STUDIES ON THE VERTICAL DISTRIBUTION OF COPEPODS IN THE OYASHIO REGION EAST OF JAPAN AND IN THE KUROSHIO REGION SOUTH OF JAPAN

KENZO FURUHASHI

Oceanogr. Section, Japan Meteorological Agency

With 7 Text-figures and 10 Tables

Introduction

Previously, the author reported the occurrence of the cold water copepod, *Metridia lucens* BOECK, in the plankton samples collected from the sea south of Japan (FURUHASHI: 1965). In that paper, it was suggested that the occurrence of such a subarctic copepod in the Kuroshio region was due to the submerged extension of the cold Oyashio current underlying the warm water flowing off the east coast of Honshū. That suggestion, however, will be accepted generally only when the ecological aspects on the pelagic copepod fauna of the Oyashio region such as the vertical distribution, the vertical migration and the life cycle, are cleared up.

The present study which is based on the material consisting of twenty five samples of the pelagic copepods collected from the deep water at five stations off the eastern and the southern coasts of Japan is to show the lower limit of distribution and the composition of the subarctic copepod population in each of the Oyashio region east of Japan and the Kuroshio region south of Japan. The comparative study of those, then, will be very helpful to learn the general outline of the ecological aspects of the subarctic copepods.

The five stations are shown in Figure 1. Six collections were made between 1646 m deep and the surface at St. S-1 in the Oyashio region off Hokkaido in May 1964, five collections between 992 m deep and the surface at St. H12 far east off Hokkaido near the southern mixing periphery of the Oyashio in the same time, five collections between 1340 m deep and the surface at St. S-2 in the sea east off Bōsō partially showing the southern limit of the Oyashio at the surface in May 1964, and six collections between 3010 m deep and the surface at St. T-1 in the sea near Torishima Island situated south to the main stream of the Kuroshio in July 1963. The collections were each made by the author in layer of different depth by vertical haul of a closing net on board the R. V. Ryōfū Maru. The net used had a 30 cm mouth diameter and was stretched with the fine bolting silk with about 0.3 mm square meshes (GG 54). In addition to those samples, three more samples were collected by Mr. K. KURODA between 526 m deep and the surface at St. N-1 in southern Enshūnada in March 1965. These collections were made by using a closing net with a 51 cm mouth diameter on board the R. V. Shumpū Maru. The composition of the copepod population in each sample is shown in Tables 6 to 10 in the middle of this article, and the vertical distribution of the water temperature at each station is given in Figure 7.

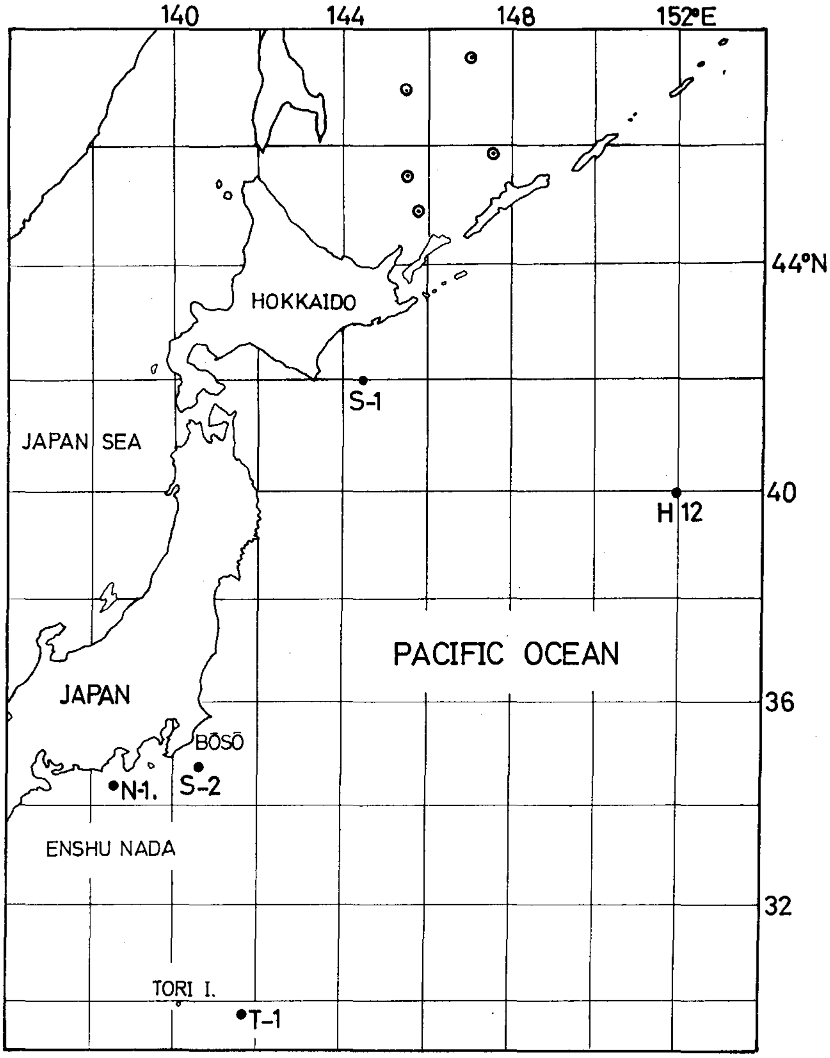

Fig. 1. Map showing the five stations (●) where the deep water copepods were collected, five stations (⊙) show the position of operations in the Okhotsk Sea.

The results of the comparative study of the vertical distributions of the cold water copepods in the northern part of the Oyashio region, the southern part of the Kuroshio region, and in the mixing area between the two regions show that the number of individuals of the cold water copepods decreases and the layer of their occurrences goes down with the distance from the proper area of the Oyashio region.

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Occurrence of copepods in the Oyashio, the Kuroshio, and the mixing regions

i) *Copepods from the Oyashio region* (Tables 1 and 6)

Forty-six species were found in the six samples taken at St. S-1 in the Oyashio region. Occurrences of respective species in each layer are shown in Table 1.

Table 1. Occurrences of copepod species in each layer at St. S-1 in the Oyashio region. D-Depth in meters; N-Total number of species appeared; N'-Number of species confined to the layer mentioned.

D	0–100	98–249	242–498	495–775	763–985	1030–1646	Total
N	10	14	14	23	23	22	46
N'	0	1	1	3	3	3	11
Dominant species	*Calanus cristatus* *Calanus plumchrus* *Eucalanus bungii bungii* *Pseudocalanus minutus* *Scolecithricella minor* *Oithona similis*	*Calanus cristatus* *Calanus plumchrus* *Eucalanus bungii bungii* *Pseudocalanus gracilis* *Scolecithricella minor* *Metridia lucens* *Metridia longa*	*Microcalanus pygmaeus* *Racovitzanus antarcticus* *Scolecithricella minor* *Metridia lucens* *Pleuromamma scutellata* *Oncaea conifera*	*Calanus finmarchicus* *Eucalanus bungii californicus* *Spinocalanus abyssalis* *Gaetanus minor* *Metridia lucens* *Isochaeta ovalis* *Heterorhabdus tanneri* *Oithona similis* *Oncaea conifera*	*Calanus finmarchicus* *Calanus helgolandicus* *Spinocalanus abyssalis* *Isochaeta ovalis* *Oithona similis* *Oncaea conifera*	*Calanus helgolandicus* *Spinocalanus abyssalis* *Isochaeta ovalis* *Heterorhabdus tanneri* *Oithona similis* *Oncaea conifera*	

As is seen in the table the total number of species is generally less in the upper layer than in the deeper layer, and the species limited to any special layer are much poorer in the Oyashio region than in the Kuroshio region (*cit*: FURUHASHI and MATSUDAIRA 1960). These facts seem to show that most copepods in the Oyashio region are living and migrating throughout the surface to the deep layer ; in other wards, their distributional ranges are very wide. On the contrary in the Kuroshio region many copepods appear to be condensed respectively in different layers. Dominant species in the upper water shallower than 250 m were the copepodite stages of *Calanus cristatus* and *C. plumchrus*, *Eucalanus bungii bungii*, *Pseudocalanus minutus* and *Scolecithricella minor*. In the mid-water *Eucalanus bungii californicus*, *Microcalanus pygmaeus*, *Gaetanus minor*, *Racovitzanus antarcticus*, *Metridia longa* and *Pleuromamma scutellata* were dominant. Some individuals of these species seemed to show the diurnal vertical migration in the surveyed regions, though most of them were found stayed still there at night. *Calanus finmarchicus*, *C. helgolandicus*, *Spinocalanus abyssalis*, *Isochaeta ovalis* and *Heterorhabdus tanneri* were dominant in the deep water. *Oithona similis* was common throughout the whole layers, and *Oncaea conifera* was dominant in the water deeper than 495 m. It is a well known fact that *Metridia lucens* shows an apparant diurnal migration, ascending to the surface at midnight. In the present material, however, the species was dominant in the mid-water, as the collection was made in the daytime.

MINODA (1958) reported on the vertical distribution of copepods at the station Os-8 in the southern part of the Bering Sea as follows: *Calanus cristatus* and *C. plumchrus* in the copepodite stage, *Eucalanus bungii bungii*, *Pseudocalanus elongatus*, *Scolecithricella minor* and *Metridia lucens* dominated in the surface water shallower than 150 m, *Calanus cristatus*, *C. plumchrus*, *Eucalanus bungii bungii*, *Pseudocalanus elongatus*, *Pareuchaeta birostrata*, *Scolecithricella minor*, *Metridia asymmetrica* and *Pleuromamma scutellata* were dominant in the mid-water (0–500 m), and *Calanus plumchrus*, *Metridia asymmetrica*, *Lucicutia ovaliformis* and *Heterorhabdus tanneri* were dominant in the deep water (500 m–2000 m). *Oithona similis* and *Oncaea conifera* were dominant throughout the surface to 2000 m. MINODA's data agree roughly with the present results, although they differ from each other in some details. *Calanus finmarchicus*, *C. helgolandicus* and *Eucalanus bungii californicus* were found only in the Oyashio region, while the dominancy of *Pareuchaeta birostrata* and *Metridia asymmetrica* was maintained only in the Bering Sea.

