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SCATTERING LAYERS AND VERTICAL DISTRIBUTION OF OCEANIC ANIMALS OFF OREGON

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ABSTRACT

This paper reviews some of the distributional features of vertically migrating micronekton off Oregon; describes a new, conducting-cable, midwater-trawl system using an eight-net, opening-closing cod-end unit; and gives some preliminary results on trawl catches relative to sound-scattering layers.

A variable complex of organisms, including euphausiids, a sergestid shrimp, and mesopelagic fishes, was often common in 12- and 38.5-kHz scattering layers. The depth range of many species was broad, and sometimes the largest catches were made at depths above or below scattering layers. Variability was large among nets that fished either horizontally or vertically during single tows.

DISTRIBUTION OF MESOPELAGIC ORGANISMS OFF OREGON

Only a few species of oceanic micronekton predominate our nighttime-midwater trawl collections in epipelagic waters off Oregon. The lanternfishes *Stenobrachius leucopsarus, Diaphus theta,* and *Tarletonbeania crenularis;* the melanostomiatid *Tactostoma macropus;* the sergestid shrimp *Sergestes similis;* and the euphausiid *Euphausia pacifica* are all abundant. All these species (except *T. macropus*) have been correlated with biological sound scattering in other areas (Barham, 1956 and 1963; Kampa and Boden, 1954; Taylor, 1968; Tucker, 1951).

Of the fishes, *Stenobrachius leucopsarus* juveniles (less than 30-mm standard length) have a gas-filled bladder, but the swimbladder of adults is regressed and surrounded by fatty tissue (Capen, 1967; Butler, 1970). We have found gas in the swimbladders or body cavities of some *Diaphus theta* and *Tarletonbeania crenularis;* gas usually occurred in small individuals but was found in individuals larger than 30 mm. All *Hierops (Protomyctophum) crockeri* and *thompsoni* examined at sea had gas-filled swimbladders (Butler, 1970).

Studies with an opening-closing cod-end unit on a 6-foot Isaacs-Kidd midwater trawl (IKMT) provide good evidence for vertical migration of the four common mesopelagic fishes and *Sergestes similis* between broad depth intervals off Oregon. In the upper 150 m, nighttime catches exceeded daytime catches; between 150 and 500 m, daytime exceeded nighttime catches (Pearcy and Forss, 1966; Pearcy and Laurs, 1966). Catches of these species between 500 and 1,000 m were low, and no diel differences were evident. The ratios of night to day catches per m^2 in the water column to 1,000 m for all species were greater than 1.0, indicating avoidance of the trawl during the daytime. Although only slightly more *Diaphus theta* were collected per m^2 at night, over four times as many *Tarletonbeania crenularis* were caught at night than during the day.

The average size of mesopelagic fishes also varied with depth; individual weight was lower in 0- to 150-m collections than in 150- to 500-m and 500- to 1,000-m collections (Pearcy and Laurs, 1966). These studies also show broad depth ranges for mesopelagic species. During the night, for example, lanternfishes and shrimps were caught at all depths within the upper 1,000 m and were not concentrated solely near the surface. Vertical migrations and distributional patterns *within* these broad depths undoubtedly occur. Pearcy (1964) found that the three common lanternfishes sometimes have different distributions within the upper 100 m at night.

In any quantitative study of pelagic animals, distributional patterns and catch variability are important considerations. Repeated tows during night or day periods suggest patchy or clumped distributions of mesopelagic fishes (Pearcy, 1964; Pearcy and Laurs, 1966). Ebeling, Ibara, Lavenberg, and Rohlf (1970) reported that most mesopelagic fishes off southern California were more clumped at middepths during the day than near the surface during the night. Donaldson (1968) found that the thickness of 38.5-kHz scattering layers was less during the day than at night off Oregon, a trend that suggests that the density of organisms within layers may be higher by day (Taylor, 1968).

The number of scattering-layer organisms may vary seasonally and annually. Significant differences in the number and biomass of midwater animals have been reported off Oregon (Laurs, 1967; Pearcy, 1964, 1965; Pearcy and Forss, 1966; Pearcy and Laurs, 1966; Pearcy and Osterberg, 1967). In oceanic waters over and beyond the continental slope, the highest biomass of small nektonic fishes, squids, and shrimps generally occurred in the summer; the lowest biomass occurred in the winter. Over the outer edge of the shelf, however, the reverse was true. Usually higher catches were made in winter than in summer.

These inshore-offshore and seasonal changes also may be related to changes in size structures of populations. The decrease in biomass in winter offshore catches was correlated with an increased recruitment of small *Stenobrachius leucopsarus.* Small lanternfishes of this species have gas-filled swimbladders, but large individuals do not. The sound-scattering potential offshore, therefore, may be higher during winter than during summer, even though the total micronekton biomass may be lower in winter.

