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RASPREDELENIYE ZOOPLANKTONA V KURILO-KAMCHATSKOM RAYONE TIKHOGO OKEANA

(Distribution of Zooplankton in the Kurile-Kamchatka region of the Pacific Ocean)

by

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ABSTRACT
(Conclusions)

1. In spring the biomass of zooplankton reaches its maximum value exceeding 500mg/m^3 in the 0-100m layer and occupying a belt 30-50 miles wide; this belt deflects somewhat from the Kurile Islands, namely, from the southernmost stations of the investigated area to the latitude of Petropavlovsk and the area SW of Kamchatskiy proliv. The water along the northern boundary of the intermixing zone was also very rich in plankton.

The same character of distribution between zones that are rich and poor in plankton is observed in the autumn, but the total biomass of plankton during the time is smaller.

2. *Eucalunus bungii*, *Calanus cristatus* and *Calanus plumchrus* are the dominant forms of zooplankton which constitute 80% of its biomass. These species determine the typical distribution of zooplankton biomass.

When comparing the distribution of large concentrations of *E. bungii* and *C. cristatus*, one can see a pronounced thermophilic character of the latter. In spring the concentrations of *E. bungii*, which exceeded 100 mg/m^3, were most often observed at temperatures ranging from +0.5 to +1.5°C, while *C. cristatus* reached large concentrations at temperatures ranging from +1.5 to +2.5°C. *C. plumchrus* does not show such a dependence upon a definite temperature interval.

3. The seasonal pattern of plankton during our investigations in the spring was very variable. In the Kurile area the spring blooming phytoplankton occurred in mid-May; a number of eggs, nauplii and small copepods were seen. By the end of May the blooming intensified, and many nauplii of *E. bungii* and early stages of copepods of *C. plumchrus* appeared. In the second half of June the main mass of copepods of *C. plumchrus* reached the peak of development in mid-June, while the zooplankton reached it in the beginning of July. In September-October the plankton biomass in the upper 100m layer decreased rapidly.

4. In the investigated area *Calanus plumchrus* had two seasonal races or generations: the spring and summer-autumn generations. The reproduction of spring race took place in April-May, that of the summer race in August-September.

5. On the basis of the distribution of species--which indicate

the origin of water and the character of quantitative distribution of plankton--it appeared to be possible to trace the distribution of water in the Kurile-Kamchatka area, namely: the penetration of Bering and Okhotsk water into the ocean and the northward movement of southern water into the Komandor-Kamchatka region where the southern water differs little from the Bering water if temperature characteristics are considered.

The author

DISTRIBUTION OF ZOOPLANKTON IN THE KURILE-KAMCHATKA REGION OF THE PACIFIC OCEAN

The study discusses the distribution of plankton in the upper 500m layer of the Pacific Ocean, which adjoins the Kurile Islands, Kamchatka and Komandorskiye ostrova. Eastward, the investigations reached 170°E, southward 40°N, where the given area was bounded by zones marking the mixing of water induced by the northerly Kuroskio and characterized by the appearance of thermophilic species and disappearance of boreal forms from the upper water layers.

Almost the entire given area is occupied here by a rather uniform subarctic water mass which is called the Oyashio. The penetrating water masses of the Okhotsk and Bering Seas play a substantial role in the formation of various water types (Uda, 1955; Burkov, 1957). Although the waters of the Okhotsk and Bering Seas are, on the whole, similar, they differ by several hydrological characteristics, peculiarities of distribution and, partly, by the composition of plankton. Individual branches of the Kuroshio penetrate the water of the Oyashio, moving far to the north. They are there intensely cooled and deformed so that it is difficult to distinguish them from the surrounding water, though they preserve a number of thermophilic organisms which make them distinct. The influence of the Kuroshio, as well as the southward movement of cold water, is very variable and is subjected to seasonal and yearly fluctuations, which affect the "productivity" or "unproductivity" of plankton in the entire Kurile-Kamchatka region in individual years.

Thus, the structure of water in this area is rather complex, which, in turn, affects the distribution of plankton.

Lately, the NW part of the Pacific Ocean is gaining in significance because of being the richest commercial fishing area. In frontal zone and a little south of it, in the open ocean, the tuna is fished; but in the Kurile and Hokkaido areas the saury is caught; the concentration of the latter is limited to places where the plankton concentration is high (Matsudaira, Iwasaki, Tsuda, 1956). The entire Kurile-Kamchatka area is a place where whales are fattening, but the area south of Komandorskiye ostrova and Blizhniye ostrova is used by salmon while living in the sea. Therefore, various scientists are interested in studying the area. However, most of the attention is usually devoted to the intermixing zone of the Oyashio and Kuroshio waters, i.e. the frontal zone; while the water of the Oyashio is only casually examined. Specific information on the hydrology of the Kurile- /61
Kamchatka area is given in studies by Watanabe (1954), Uda (1955),

Uda and Nasu (1956), Mishima and Nishizawa (1955), Burkova (1957); the plankton distribution is discussed in studies by Nakai (1952), Nakai and K. Honjo (1954), Ye. A. Lubny-Gertsyk (1955a) K. A. Brodskiy (1955 a,b), V. G. Bogorov and M. Ye. Vinogradov (1955), M. M. Sleptsov (1955), G. I. Semina (1956), Marumo (1956) and Nemoto (1957).

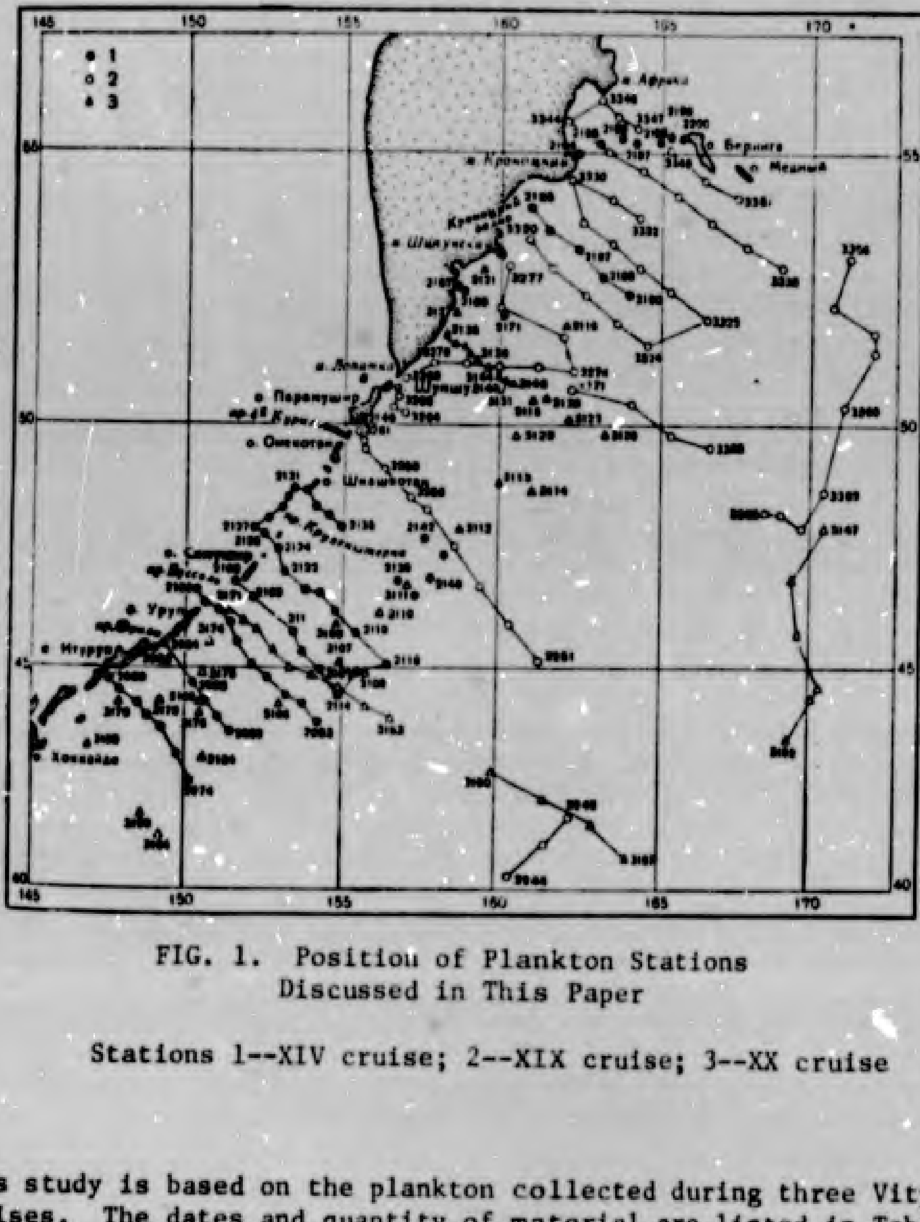

FIG. 1. Position of Plankton Stations Discussed in This Paper

Stations 1--XIV cruise; 2--XIX cruise; 3--XX cruise

This study is based on the plankton collected during three Vityaz' cruises. The dates and quantity of material are listed in Table 1, but the positions of oceanographic stations used for sampling are shown in Fig. 1. Altogether, the data of 193 plankton stations with about 800 samples were examined.

During the Vityaz' cruises, the plankton to a depth of 500m was sampled with a Juday net in which the diameter of mouth was 37cm (0.1m^2), the filtering cone was made of the finest gauze no. 38 (38 meshes per linear centimeter). The plankton water layers: 0-10m, 10-25m, 25-50m, 50-100m, 100-200m, 200-500m. /62

Table 1

Dates and Volume of Material Utilized

No. of Vityaz' cruise	Dates	Number of stations		
		East of Kurile Islands	East of Kamchatka	Total
XIV	7. V—18.VI 1953 r.	56	15	71
XIX	21.VIII—13.X 1954 r.	42	16	58
XX	15.V—13.VI 1955 r.	17	46	63

The samples were processed by a method approved by the Institute of Oceanology (Vinogradov, 1954), i.e. the number of individuals of each species was counted; in addition, each group of calanoids was counted. The data were reduced to standard weight by using a table prepared by Ye. A. Lubny-Gertsyk (1953).