Pseudocalanus elongatus (BOECK) in MINODA's paper is reported in this paper as *P. minutus* (KRÖYER). *Lucicutia ovaliformis* BRODSKY and *Isochaeta ovalis* GIESBRECHT figured by TANAKA (1963) appear to be identical with each other, and the species is reported in this paper as *Isochaeta ovalis* GIESBRECHT.

ii) *Copepods from the transitional area between the Oyashio and the Kuroshio* (Tables 2 and 3)

Sixty-four species were found throughout the five samples taken at St. H12 in the sea far east off Hokkaido where the Oyashio mixes with the extension of the Kuroshio. The majority of species were found in the sample collected from 252 m to 512 m,

Table 2. Occurrences of copepod species in each layer at St. H12 in the transitional area.

Depth in meters	0–128	128–255	252–512	425–702	795–992	Total
Total number of species appeared	17	16	47	23	14	64
Number of species confined to the layer mentioned	4	2	22	3	0	31
Dominant species	*Calanus finmarchicus* *Calanus plumchrus* *Clausocal. arcuicornis* *Pseudocal. minutus* *Lucicutia flavicornis* *Corycaeus affinis*	*Eucalanus bungii bungii* *Clausocal. arcuicornis* *Ctenocalanus vanus* *Metridia lucens* *Oithona plumifera*	*Eucalanus bungii bungii* *Clausocal. arcuicornis* *Spinocalanus abyssalis* *Metridia lucens* *Pleuromam. scutellata* *P. gracilis* *Oncaea conifera*	*Metridia lucens* *Oncaea conifera* *Spinocalanus abyssalis*	*Spinocalanus abyssalis* *Metridia lucens* *Isochaeta ovalis* *Oncaea conifera*	

Table 3. Occurrences of copepod species in each layer at St. S-2 in the transitional area off Bōsō.

Depth in meters	0–197	204–457	446–719	660–900	815–1340	Total
Total number of species appeared	35	25	10	22	29	70
Number of species confined to the layer mentioned	11	9	2	9	14	45
Dominant species	*Clausocal. arcuicornis* *Ctenocal. vanus* *Mecynocera clausi* *Pleuromamma gracilis* *Acartia negligens* *Oithona plumifera* *Oithona setigera*	*Clausocal. arcuicornis* *Spinocal. abyssalis* *Pleuromamma gracilis* *Oithona setigera* *Oncaea conifera*	*Clausocal. arcuicornis* *Spinocal. abyssalis* *Mormonilla phasma* *Oithona plumifera* *Oncaea conifera*	*Calanus helgolandicus* *Spinocal. abyssalis* *Oncaea conifera* *Oncaea ornata*	*Calanus helgolandicus* *Eucalanus crassus* *Rhincal. nasutus* *Microcal. pygmaeus* *Spinocal. abyssalis* *Isochaeta ovalis* *Oncaea conifera* *O. ornata* *Conaea gracilis*	

47 of 64 species were included in it. Moreover, the species limited to this layer were much richer than in other layers. *Calanus finmarchicus*, *C. plumchrus*, *Pseudocalanus*

minutus, *Lucicutia flavicornis* and *Corycaeus affinis* were dominant in the upper water, *Eucalanus bungii bungii*, *Ctenocalanus vanus* and *Pleuromamma scutellata* were dominant in the mid-water, *Clausocalanus arcuicornis* was a dominant species in the water shallower than 512 m, *Spinocalanus abyssalis* and *Isochaeta ovalis* were dominant in the deep water, and *Metridia lucens* and *Oncaea conifera* were distributed in the mid to deep water, as collections were made in the daytime, when they were descending from the surface layer.

Table 3 shows that 70 species were found throughout the five samples taken at St. S-2 in the sea near the eastern coast of Bōsō where the southern ends of the Oyashio extension were often observed at the surface. The total number of species limited to respective layers attains 64 per cent to the total number of species found at that station. *Mecynocera clausi*, *Ctenocalanus vanus* and *Acartia negligens* were dominant in the upper layer, *Clausocalanus arcuicornis*, *Pleuromamma gracilis*, *Oithona plumifera* and *O. setigera* were dominant in the water shallower than 457 m, *Mormonilla phasma* was dominant in the mid-water, *Spinocalanus abyssalis* and *Oncaea conifera* were dominant in the mid to deep water, *Calanus helgolandicus*, *Rhincalanus nasutus*, *Eucalanus crassus* in copepodite stages, *Microcalanus pygmaeus*, *Isochaeta ovalis*, *Oncaea ornata* and *Conaea gracilis* were dominant in the deep water.

iii) *Copepods from the Kuroshio region* (Tables 4, 5, 9 and 10)

One hundred and six species occurred in the six samples taken at St. T-1 in the sea near Torishima Island south of the main flowing of the Kuroshio. The total number of species in respective layers is large except for the deepest layer. The species found in the uppermost layer (0–217 m) are mainly the inhabitants of the surface water of the temperate and tropical regions, while none of the species found in the layer from 234 m down to 434 m shows any special vertical distribution. In other words, the species from the 234 m–434 m layer may migrate from the surface to a considerable depth. *Calanus minor*, *Eucalanus subtenuis*, *Mecynocera clausi*, *Clausocalanus furcatus*, *Ctenocalanus vanus*, *Acartia negligens* and *Copilia mirabilis* were common in the upper layer. *Clausocalanus arcuicornis* and *Oncaea venusta* were dominant in the water shallower than 616 m, *Rhincalanus nasutus*, *Scaphocalanus curtus* and *Metridia venusta* were common in the mid-water. *Spinocalanus abyssalis*, *Mormonilla minor* and *Conaea gracilis* were distributed in the water deeper than 234 m, *Calanus finmarchicus*, *Spinocalanus spinipes*, *Mormonilla phasma* and *Oncaea ornata* were dominant in the deep water. *Oithona plumifera*, *O. setigera* and *Oncaea conifera* were dominant throughout the whole layers from the surface to 3010 m. In the deepest layer, 2000 m to 3010 m, only 19 species were found; the number of individuals was very small in each species. The occurrence of the subarctic species, *Eucalanus bungii bungii* in copepodite stages, in the 582 m to 1236 m layer at this warm water station is very noteworthy, and this will be discussed later.

One hundred species occurred in the 3 samples taken at St. N-1 off the southern coast of Japan and north to the main stream of the Kuroshio current. The number

Table 4. Occurrences of copepod species in each layer at St. T-1 in the Kuroshio region.

Depth in meters	0–217	234–434	369–616	582–820	603–1236	2000–3010	Total
Total number of species appeared	55	35	53	45	43	19	106
Number of species confined to the layer mentioned	20	0	6	4	7	3	40
Dominant species	*Calanus minor* *Eucalanus subtenuis* *Mecynocera clausi* *Clausocal. furcatus* *Lucicutia flavicornis* *Oncaea venusta* *Copilia mirabilis*	*Mecynocera clausi* *Clausocal. arcuicornis* *Spinocal. abyssalis* *Scaphocal. curtus* *Pleuromamma gracilis* *Lucicutia flavicornis* *Oithona plumifera* *Oncaea conifera* *Oncaea media*	*Rhincal. nasutus* *Clausocal. arcuicornis* *Spinocal. abyssalis* *Pleuromamma gracilis* *Oithona plumifera* *Oncaea venusta* *Oncaea conifera* *Conaea gracilis*	*Calanus finmarchicus* *Spinocal. abyssalis* *Mormonilla phasma* *Oithona plumifera* *Oithona setigera* *Oncaea conifera* *Oncaea ornata* *Conaea gracilis*	*Calanus finmarchicus* *Microcal. pygmaeus* *Spinocal. abyssalis* *Mormonilla phasma* *Mormonilla minor* *Oithona setigera* *Oncaea conifera* *Oncaea ornata*	Non dominant spec.	

Table 5. Occurrences of copepod species in each layer at St. N-1 off southern coast of Japan and north to the main stream of the Kuroshio.

Depth in meters	0–97	82–301	298–526
Total number of species appeared	29	46	74
Number of species confined to the layer mentioned	11	12	41
Dominant species	*Cal. helgolandicus* *Paracalanus parvus* *Clausocal. arcuicornis* *Ctenocalanus vanus* *Oithona plumifera* *Oithona similis*	*Cal. finmarchicus* *Cal. helgolandicus* *Eucalanus bungii californicus* *Paracalanus parvus* *Claus. arcuicornis* *Ctenocalanus vanus* *Pleurom. gracilis* *Oithona plumifera*	*Cal. finmarchicus* *Cal. helgolandicus* *Eucalanus bungii californicus* *Paracalanus parvus* *Claus. arcuicornis* *Spinocal. abyssalis* *Pleurom. gracilis* *Oithona plumifera* *Oncaea conifera*

of species was largest in the deepest of the surveyed layers, from 298 m to 526 m, but smallest in the surface layer shallower than 97 m. The dominant species were all temperate or tropical forms, *Calanus helgolandicus, Paracalanus parvus, Clausocalanus arcuicornis* and *Oithona plumifera* were dominant in all of the three layers, and *Calanus finmarchicus, Eucalanus bungii californicus* and *Pleuromamma gracilis* were dominant in the mid-water from 82 m to 526 m. It is worthwhile to note that the subarctic copepods such as *Calanus plumchrus, Eucalanus bungii bungii* and *Metridia lucens,* seemingly derived from the Oyashio current, were found in the mid-water from 82 m down to 526 m, as referred to again later.

Table 6. The occurrence of copepods at St. S-1 in the Oyashio region.

