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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 Community¹⁾

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Introduction

Participating in the International Cooperative North Pacific Oceanographic Programme held in the summer of 1955 the training ship "Oshoro Maru" of the Faculty of Fisheries, Hokkaido University, made a cruise to the Bering Sea and northern portion of the North Pacific (Motoda & Fujii, 1956). Prof. S. Motoda was aboard the ship and conducted the research work at sea in this cruise. He placed a part of the plankton materials obtained in this cruise at the disposal of the author. The present studies are undertaken to observe the distribution figure of copepods which might be represented by gross pattern of hydrography.

The collection of zooplankton was made regularly at hydrographic stations by vertical hauls, usually from 150 metre depth to the surface with 45×165 cm net (0.33 mm mesh aperture); hauls were duplicated. A deep haul with 63×300 cm net (0.49 mm mesh aperture) was made at one station (Os 8) by making separate hauls with closing

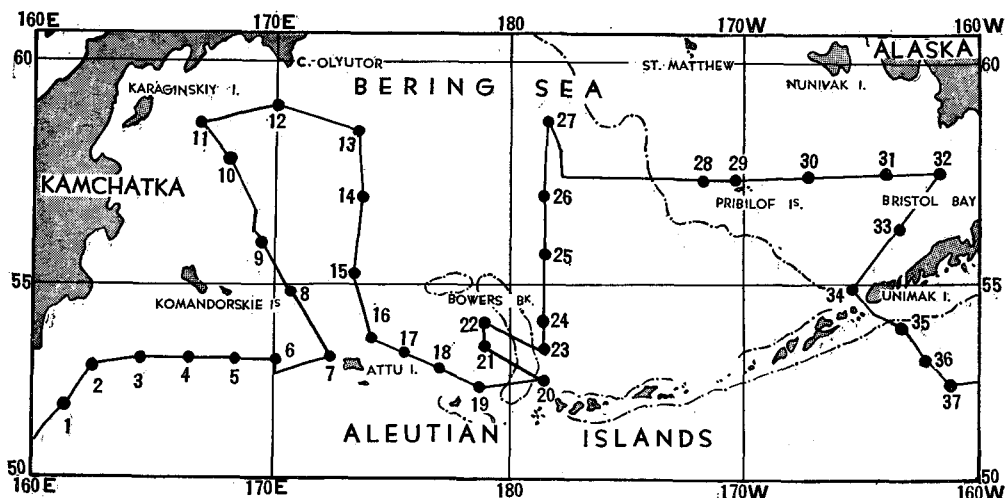


Fig. 1. Approximate location of sampling stations

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mechanism from 2000 to 1000 metres, from 1000 to 500 metres and 500 to the surface. In addition, deep hauls from usually 1000 metre depth with a couple of rectangular nets, "Twin Net" (10×10 cm at mouth, 50 cm long, 0.28 mm mesh aperture), were performed at every station. Detailed descriptions of the gear and methods of collections and of the exact location of stations are presented in the paper of Motoda and Fujii (1956); only a sketch map showing approximate location of stations is given here (fig. 1).

On this occasion the author wishes to express his sincere gratitude to Prof. S. Motoda not only for his generosity in providing the materials to the author but for his guidance throughout the present studies. He also expresses cordial thanks to Asst. Prof. T. Kawamura and Mr. M. Anraku for their valuable advices during the present studies. The writer is also obliged to the research members and crew of the "Oshoro Maru" in 1955 cruise for their work in sampling the materials at sea.

Results of Observations

The data on quantitative estimation on regular collections with 45×165 cm net are presented in "Data Record of Oceanographic Observations and Exploratory Fishing, No. 1, 1957". These data are concerned with wet displacement volume and wet weight of the materials, but in the present studies individual numbers of copepods are counted for each species (tables 1 & 2). As the net was not equipped with a flow-meter, exact filtration coefficient of the net was unknown, but the volume data were converted by assuming that the filtration coefficient of such net would be 0.76 (Motoda *et al.*, 1957). In addition, the error of hauling distance which may have happened in rough weather was corrected (Motoda *et al.*, 1957).

