VIII.—THE SALT-WATER FISHERIES OF BOHUSLAN AND THE SCIENTIFIC INVESTIGATIONS OF THE SALT-WATER FISHERIES.

By Axel Vilhelm Ljungman.*

I.

THE NECESSARY BASIS FOR CARRYING ON THE BOHUSLÄN SALT-WATER FISHERIES AND THE SCIENTIFIC AND PRACTICAL INVESTIGATIONS AND EXPERIMENTS REQUIRED FOR OBTAINING THIS BASIS.

§ 1. Every state ought to consider it as its duty to make scientific investigations, at any rate within its own limits.

In order that a comparatively poor, extensive, and thinly populated country may do its duty in this respect, it is doubtless necessary that the work be done systematically, according to a well-matured plan, if the object in view is to be attained, *i. e.*, a thoroughly scientific knowledge of one's own country. Societies or individuals may, in this respect, do as they deem best—their work and their sacrifices will in any case do some good—but the *state must act according to a distinct plan, so that from want of means one portion of the investigation may not suffer, which, by a wiser and more systematic use of all the means at the command of the state, might have led to good results without thereby injuring any other part of the investigation.*

It is always cheapest to do everything systematically, and is the surest way to reach one's object, and it is almost indispensable at a time when so considerable a portion of the public revenues must be devoted to the defense of the state against foreign enemies.

Wealthy states (especially those which possess colonies) can and ought to extend their scientific investigations also to uninhabited and uncivilized portions of the world. In this way we shall, in course of time, attain to such a complete scientific knowledge (physico-geographical, geological, mineralogical, botanical, zoological, ethnographical, linguistical, and archæological) of our world as our rapidly progressing time demands.

§ 2. The great services which science has rendered to agriculture, mining, and industry, as well as to nearly all our trades, and the losses which a lack of theoretical knowledge has frequently occasioned, show the absolute necessity of following the only certain guidance of science. In all branches of human activity a desire is manifested at the present

* *Bohusläns Hafvfisken och de vetenskapliga Hafvfiske undersökningarna. Af Axel Vilhelm Ljungman. Gottenberg,* 1878. Translated by Herman Jacobson.

time to utilize all the results of science, to abandon old prejudices and all endeavors which are only based on accidents.

The great importance of the fisheries has shown the urgent necessity of scientific investigations, so that they may be carried on in the proper manner and protected from injuries caused by ignorance and greed, a necessity which the government has recognized by making appropriations and by instituting a course of investigations.[1]

§ 3. A suitable fishery legislation and administration of the fisheries can likewise only be based on a careful scientific and practical investigation. It must be remembered that both with regard to the fisheries and other industries it is of importance that the state does not meddle more than is necessary, for by making too many rules more harm than good is often done, as, contrary to all calculations, such rules may frequently hinder the free development of any trade. To find the medium in this respect presupposes a thorough knowledge, both theoretical and practical, of the whole trade, and a well-matured plan based on this knowledge, which, without too great difficulties, may be carried out in such a manner that the results can be calculated beforehand with some degree of certainty. Without sufficient knowledge of a trade or industry it is not possible to gain any firm basis for legislation or calculate any of the possible results.

§ 4. Scientific investigations are, as will be shown below, necessary, not only for gaining a theoretical basis for legislation and for successful administration, but also for the furthering of the fisheries themselves, as even with regard to these they may bring to light facts which may prove extremely useful[2]. A common objection to this view is this: that a trade does not need the aid of science, but that it is best to let it develop freely. It is well known that science has proved useful to the fisheries as well as to agriculture and other trades, chiefly by showing the way in the making of experiments and thus facilitating any improvements or new inventions, although the great mass of people who gradually reap the advantages of such inventions hardly ever think about the scientific work which necessarily had to precede them.

Although it is best to keep the fisheries free from too much legislation and meddlesome interference of the government, a complete knowledge of the entire natural history of fish is both useful and necessary, as well as of the proper method of preparing fish for the trade; and in all these respects science may extend considerable aid.

§ 5. This whole field should be investigated scientifically even if no

[1] This paragraph, like some of the following, is taken from former articles of the author, viz: "Report on an expedition for examining the salt-water fisheries in the Skagerak and Kattegat, made during the summer of 1871, on board the royal gun-boat Gunhild," Upsala, 1873, (partly given in "*Nordisk Tidsskrift for Fiskeri*," II. Copenhagen, 1874, p. 1–14), and "*Preliminär Berättelse*," &c.—Preliminary report on the herring and herring-fisheries on the western and southern coast of Sweden. Upsala, 1875.

[2] *J. MacCulloch "On the herring"* (Quarterly Journal of Science, Literature, and Arts. XVI. London, 1824), pp. 210–211, 216, 222.

material advantage should result from such investigations in the immediate future. The history of natural sciences and trades furnishes numerous examples how a science may be studied and worked up for many years, in some cases even for a century, without yielding any practical result, until all of a sudden some grand invention surprised the public. How long, for instance, was electricity considered by the great mass of the people as a useless matter, good enough perhaps for the learned to know something about, but of no practical value, until its practical application produced a sudden and radical change in public opinion. Science ought to be cultivated conscientiously and perseveringly for its own sake, and sooner or later its results will prove useful in practical life.

§ 6. As the scientific and practical investigations which come into question here are to give us that knowledge which is indispensable for obtaining the necessary basis for carrying on and administering the fisheries in the best possible manner, as well as for useful legislation on the subject, in fact for a final solution of the whole fishery-question, it will be evident that these investigations must extend to everything concerning the fisheries. These investigations must, therefore, not be confined to technical, law, and administrative questions, but must extend to questions of economy and natural science. All the different points from which the fisheries may be viewed must be considered if any good result is to be obtained. For the omission of one of these may essentially change the results. A most thorough and complete treatment of the whole subject is absolutely necessary.

§ 7. It is well known that the so-called inductive method is the only one both in natural history and in a trade which will lead to a reliable general knowledge. From many agreeing facts a deduction is made regarding a general law, which will gain in probability in proportion as the induction is complete in all its parts. This shows the necessity of making as many observations as possible at different times and places, and of comparing these with older observations handed down to us by reliable writers. The necessity of making numerous observations during a long period of time increases, as there are very frequent exceptions from general rules which cannot always be considered as abnormal, and as a lack of agreeing facts with regard to even one or two points may make it very difficult to reach any certain conclusion. It is, of course, not possible to obtain in this way that degree of completeness which would lead to absolute certainty.

With regard to our present subject—the fisheries—one must be careful to avoid the very common mistake of making hasty observations or facts which have not been fully established[3] the basis of more or less preten-

[3] Under this head comes the use of entirely accidental methods of explanation, which is but too frequent. From an accident anything may easily be explained, but then such an explanation may be utterly worthless. Anything that is accidental has in itself something inexplicable, and stands without its proper causal connection, and it is much more difficult to assign its cause than to understand that fact which it is intended to explain.

tious and imposing scientific systems. It must be remembered that in science, as little as anywhere else, is there a royal road to reach one's object, and it is often nothing but vanity which has led persons to build such air-castles and call them scientific achievements.

§ 8. The difficulty of finding the causal connection is also much greater in that portion of natural history which is most important for our purpose, that is, the so-called physiology of relations, than in anatomy or the history of natural development. The anatomist, after having dissected a few specimens and found them to agree, may generally be certain that he has ascertained their normal condition, and that any deviations from this which may possibly be discovered in the future must be considered abnormal. The anatomist can and must often be satisfied with examining only a few specimens, and may from these draw a tolerably certain conclusion; but this would not answer in the physiology of relations with its many changes and irregularities. Here it is necessary to employ every means at our command for taking the greatest possible number of observations, and then, after critically examining their reliability, and instituting the most careful comparisons between them, and by using every method of induction, analogy, and hypothesis for reaching a conclusion, to obtain the most probably or at least approximately correct view. Thus the demonstrative certainty gradually decreases in the physico-mathematical sciences in proportion as we depart from the abstract, outward forms of objects, or from general laws or component parts, and enter the domain of organic nature, which becomes more difficult for the naturalist the more life itself comes into question.

§ 9. Regarding the general view of nature and the different methods of explaining its phenomena, it must be said that a really scientific explanation, going back to final causes, is scarcely possible, as soon as from general views we enter upon details. An explanation from absolutely certain causes, carried through consistently, must always move in a circle, because the world is a whole, developing systematically, and as the various phenomena of nature mutually depend upon each other, so that one phenomenon may depend upon another which follows it, whilst we from our youth up are accustomed to draw a conclusion by advancing from a *post hoc* to an *ergo propter hoc*. The aim of natural science is, therefore, to be as free as possible from teleological and mechanical prejudices and methods of explanation, and to endeavor to show the actual connection between the different phenomena, and not to draw philosophical *a priori* conclusions as to their absolute necessity.

On the material which has been acquired in this manner every one must, according to the best of his ability, base his more or less philosophical theories, being careful, however, to keep these latter strictly separate from the facts.

§ 10. The sources of knowledge to which we are directed as regards fish, fishing-waters, and fisheries, are: literature, the experience of fishermen and superintendents of fisheries, and direct observations and experiments.

As regards literature we must have reference not only to that more scientific portion of it contained in book form, but also to that more scattered information found in newspapers and periodicals[4] or in the various official documents in city or state archives. In order to make full use of this source of information so very important for the herring-fisheries, it is of course necessary to consult the more important foreign works and documents (for example, the Danish, Dutch, and British). The importance of studying the special literature of a subject will be self-evident if we remember the well-known fact that in those fields of human knowledge which have been cultivated most, no one, whatever his natural talents may be, can, through his own exclusive endeavors, obtain that knowledge which is stored up in literature for the benefit of posterity, much less carry his knowledge very far beyond this limit. A thorough acquaintance with all the facts which others have brought to light on a certain subject must form the starting-point for those endeavors from which the greatest possible results may be expected.

But it is not only that knowledge which is stored up in literature which must be taken into consideration, but everything which has been collected, preserved by tradition by the fishermen and the superintendents of the fisheries. The gathering and working up of this very heterogeneous material is connected with considerable difficulty, and presupposes a good deal of experience obtained by direct personal observations, as well as a varied knowledge of all the literature on the subject. The great mass of the people are often more inclined to be influenced and even prejudiced by anything coming from foreign parts; the experience of foreign countries is doubtless also in many respects richer and more varied than our own and more fully corroborated by experiments and scientific investigations. The chance of increasing our stock of knowledge by studying the experience of foreign countries should, therefore, not be neglected. In doing this, however, it should be remembered that there are great differences of nature, law, and economy between our own and other countries, which point is but too frequently lost sight of.

The material obtained from literature and the experience of fishermen must be critically sifted, and for this purpose as well as for extending our knowledge beyond this limit, direct personal observations and experiments are necessary. Experiments are moreover required to prove the correctness of opinions that have been advanced, and of hypothetical explanations.

A full description of the best means for utilizing these various sources of knowledge will be given below when each portion of the fishery investigations will be treated separately.

§ 11. Fishing is a trade which absolutely requires special experience. This experience embraces the proper use of the different fishing-appa-

[4] See *A. Boeck*, in "*Nordisk Tidsskrift for Fiskeri.*" VII. Copenhagen, 1872, p. 7.
A. V. Ljungman, "*Preliminär Berättelse*"—Preliminary report for 1873–1874, on the investigations regarding the herrings and herring-fisheries on the western coast of Sweden. Upsala, 1874, p. 70.

ratus, the preparation of fish, and the use of fish in the household. All these points must be worked up carefully and thoroughly so as to give all the necessary hints. But as all this experience cannot be gained by one man engaged in the fishing-trade—*ars longa vita brevis*—as much as possible of it must be gathered both from old documents and from the fishermen themselves, and must then be proved by personal observations, which must also be made with the view of developing and increasing the material. In order to make this material as valuable as possible it is of course highly necessary to become acquainted with the more prominent foreign fisheries, especially those which excel ours.

The technical investigations must therefore relate to the existing condition of the fisheries but also to their further development and to any possible improvements. Among the subjects which in this respect deserve special attention, the large periodical Bohuslän herring-fisheries doubtless occupy a prominent place. With regard to these fisheries we need, above everything else, a brief but complete review of all the experience gained in the course of centuries concerning the herring-fisheries, the preparation of herring, and the herring-trade; for as it is well known that these, our largest fisheries, are periodical, and cease entirely for many years at a time, we cannot expect that all the experience we need is handed down to us by tradition.[5]

The technical investigations ought moreover be specially directed to the scientific treatment of everything relating to the different methods of preparing and preserving fish.

Finally, it would be necessary to carry out according to a well-matured plan all the different experiments required to corroborate our knowledge, to try new fishing-laws, new apparatus, methods, and other improvements. In order to make such technical investigations and experiments really valuable and useful, they ought to be committed to persons who can devote their whole time to it; for of the young naturalists who are generally detailed for such investigations, it cannot be expected that they should have that undivided interest, that local knowledge, and that practical experience which are absolutely required to make such investigations truly successful.[6]

§ 12. As it is the object of the fisheries, as well as of agriculture, to utilize the productive powers of nature for human purposes, and this not only with regard to the quantity and quality of nature's productions, but also to their preservation and possible development, the chief condition of success will be a complete and reliable knowledge of the nature of these productions, of the causes which create and sustain them, and of the mechanical or chemical aids and apparatus by which they may be investigated and utilized. By comparing this knowledge with that experience which practical fishing constantly supplies, we obtain the so-

[5] *P. Dubb, "Anteckningar om sillfisket i Bohuslän" (Kgl. Vetenskaps Akademiens Handlingar* för år 1817), p. 32, 33.

[6] *A. V. Ljungman, "Om fiskerilagstiftningen för bohus-länska skärgården," IV* (Göteborgs-Posten, 1875, no. 78).

called knowledge of the trade, or, in other words, the science of the trade.

The science of the fisheries, *i. e.*, the knowledge of how to carry on the fisheries, fully developed and arranged as a whole, forms the science of fishing, properly so called, and in proportion as it is really scientific, fishing becomes a branch of natural science.

In order to make the necessary technical investigations, a good knowledge of natural science is required as well as a special knowledge of those branches of natural science which form the theoretical foundation for the special science of the fisheries.

§ 13. As fishing requires a knowledge of the mode of life and other characteristics of fish as well as of the fishing-waters, so fishing carried on as a trade requires a knowledge of the laws of economy. We therefore need an economy of the fisheries just as much as their practical and scientific knowledge, although the latter is certainly an essential condition of the former.

A wise administration must never favor one trade at the expense of another which is just as important or perhaps even more so, thereby bringing about a conflict of interests which cannot in any way be beneficial to the state. The fisheries must therefore be considered in their relation to other trades and occupations, especially agriculture and navigation, the general welfare of the state, the means of communication, &c. Special regard should also be had to the changed circumstances of our times in case the great herring-fisheries should again be revived; which event, strange to say, has for nearly half a century been rather considered as a curse than as a blessing for Bohuslän.[7] The *social question* of our coast will, therefore, likewise have to be considered—a question whose solution may puzzle our wisest men. All this becomes the subject of a special branch of knowledge, which might be termed "the economy of fisheries," whose aim would be to promote the fisheries by working up the various scientific methods and corroborating their usefulness by practical experiments, always considering the economical value of the fisheries for the public as the foundation on which all improvements in the fishery-laws and the administration of the fisheries should be based.

The fisheries should therefore form the subject of the most thorough and exact treatment even from an economical point of view, and this all the more as the want of such treatment has doubtless been the chief cause of the insufficiency of our fishery-legislation.

§ 14. The investigations must, furthermore, extend to the whole subject of law and administration; for since their purpose is to gain that knowledge which is necessary for carrying on and superintending the fisheries in the most efficient manner, attention must not be diverted from this object or extended beyond its limits. As such a course would only delay

[7] *A. V. Ljungman: "Några Ord om de stora bohus-länska sillfiskena."* Gottenburg, 1877, p. 28.

the results or prevent us from reaching them,[8] the investigations must be carried on with a special regard to the needs of a good administration, which ought, therefore, to be clearly specified.

A complete knowledge of everything pertaining to law and administration is certainly just as necessary for the legislator as a technical, economical, and scientific knowledge. This last-mentioned knowledge is necessary for proving the practicability of the legislative and administrative measures; and in order that the full significance of these measures may be understood, a sufficient knowledge of local and technical conditions is required. A satisfactory solution of the whole fishery-question, to serve as a basis for systematic investigations and for a reform of fishery-legislation, can therefore only be reached by placing each separate part of the question in thoroughly competent hands. The lack of such preliminary and preparatory measures is doubtless one of the chief causes of deplorable defects in our fishery-legislation and of practical mistakes springing from them.

What we need, therefore, is a complete and systematically arranged review of all the laws relating to the Bohuslän salt-water fisheries from the oldest times down to the present. Such a review should, as far as possible, give the causes of every amendment to these laws and tell us how the amended laws worked; the laws should be examined with the view of testing their applicability to the changed circumstances of our times, and they should finally be compared with the experience of other countries. If all this were done in a most thorough manner, we might look for truly beneficial results.

§ 15. In order to fully understand the Bohuslän salt-water fisheries, some purely historical investigations are necessary, which may yield some material of great value which could not have been obtained in any other way. As an illustration of this assertion we may quote the example of *Axel Boeck*, who, in his well-known work, "*Om Silden og Sildefiskerierne*" (On the herring and the herring-fisheries), has based his whole treatment of the important questions, "why the great periodical Scandinavian herring-fisheries have ceased"[9], and "what influence is by outward physical conditions exercised on the migrations of the herrings" on such investigations.[10] Besides, how could we without such historical investigations ever settle the question regarding the nature, spawning-time, &c., of the old Bohuslän herrings?[11] or corroborate or disprove the

[8] Thus it has often been the case that *practical* objects have been used as a bait for carrying through purely *theoretical* measures, which in no way could prove a benefit for the trade.

[9] *A. Boeck*, "*Om Silden*," &c., I, Christiania, 1871, p. 82–119.

[10] " " " " I, p. 72–82.

[11] The supposition regarding the relation of the old Bohuslän herring to the present herring forms, as is well known, the basis for all our fishery-legislation since 1852; and the opponents of this legislation, therefore, chiefly direct their attacks against this supposition. (See "*Handlingar rörande sillfisket i bohuslänska Skärgården*," Stockholm, 1843, p. 71–73, 156,172. "*Götebarg's Handels-och Sjöfarts-Tidning*, 1853, No. 147, supplement. "*Nya Handlingar, &c.*," I, Gottenburg, 1874, p. 22–24, 29–32, 63–66.)

assertion that a severe winter with much ice has a beneficial influence on the herring-fisheries, an assertion which has been so strongly made by Professor *Nilsson* and others?[12] or how could we, in any other way, ascertain the practical working of the older fishery-laws and decide in what respect and in how far the fishing-trade has improved, remained stationary, or gone down?

It will scarcely be necessary to say any more regarding the great value of historical investigations in themselves and their absolute necessity for gaining as complete as possible a knowledge of our fisheries.

As regards our largest and most famous fisheries, the great periodical herring-fisheries, we must in the first place not only examine the possible causes (real or supposed) of the periodical cessation of these fisheries, which has played such a prominent part in our fishery-legislation, but also the causes of the somewhat regular changes in the course and location of the fisheries, and in how far these changes depended on physical conditions, &c. By making these investigations we obtain a great mass of historical facts which will amongst the rest serve as a guide in framing laws in case these great fisheries should revive.[13] Much information would also be gained in this way, throwing light on many a dark point in the natural history of the herring and aiding in solving the difficult question of the migrations of the great herring-schools. The literature referring to these questions amply proves how important a complete historical review of the Bohuslän herring-fisheries is for reaching a satisfactory solution of the whole herring-question.[14]

It is evident that the history of other fisheries will also be very interesting and may furnish valuable material. The historical part of these investigations should, therefore, by no means be omitted or neglected.

§ 16. The investigations must finally embrace all the facts of natural science, which will enable us to master the theoretical conditions "of a successful carrying on and administration of the fisheries" in a much higher degree than it is possible for the uneducated fisherman. A scientific knowledge of nature forms the theoretical basis on which alone a wise and beneficial management of the fisheries can be built up. We

[12] "*Handlingar rörande, &c.*," p. 64, 67, 74, 77, 156, 163.

A. W. Malm, Naturhistoriska studier i det fria och: Rammaren. Gottenburg, 1860, p. 5.

[13] The regular changes in the course of the great herring-fisheries, and the consequent changes in the quality of the herrings require a legislation to suit these changes. Legislation should, therefore, be guided by the experience of former centuries. The first part of an approaching fishing-period cannot be considered as the standard for the whole time it lasts. In all probability it will in its course undergo considerable changes, and we must, consequently, look for this standard in the corresponding part of former fishing-periods. That this way of judging is correct is proved from the last fishing-period (1747–1808). For many of the regulations made during the latter portion of this period, and based on the experience of the first portion, proved to be antiquated and of little use, and in some cases were even more hurtful than helpful. The fishermen themselves, therefore, often demanded changes in the administration and in the laws. It must be said, however, that many of these changes were demanded from purely egotistical reasons.

[14] *Preliminär berättelse* (Preliminary report) for 1873–'74, p. 71–72.

need therefore a complete and thorough knowledge of the true object of the fisheries, of the nature of fish, and of the nature of the water in which the fish live, and finally of all those conditions on which the propagation, development, and life of fish depend.

The scientific investigations which are of importance must in the first place refer to an increased knowledge of the anatomy, physiology, development, characteristics, and varieties of fish, as well as to their distribution, and the probable causes of their appearing and remaining on different bottoms, and consequent upon this to their varying food, their isolation, hydrological relations, &c. They must also relate to the spawning of fish (time, place, whether near the surface or on the bottom), to their growth, difference of age, food, enemies, sickness, &c., dependent on physical conditions, their daily life, their regular annual migrations (caused chiefly by their desire either to seek food or to propagate the species), to their sudden appearance or disappearance, and to its causes, &c., as also to the nature of the fishing-waters, to the plants and animals contained in them as well as to their physico-geographical character. In the following we shall endeavor to point out the methods which should be followed in gathering all the material which is needed for a thorough knowledge of our salt-water fisheries.

