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A Preliminary Report on the Distribution and Life History of a Copepod, *Pareuchaeta elongata*, in the Vicinity of Sado Island, the Japan Sea

YASUHIRO MORIOKA

Abstract

Life history of a calanoid copepod, *Pareuchaeta elongata* was investigated preliminarily basing mainly upon the samples of monthly samplings in an area close to the Sado Island, the Japan Sea, October 1972–April 1974.

P. elongata showed ontogenetic vertical migration. In the earlier stages, eggs, nauplii and 1st copepodites, they are distributed mainly below 500m and II–V stage copepodites are in the 200–400m layer. The last two stages IV and V perform diurnal vertical migration between 100 and 400m. In the adult stage (VI),females also show the diurnal migration between 100 and 500m or more but males do not, remaining deep layer below 400m both in day and at night. The distribution of this species in the Sado waters is restricted to the layer lower than 100m by the presence of the warm Tsushima Current lies on the cold water domain, while they are distributed in the more shallower layer in the boreal area.

Seasonal fluctuation of egg abundance suggests that spawning is perfomed in August–October. Sex ratio may be near the unity except adult stage which showed 2. 4. But this value may be not always reasonable. The number of eggs in egg sac is assumed to be about 25 in mean In copepodites, they grow exponentially according to development except stages between V and VI in male during which they hardly grow in the terms of prosome length and body wet weight.

I. Introduction

Pareuchaeta elongata had been reported as *Euchaeta elongata* or *E. japonica*. BRODSKY (1948) adopted *Pareuchaeta japonica* (MARUKAWA) to the specimens obtainend in the Japan Sea. TANAKA (1958) stated that *P. japonica* is synonymous with *E. elongata* ESTERLY. Since its original description by ESTERLY (1913) this species has been reported from the North Pacific and adjacent seas by many authors (MARUKAWA, 1921; CAMPBELL, 1934; MORI, 1937; BRODSKY, 1948, 1950, 1952; DAVIS, 1949; TANAKA, 1958; TANAKA and OMORI, 1968; HEPTNER, 1971; MINODA, 1971). Some of them showed that this species is a typical oceanic bathypelagic species in the areas. According to LEWIS (1967) the advanced stages of this species is carnivorous. It seems that *P. elongata* is one and only carnivorous calanoid copepod in the deep sea domain of the Japan Sea. Detailed description of each post embryonic stage and some notes on the seasonal and vertical distribution of this species were presented in the straight of

Georgia, Canadian Pacific (CAMPBELL, 1934).

Present paper deals with the diurnal and ontogenetic vertical distribution and other aspects of life history of *Pareuchaeta elongata* in the Japan Sea with special reference to those in the vicinity of the Sado Island.

II. Method and Materials

Some kind of monthly quantitative zooplankton samplings and oceanographic surveys were made mainly on board the *R/V* Mizuho Maru, Japan Sea Regional Fisheries Research Laboratory at a reference station "R" (depth of sea bottom, 650m) and adjacent areas at the mouth of Ryotsu Bay, Sado Island, Japan Sea, from October 1972 to April 1974. Additional samplings were also made temporalily by *R/V* Hokko Maru, Hokkaido Regional Fisheries Research Laboratory, *R/V* Shunyo Maru, Far

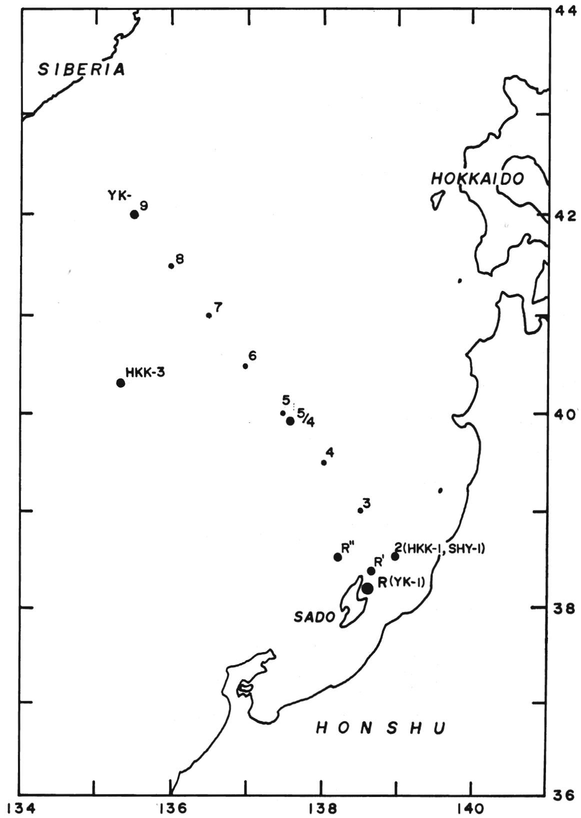

Fig. 1. Location of sampling stations.

Seas Fisheries Research Laboratory and *R/V* Yoko Maru, Seikai Regional Fisheries Research Laboratory, for the supplement of the deficiency of the serial monthly samplings at scattered stations in the Japan Sea.

Samples were obtaind by three types of gears; MTD net (56cm in mouth diameter, 180cm long, cylindoconical, 0.35mm mesh; Motoda, 1971), Q net (the same material and dimension as MTD net, and modified for stepwise vertical usage) and R–80 net (80cm in mouth diameter, 320cm long, conical, 0.35mm mesh; Kasahara, unpublished). Vertical divided hauls with Q net and simple vertical hauls with R–80 net normally from near the sea bottom to the surface were made in daytime to observe the seasonal quantitative variation of each developmental stage. The volume of water filtered and the depth of hauls were calculated by the flow-meter readings and the angle of wire cable respectively. Day-night difference in vertical distribution at the reference station and the geographical difference of the distribution were observed by samples obtained by simultaneous horizontal tows with MTD nets. Two series of 30 minutes tows, shallow and deep, were made both in daytime and at night in the selected months. To estimate the volume of water filtered and the depth of tow, TS Depth Distance Recorder was mounted on the frame of the deepest gear. The depth of each net was calculated by quota allotment from the readings of the recorder. The volume of water filtered by each net was calculated assuming that each net filtered the same volume of water in a single tow. The location of sampling stations and sampling data are presented in Fig. 1 and Appendix Table respectively.

