

VERTICAL DISTRIBUTION AND DIET OF *STENOBRACHIUS NANNOCHIR* (MYCTOPHIDAE) IN THE SOUTHERN BERING SEA, SUMMER, 1987*

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Abstract: The vertical distribution and diet of the myctophid species *Stenobranchius nannochir* were examined on samples collected at various mesopelagic depths (>600 m) day and night in the southern Bering Sea, in June and July 1987. This species exhibited no diel variation in vertical distribution, remaining at a depth of about 600 m. Stomachs were examined from 226 specimens. The diet was dominated by copepoda, mostly *Calanus plumchrus*, *Calanus cristatus*, *Eucalanus bungii bungii* and *Metridia pacifica*.

The stomach fullness and prey digestive stage indicated little evidence of feeding periodicity, suggesting that *S. nannochir* is an acyclic predator among the family Myctophidae. The acyclic feeding by this non-migrating myctophid appears to adapt it to exploit efficiently the broad vertical distribution and abundance of prey in the subarctic Pacific Ocean.

1. Introduction

The myctophid fish, *Stenobranchius nannochir* (GILBERT) (Myctophidae) was originally described as *Myctophum* (= *Lampanyctus*) *nannochir* by GILBERT (1890) from the eastern Pacific coast of North America. This species is one of the most dominant myctophid species in the subarctic Pacific Ocean. It occurs from the Bering Sea, Okhotsk Sea, off Sanriku, Japan, reaching south to about 35°N in the western Pacific Ocean (KULIKOVA, 1960; WISNER, 1974). It has not been reported from south of about 40°N in the eastern Pacific Ocean. Although most lanternfishes undertake diel vertical migrations, there are some non-migratory species. *S. nannochir* does not undertake diel vertical migration (FROST and MCCRONE, 1979; WILLIS and PEARCY, 1982). It inhabits the lower mesopelagic zone, with a maximum in abundance at 650 m (WILLIS and PEARCY, 1982), and comprises a major component of lanternfishes in the Bering Sea and adjacent northern North Pacific Ocean (PEARCY *et al.*, 1979a).

In the oceanic environment, some organic matter produced in the epipelagic zone is conveyed to the bathypelagic zone through diurnal, seasonal and ontogenetic migrations (VINOGRADOV, 1970). This process may be accelerated by diel vertical migrations

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of predators and prey. For example, *Diaphus taaningi* NORMAN, an abundant myctophid in the Cariaco Trench, Venezuela, feeds on herbivorous plankton between its evening ascent and midnight (BAIRD *et al.*, 1975). In the morning, they migrate downward in the cooler, food-poor mesopelagic zone. Most micronekton also invade the shallower waters to graze upon zooplankton at night, and leave the surface layer for the mesopelagic zone to dwell lethargically during the day (HOLTON, 1969; GORELOVA, 1977; OZAWA *et al.*, 1977; TSEYTLIN and GORELOVA, 1978; CLARKE, 1978; KINZER, 1982; ROE and BADCOCK, 1984; DUKA, 1987; SHEVCHENKO, 1987).

Because diel vertical migration of fishes is important for feeding, non-migrating myctophids may have different feeding habits from migrating species. In this paper we describe the depth distribution and feeding habits of a non-migrating lanternfish, *S. nannochir*, in the southern Bering Sea.

2. Materials and Methods

Fishes were collected in the southern Bering Sea during the cruise of the T/S OSHORO-MARU, Faculty of Fisheries, Hokkaido University, from June to July, 1987 (Fig. 1). Bottom depth varied from 2900 m to 3800 m in the study area. Thirty minutes horizontal tows were made at each depth desired with a 2.0 m \times 2.5 m non-closing rectangular midwater trawl net (NAKATANI, 1987). A total of 17 collections were obtained from six sampling stations. The sampling depths of tows were set about 600 m, 300 m and shallower than 150 m. Samples were preserved in 10% buffered formalin in sea water for 24 h. Fishes were then sorted and stored in 50% isopropyl alcohol.