Plankton Distribution in the Spring

The most numerous collections of plankton in areas of interest to us were made by the Vityaz' expedition in the spring--May-first half of June. The number of stations occupied in other seasons of the year is relatively small and, in addition, these stations were irregularly scattered over a large area. Therefore, it is difficult to obtain from these data a clear idea of the distribution of plankton. Let us discuss in greater detail the distribution of plankton in the spring and use the data obtained in other seasons only for comparisons and the elucidation of seasonal variations in the composition and distribution of plankton.

As was mentioned above, a considerable portion of subarctic surface water of the Pacific Ocean is not formed in the Arctic but in the Bering and Okhotsk Seas. According to the degree of effect of these seas, the Kurile-Kamchatka area can be divided into the

Komandor-Kamchatka and the Kurile areas. The former is freely connected with the Bering Sea and is under a continuous influence of the water flowing in via the Kamchatskiy proliv. V. A. Bunkov (1957) points out that the Komandor-Kamchatka area and the deep part of the Bering Sea represent a unique region of the World Ocean occupied by one type of water. The wide and deep Kamchatkskiy proliv does not deform the water that leaves the Bering Sea. For us, this unity with deep SW area of the Bering Sea, where large quantities of plankton were collected in various seasons of the year, is very substantial because it enables us to characterize the seasonal variations of plankton inhabiting the Komandor-Kamchatka region.

According to V. A. Burkov (observations conducted in June 1955), in the spring, the entire area from ostrov Blizhniy (o. Bol'shoy Lyakhovskiy) to Kamchatka is occupied by a single water mass and is not subjected to the influence of warm southern waters. However, some of the data obtained by him, for example, at individual stations (St. 3325), make one doubt the accuracy of such a conclusion. /63 Indeed, Watanabe (1954) remarks (data obtained in June 1952 and 1953) that warm water flows through the strait between the Komandorskiye and Blizhniye ostrova during the spring and summer; this water appears to be part of the warm water layer found by him to the east of the Kurile Islands. M. Ye. Vinagradov (1956) pointed out that, in summer and autumn warm water inhabited by thermophilic forms (*Calanus pacificus*, *Phronima sedentaria*, *Paraphronima crassipes*, *Sagitta lyra*) flows through this strait into the Bering Sea.

The hydrological regime of the Kurile area is more complex. Together with the current flowing from the Komandor-Kamchatka region in the north and known as the cold Kamchatka current, the hydrological regime in the region is also influenced by the cold Okhotsk water passing through the Kurile Straits (mainly through proliv Kruzenshterna, pr. Bussol' and pr. Friza). In contrast to the water of the Bering Sea, the Okhotsk water, passing through the Kurile Straits with pronounced tidal currents, becomes transformed as it enters the ocean. The influence of the Okhotsk water diminishes in the areas of the northern Kurile Islands (o. Paramushir and o. Onekotan) because here the ocean water (where the temperature of the intermediate water layer is above 2°C) comes close to the islands and penetrates the Sea of Okhotsk via the straits.

The SE part of the Kurile region is considerably affected by the Kuroshio Current; a number of its branches reach in summer the Kurile Islands, even forming individual cyclonic water movements in the area (Watanabe, 1954).

The water of Hokkaido and the Small Kurile Islands areas is somewhat different; but we have little data from the area and, therefore, we will not discuss it here.

When examining the charts of stations of the XIV and XX cruises of the Vityaz', it is seen that the main areas that were studied were not the same, since in 1953, the main plankton samples were obtained in the Kurile area, while only a few stations were occupied east of Kamchatka, then in 1955, the Komandor-Kamchatka area was subjected to a more detailed investigation. However, the same dates and almost identical plankton data, as well as similarities in the distribution and quantity of plankton in places examined during both of the cruises, make it possible to compare the data obtained on the XIV and XX cruises.

Distribution of the Over-All Zooplankton Biomass

During the work in the Kurile region (7 May - 1 June 1953), the water east of the islands appeared to contain the largest quantity of plankton. A rich belt 30-50 miles wide, with a mean biomass exceeding 500mg/m^3 in the 0-100m layer, stretches along the Kurile Islands and, according to the Vityaz' XX cruise, continues eastward from Kamchatka to the latitude of Petropavlovsk. This belt now reaches the Kurile Islands (at o. Onekotan), now deflects from them to a distance of 30-50 miles (off proliv Friza, pr. Bussol' and pr. Kruzenshiterna) where the action of the currents flowing from the Sea of Okhotsk is rather intense. A narrow water belt along the Kurile Islands is poor in plankton. Its biomass does not exceed 200mg/m^3.*

East of the zone with a high biomass, the quantity of plankton decreases somewhat again, fluctuating between 200 and 500mg/m^3 /64
and having some richer spots; e.g., an increase in the biomass of plankton (to 700-2,000mg/m^3) is observed at the northern boundary of intermixing zone at Stations 2093, 3244-3246.

Such distribution of biomass in the Kurile area is rather constant. This pattern is also observed in other years (Lubny-Gertsyk, 1955) and seasons (Bogorov and Vinogradov, 1955).

*Here, as elsewhere in the text, we refer to the biomass in the 0-100m layer. If a biomass of another layer is given, the layer is specifically mentioned.

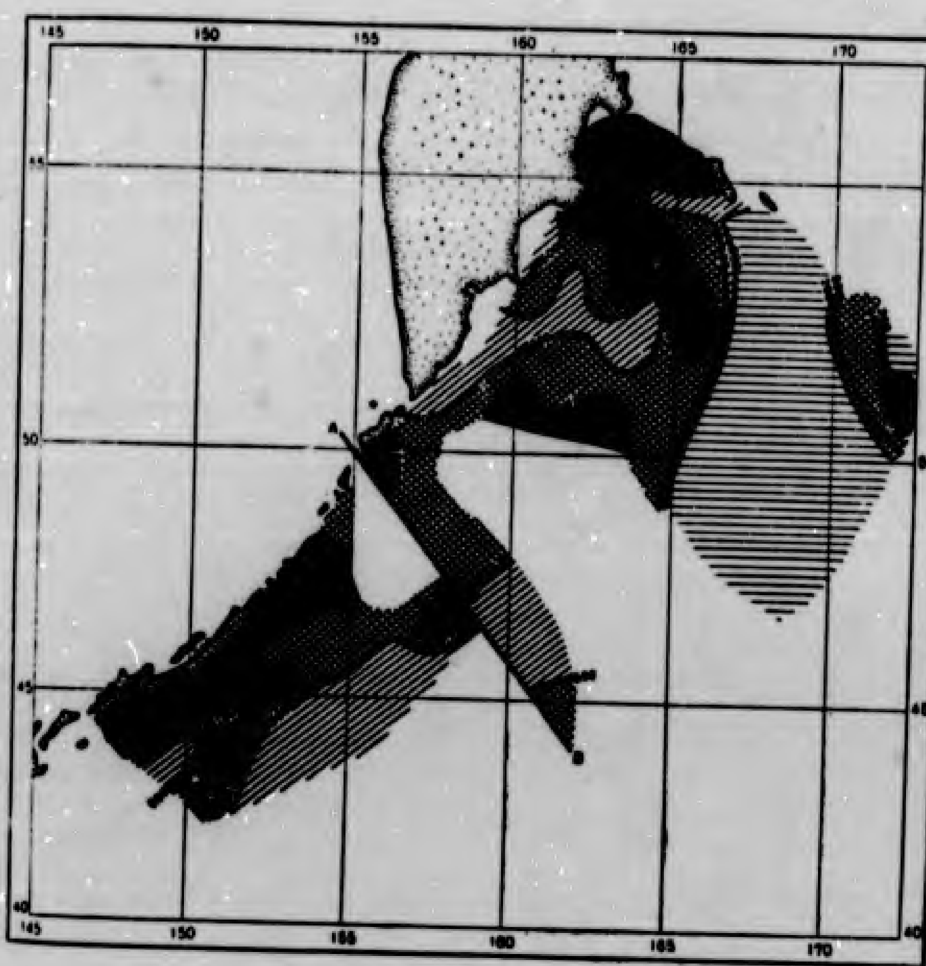

FIG. 2. Distribution of Zooplankton Biomass (mg/m) in the 0-100m layer (in spring)

In the Komandor-Kamchatka area the plankton distribution is more diverse (observations during 18 May - 13 June 1955). But it agrees well with the current pattern in the area, which was plotted by V. A. Burkov (1957) (see FIG. 10). The largest biomass of plankton (more than 500 and as high as 1,000 mg/m^3) is found in the water flowing from the Bering Sea via Kamchatskiy proliv and turning southward along Kamchatka. Here the greatest concentration of plankton, reaching at some stations 2,000-3,000mg/m^3, is limited to the 0-50m layer. A zone with abundant plankton is traceable to the mys Shipunskiy latitude, but southeast of it the rich zone is penetrated by a spot with a small quantity of plankton (less than 100-200mg/m^3), which is probably associated with the holistatic cyclonic zone.