The number of individuals was calculated under the dissecting microscope separating developmental stages and sexes following Campbell (1934).

III. Vertical Distribution and Migration

(1) Ontogenetic and diurnal behaviour

The seasonal changes of the vertical distribution in each developmental stage of *P. elongata* obtained by daytime Q net hauls and day-night MTD net tows are illustrated in Figs. 2 and 3, respectively. The distribution of eggs, both free and in egg sacs, and nauplii was restricted below 300m with maximum at 500–600m or more deep layers. Though copepodite stage I occurred in deep layer, they incline to prefer moderately shallower layer than eggs and nauplii. In stages II and III, they were observed at slightly shallower layer than the earlier stages and the center of distribution was in 200–400m. During the stages from egg to copepodite III, they don't perform diurnal vertical migration. The seasonal change of the vertical distribution of them is obsecure.

Daytime level of the female and male stage IV is slightly lower than that of stage III. But they perform upward migration from daytime level to 100–300m with maximum at 100–200m at night. This level varies according to seasons; the maxima were observed at 180m in February, at 100m in May, at 65m in June and at 100m in July again. Both sexes of stage V occurred in the nearly the same layer as stage IV

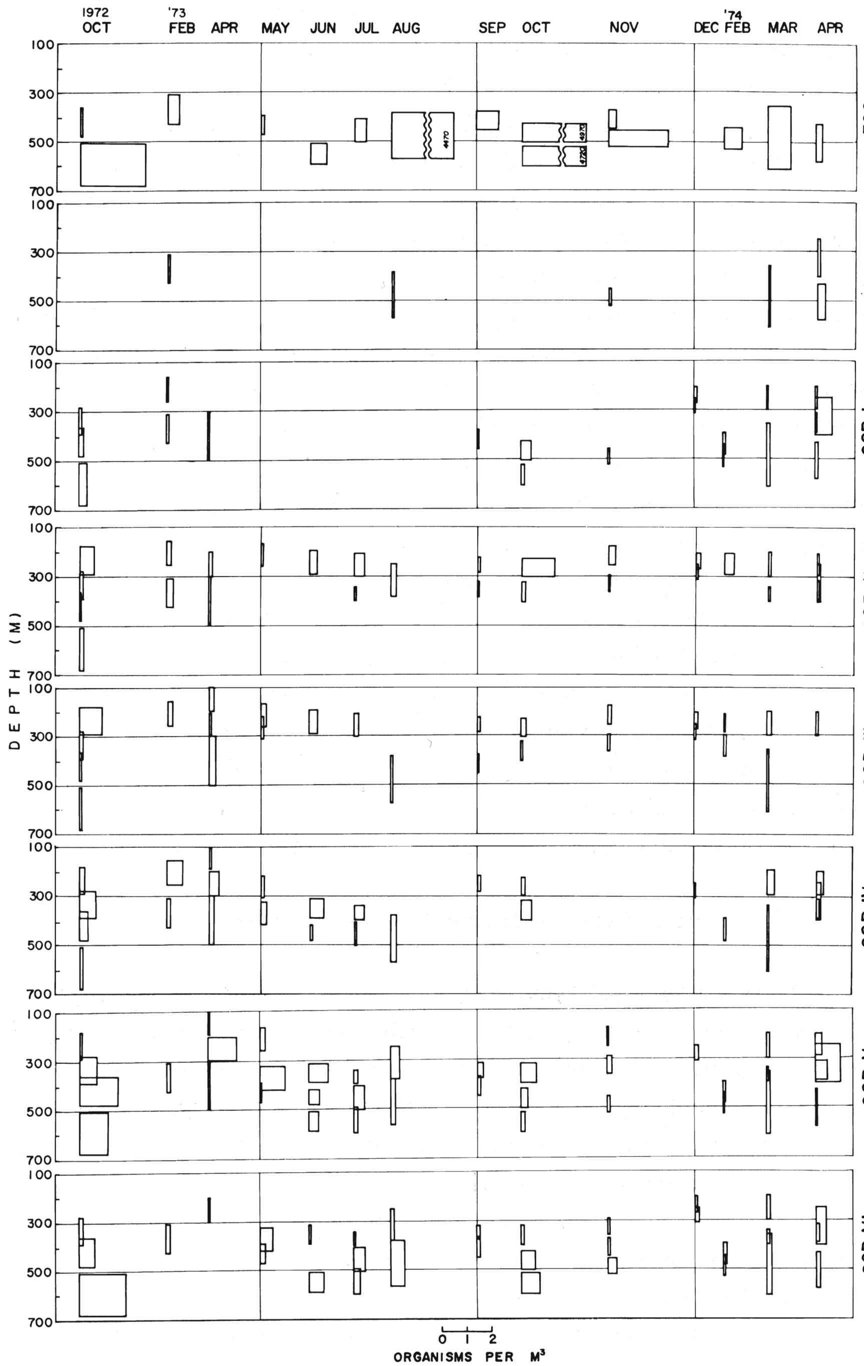

Fig. 2. Seasonal variation of daytime vertical distribution in each developmental stage of *Pareuchaeta elongata* obtained by vertical dividing hauls with Q net in an area of Sado waters, Japan Sea.

