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ABSTRACT

The food habits of the flathead sole *(Hippoglossoides elassodon)* in the eastern Bering Sea were investigated. Our analysis of 4,406 flathead sole stomachs containing food showed that the diet was composed primarily of organisms living on the bottom (epibenthic) and pelagic organisms in close association with the bottom (nektobenthic). Feeding shifted from a crustacean-based diet to an ophiuroid-based diet with increasing fish size. Flathead sole less than 30 cm total length (TL) consumed mainly mysids, gammarid amphipods, and decapod shrimps, whereas flathead sole larger than 30 cm total length (TL) consumed mainly ophiuroids, walleye pollock, and decapod shrimps. Diet composition varied with changes in bottom depth. Feeding in shallow waters (<50 m) was almost exclusively on small crustaceans and fish, but shifted to ophiuroids with increasing bottom depth for both size groups. The diet of flathead sole is indicative of a generalist feeding strategy. Dietary diversity ranged from moderately low to high as measured by Shannon-Weaver and Simpson’s diversity indices, and the diet appears to be influenced mainly by prey availability and abundance. Lower diversity values for flathead sole larger than 30 cm TL suggest that feeding becomes more selective as fish grow. Competition with other flatfish species in the eastern Bering Sea does not appear to be a major factor influencing the diet of flathead sole.

CONTENTS

INTRODUCTION

Flathead sole (Hippoglossoides elassodon) is a common pleuronectid fish occurring in the northeast Pacific Ocean, Gulf of Alaska, and the Bering Sea (Hart 1973). The species occurs throughout the eastern Bering Sea although abundance is greatest between bottom depths of 100-250 m (Allen and Smith 1988). Between 1979 and 1996, the estimated biomass of flathead sole[2] in the eastern Bering Sea increased almost sixfold, from 104,900 t to 616,400 t (Walters and Wilderbuer 1996). In 1996, flathead sole comprised nearly 10% of the total estimated flatfish biomass in the eastern Bering Sea. The large increase in population size over the last decade suggests that flathead sole is a key and increasingly important component of the benthic ecosystem of the region.

Throughout the past decade, the trend in fisheries management has been from a single-species management regime toward a more ecosystem-based approach. Livingston (1985) demonstrated the importance of quantitative data from food habits studies for developing more realistic multispecies population assessment and ecosystem models. Since the position of flathead sole in the trophic structure of the eastern Bering Sea is poorly understood, defining the trophic relationships between flathead sole and other fish and invertebrate species in the eastern Bering Sea is an important step in understanding the dynamics of the regional ecosystem. In addition, flathead sole are known consumers of several commercially important species in the Bering Sea, including walleye pollock (Theragra chalcogramma), snow crab (Chionoecetes opilio), and Tanner crab (Chionoecetes bairdi) (Livingston et al. 1986). Thus, results from this study may have direct implications for the management of some fisheries in the eastern Bering Sea.

Skalkin (1963) and Mineva (1964) examined the food habits of flathead sole in the Bering Sea, however these studies were qualitative and based on small sample sizes. Quantitative studies by Mito (1974), Livingston et al. (1986), and Lang and Livingston (1996) provided a more complete description of the diet, but they were restricted to either a single season, year, or geographic location. The objective of the current study is to provide a comprehensive, quantitative description of the food habits of flathead sole in the eastern Bering Sea based on data collected throughout the region across a 5-year time span. Spatial and die1 variations in feeding, predator size versus prey utilization, dietary diversity, the relationship of diet to morphology, competition with other flatfish species, and the impact of flathead sole predation on juvenile walleye pollock were all examined. Data from this study may be incorporated into dynamic models of the Bering Sea ecosystem which may ultimately provide better management of the region's fisheries.

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[2] Biomass estimates from National Marine Fisheries Service trawl surveys combine flathead sole with the morphologically similar Bering flounder (Hippoghsoides robustus). Thus, for the purposes of this study, H. robustus is not considered as a separate species.

METHODS AND MATERIALS

Stomachs were collected from 6,167 flathead sole in the eastern Bering Sea from 1984 through 1988 (Table 1, Fig.1). Sampling was conducted by National Marine Fisheries Service (NMFS) personnel during annual Alaska Fisheries Science Center research surveys and by foreign fisheries observers trained by the NMFS Foreign Fishery Observer Program (FFOP) working aboard foreign commercial trawlers. Samples from NMFS survey cruises were collected during daylight hours only with the exception of one cruise (see Table 1). Samples from FFOP cruises were collected throughout the 24-hour daily cycle, and all fish were collected by bottom trawl gear.

Fish showing signs of regurgitation (digested food items in the mouth or gill cavity or a flaccid or water-filled stomach) or net-feeding (freshly consumed prey items in the mouth or throat) were excluded from sampling. Stomachs from sampled fish were excised and placed into cloth bags with a specimen label containing sex, total length (TL), spawning condition (spawning or non-spawning) and station information. Stomachs were preserved in a 10% formalin solution buffered in seawater and transported to the Alaska Fisheries Science Center (AFSC) Food Habits Lab in Seattle, Washington, for analysis. Individual fish weights were not recorded at sea but were calculated using the formula:

$$W(g)=O.O040 \text{ x } L(cm)^{3.25g}$$

derived from the eastern Bering Sea flathead sole database of the AFSC's Resource Assessment and Conservation Engineering (RACE) Division.

Stomach contents were sorted, identified to the lowest practical taxonomic level, and counted. Prey digestion state and relative stomach fullness were recorded. The wet weight of each prey taxon was recorded to the nearest 0.001 gm after removing excess moisture by blotting on paper towels.

Description of the Diet

The detailed stomach content data were grouped into eight prey categories (i.e., euphausiids, decapods, mysids, miscellaneous crustaceans, ophiuroids, walleye pollock, other fish, and miscellaneous prey) to elucidate general diet trends by predator size and bottom depth. Preliminary analysis of the diet showed differences in prey utilization with ontogeny (see Pacunski 1990). In the present study, size-related feeding differences were examined by dividing samples into two size classes, (i.e., < 30 cm TL and 230 cm TL), referred to as small and large flathead sole, respectively. Overall analysis of the diet was based on 4,406 stomachs containing food. Due to interannual differences in the geographic locations of sampling from October to April, analysis of the diet by depth strata and die1 feeding were conducted using only data collected from May to September (n = 3,862, excluding empty stomachs). These months are reported as the main feeding period of flathead sole in the eastern Bering Sea by Moiseev (1953), and correspond with peak sampling by AFSC and FFOP observers.

The study area was divided into four strata for analysis of the diet by bottom depth: O-50 m, 51-100 m, 101-200 m, and greater than 200 m, and are referred to as the inner, middle, and outer continental shelves, and the continental slope, respectively (Fig. 1). These areas have been widely utilized in studies of the production processes of the eastern Bering Sea and correspond to approximate locations of major hydrographic fronts (Coachman 1986).

