

Feeding Behavior of a Vertically Migrating Lanternfish¹

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ABSTRACT: Selective fishing of the deep scattering layer, defined by echosounder recordings, with an automatic opening and closing trawl has helped to define the diurnal vertical migration and feeding behavior of *Lampanyctus mexicanus*, a lanternfish of the family Myctophidae. The feeding behavior, expressed as a percent nutrition, is thought to be affected by food available at the surface and by the decrease of oxygen content of the water at the deepest range of the vertical migration of the fish.

THIS STUDY was made during the fifteenth expedition of Hopkins Marine Station's research vessel "Te Vega." The expedition centered its research activities in the southern portion of the Gulf of California.

The "Te Vega" is equipped with Simrad Echosounders, models 586-2 and 513-1. The echosounders detected a zone of reverberation at various depths in the ocean during the daylight hours. The upper portion of this zone lay between 250 and 300 meters, and the zone consisted of many strata of varying widths and recording intensity. By using a variety of settings on the echosounders and fishing this zone with a Tucker trawl equipped with an automatic opening and closing device (Fig. 1), an attempt was made to interpret the source of the echosounder recordings. It was felt that such interpretation might give information about some members of the family of fish Myctophidae, or lanternfish, that are known to be associated with this zone (Barham, 1966).

The existence of such a zone is widely covered in the literature. Johnson (1948), Hardy (1958), and Hersey and Backus (1962) will provide a general background. This zone has been popularly named the "deep scattering layer" or "D. S. L." because of its presumed composition and behavior and the method of

its detection (Dietz, 1962). The zone has a predictable diurnal pattern of vertical movement generally referred to as migration. It remains generally stable and uniform during the daylight hours. As the sun sets, the zone moves upward and the echosounder indicates an increased stratification of the zone. The D. S. L. migrates to the surface in layered phases. Then at dawn, the process reverses. The D. S. L. migrates back to its daylight depth, and, as it descends, a stratification again is apparent on the echosounder. When the D. S. L. reaches its "normal depth" it takes on a more uniform character.

The composition of the D. S. L. will vary with geographic location, but many organisms have been associated with it, including many orders of fishes, shrimps, siphonophores of the suborder Physonectae, and many other small organisms (Percy and Laurs, 1966; Barham, 1966; Paxton, 1967). These animals migrate through several hundred meters in diurnal cycles, their travels probably being controlled by light intensity (Clark and Denton, 1962). Some members of the D. S. L.—the larger zooplankton, myctophids or lanternfishes, and various shrimp—are voracious consumers, and it is assumed that their diurnal migration is for the purpose of feeding on the surface plankton (Marshall, 1954; Hardy, 1958; and Girsá, 1960).

Jørgensen (1966) pointed out the importance of vertically migrating organisms and quoted Vinogradov (1962) and Wickstead (1962) in their studies of such "ladders of migration" for descending organic matter created by either prey-predator relationships or the deposition of feces. Moore (1958), commenting on descend-

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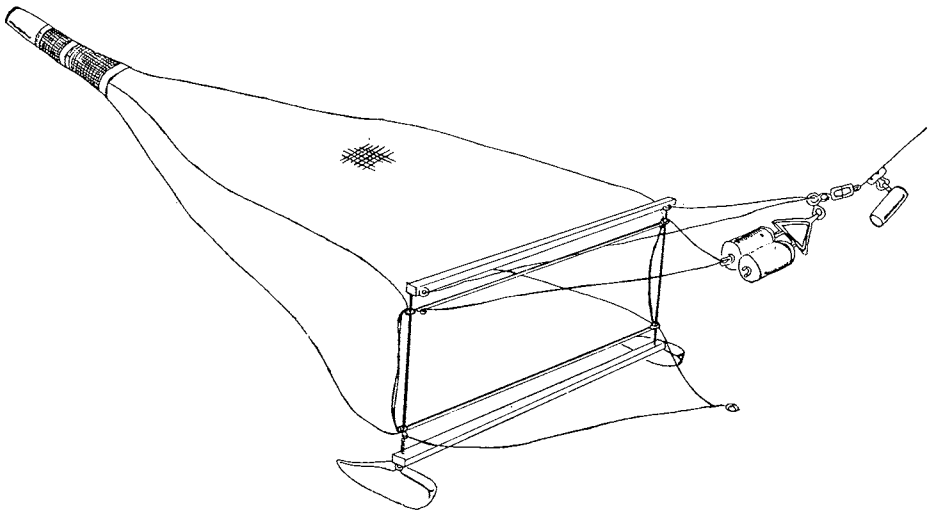


