# Distribution of Plankton and its Characteristics in the Oceanic Fishing Grounds, with Special Reference to their Relation to Fishery※

By

Arao TSURUTA

(With 38 Tables and 66 Text-figures)

## Contents



※ Contribution from the Shimonoseki College of Fisheries, No. 385.
Received Dec. 10, 1962.

## Introduction

It is the recent trend of Japanese fishery that the business depression in the coastal fishery and the fishery in the adjacent waters of our country makes the fishermen seek for and stretch their fishing grounds to such waters as the Bering Sea, the South Pacific, the Indian Oceans or even to the Atlantic Ocean. To explore new fishing ground with high possibility of economic success, it is of basic importance to examine its capacity in relation to its availability. Furthermore, for the purpose of sustaining the maximum profitable yield from these newly explored fishing grounds, it is necessary to preserve the fishes of high economic importance from over-exploitation, by applying the scientific results obtained by both commercial and scientific investigations. Taking these into consideration, the author has endeavored to clarify the distribution of plankton and its characteristics in the oceanic fishing grounds, paying special attention to relation of plankton to the fishery.

The diatoms can be cited as the most representative members of phyto-plankton and the copepods among zoo-plankton to them. In the marine ecosystem, the diatoms are the producers which convert the abiotic substances into the biotic ones. Therefore, since some decades ago, the importance of their chrolophyll contents has been marked as the key material to the organic productivity in the ecosystem; but recently, advance in the nuclear physics makes it possible for us to estimate directly their photosynthetic activity by radio-active carbon, $C^{14}$. Since all the organisms defined as phyto-plankton have no locomotive ability, their lives depend on the physical and chemical properties of the environment, therefore, there is a restriction in their occurrence both in seasons and localities. This is the reason why the seasonal changes in the plankton compositions repeat some regular series what we call "plankton calender". On the other hand, the characteristic type of the phyto-plankton association can be applied, if the seasons and locations were restricted, as an indicator of the water mass. In these cases it is important that a better result can be expected when some characteristic plankton are employed as a group but not as an individual species.

The copepods, the richest members among zoo-plankton in quantity, are the most important as primary consumers in the marine ecosystem, and play the important role in converting the vegetable protein into the animal one, the latter being higher in nutritious value than the former. And this group of small crustaceans provide the food resources directly to the fish-fry, and the small fish, even to the whale. Meanwhile, zoo-plankton consist not solely of the copepods but of tremendous kinds of animals containing almost all the phyla of the animal kingdom. But they are weak swimmers when compared with nekton. The season, the location and the habitats of these zoo-plankton are rather restricted, according to the species; therefore, the detailed examination of the geographical distribution of these zoo-plankton reveals, as it is in the case of the phyto-plankton, the characteristics of the water masses.

In this article, the author tried to discuss on the representative composition and the distribution of plankton in the following four fishing grounds newly explored, and discussed the relations of plankton to the oceanographic conditions. And he also paid some special considerations on their significance of plankton to the fishery: a) Salmon fishing ground in the North Pacific Ocean and the waters around the Aleutian Islands, b) Trawling ground in the northeastern part of the Bering Sea, c) Tuna fishing grounds in the equatorial Pacific, and d) Five fishing grounds for tuna in the Indian Ocean.

## Acknowledgement

The author wishes to express his sincere thanks to Prof. Dr. O. TANAKA of Kyushu University for his kind guidance and criticisms given throughout this study. And his thanks are also due to Prof. Dr. S. MIYAKE (Kyushu University), Prof. Dr. S. MOTODA (Hokkaido University), Dr. T. TOKIOKA (Kyoto University), Dr. T. ITO (Prefectural University of Mie), Prof. Dr. T. YAMADA, Prof. Dr. H. IRIE (Nagasaki University), and Dr. Y. KOMAKI (Tokyo University), who so kindly gave him many kind advices and allowed him to use their valuable papers. To Prof. Dr. T. CHIBA, Prof. Dr. H. YOSHIDA and Prof. Dr. I. MATSUI of our university, the author's hearty thanks are expressed here for their kind guidance and unintermittent encouragement given him during this study. The assistance of collecting the samples used here, friendly advice and collaboration offered by the following staffs of our university are highly appreciated: Prof. Dr. R. ISHIYAMA, Dr. T. TAKAI, Dr. H. MAÉDA, and Messrs. T. SATOW, M. TAKASE, Y. ŌBA, O. HIRANO, S. TSUNODA, A. KATAOKA, M. KOCHI, S. TAGAWA, K. HAYAMA and captains (Y. SASAKI, K. KOMANO, S. MINAMI and G. SAKURAI), crew and cadets of the Shunkotsu-maru and Kōyō-maru, the research and training boats of our college. And some parts of samples are offered by the following alumnae, and these are also very helpful and useful in this study: Messrs. T. DEGUCHI and H. HIROTA (Nichiro Gyogyo Co., Ltd.), T. ISHIBASHI and M. WATANABE (Taiyo Gyogyo Co., Ltd.), S. MORITA (Kochi Prefectural Fishery Experimental Station), O. HORIKE and H. WATAUCHI (Miyazaki Prefectural Oceanic Fishery Experimental Station). Before closing this section, the author would like to appreciate Dr. H. MAÉDA (ecologist), Dr. H. KOBAYASHI (physiologist), Dr. S. NISHIKAWA (cytologist) and Dr. S. KUWABARA (chemist) for their own specialities.

## Material and method

The samples used here were collected on board the research and training boats, the Shunkotsu-maru and the Kōyō-maru, during the period May, 1952 ~ Jan., 1962.

The gears used for collection and the distribution of the sampling stations are shown in detail in each chapter. The samples were fixed with 5 % formalin solution immediately after the collection. After the identification of the species, the composition and relative abundance of each species were recorded; the individual number was recorded when possible. In the former case, the grade of relative abundance of each species was, for convenience' sake, represented by the following five symbols: CC…very common, C…common, +…present, R…rare and RR…very rare. Besides, the precipitation method was employed for micro-plankton. Some of the characteristic species of cold and warm waters were sketched by the aid of camera lucida of ABBE'S type.

# Part I The distribution of plankton and oceanographic conditions

## Chapter I The North Pacific Ocean and the Bering Sea

### I. Distribution of plankton in the North Pacific salmon fishing grounds

**1. Introduction**

Our North Pacific salmon fishery had been prevalent till 1940 or thereabout in the Kamchatka Peninsula and the Kurile Islands; but the spark of The Second World War interrupted its progress; and the closure of the war compelled us to resign these bases and these good fishing grounds with high economic value. After seven-years' blank, Japanese fishermen resumed the salmon fishery in the North Pacific, but the loss of the bases and the good fishing grounds along the coast changed the details of the operation, and we were obliged to operate in the high sea where it was very hard to expect a good catch as that of the past. The most of the catch were the red, the dog and the pink salmons; the silver and the king salmons were also found in the catch. But, the season, the distribution and the migration course of these salmons were different in each species. Nowadays, there may be no one who doubts about the rich stock of salmon and denies the success of this type of salmon fishery, although this was begun rather as a trial in 1952. The gears and the operation were improved and at the same time the commercial fishing grounds were extended year by year to the Bering Sea and the Okhotsk Sea. Thus, this new type of salmon fishery grew rapidly active in the recent several years.

In this new type of fishery, fishing grounds which were located far away from the base obliged us to employ the mother-ship type. Namely, the fish were, at first, caught by the catcher boats, and then they were brought to the mother-ship and canned, refrigerated or salted on her deck; and the transporters carried them back to the base.

Meanwhile, the America-Canada-Japanese and the Japanese-USSR treaties which control the high sea salmon fishery were established for the purpose of preventing the salmon resources from over-exploitation. These treaties are set on the fishing season, the fishing gear and the fishing area. The present closed fishing area includes the migration-course of the fishes and good fishing grounds such as the whole part of the Okhotsk Sea and some parts of the Bering Sea and even a part of the North Pacific. Moreover, the total landing, which was as much as 120 thousands tons before the establishment of the treaty, was reduced to the value not over a half of it.

The fishing season, during the period from May to August, is thought oceanographically to be the season when the waters derived from the cold Oyashio Current and those from the warm Kuroshio Current run and mixed against each other at this fishing ground, and planktologically to be the blooming season in such high latitudinal waters, and biologically to be the most active feeding season of the salmons. Accordingly, all the researchers emphasize the significance of the plankton not simply as the food resources to the fish but also from the oceanographic point of view. Therefore, it is natural that we should find such a lot of valuable papers on these problems published by MAÉDA (1953), NAKAI (1952), ANRAKU (1954), MOTODA and KAWARADA (1955), TAKANO (1956), MINODA (1958) and so forth.

The author had an opportunity to participate in the first operation in 1952 on board the Shunkotsu-maru and to collect the samples from some fifty stations distributed in such wide waters extending from the adjacent waters of the Aleutian Islands to those of the Kamchatka Peninsula. On the basis of these samples the author found the outline of the species composition and the distribution of plankton in these waters, and gave a preliminary consideration on the relation of plankton to the fishing conditions. And he had opportunities as the supervisor to examine the stomach contents of the salmons on board a mother ship, the Kyokko-maru.

## 2. Composition and distribution of the species

The samples were taken by the quantitative net of KITAHARA's type, which was the standard one in Japan, and was 25 cm in mouth-diameter, 1 m in length and constructed with Müller gauze No. 5. Besides, the closing net of NANSEN's type was also employed for sampling plankton separately in each 20 m in depth range. Figure 1 represents the locations of the sampling stations, and the date of sampling is shown in Table 1. The simplicity in the composition but the richness in quantity are the most remarkable characteristics of plankton found at each station. Dominant species in each taxonomical unit are summarized as follows:

| | |
|---|---|
| 1. Diatom | *Chaetoceros atlanticus*, *C. concavicornis*, *Corethron hystrix*, *Rhizosolenia hebetata*, *Thalassiothrix longissima*, *Coscinodiscus marginatus* |
| 2. Dinoflagellata | *Ceratium longipes* |
| 3. Tintinnoinea | *Ptychocylis obtusa*, *Parafavella jorgensenii*, *P. ventricosa* |
| 4. Medusae | *Aglantha digitale*, *Muggiaea atlantica* |
| 5. Polychaeta | *Tomopteris pacifica* |
| 6. Chaetognatha | *Sagitta elegans* |

| | |
|---|---|
| 7. Amphipoda | *Themisto japonica* |
| 8. Euphausiacea | *Thysanoessa raschii, Euphausia pacifica* |
| 9. Copepoda | *Calanus plumchrus, C. cristatus, Eucalanus bungii bungii, Oithona similis* |
| 10. Gastropoda | *Limacina helicina* |

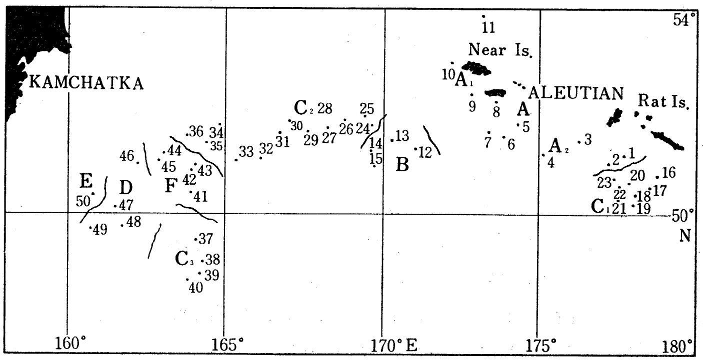



Fig. 1. Chart showing the sampling stations in the North Pacific salmon fishing grounds.

**A.** Phyto-plankton

In the phyto-plankton the relative abundance of species differed according to the stations, representing the characteristics of the sub-regions.

*Chaetoceros atlanticus* CLEVE : Abundant at Sts. 1～11, but rather common at Sts. 37～49, rare or very rare at other stations, especially almost absent at Sts. 41～45. In early July, especially dense population occurred in the waters along the Near Islands (Sts. 8～11), and changed the color of the water in yellowish brown.

*Chaetoceros concavicornis* MANGIN : Occurred in all over the stations. But most frequent at Sts. 8～23 and 46～49, common at Sts. 1～7, 24～40 and 50, but rare at Sts. 41～45.

*Chaetoceros radicans* SCHUTT : Extremely abundant at St. 50, which was the closest position to the Kamchatka Peninsula. It was present at Sts. 1～11, which were set along the Aleutian Islands. But it was rare or almost absent at the stations rather detached from the coast. This mode of distribution was reported by KOKUBO (1956), TAKANO (1956) and some other experts who mentioned that *C. radicans* was one of the neritic species in high latitude.

*Corethron hystrix* HENSEN : Distributed all over the stations, but densely at Sts. 1～7 and dilutely at Sts. 41～45.

*Coscinodiscus marginatus* EHRENBERG : Also distributed all over the stations, but densely at Sts. 1～7 and 46～50.

*Rhizosolenia hebetata* f. *hiemalis* GRAN : Absent at Sts. 41～50, but very less dense in such wide waters as Sts. 1～40, although common at Sts. 1～11.

*Nitzschia seriata* CLEVE : Common at Sts. 12～15 and 46～50, both of which were set in rather neritic waters. But rare at Sts. 1~11 and almost absent at other stations.

Besides, several species of *Chaetoceros*, *Thalassiosira* and *Rhizosolenia* were observed, but they were very few in quantity, moreover were rather restricted in the distribution to such waters as Sts. 1~11 and 50, each of which was set in rather on-shore.

From the distributions of diatoms mentioned above the fishing ground will be classified into the following some, perhaps six, sub-regions (*cf*. Fig. 1 & Table 1).

Sub-region A (Sts. 1~11) : This was characterized by the predominance of *Chaetoceros atlanticus*, and by the richness of species of neritic diatoms such as *Chaetoceros radicans*. But, rather a large gap in the density made it possible to subdivide this sub-region further into two parts: $A_1$ (Sts. 8~11) and $A_2$ (Sts. 1~7), the former was on-shore and densely populated with plankton and the latter was rather off-shore and had relatively diluted population.

Sub-region B (Sts. 12~15) : *Chaetoceros concavicornis* and *Corethron hystrix* were dominant in this sub-region; *Nitzschia seriata* was also dense in population. But the species composition of diatoms was far simpler than that in the sub-region A.

Sub-region C (Sts. 16~23: $C_1$, 24~36: $C_2$ and 37~40: $C_3$) : Although these three groups of stations somewhat separated geographically one another, the very close resemblance of the diatom composition in these three areas will indicate that the sub-region C covers these stations planktologically. All of them were predominated by *Coscinodiscus marginatus*, *Chaetoceros concavicornis* and *Corethron hystrix;* and the species composition was simple when compared with that of A and B.

Sub-region D (Sts. 46~49) : The characteristic of the diatom composition of this sub-region was the predominance of *Rhizosolenia hebetata* f. *semispina* and *Chaetoceros concavicornis*. But the composition resembled that of B in respect to the dense population of *Nitzschia seriata* and the richer diatom flora than that of C.

Sub-region E (St. 50) : The diatom composition of this sub-region resembled that of A in respect to the predominance of *Chaetoceros radicans* and the richness of the neritic species. But it was one of the most notable differences in the diatom composition between this sub-region and A that *Chaetoceros atlanticus* was poor in this sub-region in contrast with the fact that this species dominated in the sub-region A.

Sub-region F (Sts. 41~45) : This sub-region was characterized by the poorest diatom flora with the lowest density; consequently, any diatom could hardly be found except *Coscinodiscus marginatus*, which was rather abundant, and *Chaetoceros concavicornis* and *Thalassiothrix longissima*, which were far less in quantity.

**B.** Zoo-plankton

Table 1 was made for the purpose of clarifying the questions whether there was any characteristic type of zoo-plankton composition corresponding to each of the sub-regions classified above by the composition of diatoms, and if such sub-regions were present, what type of zoo-plankton could be found in each of these sub-regions. It was, of course, very natural that the distribution of Dinoflagellata and Tintinnoinea, coincides with that of diatoms: *i.e.*, in the sub-regions where diatoms were dense, they were rich not only in species but also in quantity, but poor in the other regions where diatoms were poor. For other groups of zoo-plankton, there were no remarkable differences among them in those sub-regions in the density and in the composition of the species which were so simple throughout the sub-regions.

Table 1. Relative abundance of plankton in each sub-region in the North Pacific salmon fishing grounds.

| Sub-region | $A_1$ | $A_2$ | B | $C_1$ | $C_2$ | $C_3$ | D | E | F |
|---|---|---|---|---|---|---|---|---|---|
| Station | 8～11 | 1～7 | 12～15 | 16～23 | 24～36 | 37～40 | 46～49 | 50 | 41～45 |
| Date | 6～7 June | 7～25 June | 26～28 June | 29 May ～ 1 July | 25June ～ 1 July | 9～27 July | 22 July | 27 July | 11～19 June |
| Surface water temperature (°C) | 4.8～5.0 | 5.0～5.9 | 5.5～6.2 | 4.5 | 5.0～6.2 | 6.2～7.6 | 9～10 | 9.4 | 6.8～9.5 |
| Average temperature at 100 m-depth (°C) | 3.0 | 4.0 | 3.3 | 3.4 | 2.6 | 2.7 | 1.4 | 1.7 | 1.4 |
| Transparency (m) | 6～10 | 10 | 10～15 | 15 | 12～16 | 14～16 | 14 | 6.5 | 12～14 |
| Water color | 5～6 | 4～5 | 4 | 3～4 | 3～4 | 3～4 | 4 | 6 | 3 |
| Phyto-plankton | | | | | | | | | |
| *Chaetoceros atlanticus* | CC | C | + | R | R | + | + | R | — |
| *C. concavicornis* | C | + | C | C | + | + | C | + | R |
| *C. radicans* | + | + | — | — | — | — | — | CC | — |
| *C. decipiens* | R | R | — | — | — | — | — | R | — |
| *C. debilis* | RR | RR | — | — | — | — | — | C | — |
| *Corethron hystrix* | + | CC | + | + | + | + | + | + | RR |
| *Rhizosolenia hebetata* f. *hiemalis* | + | + | R | R | R | R | RR | — | — |
| *R. hebetata* f. *semispina* | RR | C | RR | RR | — | — | C | + | — |
| *R. alata* f. *gracilima* | RR | RR | RR | RR | — | — | R | R | — |
| *R. imbricata* | RR | RR | RR | — | RR | — | + | + | RR |
| *Thalassiothrix longissima* | R | + | RR | R | RR | RR | + | + | R |
| *Thalassiosira* sp. | RR | RR | — | — | — | — | RR | RR | — |
| *Coscinodiscus marginatus* | + | C | + | + | C | CC | C | + | C |
| *Nitzschia seriata* | R | RR | + | — | — | — | C | + | — |
| *Denticula marina* | RR | R | R | R | RR | R | RR | RR | RR |
| Zoo-plankton | | | | | | | | | |
| *Peridinium roseum* | RR | RR | — | RR | — | — | — | + | R |
| *P. excentricum* | — | — | — | — | — | — | — | + | R |
| *Ceratium longipes* | R | R | + | RR | RR | RR | RR | + | RR |
| *C. lineatum* | RR | RR | RR | — | RR | RR | R | R | — |
| *C. fusus* | RR | RR | RR | — | RR | RR | R | — | RR |
| *C. tripos* var. *atlanticum* | RR | RR | RR | RR | — | — | — | — | — |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Acanthostomella norvegica* | RR | R | RR | RR | — | — | RR | — | — |
| *Ptychocylis obtusa* | RR | R | + | RR | + | R | R | R | R |
| *Parafavella subrotendata* | RR | R | RR | RR | R | — | + | — | — |
| *P. jorgensenii* | RR | R | + | RR | + | RR | + | R | — |
| *P. ventricosa* | R | RR | + | R | R | R | — | R | — |
| *Codonellopsis frigida* | RR | RR | RR | — | RR | — | — | RR | — |
| *Proplectella columbiana* | — | — | — | RR | RR | RR | R | R | RR |
| *Salpingella* sp. | — | — | — | — | — | RR | RR | R | — |
| *Oithona similis* | CC | CC | CC | CC | CC | CC | CC | CC | CC |
| *Microsella rosea* | R | R | R | R | R | R | R | R | + |
| *Oncaea conifera* | R | R | R | RR | R | R | R | R | R |
| *Pseudocalanus elongatus* | RR | + | R | R | R | R | R | R | + |
| *Scolecithricella minor* | — | — | RR | RR | — | — | RR | — | RR |
| *Metridia lucens* | R | + | + | — | + | + | R | — | — |
| *Gaetanus armiger* | — | — | — | — | RR | RR | RR | — | — |
| *G.* sp. | RR | — | — | — | — | — | — | — | — |
| *Pleuromamma robusta* | — | + | RR | — | R | R | — | — | R |
| *Scaphocalanus echinautus* | — | RR | RR | — | — | — | — | — | RR |
| *Euchaeta japonica* | — | RR | — | — | — | RR | — | — | — |
| Nauplius stage of copepods | C | C | C | CC | C | C | C | C | C |
| Fish eggs | R | R | R | RR | RR | RR | R | + | RR |
| Trochophore | RR | RR | RR | — | RR | RR | — | — | — |

As a measure of food supply for the salmons, the individual numbers of macro-plankton per haul in each sub-region are illustrated in Table 2. Here, the word, "macro-plankton" was, for convenience' sake, employed to represent zoo-plankton larger than 2 mm in length; because those smaller than this may be almost unavailable to the salmons as an excellent food. The most frequent species was *Calanus plumchrus* and this occupied more than a half of the total amount. The next one was *Eucalanus bungii bungii*, and this was found increasingly in the sub-regions E, D and $C_3$. Some attention should be paid to the fact that *Calanus cristatus*, the largest copepod in size, occurred extremely abundantly in the sub-region F, where the poorest diatom population could be found. As for Euphausiacea, it was very hard to get the data with available accuracy through the collection with such a small net as KITAHARA'S type, because Euphausiacea have rather a strong ability of swimming. Therefore, it is very probable that the data represented in the table are too low in quantity. In the sub-regions $C_2$ and F, there were rich amphipods, some of the specimens had each some ten nauplii on their ventral side. Abundant *Sagitta* were found in the sub-regions E and $C_3$, though they were present in small quantity throughout the stations. Besides, it may be worth while to mention, appendantly, that 20 and 23 individuals of cod young were present in Sts. 9 and 10 (sub-region A); from this fact it is probable that this area may be the spawning ground of cod.

It is well-known fact that the vertical distribution of each species of zoo-plankton and its daily rhythmic change differ more or less depending upon the species. To

Table 2. Density and composition of macro-plankton in each sub-region.

| Sub-region | $A_1$ | $A_2$ | B | $C_1$ | $C_2$ | $C_3$ | D | E | F |
|---|---|---|---|---|---|---|---|---|---|
| Mean of individuals per haul | 162 | 274 | 256 | 208 | 297 | 396 | 405 | 518 | 376 |
| Macro-plankton (%) | | | | | | | | | |
| *Calanus plumchrus* | 45.93 | 65.98 | 49.55 | 56.58 | 57.97 | 46.14 | 46.80 | 18.80 | 42.47 |
| *C. cristatus* | 8.52 | 7.91 | 3.12 | 6.09 | 1.98 | 2.45 | 10.51 | 4.46 | 24.57 |
| Others of *Calanus* | 8.77 | 6.33 | 12.48 | 19.80 | 13.72 | 12.05 | 13.77 | 11.08 | 9.74 |
| *Eucalanus bungii bungii* | 9.38 | 8.09 | 19.38 | 7.63 | 8.15 | 26.44 | 21.26 | 46.75 | 14.16 |
| *Euphausia* and *Thysanoessa* | 0.74 | 1.10 | 0.52 | 0.78 | 1.14 | 0.61 | — | 0.77 | 1.03 |
| *Themisto japonica* | 0.62 | 3.78 | 0.26 | 3.66 | 10.77 | 1.33 | 2.22 | 1.16 | 4.18 |
| *Conchoecia elegans* | 7.25 | 0.24 | 0.65 | 0.48 | 0.79 | 0.15 | — | — | 0.15 |
| *Sagitta elegans* | 6.54 | 1.40 | 5.98 | 0.96 | 1.19 | 7.11 | 3.46 | 11.05 | 1.28 |
| Polychaeta | 0.49 | 0.61 | 0.78 | 0.48 | 0.84 | 0.90 | 0.49 | 0.58 | 0.25 |
| Medusae | 2.35 | 2.68 | 5.32 | 1.62 | 1.87 | 1.36 | 0.87 | 2.32 | 0.59 |
| Fish-larvae | 3.09 | 0.06 | — | — | — | — | — | — | 0.05 |
| *Limacina helicina* | 1.97 | 0.73 | 1.95 | 1.80 | 1.53 | 1.06 | 0.62 | 0.39 | 1.08 |
| Zoea | 1.60 | 0.30 | — | — | — | 0.04 | — | 0.70 | 0.25 |
| *Oikopleura* spp. | 9.75 | 0.79 | — | 0.12 | 0.05 | 0.36 | — | 1.94 | 0.20 |

Note : The word employed here, macro-plankton, represents the zoo-plankton larger than 2 mm in length.

clarify these facts in this region, the vertical distributions of zoo-plankton were examined at 18.00, 22.00, 03.00, 05.00 and 08.00 on 23~24 of July at the station 51°15' in north latitude and 163°00' in east longitude. It was hard to give any reasonable discussion on account of the incorrectness derived from the small number of the specimen collected. But the general features of vertical distribution of the

Table 3. Vertical distribution of the zoo-plankton.

| Frequent species | Total number | Depth in meter | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0~20 | 20~40 | 40~60 | 60~80 | 80~100 | 100~120 | 120~140 | 140~ |
| *Calanus cristatus* | 102 | 6.9% | 76.5% | 8.8% | 5.9% | 1.9% | —% | —% | —% |
| *C. plumchrus* | 166 | 84.4 | 9.0 | 4.8 | 1.2 | 0.6 | — | — | — |
| *C.* young (copepodite stage) | 544 | 32.2 | 18.8 | 36.5 | 8.7 | 6.8 | 2.0 | — | — |
| *Eucalanus bungii bungii* | 300 | 1.0 | 9.0 | 17.4 | 12.3 | 24.3 | 19.0 | 10.0 | 7.0 |
| *Themisto japonica* | 497 | 88.5 | 8.7 | 2.6 | 0.2 | — | — | — | — |
| *Sagitta elegans* | 27 | 70.4 | 14.8 | 7.4 | 3.4 | 3.4 | — | — | — |
| *Limacina helicina* | 67 | 46.3 | 34.3 | 14.9 | 4.5 | — | — | — | — |
| Zoea | 5 | + | + | — | — | — | — | — | — |
| *Pseudocalanus elongatus* | 109 | 60.6 | 34.9 | 4.5 | — | — | — | — | — |
| *Euphausia pacifica* | 4 | — | — | + | + | + | — | — | — |
| *Pleuromamma robusta* | 11 | — | — | 27.3 | 27.3 | 27.3 | 9.1 | 9.0 | — |
| *Oithona similis* | 131,200 | 55.9 | 15.4 | 21.5 | 4.9 | 2.3 | — | — | — |
| Copepoda nauplii | 65,200 | 48.2 | 13.5 | 27.9 | 8.6 | 1.8 | — | — | — |

Note : The sign "+" indicates the value not exceeding 0.1 %.

frequent species were, neglecting the daily rhythmic change, represented in Table 3. The majority of zoo-plankton were rich in the waters shallower than 60 m deep and especially they increased with the decrease in depth. This vertical distribution was thought to be affected by the presence of the thermocline at 100 m deep, below which the cold water mass of 1~2°C in temperature was prevalent. *Eucalanus bungii bungii* and *Pleuromamma robusta* distributed most densely at 100 m layer or thereabout. The above-mentioned facts will indicate that the rich population of macro-plankton is found in the shallower layer than 60 m deep and they are important food resources to the salmons.

## 3. Consideration

These six sub-regions of the surveyed area were suggested from the distribution of diatoms. However, it may be rather hard to suppose that the results are quite free from the error due to the difficulty of collecting the samples according to the well-designed schedule which was disturbed by the ship's duty and by the successive occurrence of rough sea during the observation. Generally speaking, the dense diatom population was found in the neritic waters but diatom was poor in the off-shore waters, because the majority of the population consisted of rather neritic species which propagated explosively with the rise of the water temperature.

The waters under discussion are the mixing region of the cold Oyashio water mass and the warm Kuroshio current; and it is rational to employ the densities of warmer species and cold ones as the indicators of the mixing area of these two water masses with quite different nature. According to AIKAWA (1932), the waters from the Oyashio current are rich in *Chaetoceros atlanticus, Thalassiothrix longissima, Denticula* sp., *Calanus plumchrus, Oncaea conifera, Parafavella* sp., *etc.*, whereas the following species are rich in the Pacific water masses: *Chaetoceros criophilum, Nitzschia seriata, Eucalanus bungii bungii, Codonellopsis morchella, etc.* According to AIKAWA and the author's present results the mixing area of these two water masses is found in the sub-regions A, B and C, and a slight prevalence of the Pacific one in the sub-regions D, E and F.

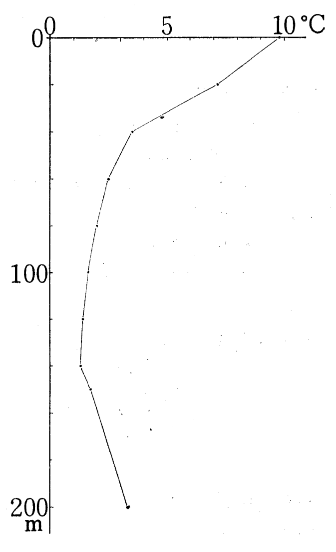


Fig. 2. Vertical distribution of water temperature.

In early June, it was highly possible that the sub-region $A_1$ is a good fishing ground, as the rich fish larvae and juvenile squids prevent the salmons to pass quickly from this sub-region. But, in early July, there occurred an explosive propagation of *Chaetoceros atlanticus* and *C. radicans* and this perhaps prevented the salmons to migrate into this sub-region. The sub-regions D and E were good fishing grounds in July. The surface layer of these sub-regions was then rich in zoo-plankton, being influenced by the presence of the cold water mass (below 1.5°C) at 100 m deep or thereabout in these regions; in addition to this, these regions were fortunately on the migrating course of the salmons; furthermore, the food habits of the salmons suggest the possibility of their schools staying longer in these regions for feeding. From the distribution of zoo-plankton, thus, it is not easy to find out some of the reasons why the good fishing grounds were formed in the sub-regions D and E.

## II. The results on the test-trawling in the Bering Sea, with reference to the distribution of plankton

### 1. Introduction

The improvement in the equipment of fishing boats under the following adversities accelerated the recent rapid development of the trawling in this water.

1) Redistribution of catchers of the mother ship type fishery for salmons in the North Pacific being subjected to the restriction of the Japan-USSR fishery treaty

2) High possibility of this water as an excellent fishing ground in the off-season of the trawling in the East China Sea and the Yellow Sea, which are the famous trawl fishing grounds but are now depressed even in the fishing season.

The trawl in the Bering Sea aims chiefly at the soles, the cods and the shrimps and brings back the catch as the frozen ones or the fish meal.

The following facts were obtained as a part of the results of the exploration entrusted by Japanese Fishery Agency to the Kōyō-maru, in June, 1961, in an attempt to estimate the economic value of the new trawling ground in the northeast of the Bering Sea. The author has had an opportunity to participate in this exploration and examined the characteristics of the composition of catches in relation to the environmental conditions and also get some knowledge on the characteristics of plankton in this fishing ground.

It was hard to find any report on plankton in this water, but fortunately the author can refer to some papers of some predecessors who investigated the characteristics of plankton in the adjacent waters. For examples, MOTODA *et al.* (1959) had studied on the plankton in the waters adjacent to the eastern and southern parts of this surveyed water, on board the Oshoro-maru of Hokkaido University in August, 1956; in addition to this, some works had been done by KAROHIJI (1958 & '59), MINODA (1958), KAWARADA (1957 & '59), IIZUKA and TAMURA (1958).

### 2. Test-trawling in the Bering Sea

**A.** Method and record on the trawling

The trawling tests were done during the period from May 31 to June 10 at the stations shown in Fig. 3.

Table 4. Data on test trawling in the Bering Sea.

| Station | | | Date 1961 | Depth (m) | Bottom character | Water temperature (°C) | | Weather | Wind | | Temperature (°C) | Time of net cast | Duration of net haul(hour) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Lat. (N) | Long. (W) | | | | Surface | Near sea bottom | | Direction | Force | | | |
| 1 | 60°31′2″ | 179°45′0″ | May 31 | 100 | Small sand | 0.4 | 0.98 | b | NW | 2 | 2.2 | 13 05 | 1.4 |
| 2 | 62°26′0″ | 178°36′0″ | June 1 | 105 | Green mud | 0.4 | 0.4 | b | N | 2 | 2.2 | 07 40 | 1.0 |
| 3 | 62°58′0″ | 178°26′0″ | 1 | 98 | Green mud | 1.0 | 0.2 | b | NNW | 2 | 3.5 | 13 05 | 1.4 |
| 4 | 62°56′0″ | 177°22′0″ | 1 | 97 | Green mud | 1.1 | 0.1 | b e | N | 3 | 3.5 | 18 55 | 1.5 |
| 5 | 60°29′0″ | 176°32′0″ | 3 | 134 | Sandy mud | 2.2 | 0.3 | b | SE | 2 | 1.5 | 17 50 | 1.3 |
| 6 | 60°37′0″ | 175°25′0″ | 3 | 113 | Sandy mud | 0.8 | 0.8 | b e | SE | 4 | 1.3 | 06 41 | 1.3 |
| 7 | 60°41′0″ | 174°25′0″ | 4 | 95 | Sandy mud | 1.1 | −1.7 | o | E | 4 | 2.2 | 13 07 | 1.4 |
| 8 | 60°13′0″ | 173°07′0″ | 4 | 62 | Sandy mud | 0.6 | −1.6 | o | SE | 4 | 1.8 | 07 05 | 1.0 |
| 9 | 59°39′0″ | 172°40′0″ | 4 | 95 | Sandy mud | 1.5 | 0.3 | o | SE | 4 | 3.0 | 12 17 | 1.6 |
| 10 | 59°17′0″ | 173°04′0″ | 5 | 103 | Sandy mud | 2.0 | −0.8 | o | SE | 4 | 3.0 | 18 00 | 1.2 |
| 11 | 58°38′0″ | 173°23′0″ | 5 | 121 | Sandy mud | 2.9 | 1.5 | d | E | 4 | 3.8 | 07 58 | 1.5 |
| 12 | 58°09′5″ | 173°31′0″ | 5 | 116 | Small sand | 4.4 | 1.9 | b e | ESE | 3 | 5.4 | 13 40 | 1.3 |
| 13 | 57°54′0″ | 173°44′0″ | 6 | 114 | Small sand | 4.7 | 3.2 | o | E | 4 | 4.7 | 17 39 | 1.4 |
| 14 | 57°58′0″ | 172°21′0″ | 6 | 110 | Sandy mud | 4.4 | 1.2 | o | — | 0 | 5.3 | 07 05 | 1.2 |
| 15 | 58°02′5″ | 171°18′0″ | 6 | 96 | Sandy mud | 5.2 | 1.2 | b | NNE | 2 | 5.7 | 12 50 | 1.2 |
| 16 | 57°59′0″ | 170°39′0″ | 7 | 82 | Sandy mud | 4.6 | 0.5 | b | N | 4 | 5.8 | 18 00 | 1.2 |
| 17 | 58°41′0″ | 170°41′0″ | 7 | 78 | Green mud | 2.9 | −0.5 | f | WNW | 6 | 1.5 | 06 30 | 1.7 |
| 18 | 59°08′0″ | 170°27′5″ | 8 | 73 | Green mud | 2.3 | −0.18 | o | W | 5 | 2.5 | 12 10 | 1.5 |
| 19 | 61°00′0″ | 170°08′0″ | 8 | 50 | Sandy mud | 1.9 | −0.59 | e | WNW | 5 | 2.1 | 06 40 | 1.2 |
| 20 | 60°54′0″ | 171°10′0″ | 8 | 60 | Sandy mud | 2.1 | −1.65 | b e | NW | 5 | 3.7 | 11 35 | 1.6 |
| 21 | 60°50′0″ | 171°46′0″ | 9 | 65 | Sandy mud | 1.8 | −1.65 | f | W | 5 | 1.5 | 17 12 | 1.2 |
| 22 | 62°41′5″ | 172°07′05″ | 9 | 50 | Green mud | 2.1 | −1.70 | o | W | 5 | 1.9 | 10 55 | 1.1 |

The trawling net with head rope of 45.6 m long (wing: 6.0 m, center: 6.08 m), ground one of 57.6 m long (wing: 25.76 m, center: 6.08 m) and bolti line of 79 m long (wing: 31.5 m, center: 16.0 m) was employed as the testing gear. But in the actual operation, the head rope was elongated to 50.4 m long in an attempt to open the mouth wider than the ordinary one by the aid of a piece of net of a triangular form. The cod of 82.5 mm (4 Sun) in mesh size being knitted by the fibers of 180 textiles of 380 deniers was reinforced with four lengthwise and three crosswise wires enclosed by the Manila twine.

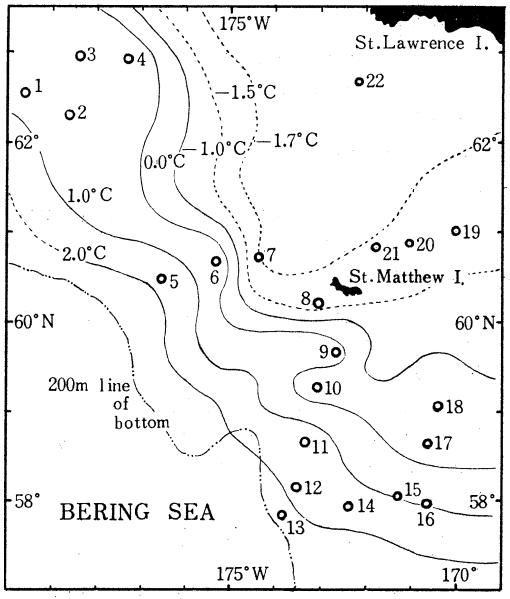



Fig. 3. Location of trawling (open circle) in the Bering Sea and horizontal distribution of water temperature at the depth near sea bottom (solid and broken lines).

The details of the operation and the oceanographic conditions at each station are represented in Table 4, but the warp length is not shown in this table since it is regulated to be 3.5~4.0 times as long as the depth. The composition in catch was examined haul by haul; then each 20 specimens of available animals caught abundantly were sampled at random and their body lengths (or in some cases carapace length) and body weights were measured; and as for the fish, the scale sampling, the sex and the gonad weighing were added.

**B.** Results of the operation

The species names of the captured animals are listed up in Table 5. Among those which are of economic value, the following species of fish and crustaceans were caught abundantly. Fishes: yellow-fin sole, halibut, Alaska pollack, Alaska cod, skate and rose-fish (or *Sebastes alutus* in scientific name), Crustaceans: "Zuwai" crab, king crab and pink shrimp.

Table 5. List of fishes and invertebrates caught by trawling in the Bering Sea.

| Scientific name | English name | Japanese name |
|---|---|---|
| Rajidae | Skate | Gangi-ei-rui |
| *Breviraja parmifera* (BEAN) | | Tsuno-kasube |
| Clupeidae | | Nishin-rui |
| *Clupea pallasii* CUVIER & VALENCIENNES | Herring | Nishin |

| | | |
|---|---|---|
| Osmeridae | Smelt | Kyuri-uo-rui |
| *Osmerus dentex* STEINDACHNER | | Kyuri-uo |
| *Mallotus catervarius* (PENNANT) | | Karafuto-shishamo |
| Zaproridae | | Bozu-ginpo-rui |
| *Zaprora silenus* JORDAN | | Bozu-ginpo |
| Zoarcidae | Eel pouts | Genge-rui |
| *Lycodes raridens* TARANETZ & ANDRIASHEV | | |
| *Lycodes palearis* GILBERT | | Hakusen-gazi |
| Scorpaenidae | | Fusa-kasago-rui |
| *Sebastes melanops* (GIRARD) | | |
| *Sebastes alutus* GILBERT | Rose-fish | Alaska-menuke |
| Gadidae | | Tara-rui |
| *Gadus macrocephalus* TILESIUS | Alaska cod | Ma-dara |
| *Theragra chalcogramma* (PALLAS) | Alaska pollack | Suketo-dara |
| *Eleginus gracilis* (TILESIUS) | Northern cod | Komai |
| Anoplopomidae | | Gin-dara-rui |
| *Anoplopoma fimbria* (PALLAS) | | Gin-dara |
| Cottidae | Sculpin | Kazika-rui |
| *Hemilepidotus gilberti* JORDAN & STARKS | | Yokosuzi-kazika |
| *Myoxocephalus stelleri* TILESIUS | | Isago-kazika |
| *Myoxocephalus jaok* (CUVIER & VALENCIENNES) | | Oku-kazika |
| *Myoxocephalus polyacanthocephalus* (PALLAS) | | Toge-kazika |
| *Dasycottus setiger* BEAN | | Ganko |
| *Gynocanthus galeatus* BEAN | | Chikame-kazika |
| *Hemitripterus americanus americanus* (PALLAS) ? | | |
| Agonidae | Sea poacher | Tokubire-rui |
| *Podothecus veternus* JORDAN & STARKS | | Onaga-tokubire |
| *Podothecus acipenserinus* (TILESIUS) | | |
| Liparidae | Rock sucker | Kusa-uo-rui |
| *Liparis megacephalus* (BURKE) | | |
| Pleuronectidae | | Karei-rui |
| *Atheresthes stomias* (JORDAN & GILBERT) | Arrow-toothed halibut | Alaska-abura-garei |
| *Atheresthes evermanni* JORDAN & STARKS | | Abura-garei |
| *Reinhardtius hippoglossoides* (WALBAUM) | | Ezo-karasu-garei |
| *Hippoglossus stenolepis* SCHMIDT | Halibut | Ohyo |
| *Hippoglossoides robustus* GILL & TOWNSEND | | Doro-garei |
| *Limanda aspera* (PALLAS) | Yellow-fin sole | Rosuke-garei |
| *Limanda sakhalinensis* HUBBS | | Karafuto-garei |
| *Pleuronectes pallasii* STEINDACHNER | | Tsuno-garei |
| *Chinoecetes opilio* O. FABRICIUS | "Zuwai" crab | Zuwai-gani |
| *Paralithodes camtschatica* TILESIUS | King crab | Taraba-gani |
| *Erimacrus isenbeckii* BRANDT | | Ke-gani |
| *Pandalus borealis* KROYER | Pink shrimp | Hokkoku-aka-ebi |
| Other Decapoda | Shrimp | Ebi-rui |

| | | |
|---|---|---|
| Tunicata | Sea squirt | Hoya-rui |
| *Gorgonocephalus caryi* LYMAN | Basket fish | Okino-tezuru-mozuru |
| *Neptunea heros* (GRAY) | | |
| Pelecypoda | Bivalve | Nimai-gai-rui |
| Egg mass of Naticidae | Naticid egg mass | Suna-jawan |
| Asteridae | Starfish | Hitode-rui |

Table 6 represents the catch compositions of the available animals at each station. From this table, it becomes clear that the composition and the total amount of the catch vary with the location of the station; and this suggests that available species occupy the different habitats; *i.e.*, for example, the northwestern parts (Sts. 1~7) are chiefly occupied by *Hippoglossoides robustus*, though the species is caught not abundantly; but in the southerly stations (from 8 to 10) it is substituted by *Atheresthes stomias* and *A. evermanni*; and if we proceed farther south (from Sts. 11 to 16), *Limanda aspera* and *Hippoglossus stenolepis* gradually take the place of *Atheresthes*, and during the course of this southward transition the total catch increases rapidly, too.

Alaska pollack (or *Theragra chalcogramma* in scientific name) and Alaska cod (or *Gadus macrocephalus* in scientific name) were caught abundantly chiefly in the southern waters (Sts. 11, 14 & 15).

At St. 13, the net was broken by the large cluster of barnacle attached on the reef; accordingly, most of the catch were lost. In spite of the accident about 1.5 ton or thereabout of rose-fish were hauled up; and it was not hard to suppose that the total catch may not be poorer than 10.0 tons when the net was not broken. But here, special attention should be paid to the fact that rose-fish preferes to occupy the habitats around the reef and that the cluster of barnacle suggests that there was a big reef on the tow course of the net.

A lot of the pink shrimps (or *Pandalus borealis* in scientific name) were hauled up in the northern waters (at St. 1) and also in the southern ones (at Sts. 15 & 16); it was highly probable that the mesh-size of the net employed during this expedition was too large and was thought to be unsuitable to catch the small animals such as shrimps. But, a good catch at St. 1 shows that it should be strongly recommended that the net should be towed in the layer a little above the bottom, because the tow immediately on the bottom caught such a tremendous amount of large basketfish (or exactly speaking, *Gorgonocephalus caryi* in scientific name) that a lot of labor was used for picking up the small shrimps hiding among the fishes and for putting the net again in the former prepared state.

The "Zuwai" crabs were caught in every station. But the distribution of "Zuwai" crab is very interesting as an example showing the difference of the habitat preference according to sex and developmental stages: the grownup male individuals of 12~13 cm in carapace length were caught abundantly in the northwest waters of St. Matthew Island (Sts. 5 & 9), whereas a lot of juvenile male were attended mixed with grownup female in the waters from southeast to northeast of this island.

Table 6. Data on catches by trawling in 1961 cruise to the Bering Sea.

| No. of trawling | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | Total (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Catch in weight per haul (kg) / Species | 235 | 52 | 66 | 15 | 1001 | 330 | 77 | 626 | 229 | 2687 | 934 | 1647 | 2744 | 675 | 4093 | 96 | 316 | 22 | — | — | 34 | |
| | Values in columns represent the percentages | | | | | | | | | | | | | | | | | | | | | |
| *Breviraja parmifera* (BEAN) | | | | | 5.5 | 6.1 | 16.9 | | | 1.7 | | 0.4 | 5.4 | | | | | | | | | 289 |
| *Atheresthes* spp. | | | 14.0 | 66.6 | 4.8 | 20.3 | 4.2 | 2.3 | 16.0 | 1.7 | 7.2 | 10.4 | | | | | | | | | | 424 |
| *Hippoglossoides robustus* GILL & TOWNSEND | 8.6 | 60.9 | 17.8 | few | few | 11.5 | 13.0 | few | few | few | 3.8 | | | | | | | | few | few | 28.6 | 158 |
| *Limanda aspera* (PALLAS) | | | | | | | | 5.3 | 9.6 | 46.1 | 57.1 | 31.4 | 10.0 | 3.2 | 97.5 | 100.0 | 99.0 | 90.9 | few | few | 13.6 | 3463 |
| *Hippoglossus stenolepis* SCHMIDT | 18.8 | | | | | 2.1 | | 4.3 | 0.6 | 6.0 | 15.3 | 12.2 | 0.5 | 5.3 | 1.1 | | 0.2 | | few | few | | 279 |
| *Theragra chalcogramma* (PALLAS) | 20.4 | 16.4 | | | 8.5 | 5.8 | | 36.3 | 55.7 | 21.6 | few | few | 73.2 | 55.4 | few | few | | | | | | 3486 |
| *Gadus macrocephalus* TILESIUS | 2.2 | | | | 13.5 | 13.5 | | 3.4 | 2.8 | 17.0 | 2.5 | few | 9.3 | 11.2 | few | | | | | | | 1037 |
| Cottidae | 25.8 | 2.3 | | | 1.2 | 6.1 | 11.7 | 3.4 | 5.9 | 5.0 | 12.1 | 2.7 | 1.6 | 3.3 | | | 0.8 | | | | 54.2 | 519 |
| *Sebastes alutus* GILBERT | 4.3 | 20.4 | 58.7 | 33.4 | 66.5 | 34.6 | 54.2 | 44.1 | 3.3 | 0.9 | 2.0 | few | few | 7.0 | few | few | Abundance of female and young male | | | | | 1241 |
| *Chinoecetes opilio* O. FABRICIUS | 4.4 | | 9.5 | | | | | 3.6 | 6.1 | | 0.4 | | | | | | | | | | 3.6 | 61 |
| *Paralithodes camtschatica* TILESIUS | 15.5 | | | | | | | | | | | | | 14.5 | 1.4 | | | 9.1 | | | | 192 |
| *Pandalus borealis* KROYER | | | | | | | | | | | 42.5 | | | | | | | | | | | 700 |

Now let us consider on the distribution of the water temperature of the bottom layer. As represented in Fig. 3, the cold water mass from the northeast, perhaps from the Arctic Sea stretches to the southeast; and this makes the meandering isothermal lines to run from the northwest to the southeast. Then it is easily understood that there is a close relation between the distribution of bottom temperature and the location of the good fishing grounds: *i.e.*, the good fishing grounds for the commercial fish distribute in the southern part with high water temperature along the 1~2°C isothermal line (Sts. 5 & 1). In summer, it is, of course, very natural that the rise of water temperature will move the distribution of the fish to the north. The frequency distributions of the body length of the important fishes are represented in Fig. 4, and the body length measurements and the characteristics of the gonad will be briefly described below:

*Atheresthes stomias* : The majority of the individuals were 24~28 cm in body length. But, it was almost impossible to identify their sex without aid of any of the magnifiers or the histological methods, because the gonads were still in immature during this test-operation.

*Hippoglossoides robustus* : The mode of the body length was at 25 cm or thereabout. And the larger individuals than 25 cm had mature gonads.

*Hippoglossus stenolepis* (Halibut) : It was impossible to examine the maturity or even the body length because they were set free as soon as hauled. But most of the individuals were supposed to be 50 cm in body length.

*Limanda aspera* (Yellow-fin sole) : The mode of the body length was at 27 cm or thereabout, but the gonads were still in immature.

Concerning the soles, Fig. 4 suggests that the female was more abundant than the male in this fishing ground. But, the number of samples examined was very small, and this suggestion is highly doubtful.

*Gadus macrocephalus* (Alaska cod) : Frequecy distribution of the body length was bimodal; and the individuals of 24~28 cm and of 40 cm in body length occupied the principal parts of the catch. One female individual of 65.1 cm in body length and 3.7 kg in body weight had the gonad of 90 g in weight, filled with the eggs at advanced stage in maturation.

*Theragra chalcogramma* (Alaska pollack) : The mode of the body length of both the female and the male was at 44~50 cm. The gonads of all the individuals were still in immature, although there were each two exceptional individuals of female and male with the gonads at the advanced stage in maturation. One of the female individuals of 48.0 cm in body length and 1.6 kg in body weight had the gonad of 360 g in weight and the gonad of the other female of 65.0 cm in body length and 2.8 kg in body weight was as heavy as 225 g while one of the male of 53.5 cm in body length and 1.7 kg in body weight and the other male of 52.1 cm in body length and 1.5 kg in body weight had the gonads of 130 g and 120 g in weight, respectively.

King crabs : In this group, not only *Paralithodes camtschatica* but also two other allied species, *Paralithodes platypus* and *P. brevipes*, were included. The king

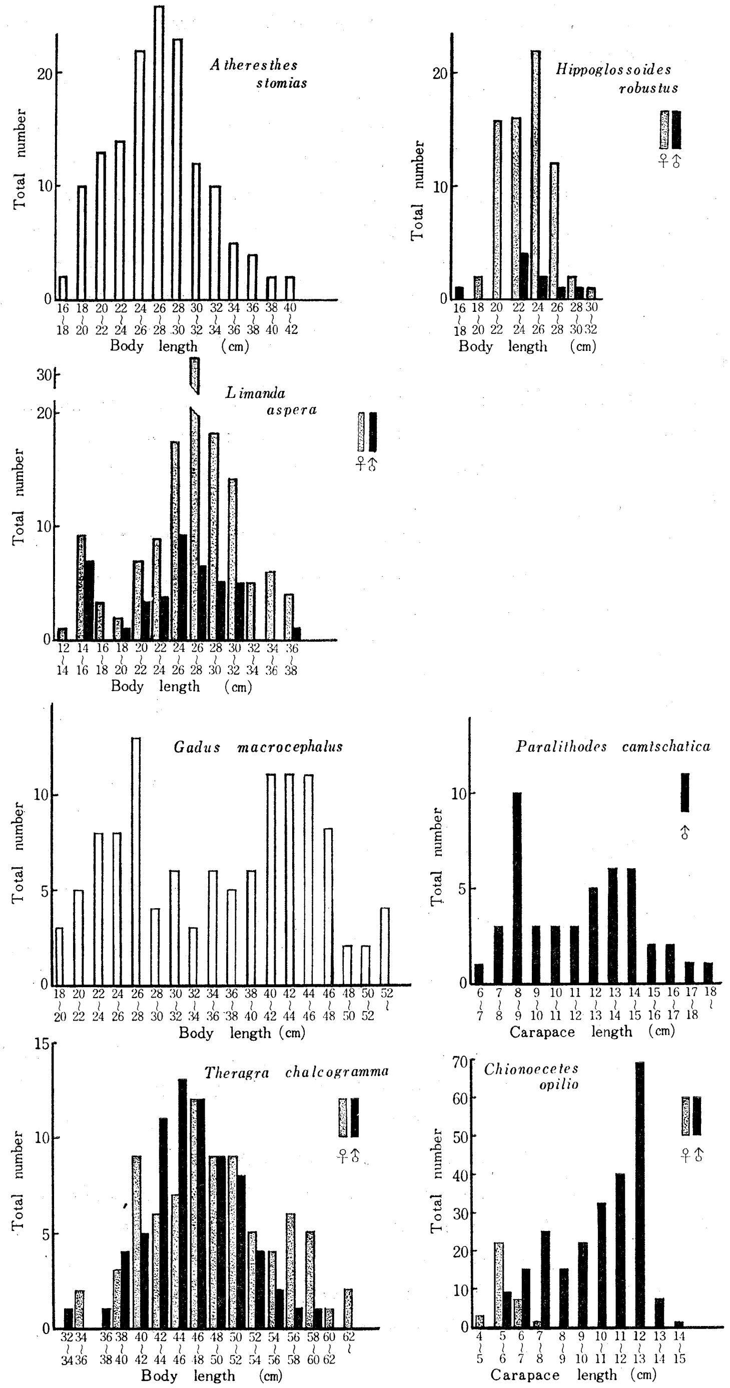



Fig. 4. Frequency distribution of body length of the fish of high commercial values caught in the Bering Sea.

crabs were the poorest group of animals in the catch. The male individuals of 9 cm and 15 cm in carapace length occupied the principal part of the catches.

*Chinoecetes opilio* ("Zuwai" crab) : The male individuals of 12 cm in carapace length or thereabout were caught abundantly; but 6 cm was the mode of the carapace length of the female individuals, as suggested by YOSHIDA (1931 & '51).

## 3. Composition and distribution of plankton in the fishing grounds

**A.** Sampling method and oceanographic conditions

The plankton samples were collected from bottom to the surface at each of 32 stations in the waters northeastern part of the Bering Sea (*cf.* Fig. 5 & Table 7) during the period from May 31 to June 10. In this case, the net of NAKAI'S type of 45 cm in mouth-diameter and 1 m in length constructed with the gauze of GG 54 in JIS was employed, and the net was hauled up vertically at the speed of 1 m per second.

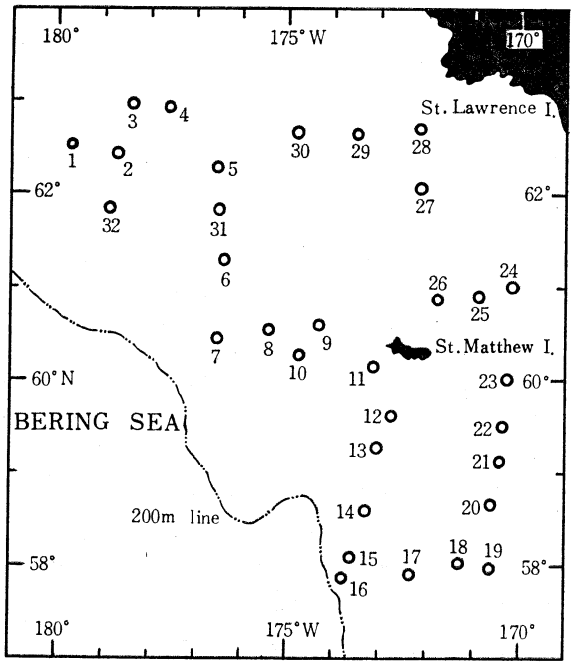



Fig. 5. Chart showing the sampling stations in the Bering Sea.

The distribution of the water temperature at each depth is shown in Fig. 6. At the surface layer (the layer shallower than 10 m deep), the waters northwest of St. Matthew Island was occupied by the cold water mass (below 1°C), and the meandering isothermal lines running from the east to the west were arranged in the south of this water mass showing the rise of the temperature to southward. At the layers deeper than 25 m, the running direction of the isothermal lines turns gradually clockwise

Table 7. Oceanographic conditions of the northeast Bering Sea observed during this expedition.

| St. | Date (1961) | Position Lat. (N) | Position Long. (W) | Ship's time | Weather | Wind Direction | Wind Force | Barometer (mb) | Sea condition | Transparency (m) | Temperature (°C) | Water temperature (°C) 0 m | 10 m | 25 m | 50 m | Near sea bottom | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | May 31 | 62°33′ | 179°41′ | 1000 | b | NW | 2 | 1012.4 | 1 | — | 2.2 | 0.4 | −0.12 | −0.23 | −0.63 | * −0.98 | * 75 m |
| 2 | June 1 | 62°26′ | 178°36′ | 0630 | b | N | 2 | 1009.1 | 1 | — | 3.0 | 0.4 | −1.53 | −1.11 | −2.52 | * 0.42 | * 75 m |
| 3 | 1 | 62°58′ | 178°26′ | 1250 | b | NNW | 2 | 1008.0 | 1 | 14 | 3.8 | 1.0 | −0.15 | −1.80 | −1.50 | * 0.19 | * 75 m |
| 4 | 1 | 62°56′ | 177°38′ | 1830 | b c | N | 3 | 1006.3 | 1 | 10 | 3.5 | 1.1 | −0.38 | −1.15 | −1.56 | * 0.12 | * 75 m |
| 5 | 2 | 62°19′ | 176°32′ | 0610 | c | NNE | 2 | 1004.1 | 1 | 4 | 2.9 | 1.2 | 1.28 | −0.23 | −1.61 | * −1.51 | * 75 m |
| 6 | 2 | 61°18′ | 176°27′ | 1340 | c | SE | 3 | 1002.7 | 1 | 5 | 2.1 | 1.8 | 0.71 | −0.01 | −1.45 | * −1.11 | * 75 m |
| 7 | 2 | 60°29′ | 176°32′ | 1715 | b | SE | 2 | 1002.1 | 1 | 15 | 5.0 | 2.2 | 0.80 | 0.61 | 0.30 | * 1.27 | * 100 m |
| 8 | 3 | 60°37′ | 175°25′ | 0600 | o | SE | 4 | 1003.3 | 2 | 5 | 1.7 | 0.8 | 0.48 | 0.10 | 0.21 | * 0.80 | * 75 m |
| 9 | 3 | 60°41′ | 174°25′ | 1155 | o | ESE | 4 | 1003.9 | 3 | 6 | 2.1 | 1.1 | 1.16 | −1.21 | −1.67 | * −1.70 | * 75 m |
| 10 | 3 | 60°20′ | 174°49′ | 1730 | o | ESE | 5 | 1001.7 | 4 | 8 | 1.7 | 1.2 | 1.12 | 0.12 | −0.95 | * −1.50 | * 75 m |
| 11 | 4 | 60°13′ | 173°07′ | 0600 | f | SE | 4 | 1002.0 | 2 | 5 | 1.6 | 0.6 | 0.46 | −0.27 | −1.50 | * −1.60 | * 60 m |
| 12 | 4 | 59°39′ | 172°45′ | 1205 | d | SE | 4 | 1004.0 | 2 | 15 | 2.1 | 1.5 | 1.23 | 1.00 | −0.11 | * 0.31 | * 75 m |
| 13 | 4 | 59°17′ | 173°04′ | 1730 | o | SE | 4 | 1005.1 | 2 | 16 | 3.4 | 2.0 | 1.68 | 0.27 | −0.81 | * −0.81 | * 75 m |
| 14 | 5 | 58°37′ | 173°19′ | 0600 | e | E | 4 | 1007.6 | 2 | 13 | 3.7 | 2.9 | 2.95 | 2.39 | 2.27 | * 1.51 | * 100 m |
| 15 | 5 | 58°08′ | 173°32′ | 1350 | o | ESE | 4 | 1008.4 | 2 | 10 | 5.2 | 4.4 | 3.82 | 3.95 | 3.49 | * 1.85 | * 100 m |
| 16 | 5 | 57°54′ | 173°44′ | 1730 | o | ESE | 4 | 1009.0 | 2 | 17 | 4.5 | 4.7 | 4.51 | 4.12 | 3.55 | * 3.12 | * 75 m |
| 17 | 6 | 57°58′ | 172°21′ | 0610 | o | — | 0 | 1011.0 | 0 | 21 | 5.3 | 4.4 | 4.47 | 3.50 | 2.30 | * 1.15 | * 100 m |
| 18 | 6 | 58°02′ | 171°18′ | 1215 | b | NNE | 3 | 1010.1 | 1 | 12 | 6.5 | 5.1 | 4.93 | 3.94 | 1.70 | * 1.22 | * 75 m |
| 19 | 6 | 57°59′ | 170°39′ | 1730 | b | N | 4 | 1009.5 | 2 | — | 5.8 | 4.6 | 4.15 | 2.98 | 0.52 | * 0.50 | * 70 m |
| 20 | 7 | 58°41′ | 170°41′ | 0600 | f | W | 5 | 1008.6 | 3 | 16 | 1.5 | 2.9 | 2.94 | 1.45 | −0.49 | * −0.50 | * 70 m |
| 21 | 7 | 59°08′ | 170°27′ | 1150 | o | W | 5 | 1008.0 | 4 | 8 | 2.5 | 2.3 | 1.99 | −0.20 | −0.18 | * −0.18 | * 65 m |
| 22 | 7 | 59°29′ | 170°20′ | 1720 | o | NW | 5 | 1007.2 | 4 | — | 1.7 | 1.7 | 1.60 | 0.44 | −0.77 | — | — |
| 23 | 7 | 60°03′ | 170°16′ | 2230 | f | NW | 6 | 1007.2 | 4 | — | 1.2 | 1.6 | 1.46 | −0.78 | −1.41 | — | — |
| 24 | 8 | 61°00′ | 170°08′ | 0600 | o | WNW | 5 | 1007.9 | 3 | 12 | 2.2 | 1.9 | 1.85 | −1.51 | — | * −1.59 | * 40 m |
| 25 | 8 | 60°54′ | 170°58′ | 1150 | c | NW | 5 | 1011.2 | 3 | 16 | 3.7 | 2.1 | 1.89 | −1.51 | −1.65 | — | — |
| 26 | 8 | 60°50′ | 171°46′ | 1700 | f | W | 5 | 1014.6 | 2 | 13 | 1.5 | 1.8 | 1.49 | −1.51 | −1.86 | — | — |
| 27 | 9 | 62°04′ | 172°10′ | 0600 | f | WNW | 4 | 1014.7 | 3 | 12 | 1.2 | 2.2 | 2.12 | −1.00 | −1.75 | — | — |
| 28 | 9 | 62°41′ | 172°07′ | 1030 | f | W | 5 | 1014.3 | 3 | 14 | 1.8 | 2.1 | 2.10 | −0.80 | −1.70 | — | — |
| 29 | 9 | 62°40′ | 173°30′ | 1700 | o | WSW | 5 | 1012.4 | 3 | 14 | 2.0 | 1.5 | 1.83 | 0.11 | — | * −2.13 | * 55 m |
| 30 | 9 | 62°44′ | 174°49′ | 2100 | o | W | 6 | 1011.8 | 5 | — | 1.8 | 1.3 | 1.34 | 0.71 | — | * −1.91 | * 65 m |
| 31 | 10 | 61°51′ | 176°30′ | 0600 | o | SW | 5 | 1009.7 | 4 | 13 | 2.5 | 1.6 | — | 1.30 | −1.20 | * −0.12 | * 100 m |
| 32 | 10 | 61°52′ | 178°55′ | 1230 | o | SSW | 5 | 1005.3 | 4 | — | 1.4 | 1.7 | 1.42 | 1.02 | −1.06 | * −0.41 | * 120 m |

with depth. The salinity was not determined because the polyethylene water bottle failed to keep the water samples on account of its imperfection in structure.

It is very interesting that even the character of the sediment is influenced by the plankton population; *i.e.*, the green mud, which may perhaps be derived from the diatom ooze, is found in the northern part where the diatom population is very rich as mentioned below; whereas in the other waters with only poorer population, the bottom characters change from green mud to muddy sand and further to sandy mud with the decrease in the latitude.

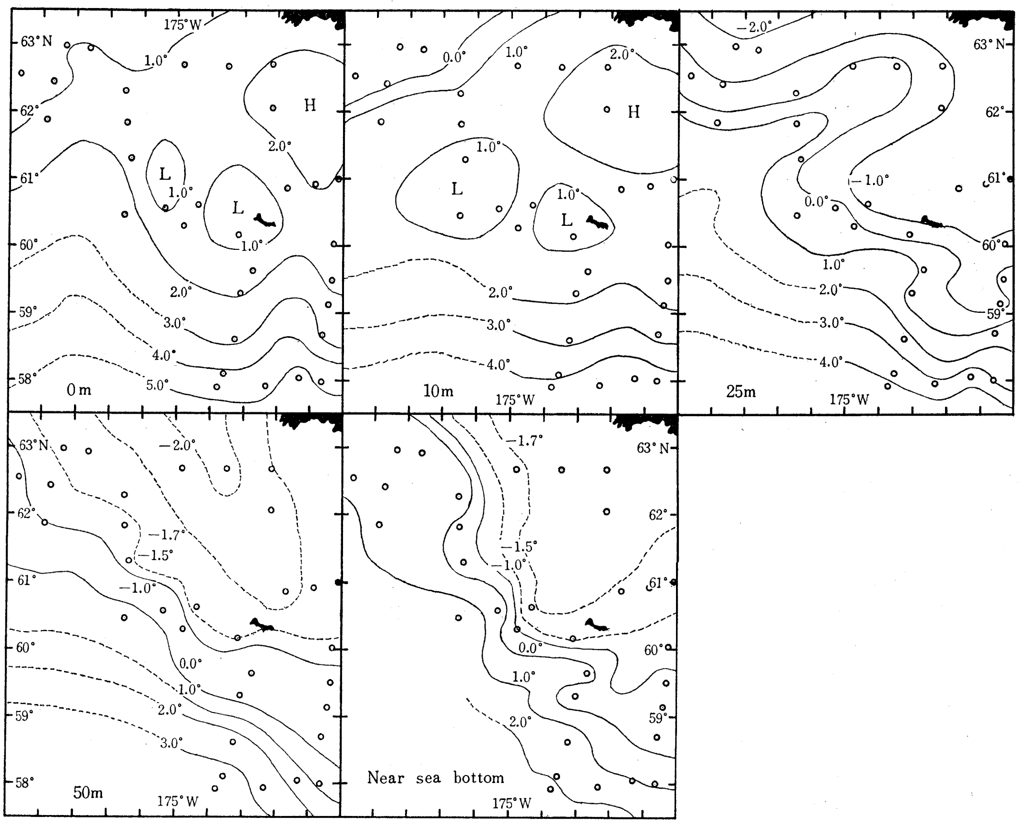



Fig. 6. Horizontal distribution of water temperature at respective depth layers observed in the northeast waters of the Bering Sea.

## B. Phyto-plankton

It is probable that the net employed in this survey was too rough in mesh to collect micro-plankton samples. Therefore, the author is afraid of the fact that the results mentioned in this paragraph may not be quite free from the unreliability. But the author could collect and identify rich plankton flora as represented in Table 8. Among them, dominant genera of diatom were as follows: *Thalassiosira*, *Fragilaria*

*Chaetoceros*, *Thalassiothrix* and *Rhizosolenia*. It is, of course, very natural that they have more or less different localities in their distributions; *i.e.*, at Sts. 1~13 the diatom population consisting chiefly of some species of *Thalassiosira*, *Fragilaria* and *Chaetoceros* with many other neritic genera, were found so dense that the water appeared green-brown in color (at 7~8 in Forel's scale). All the facts mentioned

Table 8. Composition of the phyto-plankton in the northeastern part of the Bering Sea.

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Coscinodiscus asteromphalus* | C | + | + | + | + | + | + | C | R | R |
| *Thalassiosira nordenskiöldi* | C C | C C | C C | C C | C | C | C | C C | + | C |
| *T. gravida* | C | C | C C | C C | C C | C C | + | C | C C | C |
| *T. hyalina* | + | + | + | + | + | C | + | + | C | C |
| *T. baltica* | R R | R | R | R | R | + | R R | R | R | |
| *T. condensata* | C | C | C C | C | + | C | + | C | C | C |
| *T. decipiens* | R | R | R R | R R | R R | R R | R R | | | |
| *Coscinosira polychorda* | R | + | R | | | | | | | R |
| *Stephanopyxis nipponica* | R | R R | | | | | R R | + | | R R |
| *Corethron hystrix* | R | R | R | | | | | | | R |
| *Rhizosolenia alata* (f. *inermis*) | + | + | + | + | R | R | R | + | R R | + |
| *R. imbricata* var. *schrubsolei* | | R R | R R | | | | R R | | | |
| *R. hebetata* f. *hiemalis* | R | | R R | R | | | + | + | R R | R |
| *R. hebetata* f. *semispina* | R R | R | + | + | + | R | | | | R |
| *Chaetoceros atlanticus* | + | + | + | + | R | + | + | C | R | + |
| *C. atlanticus* var. *neapolitana* | | | R R | | | R R | | | | |
| *C. concavicornis* | + | + | + | + | R | + | C | + | + | C |
| *C. decipiens* | R | R R | R | | | R | R | + | R R | |
| *C. brevis* | R R | | | | | R R | | | | R R |
| *Biddulphia aurita* | + | + | R | R | + | + | R | + | R | + |
| *Fragilaria oceanica* | C C | C C | C C | C C | C C | C | + | C | C | C C |
| *F. cylindrus* | R R | R R | R R | | R R | | R R | | R R | |
| *F. striatula* | + | + | + | + | | R | R R | R | | R R |
| *Thalassionema nitzschioides* | + | + | + | + | | R | R | R | R | R R |
| *Thalassiothrix frauenfeldii* | + | + | + | + | | R R | R | R | R | R |
| *T. longissima* | R | + | + | R | R | + | + | + | + | + |
| *Navicula septentrionalis* | + | + | + | + | | | | | | |
| *N. granii* | | | | R R | R | + | | | R | C |
| *N. vanhöffenii* | R | R | R | R | + | + | | | R | R R |
| *Amphiprora hyperborea* | + | + | + | R | + | R | | R | R | + |
| *Denticula marina* | | | | | | | | | | |
| *Nitzschia seriata* | R | R | C | C | | + | | R | R | |
| *Melosira hyperborea* | | | | R | R | | | | R | |
| *Pleurosigma* sp. | | R R | | R R | | | | | | |
| *Ceratium longipes* | R | | R | R R | | R R | R R | | R R | R R |
| *Peridinium* sp. | | | R R | | | | | R R | | |

above coincided with the characteristics of the neritic plankton in the Arctic waters defined by AIKAWA (1942). Disappearance of any of the neritic species and the presence of off-shore species such as *Rhizosolenia hebetata*, *Thalassiothrix longissima*, and very rare species such as *Denticula marina* which was unable to be collected from any other waters, though they were very small in quantity, were

| 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 24 | 25 | 26 | 27 | 28 | 29 | 32 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| + | R | | R | R | | | | R R | R R | | + | | | | R | R R |
| C | | | | | | | | | | R R | R R | + | R R | | | |
| + | + | R R | | | | | | | R | R | + | C C | C | R | + | |
| + | R | | | | R | | | + | R | + | | C C | + | | | |
| + | + | | | | | | | | | | | | | | | |
| | | | | | | | | | | | R R | R R | R R | R R | | |
| R R | R R | | | | | | | | | | | | | | R R | |
| R | R | | | | | | | | | | | | | | | |
| | | | | R R | | | | | | | | | | | | |
| R R | | | | | | | | | | | | | | | | |
| | + | | R R | R | R | R | | | R R | | | | | | | |
| R R | | | R R | R | | R | | R R | | | | | | | | |
| R | + | R R | R | | | R | | R R | | | | | | | | |
| C | C | | | | | R R | | R R | | | | R | R | | R | |
| | | | | R R | | | | | | | | | | | | |
| + | + | | | | | | | | | | R R | R | R | | | |
| + | R | | | | | | | | | R | + | C | C | R | + | |
| | | | | | | | | | | | R R | | R R | | R R | R R |
| R R | R R | | | | | | | | | | | | | | | |
| R | + | | | | | | | R R | R R | | R R | | | | | |
| R | R | | | | | | | | R R | R R | + | C | + | R | | |
| + | + | | R R | + | R | R | R | + | R | R | + | + | + | R R | R R | R |
| R R | | | | | | | | | | | | | | | | |
| R | + | | R R | | | | | | | | R R | | | | | |
| | | R R | R | R | + | | | | | | | | | | | |
| | | | | | | | | | | | | R | | | | |
| R | R R | | | | | | | | | | | R R | | R R | | R R |
| R R | R R | | | | | | | R R | | | | | | | | |

the characteristics of phyto-plankton collected in the southern parts of the surveyed waters (Sts. 14～19). Besides, the abundant copepods were also the other characteristics of plankton composition of worth mention. The features of plankton in this water may, therefore, well be said to resemble the characteristics of what we call Tricho-plankton.