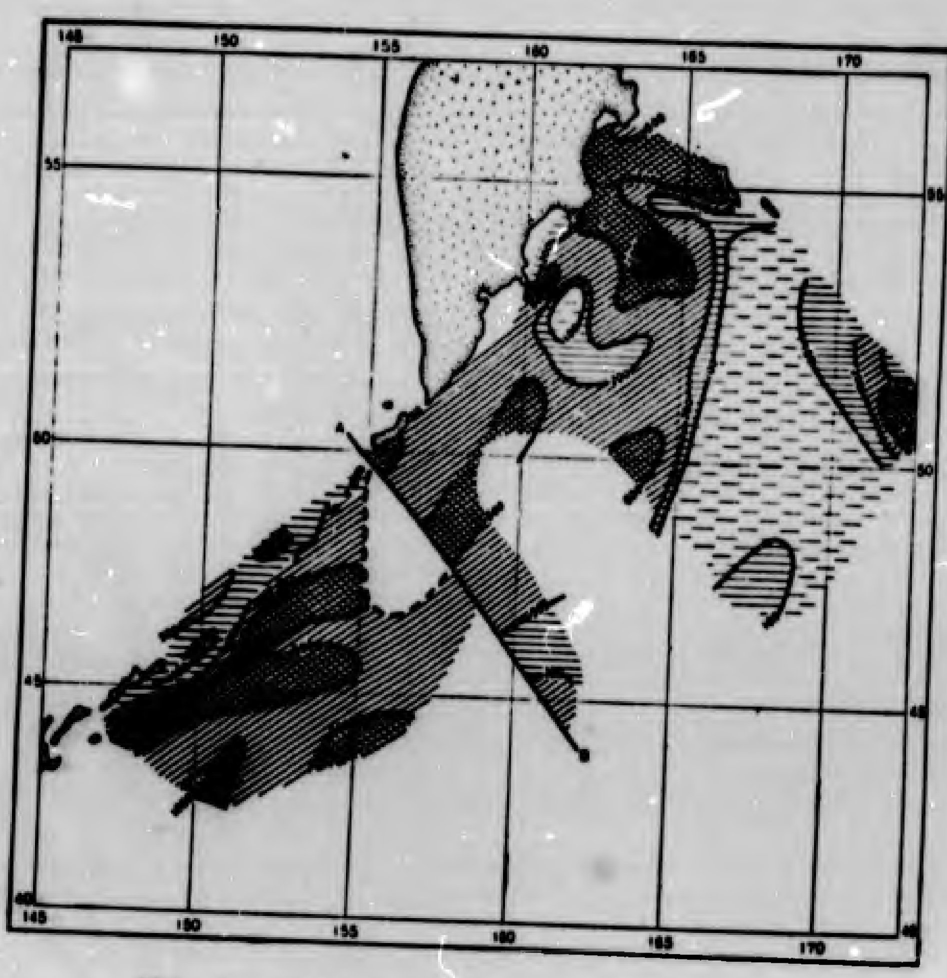

FIG. 3. Distribution of Biomass Maximum of Zooplankton in mg/m^3. North of line AB are given the data of XX cruise, south of it--the data of XIV cruise.

To the south the plankton biomass fluctuates from 200 to 400mg/m^3 and only at individual stations, east of the southern tip of Kamchatka, does it rise above 500mg/m^3.

In Kronotskiy zaliv and, possibly, in other gulfs the plankton biomass is less than 200mg/m^3 near the coast (Lubny-Gertsyk) East of 167°E, i.e. in a strait between Komandorskiye ostrova and o. Blizhniy and south of it over a large area, the plankton biomass does not exceed 100mg/m^3. In contrast to the above-mentioned rich plankton zone, the maximum concentrations (to 200mg/m^3) were observed in the 50-100m or even 100-200m layers. SW of Komandor, the water, including the southern part of the current coming from Blizhniy proliv, has a small amount of plankton; it penetrates deeply into the zone rich in plankton.

East of this vast zone with a poor plankton content (in Blizhniy ostrov area), the plankton biomass increases again to 200 and even 600mg/m^3 (Fig. 2).

As was pointed out before (Vinogradov, 1955, 1956) the intensity of diurnal migrations in most of the abundant plankton species of boreal waters of the Pacific Ocean varies noticeably by seasons. /66
In spring, the migration is not pronounced even in the oldest copepod stages (*Calanus plumchrus*, *C. cristatus*, *Eucalanus bungii*, *Pseudocalanus elongatus*); seldom does the amplitude of migrations reach several tens of meters. The migrations of the whole plankton mass consisting of young non-migrating stages are still less pronounced. Therefore, the diurnal differences of plankton biomass in the 0-100m layer were so insignificant at stations occupied during the day and night that we could dispense with them when plotting the charts of the distribution of plankton biomass.

It is important to know not only the distribution of the mean quantity of plankton in the 0-100m layer but also its concentration maximum at given depths because, even if the mean biomass of plankton is small, it can be sufficiently high and useable for the feeding of whales and fishes, and, consequently, for whaling and fishing. With this in mind, we plotted a chart of the distribution of plankton biomass maximums, i.e. of the largest quantities observed at a given station in any of the water layers (FIG. 3). The interrelation between zones with large and small quantities of plankton on these charts differs little from the values on the charts presenting the mean biomass of plankton distribution in the 0-100m layer; the absolute magnitudes, however, appear to be much higher. The greatest biomass was observed in the 0-50m layer; this was true of almost all the stations, especially those occupied in areas rich in plankton.

Distribution of Concentration of Major Species

As has been mentioned repeatedly, dominant groups of the zooplankton biomass inhabiting the North Pacific Ocean are three copepod species, whose concentrations determine the general biomass of the whole plankton; the species are: *Calanus plumchrus*, *C. cristatus* and *Euclanaus bungii*. In spring they make up 82% of the total plankton biomass in the Komandor-Kamchatka region; *C. plumchrus* constitutes 14%, *C. cristatus* 36%, and *E. bungii* 32%. In the Kurile region they make up

79% of the total biomass, namely: 22%, 25%, and 32%, respectively.

In order to elucidate the peculiarities in the distribution of total biomass of plankton in a given area, let us discuss the distribution of the three major species, selecting them in the order of significance in the plankton of a given season.

Eucalanus bungii. Boreal oceanic species which is absent from warm surface waters. The species is frequent in the Bering Sea and is found in large quantities in such cold areas as Anadyrskiy zaliv and in the warmest SW region of the sea. In the Sea of Okhotsk this species occurs throughout its deep areas but it does not form such concentrations as in the Bering Sea or the Pacific Ocean. *E. bungii* is constantly, and often in large quantities, found in the cold intermediate layer (Vinogradov, 1956).

In spring (June) in the SW region of the Bering Sea *E. bungii* prevails and forms concentrations with biomass reaching 3.0g/m^3 in the 0-50m layer, making up, at the major part of stations, more than half of the total plankton biomass. Passing across Kamchatskiy proliv, or rather across its western half, the zone of large concentrations of this species (more than 100-200mg/m^3) gradually becomes poorer in plankton and widens, reaching the southern tip of Komchatka. This zone is about 150-200 miles wide, but at places it narrows considerably under the impact of warm ocean water south of Komandorskiye ostrova and east of mys Shipunskiy. /67

Thus, the concentration of *E. bungii* in the Komandor-Kamchatka region gravitates toward the colder coastal waters which, according to the character of phytoplankton (not zooplankton), can be assigned to a neritic region (Semina, 1956). However, at the immediate coastal stations in Kronotskiy zaliv the biomass of *E. bungii* did not exceed 30-40mg/m^3 (Lubny-Gertsyk). Of course, its small quantity is typical of the entire shallow area adjoining the coast. East of the rich zone, the quantity of *E. bungii* does not usually exceed 20-30mg/m^3. Here its concentrations are limited to the 0-200m layer; above the depth of 50m it is frequently absent. SW of Blizhniy ostrov and in the southern part of the Komandor-Kamchatka region (approximately 51°N and 164-166°E) the biomass increases again to 50-100mg/m^3. In places where *E. bungii* formed concentrations, Anraku (1954) also found them in May-June 1953. In addition, according to his data, large concentrations of *E. bungii* were observed south Blizhniy ostrov at the latitude of mys Lopatka and slightly to the south of Krys'i ostrova.

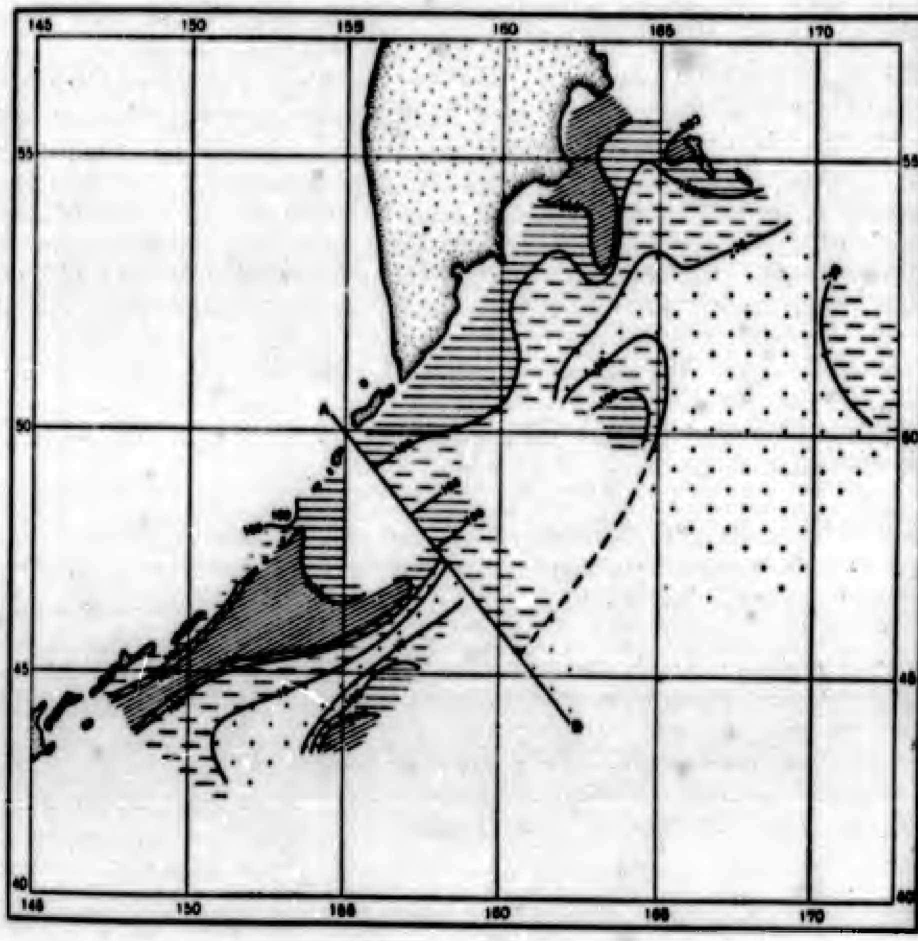

FIG. 4. Distribution of *Eucalanus bungii* Biomass (mg/m^3) in the 0-100m Layer. North of line AB are data of XX cruise, south of it--data of XIV cruise.

In the Kurile area the concentrations of *E. bungii* with biomasses exceeding 100-200mg/m^3 are about 200 miles wide, and they closely adjoin the islands; but southward the width of this dense zone narrows considerably and deflects farther away from the Kurile Islands. South of the island, the quantity of *E. bungii* does not exceed 30-50mg/m^3. /68

East of the concentration zone, the quantity of the species decreases abruptly to 1-4mg/m^3; then, at the easternmost stations of the investigated region (St. 2093 and 2116), the quantity increases again to 100-200mg/m^3 (see FIG. 4.).