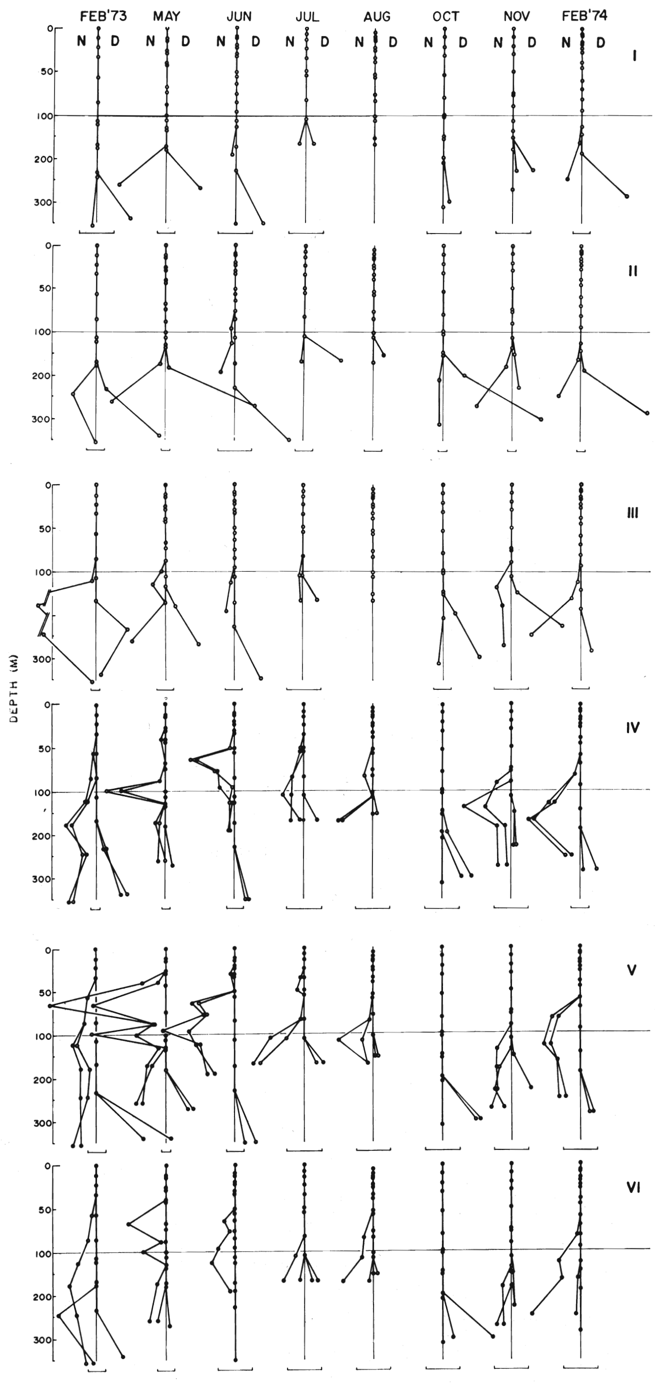

Fig. 3. Seasonal variation of day-night vertical distribution in each copepodite stage of *Pareuchaeta elongata* obtained by MTD net tows at Sta. R, Japan Sea. Roman numericals show the ordinal number of copepodite stages. Depths plotted in the figures are mean depth of horizontal tows. Scale shows 100 individuals per 1000m^3. N: night samplings, D: day samplings Open circle: female, Solid circle: male

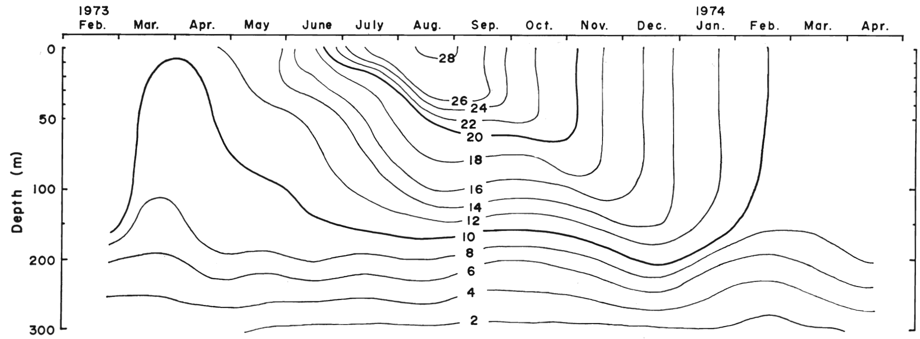

Fig. 4. Seasonal change of temperature profil (°C) at Sta. R (in March and April data are substituted by those at a station, 38°14′N, 138°40′E, by Niigata Prefecture because of lack of own data)

with maximum at 300–400m in daytime. They also showed nocturnal upward migration that is similar to stage IV. Female and male stage VI (adult) prefer the more deeper layer than stage V in daytime; they occurred in the layers lower than 200m and the number of them increased with the increase of depth. Both sexes of stage VI behave differentially at night; females showed nocturnal upward migration from daytime level to the depth of 100–300m, and males occurred at the daytime depth at night without migration in contrastwith other stages. This feature is resemble to that of a calanoid copepod, *Metridia lucens* (Morioka, unpublished) and a natantian decapod, *Acanthephyra purpurea* (Foxton, 1970). Adult male *Pareuchaeta* showed just a slight increase in body length and body weight after the moulting at stage V (see below) and masticatory edge on mandible of it degenerates being different from adult female and other copepodite stages (Campbell, 1934). Inactive behaviour in vertical migration of the adult males might be related to their inactive feeding.