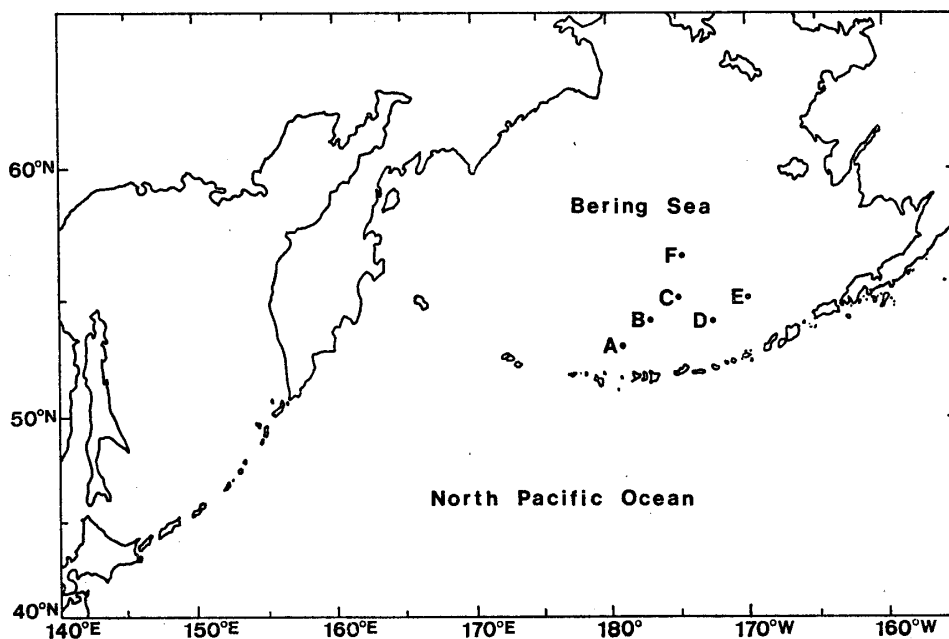


Fig. 1. Sampling location for the rectangular midwater trawl net tows during the T/S OSHORO-MARU cruise, in the southern Bering Sea from late June through early July, 1987.

In the laboratory fish were identified to species, and measured standard length, SL, to the nearest 0.1 mm. A total of 226 stomachs of *S. nannochir* were removed and the contents were weighed to the nearest milligram. Prey items in the stomachs were identified to species and counted whenever possible. The number of stomachs containing a particular food item (*F*) was expressed as a percentage of the total number of stomachs which contained identifiable food. Also, the frequency of each food item (*C_n*) was expressed as a percent of the total number of identifiable food items. Stomach fullness was categorized on a scale from 0 to 4, with 0=empty, 1=nearly empty, 2=a quarter filled, rugae not distended, 3=half filled, rugae partially distended, 4=full, no rugae, stomach extended (modified from TYLER and PEARCY, 1975; DEWITT and CAILLIET, 1972; GJØSÆTER, 1973; KINZER, 1982). The degree of digestion of the stomach contents, based mainly on crustacea, was scored: stage A=fresh; B=little digested, prey being damaged only on the body surface; C=moderately digested, exoskeletons of prey being broken but certain prey were distinguishable; D=well digested, prey unidentifiable.

Fishes from the trawl cod end were dead or dying. We accept the proposal of HOPKINS and BAIRD (1975) that the diet of mesopelagic fishes is not heavily biased from any feeding in the cod end. We sometimes found digested prey items from the esophagus to the mouth cavity, possibly evidence of regurgitation. However, we found no evidence from the appearance of the empty stomachs or everted stomachs; therefore, we assume that regurgitation by the fish did not affect appreciably the stomach fullness analysis.

Hydrographic data are quoted from the Data Record of Oceanographic Observations and Exploratory Fishing (HOKKAIDO UNIVERSITY, 1988).

3. Results

In this study fifteen different species of fishes were identified among all sampling locations (Table 1). The family Myctophidae was dominant (five species), comprised 88.3% of the total number of fishes collected. Two species of myctophids, *S. nannochir* and *S. leucopsarus*, dominated numerically.