FIG. 1. Modified Tucker trawl used for collection at midwater stations. Drawing courtesy of Bruce Robinson, Hopkins Marine Station, Pacific Grove, California.

ing organic matter as food, stated that many marine animals will feed at a rate that is controlled by food availability. If food is available in high concentrations, the animal will increase its ingestion and reduce its retention in the digestive tract, and partially digested food will pass out in the feces. "There is thus a rate at which a food supply can be utilized, but not a limit to the rate at which it can be destroyed"—or passed along to other members of the food chain, since Moore stated further that some animals have passed whole and alive through the digestive tracts of others. Thus, vertically migrating consumers feeding in a rich planktonic area at the surface and returning to D. S. L. depths could be active agents in the transport of organic material either as fecal material or undigested food.

This phenomenon of diurnal vertically migrating groups of organisms prompted a study of the numerous small fish, the Myctophidae or lanternfishes, which are found in this zone, and their importance as secondary consumers. The study was made to determine whether the diurnal vertical migration pattern would coincide with a feeding pattern, and whether migration to or through layers of oxygen-minimum water would affect the feeding pattern. The species studied was *Lampanyctus mexicanus*, a myctophid selected for its uniform availability

throughout the southern portion of the Gulf of California.

METHODS AND MATERIALS

The specimens were collected with a Tucker trawl equipped with an automatic opening and closing device and a depth-time recorder. Collection times were spaced at two- to three-hour intervals throughout the day and night. Collecting time was usually one hour except where otherwise noted on the data chart. The depth of collecting was predetermined by the sonic identification of the D. S. L., using various settings on the Simrad recorders, in an attempt to interpret portions of the recordings as fish. Numerous samples were taken at depths other than the D. S. L. depth to check the number of individuals of the species that might be nonmigratory.

The fishing depth was estimated by length and angle of the cable fed out to the net and was checked against the depth-time recorder after each trawl. Stations 1005a, 1005b, and 1016 each were fished for one hour with no changes made in the amount of cable out. Station 1009 was fished between 600 and 700 meters starting with 1400 meters of cable out and taking in 40 meters of cable every ten minutes for one hour. The depth recorder indicated the following depths during the open net time:

700, 675, 650, 620 meters. Similarly, the remaining stations were fished through their recorded ranges by adjusting the amount of cable out at intervals during the fishing or open net time.

stations that yielded *Lampanyctus mexicanus* being shaded. The unshaded stations represent trawls that did not contain *L. mexicanus*. Two of these, 31b and 31g, were performed with a one-meter net rather than a Tucker trawl. Two additional nonproducing trawls were made at

