The "Michael Sars" North Atlantic Deep-Sea Expedition, 1910 (Continued)

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any such trace of a large herbivorous animal had been noticed in Dutch New Guinea. Then as regards glaciation, it interested me very much indeed to hear that there were traces of extinct glaciers to the south of the Wilhelmina range in New Guinea, but I did not quite catch the statement as to the lowest level above the sea to which Dr. Lorentz traced the ancient evidences of glaciation in New Guinea. In Australia we have our Snowy Alps traces of a past—I mean by "past" a comparatively recent geological, probably Pleistocene, glaciation. It would be very interesting to know whether the snow-line in New Guinea has recently come down about the same distance below the modern snow-line as it did in Australia during the Pleistocene glaciation. At Kosciusko, in the Australian Alps, it formerly came down to 5000 feet above sea-level, and for 2000 feet above the 5000 feet level the whole of that plateau was intensely glaciated. The third question was in reference to those pygmies of which we have heard so much from members of the Goodfellow expedition—as to their habitat in New Guinea. I have nothing further to ask, but I should like, as a representative from Australia—the nearest great land area to New Guinea, where all of us in Australia have followed his work very closely—to convey to Dr. Lorentz very hearty congratulations on the splendid work he has accomplished, and on the bravery and heroism of himself and his fellow-comrades. I thank you for having given me this opportunity of speaking, and for the kindly welcome you have accorded me on this occasion.

Dr. Lorentz: I can answer your question in a few words. No traces were met with of a large animal in the mountains. At some 10,000 feet we met Papuans, who had round their neck a claw. I bought the thing, but I had to give it back afterwards; I think it was the claw of the *Prœchidna Bruynii.* Higher up in the mountains we saw some traces—little holes in the ground; I suppose they were made by the same animal. As to the glaciated lake, I can tell you we found that lake, with rocks with scratches on them, at a height of 13,300 feet. There we found the snow in a melted state. As I say, the height of the everlasting snow was 14,883 feet. We did not meet any pygmies. The mountain people are not so large as the people of the Lorentz (north) river.

THE "MICHAEL SARS" NORTH ATLANTIC DEEP-SEA EXPEDITION, 1910.*

By JOHAN HJORT.

If we next examine the size-distribution at the different depths, we shall see that it is perfectly clear that the smaller sizes are met with much higher up than the larger ones, which latter are mainly to be found at a depth of 1500 metres. In the northern section we find that at a depth of 500 metres the greatest number of individuals were 30 mm. in length, whereas at 1500 metres the majority attained 60 mm. At a depth of 500 metres we only came across two that were over 50 mm. in length.

The smaller and younger individuals, of a length of 20–30 *mm., live, accordingly, to a preponderating extent,* 1000 *metres higher up in the water-layers than the majority of the largest and oldest individuals.*

Whether in our material there are still smaller individuals from other depths we have not yet had time to ascertain.

* Continued from page 377.

Another remarkable fact which strikes us when we study our catches is that *the average size of the individuals is much less at the same depth in the southern than in the northern section.* The graph (see Fig. 17) shows this. We see, for instance, that in the southern section, if we want to get individuals of an average size of 30 mm., we must fish 250 *metres further down* than we would in the northern section.

The vertical distribution of *Cyclothone signata* is very different from that of *C. microdon*. We have captured many individuals at a depth of

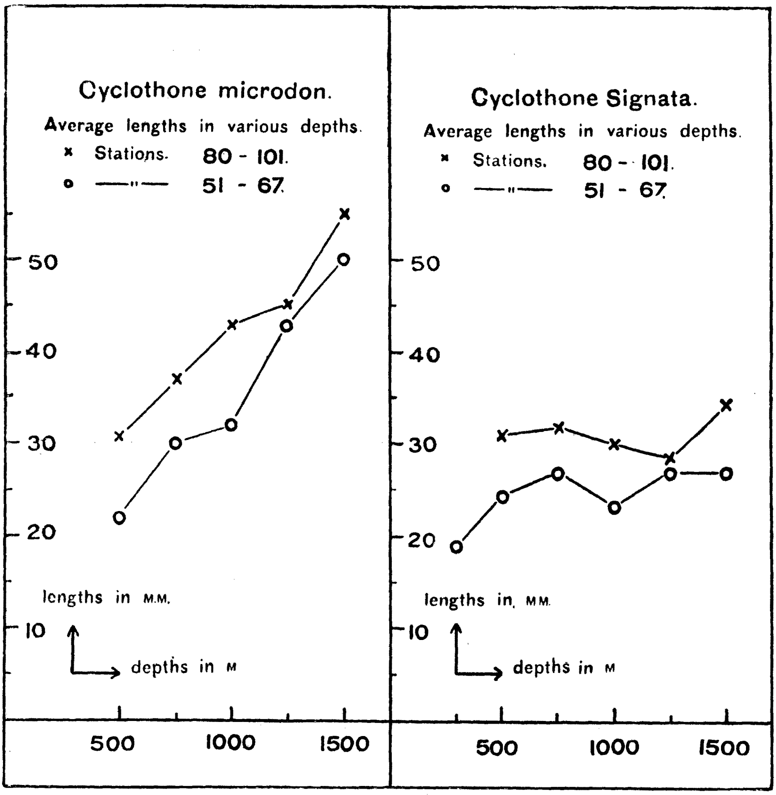


Fig. 17

300 metres, at any rate, at our southern section. The bulk, however, were found at a depth of 500 metres. In the hauls made at greater depths, the quantity diminished so rapidly that we may assume a large portion of the catches to have been made during the process of hauling in, and that there is only a comparatively thin layer below 500 metres in which they live. In a vertical haul from a depth of 4500 metres to 1500 metres we caught no individuals of this species, but we secured three individuals, on the other hand, in a haul from 1350 metres to 450 metres.

Cyclothone signata is, accordingly, found in *an intermediary layer, with a maximum in the number of individuals at about* 500 *metres*. In the case of this species, too, we note that *the younger individuals are mainly to be found high up in the water* (notice particularly the southern stations), and that the same size is to be found deeper in the southern section than in the northern (see Figs. 16 and 17).