Because the temperature and salinity structures differed little below 300 m (Fig. 2), the oceanographical differences among sampling stations were ignored and the samples were treated as a time series sampling.

3.1. Vertical distributions

Body size of *S. nannochir* ranged from 31.9 mm to 107.8 mm and the mean body size varied from 61.3 mm to 72.0 mm between samples (Table 2). There was no statistical difference in the mean length between sampling stations (F-test and t-test; $P < 0.05$). *S. nannochir* was captured from 300 m to 600 m, mostly captured at a depth of about 600 m, while *S. leucopsarus* was captured from depths between 60 m and 600 m (Fig. 3). An accurate catch depth could not be determined for the mouth of the net was open ducking settling, but the results demonstrate a lack of vertical migration of *S. nannochir*.

Table 1. Species and number of mesopelagic fishes caught by midwater trawl net in the southern Bering Sea, from late June through early July, 1987.

MYCTOPHIDAE	
<i>Protomyctophum thompsoni</i> (CHAPMAN)	8
<i>Stenobrachius nannochir</i> (GILBERT)	363
<i>Stenobrachius leucopsarus</i> (EIGENMANN and EIGENMANN)	593
<i>Stenobrachius</i> sp. ?	48
<i>Diaphus theta</i> (EIGENMANN and EIGENMANN)	1
<i>Lampanyctus</i> sp.	2
GONOSTOMATIDAE	
<i>Cyclothone atraria</i> GILBERT	10
Unidentified spp.	1
BATHYLAGIDAE	
<i>Bathylagus pacificus</i> GILBERT	17
<i>Bathylagus milleri</i> JORDAN and GILBERT	4
<i>Leurogrossus schmidti</i> RASS	32
SCOPELARCHIDAE	
<i>Benthalbella dentata</i> (CHAPMAN)	3
CHAULIODONTIDAE	
<i>Chauliodus macouni</i> BEAN	7
PLEURONECTIDAE	
<i>Hippoglossus stenolepis</i> SCHMIDT	1
GADOIDEI	
<i>Theragra chalcogramma</i> (PALLAS)	36
COTTIDAE	
	1
CYCLOPTERIDAE	
	1
Other fish larvae	22
Total	1150

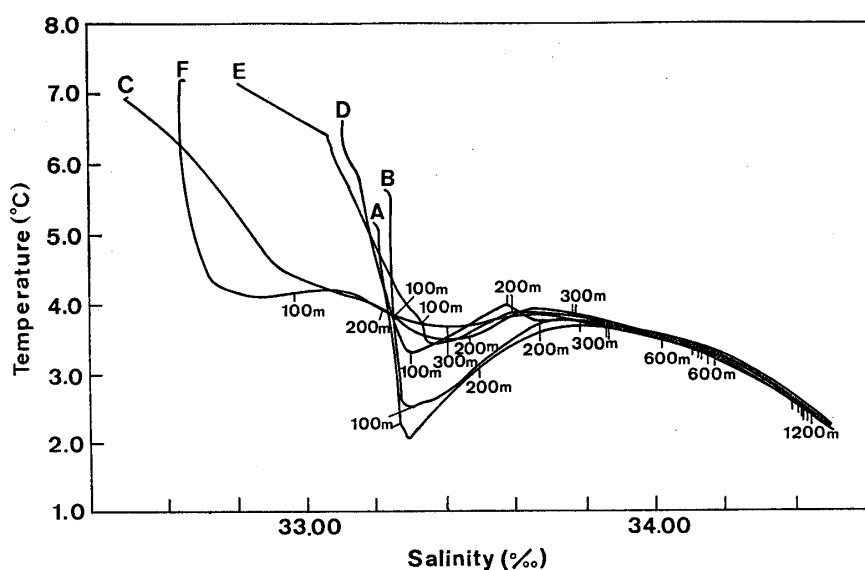


Fig. 2. T-S diagram of sampling stations (A-F), in the southern Bering Sea from late June through early July, 1987.

