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Zooplankton of the Frontal Zone of the North Atlantic in Spring 1958

(second cruise of the R/V "M. Lomonosov")

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During the International Geophysical Year (1957-1958) planktonic studies were conducted by the Soviet scientists in the Atlantic and Pacific Oceans, similar methods of research being used in both regions.

In spring 1958 plankton collections in the North Atlantic were made by the R/V "M. Lomonosov" in the area from 55 N to the Azores and from Newfoundland to Spain (Fig.1). The material collected permitted the elucidation of the pattern of distribution of zooplankton in the North Atlantic and the exposing of areas most abundant with food for fishes.

Zooplankton was sampled mainly with a No.38 (38 threads per cm) Juday net of 36 cm diameter and with No.140 (14 threads per cm) Juday net of 80 cm diameter from the following depths: 500-200 m; 200-100 m; 100-50 m; 50-25 m; 25-10 m and 10-0 m; phytoplankton was sampled horizontally with Nansen bottles at 0.5 m, 10 m, 25 m, 50 m, and 100 m.

Numerous data of various research expeditions in the Atlantic Ocean, published in different years by Hensen (1911), Lohman (1919), Hentschel (1932), Jespersen (1935), Wilson (1942), and others, were used first by Hentschel (1942), and then by Friedrich (1950) for compiling a chart of distribution of the relative density of pelagic population of the Atlantic. Hentschel, however, limited himself to establishing the oligotrophic and eutrophic regions and did not try to provide them with quantitative indices.

The data on the distribution of zooplankton biomass are given here as calculated by converting the number of planktonic organisms to their raw weight. Estimation of organisms was carried out in Bogorov's counting chamber by means of a stamp-pipette.

The North Atlantic area under investigation is heterogeneous with regard to its hydrologic regime and the distribution of water masses. Equally heterogeneous are the composition and distribution of planktonic organisms.

According to our data, suborder Calanoida, whose specific determination was given our special attention, is represented by 160 forms. The group of warm water organisms was represented by the largest number of species. Boreal species were considerably more scarce, and arctic species were represented by single individuals. The 10°C isotherm of the surface served as the southern border of mass distribution of boreal fauna and as the northern limit of the distribution of warm water species (Fig.1). South of this isotherm lies a zone of mixture, where representatives of both faunas are found together. This mixing zone occupies a vast area and extends as a wide belt from the southwest to the northeast in the direction of the North Atlantic current.

The number of boreal species of Calanoida in this zone south to Stations 140, 135, 109, 87, 69 incl. only slightly decreased - as compared with the boreal zone - north of the 10°C isotherm. South of the above stations boreal species occurred in the plankton only with few individuals, and they were entirely absent from the area of the Azores. Similar individual occurrence of warm water species was registered north of the 10°C isotherm.

The following representatives of the boreal fauna were observed most frequently north of the 10°C isotherm: Calanus finmarchicus, Microcalanus pygmaeus, Pareuchaeta norvegica, Limacina retroversa, Thysanoessa longicaudata.

Metridia lucens and Pleuromamma robusta were also observed at most stations, whereas Scolecithricella minor was somewhat more scarce.

In the area of the Newfoundland Bank the boreal fauna could be found together with arctic organisms in relatively low numbers. The most frequent were Calanus hyperboreus, Calanus glacialis; more rarely occurred Limacina helicina, Clione limacina juv.

The following representatives of the boreal fauna were most frequently observed in the zone of mixing: Calanus finmarchicus, Microcalanus pygmaeus, Pareuchaeta norvegica, Metridia lucens, Pleuromamma robusta, Limacina retroversa.

Warm water species were represented here by Calanus tenuicornis, Neocalanus gracilis, Nannocalanus minor, Mecynocera clausi, Calocalanus styliremis, C. tenuis, Paracalanus parvis, Ctenocalanus vanus, Clausocalanus arcuicornis, Euchirella rostrata, Euchaeta acuta, Pleuromamma gracilis, P. borealis, P. xiphias, P. abdominalis, Lucocicutia flavicornis, Heterorhabdus papilliger, H. spinifrons, Heterostylites longicornis, Haloptilas longicornis.