§ 17. For a thorough study of the physiology, development, anatomy, &c., of fish it is doubtless necessary, if its results are to answer the increased demands of our times, that a person should have leisure, so that he can devote his whole time to it, and that he should be in possession of all the material and scientific apparatus which are required for such investigations. For some of these investigations, well-arranged aquaria will be of special value. With regard to these studies the author recommended, guided by the experience of foreign countries,[15] in his preliminary report,[16] the establishment of a complete station for scientific investigations of the sea[17] in a suitable place on the Bohuslän

[15] In France chiefly gained by the work of *Coste* and later by that of *Lacaze-Duthier* and in England, France, and Germany by the great public aquaria, as well as in Italy by the zoological station in Naples founded by *A. Dohrn* and subsidized by the government. (See: *Bulletin de la société impérial zoologique d'acclimatation.* 1862, p. 107-114; 1863, p. XLVII-LXIII; 1864, p. 261-269; 1865, p. 533-541; 1872, p. 164-167, 268.—*Archives de zoologie expérimentel et générale.* III, p. 1-38.—*Preussische Jahrbücher.* XXX, p. 137-161—*Zeitschrift für wissenschaftliche zoologie.* XXV, p. 457-480.—*H. Beta, Die Bewirthschaftung des Wassers und die Erndten daraus.* Leipzig, 1868, p. 236-248.—*J. G. Bertram,* The harvest of the sea. 3d edition. London, 1873, p. 293-296.—*F. Buckland,* Familiar history of British fishes. London, 1873, p. XI.—On the organization and progress of the Anderson school of natural history at Penikese Island. Cambridge, Mass., 1874.)

[16] *Preliminär Berättelse* for 1873-'74, p. 71. United States Commission of Fish and Fisheries. III. Washington, 1876, p. 166.

[17] In the above-mentioned report the author has expressed the opinion that the necessary special hydrological investigations should be carried on by persons specially detailed for the purpose, who should have their headquarters at the same station. This idea, although not without its advantages, might, however, meet with considerable difficulties when carried out practically.

coast,[18] which ought to be under the supervision of competent zoologists and botanists and furnished with all the necessary scientific apparatus.

It will be self-evident that such an institution would not only further the study of this part of natural science in our country, but would be almost indispensable for such a study; nor can there be any doubt that its activity can and ought to extend to a much larger field than the mere investigations of the fisheries.

§ 18. In order to gain a sufficient knowledge of the mode of life of fish, of their migrations, &c., in a certain given region, it will be necessary to make uninterrupted observations for a number of years with all the means at one's command (especially by fishing at all seasons of the year); and in order to make such observations truly valuable they should be carried on simultaneously in different parts of the given region; for local differences in the physical conditions will also produce differences in the appearance, mode of life, &c., of the herrings; and by observing the herrings only in one place we would just as little gain a general knowledge of this fish and its mode of life as we would obtain a knowledge of the meteorological conditions of a large country by observations gathered at a single point. In order to gain the true value of phenomena observed in a certain place, a more general knowledge is required, which can only be obtained by comparative studies.

From the foregoing it will be seen how difficult it is to arrive at absolute certainty, and how necessary, therefore, to base our knowledge on the greatest possible number of systematically gathered facts. It will also be evident that both the time during which, and the number of places where, these facts are gathered should be increased in proportion as the kinds of fish which are the objects of investigation are in the former case liable to appear at longer intervals, and in the latter case are subject to more local changes.

§ 19. In order to facilitate and to accelerate the acquiring of the desired knowledge, it will be necessary to have recourse not only to historical researches, but also to the experience of fishermen. Regarding the value of this last-mentioned source of information, it must be borne in mind that the information furnished by our fishermen on the mode of life and the migrations of fish, &c., are very much on the style of the predictions of our old-fashioned weather prophets. These old signs are frequently of just as little value for the fisheries as for agriculture. But although meteorologists have long since shown the worthlessness and fallibility of such predictions, people continue to believe in them, for uneducated persons are apt to remember the few times when such predic-

[18] See also *Preliminär Berättelse* for 1874–1875, p. 18. The most suitable place for such a station would doubtless be the mouth of the Gullmar fiord in the neighborhood of Fiskebäckskil. Farther north the station could not well be, if it should answer its purpose also with regard to the investigations of the expected large periodical herring-fisheries.

tions proved true, and to forget the many times when they were not fulfilled. Such persons will never think of comparing the cases when such signs were without any significance whatever with those cases when they were followed by certain results, nor do they weigh the probability of the one or the other. They are always inclined to follow a *post hoc* by an *ergo propter hoc*. The opinions of fishermen are also often at variance with each other, even with regard to the influence of outward circumstances on the fisheries. It must finally not be forgotten that the nature of the fisheries themselves requires great caution in applying results gained by positive experience. Fishing is generally carried on with very insufficient apparatus and only at *that* time and in *those* places where the greatest gain may be expected. There is a great difference between the occurrence of fish in a certain place and the occurrence of fisheries in the same. The fish may, for instance, come in a certain way which makes it impossible to catch them with the only apparatus on hand, and the fisheries, therefore, come to an abrupt end, although there are plenty of fish. The fishermen are, moreover, frequently governed by prejudices and actually cease to fish before the most profitable period of the fishing-season has arrived, simply because they think they have noticed some adverse signs. All the information gathered from fishermen must, therefore, be sifted in the most critical manner, and the most extensive fishing must be carried on by the observer himself with every imaginable kind of apparatus, in order to corroborate or disprove the statements of the fishermen.

§ 20. In order to gain more reliable and more complete knowledge than can be obtained from fishermen or through historical researches, it is, as I remarked above, absolutely necessary to make direct personal observations in a number of places. There should be a separate observer in every place, who, following a well-devised plan, would make daily observations on the fisheries, &c., which would serve as a basis for a natural history of fishes, and for historical and statistical fishery-reports (annals of fisheries). The superintendents of the fisheries would certainly be able to render much valuable assistance in making these observations.

§ 21. The necessity of comparing the course of the fish, their mode of life, and their migrations, with the meteorological and hydrological conditions, for the purpose of increasing our knowledge of their natural history, has long since been recognized, and caused the Royal Scientific Society at Gottenburg, as early as the beginning of this century, whilst the last great herring-fisheries were still going on, to set a prize for the best treatise on "The influence of the currents on the Bohuslän herring-fisheries." When the fisheries ceased, Dr. P. Dubb, the most unprejudiced and learned of our older authors who have given attention to the Bohuslän herring-fisheries, also expressed the opinion that meteorological and hydrological causes occasioned the periodical coming and going of the

herrings on the coast of Bohuslän, and proposed that the state should make an appropriation for a scientific investigation of these causes.[19]

It is clear, however, that any scientific investigation which intends to ascertain in how far there is any periodicity in the coming and going of the herrings, and whether such periodicity applies to our herring-fisheries, and, in case this is so, what laws govern this periodicity, ought to extend over at least a century. This length of time need not frighten any one, for long before the century has come to a close such investigations will have yielded results which will amply repay for all the time and trouble.

§ 22. In order to obtain reliable results from combined observations of the fish and fisheries and of meteorological and hydrological facts, it will be necessary, as I have already said in my above-mentioned preliminary report,[20] to have as complete as possible a series of simultaneous observations. This requires a number of persons placed at suitable stations, whose observations are collected in one report, as is done, for example, with regard to the investigations of the sea made on the coast of North Germany.[21] Without such exact, reliable, and uninterrupted observations of the fisheries and their physical conditions made during a longer period and for the purpose of comparison, it will be utterly impossible to reach any higher degree of probability or certainty.

§ 23. All the necessary meteorological observations had best be made by the stations of the Royal Meteorological Central Institute, which have been established on the western coast of Sweden; but for hydrological observations, as well as for observations of the fish and fisheries, we have as yet no stations for making continuous observations[22]. As the application of hydrological data to the natural history of fish and the course of the fisheries absolutely requires that these observations should be *uninterrupted* and go on all the year round, especially during the cold season, when the principal fisheries are carried on, it will be self-evident that all hydrological observations which have been made hitherto chiefly during the summer months cannot be of any very great value. This is not said to detract from the generally acknowledged value of one or the other portion of purely theoretical hydrology, such as we possess in the investigations of the Swedish waters made by *Forchhammer*, *Edlund*, *Meyer*, *Mohn*, *F. L. Eckman*, and others; but what we

[19] *P. Dubb, Anteckningar om sillfisket i Bohuslän (Kgl. Vetenskaps Akademiens Handlingar*, 1817), p. 46. Similar investigations have for nearly the same purpose been made in several foreign countries, and some of our own writers have acknowledged their importance.

[20] *Preliminär berättelse*, 1873–1874, p. 70; 1874–1875, p. 17.

[21] See: *Ergebnisse der Beobachtungs stationen an den Deutschen Küsten über die physicalischen Eigenschaften der Ostsee und Nordsee und die Fischerei.* 1873–1876. Berlin, 1874–1877.

[22] Since this was written the Nautical and Meteorological Bureau has been established, which doubtless will supply this want, and furnish the necessary hydrological observations in the shortest time and with the least outlay.

have said merely refers to hydrology as an aid in the study of ichthyology and the fisheries.

§ 24. But the separate hydrological conditions, such as the different currents of the sea, its temperature, the proportion of salt and gas contained in the water, &c., must be studied, not only in themselves and in their relation to the fisheries, but also with regard to their influence on the vegetable and animal life of the sea. The scientific investigations of the sea must therefore endeavor to find the connection between the different organic forms, both in a general way and more especially with regard to those that are of economical value for man. Thus, with regard to the herring, science ought to find out the influence which the diatoms and other animalculæ exercise on it, and the conditions on which their occurrence and distribution depend.[23] The vegetable and animal life of the sea must therefore be studied, not only from a morphological, physiological, descriptive, and physico-geographical point of view, but also with regard to the position which each individual form occupies in the great household of nature.

§ 25. The bottom of the sea must not be forgotten, but must be made the subject of a thorough scientific investigation, both as regards its orographical and geognostical character, not only in itself but chiefly with regard to the influence which it exercises on the currents of the sea and on its vegetable and animal life.

§ 26. The extent of the different scientific investigations is thus clearly given by the very character of the study of natural history, which, the more scientific it is, the more it should be a *comparative* study, because nature forms a continuous whole where one link of the chain is connected with and depends on another, so that no satisfactory result can ever be obtained if one branch is studied as a specialty to the exclusion of those with which it is connected.

§ 27. As has been mentioned above, all such investigations of the sea and the fisheries, if they are to lead to the desired result, must be carried on simultaneously in as large a number of places as possible; for in no other way can a deep insight be gained into the hydrological conditions of the nature of the fisheries themselves, and of their connection with meteorological causes. These investigations must, therefore, as is already done in meteorology, be made by the united efforts of several nations. The investigation of the nature of those small seas round which so many of our modern civilized nations dwell—Englishmen, Dutch, Germans, and Scandinavians—and which, more than any other seas, are full of fishing and sailing vessels, should certainly be of such interest for science, the fisheries and navigation, that there should be no delay in making them. Germany has also in this respect made a beginning, by sending out expeditions, and by having daily observations taken at

[23] *J. MacCulloch "On the herring"* (The Quarterly Journal of Science, Literature, and Arts. XVI. London, 1824), p. 219.

a number of stations.[24] This example is now, to some extent, followed by Norway, where the government has, since the year 1861, instituted, at its expense, a series of investigations of the herring and cod fisheries, and where, at the present time (1876), the chiefly zoological investigations have not only been made in that portion of the open sea where, according to Prof. *G. O. Sars*, the Norwegian herring has its proper home, but also in more distant portions of the ocean. The meteorological societies of Utrecht and Edinburgh have, the former from 1856 to 1864, the latter since 1873, directed their attention to this subject, although they have, so far, at least, not published any of their results.

§ 28. In Sweden, this special branch of natural science has till quite recently been somewhat neglected by the great mass of our people, although it cannot be denied that several of our naturalists have, by their self-sacrificing labors, produced very important and valuable scientific works in some very closely related subjects. Thus there are very few parts of the world whose aquatic fauna and flora are so well known (with regard to the different species) as Bohuslän. All these labors, which certainly must aid the investigation of the fisheries, have been made for an entirely different purpose, and, therefore, as a general rule, pass by the most important points for *our* subject.

The proposition which has been made several times to institute a more or less exhaustive scientific investigation of the fisheries, has, therefore, not yet led to any positive result, the cause of which must chiefly be found in the little importance of our fisheries to the state, an importance which possibly has been somewhat undervalued. The most extensive, and doubtless the most valuable of these older propositions, is the one which Prof. *C. J. Sundevall* made with regard to the scientific and technical sides of the salt-water fisheries, more than twenty years ago.[25]

§ 29. As I have endeavored to show in the foregoing, all these investigations will be most successful and yield the fullest scientific results by, *first*, establishing a complete station for scientific investigations of the sea on the coast of Bohuslän;[26] and, *second*, by appointing a sufficient number of observers to gather continuous data regarding the fisheries at the more important fishing-stations;[27] and, *third*, by instituting a special meteorological and hydrological investigation of the sea.[28]

[24] *Jahresbericht der Commission zur wissenschaftlichen Untersuchung der deutschen Meere in Kiel.* I–III. Berlin. 1873, 1875.

[25] *Stockholm's läns Kgl. Hushållnings-Sällskaps handlingar* (Transactions of the Stockholm Economical Society), VI, p. 211–212.

[26] *Preliminär Berättelse*, 1873–1874, p. 71; 1874–1875, p. 18. See above, § 17. Since this was written, such a station for zoological investigations has been established by the liberality of Dr. *A. Regnell*, at the instigation of Prof. *S. Lovén*, at Christineberg, in the district of Skaftöland; but we do not know in how far this station will make those investigations, which are of most importance for the fisheries.

[27] *Preliminär Berättelse*, 1873–1874, p. 74; 1874–1875, p. 17–18.

[28] *Preliminär Berättelse*, 1873–1874, p. 70; 1874–1875, p. 17–19. This last-mentioned wish may be said to have been fulfilled by the establishment of the "Nautical and Meteorological Bureau," which has been placed under the direct supervision of the Royal Navy Department.

It ought to be an object of special interest for us to obtain an accurate knowledge of our own waters, especially since such a knowledge would be of as great practical and scientific importance to our fisheries and navigation as the geological investigations have been to our agriculture and mining. The proposed investigations of the sea are no less necessary, and will certainly prove just as useful.

§ 30. With regard to the arrangement of these investigations, it may be well in this place to add a few remarks concerning their scientific portion. It has, at least of late years, become a custom with us to put all such investigations into the hands of a committee of older scientists. Although cases could be mentioned where such an arrangement was not only not hurtful but proved of absolute benefit, such cases must certainly be considered as exceptions. The most extensive scientific investigation ever undertaken in Sweden, viz, the geological survey, has been arranged on a totally different plan, which, most assuredly, is the only one which deserves to be followed. In foreign countries, such investigations have, as far as known, hardly ever been placed in the hands of a committee. In Norway, where the fisheries are of much greater importance, and where, consequently, the investigations must be much more extensive, not only the making of a plan for such investigations regarding the herring and the herring-fisheries, but the whole management of the investigations has been placed in the hands of quite a young man, who had not even finished his course at the university.[29] In Germany, these investigations have certainly been entrusted to a commission, but its members do all the principal work themselves.[30] In the United States of North America, the investigations of the fisheries, both as regards their arrangement and their execution, have been placed in the hands of one and the same man.[31] If no person or persons can be found to whom the investigations may be entrusted, it is not worth while to make any; for a committee, even if its members are fully aware of the object of the investigations, can scarcely reach any valuable results through others, unless these possess the faculty of acting for themselves.

In case such a committee should, however, be considered indispensable, it will be important to place at its head a man who will not be led astray by any interest foreign to the proper object of these investigations.

If any investigations of this kind are to be truly useful, their result must be laid before the public just as it is, without any additions or emendations.

§ 31. It has already been mentioned in the foregoing, and is really self-evident, that a well-devised and detailed plan is absolutely necessary, so the object may be reached with the greatest possible saving of labor, time, and money, and to avoid the danger of entering other fields which

[29] *Nordisk Tidsskrift for Fiskeri.* VII. Copenhagen, 1872, p. 8.

[30] *Jahresbericht der Commission zur wissenschaftlichen Untersuchung der deutschen Meere in Kiel.* I–III. Berlin, 1873, 1875.

[31] United States Commission of Fish and Fisheries. I–III. Reports of the Commissioner for 1871–1872, 1872–1873, 1873–1874, and 1874–1875. Washington, 1873–1876.

have no connection with the point in question. Many a practical and scientific investigation has by its result proved the truth of this assertion.

It is, furthermore, necessary to have as complete as possible an outfit of all the required apparatus of the best construction; for as the expenses are small compared with the result, one should not, through negligence or foolish saving, run the risk of obtaining incomplete or incorrect results. No expense, labor, or care should therefore be spared to make the apparatus as complete and as efficient as possible; for the result of the investigations to a large extent depends on this.

We need not mention again, in conclusion, that such numerous and exhaustive investigations must be continued without interruption for a long period of time, and that no grand results must be looked for after a *few* years, or expected from the work of *one* person; for the different portions of the investigation ought to be distributed among a considerable number of persons.

§ 32. A rich field is thus opened for scientific investigations and for practical experiments, which must be worked up in all its parts before that knowledge and experience can be gained which is the essential condition of an entirely satisfactory arrangement and management of our salt-water fisheries. Even if the time when this point shall have been reached, as regards our knowledge of the nature of fish and of the sea, is far distant, we should not hesitate to make use of the little knowledge we possess for improving the condition of our salt-water fisheries and further their success by legislative and administrative reforms, always bearing in mind, however, the incomplete and insufficient character of that knowledge on which our reforms are based. The consciousness of the small extent and insufficiency of our knowledge should not make us indifferent or indolent, and we must not forget that a clear knowledge of difficulties is a good step forward towards overcoming them.

If a basis has to be found for legislation on which the welfare of thousands of human beings depends, no mistakes should be made; least of all such as could easily be avoided by uprightness and a little self-criticism. Our actual knowledge of the subject is unfortunately still so limited that there can be no question of demanding one or the other axiom, which has been by no means fully proved an infallible basis for legislation; but it is rather a duty to point out the defects in our knowledge and endeavor to remedy them as soon as possible. In saying this we do not mean that our knowledge, insignificant in itself, could not serve as a basis for *some* improvements in our legislation; for it must not be forgotten that as long as perfection cannot be reached we must endeavor to make the best use of what we possess. It is, under all circumstances, the duty of the scientific investigator, in a field like the fisheries, to give all the facts just as they are, and not, from a desire to appear as a great discoverer, or from fear of censure, to hide the naked truth.

II.

BRIEF REVIEW OF OUR PRESENT KNOWLEDGE OF THE MODE OF LIFE AND THE MIGRATIONS OF THE HERRING, AND THEIR PHYSICAL AND BIOLOGICAL CAUSES.

1. The rich herring-fisheries which took place on the coast of Bohuslän at the end of last year (1877) and the beginning of the present year (1878) have caused me to publish a brief statement of the present condition of the scientific investigations regarding the mode of life of the herring and its annual and other migrations, as well as of those natural conditions which may be their causes. I have done this with the special object of making the scattered scientific material accessible for the general public, as this certainly would be of practical use in case the herrings should again regularly visit our western coast in any considerable numbers. The amount of knowledge we possess is small; but if brought within the reach of a larger public it may nevertheless have a beneficial influence on the fisheries. So far, we do not possess any scientific collection of all the material prepared with a view to the special needs of our coast; just as little any general and comprehensive epitome of it. In order, therefore, to make this treatise as timely as possible I have collected all the facts in my possession, and by comparing them with the results of the most recent foreign investigations I have endeavored to make them as complete and reliable as possible, which, however, has not materially changed my previous views. These more or less strictly scientific investigations have so far not produced any result which could lead to a complete and much-needed reform in this branch of human knowledge; but in most points our knowledge is just as incomplete and as little critically sifted as it was a hundred years ago.

2. The object of this entirely preliminary review of our present knowledge of the mode of life and the migrations of the herring is, *first*, to give in as brief and as clear and systematic a form as possible all the material which has gradually accumulated in the course of time, in order to make it more accessible both to scientists and to fishermen; *second*, to give a review of the historical development of the more important points in our knowledge, in order, if possible, to prevent mistakes in the future, and to facilitate a more correct understanding of all the circumstances; and, *third*, to show the necessity and to point out the course and possible results of continued scientific investigations. An entirely satisfactory scientific review of all our knowledge presupposes an ample amount of material critically sifted, consisting in observations made uninterruptedly during a long period of time at a large number of places; for, as in meteorology, all truly scientific knowledge must be based on a collection and comparison of as large a number of observations as possible, made by reliable persons during a long period of time and in many different

places. The most extensive and most complete number of observations will bring our knowledge as near actual truth as possible. It will be self-evident that whenever, as in the case of the fisheries, we have to do with periodical changes embracing long periods of time, there will be special need of many and long-continued observations.

3. But as such entirely sufficient material is for the present not accessible, and could not possibly be procured during the comparatively short time which I have been able to devote to the investigation of the herrings and the herring-fisheries on the western coast of Sweden,[32] even if I had had ever so many able assistants, I cannot do better than to use the material on hand, which, certainly from a scientific point of view, is insufficient, but which, nevertheless, possesses some practical value. Even the most careful preparation of this heterogeneous mass of material must, however, be defective, because no satisfactory result can be reached, unless we possess a thorough knowledge of all the points based on the most comprehensive scientific material. Although, in a work like the present, it may be important to give in each case the exact source from which the information has been drawn, I have thought fit to deviate from this generally observed rule, chiefly because it is my intention to treat the whole subject more fully in a larger work which I am preparing, the title of which will be "On the Herring and the Herring-Fisheries," and also to reduce the time[33] and cost of this brief review as much as possible. I nevertheless hope that this little work may be of some use, and prove a help to those of our writers on the fishery-question who by different circumstances are confined to the observations of others.

4. Natural science, considered as a systematic review of all nature, is constantly growing more many-sided and more complicated, in proportion as it develops and as it is simplified by having many different facts condensed into general axioms (*"Les sciences progressent en se simplifiant," Leibnitz*). Nature forms a continuous whole, all parts of which are connected by an indissoluble causal connection both among themselves and with the constantly developing universe; the scientific investigation of a natural object or a natural phenomenon can reach completeness only in proportion as it is many-sided. It is a very common mistake to view the different phenomena isolated from others; and science suffers in consequence, entire systems being built on such incomplete views, which may for the time being satisfy at least the less scientific and critical portion of the public, but which are very hard to root out, all the harder

[32] Since July, 1873, I have (commissioned by the government) been busy in collecting such scientific data regarding the natural history of the herring and the herring-fisheries as I deemed necessary for improved legislation on our herring-fisheries.

[33] The greatest difficulty has been experienced and almost insurmountable hinderances placed in the way of gaining the necessary time for a work like the present, by the necessity of carrying on simultaneously the investigations regarding the other portions of the biology of the herring, and the many other different points in this whole herring question, the legislative, administrative, and economical parts of which have taken up the greater portion of my time spent on the coast of Bohuslän.

when they are propped up by the strong pillars of authority. The different changes in the development of science follow entirely different methods, and the investigations of the period immediately preceding ours, devoted more to special branches, have doubtless, through their results, furnished a very necessary basis for the more many-sided tendencies of our present science.

