ON THE POSSIBLE SEGREGATION FOUND IN THE COPEPOD FAUNA IN THE DEEP WATERS OFF THE SOUTH-EASTERN COAST OF JAPAN[1,2] (JEDS-3)

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With 3 Text-figures and 5 Tables

CONTENTS

I. Introduction

The present study based on a large collection of pelagic copepods from the deep waters off the south-eastern coast of Japan is planned to explain the differences found in the pelagic copepod fauna between the eastern and western deep waters separated from each other by the submarine ridge stretching southwards from the end of Izu Peninsula including the Ogasawara (=Bonin) Islands on its way (Fig. 1). This ridge is hereafter referred simply as "the Ridge".

Many samples have been collected in the deep waters of the Kuroshio region west of the Ridge by the Kōbe Marine Observatory since 1954. The author has examined 17 of them which came from 250 m–2000 m layers and some results obtained were reported in papers written by MATSUDAIRA and the present author (MATSUDAIRA & FURUHASHI, 1955, 1960). In addition to these, eight more collec-

1) JEDS Contribution No. 20.
2) Contribution from the Kōbe Marine Observatory.

tions were made by divided hauls in the layer from 2500 m to the surface of the same region in autumn of 1960. All the data obtained from the above-mentioned samples are to be used to explain the nature of the water mass being constituted of the warm water of the Kuroshio and the cold water forming a cyclonic vortex to the west of the Ridge.

On the other hand, in the cold Oyashio Current many hydrographical and biological observations have been made up to this day, but the collections from the deep water have scarcely been made. In the summer of 1957, however, I.G.Y. Observations worked in this region and the author had a chance to make two vertical hauls respectively from 600 m and 100 m to the surface. Copepods in these samples were fully identified and shown in Table 4 to be compared with those in the Kuroshio region. Besides, there are a few samples from the deep water of the Kuroshio region east of the Ridge. Namely, through the courtesy of Dr. MARUMO, the author had fortunately a chance to participate in the Third Japanese Expedition of Deep Sea (**JEDS-3**) on board the R.M.S. "Ryōfū Maru" and to examine a plankton sample collected by horizontal towing at the 1000 m layer. This seems to be very useful to explain the state of the Kuroshio east of the Ridge.

The deep-sea copepod fauna west of the Ridge was then compared very carefully with that east of the Ridge, and this shows the possibility of the deep-sea copepod fauna being segregated between the east and west sides of the Ridge. This is considered to be a very significant finding, since some new explanation will be needed as to the structure of the deep waters off the south-eastern coast of Japan, if the trend shown in this paper is definitely ascertained.

Before going further, the author wishes to express his hearty thanks to Dr. Yasuo MATSUDAIRA, Dr. Otohiko TANAKA and Dr. Takasi TOKIOKA for their kind encouragement and very helpful advices given throughout the present work. It is also a great pleasure to extend his best thanks to Dr. Kōzō HISHIDA and Dr. Ryūzō MARUMO for their kindness guiding the author so generously throughout the present study. He is much indebted to the members of oceanographical section of the Kōbe Marine Observatory and the crew of the R.M.S. "Shunpū Maru" for their assistances in collecting samples.

II. Material and Methods

The present material consists of the collections made at the four stations whose positions are:

Station A	30°40′N,	137°40′E,	1960-XI- 6
Station B	33°00′N,	137°37′E,	1960-X-31
Station C	38°00′N,	145°23′E,	1957-VI-20
Station D	30°01′N,	146°26′E,	1960-V-19

The stations are shown in Fig. 1, together with the bottom contours copied from the Depth Curve Chart of the Adjacent Sea of Japan by the Maritime Safety Agency of Japan (1952).

At St. A, six vertical hauls were made from 2440 m to the surface by divided hauls using a closing net, and at St. B, a single vertical haul was made from 1040 m to 580 m by a closing net. At St. C, two vertical hauls were made respectively from 600 m and 100 m to the surface by a quantitative plankton net. At St. D, horizontal towings were made at several layers by letting the ship drift for two hours, and of these samples the one came from the 1000 m layer was examined. The nets used during the above-mentioned operations have a 51 cm mouth diameter and stretched with the fine bolting silk (GG-54) having about 0.3 mm square meshes.