Phyto-plankton in the northeastern part (Sts. 20～29) was very poor not only in composition but also in quantity when compared with that found at Sts. 1～13, and was represented by a simple composition consisting of a few species of *Thalassiosira* and *Fragilaria*. This water may, thus, be said to be occupied by a type of plankton, what we call Sira-plankton.

**C.** Zoo-plankton

Generally speaking, as represented in Table 9. zoo-plankton also shows one of the most remarkable characteristics of the community in high latitude, *i.e.*, rich in

Table 9. Occurrence of the zoo-plankton in the northeastern part of the Bering Sea.

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Aglantha digitale* | | R R | | | | | R R | R R | R R | R |
| *Sagitta elegans* | R | | R R | R | + | R | R | + | + | C |
| *Calanus helgolandicus* | | | | | | | | | | |
| *C. plumchrus* | C C | R | + | + | C | + | C C | + | + | + |
| *C. cristatus* | R R | | | | R R | R R | | | | |
| *Eucalanus bungii bungii* | | | R R | R R | | | | | | |
| *Pseudocalanus elongatus* | R | R | C | C C | C | C | C | + | + | + |
| *Metridia lucens* | R | R R | R R | R R | C | C | R | R | + | |
| *Acartia longiremis* | | | | | R R | | | | R | + |
| *Oithona similis* | | | R R | R | | | R | | R R | + |
| *Eurytemora herdmani* | | | | | | | | | | |
| *Euphausia pacifica* | | R R | | | | R R | R R | R R | R R | R R |
| *Thysanoessa raschii* | | | | R R | R R | | | | | |
| *Themisto japonica* | + | | R R | | R R | R R | C | R | + | + |
| *Limacina helicina* | | | | | R R | | | | | |
| *Oikopleura* spp. | | | | R R | | | R | R | | |
| Trochophore | | | | | | | | | | |
| Polychaeta larvae | | | | | | | | | | |
| Balanus nauplii | | | R | | | | | | | |
| Zoea | R R | | R R | R R | R R | R R | | R R | | |
| Mysis stage of Brachyura | | | | | | | | | | |
| Veliger | | | R | | | | R R | | | |
| Echinopluteus | | | | | | | | | | |
| Copepoda nauplii | R | R | R | + | R | R | C | + | + | + |
| Fish eggs | | R R | R R | | | | R R | R | R R | R R |
| Fish larvae | | | | | | | | | | |

quantity but very simple in composition; they chiefly consisted of only the following five species: copepods, *Calanus plumchrus, Pseudocalanus elongatus* and *Acartia longiremis;* amphipod, *Themist japonica;* chaetognath, *Sagitta elegans.*

Zoo-plankton also differed in composition and in quantity according to the regions. These characteristics have close resemblance to those of diatoms. Namely, as already mentioned Sts. 1~13 were rich in diatom population but poor in copepod one except a large amount of *Calanus plumchrus, Pseudocalanus elongatus, Metridia lucens* and *Sagitta elegans.* On the other hand, Sts. 14~19 were poor in diatom, but were rich in zoo-plankton chiefly consisted of *Calanus plumchrus, Calanus cristatus* and *Eucalanus bungii bungii* with some small copepods such as *Pseudocalanus elongatus, Metridia lucens* and *Oithona similis.* The occurrence of zoo-plankton such as pelagic pteropod, *Limacina helicina* and planktonic tunicates, *Oikopleura* sp., in this region was the other features of worth mention. Zoo-plankton compositions at Sts. 20 ~ 29 resembled closely those of Sts. 1 ~ 13, expect the

| 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 24 | 25 | 26 | 27 | 28 | 29 | 32 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | R | R | R | | R R | | R R | R R | R R | R | R R | R R | R R | R R | |
| + | + | R | R | R | R | + | R R | + | + | R | C | + | + | R | C | R R |
| | R R | R | R | R | R | R | | | | | | | | | | |
| + | R | C | C C | C C | C C | C | + | R R | R R | | R R | | R R | R R | R | C |
| | | R | R | R | R | R R | R R | | | | | | | | | |
| | | | + | R | R | R | R | | | | | | | R R | | |
| + | C | C | C | C | C | + | + | C | C | + | + | + | + | + | + | + |
| | | + | C | C | + | + | + | R R | | | | | | | | R R |
| C | + | + | | | R | | R | + | C | C | C | C | + | + | C | + |
| + | R | R R | R R | R R | C | C | R | | | | | | | R | | |
| | | R | | | | | | | | | | | | | | |
| | | | | | R R | | | R R | | | R R | R R | | | | |
| + | + | R | R | R R | | R | | R R | | | | R R | | | R R | C |
| | | + | R | R | + | R | | | | | | | | | R | + |
| + | + | + | + | + | + | + | | | | | | | | R R | R R | R R |
| | | | | | | | | | | | | | C C | + | | R R |
| R R | | | | | R | R | R | R R | | | R | R | C | C | | |
| | | | R R | | | | | | | | R R | | | R R | | |
| | | | | R R | | R R | | | | | | | | | | R R |
| | | | | | | | | | | | | | | R R | | R |
| | | | | | | R | | | | | | | | | | R |
| C | C | C | C | C | C | C | C C | R | R | R | R | R R | R | C | C | R |
| R | + | R | | | | R | R | | | | | | | R R | | |
| | | | R R | | | | | | | | | R R | | | | |

abundant occurrence of *Acartia longiremis* and Polychaeta larvae. The compositions at St. 32 were very closely similar to those of the southern waters represented in the Sts. 14~19, despite of the fact that this station was located in the northern part; and this resemblance seems to relate to the horizontal distribution of water temperature shown in Fig. 6.

**4. Discussion and consideration**

Simplicity in the species compositions and the explosive propagation of diatoms are the common characteristics of the summer plankton community in the waters of high latitude. Many results of the present survey support the above-mentioned phenomena. The abundant species in this water were diatoms such as genus *Thalassiosira*, represented chiefly by *T. nordenskiöldi*, *T. gravida* and *T. condensata*, genus *Fragilaria* (chiefly *F. oceanica*), with some zoo-plankton such as *Sagitta elegans*, *Calanus plumchrus* and *Pseudocalanus elongatus*.

The distribution of these species suggests that the surveyed waters will be classified into the following three regions, 1) Northwestern region: this region is covered by Sts. 1~13 and occupied by the neritic plankton of the subarctic waters, 2) Southern region: this region is covered by Sts. 14~19 and occupied by Tricho-plankton and 3) Northeastern region: this region is covered by Sts. 20~29 and occupied by Sira-plankton.

It is suggested, from the results of the planktological survey, that a good fishing ground is in general found in the waters where is relatively high transparency and is warmer than 2°C in bottom layer, because a good catch is frequently observed in the waters poor in diatom population, and warmer than 2°C in bottom layer.

## Chapter II Tuna fishing grounds in the equatorial Pacific

### I. Introduction

The tuna longline fishing in the oceanic region has developed remarkably after the Second World War; and nowadays, many steel vessels of from 200 to 1,500 tons in size with very excellent equipments engage actively in this fishery in the waters all over the Pacific and the Indian Oceans and even in far distant waters such as the Atlantic Ocean. They catch chiefly the following fishes: bluefin tuna (or *Thunnus orientalis* in scientific name), albacore (*Germo germo*), bigeyed tuna (*Parathunnus sibi*), yellowfin tuna (*Neothunnus macropterus*), spearfish (*Makaira mitsukurii*), giant black marlin (*M. marlina*), black marlin (*M. mazara*), sailfish (*Istiophorus orientalis*) and swordfish (*Xiphias gladius*). Besides these fishes, the boats bring back to the market other fishes with very low economic value such as sharks, Spanish mackerel, dolphin fish, opah and skipjacks. Although they are usually called the fish in the tropical waters, they prefer to occupy more or less different habitats according to the species; and consequently, the catch composition in a certain fishing ground differs according to seasons and the position of the fishing ground.

Despite of the rapid expansion in the tuna fishing grounds, most of these newly explored ones are still left untouched in planktology. And it is doubtlessly important to clarify the planktological characteristics of these fishing grounds, not only from the food-relational point of the view but also from the stand point of applied biological oceanography. But yet there are few reports on the plankton of the equatorial Pacific except those published by MARUKAWA (1939), MOTODA (1939 & '41), TOKIOKA (1942) and WILSON (1950).

This chapter represents the results of the planktological studies on the two groups of materials. One of them was collected by the Shunkotsu-maru during the period from January to March in 1953 on her exploration cruise of new fishing grounds in the waters adjacent to the Marshals, the Gilberts and the Phoenixes; and the other was sampled by the boat on her voyage during the Japanese Bikini Expedition from May 21 to June 29, 1954 in the closed area set by U. S. for Hydrogen bomb experiment around the Bikini Atoll and in some adjacent waters.

## II. Distribution of plankton in the tuna fishing ground around the Marshal Archipelago, the Gilbert Islands and the Phoenix Islands

### 1. Sampling method and oceanographic conditions

The position of the collection and the oceanographic conditions are shown in Table 10, and these positions are also plotted in Fig. 7. In this cruise, the net of KITAHARA'S type of 25 cm in mouth-diameter and 1 m in length constructed with the

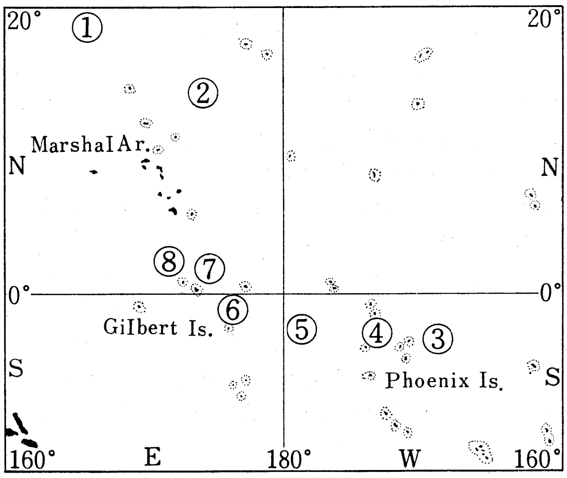



Fig. 7. Chart of the stations set around the Marshal, the Gilbert and the Phoenix Islands.

gauze of 750 meshes per sq. cm was employed and the net was hauled up vertically from the 100 m layer to surface at the speed of 50 cm per second.

## 2. Composition and distribution of plankton

**A.** The northern waters of the Marshal Archipelago

The plankton compositions in the surveyed waters, including those which will be mentioned in the succeeding paragraphs, are listed in Table 11.

Table 10. Investigation period and oceanographic conditions of the fishing grounds around the Marshal, the Gilbert and the Phoenix Islands.

| St. | Lat. | Long. | Date 1953 | Time | Weather | Water-temp. (°c) | Transparency (m) | Precipitated vol. of pl. (cc) |
|---|---|---|---|---|---|---|---|---|
| 1 | 18°25′ N | 165°18′ E | Jan. 25 | 0830 | c | 26.5 | 32 | 0.2 |
| 2 | 13 27 N | 174 41 E | 29 | 0830 | b | 26.0 | 40 | 0.5 |
| 3 | 0 25 S | 165 38 W | Feb. 23 | 1200 | b | 28.0 | 28 | 7.1 |
| 4 | 3 28 S | 170 29 W | 24 | 0800 | c | 28.5 | 25 | 3.6 |
| 5 | 3 13 S | 178 13 W | Mar. 1 | 1600 | c | 28.6 | 23 | 2.5 |
| 6 | 2 02 S | 176 14 E | 2 | 1300 | b | 28.5 | — | 3.3 |
| 7 | 1 48 N | 174 24 E | 3 | 0700 | c | 28.3 | 23 | 3.6 |
| 8 | 1 37 N | 173 57 E | 4 | 0700 | c | 28.3 | — | 3.0 |

Generally speaking, plankton was poor not only in species but also in quantity which did not exceed more than 0.2~0.5 cc in precipitated volume. *Hemiaulus haukii* was the most dominant species in phyto-plankton; and *Rhizosolenia styliformis* and *R. imbricata* succeeded to it; whereas the following species were abundant members of zoo-plankton: *Ceratium inflexum* (Dinoflagellata), *Aulacantha* sp. (Radioralia), *Calanus darwinii, Corycaeus gibbulus, C. speciosus* (Copepoda), and nauplius stage of copepods.

**B.** Adjacent waters to the Gilbert Islands and the Phoenix Islands

Any remarkable difference can not be found in plankton compositions between these two waters. This is perhaps due to the facts that they are located at the same latitude and are not separated from each other. The plankton fauna and flora of these waters were richer not only in composition but also in quantity than those of the waters adjacent to the Marshal Archipelago shown in the preceding paragraph; the precipitated volume of the samples ranged from 2.5 to 7.1 cc.

Twenty-one species were identified. Among them, the following four species were the pelagic species of the warmer waters, and were the dominant members of the phyto-plankton community: *Planktoniella sol, Rhizosolenia imbricata, R. bergonii* and *R. alata*. Among the species of genus *Chaetoceros*, though they were rather poor not only in the number of species but also in quantity, two of the warmer off-shore inhabitants, *C. peruvianus* and *C. coarctatus*, were sampled in a small quantity from each station.

Despite of the fact that *Thalassiothrix longissima* is one of the pelagic species in the waters of high latitude, this species was common even in the surveyed waters near the equator. The above mentioned facts are supported by the following observation and by several authors. For examples, the author himself has observed this species in the other parts of the tropical Pacific and in the tropical Indian Ocean; the presence of *T. elongata* in the Java Sea reported by ALLEN and CUPP (1935) seems to be one of the facts which supports KOKUBO'S opinion (1940) that the species is synonymous to *T. longissima*. On the other hand, the same species is distributed, according to AIKAWA (1932), in the North Pacific and in the Bering Sea. KOKUBO suggests in the same report that *T. longissima* is the pelagic cosmopolitan in nature. From these facts the author is inclined to support KOKUBO'S suggestion that *T. longissima* is a pelagic cosmopolitan.

The presence of Cyanophyceae, such as *Skujaella* and *Trochescia*, may be another characteristic of phyto-plankton in these waters although they are not abundant.

In these waters Dinoflagellata, Radioralia and Foraminifera were the groups of Protozoa observed abundantly not only in species but also in quantity. Among them, Dinoflagellata was the most abundant and 35 species were identified, in which 21 species belong one genus, *Ceratium*, occupying the most important portion in this group. The abundant Protozoa were as follows: Dinoflagellata—*Ceratium inflex*, *C. pulchellum*, *C. carriense*, *C. controtum*, *C. karsteni*, *C. extensum*, *Amphisolenia bidentata*, *Pyrocystis pseudonoctiluca* and *P. lunula*; Foraminifera—*Globigerina* sp.

*Sagitta enflata* and *S. bipunctata* were rich among chaetognaths.

Two or three species of tunicates were identified, but were very poor in quantity, except *Oikopleura*.

Nauplii of copepods were the most abundant members among larval plankton; veligers of gastropods succeeded to them. Besides, Polychaeta larvae, fish eggs and fish-larvae were also found in the samples but they were very poor in quantity.

Copepods were rich in species, and as much as 98 species could be identified. They were 9 species of *Candacia*, 8 species of *Calanus*, 7 species of *Sapphirina*, each 6 species of *Euchaeta* and *Centropages*, 5 species of *Pleuromamma*, each 4 species of *Acrocalanus*, *Acartia* and *Oncaea*, each 3 species of *Labidocella*, *Clytemnestra*, *Lucicutia* and *Paracalanus*, and each 1 species of *Rhincalanus*, *Ctenocalanus*, *Temora*, *Phaenna*, *Scolecithrix*, *Scolecithricella*, *Pontellina*, *Euterpina*, *Microsetella*, *Mecynocera*, *Calocalanus* and *Scottcalanus*. Among them, the following 8 species were the abundant members in zoo-plankton community: *Calanus darwinii*, *Calocalanus pavo*, *Euchaeta marina*, *Scolecithricella dana*, *Oithona plumifera*, *Corycaeus speciosus*, *C. gibbulus* and *Oncaea venusta*.

It is also worth while to describe here that the author observed, some female individuals bearing egg-sack and the males with spermatophore; this fact may indicate that the season during from January to March is the reproductive period of copepods in the tropical waters.

## 3. Consideration

In this paragraph, the author wishes to note that there is a very close intercommunication between plankton and fishery, and that plankton is important as an indicator for representing oceanographic condition.

The good catch of tuna was obtained from the waters around St. 3. The waters were rich in plankton (7.1 cc in precipitated volume) owing to the presence of the upwelling current there. From the distribution of species it is suggested that *Hemiaulus haukii* is an indicator species of the North Equatorial Current and *Planktoniella sol* is that of the Equatorial Counter Current. As reported by MARUKAWA (1939 and '40) and TOKIOKA (1942) plankton in the waters north of the Marshal Archipelago was poor in quantity in contrast with the fact that the adjacent waters of the Gilbert and the Phoenix Islands were rich in plankton. NISHIZAWA and MURAKI (1940) had reported that the waters in the Equatorial Counter Current and the South Equatorial Current were richer in nutritive salts than those in the North Equatorial Current. Therefore, it may be deducible from the above-mentioned facts that the waters north of the Marshal Archipelago are nourished by the North Equatorial Current in contrast with the fact that the waters adjacent to the Gilbert Islands and the Phoenix ones are under the influence of the Equatorial Counter Current and the South Equatorial one.

Table 11. Occurrence of plankton in the tuna fishing ground around the Marshal, the Gilbert and the Phoenix Islands in winter, 1953.

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Phyto-plankton | | | | | | | | |
| *Planktoniella sol* | R | R R | C C | C C | C | C C | C | C |
| *Bacteriastrum delicatulum* | | | | R R | | | | |
| *Coscinodiscus* sp. | | | | R R | | | | |
| *Rhizosolenia setigera* | R R | + | | | | | | |
| *R. styliformis* | R | + | | | | | | |
| *R. imbricata* | R | C | + | R | + | + | + | + |
| *R. bergonii* | R R | R R | + | C | + | + | + | + |
| *R. alata* | R R | R R | + | R | R | R | R | R |
| *R. robusta* | | | R R | R R | R R | | R R | R |
| *R. acuminata* | | | R | R R | | | | |
| *R. calcar-avis* | R R | R | | | | | | |
| *Chaetoceros setoensis* | | | | R R | | | | |
| *C. coarctatus* | | | R R | R R | R | R R | R R | R R |
| *C. laciniosus* | | | | R R | | | | |
| *C. peruvianus* | R | | R R | R R | R | R | R | R |
| *C. lorenzianus* | | | | | | | R R | R |
| *C. brevis* | | | R R | | R R | | R R | |
| *C.* sp. | | R R | R R | R R | R R | R R | R | R R |
| *C. pacificus* | | R R | | | | | | |
| *Thalassiosira* sp. | | | | | | | R R | |
| *Dactyliosolen tenuis* | | | R R | | | | | |
| *Hemiaulus hauckii* | C | C | | | | | | |
| *Nitzschia* sp. | R R | | | | | | | |
| *Navicula* sp. | | R R | | | | | | |
| *Actinoptychus undulatus* | | | | R R | | | | |

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| *Thalassiothrix longissima* | R R | | + | R | R | R | R | + |
| *T. frauenfeldii* | | | | R R | | | | |
| *Skeletonema costatum* | | | | R R | | | | |
| *Skujaella* spp. | R R | R | | R R | R R | | R R | R |
| *Trochiscia clevei* | | | R R | R R | | | R R | |
| Zoo-plankton | | | | | | | | |
| *Ceratium palmatum* | | | R R | R R | | | R R | R R |
| *C. karsteni* var. *robstum* | | | R | R | R R | R | R | R |
| *C. contortum* var. *saltans* | R R | R | R R | R R | R R | | R R | R |
| *C. azoricum* | | R R | R R | | R R | | | R R |
| *C. carriense* | R R | R | R R | R | R | R | R | R |
| *C. macroceros* subsp. *gallicum* | | R R | R R | R R | | | | |
| *C. gracile* | | | | R R | | | | |
| *C. fusus* subsp. *seta* | | R R | R R | R R | | R R | R R | |
| *C. arcuatum* | R R | | R R | R R | | | | |
| *C. lunula* f. *megaceras* | | | R R | | | | | |
| *C. pulchellum* | R R | | R | R | R | R R | R R | R R |
| *C. extensum* | R R | R R | R | R | R R | R | R R | R R |
| *C. tripos* | | | | R R | | R R | R R | R R |
| *C. inflexum* | + | R | C | + | R | C | + | C |
| *C. pennatum* | | R R | R R | R R | | R R | | R R |
| *C. canderabrum* | | | R R | R R | R R | | R R | R R |
| *C. incisum* | | | R R | | | R R | | |
| *C. gravidum* | | | | | R R | | R R | |
| *C. furca* | | | | | | | R R | R R |
| *C. longinum* | | | R | R R | | R R | | |
| *C. gibberum* f. *sinistrun* | | | | R R | | R R | | |
| *C. massiliens* | | R R | | | | | | |
| *Amphisolenia thrinax* | | | | | | R R | | R R |
| *A. bidentata* | | | R R | R | R R | R | R R | R R |
| *Ceratocorys horrida* | | | R R | R R | R R | R R | R R | |
| *Ornithocercus serratus* | | | R R | R R | R R | | R R | |
| *O. splendidus* | | | R R | | | | R R | |
| *Pyrocystis pseudonoctiluca* | | | R | R | R R | R R | R | R |
| *P. lunula* | | | R R | R R | R R | R R | R R | R R |
| *P. fusiformis* | | | R R | | | | | |
| *P. steinii* | | R R | | R R | | | | |
| *Dinophysis* sp. | | | R R | R R | | | | |
| *Peridinium inflatum* | | | | | R R | | R R | |
| *P. faltipes* | R R | | R | R R | R R | R R | R R | R |
| *P.* sp. | | | | | | | R R | |
| *Acanthometoron* sp. | R R | R | R R | | R R | | | |
| *Aulacantha* sp. | R | + | R | R R | | R | R | R |

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| *Amphilonche belonoides* | | | | R R | | | R R | |
| *Tintinnopsis* sp. | R R | | | | | | | |
| *Codonellopsis* sp. | | | | | | | R R | |
| *Globigerina bulloides* | R R | R R | + | R | R | R | + | R |
| *Sagitta enflata* | | | R | R | R | R | R | R |
| *S. bipunctata* | R R | | + | R | R | R | + | R |
| *S.* spp. | R | R | | R | R | R | R R | R |
| *Vanadis grandis* ? | | | R R | R R | | R R | | R R |
| *Tomopteris elegans* | | | | | | | R R | |
| *Oikopleura* spp. | R | R R | R | R R | R | + | R | R |
| *Doliolum tritonis* | | | | | | | R R | R R |
| *Muggiaea atlantica* | | | R R | | | R R | | |
| Nauplii (Copepoda) | C | C C | C C | C | C | C | C | C |
| Veliger (Gastropoda) | | | R | R R | R R | R R | R | R |
| Fish larvae | | | R R | | | | | R R |
| Fish eggs | | | R R | R R R | | | | |
| Polychaeta larvae | | | R R | | | | R R | R R |
| *Phronima stebbingi* | | | R R | R R | | R R | R R | |
| *Hyperia schizogeneios* | | | R R | | R R | | | R R |
| *Parascelus zebu* | | | R R | | | | | |
| *Euphausia* spp. | | | + | R | R R | R R | R R | R R |
| Ostracoda | R R | | R R | R R | | | R R | |
| Copepoda | Mean number of individuals in a haul | | | | | | | |
| *Calanus tenuicornis* | | 3 | 13 | 5 | | | | |
| *C. darwinii* | 6 | 18 | 65 | 58 | 30 | 42 | 106 | 140 |
| *C. helgolandicus* | | | 2 | | | | | |
| *C. robustior* | | | | 2 | | | | 2 |
| *C. minor* | | | 3 | | | 6 | | |
| *C. vulgaris* | | | 2 | | | | | |
| *C. gracilis* | | | 3 | | 21 | | | |
| *C. pauper* | | | | | | 5 | | |
| *Calocalanus pavo* | 1 | | 45 | 42 | 35 | 17 | 10 | 8 |
| *Rhincalanus cornutus* | | | | | 1 | | 2 | |
| *Acrocalanus monachus* | | | 16 | 8 | 5 | 4 | | 10 |
| *A. gibber* | | 10 | | 10 | | 5 | 4 | |
| *A. gracilis* | | | 10 | 6 | | | | |
| *A. longicornis* | | | 5 | | 7 | | | |
| *Clausocalanus arcuicornis* | | | 14 | 26 | 27 | 12 | 9 | 5 |
| *C. pergens* | | | 45 | 51 | 55 | | 5 | 7 |
| *C. furcatus* | | | 35 | 40 | 13 | 18 | | 8 |
| *Scottcalanua helenae* | | | 2 | 2 | 1 | | 3 | 1 |
| *Pseudocalanus minutus* | | | 24 | | | 80 | | |
| *P. gracilis* | | | | | | 28 | | |

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| *Euchaeta marina* | 2 | 2 | 54 | 45 | 32 | 25 | 58 | 75 |
| *E. wolfendeni* | | | 2 | 5 | 6 | 30 | 7 | 12 |
| *E. flava* | | | | | | | | 5 |
| *E. media* | | | | | | 10 | | 2 |
| *E. plana* | | | | 5 | | | | |
| *Ctenocalanus longicornis* | | | | | 2 | | | |
| *Eucalanus subcrassus* | | 3 | 3 | 2 | 2 | | 9 | |
| *E. attenautus* | | | 5 | 7 | | | 3 | 3 |
| *E. crassus* | | | | | 2 | | 3 | |
| *Paracalanus parvus* | | 20 | 2 | | 5 | 32 | 7 | 6 |
| *P. aculeatus* | | | 7 | | 15 | 5 | | 7 |
| *Scolecithrix danae* | | | 54 | 40 | 55 | 15 | 5 | 70 |
| *Scolecithricella orientalis* | | | | 2 | | | 3 | |
| *Labidocera detruncata* | | | | | | | | 3 |
| *L. pavo* | | | 1 | | | | 5 | 2 |
| *Pontellina plumata* | | | 3 | 3 | | | | |
| *Centropages gracilis* | | | 1 | 2 | | 5 | | 2 |
| *C. calaninus* | | | 3 | 1 | | 2 | | |
| *C. pachydactyla* | | | 2 | | | 2 | 3 | |
| *C. longicornis* | | | 2 | | | | | |
| *C. elongatus* | | | 2 | 4 | | | | |
| *Lucicutia flavicornis* | | | 1 | 4 | 2 | | | |
| *L. ovalis* | | | 2 | | | 2 | 7 | |
| *Temora turbinata* | | | | 1 | 1 | | | |
| *Phenna spinifera* | | | 3 | | | | | |
| *Bradyidius armatus* | | | 1 | | | | | |
| *Pleuromamma abdominalis* | | | | | | | 13 | |
| *P. xiphias* | | | | | | | 1 | |
| *P. robusta* | | | | | | 33 | 5 | |
| *P. minor* | | | | | | 1 | | |
| *P. gracilis* | | | 5 | | | | 3 | |
| *Mecynocera clausi* | | | 2 | | 3 | | | 3 |
| *Candacia catula* | | | 1 | 4 | 4 | | | |
| *C. simplex* | | | | 5 | | | | 5 |
| *C. bispinosa* | | 1 | 1 | | | | | 7 |
| *C. longimana* | | | | 5 | 8 | | | |
| *C. truncata* | | 2 | 3 | 15 | | 6 | 3 | 7 |
| *C. curta* | | | | | 3 | | | |
| *C. pacydactyla* | | | 2 | | 1 | 1 | | |
| *C. aethiopica* | | | 1 | | | | | |
| *C. pectinata* | | | 1 | | | | | |
| *C. bradyi* | | | 1 | | | | | |
| *Acartia longiremis* | | | | | | | 7 | |

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| *A. neligens* | | | 17 | 11 | | 8 | | |
| *A. clausi* | | 2 | 10 | | 4 | | | |
| *A. hamata* | | 4 | 10 | | 3 | | | |
| *Oithona similis* | | | 3 | | 20 | 15 | | |
| *O. plumifera* | 1 | 1 | 120 | 195 | 100 | 110 | 50 | 85 |
| *O. setigera* | | | 5 | | | | | |
| *Clytemnestra rostrata* | | 1 | 3 | 7 | 1 | | | |
| *C. scutellata* | | | 2 | 2 | | | | |
| *Euterpina acutifrons* | | | 7 | | | | | |
| *Corycaeus flaccus* | | | | | | | 11 | 9 |
| *C. catus* | | | | | | | 12 | 10 |
| *C. gibbulus* | 50 | 200 | 188 | 119 | 37 | 25 | 7 | 30 |
| *C. speciosus* | 13 | 18 | 68 | 175 | 38 | 45 | 23 | 40 |
| *C. crassiusculus* | | | 7 | | | | 6 | |
| *C. concinnus* | | | | | 13 | 23 | | |
| *C. trukicus* | | | 6 | | | | 20 | 10 |
| *C. longistris* | | | | 7 | | | 12 | |
| *C. lautus* | 3 | | | 10 | | | 16 | 13 |
| *Microsetella rosea* | 1 | 5 | 50 | 72 | 37 | 35 | 33 | 20 |
| *Macrosetella gracilis* | | | 25 | 42 | 10 | 30 | 11 | |
| *Sapphirina gastrica* | | | 2 | | | | 3 | |
| *S. opalina* | | | 2 | | | | | |
| *S. darwinii* | | | 2 | | 1 | | | |
| *S. gemma* | | | 1 | 2 | | | | |
| *S. angusta* | | | 1 | | | | | |
| *S. stellata* | | | 2 | | 2 | | 3 | 2 |
| *S. metallina* | | | 3 | 2 | 2 | | | |
| *Copilia mirabilis* | | | 2 | 6 | 3 | 2 | 4 | |
| *C. quadrata* | | | 1 | 2 | 4 | 3 | 1 | |
| *C. longistylis* | | | 2 | | 3 | | | |
| *Oncaea venusta* | | 3 | 64 | 90 | 85 | 55 | 28 | 50 |
| *O. media* | | | 7 | | | | | 4 |
| *O. medeterranea ?* | | | 3 | | | | | |

## III. Distribution of macro-plankton in the waters around the Bikini Atoll, with special reference to copepods

### 1. Sampling method

The material was collected during the period from May 21 to June 29, 1954 at the stations shown in Fig. 8 and Table 12, by the larva-net which was 130 cm in mouth-diameter and 450 cm in length being stretched with the Japanese minnow net in the anterior 350 cm in length and with the silk gauze of 60 meshes in the rest and was equipped with a 3.5 kg lead and the rope of 170 m long. The net-rope was slacked off by the drift of the ship and the net was hauled at the speed of 24 or 42.5 m per minute. Usually the sampling was repeated several times till the sufficient amount of plankton could be secured. Samples were fixed with 5 % formalin solution, divided into several taxonomical units excepting the sample of the last haul and then the radio activity was measured on respective subsamples thus classified. The samples obtained by the last haul at each station were brought to the author's laboratory and used in this study; only the sample from St. 1 was divided into two halves and one of which was offered to him for examination.

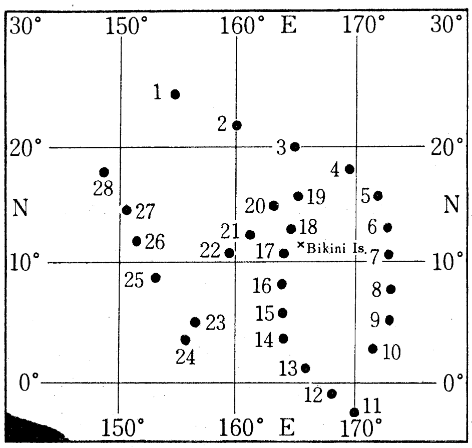


Fig. 8. Chart showing the stations set during the Japanese Bikini Expedition.

Table 12. Stations of the Japanese Bikini Expedition.

| Station | Date | Lat. | Long. | Time of observation (J.S.T.) |
|---|---|---|---|---|
| 1 | May 21 | 23°58′ N | 154°40′ E | 0500 ~ 0715 |
| 2 | 22 | 21 55 | 160 00 | 1903 ~ 2046 |
| 3 | 24 | 19 53 | 160 00 | 0909 ~ 1025 |
| 4 | 29 | 18 12 | 169 43 | 1000 ~ 1153 |
| 5 | 30 | 16 02 | 171 50 | 1100 ~ 1232 |
| 6 | 31 | 13 51 | 172 56 | 0400 ~ 0538 |
| 7 | June 1 | 10 44 | 173 03 | 0400 ~ 0600 |
| 8 | 2 | 8 02 | 173 02 | 0315 ~ 0442 |
| 9 | 3 | 5 03.5 | 172 59 | 0945 ~ 1400 |
| 10 | 4 | 3 01 | 171 59 | 0400 ~ 1244 |
| 11 | 6 | 2 21 S | 169 56 | 0400 ~ 1740 |
| 12 | 7 | 1 15 S | 168 05 | 0400 ~ 0600 |
| 13 | 8 | 1 04 N | 165 47 | 0400 ~ 0615 |
| 14 | 9 | 3 55 | 163 52 | 0400 ~ 1100 |
| 15 | 10 | 5 44 | 163 58 | 0417 ~ 0730 |
| 16 | 11 | 8 43 | 164 01 | 0800 ~ 1005 |
| 17 | 12 | 10 55 | 163 51 | 0400 ~ 0758 |
| 18 | 13 | 13 23 | 164 25 | 0800 ~ 1039 |
| 19 | 14 | 15 57 | 165 22 | 0445 ~ 0715 |
| 20 | 19 | 15 03 | 163 15 | 0400 ~ 0555 |
| 21 | 20 | 12 42 | 161 26 | 0800 ~ 1030 |

| | | | | |
|---|---|---|---|---|
| 22 | 21 | 10 21 | 159 35 | 0715 ~ 0933 |
| 23 | 23 | 5 03 | 155 53 | 0747 ~ 1300 |
| 24 | 24 | 3 24.5 | 155 34 | 0800 ~ 1025 |
| 25 | 26 | 8 59 | 152 51 | 0535 ~ 0613 |
| 26 | 27 | 12 00 | 151 10 | 0438 ~ 0530 |
| 27 | 28 | 14 46 | 149 56 | 0020 ~ 0122 |
| 28 | 29 | 18 00 | 148 38.5 | |

## 2. Composition and distribution of macro-plankton

Individual numbers of all the identified species were carefully counted in respective samples. The proportions of important animal groups are shown in Table 13. The most abundant animal was copepod and next came chaetognath. Besides, colonies of *Collozoum* and *Sphaerozoum* of Radiolaria, *Oikopleura,* some ostracods and *Pyrocystis pseudonoctiluca* of Dinoflagellata were occasionally observed in abundance, but they were not shown in this table.

Table 13. Composition of chief animal groups at each station in the waters around the Bikini Atoll.

| Group \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total number | 870 | 1838 | 629 | 147 | 477 | 761 | 456 | 846 | 769 | 2538 | 2247 | 2518 |
| Copepoda | 68.6 | 47.7 | 78.4 | 74.8 | 49.4 | 58.5 | 66.2 | 76.8 | 48.0 | 57.3 | 52.8 | 54.8 |
| Amphipoda | 0.6 | 1.8 | 1.0 | | + | + | + | + | + | + | + | 0.5 |
| Euphausiacea | 4.0 | 10.8 | 3.3 | | + | 3.0 | + | + | + | 0.6 | 0.9 | 0.8 |
| Decapoda | + | 8.3 | + | + | 1.9 | + | | + | | + | 0.8 | + |
| Phyllopoda | | + | | | | | | | | | | |
| Fish larvae, eggs | 1.1 | 1.4 | 0.8 | | 1.0 | + | 1.3 | + | + | + | 0.8 | 0.7 |
| Chaetognatha | 25.3 | 18.9 | 13.4 | 20.0 | 41.9 | 32.9 | 20.8 | 17.0 | 46.0 | 39.7 | 38.9 | 37.7 |
| Medusae | | 10.9 | 3.0 | 4.1 | 4.6 | 4.5 | 11.2 | 5.0 | 4.9 | 1.7 | 5.7 | 5.1 |

Values in columns represent the percentages.
+ : less than 0.5 %.

Abundant species among the above-mentioned animal groups were as follows: among Euphausiacea, most of which were in Furcilian stage, adults of *Euphausia krohnii* were observed abundantly at Sts. 2, 26 and 27. Besides, *Siriella thompsonii* (Mysidacea), *Thysanopoda tricuspidata* and *Stylocheiron carinatum* were observed, too, though they were less abundant. The representatives of amphipods were *Hyperia schizogeneios, Parascelus zebu* and *Phronima stebbingi;* but these species were not observed frequently. Among crustacean decapods, *Lucifer raynaudii* was observed almost at every station, especially abundantly at the Sts. 2, 5 and 27. Phyllopods other than a few *Evadne* were not observed in the samples. Chaetognaths were important animal group next to copepods and were represented by *Sagitta serratodentata pacifica, S. hexaptera, S. enflata* and *Pterosagitta draco.* The abundant species of Copelata (Tunicata) were *Oikopleura longicauda, O. fusiformis, O. rufescens, Megalocercus huxleyi* and *Stegosoma magnum*. *Muggiaea* and *Diphes* were the chief components of Medusae. Besides, there were many animals but they were unidentified because of lack of the knowledge on these animals and left out of the table.

There were 118 species of copepods. Among them *Euchaeta marina* showed the highest frequency of occurrence, occupying 20~50 % of all the copepods throughout the stations except St. 1 and was followed by *Calanus darwinii, C. minor, Scolecithrix danae, Corycaeus speciosus, Candacia truncata* and *C. aethiopica*.

### 3. Differences of plankton composition according to the currents

The surveyed area covered from 30°N to 5°S and from 145°E to 175°E, and the stations where the sampling was carried out were distributed in four oceanic currents, South Equatorial Current, Equatorial Counter Current, North Equatorial Current and the northern waters beyond the last named one. These stations were arranged on four cruise lines named conveniently A, B, C and D ranging from the east to the west.

| 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2396 | 2142 | 271 | 778 | 859 | 336 | 1504 | 1998 | 614 | 1304 | 399 | 692 | | 355 | 1907 | 1569 |
| 41.1 | 68.8 | 78.9 | 65.2 | 66.3 | 92.9 | 81.5 | 63.6 | 57.6 | 63.6 | 53.6 | 68.9 | | 65.1 | 64.8 | 66.1 |
| + | 0.5 | | + | 1.0 | 0.9 | 0.9 | + | + | 0.8 | 1.5 | + | | + | 1.6 | 0.6 |
| 0.6 | 1.0 | + | + | 1.5 | 0.9 | 1.0 | 0.8 | 1.5 | 1.7 | 1.8 | + | | + | 2.1 | 4.1 |
| + | + | + | + | + | | + | + | + | 0.9 | + | | | | + | 3.5 |
| | | | | | | | + | | | | | | | | + |
| | 2.4 | + | 1.4 | 0.7 | + | + | 0.8 | + | + | + | 1.2 | | 0.8 | + | 0.8 |
| 55.3 | 24.1 | 13.6 | 28.3 | 25.8 | 3.6 | 16.3 | 32.9 | 30.6 | 30.3 | 30.1 | 21.4 | | 30.7 | 29.0 | 8.3 |
| 2.4 | 2.8 | 6.3 | 4.1 | 4.1 | 1.2 | + | 1.3 | 8.3 | 2.3 | 12.5 | 7.7 | | 2.8 | 1.6 | 6.7 |

Each of the above-mentioned four currents was of tropical origin and differed only in the direction and each of the four cruise lines was set across these currents. It is very hard to make out the difference in the nature of the water masses only by those currents or by the cruise lines, and the similarity of the nature of the waters of these currents and that along the lines are supported by the results of the oceanographic observations. But, on the other hand, it is very interesting to clarify the nature of the water masses by the difference in composition or relative abundance of the species according to the currents or the lines with similar nature of water; and if the differences are marked, they are in support of the presence of the characteristic species in respective currents or occasionally latitudes with similar quality of water. From this point of the view, the below-mentioned examinations were done.

Table 14. Occurrence of important species in the samples collected during the Japanese Bikini Expedition.

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Number of Copepoda | 597 | 877 | 493 | 110 | 236 | 445 | 302 | 650 | 367 | 1455 |
| *Calanus darwinii* | 16.3 | 15.9 | 12.6 | 14.6 | 9.8 | 6.8 | 20.2 | 8.5 | 20.0 | 10.2 |
| *C. helgolandicus* | 8.7 | 4.8 | 29.4 | 26.4 | 2.1 | 29.2 | + | + | | |
| *C. tenuicornis* | 9.1 | 1.4 | 2.0 | | 2.1 | 2.3 | + | + | | |
| *C. robustior* | 1.3 | 1.3 | 1.2 | 1.8 | 11.4 | 1.8 | | 3.7 | 3.0 | + |
| *C. vulgaris* | | | | | | 2.0 | 1.3 | 12.9 | 3.5 | 1.3 |
| *C. gracilis* | 1.2 | + | + | | | | 3.6 | | + | |
| *C. minor* | 11.0 | 6.6 | 14.8 | 1.8 | 25.0 | 9.0 | 16.2 | 23.7 | 4.1 | 1.3 |
| *C. pauper* | 4.0 | + | + | | | | | | | |
| *Eucalanus attenuatus* | + | 1.3 | | | + | + | | | | 4.7 |
| *E. mucronatus* | | + | 4.7 | 11.8 | | + | 1.3 | + | | |
| *E. crassus* | | | + | + | | | | | | |
| *E. subcrassus* | | | | | | | | | | |
| *Rhincalanus cornutus* | | | | | | | | + | | 3.0 |
| *Acrocalanus gracilis* | + | + | | | | | | | | 3.0 |
| *A. gibber* | + | + | | | | | | | | |
| *A. longicornis* | | + | | | | | | | | 0.8 |
| *A. monachus* | | | | | | | | | | + |
| *Paracalanus aculeatus* | 1.5 | + | | | | | | | | |
| *P. arcuicornis* | + | + | | | | | | | | |
| *P. parvus* | 1.2 | + | | | | | | | | + |
| *Clausocalanus furcatus* | 4.4 | + | | | | 1.1 | | | | + |
| *C. arcuicornis* | + | 2.1 | + | | | + | | | + | 1.0 |
| *C. pergens* | 2.7 | + | | | + | | | | | |
| *Calocalanus pavo* | | | | | | | | | | |
| *Pseudocalanus elongatus* | | | | | | | | | | |
| *Scaphocalanus pacificus* | + | + | | | | | | | | |
| *Aetidius giesbrechti* | 1.5 | + | + | | | | | | | |
| *A. armatus* | | + | | | | | | | | |
| *Scottcalanus helenae* | | + | + | | | | | | | + |
| *Euchirella amoena* | + | + | 2.0 | | + | 1.6 | 1.3 | + | | |
| *Euchaeta media* | + | + | | | | | | | | |
| *E. flava* | + | + | | | | | | | | |
| *E. wolfendeni* | + | + | | | | | | | | |
| *E. marina* | + | 7.6 | 19.7 | 31.8 | 24.2 | 28.8 | 23.2 | 30.3 | 35.2 | 58.7 |
| *E. plana* | 2.0 | 4.5 | + | | | | | | | |
| *E. longicornis* | + | + | | | | | | | | |
| *Scolecithricella minor* | + | | + | | | | | | | |
| *S. bradyi* | + | | + | | | | | | | |
| *S. spinipedata* | + | | | | | | | | | |
| *S. abyssalis* | | | | | | | | | | + |
| *S. orientalis* | | | | | | | | + | | + |
| *Scolecithrix danae* | + | 1.6 | 1.8 | | 6.8 | 3.6 | 4.3 | 3.5 | 18.2 | 6.5 |

| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1187 | 1379 | 984 | 1474 | 214 | 507 | 570 | 312 | 1226 | 1270 | 354 | 829 | 214 | 497 | | 231 | 1235 | 1037 |
| 11.3 | 10.4 | 6.4 | 7.6 | 13.6 | 12.0 | 7.1 | 8.7 | 6.1 | 5.1 | 1.4 | 2.3 | 7.9 | 15.7 | | 3.0 | 5.7 | 4.2 |
| | 2.0 | 3.9 | 3.7 | | | | | + | 2.8 | 3.1 | 2.4 | | | | | 2.9 | + |
| | + | + | 0.7 | 2.8 | + | 2.8 | 1.9 | 0.8 | 1.6 | | + | + | | | 1.3 | 0.9 | 1.9 |
| | + | | 0.9 | 5.1 | | + | 2.2 | 0.9 | + | | + | | | | + | 1.4 | + |
| 1.1 | 4.9 | 4.8 | 0.9 | 11.2 | 2.4 | 7.4 | 1.9 | 3.8 | 5.4 | 1.4 | 2.5 | + | 1.8 | | 5.2 | 2.8 | 1.7 |
| 20.5 | 5.9 | 5.8 | 2.0 | 14.5 | 3.9 | 13.3 | 17.3 | 9.2 | 6.1 | 7.5 | 2.9 | 2.8 | 19.3 | | 15.5 | 1.6 | 3.9 |
| | | | | | | | | | 1.3 | | | | | | + | | |
| 23.5 | 8.3 | 5.0 | 0.9 | | + | + | + | 1.1 | 1.3 | + | + | + | + | | | + | 1.2 |
| + | | | | + | | | | | | | | | | | | + | |
| | | | | | | | | | | | | | | | | 1.9 | |
| | 1.7 | | | | | | | | | | | | | | | | |
| + | + | + | + | | | + | | | | | | | | | | | |
| | 4.0 | 1.9 | 0.7 | | | | | + | | | | | | | | 4.6 | + |
| | | + | + | | | | | | | | | | | | | | + |
| | | | + | | | | | + | + | | | | | | | 1.0 | + |
| + | + | | | | | | | | | | | | | | | | + |
| | | | | | | | | | | + | | | | | | | |
| | | | | | | | | | | | 2.5 | 13.1 | | | 1.7 | | 1.3 |
| 1.8 | 3.3 | 2.6 | 1.9 | | | | | | 3.1 | + | | | 2.3 | | | 7.6 | 1.0 |
| | 1.5 | + | + | | | | | + | + | | 1.4 | | | | 1.7 | 1.9 | |
| | | | | | | | | | + | | | | | | | | |
| | | | | | | | | | | | | | | | | | + |
| | | | | | | | | + | | | | | | | | + | + |
| + | + | | + | 1.4 | + | | 1.9 | 2.4 | 2.7 | + | + | | | | 1.3 | 1.1 | 1.4 |
| 14.5 | 35.0 | 59.7 | 33.4 | 20.1 | 46.7 | 38.4 | 26.0 | 49.2 | 49.6 | 27.1 | 40.9 | 7.9 | 30.0 | | 4.2 | 28.7 | 20.3 |
| | | | | | | | | + | | | | | | | + | 0.9 | 1.0 |
| | | | + | | | | | + | | | | | | | | | |
| | | | + | | | | | | | | | | | | | | |
| | | + | + | | | | | + | | | | | | | + | + | |
| 6.9 | 11.0 | 2.4 | 4.3 | 9.8 | 7.9 | 3.2 | 3.8 | 5.1 | 1.7 | 1.1 | 2.5 | 9.3 | 4.8 | | 3.9 | 1.4 | 1.5 |

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Phaenna spinifera* | + | | | | | | | + | | |
| *Temora turbinata* | | | | | | | | + | | |
| *Centropages abdominalis* | + | 2.1 | | | | | | | | |
| *C. bradyi* | + | + | | | | | | | | |
| *C. violaceus* | + | + | | | | 1.1 | | + | + | + |
| *C. calaninus* | | + | + | | + | | | | | |
| *C. elongatus* | | + | | | | | | | | |
| *C. gracilis* | | | | | | + | | + | + | + |
| *C. longicornis* | | | | | | | | | | + |
| *Pleuromamma gracilis* | + | 24.5 | 1.0 | | | | | + | | |
| *P. robusta* | + | 8.8 | | | | | | | | |
| *P. xiphias* | | 4.3 | + | | | | | | + | |
| *P. abdominalis* | | + | + | | | | | | | |
| *Lucicutia flavicornis* | 1.8 | + | | | | | + | + | 1.9 | + |
| *L. ovalis* | | | | | | | | + | + | + |
| *Heterorhabdus papilliger* | + | + | + | | | + | 1.3 | | | |
| *Haloptilus longicornis* | + | + | + | | | 2.9 | + | 1.7 | + | |
| *H. mucronatus* | + | + | | | | + | + | | | |
| *H. acutifrons* | + | + | + | | | + | | | | |
| *H. oxycephalus* | + | + | | | | | | | | |
| *H. ornatus* | + | + | | | | | | | | |
| *Candacia bradyi* | + | + | | | | | | | | |
| *C. discaudata* | + | + | | | | | | | | |
| *C. catula* | + | + | | | | | | | | 3.8 |
| *C. longimana* | + | + | | | | | | | | |
| *C. bipinnata* | + | + | | | | + | | | | |
| *C. truncata* | 3.9 | + | + | + | 3.0 | 3.6 | 2.3 | + | 4.1 | 2.0 |
| *C. bispinosa* | 3.2 | + | 1.2 | | + | 3.8 | | 1.4 | 1.4 | + |
| *C. aethiopica* | + | + | + | 3.6 | 4.2 | 2.0 | + | + | + | |
| *C. simplex* | 1.0 | + | + | | | 1.1 | 2.6 | + | + | 1.0 |
| *C. curta* | | | | | | + | | | | |
| *C. violaceus* | | | | | | | | | | + |
| *C. pachydactyla* | | | | | | | | | | |
| *Arietellus armatus* | + | | | | | | | | | |
| *Labidocera detruncata* | | + | | | | | | | | |
| *L. pavo* | | + | | | | | | | | |
| *L. tenuicauda* | | + | | | | | | | | |
| *L.* sp. | | + | | | | | | | | |
| *Pontella* sp. | + | + | | | | | | | | |
| *Pontellina plumata* | + | + | | | | | | + | 1.1 | + |
| *Pontellopsis perspicax* | | | | | | | | | | + |
| *P. tenuicauda* | | | | | | | | | | + |
| *Acartia neligens* | + | | | | | | 2.3 | | | |
| *A. clausi* | + | | | | | | | | | |

| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | + | | | + | | | | | | | | | | | | |
| + | + | + | | | | + | | | + | 1.1 | + | | 2.1 | | + | + | |
| | + | | | | + | 1.2 | | | | + | + | + | + | | | | + |
| | | | | 2.3 | + | | | + | | + | + | + | + | | + | + | + |
| + | + | | | + | | | | | + | + | | | | | | + | + |
| | + | | | + | | | | | | | | | | | | | + |
| + | | | | | | | | | | | + | | | | + | 4.5 | 6.6 |
| | | | | | | | | | | | | | | | + | | |
| | | | | | | | | | + | | | | | | | 10.3 | 6.2 |
| | | | | | + | | | | | | | | | | | + | 7.7 |
| 1.2 | + | + | + | + | + | + | | + | + | | + | + | 1.3 | | + | 2.8 | 1.9 |
| 1.1 | + | | + | + | | + | | + | + | | | | | | | + | 1.5 |
| | | | + | + | | | | | | | | | | | | 1.1 | + |
| | | | + | 2.8 | | + | | + | | | | | | | | | + |
| | | + | | | | | | | | | + | | | | | | |
| | | | | + | | | + | | | | + | | | | | | |
| | | | | + | | | | | | | | | | | | | |
| | + | | + | + | | | | + | + | | | | | | | | |
| 2.0 | | + | + | 2.3 | + | 3.7 | 5.1 | 2.4 | 0.8 | 4.0 | 1.9 | 3.7 | 4.0 | | 1.7 | + | 4.4 |
| + | | + | + | | | + | + | 1.6 | + | + | + | | | | | 0.9 | + |
| | + | 1.4 | 32.2 | | 2.8 | 2.8 | 6.7 | + | + | 5.9 | 1.2 | 11.2 | + | | + | 3.7 | 1.0 |
| + | + | + | | 1.4 | 3.0 | 1.6 | + | 1.5 | 4.6 | 2.0 | 1.7 | 8.4 | 1.4 | | 3.0 | 1.1 | 1.4 |
| + | + | + | | | | | | | | 1.1 | | | | | | + | + |
| + | + | + | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | + | + |
| 1.2 | 0.9 | + | + | | | | + | + | + | | + | | | | + | 1.1 | + |
| | 0.9 | | + | | + | + | | + | + | 3.1 | 1.1 | + | | | + | 1.4 | |

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Oithona plumifera* | + | | + | | + | + | | 1.1 | + | 0.8 |
| *O. setigera* | | | | | | | | | | |
| *O. robusta* | | | | | | | | | | |
| *Oncaea venusta* | + | | | | | | | | | |
| *O. media* | | + | | | | | | | | |
| *Lubbockia squillimana* | | | | | | | | | | |
| *Sapphirina daerwinii* | + | 1.1 | | | | | | + | | |
| *S. auronitens* | + | + | + | | | + | | | | |
| *S. stellata* | + | + | | | | | | | + | |
| *S. gastrica* | | + | | | | + | | | | + |
| *S. nigromaculata* | | + | | | | | | | | |
| *S. metalina* | | | | | | | | + | | + |
| *S. intestinata* | | | | | | | | | | |
| *S. quadrata* | | | | | | | | | | |
| *S. angusta* | | | | | | | | | | |
| *S. gemma* | | | | | | | | | | |
| *S. scarlata* | | | | | | | | | | |
| *Corycaeus gibbulus* | + | | | | | | | | | |
| *C. lautus* | + | + | 1.0 | | 1.7 | + | | | | |
| *C. speciosus* | 1.0 | + | 1.6 | 3.6 | 3.0 | + | | | | 11.8 |
| *C. flaccus* | 2.7 | | + | | | 16.2 | 8.0 | 5.4 | 2.4 | + |
| *C. crassiusculus* | | | | | 3.8 | + | | | | + |
| *C. longistylis* | | | | | | 1.3 | + | + | + | |
| *C. catus* | | | | | | + | + | | + | + |
| *C. trukicus* | | | | | | | | | | |
| *C. japonicus* | | | | | | | | | | |
| *Copilia mirabilis* | 1.0 | + | | + | | + | 6.0 | 1.2 | | + |
| *C. quadrata* | 2.0 | + | | 1.8 | | | + | | | |
| *C. longistylis* | + | + | | | | | | | | |
| *Pachysoma dentatum* | + | + | | | | | | | | |
| *P. punctatum* | | | | | | | | | | |
| *Undeuchaeta plumosa* | | + | | | | | | | | |
| Individual number of Amphipoda in each sample | | | | | | | | | | |
| *Oxycephalus porcellus* | | | | | | | | | | |
| *Phronima pacifica* | 2 | 4 | | | 1 | 1 | | 2 | | 4 |
| *Phronima* sp. | | | 1 | | | | | | | |
| *Leptocotis ambobus* | | 3 | | | | | | | | |
| *Parascels zebu* | | 11 | 1 | | | | | | | |
| *Phronimopsis spinifera* | | 7 | | | | | | | | |
| *Hyperia schizogeneios* | 2 | 4 | | | 1 | 3 | | | | |
| *Hyperia* sp. | | 1 | | | | | | | | |
| *Anchylomera blossevillii* | | 1 | | | | | | | | |

| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2.2 | + | + | | | | | 1.1 | + | 3.1 | 2.3 | | | | | 2.0 | 1.4 |
| 3.1 | | | | 1.9 | | | | | | | 2.7 | | | | + | | |
| + | | | | | | | + | | | | | | + | | | | |
| + | 1.3 | + | + | + | 3.2 | + | | + | | | + | 15.4 | 4.0 | | | + | 4.4 |
| | | | | | | | | | | | | | | | | | + |
| | | | | | + | | | | | | + | | | | | | |
| | | | | | | | | + | + | | | | + | | | + | + |
| | + | | + | + | + | + | 1.3 | + | | 1.4 | + | + | | | | | + |
| | + | | | | | + | | | | + | + | | + | | | | + |
| | | + | | | | | | | | | | | | | | | + |
| 1.4 | + | + | + | | | | | | | | | | + | | | | |
| + | | | | | | | | | | | | | | | | | |
| + | | | | | | | | | | | | | | | | | |
| + | | | | | | | | | | | | | + | | | | |
| | | | + | | + | | | | | | | | | | | + | |
| | | | | | | | | | | | | | | | | | + |
| + | + | | 9.9 | | | + | 4.5 | 2.3 | 1.7 | 7.5 | 3.7 | 4.8 | | | 1.7 | + | + |
| 3.9 | 1.5 | + | 2.9 | 2.8 | 5.7 | 3.7 | 3.2 | 5.5 | 4.4 | 4.9 | 11.3 | 7.0 | 3.4 | | 5.2 | 3.5 | 3.8 |
| + | + | + | 1.4 | + | | 1.1 | 7.4 | 2.0 | 4.2 | 7.6 | 4.6 | + | | | + | 2.5 | + |
| | + | | | | | 4.4 | | | + | | | | | | | | |
| + | | | | | | 1.2 | + | | | + | | | | | | | |
| | + | | | + | | | | + | | | + | | + | | 1.7 | + | |
| | | | | | + | | 1.6 | | | 3.1 | 1.1 | | | | | | |
| | | | | | | | + | | | | | | | | | | |
| + | + | | 0.7 | | 5.1 | 1.1 | 1.9 | + | + | 7.5 | 2.2 | 2.8 | 4.2 | | | + | 9.8 |
| | + | | + | + | 1.2 | + | | | | | + | | + | | | | + |
| + | | | | | + | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | + |
| | | | | | + | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| 1 | 1 | 2 | | | | | | | | | | 2 | 1 | | | 1 | |
| 1 | 7 | 1 | 2 | | | 4 | | | | | | 1 | | | 1 | | 6 |
| | | | | | | | | | | | 1 | | | | | | |
| | 1 | | 1 | | 1 | 2 | | 7 | 9 | | 3 | | 1 | | | | |
| | | | | | | 1 | | | | | | | | | | | |
| | 4 | | 6 | | 2 | 2 | 3 | 3 | | 3 | 3 | 2 | 1 | | | 30 | 4 |
| | | | 1 | | | | | 3 | | | | | | | | | |

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Individual number of Euphausiacea in each sample | | | | | | | | | | |
| *Stylocheiron carinatum* | 3 | | | | 2 | 2 | 1 | | 2 | |
| *Euphausia gracilis* | | 17 | 1 | | | | | | | |
| *E. gibba* | | 3 | | | | | | | | |
| *E. krohnii* | 1 | 106 | | | | | | | | |
| *Thysanopoda obtusifornus* | | | | | | | | | | |
| *T. tricuspidata* | | 7 | 1 | | | | 1 | 1 | 2 | |
| *Stylocheiron suhmii* | 10 | | | | | | | | | |
| Furcilian stage of Euphausiacea | 21 | 56 | 15 | | | 20 | 11 | 17 | 3 | 5 |
| *Siriella thompsonii* | | 10 | 4 | | | 1 | | | | 1 |
| *Siriella* sp. | | | | | | | | | | 1 |
| *Lucifer raynaudii* | 1 | 88 | 1 | 1 | 8 | 1 | | 2 | | 10 |
| Ostracoda | | 75 | | | | | | | | |
| Fish larvae | 4 | 15 | | | 3 | 3 | 5 | 2 | 3 | 3 |
| Fish eggs | | 10 | 5 | | 2 | | 1 | 2 | 1 | 1 |
| Zoea | | 1 | | | | | | | 1 | |
| Veliger | | | | | | | | | 1 | |
| Medusae (*Muggiaea etc.*) | 101 | 19 | 6 | 15 | 26 | 36 | 18 | 11 | 41 | 113 |
| *Collozoum* and *Sphaerozoum* | | R | P | | C | P | | | | |
| *Pyrocystis pseudonoctiluca* | | CC | CC | C | C | P | | | | |
| Total number of Chaetognatha | 220 | 347 | 84 | 30 | 200 | 250 | 95 | 144 | 354 | 1007 |
| Composition of Chaetognatha (%) | | | | | | | | | | |
| *Sagitta hexaptera* | 12.7 | + | 15.5 | 16.7 | 22.5 | 30.4 | 49.4 | 34.0 | 3.1 | 5.5 |
| *S. lyra* | 1.8 | | | | | | | | | |
| *S. enflata* | 15.9 | 6.1 | 17.9 | 16.7 | 24.0 | 7.6 | 9.6 | 20.9 | 69.2 | 67.9 |
| *S. bipunctata* | 8.2 | 12.6 | | 6.6 | 3.5 | 3.6 | 4.2 | 11.8 | + | |
| *S. ferox* | + | | | | | | | | | |
| *S. robusta* | | 3.6 | 3.6 | | 2.5 | 2.4 | 5.3 | + | 1.4 | + |
| *S. pulchra* | | | | | | | | | | |
| *S. serratodentata pacifica* | 8.6 | 70.3 | 28.6 | 40.0 | 17.5 | 35.6 | 25.3 | 15.3 | 17.5 | 14.9 |
| *S. serr. atlantica* f. *pseudoserratodentata* | + | | | | | | | | | |
| *S. neglecta* | | | | | | | | | | |
| *S. regularis* | | | | | + | | 1.0 | + | + | + |
| *S. minima* | 7.7 | | | | | | | | | |
| *Pterosagitta draco* | 35.0 | + | 27.4 | 20.2 | 27.0 | 16.0 | 4.2 | 11.8 | 7.9 | 5.5 |
| *Krohnitta subtilis* | 6.4 | | 2.3 | | | | | | | |
| *K. pacifica* | 1.8 | 6.9 | 1.1 | | | | | | | 2.3 |
| *Sagitta decipiens* | | | | | | | | | | |
| *S.* sp. | + | + | 3.6 | | 2.5 | 4.4 | 1.0 | 4.8 | + | 2.8 |

| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | | | | | | | 2 | 1 | | | | | | | 27 | |
| | | | | | | | | | | | | | | | | 7 | 6 |
| 3 | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | 39 | 28 |
| | | | | | | | | | | | | | | | | | 2 |
| | | | 44 | | 2 | 1 | | | | 2 | | | | | | | |
| | | | | | | | | | 3 | 2 | 4 | | | | | | |
| 8 | 58 | 62 | 5 | 1 | 14 | 15 | | 12 | 16 | 5 | 17 | 4 | 54 | | 2 | 38 | 82 |
| | | | | | | | | 3 | 17 | 2 | | | | | | 22 | |
| | | | | | | | | | | | | | | | | 2 | |
| 18 | 7 | 12 | 9 | | | 1 | | 1 | 5 | 3 | 9 | 1 | | | | 3 | 55 |
| | | | 7 | 4 | | 1 | | | 2 | | | | | | | 1 | 29 |
| 17 | 5 | ? | 6 | | 4 | 1 | | | 8 | 2 | 3 | | 2 | | 3 | 3 | 11 |
| 11 | 12 | ? | 45 | 1 | 7 | 5 | 2 | 3 | 7 | 1 | 3 | 1 | 6 | | | 4 | 4 |
| | 1 | 1 | | | 1 | 5 | | | | | 3 | 2 | | | | | |
| | | | | | | | | | | | | | 1 | | | | |
| 78 | 55 | 22 | 11 | 26 | 31 | 2 | 2 | 24 | 51 | 29 | 17 | 48 | | | 4 | 19 | 102 |
| | | R | C C | | | | | C | C | C | | | | | | P | P |
| | | | R | | | | | C | C | | | | | | | P | C |
| 873 | 951 | 1324 | 516 | 37 | 220 | 222 | 12 | 245 | 657 | 188 | 395 | 120 | 148 | | 109 | 553 | 277 |
| 2.2 | 31.5 | 2.2 | 11.1 | 10.8 | 6.4 | 14.4 | | 26.9 | 18.6 | 17.5 | 10.6 | + | 5.4 | | 16.5 | 31.8 | 11.9 |
| 57.7 | 57.6 | 54.2 | 34.8 | 37.7 | 53.6 | 40.9 | 66.6 | 16.7 | 15.2 | 25.0 | 59.4 | 50.8 | 37.8 | | 12.8 | 13.6 | 28.2 |
| + | + | + | + | | 1.8 | 1.4 | 16.7 | 3.3 | + | 2.6 | 1.5 | 2.5 | | | 4.6 | 4.5 | 2.2 |
| 1.4 | 2.2 | + | | | + | + | | | + | + | | + | + | | | + | |
| + | 2.4 | + | 2.9 | 8.2 | 5.0 | 2.7 | | + | + | 1 | 3.0 | 2.1 | 8.8 | | 2.8 | 4.7 | + |
| | | | | | | | | | | | | | + | | | | |
| 20.5 | 25.1 | 31.4 | 32.7 | 18.9 | 16.8 | 15.3 | | 23.3 | 40.2 | 1.0 | 10.9 | 9.2 | 27.7 | | 43.1 | 29.1 | 26.0 |
| | | | | | | | | | | | | + | | | | | |
| | | | | | + | + | | | | | | | | | | | |
| 1.6 | + | + | + | 2.7 | + | + | | | | + | | | | | + | | + |
| 11.4 | 6.0 | 10.3 | 11.8 | 10.9 | 6.8 | 17.6 | | 25.3 | 21.6 | 19.1 | 8.5 | 1.0 | 18.2 | | 12.8 | 13.2 | 20.6 |
| | | | 1.1 | | | + | | + | | | | | | | | | |
| 17.2 | 1.7 | + | | 2.7 | + | | | | | | | | + | | | | 7.9 |
| | | | | 2.7 | | | | | | | | | | | | | |
| 2.1 | + | + | 4.3 | 5.4 | 1.4 | 4.5 | 16.7 | 2.8 | 3.0 | 5.3 | 6.1 | 4.1 | | | 6.4 | 2.9 | 2.2 |

Relative abundance of Copelata in the surveyed waters neglecting of the localities of stations.

| | | | |
|---|---|---|---|
| *Oikopleura longicauda* | C | *Fritillaria pellucida* | R R |
| *O. rufescens* | C | *F. venusta* | R R |
| *O. cophocersa* | R R | *F. megachile* | R R |
| *Megalocerucus huxleyi* | R R | *Kowalevskaia tenuis* | R |
| *Oikopleura fusiformis* | C | *Fritillaria formica* | R R |
| *O. parva* | R R | *F. haplostoma* | R R |
| *O.* sp. | R R | *F. borealis* f. *sargassi* | R R |
| *Stegosoma magnum* | C | *Pelagopleura* sp. | R |

Abbreviations : C C……very common, C………common, R………rare, R R……very rare, P……present, +……less than 0.5 %

Table 15. Classification of stations.

| Current \ Cruise line | A | B | C | D |
|---|---|---|---|---|
| The waters north to the North Equatorial Current | 4 | 3 | 1, 2 | 26 |
| North Equatorial Current | 5, 6, 7 | 17, 18, 19 | 20, 21, 22 | 27 |
| Equatorial Counter Current | 8, 9 | 14, 15, 16 | 23, 24 | 28 |
| South Equatorial Current | 10, 11 | 12, 13 | | |

All the stations were, at first, classified into four groups A, B, C and D as shown in Table 15. Then, the percentages of the occurrence of respective species to the total number of the fauna at each station are shown in Table 14. As to the percentages of the total number of Chaetognatha, Euphausiacea or Copepoda in respective columns, they were converted by the angle transformation. Here, the cruise lines A and B crossed four different water masses, while the cruise lines C and D passed through only three water masses. Consequently, the author examined at first the differences in the quantity of fauna caused by the three currents (Equatorial Counter Current, North Equatorial Current and the northern waters beyond the last named current ) and four cruise lines by the analysis method of variance and then the differences according to four currents and two cruise lines (the lines A and B). The results of the examination are shown in Table 16 (A, B and C). The results of the examination of the differences of three currents and four cruise lines reveal that the differences in the percentages of *Euphausia krohnii* and *Scolecithrix danae* according to currents and those of *Calanus robustior* of Copepoda with the longitudes are regarded as significant at 0.05 level of significance. The results of the examination of the differences in the four currents and the two cruise lines show that the percentages of *Sagitta enflata, S. bipunctata, Pterosagitta draco,* and *Krohnitta pacifica* of Chaetognatha, *Hyperia schizogeneios* of Amphipoda, *Eucalanus attenuatus, Acrocalanus gracilis, Clausocalanus pergens, Euchaeta marina, Haloptilus longicornis* and *Pontellina plumata* of Copepoda vary with the currents; and these resuls are regarded to be significant at 0.05 level of significance. The differences found in other animals, however, can not be regarded as significant.

All these results mentioned above are summarized into Table 17, taking Table 14 in consideration.

Table 16—A. Results of the examinations ($F_0$) on the differences in the distribution of respective species of copepods according to the currents and cruise-lines.

| | (1) | | (2) | |
|---|---|---|---|---|
| Species | Current | Cruise line | Current | Cruise line |
| *Calanus darwinii* | 1.30 | 2.29 | 1.76 | 5.18 |
| *C. helgolandicus* | 1.99 | 1.88 | 8.39 | 0.23 |
| *C. tenuicornis* | 0.55 | 0.55 | 22.40* | 0.86 |
| *C. robustior* | 0.15 | 13.84* | 9.62 | 2.38 |
| *C. vulgaris* | 0.25 | 0.33 | 1.46 | 0.03 |
| *C. minor* | 0.65 | 1.27 | 1.97 | 0.07 |
| *Eucalanus attenuatus* | 1.41 | 5.92 | 24.36* | 0.15 |
| *E. mucronatus* | 0.96 | 2.03 | 4.69 | 0.47 |
| *Rhincalanus cornutus* | 0.50 | 1.17 | 2.72 | 0.35 |
| *Acrocalanus gracilis* | 0.63 | 1.25 | 39.34* | 0.82 |
| *Clausocalanus arcuicornis* | 1.03 | 1.97 | 20.76* | 0.97 |
| *C. pergens* | 1.58 | 3.50 | 2.38 | 0.92 |
| *Euchirella amoena* | 2.16 | 0.88 | 2.12 | 0.24 |
| *Euchaeta marina* | 0.58 | 1.74 | 47.78* | 8.79 |
| *Scolecithrix danae* | 4.83* | 0.28 | 5.31 | 0.05 |
| *Pleuromamma gracilis* | 0.92 | 1.52 | 6.50 | 0.00 |
| *P. robusta* | 0.56 | 1.31 | — | — |
| *P. xiphias* | 1.00 | 1.48 | 1.50 | 0.00 |
| *P. abdominalis* | 0.74 | 1.46 | 3.00 | 1.00 |
| *Lucicutia flavicornis* | 0.62 | 4.89 | 4.32 | 0.52 |
| *L. ovalis* | 0.74 | 0.58 | 1.77 | 0.36 |
| *Haloptilus longicornis* | 0.59 | 3.79 | 13.54* | 0.83 |
| *Candacia truncata* | 0.58 | 0.23 | 7.65 | 0.05 |
| *C. bispinosa* | 0.38 | 1.10 | 1.91 | 0.04 |
| *C. aethiopica* | 0.92 | 1.42 | 2.18 | 0.31 |
| *C. simplex* | 0.44 | 2.89 | 1.76 | 0.10 |
| *Pontellina plumata* | 0.20 | 0.67 | 24.86* | 0.00 |
| *Acartia negligens* | 1.58 | 2.29 | 3.43 | 0.10 |
| *Oithona plumifera* | 0.15 | 0.26 | 1.55 | 0.07 |
| *Oncaea venusta* | 1.17 | 1.57 | 6.45 | 2.05 |
| *Corycaeus lautus* | 0.57 | 5.38* | 6.80 | 2.02 |
| *C. speciosus* | 0.53 | 3.03 | 1.25 | 0.73 |
| *C. flaccus* | 3.08 | 1.98 | 7.35 | 0.43 |
| *Copilia mirabilis* | 0.26 | 1.17 | 8.27 | 0.03 |
| *C. quadrata* | 0.48 | 0.80 | 1.39 | 0.11 |

Table 16—B. Examinations on the differences in the distribution of chaetognaths.

| | (1) | | (2) | |
|---|---|---|---|---|
| Species | Current | Cruise line | Current | Cruise line |
| *Sagitta hexaptera* | 3.99 | 3.40 | 8.49 | 0.13 |
| *S. enflata* | 3.71 | 1.07 | 12.94* | 0.00 |
| *S. bipunctata* | 2.15 | 3.38 | 13.67* | 2.12 |
| *S. serratodentata pacifica* | 0.73 | 0.60 | 1.58 | 0.02 |
| *Pterosagitta draco* | 3.13 | 0.93 | 56.33* | 0.31 |
| *Krohnitta pacifica* | 1.86 | 2.00 | 10.81* | 0.04 |

Table 16—C. Examinations on the differences in the distribution of Euphausiacea.

| | (1) | | (2) | |
|---|---|---|---|---|
| Species | Current | Cruise line | Current | Cruies line |
| *Phronima pacifica* | 0.92 | 0.68 | 3.98 | 0.00 |
| *Parascelus zebu* | 0.86 | 5.04 | 3.00 | 1.27 |
| *Hyperia schizogeneios* | 0.35 | 1.79 | 29.77* | 5.85 |
| *Stylocheiron carinatum* | 0.06 | 1.54 | 0.85 | 0.25 |
| *Euphausia gracilis* | 4.18 | 1.50 | 3.00 | 0.33 |
| *E. krohnii* | 5.25* | 2.81 | 3.00 | 0.33 |
| Furcilian stage of Euphausiacea | 0.72 | 1.53 | 4.76 | 0.19 |
| Fish larvae, eggs | 1.34 | 2.33 | 0.97 | 0.04 |
| *Siriella thompsonii* | 2.67 | 1.23 | 2.36 | 0.27 |
| *Lucifer raynaudii* | 0.33 | 2.35 | 3.61 | 0.29 |

Notes: (1) on 3 currents and 4 cruise lines.
(2) on 4 currents and 2 cruise lines.
$F_6^3(0.05)=4.76$ $F_6^2(0.05)=5.14$ $F_3^3(0.05)=10.13$ $F_3^3(0.05)=9.28$
The values which can be regarded to be significant at 0.05 level of significance, are marked with asterisk.

