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Seasonal dynamics of population of Calanus finmarchicus (Gunner) in the Northwestern Atlantic

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In line with the IGY and IGC a great scope of data on composition and distribution of plankton in North Atlantic was collected by Soviet workers.

The qualitative composition and distribution of biomass of food zooplankton based on the material collected are mentioned by Kusmorskaya (1959,1960), Kanaeva (1960,1962,1963), Yashnov (1961,1962) and Vladimirskaya (1962,1964,1965).

The analysis of the material shows that the food zooplankton is represented, to a great extent, by boreal fauna, Calanus fimarchicus (Gunner) being its main component.

So it seems reasonable to study the seasonal distribution of the species and time of reproduction in the area investigated.

Samples of plankton collected in line with IGY and IGC on board R/V Michail Lomonosov (Cruises II,IV,VII and XI) and S/S Sebastopol (Cruise XIV) are analysed in the paper (Fig.I).

Plankton was sampled with a small Juday net (height = 36 cm) made of silk gauze N 38 from standard horizontal layers starting from the depths of 500 or 1000 m upward. A total of 810 samples at 194 stations were obtained. All the samples were treated as to the number of eggs, Nauplii, males and females, all copepodite stages being counted individually.

Hydrological conditions in the area surveyed are governed through the interaction of warm Gulf Stream waters and cold Labrador current. The application of material collected on board R/V Michail Lomonosov in the autumn of 1958 (Cruise IV) enabled Mamaev (1960) to ascertain borders among different water masses in the central North Atlantic. The application of this chart and analysis of the data on hydrologic conditions obtained in Cruise II have enabled us to compile a similar chart for the spring of 1958 (Fig.2) and this chart is referred to in the present study of distribution of plankton.

The southern border of the mass distribution of Calanus finmarchicus in the area is assumed to be the surface 10°C isotherm, i.e. the constant border of the distribution of boreal fauna according to data obtained in March-April, 1958. To the

south of the border Calanus occurs in negligible numbers and mainly at lower depths.

The pattern of the distribution of Calanus in spring is given with reference to the data obtained in March-April 1958 and March 1960 (Fig.3).

The heaviest abundance (350,000-750,000 specimens per square meter of the surface down along the water column, which for the purpose of convenience will be further referred to as "per sq.m") was observed on the northern and northeastern slopes of the Grand Newfoundland Bank influenced by the cold Labrador water masses. The lowest values were registered on the northern edge of the North Atlantic current (500-2500 specimens per sq.m).

To the east of 30°W in the subtropical water masses as well as on the border of the habitat of Calanus in the North Atlantic current no reproduction of the species was observed in the second half of March. At that time Calanus inhabited mainly the 500-200 m layer. Females and males constituted 10-40% of the population, no eggs or nauplii occurring. Sampling in the western area of the subarctic water masses was made in the second half of April. Biologically this is believed the beginning of spring in the area. Males and females constituted not less than half of the population, the counts showed 600 eggs and up to 240 nauplii per cu.m.

Actually at the same latitude (55°N) the breeding period of Calanus on the Labrador shelf starts in late May or early June (Semenova, 1964).

On the southwestern and southeastern slopes of the Grand Bank the reproduction of Calanus commences in late February or March. In late March nauplii constituted 80-90% of the population (3,000-4,000 specimens per cu.m). Of the total copepodite stages 75% fell on Stages I-III.

Mass development of Calanus was observed along the whole eastern slope of the Grand Bank in April, males and females constituted less than 10% of all copepodite stages, Stages I-III

amounting to 80% (Fig.4). A total of 1200 eggs and 900 nauplii occurred per cubic meter. At the same time the occurrence of males and females on the northeastern slope was much more frequent, but young copepodite stages were still rare. On the northern slope the reproduction only started, males and females averaged 82%, stages I-III - only 4%, the counts showed 2,300 eggs and 320 nauplii per cu.m.

Section "a-b" started in the North Atlantic current area (Fig.2, area NA), passed along the eastern part of the zone of horizontal mixing (Area 2, HM(L) where the effect of the Labrador current is very markedly pronounced. The northern half of the section was located in the Labrador water masses proper. A gradual movement of the biological spring from south to north was observed along the section. The Grand Bank shallows are distinctive in the general pattern due to their specific conditions.

However, it is not only a latitude that governs the biological spring's coming. At the same latitudes the breeding of Calanus commences in places affected by different water masses in different periods.

At section "c-d" the intensive development of Calanus was observed only in two locations (Fig.2, Area HM(L)) where the waters of the Labrador current are wedged into the zone of horizontal mixing to be under strong influence of the North Atlantic current. In the area of wedges the young copepodite stages constituted about 50% of the all copepodite stages (Fig.4) and the number of eggs increased to 1,000-4,000 per cu.m, whereas in the zone of horizontal mixing which is strongly affected by the North Atlantic current (Area HM(NA)) females were dominant and only 130-200 eggs per cu.m. were found. The population in the North Atlantic water masses proper (Area NA) consisted mainly of copepodite stage V; no eggs or nauplii were found.

The biological spring, and therefore other seasons do not come to different places at the same time. The evidence can be

supported by observations made at the latitudinal section crossing the shallow waters of the Grand Bank and Flemish Cap (Fig.I, Section "k-l").

The section started in the zone of horizontal mixing influenced by the North Atlantic current, then crossed the Labrador current zone and terminated on the Grand Bank shallows occupied by their own waters.

Observations made in mid-April, 1958 and in March, 1960 showed that the breeding season only started in the central part of the Flemish Cap Bank and on its slopes (Fig.5(I)): females and males constituted about 85% of the copepodite stages, but no stages I and II occurred.

The number of eggs of Calanus was insignificant, only 20-60 per cu.m; nauplii were either absent or their number was 4-7 times lower than that of eggs.

When moving toward the Grand Bank shallows the composition of Calanus displayed marked changes, viz. the number of males and females was considerably reduced, young copepodites gradually occurring in ever-increasing number. In the straits between the Grand Bank and Flemish Cap, that is in the zone influenced by the Labrador current the breeding season was in full swing: the number of eggs (2,400-3,500/m^3) was 3 or 4 times greater than that of nauplii.

The observations revealed an opposite relation on the Grand Bank shallows: only 200 eggs occurred in I cu.m., but the number of nauplii was 5 times as great. Of all the copepodites stages I-III constituted 91%, stage I amounting to over 50%. The distribution of Calanus is very peculiar in the area investigated. A small number of eggs occurred both in the central Grand Bank shallows and in the Flemish Cap area. However while in the first case it was associated with much heavier abundance of nauplii and dominance of young copepodite stages, in the second case, as is shown above, males and females were dominant. This leads to the assumption that no eggs had already

occurred on the Grand Bank while there were no hatching yet on the Flemish Cap.