The zone of mixture further was abundant with salps, mainly represented by Salpa fusiformis. Calanus helgolandicus, found in plankton south of the 10°C isotherm of the surface, occurred at all stations right to the Azores.

Quantitative development of plankton in the area of investigations was not uniform; the reason for this is not only the specific conditions of the regime, but also the long period of observations (from March 2 to May 1).

Studies on Sections I and II were conducted in March prior to the vernal development of phytoplankton and reproduction of Calanus, and on Section III - in the beginning, and on Sections IV and V at the height of the biological spring. Spring development of phytoplankton proceeded in the area of Newfoundland Bank (Stations 148, 149, 150, 151).

Among the most numerous diatoms were Chaetoceros atlanticus, Ch. convolutus, Rhizosolenia hebetata, Thalassiosira Nordenskoldii. Diatom bloom at Station 126 was caused by mass development of Thalassiothrix longissima which also occurred in smaller quantities in plankton at Stations 127 and 128.

At Stations 144, 132 and, to a somewhat lesser extent, at Station 145 the warm water diatom Thalassiothrix delicatula developed in considerable quantity in the 50-0 m layer. At Station 142 in the 25-170 m layer the moderate-warm water species Thalassiosira subtilis was found in great numbers. No development of this species was observed in the 25-0 m layer.

The distribution of food zooplankton+/ in the central part of the North Atlantic is in good agreement with the regime of this area

+/When compiling the chart of zooplankton biomass salps, doliforms, siphonophores and meduses were not taken into account because they were considered as non-food organisms for fishes.

(Fig.2). The waters most abundant with food plankton were situated north and northwest of the 10°C surface isotherm. South of it the biomass of zooplankton is greatly decreased. Minimum values of food zooplankton biomass were registered in the central part of the investigated area which coincides with the area of spreading of waters of the North Atlantic current. South of this impoverished area, particularly around the Azores, the quantity of food zooplankton had slightly increased, which is also confirmed by the existing literature.

The average biomass value of food zooplankton for the boreal waters north of the 10°C isotherm of the surface layer was for the 100-0 m layer - 204 mg/m^3, and for the 200-0 m layer - 138 mg/m^3.

The average value of food zooplankton biomass for the area south of the above isotherm for the 100-0 m layer was 30 mg/m^3, and for the 200-0 m layer - 24 mg/m^3.

Zooplankton of the boreal zone (north of the 10°C isotherm) was mainly represented by Calanus finmarchicus which constituted 32% of the food zooplankton biomass, Limacina retroversa (24%) and Euphausiacea (12%). Various species of the genera Pleuromamma, Clausocalanus, Calocalanus, Ctenocalanus vanus had the greatest weight in plankton biomass of the upper 200 m of water south of the 10°C isotherm.

Calanus finmarchicus, the main food organism for pelagic fishes, occurred only in large numbers north of the 10°C isotherm in conformity with the increase in biomass from northeast to southwest (Fig.3). This was caused by the local differences on one hand, and by the seasonal changes on the other, since plankton was sampled in the northern parts of sections II and I in the middle of March, on sections III and IV in the middle of April and on section V in late April. This correspondingly affected the abundance and composition of the population of Calanus finmarchicus, the main representative of zooplankton in the boreal zone.

Table 1 - The numerical strength and age-composition of the population of Calanus finmarchicus in the North Atlantic in Spring 1958 (average number in the 500-0 m layer; sampled with a Juday net, 36 cm in diameter).