Table 17. Differences of the distribution of various species according to different currents.

| Species | NN | NEC | ECC | SEC |
|---|---|---|---|---|
| *Sagitta enflata* | | | ● | ● |
| *S. bipunctata* | ● | | | |
| *Pterosagitta draco* | ● | | | |
| *Krohnitta pacifica* | ● | | | ● |
| *Hyperia schizogeneios* | | ● | | |
| *Euphausia krohnii* | | ● | | ○ |
| *Calanus tenuicornis* | | ● | | |
| *Eucalanus attenuatus* | | | | ● |
| *Acrocalanus gracilis* | | | | ● |
| *Clausocalanus arcuicornis* | | | | ● |
| *Euchaeta marina* | | | | |

| | | | | | |
|---|---|---|---|---|---|
| *Scolecithrix danae* | | | | ● | ● |
| *Haloptilus longicornis* | | | ● | ● | |
| *Pontellina plumata* | ○ | | | | ● |

Notes : ● much abundant ○ less abundant

*Calanus robustior* and *Corycaeus lautus* were abundant at stations on A and C lines.

N N : the waters north to North Equatorial Current.

N E C : North Equatorial Current.

E C C : Equatorial Counter Current.

S E C : South Equatorial Current.

In this way, as the result of the investigation, several species of zoo-plankton are different in distribution depending on the respective currents. These zoo-plankton, however, all proved to belong to the oceanic species in the sub-tropical and tropical waters and distributed very widely. Accordingly, in order to get rid of accidental error as possible as they can, it seems very important for the researchers to pay a special attention to their method of collecting samples and to the time when the investigations were carried out.

## Chapter III Distribution of plankton in the tuna fishing grounds in the Indian Ocean

### Introduction

Till about a decade ago, the Indian Ocean had been left still in unexplored state in fishery; but even in those days, the valuable fundamental studies had been done by some research boats such as the Dana, Snellius, John Murray, Planet, Discovery, *etc.* The materials and raw data thus obtained by these boats were assorted and studied by many experts. And these papers are still appreciated very highly at present days and their distinguishable achievements will be remembered forever.

But, when this ocean is compared with the other ones, this ocean is not yet enough scientifically clarified. Moreover, even among many such valuable papers as mentioned above there are some to which we can not help giving such an out-spoken criticism that the stations were set rather too restricted to only a small part of this ocean or that the mesh size of the stations was too rough. Therefore, it is natural that there are many unknown facts in the details of the oceanographic conditions, fauna and flora.

These are the reasons why SCOR is now planning an extensive international expedition receiving the whole-hearted support of UNESCO; *i.e.*, that organization is going to set on the schedule of all-round expedition from physical, chemical, geological and biological points.

All the scientists who are interested in oceanography are anxiously waiting for its success, because this expedition under planning will bring us many valuable data of oceanographic specificities of the Indian Ocean.

The following authors have reported on plankton of this ocean: W. GIESBRECHT, P. T. CLEVE, A. SCOTT, I. C. THOMPSON and A. SCOTT, N. WOLFENDEN, O. PESTA, R. B. S. SEWELL, R. GURNEY, G. P. FARRAN and W. VERVOORT, C. GEORGE, B. B. GRAY, C. C. JOHN, S. H. LELE, T. S. RAO, J. M. THOMSON, *et al.* Among them, a series of works done by SEWELL (1912~'32 & '47) are highly appreciated, he has identified 252 species of copepods collected from various parts and layers of this ocean and discussed their distributions in detail.

In 1953, the Japanese fishermen began to explore actively the tuna in this ocean; and this made our scientists and research boats to endeavour to clarify the oceanographic conditions and other scientific problems of this ocean. Especially, most of the observations and researches were carried out by many of the research boats under command of local governments. And since 1957 the records offered by these boats and assorted by the staffs of Nankai Regional Fishery Research Laboratory under cooperation of Tuna Fishery Commission of Research Boats Owners, have been risen year by year its status in science. NAKAMURA and his coworkers who are the most leading group in studying the fishing conditions and ecology of tuna reached such hypothesis that locations of tuna fishing-grounds have very close relation to the oceanic current systems. Paying attention to the records obtained by the excellent research boats such as the Dana, John Murray, *etc.*, YAMANAKA and ANRAKU (1959), who are the staffs of NAKAMURA'S Laboratory, discussed the oceanographic conditions in detail in the Indian Ocean during winter chiefly based on the records obtained during the period from 1953 to '59 by research boats under command of local governments such as the Sagami-maru, Tone-maru and Daifuji-maru, research boats under direct command of Japanese Fishery Agency such as the Syoyo-maru and by training boats of fisheries colleges such as the Umitaka-maru, Keiten-maru and Shunkotsu-maru, that of our university, needless to say.

Meanwhile, as the examples of the excellent reports treating plankton in this ocean published in our country, the author wishes to cite here those by TANAKA (1960) and by SENO *et al.* (1961), in which the details of plankton collected by the Japanese Antarctic Expedition Vessel, Soya, and her attendant boat, the Umitaka-maru, during their trans-Indian ocean voyage from 1957 were discussed. Besides these, TOYOSHIMA, HONDA and IRIE (1960) reported the details of plankton collected during the cruise in the Indian Ocean by the Chosui-maru, a training boat of Nagasaki Fisheries High School. And TOKIOKA (1955 & '56) published valuable reports on Chaetognatha of this ocean.

Under such circumstances as mentioned above, the author has had the opportunities for examining the plankton samples collected by the Shunkotsu-maru during the period from 1953 to '58 from the below-mentioned five fishing grounds of tuna, in which are included a series of samples collected from the waters eastern parts of this ocean by the author himself during the period from December, 1956 to January, '57. These samples are listed below:

I) The waters west of the Greater Sunda Islands ··········· Dec. '53 ~ Jan. '54

II) The waters central part of the North Indian Ocean …… Dec. '54 ～ Jan. '55
III) The waters southeastern part of the Arabian Sea ……… Dec. '55 ～ Jan. '56
IV) The waters eastern part of the Indian Ocean …………… Dec. '56 ～ Jan. '57
V) The Bay of Bengal ……………………………………………… Dec. '57 ～ Jan. '58

And from the results of the examinations on these samples, the author gained the comprehensive knowledges of the plankton composition and the distribution in the respective waters and discussed their specificities and the relations between plankton and oceanographic conditions. Besides, he studied the taxonomy and the distribution of Amphipoda (in Part III, Chapter I) and Chaetognatha (in Part III, Chapter II).

This chapter deals only with plankton in the tuna fishing grounds; consequently, the author is afraid of the fact that the data were too scarce and the stations were too restricted in the distribution to give any adequate discussion on plankton of this ocean as a whole. It is hoped that further examination of the samples collected by well-designed schedule should be emphasized.

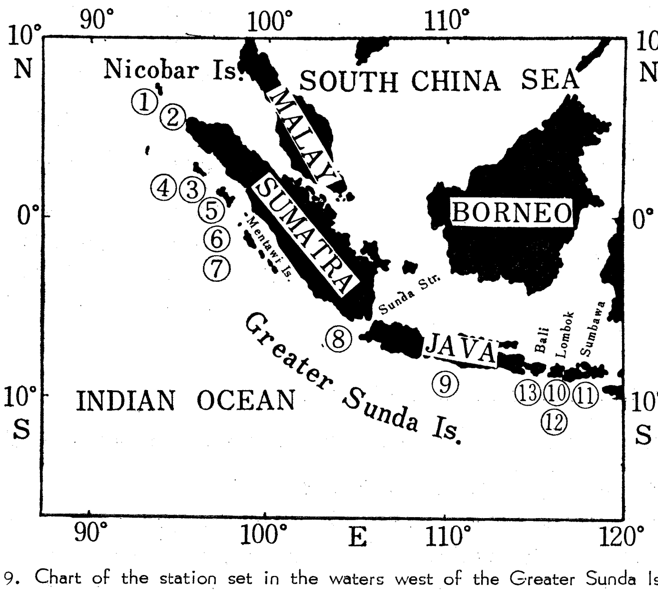


Fig. 9. Chart of the station set in the waters west of the Greater Sunda Islands.

## I. Distribution of plankton in the waters west of the Greater Sunda Islands

### 1. Sampling method

The samples were collected from the stations shown in Table 18 and Fig. 9. Here, it should be noted that these stations were set rather on-shore when compared with those discussed in other chapters and the other paragraphs of this chapter. It seems to be more rational to subdivide these stations into the following 5 parts.

A) South of the Nicobars (Sts. 1 & 2) B) Off Nias Island (Sts. 3～7)

C) Off Sunda Strait (St. 8) D) South of Java Island (St. 9)
E) South of Lombok Island (Sts. 10~13).

Plankton from 100 m layer to surface were hauled vertically at the speed of 50 cm per second by the net of 45 cm in mouth-diameter and 1.1 m in length, constructed with the gauze of 676 meshes per sq. cm. The details of the sampling, the oceanographic condition and precipitated volume are illustrated in Table 18.

Table 18. Oceanographic condition in the waters west of the Greater Sunda Islands.

| Region | Station | | | Date 1953~1954 |
|---|---|---|---|---|
| | No. | Lat. | Long. | |
| South of the Nicobar Islands | 1 | 6°49′ N | 93°21′ E | Dec. 27 |
| | 2 | 5°27′ N | 94°41′ E | 28 |
| Off Nias Island | 3 | 1°29′ N | 96°25′ E | 31 |
| | 4 | 1°28′ N | 96°21′ E | Jan. 2 |
| | 5 | 0°25′ N | 97°11′ E | 3 |
| | 6 | 0°03′ S | 97°13′ E | 4 |
| | 7 | 0°32′ S | 97°39′ E | 5 |
| Off Sunda Strait | 8 | 6°22′ S | 103°49′ E | 8 |
| South of Java Island | 9 | 8°40′ S | 110°21′ E | 16 |
| South of Lombok Island | 10 | 9°12′ S | 116°19′ E | 18 |
| | 11 | 9°29′ S | 116°47′ E | 19 |
| | 12 | 9°57′ S | 116°19′ E | 21 |
| | 13 | 9°13′ S | 115°11′ E | 22 |

## 2. Composition and distribution of plankton

The composition of plankton at each station are illustrated in Table 19.

**A.** South of the Nicobar Islands (Sts. 1 & 2)

Despite of the adequate mesh size of the used net, phyto-plankton in the samples were very poor not only in species but also in quantity; no species other than the following four could be found in the samples: *Chaetoceros coarctatus*, *Rhizosolenia imbricata*, *R. styliformis* and *Skujaella* sp. Planktonic protozoa in this waters consisted chiefly of a less abundant Dinoflagellata such as *Pyrocystis pseudonoctiluca* and *Ceratium sumatranum* f. *angulatum* and partly of *Globigerina bulloides* of Foraminifera, *Sphaerozoum geminatum* of Radiolaria, *Pyrocystis fusiformis* and *Ceratium inflexum* of Dinoflagellata. But, at St. 2, a small number of individuals of *Pyrocystis hamulus* var. *inaequalis* and *Amphisolenia thrinax* were found. The copepods were the most abundant among zoo-plankton and as much as 60 species were identified; *Oithona plumifera* and *Oncaea venusta* were especially abundant; besides them, the following 10 species are the most abundant members next to the above mentioned species of copepods: *Eucalanus subcrassas*, *Euchaeta marina*, *Scolecithrix danae, Acartia neligens, Copilia mirabilis, C. longistylis. Sapphirina gastrica, Corycaeus gibbulus, C. concinnus* and *Oncaea media.* It is worth while to describe here the presence of a several individuals of *Pachysoma punctatum,* which has never been illustrated in any of the papers in Japan. The following species were found though they were few in number: *Phronima* sp. of Amphipoda, furcilian stage of Euphausiacea larvae and *Cypridina* sp. of Ostracoda.

| Time | Weather | Water color | Transparency (m) | Water temp. (°C) | | Precipitated volume of plankton (cc) |
|---|---|---|---|---|---|---|
| | | | | Surface | 100m | |
| 11.00 | c | 2 | — | 28.2 | 21.0 | 4.5 |
| 15.00 | b | 1 | 41 | 29.7 | 19.47 | 2.9 |
| 12.00 | c | 1 | 33 | 29.0 | 26.37 | 2.5 |
| 13.00 | c | 1 | 36 | 29.1 | 27.82 | 3.1 |
| 13.30 | r | 2 | — | 28.9 | 27.22 | 7.6 |
| 12.00 | r | 1 | — | — | — | 1.8 |
| 14.00 | b | 1 | — | 29.2 | 23.73 | 1.9 |
| 11.00 | c | 1 | 35 | 29.1 | 17.85 | 2.8 |
| 14.00 | c | 1 | 35 | 29.2 | 20.93 | 2.0 |
| 15.00 | b | 3 | 24 | 30.1 | 21.75 | 10.1 |
| 15.40 | b | 3 | 25 | 30.1 | 21.10 | 7.0 |
| 13.20 | c | 2 | 24 | 30.3 | 22.13 | 5.0 |
| 13.00 | c | 2 | — | 29.3 | 23.59 | 3.8 |

The most abundant species of Chaetognatha was *Sagitta enflata,* and the following three species of this genus were also found: *S. serratodentata pacifica, S. regularis* and *Pterosagitta draco.* Very few individuals of *Oikopleura fusiformis* and *O. cophocerca* of Copelata were also found in the samples. Fish-fry, fish-eggs and bipinnarian stage of star-fish larvae were found as the members of the larval plankton, though each of them was not abundant. Abundant occurrence of Hydromedusae was one of the most remarkable characteristics of zoo-plankton composition at St. 1.

B. Off Nias Island (Sts. 3~7)

Besides the species of phyto-plankton represented in the preceding section, the following eight species occurred in this water, though each of them was very few in quantity: *Chaetoceros pervianus, Coscinodiscus* sp., *Rhizosolenia alata, R. bergonii, Stephanopyxis palmeriana, Thalassiothrix longissima, Thalassionema nitzschioides* and *Hemiaulus* sp. It aws the characteristic of the protozoan composition of this water that Foraminifera occurred in less frequently than that in the former water, but several individuals of genus *Aulacantha* of Radiolaria were found all over the stations. When the Dinoflagellata of this water was compared with that of the former wtaer, it is notable that in some stations off Nias Island *Ceratium carriense* and

*Pyrocystis pseudonoctiluca* increased but *Ceratium sumatranum* decreased till they all disappeared, but the following species took place for it and appeared in the other stations: *C. tenue*, *C. karstenii*, *C. macroceros*, *C. massiliens* and *C. bigelowii*.

**C.** Off Sunda Strait (St. 8)

Like the region A, this region was poor in the composition of plankton flora. The frequent occurrences of *Planktoniella sol* and the increased occurrence of *Skujaella* were the most remarkable characteristics of the plankton flora of this water. There were no remarkable differences in quantity and in composition between the zoo-plankton community of this water and that of the region B; but the increase in the species of genera *Calanus* and *Corycaeus* of copepods was the most remarkable characteristic of the zoo-plankton community of this water when compared with that of any other waters.

**D.** South of Java Island (St. 9)

The phyto-plankton composition of this water, which was characterized by the abundant occurrence of *Skujaella*, resembled very closely that of the region C. As to zoo-plankton as much as 55 species of copepods were identified; *Oncaea venusta* was most frequent and *Eucalanus attenuatus*, *Temora discaudata* and *Candacia curta* were the next to it. This is the characteristic of zoo-plankton community of this water.

**E.** South of Lombok Island (Sts. 10～13)

This region was richest in plankton fauna and flora not only in quantity but also in quality. The plankton flora was especially very rich at Sts. 10 and 11, consisting of as much as 21 species with the following 11 ones which were not observed in any of the other regions: *Chaetoceros lorenzianus*, *Coscinodiscus gigas*, *Lauderia borealis*, *Biddulphia sinensis*, *Rhizosolenia setigera*, *R. stolterfothii*, *Thalassiothrix frauenfeldii*, *Thalassiosira subtilis*, *Hemiaulus frauenfeldii* and *Skeletonema costatum*. And at the same time *Skujaella* was richer in this water than in any other waters. The Dinoflagellata of this water consisted of as much as 22 species including the following new members which were not observed in any other regions: *Amphisolenia bidentata*, *Ceratium extensum*, *C. pennatum*, *C. pulchellum* and *C. candelabrum*. Among them, the abundant members were as follows: *Pyrocystis pseudonoctiluca*, *Ceratium carriense*, *C. sumatranum* and *C. inflexum*. Among the copepods, 99 species were identified and the following 12 ones occurred very frequently: *Eucalanus subcrassus*, *E. mucronatus*, *Calocalanus pavo*, *Euchaeta marina*, *Euchirella galeata*, *Acartia neligens*, *A. erythrea*, *Corycaeus gibbulus*, *Oithona plumifera*, *O. nana*, *O. decipiens* and *Oncaea venusta*. Some species of *Oikopleura* and *Sagitta enflata* were the most abundant among Copelata and Chaetognatha.

The most remarkable characteristic of the plankton community of this water was the frequent occurrence of *Cypridina* sp. and furcilian stage of Euphausiacea larvae. The occurrence of *Podon polyphemoides*, one of the neritic species of Phyllopoda, was also characteristic, though this was not abundant. It is perceivable that this water is a good spawning ground for some marine animals, judging from the abundant occurrences of fish-fry, fish-eggs and brachyuran larvae in zoea stage.

### 3. Discussion and consideration on the distribution of plankton and oceanographic conditions

The followings can be summarized as the characteristics of the plankton of the surveyed waters: Generally speaking, the copepods occupied the most important portion among zoo-plankton quantitatively; especially, rich composition of species may be one of the characteristics of the copepods in this water. Dinoflagellata was also rich in species, though they were not abundant. Copelata and Chaetognatha were rich in species. But phyto-plankton were poor both in composition and quantity.

The precipitated volume of plankton was the largest at the region E, especially at St. 10 showing the largest value such as 10.1 cc, and was chiefly composed of copepods; whereas it was the smallest at the region B and was as much as 1.8~3.1 cc, except that at St. 5 where this was as much as 7.6 cc by the addition of the large individuals of Copelata.

These facts may suggest that plankton differs in quantity and in composition according to the localities of the stations; it may be said that the southern parts are richer in plankton both quantitatively and qualitatively than in that of the northern ones.

The above-mentioned facts appear to be closely supported by the following reasons: As reported by SATOW (1955), the surface waters of the northern parts are influenced by the Indian Equatorial Water which is poor in nutritive salts, on the other hand the surface waters of the southern parts are nutritive by the enriched waters from the Australian coast. Diatoms were generally very poor in quantity throughout the areas investigated. The fact was reported by T. A. KOW (1953) from the results of the preliminary survey at the Singapore Strait. He thought that phyto-plankton was less prevalent in winter and that this was a seasonal change in abundance. But the author is inclined to regard the paucity as a result of the seasonal change in the quantity of the rainfall in the tropical region which affects the concentration of nutritive salts in the sea water. However, the fertility of the water is, naturally more enriched by the current from the south, than by the seasonal changes of meteorological factors, such as temperature, precipitation and solar radiation, which affect seriously the productivity of the plankton in this region.

Table 19. Composition of plankton in the western waters of the Greater Sunda Islands.

| Species \ Station | Sex | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Chaetoceros coarctatus* | | RR | RR | RR | R | RR | RR | RR | RR | R | RR | RR | RR | RR |
| *C. peruvianus* | | | | | RR | | | | | | R | R | | |
| *C. lorenzianus* | | | | | | | | | | | | RR | | |
| *C.* sp. | | | | | | | | | | RR | R | RR | | |
| *Coscinodiscus* spp. | | | | | | R | | | | | R | RR | RR | |

| Species \ Station | Sex | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Lauderia borealis* | | | | | | | | | | | R | R | | |
| *Biddulphia sinensis* | | | | | | | | | | | R | R | | |
| *B.* sp. | | | | | | | | | | | R R | | | |
| *Rhizosolenia setigera* | | | | | | | | | | | R R | R R | | |
| *R. alata* | | | | | R | | | R R | | R R | R | R | | |
| *R. imbricata* | | R R | R R | R R | R | R R | R R | R R | R R | R R | R | R R | R R | R R |
| *R. styliformis* | | R R | R R | | R R | R R | | | R R | R R | | | | |
| *R. stolterfothii* | | | | | | | | | | | R | R R | | |
| *R. bergonii* | | | | | R | R R | | R R | | | R | R | | |
| *Stephanopyxis palmeriana* | | | | R R | R | | | R R | | | R | R | | |
| *Planktoniella sol* | | | | | | | | | R R | | | | | |
| *Thalassiothrix longissima* | | | | | R | R R | | | | | R R | R R | R R | |
| *T. frauenfeldii* | | | | | | | | | | | | R | | |
| *T. nitzschioides* | | | | | R R | | | | | | R R | R | | R R |
| *Thalassiosira subtilis* | | | | | | | | | | | + | R R | | |
| *Hemiaulus frauenfeldianum* | | | | | | | | | | | R | + | | |
| *H.* sp. | | | | | R | R R | R R | | | | | | | |
| *Skeletonema costatum* | | | | | | | | | | | R R | | | |
| *Skujaella* spp. | | R R | R | R R | R | R R | R R | R R | + | + | C | C | + | + |
| Zoo-plankton | | | | | | | | | | | | | | |
| *Globigerina bulloides* | | R | R R | R R | R R | | | | R R | R | R | R | R R | R |
| *Aulacantha scolymantha* | | | | R R | R R | R | R | R R | R R | + | + | R | R | R R |
| *Acanthometra* sp. | | R R | | | R R | R R | R | | | R | | | | |
| *Sphaerozoum geminatum* | | R | R R | | | | | | | | + | | | |
| *Rhabdonella spiralis* | | | | | R R | | | | | | | | | R R |
| *Dinophysis miles* | | | | | | R R | R R | | | | | | | R R |
| *Pyrocystis pseudonoctiluca* | | + | + | R | R | R | R | R | + | R | + | R | R | + |
| *P. fusiformis* | | R R | R | | | R R | | | R R | R | R | R R | | R R |
| *P. hamulus* var. *inaequatum* | | | R R | | | | | | | | | | R R | |
| *Amphisolenia bidentata* | | | | | | | | | | | | R | R | R R |
| *A. thrinax* | | | R R | | | | | | | R R | | R R | | |
| *Ceratium extensum* | | | | | | R R | | | R | R | R | R | R | R R |
| *C. carriense* | | R R | R | R | R | + | + | + | R | R | + | R | R | + |
| *C. sumatranum* f. *angulatum* | | R | + | R R | | | | | R R | R R | + | + | R | R R |
| *C. inflexum* | | R R | R | R | R | R | R | R | R | R | + | + | R | + |
| *C. tenue* | | | | | | R | R | | R | R | R R | R R | R R | R R |
| *C. karstenii* | | | | R | R | | | R | | | | | | |
| *C. macroceros* | | | | | R | R | R | R R | R | R | R | R | R | R R |
| *C. massiliens* | | | | | | R | R | R R | R | R | R | + | R | R R |
| *C. bigelowii* | | | | | | R R | R R | | | | | | | |
| *C. fusus* subsp. *seta* | | | | | | | | | R R | | | R R | | |
| *C. pulchellum* | | | | | | | | | R R | R R | | | | R R |
| *C. pennatum* | | | | | | | | | | | R R | | | |
| *C. candelabrum* | | | | | | | | | | R | | | | R R |

| Species \ Station | Sex | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *C. vultur* | | | | | | | | | | R | | | R R | |
| *C. deflexum* | | | | | | | | | | | R R | R R | R R | |
| *C. trichoceros* | | | | | | | | | | | | R R | | |
| *C. azoricum* | | | | | | | | | | | R R | R R | | R R |
| *C. lunura* | | | | | | | | | | | R R | R R | | R R |
| *Calanus tenuicornis* | ♀ | | | R | | | | | R R | | | R R | R R | |
| *C. gracilis* | ♀ | | | | | | | | R | | | | R R | |
| *C. helgolandicus* | ♀ ♂ | | R | | | | | | | R R | R R | | | |
| *C. darwinii* | ♀ ♂ | R R | R R | R | + | R | R | R | R | R R | R R | R R | R | R |
| *C. vulgaris* | ♀ ♂ | | | C | + | R | R R | C | R | | R R | | R R | |
| *C. minor* | ♀ ♂ | R R | | | | | | | | R | R | R R | | |
| *C. robustior* | ♀ | | | | | | | | R R | | | | | |
| *Eucalanus crassas* | ♀ | | | | | R | | | | | + | R | | R |
| *E. subcrassas* | ♀ ♂ | R | + | + | + | R | R R | + | R | R | + | + | R | R |
| *E. attenuatus* | ♀ ♂ | R | | | | | R | R | R | + | + | R R | | |
| *E. elongata* | ♀ | | | R | R | R | | | R | R R | + | | R | |
| *E. mucronatus* | ♀ ♂ | R R | | | | | | + | R | R R | + | + | R | |
| *Rhincalanus cornutus* | ♀ ♂ | | | | R | R | | + | | | R | R | R | R |
| *R. nasutus* | ♀ ♂ | | | | R | | R R | + | R | | | | | |
| *Acrocalanus gracilis* | ♂ | R | | | | | | R | | | | | + | |
| *A. gibber* | ♀ ♂ | R | | | R | R R | | | | | R | | R | |
| *A. monachus* | ♀ | | | | R R | R R | | | | | | | | |
| *Paracalanus aculeatus* | ♀ ♂ | R | R R | + | + | R | R | R | + | + | R | R | R | R |
| *P. parvus* | ♀ ♂ | R R | | + | + | | | | + | + | R | + | R R | |
| *Clausocalanus furcatus* | ♀ | | | | | | | | | | | + | R R | |
| *C. pergens* | ♀ ♂ | R | | | | R | | | | | | + | R R | |
| *C. arcuicornis* | ♀ | | | | | | | | R | | | + | | |
| *Calocalanus pavo* | ♀ | R R | R | R | R | R R | R | R R | R | R R | R | R | + | R |
| *C. plumolosus* | ♀ | | | | | | | | | | R R | | | |
| *Scottcalanus helenae* | ♂ | | | | | | R R | | | | | | | R R |
| *Pseudocalanus elongatus* | ♀ ♂ | R | | | | | | | | | | | | |
| *Bradyidius armatus* | ♀ | | | | | | | | R R | | | | | |
| *Euchaeta flava* | ♀ ♂ | | | R | | | | | R | R R | | R R | R R | R |
| *E. marina* | ♀ ♂ | R | + | + | + | + | + | + | + | R | + | + | + | C |
| *E. plana* | ♀ ♂ | | | | R R | | | | | R R | | | | |
| *E. wolfendeni* | ♀ ♂ | | | R | R | | | | R | R R | R | R R | | R R |
| *E. concinna* | ♀ ♂ | | | R | | R | R | R | | | R | R | R R | |
| *Heterorhabdus papilliger* | ♀ | | R R | | | | | | | R | | | | |
| *H. spinifrons* | ♀ | | | | | | | | | | | R R | | |
| *Haloptilus longicornis* | ♀ | | R R | | | | | | | R R | | | | |
| *H. actifrons* | ♀ | | | | | | | | | | | | R R | |
| *H. ornatus* | ♀ | | | | | | | | | | | | R R | |
| *Calanopia elliptica* | ♀ ♂ | R R | | R | R | | | | | | + | R | | |
| *Mecynocera clausi* | ♀ | | | | | | R | R R | R | R R | R R | R | R | R R |

| Species \ Station | Sex | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Scolecithrix danae* | ♀ ♂ | | + | + | + | R | R | + | R | R | + | + | R | R |
| *Euchirella galeata* | ♂ | | | | | | | | | R R | | | | |
| *Temora discaudata* | ♀ ♂ | R | | + | R | R | R | + | | + | + | R | | R R |
| *T. stylifera* | ♀ | | R | R | R | R | | | | | R | R | R R | |
| *Labidocera pavo* | ♀ ♂ | | R R | R R | | | | | | | | R | | |
| *L. bipinnata* | ♀ | | R | | | | | | | | R R | | | |
| *L. detruncata* | ♀ ♂ | | | | | | | | | | R R | | R R | |
| *L. euchaeta* | ♀ | | R R | | R R | | | | | R R | | | | |
| *L. acuta* | ♀ | | | | | | | | | | R R | | | |
| *Centropages calaninus* | ♂ | | R R | | | | | R | | | | | | |
| *C. furcatus* | ♀ ♂ | R | | R | R | R | | R | | R R | R | R | | R |
| *C. elongatus* | ♀ | | R | | | | | | | R R | | + | | R R |
| *C. longicornis* | ♀ | | R R | | | | | | | | | | | |
| *C. orsinii* | ♂ | | | R | | | | | | R R | | | | |
| *C. bradyi* | ♀ ♂ | | R | R | | | | | | | | | | |
| *C. gracilis* | ♂ | | R R | | | | | | | R R | | | | |
| *C. violaceus* | ♂ | | | | R | | | | | | | | | |
| *C. aethiopica* | ♂ | | | | R R | | | | | | | R R | | |
| *Candacia bradyi* | ♀ | | | R | R | | R | R | R | | | R | | |
| *C. discaudata* | ♀ ♂ | | | | | | | | | | R | | R R | R |
| *C. simplex* | ♀ | | R R | | | | | R | | | | | R R | R |
| *C. catula* | ♀ | | | | | | | | | + | R | R | | |
| *C. curta* | ♀ ♂ | R R | | R R | | | | R | | R | + | | R R | R |
| *C. bispinosa* | ♀ | | | | | | | R R | R R | R R | | | R | R |
| *C. truncata* | ♀ ♂ | | | R R | + | | | | | R R | | + | | |
| *C. pectinata* | ♂ | | | | | | | R | | | R R | | R R | |
| *C. logimana* | ♀ | | | | | | | | | | R | | R R | |
| *C. pachydactyla* | ♀ ♂ | | | | | | | | R R | | R R | R | | |
| *Clytemnestra scutellata* | ♀ ♂ | R R | | | | R | | | R | | | | | |
| *C. rostrata* | ♀ | R | | | R R | | | | | | R R | R R | | |
| *Scolecithricella minor* | ♀ | | | | | | | | R R | | | | | |
| *S. spinipedata* | ♀ | | | R R | | | | | R R | | | | | |
| *Pontellina plumata* | ♀ ♂ | | R | R | | | | | R | R R | R R | | | |
| *Pontellopsis armata* | ♂ | | | | | | | | | R | R | | | |
| *Pontella spinicauda* | ♂ | | R | | | | | | | | | R | R | |
| *P.* sp. | ♀ ♂ | | | | | | | | | R R | R R | | | |
| *Phenna spinifera* | ♀ | | R | R R | | | R | | R R | | R | R R | | |
| *Acartia clausi* | ♀ ♂ | R | | | | R | | | | | R | | | |
| *A. hamata* | ♀ | R | | | | | | | | | R | | | |
| *A. neligens* | ♀ ♂ | + | R | + | + | R | R | + | + | + | R | + | R | + |
| *A. erythrea* | ♀ ♂ | | R | + | + | R | R R | + | + | R | C | C | R | |
| *A. danae* | ♀ | | | | | | | | R R | | | | | |
| *A. spinicauda* | ♀ | | | | | | | R R | R | R | R | | | |
| *A. longiremis* | ♀ | | | | | | | | R | | | | | |

| Species \ Station | Sex | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Pleuromamma xiphias* | ♀ | | | | | | | | | | | R | | |
| *P. robusta* | ♂ | | | | | | | | | | | R R | | |
| *Aetideus armatus* | ♀ | R R | | | | | | | | | | R R | R R | |
| *A. giesbrechti* | ♀ | | | | | | R | | | | R | | | |
| *Lubbockia squillimana* | ♀ ♂ | R R | | | | | | | | | | | | |
| *Macrosetella gracilis* | ♀ ♂ | R R | R | + | + | + | + | C | + | R R | R R | R | R | R |
| *Microsetella norvegica* | ♀ | | | | | | | | | R R | R R | | | |
| *Miracia efferata* | ♀ | | R R | | | R R | + | | | | R | | R | R R |
| *Copilia mirabilis* | ♀ ♂ | | + | R | R | R | R R | R | | R R | | R | R R | |
| *C. longistylis* | ♀ | | + | | R | R | | | | | | | R R | |
| *C. quadrata* | ♀ ♂ | | | | R R | | R | | | R | | R | | |
| *Sapphirina auronitens* | ♂ | | R | | | | | | | | | | | |
| *S. gastrica* | ♀ ♂ | | + | R | | R | | R R | | R | | | R | R |
| *S. gemma* | ♀ ♂ | | R | R | | R | | | | | | | | |
| *S. nigromaculata* | ♀ ♂ | | | R | R | | R | R | | R | | | R R | R R |
| *S. stellata* | ♀ ♂ | | | R | | R | R R | R | | R | R | R | R R | R R |
| *S. daerwinii* | ♀ | | | | R R | | R | | | | | | | |
| *S. opalina* | ♀ | | | R R | R R | | | | | | | | | |
| *S. nitestinata* | ♀ | | | | | R R | | | R R | | | R | | |
| *S. angusta* | ♀ | R R | R | R | | | | | R R | | | | | |
| *Corycaeus speciosus* | ♀ ♂ | R | R | + | + | + | C | R | + | + | R | + | R | R |
| *C. lautus* | ♂ | | | | | | | | R R | R R | | | R | |
| *C. gibbulus* | ♀ ♂ | + | + | C | + | R | + | + | + | + | + | C | C | C |
| *C. concinnus* | ♀ ♂ | + | R | | R | | | | R | R | | R | R | R |
| *C. longistylis* | ♀ | R R | | R R | | | | | + | R | | | | R |
| *C. flaccus* | ♀ | | | | | | | | | | | | R | |
| *C. catus* | ♀ ♂ | | | | | | | | | | | | R | |
| *C. ovalis* | ♀ | | | | | | | | | | | | R R | |
| *C. crassiusculus* | ♀ ♂ | R | | | | | | | | | | R R | | |
| *Oithona plumifera* | ♀ ♂ | + | C | C | C | C | C | + | + | + | + | C | + | + |
| *O. nana* | ♀ ♂ | | | | R R | | R R | R | R R | + | + | C | + | + |
| *O. decipiens* | ♀ | | R | | | | + | | + | + | + | R | + | |
| *O. robusta* | ♀ | | | R | | | | | | R | R | R | | |
| *O. setigera* | ♀ | | | | | | | | | + | | R | | |
| *Oncaea venusta* | ♀ ♂ | C | C | C | C | C | C | C | C | C | + | C | C | C |
| *O. conifera ?* | ♀ | | | + | | | | + | R | | | | | |
| *O. mediae* | ♀ | + | + | + | | | | | R | | | | | |
| *Pachysoma punctatum* | ♀ | R R | R | | | | | | | | | | | |
| Copepodite stage | | R R | R R | R R | R | | | R R | R R | R R | R R | R R | R R | R |
| Copepoda nauplii | | R | R | R | R | R R | R R | R R | R | R | + | + | R | R |
| *Podon polyphemoides* | | | | | | | | | | | R R | R | R | R |
| Amphipoda (*Phronima*) | | R | R R | R | | | | | | R | R | R | R R | R |
| Euphausiacea (*Euhausia* larvae) | | R | R R | R | | | R R | R R | R R | R | R | R | R | R |
| Ostracoda (*Cypridina* sp. ) | | R | R | + | R | R | R | R R | R R | R R | R | + | + | + |

| Species \ Station | Sex | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Oikopleura* spp. | | R | R | R | + | + | R | R | + | R | + | + | + | + |
| *Doliolum* sp. | | R R | | R | R R | | R | R R | R R | | R | R R | | R |
| *Salpa fusiformis* | | | | | | | | | | R R | | | | |
| *Sagitta bipunctata* | | R R | R R | R | R | R R | | R R | | R | R R | R R | R | R |
| *S. serratodentata pacifica* | | R R | R | R | R | + | R | R R | + | R | R | + | R | R |
| *S. enflata* | | R | + | R | + | R | + | + | R | + | C | C | + | + |
| *S. regularis* | | R R | R | R | + | R | R | R | R R | R R | R R | | R R | R R |
| *Pterosagitta draco* | | R | R | + | R | + | + | R | R R | R | R | R | R | R |
| *Sagitta* spp. | | R R | R R | R | R R | R | R R | R R | | R | R R | R R | R | R R |
| Polychaeta | | R R | | R | R R | R R | R | | R R | | R | R | | R |
| Hydromedusae | | + | | | | R R | | | | | | | | |
| *Muggiaea atlantica* | | R | R R | R | R | | R R | R R | | R | | | R | R R |
| Gastropod larvae | | R R | R | | R R | R | | R R | R R | | R | R R | R R | R |
| Brachyuran zoea larvae | | | | | | | | | | | R | R R | | R R |
| Fish larvae | | R R | R R | R R | | | | | | R R | R R | R | R R | R |
| Fish eggs | | R R | R R | | | | | | R R | | R R | R R | | |
| Balanus nauplii | | | | | | | | | R R | | R R | | | |

## II. Distribution of plankton in the waters of the central part of the North Indian Ocean

### 1. Sampling method

The samples used in this paragraph were collected by the Shunkotsu-maru during the period from December, 1954 to January, 1955 at the stations plotted in Fig. 10. The stations, dates of the collection, localities and the oceanographic conditions are given in Table 20. In this case, plankton in the layer from 100 or 200 m deep to the surface were hauled up vertically at the speed of 50 cm per second by the quantitative net of KITAHARA'S type of 25 cm in mouth-diameter and 1 m in length constructed with the gauze of XX 16 in JIS. At the collection of plankton, the oceanographic conditions at 7 layers set at every 25 m intervals from surface to 150 m deep were observed.

### 2. Horizontal distribution of temperature and salinity

**0 m** : Attention should be paid to the fact that the water-temperature and salinity of this layer were considerably influenced from the factors such as the solar radiation, rainfall, time in the day, *etc*.; but the following tendencies may be fairly varid: the tonguelike distribution of the cold surface water of the northern part separates the warm surface waters into two parts, the southeastern part and the western one. As suggested from the distribution of salinity, the cold surface waters at the southeastern part coincide with the part of lower salinity less than 35.0 ‰, whereas the western part corresponds to the region with lower salinity less than 34.9‰, respectively.

**25 m** : The outline of the distribution of temperature was the same as that at the surface layer, but the region of very low temperature (24°C) was found at the western part. The boundary between this cold water and the warm waters at the Sts. 42 and 40 pressed against the cold water forming a steep temperature gradient between them. The distribution of salinity showed the similar features as that of the surface layer, except the disappearance of the part of low salinity at Sts. 42 and 41.

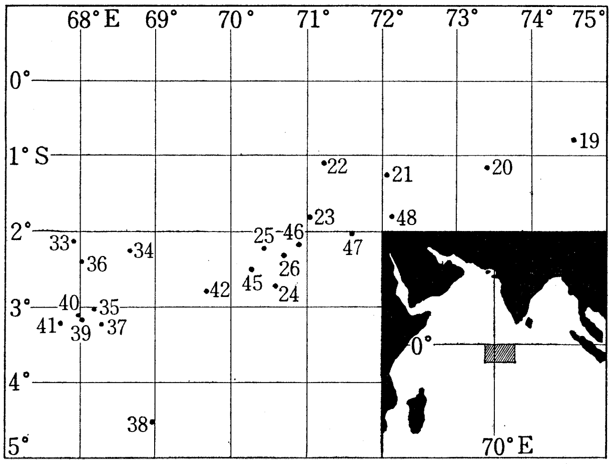



Fig. 10. Chart of the station set in the central part of the North Indian Ocean.

**50 m** : This layer differed very much from the above-mentioned two layers in the distribution of the temperature. Despite of the fact that the high temperature was found in the southern area at the surface and 25 m layers, the temperature at 50 m depth was high in the northern part but low in the southern one due to the presence of the cold water around St. 37. The wedgewise distribution of the warm water across the cold water in this layer was suggested as was suspected from the distribution at the 25 m layer. The distribution of salinity was similar to that at the 25 m layer; there were two stretches of the water of high salinity, one of which approached from the north to near St. 24 and the other was pouchformed and extended to the southwest; the center of the latter stretch was located at St. 35 and was thought to correspond to the tip of the warm water at the eastern part.

**75 m** : Two cold waters observed at the 50 m layer were still present at this layer; the stretch of cold water from the southeast changed its direction to the south, and the eastern boundary of this stretch strongly pressed the warm water derived from the north and formed the stretch around St. 47. In the northern part, this stretch of cold water was connected with the cold water at the western part, although the southern part of these two cold waters were separated by the stretch of the warm water from the south. The distribution of salinity showed conspicuous variation as that found in the distribution of temperature at the 50 m layer. Namely, the occurrence of the water of high salinity around St. 48 changed the feature of the distribution of salinity; and as the consequence, the distribution of salinity took the similar features to that of the temperature forming a tongueshaped isothermal line from the south.

**100 m** : The part of high temperature at 75 m layer around St. 39 disappeared, and this part was separated into two parts, one of which was the cold water from the southwest and the other was the tongue-like stretch of warm water from the northeast. The presence of the water of high salinity at the south or southeastern part became conspicuous, and the wedge-wise distribution of low salinity could be observed

Table 20. Oceanographic conditions in the waters of the central part of the North Indian Ocean.

| Station | | | Date | Weather | Transparency (m) | | |
|---|---|---|---|---|---|---|---|
| No. | Lat. | Long. | | | | 0 m | 25 m |
| 17 | 5°37′ N | 81°07′ E | Dec. 11, '54 | — | — | 27.45 | — |
| 18 | 4°30′ N | 77°47′ E | 13 | — | — | 27.60 | — |
| 19 | 0°43′ S | 74°36′ E | 15 | b | 23 | 27.40 | 27.00 |
| 20 | 1°13′ S | 73°20′ E | 16 | b | 22 | 27.10 | 27.17 |
| 21 | 1°19′ S | 72°03′ E | 17 | c | 19 | 27.10 | 27.26 |
| 22 | 1°08′ S | 71°15′ E | 18 | c | — | 27.07 | 27.32 |
| 23 | 1°46′ S | 71°01′ E | 19 | b | 23 | 26.95 | 27.09 |
| 24 | 2°41′ S | 70°35′ E | 20 | c | 22 | 27.22 | 27.00 |
| 25 | 2°15′ S | 70°31′ E | 21 | b | 23 | — | 27.19 |
| 26 | 2°21′ S | 70°44′ E | 22 | r | — | 27.08 | 27.03 |
| 33 | 2°12′ S | 67°55′ E | Jan. 6, '55 | b | 26 | 28.20 | 27.64 |
| 34 | 2°27′ S | 68°33′ E | 7 | b | — | 27.85 | 26.80 |
| 35 | 3°02′ S | 68°10′ E | 8 | c | — | 28.00 | 27.08 |
| 36 | 2°28′ S | 68°01′ E | 9 | b | 23 | 27.90 | 27.71 |
| 37 | 3°19′ S | 68°19′ E | 10 | b | — | 27.85 | 28.24 |
| 38 | 4°35′ S | 68°58′ E | 11 | b | — | 27.90 | 26.98 |
| 39 | 3°12′ S | 68°00′ E | 12 | b | 33 | 28.20 | 28.22 |
| 40 | 3°10′ S | 67°59′ E | 13 | b | — | 28.40 | 28.59 |
| 41 | 3°17′ S | 67°43′ E | 14 | c | — | 28.31 | 23.65 |
| 42 | 2°48′ S | 69°37′ E | 15 | c | — | 28.50 | 29.03 |
| 45 | 2°31′ S | 70°19′ E | 15 | c | — | 28.12 | 28.04 |
| 46 | 2°21′ S | 70°56′ E | 16 | b | — | 27.92 | 28.31 |
| 47 | 2°02′ S | 71°33′ E | 16 | c | — | 27.88 | 28.02 |
| 48 | 1°48′ S | 72°08′ E | 16 | c | — | 28.07 | 28.34 |

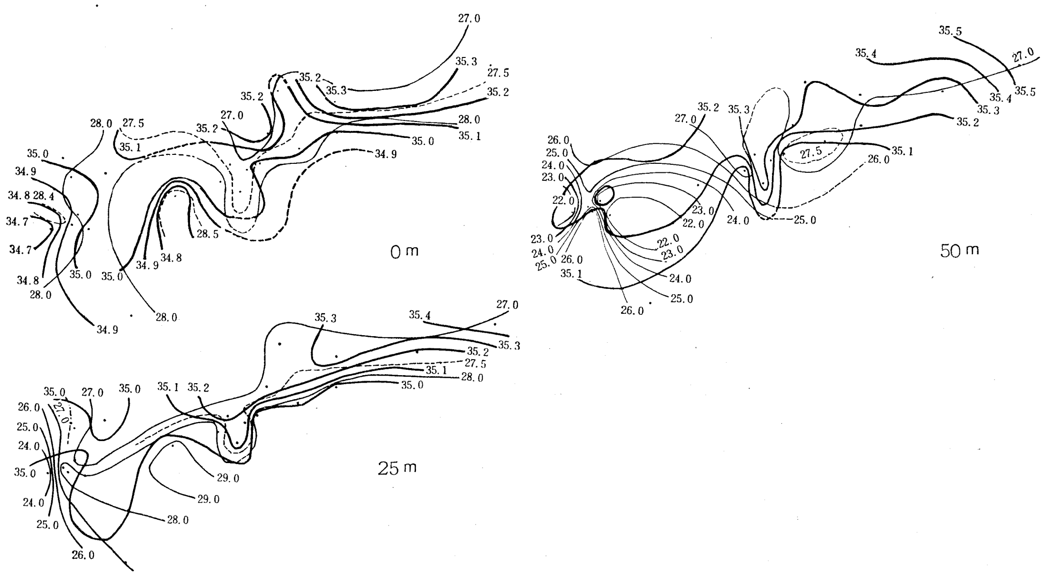
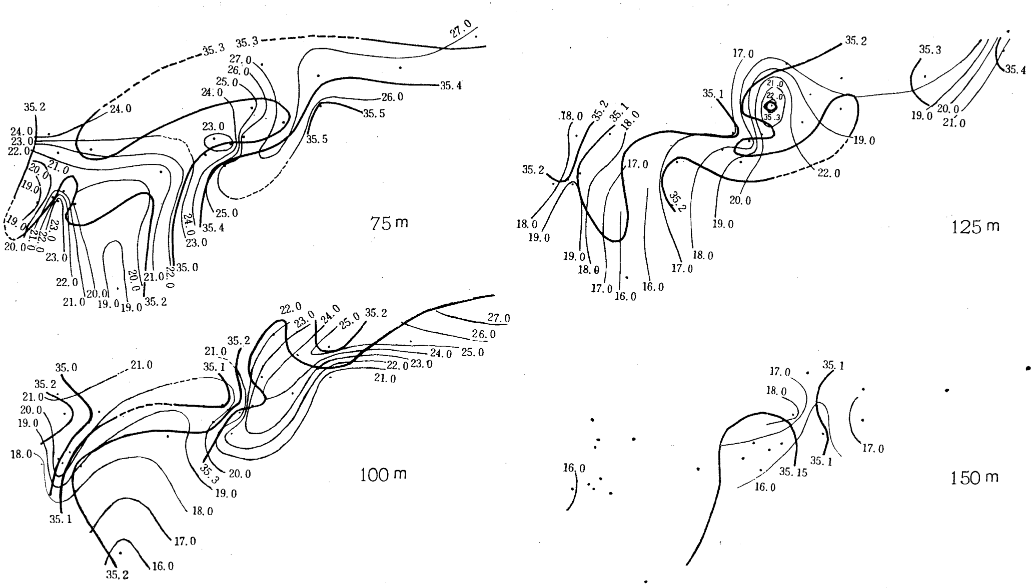



Fig. 11. Horizontal distribution of temperature and salinity in the central part of the Indian Ocean.

| Water temperature (°C) | | | | | | Salinity (‰) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 m | 75 m | 100 m | 125 m | 150 m | 175 m | 0 m | 25 m | 50 m | 75 m | 100 m | 125 m | 150 m | 175 m |
| — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 27.00 | 26.98 | 27.04 | 21.92 | 15.03 | — | 35.26 | 35.48 | 35.55 | 35.29 | 35.33 | 35.41 | — | — |
| 26.94 | 26.94 | 25.44 | 19.33 | — | — | 35.35 | 35.19 | 35.24 | 35.32 | 35.37 | 35.32 | — | — |
| 27.25 | 26.48 | 24.99 | 18.37 | — | — | 38.35 | 35.33 | 35.35 | 35.35 | 35.17 | 35.24 | — | — |
| 27.31 | 27.38 | 22.04 | 18.62 | 16.61 | — | 35.08 | 35.26 | 35.30 | 35.32 | 35.33 | 35.19 | 35.12 | — |
| 27.08 | 25.07 | 22.41 | 21.44 | 18.92 | 14.99 | 35.21 | 35.29 | 35.30 | 35.29 | 35.36 | 35.30 | 35.15 | — |
| 26.59 | 25.41 | 22.88 | 19.73 | — | — | 35.06 | 35.15 | 35.34 | 35.41 | 35.38 | 35.17 | — | — |
| 26.82 | 22.86 | 19.33 | 17.03 | — | — | 35.08 | 35.21 | 35.38 | 35.23 | 35.10 | 35.10 | — | — |
| 26.47 | 22.92 | 20.19 | 17.49 | — | — | 35.05 | 35.15 | 35.24 | 35.31 | 35.33 | 35.22 | — | — |
| 26.78 | 24.66 | 20.98 | — | — | — | 35.02 | 35.01 | 35.14 | 35.24 | 35.19 | — | — | — |
| 26.17 | 22.83 | 20.42 | 18.44 | — | — | 35.08 | 34.97 | 35.20 | 35.33 | 35.06 | 35.09 | — | — |
| 22.45 | 20.85 | 19.92 | 18.15 | — | — | 34.94 | 35.99 | 35.33 | 35.14 | 35.03 | 35.02 | — | — |
| 26.25 | 21.14 | 20.69 | 18.86 | — | — | 34.98 | 35.09 | 35.20 | 35.26 | 35.27 | 35.26 | — | — |
| 21.43 | 19.55 | 18.11 | 17.04 | — | — | 35.01 | 35.04 | 35.23 | 25.22 | 35.22 | — | — | — |
| 26.18 | 18.63 | 15.66 | 15.31 | — | — | 34.98 | 34.97 | 35.09 | 35.12 | 35.21 | 35.13 | 35.14 | — |
| 26.31 | 23.88 | 20.46 | 19.10 | 17.35 | — | 34.95 | 34.96 | 35.15 | 35.12 | 35.06 | 35.16 | — | — |
| 24.69 | 21.65 | 20.96 | 18.22 | 16.47 | — | 34.83 | 34.99 | 35.24 | 35.21 | 35.14 | 35.20 | — | — |
| 21.63 | 18.86 | 17.67 | 17.78 | 16.18 | — | 34.70 | 34.99 | 35.26 | 35.24 | 35.14 | 35.19 | — | — |
| 23.30 | 20.38 | 18.86 | 17.59 | 16.30 | 15.12 | 34.78 | 34.97 | 35.21 | 35.23 | 35.21 | 35.21 | 35.13 | 34.95 |
| 27.21 | 23.39 | 20.00 | 16.80 | 16.07 | 15.13 | 35.03 | 35.04 | 35.05 | 35.31 | 35.19 | 35.19 | 35.18 | 35.14 |
| 27.87 | 26.21 | 23.58 | 20.15 | 17.45 | — | 34.92 | 34.92 | 35.03 | 35.24 | 35.27 | 35.19 | 35.16 | — |
| 27.89 | 27.09 | 23.78 | 19.58 | 15.46 | 14.81 | 35.01 | 35.01 | 35.11 | 35.23 | 35.37 | 35.28 | 35.11 | 35.05 |
| 26.87 | 25.82 | 21.25 | 18.38 | 17.53 | — | 34.92 | 34.98 | 35.23 | 35.50 | 35.31 | 35.18 | 35.03 | — |



between this water and the water of high salinity around St. 36 stretched from the west.

**125 m** : The temperature showed quite different features from those of the upper layers. The cold water from the south became very narrow, and the stretch of warm water was separated by the cold water at the western part. There is another stretch of warm water running from the south or southeast to the north around St. 23. The feature of the horizontal distribution of salinity showed remarkable change, too. The presence of the water of low salinity at the western part was still recognizable, but generally speaking, the salinity was high in the eastern part, although the central part was separated by the stretch of the water of low salinity. And the isolated part of high salinity around St. 23 was thought to correspond to the central part of the warm water.

**150 m** : As the data collected at the observed stations at this layer were insufficient it was very hard to give an adequate consideration, but the separation of the warm water into two parts, the west and east, was ascertained by the presence of the cold water from the south.

### 3. Vertical distribution of temperature and salinity (*cf.* Figs. 12 (A), (B) & (C))

**Section I** (Sts. 41—40—37—42—45—26—46—47—48—20—19) : The thermocline along this WSW—ENE section found at 120 m depth around the St. 19, became shallower with westward transition of the stations; and at St. 41, the most westward station, this layer floated up to 25 m or thereabout. Moreover, the temperature of this layer was 20∼25°C in the eastern part but was at 25∼27°C in the part around St. 41. These facts may well suggest that the surface water of the east or northeastern part associates with the cold subsurface water in the western part and the latter has a close resemblance in the distribution of the temperature to the subsurface or middle layer of the eastern or northeastern part of the section. The dishomogeneity in the distribution of the temperature and in the depth of the thermocline in this section may well be deduced by the presence of the water masses of the different quality running in the direction crossing it. The similar tendency of the vertical distribution was observed in salinity, although this was not so conspicuous as was found in the temperature distribution. The isohaline of 35.3 ‰ was found at the 125 m layer in the

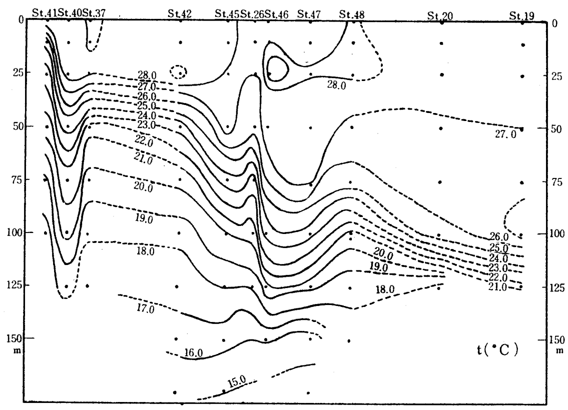



Fig. 12—A. Vertical distribution of temperature (Section I).

eastern part while that of 35.2～35.0 ‰ was observed at the 60～30 m layer in the part west of St. 45. Furthermore, besides these tendencies, the vertical distribution of salinity was very complicated, and the water of lower salinity less than 35.2 ‰ occupied the shallower layer than 50 m deep or thereabout in the area around Sts. 41～20; and on the other hand, there was the eastward stretch of the water of higher salinity more than 35.3 ‰, and its center was at 40～50 m layer in the part around St. 19. The water of higher salinity more than 35.3 ‰ occupied the subsurface layer of 100 m depth or thereabout in the part covered by Sts. 47～19, and its center was 35.5 ‰ in salinity and was located at the 125 m layer or thereabout in the part around St. 48. The other water which had a close relation to the water of high salinity was observed at the 70～130 m layer in the part covered by Sts. 26～45. At the layers deeper than this, the presence of two water masses of salinity less than 35.2 ‰ was observed, one of which occupied the layer of 80～130 m deep at the Sts. 41～40 and the other occupied the layer of 100～120 m deep in the part covered by Sts. 42～48. The low salinity with the value 34.8 ‰ was found in the surface layer at Sts. 41 and 42, but it was hard to tell the origin and nature of this water mass.

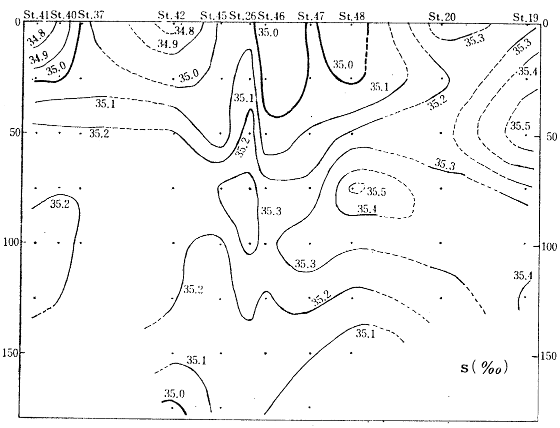



Fig. 12—B. Vertical distribution of salinity (Sections I).

**Section II** (Sts. 33—34—42—24) : This section crossed Section I at St. 42. At the crossing point the isotherms were concave in the layer shallower than 30m deep but convex in the layer deeper than this. The distribution of isohaline had a general resemblance to that of the temperature only in the surface layer.

**Section III** (Sts. 33—36—35—37) : The surface warm water in the northwestern part was pressed gradually upward, with the southeast transition of the stations, by the presence of the cold water in the deeper layer and reached its climax at St. 35. The surface water was the thinnest at St. 35, then it became deeper and extended until it reached St. 37. The presence of the water of salinity less than 35.2 ‰ in the deeper layer at St. 35 and that of high salinity of 35.3 ‰ in the middle layer agree fairly well with the above-mentioned distribution of temperature.

**Section IV** (Sts. 40—35—34) : This section crosses Section III approximately in right angle. The concave isotherms at the St. 40 were already reported in Section I. The warm surface water became thicker at the stations from St. 35 to St. 34. When the distribution of temperature on this section was compared with that on the Section III, it will be suggested that the surface water extends in the direction from ENE to WSW (Sts. 33→41). Any remarkable coincidence was not recognized

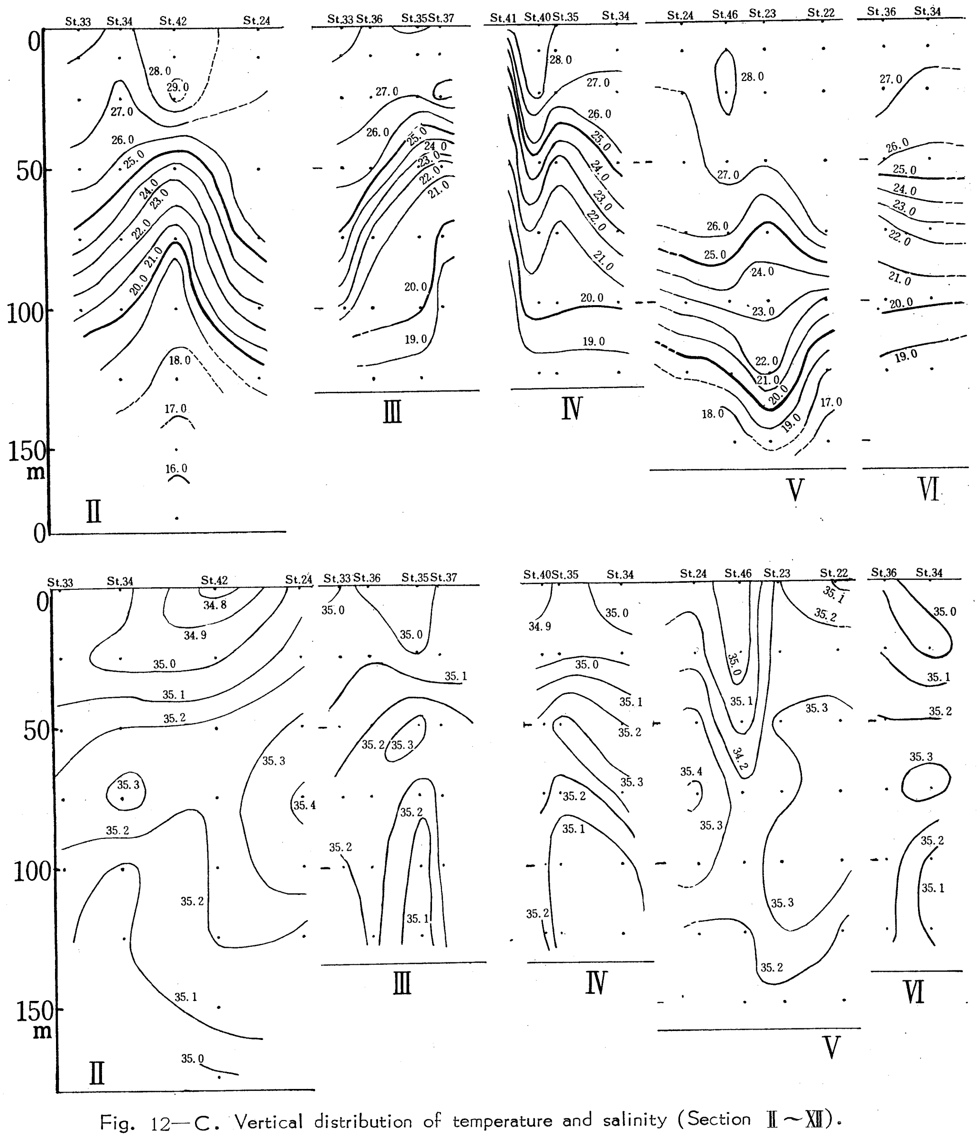
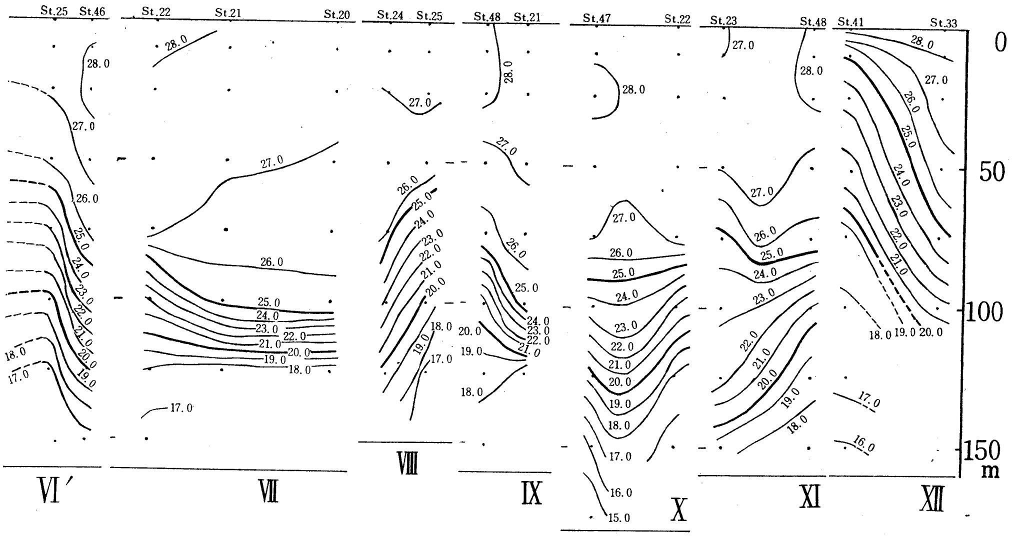
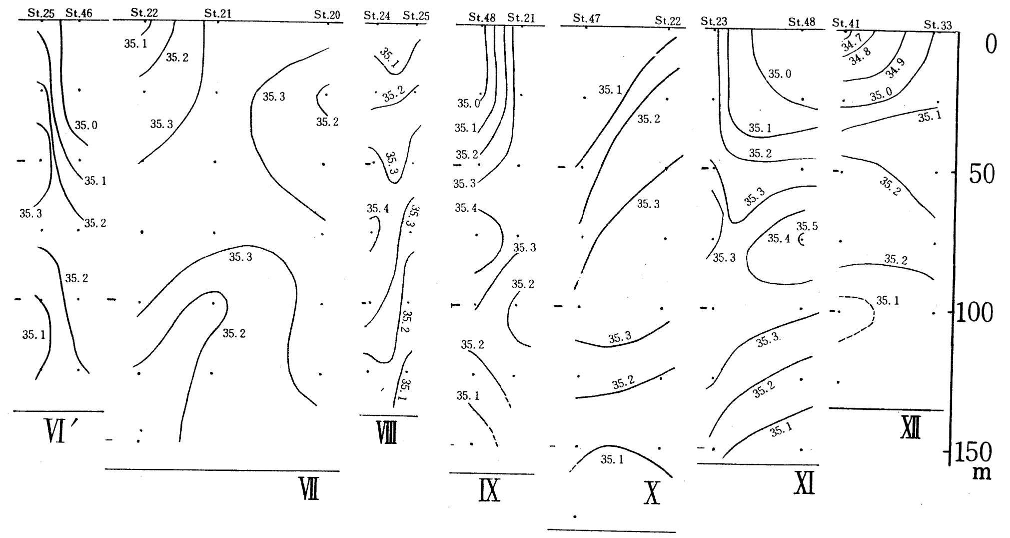



Fig. 12—C. Vertical distribution of temperature and salinity (Section II～XII).

between the distribution of the temperature and salinity.

**Section V** (Sts. 24—45—23—22) : The isotherms were convex by the presence of the warm water in the subsurface layer at St. 23. And this warm subsurface water stretched to St. 48, namely to the east (*cf.* Section II). When the distribution of temperature on this section was compared with that on the Section VII, the warm surface water (over 27°C) which stretched from the south to Sts. 46 and 47, extended its area chiefly to St. 21 and partly to Sts. 22 and 23. A good correspondence of isotherms to isohalines at the middle layer was observed.




## 4. Water masses in the central part of the North Indian Ocean

Judging from the distribution of temeprature and salinity, we can imagine 4 water masses in the surface layer, 5 masses in the subsurface layer and 3 masses in the middle layer:

**Surface layer** (The shallower layer than some 50~70 m deep)

i) The water of the highest salinity, occupying the layer from the surface to 75 m deep with the center at 50 m deep or thereabout and covering the part around St. 19, perhaps including the eastern part of this station (warmer than 26.5°C and higher than 35.3 ‰ in salinity).

ii) The warm water of high salinity (warmer than 26.0°C and higher than 35.3 ‰ in salinity), occupying the layer from the surface down to 80 m deep at the St. 21. This is supposed to be an extension of the surface water at the St. 19.

iii) The water occupying the very surface layer (0～20 m) of St. 22 (warmer than 28.0°C and lower than 35.2 ‰ in salinity).

iv) The warmer water higher than 27.0°C with lower salinity less than 35.2 ‰ occupying the shallower layer less than 40～65 m deep and extending the area covered by the Sts. 48—47—26<25/24>45—42—37—40. This water mass was expected to be originated from the south, but the bottom of this water was very shallow at Sts. 25 and 24 and its maximum depth was 30 m. This may be due to the influence of the distribution of the subsurface water. In this water, the presence of the following two sub-waters masses was suggested.

( 1 ). The warmer water higher than 28.0°C with the lower salinity less than 35.0 ‰: This occupied the layer from the surface to 30 m deep at St. 48, and the layer from 0 to 25 m deep at St. 47; this water mass was found in the layer from 10 to 35 m deep at St. 46.

( 2 ). The warmer water higher than 28.0°C with lower salinity less than 35.05 ‰, occupying the shallower layer less than 25～30 m deep in the area covered by Sts. 45—42—37—40.

v) The warmer water higher than 26.5°C with lower salinity than 35.0 ‰, occupying the shallower layer less than 30～40 m deep in the area covered by Sts. 40-35-34-36-33.

**Subsurface layer**

i) The warmer water higher than 21～22°C with salinity higher than 35.3 ‰, occupied the layer from 70 to 110 m deep or thereabout in the area covered by Sts. 19—20—48—47. In this water the presence of the isolated water mass higher in temperature (24～26°C) and higher in salinity (higher than 35.4 ‰) than the surrounding water was suggested.

ii) Relatively warmer water with higher salinity (23～26°C in temperature and higher than 35.3 ‰ in salinity), occupied the layer from 65 to 85 m deep in the area covered by Sts. 47—22. This may be related with the last mentioned isolated water mass.

iii) The warm water with high salinity (23～25°C in temperature and higher than 35.3 ‰ in salinity), occupied the layer from 80 to 125 m deep in the area covered by St. 23 : This water may have the same origin as that mentioned in (ii).

iv) The water of 22～26°C in temperature and with the salinity higher than 35.3 ‰, occupied the layer from 50～70 to 80～100 m deep in the area encircled by the line joining Sts. 26—24—45—25—26. This may have been derived from the stretch of the water mentioned in (i).

v) The wedge-shaped warm water (22～24°C in temperature and the salinity higher than 35.3 ‰), occupied the depth from 70 to 80 m at St. 34 and 45 to 55 m at St. 35. This stretched from the north to southwest till it reached St. 35.

**Middle layer**

i) The cold water with the low salinity (lower than 25°C in temperature and lower than 35.2 ‰ in salinity), occupied the layer from 90 m (at St. 25) to 130 m deep (at St. 26) with the average of 110 m deep in the area covered by Sts. 48—47—26—25—45.

ii) Another cold water of low salinity occupied the layer deeper than 120～140 m in the area covered by Sts. 24—46—23—22. This may have been derived from the same origin as that mentioned in (i).

iii) The cold water of low salinity (lower than 21.0°C in temperature and lower than 35.2 ‰ in salinity), was observed in the area covered by Sts. 40—35—34—36—33, although this was warmer than those of (i) and (ii).

## 5. Consideration on the oceanographic conditions (*cf.* Fig. 13)

The surface layer was separated from the middle layer by the presence of the remarkable thermocline, which became shallower gradually from ENE to WSW and at the same time it became warmer. The middle layer was rather homogeneous in temperature, but warmer in the east and less warmer in the northwest, although there were some deviations in the temperature distribution. The structure of the water mass was rather complicated; the warm water mass of high salinity stretching from the east to St. 19 namely to the west (A) passed through St. 21 and submerged beneath the surface water at St. 22. Its first branch did so at St. 20, but the principal part of this water mass moved and passed westwards on the surface layer at the north of St. 20. The surface water at St. 20 (B) penetrated into the subsurface layer of the water mass A at St. 21. The water mass C, which occupied the shallower layer than the water mass A at St. 22, floated up gradually with the transition of the stations from St. 23 and St. 22 to St. 46. This water mass passed through the large water mass D of the southern origin at the last-mentioned station.

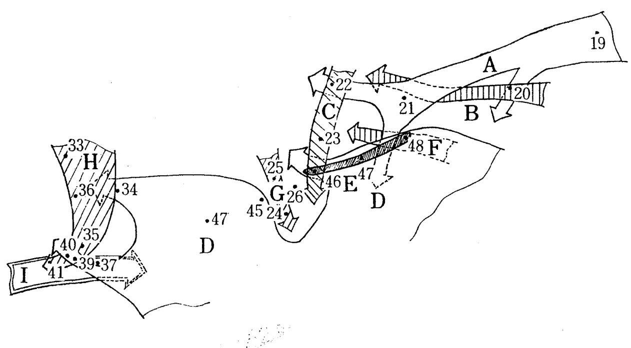



Fig. 13. Structure of water masses in the central part of the North Indian Ocean.

Meanwhile, the water mass E at the surface layer at St. 48 was depressed and occupied the layer of 25 m deep or thereabout, but this again occupied the layer from 10 to 30 m deep at St. 46, and then passed through the water mass C. This water mass E was supposed to be the relic of some other ones of more distinguishable quality. A branch of the water mass A stretched from St. 21 to the southwest, and passed through the part between Sts. 48 and 47, then submerged under the subsurface layer toward northwest. The water mass F occupied the subsurface layer at St. 48, and this stretched toward southeast then floated up. The cold subsurface water mass G stretched from St. 25 to St. 24, then penetrated the water mass D of the southern origin; and as the consequence, the latter water mass was separated into two branches, one covering Sts. 46, 47 and 48 as mentioned already and the other covering Sts. 45, 47, 37, 39 and 40; this latter sub-branch stretched from St. 47 to St. 34, then submerged beneath the water mass H of the northern origin. The water mass H sank gradually with the southern transition and submerged beneath the water mass D at

Table 21. Occurrence of plankton in the waters of the central part of the North Indian Ocean.

| Species \ Station | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|
| Diatom | | | | | | | | | |
| *Merosira* sp. | R R | | | | | | | | |
| *Ethmodiscus gazellae* | | | | | | R R | | | |
| *Coscinodiscus excentricus* | | R R | | | R R | | | R R | R R |
| *C. radiatus* | | | | | | | | | |
| *C. subtilis* | | | | | | | | | |
| *Planktoniella sol* | | R R | R | R | R | R | R | + | R |
| *Asteromphalus hepaticus* | | | | | | | | | |
| *Asterolampra grevillei* | | | R R | | | | | | R R |
| *Gossleriella tropica* | | | | | | | | | |
| *Stephanopyxis palmeriana* | R R | | R R | | R R | | R R | | |
| *Dactyliosolen antarcticus* | | | | | | | | | |
| *Guinardia flaccida* | | | | | | | | | |
| *Rhizosolenia alata* | R R | R R | R R | R R | R R | R | R | R | R |
| *R. calcar-avis* | | R R | R R | R R | | R R | | R R | |
| *R. styliformis* | | | R R | | R R | R R | R R | R R | R R |
| *R. bergonii* | R | R | + | + | + | + | + | + | + |
| *R. hebetata* f. *semispina* | R | R | | R R | R R | | R R | | |
| *R. acuminata* | R | R | + | R | R | R | + | + | R |
| *R. robusta* | R R | R R | R R | R R | R R | R | R R | R | R |
| *R. imbricata* | R R | | R | | | | R | | |
| *R. cylindrus* | | | | | | | | | |
| *Bacteriastrum* spp. | | | | | | | | R R | |
| *Chaetoceros coarctatus* | R R | R R | R | R | R | R | R R | R | + |
| *C. lauderi* | | | | | | | | | |
| *C. affinis* | R R | | | R R | | R R | | | |
| *C. laciniosus* | | | | | | | R R | | |
| *C. distans ?* | | | | | | | | | |
| *C. peruvianus* | R R | R R | R R | | R R | R R | | R R | R R |
| *C. concavicornis ?* | | | | | | | | | |

Sts. 40~35. It is highly probable that the water mass I sinks under the water mass H at St. 41, but it is difficult to certify the phenomena from the results of this series of the observations.