5. Only through long periods of time the human race can gradually reach a higher and more complete knowledge. The history of sciences shows in every branch of knowledge an exceedingly slow development, quicker at times, but at other times slow, stationary, and even retrograding. Even the gaps in the historical material, or the just as common and easily-explained custom of directing attention from the less important to the most important representatives of scientific development, lead a less experienced and thoughtful man to entirely different points than those in question. It is therefore best, as a general rule, not to look for too much "that is new in science" in an author who has in his special line of scientific investigation been preceded by many and prominent writers who have used all the old material, and who, having solved those problems which were of easy solution, have left the most difficult questions unanswered.[34] But even of the most unassuming author we may demand that he shall treat his subject from the present scientific point of view.

6. A remarkable misconception of the aim of scientific work, which even in our time is not altogether rare, is the idea that the object of the naturalist consists chiefly in increasing the scientific material by making rich collections of objects and observations, by describing everything as minutely as possible, and by combining all the facts to a whole, which is then occasionally termed in a somewhat contemptuous manner "a compilation." A higher view of science must, however, disapprove of such a lowering of that most important kind of scientific work, which is far different from mere compilation, which only aims at arranging the works of several authors systematically in one work. In saying this I do not mean to deny the value or necessity of scientific collections or compilations, but merely to raise a faint protest against those who overestimate these compilations and undervalue combined scientific activity. Science doubtless needs as complete and as critically sifted material as possible, but this material in itself is not yet science. The object of the naturalist, therefore, does not only consist in the constant accumulating of observations in order to reveal hitherto unknown facts or to corroborate known facts, but in combining the material gathered by himself and

[34] If we therefore go over the works of older authors on this subject in chronological order, we soon find that their views only very gradually become clearer and more distinct, and that the more critically sifted and arranged axioms which we intend to give we by no means owe altogether to our predecessors. Only by joining the various facts and arranging them systematically they become important, and not least by thereby showing their insufficient character if viewed from a truly scientific point of view.

others into a whole. The last-mentioned work is no less important than the former, and is actually the really scientific portion of the work.

7. Even in biology there are many questions which cannot be satisfactorily answered by *one* person, but which demand the systematic work of *several* naturalists, just as is the case in meteorology. That this is specially necessary with regard to our subject will be evident when we think of the complete series of observations which are needed—observations referring not only to biology, but also to meteorology, hydrology, &c.; for only by making full observations in *all* these directions can we arrive at any satisfactory result. And in order to have these observations as full and systematic as possible there should be a number of stations working according to one and the same plan.[35]

Although the time is certainly very far distant when sufficient observations will have been collected to furnish the necessary material for a satisfactory scientific solution of our problem, we shall see from the following that, as far as Bohuslän is concerned, a complete meteorological station would be extremely useful during a rich fishing-season. Those who devote themselves to the herring-fisheries would gain an increased knowledge of the herring, its mode of life, and its migrations, and their dependence on the changes of the weather, and such a knowledge would certainly be of great practical use to them.

8. In order to gain a correct view of the causes of the irregularities in the mode of life and the migrations of the herring, it is specially necessary to get as complete a knowledge as possible of the influence which physical and biological causes exercise on the herring.

In treating this very difficult and but little known subject it must not be forgotten that hitherto fishing, carried on as a trade, has been almost the only means of observing the influence of such causes; and as fishing is only carried on at those seasons and places and with those implements which promise the greatest success, it will be clear how incomplete and unreliable our knowledge must be. Great caution is required in gathering and receiving information, for mere fanciful and hypothetical theories lead us only farther away from our true object. This part of my work had chiefly to be confined to the collecting and arranging of all the data found in literature.

9. We must first consider the influence which the *sun* and the *moon* exercise. The sun produces day and night and the four seasons. The changes produced by the turning of the earth round its axis and round the sun act not only through the greater or smaller quantity of light, but in a still higher degree through the differences of temperature and the general changes in the weather which they produce. Attempts have

[35] Those who have to do this preparatory work should be fully impressed with the fact that the result of their labor will chiefly benefit the scientists of the future. They must, therefore, sacrifice their own scientific vanity and the hope of reaping the fruits of their labor, but be satisfied to know that it will form part of the foundation of the science of the future. This self-sacrificing work may well be said to ennoble him who engages in it, and who deserves the esteem and gratitude of humanity.

even been made to prove that the sun produces considerable periodical changes in the weather by the regularly changing number of the solar spots. The moon, on the other hand, exercises an important influence through the difference of light which her changes produce,[36] through the tides regulated by her, and the different currents occasioned by the tide, which are chiefly caused by the attraction of the earth. In this last-mentioned respect the sun exercises a similar but weaker influence, which more or less modifies that of the moon.

10. As regards the influence of *sound* on the herring, it is well known how easily it is frightened by any unusual noise. There is no doubt that the sense of hearing is not very strongly developed in the herring, although the old opinion, which was held even by *Linné*, that fish are entirely deaf, has long since been proved to be erroneous. The herring generally returns immediately to the place from which a sudden noise had scared it away. It has also been sufficiently proved that it is highly improbable that a long-continued noise may drive the herrings away from places which they have been in the habit of visiting from time immemorial. But even quite recently it has again been maintained that such has been the case, and steamboats, men-of-war, fortresses, fishermen, coopers, &c., have been accused of having by noise brought the herring-fisheries in some places to a premature end; but *no* satisfactory proof for any such assertions has ever been brought forward. The herrings have disappeared from places where the thunder of cannon has never been heard, and where no steamboats have ever come, whilst they have continued to make their appearance in localities where steamboats and the shooting of guns were frequent. As far as steamboats are concerned we may specially mention the mouth of the Thames, the Firth of Forth, the Sound, the Great Belt, &c. It is certain that thunder causes the herrings to go to so great a depth that they cannot be reached with the common fishing-implements, which will be further proved below by facts; and a violent cannonade may, of course, have the same effect. It is well known that a strong wind blowing towards the coast often hinders or interrupts the approach of the herrings, but it is scarcely probable that the roaring of the waves when dashing against the rocks produces the same effect.

11. Regarding the influence of *electricity*, we still are without the necessary observations on which any certain opinions might be based. It has been known from olden times that during a thunder-storm the herrings seek the deep water, but so far it is impossible to say whether this action is caused by the thunder, the glare of the lightning, the electricity itself, or all these influences combined. *Valenciennes* says that the herrings become violently excited by thunder, and that newly-hatched herrings

[36] There is a deeply rooted conviction among the fishermen that the changes of the moon exercise a most decided influence on the mode of life and the migrations of the herring. In examining the different opinions entertained by fishermen, it was found, however, that all this supposed influence may be reduced to the few above-mentioned cases, and that it is by no means very important.

may suddenly leave the coast from this cause. The Dutch Meteorological Institute at Utrecht says, in its report of 1859, on observations made during the so-called "great fisheries," "that during a thunder-storm accompanied by heavy rain the herrings do not come up to a height where they can be caught till dawn"; and the Meteorological Society of Edinburgh mentions "that according to their observations there will be good fishing the same day when a considerable thunder-storm extends over the greater portion of Eastern Scotland, but that there will be scarcely any fishing on the day following on that portion of the coast-waters which, so to speak, forms the outer edge of the great deep." *G. C. Cederström* believes that he has found "a surprising connection between the course of the fish and electricity." It seems, however, that this "connection" may be ascribed to other causes than the influence of "cosmic electricity."

12. Regarding the influence of *light* we possess a considerable number of observations, and opinions based on them. Light is therefore justly considered as one of the more important causes which exercise an influence on the more or less regular course of the herrings. We shall below give a full account of these observations and of the various opinions based on them. The herring, like many of our salt-water fish, cannot bear a very strong light, or prefers at any rate a dim light. *Neucrantz* therefore supposes that the glare of the lightning drives the herrings into deeper water.[37]

It is well known that both the herring and the small herring stay in deeper water during the day than during the night on account of the light, although the depth, of course, varies according to the greater or smaller intensity of the light. A bright moonlight night is therefore considered less favorable for herring-fishing, because the herring stay in deeper water. It is, however, just as probable that this opinion has been created by the increased difficulty of catching the herrings in a bright light, as by the supposition that in the darkness the herrings find some protection from their pursuers, and therefore seek dark places even during day-time.[38] This probably also causes the influence which the varying degree of transparency of the water exercises on the fish, eries, fishing always being best when the water is less transparent or turbid, or when the rays of light are broken by small waves.

The changes of light and darkness caused by the setting and rising of the sun seem to have a great influence on the herring, exciting them considerably and causing them to come up from the deep; fishing with floating nets is consequently most profitable at those times. If during very dark nights the herrings keep in such deep water that they cannot be reached with the floating nets, it happens occasionally that the light of the rising moon attracts them towards the surface so the nets

[37] To show how sensitive fish are to the influence of light, we may mention the fact, that codfish kept in shallow vessels open to the sun have become blind from the strong light.

[38] When seeking food the herrings are, even in day-time, not unfrequently found near the surface of the water.

can be quickly filled. The oblique direction in which the rays of the sun and the moon strike the surface of the water doubtless has a great influence. In many places the fishermen use torches during fishing-firmly convinced that the herrings are at night-time attracted towards the surface by light. *Valenciennes* mentions an observation made by French fishermen, "that in winter the herrings do not begin to stir until the sun rises, when they come nearer the surface, and that the same also applies to the newly-hatched herrings."

13. Of all meteorological causes, the *temperature of the air* seems to exercise the most decided influence on the herrings, chiefly through its influence on the weather in general, and more especially on the temperature of the water and the quantity of herring-food. The herring (as we shall show farther on) prefers a certain even temperature, and as this is not found near the surface or near the coast, it goes into deeper water or farther away from the coast. We thus possess numerous data showing that both the herring and the small herring have by cold weather been hindered from approaching the coast, or that the fisheries which had already commenced during mild weather have been interrupted from the same cause. During the winter herring-fisheries mild weather is therefore generally considered favorable, although this is certainly not the case under all circumstances. For it is well known from the last great Bohuslän herring-fisheries as well as from the western coast of Scotland, that the remaining of the snow on the mountains and the consequent considerable cold are thought to promise good winter fishing, whilst thawing weather produced by a southeasterly wind is considered unfavorable. Great heat has just as much influence on the fisheries as great cold, and the fisheries which are carried on during the warm season are just as much inconvenienced by the heat as the winter fisheries by the cold. The herrings seem to keep at a certain depth which is regulated by the temperature, so that in moderately mild weather they are nearer the surface, and at a greater depth either in very cold or very warm weather. *Münter* relates, that in Pomerania the wicker baskets for catching herrings must be placed deeper, as in spring the warmth of the sun increases; and it is well known from the large fisheries which during summer and the beginning of autumn are carried on in the northwestern portion of the North Sea, that cooler weather brings good fishing. After a very hot spring and summer the herrings are also said not to come so near the eastern coast of Scotland as they do otherwise. There it has, however, been noticed that a high temperature at the beginning of the fisheries, if immediately followed by a comparatively lower temperature, has been favorable to fishing. It is well known on the Limfiord (Denmark) that a warm summer is generally followed by rich autumn fisheries, so that the saying has become proverbial there, "Many flies, many herrings." Both the herring and the small herring are northern fish which like cool but not entirely cold water, and some of our most important fisheries are therefore carried on during the coldest

season of the year. If the cold is too severe, however, the herrings are thought to become torpid.

The temperature of the air thus seems to exercise its influence chiefly through its extremes, which the herrings cannot well stand, and through its influence on the spawning of the herrings. During the spawning-process the herrings need a certain even temperature, and, therefore, in case of great heat or cold, go to deeper spawning-places. The temperature of the air, therefore, has a much greater influence on the fisheries of spawning herrings than on the common herring-fisheries, whilst the latter are more influenced by wind and current. The influence of the temperature of the air will be more noticeable when fishing is carried on with floating nets than when stationary nets are used.

As different winds produce a different temperature, and thus exercise an essentially different influence on the herrings, we shall, farther on, when speaking of the influence of the wind, give more data regarding the influence which the temperature of the air has on the herring.

After a mild winter, and during a mild, early spring, the spawning of those herrings which spawn in spring and the spring-herring fisheries begin somewhat earlier than otherwise. When in spring the air gets warmer the young herrings seek shallow waters, but when cooler weather sets in they return to the deep water.

14. The *pressure of the air*, as far as known, only exercises an influence on the herrings through the changes which it produces in the weather and in the direction and force of the wind; for all we know regarding the direct influence of the pressure of the air on the sea and thereby on the herrings is the fact that it is not very considerable. Observations which in this respect have been made with regard to other fish are not sufficiently numerous and general to base any certain opinion on them.

The Meteorological Society of Edinburgh has published the results of their comparison between the observations on the course of the fisheries made by the superintendents of fisheries during the years 1867–1872, and the simultaneous meteorological observations, from which it appears that the richest hauls were generally made when the barometer was "high and steady," whilst the fishing was not so good when the barometer was "low." *Frank Buckland*, however, has recently directed attention to an article, by *J. Salmon*, of Lowestoft, in "Land and Water," January 16, 1862, according to which an "unsteady" barometer had during the autumn herring-fisheries in the Southern North Sea (the so-called "Yarmouth fisheries") been favorable to fishing. It is well known that fishing is good when the herrings keep at a moderate depth, and the strength of the wind and the motion of the water are favorable to the use of fishing-apparatus.

In the Skagerack the lower or higher state of the barometer has a considerable influence on the herring-fisheries, both through its influence on the weather in general and more especially on the wind and the currents of the sea.

15. Regarding the influence which *fog* and *haze* have on the herrings, we possess scarcely any information except the observation made by the Dutch floating-net fishermen that foggy weather is not favorable to fishing. Fog and haze probably have a similar influence as a cloudy sky, but doubtless they often injure the fisheries by impeding the sailing near the coast. Nothing definite is known concerning the influence which the different degrees of moisture in the air or the evaporations from the surface of the water may possibly have on the herrings.

16. The *clouds* also must be considered. A cloudy sky is generally thought to be favorable to fishing; this idea probably originates in the circumstance that clouds produce a subdued light, which brings the herrings nearer to the surface and renders it more difficult for them to see and escape the fishing-apparatus. During the night clouds will diminish the warmth, the lower regions of the air and the surface of the water will, therefore, become cooler, and by day-time clouds will prevent the upper portions of the water from getting too warm. The greater or less degree of cloudiness by day or night is therefore of considerable importance for the fisheries, especially during summer.

17. Regarding the influence of *rain*, *snow*, or *hail* on the herrings, it will easily be understood that this chiefly depends on its connection with other meteorological conditions. When it rains or snows the sky is generally covered with clouds, the pressure of the air is lower and the weather milder (the latter caused, among other things, by latent warmth being set free). Rain or snow is therefore generally considered favorable for fishing. Excessive rains, however, followed by floods, are considered unfavorable in Scotland. When rain is accompanied by a thunder-storm or a hurricane, it is of course these last-mentioned phenomena which exercise an influence on the herrings and the herring-fisheries.

That *snow* should scare the herrings away, as *Neucrantz* says, cannot be considered as the general rule, although this may occasionally be the case in consequence of local peculiarities (for example, when fishing is going on at a season of the year when a fall of snow would produce a considerably lower temperature), but the form in which the "falling weather" shows itself (rain or snow) seems to be immaterial. The influence which the fishermen ascribe to the snow remaining on the mountains has been spoken of above.

18. Of all the outward physical causes, the *winds* doubtless have the most important influence on the mode of life and the migrations of the herrings. This influence of the wind may, however, be occasioned by the different temperature, cloudiness, rain, &c., which it produces, by the influence which it exercises on the force, velocity, and direction of the currents by the considerable changes which it brings about in the height of the water, the motion it produces in the upper layers of the water, and the consequent greater or smaller waves, turbid state of the water, or different breaking of the rays of light. This influence of the wind is

still more increased for us by the fact that it either hinders or favors fishing in a greatly varying degree, thus influencing the very sources of our knowledge.

The influence of the wind on the herrings varies considerably as the herrings approach the coast either for the purpose of seeking food or for the purpose of spawning, a circumstance which hitherto has been too much overlooked, which makes the working-up of the material on hand peculiarly difficult.

From the observations at our command it seems to be certain that when herrings approach a coast for the purpose of spawning, they seek quiet waters. Storms often prevent them from reaching their accustomed spawning-places, or compel them, if they can wait no longer or have come close to the coast, to come quite near the land or to go far away from their usual spawning-places which are in deep water, whilst a gentle wind, from whichever quarter it may come, has very little influence on the herrings. Land-wind may, however, as a general rule be considered most favorable to the fisheries during the spawning-season.

Regarding the influence of storms on the herrings during the spawning-season fisheries, we must here give the results of that valuable comparison of facts from the Norwegian spring-herring fisheries, which we owe to the "historical investigations" of *Axel Boeck*. He found that during a violent land-storm the herrings seek the coast, when the best fishing is near the sheltered fishing-places, whilst during violent sea-wind the herrings but rarely go to those places where they are generally caught and which are quite open towards the sea. During long-continued northwesterly and southwesterly storms herrings often visit places where they never come otherwise, and go farther up the fiords. During long-continued sea-wind the spring-herring fisheries cannot be carried on in the otherwise quite regular course from south to north. *Boeck* also relates, of the same fisheries, that during calm weather the herrings often separated into smaller schools, and the chief fisheries did not commence until a southwesterly or northwesterly wind had stirred up the water and mixed the lower and warmer layers with the upper and cooler ones.

On the east coast of Scotland, near the Moray Firth, land-wind is considered favorable to the spawn-herring fisheries; but for those fisheries which are carried on farther out in the open North Sea, sea-wind is considered better, more especially on the banks far from the coast. It is, furthermore, thought that for these fisheries southern winds are better than western winds, and for the herring-fisheries near Yarmouth western winds are most favorable. For those herring-fisheries which in the northwestern portion of the North Sea, at a considerable distance from the coast, are carried on by the Dutch and Germans, northerly winds are considered more favorable than southerly, and westerly than easterly winds. The fisheries in the open sea will, of course, show a considerable difference from the coast-fisheries in regard to the influence of the winds.

Gisler relates that in the Bothnian Gulf storms do not drive the herrings from their places of sojourn far out at sea, and that the herrings, when storms prevent them from approaching the sea-coast, are supposed to spawn out at sea where there are suitable banks.

As regards our present Bohuslän herring-fisheries, they are so insignificant, the spawning-places are all in such sheltered locations, and the fisheries are carried on with so little energy, that it is very difficult to obtain sufficient data on which to found any certain opinion. We have been informed, however, that during the herring-fisheries near South Hisingen, the herrings go farther up towards the mouth of the river during land-wind, when there is good fishing in the neighborhood of Ny-Elfsborg; and when westerly and southerly winds prevail the best fishing is farther out near the coast of Andal and Hästvik.

During that part of the last great-herring fishing-period, when large numbers of herrings spawned near our coast, land-wind was generally considered most favorable to fishing.

As the most important, most profitable, and safest herring-fisheries are those which are carried on during the spawning-season (as during the other portions of the year the fish are not so fat and their course is more uncertain), it will be clear that, although physical conditions exercise a far greater influence on the last-mentioned fisheries, our knowledge of them is much more limited.

When the herrings come to the coast for the purpose of seeking food, wind and especially storm has an entirely different influence on them, and the occurrence of the herrings is chiefly determined by the quantity of herring-food found in a certain place. Thus the herrings often approach a coast with that wind which drives in large quantities of herring-food, and leave the coast with that wind which drives the herring-food away. This explains why during the last great Bohuslän herring-fishing period the herrings did not always appear in the same numbers during one and the same direction of the wind; for during that period when the herrings spawned near the coast land-wind was more favorable than sea-wind, whilst during that period when the great mass of the herrings only approached the coast for another purpose, a strong sea-wind often caused the herrings to enter the fiords and thus brought about the beginning of the fisheries.

In discussing the causes why the great-herring fisheries came to an end, people made the mistake of supposing that all manner of refuse floating in the sea and various noises kept the herrings on the outer coast and hindered them from coming nearer until the storm drove them in. Both from our last great-herring fishing period and from our later much less important herring-fisheries it is well known, however, that a south-easterly wind drives those herrings which have come for the purpose of seeking food away from the coast, because it blows from the land in such a direction that it both increases and accelerates the Skagerack current on the outer coast and directs it farther away from the coast, carrying with it the great mass of herring-food.

If we examine the observations made in different places, we shall soon find that one and the same wind will exercise a different influence, just according as in one place it blows from and in another place towards the coast. It is, for instance, reported from the Firth of Forth that during the winter of 1863 unusually long-continued westerly (*i. e.*, land-)winds hindered the small herrings from going to their usual places in the inner portion of the fiord, and caused some of them to seek shelter near the Granton breakwater, in the middle portion of the fiord. Fishing was consequently not very successful, whilst during the more severe winter of 1866 violent land-winds drove the herrings and small herrings far up into the fiord. As in that region land-wind is more common during a severe winter, such a winter is generally considered more favorable to the fisheries than a mild one, just the contrary from what it is in Bohuslän, where westerly wind and consequent milder temperature and higher water are decidedly more favorable to the fisheries than land-wind with cold temperature and low water. The same difference will become apparent when we compare Bohuslän with Norrland.

By combining all the observations made in different places, we get a small number of general axioms regarding the influence of the wind on those herrings which come to the coast for the purpose of spawning, and these would be the following: Sea-wind is favorable to the fisheries, as it causes the herrings to seek the coast; violent storms compel the herrings to seek deep water or shelter in the calmer fiords, but a brisk sea-wind is generally favorable. Small herrings often seem to seek shelter near the land, and in Bohuslän it has been observed near Hisingen that in summer during easterly wind the young herrings like to go towards the mouth of the river. As regards the Skagerack herring fisheries, it must not be forgotten that in judging of the influence of the wind one must take into consideration its direction and force, not only near the coast of Bohuslän but also out in the North Sea. In order to form a correct judgment it will therefore be necessary to have synoptic observations of the wind to refer to, and not to forget that the effect frequently will not be noticed till long after the cause.

We furthermore possess different observations and opinions about the influence of the wind on the herrings, which are of a less certain and scientific character, and of which we do not know whether they have been gathered during those fisheries when spawners were caught, or during those fisheries when only fish coming to the coast for food were caught, or from both. We finally possess some data concerning the direct influence of storms on the herrings, for example, that "immediately after a storm they keep near the surface, and are actually giddy and so weak that some are cast on shore or come near the land," and, "after the lapse of a few days, if the storm continues, get quite soft, as if their flesh was melting" (*Gisler*); that storm compels the herrings to keep closer together, and that a violent storm tends to mix the herrings and the small herrings, whilst otherwise they always keep in separate schools.

