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THE

CURRENTS, TEMPERATURES,

AND

PHYSICAL CONDITIONS OF THE SEA

IN RELATION TO

REPRODUCTION, GROWTH, AND MIGRATIONS OF FISH.

BY

W. WATT.

[*PRIZE ESSAY.*]

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ON THE CURRENTS, TEMPERATURES, AND OTHER PHYSICAL CONDITIONS OF THE SEA IN RELATION TO REPRODUCTION, GROWTH, AND MIGRATIONS OF FISH.

THE western shores of these islands are washed by the great north-easterly current or drift of the Atlantic known as the Gulf Stream, to which, as is well known, we are indebted for a geniality of climate, especially on our western coasts, such as is not elsewhere enjoyed in similar latitudes. The Gulf Stream is part of the general oceanic circulation of the globe. It may be traced all the way from the Indian Ocean. From the regions of the South Atlantic, near the western coast of Africa, it follows the north-westerly trend of the land, passing into the Caribbean Sea, thence sweeping round the Gulf of Mexico, and rushing through the Straits of Florida as a great contracted river, 30 miles broad, and 350 fathoms deep, with a velocity of 4 miles an hour, and a temperature of 85° Fah. The stream is continued north-eastward at first nearly parallel with the American coast. As the flow is continued the warm stream becomes outspread, its temperature lowered, its speed slackened, and portions of it are separated and deflected from the main course. The prevalence of south-westerly winds, and the natural effect of the rotation

of the earth on its axis serve to maintain the north-easterly flow after the original impulse has abated. The stream is continued past the British Islands into the sea between Iceland and Norway, where its speed, it has been calculated, does not exceed 1½ to 2½ miles a day, and on to the Arctic regions about Spitzbergen, where its presence has been manifested by the casting ashore of West Indian seeds. Even in those high latitudes it is still appreciable as a distinct and moving current. On the eastern side of Spitzbergen its course appears to be changed by some blocking or modifying agency. Here it was found to carry the Austrian exploring ship *Tegethoff* towards the north-west; and Mr. R. H. Scott, the secretary of the Meteorological Council, in a work just issued, records the discovery, in 1881, on the coast of Labrador, of glass fishing-net floats, of a pattern used only by Norwegian fishermen, and which, it would seem, must have been washed away from the coast of Norway, and have made the circuit round the north of Spitzbergen and along the Greenland coast to the spot where they were found. It thus appears that a portion of the warm Gulf Stream becomes lost in the ice-cold Labrador current which skirts the American shore and passes southward beneath the heated river that flows into the open Atlantic from the Gulf of Mexico.

Of the Gulf Stream a feeble wave passes up the English Channel and through the Straits of Dover; its volume, force, and warmth, however, being insufficient materially to affect the general temperature of the North Sea, or to affect it at all except within a limited area at the extreme south. By the deep-sea explorations carried out by the *Lightning* and *Porcupine* in 1868, 1869, and 1870, under the scientific direction of Dr. Carpenter, Mr. Gwyn Jeffreys, and the late Sir Wyville Thomson, it was established that along the

western side of Ireland and the Hebrides the heated water, some little distance out, has a thickness of some eight hundred fathoms. A portion of this warm water washes the shores of Orkney and Shetland, and curves round into the North Sea by the Pentland Firth and the channels between these islands. Thus it comes about that the surface water of the northern section of the North Sea is during winter and early spring higher in temperature than that of the middle and southern sections.

To counterbalance this north-eastward flow of heated water from the tropics, there is believed to be a constant creeping southward, in the depths of the sea, of water from the Arctic regions. This southward movement proceeds very slowly, and receives the name not of a current, but of an "indraught." The late Sir Wyville Thomson, a man of unique experience in deep-sea exploration, spoke of the investigation of the currents in the neighbourhood of the British Islands as being attended by "singular difficulty." Surface currents are often easily detected, but other oceanic movements of the greatest importance, involving the transfer of enormous masses of water, are so sluggish in their operation, and so liable to be masked by the drift of variable currents, that their course and progress cannot be traced.* We have, however, the broad fact that all over the ocean, even under the equator, below a certain depth, there is a great substratum of water of about the temperature at which fresh water freezes (and not 39·5° Fah. as was once supposed). Beneath the Gulf Stream, in situations where the ocean deeps are uninterrupted by shallows, the two strata are well marked—that of the surface exceptionally warm (for the latitude), that of the bottom of icy

* 'Depths of the Sea,' p. 361.

coldness. Dr. Carpenter reports* that at one sounding station near Faroe it was found that the thicknesses of the two strata were nearly equal, each being about 2000 feet, "the lower an Arctic stratum flowing in a south-westerly direction beneath the upper stratum of comparatively warm water moving towards the north-east."