## 6. Plankton composition in the waters of the central part of the North Indian Ocean

The plankton compositions of the samples are illustrated in Table 21. Among diatoms, 39 species were identified. Most of them were the pelagic species of the warm or tropical waters. The following species were abundant among the diatom community: *Rhizosolenia bergonii*, *R. acuminata*, *R. alata*, *Planktoniella sol*, *Thalassiothrix longissima* and *Chaetoceros coarctatus*.

| 26 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 45 | 46 | 47 | 48 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | R R |  |  |  |  | R R |  |  |  |  |  |  |  |  |
|  |  | R | R R | R R |  |  | R R | R R |  | R R | R R | R R | R R |  |
| R R |  |  | R R |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  | R R |  |  |  |  |  |  |  |  |
| + | + | R | R | R | + | + | + | + | + | + | + | + | R | + |
|  |  |  |  |  |  | R R |  |  |  |  |  |  |  |  |
|  | R | R |  |  | R R |  | R R | R R | R R | R R |  |  |  |  |
|  |  |  |  |  |  | R R | R R |  | R R | R R | R R |  |  | R R |
| R R |  |  |  | R R |  |  |  | R R |  | R R |  | R R |  | R R |
|  | R R |  | R R |  |  | R R | R R | R |  | R |  |  |  |  |
|  |  | R R |  |  |  |  |  | R |  |  |  |  |  |  |
| R | + | R | + | + | + | R | + | + | R | + | + | R | R | R |
| R | R | R | R | R | R | R | R | + | + | + | + | R | R | R |
| R R | R R | R | R | R R | R | + | + | R | C | + | R R | R R | R R | R R |
| R | + | + | + | + | + | + | + | + | + | + | R | R | + | R |
|  |  |  |  | R R |  | R R |  | R R |  |  |  |  |  |  |
| R | + | + | + | + | + | + | + | C | + | + | R | R | R | R |
| R R | R R | R | R R | R | R | R R | R | R | R | R | R | R R | R R | R R |
|  | R R | R R | R R |  | R R | R |  | R R |  |  | R R |  | R R |  |
|  |  |  | R R |  | R R |  | R R |  |  | R R |  |  |  |  |
|  | R R | R R | R | R R | R | R | R | + | R | R |  | R R |  | R R |
| + | R | R | R | + | + | R | R | R | R | R | R | R | R | R |
|  |  | R R | R R | R R |  | R R | R | R |  | R R | R R |  |  |  |
|  | R R |  | R R |  | R R | R | R R |  | R R |  |  |  | R R |  |
|  | R | R | R | R R | R R |  | R R | R R |  | R R | R R |  |  |  |
|  |  |  |  |  | R R | R R | R R | R R | R R | R R | R R |  |  |  |
| R | R | R | R | R | R | R | + | R | R | R | R R |  | R R | R R |
|  |  |  |  | R R |  | R R | R R | R R |  |  |  |  |  |  |

| Species \ Station | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|
| *C. atlanticus* var. *neapolitana* | | | R R | | R R | | | | |
| *C. messanensis* | | | | | | R R | | | |
| *C. lorenzianus* | | | R R | | | | | | |
| *Hemiaulus membranacus* | R R | R R | | | | | | | |
| *Cerataulina compacta* | | | | | | | | | |
| *C. bergonii* | | | | | | | | | |
| *Thalassiothrix longissima* | + | + | C | + | + | R | + | R | + |
| *T. frauenfeldii* | | | | | | | | | |
| *Nitzschia seriata* | R R | | R | | | | R R | | |
| *Skujaella* spp. | R | R | R | R | R | R R | + | R R | R |
| Dinoflagellata | | | | | | | | | |
| *Ornithocercus magnificus* | R R | | R R | | R R | | | R R | |
| *O. serratus* | | R R | | | | R | R R | R R | |
| *O. splendidus* | | | | R R | | R R | | R R | R R |
| *C. gibberum* | | R R | | R R | R R | R | | R R | |
| *Ceratium pennatum* | | | R R | | | | | R R | R R |
| *C. paradoxides* | | | | | | R R | R R | | R R |
| *C. furca* | | | | R R | | R R | R R | R R | |
| *C. massiliens* | R | | R R | | | R R | | R | R R |
| *C. gracile* var. *symmetricum* | | | | | | R R | | | |
| *C. gravidum* | R R | R R | | R R | | R R | R R | R | R R |
| *C. tripos* var. *atlanticum* | R R | R | + | + | + | C | R | + | R |
| *C. macroceros* | R | R | + | + | + | R | + | R | + |
| *C. inflexum* | R | | R | | | R | + | R | + |
| *C. pentagonum* | | | | | | | | | |
| *C. lineatum* | | | | | | | + | | |
| *C. contortum* | R R | R R | | R R | R R | R | | R R | |
| *C. fusus* subsp. *seta* | | | R R | | | R | R | | R R |
| *C. tenue* var. *buceros* | R R | R R | | | R R | | | R R | R R |
| *C. extensum* | R | | | | | R | + | R | R |
| *C. deflexum* | | | | | | | | | |
| *C. karsteni* | R | R | R | R | R R | R | R | R | R R |
| *C. reticulatum* | | | | | | | | | |
| *C. breve* | | | R | | | R | R | R | R |
| *C. azoricum* | | | R | | | R | R R | R R | R |
| *C. palmatum* | | | R R | R R | R R | R R | R R | R R | |
| *C. lunula* | | | | | | | R R | R R | |
| *C. candelabrum* | | | | | R R | | R R | | R R |
| *C. carriense* | R | R | R | R | R | R R | | R R | |
| *C. vultur* var. *divergens* | R R | R R | | | R R | | | | |
| *Peridinium* sp. | R R | R R | | R R | | | | | |
| *Dinophysis homunculus* | | | | | | | | | |
| *Ceratocorys horrida* | R R | | R R | | R R | | R R | | R R |
| *Oxytoxum scolopax* | R R | R R | | R R | R R | R R | | | |

| 26 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 45 | 46 | 47 | 48 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R | R | R R | R R | R R | R | R R | R R | R | R | | | | |
| R R | R | R | R | R | R | R | R | R | R | R | R | | R R | R R |
| | | | | R R | | R R | | | | R R | | | | |
| | | | | | | | R R | R R | | R R | | | | R |
| | | R R | | R R | R R | R | R | R R | R R | | R R | | | |
| | | | R R | | | R R | R R | R R | R R | R R | | | | |
| R | C | C | C | C | C | + | C | C | C | + | + | + | + | + |
| | | | | R R | | R R | | R R | | R R | | | | |
| | R | R | R | R | R | R | R | R | R | R | R | | R R | R |
| R | R | R | R | R | R | R R | R | R | R | R | R | R | R | R |
| | R R | R R | R R | | R R | R R | | R R | R R | R R | R R | | R R | |
| R R | | | R R | R R | R R | R R | R R | | R R | R | R | R R | R R | R R |
| | | | | | | | | | R R | | R R | | | |
| R R | | R R | | R R | | R R | R R | | R R | R R | R R | R R | R R | |
| | | | | | | | R R | R R | | | | | | |
| | R R | R R | | R R | | R R | | | R R | | R R | | R R | |
| R R | | R R | | | R R | · | | R R | | R R | | | | |
| | R R | R R | R R | | R | R R | R R | R | R R | R | R | R | R R | R P |
| R R | | | R | | | | | | | | | | | |
| R R | R | R | R R | R R | R | R R | R | R R | R R | R | R | | | R |
| R | | R | | | R R | | | R R | | R | R | | | R |
| R | R | R | R | R | R | R | R | R | R | R | R | | | R |
| | | | | | | R R | R R | R R | | R R | | R R | | |
| | | | | R R | | R R | R R | | R R | | R R | | | |
| | R R | | R R | | | R R | R | R | R | R | R R | | R R | R P |
| | R R | R R | | R | R | R R | R R | R | | | R | | | |
| R R | R R | | | | | | R R | | | R R | | | R R | |
| R | | R | | R | | | | R | R | R | R R | | | |
| | | | | R R | | R R | R R | R R | | R R | | R R | | |
| R R | R | R R | R | R | R | R R | R | R | R | R | R | R R | R R | R |
| | | | | | | | | R R | R R | R R | | | | |
| R | | R R | R | R R | | R | | R | R | R | | | | R |
| | R R | R R | | R R | R R | R R | R R | R R | | R | R | | | P |
| R R | | | | | | | | | | | | R R | R R | |
| | R R | R R | | R R | R R | R R | | R R | | | | | | |
| | | R R | | R R | R R | R R | R R | R R | | R R | R R | | | |
| R R | | | R R | | | R R | | R | R | R | R | R | R | R |
| | | | | | | | | R R | | | | | R R | |
| | | | | | | | | | | | | R R | | R R |
| R R | | R R | R R | R R | R R | R R | R R | R R | | | R R | | | |
| | | R R | | R R | | R R | R R | | R R | R R | R R | | R R | R R |
| R R | | | | | R R | | | | | | | R R | R R | |

| Species \ Station | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|
| *Amphisolenia bidentata* | R | R | R | R R | R | R | R | R | R |
| *A. thrinax* | R R | | | | R R | | | | |
| *Pylocystis fusiformis* | | | R R | | | | | R R | R R |
| *P. lunula* | | | | | | | | | |
| *P. pseudonoctiluca* | R R | | R R | | | R R | | R R | R |
| *P. hamulus* | R R | R R | R R | R R | | | R R | | R R |
| Radiolaria | | | | | | | | | |
| *Sphaerozoum geminatum* | | | | | | | | | |
| *Acanthometron pellucidum* | R | R | R | + | + | C | C | + | C |
| *Auracantha scolymantha* | | | | | | | | | |
| *Amphilonche belonoides* | | | | R R | | R R | R | R R | R R |
| Foraminifera | | | | | | | | | |
| *Globigerina bulloides* | R | R R | + | R | R | + | C | + | C |
| Ciliata | | | | | | | | | |
| *Peterotricha major* | | | R R | R R | | R R | | R R | |
| *Tintinnus frankoii* | | | | | | | | R R | |
| *Codonellopsis parva* | | | R R | | R R | | R R | R R | |
| *Epiplocylis deflexa* | | | | | | | | | R R |
| *Cyttarocylis acutiformis* | R R | R R | R R | | | R R | | R R | R R |
| *Xystonellopsis heros* | R R | R R | | R R | | | | R R | |
| *Salpingella acuminata* | R R | | R R | | | R | | | |
| *Rhabdonella spiralis* | R R | | R R | | | R | R R | R R | R R |
| *R. amor* | R R | | | | | | | | |
| Medusae | | | | | | | | | |
| *Muggiaea atlantica* | | | R | | | R | R | | R |
| Polychaeta | R R | R R | R | | R R | | | R | R |
| Pteropoda | R R | R R | R | | | R R | + | + | R |
| Euphausiacea | | | | R R | | R | R R | R R | R R |
| Amphipoda (*Phronima*) | | | | | | R R | R R | | R R |
| Phyllopoda (*Podon polyphemoides*) | | | | R R | R R | R R | R R | R R | R R |
| Ostracoda | R R | R | | | | R | R R | R | R |
| Copepoda | | | | | | | | | |
| * *Calanus helgolandicus* | R | + | R R | R R | R R | R R | R R | | |
| * *C. tenuicornis* | R | R R | R | R R | + | R | + | + | + |
| * *C. minor* | | R R | R | | R R | | R R | + | + |
| *C. pauper* | | | R R | | | | | | |
| * *C. darwinii* | + | + | + | + | + | + | R | + | + |
| * *C. vulgaris* | | R R | | | | | | | |
| * *C. robustior* | | | | | | | | | |
| *C.* sp. (*C. tonsus?*) | | | | | | | | | |
| * *C. gracilis* | | | | | | | | | |
| * *Eucalanus subcrassus* | R R | + | R R | R R | + | + | + | + | + |
| * *E. attenuatus* | R | R R | R | | | | | | |
| *E. subtenuis* | | | | | | | | | |

| 26 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 45 | 46 | 47 | 48 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R R | R | R | R | | R R | R R | | R | R | R | R | R | R R | R |
| | | | | R R | | | | | | R R | R R | | R R | R R |
| R | | | | | | R R | | | R R | | | | | R R |
| | | | | R R | R R | | R R | | | R R | | | | |
| + | | R R | R R | | | | | R | | | R R | | | |
| | | | | | | | | | | | | | R R | |
| | | | | | | | | | | | | | | |
| | | | | R | | | | R R | | | | | | |
| + | R | R | C | + | + | R | + | + | R | + | + | + | + | + |
| | R R | R | | R | R | R R | R R | | R R | | | | | |
| R R | R R | | R | R | R R | | R R | | | | | | | |
| | | | | | | | | | | | | | | |
| + | R | R | + | + | + | + | + | + | R | R | R R | | R R | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | R R | | R R | | R R | | | | R R | | R R | | R R |
| | R R | | | | R R | | | R R | | | R R | | | R |
| | | R R | | R R | | R R | R R | R R | | R R | | | | |
| | R R | | | | | | | | R R | | R R | | | |
| | | | | | | | | | R R | | | R R | R R | R R |
| | R R | | | | R R | | | R R | | R R | | | | R R |
| R | | R R | R | | R R | | | | R R | | R R | | | R R |
| | | | | | | | | | | | | | | R R |
| | | | | | | | | | | | | | | |
| R | R | | R | R | | | | R | R | R | R R | | | |
| R | R R | | | | R R | R R | R R | R R | | R | R R | | R R | R R |
| | | | R | R | R | R | | R | R | R | R | | | R |
| R | | R R | + | | R R | R R | | | R R | R | R R | | | R R |
| | | | | | R R | | | | | | | R R | | |
| R | R R | | | | | | | | | | | | | |
| | R R | R R | | | R | | | R | | | | | R R | |
| | | | | | | | | | | | | | | |
| R R | R R | R R | R R | R | R R | R | + | + | + | + | + | + | R R | R R |
| + | + | R R | | R | + | R R | R | R | R | R R | R R | R | + | R R |
| + | + | R R | | + | | | + | R | | + | R | | + | R |
| | R R | | | R R | | | | | | R R | | | R R | |
| + | + | R | + | + | C | + | + | + | C | + | + | + | + | + |
| | + | + | + | R | R R | + | + | R | | R R | | R R | R R | R R |
| | | | | R R | + | | R R | R R | | R R | | | | |
| | | | | R R | | | | | | R R | | | | |
| | | + | | | | | | | | R R | | | | R R |
| + | R | + | R | R | + | R | + | R | R | + | + | + | + | R R |
| | + | | | R R | R | | R | | | + | | | | + |
| | | | | R R | R | | + | + | + | + | | | | |

| Species \ Station | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|
| * *E. mucronatus* | | | | | | | | | |
| *E. elongata* | | | | | | | | | |
| * *Rhincalanus cornutus* | | C | | | R R | | R R | R | R |
| *R. nasutus* | | | | | | | | | |
| *Acrocalanus longicornis* | | | | | | | | | |
| * *A. gibber* | | R | | | | | | R | |
| * *A. gracilis* | | R | | | | | R R | R | + |
| *A. monachus* | | | | | | | | | |
| *Calocalanus pavo* | R R | | | | | | | | |
| * *Paracalanus aculeatus* | R R | R R | R R | R R | R R | R R | + | R R | R R |
| * *P. parvus* | | R | | | | | | | |
| *Clausocalanus furcatus* | | R | | | | | | | |
| * *C. pergens* | R R | + | R | | | | R | | |
| * *C. arcuicornis* | | R R | | | R R | | R | R | + |
| *Pseudocalanus minutus* | | | | | | | | | |
| *Mecynocera clausi* | | | | | | | | | |
| *Phaenna spinifera* | | | | | | | | | |
| * *Euchaeta marina* | R R | + | + | + | + | + | R | R | + |
| *E. plana* | | R R | | R R | | | | | |
| *E. wolfendeni* | R R | | | | | | | | |
| *E. concinna* | | | | | | | | | |
| * *Gaetanus armiger* | | | | | | | | | |
| *Euchirella amoena* | R R | + | | R | R R | | R R | | R R |
| *Pontella securifer* | | | | | | | | | |
| *P. tenuiremis* | | | | | | | | | |
| *P. spinicauda* | | | | | | | | | |
| *Scottcalanus helenae* | | | | | | | R R | | |
| *Undeuchaeta minor* | | | | | | | | | |
| * *Heterorhabdus papilliger* | | | | | | | | R R | |
| *Scolecithricella spinipedata* | | | | | | | | | |
| *S. vittata* | | | | | | | | | |
| *S. orientalis* | | | | | | | | | |
| *S. bradyi* | | | | | | | | | |
| *S. minor* | | | | | R R | | | | |
| *Bradyidius armatus* | | | R R | | | | | R | |
| * *Scolecithrix danae* | R R | | | R R | | R R | | R R | R |
| *Haloptilus acutifrons* | | | | | | | | | |
| *H. longicornis* | | R R | | | | | | | |
| *Temora discaudata* | | | | | | | | | R R |
| *T. stylifera* | | | | | | | | | |
| *Calanopia elliptica* | | | | | | | | | |
| *C. americana* | | | | | | | | | |
| *C. minor* | | | R R | | | | | | |
| *Pontellina plumata* | R R | R R | | | R R | | R R | | |

| 26 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 45 | 46 | 47 | 48 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R | + | R | R | + | R | | R | | R | R | R R | | | |
| | | | | | | | R R | | | | | | | |
| | + | C | + | + | + | + | R R | R | + | + | R | R | R | C |
| | | R R | | + | | | | | | R | | | | |
| | | | | | | | | R R | | | | | | |
| | | R | | + | R | | + | R | | | R R | | | R |
| + | + | R R | R | + | R | R | R | + | + | + | R | R | + | + |
| | | R R | | | | | | | | R | | | | R R |
| | | | | R | R R | | + | R | | R R | | | | R R |
| R | R R | R R | + | + | R R | R | + | + | R | R | R R | R R | R R | R R |
| | | | | | | | R | R | | + | + | | | R |
| | R R | | | + | | | | | | R R | R | | R | R |
| + | R R | + | + | + | R | + | + | + | + | + | + | + | + | R R |
| + | + | R | + | + | R | R | R R | R | + | + | + | R | R | + |
| | | | | | | | R R | | | | | | | |
| | | | | | | | | | | R R | | | | |
| | | | | | | | | | | | R R | | | |
| + | + | R | + | R R | + | + | R | R R | + | + | + | + | + | + |
| | | | | R R | | | | | | R R | | | | |
| | | | | R R | R R | | R R | | | | R R | | R R | |
| | | | | R R | | R R | | | | R R | | | R R | |
| | R | R R | | R R | R | | | | | | | R R | | |
| | | | R R | | | R R | | R R | R | + | R R | R | | |
| | | | | | | | R R | | R R | R R | | R R | | |
| | | | | | | | | R R | R R | R R | R R | | | |
| | | | R R | R R | | | | R R | | R R | | | | |
| | | | R R | R R | R R | | | | | R R | | | | |
| | | | | | | | | | | R R | | R R | + | R R |
| | | R R | | R R | R R | R R | | | | | | | | |
| | | | | R R | | R R | R R | | R R | | R R | | | |
| | | | | | R R | R R | R R | R R | | | | | | |
| | | | R R | R R | | R R | | | | | | | | |
| | | R R | | R R | | | | | | | | | | |
| | R | | | | | | | | | R R | R R | | | |
| R | + | + | + | + | + | + | + | + | R | + | + | + | + | + |
| | | | | | R R | | | | | | | | | |
| | | | | R | R | R | + | + | R | R R | R R | | | R R |
| | R | | | R | R | | | | | | | | | |
| | | | R R | R | R R | | R | | | | | | | |
| | | R R | | | | | R | | | | | | | |
| | | | | R R | | | R R | | | | | | | |
| | R R | | | R R | R | | R R | R R | | R R | R R | | R R | R R |

| Species \ Station | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|
| * *Haloptilus ornatus* | | | | | | | | | |
| *Aetidius armatus* | | | | | | R R | | | |
| *A. giesbrechti* | | R R | | | R R | | | | |
| *Heterorhabdus spinifrons* | | | | | | | | | |
| *Labidocera spinicauda* | | | | | | | | | |
| *L. pavo* | | | R R | | | | | | |
| * *L. detruncata* | R R | | | | | | | R R | |
| *L. acuta* | | | | | R R | | R R | R R | |
| * *Pleuromamma abdominalis* | | | | | | | | | |
| * *P. gracilis* | | | | | | | | | |
| * *P. xiphias* | | | | | | | | | |
| *P. robusta* | | | | | | | | | |
| * *Centropages furcatus* | | R R | | R R | | | R R | R R | R R |
| *C. gracilis* | | | | | | | | | |
| *C. orsinii* | | | | | | | | | |
| *C. violaceus* | | | | | | | | | |
| *C. elongatus* | | | | | | | | | |
| *Candacia bispinosa* | | | | | | R R | | R R | |
| *C. pachydactyla* | | | | | | | | R R | |
| *C. simplex* | | | R R | R R | R R | | R R | R R | R R |
| *C. truncata* | R R | R R | | R R | | R R | R R | | |
| *C. bradyi* | | | | | | | | R R | |
| *C. longimana* | | | | | | | | | |
| *C. aethiopica* | | | | | | | | | |
| *C. catula* | R R | | | | | | | | |
| *C. curta* | | | | | | | | | |
| *C. discaudata* | | | | | | | | | |
| * *Lucicutia flavicornis* | | R R | | R | + | R | R R | R | |
| *L. longicornis* | | | | | | | | | |
| * *L. ovalis* | | | | | R R | | | R R | R R |
| * *Acartia danae* | | | | | | | | | |
| * *A. neligens* | R R | R R | | R R | R | R R | + | + | + |
| *A. erythrea* | | R R | | | | | | | |
| *A. hamata* | | | | | | | | | |
| *A. clausi* | | | | | | | | | |
| *Oithona setigera* | | | | | | | | | R R |
| * *O. plumifera* | + | + | + | + | + | C | C | + | + |
| *O. decipiens* | | R R | | R R | | R R | R R | R R | |
| *O. robusta* | | | | | | | | | R R |
| *O. fallax* | | | | | | | | | |
| *Lubbockia squillimana* | | | | | | | | | |
| *Macrosetella gracilis* | | R R | | R R | R R | | R R | | |
| *Euterpina acutifrons* | | | | | | | | | |
| * *Microsetella norvegica* | + | R | R R | R R | R R | R | R | + | + |

| 26 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 45 | 46 | 47 | 48 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | R R | | R R | R | R | | | R | | R R | | | |
| | | | | R R | | R R | R R | R | | R R | | | | |
| R R | R | + | + | + | + | R | R | R | R | R R | R R | | | |
| R R | | R R | R | + | R | R | R R | + | R | R | | R R | | R R |
| | | | | | | R R | | R R | | R R | R R | | R R | |
| R R | | | | | | | | | | R R | | R R | | R R |
| | | | | | | | | | | R R | R R | | | |
| R R | | R R | | R R | R R | | | | R R | | | | | R R |
| | | | | R | R | R R | | | | R R | | | | |
| | | | | R R | | R R | | | | R R | R R | | | |
| R | R | + | R | R | R | R | + | + | R | R | + | + | R | + |
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| R R | R | + | R | R R | R | R | R R | R | R | + | R R | R | + | R |
| | R R | | | R R | | R R | R R | R R | R R | | | | | |
| R R | | | | | | | R R | | | | | | | |
| | | | | | | | R R | | | R R | | | R | |
| R | R | R | R R | R R | + | R | R | R R | R | + | R | R | + | R R |
| | | R R | | R R | R | | R R | | | + | | | | |
| | | | | R R | | | | | | R R | R | R R | | |
| | | | | | | | | | | R R | | R R | R R | R R |
| | R R | | R R | R R | | | R R | | R R | | R R | | | |
| C | C | + | + | C | C | + | + | R R | R | C | + | + | + | C |
| | | | R R | R | | | R R | | | R R | R R | | R | R R |
| | | | R R | | R R | | | R R | R R | R | R | | | |
| | | | | | | | | | | | | R R | R R | R R |
| | | | R R | R R | R R | | | | | | | | | |
| R R | | | | | R | | | | | | | | R R | R R |
| | | | | R R | R R | R R | R R | | R R | R R | | | | |
| R | R | + | R | + | + | + | + | + | + | + | R | | R R | R R |

| Species \ Station | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|
| * *Microsetella rosea* | R | R R | R R | R R | R R | R R | R R | R R | R R |
| *Clytemnestra scutellata* | | | | | | | R R | R R | R R |
| *C. rostrata* | | | | | | | | | |
| * *Copilia mirabilis* | | R R | | | R R | | R R | R R | R R |
| *C. quadrata* | | | | | | | | | |
| *Sapphirina gastrica* | | | R R | | R R | R R | | R R | |
| * *S. intestina* | | | | | | | | | |
| * *S. gemma* | | R R | | R R | | | | | |
| *S. metallina* | | | | | | | R R | R R | |
| * *S. stellata* | | | | R R | R R | | | | |
| *S. angusta* | | | | | | | | | |
| *S. daerwinii* | | | | | | | | | |
| * *S. nigromaculata* | | R R | | | | | | | |
| * *Oncaea venusta* | R | + | R | + | + | + | C | C | C |
| * *O. medeterranea* | | | | | | R R | | R R | R R |
| * *O. media* | + | + | C | + | C | + | C | C | + |
| * *Corycaeus speciosus* | R R | R R | R | R | + | R | R | + | R |
| * *C. lautus* | R R | R R | R | R | + | R | R R | R | R |
| * *C. gibbulus* | R R | + | | | | | | | R |
| * *C. longistylis* | | + | R R | | | | | | |
| *C. ovalis* | | | | | | | | | |
| * *C. flaccus* | | R R | | | | | R R | | |
| *C. crassiusculus* | | | | R R | | R R | | | |
| *C. agilis* | | | | | | | | | |
| *C. concinnus* | | | R R | R R | | | | | |
| *C. catus* | | | | | | | | | |
| Larval plankton | | | | | | | | | |
| Fish eggs & larvae | R | R | | R R | | | R R | R | R R |
| Euphausiacea furcilia | R | R R | R R | R R | R R | R R | R | + | R R |
| Copepoda nauplii | + | + | + | | + | + | + | | + |

Notes : * Species in reproductive season.

| Species | Total number | % | Frequency of occurrence |
|---|---|---|---|
| Chaetognatha | | | |
| *Sagitta hexaptera* | 58 | 2 | 16/24 |
| *S. lyra* | 15 | 1 | 7/24 |
| *S. enflata* | 679 | 22 | 24/24 |
| *S. robusta* | 30 | 1 | 14/24 |
| *S. ferox* | 19 | 1 | 11/24 |
| *S. bedoti* | 381 | 14 | 21/24 |
| *S. serratodentata pacifica* | 766 | 29 | 23/24 |
| *S. regularis* | 267 | 10 | 24/24 |
| *S. bedfordii* | 39 | 1 | 11/24 |

| 26 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 45 | 46 | 47 | 48 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R R | R R | | R R | + | + | + | R | + | + | R | R R | | | |
| R R | | | | | R R | | | | | | | | R R | |
| | | | | | | | | | | | | | | |
| R R | | R R | | | R | | R R | R R | | R R | R R | | R R | |
| | | | | | | | | | | R R | | | | |
| | | | | | | | | | | | | | | |
| | | R R | R R | R R | R R | | | | | | | | | |
| R R | R R | | | R R | R R | | | | | | | | | |
| R R | R R | | | | R | | | | | R R | R R | | | R R |
| | | | | R R | R | | R R | | | | R R | R R | R | |
| | | | | R R | | | | | | | | | | |
| | | R R | R R | | | | | | | | | | | |
| | | | | | | | | | | R R | | | | |
| C | C | + | + | + | C | + | + | C | + | C | + | + | + | C |
| | R R | | | R | R R | | R R | | | R | | | R | + |
| + | + | C | + | + | C | + | + | + | + | C | + | C | + | C |
| R | | R | R | + | | | R R | | | R R | R R | R R | | |
| R | R R | R R | + | R | | | R R | | | | R R | R R | R | |
| | | R R | + | + | R R | | R R | + | R | R R | R R | R R | | R R |
| | | R | R | + | | | R R | | R R | R R | R R | R R | | |
| | | | | | | | | | R R | R R | | R R | | |
| | R R | R | | + | | | | | | R | R R | | R R | R R |
| | | | | | | R | + | R | R | | | | R | |
| | | | | R R | | | | R R | | | | | | |
| | | | | | R R | | | R R | | R R | R R | | | R R |
| | | | | | | | | | | R R | R R | | | |
| | | | | | | | | | | | | | | |
| R | R R | | R R | | R | | | | R R | | R R | | | |
| R R | | | | | R | | R | R R | R R | | R R | | | |
| + | + | + | + | + | C | + | + | + | + | + | + | + | + | + |

| Species | Total number | % | Frequency of occurrence |
|---|---|---|---|
| *Sagitta minima* | 216 | 8 | 15/24 |
| *Pterosagitta draco* | 133 | 5 | 20/24 |
| *Krohnitta subtilis* | 40 | 2 | 16/24 |
| *K. pacifica* | 48 | 2 | 16/24 |
| Damaged individuals or juv. | 44 | 2 | 15/24 |
| | | | |
| Copelata | | | |
| *Oikopleura longicauda* | 371 | 47 | 24/24 |
| *O. fusiformis* | 91 | 12 | 21/24 |
| *O. fusiformis* f. *cornatogastra* | 1 | | 1/24 |

| Species | Total number | % | Frequency of occurrence |
|---|---|---|---|
| *Oikopleura intermedia* | 7 | 1 | 2/24 |
| *O. gracilis* | 4 | 1 | 2/24 |
| *O. graciloides* | 1 | | 1/24 |
| *O. dioica* | 6 | 1 | 4/24 |
| *O. rufescens* | 66 | 8 | 19/24 |
| *O. parva* | 11 | 1 | 6/24 |
| *O. cophocerca* | 34 | 4 | 15/24 |
| *O. albicans* | 16 | 2 | 7/24 |
| *O.* spp. (damaged) | 65 | 8 | 19/24 |
| *Megalocercus huxleyi* | 3 | | 3/24 |
| *Stegosoma magnum* | 42 | 5 | 16/24 |
| *Pelagopleura verticalis* | 5 | 1 | 4/24 |
| *Fritillaria haplostoma* | 2 | | 2/24 |
| *F. formica* f. *digitata* | 11 | 1 | 7/24 |
| *F. fraudax* | 1 | | 1/24 |
| *F. gracilis* | 2 | | 1/24 |
| *F. pellucide* | 6 | 1 | 5/24 |
| *F. borealis* f. *sargassi* (large individuals) | 4 | 1 | 3/24 |
| *F. borealis* f. *sargassi* (small individuals) | 28 | 4 | 9/24 |
| *F. borealis* f. *intermedia* | 1 | | 1/24 |
| *F. megachile* | 2 | | 2/24 |
| *F.* spp. (damaged) | 4 | 1 | 3/24 |
| *Appendicularia sicula* | 4 | 1 | 4/24 |

The general trend of the distribution of diatoms was as follows: the western waters (Sts. 33~42) were richer not only in quantity but also in the quality than the eastern waters; this may perhaps be caused by the complexity of the temperature and salinity distribution in the western waters.

It is very interesting biologically that the author observed two forms of *Rhizosolenia alata*, one of which was larger in diameter while the other was very small in it; these two forms occurred more frequently in the western part (Sts. 33~42); and at the same time the auxospores of this species were also found in this water.

The author identified more than 250 species of zoo-plankton, among which the important members were 117 species of Copepoda, 42 species of Dinoflagellata, 23 species of pelagic Copelata, 13 species of Chaetognatha and 9 species of Tintinnoinea. And the dominant species were as follows:

Copepoda : *Calanus darwinii, Eucalanus subcrassus, Rhincalanus cornutus, Euchaeta marina, Scolecithrix danae, Lucicutia flavicornis, Oncaea venusta, O. media, Oithona plumifera.*

Dinoflagellata : *Ceratium tripos* var. *atlanticum, C. macroceros, C. pulchellum, C. inflexum.*

Pelagic Copelata : *Oikopleura longicauda, O. fusiformis, O. rufescens,* *Stegosoma magnum.*

Chaetognatha : *Sagitta enflata, S. bedoti, S. serratodentata pacifica, S. regularis, S. minima.*

Foraminifera : *Globigerina bulloides.*

Radiolaria : *Acanthometron pellucidum.*

But, the distribution of these species of zoo-plankton showed no significant regional difference in the composition, although the phyto-plankton was more valid in classifying the stations into several sub-regions.

Concerning the reproductive season of the copepods, the author observed many specimens belonging to 47 species carrying egg-sacs or sperm-sacs. The egg-diameter and the sperm-sac length were determined and they are listed in Table 22.

Table 22. The egg-diameter and the sperm-sac length of copepods found in the North Indian Ocean (Dec., 1955 ~ Jan., '56).

| Species | Egg-diameter (μ) | Sperm-sac length (μ) |
|---|---|---|
| *Calanus helgolandicus* | 140~170 | 400~ 440 |
| *C. tenuicornis* | 140~170 | — |
| *C. minor* | 140~200 | 250~ 310 |
| *C. darwinii* | 150~200 | 300~ 400 |
| *C. vulgaris* | 140~170 | 400~ 500 |
| *C. robstior* | 80~110 | 700~ 730 |
| *C. gracilis* | 100~170 | — |
| *Eucalanus subcrassus* | 140~200 | — |
| *E. mucronatus* | 140~160 | — |
| *E. attenuatus* | 100~180 | — |
| *Rhincalanus cornutus* | 140~180 | 1300~1400 |
| *Acrocalanus gibber* | 100~120 | — |
| *A. gracilis* | 30~ 40 | — |
| *Paracalanus aculeatus* | 30~ 50 | — |
| *P. parvus* | 30~ 40 | — |
| *Clausocalanus pergens* | 90~110 | 300~ 350 |
| *Euchaeta marina* | 300~350 | 500~ 700 |
| *Gaetanus armiger* | 140~200 | — |
| *Heterorhabdus papilliger* | — | 600~ 700 |
| *Scolecithrix danae* | — | 1000~1200 |
| *Haloptilus ornatus* | 80~140 | — |
| *Labidocera detruncata* | — | 140~ 200 |
| *Lucicutia flavicornis* | 60~ 70 | 300~ 750 |
| *L. ovalis* | — | 700~ 770 |
| *Pleuromamma abdominalis* | 150~200 | — |
| *P. xiphias* | 140~200 | — |
| *P. gracilis* | 80~140 | — |
| *Acartia danae* | — | 100~ 130 |
| *Copilia mirabilis* | 70~100 | — |
| *Microsetella rosea* | 40~ 50 | — |

| Species | Egg-diameter ( μ ) | Sperm-sac length ( μ ) |
|---|---|---|
| *Microsetella norvegica* | 40～ 50 | — |
| *Centropages furcatus* | — | 500～ 600 |
| *Sapphirina intestina* | 70～100 | — |
| *S. gemma* | 25～ 40 | — |
| *S. stellata* | 60～ 90 | — |
| *S. nigromaculata* | 60～ 80 | — |
| *Oithona plumifera* | 70～110 | — |
| *Oncaea venusta* | 40～ 60 | 160～ 180 |
| *O. medeterranea* | 40～ 80 | — |
| *O. media* | 50～ 70 | — |
| *Corycaeus speciosus* | 70～100 | 200～ 250 |
| *C. lautus* | 100～140 | — |
| *C. gibbulus* | 40～ 60 | 140～ 160 |
| *C. longistylis* | 140～160 | 200～ 250 |
| *C. flaccus* | 100～170 | 100～ 120 |

## III. Distribution of plankton in the waters southeastern part of the Arabian Sea

### 1. Sampling method

The sampling was carried out during the period from Dec., 1956 to Jan., '57 at the 18 stations set in the waters southeastern part of the Arabian Sea. And the details of the sampling condition and the location of the stations are given in Table 23 and Fig. 14. Plankton in the layer from 50 m deep to the surface were hauled up vertically at the speed of 50～100 cm per second by the quantitative net of KITAHARA'S type of 25 cm in the mouth-diameter and 100 cm in the length constructed with the gauze of XX 13 in JIS. And the samples thus collected were fixed with 5 % formalin solution as soon as possible and were examined in the author's laboratory.

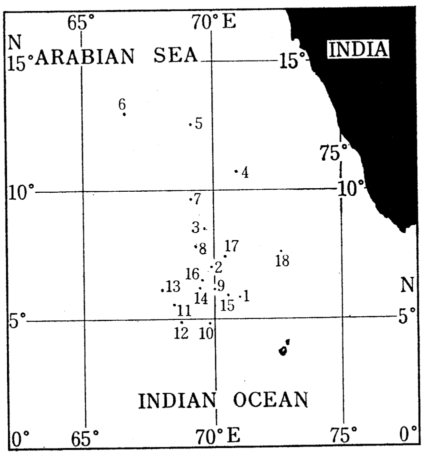


Fig. 14. Chart of the stations set in the southeastern part of the Arabian Sea.

### 2. Composition and distribution of plankton

Table 24 represents the compositions and the relative abundance of plankton sampled at respective stations.

Table 23. Stations and their positions set in the southeastern part of the Arabian Sea.

| St. | Lat. N. | Long. E. | Date | Water-color | Transparency |
|---|---|---|---|---|---|
| 1 | 5° 50′ | 71° 00′ | Dec. 25, 1955 | 2 | 28 |
| 2 | 7 00 | 69 50 | 26 | 2 | 26 |
| 3 | 8 36 | 69 35 | 27 | 2 | 32 |
| 4 | 10 45 | 70 09 | 28 | 2 | 33 |
| 5 | 12 33 | 69 18 | 29 | 2 | 31 |
| 6 | 13 24 | 66 39 | 30 | 2 | 28 |
| 7 | 9 56 | 69 11 | Jan. 9, '56 | 2 | 26 |
| 8 | 7 48 | 69 25 | 10 | 2 | 26 |
| 9 | 6 17 | 70 00 | 11 | 2 | 26 |
| 10 | 4 52 | 69 50 | 12 | 2 | 26 |
| 11 | 5 27 | 68 37 | 13 | 2 | 30 |
| 12 | 4 57 | 68 47 | 14 | 2 | 32 |
| 13 | 6 05 | 68 02 | 15 | 2 | 27 |
| 14 | 6 11 | 69 39 | 16 | 2 | 33 |
| 15 | 5 55 | 70 22 | 17 | 2 | 27 |
| 16 | 6 28 | 69 32 | 18 | 2 | 33 |
| 17 | 7 24 | 70 21 | 19 | 2 | 35 |
| 18 | 7 38 | 72 50 | 20 | 2 | 34 |

The phyto-plankton were composed of a species of Cyanophyceae and 28 species belonging to 14 genera of diatom. They were predominated by the pelagic species of the tropical or subtropical waters, such as *Skujaella thiebautie* of Cyanophyceae and *Planktoniella sol*, *Rhizosolenia alata*, *Chaetoceros coarctatus*, *C. pervianus* and *Thalassiothrix longissima* of diatom. Here, it should be kept in our mind that the above-mentioned species were also the principal components in the central part of the North Indian Ocean as already reported in the preceding paragraph.

It was one of the most remarkable differences of the diatom flora of this water from that of the central part of the North Indian Ocean that there occurred only in this water some neritic species such as *Stephanopyxis palmeriana*, *Dactyliosolen tenuis*, *Chaetoceros compressus*, *C. affinis*, *C. lorenzianus*, *Climacodium frauenfeldii*, *Hemiaulus membranacus*, *etc.* It seems to be quite natural that the author observed very commonly these neritic species at the stations 5, 4 and 18, set along the southwestern coast of India, whereas he observed them less frequently in the off-shore stations.

Zoo-plankton composed of almost all the groups of animals living in the sea from the primitive animals such as Protozoa to the well evolved ones such as fish larvae; and some of the principal components of them were arranged in order of abundance as follows: Copepoda, Dinoflagellata, Chaetognatha, larval plankton, Radiolaria, Medusae, Amphipoda, and so forth.

Among 53 species belonging to 26 genera of Copepoda, the following species were dominant: *Undinula darwinii*, *Nannocalanus minor*, *Eucalanus mucronatus*, *E.*

Table 24. Frequency of occurrence of each species in the waters of the southeastern part of the Arabian Sea.

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Phyto-plankton | | | | | | | | | | | | | | | | | | |
| *Planktoniella sol* | R R | R R | R R | R R | R R | R R | R R | R R | R R | R | R | R | R | R R | R | R R | R R | R R |
| *Asteromphalus hepticus* | | | | R R | | | | | | | | | | | | | | R R |
| *Gossleriella tropica* | | | | | | | R R | | | | | | | | | | | |
| *Ethmodiscus gazellae* | R R | R R | R R | | | | | | R R | | | | R R | | R R | | | |
| *Lauderia borealis* | | | | R R | | | | | | | | | | | | | | R R |
| *Stephanopyxis palmeriana* | | | | R R | R R | | | | | | | | | | | | R R | R R |
| *Dactyliosolen tenuis* | | | | R R | | R R | | | | | | | | | | | | R R |
| *Rhizosolenia alata* | R R | R R | R R | R | R R | R R | R R | R | R | R | R | R | R | R | R R | R R | R | R |
| *R. styliformis* | | | | R R | R R | R | R R | | | | R R | R | + | R | R R | | R R | R R |
| *R. hebetata* f. *semispina* | | | | | | | | R R | R R | R R | R R | | | R R | | | | |
| *R. calcar-avis* | | | | R R | R R | | | | | | | | | | | R R | | |
| *R. bergonii* | | | | R R | R R | | R R | | R R | | | | | | | | R R | R R |
| *Chaetoceros compressus* | | | | R | | | | | | | | | | | | | | R R |
| *C. affinis* | | | | R | R R | R R | | | | | R R | | R R | R R | | | R R | R |
| *C. pervianus* | R R | R | R R | R | R R | R R | R | R | R | R | + | + | + | R | R | R | R | R R |
| *C. coarctatus* | R | R | R R | + | + | + | R | R | + | + | R | R | + | R R | + | R | R R | R R |
| *C. atlanticus* var. *neapolitana* | | | | R R | R R | | | | | | | | | | | | | |
| *C. laciniosus* | | | | R R | R R | | | | | | | | | | | | | R R |
| *C. lorenzianus* | | R R | R | + | R | R R | | | | | | | | | | R R | R R | R |
| *C. decipiens* | | | | R | | | R R | R R | R | | | | | | | | | R R |
| *C. denticulatum* | | | | R R | | | R R | R R | R R | | | | | | | | | R R |
| *C. distans* | | | | R R | R R | | R R | R R | R R | | | | | | | | R R | |
| *Climacodium frauenfeldii* | | | R R | R | | | | R R | | | | | | | | | | |
| *Hemiaulus membranacus* | R R | R R | R R | R | R | | R R | | | R R | | | | R R | R R | | | R R |
| *H. indicus* | R R | | | | | | | R R | | R R | | R R | | | | | | |
| *Eucampia cornuta* | | | | | | | | | | | R R | R R | R R | | | | | |
| *Thalassiothrix longissima* | | R R | R R | | | R R | R | R | R R | R | R R | R | R | R R | | R R | R R | |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Nitzschia seriata* | | | | | | | + | R | R | | | | | | | | | |
| *Skujaella thiebautie* | + | + | + | R | R | R | R | R | + | + | R | + | + | + | + | + | + | R |
| Zoo-plankton | | | | | | | | | | | | | | | | | | |
| Dinoflagellata | | | | | | | | | | | | | | | | | | |
| *Amphisolenia bidentata* | | | | R R | R | | | | R R | R R | R R | R R | | R R | | R R | | R R |
| *A. thrinax* | | | | R R | | | | | | R R | | | | R R | R R | | | |
| *Ornithocercus magnificus* | R R | | R R | | | | | | | | R R | | R R | | | R R | R R | |
| *Ceratium macroceros* | | | | | R R | | R R | | R R | | | | | | R R | | | |
| *C. bucephalum* | | | | R R | | R R | | | | | | | | | | | | |
| *C. pulchellum* | | | | | | R R | | R R | R | R | R | R | R | R R | | R R | | |
| *C. breve* | | | | R R | R R | R R | R R | | | | R R | | | | | | | R R |
| *C. fusus* | | | | R R | R R | | R R | | | | | | | | | | R R | R R |
| *C. massiliens* | R | R | R | R R | R | R R | R R | R R | R | R R | R R | R | R R | R | R R | R R | R R | R R |
| *C. sumatranum* | R | R R | R | + | + | + | R R | R R | R R | R R | R | R | R R | R | R R | R R | R R | + |
| *C. pentagonum* | | | | R R | R R | | | | | | | | | | | | R R | R R |
| *C. tenue* var. *buceros* | R | + | + | + | + | + | R | R | + | R R | R | R | R | R R | R R | + | + | + |
| *C. deflexum* | R | R | R | | R R | | R | R | R | R R | R R | | R | R | R | | R R | |
| *C. lunula* | | | | R R | R R | | | | | | | | | | | | | R R |
| *Pyrocystis pseudonoctiluca* | C | + | + | R | R | R | + | + | + | C | C | + | C | C | C | C | + | C |
| *P. lunula* | R R | | | | R R | | | | | | | R R | | R R | | R R | | |
| Ciliata | | | | | | | | | | | | | | | | | | |
| *Rhabdonella striata* | R | R | + | + | R | R R | R R | | R | | R R | | R R | R | R | | R R | R R |
| *Tintinnus tenuis* | | | | R R | | R R | | | | | | | | | | | | R R |
| *Epiplocylis undella* | | | | R R | | | | | | | | | | | | | R R | R |
| Radiolaria | | | | | | | | | | | | | | | | | | |
| *Acanthometron pellucidum* | R R | R R | R | | | | | R R | | | R R | | R R | R R | | | | |
| *Amphilonche belonoides* | R R | | R R | R R | | | | | | | | | | R R | R R | | | |
| *Spharozoum geminatum* | + | R | + | R R | R R | R | R | R | + | + | + | R | + | R | + | + | R | R R |
| *Collozoum inerme* | + | + | + | R R | R R | + | R | + | + | + | R | R | + | + | + | + | + | R R |
| Foraminifera | | | | | | | | | | | | | | | | | | |
| *Globigerina* sp. | | | | R | R | | | | | | | | | | | | | |

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Medusae | | | | | | | | | | | | | | | | | | |
| *Abyla haeckeli* | R R | R R | | R R | | | R R | R R | R R | R | R R | R | R R | R R | | R R | R R | R R |
| *Diphyes dispar* | R R | R R | R R | | | R R | R R | | R R | R R | R | R R | R R | | R R | | R R | R R |
| *D. contorta* | R R | R R | R R | | R R | | R R | R R | R R | R | R R | R | R R | R R | | R R | | R R |
| *Muggiaea atlantica* | R R | R R | R R | R | R R | R R | R R | R R | R R | R | R R | R | R R | | R R | | R R | R R |
| Copepoda | | | | | | | | | | | | | | | | | | |
| *Nannocalanus minor* | + | + | R | R R | R | R | R | R | + | + | R | R | R | R | + | R | R | R |
| *Canthocalanus pauper* | R R | R R | R R | R R | R R | R R | R R | R R | R R | R R | R R | R R | R R | R R | R R | R R | R R | R R |
| *Undinula darwini* | C | C | C | + | C | C | + | C | C | C | C | C | C | C | C | C | C | + |
| *U. vulgaris* | | | | R | R | R R | R | R R | | | | R R | | R R | | | | R R |
| *Eucalanus atenautus* | | R | + | R R | R R | R R | R | R | R | + | R | | R R | | R R | | R R | R R |
| *E. mucronatus* | C | + | + | R | + | + | R | + | + | + | + | C | C | + | + | + | R | R |
| *E. subcrassus* | C | C | + | R | R | + | + | C | C | + | + | + | C | + | + | + | R | R |
| *Paracalanus aculeatus* | + | + | + | R | R | + | + | + | + | + | + | + | + | + | + | + | R | R |
| *P. nudus* | | | | | | | | | | R R | R R | R R | | | | | | |
| *P. parvus* | | | | R | R R | | | | | | | | | | | | R R | R |
| *Acrocalanus gracilis* | + | + | C | C | C | C | + | + | + | + | + | C | + | C | + | + | C | C |
| *A.* sp. | R R | R R | R R | R R | | | R R | | R R | | | | R R | | R R | | R R | R R |
| *Calocalanus pavo* | R | R R | | | | | | R R | R | R | R | R | R R | R R | R | R R | R R | R R |
| *Clausocalanus arcuicornis* | + | + | + | C | C | + | + | + | + | + | + | + | + | + | + | + | + | + |
| *C. furcatus* | R R | | | | | | | | | R R | R | R | R R | | | | | |
| *C. pergenus* | R R | | | | | | | R R | + | R | R | + | R R | | | R R | | |
| *Euchirella bella* | R R | R | R | | | | | | R R | | R R | R | R | R | R R | | | |
| *Euchaeta marina* | R | R | + | R | R | + | + | + | R | + | R | R | + | + | + | R | + | + |
| *E. wolfendeni* | | | R R | R R | R R | | R R | | | | | | | | | | R R | R R |
| *Scolecithrix danae* | R | R | R R | R | R | R | R R | R | R | R | R | R | R | R | R | R | R | R |
| *Centroparges gracilis* | R R | R | R | R | R | R | R | R | R | R | R R | R | R | R R | R | R R | R | R |
| *C. furcatus* | + | | R | | | | R | R | R R | R | R R | | | R R | + | | | |
| *C. bradyi* | | | | + | R R | | | | | | | | | | | | R R | R |
| *C. violaceus* | R R | | | | | | | | | R R | R | R R | R R | | | | | |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Temora discaudata* | + | R | | | | | | R | | | | | | | + | | R R | R R |
| *T. stylifera* | R | | | R R | | | | R R | | | R R | | | | R R | | | R R |
| *Lucicutia flavicorunis* | | | | R | R | | | | | | | | | | | | | R |
| *L. ovalis* | | R R | | | | | | | R R | | R R | | | | | R R | R R | |
| *Calanopia elliptica* | | | | | | | | | | R R | R R | R R | | | | | | |
| *Candacia aethiopica* | + | R R | R | | R R | | R R | R | + | + | + | + | + | + | R | R | R | R R |
| *C. curta* | R | | | | | | | | R | R | | | | | R R | | | |
| *C. simplex* | | | | R R | R R | | | | | | | | | | | | | R R |
| *C. bipinnata* | | | | | | R R | | R R | | R R | R R | R | R | R R | | | | |
| *C. pachydactyla* | | | | | | R R | | | | | R | R | R R | | | | | |
| *Acartia danae* | R | + | C | R | R | + | C | C | + | R | R R | R R | R | R R | R | + | C | C |
| *A. negligens* | R R | | | | | | | + | | R | R R | R R | | | R R | | | |
| *Pontellina plumata* | R R | R R | | | | | | R R | R R | | | | | R R | R R | R R | | |
| *Oithona fallax* | | | | | R R | R R | | | | R R | | | | | | | | |
| *O. nana* | | | | R R | | | | | | | | | | | | | | R R |
| *O. plumifera* | + | + | + | C | C | C | R | R | R | R | R | R | R | R | R R | R | + | C |
| *O. simplex* | + | R | R R | | | R R | R R | + | + | C | C | C | C | + | + | R R | R R | R |
| *Oncaea media* | R | + | + | R R | R R | R R | R | C | C | + | C | C | C | C | + | + | + | + |
| *O. venusta* | C | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| *Sapphirina intestinata* | | | | | | | | | R R | | R R | | | | | | | |
| *Copillia* sp. | | | | | | R R | | | | | | | | | | | | R R |
| *Corycaeus crassiusculus* | | | | | | | R R | | | R R | R R | | R R | | | | | |
| *C. speciosus* | + | R | + | R R | R R | R R | R | R | R | R | + | + | + | R | R | + | + | R R |
| *C. longistylis* | + | R | + | + | + | R | R | + | R | + | R | R R | R R | R R | R R | + | + | R |
| *C. agilis* | R R | | R R | | | | | | R R | R | R | R | R | R | | | R R | R R |
| *C. concinnus* | + | + | R | R | R R | R R | R R | R | + | C | C | C | C | R | R | R | R | R |
| *C. gibbulus* | + | R | R | + | + | R | + | + | + | R | + | + | + | + | + | + | + | + |
| *C.* spp. | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R |
| *Miracia efferata* | R R | R R | | | | | | | R R | | R R | | | R R | R R | | | |
| *Microsetella norvegica* | | | | R | R | | | | | R R | R R | R R | | | | | | |
| *M. rosea* | | | | | | | | | R R | + | R | + | R R | R R | R R | | | |

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Macrosetella gracilis* | | | | RR | RR | RR | | | | RR | | | | | | | | RR |
| Euphausiacea | | | | | | | | | | | | | | | | | | |
| *Stylocheiron* sp. | R | RR | RR | R | R | R | R | R | RR | R | RR | RR | RR | RR | R | R | R | R |
| Decapoda | | | | | | | | | | | | | | | | | | |
| *Lucifer raynaudii* | R | RR | RR | RR | RR | | R | R | R | R | RR | RR | RR | RR | R | RR | RR | R |
| Copelata | | | | | | | | | | | | | | | | | | |
| *Dolioletta* sp. | + | | | | | RR | | R | + | R | | R | | R | + | R | | |
| Larval plankton | | | | | | | | | | | | | | | | | | |
| Fish eggs | RR | RR | RR | RR | RR | | | RR | RR | RR | RR | | RR | RR | RR | | RR | RR |
| Fish larvae | RR | R | R | R | RR | | RR | RR | RR | RR | | | RR | RR | RR | | RR | R |
| Frucilian stage of Euphausiacea | RR | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R |
| Nauplius stage of Copepoda | C | C | C | C | C | C | C | C | C | C | C | C | C | C | C | C | C | C |
| Veliger | RR | RR | R | R | R | RR | | | RR | | RR | | | | | | RR | RR |
| Polychaeta larvae | | R | R | | | | | | | RR | | | RR | | | RR | R | R |

*subcrassus*, *Paracalanus aculeatus*, *Acrocalanus arcuicornis*, *Euchaeta marina*, *Candacia aethiopica*, *Acartia danae*, *Oithona plumifera*, *O. simplex*, *Oncaea media*, *O. venusta*, *Corycaeus speciosus*, *C. concinnus* and *C. gibbulus*.

It may be one of the most remarkable characteristics of the Copepoda fauna of this water that the small Copepoda occurred very richly not only in quantity but also in quality, although some large ones such as *Undinula*, *Nannocalanus*, *Euchaeta* and *Eucalanus* were observed at the same time. But, here, the adequate attention should be paid to the fact that the mesh size of the net used in this cruise was very small and was suitable only for the collection of small fauna and flora.

Sixteen species belonging to 4 genera of Dinoflagellata were identified but they were thought commonly to be the species in the temperate or tropical waters. Among them, the abundant species were as follows: *Pyrocystis pseudonoctiluca* (especially abundant in the waters south of 10°N), *Ceratium tenue*, *C. massiliens* and *C. sumatranum*.

Among Radiolaria, *Sphaerozoum* and *Collozoum* were observed abundantly.

Amphipoda and Chaetognatha will be discussed in Part III.

## 3. Consideration

Considering the results of the present observation and the general trend of the currents in the winter reported by SUDA (1938), it will be concluded that the northern half of the surveyed waters (Sts. 3~8), was under the direct influence of the current from the northwest; this current may be perhaps the extension of the clockwise counter current of the monsoon drift.

On the other hand, the southern half (Sts. 1, 2 & 9~15) is situated in the connecting area of the above-mentioned current with that running from the east to west along the 5°N line or thereabout.

According to the results of observations of the Shunkotsu-maru, the surface temperature was low in the northeastern part (*ca.* 27°C) but high in the southwestern one (*ca.* 29°C) and the isotherms run from northwest to southeast. But the distribution of the temperature in the 50 m layer is reversed to that of the surface layer; the northeastern part (23.5°C) is higher in temperature than that of the southeastern part. Then, the similar tendencies in the temperature distribution was observed even in the layers of 100 m or 150 m deep, but the gradient became steeper with the increase in depth, and it was 20°C in the northern part and 13°C in the southern part at depth of 150 m. Under these circumstances the oceanographic conditions, including the current field, of the surveyed waters may be very complicated.

Although phyto-plankton were poor, they were composed of both neritic species and pelagic ones; but in general the pelagic species predominated over the neritic ones at every station except Sts. 4, 5 and 18. These facts may suggest that the surveyed waters were under the strong influence of the off-shore waters.

The copepod fauna was richer in quality in the southern part than that in the northern part; and this was caused by the fact that the southern half was the region of the mixing of the above-mentioned two currents whereas the northern half was influenced only by the clockwise current of the monsoon drift.

## IV. Distribution of plankton in the waters eastern part of the Indian Ocean

### 1. Sampling method

The samples were collected during the period from Nov., 1956 to Feb., '57 by the author himself on board the Shunkotsu-maru in the tuna fishing grounds south of Java Island. Plankton in the layer from 100 m deep to the surface were hauled up vertically at the speed of 50~100 cm per second by the net of NAKAI'S type conveniently called Maru-Naka type in Japan, which was 60 cm in mouth-diameter and 160 cm in length constructed with the gauze of GG 54 in JIS. The sample thus collected was fixed with 5 % formalin solution as soon as possible and after 24 hours the precipitated volume of each sample was estimated after the removal of macroplankton. At each sampling station, the temperature and salinity of the following 10 layers were also observed: 0, 25, 50, 75, 100, 150, 200, 300, 400 and 500 m. The details of the oceanographic observation, the location of the stations and some remarks are represented in Table 25, and the stations are also plotted in Fig. 15.

Table 25. Oceanographic conditions in the eastern part of the Indian Ocean (1956∼'57)

| Station | | | Date | Weather | Water color | Transparency (m) | Deposition of plankton (cc) | Water temperature (°C) | | | | | | | | | | Salinity (‰) | | | | | | | | | | | Remark | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Lat. (S) | Long. (E) | | | | | | 0 m | 25 m | 50 m | 75 m | 100 m | 150 m | 200 m | 300 m | 400 m | 500 m | 0 m | 25 m | 50 m | 75 m | 100 m | 150 m | 200 m | 250 m | 300 m | 400 m | 500 m | (m) | (m) |
| 1 | 11 29.5 | 106 50.5 | Dec. 27 | b c | — | 15.5 | 6.5 | 28.60 | 28.53 | 28.51 | 26.80 | 24.10 | 21.31 | 17.22 | 11.59 | 9.62 | * 9.06 | 33.93 | 34.03 | 34.10 | 34.13 | 34.16 | 34.31 | 34.40 | 34.41 | 34.42 | 34.48 | — | * 433 | * 350 |
| 2 | 12 24 | 107 05 | 27 | b c | — | 26.5 | 9.2 | 28.30 | 27.81 | 27.10 | 25.35 | 23.32 | 19.52 | 16.27 | 11.74 | 9.68 | * 8.38 | 33.80 | 33.90 | 34.02 | 34.14 | 34.26 | 34.65 | 34.78 | 34.80 | 34.82 | 34.74 | — | * 476 | |
| 3 | 13 15 | 107 10 | 27 | b c | — | — | 7.2 | 26.70 | 26.26 | 26.20 | 24.88 | 23.70 | 20.48 | 16.33 | — | — | — | 34.11 | 34.13 | 34.15 | 34.16 | 34.16 | 34.46 | 34.49 | — | — | — | — | | |
| 4 | 14 17.7 | 107 05 | 28 | b | — | 35.7 | 6.7 | 27.80 | 27.42 | 26.67 | 23.43 | 22.46 | 17.67 | 15.57 | 13.10 | 9.98 | * 8.46 | — | 34.13 | 34.17 | 34.24 | 34.45 | 34.67 | 34.74 | 34.74 | *34.76 | — | — | * 489 | * 350 |
| 5 | 15 28 | 107 01 | 28 | b c | — | — | 9.8 | 26.90 | 26.65 | 25.43 | 23.58 | 21.65 | 20.15 | 17.21 | 13.28 | 10.38 | 8.47 | — | 34.27 | 34.25 | 34.34 | 34.61 | 34.69 | 34.79 | 34.81 | 34.83 | 34.72 | — | | |
| 6 | 16 36 | 106 53 | 29 | b c | — | 38.0 | 10.0 | 26.70 | 26.82 | 25.36 | 23.58 | 22.40 | 20.08 | 17.10 | 12.50 | 10.09 | * 9.06 | 34.04 | 34.13 | 34.22 | 34.42 | 34.61 | 34.69 | 34.69 | 34.76 | 34.74 | 34.55 | — | * 485 | |
| 7 | 17 30 | 106 59 | 29 | b c | 1 | 34.0 | 9.8 | 28.10 | 26.29 | 25.74 | 25.02 | 22.51 | 20.52 | 18.74 | 13.72 | 10.70 | * 9.15 | 34.13 | 34.16 | 34.18 | 34.18 | 34.25 | 34.76 | 34.80 | — | 34.81 | 34.76 | — | * 476 | |
| 8 | 18 22.5 | 107 11.5 | 29 | b c | — | — | 13.1 | 24.90 | 24.20 | 24.20 | 22.36 | 22.00 | 21.28 | 19.42 | 15.57 | 11.11 | *10.04 | 34.60 | 34.61 | 34.63 | 34.65 | 34.70 | 34.80 | 34.86 | 34.91 | 34.95 | — | — | * 457 | |
| 9 | 19 12 | 107 35 | 30 | b c | — | — | — | 24.40 | 24.07 | 24.01 | 22.84 | 22.28 | 21.31 | 19.46 | 17.22 | *11.29 | — | — | — | — | — | 34.76 | 34.88 | 34.94 | 34.94 | 34.93 | — | — | * 375 | |
| 10 | 20 28 | 107 0.15 | 30 | b | 2 | 40.0 | 5.6 | 24.30 | 23.76 | 22.78 | 21.88 | 21.08 | 19.93 | 19.00 | 16.53 | *12.54 | — | 34.58 | 34.82 | 34.83 | 34.83 | 34.83 | 34.87 | 34.90 | 34.90 | 34.89 | 34.86 | — | * 386 | |
| 11 | 21 17.5 | 106 59 | 30 | b | — | — | 9.1 | 23.75 | 23.51 | 22.50 | 21.51 | 20.58 | 19.32 | 18.24 | 13.65 | — | — | — | 34.58 | 34.76 | 34.81 | 34.81 | 34.81 | 34.82 | 34.83 | 34.77 | — | — | | |
| 12 | 21 54 | 106 54 | 31 | b | 2 | 32.0 | 6.5 | 23.40 | 23.11 | 21.52 | 20.78 | 20.28 | 19.43 | 17.79 | 13.27 | *11.31 | — | 34.67 | 34.67 | 34.71 | 34.75 | 34.83 | 34.86 | 34.86 | 34.85 | 34.82 | — | — | * 360 | |
| 13 | 23 26 | 107 00 | Jan. 1 | c | 1 | 28.0 | 8.2 | 23.00 | 22.93 | 21.50 | 20.13 | 19.39 | 18.00 | 16.32 | 12.73 | 10.08 | * 9.44 | 34.65 | 34.67 | 34.70 | 34.73 | 34.76 | 34.83 | 34.83 | 34.83 | 34.81 | 34.72 | *34.69 | * 433 | * 450 |
| 14 | 25 00 | 107 00 | 1 | b c | 2 | 29.0 | 10.6 | 23.14 | 23.00 | 22.31 | 20.50 | 19.42 | 17.63 | 16.41 | 12.46 | *11.83 | — | 34.69 | 34.69 | 34.70 | 34.77 | 34.79 | 34.86 | — | — | — | — | — | * 321 | |
| 15 | 25 12.5 | 108 21 | 2 | 0 | — | — | 7.2 | 22.50 | 22.49 | 21.80 | 21.00 | 20.11 | 18.02 | 16.49 | 14.98 | 12.00 | *10.13 | — | — | 34.60 | 34.60 | 34.60 | 34.63 | 34.69 | 34.70 | 34.71 | 34.72 | — | * 470 | |
| 16 | 24 00 | 108 36 | 2 | b c | 1 | 24.0 | 23.6 | 23.40 | 22.12 | 21.41 | 19.81 | 19.00 | 17.60 | 15.58 | *12.93 | — | — | 34.76 | 34.79 | 34.85 | 34.87 | 34.88 | 34.94 | 34.98 | 34.97 | 34.95 | — | — | * 265 | |
| 17 | 23 00 | 108 29 | 2 | b | — | — | — | 23.60 | 23.50 | 22.73 | 21.27 | 20.09 | 18.72 | 17.33 | 14.28 | *11.97 | — | 34.78 | 34.79 | 34.81 | 34.83 | 34.86 | 34.89 | 34.90 | 34.93 | 34.04 | — | — | * 360 | |
| 18 | 22 00 | 108 25.5 | 3 | b c | 1 | 22.0 | 9.4 | 23.60 | 23.00 | 22.50 | 21.26 | 20.24 | 18.09 | 17.68 | 13.50 | — | — | 34.74 | 34.77 | 34.84 | 34.90 | 34.90 | 34.92 | 34.90 | 34.84 | — | — | — | | |
| 19 | 21 00 | 108 30 | 3 | b c | 1 | 33.0 | 12.3 | 24.30 | 24.00 | 22.87 | 21.41 | 20.20 | 19.10 | 17.70 | 13.98 | *10.67 | — | 34.63 | 34.65 | 34.68 | 34.75 | 34.80 | — | — | — | — | — | — | * 383 | |
| 20 | 20 00 | 108 30 | 3 | b c | — | — | 15.9 | 23.40 | 23.30 | 22.86 | 21.44 | 20.25 | 18.30 | 16.12 | 11.61 | * 9.32 | — | 34.36 | 34.67 | 34.67 | 34.70 | 34.75 | 34.84 | 34.90 | — | — | — | — | * 372 | |
| 21 | 19 07 | 108 33 | 4 | b c | 2 | 26.0 | 7.3 | 24.50 | 24.30 | 23.61 | 22.50 | 21.40 | 19.78 | 18.00 | 14.00 | *10.04 | — | 4.65 | 34.66 | 34.68 | 34.70 | 34.72 | 34.77 | 34.82 | — | — | — | — | * 372 | |
| 22 | 18 00 | 108 02 | 4 | b | 2 | 35.0 | 6.2 | 24.80 | 24.50 | 24.00 | 23.00 | 21.73 | 20.29 | 19.08 | 16.27 | 12.00 | *10.42 | 34.56 | 34.62 | 34.69 | 34.74 | 34.78 | 34.85 | 34.91 | — | — | — | — | * 441 | |
| 23 | 17 50 | 109 00 | 4 | b c | — | — | 11.3 | 24.90 | 24.77 | 23.31 | 22.00 | 21.10 | 19.85 | 18.41 | 14.50 | 10.70 | * 9.85 | 34.49 | 34.51 | 34.57 | 34.66 | 34.73 | 34.85 | 34.89 | 34.94 | — | — | — | * 424 | |
| 24 | 16 46 | 108 57 | 5 | b | 2 | 31.0 | 7.2 | 25.40 | 25.00 | 24.48 | 23.20 | 22.43 | 20.50 | 18.61 | 14.23 | 9.82 | * 9.38 | 34.42 | 34.43 | 34.45 | 34.47 | 34.50 | — | — | — | — | — | — | * 415 | |
| 25 | 16 57.5 | 108 16 | 5 | b c | — | — | 9.0 | 25.90 | 25.48 | 24.00 | 22.81 | 22.20 | 20.23 | 18.63 | 14.71 | 10.45 | * 9.39 | 34.33 | 34.37 | 34.42 | — | — | — | — | — | — | — | — | * 424 | |
| 26 | 15 57 | 108 10 | 6 | 0 | 2 | 39.0 | 12.0 | 27.00 | 26.74 | 26.31 | 24.30 | 23.00 | 20.00 | 15.73 | 11.42 | * 9.77 | — | 34.67 | 34.45 | 34.15 | 34.21 | 34.35 | 34.70 | *34.87 | — | — | — | — | * 383 | * 175 |
| 27 | 14 54 | 106 18 | 7 | 0 | 1 | 26.0 | 9.4 | 27.10 | 26.75 | 26.50 | 24.30 | 22.85 | 20.59 | 18.40 | 13.60 | 9.60 | * 8.32 | 34.24 | 34.24 | 34.24 | 34.24 | 34.42 | 34.70 | 34.82 | 34.83 | 34.83 | 34.84 | *34.91 | * 457 | * 450 |
| 28 | 14 57.5 | 105 09 | 7 | 0 | — | — | 11.1 | 27.00 | 27.06 | 26.36 | 23.88 | 22.00 | 18.00 | 16.00 | 13.30 | 9.60 | * 8.94 | 34.15 | 34.11 | 34.15 | 34.16 | 34.28 | 34.68 | 34.64 | 34.29 | 34.50 | 34.75 | *34.66 | * 433 | * 450 |
| 29 | 14 04 | 105 08 | 8 | 0 | 1 | 26.0 | 7.0 | 27.60 | 27.31 | 26.53 | 24.73 | 23.00 | 20.40 | 16.73 | 13.21 | 10.45 | * 8.56 | 34.07 | 34.07 | 34.20 | 34.20 | 34.32 | 34.84 | 34.96 | — | 34.88 | 34.70 | *34.55 | * 470 | * 450 |
| 30 | 13 55 | 105 52 | 9 | b | 2 | 34.0 | 5.2 | 27.50 | 27.31 | 27.26 | 24.92 | 23.50 | 19.73 | 17.34 | 12.15 | 9.77 | * 8.52 | 34.07 | 34.07 | 34.07 | 34.07 | 34.21 | 34.60 | 34.78 | — | 34.67 | 34.54 | *34.47 | * 464 | * 450 |
| 31 | 13 13.5 | 105 46 | 9 | b c | — | — | 6.8 | 27.80 | 27.52 | 26.94 | 25.97 | 23.99 | 20.51 | 17.00 | 11.65 | 9.92 | 8.53 | 34.11 | 34.09 | 34.05 | 34.07 | 34.20 | 34.38 | 34.65 | 34.63 | 34.60 | 34.74 | 34.81 | | |
| 32 | 12 15 | 105 36 | 10 | b | 1 | 34.0 | 5.5 | 28.65 | 28.36 | 27.13 | 25.97 | 24.31 | 15.86 | 15.65 | 10.78 | 9.65 | 8.17 | 34.22 | 34.25 | 34.13 | 34.13 | 34.20 | 34.61 | 34.81 | 34.82 | 34.83 | 34.70 | 34.63 | | |
| 33 | 11 37 | 105 28 | 10 | b c | — | — | 12.6 | 28.50 | 28.21 | 27.20 | 25.37 | 23.75 | 18.39 | 15.32 | 11.00 | 9.50 | * 8.45 | 34.15 | 34.16 | 34.13 | 34.11 | 34.32 | 34.42 | 34.94 | 34.60 | 34.48 | 34.45 | 34.47 | * 485 | |
| 34 | 10 46 | 105 15 | 11 | b | 2 | 34.0 | 7.7 | 28.90 | 28.93 | 27.60 | 24.48 | 22.23 | 18.24 | 14.73 | 10.61 | 9.80 | * 8.17 | 34.24 | 34.30 | 34.42 | 34.38 | 34.36 | 34.38 | 34.38 | 34.39 | 34.40 | 34.61 | — | * 481 | |

## 2. Oceanographic conditions in the eastern part of the Indian Ocean

Generally speaking, the southeastern part of the surveyed waters was covered by the waters composed of two water masses, one of which is a part of the west wind drift of the South Indian Ocean and another is the coastal water mass of Australia. The boundary between these two water masses run approximately parallel to the longitude. But in the present observation only two lines were set along the longitude. Accordingly, the paucity in the observation lines and stations made it very hard to analyze the oceanographic conditions of the surveyed waters. But the following facts may well be worth mentioning.

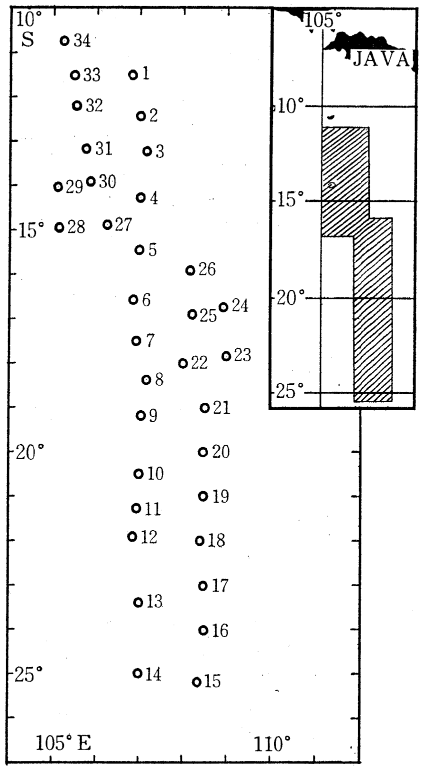


Fig. 15. Chart showing the stations set in the eastern part of the Indian Ocean.