Thus we know from Scotland that the herrings, immediately before a storm, come near the surface; and in several places in Bohuslän, especially on the coast of Fjellbacka, it has been observed that the herrings go away from the coast against storm and weather, although some time after the storm there is generally again good fishing. It must be remembered that a storm is often preceded by commotion in the water and other causes which may influence the herrings.

19. Regarding the *influence of the weather in general*, it should be noticed that the herrings evidently prefer even and mild weather, free from all extremes; and such weather is, in most cases at least, an essential condition of successful herring-fisheries. The herrings especially dislike all sudden changes in the weather, and it is even asserted that they are so sensitive in this respect that by their actions they show a distinct foreknowledge of changes in the weather, to which circumstance we shall have occasion to refer again.

It must be borne in mind that it is chiefly the general character of the weather[39] which here comes into question, and that in order to understand its influence it is necessary to have reliable and as far as possible complete synoptic weather observations covering a much larger area than a few fishing-stations. It must likewise not be forgotten that the spawning herring is much less influenced by the weather than the herring which comes to the coast to seek food, so that the fishing for the former is much more certain than that of the latter. Fishing with floating nets near a coast is much more dependent on the weather than fishing with stationary nets.

I have on the coast of Bohuslän often heard the failure of the potato crop brought in connection with good herring-fisheries, and with a certain show of reason, as weather which is favorable for the autumn and winter herring-fisheries, is generally unfavorable for the growth of potatoes. This agrees with *Gisler's* observation from the Norrland herring-fisheries, where the fishermen say that when the corn grows well on the land there is not much fishing in the sea, and when the sea is full of fish there is little corn on the land. Similar observations from the last century we find in the works of *Schöning*, *Ström*, and *Lybecker*, and there is doubtless a good deal of truth in them, especially in former times when agriculture was not so advanced as it is now, and to a great extent depended on the state of the weather.

It should finally be mentioned here that there is supposed to be a centennial periodicity in the weather caused by the relative number of solar spots, according to which larger and smaller solar-spot periods have been spoken of, and by the changing position of the moon towards

[39] The general character of the weather is best seen in the winds as the fullest expression of all its determining features, and as having the greatest influence on the mode of life and the migrations of the herrings. The general character of the weather must, however, be taken into consideration, not only during the fishing-season, or the days and weeks immediately preceding it, but also during the different seasons of the year, and for longer and shorter periods, each comprising several years.

the earth, by a change in the direction of the currents of the sea, and especially of the Gulf stream, or by the influence of the polar ice and its floating towards southern regions, &c. If future scientific investigations should prove the existence of such a periodicity, it is quite probable that light will be thrown on many a dark point in the biology of the herring.

20. Among the hydrological phenomena which for the better understanding of the mode of life and the migrations of the herring require our attention, the more or less agitated condition of the water caused by the winds is the most prominent. The *motion of the waves* seems to exercise an influence on the herrings partly by aërating the water, partly by mixing water of different temperature, and finally by the occasionally very violent agitation which is produced even in the lower regions of the water near the bottom. The last-mentioned effect of the motion of the waves, which shall form the subject of special investigations, has a considerable influence especially on the spawning herrings, which need calm waters for spawning, heavy waves often compelling them to seek spawning-places which are sheltered or in the deep water where the motion of the waves is not so perceptible. *Gisler* says that violent storms tend to weaken the herrings when near the coast, and numerous observations corroborate the fact that during such storms the herrings leave the coast or seek sheltered places; and even the heaving of the sea preceding and indicating the approach of a storm seems often to have the same effect. The direction in which this heaving takes place forms, therefore, one of the more important signs, from which the fishermen predict the future of the weather and of the fisheries. In the open sea, far from the coast, the motion of the waves seems to have no or little influence on the herrings; the Dutch so-called "large" herring-fisheries are therefore not at all influenced by it. Smaller surface waves seem always to have a favorable influence on the fisheries, probably because they break and therefore subdue the light.

21. We must also take into consideration the different height of the water which is caused by wind and tide. On coasts where the tide is very perceptible, it doubtless exercises a very considerable influence, especially on the fisheries,—much more so than on the life of the herring. *Perley* says that in the Bay of Fundy, during the spring tide, in early summer, herrings which have come to the coast to seek food are easily caught even during day-time; and at Yarmouth the richest hauls are made when the tide comes in during the three hours before and the three hours after midnight. According to *Ström* all kind of fishing is more successful at Söndmör when the tide is in than when it is out. I have been informed that on the west coast of Scotland the herrings are nearer the surface during slack tides than when the tide is high. On the coast of Bohuslän the tide is not very perceptible during the season when the principal herring-fisheries are going on; and this whole matter has been studied so little that not much can be said regarding the influence which the tide has on the herrings.

In speaking of the influence of the wind, it has already been said, that when it blows *towards* the coast and consequently produces high water it is favorable to the fisheries, whilst when it blows *from* the coast and produces low water it is unfavorable. Very high water, however, is, according to *Gisler*, not favorable to fishing on the coast of Norrland. On the coast of Bohuslän it is considered a general rule that steady and fine weather and high water are best for the fisheries. Very high water is, with us, only caused by violent winds blowing from the sea, which, of course, often interrupt the fisheries. *G. C. Cederström* says that the herrings are more lively when the water is *moderately* high than when it is *very* high.

22. Of all the hydrological causes, the *currents of the sea* doubtless exercise the most important influence on the mode of life and the migrations of the herring. This influence seems chiefly to depend on the herring-food which these currents carry, through the temperature and the nature of their water, and through the aid which they render to the migrations of the herrings.

That the currents influence the herrings in the choice of their spawning-places is chiefly caused by their influence on the temperature of the water and their carrying the necessary food for the young herrings. According to *Eckström*, it is also quite probable that the herrings in moving to a distant spawning-place take advantage of the ease with which the currents carry them towards their destination. This opinion seems to be corroborated by the place where and the direction in which those herrings which spawn in autumn came to the coast of Bohuslän during the last great herring-fisheries. On the course of the spawning herring during the spawning-season the current seems, as *Boeck* already has said, to have but little influence, as the herrings go to their spawning-places both *with* and *against* the current. This does not coincide, however, with the views of other naturalists, according to whom the herrings always go against the current. As land-wind was during our last herring-fishing period considered favorable as long as those herrings which spawn in autumn came to the coast to spawn, and as most of their spawning-places were on the southern coast, it seems that the herrings generally went against the current. The circumstance that fishing for spawning herrings near South Hisingen, at the mouth of the Göta River, is best when land-wind prevails is explained by the fishermen in this way: that the land-wind accelerates the current of fresh water which is going out and increases the intensity of the under-current of salt water with which the herrings are supposed to come in.

With those herrings which come to the coast for the purpose of seeking food, all this is different; for they are chiefly influenced by the occurrence of this food, which is again dependent on the current.[40] Thus

[40] One must be careful not to draw too rash a conclusion that spawning herrings will soon come to a coast in great quantities because many herrings come to that coast to seek food.

during the latter part of our last great herring-fisheries the herrings came with those currents that were going *towards* the coast, and currents going *out* to sea were consequently considered unfavorable to the fisheries, especially when they took their direction from a southeasterly wind. Regarding the coming to our coast of those herrings which occur in the greatest number, and especially of the so-called "old sea-herrings," there is a remarkable agreement between the place where and the order in which they came, and the direction of those currents of the sea which come from the North Sea and the Kattegat along the coast of Bohuslän and in the Skagerack. The current coming from the North Sea goes north of Skagen towards the Pater-noster Rocks, near which it is met by the current from the Kattegat going north; thereupon they both follow the coast, and after having passed Lindesnäs finally go into the North Sea in a westerly direction. The fishing for the herrings coming from the open sea has generally commenced near Tjörn and the Marstrand Islands, from which point the herrings spread towards the north and south, in the former case following the current; and as the current north of Sotenäs turns away from the coast, the herring-fisheries on the northern coast have generally been less certain and less important than those on the central coast.[41]

The young herrings often go with the current, and therefore often undertake comparatively long voyages, of which we have a proof, unfortunately hitherto overlooked, from the coast of Bohuslän, on whose southern portion especially the young of those herrings which during autumn spawn in the Kattegat are often seen.[42]

The herring delights in going with its head against the stream, especially when in search of food, and near the coast it prefers those places where there is a rapid current. The herring is a fish which likes flowing water; but this does not mean that it is driven about by the waves like a piece of wood. According to ancient and modern observations the herring goes just as easy with as against the stream, and when pursued flies as rapidly against it as with it.

During our last great herring-fisheries, and especially towards their end, it was asserted by persons opposed to the boiling of fish-oil that the refuse from the oil-refineries, which was thrown into the sea, prevented the herrings from coming near the coast, whither they were only driven by violent storms and currents. This view, however, was strongly opposed by many fishermen; but *G. C. Cederström* seems still to lean towards the view of the great power of the current over the herrings,

[41] This was probably during the last great herring-fisheries also caused by the circumstance that those herrings which spawn in autumn, as far as known, chiefly spawned on the central and southern coast, whilst those herrings which spawn in winter were far more frequent on the northern coast. With the small herring this is entirely different; for the most extensive small-herring fisheries have always been carried on on the northern coast.

[42] The coast of Bohuslän offers much better protection to the young fish, and is probably in other respects, too, a much more suitable place of sojourn for them than the open coasts of the Kattegat, which are nearly void of organic life.

and maintains that they must give way to storms and strong currents, adding, however, that in that case they either seek shelter or go into deep water.

From observations made during the English and Scotch fisheries we know that the tide, especially in narrow waters, by the regularly changing currents which it produces, exercises a considerable influence on the herring-fisheries. The richest hauls are made when the current is swiftest, because the floating net is then carried over a greater area. The rising of the tide is generally considered more favorable than its falling, and the herrings have often been observed to swim towards the tide.

The greatest difficulty in utilizing our observations of the influence of the currents on the herrings, both for science and for the fisheries, is this, that these observations almost exclusively refer to the surface-currents, although there is reason to suppose that deeper currents have often had an influence on the herrings.

23. Closely connected with and often directly dependent on the currents, at least in the North Sea, is the *color of the water*. A large number of observations made during the so-called "great" herring-fisheries in the open North Sea show that more fish are caught when the water is green than when it is blue. The green color of the water also indicates this in the northern waters, which are richer in "herring-food" and in fish; and the blue color in the southern waters, where there is less herring-food and consequently also fewer herrings. Prof. *G. O. Sars's* observations, made during the summer of 1876, show, however, that the relation between the "herring-food" and the color of the water may be exactly the reverse.

It has already been said above that thick or turbid water is better for fishing than very clear and transparent water.

24. Regarding the influence of the greater or less *saltness* of the water on the herrings there are a number of opinions, some of them directly opposed to the one held by me. Thus it has been supposed that the herrings when spawning sought less salty waters. *H. A. Meyer* believes that those herrings which are found in the western part of the Baltic and which spawn in spring, prefer sea-water mixed with a good deal of fresh water, and mentions various instances from the Schlei-fiord and other places on the Baltic. But on closer examination this does not seem necessarily to follow from these observations; but they seem rather to lead us to this conclusion, that the herrings when about to spawn only look to the convenient location of the spawning-places, and that neither a small degree of saltness, as in the Schlei-fiord, nor great saltness, as on the east coast of Scotland, prevents them from selecting a place. Because the sea-water in the fiords is in many places less salty than in the open sea, it does not follow that the herrings during the spawning-season come to the coast on account of the smaller degree of saltness of the water.[43]

[43] *Neucrantz's* hypothesis (in which he follows *Pliny*) seems more plausible: that the herrings are by their instinct led to spawn near the mouths of rivers, as these localities possess great advantages for the young fish, principally plenty of food and shelter.

In this as in many other respects the spawning herrings are less sensitive, when impelled by a natural instinct—in this case the strong desire to spawn.

The fishermen in the Scotch fiords, however, say that great floods caused by continuous rain often produce failures of the fisheries.

It is well known that herrings, especially young ones, when seeking food come to the mouths of rivers, and this fact has been explained in different ways. *Parnell* thinks that it is caused by the increased temperature produced by the mingling of fresh and salt water, whilst *Duhamel du Monceau* supposes that it can only be caused by violent storms, or that at any rate the herrings do not show the least preference for fresh water. *Boch* [possibly intended for *Boeck.—Translator's note*], again, believes that only violent persecutions by their enemies compel the herrings to seek the mouths of rivers. *G. C. Cederström* thinks that this is caused by the circumstance "that the herrings' need of acid is easier satisfied in fresh water than in salt water." Other authors think the herrings seek the mouths of rivers because they find more food[44] or better shelter from their enemies in the less salty, more turbid, and calmer water. I cannot deny that even spawning herrings are occasionally found in the mouths of rivers, but as we know so little concerning it it may well be supposed that it is caused by extreme conditions of the weather. *Valenciennes*, however, remarks that the herrings do not enter the mouths of rivers until they have spawned. As far as the Bohuslän coast is concerned it must be said that the coast-herrings peculiar to it are caught most frequently near the mouths of the Göta and Glommen Rivers.[45] Near the mouth of the Göta River, especially, it has been observed that the young herrings during summer when east wind prevails like to come near the mouth of the river. It may be mentioned, as a peculiarity, that during the last great herring-fisheries the herrings in the year 1752 accidentally went so far up the Göta River that they were caught near Tingstad, six and a half (English) miles up the river. In the year 1733 the herrings are said to have gone very far up the river Oder, in Germany.

25. It is quite probable that the quantity of *air contained in the sea-water* has some influence on the herrings; and several authors have referred to it. So far we have no direct observations of the influence which the greater or less quantity of air contained in the sea-water has on the herrings; but it is natural to suppose that coast-waters which have been well aërated by a strong sea-breeze attract a larger number

[44] It is scarcely in accordance with actual truth, as *Buckland* supposes, that the small herrings devour the refuse from the sewers of great cities, which is so frequently found near the mouths of English rivers. This refuse, doubtless, produces a large number of lower microscopical organisms, which either directly, or by serving as food for small crustaceans, &c., benefit the herrings.

[45] It must not be forgotten that in these places the herrings can easily be sold at a comparatively high price and are consequently more sought after.

of herrings, and that, therefore, after the breeze has gone down there will be good fishing in those waters.

26. Among the hydrological causes the *temperature of the water* doubtless, next to the currents of the sea, exercises the greatest influence on the herrings. There is good reason to suppose that the herrings prefer a certain even temperature of the water, and that they consequently avoid too warm or too cold water. This degree of temperature, however, differs greatly according to the different locations, fisheries, and races of herrings. The fishing for spawning herrings is, for example, on the east coast of Scotland going on at a season of the year when the temperature of the water is very high (from the middle of July till the middle of September), or very low (January to March). The observations of the Scotch and Dutch Meteorological Societies made during the Scotch and Dutch summer herring-fisheries have shown that the temperature of the water most favorable to these fisheries is about 13° C. (55.4° F.). During the Scotch winter-fisheries, however, the temperature of the water ranges from 4°.5 to 5°.5 C. (40.1° to 41.9° F.), and during the Norwegian spring herring-fisheries it only ranged from 3° to 4° C. (37.4° to 39.2° F.). But our observations are still so incomplete and relate so exclusively to the spawning-herrings, that it is impossible to say anything with absolute certainty excepting the fact that the herrings, when the temperature of the surface waters is either too high or too low, go to deeper waters. But as the changes in the temperature of the water are chiefly caused by the much better known and more fully-observed temperature of the air and by the currents of the sea, we refer the reader to what has been said above (13 and 22) regarding their influence on the herrings. It will be clear that the former has a more decided influence during summer and the latter during winter.

As has been mentioned above (18), the agitation produced in the water by strong wind is favorable to fishing, by mixing the upper and lower layers of the water and by thus equalizing its temperature.

The preference shown by the herrings for an even temperature of the water, has led to attempts to explain thereby the apparent irregularity in the occurrence of the herrings.

27. It is well known, from olden times, that the *formation of ice* on the sea has an influence on the herrings and the herring-fisheries, although we do not possess sufficient observations on this point to form any certain scientific opinion. From Professor *Edlund's* observations regarding the formation of ice in the sea, we know that the formation of bottom-ice will drive the herrings away. It is more than a mere supposition that the formation of bottom-ice not only drives the herrings away but also destroys their eggs and young ones, and on those coasts—for instance, of the Baltic—where ice is frequent in winter, the herrings do not spawn during that season. It is likewise well known that on the coast of Canada much floating ice keeps the herrings and other fish away from the coast. On the coast of Bohuslän, however, it has been observed

that the herrings occasionally go under the ice which has formed for some time,[46] and that there is good fishing when the ice has broken.

28. Regarding the influence of the *depth of the water* and the *pressure of the water* on the herrings we do not possess sufficient observations to form a definite scientific opinion. The scientific authors who have recently treated the biology of the herring have arrived at essentially different views regarding the question whether the herring must be considered as a fish specially fitted for a life near the bottom of the sea in the deep basins outside the coast, or whether its nature fits it better for a life near the banks in the open sea or comparatively nearer the surface. It is clear that the migrations of the herrings must in the latter case go on near the surface, whilst in the former case the herrings would, both in coming and going, seek deep waters.

The Dutch fishermen who use floating nets have observed that the herrings often change very suddenly from one depth to another, but it is not known whether these changes only extend to a few fathoms or to a greater depth; nor do we know whether these changes are made on account of the greater or less pressure of the water, though the last-mentioned hypothesis is certainly highly improbable.

A French naturalist, *Carbonnier*, has expressed the opinion that the herrings, like other fish, are, immediately after having done spawning, compelled to seek deeper waters to obtain the greater pressure "which has become necessary on account of their empty belly"; but although we certainly possess a number of observations all tending to show that the "empty" herrings go into deeper waters than the "full" herrings, we do not know enough on this point to justify us in embracing *Carbonnier's* opinion; for herrings have been known to come to the surface immediately after spawning, and data are not even wanting which go to show that "empty" herrings lived nearer the surface than "full" ones.

29. We must also take into consideration the influence exercised on the herrings by the *character of the bottom*, both as regards its formation and composition and its vegetation. Concerning its orography, we know, from observations made during the Scandinavian herring-fisheries, that the herrings, when approaching the coast, often follow the valleys of the bottom, probably because there they find calmer and more sheltered waters and a more even temperature, not excessively cold in winter nor very warm in summer. Thus the herrings seem, during the last great herring-fisheries, and even several times since, to have approached the southern coast of Bohuslän by way of the so-called "great furrow" or valley; and the depression of the bottom, which, from its northern end, extends towards the Marstrand fiord, has evidently something to do with the circumstance that the great fisheries generally commenced near the islands at the mouth of this fiord. Similar easily distinguished valleys

[46] This phenomenon might possibly be explained by the supposition that a layer of ice prevents the sea-water underneath from getting any colder, as the soil keeps warmer under a cover of snow.

running crosswise from the great valley direct towards the coast, which doubtless have exercised an influence on the herring-fisheries, are found on that part of the coast of Bohuslän lying south of Soten. On the northern coast it has also been observed that both the herrings and the small herrings follow the deep valley between the outer and inner coast.

Hans Ström and, recently, *G. O. Sars* in a more scientific form have mentioned that the current is always stronger near the edge of a bank rising from the depth of the sea, and that in such places there is always a greater abundance of fish-food and of fish. It is quite probable, therefore, that such banks have an influence on the migrations of the herrings, especially if we remember that all the great herring-fisheries are carried on near such banks, and that the North Sea chiefly owes its wealth of fish to such banks.

Inner coast-waters protected by islands, rocks, or rising ground from the violence of the sea, where the herrings can remain undisturbed for a great length of time (by which, however, they become almost worthless), likewise require our attention. All fishing for those herrings which have come for the purpose of seeking food is carried on in such waters, which, moreover, afford excellent shelter for the young herrings.

Regarding the geognostical character of the bottom, it is well known that the herrings when spawning like a hard and firm bottom, and avoid a muddy or clayey bottom, or a sand-bottom whose upper layer is easily stirred up by the waves. It is also well known that the herrings when spawning prefer a bottom covered with plants.

30. We must not overlook the importance of the *geographical location* of a coast in influencing the herrings, although this influence has certainly been overrated by older authors. In this connection we have to consider the greater or less distance of a coast from the poles, its location on the eastern or western side of a continent, and its greater or less distance from the open sea. The herrings do not extend their migrations, in any considerable number, at least, farther south than those regions where the fauna has a decidedly boreal character, or farther north than that point where the sea is filled with polar ice. The location of a coast on the eastern or western side of the Atlantic Ocean is highly important; and herrings are found in great numbers on the west coast of Europe in degrees of latitude (for example, in Nordland and Finmarken) in which on the east coast of America (as in Greenland) they are comparatively scarce. The nearness of the Polar Sea, with its enormous wealth of "herring-food," does not only increase the number, size, and the quality of the herrings, but also influences their selection of spawning-places. Sometimes, however, as is the case in Northeastern America, the Polar Sea may prove hurtful in its influence by large masses of floating ice preventing the herrings from coming near the coast. The greater or less distance of coast-waters from the open sea is of great importance, for experience has shown that waters, such as the Baltic, which are far

from the ocean, are never visited by any of the great schools of herrings, and, therefore, offer no opportunity for any really "great" herring-fisheries. To this circumstance Bohuslän doubtless owes, to some degree at least, the comparatively short duration of its fishery periods, and the long intervals between these periods. In addition to this, it must not be forgotten that the coast of Bohuslän is not near as much laved by northern waters containing much "herring-food" as the coasts of the North Sea.