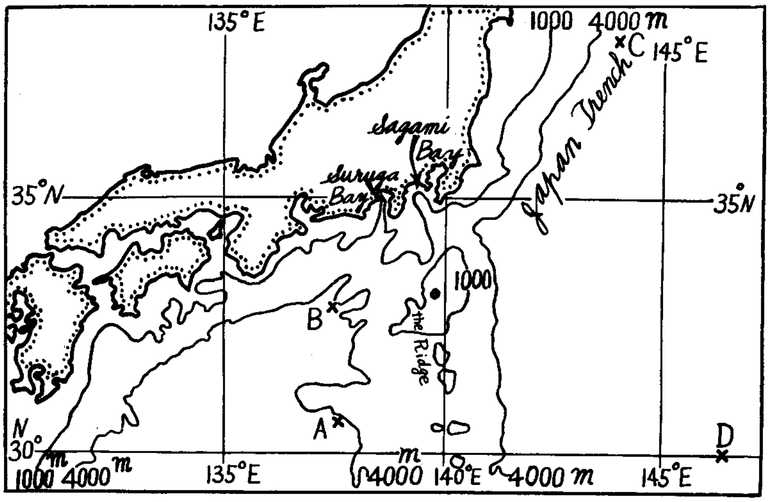

Fig. 1. Map showing the position of four stations together with 1000 m and 4000 m contours in the sea south of Japan.

III. Copepods of the Kuroshio Region West of the Ridge

In the surface layers of the Kuroshio off the southern coast of Japan there occur many tropical and subtropical species, usually up to about 40 species in a single haul. Below the 1000 m layer, however, the copepod fauna is constituted mainly of *Calanus helgolandicus*, *Eucalanus bungii californicus* and *Rhincalanus nasutus* (Matsudaira & Furuhashi, 1955, '60).

The collection made at St. A was studied in detail as to several genera of copepod and the results are shown in Table 1. The table shows clearly a rather monotonous composition consisting of *Calanus finmarchicus*, *Eucalanus bungii californicus* and *Rhincalanus nasutus*.

In my previous papers, *Calanus finmarchicus* and *Calanus helgolandicus* had often been treated under a single species, *Calanus helgolandicus*, because the difference between these two species was not clearly understood. Generally, however, two groups are easily separable from each other by size in the "Formenkreis" including these two species as TANAKA (1956b) mentions and the range of vertical distribution of each group is defined rather clearly. The smaller group is considered to represent *Calanus helglandicus*, while the larger

Table 1. Occurrences of deep sea copepods belonging to five genera in respective samples collected at Station A.

Time	23 : 50～ 00 : 11	21 : 54～ 22 : 05	22 : 33～ 22 : 38	23 : 00～ 23 : 0.4	21 : 00	20 : 45
Wire length (m)	2500-1065	1100-808	800-522	520-256	275-118	110-0
Wire angle (°)	13-26	25	17	9	15	15
Hauled depth (m)	2440-960	1000-730	760-500	510-250	265-115	105-0
Calanus finmarchicus ♀	3	—	—	—	—	—
〃 Vth copepodid	307	6	—	—	1	—
〃 IVth copepodid	1	—	—	—	—	—
Cal. helgolandicus Vth	—	19	44	—	—	—
Cal. minor Vth cope.	—	—	1	2	—	6
Calanoides sp. Vth cope.	14	—	—	—	—	—
Neocalanus gracilis ♀	—	—	—	—	—	2
Undinula darwini	—	—	♀1	♀2, ♂1	—	♀, ♂30
Und. vulgaris	—	—	—	—	—	♀1
Eucalanus elongatus ♀	1	—	3	1	—	—
Eucal. bungii californicus ♀	1	—	—	—	—	—
〃 Vth copepodid	♀9, ♂5	—	—	—	—	—
〃 IVth copepodid	♀5, ♂6	—	—	—	—	—
Eucal. crassus ♀	—	—	—	—	—	1
〃 IIIrd to Vth copepodid	12	—	—	—	—	—
Eucal. mucronatus ♀	—	—	1	1	1	—
Eucal. pileatus ♀	—	—	1	—	—	4
Eucal. misc.	—	—	—	—	3	9
Rhincalanus nasutus	39	21	4	2	—	—
Rhincal. cornutus	1	—	—	1	—	1
Pleuromamma xiphias	♀1	—	♂1	♀2	♂2	♀2, ♂1
Pl. abdominalis	—	—	♀1, ♂1	♀3, ♂1	♀1, ♂1	♀3, ♂3
Pl. robusta	—	—	♀1	—	—	—
Pl. gracilis	—	—	♀4	♀12	♀1	♀6
Metridia curticauda	♀4	♀1, ♂1	♀3	—	—	—
Met. venusta	—	—	♀3, ♂2	—	—	—
Met. brevicauda ♀	2	—	3	—	—	—

one is regarded as corresponding to *Calanus finmarchicus*. In the present material, three groups were defined by the following ranges of body length:

Calanus finmarchicus	adult female	3.65–3.80 mm
» »	Vth copepodid stage	3.0 –3.2 mm
Calanus helgolandicus	Vth copepodid	2.1 –2.5 mm