3.2. Food composition

Copepoda were most abundant in the stomach contents of *S. nannochir*, being found in 96 ($F=93.2\%$) of the 103 stomachs containing identifiable food (Table 3).

Table 2. Mean standard length and length range of *Stenobranchius nannochir* in six samples.

Date Location*	Time of horizontal tow	Sample size	SL (AVG±SD)	Max.	Min.
22 June A	1919-1949	30	62.1±20.91	99.2	31.9
23 June B	2224-2254	55	61.9±15.22	104.2	39.8
24 June C	2150-2220	75	66.9±16.21	105.1	39.0
27 June D	2225-2255	42	69.7±15.81	98.9	40.0
30 June D	0048-0118	35	61.3±18.21	107.8	34.3
2 July F	0837-0907	65	72.0±14.59	103.0	36.1

* Letters indicate the sampling locations shown in Fig. 1.

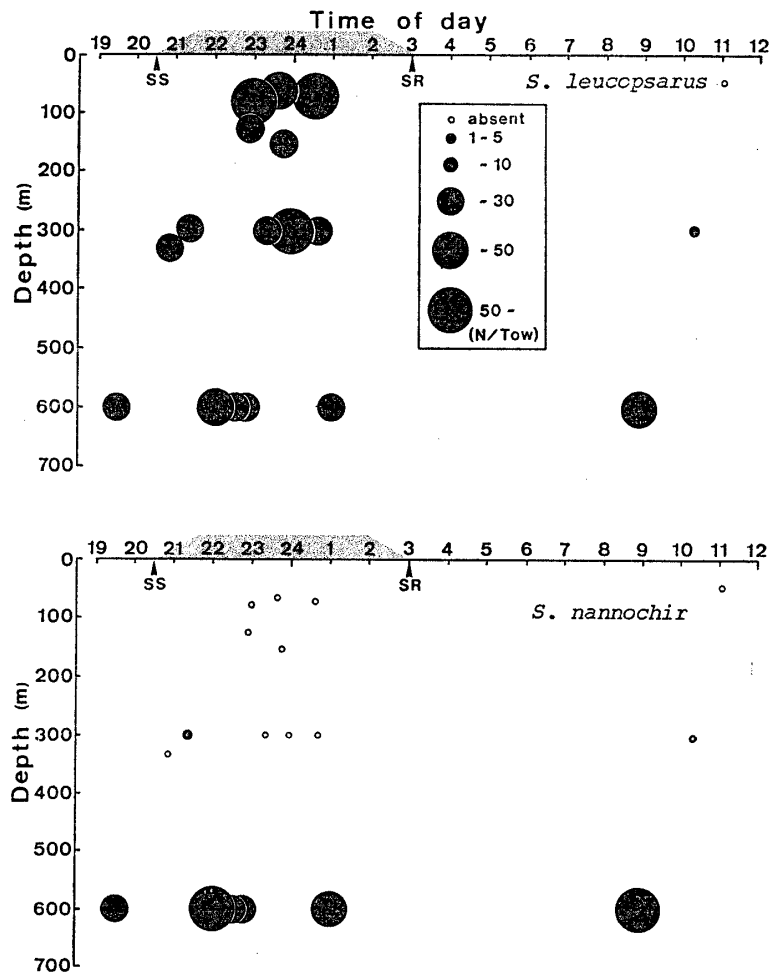


Fig. 3. Time and depth distributions of *Stenobranchius leucopsarus* (upper) and *Stenobranchius nannochir* (lower) based on catch per tow, in the southern Bering Sea from late June through early July, 1987. Arrows indicate sunset (SS) and sunrise (SR).

Table 3. Diet of *Stenobrachius nannochir* for all samples combined. Cn (%) is the percentage of the identifiable food items to the total number. F (%) is the percentage frequency of occurrence of identifiable food items.

