The Fauna of the Sea-Bottom.¹

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STUDIES of the fauna of the sea-bottom are of essential zoological significance, and many scientific questions as well as important fishery interests depend upon them. The subject, however, is so extensive that I must confine myself mainly to the different methods adopted for the investigation of the fauna of the sea-bottom.

Since 1883 I have investigated Danish waters by means of the dredge; it was my task then to give on charts the distribution, especially in the Kattegat, of every single species of marine animal, to understand the laws ruling the distribution of the animals on the sea-bottom (the cruises of the gunboat *Hauch*). Different specialists had each a group of animals to work out, and a great number of charts were printed, but I did not feel quite content with my first publication, although something was cleared off by that method. The method was, and is still, the usual one for such investigations.

Many years later the question was put before me: Why does the plaice in the western Limfjord grow very slowly, but very quickly in the middle of the Limfjord? The answer required first of all a quantitative investigation of the amount of plaice-food in both places. A small bottom-sampler on a pole, long enough to reach the bottom in the shallow fjord was made in the 'nineties of last century and proved that much food was to be found in both places; the difference in growth-rate of the plaice was found later on to depend not only upon the amount of food on the bottom, but also upon the different number of plaice living there on each square mile. The idea of overcrowding for sea-fishes was introduced for the first time.

Many years later I constructed a new bottom-sampler fastened to a wire; this I have used everywhere in Scandinavian waters down to a depth of 300 fathoms. It was my idea at first to compare the amount of fish-food per sq. metre in the Limfjord with the amount of fish-food per sq. metre in our remaining waters by means of the bottom-sampler; but I soon found it difficult to compare the animals from one water with those of another; in some places the animals were small and of great value for fishes, in others the animals were bigger and built up of carbonate of lime (chalk) mainly, and with a great content of water; chalk and water being of course of little importance as food in the sea for other animals, I realised that I should compare, first of all, the amount of food in places with the same kind of animal population, and I had to map out these places.

The bottom-sampler taught me that we have about eight such different animal communities in Danish waters from 0 to 300 fathoms, characterised by numerous large and characteristic animals. They may be echinoderms, bivalves, crustacea, etc., but are all animals living mainly on detritus, not rapacious animals. These last named are necessarily always scarcer than the more peacefully living animals, as the grass-feeding animals on the dry land are more common than tigers and lions.

One thing puzzled me in the beginning very much; the bottom-sampler showed in many hauls the most uniform content in the sieves in the same animal community, then suddenly it came up filled with quite different animals, *Modiola modiolus*, *Trophonia*, *Ophiopholis aculeata*, etc., without any corresponding difference in the depth or in the nature of the bottom. How is this to be explained?

All these new organisms were animals living not in the bottom like ordinary animals, but above the bottom, originally fixed to a small stone or a shell, as on a heath we may find lichens on stones, not heather, or as in a beech-wood, on stones we find mosses, not flowers; strong currents may help to nourish such an *epi-fauna* with its often enormously rich animal life. Every object on the sea-bottom, a stone, a shell, a wreck, living plants, may give rise to such epi-faunas; within the same community on the level sea-bottom there is the same epi-fauna, but in different communities different epi-faunas may be found. The epi-fauna is, as a rule, scattered over the bottom in spots, and it is not always easy, in single cases, to say what is the reason for its existence; it is therefore not possible to give its distribution on a chart; you may give it on the spots where you have found it, but you never will be able to give all the spots existing on the bottom. On rocky coasts the epi-faunas are dominating; the coral reefs are a kind of epi-fauna, built up mainly of chalk and water; they are of very little importance as fish-food.

In contradistinction to the distribution of the epi-faunas the communities of the level sea-bottom are of a very uniform distribution, in such localities as in Danish waters and in the North Sea. Their distribution may be easily mapped out, and their content of fish-food and other animals quantitatively determined. We have taken thousands of samples, each of $\frac{1}{16}$ sq. metre, with the bottom-sampler in Denmark, and they have nearly always shown several animals, worms, bivalves, Ophiuridæ, etc., in each; only one or two samples of them have shown no animal content.

By means of the bottom-sampler we may, therefore, using the most frequently occurring organisms, easily map out the communities of the level sea-bottom, and determine its content of fish-food.

The theory of probability will indicate the degree of accuracy; many samples will give, as a rule, more and more exactitude. We may determine how the number of organisms varies at different seasons and in different years. If we examine what the fishes eat of these organisms we may determine whether they are good or bad areas for this or that species of fish, and may get a fair idea of the productivity of the sea-bottom as a whole, not forgetting that all the small, fast-growing, short-living animals are often to be reckoned as yearly production, whereas the bigger, longer living animals must be reckoned by means of another method. We may get an idea of the whole metabolism of the sea—but I must not go too far in mentioning these problems.

With a good steamer I could in one month map out the whole of the North Sea as to its animal communities. I would take between 500 and 1000 samples spread over the whole of the North Sea, out to the 100-fathom line, about one or two per hour. Using a bottom-sampler of 0.2 sq. m. I should then have taken up only the animals of an area at 100-200 sq. m., but I am sure that I should get all the species of the common uniformly-distributed animals of the whole area, and I should be able to give a rough-sketch map of the animal communities. If we used a bottom-sampler on a heath only once, we should catch heather, and so in the sea, I should not catch many rare animals, but I do not care for rare animals; the main thing is to know the animals that make up the great bulk of the bottom population, to know their distribution and their weight per square mile. If you wish for greater exactitude than

¹ Opening of a discussion held in Section D (Zoology) of the British Association at Hull on Sept. 7.

this first trip could give, you may take more stations and investigate smaller areas more carefully.