1) Copepod species identified

The copepod species identified from the materials of regular collections with 45×165 cm net are as follows:

- * *Calanus finmarchicus* (GUNNERUS)
- * *C. plumchrus* MARUKAWA
- * *C. cristatus* KRÖYER
- * *Eucalanus bungii bungii* JOHNSON
- * *Pseudocalanus elongatus* (BOECK)
- Microcalanus* sp.
- Aetideus armatus* (BOECK)
- Gaetanus armiger* GIESBRECHT
- * *Gaidius tenuispinus* (SARS)
- * *Pareuchaeta japonica* (MARUKAWA)
- ** *Racovitzanus antarcticus* GIESBRECHT
- * *Scolecithricella minor* (BRADY)

- *** *Centropages abdominalis* SATO
- * *Metridia lucens* BOECK
- ** *Pleuromamma scutullata* BRODSKY
- ** *Lucicutia ovaliformis* BRODSKY
- * *Candacia columbiae* CAMPBELL
- *** *Acartia longiremis* (LILLJEBORG)
- *** *Oithona plumifera* BAIRD
- *** *O. similis* CLAUS
- *** *Microsetella norvegica* (BOECK)
- Oncaea conifera* GIESBRECHT

A deep haul with 60³ × 300 cm net yielded 27 species, of which the following 11 species are never found in the above regular collections from the upper zone.

- * *Microcalanus pygmaeus* (SARS)
- ** *Spinocalanus spinipes* BRODSKY
- ** *Gaidius brevispinus* (SARS)
- * *Pareuchaeta birostrata* BRODSKY
- ** *Scaphocalanus magnus* (T. SCOTT)
- ** *Onchocalanus affinis* WITH
- ** *Amalothrix inornata* (ESTERLY)
- * *Scolecithricella ovata* (ESTERLY)
- ** *Metridia asymmetrica* BRODSKY
- ** *Heterorhabdus tanneri* (GIESBRECHT)
- * *Oncaea notopus* GIESBRECHT

In addition, deep hauls with a small "Twin Net" yielded the following additions to the above two kinds of collections:

- ** *Spinocalanus abyssalis* GIESBRECHT
- Scaphocalanus* sp.
- ** *Pachyptilus pacificus* JOHNSON
- ** *Arietellus simplex* SARS

The majority of the above-mentioned species are those which have been reported to be either the boreal (*) or abyssal (**) forms, but a few are forms (***) whose distribution is known to be neritic and world-wide.

Brief mention will be made here on several species whose names have been somewhat confused or whose distribution is especially interesting.

Calanus plumchrus MARUKAWA was first described by Marukawa (1921) as new to science, but the first record in Japanese waters was earlier published by Sato (1913) under the name of *Calanus* sp. They both observed only the immature specimens. The adult forms were found from the deep water (Yamada, 1938; Nakai, 1942; Motoda et

al., 1950; Anraku, 1954a, b). Brodsky (1938; 1948; 1950) stated that this species is synonymous to *Calanus tonsus* and he divided it to two forms, *plumchrus* and *typica*. Tanaka maintained the same opinion in his past paper (1954), but after that he (1956) proposed that *Calanus plumchrus* is distinct from *Calanus tonsus*.

According to Johnson (1939), *Eucalanus bungii bungii* JOHNSON is a northern variety of *Eucalanus bungii*, and a southern variety is *Eucalanus bungii californicus*. He stated that the former variety is distributed from the northern area of Japanese waters to the Bering Sea and the latter along the California coast, but var. *californicus* was reported by Tanaka (1953) in the deep water of Sagami Bay.

Pareuchaeta japonica (MARUKAWA) was originally described by Marukawa (1921) as *Euchaeta japonica*. Brodsky (1948; 1950) reported this species from the Japan Sea, Okhotsk Sea, Bering Sea and northern North Pacific. He followed the classification of A. Scott (1909) who divided family Euchaetidae into two genera, *Euchaeta* and *Pareuchaeta*. Mori (1937) stated that the variation between the two genera is obscure and gradual, and Davis (1949) had the same opinion.

Centropages abdominalis SATO was first reported by Sato (1913) near Hokkaido, Kii Channel and Terpeniye Bay of Sakhalin. Later this species was treated as a synonym of *Centropages mcmurrichi* WILLEY 1920 by Brodsky (1948; 1950). However, the publication of Sato (1913) was the earlier, so that *Centropages abdominalis* should be used. This species is distributed in the inland sea of Japan, Okhotsk and Bering Sea, Yellow Sea and southern area of Chukchee Sea (Brodsky, 1950), Arctic Ocean, northern area of Bering Straits, Bering Sea, Grantley Harbour, Alaska, Dixon Entrance and the area adjacent to Vancouver Island (Davis, 1949).

