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Calanoid Copepods as Indicators of the Cold Watermass in the Japan Sea

YASUHIRO MORIOKA, MASANOBU NAGAHARA AND YUZO KOMAKI

Abstract

To detect the influence or presence of cold watermass in the complicated watermasses, the ranges of the distribution of each cold-water calanoid copepod in terms of temperature were examined. Samples were obtained by horizontal tows with MTD closing nets at 9 layers between 10 m and about 300 m at the stations scattered in the Japan Sea in four seasons, 1972–'73. Three grades of criteria of the cold-water indication were able to be settled; (1) Hypersensitive group including *Eucalanus bungii bungii* and adult male and female of *Calanus plumchrus*, (2) Middle group, stage V of *Calanus cristatus*, and *C. plumchrus*, and adult male of *Metridia lucens*, and (3) Insensitive group, *Pseudocalanus elongatus*, *Scolecithricella minor* and stage V and adult female of *Metridia lucens*. The highest temperatures those which they encountered varied through the year. It may be caused by the ontogenetic migration and specific adaptation to changing environment. It is noteworthy that stage V *Metridia* showed active nocturnal ascending migration to the warm water stratum with almost 22°C in the highly stratified season.

I. Introduction

Cold-water plankters frequently indicate the presence or influence of the cold watermass that is mixed with warm waters in the complicated watermasses. Each species may be distributed and behave differently according to life historical phases and seasons. But these problems have not been explored in detail hitherto. Therefore, the degree of the indication in each species or form is not clear.

This paper describes the degree of cold-water indication in the boreal calanoids in terms of temperature basing upon the plankton samples collected from various detailed depths in the Japan Sea in the months representing each season. Environmental factors other than temperature were left out of account. The difference of the salinity is slight in the Japan Sea and cold-water calanoids occurred at all the range of salinities. Data on the other chemical factors such as dissolved oxygen and inorganic compounds, etc. were not avairable for the present study.

II. Method

Simultaneous horizontal tows were carried out for 30 minutes with four or five MTD closing nets (MOTODA, 1971) in April-May, July, October 1972 and February 1973 at stations scattered in the Japan Sea (Fig. 1). In April-May and July four stations,

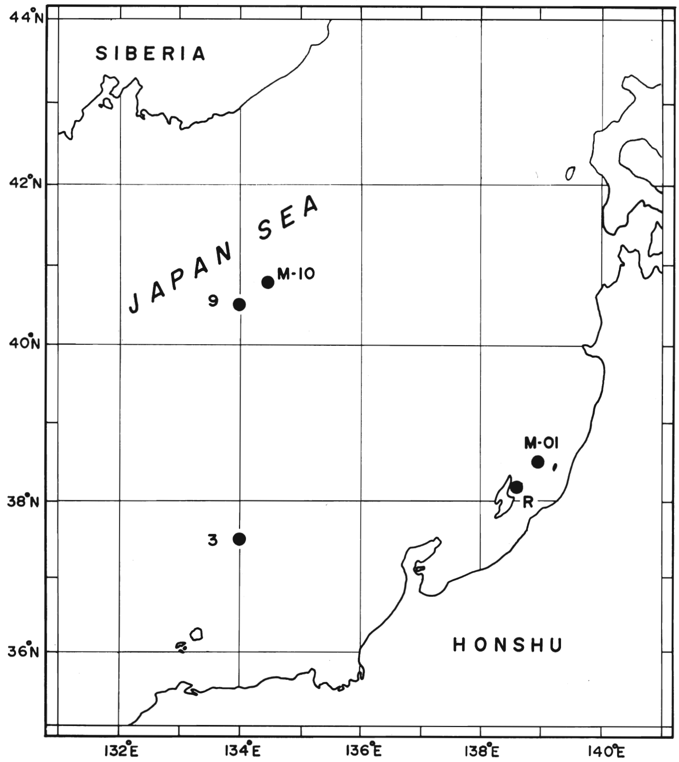

Fig. 1. Location of plankton sampling stations.

Table 1. Material sourse data (Gear: MTD closing nets).

