EXTRAIT DU „GENERAL REPORT 1902—'04"
VOL. III. DES RAPPORTS ET PROCÈS-VERBAUX DU CONSEIL
INTERNATIONAL POUR L'EXPLORATION DE LA MER, Août 1905

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THE OCCURRENCE AND DISTRIBUTION OF THE EGGS, LARVÆ AND VARIOUS AGE-GROUPS OF THE FOOD-FISHES IN THE NORTH SEA

APPENDIX E

THE OCCURRENCE AND DISTRIBUTION OF THE EGGS, LARVÆ AND VARIOUS AGE-GROUPS OF THE FOOD-FISHES IN THE NORTH SEA

ACCORDING TO THE INVESTIGATIONS
OF THE BIOLOGICAL STATION AT HELIGOLAND

BY

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WITH 4 FIGURES IN THE TEXT

(TRANSLATED FROM THE GERMAN BY *H. M. KYLE*)

CONTENTS

Introduction

The first condition for a right understanding of the habits and habitats of the food-fishes of the sea, and in general, of the production of the sea as regards useful fishes, is an exact knowledge of the occurrence and distribution of these food-fishes at all the various stages of their life, from the egg on to the adult mature form. The plaice is the most important, ground-dwelling food-fish of the North Sea. In the interests of the sea-fisheries we wish to know, under what conditions the plaice lives in the North Sea, how it nourishes itself and reproduces its kind, whether an overfishing of the stock is going on, if it is a stationary or migratory fish in the North Sea, and whether, according to the answer to this question, an influx from other seas is occurring to compensate for the fish removed or not, and whether finally, fixed protective legislation at certain regions of the North Sea has a possible prospect of good results or not. In order to settle these and many other points, we must of necessity first investigate and determine above all possibility of objection, the following facts. Where and when does the plaice spawn? Where and in what relative amounts are the free-swimming eggs and the planktonic larvæ hatched from them? When and at what size is the metamorphosis of the plaice-larvæ complete and does their life on the bottom begin? Where are these youngest bottom-stages of the plaice to be found, how fast do they grow there, and what size do these young plaice reach at the end of their first year? Where do they live and how large are they in the second, third and following years of their life? At what size and in what year of their life, do the plaice become usable for a rational fishery, at which age are they mature for the first time, and where do they frequent at that time and in the following years of their maturity? How old can a plaice in the North Sea become in general and — in connection therewith — through how many years can they, by production of eggs, contribute to the maintenance of the stock? Do the plaice make regular migrations in the course of the year from one part of the sea to another, how far do such migrations extend and do the older plaice travel further than the younger? and so on.

What we must know regarding the plaice first of all, holds also for the other important food-fishes, especially for the cod and haddock, and then also for the turbot, sole, dab, whiting etc.

The Biological Station of Heligoland, as a cooperator in the international study of the sea, has endeavoured as far as possible to determine these points concerning the natural

history of the food-fishes by special exact observations. It has been obliged in the main, to restrict its attention to the region specially assigned for the German investigations, i. e. the eastern and south-eastern part of the North Sea, and the western and southern part of the Baltic, but chief attention naturally was devoted to the North Sea. With regard to the south-eastern portion of this sea — the true German Bight — we had already collected, long before the beginning of the international investigations, a large number of observations regarding the natural history of the food-fishes, which could now be utilised and their correctness tested by fresh investigation.

The following have taken part in carrying out the investigations — both at sea as well as at the laboratory of the Station — the director Dr. Heincke, the subdirector Dr. Ehrenbaum, the scientific assistants Dr. Strodtmann, Dr. Bolau, Dr. Maier and Dr. Immermann. Ehrenbaum and Strodtmann have investigated the eggs and larvæ of the food-fishes; Heincke their youngest, fully-formed stages; Heincke, Maier and Immermann the determination of the age and maturity; the last-mentioned and Bolau the distribution of the older fishes; Bolau their food and their migrations as determined by the setting-out and recapture of marked fish. The following account of the most important results attained through the investigations of the Biological Station, is accordingly to be looked upon, as a comprehensive common report of all the workers mentioned.

As already mentioned in the beginning, the observations on the natural history of the fishes are to form the basis for an exact knowledge in the future of the habits and conditions of life of the food-fishes, for a rational comprehension of the productivity of the sea as regards food-fishes, for an answer to the questions whether overfishing is taking place in the North Sea, if protective legislation is possible with any chance of success, and for many others. One may also add, that these observations are the only possible basis for many of these questions, for all but one absolutely indispensable.

Several very serious demands are therefore made on the investigation of this region.

The first of these demands is, that very many observations must be made, in order to gain the broadest basis for our future knowledge. Above all, it is necessary to obtain many continuous series of similar observations. We must take whole series of tow-nettings for eggs, for example, during the months-long spawning-period of a food-fish, such as the plaice or cod, at short regular intervals and simultaneously if possible, at several places of the often widely-extended spawning region. Again, in order to determine exactly the occurrence of young plaice of the first and second year, we must fish for these at one and the same suitable spot with suitable apparatus throughout the entire year, if possible at weekly and not less than monthly intervals. To take a third example, in order to comprehend the migrations of the plaice within a fixed region throughout the year, e. g. in the German Bight, we must mark and set out not merely several hundreds but several thousands of plaice. Lastly, such series of observations, when once successful, must be continued for a certain minimum number of years, in the same manner as is done in other scientific fields with all series of observations, if the general rule, free from chance fluctuations, is to be learnt.

We must confess that the investigations of the Biological Station up to the present in no wise fulfil, and indeed could not fulfil, this demand for numerous and continuous observations.

We have made our observations, partly by means of the research-steamer "Poseidon", partly with the vessels of the Biological Station, in the neighbourhood of Heligoland and in the shallow waters ("Wattenmeer") and estuaries of the German coast, from the island of Röm in the north to Borkum in the west. It is only for the neighbourhood of Heligoland, however, that we have gained continuous series of observations of moderate comprehensiveness. This was not possible on the cruises with the Poseidon. From October 1902, when the voyages began, up to the present (beginning of November, 1904), it has been at our disposal altogether 122 days, and of these, 100 at most were working days at sea. In addition, we utilised the quarterly cruises of the Poseidon to make tow-nettings for fish-eggs at its stations, and occasionally also some hauls for the larger fishes. All these cruises, however, were not sufficient to make a satisfactory number or continuous series of observations; above all, it was unfortunately not possible to fish for the eggs, larvæ and youngest fully-formed stages of the fishes, at a larger number of places within the extended spawning grounds of our most important food-fishes, nor at sufficiently varied periods during the long duration of the spawning time.

The following account of our results shows everywhere these gaps in the observations. They are the consequence of the manifold difficulties, which always arise at the beginnings of so extensive a work and can only be overcome gradually.

The second demand, contained in the aim of our labours, requires that every single observation is to be of the greatest exactness possible, and that the facts are to be learnt as they are in reality. This demand for exact and certain observations is even more important than that of numerous observations. Its importance becomes clear at once, when we picture the difficulties which all observations still meet with at sea, simply on account of the sea, and consequently, the great danger there is of drawing hasty, wide reaching conclusions from imperfect, unsuccessful observations. Some examples will illustrate this point. It may be desired to ascertain the occurrence or absence at a certain place in the North Sea of the pelagic eggs and larvæ of a food-fish, e. g. plaice; granted that the eggs and larvæ of this species are so well known that they can be distinguished from those of all other species with certainty. Long experience in this field has taught us that a certain observation can only be gained in such a case, when hauls are made after Hensen's example with good egg-nets from the bottom to the surface, and not merely horizontally, but above all vertically. As we cannot fish well with one net everywhere and for all purposes, we must constantly employ several well-tried instruments one after the other, to obtain a trustworthy observation (we use 3 to 4 different kinds). The employment of a net in only one way — e. g. the horizontal surface net — will in all cases bring an uncertain, in many cases quite a false result. No eggs and larvæ at all may be caught, for example, though they are present in reality in quantities.

The difficulties are quite similar if we wish to determine the occurrence and distribution of the fry of our food-fishes, after they have given up the larval stage or better called, the purely planktonic life, and have either changed to a complete bottom habitat or have reached such a size and capability of free movement, that they can no longer be counted with the plankton, helplessly subject to the movement of the water, even though

in the free water over the bottom of the sea. Not only are quite other kinds of fishing apparatus required here than for the eggs and larvæ, but these new apparatus for young fish must also be of many different kinds and satisfy specially strict conditions, if they are to display the actual facts in any way exactly. In order, for example, to be able to determine for certain, if the first, youngest stages of the plaice and dab *(Pl. limanda)* occur at a certain part of the bottom of the sea or not, we must employ a net with sufficient stretch to cover a large area, with a ground rope sufficiently sharp to bite into the ground and lastly with a mesh in the bag as small as possible, in order that small flatfish of 10—12 mm. in length can be caught in it. With such apparatus, we must fish at the most different depths, from close to the shore to 100 m. and more, and sometimes slowly, sometimes fast; the latter especially, if we wish to take young gadoids like the cod and haddock, as well as flat-fish.

Again, other apparatus are necessary for the sure capture of the larger, active fish-larvæ, e. g. herring-larvæ, and young gadoids of 3—10 cm. and over, which swim in the free waters of the upper and middle layers. They must have, especially, as wide a mouth as possible in order to be able to fish through a relatively large section of water; they must — at least at the hinder end — have sufficiently small meshes, and they must finally, also be strong and resisting and permit so much water to pass through, that they can be towed according to requirements with a moderately great velocity — several nautical miles per hour — without tearing or otherwise hindering their fishing-capacity. They must, lastly, be usable at different depths.

All these conditions, again, cannot be fulfilled by a single kind of net alone; several different nets are constantly to be used at the same time, in order to be able to determine the true state of things. If only one kind of net is used, quite a false result may be obtained, e. g. the absence of a certain species, which really occurs in abundance.

The experience, that very different and specially constructed apparatus are necessary, and that several of them must constantly be used at the same time, in order to determine for certain the occurrence of the eggs, larvæ and later young stages of the food-fishes, is one of the principal results of our investigations in this field. This experience holds also, however, for a much larger field in the investigation of the occurrence and distribution of the food-fishes, namely, for the capture of larger and the largest fishes. It may be considered certain, that the practice of the sea fishery has no single net which takes all fish dwelling on the spots fished. Even more, there is not a single net which, even if it catches only a portion of the fish present of a species, e. g. the plaice, brings up a true, at least a natural, representation of the various sizes on the ground. The large otter trawl ordinarily used in the deep-sea fishery of the North Sea, with about 90 foot head-line (commercial trawl), catches, for example, the small plaice under 12 cm. not at all or only in relatively very small quantity; they escape through the meshes. This same net, further, catches more flat-fish or more round fish, according to the nature of the ground rope and according to the rapidity of sailing during fishing. Smaller ground nets with smaller meshes, on the other hand, bring up naturally the small plaice under 12 cm., but of the larger kinds, they obviously take relatively much too few.

Lastly, it must still be mentioned that there is, for large areas of the bottom of the North Sea — namely, all those with more or less stony rough ground — still no apparatus

whatsoever, which can give us any trustworthy information regarding the fish-population of such grounds. The line-fishery is often the only means available here and it is a very untrustworthy method. It unfortunately yields no information whatsoever regarding the younger stages of the fishes.

Although all these things are tolerably well-known, as a matter of fact, or should be known, they must always be repeated again, and they require the greatest consideration when it is a question of scientific fishery experiments and of the estimation of their results for wide-reaching conclusions, or for the formation of theories regarding the migrations of the food-fishes etc. We are of the opinion that very many wrong inferences have hitherto been made in this connection. Above all, it is necessary to strongly guard against drawing wide-reaching conclusions from negative results in scientific fishery experiments, and against building any hypothesis on them. On account of the undeveloped condition in which our technique of the scientific fishery is at the present time, it is, for example, practically never possible to conclude that no young plaice or young cod in their first year occur in this or that spot, because no one has as yet found them there. Only in single, quite few and quite special cases have we a certain right to make such a conclusion.

On the other hand, the proof furnished by a positive observation is incontestable. We rely — especially in this account of our results — only on them.

Positive results, however, have only sufficient value for further conclusions, when it is possible to distinguish with perfect certainty the captured eggs, larvæ and early young stages of food-fishes according to their true species. The difficulties here have also been greater than desirable, hitherto.

For example, the eggs of two of our principal food-fishes, the cod and haddock, are not always to be distinguished from one another in the early stages of their embryonic development, and this holds also for the larvæ of some nearly related flat-fishes, especially when the pigment characteristic for the species is lost in preserving. Our observations have shown, that very many erroneous determinations are contained in earlier works on the larvæ and young forms of the food-fishes.

The exact separation of the various age-groups of the food-fishes has proved to be quite an indispensable, though very difficult work. The methods used hitherto, of measuring the numerous fishes of a catch and then of distinguishing the age-groups by the maxima and minima of the curve constructed from the measurements, has turned out to be very untrustworthy in most cases, and given rise to many wrong conclusions. The discovery of Reibisch of Kiel, that the layers in the otoliths of fishes showed the periodic, that is, the yearly growth of the fishes, has first displayed the possibility of a true and exact determination of the age. We have devoted special attention to this matter and applied the investigations of Reibish on the otoliths, to many thousands of fishes. At the same time, similar signs of periodic growth have been found on numerous other parts of the bony skeleton of fishes, and closely studied. We believe we are in the position to record a number of positive and certain results from this work.

