V.

THE NATURAL HISTORY OF THE HERRING;

WITH SPECIAL REFERENCE TO ITS MIGRATIONS.

No. II.

By William Watt.

The point of supreme and commanding interest in the natural history of the Herring, the most important of fishes, is its migratory habits, for involved in these are the vicissitudes to which the Fishery enterprise is subject. The oft-debated question whether there is or is not a falling-off in the supply of herrings in the sea need not concern us. For our present purpose it is sufficiently disposed of by the fact that no conclusive proof on the affirmative side has yet been forthcoming. In particular localities there are the greatest fluctuations in the produce of the fishery, but the supply of herrings in the home and foreign markets is increasing, and not diminishing.

The whole subject of migration is still, to a large extent, shrouded in mystery; the migratory instinct has still to be explained. We know that the swallow and other familiar birds come and go every year; that their coming can be predicted almost to a day, and that the time of their going can also be approximately foretold. But of the faculty by which their movements are directed we know nothing for certain. There is no analogy to it in human experience. The prompting causes are also insufficiently ascertained. Food may be supposed to be one of them; but in this climate the seasons are far from uniform, and the food supply is correspondingly variable, whereas the times of the birds vary but little. Again, the instinct of reproduction apparently operates in bringing them here; but how are their movements directed? what is the faculty or power that enables them, after a sojourn of more than half the year at thousands of miles' distance, to find their way back to the old country and the old nest? It is a strange and most interesting phenomenon, the full meaning of which the human mind has not yet been able to grasp. We know only the fact of the migration, with some of the circumstances

attending it; and we can form some estimate of the utilities it serves. Beyond this all is mystery.

Yet the movements of the birds are under direct human observation. The actual migratory flight may not be witnessed by everybody, but the birds are seen preparing for their long journey, and they are also occasionally seen on the passage. And if the mystery is unsolved in the case of the birds, we need hardly expect to lay hold of the key to the corresponding mystery in the case of the inhabitants of the deep. The salmon has through untold ages ascended our rivers from the sea, and the young salmon has made its way seaward from its birth-place in the upper waters of inland streams. Much more is seen and known of the salmon than of fishes that never leave the sea. In modern times this lordly fish has been cared for by anglers, by "salmon lairds" and lessees with the interests of their pockets at stake, and by stipendiary watchers and a non-descript tribe of illegitimate practitioners of the piscatorial craft. But though constantly cared for and vigilantly watched over by all these keen-eyed persons, and by professed naturalists to boot, the salmon long eluded the call to divulge the story of his career, and it is only within the range of living memory that the materials for anything like a complete salmon biography have been accumulated, while to this day there are sundry little matters still to be cleared up. No other migratory fish affords anything like the same opportunities to the observer. Only in his sea-wanderings is he so completely out of sight that an occasional glimpse of him cannot be had. From his first appearance as a tiny, shapeless, living thing at the hatchery till he is ultimately brought to land a full-grown adult, the salmon is an object of unremitting attention. And yet he has managed remarkably well to keep his secrets to himself.

The plebeian and multitudinous herring, there is reason to believe, pursues a career not altogether dissimilar to that of the salmon. In some general characteristics, at all events, there is an apparent similarity. The herring periodically approaches the land—visits creeks, bays, and estuaries, for the purpose of shedding spawn. Sometimes, indeed, it chooses a spawning-ground where the water is only slightly brackish, and not more than two or three feet deep;[1] while its cousin, the shad, approximates still more closely to the spawning habits of the salmon, by ascending the fresh waters of the Severn and some other English and many American rivers for a like purpose. Much of our knowledge of the natural history of the salmon has been obtained or verified by the expedient of marking numbers of the fish at some stage of their juvenile career, and returning them to their fluviatile habitat, there to pursue their

[1] Huxley, Norwich Lecture; Kupffer, German West Baltic Reports.

