval is shown. At 17.2 mm on the average (one mm wider for 4 females), Sooty Shearwaters had the widest bills of the five species, but the average was wider to a high degree only when compared to Black-legged Kittiwakes, i.e., there was no overlap in the 95% confidence intervals. The data on net body weight (Figure 9) and fat index (Figure 10) both show little change from June through August, but an increase in September. These data no doubt reflect the annual pre-migratory fattening necessary before the shearwaters can embark on their long migration to the southern hemisphere for the breeding season.

Short-tailed Shearwater (Puffinus tenuirostris)

Pelagic Biology and General Background The Short-tailed Shearwater is probably the single most abundant species of marine bird occurring in Alaska waters. The exact timing of their migration from the southern hemisphere is not yet well known, and it probably varies annually. They probably begin arriving over the shelf of the northern Gulf of Alaska by late April - early May (Shuntov 1972; Gould et al 1978). They occurred in the study area, generally over the shelf, during each month of the study. The average density of shearwaters in late May - early June was 51 birds/km^2 (Table 3). Since none of the shearwaters seen then were identified as sooties, this figure probably included all or mostly short-tails. The highest shearwater densities (74 birds/km^2) occurred in August. Unknown numbers of sooties were present then, but they were still far fewer than the short-tails. Most of the shearwaters were over the shelf within a few miles offshore from the headlands but they also occurred as far offshore as the surveys transited. In August and September they occurred in flocks of up to a few thousand birds off Whale Passage at the mouth of Kizhuyak Bay, out of sight of the open ocean.

The birds were usually seen flying, but it was impossible to tell if the flights were local movements within the Kodiak area, or birds passing through. We had several opportunities to observe feeding Short-tailed Shearwaters at close range. The short-tails typically fed by pursuit plunging (Ashmole 1971; see also Wiens et al 1978, and Guzman 1976), in flocks ranging from several hundred to a few thousand birds within a relatively small area.

A particularly noteworthy example of atypical feeding behavior bears mentioning in some detail. At 1200 on 22 June, on a flat-calm day about 5 miles off the mouth the south entrance to Sitkalidak Strait, Sanger, Juan Guzman and Doug Forsell were able to row their skiff into the middle of a sitting flock estimated at 8-10,000 birds. We observed their feeding and general behavior for about 1.5 hours at distances as close as 10 m. A pattern soon because evident as we watched the birds from the drifting skiff. The birds were grouped in scattered, loosely defined "sub-flocks" of 20 to 100 or 200 birds. Scattered birds sporadically immersed their heads beneath the water for several seconds, turning them back and forth, apparently looking for prey (i.e., "peering" behavior). When one bird apparently saw something, presumably food, it would "run" a few steps across the water and dive beneath. The running was apparently necessary to gain enough momentum to plunge beneath the surface. The action of the one bird would immediately precipitate a like reaction by the rest of the sub-flock which would focus on the spot the first bird dived. The length of time the birds stayed under water varied between about 15 and 30 seconds with a modal time of about 20 seconds, but it was difficult to determine this precisely because it was impossible to follow individual birds. Upon resurfacing, the shearwaters usually shook down their prey by rising up in the water by flapping their wings and paddling their legs while shaking their upper body rapidly.

This behavior continued off and on for the duration of the time we observed the birds. Except for the brief periods that the shearwaters pattered across the water and dived beneath, there was little hurry about this behavior; it was methodical and deliberate, with no resemblance to the feeding frenzies which beat the water to a froth usually associated with feeding shearwaters. Subsequent examination of the stomach contents of the birds collected from this flock revealed that they had eaten euphausiids (Thusanoessa inermis and T. spinifera) almost exclusively. The euphausiids were thus not right at the surface, but had to have been within 5-7 m of it, the maximum depth shearwaters are probably able to dive.

Feeding Habits One-hundred-sixty Short-tailed Shearwaters were collected in this study, of which 142 (88.8%) had food in their stomachs. This species was fairly evenly represented in the collections among the five sampling periods (Table 1). Due to their behavior of consistently flocking in large numbers and their easy approachability, samples could be collected nearly at will. We were better able to sample series of specimens of this species at the same time and place than the others.

Thysanoessa euphausiids comprised nearly half (47%) of the overall diet of Short-tailed Shearwaters (Figure 2). Capelin were also important (20%), and with the unidentifiable osmerids, comprised about 28% of the diet. Together with Sandlance (4%) and unidentifiable fish (10%), fish totaled about 42% of their diet (Table 2). Squid equaled about 9% of their diet by volume, but had an overall frequency of occurrence of 29% (Table 2) so their importance is greater than suggested by volume alone.

There were definite seasonal changes in the occurrence of prey in the short-tail stomachs. The percent composition by volume (Figure 11) and frequency of occurrence (Figure 12) both show that euphausiids were relatively more important earlier in the season, but diminished in both occurrence and volume by September. Fish generally showed an inverse relationship to the squid, and comprised 92% of the diet in September when they occurred in all birds collected. Squid accounted for 25% of prey volume in late May - early 13 June, but steadily decreased in importance, comprising only 1% of the volume in September. However, the frequency of occurrence of squid was never lower than 17% (August), and was acutally 30% in September.

Capelin and unidentifiable osmerids together comprise only 3.5% of the frequency of occurrence (one bird) in June (Figure 13), but occurred in nearly 60% of the stomachs by September. Similarly, percent volume of Capelin/osmerids increased from none at the start of the study to over 50% in September (Figure 11).

The overall lengths of Capelin in Short-tailed Shearwater stomachs ranged from 55 to 155 mm, with a modal length of about 90 mm (Figure 14). The data are scanty, but the length frequency distribution of Capelin eaten in July suggests a bi-modal length distribution (which suggests two year classes of fish), with modes at about 70 mm and 130 mm; no fish in the 90-110 mm range were found then.

Amount of Food Eaten Short-tailed Shearwaters displayed the highest food percent of body weight of the five key species (20%, or 125 g of food in a 625 g bird), but the birds collected still tended to have relatively little in their stomachs (Figure 15). Thirty-five of the birds (28%) had a food percent of stomach contents of 0.1% or less, and in 81% of the birds it was 5% or less. Only four of the birds (2.5%) had a figure in excess of 15%. The filling index data (Figure 16) shows that nearly a third of the birds had only 1% or less of the proportion of food as the fullest. In 62% of them it was 10% or less, and only 14 birds (about 9%) had a filling index in excess of 50%.

Biological Data The width of Short-tailed Shearwater bills averaged about 15.3 mm, nearly 2 mm smaller than their congeners the Sooty Shearwaters, but there was overlap in their 95% confidence intervals (Figure 8). The bill widths of the short-tails is very similar to the Tufted Puffins, but it is significantly larger than Black-legged Kittiwakes and significantly smaller than Common Murres on the average (Figure 8).

From late May through August, the average net bodt weight of the Short-tailed Shearwaters ranged between about 630 and 680 g (Figure 9), but it dropped to about 510 g in September. This is curious, because the weight should increase by September, in preparation for migration to the southern hemisphere, such as observed in the Sooty Shearwaters (Figure 9). The smaller average September weight is possibly an artifact of the relatively small sample size (7 females, 5 males), or it possibly represents a different population or age class of birds. An error in weighing technique in the field seems to be ruled out because the other four species were not similarly affected.

The seasonal changes in fat index (Figure 10) follow the same general trend as the body weight: The averages ranged from about 2.5 to 3.8 until September, when they dropped to 1.4 for the seven females and 1.2 for the five males. These means are lower than earlier samples (except for a slight overlap in the 95% confidence interval with females in June). Low fat indices occurred in July and (for males) June, probably reflecting the physiological drain of molting on the birds at that time. The August fat indices are higher than those in July, but then in September they dropped to their lowest values. This pattern is no doubt related to the low body weights at that time.

The reduced fat index and weight in September was possibly related to kind of prey in the diet. September was marked by the highest proportion of fish in their diet, and the lowest proportion of squid and euphausiids (Figure 11). The fat index in particular may be related to the kind of food eaten. The fat index can be considered to be an integration of the quality of food eaten over some unknown period of time immediately prior to collection. Studies on shorebirds (i.e., Mascher 1966; Minton 1969) have shown that some species can add fat to their bodies at a rate of 10% or more per day prior to migration, so it seems possible that the fat index could be an integration of the quality of food eaten for a very few days immediately prior to when a bird was collected.

Assuming that the food in the shearwater stomachs at the time of collection is the same type that determined their amount of fat at the time of collection, determining the degree of correlation between fat index and the volume of a given prey type would determine the influence of that prey on the amount of fat. Figure 17 shows the relationship between average fat indices and average volume of euphausiids in the diet, plotted by cruise. The data from male and female birds are plotted separately. The sample size is small (n=10, i.e., five cruises each for each sex) and the correlation coefficient is relatively low (r=0.70) when the data are fitted as a first degree polynomial. When the data are fitted as a second degree polynomial, the correlation coefficient is much better (r=0.90). Either way, however, the general trend suggests that the fat index is positively correlated with the amount of euphausiids in the diet.

Black-legged Kittiwake (*Rissa tridactyla*)

Pelagic Biology and General Background. The Black-legged Kittiwake is the second most abundant Alaskan breeding bird occurring over Kodiak Island waters (Sowls 1978). Birds associated with all colonies between southern Afognak Island and the Sitkalidak Island area number about 169 thousand; most of these (*ca.* 128 thousand) are from south of Ugak Island.

The densities of birds for each leg of the cruise were separated between the bays and waters over the continental shelf, and the average densities are shown plotted in Figure 18; the two lines represent the 95% confidence interval around the mean. Densities over the shelf were generally lower than 4 birds/km^2, with little or no difference between months. In the bays, however, densities increased dramatically between June and July, from about 5 to 17 birds/km^2, and they remained high through September. The high densities in the bays correspond to the chick stage on the colonies.

Away from colonies, the kittiwakes tended to be dispersed. Flocks occurred apparently in response to localized food sources or from social roosting. 70% to 80% of all sightings of flying birds were of individuals. Kittiwakes occurred more frequently in bays and fjords (85-91% of transects there) than over the continental shelf (40% of transects). Feeding flocks of kittiwakes ranged in size from a few up to an estimated 1,400 birds (average-39), and occurred up to 20 miles from land and 25 miles from the nearest colony. During the chick stage, feeding flocks occurred only out to ten miles from land and 17 miles from the nearest colony.

As we learned with increasing frustration as the field season progressed, birds that appeared to be feeding in flocks, i.e., milling in a restricted area close to the water, alighting on and diving momentarily beneath water, often had very little or no food in their stomachs. There is no sure reason for the scarcity of food in "feeding" birds. The kittiwakes were likely milling over prey, but the prey may have been too deep in the water for them to reach. A number of times Tufted Puffins and shearwaters were collected along with the kittiwakes in multi-species "feeding" flocks. If a comparison of prey among these species shows Capelin to be in the divers, but not the kittiwakes this suspicion will be confirmed.

Feeding Habits

Eighty-two (93.2%) of the 88 kittiwakes collected had food in their stomachs. Capelin comprised nearly 45% of the volume of all prey species (Figure 2). The unidentifiable osmerids were most likely capelin, so at 60-65% of their diet, the importance of Capelin to Black-legged Kittiwakes in the Kodiak area is evident. Sandlance, and pollock plus unidentifiable gadids, each accounted for 9% of the prey volume. Together with unidentifiable fish, fish made up 97% of the diet of the kittiwakes. *Thysanoessa* euphausiids, clams and polychaete worms together comprised the remaining 3% of the diet (Figure 2).

Seasonal changes in the aggregate percent volume of prey in the diet of kittiwakes are evident (Figure 19). Capelin/osmerids clearly dominated the diet except in September, when Sandlance and gadids were each slightly more important. *Thysanoessa* euphausiids averaged 15% of the diet in May-June, but were then absent until September when they comprised 40% of the diet of one of the 26 birds collected. Figures 20 and 21 compare the seasonal changes in prey volume in the kittiwake stomachs between the northern and southern areas. The same general trend as the composite data (Figure 19) is seen, except euphausiids and gadids were present only in the southern area in early June; the lone kittiwake with euphausiids in September noted above was collected in the northern area. Otherwise, trends in prey composition were similar for the two areas.

The frequency of occurrence of prey in the kittiwakes repeats the general patterns as their volumetric composition (Figures 22 through 24). However, a relatively wider variety, but lower incidence of prey is noted in September (Figure 22), and *Thysanoessa* euphausiids were in all four birds collected on June 1 in the southern area (Figure 24).

The composite prey length frequency data is noted in Figure 25. We attempt to show here simultaneously the length frequency of each prey in each of the two areas. The fish in the kittiwake stomachs ranged in length from about 50, to nearly 140 mm (modal-about 90-100mm). The mean length of euphausiids was about 23 mm, considerably smaller than the fish. It seems that euphausiids would have to be extremely abundant for it to be energetically profitable for the kittiwakes to eat them.

Amount of Food Eaten The weight of the preserved stomach contents ranged from empty to 43.4 g. Most of the kittiwakes had very little or nothing in their stomachs (Figure 26). Forty-eight birds (54%) had food weights of 1% or less than their body weight, and 85% had food weights of 4% or less. The maximum observed food weight percent of body weight for Black-legged Kittiwakes in our data base is 12.2%, and the maximum observed in these samples was 8.4%.

The maximum observed filling index in these samples was 69% (i.e., 8.4% of the 12.2% maximum, Figure 27). Generally, these data reflect the trend of Figure 26 that there was not much in the kittiwake stomachs; 60% of the birds had a fullness index of 10% or less.

There are two possible reasons that the birds we collected had little in their stomachs: 1) Black-legged Kittiwakes generally subsist by several small feedings per day, or 2) Even though we sampled the kittiwakes when they exhibited "feeding behavior", they may have actually fed at times of the day other than when we collected them. Figure 28 suggests that there was no apparent relationship between the time of day that the birds were collected and their filling index. However, as Figure 29 demonstrates, we sampled the kittiwakes during approximately the middle third of the day. The evening, and particularly the early morning hours were not sampled. Samples during these hours are needed before we can draw conclusions regarding the significance of the sparsely filled stomachs.

Biological Data Black-legged Kittiwakes have the narrowest average bill width of the five species (Figure 8). There was little or no variation in the net body weight from May through August, but the September weights of males and females were lower than the preceding months (Figure 9). There is no ready explanation for this; it could be tied in with the breeding cycle in the continued demands of large chicks on the nests. Possibly the drop in weight was related to food availability or the kinds of prey eaten. As noted above, Capelin formed a relatively low proportion of their diet in September compared to earlier months, and gadids and Sandlance had relatively greater proportions. The birds begin to molt into their winter plumage by September, and this could also have reduced the body weight. Eleven of the 19 birds with weight data in September were fledglings and averaged 365 g, falling in the range of all 19.

Data on seasonal changes in the fat index is inconclusive (Figure 10). There was no significant difference from May through August. Quite curiously, the females had less fat than the males in September. The females had the lowest average fat index of any similar group of birds for the entire study periods, while the males had the highest fat index. The 11 fledglings collected had an average fat index of 3.1; five of the six of these which could be sexed were males.

Common Murre (Uria aalge)

Pelagic Biology and General Background. The Common Murre is the third of the key species breeding in Alaskan waters, but it is relatively rare around Kodiak Island. The best estimate of numbers associated with colonies located within the study area is 2,300 birds (Sowls 1978). Common Murres are possibly just now expanding their range into the Sitkalidak Strait area. During reconnaissance surveys in the area in June 1976, very few murres were seen there. However, in 1977 they were fairly common at sea for the duration of the study (Table 3). They were mostly concentrated in the outer part of the bays and inlets, particularly so in the outer part of Chiniak Bay and the northern (eastern) entrance to Sitkalidak Strait. Moreover, they were discovered roosting, up to 20 birds at once, on 19 June at the kittiwake colony at Inner Right Cape at the mouth of Kiliuda Bay. A few were also seen around the kittiwake colonies at Boulder Bay, and at Cathedral Island (up to six) (Baird and Moe 1978). In Sitkalidak Strait they were most frequently encountered in tide rips and convergence lines, in flocks of three or four, occasionally up to 10-15 birds. Out of the 45 birds collected (see below), 44 were sub-adults as determined by bursa length (average about 20 mm). If these birds were representative of all those in this area, this area bears continued watching for a potential range expansion. Presumably, potential pioneering birds in a new area are most likely sub-adults (Lack 1954).

Average densities (Table 3) at sea were highest in September ($9/km^2$), and lowest in July (1.5/km2). These densities belie the low number of birds breeding in the area. Murres were relatively rare more than a few miles offshore from the major headlands.

Feeding Habits Forty-five Common Murres were collected for stomach analysis, and 27 (60%) of these had food in their stomachs (Table 1). This proportion of stomachs with food is by far the lowest among the five species.

The Common Murre was the only species studied that was exclusively piscivorous (Figure 2). Capelin plus unidentifiable osmerids comprised 56% of their overall diet, and Sandlance, and Pollock plus unidentifiable gadids comprised about 11% each. Again bearing in mind the small sample sizes, the Common Murre appeared to be somewhat more varied in its fish diet than the other species. Capelin and unidentifiable osmeridae comprised 100% of their diet in June, but otherwise they formed no more than 50% of their diet (Figure 30). Pollock plus unidentifiable gadids comprised 66% of their diet in late May-early June, and 25% in August; Sandlance comprised 37% of their diet in September. The frequency of occurrence data (Figures 31 and 32) generally reflect the same trend as the prey volume data.

The modal length of the measurable fishes consumed by the murres was about 90 mm, and the range was 65 to 125 mm (Figure 33). Sandlance, with a modal length of about 95 mm, were about 5 mm longer than the Capelin.

Amount of Food Eaten. The maximum amount of food found in the stomach of a Common Murre in this study was 72.6 g, 6.7% of its body weight. As briefly noted above, this species had the least amount of food in their stomachs among the five species studied. Ninety-one percent of the birds had a food percent of their body weight of only 2% or less (Figure 34), a trend reflected by the filling index data (Figure 35). Of the 43 birds graphed here (no weights were taken on two of the 45 collected), 40 (93%) had a filling index of 50% or less. Most of the birds were collected in the middle of the day, and the fact that the Common Murres had less in their stomachs than the other species suggests that they are relatively more nocturnal in their feeding than the other species.

Biological Data The bill widths of the murres averaged about 17 mm, and were wider than all other species except the Sooty Shearwater (Figure 8). A small amount of overlap was noted between the murres (lower 95% C.I. = 16.38 mm for males, 16.47 mm for females) and male Tufted Puffins (upper 95% C.I. = 16.52 mm).

Individual body weights of murres ranged from about 880 g to 1,280 g (except for a 410 g immature included in the September data) (Figure 9). The small sample sizes make it impossible to tell if there were seasonal changes in body weight. The fat indices tended to be low (Figure 10), averaging about two for the season; only one bird (in May) had a fat index of four.

Tufted Puffin (*Lunda cirrhata*)

General Background and Pelagic Biology This species is the second most abundant breeding marine bird in the Kodiak area. An estimated 150 thousand breed within the study area (Sowls 1978), and an undetermined number of subadult birds are associated with the colonies during the breeding season.

Their average pelagic density ranged from less than one at the start of the study to 16 birds per km^2 in July at the peak of the chick stage (Table 3). At this time, the birds were particularly concentrated in the outer part of the bays and were rarely seen more than a few kilometers offshore. Even though their estimated breeding population is lower than the kittiwakes, their average pelagic density was higher.

Their average density for September (3.1 birds/km^2) was markedly lower than the 12.2 August figure; many of the birds seen in September were immatures, suggesting that adults had already begun their post breeding migration to oceanic waters. Shuntov (1972) noted the abrupt post-breeding seaward migration of Tufted Puffins from the Bering Sea, and a similar phenomenon is probably happening in the Kodiak area.

Tufted Puffins were often observed feeding in association with Black-legged Kittiwakes, particularly in eastern Sitkalidak Strait (see also Baird and Moe 1978). Puffins feed by pursuit diving (Ashmole 1971), i.e., chasing their prey underwater by swimming with wings (primarily) and feet, and grasping them one at a time in their bill; they may or may not be swallowed underwater. Puffins are able to dive to considerable depths, and probably get much of their food from mid-depths to the bottom while in the bays and inlets of the Kodiak area.

Feeding Habits One-hundred Tufted Puffins were collected in the course of this study; 89 of these had food in their stomachs. Numbers of specimens were fairly well divided among the first four study periods (21-28 birds each), but only six birds were sampled in September. This species was largely piscivorous in its diet (Figure 2, Table 2). Fish comprised 91% of the average volume of stomach contents, and Capelin and unidentifiable osmerids accounted for most (66%) of this. On the average, euphausiids were eaten by 6% of the birds, and squid by 12% (Table 2). Trace amounts of Pacific Sandfish, crab larvae and pelagic polychaete worms were also present in the Tufted Puffin stomachs.

Capelin comprised no less than 35% of the diet of the Tufted Puffins in each of the five study periods, and well over 80% in July and August (Figure 36). Pollock occurred in their diet only in August, when they comprised 20% of the average volume in the 25 birds collected. Sandlance were present in August and September, but occurred in fair amounts (15%) only in September. Euphausiids were present only in August (17% of the average volume). Squid were present each study period except June, but they only represented more than a slight fraction of the diet during the first cruise (13% of volume), and again in September (17%).

Fish as a whole occurred in the stomachs in no fewer than 67% of the birds sampled in any one cruise (Figure 37). Squid occurred in 20-25% of the birds during three of the time periods (12% of total frequency of occurrence, Table 2), and euphausiids were present in 25% of the birds taken in August. The frequency of occurrence of fish prey by species is indicated in Figure 38; generally, they repeat the patterns discussed above.

Tufted Puffins had enough measurable Capelin in their stomachs to permit separation of the length frequency data by time period (Figure 39). Generally, the Capelin ranged from about 35 mm to 125 mm in length, with an overall modal length of about 80 mm. From late May through July, their modal length in the puffins increased from about 65 mm to 85 mm, where it remained through September. This would seem to indicate a growth in the ambient Capelin rather than the birds eating progressively larger Capelin from May through July. But it isn't clear why the size of the Capelin apparently remained the same from July through September. The modal length of the Sandlance, eaten only in August and September, was about 95 mm. The euphausiids eaten in August (*Thysanoessa inermis*, *T. spinifera* *T. raschii*; not graphed in Figure 39) had a modal length of about 25 mm.

Amount of Food Eaten Tufted Puffins repeated the trend of the other species in generally having little in their stomachs. Of the 99 birds with body weight data, 52% had a food percent of body weight figure of 1% or less, and in 90% of the birds it was 5% or less (Figure 40). The highest food percent of body weight figure was 10.5%, and only 5 (2%) of the birds had a value greater than 8%. The index of filling (Figure 41) generally reflects the above trend: 91% of the birds had a filling index of 50% or less.

Biological Data With an average bill width of about 16 mm, the Tufted Puffins are similar to the Short-tailed Shearwaters (Figure 8). At the 95% confidence interval, their mean bill width is greater than the Black-legged Kittiwake, it is less than the Common Murre, but it overlaps with both shearwaters.

The overall body weights ranged from 540 to 985 g. (Figure 9). The males averaged about 850 g, and the females about 795 g. No seasonal change in body weight was evident.

The puffins generally had little fat throughout the study (Figure 10). The fat index was 4 on one bird in September, and 3 on a few more, but it averaged about 1.5 for all birds sampled. No seasonal change in the fat index was apparent.

Feeding Relationships

A full assessment of the trophic relationships among the five key bird species will be made when the data has been more completely analyzed. In particular, when these data have been synthesized with the feeding data of Nysewander (1978) and Baird and Moe (1978), a reasonably complete picture of the feeding ecology and trophic relationships of the key species of marine birds in the Kodiak area in May-September 1977 should emerge.

Meanwhile, a few general observations on the birds and their prey are possible. Figure 42 attempts to show at the same time the overall importance of the major prey types to each bird species by pooling the data from all specimens collected. It allows the examination of the data from the standpoint of the prey as well as the birds. Three criteria for "importance" of the prey are used: 1. The aggregate percent volume, omitting birds with empty stomachs. This gives an idea of the importance of a prey species in terms of biomass; 2. The average frequency of occurrence in the birds. This ignores how much, but gives an idea of how persistently the prey was consumed, and; 3. The frequency of occurrence by time period, i.e., what percentage of the five cruises the prey was found in at least one bird. This factor ignores both volume and frequency of occurrence by number of birds, but it gives an idea of the extent of time over which the species ate the prey.

Clearly, Capelin were overwhelmingly important to the birds. They were relatively less so to Short-tailed Shearwaters (the most abundant bird species in the Kodiak area) than the other four species. But even in the short-tails they showed up on 80% of the cruises, in nearly 30% of the birds, and comprised nearly 30% of the volume. By their sheer numbers, Short-tailed Shearwaters are probably one of, if not the major avian consumer of Capelin in the Kodiak Island area. Sandlance and Pollock were far less important in terms of biomass, but Sandlance were fairly persistent (20%-40% of the cruises in all species except the Sooty Shearwater), and Pollock showed up in all three of the Alaskan breeders on 60% to 80% of the cruises. Moreover, since Baird and Moe (1978) report a higher frequency and volume of Sandlance and Pollock in food samples from Black-legged Kittiwakes and Tufted Puffins in Sitkalidak Strait than we report here, the overall importance of these two prey species to birds is probably greater than this preliminary assessment suggests.

