SCIENCE AND
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See page 20 onwards

BY

A. C. HARDY.

Hull
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1930.

PRICE SIXPENCE.

SCIENCE AND THE FISHING INDUSTRY

BEING A CIVIC WEEK LECTURE DELIVERED AT THE UNIVERSITY COLLEGE, HULL, ON OCTOBER 16th, 1929.

BY

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SCIENCE AND THE FISHING INDUSTRY

ALL will agree that no apology is needed for including a lecture relating to the fishing industry among those given at this University College of Hull during Civic Week. It is said that at least one in five of the population of Hull is concerned either directly or indirectly with fish.*

You will not expect me to give you a history of your own industry; it would be impertinent for me to attempt to do so, when there are so many in Hull who can tell it from the inside, and some here to-night who have helped to make and are making that history. You will want rather to hear from me, as a student of marine biology, something of the relation of that science to your work. You will expect some answers to the questions often put: what has science done for the Trade?—what can it do?

I am particularly glad of the opportunity for speaking upon this subject this week, the first week after the College has been officially opened, because we want in our biological research departments here to specialize upon the study of marine life. There is no other University or University College that is so well placed, or, indeed, can be so well placed, in relation to the fishing industry as this. This is no brag; it is a measure of our responsibility. We have upon our arms the lily of Lincolnshire as well as the white rose of York; the two great Humber ports of Great Grimsby and Kingston upon Hull

* *Hull and the Fishing Industry*, by T. Sheppard, Hull Museum Publications, No. 153, page 7.

form together the most important fishing centre in the whole world. We hope that in our efforts we may have the interest, sympathy, and support of both communities.

There is an old sea chanty which has been sung by the herring fisherman of Yarmouth for centuries. It runs like this :—

The farmer has his rent to pay ;
    Haul, you Joskins, haul !
And seed to buy, I've heard him say ;
    Haul, you Joskins, haul !
But we who plough the North Sea deep,
Though never sowing, always reap
The harvest that to all is free ;
And Gorleston Light is home to me.
    Haul, you Joskins, haul !

One great difference between the harvest of the sea and that of the land is that whereas on the land we can see the whole process : the plant springing from the seed in the soil, growing under the influence of sun and rain to produce the ripe grain, or the sheep and cattle feeding on the grass and growing to maturity ; in the sea all is hidden from us. We see the great expanse of the grey North Sea, and out of it, drawn up in the nets, come the millions and millions of fish. Everything that we must find out about the lives of these fish and the conditions under which they grow and multiply must be groped and delved for below this opaque and at times, none too smooth surface.

The science of the sea is comparatively young; only half a century ago its foundations were laid by the great Challenger Expedition. Before this time it was generally thought that life could not exist at a depth greater than two or at most three hundred fathoms. In 1868 Thompson and Carpenter dredged down to 650 fathoms and revealed a new world of life on the sea floor. Subsequently the Challenger Expedition showed that life existed in even the greatest depths. This was remarkable; but still more remarkable was the discovery made somewhat earlier by Johannes Müller by the simple process of towing a conical net of fine mesh muslin or silk through the upper layers of the water. He discovered that the sea teemed with minute forms of life, both animals and plants, invisible to the naked eye. Other naturalists followed him, and in 1887, Hensen, a German, who made a special study of this kind of life, introduced the term *plankton*, to distinguish all these organisms which are passively drifted by the ocean currents, winds, and tides from those larger swimming creatures of the sea—the fish and whales—which can actively migrate against them. To understand the life of fish, it is necessary to realise the important part played by this plankton in the economy of the sea. A fantastic illustration will, I think, help us to realise it. Let us imagine for a moment that the herring is not a fish, but a land animal. We know that some three thousand million herring are landed every year at ports in the British Isles. These, together with those landed in other countries, must only be a fraction of the total in the sea. We know that all animal life is dependent either directly or indirectly upon plant life: one animal may eat another, and that one another—but, ultimately, the nutritive chain must end in the plant which takes its energy from the sun. For simplicity's sake let us imagine these herrings feeding directly upon plants, and let us imagine them in their unnumbered millions sweeping across the continent. If we do this it needs no imagination to see that the countryside would be stripped of vegetation as if by locusts. Where then, we will ask ourselves, is the plant life in the sea, to feed not only these herrings, but all the other fish and the teeming crawling invertebrate life of the sea bottom? The seaweeds will not suffice, for they form but a fringe in the shallow waters of the coast. The townet—the little net of fine mesh silk—has given us the answer: it is in the plankton.