We have a remarkable parallel to the areas of vertical distribution of

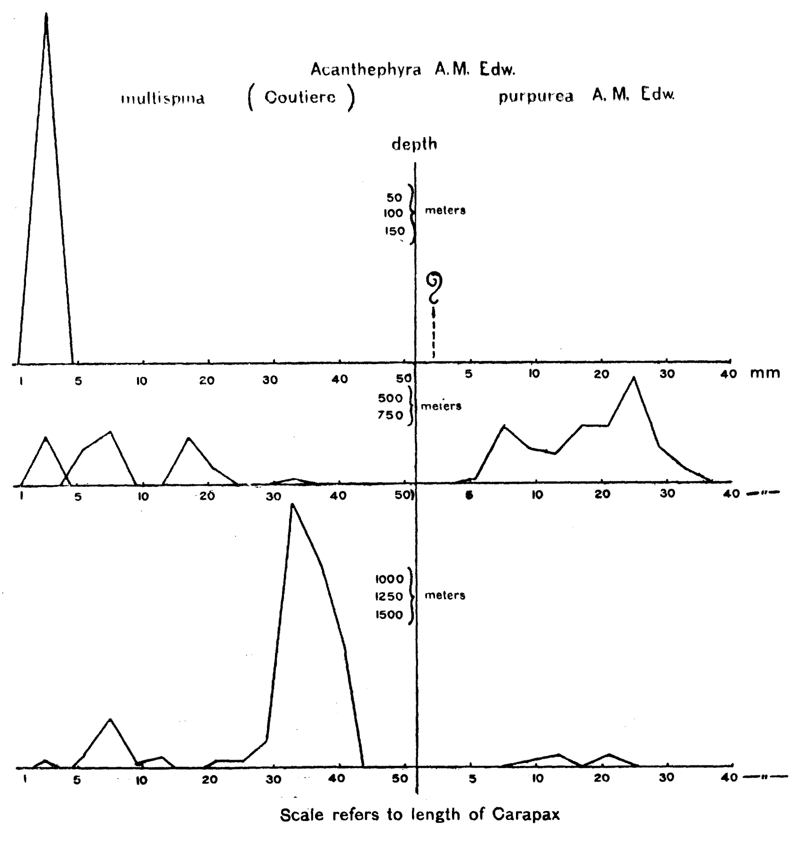


Fig. 18

these two fish species in the case of the red prawn species. These latter unite with the black fishes in forming a populous and characteristic "community." We have come across no fewer than twenty-six species of prawns, of which we shall here refer to *Acanthephyra multispina* and *A. purpurea*.

Acanthephyra multispina shared with *Cyclothone microdon* the peculiarity of the largest and oldest individuals being found in the nets towed at the greatest depths, say, at 1000–1500 metres (see Fig. 18). At depths between 500 metres and 750 metres we met with middle-sized specimens; and in the upper layers, at from 50–150 metres, we found the larvæ. These larvæ were taken in quantities, whereas formerly only a single individual was known, namely, one which belonged to the collections of the Prince of Monaco. The specimen found previously had been described by Coutière as *Hoplocasicyphus similis*, but this has now been identified as a larva of *Acanthephyra multispina*.

Acanthephyra purpurea resembles *Cyclothone signata*, in that its distribution is chiefly confined to an intermediary layer between 500 metres and 750 metres in depth. Our appliances at greater depths captured so few individuals, that we may safely assume even these to have been caught during the process of hauling in. A vertical haul at station 63, from a depth of 4500 metres to 1500 metres, yielded 5 individuals of *A. multispina*, but none of *A. purpurea;* while another haul from 1350 metres to 450 metres gave us 2 *A. multispina* and 33 *A. purpurea*. The larvæ of the latter have not yet been met with in our material, though they will probably be found in the higher layers of water, just as is the case with *A. multispina*.

What has just been said illustrates the conditions on the northern section from Newfoundland to Ireland, and if we examine the material from the stations farthest south in the Sargasso sea, we are confronted with exactly the same difference that we encountered in the case of the species of Cyclothone, namely, that the same forms descend to greater depths in the south than they do in the north. The larger individuals of *Acanthephyra purpurea*, for instance, occur at depths between 500 and 750 metres in the northern section, whereas in the south they were not captured by the net towed at 500 metres, though present in large numbers at a depth of 1000 metres. The intermediary layer in which these animals live is thus there situated several hundred metres deeper, just as we found to be the case with Cyclothone.

The instances I have given show the utility and exactness of our method of working. Where we have to deal with catches of great numbers of individuals, our errors and inaccuracies will undoubtedly be very small. The catches which the *Michael Sars* made of such forms as Cyclothone and Acanthephyra were certainly most satisfactory in this respect. But when we come to the catches which the expedition made of rare forms, or forms more difficult to capture, then we are bound to own that the method of working even of the *Michael Sars* is not sufficiently effective. Still, it is interesting to examine a few of the results yielded by the method we employed, with the object of discovering some conformity, or some general rule for the peculiar distribution of the different organisms at different depths.

I will commence with the view I formed during the cruise itself from the appearance of the catches on board, which view I find has also, to a certain extent, forced itself upon other observers, chief amongst whom I may mention Professor A. Brauer, to whom was confided the treatment of the fishes of the *Valdivia* expedition. I found on examining the catches from great depths that the black and dark-red forms were the all-prevailing ones among animals from the greatest depths.

I have not yet been able to examine the whole of the material with the object of ascertaining whether this is an invariable rule, but I will put forward here a few instances of what we found. Fig. 19 shows the vertical distribution of a number of black-coloured pelagic fish. These fishes are few in number, though they might be termed numerous, if we take into

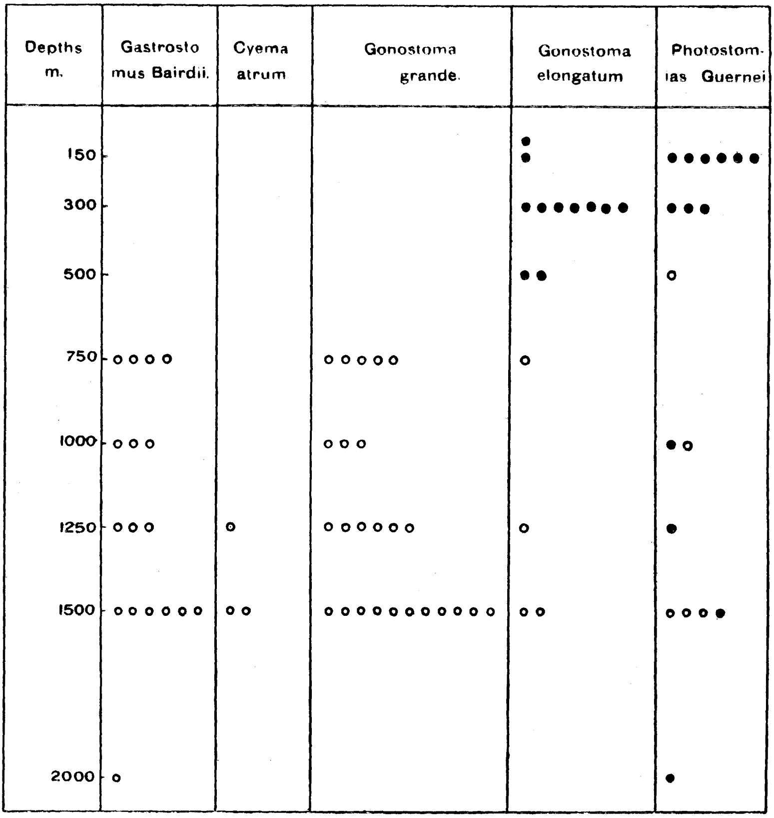


Fig. 19

VERTICAL DISTRIBUTION OF BLACK-COLOURED PELAGIC FISH.

account what was previously known concerning "rare" forms. As will be seen, *Gastrostomus Bairdii*, *Cyema atrum*, and *Gonostoma grande* were only caught at depths from 750 metres downwards. The two species *Gonostoma elongatum* and *Photostomias Guernei* were caught in deep as well as shallow water, even in some cases as high up as 150 metres below the surface. The rule, then, that the black forms are only to be found at great depths, cannot be said to hold good universally.

The question, accordingly, arises whether among the black forms there may not be said to be groups or different types. In common with several previous observers, I have been struck by the fact that even the anatomical structure of the black fishes points to different modes of living. If we compare, for instance, the pictures of the above-mentioned five species of fish, we will see that of the three species which were only found at great depths, *Gastrostomus Bairdii* and *Cyema atrum* are quite without light organs, and *Gonostroma grande* has only small ones, as is also the case with *Cyclothone microdon*. In *Gonostoma elongatum* and *Photostomias Guernei* the light organs are much more highly developed (as is also the case with *Cyclothone signata*). It is an interesting fact now to notice that every single individual of these two species which was captured higher up than 500 metres, was caught *at night*, which coincides with previous observations regarding black forms such as *Idiacanthus* and *Astronesthes*, which have been caught at night right close up to the surface. We may assume, accordingly, that among the black deep-sea fishes there are several different modes of life; that is to say, several different "biological types."