The two major invertebrate prey types, euphausiids and squid, were generally less important than the fishes, particularly to the breeding species. However, squid were very important to both species of shearwater. They occurred in both species on all cruises, in 70%

(24% volume) of the Sooty Shearwaters and 30% (9% volume) of the Short-tailed Shearwaters. Squid occurred in Tufted Puffins on 80% of the cruises, and in 12% of the birds. After Capelin, squid were actually the most important prey type to the puffins.

Euphausiids (mainly Thysanoessa inermis, some T. spinifera and raschii) were generally less important than squid. However, they were very important to Short-tailed Shearwaters (present all cruises, in 47% of the birds, and comprising 47% of their diet), and were eaten in some numbers by the kittiwakes and puffins. Pelagic polychaete worms showed up sporadically in both shearwater species and the puffins, but they were of minor importance even in these species.

The Tufted Puffin ate all five of the major prey types in varying degrees, while the Short-tailed Shearwaters and Black-legged Kittiwakes contained four each of the prey types, and Common Murres ate three prey types and Sooty Shearwaters only two.

Statistical Adequacy of Samples

We have had a continuing concern over the adequacy of the sizes of the samples of birds we have collected for the feeding studies. This has been particularly true in this study, where a comparison of samples on a geographic and temporal basis is an important part of the study. A large part of determining the statistical adequacy of sampling in this study is in deciding what constitutes a sample. That is, what areal and temporal frame of reference should be used to distinguish a given sample? The ideal adequate sample would have all of the birds collected at the same time and place. But for marine birds, that ideal is rarely possible or practical. The numeral 30 is often cited as the minimum sample size for statistical significance. However, the Short-tailed Shearwater is the only species where it would be possible to sample this number of birds at the same time and place. And even then, it may be hard to consistently sample this number. The very act of collecting birds from a flock at sea usually disperses them, except for the kittiwakes and sometimes other gulls, who are often attracted to the scene.

As noted above, attempts were made to collect at least five birds of a species at the same time and place. This was often impossible, but sometimes more than this were collected. A thorough statistical analysis of all of the samples is beyond the scope of this report, but two brief statistical tests were conducted. In the first, outlined in Table 4, the variation in the percent volume of Capelin in samples of 15 birds was determined. It was impossible to compile a sample of 30 birds from the same cruise for most species, and even the

15-bird samples had to be obtained by pooling collections from different days for a given cruise. In the case of the Common Murres and Sooty Shearwaters, samples from the northern and southern areas had to be pooled to achieve even the 15-bird sample. The coefficient of variation in the percent volume of Capelin in individual birds is excessively large in each case (Table 4). The predicted sample sizes needed, given this amount of variation, ranged from 476 to 9,006 birds per area and cruise, obviously an artifact of the small sample size. Also, it may have been due to natural variations resulting from pooling samples from different dates and areas. Ideally, the birds in a sample should have eaten their prey at the same time. The proportions of prey species in a stomach may change with stage of digestion, and unless the birds contained prey all at the same stage of digestion, their proportions could be biased. At the very least, this simple test shows the pitfalls in pooling samples too widely scattered in time and space. Except in the relatively rare cases of sampling a few birds from a very large flock, as noted below, this suggests that our samples have generally been too small.

In a few cases, a large number of Short-tailed Shearwaters were sampled together. On 29 May, 21 were collected off Sitkalidak Island; a random sub-sample of five of these was selected. Table 5 summarizes calculations made on these two samples, using the mean and standard deviation of the percent volume of euphausiids and squid in individual birds. A student's "t" test gave a t value of 0.04 for the euphausiids, and a probability of correlation coefficient greater than 0.90, while the squid had a t value of 0.25, and a correlation coefficient of greater than 0.88. Thus, a sample of five birds from a large flock which had recently fed at about the same time would adequately sample the larger population.

Interpolation of Fish Lengths From Their Parts

An accurate characterization of the trophic level(s) of a prey species probably depends largely on an accurate knowledge of their size frequency and distribution. If so, it is important to have a large enough sample size of prey from the stomachs to accurately reflect the size frequency distribution of the prey. Whole, and thus readily measurable fish have been relatively rare in the stomachs of the birds we have studied. Thus, the utility of being able to extrapolate original fish lengths from the lengths of their parts is mainly in increasing the sample size of measurable fish.

For prey parts to be useful in extrapolating original whole prey sizes they should be readily identifiable to species and their lengths should accurately reflect the whole prey length. The vertebral column and P-bone of Capelin and Sandlance are two such parts which meet these criteria. A regression of the vertebral column length on the total length of 67 Capelin (Figure 43) had a high degree of correlation (r=.99), as did the regression of the P-bone length on total length of 63 Capelin (r=.97, Figure 44). A similar relationship for the vertebral columns of 112 Sandlance (Figure 45) is also highly correlated (r=.96), but for the regression of P-bone length on total length (Figure 46), it is not quite so high (r=.85), perhaps because of the small sample size (n=34).

Table 6 summarizes data on the combined numbers of vertebral columns and P-bones of Capelin and Sandlance as a proportion of their total measurable numbers. In the Short-tailed Shearwater and Common Murre, the parts comprised about a third of the total measurable fish, and in the other three species, the parts comprised well over half. The overall average proportion of parts in all measurable Capelin and Sandlance in the five species was 61%. Clearly, the use of these extrapolations have been useful in increasing the sample sizes of measurable fish.

Prey Reference Collection

A number of species, and parts of species were added to our taxonomic reference collection over the past year. The current total inventory of species and their parts in the collection is listed in Table 7.

GENERAL DISCUSSION AND CONCLUSIONS

It should be emphasized that this report is a preliminary assessment of data collected over one four-month period. Accordingly, broad generalizations should be avoided. There had been little precedent for this type of study, i.e., simultaneously studying the feeding ecology, distribution and abundance of marine birds at sea, repeated over several months in succession.

We decided to concentrate on the five "key" species suspected to form most of the numbers and biomass of the marine bird community in the Kodiak Island area in spring and summer. Our observations bear out this suspicion (Table 3). Bearing in mind the preliminary nature of the study, we offer the following tentative conclusions regarding the key species of marine birds and their prey:

1. In terms of numbers and biomass, the Short-tailed Shearwater is the most important species. Other key species are Black-legged Kittiwake, Tufted Puffin, Sooty Shearwater and Common Murre. We are aware that criteria besides numbers and biomass may determine other "key" species, but such a determination is beyond the scope of this report.

2. Capelin is overwhelmingly the most important prey species to marine birds. Walleye Pollock and Pacific Sandlance are also key prey species, though of lesser importance than Capelin.

3. The macroplanktonic euphausiid crustacean, Thysanoessa inermis is very important to Short tailed Shearwaters, and sporadically important to Black-legged Kittiwakes and Tufted Puffins. Two other euphausiids, T. spinifera and T. raschii, have been presenet in the birds' diet, but are of lesser importance.

4. Gonatid squid are key prey of Short-tailed and Sooty Shearwaters, and occasionally to Tufted Puffins.

We are just beginning to understand the winter situation. We know there is a dramatic shift in the species compostion of the marine bird community in the Kodiak area from summer to winter. The Common Murre is the only summer key species which remains in numbers in the Kodiak area over winter. A few Black-legged Kittiwakes stay around, but the other three key species in summer are essentially gone from the area from fall through early spring. Large numbers of marine waterfowl such as White-winged Scoters and Oldsquaw form the bulk of numbers and biomass in winter. Consequently, we may expect an equally dramatic shift in kinds and numbers of prey consumed in winter. The winter aspects of our broader study will be addressed in subsequent reports.

The possiblity of the kind of prey influencing the physiological condition of birds, such as suggested by the amount of euphausiids in the diet of Short-tailed Shearwaters influencing their fat index, suggests that an understanding of the biomass of prey consumed only tells part of the story of trophic relationships. The energy value of different prey, as well as their assimilation rates in the birds, will have to be understood before trophic relationships can be understood beyond the preliminary level presented here.

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LITERATURE CITED

Ashmole, N.P. 1971. Sea bird ecology and the marine environment, pp. 223-286, In: Avian Biology, V. 1, D. S. Farner and J. R. King, Eds. Academic Press, NY. 586 p.

Baird, P.A. and R.A. Moe. 1978. Population ecology and trophic relationships of marine birds at Sitkalidak Strait - 1977, Appendix IV, In: Population dynamics and trophic relationships of marine birds in the Gulf of Alaska and southern Bering Sea, C.J. Lensink and K.D. Wohl, Principal Investigators, Annual Report, OCSEAP RU-341. U.S. Fish and Wildlife Service, OBS-CE, Anchorage, AK 1 April 1978.

Dick, M. 1977. Notes on the winter seabirds of Chiniak Bay, Kodiak Island, Alaska. U.S. Fish and Wildlife Service, OBS-CE, Anchorage, AK. Unpublished MS, 38 pp. December 1977.

Divoky, G. 1977. The distribution, abundance and feeding ecology of birds associated with pack ice, pp. 525-573, In: Environmental assessment of the Alaskan continental shelf. Annual reports of principal investigators for the year ending March 1977, V. II Receptors - Birds U.S. Dept. Commerce, NOAA and U.S. Dept. Interior, BLM. 574 pp.

Drury, W. 1977. Birds of coastal habitats on the south shore of the Seward Peninsula, Alaska, pp. 1-78, In: Environmental assessment of the Alaskan continental shelf. Annual reports of principal investigators for the year ending March, 1977, V. III Receptors - Birds. U.S. Dept. Commerce, NOAA and U.S. Dept. Interior, BLM. 638 pp.

Gould, P.J., C.S. Harrison and D.J. Forsell. 1977. Distribution and abundance of marine birds - south and east Kodiak Island waters. Annual Report, OCSEAP RU 337, C.J. Lensink Principal Investigator. U.S. Fish and Wildlife Service, OBS-CE, Anchorage, AK. 1 April 1978.

Guzman, J. 1976. Ecology and behavior of Southern Hemisphere Shearwaters (Genus Puffinus) and other seabirds, when over the Outer Continental Shelf of the Bering Sea and Gulf of Alaska during the Northern Summer, pp. 1-52, In: Environmental assessment of the Alaskan continental shelf, V.3. Marine birds. Principal investigators Reports for the year ending March 1976. U.S. Dept. Commerce, NOAA and U.S. Dept. Interior, BLM. 644 pp.

Hunt, G. 1977. Reproductive ecology, foods, and foraging areas of seabirds nesting on the Pribilof Islands, pp. 196-371, In: Environmental assessment of the Alaskan continental shelf. Annual reports of principal investigators for the year ending March 1977, V. II. Receptors - Birds. U.S. Dept. Commerce, NOAA and U.S. Dept. Interior, BLM. 574 pp.

Kajimura, H. and G.A. Sanger. 1975. Pelagic studies - Bering Sea, pp. 38-54, In: Fur seal investigations, 1974. U.S. Dept. Commerce, NMFS, Northwest Fisheries Center, Marine Mammal Division, Seattle. February 1975, 125 pp.

Lack, D. 1954. The natural regulation of animal numbers. Oxford U. Press, Oxford. 343 pp.

Lensink, C.J., J.C. Bartonek and G.A. Sanger. 1976. Feeding ecology and trophic relationships of Alaskan marine birds, pp. 321-344, In: Environmental assessment of the Alaskan Continental Shelf, V. 4. Marine Birds. Principal Investigators' Reports for the year ending March 1976. U.S. Dept. Commerce, NOAA and U.S. Dept. Interior, BLM. 361 pp.

Mascher, J. W. 1966. Weight variations in resting dunlins (*Calidris a. alpina*) on autumn migration in Sweden. Bird-Banding 43: 107-113.

Minton, C.T.D. 1969. The curlew sandpiper invasion. B.T.O. News 36:3-4.

Morrow, J.E. 1977. Illustrated keys to otoliths of forage fishes of the Gulf of Alaska, Bering Sea and Beaufort Sea, In: Environmental assessment of the Alaskan continental shelf. Annual reports of principal investigators for the year ending March 1977, V. VIII. Receptors - Fish. U.S. Dept. Commerce, NOAA and U.S. Dept. Interior, BLM.

Nysewander, D. and E. Hoberg. 1978. The breeding biology of marine birds at Chiniak Bay, Kodiak Island - 1977, Appendix V, In: Population dynamics and trophic relationships of marine birds in the Gulf of Alaska and southern Bering Sea, C.J. Lensink and K.D. Wohl, Principal Investigators, Annual Report OCSEAP RU 341. U.S. Fish and Wildlife Service, OBS-CE, Anchorage, AK.

Sanger, G.A. and P.A. Baird. 1977. The trophic relationships of marine birds in the Gulf of Alaska and the southern Bering Sea, pp. 694-757, In: Environmental assessment of the Alaskan continetal shelf, Annual Reports of principal investigators for the year ending March 1977. V. IV. Receptors - Birds. U.S. Dept. Commerce, NOAA and U.S. Dept. Interior, BLM. 757 pp.

Shuntov, V.P. 1972. Sea birds and the biological structure of the ocean translated from Russian by the Agence Tunisienne de Public-Relations, Tunis, Tunisia - 1974 (NTIS No. TT 74-55032).

Skalkin, V.A. 1963. Diet of flatfishes in the southeastern Bering Sea, pp. 235-250, In: Soviet Fisheries Investigations in the Northeast Pacific, Part I. VNIRO, Trudy, V. 48 (Translated from Russian).

Sowls, A. 1978. Catalog of Alaskan seabird colonies. U.S. Fish and Wildlife Service, Office of Biological Services (In preparation).

Wiens, J.A., D. Heinemann and W. Hoffman 1978. Community structure, distribution, and interrelationships of marine birds in the Gulf of Alaska. Final Report, RU#108, Phase I. Oregon State U. 16 Jan 1978. 175 pp.

Table 1. Summary of cruise dates and numbers of key species of marine birds collected for feeding habits studies in the Kodiak area, May - September 1977. No. = Chiniak/Marmot area. So. = Sitkalidak area.

NUMBER OF BIRDS COLLECTED																		
Cruise Dates	Sooty Shearwater			Short-tailed Shearwater			Black-legged Kittiwake			Common Murre			Tufted Puffin			TOTALS		
	No.	So.	Tot	No.	So.	Tot.	No.	So,	Tot.	No.	So.	Tot.	No.	So.	Tot.	No.	So.	Tot
26 May 05 June	0	0	0	0	27	27	4	4	8	6	1	7	21	2	23	31	34	65
12-29 June	6	1	7	5	25	30	4	8	12	3	4	7	12	9	21	30	47	77
06-29 July	4	2	6	17	28	45	5	16	21	6	10	16	8	14	22	40	70	110
11-23 August	0	6	6	40	4	44	13	8	21	2	5	7	16	12	28	71	35	106
07-19 September	10	6	16	8	6	14	9	17	26	8	0	8	3	3	6	38	32	70
TOTALS	20	15	35	70	90	160	35	53	88	25	20	45	60	40	100	210	218	428
Empty N			2			18			6			18			11			55
Stomachs %			5.7			11.2			6.8			40.0			11.0			12.8

Table 2. Mean frequency of occurrence and mean percent volumetric composition of major prey-types in the five key species of marine birds in Kodiak Island waters, May-September 1977.

Sample Size (n)	Sooty Shearwater			Short-tailed Shearwater		
	35		33	158		142
Prey Type	$\bar{X}$ Frequency of Occurrence		$\bar{X}$ % Composition,[2] by Volume	$\bar{X}$ Frequency of occurrence		$\bar{X}$ % Composition,[2] by volume
	N	%		N	%	
Total Fish[1]	26	74	76	72	46	42
Capelin & Un. Osmeridae	23	66	67	45	28	28
Pollock & Un. Gadidae	0	0	0	0	0	0
Sandlance	0	0	0	6	4	4
Euphausiids	0	0	0	74	47	47
Squid	25	71	24	46	29	9
Polychaeta	2	6	+	5	3	1

1 Includes unidentifiable fish.

2 Excludes birds with empty stomachs.

[illegible] and mean percent volumetric composition of major prey-[illegible] key species of marine birds in Kodiak Island waters, May-September [illegible].

Sample Size (n)	Black-legged Kittiwake			Common Murre			Tufted Puffin		
	88		82	45		27	100		89
Prey Type	$\overline{X}$ Frequency of Occurrence		$\overline{X}$ % Composition by Vol.[2]	$\overline{X}$ Frequency of Occurrence		$\overline{X}$ % Composition by Vol.[2]	$\overline{X}$ Frequency of occurrence		$\overline{X}$ % Composition by Vol.[2]
	N	%		N	%		N	%	
Total Fish[1]	82	93	97	27	60	100	85	85	91
Capeline & Un. Osmeridae	53	60	61	24	53	56	65	65	66
Pollock & Un. Gadidae	11	12	8	6	13	11	8	8	6
Sandlance	7	8	8	3	7	11	2	2	4
Euphausiids	5	6	2	0	0	0	6	6	5
Squid	0	0	0	0	0	0	12	12	4
Polychaeta	0	0	0	0	0	0	1	1	+

1 Includes unidentifiable fish.

2 Excludes birds with empty stomachs.

Table 3. Average estimated densities of five key species of marine birds in the northeast Kodiak area, May-September 1977.

Time Period	No. of 10-min. Transects	$\bar{X}$ Density, Birds per km^2 Sooty & Short-tailed Shearwaters	Black-legged Kittiwake	Common Murre	Tufted Puffin
26 May - 5 June	266	50.9	3.8	5.2	0.5
18-29 June	240	67.3	2.0	3.2	5.2
6-29 July	306	67.8	8.1	1.5	15.8
11-23 August	243	74.0	4.1	1.8	12.2
7-19 September	211	37.5	12.0	9.3	3.1
TOTALS	1,266	59.5	6.0	4.2	7.4

Table 4. Statistical data on the percent volume of osmerid fishes in samples of 15 birds each of Sooty Shearwaters (SOSH), Short-tailed Shearwaters (STSH), Black-legged Kittiwakes (BLKI), Common Murres (COMU) and Tufted Puffins (TUPU).

	Bird Species				
Statistical Parameter	SOSH	STSH	BLKI	COMU	TUPU
$\bar{X}$ percent volume	84.7	77.8	20.0	26.6	85.3
Standard Deviation	34.5	40.4	41.4	45.8	35.0
Coefficient of Variation	41	52	207	171	41
Predicted Sample Needed	9,006	354	6,190	476	566

Table 5. The mean and standard deviation of the percent prey volume in a sample (n=21) and random subsample (n=5) of Short-tailed Shearwaters, and their corresponding "t" values and probability coefficients.

Prey Type	Bird Sample Size	$\bar{X}$ %	S. D.	"t" Value	Probability Coefficient
Euphausiids	n_1=21	75.3	39.9	0.04	0.90
	n_2=5	76.0	40.0		
Squid	n_1=21	16.1	35.2	0.25	0.88
	n_2=5	20.2	44.3		

Table 6. Capelin and Sandlance vertebral columns and parasphenoid bones as a proportion of total measurable fish taken from the stomachs of five key species of marine birds from the Kodiak Island area, May-September 1977.

	Number of Measurable Fish			
			Vert. Cols. + P-bones	
Bird Species	Total	Whole Fish	No.	% of Total
Sooty Shearwater	106	46	60	57
Short-tailed Shearwater	167	114	53	32
Black-legged Kittiwake	49	20	29	59
Common Murre	65	41	24	37
Tufted Puffin	318	54	264	83
TOTALS	705	275	430	61%

Table 7. Species present in the OBS-CE reference collection, as of March 1978. Each species is represented by at least one whole specimen, plus parts as indicated: O = otolith; P = parasphenoid bone; V = vertebral column.

FISHES	
Allosmerus elongatus	
Ammodytes hexapterus	O,P,V
Clupea harengus pallasi	O,P
Gadus macrocephalus	O
Gasterosteus aculeatus aculeatus	
Hemilepidotus hemilepidotus	
Hexagrammos decagrammus	
Hexagrammos stelleri	
Hexagrammos lagocephalus	
Hypomesus pretiosus pretiosus	P
Lampanyctus beringensis	
Lumpenus sagitta	
Mallotus villosus	O,P,V
Pholis laeta	
Pleurogrammus monopterygius	
Pungitius pungitius	
Scorpaenidae sp.	
Spirinchus starksi	
Spirinchus thaleichthys	
Tarletonbeania crenularis	
Thaleichthys pacificus	
Theragra chalcogramma	O,P,V
Trichodon trichodon	P,V
Triglops sp.	
Triglops pingeli	
EUPHAUSIACEA	
Euphausia pacifica	
Thysanoessa inermis	
Thysanoessa raschii	
Thysanoessa longipes	
Thysanoessa spinifera	
ISOPODA	
Pentidotea sp.	
Saduria entomon	
DECAPODA	
Cancer magister	
Crangon septemspinosa	
Hymenodora frontalis	
Lebbeus polaris	
Pandalopsis ? sp.	
Pandalus borealis	
Pandalus goniurus	
Telmessus cheiragonus	?
BRANCHIPODA	
Anostracan sp.	
CUMACEA	
Cumella vulgaris	
MYSIDACEA	
Neomysis intermedia	
COPEPODA	
Harpactacus sp.	
AMPHIPODA	
Caprellidea	
Caprella californica	
Gammaridea	
Anisogammarus pugettensis	
Anonyx nugax	
Atylus collingi	
Calliopius laeviusculus	
Cyphocaris anonyx	
Cyphocaris challengeri	
Eusirid sp. (?)	
Eusiridae sp. (?)	
Gammaridea sp. B	
Gammaridea spp.	
Halice sp. (?)	
Haustoriid sp. A; sp. B	
Leucon sp.	
Melphidippa sp.	
Paracallisoma alberti	
Paraphoxus sp.	
Protomedeia sp.	

Table 7. (Cont'd.)

Hyperiidea
Crarocephalus scleroticus
Hyperia medusarum f. hystrix
Hyperietta stephenseni
Hyperoche mediterranea
Hyperoche medusarum
Lanceola clausi
Lanceola loveni
Lanceola sayana
Lycaea pulex
Oxycephalus clausi
Paraphronima crassipes
Paraphronima gracilis
Parathemisto libellula
Parathemisto pacifica
Parathemisto japonica
Phronima sedentaria
Primno macropa
Proscina sp. (?)
Scina borealis
Scina rattrayi
Scina stebbini
Scypholanceola vanhoeffeni
Streetsia challengeri
Syrrhoe crenulata
Tryphaena malmii
Vibilia australis
Vibilia caeca
Vibilia sp.

GASTROPODA
Aplexa sp.
Clione limacina
Limacina helicina
Littorina sitkana
Lymnaea sp.
Margarites rhodia
Odostomia sp.
Oenopota sp.

PELECYPODA
Astarte rollandi
Clinocardium muttallii
Gemma ? sp.
Glycymeris subobsoleta
Humilaria kennerleyi
Liocyma fluctuosa
Macoma balthica
Macoma expansa
Mya sp.
Mysella ? sp.
Mytilus edulis
Nuculana sp.
Nucula tenuis
Orobitella ? sp.
Protothaca staminea
Sphenia ? sp.

POLYCHAETA
Ampharetidae sp.
Arenicolidae sp.
Capitella capitata
Eteone californica
Eteone longa
Glycinde picta
Heteromastus sp.
Heteromastus filiformis
Mediomastus sp.
Nephtys ciliata
Nephtys longosetosa
Nephtys ricketsi
Owenia sp. #1
Owenia fusiformis ?
Pectinaria granulata
Pholoe minuta
Polydora caullervi
Polydora quadrilobata
Spio filicornis
Spionidae sp.
Spiophanes bombyx
Syllidae sp.

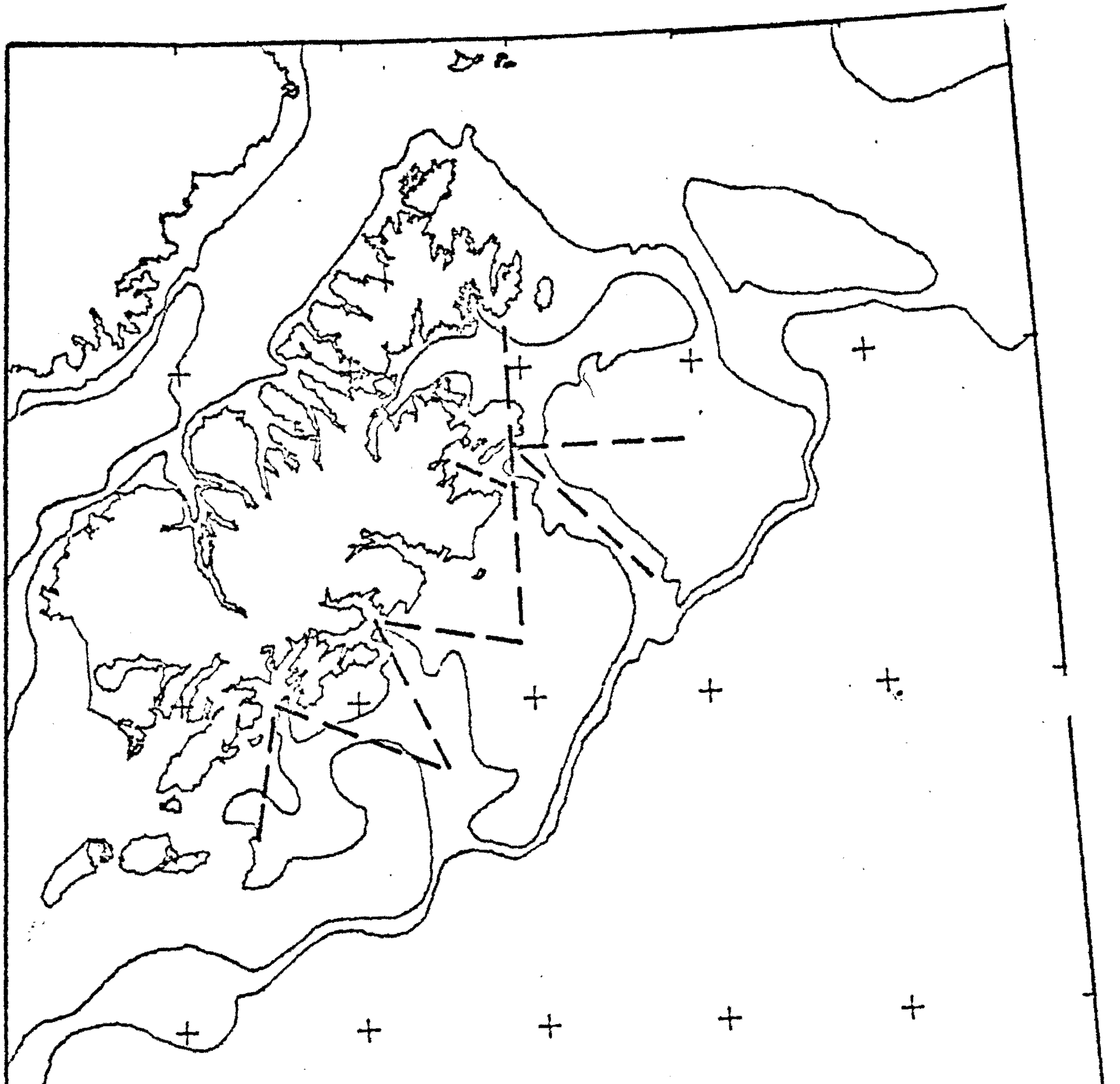

Figure 1. General study area off Kodiak Island showing nominal cruise track (- - - - - - -). Wavy lines indicate 100 m and 200 m depth contours.