Major prey groups are described in terms of percent total stomach content weight (% W) and frequency of occurrence (%FO) and were computed for each sample group using the program ECO-INDEX (Vodopich and Hoover 1981). Both measures are used since it was felt that using only percent weight tends to underestimate the importance of small, rapidly digested organisms (e.g., mysids, euphausiids) or overestimate the importance of large, slowly digested prey (e.g., fish).

Die1 feeding was examined by separating sample data from both size groups into eight 3-hour time periods. A one-way analysis of covariance (ANCOVA) was performed on each size group to evaluate discontinuous feeding trends (Jenkins and Green 1977). Empty stomachs were excluded from this analysis for two reasons: 1) we were trying to characterize the behavior of fish that were actively feeding, and 2) to exclude any samples in which undetected regurgitation had occurred, which would bias the results.

Dietary diversity was measured based on the weight of major prey groups in the diet using the indices of Shannon-Weaver (1963) and Simpson (1949):

Shannon-Weaver $$H' = -\Sigma(x_i/X)\log(x_i/X)$$

Simpson $$s = 1/\Sigma(x_i/X)^2 \quad ,$$

where Xi = the weight prey category i, and X = the total weight of all prey categories. The Shannon-Weaver index measures species richness and species evenness and is most sensitive to changes in rare categories. The maximum value of H' = log 8 (where 8 = the number of prey categories) and is attained when all categories are evenly represented in the diet (Peet 1974). Simpson's index measures dominance and compliments the Shannon-Weaver index by being sensitive to changes in the most common prey categories (Peet 1974). Values of s approaching 1 indicate dominance of the diet by a single prey group, while values approaching 8 (the number of prey categories) indicate homogeneity of the diet. The calculated

Shannon-Weaver values were subjected to a t-test (Zar 1984) to compare dietary diversity between size classes within depth strata as possible evidence of resource partitioning.

RESULTS

In total, 6,167 flathead sole stomachs were examined, of which 29% (n = 1,761) were empty. Prey items identified from the remaining 4,406 stomachs containing food represented 177 taxa from 11 phyla (Appendix). In terms of the major prey groups consumed, ophiuroids (brittlestars) were the principle component of the diet, comprising 47% of the diet by frequency of occurrence and 42 % by weight (Table 2). Large crustaceans, mainly shrimp (families Crangonidae and Pandalidae) and hermit crabs (family Paguridae), were the second most common prey item (33 % FO) and accounted for 13 % of the diet by weight. Mysids and miscellaneous crustaceans (mainly gammarid amphipods) were also common prey items (19 % and 29% FO), but together comprised less than 3 % of the diet by weight. Juvenile walleye pollock (ages 0 and 1) were uncommon (8 % FO) but comprised 20 % of the diet by weight. Fish other than walleye pollock were slightly more common (11% FO) but less important in terms of weight (11%). Polychaetes, bivalve clams, and fishery processing offal (fish remains from commercial fishery operations) constituted the majority of the miscellaneous prey category (33 % FO, 11% W). As a group, these foods appear to be significant in the overall diet; however, polychaetes accounted for over one-half of the percent frequency of occurrence of this group but made up less than 2% of the diet by weight. Conversely, bivalve clams and fishery offal were responsible for 7% of the diet by weight but occurred in only 7% of the stomachs examined.

Feeding and Bottom Depth

Diet composition varied between depth strata (Figs. 2 and 3) for the two size groups. At bottom depths less than 50 m the diets of both size groups were composed almost exclusively of crustaceans and fish. Mysids and decapods were the most common prey items, whereas walleye pollock and decapods predominated by weight. Euphausiids were also important to large flathead sole in shallow waters.

A distinct change in feeding occurred in the middle shelf area (bottom depths 51-100 m) as marked by the appearance of ophiuroids in the diet (Figs. 2 and 3). No single prey group dominated the diet of small fish at these depths, with miscellaneous crustaceans, mysids, miscellaneous prey, decapods, and ophiuroids all being common prey items (25 % to 40 % FO). Walleye pollock was the least common prey item (4 % FO), but it dominated the diet by weight (29 % W), followed by decapods (17 %) and ophiuroids (14 %). Large flathead sole fed mainly on ophiuroids (35 % FO, 21% W), decapods (32% FO, 11% W), and walleye pollock (18% FO, 42% W).

In the outer shelf area (100-200 m), ophiuroids (54 % FO, 3 1% W) were the dominant prey of small flathead sole, although decapods (37% FO, 29% W) and miscellaneous prey (35% FO, 17% W) were also important. The diet of large flathead sole was dominated by ophiuroids (73 % FO, 63 % W). Miscellaneous prey and decapods were the next most common prey groups (32 % FO and 27 % FO) but together accounted for only 18 % of the diet by weight. Walleye pollock were found in < 8% of stomachs of both size groups and made up 10% and 13 % of the diets of small and large flathead sole, respectively.

In the continental slope zone (> 200 m), ophiuroids remained the dominant prey item of small flathead sole (62% FO, 62% W). Decapods occurred in 25 % of the stomachs and comprised 25 % of the diet by weight. Miscellaneous prey and miscellaneous crustaceans were common prey items (28 % and 25 % FO) but made up < 5 % of the diet by weight. No walleye pollock were found as prey of small flathead sole at these depths. Consumption of ophiuroids by large flathead sole increased to 86% FO and 75 % W from the outer shelf area. Miscellaneous prey (55 % FO, 12 % W) and decapods (20% FO, 9% W) were the next most important prey, and walleye pollock (< 1% FO, 2 % W) were virtually absent from the diet of large fish at these depths.

Die1 Feeding

The mean percent body weight (%BWT) of stomach contents of small flathead sole decreased from post-midnight (0000-0259 h) to late morning (0900-l 159 h), then increased from morning to midnight, suggesting a possible diurnal feeding pattern (Fig. 4). No discernable pattern was seen for large flathead sole; the mean %BWT of stomach contents ranged between 0.8% and 0.95% except for the time periods 0300-0559 h and 1200-1459 h when the mean %BWT was 0.4% and 0.7%, respectively. Results of the ANCOVA on each size group showed no significant differences in stomach content weight between time periods after adjusting for fish weight.

Diet Diversity

Shannon-Weaver diversity indices for the overall diet based on percent weight were 0.804 for small flathead sole and 0.700 for larger fish. T-tests on Shannon-Weaver diversity indices showed significant differences (a = 0.05) between the diets of small and large flathead sole in the inner, middle, and outer continental shelf zones, but not in the continental slope zone (Table 3). At bottom depths greater than 50 m, the diet of small flathead sole was less diverse than large flathead sole, which can be attributed to the dominance of walleye pollock and decapods as prey. At bottom depths greater than 50 m, small flathead sole showed higher dietary diversity than larger fish due to the more even distribution of prey groups in the diet. Dietary diversity was highest for small flathead sole at bottom depths of 51-100 m, and for large fish at bottom depths less than 100 m. Both size groups showed lowest dietary diversity along the continental slope (> 200 m), where ophiuroids were the dominant prey consumed.