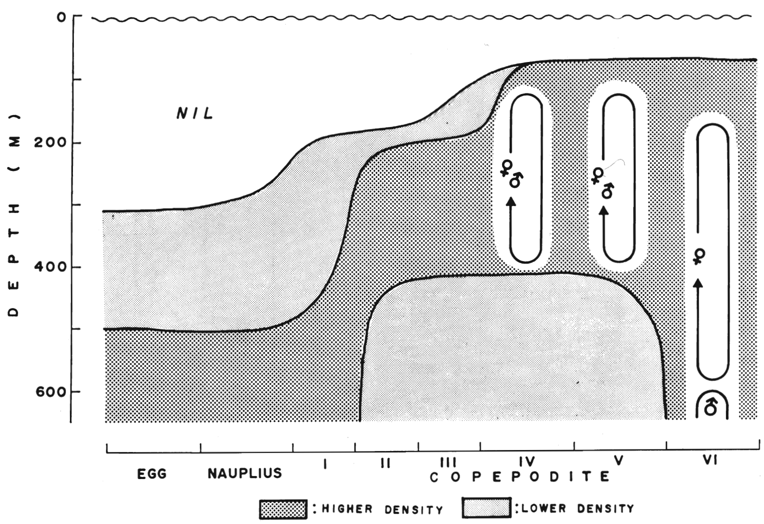

Fig. 5. Schematic diagram of diurnal and ontogenetic vertical migration in *Pareuchaeta elongata* in Sado waters, Japan Sea.

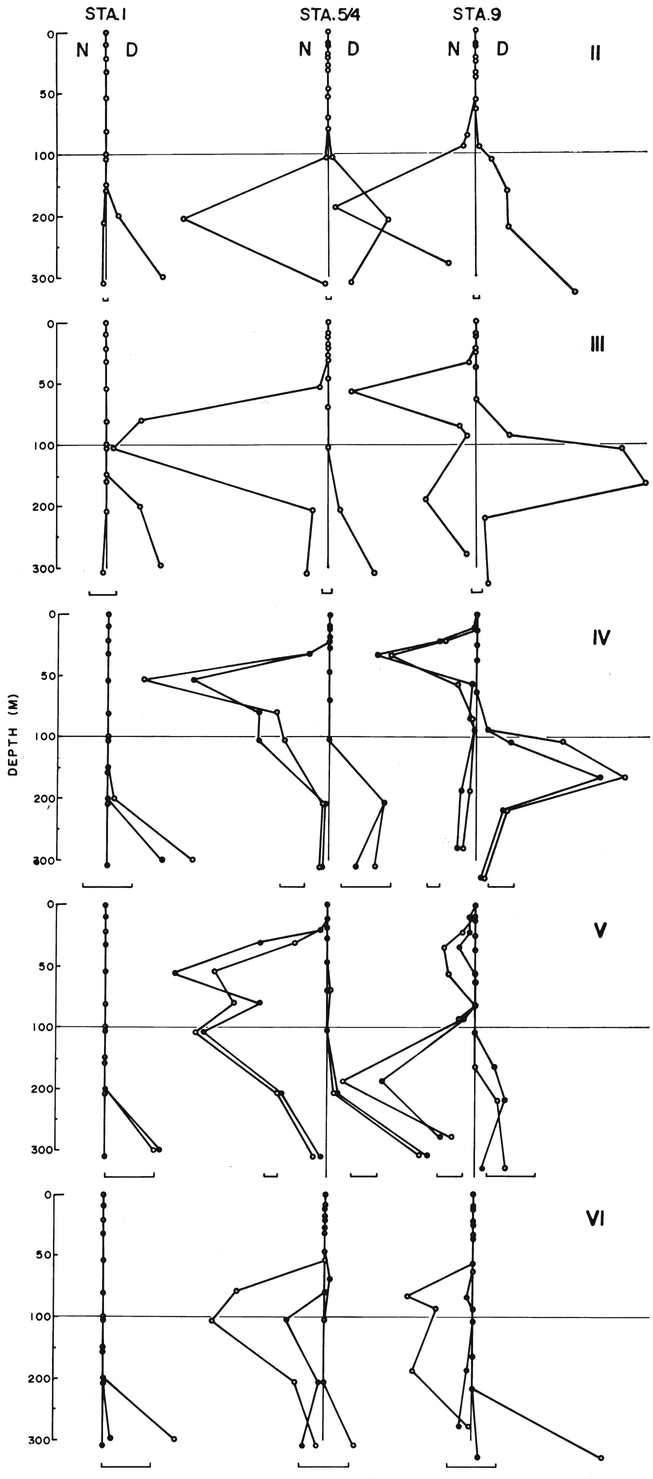

Fig. 6. Vertical distribution in each copepodite stage of *Pareuchaeta elongata* obtained by MTD net tows at three stations on Cruise YK-73, October 1973. For detailes see Fig. 3.

Stage V and female stage VI *Pareuchaeta* showed seasonal variation of vertical distribution. The patterns are similar to that of stage IV with a little exceptions. It was observed that they came up to the layer most closest to the surface in May through a year. The pronounced upward nocturnal migration of copepodite stages IV in June, and V and VI (female) in May is not always correlated with water stratification (Fig. 4). The pattern of the ontogenetic and diurnal migration of *P. elongata* is summarized in Fig. 5.

(2) **Areal characteristics**

Here are shown in Fig. 6 the vertical distribution of each copepodite stage of the species at three stations representing the warm, cold and intermediate areas of the Japan Sea. The stations were occupied on the Cruise YK 73 in October 1973.

Stage I rarely occurred at the deepest layers of Stas. 1 and 9, and the illustration of the distribution is excluded from Fig. 6. Total plankton catches by deep series of night tow at Sta. 1 (Sta. R) were very small probably due to the unknown failure of operation and the number of all copepodite stages of this species observed was also very small. Patterns of the day-night distribution in each stage were very similar to those observed at year round serial investigations at Sta. R and the area nearby. But the night levels of the distribution at Stas. 5/4 and 9 were apparently more shallower than those at Sta. R in the warm area. This might mean that the vertical distribution of *Pareuchaeta* in the Sado waters is controlled by the warm water lies on the cold water where they inhabit (Fig. 7).