MIDWATER TRAWL SYSTEM

A conducting cable system using a 6-foot IKMT with an eight-bar multiple plankton sampler (MPS) (Bé, 1962; Pearcy and Hubbard, 1964) as an opening-closing cod-end device sampled oceanic animals to 1,000 meters (Fig. 1). Pressure (depth), temperature, flow (revolutions), and net opening were scanned sequentially and transmitted as frequency-modulated (FM) signals from transducers on the IKMT-MPS to recording units on deck.

The electrical system is illustrated in Figure 2 as a block diagram. One hundred fifty milliamperes at 50 volts direct-current is transmitted down the 4,600 m of 11-mm coaxial cable (U.S. Steel Corp.) into the pressure housing on the MPS. This housing contains the net actuator, transducer, and scanning and signal transmission electronics. When a net release button is pushed on shipboard, a polarity reversal of the voltage to the MPS takes place. When the net release button is returned to its normal position, the motor circuit actuates a 2-rpm gear motor for one shaft revolution that opens one net and closes another. Cams located on top of the MPS are coupled directly with the motor shaft in the electronics package. During one motor-shaft revolution, one cam turns 360°, releasing one lever bar that holds the net bar in a cocked position.

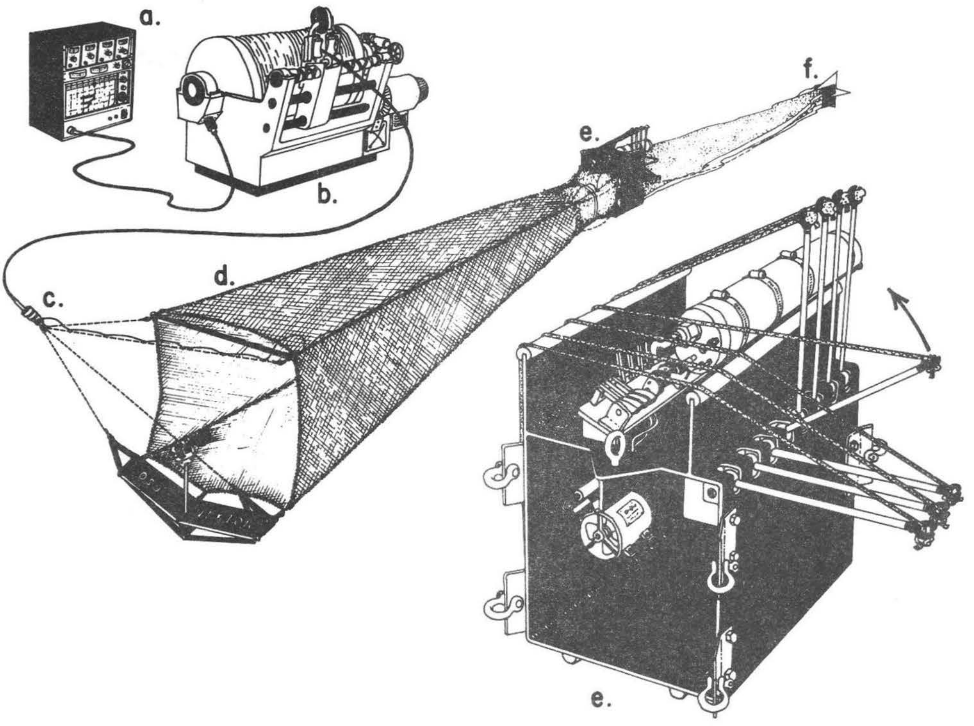

Figure 1. A conceptual drawing of the components of a conducting-cable, midwater-trawl MPS system with the following parts: (a) deck readout recorders, (b) deck winch with slip rings and conducting cable, (c) electric swivel, (d) 6-foot IKMT, (e) eight-bar MPS, and (f) eight sample nets.

This operation is repeated eight times for release of eight nets. During the motor operating period, an FM signal that identifies which net is opened is transmitted to the surface.

Actuation of the net release motor interrupts the automatic scan sequence of the transducer outputs. Between net actuations, the electronic scanner sequentially connects the transducer outputs for discrete periods of time to a voltage-controlled oscillator (VCO) generating FM signals. The VCO output is coupled through an electronic driver stage to the coaxial cable. Signals are displayed aboard ship in two ways: on an analog strip-chart recorder, and on a digital counter. The recorder offers a quick observation of a tow pattern of the trawl. The digital readouts, which are periodically written on the strip-chart record, give the greatest resolution. The maximum resolving capability in the monitoring system is one part in one thousand of transducer output signal.