### A. Horizontal distribution of temperature and salinity (*cf*. Fig. 16)

The most remarkable characteristic of the horizontal distribution of isotherms on each of the isobaric surfaces between the surface and the 400 m layer was the similarity of the isothermal lines. The same characteristic was found also in the horizontal distribution of isohalines. These facts may suggest that the stations were covered by the waters in which the water masses from the east and that from the west contacted intimately each other down to depth 0～400 m. Generally speaking, the temperature was high in the north and was low in the south, and its gradient was steepest at the central part of this area investigated (15°～18°S). The direction of meandering isotherms shifted gradually to north and south direction with an increase in depth, they practically run north and south on the isobaric surface of 400 m.

The salinity was high in the north; but the isohalines ran nearly north and south even in the layer as shallow as 200 m in the southern half of the surveyed waters, like the isothermal lines and the gradient was steepest around 15° ～18°S.

### B. Vertical distribution of temperature and salinity at respective stations

#### 1). Water temperature (Fig. 17)

The vertical distribution of the temperature at each station set in the northern half of the surveyed waters is summarized as follows: The vertical distribution of the

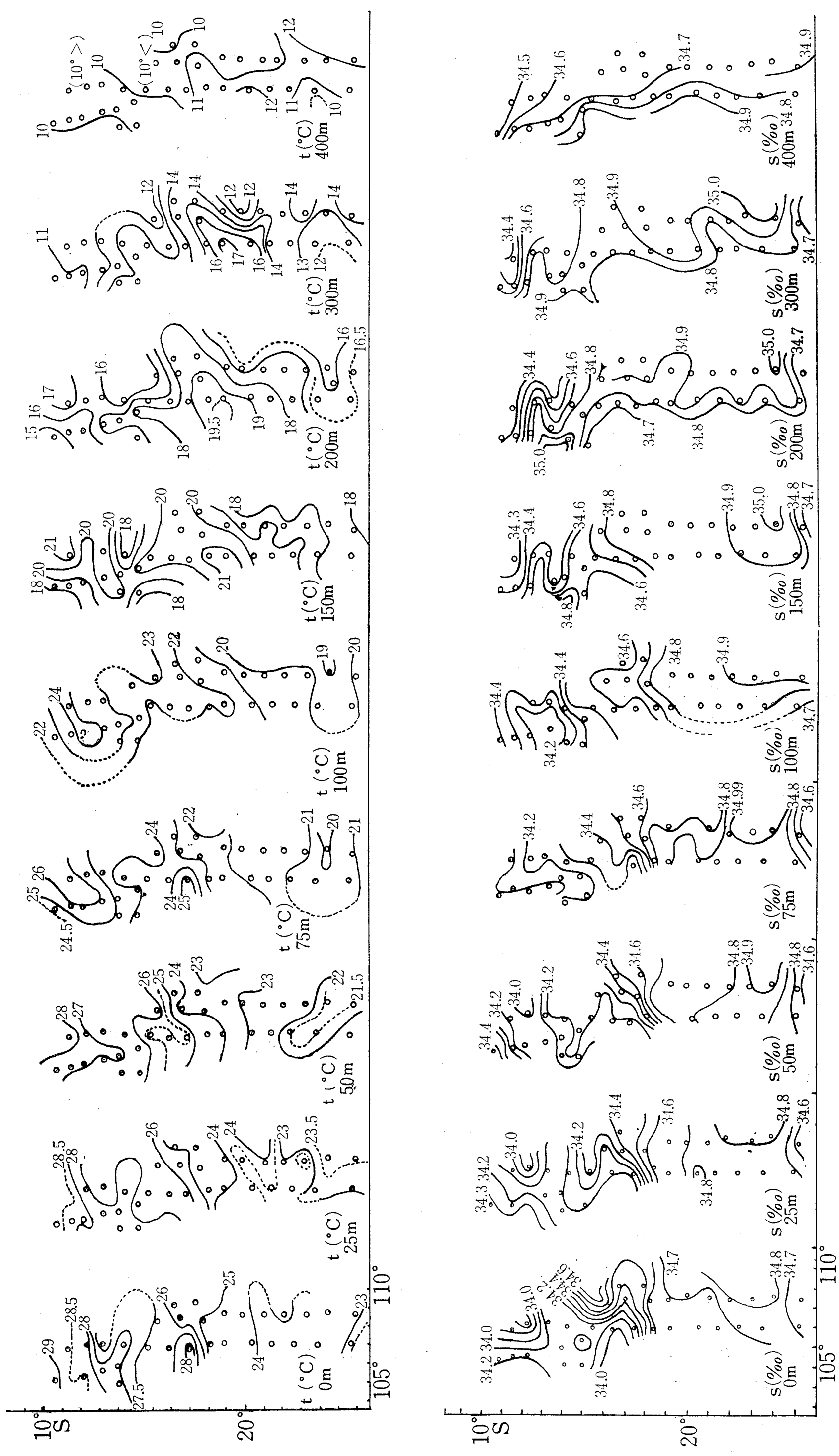

Fig. 16. Horizontal distribution of water temperature and salinity.

temperature in the stations 1~6, 30 and 31 was similar in general trend below the depth 50 m down to 300 m deep, but a little steeper in the layer deeper than 300 m. These facts may suggest the presence of a thermocline at a depth between 50 and 300 m although this is not remarkable. The temperature at the St. 4 showed a peculiar type of vertical distribution in the layer deeper than 50 m. The temperature decreased showing an inflection at 150 m deep; this peculiarity will tell that the thermocline was found in the depth between 50 and 150 m. On the other hand, Sts. 32~34 set on the left handed line had similar type in the tendency of the temperature distribution as

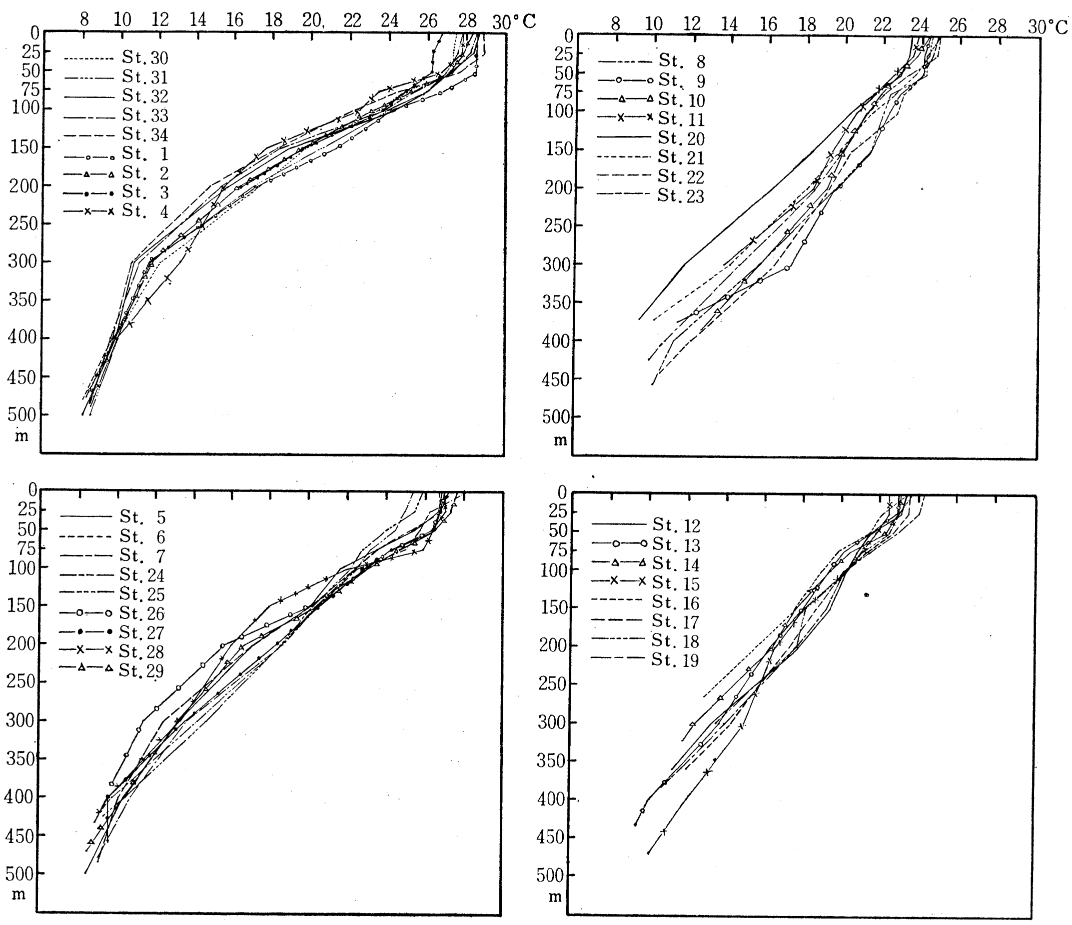


Fig. 17. Vertical distribution of water temperature observed at the stations shown in Fig. 15.

that observed at St. 4; a sudden fall of the temperature was also found in the layers between 25 and 150 m deep. But the types of temperature distribution in the layer from 150 to 300 m deep and those in the deeper layer more than 300 m deep in these stations were different not only from each other but also from those of the corresponding layers at St. 4. Thus, the type of the fall of temperature in the layer not deeper than 300 m differed according to the location of the stations, but the horizontal distribution of the temperature in these stations was much alike below the depth 450 m layer or thereabout.

Then, let us describe some characteristics of the distribution of temperature in the central part of the eastern Indian Ocean. Any similarity was not found in the type of the vertical temperature distribution between two groups of stations, one of which was that at Sts. 21 and 23~25 and the other at Sts. 7, 8, 22 and 26~28. They differed each other in the following: the temperature of the former group fell gradually at the constant rate with the increase of depth more than 25 m; the temperature in the layer deeper than 150 m at St. 27 had the type similar to that at Sts. 29~31. Moreover, a considerable variation of the temperature was found in such a deep layer as 400~450 m.

In the southern part a considerable difference was found in the distribution of the temperature between any two stations excepting the difference found between Sts. 12 and 17~19 and that found in the shallower layers less than 150 m at Sts. 13, 14 and 16.

2). **Salinity** (Fig. 18)

In the northern part, the similarity in the distribution of salinity is acceptable in the following 4 groups of the stations; i) Sts. 2 and 4 (in the depth between 50 and 150 m), ii) Sts. 2, 27 and 28 (in the depth between 50 and 350 m), iii) Sts. 2, 29 and 30 (in the depth between 50 and 200 m) and iv) Sts. 2 and 32 (in the depth between 50 and 400 m). As to St. 2, the salinity increased to the highest from 0 to 150 m deep, then kept rather stable in the depths between 200 and 400 m and was higher in the depth between 200 and 300 m. The distribution of salinity in other stations had each the characteristic features in its own: that is, the salinity in Sts. 34, 33, 27 and 30 seems to be typical in its distribution; they are as follows: at St. 34, salinity remarkably increased from the surface to 50 m deep and attained the maximum at 50 m depth, and kept nearly constant in the layers from 100 to 300 m deep, then it increased again with the depth. Meanwhile, at St. 33, the salinity distribution was extremely irregular: namely, the salinity showed the minimum at the 75 m layer, but attained the maximum at the 200 m layer; a remarkable change in temperature was found in the layers between 75 and 100 m and that between 150 and 200 m layers. The temperature in the deeper layers more than 300 m was kept nearly constant. In contrast to the complexity in the vertical distribution of salinity at Sts. 34 and 33 the distribution in the Sts. 27 and 30 was rather simple throughout a thick layer such as from the surface to the depth 75 m.

Generally speaking, the distribution of the isohaline is much alike in the stations of the central part such as Sts. 5~17 and 27~28; but they differ in the minute points; namely, the depth of the steepest layer in the salinity gradient was found in the depth between 50 and 100 m at the St. 6, and in the layers between 100 and 150 m at St. 7, whereas, it was found in the layer between 100 and 200 m at Sts. 27 and 28; the depth of the maximum in salinity was found at 300 m or thereabout at Sts. 5 and 6, but the salinity was kept constant between the layer from 200 to 400 m at St.

7. The salinity curves at Sts. 8 and 19~23 are of similar type in respect to the gradual increase from the surface to 200 or 250 m deep, but there still remained some uncertainties because of the absence of the data gathered in the layer further below that depth. The extreme low salinity in the layers between 0 and 100 m deep was found at 50 m deep at St. 26. This is the remarkable difference found in the salinity of this station from those at the above-mentioned groups of stations, although the salinity in the deeper layer more than 50 m at St. 25 was not observed; but the surface temperature was proved to be similar to that at St. 6.

The common features throughout the stations in the southern areas are that they are nearly uniform in salinity in comparison with the waters in the northern and the central parts; the change between the layers from the surface to the 400 m depth is 0.2 ‰, excepting at St. 17. Station 15, the southernmost station on the western line, was quite different in salinity from any other stations in the vertical distribution; the layer from the surface to 100 m was constant in salinity, and moreover it was extremely lower than any other stations; the salinity was kept constant in the deeper layer than 200 m, though it was slightly lower.

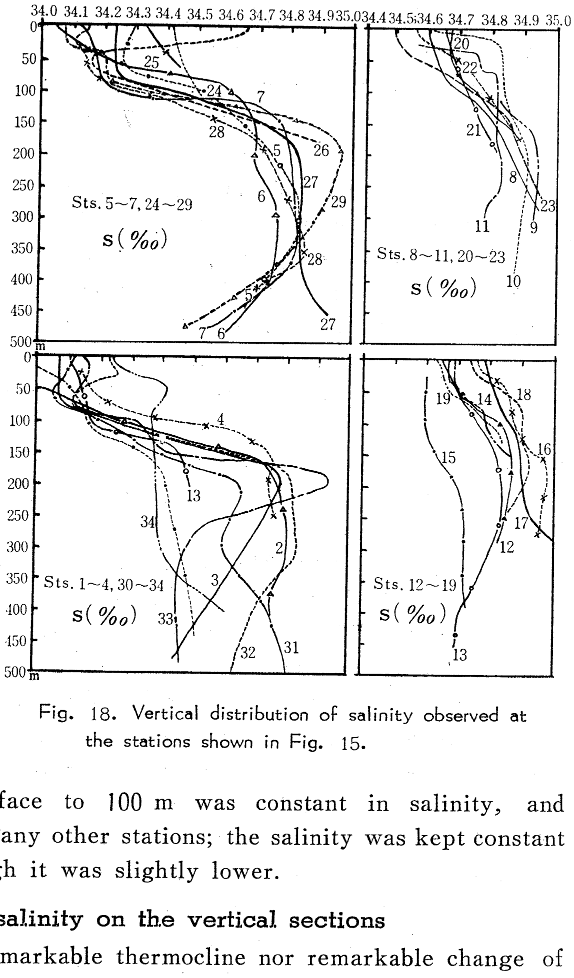


Fig. 18. Vertical distribution of salinity observed at the stations shown in Fig. 15.

## C. Distribution of temperature and salinity on the vertical sections

In this area there were neither remarkable thermocline nor remarkable change of the isohalines as has been reported by SATOW (1955) during the oceanographic investigation carried out in the southern region of the Greater Sunda Islands in winter, 1953~'54.

The distribution of stations in Figs. 19 A, B, C, D and E suggests that it is more rational to arrange the stations into the following 5 sections.

i) Section A: This section was comprised of Sts. 1~14 and run from north to south along about 107°E. The water of high temperature and low salinity perhaps originated from the north occupied the surface layer of the northern half (Sts. 1~7), whereas, the other water with low temperature and high salinity, perhaps originating from the south, stretched with a considerable thickness and submerged beneath the abovementioned northern water. Consequently, the thermocline was, though not conspicuous, found at the boundary between the surface and the middle layer, and it was observed at the depth between 100 and 150 m at Sts. 1～4, and this sunk to depth about 300 m with the southern transition of the stations; it was deepest, reaching 300～350 m deep at St. 9, then floated up in the south of this station, and at the same time it became obscure. On the other hand, the presence of the other thermocline was also recognized at depth 75 m or thereabout at Sts. 4～7, and this floated up to the surface at the midway between Sts. 7 and 8; this may be the boundary between the southern and the northern water masses.

ii) Section B: Stations 26～15 were set along the line about 90 miles east of the Section A arranging from north to south. In this section no conspicuous thermocline was observed. It is probable, though they are obscure, that there are two thermoclines; one of which runs from the layer at depth of 75 m or thereabout at St. 26 and floats up to the surface in a region a little south of St. 25; this may correspond to the one found at Sts. 7～8 on the Section A. The other thermocline, though very feeble, was found meandering between the depths 250 and 300 m throughout the stations on this line. It may be one of the most remarkable characteristic in the distribution of the salinity on this section that the isohalines run vertically between Sts. 16 and 15; this may suggest that the water at St. 15 was different in their origin from that of the north of the St. 16.

iii) Section C: Stations 34～28 were set along the line about 100 miles west of the northern part of Section A. In this section a remarkable thermocline was observed between depths 100 and 150 m, and the salinity gradient was also steepest at this layer. But, the oceanographic conditions of the Section C differ from those of the northern part of Section A in the distribution of isohalines and isotherms; there was a water of very high in salinity at depth 50 m or thereabout of St. 34; accompanied with this a water with the temperature higher than 28°C occupied the area enclosed by the isohaline of 34.2 ‰, which runs upward from the layer at depth 75 m of St. 34 to the surface on the midway between Sts. 32 and 31. These characteristic features of the distribution of the isohalines and isotherms will indicate that the water of high salinity and temperature must have stretched from the northwest or west.

iv) Sections D and E: The Section D was set joining the Sts. 29, 27, 5, 26 and 24, and Section E was joining Sts. 28, 6, 25 and 23. It is hard to find a remarkable thermocline in these sections, but a layer of steep gradient in salinity was found in each section; one of which runs from the layer at depths between 100 and 150 m at Sts. 29～26 floating up to the surface at St. 24 in the Section D; the other runs in the Section E from the layer at depth 100 m of St. 28 floating up to the surface in the region a little northwest of St. 25. The steepest layer in salinity gradient on the Sections D and E and that on the Sections A and B will illustrate that there were water masses in the shallower layer less than 150 m, which passed the surface on the Sections A, B and D at the following stations, *viz.* midway between Sts. 7 and 8 in the Section A, at St. 25 or thereabout in the Section B, and at the midway between Sts. 26 and 24 in the Section D, respectively.

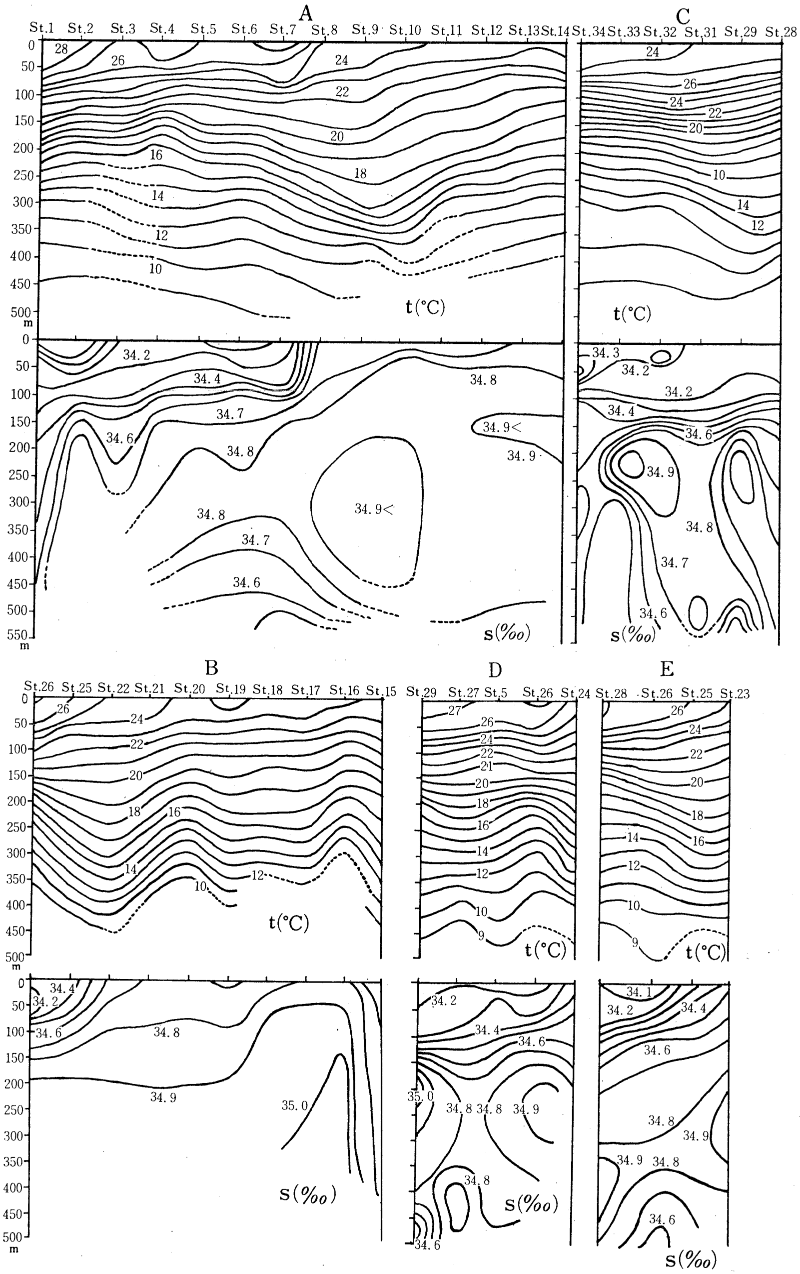

Fig. 19. Distributions of temperature and salinity in the vertical sections A, B, C, D and E (eastern part of the Indian Ocean).

**D. Water masses in the eastern part of the Indian Ocean**

As was suggested by Fig. 20, it is imaginable that there were 6 water masses in the surface layer (0∼100 m), 4 in the sub-surface one (150∼200 m) and 2 in the middle one. They are:

**i. Surface layer**

Water mass A: t=27∼28°C, s=34.40∼34.45 ‰; this mass has its center at depth 50 m around St. 34 (or probably located more northwest or west); this may perhaps, be derived from the off or on the southwest of the Greater Sunda Islands.

Water mass B: t=23∼29°C, s=34.0∼34.3 ‰ (lower than the water mass A); this mass occupies the layer shallower than the depths between 75 and 100 m of Sts. 1∼7 and 26∼33; this may be the tip of the tongue-shaped extension of the water mass situated at a considerable depth off the southeast coast of Java Island.

Water mass C: t=21∼25°C, s=34.4∼34.7 ‰; this mass occupies the layer shallower than the depth between 75 and 100 m at Sts. 8, 9, 11, 19 and 25 respectively; perhaps, this is superficial water mass covering the sub-surface layer of all over the stations, but is retained more or less on the surface only at St. 18; this mass may be, perhaps, the same origin as that of the water mass D but lower in salinity than D.

Water mass D: The water mass of higher in salinity than C occupies the very surface layer of Sts. 16∼18 and the subsurface layer of the southern half; perhaps, this may be the superficial oceanic water in the eastern part of the Indian Ocean.

Water mass E: t=20∼23°C, s=34.70∼34.75 ‰; this occupies the deeper layer more than the depth 50∼75 m at Sts. 12∼14, and is connected with the water mass C at Sts. 10∼11, and covers the water mass D; this mass may have been derived from a western water.

Water mass F: High in temperature ranging from 20° to 22°C but low in salinity with the range of 34.6 to 34.7 ‰; this mass occupies St. 15, and differs in its nature from any other water masses of the north and northwestern parts; its origin may be the coastal water from the southwest or west of Australia.

**ii. Sub-surface layer**

Water mass G: t=16∼21°C, s=34.35∼34.50 ‰; this mass occupies the layer at depths between 150 and 200 m at Sts. 1, 3, 31, 33 and 34; perhaps, this may be the water mass stretched out eastwards along the southern coast of Java Island.

Water mass H: t=15∼20°C, s=34.6∼34.8 ‰; this mass occupies the layer from 150 to 200 m deep of Sts. 2, 4, 6, 27∼30 and 32; it submerges beneath the water mass G, but floats up gradually with the southern transition of stations, and covers the water mass I.

Water mass I: t=17∼20°C, s=34.95 ‰; this mass occupies the layer of the depths between 150 and 200 m at Sts. 8∼14, 16∼18, 20 and 22∼26; and its southern limit is found at St. 15; a branch stretches to northeast (to Sts. 24∼26) and the other penetrates into the 200 m layer at St. 27.

Water mass J: t=15∼18°C s=34.6∼34.7 ‰; this mass occupies the layer of the depths between 150 and 300 m or thereabout at St. 15, and has the same origin as that of the water mass F.

### iii. Middle layer

Water mass K: t=8~12°C, s=34.35~34.50 ‰; this mass occupies the layer between 300 and 450 m deep at Sts. 1, 30, 33 and 34.

Water mass L: t=8~12°C, s=34.60~34.85 ‰; this water is higher in salinity than that of water mass K, and occupies the layers deeper than 300~400 m at Sts. 2, 4, 7, 13, 27~32 and 34.

Besides, there were some other waters which do not belong to any of the above mentioned water masses; they were found at depths of the following stations: (1) the 450 m layer of St. 27 (t=8~9°C, s=34.85~34.95 ‰), (2) the 450 m layer of St. 29 (t=8~9°C, s=34.55~34.65 ‰) and (3) the 400 m layer of St. 30 (t=9~10°C, s=34.50~34.55 ‰); but the first water was similar to the water mass L in nature, while the latter two were the intermediate between the water masses K and L.

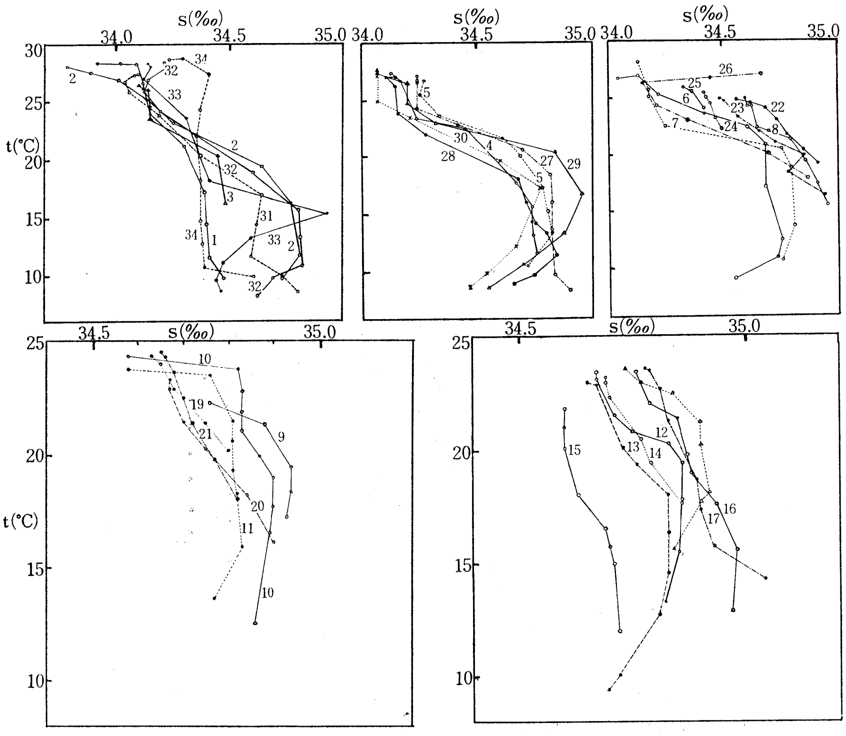


Fig. 20. T-S diagrams of each station (eastern part of the Indian Ocean).

It may be concluded from the above-mentioned facts that the surveyed waters cover two areas with quite different nature in oceanographic conditions; one of which is the area where a branch of the west wind drift from the southern part of the Indian

Ocean turns to the northwest after running against the southwest coast of Australia, and another is the coastal current of the west of Australia which runs northwest keeping contact with the branch of the west wind drift.

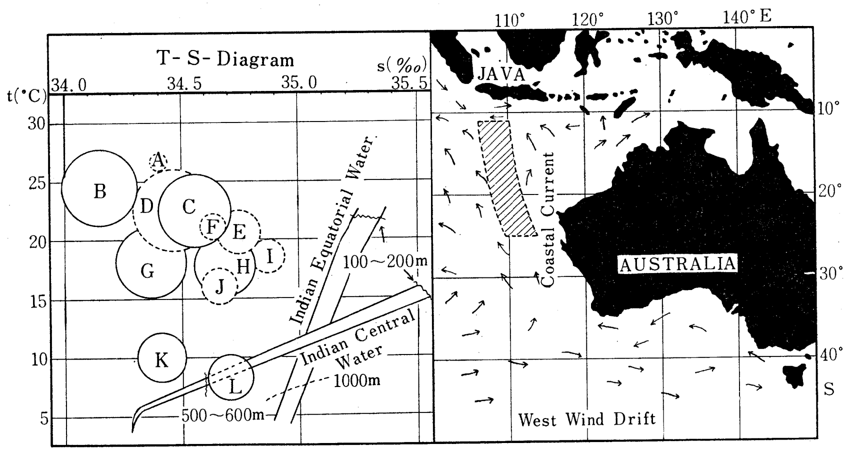


Fig. 21. Water masses shown in T－S diagram.

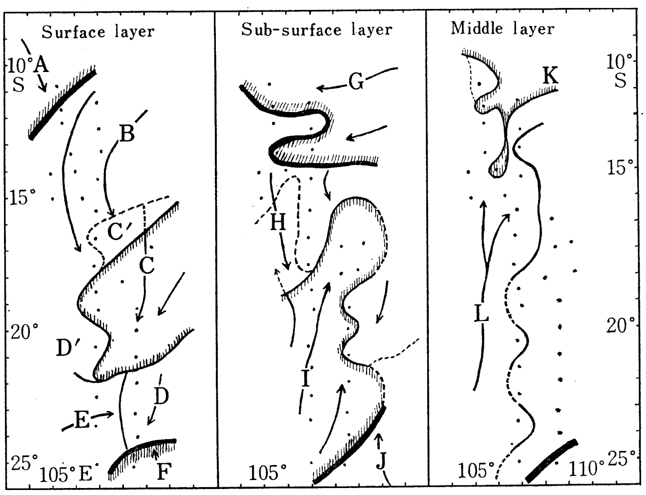


Fig. 22. Water masses in the eastern part of the Indian Ocean.

Accordingly, the lines of demercation between those two currents are influenced by these two water-systems; and the striking meandering of the equiscalar lines observed in the horizontal distribution of salinity and temperature (*cf*. Fig. 16) may support the above-mentioned current systems.

According to the T-S diagram hitherto been recorded the waters in the layer at depths between 100 and 200 m of the central part of the Indian Ocean are represented by a band of t=14 ~16°C in temperature and s=35.4~35.5 ‰ in salinity, in the diagram as illustrated in Fig. 21, and the waters in the layer at depths between 500 and 600 m are represented also by another band of t=7~8°C in temperature and s=34.6~34.7 ‰ in salinity.

Judging from the above-mentioned descriptions, it may well be said that among 12 water masses only the water mass L in the middle layer is regarded as a part of the central water of this ocean (*cf.* Fig. 21).

Before this paragraph closed, the distribution of each water mass and their stretching direction are appendantly shown in the Fig. 22, for making the abovementioned descriptions easily understandable.

## 3. Composition and distribution of plankton

The composition and relative abundance of plankton at each station are illustrated in Table 26. The relative abundance of the fauna and flora were arranged in order of abundance as follows: Copepoda, Chaetognatha, Euphausiacea, crustacean Decapoda, Ostracoda, Gastropoda, pelagic Copelata, Amphipoda, Medusae, larval plankton, Foraminifera, Radiolaria, Dinoflagellata, Cyanophyceae, Bacillariophyta (diatom), Polychaeta. Among them the Copepoda dominated over the others and this single class occupied more than a half of the individuals of plankton.

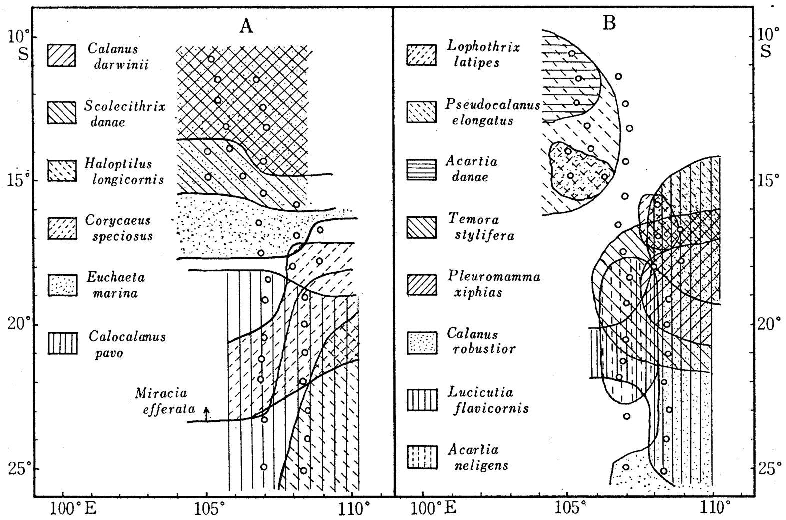


Fig. 23. Horizontal distribution of copepods in the eastern part of the Indian Ocean.

As much as 118 species of copepods were identified, although they differed more or less in relative abundance according to the stations. The following 11 species were the copepods observed commonly throughout the stations: *Calanus robustior* (especially abundant in the southeastern part represented by Sts. 14~26), *Eucalanus attenuatus*, *Paracalanus aculeatus*, *Clausocalanus pergens*, *C. arcuicornis*, *Scolecithrix danae* (abundant at Sts. 1～5 & 27～34), *Acartia clausi, Corycaeus lautus, C. gibblus* (especially abundant at Sts. 19～34), *Oithona plumifera* (abundant throughout the stations) and *Oncaea venusta* (also abundant throughout the stations).

The distribution patterns of the dominant copepods are represented in Fig. 23 A and B. Namley, *Calanus darwinii* (Sts. 1～4 & 31～34), *Euchaeta marina* (Sts. 1～7 & 25～34) and *Scolecithrix danae* (Sts. 1～5 & 27～34) occurred abundantly in the northern half of the surveyed waters; on the other hand, *Calocalanus pavo* (Sts. 8～21), *Haloptilus longicornis* (Sts. 15～19) and *Corycaeus speciosus* (Sts. 10～13 & 18～23) dominated in the southern half. *Miracia efferata, Labidocera euchaeta, etc.* were the species exclusively dominated in the waters north of the line from Sts. 11 to 23, although each of them was poor quantitatively.

It is generally accepted that the distribution of plankton is affected by the environmental conditions. The above-mentioned two types of distribution were clearly parallel to the isotherms and isohalines in the surface layer.

The boundaries of the distribution clearly coincided with the regions of the steepest gradient in the temperature and salinity, which was found in the area between 15° and 18°S. In the southern part of the boundaries the line of the distribution of *Haloptylus longicornis, Corycaeus speciosus* and *Miracia efferata* runs north and south direction in contrast to the parallel distribution of the organisms in the latitude, but this phenomenon was not peculiar when we take the direction of isotherms into consideration. On the other hand, as shown in Fig. 23 B, the following 8 species were the examples observed abundantly along the longitudinal lines or in the limited area: *Calanus robustior* (at Sts. 14～26 & 27～29), *Pseudocalanus elongatus* (Sts. 22～34), *Lucicutia flavicornis* (Sts. 10～11 & 15～26), *Temora stylifera* (Sts. 7～10, 19 & 24～25), *Lophothrix latipes* (Sts. 25～29), *Acartia neligens* (Sts. 8～12), *A. danae* (Sts. 32～34) and *Pleuromamma xiphias* (Sts. 20～25). These distribution patterns were, as shown in Table 27, indicating that the distribution of plankton closely depends on the water masses.

Concerning members of Amphipoda, some species of the genera *Phronima, Parascelus* and *Hyperia* were identified, but they were so poor in quantity and only less than 15 individuals were obtained from each station in a haul, except Sts. 3, 16, 19, 20 and 28. The details of Amphipoda will be reported in the Part III.

The following were the representatives of Euphausiacea sampled in this water, but most of them were distributed abundantly at some of the stations in the northern half of this water, such as Sts. 3, 5, 8, 11, 20 and 28: they are *Euphausia krohnii, E. gracilis, E. gibba* and several species of the genus *Stylocherion.* Mysidacea was represented by *Siriella thompsonii* and by some species of other genera. And, it is worth mentioning that a large population of the larvae in furcilian stage of Euphausiacea was observed in the northern half.

*Lucifer raynaudii* is distributed very widely in the temperate or tropical waters and was collected in such a wide area from 40°N to 40°S; it is especially abundant in the area from 10°N to 10°S, but is rather seledom in the other regions. In this surveyed water, *Lucifer* was sampled abundantly from all over the stations;

for instance more than 30 individuals were collected by a single haul at Sts. 8, 10, 16, 20, 24 and 25.

Chaetognatha were rich in quantity next to copepods, and they consisted chiefly of the following species: *Sagitta serratodentata pacifica*, *S. enflata*, *S. regularis*, *S. minima*, *S. hexaptera* and *Pterosagitta draco*. And they were collected most abundantly at Sts. 5~7 and 26~27 (more than 200 individuals in a single haul).

The planktonic Gastropoda comprised of the genera *Atlanta*, *Cavolinia*, *Diacria*, *Creseis*, *Clio*, *Styliola*, *etc.*, of which *Atlanta* and *Creseis* occurred most frequently; and they were collected most abundantly at Sts. 8, 16, 19 and 28.

So far as the larval plankton were concerned, some fish-fries and fish-eggs were observed in every station, but they were sampled only less than 10 specimens in a haul at every station except Sts. 5, 8, 16, 20, 23, 25 and 28.

The planktonic protozoans consisted chiefly of Foraminifera, Radiolaria and Dinoflagellata; among them, a certain species of Foraminifera and *Amphisolenia bidentata* and *A. thrinax* of Dinoflagellata occurred with some characteristic patterns; *A. bidentata* was distributed very abundantly only in the southeastern part (Sts. 10~24). However, several individuals of *A. thrinax* were found only in the northern part such as Sts. 1~8 and 24~34.

The diatoms consisted of the species only a little more than 10 in number. They occurred in a small quantity, and were chiefly composed of *Chaetoceros coarctatus*, *Rhizosolenia alata*, *R. styliformis*, *etc.* in the waters north of the line from St. 8 to St. 20.

*Skujaella* was found at each station, but was abundant at such Sts. 7, 20, 24 and 25 in the central part.

The relation between the composition of plankton and the surface water masses was discussed in the preceding paragraph and the plankton compositions in each water mass are illustrated in Table 27. It may be suggested from this table that the following species are the dominant (or in animal ecology, abundant) or characteristic species in the respective water masses, and each of them appears to be valid as an indicator of the water masses;

Water mass A : *Calanus darwinii*
Water mass B : *Euchaeta marina*
Water mass C : *Skujaella* sp., *Lucifer raynaudii* and *Pleuromamma xiphias*
Water mass D : *Haloptilus longicornis* and *Calanus robustior*
Water mass E : a certain species of Foraminifera
Water mass F : *Haloptilus longicornis* and *Calanus robustior*

But there were some stations in which the type of the plankton composition was not similar to that of the other stations even in the same water mass; on the other hand, they are similar to that of the stations in the neighbouring water mass; these disagreements in the distribution of plankton and water masses may be caused by the presence of the submerged water mass beneath the surface or by some other reasons. For example, there were few characteristics in the plankton composition common to both water masses C and any of the neighbouring one such as the water mass B, D or E, whereas, hardly any difference was found in the composition between the water mass D or E.

There were some differences in the composition and the distribution of plankton,

Table 26. Occurrence of the plankton in the eastern part of the Indian Ocean.

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Copepoda | | | | | | | | | | | | | |
| *Calanus tenuicornis* | | R R | R R | | | R R | R R | R R | | R R | | | R R |
| *C. gracilis* | | R R | | | | | | | | | | | |
| *C. helgolandicus* | R | R R | R R | R R | R R | | R R | | R R | R R | | | |
| *C. darwinii* | C C | C | C | C | C | + | R | R | R | R | R | | |
| *C. vulgaris* | | R R | R R | | | | | | | | | | |
| *C. minor* | R | R | R R | R R | R | R R | R | | R R | | | R R | |
| *C. robustior* | | R | R | R R | R R | R R | R R | R | R | R | R R | R | + |
| *C. pauper* | R R | R R | R | R R | R R | R R | R R | R | R | R | R R | R R | R R |
| *C. plumchrus* | | | | | | | | | | | | | R R |
| *Eucalanus subcrassas* | | R R | | | | | | R R | | | | | R R |
| *E. attenuatus* | C | + | + | + | + | R | R | R | R | + | + | R | + |
| *E. elongata* | | R | R R | | | R R | | | | | | R R | |
| *E. mucronatus* | R | R R | | | | | | | R R | R R | R R | R R | R R |
| *Rhincalanus cornutus* | R R | R R | | | | | | | | | | | |
| *Acrocalanus gracilis* | R R | R R | R R | R R | R R | | R R | R R | | R | R R | R | + |
| *A. gibber* | | R R | R | R R | | R R | | R R | R R | R R | R | R | R |
| *A. monachus* | | R R | R R | R R | R R | | R R | R R | | R R | R | R | R |
| *Paracalanus aculeatus* | C | C | + | + | + | + | + | + | + | C | + | + | + |
| *P. parvus* | R R | | | | | | | R R | | R R | | | |
| *Clausocalanus furcatus* | | | R R | | R R | | R R | R | R | R | | R | |
| *C. pergens* | | R | R R | R R | R | | R R | R | + | + | + | + | + |
| *C. arcuicornis* | + | C | + | + | + | + | + | ¬ | R | + | + | C | + |
| *Calocalanus pavo* | R R | R R | R R | R R | R R | R R | R R | + | + | + | + | R | R |
| *C. plumolosus* | | R R | R R | | R R | | | | | | | | |
| *Scottcalanus helenae* | | | | | | | | | | | | | R R |
| *Pseudocalanus elongatus* | | | R R | | | R R | | R R | R | R R | | R R | R |
| *Bradyidius armatus* | | | | R R | | | | | | | | R R | |
| *Euchaeta marina* | C C | C C | C C | C C | C C | C | C | + | + | C | + | R | + |
| *E. plana* | | | | | | | | | | | | | |
| *E. wolfendeni* | | | | | | | | | | | | | |
| *E. concinna* | | | | | | | | | | | | | |
| *E. longicornis* | | | | | | | | | | | R | R | |
| *Lucicutia flavicornis* | R R | R | R | R | R R | R | R R | R | + | + | + | R | R |
| *L. ovalis* | | | | | | | | | R R | | | | |
| *Heterorhabdus papilliger* | | | | R R | R | | R R | | R R | R R | R R | R R | R R |
| *H. spinifrons* | | | | | | | | | | R R | R R | R R | |
| *Holoptilus oxycephalus* | | | | | | | | | | | | R R | |

between the waters north and south of the water mass C.

This difference was caused by the presence of the steepest gradient in temperature and salinity at the northern boundary of the water mass C, which was located at 15°$\sim$18° S. These gradients may be a barrier to the distribution of plankton.

| 15 | 16 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RR | RR | RR | R | RR | RR | RR | RR | RR | R | R | | RR | | | RR | RR | RR | RR |
| | | | | | | | | | | | | RR | | | | | | |
| | | RR | | RR | RR | | | | RR | RR | RR | RR | | | | RR | | |
| | | | R | | | | | | + | + | + | + | R | + | C | C | C | C |
| | | | | | | | | | | | | | | RR | R | R | R | R |
| | | | | | | | RR | | RR | RR | RR | RR | R | RR | | R | RR | R |
| + | + | + | + | + | R | + | R | C | + | C | + | C | + | RR | R | RR | + | R |
| | | R | | | | | RR | R | R | R | R | R | R | | | RR | RR | RR |
| R | R | + | + | R | | R | R | RR | R | R | RR | R | R | RR | RR | RR | RR | RR |
| RR | + | + | + | RR | + | + | + | + | + | + | + | + | + | + | R | + | + | + |
| | | | R | | | | | | | | RR | R | | | | | | |
| | | R | | | R | | RR | RR | R | RR | | | | RR | RR | + | R | R |
| | | | | | | | RR | RR | | | RR | | | | | RR | RR | |
| R | RR | RR | RR | R | RR | R | R | | RR | RR | RR | R | | RR | RR | R | RR | R |
| R | + | RR | R | R | R | RR | R | RR | RR | + | RR | R | R | R | RR | | R | R |
| | RR | RR | R | R | R | R | R | | RR | R | R | R | RR | R | R | R | R | + |
| + | C | + | C | + | + | + | + | C | + | C | + | + | C | + | + | + | C | C |
| | | | | | | | RR | | | | | | | | | | | |
| | | R | R | R | R | RR | R | + | R | R | RR | | R | | R | R | RR | RR |
| + | + | + | + | + | R | R | + | R | R | + | + | + | C | + | + | + | + | + |
| + | C | + | + | + | R | + | + | + | C | C | + | C | + | C | + | C | C | C |
| R | R | RR | + | + | + | R | R | R | R | + | R | R | | | | R | RR | |
| | | | | | | | | | RR | | | | | | RR | | | |
| | RR | R | R | R | R | R | + | + | + | + | + | R | + | + | + | + | + | + |
| | RR | RR | RR | | | | | | | | | | | | | | | |
| RR | | RR | R | R | + | + | + | R | C | C | CC | CC | C | C | + | C | C | + |
| | | | | | RR | R | | | R | | | | | | | | | |
| | | | | | | | | | | | | | | | R | | | |
| | RR | | R | | | | | | | | | | | | RR | | | |
| | | R | RR | RR | RR | R | | RR | | | | | | | | | | |
| + | + | + | + | + | + | + | R | R | R | + | + | + | R | R | R | R | R | R |
| | | | | | | | | | | | | | | RR | | | | |
| | RR | | R | | RR | RR | RR | | RR | RR | | RR | | | | | | |
| | | | | | | | RR | | | | | | | | | | | |
| | | | RR | | | | | | | | | | | | | | | |

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *H. actifrons* | | RR | RR | RR | RR | | RR | | | | RR | RR | RR |
| *H. ornatus* | | | RR | RR | | RR | | | | | RR | RR | RR |
| *H. longicornis* | | | | | | RR | | RR | RR | RR | RR | R | R |
| *H. spiniceps* | | | | | | | | | | | | | |
| *Mecynocera clausi* | | | | | | | RR | R | R | R | R | R | RR |
| *Scolecithrix danae* | + | C | + | C | + | R | R | R | R | R | R | RR | RR |
| *Euchirella grandicornis* | | | | | | RR | | | | | | | |
| *E. galeata* | | | | RR | RR | | | | | | | | |
| *E. amoena* | | | | RR | RR | RR | | | | RR | | RR | RR |
| *Temora discaudata* | RR | RR | RR | | | | | | RR | RR | | RR | RR |
| *T. stylifera* | | | RR | RR | RR | R | R | + | + | R | R | RR | RR |
| *Lophothrix latipes* | | | | | | | | | | | | | |
| *Lavidocera pavo* | RR | | RR | RR | | | | | | | | | |
| *L. detruncata* | | | | | | | | | | | | | |
| *L. euchaeta* | | | | RR | RR | RR | | RR | RR | RR | | | RR |
| *Centropages calaninus* | | | | | | | RR | RR | RR | RR | RR | RR | RR |
| *C. furcatus* | | | | | | | | | | | | | RR |
| *C. elongatus* | | | | | | | | | | | | RR | RR |
| *C. bradyi* | | | | | | | | RR | RR | RR | RR | RR | |
| *C. gracilis* | | | | | | | | | | | | | |
| *Candacia aethiopica* | | | R | | | RR | + | RR | RR | RR | R | RR | RR |
| *C. bradyi* | | RR | | | | | | | | | | | |
| *C. discaudata* | | | | RR | RR | | | | | | | | |
| *C. simplex* | | | | | | | RR | R | | | RR | RR | |
| *C. catula* | RR | RR | | | | RR | | RR | | | | | |
| *C. curta* | | + | | | | | RR | R | RR | RR | RR | | |
| *C. bispinosa* | | | R | R | R | RR | RR | R | | | | RR | RR |
| *C. truncata* | | R | | RR | RR | | | | | | | | |
| *C. pectinata* | | | | RR | RR | | | | | | | | |
| *C. longimana* | | | | | | | | RR | | | | | |
| *C. pachydactyla* | | | RR | R | R | RR | RR | | | | RR | | |
| *C. pacifica* | | | | RR | | | | | | | | | |
| *C. bipinnata* | | | | | | | | | | | | | |
| *Clytemnestra scutellata* | | | | | | | | | | | | | |
| *C. rostrata* | | | | | | RR | | | | | | | |
| *Scolecithricella minor* | | RR | RR | | | | | | | | | | |
| *Pontellina plumata* | | | | | | | | | | | | | |
| *Pontella indica* | | RR | | | | | | | | | | | |
| *Phenna spinifera* | | | | | | | | | | | R | R | |
| *Acartia clausi* | + | R | R | RR | RR | R | R | + | + | + | + | + | + |
| *A. hamata* | | | | | | | | | | | RR | RR | RR |
| *A. neligens* | RR | RR | | RR | RR | | RR | + | R | + | + | + | R |
| *A. erythrea* | R | RR | | RR | R | R | | | | | | | |
| *A. danae* | | | RR | RR | RR | | | | | | | | |

| 15 | 16 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R R | | + | R R | | | R R | R R | | | R R | | | | | | R R | R R | |
| | | | R R | | | R R | | | R R | | | | | | | | | R R |
| + | + | | + | R | R | R R | R R | R | R R | R R | R R | | | | | | | |
| | | R | | | | R R | R R | | | R R | | | | | | | | |
| | | | R | | | | R | R | | R R | | R R | R R | R R | R R | R R | R R | |
| R R | R | | + | R R | + | R | R | + | R | + | R | + | + | + | + | + | + | + |
| | | R R | | | | | | R R | | R R | | | | | | | | |
| | | | | | | | | | | | | R R | R R | R R | | | | |
| | | | | | | | | R R | R R | R | R | | | | | | | |
| | | | R R | | R R | R | + | R | R | R R | | R R | R R | | | | | |
| R R | | | + | R | R | R R | R | + | + | R | R R | | | | | | | R R |
| | | | | | | | | | R | R R | R R | R | R | | | | | |
| | | | | | | | | | | R R | R R | | | R R | | | | |
| | R R | R R | R R | | | | | | | R R | R | | | | | | | |
| | | | | | | | | R R | R R | R R | | R R | | | R R | R R | R R | |
| R R | | | R R | | R R | | | R R | | | | R R | | | | R R | R R | R R |
| | | R R | | R R | | | | | R R | | | | | R R | | | | |
| | | | R R | | | | | | | | | | | | | | | |
| R R | | R R | R R | | | | | | | | | | | | R R | R R | R R | R R |
| | R R | | | | | | | | | | | | | | | | | |
| R R | R R | | | | | | | R R | R | + | + | R | R R | R | R | R R | R R | R R |
| | | | | | | | | | | | | R | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | R R | R R | | R R | R R | | | | | | | |
| | R R | | | | | | R R | | | R R | R R | R | | R R | | R R | | |
| | | | R R | R R | R R | | R R | | | + | + | + | R | | R R | R | | R R |
| | | | R R | | | | | | R R | R R | | | | | | | | |
| | | | | | | | | R R | | | | | | R R | | | | R R |
| | | | | R R | | | R | | | | | R | | | | | | |
| | | | | | | | | R | | R | | | R R | | | | R R | |
| | | | | | | | | | | | | | | | | | | |
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| | | | | | | | | | R R | R R | R R | | | | R R | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | R R | | | | | | | | |
| + | + | R | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| R R | R | R | R | + | + | + | | | R | R R | | | | | R | R | R | R |
| R R | R R | R R | R R | R R | | R R | | | | R R | | | | | | | | |
| | | | | | | | | | | R R | R R | R | | | | | | R R |
| | | | | | | | | | | R R | R R | R R | R | R R | R | + | + | + |

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *A. longiremis* | | RR | | RR | RR | R | RR | RR | RR | RR | RR | RR | R |
| *Pleuromamma abdominalis* | | | | | RR | | | RR | | | | | |
| *P. robusta* | | | RR | | RR | | | | | | | | |
| *P. xiphias* | | | RR | RR | RR | RR | | + | | R | | | |
| *P. gracilis* | | | | | | | | | | | | | |
| *Aetideus armatus* | RR | RR | RR | RR | RR | RR | | | | | | RR | RR |
| *A. giesbrechti* | RR | | RR | | | RR | RR | RR | RR | R | R | R | RR |
| *Lubbockia squillimana* | | | | | | | | | | | | | |
| *Macrosetella gracilis* | | | | | | | | | | | | | |
| *Euterpina acutifrons* | | | | | | | | | | RR | | | RR |
| *Miracia efferata* | | RR | RR | RR | | RR | | RR | | | RR | | |
| *Copilia miravilis* | | + | + | | | R | R | RR | RR | R | + | + | R |
| *C. longistylis* | | RR | RR | | | | RR | RR | RR | RR | | RR | RR |
| *C. quadrata* | RR | + | | | | RR | R | RR | RR | | RR | RR | R |
| *Sapphirina gastrica* | | RR | | RR | RR | | | | | RR | RR | RR | RR |
| *S. gemma* | | | | | | RR | RR | RR | RR | RR | RR | RR | |
| *S. nigromaculata* | R | RR | | RR | RR | | | | R | R | RR | RR | RR |
| *S. stellata* | | | RR | | | RR | RR | RR | | RR | | RR | |
| *S. daerwinii* | | | | | | RR | RR | RR | | RR | | | |
| *S. opalina* | | RR | | | | | | | | | | RR | |
| *S. angusta* | | | | | RR | | RR | | RR | | | | RR |
| *S. metallina* | | | | RR | | RR | RR | | | | RR | RR | RR |
| *Corycaeus speciosus* | R | R | R | R | R | R | RR | R | + | + | + | R | R |
| *C. lautus* | RR | RR | | | RR | | RR | RR | RR | RR | RR | | + |
| *C. gibbulus* | R | R | + | + | R | R | R | R | + | + | R | RR | RR |
| *C. concinnus* | RR | RR | | RR | | | | RR | R | R | | | RR |
| *C. longistylis* | R | R | R | | | R | RR | R | | RR | RR | RR | RR |
| *C. flaccus* | | RR | | RR | RR | R | | RR | RR | | RR | RR | R |
| *C. catus* | | | | RR | | RR | RR | RR | | RR | RR | R | RR |
| *C. ovalis* | RR | RR | | | RR | RR | RR | RR | RR | | | RR | RR |
| *C. crassiusculus* | RR | RR | RR | | RR | | R | R | R | R | R | R | RR |
| *Oithona plumifera* | C | + | + | C | C | C | C | C | C | C | C | C | C |
| *O. decipiens* | RR | R | RR | RR | RR | R | R | R | R | R | R | R | R |
| *O. robusta* | | | | RR | | | | | RR | | | RR | |
| *O. setigera* | | RR | RR | RR | RR | RR | R | + | + | + | R | R | + |
| *Oncaea venusta* | R | R | R | + | + | + | + | C | C | C | + | C | C |
| *O. conifera ?* | RR | RR | R | RR | R | | | | | | R | + | R |
| *O. mediae* | RR | R | R | RR | RR | RR | R | R | + | R | R | + | R |
| Amphipoda | | | | | | | | | | | | | |
| *Vibilia viator* | | | | | | | | | | | | | |
| *Oxycephalus porcellus* | | RR | | | | RR | | | | | | | |
| *Phronima pacifica* | | | | | RR | | | | | | | RR | |
| *Phronima* sp. | | | RR | | RR | RR | RR | RR | RR | RR | | RR | RR |
| *Leptocotis ambobus* | | | RR | | | | | | | | | | |

| 15 | 16 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | RR | | RR | RR | | R | R | RR | RR | | RR | RR |
| | + | RR | | | | | | | | | | | | | | | | |
| | + | RR | | C | + | C | C | + | C | | RR | C | | | RR | | RR | |
| | | | | | | RR | RR | R | R | RR | | RR | RR | RR | | | RR | |
| RR | RR | | | RR | RR | RR | RR | | RR | RR | RR | | RR | RR | RR | | RR | R |
| | RR | | RR | R | R | RR | RR | | RR | RR | R | | | | | | | RR |
| | | | | | | | | RR | RR | | | RR | | | | | | |
| | | | | | | | RR | | RR | | RR | RR | | | | RR | | RR |
| | | | | | | | RR | RR | RR | RR | RR | RR | RR | RR | | RR | RR | RR |
| RR | RR | | | RR | RR | | RR | RR | RR | RR | RR | | RR | | RR | RR | RR | RR |
| | RR | | RR | RR | RR | | RR | RR | RR | | | | RR | RR | | | RR | RR |
| | RR | | | | | | | | | | | | | | | | | |
| RR | RR | RR | RR | RR | | | RR | RR | | | | | RR | | | | | |
| | RR | | | | RR | | | | | RR | RR | | | | | | | |
| RR | RR | RR | RR | RR | | | RR | | | | | | RR | | | | | RR |
| | | | | | | | RR | | | | | RR | | | | | | |
| | | | RR | | RR | | | | RR | | RR | | | | | | | RR |
| | | | RR | | | | RR | | RR | RR | RR | RR | | | | | | |
| | R | RR | RR | RR | | RR | RR | RR | RR | RR | RR | | | | | | RR | RR |
| RR | R | + | R | + | + | R | + | R | + | R | R | RR | RR | | R | R | R | |
| R | + | + | + | + | + | + | R | R | + | + | + | R | R | + | + | + | + | + |
| RR | | R | C | + | + | + | C | C | C | C | C | C | + | C | C | C | C | C |
| | | | | | RR | | RR | RR | R | RR | | R | R | | + | + | + | + |
| RR | | RR | | RR | RR | R | RR | R | RR | | RR | RR | RR | RR | RR | RR | RR | R |
| | R | RR | | | | RR | RR | | RR | R | RR | | | | RR | RR | RR | |
| | | | | | RR | RR | RR | | RR | | RR | | | RR | | RR | RR | |
| | | | RR | | | | RR | | RR | R | RR | | | | RR | RR | R | R |
| RR | R | RR | | | R | R | RR | R | R | + | R | R | R | R | + | + | + | |
| + | + | + | + | + | + | + | + | C | C | + | C | + | + | + | R | C | C | C |
| R | + | + | + | + | + | + | + | + | R | + | + | R | RR | RR | + | + | + | + |
| | RR | | RR | R | R | R | RR | R | R | R | R | R | RR | RR | RR | R | + | + |
| R | + | R | + | + | R | + | R | R | R | + | + | R | + | + | R | + | + | + |
| + | + | + | R | R | + | + | C | C | C | C | C | C | + | + | C | C | C | C |
| R | + | RR | R | R | R | R | + | + | + | + | + | + | R | R | R | R | + | R |
| R | + | R | R | RR | R | R | + | + | + | C | + | + | R | R | R | + | + | + |
| | | | | RR | | | | | RR | | | RR | | | | | RR | |
| | | | | RR | | | | | RR | | | RR | | | | | | |
| | RR | RR | | RR | | | RR | | | RR | | RR | | | | RR | | |
| | | RR | RR | RR | RR | RR | RR | RR | RR | RR | RR | RR | RR | | RR | | | RR |

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Parascaelus zebu* | | | RR | RR | RR | | | RR | RR | RR | RR | RR | RR |
| *Phronimopsis spinifera* | RR | R | RR | RR | | | | | | | | | RR |
| *Hyperia schizogeneios* | RR | RR | R | RR | | | | | | | | | RR |
| *H.* sp. | | | | RR | | RR | RR | RR | | RR | RR | RR | RR |
| *Anchylomera blossevillii* | | | | | | | | RR | | | | | |
| *Scina borealis* | | | | | RR | | | RR | RR | RR | | | |
| *Rhabdosoma brevicaudatum* | | | | | | | | | | | | | |
| *Leptocotis ambobus* | | | | | | | | | RR | | | | |
| *Themisto gracilipes* | | | | | | | | | | | | | RR |
| Ehphausiacea | | | | | | | | | | | | | |
| *Euphausia gracilis* | | RR | | | RR | | RR | RR | | RR | | RR | |
| *E. gibba* | | | | RR | RR | | | RR | | | | | |
| *E. krohnii* | | RR | R | RR | RR | RR | RR | R | RR | R | RR | RR | RR |
| *Thysanopoda obtusifrons* | | | RR | | RR | RR | | | | | | | |
| *T. tricuspidata* | | | RR | RR | RR | | | | | R | RR | RR | |
| *Stylocheiron carinatum* | | RR | RR | | RR | RR | RR | RR | | | | | |
| *S. suhmii* | | | | RR | | | | R | | | | RR | |
| *S.* spp. | | | | | | | | | | R | | | |
| *Siriella thompsoni* | | | RR | RR | RR | | RR | RR | | | RR | | |
| *S.* sp. | | | RR | | RR | | RR | RR | | | | | RR |
| Decapoda | | | | | | | | | | | | | |
| *Lucifer raynaudii* | | R | RR | RR | RR | | RR | + | + | R | + | RR | + |
| Other Decapoda | RR | | RR | RR | RR | | RR | R | RR | | RR | RR | RR |
| Ostracoda | RR | R | C | R | R | + | RR | R | RR | R | RR | R | R |
| Gastoropoda | RR | C | C | RR | R | RR | RR | CC | R | R | C | RR | C |
| Larval plankton | | | | | | | | | | | | | |
| Fish larvae | RR | RR | R | | R | RR | RR | + | RR | RR | RR | R | RR |
| Zoea | | | | | | RR | | | | | | RR | |
| Furcilian stages | R | + | C | + | C | C | C | CC | + | + | + | R | RR |
| Fish eggs | RR | RR | R | R | + | R | R | + | RR | R | RR | R | RR |
| Medusae | | | + | R | + | R | R | + | R | R | RR | R | R |
| Polychaeta | | RR | RR | | R | R | RR | R | RR | R | RR | R | R |
| Chaetognatha | R | + | + | + | CC | C | CC | C | + | + | R | + | + |
| *Oikopleura* spp. | RR | | R | C | + | + | + | + | R | RR | RR | + | RR |
| *Doliolum* sp. | | RR | RR | | RR | RR | RR | | RR | | | | RR |
| Protozoa | | | | | | | | | | | | | |
| *Collozoum* & *Sphaerozoum* | RR | RR | RR | RR | R | RR | RR | RR | R | RR | R | RR | RR |
| *Aulacantha scolymantha* | RR | R | + | R | R | R | RR | RR | | RR | | RR | RR |
| *Acanthometra* sp. | RR | RR | RR | RR | | RR | | RR | | | | RR | |
| *Globigerina bulloides* | RR | RR | RR | R | R | R | RR | RR | RR | RR | | RR | |
| A species of Foraminifera | | RR | | RR | | | RR | + | + | C | + | C | C |
| *Pyrocystis pseudonoctiluca* | R | + | C | C | C | C | + | C | + | R | + | + | + |
| *P. fusiformis* | | | | | | | RR | | RR | | RR | | RR |
| *P. hamulus* var. *inacquatum* | | | | | | RR | RR | | | | | | |

| 15 | 16 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 |
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| | RR | | RR | RR | RR | | RR | RR | RR | | RR | RR | RR | RR | RR | RR | RR | |
| RR | RR | | | RR | | RR | | | | | | | | | | | | |
| RR | RR | RR | | RR | | | | | | | | | | | | | | |
| RR | R | RR | R | RR | RR | RR | RR | RR | | RR | RR | RR | RR | RR | RR | RR | RR | RR |
| | | | | RR | | RR | | | | | | | | | | | | |
| RR | RR | | RR | RR | | | | | | | | R | | | | | | |
| | | | | | | | | | | | RR | | | | | | | |
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| | | | RR | | | RR | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | RR | RR | | R | RR | RR | RR | | RR | | | | | | RR | | RR | RR |
| RR | RR | | RR | RR | RR | | RR | RR | RR | RR | | RR | RR | | RR | RR | RR | |
| | RR | RR | RR | RR | | RR | RR | | RR | RR | RR | RR | RR | | RR | RR | RR | RR |
| | | RR | RR | R | RR | RR | RR | RR | RR | RR | RR | RR | RR | | | RR | RR | RR |
| RR | RR | RR | | | | | | | | | | | | | | | | |
| | RR | | | | | | | RR | | | RR | | | | | | | |
| | RR | | | RR | | | RR | RR | | RR | | RR | | | | RR | | |
| | | | | | | | | RR | | | | | | | | | RR | |
| | | | | RR | | | | | RR | | | RR | | | | | | RR |
| | RR | | RR | RR | | | | | | | | RR | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | + | R | RR | + | R | R | R | + | + | R | RR | RR | RR | | RR | | RR | |
| R | RR | RR | RR | R | RR | RR | RR | RR | RR | RR | RR | RR | RR | | RR | | RR | |
| C | C | R | C | R | RR | R | C | RR | C | CC | R | C | RR | R | RR | C | C | C |
| C | CC | R | CC | C | R | C | CC | C | C | C | RR | CC | R | R | RR | RR | R | RR |
| | | | | | | | | | | | | | | | | | | |
| | R | RR | RR | R | RR | RR | + | RR | R | | RR | R | RR | | RR | RR | R | RR |
| | | RR | | | | | | | | | | | | | | | | |
| R | + | R | + | C | R | + | C | R | CC | + | + | C | + | RR | + | R | + | R |
| R | RR | RR | RR | R | RR | C | R | RR | RR | R | R | R | R | RR | RR | RR | RR | |
| R | C | RR | RR | R | RR | R | + | RR | R | RR | R | R | RR | RR | RR | R | R | + |
| R | RR | RR | R | RR | R | RR | C | RR | + | RR | RR | R | RR | RR | RR | RR | RR | RR |
| RR | C | R | + | + | + | + | + | + | + | C | CC | + | + | RR | RR | + | R | + |
| RR | RR | | RR | R | | RR | R | RR | R | RR | R | R | RR | RR | RR | RR | R | R |
| RR | RR | | | | | | RR | | RR | RR | RR | RR | RR | RR | | RR | | RR |
| | | | | | | | | | | | | | | | | | | |
| R | RR | RR | RR | R | RR | R | RR | RR | RR | RR | RR | RR | RR | RR | RR | RR | RR | RR |
| RR | RR | RR | RR | RR | RR | RR | RR | RR | | RR | RR | RR | RR | RR | | | | RR |
| RR | RR | RR | RR | RR | RR | | | RR | | RR | | | RR | RR | | | | |
| | RR | RR | RR | RR | RR | | RR | RR | RR | RR | RR | RR | RR | RR | | | RR | RR |
| + | + | R | C | C | C | + | R | + | + | RR | | RR | | RR | | | | RR |
| + | C | + | C | C | C | C | C | C | CC | C | C | + | C | R | R | R | + | + |
| RR | RR | RR | | RR | RR | | RR | RR | RR | | | | | | | | | |

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Amphisolenia bidentata* | R R | R R | R R | R R | R R | R R | R R | R R | | | | | |
| *A. thrinax* | | | | | R R | R R | R R | | | | | | |
| *Ceratium extensum* | | | | | | | | | | | | | |
| *C. carriense* | | R R | R R | R | R R | R R | R R | R R | R R | R R | R R | R R | R R |
| *C. sumatranum* f. *angulatum* | | + | | + | R R | | | R R | | R R | R R | | |
| *C. inflexum* | | | R R | R R | | R R | | | | | | | |
| *C. tenue* | | | | R R | | | | R R | | | R R | | R R |
| *C. karstenii* | | R R | | | | R R | R R | | | | | | |
| *C. macroceros* | | | R R | | R R | | | | | | | R R | R R |
| *C. massiliens* | | | | | | | R R | | R R | R R | | | |
| *C. pulchellum* | | | R R | R R | | | | R R | | R R | | R R | |
| *C. pennatum* | | | | | | | | | | | | | |
| *C. vultur* | | | | | R R | | R R | | | | R R | | |
| *C. deflexum* | | | | | | | R R | | | | | | |
| *C. trichoceros* | | | | | | | | | | | | | |
| *C. lunura* | | R R | R R | | R R | | | R R | | | | R R | |
| *C. contortum* | | | | | R R | | R R | | | | | | |
| *C. reticulatum* | | | | | | R R | | | R R | | | | |
| *C. inflatum* | | | | | | | | | | | | | |
| *C. fusus* subsp. *seta* | | | | | | | | | | | | R R | R R |
| *C. belon* | | | | | | | | | | | | | |
| *C. pentagonum* | | | | | | | | | | | | | |
| Phyto-plankton | | | | | | | | | | | | | |
| *Chaetoceros coarctatus* | R R | R R | R | R R | R R | R R | R R | R R | | | | | |
| *C. peruvianus* | R R | R R | R R | | | | | R R | | | | | |
| *Coscinodiscus* spp. | | R R | R R | R R | R R | R R | R R | R R | R R | | | R R | R R |
| *Rhizosolenia alata* | R R | R R | R R | R R | R R | R R | R R | R R | | | | | R R |
| *R. imbricata* | | R R | R R | | R R | R R | | | | | | | |
| *R. styliformis* | R R | R R | R R | | | R R | R R | R R | R R | | | | |
| *R. bergonii* | | | R R | | | R R | R R | | | | | | R R |
| *Thalassiothrix longissima* | | R R | R R | R R | R R | R R | R R | | | | | | |
| *T. frauenfeldii* | | | | R R | | | | R R | | | | | |
| *Skujaella* spp. | R R | R | R | R | R R | R R | C C | R | R R | R R | R R | R R | R R |

Abbreviations : C C…very common, C…common, +…present, R…rare, R R…very rare

| 15 | 16 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | R R | | | R R | R R | R R | R R | R R | R R | R R | R R | R R | R R |
| | | | | | | R R | | R R | | | R R | | R R | | R R | | R R | R R |
| | | R R | | | | | | | | | | | | R R | | | | |
| R R | R R | R R | R R | R R | R R | | R R | R R | | R R | R R | R R | R R | R R | R R | | R R | |
| R R | | R R | | R R | | R R | R R | | R R | + | R R | | R R | | R R | | | |
| R R | | | | | | | | | | | | | | | | | | |
| | | R R | | | | | | | | | R R | | | | | | | |
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| | | | | R R | R R | R R | | R R | R R | | | | | R R | | | | |
| R R | | R R | R R | R R | R R | | | | | | | | R R | R R | R R | R R | | |
| R R | | | | | | | | | | | | | | | | | | |
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| | | | | R R | R R | | | | | | | | R R | | | | | |
| | R R | | | | | | | | | | | | | | | | | |
| R R | | | | | | | | | | | | | | | | | | |
| | | | | | | R R | | | | | | | | | | | | |
| R R | | | | | | | | | | | | | | | | | | |
| | | | | R R | R R | | | R R | R R | | R R | | R R | R R | R R | R R | R R | R R |
| R R | R R | R R | R R | R R | | R R | R R | | R R | | | | R R | | R R | R R | | R R |
| | | | | | | | | | | | R R | | R R | R R | R R | R R | R R | R R |
| | | | | | | R R | | | R R | | R R | | R R | | R R | R R | | R R |
| | R R | | | | | | | | | | R R | | R R | R R | R R | R R | R R | R R |
| R R | | | R R | | | R R | | R R | R R | R R | R R | | | | | | R R | |
| R R | | | R R | | | R R | | R R | R R | | | | | | R R | | | |
| R R | R R | + | + | C | + | + | + | C | C | R | + | R | R | R R | R R | C | R R | R |

Table 27. Distribution of some species suggesting the possibility of being adopted as the indicators of the respective water masses observed in the eastern part of the Indian Ocean.

| Species \ Water mass | | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|
| A species of | Foraminifera | R R | R R | + | + | C | + |
| *Amphisolenia* | *bidentata* | | R R | R R | | | |
| *A.* | *thrinax* | | R R | R R | | | |
| *Chaetoceros* | *coarctatus* | R R | R R | R R | | | |
| *C.* | *peruvianus* | | R R | R R | | | |
| *Rhizosolenia* | *alata* | R R | R R | | | | |
| *R.* | *bergonii* | | R R | R R | | R R | R R |
| *Skujaella* | sp. | R | R | C | R | R R | R R |
| Euphausiacea | | R R | + | + | R R | R R | R R |
| *Lucifer* | *raynaudii* | R R | R | C | + | + | R |
| *Acartia* | *neligens* | | | R | + | | |
| *A.* | *danae* | | R R | | | | |
| *Calanus* | *darwinii* | C | C | R | | | |
| *C.* | *robustior* | R R | R | + | + | R | + |
| *Rhincalanus* | *cornutus* | | R R | R R | | | |
| *Pseudocalanus* | *elongatus* | R R | | + | | | |
| *Lophothrix* | *latipes* | | R R | | | | |
| *Euchaeta* | *marina* | + | C C | + | R R | + | R R |
| *Lucicutia* | *flavicornis* | | R | + | + | | + |
| *Haloptilus* | *longicornis* | | R R | R | + | R | + |
| *Scolecithrix* | *danae* | + | + | R | R | R R | R R |
| *Temora* | *stylifera* | R R | R R | + | | R R | R R |
| *Pleuromamma* | *xiphias* | | R R | C | R | | |
| *Miracia* | *efferata* | R R | R R | R R | | | |
| *Corycaeus* | *speciosus* | R R | R | + | R | R | R R |
| *C.* | *gibbulus* | C | C | C | + | R R | R R |

## V. Distribution of plankton in the Bay of Bengal

### 1. Sampling method

The survey was carried out during the period from Dec. 24, 1957 to Jan. 20, 1958 at the 29 stations shown in Table 23 and Fig. 24. Plankton in the layer at depths between 100 m and the surface were hauled up vertically at the speed of 50 cm per second by the net of NAKAI's type of 45 cm in the mouth-diameter and 1 m in length constructed with the gauze of XX 13 in JIS. The samples thus collected were fixed with 5 % formalin solution just after the hauling. And they were used in this study, but there were some samples collected from the layer shallower than 100 m to the surface of the stations set in rather neritic waters.