A. The apparatus and methods used

1. The fishing for planktonic eggs and larvæ.

For this we have four different nets in use, two for vertical and two for horizontal fishing, or in other words, for quantitative and qualitative hauls respectively. A detailed description of these apparatus and the method we use in fishing with them, is given in the work of Ehrenbaum and Strodtmann on the eggs and young forms of the Baltic fishes (Wissen. Meeresunters. VI. Abteilung Helgoland. 1904. p. 57 et seq.)

The most important of these nets is the quantitative egg-net, designed by Hensen (see Hensen u. Apstein, "Ueber die Menge der im Winter laichenden Fische". Wissensch. Meeresunters. II. Abteilung Kiel. 1897. p. 1 et seq.). It is furnished with silk-gauze No. III and so measured, that it filters vertically a column of water of ca. $^1/_3$ m^2 by an average velocity of 0·5 m. in the second. Then the actual catch of the net has to be multiplied by 3, in order to obtain the number of the eggs and larvæ occurring under one square meter of the surface. The great importance of this net is twofold. Firstly, it fishes through the entire column of water from the bottom to the surface, and thus gives information whether eggs and larvæ occur at all at a definite spot in the sea. Secondly, it gives information regarding the quality, i. e. the relative abundance (per square meter of the surface) of the planktonic eggs and larvæ in a fairly large, uniform region of the sea. Numerous parallel hauls, which we have made with this net, have unmistakeably confirmed again and again the assumption underlying all Hensen's quantitative plankton investigations, viz. that the fish-eggs and larvæ floating in the sea within a region of limited extension, are equally distributed. Consequently, the quantitative egg-net of Hensen is, in fact, the only apparatus at present, which can give us any, approximately true information with regard to the occurrence and quantity of the fish-eggs and larvæ of the different species. The information given below for the various species, has been gained with this net particularly.

A fault of this net is, that it takes very small quantities of eggs, on account of its small dimensions. Thus, the occurrence of very sparsely distributed eggs of a species (1 or but a broken piece, per square meter) may escape detection, if no parallel hauls or only a few, are made with it. Also, the small number of the eggs and larvæ taken, is naturally a difficulty otherwise. This is helped out by using the so-called large quantitative vertical egg-net which has a diameter at the opening of 2·5 m. (the foremost ring is in the form of a hinged closing hoop), and in a vertical haul filters the column of water contained beneath ca. 2 square meters of the surface. The manipulation of this large net is certainly difficult and, especially in the superficial layers, untrustworthy, whereas it is of good service where, as in the eastern parts of the Baltic, the planktonic eggs are quite absent in the upper layers and only occur in the deeper.

To take very large quantities of eggs and larvæ, our qualitative horizontal nets are of use. A suitable apparatus for the surface layers is the well-known and often described Heligoland young-fish net, constructed by us. For horizontal fishing in the deeper layers, at a certain distance about 5 to 10 m. from the bottom, we use the so-called Heligoland otter young-fish net which is described in detail and figured, in the work

cited above of Ehrenbaum and Strodtman and in Appendix E of the Proceedings of Committee B, Amsterdam, December 1903[1].

The bag of the net is constructed either of fine-canvas, canvas, so-called 'iron'-yarn, or silk gauze No 1, and is about 3 m. long with a beaker or bucket at the end. This is made fast to a quadrilateral frame of gas-tubing ca. 18 mm. in diameter. On the under side of the frame, there is a zinced iron plate of 72 × 72 cm. surface, movable on hinges, which can be fixed by iron bars at an oblique angle of 125° inclining downwards and forwards — the so-called 'shearing-board'. The whole net is connected with a wire warp of 7 to 8 mm. thick, by means of 6 wire bridles of the same thickness. The net is let down perpendicularly to the required depth, and the boat going quite slowly or even drifting, it fishes steadily almost horizontally at the fixed depth, as it tends to go downwards from the strain on the rope and the resistance of the water pressing on the shearing-board. This net has proved to be very useful for the capture of the larvæ and young forms of the food-fishes, which occur usually in greater numbers in deeper layers of the water than in the upper, but it is also very useful for the qualitative fishing of eggs in deeper water. The net has already had a wider distribution and is at present being used in neighbouring countries.

2. The fishing for pelagic young fish.

For these, we chiefly employ two different kinds of nets, in addition to the otter young-fish net, with which tolerably large, fully-formed young fish of several centimeters long are occasionally caught.

Firstly, the so-called Hjort's ring-net, constructed from the model of the net used by Dr. Hjort for pelagic young fish. A conical net of hemp of about $5^1/_4$ m. long with a detachable bucket at the end, is fastened to a round ring of zinced gas-tubing $3^1/_3$ cm. thick with a diameter of 2·60 m. The net is connected to a 7 mm. strong steel warp by means of 3 bridles each 4 m. long, and is towed very slowly or simply when drifting, through the water. To keep the heavy ring near the surface or above a certain depth, a skin or leather buoy is made fast to it with a sufficiently long line. This ring-net of Hjort's fishes excellently the smaller pelagic young fishes, at various depths, but does not stand rapid towing and can therefore catch relatively few fish — the quick swimming young fish, as herring and mackerel etc., almost not at all. Our second pelagic young-fish net is the so-called Heligoland three otter-boards net which we have constructed for our own special purposes. It is an apparatus of the largest dimensions. The net is conical in shape, made of hemp, with 600 meshes round, 30 m. along the side, and so made that the size of the mesh decreases gradually through 20 stages from 8 cm. in front to $^3/_4$ cm. behind; then follows a cylindrical sack of 4 m. in length with 600 meshes, $^1/_2$ cm. wide, in the round. The sack can be closed behind. The opening of the net is hung to a hemp rope of ca. 2·7 cm. thick and is 45 m. in circumference. Three pairs of eyes or loops are made in the hemp rope at distances of 14 m. apart, to which the 3 otter-boards are attached by means of shackles. These 3 boards are of oak, 3 cm. thick, 1 m. long and 70 cm. broad, strengthened with iron bars. Of these boards, the two upper have quite the structure of trawl otter-boards and are also used by us for the Heligoland young-fish trawl, to be described below. The third or lower board is constructed somewhat differently; it is weighted with iron only on one of the shorter borders, not as is usual on the longer

[1] Conseil Intern. p. l'explor. de la mer: Rapports et Procès-Verbaux des Réunions. Vol. II. 1904. p. (62).

border, and this border weighted tends to go downwards in fishing. Each board is connected by 4 chains to a bridle of 12 mm. wire-warp; the three bridles are each 90 m. long and are shackled on to the large steel warp of the Poseidon. The manipulation of the net is done in the following manner. The warp with the 3 bridles runs from the winch over a large block fastened to a boom on the foremast, and on running out lets the 3 boards, lying loosely together with the attached net, go overboard into the water. When the 3 boards and the bridles are some distance out in the water and the ship is set in motion, the 3 boards spread out from one another in 3 directions, in consequence of their structure and the peculiar manner of fastening the chains to the bridles. The net thus opens of itself and remains open so long as it is pulled through the water. The width or stretch of the net depends upon the speed of the ship, the depth in which it fishes and the length of warp out. If the net is quite open, it has a triangular opening of about 100 square meters, if only $^2/_3$ open — which is more frequently the case — it has always still 50 square meters as the area of the opening.

The advantages of this net, which has proved an excellent net, are various. Firstly, the easy and convenient manipulation from the steamer, where a steam-winch, strong, steel warps and a boom are disposable for shooting the net. Then the possibility of towing relatively fast — we fish ordinarily with a speed of 3 to 5 nautical miles per hour and mostly for an hour. Thirdly, the size of the net, which, along with the speed, allows, not only the pursuit of the young fish through large stretches of water and the catching of many, but also the capture of larger fish. For example, we have taken herring up to 24 cm. in length with it (in January 1904, we caught in an hour's haul in the mouth of the Elbe, ca. 5400 herring and sprat of 7 to 16 cm. in length), also whiting up to 26 cm. in length, and plaice and flounder of similar size. On the other hand, the net also catches small, even the smallest young fish and larger larvæ of 1 cm., also smaller, in quantities. Fourthly, the possibility of fishing in all layers of water, even just above the ground. Thus, in the Skager Rak we once let out a length of 350 meters warp, and the net was for some time on the ground. It brought up various whiting and haddock up to 35 cm. in length, and smaller ground-dwelling animals such as sea-urchins, polyzoa etc. In July 1904, we made two parallel experiments with Hjort's ring-net and the 3-otter-boards net, at the same spot on the slope of the western Skager Rak, over 109 m. in depth; both times the hauls were made at slow speed, for one hour close to the surface. Hjort's net brought in 130, the 3-otter-boards net about 1000 young fish of 2·5 to 11 cm. in length, the larger of which were only in the latter net. On hauling in the 3-otter-boards net, it was observed that many, obviously hundreds of fishes, probably young, escaped through the meshes and were lost.

A fault of the net is that it lets many young fish escape, as mentioned above, as the meshes are only small enough in the hinder part of the net. If we make the meshes smaller in front, the permissible speed and the power of resistance of the net are distinctly lowered. Perhaps it is advisable to construct a smaller, similar net in addition to our large one, which would have smaller meshes of about 3 to 4 cm. at the opening.

3. The fishing for small and the smallest bottom-stages of the young fishes.

After we had, at the beginning of our investigations, used the so-called Petersen trawl suggested by C. G. Joh. Petersen, we constructed in consequence, a specially small net

with bag of very small meshes, for the capture of the youngest bottom-stages of the food-fishes. We call this apparatus the new Heligoland young-fish trawl. It is a trawl of 20 m. in length, 5 m. in the wings in front, 3 m. in the bag and 12 m. in the true middle part of the net. The ground-rope and head-rope measure each 14 to 15 m. in length. The two wings, which each join on to 1/3 of the front part of the middle portion of the net, are constructed in the same round shape as the middle portion. The ground rope is a so-called leaded rope, i. e. a hemp rope with lead weights round it. The width of the meshes of the net, decreases from ca. 4 cm. in front to 1/2 cm. behind, by 9 stages; the mesh in the bag, which is 3 m. long, is also 1/2 cm., and is reduced on tarring the net to 4 mm. The bag is closed by a rope.

The same two otter-boards are used in this trawl, as serve for the upper boards of the 3-otter-boards net. The chief differences between this and the ordinary otter-trawl are, that the upper and lower parts of the net are exactly alike; it differs from Petersen's trawl by its smaller length and the quite different structure of the wings. Its great capacity for taking the bottom-fishes seems to be due to this special construction, as well as the leaded ground-rope and the small size of mesh in the bag. It bites deep into the ground right from the wings; the edges of these are arched inwards like the middle portion of the net; lastly, the small mesh does not permit even the smallest of the bottom fishes to escape.

We fish with this Heligoland young-fish trawl at all depths and even on tolerably rough ground, usually however but a short time, about 15 to 30 minutes and with the low speed of 1 nautical mile per hour. With longer fishing, the net fishes so well and is often so full, that it is difficult to get it in and it may be torn, though on the whole, it has the advantage of great resisting power.

This net undoubtedly catches the youngest stages of all our food-fishes; we can well believe this at least, for the plaice, dab, long-rough dab, whiting (*G. merlangus*), cod, haddock, *Gadus Esmarki* and others. We have not rarely obtained several hundreds of the commoner species from the most different depths down to 140 m., thousands indeed in a single short haul of 20 to 30 minutes; in addition also, numerous individuals in older stages and even quite large specimens, 50 cm. and more. The catches of the various invertebrates of all classes were, in many cases, enormously large. As a specially striking proof of the great fishing capacity of this net, it may be mentioned that we have taken the interesting small gobioid, *Crystallogobius Nilssoni*, which has hitherto been considered a rare fish, in thousands of specimens.

A second net we employ for the capture of ground-dwelling young fish with good results, is the so-called shrimp-net or trawl, which the fishermen of our shallow seas ("Wattenmeer") use for catching *Crangon vulgaris* — but with the difference, that we fix the net to otter-boards instead of a beam, and make the bag of the same thick material as for the Heligoland trawl.

The shrimp trawl differs from the Heligoland trawl by its smaller size (10 m. in length, of which 3 m. go to the bag; 6 m. in breadth, in front) and by the complete absence of wings. It fishes just as sharply and is usable in the same depths as the other — but it catches much less.

4. The fishing for the larger bottom fish.

For this purpose, we ordinarily use on our research-steamer the large otter-trawl with

90 foot head-line, as used on the German steam-trawlers. We vary the experiments with this net, employing different kinds of ground-rope and different cod-ends (with different sizes of mesh). Further, we employ a smaller otter-trawl of only 50 foot head-line, the so-called Hjort's trawl from data given by Hjort. We have not yet used a beam trawl on the Poseidon. On the motor boat of the Biological Station at Heligoland, we employ mostly a small otter-trawl of 50 foot head-line, also a small beam trawl.

B. The method of determining the age of fishes

We begin here with the determination of the age of the plaice and other flat-fish by means of the otolith-rings. It was first pointed out by Reibisch, that the otoliths of the plaice showed alternating dark and white rings in addition to a white kernel by reflected light, and that a dark and white ring together denoted a year's growth.

Along with the Kiel naturalists, we have extended these investigations on the otoliths to other fishes, and have deepened the entire investigation and examined the otoliths of many thousands of fishes.

