日水研報告, (27) : 91—101, 1976.
Bull. Jap. Sea Reg. Fish. Res. Lab., (27) : 91—101, 1976.

Vertical Invasion of Boreal Calanoid Copepods into the Shallow Warm Stratum

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Abstract

Diurnal vertical migration of boreal calanoid copepods, *Calanus plumchrus*, *Pareuchaeta elongata*, *Scolecithricella minor* and *Metridia lucens*, was observed at a station in the vicinity of Sado Island, the Japan Sea in the middle October 1972. Total community of them kept the deepest during the period from dawn to twilight and the shallowest at night. Some of them invaded into the shollaw warmer stratum where the tropical and subtropical fauna is prevailed. The estimated biomass of them was 4.6mg/m³ in wet weight and 15.3 % of total copepod community at that layer.

I. Introduction

Some cold-water calanoid copepods dare to invade into the upper warm stratum from the deep cold water during their nocturnal vertical migration in the Tsushima Current area of the Japan Sea (MORIOKA, 1973). They might actively transport the organic matter from the depths to the warm surface zone and *vice versa* through the developed thermocline during the diurnal vertical migration.

Present paper describes the diurnal vertical migration in cold-water calanoid copepods popular in the Japan Sea, *Calanus plumchrus*, *Pareuchaeta elongata*, *Scolecithricella minor* and *Metridia lucens*, and estimates the effect of these organisms on the warm shallow water ecosystem. These animals cover the typical forms of the manner of nutrition respectively ; *Calanus* is herbivorous, *Pareuchaeta* is carnivorous and latter two are omnivorous. The morphology on some undescribed copepodite stages in the latter two species is preliminarily described and illustrated.

II. Methods and Material

Four series of 30 minutes MTD net (MOTODA, 1971) simultaneous horizontal tows representing daytime, twilight, night and dawn were made on board the *R/V* "*Mizuho Maru*" at a station at the mouth of Ryotsu Bay, Sado Island, the

Japan Sea (38°24′N, 138°42′E) in October of 1972 (Table 1). Detailed sampling operation is informed elsewhere (MORIOKA, 1975). Two casts of tow, shallow and

Table 1. Plankton sampling data by MTD net simultaneous horizontal tows at a station near Sado Island (38° 24′ N, 138° 42′E), October 1972 (*R/V "Mizuho Maru"* Cruise MZ72-K1)

Date	Hour	Depth of sampling (m)
Oct. 10	0936–1010	8–13 (9), 16–27 (19), 24–40 (38), 40–67 (47), 60–100(80)†, 133–87 (93), 200–130 (140), 267–173 (186), 400–260 (280)†
Oct. 14	1726–1756	65, 98, 130, 195, 260†
	1953–2126	8–11 (9), 16–21 (19), 24–32 (28), 40–53 (47), 60–80 (70)†, 87–97 (93), 130–145 (140), 173–193 (186), 260–290 (280)†
Oct. 15	0448–0518	45–65 (48), 68–98 (71), 90–130 (95), 135–195 (142), 180–260 (190)†

†TS Depth Distance Recorder was mounted.
Numbers in parentheses are mean depths. Hour of dawn, Oct. 15 : 0432–0556.
Hour of twilight, Oct. 14 : 1710–1838.

deep, were carried out in daytime and at night between the surface and about 300 m. Both twilight and dawn samples were collected by a single tow each between 50 and over 200 m being centered the thermocline.

The number of organisms in each species was counted under the dissecting microscope separating developmental stages and sexes. Wet weight of the organisms was refered or calculated by the conversion factors from the previous studies.

III. Copepodite Stages

Complete illustration and description of post-embryonic stages in calanoid copepods have scarcely been made except restricted species. Of four copepods dealed in the present paper had been fully described and illustrated two species, *Calanus plumchrus* and *Pareuchaeta elongata* by CAMPBELL (1934). Some of the undescribed copepodite stages of *Scolecihricella minor* and *Metridia lucens* were illustrated and the developmental stages were determined basing upon the morphology of the 5th swimming feet and the number of the abdominal segments. It was tentatively assumed that both the number of the somites of 5th foot and of urosome usually increase by one with the progress of each developmental stage.