journey towards the ocean and adolescence. When a considerable number of salmon are thus marked, the chances are that some of them will be caught again, from time to time, by the angler's hook or the fisherman's net; and a comparison of dates and whereabouts will afford a certain quantum of definite information. But this method of inquiry is not usefully available in the case of the herring, for even if many individuals in the stage corresponding to that of the salmon smolt or parr were caught alive, decorated with a piece of metal, and turned loose again, the probabilities of their recapture by human instrumentality would not be great; and more likely than not such problematical recapture would take place near the coast, in a place differing in no essential respect from the scene of the original emergence from and return to the deep. Nor, in truth, could a very great deal be learnt in this way. Cases are conceivable of opportune captures and recaptures, by which some light would be thrown on questions relating to the growth, age, and condition of the fish; but there can be little hope of thus learning a single essential fact with regard to its migration, or its experience during the intervening wanderings. Keep the fish prisoner in an aquarium, or caged within some nook of the sea, and—preservation of its life being taken for granted—we should get at certain facts, perhaps, but should be as much in the dark as ever concerning the nature of the migratory impulse, and the method by which the migrations are directed to particular marine areas. We should, in short, learn very little by such means of the habits of the fish in a state of nature, or of the food conditions or meteorological conditions by which its movements are affected.

A useful discussion of the migrations of the herring is attended by very great difficulty. Not only does the fish itself pursue its career beyond the range of direct human observation, but it feeds on numerous species of smaller creatures of which far less is known. A complete natural history of the herring involves a complete acquaintance with the species on which it feeds and the conditions under which these species flourish and multiply. For generations the subject has attracted much laborious and painstaking research. The older naturalists made a certain degree of progress with it, and the results of their labours are set forth in the lucid description contained in Valenciennes' edition of Cuvier's uncompleted work. Since the days of Cuvier and his able editor numerous researches have taken place under Government authority. In 1843, Von Wright, Chief of the Civil Department at Stockholm, prepared an elaborate official report on "The Herring and the Causes of its Scarcity on the Swedish Coasts." Five years later the Dutch Meteorological Society published the results of observations

undertaken on board forty-five herring busses in the North Sea, at the instance of the Government of the Netherlands, the object being a practical one having regard to the conditions of a successful fishery. In 1855 the migrations of the herring formed the subject of a learned but resultless discussion in the French Academy. In 1857 the British Board of Trade issued a list of questions which were to be answered through "a series of observations to solve the natural history of the herring." The observations did not lead to any such important result, or, indeed, to much result of any kind; and though a great many more fruitful observations have been made since then, the natural history of the herring is still by no means complete. Within the last twenty years there have been numerous Commissions and Committees of Inquiry—*e.g.* the Trawling Commission of 1862, the Royal Sea Fisheries Commission of 1863, the Select Committee on the Sea Coast (Ireland) Fisheries Bill of 1867, and the Commission on the Herring Fisheries of Scotland, which reported in 1878. Some useful work, bearing more or less on the herring, though relating chiefly to other fisheries, has also been done by the permanent United States Fish Commission, established in 1871; and a substantial advance has been made in connection with recent German inquiries, prosecuted at the instance of the Government, in the Baltic and North Sea.

The "Icy Sea" Theory and its Refutation.

The theory, as is well known, was once confidently held—theories are always confidently held when knowledge is scarce—that the herring came down in their shoals from the Arctic Ocean, visited the British coasts in summer and autumn, and apparently—though on this point the theory seems not to have been so clear—returned northward again to enjoy the rigours of winter in their icy home. This notable theory attributed an extraordinary travelling power to the little fish, but some names of repute were associated with it, and it certainly had the support of the circumstance that the great summer fishery begins earliest at the Shetland and Orkney Islands, and gradually passes down the east coasts of Scotland and England, till it becomes the autumn "home voyage" of Yarmouth and Lowestoft. Pennant (1776) and other writers of last century—some of them before Pennant's time—gave forth this doctrine of migration from beyond the Arctic Circle with an air of certitude befitting a definitely-ascertained scientific truth. Their doctrine had the fortune to be generally accepted, and for generations it was a little-disputed article of faith. In the Report already referred to, published by the Dutch Meteorological