Figure 2 indicates depth versus time, with the

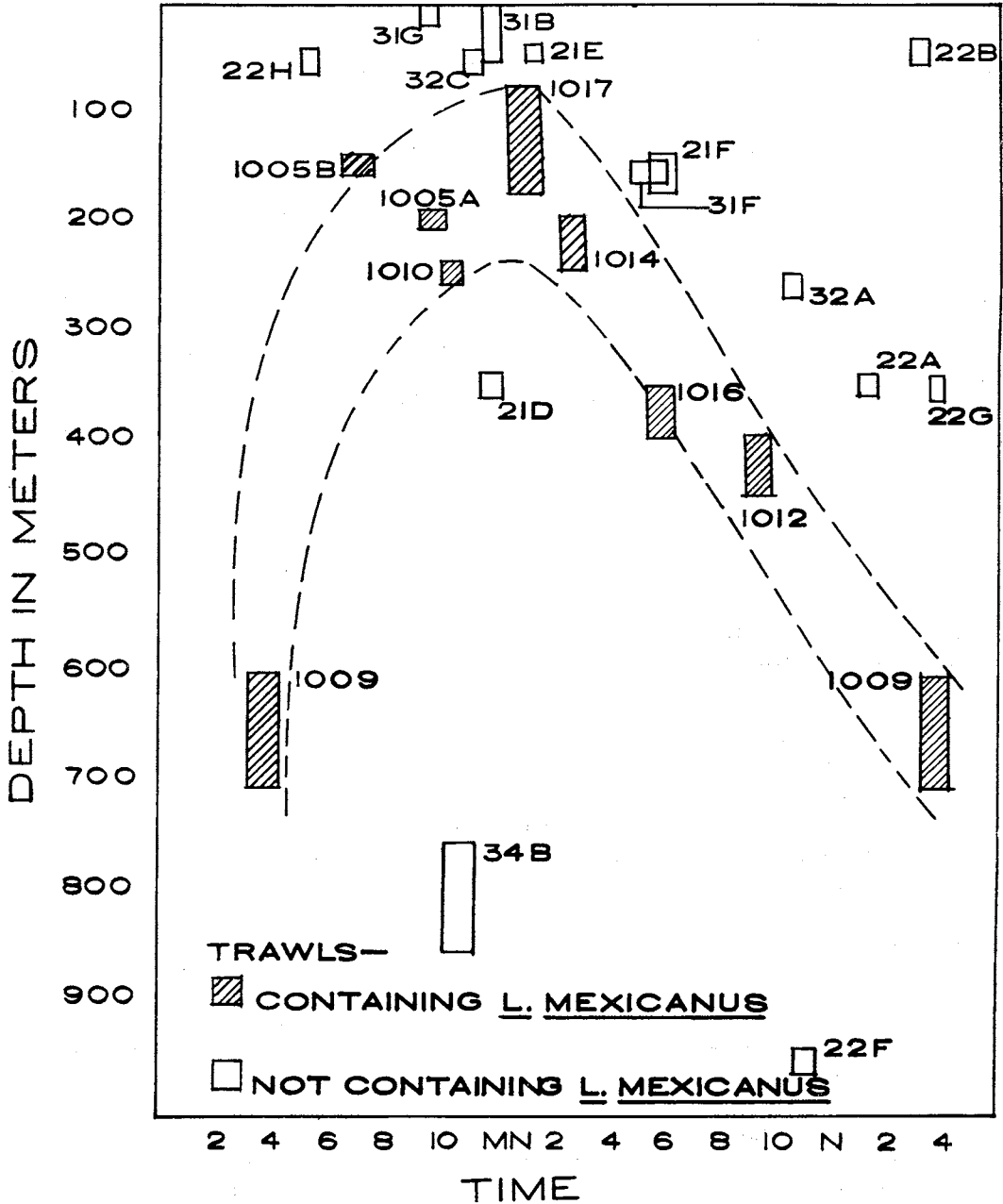


FIG. 2. Collecting sites: Depth vs. time.

1050 to 1150 meters and 1150 to 1250 meters and are so recorded on the data chart. The lines connecting the *L. mexicanus*-producing trawls on Figure 2 indicate the depth range of the collecting sites.

The fish collected were mature specimens between 8 and 10 cm in length. Ten fish were taken at random from each catch except sample 1010, which produced only seven fish and only five of these were examined. Only nine of the ten fish of sample 1005a were used, because later examination after selection showed one to be severely mutilated and unusable.

The procedure used by Kow (1950) was modified as follows. Collected specimens were placed in a container of sea water with 10 percent buffered formalin for 12 to 24 hours. The total gut and its contents were later removed from each specimen, examined, and placed on a preweighed piece of aluminum foil. The remainder of the fish was quartered for convenience in handling and also placed on a preweighed piece of aluminum foil. To obtain a dry-weight comparison, the gut and its contents and the fish carcass were oven-dried at 88 to 90° C for one hour, and then weighed on a Cohn portable electrobalance.