DISCUSSION

Flathead sole in the eastern Bering Sea consumed mainly invertebrates living on the bottom (epibenthic) and pelagic invertebrates in close association with the bottom (nektobenthic) invertebrates, and some demersally occurring fishes. Ophiuroids, shrimp, mysids, and gammarid amphipods were the most important invertebrate prey items identified in the present study. The majority of fish prey were juvenile walleye pollock, although rockfish (family Scorpaenidae), gunnels (family Stichaeidae), and a few flatfish (family Pleuronectidae) were consumed. Clams, polychaetes , and fish processing offal supplemented the diet but were not staple foods. Previous studies of flathead sole food habits in the eastern Bering Sea have shown similar results. By frequency of occurrence, Mineva (1964) found ophiuroids, shrimp, amphipods, fish remains (assumed to be fishery offal by the authors), and bivalves (Yoldia spp.) to be the main foods of flathead sole in the Bering Sea. We did not find high frequencies of bivalves in the diet, which may be due to the broader geographic distribution of sampling of our study. In terms of weight, Mito (1974) reported Ophiura spp. and Pandalus borealis to be the primary foods of flathead sole along the eastern Bering Sea continental slope. Livingston et al. (1986) found that in summer, flathead sole less than 25 cm consumed mainly crustaceans and walleye pollock (by weight), while the diet of larger fish was composed mainly of brittlestars (ophiuroids) and walleye pollock.

Miller (1970) and Flora (1980) reported that flathead sole feed benthopelagically in East Sound, Orcas Island, Washington, and Auke Bay, Alaska, respectively. Mysids were predominate in the diet in both areas, although shrimp and fish were also important. In contrast to our results, clams and polychaetes were important foods while ophiuroids were almost completely absent from the diet in both areas. Differences in prey assemblages between study areas probably account for these differences, although detailed information on the faunal communities of East Sound and Auke Bay are unavailable to support this hypothesis.

One size-dependent feeding pattern was apparent from our results; feeding on crustaceans was greater by small flathead sole, but shifted to ophiuroids as fish size increased. Mito (1974) observed the same trend in one group of flathead sole studied along the eastern Bering Sea continental slope. Miller (1970) reported size-dependent feeding by flathead sole in East Sound, Orcas Island, Washington; mysids were the main food of fish 40-179 mm TL, but as predator size increased, shrimps, then fishes (mainly herring) and clams became the most important foods, although mysids remained important to all size groups.

American plaice, Hippoglossoides platessoides, the ecological counterpart of flathead sole in the Atlantic Ocean (Allen 1984), undergoes a size-related feeding transition similar to that of flathead sole. Powles (1965) and Scott (1973) reported that the diet of American plaice in the Magdalen Shallows and Gulf of St. Lawrence, respectively, shifted from crustaceans to echinoderms with increasing fish size. Scott (1973) points out that this transition involves a change from highly nutritious to relatively poor-quality food groups, and hypothesized that the ease of capture and relative abundance of echinoderms compensates for their low nutritive value and thus supports the change in food habits. *Ophiura* sp. and *0. sarsi*, the dominant ophiuroids consumed by flathead sole in this study, are widespread along the outer shelf and continental slope regions of the Bering Sea, often occurring in enormous numbers (D'yakanov 1954). Consequently, Scott's (1973) hypothesis for American plaice may be applicable to flathead sole in the eastern Bering Sea.

The shift from crustaceans to ophiuroids in the eastern Bering Sea may also be a function of energy cost. One or a few small crustaceans may be sufficient to sustain small flathead sole; however, as fish grow, the energy expended to capture sufficient quantities of these organisms may exceed the energy obtained from their consumption, resulting in a transition to a more abundant and easily captured prey (i.e., ophiuroids).

Size-related changes in foraging behavior may result from the shift from highly mobile nektobenthic prey (crustaceans) to slow-moving epibenthic prey (ophiuroids) . At smaller sizes, flathead sole appear to utilize a pursuit-oriented strategy, whereas larger fish are probably searcher-grazers. Our results support Allen's (1984) characterization of flathead sole as an active ambusher/searcher/pursuer; however, this study is the first to propose differences in foraging behaviors between size groups.

Differences in diet composition between depth zones appear to be related to prey distribution. Quantitative results from this study confirm observations made by Skalkin (1963) that ophiuroids disappeared from the diet as flathead sole migrated to shallower waters. Ophiuroids do not occur in large numbers within the inner shelf of the eastern Bering Sea, but are dominant members of the faunal community at bottom depths greater than 50 m (D'yakanov 1954, Zenkevitch 1963, Ivanov 1964, Haflinger 1981, Stoker 1981). This distribution pattern, coupled with a decreasing availability of pelagic fish and crustaceans with depth, probably accounts for the absence of ophiuroids in the diet of flathead sole collected from the inner shelf region and the increasing utilization of these organisms by flathead sole in deeper waters. Conversely, the majority of mysids consumed by flathead sole in this study are described by Mauchline (1980) as inshore species, thus the predominance of these organisms in the diet at depths less than 50 m can be attributed to their greater abundance in shallow waters.

Euphausiids were generally of little importance as prey, which is likely due to their mainly pelagic nature (Mauchline 1980). However, at bottom depths less than 50 m, these organisms (mainly *Thysanoessa raschii)* made up a substantial portion of the diet of a few large flathead sole (n= 13) near the Alaska Peninsula. Smith et al. (1978) documented a high incidence of *T. raschii* in the diet of flathead sole collected from shallow waters near the Alaska Peninsula in the Gulf of Alaska. Similarly, Skalkin (1963) reported that yellowfin sole fed heavily on euphausiids in some areas of the eastern Bering Sea inner shelf, Due to the small sample size in our study, we cannot conclude with any confidence whether euphausiids are a major food of flathead sole in this area of the Bering Sea, or whether feeding on these organisms was an opportunistic response to a locally abundant resource.

Juvenile walleye pollock were most commonly consumed in the inner and middle shelf areas at bottom depths less than 100 m. Hydroacoustic surveys of juvenile walleye pollock in the eastern Bering Sea conducted in 1982, 1984, and 1985 showed that densities of age-0 walleye pollock were highest over the inner and middle shelf areas (Walters et al. 1988), and only small quantities of age-0 pollock were observed at depths greater than 100 m in 1979 and 1982 (Traynor 1986). Thus, the results of the present study should be expected assuming the spatial distribution patterns of age-0 pollock remains consistent on an annual basis. In contrast to our results, Mito (1974) reported that age-0 pollock made up 15 % (by weight) of the diet of 15l-250 mm flathead sole collected on the continental slope. However, his sample size was small, and, as seen from our results, a high weight percentage does not necessarily imply a high frequency of occurrence, making comparisons with the present study difficult.