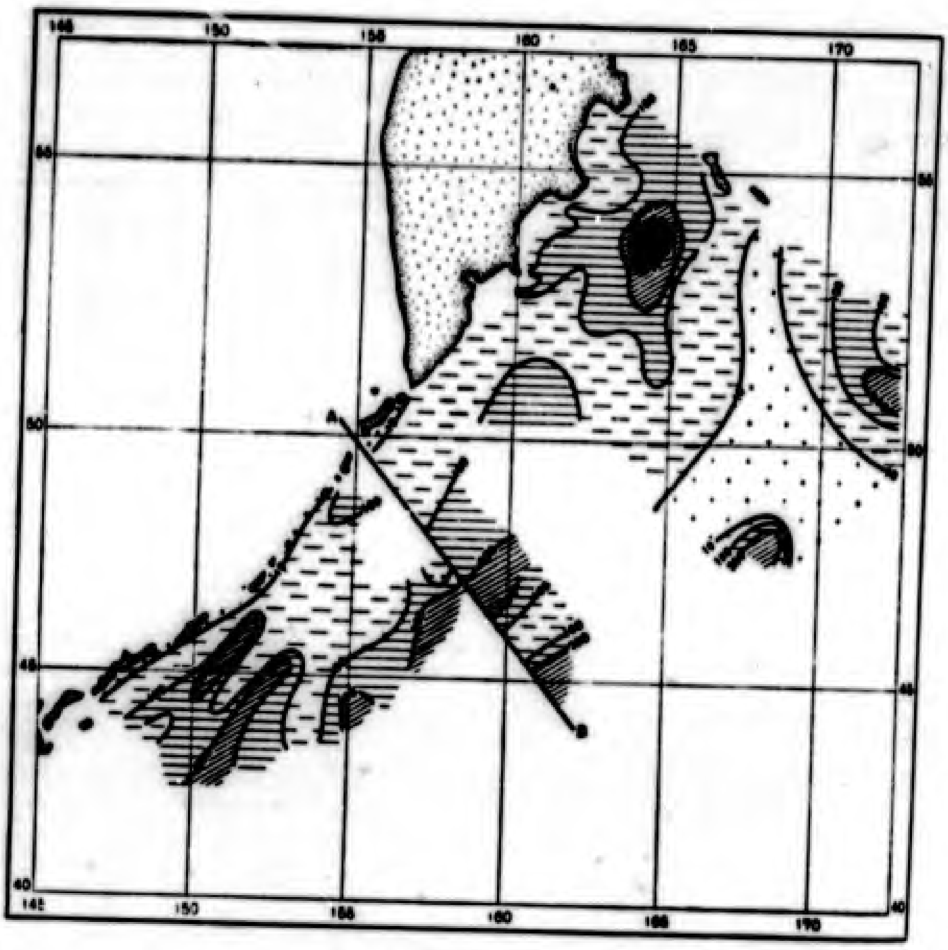

FIG. 5. Distribution of the Biomass of *Calanus cristatus* (mg/m^3) in the 0-100m layer. North of line AB are shown day of the XX cruise, south of it--the data of the XIV cruise.

Calanus cristatus is a boreal oceanic species which avoids the cold intermediate layer. In contrast to *E. bungii*, *C. cristatus* does not form large concentrations in the cold boreal region. Thus, for instance, in the cold Anadyrskiy zaliv of the Bering Sea, the species is found in small numbers and it is more restricted to the stream of the central Bering water than is *E. bungii* (Vinogradov, 1955). *C. cristatus* is widely distributed in the Sea of Okhotsk, but, usually, it does not form considerable concentrations.

In the Komandor-Kamchatka region, the zone of main concentrations of the species lies somewhat seaward of the concentrations of *E. bungii*. Here the biomass of *C. cristatus* exceeds 100mg/m^3, at individual stations even 1,000mg/m^3. Nearer to the coast, where the biomass of *E. bungii* reached maximum values, the biomass of *C. cristatus* does not exceed 50-60mg/m^3; only off the mys Shipunskiy does it increase to 300mg/m^3. An especially high biomass of *C. cristatus* was noted at St. 3332 where in the 25-50m layer it reached 3,000mg/m^3 (725 ind. per 1m^3). At the majority of stations the concentrations of *C. cristatus* are limited to the 25-100m layer.

South of the line running from St. 3320 to St. 3324, the quantity of *C. cristatus* decreases; then, at the latitude of mys Lopatka and the northern Kurile Islands the quantity again somewhat increases. In the E. sector where the biomass of the species exceeds 100mg/m^3, the zone bounds on 165-166E. S and SE of Komandorskiye ostrova the quantity does not exceed 10-40mg/m^3, and only SW (St. 3359) and somewhat to the S (St. 3305) of Blizhniy ostrov does it increase to 250-450mg/m^3, as in the case of *E. bungii* (see FIG. 5). Anraka (1954) points out that *C. cristatus* is found S of Krys'i ostrova, NW and SW of Blizhniy ostrov and, especially, south of the islands--at Stations 3362-3365.

In the Kurile region, the largest quantities of *C. cristatus* are observed in the southern part and in the area adjacent to the mixing zone (St. 2093, 2114, 2139, 2141, 3245, 3246); at the immediate boundary of the mixing zone, at St. 3245 and 3246, the biomass reaches maximum values. The same trend of forming large concentrations on the boundary between the boreal and mixing zones is noted in other seasons in *C. cristatus* (Bogorov and Vinogradov, 1955). In the mixing zone the quantity of *C. cristatus*, as well as that of *E. bungii*, sharply decreases. The species disappears from upper water layers and on the boundary of Kuroshio water it is not found above the depth of 500m; farther from this boundary it is not found above 1,000m (Bogorov and Vinogradov, 1955).

Calanus plumchrus is a boreal oceanic species which avoids the cold intermediate layer. Like the two preceding species, *C. plumchrus* is abundant in the Bering Sea; but, in contrast to the former, it forms the largest concentration (to 6,000mg/m^3) in southern and central areas of the Sea of Okhotsk.

In the Komandor-Kamchatka region, the area of concentration (more than 100mg/m^3) is limited, forming a small triangle from o. Beringa to mys Kamchatskiy and m. Kronotskiy (Fig. 6). The /69 greatest concentrations, with a biomass of 200mg/m^3, are observed in Kamchatskiy proliv at St. 3346 and 3347.

In the Kurile area, the biomass of C. *plumchrus* usually does not exceed 25-60mg/m^3, and only in a narrow belt over the axis of the Kurile-Kamchatka depression does it exceed 100mg/m^3; but in the southernmost and southeasternmost parts of the region it reaches 300mg/m^3. C. *plumchrus*, as C. *cristatus*, is most abundant (1,000-1,800 mg/m^3) on the boundary of the mixing zone (St. 3244-3246). True, the increase of biomass can also be explained by a somewhat later biological season in the relatively warm area when the biomass of C. *plumchrus* increases due to the growth of young.

Thus, the distribution pattern of these three major species of copepods is almost similar. Their major concentrations are observed NE of mys Shipunskiy, in the Kurile-Kamchatka Trench area and on the boundary of the mixing zone. The immediate area of the Kurile Islands and the area E of the strait separating Komandorskiye ostrova from Blizhniy ostrov contain a small amount of zooplankton.

However, if one compares the distribution of large concentrations of the species, it appears that their locations do not coincide. /70
The greatest concentrations of E. *bungii* are limited to the colder Kamchatka water, but that of C. *cristatus* to the warmer seaward water, which is apparent when comparing the positions of stations at which large concentrations of the species were observed. In the case of E. *bungii* the concentration area forms a wide band from Kamchatskiy proliv to the southern Kurile Islands, closely adjoining the coast of Kamchatka and somewhat deflecting from the Kurile Islands. The concentrations of C. *cristatus*, on the other hand, are scattered over the investigated area seaward of this zone; it is typical that the zones with large concentrations of E. *bungii* and C. *cristatus* are nowhere overlapped.

In the concentration areas of E. *bungii*, the main quantity of the species is found in the upper 50m layer; deeper its quantity decreases. In areas where C. *cristatus* and E. *bungii* prevail, C. *plumchrus* is very poorly represented and is even absent in the 100m layer where C. *cristatus* abounds. However, below the 100m layer, the quantity of C. *plumchrus* is often rather high. Such relationship, observed in the Komandor-Kamchatka and Kurile /71
areas, can be demonstrated in a cross section perpendicular to the Kurile Islands and intersecting the concentration areas of E. *bungii* and C. *cristatus*. With a distance from the islands, the main mass of E. *bungii* decreases and moves to deeper layers, while its role in the upper layer is replaced by C. *cristatus* (FIG. 7). The same pattern is observed in the cross section running parallel to the Kurile Islands and containing large concentrations of C. *cristatus* (FIG. 8).