Spinocalanus spinipes, *Pareuchaeta birostrata*, *Metridia asymmetrica*, *Pleuromamma scutullata* and *Lucicutia ovaliformis* were reported by Brodsky (1950) from the northern North Pacific, Bering Sea and Okhotsk Sea. These species are oceanic, bathybic or abyssal.

2) Characteristic distribution of representative copepod species

It is reported that the water which originated from the Gulf of Alaska flows westward and turns northward into the Bering Sea passing through the Aleutian Chain. Some of this water passes out through the Bering Straits and some is flowing as a counterclockwise circulation in the Bering Sea. Along the eastern coast of Kamchatka Peninsula, a part of this current flows still farther southward and finally it is mixed with the water which has poured from the Okhotsk Sea, while another part of the water is thrust into the Subarctic Water and reached the Gulf of Alaska (Fleming, 1955; Mishima & Nishizawa, 1955).

Among the copepods collected, *Calanus finmarchicus*, *C. plumchrus*, *C. cristatus*,

Eucalanus bungii bungii, *Pseudocalanus elongatus*, *Metridia lucens*, *Acartia longiremis* and *Oithona similis* are numerically important.

All specimens of *Calanus plumchrus* in the samples of 45×165 cm net represent copepodid stages I to V, while the adult forms were usually collected by deep hauls with "Twin Net" and with 63 × 300 cm net. Off the east of Karaginskiy Island (Os 11), and off the southeast of Cape Olyutor (Os 13) and at Os 15, this species occupied the bulk of samples counting more than 200000 individuals per 1000 m³ of water, while in other stations (Os 2, 8-10, 12, 14, 16, 17, 21, 22, 24 and 26) the number of individuals was 100000 or more. At Os 4 and 5 off the southern part of Komandorskie Islands and at Os 28 and 29 in the shallow eastern Bering Sea, this species occurred to the number of about 5000 individuals per 1000 m³ of water. In shallow hauls on the continental shelf extending from Alaska (Os 28-30, 33 and 34) this species diminished gradually, but the adult forms were collected there in spite of shallow hauls, probably being brought in with water upwelling from the deep. No specimen of this species was collected at Os 31 and 32 in Bristol Bay.

Calanus finmarchicus appeared in considerable number replacing *C. plumchrus* in Bristol Bay. The number was counted as 3000000 individuals per 1000 m³ of water in one of the duplicate hauls at Os 31. In the west and central Bering Sea except neighbouring Bower's Bank this species disappeared in the samples of 150 metre vertical hauls as well as deep hauls.

Immature individuals of *Calanus cristatus* occupied the largest bulk of 45×165 cm net samples at Os 11 and 27, counting about 5000 to 9000 individuals per 1000 m³ of water. The number of individuals was between 100 and 5000 in the west and central Bering sea. In Bristol Bay (Os 30, 31 and 32) this species was not collected. The adult forms were sometimes collected only from the deep layer below 150 metre depth in the west and central Bering Sea.

Eucalanus bungii bungii occurred in extraordinary abundance at Os 16, 17 and 18, about 1500000 individuals per 1000 m³ of water, and at Os 11 and areas near Bower's Bank (Os 20, 22 to 26) the number was also very large. But no one was collected at Os 30 to 32. The adult forms were included in the samples of 150 metre vertical hauls at every station.

Pseudocalanus elongatus was widely distributed at all stations, the most numerous in Bristol Bay (Os 30 to 32), but comparatively less in number in the off-shore region of the Bering Sea and south of Alaska Peninsula.

Very abundant copepodids of *Metridia lucens* with a few adult forms were collected around Bower's Bank (Os 20 to 26) in 150 metre hauls. At Os 11 only copepodid stages were collected rather abundantly in 150 metre hauls, while many adult forms appeared in the deep "Twin Net" samples. This species become less in the southwestern

Bering Sea, *i. e.*, area south of Komandorskie Islands (Os 2 to 6), at Os 30 and 33. Neither copepodid nor adult occurred at Os 31 and 32.