Area	Stations 77,79,80,81 March 13-20		Stations 115,117,118, 119,120,121 April 10-15		Stations 148,149,150,151 April 28-May 1	
Stages of Development	Number	%	Number	%	Number	%
I	-		8	0.8	1011	30.8
II	-		23	2.2	466	14.3
III	-		25	2.4	247	7.5
IV	29	10.9	80	7.7	237	7.2
V	198	74.0	189	18.5	290	8.9
VI	12	4.5	500	48.8	966	29.6
VII	28	10.6	200	19.6	55	1.7
Total	267	100.0	1025	100.0	3274	100.0

In the area of stations 77, 79, 80 and 81 the population of Calanus finmarchicus was found in the lower water layers. The species was caught only from the depth 500-200 m. Since there were no catches from the deeper layers it is hard to say whether calanus occurred below 500 m. In spite of rather high temperature of the upper water layers (7-9°C) the population kept all the time below 200 m, never ascending to the surface, not even in the evening or at nighttime.

In the area of stations 115, 117, 118, 119, 120 and 121 all age-groups were present in the population, though females dominated in number. Calanus was caught in all water layers from 500 m to the

surface, i.e. the population was in the stage of ascending after the winter and just entering the period of spring reproduction. Water temperature was somewhat lower than in the area just discussed, though at most stations the beginning of the warm-up of the surface layer and the stratification of the water were observed. At some stations spring diatoms appeared in small numbers.

Intensive development of Calanus finmarchicus was observed in the Newfoundland Bank area. The young were dominating. The eggs and nauplii numbered tens of thousands in one cubic meter of water throughout the whole water layer, but especially in the upper 50 m layer.

The distribution of the arctic representative of plankton - Calanus hyperboreus shows that it was most abundant in the area of the Newfoundland Bank (Fig.4). The pattern of its distribution is determined apparently by the transport of water from the Labrador Sea to the more southern areas of the North Atlantic as well as by their deflection in the 50°N direction approximately up to 30°W.

The population of Calanus hyperboreus was not numerous and was composed principally of stages IV and V and of adult females. The eggs and nauplii were only found in the plankton of the Newfoundland Bank, where the lowest temperatures were recorded.

Quantitative distribution of salps in the North Atlantic is indicative of supply of the water of the North Atlantic current (Fig.5).

The greatest numbers of salps were found in plankton of the southern stations of section V and in the central part of the area, characterized by the minimum biomass of food zooplankton (Fig.2). Salps were almost absent from the southern part of the first three sections; here in great numbers occurred doliforms (Doliolidae). Salpa fusiformis and Doliolum mulleri were found in mass numbers.

When comparing the composition and quantitative distribution of zooplankton in the investigated area of the North Atlantic, it appears that in the spring of 1958 the zone of mixture of boreal and tropical fauna showed the lowest quantities of food plankton. The analysis of the material showed that zooplankton biomass in the investigated area decreases with increasing numbers of warm water species of Calanoida.

Let us consider the distribution of food zooplankton by species and biomass on sections III, IV and V (Fig.6). The numbers of