The intensive reproduction of Calanus follows the development of phytoplankton (Fig.6). This gaph is compiled according to Movchan's data (1962). The peak development of phytoplankton in the Labrador waters was always followed by most intensive reproduction of Calanus.

In July 1959 some hauls of zooplankton were made mainly in the 50-0 m layer, and only at some stations the 100-0 m or 200-0 m layers were sampled.

Fig.7 illustrates that Calanus was observed to be most abundant in the 50-0 m layer (which is also true for spring time) in the northeastern Grand Bank area influenced by the Labrador current (500,000-700,000 specimens per sq.m) and to the northeast of Flemish Cap (450,000 specimens).

Mass development of Calanus was observed on the Grand Bank. Eggs occurred in insignificant number while the number of Nauplii amonted to 5,000-12,000 per cu.m. Of all the copepodites 75-98% fell on stage I. To the north of Flemish Cap Stages III-IV or II-IV were dominant (82-94%). Eggs and Nauplii either were not present at all in the samples or occurred in negligible number (200-500 specimens per cu.m.). In the mixed waters of the North Atlantic current (to the east of the Grand Bank and Flemish Cap and on the Flemish Cap shallow waters) the samples contained only 10-50 specimens per m^2 and not more than 100 eggs and nauplii per cubic meter. Stages IV and V constituted 80-90% of all the copopodites in the area.

In early autumn (late September-early November 1961) the abundance of Calanus ranged from 320,000 to 100 specimens per square meter (Fig.8). The heaviest abundance was observed in the vicinity of the eastern and southwestern slopes of the Grand Bank, 320,000 and 107,000 specimens per square meter respectively. The lower values are specific for the southwestern part of the Grand Bank shallows (100-200 specimens per sq.m).

Similar to the spring observations water masses differed markedly from one another as to the composition of the population of Calanus. On the northern and northeastern edges of the Grand Bank shallows influenced by the Labrador water masses the population consisted, in the main, of young forms. Near the southeastern slope and to the east of the Grand Bank, in the zone of horizontal mixing of water, the population turned to wintering.

In early October latitudinal section "n-l" was made. It resembled section "k-l" made in spring, but it was more extensive (Fig.I). On the northern edge of the Grand Bank shallows Stages I-III constituted over 50% of all the copepodites (Fig.5(2)), nauplii occurred individually. The main stream of the Labrador current passed along northeastern part of the Grand Bank (middle part of the section). Stages I-III constituted 90%, the number of nauplii was over 200/m^3. In the central part of Flemish Cap and on its slopes, that is, in the North Atlantic current waters, the young forms were represented in negligible number, Stage V and females prevailing, The wintering stock (Stages IV and V) accounted for 65-90% on the southwestern part of the Grand Bank shallows and near its southwestern slopes.

The population of Calanus inhabited mostly the layers below 100 m. More than half of the population occurred in the off - bottom layer due to a negative temperature of water both on the southern and northern edges of the Grand Bank shallows. On Flemish Cap and its slopes almost all the population sank below 100 m. In the areas of lower depths the majority of Calanus preferred the layers below 200 m or even 500 m. Only young forms occurred on the upper layer.

Thus by early October 1961 Calanus had already turned to wintering almost all over the areas investigated, excepting the zone influenced by the Labrador water masses.

In the autumn of 1958 (late October-early December) the samples were taken at the same stations as in spring 1958

(Fig.I). The heaviest abundance of Calanus (150,000-100,000 specimens per sq.m) was observed in the area influenced by the Labrador water masses, viz: on the northern edge of the shallows and northern slope of the Grand Bank (Fig.9), whereas the lower abundance, as in spring, was registered at the northern edge of the North Atlantic current (300-400 specimens per sq.m).

The high abundance of the population of Calanus in the Labrador waters can be explaind, to a considerable extent, by the availability of young forms. The number of nauplii ranged from 9,000 to 12,000 per cu.m and Stages I-III amounted to 75% of all the copopodites (Fig.10, Section "a-m").

While extending to the south the percentage of young forms decreases. Near the eastern slope of the Great Bank (Fig.10, right) a wintering population was discovered , Stages IV and V amounting to 96%. This part of the section was placed in the zone of horizontal mixing. In parallel with changes in the composition of the population along the section, the depth where the bulk of Calanus occurred also changed. In places where the bulk of the population was represented by young forms (nothern slope and northeastern shallows of the Great Bank) concentrations of Calanus were found in the upper 50 m layer. In the zone of horizontal mixing the wintering stock sank to the depth as low as 200 m. The same pattern is known for Section "c-d". In autumn no sharp alternations of water masses were observed as compared to the spring of 1958. The abundance and ratios of age groups were relatively uniform along the section. Fig.10 (Section "g-p") illustrates the ratios of age-groups on Flemish Cap and its slopes. About 90% of the total copepodites fell on Stages IV and V. The bulk of Calanus occurred in the off-bottom layer on Flemish Cap and at the depth of over 200 m on its slopes.

In the area influenced by the subarctic water masses the frequency of occurrence did not exceed 10,000 specimens per square meter. The population consisted mainly of Stages IV and V and inhabited the layers below 200 m.

Along the northern edge of the North Atlantic current, at the extremity of the habitat of Calanus, only about 100 speci-

mens occurred per square meter. Most of them were at Stages IV and V and inhabit the layers below 200 m.

Thus the population of Calanus turns to wintering in the area investigated in October and leaves the upper layers, the exception is known for the area influenced by the Labrador water masses where a considerable number of copepodite stages I-III and even nauplii occurred till late November.

Conclusions.

The material obtained enables us to come to the following conclusions. In the Northwest Atlantic Calanus finmarchicus is distributed in the subarctic and Labrador water masses, that is in an area characterized by boreal fauna. It is believed that the southern border of the habitat is the northern edge of the North Atlantic current where the frequency of occurrence is not more than 100 specimens per square meter.

The heaviest abundance (up to 750,000 specimens per sq.m including nauplii and copepodite stages I-VI) is observed in spring, that is in the period of its mass development in the area influenced by the Labrador current.

The spring breeding season of Calanus starts southward of the Grand Bank and gradually extends to the worth in late February or early March. In the subarctic water masses at 55°N the breeding is observed in late April, on the Labrador shelf in the waters of the Labrador current it occurs in late May or early June.

The reproduction of Calanus starts at the same latitudes at different periods, which depends on the peculiarities of water masses it inhabits.

The development of the second generation is very likely to start on the Grand Bank in July and on Flemish Cap a little later. In early October the population turns to wintering all over the area and sinks to lower layers.

To the northwest of the Grand Bank the second generation seems also to start developing in August, which can explain the occurrence of young forms observed on the northern edge of the Grand Bank in October-November.