Oithona similis occurred in the largest number off the eastern coast of Kamchatka (Os 2 and 11) in the 150 metre hauls, and diminished gradually to the offing. In the neighbourhoods of Near Islands, Bower's Bank and Bristol Bay except Os 32, it was comparatively increased in number.

Acartia longiremis was collected near Bower's Bank, Bristol Bay and Alaska Peninsula in 150 metre vertical hauls.

Scolecithricella minor was collected by 150 metre hauls in all stations except Os 29 to 32 in Bristol Bay.

Centropages abdominalis was collected at Os 1 off the east of Kamchatka and Os 33 to Os 36 near Unimak Pass.

Among copepods collected by the deep hauls with "Twin Net" and with 63 × 300 cm net, *Gaetanus armiger*, *Racovitzanus antarcticus*, *Pleuromamma scutullata* and *Lucicutia ovaliformis* were also sometimes collected by 150 metre vertical hauls. From upper 150 metre zone, *Gaetanus armiger* was collected near Bower's Bank (Os 20 and 21) and in the southern portion of Unimak Pass (Os 36), again *Racovitzanus antarcticus* in the west and central Bering Sea, and the southern portion of Unimak Pass, *Pleuromamma scutullata* at Os 10, 14, 20 to 22 and 35, and *Lucicutia ovaliformis*

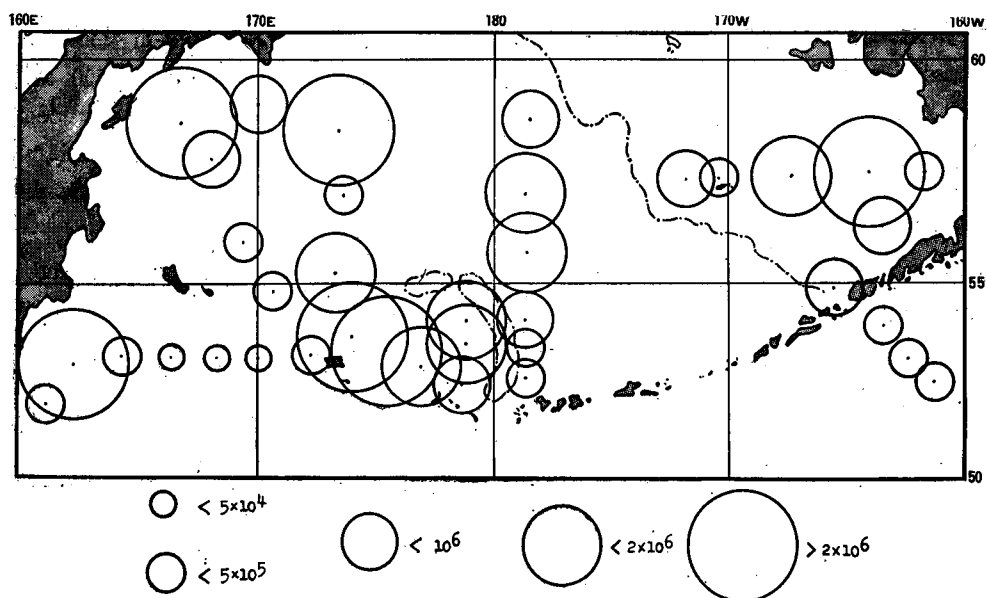


Fig. 2. Number of copepods occurring in upper 150 metre zone
(Individual numbers/1000 m³ of water)

at Os 9.

In the upper 150 metre zone, *Calanus plumchrus*, *C. cristatus*, *Eucalanus bungii*, *Metridia lucens* and *Oithona similis* were distributed normally and abundantly in the Bering Sea except Bristol Bay. They were as a whole the most abundant at Os 2, 11 and 13 off the east coast of Kamchatka and Os 16 and 17 off the northeast of Attu Island; comparatively abundant in the northern and western portions of Bower's Bank (Os 15, 18, 21, 22, 25 and 26) (fig. 2).

In Bristol Bay, the community of copepods, comprising mainly *Calanus finmarchicus*, *Pseudocalanus elongatus* and *Acartia longiremis*, was the most numerous at Os 31, with Os 30 following (fig. 2).

In the south of Unimak Pass, *Calanus plumchrus*, *C. cristatus*, *Eucalanus bungii* and *Metridia lucens* increased again, while *Calanus finmarchicus* decreased.

