XVI.—ON THE OCCURRENCE AND QUANTITY OF THE EGGS OF SOME OF THE FISH OF THE BALTIC, ESPECIALLY THOSE OF THE PLAICE (PLATESSA PLATESSA), THE FLOUNDER (PLATESSA VULGARIS), AND THE COD (GADUS MORRHUA).*

BY V. HENSEN.

[From the Fourth Report o the Commission for the Investigation of the German Seas. Berlin, 1883.]

BY orders of the Commission I have, for four years, endeavored to make observations regarding the spawn of the above-mentioned fish. As regards the spawning of the cod on the coasts of Norway, we are well informed by Mr. G. O. Sars'† admirable observations; and as regards this fish the only problem to be solved was whether the spawning of the Baltic cod took place in the same manner. The same, however, cannot be said relative to the plaice (*Platessa platessa*). A circular of inquiry, addressed by the Royal Government of Schleswig to the different fishery associations, elicited the most contradictory statements, even as regards the time of spawning, and it became evident that not a single one of the numerous answers showed a knowledge of the actual condition of the eggs after spawning.

In going over the literature on the subject, we find that Alex. Agassiz‡ has seen floating eggs of the plaice, of which he gives a drawing; and that Malm § has artificially impregnated eggs of the plaice, without, however, succeeding in hatching young fish. According to Malm, the eggs slowly sink to the bottom. Only at a late stage in the course of my investigations was my attention directed by Professor Metzger to Malm's observations. This fact probably has been the cause of reaching my conclusions somewhat later than would otherwise have been the case.

The eggs of the plaice are, like those of the cod, transparent, have a

* "*Ueber das Vorkommen und die Menge der Eier einiger Ostseefische, insbesondere derjenigen der Scholle* (*Platessa platessa*), *der Flunder* (*Platessa vulgaris*), *und des Dorsches* (*Gadus morrhua*)." Translated from the German by HERMAN JACOBSON.

† *Indberetninger til Departementet for det Indre, angaaende Torskefiskeriet i Lofoden,*" Christiania, 1869.—English translation in Report of U. S. Fish Commission, 1877. Sars' work is one of the greatest achievements in this field of scientific investigation.

‡ Alex. Agassiz: "Proceedings of the American Academy of Arts and Sciences," Vols. XIV and XVII, on the young stages of osseous fishes, II and III.

§ A. W. Malm: "*Bidrag till Kännedom af Pleuronektidernes utveckling.*" *Svenska Vetenskaps Akad. Handlinger*, Vol. VII, 1867 and 1868.

thin shell, and do not contain drops of fat. The shell of the egg, under a powerful magnifying glass, has the appearance of fine wavy fibers, crossing each other irregularly. There are, however, no real fibers, but they are simply thicker portions of the egg shell. These thick places vary greatly in different eggs; in some they are not found at all, but in that case the porous channels appear very distinctly as numerous delicate dots. In my opinion, this fibrous appearance is caused by a shrinking of the contents of the egg, which gives less tension to the egg shell, but does not hinder the development of the egg. The mature eggs are not sticky. The eggs of the plaice are large, and those of the flounder small; but the smallest of all (less than one millimeter) are those of the *Platessa limanda*. I have not been able to observe any difference between the eggs of the cod and of the plaice, excepting in the outer structure of the shell, unless it be that in the egg of the plaice there is by the side of the micropyle a dot, almost resembling a second micropyle, which I did not see in the eggs of the cod. Impregnated eggs, which have not yet developed, can only be distinguished from other eggs, with the naked eye, by the circumstance that the yolk of the cod egg is decidedly yellowish, whilst in the plaice egg it is colorless.

When I received the first specimens of mature female plaice their developed eggs, when placed in water, sank to the bottom. Judging from this observation it seemed possible that the eggs were piled up in holes in the bottom or laid in nests, or that the fish simply scattered their eggs on the bottom. The first question, therefore, was to find the place where the fish deposited their spawn. I was informed that in March (the spawning season of the plaice and flounder being in March and April, and that of *Platessa limanda* in May) plaice had occasionally been found lying close to the side of each other on the coast near Friedrichsort (bay of Kiel), just as if they had gathered in certain places for the purpose of spawning.

Young plaice are, in autumn, found in great numbers among the seaweed, and in shallow places near the coast. I have found them particularly near Eckrenförde; but similar reports have also reached me from Flensburg and from Stein on the bay of Kiel. In summer Professor Möbius has also caught young fish floating about freely in the inner bay of Kiel; but we have not yet succeeded in catching very young fish. Therefore, it seemed proper to commence the investigation by endeavoring to obtain some of these fish.

For a number of years but very few plaice have been caught in the inner part of the bay of Kiel. Only in 1882, when the saltness of the water was unusually marked, and when a number of marine animals from the North Sea—otherwise not found in these waters—had made their appearance, and then but temporarily, did the plaice fisheries flourish in the inner bay. For this reason the attempt to catch young fish had to be made near the mouth of the bay. I could not take part in these experiments, and the fishermen whom I had engaged for the purpose only succeeded on the 14th of May in getting a few specimens of young fish. These had already lost their symmetrical shape, and measured about 12 centimeters in length. They had been found among the algæ a short distance beyond the mouth of the bay. If nothing else was gained, we had at any rate discovered a place where search for such fish might be made.

The experiments in developing eggs did not succeed. The vessels in which I had placed them were attached to poles and sunk in the bay, but the motion of the waves had thrown the eggs too violently against the sides of the vessels, and from this cause probably they had perished.

Therefore, the following year it was our purpose to obtain the eggs which might be freely scattered over the bottom. The eggs will slip through the meshes of a common dredge, and by a net with narrow meshes the bottom cannot be sufficiently scoured, because the net will be filled with particles of mud from the bottom as soon as it becomes the least embedded in the ground, or is dragged over a soft bottom. It is important that the eggs should, if possible, be obtained by small quantities at a time. For this purpose we used the contrivance shown in the accompanying illustration.

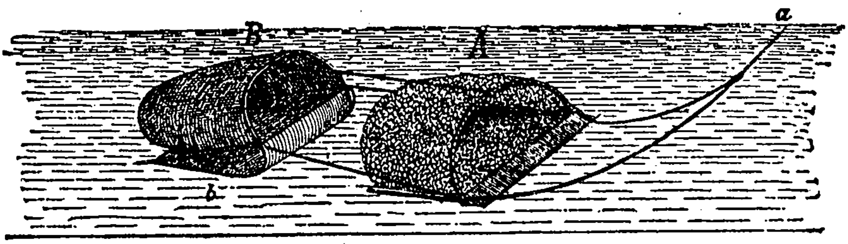

FIG. 1.—Dredges for collecting fish eggs.

At the distance of about a foot from the bag of a common dredge (A), a second light dredge with very narrow meshes (B) is fastened to the first by three cords; it rests on a bent piece of thin tin (*b*), in such a manner that the opening of the net is entirely raised from the bottom, and does not touch it at all. Any light objects stirred up from the bottom by the preceding dredge, if small enough to pass through its meshes, are caught by the tight bag of the second net, whilst heavy objects, such as sand and small stones, fall to the ground before the opening of the second net. This contrivance has been found exceedingly practical in fishing lower forms of animals.

In 1881 only dead eggs were caught in the inner bay, which probably came from the numerous plaice and cod caught during that year.

It was not until we reached buoy No. 1, outside the mouth of the bay, at a distance of 18 kilometers from the city of Kiel, that at every haul, going to a depth of 18 and less meters, we caught, close to the deep channel of the Kiel bay, which begins here, a number of eggs which floated about freely and did not adhere to any objects. Sometimes we found them singly, and occasionally in clusters of 30 to 50. From this circumstance we concluded that these eggs, which first were found on the 23d of April, and for the last time on the 11th of May, were scattered freely over the bottom and did not adhere to any objects.