Three adult females of *Calanus finmarchicus* were found only in the deepest layer surveyed together with many specimens of the Vth copepodid stage. While none of adult specimens of *Calanus helgolandicus* was found at the same station (A), although the specimens of the Vth copepodid stage were found at the layer from 1000 m to 500 m. It can be seen clearly from the data shown in Table 1 that the distributions of these two species were differently limited by the depth in the Kuroshio region. The water temperature ranged from 1.79°C (at 2440 m) to 10.74°C (at 500 m) during the observations. Here, however, it is to be noticed that many adult forms of the two species were ever found in samples collected from the upper layer at a central station in the cold water domain in March, 1958. The body length of these specimens varied as follows:

Calanus finmarchicus	adult female	3.6 –4.0 mm
» »	adult male	3.2 –3.3 mm
Calanus helgolandicus	adult female	2.35–2.90 mm
» »	adult male	2.6 –2.8 mm

At that time, the water temperature ranged from 16.1°C (at the surface) to 12.4°C (at 100 m). In this case, the distributions of these species seemed to be limited superficially by the water temperature.

Eucalanus bungii californicus is the most important species in the deep water of the Kuroshio, and during the present observations at St. A an adult female and many specimens of copepodid stages were collected exclusively from the water layer deeper than 960 m. On the other hand, a considerable number of this species were found in the subsurface water in March and May, 1960. Nevertheless, it seems very probable that the majority of this species live in the deeper water of the Kuroshio region.

Rhincalanus nasutus was found in the layer from 2440 m to 250 m, the majority being confined to the deepest layer surveyed.

Although, four species of *Pleuromamma* appeared rather in upper layers than in deeper waters during the present observations, this does not show that the species are the inhabitants of the shallow water, since the forms belonging to this genus show a very striking diurnal migration in the Kuroshio region as shown below. As the samples were collected at St. A at night from 20:45 to midnight on November 6th, it is not strange that a number of *Pleuromamma* were met in the shallower layers. Many pelagic copepods are known to show a diurnal migration, the range of migration seems, however, to be less than one hundred meters in the Kuroshio region. But, the species belonging to the genus *Pleuromamma* are considered to migrate diurnally for the range of one hundred meters or more. For this reason, *Pleuromamma* spp. had better be excluded out of the general discussion of the vertical distributions of deep-sea copepods.

Three species of *Metridia* were found only in the layers deeper than 500 m. The similar distribution had already been known in previous studies, although *Metridia longa* and *Met. lucens* has never been found in the Kuroshio region west of the Ridge.

IV. Diurnal Migration of *Pleuromamma*

There are few studies on *Pleuromamma* in the Northwestern Pacific. Only MOTODA and ANRAKU (1955) state briefly that *Pleuromamma* was not found in any samples collected in the daytime from the layers upper than 64 m in the Kuroshio region because of its preference of comparatively deep-water.

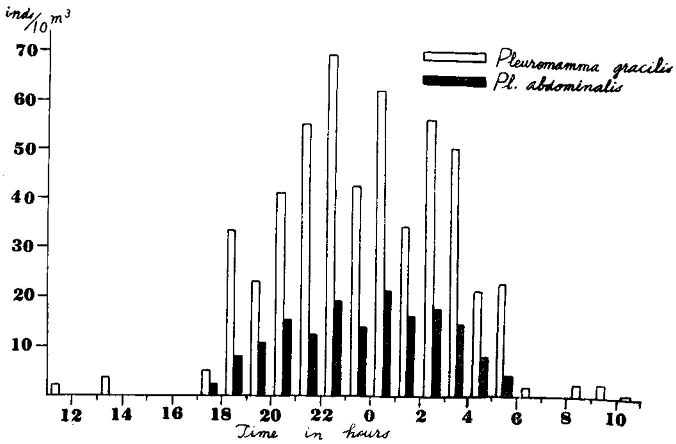

Fig. 2. Occurrences of *Pleuromamma gracilis* and *P. abdominalis* in the sea south of Honshū Island, Japan.