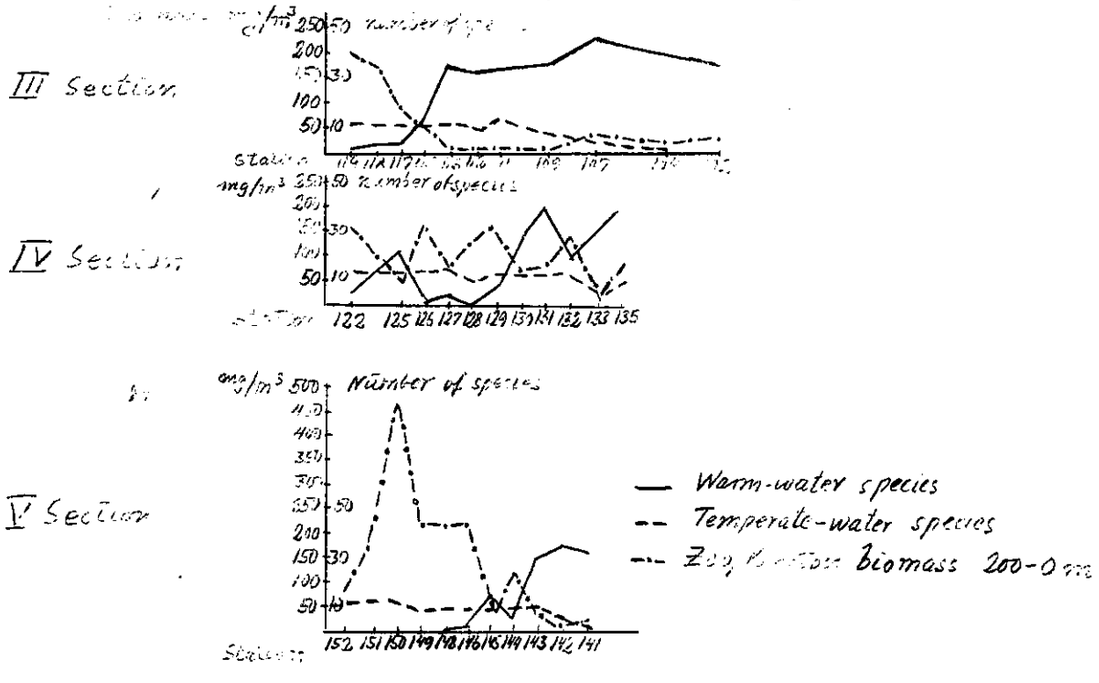

Figure 6 - Variations in the number of species of Calanoida and biomass of food zooplankton by latitudes in the North Atlantic.

boreal species of Calanoida in the northern half of section III up to station 111 incl. remained unchanged; then they gradually decreased in number until they entirely disappeared from the area of Azores. The number of warm water species began to increase from station 115 (the 10°C isotherm at the surface). At station 113 there is a sharp increase in number of these species and they remain at the high level with small variations up to the end of the section. The biomass of food zooplankton also undergoes a sharp decrease in proportion with the increase of warm water species in plankton, reaching its minimum at stations 113-109 despite almost unchanged number of boreal species. The latter inhabit the zone of mixture mainly at the depth below 100 meters, though their number here is not very large. On section IV the ratio between the number of warm water species and the biomass of food zooplankton is the same as in section III. Plankton at station 125 is characterized by the presence of considerable numbers of warm water species and large number of salps. At station 126 the boreal species dominated with an admixture of arctic organisms; no warm water species were observed. The number of warm water species in the Flemish Cap area (stations 127, 128) was insignificant; more southerly they occurred in great numbers.

A rather large decrease in the number of warm water species was observed only at station 132 where warm water mixed with cold water flowing at different levels. Thus, Calanus finmarchicus was found in large quantities in the 50-0 m layer. This species was not observed in plankton between 50 and 200 m, but below 200 m it could be found in considerable numbers together with Calanus hyperboreus. At the same time many salps were found in the 50 to 200 m layer which is indicative of a supply of water from a warm current. The number of boreal species at the stations in this section was very stable, but their numerical strength and, consequently, their biomass fluctuated greatly. Distribution of warm water species on section V was somewhat different from that on the two preceding sections. In the northern half of the section (Newfoundland Bank) warm water species were not observed. They appeared only at station 146 and reached the maximum number in the southern part of the section (stations 143, 142, 141) characterized by a very small quantity of food zooplankton and a low mass development of salps, which indicates a supply of warm water from the Gulf Stream.

From the consideration of the composition and distribution of zooplankton of the frontal zone of the North Atlantic in spring 1958 it may be concluded that the areas characterized by the 10°C surface isotherm were poor in abundance of food plankton. These areas were distinguished by the presence of a great number of warm water species with low numerical strength and biomass. The areas situated to the north of the 10°C surface isotherm showed the presence of a limited number of boreal species in the plankton, however with great numerical strength and, thus, of much greater biomass.

As the 10°C surface isotherm appears to be the northern border of distribution of salps, it may be assumed also to be the northern limit for the spread of the North Atlantic current whose waters in spring 1958 were distinguished by a poor development of food zooplankton.