Location Lat. N Long. E	41°-59.0' 144°-27.5'					
Date	1964-5-12					
Time	1343–1345	1330–1333	1300–1304	1224–1229	1134–1138	1711–1724
Hauled distance (m)	0–100	98–250	244–500	495–775	775–1000	1032–1650
Wire angle (°)	5	4	5	0	10	4
Hauled depth (m)	0–100	98–249	242–498	495–775	763–985	1030–1646
Calanus cristatus KRÖYER	—	—	—	♀ 1	♀ 1	—
〃 copepodite stage	38	12	1	—	—	—
C. finmarchicus (GUNNERUS) copepodite stage	—	—	—	7	5	1
C. helgolandicus (CLAUS) copepodite stage	—	—	—	1	14	27
C. plumchrus MARUKAWA	—	—	—	♀ 1	♀ 1	♀ 1, ♂ 1
〃 copepodite stage	105	6	—	—	—	—
Eucalanus bungii bungii JOHN.	♀ 21	♀ 3	♀ 1	—	♀ 2	—
〃 copepodite stage	58	4	—	—	1	—
E. bungii californicus JOHNSON	—	—	1	♀ 3	—	—
E. elongatus (DANA)	—	♂ 2	—	—	—	—
Rhincalanus nasutus GIESBRECHT	—	—	—	—	♀ 1	—
〃 copepodite stage	—	—	—	—	1	—
Pseudocalanus gracilis SARS	♀ 10	♀ 7, ♂ 1	—	—	—	—
P. minutus (KRÖYER) ♀	30	4	—	—	2	1
Microcalanus pygmaeus SARS	—	—	♀ 1, ♂ 5	♀ 1	—	♀ 2, ♂ 1
M. sp.	—	—	♀ 3	♀ 1	—	—
Spinocalanus abyssalis GIESBR.	—	—	—	♀ 6, ♂ 1	♀ 19	♀ 18
S. spinosus FARRAN	—	—	—	—	—	♀ 1
S. pseudospinipes BRODSKY	—	—	—	♂ 1	—	—
Gaidius moderatus TANAKA	—	—	—	♀ 2	—	—
Gaetanus minor FARRAN	—	—	—	♀ 2, ♂ 4	—	—
G. kruppi GIESBRECHT	—	—	—	—	♂ 1	—

Table 6. (Continued)

Hauled depth (m)	0–100	98–249	242–498	495–775	763–985	1030–1646
Pareuchaeta birostrata BRODSKY	—	—	—	—	♀ 1	♀ 1
P. elongata (ESTERLY)	—	♂ 1	♀ 1	—	—	—
Cornucalanus sp.	—	—	—	—	1	—
Scaphocalanus affinis (SARS)	—	—	—	—	—	1
S. brevicornis SARS	—	—	—	—	♀ 1, ♂ 1	♂ 1
S. magnus (T. SCOTT)	—	—	—	♀ 1	—	—
S. subbrevicornis (WOLFENDEN)	—	—	—	—	♂ 1	♀ 2
Racovitzanus antarcticus GIESB.	—	♀ 1	♀ 4	—	—	—
R. levis TANAKA	—	♂ 1	—	—	—	—
Scolecithrix sp.	—	—	—	—	♀ 1	—
Scolecithricella minor (BRADY)	♀ 30	♀ 10, ♂ 1	♀ 9, ♂ 3	♂ 1	♀ 1	—
S. ovata (FARRAN)	—	—	♀ 1	—	—	—
Metridia curticauda GIESBR.	—	—	—	♀ 1	♀ 1	♀ 1, ♂ 1
M. lucens BOECK	♀ 1	♀ 72	♀ 10, ♂ 1	♂ 14	♀ 1, ♂ 1	—
〃 copepodite stage	1	9	4	6	2	2
M. longa LUBBOCK	—	♀ 27	♀ 2	—	—	—
〃 copepodite stage	—	—	2	—	—	—
Pleuromamma scutellata BRODSKY	—	—	♀ 5, ♂ 2	♀ 2	♀ 1	—
Lucicutia curta FARRAN	—	—	—	—	—	♀ 1, ♂ 1
Isochaeta ovalis GIESBRECHT ♀	—	—	—	7	14	3
Heterorhabdus robustus FARRAN	—	—	—	♂ 1	—	♀ 1
H. tanneri (GIESBRECHT)	♀ 1	—	—	♀ 2, ♂ 2	♂ 1	♀ 4
Haloptilus oxycephalus (GIESB.)	—	—	—	—	—	♀ 1
Oithona plumifera BAIRD ♀	1	1	—	—	—	—
O. robusta GIESBRECHT	—	—	—	—	♀ 1	—
O. similis CLAUS ♀	990	6	1	6	11	21
Oncaea conifera GIESBRECHT	—	—	♀ 13, ♂ 9	♀ 2, ♂ 3	♀ 5, ♂ 1	♀ 2, ♂ 2
O. ornata GIESBRECHT	—	—	—	♀ 1	—	♀ 2
Lubbockia squillimana CLAUS	—	—	—	♀ 1	—	—
L. sp.	—	—	—	—	—	♂ 1

Table 7. The occurrence of copepods at St. H12 in the transitional area.

Location Lat. N Long. E	40°–03' 152°–01'				
Date	1964–5–1				
Time	1440–1443	1420–1422	1530–1534	1600–1604	1335–1339
Hauled distance (m)	0–130	130–260	255–520	490–810	810–1010
Wire angle (°)	11	11	10	30	11
Hauled depth (m)	0–128	128–255	252–512	425–702	795–992
Calanus cristatus KRÖYER copepodite stage	2	4	1	—	—
C. finmarchicus (GUNNERUS)	♀ ♂ 57	—	—	—	—
〃 copepodite stage	297	—	6	11	2
C. tenuicornis (DANA)	♀ 2, ♂ 1	—	♀ 1	—	—
C. helgolandicus (CLAUS) copepodite stage	2	—	—	—	2
C. plumchrus MARUKAWA	—	—	♀ 2	♂ 1	—
〃 copepodite stage	140	1	4	4	1
Eucalanus bungii bungii JOHN.	—	♀ 1, ♂ 3	♀ 11	♂ 3	—
〃 copepodite stage	—	22	31	—	—
E. bungii californicus JOHNSON	—	♀ 7, ♂ 1	♀ 7	♀ 2	—
〃 copepodite stage	—	1	1	—	1
E. elongatus (DANA)	—	—	♂ 3	—	—
Rhincalanus cornutus DANA	—	—	♀ 1	—	—
R. nasutus GIESBRECHT	—	—	—	2	1
Paracalanus parvus (CLAUS)	♀ 10	—	—	—	—
Acrocalanus spp.	♀ 5	—	—	—	—
Clausocalanus arcuicornis (DANA)	♀ 30	♀ 90, ♂ 25	♀ 20	♀ 1	—
Ctenocalanus vanus GIESBRECHT	♀ 10	♀ 10, ♂ 10	—	—	—
Pseudocalanus gracilis SARS	—	—	♀ 10, ♂ 10	—	—
P. minutus (KRÖYER)	30	♀ 5, ♂ 20	—	—	—
Microcalanus sp.	—	—	♂ 5	—	—
Mimocalanus cultifer FARRAN	—	—	♀ 1	—	—
Spinocalanus abyssalis GIESB.	—	—	♀ 50	♀ 6	♀ 3, ♂ 1
S. spinosus FARRAN	—	—	—	♀ 1	—
Gaidius moderatus TANAKA	—	—	♀ 2	—	—
Gaetanus armiger GIESBRECHT	—	—	♀ 3	♀ 1	—
G. miles GIESBRECHT	—	—	♀ 1	—	—
G. minor FARRAN	—	—	♀ 1	—	—

Table 7. (Continued)

Depth in meters	0–128	128–255	252–512	425–702	795–992
Euchirella rostrata (CLAUS)	♀ ♂ 16	♀ 8, ♂ 1	♀ ♂ 6	—	—
Euchaeta media GIESBRECHT	—	—	♀ 3	—	—
Pareuchaeta elongata (ESTERLY) copepodite stage	—	—	2	1	3
P. tonsa (GIESBRECHT)	—	—	♀ 1	—	—
Lophothrix frontalis GIESBR.	—	—	♀ 1	—	—
Scaphocalanus brevicornis SARS	—	—	♂ 4	♀ 1	—
S. curtus FARRAN	—	—	♀ 5	—	—
S. echinatus FARRAN ♀	—	—	11	1	—
S. longifurca (GIESBRECHT)	—	—	♂ 5	—	—
S. subbrevicornis (WOLFENDEN)	—	—	♀ 1	—	—
Racovitzanus antarcticus GIESB.	—	♀ 1, ♂ 1	♀ 2	—	—
Scolecithrix danae (LUBBOCK)	—	♀ 1	—	—	—
Scolecithricella arcuata (SARS)	—	—	—	♀ 1	—
S. minor (BRADY)	—	—	♀ 5	—	—
Metridia curticauda GIESBR.	—	—	♂ 1	♀ 2, ♂ 1	—
M. lucens BOECK	—	—	♀ ♂ 326	♀ 17, ♂ 8	—
〃 copepodite stage	—	140	254	40	18
M. venusta GIESBRECHT	—	—	♀ 1	—	—
Pleuromamma abdominalis (LUBBOCK)	—	—	♀ 5, ♂ 5	—	—
P. gracilis (CLAUS)	—	♀ 6	♀ 22, ♂ 15	—	—
P. scutellata BRODSKY	—	—	♀ 7, ♂ 4	♀ 3, ♂ 2	—
P. xiphias GIESBRECHT ♀	—	—	4	1	—
Lucicutia flavicornis (CLAUS)	♀ ♂ 30	♀ 5, ♂ 10	♀ 5, ♂ 5	—	—
Isochaeta ovalis GIESBRECHT	—	—	—	—	♀ 1, ♂ 1
〃 copepodite stage	—	—	—	4	2
Heterorhabdus robustus FARRAN	—	—	—	♀ 1	—
H. tanneri (GIESBRECHT)	—	—	♂ 3	—	—
Heterostylites longicornis (GIES.)	—	♀ 1	—	—	—
Haloptilus oxycephalus (GIESBR.)	—	—	♀ 1	—	—
Mormonilla minor GIESBRECHT ♀	—	—	—	1	2
M. phasma GIESBRECHT ♀	—	—	5	1	—
Oithona plumifera BAIRD ♀	5	20	5	—	—
O. robusta GIESBRECHT	—	—	♀ 5	—	—
O. similis CLAUS	♀ 15	—	—	—	♀ 3
Oncaea conifera GIESBRECHT	—	♀ 5	♀ 50, ♂ 10	♀ 8, ♂ 7	♀ 7
O. ornata GIESBRECHT ♀	—	—	5	4	—
O. venusta PHILIPPI ♀	10	—	5	—	—
Conaea gracilis (DANA)	—	—	♂ 5	—	—
Sapphirina scarlata GIESBR.	♀ 2	—	—	—	—
Corycaeus affinis MCMURRICH	♂ 10	—	—	—	—

Table 8. The occurrence of copepods at St. S-2 in the transitional area.