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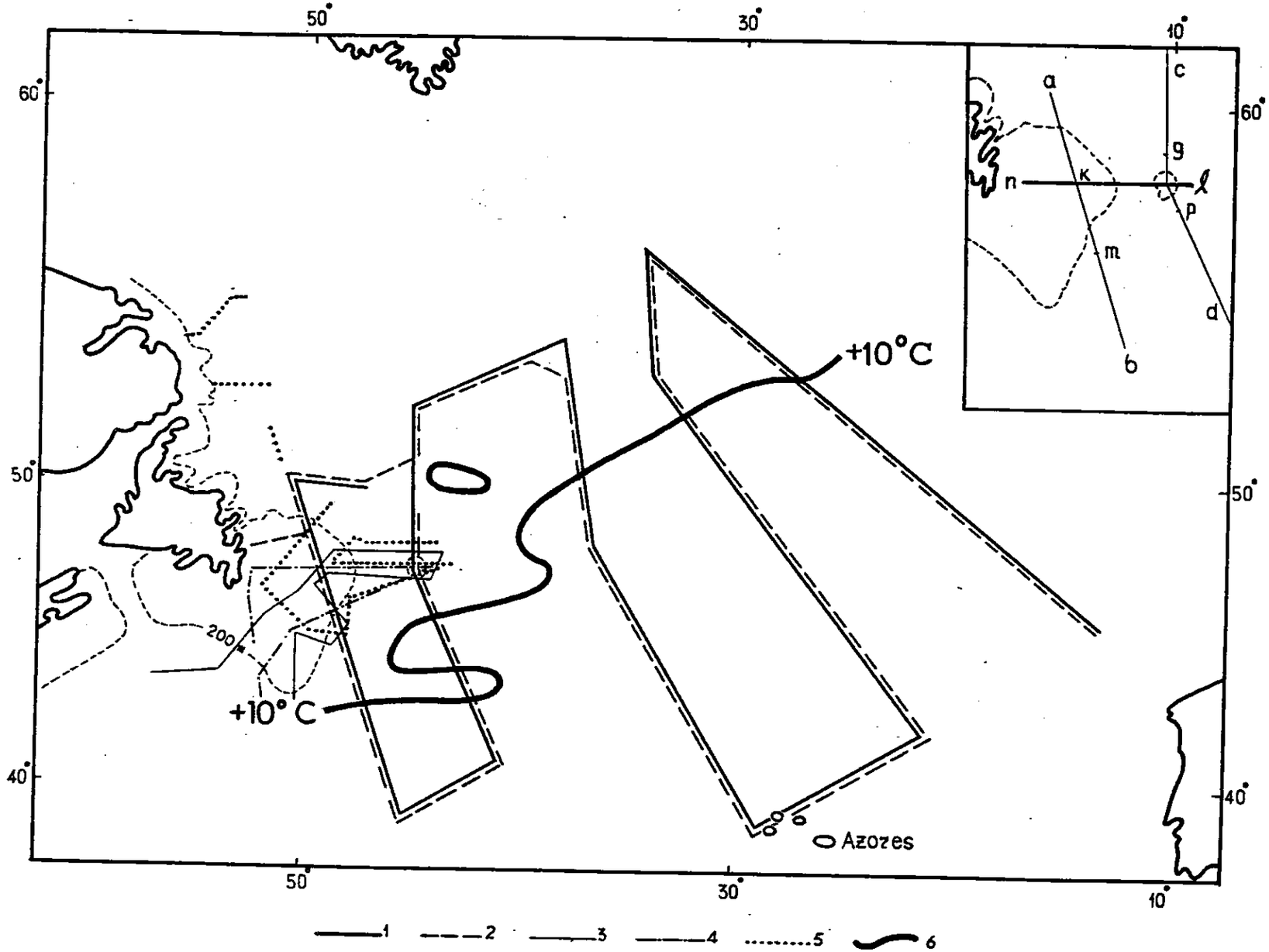


Fig. 1. Cruises

1. R/V Michail Lomonosov, Cruise II (6 April - 2 May 1958)
2. -"- -"- Cruise IV (18 October - 2 December 1958)
3. -"- -"- Cruise VII (17-31 March 1960)
4. -"- -"- Cruise XI (25 September - 7 October 1961)
5. S/S Sebastopol Cruise XIV (7 July - 11 August 1959)
6. 10° C isotherm ruise II)