With a view to a better understanding of the occurrence of these black and red types in the sea, I have endeavoured to compare their vertical distribution with the intensity of the sunlight in different depths and at different parts of the ocean.

We have seen that the upper limit for *Cyclothone microdon* and the red crustaceans, in the northern section from Newfoundland to Ireland, or about 50° N. lat., was approximately 500 metres below the surface; and we have also noticed that the limit of depth for the same forms at the southernmost stations, or about 33° N. lat., was some 200–300 metres deeper. In the Norwegian sea I have previously investigated the intermediary pelagic fauna, and found pelagic red prawns as well as the dark-red fish *Sebastes norvegicus* at depths of about 200 metres below the surface. Sebastes was taken, for instance, with floating long lines in considerable quantities on a course Jan Mayen-Lofoten—that is to say, in about 67° N. lat., at a depth of 200 metres—and it was even found, though in decreasing quantities, higher up. Along the Norwegian coast, in the fjords and sounds, we have a particularly rich fauna of red crustaceans (especially *Pandalus borealis*), occupying depths whose upper limit in the north, at any rate, may be put at above 200 metres. Now, if we calculate the depth to which the rays of the sun penetrate, after passing through the same distance in the water, assuming always that the rays are direct, and that the rate of absorption is the same, we find that the rays will have passed through the same distance to reach a depth of 500 metres in 50° N. lat., that they will pass through to reach 650 metres in 33° N. lat., or 300 metres in 67° N. lat.

However, the transparency of the water varies greatly in different regions. If we take the results of previous observations during different expeditions, we may set down the visible depth in the open sea as being roughly 50 metres in 33° N. lat., 40 metres in 50° N. lat, and 25 metres in the Norwegian sea in 67° N. lat.* Taking this into consideration, we find that there will be the same *intensity* from the rectilinear rays—

In 33° N. lat.,	at about	800	metres'	depth.
,, 50° ,,	,,	500	,,	,,
,, 67° ,,	,,	200	,,	,,

The red and black animal forms, therefore, as has been found in the investigations I have just described, have an *upper limit* in the different waters which corresponds everywhere with the *same intensity of light.*

During the Atlantic cruise of the *Michael Sars* we undertook a series

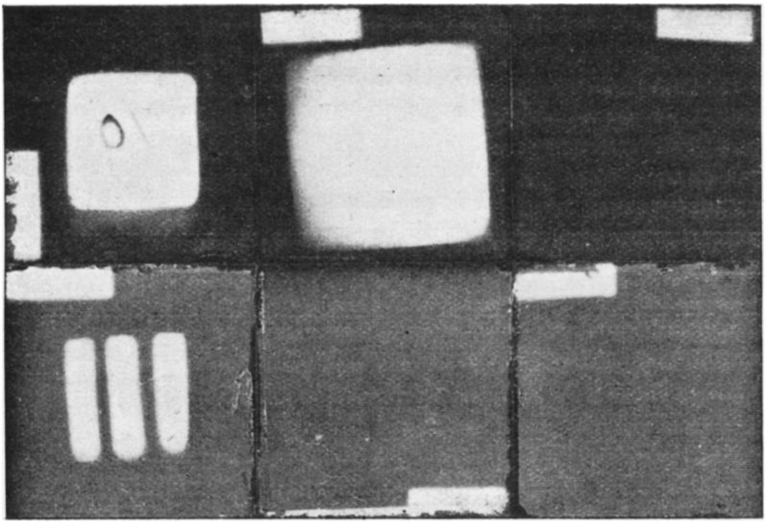


Fig. 20

PHOTOGRAPHIC PLATES FROM VARIOUS DEPTHS.

of measurements of the intensity of light with a photometer constructed by Dr. Helland-Hansen; to determine the intensity of the different colour rays, Dr. Helland-Hansen made use of panchromatic plates and gelatine colour-filters. The observation south and west of the Azores (that is to say, at the southern stations) showed that the rays of light strongly affected the plate at a depth of 100 metres. The red rays were weakest here, while the blue and violet rays were strongest. At a depth of 500 metres the rays from the blue and violet part of the spectrum were still distinctly visible, and at a depth of 1000 metres the violet or ultra-violet rays were yet perceptible. In 1700 metres, however, there was not the faintest trace

* In coastal waters the transparency must be less than in the open sea, and it must vary with local circumstances. Special investigations will therefore to a great extent be needed in this new line of research.

of light, even after the plates had been exposed for two hours in broad daylight.

Fig. 20 shows some of the photographic plates exposed in Dr. Helland-Hansen's apparatus. The top row is from station 51. The left corner plate in this row is from 500 metres, exposure 40 minutes; the middle one from 1000 metres, exposure 80 minutes; the right one from 1700 metres, exposure 120 minutes. The lower row is from station 55, all plates from 500 metres and all exposed for 40 minutes. The plate to the left was taken without colour-filter; the middle one was taken with a blue colour-filter; the right one was taken with a green colour-filter. According to experience, the blue filter requires an exposure six times as long as a plate without a filter; the green filter eighteen times as long. On the middle one a faint roman V can be seen; on the right there is no trace of influence of the light.

In the above-mentioned depth, which denotes the upper limit for the black and red forms during the daytime, we may after this, no doubt, assume that there are only to be found chemically effective rays from the violet portion of the spectrum. Now, seeing that the coefficient of absorption for the red rays, as compared with the violet, is about in the proportion of 30 to 1, and that our observations failed to trace any red rays at a depth of 500 metres, it follows that *the red animals at this depth must be quite as invisible as the black ones.* It is interesting to note in this connection that it is only at night that the black fish with large light organs are found high up in the water, and that red crustaceans in the arctic regions, as was noticed by Scoresby in the case of *Hymenodora glacialis*, are to be found right up to the edge of the ice at the surface of the sea.

Above the region I have hitherto been describing, with its black and red forms, our parallel hauls have shown us an equally characteristic though very different group of pelagic fishes. Their peculiarity is that their body is always more or less *compressed laterally.* In colour they are *dark along the back and silvery or shining, with a bluish-violet gleam along the sides, their eyes are large, and often telescopic,* and most characteristic of all, I suppose, are their strongly developed light organs; characteristic forms are especially to be met with among the families *Sternoptychidæ* and *Stomiatidæ.*

Fig. 21 shows the depth at which a number of these forms occur. It will be seen that 500 metres may be taken as their *lower* limit, and that *the greatest number of individuals live at a depth of* 300 *metres;* above 150 metres there were only a few found, and even those that were met with in 150 metres, or higher up, were with very few exceptions taken *at night.*

Cyclothone signata may be said to approximate to this group, as far as distribution is concerned; and this form also has large, well-developed light organs. A closer analysis of the occurrence of these forms in different latitudes would probably reveal much of interest, though this must be reserved for subsequent investigations.