SUMMARY

1. Studies in line with the IGY programme have been carried out on board the R/V "M. Lomonosov" in the North Atlantic from the coasts of Spain to Newfoundland.
2. Zooplankton was sampled with a No.38 (38 threads per cm) Juday net of 36 cm diameter from the depths 500-200 m, 200-100 m, 100-50 m, 50-25 m, 25-10 m, 10-0 m, and in addition at some stations with a No.140 (14 threads per cm) Juday net of 80 cm diameter. Phytoplankton was sampled horizontally with Nansen bottles at 0.5 m, 10 m, 25 m, 50 m, 100 m. The quantitative treatment of the plankton samples was made by means of a reciprocating pipette in Bogorov's counting chamber.

3. The North Atlantic region covered by the investigations was not homogeneous with regard to its hydrological regime and character of water masses affecting the composition and distribution of planktonic organisms. Tropical organisms prevailed in the plankton; there were less boreal forms, and arctic species occurred only as single specimens. The 10°C surface isotherm served as a border for the southward distribution of the mass of boreal forms and at the same time as the northern limit to the spreading of representatives of the tropical fauna. South of the 10°C isotherm was a transition zone where representatives of both faunas occurred together.
4. The zone of mixture of faunas occupies a vast space stretching for hundreds of miles as a wide belt from the southwest to the northeast following the direction of the North Atlantic current.
5. The quantitative distribution of food zooplankton is in good agreement with the regime in the area. Most abundant in food zooplankton were waters north and northwest of the 10°C surface isotherm. South of it zooplankton biomass greatly decreased, and minimum values were observed in the central part of the area corresponding to the area of the North Atlantic current.
The average biomass values of food zooplankton for boreal waters north of the 10°C surface isotherm were: for the 100-0 m layer - 204 mg/m^3, for the layer 200-0 m - 138 mg/m^3; for the area south of this isotherm the values were 30 mg/m3 and 24 mg/m3.
6. The main representatives of food zooplankton in the boreal zone were Calanus finmarchicus (32% of plankton biomass), Limacina retroversa (24%) and Euphausiacea (12%).
7. Distribution of the arctic species Calanus hyperboreus shows that its greatest concentrations were in the area of the Newfoundland Bank. The pattern of distribution of Calanus hyperboreus is apparently determined by the supply of water masses from the Labrador Sea to the more southerly areas of the North Atlantic and by their deflection in the direction of 50°N parallel approximately up to 30°W.
8. Quantitative distribution of salps in the North Atlantic may serve as an index of the extension of the northern current. The largest number of salps were observed at the southern stations of section V (from 38°30' to 41°20') and in the central part of the investigated area characterized by a minimum biomass of food zooplankton.

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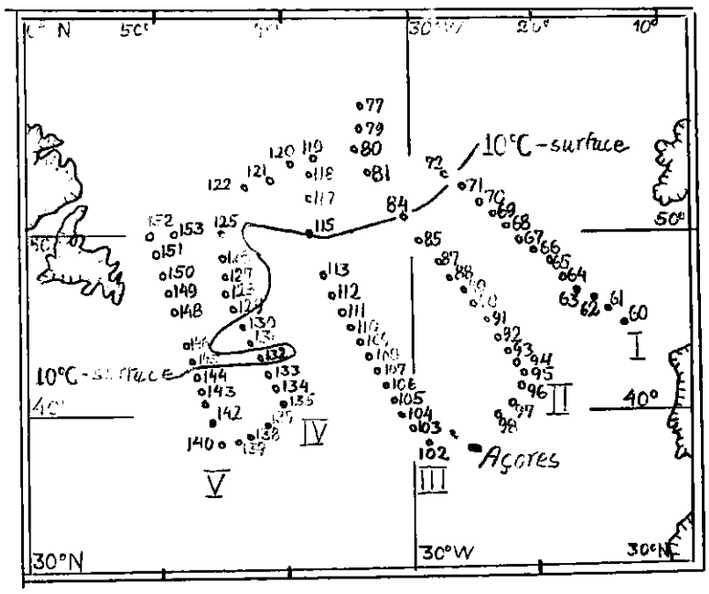

Figure 1 - Pattern of Stations worked in Spring 1958 in line with the IGY programme.