We found large and small eggs of different kinds mixed. Some of the small eggs, having a diameter of about 0.93 millimeter, contained in their inside a yellow or yellowish-brown drop of fat; but we also found some larger eggs, measuring as much as 1.3 millimeters in diameter, seemingly of the same kind, and probably belonging to a species closely related to the former. Occasionally we found in these eggs several drops of fat instead of one. Other eggs, as to their size, homogeneity of contents, fibrous appearance of the shell, and colorless appearance of the yolk, strongly resembled the eggs of the plaice. We finally found small colorless eggs, without fat, measuring 1.15–1.27 millimeters, which proved to be eggs of the flounder. As I ascertained at a later date, similar eggs, having a diameter of 0.85 and 0.9 millimeter, and the considerable specific gravity of 1.020, are found in May; these are the eggs of *Platessa limanda.*

At the same time that we investigated the bottom, which only yielded any result outside of the bay, we scoured the surface. During the same period we here found two kinds of eggs, one with yellow drops of fat, not distinguishable from the larger eggs of the same kind found at the bottom, and a second kind, having a diameter of 1.24 millimeters, and without drops of fat, but characterized by the circumstance that the yolk appeared broken by even planes crossing each other almost at right angles.

These different eggs were hatched, with the following results: From the two kinds of eggs containing drops of fat there slipped small fish having a deep black pigment, and measuring at most 2.43 millimeters in length. The large yolk-bladder projected somewhat beyond the head, the eyes were pigmentous, the sphincter was close to the yolk-bag, and the chorda consisted of several rays.

The young plaice, after slipping out of the egg, remained alive 11 days. Their eyes showed some pigment. The length of the body was 5.26 millimeters. The yolk-bag was large, and the sphincter close to it. The chorda cells consisted of several links; the arch of the gills and the lower jaw were not yet developed. The young fish hatched from the flounder eggs were but little developed. Their eyes showed no trace of pigment; their length was about 3.6 millimeters. The sphincter, lying close to the yolk, was connected with the intestinal canal only by a thin cord, and the chorda had several rays. From the eggs whose yolks appeared broken there came narrow fish 3.7 millimeters in length. They were not much developed; their eyes had no pigment; they distinguished themselves from the young fish mentioned before by the construction of the chorda, which had only one ray, and also by the circumstance that the sphincter is not close to the yolk, but opens very far back, and only about 0.5 millimeter from the tip end of the tail. In this particular as well as in their form and shape, after the yolk had been absorbed, these fish closely resembled the herring. The intestinal canal, back of the stomach, however, takes a somewhat different and more crooked course. They also somewhat resemble the small fish called by Agassiz *Osmerus mordax.* Nothing is said, however, about the construction of the chorda in this last-mentioned fish. Both the herring and the *Osmerus* have bubbly yolk, and therefore differ very noticeably from the fish observed by me. In 1882 I caught large numbers of eggs, whose yolks had a broken appearance, near the Dänenkathe, opposite Friedrichsort, and between Jägersberg and Korügen, therefore near the mouth of the bay. All the fish mentioned so far did not have red blood, prior to the absorption of the yolk.

Other eggs observed by me were those of the *Cottus scorpio*, which adhered to piles in the bay in large numbers (during January to April), and of *Cyclopterus lumpus* (April). These last-mentioned eggs Professor Mobius obtained from Eckernforde, where they were found adhering to a pile in such a large lump as to render it improbable that they were laid by one fish. The eggs of the *Cottus* showed numerous protuberances and measured 1.4 millimeters, whilst the young fish measured 5.4 millimeters. The eggs of both these fish contain drops of fat, which, especially in those of the *Cyclopterus*, are very large and almost colorless. The young of both these kinds of fish, when leaving the egg, show a complete circulation of red blood, and are exceedingly lively and well developed. The *Cottus* forms a beautiful object under the microscope, whilst the *Cyclopterus* is opaque, with a thick-set body and a small tail. The suction disk makes its appearance a few days after the fish are hatched, and is put to frequent use. The protuberances on the head and dorsal fin do not develop until the yolk has been absorbed. Numerous older specimens of *Cyclopterus* were, in May, found among the sea-weeds outside of the bay. In both these fish the chorda has several rays, and the sphincter is close to the yolk. The only fish whose sphincter was midway between the yolk and the end of the tail (similar to the *Ctenolabrus cœruleus** according to Agassiz) was a small *Gobius*, whose eggs were found adhering to sea-weeds.

The object in view, to find spawn of the plaice and the flounder discharged in a natural way, seemed to be attained. The eggs were found scattered and lying loosely on the bottom in deep places of the sea near the coast, in places where plaice fisheries were carried on. This agreed with Malm's statement, that the impregnated eggs gradually sink to the bottom, but not with Agassiz's statement, that he had found eggs of flat-fish (*Pseudorhombus oblongus* Stein) floating about near the surface. Strictly speaking, the object in view could only be considered as attained so far as the year 1881 was concerned, as became evident later.

* *C. Sundewall:* "Om Fiskyngels utveckling." Kgl. Svenska Vetensk. Akad. Handlinger, N. F., Vol. I, 1855, gives drawings of young fresh-water fish, according to which the sphincter occupies a position in the middle in *Perca, Esox* (very far back), *Cyprinus rutilus* and *idus.*

It seemed very surprising that no floating cod eggs had been found, although at that period some of these fish had not finished spawning. When I took some cod-eggs and impregnated them, it appeared that they did not float either, but sank to the bottom like the eggs of the plaice.

This discovery made new investigations necessary, but these could not be made till the spring of 1882. I impregnated the eggs of cod, plaice, and flounder; and by keeping, by means of ice, the temperature of the water at 4°—8° Celsius, and by keeping the water in motion through a glass funnel drawn up and down, I succeeded in hatching a number of young fish. At some future time I intend to give a full report of their development; and so I will only state here that plaice and cod were hatched in about fourteen days and flounders in eight days. My diagnosis of the previous year was, therefore, entirely confirmed. It appeared, however, that the capacity of the eggs of these three kinds of fish for floating in the water is limited and varies very much. Inconsiderable fluctuations in the saltness of the water are sufficient to cause the fresh-laid eggs either to rise or sink. Moreover, when the saltness of the water is not very great, many impregnated and developed eggs sink to the bottom after a short time; whilst *all* eggs which have either not become impregnated, or which have ultimately died, always sink to the bottom.

The way the eggs would act could not be stated beforehand with such certainty as people will be inclined to suppose. There was no fact to indicate that the capacity for floating of the eggs, which frequently contained a great deal of oil, was very small, and adapted itself so little to external conditions. As matters stood, a more thorough examination of this subject appeared to be of practical and scientific interest. I therefore deem it proper to give exhaustive statements relative to the weight and number of the eggs—statements which for the present may appear, perhaps, too detailed.

*R. E. Earll** has given us an excellent treatise containing full data relative to the cod, the plaice, and the *Gadus pollachius*. From his experiments in impregnating fish-eggs it appears that invariably only a certain quota of the total number of eggs contained in a fish could be successfully preserved. Thus, for instance, of a fish containing 2,700,000 eggs, only 400,000 eggs, or one-seventh of the entire quantity, could be preserved; the remainder matured later and were discharged in the hollow of the ovarium. Earll comes to the conclusion that, in such a fish, about 337,500 eggs matured per week, and that its spawning period lasts two months. He also shows that all fish ultimately discharge all their eggs. The mature eggs of a cod weighing 75 pounds would weigh about 45 pounds; and it is impossible that any fish could at one and the same time contain this quantity.

I have no objection to these important observations, as all my ob-

* United States Commission, Fish and Fisheries. Report of the Commissioner, 1878. Part VI, p. 685.

servations tend to confirm them; but I must state that, according to my observations, the eggs in the ovarium show five very distinct stages: (1) free, (2) mature, (3) clear, (4) large muddy, and (5) small muddy eggs. Even in the immature ovarium three distinct stages can be distinguished, and this whole matter will have to be studied more closely.

Earll ascertained the number of eggs by weighing first the entire ovarium, then pieces of it, and by counting the number of eggs in some of these. This proceeding may be considered as leading to reliable results, as, according to my observations, the character of the ovarium is very much the same in its different parts, and as it would almost be impossible to count the eggs in any other way. It is, of course, possible that some of the small eggs do not reach maturity, but are, especially towards the end of the period, again absorbed. My observations relative to this matter, however, have, so far at least, only yielded a negative result.