It is important to lay stress upon the fact that these *shining colours,*

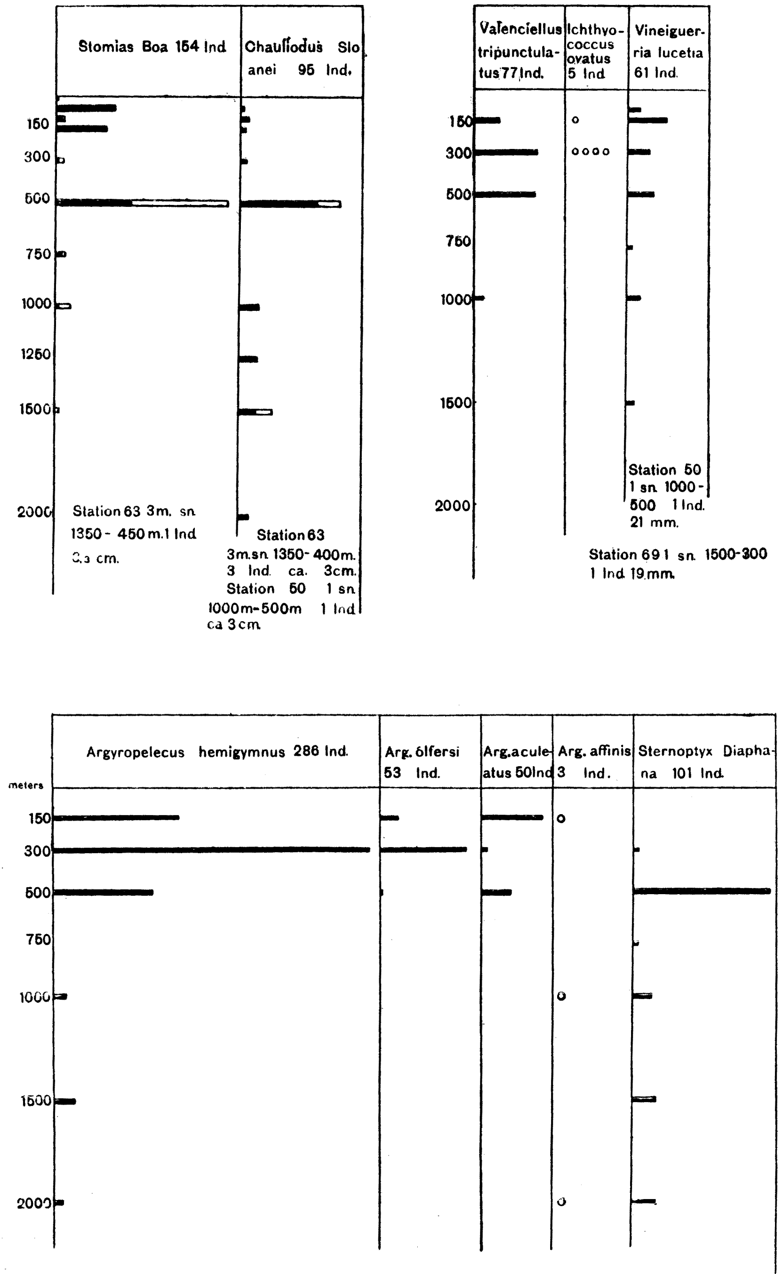

Stomias Boa 154 Ind.
Chauliodus Sloanei 95 Ind.
150
300
500
750
1000
1250
1500
2000
Station 63 3m. sn. 1350 - 450 m. 1 Ind. 3,3 cm.
Station 63 3m. sn. 1350 - 400m. 3 Ind. ca. 3cm. Station 50 1 sn. 1000m - 500m 1 Ind. ca 3cm.
Valenciellus tripunctulatus 77 Ind.
Ichthyococcus ovatus 5 Ind.
Vineiguerria lucetia 61 Ind.
Station 50 1 sn. 1000-500 1 Ind. 21 mm.
Station 69 1 sn. 1500-300 1 Ind. 19 mm.
meters
Argyropelecus hemigymnus 286 Ind.
Arg. ólfersi 53 Ind.
Arg. aculeatus 50 Ind.
Arg. affinis 3 Ind.
Sternoptyx Diaphana 101 Ind.

Fig. 21

remarkable light organs, and peculiar telescopic eyes do not belong to the dark region in the sea, where the sunlight never penetrates, but, on the contrary, to a region where there are, at any rate, *considerable quantities of the rays which are nearest to the blue, violet, and ultra-violet portion of the spectrum.*

There has been a good deal of discussion as to whether the light emitted by the light organs was entirely produced by the vital energy of the organisms, or whether the organisms had the power of *transforming* the ultra-violet rays of the sunlight into rays of lesser wave-length. The observations I have described here cannot, of course, decide questions of this kind, but they show, at any rate, that light-emitting organisms live in water-layers in which there are quantities of rays from the sun. And we recognize, further, in these forms a new biological type of organisms, a separate group with quite characteristic outward conditions of existence.

The higher up we ascend towards the surface of the sea, the more varied become the forms and colours of the organisms and the more diversified become also, probably, their conditions of life. I have so far only been able to examine a portion of the large mass of material from the uppermost water-layers, and will merely mention a single group from this region, namely, *the larvæ and young fish forms*. Of these we have collected a very large quantity, amounting to thousands. It has been impossible to determine them all, as this will be a long and laborious task.

Fig. 22 shows how out of 3600 transparent larvæ and young fishes, 90 per cent. were secured in the appliances operated from the surface down to a depth of 150 metres. These forms are young stages of many different kinds of fishes. There are the crystal-clear young of black fishes like *Gonostoma elongatum*, light-coloured young of a deep-living bottom fish like the genus Macrurus, of fish with large light organs like Vinciguerria, and the numerous species of Scopelids and of surface fishes (Caranx, Scombridæ, etc.). To this group belong also the Leptocephalidæ, whose depth-distribution, as will be seen, quite corresponds with the other transparent larval forms. Two groups of larvæ and young fish have so far been found with a peculiar mode of life; one being larvæ of the genus Argyropelecus, whose maximal occurrence corresponds with that of the grown forms, namely, at a depth of 300 metres, and the other belongs to the genus Alepocephalus. The grown forms of the latter genus are generally considered to be among the most pronounced of the deep-water fishes, and they have been taken with the trawl at great depths, or else pelagic at the lowest depths (by the *Michael Sars* amongst others). They are totally devoid of light organs. Larvæ with yolk-sac, as well as all stages of young fish of all sizes, have been found by the expedition in considerable quantities, the whole of which were taken *at depths from* 500 *metres down to* 2000 *metres*. It seems, accordingly, that these fishes from their earliest stages of development are denizens of the deepest regions. Johs. Schmidt * has previously

* See Johs. Schmidt, "Contributions to the Life-history of the Eel (*Anguilla vulgaris*, Flem.)." 'Rapport et Procès-verbaux du Conseil perm. intern. pour l'exploration de la mer,' vol. 5. Copenhagen: 1906.

found bathypelagic eggs of deep-sea fishes, but, as far as I know, not of this genus. Now, what makes these two groups of larval forms so remark-