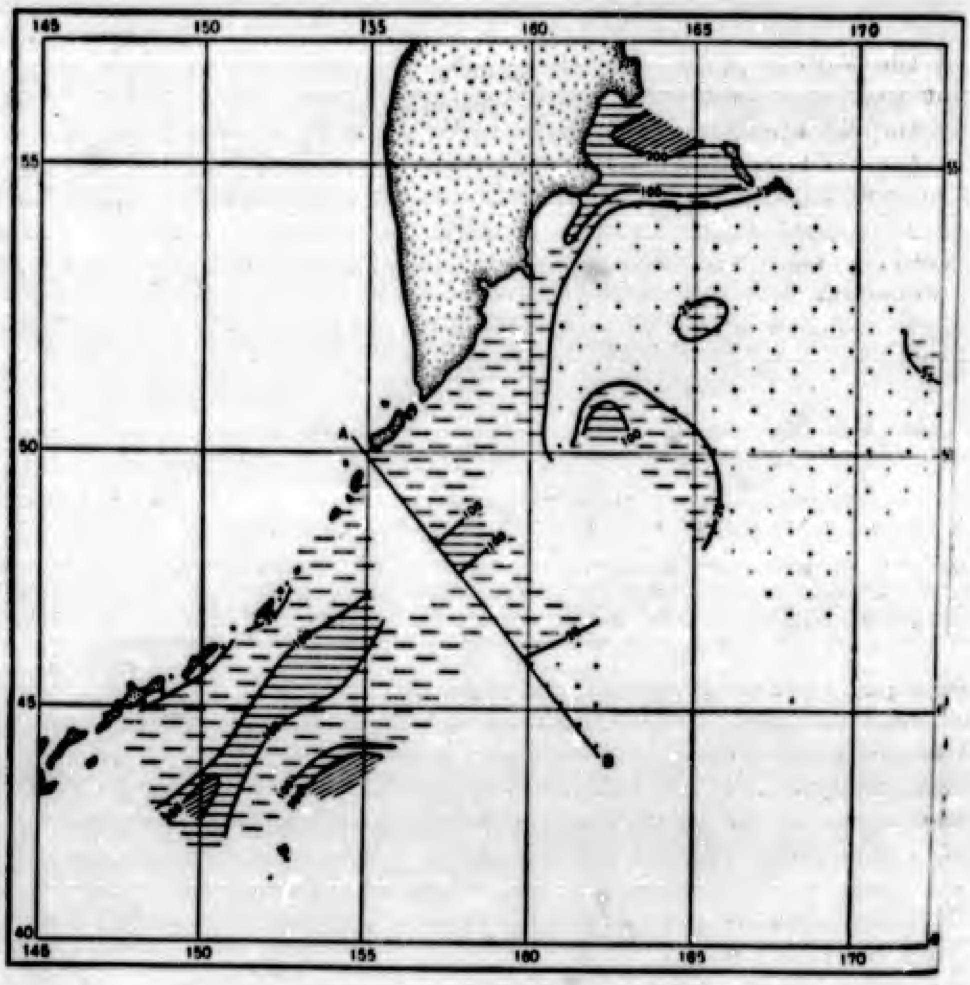

FIG. 6. Distribution of *Calanus plumchrus* biomass (in g/m^3) in the 0-100m layer.
North of line AB are presented the data of the XX cruise, south of it--the data of the XIV cruise.

Thus, the horizontal and vertical distributions of these species demonstrate that the concentrations of *E. bungii* are limited to colder water than the concentrations of *C. cristatus*. /71

We endeavored to determine the water temperatures at which these species form considerable concentrations, assuming that the conditions for the concentrations are optimal for the species. Because the main mass of populations made up of *C. cristatus* and *E. bungii* consists of one age group as a rule (small copepods of *C. cristatus* and similar in size and ecology IV-VI stages of *E. bungii*), we considered it possible to consider the behavior

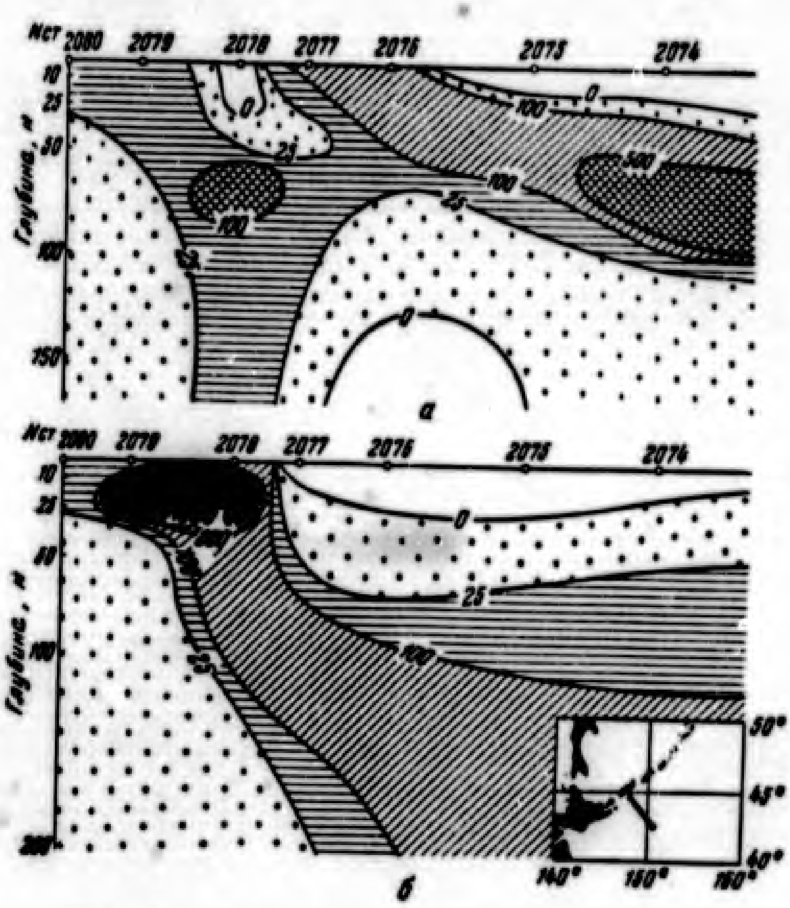

FIG. 7. Distribution of the Biomass of *Calanus cristatus* (mg/m^3) (a) and *Eucalanus bungii* (b) in the cross section o. Iturup--ocean.

of the population as a whole, without dividing it into age groups. For the 0-100m layer, we counted the frequency of occurrence of *C. cristatus*, *E. bungii* and *C. plumchrus* in concentrations exceeding 100 and 250mg/m^3 at various water temperatures.

The Komandor-Kamchatka (data of XX cruise) and Kurile (data of /73
XIV cruise) regions were separately examined. The curves of both of the areas are identical. The concentrations of *E. bungii* exceeding 250mg/m^3 occurred even at temperatures -1.5 to -0.5°C; in the temperature range from -0.5 to +0.5° their quantity increased, and at temperatures 0.5-1.5°C they reached a maximum concentration. In this range about half of the concentrations of *E. bungii* which exceeded 100mg/m^3 occurred. With a further increase in temperature, the frequency of concentrations sharply

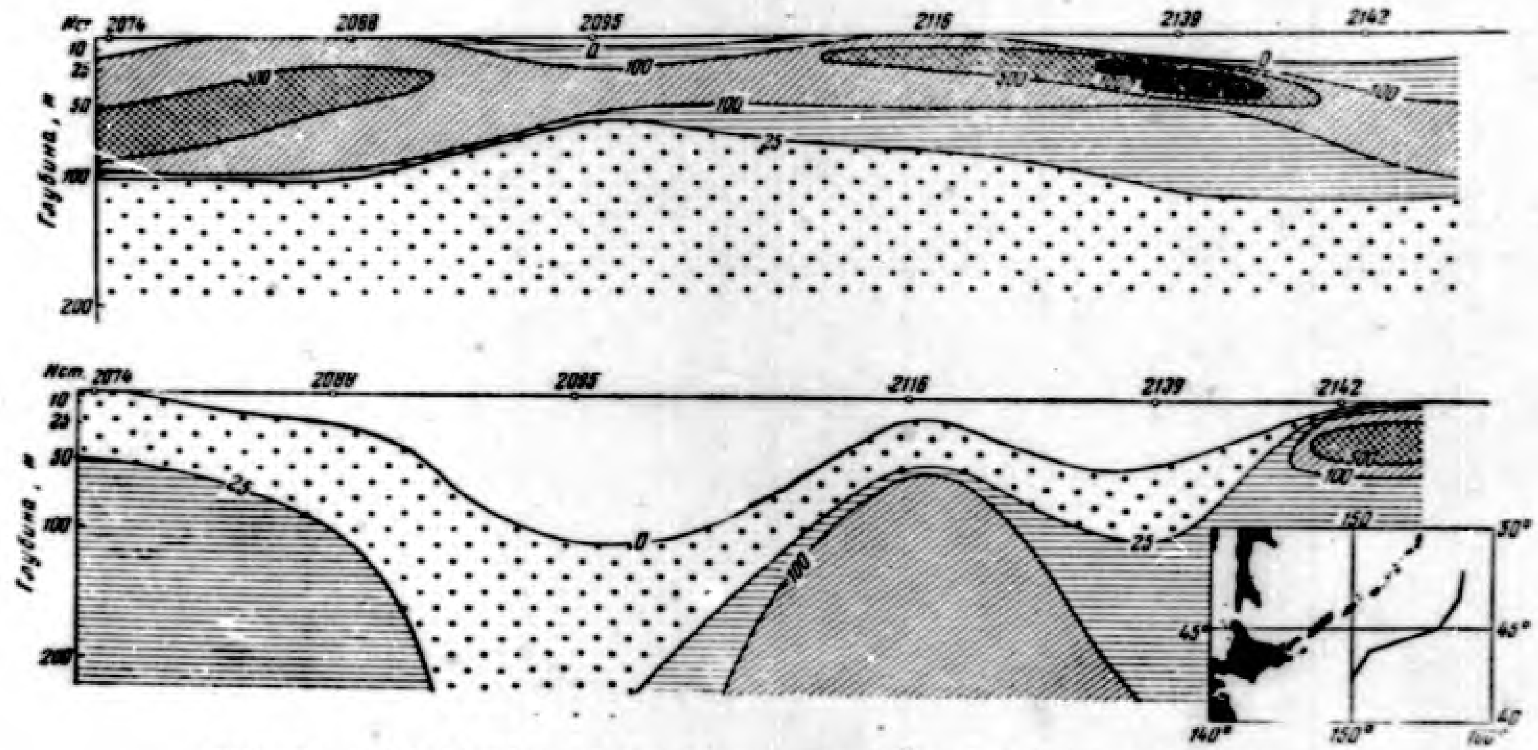

FIG. 8. Distribution of the biomass (mg/m^3) of *Calanus cristatus* (a) and *Eucalanus bungii* (b) in the cross section along the Kurile Islands in a concentration zone of *C. cristatus*

decreased. Also Z. V. Chernykh (1940) notes that the greatest concentration of E. *bungii* were observed at temperatures of 1-2°C.

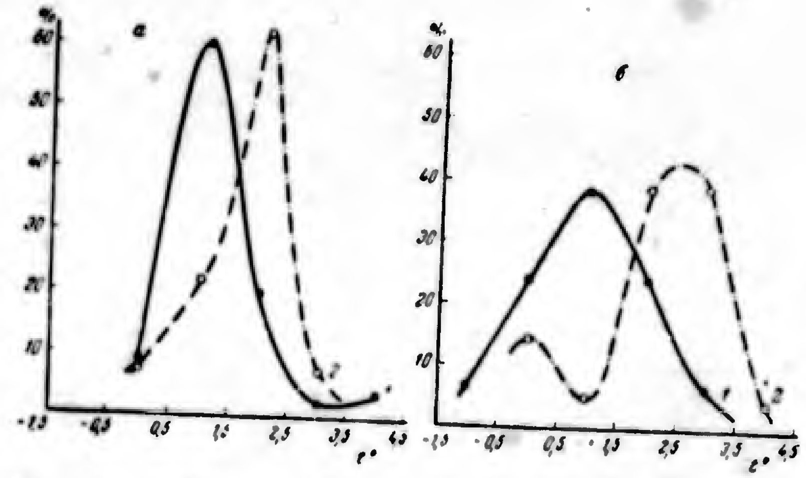

FIG. 9. Frequency of Concentrations of C. *cristatus* (1) and E. *bungii* (2) (exceeding 250mg/m^3) at Various Water Temperatures.

a--Kurile region; b--Kurile-Komandor region.