More than 500 vertical hauls from 100 m to the surface were made in the waters off the southern coast of Japan by the R.M.S. "Shunpū Maru" of the Kōbe Marine Observatory during the period from May, 1954 to August, 1958 (Oceanographical section, K.M.O., 1955–'60). In this surveyed area, there was a cold water domain near the coast and the Kuroshio made a detour around its southern edge. The horizontal gradient of the water temperature was generally smaller than the vertical one in the water upper than 100 m and the towings were made for 100 m in wire length, so that the effect of the water temperature may be disregarded for different stations. Examinations were made on *Pleuromamma gracilis* and *P. abdominalis* found in those samples. Mean individual number per 10 m³ appeared in every hour was calculated in each species and plotted in Fig. 2. Though the number of collections made in every hour fluctuates from 17 at midnight to 34 at noon, the trend shown in Fig. 2 may be safely accepted without any correction. The figure shows evidently that there occur few animals in the daytime, but they increase rapidly after the sunset. The maximum is seen at midnight and then they decrease towards the dawn. The previous data show that these species are distributed chiefly in the layer from 700 m to 100 m and occur most abundantly in the layer from 200 m to 100 m in the daytime. It seems very possible that these animals migrate at least one hundred meters in six hours, or they can travel vertically about 30 cm in a minute.

V. Copepods of the Cold Water Region West of the Ridge

Several vertical hauls have been made from 1000 m or more to the surface in the cold water region off the southern coast of Japan west of the Ridge. And the examination of these samples revealed that the differences found between the vertical distribution of copepods in the cold water region and that in the Kuroshio making a detour around the southern edge of the region might be caused by the upwelling of the deep water of the cold water region (MATSUDAIRA & FURUHASHI, 1960).

Table 2. List of species collected at St. B by a vertical haul from 1040 m to 580 m.

GYMNOPLEA			
Calanus finmarchicus (GUNNERS) ♀	1	*Scolecithricella dentata* (GIESBRECHT) ♀	1
" V th copepodid	19	*Scol. propinqua* SARS ♀	1
Cal. minor (CLAUS) V th cope.	1	*Scol. emarginata* FARRAN ♀	1
Cal. helgolandicus (CLAUS)	13	*Metridia curticauda* GIESBRECHT ♀	2
Calanoides sp. V th copepodid	3	*M. brevicauda* GIESBRECHT ♀	1
Eucalanus attenuatus (DANA) ♀ 2, ♂	3	*Lucicutia ovalis* WOLFENDEN ♀	1
Eucal. elongatus (DANA) ♀ 1, ♂	1	*Luc. flavicornis* (CLAUS) ♀	1
Eucal. bungii californicus JOHNSON		*Luc. wolfendeni* SEWELL ♂	1
IV th copepodid ♀	1	*Heterorhabdus vicinus* TANAKA ? ♀	1
V th copepodid ♂	1	*Phyllopus helgae* FARRAN ♀	2
Eucal. crassus GIESBRECHT ♀ 6, ♂	4	*Labidocera acuta* (DANA) ♀	1
Eucal. pileatus GIESBRECHT ♀	1	*Acartia danae* GIESBRECHT ♀	4
Rhincalanus nasutus GIESBRECHT ♀, ♂	26	*Acar. negligens* DANA ♀	2
Paracalanus aculeatus GIESBRECHT ♀	1		
Clausocalanus arcuicornis (DANA) ♀	1	PODOPLEA	
Spinocalanus abyssalis GIESBRECHT ♀	5	*Mormonilla phasma* GIESBRECHT ♀	11
Spinocal. spinosus FARRAN ♀	8	*Oithona plumifera* BAIRD ♀	1
Spinocal. magnus WOLFENDEN ♂	1	*Oith. similis* CLAUS ♀	1
Monacilla typica SARS ♀	1	*Aegisthus aculeatus* GIESBRECHT ♀	1
Aetideopsis multiserrata WOLFENDEN ♀	1	*Oncaea venusta* PHILIPPI	6
Gaetanus sp. ♀	1	*On. conifera* GIESBRECHT	2
Undeuchaeta plumosa (LUBBOCK) ♀	1	*Conaea rapax* GIESBRECHT ♀ 15, ♂	12
Scaphocalanus sp. ♀	1		

In the sample collected at St. B, thirty-three species of Gymnoplea and 7 species of Podoplea were identified, as they are listed in Table 2 together with their individual numbers found in that haul.

No conspicuous differences are found between the composition of the copepod fauna given above and that seen in the Kuroshio region. Most species collected from the cold water region seem to be abyssal forms, although some of them are found in the surface water of the region, too. And all of these species were also found actually in deep water samples from the Kuroshio region.

VI. Copepods from the Kuroshio Region East of the Ridge

The author has hardly been able to find any studies of deep-water copepods in the Kuroshio region off the south-eastern coast of Japan east of the Ridge. The results of the examination of a sample collected by the R.M.S. "Ryōfū Maru" at St. D in the JEDS-3 Cruise is shown in Table 3, in which 29 species of Gymnoplea and 5 species of Podoplea were identified.

The comparison of this table with Tables 1 and 2 shows the following significant facts:

1. Both adult and immature females of *Calanus finmarchicus* are abundant and predominate over others in the sample from the station, while *Calanus helgolandicus* is quite missing.