	Cn	F		Cn	F
CRUSTACEA (total)	97.1	95.5	Amphipoda	2.9	1.0
COPEPODA (total)	93.2	91.3	Euphausiacea	2.9	1.0
<i>Calanus cristatus</i>	20.3	9.7	Ostracoda		
<i>Calanus plumchrus</i>	52.4	35.1	<i>Conchoecia</i> spp.	4.8	2.0
<i>Eucalanus bungii bungii</i>	32.0	17.5	CHAETOGNATHA		
<i>Gaidius variabilis</i>	2.9	1.0	<i>Sagitta</i> sp.	6.7	3.1
<i>Gaidius</i> spp.	1.9	0.6	Larvacea		
<i>Gaetanus simplex</i>	2.9	1.0	<i>Oikopleura</i> sp.	0.9	0.3
<i>Pareuchaeta birostrata</i>	0.9	0.3	SALPIDA	1.9	0.6
<i>Pareuchaeta</i> sp.	0.9	0.3	MEDUSA	0.9	0.3
? <i>Euchaeta</i> sp.	0.9	0.3			
<i>Metridia pacifica</i>	29.1	13.1			
<i>Pleuromamma scutullata</i>	2.9	1.0	Number of prey items	290	
<i>Heterorhabdus robustoides</i>	2.9	1.0	Number of stomachs containing		
Small unidentified spp.	2.9	1.0	identifiable food	103	
Unidentified spp.	22.6	22.1	Number of stomachs examined	226	

The abundance of prey in decreasing order was *Calanus plumchrus*, *Eucalanus bungii bungii*, *Metridia pacifica* and *Calanus cristatus*. Other groups such as Ostracoda, Amphipoda, Euphausiacea and Sagittidea occurred in small numbers. GORDON *et al.* (1985) found that copepods were also the dominant food items for *S. nannochir* in the Pacific coast of Hokkaido.

The mean number of identifiable food items per stomach was 2.8 (± 2.4 S.D.) with a range from 1 to 15. This indicates that *S. nannochir* in the southern Bering Sea ate more prey than in the subarctic Pacific Ocean (1.7 with a range from 1 to 8; GORDON *et al.*, 1985).

3.3. Stomach fullness and stage of digestion

The percentage of empty stomach was high (34.3–60.5%) at night and low (19.0–27.6%) during the day (Fig. 4). The difference of stomach fullness between day and night samples were statistically significant (MANN and WHITNEY'S U-test: $P < 0.05$). Freshly ingested food items were found during daytime and nighttime. There was no significant difference in the stomach digestion indices between day and night samples. In addition, specimens with full stomachs were found in all but one night sample.

The absence of pronounced diel trends in feeding and the presence of fresh food items in the stomachs suggest that *S. nannochir* does not feed periodically but is acyclic in feeding.

4. Discussion

S. nannochir exhibited no diel variation in vertical distribution, remaining in the lower mesopelagic zone in the southern Bering Sea. Our results confirm the previous findings that *S. nannochir* was never captured in midwater trawls shallower than 150 m

