# Feeding Habits of Sablefish, *Anoplopoma fimbria*, off the Coast of Oregon and California

THOMAS E. LAIDIG, PETER B. ADAMS

*Southwest Fisheries Science Center*
*National Marine Fisheries Service, NOAA*
*3150 Paradise Drive*
*Tiburon, California 94920*

WAYNE M. SAMIERE

*International Ocean Traders*
*46-055 Lilipuna Drive*
*Kaneohe, Hawaii 96744*

**ABSTRACT**

The stomach contents of 1,868 sablefish, *Anoplopoma fimbria*, were examined from nine bottom trawl cruises between 1987 and 1992. The sablefish were found to be highly piscivorous. Their diet varied with length: the smallest sablefish ate mostly fish and small crustaceans, and the largest sablefish ate fish and cephalopods. Smaller sablefish took more prey that originated in midwater; larger sablefish foraged predominately on the benthos. The size of the prey increased with an increase in sablefish length. As noted in existing literature, change in diet with length coincided with a size–depth relationship in which smaller sablefish were found in shallow water, and larger fish occurred at varying depths, except in the shallowest areas. Geographic differences were evident: sablefish in the south consumed more midwater prey than those in the north.

## Introduction

Sablefish from trawl landings off the U.S. west coast are typically caught with a mixture of other species including Dover sole, *Microstomus pacificus*, and thornyheads, *Sebastolobus* spp. This complex accounts for approximately 40% of groundfish landings, excluding Pacific whiting, *Merluccius productus*. Sablefish ranked second in landings of this complex (after Dover sole) and are third in overall trawl landings (after Pacific whiting and Dover sole; Pacific Fishery Management Council[1]). Landings have decreased in the last ten years, mostly because of management constraints.

Despite their importance in commercial landings, little has been published about the trophic ecology of sablefish. Sablefish are carnivores, feeding primarily on fishes (Grinols and Gill, 1968; Cailliet et al., 1988). Top predators play an important role within the community by controlling species composition and abundance (Regier et al., 1979). Since sablefish have an estimated biomass of 152,323 t (Methot[2]), their predation is likely to have indirect effects that cascade down through the system. Therefore, we examined sablefish feeding and its implications for trophic interactions and management.

## Methods

Sablefish stomach samples were collected on nine bottom trawl cruises from 1987 to 1992. Cruises were con-

[1] Pacific Fishery Management Council. 1992. Status of the Pacific coast groundfish fishery through 1992 and recommended acceptable biological catches for 1993. Pac. Fish. Manage. Council, Metro Center, Ste. 420, 2000 S.W. First Ave., Portland OR, 80 p.

[2] Methot, R. D. 1993. Assessment of the west coast sablefish stock in 1994. *In* Appendices to the status of Pacific Coast groundfish fishery through 1993 and recommended acceptable biological catches for 1994, Appendix B, 31 p. Pac. Fish. Manage. Council, Metro Center, Ste. 420, 2000 S.W. First Ave., Portland, OR 97201.

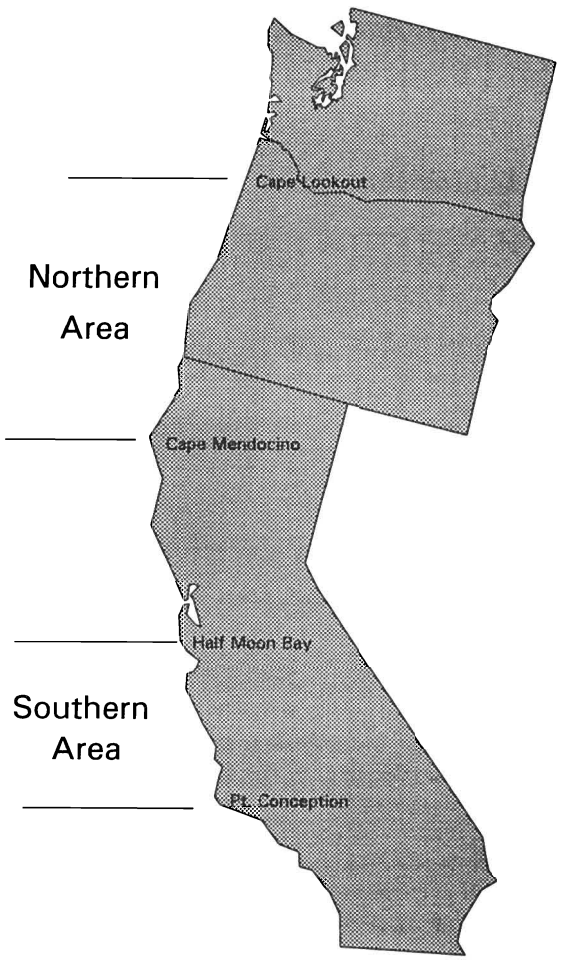


**Figure 1**
Map of the survey area showing northern (from 45°23' to 40°32'N) and southern (37°31' to 34°31'N) areas.

ducted off the coast of Oregon and California, in two areas: northern (Cape Mendocino, CA, to Cape Lookout, OR) and southern (Pt. Conception, CA, to Half Moon Bay, CA; Fig. 1). All cruises took place in fall or winter. Trawl stations were placed on fixed tracklines stratified into six depth strata: 183–366, 367–549, 550–732, 733–914, 915–1,097, and 1,098–1,280 m (100–199, 200–299, 300–399, 400–499, 500–599, and 600–699 fm). Stations were randomly placed within the depth strata. A total of 286 trawls were made (190 in the northern area and 96 in the southern area). Trawls lasted 30 minutes at depth for depths shallower than 732 m, and one hour for depths 732 m and deeper.

Catch sampling and processing followed procedures outlined by Smith and Bakkala (1982). Up to 15 fish were selected from any one trawl for stomach samples; only non-empty stomachs were used. Fish were selected to cover the entire length range found in the trawl sample.

In the laboratory, total volume was determined for each stomach. Prey from stomach samples were identified to the lowest taxon possible and enumerated. When possible, prey lengths (mm) were measured (standard length for fish, carapace length for crustaceans, mantle length for cephalopods, and the longest body diameter for the remaining taxa). The relative volume for each taxonomic group in a stomach was calculated. Frequency of occurrence was determined for each prey item individually and grouped by taxon; it was defined as the number of stomachs with that specific prey item (or taxon) divided by the total number of stomachs. Mean number of prey was calculated for each prey item individually and grouped by taxon. Prey species were classified by habitat (whether they spent greater than 50% of their time in the water column or on the bottom). An index of relative importance (IRI) was computed for each taxon (Pinkas, 1971) by multiplying percent frequency of occurrence by the sum of percent by relative volume and percent by number. Horn's index of overlap was calculated with the IRI data to compare sablefish diet from the north and south areas (Krebs, 1989). Sufficiency of sample size was shown by plotting the cumulative number of prey taxa against the number of stomachs examined (Cailliet et al., 1988).

Size analysis of sablefish feeding was conducted by pooling sablefish into length classes. To analyze general patterns in sablefish diet with size, we used the following length classes: less than 300, 300–399, 400–499, 500–599, 600–699, and more than 699 mm FL. For simplicity, we refer to these length classes by their midpoint value (e.g., 400–499 mm as 450 mm). For the studies of diet change with depth for same-sized fish, and of prey habitat versus size, we used smaller length classes with a range of 50 mm (e.g., 550–599 mm) to give sharper definition to trends with size.

We used regressions and correlations to give a sense of scale to increasing or decreasing trends in the following comparisons: diet measures (percent frequency of occurrence, percent diet volume, and mean number per sablefish) versus length classes of sablefish, and versus depth of capture; size of individuals in a prey taxon versus sablefish length; sablefish length versus depth of capture; and prey habitat versus sablefish length. We examined heterogeneity of slopes to detect differences in trends for sablefish length and depth between the north and south areas.

## Results

### Overall Diet

Fishes were the major prey of all sablefish combined, accounting for more than 75% of diet volume, occur-

ring in greater than 63% of the sablefish sampled, and having a high IRI value of 4,911.6 (Table 1). Of the identifiable prey fish, scorpaenids—*Sebastolobus alascanus*, *S. altivelis*, and various species of *Sebastes*—accounted for the largest portion of the percent diet volume, highest IRI, and highest frequency of occurrence. A complex of midwater fishes including Pacific whiting, myctophids, and bathylagids ranked second in percent diet volume, IRI, and frequency of occurrence. Within this midwater complex, Pacific whiting accounted for 82.4% of the diet volume, had the highest IRI, and made up nearly half the total number of midwater fish eaten. Pacific whiting had a frequency of occurrence of 4.6%, again about half of all midwater fish. Unidentifiable fish made up a large portion of fish prey, accounting for almost one quarter of the diet volume and occurring in over 40% of the sablefish stomachs. Two adult sablefish each ate a single sablefish.

