# X.—POPULAR EXTRACTS FROM THE INVESTIGATIONS OF THE COMMISSION FOR THE SCIENTIFIC EXAMINATION OF THE GERMAN SEAS.

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## PREFACE.

The following treatise has been prepared at the special request of the Minister of Agriculture, &c., with a view to making some of the more important results of our investigations accessible to *practical fishermen*, and for the purpose of encouraging them to aid us by all the means at their command in continuing our work in the interest of the salt-water fisheries.

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[The Ministerial Commission for the scientific examination of the German waters: H. A. Meyer, K. Möbius, G. Karsten, V. Hensen.]

## A.—THE PHYSICAL CONDITION OF THE BALTIC AND THE NORTH SEA.

At first sight the knowledge of the condition of the sea-water seems to be of small importance for the practical salt-water fisheries. Fishing has been carried on by men for a long time without any special regard to the temperature, saltness, and currents of the sea; experience and accident taught men the seasons and places where fishing could be carried on with hopes of good results. No one thought of inquiring whether the success of the fisheries, varying every year, had something to do with the changes in the condition of the sea-water; and yet it is an undoubted fact that an intimate connection exists between the two. It is not purely accidental that many plants and animals found in a belt extending from the eastern shores of the North Sea to the western shores of the Baltic vary greatly in size and strength, according to the more or less plentiful food or the larger quantity of solid particles in the sea-water; nor is it accidental that the changing condition of the water in one and the same place produces a varying development of plants and

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* *Gemeinfassliche Mittheilungen aus den Untersuchungen der Commission zur wissenschaftlichen Untersuchung der deutschen Meere. Herausgegeben im Auftrag des Königlichen Ministeriums für Landwirthschaft, Domänen und Forsten. Kiel*, 1880.—Translated by Herman Jacobson.

animals. Warmth, which furthers the rapid development of plants and small animals which serve as food for fish; currents, which carry plants and embryonic animals in constantly varying quantity to the fishing-places, are some of the causes which necessarily must exercise an influence on the migrations of fish to such places.

No one will expect that fishermen should go to sea with thermometers and areometers; but the fishermen will be benefited if the above-mentioned conditions of the sea-water are regularly examined and compared with the results of the fisheries. The fishermen, without making any scientific investigations, may aid greatly in extending our knowledge of these matters, and may benefit their trade by paying close attention to such easily recognizable circumstances as high or low temperature, currents, and to various phenomena connected with the spawning of fish, the greater or less quantity of fish at different places and seasons, &c., and by making their observations public.

These considerations induced the Ministry of Agriculture, &c., in the year 1870, to appoint a commission at Kiel for the purpose of making scientific examinations of the German waters, which might aid in gaining a better knowledge of those conditions on which the success of the salt-water fisheries—their improvement and extension—depends. For this purpose a number of stations have been established where the condition of the sea-water is regularly examined, whilst, at the same time, similar observations are made by several vessels following a certain regular course. At some of these stations observations are also made with a view of ascertaining (in exact figures) the result of the fisheries. A beginning has also been made in making observations regarding the spawning places and seasons, the development of fish, &c.

Our knowledge is still quite limited, and so far, at least, the practical result of these investigations has not been very great; but we must take into consideration the fact that but a short time has elapsed since these investigations were commenced.

No year resembles another in its atmospheric conditions, and meteorology, although studied for several centuries, has not yet been able to fix with absolute certainty the rules from which for some time in advance the condition of the weather could be calculated. The sea has likewise its atmospheric changes, dependent on many different circumstances, and many years will pass before we shall ascertain the causes of these changes observable in different years. The conditions of life and the habits of salt-water fish have scarcely begun to be studied. Fishermen themselves know but little with absolute certainty regarding the spawning places and seasons of the more important salt-water fish of their own familiar waters. It may as well be acknowledged that so far we only know a few facts regarding the spawning places and seasons and the development of one species of fish—a very important one, to be sure—the herring; but even these observations have reference to only a few localities. But what we know is highly important, because it has plainly demonstrated the intimate connection existing between the development of this fish and the condition of the water.[1]

Here is the point at which the fishermen themselves can aid and further the fishing interests, if they will give careful attention to the spawning of all the more important fish and to the accompanying general conditions of the sea.

In the following we shall endeavor to give all the results which have been gained by observations of those conditions in the Baltic and the North Sea which probably exercise a considerable influence on the fisheries.

2. There are three conditions of the sea-water which exercise a decided influence on animal and vegetable life, viz: (1) *temperature*, (2) *saltness*, (3) *currents;* and all three are influenced by the atmosphere and the nature of the bottom. Another important fact as regards the condition of the water of the Baltic and the North Sea is their varying connection with the ocean, and the varying quantity of fresh water flowing into them from different streams and rivers. The conditions of these two waters are so different that we must treat of them separately.

A. THE BALTIC is a very shallow sea. If we except the deep waters east and southeast of Gotland we rarely find a greater depth than 100 meters. The three channels leading into the North Sea, the Sound and the two Belts, are shallow. Large streams flow into the Baltic, carrying into the sea rain and snow water from a territory three times the size of that from which the North Sea is supplied. When two masses of water of different weight meet, the heavier of the two will generally sink lower down; the heavier water from the Kattegat will therefore enter the Baltic and form its undercurrent, whilst the lighter water of the Baltic flowing into the Kattegat will become its surface water. On account of the very large quantity of fresh water flowing into the Baltic (especially in spring, when the ice and snow begin to melt, and in summer during continued rainy seasons), the upper current which flows out of the Baltic is much more powerful than the undercurrent which enters it.

The saltness of the Baltic therefore decreases from west to east, but not uniformly; but, influenced by the wind, sometimes quick and at other times slow, and also influenced by the nature of the bottom, quicker in one direction than in another.

Continued east wind favors the flowing of the water of the Baltic into the Kattegat; the upper current containing but little salt, becomes stronger in the Sound and the Belts, and the salt Kattegat water is forced back. Continued west wind, on the other hand, drives the water east and favors the entering of salt water. The advance of the last-mentioned water from west to east varies considerably, according to the

[1] Compare: Dr. H. A. MEYER, "*Biologische Beobachtungen bei Künstlicher Aufzucht des Herings der westlichen Ostsee.*" *Berlin*, 1878. (Biological observations made during the artificial rearing of herrings in the Western Baltic.)

nature of the bottom. On the German coasts on the west of the Baltic the heavy water enters far into the fiords, whilst the undercurrent entering through the Sound and the Great Belt is broken by the shallow places known as the "Rönne-bank" and the "Oder-bank," between the islands of Reizen and Bornholm, and advances with no great force after it has passed this line, decreasing rapidly in saltness as it goes farther east. Between Bornholm and the Swedish coast the depth of the sea is greater, and this explains the circumstance why the heavy water can here advance farther east, making the water in the Gulf of Finland saltier than that of the Bay of Dantzig or that of the Baltic near Memel.

The following figures, the result of observations made at different stations, will fully prove all that has been said in the above regarding the *saltness of the Baltic:*

| | Average per year. | Spring. | Summer. | Autumn. | Winter. | Maximum. | Minimum. |
|---|---|---|---|---|---|---|---|
| **SONDERBURG.** | | | | | | | |
| Surface water: | | | | | | | |
| Specific weight | 1. 0131 | 1. 0122 | 1. 0123 | 1. 0139 | 1. 0138 | 1. 0214 | 1. 0100 |
| Per cent. salt | 1. 72 | 1. 60 | 1. 61 | 1. 82 | 1. 81 | 2. 80 | 1. 31 |
| Bottom water: | | | | | | | |
| Specific weight | 1. 0141 | 1. 0137 | 1. 0136 | 1. 0146 | 1. 0233 | 1. 0283 | 1. 0108 |
| Per cent. salt | 1. 85 | 1. 79 | 1. 78 | 1. 91 | 3. 05 | 3. 05 | 1. 41 |
| **KIEL.** | | | | | | | |
| Surface water: | | | | | | | |
| Specific weight | 1. 0124 | 1. 0115 | 1. 0117 | 1. 0137 | 1. 0117 | 1. 0201 | 1. 0043 |
| Per cent. salt | 1. 62 | 1. 51 | 1. 53 | 1. 79 | 1. 60 | 2. 63 | 0. 56 |
| Bottom water: | | | | | | | |
| Specific weight | 1. 0146 | 1. 0147 | 1. 0144 | 1. 0147 | 1. 0152 | 1. 0220 | 1. 0115 |
| Per cent. salt | 1. 91 | 1. 93 | 1. 89 | 1. 93 | 1. 99 | 2. 88 | 1. 51 |
| **WARNEMÜNDE.** | | | | | | | |
| Surface water: | | | | | | | |
| Specific weight | 1. 0089 | 1. 0085 | 1. 0082 | 1. 0095 | 1. 0095 | 1. 0132 | 1. 0060 |
| Per cent. salt | 1. 17 | 1. 11 | 1. 07 | 1. 24 | 1. 24 | 1. 73 | 0. 79 |
| Bottom water: | | | | | | | |
| Specific weight | 1. 0103 | 1. 0102 | 1. 0093 | 1. 0107 | 1. 0109 | 1. 0146 | 1. 0068 |
| Per cent. salt | 1. 35 | 1. 34 | 1. 22 | 1. 40 | 1. 43 | 1. 91 | 0. 80 |
| **LOHME (RÜGEN).** | | | | | | | |
| Surface water: | | | | | | | |
| Specific weight | 1. 0071 | 1. 0071 | 1. 0068 | 1. 0070 | 1. 0077 | 1. 0104 | 1. 0032 |
| Per cent. salt | 0. 93 | 0. 93 | 0. 89 | 0. 92 | 1. 01 | 1. 36 | 0. 42 |
| Bottom water: | | | | | | | |
| Specific weight | 1. 0075 | 1. 0073 | 1. 0072 | 1. 0073 | 1. 0081 | 1. 0112 | 1. 0050 |
| Per cent. salt | 0. 98 | 0. 96 | 0. 94 | 0. 96 | 1. 06 | 1. 47 | 0. 66 |
| **HELA.** | | | | | | | |
| Surface water: | | | | | | | |
| Specific weight | 1. 0057 | 1. 0055 | 1. 0058 | 1. 0056 | 1. 0058 | 1. 0066 | 1. 0014 |
| Per cent. salt | 0. 75 | 0. 72 | 0. 76 | 0. 73 | 0. 76 | 0. 86 | 0. 18 |
| Bottom water: | | | | | | | |
| Specific weight | 1. 0058 | 1. 0057 | 1. 0059 | 1. 0058 | 1. 0059 | 1. 0068 | 1. 0014 |
| Per cent. salt | 0. 76 | 0. 75 | 0. 77 | 0. 76 | 0. 77 | 0. 89 | 0. 18 |

From these figures the following rules may be deduced:

1. The weight and saltness of the water of the Baltic decrease from west to east, the entry of the heavy water into the depths of the sea ceasing near the island of Rügen.