Let us consider the economy of the sea in its simplest form. We have the sun shining down, its rays penetrating the upper layers of the water; we have the gases, oxygen and carbon di-oxide, dissolved into it from the atmosphere; and we have mineral salts, continually being brought in by the erosion of the land, scattered through its volume. These are ideal conditions for plant growth. Just as these conditions are spread through the water, so is the plant life, scattered as a fine aquatic dust of microscopic plants in untold billions. Under every square foot of ocean, as the late Sir William Herdman has said, there are more of these specks of plant life than there are stars visible in the heavens. Upon these plants feed a vast population of minute animals, plankton animals—for the most part little shrimp-like forms. Upon these animals many fish—such as the herring, pilchard, sprat and mackerel—feed directly, and, curiously enough, so do the greatest mammals of the world, the rorqual whales, which form the object of such a prosperous fishery in the far South. Now from this welter of microscopic planktonic life there falls a never ceasing rain of dead and dying material to the sea bed, and here we find "forests," not of seaweeds, but of animals which look like plants, rooted to the bottom and stretching out their branch-like "arms," umbrella fashion, to catch this rain of food. Or we find shellfish with remarkable mechanisms for trapping this finely scattered diet. Upon these feed the crawling forms of life, and upon these, and the shellfish, feed bottom-living fishes—and again, other fish on them. Then comes man, catching the herring and mackerel with miles of drifting net, shooting the great whales with explosive harpoons, and sweeping the sea bottom with his trawl. From the North Sea alone over a million tons of fish are taken every year. Over vast stretches of the North Sea every square foot is, on an average, trawled over two or three times a year.

It is not surprising that man is at last beginning to study the factors underlying this great production of wealth and food. The beginning of this century saw the formation of the International Council for the Exploration of the Sea, the different nations of Europe each undertaking a series of investigations to form part of one great plan. Not only are they inquiring into the life of the fish themselves—their life history, food and feeding habits, migrations, age, growth, fecundity, etc.—but with continually improving oceanographical equipment into the distribution of the different plankton forms and the conditions under which they live, the movement of water masses, the chemistry of the sea, the nature and animal life of the sea bottom. The different nations have their research vessels; for example, the Ministry of Agriculture and Fisheries own the Research Trawler *George Bligh*, and the Scottish Fishery Board the *Explorer*.

Let us consider some of the activities of these research workers and see the bearing of their work upon the Fishing Industry. Let us begin with the background to the picture, the movement and the nature of the water itself, and then deal with the life that is in it. The problems of the background may seem remote from the centre of attention, the actual catching of fish; but I hope to show how they are vitally connected with this operation.

We want to know at what speeds and in what directions the waters of the seas are moving. We know that cocoanuts falling from the trees on Pacific islands drift far across the ocean and fetch up upon some distant shore. Some of the first experiments in charting the currents of the sea were made with numbered cocoanuts. Then science seized upon that more romantic object, the floating bottle with the sailor's message home. Thousands and thousands of such bottles, each carrying a letter of instructions printed in the different languages of Europe and a post card for the return of a description of its finding, have been dropped into the sea at hundreds of different points; and thousands of them have been returned. The bottles used are of two kinds, those which float at the surface and those which, furnished with a long trailing wire, drift along a few feet from the sea bottom. The former are recovered from some distant shore, the latter are trawled up by fishermen and returned with the date and position of capture. So, laboriously, have the movements of the North Sea been accurately charted for different times of the year. We see a great influx of water from the Atlantic sweeping down the north-east coast of these islands, and curving round in the southern part of the North Sea as it meets a smaller influx coming from the west through the English Channel. The speed of these currents may be affected by weather conditions, a wind up or down Channel speeding up and slowing down the current respectively. But do such things as wind affect our fisheries? Yes: this speeding up or retarding of the moving water, if it carries the floating eggs of fish or their newly hatched young, may possibly have its effect upon the number reaching their normal destination.