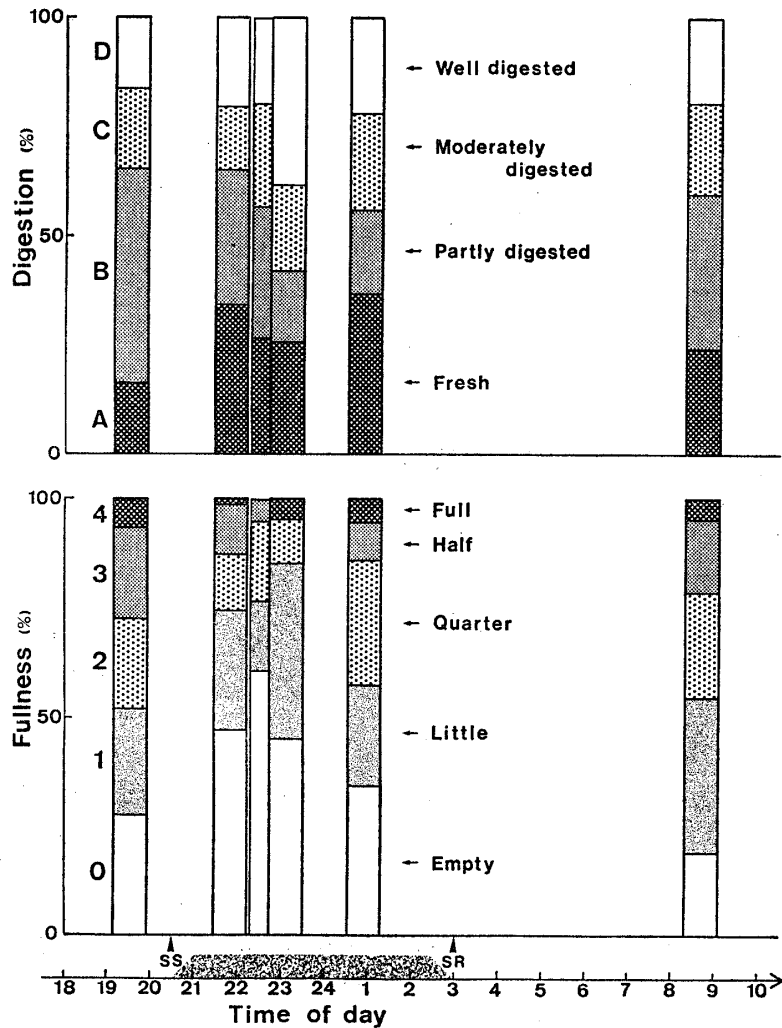


Fig. 4. Diurnal variation in degree of fullness (lower) and stage of digestion (upper) of stomach contents of *Stenobranchius nannochir*. Samples were obtained from the rectangular midwater trawl net tows in the southern Bering Sea from late June through early July, 1987. Arrows indicate sunset (SS) and sunrise (SR).

(in the Bering Sea; PEARCY *et al.*, 1988) and our results confirm findings that they occurred in maximum numbers at a depth below 440 m (at Ocean Station P: lat. 50°N, long. 145°W; FROST and MCCRONE, 1979; PEDEN *et al.*, 1985) and below 500 m (off Oregon; WILLIS and PEARCY, 1982) in the subarctic Pacific Ocean.

S. nannochir preys mostly on copepods, *C. plumchrus*, *E. bungii bungii*, *M. pacifica* and *C. cristatus*. These copepods were common species in the subarctic Pacific Ocean and their vertical distributions have been previously studied. MILLER *et al.* (1984) reported that *C. plumchrus* (= *Neocalanus plumchrus* in their study) reproduces at depths below 250 m from July through February in the eastern subarctic Pacific Ocean. Copepodite stages of *C. plumchrus* were present in surface layers from October through August. Fifth copepodites (C_5) prepared for diapause during spring and descended to depths below 250 m to 1000 m. The life history of *C. cristatus* (= *Neocalanus cristatus*)

closely resembles that of *C. plumchrus*, but their vertical distribution extends to greater depth. All stages of *E. bungii bungii* (C₃-C₆) spent the seven months from September through March in diapause. The bulk of the diapause population is consistently present between 250 m and 500 m (MILLER *et al.*, 1984). *M. pacifica* was equally abundant in 0 m to 100 m depth and 250 m to 500 m depth strata throughout the year, although relatively few occurred below 500 m (BATCHELDER, 1985). Those studies suggest that *S. nannochir* is easily accessible to the abundant prey species only in the lower mesopelagic zone.

The food of *S. nannochir* off the Pacific coast of Hokkaido was mostly *Gaidius variabilis* and *Pleuromamma* sp. (GORDON *et al.*, 1985). Those food items, however, were found to be of less importance in the southern Bering Sea. These differences of main food items may reflect regional and seasonal variability of diet. The variation of food availability particularly affects *S. nannochir* which preys on copepods. As *S. nannochir* can change easily its main food organisms in acyclic feeding, this species can be regarded as a feeding generalist.