Invertebrates accounted for a much smaller diet volume than fish, about one quarter of the IRI, and were present at lower frequencies. Cephalopods—mainly squids (Teuthoidea)—were the dominant invertebrate prey. Squids constituted 7.4% of diet volume, were found in 9.8% of the sablefish, and had the highest IRI of all invertebrates. Heteropods—*Carinaria* spp.—were the next most abundant prey, present in 9.5% of all sablefish. Another prominent gelatinous prey was thaliaceans, present in over 6% of the sablefish. Of the remaining invertebrate prey, shrimps (natantian decapods)—most abundantly *Sergestes similis*—crabs (reptantian decapods)—most abundantly *Chionoecetes tanneri*—and small crustaceans, including mysids, gammarid amphipods, and euphausiids, were common components of the diet.

Some major differences were found between the diets of sablefish taken in the south and those from the north. The Horn's index of overlap of 0.36 indicates low similarity between sablefish diets in these two areas. Large gelatinous prey (heteropods and thaliaceans) were more important in the southern diet (Table 2, 3). Heteropods had a higher frequency of occurrence in the south (26.2% vs. 0.3% in the north), percent diet volume (14.5% vs. 0.03%), average number per sablefish (0.2 vs. 0.01), and IRI (386.7—the highest of any prey group in the south—vs. <0.1). Thaliaceans also had a higher frequency of occurrence in the south (13.5% vs. 2.9% in the north), percent diet volume (9.6% vs. 0.9%), and IRI (130.7 vs. 3.1), whereas the average number per sablefish was similar in the south (0.1) and north (0.2). Fish showed the opposite trend: in the south they were lower in percent occurrence (52.3% vs. 74.2% in the north), percent diet volume (51.0% vs. 80.4%), and IRI (122.5 vs. 6,072.9). Sablefish ate similar numbers of fish in both the south (1.6) and the north (1.5).

Cumulative prey curves for all fish and for fish from the northern or southern regions showed that adequate samples were taken in each analysis (Fig. 2, 3).

## Change in Diet with Fish Size and Depth

Diet, characterized as percent frequency of occurrence in all guts within a length class, varied with increasing sablefish length, and length increased with depth. However, this change in diet composition with depth occurred only for a few prey groups.

**Diet Change with Length**—The composition of the sablefish diet changed with length (Fig. 4–6). Fish were the

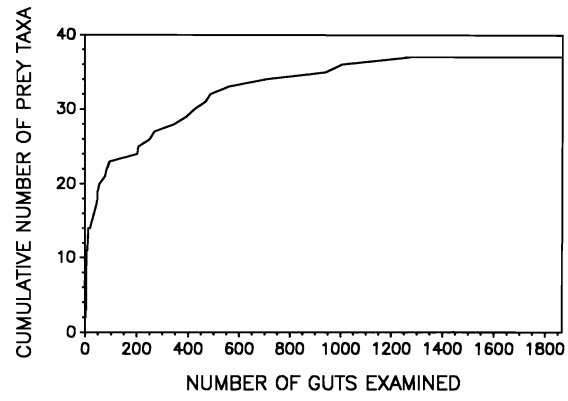


**Figure 2**
Cumulative number of prey taxa by the number of sablefish stomachs examined, for all sablefish.

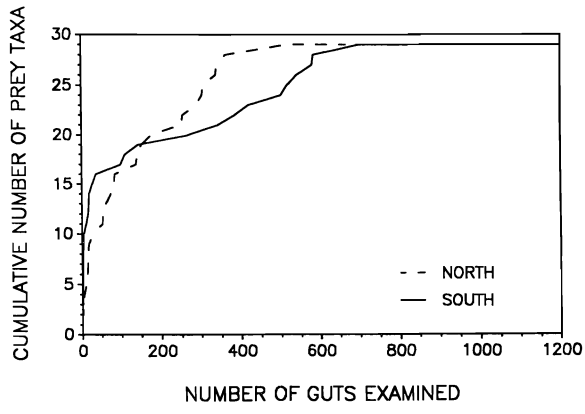


**Figure 3**
Cumulative number of prey taxa by the number of sablefish stomachs examined, for sablefish from the northern area (dashed line) and southern area (solid line).

**Table 1**
Average diet of all sablefish, *Anoplopoma fimbria*, captured from California and Oregon, 1987–92 ($N$ = 1,868 sablefish).

| Prey | Number per sablefish | % Diet volume | Avg size of prey | FO[1] (%) | IRI[2] | Habitat[3] |
|---|---|---|---|---|---|---|
| **Pisces** (all) | 1.500 | 76.45 | 116.99 | 63.01 | 4,911.6 | |
| **Benthic Pisces** | 0.177 | 40.94 | 164.30 | 16.32 | 1,623.4 | B |
| Myxinidae | 0.007 | 1.18 | 204.00 | 0.64 | 0.8 | B |
| *Eptatretus deani* | 0.002 | 0.41 | 209.00 | 0.16 | 0.1 | B |
| *E. stoutii* | 0.002 | 0.72 | 365.00 | 0.21 | 0.2 | B |
| Myxinidae egg case | 0.003 | 0.04 | 37.50 | 0.21 | <0.1 | B |
| Petromyzonidae | 0.001 | 0.01 | 200.00 | 0.05 | <0.1 | B |
| Chondrichthyes | 0.005 | 0.70 | 275.00 | 0.48 | 0.3 | U |
| Chondrichthyes unid. | 0.002 | 0.03 | 0.00 | 0.16 | <0.1 | U |
| *Apristurus brunneus* | 0.001 | 0.05 | 150.00 | 0.05 | <0.1 | B |
| Scyliorhinid egg case | 0.001 | 0.00 | 0.00 | 0.05 | <0.1 | B |
| *Squalus acanthias* | 0.002 | 0.35 | 400.00 | 0.16 | 0.1 | U |
| Rajidae | 0.001 | 0.27 | 0.00 | 0.05 | <0.1 | B |
| Chimaeridae | | | | | | |
| *Hydrolagus colliei* | 0.001 | 0.27 | 0.00 | 0.05 | <0.1 | B |
| Pleuronectiformes | 0.004 | 0.61 | 158.60 | 0.37 | 0.2 | B |
| Pleuronectiformes unid. | 0.001 | 0.03 | 0.00 | 0.05 | <0.1 | B |
| *Embassichthys bathybius* | 0.001 | 0.00 | 58.00 | 0.05 | <0.1 | B |
| *Lyopsetta exilis* | 0.002 | 0.27 | 158.33 | 0.16 | <0.1 | B |
| *Microstomus pacificus* | 0.001 | 0.31 | 260.00 | 0.11 | <0.1 | B |
| Macrouridae | 0.001 | 0.46 | 190.00 | 0.11 | 0.1 | B |
| *Albatrossia pectoralis* | 0.001 | 0.30 | 190.00 | 0.05 | <0.1 | B |
| *Coryphaenoides acrolepis* | 0.001 | 0.16 | 0.00 | 0.05 | <0.1 | B |
| Alepocephalidae | | | | | | |
| *Alepocephalus tenebrosus* | 0.002 | 0.81 | 173.33 | 0.16 | 0.1 | B |
| Anoplopomatidae | | | | | | |
| *Anoplopoma fimbria* | 0.001 | 0.39 | 0.00 | 0.11 | <0.1 | B |
| Liparididae | | | | | | |
| *Careproctus melanurus* | 0.001 | 0.31 | 140.00 | 0.11 | <0.1 | B |
| Cottidae | 0.001 | 0.00 | 25.00 | 0.11 | <0.1 | B |
| Scorpaenidae | 0.149 | 35.39 | 120.06 | 13.70 | 486.9 | B |
| Scorpaenidae unid. | 0.001 | 0.05 | 105.00 | 0.11 | <0.1 | B |
| *Sebastes alutus* | 0.002 | 0.86 | 175.00 | 0.16 | 0.1 | B |
| *S. caurinus* | 0.001 | 0.12 | 130.00 | 0.05 | <0.1 | B |
| *S. crameri* | 0.002 | 0.45 | 192.50 | 0.11 | <0.1 | B |
| *S. diploproa* | 0.001 | 0.16 | 150.00 | 0.05 | <0.1 | B |
| *S. jordani* | 0.002 | 0.78 | 116.67 | 0.16 | 0.1 | B |
| *S.* spp. | 0.003 | 0.53 | 110.00 | 0.32 | 0.2 | B |
| *Sebastolobus alascanus* | 0.004 | 1.41 | 153.71 | 0.43 | 0.6 | B |
| *S. altivelis* | 0.132 | 30.20 | 117.64 | 12.10 | 367.0 | B |
| *S.* spp. | 0.002 | 0.82 | 110.00 | 0.21 | 0.2 | B |

[1] FO = frequency of occurence.
[2] IRI = index of relative importance.
[3] U = undetermined; B = benthic; WC = water column.