2. The surface water is invariably lighter, and contains less salt than the deep water; the difference between the two decreases in the direction from west to east.

3. On an average the water is heavier and contains more salt in autumn and winter than in spring and summer; this difference likewise decreases in the direction from west to east.

4. The variations of the specific weight and the saltness of the water, that is, the differences between the temporary variations of the water, are also much more considerable in the west than in the east. Near Sonderburg, and even near Kiel, the deep water occasionally contains so much salt that it differs very little from the North Sea water in this respect, whilst near Lohme, and still more near Hela, the heaviest water contains little more than the average quantity of salt.

As regards the second important condition of the water, viz, its temperature, the Baltic shows the following phenomena:

On account of its comparative shallowness, and because it cannot exchange its warmth with that of the oceanic water through wide open channels, the temperature of the water of the Baltic will mainly be regulated by the temperature of the atmosphere, and will in different years be more or less dependent on the atmospheric temperature of those years. As the water absorbs warmth slowly, and likewise cools off slowly, the water will grow warmer or cooler somewhat later than the atmosphere, and the deeper the water the slower will be this process. The warmth and cold of the atmosphere will be the same in the water, only it will occur later in point of time and will decrease in the direction of the deep water.

The temperature of the water, which is dependent on the local temperature of the atmosphere, is somewhat changed by the currents. The cold water, which in spring flows into the Baltic in enormous quantities from the north and east, and which is chiefly produced by the melting of the snow, creates a cold upper current flowing in a westerly direction; and this current delays the warming of the water by the atmosphere, and even tends to make the atmosphere cool (the cold days of May!). The more or less powerful undercurrent from the North Sea will communicate to the deep water in the Western Baltic the warmth of the North Sea water. As these undercurrents are strongest in autumn and winter, and as the North Sea water is warmer during those seasons than the water of the Baltic, the temperature of the deep water is raised as far as the influence of these currents extends.

The observations relative to this question made at the different stations show the following result:

*Warmth of the surface water (t) and the bottom water (T) in degrees C.*

| Stations and depth in meters. | January. | | February. | | March. | | April. | | May. | | June. | | July. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *t.* | T. | *t.* | T. | *t.* | T. | *t.* | T. | *t.* | T. | *t.* | T. | *t.* | T |
| Sonderburg, depth 36 meters | 1.9 | 2.2 | 1.0 | 1.4 | 1.5 | 1.6 | 4.8 | 4.8 | 8.8 | 7.5 | 13.9 | 10.3 | 15.8 | 13.0 |
| Kiel, depth 58 meters | 2.3 | 3.9 | 1.7 | 3.7 | 2.4 | 3.2 | 6.5 | 3.8 | 10.5 | 5.0 | 15.7 | 5.4 | 18.7 | 6.5 |
| Warnemünde, depth 18 meters | 1.9 | 2.1 | 1.1 | 1.2 | 2.0 | 2.0 | 5.2 | 4.7 | 9.3 | 8.4 | 14.9 | 14.2 | 17.7 | 17.1 |
| Lohme, depth 36 meters | 1.6 | 2.1 | 1.4 | 1.8 | 2.8 | 3.0 | 6.0 | 5.1 | 9.1 | 7.3 | 14.6 | 11.9 | 16.8 | 15.6 |
| Hela, depth 42 meters | 1.9 | 3.9 | 1.0 | 1.7 | 2.4 | 2.2 | 5.6 | 5.3 | 9.6 | 9.1 | 15.0 | 12.6 | 18.3 | 16.4 |

| Stations and depth in meters. | August. | | September. | | October. | | November. | | December. | | Year. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *t.* | T. | *t.* | T. | *t.* | T. | *t.* | T. | *t.* | T. | *t.* | T. |
| Sonderburg, depth 36 meters | 17.0 | 15.1 | 14.7 | 14.4 | 11.1 | 11.6 | 6.7 | 7.2 | 3.0 | 3.8 | 8.4 | 7.7 |
| Kiel, depth 58 meters | 18.6 | 9.1 | 16.2 | 12.1 | 12.1 | 12.5 | 7.3 | 9.8 | 2.8 | 6.0 | 9.6 | 6.8 |
| Warnemünde, depth 18 meters | 18.6 | 17.9 | 15.7 | 15.7 | 12.3 | 12.6 | 6.9 | 7.6 | 3.3 | 3.8 | 9.1 | 9.0 |
| Lohme, depth 36 meters | 16.7 | 16.0 | 14.5 | 14.0 | 10.4 | 10.4 | 5.6 | 6.8 | 2.5 | 3.0 | 8.5 | 8.1 |
| Hela, depth 42 meters | 18.8 | 16.7 | 15.6 | 15.9 | 11.4 | 11.8 | 5.8 | 5.7 | 2.5 | 3.8 | 9.0 | 8.8 |

From an analysis of this table it appears: 1. The warmth of the atmosphere is followed by the warmth of the surface water with some slight delay, so that in the water, February is the coldest month, and not January, as in the atmosphere. 2. In the deep water the influence of the atmospheric warmth is delayed, and this is most noticeable in deep water where there are no strong currents, for example, in the deep water near Kiel, October is the warmest and March the coldest month.

The spawn which, during the first months of the year, is by the fish ejected in shallow water would therefore first be in cold water, but would soon find the temperature rising, whilst the spawn ejected in autumn in deep water would find a high temperature which would favor a rapid development.

In the surface water, which in winter may reach as low a temperature as zero, and even lower, the fish could not live, whilst in deep water they find warm places of retreat during winter.

We must mention another important circumstance which is caused by a remarkable quality of the water.

Like all other bodies, water becomes specifically heavier the colder it gets; but in water there is a limit to this. When fresh water has cooled down to a temperature of 4° it grows continually lighter until it freezes. The water having a temperature lower than 4°, therefore, continues to float above the heavy water of 4°, and the deep water of deep fresh-water lakes, consquently, never reaches a temperature lower than 4°.

This quality of fresh water is somewhat changed by the salt contained in the sea water, and the extreme limit of density is found in water having a low temperature. Thus, water containing ¾ per cent. salt, such as is found in the eastern portion of the Baltic, reaches its greatest density at a temperature of + 2°, whilst water containing 1½ per cent. salt would reach its greatest density at a temperature of about zero. Water containing 2 per cent. salt would be heaviest at a temperature of − 1°.1; water containing ¾ per cent. salt freezes at a temperature of about − 0°.6, and 1½ per cent. at − 1°, and 2 per cent. at − 1°.2.

From these figures the following rules may be deduced as regards the water of the Baltic: In the eastern part, where the saltness of the deep water is not very considerable, the temperature will always be above zero, whilst in the western part it may happen that the water with a high degree of saltness and a low temperature of the atmosphere shows a temperature considerably below zero.

From this quality of the water many phenomena may be explained. If, for instance, the western part of the Baltic in some year, through the influx of a considerable quantity of North Sea water, receives a large number of animal germs from the North Sea, these may develop and flourish for a time, until the unfavorable temperature of a single winter destroys them; so that such animals cannot be permanently acclimatized in the Baltic. On the other hand, the above-mentioned quality of the water will explain the circumstance that in the northern and eastern parts of the Baltic, on account of the more favorable temperature of the deep water containing but little salt, the spring spawning season, and the migration of the fish connected with it, begin much earlier than in the western and southern parts.

B. THE NORTH SEA.—The conditions of saltness, temperature, and currents are entirely different from those of the Baltic. In the North Sea three parts may be distinguished by their different depth: *First*, the southern and shallowest part, with a depth of about 35 meters, connected with the ocean by the narrow British Channel. To this part belong the Doggerbank and the coast waters of the Schleswig-Holstein and Jutland coasts. *Second*, the central part, extending northward as far as a line drawn from Peterhead, in Scotland, to Cape Skagen (Jutland), with a depth of about 100 meters. *Third*, the northern part, with much greater depths. This last-mentioned part has free communication with the Northern Atlantic. All three parts meet in the Skagerack, and through its waters are connected with the Baltic.

The North Sea, therefore, freely mingles its waters with those of the Atlantic, but the manner in which this is done differs in its different parts. The mingling of the waters takes place most freely in the northern part, but on account of its connection with the Baltic, the North Sea receives from the former some of its water containing less salt. Several large rivers also tend to decrease its saltness, which is therefore less than that of the Atlantic.

As regards the saltness of the North Sea, we therefore arrive at the following result: that it is less near the German and Danish coasts where the influence of the Baltic and the rivers is strongest, than in the central and northern parts, although the strong tide of the North

Sea tends to mix the waters. The following figures are the result of actual observations:

| List. | Year. | Spring. | Summer. | Autumn. | Winter. | Maximum. | Minimum. |
|---|---|---|---|---|---|---|---|
| ISLAND OF SYLT. | | | | | | | |
| Surface water: | | | | | | | |
| Specific weight | 1.0235 | 1.0231 | 1.0247 | 1.0235 | 1.0227 | 1.0263 | 1.0208 |
| Per cent. salt | 8.08 | 8.03 | 3.24 | 8.08 | 2.97 | 3.45 | 2.72 |
| Bottom water: | | | | | | | |
| Specific weight | 1.0238 | 1.0234 | 1.0249 | 1.0237 | 1.0230 | 1.0266 | 1.0816 |
| Per cent. salt | 8.12 | 3.07 | 3.26 | 3.13 | 3.01 | 3.48 | 2.83 |
| WILHELMSHAFEN. | | | | | | | |
| Surface water: | | | | | | | |
| Specific weight | 1.0249 | 1.0247 | 1.0251 | 1.0249 | 1.0247 | 1.0271 | 1.0203 |
| Per cent. salt | 3.26 | 3.24 | 8.29 | 3.26 | 8.24 | 3.55 | 2.66 |
| Bottom water: | | | | | | | |
| Specific weight | 1.0250 | 1.0247 | 1.0252 | 1.0251 | 1.0249 | 1.0272 | 1.0205 |
| Per cent. salt | 8.28 | 3.24 | 8.30 | 3.29 | 3.26 | 3.55 | 2.69 |
| HELIGOLAND. | | | | | | | |
| Surface water: | | | | | | | |
| Specific weight | 1.0255 | 1.0251 | 1.0249 | 1.0260 | 1.0261 | 1.0279 | 1.0188 |
| Per cent. salt | 3.34 | 3.29 | 3.26 | 3.41 | 8.42 | 8.65 | 2.46 |
| Bottom water: | | | | | | | |
| Specific weight | 1.0256 | 1.0254 | 1.0249 | 1.0261 | 1.0261 | 1.0280 | 1.0216 |
| Per cent. salt | 8.35 | 3.33 | 8.26 | 8.42 | 8.42 | 3.67 | 2.82 |
| OUTER LIGHTSHIP, RIVER WESER. | | | | | | | |
| Surface water: | | | | | | | |
| Specific weight | 1.0256 | 1.0253 | 1.0250 | 1.0256 | 1.0264 | 1.0271 | 1.0203 |
| Per cent. salt | 3.35 | 3.31 | 8.28 | 3.35 | 3.46 | 3.55 | 2.66 |
| Bottom water: | | | | | | | |
| Specific weight | 1.0256 | 1.0253 | 1.0250 | 1.0256 | 1.0204 | 1.0272 | 1.0205 |
| Per cent. salt | 8.35 | 8.31 | 8.28 | 3.35 | 3.46 | 3.56 | 2.69 |

The annual average saltness is therefore much more uniform at every place above mentioned than in the Baltic. The occasional fluctuations, especially the lower figures, are caused by a large influx of fresh water, and they consequently occur more frequently in surface than in deep water. If the water at times is heavy, this is a sign that water from the ocean has entered the North Sea, whilst if it is light, it shows a considerable influx of river or Baltic water. The same influences are at work as regards the remarkable temperature of the North Sea.