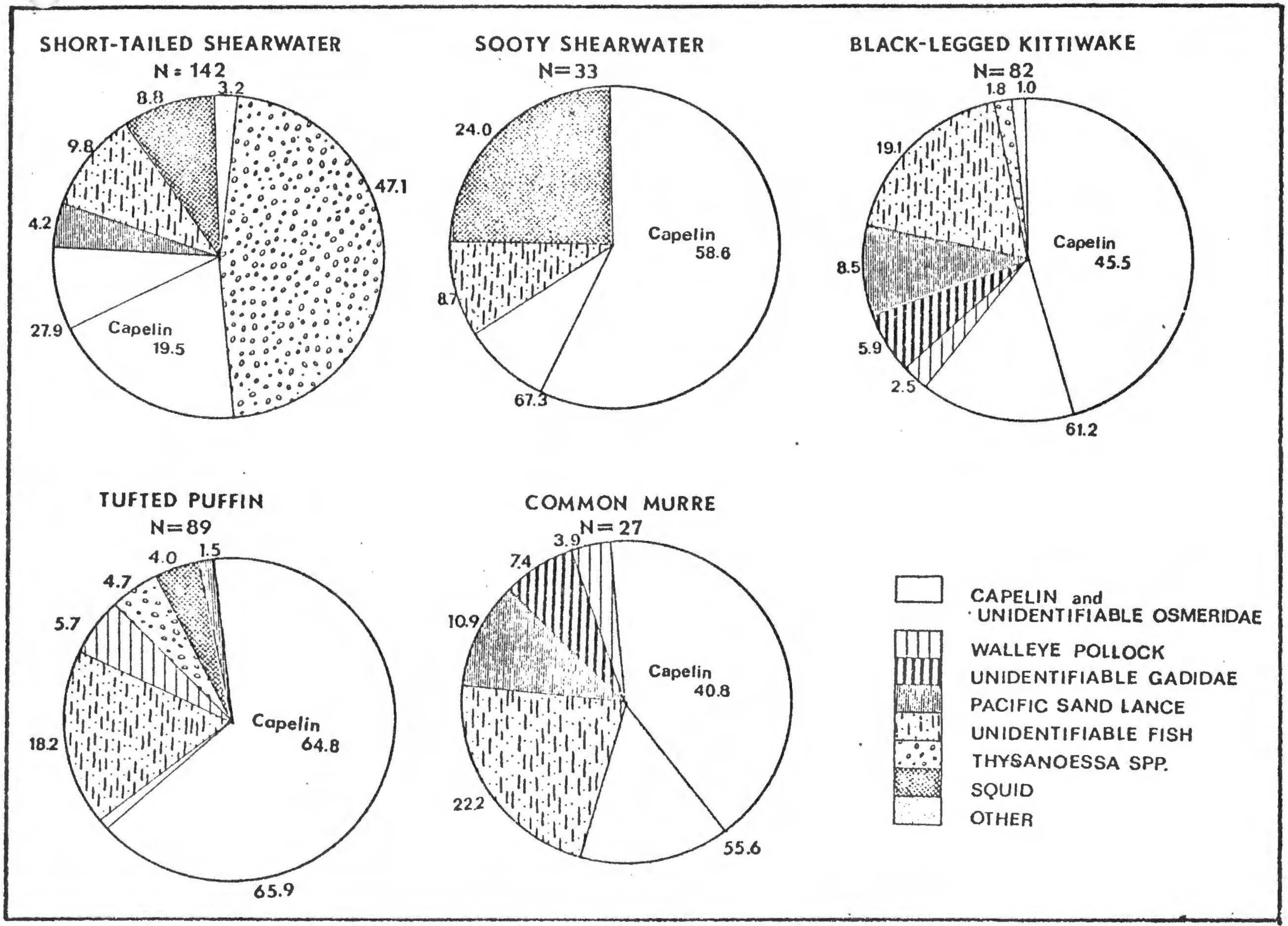

Figure 2. Aggregate percent volume of prey in the five key species of marine birds in the Kodiak Island area; May-September 1977.

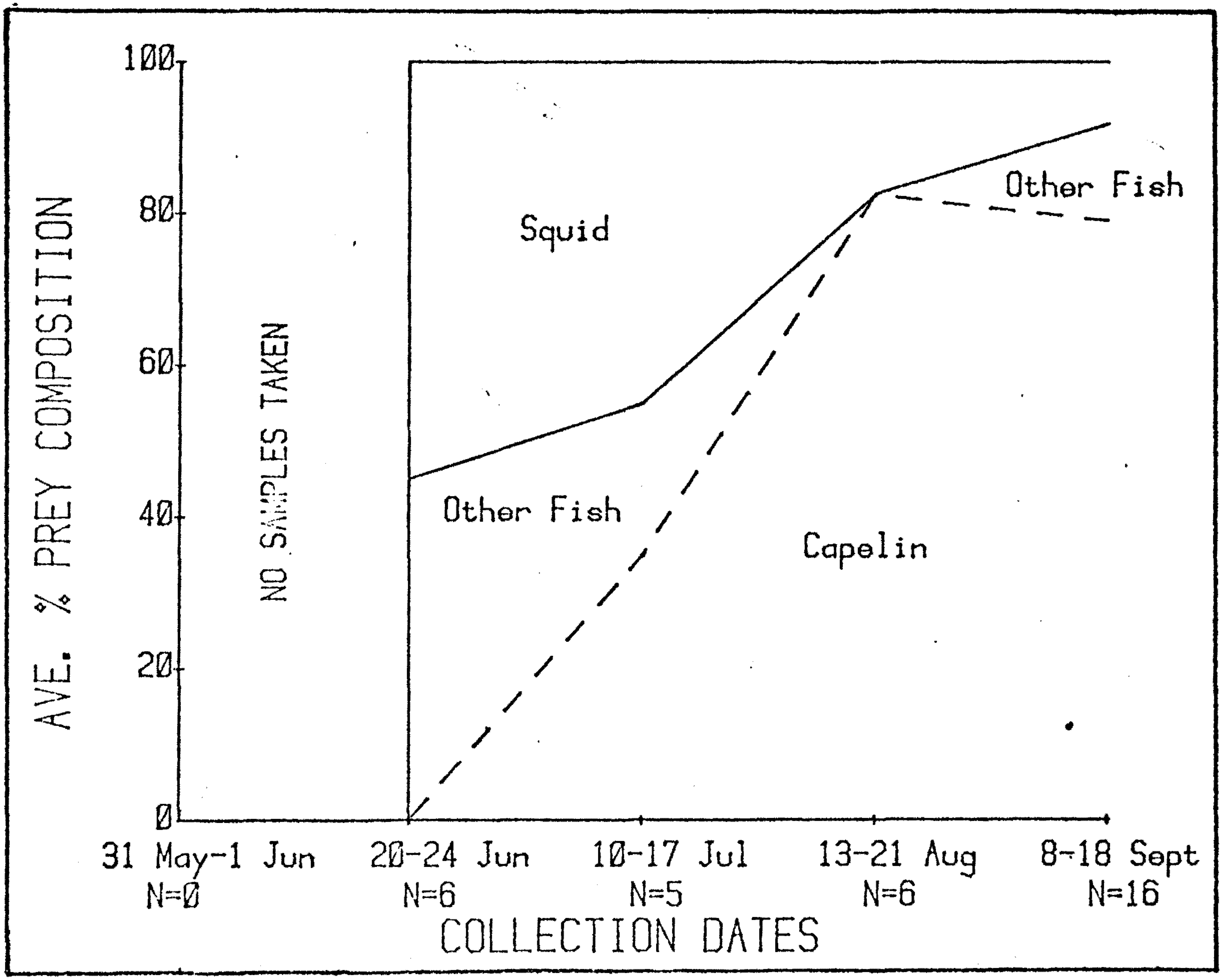

Figure 3. Seasonal changes in the percent volume of prey in Sooty Shearwaters from the Kodiak Island area, 1977.

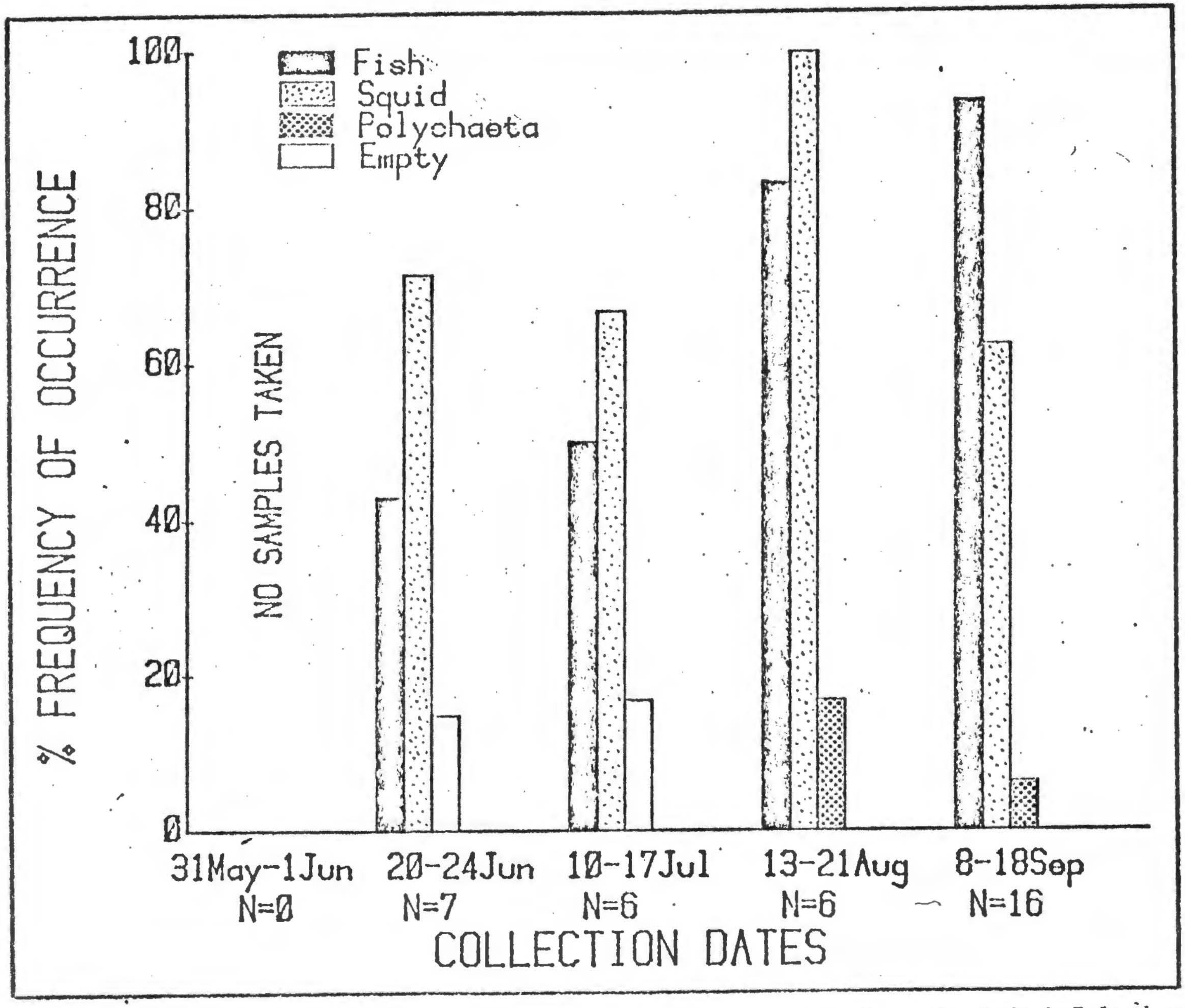

Figure 4. Seasonal changes in frequency of prey in Sooty Shearwaters from the Kodiak Island area, 1977.

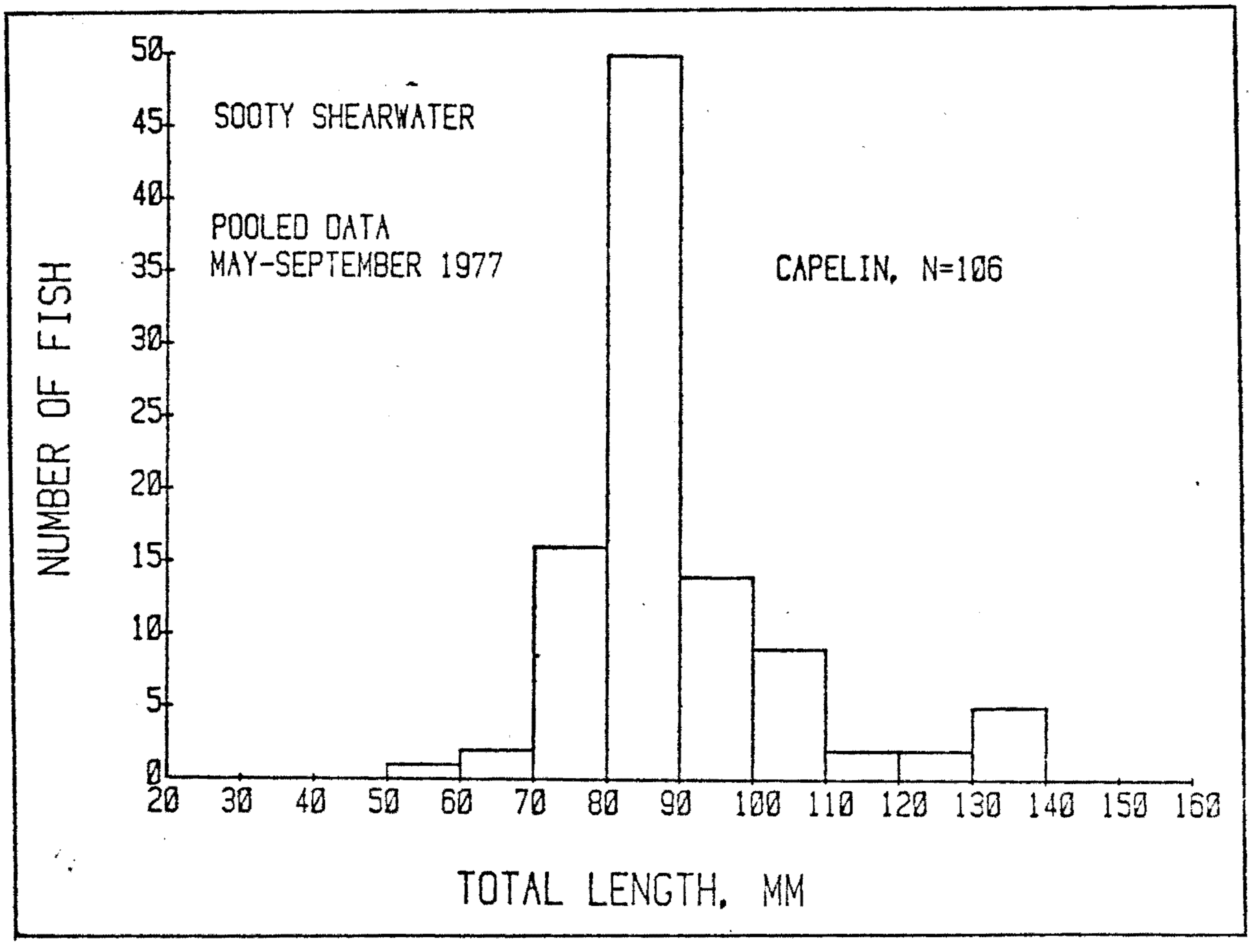

Figure 5. Length frequency of Capelin in the stomachs of Sooty Shearwaters from the Kodiak Island area, 1977.

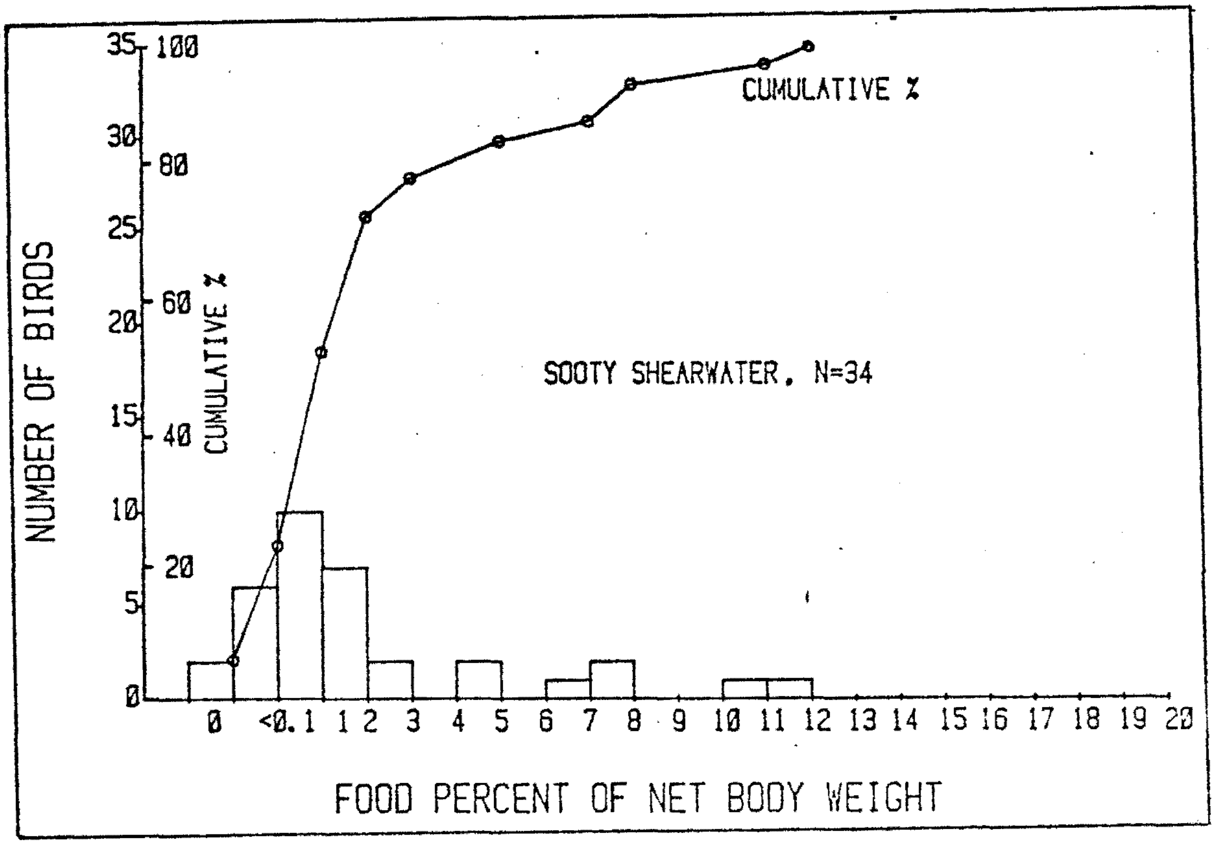

Figure 6. Weight of stomach contents as a percent of net body weight of Sooty Shearwaters from the Kodiak Island area, 1977.

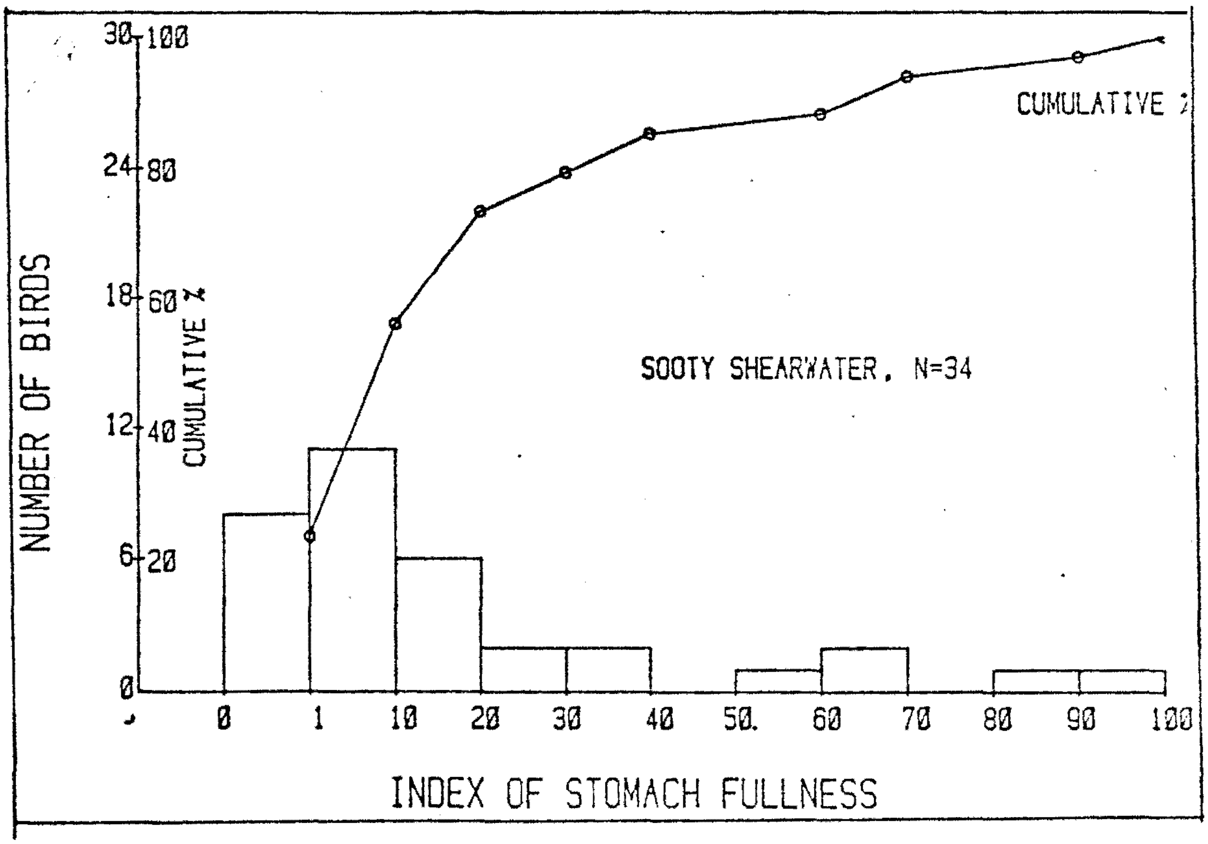

Figure 7. Index of stomach fullness for Sooty Shearwaters from the Kodiak Island area, 1977.