Earll makes the following calculations:

	Eggs.
Cod, 75* pounds, 9,000,000 eggs, per 500 grams	160,750
Cod, 51 pounds, 8,489,094 eggs, per 500 grams	236,150
Cod, 30 pounds, 3,715,687 eggs, per 500 grams	165,950
Cod, 27 pounds, 4,095,000 eggs, per 500 grams	203,200
Cod, 22$\frac{3}{4}$ pounds, 3,229,388 eggs, per 500 grams	190,200
Cod, 21 pounds, 2,732,237 eggs, per 500 grams	174,300
Average	188,425
Plaice, 9$\frac{9}{16}$ pounds	1,834,581
Plaice, 6$\frac{3}{16}$ pounds	849,315
Plaice, 4 pounds	403,132
Plaice, 3$\frac{3}{16}$ pounds	298,976
Gadus pollachius, 23$\frac{1}{2}$ pounds	4,029,200
Gadus pollachius, 13 pounds	2,769,753

The following are the dimensions of the eggs: Those of the largest cod 1 5 millimeters, and those of the smallest cod 1.34 millimeters in diameter; *Gadus pollachius*, 1 millimeter. No measurement is given of the plaice. The specific gravity is given as varying between 1.020 and 1.025; but I presume that this is only an estimate based on the specific gravity of the sea, for otherwise these figures would be very remarkable.

The period consumed in hatching the eggs of the cod was: At 7.5° C., 13 days; 5° C., 16 days; at 3° C., 20 days; at 2.2° C., 24 days; at 0.5° C., 34 days;—1.2° C., 50 days; when the temperature is lower the eggs perish. Some eggs develop the young fish slower; those fish which are hatched first and last are not very strong.

With a view to distinguishing with greater certainty the eggs of dif-

* This seems to be Troy weight, therefore only 373.2 grams per pound.

ferent species, and to comparing them with each other, I have endeavored to obtain average figures relative to the measurements, but in doing this I encountered innumerable difficulties. By measuring eggs which had not yet been impregnated, I found that as a rule they are ellipsoids, and not globes. In measuring such eggs, it is not absolutely certain whether one measures the long or short axis. Moreover it is necessary to measure a considerable number of free eggs, which is a very tiresome process. It would be better if the average diameter could be gained from the weight, numbers, and specific gravity; but the exceedingly tender nature of the eggs became an insurmountable obstacle when I attempted to measure in this manner eggs which had not yet been impregnated.

The freshly laid eggs lie in a liquid which may well be designated as *Liquor folliculi*, as it probably originates in Graf's follicles. This liquid has less specific gravity than the eggs, and has, therefore, to be examined separately. As the shell of fresh eggs when exposed to the air is very apt to burst, partly through the weight of the eggs, no method could be found to weigh the eggs in a dry condition. The liquid would have to be removed by washing the eggs, which would cause them to swell and possibly produce transudation, thus changing the original character of the eggs. The eggs, after having been laid in salt water undergo very considerable changes. After a while they become so hard that they can be rolled between the fingers, and their presence among other matter brought up from the water can easily be ascertained by the touch. Eggs which have not been impregnated do not become so hard, because after awhile they begin to dissolve. For 14 days, however, and even longer, their shape remains well preserved, and, compared with fresh eggs, they seem hard. The hardening process, in order to become perfect, requires one day. But I have not followed this process closely, and must mention this circumstance because afterwards my attention was directed to a very striking observation made by Mr. Earll. He says, on page 721:

"It was found desirable to leave the eggs for fully half an hour together with the milt; and sometimes a longer time was required to make them quite hard."

Earll, therefore, seems to assume, as a well known fact, that fish-eggs harden in consequence of impregnation. If there are any facts relative to this subject in literature, they must have escaped me. Hitherto I have considered the hardening process as owing to the effect of the water, and the gases contained in it; which is undoubtedly correct as regards the hard crust found on many eggs. If impregnation by itself cause a hardening of the eggs, this must be considered as a fact not yet sufficiently noted and examined by science.

As regards eggs which had not yet been impregnated I have, in the following manner, endeavored to obtain approximately correct data: I first determined the specific gravity of the liquid, then that of the eggs in the liquid. Thereupon the weight of a certain known number of eggs with liquid in air. Finally I measured the eggs of the same fish, and from all these observations I determined their true weight and their specific gravity.

The mature eggs of three female cod each weighing 1½ pound, were placed on filters, in order to obtain the liquid. It is advisable for this purpose to remove the ovary from the fish, to open them, and let the eggs run out into a vessel. In this manner more eggs, and generally ones in a better condition, are obtained than by squeezing them out, which process is also apt to let other secretions mingle with the eggs.

The specific gravity of this liquid, as determined by the picknometer, was 1.01115, at a temperature of 8.7° C. The specific gravity of a quantity of eggs, with liquid, of the same fish was 1.01542, at a temperature of 7.2° C. Nine hundred and sixty-one of these eggs weighed 1.9038 grams.

To find the relative quantity of the liquid, the diameter of these eggs had to be ascertained. In order to avoid their pressing against each other, they were placed in the remainder of the filtered liquid, and after 23 measurements the maximum diameter was found to be 1.4119 millimeters, the maximum 1.5099, and the average 1.4375. The average volume of an egg $\left(\frac{\pi}{6}d^3 = \text{vol.}\right) = 0.5236$ multiplied by $2.9705 =$ 1.5553 cubic millimeters. The above mentioned 961 eggs, therefore, had a volume of 1494.6433 cubic millimeters.

As the specific gravity of the eggs with the liquid had been 1.01542, the volume of the above 1.9038 grams eggs with liquid was 1.9038 divided by 1.01542=1.8749 c. c.; subtract from this the volume of the 961 eggs, which is 1.4946, and the volume of their liquid is 0.3803 c. c.

Calculating the percentage on the quantity of eggs in these three fish, we find, that of the total quantity of matter discharged from the ovaria 79.72 per cent. was egg substance and 20.28 liquid.

As this mixture had a specific gravity of 1.01542, and the liquid a specific gravity of only 1.01115, the specific gravity of the eggs, at a temperature of 8.3° C., is found to be 1.01664. The equation from which this result is obtained would be the following (x standing for the specific weight of the eggs):

$$79.72x + 20.28 \times 1.01115 = 100 \times 1.01542.$$

It must be observed, however, that small differences in the micrometric measurement change the results considerably. Careful measurements of 23 eggs, from a cod weighing 9 pounds, showed the large diameter to be 1.502, and the small diameter 1.457 millimeters. Calculated from these figures the volume of the ellipsoid was found to be 1.6703 cubic millimeters, and from this, the average diameter of the globe of the egg 1.4721 millimeters. If I use this diameter for the above calculation I find per 100 volumes eggs 85.61 per cent. egg substance and 14.36 per cent. liquid. The specific gravity of the eggs by themselves, is, therefore, 1.016165. The fourth decimal, therefore, shows already differences. Other experiments show that the quantity of liquid is not always the same; but the above mentioned 20 per cent. is probably to be considered as a large percentage. If, in order to test the matter, we suppose that there is enough liquid between the globes of the eggs, to allow them to fill the space, without pressing against each other, it follows that every egg having a radius = 1 must lie in a dodecahedron, whose half height h would be =1.6343, whose basis at the plane of this half would be 5.1955 square meters (g), whose hollow space would therefore, be—

$$\left(\frac{v={}^{2}gh}{3}\right)=5.678 \text{ cub.}$$

whilst the globe r would be=1=4.186 cub.

so that the quantity of liquid in the mass of eggs would be=1.489 cub.

This would be 26.21 per cent. liquid. As the eggs actually pressed against each other, and as no liquid gathers on the top of them, the percentage of liquid must be less that 26.21; and the actual quantity of liquid would be between 14 and 20 per cent., but it is certain that the *percentage of liquid varies greatly. The liquid acts as a strong alkaline* reagent, and contains an albuminous substance, which can be obtained by boiling and by acetic acid, and which, when precipitated by alcohol, cannot be dissolved again.