The southern part of the North Sea resembles the Baltic; it is shallow, and its nearest communication with the ocean is a narrow channel. In this part of the North Sea the temperature of the water, like that of the Baltic, is controlled by the temperature of the air. The only perceptible differences are caused by the influx of warm water from southern latitudes through the channel and by water from the rivers Weser and Elbe, as well as by water from the Baltic, varying in its temperature according to the seasons, entering the North Sea.

The central part receives water from the south and north at a greatly varying temperature during the course of the year. In summer the surface water coming from the south, from rivers and from the Baltic, is warm, whilst the water from the north, passing by and over shallow places, is cold. In winter this condition of things is reversed, as the shallow southern part then grows cold; the same applies to the Baltic and river water, whilst in the north the branch of the Gulf-stream which enters the North Sea is comparatively warm.

The northern part, as far as its temperature is concerned, entirely depends on the currents of the ocean, the above-mentioned branch of the Gulf-stream, and a deep, cold under-current coming from the north. Thus the distribution of warmth is constantly changing throughout the year; as far as the surface water is concerned, an attempt has been made to represent these changes graphically in the small maps found at the end of this pamphlet. These maps have been prepared in the following manner: A large number of observations made at coast stations or on board ships were collected from different parts of the North Sea, and from these figures the average temperature has been calculated. All points having an equal average monthly temperature are connected by a line. Blue indicates the lowest and scarlet the highest temperature, and the transitions from blue to scarlet are indicated by green, yellow, and orange lines. In examining these maps the above statements will be found correct. In January the water is warm in the north and in the extreme south, in the former region on account of the Gulf-stream, and in the latter on account of the warm water from southern latitudes. Along the German coast the water is cold on account of the Elbe and Baltic water. February closely resembles January; and even in March the water on our coast is cold. In April this condition begins to be reversed, and the water on our coast grows warmer; in May and June the temperature of the water is low as far as the Doggerbank, whilst during these months the shallow southern part and the coast waters, which receive much Baltic and Elbe water, are much warmer.

From July to September the water keeps warm in the southern and southwestern parts of the North Sea, a circumstance well known in our North Sea watering places, which are frequented till far into September. In October the water begins to cool off, beginning at the Baltic, and continues to grow cooler during November and December.

These graphic representations are, of course, only in the nature of a first attempt, which will have to be improved and supplemented by future observations, especially in deep water; but even the little we know regarding these changes in the temperature of the water is sufficient to show that they must exercise a decided influence on the migration and life of the fish. The appearance of the herring first in the north, then gradually farther south, the wealth of fish near the Doggerbank, which is washed by cold water during the months of April, May, and June, are hints pointing to the intimate connection existing between the temperature of the sea and its animal life.

To further investigate this connection should be the first object of scientists during the next few years; and practical fishermen can greatly aid in solving the problem, if they will watch those natural conditions which either rewarded their toil by rich hauls of fish, or which failed to crown their most earnest endeavors with success.

G. KARSTEN.

## B.—SCIENTIFIC INVESTIGATIONS UPON THE FISHES PROFITABLE TO THE FISHERIES.

How can we explain the circumstance that our knowledge of the many salt-water fishes which form the chief support of our fishermen on the coasts of the Baltic and the North Sea is exceedingly limited, in spite of the fact that for several centuries millions of these fish have been caught by experienced fishermen, and that one generation of fishermen has transmitted to the other all they had either heard concerning these fish or had themselves observed?

We believe that our fishermen are acquainted with the nature and life of their fish as far as their eyes and instruments, as well as their education and the age in which they live, will permit.

If we wish to go beyond the very considerable and important knowledge of the fishermen, as regards the nature and conditions of life of food-fish, we must use other means. We must investigate fish with all the means which science places at our command. We must not be satisfied with observing fish at those seasons when fishermen are catching them for the market, but we should follow them at all seasons, and carefully examine them at all stages of their life. When the fish no longer congregate for the purpose of spawning, we must, with suitable instruments, hunt them up in their retreats. We must find out their spawning places and endeavor to ascertain what peculiarities attract the fish to these places during the spawning season. We must not rest satisfied with knowing various outward characteristics, but we must study the internal structure of every species of fish; we must dissect their stomachs and entrails to see what kind of food they use.

In order to learn the internal structure of fish it is not sufficient to dissect them with knife and scissors, but every portion of their organism, even their eggs during the time that the young fish develop in them, should be examined under powerful microscopes.

The use of all these means for entering the mysterious life of fish has to be learned just as much as fishing. Practical fishing and the scientific investigation of fish have their own peculiar difficulties, and a special talent is required for each.

The highest aim of the trained ichthyologist is to learn to know as thoroughly as possible the nature and mode of life of fish. He rejoices whenever his labor is rewarded by an increase of knowledge, and he values these achievements higher than any other result of his observations. By making his observations known to others he gladly increases the pleasure and profits of his fellow-beings.

The more thorough the knowledge of the ichthyologist, and the farther he advances in it, the greater will be the profit which the practical fisherman will derive from his teachings. No intelligent fisherman of our day would therefore do without the scientific ichthyologist.

Experienced fishermen who have recognized the value of scientific investigations for their trade, who appreciate such investigations, and who have a keen eye for the life of fish, are the best aids to the scientific investigator.

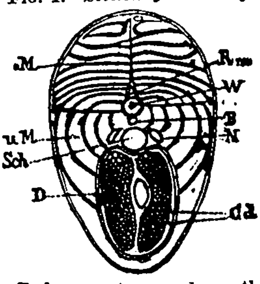
People who wish to communicate to each other details of one and the same subject must converse in a language which both of them understand.

The ichthyologist will quicker learn the language of the fisherman than the fisherman the language of the ichthyologist, for the latter will speak of matters connected with the life of fish which the fisherman either does not know at all, or very imperfectly, because he knows the fish only by the various characteristics exhibited by them during the fishing season, and by their flavor and market price. The fisherman, however, can easily understand everything in the language of the ichthyologist which is necessary for aiding the latter in his endeavors to gain an insight into the life of fish, provided the scientist makes his descriptions of the fish of such a nature that a practical man, without any higher education, can easily understand them. We will make this attempt by giving some information regarding the nature and mode of life of the herring. What we are going to say will not have as its immediate consequence a considerable increase in the number of fish caught by the fishermen or higher market prices; but we are of opinion that every fisherman who is proud of his trade, and who takes pleasure in it, will gladly embrace every opportunity of becoming better acquainted with that class of animals with which he comes in constant contact, and which are the support of himself and his family. By all new information regarding them his attention to their life and its various phenomena becomes sharpened. He learns to observe them from new points of view, of which he had never thought before, and thereby he gains a firmer basis for a better and more profitable way of carrying on his trade.

### 1.—Observations on the Structure of the Herring.

The herring is a good swimmer, and, like all fish having a broad back, can move forward very rapidly. This broad back is produced by the thick masses of flesh on both sides of the body, which are separated by the backbone and the ribs. In Fig. I these masses of flesh and the large side-muscles are shown cut across. Every side-muscle consists of two portions, an upper one (oM) and a lower one (uM), composed of fine fibers, which can easily be observed in eating a smoked herring. These fibers exercise collectively the strong motive power which the herring exercises when swimming. If the fibers of the left side-muscle are shortened, the back part of the body bends towards the left; whilst if the right side-muscle is shortened, the back part of the body bends towards the right. And if these bending movements

Fig. I.—*Section of a herring.*




B, large artery underneath the backbone; D, intestinal tube; G d, ovaries; o M, upper portion of the large side-muscle; u M, lower portion of the large side-muscle; N, kidneys; Rm, spinal marrow; Sch, swimming bladder.

follow each other in rapid alternation they impel the body forward, just as a boat is propelled by an oar turned right and left at its stern.

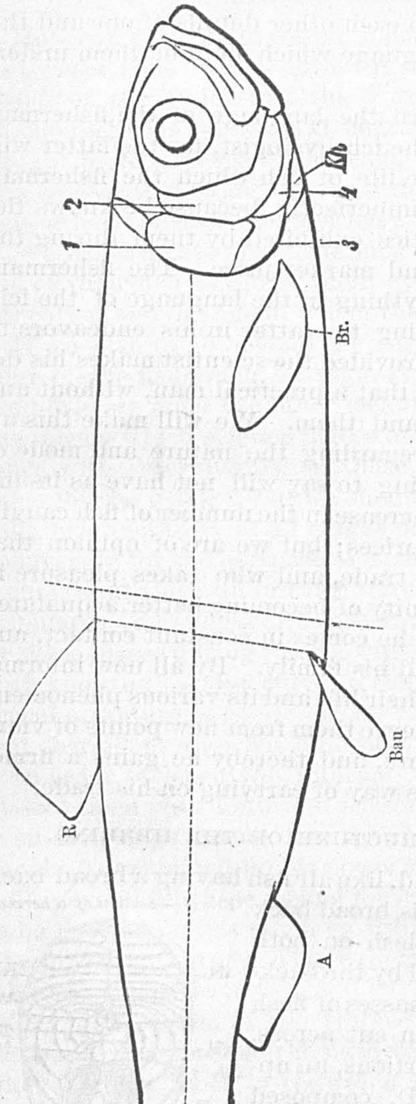



FIG. II.—*Outline of a herring from the North Sea.*

A, anal fin; Bau, ventral fin; Br, pectoral fin; Kh, gill-membrane; R, dorsal fin; Sch, caudal fin; 1, 2, 3, 4, the gill covers or opercles. The dotted lines in front of the dorsal and ventral fins indicate the places where these fins are found in the Baltic herring.

