DAILY CHANGE OF VERTICAL DISTRIBUTION OF PLANKTON ANIMALS NEAR WESTERN ENTRANCE TO THE TSUGARU STRAIT, NORTHERN JAPAN

Sigeru MOTODA and Masateru ANRAKU
Faculty of Fisheries, Hokkaido University

Two net hauls for plankton sampling, one in the daylight and another one at darknight, were carried out at a station, 41°34′N, 139°54′E, near western entrance to the Tsugaru Strait in northern Japan on 20th and 21st October, 1953.

For sampling the plankton by vertical haul from the strata of 450 m—300 m, 300 m—150 m and 150 m—0 m separately, a specially disigned iron cap (fig. 1) was used for closing the net. It is a cone-shaped covering, made of iron plate of 2 mm thickness, 45 cm in diameter at the lower edge, 47 cm long along the side, and 6.1 kg in total weight. At the top there is a cylindrical neck (fig. 2,a), 10 cm in height and 4.5 cm in diameter, in the axis of which a hole, 2.7 cm in diameter, is pierced. A rod (fig. 2,b) which is divisible longitudinally to two halves may be screwed into the above hole of the neck, so as to leave a narrow hole, 7 mm in diameter, which allows the wire to run. There are three large openings around the upper part of the side of the cap, each being closed with a cover (fig. 1).

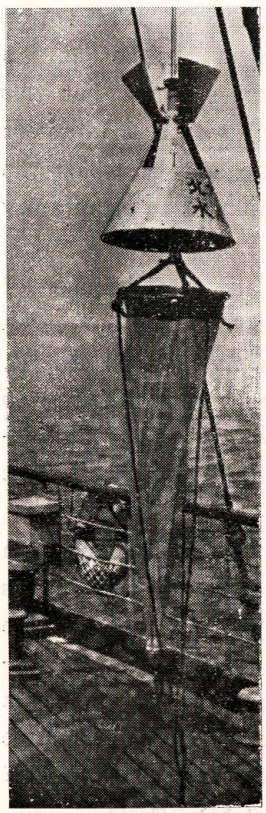

Fig. 1. Iron cap and plankton net hanging on the deck

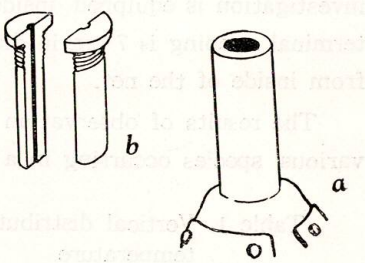

Fig. 2. Neck part of the cap (a) and inner rod (b)

The cap goes down into the depths sliding on the wire as fast as about 50 cm per second, and completely covers the mouth of the net when it rests on the net, no more sampling being made.

The plankton net used is 35 cm in mouth diameter, 130 cm long at the side, and made of bolting silk, GG 58, i. e., 56.5 meshes to a linear inch. Although the cap is rather clumsy and there is much resistance to the current of water, it is highly reliable for closing the net at desired depth.

After a preliminary experiment with the iron cap of original pattern was made, this pattern was somewhat improved. In the second type cap (fig. 3) lower edge is

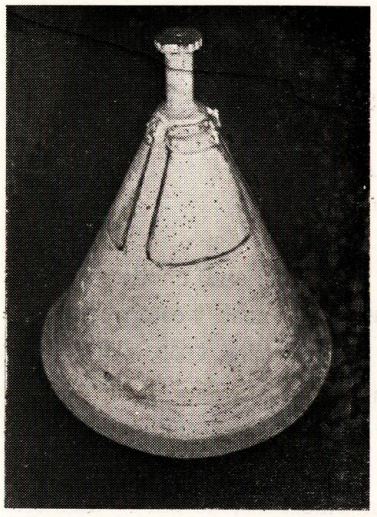

Fig. 3. Improved type of cap

elongated by 6 cm, becoming 50 cm in diameter to cover the net of 45 cm in mouth diameter. Such net has been used as a standard net, so-called "Marutoku-net", in the sardine research of the Fishery Agency. Together with this enlargement, the edge was fringed with a brim bending outward as long as 3 cm. By this improvement the cap will be easily slid along the bridle of the net, and will successfully cover the mouth of the net. This type of cap weighs as heavy as 8.4 kg, and the sinking velocity is about 50 cm per second.