Eggs which had not been impregnated, when thrown in salt water, float near the surface, the specific gravity being 1.0156 and the temperature 5.3° C., and the specific *gravity being 1.0141, the temperature* 17.5°, and the saltness 1.85 per cent.; they begin to sink at a specific gravity of 1.0146 and 5.3° C. = 1.0131 specific gravity at 17.5° = 1.72 per cent. saltness. Of the impregnated eggs one-half float near the surface at a specific gravity of 1.0155, at 7.04° C. = 1.0145 at 17.5° C. = 1.90 per cent. saltness. Probably, however, these eggs were still covered with spawn to a considerable extent, for in the open sea they floated near the surface at a less specific gravity. When the eggs are impregnated in a thin solution of salt, and are then examined as to their capacity for floating, they do not appear noticeably lighter than when they are immediately thrown in a concentrated solution. At least the difference is very small.

As in liquid the eggs have a specific gravity of at least 1.0161 at 8.7° C., but in salt water of 1.0155 at 7.4° C., it seems that in the latter they absorb some of the water which does not contain much salt. For practical purposes, however, it is sufficient to know that in order to keep the eggs afloat near the surface, the percentage of salt in the water should not be less than 1.85 per cent., and should at any rate be higher than 1.72 per cent. The weight of the eggs is not entirely the same. I have not yet examined eggs which had developed more, as to their weight, which probably had changed somewhat. Cod eggs freshly laid in the water would, at a specific gravity of 1.015, weigh from 1.5 to 1.7 milligrams.

In a similar manner the eggs of the plaice (*Goldbutte*) were determined. For this purpose I selected four fish having an average weight of 1 pound and an average length of 30 centimeters. The specific gravity of the liquid was 1.01022 at 7.5° C., and of the eggs with the liquid 1.01430. After having been weighed and counted, the weight of one egg with the liquid belonging to it was 3.363 milligrams. The average diameter of the egg, calculated from 30 measurements, was found to be as follows: long axis, 1.76163 millimeters; short axis 1.71686, the minimum, 1.608; and the maximum 1.804. The volume would, therefore, according to these figures, be 0.0027188 cubic centimeters. The mass of eggs taken from the ovarium was therefore composed of 82 parts eggs and 18 parts liquid, and the specific gravity of the eggs by themselves 1.01557 at 4°.5 C.

These eggs, when thrown into salt water had a specific gravity of 1.01496 at 6.8° C=1.0136 at 7.5°=1.78 per cent. salt. It does not admit of a doubt, that these eggs had begun to swell, for the difference of weight between the eggs from the ovary and the eggs from the water is very considerable. Taking the specific gravity of the swelled egg, calculations show its volume to be 0.003081 c. c. at 7°, it weight 3.127 millimeters, and its average diameter 1.801 millimeters; whilst *calculated on the basis of the original volume of the egg, it is only* 1.732 millimeters. Comparisons made between the average measure of eggs taken from the sea, and eggs taken from a fish will not lead to absolutely certain results, but if the eggs are thrown into salt-water, a comparison of those eggs which have not yet been very much developed will be tolerably exact. It is of some interest to embryolgy to know that the eggs swell, considerably, so that they increase 11 per cent. of their volume and 4 per cent. of their diameter; the shell of the eggs is so thin that their swelling cannot be 0.07 millimeters. Unfortunately I neglected to make the necessary investigation of more developed eggs, which would of course require a considerable number of eggs. It would be interesting to know whether the small fish of the Baltic have as large eggs as the great fish of the ocean.

The specific gravity is, as we know, of peculiar importance as regards the Baltic. Our monthly reports show the following data as to the saltness of the water of the Baltic, at same depth, in the Bay of Kiel near Friedrichsort:

Percentage of saltness in deep water.

Year.	February.		March.		April.		May.	
	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.
1873	2.06	2.08	1.76	2.08	1.67	1.83	2.20	2.29
1874	2.48	2.53	2.43	2.52	2.24	2.40	1.59	1.72
1875	1.78	1.88	1.64	1.77	1.59	1.61	1.78	1.83
1876	1.90	1.94	1.93	1.99	1.90	2.02	1.57	1.85
1877	1.81	2.17	1.90	2.02	1.79	1.94	1.53	1.69
1878	1.73	1.74	1.76	1.81	1.65	1.86	1.39	1.68
1879	1.59	1.70	1.51	1.72	1.51	1.69	1.40	1.45
1880	1.82	1.91	1.81	2.10	1.56	1.83	1.47	1.40
1881	1.39	1.78	1.28	1.55	1.47	1.60	1.51	1.59
1882	2.11	2.17	2.14	2.16	2.08	2.15	1.69	1.76
1883	1.82	1.86	1.79	1.89	1.86	2.00	1.68	1.90

The saltness given in the above table relates to the quantity of salt which would be contained in a solution of cooking salt of the specific gravity found in the sea.* Our areometers, according to *Behrens* and *Jacobsen*† generally give the quantity of salt somewhat too high.

Presuming that these observations also apply to the open sea, we find that cod eggs, which require about 1.8 per cent. for floating, were during the last eleven years laid in water, which on an average was too fresh, four times in February, six times in March, and seven times in April. We also find that during the three months referred to the water was three times per month so fresh that the eggs could not float at all. For the plaice eggs, which only require 1.78 per cent. salt, the average condition of the water was too fresh, five times in March, three times in April, and ten times in May. The maximum saltness did not reach the necessary height 3 times in March, three times in April and seven times in May. In the open sea the conditions of saltness may be somewhat more favorable; but beyond the Island of Rügen, in the eastern part of the Baltic, the sea water will hardly ever possess the degree of saltness necessary for floating the eggs near the surface, unless the eggs in those waters have a different weight.

It did not seem probable that the saltness of the water would have to be taken into consideration in observing the spermatozoa composing the spawn, as so far the observations had shown that, as a general rule, ½ to 1½ per cent. of cooking salt would suffice to keep the spermatozoa in healthy motion.‡ Nevertheless it seemed necessary to investigate this matter. Strange to say it was found that the spermatozoa of the cod and the plaice were influenced very strongly by the degree of saltness of the water. Probably this whole subject is more complicated than was supposed in the beginning. The condition of the fish may have something to do with it, and the temperature may be of some importance. Observations made at a temperature of 0 to 4°, however, proved beyond doubt that mature spawn taken from the cod when not diluted, did not show any motion, whilst, when placed in sea water (taken from the aquarium) with a saltness of 1.9 per cent., it immediately showed very lively motions, lasting as long as one and a half hours. I have certainly seen a spermatozoon (in the micropyle of an egg which had probably been impregnated) in motion for that length of time. When further diluted the general motion seems to decrease; at 1.4 per cent. and below the spermatozoa remain motionless for a period of one to two hours, when there is again some motion, though less energetic and less general. When the spawn is diluted by an admixture of light sea water, there will always be a zone, within which the spermatozoa will be in motion. In this case, however, the liquid of the spawn has been suitably mixed with the water. This observation, however, should

* See Meyer: "*Untersuchungen über die physikalischen Verhältnisse der Ostsee,*" p. 10.

† *Jahresbericht* for 1871, p. 53.

‡ See Hensen: "*Physiologie der Zeugung*"; Leipzig, 1881, p. 95.

not be taken into account, because in natural impregnation the spawn immediately become mixed with the overplus of the surrounding medium.

I have also made experiments with solutions of rock-salt and of sea-salt which was not quite dry. The results were the same, and I found it impossible to dilute the solution of rock-salt as much as that of sea-water, without decreasing the mobility of the spermatozoa. The spawn of the plaice acts the same way as that of the cod.

This experience cannot, in my opinion, be generally applied, for otherwise the propagation of fish in the eastern part of the Baltic would come to a standstill, whilst we know that both cod and flounders are found beyond Memel. I am not able to furnish an explanation of the matter. In order to do this direct investigations would have to be made on the spot.

For the questions which both here and later will be of interest, the composition of the sea-water is of greater importance, as for instance, it cannot be immaterial what kind of salt is dissolved in the spawn mixture. I, therefore, give below the latest results as to the composition of the sea-water, from the analyses of the Norwegian expedition, principally based on Schmelck's * analysis, arranged in tabular manner for immediate practical use.