If we examine, in the summer months, the young plaice of about 30 to 50 mm. in length, which have been born without any doubt in the beginning of the same year and therefore belong to the 0-group, according to the notation used by C. G. Joh. Petersen and adopted by us, we find that the otolith by reflected light shows an inner white kernel and an outer dark more transparent ring. The inner kernel consists frequently, further, of an inner small, particularly white, kernel point, round this a thin darker ring — the intermediate kernel ring, and a broad white ring — the kernel ring which forms the chief mass of the kernel. If we now examine other young plaice of about 100 to 150 mm. in length, caught on the same ground and at the same period of the summer when the 30 to 50 mm. plaice are taken, we find the otoliths very different; they consist now of white kernel, dark ring, white ring, dark ring. Such plaice belong to the so-called I-group of Petersen, that is, they have lived one full year. In plaice of 180 to 220 m. in length, examined in the summer, the rings of the otoliths of the I-group are increased by another white and dark ring; we have here the II-group of over two full years and so on. Consequently, the number of the completed years a plaice has lived, is indicated by the number of the white otolith-rings which are present outside the kernel.

This method of determination is, according to our thorough investigations, always reliable. We find further, that the white rings contain more organic substance than the dark, the latter more inorganic; also, that the former are formed in spring, the latter in summer and autumn; and that the growth of the otoliths ceases probably for a time in winter, from which arises a sharper boundary between an inner dark ring and the next following white ring.

In the plaice, the first 4 to 6 white rings succeeding the kernel, can usually be very clearly distinguished. In larger and older plaice, the otolith becomes thicker and more

opaque, and the new annual rings appearing become thinner and thinner, so that the determination of the age from the otoliths becomes more uncertain, even when sections are made. As the majority of all the plaice taken in the North Sea are, however, not over 6 years old, this difficulty is not much met with in practice.

It is especially remarkable, that the investigation of the otoliths almost always permits, with sufficient certainty, the separation of the 0-group of plaice, i. e. those which have not yet completed one full year and are thus in the year of their birth, from the plaice of the I-group and later years.

The results of our method in analysing a catch of plaice according to number, size and age, and the value of this analysis for the determination of the age can be seen from

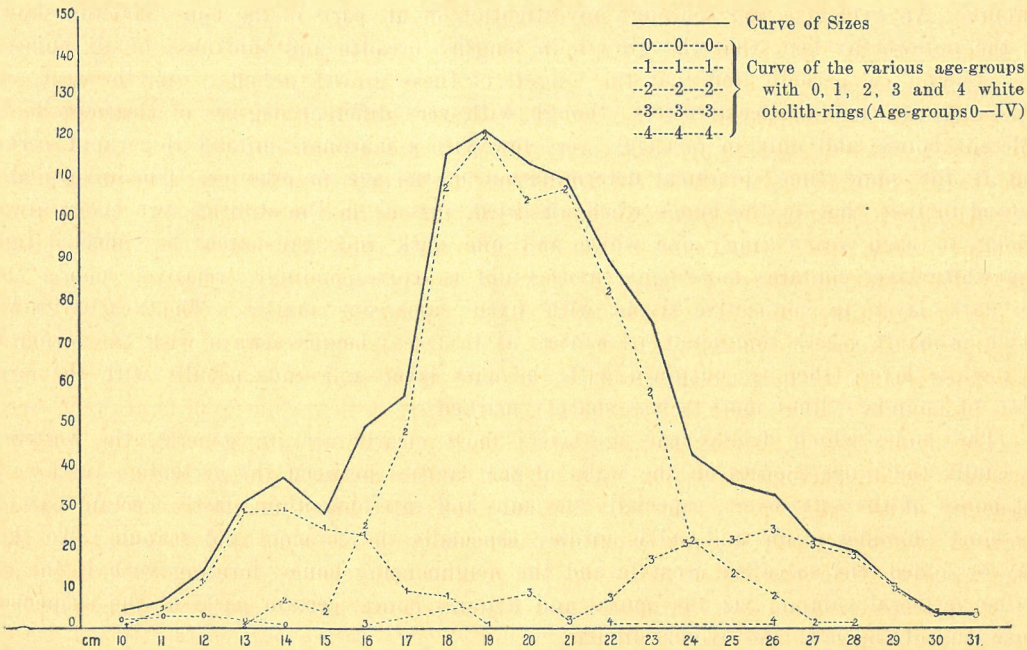

Fig. 1. Analysis according to size and age, of a catch of plaice made with the 90-foot trawl on Sylt inner-ground on March 19th 1904 (1024 specimens)

the accompanying curves (Fig. 1). The otoliths of all the plaice represented here (1024), the result of a single catch, have been examined for the number of white rings. It will be observed that, (1) groups of 5 years occur together, one however greatly predominant in number, (2) the curves of sizes of the separate groups greatly overlap, (3) the maxima of the curves 1, 2 and 3, representing the age, have exactly the same position as the 3 maxima of the curve of sizes and (4) the average difference in length between the I- and II-groups is about 6 cm., that between the II- and III-groups about 8 cm. From such differences we may perhaps learn, in what year of life the plaice of the North Sea grows most in length; to judge from this case, it is about 8 cm. on the average in the third year against 6 cm. in the second year.

In other flatfishes, especially however in the gadoid food-fishes, the otoliths do not

form such favourable characters for the age-determation as in the plaice, owing to their irregular lines or their relatively greater thickness. The separation of the 0- and I-groups can be made here also, almost always without great difficulty, but the older stages are often very difficult to distinguish or not at all, by means of the otoliths. It was desirable therefore, to discover, if possible, still other anatomical signs of the age. First of all, the scales had to be thought of, as undoubted age rings had long ago been discovered in them, e. g. in the carp. Recently also, J. Stuart Thomson had closely studied, with some success, the age-layers on the scales of sea-fishes. We have also examined the scales and found them useful for the determination of the age in a few fishes, e. g. in the lemon dab (*Pleuronectes microcephalus*).

We have soon discarded the scales, however, as we discovered other organs more suitable. An extensive and thorough investigation of all parts of the bony skeleton showed us the noteworthy fact, that the growth in length, breadth and thickness of all bones of the skeleton, is periodic and that the longest of these growth-periods, viz. the year, was constantly marked in special layers, though with very different degrees of clearness in the different bones, and only in relatively very few with a sharpness suitable to a rapid, certain and at the same time, practical determination of the age in practice. The investigation showed further, that in the bones when air-dried, just as in the otoliths, two layers always belong to each year's ring, one white and one dark and transparent by reflected light. The white layer contains more bony cavities and is, correspondingly, relatively poorer than the dark layer in connective tissue with fixed calcareous matter. The yearly growth, which probably ceases completely in winter, as in trees, begins always with the formation of a white layer, then is continued with the dark layer and ends usually with the formation of boundary lines more a less sharply marked.

The bones which display the age-layers most clearly are, in general, the vertebræ, especially the inner aspects on the walls of the cavities between the vertebræ, further the flat bones of the gill covers, especially the sub- and interoperculum, lastly, certain parts of the bony shoulder girdle and pelvic girdle, especially the coracoid and scapula. To these may be added, the so-called urostyle and the neighbouring bones, forming with it the end of the vertebral column, viz. the epural and hypural bones, certain parts of the suspensory apparatus of the jaw, the hyomandibular.

It is not the same bones of the skeleton in all species, which show the age-layers most distinctly. In the plaice, it is the vertebræ — the rings on the inner side of the cone — and the sub- and interoperculum, which determine the age almost as clearly as the otoliths. This holds also for the turbot. In the sole, it is practically only the vertebræ that can be used. In the gadoids, the flat bones of the pectoral girdle, the coracoid and scapula, are best suited for the determination of the age, especially in the cod which, for the rest, is one of the most difficult species on which to determine the age. For the haddock, the vertebræ especially are very useful, and quite exceptionally, likewise the rounded swollen lower part of the *Clavicula* of the shoulder girdle, characteristic of this species; a section across this bone is usually sufficient for a certain determination of the age. In the herring again, the vertebræ are very suitable, also, especially for the 0-, I- and II-groups — the bones of the gill-cover.

The proof, that these layers in the bones are just as good age-layers as those of the otoliths, can be undoubtedly displayed by us and others from numerous comparisons, e. g.

the number of the otolith-rings agrees with the number of rings on the vertebræ in one and the same fish.

The extension of the age-investigations from the otoliths to other parts of the bony skeleton of fishes, gives an essentially wider and more certain basis than hitherto, for the determination of the age. The information they give, render it possible above all, to detect and to distinguish also the age of the older and the oldest stages of the food-fishes. For example, the annual rings on the bones of the gill-cover enable one to detect with certainty, that large plaice from 60 to 70 cm. in length are 20 years old and more, and that, from the 8th year onwards, the yearly growth in length is small in comparison with the earlier rate of growth and decreases more from year to year. A turbot of 19 pounds weight (21 lbs. English) is at least 11 years old, a large cod of 100 to 120 cm. 9 to 11 years. Large Norwegian herring of about 300 to 350 cm. in length are 6 to 8 years old.

C. Statement of the results

It may be explained in the beginning, that special cruises for the investigation of the eggs and larvæ of the food-fishes, were only made by our research-steamer "Poseidon" during March 1903 and 1904, in July 1903 and in June 1904. On the other hand, in the important spawning months of January and February, either no hauls at all could be made or only in February during the hydrographical seasonal cruises, and then, only qualitative hauls for the most part. During 1902, 1903 and 1904, eggs and larvæ were also sought for during the May seasonal cruises, mostly qualitatively, more rarely also quantitatively. Cruises with the Poseidon for fishery investigations, for the young and larger fish, were also made in October and November 1902, in March, July and September 1903 and in January, March, June and July 1904. It must also be specially mentioned here, that everywhere, where a series of hauls of all kinds was made, the temperature and salinity were also determined.

1. The plaice (*Pleuronectes platessa*)

Eggs and larvæ. Plaice eggs were fished by us during the March cruises in such small quantities, that we must believe that the spawning period of the plaice was practically over by this month. A further sign of this was, that just as many larvæ (74) as eggs, were taken altogether (all the vertical hauls taken together).

The largest quantity of eggs and larvæ was taken on the 6th of March 1903, N.W. from Heligoland near the 40 m. line (German Station I), namely, about 32 per square meter of surface; almost as large a number was met with close to this spot, both to the north (Sylt outer ground) and to the south (N. from Terschelling), but only on the 40 m. line. Smaller quantities were also found nearer to the land, about the 20 m. line, both in the southern and northern parts (to 56° N. L.) of the region sailed through. In the open North Sea (Great Fisher Bank, Dogger Bank), plaice eggs were often met with singly but

never in great quantities. Of the larvæ, some were often far on in development (stage when the fin-rays were forming), so that from this also, it may be supposed that the height of the spawning period was already over.

On the May cruises, plaice eggs were no longer met with in the North Sea, here and there, however, larvæ and several times older stages, but never in any quantity. In the hauls made in the open North Sea, on the Dogger Bank and Great Fisher Bank, these larvæ were obtained only very rarely[1], e. g. once on the northern part of the Great Fisher Bank and on the western edge of this bank (German Station IV); more frequently, though still on the whole rarely, on the stations near the coast within the 40 m. line, in the north near to the Jutland coast and in the south in the German Bight.

The small number of plaice larvæ, also of the younger plaice (without fin-rays) met with in May, leads one to suppose that the largest quantity of these had already taken up the bottom habitat.

Amongst the numerous young flat-fishes in the latest planktonic stage, which were taken in July, the plaice never occurred in the open North Sea.

The planktonic plaice larvæ, according to our observations in the North Sea, reach a length up to 17 mm., yet, as a rule the metamorphosis to the adult form and the pelagic life, are ended at 14 to 15 mm. in length.

The youngest bottom-stages and the 0-group. The smallest completed bottom-stage of the plaice observed by us (incomplete stages i. e. still in the process of metamorphosis, were never found on the bottom), measured about 13·5 mm. in length. We have taken these earliest bottom-stages, and the somewhat larger stages to 50 mm. in length, from the beginning of June to the end of August, and with but isolated exceptions only within the 20 m. line in the immediate neighbourhood of the land, mostly on sandy ground, more rarely on muddy ground. We have hitherto obtained the youngest stages from 14 to 25 mm. in length, always and only when we fished with suitable small-meshed hand-nets and shove-nets quite close to the shore in 0—3 m. in depth, thus within the tidal region; for example, at the base of the rocks and on the sandy island at Heligoland. At the latter place we take them, for example, in June, often in quantities in the so-called "Seyen", that is, the small, shallow pools left on the beach of the island at ebb-tide, in whose loose sand warmed by the summer sun the small plaice like to revel. The somewhat older bottom-stages of the 0-group (from 25 to 50 mm. in length) were mostly found at the same spot, but also in smaller numbers further out, 2 to 4 nautical miles from land, on somewhat deeper ground, 10 even 20 m. in depth. On the 9th and 10th of July 1903, we caught 2 small plaice of about 30 to 40 mm. in length, with the Heligoland trawl on sandy ground in 16 and 25 m. depth, the one 20 sea miles W. from Amrum, the other about 25 sea-miles from land at Vyl light-ship.

In the open North Sea, we have only once taken a small plaice of the 0-group in our numerous hauls with the Heligoland trawl and the shrimp trawl, which otherwise brought up many thousands of small young fish, especially many young flat-fish of the species *Limanda* and *Drepanopsetta*. This specimen was 48 mm. long and was taken on the South-west Patch of the Dogger Bank, where we fished on fine sandy ground within 19 to 32 m. Its otoliths showed no white ring round the kernel. It would be of the

[1] The determination of these larvæ with certainty, and especially their separation from the dab (*Pleur. limanda*), leaves much to be desired on defective preservation.

greatest interest to learn, whether such plaice of the 0-group occur frequently and regularly on this south-west patch of the Dogger Bank, the shallowest part of the open North Sea.