Large concentrations of C. *cristatus* were observed only at temperatures exceeding -0.5°C, the maximum being at 1.5-2.5°C; thus C. *cristatus* is more thermophilic than E. *bungii* (Fig. 9). C. *plumchrus* does not show such an adherence to a definite temperature range. In the Kurile region, a smooth frequency maximum of large concentrations is associated with water temperatures 0.5-1.5°C, but in the Komandor-Kamchatka region--this maximum is observed at temperatures of -0.5° to +2.5°C, the frequency being almost evenly distributed within this temperature range.

It need be pointed out once more that all these calculations pertain to the summer season when the water temperature exceeded 3-3.5°C at only a few stations. With a warming of water, the frequency maximum for all the three species may be displaced toward the higher temperature.

Most of the other species of planktonic animals were found in small quantities throughout the investigated areas; but nowhere did they form large concentrations, though at individual stations their biomass reached considerable magnitudes. Thus, at St. 2127, in the 10-25m layer, the biomass of *Metridia ochotensis* exceeded

45000mg/m^3 (more than 3000 ind/m^3); at St. 2126 the biomass of *M. pacifica* made up about 150mg/m^3; at St. 2079 the biomass of *Oithona similis* amounted to 100mg/m^3 (14,000 ind/m^3), etc.

Seasonal Status of Plankton

/74

At the beginning of our study in the Kurile region, the plankton was in a state of biological spring. Relatively large quantities of diatoms *Thalassiosira nordenskiöldii* and *Th. gravida* were observed only at o. Iturup. At other stations the quantity of phytoplankton was very small. Of course, its spring development had not yet started, which is attested by the content of phosphates and other biogenic elements in the upper water layers. When moving in a south-north direction, such a status of plankton was observed by us to the latitude of o. Simushir. Then the quantity of phytoplankton began to increase, while that of the biogenic matter began to decrease. Thus, off the northern Kurile Islands (o. Shiashkotan, o. Onekotan), at Stations 2133, 2146, 2147, 2151 we observed the beginning of spring "blooming" in which the cryophilic neritic diatoms were involved, mainly *Th. nordenskiöldii* and *Fragilaria oceanic*.*

In the southern part of the region, large amounts of nauplii and the first stages of copepods *Pseudocalanus elongatus* were observed. The quantity of large copepods was very great in surface layers. At a number of stations, we encountered huge quantities of eggs (to 10,000 ind/m^3); at others also the eggs of nauplii of *E. bungii* and *C. plumchrus* were found. At one station we observed early stages of copepods together with nauplii. In *E. bungii* the greatest concentration of nauplii was observed in the 10-50m layer where 500-2,500 ind/m^3 were encountered. Despite our movement northward, their number increased from day to day. After 25 May, the numbers in surface layers exceeded 500 ind/m^3 at almost all of the stations; but on 30 May the number reached 7,000-10,000 ind/m^3 at some of the stations (2132, 2133, 2197). However the early stages of *E. bungii* were not found.

In the Komandor-Kamchatka region, *E. bungii* was represented mainly by the III, IV and V copepod stages and by mature forms. True, Ye. A. Lubtsy-Gertsyk points out that by the end of May, at a number of stations in Kronotskih zaliv, the quantities were surprising (as many as 30,000 ind/m^3) which seem to be made up by *E. bungii*. Its I and II stages begin to appear only during the last days of May and the beginning of July, but we did not observe their propagation en masse. According to data by Z. V. Chernykh (1940), they appear in large quantities during the first half of July.

The main mass of C. *cristatus* in the upper 500m layer was made up of the V copepod stage, but at many stations we encountered rather large quantities of IV and III stages, sometimes II and even I stages.

In order to elucidate the seasonal status of plankton, we analysed data on the relationship of C. *plumhra* stages. A multitude of various copepod stages were found in this species during our spring studies.

When characterizing the age groups of C. *plumphrus*, we calculated the relationship between percentages of various stages of development at each station; then the mean percentage was determined for all the stations of the given region. The calculation was made for the 0-100m layer because it contained the main mass of young copepods, while deeper their quantity decreased sharply with predominance of the V stage of copepods and mature individuals. Comparing the percentage of copepod stages, it is seen (Table 2) that by mid-May in the southern part of the Kurile region (surface temp. 1-3°C) prevail, evidently, the III and IV copepod stages that have survived the winter, although younger copepods are also present, but in a smaller quantity. /75

Table 2

Age Groups of *Calanus plumchrus* Populations (%)
(number of stations in parenthesis)

Copepod stage	Kurile region				Komandor-Kamchatka region				
	S		N		W of 165E				E of 165E
	May	Aug	May	Aug	May	June	Aug	Sept	May-June
	9–24.V 1953	22–24.VIII 1954	26.V–1.VI 1953	25–27.VIII 1954	19.V–4.VI 1955	10–17.VI 1953	28.VIII 1954	4–18.IX 1954	27.V–13.VI 1955
	26	(•)	(14)	4)	(27)	(9)	(2)	(11)	(12)
I	16,9	9,0	32,2	18,4	33,8	10,7	1,7	35,5	7,3
II	14,6	3,0	12,5	19,6	18,2	14,7	3,1	22,1	11,3
III	25,9	5,0	9,2	16,7	12,6	20,7	18,8	18,2	12,5
IV	24,1	17,0	25,1	19,7	20,6	21,8	23,2	7,6	35,1
V	18,5	66,0	19,0	25,6	14,8	32,8	53,2	17,2	34,4

During the last days of May in the northern part of the Kurile region (surface temp. 2-4°C) the I and II stages of copepods prevail, which was also observed in the second half of May in Kamchatka sector (W of 165E) of the Komandor-Kamchatka region (surface temp. 3-5°C) where a luxurious development of phytoplankton is observed in the neritic zone, mainly *Thalassiosira nordenskiöldii*, yielding several grams of biomass per $1m^3$ in the surface layer (Semina, 1956).

In the well-heated coastal areas and gulfs, the reproduction of phytoplankton begins in April, reaching its maximum in May (Snasskiy, 1940). Also in such areas, the reproduction of copepods begins evidently somewhat earlier than in cooler water far off the coast. Thus, according to data by A. K. Geynrikh (1952), in Avachinskiy zaliv the I copepod stage of C. *plumchrus* prevails as early as in the second half of April.

According to our data, by the end of May the II and III copepod stages, not the I and II), prevailed in the immediate coastal belt of this area, as was the case at stations farther off the coast.

By mid-June the main mass of young C. *plumchrus* reaches the II-V stages, while the number of younger copepods, noticeably decreases, especially the number of I copepod stage.

However, in the water to the south and southeast of Komandorskiye ostrova (E of 165°E), the development of C. *plumchrus* occurs at a more rapid rate and the IV and V stages of copepods predominate by the end of May and the first half of June. Off the Kurile Islands, one can also observe a somewhat earlier development of C. *plumchrus* population in the warm water bounding on the zone of intermixing at a distance from the islands; this development is, however less pronounced here than in the Komandor-Kamchatka region.

Let us point out that the predominance of IV and V stages of copepods is still observed in August. By that time, in layers below 200m, the number of mature individuals increases. Percentage wise, in September, the I and II stages of copepods prevail again.

Thus, in the Kurile-Kamchatka region of the Pacific Ocean two generations or two seasonal races of this species exist, i.e. of the same cycle, which is present in the Bering Sea population /76
of C. *plumchrus* (Geynrikh, 1956a).

The vertical distribution of copepod stages of C. *plumchrus* shows (Table 3) a noticeable differentiation. In the 0-25m layer the first copepod stages (I and II) prevail. The only exceptions are

Table 3

Seasonal Variations of Age Groups in *Calanus plumpiura* (in %) by Water Layers in Various Areas (Number of Stations on which the Data are based is pointed out in parenthesis)

Southern Part of the Kurile Region

Copepod stage	May					Aug.					Oct				
	10—0 м (12)	25—10 м (13)	50—25 м (13)	100—50 м (13)	200—100 м (12)	10—0 м (3)	25—10 м (4)	50—25 м (4)	100—50 м (2)	200—100 м (2)	10—0 м (3)	25—20 м (4)	50—25 м (4)	100—50 м (6)	200—100 м (7)
I	26%	22%	14%	6%	7%	0%	2%	0	43	0	33	33	6	19	7
II	33	17	12	10	1	0	0	22	0	0	33	24	53	10	0
III	24	30	20	23	24	0	4	2	0	0	0	15	26	29	14
IV	3	13	28	29	24	14	17	4	16	27	0	2	11	36	16
V	14	18	26	32	44	86	77	70	41	73	34	26	4	6	46
VI															17

Northern Part of the Kurile Region

	May					August				
	10—0 м (12)	25—10 м (1)	50—25 м (13)	100—50 м (10)	200—100 м (12)	10—0 м (3)	25—10 м (5)	50—25 м (6)	100—50 м (4)	200—100 м (2)
I	36%	25%	25%	10%	4%	14	23	22	0	0
II	14	15	11	13	1	14	15	27	6	10
III	17	20	21	12	4	51	19	2	17	0
IV	13	17	29	44	23	21	27	21	0	70
V	20	23	14	21	68	0	16	28	77	20
VI										

Komandor-Kamchatka Region

	May					June					September				
	10—0 м (15)	25—10 м (14)	50—25 м (16)	100—50 м (16)	200—100 м (9)	10—0 м (11)	25—10 м (8)	50—25 м (10)	100—50 м (10)	200—100 м (12)	10—0 м (7)	25—10 м (9)	50—25 м (7)	100—50 м (7)	200—100 м (6)
I	54	22	20	18	9	19	9	6	9	8	9	37	33	0	0
II	17	21	8	16	0	13	18	12	4	6	21	22	36	12	0
III	12	16	14	12	0	14	22	12	16	12	29	13	26	20	0
IV	10	25	27	16	21	15	12	20	20	41	10	9	4	11	2
V	7	16	31	38	69	39	38	50	30	44	31	19	1	38	78
VI	00	0	0	0	1		1				0	0	0	19	20

observed in summer (July-August) when the number of copepods of the first stages was very small. In the 25-50m layer stages III, IV, and V prevail at various times and in various locations. Deeper, however, the V stage prevails. Mature individuals of this species are usually found below the depth of 200m where they dominate in the 200-500m layer.