The 24 hour-precipitated volumes of the samples were estimated after the removal of macroplankton such as Chaetognatha, Amphipoda, Copelata, Polychaeta and Medusae; and they are illustrated in Table 28. Generally speaking, it is suggested from this table, that the neritic waters in the north or eastern part of this bay are the richest in the quantity, then the waters west of the Nicobar Islands succeed to this, but the waters west of the Andaman Islands, the central part and the northwestern coast of this bay are the poorest in the quantity.

Table 28. Oceanographic conditions observed in the Bay of Bengal.

| St. | Locality | | Date (1957~'58) | Time | Sampling depth (m) | Water color | Trans-parency (m) | Precipi-tated vol. of pl. (cc) | Water temperature (°C) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lat. (N) | Long. (E) | | h m | | | | | 0 m | 50 m | 100 m | 150 m |
| 2 | 6°41′05″ | 93°12′00″ | Dec. 24 | 22 30 | 100→0 | — | — | 1.1 | 28.30 | 28.19 | 22.32 | 17.31 |
| 3 | 7 42 00 | 92 37 05 | 25 | 07 15 | 〃 | 3 | 23 | 1.8 | 27.90 | 27.78 | 21.60 | 14.67 |
| 4 | 8 48 50 | 92 10 00 | 25 | 22 00 | 〃 | — | — | 2.7 | 27.55 | 27.16 | 27.06 | 15.39 |
| 5 | 9 39 00 | 91 30 00 | 26 | 07 30 | 〃 | 2 | 24 | 1.7 | 27.95 | 28.04 | 23.56 | 16.55 |
| 6 | 10 04 05 | 91 34 05 | 26 | 22 00 | 〃 | — | — | 2.8 | 28.05 | — | 24.16 | 16.82 |
| 7 | 11 46 00 | 91 21 00 | 27 | 07 40 | 〃 | 3 | 24 | 0.9 | 28.05 | — | 25.11 | 17.38 |
| 8 | 12 41 00 | 91 00 05 | 27 | 21 52 | 〃 | — | — | 1.5 | 28.05 | 28.42 | 22.58 | 17.17 |
| 9 | 13 41 00 | 90 22 05 | 28 | 07 45 | 〃 | 3 | 22 | 1.5 | 27.75 | 26.48 | 24.22 | 15.79 |
| 10 | 14 35 00 | 90 02 00 | 28 | 20 00 | 〃 | — | — | 1.4 | 27.05 | 28.10 | 23.31 | 18.93 |
| 11 | 15 25 05 | 89 25 00 | 29 | 08 00 | 〃 | 2 | 28 | 0.7 | 27.15 | 26.47 | 22.31 | 15.57 |
| 12 | 14 33 00 | 88 44 00 | 29 | 22 15 | 〃 | — | — | 1.7 | 26.38 | 28.11 | 23.94 | 18.93 |
| 13 | 13 36 00 | 87 59 00 | 30 | 08 30 | 〃 | 3 | 22 | 1.4 | 27.31 | 26.47 | 17.57 | 10.73 |
| 14 | 12 49 00 | 87 19 00 | 30 | 21 45 | 〃 | — | — | 2.2 | 27.26 | 26.80 | 21.61 | 18.65 |
| 15 | 11 49 05 | 86 37 02 | 31 | 08 20 | 50→0 | 3 | 22 | 1.3 | 26.96 | 27.51 | 22.18 | 18.09 |
| 16 | 11 55 00 | 84 55 00 | Jan. 1 | 00 25 | 100→0 | — | — | 1.5 | 26.57 | 27.60 | 21.95 | 18.73 |
| 17 | 13 12 15 | 84 53 00 | 1 | 10 45 | 〃 | 2 | 27 | 1.9 | 26.86 | 27.35 | 21.67 | 18.57 |
| 18 | 14 27 05 | 84 46 00 | 1 | 20 00 | 〃 | — | — | 0.4 | 26.27 | 26.85 | 22.38 | 18.27 |
| 19 | 15 46 00 | 84 46 00 | 2 | 05 10 | 〃 | — | — | 0.6 | 27.45 | 26.75 | 21.71 | 16.44 |
| 20 | 17 08 00 | 84 51 00 | 2 | 14 30 | 〃 | 3 | 32 | 2.0 | 27.45 | 26.89 | 23.43 | 18.05 |
| 21 | 18 18 05 | 85 00 00 | 2 | 22 55 | 〃 | — | — | 1.6 | 26.51 | 27.31 | 22.45 | 17.13 |
| 22 | 19 03 00 | 85 03 00 | 3 | 05 55 | 50→0 | 3 | 23 | 1.1 | 25.97 | 26.16 | — | — |
| 23 | 19 22 00 | 88 23 00 | 13 | 19 18 | 100→0 | — | — | 1.5 | 27.15 | 26.90 | 22.64 | 17.72 |
| 24 | 18 03 05 | 88 22 00 | 14 | 07 45 | 〃 | 2 | 22 | 1.0 | 26.16 | 26.67 | 23.59 | 18.89 |
| 25 | 20 44 05 | 88 54 05 | 15 | 07 45 | 80→0 | 5 | 17 | 3.9 | 25.00 | 26.19 | 22.41 | — |
| 26 | 18 33 00 | 91 28 00 | 16 | 17 35 | 100→0 | 3 | 24 | 1.5 | 26.66 | 26.54 | 23.23 | 15.43 |
| 27 | 15 09 05 | 95 18 00 | 18 | 04 45 | 30→0 | 6 | 13 | 16.9 | 27.35 | 25.65 | — | — |
| 28 | 14 40 00 | 95 37 00 | 19 | 08 30 | 100→0 | 4 | 21 | 5.5 | 26.36 | 25.30 | 19.78 | — |
| 29 | 12 18 00 | 96 26 00 | 20 | 01 15 | 〃 | — | — | 3.3 | 27.95 | 26.73 | 19.81 | — |

## 2. Composition and distribution of phyto-plankton

The author identified 91 species of diatoms belonging to 27 genera. The details are listed up in Table 29. The species of the following three genera were the principal components of the diatoms in the Bay of Bengal and each of them occurred very abundantly. They were *Chaetoceros*, *Rhizosolenia* and *Planktoniella*.

The following species were the members of the diatoms observed throughout the stations: *Chaetoceros coarctatus*, *Planktoniella sol*, *Rhizosolenia alata* and *R. styliformis*. It is very natural that they differed more or less in the relative abundance according to respective stations. The following species occurred commonly throughout the stations though less quantitatively: *Chaetoceros lorenzianus*, *Thalassiothrix logissima*, *Rhizosolenia hebetata* f. *semispina* and *Rhizosolenia calcar-avis*. On the other hand, the following species occurred only in some limited parts of the surveyed waters: *Nitzschia seriata*, *Hemidiscus cuneiformis*, *Chaetoceros compressus*, *C. didymus*, *C. pelagicus*, *C. deversus*, *Biddulphia sinensis*, *Ditylum sol*, *Bacteriastrum varians*, *Thalassionema nitzschioides* and *Thalassiothrix frauenfeldii*.

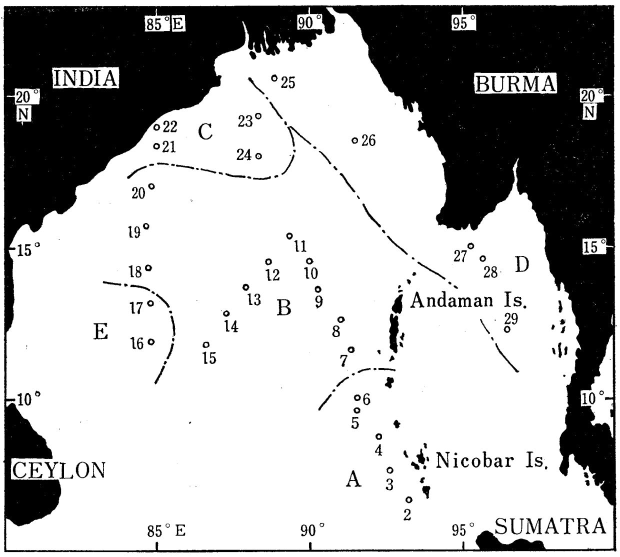


Fig. 24. Chart showing the sampling stations in the Bay of Bengal.

It is possible to classify the stations into 5 regions from the distribution and the composition of diatoms, as shown in Table 29. They are as follows:

**Region A (Sts. 2~6)** : This was the waters west of the Nicobar Islands. The dominant species were *Chaetoceros lorenzianus* and *Rhizosolenia alata*; and the next ones were *Thalassiothrix frauenfeldii*, *Chaetoceros coarctatus* and *Rhizosolenia styliformis* var. *latissima*. *Planktoniella sol*, which is one of the representatives of the oceanic species in the warm waters, occurred very less frequently in the surveyed waters, but at the same time there were some specimens of the neritic species such as *Nitzschia seriata*, *Chaetoceros compressus*, *Rhizosolenia fragilissima* and *Hemidiscus cuneiformis* in the samples, although each of them was not abundant. Accordingly, this region was thought to be the waters in which some neritic species and other oceanic ones mixed with each other, but the neritic species dominated slightly over the oceanic ones.

**Region B** (Sts. 7~15 & 18~20) : This region is situated to the west of the Andaman Islands at the central part of the Bay of Bengal. The samples contained abundantly the oceanic species such as *Planktoniella sol*, *Chaetoceros coarctatus*, *Rhizosolenia styliformis*, *Chaetoceros peruvianus* and *Thalassiothrix longissima*. But, when the composition of this region was compared with that of the region A, this region was characterized by the disappearance of the neritic species and the simplicity of the composition; and as the consequence, the diatom flora of this region was simpler in the composition than any of that in other regions. Accordingly, this region appears to be the waters under the strongest influence of the oceanic waters.

**Region C** (Sts. 21~24) : This is situated in the northwestern part of the bay. *Planktoniella sol* and *Chaetoceros coarctatus* occurred abundantly and then *Chaetoceros peruvianus*, *Climacodium biconcavum*, *Biddulphia sinensis* and *Rhizosolenia styliformis* succeeded to them in abundance. Especially, the increase of the neritic species in the eastern part of this region such as *Chaetoceros lorenzianus* and *Rhizosolenia styliformis* could be recognized. And each of the stations set in this region was thought to be the mixing area of the neritic species with the oceanic ones.

**Region D** (Sts. 25~29) : This region occupies the eastern part of the bay along the Peninsula of Burma and Malay. The species occurred abundantly were *Chaetoceros lorenzianus*, *C. compressus*, *Bacteriastrum varians* and *Thalassiothrix frauenfeldii*. And *Thalassiothrix nitzschioides*, *Nitzschia seriata*, *Skeletonema costatum*, *Biddulphia sinensis*, *Ditylum sol* and *Chaetoceros coarctatus* followed the above-mentioned species. *Planktoniella sol* and *Chaetoceros pelagicus* occurred abundantly in the regions B and C, but decreased very much in this region. And the rich species of the genus *Rhizosolenia* was one of the most remarkable characteristics of the diatom flora of this region. Accordingly, this region was thought to be the waters in which the neritic species predominated over the pelagic ones in the composition.

**Region E** (Sts. 16~17) : This region covered the western part of the bay. *Planktoniella sol* was the most dominant species. The most remarkable difference in the composition of this region from that of the region B was the occurrence of some neritic species such as *Chaetoceros compressus*, *C. pelagicus*, *Bacteriastrum varians*, *Ditylum sol*, *Skeletonema costatum* and *Cerataulina bergonii*. The occurrence of these neritic species may have been influenced by the waters along the eastern coast of Ceylon. Accordingly, this region may be the waters in which some neritic species and other oceanic ones mixed with each other.

### 3. Consideration on the distribution of phyto-plankton

The author has discussed on the nature and the origin of the water masses by the composition of phyto-plankton therein; but in this case, it is of course rational to employ some species as a group rather than to employ them as an individual species, and it is commonly recognized that plankton flora with some characteristics can enough be used as an indicator of the water masses, if the season under consideration was limited. In the present survey the dominant species in the neritic area were *Chaetoceros compressus*, *C. lorenzianus*, *C. pelagicus*, *Biddulphia sinensis*, *Bacteriastrum varians*, *Thalassionema nitzschioides*, *Thalassiothrix frauenfeldii* and *Nitzschia seriata*; while those of the central parts of the bay were *Planktoniella sol*, *Chaetoceros coarctatus*, *C. peruvianus* and *Thalassiothrix longissima*; and each of them was well qualified to be an indicator species of the water masses. From the distribution of these species at the respective stations, it was suggested that the regions A, C and E were the mixing area of the coastal waters with the oceanic ones, although there were some differences in the mixing rate of these waters. The region B was under the influence of the oceanic water, on the other hand the region D was strongly affected by the coastal waters.

Table 29. Occurrence of the diatoms in the Bay of Bengal (Dec., 1957 ~ Jan., '58).

| Species \ Station | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Coscinodiscus* | *excentricus* | | | | | | | R R | R R | |
| *C.* | *lineatus* | R R | R R | | R R | | | | | |
| *C.* | *radiatus* | | R R | | | | | | R R | R R |
| *C.* | *subtilis* | | | | | R R | | | | |
| *C.* | *granii* | | | | | | | | | |
| *C.* | *centraris* | R R | | | | | R R | | | |
| *C.* | *asteromphalus* | | | | | | | | | |
| *C.* | *gigas* | | | R R | | | | R R | | |
| *C.* | *janischii* | | | R R | | | | | | |
| *C.* | *nobilis* | | | | | | | | | |
| *Planktoniella* | *sol* | C | R | R R | R R | R | C C | C | C C | C C |
| *Asterolampra* | *marylandica* | | | | | | | | | |
| *A.* | *hepaticus* | | | | | | R R | | | |
| *A.* | *grevillei* | | | | | | | | | |
| *Gossleriella* | *tropica* | | R | R R | R R | R R | R | R | R | |
| *Lauderia* | *borealis* | | | | | R R | | | R R | |
| *Schrödella* | *delicatula* | R | | | R | | | | | |
| *Skeletonema* | *costatum* | R | | R R | | | | | R R | + |
| *Stephanopyxis* | *palmeriana* | + | | + | | + | R R | R R | | |
| *Dactyliosolen* | *tenuis* | | | | | | | R R | | |
| *Leptocylindrus* | *danicus* | | | | R | R R | | R R | | |
| *L.* | *adriaticus* | | | | R | R R | | R R | | |
| *Guinardia* | *flaccida* | R | | | | | | | | |
| *G.* | *blavyana* | | | | | | | | | |
| *Rhizosolenia* | *alata* | C C | C C | C C | C C | C C | C C | C C | C | C C |
| *R.* | *alata* f. *gracillima* | R R | R R | | R | + | | | R R | R R |
| *R.* | *alata* f. *indica* | | R R | | | | | | | |
| *R.* | *fragilissima* | R | R R | | R R | + | | | | R R |
| *R.* | *stolterfothii* | | | | R R | + | | | | R R |
| *R.* | *cylindrus* | | R R | C | | | | | | |

The dense population of diatoms was found in the neritic waters of the north to eastern coast of the bay, especially at Sts. 25, 27 and 28, which were set near the estuaries of the rivers Irawadi and Ganges. As to the currents hereabout during the winter, one of the branches of the North Equatorial Current of the Indian Ocean, which flows from the east to the west of the southern part of the bay, turns to the north under the influence of the monsoon and proceeds clockwise, then flows along Ceylon Island and the eastern coast of the Indian Peninsula and again turns to the south along the Peninsula of Burma and Malay. The above-mentioned distribution of planktonic diatoms appears to be brought out the nutritive salts contained in this current, enriched by the out-flow of rivers from the continent.

| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RR | | | | | RR | | | | RR | | | | | | | | | |
| | | RR | | | | | | | | RR | | RR | | | | | | |
| | | | | | | | | | | | | | | | | | | RR |
| | | | | | | | | | | | | | | | | | | |
| | RR | RR | | | | | | | | RR | RR | RR | | + | RR | | | |
| | | RR | | | | | | | | | | | RR | RR | | RR | RR | RR |
| | | | | | | | | | | RR | RR | | RR | + | | RR | RR | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | RR | | | | R | | | | |
| CC | CC | CC | C | C | CC | C | + | CC | C | CC | + | C | CC | RR | + | | RR | C |
| | | RR | | | | | | | | RR | | RR | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| RR | RR | | RR | | | | | | | | | | | | | | | |
| + | RR | R | RR | RR | R | RR | | | | | | RR | RR | | RR | | | RR |
| | | | | | | | | | | | | | | | | RR | | |
| | | | | | RR | | | | | | | | RR | R | RR | R | R | RR |
| | | | | | RR | RR | | | | | | | | RR | + | C | + | |
| | | | | | | | | | | | | RR | | RR | | | | |
| R | RR | R | RR | RR | | R | R | RR | RR | | RR | | | RR | RR | | RR | RR |
| | | | | | | | | | | | | | | RR | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | RR | RR | | | | | | |
| + | + | R | C | CC | R | R | R | RR | + | | RR | C | + | CC | + | RR | + | C |
| | | RR | + | R | RR | R | + | | | | | R | RR | RR | RR | | RR | + |
| | | | | | | | | | | | | RR | | RR | | | | |
| | | | | | RR | | | | | | | | | R | RR | + | R | |
| | | | | | | | | | RR | RR | RR | | RR | RR | RR | RR | R | |
| | | | | RR | | | | | RR | | | | | RR | RR | RR | RR | |

| Species \ Station | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Rhizosolenia* | *robusta* | | | | | + | R R | + | | |
| *R.* | *imbricata* | | R R | | | | | | | |
| *R.* | *setigera* | | R R | | | R | | R R | | |
| *R.* | *styliformis* | R | C C | | R | C C | R | R R | R R | + |
| *R.* | *styliformis* var. *latissima* | + | C | C | C | C | R | R | | C C |
| *R.* | *calcar-avis* | | R | R R | R R | C | R R | R R | | R |
| *R.* | *hebetata* f. *semispina* | C | C | | R R | R | R R | + | R | + |
| *R.* | *acuminata* | R R | | + | | R | | | | |
| *R.* | *bergonii* | R | R R | R | + | R | R | R | R R | R R |
| *R.* | *castracanei* | | | | | R R | R R | R R | R R | + |
| *R.* | *arafrensis* ? | | | R | | | | | | |
| *Bacteriastrum* | *varians* | C | | | R R | | | R R | | R R |
| *B.* | *hyalinum* var. *princeps* | | | | | | | | | |
| *B.* | *delicatulum* | | | | | | | | | |
| *B.* | *comosum* | | | | R R | | | | | |
| *B.* | *minus* | | | | | | | | | |
| *B.* | *elegans* | | | | | | | | | |
| *Chaetoceros* | *atlanticus* | | | | R | R R | | R R | | |
| *C.* | *coarctatus* | | R | C | + | + | + | + | R R | + |
| *C.* | *tetrostichon* | | | | | | | | | |
| *C.* | *denticulatum* | | | | | | | | | |
| *C.* | *indicum* | | | | | | | | R R | |
| *C.* | *peruvianus* | | | | R R | R | | R | R | R R |
| *C.* | *pendulus* | | | | R | R R | R R | R | | R R |
| *C.* | *decipiens* | | | R | C | | | | R R | |
| *C.* | *decipiens* f. *singularis* | | | | | | | | | |
| *C.* | *lorenzianus* | C C | C | R | C C | C C | R | R | R | |
| *C.* | *affinis* | + | | | + | + | | R R | + | |
| *C.* | *laciniosus* | | | R R | | | | R R | | |
| *C.* | *distans* | | | | | | | | | |
| *C.* | *compressus* | R | R R | + | | | | | | |
| *C.* | *van heurckii* | | | | | | | | | |
| *C.* | *pelagicus* | | | | | | | | | |
| *C.* | *brevis* | | | | | | | | | |
| *C.* | *subsecundus* | | | | | | | | | |
| *C.* | *deversus* | | | R R | | | | | | |
| *C.* | *messanensis* | R R | | | C | + | R R | | + | R R |
| *C.* | *pseudocurvisetes* | | | | | | | | | |
| *C.* | *didymus* | | | | R | | | | | |
| *Biddulphia* | *sinensis* | | | R | | R R | | | R R | R R |
| *B.* | *pulchella* | R R | | | | | | | | |
| *B.* | *mobilensis* | | | | | | | | | |
| *B.* | *longicrusis* | | | | | | | | | |
| *Hemiaulus* | *sinensis* | | | | | R | | | R R | |

| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | RR | | | | RR | | | | | | | | | |
| | | RR | | | | | | | | | | | | RR | | | | |
| | | | | | RR | | | | | | | RR | | + | RR | RR | R | |
| R | CC | C | CC | C | + | CC | CC | C | C | + | + | R | + | R | RR | RR | R | R |
| R | R | | R | + | | RR | | R | R | R | | RR | + | + | RR | RR | + | + |
| | | R | | + | + | R | | | + | RR | RR | RR | + | C | + | + | + | + |
| C | | C | | R | | CC | C | RR | + | | | | C | + | RR | + | C | CC |
| RR | | RR | | RR | | | RR | R | RR | | | RR | | | | | | |
| R | R | | | + | + | R | | | | RR | | | | | | | RR | + |
| RR | R | | | RR. | | RR | | R | R | R | RR | RR | R | RR | | RR | RR | RR |
| | | | | | | | | | | | | | RR | | | | | |
| RR | | | | | R | + | | | RR | R | R | | | C | C | CC | CC | |
| | | | | | | | | | | | | | | R | | R | | |
| | | | | R | | | | | | | | | | | | | | |
| | | | | | | | | RR | | | | | | RR | R | | | |
| | | | | | | | | | RR | | | | | | | | | |
| | | | | | | | | | | | | | | | RR | | | |
| | | | | | | RR | RR | | R | | RR | RR | R | | | | | |
| C | RR | CC | CC | CC | + | CC | C | CC | CC | CC | CC | CC | CC | CC | C | R | + | RR |
| | CC | | | | | | | RR | RR | | | | | | | | | |
| | | | | | | | | | | | | | | + | | | RR | |
| | | | | | | R | R | | | | | RR | | | | | | RR |
| RR | + | + | C | C | + | CC | + | R | C | + | + | R | C | RR | + | | R | RR |
| C | + | RR | | R | | RR | RR | | RR | RR | RR | RR | RR | RR | RR | RR | RR | |
| RR | | RR | R | | | | | | | | RR | RR | | + | | | | R |
| | | R | | | | | | | | | | | | | | RR | | |
| R | R | | R | R | + | + | R | R | R | RR | RR | R | + | CC | CC | C | C | R |
| RR | R | RR | | RR | R | | | + | | + | | R | + | + | | | RR | + |
| | | RR | | R | | | | RR | RR | | | RR | | RR | | R | | |
| | RR | | RR | R | | | | | | RR | | RR | | RR | | | | R |
| | | | | | RR | RR | | | | | | | RR | C | C | CC | CC | |
| | | | | | + | RR | | | | | | | | | | R | | |
| | | | | | + | RR | | | | | | RR | | R | + | C | + | |
| | | RR | | R | RR | | | RR | | | | | | RR | RR | | | |
| | | | | | RR | | | | | | R | | | | RR | + | RR | |
| | | | | | RR | RR | | | RR | | | RR | | | | | | RR |
| | RR | RR | | | | | | | | | | | | | RR | | | |
| | | | | | RR | RR | RR | | | | | | | RR | + | R | + | |
| | | | | | RR | RR | | R | RR | + | + | + | + | C | C | + | C | |
| RR | RR | | RR | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | + | + | R | |
| | | | | | | | | | | | | | | | | RR | RR | |
| RR | | | | | | RR | RR | | RR | RR | | | RR | + | R | R | R | |

| Species \ Station | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Hemiaulus* | *hauckii* | | | | | | | | | |
| *H.* | *membranacus* | | RR | RR | RR | RR | RR | | | |
| *Cerataulina* | *bergonii* | | | RR | + | | | | RR | |
| *Ditylum* | *sol* | C | RR | RR | + | | RR | RR | RR | |
| *Eucampia* | *cornuta* | | | | | R | | RR | | |
| *E.* | *zoodiacus* | RR | | | | | | | | |
| *Climacodium* | *frauenferdianum* | | + | C | | + | | R | | |
| *C.* | *biconcavum* | | R | | RR | + | | + | + | RR |
| *Streptotheca* | *india* | | RR | | | RR | | | | |
| *Asterionella* | *japonica* | | | | | | | | | |
| *Thalassionema* | *nitzschioides* | + | RR | RR | | | | | | |
| *Thalassiothrix* | *frauenferdii* | C | CC | + | RR | + | R | R | RR | |
| *T.* | *longissima* | | + | RR | RR | | | RR | + | R |
| *Pseudoeunotia* | *doliolus* | | RR | | RR | | | | RR | |
| *Nitzschia* | *seriata* | + | | RR | RR | RR | | | RR | |
| *Hemidiscus* | *cuneiformis* | RR | RR | RR | RR | | RR | | | |
| *Triceratium* | *gibbosum* | RR | | | | | | | | |

Remarks : CC…very common, C…common, +…present, R…rare, RR…very rare,

## 4. Composition and distribution of zoo-plankton

It seems better to discuss here on the distribution of copepods, as they are most abundant both in quality and quantity in this area.

The following species of the copepods were found in the central part of the bay which was under strong influence of the oceanic water: *Calanus tenuicornis* DANA, *Neocalanus gracilis* (DANA), *Nannocalanus minor* (CLAUS), *Undinula darwini* (LUBB.), *Eucalanus crassus* GIESBR., *E. mucronatus* GIESBR., *Rhincalanus cornutus* (DANA), *Mecynocera clausi* THOMPSON, *Acrocalanus gracilis* GIESBR., *Clausocalanus furcatus* (BRADY), *Euchaeta wolfendeni* A. SCOTT, *E. marina* PRESTANDREA, *Scolecithrix danae* (LUBB.), *Centropages calaninus* (DANA), *C. furcatus* (DANA), *Temora discaudata* GIESBR., *Lucicutia flavicornis* (DANA), *L. ovalis* WOLFEND., *Candacia bispinosa* CLAUS, *C. catula* GIESBR., *C. truncata* DANA, *Acartia danae* GIESBR. and *A. negligens* DANA. Among them, the following genera dominated : *Undinula, Eucalanus, Nannocalanus, Euchaeta, Acrocalanus* and *Clausocalanus*.

The waters along the coast of Thailand differed in the species composition from that of the central part of the bay, and the following species occurred rather abundantly: *Paracalanus aculeatus* GIESBR., *Undinula vulgaris* (DANA), *Acrocalanus gibber* GIESBR., *Eucalanus subcrassus* GIESBR., *Temora turbinata* (DANA), *Centropages furcatus* (DANA) and *Macrosetella gracilis* (DANA). It may be worth while to note that one of the brackish species *Pseudodiaptomus* sp., was obsereved in the coastal region, though this was very rare.

| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | R | | | | |
| | | | | | R R | | | | | | | | | | | | | R R |
| | | | | | R R | R R | | | | | | | | | R R | + | | |
| | | | | | R R | R R | | | R R | | | | | + | C | + | + | + |
| | | | | | R R | | | | | | | | | | | R R | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | R R | + | | | |
| | | | | | | | | | | | | | | R R | R R | | | |
| | | | | | R R | R R | | | | | | | | + | + | C | + | |
| | | | | R R | R | R R | R R | | | | R R | | | C | C | C C | C | R R |
| + | C | + | C | C | C | C | | | R R | R R | R R | | | R R | R R | | | R R |
| | | R R | R | R R | R | R | R R | R | | | | R R | R | R | R | + | R | R |
| | | | | | | | | | | | | R R | R | + | C | C | C | R |

## Chapter V. Studies on the water masses indicated by plankton

### I. Introduction

Plankton has its own range of distribution according to the characters of water masses. The author discussed the distribution of the following 25 species of pelagic diatoms and 16 species of copepods together with the distribution of temperature and salinity so as to make a basic study on the plankton as an indicator of water masses.

Diatom :

*Chaetoceros atlanticus* CLEVE
*C. atlanticus* var. *neapolitana* (SCHROD.)
*C. concavicornis* MANGIN
*C. coarctatus* LAUDER
*C. decipiens* CLEVE
*C. didymus* EHRENBERG
*Thalassiosira nordenskiöldi* CLEVE
*Rhizosolenia alata* BRIGHTWELL
*R. hebetata f. hiemalis* GRAN
*R. hebetata* f. *semispina* (HENSEN) GRAN
*R. styliformis* BRIGHTWELL
*Corethron hystrix* HENSEN
*Stephanopyxis nipponica* GRAN & YENDO
*S. palmeriana* (GREVILLE) GRUNOW
*Lauderia borealis* GRAN
*Planktoniella sol* (WALLICH) SCHÜTT
*Skeletonema costatum* (GREVILLE)
*Biddulphia longicuris* GREVILLE
*B. sinensis* GREVILLE
*Fragilaria oceanica* CLEVE
*Eucampia zoodiacus* EHRENBERG
*Thalassiothrix frauenfeldii* GRUNOW
*T. longissima* CLEVE & GRUNOW
*Thalassionema nitzschioides* GRUNOW

*Nitzschia seriata* CLEVE

Copepoda :

*Calanus plumchrus* MARUKAWA
*C. helgolandicus* (CLAUS)
*Undinula darwini* (LUBBOCK)
*Eucalanus attenuatus* (DANA)
*Paracalanus parvus* GIESBRECHT
*Centropages abdominalis* SATO
*Oithona similis* CLAUS
*Euterpina acutifrons* (DANA)
*C. cristatus* KROYER
*C. minor* (CLAUS)
*U. vulgaris* (DANA)
*E. crassus* GIESBRECHT
*Clausocalanus pergens* FARRAN
*Acartia clausi* GIESBRECHT
*O. nana* GIESBRECHT
*Oncaea conifera* GIESBRECHT

In this study the author consulted with the papers dealing with the plankton of the Bering Sea and the Indian Ocean. But some of these papers failed to prepare the data of temperature and salinity. Consequently the author discussed on the distribution of the plankton by using the oceanographic records by the previous authors.

The depths of the collection of samples were 25 m in the case of diatoms and 50 m in copepods, respectively. The author has chosen and enumerated the typical types of cold and warm species by the results obtained from the geographical distribution of the species and discussed in Part I in the Chapters I～III and given them in the appendix in Section IV in this chapter.

## II. Geographical distribution of 25 species of diatoms (Figs. 25 & 26)

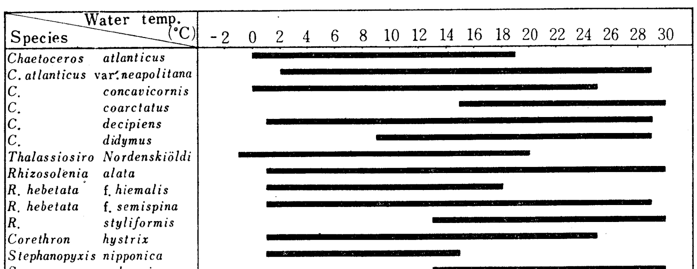


Fig. 25. Distribution of 25 species of diatoms according to water temperature.

Figure 25 illustrates the distribution of the species according to water temperature, and they were classified as follows:

**Stenothermal species**

Cold water species :

*Chaetoceros atlanticus* — *Thalassiosira nordenskiöldi*
*Rhizosolenia hebetata* f. *hiemalis* — *Stephanopyxis nipponica*
*Fragilaria oceanica*

Warm water species :

*Chaetoceros coarctatus* — *C. didymus*
*Rhizosolenia styliformis* — *Stephanopyxis palmeriana*
*Lauderia borealis* — *Planktoniella sol*
*Skeletonema costatum* — *Biddulphia longicuris*
*B. sinensis*

**Eurythermal species :**

*Chaetoceros atlanticus* var. *neapolitana* — *C. concavicornis*
*C. decipiens* — *Rhizosolenia alata*
*R. hebeta* f. *semispina* — *Corethron hystrix*
*Thalassionema nitzschioides* — *Thalassiothrix frauenfeldii*
*T. longissima* — *Nitzschia seriata*

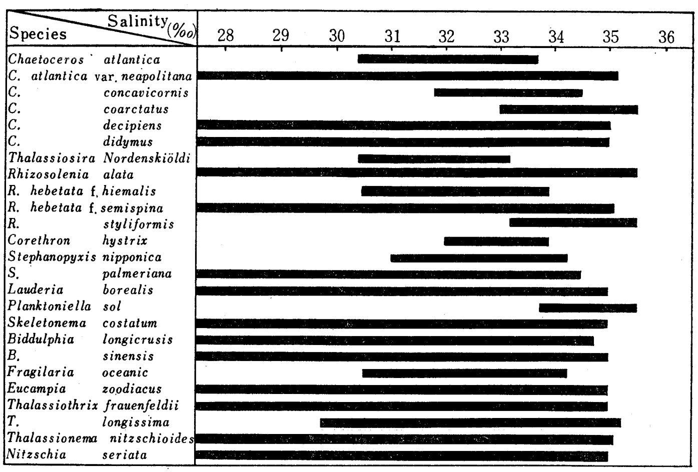


Fig. 26. Distribution of 25 species of diatoms according to salinity.

Figure 26 illustrates the distribution of the species according to salinity, and they were classified as follows:

**Stenohaline species**

Low haline species :

*Chaetoceros atlanticus* — *C. concavicornis*
*Thalassiosira nordenskiöldi* — *Rhizosolenia hebetata* f. *hiemalis*
*Corethron hystrix* — *Stephanopyxis nipponica*
*Fragilaria oceanica*

High haline species :

*Chaetoceros coarctatus*
*Planktoniella sol*
*Rhizosolenia styliformis*

**Euryhaline species :**

*Chaetoceros atlanticus* var. *neapolitana*
*C. didymus*
*R. hebetata* f. *semispina*
*Lauderia borealis*
*Biddulphia longicruris*
*Eucampia zoodiacus*
*T. longissima*
*Nitzschia seriata*
*C. decipiens*
*Rhizosolenia alata*
*Stephanopyxis palmeriana*
*Skeletonema costatum*
*B. sinensis*
*Thalassiothrix frauenfeldii*
*Thalassionema nitzschioides*

PFEFFER and ORTMANN (1897) mention that the distribution of marine plankton is defined by the oceanographic conditions as well as the geographical and astronomical factors, also by biological ones in a broad sense.

Most of the oceanic plankton are of the autogenetic and permanent type and are scarcely affected generally by the oceanographic conditions; no remarkable changes in the seasonal succession of the species and its association are observed.

On the contrary, the neritic plankton are capable of adaptation to a great change in environmental factors and are clearly observed as we usually record them as seasonal changes in species composition in a plankton calender. The neritic plankton depends on the land strongly and is said to be influenced by it in the area about 300 miles off the coast. Although, as mentioned above, it is difficult to distinguish the neritic diatoms from the oceanic ones by the characters which define the geographical distribution such as temperature and salinity, but the following classification may be acceptable.

Neritic species :

*Chaetoceros decipiens*
*Thalassiosira nordenskiöldi*
*S. nipponica*
*Biddulphia longicruris*
*Eucampia zoodiacus*
*Thalassionema nizschioides*
*C. didymus*
*Stephanopyxis palmeriana*
*Lauderia borealis*
*B. sinensis*
*Thalassiothrix frauenfeldii*
*Nitzschia seriata*

Oceanic species :

*Chaetoceros atlanticus*
*C. coarctatus*
*R. styliformis*
*Planktoniella sol*
*Thalassiothrix longissima*
*C. concavicornis*
*Rhizosolenia hebetata* f. *hiemalis*
*Corethron hystrix*
*Fragilaria oceanica*

## III. Geographical distribution of 16 species of copepods (Figs. 27 & 28)

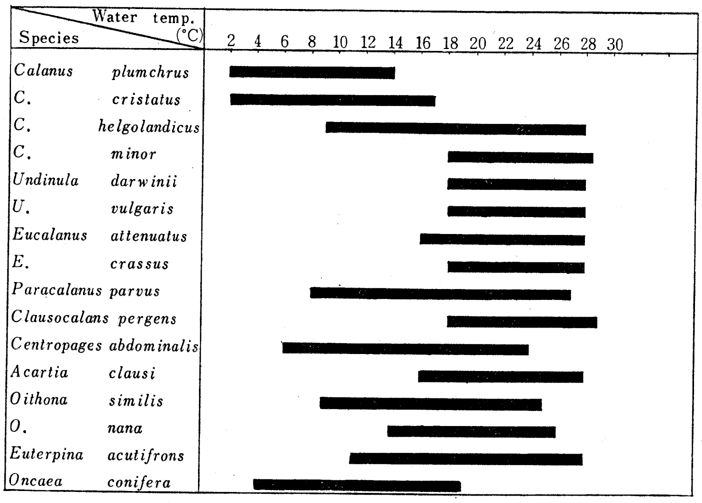


Fig. 27. Distribution on temperature of 16 species of copepod.

The copepod is very sensitive toward the changes in physical and chemical environmental factors such as temperature, light and salinity.

Even in the same species the vertical distribution varies with the developmental stages. The larva generally distributes in the surface, the adult beneath it; *Calanus cristatus* is the species which is abundant in the cold waters of Japan, the Aleutian Islands, and the Bering Sea. Most of the individuals collected from the surface layer less than 100 m in depth are immature specimens, and the adult were found by TANAKA (1938) from the depth more than 1,000 m in Sagami Bay.

On the other hand, *Calanus finmarchicus* has an active vertical movement in the stages earlier than Copepodid Stage V; their depth varies in accordance with the growth stages: It is recognized that nauplius and Copepodid Stage I prefer the surface layer, the Copepodite Stage III~IV is found in the deeper layer, and the Copepodid Stage V and adult in the deepest layer. MARSHALL and ORR (1955) have given a full account of *Calanus finmarchicus* and state that most of individuals in the Copepodid Stage V of this species show no vertical distribution. The larvae incubated during the period between spring and summer, become Copepodid Stage V and adult during the seasons of autumm and winter; at this period diatom is too scanty for them as food, they cease to move vertically in order to avoid using unnecessary energy, and remain in the deep layer where there is no change in water temperature and metabolism is not remarkably caused by the light. It is not easy to define the geographical distribution of copepods according to the temperature and salinity, but it may be probable that the following results are generally acceptable.

Stenothermal species and eurythermal ones are classified from Fig. 27 as follows:

**Stenothermal species**

Cold water species :

*Calanus plumchrus* *C. cristatus* *Oncaea conifera*

Warm water species :

*Calanus minor* *Undinula darwini* *U. vulgaris*
*Eucalanus attenuatus* *E. crassus* *Clausocalanus pergens*
*Acartia clausi*

**Eurythermal species :**

*Calanus helgolandicus* *Paracalanus parvus* *Centropages abdominalis*
*O. nana* *Euterpina acutifrons*

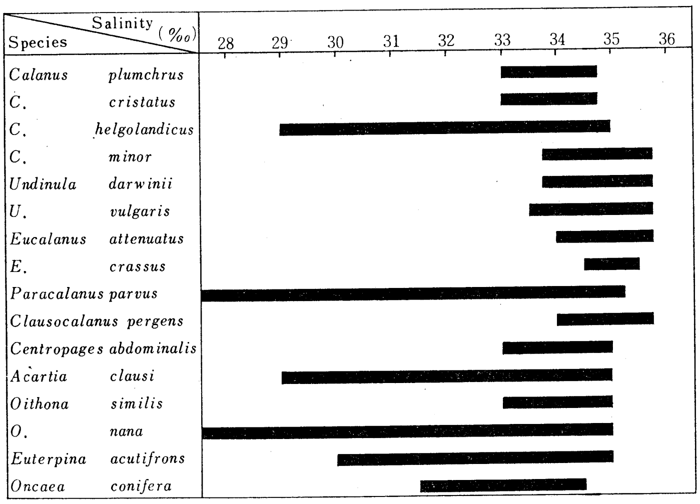


Fig. 28. Distribution on salinity of 16 species of copepod.

Stenohaline species and euryhaline ones are classified from Fig. 28 as follows :

**Stenohaline species**

Low haline species :

*Calanus plumchrus* *C. cristatus* *Centropages abdominalis*
*Oithona similis* *Oncaea conifera*

High haline species :

*Calanus minor* *Undinula darwini* *U. vulgaris*
*Eucalanus attenuatus* *E. crassus* *Clausocalanus pergens*

**Euryhaline species :**

*Calanus helgolandicus* *Paracalanus parvus* *Acartia clausi*
*Oithona nana* *Euterpina acutifrons*

Generally speaking, copepod is widely distributed in the sea, but each species has its own range of distribution. It is said that neritic species is influenced by land as well as by temperature and salinity, and the oceanic species depends on the oceanic currents. In general there are two currents, warm and cold currents in the sea, so the marine animals are classified into two according to the character of the currents in which they live. The warm current prevails at the surface layer of the tropical and subtropical regions. The cold water which occupies most of the seas in the world extends in the layers from subpolar convergence to a great depth in the lower latitudes. Accordingly cold water species are much greater in quantity than warm water ones. FARRAN (1936) indicated that the ratio of the warm water species to the cold one is about 5 : 2. However, TANAKA (1956) reports that the number of species collected from the surface is about the same with those from the middle layers of the Izu region.

The oceanic copepod is distributed both in warm and cold waters in the surface layer; but it is difficult to define the geographical distribution of the species which are capable of changing its vertical distribution according to the regions in which they live since it is well known that the cold surface species are able to live in the deep layer in the lower latitudes. On the other hand, the warm water species are distributed in the tropical and subtropical regions shallower than 200 m. The geographical distribution of copepods in the surface layer has been defined by STEUER (1933) as follows:

1). Circum-polar ·························· Arctic, including sub-arctic
2). Circum-equatorial ····················· Tropic, including sub-tropic
3). Circum-polar ·························· Antarctic, including sub-antarctic

The Atlantic, Pacific and the Indian oceans can be each defined as noted above, where the water extending from the subtropical region to subarctic region has a great influence on the distribution of the marine animals. In the North Pacific Ocean the subpolar convergence is the boundary of the distribution of stenothermal species where the Kuroshio contacts with the Oyashio. It is needless to say that the region of subpolar convergence varies with the seasons and years. The warm species which were carried away beyond the subpolar convergence can maintain their life for a while, but they are not able to reproduce in this circumstances unles they can adapt to the new environments.

## IV. Cold water and warm water plankton

The plankton suitable as an indicator of the water masses are those which are stenothermal and stenohaline.

The species of cold water plankton is less than one tenth of those of the warm water plankton but the former is great in quantity, whereas the latter has a great variety of species, but low in quantity.

The typical cold and warm water species examined by the author are as follows:

**Cold water species**

Diatom :

*Thalassiosira nordenskiöldii*
*T. decipiens*
*T. gravida*
*T. hyalina*
*T. condensata*
*Coscinosira polychora*
*Coscinodiscus asteromhalus*
*Stephanopyis nipponica*
*Corethron hystrix*
*Rhizosolenia hebetata* f. *hiemalis*
*Chaetoceros atlanticus*
*C. concavicornis*
*C. radicans*
*Biddulphia aurita*
*Navicula septentrionalis*
*Denticula marina*

Dinoflagellata : *Ceratium longipes*
*Peridinium conicum*

Tintinnoinea : *Ptychocylis obtusa*
*Parafavella jorgensenii*
*P. ventricosa*

Medusae : *Aglantha digitale*

Polychaeta : *Tomopteris pacifica*
*Phalacrophorus borealis*

Pteropoda : *Limacina helicina*

Copepoda :

*Calanus cristatus*
*C. plumchrus*
*C. finmarchicus*
*Eucalanus bungii bungii*
*Pseudocalanus elongatus*
*Euchaeta japonica*
*Scolecithricella minor*
*Metridia lucens*
*M. longa*
*Acartia longiremis*
*Oncaea conifera*

Euphausiacea : *Thysanoessa raschii*
*Euphausia* sp.

Amphipoda : *Themisto japonica*

Chaetognatha : *Sagitta elegans*

**Warm water species**

Diatom :

*Coscinodiscus janishii*
*Planktoniella sol*
*Gossleriella tropica*
*Rhizosolenia robusta*
*R. styliformis*
*R. alata* f. *indica*
*R. calcar-avis*
*R. bergonii*
*R. stolterfothii*
*Dactyliosolen tenuis*
*Chaetoceros lorenzianus*
*C. coarctatus*
*C. pervianus*
*Climacodium biconcavum*
*Ditylum sol*
*Hemiaulus hauckii*

Cyanophyceae : *Skujaella erythraeum*
*S. thiebauthii*

Dinoflagellata :

*Pyrocystis pseudonoctiluca*
*P. lunula*
*P. hamulus*
*Dinophysis miles*
*Ceratocorys horrida*
*Ornithocercus serratus*
*O. splendidus*
*Amphisolenia bidentata*

*A. thrinax*
*C. karstenii*
*C. massiliens*
*C. pulchellum*
*C. vultur*
*Ceratium candelabrum*
*C. macroceros*
*C. bigelowii*
*C. pennatum*
*C. azoricum*

Foraminifera : *Globigerina bulloides*

Radiolaria : *Sphaerozoum geminatum*
*Collozoum inerme*
*Acanthometron scolymantha*

Tintinnoinea :
*Peterotricha major*
*Codonellopsis parva*
*Xystonellopsis heros*
*Rhabdonella spiralis*
*Tintinus frankoii*
*Epiplocylis acutiformis*
*Salpingella acuminata*
*R. amor*

Medusae : *Diphyes bojani*
*D. contorta*
*Abyla haeckeli*
*D. dispar*
*Muggiaea spiralis*

Pteropoda :
*Cavolina tridentata*
*Diacria trispinosa*
*Hyalocylis striata*
*C. virgula conica*
*C. globulosa*
*Hyaloea depressa*
*Creseis virgula virgula*
*C. acicula*

Chaetognatha :
*Sagitta lyra*
*S. hexaptera*
*S. enflata*
*S. serratodentata pacifica*

Copelata :
*Oikopleura longicauda*
*O. rufescens*
*Fritillaria borealis* f. *sargassi*
*Ihlea asymmetrica*
*O. fusiformis*
*Stegosoma magnum*
*Doliolетta denticulatum*

Copepoda :
*Calanus minor*
*Neocalanus gracilis*
*Undinula darwini*
*Eucalanus attenuatus*
*E. subcrassus*
*Rhincalanus cornutus*
*Mecynocera clausi*
*Acrocalanus gibber*
*Calocalanus pavo*
*Euchaeta marina*
*E. media*
*Scolecithrix danae*
*Canthocalanus pauper*
*N. robustior*
*U. vulgaris*
*E. crassus*
*E. mucronatus*
*R. nasutus*
*Paracalanus aculeatus*
*A. gracilis*
*Euchirella amoena*
*E. wolfendeni*
*Phaenna spinifera*
*Scolecithricella bradyi*

*Centropages furcatus*
*L. flavicornis*
*C. pachydactyla*
*L. euchaeta*
*Pontellopsis regalis*
*Acartia dane*
*Corycaeus crassiusculus*
*C. gibbulus*
*S. angusta*
*Copilia mirabilis*
*C. quadrata*
*Miracia efferata*
*Lucicutia ovalis*
*Candacia aethiopica*
*Labidocera detruncata*
*Pontella securifer*
*Pontellina plumata*
*Oithona plumifera*
*C. speciosus*
*Sapphirina gemma*
*S. nigromaculata*
*C. longistylis*
*Clytemnestra scutellata*

Euphausiacea :
*Euphausia gracialis*
*Stylocheiron suhmii*
*E. pellucida*
*Siriella thompsoni*

Crustacean Decapoda : *Lucifer raynaudii*

Amphipoda :
*Vibilia viator*
*Phronima atlantica*
*Oxycephalus porcellus*
*Parascelus zebu*

# Part II Food of salmon and the gonad weight

## I. Introduction

One of the aims of the plankton resarch is to clarify the relation between plankton and fishery. Plankton researches have for a long time been aimed at the following items:

1. Plankton as a food of marine animals.
2. Plankton as an indicator of fishing ground and fishing conditions.
3. Commercial plankton fishery.
4. Plankton as an obstacle to fishing gear and fishing operation.

Many reports of investigations have been published on the relation between plankton and fishery. But most of them have dealt with the two problems; the first is the plankton as a food of fishes, and the second is the evil effect of plankton on fishery such as the red water and a similar phenomenon.

The author discussed in Part I Chapters I~III, on the relation between the distribution of plankton in the fishing grounds and the oceanographic conditions there; some of them dealt with the relation between the plankton and fishes. In this chapter the author discussed on the plankton as a food of salmons.

## II. Materials and method

The material was composed of each thirty specimens of dog salmon, red salmon, pink salmon, king salmon and silver salmon caught during the period May～July 1959; their body weight and length were measured and their scales were sampled; furthermore their gonad weight was measured, and their stomach contents were examined.

The food amount was classified by the naked eye observation into three parts; (a)…empty, (b)…average, (c)…full.

Though the fishing season extended over a long period of time, and the fishing ground shifted much, it seems reasonable to classify fishing grounds into five regions. (*cf*. Fig. 29)

Fishing ground I
May 24～June 11, 1956
Fishing ground II
June 12～June 20, 〃
Fishing ground III
June 21～July 6, 〃
Fishing ground IV
July 7～July 11, 〃
Fishing ground V
July 12～July 23, 〃

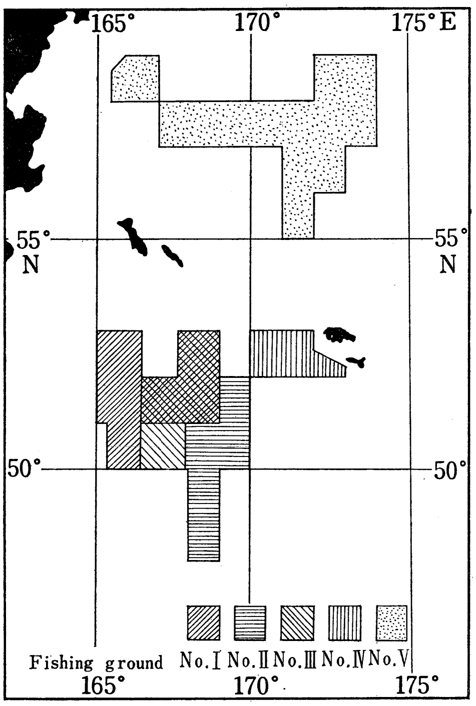


Fig. 29. Sketch chart of fishing grounds.

## III. The food composition of salmons

The results obtained from the examination of the stomach contents of each species were given in Table 30.

The organisms found in the stomch were as follows:

Zoo-plankton

Copepoda……………………*Calanus plumchrus, C. cristatus*

Euphausiacea ………………*Thysanoessa raschii, Euphausia pacifica*

Table 30. Stomach contents of salmons.

| Prey / Fishing ground | Fish fry | Myctophids | Squids | Euphausiacea | Copepoda | Amphipoda | Pteropoda | Zoea | Medusae | Chaetognatha |
|---|---|---|---|---|---|---|---|---|---|---|
| *Oncorhynchus nerka* | | | | | | | | | | |
| I | 24 | 46 | 7 | 200 | 177 | 101 | 65 | 0 | 0 | 0 |
| II | 4 | 9 | 3 | 77 | 70 | 60 | 28 | 0 | 0 | 0 |
| III | 3 | 7 | 7 | 169 | 43 | 128 | 59 | 0 | 2 | 0 |
| IV | 1 | 0 | 0 | 17 | 7 | 53 | 2 | 0 | 1 | 0 |
| V | 4 | 1 | 11 | 18 | 3 | 120 | 4 | 5 | 1 | 0 |
| *Oncorhynchus keta* | | | | | | | | | | |
| I | 39 | 38 | 1 | 148 | 107 | 172 | 233 | 0 | 97 | 0 |
| II | 10 | 27 | 0 | 56 | 39 | 47 | 150 | 0 | 20 | 0 |
| III | 14 | 11 | 3 | 171 | 11 | 116 | 270 | 0 | 52 | 0 |
| IV | 11 | 8 | 3 | 6 | 0 | 81 | 0 | 0 | 33 | 0 |
| V | 4 | 26 | 1 | 3 | 0 | 23 | 16 | 2 | 6 | 0 |
| *Oncorhynchus gorbuscha* | | | | | | | | | | |
| I | 56 | 11 | 2 | 35 | 44 | 25 | 27 | 0 | 0 | 0 |
| II | 78 | 6 | 11 | 92 | 83 | 65 | 46 | 0 | 0 | 0 |
| III | 77 | 5 | 20 | 206 | 89 | 112 | 94 | 0 | 1 | 0 |
| IV | 14 | 0 | 0 | 36 | 24 | 81 | 0 | 0 | 0 | 0 |
| V | 14 | 4 | 5 | 29 | 10 | 84 | 8 | 35 | 2 | 2 |
| *Oncorhynchus tschawytscha* | | | | | | | | | | |
| I | 0 | 4 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| II | 2 | 1 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| III | 25 | 1 | 6 | 31 | 3 | 0 | 0 | 0 | 0 | 0 |
| IV | 8 | 0 | 4 | 2 | 3 | 1 | 0 | 0 | 0 | 0 |
| V | 0 | 0 | 1 | 1 | 1 | 3 | 0 | 1 | 0 | 0 |
| *Oncorhynchus kisutch* | | | | | | | | | | |
| I | 2 | 5 | 3 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| II | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| III | 49 | 0 | 7 | 35 | 1 | 0 | 0 | 0 | 0 | 0 |
| IV | 13 | 0 | 6 | 5 | 1 | 1 | 0 | 0 | 0 | 0 |
| V | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |

Amphipoda ···················· *Themisto japonica*
Pteropoda ···················· *Limacina helicina*
Chaetognatha ················· *Sagitta elegans*
Medusa ······················· *Aglantha digitale*
Fishes ································ Myctophids, fry of cod and some other fishes
Molluscs ····························· Squids

**A.** The food composition of red salmon (*Oncorhynchus nerka*)

The fish preyed mainly on small crustaceans such as Euphausiacea, Copepoda, Amphipoda; more than 70% of stomach contents were composed of these small crustaceans; Pteropoda followed them.

**B.** The food composition of dog salmon (*Oncorhynchus keta*)

They eat abundantly small crustaceans such as Euphausiacea, Copepoda, Amphipoda and Pteropoda, but a dog salmon is rather omnivorous as compared with red salmon; most of them feed on fish fry or myctophids, dog salmon feeds sometimes Medusae (*Aglantha digitale*). This feeding habit was seldom seen in red salmon.

**C.** The food composition of pink salmon (*Oncorhynchus gorbuscha*)

They eat abundantly such small crustaceans as Euphausiacea, Copepoda, Amphipoda and Pteropoda and a considerable quantity of fish fry.

**D.** The food composition of king salmon (*Oncorhynchus tschawytscha*)

Many individuals of this species take squids and fish fry. They prefer large edible marine animals to small crustaceans.

**E.** The food composition of silver salmon (*Oncorhynchus kisutch*)

This species feed chiefly on fish fry, squids and Euphausiacea as king salmon do.

From above the species which feed chiefly on Euphausiacea, Copepoda, Amphipoda and Pteropoda is red salmon and is followed by pink salmon and dog salmon, while king salmon and silver salmon tend to feed mainly on fish fry and squids. On the other hand, the food composition of fish varied to some extent with the transition of fishing ground.

## IV. Relation between the food amount of dog salmon and the gonad weight

The body length distribution of dog salmon, the sex and fishing ground were separately shown in Table 31. This species has a mode in body length in 43~65 cm and most of them are 52~57 cm in body length regardless to the difference in sex and fishing ground.

The body length distribution was classified into the following four parts; 1) Less than 52.0 cm, 2) 52.1~55.0 cm, 3) 55.1~58.0 cm and 4) over 58.1 cm. The comparison of the food composition and the gonad weight of the female was shown in Table 32 and that of the male in Table 33.

From these tables it is clear that the gonad weight of both male and female over 55 cm in body length increased with advancement of the fishing season; therefore it is probable that individuals over 55 cm in body length are capable of spawning.

Table 31. Frequency distribution in body length of *Oncorhynchus keta* in each fishing ground.

| Sex | Female | | | | | | Male | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fishing ground / Body length (cm) | I | II | III | IV | V | Total | I | II | III | IV | V | Total |
| ~43.0 | | | | 2 | | 2 | | | | 1 | | 1 |
| 43.1~44.0 | | | | 1 | 1 | 2 | | | | | | |
| 44.1~45.0 | | | 1 | | 2 | 3 | | | | | 1 | 1 |
| 45.1~46.0 | | 1 | 1 | 1 | | 3 | | 2 | | 1 | | 3 |
| 46.1~47.0 | 1 | 3 | 3 | | 4 | 11 | | 2 | 1 | 1 | 4 | 8 |
| 47.1~48.0 | 1 | 11 | 7 | | 4 | 23 | | 12 | 5 | 1 | 8 | 26 |
| 48.1~49.0 | 1 | 13 | 4 | 1 | 3 | 22 | 2 | 6 | 6 | 1 | 4 | 19 |
| 49.1~50.0 | 8 | 15 | 14 | 1 | 10 | 48 | 4 | 14 | 13 | 3 | 11 | 45 |
| 50.1~51.0 | 25 | 12 | 16 | 3 | 12 | 68 | 7 | 8 | 14 | | 12 | 41 |
| 51.1~52.0 | 30 | 14 | 17 | 4 | 10 | 75 | 23 | 9 | 8 | 1 | 8 | 49 |
| 52.1~53.0 | 48 | 15 | 21 | 8 | 12 | 104 | 24 | 6 | 12 | 11 | 9 | 62 |
| 53.1~54.0 | 53 | 17 | 21 | 7 | 11 | 109 | 33 | 8 | 13 | 2 | 9 | 65 |
| 54.1~55.0 | 54 | 12 | 27 | 7 | 20 | 120 | 43 | 4 | 21 | 8 | 17 | 93 |
| 55.1~56.0 | 37 | 11 | 41 | 13 | 18 | 120 | 39 | 9 | 13 | 5 | 6 | 72 |
| 56.1~57.0 | 21 | 9 | 38 | 15 | 12 | 95 | 23 | 6 | 18 | 5 | 6 | 58 |
| 57.1~58.0 | 16 | 3 | 29 | 6 | 10 | 64 | 20 | 3 | 17 | 7 | | 47 |
| 58.1~59.0 | 10 | 2 | 15 | 8 | 8 | 43 | 8 | 1 | 11 | 4 | 2 | 26 |
| 59.1~60.0 | 10 | 4 | 16 | 10 | 2 | 42 | 12 | 1 | 8 | 6 | 4 | 31 |
| 60.1~61.0 | 1 | | 15 | 2 | 5 | 23 | 7 | | 10 | | 1 | 22 |
| 61.1~62.0 | 1 | | 4 | | 1 | 6 | | | 4 | | 5 | 9 |
| 62.1~63.0 | 1 | | 6 | | | 7 | | 4 | 2 | 2 | 2 | 6 |
| 63.1~64.0 | | | 2 | | 1 | 3 | 1 | 1 | | | 3 | 5 |
| 64.1~ | | | 1 | | | 1 | | 1 | 2 | | 1 | 4 |
| Total | 318 | 142 | 299 | 89 | 146 | 994 | 246 | 96 | 179 | 59 | 113 | 693 |

Throughout the fishing season the change in the daily food amount of this species is shown in Fig. 30.

As seen from Fig. 30 and Tables 32 and 33, it will be seen that the food amount decreases a little in accordance with the change in fishing season and ground. But many individuals continue to feed on in spite of the increase in the gonad weight until the period when they are matured. It is believed that salmons cease to take food and their stomachs are empty in most cases in their spawning season. Accordingly, it is probable that the spawning migration takes place around the estuary. The decline in feeding amount in the fishing ground V is probably attributed to the fact that the distribution amount of zoo-plankton in this fishing ground is lower than any other fishing grounds.

Table 32. Relations between gonad weight of dog salmon (female) and food-volume found in its stomach, with references to its body length and the fishing ground where it was caught.

| B.L.(cm) | ～52.0 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F. G. | I | | | II | | | III | | | IV | | | V | | |
| G.W. \ F. | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c |
| ～ 10 | | | | 5 | 5 | | 3 | 1 | 1 | | | | 2 | 2 | |
| 11～ 20 | 4 | 8 | 1 | 5 | 9 | 1 | 10 | 17 | | 2 | 1 | | 9 | 7 | |
| 21～ 30 | 2 | 5 | | | 6 | | 1 | 1 | | | | | 1 | 1 | |
| 31～ 40 | 1 | 4 | 1 | 1 | 5 | | | 1 | | | | | | | |
| 41～ 50 | | 6 | | | 6 | | | | | | 1 | | 1 | 1 | |
| 51～ 60 | | | | | 3 | | | 1 | | | | | | | |
| 61～ 70 | | | | | 4 | | | | | | 1 | | | | |
| 71～ 80 | | 1 | | | 1 | | 2 | 2 | | | | | | | |
| 81～ 90 | | | | | 1 | | | 1 | | | | | 1 | | |
| 91～100 | | | | | | | | | | 1 | | | | | |
| 101～110 | | | | | | | 1 | | | | | | | 1 | |
| 111～120 | | | | | | 1 | | 1 | | | | | 1 | | |
| 121～130 | | 1 | | | | | | | | | | | 2 | | |
| 131～140 | | | | | | | | | | | 1 | | | | |
| 141～150 | | | | | | | | | | | | | | | |
| 151～160 | | | | | | | | 1 | | | 1 | | | 1 | |
| 161～170 | | | | | | | | | | | | | | | |
| 171～180 | | 1 | | | | | | | | | | | | | |
| 181～190 | | | | | | | | | | | | | | | |
| 191～200 | | | | | | | | 1 | | | | | | | |
| 201～210 | | | | | | | | | | | | | | | |
| 211～220 | | | | | | | | | | | | | | | |
| 221～230 | | | | | | | | | | | | | 1 | | |
| 231～240 | | | | | | | | | | | | | | | |
| 241～250 | | | | | | | | | | | | | 1 | | |
| 251～260 | | | | | | | | | | | | | | | |
| 261～270 | | | | | | | | | | | | | | | |
| 271～280 | | | | | | | | | | | | | 1 | | |
| 281～290 | | | | | | | | | | | | | | | |
| 291～300 | | | | | | | | | | | | | 1 | | |
| 301～310 | | | | | | | | | | | | | | | |
| 311～320 | | | | | | | | | | | | | | | |
| 321～330 | | | | | | | | | | | | | | | |
| 331～340 | | | | | | | | | | | | | | | |
| 341～350 | | | | | | | | | | | | | | | |
| 351～360 | | | | | | | | | | | | | | | |
| 361～370 | | | | | | | | | | | | | | | |
| 371～380 | | | | | | | | | | | | | | | |
| 381～390 | | | | | | | | | | | | | | | |

| B.L.(cm) | 52.1～55.0 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F. G. | I | | | II | | | III | | | IV | | | V | | |
| G.W. \ F. | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c |
| ～ 10 | | | 1 | | | 1 | | | | | | | 1 | 2 | |
| 11～ 20 | 2 | 6 | | 2 | 3 | | 7 | 3 | 2 | 1 | 3 | | 12 | 4 | |
| 21～ 30 | 5 | 14 | 3 | | 4 | | 1 | | | | | | 2 | | |
| 31～ 40 | 9 | 22 | 4 | 1 | 3 | 1 | 1 | 2 | | | | | | | |
| 41～ 50 | 4 | 17 | 3 | | 2 | | 1 | | | 1 | 1 | | | | |
| 51～ 60 | 2 | 13 | 1 | | 4 | | | | 1 | 1 | | | | | |
| 61～ 70 | | 5 | 1 | 1 | 4 | | | 3 | | | | | | | |
| 71～ 80 | 1 | 4 | 1 | | 5 | | | 2 | 1 | | | | | 1 | |
| 81～ 90 | | 2 | 2 | 1 | 8 | | 2 | 1 | | | | | | | |
| 91～100 | 1 | 3 | | | 2 | 1 | | 4 | 4 | 1 | | | | | |
| 101～110 | | 3 | | | | | 1 | | | 1 | 1 | | | | |
| 111～120 | | | | | 1 | | | 4 | | | | | | | |
| 121～130 | | 3 | | | | | 1 | 5 | | | 1 | | 1 | 1 | |
| 131～140 | | | | | | | 1 | 5 | | | | | 1 | 1 | 1 |
| 141～150 | | | | | | | | 1 | | | 1 | | 1 | 2 | |
| 151～160 | | | | | | | | | | | | | 1 | | |
| 161～170 | | | | | | | | 1 | 1 | | 1 | | | | |
| 171～180 | | | | | | | | 1 | | | | | | 1 | |
| 181～190 | | | | | | | | 2 | | | | | | 1 | |
| 191～200 | | | | | | | | | | | | | 1 | | |
| 201～210 | | | | | | | | | | | | | 1 | | |
| 211～220 | | | | | | | | | | | | | 1 | | |
| 221～230 | | | | | | | | | | | | | 2 | | |
| 231～240 | | | | | | | | | | | | | | | |
| 241～250 | | | | | | | | 1 | | | | | | | |
| 251～260 | | | | | | | | | | | | | | | |
| 261～270 | | | | | | | | | | | | | | | |
| 271～280 | | | | | | | | | | | | | | | |
| 281～290 | | | | | | | | | | | | | | | |
| 291～300 | | | | | | | | | | | | | | | |
| 301～310 | | | | | | | | | | | | | | | |
| 311～320 | | | | | | | | | | | | | | | |
| 321～330 | | | | | | | | | | | | | | | |
| 331～340 | | | | | | | | | | | | | | | |
| 341～350 | | | | | | | | | | | | | | | |
| 351～360 | | | | | | | | | | | | | | | |
| 361～370 | | | | | | | | | | | | | | | |
| 371～380 | | | | | | | | | | | | | | | |
| 381～390 | | | | | | | | | | | | | | | |

| B.L.(cm) | 55.1～58.0 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F. G. | I | | | II | | | III | | | IV | | | V | | |
| G.W. \ F. | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c |
| ～ 10 | 2 | | | | | | | | | | | | | | |
| 11～ 20 | | 6 | 1 | | 1 | | 2 | | 1 | | | | 6 | 1 | |
| 21～ 30 | 3 | 7 | 4 | | 2 | | 1 | | | | | | 1 | | |
| 31～ 40 | 1 | 10 | 2 | | 1 | | | 2 | | | | | | | |
| 41～ 50 | 4 | 9 | 4 | | | | | 2 | | 1 | 2 | | 1 | | |
| 51～ 60 | 2 | 10 | 1 | | 2 | | 1 | 1 | | | | | | 1 | |
| 61～ 70 | 1 | 9 | 3 | | 1 | | 1 | 3 | | | 1 | | 1 | | |
| 71～ 80 | 1 | 8 | 1 | | 4 | | 1 | 3 | 1 | | 1 | | | | |
| 81～ 90 | | 4 | | 1 | 3 | | 1 | 3 | | 1 | 1 | | | | |
| 91～100 | | 8 | 1 | | 3 | | 2 | 5 | 1 | | | | 2 | 1 | |
| 101～110 | 1 | 2 | 1 | | 4 | 1 | | 5 | | 1 | | | | 3 | |
| 111～120 | | 2 | | | 3 | 2 | 1 | 4 | 1 | | 1 | | | | |
| 121～130 | 1 | 1 | | | | | | 9 | 2 | 1 | 2 | 2 | | 2 | |
| 131～140 | | | | | 1 | 1 | | 7 | 3 | | 1 | | 1 | | |
| 141～150 | | | | | 1 | | | 4 | 4 | | 1 | | 2 | 2 | |
| 151～160 | | | | | | | 2 | 5 | | | 1 | | 2 | | |
| 161～170 | | | | | | | 1 | 2 | 1 | 1 | 1 | | | 1 | |
| 171～180 | | | | | | | | 5 | 2 | 1 | 2 | | | | |
| 181～190 | | | | | | | 2 | 2 | | 1 | 2 | | 2 | | |
| 191～200 | | | | | | | | 3 | 2 | 1 | 3 | | 4 | | |
| 201～210 | | | | | | | 1 | 2 | | | | | 6 | 1 | |
| 211～220 | | | | | | | | 3 | | | | | 1 | | |
| 221～230 | | | | | | | | | | | 1 | | 1 | | |
| 231～240 | | | | | | | | | | | | | | | |
| 241～250 | | | | | | | | | | | | | 3 | | |
| 251～260 | | | | | | | | | | | | | 2 | | |
| 261～270 | | | | | | | | | | | | | 2 | | |
| 271～280 | | | | | | | | | 1 | | | | | | |
| 281～290 | | | | | | | | | | | | | | | |
| 291～300 | | | | | | | | | | | | | 1 | | |
| 301～310 | | | | | | | | | | | | | | | |
| 311～320 | | | | | | | | | | | | | | | |
| 321～330 | | | | | | | | | | | | | | | |
| 331～340 | | | | | | | | | | | | | | | |
| 341～350 | | | | | | | | | | | | | 1 | | |
| 351～360 | | | | | | | | | | | | | | | |
| 361～370 | | | | | | | | | | | | | | | |
| 371～380 | | | | | | | | | | | | | | | |
| 381～390 | | | | | | | | | | | | | | | |

| B.L.(cm) | 58.1～ | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F. G. | I | | | II | | | III | | | IV | | | V | | |
| G.W. \ F. | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c |
| ～ 10 | | | | | | | | | | | | | 1 | 1 | |
| 11～ 20 | | 1 | | | 1 | | | 1 | 1 | | | | 4 | 1 | |
| 21～ 30 | | | | | | | | | | | | | | | |
| 31～ 40 | 1 | 4 | | | 1 | | 1 | | | | 2 | | | | |
| 41～ 50 | 1 | 1 | | | | | | | | 1 | | | | | |
| 51～ 60 | 3 | | | | | | | 2 | | | 1 | | | 1 | |
| 61～ 70 | | 3 | 1 | | | | | 1 | | 1 | | | 1 | | |
| 71～ 80 | | 1 | 3 | | | | | | | 1 | 1 | | | | |
| 81～ 90 | | 1 | | | | | | 2 | | | | | | 2 | |
| 91～100 | | 2 | 1 | | 1 | | | | | 1 | | | | 1 | |
| 101～110 | | 1 | | | 1 | | 1 | 2 | | 2 | | | 1 | | |
| 111～120 | | 1 | | | 2 | | | 1 | 2 | | | | 1 | | |
| 121～130 | | 3 | | | | | | 4 | 1 | | | | 1 | 2 | |
| 131～140 | | 1 | 1 | | | | | 6 | 3 | 1 | | | | | |
| 141～150 | | 3 | | | 1 | | 2 | 3 | 2 | | 1 | | | | |
| 151～160 | | | | | | | 1 | 6 | 4 | 1 | | 1 | | 1 | |
| 161～170 | | 2 | | | | | | 8 | | | | | | 1 | |
| 171～180 | | | 1 | | | | | 3 | 3 | 1 | | | | | |
| 181～190 | | 1 | | | | | | 7 | 1 | | 1 | | | 1 | |
| 191～200 | | 1 | | | | | | 1 | 3 | | 3 | | 1 | | |
| 201～210 | | | | | 1 | | | 3 | | | 1 | | | | |
| 211～220 | | | | | | | | 4 | | 2 | | | 2 | | |
| 221～230 | | | | | | | | 1 | | | | | 1 | | |
| 231～240 | | | | | | | | | | | | | 1 | | |
| 241～250 | | | | | | | | | 1 | 1 | | | 3 | | |
| 251～260 | | | | | | | | | 1 | | | | | | |
| 261～270 | | | | | | | | | | | | | | | |
| 271～280 | | | | | | | | | | | | | 1 | 1 | |
| 281～290 | | | | | | | | | | | | | 3 | | |
| 291～300 | | | | | | | | | | | | | 1 | | |
| 301～310 | | | | | | | | | | | | | | | |
| 311～320 | | | | | | | | 1 | | | | | 1 | | |
| 321～330 | | | | | | | | | | | | | | | |
| 331～340 | | | | | | | | | | | | | 2 | | |
| 341～350 | | | | | | | | | | | | | 1 | | |
| 351～360 | | | | | | | | | | | | | | | |
| 361～370 | | | | | | | | | | | | | 1 | | |
| 371～380 | | | | | | | | | | | | | | | |
| 381～390 | | | | | | | | | | | | | | | |

Notes : B.L., body length; F.G., fishing ground; F., food-volume; G.W., gonad weight.