Depth was monitored with a potentionmetric type Servonic model H-172-5 pressure transducer. The transducer was calibrated in the lab with a temperature-corrected Heise pressure gage. The depth resolution was ± 1 m and was transducer limited.

Water temperature was sensed by a 10-kΩ thermistor (Yellow Springs Instrument Corp.) at 25°C. It was calibrated to ±0.02°C in an ice bath with a Hewlett-Packard quartz thermometer and referenced by a platinum thermometer and Mueller bridge. The thermistor time constant was 1.3 min.

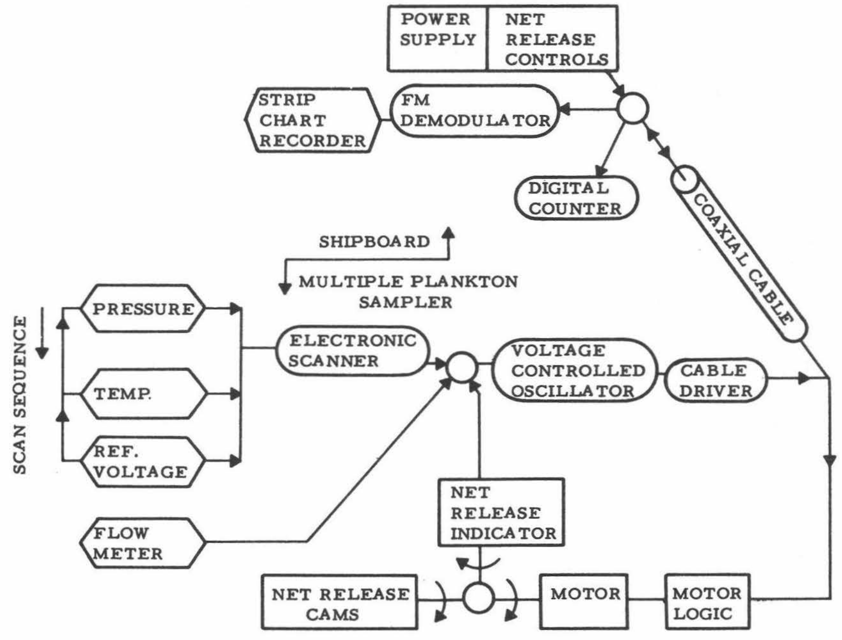

Figure 2. Block diagram of the electronic modules inside the MPS electronics case

A voltage reference was used to excite the pressure and temperature transducers and to act as a figure of merit. This reference is monitored each scan cycle along with the transducer signals. If our reference has changed during a tow, it indicates not only an error in data but an electrical malfunction in the transmitting electronics.

The electronics scanner was set to sense pressure for 20 sec and temperature and reference for 10 sec each. As indicated in Figure 2, however, the flowmeter has a priority to interrupt the scanner at any time. This is because the flowmeter is a revolution counter, recording a signal every 1,000 revolutions of an impellor by causing the VCO input to go to zero. On the strip-chart recorder, the flowmeter signals appear as event marks that interrupt the regular analog records of pressure and temperature.

The MPS box (40 X 40 X 51 cm) is made of 7-mm aluminum and weighs 30 kg complete with the electronic package on top. The MPS nets, 3 m long, are of 0.571-mm Nitex. The liner of the IKMT is 5-mm mesh.

The electrical IKMT-MPS system was used successfully on a cruise from 12 to 18 November 1969. Twenty-six separate tows were made; opening-closing malfunctions occurred on five tows, usually because of human error in resetting the equipment. The flowmeter, mounted inside the MPS box, worked on only eight tows because of a short in the magnetic switch. The flow through the MPS on these eight tows was fairly uniform throughout an entire tow. There was no evidence for closure of the MPS mouth caused by twisting of the net. However, in one case, an interruption in the flow was caused by a squid caught in the impellor.

Catches were calculated on the basis of grams (wet weight) collected per minute. Tow speeds were fairly constant within a single tow and ranged from 3.4 to 4.6 knots among tows. At this speed, a 6-foot IKMT (mouth area of 2.9 m^2) with a filtration efficiency of 85% (Pearcy and

Laurs, 1966) filters about 260 to 350 m^3/min. All tows were beyond the continental slope off central Oregon between latitudes 44° 12′ and 44° 55′ N and longitudes 125° 25′ and 126° 05′ W).

When the trawl descended to the maximum tow depth, the first MPS net fished obliquely over a large depth range. Because of this, and the fact that flow rate was usually lower in this net, the first net often was not included in the catch results of all tows.

Two echo sounders were used during this cruise: (1) a 12-kHz Edo model 248 transceiver with a pulse power of 1,400 watts and an Edo 333B recorder and (2) a 38.5-kHz Simrad 510-5 echo sounder with a pulse power of 450 watts. Gain was reduced in surface waters of both recorders to accentuate subsurface scattering layers; hence, surface scattering layers in the upper 36 m usually were not recorded.