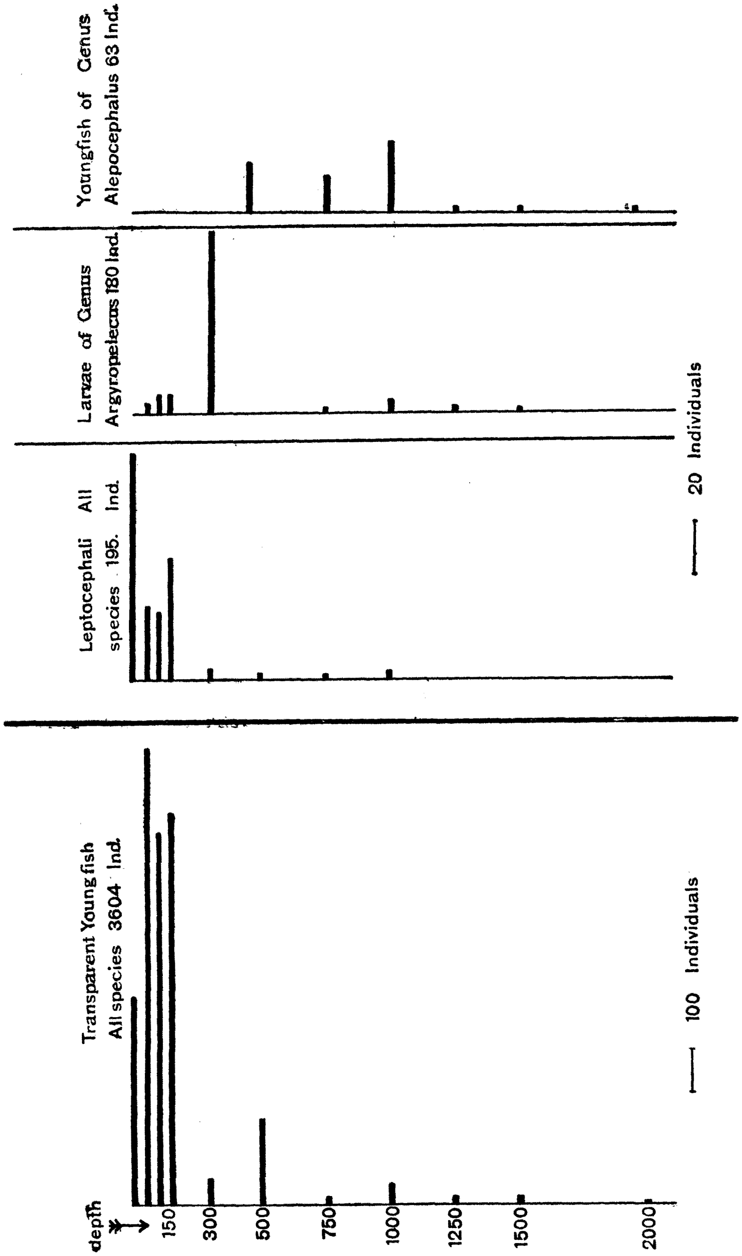


Fig. 22

young fish from all Stations

able is this, that *the larvæ of Argyropelecus* from a very early stage have *a shining appearance, and very large light organs,* whereas *the larvæ of Alepocephalus*—even while still with the yolk-sac—develop the *black pigment* *which characterizes the grown animal.* We have thus instances of how the peculiarities of colour (referred to previously) may occur even at the earliest period of growth, in cases where the young stages have the same characteristic depth-distribution as the grown individuals.

A very interesting and important question is the quantity of animals in the different depths. This question has not been much studied yet. I believe myself that the upper limit of the red and dark-coloured forms is particularly rich. In the Norwegian sea I found * that the occurrences of a rich intermediate pelagic life corresponded to a great rise in the density of the sea-water, and I explained this thus, that the food of the animals sinking down from the upper layers might accumulate there. The closer study of our material may give more information about this interesting question.

In my preceding remarks I have given a number of instances of the observations we were able to make regarding the depth-distribution of fishes, when we examine material collected by means of parallel hauls. But it is obvious, too, that this material may equally well be used for ascertaining their horizontal or geographical distribution; and it is only after studying simultaneously their vertical as well as horizontal distribution, that we can characterize the outward conditions under which they live. If we look at the horizontal distribution as found by the *Michael Sars* and compare it with previous observations in the Northern Atlantic, we shall get some idea of how little knowledge we possess concerning the most ordinary forms inhabiting the ocean between Europe and the coast of the United States. I will base my comparison entirely on Brauer's valuable summary of what was previously known, and on the same instances that I have employed when discussing the vertical distribution.

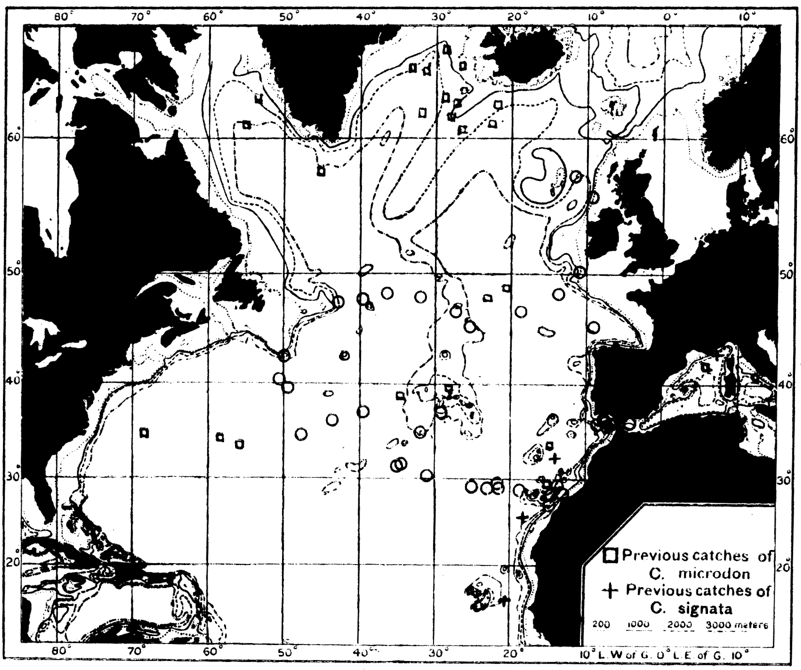
Black fishes and red crustaceans were caught at *all* the stations during the cruise of the *Michael Sars* in the Atlantic, wherever we lowered our appliances to greater depths.

Chart, Fig. 23, gives all these stations, and shows us accordingly at the same time the stations where *Cyclothone microdon* and *C. signata* were captured. It will be seen that these species are distributed everywhere from the Iceland-Shetland ridge to south of the Canary islands and to the Sargasso sea. During the cruise we also secured the following species of this genus: *C. microdon pallida, livida, acclinidens,* and *signata alba.* With the exception of the last-named, however, these were all caught at the *southernmost stations* of our cruise, and in exceedingly small quantities. They may therefore all be assumed to be *southerly forms.* The chart shows the places where *C. microdon* (□) and *C. signata* (+) were previously caught. *C. microdon* had been taken at quite a number of places, especially in the north, whereas *C. signata* had only been met with in a few localities,

* Johan Hjort, 'Die erste Nordmeer-Fahrt des norw. Fischereidampfer *Michael Sars.*' 1900. *Petermanns Mittl.*, Bd. 47. 1901.

though they were found on this occasion by the *Michael Sars* in thousands, and distributed over the entire area investigated.