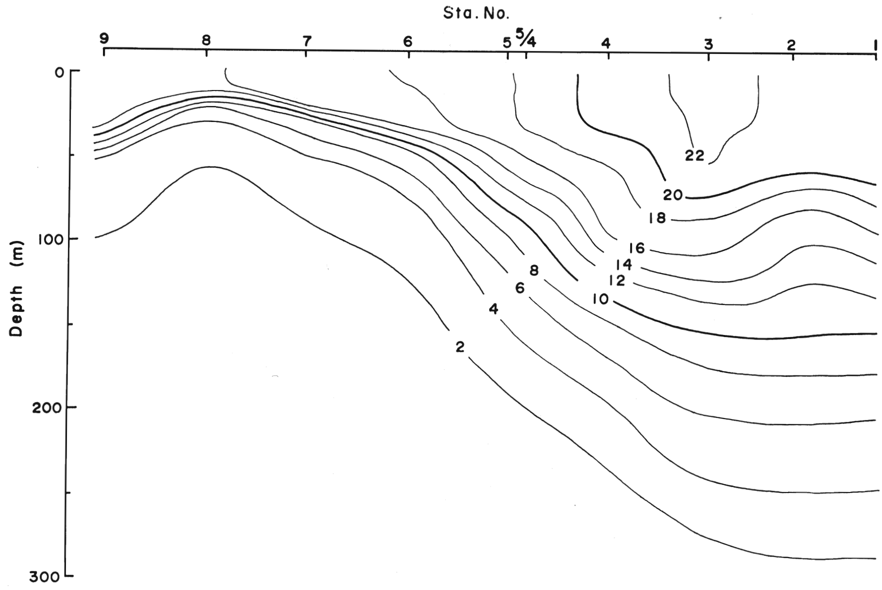

Fig. 7. Vertical section of temperature (°C) from Niigata to Siberia on Cruise YK–73, October 1973.

IV. Some Aspects of Life History

(1) Distribution density and spawning season

Fig. 8 shows the seasonal variation of the population density in each stage in the layer where they occurred at Sta. R and adjacent areas. Though the density of each stage fluctuated seasonally, the present data are insufficient enough to show certain regular patterns of seasonal distribution except egg stage. Eggs both in dispersal and in egg sac were scarce in winter and spring, and abundant in summer and autumn centering in August, September and October. In these months the percentages of VI females with egg sac were also high (Fig. 9). The percentages were calculated assuming that adult female carries 25 eggs in her egg sac (see below). This suggests that the spawning may be mainly performed in August-October.

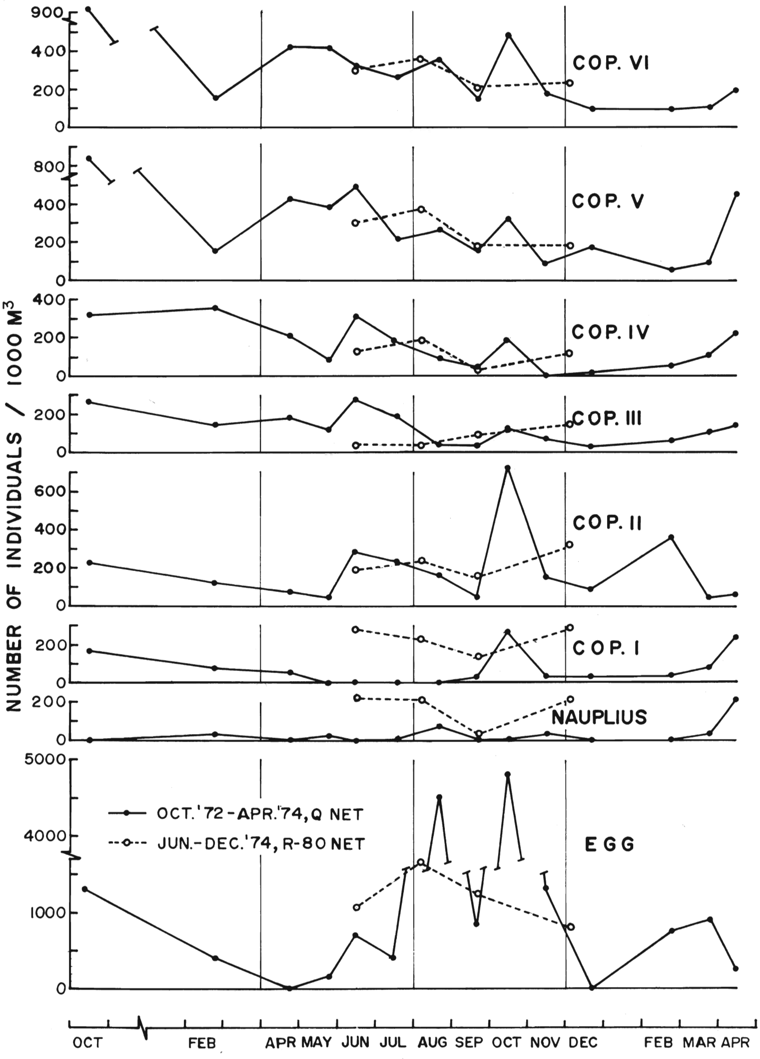

Fig. 8. Seasonal fluctuations of the number of each developmental stage in *Pareuchaeta elongata* in an area of Sado waters, Japan Sea.