**Table 1 (continued)**

| Prey | Number per sablefish | % Diet volume | Avg size of prey | FO[1] (%) | IRI[2] | Habitat[3] |
|---|---|---|---|---|---|---|
| Zoarcidae | 0.005 | 0.82 | 123.75 | 0.48 | 0.4 | B |
| Zoarcidae unid. | 0.003 | 0.19 | 101.00 | 0.27 | 0.1 | B |
| *Bothrocara remigerum* | 0.001 | 0.24 | 310.00 | 0.05 | <0.1 | B |
| *Lycodes diapterus* | 0.001 | 0.32 | 80.00 | 0.11 | <0.1 | B |
| *L. pacifica* | 0.001 | 0.07 | 95.00 | 0.05 | <0.1 | B |
| **Midwater Pisces** | 0.085 | 13.48 | 123.05 | 8.24 | 111.8 | WC |
| Merlucciidae | | | | | | |
| *Merluccius productus* | 0.047 | 11.11 | 169.27 | 4.55 | 50.8 | WC |
| Bathylagidae | 0.008 | 1.08 | 112.69 | 0.80 | 0.9 | WC |
| Bathylagidae unid. | 0.006 | 0.50 | 111.67 | 0.59 | 0.3 | WC |
| *Bathylagus pacificus* | 0.002 | 0.58 | 136.67 | 0.16 | 0.1 | WC |
| *Leuroglossus stilbius* | 0.001 | 0.00 | 50.00 | 0.05 | <0.1 | WC |
| Chauliodontidae | | | | | | |
| *Chauliodus macouni* | 0.004 | 0.48 | 176.67 | 0.43 | 0.2 | WC |
| Clupeidae | 0.001 | 0.16 | 120.00 | 0.05 | <0.1 | WC |
| Engraulididae | | | | | | |
| *Engraulis mordax* | 0.001 | 0.00 | 25.00 | 0.05 | <0.1 | WC |
| Malacosteidae | | | | | | |
| *Tactostoma macropus* | 0.001 | 0.19 | 220.00 | 0.11 | <0.1 | WC |
| Nemichthyidae | 0.001 | 0.05 | 440.00 | 0.11 | <0.1 | WC |
| Nemichthyidae unid. | 0.001 | 0.03 | 440.00 | 0.05 | <0.1 | WC |
| *Nemichthys scolopaceus* | 0.001 | 0.01 | 0.00 | 0.05 | <0.1 | WC |
| Scomberesocidae | | | | | | |
| *Cololabis saira* | 0.005 | 0.07 | 115.00 | 0.43 | <0.1 | WC |
| Myctophidae | 0.018 | 0.35 | 74.45 | 1.77 | 0.7 | WC |
| Myctophidae | 0.013 | 0.05 | 61.46 | 1.23 | 0.1 | WC |
| *Lampanyctus ritteri* | 0.002 | 0.26 | 126.25 | 0.21 | 0.1 | WC |
| *Stenobrachius leucopsarus* | 0.002 | 0.04 | 57.50 | 0.16 | <0.1 | WC |
| *Tarletonbeania crenularis* | 0.002 | 0.00 | 70.00 | 0.16 | <0.1 | WC |
| Pisces misc. | 1.238 | 22.02 | 83.50 | 41.33 | 961.3 | U |
| Pisces unid. (entire animal) | 0.238 | 19.52 | 109.68 | 23.82 | 470.6 | U |
| Pisces bones | 0.196 | 2.28 | 176.67 | 16.06 | 39.8 | U |
| Pisces scales | 0.027 | 0.00 | 0.00 | 0.64 | <0.1 | U |
| Demersal Pisces egg | 0.536 | 0.09 | 8.32 | 0.75 | 0.5 | U |
| Pisces egg case | 0.236 | 0.13 | 21.50 | 0.27 | 0.1 | U |
| Pisces larvae | 0.005 | 0.01 | 20.40 | 0.37 | <0.1 | U |
| **Algae** | 0.003 | 0.02 | 0.00 | 0.27 | <0.1 | B |
| **Invertebrata** | 3.967 | 23.15 | 55.72 | 50.91 | 1,380.5 | U |
| Porifera | 0.001 | 0.01 | 0.00 | 0.11 | <0.1 | B |

[1] FO = frequency of occurence.
[2] IRI = index of relative importance.
[3] U = undetermined; B = benthic; WC = water column.

**Table 1 (continued)**

| Prey | Number per sablefish | % Diet volume | Avg size of prey | FO[1] (%) | IRI[2] | Habitat[3] |
|---|---|---|---|---|---|---|
| Hydrozoa | 0.001 | 0.03 | 0.00 | 0.05 | <0.1 | WC |
| Scyphozoa | 0.001 | 0.00 | 0.00 | 0.11 | <0.1 | WC |
| Anthozoa | 0.005 | 0.08 | 72.50 | 0.37 | <0.1 | B |
| Nemertea | 0.001 | 0.00 | 80.00 | 0.05 | <0.1 | B |
| Polychaeta | 0.027 | 0.06 | 64.06 | 1.71 | 0.1 | B |
| Polychaeta unid. | 0.008 | 0.01 | 41.25 | 0.64 | <0.1 | B |
| Polychaeta, pelagic | 0.001 | 0.00 | 110.00 | 0.11 | <0.1 | WC |
| Polychaeta, sedentary | 0.001 | 0.00 | 90.00 | 0.05 | <0.1 | B |
| Polychaeta tubes | 0.001 | 0.00 | 0.00 | 0.11 | <0.1 | B |
| Alciopidae | 0.001 | 0.00 | 60.00 | 0.05 | <0.1 | B |
| *Aphrodita* spp. | 0.005 | 0.03 | 64.17 | 0.43 | <0.1 | B |
| Flabelligeridae | 0.002 | 0.00 | 33.00 | 0.05 | <0.1 | B |
| Glyceridae | 0.009 | 0.03 | 77.50 | 0.27 | <0.1 | B |
| Gastropoda | 0.021 | 0.49 | 21.60 | 1.77 | 0.9 | B |
| Gastropoda unid. | 0.005 | 0.02 | 32.00 | 0.43 | <0.1 | B |
| Gastropod egg capsule | 0.002 | 0.18 | 0.00 | 0.21 | <0.1 | B |
| *Amphissa versicolor* | 0.005 | 0.01 | 5.56 | 0.43 | <0.1 | B |
| *A.* spp. | 0.008 | 0.05 | 7.81 | 0.43 | <0.1 | B |
| *Neptunea priboloffensis* | 0.001 | 0.05 | 0.00 | 0.11 | <0.1 | B |
| Nudibranchia | 0.002 | 0.19 | 88.00 | 0.16 | <0.1 | B |
| Heteropoda | 0.149 | 4.02 | 94.15 | 9.53 | 39.7 | WC |
| *Carinaria japonica* | 0.020 | 0.65 | 63.29 | 1.18 | 0.8 | WC |
| *C.* spp. | 0.129 | 3.37 | 97.42 | 8.35 | 29.2 | WC |
| Bivalvia | 0.009 | 0.10 | 41.38 | 0.75 | 0.1 | B |
| Bivalvia unid. | 0.002 | 0.01 | 0.00 | 0.21 | <0.1 | B |
| *Nuculana conceptionis* | 0.001 | 0.00 | 15.00 | 0.05 | <0.1 | B |
| *Solemya* spp. | 0.006 | 0.10 | 0.01 | 0.48 | 0.1 | B |
| Cephalopoda | 0.185 | 11.20 | 86.67 | 17.56 | 199.9 | U |
| Cephalopoda unid. | 0.063 | 1.82 | 57.25 | 6.10 | 11.5 | U |
| Octopoda | 0.009 | 0.47 | 0.00 | 0.86 | 0.4 | B |
| Octopoda unid. | 0.007 | 0.47 | 0.00 | 0.64 | 0.3 | B |
| *Octopus* spp. | 0.002 | 0.00 | 0.00 | 0.21 | <0.1 | B |
| Teuthoidea | 0.103 | 7.44 | 89.48 | 9.79 | 73.8 | WC |
| Teuthoidea unid. | 0.091 | 4.39 | 80.12 | 8.83 | 39.6 | WC |
| Architeuthidae | 0.001 | 0.48 | 0.00 | 0.11 | 0.1 | WC |
| *Galiteuthis* spp. | 0.001 | 0.03 | 200.00 | 0.05 | <0.1 | WC |
| *Gonatopsis borealis* | 0.001 | 0.33 | 210.00 | 0.05 | <0.1 | WC |
| *Gonatus* spp. | 0.001 | 0.00 | 0.00 | 0.05 | <0.1 | WC |
| *Histioteuthis* spp. | 0.001 | 0.51 | 80.00 | 0.11 | 0.1 | WC |
| *Loligo opalescens* | 0.004 | 0.78 | 93.00 | 0.32 | 0.2 | WC |
| *Octopoteuthis* spp. | 0.001 | 0.29 | 57.50 | 0.11 | <0.1 | WC |
| *Onychoteuthis* spp. | 0.002 | 0.60 | 106.67 | 0.16 | 0.1 | WC |
| Vampyromorpha | 0.011 | 1.50 | 95.00 | 1.12 | 2.6 | B |
| *Vampyroteuthis infernalis* | 0.011 | 1.50 | 95.00 | 1.12 | 2.6 | B |