The dry-weight comparison of the total gut and its contents to the total weight of the fish is referred to as the percent nutrition, according to the following formula:

$$\frac{\text{dry wt. gut and contents} \times 100}{\text{dry wt. gut and contents} + \text{dry wt. of carcass}} = \% \text{ nutrition}$$

Oxygen concentrations were taken from the ship's data. Concentrations of oxygen were measured from Nansen bottle samples by standard titration techniques. In each instance the information from the hydrostation geographically nearest the collecting site is used.

RESULTS AND DISCUSSION

From the eight productive stations a total of 74 fish were examined. These eight productive stations are identified geographically and the total number of *Lampanyctus mexicanus* collected are noted on the data chart. The variation in the number of fish collected per station can be explained by coincidence or by a combination

of possibilities. Percy and Laurs (1966) have demonstrated that lanternfishes can avoid a 6-foot Isaacs-Kidd trawl, larger than the Tucker trawl used here. But since the fish tend to school in shallow bands while ascending, descending, or residing in the D. S. L., then it might be expected that a larger catch would be obtained when the fish are so concentrated than when the fish have spread out over a depth of 100 to 175 meters during the night hours. Such behavior would also help to explain twelve of the nonproductive trawls. The nonproductivity of trawls 34b and 22f were nonproductive probably because they were made beyond the depth range of *L. mexicanus*.

The success of the attempt to interpret the echosounder recordings is shown in the large number of *L. mexicanus* collected in trawls 1005b, 1012, and 1016. Each evening shortly before sundown, a separate and distinct band formed in the D. S. L. (Fig. 3). This band would disassociate from and precede the D. S. L. in its ascent to the upper waters. Before sunrise, again a narrow, distinctly separate band would precede the activity of the major portion of the D. S. L. and descend to a depth between 320 and 400 meters and then disperse. Trawls 1005b, 1012 and 1016, were set to fish only in this band in its ascent and descent, and the settings were successful according to the open time of the net and the recording of the depth recorder of these trawls when compared with the echosounder recordings. The catch of these trawls was exclusively *L. mexicanus*.

The results of the examination and the computation of the percent nutrition of the eight productive trawls are listed in Table 1. Comparing the percent nutrition with time (Fig. 4) and with depth (Fig. 5) we can generalize that the highest value for percent nutrition for *L. mexicanus* can be found in fish taken at night in the upper range of their vertical migration, and the lowest value is found in fish taken during the day in the deepest range of their vertical migration. Thus the feeding behavior of *L. mexicanus* is related to its pattern of vertical migration. Whatever may be the purpose or cause of the vertical migration pattern for these fish, they feed more nocturnally than diurnally, probably because of the greater amount of food in the surface waters. More interesting, however,