Distribution of Major Species

The distribution of various types of water in this area can be traced by the distribution of some of the major species. There are three groups:

1) Species that characterize coastal neritic water; 2) cryophilic forms typical of the colder part of boreal water; 3) thermophilic forms inhabiting intermixing zones.

Early in the spring, when we began our work, the special neritic forms of zooplankton were still absent, and the neritic complex was represented only by larvae of polichaets, echinoderms and cirripeds. Only at St. 2167, which was occupied in mid-June near the coast of southern Kamchatka at a depth of 100m, did we find several individuals of neritic copepods: *Centropages macmurichi*, *Acartia longiremis* and rotifers, *Synchaeta*. The larvae of polichaets and echinoderms as was pointed out for the Bering Sea (Vinogradov, 1956) are, in spring, widely distributed not only in the neritic belt but also in oceanic areas. In the region which we investigated they were observed at all the stations located not farther than 250-300 miles from the shores. Under the influence of cyclonic action at the latitude of Kronotskiy zaliv, the zone of their distribution narrows somewhat. Generally, however, their distribution coincides with the areas where large concentrations of E. *bungii* and C. *cristatus* occur. The nauplii of cirripeds were found at stations located not farther than 100 miles from the coast, off the Kurile Islands, Kamchatka, Komandorskiye ostrova and in Kamchatka region the area of their distribution coincides, for example, with the zone where a luxurious development of phytoplankton occurs (FIG. 10). The largest number of nauplii, reaching 26,000 ind/m^3 was observed in the 10-25m layer of the shoaling coastal water.

The cryophilic species of *Calanus finmarchieus* and *Parathemisto libelulla*, which inhabit the coldest northern areas of the Sea of Okhotsk and the shallow northern sector of the Bering Sea, propagate along the Korean coast with the cold discharge current (Lubny-Gertsyk, 1955b; Vinogradov, 1956) and farther along the shores of Kamchatka and Kurile Islands, penetrating far into the southern waters. C. *finmarchicus* is found in proliv Bussol', but

P. libellula in proliv Friza (see FIG. 10). The upwelling of cold water in the Kurile Island area creates the needed conditions for the existence of the species. In spring, when the surface water temperature is rather low, these species were found at a considerable distance (50-60 miles) from the coast of southern Kamchatka and Kurile Islands.

In autumn, with its prevailing warm surface water, various thermophilic species were widely distributed in the area we investigated. For the winter, the area inhabited by the species shrinks considerably, and the species are preserved only in areas that are subjected to the influence of the warm water of intermixing zone or lie near it. In spring, during the period of our work, the warming up had just began and we were faced with the winter pattern of the distribution of thermophilic species. *C. pacificus* was distributed most widely (see FIG 10). It was found in great numbers at stations /78
occupied in the mixing zone; north of it, the number was small in cold water layers. The area inhabited by the species coincides with the area having the smallest quantities of Far Eastern plankton and lying east of the zone inhabited by large numbers of *C. cristatus* and *E. bungii* and larvae of polichaets and echinoderms (St. 3251, 3252, 3325, 3339, 3357, 3360, and 3362). It is interesting that at Stations 3358, 3359, 3364, 3365, and 3368, i.e. in area where, according to Anraku (1954) and our data, concentrations of *C. cristatus* and *E. bungii* were observed; evidently, with the presence of Bering Sea water in the area, *C. pacificus* was absent.

The discussion of various plankton animals enables us to visualize the following picture of water distribution in the Kurile-Kamchatka area during the spring. The Bering water enters the area via the Kamchatskiy proliv, widening southward and flowing along the coast of Kamchatka; the water preserves its features as far as the latitude of Kronotskiy zaliv--mys Shipunskiy. A certain amount of /79
Bering water also passes through the western part of Blizhniy proliv and circumvents o. Mednyy from south, sharply deviating westward. All these waters are characterized by a large biomass of zooplankton, great concentrations of *C. cristatus* and *E. bungii*, as well as by the presence of larvae of polichaets, echinoderms, and a luxurious development of phytoplankton.

The Bering Sea water flowing eastward is gradually replaced by waters that have a different oceanic origin. A rough boundary between these types of water can be drawn along the line connecting Stations 3351 and 3369. The current moving westward, south of Komandorskiye ostrova, and a cyclonic turbulence on the latitude of Kronotskiy, brings these waters deep into the zone occupied by the "Bering Sea Current." These waters are characterized by (1) a sharp decrease of zooplankton biomass, notably, the biomass of

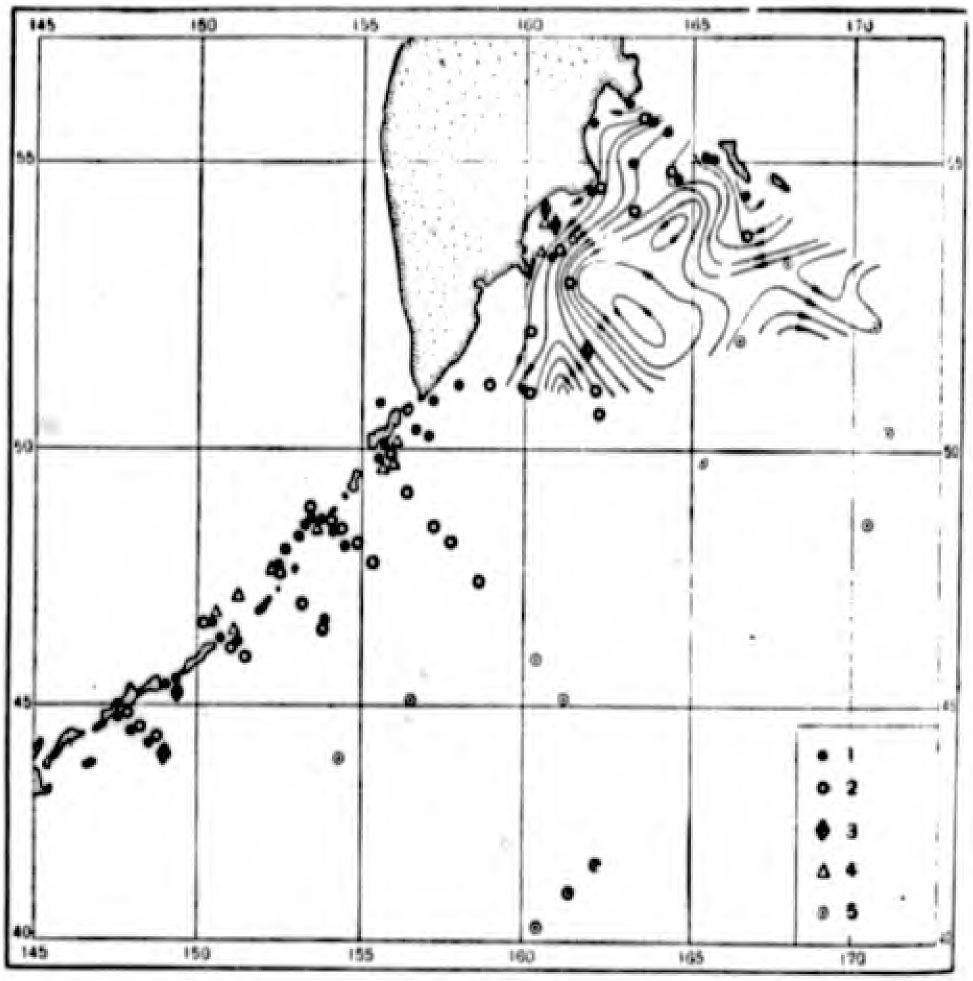

FIG. 10. Distribution of Major Species in May-June.

1--Cirripedia nauplii; 2--larvae of echinoderms (pluteus); 3--*Parathemiste libellula*; 4--*Calanus finmarchicus*; 5--*C. pacificus*. Arrows indicate currents (Burkov, 1957).

E. bungii, *C. cristatus* and *C. plumchrus*, in which the late stages of development predominate, as well as by (2) the disappearance of larvae of echinoderms and polichaets and the appearance of *C. pacificus*. All this demonstrates that, by its nature, this type of water is entirely different from the water arriving from the Bering Sea. The presence of *C. pacificus* make us consider it to be associated with the warm water of the /79 mixing zone of course, this is the warm current caused by the northern branch of the Kuroshio (Watanabe, 1954) with which in summer, at the peak of their development, many thermophilic organisms are brought into the Bering Sea (Vinogradov, 1956).

In the easternmost part of the Komandor-Kamchatka region one can observe the appearance of water containing great biomasses of *C. cristatus* and *E. bungii* and being devoid of *C. pacificus*. According to data by Anraku (1954), this water lies south of Krys'i ostrova.*

The water reaching the Kurile Islands from the north is considerably deformed by currents flowing through the Kurile Straits. The zone where the water is most deformed forms a belt 10-40 miles wide along the Kurile Islands. This belt has a low zooplankton biomass; sometimes the concentration of *M. ochotensis* is great, and also *C. finmarchicus* often is present. All the remaining part of the Kurile area is occupied by waters in which the composition of plankton is generally similar to that of the Kamchatka area. Only somewhat more abundantly are here represented several oceanographic species, such as *Cyphocaris challengeri*, *Enphausia pacifica* and, especially at depths exceeding 200m, the Okhotsk species *Metridia ochotensis*.

Only two easternmost stations (2093 and 2116) evidently abut the warmer water of the mixing zone, which can be inferred from the appearance of *C. pacificus*. Stations 3244-3246 were occupied in waters bordering on the intermixing zone. As it is typical of the front belt, the plankton biomass is here very large.