SCATTERING LAYER VARIATIONS

The depth and thickness of 12-kHz scattering layers for two diel periods during the cruise are replotted in Figure 3. Variability is pronounced. Layers were recorded within the upper 100 m during both day and night periods. Sometimes these surface layers deepened or shoaled within day or night periods. Migration of layers occurred during twilight periods (sunrise was about 0600 hours; sunset, 1730 hours, local mean time). The descent on 18 November was to greater depths than on 14 November. Ascent toward the surface occurred during midafternoon on both days. Note that a layer descended from the main ascending migratory layer at about 1800 hours on 18 November; it migrated downward to about 400 m, but then ascended to rejoin the main layer at 2400 hours. This descent of a secondary layer from a main ascending layer was observed on another day; but in this second instance, it remained at 400 m and did not ascend to join the main layer. Echo groups or "tent fish" were recorded near the surface after descent of the mi-

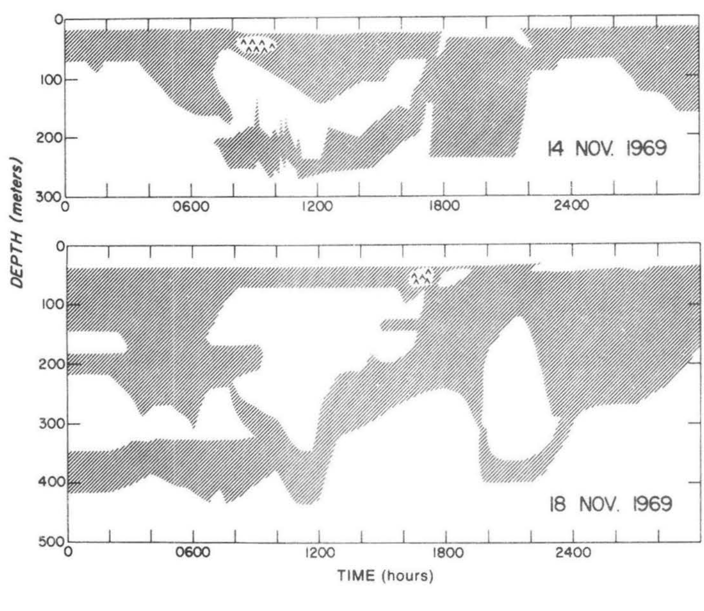

Figure 3. Depth distribution of 12-kHz sound-scattering layers over two diel periods of the November cruise. ⋀⋀ indicates echo groups.

gratory scattering layers on 14 November and before ascent of the migratory layer on 18 November (see also Fig. 4).

MIDWATER TRAWL CATCHES AND SCATTERING LAYERS

The catches of midwater animals relative to sonic-scattering layers are summarized for six of our IKMT-MPS tows in Tables 1 through 6 and Figures 4 through 9. These tows indicate some of the spatial and temporal variations of the catches.

Variability within Depths

Repeated collections were made at 40 m within a scattering layer after it ascended into surface waters (Fig. 4 and Table 1). Each net in this series sampled for 20 min, filtering approxi-

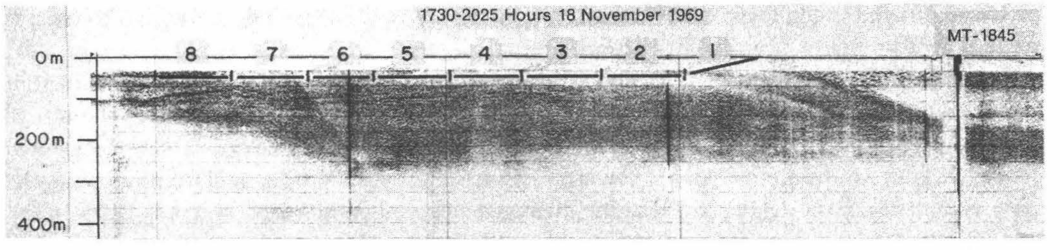

Figure 4. A 12-kHz echogram taken from 1730 to 2025 hours on 18 November 1969. In Figures 4 through 9, the echogram is superimposed on the trajectory of the trawl and numbers of the MPS nets. The times given apply to the duration of the tow, time increasing from right to left.