The fins aid but little in propelling the body of the fish. Their chief object is to keep the back upward, and to give to the body the direction which it is to follow. The herring has two pectoral fins (Fig. II, Br), two ventral fins (Bau), one dorsal fin (R), one anal fin (A), and one caudal fin (Sch), whose lower lobe is somewhat longer than the upper one. The skin of the fins is extended between the thin bones, termed the rays of the fins, at whose roots there are small muscles, by means of which the fins can be moved. Every fin has its certain number of rays. The scales of the herring adhere to the skin so loosely that in hauling in the net they come off very easily. The opercles or gill-covers at the sides of the head, back of and below the eyes, are alternately opened and closed by the fish, in order to draw in water for breathing through the mouth over the gills to be discharged through the gill-opening. Each opercle or gill-cover consists of four bony plates. In Fig. II these are marked 1, 2, 3, 4. The folds of the herring differ in shape from those of the sprat (Figs. II and III). Below there is joined to the third and fourth plates a skin or membrane kept extended by means of small bones (the gill or branchiostegal rays, Kh, in Fig. II), which contributes towards making the covering of the gills fit closely.

The herring has four pairs of gill-arches (Fig. IV, B.) To these are fastened at the back two rows of gristly gill-leaflets (Fig. IV, B), which are covered with so thin a skin that in the live fish they look dark red from the blood passing through them.

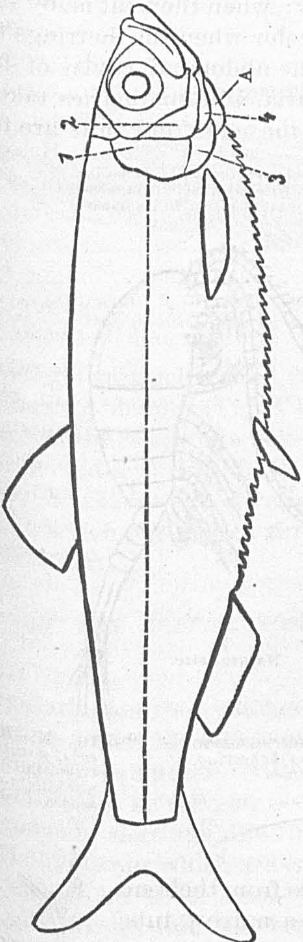
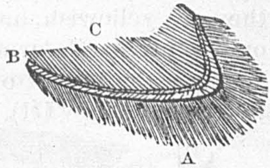



FIG. III.—*Outlines of a sprat from the Baltic.*

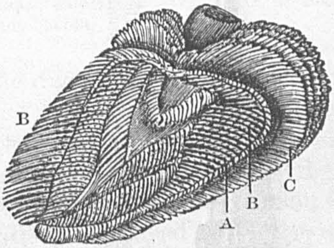
A, gill-membrane; 1, 2, 3, 4, the four plates of the gills or opercles. The points of the scales on the lower side of the fish are drawn somewhat more prominently than they appear in nature.

FIG. IV.—*The arch of a gill of the herring (natural size).*



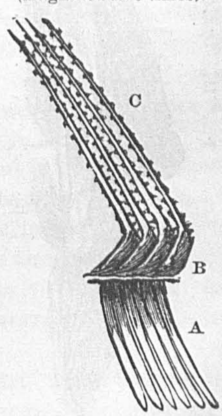

A, leaves of the gills (blood red in live fish); B, arch of the gills; C, gill-rakers or slender appendages on the anterior border of the arch.

FIG. V.—*The gills of a herring (natural size).*




A, arch of the gills; B, the anterior border of the gills, garnished with the rows of gill-rakers; C, leaves of the gills. The tube protruding between the four rows of leaves is the beginning of the œsophagus.

FIG. VI.—*Part of the arch of the gill of the herring* (magnified five times).




A, leaves of the gills (blood red in the live fish); B, part of the arch of the gills; C, gill-rakers covered with small spines.

In front the arches of the gills have a dense row of slender appendages, technically called gill-rakers, on each side of them (Fig. IV, C; Fig. V, B, and Fig. VI, C.) All water which the herring takes in its mouth to let it flow out again over the gills in breathing must pass through the fine grating formed by these spinous points. By this process all small animals which, with the water, enter the mouth and gill-cavity are retained in it, and accumulate till they are swallowed. This enables the herring, whenever the water is full of small life, to fill its stomach in a short time with thousands of them. In February, 1872, I found in the stomach of one herring 15,000 small crustaceans, in another 19,000, and in a third one even 60,000. These small crustaceans are only about 1 millimeter long. Fig. VII shows one of these crustaceans mag nified 50 times. These crustaceans are the best food for herrings and sprats. By feeding on them they become fatter and get a better flavor than from any other food. Whenever herrings feed on these crustaceans their excrements have a reddish color; when they eat many small worms they are yellowish, and of a dark color when the herrings feed chiefly on floating snails or mussels. In the abdominal cavity of fully grown herrings the sexual organs, the ovaria, and spermaries take up the largest room (Fig. VIII). As soon as the eggs and milt are fully

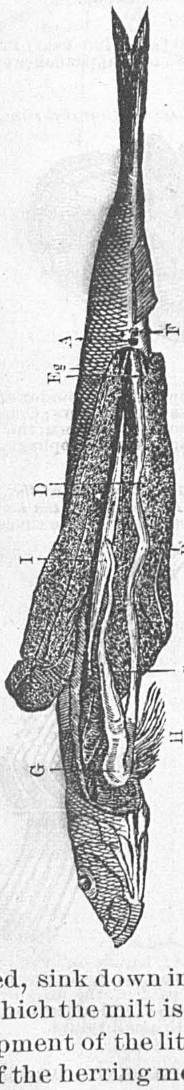



FIG. VIII.—*Opened herring, half its natural size.*

A, anus; B, intestinal canal; C, canal connecting the stomach and swimming-bladder, the pneumatic duct; D, sexual organs; E, emissory canals of the sexual organs, which open at F, opening back of the anus; G, stomach; H, appendages of the stomach; I, swimming-bladder.

FIG. VII.—*A male crustacean (Temora longicornis)*, from the Bay of Kiel, magnified 50 times. Below it is given in its natural size.

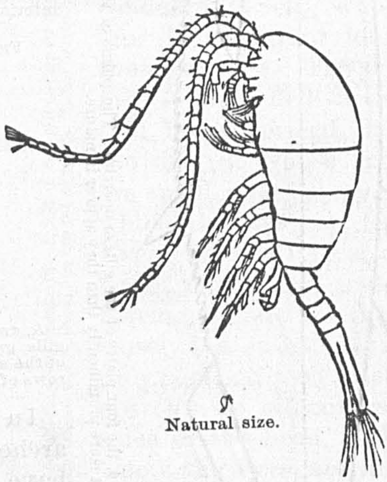



FIG. IX.—*A spermatozoan* (from the milt) *of the herring*, magnified 375 times.

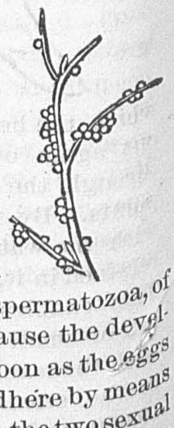
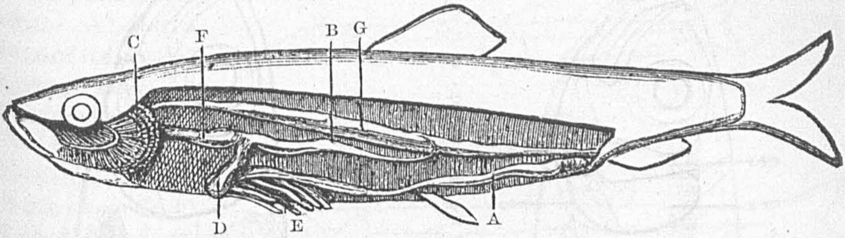


FIG. X.—*Herring eggs, natural size* (from the Schlei), *sticking to Potamogeton pectinatus.*

matured they pass from their envelopes through a narrow tube toward an opening which is immediately back of the anus (Fig. VIII, F). In spawning the milters swim by the side of the spawners and emit their milt. Whilst the eggs, after having been emitted, sink down in the water, the fine thread-like particles, spermatozoa, of which the milt is composed (Fig. IX), enter the eggs and cause the development of the little fish from the egg to commence. As soon as the eggs of the herring meet with plants or touch the bottom they adhere by means of a sticky substance which covers them (Fig. X). Between the two sexual organs lies the intestinal canal (Fig. VIII and Fig. XI, A). It starts from the stomach (Fig. XI, D), at whose back there are hollow tubes (Fig. VIII and Fig. XI, E) which, when food is plentiful, are filled with a fatty juice. In front of the stomach there is a short and wide cavity (Fig. XI, F).

FIG. XI.—*Entrails of the herring.*




A, intestinal canal; B, air-passage between stomach and swimming-bladder; C, gills; D, stomach; E, appendages of the stomach; F, œsophagus; G, swimming-bladder.

From the stomach a tube, the pneumatic duct (Fig. XI, B), passes to the swimming-bladder (Fig. VIII and Fig. XI, G), which shines like silver, and has the shape of a spindle. On either side of the swimming-bladder are the kidneys (Fig. I, N), and between these and close below the spine there is a large blood-vessel (Fig. I, B) in which a large portion of the blood which has passed through the gills is conveyed to the lower part of the body.

## 2.—ON THE DIFFERENCES BETWEEN THE SEA-HERRING AND THE COAST-HERRING.

The opinion that the herrings come to our shores from the northern seas, and that all which are not either devoured by other fish or are caught by fishermen return to those seas after the spawning season is over, cannot be correct, because the different parts of the ocean are inhabited by herrings differing in shape and size.

The herrings which are caught in the North Sea and in the Baltic have grown up in those seas. They may be divided into two varieties, the coast-herring and the sea-herring. The coast-herring of the Baltic spawns in spring in the shallow coast waters, where the bottom is covered with a rich vegetation. The sea-herring spawns in deep water, and its principal habitation is the North Sea. The sea-herring of the Baltic spawns at a depth of 4 to 5 meters.

Sea-herrings only make their appearance a short time before the spawning season, as migratory fish, coming in dense schools, and soon afterwards disappear again.

Coast-herrings, on the other hand, stay near the coast all the year round, in greater or smaller numbers. In placing a coast-herring by the side of a sea-herring (both being of the same length), the fore part of the body of the sea-herring appears longer and more slender (Fig. XII) than the fore part of the body of the coast-herring (Fig. XIII), because in the latter the dorsal fin (D) extends a little farther forward than in the sea-herring.