One reason for believing that there is a southward indraught of water from the Arctic regions is found in the distribution of Arctic fauna. Reasoning as a naturalist, and with the results of a most extensive series of dredging operations before him, Sir Wyville Thomson concluded that "there is a direct movement of cold water from the Spitzbergen Sea into the North Sea."† The North Sea slopes to the north, becoming gradually shallower towards the south. There is great abundance of animal life in the Arctic regions, and great abundance of Arctic types of life in the deep water in the neighbourhood of the Shetland Islands.‡ The influence of the indraught of cold water from the north becomes less and less apparent as we proceed southward towards the shallower waters between Scotland and Denmark. By the time we reach the Dogger Bank the northern fauna has entirely disappeared. On the western side of the British Islands, however, northern species are to be found down to and beyond the southern limit of the British area. For this reason Sir Wyville Thomson suspected that the water of the Gulf Stream amalgamated, before touching these islands, with a portion of the northern water. "Since 1860," he wrote,§ "I have been

* Proc. Royal Society, xvii. p. 441.

† 'Depths of the Sea,' p. 112.

‡ See Reports of British Association, 1862–68. Reports by Mr. Gwyn Jeffreys, Rev. A. M. Norman, &c.

§ 'Depths of the Sea,' p. 400.

led to suspect that a portion of the Arctic water oozes down the Scottish coast, much mixed and sufficiently shallow to be affected throughout by solar radiation. About 60 or 70 miles from shore the isothermal lines have a slight but uniform deflection. Within that line types characteristic of the Scandinavian fauna are numerous in shallow water, and in the course of many years' use of the towing-net I have never met with any of the Gulf Stream Pteropods or of the lovely Polycystina and Acanthometrina which absolutely swarm beyond that limit." In further corroboration of his suspicion Sir Wyville added that the difference in mean temperature between the east and west coasts of Scotland, amounting to about one degree Centigrade, was also somewhat less than might be expected if the Gulf Stream came close to the western shore.

On the other hand we have the significant fact that southern species travel northward by the western and rarely by the eastern sea. They are to be found along the whole western coasts of Ireland and Scotland, in the Moray Firth, at Orkney and at Shetland ; but sparingly in the more southerly latitudes of the east coast of Scotland, and more sparingly still in the latitude of Yorkshire. This is especially true of crustaceans, and these facts as to their distribution seem to leave no doubt as to the route by which they have travelled.*

Currents influence the distribution of marine life in two ways : (1) by acting as means of transport, and (2) through temperature. When there is a decided flow or set of water in one direction it necessarily carries with it a great many floating objects. These may include the incubating ova of fishes and invertebrata, the free-swimming larvæ of innumerable species, and even, to a certain extent, the adult members of these species, when they are free swimmers,

* Compare Rev. A. M. Norman, British Assoc. Report for 1868.

though the movements of adults are greatly affected by the pursuit of food. Fishes when inactive may be floated along by a current, but it is a well-authenticated trait of fish life that they turn themselves against the stream in order to feed upon the organisms it bears along. And a warm or cold current passing through water of different temperature is an extension of the warm or the cold area, as the case may be. With this extension of area we may look for an extension of its appropriate fauna.

Of currents as means of transport I have already given the illustration of West Indian fruits cast ashore at Spitzbergen, and of glass floats apparently conveyed from Norway to Labrador by way of Spitzbergen and the eastern side of Greenland. Further illustrations might be drawn from the every-day experiences of nautical life. Thus Rennel's current, turned northward at Cape Finisterre and westward at Ushant, sends ships entering the Channel so far out of their reckoning that in fogs they are apt to strike on the Scilly Isles. Other vessels, sailing from Liverpool, have their reckoning and the guidance of the compass overborne by the drift of surface-water, and are driven aground at the south of Ireland. Along the whole of the British coasts there are currents more or less variable and of greater or less velocity, those on the west side having in general a northerly flow, and those on the east side accompanying the tidal flood-stream towards the south. Then, again, there are the surface currents produced by winds, now drifting towards the land and bringing the floating ova and larvæ of marine creatures from the deep sea to the shores, now acting as forces of dispersal conveying great masses of germinal existence out to sea. In this way species are diffused as widely as the climatal conditions of their existence. Myriads of the larvæ of shore molluscs are thus carried far from their proper habitat and perish, and not of