Location Lat. N Long. E	34°–48.5′ 140°–38.0′				
Date	1964–5–27				
Time	2034–2038	2021–2025	1959–2003	1933–1937	1850–1902
Hauled distance (m)	0–200	210–470	465–750	730–1000	970–1530
Wire angle (°)	10	14	17	26	33
Hauled depth (m)	0–197	204–457	446–719	660–900	815–1340
Calanus cristatus KRÖYER copepodite stage	—	—	—	1	—
C. finmarchicus (GUNNERUS)	—	—	—	—	♀ 1
〃 copepodite stage	—	—	—	—	2
C. helgolandicus (CLAUS)	—	3	—	15	36
Eucalanus attenuatus (DANA)	—	—	—	—	♂ 1
E. bungii bungii JOHNSON copepodite stage	—	—	—	—	3
E. bungii californicus JOHN. copepodite stage	—	1	—	—	—
E. crassus GIESBRECHT copepodite stage	—	—	—	—	20
E. subtenuis GIESBRECHT	—	♀ 1	—	—	—
Rhincalanus nasutus GIESBR.	—	♀ 1	—	♀ 1	♀ 5
Mecynocera clausi THOMPSON	♀ ♂ 75	—	—	—	—
Calocalanus styliremis GIESBR.	♀ 5	—	—	—	—
C. sp.	♀ 5	—	—	—	—
Clausocalanus arcuicornis (DANA)	♀ ♂ 105	♀ ♂ 11	♀ 5	♀ 1	—
Ctenocalanus vanus GIESBR.	♀ ♂ 51	♂ 2	—	—	—
Microcalanus pygmaeus SARS	—	—	—	♀ 2	♀ 12, ♂ 1
Spinocalanus abyssalis GIESBR.	♀ 5	♀ 14	♀ 4	♀ 4, ♂ 1	♀ 11, ♂ 2
S. caudatus SARS	—	—	♀ 1	—	—
S. magnus WOLFENDEN	—	—	—	♀ 1	—
S. longispinus BRODSKY	—	—	—	♀ 1	—
Chiridius poppei GIESBRECHT	—	♀ 1, ♂ 1	—	—	—
Gaetanus minor FARRAN ♀	1	1	—	—	—
Undeuchaeta plumosa (LUBBOCK)	♀ 1	—	—	—	—
Euchaeta media GIESBRECHT	♀ 3, ♂ 1	—	—	—	—
Pareuchaeta crassa TANAKA	—	—	—	—	♀ 1
P. elongata (ESTERLY) copepodite stage	—	1	—	—	—

Table 8. (Continued)

Depth in meters	0–197	204–457	446–719	660–900	815–1340
Scaphocalanus elongatus A. SCOTT	—	—	—	—	♀ 1
S. longifurca (GIESBRECHT)	—	—	—	—	♀ 1
S. major (T. SCOTT)	—	—	—	♂ 1	—
Scolecithricella dentata (GIESBR.)	♀ 1	♀ 1, ♂ 1	♂ 1	—	1
S. gracilis SARS	—	—	—	♀ 1	—
S. tenuiserrata (GIESBRECHT)	♀ 5	—	—	—	—
Centropages bradyi WHEELER	♀ 1	—	—	—	—
Temoropia mayumbaensis T. SCOTT	♂ 5	—	—	♀ 1	—
Metridia brevicauda GIESBR.	—	♀ 1	—	♀ 2	—
M. curticauda GIESBRECHT	—	—	—	♀ 1	—
M. lucens BOECK	—	—	—	♀ 1, ♂ 1	♀ 3
M. venusta GIESBRECHT	—	♂ 2	—	—	—
Pleuromamma abdominalis (LUB.)	♀ 1, ♂ 3	3	—	—	—
P. gracilis (CLAUS)	73	♀ 19, ♂ 1	—	—	—
P. robusta (F. DAHL)	♀ 1	—	—	—	—
P. xiphias GIESBRECHT	—	1	—	—	—
Lucicutia flavicornis (CLAUS)	♂ 5	♀ 2	—	—	—
Isochaeta ovalis GIESBRECHT	—	—	—	♀ 1	♀ 4, ♂ 2
Heterorhabdus abyssalis (GIESB.)	—	—	—	—	♀ 1
H. pacificus BRODSKY	—	—	—	—	♀ 2
H. papilliger (CLAUS)	—	♂ 1	—	—	—
H. robustus FARRAN	—	—	—	—	♂ 1
H. tanneri (GIESBRECHT)	—	—	—	—	♀ 1
Haloptilus ornatus (GIESBR.)	—	—	—	—	♀ 1
Euaugaptilus longimanus (SARS)	—	—	—	♀ 1	—
Pachyptilus sp.	—	1	—	—	—
Arietellus simplex SARS	—	—	—	♀ 1	—
Candacia longimana (CLAUS)	♀ 1, ♂ 1	—	—	—	—
Acartia danae GIESBRECHT	♀ 1	—	—	—	—
A. negligens DANA	♀ ♂ 95	—	♂ 1	—	—
Mormonilla minor GIESBRECHT	—	—	♀ 1	—	—
M. phasma GIESBRECHT	—	♀ 3	♀ 4	—	♀ 1
Oithona plumifera BAIRD ♀	175	1	9	—	1
O. robusta GIESBRECHT	—	—	—	—	♀ 1
O. setigera DANA ♀	40	12	—	—	—
O. similis CLAUS	♀ 5, ♂ 5	—	—	♀ 1	♀ 5
Oncaea conifera GIESBRECHT	♀ 5, ♂ 5	♀ 7, ♂ 1	♀ 9	♀ 2, ♂ 2	♀ 6, ♂ 8
O. media GIESBRECHT	♀ 5	—	—	—	—
O. ornata GIESBRECHT	—	♀ 2	♀ 1, ♂ 1	♀ 7	♀ 7
O. venusta PHILIPPI	♀ 5	—	—	—	—
Conaea gracilis (DANA)	♀ 5, ♂ 5	—	—	♂ 2	♀ 3, ♂ 5
Corycaeus limbatus BRADY	♀ 5	—	—	—	—
Pontoeciella sp.	—	—	—	—	♀ 1
Aegisthus aculeatus GIESBR.	—	—	—	♀ 2	—
A. mucronatus GIESBRECHT	—	♀ 1	—	—	—

Table 9. The occurrence of copepods at St. T-1 in the Kuroshio region.

Location Lat. N Long. E	29°–47′ 141°–40′					
Date	1963–7–8					
Time	10:00	1020–1040	1050–1125	1145–1205	1307–1239	1335–1340
Hauled distance (m)	0–250	270–500	450–750	780–1100	975–2000	2022–3052
Wire angle (°)	30	30	35	42	52	10
Hauled depth (m)	0–217	234–434	369–616	582–820	603–1236	2000–3010
Calanus finmarchicus (GUNNERUS)	—	—	1	46	131	3
C. minor (CLAUS)	♀ ♂ 54	♀ 1	♀ 2	♀ 2	—	—
C. tenuicornis (DANA)	♀ ♂ 19	—	♀ 1	—	—	—
Calanoides sp.	—	—	1	—	—	—
Canthocalanus pauper (GIESBR.)	♀ 1	—	—	—	—	—
Neocalanus gracilis (DANA)	♀ 2	—	♀ 1	—	—	—
N. robustior (GIESBRECHT)	—	—	♂ 1	—	—	—
Undinula vulgaris (DANA)	♀ 1	—	—	—	—	—
Eucalanus attenuatus (DANA)	♀ 5	—	—	—	♀ 3	—
E. elongatus (DANA)	6	1	—	—	—	—
E. bungii bungii JOHNSON copepodite stage	—	—	—	1	1	—
E. crassus GIESBRECHT ♂	—	—	—	1	1	1
E. pileatus GIESBRECHT	♀ 1	—	—	♂ 1	—	—
E. subtenuis GIESBRECHT ♀	40	—	1	—	—	—
Rhincalanus nasutus GIESBRECHT	1	6	11	3	—	—
Mecynocera clausi THOMPSON	♀ ♂ 75	♀ 7, ♂ 1	♀ 2	♀ 1	♂ 1	—
Paracalanus aculeatus GIESBR.	♀ 10	♀ 1	♂ 1	—	—	—
Acrocalanus gibber GIESBRECHT	♂ 5	—	—	—	—	—
Calocalanus pavo (DANA) ♀	15	1	—	—	1	—
C. plumulosus (CLAUS)	♀ 5	—	—	—	—	—
Clausocalanus arcuicornis (DANA)	♀ 11	♀ 7, ♂ 1	♀ 12	♀ 2	♀ 1	—
C. furcatus (BRADY)	♀ ♂ 40	♂ 2	—	—	—	—
Ctenocalanus vanus GIESBRECHT ♀	35	1	1	—	—	—
Microcalanus pygmaeus SARS ♀	—	—	—	1	7	3
Spinocalanus abyssalis GIESBR. ♀	—	11	14	12	8	2
S. spinosus FARRAN	—	—	—	—	♀ 4, ♂ 1	♀ 3
S. magnus WOLFENDEN	—	—	—	—	—	♀ 4
S. stellatus BRODSKY	—	—	—	—	—	♀ 1
Monacilla sp.	—	—	2	1	—	1

Table 9. (Continued) (1)

