Food Habits of Larval Sablefish *Anoplopoma fimbria* from the Bering Sea

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Sablefish *Anoplopoma fimbria* spawn at depths exceeding 400 m (Mason et al. 1983) and their larvae ascend to surface waters soon after hatching (Kendall and Matarese 1987). While in the neuston, they are subjected to highly variable oceanographic conditions. A comparison of the diet of sablefish larvae collected off Oregon and Washington between years that differed markedly in oceanographic conditions (1980 and 1983) revealed a difference in the size of copepods that were ingested (Grover and Olla 1987). Clearly diet can vary between years in one location in re-sponse to oceanographic conditions, yet it is unclear how larval diet might vary between distant geographical areas of differing oceanographic conditions.

The aim of the present work was to examine the food habits of larval sablefish that were collected in the Bering Sea in 1979 and compare these findings with those from an earlier study of specimens collected off Oregon and Washington (Grover and Olla 1986, 1987).

Methods

Sablefish larvae were collected dur-ing 1979 as part of an ichthyoplankton survey in the Eastern Bering Sea (Walline 1981). Samples were collected using a modified Sameoto neuston sampler, 0.3×0.5 m with 0.505-mm mesh, towed at the surface for 10 minutes at 2–3 knots. Surfacewater temperatures ranged from about 6°C to just over 8°C. Collections were made from the RV *Miller Freeman* between 17 June and 10 July 1979.

All specimens ($N = 127$) from 5 stations (Fig. 1) where larval densities were at least $1/10$ m^2 surface area were examined. This represents more than 40% of the total number of sablefish larvae that were collected in 1979.

Larvae were preserved in 10% formalin and were switched into 5% formalin after sorting. Standard length (SL) of each larva was measured, the digestive tract was removed, and contents from the entire digestive tract were identified.

Diet was analyzed in terms of numerical percentage composition (%N), percent frequency of occurrence (%FO), and volumetric percentage composition (%VOL). Prey volumes were calculated from prey dimensions (Grover and Olla 1987). An index of relative importance (IRI = (%N + %VOL) × %FO) (Pinkas et al. 1971) was used for a more comprehensive assessment of prey importance. Data were examined by larval size group (12–15 and 16–23 mm SL).

Prey was categorized as diatoms, copepod eggs, copepod nauplii, *Oithona similis*, *Pseudocalanus* sp. adults and copepodites, *Acartia longiremis*, *Acartia* spp., unidentified copepods, amphipods, and all other prey items.

Prey widths that were used to examine prey-size selection were obtained only from items that were not badly broken or flattened. Over 2900 prey items were measured.
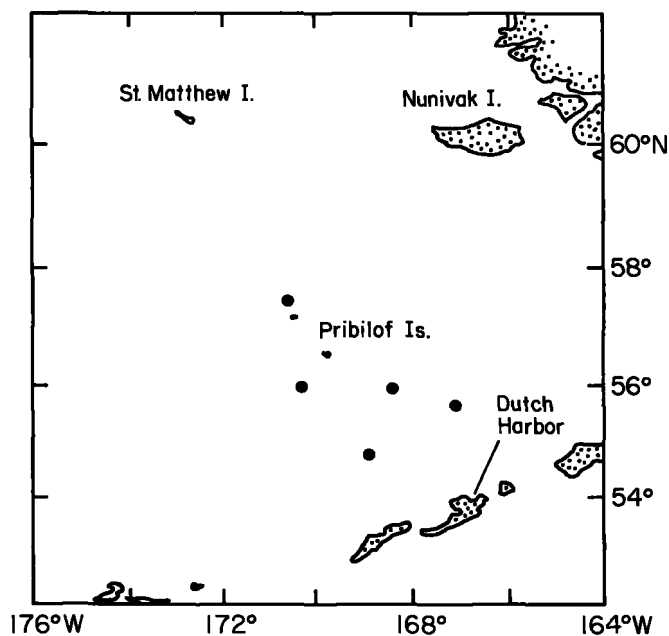

Figure 1
Location of collection stations in the eastern Bering Sea.