molluscs only but of the general fauna of the littoral and laminarian zones. Echinoderms, on the other hand, which dwell in Forbes's coralline zone (fifteen to fifty fathoms), suffer by being transported into shallower water with its greater extremes of temperature. Deep-water species have no doubt, on the whole, a better chance of passing through the larval and free-swimming stage in safety than the species of the shore. The deep sea is far greater in extent than the littoral fringe, and the chance correspondingly stronger, that when the free-swimming career is exchanged for a sedentary life in the depths, the descent will be made in a suitable locality. No accurate estimate has ever been formed of the power of currents as agencies of transport and distribution. But we know that the great Labrador current, for instance, transfers from north to south enormous quantities of Arctic forms of life in the early stages of their existence. The "Grand Banks" of Newfoundland teem with this life at certain periods of the year, affording an inexhaustible supply of food to the cod by which these banks are frequented, and to the shoals of smaller fishes that are the prey of the cod. In our European seas, and especially in those around the British Islands, the mutability of surface currents makes it almost impossible to trace out their path over any wide area of ocean, but some broad facts bearing on fish life may be clearly traced.

There are to be found on the coasts of England, France, Holland, and Germany, every spring, great quantities of young flat-fishes. These fry are met with in extremely shallow water, in rock pools, and on sandy beaches. Obviously they must have been transported thither as eggs or as larvæ by the action of the sea. There are none of the adult fish in such places, and few may be caught within miles of localities where the fry are abundant. On the low-

lying coasts of Hanover and Holland the larval flat-fishes have come, there can be no doubt, from the deeper water some distance to the north. Plaice, for example, are known to spawn about the regions of the Great Fisher Bank, and the east end of the Dogger. From these regions the ova appear to be carried southward by currents, and when the larvæ are hatched out they are close to the shore. So it is with other flat-fishes. They are carried towards the land by surface currents, either as embryoes, or as larvæ. And not with flat-fishes alone, but all other fishes produced from floating eggs. It is a rule to which there is no known exception, that fishes have in their first days a period of pelagic life at the surface of the sea. This rule applies equally to the herring, which comes from an egg that has undergone the process of incubation on the sea-floor, and to the turbot or plaice whose eggs float in the water. The herring is permanently a surface-swimmer; the turbot and plaice soon descend to the sea-floor, there to pass the remainder of their days. As larvæ they are all equally surface-swimmers. The south-west of England intercepts and divides an outlying portion of the Gulf stream. It also meets the prevalent south-westerly winds of the Atlantic that in their degree guide or intensify the drift of the current. We should naturally expect that great masses of living organisms would be transported by these influences to the Cornish coast; and such, in point of fact, is the case. The great pilchard shoals are attracted thither by the abundance of larval and crustacean food which they find; this food they follow even into the bays and creeks, where they are enclosed by seine-nets and captured *en masse*.

But the currents of the sea, especially those created by winds, do not always bear in the direction of land so near

as to be within reach. Sometimes the gale blows directly away from the land, in which event objects floating at the surface, even objects so minute as fish eggs and larvæ, would be carried out to sea. That multitudes of young fishes as well as of molluscs are destroyed in this way seems tolerably certain. Far out at sea, and floating at the surface, are found curious creatures called Leptocephalids. They are quite transparent, with cartilaginous skeletons, never sexually mature, and bear all the marks of development arrested at an early stage of life. Dr. Günther concludes* that these Leptocephalids are the young of shore fishes whose spawn has either been shed far out at sea or carried thither by currents, and that when thus removed from the natural conditions of their existence the young "grow into undeveloped hydropic creatures such as the Leptocephalids appear to be." Many of them seem to be the young of the conger, which is pre-eminently a shore fish. The same kind of arrested or abnormal development is seen in flat-fishes also taken at the surface of the open ocean far beyond the limits at which flat-fishes exist at the bottom. There would seem to be no doubt that these hydropic surface-swimming *platessæ* have been carried out to sea by currents. On descending into the water they may have gone far beyond their natural depths, and still finding no floor, no resting-place or means of subsistence, have returned to the surface to languish out a miserable career. Within the geographical limits of the several species of marine animals that spring from floating eggs or larvæ, currents serve as an agency of dispersal and means of distribution. This rule applies not only to fishes themselves, but to nearly all forms of invertebrate life constituting the supply of fish-food—to annelids, crustaceans, most

* 'Introduction to the Study of Fishes,' p. 181.

molluscs, echinodermata, sponges and polyps. When they are carried beyond their geographical limits they perish.