Cruise No.	HKK72-2		SHY72-2		MZ72-K1	MZ73-01
Vessell	*Hokko Maru*		*Shunyo Maru*		*Mizuho Maru*	
Sta. No.	3	9	M-01	M-10	R	R
Date	Apr. 27, '72	May 1, '72	July 25, '72	July 28, '72	Oct. 14, '72	Feb. 26, '73
Hour	20:00-21:22	20:08-21:23	21:23-22:50	21:13-22:34	19:53-21:26	20:50-22:48
Sampling depth (m)	-	-	-	-	0	0
	12- 13	9- 13	8- 11	9- 12	8- 11	9- 12
	24- 26	18- 26	16- 21	19- 24	16- 21	19- 24
	36- 40	28- 40	24- 32	28- 36	24- 32	28- 36
	60- 67	47- 67	40- 53	47- 60	40- 53	47- 60
	90-100†	70-100†	60- 80†	70- 90†	60- 80†	70- 90†
	103-126	103-133	80-110	90-100	87-107	100-106
	155-190	155-200	120-165	135-150	130-161	150-155
	206-253	206-266	160-220	180-200	173-187	200-206
	310-380†	310-400†	240-330†	270-300†	260-280†	300-310†

† TSK Depth Distance Recorder was mounted.

a couple in the warm waters, and the other in the cold waters, were occupied. In the other months samplings were made only in the warm waters. The zooplankton samples were obtained from nine layers between 10 m and 300 m by two series of tow at each station. In addition to these, occassionally, the surface tows were made simultaneously with the same sized net as MTD (Table 1). Samplings were made both in daytime and at night. The night data alone are dealt in the present study as regards to the consideration on the temperature-occurrence relations, because zooplankton generally show their shallowest habitat at night and encounter the more warmer water than in daytime. Depth and distance of tow were estimated by the readings of a TSK Depth Distance Recorder. The density of each calanoid species was calculated by the counting of the individual number separated into sex and stage and the estimated volume of water filtered. However, stages younger than copepodite IV in each species were excluded due to its small number in occurrence.

III. Results

Six calanoid copepod species are concerned; *Calanus cristatus*, *C. plumchrus*, *Eucalanus bungii bungii*, *Pseudocalanus elongatus*, *Scolecithricella minor* and *Metridia lucens*. These are commnon boreal species not only in the North Pacific but also in the Japan Sea (Brodsky, 1950). The depth distribution of each species varied according to the difference of the feature of the temperature profiles. In the present study, regardless to this, the maximum temperature at which each species or form encountered in each diel migration was concerned. Fig. 2 shows the temperature range at the layer in which the net was towed, and also the quantitative occurrence of the animals at each depth.

(1) April-May 1972

Temperature at depths in which nets were towed ranged between 0.2 and 6.6°C at sta. 9 and between 0.8 and 13.5°C at sta. 3. Stage V of *Calanus plumchrus*, *Pseudocalanus elongatus*, stage V and adult female of *Metridia lucens* occurred through the range of temperature. *Scolecithricella minor* occurred at rather lower temperature. The occurrence of the adults of *Calanus plumchrus*, adult male of *Metridia* and stage V of *C. cristatus* were limited at depths cooler than 10°C. The adults of *C. plumchrus* are favourable to the lowest temperature at the deep layer.

(2) July 1972

Temperature ranged 0.4–22.8°C at sta. M-10 and 1.5–24°C at sta. M-01. Many forms excluding *Eucalanus*, adult male *Metridia*, *C. plumchrus* and *C. cristatus* occurred at fairly higher temperature. *Scolecithricella*, *Pseudocalanus*, and adult female and stage V *Metridia* are also distributed at depth higher than 15°C. The last one occurred even at 22°C.

(3) October 1972

Similar to the July feature, *Scolecithricella* and stage V and adult female *Metridia* occurred at relatively higher temperature. Stage V *Metridia* also occurred at nearly 20°C