Micronekton in tropical water in the surface layers of the epipelagic zone have more specialized diets (GORELOVA, 1974). Differences of fish in depth distribution at night probably reduce diet overlap among predators. As a result, these tropical species will perhaps have a more specialized diet than their counterparts in high latitudes (CLARKE, 1980). On the contrary, the diverse diets and broad array of available food items of subarctic myctophids (TYLER and PEARCY, 1975) suggest that they are feeding generalists. Acyclic feeding may result in more generalized than specialized feeding, though this feeding and the occurrence of non-migration of lanternfishes are very rare (GJØSÆTER and KAWAGUCHI, 1980).

KAWAGUCHI (1977) suggests that there are relationships between the types of vertical migration and taxonomic groups of Myctophidae. Osteological features show that the family Myctophidae consists of two major subfamilies: Myctophinae and Lampanyctinae (PAXTON, 1972). KAWAGUCHI (1977) suggests that almost all of the surface migrating species possibly belong to the subfamily Myctophinae, and the remainder with a lack of surface migration belong to the subfamily Lampanyctinae. The difference of vertical migration between the two subfamilies supports the hypothesis that surface migration was obtained in early phylogeny, and it would have exerted great influence on the differentiation at subfamilial, generic and specific levels. Genus *Stenobrachius* belongs to the subfamily Lampanyctinae. *S. nannochir* has only one congener, *S. leucopsarus* which is also abundant and has migratory and non-migratory individuals within a population (PEARCY *et al.*, 1977). The vertical distribution of *S. leucopsarus* indicates that the majority of individuals perform a diel vertical migration, while *S. nannochir* remains continuously in the lower mesopelagic zone as found by FROST and MCCRONE (1979).

Restricted vertical migration is known from some other lanternfishes. The gravid females of some *Diaphus* species undergo weak or no migrations (NAFPAKITIS, 1968). HOLTON (1969) states that the mature individuals of *Lampanyctus mexicanus* (GILBERT)*, are not found near 300 m in the southern Gulf of California, but are found in deeper

* At present, this species is included in the genus *Triphoturus*.

waters (600 m–700 m). *S. leucopsarus* exhibits a bimodal distribution at night, particularly in winter, when the thermocline is weakly developed (PEARCY *et al.*, 1977). *S. leucopsarus* in deep water at night probably did not feed exclusively in shallow water at night and possibly fed in deep water during the daytime (PEARCY *et al.*, 1979b). They explained that any “energy bonus” would theoretically be small because of minimal temperature differences between day and night depth distributions of the fish. The main prey items of *S. nannochir*, such as *C. plumchrus*, *C. cristatus*, *E. bungii bungii* and *M. pacifica*, are distributed broadly. This broad vertical distribution of prey does not require a nighttime ascent by predators for food intake in the subarctic ocean. The food supply in the lower mesopelagic zone is adequate to maintain the population of *S. nannochir*.

In conclusion, the feeding characteristics of mesopelagic fishes can be grouped into three types in accordance with their adaptation to the environment.

Nocturnal feeders (Type A): Vertical migrators which encounter abundant zones of food and feed intensively in the upper layers in high temperatures and high prey concentration at night (*e.g.* myctophids: BAIRD *et al.*, 1975; CLARKE, 1978, etc.).

Diel feeders (Type B): Non-migrators that feed in the mesopelagic layers during daytime when the prey concentration is similar to that of the upper layers at night (*e.g.* stomiatoids: CLARKE, 1978).

Acyclic feeders (Type C): Non-migrators that feed not periodically but when prey are available (*e.g.* hatchetfish: HOPKINS and BAIRD, 1973).

Almost all species of the family Myctophidae are vertical migrators and primarily nocturnal feeders (Type A), while other mesopelagic fishes of different families are diel or acyclic feeders (Type B or C) and their morphological shapes are quite differentiated and adapted to the deep sea environment.

S. nannochir adopts a different feeding type from other Myctophidae as acyclic feeders without vertical migration (Type C). The food availability in the subarctic ocean where prey are distributed widely and abundantly in the water column from the surface to the lower mesopelagic zone may allow *S. nannochir* to adopt a different feeding behavior from other lanternfishes.

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