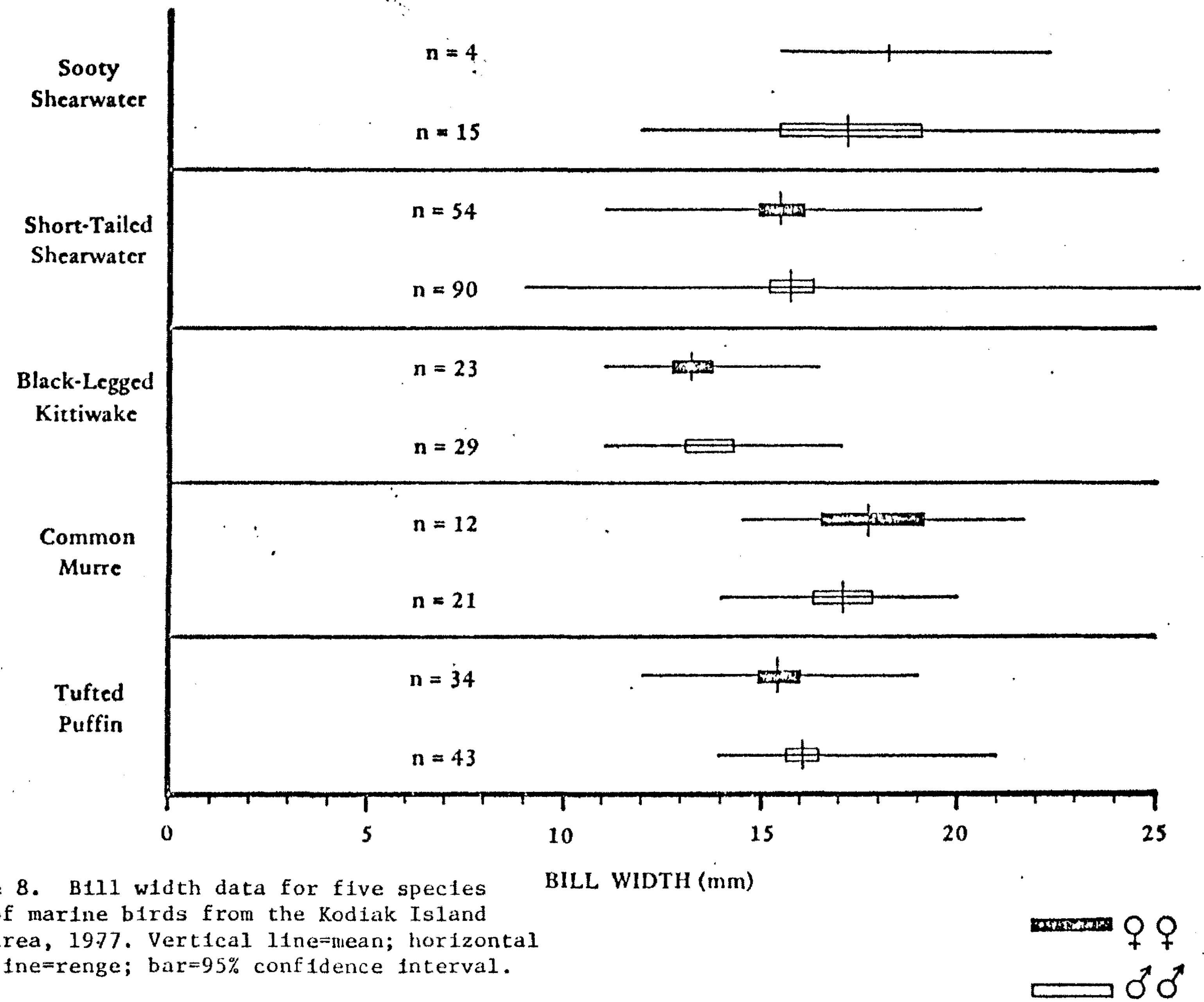

Figure 8. Bill width data for five species of marine birds from the Kodiak Island area, 1977. Vertical line=mean; horizontal line=renge; bar=95% confidence interval.

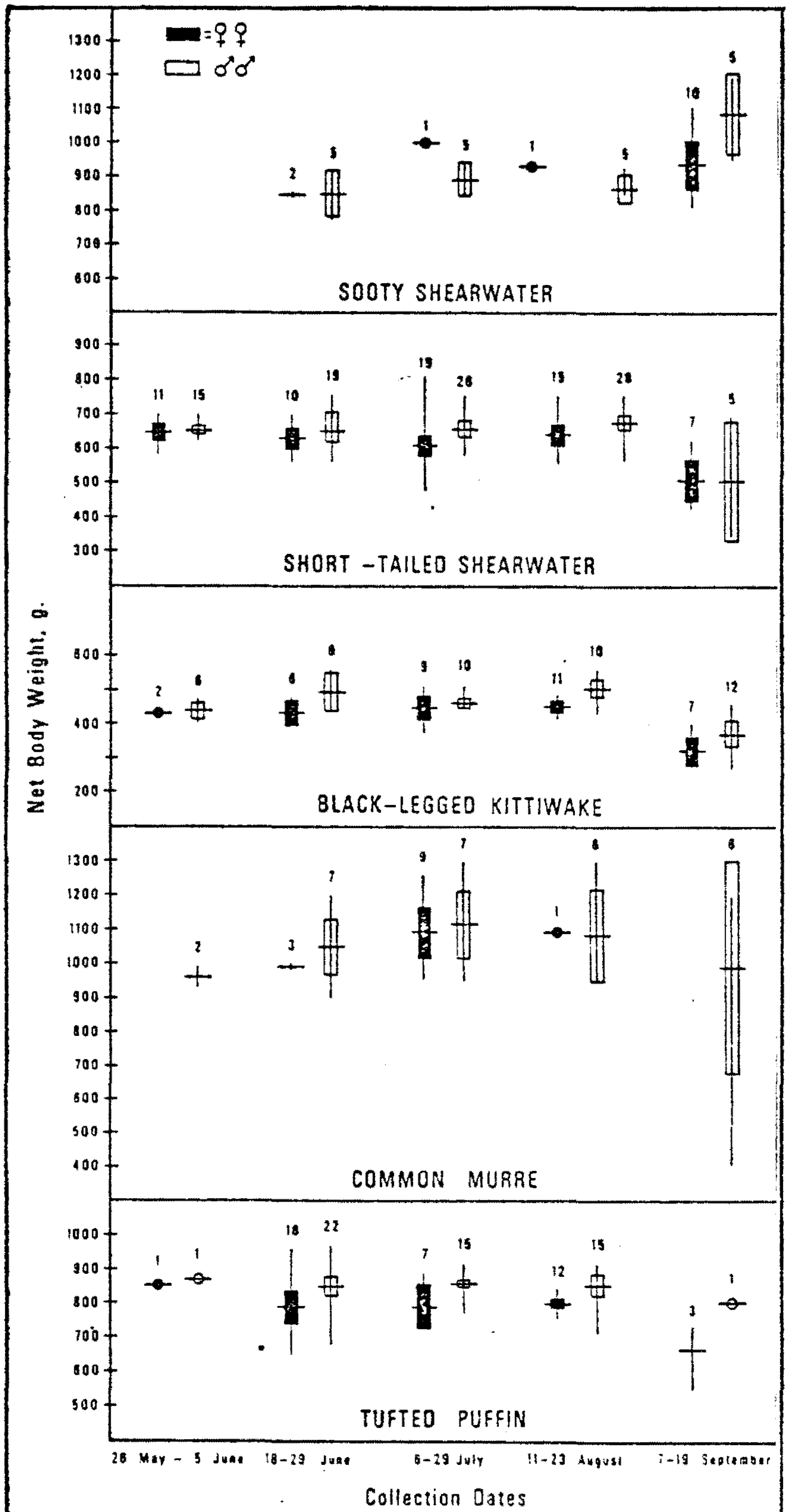

Figure 9. Seasonal changes in the body weights of five species of marine birds from the Kodiak Island area, 1977. Horizontal line=mean; vertical line=range; bar=95% confidence interval around mean.

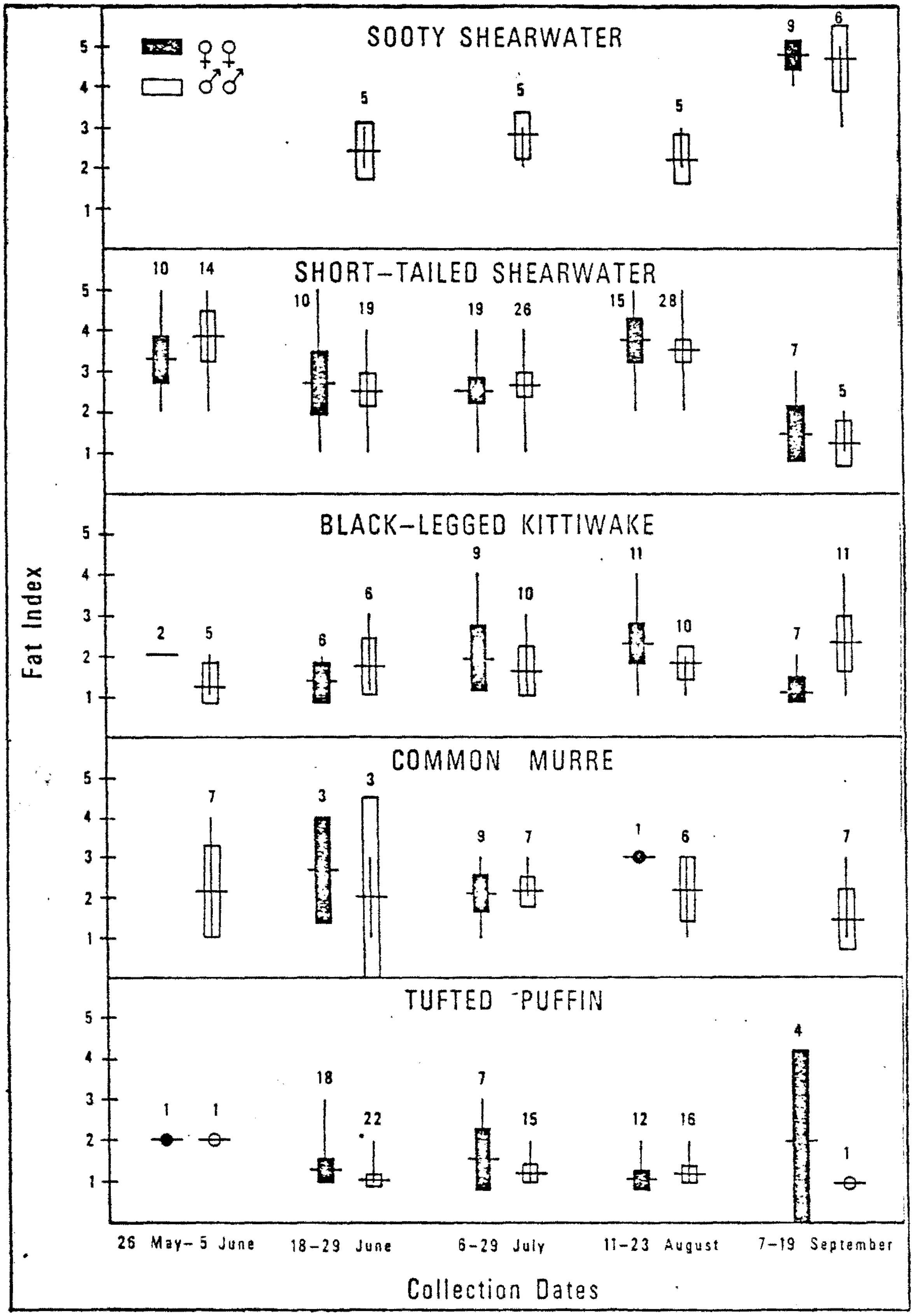

Figure 10. Seasonal changes in the fat index for five species of marine birds from the Kodiak Island area, May-September 1977. Horizontal line=mean; vertical line=range; bar=95% C.I.

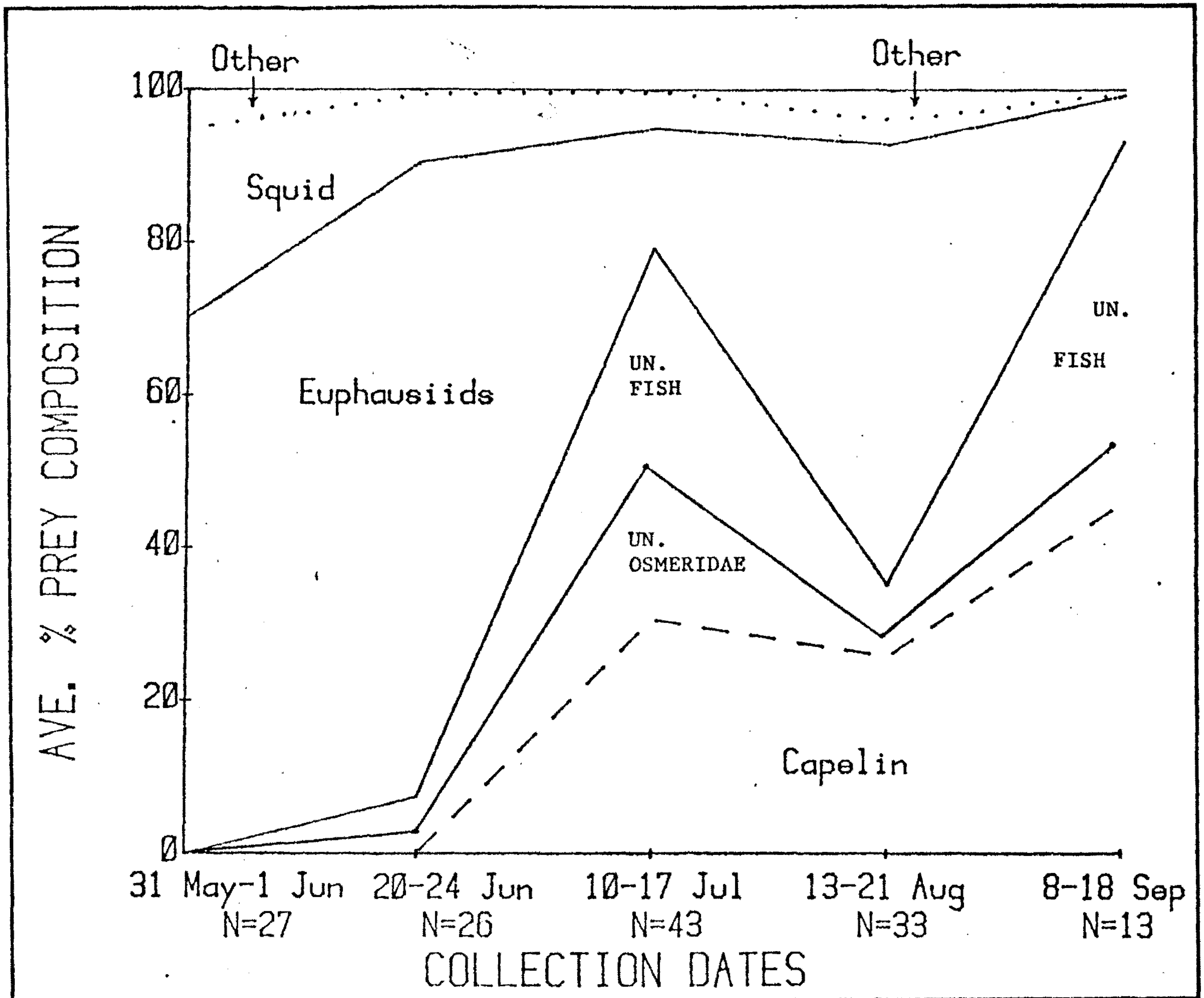

Figure 11. Seasonal changes in percent volume of prey in Short-tailed Shearwaters from the Kodiak Island area, 1977.

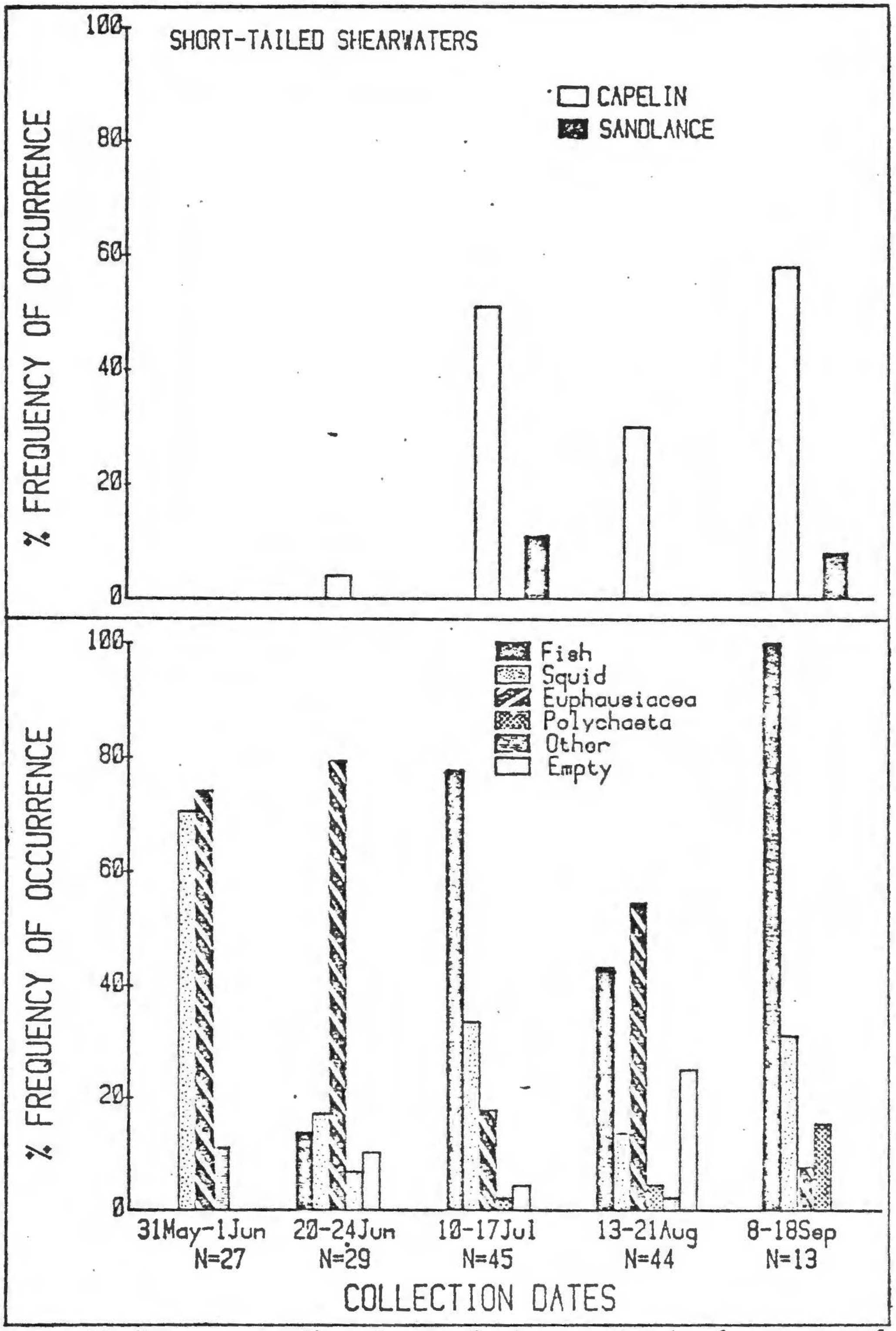

Figure 12 (bottom panel). Seasonal changes in the frequency of prey in Short-tailed Shearwaters from the Kodiak area, May-Sept 1977.

Figure 13 (top panel). Seasonal changes in the frequency of fish prey in Short-tailed Shearwaters from the Kodiak Island area, 1977.

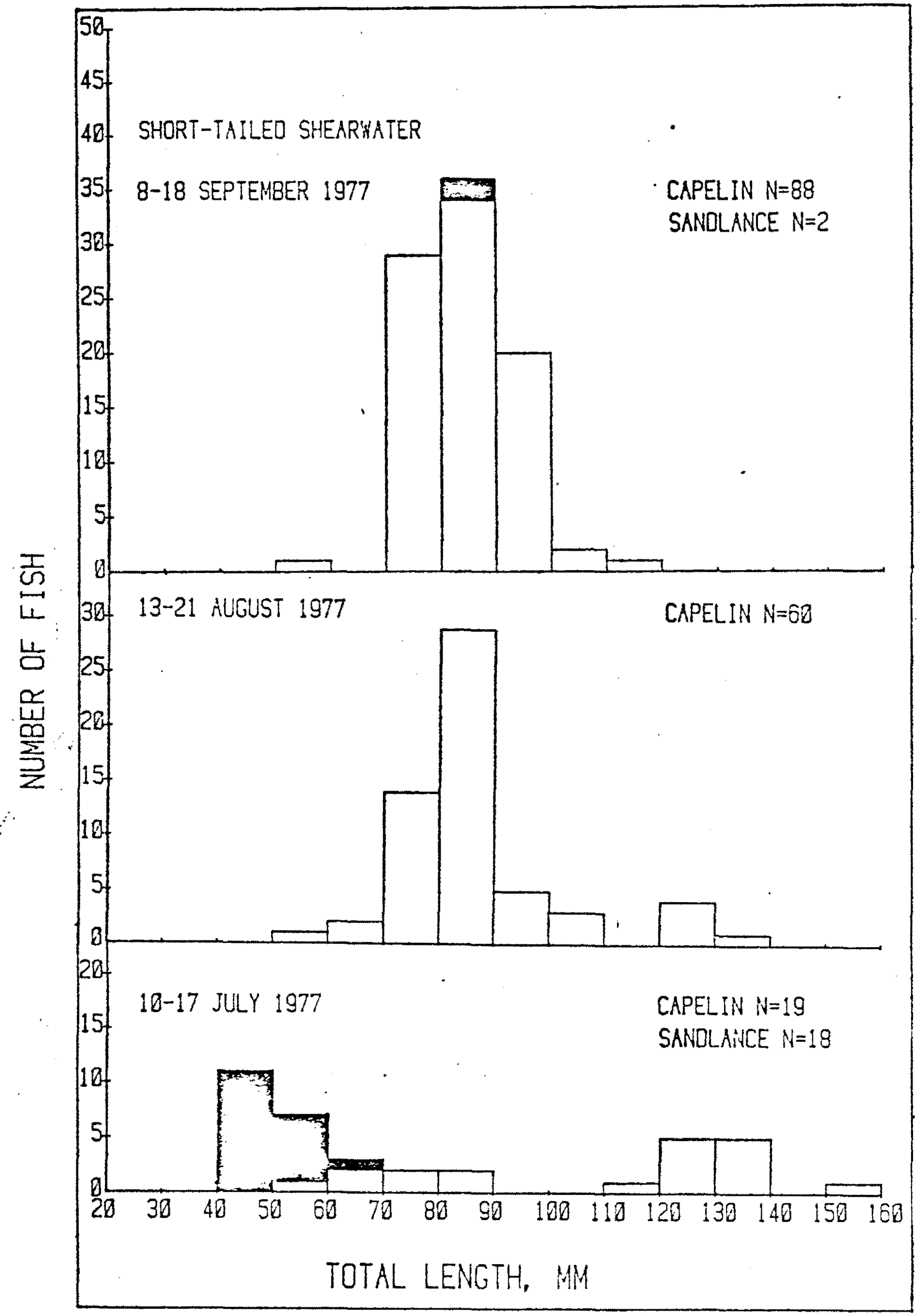

Figure 14. Length frequency of Capelin and Sandlance in the stomachs of Short-tailed Shearwaters from the Kodiak Island area, 1977. No data for May-June.

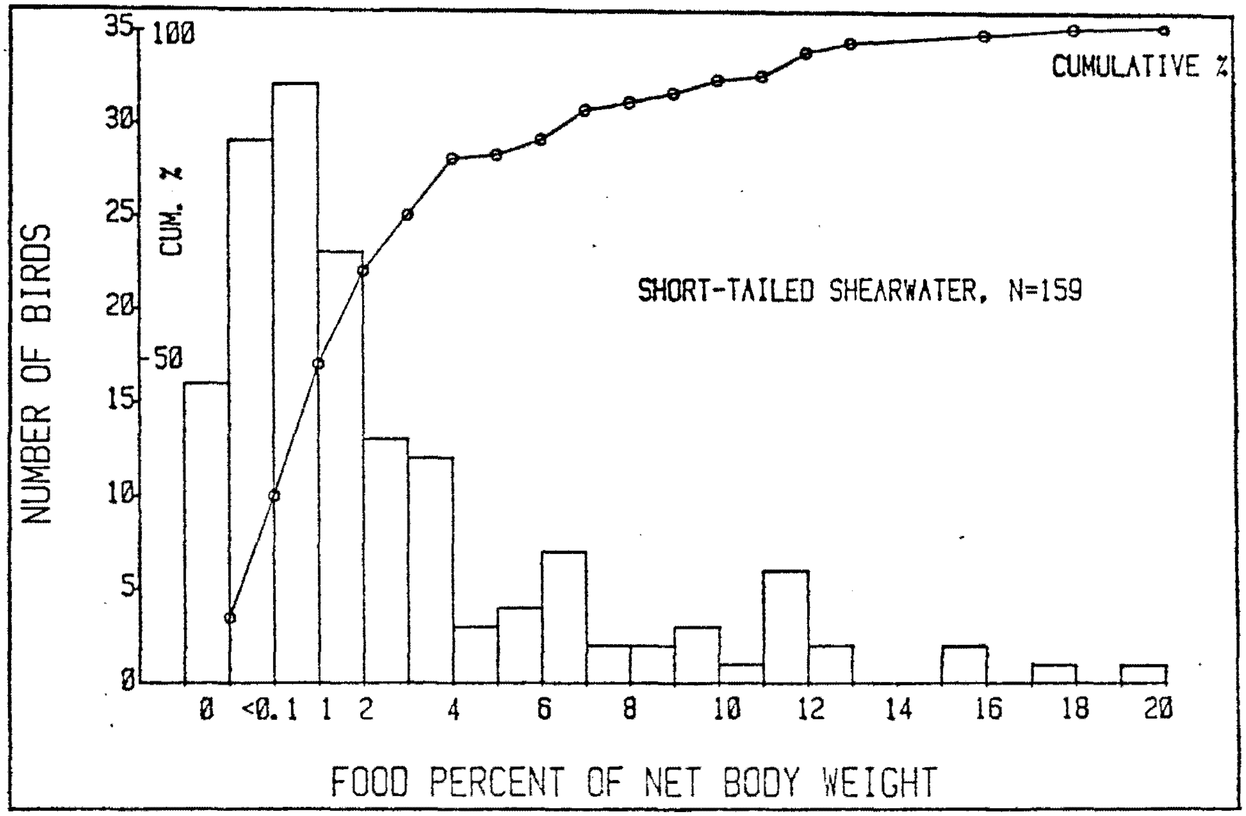

Figure 15. Weight of stomach contents as a percent of net body weight of Short-tailed Shearwaters from the Kodiak Island area, 1977.