The still older plaice of the 0-group, of over 50 mm. in length, have been fished in very large quantities in late summer and autumn, but with few exceptions, always within the 20 m. line and here almost constantly in the neighbourhood of the land, especially, on the shallow sands of the Elbe and Weser estuaries in the "Wattenmeer" and immediately off the shallows of the German coast. The 0-group occurs here, without exception with the I-group. Both groups considerably overlap as to size. Towards the end of their first year, i. e. in December, the young plaice reach an average length of about 7 to 8 cm., from 9 to 10 cm. as a maximum, according to our observations in the German Bight of the North Sea. We have, unfortunately, not made any extended observations as yet, regarding their habitat in winter.

The plaice of the second year, therefore of the I-group, which have lived a complete year, reach an average length of 13 to 16 cm. in the German Bight of the North Sea, from 18 to 20 cm. as a maximum. These also, we have only taken — with very few exceptions — within the 20 m. line, where, with the plaice of the third year (II-group), they form the great mass of the so-called under-sized plaice on the young-fish grounds. The richest of these young-plaice grounds lie off the islands of Amrum and Sylt in the north, off the mouths of the Elbe and Weser in the centre, and off the islands of Juist, Borkum, Ameland and Terschelling in the west.

The third year's group of the plaice just mentioned (II-group), reach an average size of 18 to 20 cm., about 25 to 28 as a maximum. We have found it in great quantities within the 20 m. line, outside this line also, though in smaller quantities, as far as the 40 m. line, but beyond the latter line only very exceptionally.

It is the fourth year's group of plaice (III-group), with an average length of 25 to 27 cm., which is first caught in quantities worth mentioning in the open North Sea beyond the 40 m. line, although it has also been met with in greatest numbers within that line.

These discoveries — which, it must be remenbered, are limited to the period March to October — have shown without exception the noteworthy fact, that the occurrence of the young plaice, from the coast to the open sea, is arranged like the steps of a ladder as regards the increase in size; the smallest and youngest occur quite close to the land, the largest and oldest the furthest out.

The curves added here (Fig. 2) give the percentages of 7 hauls of plaice made by us on the 23rd and 24th July 1903, on a ground to the north-west of the island of Juist as far as the 40 m. line: 5 hauls with the 90-foot trawl and 2 with the Heligoland young-fish trawl. We see (1), that the number of plaice caught increases as we pass from the open sea towards the coast, (the number 1561 of the haul made close to the land with the Heligoland trawl, should be multiplied several times for a true comparison, as this haul lasted only 35 minutes, whilst those with the large trawl were always much longer, from 2 to 4 hours); (2) that the average size of the plaice steadily decreased from the sea towards the land, from about 24 cm. to 9 cm. The two parallel hauls with the large and the small trawl (V and Va) at the same place, are worthy of remark; they show very clearly, that the hauls with the large trawl do not take all the size-groups present, and

that many more of the smaller plaice are only retained by the narrow-meshed young-fish trawl. Just as remarkable is the fact, that a haul with this latter net, on the same spot and immediately after haul I with the large trawl, brought in only 5 plaice, of which none were under 24 cm. in length. From this we may conclude that smaller plaice, than those shown by curve I, did not really occur there in any quantity worth mentioning.

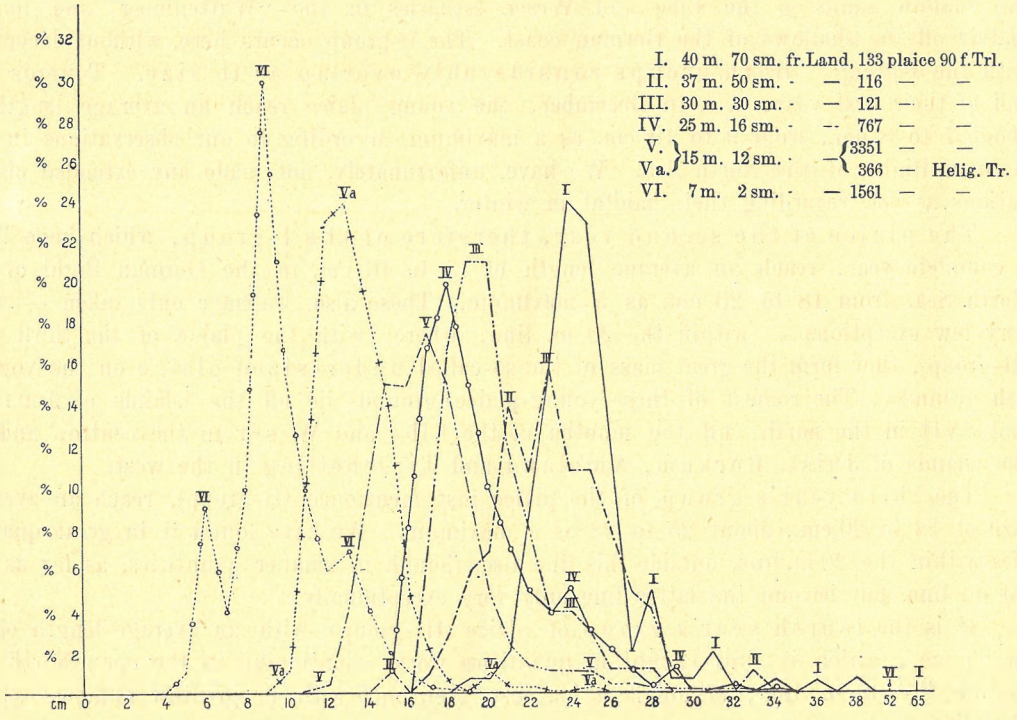

Fig. 2. Analysis of 7 hauls of plaice with the 90 foot trawl (I—V) and the Heligoland young-fish trawl (Va & VI), arranged according to size. The numbers are the percentages of the total caught each haul. The 7 hauls were made on the 23rd and 24th of July 1903, on a line north-west from the island of Juist as far as to the 40 m. line.

The results of the 7 hauls just mentioned, are again represented graphically in the accompanying table (Fig. 3) in somewhat different form, in order to show the relation between the size of the plaice and the depths and distance from land more clearly.

With regard to the distribution of the various size-groups of the plaice in the winter months, we still lack sufficiently numerous observations. It is probable, that the relations are somewhat different from what they are in the summer. Many places of the coastal waters within the 20 m. line, where small and medium plaice, to 30 cm. in length, are caught in quantities in the summer, are fished in winter without result, at least from November to February, as e. g. in the neighbourhood of Heligoland. On the other hand, it has repeatedly been shown by positive results, that relatively more large plaice of 40 to 60 cm. occur even on these grounds in winter, from January to March, than in summer.

Otherwise, the plaice of the older years (6 and over) are relatively, and indeed absolutely, more numerous beyond than within the 40 m. line.

The two sexes of the plaice. Commencement of maturity. We have determined the sex of very numerous plaice and found, (from 43,500 specimens in round numbers), that in every 100, about 53 are males and 47 females on the average. Within our region of observation the females are, on an average, somewhat larger than the males at the same age; how much larger they are, cannot as yet be exactly determined.

So far as the age is concerned, at which the plaice becomes mature, i. e. spawns for the first time, we have not found a single female which did not possess at least 4 white otolith rings and had therefore completed 4 full years, amongst the plaice which were undoubtedly ripe and whose otoliths were examined. On the other hand, we found several males which were ripe after 3 full years. The average size of the plaice at first-maturity in the German Bight of the North Sea is for the males, about 30 to 35 cm., for the females 35 to 40 cm.

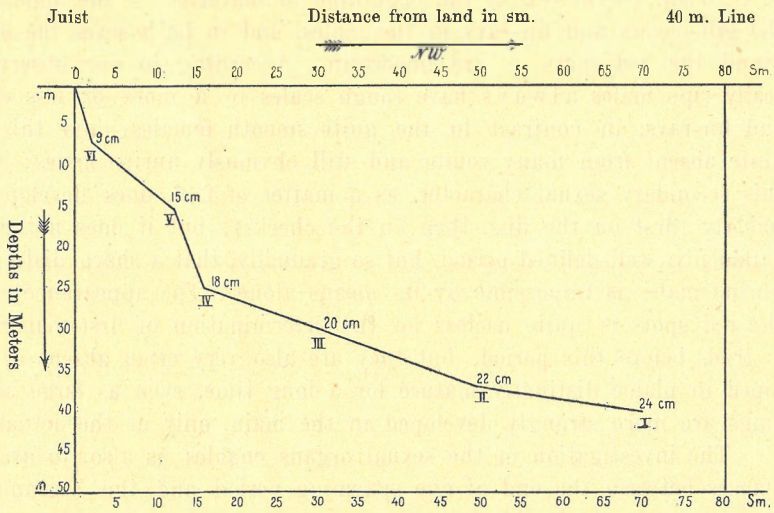

Fig. 3. Distribution of the plaice caught in the 7½ hauls mentioned, graded according to depth, distance of the fishing-ground from land, and their average size.

The yearly increase of growth in the plaice is greatest in the 2nd to the 4th year, especially in the 3rd, according to our investigations; after the attainment of maturity, the yearly growth gradually becomes less and is very small in the older stages. We have examined some large plaice of 66 to 70 cm., which were certainly 20 years old and over that, and had consequently spawned 15 times and more. Unfortunately, we have caught relatively few large plaice, as yet, of over 55 cm. in length, probably because we have made relatively few hauls in the open North Sea and it appears from our observations already mentioned, that the largest and oldest plaice are caught furthest out in the sea.

We have not been able, as yet, to determine from our own observations, at what parts of the North Sea the spawning or fully-ripe plaice collect together in large shoals. The spawning time must occur between January and April, with the maximum probably in February, but hitherto, we could only begin our investigations as a rule in March. A moderate number of large ripe plaice was twice taken in this month, 30 sea-miles N.W. from Heligoland and on the Oyster Bank; a smaller quantity was found c. 65 sea-miles N.W. on the 40 m. line, in the so-called Clay Deep, the southern mud bank on the southern part of the Jutland Bank. These discoveries of spawning plaice were made in

the same region where the plaice eggs were found in March. It may be considered, that a spawning ground has thus been discovered W. and N.W. from Heligoland between this place and the 40 m. line.

At the end of September, we caught a number of large plaice up to 60 cm. in length on the Great Fisher Bank and north of this on the Fladen ground. Amongst these, the spawn was running from one female of 60 cm. in length, and several males were nearly ripe.

We have examined a large number of plaice with regard to the degree of maturity of the sexual products. This is a method partly of distinguishing between the ovaries and testes which have never spawned and those which have spawned at least once, i. e. it can show the limits between the unripe and ripe plaice. Hitherto, this examination of the sexual products has been the only sure way to determine ripeness; the signs given by C. G. Joh. Petersen of the beginning of maturity — the appearance of rough scales on the gill-covers and fin-rays in the males, and in both sexes the appearance of white rings round the red spots — are uncertain. According to our observations, it is true, the really ripe males always have rough scales to a more or less extent on the gill-covers and fin-rays, in contrast to the quite smooth females, and this roughness is as a rule quite absent from many young and still obviously unripe males; it is clear, therefore, that this secondary sexual character, as a matter of fact, does develop at the age of so-called puberty (first on the fins, then on the cheeks), but it does not make its appearance at a sufficiently well-defined period, but so gradually, that a sharp distinction of the ripe from the unripe males is impossible by its means alone. The appearance of the white rings round the red spots is quite useless for the determination of first-maturity; they occur rarely, it is true, before this period, but they are also very often absent or extremely slightly developed in plaice distinctly mature for a long time, even as large as 60 cm. Probably these rings are more strongly developed in the main, only at the actual spawning time.

The investigation of the sexual organs enables us also, to ascertain the interval which elapses between the end of one spawning period and the beginning of another, and the rapidity with which the formation of new sexual products proceeds. We have observed, that the most developed sexual products in the middle of July have reached stage IV on our scale, the majority however, only II—III or III, that is, the eggs were clearly recognisable with the naked eye or at most already flattened against one another. On the 8th of July 1904, we caught 10 large plaice of 40 to 56 cm. in length, north from the Dogger Bank, the sexual products of most of which were in stage III—IV, but one female of 53 cm. and one male of 41 cm. were in stage VII, i. e. had not quite spawned, as numerous ripe eggs were present in the mostly emptied ovary of the one, and some milt still ran from the other.

The migrations of the plaice in the German portion of the North Sea. Direct positive results with regard to the migrations of the plaice, are only given by the marking of the fish and setting them out again into the water. In the 2 years from the 25th of September 1902 to the 24th of September 1904, we have put out 4015 marked plaice in all, 1764 with aluminium rings and 2251 with marks of vulcanised india-rubber. To obtain the percentage of fish returned, we must deduct from these, 800 which were only set out on the 23rd of September 1904. Of the remaining 3215 plaice, 372 were recaught, i. e. 11·6 % of the number set out. These numbers are much too small to give a satisfactory basis for further conclusions, even with regard to the German Bight. We

shall content ourselves here, with stating the most obvious of the positive results of the experiments and with making a few appropriate and, it appears to us, simple and certain conclusions.

The greatest quantities of these 3215 marked plaice, viz. 2004 specimens or 63 %, were set out in only two regions, namely, in the neighbourhood of Heligoland (20 sea-miles round) and in the neighbourhood of Horns Reef. Of 1320 plaice set out at Heligoland, 183 were recaught; no less than 168 at Heligoland itself, within 1 to 443 days of replacing them in the water, and only 15 in other parts of the North Sea. Of the 689 plaice set out at Horns Reef, 90 in all were retaken, 83 at Horns Reef, therefore near to where they were set out, within 1 to 184 days and only 7 in other parts of the North Sea.