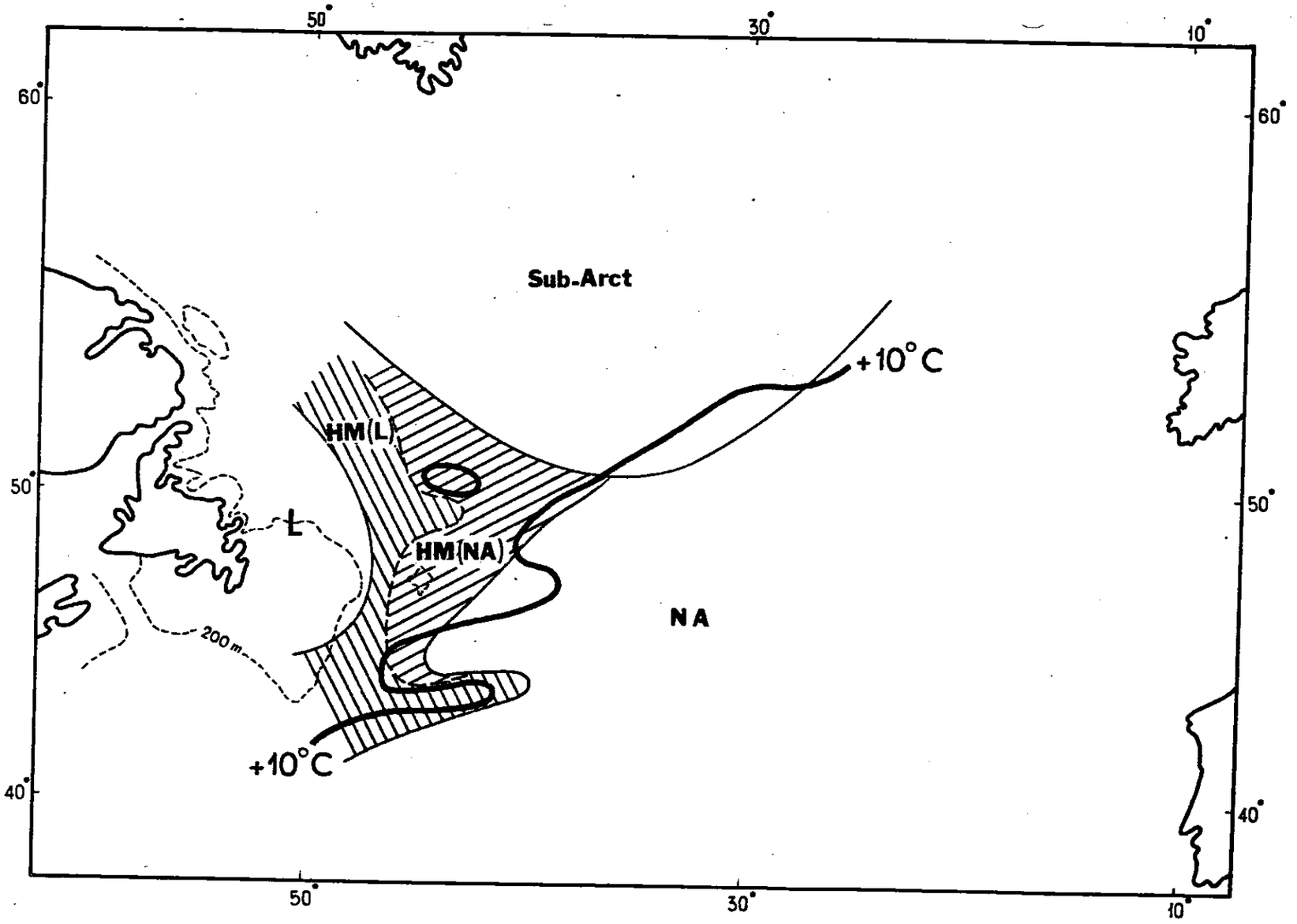


Fig. 2. Distribution of water masses, spring 1958.
L - Labrador water masses
HM(L) - part of the zone of horizontal mixing influenced by Labrador current.
NA - North Atlantic water masses.
HM(NA) - part of the zone of horizontal mixing influenced by North Atlantic current.
Sub-Arct - Subarctic water masses.

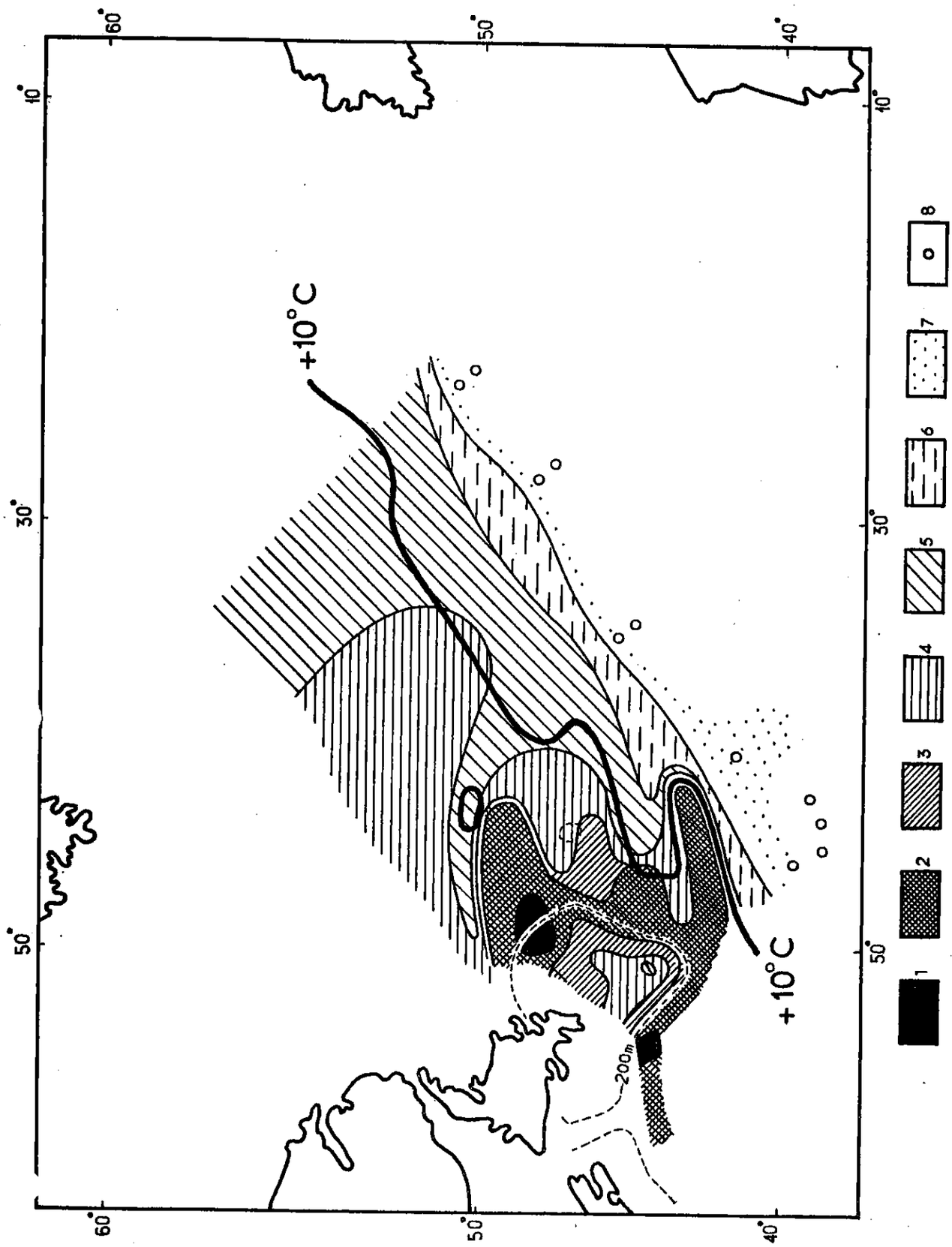


Fig. 3. Distribution of Calanus finmarchicus in spring (thousands of specimens per sq m): 1) more than 500; 2) 500–100; 3) 100–50; 4) 50–10; 5) 10–1; 6) 1–0.1; 7) less than 0.1; 8) No occurrence.