The plankton materials which had been captured in the net during the vertical haul often outflows from the mouth of the net at the moment of closing by ordinary Nansen's closing method (Barnes, 1954), but this may be eliminated by use of the iron cap. Moreover, the net used in the present investigation is equipped inside with an inner cone of bolting silk of which the terminal opening is 7 cm in diameter. This prevents the agile animals to swim away from inside of the net.

The results of observation are given in table 2 in which the total number of various species occurring in a haul at different strata is calculated. The surface temperature was as high as 19.5°C, but it was greatly decreased at 100 metres, as low as 5.80°C, being gradually decreased with depth below that (table 1).

Table 1. Vertical distribution of temperature

Depth (m)	Temperature (°C)
0	19.50
100	5.80
200	1.55
300	0.92
400	0.46

Comments on the distribution figure will be made on the species which have occurred in considerable number. The species occurring exclusively or in majority in the strata shallower than 150 metres in daytime as well as at night are considered to be those which dislike the deep cold water. *Calanus helgolandicus*, *C. tenuicornis*, *C. darwinii* (though one individual was collected from the deep layer at night), *Candacia* sp., *Oncaea* spp. and *Corycaeus* spp. are considered to prefer warm water. Microcalanoid copepods, such as *Paracalanus*, *Clausocalanus* and *Scolecithricella*, as well as a majority of the chaetognaths and appendicularians, were also abundantly distributed in the shallow layer, probably due to the preference for shallow lighted water. However, among the chaetognaths, *Sagitta elegans*, which has been known as a cold

Table 2. Number of individuals of various species occurring at different strata in daytime and at darknight

Day or night	Day (10:00—10:40 a. m.)			Night (0:00—0:40 a. m.)		
Hauling layer	150-0m	300-150m	400-350m	150-0m	300-150m	400-350m
Calanus helgolandicus	8	2		15	2	
C. cristatus			7		2	12
C. plumchrus	6	24	18	2	24	11
C. tenuicornis	12	2		9		
C. minor	1					
C. darwinii	4					1
Eucalanus spp.	2		2			3
Euchaeta spp.	13	2	20	11	9	6
Scolecithricella spp.	2			2		
Metridia lucens	27	4	195	49	15	141
Bradyidius armatus				1		
Gaidius spp.			4		2	2
Gaetanus sp.				1		
Candacia sp.	4			4		
Paracalanus & Clausocalanus	294	37	20	510	50	51
Oithona spp.	81	21	17	54	16	41
Temora sp.	1					
Lucicutia sp.		1				
Clytemnestra sp.	9			2	2	
Setella gracilis	1		1	3	2	
Oncaea spp.	101	10	33	145	12	5
Corycaeus spp.	28	3		8	2	
Themisto sp.	6	3	8	39	14	3
Primno sp.			1		3	2
Euphausia pacifica			3	2		
Thysanoessa sp.					2	2
Conchoecia elegans		2	141	7	15	240
Sagitta spp.	25	7	10	20	2	5
Oikopleura spp.	18	3		19		
Doliolum sp.	1			1		1
Aglantha digitale	1	2	45		4	16
Polychaeta larvae			1	1		
Total	645	123	526	905	178	542

water form, was mainly collected from the deeper layer.

Some species were abundantly collected from the strata below 150 metres. They must have been distributed there by their preference for cold water or their characteristic abyssal nature. *Calanus cristatus*, *C. plumchrus*, *Metridia lucens*, *Gaidius* sp., *Primno* sp., *Conchoecia elegans* and *Aglantha digitale* are the examples of such forms. Thus, attention is drawn to the significance of the preventive effect of large temperature gradient upon vertical migration of a majority of the plankton animals.