How do we know the exact speed of these water movements? Several ingenious machines—current metres—have been designed, which will record the exact speed and direction of water movements at any particular place. A knowledge of the composition of the sea water, its varying saltness in different places, and the altering proportions of the different kinds of salts throughout the year, is of great importance in understanding the production and distribution of fish food, and even of the fish themselves. We obtain such information by taking samples from a large number of positions on definite lines across the area concerned. The samples are taken in specially constructed bottles which, being insulated, fitted with thermometers and closed at will, record the temperature of the water at any depth. From a vast number of such chemical observations in a given area, by a process that remains to me a mathematical miracle, the details in the patterns formed by the curving water masses can be theoretically calculated. Science is building up a very complete picture of this physical background, a knowledge which, as we shall presently see, is all important to the understanding of the life scattered through it.

I have already stressed the importance of the plankton; through it, as we have seen, the fish are linked by nutritive chains to this physical and chemical background. The distribution of the different kinds of minute drifting animals and plants, in different parts of the sea and at different seasons, is studied by taking samples with fine silk nets and examining them under the microscope. Let me take an instance from work upon which, with others, I have recently been engaged. The Discovery Expedition, under the leadership of Dr. Stanley Kemp, has been and still is investigating the biology of the whales, which form the object, as I have said, of such a great fishing in the Antarctic seas. It is trying to find out all it can about these animals—their habits and the conditions under which they live—so that sound scientific data will be to hand when the time comes for the regulation of the industry; and at the rate at which they are now being killed, some 20,000 a year in the Antarctic, who can doubt that this time is close upon us? The work falls naturally into two categories—that upon the whales themselves, and that upon their environment, their food and the conditions underlying its supply. The former was carried out by research workers at the whaling stations, and their work, which is to be published shortly, has gone far to provide the answers to the hitherto unanswered questions regarding their rate of growth, age of maturity, breeding seasons, period of gestation, number of young, length of suckling period, and so on: all essential points in the framing of regulations. The latter, that is work on the environment, had to be carried out from ships traversing the ocean. The *Discovery,* originally built for Captain Scott, was fully re-equipped for this oceanic work, and was joined later by a small fast full-powered vessel of the whale-catcher type, the *William Scoresby*, built at Beverley and equipped at Hull. (Her name is also of local interest, for she is named after William Scoresby, the younger—the greatest whaling captain England has ever had, a Yorkshireman, a native of Whitby, who lived a hundred years ago when Yorkshire, and particularly Hull, was one of the great centres of the whaling industry. Not only was he a most successful whaling captain, but he was a scientist, elected a Fellow of the Royal Society, and the father of whaling research.) These two ships, the *Discovery* and the *William Scoresby*, investigated among many other problems the distribution of the food of these great whales. Their food is a plankton organism—a member of this drifting life—a small shrimp-like animal. The whale, when feeding, takes great gulps of water and passes it through a sieve-like apparatus in the mouth, the so called whale-bone or baleen plates which hang, fringed with interlacing " fibres," from the upper jaw. It was important to find out if this food was distributed widely over the Southern Ocean, or only concentrated in certain localities. Some whalers have said, " What does it matter how many whales we kill in the region of South Georgia and the South Shetlands, when these are such small areas compared with the great expanse of the Southern Ocean ? " By crossing and recrossing the ocean several times, and taking samples of the plankton at a number of different points along each route, we have been able to show that the regions of available food are strictly limited. By making more intensive investigations in these particular regions we have come nearer to understanding the causes underlying the production of this food in these places.

Work is still being continued on the material we brought back, partly at this new University College—and as this is Civic Week in Hull I think you will feel with me a certain pride that the first biological research work to be done here should be in connection with the whaling industry, a great industry which died in Hull through lack of scientific regulation. I will return to the importance of plankton reseach, particularly in relation to North Sea fish, towards the end of my lecture, but let me say here that I believe from the study of the plankton we can make great steps forward toward the solution of fishery problems.

Let us now take the work done upon the fish themselves. Let us consider as an example the Plaice. Like nearly all other sea fish, the herring being the only important exception, the Plaice lays floating eggs. Its eggs drift, like the plankton animals, in the currents of the sea. The discovery of this fact was one of the first gifts of economic importance to be made by science to the industry, though now it is almost forgotten. When the trawl was first being used in the North Sea great was the outcry. "The trawl is destroying the spawn on the sea bottom: forbid its use by law," people cried. There was a Royal Commission. In the meantime the fine silk net and the microscope told the trade that these fears were without foundation, and so the development of the trawl went on. If this fact had not yet been discovered, would not the present shortage of fish have been attributed in part to the destruction of spawn by the trawl? The trawl might have been limited in size by law.