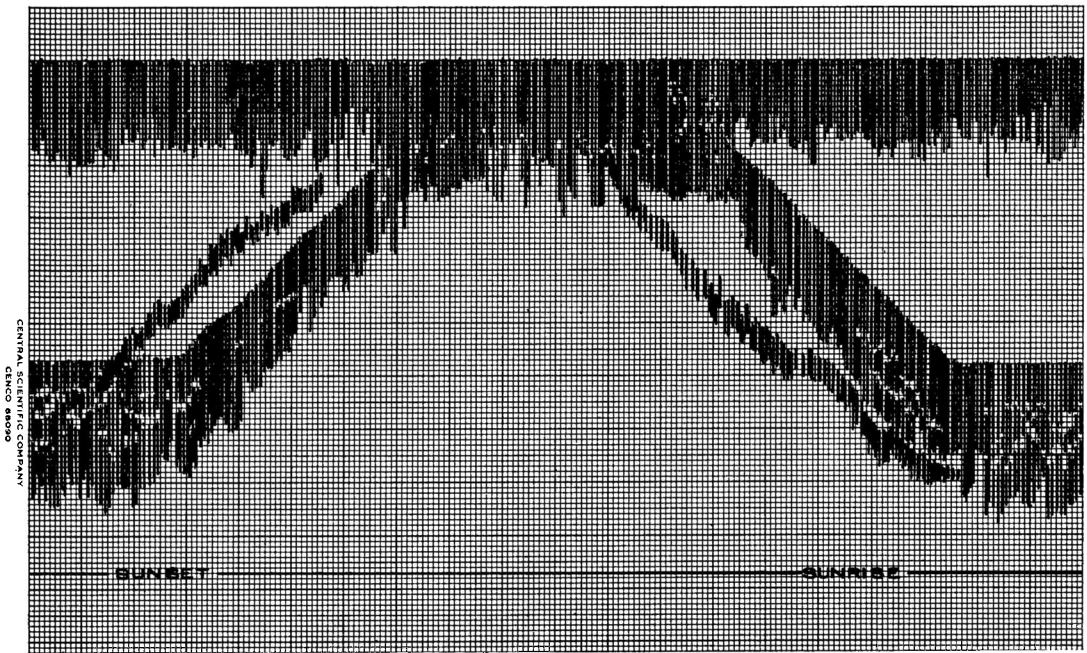


FIG. 3. Typical echosounder recording.

TABLE 1
LOCATION OF SITES AND TABULATION OF DATA FOR *Lampanyctus mexicanus*

PRODUCTIVE STATIONS							
NUMBER	NUMBER COLLECTED—EXAMINED	TIME	DEPTH (meters)	RANGE % NUTRITION	AVERAGE % NUTRITION	S.D.	O ₂ CONC. (ml/l)
1005a	16-9	9:30-10:30PM	185-200	4.8-8.2	6.1	0.9	1.04
1005b	162-10	6:45-7:45PM	144-155	3.6-9.7	5.0	1.4	1.04
1009	440-10	3:20-4:20PM	600-700	2.9-14.3	4.7	2.5	0.17-0.20
1010	7-5	10:15-11:15PM	230-250	5.0-11.4	7.2	1.7	1.5-2.9
1012	588-10	9:00-10:00AM	336-384	3.1-5.5	4.4	0.7	0.21-0.29
1014	57-10	2:20-3:20AM	190-244	2.6-8.3	3.7	0.8	0.83-1.34
1016	280-10	5:30-6:30AM	292-332	3.4-5.6	4.2	0.5	0.21-0.40
1017	19-10	12:45-1:45AM	not rec.	3.3-8.9	4.6	1.3	0.83-2.84
NON-PRODUCTIVE STATIONS							
NUMBER	DEPTH (meters)	TIME	NUMBER	DEPTH (meters)	TIME		
21d	330-350	11:45-12:15AM	31b	60-surface*	11:35-12:10AM		
21e	30-50	1:10-1:40AM	31f	140-160	5:15-6:15AM		
21f	140-160	5:25-6:25AM	31g	15*	9:30-10:00PM		
22a	330-350	1:15-1:45PM	32a	240-260	10:36-11:04AM		
22b	30-50	3:05-3:35PM	32c	40-60	11:00-11:30PM		
22f	940-960	11:00-11:45AM	34b	750-850	10:45-11:45PM		
22g	330-350	3:50-4:05PM	34c	1150-1250	12:45-1:45PM		
22h	30-50	5:15-5:30PM	36a	1050-1150	1:30-2:30PM		

* Collected with a meter net.

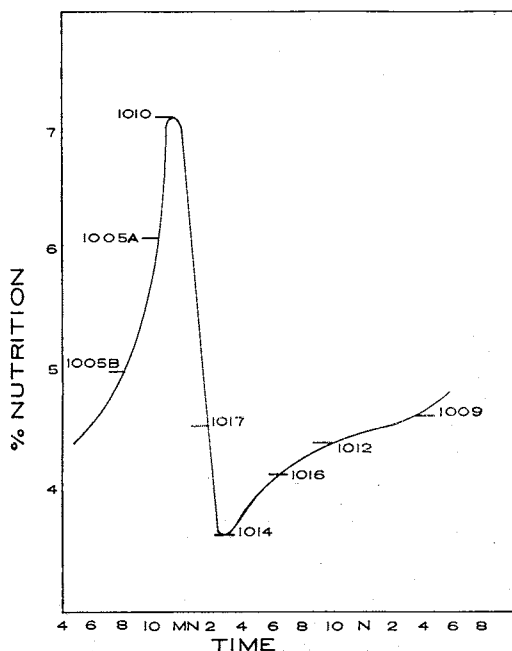


FIG. 4. Percent nutrition vs. time for *Lampanyctus mexicanus*.