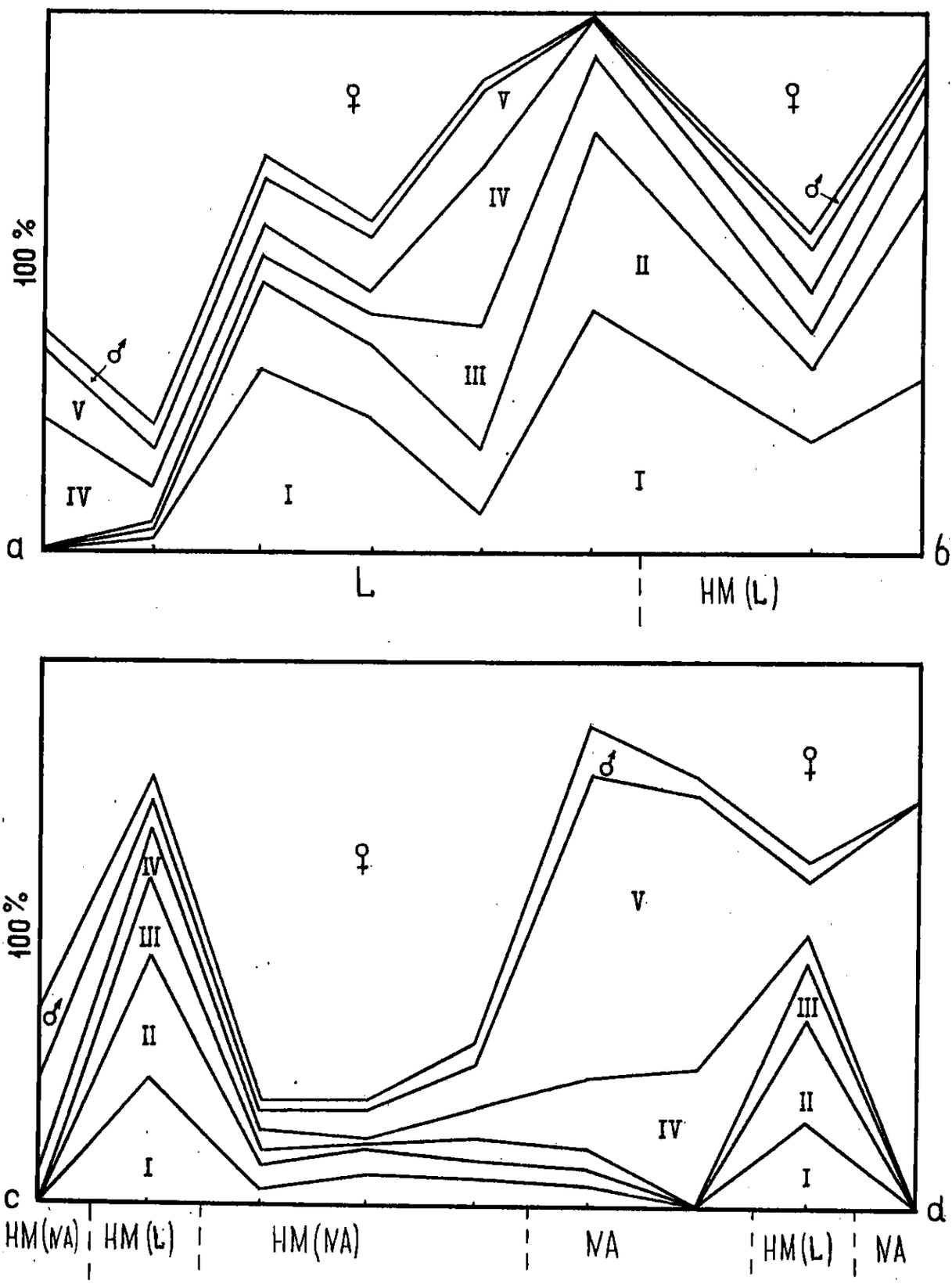
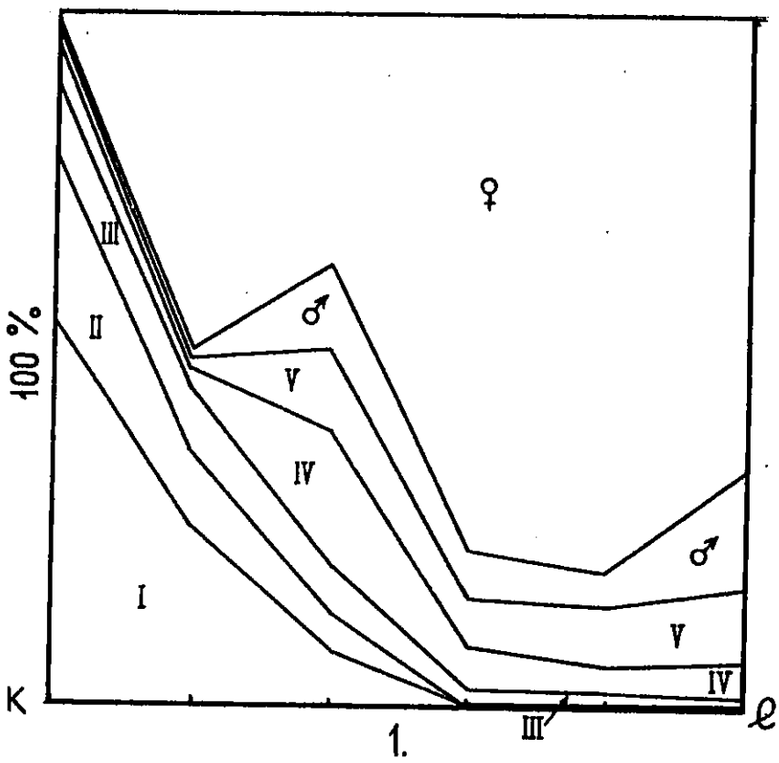


Fig. 4. Frequency of occurrence of copepodite stages of Calanus finmarchicus, spring 1958, Sections "a-b" and "c-d".