Depth in meters	0–217	234–434	369–616	582–820	603–1236	2000–3010
Aetideus armatus (Boeck)	—	—	—	—	♀ 1	—
A. bradyi A. Scott	♂ 1	—	—	—	—	—
A. acutus Farran	♀ 4, ♂ 1	—	—	—	—	—
Chiridius poppei Giesbrecht	♀ 1	—	2	—	—	—
Chiridiella sp.	—	—	—	♀ 1	—	—
Gaidius tenuispinus (Sars)	—	—	♂ 1	—	—	—
Gaetanus minor Farran	—	♀ 3, ♂ 1	1	—	—	—
Chirundina streetsi Giesbr.	—	—	—	♀ 1	—	—
Euchaeta marina Prestandrea	♂ 1	—	—	—	—	—
E. longicornis Giesbrecht	♂ 1	—	—	—	—	—
E. media Giesbrecht	—	—	♀ 2	—	—	—
Scaphocalanus elongatus A. Scott	—	—	—	♀ 1	♀ 1	—
S. major (T. Scott)	—	—	—	—	♀ 1	—
S. longifurca (Giesbrecht)	—	—	—	—	♂ 1	—
S. echinatus Farran ♀	—	—	1	2	—	—
S. curtus Farran ♀	—	9	3	1	—	—
S. sp.	—	3	4	6	3	1
Scolecithricella bradyi (Gies.)	♀ 1	♂ 1	—	♀ 1	—	—
S. dentata (Giesbrecht)	—	♀ 1	♀ 2, ♂ 1	—	—	—
S. ctenopus (Giesbrecht)	♂ 5	—	—	—	—	—
S. vittata (Giesbr.) ♀	6	1	—	—	—	—
Centropages gracilis (Dana)	♀ 1	—	—	—	—	—
Temora discaudata Giesbr.	♀ 6	—	—	—	—	—
Metridia curticauda Giesbr.	—	—	—	♂ 1	♀ 2, ♂ 3	—
M. venusta Giesbrecht	—	♀ 1	♀ 4, ♂ 2	♀ 1	♀ 1	—
M. brevicauda Giesbrecht	—	—	♀ 2	♂ 1	♀ 3, ♂ 1	—
Pleuromamma abdominalis (Lub.)	—	♀ 3, ♂ 3	♀ 4	♂ 1	—	—
P. xiphias Giesbrecht	—	♀ 1	♀ 2, ♂ 2	—	♀ 3	—
P. gracilis Claus	♀ 2	♀ 7, ♂ 2	♀ 4, ♂ 5	—	♂ 1	—
Lucicutia ovalis Wolfenden	♀ 5	—	—	—	—	—
L. longiserrata Giesbr. ♀	—	—	1	—	1	—
L. magna Wolfenden	—	—	—	♀ 1	—	—
L. flavicornis (Claus)	♀ ♂ 40	♀ 7, ♂ 2	♀ 4, ♂ 1	—	♀ 1	—
Isochaeta ovalis Giesbrecht	—	—	—	—	♀ 3	—
Heterorhabdus papilliger (Claus)	♀ 7, ♂ 1	♀ 1	♀ 3, ♂ 1	—	—	—
H. pacificus Brodsky ♂	—	—	—	1	2	—

Table 9. (Continued) (2)

Depth in meters	0–217	234–434	369–616	582–820	603–1236	2000–3010
Heterorhabdus robustus FARRAN	—	—	—	—	♀ 1	—
H. sp.	1	—	1	1	4	—
Euaugaptilus palumboi (GIESBR.)	—	—	♀ 4, ♂ 1	♀ 1	—	—
Haloptilus longicornis (CLAUS) ♀	6	2	2	—	—	1
H. spiniceps (GIESBRECHT)	♀ 1	—	—	—	—	—
H. ornatus (GIESBRECHT)	♀ 3	—	—	—	—	—
H. mucronatus (CLAUS)	♀ 1	—	—	—	—	—
Phyllopus helgae FARRAN	—	—	♀ 1, ♂ 2	♀ 1, ♂ 1	—	—
Candacia longimana (CLAUS)	—	—	♀ 1	—	—	—
Acartia danae GIESBRECHT	—	—	♀ 2	—	—	—
A. negligens DANA ♀	35	1	3	1	—	—
Mormonilla phasma GIESBRECHT ♀	—	—	3	8	12	—
M. minor GIESBRECHT ♀	—	2	1	1	7	4
Oithona plumifera BAIRD ♀	10	12	16	12	3	1
O. setigera DANA ♀	25	2	8	11	7	2
Macrosetella gracilis (DANA)	—	—	1	1	1	—
Aegisthus aculeatus GIESBR.	—	—	—	—	♀ 1	—
Oncaea venusta PHILIPPI	♀ ♂ 99	♀ 6, ♂ 1	♀ 8, ♂ 1	♀ 3, ♂ 1	♀ 2	—
O. mediterranea CLAUS	♀ 25	—	♀ 5	♀ 1	♀ 3, ♂ 2	—
O. media GIESBRECHT	—	♀ 3, ♂ 4	—	♀ 1	—	—
O. conifera GIESBRECHT	♀ 15	♀ 9	♀ 15	♀ 7, ♂ 3	♀ 9, ♂ 9	♀ 1
O. minuta GIESBRECHT	—	—	—	♀ 2	—	—
O. notopus GIESBRECHT	—	—	—	—	—	♀ 1
O. ornata GIESBRECHT	—	—	♀ 5	♀ 18, ♂ 3	♀ 27, ♂ 2	♀ 2
O. sp.	—	—	1	1	1	2
Conaea gracilis (DANA)	—	♀ 2	♀ 8	♀ 8, ♂ 5	♀ 4, ♂ 1	♂ 2
Sapphirina metallina DANA	♀ ♂ 15	—	—	—	—	—
Copilia mirabilis DANA	♀ ♂ 55	♀ 1	—	—	♀ 1	—
C. quadrata DANA	♂ 10	—	—	—	—	—
C. vitrea HAECKEL ♂	—	—	—	1	1	—
Corycaeus speciosus DANA	♀ 5	—	♂ 1	—	♂ 1	—
C. furcifer CLAUS	♂ 10	♀ 2	♀ 1	♀ 1	—	—
C. lautus DANA	♂ 5	—	—	—	—	—
C. typicus KRÖYER ♀	5	—	1	—	—	—
C. agilis DANA	♀ 5	♀ 1	—	♂ 1	—	—
C. catus F. DAHL	♀ 5	—	—	—	—	—
C. giesbrechti F. DAHL ♀	5	1	—	—	—	—
C. concinnus DANA	♀ 20	—	—	—	—	—

Table 10. The occurrence of copepods at St. N-1 in the Kuroshio region.

Location Lat. N Long. E	34°–36′ 138°–34′		
Date	1965–3–7		
Time	14:00	14:40	14:10
Hauled distance (m)	0–100	95–350	340–600
Wire angle (°)	15	31	29
Hauled depth (m)	0–97	82–301	298–526
Calanus finmarchicus (GUNNERUS)	♀♂ 8	♀♂ 134	♀♂ 156
C. helgolandicus (CLAUS) ♀, ♂	712	624	97
C. minor (CLAUS)	—	2	—
C. plumchrus MARUKAWA	—	—	♀ 1
C. tenuicornis (DANA)	—	♀ 10, ♂ 8	♀ 2
Undinula darwini (LUBBOCK)	—	♂ 2	—
Eucalanus attenuatus (DANA)	♂ 2	4	♀ 1
E. bungii bungii JOHNSON	—	—	♀ 1
〃 copepodite stage	—	2	3
E. bungii californicus JOHNSON	♀ 2, ♂ 2	♀ 22, ♂ 70	♀ 47, ♂ 16
〃 copepodite stage	—	120	48
E. crassus GIESBRECHT	—	—	♂ 1
E. elongauts (DANA)	—	—	♀ 3, ♂ 15
E. subcrassus GIESBRECHT	♀ 2	—	—
E. subtenuis GIESBRECHT ♀	6	2	—
Rhincalanus cornutus DANA	—	—	2
R. nasutus GIESBRECHT	2	22	29
Mecynocera clausi THOMPSON	20	20	—
Paracalanus aculeatus GIESBR.	—	20	—
P. parvus GIESBRECHT ♀, ♂	2080	1460	60
Calocalanus sp.	20	20	—
Clausocalanus arcuicornis (DANA)	281	♀♂ 540	♀♂ 205
〃 minor form	—	120	—
C. furcatus (BRADY)	10	—	—
C. pergens FARRAN	♀ 10	—	—
Ctenocalanus vanus GIESBRECHT	120	♀♂ 480	♀ 10
Microcalanus pusillus SARS	—	—	♂ 5

Table 10. (Continued) (1)

Depth in meters	0–97	82–301	298–526
Spinocalanus abyssalis GIESBR.	—	—	♀ 26, ♂ 5
S. caudatus SARS	—	—	♀ 5
S. magnus WOLFENDEN	—	—	♀ 1
S. pseudospinipes BRODSKY	—	—	♀ 2
S. sp.	—	—	3
Aetideus acutus FARRAN	2	♀ 6	—
Chiridius gracilis FARRAN	—	—	♀ 10, ♂ 4
C. poppei GIESBRECHT	—	—	♀ 2
Gaidius tenuispinus (SARS)	—	—	♀ 1
Gaetanus armiger GIESBRECHT	—	—	♀ 2
G. minor FARRAN ♀	—	4	1
Euchirella messinensis CLAUS	—	—	♀ 1
E. rostrata (CLAUS)	—	♀ 10	♀ 5, ♂ 9
Chirundina streetsi GIESBR.	—	—	♀ 1
Undeuchaeta plumosa (LUBBOCK)	—	—	♀ 3, ♂ 1
Euchaeta longicornis GIESBR.	—	♀ 2	—
E. media GIESBRECHT	—	♀ 2	—
E. plana MORI	—	♂ 2	—
Pareuchaeta elongata (ESTERLY)	—	—	juv. 2
P. simplex TANAKA	—	♀ 2	♀ 3, ♂ 2
P. tonsa (GIESBRECHT)	—	—	♀ 1
Undinella brevipes FARRAN	—	—	♀ 1
Scottocalanus helenae (LUB.)	—	—	♀ 1
S. rotundatus TANAKA	—	♀ 2	—
S. securifrons (T. SCOTT)	—	—	♀ ♂ 12
Undinothrix spinosa TANAKA	—	—	♂ 1
Scaphocalanus brevicornis SARS	—	—	♂ 3
S. curtus FARRAN	—	—	♀ 3, ♂ 4
S. echinatus FARRAN	—	♀ 2, ♂ 4	♀ 13
S. elongatus A. SCOTT	—	—	♀ 1
S. longifurca (GIESBRECHT)	—	—	♂ 2
Racovitzanus sp.	—	♂ 2	—
Scolecithrix danae (LUBBOCK)	♀ 4	♀ 6, ♂ 2	—
S. nicobarica SEWELL	—	—	♀ 2
Scolecithricella dentata (GIESB.)	—	♀ 2	♀ 4, ♂ 11
S. bradyi (GIESBRECHT)	—	♀ 2	—
S. minor (BRADY)	—	—	♀ 5
S. ovata (FARRAN)	—	—	♀ 1, ♂ 1
S. profunda (GIESBRECHT)	—	—	♂ 2