[1] FO = frequency of occurence.
[2] IRI = index of relative importance.
[3] U = undetermined; B = benthic; WC = water column.

**Table 1 (continued)**

| Prey | Number per sablefish | % Diet volume | Avg size of prey | FO[1] (%) | IRI[2] | Habitat[3] |
|---|---|---|---|---|---|---|
| Small Crustacea | 3.261 | 1.16 | 24.31 | 12.10 | 53.5 | U |
| Crustacea unid. | 0.035 | 0.11 | 0.00 | 3.64 | 0.5 | U |
| Calanoida | 0.001 | 0.00 | 4.00 | 0.11 | <0.1 | WC |
| Mysidacea | 0.020 | 0.54 | 51.77 | 1.98 | 1.1 | WC |
| Mysidacea unid. | 0.002 | 0.00 | 13.00 | 0.16 | <0.1 | WC |
| *Gnathophausia gigas* | 0.008 | 0.11 | 64.25 | 0.75 | 0.1 | WC |
| *G.* spp. | 0.010 | 0.44 | 61.40 | 1.02 | 0.5 | WC |
| *Siriella* spp. | 0.001 | 0.00 | 20.00 | 0.05 | <0.1 | WC |
| Cumacea | 0.001 | 0.00 | 6.00 | 0.05 | <0.1 | B |
| Isopoda | 0.004 | 0.00 | 15.20 | 0.32 | <0.1 | B |
| Isopoda unid. | 0.003 | 0.00 | 18.00 | 0.27 | <0.1 | B |
| Cirolanidae | 0.001 | 0.00 | 4.00 | 0.05 | <0.1 | B |
| Gammaridea | 0.195 | 0.13 | 7.49 | 1.45 | 0.4 | B |
| Gammaridea unid. | 0.170 | 0.04 | 8.19 | 1.12 | 0.2 | B |
| Gammaridae | 0.001 | 0.01 | 0.00 | 0.05 | <0.1 | B |
| Lysianassidae | 0.025 | 0.04 | 5.75 | 0.21 | <0.1 | B |
| *Metaphoxus* spp. | 0.001 | 0.05 | 0.01 | 0.05 | <0.1 | B |
| Hyperiidea | 0.004 | 0.01 | 10.50 | 0.21 | <0.1 | WC |
| Hyperiidea unid. | 0.002 | 0.00 | 14.25 | 0.11 | <0.1 | WC |
| Hyperiidae | 0.001 | 0.00 | 3.00 | 0.05 | <0.1 | WC |
| *Scina* spp. | 0.001 | 0.00 | 0.00 | 0.05 | <0.1 | WC |
| Euphausiacea | 3.001 | 0.37 | 17.97 | 4.93 | 16.6 | WC |
| Euphausiacea unid. | 0.093 | 0.01 | 14.67 | 1.82 | 0.2 | WC |
| *Euphausia pacifica* | 1.798 | 0.24 | 14.25 | 2.30 | 4.7 | WC |
| *Nematoscelis difficilis* | 0.002 | 0.00 | 20.67 | 0.16 | <0.1 | WC |
| *Stylocheiron longicorne* | 0.001 | 0.00 | 12.00 | 0.05 | <0.1 | WC |
| *Thysanoessa spinifera* | 1.107 | 0.12 | 23.00 | 0.75 | 0.9 | WC |
| Reptantia | 0.033 | 1.91 | 44.50 | 2.94 | 5.7 | B |
| Reptantia unid. | 0.011 | 0.57 | 22.50 | 0.75 | 0.4 | B |
| *Calocaris quinqueseriatus* | 0.001 | 0.01 | 0.00 | 0.05 | <0.1 | B |
| *Callianassa goniophthalma* | 0.004 | 0.15 | 85.00 | 0.43 | 0.1 | B |
| *C.* spp. | 0.001 | 0.03 | 48.00 | 0.11 | <0.1 | B |
| *Cancer* spp. megalopa | 0.001 | 0.00 | 4.00 | 0.05 | <0.1 | B |
| *Chionoecetes tanneri* | 0.013 | 1.07 | 0.00 | 1.28 | 1.4 | B |
| Paguridea | 0.001 | 0.00 | 0.00 | 0.05 | <0.1 | B |
| *Pagurus tanneri* | 0.001 | 0.00 | 0.00 | 0.05 | <0.1 | B |
| *P.* spp. | 0.001 | 0.00 | 0.00 | 0.05 | <0.1 | B |
| *Paralomis* spp. | 0.001 | 0.07 | 0.00 | 0.11 | <0.1 | B |
| Natantia | 0.074 | 0.41 | 38.21 | 5.89 | 2.9 | U |
| Natantia unid. | 0.021 | 0.09 | 36.50 | 1.82 | 0.2 | U |
| *Eualus macrophthalmus* | 0.001 | 0.00 | 0.00 | 0.05 | <0.1 | WC |
| *E.* spp. | 0.001 | 0.00 | 45.00 | 0.05 | <0.1 | WC |
| *Palaemon ritteri* | 0.001 | 0.00 | 40.00 | 0.05 | <0.1 | B |
| *Pandalus jordani* | 0.001 | 0.05 | 75.00 | 0.11 | <0.1 | B |
| *P.* spp. | 0.002 | 0.00 | 70.00 | 0.11 | <0.1 | B |
| *Pasiphaea pacifica* | 0.003 | 0.06 | 60.00 | 0.27 | <0.1 | WC |
| *P. tarda* | 0.002 | 0.12 | 150.00 | 0.16 | <0.1 | WC |
| *Sergestes similis* | 0.039 | 0.08 | 31.22 | 3.21 | 0.2 | WC |
| *Spirontocaris* spp. | 0.006 | 0.01 | 12.17 | 0.16 | <0.1 | WC |
| Sipunculida | 0.001 | 0.00 | 0.01 | 0.11 | <0.1 | B |

[1] FO = frequency of occurence.
[2] IRI = index of relative importance.
[3] U = undetermined; B = benthic; WC = water column.

**Table 1 (continued)**

| Prey | Number per sablefish | % Diet volume | Avg size of prey | FO[1] (%) | IRI[2] | Habitat[3] |
|---|---|---|---|---|---|---|
| Echiura | 0.006 | 0.02 | 0.01 | 0.54 | <0.1 | B |
| Asteroidea | 0.002 | 0.02 | 18.00 | 0.21 | <0.1 | B |
| Ophiuroidea | 0.012 | 0.02 | 0.01 | 0.80 | <0.1 | B |
| Ophiuroidea unid. | 0.010 | 0.03 | 0.01 | 0.59 | <0.1 | B |
| *Ophiopthalmus normani* | 0.002 | 0.01 | 0.01 | 0.21 | <0.1 | B |
| Echinoidea | 0.007 | 0.02 | 0.00 | 0.70 | <0.1 | B |
| Holothuroidea | 0.038 | 0.27 | 0.01 | 2.78 | 0.9 | B |
| Holothuroidea unid. | 0.009 | 0.07 | 0.01 | 0.75 | 0.1 | B |
| *Scotoplanes* spp. | 0.028 | 0.21 | 0.01 | 2.09 | 0.5 | B |
| Ascidiacea | 0.004 | 0.30 | 35.00 | 0.37 | <0.1 | B |
| Thaliacea | 0.125 | 2.98 | 66.56 | 6.26 | 19.4 | WC |
| Thaliacea unid. | 0.058 | 0.69 | 55.71 | 2.84 | 2.1 | WC |
| *Iasis zonaria* | 0.002 | 0.01 | 36.00 | 0.16 | <0.1 | WC |
| *Pyrosoma* spp. | 0.032 | 1.86 | 74.57 | 2.57 | 4.9 | WC |
| *Salpa maxima* | 0.002 | 0.00 | 37.50 | 0.16 | <0.1 | WC |
| *S.* spp. | 0.021 | 0.09 | 65.00 | 0.54 | 0.1 | WC |
| *Thetys vagina* | 0.009 | 0.34 | 71.50 | 0.43 | 0.2 | WC |
| **Miscellaneous** | | | | | | |
| Eggs undet. | 0.055 | 0.00 | 1.22 | 0.37 | <0.1 | U |
| Gravel | 0.000 | 0.00 | 0.00 | 0.05 | <0.1 | B |
| Sand | 0.005 | 0.04 | 0.00 | 0.70 | <0.1 | B |
| Tubes undet. | 0.002 | 0.00 | 0.00 | 0.11 | <0.1 | B |
| Aves | 0.006 | 0.05 | 0.00 | 0.27 | <0.1 | U |