Society in 1848, it was stated, with the utmost precision, that the herrings leave the east side of Shetland and proceed by two different routes to the south; that in July they remain principally between the 56th and 57th degrees of north latitude, proceeding in August towards the Scottish coast between the 55th and 56th degrees—the Scottish coast apparently being supposed to include Northumberland; and that they retrace their course in September, were most abundant in October between 58° and 60°, and by November were not to be found south of 59°. Notwithstanding these specific averments, and a great deal of other dogmatism to boot, the theory was first questioned, then discredited, and at last discarded as utterly groundless. One of its most effective assailants was Yarrell,[1] who came to the conclusion, and gave good reasons for doing so, that the herring inhabits the comparatively deep water surrounding the British Islands at all seasons of the year, only coming nearer the land "for the purpose of depositing its spawn within the immediate influence of the two principal agents of vivification—increase of temperature and oxygen." Various considerations opposed to the "Arctic theory" are advanced by Mitchell in his important work on the Herring,[2] including these points:—(1.) That no shoals of herrings have ever been seen proceeding southward in high latitudes; (2.) that no shoals have ever been ascertained to exist in the Greenland seas; (3.) that the whales that feed principally on the herring are those that frequent our own coasts and those of Norway; and (4.) that it has been established that fishes of a similar size found in fresh water could not make, from spring till autumn, the long journey attributed to the herring.

The gathering of the Shoals, and the Spawning.

It is now a well-ascertained fact that herrings are to be found on the British coasts at all periods of the year. A herring-fishery may indeed be said to be continuously in progress on some part of these coasts. In Scotland there are the winter, spring, and summer fisheries, and in England there is the autumn fishery in the North Sea, gradually passing down the Channel as winter advances. Even when there is no active fishery, herrings can be caught in a desultory way; and their arch-enemy, the cod, whether taken from his favourite "banks" or from the adjacent seas, may always be expected to reveal to his dissector a herring or two in process of being digested. The great shoals, it is true, appear only at certain seasons; but there

[1] *The History of British Fishes*, by William Yarrell, vol. ii. pp. 183-6. Second Edition; London, 1841.

[2] *The Herring, its Natural History and National Importance.* By J. Mitchell. Edinburgh: Edmonston and Douglas, 1864. See p. 88, etc.

is no proof—and no reason to suppose—that the fish ever retire to any great distance from our shores. Between two and three months before the spawning period, the "matties," as they are called—herrings in which the milt and roe are advancing in development—begin to crowd together, "as the sands of the sea, without number." At no period of its existence is the herring strictly a deep-water fish, any more than the North Sea, its principal habitat, is a deep-water sea. The maximum depth of the North Sea, except at one great gorge near the Norwegian shore, is under six hundred feet; and a zone of similar depth fringes the British Islands to the west. In these shallow seas, which have little in common with the great pelagic abysses, the herring lives, and thrives, and multiplies, and maintains its not unsuccessful warfare with innumerable enemies. It usually dwells at moderate depths, according to the North Sea standard of depth. When the herrings are caught in the fishermen's nets, they are near the surface; but it is only temporarily that they are to be found there in great numbers. The cod, which is caught with long lines at or near the bottom, is always able to find a supply of herrings within reach. In other words, the herrings must pass much of their time within or near the favourite haunts of the cod. The shoals, as we know them, are formed at the surface of the water, when the fish are in the "mattie" stage, and remain together till after the shedding of the spawn, when they rapidly disappear. They may therefore be justly regarded as a manifestation of the reproductive instinct. At all periods of its existence, even in its very earliest days, the herring is gregarious in its habits; but the huge and compact collections to be met with, first as "matties," and then as full spawning fish, do not remain permanently concentrated together in such extreme fashion. After the accomplishment of the great function of their nature, they begin to segregate. The "spents" of the end of the fishing season are not found in the dense masses of the earlier shoals, but in flocks more or less spread out. The food problem has now become serious. The shoals were content to fast, but the emaciated "spents," or "shotten" herring, are so ravenous with hunger that they do not spare even the spawn and young of their own kind. Their excessive sociability now vanishes, and, instead of crowding together, they begin to look after their prey with great keenness, and to spread themselves over a wide area of sea—most probably without regard to locality or special order in their movements. Some remain near the shore, but the great mass appear to wander indefinitely through the sea. Food is now the dominating idea and sole aim of the herring—to find food for itself, and to avoid becoming the food of some larger fish.

The Food Element.