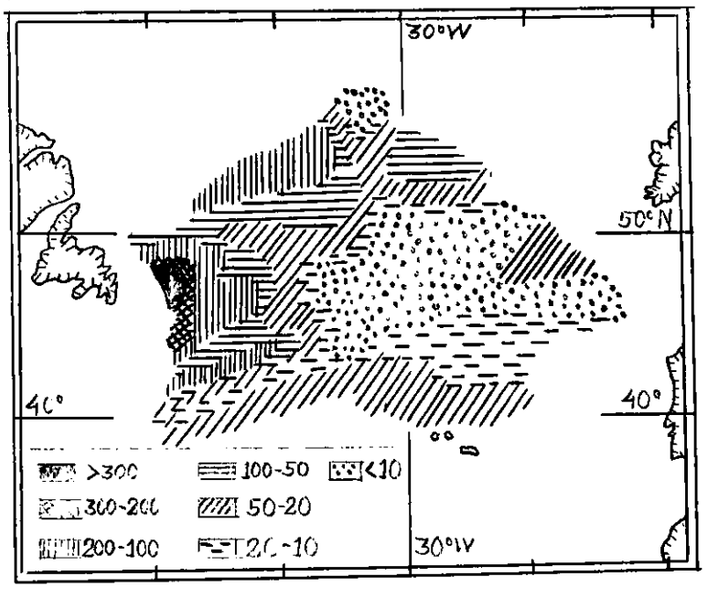

Figure 2 - Distribution of food zooplankton in the 200-0 m layer in spring 1958.

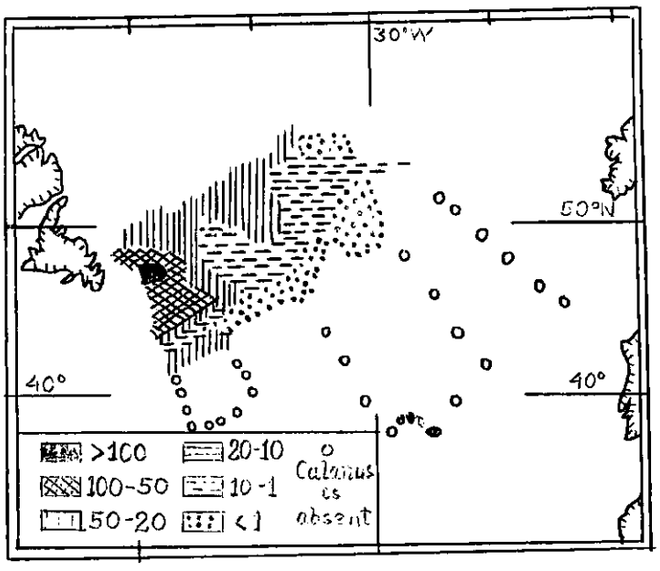

Figure 3 - Distribution of biomass of Calanus Finmarchicus in the 200-0 m (mg/m3) in the North Atlantic in spring 1958.