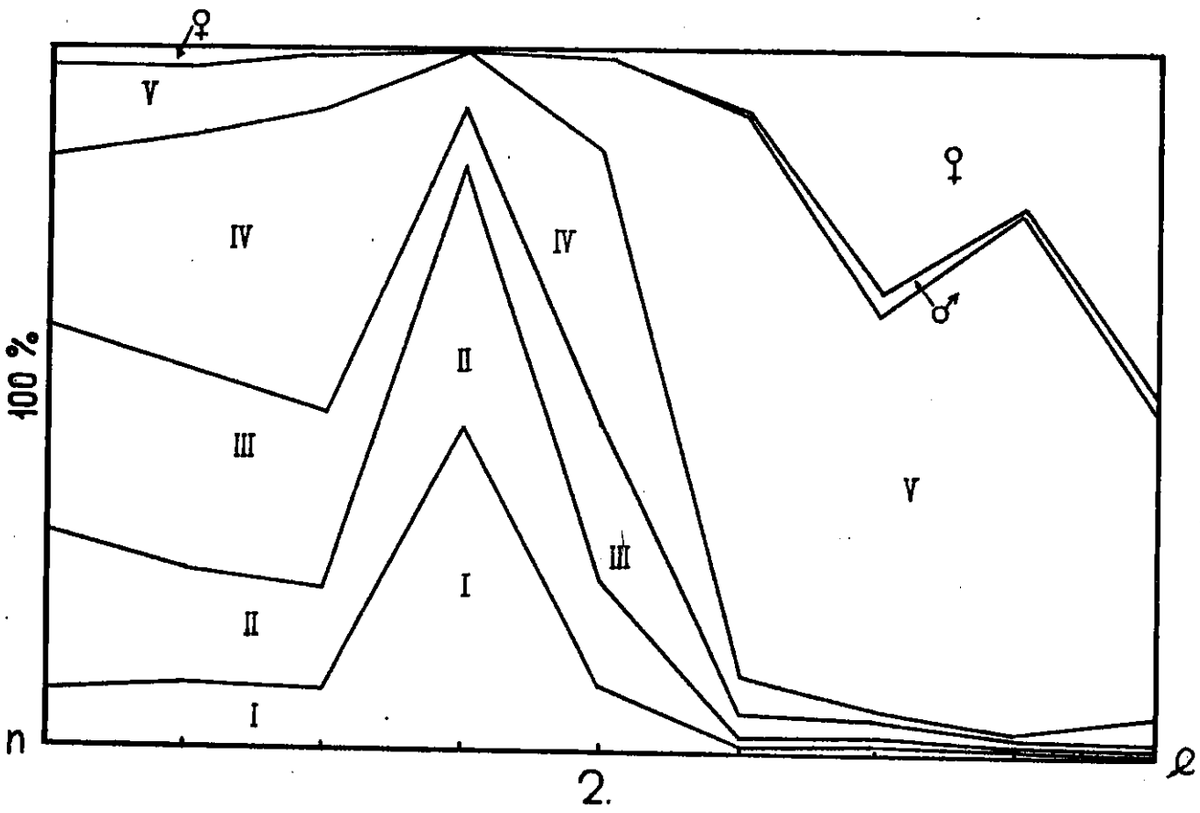


Fig. 5. Frequency of occurrence of copepodite stages of Calanus finmarchicus in different water masses.
1 - spring 1960, Section "k-l"
2 - autumn 1961, Section "n-l".

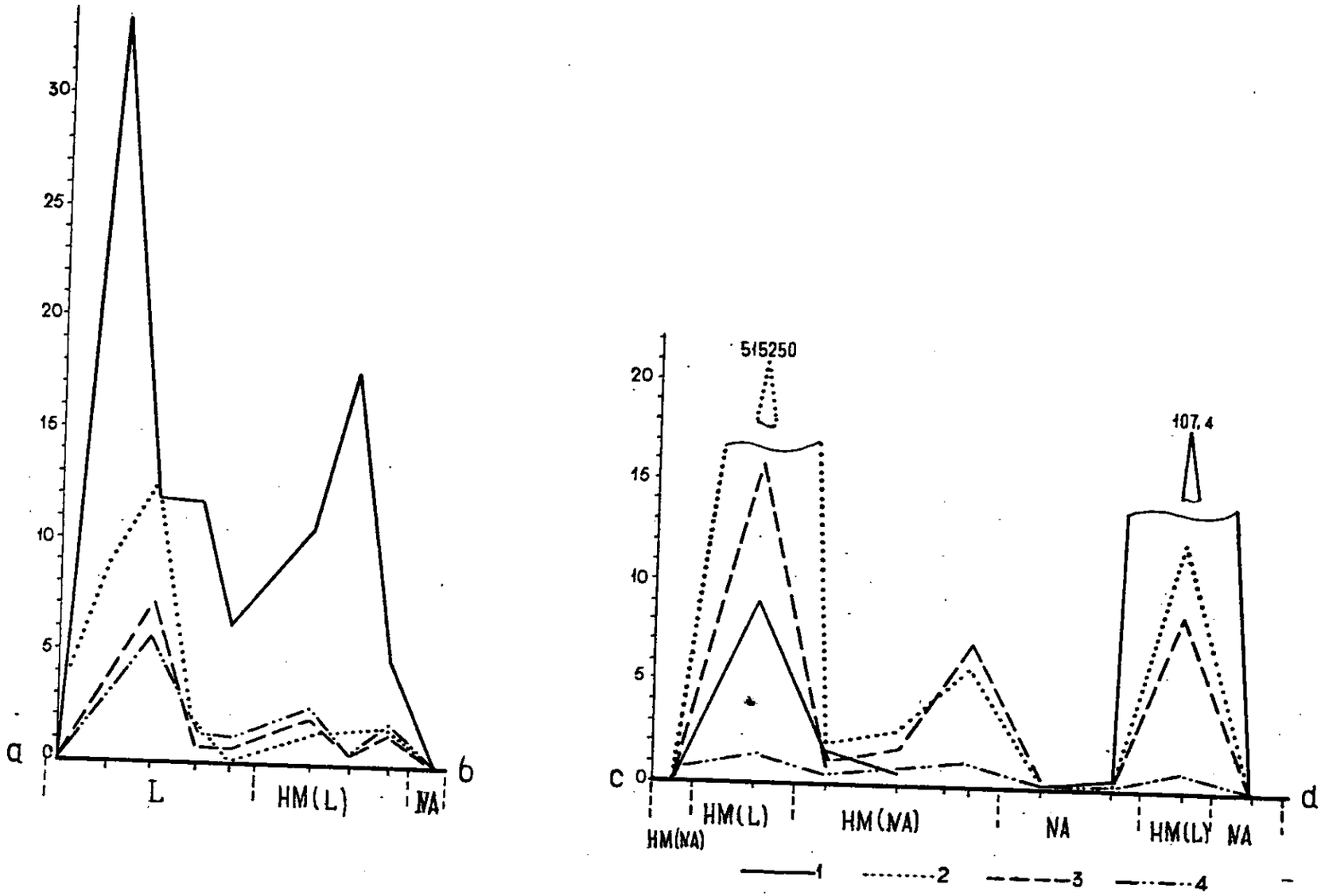


Fig. 6. Development of phytoplankton and Calanus finmarchicus in different water masses, spring 1958.
1 - phytoplankton: at Section "a-b" (1 point = 10 million cells/m^3) at Section "c-d" (1 point = 1 million cells /m^3)
2 - Eggs of Calanus: (1 point = 100,000 eggs/m^2) 3 - nauplii (1 point = 100,000 nauplii) 4 - copep te stages I-VI (1 point = 10,000 specimens)