Table 1. Catches of Midwater Animals from 1730 to 2025 Hours on 18 November 1969

Depth range of sound-scattering layer (m)		Depth of each net fished		Biomass[a] (grams wet weight/minute)				Number of *S. leucopsarus*
38.5 kHz	12 kHz	Net	Depth (m)	F	S	E	P	
10-60	36-250	2	40	0.11	0	3.20	0.54	6
		3	40	0.30	T	2.25	0.40	0
		4	40	T	T	4.80	0.26	8
		5	40	T	T	5.32	0.61	2
		6	40	T	T	1.05	0.70	1
		7	40	0.06	0.05	4.36	0.38	3
		8	40	0	0	4.80	0.30	0

[a]Catches are represented as follows: F = Fishes, S = shrimps, E = euphausiids, and P = plankton. Large catches are underlined. T indicates trace, less than 0.01 g/min. S or L refers to the numbers of small (less than 30-mm standard length) or large (greater than 30-mm standard length) *Stenobrachius*. Genera in parentheses were common but did not predominate the catch.

mately 5,000 m^3 at 3.4 knots. Variations in the biomass (grams wet weight per minute) of fishes and shrimps were large among samples. Catches of euphausiids and plankton, however, were less variable. The numbers of the common lanternfish *Stenobrachius leucopsarus* also indicated a clumped or patchy distribution.

The tow depicted in Figure 5 and Table 2 shows both horizontal and vertical variability of catches. The largest catches of fishes, shrimps, euphausiids, and plankton were made in the first net at 0 to 35 m. Although the 12-kHz scattering layer started 18 m from the surface and the 38.5-kHz layers started 10 m from the surface, the layers probably continued to the surface through the gated-out portion of the echograms. Two of the three samples at 35 to 38 m had large fish biomasses; only one of the three samples below the scattering layer at 77 m had a large *Sergestes* biomass. The biomass of *Euphausia pacifica*, on the other hand, was uniformly large between 35 and 77 m and small below 77 m. Thus, large catches were made within the scattering layer, and smaller catches were made below the scattering layer. Variability within horizontal strata was again large, and variability was larger for fishes and shrimps than for euphausiids.

Table 2. Catches of Midwater Animals from 2040 to 0010 Hours on 14 November 1969

Depth Range of sound-scattering layer (m)		Depth of each net fished		Biomass[a] (grams wet weight/minute)				Abundant genera	
38.5 kHz	12 kHz	Net	Depth (m)	F	S	E	P		
10-50	18-70	1	0-35	5.56	1.95	20.56	24.01	*Stenobrachius* (S > L)	Medusae
		2	35	2.46	0.30	3.00	0.71	*Tactostoma*	*Euphausia*
		3	35-38	2.38	0.58	5.40	0.13	*Diaphus*	*Sergestes*
		4	38	0.79	0.06	3.99	0.04	*Tarletonbeania*	
		5	38-77	2.11	0.43	3.18	0.76	*Tactostoma*	
		6	77	0.13	0.46	0.18	0.15		
		7	77	0	0.08	0.09	0.06		
		8	77	0.67	1.17	0.20	0.28	*Sergestes*	

[a]See Table 1.

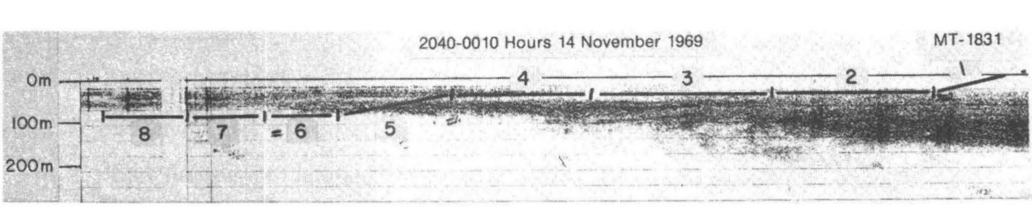

Figure 5. A 12-kHz echogram taken from 2040 to 0010 hours on 14 November 1969

Variability Among Depths

Two tows sampled similar depths and fished through and below a scattering layer during one night (Figs. 6 and 7 and Tables 3 and 4). The layer, which first shoaled and then deepened, was from 18 to 90 m on the 12-kHz Edo. Two layers within this depth range appeared on the 38.5-kHz Simrad echogram. In the first tow *Sergestes similis* biomass peaked between 10 and 45 m; the *Euphausia pacifica* biomass was largest at 45 m (within both the 38.5- and 12-kHz layers); and the fish biomass (mainly *Tactostoma macropus*) was largest between 96 and 144 m, near the lower edge of the thick portion of the layer (Table 3).