Walleye pollock support the largest commercial fishery in the eastern Bering Sea, consequently, predation impacts on this species are an important concern of fishery managers. Juvenile walleye pollock were found in over 30% of the flathead sole stomachs collected from the inner and middle shelf regions. Since 35 % of the population of flathead sole occurs at bottom depths less than 100 m (Allen and Smith 1988), the impact of flathead sole predation on this species might be significant, and was therefore investigated (see Pacunski 1991). Estimates of the number of juvenile pollock consumed annually ranged from 7.1 billion to 9.9 billion fish between 1984 and 1986. In contrast; estimates of adult walleye pollock consumption of juvenile walleye pollock ranged from 118 billion to 624 billion for the same time period (Livingston 1991), about 20 to 90 times the number eaten by flathead sole. From these results, it was concluded that flathead sole predation does not significantly impact populations of juvenile walleye pollock in the eastern Bering Sea.

The use of diversity indices provided a quantitative measure of changes in flathead sole diet between depth strata. Diversity values were highest for small flathead sole between 51 m and 200 m bottom depth, corresponding to a more heterogeneous distribution of prey in the diet at these depths. Lower values in the shallowest and deepest zones are directly related to the two main prey groups in the diet; walleye pollock and decapods in the shallowest zone, and ophiuroids and decapods in the deepest zone (Figs. 2a-3b). Large flathead sole did not show the same pattern as small fish. Increasing bottom depth was accompanied by a decline in diversity values, which can be attributed to the increasing proportion of ophiuroids in the diet. Results of t-tests on calculated Shannon-Weaver indices indicated that, in terms of weight, the diet diversity values of small and large flathead sole were significantly different in all depth strata except the continental slope strata.

While most fish are specialized in their feeding to some extent, their actual diet is influenced by the availability of both common and uncommon prey items (Ivlev 1961). Feeding in generalist fishes is mainly a response to available food resources, whereas specialists feed primarily on a specific prey type (or types) regardless of abundance. Flathead sole in this study consumed a wide variety of prey ranging from clams and polychaetes to crustaceans, ophiuroids, and fish. As seen in the depth strata analysis, the diet of flathead sole corresponds well with the distribution of the major prey types consumed in this study. Our results generally support Allen's (1984) conclusion that flathead sole are generalist feeders, although results of diversity analyses indicate that large flathead sole are more specialized feeders than small flathead sole, especially between bottom depths of 50 to 200 m.

Ivlev (1961) suggests that competition with other fishes may play a significant role in influencing a fish's diet. Yellowfin sole *Pleuronectes asper*, rock sole *P. bilineata*, and Alaska plaice *P. quadrituberculatus* are the most abundant pleuronectids in the eastern Bering Sea. These species are similar in size to flathead sole and occur sympatrically in portions of their range. However, the diets of yellowfin sole, rock sole, and Alaska plaice are dominated by polychaetes and clams (Livingston et al. 1986, Lang 1992), prey rarely utilized by flathead sole. These three species have much greater spatial overlap with each other in the inner and middle shelf areas of the eastern Bering Sea than they do with flathead sole, whose distribution is greater over the middle and outer shelf areas.

Previous studies of pleuronectids have shown that alimentary tract morphology and food habits are highly interrelated. Moiseev (1953), DeGroot (1971), and Allen (1984) concluded that piscivorous flatfish generally have large, symmetrically opening mouths, large stomachs, and very short intestines, with benthic feeders being characterized by a small, downwardly protractile mouth, a medium-sized stomach, and an intestinal loop of moderate length and complication. Flathead sole fall somewhere in the middle of these two morphological types, possessing a large, almost symmetrically opening mouth, relatively large stomach and medium length intestine, and would be predicted to have a diet somewhere between piscivores and benthic feeders. With a diet comprised mainly of epibenthic invertebrates but including some fish, the food habits of flathead sole are consistent with the species' morphology. Yellowfin sole, rock sole and Alaska plaice conform to the morphology of benthic feeders (Allen 1984), thus the predominance of buried, benthic prey in their diets is predicted by DeGroot (1971).

Based on differences in prey utilization and morphological differences in feeding structures, we conclude that competition with sympatric flatfishes in the eastern Bering Sea is minimal and has little influence on the flathead sole diet. Food competition might occur more between flathead sole and some of the lesser-studied groundfish of the middle and outer shelf areas of the eastern Bering Sea such as zoarcids and cottids. More detailed dietary analysis of these species is warranted to better understand their role in benthic energy transfer in the eastern Bering Sea.

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Table l.-- List of cruises in the eastern Bering Sea where flathead sole stomachs were collected, 1984 -88.

Vessel	Cruise* Type	Collection Period	Total Stomachs
Chapman	AFSC	6\01\84 - 8\30\84	327
Shikashima Maru	FFOP	6\16\84 - 7\16\84	127
Alaska	AFSC	6\30\84 - 7\15\84	252
Zuiyo Maru	FFOP	8\20\84 - 10\15\84	64
Nishan Maru	FFOP	8\23\84 - 10\10\84	134
Miller Freeman **	AFSC	8\28\84 - 9\07\84	233
Soyo Maru	FFOP	9\06\84 - 10\04\84	305
Shikahima Maru	FFOP	9\18\84 - 10\02\84	140
Haruna Maru	FFOP	9\28\84 - 10\31\84	58
Tsuda Maru	FFOP	10\19\84 - 11\09\84	112
Pollux	FFOP	11\03\84 - 11\18\84	70
Miller Freeman	AFSC	1\23\85 - 2\14\85	102
Eikyu Maru #35	FFOP	4\23\85 - 4\25\85	47
Fukuho Maru #23	FFOP	4\30\85 - 5\03\85	84
Hokuyu Maru #68	FFOP	5\10\85 - 5\15\85	27
Akebono Maru #22	FFOP	6\11\85 - 6\22\85	92
Alaska	AFSC	6\13\85 - 6\21\85	80
Argosy	AFSC	7\06\85 - 8\13\85	523
Miller Freeman	AFSC	8\06\85 - 8\22\85	245
Zuiyo Maru #28	FFOP	8\11\85 - 8\25\85	72
Zuiyo Maru #2	FFOP	8\21\85 - 10\19\85	79
Hamayoshi Maru	FFOP	11\15\85 - 11\27\85	60
Gae Yang Ho	FFOP	5\07\86 - 5\08\86	30
Morningstar	AFSC	6\04\86 - 8\01\86	1240
Sunflower #7	FFOP	9\19\86 - 10\04\86	61
Oyang Ho	FFOP	10\24\86 - 11\07\86	39
Tymousk	FFOP	3\18\87 - 4\22\87	52
Shinan Ho	FFOP	4\11\87 - 5\13\87	60
Alaska	AFSC	6\02\87 - 7\30\87	250
Pat San Marie	AFSC	6\24\87 - 7\11\87	286
Miyajima Maru	FFOP	9\11\87 - 9\27\87	74
Tae Baek Ho	FFOP	9\29\87 - 10\03\87	75
Oyang Ho	FFOP	2\22\88 - 2\28\88	30
Salvia	FFOP	4\03\88 - 5\05\88	80
Mys Yudina	FFOP	4\26\88 - 4\26\88	18
Chikozen Maru	FFOP	4\29\88 - 5\19\88	55
Tenyo Maru	FFOP	4\29\88 - 5\22\88	30
Alaska	AFSC	6\06\88 - 7\29\88	405
Miller Freeman	FFOP	9\04\88 - 9\21\88	149

* AFSC = research surveys conducted by the Alaska Fisheries Science Center

FFOP = foreign commercial fishing monitored by the Foreign Fisheries Observer Program

**24-hour sampling period

Table 2 .--Percent by weight (% W) and frequency of occurrence (% FO) of major taxonomic groups consumed by flathead sole *Hippoglossoides elassodon* in the eastern Bering Sea from 1984 to 1988.