Of the 15 plaice set out at Heligoland, but retaken elsewhere, 10 did not leave the German Bight (i. e. Borkum — Tail of Dogger Bank — Horns Reef); the interval between the setting out and recapture varied from 68 to 354 days; the places of recapture lay in all directions. Of the 5 others, which had migrated out of this region only one was retaken to the north, namely, on the Little Fisher Bank after 472 days; the other 4 had gone to the west and south-west, one in 116 days as far as Puzzle Hole (c. 145 s. m.), the second in 313 days, as far as the eastern edge of the Brown Ridges (c. 180 s. m.), the third in 125 days, to off Scheveningen (c. 200 s. m.), the fourth lastly, in 281 days to off the mouth of the Maas (c. 210 s. m.).

Of the 7 plaice set out at Horns Reef, but not recaught there, none were retaken over 120 s. m. from where they were put into the water; 4 had gone to the south, 2 in 28 and 29 days as far as Norderney (88 s. m.); 3 to the north, 1 in 43 days as far as Lökken in the Skager Rak (c. 120 s. m.).

Concerning the plaice set out in other parts of the North Sea than at Heligoland and Horns Reef, some of those retaken are especially remarkable, namely, 7 put out on the Great Fisher Bank at the end of September 1903. With the exception of one, which had gone easterly as far as Holmen's Ground (c. 85 s. m.) in 104 days, all had wandered to the south, one for example in 138 days to the Oyster Bank (c. 170 s. m.), another in 214 days to Graadyb (c. 195 s. m.)

The noteworthy results of these experiments seem to us the following:

(1) The great majority of all the plaice marked were retaken within the same narrow region in which they were set out. Of all those set out in the German Bight, only a few, about 3 to 4 %, were recaught beyond the bonndaries of this region, and most of these had gone to the south, west and south-west along the German and Dutch coasts. It cannot as yet be concluded, therefore, that the great mass of plaice, especially of the still immature, in the German part of the North Sea, make relatively extensive migrations yearly, over 50 to 100 s. m. and more in one direction. The critical value of this conclusion is frankly not very great, as yet. We do not know, for example, whether the plaice set out at Heligoland, and recaught there only after a large number of days, have not in the interval wandered some distance away and returned; we must remember also, that the probability of retaking the plaice marked, is greater where and when the fishery is greater, and smaller when the plaice wander far and distribute themselves in all directions. It is quite possible, therefore, that relatively many more plaice have in reality wandered far beyond the region investigated, than the experiment allows one to suppose.

(2) The plaice may wander very quickly at times from one region to another. The two plaice which had gone from the Horns Reef into the Norderney district (c. 88 s. m.) in 28 days, had travelled daily on an average not less than 3 s. m., and this holds good also for a plaice which had wandered from the Horns Reef towards the Skager Rak, ca. 120 s. m., in 43 days.

To obtain certain conclusions here, many more plaice must be set out yearly than has hitherto been the case, and the experiments must be continued over a larger number of years.

The question whether two or more distinct local races of the plaice exist in the North Sea, has not as yet been closely investigated by us. We have, nevertheless, some grounds for believing, in agreement with English naturalists, that two races occur, viz. a southern plaice, extending from the English Channel to Heligoland, and a northern plaice, extending from Heligoland to the North, the first of which is constitutionally smaller than the second. We have once received spawning plaice of very small size, caught at Borkum by a German sailing cutter in the month of March; one female with running spawn, measured only 22 cm.

Speaking in general from our experiences, the biology of the plaice in the eastern parts of the North Sea presents the following picture. The spawning of the eggs takes place on wide areas from the 20 to the 40 m. line and even further out; from these areas, the larvæ, when they approach the end of their metamorphosis, wander — at least the great majority do — into the warm, shallow waters close to the shore and pass the youngest bottom-stages there. From the end of their first year onwards, the young plaice migrate gradually in a mass, as they become larger and older, further out to sea into greater depths, and one finds, furthest from land in the open sea, scarcely any but the older groups of 5 years and over.

2. The flounder (*Pleuronectes flesus*)

The eggs and larvæ.

The data concerning these are not quite exact, in so far as the eggs could not always be distinguished with certainty from those of the dab and the sprat, nor the larvæ from those of the dab.

In our vertical hauls during the March cruises, 91 eggs and 79 larvæ were taken altogether. Thus, the spawning period for the flounder seems also to be over, for the most part, in March. At Heligoland, we found flounder eggs from the end of January to the middle of April. In agreement with our earlier observations, the main quantities of the eggs and larvæ were met with over depths of 20 to 40 m., yet nearer the 20 than the 40 m. line, thus somewhat nearer land than for the plaice. They were found in this zone, both in the southern and northern parts of the region fished, as far as Skagen, and especially numerous N.W. from Heligoland. Beyond the 40 m. line, they occurred but rarely, and not at all in the open North Sea.

Older larvæ (in the metamorphosing stages) were not yet noticed in March. They appear, however, in the plankton at Heligoland in the second half of April and beginning of May with greater regularity, and are 9 to 12 mm. long. Similarly, isolated specimens were found during the seasonal cruise in May e. g. on the outer Jutland Bank on the 40 m. line. In May, the older metamorphosed stages are already met with in brackish

water and in the rivers, in smaller qnantities also in the "Wattenmeer". The larvæ leave the open sea, as a rule, before the migrating eye has reached to the ridge of the head.

Young and older stages.

Just as we have never found the eggs of the flounder in rivers or in brackish water, we have on the other hand, never observed the first bottom-stages (about 13 to 15 mm. long), and on the whole, the 0-group, except at these places; for example, on the sandy beach at Twielenfleth on the Elbe a little below Hamburg, where we caught them with the hand-nets in very large quantities on the 12th of June 1903. How far the flounder of the 0-group occur in the "Wattenmeer", has yet to be determined. Flounder of the I-group occur together with plaice of the same size in the "Wattenmeer", and occasionally also off this, as well as in the rivers and in brackish water.

Flounder of the older years' groups are accustomed to venture considerably further out to sea; we have met with them regularly, in great numbers, between the mainland and Heligoland as well as close to Heligoland on the rocky ground of the island, especially in autumn and winter, further, in isolated specimens as far out as the 20 m. line all along the German coast.

The flounder grows much more slowly than the plaice, and does not grow to so large a size; we have taken them up to about 50 cm. only. A female flounder of 42 cm. in length, caught at Heligoland in November, was at least already 8, probably however 9, years old according to the rings of the otoliths and the bones; a plaice of similar size is only 4 to 5, at most 6, years old. Corresponding to this, the flounder reaches maturity at a smaller size. We have received spawning flounder of 23 cm. and onwards; in Scotland, mature flounders have been observed at only 18 cm. in length.

We have taken flounders with running spawn in the beginning of January, once in great quantities off the mouth of the Weser just beyond the 20 m. line. In March, we found similar flounders or specimens just spawned, further out to sea, 30 sm. N.W. from Heligoland and at Borkum Reef on the 40 m. line, also in the neighbourhood of Horns Reef and on the southern Mud Bank.

The biological character of the flounder is similar to that of the plaice, but it is more of a coast-fish and passes the first years of its life on the bottom, mostly in brackish water and in rivers. Like the plaice, it spawns always in salt water; its larvæ wander from there during the metamorphosing stages towards the coast and the first bottom-stages, which, like those of the plaice, are always formed perfectly symmetrical, are found in quite shallow water immediately on the shore.

3. The dab (*Pleuronectes limanda*)

Eggs and larvæ.

5124 eggs and 228 larvæ altogether were taken in the vertical hauls of March 1903. The developmental stages of no other fish were taken in such enormous quantities. This arises partly, from the fact that the spawning of this fish is at its height in March, partly because the dab is certainly the commonest fish within the region investigated.

The eggs were found in greatest numbers in the shallower parts of the southern North Sea, between the 20 and 40 m. lines. The maximum, with ca. 800 eggs and larvæ per square meter of surface, was met with to the north of Schiermonnikoog over 27 m. in

depth. A spawning centre obviously occurred here. Very large quantities of eggs were also found, however, to the north and west of this, in the deeper waters between the Dogger Bank and the Dutch-German coast. The quantities decreased further to the north beyond Horns Reef, occurred only sparingly at the Skaw and were quite absent in the hauls over the deeper parts of the Skager Rak. On the Dogger Bank itself they were somewhat scarce, but again became more numerous on its northern edge and then, in the direction towards the Great Fisher Bank, they gradually decreased. They also occurred afterwards at the Great Fisher Bank to the amount of 25 per square meter of surface. Older larval stages were not taken in any quantity worth mentioning.

In May also, we still found very large quantities of dab eggs, though not to such an extent as in March. We obtained the largest quantities of 50 to 70 eggs per square meter on our Stations I (40 m. line, N.W. from Heligoland), II (south-east corner of the Dogger Bank), XV (southern Horns Reef) and V (northern portion of the Great Fisher Bank); at the last place, the spawning had without doubt begun later than in the southern North Sea; (even in August, considerable quantities of dab eggs were taken on the Great Fisher Bank and some single eggs also, at the end of September). We took somewhat smaller quantities, but still worth mentioning, of 20 to 30 eggs per square meter on Stations III and IV (south and west of the Great Fisher Bank) and XIV (south of the Jutland Bank). On the other hand, but insignificant quantities were taken at all the Stations VI to XII lying within the region of the Skager Rak.

Dab eggs were taken at Heligoland from the end of January to the middle of July, in greatest quantities from March to May. Larvæ were also taken with the eggs, as a rule often in very considerable numbers and always in young stages of development, before the formation of the fin-rays. These stages, however, are mostly no longer quite young but are so far advanced, that their separation from plaice larvæ of similar size, as above mentioned, presents considerable difficulties.

In July, further advanced larvæ of the dab were taken in no small numbers at numerous points of the region under survey. They were mostly in the earlier and later stages of the formation of the fin-rays.

Thus, all stages of the metamorphosis were observed, partly from the planktonic specimens, partly from those taken on the bottom, and at the same time a very striking fact was displayed. It appears namely, that the dab is distinct from all other flatfishes in that the stages, where the left eye is already on the ridge of the head, are never taken in the plankton. The dab thus changes over to the bottom-life at an earlier stage of metamorphosis than its nearest allies, the plaice and flounder, in which all the metamorphosing stages are always planktonic. Specimens with the eye on the ridge, usually 15 to 17 mm. long, represent already the earliest bottom-stages. In these, the body-pigment, which develops greatly during the first period on the bottom, is seen in active process of formation.

The earliest bottom-stages and the fully-developed 0-group of the dab have been taken by us, from June on, at very numerous places of the entire region under survey, in the eastern and northern North Sea, from the mouths of the Elbe and Weser as far as to the 100 m. line between Scotland and Norway, in depths from 1 to 100 m. and under the most varied conditions of salinity and temperature, from 31 to 35 per mille and 6 to 13° C. Beyond the 100 m. line, they gradually became scarcer. It was remark-

able, that we took the 0-group of the dab in almost every haul, but in none in very great quantity (100 to 1000), as e. g. whiting, cod, Drepanopsetta etc. of similar age, although we should expect this judging from the enormous number of eggs. The largest quantity we caught, amounted to 57 and was taken in one of our hauls with the Heligoland trawl, which usually lasted from 20 to 30 minutes, on the 21st of July 1904 in 37 m. on the northern portion of the southern Mud Bank. It is further remarkable, that we have taken the youngest stages, the 0-group of the dab, extremely seldom in quite shallow water immediately on the beach, as is the rule with the plaice and also the flounder; almost without exception they were found in deeper water. This great and striking difference between the occurrence of the plaice and flounder on the one hand, and that of the dab on the other, as well as in the distribution of the youngest bottom-stages, is shown also in the older stages. These stages of the dab are distributed over the entire region investigated, intermingled with one another, and never in such a graded distribution from the coast outwards as with the plaice. Young dabs of 6 cm. in length, were found at numerous places from the Great Fisher Bank southwards as far as the beach at Heligoland, to the mouth of the Elbe and to the "Wattenmeer", in common with others of 15 to 20 cm. and larger. At Heligoland, we have several times caught, on previous occasions, thousands of dabs of the I- and II-groups with one haul of our small trawl in about 10 to 20 m. depth. Dabs of the most different sizes are so regular in their appearance in the hauls with the large trawl, that we were once very much astonished at not catching a single dab, either in our large or small trawls, at a spot beyond the 100 m. line, 58° N. L. and 1° 10′ E. L. in 134 m. It seems almost, as if the limit of this, the commonest of the North Sea flat fishes, occurred here. In the Skager Rak, we have taken dabs at even greater depths than 100 m.

According to our observations, the dab becomes mature at a very small size, in the Heligoland region, at any rate, from 16 cm. onwards. We have not yet made very close investigations into the age of the dab.

The picture which the biology of the dab in the North Sea offers us, is essentially different from that of the plaice, as our observations show. The dab appears to be distinctly a stationary fish, as the eggs, larvæ and all the older stages of the adult are distributed uniformly and beside one another over a wide area. A graded distribution of the various age-groups, according to depth and distance from the coast, does not occur; just as little is there a migration of the metamorphosing larvæ from the sea to the coasts in order to reach the bottom there — a phenomen so characteristic for the plaice and flounder.