Median widths of diatoms were the smallest (0.01–0.10 mm), followed by copepod eggs, nauplii, and *O. similis* (0.11–0.20 mm), *Pseudocalanus* copepodites, *A. longiremis*, *Acartia* spp., unidentified copepods, and other prey (0.21–0.30 mm), and *Pseudocalanus* sp. adults and amphipods (0.31–0.40 mm).

Results

A single prey-size class was most often ingested by all larvae (Fig. 2A). While both large and small larvae consumed small prey, the ingestion of larger prey by large larvae resulted in the two curves being significantly different (*P*<0.01, Kolmogorov-Smirnov test; Conover 1980). The shared mode of the two curves was attributed to large larvae ingesting a number of small prey items, particularly copepod eggs (0.11–0.20 mm) (Table 1). When we eliminated copepod eggs from the analyses, assuming that they were taken incidentally in the course of ingesting adult female *Pseudocalanus* sp., the prey-size distribution of small larvae did not change noticeably (Fig. 2B). But the removal of copepod eggs from the diet of large larvae shifted the prey-size mode towards larger prey.

Copepod nauplii were the primary prey of small larvae (Table 1). *Pseudocalanus* sp. also comprised a major portion of the diet, with adults and copepodites nearly equal in importance. Unidentified copepods made a small contribution, while *Acartia* spp., *Oithona similis*, and copepod eggs were rather insignificant in the diet of small larvae.

Copepods were the primary prey of large larvae (Table 1), with *Pseudocalanus* sp. adults predominant over copepodites and all other species. A large number of copepod eggs were ingested, while amphipods, unidentified copepods, *Acartia longiremis*, and copepod nauplii made progressively smaller contributions to the diet. The relatively large size of amphipods likely contributed to their being ingested only by large larvae.

The mean number of prey items ingested by small larvae was 26.9, compared with 34.1 by large larvae. The incidence of feeding was 100%.

Discussion

The pattern of prey-size selection observed in the Bering Sea contrasts with the pattern seen for larvae collected off the Oregon and Washington coasts in 1980 (Grover and Olla 1986). In each study functional breaks in diet (e.g., the shift away from dependence on copepod nauplii) were used to define larval size groups. The Oregon-Washington collections were categorized into three size groups: 8.2–12.5, 12.6–20.5, and 20.6–28.5
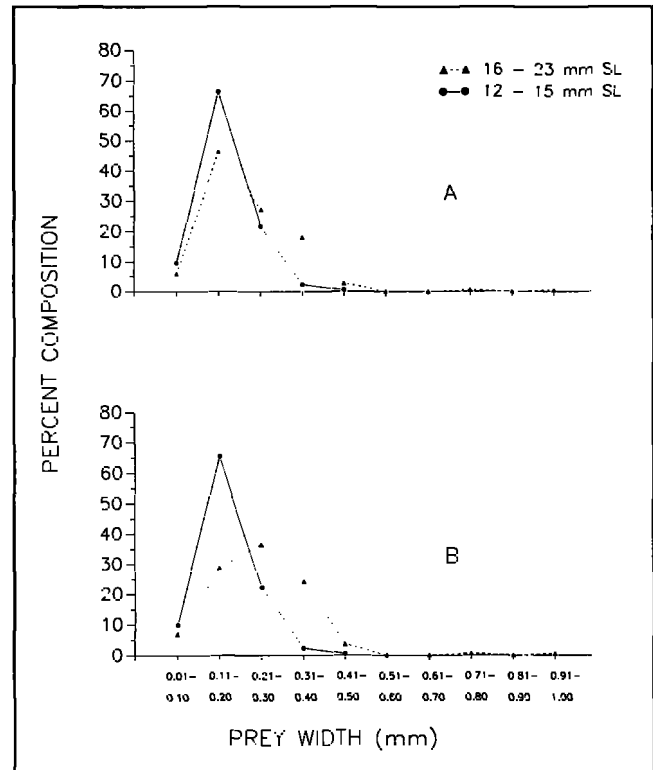

Figure 2

Size of prey selected by two size classes of larval sablefish (12–15 and 16–23 mm SL) in the Bering Sea in 1979: (A) including copepod eggs, (B) omitting copepod eggs.

mm SL. Each size group favored a different peak prey size, with the smallest larvae ingesting the smallest prey, and the largest larvae ingesting the largest prey (Grover and Olla 1986). However, peak prey sizes for the two size groups from the Bering Sea were the same as long as copepod eggs were included in the analyses. Their removal shifted the prey-size utilization curve of large larvae in the Bering Sea towards larger prey.