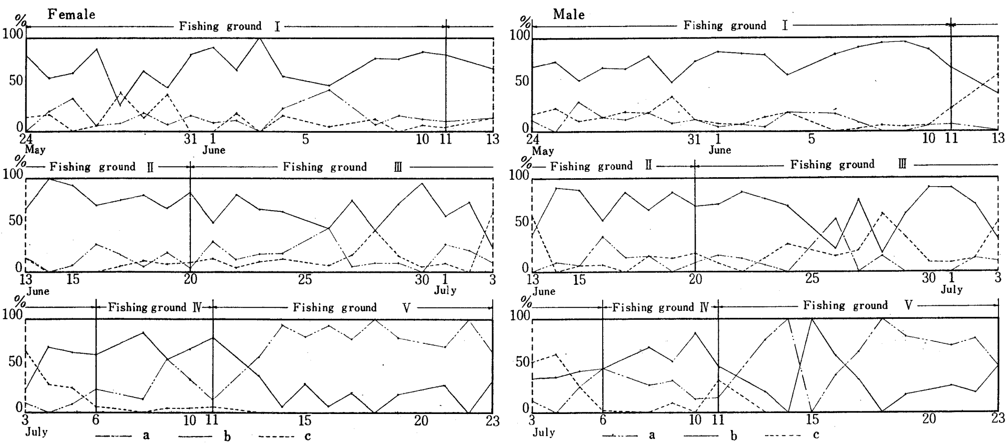


Fig. 30. The change in the daily food amount of dog salmon shown by percentage of individuals.

Table 33. Relations in dog salmon (male).

| B.L.(cm) | ~52.0 | | | | | | | | | | | | | | | 52.1~55.0 | | | | | | | | | | | | | | | 55.1~58.0 | | | | | | | | | | | | | | | 58.1~ | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F.G. | I | | | II | | | III | | | IV | | | V | | | I | | | II | | | III | | | IV | | | V | | | I | | | II | | | III | | | IV | | | V | | | I | | | II | | | III | | | IV | | | V | | |
| G.W. \ F. | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c |
| 0~ 5 |1|3| |6|20|3|17|11|3|4|2| |24|8| |5|12| |4|9| |2|8|3|2| | |10|12| |1|8| |2|3| |6|3| |2| | |13|7| |1|4|1| | | |1|3|2| |1| |3| | |
| 6~ 10 |2|3| | |6|1| | | | | |1| | | |5|16|2| |3| | |1| |1| | | | | |1|23|3| |1|1| |2| |1| | | | |1|1|5| | |2| | | | | |1| |1| | |
| 11~ 15 | |1| |1|4| | | | | | | | |1| | |13|3| |1| | | | | | | | | | |4|11|5| |2|1| |1| |2| | | | | |1|7|1| | | | |1| | |1| | | | |
| 16~ 20 |1| | | |2| | | | | |1| | | | |1|7|1| |3|1|1| | | | | | | | |1|13|1| |1|1| | | | | | |1| | | |3|3| | | | |1| | |1| | | | |
| 21~ 25 | | | | | | | | | | | | | |1| | |5| | | | | | |1|1| | |1|1| | |5|3| | |1|1|1|1|2| | | | | | |5|2| |1| | | |1|1| |1| | | |
| 26~ 30 | | | | | | | | | | | | | | | | |4|2| | | | |2| | | | | | | | |9|1| |3| | | |1| |1| | | | | |5| | | |1| |2|1| | | | | | |
| 31~ 35 | | | | | | | |1| | | | | | | | | | | | | | | | | |1| | | | | |3|1| |1| |1|2|3| | | | | | | |1|1| | |1| |1| | | | | | |
| 36~ 40 | | | | |1| | | |2| | | | | | | |1| | | | | |3|1| |1| | | | | |3|1| | | | |2|1| | | | | | | |2|2| | |1| |1| | | | | | |
| 41~ 45 | | | | | | | | | | | | | | | | |1| | | | | |1| | | | | | | | |2| | |1| |1|1|1| | | | | | | | | | |1| | |1| | | | | | |
| 46~ 50 | | | | | | | |1| | | | | | | | |2| | | | | |3| | | | | | | | |1| | |1| | |2| | | | | | | | |1|1| |1| |1|1| | | | | | |
| 51~ 55 |1| | | | | | | | | | | | | | | |2| | |1| | |1| | | | | | | | | | | | | | |1| | | | | | | | |1| | | | | |1| |1| | | | |
| 56~ 60 | | | | | | |1| | | | | | | | | | | | | | | |2| | | | | | | | | | | | | | |1|1| | | | | | | | | | |2| | |1|1| |1| | | |
| 61~ 65 | |1| | | | | | | | | | | | | | | | | | | | |1| | |1| | | | | | | | | | | |1| | | | | | | | | | | | | | |2| |1| | | | | |
| 66~ 70 | | | | | | | | | | | | | | | | | | | | | | | | | | |1|1| | | | | | | | | |1| | | | | | | | | | | | |1| |1| |1| | | | | |
| 71~ 75 | | | | | | | |1| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |1| | |1| | | | | | | | | | | |2| | | |1| | |
| 76~ 80 | | | | | | | | |1| | | |1| | | | | | | | | | | | | | | | | | | | | | | | |4|1| | | | | | | | | | | | | | | | | | | | |
| 81~ 85 | | | | | | | | | | | | | | | | | | | | | | | | | |1| | | | | |1| | | | | | |1| | | | | | | |1| | | | | |1|1| | | | | | |
| 86~ 90 | | | | | | | | | | | | | | | | | | | | | | |2| | | | | | | | |1| | | | |1|1|1| | | | | | | | | | | | | |3| | |1| | | | |
| 91~ 95 | | | | | | | | | | | | | | | | | | | | | | | | | | | |1|2| | | | | | | | |1| | | | | |1| | | | | | | | |2|2| | | | | | |
| 96~100 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |1| | | | | | | |1| |1| | | | | | | | | | | |2|1| | | | | | |
| 101~105 | | | | | | | | | | | | |1| | | | | | |1| | | | | | | | | | | |1| | | | | | |1|1| | | | |1| | | | | | | |1| | |2| | | | |
| 106~110 | | | | | | | | | | | | |1|1| | | | | | | | | | | |1| | | | | | | | | | | |1| | | | |1| | | | | | | | |1|2| | | |1| | |
| 111~115 | | | | | | | | | | | | | | | | | | | | | | | | | |1| | | | | | | | | | | | | | | | | | | | | | | | | |2|2| | | |1| | |
| 116~120 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |3| | |1| | | |1|
| 121~125 | | | | | | | |1| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |2| | | | |1| | |
| 126~130 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |1|1| | | | | | | | |1| | |1| | | | |
| 131~135 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |1| | | | | | |
| 136~140 | | | | | | | | | | | | |2| | | |1| | | | | | | | | | | |1| | | | | | | |1| |1| | | |1|2| | | | | | | | |1|1| | | | | | |
| 141~145 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 146~150 | | | | | | | | | | | | | |1| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |1| | | | | | | | | |1| | | |2| | |
| 151~155 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 156~160 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 161~165 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |1| |1| |1|
| 166~170 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 171~175 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 176~180 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 181~185 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |1| | |
| 186~190 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |1| | |
| 191~195 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 196~200 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |1| | |
| 201~205 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 206~210 | | | | | | | | | | | | | | | | | | | | | | | | | | | |1| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 211~215 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 216~220 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |1| |
| 221~225 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 226~230 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 231~235 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 236~240 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 241~250 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |1| | | | | | | | | | | | | | |1| | |
| 251~255 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 256~260 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Notes : Remarks are the same as in Table 32.

# Part III Taxonomical studies of Amphipoda, Chaetognatha and Copepoda

## Chapter I Pelagic Amphipoda, suborder "Hyperiidea"

### I. Introduction

In spite of the importance of the study on the members of the suborder "Hyperiidea" in Amphipoda not only in taxonomy but also as a food of fishes, there have been only several papers which dealt with this group even in the present days. Hyperiidea has been described by the following authors: C. BOVALLIUS (1887 & '89); T. R. R. STEBBING (1888); U. OGAMI (1901); C. R. SHOENAKER (1925); Ed. CHEVREUX and L. FAGE (1925); K. H. BARNARD (1930, '32 & '37). M. E. VINOGRADOV (1957) and H. IRIE (1957 & '59) have published the excellent papers on this group collected from the northwestern part of the Pacific Ocean and from the waters adjacent to Japan. Among them IRIE'S comprehensive report on the morphology of the pelagic Amphipoda should be highly appreciated.

The material used in this chapter was composed of 505 specimens of Hyperiidea found in the plankton samples collected in the five surveyed regions of the Indian Ocean (*cf.* Fig. 31) discussed in the Part I. The author identified 30 species, and discussed chiefly on their distribution.

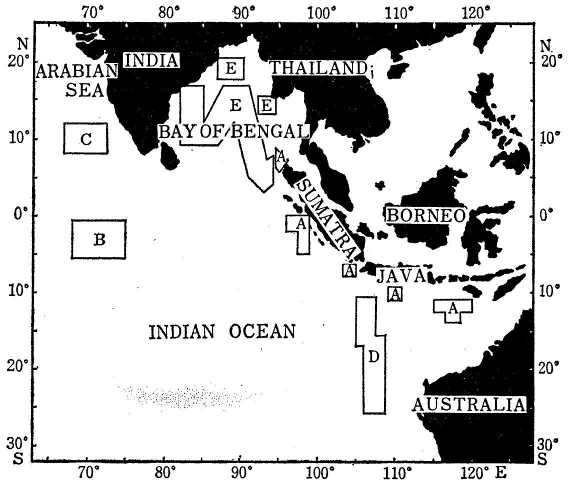

Fig. 31. Localities of the waters from where the specimens were collected.

## II. Classification system employed in this report

The author employed in this chapter the classification system proposed and employed by Ed. CHEVREUX and L. FAGE (1925), J. REIBISH (1927) and H. IRIE (1957 & '59).

### Suborder Hyperiidea

Antennae generally remarkably different in both sexes, especially the 2nd undeveloped and often absent in the female. Mouth parts undeveloped, both inner lobes of maxillipeds coagulating. Gnathopods generally not so remarkably different in both sexes. Dactyla of 3rd and 4th pereiopods direct backwards, those 5th~7th forwards. 2nd and 3rd urus-segments coagulate.

Suborder Hyperiidea are subdivided into following 3 legions by the structures of eye, 2nd antenna and thoracic appendages.

| | | |
|---|---|---|
| Legion 1 | Hyperiidea | Gammaroidea |
| Legion 2 | Hyperiidea | Genuina |
| Legion 3 | Hyperiidea | Anomala |

### Key to Legions

1. Head not so dilate, eye comparatively small and concentric to a lateral part of

head on both sides. ······ Legion Hyperiidea Gammaroidea

Head dilate and large, eye occuping almost all part of head. ······ 2

2. 2nd antenna of the male not folded, 3rd～5th pereiopods not so remarkably different in structure and magnitude. ······ Legion Hyperiidea Genuina

2nd antenna of the female folded zigzagly. Bases of 5th and 6th pereiopods wider than those of others generally. 7th pereiopod very smaller than others generally. ······ Legion Hyperiidea Anomala

### Legion Hyperiidea Gammaroidea

Key to Families

lst antenna lanceolate. Dactylus of 7th pereiopod telson-shaped, distal end pointing. ································ Fam. Scinidae

lst antenna spatulate. Dactylus of 7th pereiopod finger-shaped, distal end round. ································ Fam. Vibiliidae

### Legion Hyperiidea Genuina

Key to Families

1. Head cubic. ············································ Fam. Paraphronimidae

Head conic. ············································ Fam. Phronimidae

Head spherical. ············································ 2

2. 5th pereiopod not so large and robust, basis not so dilate and wide. ································ Fam. Hyperiidae

5th pereiopod large and robust, frontal margin of carpus with massive serration. ································ Fam. Anchylomeridae (Phrosinidae)

5th pereiopod of male very narrow and long, in female moderate. ································ Fam. Lycaeopsidae

### Legion Hyperiidea Anomala

Key to Families

1. Head elongate forwards, frontal end pointing. Basis of 5th pereiopod somewhat dilate and wide. ········································ Fam. Oxycephalidae

Head almost spherical, with a beak-shaped rostrum. Basis of 5th pereiopod remarkably dilate and laminate. ···················································· 2

2. Basis of 6th pereiopod not so dilate as to cover all other legs. ······ 3

Basis of 6th pereiopod so dilate as to cover almost all other legs. ······ 4

3. Rear margins of carpus and propodus in both gnathopods with serration. ································ Fam. Brachyscelidae

Rear margins of carpus and propodus in both gnathopods without serration. ································ Fam. Lycaeidae

4. Telson not coagulated with urus. ················· Fam. Pronoidae

Telson coagulated with urus. ····························· 5

5. Distal several articles in both gnathopods chelate or prehensile. Both gnathopods simple. ································ Fam. Typhidae (Platyscelidae)

## III. The species and their distribution

Among the specimens collected in the five surveyed regions of the Indian Ocean, the author identified the below-mentioned 30 species belonging to 18 genera of 11 families of suborder Hyperiidea. Besides, he found each one species of the genera *Vibilia, Phronima, Hyperia* and *Oxycephalus,* two of the genus *Phronimella* and one species of the family Hyperiidae, but it was hard to identify them with the present author's knowledge of classification.

| Family | Genus | Species | Remarks |
|---|---|---|---|
| Scinidae | *Scina* | *borealis* G. O. SARS | Fig. 32 |
| | | *crassicornis* (FABR.) | Fig. 33 |
| Vibilidae | *Vibilia* | *jeangerdi* BOVALLIUS | Fig. 34 |
| | | *viator* STEBBING | |
| | | *armata* BOVALLIUS | Fig. 35 |
| | | sp. | Fig. 36 |
| Paraphronimidae | *Paraphronima* | *gracilis* CLAUS | Fig. 37 |
| | | *crassipes* CLAUS | |
| Phronimidae | *Phronima* | *stebbingi* VOSSELER | Fig. 38 |
| | | *atlantica* GUERIN | Fig. 39 |
| | | *sedentaria* (FORSK) | |
| | | *colletti* BOVALLIUS | |
| | | sp. | |
| | *Phronimella* | *elongata* CLAUS | Fig. 40 |
| | | sp. A | Fig. 41 |
| | | sp. B | Fig. 42 |
| Hyperiidae | *Hyperia* | *galba* (MONTAGU) | Fig. 43 |
| | | *schizogeneios* STEBBING | Fig. 44 |
| | | *latissima* BOVALLIUS | Fig. 45 |
| | | sp. | Fig. 46 |
| | *Phronimopsis* | *spinifera* CLAUS | |
| | *Temisto* | *gracilipes* NORMAN | Fig. 47 |
| | Gen. A | | Fig. 48 |
| Phrosinidae | *Phrosina* | *semilunata* RISSO | |
| | *Euprimno* | *macropus* GUERIN | Fig. 49 |
| | *Anchylomera* | *blossevillei* MILNE-EDWARDS | Fig. 50 |
| Platyscelidae | *Platyscelus* | *serratulus* STEBBING | Fig. 51 |
| | | *ovoides* (RISSO) | Fig. 52 |
| Scelidae | *Parascelus* | *zebu* T. R. R. STEBBING | |
| | | *typhoides* CLAUS | |
| Phronoidae | *Eupronoe* | *minuta* CLAUS | Fig. 53 |
| Lycaeidae | *Brachyscelus* | *crusculum* SP. BATE | Fig. 54 |

| | | | |
|---|---|---|---|
| Oxycephalidae | *Oxycephalus* | *porcellus* CLAUS | Fig. 55 |
| | | sp. | Fig. 56 |
| | *Rhabdosoma* | *brevicaudatum* T. R. R. STEBB. | Fig. 57 |
| | | *armatus* (MILNE-EDWARDS) | Fig. 58 |
| | *Leptocotis* | *ambobus* T. R. R. STEBBING | Fig. 59 |

The distribution of these species in the five surveyed regions of the Indian Ocean is summarized in Table 34. The outline of their occurrence in respective waters was as follows:

i) The waters west of the Greater Sunda Islands

There occurred 8 speices, in which *Hyperia galba* and *H. schizogeneios* were abundant; especially the latter one was very abundant in the waters south of the Nicobar Islands perhaps forming a large patch.

ii) The waters central part of the North Indian Ocean

There occurred 13 species. Among them, *Eupronoe minuta* was fairly abundant in this water, but did not occur in other waters. *Hyperia galba* and *Anchylomera blossevillei* were the species occurred most abundantly next to the preceding species.

Table 34. Occurrence of the Hyperiidea in the five surveyed waters of the Indian Ocean.

| Region | The waters west of the Greater Sunda Islands |||||||||||| The waters central part of the North Indian Ocean ||||||||||||||||||||||| The waters southeastern part of the Arabian Sea |||||||||||||||||
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species / Station |1|2|3|4|5|6|7|8|9|10|11|12|13|17|18|19|20|21|22|23|24|25|26|33|34|35|36|37|38|39|40|41|42|45|46|47|48|1|2|3|4|5|6|7|8|9|10|11|12|13|14|15|16|17|18|
| *Scina borealis* |||||||||||||||||||||||||||||||||||||||||||1||1||||||||||
| *S. carassicornis* |||||||||||||||||||||||||||||||||||||||||||||||||||||||||
| *Vibilia jeangerardi* |||||||||||||||||||||||||||||||||||||||||||||||||||||||||
| *V. viator* |||||||||||||||||||||||||||||||||||||||||||||||||||||||||
| *V. armata* |||||||||||||||||||||||||||||||||||||||||||||||||||||||||
| *V.* sp. ||||||||||||||||||||||||||1||4|||||||||||||||||||||||||||||
| *Paraphronima gracilis* |||||||||||||||||||||||||||||||||||||||||||||||||||||||||
| *P. carassipes* |||||||||||||||||||||||||||||||||||||||||||||1|1|||||||||
| *Phronima stebbingi* |||||||||||||||||||||||||||||||||||||||||||||||||||||||||
| *P. atlantica* |||||||||||||||||||||||||||||||||||||||||||||||||||||||||
| *P. sedentaria* |||||||||||||||||||||||||||||||||||||||||||||||||||||||||
| *P. colletti* ||||1|||||||||||||||||||||||||||||||||||||3||||||1||||||||||
| *P.* sp. |||||||||||||||||||||||||||||||||||||||||||||||||||||||||
| *Phronimella elongata* ||1||||||1|||1|||||||||||||||||||||||||||||||||||||||||||1||||||
| *P.* sp. A |||||||||||1|||||||||||||||||||||||||||||||||||||||||||||
| *P.* sp. B |||||||||||||||||||||||||||||||||||||||||||||||||||||||||
| *Hyperia galba* |1||||1|1|||2|1|1||1||||||||||2||1|||2||||||||||||1||1|1|2|2|2|2|1|||1|1|1||||
| *H. schizogeneios* |6|||||1||||||1||||||1||||1||||||||||||||||||||||1|1||1||||2|1|||1|
| *H. latissima* |||||||||||||||||||||1|||||||||||||||||||1|||||||||||||1||
| *H.* sp. |||||||||||||||||||||||||||||||||||||||||||||||||||||||||
| *Phronimopsis spinifera* |||||||||||||||||||||||||||||||||||||||||||||||||||||||||
| *Temist gracilipes* |1|||||||||||||||||||||||||||1||||||||||||||||||||||||||||
| Gen. A |||||||||||||||||||||||||||||||||||||||||||||||||||||||||
| *Phrosina semilunata* |||||||||||||||||||||||||||||1||||||||1|1|||||||1||||1|2|1|||
| *Euprimno macropus* |||||||||||||||||||||||||||||1|1|||||||1||||||||1|1|1|||1||||
| *Anchylomera blossevillei* |||||||||||||||||||2||1|||||||1||||||||||||||||||||||||||||
| *Platyscelus serratulus* ||||||||1||||||||||||||1|||||1|||||||||||||2|1||1||||||||||2|1|1|||
| *P. ovoides* |||||||||||||||||||||1|||||||||||||||||||||||||||||||||||
| *Parascelus zebu* ||||||||||1||1||||||||||||||||||||||||||||||||||||||||||||
| *P. typhoides* ||||||||||||||||||||||||1||1|||||||||||||||||1||1|||||||||||
| *Eupronoe minuta* |||||||||||||||||||||1||||1|3|1|2|1|||||||||||||||||||||||||||
| *Brachyscelus crusculum* |||||||||||||||||||||1|||||||||||||||||||||||||||||||||||
| *Oxycephalus porcellus* ||||||||||||||||||||||||||||||||||||||||||||||||||||||1|
| *O.* sp. |||||||||||||||||||||||||||||||||||||||||||||||||||||||||
| *Rhabdosoma brevicaudatum* |||||||||||||||||||||||||||||||||||||||||||||||||||||||||
| *R. armatus* |||||||||||||||||||||||||||||||||||||||||||||||||||||||||
| *Leptocotis ambobus* ||||||||||||||||||||||||||||||||||||||||||||1|||||||||||
| *Neohala* sp. ? (Gammaridea) |1||1||||||||1|||||1|||1||||4|||||1||1||||||||||||||||||||2|||1|||||||

iii) The waters southeastern part of the Arabian Sea

There occurred 12 species, among which *Hyperia galba*, *H. schizogeneios*, *Phrosina semilunata*, *Platyscelus serratulus* and *Euprimno macropus* were abundant. Besides, *Paraphronima crassipes* exclusively occurred in this water, although this was very rare even in this region.

iv) The waters eastern part of the Indian Ocean

This was the water in which the Hyperiidea fauna was richest of all the surveyed waters, and the author detected as much as 30 species. And the abundant species were *Phronima stebbingi*, *Hyperia galba*, *H. schizogeneios* and *Parascelus zebu;* and most of them occurred all over the stations.

v) The Bay of Bengal

There occurred 7 species, among which *Hyperia galba*, *H. schizogeneios*, *H. latissima* and *Themisto gracilipes* were observed less abundantly (the last species exclusively observed in the northern part of the bay). But it was very hard to observe in this water any specimen of Phronimidae and Vibilidae though they were observed in the other waters.

|The waters eastern part of the Indian Ocean| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |The Bay of Bengal| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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|1|1|14|1| | |1| | | | | | |7|4|5| |2|1|2| | |2| | | | |1|2| |1| |1| | | | | | |1| |1|3| | | | | | | | | | | | | | |1| |1|1| | |
| | | |1| | | | | | | | | |3| | | |1| | | | |1| | | | |1| | | | |1| | | | | | | | | | | | | |1| |1| | | | | | |1|2| |1| | | | |
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| | |6|3|7| |4|1| |2|5|1|1|1| |5| |1|1|4|1| |2|1|5| |3|2|2|1|1|1|1| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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Generally speaking, the above-mentioned species appear to have the following characteristics: Most of the specimens collected from the Indian Ocean were arranged in the body lengths between 3 mm and 10 mm, although there were some exceptions as those found in *Phronima atlantica* (18 mm), *Rabdosoma brevicaudatum* (53 mm in total length) and *Platyscelus serratulus* (29 mm). Their bodies are usually colorless and pellucid while they have some reddish, purplish or yellowish pigments in their eyes or appendages.

The amount of the Hyperiidae of the Indian Ocean was poor except the eastern part; the highest amount per haul of the Hyperiidae proved to be only 46 specimens. It shows us that the Hyperiidae are rather poor in the Indian Ocean and are of minor importance in the constituent of plankton communities in this ocean.

On the other hand, the adequate attention should be paid to the facts that a lot of *Platyscelus serratulus* were found in the stomach of *Alepisaurus borealis* caught by the tuna longline from the depth about 150 m, and that more individuals of the same species were collected at night than in the daytime; these facts may suggest that Hyperiidea prefers deeper layer in the daytime.

## IV. Description on the species

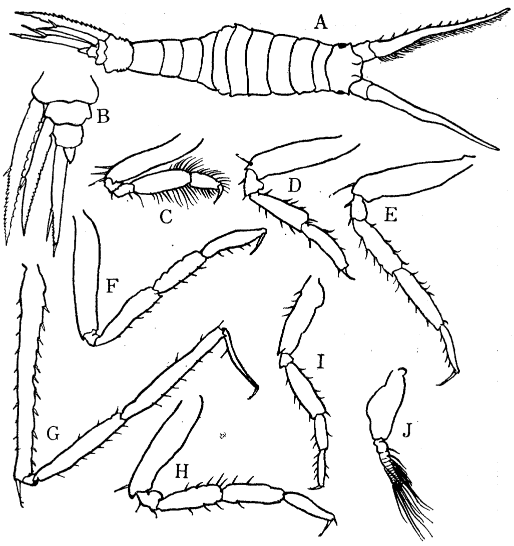


Fig. 32. *Scina borealis* G.O. SARS.
A : Dorsal view B : Urosome
C : Gnathopod 1 D : G. 2
E : Pereiopod 3 F : Pereiopod 4
G : P. 5 H : P. 6
I : P. 7 J : Pleopod

Family Scinidae

Genus *Scina* PRESTANDREA

*Scina borealis* G. O. SARS Fig. 32

G. O. SARS 1895, Ed. CHEVREUX & L. FAGE 1925, H. IRIE 1957.

1st antenna nearly as long as a half of body length (from rostrum to posterior end of urosom). 7th pereiopod a little shorter than a half of 5th pereiopod in length. Basis of 5th pereiopod a little shorter than a half of total length of 5th pereiopod, and upper and lower margins of basis serrated.

Length : 4~9 mm

Distribution : This species has been recorded from the North Pacific, North Atlantic and Mediterranean Sea, and found by the author from the eastern part of the Indian Ocean and Arabian Sea.

*Scina crassicornis* (FABR.) Fig. 33

*Tyro sarsi* BOVAL. 1885, *Scina Edwardsi* FARB. 1896, *Scina crassicornis* Ed. CHEVREUX & L. FAGE 1925.

1st antenna nearly as long as body. 7th pereiopod far longer than a half of 6th pereiopod in length. Basis of 5th pereiopod longer than a third of pereiopod, basis serrated only on its lower margin.

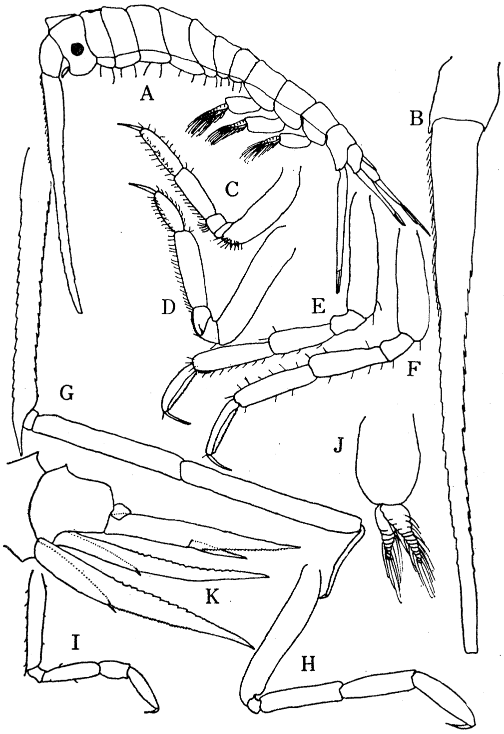


Fig. 33. *Scina drassicornis* (FABR.).
A : Lateral view B : Antenna 1
C : Gnathopod 1 D : Gnathopod 2
E : Pereiopod 3 F : Pereiopod 4
G : P. 5 H : P. 6
I : P. 7 J : Pleopod
K : Urosome

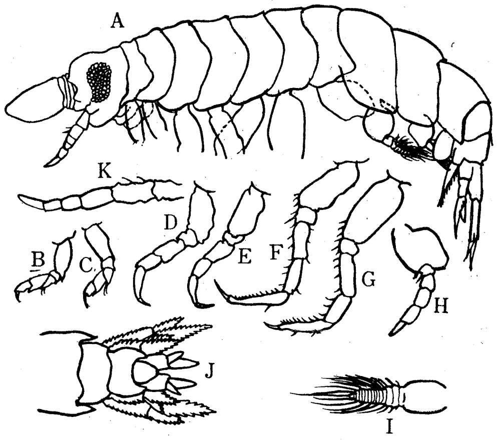


Fig. 34. *Vibilia jeangerardi* BOVAL.
A : Lateral view B : Gnathopod 1
C : G. 2 D : Pereiopod 3
E : P. 4 F : P. 5
G : P. 6 H : P. 7
I : Pleopod (dorsal view)
J : Urosome (dorsal view)

Length : 7～15 mm

Distribution : This species has been reported from the Atlantic and Mediterranean Sea, and found by the author from the eastern part of the Indian Ocean.

Family Vibiliidae

Genus *Vibilia* MILNE-EDWARDS

*Vibilia jeangerdi* BOVAL. Fig. 34

BOVAL. 1887, Ed. CHEVREUX 1900, Ed. CHEVREUX & L. FAGE 1925.

Posterior end of ischium of 1st gnathopod not pointed. Anterior margin of palm of 2nd gnathopod flattened without any articles. Dactylus and inner margin of propodus of 1st gnathopod and inner margin of dactylus of 2nd gnathopod have small serrations. Distal end of outer margin of 1st segment of urosome pointed. Distal ends of 1st and 3rd uropods end with the same position. Telson oval.

Length : 8~10 mm

Distribution : This species has been reported from the Atlantic and Mediterranean Sea and found by the author from the eastern part of the Indian Ocean.

*Vibilia armata* BOVAL. Fig. 35

*V. gracilis* BOVAL., *V. gracilenta* BOVAL., *V. armata* BOVAL 1887, Ed. CHEVREUX 1892, Ed. CHEVREUX & L. FAGE 1925.

Dactylus of 1st gnathopod and propodus have inner margines with fine serrations, and propodus has 3 setae on its inner margin; and palm has a spine at the distal end of outer margin and 2 setae on inner margin. Basis, ischium and carpus have some setae respectively at distal end of their inner margins. To 2nd gnathopod, elongated palm with serration on both sides and propodus with serration on both sides and propodus with serrated inside form chela. Frontal end of 1st antenna tongue-shaped when compared with any other species of this genus. 3rd urosome has rounded processes on outside of posterior margin. Telson conical. Pereiopods have the inside with fine serration. Basis of 6th pereiopod has 3 spines near distal end of inner margin.

Length : 6~10 mm

Distribution : This species has been recorded from the Atlantic, Pacific and Indian Oceans.

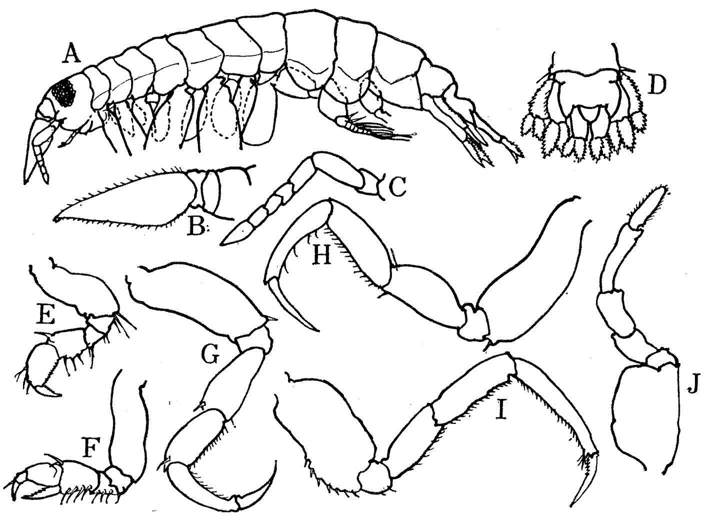


Fig. 35. *Vibilia armata* BOVAL.

A : Lateral view B : Antenna 1 C : A. 2
D : Urosome (dorsal view) E : Gnathopod 1 F : G. 2
G : Pereiopod 3 H : P. 4 I : P. 5
J : P. 7

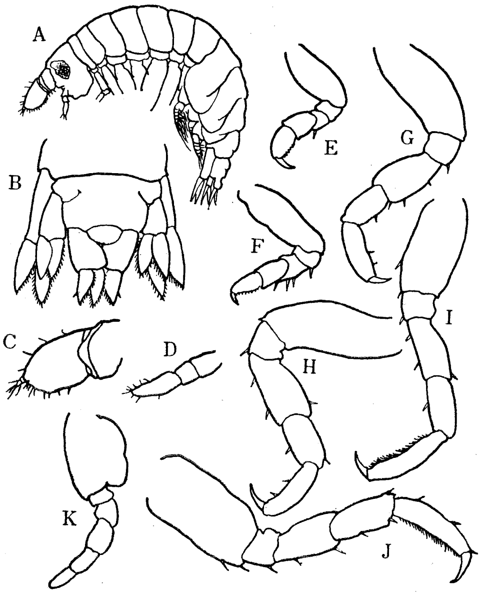


Fig. 36. *Vibilia* sp.
A : Lateral view B : Urosome
C : Antenna 1 D : A. 2
E : Gnathopod 1 F : G. 2
G : Pereiopod 3 H : P. 4
I : P. 5 J : P. 6
K : P. 7

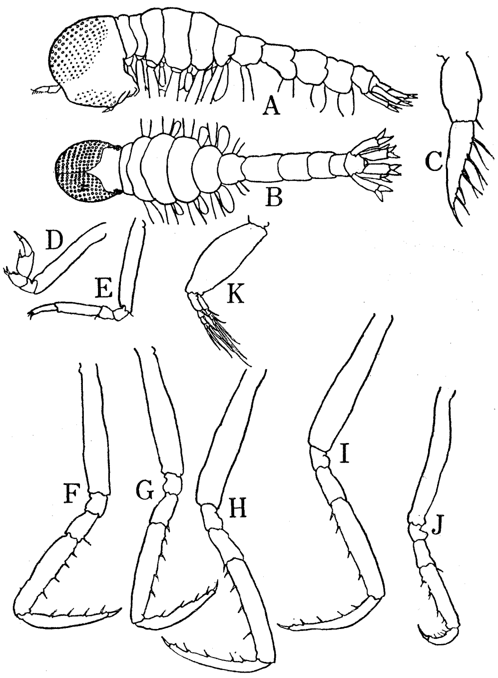


Fig. 37. *Paraphronima gracilis* CLAUS
Male.
A : Lateral view B : Dorsal view
C : Antenna D : Gnathopod 1
E : G. 2 F : Pereiopod 3
G : P. 4 H : P. 5
I : P. 6 J : P. 7
K : Pleopod

Family Paraphronimidae
Genus *Paraphronima* CLAUS
*Paraphronima gracilis* CLAUS Fig. 37
BOVALLIUS 1887, *P. Edwardsi* BOVAL. 1885, *P. cuivis* STEBBING 1888, *P. gracilis* H. IRIE 1957.

Male : Height of head superior to its length. Pereiopods have many fine setae on their marginal parts. 7th pereiopod remarkably shorter than 6th one. Positions of distal ends of uropods arranged 3—2—1 from anterior to posterior.

Length : 11 mm

Distribution : This species has been recorded from the temperate and tropical waters of the Atlantic, Pacific and Indian Oceans and Mediterranean Sea.

## Family Phronimidae

Key to Genera

Both body and appendages neither so flexible nor so elongated. Frontal 2 segments of mesosome not coagulated. Anterior margin of each segment of 5th pereiopod smooth. 2nd uropod not degenerated. ........................................................ Genus *Phronima*
Both body and appendages flexible and elongated. Frontal 2 segments of mesosome coagulated. Coarse serration on anterior margin of each segment of 5th pereiopod. 2nd uropod degenerated to bud-shaped. .................................... Genus *Phronimella*

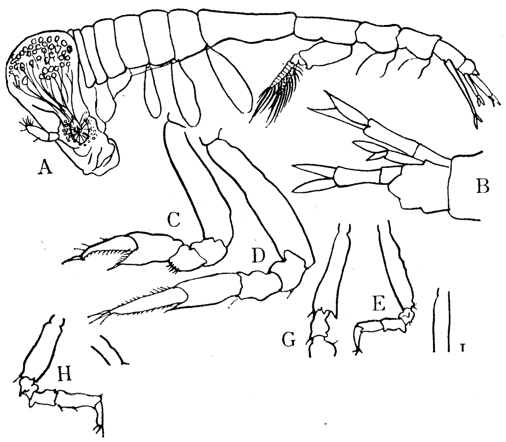


Fig. 38. *Phronima stebbingi* VOSSELER, female.
A : Lateral view
B : Urosome (dorsal view)
C : Gnathopod 1 D : G. 2
E : Pereiopod 3 F : P. 4
G : P. 5 H : P. 6
I : P. 7

Genus *Phronima* LATREILLE

*Phronima stebbingi* VOSSELER 1901 Fig. 38

*P. pacifica* STEBB. 1888, VOVAL. 1889, *P. stebbingi* Ed. CHEVREUX & L. FAGE 1926, H. IRIE 1957.

This species occurs, as *Phronima pacifica*, commonly in the temperate and tropical waters of the Pacific Ocean. 2nd uropod very short and very fine, when compared with 1st and 3rd ones; its interior branch shorter than a half of exterior one. In male, 2nd antenna well-developed. In female, posterior margin of epimeral plate not pointed.
Length : 5~9 mm
Distribution : This species has been recorded from the subtropical waters of the Pacific and Atlantic Oceans.

*Phronima atlantica* GUERIN Figs. 39-A and 39-B

VOSSELER 1901, *P. solitaria* GUERIN 1837, *P. sederia* CLAUS 1872, CHUN 1895, *P. atlantica* H. IRIE 1957.

Female : Posterior margin of epimeral plate not pointed. Carpus of 5th pereiopod shorter than its basis; its anterior margin of palm nearly horizontal; solid angle not so extensile; palm has furcate rami at ventral part; its height nearly the same position as solid angle. Central part of anterior margin of propodus a little thickned, but not dilate.
Male : 2nd antenna well-developed. Propodus of 5th pereiopod far longer than frontal end of this palm. To 2nd uropod, none noteworthy.
Length : about 9 mm in male, 10~20 mm in female.
Distribution : This species has been recorded from the Pacific, Atlantic Oceans, China Sea and Mediterranean Sea.

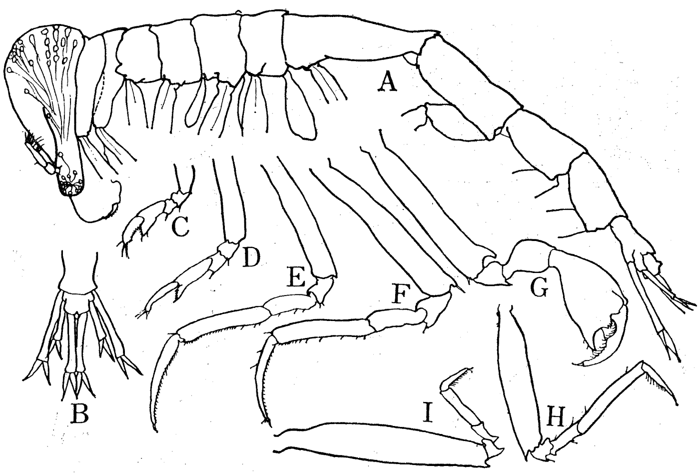


Fig. 39—A. *Phronima atlantica* GUERIN, female.
A : Lateral view B : Urosome (dorsal view)
C : Gnathopod 1 D : G. 2 E : Pereiopod 3
F : P. 4 G : P. 5 H : P. 6
I : P. 7

Genus *Phronimella* CLAUS

*Phronimella elongata* CLAUS

Figs. 40-A & 40-B

VOSSELER 1901, Ed. CHEVREUX & L. FAGE 1925, H. IRIE 1957.

Both body and appendages flexible and elongated. Anterior 2 segments of mesosome coagulated. 5th pereiopod has coarse serration on the anterior margin of each segment. 2nd uropod of female degenerated to bud-shaped. That of male very small and short, when compared with any other species of this genus.
Length : 6.0~8.0 mm in male, 11.0~11.5 mm in female.
Distribution : This species has been recorded from the Pacific Ocean and Mediterranean Sea.

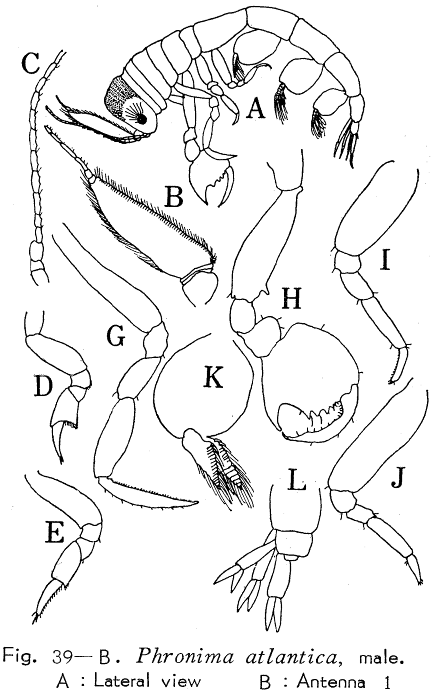


Fig. 39—B. *Phronima atlantica*, male.
A : Lateral view B : Antenna 1
C : A. 2 D : Gnathopod 1
E : G. 2 G : Pereiopod 4
H : P. 5 I : P. 6
J : P. 7 K : Pleopod
L : Urosome (dorsal view)

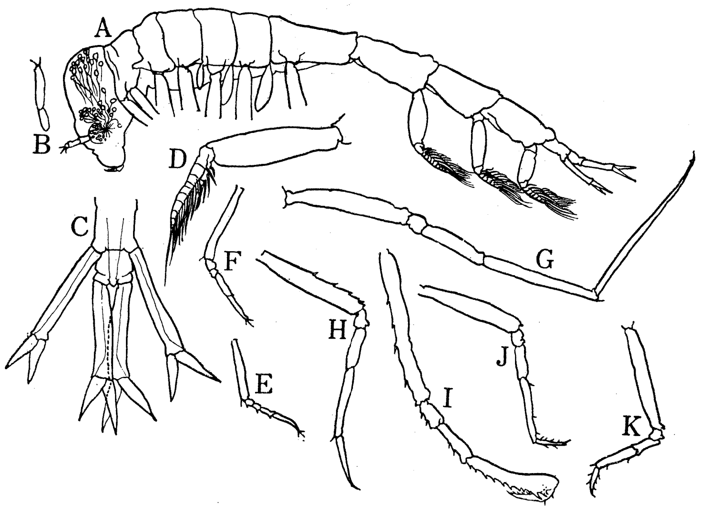


Fig. 40—A. *Phronimella elongata* CLAUS, female.

| | | |
|---|---|---|
| A : Lateral view | B : Antenna | C : Urosome (dorsal view) |
| D : Pleopod | E : Gnathopod 1 | F : G. 2 |
| G : Pereiopod 3 | H : P. 4 | I : P. 5 |
| J : P. 6 | K : P. 7 | |

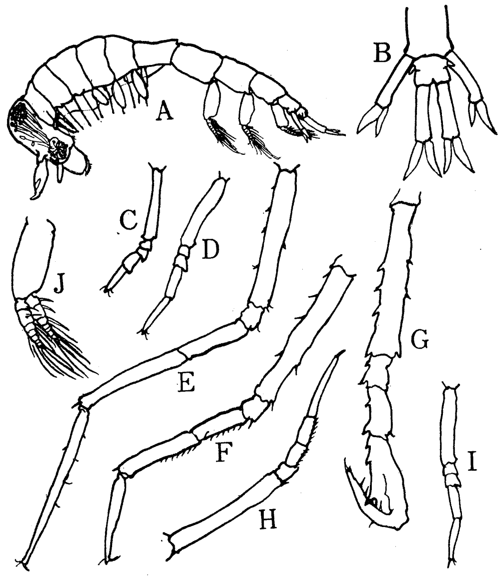


Fig. 40—B. *Phronimella elongata*, male.

| | |
|---|---|
| A : Lateral view | |
| B : Urosome (dorsal view) | |
| C : Gnathopod 1 | D : G. 2 |
| E : Pereiopod 3 | F : P. 4 |
| G : P. 5 | H : P. 6 |
| I : P. 7 | J : Pleopod |

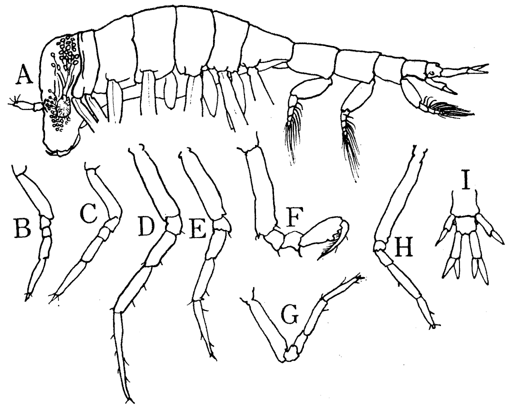


Fig. 41. *Phronimella* sp. A.

| | |
|---|---|
| A : Lateral view | B : Gnathopod 1 |
| C : G. 2 | D : Pereiopod 3 |
| E : P. 4 | F : P. 5 |
| G : P. 6 | H : P. 7 |
| I : Urosome (dorsal view) | |

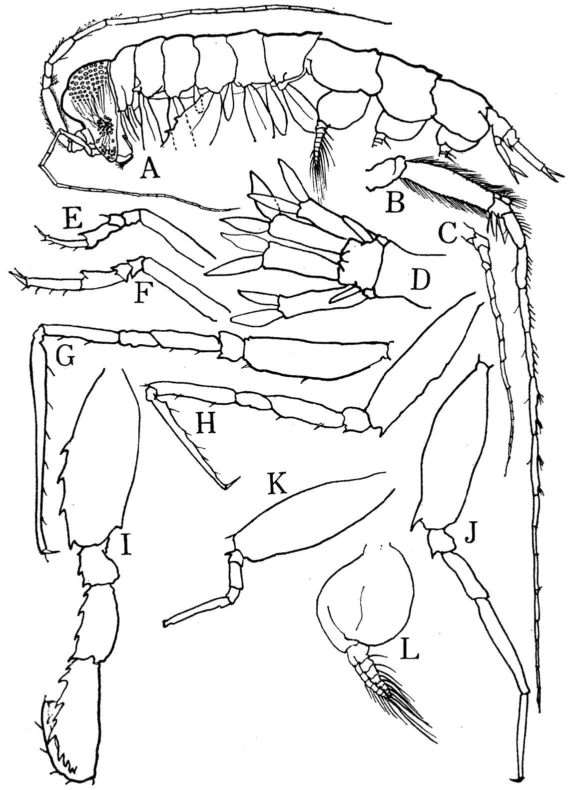


Fig. 42. *Phronimella* sp. B.

| | |
|---|---|
| A : Lateral view | B : Antenna 1 |
| C : A. 2 | D : Urosome (dorsal view) |
| E : Gnathopod 1 | F : G. 2 |
| G : Pereiopod 3 | H : P. 4 |
| I : P. 5 | J : P. 6 |
| K : P. 7 | L : Pleopod |

**Family Hyperiidae**

Key to Genera

1. The 1st gnathopod simple in form. Propodus and dactylus of 2nd gnathopod form chela. ········ Genus *Phronimopsis*
   Posterior margin of gnathopods exserted forwards. ········ 2
2. Carpuses of 3rd and 4th pereiopods dilate. ········ Genus *Themisto*
   Carpuses of 3rd and 4th pereiopods not dilate. ········ 3
3. Distal ends of posterior margins of gnathopods a little elongated forwards and spoon-shaped, but posterior margins of carpus of 3rd and 4th pereiopods not especially dilate. ········ Genus *Hyperia*
   Posterior margins of gnathopods elongated, propodus and dactylus form chela,

Posterior margins of 3rd and 4th pereiopods exserted. ............... Genus *Hyperoche*

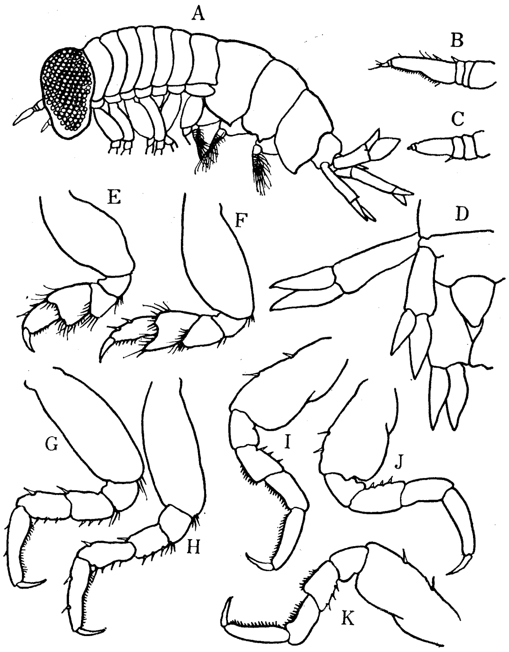


Fig. 43. *Hyperia galba* (MONTAGU), female.
A : Lateral view B : Antenna 1
C : A. 2 D : Urosome
E : Gnathopod 1 F : G. 2
G : Pereiopod 3 H : P. 4
I : P. 5 J : P. 6
K : P. 7

Genus *Hyperia* LATREILLE

*Hyperia galba* (MONTAGU) Fig. 43

*H. galba* G. O. SARS 1895, *H. Latreilli* M. EDW., *H. medusarum* BOECH, O. F. MULLER, *H. spinigera* BOVAL., *H. gabla* Ed. CHEVREUX & L. FAGE 1925, H. IRIE 1957.

Head relatively small and not exserted vento-laterally. Anterior margin of basis of 1st gnathopod not dilate. Each segment of mesosome distinguishable clearly. Segments at distal end of gnathopods have many setae.

Length : 12~14 mm in female, 12~13 mm in male.

Distribution : This species has been recorded from the Baltic Sea, Pacific, Atlantic and Indian Oceans.

*Hyperia schizogeneios* STEBBING Fig. 44

STEPHENSEN 1888, BOVAL. 1889, Ed. CHEVREUX 1900, STEPHENSEN 1924, *H. promontorii* STEBBING 1888, *H. schizogeneios* Ed. CHEVREUX & L. FAGE 1925.

Head relatively large and longer than the anterior 3 segments of mesosome. And head exserted vento-laterally. In female, 3 segments of mesosome coagulated. Anterior margin of basis of 1st gnathopod dilate remarkably. A few setae on the segments at distal parts of gnathopods and a seta on anterior margin of propodus.

Length : 2~4 mm in female, 2~4 mm in male.

Distribution : This species has been recorded from the Mediterranean Sea, Pacific and Atlantic Oceans.

*Hyperia latissima* BOVALLIUS Fig. 45

BOVALLIUS 1889, *H. hydrocephala* VOSSELER 1901, STEUER 1911, *H. macrophthalma* VOSSELER 1901, STEPHENSEN 1924, *H. latissima* Ed. CHEVREUX & L. FAGE 1925, H. IRIE 1957.

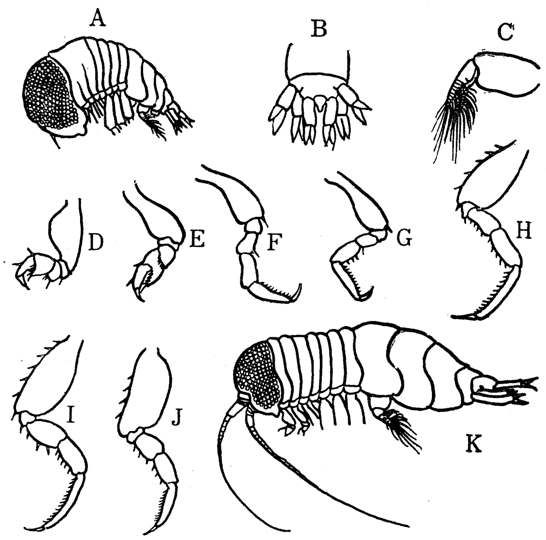


Fig. 44. *Hyperia schizogeneios* STEBBING, female.

A : Lateral view B : Urosome
C : Pleopod D : Gnathopod 1
E : G. 2 F : Pereiopod 3
G : P. 4 H : P. 5
I : P. 6 J : P. 7
K : Lateral view of male

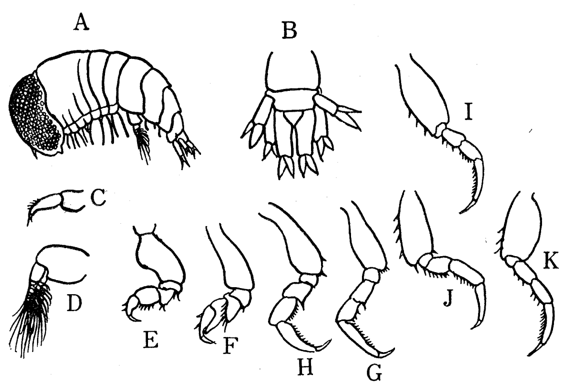


Fig. 45. *Hyperia latissima* BOVALLIUS, female.

A : Lateral view B : Urosome (dorsal view)
C : Antenna D : Pleopod
E : Gnathopod 1 F : G. 2
G : Pereiopod 3 H : P. 4
I : P. 5 J : P. 6
K : P. 7

Head relatively large and exserted vento-laterally. Anterior margin of basis of 1st gnathopod a little extensile. A few setae on segments at distal parts of gnathopods, and 2 setae on anterior margin of propodus. In female, 4~5 segments of anterior part of mesosome coagulated.
Length : 2~3 mm in female, 2~4 mm in male.
Distribution : This species has been recorded from the Mediterranean Sea, Pacific, Atlantic and Indian Oceans.

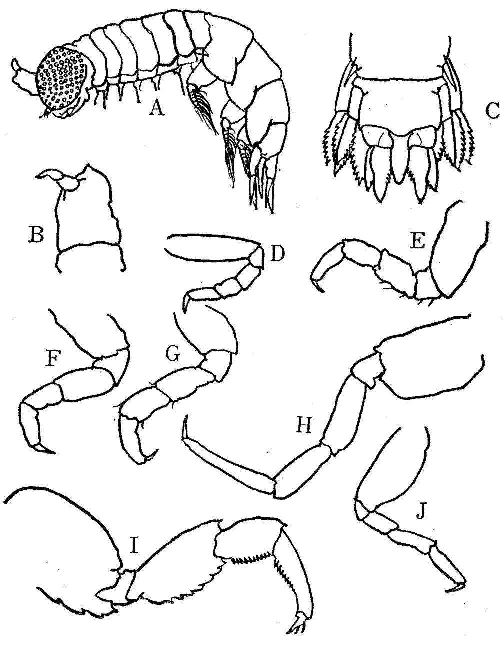


Fig. 46. *Hyperia* sp.
A : Lateral view B : Antenna 1
C : Urosome (dorsal vew)
D : Gnathopod 1 E : G. 2
F : Pereiopod 3 G : P. 4
H : P. 5 I : P. 6
J : P. 7

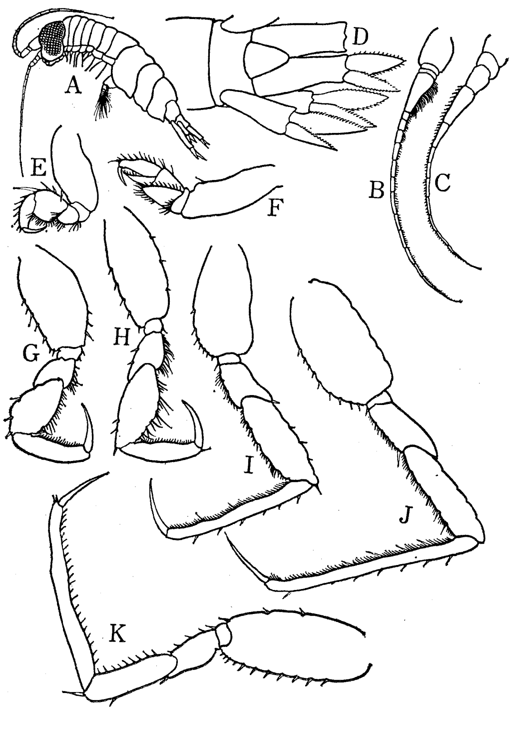


Fig. 47. *Themisto gracilipes* NORMAN, male.
A : Lateral view B : Antenna 1
C : A. 2 D : Urosome
E : Gnathopod 1 F : G. 2
G : Pereiopod 3 H : P. 4
I : P. 5 J : P. 6
K : P. 7

Genus *Themisto* GUERIN

*Themisto gracilipes* NORMAN Fig. 47

H. IRIE 1957.

Carpuses of 3rd and 4th pereiopods a little dilate, and this and anterior segment have many setae on their inner margins. Propodus has a serrated inner margin. Distal 3 segments of gnathopods have many setae either on their inner margin or on outer. Posterior margin of 2nd gnathopod elongated and forms chela with propodus. Distal 3 segments of 5th and 6th pereiopods have dense setae on their inner margins. Dactylus of each pereiopod relatively long.

Length : 4∼10 mm.

Distribution : This species has been recorded from the Pacific Ocean and Japan Sea.

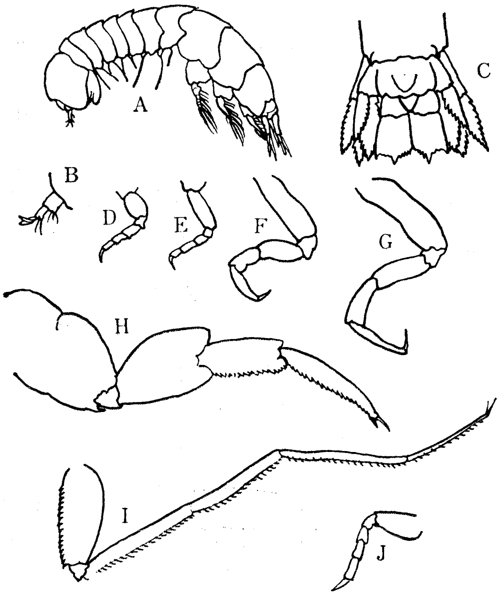


Fig. 48. Fam. Hyperiidae, Gen. A.
A : Lateral view B : Antenna 1
C : Urosome (dorsal view)
D : Gnathopod 1 E : G. 2
F : Pereiopod 3 G : P. 4
H : P. 5 I : P. 6
J : P. 7

**Family Phrosinidae**

Key to Genera

1. Only distal end of basis of 7th pereiopod degenerated. Distal ends of 3rd∼6th pereiopods chelate. Telson triangular. ········· ··············· Genus *Phrosina*

7th pereiopod has finger-shaped appendage being consisted of few segments. ···2

2. With rostrum. Distal end of branch of uropod conical and pointing. ·················· ··················Genus *Euprimno*

Without rostrum. Distal end of branch of uropod round. Telson hemispherical. ········ ···············Genus *Anchylomera*

Genus *Euprimno* BOVALLIUS

*Euprimno macropus* GUERIN Fig. 49

*Primno macropa* STEBBING 1888, BOVALLIUS 1889, VOSSELER 1901, *Euprimno macropus* Ed. CHEVREUX & L. FAGE 1925.

Gnathopods of female rather simple in form and have a fine serration on anterior margin of palm. 2nd gnathopod superior to 1st one in length; especially basis of 2nd

gnathopod dilate. A coarse serration on carpus of 5th and 6th pereiopods.
Length : 5～10 mm.
Distribution : This species has been recorded from the tropical and subtropical waters of the Pacific and the Atlantic Oceans.

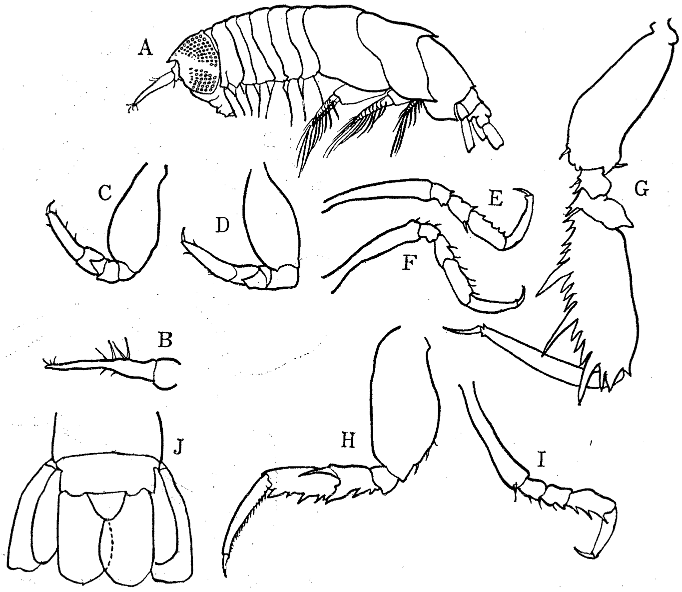


Fig. 49. *Euprimno macropus* GUERIN, female.
A : Lateral view B : Antenna
C : Gnathopod 1 D : G. 2
E : Pereiopod 3 F : P. 4
G : P. 5 H : P. 6
I : P. 7 J : Urosome (dorsal view)

Genus *Ancylomera* MILNE-EDWARDS
*Ancylomera blossevillei* MILNE-EDWARDS Figs. 50-A & 50-B
STEBBING 1888, BOVALLIUS 1889, VOSSELER 1901, Ed. CHEVREUX & L. FAGE 1925, H. IRIE 1957.

Without rostrum. A fine serration on the anterior margin of palm of gnathopods. Propodus of 3rd and 4th pereiopods fine and elongated, with a triangular ramus on their posterior part of the inner margin of carpus. Many setae on the distal end of the outer margin of carpus and propodus. Finger-shaped appendage of 7th pereiopod consists of 5 segments in male and 1～2 ones in female. Telson hemispherical.
Length : 2～8 mm.
Distribution : This species has been recorded from the temperate and tropical waters of the Pacific and Atlantic Oceans.

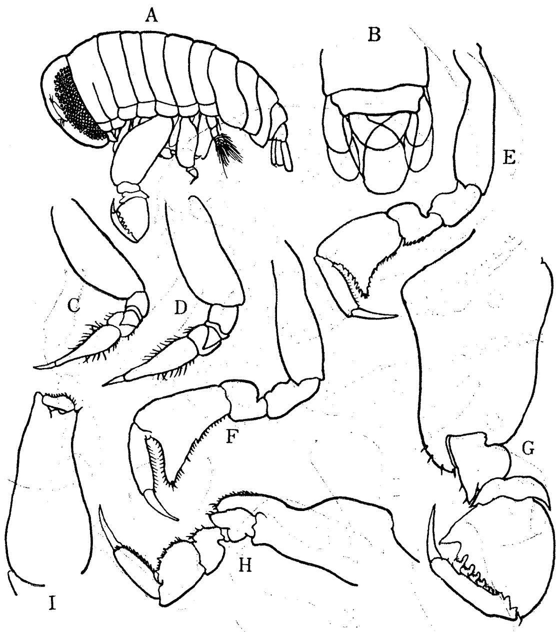


Fig. 50—A. *Anchylomera blossevillei* MILNE-EDWARDS, female.

A : Lateral view  B : Urosome
C : Gnathopod 1  D : G. 2
E : Pereiopod 3  F : P. 4
G : P. 5  H : P. 6
I : P. 7

Family Platyscelidae
Genus *Platyscelus* SP. BATE
*Platyscelus serratulus* STEBBING Fig. 51

STEBBING 1886, *Eutyphis serratus* CLAUS 1887, *Platyscelus serratulus* Ed. CHEVREUX & L. FAGE 1925, H. IRIE 1957.

Posterior margin of gnathopods elongated and form chela together with their propodus. A few setae on the distal 2 segments of gnathopods.
Length : 7~10 mm.

During this study, the author could collect 10 specimens with 25 mm on an average and 29 mm of the largest value.
Distribution : This speies has been recorded from the Atlantic, the Pacific and the Indian Oceans and Mediterranean Sea.

*Platyscelus ovoides* (RISSO) Fig. 52

*Eutyphis ovoides* CLAUS 1887, *Platyscelus ovoides* Ed. CHEVREUX & L. FAGE 1925.

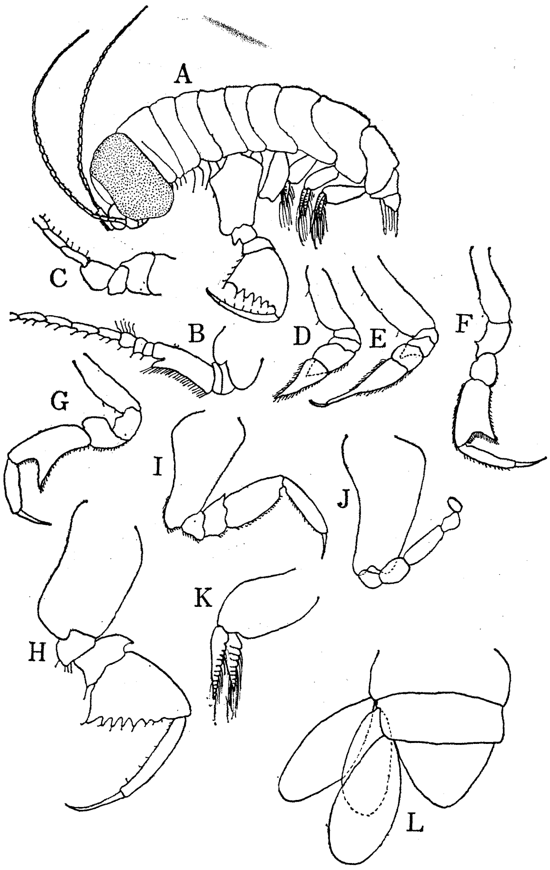


Fig. 50—B. *Anchylomera blossevillei*, male.

| | |
|---|---|
| A : Lateral view | B : Antenna 1 |
| C : A. 2 | D : Gnathopod 1 |
| E : G. 2 | F : Pereiopod 3 |
| G : P. 4 | H : P. 5 |
| I : P. 6 | J : P. 7 |
| K : Pleopod | L : Urosome |

A group of setae on the foremost part of the outer margin of the distal 2 segments of gnathopods, and many setae on the inner margin and the lateral side of them. The spoon-shaped elongation of 7th pereiopod is the most remarkable difference of this species from the above-mentioned one.

Length : 8~11 mm.

Distribution : This species has been reported from the Mediterranean, the Indian and the north part of the Atlantic Ocean.

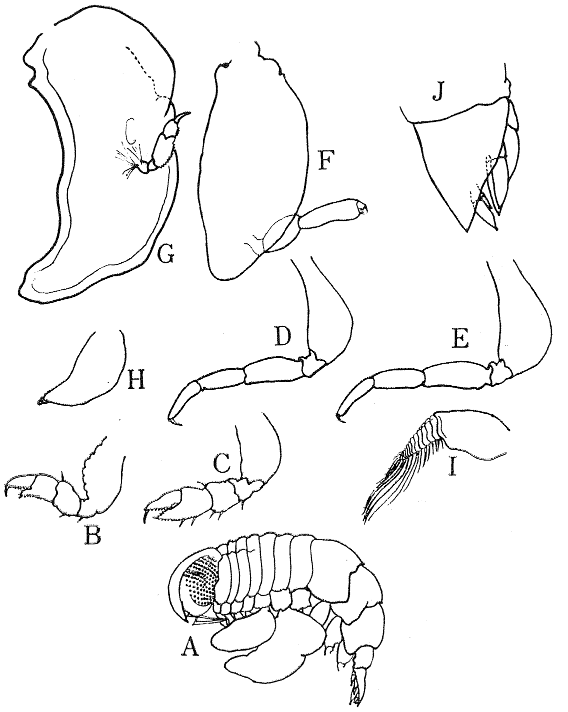


Fig. 51. *Platyscelus serratulus* STEBBING, female.

| | |
|---|---|
| A : Lateral view | B : Gnathopod 1 |
| C : G. 2 | D : Pereiopod 3 |
| E : P. 4 | F : P. 5 |
| G : P. 6 | H : P. 7 |
| I : Pleopod | J : Urosome (dorsal view) |

Family Phronoidae

Genus *Eupronoe* CLAUS

*Eupronoe minut* CLAUS Fig. 53

CLAUS 1887, Ed. CHEVREUX 1913, Ed. CHEVREUX & L. FAGE 1925, H. IRIE 1957.

Head rather conical and pointed towards ventral side. The most distinguishable character of this species is a little tortuos basis of 1st gnathopod. A fine serration on inner margin of its carpus and palm. Propodus of 2nd gnathopod and elongated part of the posterior margin of its palm form serrated chela. The inner margin of distal 2 segments of 5th pereiopod and that of 2～3 segments of finger-shaped appendage of 6th pereiopod serrated. Telson nearly equilaterally triangular.

Length : 3～6 mm.

Distribution : This species has been recorded from the temperate and subtropical waters of the Atlantic, Pacific and the Mediterranean Sea.


Fig. 52. *Platyscelus ovoides* (RISSO), female.

A : Lateral view B : Gnathopod 1
C : G. 2 D : Pereiopod 3
E : P. 4 F : P. 5
G : P. 6 H : P. 7
I : Urosome (dorsal view)

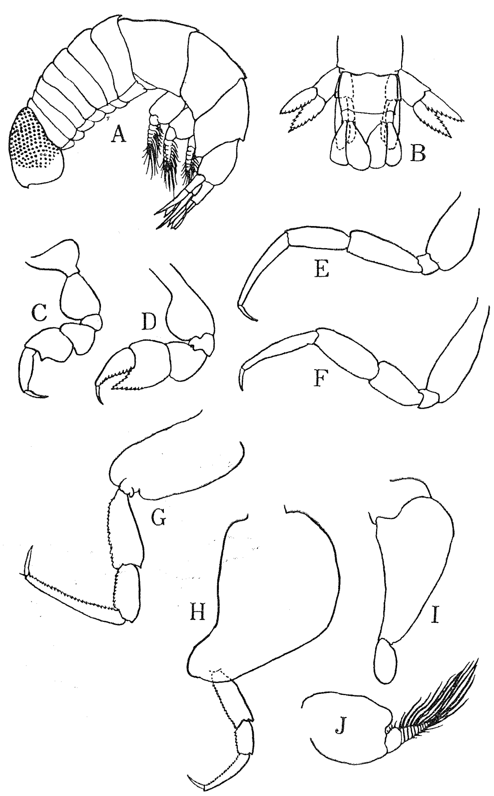


Fig. 53. *Eupronoe minuta* CLAUS, male.

A : Lateral view B : Urosome (dorsal view)
C : Gnathopod 1 D : G. 2
F : Pereiopod 3 F : P. 4
G : P. 5 H : P. 6
I : P. 7 J : Pleopod

Family Lycaeidae

Genus *Brachyscelus* Sp. BATE

*Brachyscelus crusculum* Sp. BATE Fig. 54

STEBBING 1888, Ed. CHEVREUX 1893, *Thamyris mediterraneus* Cl. SENNA 1903, *Brachyscelus crusculus* Ed. CHEVREUX & L. FAGE 1925, H. IRIE 1957.

Palm and propods form a chela with a coarse serration on the inner margin. Fine setae on the posterior margin of palm of 3rd and 4th pereiopods. Serration on the anterior margin of basis of 5th and 6th pereiopods. Positions of distal ends of uropods arranged 3—2—1 from anterior to the posterior. Distal end of telson posterior to that of 3rd uropod in the position.

Length : 4~7 mm

Distribution : This species has been recorded from the Mediterranean Sea, the Atlantic and the Pacific Oceans.

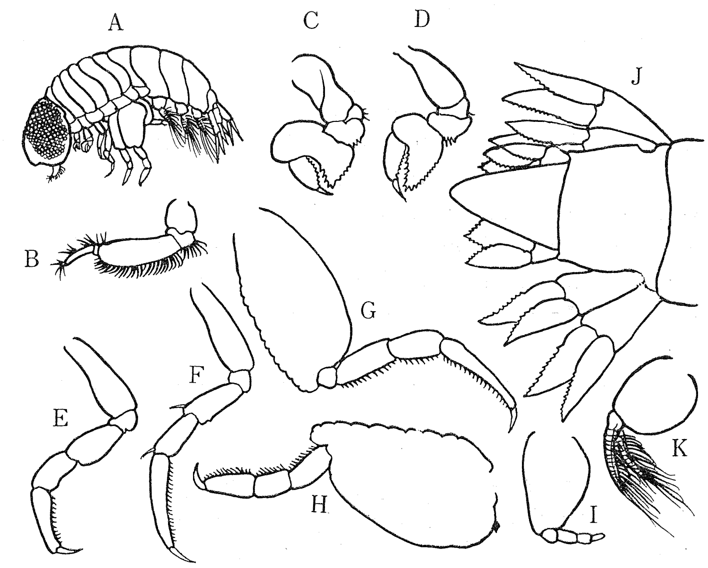


Fig. 54. *Brachyscelus crusculum* Sp. BATE, male.

A : Lateral view B : Antenna 1 C : Gnathopod 1
D : G. 2 E : Pereiopod 3 F : P. 4
G : P. 5 H : P. 6 I : P. 7
J : Urosome K : Pleopod

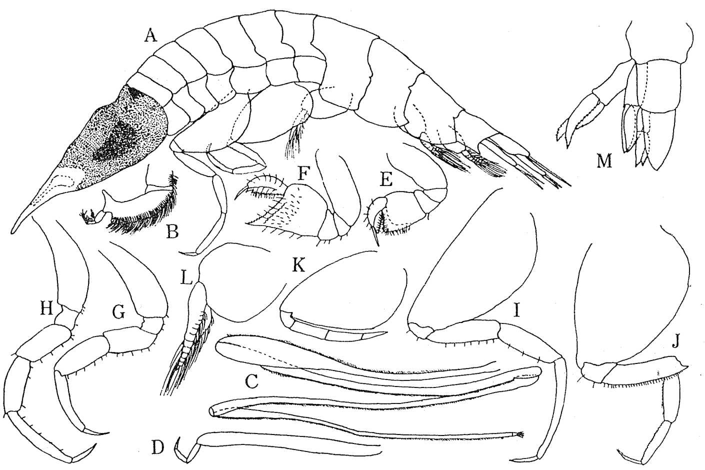


Fig. 55. *Oxycephalus porcellus* CLAUS, male.