Table 3. List of species collected by a horizontal haul at the depth of 1000 m at St. D off the south-eastern coast of Japan.

GYMNOPLEA			
Calanus finmarchicus (GUNNERS) ♀	284	*Metridia curticauda* GIESBRECHT ♀	3
〃 V th copepodid	1743	*Met. venusta* GIESBRECHT ♀	1
Cal. cristatus KRÖYER imm. ♀	1	*Met. princeps* GIESBRECHT ♀ 4, ♂	2
Megacalanus princeps WOLFENDEN ♀	1	*Met. brevicauda* GIESBRECHT ♀	1
Eucalanus elongatus (DANA) ♀	1	*Met.* juv.	5
Eucal. bungii bungii JOHNSON ♀ 1, ♂	1	*Pleuromamma xiphias* GIESBRECHT ♂	1
Eucal. bungii californicus imm. ♀	1	*Lucicutia curta* FARRN ♀	1
Rhincalanus nasutus GIESBRECHT ♂	1	*Isochaeta ovalis* GIESBRECHT ♂	1
Clausocalanus arcuicornis (DANA) ♀	20	*Heterorhabdus dubius* TANAKA ♀	1
Monacilla typica SARS ♀	2	*Het. abyssalis* GIESBRECHT ♂	1
Gaetanus kruppi GIESBRECHT ♀ 2, imm. ♂	1	*Het. robustus* FARRAN ♂	1
Chirundina streetsi GIESBRECHT ♀	27	*Arietellus simplex* SARS ♀	2
Undeuchaeta major GIESBRECHT ♀ 26, ♂	3		
Und. plumosa (LUBBOCK) ♀	1	PODOPLEA	
Pareuchaeta confusa TANAKA ? ♀	1	*Mormonilla phasma* GIESBRECHT ♀	40
Par. tonsa (GIESBRECHT) ♀	2	*Mor. minor* GIESBRECHT ♀	10
Par. comosa TANAKA ♂	1	*Oithona plumifera* BAIRD ♀	90
Par. juv.	10	*Oncaea venusta* PHILIPPI ♀, ♂	100
Lophothrix frontalis GIESBRECHT ♀	2	*Conaea rapax* GIESBRECHT ♀	100
Scaphocalanus sp. ♀	1		

2. An immature *Calanus cristatus*, and a female and a male of *Eucalanus bungii bungii* are found. *Eucalanus bungii californicus* and *Rhincalanus nasutus* are also found, but each represented by only a single individual.

3. A female specimen of *Megacalanus princeps* was obtained; this species had been recorded from both Sagami and Suruga Bays by TANAKA (1956a), but never been found from the deep water west of the Ridge.

4. Great numbers of *Chirundina streetsi* and *Undeuchaeta major* were obtained, while they are rather scarce in the Kuroshio region west of the Ridge.

5. A male of *Isochaeta ovalis* was obtained, this had been recorded by TANAKA from Sagami Bay.

The hydrographic condition at St. D was very similar to that in the west of the Ridge, as is seen clearly in Fig. 3 which gives the diagrams of vertical distributions of the water temperature at Stations A, B and D. It can be seen easily from this figure that the differences of the water temperature between the Kuroshio region west of the Ridge and that east of the Ridge is less than the difference found between the Kuroshio region and the cold water region west of the Ridge.

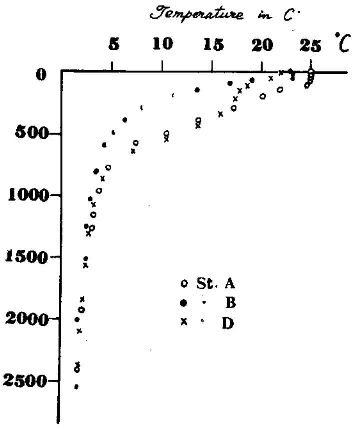

Fig. 3. Vertical distribution of the water temperature at Stations A, B and D off the southern coast of Japan.

VII. Copepods of the Oyashio Region

Although there are many hydrographical and biological studies of the Oyashio Current which are considered to be enough so that the nature of the upper water can be easily compared with that of the midwater, two samples respectively hauled from 100 m and 600 m to the surface at St. C were examined exactly and the detailed results of identification of copepods are shown in Table 4.

Only 10 species of Gymnoplea and 3 species of Podoplea occurred in the upper water sample, while 26 species of Gymnoplea and 6 species of Podoplea were found in the other sample hauled from 600 m to the surface. In the Oyashio region, adults of certain copepods occur usually in the deep water, whereas immature individuals of the same species are found only in the upper water. In the present examined samples, this tendency was observed especially distinctly in *Calanus helgolandicus*, *Calanus plumchrus*, *Eucalanus bungii bungii*, *Eucal. bungii californicus* and *Metridia lucens*. Neither adults nor immature specimens of *Calanus cristatus*, *Pareuchaeta elongata* (=*Par. japonica* MORI) and *Pseudocalanus gracilis* were found in the upper water sample, although these

Table 4. Individuals of respective copepods collected at Station C in the Oyashio region.