4. The long-rough dab *(Drepanopsetta platessoides)*

Of the eggs and larvæ of this species, 77 eggs and 8 larvæ altogether were taken in the vertical hauls of the March cruises of 1903. The height of the spawning was, however, not yet passed in March. The greatest numbers, 36 eggs and larvæ per square meter of surface, were taken at the north edge of the Dogger Bank. Quantities of 12 to 20 per square meter were found on the Great Fisher Bank, and of 6 to 8 in the neighbourhood of the Skaw. Further, small quantities were also taken on the outer Horns Reef ground. In the south eastern portions of the North Sea, they were practically absent.

On the May cruises *Drepanopsetta*-larvæ were found regularly, especially to the north of the Dogger Bank and in the vicinity of the Great Fisher Bank; they were mostly

young forms, often in the stage when the fin-rays are forming; eggs were still found in the beginning of May. Some eggs and larvæ still occurred in May at the Skager Rak Stations VI—XII, though fewer than on the Great Fisher Bank.

The largest planktonic larvæ of Drepanopsetta we have caught in the North Sea, measured about 26 mm. in the fresh condition, the smallest fully formed bottom-stage i. e. with completed metamorphosis, was about 24 mm. It may be expressly mentioned here that, just as in the dab so also in Drepanopsetta, the change from the planktonic to the bottom-life often occurs before the completion of the metamorphosis, as we have not rarely found the latest transition-stages already on the bottom.

The 0-group of Drepanopsetta, from about 24 mm. in length onwards, we have as yet never found in the southern parts of the North Sea, but only to the north of the southern part of the Dogger Bank, as far as the slope of the North Sea plateau towards the ocean and the Norwegian channel, in depths of 22 to 148 m. (Skager Rak), mostly on muddy sand or purely muddy ground, with a bottom-temperature of 6° to 9° C. and salinity of 35·1 to 33·2 ‰. We took it in greatest quantities (from 35 to 220 in one 20 minutes haul of the Heligoland trawl) on the Great Fisher Bank (66 m.), and north from the Fladen Ground (134 and 87 m.), less on the slope towards the Skager Rak, still less south of 56° N. L.; only on the western edge of the Dogger, were 12 per haul still caught. All these hauls were made in July; the largest specimens of the 0-group then taken, measured 45 mm. in the preserved condition.

Older Drepanopsetta of the I- and II-groups etc. have only been taken, in our hauls with the large and the young-fish trawl, in essentially the same region in which we took the eggs, larvæ and young bottom-stages. We have taken Drepanopsetta only in quite isolated examples south from the Dogger Bank, on the Oyster Bank and Heligoland Ground, and then always somewhat larger, over 20 cm. in length. Most of them were taken on the 100 m. line and beyond, north of the Fladen Ground and on the southern slope of the Skager Rak, further on the Great Fisher Bank, just where the majority of the bottom-stages of the 0-group were found; lastly, in the deep region north of the Dogger Bank, somewhat less on the northern and southern Mud Bank. Younger stages from 8 cm. on, were found together with the older of 30 cm. and more in length. It is remarkable that we never caught very large quantities in the hauls with the large trawl, at the most, 350 specimens in one haul.

Concerning the age, rate of growth, commencement of maturity, spawning etc. we have as yet made no observations.

The long-rough dab seems, therefore, a flatfish which is limited in its occurrence almost entirely to the northern North Sea. It gives the impression of being a stationary fish, whose biological character is similar to that of the dab *(Pl. limanda)*.

5—6. The cod *(Gadus morrhua)* and haddock *(Gadus aeglefinus)*

The eggs and larvæ of these two species must preliminarily be dealt with together, as they cannot always be separated with certainty according to the species. Their eggs can only be distinguished, when the embryos are so far developed, that they show the pigmentation characteristic for each species. We have therefore not been able to determine, how many eggs of cod, and how many eggs of haddock were contained in each of our hauls, but had to be contented with determining, whether the well-developed embryos

represented only the cod, or only the haddock, or both species. The occurrence of larvæ of both species can always to some extent be settled with certainty. A confusion of the larvæ of the cod with that of the saithe *(Gadus virens)*, which might easily occur, will scarcely come into consideration in the present work, as the saithe plays no great part, probably, in the region investigated in March.

In March 1903, altogether 3750 eggs of these two species were taken in the vertical hauls; amongst these, there were only 114 with certain haddock-embryos and about twice as many with certain cod-embryos. Of the larvæ taken with these eggs, 65 in all were those of the haddock and 534 those of the cod.

From this, the following is clear. As the spawning time of both species, to our knowledge, is essentially the same (January to May), many more haddock larvæ should be taken than in the case in reality, when we consider the relative numbers of the cod and haddock in the North Sea, namely, that the haddock is relatively much more abundant than the cod. We may conclude with certainty therefore, that our March cruises have not, in the main, lit upon the principal spawning grounds of the haddock so much as those of the cod. From observations made in previous years, it appears, that very great masses of haddock eggs occur about the middle of March in the open North Sea to the north of the Great Fisher Bank, between 59° and 60° N. L. On the other hand, we have never found spawning haddock in the southern North Sea, though spawning cod have been taken; consequently, cod eggs and larvæ are certainly to be expected here principally, if not almost exclusively.

Haddock.

In the neighbourhood of the land, as far as to the 40 m. line, unmistakeable haddock eggs and larvæ were taken during our seasonal cruises either not at all, as in the southern part[1] of the North Sea, or only in very small quantities, as in the neighbourhood of Horns Reef and at the Skaw. In the south eastern parts of the North Sea, haddock eggs become somewhat more common towards the centre between the 40 m. line and the south edge of the Dogger, and increase further in numbers in the neighbourhood of the latter. On the Dogger Bank and beyond its northern edge, they were often just as numerous as those of the cod, taken at the same time. Haddock eggs were also found in the few hauls made on the Little Fisher Bank. On the Great Fisher Bank, the number of the well-developed, certain haddock eggs amounted to about three times those of the cod, in a total quantity of 300 eggs of both species per square meter.

Cod.

Cod eggs and larvæ were taken in March at all the regions investigated, almost without exception, from the 70 m. line in towards the land they were distinctly scarcer and were sometimes quite absent. Greater abundance of eggs, to over 100 to 450 eggs and larvæ per square meter, occurred N.W. from Heligoland within and beyond the 40 m. line in the centre of the southern corner of the Dogger (Clay Deep), further, on the north corner of the Dogger and the centre of the Great Fisher Bank. Contrary to expectations, few cod eggs were found on the Jutland Bank and at Horns Reef (10 to 30 per square meter); they only increased to the west of this in the neighbour-

[1] In the Heligoland plankton, we have previously taken but few isolated haddock eggs — 1—2 yearly.

hood of the 40 m. line (40 to 100 p. square meter). In the neighbourhood of the Skaw, as in the true Skager Rak, their number was very small.

Eggs and larvæ of cod and haddock in May.

Both the eggs and larvæ of these two species were still taken at most of the German Stations in the beginning of May; altogether, there were about $^2/_3$ as many larvæ as eggs, a sign that the spawning time was essentially already past.

At Station I, some few eggs only were taken, at Stations II to VI but increasingly towards the north, eggs and larvæ of both species. The maximum, at Station VI (northern Fladen Ground) amounted to 72 eggs, as well as 6 larvæ of cod and 48 larvæ of haddock per square meter. Considerable numbers of haddock (24 per square meter) were also found on the west slope of the Great Fisher Bank (St. IV). On the Skager Rak stations, eggs and larvæ of both species were found in very varying quantities. On the Little Fisher Bank, the Jutland Bank and at Horns Reef (Station XIII—XV), they also occurred, but in very small numbers. It is very remarkable, that the size of the larvæ of the cod and haddock, taken in the May hauls, did not exceed a total length of 10 mm. as a rule.

The fully formed cod.

The smallest fully formed bottom-stages of the cod taken by us, had a length of 25 mm. in preserved condition (alcohol); this was in the middle of July. The average size, at which the larval stage of the cod ends, in the region under our survey, cannot as yet be stated with certainty, owing to the lack of the necessary complete data.

We have searched at very many different places (over 100) for the young bottom-stages and the 0-group of the cod, in our region from the mouths of the Elbe and Weser as far as the Dutch coast, N. W. of the Dogger Bank and to the 100 m. line, over this easterly as far as the Skager Rak, chiefly in June and July in the open sea, but also from August to December on the coasts of the German Bight. The noteworthy result of these observations, is, that the 0-group of the cod is distributed over the whole of our wide region in the summer and autumn months, and occurs, though not at every part of the sea, yet, in each of the somewhat larger regions. The smallest bottom-stages under 30 mm. in length, however, have as yet only been found by us in the northern North Sea (northern Mud Bank and Great Fisher Bank). This may only arise, because we have insufficient observations for the southern North Sea for June and July, We found specimens of 30 mm. and onwards at several parts of the southern North Sea. e. g. between Heligoland and the Dogger Bank on the 40 m. line, on the southern Mud Bank as well as far to the north, on the 100 m. line. We have found specimens of 40 mm. and onwards, from the middle of June to the beginning of July, also quite close to the land, e. g. at Lister Deep near Sylt in 10 m. depth in great quantities, and in the mouths of the Ems and Elbe, in the latter river, as far as the opening of the North Sea-Baltic canal.

The greatest quantities of these young cod of the 0-group — from 100 to over 200 specimens in one haul of our young-fish trawl — were taken in the first half of July, on the Great Fisher Bank and the northern Mud Bank (27 to 66 mm. long); many more also (from 40 to 100 in one haul), in the middle of June between Heligoland and the Dogger Bank on the 40 m. line, as also in the Lister Deep at Sylt, and in the Skager Rak at 108 m. in the middle of July; somewhat fewer (20 to 40 in one haul), on the southern Mud Bank, N. W. from Heligoland on the 40 m. line, on the sands at the mouth of the

Elbe, in the Clay Deep at the south corner of the Dogger, and in the deep water of the north-west corner ot this bank, as well as on the eastern parts of the Oyster Bank etc.

The temperature and salinity of the water, where these small cod were taken, varied from 6° C. and 35 ‰ salinity in the region of the Great Fisher Bank, and beyond the 100 m. line in depths of 70 to 134 m., up to 20° C. in the shallower coastal waters of the southern North Sea at 10 m. depths, and down to salinities of 31·30 and less pro mille in the mouth of the Elbe.

The places, where we obtained most cod of the 0-group in June und July, agree in general with those spots, where most eggs and larvæ had been fished previously. Nevertheless, it is indisputable, that, as the eggs and larvæ were not found in the immediate neighbourhood of the coast, the young fry must have spread out from the regions, where they were born and thus succeeded also in coming close into the land.

It is remarkable, that we caught practically no young cod in our hauls with the surface nets (Hjort's net, three-otterboards net), which brought us numerous other young fish of the year. We obtained some few specimens, of 3 to 5 cm. in length, but three times with these nets, namely, once respectively on the Fladen Ground, at Horns Reef and on the east edge of the Dogger Bank, in the middle of July. It seems, therefore, as if the pelagic life of the young cod in the North Sea ceased soon after the completion of the metamorphosis, and that, when they have once changed over to the life on the bottom, they rise again but rarely into the upper water-layers.

The further fate of the 0-group has been investigated by us on the German coast and at Heligoland. Whilst we found them in June mostly 3 to 5 cm., at the highest 8 cm. long, in July mostly 4 to 6 cm., at the highest 11 cm., in August some were already 12 cm. and in September 13 cm. At the beginning of October the most of the young cod on the coasts of the mouth of the Elbe were 10 to 15 cm. long, the smallest but 7, the largest 18 cm. We found them at Heligoland to be from 6 to 18 cm. in length in October and from 12 to 20 cm. in November. It may reasonably be doubted, whether all these small cod belong still to the 0-group, and not — at least some — to the I-group, and this can only be solved by close investigation of the age on the otoliths and bones. We have already made such determinations, but not yet in sufficient number as the cod is a very difficult subject in this regard. We may, however, believe, e. g. that a small cod of 17 cm. in November certainly belongs to the 0-group, another of 20 cm. on the other hand already to the I-group. We have reasons for believing, that the small cod at Heligoland are on an average about 14 cm. at the end of their first year, 18 cm. perhaps at a maximum and 8 to 10 cm. at a minimum. Cod of the 0-group kept in our aquarium grow very quickly in the summer and autumn, especially with good feeding, e. g. from the beginning of August to the middle of September not less than 1 mm. daily on an average, from the middle of September to the end of October, still $^1/_2$ to $^1/_3$ mm. daily; in the middle of November we had cod of the 0-group in our aquarium up to 15·5 cm. In the open sea, the growth would certainly be greater.

Shortly before closing this report, we were able to make some further hauls with the young-fish trawl on different stations of the seasonal cruises, from the 14th to 23rd of November, and in some of them we captured the cod of the 0-group. In the deep sea north of the Dogger (69 m., Stat. III), these measured 6 to 13 cm., at St. XI (southern slope of the Skager Rak) 7—9 cm., at Stat. XV (off Sylt, 25 m.) 6 to 18 cm.; the two largest

of these — 17 and 18 cm. — might belong to the I-group, whilst those of a complete series from 6 to 15 cm. are certainly all of the first year.

Cod of the I-, II- and III-groups.