Table 10. (Continued) (2)

Depth in meters	0–97	82–301	298–526
Metridia brevicauda GIESBR.	—	—	♀3, ♂1
M. curticauda GIESBRECHT	—	—	♀ 2
M. lucens BOECK	—	♂ 4	♀6, ♂6
〃 copepodite stage	—	6	2
M. venusta GIESBRECHT	—	—	♀2, ♂1
Pleuromamma abdominalis (LUBBOCK)	—	18	♀ 18, ♂2
P. gracilis (CLAUS) ♀ ♂	—	130	77
P. xiphias GIESBRECHT	—	♀ 2	♀9, ♂1
Lucicutia curta FARRAN	—	—	♂ 1
L. flavicornis (CLAUS) ♀	—	40	11
Heterorhabdus abyssalis (GIESBR.)	—	♀ 6	♀7, ♂1
H. pacificus BRODSKY	—	—	♂ 2
H. papilliger (CLAUS)	—	♂ 6	♀2, ♂6
Haloptilus acutifrons (GIESBR.)	♀ 2	—	—
H. longicornis (CLAUS) ♀	—	2	1
H. oxycephalus (GIESBRECHT)	—	—	♀ 1
Euaugaptilus palumboi (GIESBR.)	—	—	♀ 1
Phyllopus helgae FARRAN	—	—	♀1, ♂2
Candacia bipinnata GIESBR.	♀ ♂10	♀ ♂42	♀4, ♂1
Acartia clausi GIESBRECHT	60	—	—
A. danae GIESBRECHT	—	♀20	—
A. negligens DANA	♀20	—	—
Mormonilla phasma GIESBR.	—	—	♀10
Oithona plumifera BAIRD	♀380	♀ ♂780	♀90
O. setigera DANA	—	♀20	—
Oithona similis CLAUS	♀180	—	—
Aegisthus mucronatus GIESBR.	—	—	♀ 1
Oncaea conifera GIESBRECHT ♀	—	40	35
O. mediterranea CLAUS	—	—	♀10
O. ornata GIESBRECHT	—	—	♀10
O. venusta PHILIPPI ♀	160	80	20
Conaea gracilis (DANA)	—	—	♀10, ♂10
Corycaeus affinis MCMURRICH ♀	20	40	—
C. catus F. DAHL ♀	60	—	5
C. asiaticus F. DAHL	♂40	—	—
C. clausi F. DAHL	♀20	—	—
C. dahli TANAKA	♀ ♂40	—	—
C. flaccus GIESBRECHT	♀20	—	—
C. furcifer CLAUS	—	♀ ♂40	♀ 5
C. speciosus DANA	—	—	♀ 5

Composition of dominant copepods in the Oyashio and the Kuroshio regions

The following species were abundant only in the Oyashio region: *Scolecithricella minor* and the copepodite stages of *Calanus cristatus* in the upper layer, *Racovitzanus antarcticus* and *Metridia longa* in the mid-water and *Heterorhabdus tanneri* in the deep water.

Calanus plumchrus in copepodite stages and *Pseudocalanus minutus* were dominant in the upper water of both the Oyashio and the transitional area and *Pleuromamma scutellata* was dominant in the mid-water of the same regions. The last species was shown as *Pleuromamma* sp. in my previous paper (FURUHASHI: 1961, p. 10), occurred at that time in the midwater of the Oyashio region. The vertical distribution of this species at four stations is shown in Fig. 2. The species is completely missing in the Kuroshio region. *Metridia lucens* is dominant in the mid to deep water in the Oyashio region and the transitional area when the collection is made in the daytime, while it is found abundantly in the surface to subsurface samples obtained in the same regions when the collection is made at night.

It is noteworthy that MINODA (1958) recorded the frequent occurrences of *Pleuromamma scutellata* and *Racovitzanus antarcticus* in the surface water of the Bering Sea and

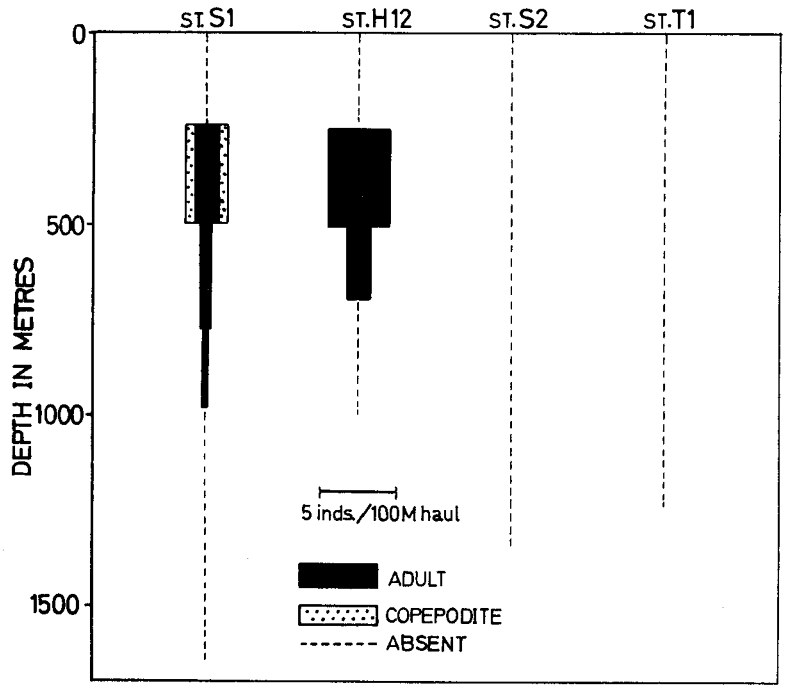

Fig. 2. Vertical distribution of *Pleuromamma scutellata* BRODSKY at four stations.

that the present author confirmed the rich occurrences of *Metridia longa* in the surface water of the Okhotsk Sea by examining the plankton samples collected by the Hakodate Marine Observatory in summer of 1961. These facts may illustrate that the populations of the above mentioned three spceies are originated respectively in the Bering Sea and the Okhotsk Sea.

On the other hand, in the Kuroshio region, *Scaphocalanus curtus* and *Metridia venusta* dominated in the mid-water and *Conaea gracilis*, *Mormonilla phasma* and *M. minor* were dominant in the deep water. The distribution of *Conaea gracilis* is shown in Fig. 3. *Isochaeta ovalis* was dominant in the deep water of both the Oyashio and the Kuroshio region east of the Bonin submarine ridge. *Oncaea ornata*, *O. conifera* and *Spinocalanus abyssalis* were dominant in the mid-water at all stations. The distribution of *Oncaea ornata* GIESBRECHT is given in Fig. 4 as an example. This species was found widely distributed in the deep water of the whole observed area, though the occurrence of the species in the area referred to in this paper was confirmed for the first time. ANRAKU (1952) reported that the female specimens of *Oncaea conifera* from the deep water of the Oyashio had all a pair of egg-sacs in November 1948, the similar trend was observed also in the specimens of the present material.

Calanus helgolandicus and *C. finmarchicus* were distributed widely both horizontally and vertically. They were predominant in the surface or subsurface water in the

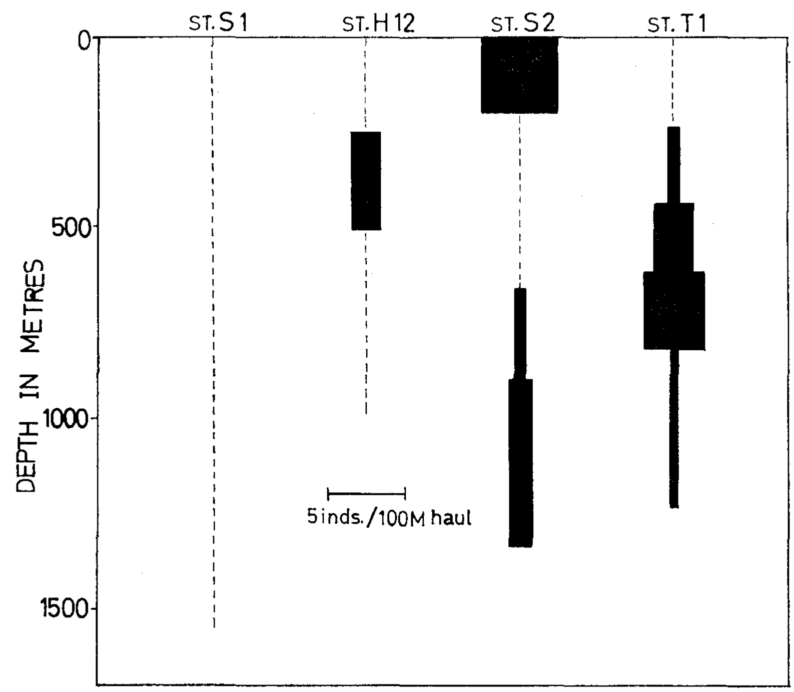

Fig. 3. Vertical distribution of *Conaea gracilis* (DANA) at four stations.