A : Lateral view B : Antenna 1 C : A. 2
D : Mandible E : Gnathopod 1 F : G. 2
G : Pereiopod 3 H : P. 4 I : P. 5
J : P. 6 K : P. 7 L : Pleopod 1
M : Uropod

Family Oxycephalidae

Genus *Oxycephalus* MILNE-EDWARDS

*Oxycephalus porcellus* CLAUS Fig. 55

H. IRIE 1957

Cephalosome equal to the anterior 6 segments of mesosome in length. Compound eyes in the posterior half of head. Propodus and palm of gnathopods form chela with fine setae on outside. Basis of 5~7th pereiopods a little dilate. 5th and 6th pereiopods have a serration near the distal end of the outer margin of the basis and have fine setae on the outer margin of the distal segments. Telson slender and conical and its distal end lanceolate. The positions of the distal ends of uropods arranged 3—1—2 from the anterior to the posterior.

Length : 8~20 mm

Distribution : This species has been recorded from the Pacific Ocean.

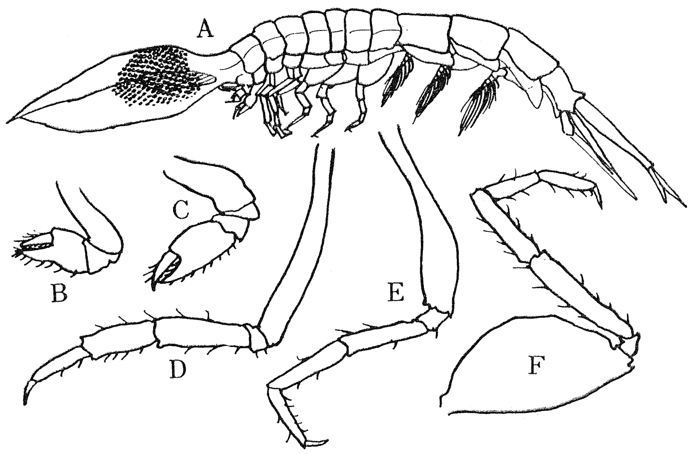


Fig. 56. *Oxycephalus* sp.
A : Lateral view B : Gnathopod 1
C : G. 2 D : Pereiopod 3
E : P. 4 F : P. 5

*Rhabdosoma brevicaudatum* T. R. R. STEBBING Fig. 57

Body remarkably elongated and cylindrical. Rostrum also remarkably long. Neck elongated. 1st antenna in anterior part to eye and on ventral side. 2nd antenna 4-segmented with some appendages and elongated. Propods of gnathopod and elongation of posterior margin of its palm form chela. 7th pereiopod remarkably degenerated. 1st uropod considerably elongated and its exterior branch very long, but interior one very short. Both of branches have a serrated margin. Uropods arranged 1—3—2 from long to short.

Length : About 5.0 mm.

Distribution : This species has been recorded from the tropical and subtropical waters of the Atlantic and Pacific Oceans.

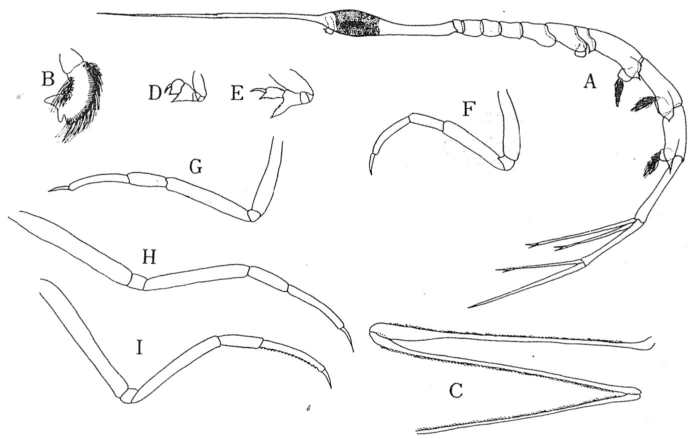


Fig. 57. *Rhabdosoma brevicaudatum* T.R.R. STEBBING.
A : Lateral view B : Antenna 1 C : A. 2
D : Gnathopod 1 E : G. 2 F : Pereiopod 3
G : P. 4 H : P. 5 I : P. 6

*Rhabdosoma armatus* (MILNE-EDWARDS) Fig. 58

The most remarkable difference of this species from the above-mentioned one is the extremely elongated uropods: especially 3rd one is far longer than metasome. The uropods arranged 3—1—2 from long to short.

Length : About 50 mm.

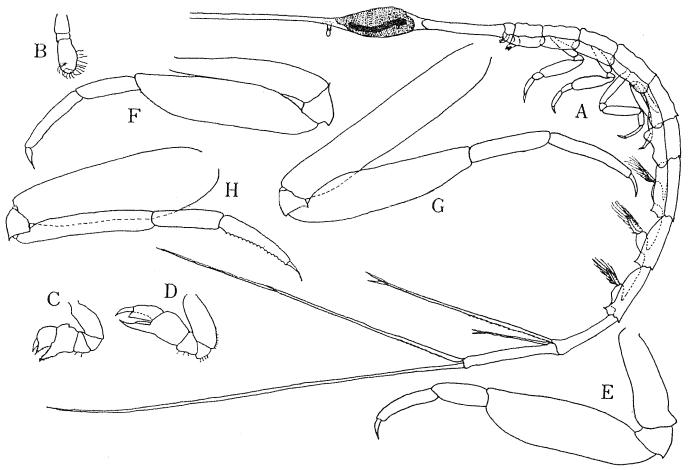


Fig. 58. *Rhabdosoma armatus* (MILNE-EDWARDS), female.
A : Lateral view B : Antenna 1 C : Gnathopod 1
D : G. 2 E : Pereiopod 3 F : P. 4
G : P. 5 H : P. 6

Distribution : This species has been recorded from the temperate and tropical waters of the Pacific Ocean.

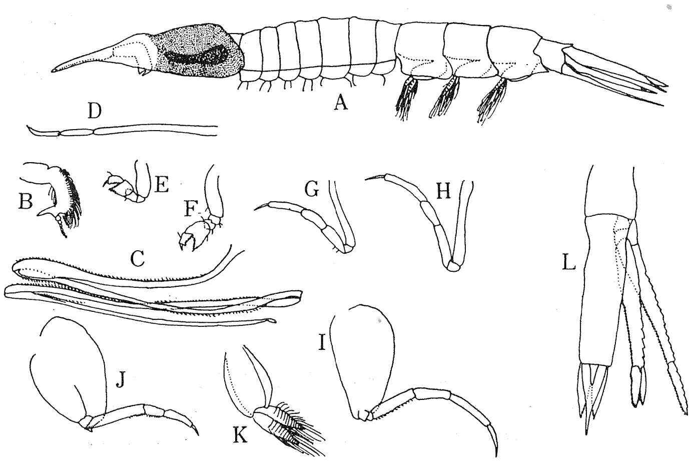


Fig. 59. *Leptocotis ambobus* T.R.R. STEBBING, male.
A : Lateral view B : Antenna 1 C : A. 2
D : Mandible E : Gnathopod 1 F : G. 2
G : Pereiopod 3 H : P. 4 I : P. 5
J : P. 6 K : Pleopod 1 L : Urosome

## Chapter II Chaetognaths

### I. Introduction

The Chaetognatha is a most abundant group of animals next to the Copepoda and occupies a very important position in the plankton constituents of the Indian Ocean.

On the other hand, there are many species of Chaetognatha which are employed as the excellent indicators of the water masses. Therefore, a lot of important suggestions to the marine biological problems will be brought out by the extensive studies on Chaetognatha in the Indian Ocean.

The Chaetognatha in the Indian Ocean was studied by many authors. But most of the samplings were restricted geographically only to the limited waters or were done by the schedule not so well systematized. The Chaetognatha of this ocean has been studied by the following authors: S. T. BURFIELD & E. J. W. HARVEY (1926); S. T. BURFIELD (1927); M. L. FURNESTIN (1958); P. N. GANAPATI & T. S. S. RAO (1954); E. GHIRARDELLI (1948); C. C. JOHN (1933, '37); S. H. LELE and P. B. GAE (1936); T. S. S. RAO (1958); T. S. S. RAO & P. N. GANAPATI (1958); R. von RITTER-ZAHONY (1909 & '11); H. SCHILP (1941); O. STEINHAUS (1896); J. M.

THOMSON (1948); T. TOKIOKA (1952, '55, '56a & '56b). According to TOKIOKA (1962), following species have been found in this ocean by them.

| | |
|---|---|
| *Sagitta hexaptera* | *S. maxima* |
| *S. lyra* | *S. gazellae* |
| *S. enflata* | *S. hispida* |
| *S. bipunctata* | *S. robusta* |
| *S. ferox* | *S. pulchra* |
| *S. bedoti* | *S. serratodentata* |
| *S. tenuis* | *S. neglecta* |
| *S. serratodentata pacifica* | *S. bedfordii* |
| *S. regularis* | *S. minima* |
| *S. bombayensis* | *S. planctonis* |
| *S. decipiens* | *S. macrocephala* |
| *Pterosagitta draco* | *Spadella cephaloptera* |
| *Krohnitta subtilis* | *K. pacifica* |
| *Eukrohnia hamata* | *E. fowleri* |
| *E. richardi* | |

Among the samples collected from the five surveyed waters mentioned in Chapter III, Part I, those from the waters west of the Greater Sunda Islands and from the central part of the North Indian Ocean were offered by the author to Dr. T. TOKIOKA of Seto Marine Biological Laboratory, who is an expert in the study of this group of animals. And the details of the above-mentioned samples were reported by him in 1955 and '56. The author studied on the samples collected from the other three waters, and discussed on the distribution of Chaetognatha in the five surveyed waters.

## II. Material and method

The specimens treated here were found from the samples collected from the southeastern waters of the Arabian Sea, from the eastern part of the Indian Ocean and from Bengal Bay. There were some specimens which were very hard to identify because of the unsuitable fixation and inadvertence during the storage. But most of the specimens were well preserved. And all the measurements of them were made with a calibrated ocular micrometer.

## III. Description on the species

The following 15 species of Chaetognatha were detected in the five surveyed regions in the Indian Ocean:

| | |
|---|---|
| *Sagitta hexaptera* d' ORBIGNY | *S. lyra* KROHN |
| *S. enflata* GRASSI | *S. bipunctata* QUOY et GAIMARD |
| *S. ferox* DONCASTER | *S. robusta* DONCASTER |

| | |
|---|---|
| *S. bedoti* BERANECK | *S. serratodentata* KROHN |
| *S. serratodentata pacifica* TOKIOKA | *S. neglecta* AIDA |
| *S. regularis* AIDA | *S. minima* GRASSI |
| *S. bedfordii* DONCASTER | *Pterosagitta draco* KROHN |
| *Krohnitta substili* GRASSI | *K. pacifica* AIDA |

The outline of the morphological characters of each of the above-mentioned species is as follows:

*Sagitta hexaptera* d' ORBIGNY

Body large and transparent. Tail segment 18~20 per cent of total length of body; hooks 6~8; anterior teeth 3~4, while the posterior teeth 2~3. Anterior fins widely separated from ventral ganglion; narrow and rounded. Posterior fins not joining seminal vesicles. Caudal fin closes to, but not joining, seminal vesicles.
Body length 22~35 mm.

*Sagitta lyra* KROHN

Body large (*ca.* 35 mm), flaccid and opaque. Tail segment 12~14 per cent of total length; hooks 6~8; anterior teeth 4~5; posterior teeth 3~6. Anterior fins remarkably long, and triangle-shaped, reaching ventral ganglion, joining posterior fins. Posterior fins shorter and broader than anterior ones, touching seminal vesicles.

*Sagitta enflata* GRASSI

Body flaccid and transparent; posterior part of head constricted. A marked constriction by tail-septum between trunk and tail. Tail segment 15~18 per cent of total length; hooks 8~9; anterior teeth 5~8; Anterior fins round, removed from ventral ganglion by a distance greater than the length of the fin, narrower than posterior fin. Posterior fins do not touch seminal vesicles, widest at level of tail-septum, or a little anterior. Caudal fin joining seminal vesicles. Seminal vesicles round. Ovaries short.

*Sagitta bipunctata* QUOY et GAIMARD

Small in size. Usually smaller than 15 mm in body length. Body firm and moderately opaque. Tail segment 23~27 per cent of total length; hooks 8~10; anterior teeth 4~7; posterior teeth 8~14. Anterior fins start at posterior end of ventral ganglion. Posterior fins do not reach seminal vesicles; wider and slightly longer than anterior fins, widest behind tail-septum. Caudal fin joins seminal vesicles.

*Sagitta ferox* DONCASTER

Body firm, opaque, short and robust and of equal width for most of the length of body segment. Tail segment 24~26 per cent of total length; hooks 6~7; anterior teeth 6~13; posterior teeth 9~11. Anterior fins reach the posterior end of ventral ganglion. Posterior fins and tail fin close to, or touching, seminal vesicles. Posterior fins longer than anterior fins. Intestinal diverticula present; often removed from neck. Seminal vesicles angular, with anterior edge slanting posterio-laterally.

*Sagitta robusta* DONCASTER

Boby length 13.0～16.5 mm. Body perfectly opaque, firm and of uniform width from neck to tail-septum. Tail segment 25～27 per cent of total length; hooks 5～7; anterior teeth 7～11; posterior teeth 12～14. Anterior fins start at posterior end of ventral ganglion. Posterior and caudal fins both reaching seminal vesicles. Seminal vesicles long-tapered posteriorly.

*Sagitta bedoti* BERANECK

Body firm and moderatly opaque. Tail segment 21～24 per cent of total length; hooks 6～7; anterior teeth 10～13; posterior teeth 23～27. Anterior fins long tapered, starting at ventral ganglion. Posterior and caudal fins close to, or touching, the seminal vesicles. Seminal vesicles oval. Collarette obvious, but not covering head.

*Sagitta serratodentata* KROHN

There occurred small individuals which are 7～12 mm in body length. Body elongated, not especially firm. A pair of lateral fins separated each other and round. Posterior fins as equal as or longer than anterior fins. Posterior fins the widest behind tail-septum. Hooks with a serration on the inner margin; distal end pointing, bending inwards. Tail segment 22～24 per cent of total length; hooks 6～7; anterior teeth 8～10; posterior teeth 15～20. Seminal vesicles relatively long and large, touching caudal fin, jointed from posterior fins by the triangle-shaped membrane.

*Sagitta seratodentata pacifica* TOKIOKA

Body firm and opaque. Tail segment 23～25 per cent of total length; hooks 5～7; anterior teeth 7～9; posterior teeth 13～18. Anterior fins tapered and narrower than posterior ones, extending anterior to posterior end of ventral ganglion. Posterior fins widest behind tail-septum; close to, or touching seminal vesicles. Seminal vesicles greatly expanded anteriorly, armed laterally with 3～10 chitinous spines. The individuals of 8～13 mm in body length occurred abundantly.

*Sagitta neglecta* AIDA

Small in size. The individuals not longer than 10 mm in body length occurred in the Indian Ocean. Body firm and semiopaque. Tail segment 28～31 per cent of total length; hooks 6～7; anterior teeth 5～7; posterior teeth 13～18. Anterior fins start from the posterior end of ventral ganglion. Posterior fins reaching seminal vesicles. Seminal vesicles oval, separated by a distance as long as the length or as long as a half of it from caudal fin. Collarette narrow, obvious at the posterior part of neck. Interstinal diverticula present.

*Sagitta regularis* AIDA

Small in size. The individuals of 4～7 mm in body length occurred in the Indian Ocean. Body firm and opaque. Tail segment 32～34 per cent of total length; hooks 7～8; anterior teeth 2～4; posterior teeth 4～6. Two pairs of fins separated from each other. Anterior fins start at posterior end of ventral ganglion. Posterior fins wider than anterior ones. Voluminous collarette usually present, covering head and most of body.

*Sagitta minima* GRASSI

Small in size. The individuals of 5~9 mm in body length occurred in the Indian Ocean. Body flaccid, transparent, and of obscure constriction at tail-septum. Tail segment 16~20 per cent of total length; hooks 5~8; anterior teeth 3~5; posterior teeth 4~10. Anterior fins elongated, round, not rayed, start apart from ventral ganglion. Posterior fins do not reach seminal vesicles. Caudal fin connected to seminal vesicles.

*Sagitta bedfordii* DONCASTER

The individuals of 3~4 mm in body length occurred in the Indian Ocean. Body sturdy, opaque, uniform width. Tail segment 34~38 per cent of total length; hooks 9~12; anterior teeth 2~3; posterior teeth 1~3. Anterior teeth longer than posterior teeth. Anterior fins begin at posterior end of ventral ganglion completely rayed. Posterior fins about twice as long as anterior ones covering more on tail than on trunk, widest behind tail-septum, completely rayed. Collarette reaching level of posterior end of ventral ganglion. Interstinal diverticula very conspicuous.

*Pterosagitta draco* KROHN

The individuals of 8~9 mm in body length occurred in the Indian Ocean. Body firm and opaque. Tail segment 34~38 per cent of total length; hooks 8~9; anterior teeth 6~9; posterior teeth 12~17. Single pair of lateral fins present only at tail segment. Fins broad, posterior end reaching seminal vesicles. Collarette voluminous, anterior broader, extending from head to the anterior end of fins. Confluent with fin.

*Krohnitta subtilis* GRASSI

The individuals of 8~11 mm in total length occurred in the Indian Ocean. Body elongated and firm. Tail segment 30~34 per cent of total length; hooks 6~7; teeth 9~11. Lateral fins a little broad, round, separated far from ventral ganglion, start at anterior end of seminal vesicle not rayed inwards and widest at level of tail-septum. Caudal fin touching seminal vesicles.

*Krohnitta pacifica* AIDA

The individuals of 6~7 mm in body length occurred in the Indian Ocean. Body slender. Head small. Single pair of lateral fins long and tapering; fins extend anteriorly from seminal vesicles over posterior 1/3 of trunk, widest behind septum, the part of the basis around tail-septum not rayed, and part not-rayed occasionally very broad. Tail segment 28~31 per cent of total length; hooks 8~10, bending on ventral side, looking as if broken at the middle part. Teeth 11~12, arranged along a single line. Lateral fin and caudal fin joining seminal vesicles. Caudal fin spatulate.

## IV. The species and their distribution

### 1. The Chaetognatha in the western waters of the Greater Sunda Islands

Since the author had an honor of offering the whole samples of Chaetognatha collected in this region to Dr. T. TOKIOKA, let the author refer to Dr. TOKIOKA'S thesis (1955) in this region to compare with the data collected in the other three regions of the author's investigation.

The present material consists of three samples respectively collected in the following localities during the exploring voyages of the Shunkotsu-maru, a research ship of the Shimonoseki College of Fishries.

i. Near Nicobar Islands (0～100 m), Dec. 27～28, 1953 (11～15 h) ; obtained by two hauls.

ii. Near Nias Island (0～100 m), Jan. 2～5, 1954; obtained by three hauls.

iii. Between Bali and Lombok (0～100 m), Jan. 18～22, 1954 (13～16 h); obtained by three hauls.

This contains the following 13 forms as shown below.

| Species | Nicobar | Nias | Bali—Lombok |
|---|---|---|---|
| *Sagitta hexaptera* | 2 ( 3) | 4 ( 3) | 3 ( 2) |
| *S. enflata* | 20 (30) | 34 (21) | 55 (35) |
| *S. bipunctata* | 1 ( 2) | — | 4 ( 3) |
| *S. bedoti* | 3 ( 4) | 5 ( 3) | 15 ( 9) |
| *S. pulchra* | — | — | 1 ( 1) |
| *S. robusta* | 5 ( 8) | 3 ( 2) | 5 ( 3) |
| *S. serratodentata pacifica* | 6 ( 9) | 38 (24) | 32 (20) |
| *S. neglecta* | 3 ( 5) | 7 ( 4) | 3 ( 2) |
| *S. aregularis* | 8 (12) | 34 (21) | 10 ( 6) |
| *S. minima* | — | 1 ( 1) | — |
| *Pterosagitta draco* | 18 (27) | 34 (21) | 27 (17) |
| *Krohnitta subtilis* | — | — | 1 ( 1) |
| *K. pacifica* | — | — | 2 ( 1) |
| Total | 66 | 160 | 150 |

Numerals in parentheses indicate the percentages.

### 2. The Chaetognatha in the central part of the North Indian Ocean

The Chaetognatha in this region has been reported by TOKIOKA (1956). The present material comprised of the following 13 species, and its occurrence is shown in Table 35.

| Species | Number of individuals | Percentage |
|---|---|---|
| *Sagitta hexaptera* | 58 | 2 |
| *S. lyra* | 15 | 1 |
| *S. enflata* | 579 | 22 |

Table 35. Details of the occurrence of Chaetognatha in the central part of the North Indian Ocean.

| Station | 11 | | 19 | 22 | | 23 | 24 | | 25 | 33 | | 34 | | 35 | 36 | 37 | | 38 | 39 | 40 | | 41 | 43 | 44 | 45 | 47 | F. O. | M.N./H. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Haul Distance | 0–100 m | ? | 0–100 | 0–100 | 0–500 | 0–100 | 0–100 | ? | 0–100 | 0–100 | 0–100 | 0–100 | 0–100 | 0–200 | 0–100 | 0–100 | 0–200 | 0–100 | 0–100 | Sur. | 0–100 | 0–200 | 0–100 | 0–100 | 0–100 | 0–200 | | |
| *Sagitta hexaptera* | | | | | 6 | 2 | | | 1 | 4 | | 2 | 2 | | | | 4 | 3 | 1 | 6 | 2 | 3 | 5 | 1 | 9 | 7 | 16/26 | 3.6 |
| *S. lyra* | | | | | | | 1 | | | | | 4 | | | | | 3 | 1 | | | 1 | | 3 | 2 | | | 7 | 2.1 |
| *S. enflata* | 1 | 1 | 4 | 15 | 35 | 25 | 21 | 5 | 45 | 43 | 46 | 51 | 3 | 24 | 10 | 8 | 17 | 22 | 33 | 7 | 23 | 32 | 12 | 64 | 18 | 14 | 26 | 22.3 |
| *S. robusta* | | | | 2 | 4 | 1 | 2 | | | 5 | | 2 | | 1 | 6 | 1 | | 1 | | 2 | | | 1 | 1 | | 1 | 14 | 2.1 |
| *S. ferox* | 1 | | 1 | | 2 | | | | | | 1 | | 1 | 2 | | | | | 4 | 1 | 1 | | 3 | 2 | | | 11 | 1.7 |
| *S. bedoti* | | 1 | 4 | 6 | 15 | 27 | 10 | | 18 | 43 | 14 | 26 | 9 | 9 | | | 4 | 6 | 8 | | 9 | 4 | 31 | 74 | 45 | 18 | 21 | 18.1 |
| *S. serratodentata pacifica* | 10 | 3 | 12 | 13 | 91 | 41 | 10 | 5 | 27 | 36 | 73 | 90 | 9 | 54 | 8 | 7 | 43 | 13 | 17 | 5 | 18 | 32 | 32 | 45 | 40 | 32 | 26 | 29.5 |
| *S. regularis* | 5 | 3 | 1 | | 5 | 6 | 7 | 1 | 10 | 16 | 2 | 6 | 2 | 2 | 66 | 1 | 5 | 13 | 10 | 12 | 12 | 13 | 19 | 22 | 25 | 3 | 25 | 10.7 |
| *S. bedfordii* | | | | 2 | | | 1 | | 5 | | 2 | | | | 1 | | | 14 | | | 1 | 5 | | 1 | 5 | 2 | 11 | 3.5 |
| *S. minima* | | | | | | | 1 | | | 49 | 24 | 27 | 6 | 18 | | 5 | 9 | 8 | 15 | | 14 | 2 | 25 | 12 | 1 | | 15 | 14.4 |
| *S.* spp. | | | | 2 | 4 | 1 | 4 | | | 5 | 1 | 2 | 2 | 1 | | 14 | | 1 | 2 | | | 1 | | 3 | | 1 | 15 | 2.9 |
| *Pterosagitta draco* | 5 | | 2 | 6 | 23 | 3 | 4 | | 5 | 10 | 4 | 10 | | 5 | | | 5 | 9 | 2 | | 1 | 2 | 12 | 9 | 6 | 10 | 20 | 6.7 |
| *Krohnitta subtilis* | | | | | 3 | 1 | 1 | | 1 | 2 | | 3 | 1 | 3 | | 1 | 7 | 3 | 1 | | 3 | 3 | | 5 | | 2 | 16 | 2.5 |
| *K. pacifica* | | | | 2 | | 1 | 3 | 1 | 4 | 9 | 5 | 8 | | | | 1 | 1 | 1 | | 1 | 1 | 2 | | 7 | 1 | | 16 | 3.0 |
| Total | 22 | 8 | 24 | 48 | 188 | 108 | 65 | 12 | 116 | 222 | 172 | 231 | 35 | 119 | 91 | 38 | 98 | 95 | 93 | 34 | 86 | 99 | 143 | 248 | 150 | 90 | | |

Notes : F. O. ……Frequency of occurrence, M. N. /H. ……Mean number of individuals per haul.

| | | |
|---|---|---|
| *S. robusta* | 30 | 1 |
| *S. ferox* | 19 | 1 |
| *S. bedoti* | 381 | 14 |
| *S. serratodentata pacifica* | 766 | 29 |
| *S. regularis* | 267 | 10 |
| *S. bedfordii* | 39 | 1 |
| *S. minima* | 216 | 8 |
| *Pterosagitta draco* | 133 | 5 |
| *Krohnitta subtilis* | 40 | 2 |
| *K. pacifica* | 48 | 2 |
| Damaged individuals or juv. | 44 | 2 |

*Sagitta serratodentata pacifica* and *S. enflata* are the dominant species and followed by *S. bedoti* and *S. regularis*. *Pterosagitta draco* occurs frequently, but rather in a small number. *Sagitta minima* occurs less frequently than *P. draco*, but its population is denser than that of the latter.

The surveyed area is located near slightly north of Area I of the "Sea lark" Expedition in 1905. But, the difference found between the Chaetognatha fauna found in that expedition and that in the present survey seems to be rather remarkable: *S. bedoti* occurred much oftener in the present material than that in the "Sea lark" material, *S. minima* was found in a considerable quantity in the former, although it was quite absent in the latter. Comparing the present results with those of the expedition in May~June 1954 in the waters around the Marshal Islands in the Pacific, the relative abundance of *S. serratodentata pacifica*, *S. bedoti*, *S. regularis* and *S. minima* and the scarcity of *S. bipunctata* in the central part of the Indian Ocean seem to be very impressive.

### 3. The Chaetognatha in the waters southeastern part of the Arabian Sea

The material comprises the following 16 species. The detail of the occurrence is shown in Table 36.

| Species | Number of individuals | Percentage |
|---|---|---|
| *Sagitta hexaptera* | 21 | 1.1 |
| *S. lyra* | 2 | 0.1 |
| *S. enflata* | 597 | 31.9 |
| *S. robusta* | 44 | 2.4 |
| *S. ferox* | 8 | 0.4 |
| *S. bedoti* | 11 | 0.6 |
| *S. serratodentata* | 62 | 3.3 |
| *S. serratodentata pacifica* | 563 | 30.1 |
| *S. regularis* | 177 | 9.5 |
| *S. neglecta* | 96 | 5.1 |
| *S. bedfordii* | 10 | 0.5 |
| *S. minima* | 136 | 7.3 |

| | | |
|---|---|---|
| *S. bipunctata* | 3 | 0.2 |
| *Pterosagitta draco* | 120 | 6.5 |
| *Krohnitta subtilis* | 16 | 0.8 |
| *K. pacifica* | 4 | 0.2 |
| Total | 1870 | 100.0 |

*Sagitta enflata* and *S. serratodentata pacifica* were the dominant species and they were followed by *S. regularis*, *S. minima* and *Pterosagitta draco*.

When compared with Dr. TOKIOKA's record (1956), it is worthy of note *Sagitta neglecta*, *S. serratodentata* and *S. bipunctata* were added to the list of occurrence, but *S. bedoti* was rare.

Table 36. Detail of the occurrence of Chaetognatha in the waters southeastern part of the Arabian Sea.

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sagitta hexaptera* | 2 | 3 | 3 | | | | 5 | 2 | 1 | | 1 | | | 1 | | 5 | | | 21 |
| *S. lyra* | 1 | | | | | | | | | | | | | | | | | 1 | 2 |
| *S. enflata* | 78 | 12 | 21 | 10 | 29 | 43 | 14 | 43 | 26 | 57 | 25 | 28 | 29 | 15 | 23 | 75 | 14 | 55 | 597 |
| *S. robusta* | 1 | 6 | 3 | | 1 | 1 | 2 | 7 | 1 | 3 | 2 | 1 | 3 | 1 | 3 | 2 | 4 | 3 | 44 |
| *S. ferox* | | 3 | 1 | | 1 | | | 1 | | | | 1 | | | | 1 | | | 8 |
| *S. bedoti* | 2 | 1 | | 1 | | | 1 | | 2 | | 1 | | 1 | | 1 | | 1 | | 11 |
| *S. serratodentata* | | | | 12 | | 4 | 3 | 21 | 3 | | | 1 | 1 | | | | | 17 | 62 |
| *S. serratodentata pacifica* | 47 | 2 | 32 | 9 | 8 | 10 | 24 | 44 | 21 | 24 | 36 | 35 | 115 | 16 | 67 | 37 | 10 | 26 | 563 |
| *S. regularis* | 33 | 4 | 2 | 1 | 1 | 2 | 1 | 1 | 22 | 9 | 15 | 10 | 20 | | 6 | 15 | 19 | 16 | 177 |
| *S. neglecta* | 11 | 5 | 2 | 1 | 1 | | 2 | 2 | 7 | 6 | 11 | 4 | 32 | 5 | 2 | | | 5 | 96 |
| *S. bedfordii* | | 1 | 2 | | | | | 2 | 1 | | | | 1 | | | | 1 | 2 | 10 |
| *S. minima* | 3 | 4 | 3 | 7 | | 7 | 1 | 14 | 10 | 12 | | 5 | 20 | 7 | 10 | 12 | 8 | 13 | 136 |
| *S. bipunctata* | | | | 1 | | | | 1 | | | | | | | | | | 1 | 3 |
| *Pterosagitta draco* | 20 | 6 | 7 | 4 | | 3 | 7 | 2 | 3 | 2 | 2 | 7 | 8 | 3 | 17 | 6 | 10 | 13 | 120 |
| *Krohnitta subtilis* | 1 | 3 | | | 1 | 1 | | | | | 1 | | 3 | | 4 | | 2 | | 16 |
| *K. pacifica* | | 1 | | | | | | | 1 | | | | | | 1 | 1 | | | 4 |

## 4. The Chaetognatha in the waters eastern part of the Indian Ocean

The material comprises the following 15 species. The detail of the occurrence is shown in Table 37.

| Species | Number of individuals | Percentage |
|---|---|---|
| *Sagitta hexaptera* | 599 | 14.1 |
| *S. lyra* | 72 | 1.7 |
| *S. enflata* | 859 | 20.2 |
| *S. bipunctata* | 140 | 3.4 |
| *S. robusta* | 184 | 4.3 |
| *S. bedoti* | 157 | 3.7 |

| | | |
|---|---|---|
| *S. pulchra* | 13 | 0.3 |
| *S. serratodentata pacifica* | 1326 | 31.2 |
| *S. serratodentata* | 128 | 3.1 |
| *S. neglecta* | 149 | 3.5 |
| *S. regularis* | 132 | 3.1 |
| *S. minima* | 286 | 6.7 |
| *Pterosagitta draco* | 182 | 4.3 |
| *Krohnitta subtilis* | 14 | 0.3 |
| *Krohnitta pacifica* | 5 | 0.1 |
| Total | 4246 | 100.0 |

*Sagitta serratodentata pacifica*, *S. enflata* and *S. hexaptera* are the dominant species in this water and *Sagitta robusta*, *S. bedoti*, *S. regularis*, *S. minima*, *S. neglecta* and *Pterosagitta draco* followed the preceding species.

The characteristic distribution of the Chaetognatha in this water is as follows: *Sagitta hexaptera*, though it is oceanic in its nature, has a comparatively wide adaptability to temperature and occurred abundantly and in a great quantity in the surface waters.

Table 37. Detail of the occurrence of Chaetognatha in the waters eastern part of the Indian Ocean.

| Species \ Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sagitta hexaptera* | 7 | 15 | 9 | 6 | 21 | 30 | 24 | 49 | 19 | 17 | 23 | 30 | 25 | 9 | 38 | 15 | 21 | 26 | 13 | 18 | 19 | 24 | 6 | 37 | 43 | 14 | 19 | 1 | 5 | 6 | 3 | 7 | 599 |
| *S. lyra* | 2 | | | | 10 | 16 | 4 | 13 | | | | | 1 | | 3 | | | | | | | 2 | | 11 | 7 | 2 | | | 1 | | | | 72 |
| *S. enflata* | 21 | 41 | 37 | 59 | 66 | 56 | 39 | 48 | 26 | 40 | 22 | 16 | 24 | 7 | 21 | 10 | 14 | 6 | 18 | 14 | 19 | 11 | 23 | 54 | 43 | 21 | 13 | 8 | 7 | 16 | 31 | 28 | 859 |
| *S. bipunctata* | 4 | 2 | | | 7 | 3 | 8 | 4 | | | 14 | 6 | 13 | 4 | 7 | 15 | 21 | 13 | | 2 | | 3 | | 5 | 1 | 4 | | 1 | | 3 | | | 140 |
| *S. robusta* | 8 | 5 | | 10 | 18 | 6 | 4 | 12 | 7 | 7 | 3 | 11 | 1 | 4 | 3 | 6 | 9 | 8 | 3 | | 1 | 1 | 11 | 16 | 13 | 5 | 1 | | 1 | | 7 | 3 | 184 |
| *S. bedoti* | 6 | 3 | 1 | 5 | 3 | 8 | 3 | 4 | 1 | 1 | 5 | 21 | 8 | 11 | 8 | 2 | 5 | 1 | | 6 | 2 | 4 | 1 | 8 | 10 | 13 | 2 | 3 | 4 | 1 | 1 | 6 | 157 |
| *S. pulchra* | 1 | 1 | | 2 | | 1 | | 2 | | | | | 1 | | | | | | | | | | | | 2 | 1 | | | | 1 | | 1 | 13 |
| *S. serratodentata pacifica* | 36 | 49 | 48 | 33 | 78 | 96 | 41 | 34 | 75 | 42 | 58 | 45 | 23 | 18 | 31 | 24 | 36 | 28 | 23 | 41 | 31 | 27 | 36 | 98 | 85 | 23 | 19 | 11 | 16 | 60 | 18 | 43 | 1326 |
| *S. serratodentata* | 3 | 6 | 8 | 4 | 3 | 16 | | 13 | 2 | 4 | | | 13 | 4 | 3 | 11 | | | 8 | | | | | 3 | | | 2 | 11 | 1 | 4 | 6 | 3 | 128 |
| *S. neglecta* | 3 | 10 | | 24 | | 8 | 5 | 3 | | | | 10 | 32 | 4 | 16 | 11 | 1 | | 2 | | 1 | 2 | 7 | | 1 | 4 | | 1 | 3 | 1 | | | 149 |
| *S. regularis* | | 2 | | | 2 | 16 | 8 | 14 | 11 | | | 3 | 12 | 5 | 20 | 9 | | | 1 | | 5 | 7 | 4 | 1 | 3 | 1 | 5 | | | 2 | | 1 | 132 |
| *S. minima* | 12 | 11 | 6 | 5 | 21 | 18 | 12 | 1 | 3 | 7 | 16 | 17 | 16 | 4 | 19 | 2 | 16 | 21 | 7 | 4 | 1 | 8 | 1 | 13 | 14 | 1 | 4 | 2 | 5 | 7 | 3 | 9 | 286 |
| *Pterosagitta draco* | 5 | 3 | 11 | 4 | 2 | 5 | 23 | 4 | 4 | 3 | 2 | 1 | 7 | | 14 | | 2 | 1 | 10 | | 4 | | 7 | 14 | 18 | 9 | | 7 | | 6 | 5 | 11 | 182 |
| *Krohnitta subtilis* | 1 | | 1 | | 2 | | | | 1 | 1 | | | | | | | | | | | | | | 1 | 3 | | 1 | | | 1 | | 2 | 14 |
| *K. pacifica* | | 1 | | | 1 | | | | | | | | | | | | | | | | | | | | | | | 1 | | | 1 | 1 | 5 |

## 5. The Chaetognatha in the Bay of Bengal

The material comprises the following 13 species. The detail of the occurrence is shown in Table 38.

| Species | Number of individuals | Percentage |
|---|---|---|
| *Sagitta hexaptera* | 55 | 3.7 |
| *S. lyra* | 25 | 1.6 |
| *S. enflata* | 190 | 12.8 |
| *S. bipunctata* | 24 | 1.6 |
| *S. bedoti* | 12 | 0.8 |

| | | |
|---|---|---|
| *S. robusta* | 304 | 20.4 |
| *S. serratodentata pacifica* | 95 | 6.4 |
| *S. serratodentata* | 106 | 7.1 |
| *S. neglecta* | 284 | 19.1 |
| *S. regularis* | 49 | 3.3 |
| *S. minima* | 192 | 12.9 |
| *Pterosagitta draco* | 123 | 8.3 |
| *Krohnitta subtilis* | 30 | 2.0 |
| Damaged individuals | 142 | |

*Sagitta robusta* and *S. neglecta* are the dominant species and *S. minima* and *S. enflata* followed them.

As shown in Part I Chapter III, Paragraph V, the author assumed three areas, oceanic, neritic, and the mixed areas in this water on the basis of the distribution of diatom. It was found that the distribution of Chaetognatha had a slight resemblance to that of diatom; *S. hexaptera* and *S. enflata* which are oceanic species occurred abundantly in the central part of the bay whereas *S. minima* appeared in a great quantity in the mixed water. And *S. bipunctata* occurred in a small quantity near the north coast of the bay.

Table 38. Detail of the occurrence of Chaetognatha in the Bay of Bengal.

| Species \ Station | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sagitta hexaptera* | 2 | 1 | 1 | 1 | 1 | 1 | | 6 | 3 | 4 | 2 | 3 | 8 | | 10 | | | | 8 | | 1 | | 2 | | | | 55 |
| *S. enflata* | 5 | 6 | 12 | 14 | 18 | 8 | 10 | 7 | 17 | 3 | 12 | 11 | 11 | 8 | 4 | 1 | | 7 | 1 | 3 | 8 | 2 | 10 | 10 | 1 | 1 | 190 |
| *S. lyra* | | 1 | | | 1 | | 1 | | 2 | 1 | 2 | | | | | | | 2 | | | | 3 | 1 | 6 | | 5 | 25 |
| *S. bipunctata* | | | | | | | | | | | | | | 8 | 1 | 2 | | | | 9 | | 1 | | 2 | | 1 | 24 |
| *S. bedoti* | | 1 | 1 | 1 | 1 | | | | | | 1 | 2 | 1 | | | | | | 1 | 1 | 1 | 1 | | | | | 12 |
| *S. robusta* | | 6 | 42 | 23 | 28 | 37 | 23 | 13 | 9 | 12 | 14 | 10 | 19 | | 7 | 3 | 3 | 13 | 10 | 1 | 9 | 5 | 10 | 4 | | 3 | 304 |
| *S. serratodentata pacifica* | | 6 | 2 | 1 | 8 | | | 1 | 8 | 3 | 1 | 21 | 9 | 7 | 2 | 1 | 1 | | 3 | 5 | 1 | 1 | 3 | 1 | 6 | 4 | 95 |
| *S. serratodentata* | | | 6 | | | | | 1 | | | | | | 1 | 8 | 3 | 1 | 21 | 9 | 7 | 13 | 20 | 1 | 8 | 1 | 6 | 106 |
| *S. neglecta* | | 2 | 9 | 10 | 2 | 12 | 15 | 13 | 23 | 11 | 10 | 38 | 24 | 10 | 22 | 3 | 1 | 5 | 21 | 4 | 6 | 23 | 14 | 3 | 1 | 2 | 284 |
| *S. regularis* | 1 | 1 | 1 | 3 | 4 | 3 | 1 | 1 | | | | | | | 5 | | | | 12 | | | 8 | 7 | 2 | | | 49 |
| *S. minima* | 6 | 1 | 10 | 3 | 7 | 10 | 5 | 3 | 9 | 5 | 1 | 7 | 8 | 7 | 17 | 21 | 12 | 6 | 5 | 2 | 4 | 13 | 5 | 14 | 2 | 9 | 192 |
| *Pterosagitta draco* | | | | | | | 14 | | 10 | 4 | | | | 3 | 7 | 4 | | 11 | | | 2 | 10 | 39 | 18 | 1 | | 123 |
| *Krohnitta subtilis* | | 4 | 4 | | | 1 | 1 | | 1 | | 1 | | 5 | | | | | 2 | | | 3 | 1 | 6 | 1 | | | 30 |
| Damaged individuals | 18 | 3 | 6 | 11 | 14 | 6 | 5 | 3 | 8 | 1 | | | 2 | 6 | | 3 | | 7 | | 1 | | | | 13 | 15 | 20 | 142 |

## Chapter III Pelagic Copepoda

### I. Introduction

In both Europe and America, many taxonomic studies on pelagic copepods were done by C. CLAUS, W. GIESBRECHT, G. BRADY, J.C. THOMPSON, T. SCOTT, G.O. SARS, R. N. WOLFENDEN, G. P. FARRAN, C. B. WILSON, A. SCOTT, O.

PESTA, VAN BREEMEN, C. ESTERLY, A. WILLEY, M. DAHL, C. WITH, I. ROSENDORN, A. STEUER, R. B. SEWELL, R. GURNEY, K. LEHNHOFER, P. H. SCHMAUS, M. ROSE, S. SMIRNOV, W. KLEVENHUSEN, K. LANG. P. JESPERSEN, M. JOHNSON, A. G. NICHOLLS, W. VERVOORT and others, and they identified as many as 800 species. On the other hand in our country the studies of Copepoda have been chiefly made by H. MARUKAWA ('08, '21 & '28), T. SATO ('13), T. MORI ('32 & '37), T. YAMADA ('35 & '38), O. TANAKA ('35~'60), T. CHIBA ('56) and others, and the number of the species of Copepoda reported by them attained about 200 species from the sea around Japan. Among these studies, O. TANAKA's works were important and he studied on the samples collected not only from the surface layer of the sea, but also from the layer of 1,800 m in the depth.

In this chapter the author described Copepoda, collected from the Bering Sea, central part of the Pacific Ocean, and the Indian Ocean.

## II. Description on the species

*Canthocalanus pauper* (GIESBRECHT) Fig. 60

*Calanus pauper*, GIESBRECHT, 1892, p. 91, Taf. 6, f. 4; Taf. 8, f. 25; *Canthocalanus pauper*, A. SCOTT, 1909, p. 9; *Calanus pauper*, FARRAN, 1929, p. 215; *Canthocalanus pauper*, SEWELL, 1929, p. 25; *Calanus pauper*, FARRAN, 1936, p. 77; MORI, 1937, p. 18, pl. 6, figs. 4~10; *Canthocalanus pauper*, VERVOORT, 1947, p. 36; TANAKA, 1956, p. 260.

Since the detailed description of this species was made by many investigators, the 5th foot and the urosome in male, of which characters seem to be available in the identification of the species, were shown in Fig. 60.

Total length: 1.35~1.45 mm in female and 1.35~1.40 mm in male.

Distribution: This species has been recorded from the tropical and subtropical regions of the Pacific and the Indian Oceans. In the waters around Japan it has been recorded from the warm currents. The author has found this species at the tropical portions of the Pacific and the Indian Oceans.

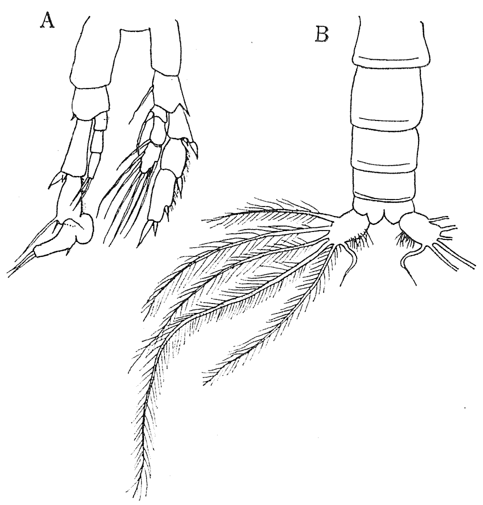


Fig. 60. *Canthocalanus pauper* (GIESBRECHT).
A : Male, 5th pair of feet
B : Male, urosome (dorsal view)

*Euchirella bella* GIESBRECHT Fig. 61

*Euchirella bella* GIESBRECHT, 1888, *E. amoena*, GIESBRECHT, 1892, p. 233, Taf. 15; GIESBRECHT & SCHIMEIL 1898, p. 36; ESTERLY 1905, p. 155, fig. 21; A. SCOTT, 1909, p. 53; MORI 1937, p. 42, pl. 18, figs. 1~9.

Female: Metasome elliptical, twice as long as its width; forehead slightly pointed; rostrum short and conical; posterior corners smoothly round. Urosome a quarter of metasome in both length and width; Genital segment asymmetrical, protruding to the left and making segment with its broader width than its length. Length of furcal style about equal with that of its width. First antenna, when it is bend, reaches mostly to anal segment. 4th legs have 3-segmented rami; each of two proximal exopodite segments carries two spines at outer distal corner and carries inner seta, too; each of the segments has two outer spines a stout serrated terminal spine and four inner setae at both distal corners, respectively. In the present species most of the females carry a large plumose seta and a row spines whose three or four spines are fused at their bases. Total length about 3.3 mm.

Distribution: This species is distributed over the Atlantic, the Pacific and the Indian Oceans. The author has collected it in the tropical and subtropical regions of the Indian Ocean.

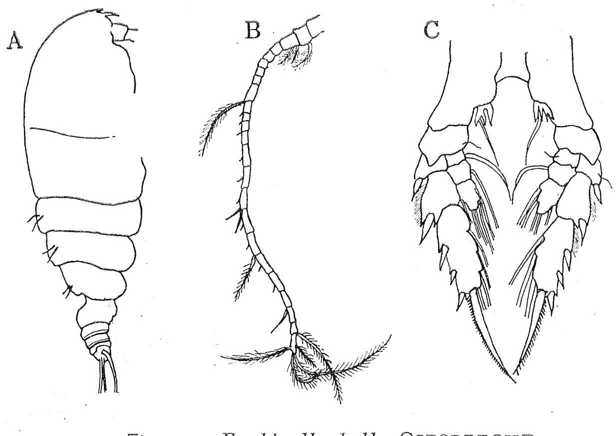


Fig. 61. *Euchirella bella* GIESBRECHT.
A : Female, (lateral view)
B : 〃 , 1st antenna
C : 〃 , 5th pair of feet

*Centropages calaninus* (DANA)

*Hemicalanus calaninus*, DANA, 1852, p. 1105, pl. 78; *Centropages calaninus*, GIESBRECHT, 1892, p. 305, Taf. 17, Taf. 18 and Taf. 38; GIESBRECHT & SCHMEIL, 1898, p. 58; A. SCOTT, 1909, p. 112; MORI, 1937, p. 61, pl. 30, figs. 1~3.

Female: Posterior corners of the last thoracic segment round. Genital segment somewhat swelled and symmetrical. Anal segment 2 times as long as or longer than the 2nd segment of urosome. Furca asymmetrical.

Inner marginal spine of 2nd segment of exopodite of 5th foot, longer than that of 3rd segment. A notch on inner margin of 1st segment of exopodite of 5th foot. Total length 1.7~1.9 mm.

Male: Terminal claw of grasping foot longer than thumb, and sharply bent. Total length 1.6~1.8 mm.

Distribution: This species is distributed in the tropical zone of the Pacific Ocean and also in the Malay Archipelago. In the waters around Japan, this species appears in the warm currents. The author has collected in the tropical and subtropical regions of the Indian Ocean.

*Temora discaudata* GIESBRECHT

*Temora discaudata*, GIESBRECHT, 1892, p. 328, Taf. 17, f. 3, 20, 23; Taf. 38, f. 24, 25, 28; A. SCOTT, 1909, p. 118; SATO, 1913, p. 31, pl. VI, figs. 77~80; pl. V, fig. 82; MORI, 1929, p. 175, pl. VI, figs. 8~13; MORI, 1937, p. 65, pl. 32, figs. 9~12.

Female: Posterior corners of last metasome segment protruded into the spines. Anal segment and caudal rami asymmetrical. Terminal setae of furca not swelled at bases.

5th pair of feet symmetrical. Inner marginal spine of 3rd segment much longer than both terminal spines which are about equal in length. Total length 1.7~2.0 mm.

Male: Posterior corners of last metasome segment pointed, and slightly asymmetrical. Middle section of grasping antenna swelled.

Thumb-like process of 2nd segment of the left 5th foot wide. Terminal segment of that foot lamelliform, and furnished with 5 marginal spines.

Last segment of the right 5th foot hook-like, and sharply bent back against outside of the foot. Total length 1.7~1.9 mm.

Distribution: This species is distributed over the Pacific Ocean and the Red Sea. In the waters around Japan, this species appears commonly in the warm currents. The author has collected it in the tropical and subtropical regions of the Pacific and the Indian Oceans.

*Eurytemora herdmani* THOMPSON & SCOTT

*Eurytemora herdmani*, THOMPSON & SCOTT, 1897, p. 78, pl. 5 figs. 1~11; GIESBRECHT & SCHMEIL, 1898, p. 103; BREEMEN, 1906, p. 100, figs. 11a~c; SATO, 1913, p. 32, pl. VI, figs. 83~86; WILSON, 1932, p. 112, figs. 75a~b; MORI, 1937, p. 66, pl. 33, figs. 3~11.

Male: Abdomen, 5 segments. Right anterior antenna modified into grasping organ. 5th pair of the feet asymmetrical. Right foot 5 segments. Terminal segment longer than the preceding one. 3rd segment longer than 2nd, and the combined length of 4th and 5th. Left foot 4 segments. 2nd segment without spine, swelled but a little. 4th segment enlarged distally and terminated at truncated end. Total length 1.2 mm.

Distribution: St. Lawrence River (THOMPSON & SCOTT); Gulf of Maine

(BIGELOW); Narragansett Bay (WILLIANS); Woods Hole (SHARPE, FISH); Sea around Hokkaido (MORI). In the author's collections, only a male of this species was recorded at the northeast waters of the Bering Sea.

Remarks; The author identified this species as *E. hirundoides*(?) in the previous report (TSURUTA, '62), but he was obliged to correct it as *E. herdmani* according to the detail observations of it.

*Metridia lucens* BOECK 1864

*Metridia hibernica*, GIESBRECHT, 1892, p. 340, Taf. 33; *M. lucens*, GIESBRECHT & SCHMEIL, 1898, p. 106; SARS, 1903, p. 113, pl. LXXVII; ESTERLY, 1905, p. 177, figs. 35a~d; BREEMEN, 1906, p. 108, figs. 124 a~c; SATO, 1913, p. 36, pl. V; SARS, 1925, p. 198; WILSON, 1932, p. 119, figs. 79 a~f.

Female: Posterior corners of 5th segment angular, but without spines. Furcal style about twice as long as its width. Genital segment slightly shorter than the combined length of its two succeeding segments. 5th foot uniramous, and 3 or 4-segmented.

Male: Posterior corners of 5th segment angular as those in the female; urosome relatively shorter and narrower; caudal rami about twice as long as its width, left 5th leg a little shorter than right one, 5th segmented, the end segment longer than the rest of the leg and not taperd distally, 2nd segment has an inner fringe of hairs; 3rd segment of the right 5th leg denticulate distally, Total length 2.0~2.5mm.

Distribution: Arctic Ocean (LUBBOCK, MRDZESK); Greenland (BUCHHOLZ); Spitzbergen (LILLJEBORG); Northern Atlantic (CLEVE), Northern Pacific (ANRAKU); Sea around Hokkaido (MORI); middle and deep layers of sea in the coast off the Peninsula Izu (TANAKA); the Northern Pacific Ocean and the Bering Sea (Author)

*Candacia curta* DANA 1849

*Candacia pectinata*, BRADY, 1883, p. 67, pl. XXX, figs. 10, 12, 13; *C. curta*, GIESBRECHT, 1892, p. 424, Taf. 21, f. 15; Taf. 22, f. 12, 24; Taf. 39, f. 8~10, 12; *C. intermedia*, T. SCOTT, 1894, p. 61, pl. IV, figs. 30~37; *C. curta*, GIESBRECHT & SCHMEIL, 1898, p. 129; ESTERLY, 1905, p. 196, figs. 46a~c; SARS, 1925, p. 351; *C. bicornuta*, MORI, 1932, p. 170 & 175, pl. III, figs, 1~7; *C. curta*, YAMADA, 1935, p. 72, pl. IV, figs, 1~12; TANAKA, 1935, p. 212, pl. II, figs. 9~13; pl. III, figs. 1~9; MORI, 1937, p. 83, pl. 56, figs. 1~8; pl. 57, figs. 1~5.

Female: The results observed morphologically in a number of the individuals, were coincided with those described by TANAKA (1935) and MORI (1937). However, the author described especially this species here because of the fact that he obtained the samples which had not spines at the genital segment from the Arabian Sea.

*Labidocera detruncata* (DANA) 1849 Fig. 62

*Pontellina detruncata*, DANA, 1852, p. 1143, pl. 80; *Pontella detruncata*, BRADY, 1883, p. 90, pl. XXVI, figs. 8~15; XIV, fig. 20; *Labidocera detruncata*, GIESBRECHT, 1892, p. 445, Taf. 23, f. 14, 34; Taf. 25, f. 28; Taf. 41, f. 9, 30, 31;

GIESBRECHT & SCHMEIL, 1898, p. 135; A. SCOTT, 1909, p. 165; MORI, 1937, p. 92, pl. 42, figs. 1~6.

Female: Forehead round. The head has no lateral hooks. Lateral angles of last thoracic segment pointed, and somewhat asymmetrical. The abdomen indistinctly 3 segmented. Furca symmetrical and each style broad.

5th pair of feet symmetrical. Exopodite has 3 outer marginal spines, and terminates into bifurcate end.

Male: Lateral angles of last thoracic segment round. Abdomen 5 segmented. The right 1st antenna provided with a grasping organ. 5th pair of feet asymmetrical. The right foot forms a pair of forceps. Thumb short. Outer margin of 1st segment of exopodite smooth. Terminal claw nearly as long as preceding segment.

Total length: 2.2~2.5 mm.

Distribution: This species has been recorded from the Pacific and the Indian Oceans. Near Japan, this species appears in the warm currents.

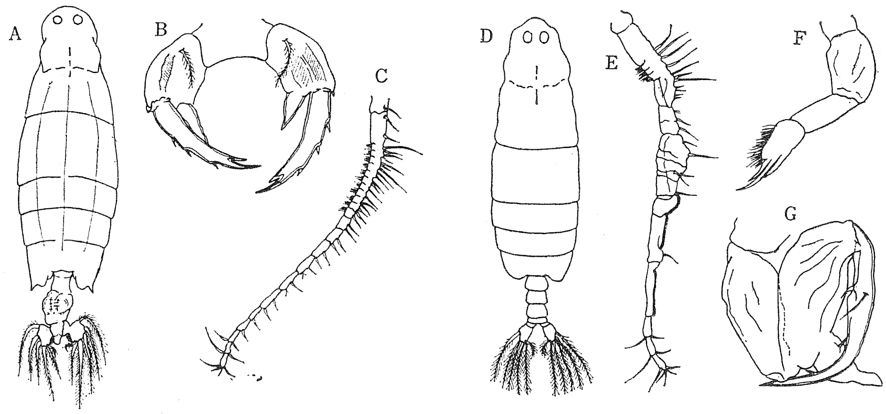


Fig. 62. *Labidocera detruncata* (DANA).
A : Female, (dorsal view)
B : 〃 , 5th pair of feet
C : 〃 , 1st antenna
D : Male, (dorsal view)
E : Male, 1st antenna
F : 〃 , left 5th foot
G : 〃 , right 5th foot

*Pontella securifer* BRADY Fig. 63

*Pontella securifer*, BRADY, 1883, p. 96, pl. 45, figs. 1~9; WILSON, 1950, p. 297, pl. 17, figs. 207~214; pl. 28, figs. 421~425.

Female: Head more or less fuses with first segment and lateral hooks small and nearly straight. Dorsal eyes well separated, two rostral lenses contact with their inner walls and swell into a large sphere. Posterior corners of metasome produce into triangular acute spines, the left angle being much larger than the right one. Genital segment much larger than anal segment, covering with an irregular dorsal carapace, widely extends backward to cover all the anal segment and some parts of caudal rami. 1st antenna rather slender and reaches the middle of 3rd thoracic segment. Each ramus of 5th leg 1-segmented, exopodite four times as long as endopodite, strongly curved inward, with four small spines on convex margin and acuminate at the tip. Endopodite bifurcate with about 1/3 of its length.

Male: Metasome similar to that of the female, but narrower, more pointed anteriorly, and with nearly symmetrical spines on posterior corners. Caudal rami also symmetrical, more than twice as long as their width. The right 1st antenna provided with a grasping organ. In the chela of the right 5th leg the movable finger slender and bent into a half circle; and thumb short, straight, and blunt. Inside thumb with a longer curved process, transversely ridged, with an acute spine and a hemispherical process. End segment of the left leg tipped with two equal spines, with three other spines and long rows of hairs on surface.

Total length: 4.2~4.5 mm in female, about 4.2 mm in male.

Distribution: This species has been recorded from the tropical and the subtropical regions of the Pacific and the Indian Oceans.

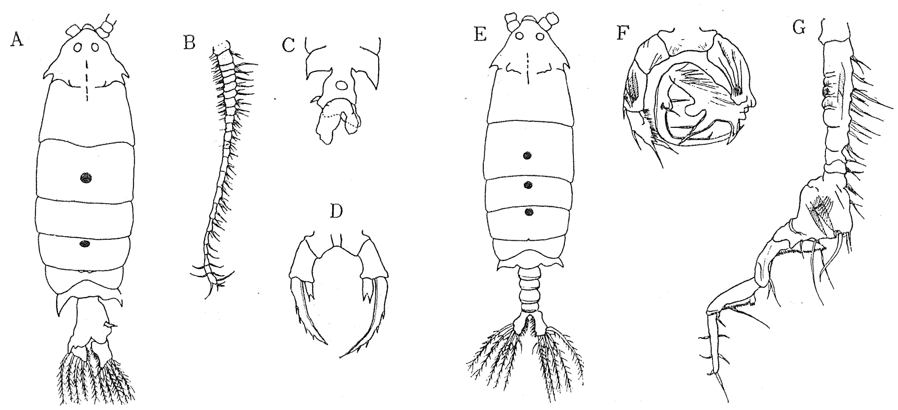


Fig. 63. *Pontella securifer* BRADY.
A : Female, (dorsal view)
B : 〃 , 1st antenna
C : 〃 , urosome (ventral view)
D : 〃 , 5th pair of feet
E : Male, (dorsal view)
F : 〃 , 5th pair of feet
G : 〃 , 1st antenna

*Pontella* sp. Fig. 64

Male: Lateral angles of last thoracic segment produced into wing-like, pointed projections. Dorsal eyes well separated, two rostral lenses contact with their inner walls and swell into a large sphere. Posterior corners of metasome not produced into triangular acute spines. Caudal rami symmetrical, more than three times as long as width. 5th pair of feet uniramous, and asymmetrical. The right foot forms a forceps.

Total length: 2.4～2.6 mm

Distribution; The author has found this species in the tropical region of the Indian Ocean.

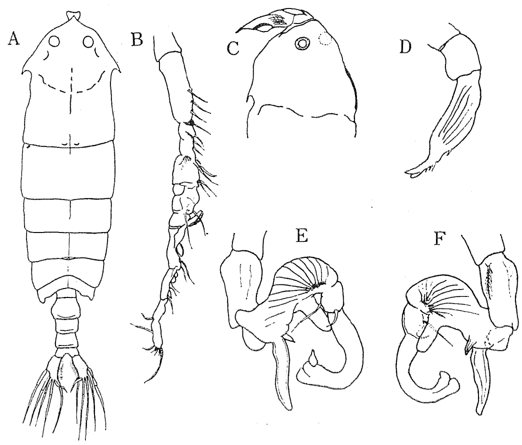


Fig. 64. *Pontella* sp.
A : Male, (dorsal view)
B : 〃 , 1st antenna (right)
C : 〃 , head (lateral view)
D : 〃 , left 5th foot
E and F : 〃 , right 5th foot

*Pontellopsis regalis* (DANA) Fig. 65

*Pontella regalis*, DANA, 1849, p. 31; *Monops regalis*, GIESBRECHT, 1892, p. 486, pls. 1,26,41; *Pontellopsis regalis*, WILSON, 1932, p. 157, fig. 107.

Famale: Metasome a little more than twice as long as width, much narrowed anteriorly, very little posteriorly; Posterior lobes of 5th segment symmetrical, reaching beyond the center of genital segment; urosome 2-segmented, asymmetrical; genital segment twisting to right; endopodite of 5th legs short and tipped with two pointed processes of equal length; exopodite three times as long as endopodite, curved and tipped with two unequal spines, with a larger spine on the inner margin and three minute spinules on the outer margin.

Male: Right corner of 5th segment much longer than left, reaching the 3rd abdominal segment and has a knoblike process on the right side of the 2nd abdominal segment; caudal rami symmetrical; left 5th leg 5-segmented, tipped with two or three unequal spines; thumb of chela on right 5th leg longer than finger; no processes on the hand.

Total length: 4.0～4.5 mm in female, 3.3～3.5 mm in male.

Distribution : This species has been recorded from the tropical and subtropical regions of the Atlantic, Pacific, and the Indian Oceans. The author has found this species at the Bay of Bengal and the tropical portion of the Indian Ocean.

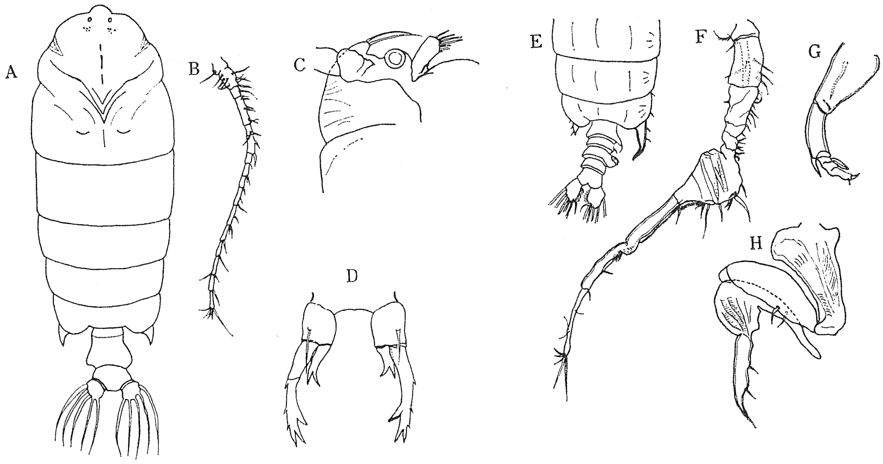


Fig. 65. *Pontellopsis regalis* (DANA).

A : Female, (dorsal view)
B : 〃 , right 1st antenna
C : 〃 , head (lateral view)
D : 〃 , 5th pair of feet
E : Male, urosome
F : 〃 , right 1st antenna
G : 〃 , left 5th foot
H : 〃 , right 5th foot

*Pontellina plumata* (DANA) Fig. 66.

*Pontellina plumata*, DANA, 1852, p. 1136, pl. 79; *Pontellina turgida*, DANA, 1852, p. 1136, pl. 79; *Calanops messinensis*, CLAUS, 1863, p. 212, Taf. II, fig. 11; Taf. XXXVI, f. 13~16; Taf. XXXVII, f. 10; *Pontella plumata*, BRADY, 1883, p. 92,

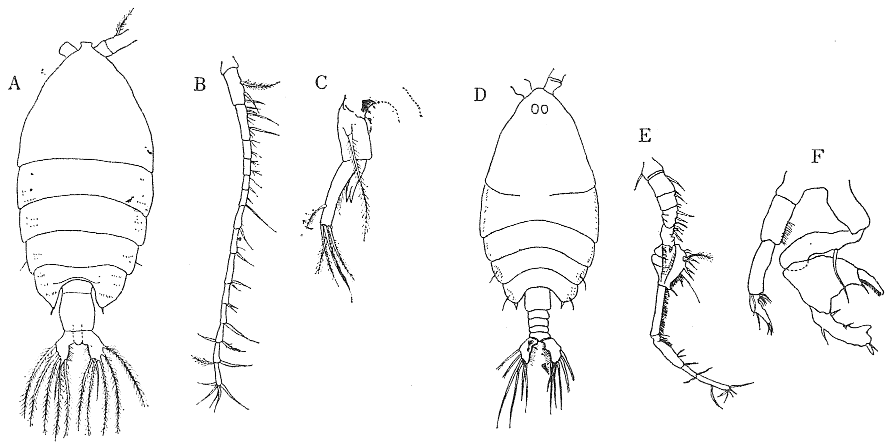


Fig. 66. *Pontellina plumata* (DANA).

A : Female, (dorsal view)
B : 〃 , right 1st antenna
C : 〃 , left 5th foot
D : Male, (dorsal view)
E : 〃 , right 1st antenna
F : 〃 , 5th pair feet

pl. XXXVII, figs. 1~11; *Pontellina plumata*, GIESBRECHT, 1892, p. 497, Taf. 4, f. 11; Taf. 25, f. 4, 18, 26, 36; Taf. 40, f. 49~53; T. SCOTT, 1894, p. 88; GIESBRECHT & SCHMEIL, 1898, p. 149; A. SCOTT, 1909, p. 175; WILSON, 1932, p. 156, fig. 106; MORI, 1937, p. 100, pl. 47, figs. 7~11; pl. 48, figs. 1~12.

Since the detailed description of this species was made by many investigators, 1st antenna, 5th foot and dorsal view of body in the both sexuality in specimens, the characters of which seem to be available in the identification of the species, are shown in the figure.

Total length: 1.6~1.8 mm.

Distribution: This species appears to be commonly distributed in the warm regions of all the oceans.

*Acartia danae* GIESBRECHT 1889

*Acartia danae*, GIESBRECHT, 1892, p. 508, Taf. 30, f. 1, 23; Taf. 43, f. 8; BREEMEN, 1906, p. 195, figs. 176 a~b; A. SCOTT, 1909, p. 187; SATO, 1913, p. 46, pl. VIII, figs. 126~127; SARS, 1925, p. 362; WILSON, 1932, p. 160, figs. 108a~b; MORI, 1937, p. 102, pl. 49, figs. 5~15.

Female: Body narrow and elongate; 5th segment has short spines at the corners; Urosome 1/3 of the length of metasome; Genital and 1st abdominal segments have minute spinules along their posterior margines; 1st antenna reaches the tips of caudal rami; end segment of 5th leg swollen at its base, and stoutly toothed in distal part from its center, and less than half as long as slender plumose seta of 2nd segment.

Total length : 1~1.2 mm.

Distribution: This species has been recorded from the tropical Atlantic and the Pacific Oceans, the south African coast, the Banda Sea, the Bay of Bengal, Gulf of Manaar. The author has found this species in the Arabian Sea and the Bay of Bengal.

*Acartia longiremis* LILLJEBORG 1853

*Acartia longiremis*, GIESBRECHT, 1892, p. 507, Taf. 43, f. 17, 25; GIESBRECHT and SCHMEIL, 1898, p. 153; SARS, 1903, p. 149, pls. XCIX & C; SATO, 1913, p. 45, pl. VIII, figs. 122~123; pl. VII, figs. 124~125; SARS, 1925, p. 362; WILSON, 1932, p. 165, figs. 113a~c; MORI, 1937, p. 104, pl. 51, figs. 6~6.

Female: Rostral filaments absent. Posterior corners of the last metasome segment rounded and furnished with a slender spine. Posterior margins of abdominal segments are furnished with fine spinules. Furcal style nearly 3 times as long as its width. First antenna has no spines on proximal segments and extends beyond end of metasome. Terminal segment of 5th foot curved at the middle portion, and longer than that of the marginal seta.

Total length : 1.2~1.4 mm.

Distribution: This species has been recorded from the Pacific and Atlantic Oceans. The author found this species in the Bering Sea.

## Summary

From 1952, the author endeavored to examine the composition and distribution of plankton in the several fishing grounds newly explored, and discussed the results in relation to the oceanographic conditions observed during the collection of the plankton samples, furthermore, paid his attention to finding out the significance of the results of his study to the commercial fishery. This thesis consists of three parts.

Part I The distribution of plankton and oceanographic conditions

In the North Pacific salmon fighing-grounds, the features of the mixing of the cold water mass with the warm one were induced from the composition and distribution of plankton therein; and it became clear that the good fishing-grounds for salmon from June to July were usually not found in the inshore waters where rich population of diatoms was propagating but in rather off-shore where large-sized zoo-plankton chiefly copepods populated densely.

As to the trawling grounds in the Northeast Bering Sea, the distribution of respective species of plankton in June suggested the rationality of classifying the surveyed waters into three regions; they were 1) the northwestern region represented by the neritic plankton of the subarctic waters, 2) the southern region represented by Tricho-plankton and 3) the northeastern region represented by Sira-plankton. On the other hand, the results of the test trawling suggested that a good fishing-ground with high possibility of economic success was usually found in the waters south of 58°N with transparency relatively high and temperature more than 2°C on the bottom, namely in the region covered by the Tricho-plankton. The yellow-fin sole, halibut, Alaska ccd, Alaska pollack and pink shrimp were the important members of the catch.

It was the characteristic of the plankton in tuna fishing grounds in the Equatorial Pacific that the waters in the North Equatorial Current were poor in plankton whereas those in the Equatorial Counter Current were very rich. It seems to be due to the facts that the waters in the Equatorial Counter Current which flows from the Phillipine Islands to the Marshall and Caroline Islands then far eastwards are more nutritive than those in the North Equatorical Current which flows westwards in the Central Pacific. And it may be safely said that *Hemiaulus haukii* and *Planktoniella sol* can be adopted as the indicator species of the diatom to the North Equatorial Current and the Equatorial Counter Current, respectively. On the other hand, the adjacent waters of the Phoenix Islands where the presence of an upwelling was already reported were very rich in plankton flora and fauna and a good catch of tuna was observed there.

Concerning with the Indian Ocean, the following 5 waters were surveyed : 1) the waters west of the Greater Sunda Islands, 2) central part of the North Indian Ocean, 3) southeastern part of the Arabian Sea, 4) eastern part of the Indian Ocean and 5) the Bay of Bengal.

In the tuna fishing grounds west of the Greater Sunda Islands, plankton were

richer not only quantitatively but also qualitatively in the southern parts (the adjacent waters of Bali, Lombok and Sumbawa) than in the norhern parts (the adjacent waters of Sumatra). This fact was thought to be due to the following reason that the southern parts are nourished by the enriched waters of the northwest Australian coast origin flowing northwards.

In the waters of the central part of the North Indian Ocean, rich plankton were found in the western waters where the water masses of both surface and subsurface layers mixed with each other.

In the eastern part of the Indian Ocean, the presence of a steep gradient of temperature and salinity was observed between 15°S and 18°S; this was thought to form the latitudinal boundary in the distribution of plankton.

In the winter, the composition of plankton in the Bay of Bengal showed somewhat remarkable local specificity; namely the oceanic species occurred rather exclusively in the central parts whereas the neritic ones predominated in the on-shore. And the features of the distribution of both the oceanic and neritic water masses could be induced from the frequency of occurrence of these species. Besides, dense population of diatoms was found in the on-shore waters from the north of the bay to the east; this is thought to be more or less due to the influence of the monsoon drift and of the inflowing of the Ganges and Irawady.

On the other hand, among some very commonly observable and very easily identifiable species, if there are some species capable of being applicable to the indicator, they are surely of convenience with very high practical value. From this stand-point, the author intended to find out such a species mentioned above and examined the frequently observable range of 25 species of diatoms and 16 of copepods in relation to the temperature and salinity of their habitat and as the results, he fortunately found out some common species capable of being applicable to the indicator to either cold, warm, oceanic or neritic waters.

Part II Food of salmons and the gonad weight

The author examined the stomach contents of 5 species of salmons in the north Pacific ; especially for the dog salmon he did the change in the amount of stomach contents in relation to the gonad maturity. And he found that the composition of stomach contents more or less differed with species of fish and that the gonad of dog salmon had considerably developed near the end of the fishing season, late in July, but they were still in the feeding migration.

Part III Taxonomical studies of plankton

This part treated on the identification and taxonomical description of 30 species of suborder "Hyperiidae" of pelagic Amphipoda and 16 species of Chaetognatha both of which were collected from the Indian Ocean. And the distribution of these species were added here, too. During this study, the author had an opportunity of getting the samples of 14 species of Copepoda so rare as to be not commonly described in the adjacent waters of Japan.

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The title of the reference enclosed by parentheses is written in Japanese and is translated, for convenience' sake into English by the present author.