The Plaice lays its eggs in the Southern Bight of the North Sea; and after being so laid they are carried along in the current flowing from the Straits of Dover towards the Dutch coast. As they are carried they develop. We can see the little growing fish curved round its supply of yolk in its small transparent globe; and eventually, still floating in an easterly direction, it hatches out. At first it is a minute fish, one-quarter of an inch in length, transparent except for its jet black eyes, and still carrying on its underside a sac of yolk, which gives it food in its first few days of free life. But this yolk is gradually used up, and the little fish has to open its mouth and feed. It starts feeding upon the minute specks of plant life in the plankton. Continually drifting eastwards it reaches the shallow water of the Dutch coast, growing all the time; and here it leaves the plankton and settles down on the sea bottom. Its eyes move round to the right; it swims no longer in an upright position; it becomes a little flat fish, swimming along the surface of the sea bed on its side. How do we know all this about the distribution of the eggs and their movement towards the Dutch coast? By travelling backwards and forwards across the North Sea in a research ship, stopping at intervals, and taking exactly similar hauls with a standard type of net, we can estimate the different quantities of eggs per unit volume of sea in different parts. By doing this at different times of the year, and repeating it in several years, the complete picture has been filled in. Not only have we the evidence from the different stages of developing eggs and growing fish caught in these standard nets; but by liberating a vast number of drift bottles in the area where the eggs are laid, and afterwards finding them only on the coasts of Holland and Denmark, we know surely that the currents are carrying these glass-like floating eggs even as they carry the bottles. Indeed, what are these floating eggs but "sailors' bottles," containing not messages but babies, cast into the sea by their mothers in millions, in the "hope" that some will be carried "home" to the nurseries, and that of these a few will reach maturity? The Plaice lays three hundred thousand eggs, the Turbot up to nine million in one season.

We can now watch the young Plaice grow, can measure the growth year by year, and see the fish as they get older and older move out into the deeper and deeper water away from the shallow coastal waters. This growth is studied, not in the artificial conditions of an aquarium, but in the fishes' natural home, the sea. We can tell the age of a Plaice, as of many other fish, by the rings which appear in the little ear bones, the so-called otoliths, like the annual rings seen in the trunk of a tree when it is sawn across. Each ring represents a year. But how can we measure the rate of growth of actual fish? This is done by "marking", by catching a fish and attaching to it by silver wire a little numbered button and then letting it go again. A reward is offered for its return when recaught. The amount it has grown in the interval is measured. Thousands and thousands of such fish have been marked, and hundreds returned. So we can compare the rate of growth in different areas; so, too—and this is most important—we can work out the migrations of the Plaice. We can see how far and in what direction a fish has travelled in the interval between being marked and recaught. Thus we can complete the story of the life history of the Plaice, for we can trace a definite migration of fish to the spawning area, which was discovered, as we have just seen, by the study of the distribution of the eggs. It all fits together: it is a complete story. This work was inaugurated at Lowestoft by Professor Garstang, now of Leeds University, and has been carried on since by a number of workers.

The food of the Plaice has been studied in great detail. So has the animal life on the sea bottom been studied and charted, also the nature of the sea bottom itself. By means of a special instrument—a grab invented by Dr. Petersen, a Dane—we can measure the exact quantity of animal food per unit area of sea floor in different parts. These grabs are now made by the celebrated firm of grab manufacturers—Messrs. Priestman Bros., in this city of Hull. So the amount of suitable food available for Plaice in many different parts of the sea has been estimated. This has led to one of the most interesting practical experiments of marine research, that of transplantation. We have seen that nature carries the young Plaice on to the Dutch coast: they are borne thither at the mercy of the currents. If only these currents could be made to flow towards the Dogger Bank the young Plaice would find a richer feeding ground and more room to develop; but we may as well try to make a river run up a mountain as alter the path of an ocean current. However by steamship we can carry the young fish, in large numbers, from the crowded regions of the coast to the promised land of plenty. This has been done, and by marking the young fish liberated on the Dogger Bank, we have seen that their growth is as much as twice or three times as great as that of their brothers left behind. These results are obtained not from a few marked fish, but from hundreds and hundreds. Here a practical way has been shown by which we can increase the wealth of the sea. A few journeys each year with ships provided with suitable tanks would convey many millions of young fish to regions of greater growth. When the North Sea is properly farmed this will be done, but at present the organisation of the industry will not allow of it. A few would pay for the experiment, all would benefit: it is therefore not yet economically possible.