According to Jacobsen † the calcium in the Baltic amounts to 1.208 and 1.337 per cent. He also finds that the average quantity of sulphuric acid in the ocean is 6.493 per cent. of the salt a difference which would not be equalized, even if the salt was calculated at 99.6, instead of 100 parts. The remaining 0.36 parts are probably composed of iodine and bromine.

But to return to the eggs. It has already been shown that the eggs can develop both when floating near the surface and when lying at the bottom. The danger of their being devoured, therefore, seems to be varying according to circumstances. The floating eggs may be carried ashore, which, however, occurs comparatively seldom, or they may be devoured by other marine animals floating about near the surface. I do not consider these dangers as very great, but will, nevertheless, report on this subject below. In my opinion the danger is much greater when the eggs lie on the bottom. Here crabs, snails, worms, and star-fish are crawling about in large numbers; here shell-fish of different kinds, hidden in the bottom, whirl the currents of water which contain their food into their interior. Every fish floating past moves the water sufficiently to drive the eggs along the bottom and bring them within the reach of these whirlpools. In fact, the possibility of being devoured seems much greater. I am, so far at least, not able to form a definite opinion as to the quantity of marine animals at the bottom of the sea, which probably varies greatly in different locations. By digging in

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* *Schmelck: "Der Norske Nordhavs expedition."* Christiania, 1882.

† *Jahresbericht*, 1871, p. 55, and 1874-'76, p. 241.

sandy parts of the coast I, as have others before me, found such a large quantity of small animals within a narrow space as to make it a matter of surprise that there are any eggs at all on the bottom of the sea.

Inorganic components of the sea-water.

[Per 100 parts salt.]

Metalloids and acids.		Metals.								Totals.
S.	C.	H.	Na.		K.	Mg.		Ca.		Metals.
2.523	0.0672	0.005654	36.361		1.12	3.766		1.1988		36.45145
			30.231	0.13006	1.12	2.58	1.186	1.176	0.0228	36.4458
O. in bases 1.3515	0.000476			0.220536						Oxides 3.87496
	0.7902						1.9762			
	0.4703							1.0463		
	0.00912								0.03192	
Cl. 55.249	46.609		76.84							Combinations of chlorine 89.18.
	1.02				2.14					
	7.62					10.2				
SO_3 6.307	3.9553						5.93			Combinations of sulphuric acid 9.93.
	2.3537							4		
CO_2 0.2739	0.24881	0.254464		0.475						Combinations of carbonic acid 0.532.
	0.02508								0.057	
Cl. + SO_3 + CO_2 61.8229			Na. Cl.	Na. HCO_3	K. Cl.	Mg. Cl_2	Mg. SO_4	Ca. SO_4	Ca. CO_3	Indissoluble combinations. 99.642
Salts										

It is, at any rate, the normal condition of the eggs of these fish to float near the surface. I have, therefore, been led to suppose that in those years and those locations where the eggs remain floating, a quantitative calculation of their average would at least furnish an approximately correct estimate of the number of fish which had spawned at such times and in such locations.* In following up this idea we find that a vast and seemingly fertile field opens out for investigation, which, though barely entered, could not be passed in silence, all the more, because a knowledge of the facts given below would, a short time ago, have been of great value to me.

Counting the eggs of plaice not fully matured has given the following results:

Plaice 48 centimeters long, weight, 1,050 grams: ovary, 66 grams; number of eggs, 300,000.

* In order to prevent any erroneous ideas, I will define my idea of an "approximately correct estimate." At present I would not venture to decide, whether in the set near Eckernförde, taken as an example, there are annually caught 5 to 75 per cent. of all the grown fish, *i. e.*, whether four-fifths of the fish caught, or twenty times their number, live in that area; or to express it still differently, whether, scattered over the area, there would be 30 or 472 eggs to the square meter. The possibility of approaching a solution of this question by direct experiments is what I understand by an "approximately correct estimate."

Plaice 36 centimeters long, weight, 457 grams: ovary, 132.5 grams; number of eggs, 80,940.

Plaice 31 centimeters long, weight, 374 grams: ovary, 113.4 grams; number of eggs, 111,300.

Cod* 30 centimeters long weight, 525 grams: ovary, 141 grams; number of eggs, 305,900.

The smallest mature plaice which has come under my observation was 25.5 centimeters long, and weighed 142 grams without the ovary, which weighed 57 grams. It is, for the present, not very important to know exactly the average quantity of eggs of plaice. Not to make too high an estimate, I assume that a female plaice lays, on an average, 75,000, and codfish, per pound, 200,000 eggs. I furthermore assume that half of the fish caught are females, although passing through a fish market one gets the impression that there are more female than male plaice.†

Using these estimates in my calculations I obtained the following result: Near Eckernförde there were caught during a period of 9 years 1,706,848 plaice. Assuming that half of that number were females, we get 853,000 multiplied by 75,000=73,985,000,000 plaice eggs (228 cubic meters, or 231,348 kilograms). The quantity of cod caught was 354,162 pounds; assuming half of that quantity to have been females, we get 117,000 multiplied by 200,000=23,400,000,000 codfish eggs. The spawning season of both these kinds of fish lasts about two months, and it takes the young fish about fifteen days to be hatched. It is, therefore, probable that in the middle of the spawning season there is, on an average, at least one-fourth of that number of eggs in the fishing area at one and the same time. The calculation, therefore, shows that within the fishing area there must be at least 15,996,000,000 plaice eggs, and 5,850,000,000 codfish eggs.

The reliability of this calculation depends on the correctness of the statistics and a sufficient number of egg-counts. It is certain that we have not yet reached a sufficiently large number of the latter, but there is nothing to hinder more extensive counts. For the present, it is immaterial whether the figures obtained should be doubled or halved; for all we aim at is to get an approximate idea of the real condition of this matter. The objection might also be made, that of the total number of fish caught during the year, a portion is taken from the sea in a mature condition, and should, therefore, be subtracted. As regards my simple question, "Is the number of spawning fish as large, or larger, than the number of fish caught per annum?" the circumstance referred to is of no great weight, for the number of fish caught per annum is nothing but a number from which this question may conveniently be started, if you

* A *Platessa limanda* weighing 642½ grams contained 807,467 eggs.

† The same applies to the codfish; but Earll found among 13,300 codfish 67 per cent. males. According to Möbius (paper read at the general meeting of the Schleswig-Holstein Fishery Association, March 1, 1883), a plaice weighing 450 grams contained 281,380 eggs. He counted 120,000 eggs per plaice, and two to three females to one male.

like, a measure which may serve as a starting point. Apart from this, the number of fish which, owing to their being caught during the spawning season, should be counted out, is fully compensated by the circumstance that we have only counted the number of fish caught by the Eckernfórde fishermen, although within the same area many Kiel fishermen carry on fisheries.

This area embraces about 16 German square miles. One square mile = 5,500 hectares = 550,000 ares = 55,000,000 square meters; 16 square miles are, therefore, equal to 880,000,000 square meters. If the number of eggs which must be within the fishing area are distributed evenly, there will be per square meter 17 plaice and 6.6 codfish eggs, therefore in all 23.6 eggs; that is to say, a quantity of eggs sufficiently large to admit of an investigation.

There is no reason to suppose that in some other places in the Western Baltic there are fewer fish than the number given above; on the contrary, fishermen maintain that the places referred to are overstocked with fish, at least as regards plaice. If, therefore, the eggs laid within this area were driven to other places, a sufficient number of eggs, coming from the west or northeast, would take their place. It is probable, however, that a current, running for a long time continuously in one direction, would soon drive the eggs from the Western Baltic, unless there are other circumstances to prevent such an occurrence. This seems to be the case, and possibly makes this very basin of the sea a peculiarly interesting field for observation. It seems that the floating eggs cannot escape towards the north and towards the east. They cannot pass through the Great Belt, because (as Meyer has shown in his observations) the surface current going north through the Belt, in March, and especially in April, contains less than 1.8 per cent. salt. This current principally comes from the Eastern Baltic, and, therefore, does not carry any eggs. But if waters from the Western Baltic—containing eggs—mingle with it, they begin to sink, and therefore either get in a zone where there is hardly any current, or into the lower current floating south, which brings them back to the place from which they started. At any rate, the free movement of the eggs is hindered. Only direct observations, taken in the Great Belt, will show whether the movement of the eggs is stopped entirely, whether more eggs enter from the North Sea than those which leave the Baltic, or whether the reverse is the case. Towards the east the floating eggs cannot make much progress, because they would sink to the bottom, owing to the water gradually losing its saltness the farther east you get.