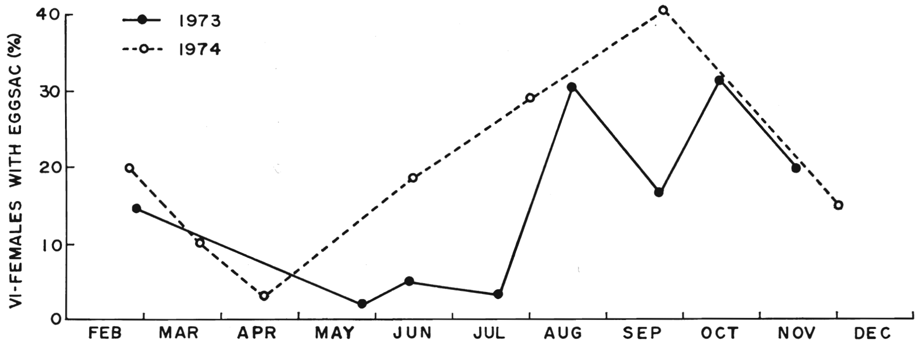

Fig. 9. Seasonal variation of percentage of adult females of *Pareuchaeta elongata* carrying egg sac obtained by Q net and R–80 net hauls in Sado waters, Japan Sea.

(2) **Sex ratio and fecundity**

In *P. elongata* the sex differentiation in external morphology appears at copepodite stage IV (Campbell, 1934). Sex ratios of the last three copepodite stages obtained by Q net and R–80 net hauls are given in Table 1. In stages IV and V the ratios were near the unity being different from stage VI. As mentioned above, males and females have same patterns of the distribution and migration in stages IV and V, while both sexes act differently in stage VI; adult males inhabit in the layer below 500m both in day and at night in contrast to females which have day-night vertical migration. The high sex ratio 2.4 in adult stage in the present study seems to be caused that the adult males are distributed abundantly in the deeper layers where nets seldom reached and/or they are short lived than females.

Table 1. Sex ratio of each copepodite stage in *Pareuchaeta elongata*

Stage	Sex	Number of animals counted	Sex ratio
IV	♀	65	0.88
	♂	74	
V	♀	166	1.05
	♂	158	
VI	♀	224	2.38
	♂	94	

In *P. elongata* the spawned eggs are carried in the egg sac which is attached to the abdominal side of the 1st abdominal segment of the mother by the connecting apparatus like a button (Fig. 10). The eggs are indigoblue coloured when they are alive and ball-like with diameter of 0.45–0.55mm or oval with long diameter of 0.6–0.7 mm and short diameter of 0.4–0.5mm. The difference of the shape may be due to the difference of the stages of the embryonic development. First stage of nauplius is oval (Campbell, 1934), and the egg sacs were rigid with ball-like eggs and tattered with oval eggs. In many cases the egg sacs were removed from the mothers' body probably due to the mechanical effect at the plankton hauls. Therefore little informations on the relation between the number of eggs and the size of the adult females

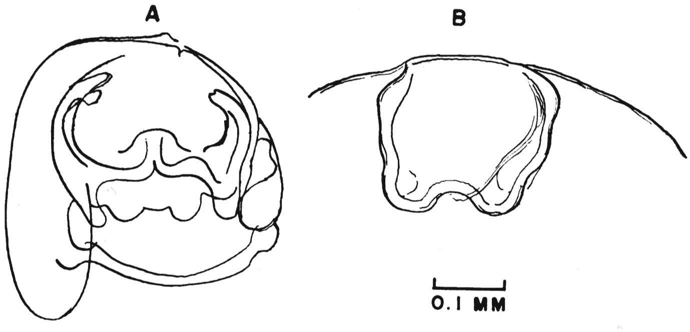

Fig. 10. Button-like connecting apparatus of egg sac and mother's genital segement of *Pareuchaeta elongata.* A: Abdominal view of the genital opening, B: Mouth of egg sac connected with genital opening.

are available. The number of eggs in an egg sac varied ranging from 2 to 36 among 49 egg sacs examined. Assumed mean number of eggs in a sac was about 25. No precise number is available because some of eggs had been released to the seawater in some cases.

(3) **Growth**

Body length frequency histograms in each stage in different seasons are illustrated in Fig. 11. As little informations on the feature of the dominant stage-class

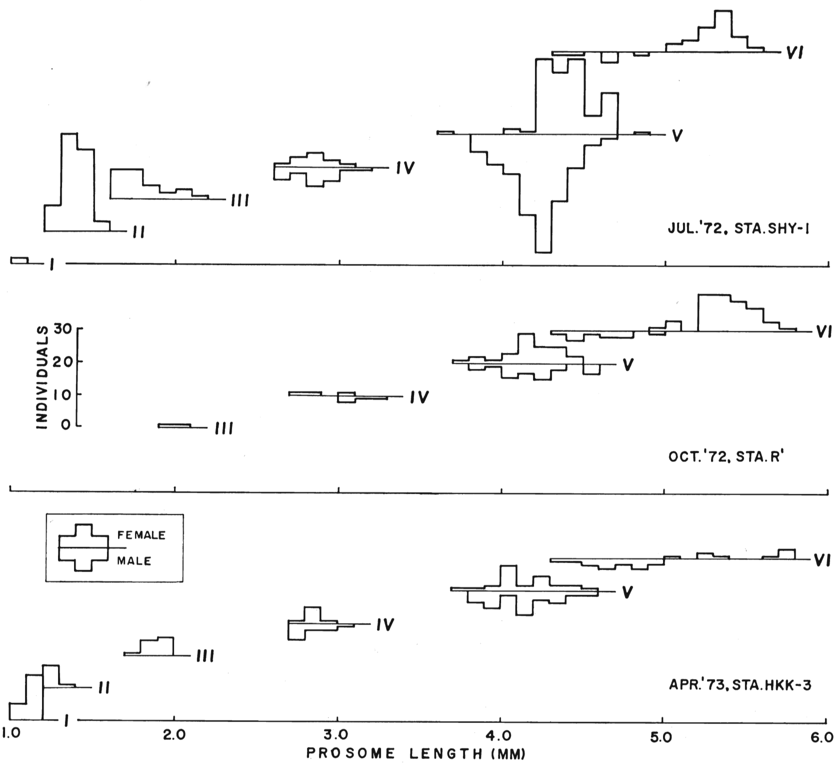

Fig. 11. Prosome length histograms in copepodite stages of *Pareuchaeta elongata* obtained at different stations and different months in the Japan Sea. Roman numericals show the ordinal number of copepodite stages.