Gastrostomus Bairdii was previously caught by the *Albatross* on the slope off the coast of the United States and nowhere else. It was taken by the *Michael Sars* south of the Canary islands, between those islands and the Azores, and to the south and east of the Newfoundland banks. It therefore, apparently, is also to be found over the greater part of the Northern Atlantic, at any rate to the south and west of the Azores. A similar distribution is shared by *Photostomias Guernei*, which had pre-



○Cyclothone Signata and microdon
caught by "Michael Sars"

Fig. 23

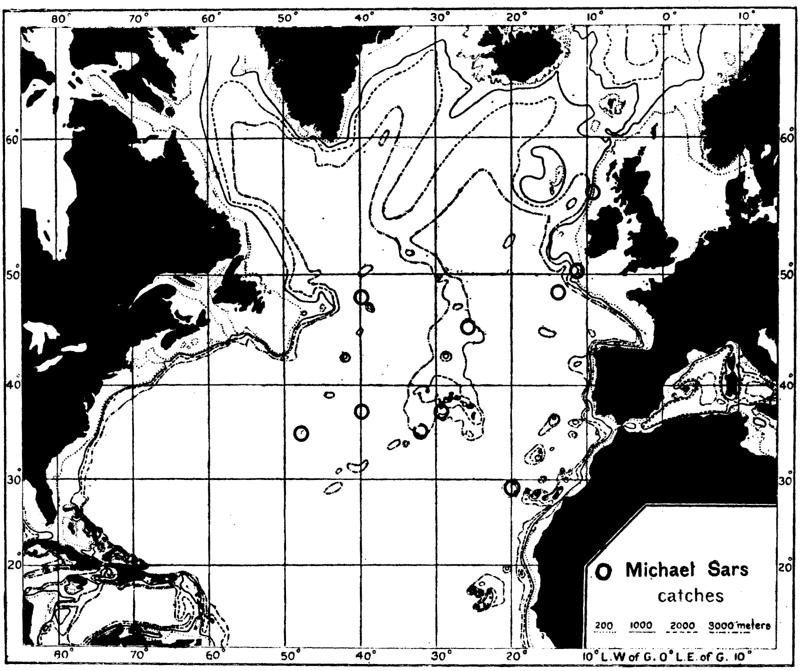
viously only been taken near the Azores, and also the rare *Gonostoma grande* (Fig. 24); they were found over the whole area. Most interesting, too, are a number of very "rare" forms of the *Ceratiidæ*. We found at least eight species, of which I am inclined to believe five are new. One species (*Melanocetus Krechi*) had only once been previously found, a specimen having been captured in the Indian ocean. We secured two specimens to the south of the Azores.

The genera *Aceratias*, *Opisthoproctus*, *Malacosteus*, and *Cyema* afford interesting examples of rare deep-sea fishes that had previously only been taken singly or in localities remote from the course of the *Michael Sars*.

Of the group with large light organs, which we found in the intermediary layer at about 300 metres, we see that *Argyropelecus hemigymnus* and *A. Olfersi*, *Sternoptyx diaphana*, *Stomias boa*, *Chauliodus Sloanei* (Chart, Fig. 25), and *Vinciguerria lucetia*, occur over the whole or the greater portion of this vast area. These had formerly only been caught off the North American slope, on the coast banks of Europe or near the Azores, where most previous researches have been made.

Argyropelecus aculeatus and *A. affinis* were only caught at the southern stations.

Transparent young fish were captured over the whole area of investiga-



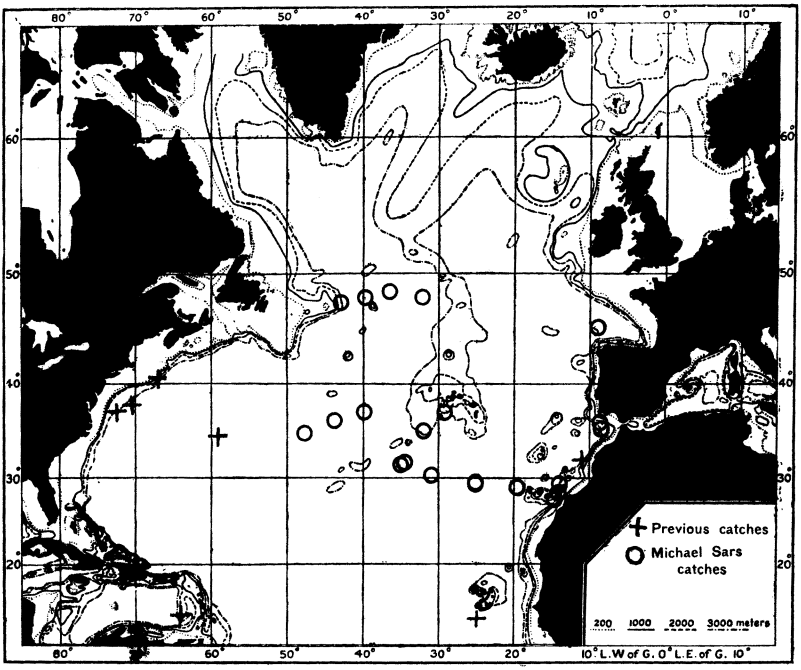
Gonostoma grande

Fig. 24

tion, though in very varying quantities. The chart (Fig. 26) shows their quantitative occurrence in three groups, namely, fewer than 100, between 100 and 250, and over 250. The largest quantities were taken south of the Azores, west of the Canary islands, and east of the Newfoundland banks. This great abundance of young fish a short distance beyond the slope of the coast banks is of the utmost interest. We shall only, however, grasp its full significance, when we have succeeded in determining all the numerous forms of which this large group is composed.

In the open sea over the greatest depths the Scopelidæ are undoubtedly the most numerous group among the young fish. We find also many extremely interesting forms with stalk eyes, telescope eyes, and so on. Amongst those with telescope eyes there are many of a perfectly transparent new form, which may in all probability be assigned to the genus Dysomma. They were mostly caught in the uppermost 150 metres.

When we have succeeded in determining these young stages, we will be able to throw much light upon the life history of many important species of fish. The numerous forms of the group Leptocephalidæ will by no means be the least interesting among them. The 195 individuals that were found



Chauliodus Sloanei

Fig. 25

are believed to belong to no fewer than 20 species, of which a good many are entirely new.

I have previously (in *Nature* of November 24, 1910) published a short description of a number of these Leptocephalidæ, which we were able to prove to be the larvæ of the European eel. These larvæ (44 specimens in all) have this much of interest in them, as compared with previous finds, that they were met with right out in the Atlantic ocean, far away from the slopes where they previously had been discovered.* Two groups were come across in our material, of which one consisted of full-grown larvæ, the other of younger stages of development, the smallest being 41 mm.

* Schmidt, *loc. cit.*

in length. These young stages were only found in the sea to the south of the Azores, a fact which gives rise to many questions regarding the wanderings of this remarkable species of fish; and this discovery will probably contribute its share towards the solution of the old problem about the eel's spawning grounds. We have also young fish of genera (to which belong important food-fishes) like Scomber, Clupea, Caranx, and others, but they have not yet been studied.

It seems to me that these instances are sufficient to make it clear that the Atlantic offers a fruitful field for future investigations into the pelagic animal life of the ocean. I hope, also, that it will be conceded that the