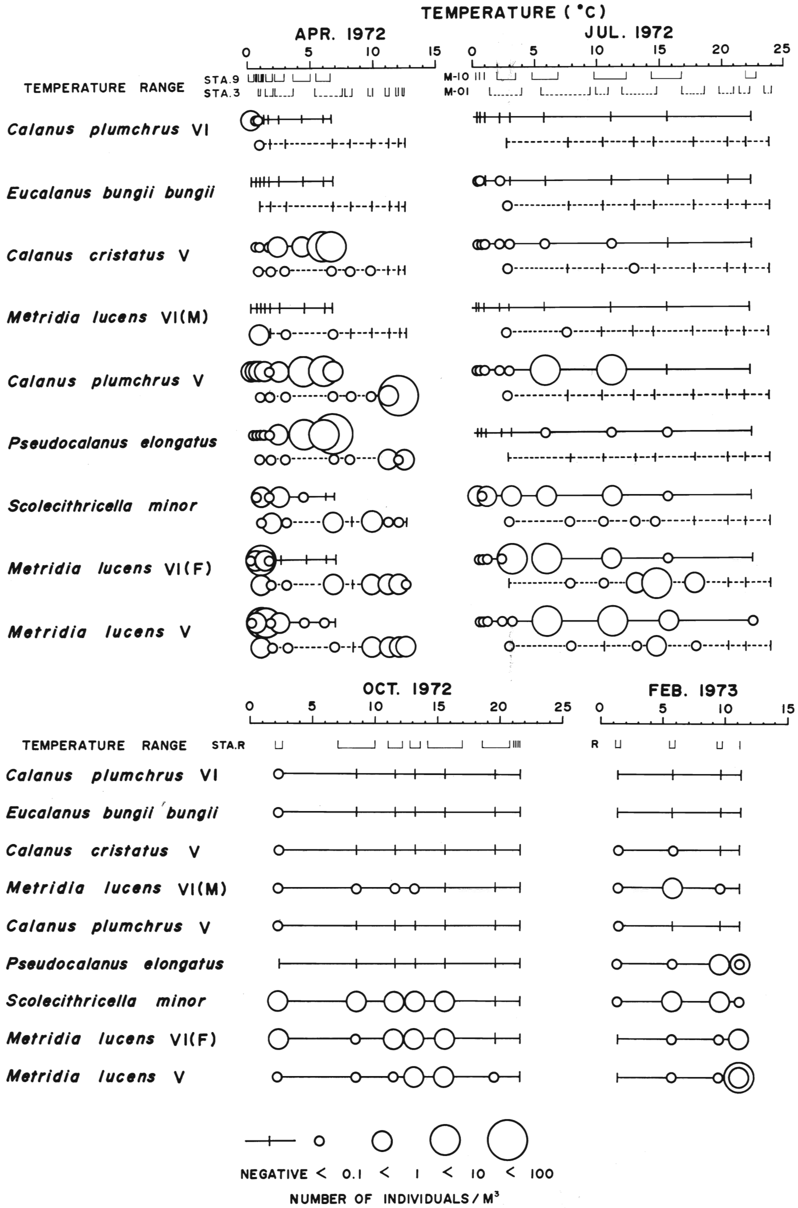

Fig. 2. Range of temperature at the towing depths and the quantitative occurrence of cold-water copepods at each depth.

(4) February 1973

Temperature is the lowest through the year with maximum 11°C. Though the distribution of *C. plumchrus*, *C. cristatus* and adult male *Metridia* was limited at depths cooler than 10°C, *Pseudocalanus*, *Scolecithricella*, V stage and adult female *Metridia* occurred at the maximum temperature prevailed.

IV. Discussion

In the Japanese coastal waters of the Japan Sea the warm Tsushima Current overlies upon the deeper cold watermass which is made by excessive winter cooling in the northern part of the sea. Inhabitants of the cold watermass sometimes occur in the shallow warm waters through the diel vertical migration and/or the complicated process of water movement. The process of inflow of the cold watermass to the warm waters and the mixing of those two watermasses is traced to some extent by the inhabitants of the cold watermass (MORIOKA, 1973).

The criteria of the distribution of the cold-water zooplankters have been set at temperature lower than 11°C in the Japan Sea (FURUHASHI, 1953), and at temperature lower than 12°C, chlorinity lower than 19.10‰ and *dt* lower than 26.20 in the Pacific coastal waters of Honshu (NAKAI *et al.*, 1966). The criteria differ from species to species even among the cold water forms (KIMURA and ODATE, 1957).