(1) *Scolecithricella minor*

The occurrence of this species in the plankton samples was limited to both females and males of the last three copepodite stages IV, V and VI. Both sexes of the adult stage have been described by many authors. WITH (1915) took a particular attention to the post-larval development of copepods and illustrated male copepodite stage IV and both sexes of stage V in this species. Newly and

previously described copepodite stages in *Scolecithricella minor* are breiefly informed in Figs. 1, 2 and Table 2.

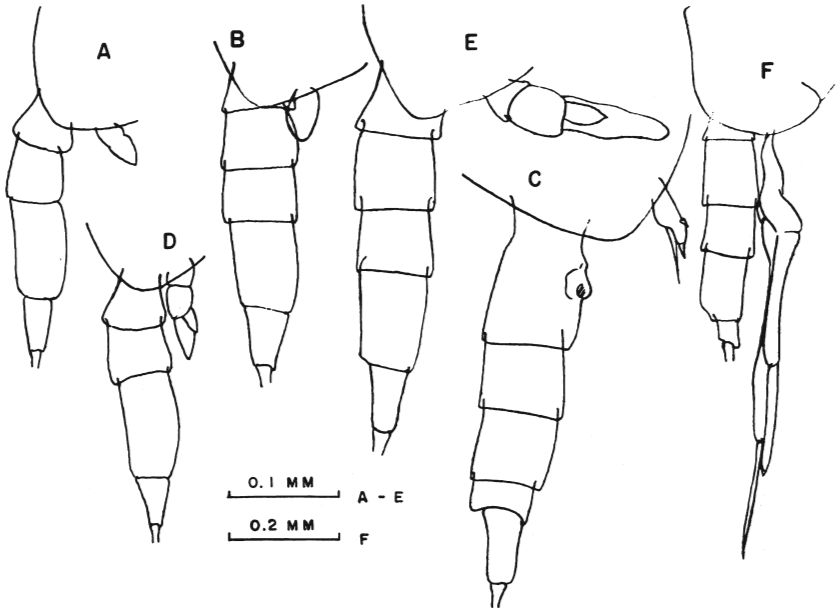

Fig. 1. *Scolecithricella minor*, abdomen, lateral view. A-C, female stages IV–VI ; D–F, male stages IV–VI.

Table 2. Identification table for the copepodite stages of *Scolecithricella minor*

Copepodite stage	IV		V		VI	
Sex	♀	♂	♀	♂	♀	♂
Number of urosome segments	3	3	4	4	4	5
Number of 5th feet segments†	1	exo 1 endo 1	2	exo 2 endo 1	1	exo 3 endo 1
Body length (mm)	1.01	1.02	1.25	1.3	1.4	1.4

†Number of somites excluding lst and 2nd basipodite in male.

exo : exopodite, endo : endopodite.