From its earliest days to the time when the spawn approaches maturity, the herring is a hearty, not to say voracious, feeder. For the few first days after the completion of the hatching process, it subsists on the contents of the vitelline sac which it brings with it from the parent egg; but it very soon begins with characteristic energy to fight the battle of life on its own account. Attempts have frequently been made to rear the young herring to adult age in an aquarium, but hitherto without success. Most valuable observations on its growth up to a certain point have, however, been placed on record by Dr. H. A. Meyer, an eminent German observer, by whom a highly important series of researches have been carried out at the Baltic sea-port of Kiel and elsewhere, both in the Baltic and the North Sea. Dr. Meyer was able to keep the young fry alive for five months. When only a few days old, they began to prey industriously on the microscopic forms of life existing in the water. In a month they were feeding on minute crustacea. When the sea-water had direct access, and they were as near as might be in a state of nature as to food, the fry grew rapidly, and at the end of the third month had attained a length of from 1·60 inch to 1·78 inch, or say an inch and three-quarters. In an aquarium, under more defective food conditions, they were stunted in growth, only measuring from an inch to an inch and a half; but on obtaining access to the more abundant food, the stunted fry took a start in growth, and by the end of the fifth month had made up all the lost ground, and were undistinguishable from those whose lot had from the first been cast in the comparatively more pleasant place. Beyond five months they could not be kept alive, at which time they measured 2⅓ to 2½ inches long. This is probably a good deal less than the size to which they would have attained in the same period had they not been in confinement. The appetite of the young and growing herring seems never to fail. The time it requires in order to reach mature spawning condition is now estimated at from a year to eighteen months. There seems to be no reason to doubt that in a favourable environment, with plenty of food, the shorter period is sufficient. As the fish grows up it puts on fat until it is saturated in every pore, and moves about as a living oleaginous mass. It eats voraciously, and assimilates with rapidity. The herrings caught yearly by man in the North Sea are computed in thousands of millions; and when due allowance is made for the far greater depredations of the active company of whales, dolphins, porpoises, dog-fish, cod, gannets, cormorants, gulls,

and their thousand other enemies, some faint notion may be formed of the quantity of food required to maintain the stock unimpaired. As many as seven dozen little shrimps have been taken from the crop of a single herring, and if a similar allowance—regard being had to the size of the prey—were made for the whole race of herrings in the North Sea, and to be repeated every day, we should begin to marvel how even the resources of Nature could bear such a strain!

The principal food of the herring appears to consist of small crustaceans. Some species of this family are produced in remarkable profusion. Thousands of gallons of shrimps and prawns are caught daily on the English coasts during the season. The *Thysanopoda* flourish in British waters from Cornwall to Shetland, and large patches of the sea are occasionally to be seen blood-red with those diminutive shrimp-like creatures. On the Norwegian coasts they are still more abundant. Herr Robert Collett, an eminent Norwegian naturalist, mentions, in connection with a research into the habits of the blue whale, carried out in 1874, that this great animal comes down from the north in April and May, and towards the end of the latter month enters the larger fiords to feed upon the enormous quantities of *Thysanopoda inermis* then found there. Both Herr Collett and another distinguished labourer in the domain of marine biology, Professor G. O. Sars, of the University of Christiania, examined various specimens of the whale without finding one that contained any other food; but of this species as much as two or three barrels, or even more, would be taken from a single stomach. The *Astacus* or "roé-aat" serves with the *Thysanopoda* as a staple food of the Norwegian herring. An entire shoal is sometimes found gorged to repletion with the roé-aat, and the fish, should they enter a narrow fiord in this state, are sometimes kept prisoners for a day or two, by the interposition of a barrier of nets between them and the sea, in order that they may digest their food and be in a better condition for a satisfactory cure. Still more important, however, in the food economy of the herring, is the order of *Copepoda*, including, besides the well-known *Cyclops*, several of the species which contribute to the "phosphorescence of the sea." The different species of *Cetochilus*, minute as they are, display a fecundity which is truly prodigious—myriads in number, and a great many generations in descent, proceeding from the eggs of a single specimen in the course of a year. The colour of the sea is often changed by these and kindred species over miles of its area. They constitute the "pasture of the whales" of the South Atlantic, and the "cow-water" of the Cornish pilchard fishery, and are extremely abundant on parts of the Scottish coasts during the