Table 3. Catches of Midwater Animals from 2048 to 2351 Hours on 13 November 1969

Depth range of sound-scattering layer (m)		Depth of each net fished		Biomass[a] (grams wet weight/minute)				Abundant genera	
38.5 kHz	12 kHz	Net	Depth (m)	F	S	E	P		
10–25		7	10-45	5.54	3.09	0.13	0.34	*Sergestes*	(*Stenobrachius*)
40–50	18–70								
		6	45	0.74	0.52	0.21	1.09	*Euphausia*	*Stenobrachius*, *Tactostoma*, *Euclio*
		5	45-91	0.68	1.10	0.10	0.14		
		4	91-96	0.49	0.70	0.02	0.10		
		3	96-144	1.20	0.29	0.01	0.18	*Tactostoma*	
		2	141-145	0.41	0.17	0	0.35		

[a]See Table 1.

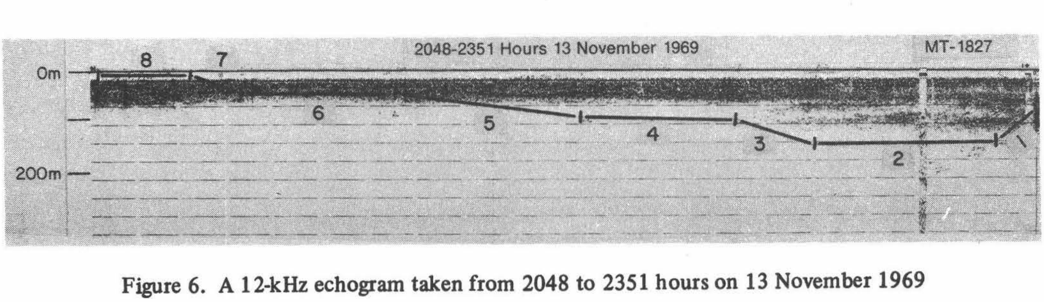

Figure 6. A 12-kHz echogram taken from 2048 to 2351 hours on 13 November 1969

The second tow (Table 4, Fig. 7) which started about 2 hours after the end of the first one, had the largest catches of fishes, shrimps, and euphausiids in the 97-145 m net, below or in the lower edge of the scattering layer. Most of the fish biomass caught at the depth of the scattering layer was from *Tactostoma macropus*. These changes in vertical distributions may be caused by horizontal patchiness or the descent of *Sergestes* and *Euphausia* within the scattering layer during the sampling period.

Table 4. Catches of Midwater Animals from 0200 to 0535 Hours on 14 November 1969

Depth range of sound-scattering layer (m)		Depth of each net fished		Biomass[a] (grams wet weight/minute)				Abundant genera
38.5 kHz	12 kHz	Net	Depth (m)	F	S	E	P	
15-25		1	0-10	0.08	0.25	0.06	0.58	
40-50	18-90	2	10-50	0.76	0.04	0	0.15	(*Tactostoma*) (nets 2-3)
		3	50	0.62	0.04	0.08	0.30	
		4	50	0.41	0.06	0.23	0.25	
		5	50-97	0.15	0.28	0.14	0.21	
		6	97	0.05	0.46	0.26	0.20	
		7	97-145	1.17	0.86	0.49	0.39	*Stenobrachius* (S) *Tactostoma* *Sergestes* *Euphausia*

[a]See Table 1

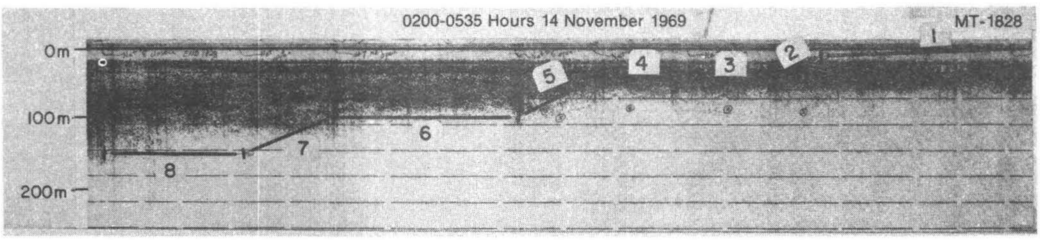

Figure 7. A 12-kHz echogram taken from 0200 to 0535 hours on 14 November 1969

Deep Scattering Layers

Sometimes during the day, and less commonly at night, a deep scattering layer (DSL) was apparent on 12-kHz echograms at 350 to 420 m (Figs. 8 and 9). Tables 5 and 6 show the catches above and within such a deep layer on two consecutive tows.

During the daytime tow (Figure 8 and Table 5), catches of fishes and shrimps were larger in samples in the DSL than above the DSL. (Nets 1 and 2 fished in the surface scattering layer but caught almost nothing.) Euphausiids were most numerous in and just above the DSL (324 to 410 m). The large plankton biomass in net 4 resulted from *Lensia*, a nonphysonect siphonophore. The most numerous fish in the DSL was small *Stenobrachius leucopsarus* (less than 30 mm).