is the rapid decrease in the percent nutrition and the low values maintained during the daylight hours. The percent nutrition is in its lowest range (3.5 to 4.5) while the fish is in oxygen-minimum waters. It is possible that this fish does not continue digestion of the food it has consumed in the surface waters, but regurgitates the undigested portion while descending in order to reduce metabolic oxygen needs while residing in oxygen-minimum waters.

The gut contents indicated that the fish were feeding on ostracods, copepods, and small shrimp. Two stomachs contained small fish larvae. Sources of error involved here include the possibility that the fish may feed while captured in the net, even in gasping just before death. This possibility is somewhat negated by the condition of the fish when they reached the surface: (1) The net, the speed of the trawl, and the rapid changes in temperature and pressure were physically brutal to a large number of the fish. They were broken, partially skinned, and otherwise mutilated. Their death did not appear to be slow. (2) The large number of fish in the net tended to exclude other material in the trawl. A 2-quart canister containing 150 to

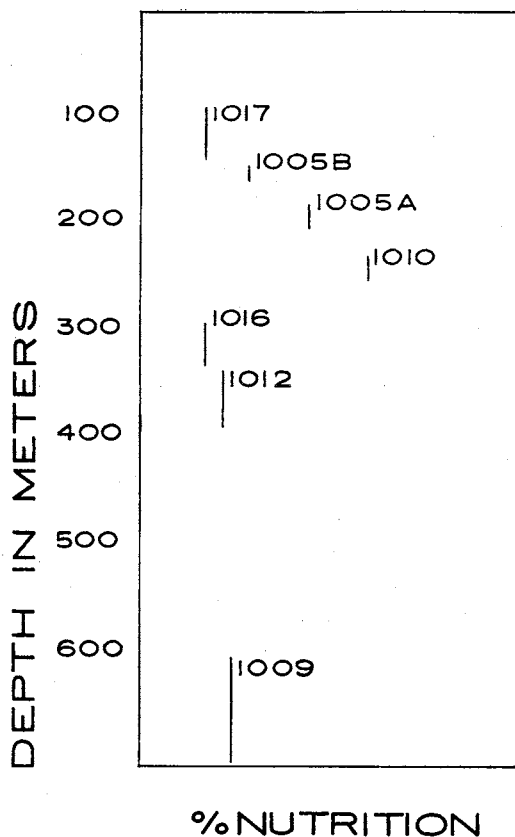


FIG. 5. Percent nutrition vs. depth for *Lampanyctus mexicanus*.

nearly 600 fish has little room for much else. For food material to be "gassed" down it would have to be a common component in the trawl-catch, and this was not the case. Indeed, the food material was common in shallower trawls and the fish were more commonly present at the lower level of the surface plankton.

Trawl data indicate that the majority of individuals of this species is not associated with the D. S. L. during the daylight hours. While some immature *L. mexicanus* were found in the D. S. L., the adult majority were found near 400 meters by 8 AM and between 600 and 700 meters by midday.

CONCLUSIONS

Lampanyctus mexicanus performs a diurnal vertical migration to the surface waters that coincides with its pattern of feeding behavior. On

ascending, the fish are active consumers. When they descend, it is possible that the fish empty their stomachs by regurgitation, indicated by the rapid decrease in the percent nutrition, probably to decrease the amount of oxygen consumed while they reside in or travel through oxygen-minimum water layers. The mature fish are not associated with the deep scattering layer found near 300 meters in the southern portion of the Gulf of California, but are found in deeper waters (600 to 700 meters), probably forming part of a food chain for larger deep-water predators. The behavior of the fish in their diurnal migration between 300 meters and the surface was recordable and discernible on the Simrad echosounders.

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