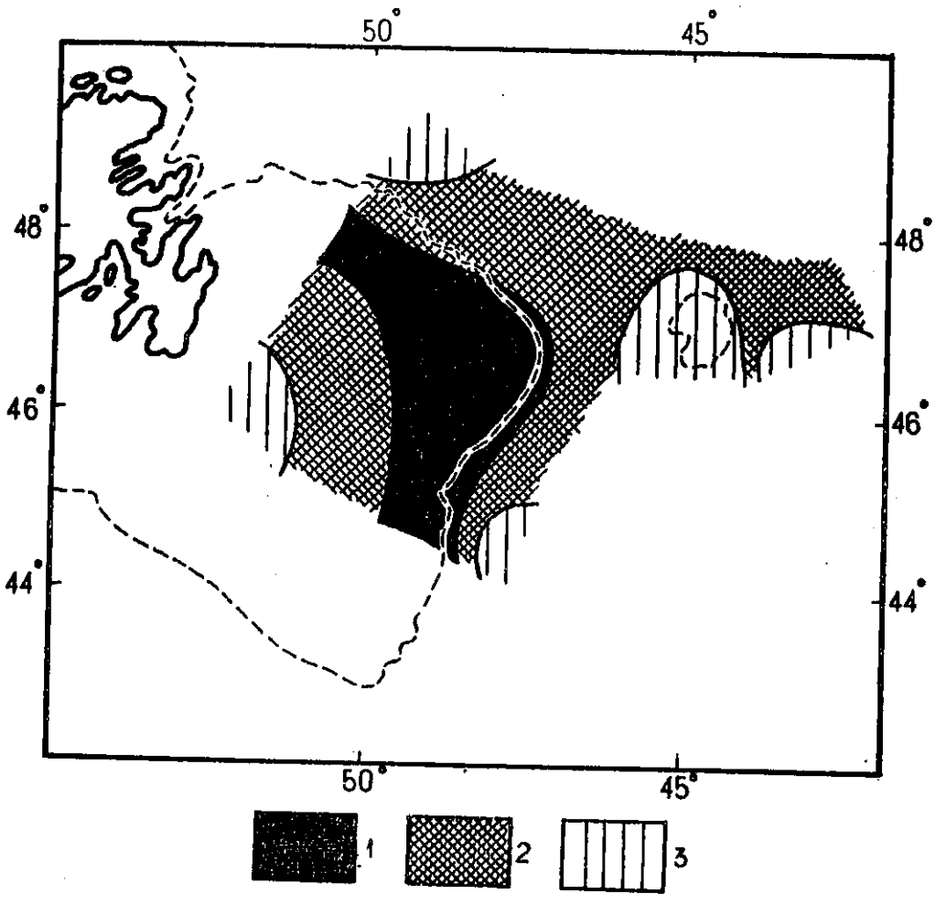


Fig. 7. Distribution of Calanus finmarchicus, summer 1959 (thousands of specimens per sq m): 1 - over 500; 2 - 500-100; 3 - 100-10.

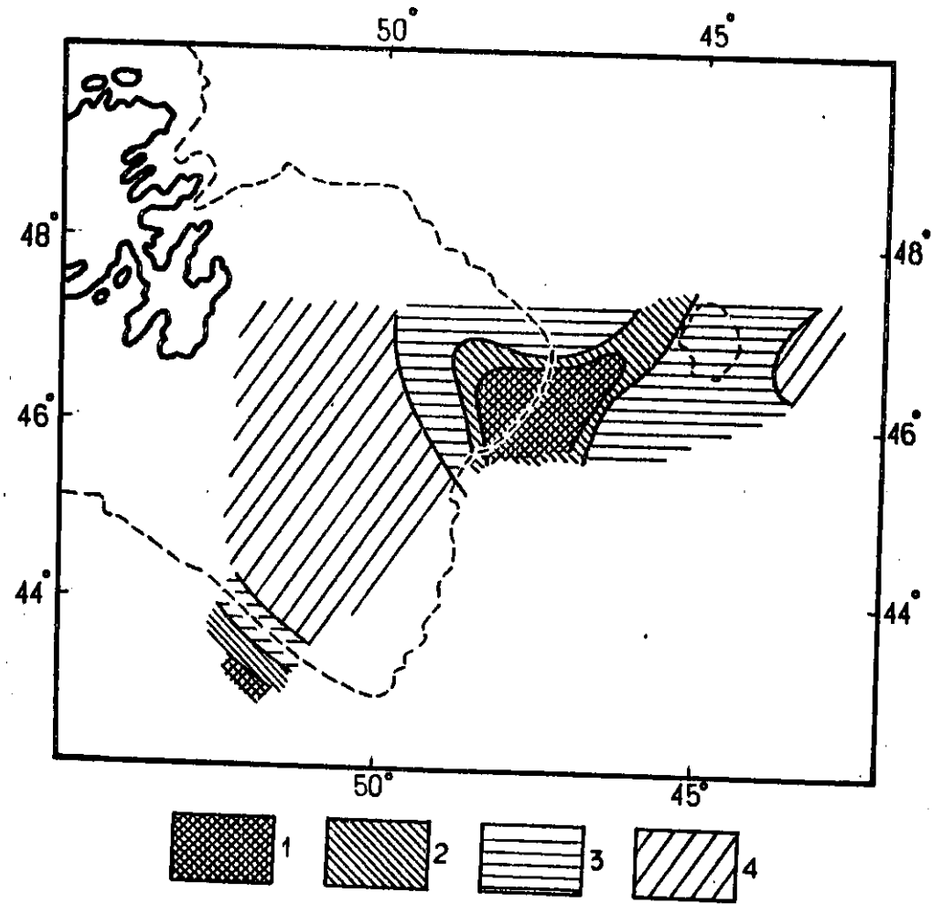


Fig. 8. Distribution of Calanus finmarchicus, autumn 1961 (thousands of specimens per sq m): 1 - over 500; 2 - 500-100; 3 - less than 100.