Prey Category	%W	%FO
Ophiuroids	42.1	47.3
Walleye pollock	20.2	7.5
Decapods	12.5	32.8
Misc. prey	11.4	33.6
Other fish	8.0	10.7
Euphausiids	3.3	7.9
Mysids	1.8	19.0
Misc. crustaceans	0.9	28.7

Table 3.--Diversity indices for two size groups (based on total length) of *Hippoglossoides elassodon*, by bottom depth, based on percent weight of prey in diet.

	Shannon-Weaver			Simpson	
Bottom Depth	<30 cm	230 cm		< 30 cm	230 cm
<50m	0540	0665	**	2.951	4.319
51-100 m	0:826	0:665	***	5.804	3.725
101-200 m	0.736	0.506	***	4.473	2.220
>200 m	0.446	0.379	n.s.	2.106	1.720

** P< 0.01, *** P< 0.001, n.s. = not significant

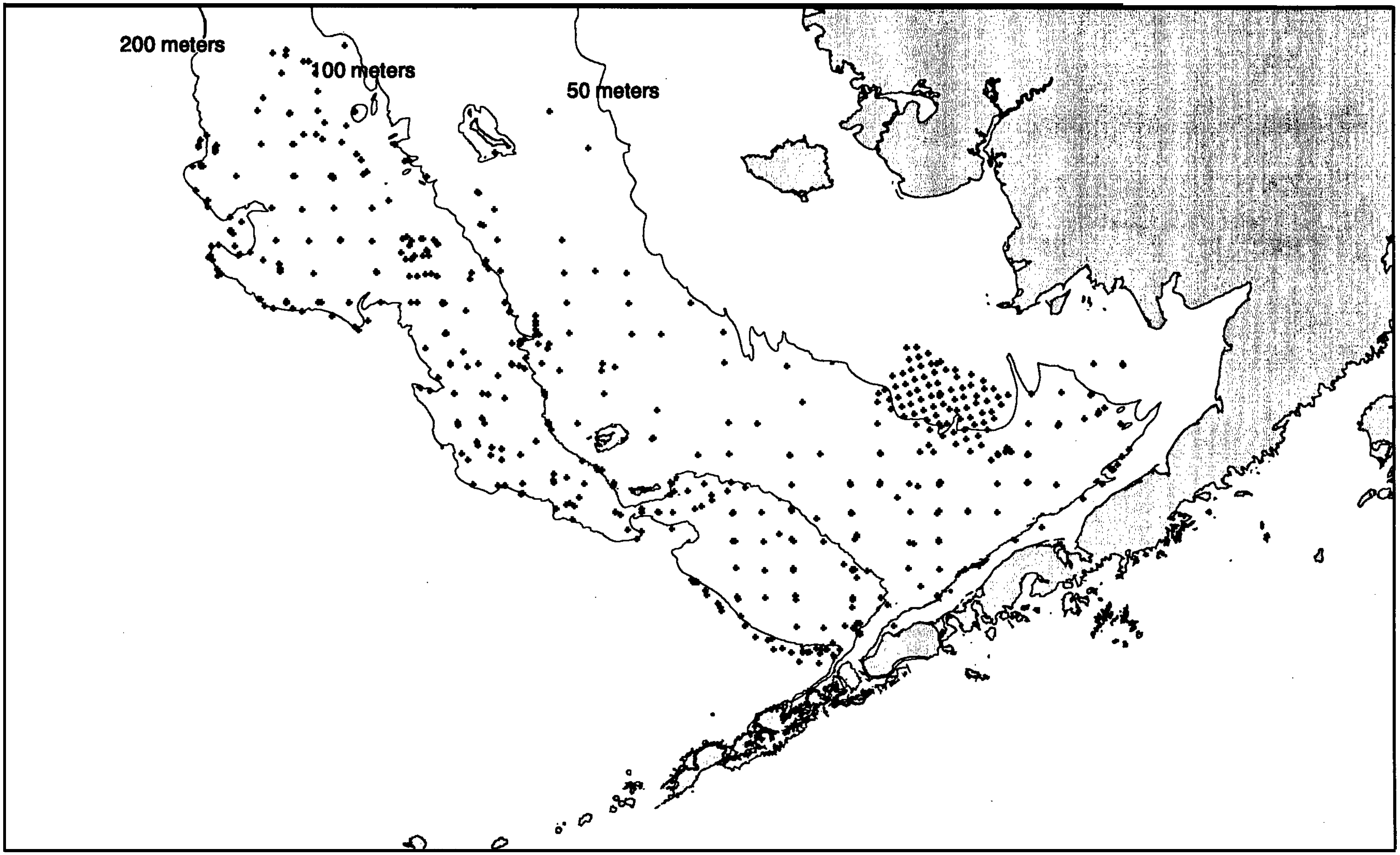

Figure 1.--Sampling locations for flathead sole stomachs in the eastern Bering Sea from 1984 to 1988.