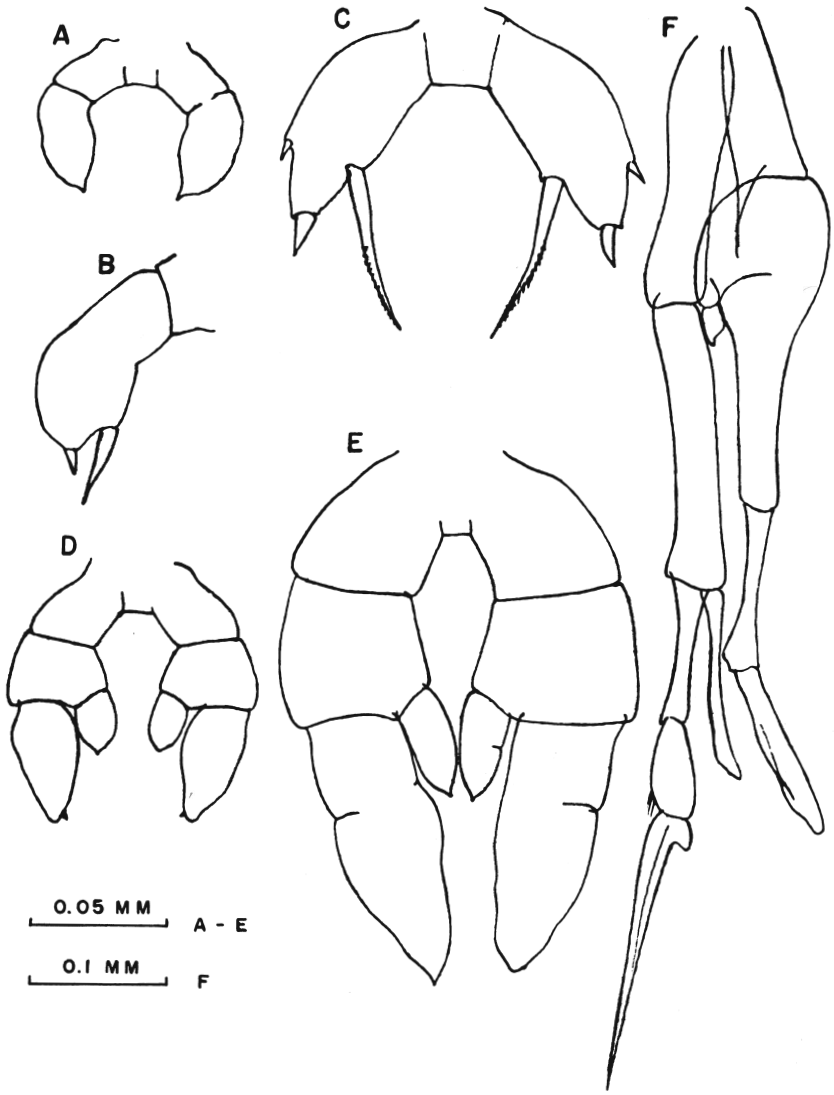

Fig. 2. *Scolecithricella minor*, fifth feet. A–C, female stages IV–VI; D–F, male stages IV–VI.

(2) *Metridia lucens*

In this species naupliar stages were described by GIBBONS (1938, cited from OGILVIE, 1953) and adult forms by many workers hitherto. Present paper shows copepodite stages III-VI (Figs. 3, 4 and Table 3). I was indicated that the sexes are distinguishable on appeapance of 5th swimming feet after copepodite stage IV like *Chiridius gracilis* (MACLELLAN and SHIH, 1974), *Pareuchaeta elongata* (CAMPBELL, 1934), *Labidocera pectinata* (PILLAI, 1971) *etc.* among copepods. In addition to the stages above mentioned another copepodite stage younger than III was obtained. But it is not ascertained whether it belongs to stage I or II. The speciemen