There is every reason to believe that the migrations of herrings in the North Sea are partly governed by currents, through the distribution of food, just as the migration of cod at Newfoundland is directly traceable to the effects of the Labrador current. At all events, the coast waters which have a general southward motion are resorted to by the great summer shoals. And if it be the case that currents are a main agency of distribution with respect to marine invertebrata, it follows that indirectly, through food, they also determine the distribution of fishes.

Let us next consider the effects of temperature. Currents are an agency in the distribution of temperature as well as of animal forms. Warm water has a fauna of its own, cold water another and entirely distinct fauna. The former, as we have seen, is brought to these shores by the Gulf Stream ; the latter by the great submarine indraught from the Arctic regions. The surface temperature of the sea is also affected to some extent by the temperature of winds. Mainly, however, it is determined by the direct heat of the sun. Accordingly, surface-temperature varies with the seasons, while the temperature of the depths is uniform throughout the year. In temperate regions the heat of the sun does not penetrate many fathoms, and as the heated water is of less specific gravity than the cold water below, it remains on the surface as a distinct stratum, not sharply defined, but gradually merging in that on which it is superimposed. Mr. Scott, of the Meteorological Office, in giving a general account of the sea surface-temperature round the British Islands for the months of February and August, states * that in February the

* 'Elementary Meteorology,' 1883, p. 319.

temperature never reaches 50°, but closely approaches that degree at the entrance of the Channel, ranges about 45° round Ireland, and does not much exceed 40° on the east coast, from the Thames to Shetland. In August the temperature round Ireland is about 55°, and in the Channe and southern part of the North Sea as far as the Wash about 60°, while along the remaining British coasts the mean is again about 55°. Thus it appears that in the track of the Gulf Stream the variation between the summer and winter temperature is only about 10°, whereas on the East Anglian coast it is 20°, and on the east coast of Scotland 15°, all of the Fahrenheit scale. The physical conditions of the North Sea were thoroughly investigated some twelve years ago by a German Commission headed by Dr. H. A. Meyer, of Kiel, for which purpose the Government vessel *Pomerania* was placed at their disposal. The results of these investigations, as regards temperature, were to this effect :—In January the surface temperature is highest in the extreme south and in the north by reason of the Gulf Stream waters poured in through the Straits of Dover and by the Orkneys, while on the German coast it is exceptionally low on account of the masses of water bordering on freezing point received from the Rhine, the Weser, the Elbe, and the Baltic. This state of things continues till April, in which month the temperature of the coast waters begins to rise. The rivers warm as summer approaches, and during July, August, and September, the southern parts of the North Sea are considerably warmer than those farther north. In April, May, and June, when the coast temperature is gradually rising, the Dogger remains cool, and after the beginning of October the cooling process sets in rapidly on the German coast until the state of matters that existed at

the beginning of the year is restored.* Generalising these observations still further, it may be stated that in winter, with the exception of a small area near the Straits of Dover, the shallow southern part of the North Sea is cold, while the surface waters of the north are relatively warm, whereas in summer the southern waters are warm and the northern surface waters relatively cold. The temperature of the northern part of the North Sea is much more equable than that of the southern part.