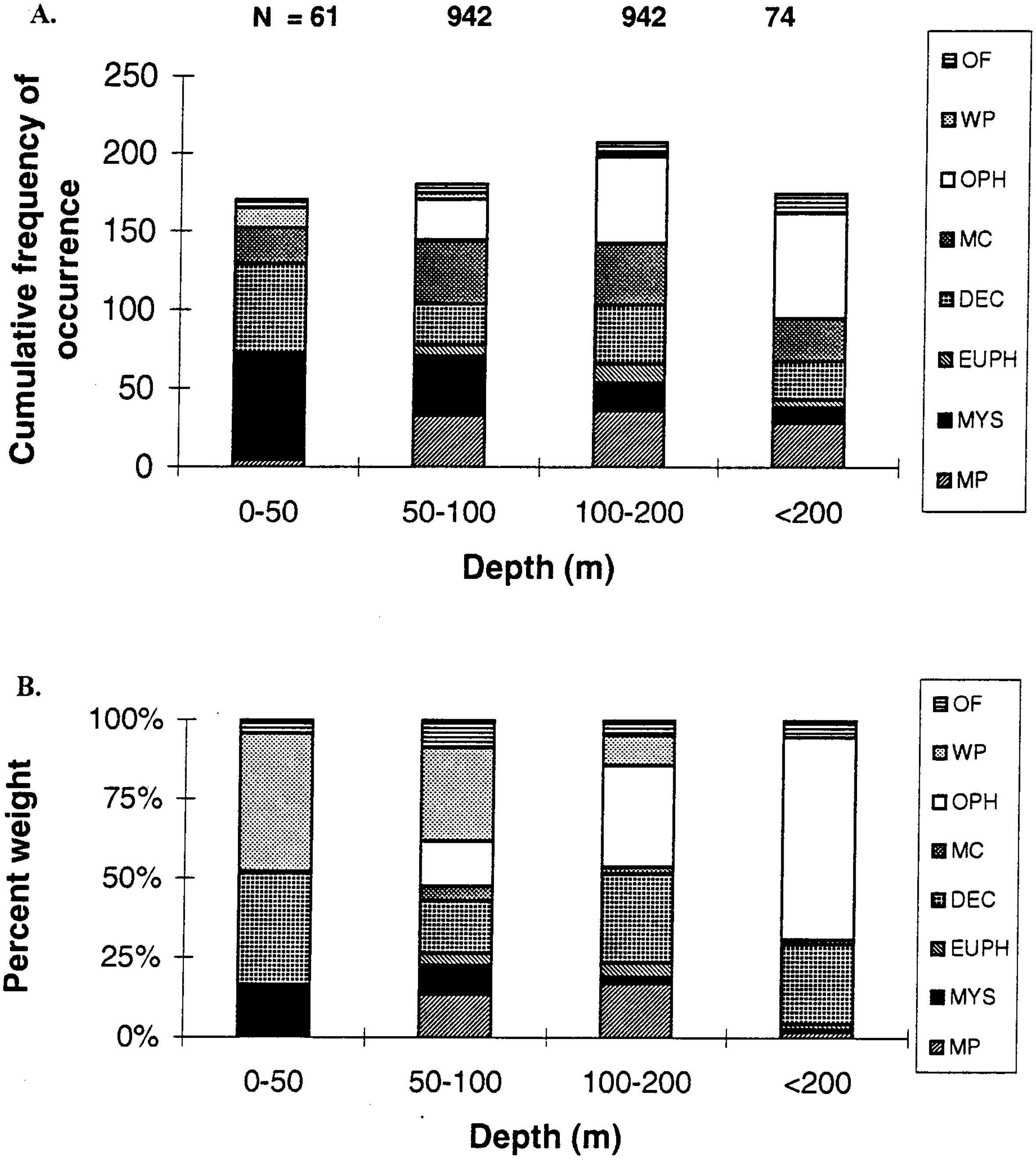

Figure 2.-- A. Percent frequency of occurrence (%FO) and B. Diet composition by percent weight (% W) for < 30cm flathead sole, by bottom depth. (Mys =mysids, Euph = euphausiids, Dee = decapods, Oph = ophiuroids, WP = walleye pollock, OF = all other fish prey, MC = miscellaneous crustaceans, MP = all other prey including unidentified material).

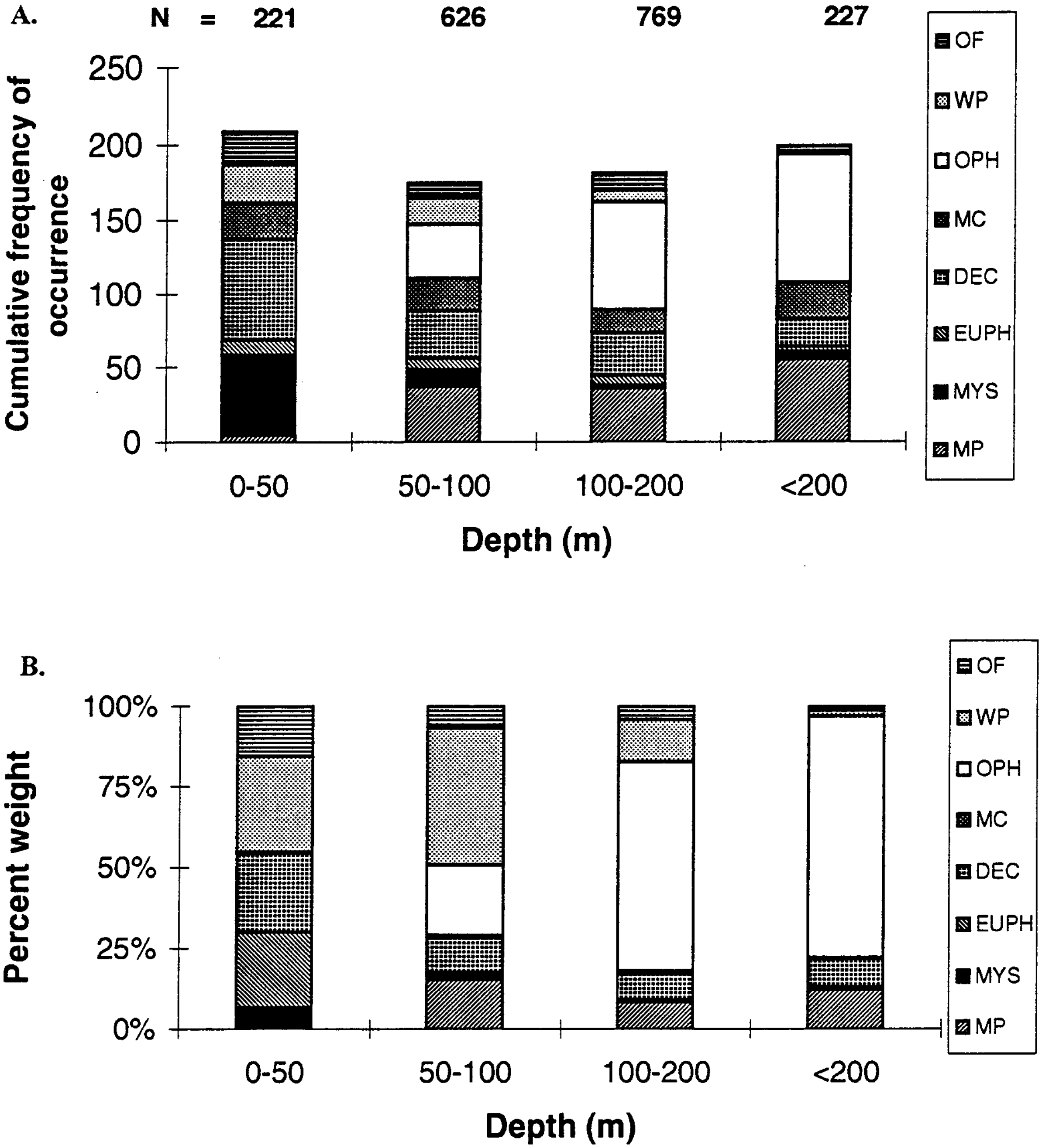

Figure 3.-- A. Percent frequency of occurrence (%FO) and B. Diet composition by percent weight (%W) for >30cm flathead sole, by bottom depth. (Mys=mysids, Euph = euphausiids, Dee = decapods, Oph = ophiuroids, WP = walleye pollock, OF = all other fish prey, MC = miscellaneous crustaceans, MP = all other prey including unidentified material).