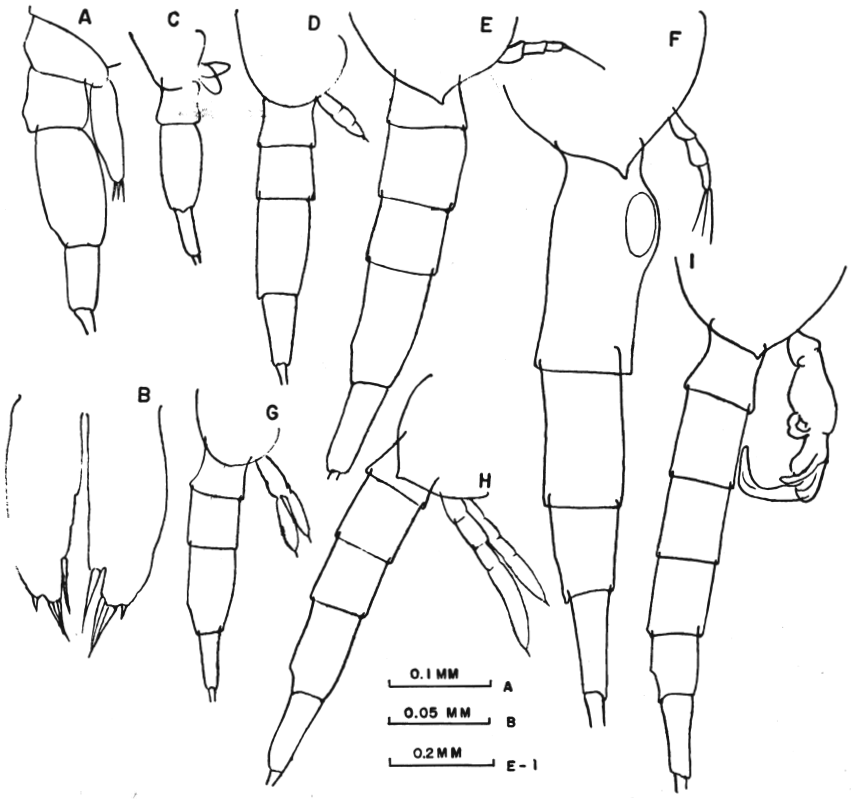

Fig. 3. *Metridia lucens*, A, C–I, abdomen, lateral view. A, stage I or II ; C, stage III ; D–F, female stages IV–VI ; G–I, male stages IV–VI ; B, 4th feet of stage I or II.

Table 3. Identification table for the copepodite stage of *Metridia lucens*

Copepodite stage	I or II	III	IV		V		VI	
Sex			♀	♂	♀	♂	♀	♂
Number of urosome segments	1	2	3	3	4	4	3	5
Number of swimming feet	4	5	5	5	5	5	5	5
Number of 5th feet segments	0	1	3	3	4	4	3	5
Body length (mm)	0.80	1.0–1.2	1.3–1.7		2.25–2.7	1.95–2.2	2.8–3.6	2.0–2.4

of this stage are very scarce in the primary examination not only in the present plankton samples but also in those collected by means of nets of more finer meshes throughout the year in the adjacent area of Sado Island.