[1] FO = frequency of occurence.
[2] IRI = index of relative importance.
[3] U = undetermined; B = benthic; WC = water column.

most frequent prey category throughout all length classes, increasing significantly (slope=0.08%/mm; $r^2$=0.85; $F_{1,5}$= 23.3; $p$<0.01) from 45% in sablefish smaller than 300 mm to 75% in sablefish longer than 600 mm. Fish also represented the highest percent diet volume in each length class and increased significantly (slope=0.06%/mm; $r^2$=0.73; $F_{1,5}$=10.6; $p$=0.03) from 45% in the smallest length class to greater than 65% in the three largest length classes. Mean number of fish per stomach was low in the smallest length classes (0.45/fish) but higher in larger classes (but not a significant increase—p=0.14), with a peak of 2.7 fish/stomach in the 450-mm length class. Some fish prey species changed in abundance with sablefish length (rockfish and eelpouts decreased while thornyheads increased), although most species showed no change.

Small crustaceans were frequent in smaller sablefish stomachs up to the 350-mm length class, but less so in larger classes. Frequency of occurrence, percent diet volume, and mean number per sablefish all showed this pattern (Fig. 4–6). The peak mean numbers were more extreme than the other measures (Fig. 6); this peak stems largely from two hauls where the sablefish had fed primarily on *Euphausia pacifica.* Other than this feeding on euphausiids, no change in species composition of small crustaceans was noted as length changed.

Heteropods were frequent in the diet of smaller sablefish (at 350–450 mm), but less so in larger fish (Fig. 4–6).

Sablefish fed on different-sized prey as they grew. Thornyheads and cephalopods were significantly larger in the stomachs of larger sablefish. Thornyheads increased in size at a rate of 0.019 mm per 1.0 mm of sablefish length ($F_{1,220}$=13.7; $p$<0.01). For cephalopods, the rate of increase was 0.027 mm per mm of sablefish length ($F_{1,43}$=6.3; $p$<0.02). The size of heteropods in sablefish stomachs decreased with increasing sablefish

**Table 2**
Prey groups eaten by all sablefish from the southern area of the survey.

| Prey group | Number | Number per sablefish | % Diet volume | FO[1] (%) | IRI[2] |
|---|---|---|---|---|---|
| Pisces | 1,909 | 1.59 | 51.00 | 52.33 | 122.5 |
| Algae | 4 | 0.00 | 0.06 | 0.60 | <0.1 |
| Porifera | 2 | 0.00 | 0.01 | 0.30 | <0.1 |
| Nemertea | 1 | 0.00 | 0.01 | 0.15 | <0.1 |
| Polychaeta | 40 | 0.03 | 0.42 | 3.61 | 1.6 |
| Gastropoda | 37 | 0.03 | 1.38 | 4.36 | 6.1 |
| Heteropoda | 275 | 0.23 | 14.53 | 26.20 | 386.7 |
| Bivalvia | 3 | 0.00 | 0.01 | 0.45 | <0.1 |
| Cephalopoda unid. | 39 | 0.03 | 2.60 | 4.36 | 11.5 |
| Octopoda | 14 | 0.01 | 1.05 | 2.11 | 2.2 |
| Teuthoidea | 77 | 0.06 | 9.32 | 10.98 | 103.0 |
| Copepoda | 2 | 0.00 | 0.01 | 0.30 | <0.1 |
| Mysidacea | 31 | 0.03 | 1.98 | 4.66 | 9.4 |
| Cumacea | 1 | 0.00 | 0.01 | 0.15 | <0.1 |
| Isopoda | 5 | 0.00 | 0.02 | 0.60 | <0.1 |
| Gammaridea | 67 | 0.06 | 0.14 | 2.56 | 0.5 |
| Euphausiacea | 2,080 | 1.73 | 0.45 | 5.86 | 12.8 |
| Reptantia | 32 | 0.03 | 3.53 | 3.91 | 13.9 |
| Natantia | 85 | 0.07 | 1.30 | 9.32 | 12.8 |
| Sipunculida | 2 | 0.00 | 0.08 | 0.30 | <0.1 |
| Echiura | 7 | 0.01 | 0.10 | 0.90 | 0.1 |
| Asteroidea | 10 | 0.01 | 0.19 | 1.35 | 0.2 |
| Echinoidea | 7 | 0.01 | 0.08 | 1.05 | 0.1 |
| Holothuroidea | 6 | 0.00 | 0.26 | 0.90 | <0.1 |
| Ascidiacea | 2 | 0.00 | 0.10 | 0.30 | <0.1 |
| Thaliacea | 127 | 0.11 | 9.55 | 13.53 | 130.7 |
| Eggs unid. | 74 | 0.06 | 0.02 | 0.90 | 0.1 |
| Tubes unid. | 2 | 0.00 | 0.01 | 0.15 | <0.1 |
| Aves | 1 | 0.00 | 0.01 | 0.15 | <0.1 |

[1] FO = frequency of occurence.
[2] IRI = index of relative importance.

length, but the decrease was not significant at the 0.05 level ($F_{1,67}$=3.6; $p$=0.06).

**Size–Depth Relationship**—Sablefish length showed a significant, gradual increase as depth increased, with a high degree of scatter (Fig. 7; slope=0.32 mm/m; $F_{1,16,419}$=9,527; $p$<0.01; $r^2$=0.35). Typically, sablefish smaller than 400 mm were found in the shallowest depths (400 m or less). Two groups of small fish were collected at approximately 380 and 840 m. These represent small, pelagic individuals which were probably captured in midwater during either deployment or retrieval of the bottom trawl. The distribution for larger sablefish was not as evident, and they could be found throughout the entire range, except in the shallowest depths (less than 200 m). The distribution patterns were more pronounced in the south (slope=0.4 mm/m; $F_{1,1,545}$=2,241; $p$<0.01; $r^2$=0.59) than in the north (slope=0.3 mm/m; $F_{1,5,498}$=2,659; $p$<0.01; $r^2$=0.33). The rate of change of length with depth was different in the two areas (a test for heterogeneity of slopes showed a significant difference; depth*geographic area interaction: $F_{1,16,227}$=37.5; $p$<0.01).