are given through the months observed (Fig. 8), velocity of growth is unknown. In spite of small number of animals examined, prosome length in each stage and sex appears to be constant during three seasons and is monomodal without overlaps between stages except stage V and stage VI males. This is more striking in body weight. Though female showed an exponential growth, male did an immaterial increase or even decrease according to circumstances (Fig. 12). The most extremely rapid growth was shown between stages III and IV (Table 2). This might be correlated with the ontogenetic inception of the active nocturnal migration and feeding

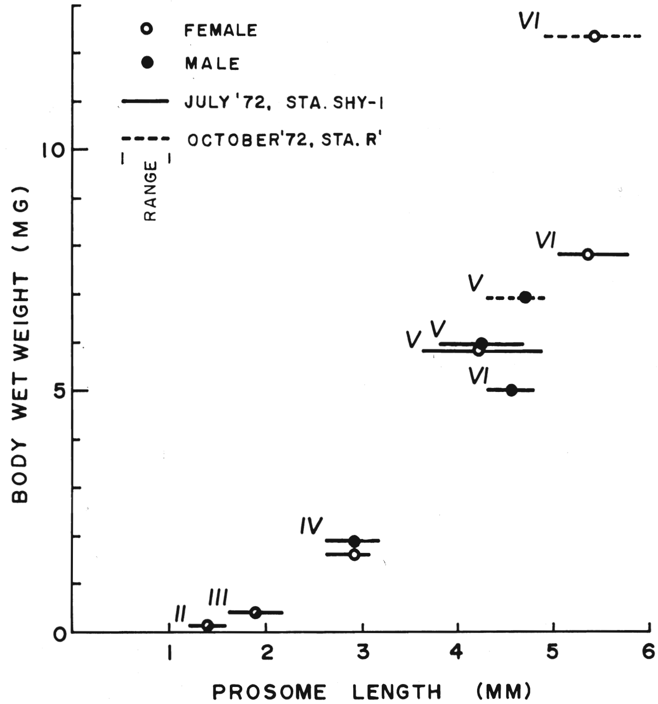

Fig. 12. Body weight-length relation in copepodite stages of *Pareuchaeta elongata* in the Sado waters, Japan Sea. Roman numericals show the ordinal number of copepodite stages.

Table 2. Growth rates (%) between each copepodite stage of *Pareuchaeta elongata* (SHY-1, July 1972)

Stage	Wet weight (mg)		Wet weight (%)		Prosome length (mm)		Prosome length (%)	
	♀	♂	♀	♂	♀	♂	♀	♂
I	—				1.05			
			—				33.3	
II	0.13				1.4			
			207.7				28.6	
III	0.4				1.8			
			300.0	375.0			58.3	58.3
IV	1.6	1.9			2.85	2.85		
			262.5	210.5			54.4	57.9
V	5.8	5.9			4.4	4.5		
			34.5	−15.3			20.5	2.2
VI	7.8	5.0			5.3	4.6		

in the shallower layer. Wet body weight in October is heavier than in June. If this is reasonable, heavy weight in October may be correlated with the nutrients accumulation for the ovogenesis.

Acknowledgments

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佐渡近海における橈脚類 *Pareuchaeta elongata* の分布と生態

森 岡 泰 啓

要 旨

Pareuchaeta elongata は発育に伴つて分布層を変えることが認められた．昼間の分布の中心深度は卵，ノウプリウス各期およびコペポダイトⅠ期には約500m以深，コペポダイトⅡ期からⅤ期にかけては200—400m，そして成体であるⅥ期には500mないしはそれ以深である．昼夜の垂直移動はコペポダイトⅢ期以前にはみられず，Ⅳ期以後にみられる．すなわち，Ⅳ期とⅤ期には雌雄とも夜間には昼間の分布層からおよそ100—200m層まで上昇する．Ⅵ期には雌は100—200mと500mまたはそれ以深の間で昼夜移動を行うのに対し，雄は移動を行わず，昼夜とも400mまたはそれ以深に滞留している．Ⅳ期とⅤ期の雌雄およびⅥ期の雌の夜間の分布層は月によつて異つているが，そのことは外界の温度の分布と直接関連していない．

本種の分布層は佐渡近海においては北方の寒海域におけるよりも総じて深い．その理由は，寒海性である本種の分布の上層への拡がりが暖水塊によつて上方から圧迫されているからであろう．

卵の出現量を季節的に調べた結果から産卵が行われるのは主に8月から10月にかけてと思われる．しかし，他の発育期においては出現量の変化が季節的に認められるにせよ，それは法則性を示すほどではない．性比は性分化が外見上みとめられるⅣ期とⅤ期にほぼ1で，Ⅵ期には2.4と計算された．Ⅵ期には雌雄の分布層が互に異つているので，この値が妥当であるとはいいきれない．親がもつている卵のう内の卵数はおよそ25と見積られる．本種の体は発育期の進行とともに指数関数的な発育を遂げるが，雄がⅤ期からⅥ期になるときは例外で，頭胸長や体重（湿重量）においてほとんど増加が認められない．