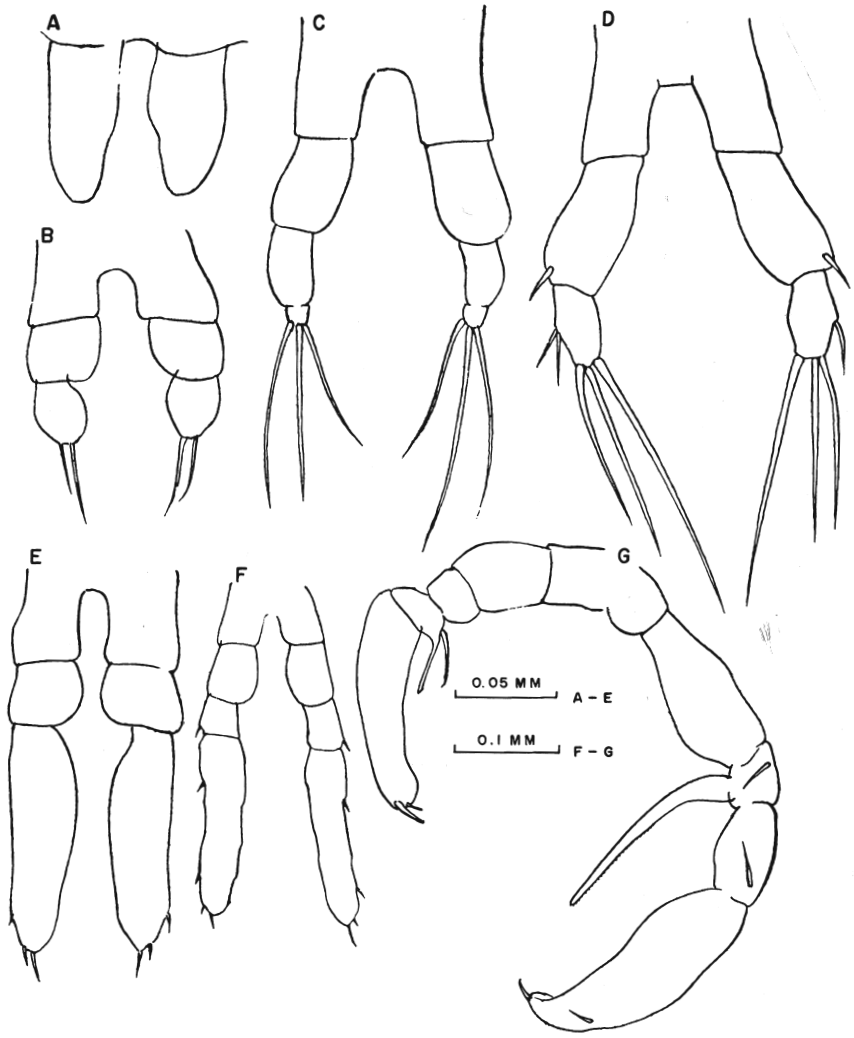

Fig. 4. *Metridia lucens*, fifth feet. A, stage III ; B–D, female stages IV–VI, E–G, *male stages* IV–VI.

IV. Diurnal Vertical Migration

It was observed that species except *Calanus plumchrus* keep the most deepest layer during daytime and twilight, and the most shallowest at night. It dwells at the intermediate depth in dawn (Fig. 5).

Calanus plumchrus being dominated by copepodite stage IV and followed by stages V and VI stayed at depths deeper than 200 or 250 m in day and at night. This feature is slightly different from that shown by FULTON (1973) who observed the descent of this species to the depths during autamn at stage V in the Straight of Georgia, Canada.

Pareuchaeta elongata usually shows a maximum concentration at certain depths between 50 and 200 m at night in the vicinity of Sado Island (MORIOKA, 1975).

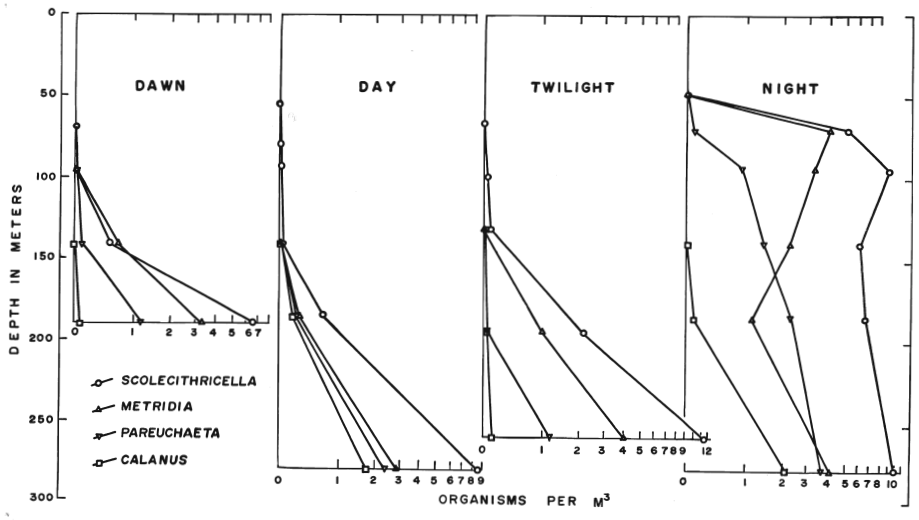

Fig. 5. Diurnal change of vertical distribution in *C. plumchrus*, *P. elongata*, *S. minor* and *M. lucens* at the station in the Sado waters in October 1972. All copepedite stages occurred are included in each species.