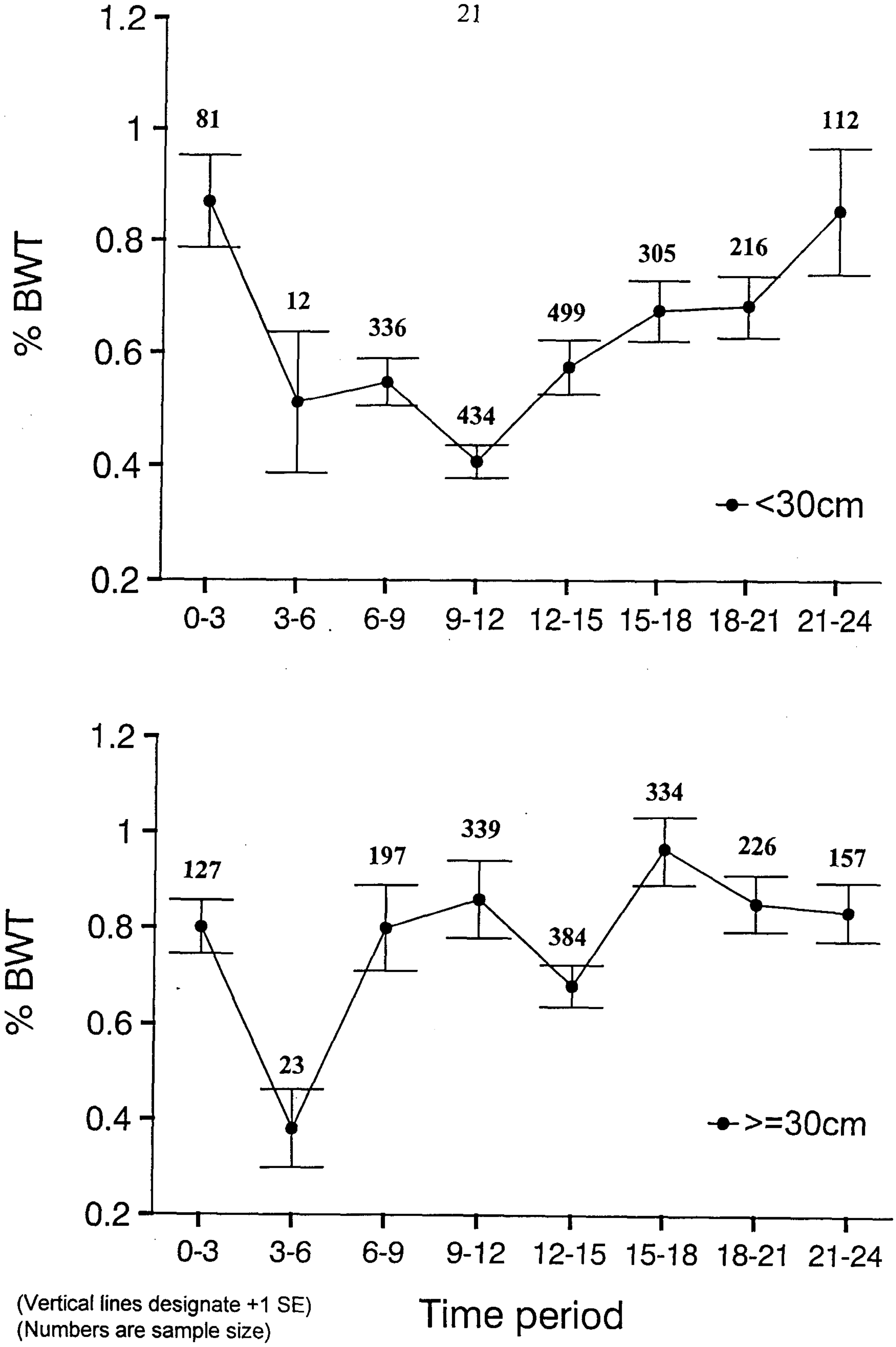

Figure 4.--Diel changes in mean stomach content weight (%BW + 1 SE) in the stomachs of two size classes of flathead sole (numbers above bar are sample size).

Appendix.-- Prey items identified during analysis of 6,167 flathead sole stomachs (9% of stomachs were empty) collected from the eastern Bering Sea from June 1984 to September 1988.

%FO = percent frequency of occurrence
%N = percent of total prey numbers
%W = percent of total prey weight

Prey Taxa	%FO	%N	%W
Hydrozoa	0.0	0.00	0.00
Anthozoa	0.0	0.00	0.00
Polychaeta	17.1	1.29	1.79
Aphroditidae	0.1	0.00	0.10
Nereidae	0.0	0.00	0.00
Nephtyidae	0.0	0.00	0.03
Opheliidae	0.0	0.00	0.00
Maldanidae	0.3	0.00	0.17
Owenidae	0.0	0.00	0.00
Cistenedes sp.	0.1	0.00	0.01
Ampharetidae	0.1	0.00	0.04
Terebellidae	0.0	0.00	0.03
Hirudinea	0.0	0.00	0.00
Mollusca	0.1	0.00	0.02
Gastropoda	0.6	0.03	0.01
Thecosomata	0.0	0.00	0.00
Bivalvia	4.5	0.35	0.58
Nuculanidae	0.0	0.00	0.02
Nuculana sp.	1.7	0.43	1.11
Nuculana fossa	0.2	0.02	0.02
Yoldia sp.	0.6	0.03	0.62
Yoldia scissurata	0.0	0.00	0.03
Cyclopecten sp.	0.2	0.02	0.11
Clinocardium sp.	0.0	0.00	0.01
Cephalapoda	0.1	0.00	0.07
Teuthoidea	0.0	0.00	0.03
Gonatidae	0.0	0.00	0.06
Octopoda	0.0	0.00	0.03
Arthropoda	0.0	0.00	0.00
Arachnida	0.1	0.00	0.00
Pycnogonida	0.0	0.00	0.00

Appendix -- (cont.).

Prey Taxa	%FO	%N	%W
Crustacea	0.1	0.00	0.00
Ostracoda	0.2	0.01	0.00
Copepoda	0.2	0.10	0.00
Calanoida	2.0	0.84	0.01
Calanidae	0.1	0.06	0.00
Calanus sp.	0.2	0.01	0.00
Calanus cristatus	0.1	0.00	0.00
Mysidacea	0.2	0.09	0.01
Mysida	1.8	0.10	0.05
Mysidae	3.5	0.00	0.00
Acanthomysis dybowskii	0.8	0.09	0.05
Acnathomysis macropsis	0.0	0.01	0.00
Acanthomysis nephropthalma	0.1	0.01	0.00
Acanthomysis pseudomacropsis	0.7	0.30	0.11
Acanthomysis stelleri	0.5	0.13	0.09
Exacanthomysis alaskensis	0.2	0.01	0.01
Holmsiella anomala	0.0	0.00	0.00
Meterythrops sp.	0.2	0.02	0.01
Meterythrops micropthalma	0.0	0.00	0.00
Neomysis sp.	0.1	0.00	0.00
Neomysis czerniawskii	3.4	0.78	0.49
Neomysis kadiakensis	0.2	0.02	0.04
Neomysis rayii	1.3	0.17	0.30
Pseudomma sp.	0.5	0.29	0.06
Pseudomma truncatum	6.9	3.94	0.36
Cumacea	6.3	0.73	0.02
Diastylidae	0.0	0.00	0.00
Isopoda	0.8	0.04	0.02
Flabellifera	0.2	0.01	0.03
Gnorimosphaeroma sp.	0.0	0.00	0.00
Amphipoda	0.1	0.00	0.00
Gammaridea	20.2	2.91	0.53
Acanthonotozomatidae	0.0	0.00	0.00

Appendix -- (cont.).