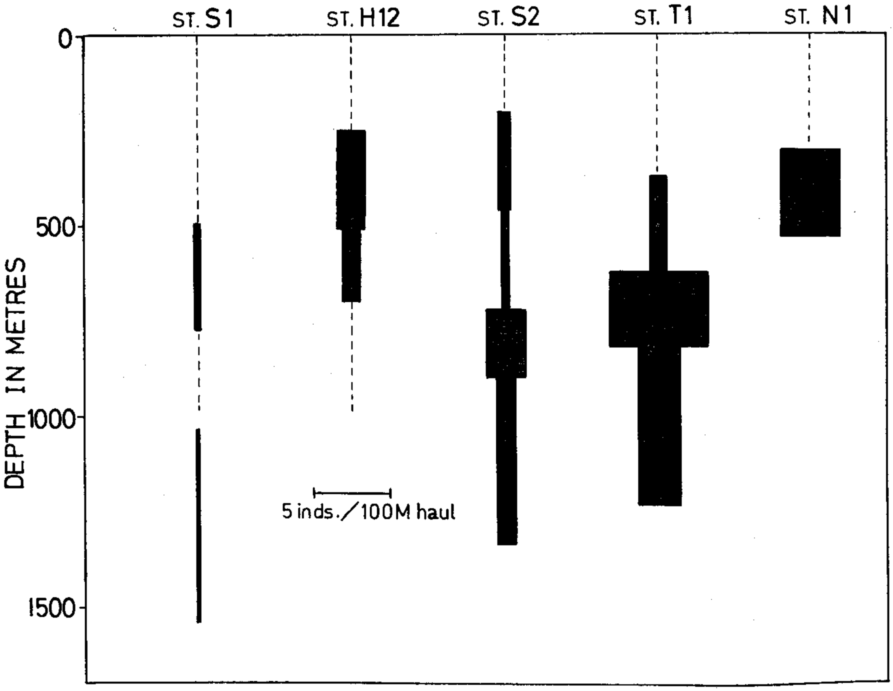

Fig. 4. Vertical distribution of *Oncaea ornata* GIESBRECHT at five stations.

Kuroshio region in early spring and in the transitional area in late spring. Such occurrences may possibly be attributed to their reproductive activity. The geographical distributions of these two species are overlapping each other in the adjacent seas of Japan. BRODSKY (1950) pointed out the morphological differences, especially those in the structure of the fifth feet of the male specimen, found between the specimens of these two species from the north western Pacific and those from the Atlantic. *Calanus helgolandicus* in the present material possibly corresponds to *Calanus pacificus* BRODSKY. *Calanus finmarchicus* in the present material, 3.6–4.0 mm in female and 3.2–3.3 mm in male, does not fit any Pacific species reported by BROSKY, but it resembles TANAKA's (1956) large-sized specimens of *Calanus finmarchicus* from the Izu region, which were 3.5–4.07 mm in female and 3.0–3.7 mm in male.

Successive changes of the vertical distribution of the cold water copepods from the Oyashio region to the Kuroshio region

According to their distributions, copepods found in the surveyed area may be grouped in the following six categories:

a) Temperate or tropical species which are distributed in the surface water of the Kuroshio region. This group contains more than 20 species.

b) Abyssal forms distributed in the mid- or deep-water of the Kuroshio region.
c) Abyssal forms living in the deep water of the Oyshsio region.
d) Species distributed in the mid-water of the Oyashio region.
e) Subarctic species living in the surface water in the Bering Sea or the Okhotsk Sea, but submerging to the mid-water in the Oyashio region.
f) Subarctic species living in the surface water of the Oyashio region, but descending to the mid-water in the transitional area.

The population of the last group is considered to be originated in the Oyashio and thus to be available effectually to trace the water mass of the Oyashio current moving down to the transitional area and then to the Kuroshio region. For instance, *Eucalanus bungii bungii* of this group shows the following vertical distribution at five stations (Fg. 5). This species was found frequently in the surface layer at St. S-1, but the population of the adult was much smaller than that of the copepodite. The number of total individuals becomes smaller in deeper layers, but the ratio of the adult to the copepodite increases there. With the distance from the Oyashio region, the population of this species moves down to the deeper layers and also becomes smaller.

The copepod fauna at St. H12 seems to be mostly derived from the Oyashio region, with some addition of the warm water species. The subarctic species found

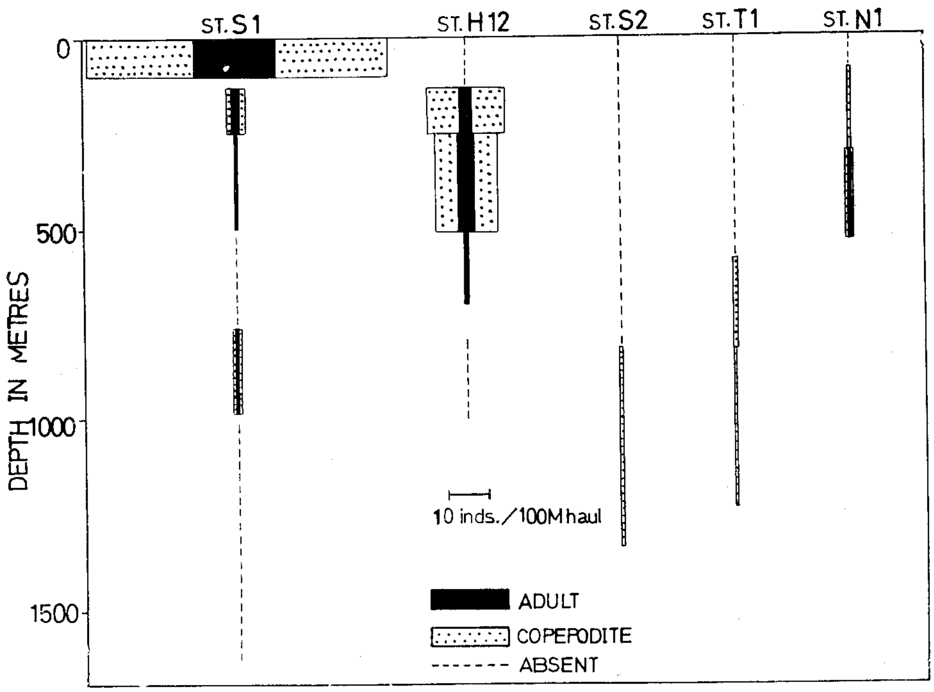

Fig. 5. Vertical distribution of *Eucalanus bungii bungii* JOHNSON at five stations.

at St. T-1 are considered to have reached there, being carried across the Kuroshio current, for instance, by cold-water eddies formed at the end of meanders of the Kuroshio extension. The cold-water pelagic animals at St. N-1 are seemingly transported there from the Oyashio extension along the coast of Jōban, the eastern district of Honshū Island, and then gradually sinking under the warm water off Enshū-Nada (FURUHASHI: 1965). The composition of copepods at three stations H12, N-1 and T-1, is influenced not only by the relative geographical situation of respective stations to the proper part of the Oyashio region, but also by the migration of the cold water masses. Figure 6 shows schematically the relative vertical distribution of *Eucalanus bungii bungii* JOHNSON at these stations. The more the distance is from the proper part of the Oyashio region, the more deeply the animals go down. The sinking gradient is calculated here tentatively as 100 m per 120 nautical miles.

The cold-water species of the Oyashio region, such as *Calanus cristatus*, *C. plumchrus*, *Eucalanus bungii bungii*, *Pareuchaeta elongata* and *Metridia lucens* are found there most abundantly in the surface layer. However, the most part of their surface populations consists of their copepodite stages, and the adults are always found in the deeper water. This vertical separation might be due to the vast demand of food in youngs. The quantity of food in the Kuroshio region is estimated as about one tenth of that in the Oyashio region.

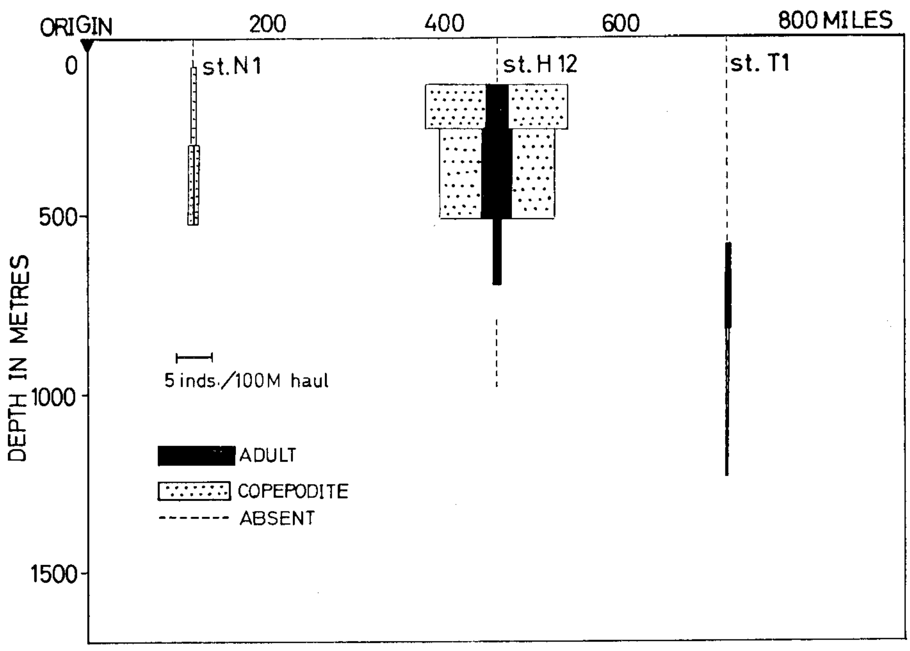

Fig. 6. Schema showing relatively the vertical distribution of *Eucalanus bungii bungii* JOHNSON at three stations. The respective stations are arranged in this figure in the order of the distance from the supposed station where factors are most representative of the Oyashio.

The author indicated in his previous paper (FURUHASHI: 1953) that the limit of the distribution of the cold water forms in the Japan Sea followed approximately the isotherm of 11°C. He also reported that the occurrence of *Metridia lucens* in the daytime was usually limited to the water layer with the temperature in the range 0.42°C–11°C, though it was found migrated up to the layers with the temperature 12°C–15°C at night in the Oyashio region (FURUHASHI: 1965). The cold water copepods transported to the deep layers of the Kuroshio region by the Oyashio extension underlying the warm water may survive for a considerably long time, but they will be unable to reproduce there. Recently, KITOU (1965) reported that four boreal species, *Calanus cristatus*, *C. plumchrus*, *Eucalanus bungii bungii* and *Metridia lucens*, were found in the deep water of the Kuroshio region, but the earlier copepodid stages of these species were not found in the southern part of the Kuroshio extension.