31. Regarding the influence on the herring of *biological* causes, it will be clear that, in one respect at least, viz, the satisfying of the herrings' demand for food, they exercise a very decided influence, and also that they entirely depend on climatical, hydrological, orographical, and geognostical conditions. From the foregoing it will be clear that the "herring-food," both by its quantity and by the depth in which it is found, will have an influence not only on the herrings but also on the herring-fisheries. Although the herrings certainly do not take any food whilst spawning, the occurrence of "herring-food" has, nevertheless, also an influence on the spawning herrings' course near the coast; since they still need a little food, and all the more, the longer before the commencement of the spawning-season, they come near the coast. It is self-evident that the quantity of "herring-food" in certain coast-waters will determine the size of the herrings living in these waters; and even the greater schools of herrings living in the open sea seem to a great extent to be dependent—at least as far as their young ones are concerned—on the quantity of food found near the spawning-places. As the quantity and occurrence of "herring-food" are dependent partly on the above-mentioned physical conditions and partly on the quantity of food and of organic matter necessary for its formation,[47] it will easily be understood how important it will be to obtain an accurate scientific knowledge on this subject, based on the horizontal and vertical distribution of the "herring-food," with a special view to its dependence on physical conditions; and as the acquiring of such a knowledge involves much trouble and time, very little has so far been done in this direction, so that our knowledge

[47] See: *K. Mœbius, Das Thierleben am Boden der Deutschen Ost- und Nordsee*, Berlin, 1871, p. 9, and: *Die Auster und die Austern wirthschaft*, Berlin, 1877, p. 83, in which last-mentioned place he says: "Every cenobitic region possesses in every period of generation the highest degree of life which it is capable of forming and sustaining. All the organic matter contained in such a region is, therefore, completely absorbed by the beings produced there. It is probable, therefore, that in no part of the earth capable of producing life any organic matter is left for spontaneous generation." But is it not possible that exceptional conditions in one place may destroy a species which, also, without limiting the other species belonging to this cenobitic region, could exist there? And might there not be places where a species might flourish and live in large numbers, no matter whether it was formed there or brought there from other places, but where, owing to the want of the conditions necessary for utilizing the organic matter found there, such matter is stored up for the future? And does not geology furnish many similar instances? And do not the Polar regions owe their extraordinary wealth of organic matter to some such process of storing up during milder climatic conditions?

is consequently somewhat incomplete.[48] It will, therefore, scarcely be necessary in this place to adduce further proof of the necessity of soon acquiring such knowledge, which, in the future, will be of great practical use.

The "herring-food," which is chiefly composed of small crustaceans, depends, as to its occurrence and numbers, on lower and smaller organisms, through which it indirectly absorbs all the organizable matter in its neighborhood. Without an exact knowledge of these organisms and the conditions under which they are found we shall never attain to a correct view of the causes producing the "herring-food" and the herrings. It has long since been known that among these microscopic lower organisms, diatoms occupy a prominent place. On the coast of Bohuslän, especially near Fjellbacka, the fishermen have observed that the tender young herrings generally stay among the greenish "slime," which is chiefly found where fresh-water courses empty into the sea; and as they had not observed the spawning of the herrings they drew from this the remarkable conclusion that the young herrings originated from this "slime," chiefly consisting of diatoms. The more frequent occurrence of diatoms in the mouths of rivers is probably also one of the causes of attraction which draws especially the young herrings thither. In the Christiania fiord Prof. *G. O. Sars* has observed a similar organic "slime," consisting chiefly of diatoms, in great quantities, early in spring or immediately after the breaking of the ice; and in the open Skagerack I, myself, whilst examining the so-called "Koster Grounds" during the summer of 1871, found large numbers of diatoms in the current going along the outer coast of Bohuslän.[49] In the Polar seas *Scoresby* has already observed large numbers of diatoms, and his observations have been corroborated by the Swedish Arctic expeditions. The cenobitical and practical importance of the diatoms, as well as their development from a "formless organic slime" ("free indefinite protoplasm," "formless indefinite organic matter") has recently been discussed by Prof. *Youle Hind* and Prof. *G. O. Sars*. As this "sea-slime" chiefly occurs in the Polar seas, especially where there is Polar ice, and is by the currents driven farther south, Professor *Sars* very beautifully remarks that "in the inhospitable Polar Sea, filled with ice, we find the last causes of the inexhaustible wealth of the more temperate seas." The influence of the Polar regions and the Polar ice on the herring-fisheries

[48] Prof. *K. Moebius*, of Kiel, a member of the commission appointed to investigate the German seas, says very truly: "We are still woefully ignorant regarding the physical conditions of a cenobitic region and their relation to the plants and animals of such a region, as also regarding the mutual influence of the plants and animals existing there at one and the same time. So far we know but very little regarding the cenobitic life of the different and distant regions of land and water."—*Zeitschrift für wissenschaftliche Zoologie, XXX.* Supplement, p. 376.

[49] As even at that time I was convinced of the importance to the fisheries of these microscopic organisms, I have repeatedly pointed to the necessity of making them an object of special scientific investigations.

has thus again been brought into prominence, but in a different form and free from all those fanciful ideas which are characteristic of the last century.

32. Among the biological conditions which exercise a great influence on the herrings we must mention the *persecutions of their enemies.*

From the observations of the fishermen it is well known that fish-of-prey, especially the codfish, can, by sudden and determined attacks, scatter whole schools of herrings; and on the west coast of Norway the small schools which either go by the side of the larger ones or follow them are supposed to be chased by codfish.

Whales and seals seem not to have such an influence on the schools of herrings, and the first mentioned owe it chiefly to their colossal size that they are reported as capable of driving the herrings wherever they please. Even in the old Norwegian laws it was forbidden to kill whales which drove herrings towards the coast during the herring fisheries, and even at much later times various authors have spoken of the whales "as commissioned by Providence to lead or rather drive the herrings to those coasts for which our Lord had destined this blessing"; and have also considered it as a special providence "that the whales and fish-of-prey again cause the herrings to fly to their proper home, the eternal ice of the Polar seas, whither their enemies could not follow them and disturb them in the peaceful enjoyment of their rest." Even in our days the Norwegian fishermen not unfrequently ascribe the failure of the fisheries to the circumstance that the herrings have not been properly chased by the whales and fish-of-prey. That the whales and fish-of-prey follow the herrings instead of leading them, for the sole purpose of devouring them, has long since been proved by *Martin*, *Jessen*, *Bloch*, *Nilsson*, and others. It is quite probable, however, that the whales and fish-of-prey cause the herrings to keep closer together.

As regards the other larger enemies of the herrings, we know of none which can exercise the slightest influence on their migrations; but they may, as is especially the case with birds, indicate the place where herrings are, and thus be of great importance to the fishermen.

Among the enemies of the herring we must undoubtedly also count *man*. But man's influence on the mode of life and the migrations of the herring is very insignificant in comparison with the above-mentioned larger animals and fish-of-prey. The chief means by which man persecutes the herrings is the different fishing-apparatus, among which only the net influences the course of the herrings to any degree.

The herrings keep somewhat shy of the nets, and this is the reason why darkness, turbid water, or a surface agitated by the wind is most profitable for net-fishing. When the water is turbid, fishing with floating nets may occasionally be successful even by day time. If the water is too much agitated, fishing with floating nets will generally be unsuccessful. When the herring keep near the surface of the water, but seem unwilling to enter the floating net, they may occasionally be driven into

it by making a noise. Fishing with stationary nets is of course somewhat different, because such nets are always set in such a manner that the herrings must strike them in moving from one place to the other.

When a school of herrings during their migration strike a net they are not thereby hindered in their progress, but they go either above or below it, and after having passed it again pursue their course at their usual depth. This makes it possible by placing several nets in a row to catch the whole school. It is generally thought, however, that by placing the nets too close together the herrings are hindered from entering the fiords.

During the spawning-season the herrings are not afraid of the net, even in broad daylight, but rush blindly towards it, seemingly with the intention of squeezing themselves into its meshes, and this in such a furious style that they frequently push down the net entirely. Fishing by day-time with stationary nets or with drag-nets held by anchors may generally be carried on only during the spawning-season or when the water is very turbid. This proves that the herrings are much less afraid of their enemies when animated by the propagating desire than when merely seeking their food. *Kröyer* says very truly with regard to those annual visits which the herrings pay to the coast for the purpose of spawning: "If we consider how little the herrings are disturbed in their course, and how calmly they allow themselves to be caught or devoured by other fish, we must become convinced that fear does not put them to flight and that noise does not scare them, but that their instinct guides them on the way they must follow."

Farther on I shall have occasion to speak of the influence which the enemies of the herrings exercise on their periodical visits (55, 56, 60.)

33. The different outward *conditions of nature* must, however, as regards their influence on the herrings, be considered not only separately, but combined and connectedly. But as different effects spring from the same cause, owing to difference of the seasons, different local circumstances or different objects of the herrings' visits to the coast, and as fishing with different apparatus produces very different results, it will be necessary, in comparing observations from different places and times and from different kinds of fisheries, first to combine those that are more closely connected, so as to obtain an exact knowledge of every kind of fishery during every season of the year, before one can draw general conclusions. Both in collecting and arranging the observations too little regard has in general been paid to the above-mentioned points, or to the mutual relations of the various meteorological, hydrological, orographical, and geognostical data and their relation to biological facts. This has also made it very difficult for me to give a complete review of the observations and opinions of myself and others.

Thus, for example, the physical investigations of the herring-fisheries made by the Dutch and Scotch Meteorological Societies have been made with too exclusively a practical object, and thus only furnished informa-

tion regarding the conditions of the weather under which the herrings make their appearance in a manner favorable to the floating-net fisheries, whilst they leave us entirely in the dark with regard to many other interesting points.

The great majority of all the observations we possess relate to fishing during the spawning-season; and it is well known that these fisheries are both richer and more certain than those carried on at other seasons, and have therefore generally been considered more important. The catching of those herrings which have come to the coast to seek food has only recently become more important; and we therefore do not as yet possess a sufficient number of observations on these fisheries, which is to be deplored, as the herrings when seeking food are much more dependent on outward natural conditions than when they are spawning.

The physical conditions prevailing in certain waters (among them principally the differences of saltness and climate as being dependent on the weather and the currents of the sea), the geographical location and the orographical and petrographical character of the bottom, will of course exercise a great influence on all the organic beings found in these waters, or, in other words, on their whole cenobitic life; it will be clear therefore that only a complete knowledge of all these conditions, both in the present and in former times, will satisfactorily explain all the phenomena presented by the races of herrings belonging to these waters, such as the different spawning-seasons, the varying degree of fatness, flavor, &c., as well as the more or less regular periodical changes in the migrations of the herrings. Unfortunately our knowledge of all these matters is so far very limited; we thus neither possess very exact knowledge regarding the influence of the weather on hydrological conditions, nor regarding the influence of these last-mentioned conditions on the different biological conditions. Such knowledge, in order to answer its purpose, should not be confined to one locality, but should extend to a large number of fishing-stations, which would enable us to gain more general and satisfactory opinions regarding the combined influence of physical and biological causes on the herrings and their migrations and consequently on the herring-fisheries.

In order to obtain such knowledge it will be necessary to have access not only to good orographical and petrographical maps, as well as to synoptic weather statistics, but also to synoptic tables of hydrological and biological observations.

34. After having considered as fully as my limited time would allow, the influence of physical and biological causes on the herrings and the herring-fisheries, I will go over to a more direct representation of the migrations of the herrings, referring, of course, to all the foregoing observations and opinions.

In order to reach a sufficiently distinct terminology and a more complete knowledge of the whole subject, it will be necessary by way of introduction to give a brief systematized review of fish as to their place of

sojourn.[50] The place where fish are found may be considered by itself, or as a basis for dividing the fish into different groups. With regard to the former we can distinguish between the uninterrupted and a more or less accidental or periodical, that is, occasionally interrupted occurrence of fish. The periods may be daily, yearly, or extend to a longer space of time. With regard to the second point, the fish may be divided in the different groups mentioned below, using as a basis either the character of the water where the fish are found, on the geographical location, or the degree of regularity with which fish make their appearance, the extent of time and space of their periodical appearance, and the greater or less stability as to their place of sojourn. It will be clear, however, that these groups cannot always be distinctly defined, but that the lines of demarcation are often somewhat vague, especially between the subdivisions coming under one and the same head.

A.—WITH REGARD TO THE CHARACTER OF THE WATER, FISH MAY BE DIVIDED

1. *as to the saltness of the water*, into
   a. fresh-water fish, and
   b. salt-water fish (or sea-fish).

   Between these two groups there is, however, a sort of neutral territory, some kinds of fish living in either water. There are also some "sea-fish" which ascend the rivers for the purpose of spawning, their young ones returning to the sea (so-called "*anadroms*") in order to grow to maturity, or in order to satisfy their craving for food, in which case the fish which have grown to maturity in fresh water go into the sea for the purpose of spawning (so-called "*katadroms*").

2. *as to its degree of agitation* (flowing or stagnant water), into
   a. river or brook fish, and
   b. sea or lake fish.

   Among the lake-fish there are likewise some which occasionally go up into the rivers.

B.—WITH REGARD TO THE GEOGRAPHICAL LOCATION, FISH MAY BE DIVIDED

1. *with regard to their horizontal distribution*, into
   a. littoral or coast fish,[51] that is, fish which always stay near the coast,
   b. pelagian or sea fish, that is, fish which always, or at least the greater portion of the year, live in the open sea.

[50] An entirely different subject, foreign to my present investigation, is the question of the general geographical distribution of fish over the globe, and their geological distribution throughout the ages.

[51] *J. R. Lorenz, Physikalische Verhältnisse und Vertheilung der Organismen im Quarnerischen Golfe.* Vienna, 1863, p. 332.

2. *with regard to their vertical distribution*, into

a. bottom-fish, that is, fish which always, or the greater part of the year, live near the bottom. With regard to the character of the bottom, we can again distinguish among these *fish which live on clayey* bottoms, and *fish which live on rocky or stony* bottoms, on *banks* or on the slopes extending from the coast to the great deep,[52] and

b. surface-fish, that is, fish which generally live near the surface of the water.

C.—WITH REGARD TO THE DEGREE OF REGULARITY WITH WHICH FISH MAKE THEIR APPEARANCE, AND THE EXTENT OF TIME AND SPACE OF THEIR PERIODICAL APPEARANCE, FISH MAY BE DIVIDED, INTO

1. *stationary fish, which live always in the same locality.*
2. *migratory fish, fish which only periodically appear in a place with a certain degree of regularity.*[53]

These migratory fish may be subdivided

a. with regard to the direction of the migration or its local object into
- *α.* fish moving chiefly in a horizontal direction and seeking other waters. These are therefore principally found among the coast-fish,
- *β.* fish moving chiefly in a vertical direction and seeking deeper or shallower waters,
- *γ.* fish moving both in a horizontal and vertical direction seeking not only a different depth but entirely different waters.

b. with regard to the local object of the migration within a certain given region, into
- *α.* fish which limit their migrations to this region, and
- *β.* fish which occasionally extend their migrations farther.

c. with regard to the chief object of the periodical migration, into
- *α.* fish seeking spawning-places, that is, fish which leave their accustomed dwelling-places principally for the purpose of spawning, and
- *β.* fish seeking food,[54] that is, fish which migrate chiefly to seek food, and which, therefore, are less regular, both as to the length and course of their migrations, because the occurrence of food depends on changeable physical conditions. For this reason those fish which visit certain localities for the special purpose of seeking food are occasionally classed in one group with the other migratory fish under the general name of "roving fish"

[52] This would be the place to draw attention to the division proposed by *Lorenz* (in the above-mentioned place) of the littoral fish into "stationary bottom-fish" and "roving bottom-fish."

[53] It is evidently nothing but gross ignorance which has caused a few of our writers on the fishery-question to use the term "wandering fish" (from the German) instead of the old Swedish term "*flytt fish.*"

[54] The term is taken "*a parte potiori*," which is assuredly the desire for food, which is doubtless stronger than a desire for rest and quiet well-being.

(*strykfiskar*[55]). They may, under the influence of less common physical conditions occasionally appear in places where they are not found otherwise, and where they must therefore be considered as accidental visitors.

d. with regard to the season when these migrations take place, into "winter-fish" and "summer-fish," &c.

e. with regard to the number of periodical visits paid to a coast during the year, into fish which come *once* a year and fish which come *several* times a year.

f. with regard to the steadiness of the visits to a certain locality, into

α. resident fish, and

β. periodical fish.

3. *Erratic fish, that is, pelagian fish which roam about irregularly and only visit a coast accidentally.*[56]

D.—WITH REGARD TO THE GREATER OR LESS STABILITY IN THEIR PLACE OF SOJOURN, the fish may finally be divided into

1. *fish which, on account of the torpor of winter or summer, by sucking themselves fast to objects resting at the bottom or floating about in the water, or from other causes, are generally in a state of rest.*

2. *fish which are more or less in motion, which, with many, assumes the character of a* REGULAR DAILY MOTION. (*Even those fish which generally are in a state of rest may occasionally be classed in this group.*)

35. After giving the above outline of the way in which fish may be divided into different groups, we must ascertain what position the herring holds with regard to these different divisions and subdivisions.

The herring is most decidedly a *salt-water fish*, although it certainly also occurs occasionally in water whose saltness is very limited, for instance, in the northern portion of the Gulf of Bothnia; and for short periods, whilst spawning or seeking food, it will also enter bays and mouths of rivers whose waters contain very little salt.

36. The herring is both a *littoral* and a *pelagian* fish. When young it generally stays near the coast, but begins comparatively early to follow the currents of the sea and go some distance from the coast. As a general rule, however, the herring is more of a littoral fish when young, and a pelagian fish when older. Very small shoals of herrings may sometimes be altogether littoral, the individuals composing them, as far as known, scarcely ever going any distance from the coast. The larger shoals, however, generally spend the greater part of the year out in the open sea, and the great schools are altogether pelagian in their character, visiting the coast only during comparatively short periods of the year.[57]

[55] *S. Nilsson, Förnyad underdånig berättelse om fiskeriarne i Bohuslän.* Stockholm, 1828, p. 15. *Handlingar rörande sillfisket i bohuslänska Skärgården.* Stockholm, 1843, p. 37.

[56] *S. Berthelot, Oiseaux voyageurs et poissons de passage.* II. Paris, 1878, pp. 99 and 125.

[57] Instances are not wanting, however, when such pelagian herrings have, under peculiar circumstances, remained near the coast for a longer time.

It has even been supposed that some schools of herrings spawn on the banks far out in the open sea, without ever approaching the coast for that purpose.

Those herrings which remain stationary near a coast, or which only go a very short distance from it, will best be called "coast-herrings," to distinguish them from the more pelagian or "sea herrings." This difference, although only a relative one, is certainly one which has a considerable influence on the fisheries.

With regard to the place of sojourn and its influence on the character of the herring, a number of different opinions have been advanced in course of time. It is well known from the herring-fisheries in the western part of the North Sea, and especially from the Dutch fisheries, that the herrings, both before and after spawning, are found in large numbers at a considerable distance from the land; and that the herring-fisheries on the eastern and southern coasts of Great Britain proved successful at certain regular intervals; the supposition therefore seemed highly probable that it was the same school of herrings touching the English coasts on their southward journey, and people seemed naturally inclined to ascribe to the herring a decidedly pelagian character, and from these originally popular opinions *Anderson*, and, later, *Gilpin*, developed their strange theories of the migrations of the herring. On the western coast of Scandinavia people had certainly not been in a position, like those on the eastern coast of Great Britain, to base their views on the course of the floating-net fisheries; but the opinion had gradually gained ground (probably through observations made by seamen and fishermen) that the herrings during the time they were not near the coast lived out in the open sea in a northwesterly direction from the region which they used to visit for the purpose of spawning. Gradually, however, *Anderson's* migration theory gained adherence here and there among the educated classes. Thereupon this theory was gradually opposed by *Bloch*, *Lacépède*, *MacCulloch*, and *Nilsson*, the last-mentioned one specially endeavoring to prove the entirely littoral character of the herring, an opinion which, though strongly opposed by fishermen, gradually gained numerous adherents among the naturalists, but which nevertheless is only correct in part, only being applicable to comparatively small schools of herrings. In opposition to this too one-sided opinion of Professor *Nilsson*, *Axel Boeck* has maintained the old distinction made by the fishermen from time immemorial between "sea-herrings" and "coast-herrings," but has not gone so far as to ascribe to the former a thoroughly pelagian character. This has been done, however, on truly scientific grounds by Prof. *G. O. Sars;* and, finally, *G. Winther* and myself have more in detail developed the views which have here been presented regarding the chief place of sojourn of the herrings.

37. The opinion that the herring is a *surface-fish* has only recently begun to gain ground in scientific circles, although, strange to say, it had for a long time been quite prevalent among the fishermen. Herring-

fishing has principally, and in olden times exclusively, been carried on with apparatus that could only be lowered to a comparatively insignificant depth both in the open sea and near the coast; and as these fisheries were going on at different seasons of the year, and as herrings were occasionally seen by seamen, it will be easily understood that the herring was first considered as a surface-fish, none of the older writers on the herring-question having apparently entertained any other opinion. It was *Anderson*, always inclined to the wonderful, who first pronounced another opinion, viz, that the proper home of the herring was the "bottomless deep," under the polar ice, where sharks and codfish could not breathe and disturb the herring in its "proud repose." Although *Anderson's* theory had many adherents, and for nearly a century enjoyed almost universal popularity among naturalists, but little attention seems to have been paid to the question whether the herring was a bottom-fish or not. *Nilsson*, however, pronounces a more distinct opinion on this subject. He supposed that the herring was, properly speaking, a deep-water fish, which, in his opinion, was proved by the fact that herrings are found in the stomachs of codfish, but he most emphatically opposes *Anderson's* view that the herring could only live in very deep water.[58] This view has since then been embraced and further developed by *Axel Boeck*, who, however, went much further than Professor *Nilsson*, and thus, for example, placed the proper home of the Norwegian so-called "spring herring" at the bottom of the deep valley which extends along the coast of Norway; and in proof of his assertion, has mentioned the fact that in the stomach of herrings caught immediately on their arrival remnants of small crustaceans had been found which only live at a very great depth. A different opinion, however, was soon after advanced by Prof. *G. O. Sars*, who at first considered the herring as a "bank-fish," like the codfish,[59] but later as a surface-fish, like *G. C. Cederström*, who, though inclining to the opinion that the herring, like the eel, sometimes concealed itself on the bottom, nevertheless raised some well-founded objections to *Axel Boeck's* assertion, and his mode of proving it.[60] The proofs which have been brought forward in support of the theory that the herring was specially formed for a life at the bottom of the great deep, have been thoroughly refuted by the two above-mentioned authors, and are in no wise re-established by the direct observations made on the west coast of Norway, through which we know that the spawn of herrings, though seldom, is still found as deep as 60 to 100 fathoms, and that herrings are occasionally caught with stationary nets at a depth of 50 to 60 fathoms.

[58] *Nilsson*, strange to say, mentions the unusual pressure of the water, to prove the unreasonableness of *Anderson's* opinion.

[59] Quite recently this opinion has been modified by saying that the herring, although a "surface-fish," nevertheless showed a decided preference for the banks where the codfish live, on account of the stronger current generally found there.

[60] Even *Cederström* mentions the strong pressure of the water, "exercising a hurtful influence on the gills," as the principal cause why the herrings did not go into deeper waters.

From what has hitherto been known, it will be evident that the herrings can certainly go as deep as 100 fathoms, but that they must nevertheless be considered as "surface-fish," which, according to accidental physical causes, change the comparatively short distance from the surface at which they generally live. The circumstance that the herrings, when near the coast, often go into deeper water, might possibly be ascribed to the milder winter temperature and to the cooler summer temperature, as well as to the greater calm and shelter which the deep waters doubtless offer. Whilst spawning, the herrings must, of course, go towards the bottom.