Species \ Depth	0–100 m	0–600 m
Calanus finmarchicus (GUNNERS) III rd cope.	—	8
Cal. helgolandicus (CLAUS)	♀40, ♂8	♀56
" V th copepodid	96	168
" IV th copepodid	28	—
" III rd copepodid	31	—
Calanus plumchrus MARUKAWA	—	♀3, ♂10
" V th copepodid (4.5 mm–4.8 mm)	112	30
(4.1 mm–4.2 mm)	32	45
" IV th copepodid	44	65
" III rd copepodid	4	24
Cal. cristatus KRÖYER V th copepodid	—	14
" IV th copepodid	—	1
Cal. tenuicornis (DANA)	340	144
Cal. juv.	450	608
Eucalanus bungii bungii JOHNSON	—	♀24
" V th copepodid	—	♀14, ♂10
" IV th copepodid	♂4	♀80, ♂48
" III rd copepodid	878	1224
" II nd copepodid	1244	1968
" I st copepodid	240	80
Eucal. bungii californicus JOHNSON	—	♀1
" IV th copepodid	8	—
" III rd copepodid	4	—
Eucal. crassus GIESBRECHT V th copepodid	4	—
Paracalanus parvus GIESBRECHT	♀570, ♂150	♀4760, ♂440
Clausocalanus pergens FARRAN	—	♀280
Ctenocalanus vanus GIESBRECHT	—	♀80
Pseudocalanus minutus (KRÖYER)	♀, ♂994	adult ♀160, V th cope. 40 ♂1
Pseudocal. gracilis SARS V th copepodid	—	♀600, ♂520
Aetideus armatus (BOECK)	—	♀2, ♂2
Pareuchaeta elongata (ESTERLY)	—	♀2, ♂1
" V th copepodid	—	♀5, ♂1
Par. juv.	—	♀12
Scolecithricella ovata (FARRAN)	—	♀16
Scol. emarginata FARRAN	—	48
Metridia princeps GIESBRECHT V th copepodid	—	♀1
Met. longa LUBBOCK	—	♀23
" V th copepodid	—	♀41, ♂24
Met. lucens BOECK	—	♀256, ♂240
" V th copepodid	♀156, ♂116	♀1216, ♂1016
Met. juv.	3900	7240
Pleuromamma abdominalis (LUBBOCK)	—	♀2, ♂2
Pl. xiphias GIESBRECHT	—	♀1
Pl. sp.	—	♀10, ♂16
Heterorhabdus devius TANAKA	—	♀1
Heterostylites longicornis (GIESBRECHT)	—	♀2
Candacia bipinnata (GIESBRECHT)	♂4	—
Can. norvegica BOECK	—	♀1
Can. juv.	4	—
Acartia clausi GIESBRECHT	♀120, ♂30	♀, ♂480
Acar. juv.	—	120
Gymnoplea juv.	210	2584
PODOPLEA		
Oithona plumifera BAIRD	♀690	♀1760
Oith. similis CLAUS	♀180	♀3320, ♂240
Oncaea venusta PHILIPPI	—	♀80
On. media GIESBRECHT	—	♀160
On. conifera GIESBRECHT	—	♀40, ♂40
Sapphirina nigromaculata CLAUS	4	—
Sapph. juv.	4	—
Corycaeus affinis MCMURRICH	♀420, ♂1140	♀920, ♂880
Cor. juv.	150	2440

specimens occurred in the deeper water sample. Comparing Table 4 with Tables 1 and 2, the following five points may be perceived:

1. Only the third copepodid stage of *Calanus finmarchicus* was found in the deeper water sample, while many *C. helgolandicus* were found in both upper and deeper water samples; the adult female of the latter was 2.8–3.0 mm in body length.

2. Many *Calanus plumchrus* occurred in both upper and deeper water samples, and the fifth copepodid stage of this species was divided into two groups respectively characterized by 4.5–4.8 mm and 4.1–4.2 mm body length.

3. KITOU states that the adults of *Eucalanus bungii bungii* appeared in the shallow 15–40 m layer in the Oyashio region (MARUMO, KITOU & OHWADA, 1958), but in the present materials, no adults were found in the upper water sample. Both the adults and individuals of all copepodid stages occurred abundantly only in the sample from 600 m to the surface, and it is very noteworthy that the 2nd basal joint of the mandible is already provided with three setae even in the first copepodid stage in these examined specimens. *Eucalanus bungii californicus* were also found in the materials, though they were very scarce.