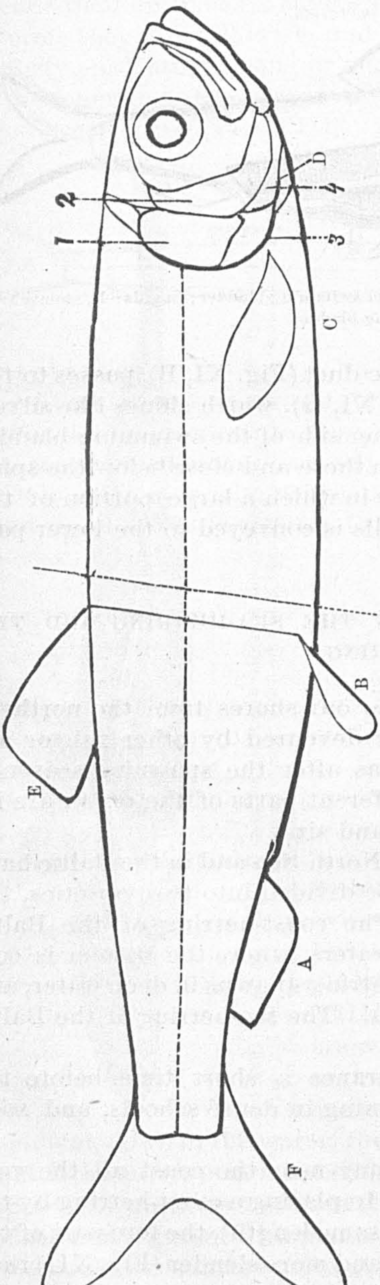



FIG. XII.—*Outline of a sea-herring from the North Sea.*

A, anal fin; B, ventral fin; C, pectoral fin; D, gill membrane; E, dorsal fin; F, caudal fin; 1, 2, 3, 4, the four plates of the gill-coverings, or opercles. The dotted line to the right of the dorsal and ventral fin shows the places where the roots of these fins are in the Baltic herring.

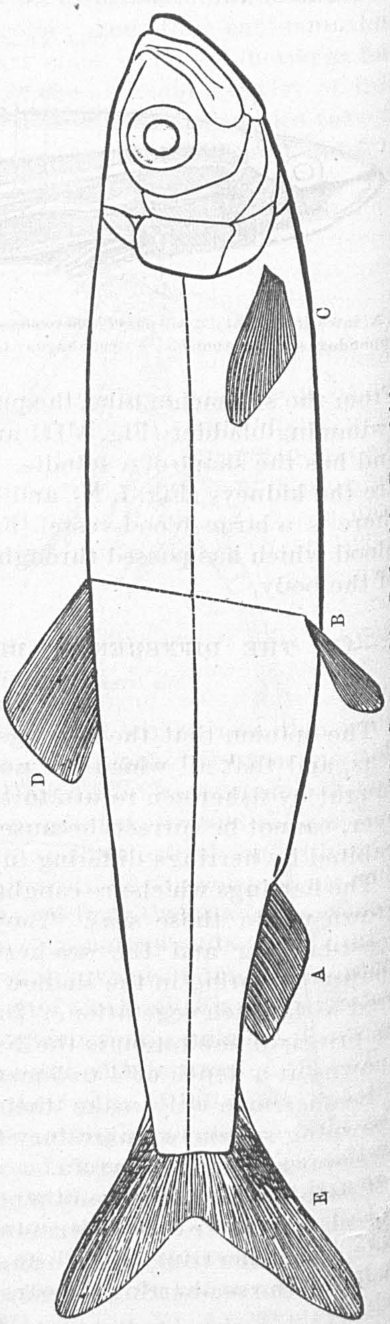



FIG. XIII.—*Outline of a coast-herring from the Baltic.*

A, anal fin; B, ventral fin; C, pectoral fin; D, dorsal fin; E, caudal fin.

### 3.—THE DIFFERENT AGES OF THE HERRING.

When the young herring leaves the egg it does not have the shape of an old herring; it is much more slender than the old herring (Fig. XIV) and almost as thin as a ribbon. Its dorsal fin is proportionately long, and is placed far back. At this stage of its life the herring may be said to be a larva. The fish retains this shape until its length exceeds 30 to 40 millimeters. As soon as the sexual organs begin to grow rapidly, indicating the approach of the spawning season, other changes in the shape of the body can be noticed.

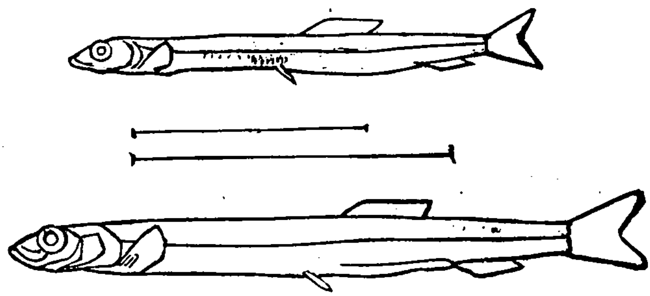


FIG. XIV.

The upper figure shows the outline of a spring-herring larva from the *Schlei*, magnified twice. The lower figure shows the outline of an autumn-herring larva from the Bay of Eckernförde, magnified twice. The lines between the two figures show the natural size.

The sexual organs of small herring, measuring less than 210 millimeters in the Bay of Kiel, are but little developed. In herrings measuring 210 to 290 millimeters in length, the sexual organs grow from October till the spawning season in spring.

As the spermaries grow faster from October to December than the ovaries, the male herrings are during these months thicker than the female ones, whilst from January to April the female herrings look thicker, because during that period their ovaries increase more rapidly than the spermaries of the male fish.

When the spawn and the spermatozoa approach maturity, the herrings decrease in size as their quantity of fat diminishes, although even then we occasionally find herrings which in spite of the strong development contain a large quantity of fat.

In April the larger herrings whose spawn and milt have been fully matured generally leave the Bay of Kiel and go into the shallow brackish waters of the Schlei, and their places in the Bay of Kiel are occupied by smaller herrings, measuring less than 200 millimeters in length.

The Schlei herring which is caught in spring is therefore not a different race from the Kiel herring, but simply a fully-matured herring of the kind found along the whole eastern coast of Schleswig-Holstein. In this Schleswig-Holstein race of coast herring the following stages of age and size may be distinguished:

1. The larval form, measuring at most 40 millimeters in length (Fig. XIV). It is much more slender than the juvenile form of the herring. A larva measuring 33 millimeters in length is only 2 millimeters high, whilst the height of a herring which has already assumed its juvenile

form when measuring 40 millimeters, is 6 to 7 millimeters. The larvæ are transparent. The juvenile form has transparent scales glittering like silver.

2. The young form, measuring 40 to 120 millimeters in length. It appears in the Bay of Kiel in autumn and winter, whilst in the Schlei it is found all the year round, but principally from July to January.

3. The middle form, measuring 120 to 140 millimeters in length. At this age the herrings are generally very fat. The sexual organs are as yet undeveloped. Herrings of this shape and size are frequently caught in the bays of Kiel and Eckernförde in March and April, and often in February. They compose more than half the number of all the herrings caught in these bays.

4. The sexually mature form, measuring 210 to 290 millimeters in length. Herrings of this shape and size are found all through the winter in the bays of Kiel and Eckernförde. Towards the end of March they disappear and go to the Schlei.

In the Kattegat along the Swedish coast the smallest fully-matured herring measure 200 to 210 millimeters in length. In the North Sea on the coast of Scotland they measure 215, and on the west coast of Norway 225 millimeters.

It is probable that the herring does not reach its full size till its fourth year, but the observations made hitherto have not yet led to any absolutely certain result.

As soon as the herring has entered its juvenile age, the number of rays in all its fins (excepting the anal fin) does not change any more. At that period the pectoral fin has 17 rays, the ventral fin 9, and the dorsal fin 19. After the juvenile age has been reached the positions of the dorsal and anal fins and of the anus do not change any more, but remain henceforth at a comparatively uniform distance from the point of the lower jaw.

The length of the head, however, and the height and breadth of the body do not hold a fixed relation to the length of the whole body, but change with its size. Thus the length of the head increases with comparative suddenness, when the herring leaving its larva period enters the juvenile period. But the growth of the head in length remains behind the growth of the body, after the body of the young herring has exceeded a length of 70 millimeters.

The large and fat yellowish herring, measuring 210 to 290 millimeters, which in autumn are caught in drag-nets near Korsör (Denmark), belong to the variety of sea-herrings. They spawn in autumn probably near the coast of Langeland.

The so-called "Bund-garn" or "Reusen" herring of Korsör, which measure 150 to 200 millimeters, have in autumn but little developed sexual organs and a blue color, and are more slender and thinner, and do not possess the delicate flavor of the fat herrings caught in the same waters. They belong to the coast herrings.

### 4. What causes the herrings to migrate and to gather in schools?

Profitable herring fisheries can only be carried on in places where the herrings gather in schools.

In February, 1872, 240,000 herrings were caught every day in seines in the inner Bay of Kiel. To take so many fish out of the water in one day would have been an impossibility if they had been scattered over the whole bay; for even the largest seine is small compared with the area of the Bay of Kiel.

The principal causes why the scattered herrings gather in schools and migrate to certain parts are the desire for food and the desire to propagate the species.

The herrings which live outside the bays of Kiel and Eckernförde and the Schlei cannot know whether they will find sufficient food in these bays, not even when they have been there during their early youth; but they enter these bays, gradually proceeding towards the inner parts, because there they find more food than outside. Whenever these bays contain a great quantity of good food as, for example, in February and March, 1872, when the waters of the Bay of Kiel were literally swarming with small crustaceans (Fig. VII), an unusually large number of herrings will enter the bay. So many herrings had not been caught before in the Bay of Kiel within the memory of the oldest inhabitant as were taken during the winter of 1871–'72. During the same period an extraordinarily large number of large codfish were also caught. The codfish followed the schools of herrings, and feeding on them soon grew large and fat.

The second cause why the herrings gather in schools is the desire to propagate the species. The rapid growth of the sexual organs must necessarily awaken hitherto unknown desires which mutually draw the milters and spawners together, and keep them near each other even after the desire for food no longer unites them.

In the Western Baltic the mature herrings gather in spring, especially in shallow places where the bottom is covered with sea-weeds and other plants, and where the water contains but little salt and is easily warmed by the rays of the sun.

It would be a mistake to suppose that the herrings go into these waters because they have some knowledge of their condition, and because they think that they are best suited for receiving and developing the spawn. Without having the slighest knowledge of the purpose of their gathering, they nevertheless gather in schools, because they are all animated by the same desires and instincts.