Summer-Autumn Distribution of Plankton

A comparison of the mean biomass of the Kurile and Komandor-Kurile regions with that of other water areas in the Far East is interesting, first of all, with the central areas of the Bering Sea which, as has been repeatedly pointed out before, are most closely linked with the given region. /80

In spring, the mean biomass of plankton for the 0-100m layer in

*When this study was in press, a paper by H. Koto and T. Fujii was published. (Structure of the Bering Sea and the Aleutian region. Bull. Fac. of Fisheries Hok. Univ. v. 9, no. 3, 1958); this paper analyses hydrological properties and discriminates in this area the same types of water as we do with approximately the same boundary lines.

the Kurile area equalled 408mg/m^3 (collections from 7 May to 1 June 1953), but in the Kamchatka area it was 321mg/m^3 (collections from 18 May to 13 June 1955). A smaller biomass in the Komandor-Kamchatka area resulted from the stations occupied in the water of southern origin, where the quantity of plankton was small indeed. If, however, only the stations west of the line are considered, the mean biomass makes up 412mg/m^3.

In spring, the mean biomass of plankton inhabiting the southern and central areas of the Bering Sea equalled 747mg/m^3 (collections from 25 May to 1 June 1952).

It is, however, correct to consider that the quantity of the plankton of the Bering Sea is greater than that of the Kurile-Kamchatka region of the Pacific Ocean?

One must keep in mind that in the Komandor-Kamchatka area the plankton was collected 10 days later than in the Kurile area; but in the Bering Sea it was collected half a month later than in the Kurile-Kamchatka area. The changes that had taken place in the plankton during the time would not remain without effect on the biomass of plankton.

During our work in the Bering Sea we observed large quantities of nauplii of *E. bungii*, and other copepods were present in the plankton (up to 3-5 thousand per 1m^3), as well as copepod stages of *C. plumchrus* (Vinogradov, 1956). The main mass of maturing *E. bungii* had reached the V and VI stages. As a result of these changes, the biomass of plankton considerably increased. A. K. Geynrikh (1956a) thinks that at the time the zooplankton has reached its maximum quantity in the Bering Sea.*

At the same time, it is evident that in the Kurile-Kamchatka region the biomass of plankton had not reached its annual maximum at the time of our work; judging from the age groups, it appears that the maximum is reached later. Indeed, according to K. A. Brodskiy (1955a), in Kurile area, the quantity of *C. plumchrus* reaches its maximum in July, i.e. half a month after our sampling, 200-800 ind/m^3 (600-2,100mg/m^3). In August, the quantity of *C. plumchrus* reached 1,500mg/m^3 at several stations

*Of course, the yearly maximum of zooplankton in the Bering Sea is reached in July when the quantity of plankton increases considerably over the larger part of the area as a result of further growth of populations of *C. plumchrus* and *other large copepods*.

of this area, but the total biomass of plankton amounted to 1,000-2,000mg/m^3 over a considerable area of the Kurile region; SE of mys Lopatka the quantity equalled 5,000mg/m^3 (Lubny-Gertsyk, 1955a).

Thus, during the summer peak, the biomass of zooplankton over the greater part of the Kurile-Kamchatka region does not lag behind the maximum biomass of plankton in the Bering Sea, but may even exceed it.

According t data by K. H. Brodskiy (1955b), the greatest biomass of zooplankton in the Kurile area is observed in July and in the first half of August; in the second half of August and in September the biomass begins to decrease. The decrease is caused by the comsumption of plankton by various plankton-eaters and by the migration of larger copepods to deeper layers (Vinogradov, 1956).

As was pointed out by M. M. Sleptsov (1955), in certain years the biomass of plankton may again increase by the beginning of October in the 0-100m layer; this phenomenon is caused by an increase in the quantity of C. *plumphrus*, *Euphausia pacifica*, and *Thysanoessa longipes* (observed in 1954). Regrettably, the author does not list detailed data that would enable us to learn how the increase in the biomass of these species occurs so late in autumn when they travel in large numbers to the lower strata. /81

Our autumn investigations from 21 August to 13 October 1954 were carried out during a period when the biomass of plankton decreased rapidly after the maximum of July and its magnitude (in the 0-100m layer) was about 320mg/m^3. As in the spring, a narrow zone running along the Kurile Islands at a distance of several tens of miles from the islands was the richest in plankton (more than 500mg/m^3 South of o. Iturup the zone runs almost along the coastline, widening considerably so that a vast area SE of Hokkaido is occupied by the zone* (Bogorov and Vinogradov, 1955, Fig. 3; Sleptsov, 1955, Fig. 9). The plankton biomass here reaches 400-700mg/m^3, but at some stations in the 10-50m layer even 2,000mg/m^3.

*As was mentioned, the autumn collections were made east of the Kuriles. Only a few stations were employed in the Komandor-Kamchatka region. Therefore, the data given below pertain only to the Kurile area.

In other years the distribution pattern of the summer-autumn zooplankton may be somewhat different. Thus, according to data by K. A. Brodskiy (Sleptsov, 1955, Fig. 7) in Sept. 1953, the plankton biomass in the Kurile-Kamchatka region was small, and only E of southern Kamchatka was found a patch with a large biomass. In the Kurile region, the richest plankton zone forms a narrow belt closely adjacent to the Kurile Islands from the side of the Sea of Okhotsk and the ocean. Regrettably, K. A. Brodskiy does not list figures of the absolute biomass of plankton; instead, he makes the evaluation on the basis of the subjective visual method (in balls, i.e., points).

In various years the predominance of certain plankton forms may also change. On the basis of food used by whales, Nemoto (1957) concludes that in 1953, C. *cristatus* was abundant ("Calanus year"), but in 1954 and 1956 euphausiids prevailed ("Euphausiid year").

Such a distribution of plankton is evidently caused by the annual variations of the hydrological regime; first of all, by the effect of the Kuroshio. According to data by M. M. Sleptsov, in 1954, the warm water of the Kuroshio was farther away from the south Kuriles than in 1951 and 1953. Sleptsov is inclined to explain by this the presence of a large biomass of plankton off the south Kuriles in the autumn of 1954.

In autumn, as well as in spring, the zooplankton biomass is composed basically of concentrations of C. *cristatus*, E. *bungii* and C. *plumchrus*. The latter formed considerable concentrations reaching in the 10-25m layer 1,000-1,700mg/m^3 at some of the stations (22 Feb. 1954 at St. 3105, 23 Aug. 1954 at St. 3106). However, during our explorations its quantity in the upper 200m layer continued to decrease rapidly. SE of proliv Bussol', the biomass of the species fluctuated from 250 to 50mg/m^3 in the 0-100m layer at St. 3104-3109 by the end of August, while at St. 3164-3176 the biomass had dropped to 0.4-24mg/m^3 by 2-5 Oct. 1954. The quantity of the population was made up mainly by the V copepod stage in the upper 500m layer.

In C. *cristatus* the quantity of population consisted mainly of IV-V stages of copepods. At some stations we observed limited quantities of stage III, at times also stage II, which are absent at the time from the plankton of the Bering Sea. Evidently, in the Kurile region the reproduction period of C. *cristatus* is longer, or the species may have two seasonal races in the Bering Sea, as in the case of C. *plumchrus*, which are reproduced at various times.

The population of E. *bungii* has a larger variety of age groups, /82 although its main portion consists of older copepods, namely, V and VI (only females; males of stage VI are absent) as in the case of the two other species. The young, including nauplii, were observed everywhere during the entire period of our exploration; at some stations their quantity was considerable. Especially numerous nauplii and young copepods were off the east coast of south Kamchatka in the zone of the cold discharge current (10-15 Sept. 1954) where they form large concentrations, as, for instance, at St. 3127. Here the biomass of *E. bungii* (stages I-III only) reached about 596mg/m^3 in the 0-80m layer, but in the 50-80m layer the value was 1,407mg/m^3; i.e. about 500 ind. per m^3. But also at many other stations of the Kurile region the biomass of *E. bungii* was rather great (St. 3112, stages I-IV and nauplii constituted 1,438mg/m^3 in the 10-25m layer; at St. 3113 the composition in the same water layer was similar, amounting to 330mg/m^3). Only in warmer water, far off the coast (St. 3147-3163) and SE of Hokkaido (St. 3178-3179/3189-3194) were stages I-III absent. Thus, the reproduction of *E. bungii*, which begins by the end of May in warmer areas, ends in the boreal zone by the beginning of August; in the cold water off Kamchatka and Kurile Islands we observed nauplii as late as in September, though the absence of sexually-mature males and the numerical domination of older copepods attests to the cessation of large-scale reproduction by the beginning of September. As the main mass of population reaches older stages, the total biomass of *E. bungii* may exceed the value observed in summer.

In summer and autumn, as a result of general warming of surface water layers with temperatures rising from 1.5-2.0°C in May to 4-14°C in September (in the Kurile region in the transect of o. Simushir, for example) and the intensification of the effect of Kuroshio, one can see that differences in the status of seasonal populations in various types of water are more pronounced than in spring.

During this time, the neritic group reaches the peak of development; i.e. the species forming considerable concentrations in the neritic zone and can be traced in small quantities far into the ocean. In the north, off the coast of Kamchatka, the group is characterized by *Acartia longiremis* and *Centropagos macmurrichi*, which inhabit the coastal belt about 200 miles wide. In the immediate coastal belt one can at the time observe numerous *Podon leucharti* and *Evadne nordmani* (Geynrikh, 1952). Off the Kurile Islands, the area inhabited by neritic species narrows considerably. According to data by K. A. Brodskiy (1955a) in September in the southern sector the neritic forms (*Penilia airrostris*, *Labidocera japonica*) are brought by the Kuroshio into the open ocean to a distance of almost 1,000 miles from the coast.

The area inhabited by thermophilic forms was also widening and projecting northward. *C. pacificus* was found almost throughout the investigated area, in addition to a wide belt along the east coast of Kamchatka and a narrow belt along the northern and central Kuriles, i.e. the zones exposed to the immediate action of the cold Bering and Okhotsk waters. Brought by a branch of the Kuroshio, which moves northward and is well pronounced during the season and reaches the depth of 250-300m, *C. pacificus* passes through the strait between o. Mednyy and o. Attu into the Bering Sea where the species inhabits the surface layer in small quantities, reaching 60°N (Vinogradov, 1950). In some years the species is still more widely distributed and it reaches the coast of Kamchatka (Geynrikh, 1952).

Such thermophilic species as *Clausocalanus* and *Paraclaanus parvus* are usually observed to 45°N.

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