**Diet Change with Depth**—The only prey groups whose occurrence had a significant relationship with depth over all fish sizes were thaliaceans, small crustaceans, cephalopods, and shrimps. Thaliaceans had a higher frequency of occurrence (slope=3.3%/m; $r^2$=0.33; $F_{1,13}$=6.3; $p$=0.03) with increasing depth. On the other hand, small crustaceans, cephalopods, and shrimps had a lower frequency of occurrence with increasing depth. Small crustaceans had a lower frequency of occurrence (slope=–1.4%/m; $r^2$=0.38; $F_{1,13}$=8.0; $p$=0.01) and a smaller mean number per sablefish (slope=–1.1 individuals/m; $r^2$=0.27; $F_{1,12}$=4.5; $p$=0.05) with an increase in depth. Cephalopods had a lower percent diet volume (slope=–0.01%/m; $r^2$=0.40; $F_{1,12}$=7.8; $p$=0.02) with an increase in depth. Shrimps had a significantly lower percent diet volume (slope=–2.4 %/m; $r^2$=0.32; $F_{1,12}$=5.9; $p$=0.03) with an increase in depth. Fish showed no

**Table 3**
Prey groups eaten by sablefish from the northern area of the survey.

| Prey group | Number | Number per sablefish | % Diet volume | FO[1] (%) | IRI[2] |
|---|---|---|---|---|---|
| Pisces | 964 | 1.45 | 80.45 | 74.15 | 6,072.9 |
| Algae | 4 | 0.01 | 0.86 | 0.33 | 0.3 |
| Hydrozoa | 1 | 0.00 | 0.09 | 0.08 | <0.1 |
| Scyphozoa | 2 | 0.00 | 0.01 | 0.17 | <0.1 |
| Anthozoa | 9 | 0.01 | 0.27 | 0.58 | 0.2 |
| Polychaeta | 10 | 0.02 | 0.08 | 0.67 | 0.1 |
| Gastropoda | 4 | 0.01 | 0.24 | 0.33 | 0.1 |
| Heteropoda | 5 | 0.01 | 0.03 | 0.33 | <0.1 |
| Bivalvia | 13 | 0.02 | 0.36 | 0.91 | 0.3 |
| Cephalopoda unid. | 90 | 0.14 | 1.90 | 7.07 | 14.4 |
| Octopoda | 24 | 0.04 | 2.09 | 1.91 | 4.1 |
| Teuthoidea | 114 | 0.17 | 5.79 | 9.14 | 54.5 |
| Mysidacea | 6 | 0.01 | 0.09 | 0.50 | 0.1 |
| Isopoda | 2 | 0.00 | 0.01 | 0.17 | <0.1 |
| Gammaridea | 306 | 0.46 | 0.28 | 1.16 | 0.9 |
| Euphausiacea | 3,526 | 5.30 | 1.15 | 4.66 | 30.1 |
| Reptantia | 29 | 0.04 | 1.48 | 2.41 | 3.7 |
| Natantia | 55 | 0.08 | 0.66 | 4.16 | 3.1 |
| Echiura | 4 | 0.01 | 0.08 | 0.33 | <0.1 |
| Asteroidea | 17 | 0.03 | 0.09 | 0.83 | 0.1 |
| Echinoidea | 6 | 0.01 | 0.09 | 0.50 | 0.1 |
| Holothuroidea | 64 | 0.10 | 1.26 | 3.91 | 5.3 |
| Ascidiacea | 5 | 0.01 | 0.51 | 0.42 | 0.2 |
| Thaliacea | 106 | 0.16 | 0.89 | 2.91 | 3.1 |
| Eggs unid. | 30 | 0.05 | 0.01 | 0.08 | <0.1 |
| Sand | 13 | 0.02 | 0.23 | 1.08 | 0.3 |
| Gravel | 1 | 0.00 | 0.01 | 0.08 | <0.1 |
| Tubes unid. | 1 | 0.00 | 0.01 | 0.08 | <0.1 |
| Aves | 11 | 0.02 | 0.38 | 0.33 | 0.1 |

[1] FO = frequency of occurence.
[2] IRI = index of relative importance.

significant trend as a group, but thornyheads demonstrated a significantly higher mean number per sablefish with increasing depth (slope=0.02 individuals/m; $r^2$=0.43; $F_{1,12}$=16.8; $p$=0.02).

Sablefish of the same size showed no change in diet composition with change in depth. For the four largest length classes (450–499, 500–549, 550–599, and 600–649 mm), frequency of occurrence showed large fluctuations, but no consistent trend with depth. See Figure 8 for an example (the 550–599-mm length class).

## Prey Habitat

The prey in the sablefish stomachs came from both the water column and the benthos (Table 1). Major midwater prey consisted of heteropods, thaliaceans, squids, euphausiids, and midwater fishes, whereas major bottom prey consisted of gastropods, crabs, echinoderms, and bottom fishes. Overall, midwater prey occurred more frequently than benthic prey (76.7% and 51.8%, respectively). Of the 1,212 sablefish with prey that could be categorized by prey habitat, 1,041 (85.9%) had prey entirely from either the bottom or midwater habitat, and 171 (14.1%) had prey from both habitats. For sablefish with more than one prey item in their stomachs, mixed midwater and benthic feeding appeared in 31% (145 fish). Of the remaining 69% (325 fish) of sablefish with multiple prey items, approximately one third (110 fish) ate only benthic prey, and two thirds (215 fish) ate only midwater prey.

There was a significantly lower frequency of occurrence of midwater prey with increasing sablefish length (slope=–0.103%/mm; $F_{1,10}$=21.8; $p$<0.01), whereas benthic prey were more common with greater fish length (slope=0.01%/m; $F_{1,10}$=25.4; $p$<0.01; Fig. 9). The trend of decreased feeding on midwater prey with greater fish length was present for midwater fishes, squids, mysids, heteropods, and thaliaceans. Sablefish that fed on midwater prey averaged 484.2 mm long; sablefish that fed on benthic prey had a significantly greater average length of 520.3 mm (df=367; $t$=–8.8; $p$<0.01).

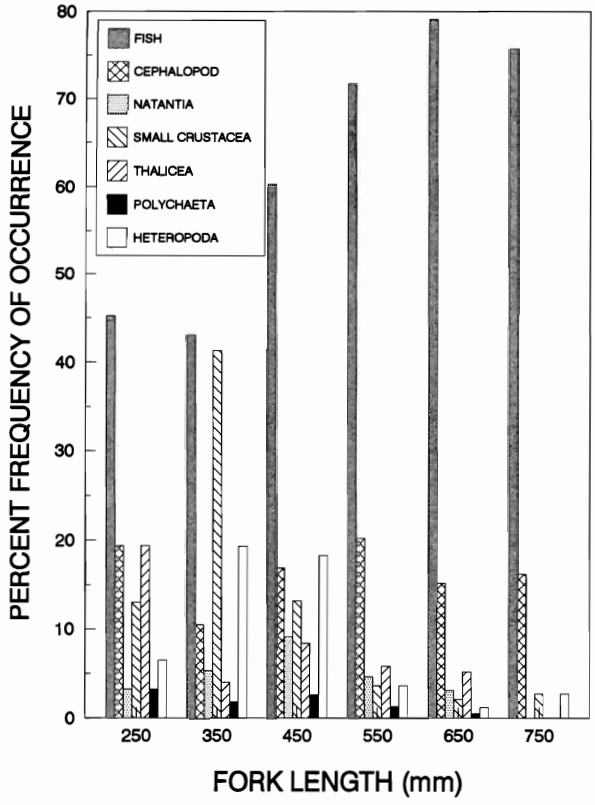


**Figure 4**
Percent frequency of occurrence of major prey categories by sablefish fork length, for all sablefish.

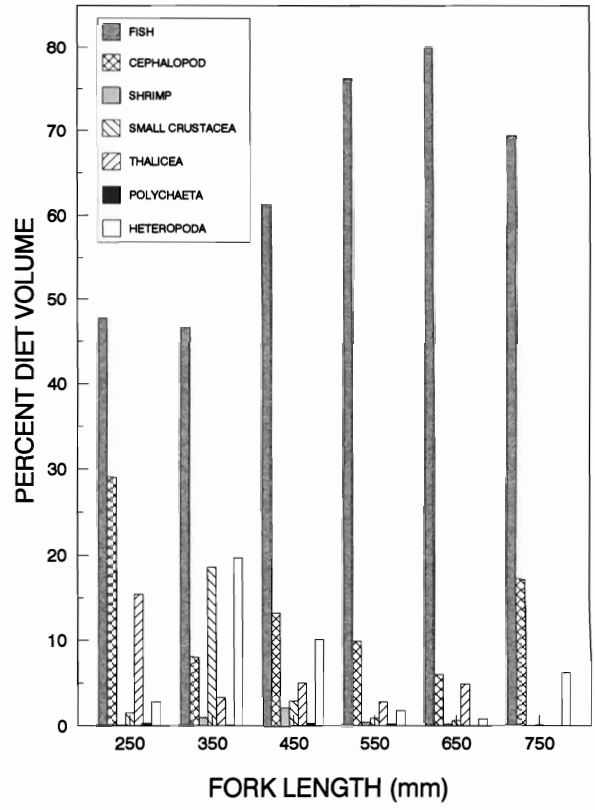


**Figure 5**
Percent diet volume of major prey categories by sablefish fork length, for all sablefish.

Sablefish from the south ate more midwater prey than fish from the north. In the south, the frequency of occurrence was 81.7% for midwater prey and only 33.9% for benthic prey. In the north, the frequency of occurrence was 32.8% for midwater prey, and 33.7% for benthic prey. This same trend emerged for percent diet volume: in the south it was 48.0% for midwater prey and 30.3% for bottom prey; in the north it was 26.2% for midwater and 40.5% for benthic prey. In both areas, the mean numbers of prey per sablefish were highest from the midwater prey category, because of the high numbers of euphausiids eaten.