4. Considerable numbers of *Pseudocalanus minutus*, *P. gracilis*, *Pareuchaeta elongata*, *Metridia longa* and *Met. lucens* occurred in these samples, although they have never been found in the water west of the Ridge.

5. Both females and males of *Corycaeus affinis* (=*Cor. japonicus* MORI) were abundant in samples and the occurrence seemed to be confined to the water layer upper than 100 m. A few specimens of this species can be seen in the surface water of the Kuroshio, but they are quite rare as compared with other species belonging to the same genus.

VIII. Discussion on the Differences between the Copepod Distribution West of the Ridge and That East of the Ridge

So far as the data presented in the preceding chapters are concerned, some distinct differences are perceived clearly between the copepod fauna west of the Ridge and that east of the Ridge. For example, the occurrence of thirteen representatives are given in Table 5.

The first column of the table is filled with data quoted from MORI's work (1937) covering nearly all surface-living pelagic copepods of Japanese waters, records of the 13 species in the Kuroshio region west of the Ridge and those in the Oyashio region east of the Ridge are shown. The middle column shows the data quoted from TANAKA's comprehensive works on Gymnoplea from the Izu region which includes two prominent bays, Suruga Bay in the west and Sagami Bay in the east, these respectively represent topographically the northernmost parts of the regions west and east of the Ridge. And the last one comprises the summaries of the data given in this paper. This table shows the following five significant trends:

1. All these 13 species have never been recorded from the surface water of the Kuroshio.

2. Seven of them, *Calanus plumchrus, Cal. cristatus, Eucalanus bungii bungii, Pareuchaeta elongata, Pseudocalanus minutus, Metridia longa* and *Met. lucens* have never been found in either the surface- or deep-water west of the Ridge.

Table 5. The occurrences of 13 representatives of the deep sea copepods.

<table>
<tr><th rowspan="3">Observers & area / Species</th><th colspan="2">MORI</th><th colspan="2">TANAKA</th><th colspan="4">FURUHASHI</th></tr>
<tr><th rowspan="2">Kuroshio (West of the Ridge)</th><th rowspan="2">Oyashio (East of the Ridge)</th><th rowspan="2">Suruga Bay (West)</th><th rowspan="2">Sagmi Bay (East)</th><th colspan="2">West of the Ridge</th><th colspan="2">East of the Ridge</th></tr>
<tr><th>Kuroshio</th><th>Cold water</th><th>Kuroshio</th><th>Oyashio</th></tr>
<tr><th></th><th colspan="2">Surface-water</th><th colspan="2">Deep-water</th><th colspan="2">Deep-water</th><th colspan="2">Deep-water</th></tr>
<tr><td>Calanus finmarchicus</td><td>−</td><td>+</td><td>+</td><td>+</td><td>+</td><td>+</td><td>+</td><td>+</td></tr>
<tr><td>Cal. plumchrus</td><td>−</td><td>+</td><td>−</td><td>+</td><td>−</td><td>−</td><td>−</td><td>+</td></tr>
<tr><td>Cal. cristatus</td><td>−</td><td>+</td><td>−</td><td>+</td><td>−</td><td>−</td><td>+</td><td>+</td></tr>
<tr><td>Eucalanus bungii bungii</td><td>−</td><td>+</td><td colspan="2">+</td><td>−</td><td>−</td><td>+</td><td>+</td></tr>
<tr><td>E. bungii californicus</td><td>−</td><td>−</td><td>+</td><td>−</td><td>+</td><td>+</td><td>+</td><td>+</td></tr>
<tr><td>Pseudocalanns minutus</td><td>−</td><td>+</td><td>−</td><td>+</td><td>−</td><td>−</td><td>−</td><td>+</td></tr>
<tr><td>Pareuchaeta elongata</td><td>−</td><td>+</td><td>−</td><td>+</td><td>−</td><td>−</td><td>−</td><td>+</td></tr>
<tr><td>Metridia curticauda</td><td>−</td><td>−</td><td colspan="2">+</td><td>+</td><td>+</td><td>+</td><td>−</td></tr>
<tr><td>Met. venusta</td><td>−</td><td>−</td><td colspan="2">+</td><td>+</td><td>+</td><td>+</td><td>−</td></tr>
<tr><td>Met. brevicauda</td><td>−</td><td>−</td><td colspan="2">+</td><td>+</td><td>+</td><td>+</td><td>−</td></tr>
<tr><td>Met. princeps</td><td>−</td><td>−</td><td colspan="2">+</td><td>+</td><td>+</td><td>+</td><td>+</td></tr>
<tr><td>Met. longa</td><td>−</td><td>−</td><td colspan="2">+</td><td>−</td><td>−</td><td>−</td><td>+</td></tr>
<tr><td>Met. lucens</td><td>−</td><td>+</td><td colspan="2">+</td><td>−</td><td>−</td><td>−</td><td>+</td></tr>
</table>

3. Of the above-mentioned seven species, *Cal. cristatus* and *Eucalanus bungii bungii* were found in the sample collected from the deep water of the Kuroshio region east of the Ridge.