It was held by naturalists so experienced and observant as Edward Forbes and Sir Wyville Thomson that the distribution of marine animals is determined almost exclusively by temperature. Currents act as means of transport, but temperature fixes the limits of habitableness. Now, it is a curious fact that all our great fisheries are fisheries of the cold water. The cod fisheries of Loffoden, of Iceland, of Faroe, of Shetland and of Newfoundland are all carried on in water from the Arctic Ocean. The Dogger, Great Fisher, and Well Banks are by no means warm places, especially in the cod season. The principal herring fisheries are carried on in the northern half of the North Sea. Trawling for flat-fishes is prosecuted more to the south, but it is not to be forgotten that the British area altogether is north of the 50th parallel of latitude. Our two most southern fishes are the mackerel and pilchard. Farther south the fisheries are comparatively unimportant, and the fishes soft in texture and insipid to the taste. So likewise in the Pacific the best fisheries are those of China and Japan, of the Russian dominions, Alaska and British Columbia and a portion of the western sea-board of the United States. Marine life is extremely abundant in the coldest water out-

* Karsten, in Report of German Commission (trans. in U.S. Commissioner's Report for 1879).

side the limits of Arctic ice, and also extremely varied Small free-swimming crustaceans and pteropods are me with on the borders of the Arctic regions in such quantity as to form the sustenance of the whale. Gadoids are abundant at Spitzbergen and in the cold water that oozes into the North Sea between Shetland and Norway ; cod ling, torsk and halibut are found there in the greatest perfection both as to size and quality. Arctic molluscs, crustaceans and echinoderms are to be met with on the Shetland "Haaf" in the utmost profusion. Great marine arachnids and other characteristic boreal forms contribute their quota of food to the rapacious and thriving shoals of large and powerful fishes that flourish in those seas. These Arctic forms of life, it is believed, are being constantly reinforced by new arrivals from deeper waters and more northerly latitudes, the surface water of Shetland being probably too warm for their larval development at the free-swimming stage. At all events fishes of the Gadoid family are large, well fed, and of excellent quality in the deepest waters of the North Sea ; and near the surface of the same waters, heated to a certain extent by the warm Gulf Stream, vast shoals of herrings live and thrive in the highest perfection.

Sir Wyville Thomson was of opinion that distribution of marine animals was probably determined by extremes of temperature rather than by means. The extreme cold of winter in the southern part of the North Sea as contrasted with the heat of summer may explain why it is that fishes that prefer moderately warm water, such as the mackerel and pilchard, are not more plentiful there. We have seen that the mean variation of surface temperature in East Anglian waters is 20°, but the extreme variation, especially in seasons of exceptional severity, is considerably greater. In wintars of severe and protracted frost the

fauna of the intertidal zone suffers not a little; and even oysters not subject to exposure by the recession of the tide occasionally perish in great numbers. Certain fishes are also highly sensitive to cold. In times of biting north wind, with very low temperature protracted for days, congers in the genial waters of the south-west of England —both north and south of Devonshire—have been found in shoals floating helplessly numbed on the surface of the water. Surface-swimming fishes at such times take refuge in comparatively deep water beyond the range of these meteorological fluctuations. During the winter season mackerel in the English Channel swim near the ground, and in the deeper water of the Atlantic they may be far from the bottom, but at all events do not present themselves at the surface. The movements shoreward of pilchards are delayed in the storms of a protracted winter. The Scotch winter herring swims low in the water, and thus takes refuge from the wintry gales and frosts. Of Gadoids, this sensitiveness to cold has, probably with justice, been attributed to the southern whiting. The apparent delay of the cod in presenting itself on the Norwegian banks, of which Professor G. O. Sars has taken note, is possibly due to the action of cold and stormy weather, not directly on the cod itself, but on the surface fauna on which it feeds. If the small Clupeoids that constitute so large a part of the food of cod are prevented from emerging from deep water the cod has no occasion to change his ground. And as he is accustomed to ice-cold water in the depths there is no obvious reason why he should shrink back from the cold of the surface. In the shallow parts of the North Sea the flat-fishes which there abound retire in very severe seasons into the deepest water they can find—into the Great Silver Pit and other hollows of like character

near the coasts of Lincolnshire and Norfolk. In shallow water of less than twenty fathoms the effects of storms would be considerable even at the sea-floor, but in the deeper water of the "pits" the conditions would be much nearer those of a normal season.

It is the sole that chiefly shows this sensitiveness, and the sole is a fish hardly to be met with in the colder and deeper water of the Scottish section of the North Sea. Next to the surface fauna the ground fishes of the shore exhibit in the greatest degree this sensitiveness to cold and storms. In deep water there is protection against extremes or even serious changes of temperature, and also against the fury of the gale.