It is to be noticed that the occurrences of the subarctic copepods were confirmed frequently by several authors in the Kuroshio region west of the Bonin submarine ridge after 1963. Such subarctic copepods derived from the Oyashio region had never been found in that region before 1961 (FURUHASHI: 1961). It is well known that a cold water domain had been maintained in the sea south of Honshū scince 1954 and the main stream of the Kuroshio flowed first to the south around this cold water domain before the stream approached Bōsō Peninsula in the north. That time, the

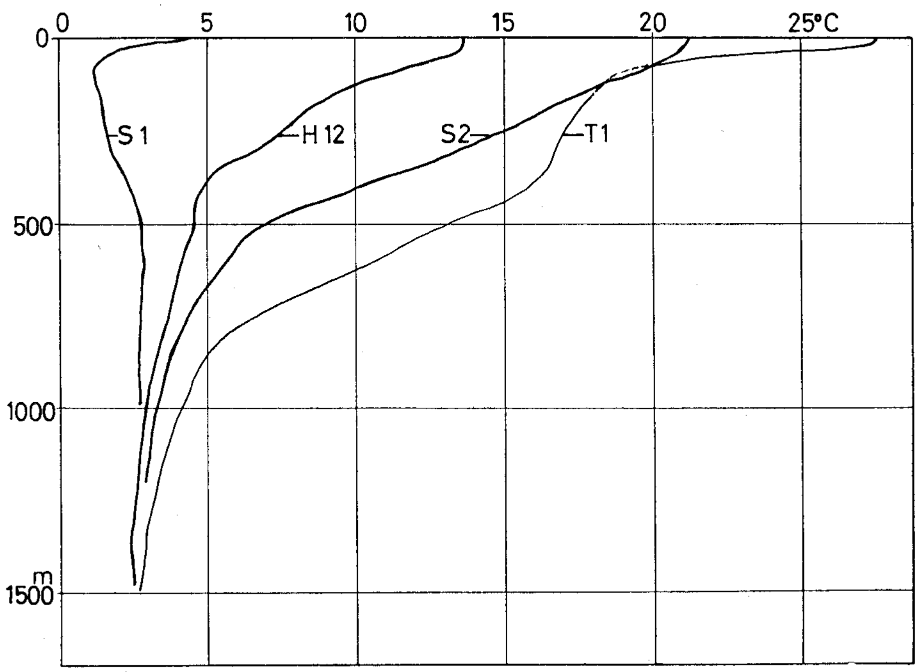

Fig. 7. Vertical distribution of the water temperature at four stations.

Oyashio extension was limited to the coastal region north of the Kuroshio current east off Japan. This cold water domain disappeared in 1963 and the Kuroshio current flows now towards the east, often keeping a large distance to Bōsō Peninsula. On the other hand, the Oyashio flows southwest towards the Kuroshio region along the coast of Honshū this time. In such circumstances, the following conclusions may be accepted very easily:

a) The occurrence of the subarctic species in the mid-water of the Kuroshio region indicates the existence of some extension of the Oyashio current deep under the warm water layers. Here "the warm water" does not mean the Kuroshio current axis.

b) The existence of the Oyashio water under the warm water can be confirmed as long as those subarctic species survive within that cold-water mass. According to BRODSKY (1938) *Calanus cristatus* is said to reproduce once a year in the subarctic water of the Japan Sea, but no study has ever been made on the life cycle of the subarctic copepods in the area referred to in this paper.

The author assumed in his previous paper (FURUHASHI: 1961) that the absence of the cold-water copepods in the Kuroshio region might deny the existence of the Oyashio water under the warm water. But now his supposition must be changed as follows: the occurrences of the cold water copepods in the deep water of the Kuroshio region indicate the existence of the Oyashio water *recently supplied* there. However, it is impossible that such subarctic copepods carried from the Oyashio region will survive in the Oyashio water underlying the warm water for so long time. After the migration for a long time beyond the life span of those subarctic copepods, the existence of the submerged Oyashio water under the warm water will not be confirmed biologically.

Summary

1. In the Oyashio region *Scolecithricella minor* and the copepodite stage of *Calanus cristatus* were dominant in the surface layer, *Racovitzanus antarcticus* and *Metridia longa* in the mid-water, and *Heterorhabdus tanneri* was dominant in the deep water.

2. *Calanus cristatus, C. plumchrus, Eucalanus bungii bungii, Scolecithricella minor* and *Metridia lucens* were dominant in the surface water of the Oyashio region, but they were distributed, too, in the mid-water of the transitional area.

3. *Scaphocalanus curtus, Metridia venusta* and *M. curticauda* were dominant in the mid-water of the Kuroshio region, but *Conaea gracilis, Mormonilla phasma* and *M. minor* in the deep water.

4. *Oncaea conifera, O. ornata* and *Spinocalanus abyssalis* were abundant in the mid to deep water at every station.

5. The cold-water copepods may indicate the existence of the Oyashio water at the deeper level in the Kuroshio region, and at the same time the existence of such copepods may tell us the length of the history of that Oyashio water mass in the warm water region.

LITERATURE

ANRAKU, M., 1952. Plankton copepods collected by R.S. "Yushio-Maru" in Pacific waters to the east of northern Japan during the cruise in November 1948. Bull. Fac. Fish. Hokkaido Univ., Vol. 3, No. 1, pp. 31–39. (In Japanese)

———, 1953. Seasonal distribution of pelagic copepods at Oshoro Bay, west coast of Hokkaido. Ibid., Vol. 3, No. 3, pp. 187–192.

———, 1954a. Distribution of plankton copepods off Kitami, Hokkaido, in Okhotsk Sea in summer, 1949 and 1950. Ibid., Vol. 4, No. 4, pp. 249–254.

———, 1954b. Copepods collected on the whaling grounds off northern Japan and around Bonin Islands. Ibid., Vol. 5, No. 1, pp. 1–8.

BRODSKY, K. A., 1938. Contribution to biology and systematic of Copepoda (*Calanus cristatus* KR.). Bull. Far eastern Branch Academy Sci. No. 29(2), pp. 147–171. (In Russian)

———, 1950. Calanoida of polar and far-eastern seas of the U. S. S. R. Opredeliteli po Fauna S. S. S. R., Izdavaemi, Zoologicheskim Institutum Akademii Nauk, S. S. S. R. 35, pp. 1–442. (In Russian)

GIESBRECHT, W., 1892. Systematik und Faunistik der pelagischen Copepoden des Golfes von Neapel u. d. angrenzenden Meeresabschnitte, 19, pp. 1–831.

FURUHASHI, K., 1953. On the vertical distribution of animal plankton in the sea of Japan off San'in-District in summer of 1952. Publ. Seto Mar. Biol. Lab., Vol. 3, No. 1, pp. 61–74.

———, 1961. On the possible segregation found in the copepod fauna in the deep waters off the south-eastern coast of Japan. Ibid., Vol. 9, No. 1, pp. 1–15.

———, 1965. Occurrence of cold water copepod, *Metridia lucens* BOECK, in the Enshunada of the Kuroshio region. Inform. Bull. Planktology in Japan, No. 12, pp. 49–51. (In Japanese)

FURUHASHI, K. and MATSUDAIRA, Y., 1960. On the vertical distribution of pelagic copepoda collected from the Kuroshio region south of Honshu. Memoirs of the Kobe Mar. Observatory, Vol. 14, pp. 1–8.

KITOU, M., 1958. Distribution of plankton copepods at the Ocean Weather Station "X", May 1950 to April 1951. Oceanogr. Mag. Vol. 10, No. 2, pp. 193–199.

———, 1965. The distribution of the four boreal species of copepoda in the western north Pacific. Ibid., Vol. 17, Nos. 1–2, pp. 95–107.

MARUMO, R., KITOU, M. and OHWADA, M., 1958. Vertical distribution of plankton at 40°N, 150°E in the Oyashio water. Ibid., Vol. 10, No. 2, pp. 179–184.

MARUMO, R., KITOU, M. and ASAOKA, O., 1960. Plankton in the Northern North Pacific Ocean in summer of 1958. Ibid., Vol. 12, No. 1, pp. 17–44.

MOTODA, S. and ANRAKU, M., 1951. An observation on the vertical distribution of plankton at Ishikari Bay, Hokkaido. Jour. Oceanogr. Soc. Japan, Vol. 6, No. 4, pp. 194–201. (In Japanese)

———&———, 1954. Daily change of vertical distribution of plankton animals near western entrance to the Tsugaru Strait, Northern Japan. Bull. Fac. Fish. Hokkaido Univ., Vol. 5, No. 1, pp. 15–19.

———&———, 1955. Further observation on the daily change in amount of catches of plankton animals in vertical hauls. Ibid., Vol. 6, No. 1, pp. 15–18.

MOTODA, S. and MARUMO, R., 1963. Plankton of the Kuroshio water. Proceed. Symp. on the Kuroshio, Oct., 29, 1963., pp. 40–61.

MINODA, T., 1958. Report from the "Oshoro Maru" on oceanographic and biological investigations in the Bering Sea and northern north Pacific in the summer of 1955. V. Observations on copepod community. Bull. Fac. Fish. Hokkaido Univ., Vol. 8, No. 4, pp. 253–263.

NAKAI, Z., et al, 1957. A preliminary report on the biological survey in the "Kuroshio" area, south of Honshu, June-July 1955. Oceanogr. Wsk. Japan, Spec. No., New Series, pp. 159–196.

ODATE, K., 1962. On the properties of zoo-plankton in the north-eastern sea region along the Pacific coast of Japan. Bull. Tohoku Reg. Fish. Res. Lab., No. 21, pp. 93–103. (In Japanese)

TANAKA, O., 1956–1965. The pelagic copepods of the Izu Region, middle Japan. Systematic account I–XIII. Publ. Seto Mar. Biol. Lab., Vol. 5, No. 2, pp. 251–272, Vol. 5, No. 3, pp. 367–406, Vol. 6, No. 2, pp. 169–207, Vol. 6, No. 3, pp. 327–367, Vol. 8, No. 1, pp. 85–135, Vol. 9, No. 1, pp. 139–190, Vol. 10, No. 1, pp. 35–90, Vol. 11, No. 1, pp. 7–55, Vol. 12, No. 1, pp. 1–37, Vol. 12, No. 1, pp. 39–91, Vol. 12, No. 3, pp. 231–271, Vol. 12, No. 5, pp. 379–408.

TSURUTA, A. and CHIBA, T., 1954. On the distribution of plankton at the fishing ground of Salmons in the North Pacific Ocean 1952. Jour. Shimonoseki Col. Fish., Vol. 3, No. 3, pp. 239–245. (In Japanese)