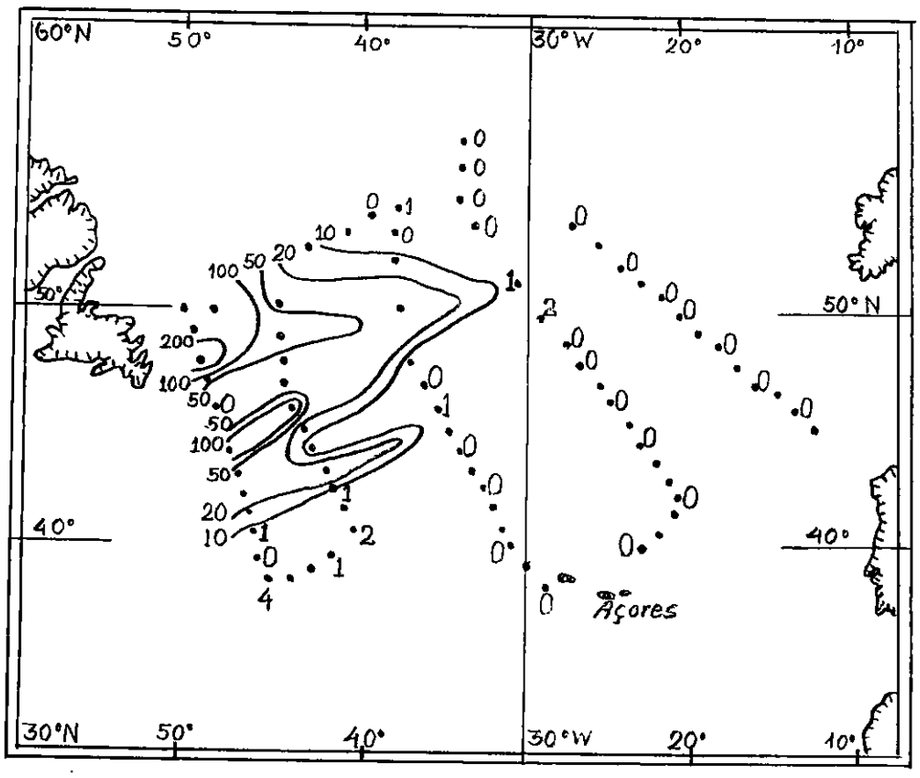

Figure 4 - Distribution of Calanus hyperboreus in the North Atlantic in spring 1958 number of specimens caught with a Juday net (38 cm diameter) in the 500-0 m layer.

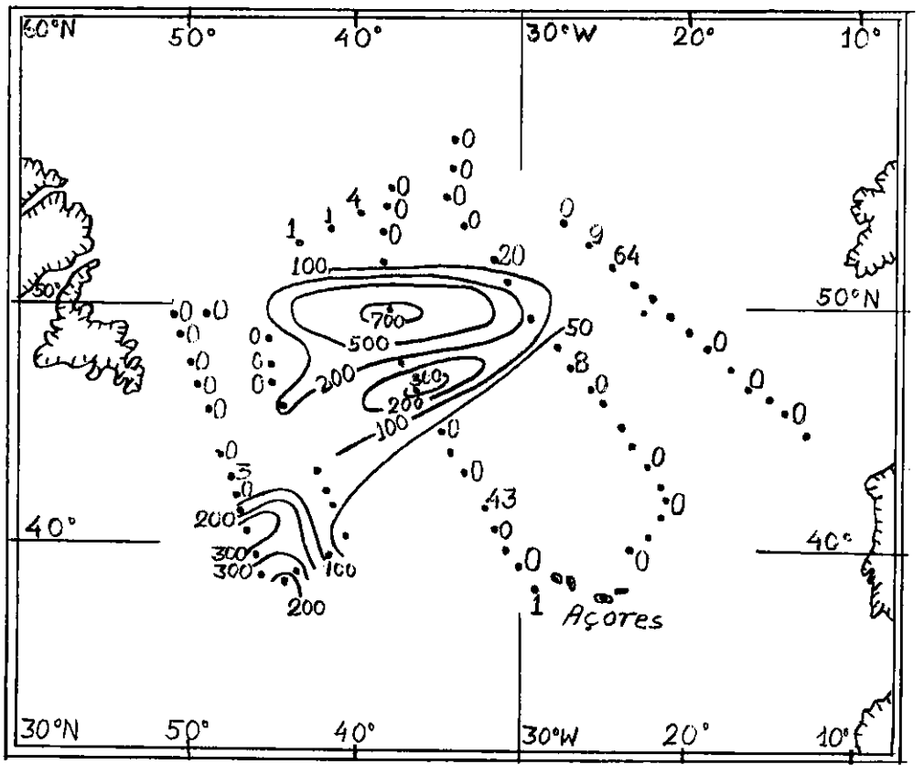

Figure 5 - Distribution of salps in the North Atlantic in spring 1958 (number of specimens caught by a Juday net (38 cm diameter) in the 500-0 m layer).