Discussion

In the present observation, so far as the upper zone (0-150 metres) is concerned, two divisions of distributional area of copepods are considered, that is, *Calanus plumchrus*—*Eucalanus bungii* area in the west and east Bering Sea, and *Calanus finmarchicus*—*Acartia longiremis* area in the eastern shallow Bering Sea (fig. 3).

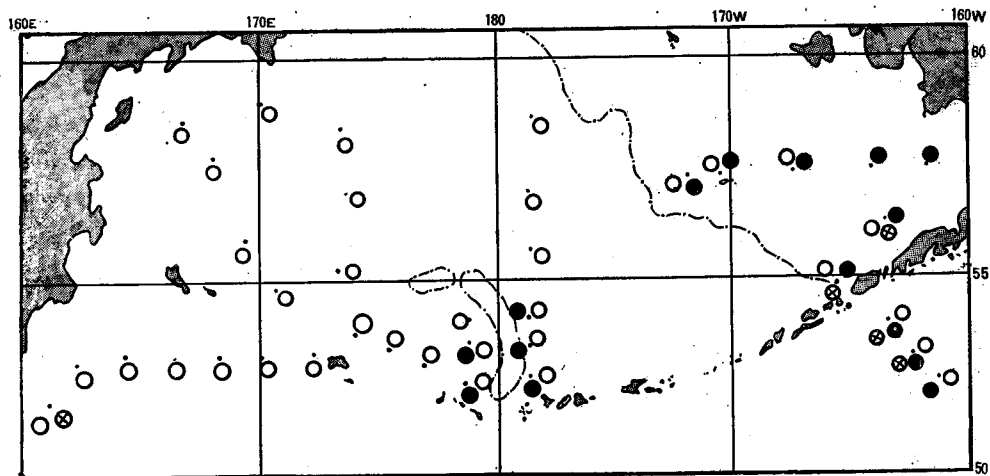


Fig. 3. Distribution figure of three types of copepod populations

- *Calanus plumchrus*—*Eucalanus bungii* population
- *Calanus finmarchicus*—*Acartia longiremis* population
- ⊗ *Centropages abdominalis*

Calanus plumchrus—*Eucalanus bungii* population nearly all consisting of copepodids and nauplii usually occurs in company with *Calanus cristatus* and *Metridia*

lucens. They are all oceanic forms. *Oithona similis*, eurythermic and euryhaline copepod form, is also included in these populations. The above population involving these species is widely distributed in the west and central Bering Sea making up the largest group off the east coast of Kamchatka and in western portion of Bower's Bank, but they are rare in the western area of the Near Islands. They are diminishing toward the inshore of Alaska and replaced by *Calanus finmarchicus*—*Acartia longiremis* population.

In the region to the west of the Pribilof Islands and adjacent to Unimak Pass a mixed population of *Calanus plumchrus*—*Eucalanus bungii* and *Calanus finmarchicus*—*Acartia longiremis* is observed.

Calanus finmarchicus—*Acartia longiremis* population is found only at Os 31 and 32 in Bristol Bay.

Johnson (1953) reported two communities in the eastern Bering Sea and in the Chukchee Sea; (1) a western community characterized by offshore deep-water species extends somewhat eastward just north of the Aleutian Islands, and northward through the Bering Straits on the Siberian side, (2) an eastern neritic community characterized by neritic or estuarine forms exists in the Pribilofs, Nunivak Island and off the Alaskan coast. According to Brodsky (1955), the population in the offshore of the southern Bering Sea is similar to the northern North Pacific population consisting of *Calanus tonsus*, *C. cristatus*, *Eucalanus bungii*, *Scolecithricella minor*, *Pareuchaeta japonica* and *Metridia pacifica*, extending to the Gulf of Alaska, to near southeastern Hokkaido and to the central Okhotsk Sea. The neritic population of eastern Bering Sea is extending along the Aleutian Chain to Near Islands. Vinogradov (1956) reported that the copepod population in the offshore of southern Bering Sea extends far to the Bering Straits and the population of the coastal region of west Bering Sea occurring abundantly in the Gulf of Anadir is extending far to the region adjacent to the Pribilof Islands; moreover, *Calanus tonsus* and *Eucalanus bungii* constitute characteristic southern population, and *Calanus finmarchicus* occurs in the population in the Gulf of Anadir.