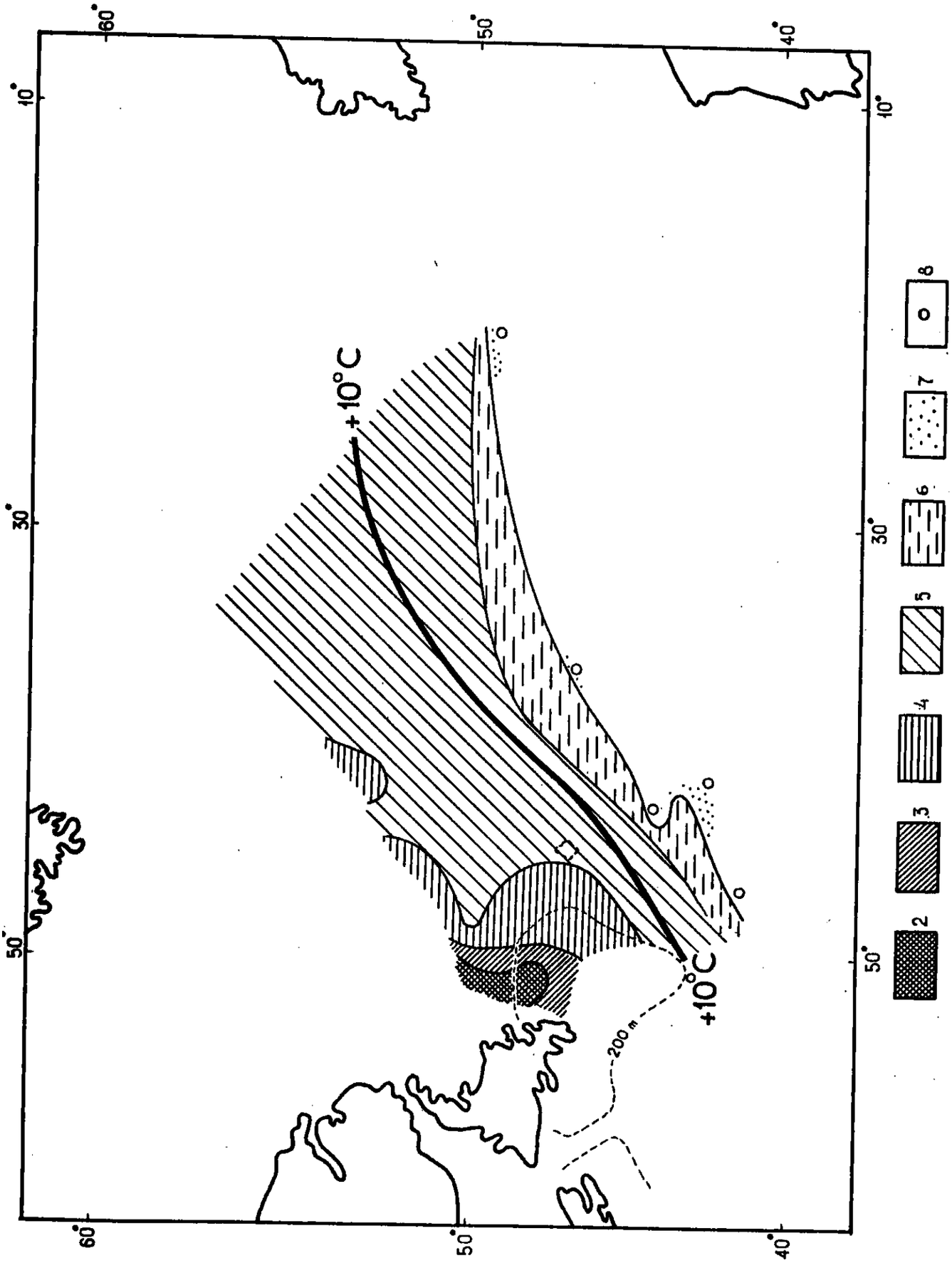


Fig. 9 - Distribution of Calanus finmarchicus, late autumn 1958. (The same key as in Fig.3)

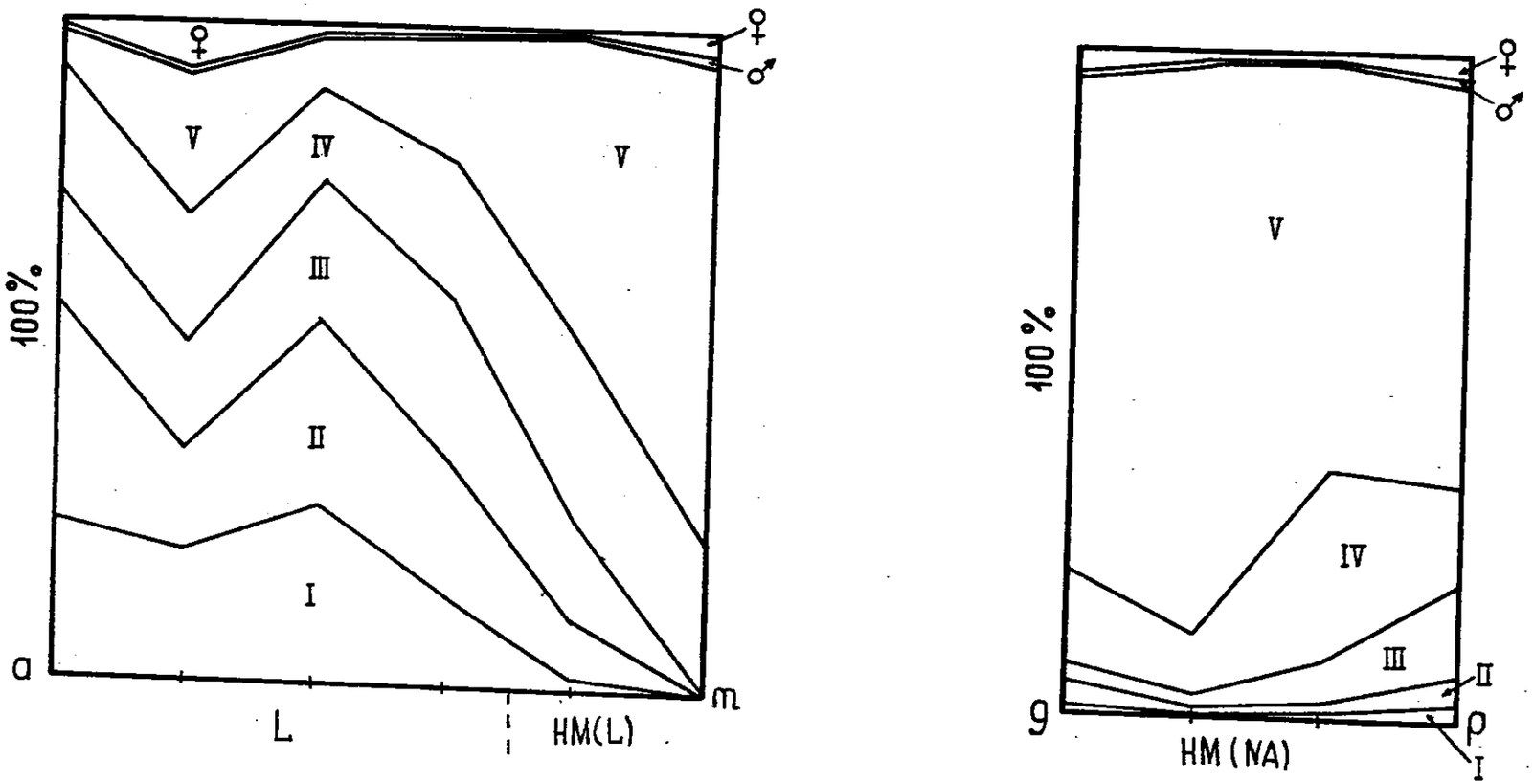


Fig.10. Frequency of occurrence of copepodite stages, autumn 1958, Sections "a-b" and "g-p".