38. Although there may be very small schools of coast-herrings, composed of stationary fish, the herring must, in a general way, be considered as an entirely *migratory fish.*

From the fact that the herring is a surface-fish, it almost necessarily follows that the migrations of the herring generally go in a *horizontal* direction, an opinion, however, which science has only reached quite recently; for, according to *Anderson*, *Nilsson*, *Axel Boeck*, and several other naturalists, the migrations of the herring go in a vertical direction, having for their object a different depth of water with varying pressure and temperature.

With regard to a certain region, the migrations of the herring may be specially directed towards this region, or they may only pass through it, in which latter case the herring would only be a *fish-of-passage* as far as that region is concerned.

The herrings which visit a coast are, with regard to the object of this visit, either herrings which seek a spawning-place or herrings which seek food, in which latter case their coming and going is less regular and more dependent on physical conditions.[61]

With regard to the season when the herrings visit the coast, they are divided into winter-herring, spring-herring, summer-herring, or autumn-herring.

The sea-herrings generally visit the coast only once a year, but sometimes also twice.

With regard to the steadiness of the herrings' visits to a certain coast the herrings must be considered *regular* migratory fish, as far at least as the extent of coast is not too much limited, and not too much regard is paid to the irregularities of those herrings which come in search of food; but the very large schools of sea-herrings may also, as will be shown below, be considered as *periodical* visitors to the coast—such periods extending over eighty to one hundred years.

39. With the exception of those parts of the day when the herring is

[61] This circumstance has given rise to the often quoted and misunderstood saying of *MacCulloch* that the herring is "an apparently most capricious fish." (Quarterly Journal of Science, Literature, and the Arts, XVI, No. XXXII, London, 1824, p. 214.) Most of the instances of the capriciousness of the herrings seem to have been taken from the herring-fisheries on the western coast of Scotland, which have for their object only herrings which have come in search of food.

supposed to be asleep it is in constant motion, and its *daily course*, especially whilst near the coast, is entirely regular.

It is well known now that the herrings generally keep quiet during the middle of the day and the middle of the night, but are in motion mornings and evenings, and that they go into deeper waters by day-time and near the surface by night. The herrings are, therefore, undoubtedly influenced by the changes of light, especially when the rays of light strike the water in a very oblique direction at the rising and setting of the sun or moon, which seems to waken the herrings to new life and cause them to seek those depths which are best for fishing. The principal changes in the daily course of the herrings are doubtless caused by the varying occurrence of the "herring-food" and by the herrings' desire to find shelter from their enemies.

It is also well known that the herrings go near the coast towards sunset and return to the deep about sunrise. According to *Axel Boeck* the Norwegian spring-herrings during the spawning-season go to the spawning-places at nightfall and leave them in the morning, but towards the close of the spawning-season they also come to the coast during the day, so that the fishermen generally consider rich day-fisheries as an indication that the fisheries are approaching their close, a prediction which, however, is not always fulfilled. *G. C. Cederström* says that in the Baltic the autumn-herrings often go into the deep at night, and come nearer the coast towards morning, but that the reverse may also occasionally be the case.

40. Regarding the *annual migrations* of the herrings to and from the coast, a number of different opinions have been advanced in course of time. Some of these I have briefly hinted at when speaking of the character of the herring as a littoral or pelagian fish (36).

Older writers, and the fishermen themselves, seem not to have entertained any other opinion than that the herrings coming from the ocean approached the coast at certain times of the year, generally in a direction from north to south. The idea that the proper home of the herrings might be the Polar Sea, near the North Pole, never entered the mind of the older writers on the fishery-question, who knew that the herring-whales keep farther south than the great whales of the ice-filled Polar Sea; that these last-mentioned whales lived on entirely different food than herrings, and that no herrings had been seen near Spitzbergen, or, as a general rule, farther north than the North Cape in Finmarken. The herring-fishermen, with their limited geographical knowledge, were scarcely able to form or entertain a Polar-migration theory.

The herring-fisheries on the coasts of Shetland, Scotland, and England gradually go farther south in proportion as the spawning-season comes later during the year. The English at the spawning-time generally fished near the coast, and the Dutch had their principal herring-fisheries only in the North Sea. Their knowledge of the herring was consequently limited and led them to suppose that it was one and the same great school of

herrings which coming from the north went all round Great Britain and thus produced the different fisheries. This opinion soon became a generally-received axiom, and is as such given in the older works on the herring-question (for example, the works of *Camden*, *Schoock*, and *Ionston*).

This was the origin of the great migration-theory which was by later authors advanced in the *Atlas maritimus et commercialis* published in London in 1728,[62] according to which the herrings were supposed—from want of room and food—to come from the north in such enormous masses that in passing between Greenland and the North Cape (which large space of sea was for them only a narrow sound), they had to keep very close together in order to pass. It was also supposed that after having passed this sea the herrings divided into two schools, the one (again divided in two smaller schools by Ireland) going west and the other east of Great Britain, not to be seen again after they had reached its southern coast. According to this opinion the herrings were supposed to propagate not only near the North Pole but also near the coasts of Great Britain.

Fascinated by these bold conjectures *Johan Anderson*, always inclined towards fantastic opinions, determined to work them up in detail; and he did not forget the Scandinavian countries with their separate divisions of the great school of herrings, which, as he supposed, did not only have their proper home in the "bottomless deep" under the Polar ice, but also sheltered from the persecutions of men and fish-of-prey, increased to such an extent that an enormous number of herrings was forced every year to leave their home and visit those coasts which Providence intended to bless in a special manner. It will not be necessary to dwell any longer on this strange and fanciful theory, especially as nearly every one who has written on the migrations of the herrings has devoted far more time to it than it deserves, even to the exclusion of really important scientific questions. This theory, worthy of *Münchausen*, may serve, however, as an example of the credulity and the total want of critical discernment prevailing not only among the great mass of the people, but also among naturalists, some of whom give this opinion in their works as if it were a scientific truth.

But as another fish—popularly called "herring," and by many considered identical with the herring proper—comes to the eastern coast of North America from the south, it became necessary to modify the migration-theory with regard to America. And this was done by *John Gilpin*, who let the herrings follow the declination of the sun and annually wander in an elliptic course between the Polar circle and the Tropic of Cancer all round the northern part of the Atlantic Ocean, thus constantly avoiding both excessive heat and excessive cold. It will not be necessary, either, to give much time to this fantastic theory, which,

[62] *Dott* according to *M. E. Bloch, Oeconomische Naturgeschichte der Fische Deutschlands*, I, Berlin, 1782, p. 188, a statement which, however, seems to be doubtful.

although it has never become general, has been fully described in the well-known works of *Kröyer* and *Axel Boeck*.

Anderson's migration-theory, which finds adherents to this very day, has, in course of time, undergone various changes. Thus some suppose that the herrings go into southern waters for the sake of propagating, and then return with their young to the Polar Sea, which offers an abundance of food (*Pennant* and others), because the herrings were seen to come near the coast full of roe or milt and leave it empty; and because *Anderson's* explanation of this fact seemed insufficient, one began to think of analogous facts in the life of birds and other migratory animals, or was forced to the opinion that there were inconsiderable changes in the herrings' visits to the coast in the direction of their journey, &c.

41. *Anderson's* migration-theory was subjected to a thorough and annihilating criticism by the distinguished ichthyologist *Bloch*, whose opinion has been shared by *Noël de la Morinière*, *Lacépède*, and *Quensel*. With more originality *MacCulloch* has also followed *Bloch's* opinion, and has directed attention to the impossibility of making *Anderson's* theory agree with the evident irregularities in the course of the herrings. Some years before *MacCulloch*, *Couch* had opposed the migration-theory and had described the character of the herring as a "local fish" on the coast of Cornwall. *S. Nilsson* has with great emphasis pronounced himself in opposition to the theory of a central school of herrings near the Pole, and has specially mentioned the physical impossibility of the young herrings developing in the great deep of the Polar Sea; he has also opposed the opinion that every coast should have its special race of herrings distinguished by outward marks and a separate spawning-season, being, consequently, more local and littoral in its character.[63] Professor *Nilsson*, therefore, not only opposed the theory of a central race of herrings near the North Pole, but of such a central race altogether. The dispute caused by Professor *Nilsson's* writings on the regulation of the Bohuslän herring-fisheries caused the Rev. *O. Lundbeck*, pastor of the church at Klädesholmen, to advance the theory of a central race of herrings probably living in the North Sea, to which we owed the great herring-fisheries, and from which, in course of time, the smaller races of coast-herrings had separated, a theory which might possibly be harmonized with the views advanced in *Bloch's* criticism of *Anderson's* theories,[64] but which is in direct opposition to the facts and opinions given by Professor *Nilsson*. *Lundbeck's* hypothesis found no adherents, and seems to

[63] Professor *Nilsson* went so far in his zeal to give to every coast its special local race of herrings, as to entirely deny the possibility of two or more different races occurring "on one and the same coast and under exactly the same natural conditions." This one-sided and doubtless erroneous opinion has recently found an adherent in Prof. *G. O. Sars*.

[64] *Bloch* believes that the time of spawning depends on age and temperature, and from this opinion it may easily be deduced that the herrings which spawn in the North Sea during autumn, and which are actually somewhat smaller than the common herrings, are only the young of the Norwegian spring-herrings.

have been entirely consigned to oblivion. *MacCulloch's* opinion, however, has met with great and universal favor, and has been shared by *Yarrel*, *Parnell*, and others, whilst Professor *Nilsson's* opinion is held by *C. S. Sunderall*, *Ekström*, *Valenciennes*, *Mitchell*, *Berthelot*, and others.

Recent theories regarding the annual migrations and coast-visits of the herrings chiefly differ from each other in this, that the migration is thought to extend over a greater or less territory, just in proportion as the herring is considered a more littoral or more pelagian fish, and in ascribing various natural instincts as the causes of these migrations.

42. We must finally mention the theory advanced in explanation of the fisheries of new herrings on the western coast of Norway, that the herrings do not, as is generally supposed, spawn every year, but only every other year.[65] This theory was in the beginning only used in explanation of the exceptional occurrence of a small number of so-called "herrings-of-passage," but was more generally applied when people began to take into consideration the unusual and frequent occurrence of so-called "new herrings" or "winter herrings." If this theory is correct, the same herrings would, as a general rule, visit the same coast only every other year for the purpose of spawning, and the annual fisheries of spawning-herrings must, therefore, principally be caused by herrings which alternate in their years of spawning. The frequent visits which herrings pay to the coast between the spawning of every other year, but during the spawning-season, must, therefore, be considered as exceptions occurring at the end (or the beginning) of a period of fisheries (for spawners). After having spawned the spring-herrings would not occur among the summer-herrings during the following summer and grow fat, which, as we know, takes place quick enough, but would remain lean for more than a year. Still less is there any cause why the so-called "new herrings" should appear so seldom during the fishing-season and so frequently after its close. This theory* may be convenient for explaining the above-mentioned phenomena, but it cannot be fully accepted unless it can be harmonized with other phenomena, which are the principal ones to demand an explanation.[66] The investigation of the subject only becomes more complicated through such theories, whose value is, therefore, very doubtful.

43. It has been mentioned before (22) that the young herrings begin to wander about at an early age, chiefly to seek food or shelter from their enemies, or possibly more agreeable places of sojourn. It has frequently

[65] Although it is generally supposed that herrings can spawn several times in succession, we have no positive proof of this, and this question seems actually never to have been examined scientifically.

* The theory mentioned in the beginning of 42.—Translator's note.

[66] I do not mean to imply by this that every herring capable of propagating the species must spawn every year, but merely that when possessed of full health and strength every herring will generally do it. It must, moreover, be remembered that the individual fish composing one and the same school do not all become capable of propagating the species at the same age.

been observed that the young herrings, as they grow up, leave the shallow waters near the coast and go into deeper waters farther out towards the ocean, whence, after a while, they return to the coast in company with the older herrings. The knowledge of the details of these migrations is, like our knowledge of their physical and biological causes, so limited that very little can be said regarding them.

Regarding the coming of the herrings from the sea to the coast we only know that during the spawning-season they generally approach the spawning-places in dense schools, coming from the north, and that when visiting the coast for other purposes the schools are smaller and more scattered, extending over a larger stretch of coast, and come both from the north and the south. Those herrings which come to seek food generally remain for some time in the outer waters before they come near the coast, and their visits are neither as regular nor as long as when they come to spawn. But even the great mass of herrings does, during the spawning-season, not remain near the coast longer than one or two months, exceptions from this rule being very rare indeed. Herrings which have thus remained near the coast over their regular time become almost entirely worthless. During the last great Bohuslän herring-fisheries this seems to have occurred more frequently.

In approaching the coast the herrings generally begin at a certain point, spreading from it either to the left or right or in both directions, influenced in this by the weather, the currents of the sea, and the nature of the bottom. The herrings do not like to visit the place where they have spawned, a second time. It has also been noticed that the large herrings do not go as high up the fiords as the small ones, and that when the spawning-season comes in winter or spring the large herrings spawn before the small ones, whilst when the spawning-season comes in summer or autumn the small or younger herrings spawn before the larger and older ones. After spawning, the herrings have often been observed to go nearer the coast than before spawning; fishing with drag-nets may therefore be carried on long after fishing with stationary nets has ceased, as the "empty" fish (those that have spawned) do not easily enter a stationary net.

The going-out of the herrings is generally a much quicker process than their coming-in, and as it is more difficult to catch herrings whilst they are leaving the coast, we know very little about it. After the herrings have left the coast, they do not stay outside any length of time, but immediately go out to sea to seek food and enjoy the greater protection which the deeper water affords. When the herrings have been to the coast for the purpose of spawning, they generally leave the coast in a northerly direction.

With regard to the extent of the annual migrations of the herrings, I have already mentioned the different opinions, and I will only add here that the larger a school of herrings is, the greater will be the extent of territory where they must seek their food, and the farther from the coast

must they extend their migrations. It is not known from direct observations how far the largest schools of herrings extend their migrations, but certainly much farther than *MacCulloch*, *Nilsson*, *Boeck*, and their followers assert.

44. The annual migrations of the herrings may be influenced by physical causes both as regards their time and their direction. It is well known that favorable, mild weather accelerates, whilst bad weather retards the approach of the herrings to the coast,[67] and that wind and current may bring a much greater number of herrings to one part of the coast than to another near it. The general rule, however, is that the herrings, when coming in to spawn, visit the place where they were born. When the herrings come in to seek food, they will generally go to those waters where they have been accustomed to find food in the greatest abundance; those physical causes, therefore, which have an influence on the occurrence of food will also influence the direction of the herrings' migrations, as I have had occasion to remark before.

45. The annual migrations of the herrings are chiefly caused by the desire to propagate the species and to seek food. For spawning, the herrings need a suitable bottom for depositing their eggs, a bottom which also must contain a sufficient quantity of food for the young herrings and afford shelter for them. All these requirements are only met near a coast. Even if herrings, as has sometimes been said, not without a show of reason, spawn on the Dogger-Bank or other still more distant banks in the North Sea, this does not disprove our assertion, for it is doubtless only the greater ease with which the young fish can reach the coast from these banks which has made it possible for the herrings to spawn there.[68]

The grown herrings must again go to the ocean to seek their food, which they chiefly find in the currents and those waters which come from the Polar Sea. In some places, however, they find the required food during some part of the year near the coast; and thus there may be fishing towards the end of summer and the beginning of autumn, as on the western coast of Norway, or during autumn and winter, as on the coast of Bohuslän. The influence which the desire for food exercises on the annual migrations of the herrings has sometimes been overrated, so that it has occasionally been considered as the chief cause, even in cases when the desire to propagate was undoubtedly the principal cause.

As the spawning herrings, on account of their being packed more closely together and on account of the steady course which they pursue, are more exposed to the persecutions of their enemies, and as this danger of course increases the nearer they get to the coast, they generally go

[67] See 13. This is applicable chiefly to those herrings which spawn in spring (that is, after the close of winter when the ice is breaking up). On coasts like those of Norway and Scotland, laved by warm currents of the sea, this is less noticeable.

[68] It is therefore not improbable that the young herrings which in such large number are found near the western coast of Norway are at least in part the offspring of herrings which have spawned on the North Sea banks.

into deep water immediately after having spawned, in order to find the necessary shelter, and leave the coast much quicker than they came. The larger herrings seem likewise to thrive better in the open sea than near the coast, and consequently do not stay there longer than is absolutely necessary. *Neucrantz*, however, goes too far when he supposes that the herrings leave the coast only to escape unpleasant physical conditions, for instance, cold or violently agitated water. It has already been mentioned that want of space or the persecutions of enemies have in former times by some been considered as the chief causes of the annual migrations and regular coast-visits of the herrings. Such opinions are, however, no longer entertained, and therefore cannot claim our attention.

46. The great periods (eighty to one hundred years) of the large races of sea-herrings have long since been known, as far as certain points on the coast of Bohuslän are concerned, but have not formed the subject of scientific investigations till the present century. In olden times this phenomenon, as peculiar as it was important from an economical point of view, was connected with religious ideas or with some superstitious notion of the period, and it was only *Ström*, *Lybecker*, *Dubb*, and *MacCulloch* who spoke of these almost inexplicable facts in a scientific manner, From the last-mentioned author we have the expression, often quoted in season and out of season, that the herring is an entirely "capricious" fish.

Nilsson, who had set himself the special aim to find the causes why the Bohuslän herring-fisheries came to an abrupt end in the year 1808, for the first time examined the question regarding the long periodical visits of the so-called "old" or "genuine sea-herrings" to the coasts of the Skagerack in a truly scientific manner. The result of it was, that their conformity to natural laws was totally denied, and the periodicity of our great herring-fisheries was explained by the herrings having been driven away by man, enough young fish, however, having been left every time to gradually produce new fisheries, to be followed in turn by the final expulsion. This opinion, which was stubbornly opposed by the fishermen who in *Lundbeck* had found a literary spokesman, who maintained that it was the nature of the herring "to change its place, and that its visits to our coasts were periodical," was generally shared by the naturalists of that time, such as *C. J. Sundevall*, *S. Lovén*, *W. von Wright*, *Ekström*, *Malm*, *Widegren*, and others. Even *Kröyer* shared this opinion to some extent, as in these migrations of the herrings continuing for many years and then ceasing all of a sudden he could see nothing else but the changes to which all sea-fisheries are subject; at a later time he chiefly ascribed the undeniable fact of these migrations to the increase in the number of birds and fish-of-prey, changes in the weather, the character of the bottom, the sea-water, and excessive fishing with destructive apparatus.

In direct opposition to this view supported by the most influential scientific authorities, *Löberg* and *Axel Boeck*, sustained by popular opinion and by the history of the herring-fisheries of Western Scandinavia,

have endeavored to prove that those races of herrings which visit the coasts of Bohuslän and Western Norway change their spawning-places periodically, although they could give no reason why it should be so. *Axel Boeck*, following in part *H. Ström* and other older authors, also showed that there are several tolerably regular changes in the course of the herring-fishery during the great fishing periods. Later *G. O. Sars* has made an ingenious attempt to explain one phase in these changes, viz, the arrival of the herrings at different times during the fishing period, by the varying occurrence of the "herring-food" supposed to depend mostly on meteorological and hydrological conditions; in the beginning, however, he seemed inclined, like *Nilsson*, to deny the periodicity and to suppose that the visits of the herrings continued without interruption unless checked or hindered by man's interference, but later entertained an opinion which agreed more with that of *Boeck*. *G. Winther* has also shared *Boeck's* view in describing the analogous Sound fisheries, whose changes, however, are less marked. Finally I have attempted to explain the periodicity partly by the tendency of the school of herrings to become great through the influence which its size must exercise on the cenobitic conditions in the disproportionately small spawning-places, partly by the greater distance from the spawning-places at which the herrings just on account of the size of the school must seek their food, which depends on supposed periodical changes in the meteorological and hydrological conditions.

47. The great migration periods of the large schools of herrings are marked by very regular changes both in the time of the herrings' annual arrival at the coast and in the locality where they arrive. It must be remembered, however, that all the knowledge we possess of these changes is derived from the fisheries, and that the too exclusive use of apparatus only suited to coast-fishing has made the coast-fisheries more prominent than they would have been otherwise. But wherever herring-fisheries are carried on not only near the coast but also with floating nets at a considerable distance from the land, such as is the case, for example, near the east coast of Scotland, or with purse-nets as on the northeastern coast of North America, the changes are much less marked and have therefore hitherto almost entirely escaped attention. *MacCulloch* has some observations on this point chiefly with regard to the fisheries on the eastern coast of Scotland, but it is only recently that I among others have directed attention to the fact that the herrings on the eastern coast of Scotland have changed their chief place of visit to a point about 100 English miles farther south, and have left the Moray Firth, and that they have commenced to come near the coast earlier during the season, so that the September fisheries are very insignificant now compared to what they were formerly. On the coasts of Bohuslän and Norway, where fishing is chiefly carried on with seines and stationary nets, such changes have been known from time immemorial.

48. Thus Prof. *Hans Ström* in Norway observed that the herrings

during the period they visited the coast of Söndmör (1736–1756) came later and later every year, and predicted, in accordance with an old tradition and the experience had at Stat, that the herring-fisheries of Söndmör would come to an end. This really took place in Bohuslän, where it had been observed already towards the middle of the last great fishery-period, that the herrings came to the coast later and later every year, which led people to fear that as in times of old the herrings might again gradually leave the Swedish coasts. Somewhat later (1782) *Ström* compared the Bohuslän fisheries with those of Norway, and, basing his opinion on their evident similarity, predicted that the end of the Bohuslän fisheries was near at hand.

About ten years later *Lybecker* expresses himself more distinctly, as follows: "If with prophetic eye we could see the future and predict the fate of the fisheries, we might say with a great degree of probability that a change will take place soon. We know from history that when herrings or other fish-of-passage arrive near the coast later and later, and at the same time keep farther and farther away from the coast, this means a change in the migrations of the herrings, and may even point to their leaving the coast entirely. This has been the course of the Norwegian herring-fisheries, and even of the Swedish herring-fisheries during their older periods, and in fact with all those fisheries where fish-of-passage are the principal object, with the only exception of the Scotch and English fisheries. * * * If we take into consideration the roving nature of the herrings and the examples from olden times, it is highly probable that the herrings will come later every year and finally leave our coast altogether."