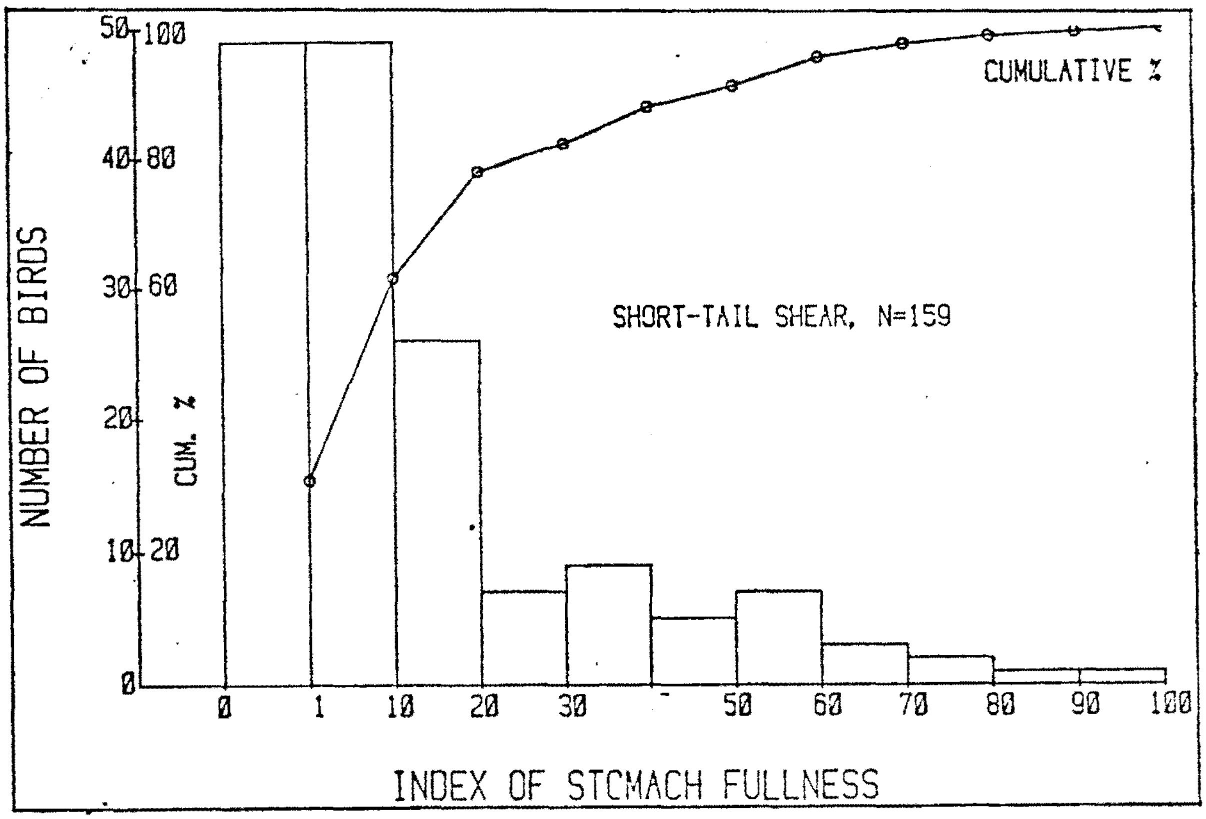

Figure 16. Index of stomach fullness for Sjort-tailed Shearwaters from the Kodiak Island area, 1977.

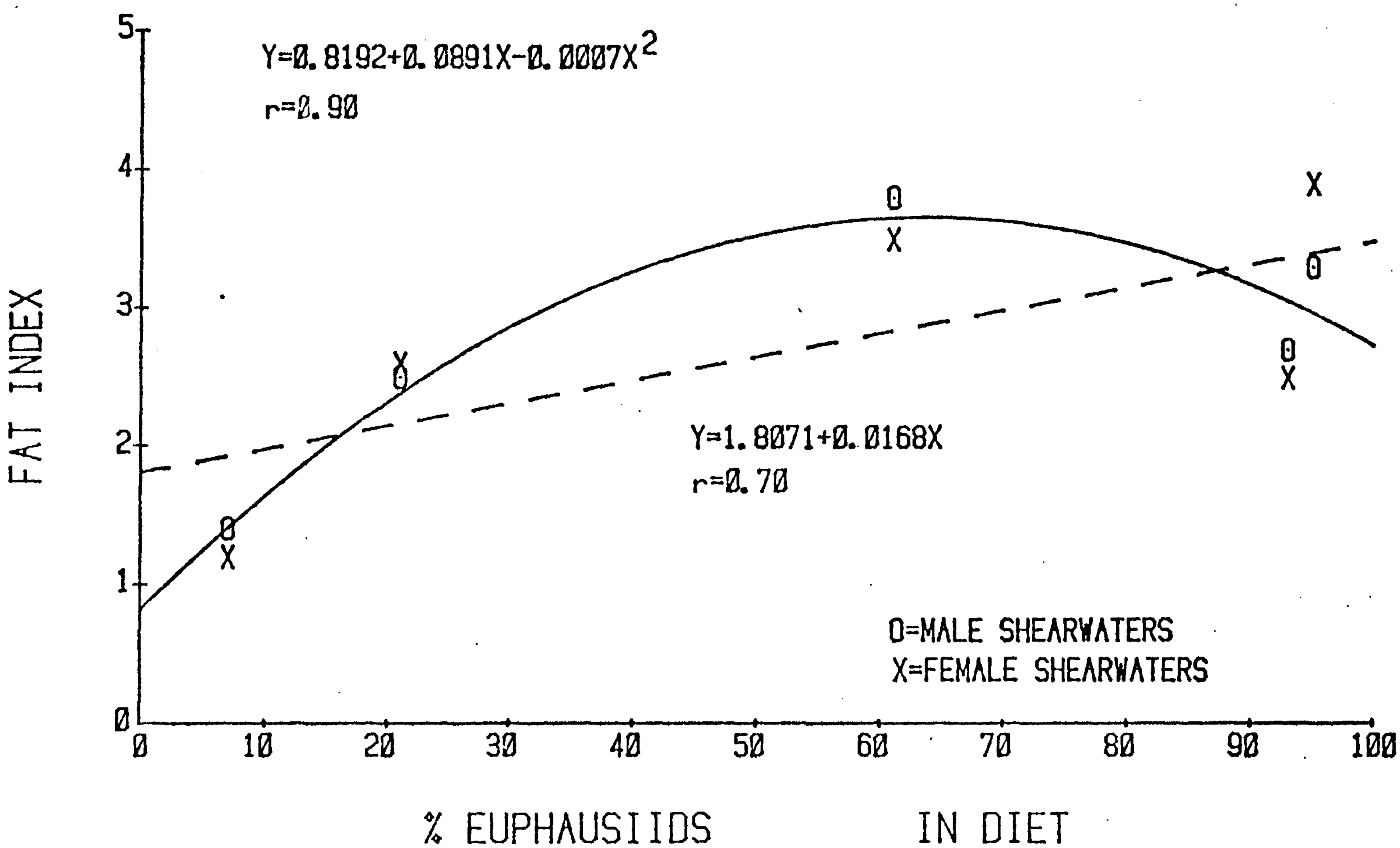

Figure 17. Relationship between the average fat index and the average percent volume of euphausiids in the diet of Short-tailed Shearwaters from the Kodiak Island area, 1977. Each point represents the mean value for a cruise.

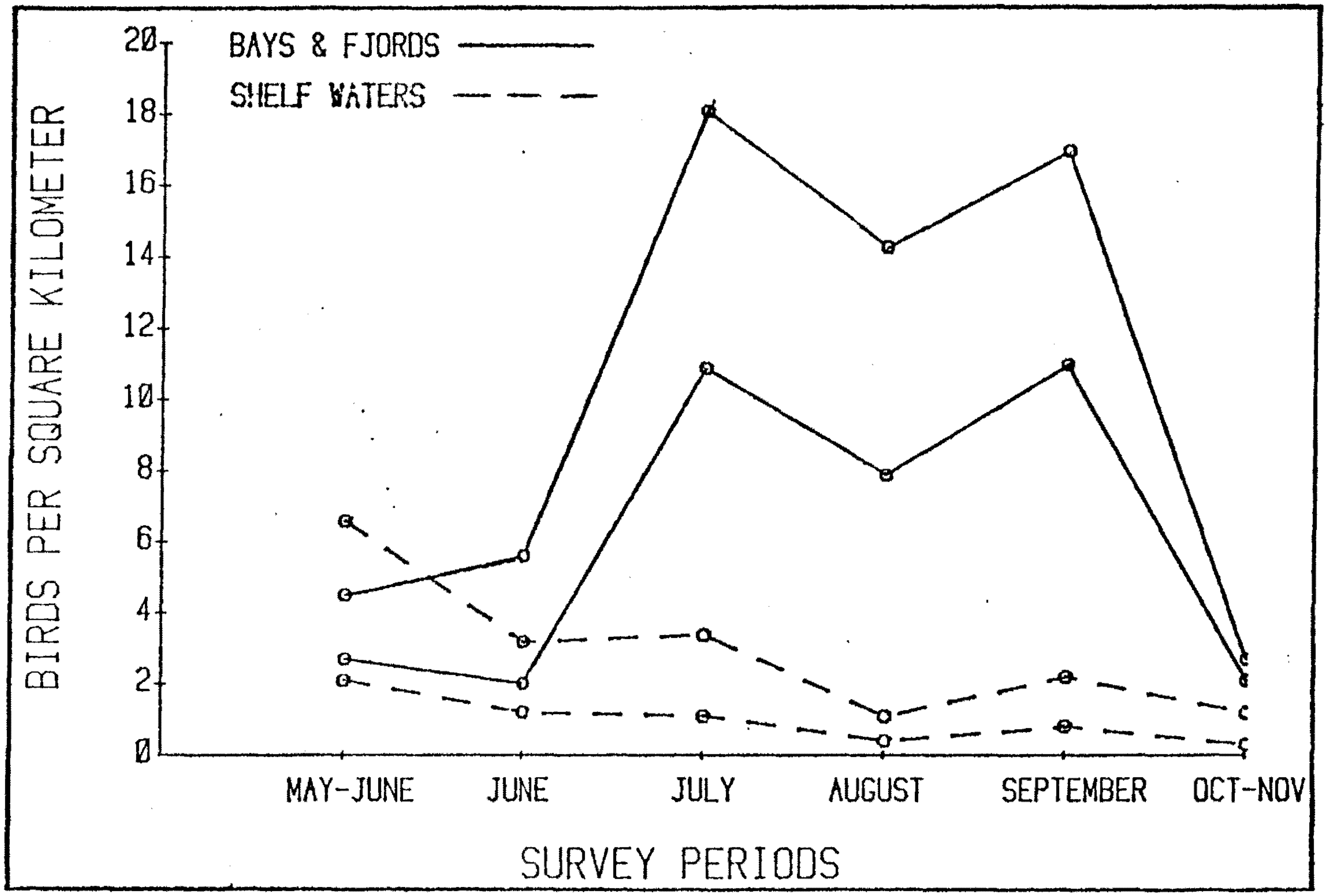

Figure 18. Seasonal changes in the mean pelagic densities (birds/km^2) of Black-legged Kittiwakes in the bays and offshore waters of the Kodiak Island area, May-November 1977 (Adapted from Gould et al 1978). October-November data from observations aboard the RV Miller Freeman. Lines are 95% confidence intervals around mean density values.

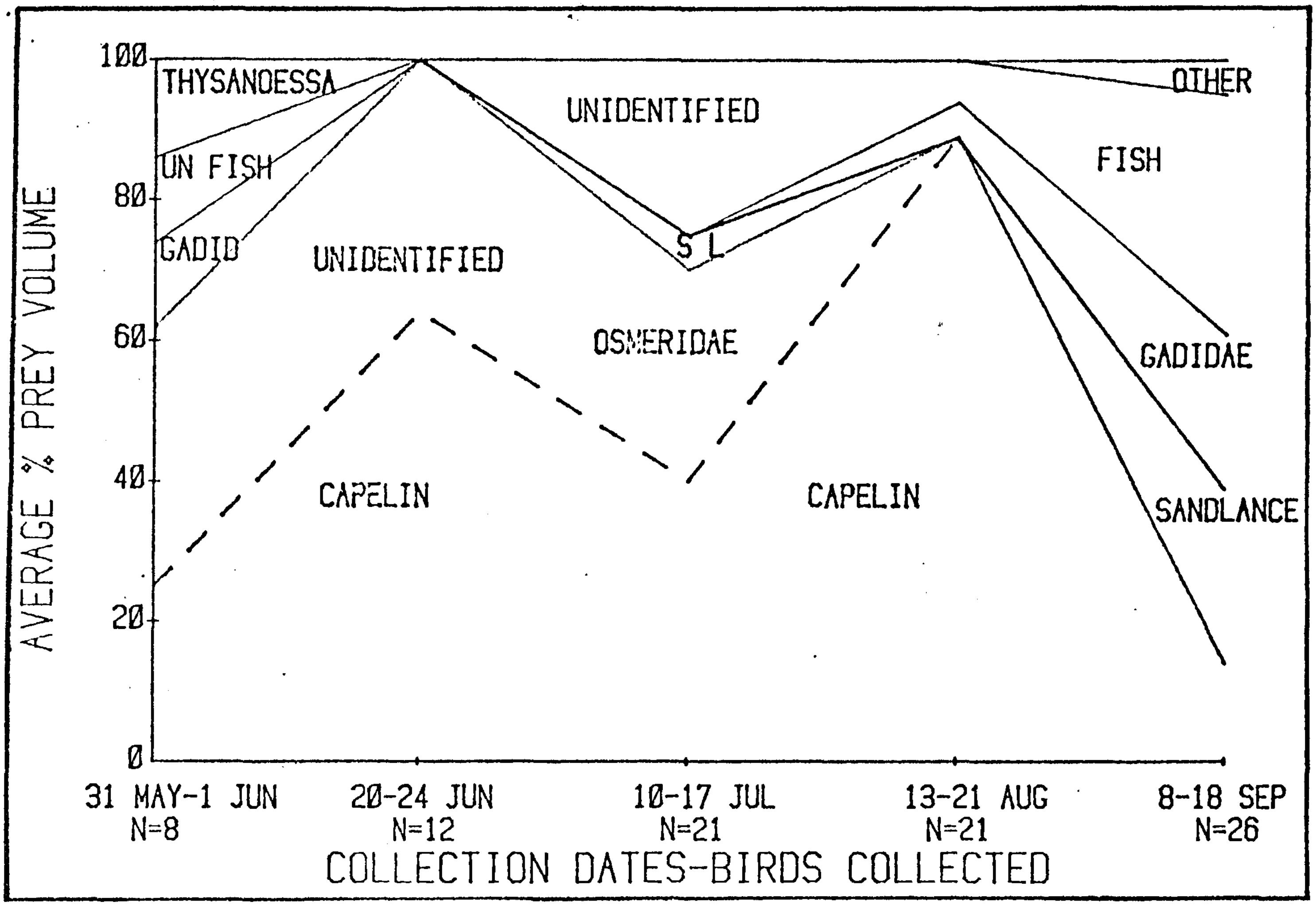

Figure 19. Seasonal changes in percent volume of prey in Black-legged Kittiwakes from the Kodiak Island area, 1977 (composite of all data).

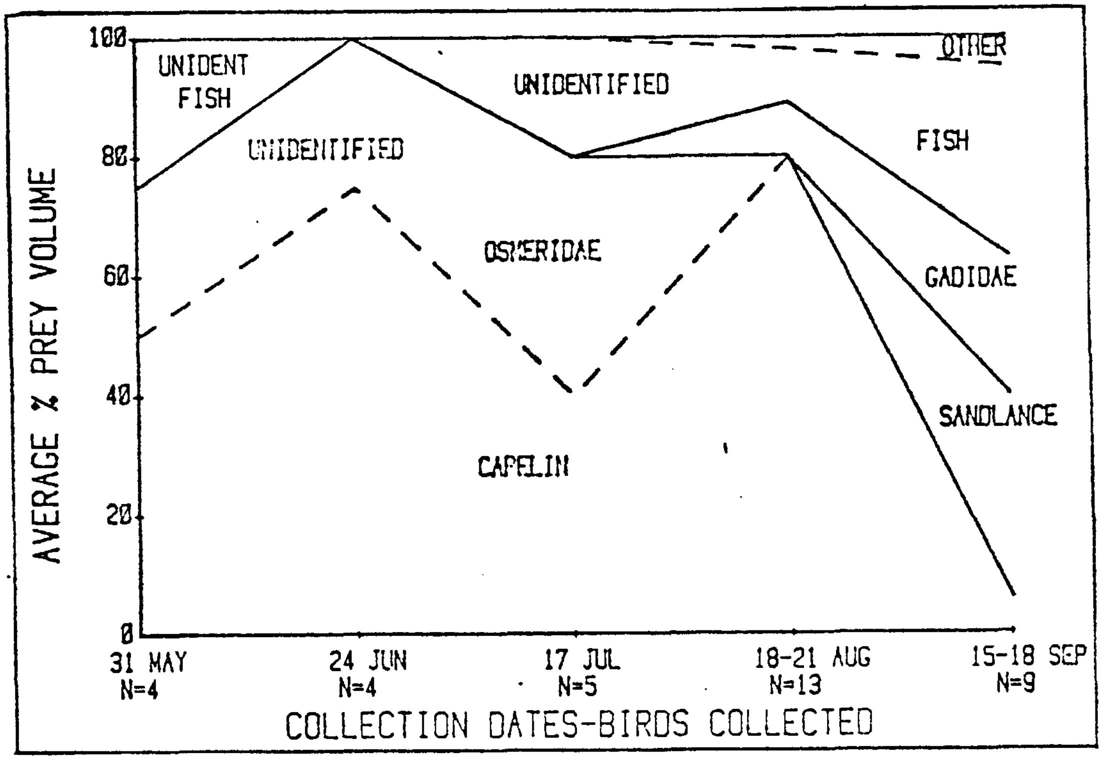

Figure 20. Seasonal changes in percent volume of prey in Black-legged Kittiwakes from the Chiniak/Marmot Bay area of Kodiak Island, 1977.

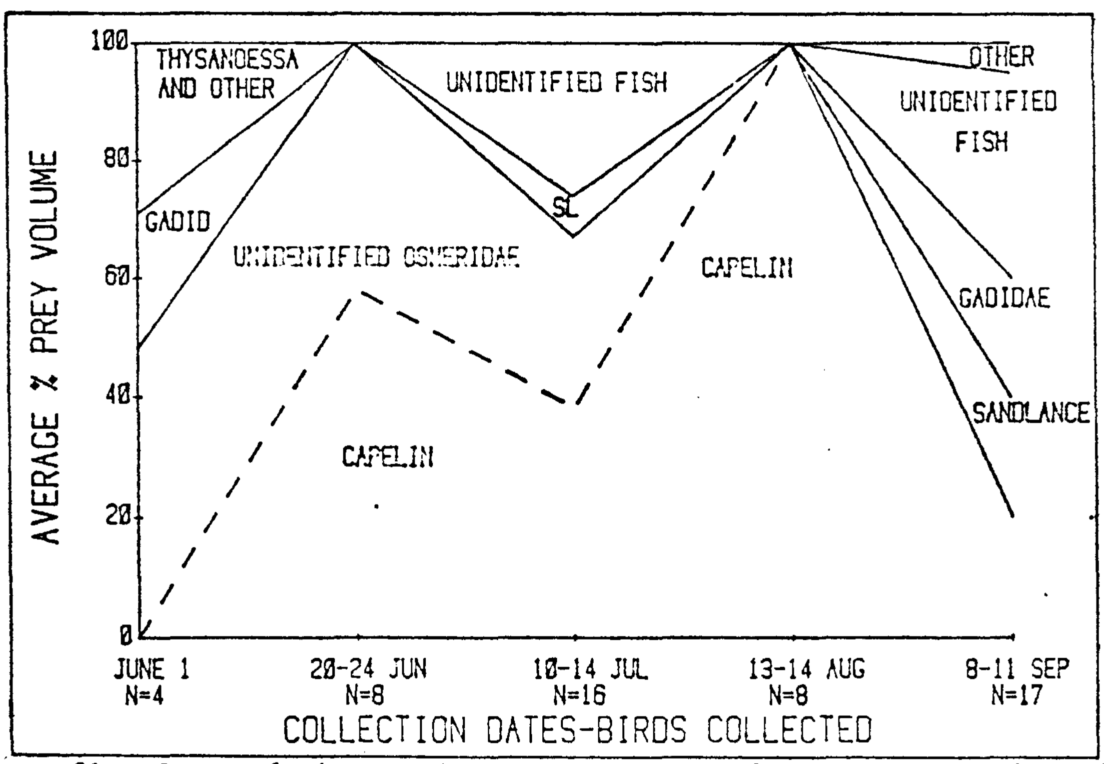

Figure 21. Seasonal changes in percent volume of prey in Black-legged Kittiwakes from the Sitkalidak area of Kodiak Island, 1977.

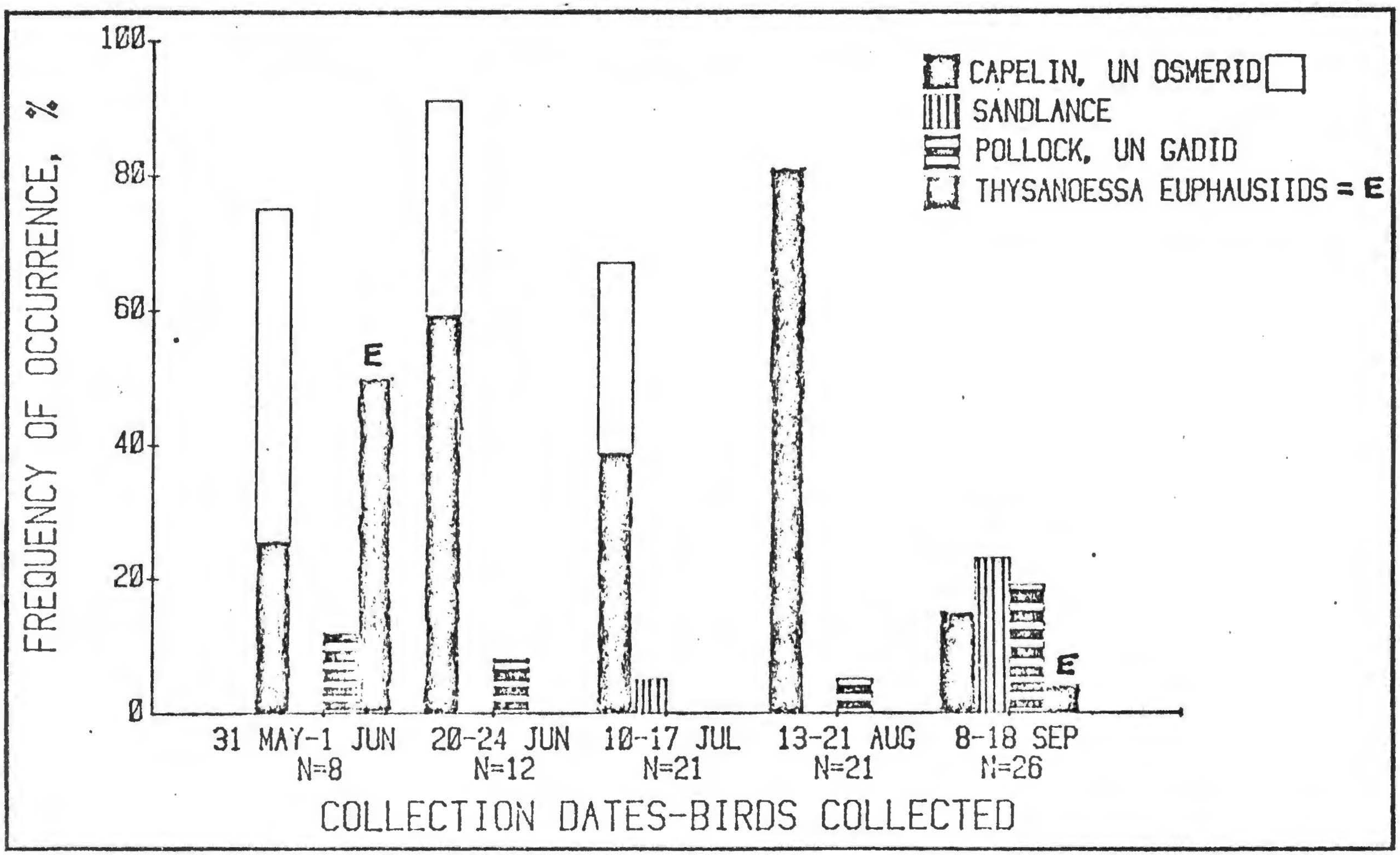

Figure 22. Seasonal changes in the frequency of prey in Black-legged Kittiwakes from the Kodiak Island area, 1977 (composite data).