So far the practical results did not seem to correspond at all with the observations given above; nevertheless, I felt convinced that they were approximately correct. Hence in 1883 I commenced to make direct observations as to the quantity of the eggs, and below I give the results. I fished with three nets; the net for fishing at the bottom has already been described; it measured 38 centimeters in breadth; the floating surface net measured 80 centimeters in breadth; the vertical net was closed and thus let down to the bottom, and hauled up thence. Its opening was 0.1182 square meters. The result of my observations was as follows:

Location.	Observations.	No. of eggs per square meter (surface).[15] Single haul.	No. of eggs per square meter (surface).[15] Percentage of all the hauls.
Off Danen-Rathen	*April* 7, 1883: 11 *hours from Kiel;* weather very fine, sea calm; specific gravity 1.0158 at 3.8° (at 17.5° = 1.0142 sp. g. = 1.86 per cent. salt): drew surface-net 96 meters; many diatoms, some *Sarsia;* the diatoms almost exclusively *Chätoceros*, *Sarsia tubulosa*, and occasionally *Dysmorphosa fulgurans*.—No eggs.		
Buoy No. 1 in the open sea, about 19 kilometers from Kiel.	Sp. g. 1.0157, at 2.7° (at 17.5° = 1.0142 sp. g.) surface-net 96 meters; diatoms; 420 eggs, among them 19 small ones; and among these 3 with drops of fat	5.5	
	Bottom-net on red algæ 96 meters; 23 eggs; among these 1 codfish egg, 19 plaice eggs, and 3 flounder eggs.	0.6	6.04
	Bottom-net; sandy bottom 50 meters; 44 eggs; among these 16 small ones; 28 plaice eggs and codfish eggs	1.2	
4 kilometers farther northeast.	Surface fished for 96 meters; many diatoms; 2,399 eggs; among these three with drops of fat (probably more), and 64 small eggs (flounder.)	31.2	32.2
	Bottom-net 99 meters, depth 10 fathoms; 33 large eggs, which did no longer float	1	
4 kilometers farther	Surface 96 meters; no diatoms; many entomostracans; 1,554 eggs; among these 19 with drops of fat; 65 flounders	20.1	20.1
Buoy No. 2; 15 kilometers from Kiel.	After sunset, the sea perfectly calm; fish playing near the surface. A great many diatoms; fished 180 meters; 6 eggs; 2 of these small; all eggs caught this day, young; no pigment in the eyes of any of the embyros. Back in Kiel at 10 p. m.		
Stoller-Grund; 21 kilometers from Kiel; 7 kilometers from Bilk.	*April* 13, 1883; 10½ *hours from Kiel.* East wind; sea a little rough. Sp. g. 1.0152 at 3.4°, at 17.5° 1.0138 sp. g. = 1.81 per cent. salt. Surface-net, 50 meters; diatoms; 53 eggs; 3 small eggs and 50 cod and plaice eggs	1.3	24
	Vertical net; depth 10 meters; hauled up net once; 2 eggs.	17	
	Bottom-net, 80 meters; stony bottom; 215 eggs; among these 34 small eggs, 65 plaice eggs, and 1 spoiled egg	7	
5 kilometers from the Stoller-Grund beacon; 12 kilometers from Bilk.	Surface-net 96 meters; diatoms; 179 eggs; among these 11 small ones	2.3	
	Surface-net, kept at same depth, drawn 96 meters; 35 eggs; among these 2 small ones; ½ egg per square meter		102
	Vertical net, hauled 3 times at a depth of 13 meters; 36 eggs	101	
	Bottom-net 96 meters; 13 eggs	0.4	
21 kilometers north of Bilk.	Surface-net 96 meters; many diatoms; 110 eggs	1.4	
25 kilometers north of Bilk.	Surface-net 96 meters; hardly any diatoms; 1,121 eggs; of these 124 small ones, and of these 60 with drops of fat	14.6	
	Bottom-net; many diatoms; no eggs, it seems; some of them, however, may have been overlooked	....	84.5
	Vertical net hauled 3 times, at a depth of 18 meters; 31 eggs	84.5	
28 kilometers north of Bilk; Aaro in view.	Sp. g. 1.0134, at 3.2° (at 17.5° = 1.0120 sp. g. = 1.54 per cent. salt). Surface net 96 meters; 3 eggs in the net, which probably had been in it from the last haul; no diatoms; many entomostracans. A strong current; it evidently was met by water which, driven by the east wind, was rapidly flowing from the Eastern Baltic towards the Sound and the Belts.		
5 kilometers north of Bilk	Sp. g. 1.0151 at 3.5° (at 17.5° 1.0135 sp. g. = 1.77 per cent. salt). Water rough; surface-net 50 meters, 58 eggs; no diatoms; many *Sarsia* and *entomostracans*	1.5	
Buoy No. 1	Same; 21 eggs; many eggs contained embryos which were considerably developed; back in Kiel at 9 p. m.	0.5	

[15] The calculation per square meter is as follows: The surface-net of a breadth of 0.8 meters drawn a distance of 96 meters, 0.8 = 76.8 square meters with (e. g.) 420 eggs, $\frac{420}{76.8}$ = 5.5 eggs per square meter. The vertical net drawn 3 times corresponds to a surface of 3 × .01182 = 03546 square meters with a haul (e. g.) of 36 eggs, $\frac{36}{.03546}$ = 101.5 eggs per square meter. Add to this eggs at the bottom, 0.4 per square meter, and we get 102 eggs per square meter surface.

From that time the weather became unfavorable. Trips made on the 27th of April, and during the night from the 11th to the 12th of May, proved failures, because the wind, and partly also the specific gravity of the water, made it impossible to take any observations.

The observations given above share all the shortcomings of first attempts. On the first trip I had not taken a vertical net; and even on the second trip I had no distinct idea of the importance of this apparatus, which I had used of too small a size. I also made the mistake of neglecting to examine everywhere the deep water and the bottom. Moreover, I could not count the eggs immediately, and it was impossible to make them the subject of systematic observations. As regards rational observations of the density of the eggs, I was not fully prepared either as to apparatus or as to the preliminary studies which should have preceded such observations.

Nevertheless, I am of opinion that, in some respects at least, the results are important. In the first place, of course, as to the methods for pursuing such investigations; but in the second place I feel compelled by the first impressions received from these quantitative preliminary experiments, to propound the idea, that it is principally quantitative experiments—not only as to eggs, but also as to the floating diatoms, entomostracans, &c. (all of which use their power of motion principally in a vertical direction)—which will bring about such a development of the biology of the sea, and the trades connected therewith, as we have a right to demand of science. The great problem, What cycles of organic masses are fanned into life by the biological use of the sun-power, to which the large sea surfaces of the globe are exposed, has practically been barely approached. We know from Murray's observations a little as regards the life-cycles of the ocean; but we do not know through what long stages the parasitism of animal beings runs on the light-born world of plants. We do not know whether the principal cycle should be called diatom-monads, or whether some important cycle still embraces the vertebrates. In all probability both is the case; but quantitative investigations alone can reveal to us which must be considered the principal and which the subordinate type.

As regards the method to be pursued in this special case, I would state that, without a steamship suitably arranged for the purpose, not much can be done; I will not, however, insist on this.

For fishing I would recommend a vertical net of somewhat large dimensions; the best will be one with a ring having a diameter of 80 centimeters, so that it is possible to fish a space of 0.5 square meters. The net itself should almost taper off in a sharp point. It is very important that one should be able to fish with this kind of net even in a somewhat rough sea.

The surface-net is not as essential; under favorable circumstances it yields larger masses than can be easily manipulated. Occasionally, however, it will be desirable to catch large quantities with a view to make comparisons of the different stages of development and of the different species of fish. Nets of the breadth of one meter should be used, so that, after the eggs have been counted, there is no risk of being hindered by calculations from making the best possible use of fine weather.