## Discussion

As sablefish increase in length, they change from a diet of small, midwater prey to large prey primarily from the benthos. The major prey of small sablefish are small crustaceans (mostly euphausiids, gammarid amphipods, and mysids), heteropods, and small fish (myctophids, deepsea smelts, etc.). Large, adult sablefish eat many different prey: fish, primarily thornyheads, are predominant, followed by cephalopods. Since there is little difference in the diets of sablefish of the same size over depth, the change in diet seems related to differences in size rather than depth. A similar change in diet with size was noted by Cailliet et al. (1988) off central California, and by Conway (1967) off southern California. However, Cailliet et al. (1988) observed that fishes were the principal prey for the largest length classes of sablefish, but that cephalopods were less important than euphausiids, amphipods, and decapod shrimps. McFarlane and Beamish (1983), working off the west coast of Canada, also found fish and cephalopods to be the two dominant prey groups, although no specific sablefish length classes were noted.

Sablefish feed on increasingly larger prey as they grow. This change in prey size is due both to change in predation tactics (mouth size, speed, etc.) with size and to the different habitats that sablefish inhabit as they mature. Conway (1967) observed a similar trend: two-year-old sablefish fed on small *Sebastolobus alascanus*, while older sablefish ate larger *S. alascanus*. This relationship has also been seen in species other than sablefish. Prince and Gotshall (1976) found that the size of

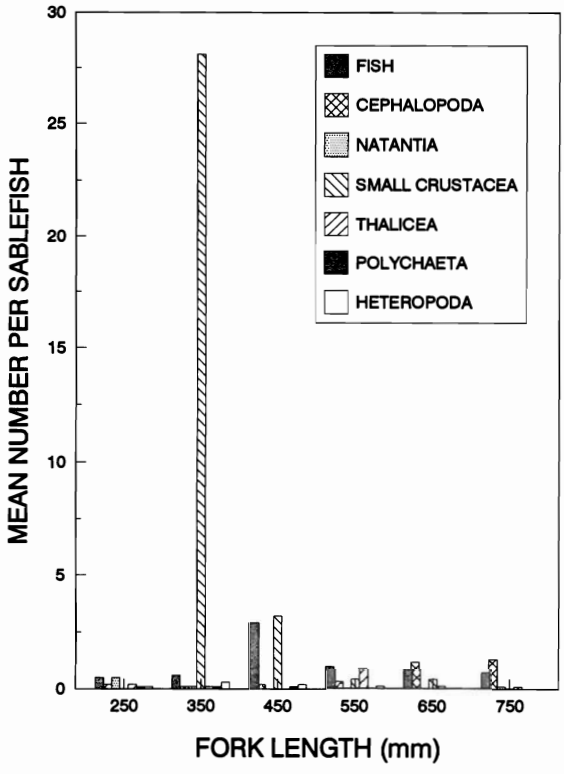


**Figure 6**
Average number per fish of major prey categories by sablefish fork length, for all sablefish.

prey for copper rockfish, *Sebastes caurinus*, increased with increasing fish size. In large leopard searobin, *Prionotus scitulus*, prey size increased with increasing fish length (Ross, 1978).

Sablefish show geographic differences in both diet and size distribution. Sablefish in the south feed more prominently on midwater prey than fish in the north. Sablefish in the southern area are smaller (Methot[3]) and have a more pronounced depth–size relationship. There may be some link between the smaller size in the south and the pelagic feeding mode, but the mechanism is not clear.

Different prey are taken in the two feeding modes—in midwater and on the benthos. This pattern may reflect the habitat that sablefish occupy at different life stages, possibly showing an ontogenetic transition from the pelagic juvenile stage to a benthic existence as adults. During this transition, sablefish reduce their midwater feeding and presumably their time in midwater, and become more strongly associated with bottom feeding. Although the time in midwater is reduced, sablefish are taken as bycatch in the midwater Pacific whiting fishery (Sampson et al., 1997). This gradual transition in feeding mode may help to explain

3 Methot, R. D. 1992. Assessment of the west coast sablefish stock in 1992. *In* Appendices to the status of the Pacific coast groundfish fishery through 1992 and recommended acceptable biological catches for 1993, App. D, 96 p. Pac. Fish. Manage. Council, 2000 S.W. First Ave., Metro Center, Ste. 420, Portland, OR 97201.

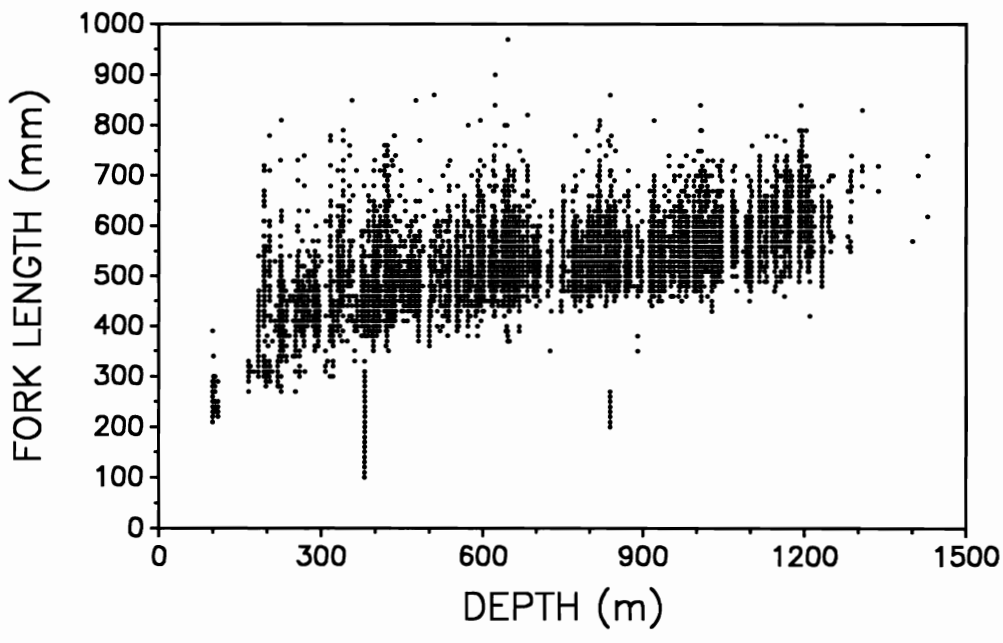


**Figure 7**
Fork length by depth of capture for all sablefish. The small individuals from approximately 380 m and 840 m are small pelagic fish which probably were collected in midwater.

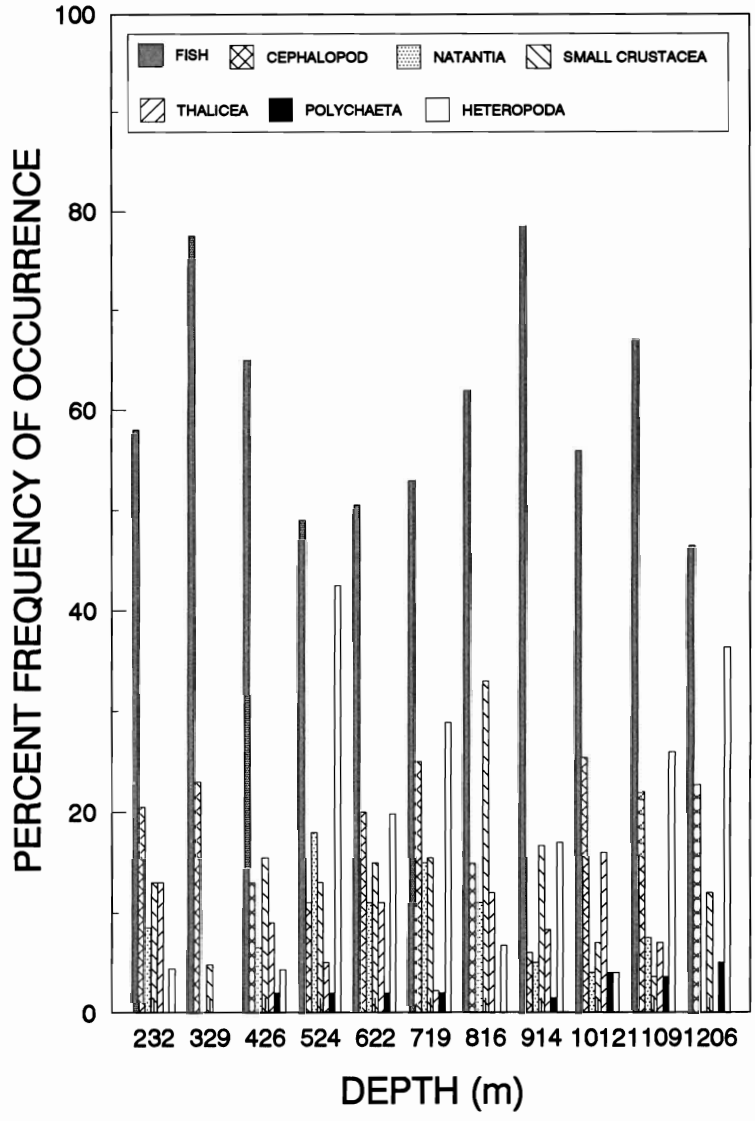


**Figure 8**
Percent frequency of occurrence of major prey categories by depth for sablefish from 550 to 599 mm in fork length.

why sablefish is one of the few species whose distribution extends from shallow water onto the slope.