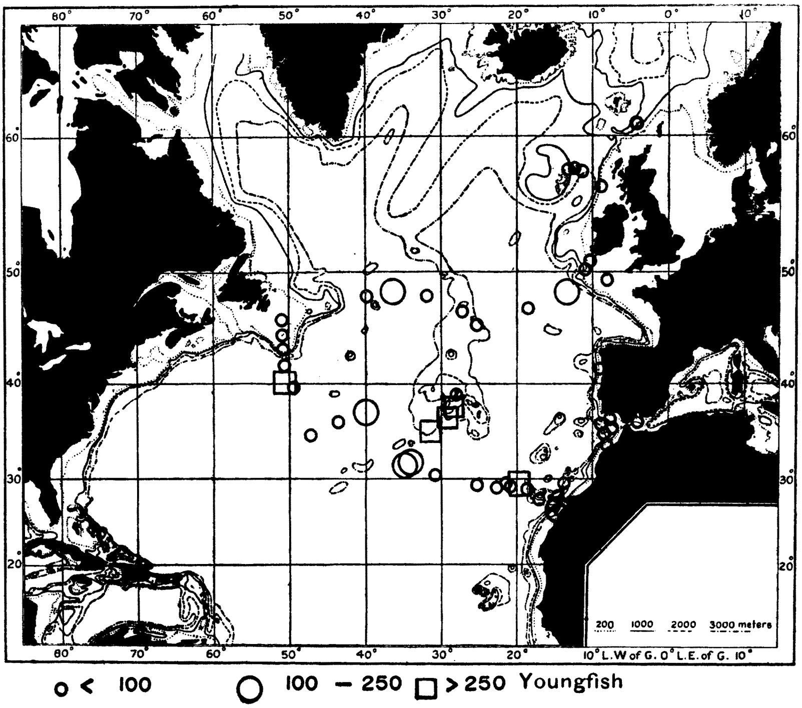


Fig. 26

methods of work adopted by the *Michael Sars* expedition has yielded, and will continue to yield, wider and more reliable information regarding the geographical distribution of pelagic animal life, as well as concerning its biological conditions of existence. However, I feel bound to admit that our expedition was necessarily restricted in its mode of operations. Nor could it well be otherwise. Practical reasons forbade the use of more than a limited number of appliances, and no appliance can be adopted to catch all kinds of animals. If the *Michael Sars* succeeded in securing large quantities of certain forms, its catches of other forms were insignificant. We need unquestionably a new expedition, if we are to acquire more accurate information, especially with regard to the larger forms. It will be necessary, too, to make use of bigger and wider-meshed instruments, though even then I feel convinced that the method we adopted, of making many hauls simultaneously at different depths, will prove to be the most serviceable and the most likely to promote our knowledge of the depths in which the animals are living.

Trawlings.

Brauer has made out a statement of the distribution of the deep-sea fishes along the bottom of the sea, based on the material of the *Valdivia* expedition. He founds his interesting survey chiefly on observations of the distribution of different species of the genus Macrurus, which is generally regarded as a representative of the most typical bottom and deep-sea fish.

Brauer's principal conclusions are as follows: Whereas the genus Macrurus is distributed over all the seas of the world, particular species are very restricted in their areas of distribution. Secondly, not more than a few species are known to be common to several of the great oceans. This is due, in his opinion, to the fact that only a few species are met with far out from the coasts (or more strictly speaking, the slopes of the coast-banks). In any case we do not find the same species existing both in the neighbourhood of the coast banks and out on the deep ocean floors. To this he adds that the young stages of the genus Macrurus do not inhabit surface-layers, or layers whose movements would be likely to distribute them over considerable areas. "The fact remains that up to now no eggs or larvæ of deep-sea Macruridæ have been met with high up in the water." The various species are, therefore, comparatively local and adapted to peculiar conditions in a definitive restricted district.

This interesting view is, however, unsupported by conclusive proofs. We know as yet but little either regarding the propagation of deep-sea fishes, or about the physical conditions under which they live. I have mentioned above that we during our expedition have found various stages of the young of Macrurus in the uppermost 150 metres. Schmidt * has previously described bathypelagic eggs of this genus. Larvæ and young stages of the genus Alepocephalus were taken floating in the deep layers below 500 metres.

The plan I proposed for trawling, in combination with our hydrographical investigations, was to undertake a series of hauls at a number of localities from the coast banks over the slopes, and down to the deep ocean floor. In the twenty-four hauls made by the *Michael Sars* we succeeded in carrying out three such series: one from the south-west coast of Ireland, one in Cadiz Bay, west of Tangier, and one to the south of the Canary islands. We also made a few hauls at great depths in the Bay of Biscay, between the Canary islands and the Azores, and to the north of the Azores.

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* Schmidt, *loc. cit.*

The large mass of material collected is still only partially examined, so that I am obliged to have recourse to the notes made on board at the time. However, these are perhaps sufficient to justify me in mentioning a few particulars, which will give a fairly good idea of some of the results.

For trawling we used a large otter-trawl, of the usual construction, with 50-feet headrope. It took a good deal of practice to lower this large appliance down to great depths, but we succeeded, and made some excellent hauls, which yielded extremely satisfactory catches, especially of fishes; and the material thus collected furnishes a good illustration of the fish fauna, even if nothing essentially new was caught in the way of unknown types.

In the shallower waters—down to a depth of 200 fathoms—the fauna proved for the most part, as was already known, very different in the three series. The following are a few examples from the catches, the list of the names being taken from a preliminary determination on board. In the case of the Sparidæ we were unfortunately not able to determine the specimens on board.

Off the Irish Coast. 100 fathoms.	Bay of Cadiz. 90 fathoms.	West of Africa 26° N. 150 fathoms.
1 Gadus æglefinus.		
8 „ poutassou.		
5 Merluccius vulgaris.	52 Merluccius vulgaris.	10 Merluccius vulgaris.
1 Phycis blennioides.		250 Sparidæ.
40 Gadiculus argenteus.		
3 Solea vulgaris.	1 Solea vulgaris.	Many Centriscus scolapax.
170 Zeugopterus megastoma.	Mullus surmuletus.	1 Mullus surmuletus.
	Centrodontus pagellus.	
	Sparidæ.	
5 Arnoglossus lophotes.		
2 Caranx trachurus.	8 Caranx trachurus.	2 Caranx trachurus.
12 Trigla gurnardus.	2 Trigla gurnardus.	
30 „ cuculus.	16 „ cuculus.	1 Trigla cuculus.
5 Callionymus.	25 „ hirundo.	Many Trigla hirundo.
2 Capros aper.	30 Capros aper.	Few Capros aper.
4 Lophius piscatorius.	4 Zeus faber.	1 Peristedion.
4 Argentina silus.	1 Peristedion.	5 Argentina silus.
8 Acanthias vulgaris.	4 Acanthias vulgaris.	5 Acanthias vulgaris.
5 Scyllium canicula.	4 Scyllium canicula.	1 Scyllium canicula.
25 Raja clavata.	Raja sp.	25 Raja sp.
1 „ circularis.		2 Rhina squatina.
1 „ oxyrhynchus.		

It will be seen from these and other hauls that a number of forms are common to all the series from Ireland down to 26° N. lat., such as, for instance, *Merluccius vulgaris*, *Solea vulgaris*, *Arnoglossus lophotes*, *Caranx trachurus*, *Trigla cuculus*, *Capros aper*, *Argentina silus*, *Acanthias vulgaris*, and *Scyllium canicula*.

The Gadidæ present the most striking difference, being represented by a large number of species off the west of Ireland, but merely by *Merluccius vulgaris* from Cadiz Bay southwards. This last fish is shown by the catches of the trawlers to be still very plentiful along the west coast of North Africa.

The abundance of Sparidæ, Mullidæ and Triglidae, from shallow water down to 150 fathoms, is typical of the southernmost series. These light-red or silvery forms constitute the bulk of the catches made by the fishermen of the Canary islands upon the African coast, and they give the whole fish fauna its distinctive character. During our stay on the African coast we were able to watch the fishermen catching different kinds of Sparidæ, and I have rarely seen a handline-fishing yield such excellent results. I shall describe this subsequently at greater length, when our material has been completely examined.

That the fauna, down to a depth of 200 fathoms, must vary in character in the long stretch of sea from the Wyville-Thomson ridge to the north of Africa, is natural enough. The chart in Fig. 4 shows that salinities and temperatures vary considerably at this depth. South of the Wyville Thomson ridge we have a temperature of 8° C., off the south-west coast of Ireland we get 10° C., in Cadiz Bay over 12° C., and nearly 14° C., southwards of the Canary islands.