We estimate the average length of the I-group of cod of the southern North Sea at 20 to 25 cm. during their second summer, that of the II-group in their third year at about 35 to 40 cm. Both of these groups will naturally overlap considerably as to size, just as with all fishes. With regard to the occurrence and distribution of these three groups (of the second to the fourth year), it is a remarkable result of our hauls, that all three groups of the young, immature cod are found everywhere intermixed over the whole region under survey, and that there is no regular division according to age and size. We have taken cod of 16 to 25 cm., of the I-group therefore, both in depths over 100 m. on the Fladen Ground and in the Skager Rak, and at the German coast and at Heligoland, also on the Great Fisher Bank, to the west and east of the Dogger Bank, at Horns Reef and elsewhere — and the same holds good for the other groups. At Heligoland, especially, all three groups are met with, both close to the rocky ground on the island and further off the whole year through; the fish of the II- and III-group are relatively more abundant further out to sea, than those of the I-group. The two former groups, therefore cod of about 30 to 50 cm. in length, are taken in quantities with hand-lines from spring to late autumn.

On account of our insufficient observations up to the present, we cannot yet state with certainty, at what age, and at what size the cod spawn for the first time in the North Sea, or in the southern North Sea in particular, chiefly because we have not yet had the opportunity of catching large quantities of spawning cod, or cod approaching ripeness, or even those which had spawned. It is certain, that we have taken such cod in small number from 60 cm. onwards in length, and it is probable, that some spawn for the first time at 50 cm. or a little greater length. We learn from the bones, that a cod 50 cm. long has lived at most 4 complete years, and we believe — provisionally — that the cod does not spawn for the first time, until it has lived 4 complete years, probably at the end of its 5th, at latest the 6th year. We kept a female cod in our Heligoland aquarium from September 1902 to June 1904; it spawned there in January 1904 (but not in the previous year) and measured, in June, 66 cm. in length. Its age, according to the vertebræ and bones, was $5^1/_2$ years. It had therefore spawned at the end of its 5th year for the first time, but the sexual products had begun to ripen in autumn 1903, therefore after the completion of the 4th and in the course of the 5th year.

Our further investigations on the age permit us to take as tolerably certain, that a North Sea cod of 75 cm. in length is at least 7 years old, one of 85 cm. at least 8, of 95 cm. in length about 9, and of 100 to 110 cm. in length at least 9 to 11 years old. Certainly, the yearly increase of growth also decreases here after the beginning of maturity.

Such large and older cod have been found within the region under our survey, mostly far distant from land in the open North Sea in summer; in winter, however, especially on our March cruises, they are also common near and on this side of the 20 m. line and often quite close to the land, e. g. close to Heligoland, Horns Reef etc. It is known, that very large and dense shoals of large cod, quite near spawning, occur on the trawling grounds to the north and south of Horns Reef between the 20 and 40 m. line in winter, especially in December, and give occasion to a very rich fishery. We have, unfortunately, not yet had

the opportunity of fishing there at this time for the mature cod; we have met with these on our seasonal cruises, only in March 1903 and 1904, and always in small quantities only, as also on the fishing grounds of Borkum Reef, Oyster Bank, Heligoland, Sylt inner ground, Horns Reef and southern Mud Bank.

The biological picture, which we obtain of the cod in our region from the investigations sketched above, is strikingly similar to that of the dab *(Pl. limanda)*. The cod appears here as a stationary fish, whose developmental stages from the egg to the spawning fish are all passed through within the same region; to such a degree, indeed, that all the stages are found intermingled at the most different places, without anywhere or at any time, showing a graded distribution according to age and depth. Only the larger and older specimens seem to make any migrations worth mentioning, as, in the summer they live more in the open sea, e. g. in the south-eastern parts of the North Sea, whilst in winter — assuredly for the purpose of spawning — they frequent the shallower parts of the region from the 40 m. landwards. The largest cod of 1 m. and more in length and 10 and more years old, live furthest from land apparently and in the deepest part of the region.

We are not yet able to show positive results concerning the migrations of the cod by means of the marking and setting out of fish.

The fully formed haddock.

The smallest fully formed young haddoch taken by us, measured 24 to 26 mm. in preserved condition. We are unable to state, as yet, at what average length the transition from the larvæ to the adult form is completed.

The occurrence and distribution of the fully formed haddock of the first year — of the 0-group — shows an important and very striking difference from that of its two nearest allies, the cod and the whiting *(Gadus merlangus)*. We have hitherto taken them only north of 55° N. L. and mostly far out to the north of 57° N. L. in and over the great depths from 60 to 100 m. and more. We have captured but one single specimen south of the Dogger Bank, on its south-eastern edge in the so-called Clay Deep from 47 m. (middle of July, 1903), also once a single specimen on the southern Mud Bank in the three-otterboards net (middle of July, 1904).

The greatest quantities were found in the first half of July, 1904, north from the Fladen ground on muddy ground at 134 m.; 2 hauls of our Heligoland trawl, of 20 minutes in all, brought up here 237 small haddock of the 0-group from 3 to 10 cm. long, most of them 6 and 7 cm. Large quantities (from 40 to 50 in one haul) were also taken, further to the north of the first-named place in 106 m.; otherwise, we mostly obtained only 1 to 10 specimens in one haul with the ground-nets. It was remarkable, that we brought up but very few young cod at the places, where we obtained many young haddock on the ground, and conversely, where many cod of the 0-group were found, very few haddock were taken. The former occurred chiefly on sandy, the latter on muddy ground. Another remarkable difference in the occurrence of the 0-group of cod and haddock was also observed; in our surface nets (three-otterboards net and Hjort's net,) we obtained the cod very rarely, as already mentioned, and always only in some few specimens, where the haddock was often abundant. Our greatest catch of young fish with the three-otterboards net was made on the slope of the Great Fisher Bank towards the Skager Rak over

a depth of 103 m. on the 12th of July 1904, and brought up over 1000 young fish in one hour from 1 to 15 m. depth, consisting of about 900 whiting and 100 haddock, the latter from 3 to 11 cm. in length; cod were quite absent. On the following day, further to the east on the southern edge of the Skager Rak, in 184 m., we obtained not a single haddock with the ground net, but 29 haddock of 3 to 10 cm. in length with the three-otter-boards net. A haul with the Heligoland trawl on the Fladen Ground in 83 m. depth, on the 9th of July, only brought up some few whiting; a haul with the three-otterboards net at the same place, in about 1 to 30 m. depth, gave several hundreds of young fish, mostly whiting, but also 17 haddock from 3 to 6 cm. in length.

We may therefore conclude, that the young haddock of the North Sea retain the pelagic habitat after the completion of the larval stage longer, and up to a greater length (11 cm.) than the cod, or otherwise, comes up from the bottom into the upper water-layers oftener than the latter. It is similar in this to the whiting.

The salinity of the water at those places of the North Sea, where we caught young haddock of the 0-group with the ground-net, varied from 34·6 to 35·1 ‰ and the corresponding temperatures from 6·5° to 7·1° C. On the other hand, the salinity and temperature of the surface water-layers, in which we found the 0-group with our pelagic nets, varied from 32·1 to 35·1 ‰, and from 12·4° to 15·7° C. The low surface salinity of 32 ‰ was found in the Skager Rak (Baltic stream), where 35 ‰ was found at the bottom. As some haddock were also taken at the bottom here, though very few, we may conclude, that the young haddock, from 3 to 10 cm. in length, may stand well a somewhat great and sudden change in the salinity and temperature of the water.

From lack of sufficient material, we cannot as yet say with certainty, what average size the young haddock reach at the end of their first year. Similarly, our investigations concerning the older stages of the haddock from the I-group to the spawning age, are also very deficient, especially as regards the determination of the age from the otoliths and bones. Nevertheless, we have some certain discoveries to show, and these allow some few, but important conclusions concerning the biology of this fish.

In July, 1904, we caught not only many haddock of the 0-group, but also large quantities of the succeeding age-groups, in the north-western part of the North Sea on the 100 m. line with our shrimp-trawl. These captures, which along with some smaller, we were able to make in various parts of the northern North Sea in the middle of November of this year, shortly before closing this report, gave some data regarding the relation between the 0-group and the I-group. The accompanying curve (Fig. 4), gives a graphic representation of the size-relations of the 1836 haddock taken in these hauls. From the hauls I and II, which were made at the same place, but the one with the Heligoland young-fish trawl, the other with the large trawl, we see at once, that the first net (I) with its small meshes catches chiefly the small and smallest fish from 3 to 10 cm., representing here the 0-group of the haddock, but the larger, belonging to the I-, II- and succeeding groups, in smaller numbers. The large trawl (II) has taken no haddock under 14 cm., those from 15 to 21 cm. chiefly, also a goodly number from 24 to 32 cm. in length.

We learn from this table the following: (1) The curve, giving the measurements of all the haddock taken on the 10th of July, shows two deep and one shallower depression and two high and two lower maxima. The deep minima lie at 11 and at 22 and 23 cm.; they obviously separate the 0-group, with the maximum at 6 cm., from the I-group with

the maximum at 19 cm. and further, the latter also from the II-group with a maximum at 26 cm. The shallow depression at 30 cm. seems to indicate the boundary between the II- and III-groups, with the apex of the latter at about 32 cm. From this, the haddock taken in July of 3 to 10 cm. in length, would be 2 to at most 6 months old (0-group), those of 14 to 21 cm. 14 to 18 months (I-group), and those of 23 to 27 cm. 26 to 30 months old (II-group). (2) In November, the size-groups are essentially different. The curve (III) clearly shows a very deep depression at 20 and 21 cm. and another shallow one at

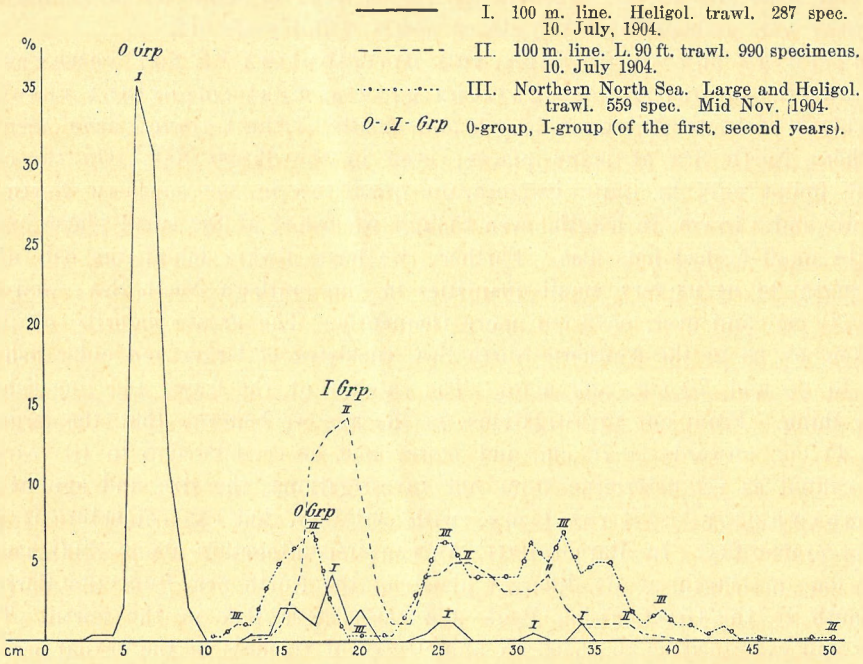

Fig. 4. Analysis of catches of haddock in the northern North Sea, according to length and number. Percentage curves. 1836 specimens altogether of 3 to 50 cm. in length. I und II were made — in July, 1904 — at the same place, one after the other (58° 0′ N. L. — 1° 10′ E. L. 100—134 m.), the first with the Heligoland young-fish trawl, the second with the large 90 ft. trawl. III is composed of 4 different hauls made, from the 10th to 22nd of November 1904, at different parts of the northern North Sea in 64 to 100 m., partly with the young-fish trawl, partly with the large trawl.

27 to 30 cm., also 3 distinct maxima at 17, 26 and 33 cm. It is certain, that the first maximum at 17 cm. represents the 0-group, which have thus grown, on an average, from 10 to 11 cm. in the four months from the middle of July to the middle of November, therefore very considerably. The maximum at 26 cm. may represent the I-group, which have therefore grown about 7 cm. on an average, in the four months. Whether the maximum at 33 cm. represents the size of the II-group must remain uncertain. (3) The 0-group in November and the I-group in July are relatively but little distant from one another as regards average size, namely, only about 2 to 3 cm.

Although it is certain, that this separation of the various age-groups in July and November will have to be altered on further more exact investigations, especially the position of the minima and maxima of the curves, some correct conclusions may yet be drawn

already, namely firstly, that the young haddock of the 0-group grow very quickly in the months of the summer and autumn, and may be about 14 to 17 cm. long at the end of their first year, and secondly. that the rate of growth must be much slower in the winter and spring, perhaps only half as great or even less.

Our investigations of the age of the haddock, from the otoliths and bones, are as yet, too defective to permit of certain results. Nevertheless, we have found, that haddock, taken in March of about 25 cm. in length, were at least 2 full years, perhaps already 3 years old, according to the rings on the bones; those of about 30 cm. in March, were at least 3 years old, perhaps already quite or nearly 4 full years old.

Concerning the occurrence and distribution of the youngest stages of the haddock, our investigations give a most important result. These small haddock of 14 to 20 cm. in length and mostly of the I-group, have been taken in the northern North Sea at many places, even in the Skager Rak. On the other hand, they were found only in quite insignificant quantities in the southern North Sea, and none at all under 18 cm. in length, even though we fished at the same places with various nets, quite small-neshed nets also. Further, we have always found the fish of 20 to 25 cm. in length, to be in very small quantities in the southern North Sea, and only those of 25 to 30 cm. and over, occurred more frequently. The great majority of all the haddock, taken by us in the southern North Sea, consisted of larger and older fish of 35 cm. onwards to 60 and 70 cm. and more. The catches of the trawl and line-fisheries show the same thing. From our investigations on the age we believe, that the larger haddock of about 45 cm. onwards to 70 cm. and more must be considered 5 to 10 years old.