More recent work upon the Plaice consists in studying the proportions of the different age-groups in different stocks of fish. Thus, to take an imaginary case, we may say of a certain stock that there are 10 per cent. of the fish one year old, 30 per cent. two years old, 40 per cent. three years old, 10 per cent. four years old, 7 per cent. five years old, and 3 per cent. six years old. As time goes on, year after year, we can see these figures changing; a certain year-class, *i.e.*, those fish born in one particular year, will occupy a greater proportion of the stock than other year-classes have done. It has been a more successful year-class. From the study of these developing year-classes, good and bad, we shall be able to foretell to some extent the quantity and quality of future stocks of fish.

I have taken the work done upon one fish and followed it out in some detail. I have taken the Plaice partly because perhaps more work has been done upon this fish than upon any other, although similar work is being done upon many other fish, such as the Cod, the Haddock and the Herring. The trade may tell me at Hull they are not so much interested in Plaice, for the catch of Plaice in the North Sea has fallen off so much that they fish elsewhere. This fall is a very real one. We saw the catch gradually falling away before the war; then came the interesting experiment of forced closure during the war producing its recovery of catch upon renewed fishing, to be followed by a rapid fall again. I know that the interest of the trade centres more and more in the wider areas to the North, that they think more of Cod, Haddock and Halibut; and news has come only recently of a new fishing ground in the region of Bear Island in the Arctic. But I chose the Plaice particularly, not only because more work has been done on it, but also because it gives us a warning. The trawlable areas of the North are limited; at present we are still expanding, but these limits must in time be reached. With increased intensity of fishing the same story of decline must follow with other fish on a larger scale. I have little doubt that the future will see huge floating factories adding to this intensity. Some in the industry may say, "But what can science do? Scientists have been for twenty years working on the Plaice, and the only practical suggestion is that of transplantation, which, in our present organisation, we cannot economically carry out." They may also say with justification that scientists are still arguing over the question of overcrowding and growth rate, and are not agreed as to whether certain areas should be closed or not. This is true; but more work is being done on this problem, and the correct answer must soon come.

In reply to the question, "What can science do ?" I would ask, "How can the Trade expect a small group of scientists to give them the answers quick enough when, with its complexity and magnitude, the problem is so great ?" But it is not hopelessly great. I will put it in another way. The value of the fish landed each year in Great Britain is in the region of £20,000,000—or about £14,000,000 for England and Wales. Last year between £6,000,000 and £7,000,000 of this passed through the gates of the Humber. The Government are at the most spending a few thousands on research * and they dare not spend more. Many taxpayers, as it is, protest loudly. As far as I know, the trade pays but a few hundred pounds to research institutions, more as a kind of charity than as an economic outlay—·oox per cent. Of course, I do not think that this £20,000,000 is all profit, but there must be a million or so of dividends. Is it economical to be taking all this wealth from the sea without paying something to safeguard the future ? Surely research should be carried on upon a scale bearing a reasonable relation to the magnitude of the industry. I do not believe that science can be of great benefit to the industry until it is supported, not as a charity, but as an economic investment.

> But we who plough the North Sea deep,
> Though never sowing, always reap
> The harvest that to all is free.

So runs the old chanty, but to-day, if we are to reap to the fullest extent, we must sow the seeds of a fuller knowledge. A time of depression in the trade —in this city—must come surely if steps are not taken towards a scientific working of the industry in the future.

* Since this lecture was given, the Government has decided to equip a ship for work in the north ; but this ship will, I understand, be more concerned with surveying new fishing grounds than with biological research.

Scientists who devote themselves either freely or as Government servants to fishery research, sometimes feel that their work is not appreciated by the trade, or at least by some members of the trade, as fully as they might reasonably expect. Perhaps, having been a Government scientist myself, I ought not to say what I am going to say; but, because of criticisms sometimes heard I must: I think they are doing wonderful work. They are patiently piecing bits of the story together, building a steady structure, brick by brick, for the sake of the future. There are only a few of these workers, and they want more support, more encouragement. There should be more of them. These bits of the story are not easy to pick up in the North Sea, especially in winter, and the disappointments are many. We must remember too that to benefit the industry is not the only function of a Government Department: it has to think of the future of the country as a whole, and it is proper that much of its work should be the accumulation of knowledge, which can be of no *immediate* financial benefit to the trade, and which may even form the basis of future legislation to curtail the activities of the industry in some direction for a time, if needs be, for the sake of the future supply. This disregard of some members of the trade for research is one side of the problem of the relation of science to the industry, but there is another of which I am only too well aware. The results of these researches are published in blue books, often quite unreadable by the layman. We scientists usually write for our colleagues who are working on similar problems, often working in other countries, and we write in a jargon of our own, often with a welter of statistics. Some of the plankton papers published look more like fantastic railway guides than accounts of life in the sea; and even scientists have been known to sigh as they turn their pages. How can we expect the trade to understand and sympathise? I think it would be a great service if the Government or the trade employed a trained person to summarise these papers in plain English. Again, and this is happily becoming more commonly the case, the scientist and the trade should come together. They both have their contributions to make to the sum of the knowledge of the sea. The fisherman with his life-long experience has much to tell the scientist.