At *a depth of* 500 *fathoms* the position of affairs is different. For, as will be seen on the chart (Fig. 2), we get the same temperature of 7°–8° C. immediately south of the Wyville-Thomson ridge that we get to the south of the Canary islands. The Bay of Cadiz alone forms an exception, since the temperature there rises to 10°, owing to the influence of the warm water which streams out from the Mediterranean. In 500 fathoms, accordingly, we find a very uniform fauna. I give below a few instances; the Macruridæ are not yet determined.

South of Ireland. 500 fathoms.	Bay of Cadiz. 700 fathoms.	Africa, 28° N. Lat. 740 fathoms.
24 Coryphænoides.		
160 Macrurus.	11 Macrurus.	Many Macrurus.
16 Trachyrynchus Murrayi.	19 Trachyrynchus Murrayi.	4 Trachyrynchus Murrayi.
31 Lepidion eques.		
70 Mora mora.	36 Mora mora	4 Mora mora.
1 Antimora viola.		
1 Halosaurus.	3 Halosaurus.	
9 Alepocephalus Giardii.	4 Alepocephalus Giardii.	5 Alepocephalus Giardii.
3 Hoplostethus Mediterraneum.		
3 Scorpæna echinata.	1 Bathypterois.	10 Bathypterois.
3 Synaphobranchus.	1 Synaphobranchus.	Many Synaphobranchus.
8 Chimæra mirabilis.		
1 Raja nidrosiensis.		

Although this list must necessarily remain incomplete until all the forms have been fully determined, it illustrates the striking uniformity of the fauna on the slopes of the coast banks from 60° N. lat. right down to 28° N. lat.

Some years ago I made two series of trawlings to the south and north of the ridges which separate the Norwegian sea from the Atlantic, running from Iceland to the Faroes and Shetland. In a review of our fishing investigations * Dr. Appellöf has compared the invertebrate fauna of the two series, and I have treated the fishes. Our research gave the following result: to the south of the ridges we found some species which did not occur to the north of the ridges, *i.e.* in the Norwegian sea. Then we found some which also are distributed in the boreal and boreoarctic areas of the Norwegian sea. This applies to invertebrates as well as to fishes which live in the Norwegian fiords, on the coast banks and the upper part of the slopes towards the deep basin of the Norwegian sea.

In the deepest parts of the Norwegian sea, however, where the temperature is quite low (under 0° C.), there is a fauna of Arctic character, which is entirely lacking in the Atlantic.

The Danish zoologists, Professor Jungersen and Dr. Ad. Jensen, have especially shown this latter fact in all details. The previous investigations of the *Michael Sars* have also contributed towards the knowledge on this subject, and during the Atlantic cruise of 1910 some very successful hauls were made in deep water (1000–600 fathoms), south and north of the Wyville-Thomson ridge. The material obtained confirm our previous experience as to the character of the fauna in the two areas in regard to fishes as well as to invertebrates (*e.g.* echinoderms).

To operate the big trawl at the greatest depths of the North Atlantic, in about 2500 or 3000 fathoms, proved a very difficult task. However, two of our hauls were quite successful. The first was in the Bay of Biscay, at a depth of 2500 fathoms. Our catch contained a number of invertebrates, including holothurians of the genus *Elpidia*, Alcyonidæ, sponges, and ascidians, and two fishes belonging to the genus Macrurus.

The second haul, between the Canary islands and the Azores, at a depth of 3000 fathoms, yielded only a very few living organisms. In the half-barrel of mud brought up by the trawl, we found 30 pumice-stones, overgrown with Stephanocyclis and Limopsis, and there were also two holothurians (*Lœtmogone violacea* and *Elpidia, sp.*), Sertulariæ, fragments of an Umbellularia, an Antipathes, a spike of a Cidaris, fragments of shell of Argonauta, as well as one Bulla tympanica of a whale, and two sharks' teeth, of which the first belonged to a Carcharodon, and the second to an Oxyrhina. Of fishes there were one Malacosteus, one Alepocephalus, one Leptocephalus, one Argyropelecus, and a form not yet determined. All these fishes I believe to have been pelagic, and to have been taken during the process of hauling in. Regarding one form alone there was doubt whether to class it as a bottom fish or as pelagic, namely, an unquestionably new species much resembling *Ipnops Murrayi*.

Judging from the appearance of the trawl when being lowered and when being afterwards hauled in, I consider this haul to have been, technically speaking, a success, and I cannot explain the catch otherwise than

* Norsk Havfiske, *Norges Fiskerier*, I. Bergen: 1905.

by supposing that *at those profound depths there was a poverty of animal life.* It remains a question whether all these great ocean floors are equally barren in regard to animals, and especially fishes. So far as I know the literature on the subject only records the capture of a few Macruridæ from the greatest ocean deeps, this being all the evidence that there is to favour belief in the occurrence of larger fish there. But is it perfectly certain that even those are not also pelagic? On several occasions during the cruise our tow-nets captured over the greatest ocean depths pelagic specimens of Alepocephalus, which is generally brought up by the trawl (see the catches from 500 fathoms). In any case the animal life there must be extremely scanty. And this is borne out by the vertical hauls with our big net, below 1500 metres, which I have referred to when discussing *Cyclothone microdon.*

The few instances from our trawliugs that I have given here are perhaps insufficient for a complete illustration. A fuller examination of the material will certainly reveal more. But what I have said in this and the preceding sections of my lecture will, at any rate, make clear to you the aims and method peculiar to this expedition, and will, I hope, be of value for planning further investigations in the interesting marine area which formed our field of operations.

The PRESIDENT (before the paper): In the announcement of the lecture to-night two names appear, those of Sir John Murray and of Dr. Hjort; but the lion's share of the lecture will, as I understand, in truth, fall to our distinguished foreign guest, Dr. Hjort. In his discourse he will describe the oceanographic researches which have been made on board the steamer *Michael Sars*, a steamer which was built by the Norwegian Government especially for this class of scientific work. Dr. Hjort is amply qualified to speak on all the subjects he will touch on to-night. He was for some years a lecturer in Zoology in Christiania. Since the year 1893, he has been engaged in fishery investigations, and since 1900 he has been the Government Fishery Director for Norway and in command of this *Michael Sars* steamer—a steamer which has been employed frequently in the North Sea and in the eastern parts of the Atlantic. The record of the work done is one of which he may well be proud. As to the other name, that of Sir John Murray, I think Dr. Hjort will tell us all about his connection with this expedition, and I will at once, therefore, call on the lecturer to address us.

Sir JOHN MURRAY (after the paper): Some ten or twelve years ago, Dr, Hjort did me the honour to say that he was a pupil of mine, but during the last eighteen months I think I can pretty well say I have been a pupil of Dr. Hjort's. We have often discussed together the problems of the deep sea, and owing to the interest which the Norwegian Government takes in deep-sea investigation, we were able to plan this little cruise during 1910. From what Dr. Hjort has told us, I think you will be convinced that an advance has been made in the methods of deep-sea study. During the last ten years in the International Fisheries investigation, Dr. Hjort, amongst others, had made very great advances in the study of the economic fishes, that is to say, as to where they lay their eggs, where the larvæ are found, and what the rings on scales and ear-bones mean. The methods of taking temperatures, the water-bottles, current meters, and light investigations have all been improved. It was desirable to see how