It is probable that at the time when the sexual organs approach maturity, the less degree of saltness and the greater warmth of the shallow coast waters is pleasanter for them than the cold and strong saltness of the deep waters; and they consequently swim in the direction in which the saltness decreases and the warmth increases, and pursue their course until they finally meet at the time when the spawn and milt are fully matured, in places which resemble their own birth-places.

As soon as the sexual organs have been emptied, the desire which led the herrings of both sexes to the spawning-places dies out. The large schools do not permanently find sufficient food in these confined waters. The desire for food therefore compels them to scatter again. Swimming hither and thither in search of food, they find more towards the open sea than in the direction of the coast, because most of the small marine animals (crustaceans, &c.) on which the herrings feed could increase and develop more undisturbedly in the open sea, as long as the whole host of their inveterate enemies (the herrings) staid in the bays.

Not only old, fully-grown herrings, but also the young ones migrate. From the Schlei many young herrings, measuring only 60 to 70 millimeters, go to the Baltic in August.

The migration of the herrings from the open sea into the bays and back again to the open sea is a means employed by nature in order to raise large numbers of fish; for because the herrings wander, they always have plenty of food; and their migrations are generally brought about by the fact that they continue to swim in that direction where they find the most food.

When the herrings come from the open sea into our bays, and are caught, they furnish us with healthy food which has been formed by small marine animals, which, without the herrings, would be of no use whatever to us.

In the Western Baltic there are two seasons of the year when herrings spawn, namely, spring and autumn.

In the Schlei most herrings spawn in April and May, and but few of them in March and June.

In the Kattegat the herrings likewise spawn in March, April, and May, whilst on the west coast of Norway they spawn as early as February and March.

The herrings which spawn in autumn are not the same which have spawned in spring.

Autumn spawn is ejected by the herrings in the western and eastern parts of the Baltic from September to November.

The herrings which reach their maturity in autumn spawn in deeper waters than those which spawn in spring. As in autumn the water is warmer in the deep places than near the surface, it is probable that the fully matured herrings which spawn in autumn are, just like those which spawn in spring, compelled to congregate in deeper waters by the difference of temperature in the different depths of water.

In the western part of the Baltic the saltness of the water increases the deeper we go. The autumn spawn, therefore, is developed in much salter water than the spring spawn which has been deposited in shallow brackish bays. The eggs of the herring can stand a great difference of degree of saltness.

In the North Sea they develop in water whose percentage of saltness is 3.5, on the eastern coast of Rügen in water containing 0.8 per cent. of salt, and on the coasts of Prussia and Scotland in water having an even smaller percentage of saltness.

In the northern part of the North Sea the herrings which spawn in autumn reach maturity much sooner than in the southern part. On the east coast of Scotland they spawn as early as July and August, on the east coast of England in September and October, and in the neighborhood of the Channel even late in autumn.

The autumn eggs are generally deposited in warmer water than the spring eggs; but whilst the young spring herrings grow up with increasing warmth of the water, the autumn herrings develop in water whose warmth is decreasing.

The herring eggs can stand a great difference of temperature. Their development is not interrupted when they are cooled off by a temperature approaching zero, nor by a temperature rising as high as 15° C. In cold water their development is slower than in warm water. With a temperature of 3°.5 the young Baltic herring leaves the egg after forty days, at 7° to 8° in fifteen days, 10° to 11° in eleven days, and with a still higher temperature in six to eight days.

The development of eggs which have been laid in November or December, therefore, generally takes somewhat longer than the development of eggs laid in spring. This explains the circumstance why the larvæ which have come from November or December eggs do not have the same length in April as the larvæ which have come from the October spawn.

Autumn larvæ from the Bay of Eckernförde (Fig. XIV, lower figure) differ from spring larvæ from the Schlei (Fig. XIV, upper figure) in the following particulars: In the autumn larvæ the ventral fins do not begin to appear until they have reached a length of 33 to 34 millimeters, whilst in spring larvæ they appear when the little fish are only 25 to 26 millimeters long.

The autumn larvæ have comparatively smaller heads than the spring larvæ; they do not leave the larva stage until they have reached a length of at least 44 millimeters, and even when they measure 60 millimeters they are frequently not yet fully covered with scales.

## 5.—Comparison of the herring and the sprat.

The sprat resembles a herring of the same length to such a degree that a person who is not thoroughly acquainted with the differences between the two kinds of fish cannot easily distinguish the one from the other.

In carefully comparing the two we shall find the following differences (Fig. III and Fig. XIII):

The shape of the body of the herring is more slender, whilst the sprat is thickset. Corresponding with this the height of body is, in proportion to the length, greater in the sprat than in the herring. And this height is greater in the sprat from the point of the head to the root of the caudal fin.

The side-length of the head is about the same in both, and is one-fifth of the length of the body. The length of the top of the head from the point of the lower jaw to the point where the scales commence is the same in both. The lower length of the head, from the point of the lower jaw to the hindermost point of the gill-membrane (Fig. II, Kh, and Fig. III, A), is greater in the sprat than in the herring. The height of the head is a little greater in the sprat at the end of the upper length of the head, but a little smaller at the joint of the lower jaw.

The lower jaw of the sprat is shorter than that of the herring. This, and the difference in the height of the head, make the head of the sprat appear more thickset, and the snout more pointed, than that of the herring. When the mouth is closed the point of the lower jaw of the sprat is about as high as the center of the eye, whilst that of the herring is higher.

At the top of the head, between the eyes, the sprat is broader than the herring.

The bony plates of the gill-coverings or opercles are differently shaped in the two kinds of fish.

The principal plate (Fig. III, 1) of the sprat is broader than that of the herring, and its lower front corner extends lower than in the herring.

A straight line drawn from the upper root of the pectoral fin towards the lower front corner of the principal plate (1) of the gill-covering, if extended would, in the herring, go through the eye, and in the sprat, below the eye, towards the point of the upper jaw.

The upper portion of the gill-membrane (Figs. II and III) below the middle plate (4) of the gill-covering is longer in the sprat than in the herring. In the herring the hinder edge of the gill-membrane and the lower edge of the gill-covering (3) form a distinct angle, whilst in the sprat they almost run in the same direction.

The ventral fins of the herring are longer and broader than those of the sprat, and have generally 9 rays, whilst those of the sprat have only 7.

The dorsal fin of the sprat has 17 rays, and is placed farther back than that of the herring, which has 19 rays. In the herring it is placed in front of the center of the whole length of the body, whilst in the sprat it is set back of this point.

The ventral fins of the herring are found at a considerable distance behind the origin of the dorsal fin, whilst those of the sprat are in front of it.

The anal fin of the sprat has 19 rays, and has a much longer line of origin than the anal fin of the herring, which has only 17 rays.

The pectoral fin of the herring has 17, and that of the sprat only 16 rays.

The lower edge of the body of the sprat, in the direction from head to tail, is much sharper to the touch than that of the herring, because the ventral carinated scales of the sprat are much larger, and have more projecting points than those of the herring (Fig. III). From the head to the ventral fins the herring has 31 ventral scales, and the sprat only 22.

### 6.—The larval form of the flat-fish.

As very young flat-fish are comparatively little known, we give a picture of one caught in the Bay of Kiel. Like other fish it has one eye on the right side and the other on the left (Fig. XV); has the same color on both sides, and possesses a small swimming-bladder, which is wanting in fully-grown flat-fish. These small flat-fish are found swimming in a perpendicular position near the surface of the water, where they can easily be caught with fine nets.

FIG. XV.

A *young flat-fish*, natural size, caught in the Bay of Kiel. One eye lies on the right and the other on the left side of the head.

### 7.—Something concerning the food of fish.

The North Sea and Baltic can furnish large numbers of food-fish, because they are inhabited by enormous numbers of other marine animals. The following kinds of marine animals compose the greater portion of the food of fish: crustaceans, worms, snails, mussels, and echinoderms. As most of these animals live at the bottom of the sea, the fish will generally seek their food there.

Herrings, sprats, and mackerel often find large quantities of small crustaceans near the surface of the water. For the young fish which have just left their eggs small microscopic animals, which can scarcely be seen with the naked eye, are of the highest importance. At the very time when the fish leave their eggs, the sea is full of larvæ of crustaceans, worms, snails, mussels, echinoderms, &c., so that the fish receive a number of small animals with the water which at every breath they inhale through their gills. Young fish when kept in aquaria generally die very soon, because they do not get the food which they need, namely, the larvæ of the above-mentioned small marine animals. These animals on which the fish feed live partly on other living or dead animals. The last sources of their food, however, are aquatic plants and those particles of organic matter which the rivers carry into the sea.

During the autumn and winter months large masses of sea-weeds and algæ are torn out by the waves, lose the air which during life had kept them floating, and sink to the bottom. Here they gradually decompose, and finally form the principal component part of the dark mud from which innumerable mussels and worms derive their food.

### 8.—SOMETHING CONCERNING THE CULTIVATION OF THE MUSSEL (MYTILUS EDULIS).

The cultivation of the mussel can be profitably carried on in all the sheltered bays of the western part of the Baltic. The best method is to use trees with all their branches, about 6 meters high. The lower end of the trunk is pointed and rammed deep into the bottom of the sea, so that the waves cannot uproot it. The tops of the trees must not protrude above the surface, even at low water. The latest time to set them is the middle of June, as during the second half of this month the young mussels leave their eggs, swim about in the water, and soon stick to any hard object they find. After three to five years the mussels are large enough for the market. During the winter months the mussel-trees are lifted. After the harvest has been gathered in they are set again as long as they last.

K. MÖBIUS.

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## C.—THE SPAWNING PROCESS OF SALT-WATER FISH, AND ITS IMPORTANCE TO FISHERMEN.

The object of the coast fishermen is of course to catch as many fish as possible, because the amount of their annual income will chiefly depend on this. This object they have in common with the river fishermen, but their method of reaching this object is different, and is not equal to the one employed by the river fishermen.

The river fishermen, like the coast fishermen, endeavor to catch the largest possible number of fish by means of their knowledge of those localities where the fish congregate, and by means of good nets, but they are less dependent on wind and weather than the latter; they can to some degree select the time when they want to have fish for the market, and can therefore obtain higher prices for their fish. The coast fishermen, on the other hand, have the advantage that their fishing area is larger, but not even taking into account the circumstance that the sea does on the whole not contain as many fish as an equal area of coast water, the fishing on the high seas requires a greater outlay of material and strength than the coast fisherman has at his command. The difference is more important as regards the cultivation of fish. This is carried to perfection as far as the carp is concerned, for not only are its eggs hatched artificially, but it is nursed and tended like a domestic animal. Even on fish living in a state of liberty a certain amount of care can be bestowed by protecting the fish during the spawning season, either by voluntary regulations made by the owners of the respective waters or by legislative measures. Every fisherman knows that a twofold harm is done by catching fish during the spawning season by destroying an enormous number of eggs about to be laid, and by catching too large a number, comparatively speaking, of fish, because at no time is it easier to catch fish than whilst they are spawning. To this must be added the injury done by destroying eggs which have been laid and young fry. No intelligent fisherman would therefore violate the rule of protecting the fish during the spawning season, if necessity did not compel him, or if the alternative were not placed before him either to catch the fish himself or to let others catch them, and thus deprive him of a benefit which he might have enjoyed. In such cases the excuse is made that the fecundity of fish is large enough to neutralize all losses by the eggs of the remaining fish.