What is the *problem* of which I speak so airily? And how can its solution help the industry?

The problem is the sum of a great many problems, some of which have already been solved. Its complete solution we can never hope for, any more than we can hope for complete knowledge about any part of the universe; but we may hope, nay, be certain, that with sufficient work we can gain a knowledge complete enough to form a framework to be of service, just as our knowledge of the weather is now complete enough to be of service to aerial navigation. The *problem* is the piecing together of the many facts and factors, some known, many yet unknown, that will give us a fairly complete picture, at first only in broad outline, of what is going on below the surface of the sea; so that from our knowledge of this picture we can tell the industry why fish turn up in some places one year and not the next, why there are more fish here and fewer there, why fish are bigger or smaller than they used to be; moreover, where fish *will* turn up later in the season, and what must be done to preserve this and that stock of fish. The problem is to see the thing as a whole—to piece together the jigsaw puzzle. We must be content first of all to solve a puzzle of only a few big pieces; then as we get more and more knowledge we can attempt puzzles of smaller and smaller pieces. We must look at the thing broadly. We must not concentrate too much upon the figures of the foreground until we have a good deal of the background filled in, and the figures in the foreground are the fish. Already a great deal, as I have said, has been learned about the physical and chemical background; much less is known about that living background, the plankton. And I want now to plead for more and more work to be done on this. This microscopic drifting life must seem to those unacquainted with it far removed from the money made on the fish market, yet I believe, and hope to convince you, that it is closely connected with it. Indeed I believe that greater immediate returns in £ s. d. are likely to come from this research than from any other.

Let me speak for the moment of the Herring. The herring is a fish which feeds directly upon some members of this plankton. It comes in enormous numbers to our coasts, in great shoals in summer for feeding, and in autumn for spawning. Those landed we have said are numbered in thousands of millions, amounting sometimes to the value of over £5,000,000. There are good and bad years. In some years they turn up where they are expected, and in other years they do not and the trade suffers heavily. Now when these herrings do not turn up in their usual numbers, it is not always because there are fewer herring in the sea that year. For instance, 1921 was a very bad year for the trade, but we know from the study of age-groups in the stock of fish of later years that the spawning of 1921 produced an exceptionally heavy crop of young. It seems likely that there were plenty of fish in the sea that year, although they did not turn up in their usual place. Indeed, the fishermen know that the fish move their ground from time to time. Usually they can find them, but sometimes they cannot, at any rate in sufficient numbers to make a successful season. This year, for the first time in history, science has been able to make a forecast as to the quality of herring to be caught in the East Anglia fishing. It was made a fortnight ago in *The Fishing News*, by Mr. W. C. Hodgson, of the Lowestoft Laboratory, as a result of his patient researches into the age compositions of the stocks of fish. This is a great achievement: but, as he says, we cannot be sure these good quality herrings will turn up; they may be deflected from their normal course. No one will doubt that the movement of these fish must have a definite cause. We know that the nature of the drifting life—the plankton—changes from year to year. Some years there are more of one organism than another, and these different organisms are not evenly spread throughout the sea, but occur in patches, sometimes small, sometimes large. These patches are carried along by the ocean currents; they change shape; they may enlarge by the multiplication of the individuals comprising them; they may be torn apart into smaller ones by converging and conflicting currents. For instance in 1921, which, as we have already said, was a bad herring year, there was an abnormal influx of Atlantic water into the North Sea; there was a disturbance of the normal planktonic conditions. There is good evidence to show that when feeding the herring congregates, as one would expect, in water where the tiny animals on which they feed are most abundant. If this food is displaced from its usual situation it is likely that the shoals of fish will follow it. Again there is good evidence, from several sources, that the herring tends to avoid water in which certain other organisms—certain plant forms—preponderate. These dense patches of plant life, clouds of innumerable microscopic specks stretching for miles in extent, are to be found in different positions in different years, and in greater quantities some years than others. They change their position too with the slow movement of ocean currents week by week. Let us, to see it clearer, in imagination remove these clouds from the obscurity of the opaque sea; let us pretend, as the children say, that they are occurring in the atmosphere over the land. If this were so, then we might see banks of dull green fog hanging here and there over the country side; for one season, if the winds were as slow as the ocean currents, they might hang and drift over Yorkshire and the Midlands, for another over the Southern counties. Now suppose the presence of these banks of green fog meant a loss to the farmers wherever they occurred—a loss, shall we say, equal to that sustained by the herring industry in 1921 and 1927, when these green banks in the sea were known to be near the usual fishing grounds: would not the farmers of the whole country cry out for information regarding the movements of these clouds of green fog?