In the area adjacent to Bower's Bank, copepods collected are only oceanic and bathybic forms (Anraku, 1954b), while diatom population is occupied by neritic forms (Motoda & Kawarada, 1955).

In the present cruise, it is considered that the water from the Pacific pouring into the Bering Sea is characterized by *Calanus plumchrus*—*Eucalanus bungii* population which are oceanic and bathybic forms, and the water in the eastern shallow Bering Sea is characterized by presence of *Calanus finmarchicus*—*Acartia longiremis* population which are boreal or neritic forms. The water in Bower's Bank, around the Pribilof Islands and in Unimak Pass are inhabited by the mixed populations of the above forms.

Summary

Regular samplings were made by 150 metre vertical hauls with 45×165 cm net and by 1000 metres or more deep hauls with a couple of $100 \text{ cm}^2 \times 50$ cm "Twin Net". A deep haul extending to 2000 metres was made with 63×300 cm net at one station. Thirty-seven species of copepods were identified from such collections.

So far as the upper 150 metre zone is concerned, *Calanus plumchrus*, *C. cristatus*, *Eucalanus bungii bungii*, *Scolecithricella minor* and *Metridia lucens* which are oceanic forms, are commonly distributed in the west and central Bering Sea, and in the southern offshore region of the Alaska Peninsula. *Calanus finmarchicus* and *Acartia longiremis* are distributed around Bower's Bank and in the eastern shallow Bering Sea. *Pseudocalanus elongatus* and *Oithona similis* are widely distributed in the Bering Sea and in the southern offshore region of the Alaska Peninsula. The distribution of *Centropages abdominalis* is restricted to the southern side of Kamchatka and waters adjacent to Unimak Pass.

In the upper zone of the Bering Sea, three areas are distinguished with respect to the copepod populations; that is, (1) *Calanus plumchrus*—*Eucalanus bungii* area in the west and central Bering Sea, (2) *Calanus finmarchicus*—*Acartia longiremis* area in the eastern shallow Bering Sea, (3) Mixed area of these forms around Bower's Bank, the Pribilof Islands and Unimak Pass.

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Table 2. Number of individuals (per 1000 m³ of water) of each species of copepoda occurring in separate vertical zone at station Os 8
(Error of filtration coefficient of the net is not corrected)

Species	500-0m	1000-500m	2000-1000m
<i>Calanus plumchrus</i> (adult)	928	13	13
" (copepodid)	3377	96	22
<i>C. cristatus</i> (adult)	19	58	10
" (copepodid)	600	232	
<i>Eucalanus bungii bungii</i> (adult)	2858	426	3
" (copepodid)	1109	84	6
<i>Pseudocalanus elongatus</i> (adult)	671	26	3
" (copepodid)	103	45	
<i>Microcalanus pygmaeus</i>		19	16
<i>Spinocalanus spinipes</i>	52	19	
<i>Gaidius tenuispinus</i>	52	45	13
<i>G. brevispinus</i>	103	71	10
<i>Gaidius</i> " copepodid	103		
<i>Gaetanus armiger</i>	180	32	3
<i>Pareuchaeta japonica</i>	19		3
<i>P. birostrata</i>	32	13	3
<i>Pareuchaeta</i> " copepodid	491	129	6
<i>Scaphocalanus magnus</i>	52	6	3
<i>Onchocalanus affinis</i>		13	
<i>Amalothrix inornata</i>	103	45	
<i>Racovitzanus antarcticus</i>	129		
<i>Scolecithricella minor</i>	516	32	6
<i>S. ovata</i>		19	
<i>Scolecithricella</i> " copepodid	77	142	
<i>Metridia lucens</i>	129	174	3
<i>M. asymmetrica</i>		206	16
<i>Metridia</i> " copepodid	2476	123	6
<i>Pleuromamma scutullata</i>	439	13	
<i>Lucicutia ovaliformis</i>	181	497	23
<i>Heterorhabdus tanneri</i>	52	581	
<i>Oithona similis</i>	491	194	61
<i>O. plumifera</i>		6	
<i>Microsetella norvegica</i>	26		
<i>Oncaea conifera</i>	491	155	6
<i>O. notopus</i>			10
Other copepodid stages	774	271	16
Copepod nauplii	155	45	6
Total	16788	3930	267