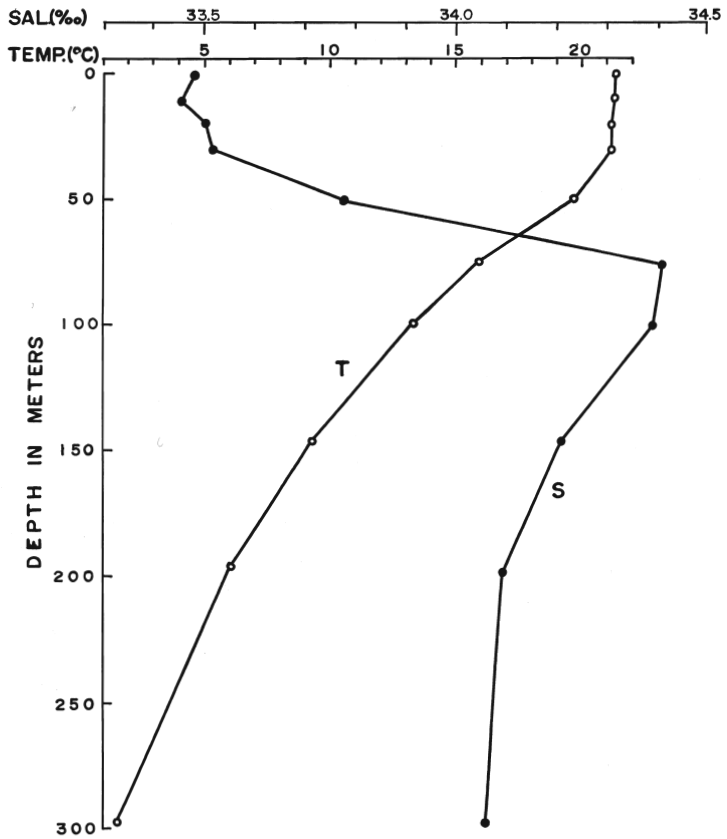

Fig. 6. Vertical profil of temperature and salinity at the station, October 11, 1972.

Conversely the abundance of the species, being composed of stages V, IV, III, II, and VI (order of abundance), increased with the depth in the present observation. The plankton samplings were made in the early hour of night, and it is probable that upward migration is in the early phase. Some of them, however, occurred at the depth of 70–93 m, being almost associated with the thermocline and intermediate saline water at night (Fig. 6).

The other two species, *Scolecithricella minor* abounding in adult males and females and *Metridia lucens* (dominated by stage V and followed by VI and IV, in turn), showed similar patterns of distribution to that of *Pareuchaeta* during dawn and twilight. But in the night figure *Scolecithricella* and *Metridia* presented a peak of abundance at 93 m and 70 m respectively.

V. Ecological Significance

The vertical distribution of biomass of four species in wet weight at night is illustrated in Fig. 7. Wet weight of animals was calculated from the previous

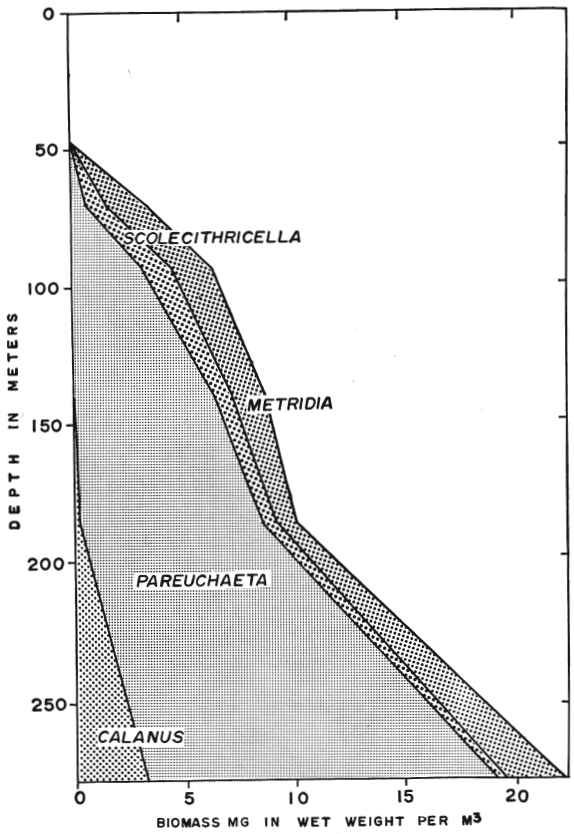

Fig. 7. Vertical distribution of the biomass of *C. plumchrus*, *P. elongata*, *S. minor* and *M. lucens* at the station in the Sado waters at night, October 14, 1972.