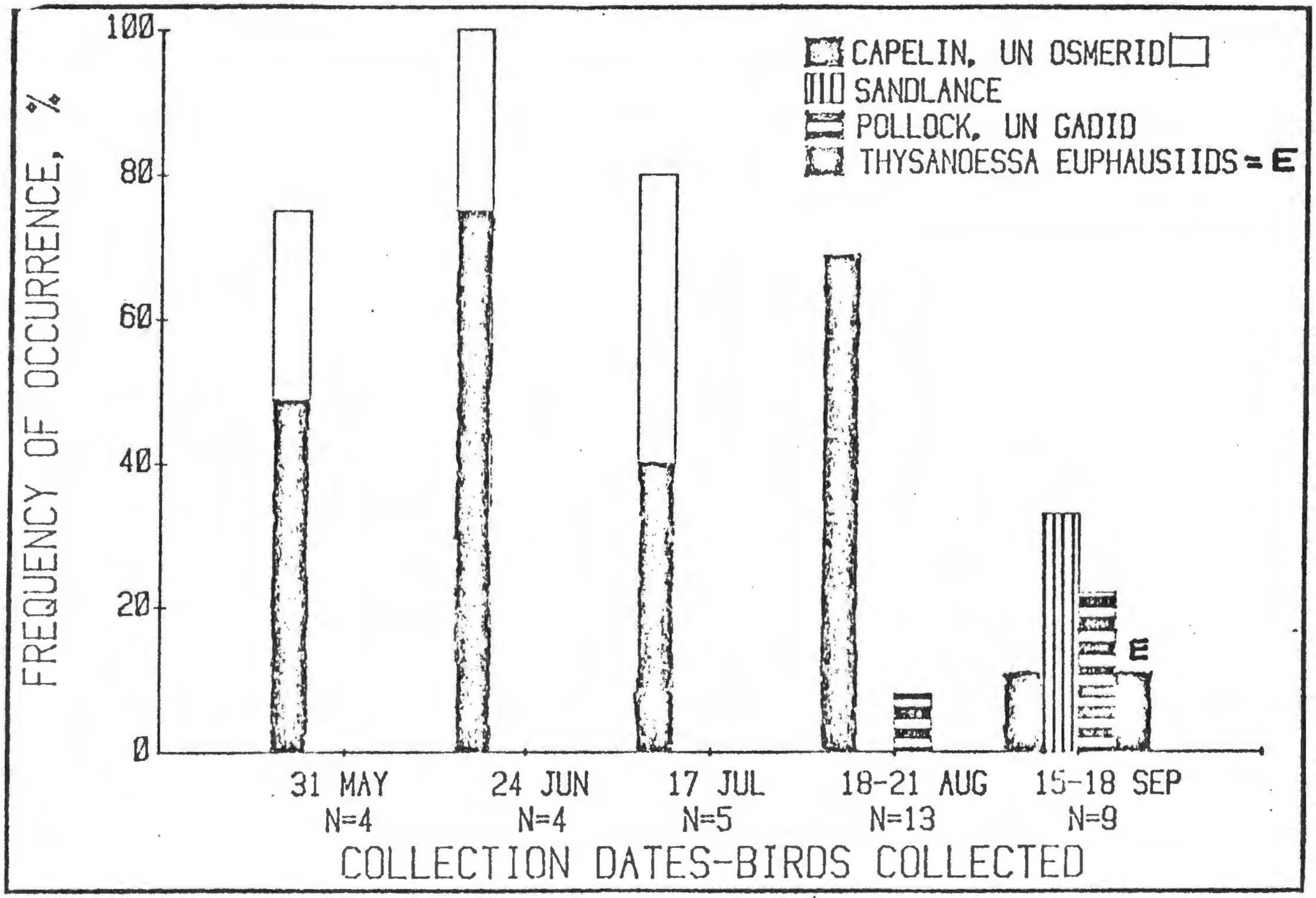

Figure 23. Seasonal changes in the frequency of prey in Black-legged Kittiwakes from the Chiniak/Marmot Bay area of Kodiak Island, 1977

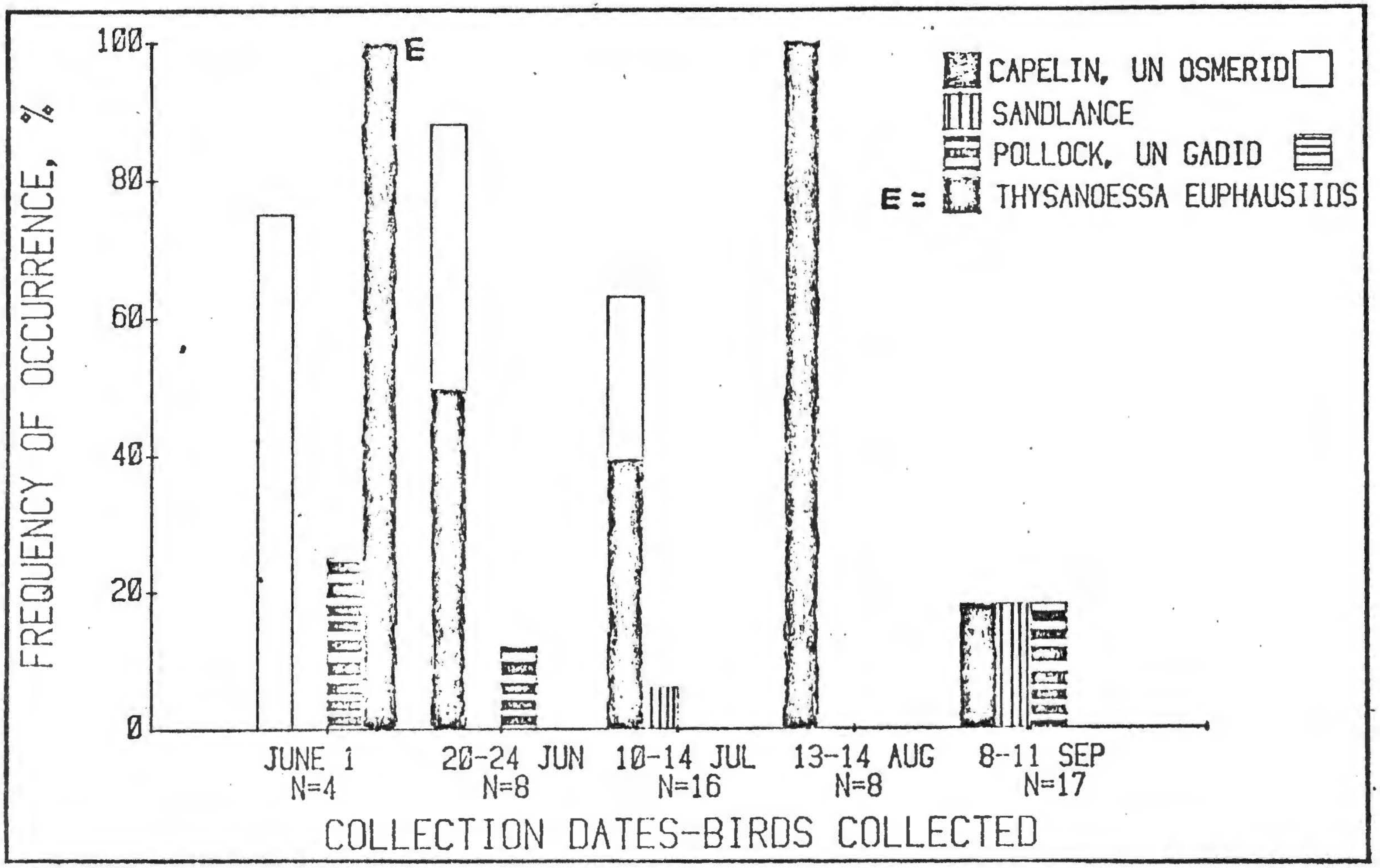

Figure 24. Seasonal changes in the frequency of prey in Black-legged Kittiwakes from the Sitkalidak area of Kodiak Island, 1977.

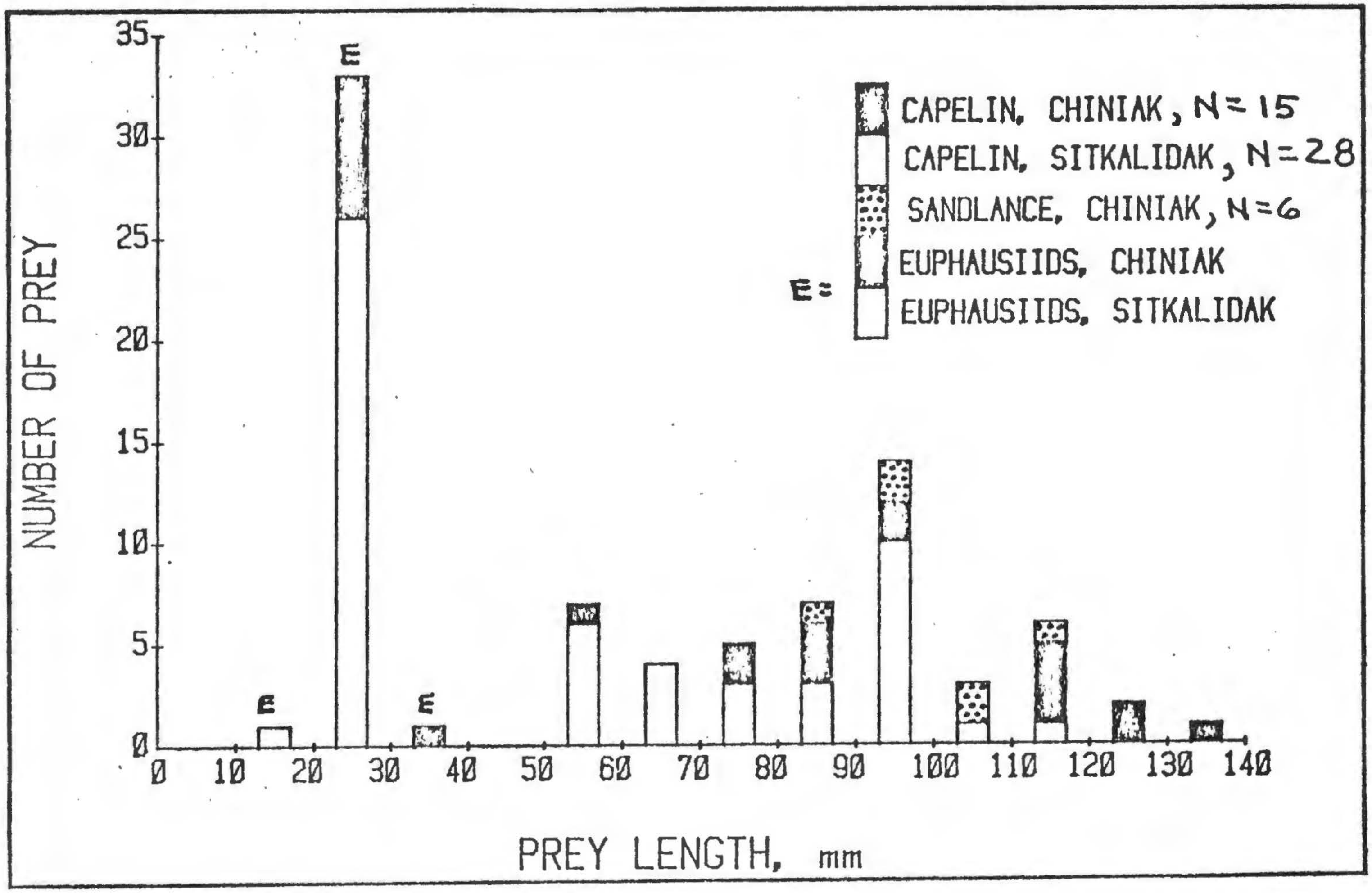

Figure 25. Length frequencies of prey in the stomachs of Black-legged Kittiwakes from the Kodiak Island area, 1977.

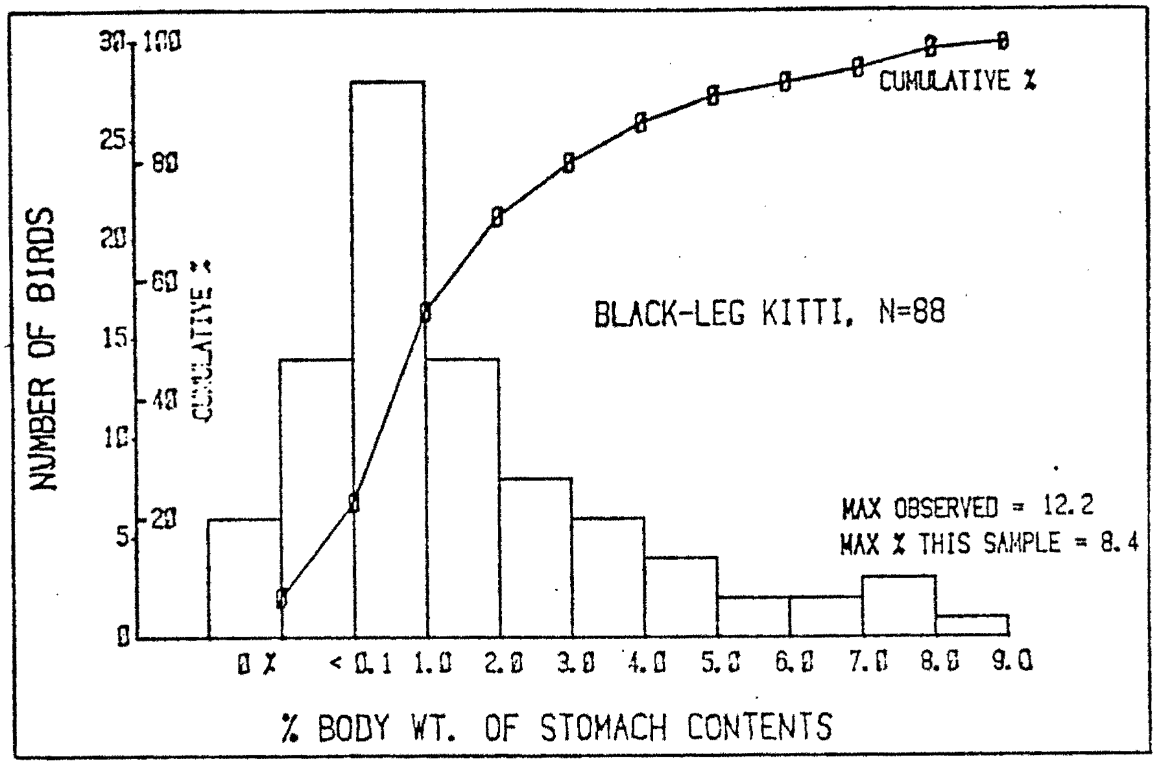

Figure 26. Weight of stomach contents as a percent of net body weight of Black-legged Kittiwakes from the Kodiak Island area, 1977.

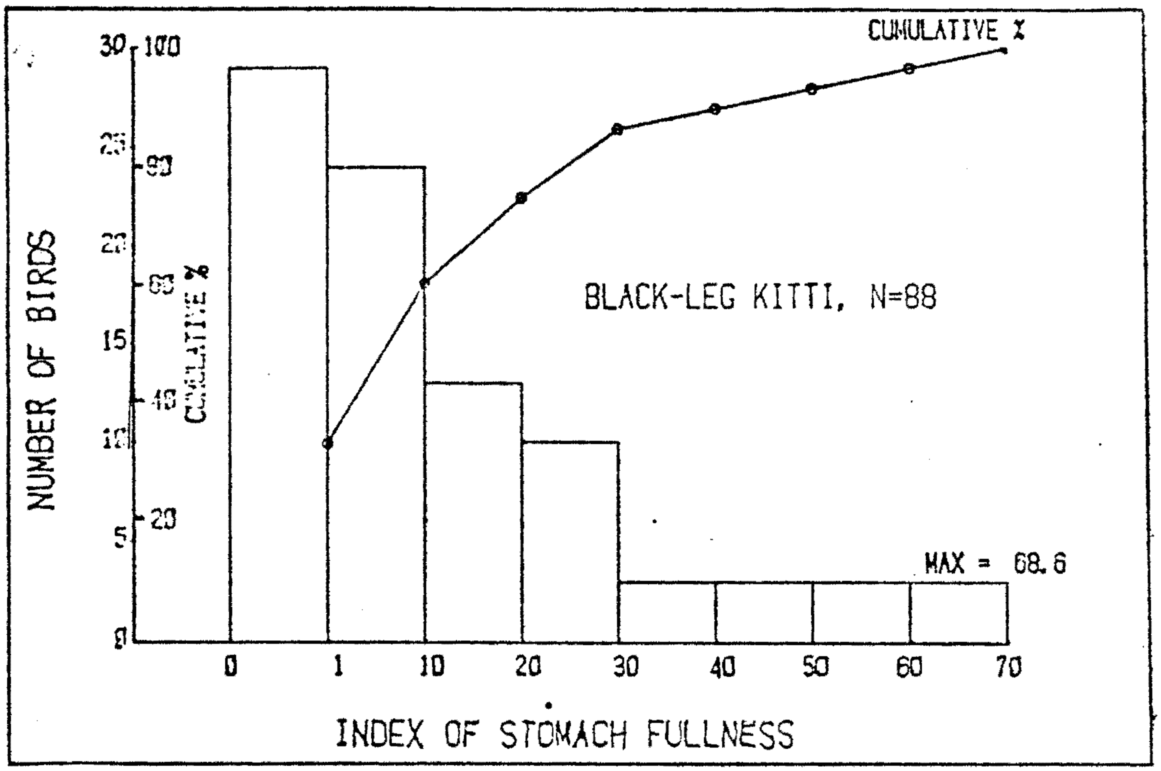

Figure 27. Index of stomach fullness for Black-legged Kittiwakes from the Kodiak Island area, 1977.

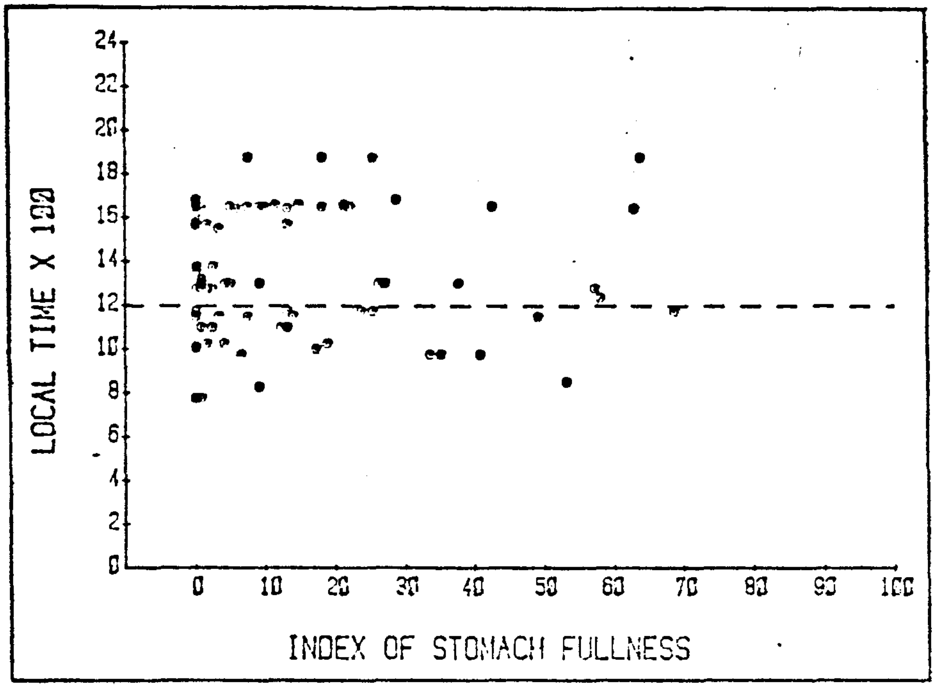

Figure 28. Relationship between the time of day of collection and the index of stomach fullness for Black-legged Kittiwakes from the Kodiak Island area, 1977

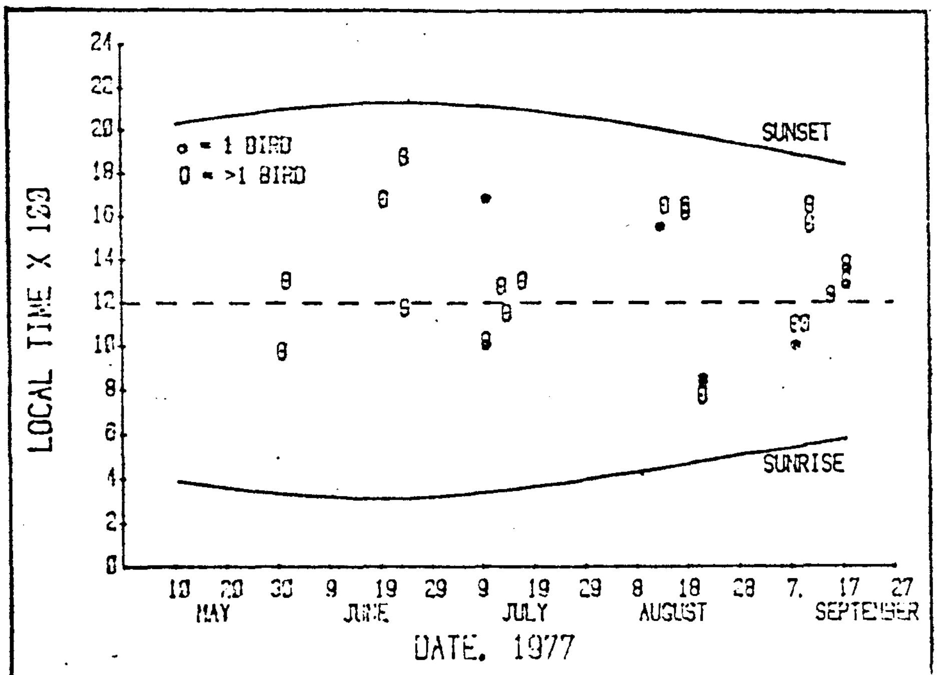

Figure 29. Relationship between the time of collection and date of collection for Black-legged Kittiwakes from the Kodiak Island area, 1977.

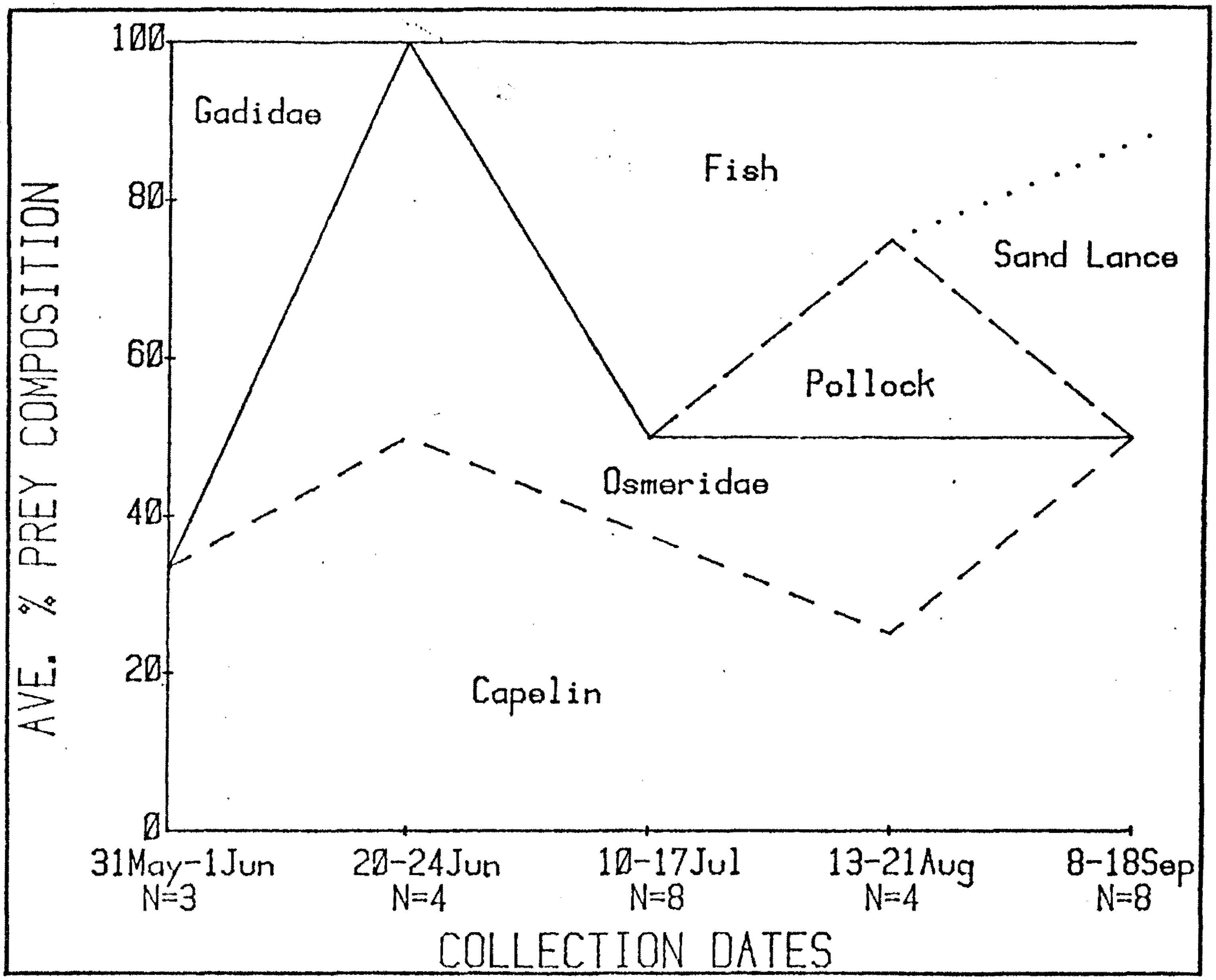

Figure 30. Seasonal changes in percent volume of prey in Common Murres from the Kodiak Island area, 1977.