4. All these 13 species were found in some of the samples collected in the regions east of the Ridge.

5. There is practically no difference about the occurrence of respective species between the cold water region and the Kuroshio region west of the Ridge.

It is a very noticeable fact that the difference of the deep-sea copepod fauna between Suruga and Sagami Bays is quite parallel to that found between the Kuroshio and the cold water regions west of the Ridge and the Kuroshio and the Oyashio regions east of the Ridge. These two bays are located side by side, being less than 40 miles apart. And TANAKA's collections were made chiefly by the towing from 1000 m to the surface during the years 1936–1940. ICHIYE (1957) states that a cyclonic vortex west of the Ridge was observed during 1936–1944 and again it appeared since 1954. The results of a serial hydrographic observations carried by the Kōbe Marine Observatory since 1954 show that the Kuroshio makes a detour around a cyclonic vortex to the south and then along the west of the Ridge to the north, and then flows eastward over the Ridge south of Izu Peninsula. Therefore, the upper water of two bays are to be considered as the tropical or subtropical water. Under such oceanographical conditions, the segregation found in the deep-sea copepod fauna between the areas west and east of the Ridge can be explained only when the cold-water species maintained in the Western North Pacific Central Water are distributed under the Kuroshio east of the Ridge. As seen in Fig. 1, a wedge-shaped 1000 m contour goes deeply into the heart of Sagami Bay connecting it with the Japan Trench, while the trough in Suruga Bay is separated from the trough in Sagami Bay and the Japan Trench by the Ridge. On the other hand, according to ICHIYE's calculation (ICHIYE, 1960) the water shows the motionless state at 1000 m–1200 m in the whole area of the Kuroshio. Thus, it is very probable that the Oyashio can mingle with the deep water of Sagami Bay, but not with that of Suruga Bay.

Here it must be remembered that the composition of copepod fauna in the cold water region west of the Ridge resembles closely that in the Kuroshio region of the same area. For this reason, it is very possible that the water mass of the cold water region is quite the same as the deeper water mass of the Kuroshio region west of the Ridge.

ICHIYE published a very interesting theory concerning the variation of the Kuroshio pointing out the importance of the deep current and the submarine ridge south of Japan; according to this the cold water domain west of the Ridge is nothing but the upwelled deep water piled up by the counter current under the Kuroshio deflected to the north by the Ridge (ICHIYE, 1960). However, to satisfy this theory it seems necessary to demonstrate the existence of some Oyashio-living animals in the deeper water, so-called submerged counter current under the Kuroshio west of the Ridge.

Although much more detailed observations are needed to give the definite conclusion concerning the occurrence of the cold water domain and to clarify the nature of the counter current under the Kuroshio west of the Ridge, the complete absence of any Oyashio-living animals in both the surface and deep water west of the Ridge seems to offer a very important and significant clue to this problem. Anyhow, it seems very doubtful that the deeper water under the Kuroshio west of the Ridge and the submerged Oyashio water can be defined under a single name of the Western North Pacific Central Water.

IX. Summary and Conclusions

1. The effect of the Bonin Ridge on the distribution of deep-sea copepods in the deep waters off the south-eastern coast of Japan is discussed and this seems to urge further studies on the biogeographical effect of the Ridge upon the plankton animals in the deep waters in this area. The Ridge seems to prevent the invasion of the Oyashio-living copepods maintained in the submerged water to the sea west of the Ridge. On the other hand, the Kuroshio carries the surface-living tropical or sub-tropical copepods to the sea east of the Ridge even to the cold Oyashio region over the Ridge.

2. *Calanus plumchrus*, *Cal. cristatus*, *Eucalanus bungii bungii*, *Pareuchaeta elongata*, *Pseudocalanus minutus*, *Metridia longa* and *Met. lucens* of Oyashio-living species have never been found in the sea west of the Ridge, although these species were found in the deeper water samples from the Kuroshio region east of the Ridge.

3. The water mass of the cold water domain forming a cyclonic vortex off the southern coast of Japan is considered to belong to the same water mass as that of the deeper layer of the Kuroshio region west of the Ridge because of the biological proof based upon the studies on the distribution of deep sea copepods.

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