The study of the plankton is like the study of the weather, only we are dealing with centres of high and low production of plant and animal life instead of centres of high and low pressure. Their movement must be charted and studied from month to month if we are to forecast the future. The patches in the sea move more slowly than do the centres of high pressure of the atmosphere for they are carried by the slow ocean currents. We cannot yet say definitely that it is these green masses which deflect the herring from their normal path, but there is good evidence in favour of the view. What we can be certain of is that a better understanding of the movement of these plankton masses from year to year and at different seasons is essential to the understanding of the movements of fish that swim through them.

Is it a hopelessly difficult task to attempt this charting of life in the sea? To chart it, that is, sufficiently quickly and frequently to give one an idea of its changing whole; to be able to produce monthly plankton charts, like weather charts, which may be correlated with the movements of fish such as the herring, and in time enable us to forecast their position some weeks in advance? I believe it is neither impossible nor difficult, but it cannot be done by one or even two research ships. We must seek some other means.

As this is somewhat in the nature of an inaugural address, the first public lecture I have given at the College, I may be excused perhaps for ending it by giving some indication of the work I hope will be carried on in the fishery research department here. I want to make it a centre for the study of these broad plankton movements.

To start with I would suggest two lines of work. The first and smaller experiment definitely concerns the herring industry so will perhaps, be of more interest to Grimsby than to Hull, yet Hull is the greatest centre for the import of foreign Herrings in the country. Preliminary tests are already being made for me in Norwegian waters. The second and larger experiment is the one to which I have just referred, which should also particularly interest the herring industry, but which may, I hope, have an even wider application to the whole trade. To explain the latter and more important one I must first explain the former. Since we know that the herring at certain times of the year follows water rich in food and appears to avoid water containing a preponderance of certain plant forms, it is an easy matter to construct a simple instrument, which will give a rapid indication to the fisherman of the type of water he is in before he shoots his nets. Such an instrument consists in a little metal torpedo-shaped cylinder open at each end and fitted with small planes, like a paravane, so that when thrown into the water on a line it can be towed below the surface behind the ship like a ship's automatic log. Before it is thrown over it is opened like the breach of a gun at the hind end, and a disc of fine mesh silk supported on a brass ring is inserted. This disc is held in position across the path of water which rushes through the instrument as it is towed along. After ten minutes' towing, without stopping the ship, the instrument is pulled in and the disc taken out and examined. Now if the herring food is present in the water in large numbers—they are minute shrimp-like creatures—they will be plastered on the silk in masses like jam, and will give it a pinkish tinge. Again there may be very little plankton in the water and the disc will then appear blank. Or yet again there may be a preponderance of those plant forms, which, we believe, the herring avoid: then the disc will be green. The instrument has yet to be fully tested. If it works as we hope, then if the fisherman gets a green disc it will pay him to steam on perhaps ten miles and try again, and so try to get into water which is free of it, or, better still, into water where a pink disc indicates the presence of the herring food.

Before going on the Discovery Expedition I started experiments on these lines in the North Sea, but with an instrument which was not fitted with vanes, and which I have reason to believe was not always used properly below the surface. The new instrument is so made that it must dive below to a proper level. I had to give up the experiments when I went south before they were properly tested, and whilst a pink disc did not give a sure indication of the presence of fish, as far as the experiments went a green disc did give a forecast of poor fishing. Even if the instrument only works in this negative way, it will mean a great saving in preventing the fishermen from wasting two or three nights in the season fishing in unprofitable waters. To prove it an experiment must be made in which a number of vessels use this instrument throughout a season, correlating the amount of fish caught each time with the condition of the disc obtained immediately before shooting the the nets. It is not an expensive experiment.