The bottom-net referred to in my observations can, probably, be better arranged for quantitative investigations. The results which I obtained with this net hardly give the number of eggs high enough. Such a net, moreover, can only be used when the sea is very calm, as the waves disturb the even movement very much. This might be remedied by tying a weight to it.

I have based my calculation on the supposition that the water passes through the opening of the hoop of the net, just as if there was no net. This is, of course, not absolutely correct, because the meshes of the net offer resistance to the water. It is my opinion that all water, with the exception of a very small quantity in front of the net, goes through it, when the motion is slow; for my observations showed that objects floating in front of the net did not avoid it. So far I have not been able to discover any way to utilize the water which avoids the net. It is, however, sufficient to know that, in consequence of this circumstance, one has obtained a catch which is too small in proportion to the fishing area. The length of the area is obtained by means of a log with a line divided into meters (a white rag being fastened to the line at every two meters, and a different-colored rag at every 10 meters).

Besides the apparatus mentioned, another net is required, with which fishing can be carried on at full, or at any rate, half-steam power. The apparatus required is one which will decrease one-tenth the velocity of the current passing through the mull-net at the rate of 10 kilometers per hour. For this purpose I have had constructed a hollow cane with an obtuse top, made of wicker-work, the base of the cone also being closed by wicker-work. The dimensions of this apparatus were as follows: Diameter of opening at top, 8 centimeters; diameter of base, 32 centimeters; depth, 25 centimeters. In the hoop is placed a mull-net of similar shape. The whole is supported by a pole and rope attached to the prow of the vessel. I intend to still further improve this apparatus; but even in its present condition, it retains alive and well a portion of the medusæ and crabs which have been caught, even if the current should have a velocity of 9.7 kilometers per hour. So far, this apparatus cannot yet be used for catching large quantities, but it can direct attention—through different particles adhering to it—to every change in the character of the contents of the water.

A second condition of a successful method is the possibility of ascertaining immediately and quickly the quantity and quality of the catch; for only by the possession of this knowledge can systematic observations be carried on.

As the nets have to be washed, a good deal of water—at least 3 to 4 liters—has to be examined; and small crabs, diatoms, and medusæ often prove great hindrances. The eggs will cling so firm to the jelly-like mass of the medusæ, as soon as the water has been removed, that it becomes exceedingly hard to find them and separate them from the object to which they adhere. The *Sarsia*, which became a special source of annoyance, do not make their appearance in the Baltic in any considerable numbers till the end of the egg-period; and they have finally to be removed by means of a sieve in the wide openings. The diatoms which often are found in quantities a hundred and thousand times as great as that of the eggs, prove a serious hindrance. They and the entomostracans—which are not near as annoying—can quickly be removed by means of the following apparatus: To a metal tube having a diameter of 8 centimeters little feet are attached, measuring from 3 to 4 millimeters in length, so that it can be placed vertically on a glass plate. In this metal tube another tube fits, which is partly arranged as a screw, so that according to the necessity of the case, it may rise from 1 to 4 millimeters above the glass plate on which it rests. Into this tubular vessel the water containing the eggs is poured. The water immediately flows off through the slit below, whilst the eggs and all other larger objects remain on the glass plate. For the first idea of this exceedingly practical apparatus—which I have only described above as to its leading principles (in the improved edition it has only one foot)—I am obliged to Count Spee, assistant at the physiological institute, to whom I hereby also express my best thanks for his cheerful assistance during my excursions. The counting may be done conveniently after the tube has been removed from the glass, by placing over the eggs a thin sheet of mica, on which squares are marked. Unfortunately I did not have the opportunity of gathering observations in this respect.

It need hardly be mentioned that the discovery of floating eggs announces to the scientific investigator the presence of the kind of fish with which these eggs originate, and that, by following them against the current, the spawning places must ultimately be reached, and that the distribution of the eggs will indicate the direction of the currents.

I shall now endeavor to explain the view that it is possible to obtain an approximately correct estimate as to the quantity of the eggs. In the first place a distinction must be made between the eggs which float and those which do not float; for, as regards the latter, it seems utterly impossible to get at even an approximately correct estimate, and as regards the floating eggs, it should be borne in mind that, if sufficient time is allowed, they will gradually spread evenly throughout the sea which is before them. I must confess that I have considered this fact as self-evident, and have, therefore, neglected to gather experimental data in this direction. I can therefore merely state that, (1) eggs which were thrown into the sea for the purpose of impregnation did not remain close together, but were scattered in a few minutes; (2) the result of my observations given above (observations made at an interval of six days) strongly favor the idea that the eggs scatter evenly over a considerable area. I have not found any data relative to the mechanical distribution of such objects by shaking; nevertheless it remains an undoubted empiric fact that the process of shaking and stirring causes an even distribution of hard bodies, such as grains of corn or seed, and of hard bodies in fluids (*e. g.*, in emulsions).

The reason why irregular pushing motions, made in every direction and of a certain duration, applied to a large number of bodies, produce a tolerably even distribution of such bodies, must be found in the following circumstances:

Bodies like eggs receive such pushes either in a direction perpendicular to their radius or in any other direction. In the latter case the pushing motion becomes divided, one motion turning the eggs, the other simply pushing them; but as in the water the entire surface of the egg is almost invariably struck simultaneously in one and the same direction, rotation sets in but very seldom.

If thrusts of equal strength struck the globe at all its radii at one and the same time, for whose endless number of radii we will assume a certain large fixed number, the globe would not move; and if all these thrusts were made in quick succession, the globe would, after a certain number of thrusts, assume its original position. The intervals in which these thrusts are made may vary; it is also possible that each radius must receive a three or four fold number of thrusts before the cycle of motions is completed; but the globe of the egg would invariably have to return to the same spot. If the motions, however, become entirely irregular it becomes highly improbable that a cycle of motions will be completed after a small number of such thrusts; only after an illimitable number of thrusts, therefore after an illimitable period has elapsed, there will be a probability that such a series of cycles has been completed, and that, thereby, the body has been brought back to its old place or within its neighborhood.

What applies to one egg, applies to all. There remains, therefore, only the possibility that all eggs move from their starting-point in one and the same direction, and that, consequently, they do not scatter. This becomes all the more improbable the larger the number of the eggs; for this would presuppose that all the thrusts which strike the eggs are made absolutely parallel with each other. This may occasionally be the case in currents; but as soon as the thrusts are made irregularly in different directions, the eggs will scatter. Every radius of each individual egg runs the same chance of being struck, and as the thrusts are made in different directions, the individual eggs will receive them in different ways. The more the eggs are scattered, all the more—and in proportion to the cube of the distances—will the probability disappear that they will meet again at any time.

It will not be necessary to discuss the question in what manner an even distribution through space is finally brought about, because such a distribution would require too long a time to occur in the case in question. If there is actually a very considerable uniformity in the distribution of the eggs, it is mainly caused by the circumstance that probably the spawning process along the coasts takes place within an area embracing the Western Baltic, so that thence the mingling can take place with greater ease.

In our special case, the question is, whether actual thrusts or pushes are made against the eggs in all directions? Simple waves have only motions resembling that of the pendulum, ending perpendicularly towards the surface; they cannot, therefore, scatter the eggs horizontally. The waves, however, are not simple waves, but each large wave consists of a number of small waves of different size. By superposition they cause the tops and valleys of the waves to become sharp edges. The tops are bent by the wind, and are even torn and dashed into a mass of spray, and the sharp edges of the valleys fall down. Thus there arise numerous horizontal movements, and when the waves begin to foam, when during a storm the sea resembles a seething caldron, the horizontal thrusts are sufficiently numerous. Possibly the eggs also glide along the surface of the waves, and the wind lashing the surface of the water scatters the eggs, both those which float near the tops and those which are in the valleys. It can hardly be presumed, however, that such occurrences can do more than cause the distribution of the eggs, which were originally close together, over a limited area, in the most favorable case, about one square mile. Direct observations frequently offer technical difficulties, for when the sea is rough, bodies sunk below the surface are immediately lost to sight. I let three glass floats, which, like the areometers, rose but little above the surface, swim in the Kiel harbor when the waves were but small, but when there was a tolerably strong west wind. After they had been separated and had again come together, the smallest of the three was, after 10 minutes, found about 3 meters from the two others, which were deeper in the water, and which were about one-half meter from each other. Soon after this observation I unfortunately lost sight of them. Three meters in 10 minutes makes 18 meters per hour, and 6 kilometers in 14 days; and as the waves were very small when I made this experiment, and as floats like those employed by me have rather an unfavorable shape, the area of one square mile (German) for the open sea, as given above, does not appear too large.