Prey Taxa	%FO	%N	%W
Ampeliscidae	1.1	0.68	0.19
Ampelisca sp.	0.0	0.00	0.00
Ampelisca macrocephala	0.1	0.00	0.00
Byblis sp.	0.2	0.01	0.01
Byblis gaimardi	0.1	0.02	0.01
Corophiidae	0.0	0.00	0.00
Rhachotropis oculatus	0.1	0.00	0.00
Gammaridae	0.0	0.00	0.01
Isaeidae	0.1	0.02	0.00
Photis sp.	0.0	0.01	0.00
Protomedia sp.	0.1	0.07	0.02
Protomedia grandimana	0.2	0.09	0.02
Ischyroceridae	0.0	0.00	0.00
Lysianassidae	0.2	0.02	0.02
Oedicerotidae	0.7	0.06	0.00
Monoculodes zernovi	0.6	0.04	0.00
Stenothoidae	0.0	0.00	0.00
Hyperiidea	0.4	0.02	0.00
Caprellidea	0.3	0.01	0.00
Eucarida	0.6	0.04	0.03
Euphausiacea	3.0	0.42	0.23
Euphausiidae	0.1	0.04	0.02
Thysanoessa sp.	2.0	0.71	0.61
Thysanoessa inermis	1.1	0.43	0.28
Thysanoessa raschii	1.7	2.40	2.14
Thysanoessa spinifera	0.2	0.01	0.01
Decapoda	0.3	0.02	0.01
Caridea	3.9	0.33	0.39
Hippolytidae	0.8	0.08	0.07
Eualus sp.	0.9	0.04	0.08
Eualus pusiolus	0.1	0.01	0.00
Eualus avinus	0.8	0.04	0.12
Pandalidae	2.2	0.15	0.67
Pandalus sp.	2.1	0.22	0.89

Appendix -- (cont.).

Prey Taxa	%FO	%N	%W
Pandalus borealis	0.8	0.03	1.17
Pandalus goniurus	0.4	0.02	0.14
Pandalus jordani	0.1	0.01	0.01
Pandalus montague tridens	0.0	0.00	0.01
Pandalopsis sp.	0.0	0.00	0.01
Crangonidae	2.0	0.15	0.24
Crangon sp.	2.7	0.19	0.26
Crangon dalli	6.3	0.82	2.98
Crangon communis	5.3	0.30	1.28
Argis sp.	0.0	0.00	0.00
Argis lar	0.1	0.00	0.02
Argis dentata	0.0	0.00	0.02
Argis ovifer	0.0	0.00	0.00
Natantia	0.6	0.04	0.03
Anomura	0.0	0.00	0.00
Paguridae	5.0	0.34	1.81
Brachyura	0.0	0.00	0.00
Majidae	0.9	0.05	0.07
Hyas sp.	0.1	0.00	0.00
Hyas lyratus	0.2	0.01	0.03
Chionoecetes sp.	1.9	1.41	1.01
Chionoecetes opilio	0.6	0.03	0.31
Chionoecetes bairdi	2.7	0.80	0.79
Chionoecetes hybrid	0.0	0.00	0.02
Sipuncula	0.1	0.00	0.24
Echiura	0.1	0.01	0.01
Echiurinae	0.0	0.00	0.00
Echiruidae	0.5	0.16	0.25
Echiurus sp.	0.3	0.06	0.13
Echiurus echiurus	2.4	0.51	0.91
Priapulida	0.0	0.00	0.03
Echinodermata	0.0	0.00	0.00
Asteroidea	0.0	0.00	0.00
Ophiuroidea	3.0	6.37	3.25

Appendix -- (cont.).

Prey Taxa	%FO	%N	%W
Ophiurida	22.7	36.01	19.88
Ophiuridae	13.6	19.17	12.08
Ophiura sp.	6.5	11.45	4.32
Ophiura sarsi	2.2	0.62	1.90
Ophiocantha normani	0.4	0.04	0.61
Amphiuridae	0.0	0.00	0.00
Amphipholis squamata	0.5	0.03	0.01
Clypasteridae	0.0	0.00	0.00
Holothurodea	0.1	0.00	0.00
Chaetognatha	0.5	0.11	0.02
Sagitta sp.	0.0	0.00	0.00
Urochordata	0.1	0.00	0.00
Larvacea copelata	0.1	0.04	0.00
Osteichthyes			
Actinopterygii Teleostei	6.9	0.27	2.43
Osmeridae	0.0	0.00	0.17
Mallotus villosus	0.1	0.00	0.88
Bathylagidae	0.0	0.00	0.00
Myctophidae	0.0	0.00	0.05
Gadidae	0.3	0.02	0.53
Gadus macrocephalus	0.2	0.01	0.34
Theragra chalcogramma	7.5	0.48	20.16
Zoarcidae	0.2	0.01	0.06
Lycodes sp.	0.1	0.00	0.01
Lycodes brevipes	0.1	0.00	0.05
Scorpaenidae	0.0	0.00	0.00
Sebastes sp.	0.8	0.10	1.74
Cottidae	0.2	0.01	0.06
Icelus spiniger	0.0	0.00	0.06
Dasycottus setiger	0.0	0.00	0.07
Icelinus filamentosus	0.0	0.00	0.01
Agonidae	0.1	0.00	0.01
Aspidophoroides bartoni	0.0	0.00	0.01
Liparididae	0.0	0.00	0.00

Appendix -- (cont.).

Prey Taxa	%FO	%N	%W
Nectoliparis pelagicus	0.0	0.00	0.03
Bathymasteridae	0.0	0.00	0.00
Bathymaster sp.	0.3	0.03	0.36
Stichaeidae	0.2	0.01	0.16
Lumpenus sp.	0.0	0.00	0.07
Lumpenus maculatus	0.1	0.01	0.14
Lyconectes aleutensis	0.0	0.00	0.13
Ammodytes hexapterus	0.0	0.00	0.00
Pleuronectidae	0.3	0.01	0.17
Hippoglossoides elassodon	0.0	0.00	0.00
Lepidopsetta bilineata	0.2	0.01	0.19
Pleuronectes quadrituberculatus	0.0	0.00	0.00
Unidentified organic material	1.2	0.07	0.10
Unidentified eggs	0.1	0.03	0.02
Unidentified worm-like organism	0.0	0.00	0.07
Fishery offal	1.2	0.04	4.22
Unidentified tube	6.8	0.77	0.40

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