summer months. Herrings are generally found to contain the remains of these and others of the smaller crustacea. Nothing, however, in the way of food comes amiss to the clupeid; it readily snatches even at a clear unbaited hook. If it feeds chiefly on crustacea, the reason is that it finds crustacea most abundant on its path. There are indeed some indications of a preference for other kinds of food on its part. The "mattie" herring is a great gourmand, and appears at a certain stage to have a distinct liking for such delicacies as the sand-eel and the various small fry to be found in the firths or lochs or near the shore. But the same net often brings up "matties" filled to repletion with sand-eels, more or less mixed with other food, and fish with the spawn fully developed that are nearly in a fasting condition. The fattening properties of the sand-eel as food for other fishes were noted by Mr. Buckland, who remarked that salmon were always fatter in the estuaries where sand-eels abound than in those where they did not exist.

The question has frequently been asked, Why, if it is the spawning instinct that brings the herring towards the shore, should the "mattie" shoals also approach the land? Two answers may be given, at least by way of suggestion. The salmon spawns in the upper stretches of rivers which it has occupied a long time in ascending from the sea, but it is not therefore unreasonable to conclude that the spawning impulse made it start on the journey. So it may be with the mattie herring. It makes its way towards the shore several weeks before the spawn is to be shed, but the journey and the spawning seem to be parts of one great function. The quest of food, and especially of more suitable food, would come in as an auxiliary explanation. It is impossible to give proof either for or against these suggestions that can be regarded as absolutely conclusive, but at least they seem to harmonise with the known facts, and to be not inconsistent with the probabilities of the case.

From these considerations, then, it may be concluded that food is one of the main agencies influencing the movements of the herring; though the assembling of the great shoals seems primarily due to the reproductive impulse. Two kinds of movement may be distinguished—the general progress shorewards, and minor deflections in the course. These minor deflections may make all the difference in the world in the point ultimately reached. In order that these subordinate movements may be properly understood we require a much more minute knowledge of the physical and biological conditions of the sea than at present exists. A distinct advance has been made in recent years through the researches of the German North Sea Commission, under the direction of Dr. Meyer. The

general character of the North Sea fauna has been pretty well ascertained, but of the laws that govern its distribution next to nothing is known. The temperature of the sea, the direction of marine currents, and, as regards species that flourish at the surface of the water, variations of winds, and in the amount of unclouded sunshine, may be supposed to come into play. In the case of the herring itself, it is now definitely known that temperature has much to do with the length of time required for the development of the incubating ova. The German Commission found in the Baltic that the period of incubation, in a temperature of 53° Fah., is about a week—within a day more or less; but that in a temperature of 38° the period is extended to six weeks. These are apparently about the extreme limits of variation, as the raising of the temperature above 53° was found not to be accompanied by any material acceleration of the process. Between these limits there is much latitude, but it may be gathered that the summer brood are hatched out much quicker than that which makes its appearance in winter. Thus we can definitely fix upon one important effect of temperature in relation to the herring. Various attempts have been made to connect the movements of the fish and their position in the water with thermal conditions—as yet with doubtful success. The shoals visit our coasts in summer and in winter, and though they are in no way averse to a summer heat of 53° Fah., or a little more, they are content to retire after spawning to the lower temperature of the depths. But, indirectly, temperature may have considerable influence on the movements of the shoals through its effect on the surface fauna. This subject, however, has still to be systematically investigated. The distribution of the minuter species presents some problems that can be successfully attacked only by laborious and patient research, the means for which can scarcely be said to exist in this country. Private enterprise is not adequate to the task. Innumerable observations are necessary—observations including in their scope the whole field of the natural conditions affecting marine life. Until we know all about the smaller organisms that are the food of the herring, and the food of its food, we shall never be able to give an adequate or authentic explanation of all that concerns the fluctuations of the fishery. Not a little has been done to encourage scientific research into the causes that influence these fluctuations by the Governments of Norway, Holland, Germany, and the United States. In this country various deep-sea exploring expeditions have been sent forth either by the Government or with its co-operation and assistance; and the last and greatest of these—the *Challenger* expedition—will probably long remain pre-eminent and unique in the magnitude of its results.

But it is well worth consideration whether something might not still be done in the way of exploring more systematically and exhaustively so important a source of our national wealth as the North Sea.[1]

The Fluctuations of the Fishery.