The present results show three different grades of criterion of the cold-water indication in copepods (Table 2). *Eucalanus bungii bungii* and adults of *Calanus plumchrus* were restricted to temperature lower than 3°C through the year. These are the hypersensitive group of the cold-water indicators. In addition to these, adults of *Calanus cristatus*, *Pareuchaeta elongata* and *Gaidius brevispinus* among copepods might be also included in this group. These are deep-water forms in the Japan Sea (BRODSKY, 1948). While, *Pseudocalanus elongatus*, *Scolecithricella minor*, stage V and adult female of *Metridia lucens* are insensitive to temperature putting up with highest temperature as high as 16–22°C. Above all, stage V *Metridia* is the most insensitive. Stage V of *Calanus cristatus*, adult male of *Metridia lucens* and stage V of *C. plumchrus* are ranked between above two groups inhabiting the water with temperature around 10°C. Some of these values of temperature are considerably higher than those have

Table 2. Highest temperatures (°C) those which each coldwater calanoid encountered in the Japan Sea, April 1972 through February 1973.

Thermosensitive grouping	Apr.–May	July	Oct.	Feb.
Hypersensitive group				
Calanus plumchrus VI	1	1	3	–
Eucalanus bungii bungii	–	2	3	–
Intermediate group				
Calanus cristatus V	9	12	3	6
Metridia lucens VI (♂)	6	7	12	10
Calanus plumchrus V	12	11	2	2
Insensitive group				
Pseudocalanus elongatus	12	16	–	10
Scolecithricella minor	12	16	16	11
Metridia lucens VI (♀)	12	17	15	11
Metridia lucens V	12	22	20	11

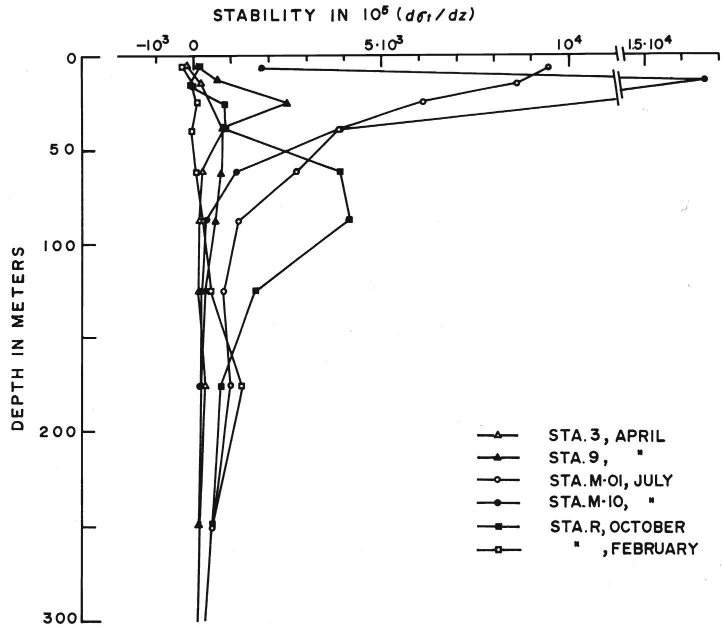

Fig. 3. Vertical stability of the water at each sampling station (unpublished data of M. NAGAHARA).