Table 4. Mean weight of calanoid copepods (wet weight, mg)

Copepodite stage / Sex	I	II	III	IV ♀	IV ♂	V ♀	V ♂	VI ♀	VI ♂	References
Calanus plumchrus†	0.02	0.06	0.28	0.67		3.05		3.5	2.7	Bogorov, 1957
Pareuchaeta elonggata††	–	0.13	0.4	1.6	1.9	5.8	5.9	7.8	5.0	Morioka, 1975
Scolecithricella minor††	–	–	–	0.026†††		0.048†††		–	–	Present author
Scolecithricella minor†	–	–	–	–		–		0.16	0.1	Bogorov, 1957
Metridia lucens†	0.01	0.04	0.06	0.07		0.27		0.87	0.16	Bogorov, 1957

† Specimen form the Bering Sea and Okhotsk Sea.

†† Specimen from the Japan Sea.

††† Calculated from the body length by the formula of Kamshilov (1951) ; Body weight, mg=(Body length, mm×0.286+0.005)^3.

data given in Table 4. *Metridia* and *Scolecithricella* are major constituents in number but minor in weight. *Pareuchaeta* is the dominant form in biomass. Total biomass of four species increased with depth showing a maximum at 280 m below which any nets were no towed. At the same time some of them also occurred in the upper layer of the thermocline and halocline where subtropical and tropical plankton fauna is prevailed. In those layers *Pareuchacta* diminished and *Scolecithricella* and *Metridia* constructed the main components among boreal copepods. Generally, the thermocline and halocline is the very border between the upper warm Tsushima Current water and lower cold watermasses in the present region. The boreal invadors to the upper warmer stratum feed on the various kind of biological products and excrete certain amount of organic and inorganic matter during their stay in the shallow layer at night. They very likely contribute to the nutrition for the other filter-feeding animals and accerate the process of decomposition of the organic matter to the inorganic one through feeding and excretion. At the same time they might be fed by the carnivorous animals in the layer. They also contribute to the nutrition in the identical manner for the deep sea environment during the descent to the depths and staying there. It is probable that they go up and down in a water column by at least 200-300 meters a day. Sinking rates of natural fecal pellets from euphausiids range from 126-862 m/day varying according to the size of pellets in the experimental condition (Fowler and Small, 1972). These values seem to be comparable with those of the migratory animals. Although not well documented quantitatively, the sinking velocity of the particles are lowered in high gradient of density of the sea water. But for the active vertical movement of animals, therefore, transportation of the organic matter to the depths must be kept stagnant in the stratified environment such waters as under consideration.

Total biomass of the three species was 3.1 mg/m^3 in wet weight at 70 m and 6.2 mg/m^3 at 93 m. The estimated amount of nocturnal invadors into the shallow water kingdom was at least 4.6 mg/m^3 in wet weight and 15.3% of total copepods which are dominated by the tropical and subtropical elements following chaeto-

gnaths (14.1mg/m³) and an amphipod *Parathemisto japonica* (9.1mg/m³).

Acknowledgements

The author is indebted to Dr. Yuzo Komaki, Japan Sea Regional Fisheries Research Laboratory, for his valuable suggestions given to the study and kind help in collecting samples at sea. The efforts in sampling given by officers and crew of *R/V Mizuho Maru* are also acknowledged.

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対馬暖流域における寒海性橈脚類の日周鉛直移動

森　岡　泰　啓

要　　旨

日本海において量的に卓越し，いろいろな食性を包括する4種の寒海性橈脚類，*Calanus plumchrus*, *Pareuchaeta elongata*, *Scolecithricella minor* および *Metridia lucens* の日周の鉛直移動の様相をMTDネット各層曳によつて1972年10月に佐渡近海の1地点において調べた．日周の鉛直移動は *Calanus* を除く3種にみられた．それらは夜間に深層から，表層の温暖な水塊と下層の寒冷な水塊との間に発達した温度躍層の中心（水深70～93m）にまで上昇した．その層は熱帯・亜熱帯性プランクトンの領域である．すなわち，これらの動物は鉛直移動によつて，異なる水塊，異なる生物相の世界を日を単位にして往復し，捕食・排泄を通じて生物起源の物質の鉛直的な輸送に与つているといえよう．その距離はおよそ200～300m，生物量は湿重量に換算して4.6mg/m³で，その層の全橈脚類のそれの15.3%を占めた．