Meanwhile one or two further considerations may be provisionally advanced with regard to the fluctuations of the fishery. A great point upon which ingenuity has been exercised is the desertion of the lochs and fiords. For this a great many fanciful reasons have been assigned, from the disturbance of the waters by steamboats to the ringing of church-bells and the wickedness of the people. The inshore fishings as a whole are very uncertain. In some seasons, it may be for a succession of years, the fish are abundant and easily caught. Then comes a season in which they fail to make their appearance; and, reliance having been placed on the fishery, great disappointment and distress overtake the poorer fishing population of the neighbourhood. The herrings failed to come to the fishermen, and the fishermen failed to go to the herrings, and accordingly there was no catch. The Norwegian method of catching herrings by enclosing them in a creek by extending a seine-net across the entrance—a method also practised in the Cornish pilchard fisheries—has its obvious advantages, provided only that the herrings can be got to enter the creek; and enormous quantities of fish have sometimes been caught in this way. The misfortune is that all the shoals sometimes miss the particular creek or fiord where their presence is most anxiously desired. This easy-going mode has the drawback of being highly precarious; with drift-fishing in the open sea, the free use of the telegraph, and readiness to follow the movements of

[1] The *Scotsman* of August 29, 1882, says :—"We do not with certainty know the causes that bring herrings to our shores, and we are yet but imperfectly acquainted with the signs of their presence and their habits after they have appeared off the coast. Without entering into details of the results of scientific inquiries, it may be said that many of those best fitted to judge have come to the conclusion that the chief inducement leading the shoals of fish into British waters is the search for food; no doubt, they also spawn in the shallower water on the coast, but the primary object is said by experts to be food. Further than this, it is established beyond doubt that sea temperature and the electric condition of the atmosphere reacting upon the water, both tell very materially on the shoals of fish when once they have shown themselves in any locality. Thus practical experience has shown that bright sun is not favourable to the fisherman, for the herrings at once seek greater depths, whether because the light annoys them, or for the reason that it causes the smaller creatures forming their food to sink lower, we know not. Again, the boats have learned that after thunder the chances of any catch are but small, though their nets may have been well filled on the same ground shortly before or during the electrical disturbance. To establish a connection between the fortunes of the fishing and these more or less occult electric or barometric changes necessarily involves many careful observations spread over a series of years; but if once the key to the solution of the problem were found, there is every reason to suppose the fishing community must largely benefit."

the fish, far greater certainty of a prosperous fishing is obtained. In the Norwegian fisheries the telegraph is now much used, and there is less disposition than of old to wait until the fish are kind enough to enter the trap. The records of the Scotch loch and firth fisheries tell of perpetual fluctuations of the same kind. The Firth of Forth has been often the scene of a highly productive industry, but at times the fishing has been almost a blank. For centuries the town of Dunbar has been a fishing place of no little importance. It is the "fishery town famous for the herring fishing" reported on by Tucker to Cromwell's Commissioners in 1656, and of which Ray the naturalist, writing five years later, says that "yearly about this time," namely, the month of August, "there is a great confluence of people to the herring fishing; they told us sometimes to the number of twenty thousand persons." Ray had his natural doubts whether so small a town could contain so great a multitude. Statistics were not very exact in those days, especially popular statistics such as an itinerant naturalist would pick up by the wayside. But we may take it that Dunbar was a very important place. It has had many ups and downs since then. Within recent times it was the great centre of the fresh fish trade with England; but the compendious summing-up of its history before the last Commission of Inquiry was that along the whole coast from Dunbar to Berwick the herrings had "completely gone." Similar irregularity has been exemplified in the Moray Firth, and the fluctuations on the West Coast have led to the entire abandonment of old fishing-grounds in favour of the open waters. The record might be extended by reference to the Bristol Channel and other parts of the English coast.

It has been observed, on the East Coast of Scotland, that the inshore fishing—say within the three-mile limit—is subject to very great fluctuations, and that at distances of thirty, fifty, or seventy miles from the land, there is far greater surety of encountering the shoals. When successful, however, the inshore fishing is by far the heaviest; and nets are far more liable to be broken or lost through overloading near the land than at a distance out. The obvious explanation is that the vanguard of the shoal finds itself confronted by the land, and pulls up, while the main body are still pushing forward, and thus a concentration of the forces takes place. Instances are on record of great quantities of the fish being cast ashore in this country, and more particularly in Norway, by the receding tide.