I am glad to be able to say that in 1921 Dr. Russell, on the English steamer *John Bligh*, made the first trip across the North Sea with my bottom-sampler, guided by my assistant, Dr. H. Blegvad; they found some of the same communities between Lowestoft and Esbjerg as we know from the Kattegat.

Thanks to the bottom-sampler we can now speak about areas with a *Venus* mussel community, an *Amphiura filiformis* community, a *Brissopsis Amphiura chiajei* community, and so on, as we on land speak about a heath, a beech-wood, a meadow, etc.; we are also able to get a quantitative idea of the amount of animals on the sea-bottom, and are able to follow seasonal or other variations therein.

A dredge will sometimes give us, when well used, a bagful of animals, belonging to the epi-fauna as well as to the ordinary communities, and taken up from all the communities it has been towed over. The dredge is inclined, moreover, to take all animals *on*, not *in*, the bottom, and its content is therefore not a true illustration of what is living *in* or *on* the bottom, but a mixture mostly of epi-fauna from different communities, without giving the slightest idea of quantity per square metre. The content of a dredge and a bottom-sampler used on the same station will very often give quite different collections of animals.

The dredge has given excellent information to zoologists wishing to collect rare animals for preservation in alcohol, and for dredging oysters, and so on, but a true illustration of the fauna on the sea bottom it never has given and never will give.

I admit one thing: it is easy for me to speak and write about the bottom-sampler work, but it never will be well understood without seeing the work going on on board ship; many men of science from Europe have seen how quickly the sampler may be used, like an ordinary sounding machine, and how well it works. I should be glad to welcome many more visitors at the Danish Biological Station, not only to see the bottom-sampler working, but also to be able to discuss with them the problems which have arisen in my mind while using this method during the last 10 to 12 years.

It was a Dane, O. Fr. Müller, who first introduced

the dredge in northern Europe for scientific use, and it will always be used by zoologists and for special purposes, but only the bottom-sampler is able to give a true and quantitative representative illustration of the bottom fauna.

Finally, I wish to say that to have a bottom-sampler and to use it is not enough to become a great marine biologist; it depends much upon the possession of working ideas. The bottom-sampler is not able to solve every question; it cannot, *e.g.*, take animals living very deep in a hard bottom, and the apparatus must be modified for special work, according to the size of the ship used, the depth at which you are working, etc., and it is necessary to supplement the investigation by means of other apparatus, fishing-gear, dredges, etc. But without quantitative work it is not possible to understand the principal features of the fauna of the sea-bottom.

It would be a matter of great scientific interest to have a bottom-sampler used down the slope of the continent at all depths, out on the very ocean floor, to determine all the communities living here, and to prove how barren the ocean floor really is. It would also be of great interest to follow our European communities from the North Pole down to Cape Town, to study their geographical distribution, to determine the perfectly unknown Arctic communities, and the unknown tropical communities. I have given a hypothetical chart in my Report No. 22, but it has to be verified. I am too old to do that, and my steamer too small. I hope other men will do it. I am sure the geologists would be glad to know something about these communities, based upon the common animals. I am certain that, like me, they care much more for common characteristic species and their distribution than for "rare" animals.

The productivity of the bottom fauna in European waters is by no means unlimited; it is, therefore, a matter of the greatest importance for some of the greatest fishery questions to know as much as possible about this productivity. The English fishermen are, as I often have heard, the backbone of the English navy; they depend upon the fishes, and these in turn depend upon the fish-food. Careful investigation of the latter is, therefore, a matter of great importance—particularly for Great Britain.

Adhesives.

By EMIL HATSCHEK.

THE treatise of Theophilus Presbyter, entitled "Diversarum Artium Schedula," and well known to all students of the history of painting, gives directions for the preparation and use of glues from leather and deers' antlers, of plum- and cherry-gums, and of mixtures of cheese and lime described as "cheese glues." This list of adhesives familiar to craftsmen at the end of the eleventh century covers practically all the types in use at the beginning of the twentieth century. A similar degree of old empirical perfection is shown by many arts employing colloidal material, and the student of colloid chemistry anxious to magnify his office is perpetually confronted with the task of explaining the *rationale* of traditional procedure and of suggesting improvements based on theoretical grounds.

The difficulties of this task are well illustrated by the first report of the Adhesives Research Committee.¹ Towards the end of the war a shortage of glue and of the chief substitute, casein, threatened to limit the output of aircraft, and the labours of the committee

were accordingly directed, on one hand, to a close study of glue, and, on the other, to the discovery of possible substitutes other than casein. The report contains much interesting and novel matter under both heads.

The difficulties in the way of a rational study of glue seem to be twofold. The first is that the only criterion of its value as adhesive is a mechanical test of a glued joint between wooden test pieces of specified nature and size. The report describes the conditions of such a test, as finally adopted, and sets forth the possible sources of error. Both on theoretical and on practical grounds (about five days have to elapse from the soaking of the glue to the actual breaking test), it is desirable to find some easily measured constant which shows a simple quantitative relation with the breaking strength. No such constant is yet known, although empirically the setting time of the glue sol, the melting point of the gel and its "strength," *i.e.* roughly speaking, its modulus of elasticity, furnish some indication of its quality.

The second difficulty is of a more fundamental nature. It is known that pure gelatin is not a good

¹ Department of Scientific and Industrial Research. "First Report of the Adhesives Research Committee," pp. iv + 129. Price 4s.