Low temperature has been supposed to retard the spawning of fish. If, however, for the reasons connected with surface food just indicated, the shoreward movement is delayed, all that can be said with certainty is that the spawning fish are not met with so early as usual. Food is no doubt obtained in greater abundance when compressed into a smaller thickness of water, and it is possible, of course, that the superior nutrition of the banks may have an influence in expediting the ripeness of the spawn which is missed when the arrival on the banks is delayed.

The process of incubation is much affected by temperature. The period required for hatching herring ova varies from a week when the temperature is 54° to six weeks when it is 38°. In the case of cod, a range of from thirteen to fifty days has been observed, and so on with other fishes.

Lastly, there are the effects of temperature on the relative scarcity or abundance of food. In this branch of the investigation little progress has yet been made. There is reason to suspect considerable differences from year to

year in the supply of surface food—entomostraceans, crustaceans, &c.—corresponding to the differences in the swarms of locusts, flies, and other insects on land. Sometimes the herring shoals find a sufficient supply without coming near the land; in other seasons the shoals approach very closely to the shore. Dr. Ljungman, of Gothenburg, has ingeniously suggested a "secular periodicity" of herring fisheries corresponding with the supposed periodicity of sun-spots and aurora. Certain coincidences of a somewhat striking character are apparently established, but the subject is one requiring a much larger array of data than are yet forthcoming before such a correspondence can be satisfactorily made out. The precise effects of heat and cold on the production of the different marine invertebrates have also still to be determined. The ova of molluscs and annelids have been found in the Baltic at all seasons of the year, but seasonal variations and intermissions of the reproductive process seem to be the all but universal rule, and there is at least probability in the remark of Prof. Möbius, that "the periodical increase and decrease of nutritive matter in the different parts of the sea depend on the degree of warmth and light which during the changing seasons they receive from the sun."

Light is the main or sole cause of the diurnal migrations of the surface fauna. This fauna rises to the surface in the evening, and descends to some depth in the morning. Drift-net fishing operations are conducted at night when the fish have followed their prey to the surface. Within a few fathoms of the surface the light becomes greatly dimmed, and the animals moving about there are as in a twilight. To a zone of dimness, though not of total darkness, the pelagic animals descend at sunrise, emerging

again in the shades of evening. During the day the surface of the sea is comparatively void of animal life.

The great rivers that flow into the North Sea affect not only its temperature, but its salinity. From the Elbe, the Weser, and the Rhine on the one side, and the Humber, the Ouse, and the Thames on the other, to say nothing of less considerable streams, an immense volume of fresh water is daily poured into a part of that sea which is of no great depth, and the mass of water is therefore small when compared with that of an equal area farther north. The effect of this great supply of fresh water is to dilute the saline water. Again, a great quantity of brackish water is received from the Baltic, especially in spring and early summer, when the surface ice liquifies, and the Russian, Prussian, and Swedish rivers are all in flood. Accordingly it is found that the salinity of the North Sea is lowest in the shallow parts that fringe its southern coasts. Those parts are principally inhabited by flat-fishes, and flat-fishes generally have no dislike to brackish water. Many of them visit large estuaries, and some even ascend long distances into fresh-water streams. Herrings and some Gadoids can also bear comparatively fresh water without injury. Young herrings, indeed, are often found with sprats in the upper reaches of estuaries, in that of the Forth for instance; and in the West Baltic the older fish live and spawn in water so low in salinity as to be quite drinkable. Baltic species of fish are usually smaller than those of the North Sea, but fishes generally seem to be able to withstand considerable modifications in the chemical constituents held in solution by the water without suffering apparent inconvenience. The food of fishes in estuarine waters differs, no doubt, from that which they find in the sea; and in the flounder, plaice, and others this difference of food produces changes of

shape and texture, and deteriorates the quality of the flesh. The herring of the North Sea is larger in the latitude of Shetland than in that of Yarmouth, and the quality, to say the least, is not inferior. The larger Gadoids also flourish in greatest perfection in the deep, cold, highly saline waters of the North, with their bountiful supplies of crustacean and other food. It seems indeed that at the younger stages of fish life the "soft food" of the estuary is most suitable to the condition and growth of many species, but the hardier Gadoids thrive and grow without such help, and the Shetland herring is also beyond its reach.

There is still great room and necessity for physical and biological researches into the conditions of fish existence. The conditions affecting the distribution of the various orders of animals that are the food of fishes are still but little known. Systematic observations by many labourers and on a common plan are absolutely necessary if rapid progress is to be made in this highly important department of knowledge.

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