It is absurd to look for any greater uniformity in the movements of the herrings than is observed in the seasons, or in any department of animate nature. The general character

of their movements is, no doubt, the same from year to year, but they do not follow any law of mathematical exactitude. We must look for diversity as well as uniformity. I am disposed to attach importance to the element of *fortuity* in the whereabouts of a herring-shoal. Meteorological conditions, currents, food conditions, may all have their influence, but the evidence is insufficient to warrant definite conclusions as to the efficacy of such influences. The wanderings of a flock of sheep, for instance, cannot be reduced to such a law of uniformity as would enable us to foretell the concentration of the flock in any particular part of an open expanse of pasture at a given time. Neither should we look for such uniformity in the case of the herring.

The notion that there is a certain "periodicity" in the movements of the herring, and that the fluctuations of the fishery follow a definite cyclical order, has sometimes been broached. I can find no substantial evidence in support of this suggestion. There is no regularity of sequence observable, for instance, in the well-authenticated statistics collected for three-quarters of a century by the Scotch Fishery Board. A progressive increase in the average quantity caught is exhibited; but this increase is attributable to increase of netting, and the prosecution of the industry on a continuously advancing scale. The fluctuations from year to year do not follow any recognisable order. It must be allowed however that, as regards the abundance or scarcity of fish on the coasts, the evidence is far from complete. Districts where the fishing is poor for two or three years in succession are apt to be neglected altogether, or left to be fished by inferior craft and unenterprising men. At some of the Moray Firth stations the first-class boats, well equipped with nets, have been "well fished" in recent years; but most of the best boats have been fishing from the great centres of the trade in Aberdeenshire.

Again, the success of the fishing depends quite as much on the weather as on the fish. When the weather is unfavourable the number of working-days during the season is reduced; and now that the boats are going so far out, calms as well as storms are prejudicial to success. Boats are detained at sea, and the number of "shots" is thereby lessened. The question of periodicity may be best examined in connection with the weather, which affects both the fishery operations and the marine conditions.

Then as to the earlier beginning of the fishing in the northern part of the North Sea, to which reference has already been made, it is a question whether the appearances are not to a certain extent illusory, and whether we are not looking for recondite explanations when a very simple one would suffice.

There is a great amelioration of climate due to the flow of warm water north-eastward from the equatorial regions, past the Hebrides, Orkneys, and Shetland Isles, and onwards towards Lofoden, the northern shoulder of the Scandinavian Peninsula, and the Spitzbergen Sea. It is just possible that this flow of warm water may have some bearing on the earlier appearance of the fish in the north; but I venture to suggest another explanation of the phenomenon, based not on meteorological or biological conditions, but on physical geography. The North Sea is narrowest at the northern limit. From the Shetlands to the outlying islands of the Norwegian coast, near Bergen, is less than 200 English miles. From the coasts of Caithness and Aberdeenshire to Norway is about 300 miles; and from the north-east of England to either Norway or Denmark about 400 miles. Assuming the herring to be spread over a wide expanse of sea, the greater distance to be traversed before the full concentration into great shoals can take place would appear sufficiently to account for the difference of time in the appearance of these shoals. It is observed, moreover, that the fauna of the temperate northward flow of water of the West Coast of Scotland differs materially from that of the cold indraught along the East Coast.[1] The herring is found in greatest abundance on the eastern side, but the shoals arrive in the Hebridean waters some time before they are readily to be met with in the North Sea.

Conclusion.

The North Sea is the most productive fishing-ground in the world, and yet how imperfectly has its natural history been explored! We know, of course, most of the species by which it is inhabited, but the distribution and life-history of most of them has still to be investigated. Until further progress shall have been made in this direction, with regard to the interdependent species that are its principal food or its most formidable enemies, it will be impossible to add very much to the ascertained facts about the herring. Sooner or later, we may hope, a properly organised Fishery Department will be called into existence in this country; and if the Department had a competent scientific branch, with reasonable resources at command, we might expect soon to know a great deal more, not only about the herring, but about the other sea fishes that contribute so largely to the national wealth.

[1] Wyville Thomson, *Depths of the Sea*, p. 42.