The second and more important experiment is the charting of the plankton on a broad scale. A development of this instrument which I have just described has been devised; the continuous plankton recorder it is called. It is a somewhat larger instrument. In place of the single netting disc there is a long roll of fine silk netting which is arranged to wind across the stream of water from one roller to another like a Kodak spool. The rollers are driven through a gear box from a propeller turned by the flow of water through which it is towed. It is towed behind a steamer, and as it is towed the roll of netting is wound on. The roll is ruled with transverse lines dividing it into numbered divisions. The plankton organisms are caught on this roll and wound up, being preserved in the process in formaline for future examination. When one roll is finished it is changed for a new one: just like reloading a Kodak. Later on the rolls are unwound across the stage of a microscope, and the varying quantity and quality of the plankton are determined. The amount of sea traversed between putting the instrument out and taking it in is known from the ship's log, so that each division on the silk roll is known to represent so many miles of sea. Thus the varying density of plankton traversed along the route of an ordinary steamer may be charted, showing that here it passes through a belt of herring food and there a zone of " noxious " plants. Tests have been made with this instrument during the last there years, and it has undergone much modification and improvement. It has now recorded some three thousand miles of plankton. Last Easter it made four continuous records across the North Sea. A new instrument is being constructed with a roll capacity of 400 miles without recharging.

The experiment which I want to make from this College consists in running a number of these instruments on definite steamship routes across the North Sea, such as from Newcastle to Bergen, Hull to Oslo, Hull to Hamburg, etc., at definite monthly intervals. The instruments will be little trouble to run from the ships, and I am sure that the hearty co-operation of ships' officers would be readily obtained. The rolls would be worked up here, and charts made from the results. The experiment must be carried on over a period of at least five years before we can hope to look for any economic result. When these charts are examined and the results compared with the positions of herring shoals from year to year, we shall know whether or not we can forecast the position of the fish from the distribution of the plankton. I do not want to *promise* the trade any economic result. I would say to them that it is a gamble, but I believe it is economically worth trying, that it is worth the money invested. At any rate it must give us a better understanding of the North Sea as a whole, and if it does not give us an immediate key to the understanding of the movement of shoals of fish, at least it will have been a definite step taken in one direction and will help us to determine the direction of the next. These varying movements of fish must have a definite ascertainable cause, and once ascertained, forecasting cannot be difficult. I have said that this experiment may have a wider bearing than upon the herring trade only. The instrument records not only the ordinary plankton organisms, but also the eggs and young stages of many fish. By charting the relative abundance and positions of these from year to year we may learn a great deal about the movements and relative strengths of the present and future stocks of these fish. These records will be a series of simultaneous lines of observation across the North Sea. As well as these steamships on regular routes, trawlers could take instruments to and from the fishing grounds, giving useful lines of observation.

These instruments are unfortunately expensive, and the experiment may be regarded by some as too costly, but I believe it is a very small outlay when we consider the money involved and lost through a bad season's fishing. The instruments will cost close on £100 each. I estimate that the total cost of a five years' trial will be approximately £7,250, or or £1,450 per annum, made up as follows :

Initial outlay of instruments . . .	£1,000
Equipment of laboratory for working up results	500
Running expenses for five years at £250 per annum	1,250
Salaries of three research assistants to work up the rolls at £250 to £350 per annum each (rising scale)	4,500
	£7,250

I consider it useless to attempt the experiment on a smaller scale, and much better if it can be done on a still larger one.

I do not wish to appeal to the industry to support this experiment in the spirit of charity, but as an economic investment, in the hope of producing results which will benefit them. Let me repeat that I cannot *promise* definite results. It is a speculation, but I believe a good one. If it fails to yield useful results, it will not be science that has failed; it will be because the experiment is not big enough, bold enough, for the problem concerned. Scientists are sometimes inclined to *beg* for support from industry; if they are engaged on research of economic value I believe they are making a big mistake; they cannot expect to inspire confidence. They should *recommend* to industry lines of investigation.

If I have faith in anything, and I am no cynic, I have faith in this—that scientific research will ultimately be of great benefit to the fishing industry.

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