The DSL started to rise toward the surface at 1400 hours on 17 November (Fig. 8). The migration of this layer continued toward the surface and is apparent between 200 and 300 m in Figure 9. A portion of this migratory layer appeared to split off at 1630 hours (just below start of net 2 in Fig. 9) and descend to 360 to 420 m, the original day depth of the layer in Figure 8. A second layer also appeared to descend from the main layer at 1730 hours (end of net 3) to form an intermediate layer at about 200 m.

The IKMT-MPS was towed horizontally at 173 to 180 m while the main layer migrated upward (Fig. 9 and Table 6). Catches in net 2, which appeared to fish in the densest part of the layer, were low. Many euphausiids were caught in net 3 after the main layer migrated above the tow depth and when the net fished in the vicinity of the intermediate layer. *Sergestes* also was caught at 175 m, but mainly in net 4. The largest fish biomass was caught in the two nets that fished the DSL, which was located between 360 and 420 m.

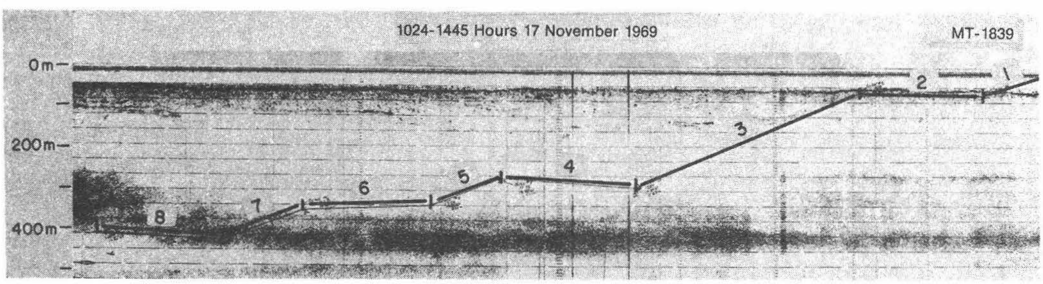

Figure 8. A 12-kHz echogram taken from 1024 to 1445 hours on 17 November 1969

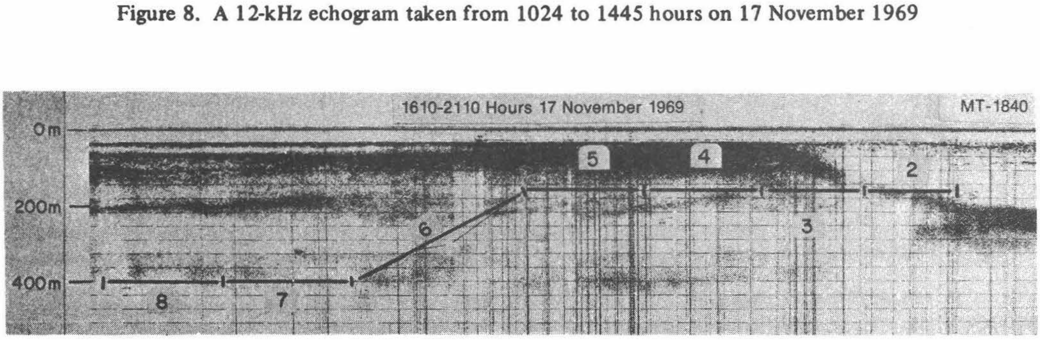

Figure 9. A 12-kHz echogram taken from 1610 to 2110 hours on 17 November 1969

Table 5. Catches of Midwater Animals from 1024 to 1445 Hours on 17 November 1969

Depth range of sound-scattering layer (m)	Depth of each net fished		Biomass[a] (grams wet weight/minute)				Abundant genera
12 kHz	Net	Depth (m)	F	S	E	P	
37–70	2	53–48	0	0	T	0.14	
	3	48–277	T	T	0.01	0.23	
	4	277–256	0	0	0.04	5.16	*Lensia*
	5	256–324	T	T	0.01	0.48	*Euclio* (nets 5–7)
	6	324–330	0.03	0	0.16	0.53	*Euphausia* (nets 6–8)
350–420	7	330–405	0.12	0.12	0.16	0.27	*Diaphus*, *Sergestes*, *Stenobrachius* (S) (nets 7–8)
	8	405–410	0.42	0.11	0.17	1.09	

[a]See Table 1.