It had frequently been maintained that too much fishing, and fishing with destructive apparatus, were the proper causes of the herrings coming later every year, and might even lead to the complete cessation of the fisheries; and people therefore made futile attempts to obviate this danger by legislation. As the ominous predictions regarding the herring-fisheries were, however, not immediately fulfilled, they were almost forgotten; but when the herring-fisheries came to an end in the year 1808 people imagined that the herrings arriving later and later every year fully proved the assertion that they had been driven away by the imprudent action of the fishermen. It was said that refuse thrown into the water, and noise, had prevented the herrings from coming near to the coast, that they had spawned in the open sea, and had, then, in consequence of the languor and weakness following the spawning, been driven towards the coast by storms.

During the more recently closed Norwegian spring-herring fisheries it was (according to *Löberg*) noticed, not without anxious forebodings, that the herrings, which in the beginning of the fishing-period did not come near the coast till early in February, gradually came earlier and earlier, so that finally the fisheries commenced before New Year; and that this change was followed by another, the herrings again coming later and

later, till the fisheries did not commence before February. This peculiarity, however, was thought to be a consequence of the irregularity with which the herrings visited the same places on the coast. It was not till *Axel Boeck* began to investigate the matter that this whole question was treated from a more scientific standpoint. He showed that the coming of the herrings to the coast at different times during the period was subject to certain rules, and that this regularity in the movements of the herrings was observed not only during the Norwegian spring-herring fisheries of the seventeenth and eighteenth centuries, but also during those herring-fisheries which were going on on the coast of Bohuslän during the second half of the fifteenth and seventeenth centuries. This peculiar phenomenon has therefore become far more important than it was thought to be in former times; and it may well be said to contain the key to the question of the periodicity of the great Scandinavian herring-fisheries. *Boeck* was not able to assign any cause for these entirely regular changes in the time of the herrings' visits to the coast. This has been attempted, however, by *G. O. Sars* and myself, and an account of these attempts will be given below.

49. At a very early period of the last great Bohuslän herring-fisheries it had been observed that the herrings came to the coast a little farther north every year. This became so noticeable that it was mentioned in the Parliamentary Fishery-Commission's report of January 15, 1770. These changes took place in the following order: the fisheries commenced on the central (or as it was then called "northern" coast),[69] but soon after turned to the southern coast, and during the years 1760–1765 went as far south as the northernmost part of the Holland coast, although the coast near Elfsborg and Marstrand was the principal fishing-place. Up to the year 1780 the herrings gradually left the southern coast and chiefly visited the central coast, going as far north as Strömstad from 1773 on, and making their appearance near the Hval Islands in the southern part of Norway from 1778. These changes also attracted the attention of foreigners, and *Lybecker* speaks of them as sure signs that the Bohuslän herring-fisheries were approaching their end.

When the herring-fisheries actually came to a close, and people began to argue about the causes of this misfortune, those who ascribed it to imprudent and destructive fishing saw in these changes a proof of their assertions. They maintained that as soon as the southern coast began to be covered with salting-houses the herrings left this coast and came to the northern coast, and when this too began to be filled with similar establishments, "the herrings seemed disturbed and scared, and came in smaller schools, approaching both the northern and the southern coast in those places where there was least noise and where least refuse was thrown into the water." (*Svensson.*)

[69] *Axel Boeck's* assertion that during the last great Bohuslän fisheries fishing first commenced on the southern coast (*Om Silden og Sildefiskerierne*, p. 106) is therefore not correct.

Even on the west coast of Norway it had (according to *Löberg*) been observed during those spring-herring fisheries which had been going on there since the close of the Bohuslän herring-fisheries in 1808, that the herrings changed the places of their annual visits, and many attempts were made to explain this phenomenon. None of these attempts, however, found much favor, and *Löberg* therefore maintained that probably these changes were caused by the influence of wind and current.

New interest began to be taken in this question when *Axel Boeck* proved that these changes were to some extent regular, and had been shown to be regular not only during the older fisheries, concerning which our sources of information were very meagre, and during the last Norwegian spring-herring fisheries, but also during the great Bohuslän herring-fisheries of the sixteenth and eighteenth centuries.[70]

Boeck has not assigned any natural cause for this regularity in the changes of the herrings' visits, and I believe that I am the first who has made any attempt to find the causes of this phenomenon. I supposed that during *that* part of the fishing-period when the herrings came to the coast for the purpose of spawning, they preferred its northern portion, because the temperature of the water was higher and more even during the later part of the season when they came there, whilst the southern coast would again offer peculiar advantages of temperature during the earlier part of the season when they came there. During that part of the fishing-period, however, when the herrings came to the coast for other purposes than spawning, their choice of a place would chiefly depend on current and wind; fishing on the central and northern coasts was therefore more certain than on the southern coast. More will be said farther on (60, 63) concerning these attempts to explain the changes in the migration of the herrings.

50. Among the peculiar phenomena of the latter part of the last great Bohuslän fisheries, attention has been drawn to the unusual occurrence of small herrings among the larger ones during the last thirty years. This phenomenon has also become more significant since *Axel Boeck* has shown that something very similar took place prior to the close of the last Norwegian spring-herring fisheries, thus seemingly being an indication that the fisheries are approaching their end. During the above-mentioned herring-fisheries none but large herrings were caught, and on the coast of Bohuslän, for example, it was only immediately before and after the annual fisheries that small herrings were caught among them. The Norwegian spring-herring fisheries generally begin every year with straggling herrings and are mostly followed by smaller herrings.

The case which *Boeck* mentions from the Stavanger coast and from the year 1766 does evidently not belong here, as it only proves a less productive local autumn-herring fishery, when herrings of different size are generally caught.

[70] It is highly probable that the same was the case during the Bohuslän fisheries of the second half of the sixteenth century, as the fisheries came to an end much earlier in the southern than in the other parts of the coast.

51. In order to get a more correct idea concerning this peculiar mingling of great and small herrings towards the end of a fishing-period, it will be necessary to consider another phenomenon which seems to be connected with it, and which has hitherto been overlooked. It is known from the last great Bohuslän herring-fisheries that during the last thirty or forty years (therefore during more than half the period) the herrings came to the coast for entirely different purposes than spawning, and that the herrings, though not exactly being a mixture of great and small fish, differed greatly in size, fatness, and general quality.[71] It then became customary to call the full-grown herrings—whose number was small—by a characteristic name, "select herrings" or "fat herrings." It was thought that impure water and noises had caused the herrings to stay in the open sea, until after spawning they were in so weak a condition that a strong wind would drive them towards the coast.

A similar phenomenon has during the last ten years been observed in the Norwegian spring-herring fisheries, so that instead of spawning herrings ("genuine spring-herrings") an inferior kind of herring has been caught, which is called "mixed herring" or "new herring," the number of full-grown herrings being exceedingly small; their spawning-season seems moreover to come somewhat later than that of the genuine spring-herring, which spawns in winter, and they might therefore possibly belong to a small race of coast-herrings which spawn in spring. *Boeck* considered this phenomenon as a dark and mysterious enigma; *G. O. Sars* was the first who—as far as the Norwegian spring-herring fisheries were concerned—examined the whole question from a scientific point of view. As regards our (the Bohuslän) fisheries, it was scarcely possible to suppose that the so-called "new herrings" were spring-herrings which only visited our coast after having spawned, as the well-known characteristics of the "new herrings" prevented their being considered as spring-herrings which had but recently done spawning. It was therefore supposed that they were old and young fish which would not spawn till the following winter, and which during the preceding autumn would keep nearer the coast than the spring-herrings, which latter would, when going to their new spawning-places in the outer deep coast-waters, drive the "new herrings" towards the coast. But *Sars* has failed to explain why such a "driving-in" of great masses of "new herrings" did not take place during the preceding period when the herrings came to the coast for the purpose of spawning. It is tolerably certain that these so-called "new herrings" are, to a great extent at least, such fish as have not yet reached the age when they are capable of spawning; but as this would not apply to the great mass of the herrings, the supposi-

[71] See *H. Ström* "*Sammenligning imellem de Norske og Svenske Fiskerier*" (Comparison between the Norwegian and Swedish fisheries) in *Dansk Museum*, January 1782, p. 7, 9–11, where he supposes that the above-mentioned Bohuslän herrings are the young of the spring-herrings which have emigrated from the Norwegian coast, and are therefore the same as those which at that time were in Norway called "winter-herrings."

tion gained ground that the herrings only spawned every other year, an opinion to which I cannot give positive assent, at least to such an extent as would be necessary.

In comparing the above-mentioned Norwegian and the Bohuslän fisheries (the latter having for their object herrings which come to the coast for a totally different purpose than spawning), it will soon be found that the phenomena are very similar, and that the spawning-herring fisheries are immediately followed by a longer or shorter period of new-herring fisheries; and I have even been led to suppose, basing my opinion on the development of the last great Bohuslän herring-fisheries, that all great herring-fisheries, at least in Bohuslän, are not only followed but also preceded by a similar period of "new-herring" fisheries. By this term as well as by the term "period of spawning-herring fisheries," I understand, of course, only separate portions of one and the same great period of herring-fisheries; and as the intervals between two such great periods on the coast of Bohuslän generally last from sixty to one hundred years (an average of seventy), these intervals would be shorter on coasts which are nearer that part of the ocean where the herrings chiefly find their food, for instance, the western coast of Norway, and possibly in very favorable localities almost imperceptible. It is evident that the "new-herring fisheries" are much less certain than the "spawning-herring fisheries," which is very noticeable on the west coast of Norway.

It is also my opinion that the "new herrings" on the west coast of Norway belong to an entirely different race of herrings from the Norwegian spring-herring,[72] and that they may possibly be identical with those herrings which periodically visit the coast of Bohuslän. The circumstance that the "new herrings" were not generally seen during that part of the fishing-period when spawning-herrings were caught, such as was the case during the Norwegian spring-herring fisheries, is said to be owing to the weaker "new herrings" having been chased by the stronger spawners to those regions which these had formerly occupied themselves. According to this supposition it would seem impossible that great spawning-herring fisheries could be going on simultaneously on the coast of Bohuslän and on the western coast of Norway; but quite likely that those herrings which during autumn have visited the coast of Bohuslän for the purpose of spawning, visit the west coast of Norway later in winter as "new herrings" or "winter-herrings."

These suppositions of mine do not claim any higher scientific value, but may nevertheless prove useful by possibly directing attention to the necessity of collecting and combining facts relating to the history of the herring-fisheries much more than has been done hitherto.

52. After having thus briefly mentioned the different theories regarding the migrations of the large races of herrings and the phenomena which characterize the large fishery-periods, we must mention the nu-

[72] Compare, however, the above-mentioned entirely different opinion regarding the relation of the "winter-herring," communicated by *H. Ström.*

merous attempts to find the *causes* of these migrations; this is probably the most difficult and most violently disputed part of the whole herring-question. As these fishery-periods have been most distinctly marked by long intervals on the coast of Bohuslän, as there they have caused the greatest economical revolutions, and as consequently they are better known, having at an early period been made the subject of scientific investigations, a brief review of the successive views regarding the causes of the cessation of the last great Bohuslän fisheries will be in place here.

When the great herring-fisheries came to an end in the year 1808, and many men experienced heavy losses, causing great want and suffering on the coast of Bohuslän, it was quite natural that in Bohuslän, at least, people began to think seriously about the causes of this great misfortune and about the possibility of retrieving it. When by direct observations it had been ascertained as an undeniable fact that the so-called "old herrings" had really left the Skagerack, the opinion gained ground among the more educated classes that the herrings had been chased away by destructive fishing, by noise, and by the great quantities of refuse from the oil-refineries which had been thrown into the sea; this opinion was publicly expressed in a pamphlet published in 1822 by *Mr. Svensson*, the proprietor of large salting establishments. This as well as the repeated demands for subsidies from the state to promote the fishing interests and help the impoverished fishermen finally induced the government to order a scientific investigation of the whole matter. This investigation was entrusted to Prof. *S. Nilsson*, who during the summer seasons of 1826, 1827, 1832, and 1833 visited the coast of Bohuslän. In his reports he gave his above-mentioned opinion as to the cause why the herring-fisheries had come to an end. But when he proposed, in order to help the Bohuslän herring-fisheries, that fishing with close nets should be prohibited and in its place fishing with stationary nets having wide meshes should be introduced, his general views began to be opposed, especially the one that the herrings should have been driven away by too much fishing, which last-mentioned idea people thought they could trace in his report for 1828. Professor *Nilsson* replied that his expressions had been entirely misunderstood, that he had never "either entertained or expressed" such an "unreasonable idea." During the conferences with a number of fishermen which were held in the year 1833, the opinion that the herrings should have been driven away by too much fishing, by noise, or by impure water was strongly opposed. When the above-mentioned causes no longer found favor, the opinion gained ground that the fisheries had come to an end through the use of close nets, an opinion which found some support in an "ominous" expression of the distinguished ichthyologist Mr. *Bloch*. This opinion was not directly submitted to the criticism of the coast population, and consequently remained in favor for some time, but was finally also abandoned.

Thus one opinion followed the other, and finally it was maintained in a somewhat dictatorial manner that in all these causes which had been assigned for the cessation of the fisheries there was at any rate some particle of truth.

53. In other places, likewise, where the herring-fisheries had ceased or had decreased, the question as to the causes of this phenomenon had become the subject of discussion, and various explanations were attempted, all of which were also applied to Bohuslän. None of these explanations, however, gained general favor; they were, nevertheless, subjected to a thorough criticism by *MacCulloch*, *Kröyer*, *Löberg*, *Axel Boeck*, and others. In spite of this they continued in one shape or the other to be believed and contradicted, and even in our own times attempts have been made to solve the problem by following some of these old-fashioned ideas. There are, besides, quite a number of modern explanations or suppositions which explain the phenomenon by purely natural causes, whose value cannot yet be determined, because these natural causes are not fully understood. Explanations have, however, been attempted, not only by such more or less probable causes, but even by myths or entirely accidental circumstances. The desire to find the causes of all natural phenomena is deeply implanted in human nature, and when science or ingenuity is unable to find these causes people will resort to accidents and myths. Only those persons, however, who are of a strictly critical and thoughtful nature, and who, consequently, both appreciate the difficulties and are but too well acquainted with the defects and the limits of human knowledge, will feel inclined, at times at least, to give up all hope that the question will ever be satisfactorily answered.

54. In examining, however, all the causes which have been assigned for the cessation of the fisheries, we find that they may be arranged under three heads. The *first* of these embraces mythical or accidental causes; the *second*, causes produced by human agencies; and the *third*, biological and physical causes.

A.—*Mythical and accidental causes:*

1. God's wrath on account of the abuse of his gifts, human godlessness and ingratitude, Sunday fishing, refusing to pay tithes to the clergy, &c., or dissatisfaction with the laws and regulations made by the government, &c.;
2. Magic;
3. Spilling of blood;
4. Cruelty shown towards the herring;
5. Using herrings as manure;
6. Occurrences which accidentally took place at the same time when the herrings disappeared, such as conflagrations on the coast, the erecting of new light-houses, &c.;
7. Neglect on the part of the whales and other so-called "herring-hunters" to drive the herrings towards the coast;

8. The capriciousness of the herring or its innate instinct independent of outward circumstances.

B.—*Causes produced by human agencies:*

1. The gradual destruction of the herrings by:
   a. too much fishing, and more especially by catching young herrings in close nets,
   b. preventing the herrings from reaching suitable spawning-places,
   c. destroying the spawn, or
   d. destroying the places where the young fish are accustomed to seek food and shelter;
2. The gradual expulsion of the herrings from the coast-waters by:
   a. noise,
   b. too many fishermen,
   c. disturbing methods of fishing, especially fishing with floating nets too early in the season,
   d. disturbing the spawning-process,
   e. disturbing the spawning-places by fishing or throwing refuse into the water,
   f. leaving dead herrings on the bottom, or throwing guts and gills of fish into the water,
   g. making the water impure by refuse from oil-refineries, &c.,
   h. hindering the herrings from going undisturbedly to their spawning-places,
   i. insufficient and delayed fishing and the consequent scarcity of food for the herrings.

C.—*Biological and physical causes:*

1. Gradual destruction of the herrings by unfavorable weather, an unusual increase in the number of fish-of-prey and birds-of-prey, lack of food, &c.;
2. The forced expulsion of the herrings from the coast-waters by:
   a. the increasing number of fish-of-prey and birds-of-prey,
   b. the lack of food,
   c. a change in the nature of the coast-bottoms, making them unfit for spawning (these changes may be brought about by bottom-ice or floating ice or by the changed nature of the local fauna and flora of the sea),
   d. changes in the meteorological and hydrological conditions or in their periodicity,
   e. the herrings having to go too far from the coast in search of food.

55. It will scarcely be necessary to say that frequently a greater or less number of the above-mentioned causes have been combined in order to produce a greater effect. Nor will it be necessary to give much attention to the causes mentioned under the first heading (A), although they have for a long time met with great favor among the common people. As regards the causes mentioned under the second heading (B), they might practically be divided into two subdivisions different from

those mentioned above, the first embracing all those causes based on the idea that the herrings were either destroyed or driven away by human agencies, and the second embracing all those causes based on the idea that the herrings had been forced to leave the coast from lack of food. The causes mentioned under the first heading have, generally speaking, not met with universal favor, many of their defenders being led by ill-concealed feelings of envy; and the causes mentioned under the second heading are generally in direct opposition to the first. Strange to say, the method of explanation which has recently been adopted by *G. C. Cederström* has seemingly met with some opposition by the knowledge which we have gained concerning the great Bohuslän herring-fisheries, that those fishing-periods lasted longest during which fishing was carried on with the greatest zeal, whilst those were shortest during which fishing was neglected.[73] It ought scarcely to be necessary to refute this theory, and as far as the above-mentioned theories of explanation are concerned, we may point to the, generally speaking, reliable opinions of the authors mentioned before (53). It must be granted that the influence of human agencies on small fisheries may be noticeable; but their influence on the great herring-fisheries is doubtless exceedingly small, and can in no wise be the cause of such phenomena as the cessation of the great herring-fisheries. At the present time it is very rare to find any scientist who still holds to the old and fully refuted opinions.

56. The biological and physical causes doubtless deserve more attention. With regard to them a distinction may be made between the theory that the herrings are periodically destroyed and that they leave the coast during long intervals. *Kröyer* has mentioned that if a school of herrings is by unfavorable weather compelled to spawn in unsuitable places for several years in succession, it may be entirely destroyed or at least be diminished to such a degree that the fisheries must come to an end. Later, *G. C. Cederström* has thrown out the hint that unfavorable outward conditions had towards the end of the last great Bohuslän fishery-period decimated the herrings and thereby brought about the end of the fisheries. All the suppositions, however, cannot explain the periodicity of the great herring-fisheries; for these fisheries, as, among the rest, has been said by *Nilsson*, *Löberg*, and *Boeck*, have come to an end, not from lack of herrings, but because the herrings left those regions where they had been accustomed to come. If this were not the case, a gradual decrease in the number of herrings ought to have been noticed towards the end of a fishery-period, but nothing of the kind has ever been observed. There is far greater probability in the supposition that from some outward causes the herrings have been induced to periodically leave those regions which for a long time they had visited regularly. The most prominent among them is this, that the herrings should have

[73] This supposition is by some people harmonized even with the actual deterioration in the quality of the herrings which undoubtedly takes place towards the end of a fishery-period.

been driven away by the increased number of fish-of-prey and birds-of-prey. This originally popular explanation is quite old, and has been mentioned in a somewhat fault-finding manner by *Dubb*, and has been attacked by *Axel Boeck*, but has, nevertheless, quite recently (in the "Book of Inventions") found a scientific champion in Prof. *F. N. Smitt*. He expresses himself regarding the causes of the periodicity of the herring-fisheries as follows: "In all probability it is chiefly to be sought in the common occurrence that when a race of animals which serves as food for others, under peculiarly favorable circumstances increases in a very marked degree, it also attracts more enemies, which increase in number in proportion as the quantity of their food increases. The weaker gives way to the stronger; the herrings, therefore, seek new spawning-places which afford better protection. When on the other hand the fish-of-prey and birds-of-prey do not find the same quantity of food, they diminish in number. If, therefore, a new race of herrings comes to the old spawning-place and again finds its condition favorable, they may increase at a very rapid rate." According to this explanation all herring-fisheries ought to be periodical, for there is scarcely a region where the herrings are not exposed to enemies; but such a complete periodicity as is here spoken of will only be found with very few herring-fisheries. Nor do we find in any fishery-period an uninterrupted increase in the number of the enemies of the herrings. Thus there were rich shark-fisheries on the coast of Bohuslän immediately before and in the beginning of the great herring-fisheries of the sixteenth century; and it is well known that in Scotland and other places the sharks and other powerful enemies of the herrings are very irregular as to the number in which they occur; this is easily explained, as they cannot for their food rely entirely on the herrings, which only visit the coast for a short time every year, because they need rich food all the year round. Very erroneous ideas seem to be entertained quite generally regarding the occurrence of fish-of-prey during coast-herring fisheries, and their dependence on such fisheries. These fish-of-prey, which otherwise are scattered over a large area, gather in dense schools during the herring-fisheries, and are, therefore, noticed more than at other times. Some of these fish-of-prey chiefly depend for their food on the fisheries, and the herrings are by no means as easy a prey as is generally supposed. It will, therefore, be clear, that according to this theory the enemies of the herring ought to increase in proportion as the mass of herrings increases, whereby the herrings would again decrease. This generally takes place, so that the unusual increase of one or the other kind of fish is soon neutralized again. If, therefore, an increase in the number of fish-of-prey were the cause of the herrings moving away from the coast, some cause ought to be assigned explanative of the very strange disturbance of the natural balance between the number of herrings and that of their enemies. And this cannot be done, at least if Professor *Smitt's* supposition is correct, that when the herrings under favorable circumstances increase

very rapidly, the same should also be the case with the fish-of-prey. But on the other hand we seem justified in supposing with *Kröyer* and *N. W. Malm*, that a decided increase or decrease of fish-of-prey may cause a temporary decrease or increase of the herrings at least in some of the smaller herring-fisheries.