It is certain that the currents which are caused by the changes of the pressure of the air on the water, and which run parallel with the wind, have likewise a considerable influence on the distribution of the eggs. These currents cause a very considerable motion in the Baltic; in the open sea they certainly run frequently $\frac{1}{8}$ mile (German) an hour, there fore in 8 hours 7.5 kilometers. This causes a considerable motion and upper and lower currents, which may cross each other at different points, and taking into account the constantly progressing distribution caused by the motion of the waves, it becomes probable that all these motions combined cause the distribution of the eggs over a large area. The occurrence in coast waters of water-areas, belonging according to their character and fauna to the high seas, as has been observed for a long time in the Gulf of Naples, will influence the distribution of the eggs. The mechanism of the currents caused thereby has so far, however, not yet been made the subject of scientific investigation.

On the other hand, however, currents may also impede the even distribution of the eggs, partly by causing stoppages and whirlpools in the water, but principally by changing the specific gravity of the water. In my opinion the very rare occurrence of codfish and plaice eggs in the harbor and the Bay of Kiel must be explained, at least in part, by the circumstance that the fresh water which flows into the harbor from the river Schwentine and other streams hinders the entrance of the eggs. By such currents and the water losing some of its saltness the distribution of the eggs at the bottom may became very irregular. My observations, however, did not clear up this question. It is also probable that during storms the bottom of the shallow Baltic is sufficiently stirred up to scatter the eggs lying at the bottom.

My observations, however, have proved, at least made, it highly probable that eggs are scattered in the Baltic over a large area. Even far out in the Baltic I found numerous eggs, viz, 85 per square meter of the surface, and only the entrance of fresh water from the north prevented further observations. The evenness of the distribution has also become more probable by my having found 32 and 20.2 eggs per square meter at intervals of one half mile (German) in a perfectly calm sea. I must also state that I always found in these masses of eggs not only different kinds of eggs, but also eggs in many different stages of development. It is hardly probable that the fish from which these eggs came had spawned all over the Baltic, the different species mingling with each other.

However this may be, the quantitative examination of this subject (perhaps by fishing along the sides of a triangular area) is of great interest in itself, for only thereby we can arrive at an approximately correct knowledge of the whereabouts and the fate of the eggs, and of the dangers which threaten them at this stage of their development. It will, moreover, be a great advantage, if our investigations as to the occurrence of different kinds of fish can be made without regard to the statements of fishermen and data gathered during the fisheries. The latter are occasionally very one-sided.

As regards the idea from which I started—to obtain an approximate estimate as to the quantity of certain kinds of fish found within certain areas of water—the reader will, after all that has been said, be better able to appreciate the difficulties connected with these observations.

It might be possible to obtain, by numerous counts, an approximate estimate of the number of eggs per kilogram of spawning fish; but then the question arises, How many of these eggs are actually impregnated? The eggs which have not been impregnated may remain floating for several days. It would, therefore, be necessary, for obtaining tolerably correct average figures, to gather the eggs above the spawning fish, and determine the percentage of eggs which have not been impregnated, by taking them from the water in the most careful manner. The question can only be decided if the eggs can be kept alive for about 24 hours, which is only possible by taking ice along in the boat. In boats which are not constructed in such a manner as to allow of microscopic observations on board, this is recommended under all circumstances, for below deck the water soon becomes warm, and on deck it is difficult to protect the glass vessels against the sun, as the vessel often changes her course, and as the attention of the scientist is required in other directions.

We furthermore ask, How many of the eggs die prematurely? With regard to this question I feel justified to state that their number is, on the whole, not very large. Dead eggs, as I have found by direct observations in the aquarium, will very well keep from 8 to 14 days. If, therefore, there had been any, I must have caught some with the bottom-net. It is true that I brought up a certain number of such eggs—every catch yielding one or two, and on the 27th of April I even got—near Buoy No. 1—16 dead eggs along with 50 live ones, the average distribution being 1.8 egg per square meter of the bottom; but here the spawning period was over, and a large number of eggs had probably accumulated owing to this fact. Finally, the exceedingly difficult question remains to be answered—how many eggs are devoured by various marine animals. The dangers which arise, when the eggs touch the bottom, have already been mentioned.

The Entomostracans do not seem to hurt the eggs. I am, of course, not absolutely certain on this point, as eggs which had been bitten would run out; and as it requires special observations to ascertain whether egg-shells are found which are sinking or about to sink. The number of small crustaceans is frequently so great that the eggs must be entirely annihilated if these animals were among their enemies. I have also often, in the large aquarium of the commission, observed eggs floating among the crustaceans, and never could I find that they were in the least molested by them.

Fish are hardly dangerous to the scattered eggs, for on account of their great transperency they are, when occurring singly, hardly perceptible, nor would it pay the fish to hunt for them. Sars says: "It seems that not only other marine animals, but even the codfish themselves, when they return to the high sea, destroy a large number of the eggs which fill the ocean." Although the fact does not seem to be positively proved by this statement, it seems certain that, wherever the eggs occur in very dense masses, they are devoured by fish. No estimate as to the quantity of eggs destroyed in this manner could be gained, unless one could be directly over the spawning masses of fish.

The *medusæ* are probably a dangerous enemy to the eggs. Earle states:

"One day I placed a medusa or medusoid, measuring only 1½ inch in diameter, in a trough containing eggs; and in less than five minutes it had gotten 70 eggs in its tentacles, which weighed them down to such a degree as to cause them to be torn off the medusa, as it floated through the water."

The wording of this statement does not prove that the *medusæ* actually eat and digest fish eggs, but I have not the slightest doubt that they do this, as, according to Sars's observations, which are confirmed by mine, they even take young fish. It is only the *medusæ* proper, however, and among these only the *Medusa aurita* and *Cyanea capillata*, which can come into consideration, as far as the Baltic is concerned. In 1882, the *Cyanea* was very numerous in the Bay of Kiel, but in March they were still so small that they could not prove dangerous to the eggs. The *Medusa aurita*, so far as I know, makes its appearance later in the season. In 1883, both these kinds were so scarce, that I only met with 3 or 4, and during that year at least they cannot possibly have destroyed many eggs.

On the 14th of May I made the somewhat unexpected observation that the small *Sarsia tubulosa*, measuring only 1½ centimeter, eats fish eggs. I had placed a small number of eggs with broken yolks, measuring on an average 1.2 millimeters, in a glass vessel into which a large *sarsia* had accidentally found its way. When later I took out the eggs for the purpose of examining them several were missing, and the stomach part of the *sarsiæ* was swelled out considerably. In dissecting the *sarsia*, I found an egg in the process of decomposition, the shell being still well preserved. It, therefore, seems highly probable that, also in the open sea, the *sarsiæ* will seize and swallow eggs. I have, of course, not been able to make direct observations on this subject. For the present I do not, therefore, know whether the *sarsiæ* will swallow the larger eggs of the codfish and plaice, and how large they must be to do this. In March and April the *sarsiæ* are generally very small and immature, and their sexual organs do not reach perfection till May. If it should be proved that young *sarsiæ* can swallow eggs, it may be presumed that they destroy a very large number of eggs especially in the bays, for here a single haul of the net often brings up handfuls of these animals. In the open sea I have not found them so frequently, but here I found the *Syncocyne sarsii*, so that there can be no doubt as to their occurrence.

These different facts, and in addition the possibility that the wind drives ashore large quantities of eggs from the surface water, show that the counting of eggs can only give minimum figures as to the number of fish; but even these would be valuable.

Provided the water possesses sufficient gravity, no portion of the sea is better suited for such experiments than the western basin of the Baltic.

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NOTE.—The references are to page-figures in brackets.