Table 6. Catches of Midwater Animals from 1610 to 2100 Hours 17 November 1969

Depth range of sound-scattering layer (m)		Depth of each net fished		Biomass[a] (grams wet weight/minute)				Abundant genera
38.5 kHz	12 kHz	Net	Depth (m)	F	S	E	P	
down to 175	down to 175	2	173–180	0	T	0.32	0.23	
		3	173–175	0.33	0.32	1.08	0.35	*Euphausia*
		4	175	0.17	0.89	0.12	1.64	*Sergestes*, siphonophore
		5	175	0.11	0.43	0.10	0.21	
	360–420	6	175–400	0.66	0.57	0.15	0.89	*Stenobrachius* (S > L), siphonophore; *Tactostoma*
		7	400–410	0.58	0.12	0.06	0.57	*Stenobrachius* (S > L); *Hierops*; *Chauliodus*

[a]See Table 1.

Small *Stenobrachius leucopsarus* were numerous in the DSL (350 to 420 m) during both the daytime and nighttime tows (Tables 5 and 6). These fish have gas-filled swimbladders (Capen, 1967) and may be principal contributors to this 12-kHz sound-scattering layer off Oregon. *Sergestes* and *Euphausia*, on the other hand, were common within depths of the DSL during the day but were most common above the deep layer at night. Small *S. leucopsarus* of the same age group also were caught in large numbers near the surface at night. They were common in a scattering layer in the upper 50 m later during the night of 17-18 November, the same night they were captured in deep water (Table 6). This suggests two centers of abundance or migratory and nonmigratory individuals of this age group within the population.

Summary of Occurrences Relative to Scattering Layers

Table 7 shows how frequently common groups of animals had peak abundance in, above and below scattering layers. These data are only from tows that sampled through layers.

Table 7. Occurrence of Maximum Catches of Various Midwater Animals

		Euphausiids	Sergestids	Siphonophores	Pteropods	*Stenobrachius*	*Lampanyctus*	*Diaphus*	*Tarletonbeania*	*Hierops*	*Tactostoma*	*Chauliodus*
0–100 m Night	12 kHz (9 tows)	AA IIIII BB	AAA III BB	B	AA II	A IIIII* BBB		III B	II		III BBBB	
	38.5 kHz (8 tows)	IIIIII B	IIIII BB		III	A IIIII*I* BB		A III B	I		II BBBB	
Day	12 kHz (4 tows)	I BB	B	B	I B	BB	B	B	B			
	38.5 kHz (4 tows)	I BB	B	B	I B	BB	B	B	B			
100–275 m Day/night	12 kHz (4 tows)	A II B	II B	II		I BBB*		II B	B	B	B	BB
Day/night	38.5 kHz (3 tows)	A I B	BB	A B	A	A B		A	BB	B		B
350–420 m Day/night	12 kHz (4 tows)	A III	AA I	AAAA		IIII B*		I		II		I

***This table shows how often the maximum catches of various common midwater animals occurred in (I), above (A), and below (B) the sound-scattering layer sampled. Night and day tows were tabulated separately when four or more tows could be included. An asterisk indicates a preponderance of *Stenobrachius* larger than 30 mm.**

Within the upper 100 m at night, euphausiids, *Sergestes*, and *Stenobrachius* peaked at scattering-layer depths more frequently than other animals. Euphausiids, for example, were common at scattering-layer depths in seven out of eight tows through 38.5-kHz layers. The higher occurrence of peaks in 38.5- than in 12-kHz scattering layers was influenced by the greater portion of the 12-kHz echograms that were gated out near the surface.

During the day, catches of most groups of animals were largest below both the 38.5- and 12-kHz layers. Only euphausiids and pteropods peaked at scattering depths, and then only infrequently.

Poor correlations also were found between abundances and scattering between 100 to 275 m during day and night periods, but the total number of tows was low. Small *Stenobrachius leucopsarus* were common in all four tows in 12-kHz layers between 350 and 420 m. Euphausiids were also more abundant in this DSL than above it in three of the four tows.

CONCLUSIONS

1. The depth and migratory pattern of scattering layers observed on echograms was variable among diel periods.
2. Replicate samples at discrete depths indicated patchy distributions of fishes and *Sergestes similis*. Catches of *Euphausia pacifica* were less variable.
3. Sampling during single nocturnal periods suggested that the depth distribution of species and species groups may change within surface scattering layers.
4. Although catches of species often varied among depths, many species were caught over wide depth ranges and were not completely aggregated into high-density, thin layers.
5. Catches of fishes, shrimps, and euphausiids were sometimes largest at scattering-layer depths. Sometimes catches of animals were low at scattering-layer depths, however, and sometimes large catches were made where no dense scattering layer was recorded.
6. *Euphausia pacifica*, *Sergestes similis*, and *Stenobrachius leucopsarus* were the animals that were caught most often in largest numbers in scattering layers, especially in the upper 100 m at night.
7. Small *Stenobrachius leucopsarus* (with gas-filled swimbladders) were caught in all tows that sampled the DSL (350 to 420 m) during day or night periods.

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