The decline in midwater feeding with length, and thus in time spent in the water column, may result in a differential vulnerability to bottom trawl gear. Since, at any given time, a larger proportion of smaller fish would be feeding in midwater, bottom trawl estimates would be lower for smaller fish than for larger fish. It is difficult to assess from the data presented here how large an effect this trend would have, but the reduction in frequency of occurrence of midwater prey is substantial from the largest to the smallest length class. This trend is similar to that seen in differential vulnerability to trawl gear due to diel behavior reported in the northeastern Atlantic (Walsh, 1991; Engas and Soldal, 1992). The differential vulnerability of fish to the trawl would bias any trend of relative abundance from smaller to larger fish and therefore reduce apparent mortality.

Predatory fish play a dominant role in marine groundfish ecosystems, and changes in abundance of major piscivorous fish will cause a cascade of effects on these ecosystems (Bax, 1991). Attempts to incorporate these kinds of species interactions have been considered critical in heavily exploited ecosystems such as the North Sea, where consumption by fish, marine mammals, and seabirds are many times the amount taken by the fish-

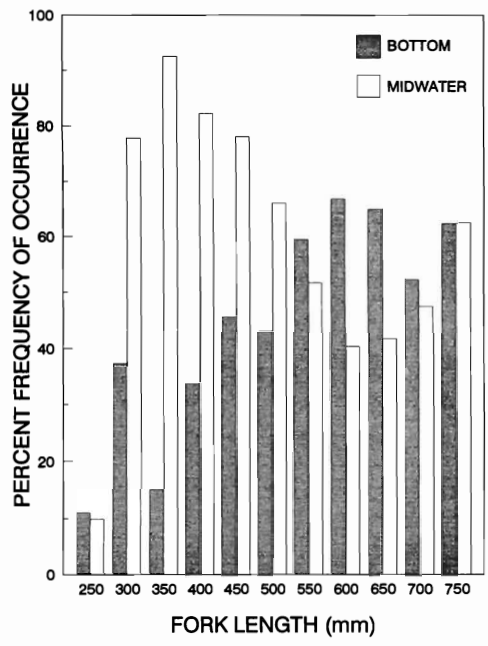


**Figure 9**
Percent frequency of occurrence of midwater and bottom prey, by sablefish fork length.

ery (Pope, 1991). This need has led to the development of multispecies virtual population analysis (MSVPA) where natural mortality consists primarily of abundances of major predators multiplied by their feeding rates on other harvested fish. The MSVPA assessments produce results that often contradict single-species assessments, and the question as to which of the contradictory predictions from single-species or MSVPA assessments is more accurate has not been resolved.

The combination of predator relations and the harvesting of sablefish and the two thornyhead species in the slope community presents the same situation that led to contradictory advice from single-species and MSVPA assessments in the North Sea. Sablefish and the two thornyhead species are harvested together, and sablefish are a major predator on the two species of thornyheads, particularly *S. altivelis*. Stock assessment of sablefish under the most optimistic conditions indicates that biomass has decreased to less than one half of 1971 levels (Methot[2]), and potentially the decrease could be much greater. Under the assumption of a MSVPA management regime, the reduced sablefish biomass would lead to a substantial reduction in natural mortality of *S. altivelis* and, to a lesser degree, *S. alascanus*, although the degree of reduction is impossible to predict, since it would be a function of a number of factors not known here, such as predation rate, digestion rate, etc. Thornyhead landings have increased ninefold in the same period as the sablefish decrease (Ianelli et al.[4]) and although there is a great deal of uncertainty associated with the assessment, *S. altivelis* is considered a lightly exploited stock, and *S. alascanus* is considered a highly exploited stock. If MSVPA assumptions become accepted, assessments of these two thornyhead species would change dramatically.

## Acknowledgments

We would like to thank Kristie Miller and Kelly Silberberg for help in collecting stomach samples. We would also like to thank the crews and scientific personnel from the F/V *Gus-D*, F/V *Golden Fleece*, R/V *David Starr Jordan*, and R/V *Miller Freeman*. We would also like to thank Dan Howard and Kelly Silberberg for their valuable input.

## Literature Cited

Bax, N. J.
1991. A comparison of the fish biomass flow to fish, fisheries, and mammals in six marine ecosystems. ICES Mar. Sci. Symp. 193:217–224.

Cailliet, G. M., E. K. Osada, and M. Moser.
1988. Ecological studies of sablefish in Monterey Bay. Calif. Fish Game 74(3):132–153.

Conway, J. B.
1967. Food relationships and general population biology of the sablefish, *Anoplopoma fimbria*, and Pacific hake, *Merluccius productus*. M.S. thesis, San Diego State College, San Diego, CA, 109 p.

Engas, A., and A. V. Soldal.
1992. Diurnal variations in bottom trawl catch rates of cod and haddock and their influence on abundance indices. ICES J. Mar. Sci. 49(1):89–95.

Grinols, R. B., and C. D. Gill.
1968. Feeding behavior of three oceanic fishes (*Oncorhynchus kisutch*, *Trachurus symmetricus*, and *Anoplopoma fimbria*) from the northeastern Pacific. J. Fish. Res. Board Can. 25:825–827.

Krebs, C. J.
1989. Ecological methodology. Harper Collins, New York, 654 p.

McFarlane, G. A., and R. J. Beamish.
1983. Biology of adult sablefish (*Anoplopoma fimbria*) in waters off western Canada. *In* Proceedings of the International Sablefish Symposium, March 29–31, 1983, Anchorage, Alaska, p. 59–80. Alaska Sea Grant Rep. 83-8.

Pinkas, L.
1971. Food habits study. *In* L. Pinkas, M. S. Oliphant, and I. L. K. Iverson (eds.), Food habits of albacore, bluefin tuna,

[4] Ianelli, J. N., R. Lauth, and L. D. Jacobson. 1994. Status of the thornyhead (*Sebastolobus* spp.) resource in 1994. *In* Appendices to the status of Pacific Coast groundfish fishery through 1994 and recommended acceptable biological catches for 1995, Appendix D, 58 p. Pac. Fish. Manage. Council, Metro Center, Ste. 420, 2000 S.W. First Ave., Portland, OR 97201.

and bonito in California waters, p. 5–10. Calif. Dep. Fish Game, Fish Bull. 152.

Pope, J. G.
1991. The ICES multispecies assessment working group: evolution, insights, and future problems. ICES Mar. Sci. Symp. 193:22–33.

Prince, E. D., and D. W. Gotshall.
1976. Food of the copper rockfish, *Sebastes caurinus* Richardson, associated with an artificial reef in south Humboldt Bay, California. Calif. Fish Game 62(4):274–285.

Regier, H. A., J. E. Paloheimo, and V. F. Gallucci.
1979. Factors that influence the abundance of large piscivorous fish. *In* R. H. Stroud (ed.), Predator–prey systems in fisheries management, p. 333–342. Sport Fishing Inst., Washington, D.C.

Ross, S. T.
1978. Trophic ontogeny of the leopard searobin, *Prionotus scitulus* (Pisces: Triglidae). Fish. Bull. 76(1):225–234.

Sampson, D., W. Barss, M. Saelens, and C. Wood.
1997. The bycatch of sablefish, *Anoplopoma fimbria*, in the Oregon whiting fishery. *In* M. Wilkins and M. Saunders (eds.), Biology and management of sablefish, *Anoplopoma fimbria*, p. 183–194. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 130.

Smith, G. B., and R. G. Bakkala.
1982. Demersal fish resources of the eastern Bering Sea: spring 1976. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-754, 129 p.

Walsh, S. J.
1991. Diel variation in availability and vulnerability of fish to a survey trawl. J. Appl. Ichthyology 7(3):147–159.