It was indicated that in *Calanus cristatus* and *Metridia lucens* the larger individuals were distributed in the deeper layer, while smaller ones in the shallow layer (table 3). This tendency was not perceived in *Calanus plumchrus*. In *Calanus*

Table 3. Mean body length of three species of copepods from different strata (mm)

Hauling layer	150m—0m		300m—0m		450m—0m	
Day or night	Day	Night	Day	Night	Day	Night
Calanus cristatus	—	—	6.71	5.89	9.31	9.31
Calanus plumchrus	4.35	2.67	3.50	3.21	4.04	3.88
Metridia lucens	1.92	2.37	2.09	2.19	3.26	3.02

cristatus and *C. plumchrus* the individuals which were found in the shallow layer were almost those of immature forms of the last stage of copepodite, the mature individuals in adult stage being found only in the deeper layer mingled with immature forms. However, the body length was not so variable as to be distinguishable between the individuals of the above two stages.

A few other species were apparently observed to make daily vertical movement. *Themisto* sp. (closely allied form to *T. abyssorum*) appeared abundantly in the layer of 150 m—0 m at night, while few in daytime, showing the upward movement at night. In yonng *Euphausia pacifica* a few individuals have occurred in 450 m—300 m in daytime, but in 150 m—0 m depth at night. They seemed to migrate up and down diurnally passing through the strata of different temperatures.

The number of *Conchoecia elegans* in 450 m—300 m was greatly increased at night comparing with in daytime, the number in the layers shallower than 300 metres being also considerably increased at night. There is evidence of vertical migration in the last species too, but the migration takes place mainly within the deep water.

In the routine oceanographic cruise the plankton hauls are usually carried on notwithstanding whether it is day or night. In order to eliminate the difference in occurrence of species as well as distribution number of plankton by day and night, the haul must be made from certain depth. In table 4 is shown the number of

Table 4. Total number of plankton obtained by three hauls from different depths in daytime and at darknight

Hauling layer		150 m—0 m		300 m—0 m		450 m—0 m	
Day or night		Day	Night	Day	Night	Day	Night
Total animal plankton	Number of individuals	645	905	768	1083	1294	1625
	Ratio of night to day	100	140	100	141	100	126
Animal plankton excluding *Themisto*, *Euphausia* and *Conchoecia*	Number of individuals	639	857	757	1006	1131	1305
	Ratio of night to day	100	134	100	133	100	115

plankton occurring in the strata from different depths to the surface in daytime and at night. From this table it is learned that the number of total plankton sampled in daytime and at night varies remarkably with each other in the 150 m−0 m and 300 m−0 m hauls, and that the number varies considerably too in the 450 m−0 m haul. Even though the number of *Themisto*, *Euphausia* and *Conchoecia* which make conspicuous diurnal migration is excluded, the number of plankton sampled by the 150 m−0 m and 300 m−0 m hauls at night is increased by over 30 per cent of the number sampled in daytime.

The authors are indebted to Captain T. Fujii and his crew of the T. S. Hokusei Maru of the Faculty of Fisheries, Hokkaido University, for making facilities available for carrying out the sampling, and to Mr. N. Ogawa for help during the work at sea. Financial aid granted from the Fishery Agency for the present investigation is gratefully acknowledged.

Summary

(1) A newly devised iron cap for closing the net in vertical haul is described.
(2) The species preferring warm water stay in large number in the upper warm water all day long, and those preferring cold water in the deep cold water, both having not displayed any remarkable vertical migration.
(3) *Themisto* sp. and *Euphausia pacifica* made a distinct vertical migration passing through the large temperature gradient.
(4) *Conchoecia elegans* makes migration too, but the migration is limited within the deep water.
(5) Total number of plankton sampled by vertical haul from the depth of 450 m varies considerably by day and night.

Reference

Barnes, H. (1949). A statistical study of the variation in vertical plankton hauls, with special reference to the loss of the catch with divided hauls. *Jour. Mar. Biol. Ass.* **28** (2), 429—446.