Appendix Table. Plankton sampling data

Cruise No.	Sta. No.	Date	Hour	Depths (m)
Q net Vertical Dividing Haul				
MZ 72-K1	R′	Oct. 10, '72	1054-1211	95-0, 193-68, 289-180, 387-282, 477-365, 680-508
MZ 73-01	R′	Feb. 26, '73	1134-1330	93-0, 173-80, 260-0, 254-157, 424-310
HKK 73-1	HKK-1	Apr. 25, '73	1712-1810	100-0, 187-99, 296-187, 489-299
	HKK-3	Apr. 27, '73	1356-	440-291*
MZ 73-02	R	May 22, '73	1317-1500	93-0, 181-78, 260-165, 306-217, 424-326, 473-388
MZ 73-03	R	Jun. 13, '73	1033-1245	98-0, 193-95, 288-194, 391-316, 481-419, 587-501
MZ 73-04	R	Jul. 19, '73	0930-1110	100-0, 200-102, 299-206, 400-339, 497-410, 596-496
MZ 73-05	R	Aug. 20, '73	1223-1350	101-0, 189-96, 282-201, 378-247, 571-379
MZ 73-06	R	Sep. 19, '73	1051-1317	100-0, 168-91, 229-164, 282-220, 379-314, 452-373
YK 73	R(YK-1)	Oct. 16, '73	1429-1615	100-0, 200-110, 300-224, 398-321, 500-423, 600-520
MZ 73-07	R	Nov. 13, '73	1521-1658	88-0, 177-93, 249-173, 360-289, 446-368, 520-452
MZ 73-08	R	Dec. 21, '73	1234-1332	104-0, 160-92, 230-162, 268-204, 308-254
MZ 74-02	R	Feb. 24, '74	1038-1155	100-0, 197-100, 288-207, 380-279, 483-388, 530-442
MZ 74-03	R	Mar. 20, '74	1350-1434	100-0, 200-103, 300-200, 398-337, 613-356
MZ 74-04	R	Apr. 17, '74	0819-1000	100-0, 199-149, 296-205, 394-246, 394-312, 577-431
MTD net Simultaneous Horizontal Tow				
SHY72-2	SHY-1	Jul. 25, '72	1815-1845	266*, 400*
MZ 73-01	R′	Feb. 26, '73	2050-2248	0, 8-15, 16-29, 24-44, 40-73, 60-110**, 106-136, 155-200, 207-280, 310-400**
		Feb. 27, '73	0929-1110	0, 8-15, 16-29, 22-44, 40-73, 60-110**, 93-136, 140-200, 187-280, 280-400**
MZ 73-02	R	May 22, '73	1445-1613	0, 13-16, 27-32, 40-48, 67-80, 100-120**, 67-113, 100-170, 133-227, 200-340**
			2117-2245	0, 13, 27, 40, 67, 100**, 70-103, 105-155, 140-207, 210-310**
MZ 73-03	R	Jun. 12, '73	2131-2255	0, 7-13, 13-27, 20-40, 33-67, 50-100**, 53-73, 80-110, 107-147, 160-220**
			1340-1510	0, 9-13, 19-27, 28-40, 47-67, 70-100**, 100-130, 150-195, 200-260, 300-390**
MZ 73-04	R	Jul. 18, '73	1433-1600	0, 5-8, 11-16, 16-32, 27-40, 40-60**, 43-67, 65-100, 87-133, 130-200**
		Jul.18-19,'73	2258-0023	0, 5-8, 11-16, 16-32, 27-40, 40-60**, 43-67, 65-100, 87-133, 130-200**
MZ 73-05	R	Aug. 19, '73	2144-2316	0, 4-5, 8-11, 12-16, 20-27, 30-40**, 43-67, 65-100, 87-133, 130-200**
		Aug. 20, '73	0844-1025	0, 5, 11, 16, 27, 40**, 37-67, 55-100, 73-133, 110-200**
YK 73	R(YK-1)	Oct. 16, 73	1235-1401	0, 9-12, 19-24, 28-36, 47-60, 70-90**, 87-113, 130-170, 173-227, 260-340**
			1859-2021	0, 9-12, 19-24, 28-36, 47-60, 70-90**, 97-110, 145-165, 193-220, 290-330**
	YK-5/4	Oct. 18, 73	1250-1415	0, 8-11, 16-21, 24-32, 40-53, 60-80**, 100-107, 200-213, 300-320**

(to be continued)

Appendix Table. continued

Cruise No.	Sta. No.	Date	Hour	Depths (m)
YK 73	YK-5/4	Oct. 18, '73	2150-2315	0, 8-13, 16-27, 24-40, 40-67, 60-100**, 100-107, 200-213, 300-320**
	YK-9	Oct. 20, '73	1231-1353	0, 9-16, 19-32, 28-48, 47-80, 70-120**, 100-120, 150-180, 200-240, 300-360**
			1855-2015	0, 9-13, 19-27, 28-40, 47-67, 70-100** 80-107, 160-213, 240-320**
MZ 73-07	R	Nov. 13, '73	1257-1434	0, 7-13, 13-27, 20-40, 33-67, 50-100**, 53-100, 80-150, 107-207, 160-300**
			1850-2024	0, 8-12, 16-24, 24-36, 40-60, 60-90**, 73-107, 110-160, 147-213, 220-320**
MZ 74-02	R	Feb. 22, '74	1315-1440	0, 5-13, 11-27, 16-40, 27-67, 40-100**, 77-113, 115-170, 153-227, 230-340**
		Feb. 24, '74	1822-1950	0, 7-9, 13-19, 20-28, 33-47, 50-70**, 57-107, 85-160, 113-213, 170-320**
R-80 net Vertical Haul				
MZ74-R1	R''	Jun. 15, '74	0520-0550	598-0
MZ74-R2	R	Aug. 6, '74	1500-1527	598-0
MZ74-R3	R	Sep. 20, '74	0630-0640	577-0
MZ74-R4	R	Dec. 2, '74	1323-1350	564-0

* Samples used only for body length and body weight measurement

** Depths at which Depth Distance Recorder was mounted

MZ-cruise: R/V Mizuho Maru

YK-cruise: R/V Yoko Maru

HKK-cruise: R/V Hokko Maru

SHY-cruise: R/V Shunyo Maru