These are all well-known facts, which have only been mentioned here with a view of urging a consideration of the question whether more could not be done than is done at present to further and protect the propagating process and to shelter the young fry. In considering this question it should be distinctly understood that there can be no limitation of fishing, for the fishermen are, as a general rule, by no means in a position to submit to such limitations.

The consideration of this question should be of special importance to the coast fishermen, for quite a number of fish are only caught in large numbers because they approach the coast for the purpose of spawning. But with regard to these matters most fishermen are grossly ignorant, as they know neither the spawning places nor the places where the young fry stay. This ignorance is so great that it is absolutely necessary to spread a better knowledge.

An example may serve to illustrate this. In answer to many requests to establish a season of protection for plaice and flounders, the provincial government of Schleswig some time ago determined to obtain certain information on the subject, and sent extensive question-sheets to many fishing associations. Numerous answers were returned, but with the least possible results. Only one small fishing village pretended to know any spawning places, but the places which were mentioned were many miles distant and located near much larger and more important fishing stations, where nothing concerning them was known, and the time of spawning mentioned in the answers was entirely incorrect. No other place, not even Eckernförde, where most of the extensive flounder fisheries on the whole Prussian coast are carried on, knew of those spawning places. There was the greatest difference in determining the time of spawning, which is easily ascertained, because at the beginning of the spawning season the spawn may be seen to flow from the fish which have been caught, whilst at the end of this season the fish are quite empty. According to the data obtained by the above-mentioned question-sheets the spawning season would be either in December and January, or in March and April. The fact of the matter is that this year the spawning season of the flounders in the Western Baltic commenced about the end of February, and had almost finished in the beginning of April. If fishermen make such erroneous statements, no other cause can be assigned for it than their utter indifference to this important question. The young fry has been observed by nearly all fishermen, but although there were great complaints that the number of flounders was decreasing, no one had thought to observe whether the young fry was more numerous in one year than in another, and still the fisheries of the coming years depend entirely on the young fry.

What can the authorities do in view of such a condition of affairs? As nothing is known with absolute certainty, no sure steps can be taken, and nothing remains but to let things go on until the complaining fishermen show that they are well enough acquainted with the matters about which they complain to prove the correctness of their assertions.

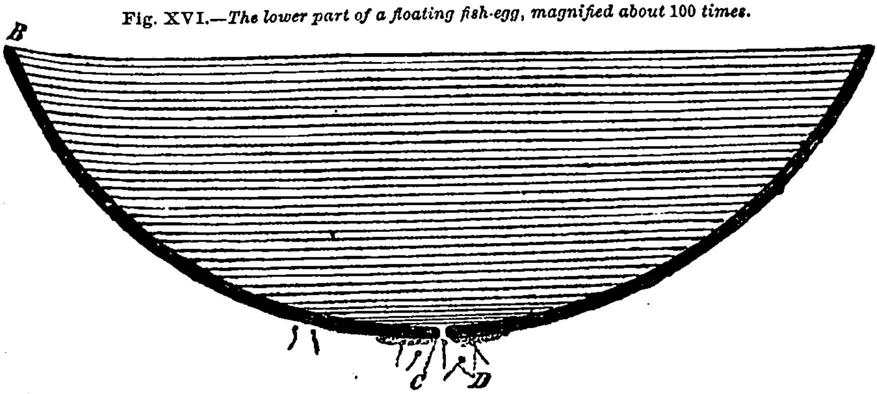
From this example from recent times it will be seen that a knowledge of how to take care of the fish during the spawning season is important to the fishermen in more than one respect. It may be said that there will scarcely be a single case where fishermen have raised complaints in which a knowledge of the spawning places and of the young fry would not be of vast importance. Even if in an exceptional case the knowledge of the spawning of fish were of no importance, the statements of those fishermen would deserve and receive the greatest attention who could give reliable information regarding the spawning places within their fishing area and regarding the life and habits of the young fry.

*The following pages are intended to aid the fishermen in gaining the necessary knowledge.* Scientific investigation has so far only extended to the history of the development of a few species of fish, but it may be said that as to general principles all fish will more or less resemble each other in this respect, whilst, of course, they will greatly differ as to the details, which are comparatively little known. We know that in laying their eggs the fish empty their sexual organs so completely that they appear quite small, and that the diminutive eggs of the next spawning period can only be recognized by means of a microscope. These eggs gradually mature till the next spawning period, and the sexual organs finally occupy the largest part of the abdominal cavity. At that time many eggs may be seen in the ovaries which are as large as ripe eggs, but besides these many smaller ones, less transparent, which are still growing. A person not acquainted with these matters would believe that the large eggs are ready for laying, whilst in reality this is not the case. The fishermen know this very well, for only when the eggs are ejected from the sexual opening of the fish at the slightest pressure (compare the preceding treatise by Professor Möbius) are they ready for development, and the fisherman declares that the spawning season has come.

At this period most of the eggs in the sexual organs are large, lie very loosely in the glands, and come out at the least pressure, often by the mere motion of the fish. From the abdominal cavity they pass outside through the ovarian tubes. This complete maturity of the eggs seems to be very sudden. Some fish with almost mature eggs roam about for weeks without any perceptible change in their ovaria, until on their arrival at the spawning places the eggs begin to loosen very rapidly and the ovaries are emptied in a short time. Of many fish, such as the stickleback, the pike, and others, it is known that they lay their eggs very rapidly, because they either, like the first-mentioned fish, deposit them in a sort of nest, which could be observed, or because the spawning season, after it had once fairly commenced, was finished in about two weeks. Other fish probably require a longer time for spawning. The spawning season may be either delayed or accelerated by about a month, according to difference in temperature. After the eggs have been laid they must be immediately impregnated. The semen of the male fish, inclosed in a white sexual organ (the spermary), matures at the same time as the eggs, and when fully matured is ejected by the male fish as a milky-white fluid. With the naked eye no compact particles can be discovered in this fluid, but seen through the microscope, the milky condition of the fluid is proved to be caused exclusively by the so-called semen threads, spermatozoa composing about one-half of it. These particles (see Fig. IX) consist of a head, which is generally round and flat on the top, and a long thread termed the tail; this thread moves vehemently to and fro and propels these particles quite rapidly. As at least one-half of the entire semen of a fish is composed of these small particles, thousands of which do not weigh as much as a single fish-egg, the male fish ejects millions of them. If an egg is to be impregnated, it is necessary that at least one of these particles should enter it. This process has frequently been observed.

When, for example, the codfish lays its eggs, they float on the surface because they are a little lighter than the water. A somewhat marked

Fig. XVI.—*The lower part of a floating fish-egg, magnified about 100 times.*




A, the yolk; B, the skin of the egg; C, a small orifice, the micropyle; D, semen threads (spermatozoa), one of which is just entering the micropyle.

portion of the egg is turned downward, because the egg is a little heavier in that place than in others. Such an egg consists of a transparent mass, containing in some fish a few drops of oil and of a skin, the egg membrane (Fig. XVI, B) which protects the egg and keeps it together.

On the lower side of the floating codfish egg there is a very small opening in the membrane, and this opening is surrounded by a sticky matter, such as is frequently found on eggs just after they have been laid, and which causes some other fish-eggs to stick to any object with which they come in contact. In the codfish eggs the floating spermatozoa enter this matter, some of them reach the small opening in the shell of the egg and through it enter the body of the egg. What becomes of them has not been observed in the codfish egg, but from observations made on the eggs of other animals it is known that the spermatozoa dissolve inside the egg and assimilate with it. When this has been accomplished, the egg is impregnated, and the young fish begins to make its appearance. If there is no impregnation the egg rots.

It has also been observed that spermatozoa only enter newly-laid eggs. Even if only half an hour or less has elapsed, the water has produced changes in the egg which make it impossible for the spermatozoa to impregnate the egg. But even the spermatozoa do not retain their fructifying power for any length of time after they have been in the water. On this circumstance depends a peculiar and, to the fisherman, very important practice of the spawing fish. Fish spawn either by couples, or groups of three, or whole schools. In the first-mentioned case the male keeps quite close to the female, in order to squirt the milt upon the eggs immediately after the female has spawned. In some fish, for instance the stickleback, this is very noticeable. The male stickleback builds a nest of vegetable fiber among the algæ, and when this is finished fetches the female, which enters the nest and lays her eggs. The male impatiently waits till the female is done, and finally pushes her out, so that he may enter the nest and impregnate the eggs. This practice can easily be observed during the months of May and June, for these nests are only a few feet below the surface of the water.

Other fish do not take such good care of their eggs, but simply lay them and let them sink and stick to the bottom, like the herring, or float about in the water like the codfish. If in this case eggs are to be impregnated, it is necessary that the water be full of freshly emitted spermatozoa. This is probably the reason why these fish are always found in large schools during the spawning season. All through this school the male fish emit their semen, so that the water, as I have myself observed (see Annual Report of the Commission, 1874–'76, p. 26), looks, if not white, at any rate quite muddy. In this water the eggs are laid, and are copiously covered with the spermatozoa. If the fish were to swim near the surface in couples the impregnation would be very uncertain, but the larger the school of fish the more evenly will the spermatozoa be distributed in spite of wind and current. Fish which spawn in this manner must therefore first of all gather in schools. It seems that on reaching the coast they move to and fro for some time (weeks or months), and during this time gather in schools, all of the fish which compose them having about equally-developed sexual organs. This is the reason why the herring fisheries yield such a good income. The fish are so closely massed together that large numbers can be caught with little trouble and loss of time. When passing over so-called codfish banks, such as are formed by the codfish whilst spawning, the plummet will scarcely reach the bottom, because it falls from fish to fish. When the herrings on their way to the spawning places pass through narrow channels like the Schlei, they can be easily speared or caught with a hook, as the water is completely filled with them. If the herrings spawned in pairs, the method of fishing would have to be different from what it is now, and the fisheries would scarcely be profitable.