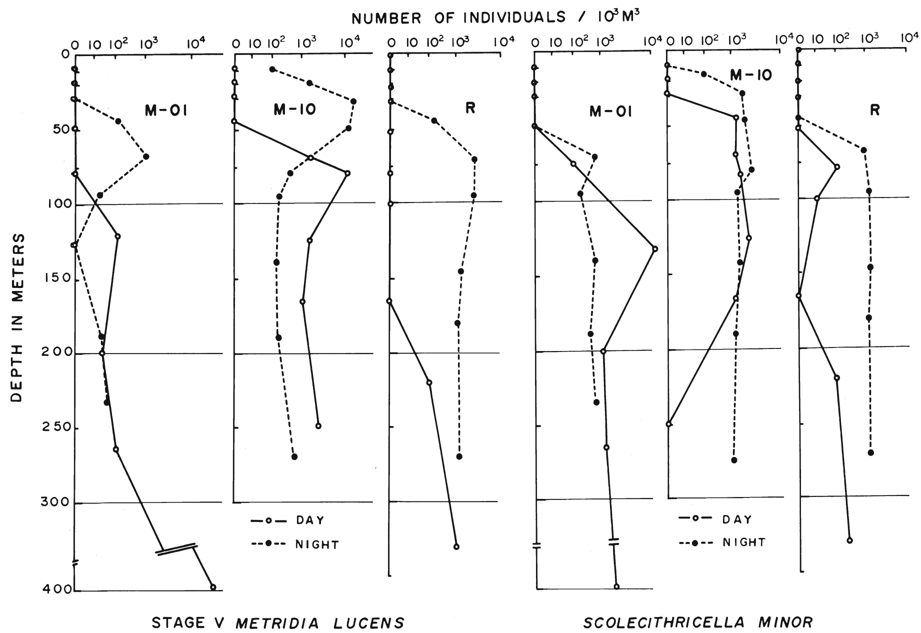

Fig. 4. Day-night difference of vertical distribution in two forms of copepods in the stratified seasons (M-stations in July and sta. R in October 1972).

been adopted. These findings are apparently caused by the sampling method; samples were obtained from detailed depths by simultaneous horizontal tows. Previous authors were obliged to assume the upper limit of the temperature the lowest owing to the plankton collection from vast vertical range of the depths by means of the vertical hauls.

The highest temperature they encountered through the year varied especially in the intermediate and insensitive groups. *Calanus cristatus* and *C. plumchrus* prefer the shallow layer at their younger stages and descent to the cold depths with the development of stages to the adult during autumn-winter season (HEINLICH, 1962, FULTON, 1972). The period of thier dwelling at shallow layer coincide with the temperature maximum season through the year. The vertical stability of the water in summer-autumn is high in the shallow stratum (Fig. 3). It is conspicuous in July due to the extrem heating by the solar radiation. Day-night difference in stage V *Metridia lucens* and *Scolecithricella minor* is illustrated in Fig. 4. In spite of the high stability of upper layer water, stage V *Metridia* occurred at that layer, and *Scolecithricella* was distributed at the boundary depth with maximal density through vertical column with a slight variation in day-night vertical distribution. These mean that stage V *Metridia* was not passively transported to the upper layer by the water movement but performed actively its own extensive nocturnal upward migration. Stage V *Metridia* endures or accomodates itself to the tremendously high temperature during summer-autumn season. It is likely due to the adaptation of the brood at higher temperature with the changing of the seasons.

In winter-spring season particularly in February the vertical stability of the water is low, and it may be probable that the cold-water forms are transported to the upper layer through the vertical turburence of the water. In this season, the upper layer may be cold enough to dwell for many cold-water forms. Active migration to the upper stratum, therefore, is also possible. However, no cold-water forms except *Pseudocalanus elongatus* appeared at the layer, where they were replaced by the warm-water type *Calanus finmarchicus*, s. l.

Seasonal variety of the highest temperature the boreal forms encountered is likely attributable to the specific and brood adaptation to the changing environment through their ontogenetic vertical migration.

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日本海における寒海性橈脚類の水塊指標性

森岡泰啓・永原正信・小牧勇蔵

要　旨

寒海性と称せられる何種かの橈脚類が日本海の暖水域において どれほど冷水塊を指標するかの吟味を行なった.

試料は1972〜'73年の四季を代表するであろう 4 つの月にＭＴＤネットによって, 日本海に点在する 5 地点の表面からおよそ 300 *m* の間の 9 〜10層から得られた.

対象とされたいくつかの種の棲息温度の上限は, 性および発育段階によって, また季節によって異なっていた. 高温域にも棲むことができるものを寒海の指標性が低く, その反対に低温域にしか棲息できないものを寒海の指標性が高い, という具合に考えると, 指標性の度合いは 3 つに大別できた. それらのうちの "Insensitive group"（寒海性種でありながら高温域にも棲息できる群）の棲息可能な水温は, 従来行われていた寒海性種のそれの上限をはるかに上廻っていた. いくつかの種は成長につれて鉛直移動を通じ自ら棲息環境を変え, また環境の季節的な変化にも充分に順応し, かなりの高温にも耐えられるといえる.

殊に *Metridia lucens* はコペポデイッド第 5 期には鉛直移動の習性によって夜間に深層から浮上して表層の22 ℃という非常に高温の水帯にも出現する.