Copepod eggs had a greater impact on the diet in the Bering Sea than off Oregon due to a difference in the biology of the dominant copepod species ingested in the two regions. The dominant copepod in the diet of large larvae collected off Oregon in 1980 was *Paracalanus parvus* (Grover and Olla 1987), a species that broadcasts its eggs into the sea (Checkley 1980). *Pseudocalanus* sp., the dominant copepod in the diet of larvae collected from the Bering Sea, carries its eggs (Corkett and McLaren 1978) which could thus be ingested incidental to the adults. Nevertheless, as female copepods with eggs were not observed in sablefish guts, and as other copepods that broadcast their eggs (such as all *Acartia* spp.) contributed to the diet, it remains a possibility that some eggs were ingested independently

Table 1
Composition of the diet of larval sablefish in the Bering Sea in terms of the Index of Relative Importance (IRI) and its components: Numerical percent composition (%N), frequency of occurrence (%FO), and volumetric percent composition (%VOL), by size class.

	Larval size class							
	12–15 mm				16–23 mm			
Prey	%N	%VOL	%FO	%IRI	%N	%VOL	%FO	%IRI
Diatoms	0.2	<0.1	4.5	<0.1	3.3	<0.1	30.8	0.8
Copepod eggs	2.6	0.3	22.7	0.4	20.2	0.8	74.4	11.2
Copepod nauplii	74.1	41.6	100.0	77.9	12.9	3.0	43.6	5.0
Oithona similis	2.4	2.5	27.3	0.9	5.0	2.2	38.5	2.0
Pseudocalanus sp. adults	4.2	23.6	39.8	7.4	23.7	55.7	92.3	52.7
Pseudocalanus copepodites	9.6	17.8	50.0	9.2	9.4	8.2	74.4	9.4
Acartia longiremis	0.3	0.8	1.1	<0.1	8.4	8.6	41.0	5.0
Acartia sp.	2.4	4.7	19.3	0.9	2.1	1.7	38.5	1.1
Unident. copepods	3.7	7.4	40.9	3.1	7.5	6.3	56.4	5.6
Amphipods					7.2	13.2	48.7	7.1
Other	0.5	1.2	10.2	0.1	0.3	0.3	7.7	<0.1

of females. However, since the number of copepod eggs in the diet appeared to be positively correlated with the number of adult *Pseudocalanus* sp. ingested, we conclude that most copepod eggs were probably attached to adult female *Pseudocalanus* sp. when they were ingested. The mechanical action of ingestion most likely liberated the eggs from their delicate egg sacs (see Grover 1990). These data suggest that copepod eggs may be important in the diets of larval sablefish and other species in the Bering Sea.

In contrast to the larval diet off Oregon and Washington, copepods >2 mm were inconsequential in the diet of larvae in the Bering Sea. While copepod species with southern affinities were absent from the diet of sablefish larvae collected in the Bering Sea, species with northern affinities, i.e., *Pseudocalanus* sp. and *A. longiremis*, occurred more frequently in the diet of larvae collected in the Bering Sea than off Oregon (Grover and Olla 1987). Euphausiid larvae, appendicularians, and pteropods were absent from the diet of sablefish larvae collected in the Bering Sea, while they made a noticeable contribution to the diet of sablefish larvae collected off Oregon.

Specific differences in prey items could be expected when comparing geographically separated populations; however underlying principles of prey-size selection are assumed to be universal in nature (Hunter 1981). We looked beyond the initial data plots and found a biological explanation as to why the size of prey consumed by large larvae in the Bering Sea differed from the pattern observed off Oregon (Grover and Olla 1986). Our data revealed that copepod eggs have such a confounding influence on prey-size distributions that the mode

of their ingestion (i.e., free-floating vs. attached to adults) must be recognized in order to adequately interpret prey-size selection patterns.

Acknowledgments

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