The dangers to which the eggs are exposed differ according to the manner in which they are laid. Eggs floating about in the water run the risk of being cast ashore and perishing there. The eggs are therefore laid not too close to the coast, and as the waves move floating objects but very slowly, and as the wind does not hurt the eggs, which are so heavy that they protrude but little, and not at all during stormy weather, fewer eggs than might be thought perish from this cause. The eggs are the favorite food of numerous animals. Among the fish the eel and stickleback are notorious for their voracity. Eggs which float about freely have not much to fear from such enemies, for they swim about singly, and are so transparent that they cannot easily be seen. Large animals cannot fish for such eggs, and only occasionally they are pierced and devoured by the small crustaceans which float near the surface. The case is very different with those eggs which lie at the bottom. If the fish spawn in pairs the eggs lie in heaps in different places, and if an eel or stickleback finds them, he will devour all or leave but very few. But as the fish spawn in different and widely scattered places the eggs are hard to find, and whole heaps of them thus escape their enemies.

Mold is a dangerous enemy to fish-eggs. It will go through the eggs, and going from egg to egg quickly destroy their life. Whenever attempts have been made to develop fish-eggs in aquaria, the eggs have almost without exception grown moldy before the young fish were ready to leave the eggs. In the open air, or in water which has waves, this danger is not so great; it seems that the germs of the mold, of which there are always many in the water, find no time to stick to the eggs, but are constantly washed away by the waves. I have occasionally observed moldy fish-eggs in shallow places near the shore where there was stagnant water, but on the whole this kind of destruction is not of very frequent occurrence in the sea. If the eggs are scattered, as is the case with the herring eggs, they are distributed all over the bottom of the sea, and cling to any objects or plants which come in their way. Here is a rich harvest field for egg-devouring animals, and the only drawback is that the eggs are so scattered. But on this very account it is difficult to destroy large masses of them, and some will invariably escape. I am astonished that I have never seen it mentioned that eels are frequent in such places, for it would certainly seem highly probable that such an "egg-field" would attract them. The fishermen do not at all observe such places, and in the rare cases when they know of them they will hardly fish there. I am inclined to think that a considerable number of herring eggs are devoured by other fish and marine animals, because I have found great masses of freshly laid eggs sticking to aquatic plants in the Schlei, whilst I found but few and scattered developed eggs. It would certainly be important for the fisherman to observe the destroyers of fish-eggs a little more closely than is done at the present time.

Imperfect as our knowledge of the spawning process is, we can nevertheless get a general idea of it. This will be, however, of little practical use, for in questions of practice the location of the spawning place, its depth, the nature of its bottom, its vegetation, &c., would have to be considered. It might, however, be possible to favor in this respect certain food-fish, and to increase their number, by protecting the vegetation in the spawning places, by not removing the stones in such localities, or by even adding a few stones, and by setting eel-traps, or by catching the sticklebacks with a fine net a short time before the spawning season. The experiment would have to be made whether such measures, if simultaneously pursued on different parts of the coast, would have a favorable result. All we wish to do is to hint that these questions may probably be of considerable importance to fishermen. But all such experiments presuppose that our knowledge of the localities where the fish spawn is not, as now, confined to a few scattered places, but extends to many places.

No one but the fishermen can aid us in gaining this extensive knowledge, and if they were to give the desired aid it would certainly be to their own immediate profit. If it were so easy to find the spawning places they would have long since become generally known, but as the difficulties in the way of finding them are manifold, we take the liberty to give some well-meant advice.

A good deal depends, in the first place, on keeping books and noting down every observation. It is useless if one or the other fisherman reports that here and there he has seen one or another fish during its spawning process. He may mistake; he may have forgotten the place, or he may have taken one fish for the other, and even at best such things soon escape the memory. If such observations are to be valuable and of practical use, suitable for a basis of scientific investigations and decisions, the first thing to be done is to procure a little notebook, which can be bought for about two cents, and one of the older fishermen, or anyone else suited for it, should undertake to "keep account." On the cover should be written, "Observations on the spawning of fish, commenced in 1880."

In this book one page should be devoted to every kind of marketable fish. Thus the first page, for instance, should be headed "Plaice," the second "Codfish," the third "Sturgeon," &c. Below the name of the fish a few lines should be drawn and columns arrranged as follows:

*Herring.*

| Containing mature spawn. | | Empty. | Place where the mature fish is caught. | Remarks on the weather. |
|---|---|---|---|---|
| 1880. | First<br>Last | First | | |
| 1881. | First<br>Last | First | | |
| 1882. | First<br>Last | First | | |
| 1883. | First<br>Last | First | | |
| 1884. | First<br>Last | First | | |
| 1885. | First<br>Last | First | | |
| 1886. | First<br>Last | First | | |
| 1887. | First<br>Last | First | | |
| 1888. | First<br>Last | First | | |
| 1889. | First<br>Last | First | | |

The fisherman who keeps accounts, and whom we will designate as the "bookkeeper," will have to inquire when fish containing mature spawn were caught first and when last, understanding thereby fish with flowing spawn. The date when such fish are caught is to be entered on the book, as well as the place where they were caught, and the date when the first empty fish were caught. Some remarks on the weather, as far as, in his opinion, it has had any influence on the spawning season, should be added. To do this involves so little trouble and expense that it is to be hoped that such books will soon be kept in many fishing stations.

It is, of course, to be expected that objections will be raised. Some will say: "Such and such fish do not spawn in our waters; we can, therefore, make no observations regarding them, and consequently we cannot keep such a book." Others again will say: "What is the use of putting down all this. We know most of what is going to be entered on the book, and new things, such as where the fish-eggs are lying, where the young fry stay, on what they live, &c., are not to be entered; these things the learned people should find out for themselves." The consequence will be that no book will be kept; in fact, no matter what objections are raised, the result in all cases will be the same, namely, that nothing will be done!

The only answer to all these objections is simply that some time or other a beginning must be made, for it is time that some attention be paid to the increase of fish, and not merely to the increase of fishing apparatus. When measures shall have been taken for increasing and protecting the fish on our coasts, and such measures will undoubtedly be inaugurated at no distant period, it will make a great difference whether fishermen are *able* to pronounce an opinion on this subject, and can corroborate their assertions by written statements from their books, or whether they know nothing about it. If they can pronounce an opinion they will be heard, and the most correct and suitable measures will be selected and carried out. If, on the other hand, they cannot prove their assertions by facts or written statements made from actual observations, and without keeping books they cannot possibly do this, the measures introduced for protecting and increasing the food-fish will be much less certain of a favorable result, and it is probable that more harm than good will be done.

The usefulness of putting down observations is, however, by no means exhausted by what has been said. On the contrary, it is to be expected that here and there a fisherman will show more talent for making such observations than he could hitherto display, or than he knew himself. If any one can be found who will enter his observations in a book and preserve them for future times, so that a naturalist, in looking over the book, can extract from it all the more important observations, the observer will take an increasing interest in fish and their life, and will put down everything that he deems important.

With the means at their command, fishermen can make many important observations, and do it much easier than scientific investigators. As has been said before, it is extremely difficult to develop the eggs of salt-water fish in aquaria, and at best we do not know whether the young fish leave the eggs just as quick or just as slow in the aquaria as in the open sea. The fisherman can either place artificially impregnated eggs in suitable places on the coast and observe how soon the young fish are hatched, or he can make observations on the spawn which has been laid and impregnated in a natural manner. This is, however, somewhat difficult, because it is not always easy to find the spawn. Artificial impregnation is on the whole so easy a process that by it our knowledge of the fish-eggs and their development will probably be increased most rapidly. All that is required is to procure a live milter containing mature milt (that is, a fish from which the milt flows), and a live spawner containing mature spawn (a fish from which the spawn flows). Some eggs, about 100 to 1,000, are then allowed to flow into a flat empty vessel, which has just been washed with salt water. Upon these eggs a few drops of the milt are squeezed from the live milter, they are stirred two or three times with the hand, and sea water is added. The vessel must not be warmer or colder than the water which is added. The eggs thereupon become impregnated and begin to develop. If the vessel is covered with a piece of gauze, so the eggs cannot be destroyed by fish and other marine animals, and placed in the sea in some suitable location, the eggs will develop just as well as if they had been laid by the fish. By keeping a close watch over the vessel, and by occasionally taking out a few eggs and examining them at home, it will be possible to obtain exact data regarding the gradual development of the fish till the time of hatching, and regarding the nature and mode of life of the young fry. But few, if any, such observations have been made; but, to judge from the experience of the piscicultural establishments, the result of such observations, if properly made, can scarcely be doubted, although a few experiments may probably prove failures.

The development of the egg can easily be observed with the naked eye. As soon as the little fish begins to form inside the egg, the two eyes are distinctly seen in the otherwise transparent egg like two black dots (see Fig. XVII), and some time—according to the slower or more rapid development of the fish, days or weeks—before the fish is hatched the eyes are seen so distinctly that there cannot be the slightest doubt that they are really the eyes of the young fish. Of the body of the fish nothing can as yet be seen with the naked eye, because many fish, as long as they are in the egg, are as transparent as water. Other young fish, for instance the pike, have even in the egg a somewhat brownish color, so that the whole fish can be distinguished. When the eggs have reached this stage, some of them should be taken home in a flat vessel containing water, which should be kept in a cool place. If it wants only two or three days till the hatching, the observer will succeed in observing how the little fish act on leaving the egg. As soon as an empty egg is noticed it will be easy to find the little fish which has left it, as it will betray itself by its black eyes. Note is taken of the time which elapses from the impregnation of the eggs till the fish are hatched. This time of course varies according to the temperature of the water, but as the temperature of the water at the bottom at the same time in different years does not differ very much, the time which has been observed will very nearly be the right time.

FIG. XVII.

A *fish-egg*, on a dark background, magnified twice its natural size. In the transparent egg the two dark eyes are seen. In their center is the light lens. When the little fish is almost ready for hatching, the eyes are seen still more distinctly.

As regards the actions of the young fish we know too little to give any details. When being hatched the abdominal cavity of most fish is still filled with the matter contained in the egg (the yolk), and their abdomen therefore looks somewhat bloated. As long as the fish feed on this matter they take no other food, and move about very little, generally staying quietly on the bottom. As soon as the yolk has been consumed they begin to seek their food. Many fish at this period of their life stay in quiet waters near the surface, and have the advantage that on account of their transparency they can hardly be seen by their enemies. Gradually they begin to scatter in different directions, although some kinds, such as the herrings, keep together. Gradually the scales begin to appear, and the body begins to assume some color. The fish then seek shelter, and are able to take coarser food, such as the small animals and plants floating near the surface of the water. For some time they stay in the shallow places near the coast, and finally seek those localities where the older fish live.

All the details, on which after all the correct views as to the possibility of furthering the development of food-fish will depend, can only be ascertained by more accurate observations. The proper persons to make such observations at the right time will principally be found among fishermen.

V. HENSEN.