57. Lack of food has likewise been considered as a cause why herrings have gradually left a coast. *Leeuwenhoek* already has considered the varying quantity of food as the principal cause why herrings changed their place of sojourn; but, as far as I know, this idea did not become general until the question of oil-refuse was discussed during the last great Bohuslän fisheries;[74] and when the herrings had ceased to come to the coast of Bohuslän, a gradual decrease in the quantity of food was assigned as one of the causes of this misfortune. This last-mentioned opinion has, so far as the Bohuslän herring-fisheries are concerned, been embraced by Prof. *G. O. Sars*. If we now suppose, with Professor *Smitt*, that the revival of the great herring-fisheries is owing to the accidental arrival of a new "race of herrings," which increased at a rapid rate, it is reasonable to suppose that this rapid increase produces lack of food, and this explanation will seem more plausible than an increase in the number of fish-of-prey from the same cause. But even then it will be difficult to explain why not all herring-fisheries are periodical, which is certainly the case only with a few. This periodicity ought also to be particularly noticeable with those herrings which come to the coast for the purpose of seeking food, which is by no means the case. The theory that the periodicity of the herring-fisheries is dependent on the varying quantity of "herring-food," has been further developed by Prof. *G. O. Sars*, who supposes that the herrings are obliged to seek their food in a certain regular order at a greater or less distance from the coast. By means of this supposition, he endeavored to prove that the Norwegian spring-herring fisheries are not periodical in the proper sense of the word, but that the occasional decrease of these herrings, or their staying away entirely, is caused by the circumstance that at times these herrings had to seek their food so far out at sea that they could only come to the coast late in the season. They would, consequently, have to spawn immediately on the very outermost bottom. The fisheries would, therefore, be short and insignificant.[75] The circumstance that the Norwegian summer-herrings continue to be very flourishing has also induced Pro-

[74] About the same time, Prof. *H. Ström* had directed attention to the circumstance that the "herring-food" may be found in a place one year and stay away the next, and that the herrings would consequently have to follow it up. *Ström* also mentions that the small crustaceans, which principally compose the "herring-food," prefer the currents of the sea, and that the varying direction of those currents may also cause the crustaceans to change their place, and consequently produce new migrations of the herrings. The wind may also have a good deal to do with all these changes.

[75] According to *Axel Boeck*, it is an old opinion in Norway that the herrings, in the intervals between the great fishery-periods, have not left the coast, but have only transferred their spawning-places to inaccessible bottoms. This opinion has, however, been almost entirely abandoned at the present time.

fessor *Sars* to oppose the general opinion that a period of spring-herring fisheries had recently come to an end. Although it has not been sufficiently proved by actual observations that the spring-herrings do no longer spawn in their usual places, this seems scarcely probable; and this explanation would in no wise be applicable to the great Bohuslän herring-fisheries, which, as far as known, agree with the Norwegian spring-herring fisheries in all essential points. From the circumstance that the summer-herring fisheries continue to be just as productive (and occasionally even more so) as during those years when there were still spring-herring fisheries, no such conclusion as the one mentioned above can be drawn with regard to the latter; for it does not follow that, because the spring-herrings have left their old spawning-places, the summer-herrings should also leave the western and northwestern coasts of Norway; nor does the fact that the summer-herrings remain prove that the spring-herrings must do the same.[76] Professor *Sars* seems also to be somewhat undecided with regard to his theory, for he has at a later time, in accordance with a very general opinion in Norway, expressed the idea that there is a direct connection between the Norwegian spring-herring fisheries and the great herring-fisheries. The above-mentioned opinion of Professor *Sars* may, however (as will be shown below, 63), be developed so as to become more generally applicable; and it is, therefore, not impossible that this very opinion contains the germ of a final solution of the problem regarding the migrations of the great shoals of herrings.

58. Intimately connected with this question is the explanation of these migrations from physical causes. The opinion is very old that changes in the physical conditions are the probable cause of the periodicity of the herring-fisheries. The learned and thoughtful Prof. *H. Ström* began already to see the error in the usual method of explaining the periodical cessation of the herring-fisheries by human agencies, and endeavored to explain the greater or less quantity of herrings, and even the fact of their leaving the coast entirely, by physical causes.[77] He mentioned, for instance, that the rich spring-herring fisheries which took place during his stay at Söndmör occurred at a time when the weather was very unfavorable to agriculture, causing a total failure of the crops, and that such failures are generally indicated beforehand by the frequent occurrence of a fish—the horngädda—which generally lives in more southern regions. Dr. *P. Dubb* likewise supposes that changes of weather and current are the true cause of the periodical coming and going of the genuine "sea-herrings" on the coast of Bohuslän. *Ekström* has explained the circumstance that on the coast of Södermanland the herrings are more

[76] See 45; also, *H. Ström, Söndmör*, I, p. 468; *Dansk Museum*, January, 1782, p. 3–4; *A. Boeck, Om Silden*, p. 130; *A. V. Ljungman, Preliminär berättelse* for 1873–'74, p. 6.

[77] *H. Ström, Dansk Museum*, January, 1782, p. 3–9. In this passage he points out that changes in the condition of the ice near the North Pole probably cause the periodicity in the migrations of the herrings.

frequent than on the coasts of Stockholm and Oestgöta, by the different direction of the wind prevailing during the time when the herrings come near the coast. In the seventeenth volume of the Encyclopædia Britannica (last edition) the irregularities in the visits of the herrings to the west coast of Scotland have, in accordance with the opinion of *Pennant* and *MacCulloch*, been explained by well-known changes in the Gulf Stream, which changes should cause the herrings, which always seek an even temperature, to change their old places and seek new ones. This opinion has recently been taken up by *Frank Buckland*. Prof. *G. O. Sars* has finally endeavored to prove that periodical changes, connected with the movement of the great herrings towards the north, probably take place in the currents of the sea on the northern coast of Norway. He thinks that these changes are indicated by the periodical occurrence of wood, &c., washed ashore from foreign countries, and maintains that his theory of the "herring-food" being found at different times at different distances from the coast presupposes regular periodical changes in the currents of the sea.

59. After having given the above historical review of the different theories regarding the biological or physical causes of the periodicity of the herring-fisheries, it remains for me to indicate the manner in which I have further developed these theories during the last five years. I started with an investigation of the question, "Which fisheries are periodically regular, and which not"; and I have found that only very *large* fisheries carried on near the coast and dependent on the propagating instinct of fish are periodically regular. From this I have drawn the conclusion that it is the *number* of a race of herrings which chiefly causes them to periodically change their spawning-places near the coast. Other fisheries show irregularities with regard to the coming of the herrings, but no periods marked by a complete cessation of the fisheries and by regular changes. Thus the Norwegian summer-herring fisheries owe their existence to one or several large races of herrings; but, as far as known, they are not periodical. This seems also to be the case with those fisheries which are carried on in the open sea at some distance from the coast, where the fishermen follow the herrings to their spawning-places. Our knowledge of these herring-fisheries, however, is very incomplete, for we know very little regarding the quality of the herrings and the possible changes of time and place.

The races (or schools) of herrings may nevertheless practically be divided into large and small ones, the line between the two not being very sharply drawn. And the very fact of certain races of herrings being large has led me to explain the periodicity of the herring-fisheries in two different ways, which I shall give below.

60. The enormous numbers in which the large races of herrings make their appearance must doubtless (especially when they select a limited extent of coast for their spawning-place) produce a great change in the natural condition of the coast-waters, both by their furnishing food to

numberless marine animals, and by their consuming a large quantity of food. This change may finally become so marked as to make these waters unfit for spawning, at least for a large race of herrings. The only, and nearly always sufficient, protection of the herring in its combat for existence is its fecundity; and although we must acknowledge, with *Kröyer*, that "danger does not put the herrings to flight, and that noise does not scare them away, but that their instinct points out the way they have to follow," this very instinct would naturally lead them to leave spawning-places which are no longer fit for spawning and seek new ones. It will therefore be clear that in proportion as the extent and nature of the spawning-places no longer correspond with the size of the race of herrings, the influence of this size will make itself more and more felt, and produce a change of time and place in the fisheries.

In order to judge the probability of this theory it will be necessary to find out how the above-mentioned regular changes of time and place of the herrings' visits to the coast can be explained by it. When a large race of herrings is compelled to seek another and distant spawning-place (in the case of Bohuslän, a more easterly one), they will, in consequence, come later in the year; but if they extend their "hunting-excursions" so as to come a little nearer, or the spawning in a still undisturbed spawning-place occupies less time, they may come earlier, and after having spawned, return earlier to their former district. Thus the herrings would gradually come earlier and extend their visits to other parts of the coast (in Bohuslän farther south) until they have brought their "hunting-district" as near the coast as possible. As this was really the case, and as the farthest spawning-places (in Bohuslän those on the southern coast) were disturbed, the herrings were compelled to seek their spawning-places nearer and nearer to the point where they first approached the coast (in Bohuslän farther north). The search for spawning-places took up some time; the herrings consequently came later and also left the coast later. They therefore also arrived later at their "hunting-grounds," and left the grounds later for the purpose of spawning. In proportion as they reached the "hunting-grounds" later, they would have to advance farther (that is, farther north) into these, because they would arrive in a more starved condition, and therefore require more food, which could only be obtained by scouring through a larger extent of water. The circumstance that during the last great Bohuslän fishery-period the herrings irregularly visited the southern, central, and northern coast, is easily explained by the fact that they did not come to the coast for the purpose of spawning, and that they always waited for some time outside the coast before coming nearer.

61. This theory of the successive disturbance of the spawning-places may possibly also explain the more incomplete periodicity which, as an experienced fisherman informed me, is noticed in the Sound and in the Great Belt, where the herrings seem to alternate between eastern and western spawning-places, so that one year there is good fishing in the

Sound and the next year in the Great Belt.[78] A similar alternation, although, of course, on a much larger scale, might well be supposed to take place between the eastern and western shore of the North Sea.[79]

62. At the first Scandinavian Fishery-Exposition held at Aalesund in 1864, *Axel Boeck* is said to have advanced the opinion that the end of the last Bohuslän fishery-period was contemporaneous with the recommencement of the Norwegian spring-herring fisheries, because the Bohuslän herrings had transferred their spawning-places to those banks in the North Sea which the spring-herrings had been accustomed to visit during those years when the spring-herring fisheries had ceased. The spring-herrings, therefore, on finding their spawning-places taken up had returned to the west coast of Norway. Afterward *Boeck*, it seems with good reason, abandoned this opinion, but the attempt to connect the migrations of two great races of herrings with each other nevertheless deserves attention. The same opinion has been entertained by other writers both before and after *Boeck*. When during the last winter a race of herrings, similar to the "new herrings," visited the coast of Bohuslän, I expressed the opinion that these herrings had been forced to give way to the Norwegian spring-herrings, which about ten years ago had begun to leave their old spawning-places on the west coast of Norway. However this may be, it cannot be doubted that the movement of one race of herrings has an influence on that of other herrings, although this influence may by no means be instantaneous.[80] It is clear that the coming in of larger masses of herrings in one and the same place, though at different seasons of the year, will essentially increase the influence of the disproportionately large races of herrings on a limited extent of coast-waters. It may also be possible for a race of herrings to be driven from its territory by a larger and stronger race, especially if the latter finds its territory too limited in proportion to its size.

This explanation has also opened out new views by applying it to the distinction made between the "new-herring fisheries" and the "spawning-herring fisheries" properly so called, for to some extent, at least, it may explain the fact that "new-herring fisheries" both precede and close a large fishery-period. It also facilitates the explanation of the regular changes of time and place in the visits of the herrings during a fishery-

[78] Although it has not been fully proved that such a mutual periodicity exists between the herring-fisheries in the Sound and the Great Belt, this whole matter deserves attention and ought to be investigated.

[79] A fact which may well be connected with the migrations of the herrings from the western to the eastern part of the North Sea, is the cessation of the otherwise regular whale-fisheries near the Faroe Islands from 1754–1776. But this fact, like the great migrations of the herrings in the North Sea, may be explained by supposing that the fish moved in a northern and southern instead of an eastern and western direction.

[80] Even herrings of different age, though belonging to one and the same race, may thus have to give way to each other, and the proposed method of explanation may be applied to the different theories regarding the relationship and maturity of the "new herrings" advanced by *H. Ström*, *G. O. Sars*, and myself.

period. The chief difficulty consists in finding a "*primus motor*" or the original cause which makes the great races of herrings move; and until a better explanation is found I would assign as this cause the change of biological conditions produced by the great size of a race of herrings, and a supposed periodicity of meteorological and hydrological causes, and possibly a combination of both.

63. The other and perhaps simpler way of explaining the periodicity of the herring-fisheries by the size of the race of herrings, may be reached by considering the very evident effect of this cause, viz, that the herrings are compelled to seek their food on a larger territory, farther from the coast, and more dependent on the changes of weather and current; and here Prof. *G. O. Sars's* theory regarding the visits of the herrings at different times during a fishing-period would come in well. In accordance with this theory it might well be supposed that the herrings would finally have to seek their food at such a distance that they could not reach their old spawning-places at the right time, but would have to select other spawning-places which were within easier reach. But as the herrings chiefly live on small crustaceans floating about in the water, we must, in following this theory, suppose a change in the occurrence of this "herring-food," which could scarcely be explained except by a periodicity of the currents and by the changes in the weather which principally produce this periodicity. No one has so far, however, been able to show the existence of such a periodicity, although it has been supposed to exist, and although there are facts which point in this direction. This hypothetical explanation is, therefore, nothing but a further development of the old opinion that the periodicity of the herring-fisheries is caused by physical changes, and its chief merit consists in indicating by the very point from which it starts the cause why not all herring-fisheries are periodical in consequence of these changes.

It will be clear, however, that this explanation can easily be harmonized with the regular changes of time and place in the so-called "landing" of the herrings, and this consideration should by no means be lost sight of. When the herrings are near the coast they can also land sooner and go farther along the coast (in Bohuslän and Western Norway farther south) than when they are far from the land in the open sea. Regular changes in the one will, therefore, also produce regular changes in the other. It will be more difficult, however, to explain in this way the exceptions from this regular course of changes in the fishery during a fishery-period. And such exceptions have occurred both during the last Norwegian spring-herring fisheries and during the latter part of the last Bohuslän fisheries. This theory may also be further developed by combining it with the other theory that the one race of herrings has to give way to the other so that the great races of herrings would be uninterruptedly moving backward and forward.

64. If, as I have supposed, two great herring-fisheries should be inti-

mately connected with each other, it must also be supposed that the regular changes of time and place are likewise connected. The later arrival of the herrings in a more northerly place than usual would indicate the near end of a fishing-period in one case as an earlier arrival in a more southern place in the other.

65. The favorable conditions on which the development of a great race of herrings depends are only found on a coast which is near the open sea. The great race of herrings which has periodically visited the coast of Bohuslän can scarcely be supposed to have developed there (at least not under conditions like the present), and the greater distance from the sea (and more especially from the Polar currents with their abundance of "herring-food") is doubtless the chief cause why the Bohuslän fishery-periods are more distinct, shorter, and separated by longer intervals than, for example, the fishery-periods of Western Norway. The same cause might also explain the fact that the sea-herrings for a number of years came sooner to the western coast of Norway than to the coast of Bohuslän, and that the space of time between the earliest and the latest arrival of the herrings near the coast was so much greater during the last Bohuslän than during the last West Norway fishery-period.

Another cause of the relative shortness of the Bohuslän fishery-periods may be found in the circumstance that, as the herrings belonging to the coast of Bohuslän spawn in spring, this season is the most suitable for spawning on this coast, whilst in the Kattegat, the Sound, and the Belts autumn is the more favorable season. As the sea-herrings which visited the coast of Bohuslän during the great fishery-periods chiefly spawned in autumn, it must be supposed that during their visit to the Skagerack they were compelled to spawn under comparatively unfavorable conditions, especially as regards the newly hatched young ones. This may, to some extent, have induced them to seek other spawning-places sooner than would have been the case otherwise. It is also quite likely that the coast of Bohuslän, towards the end of the fishery-period, when the herrings did not come in till December, was less inviting (at least for those herrings which spawned during winter). This may also have been caused by unfavorable weather. If, as *Axel Boeck* has shown, a temperature of the water of + 3° C. (37.4° F.) is not injurious to the herrings, it does not follow that this is not the case with a lower temperature accompanied by the formation of bottom ice. As most of the spawning-places on the coast of Bohuslän are located in shallow water, the cold must produce far greater changes in the temperature of the water than in the spawning-places on the western coast of Norway, which are located in deeper waters and are exposed to a much more powerful current of the sea with a far more even temperature. Too little attention seems to have been paid to the great injuries which several closely following severe winters must have inflicted on the spawning-places of the herrings. This unsuitableness of the coast of Bohuslän as a spawn-

ing-place for a great race of herrings which are accustomed to spawn in winter, would be another reason for opposing the idea that the Norwegian spring-herrings had alternated their visits between the coast of Bohuslän and the west coast of Norway.[81]

66. For the sake of comparison and completeness, we must also give an account of those circumstances which have been assigned as the causes of the disappearance or diminution of fish in localities where they have been observed for a long time. Among the causes which have been mentioned, the following are the principal ones: *Epidemics among the fish, changes in the nature of the water or of the bottom* by volcanic eruptions or by the accumulation of mud (caused, among other things, by the increased denudation of the coast consequent upon the destruction of the forests), and *steamboat traffic.*

In carefully examining the rich literature on this subject, it will be found that of all the causes which have been mentioned as having an injurious influence on the fisheries, only the following have been more generally accepted: *Excessive fishing, fishing with destructive apparatus*, destroying the vegetation of the bottom, the eggs, and the young ones, *preventing the fish from reaching their spawning-places, impure or turbid water, fish-of-prey*, and, finally, *lack of food* (which may be caused by human agencies).

Among those fish which, like the herrings, have either entirely or to some extent left places where formerly they have been very common for longer or shorter periods, we may here mention the following North Sea fish: The codfish, the haddock, the mackerel, and the shark. On the northeastern coast of America there are a number of fish of which the same is known. It thus appears that just the most important sea-fish are quite irregular in their coming and going, and, unfortunately, our knowledge of the causes of this phenomenon is exceedingly limited. Not only our scientific but also our historical knowledge of these fish, and especially of the herrings, is so limited that at present there is very little hope of having this scientific problem satisfactorily solved in the near future. Such a work requires not only a most extensive biological and physical knowledge of our waters, but also a thorough acquaintance with the history of the different fisheries. It is greatly to be lamented that *Axel Boeck's* premature death put an end to the important study of the history of the Norwegian herring-fisheries, to which he had devoted himself for several years, and that the rich material which he had collected for a history of the Scotch and Dutch herring-fisheries has not been worked up. It is quite likely that this material, properly worked up in a scientific manner, would furnish many and important contributions towards the solution of the problem regarding the migrations of the great races of herrings.

[81] It is entirely different, however, with those sea-herrings that visit the coast of Bohuslän or the west coast of Norway during winter for other purposes than spawning.

From the little that is known regarding the periodicity of the great herring-fisheries, it will be clear that the periodical coming and going of the herrings, which on the coast of Bohuslän has been observed for six successive centuries, cannot possibly be purely *accidental*, although the causes of this phenomenon can so far only be guessed at. All attempts to explain this phenomenon from accidental causes must therefore be classed with the mythical explanations.

67. In briefly recapitulating the different scientific theories regarding the migrations of the herrings, it will be found that they may all be arranged under the following heads:

A.—*The theory of a central race of herrings*, according to which all herrings which are in the world belong to one great central race, from which all kinds of herrings, both great and small, come. This theory is varied as follows:

1. This central race of herrings is supposed to live in the Northern Polar Sea, from which large schools emigrate every year to those coasts where herring-fisheries are carried on (*Anderson*, *Pennant*, and others).
2. This central race of herrings is constantly moving through the Northern Atlantic Ocean in a circle, whose extent is regulated by the declination of the sun (*Gilpin*).
3. Besides this great central race of herrings living in the Northern Atlantic Ocean, causing the great herring-fisheries, smaller local races have separated in course of time, causing the smaller coast-fisheries (*Lundbeck*).

According to the first two of these three theories there would be no regular migrations, whilst such would take place according to the third.

B.—*The theory of separate races of herrings*, according to which the different fisheries are caused by separate races of herrings, each having its own locality. This theory is varied as follows:

1. The theory of a *coast-race of herrings*, considering the herring exclusively as a bottom-fish. This may again be subdivided:
   a. Some suppose that there is only one local race of herrings in every place, which, if not driven away by human agencies, always stays near the coast. There is consequently no difference between coast-herrings and sea-herrings, and there are no regular migrations (*Nilsson*).
   b. Others think that more than one race of herrings may occur in one and the same place. There is consequently a difference between coast-herrings and sea-herrings, and there are regular migrations; but the proper homes even of the sea-herrings are the deep valleys on the bottom of the sea near the coast (*Axel Boeck*).
2. The theory of a *sea-race of herrings*, considering the herring as a surface-fish. This theory is also subdivided:

a. Some deny the occurrence of more than one race of herrings in one and the same place, the difference between coast-herring and sea-herrings (littoral and pelagian herrings) and regular migrations (*G. O. Sars*).

b. Others maintain that there is a relative difference between coast-herrings and sea-herrings, that more than one race of herrings may be found in one and the same place, and that the great schools of herrings migrate regularly (*A. V. Ljungman*).

68. It is doubtless necessary from time to time to give a review of the results of the scientific investigations, so as to obtain a suitable starting-point for new and systematic researches. As the scientific material has been considerably increased during the seven years since *Axel Boeck* published his well-known work "*Om Silden og Sildefiskerierne*" (The herring and the herring-fisheries), a new review of this material had become necessary to show the extent and character of our present knowledge, and to present the different opinions on a subject of such vast economical importance as the herring-fisheries. In endeavoring to contribute *my* share towards the solution of this important problem, I have invariably directed attention to the necessary theoretical premises, which, unfortunately, has often been neglected. In doing this one is less exposed to the danger of being led astray by the false hope of having hit the right thing in every case; a clearer view of all the points is gained, as well as a knowledge of the difficulties and of the insufficient character of the means by which these difficulties can be overcome. This will make us more humble and more cautious, and help us to avoid the proud certainty which is so often found in older and less critical works. As it cannot be expected that this in itself most difficult and practically most important question regarding a part of the biology of the herrings can be quickly solved by the labor of *one* person, it will be necessary that naturalists who have given attention to this subject should freely communicate to each other their different theories and the results of their investigations. The historic review of these investigations shows how beneficial and indispensable this interchange of ideas has been. The mere gathering of facts does not lead to any great result. These facts must be compared and combined into more or less developed theories, always, of course, remembering that there is a chance of these theories leading to no results or only to partial results. Theories are frequently apt to mislead; but even from the most erroneous theories some useful truth may finally be developed by constant work and by a continued purifying and eliminating process. Mistakes play an important part in the development of human knowledge and lead to greater caution and thoughtfulness in the future. The very knowledge that something is not as we supposed at first, is a step forward; in order that an erroneous opinion may be refuted, such an opinion must first have been advanced. *My* opinion on this point may also serve as an explanation of the circumstance that both in this and in former articles I have given

theories with whose errors I was well acquainted, errors chiefly owing to the fact that all the conditions for a satisfactory development of these theories had not been fulfilled.

If by the foregoing treatise I have succeeded *in making the accumulated scientific material more accessible, and in directing attention to the absolute necessity of more complete and more exhaustive scientific investigations* regarding the important fishery-question, my principal object has been reached.