We cannot as yet determine from our investigations, the size and age at which the haddock spawns for the first time, with certainty, but can conjecture it with some amount of probability. In March, 1904, we captured altogether about 1500 haddock from 16 to 66 cm. in length at six different places of the North Sea from the Barren Ground in the south to the Great Fisher Bank and the Skager Rak in the north. These were measured and examined as to their sex and degree of ripeness of the sexual products. The great majority of these haddock were found at the spawning time, i. e., they were almost ripe, had running spawn or were even spent. The smallest female distinctly ripe, measured 28 cm., the smallest ripe male 26 cm. The great majority of all the ripe fish measured, however, 32 to 36 cm. It may be considered certain, that the majority of these were going to spawn for the first time in their life. They were thus about 33 to 34 cm. long on an average, at first-maturity, and the majority were probably just four years old, in any case three.

It is only the hauls just mentioned, made in March, which have given some conclusions regarding the places, within the region under our survey, where large quantities of spawning haddock occur. With exception of the haul on the Barren Ground, these were all made in the northern North Sea. Otherwise, with quite insignificant exceptions, we have never found spawning haddock in the southern North Sea. Numerous large haddock (to over 90 cm. in length) used, in earlier years, to be taken in quantities with long-lines by the Heligoland fishermen and by ourselves on the fishing-grounds in the neighbourhood of Heligoland, in autumn to December, and in spring from the end of March onwards, but only extremely seldom were

any found with almost ripe or quite ripe sexual products. · Apart from these, all those taken in autumn were in various stages of ripeness, those taken in the spring were all spent.

We have several times caught medium and large haddock on our June and July cruises; so far as their sexual products were examined, they were all spent or — in July — in process of developing new sexual products for the ensuing spawning period.

We may therefore conclude with considerable certainty, that the mature haddock spawn only exceptionally in the southern North Sea, but that, they not only occur there in the last months of the year before the spawning time, often in great quantities, but also return after the completion of spawning, often in very large swarms.

We can thus recognize distinct migrations from and to the spawning and feeding regions; and these migrations extend at times over very great distances. Positive observations on the wanderings of the haddock, by means of marking and setting out fish, have not yet been made by us.

The picture, which the above investigations present to us regarding the biology of the haddock, is essentially different from that of the cod. The haddock is distinctly a migratory fish. It is born in the northern, deeper parts of the North Sea, in greatest quantities on both sides of the 100 m. line, and it always passes here the first and, with few exceptions, also the second year of its life. It is only from the beginning of the third year, but mostly only in the fourth, that it undertakes further migrations; thus, the haddock come to frequent the shallower regions in the southern North Sea, in seeking for the feeding places there. When they are becoming ripe, they return again to the northern North Sea in the course of the winter, in order to spawn there (from January to April). On the completion of spawning, they migrate again to the south to the feeding places — and it appears, as if this to and fro migration were repeated regularly each year.

7. The Whiting *(Gadus merlangus)*

The eggs and larvæ of this species may be regarded as rightly determined for the most part, although, in many points of the region investigated, especially in the May hauls of the northern part of the North Sea, confusion with other gadoid eggs of the pollack — poor cod groups (*pollachius-minutus*) is not impossible; the eggs and larvæ of these groups are insufficiently known, but are probably very like those of the whiting.

In the quantitative hauls of March, 2000 eggs and 257 larvæ were taken altogether. By far the greatest quantities, from 100 to over 400 eggs and larvæ per square meter, were taken in the centre of the south border of the Dogger, in the so-called Clay Deep, where great masses of the eggs of cod and dab were also found. Apart from these, about 130 eggs and larvæ per square meter were taken 40 miles N. W. from Heligoland in over 40 m. depths, of which the great majority (2/3) were larvæ. Both stations seemed spawning regions, as the eggs were taken but sparingly in the intervening regions.

The quantities of eggs taken at all other parts of the region investigated were smaller, although they never quite failed in the south-eastern North Sea. As with the cod eggs, they were very rare or were quite absent in the immediate neighbourhood of the coast. North from the Dogger and from Horns Reef, the whiting eggs were met with only in small quantities; their number was also very small on the Great Fisher Bank and in the Skager Rak. They were absent at the Skaw.

At the beginning of May, eggs and larvæ of whiting occurred at almost all the stations, and the eggs so outnumbered the larvæ, that the end of the spawning period seemed far distant. The greatest quantities were found on the northern part of the Great Fisher Bank at Stations V and VI with 98 and 204 eggs and larvæ per square meter, then at Stations IV and II west of the Great Fisher Bank and on the Dogger Bank, with 44 eggs and larvæ per square meter.

At the end of May, eggs were still found, though in smaller quantities. A maximum with 59 eggs and larvæ per square meter occurred at Station V in the Skager Rak. Some eggs were still found even in the middle of June 1904, in the southern North Sea. The larvæ were in all possible stages of development, even to the fully formed little fish. Young forms of 20 to 23 mm. were taken already at the end of April.

We took the whiting eggs at Heligoland from the end of January to the end of May.

The 0-group of the whiting (first year). As in all gadoids, so with the whiting, the boundary-line between the later larval stages and the fully formed young-fish cannot be sharply drawn; it lies between 15 and 20 mm. in length. We have found these youngest stages of the fully formed whiting and the larger fish of the 0-group in the summer months, especially from the beginning of June onwards, everywhere in the entire region under our survey, from the mouths of the Elbe and Weser to the 100 m. line and mostly, in greater quantities than any other young of the food-fishes. We took them in great quantities both with our young-fish trawl (up to 1000 and more in half an hour) and our pelagic nets; once, we took 900 specimens in an hour with our three-otter boards net. The following remarkable phenomen occurred in our numerous hauls in July. The smaller and younger whiting of 2 to 5 cm. in length, were taken pelagically in far greater numbers than on the ground, where, as a matter of fact, they were very rarely observed under 4 cm. in length, and only from 5 cm. and more in great quantities. For example, amongst the 900 whiting taken in the great haul with the three-otterboards net, as mentioned above, only about 50 specimens were from 6 to 7 cm. in length, all others measured only 2 to 5 cm. the most 3 and 4 cm. Conversely, of several thousands of young whiting, which we caught in 2 hauls with our young-fish trawl on the southern Mud Bank in July 1903, only a small percentage was under 5 cm. in length, most measured 5 to 8 cm. Further, it was found to be characteristic of many of our pelagic young fish hauls, that the largest fish taken in them were almost always whiting, and that our three-otterboards net caught those from 20 to over 25 cm. by no means seldom.

We may therefore conclude, that the whiting of the North Sea retains the pelagic habit for a very long period in its youth, even longer than the haddock and longer than the cod especially, and that it often rises in great quantities into the upper water-layers after its first descent to the bottom, even in the older stages. In agreement with this, we have noticed in our aquarium, that young cod and whiting of the 0-group show a characteristic difference in their habits. Whilst the young cod prefers to remain on the bottom and to seek hiding-places between stones and plants, the whiting always moves about more in the middle and upper water-layers.

It is well known, that the young whiting, so long as they are still small and lead a pelagic life, are almost always found together with jellyfish (mostly *Cyanea*). Whether this characteristic resort of the young-fish, close beside the jelly-fish, even between their tentacles— as we have often remarked in our aquarium and sometimes near the surface in the

open sea — is a kind of true commensalism or not, and of what kind, is not yet known. It is certain, that we have practically, never taken the pelagic whiting in our surface net without also taking the jelly-fish, and usually, the more whiting there were the larger was the number of jelly-fish. For the rest, we are unable as yet to say definitely, from lack of definite observations, how far the young fish of other gadoid species, e. g. young haddock and cod, also live together with jelly-fish; wa may only mention, that all our pelagic young-fish hauls contained jelly-fish, and that haddock and cod, if they occurred in such hauls, were always found together with whiting, and the latter was in the majority almost with exception.

When the young whiting of the 0-group descend to the bottom of the sea, they also succeed in getting to the coast very quickly and even tolerably far into the mouths of rivers. We have, for example, found them in quantities, from 55 m. in length and more on the sands of the Elbe estuary along with young plaice, in July and August, and once together with cod as far as the opening of the North Sea — Baltic canal. They penetrate also into the "Wattenmeer" and in autumn are in very great quantities, in length from 6 to 15 cm., both here and on the entire coast of the southern North Sea; at this time, they already mix with the I-group and with small plaice and cod. Many hundreds may be taken here with one haul of the narrow-meshed ground net. Small shrimps (*Crangon*) form part of the chief food for the young. Beyond the rocky ground at Heligoland also, we have found young whiting of the 0- and I-groups in great quantities in autumn.

From lack of sufficient and suitable investigations we are unable as yet to say, how large the whiting is on an average at the end of its first year, and how large the various older stages (I-group etc.) are. We have observed in our aquarium, however, that the whiting grows relatively very quickly in its first year. A young and well-fed whiting, for example, grew from 60 to 115 mm. in length from the 30th of July to the 19th of September i. e. in 50 days, therefore on an average 1·1 mm. daily. In the middle of November, whiting of the 0-group reared in our aquarium measured up to 14 cm. in length.

With regard to the occurrence and distribution of the older stages of the whiting (from the second year onwards), it appears from all our observations, that they are distributed like the 0-group over the entire region investigated, and the age-groups show no separation in place or time. We have taken whiting of all sizes and stages, beside one another, both beyond the 100 m. line in depths of 100 to 200 m. and in close proximity to Heligoland and the German coast, and usually in no less quantities in the depths of the northern North Sea than in the shallow parts of the southern.

We have not yet closely investigated the size and age at which the whiting are ripe for the first time. Whiting with running spawn have often been taken at various places in the region under our survey, from March to June; in great quantities at Heligoland from March to May at sizes from 18 to 49 cm. As spawning whiting have already been observed at a length of 20 cm. and less, we may conclude with tolerable certainty, that the maturity of this gadoid begins earlier than with the cod and haddock, probably at the end of the third year, perhaps exceptionally and in the smaller males even earlier.

The biological picture we get of the whiting, agrees in general with that of the dab and cod. Like these two species the whiting is a stationary fish, whose eggs, larvæ and fully-formed individuals of all ages occur everywhere at the

same spots, and intermingled with one another, within the region investigated. The whiting has this in common with the dab especially, that it is the most abundant species of its genus in the North Sea. A specific characteristic of the whiting, which distinguishes it, especially from the cod but also from most other gadoids, is the strong tendency towards a pelagic habit of life during the first year, which, also, it never seems to give up entirely in later years.

8. Concluding remarks

We have still to describe a large number of observations, made in the region under our survey, concerning a number of other food-fishes, above all the turbot, sole, witch (*Pl. cynoglossus*), sprat and herring, but these observations have not yet been so far worked up, as to enable us to make a comprehensive report regarding them.

If we summarise the results of our investigations in the German portion of the North Sea, described briefly in preceding pages, it appears, that many important facts concerning the distribution of the food-fishes could already be determined in the two years since the beginning of our investigations, and that a view has been gained of the right course to be taken, in order to advance. It is also clear, however, that very great gaps have yet to be filled up in our region by new and continued observations, in order to attain the end placed before the international investigations. As regards the earliest developmental stages, the eggs and larvæ of our food-fishes, more frequent observations must above all be made in the months of January to March, and especially in February, in the northern North Sea; further, special attention must be paid to the, as yet, but little known eggs and larvæ of certain gadoids, e. g. of the saithe (*G. virens*), pollack (*G. pollachius*) and of the pouts (*G. luscus*, *G. minutus* and *G. Esmarki*). As regards the young fish in their first year, similar investigations are desirable in May and June, especially in the northern North Sea, in order to know, more accurately, the transitional stages between the larvæ and earliest bottom-forms, even for the haddock and cod, and their occurence as regards the especially latter species; these are specially necessary at such parts of the sea-bottom, where the ordinary fishing apparatus cannot as yet be used. With respect to the occurrence, migrations and spawning of the older stages of the food-fishes, the following investigations have still to be made. Research-cruises must be undertaken in the winter months, in order to determine, for the North Sea, the regions and periods at which great collections of spawning plaice, cod and haddock occur. The number of marked plaice set out must be considerably increased and similar experiments have to be made with the cod and haddock.

The method of determining the age of the food-fishes has to be extended and applied to more species, and at the same time, their rate of growth must be tested experimentally. Lastly, more exact investigations are to be made regarding the proportion of the sexes, and the fertility of the fishes and also, regarding the various stages in the maturation of the sexual products.

Additional note

In the preceding report, an explanatory remark has been omitted from Section C ("Statement of Results") p. 15, with regard to the extension of the cruises made by the Biological Station in the North Sea, in search of the eggs of fishes. This remark is necessary, so that others may know in what parts of the North Sea we have made hauls for fish-eggs. The following note may be expressly added, therefore:

In March 1903, these cruises extended from Heligoland in a north-westerly direction over the Dogger Bank as far as to 56° N. L., and in a northerly direction, as far as the neighbourhood of Horns Reef and the Jutland Bank. Further, some hauls were made to the east and to the west of Skagen. In March 1904, egg-hauls were only made incidentally, and that, chiefly at the 17 fixed trawling stations of the "Poseidon", with exception of the extreme west and south. Thus, the occurrence of the eggs and larvæ within a large part of the North Sea, especially the whole of the very important north-western part, has practically been omitted, so far, from our investigations.