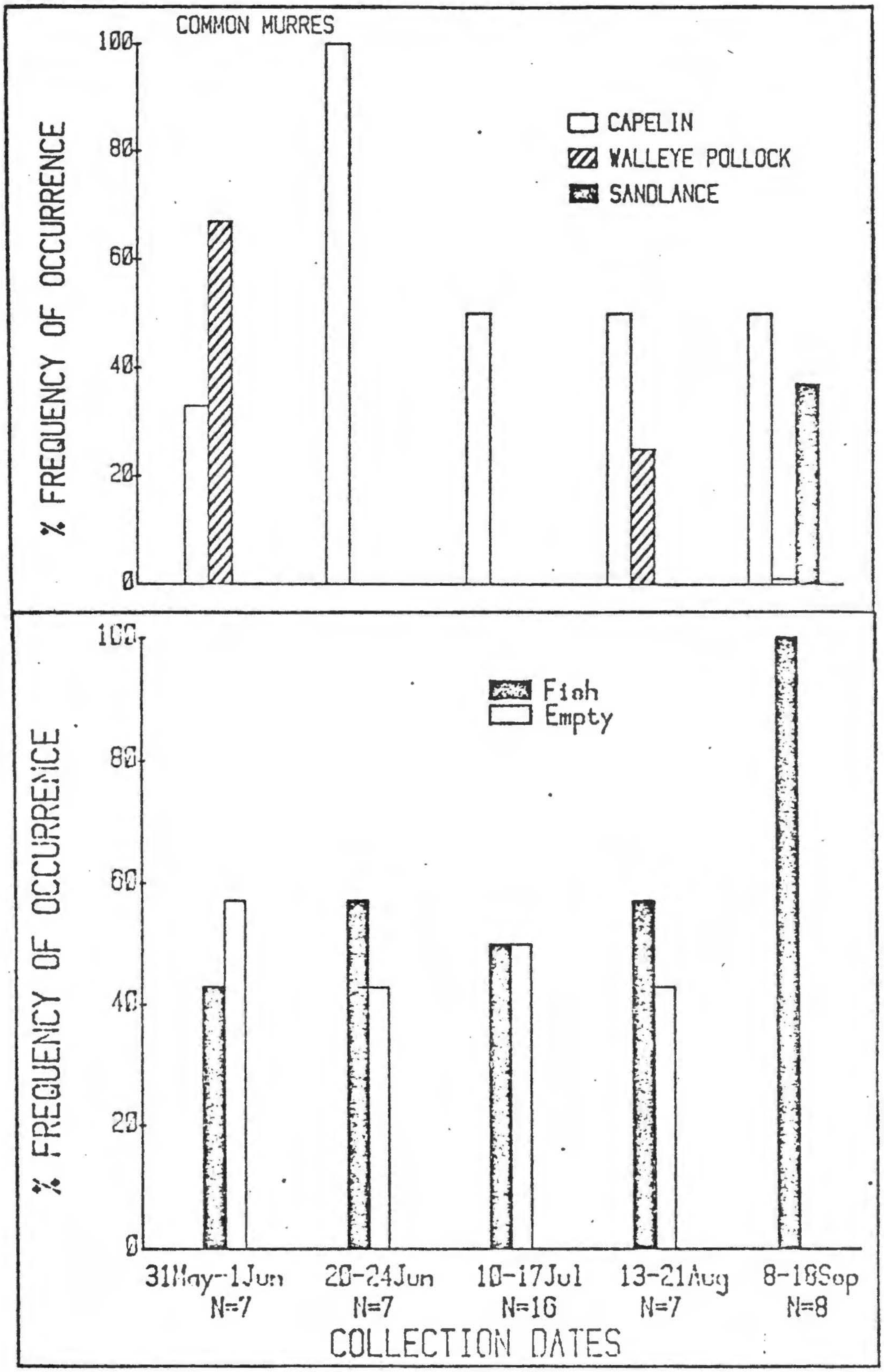

Figure 31 (bottom panel). Seasonal changes in the frequency of fish and empty stomachs in Common Murres from the Kodiak area, May-September.
Figure 32 (top panel). Seasonal changes in the frequency of fish prey in Common Murres from the Kodiak Island area, May-September 1977.

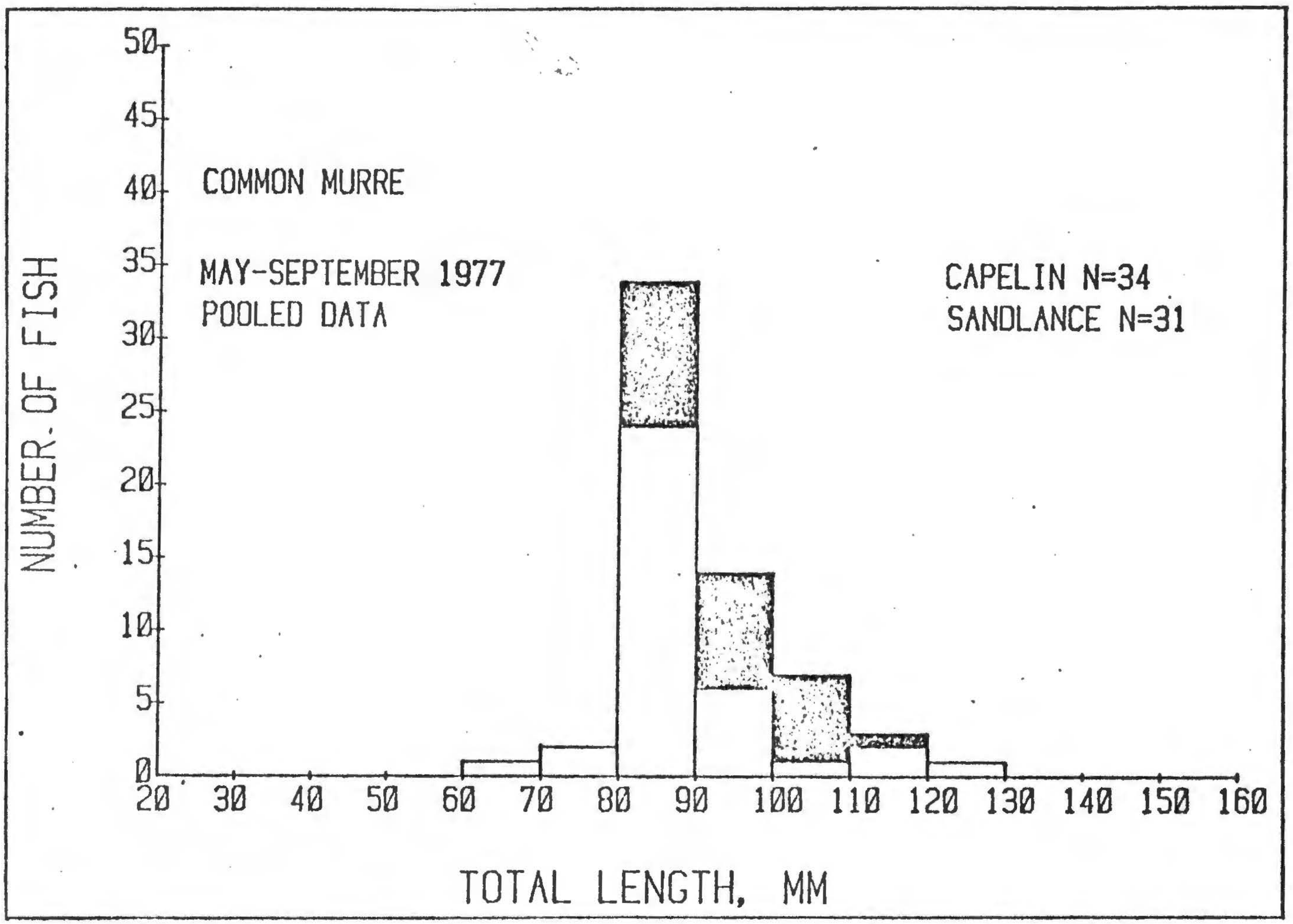

Figure 33. Length frequency of Capelin and Sandlance in the stomachs of Common Murres from the Kodiak Island area, 1977.

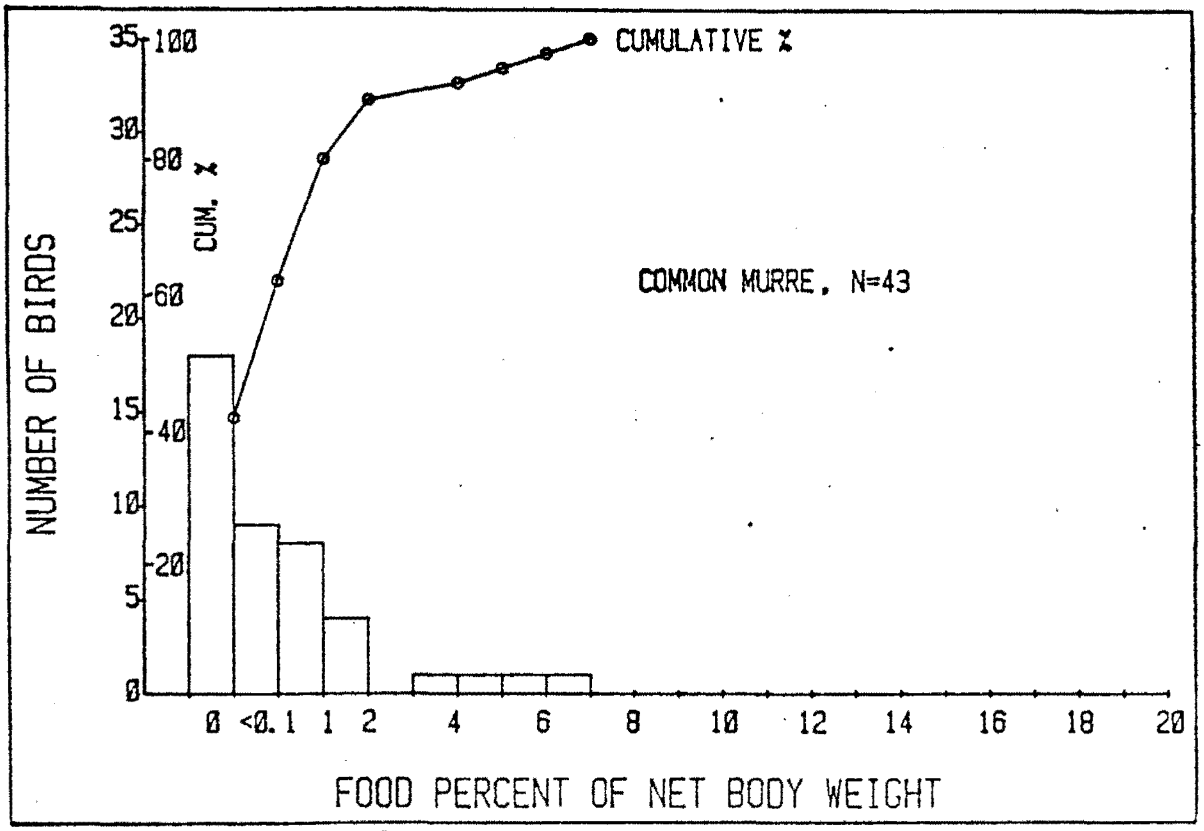

Figure 34. Weight of stomach contents as a percent of net body weight of Common Murres from the Kodiak area, May-September 1977.

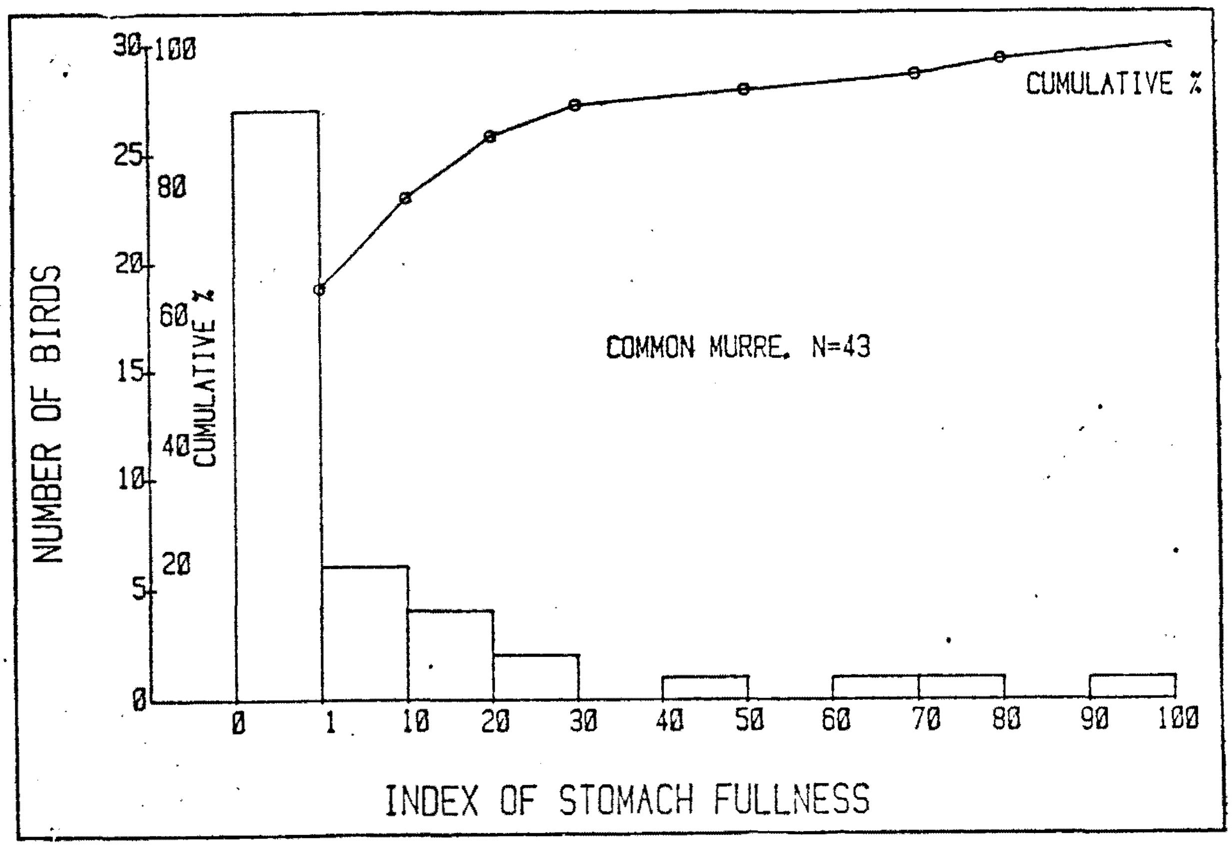

Figure 35. Index of stomach fullness for Common Murres from the Kodiak Island area, May-September 1977.

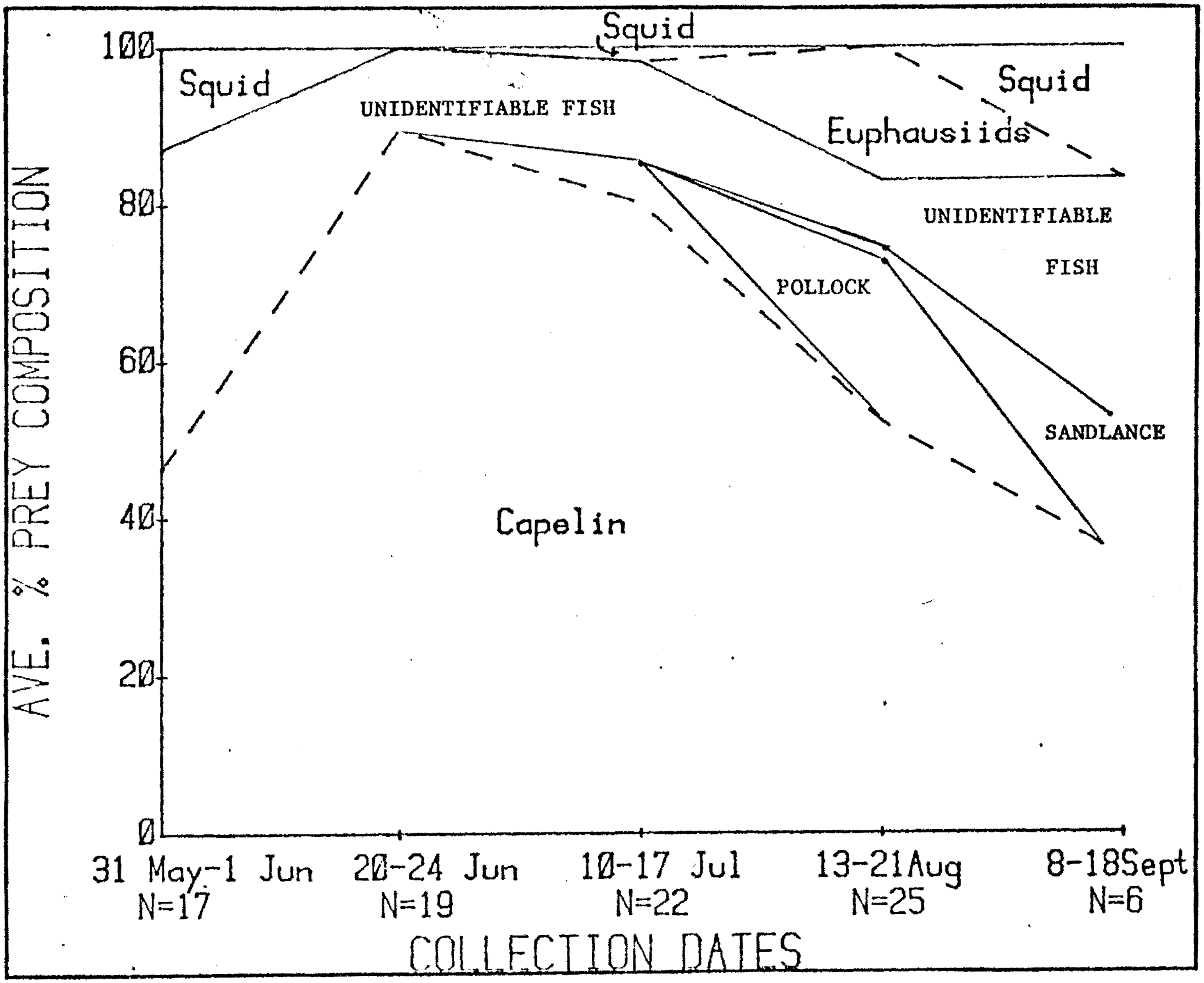

Figure 36. Seasonal changes in percent volume of prey in Tufted Puffins from the Kodiak Island area, May-September 1977.

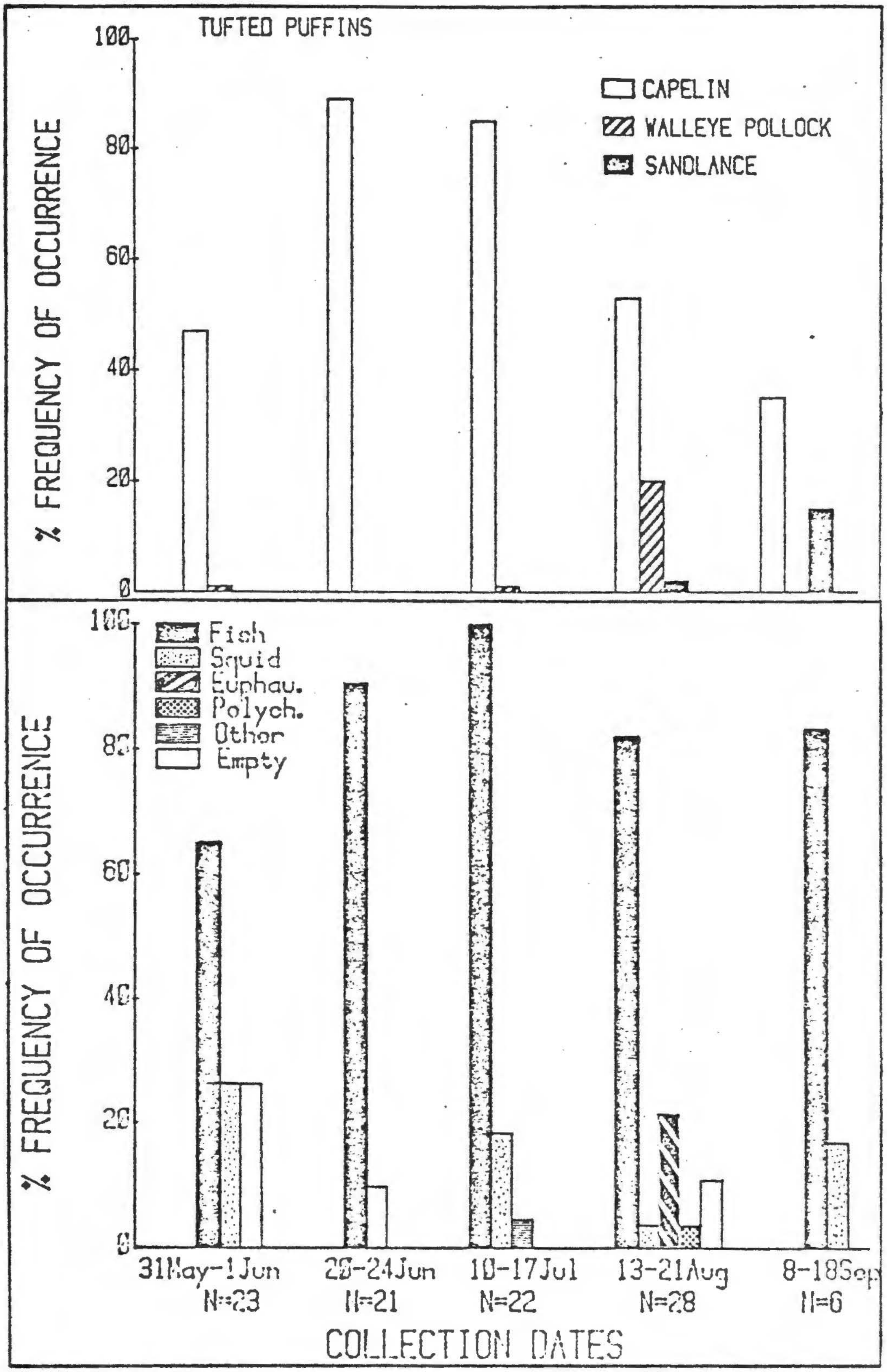

Figure 37 (bottom panel). Seasonal changes in the frequency of prey in Tufted Puffins from the Kodiak Island area, May-September 1977.
Figure 38 (top panel). Seasonal changes in the frequency of fish prey in Tufted Puffins from the Kodiak Island area, May-September 1977.

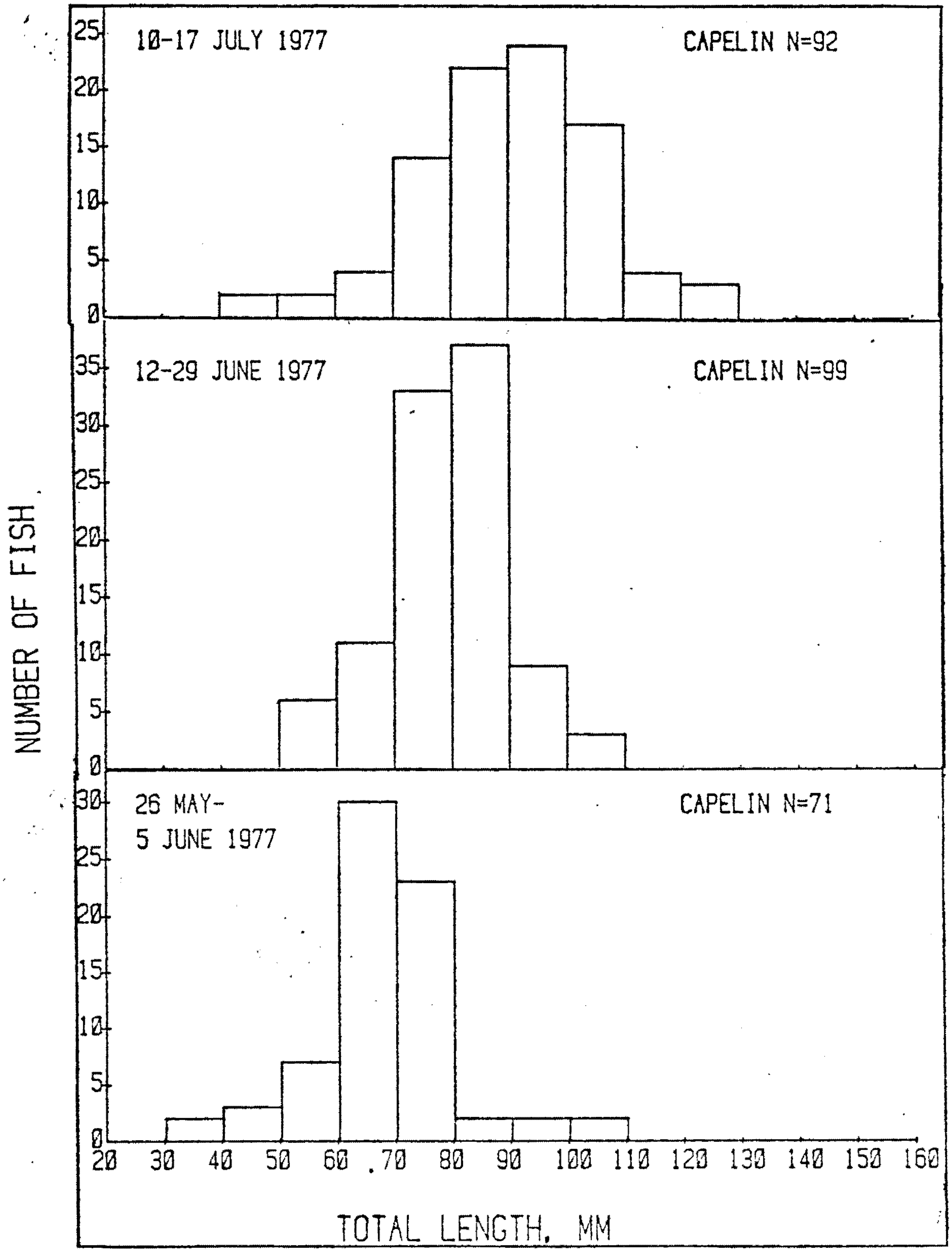

Figure 39. Length frequency of Capelin and Sandlance in the stomachs of Tufted Puffins from the Kodiak Island area, May-September 1977 (continued) . . .

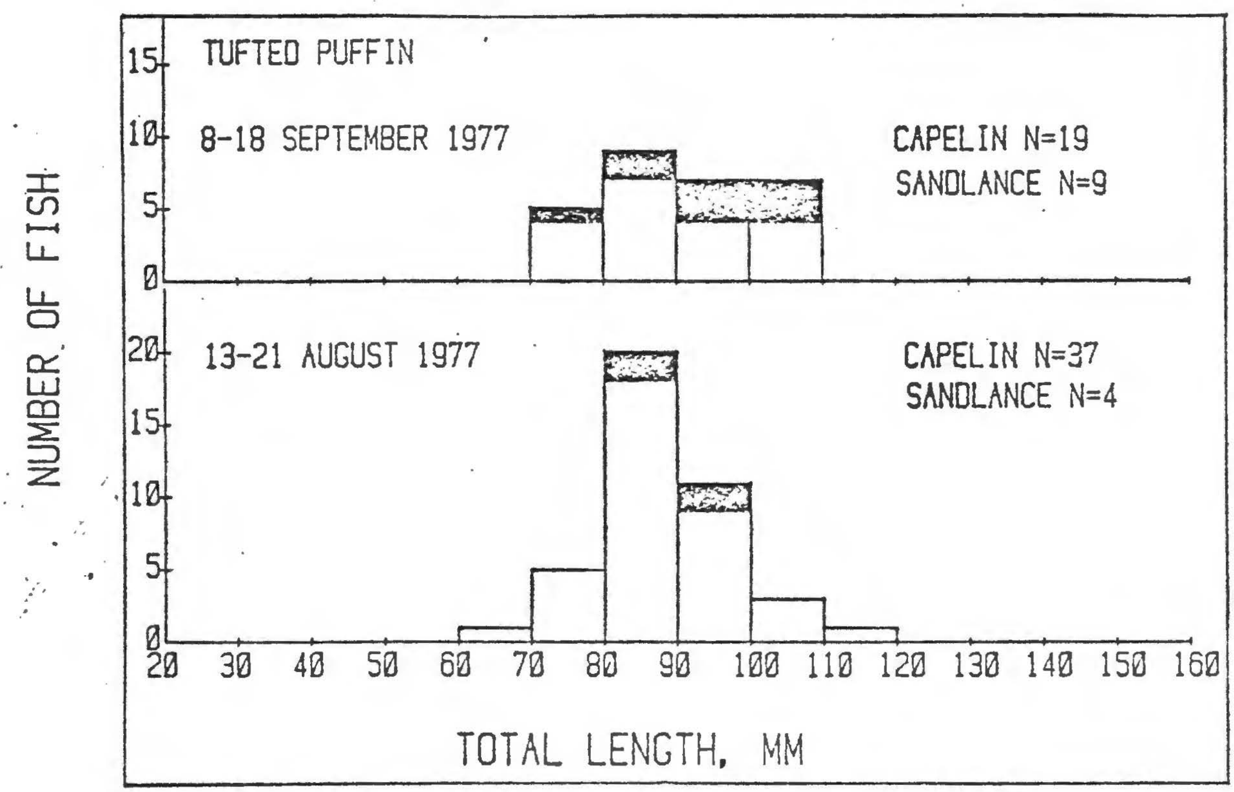

Figure 39 (cont'd). Length frequency of Capelin and Sandlance in the stomachs of Tufted Puffins.

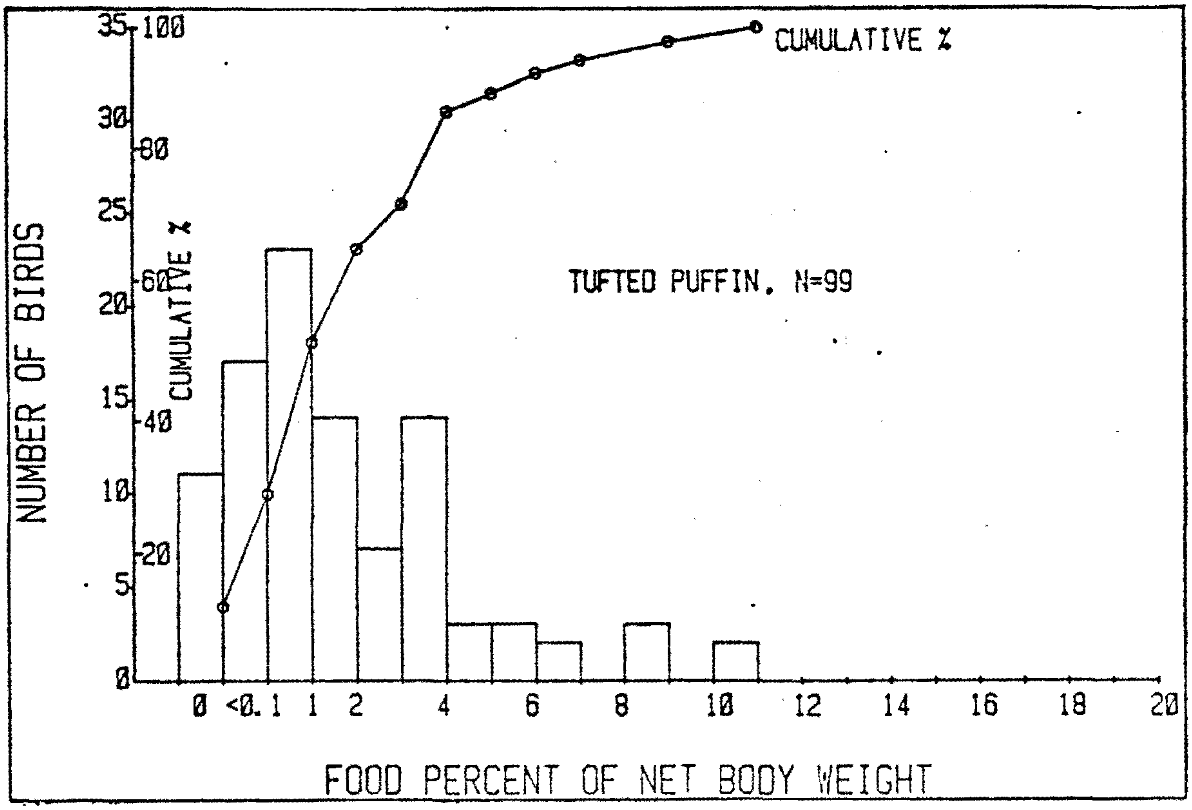

Figure 40. Weight of stomach contents as a percent of net body weight of Tufted Puffins from the Kodiak Island area, 1977.

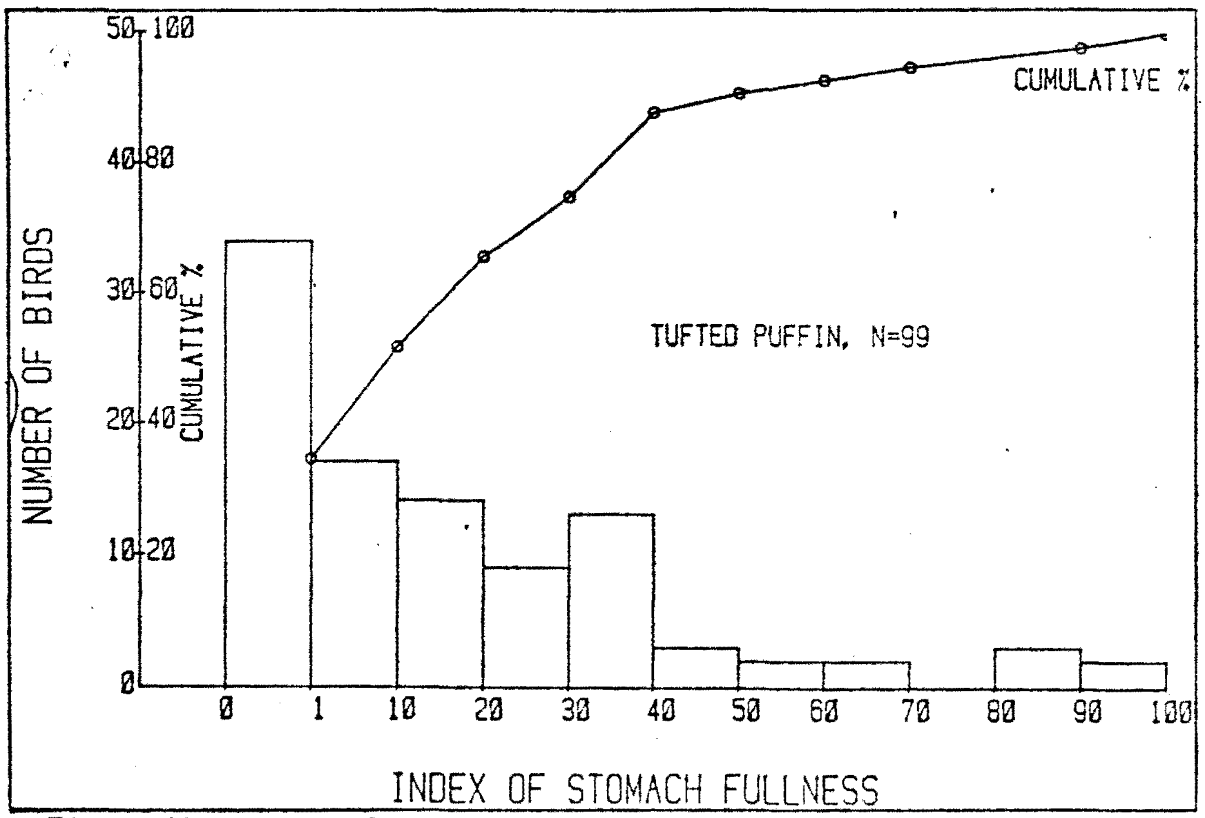

Figure 41. Index of stomach fullness for Tufted Puffins from the Kodiak Island area, 1977.

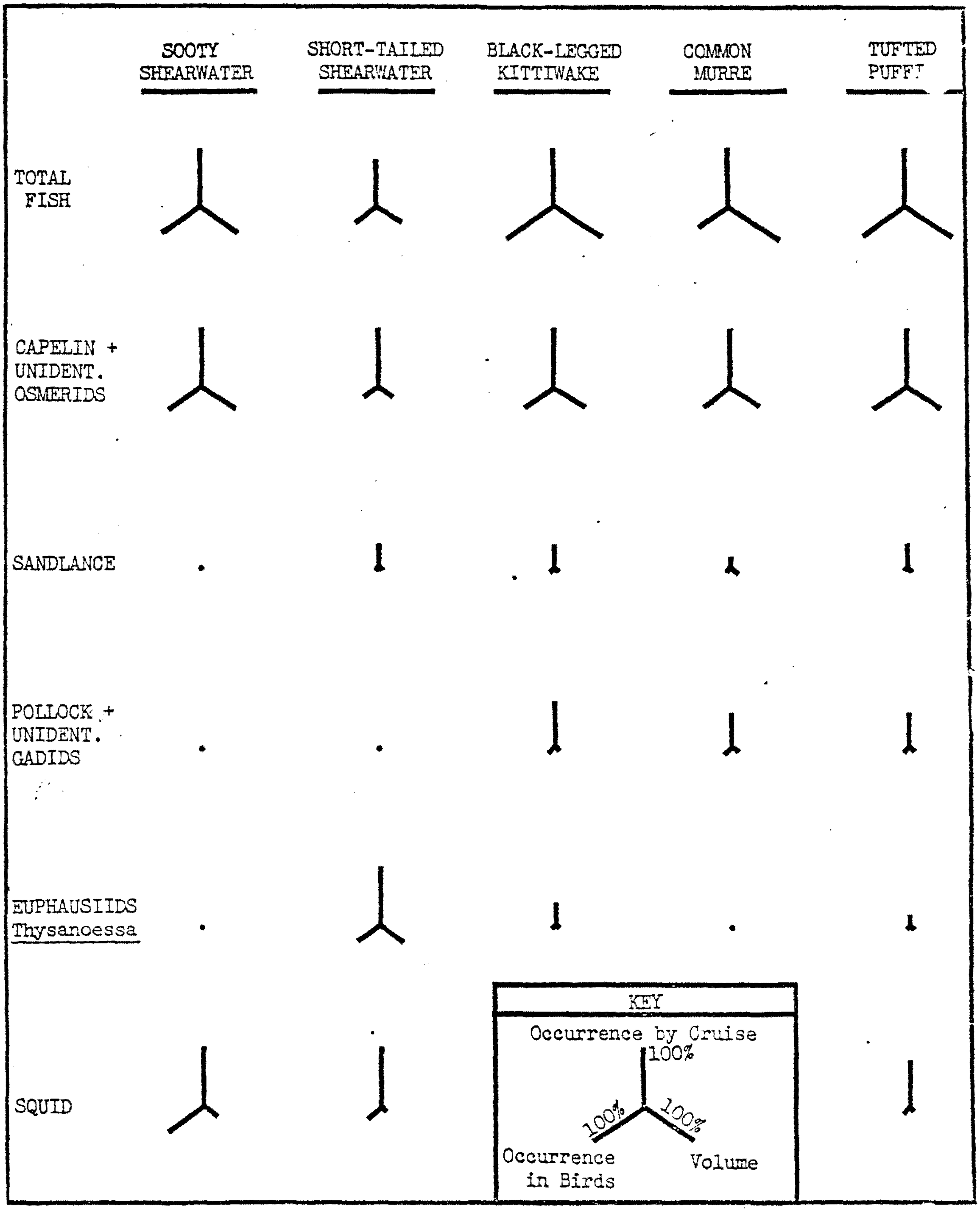

Figure 42. Summary of the aggregate percent volume, frequency of occurrence in the birds and frequency of occurrence by cruise for the five major prey types in the five key species of marine birds in the Kodiak area, 1977.

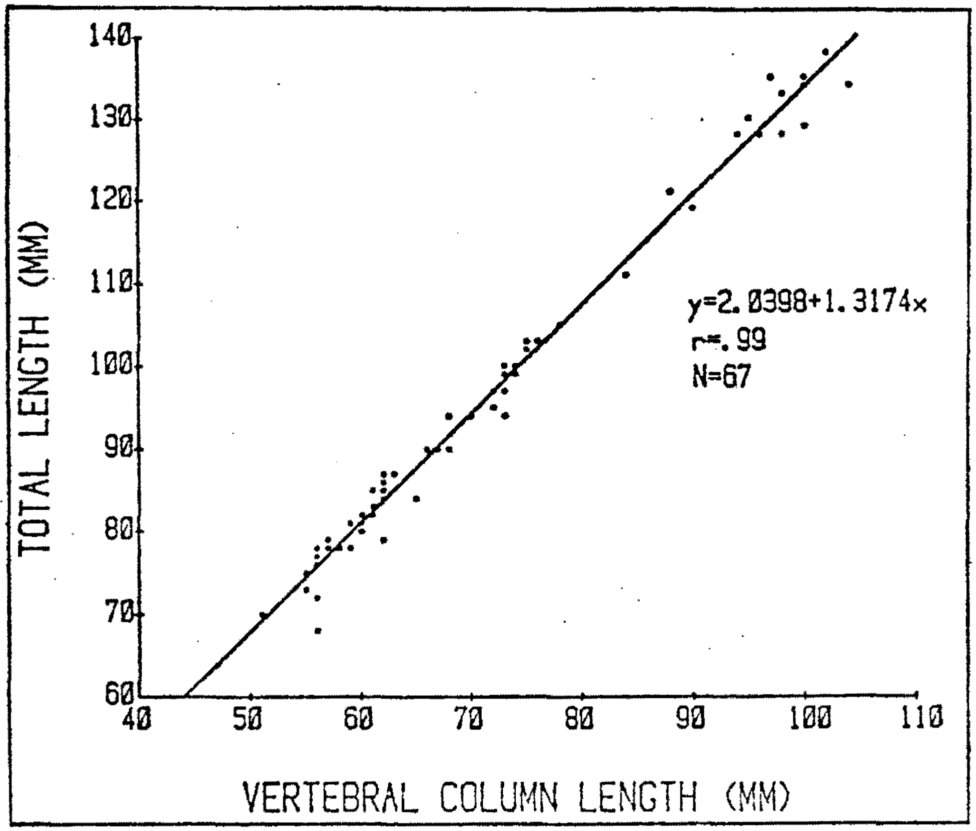

Figure 43. Relationship between total length and vertebral column length for Capelin.

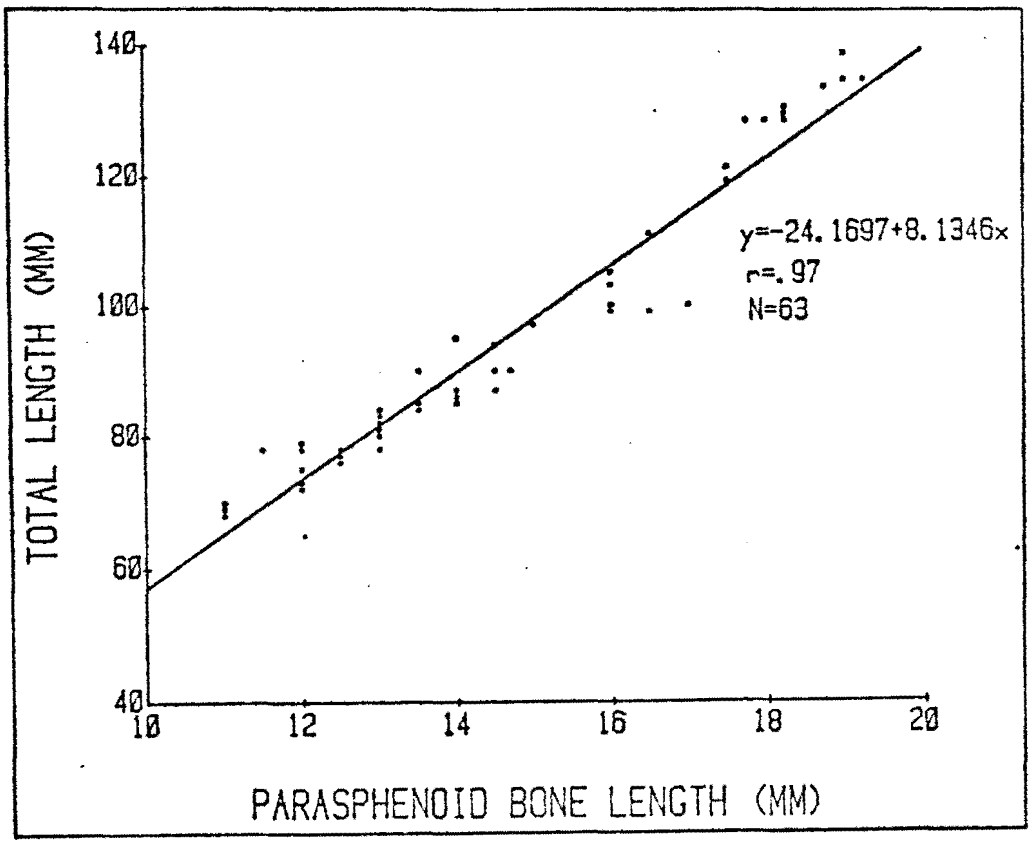

Figure 44. Relationship between total length and parasphenoid bone length for Capelin.

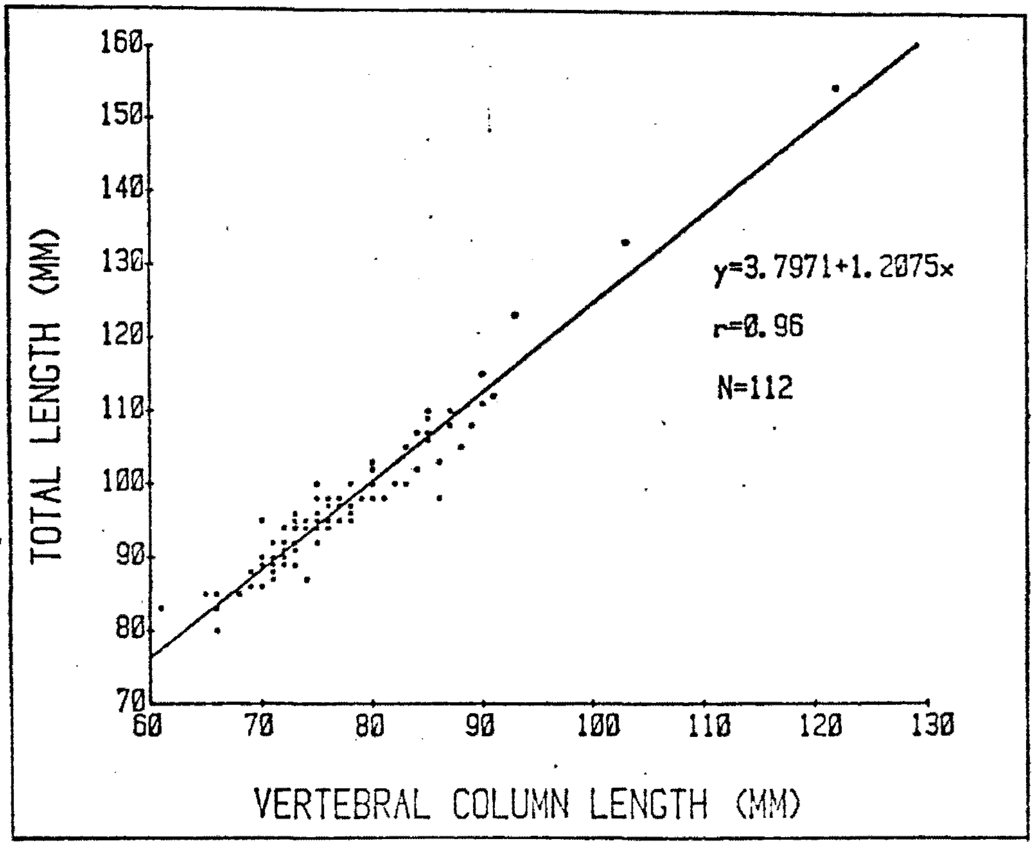

Figure 45. Relationship between total length and vertebral column length for Pacific Sandlance.

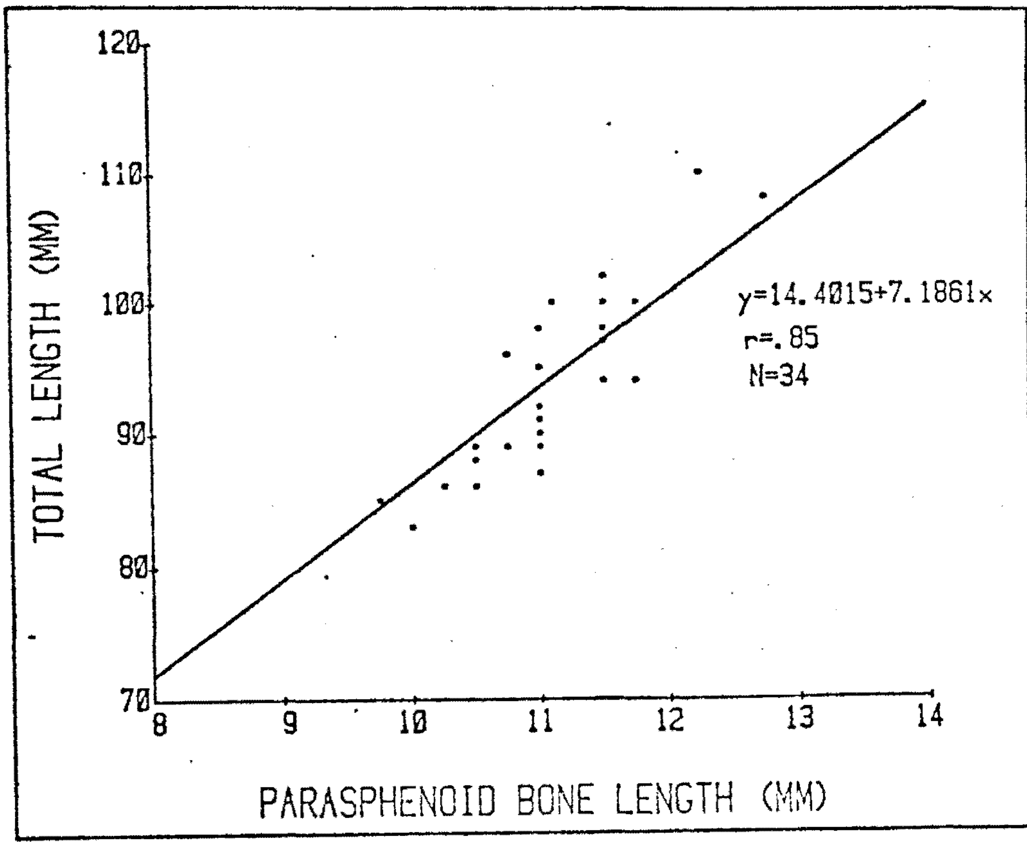

Figure 46. Relationship between total length and parasphenoid bone length for Pacific Sandlance.