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50 Years of Progress in Solving Fishery Problems

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The subject under consideration is a broad one, for accomplishments in the field of fishery biology are many. They may be found in the way of general additions to knowledge, contributions to the philosophical or practical solution of problems, benefits to the individual, and doubtless many others. However, this discussion will be confined to accomplishments in solving, or contributing to the solution of problems of fishery conservation and productivity, particularly in the field of commercial fisheries. The term "accomplishments" will be considered in its broadest sense, for fishery biology has contributed to many non-biological accomplishments.

The State of Fishery Knowledge 50 Years Ago

One procedure for checking on accomplishments is to consider the state of knowledge in the field of fishery biology 50 years ago, as a starting point from which to measure progress. Any difference in the situation then and now can be considered as an accomplishment, whether good or bad.

The Proceedings of the Fourth International Fishery Congress held in Washington, D.C., in 1908 provide a good source of information on this subject. Assuming some lag between the development of ideas and the presentation of such ideas in print, it may be reasonable to conclude that the reports at this Fishery Congress in 1908 reflect the general situation in the field of fisheries some 50 years ago.

In discussing international regulations of fisheries on the high seas, Mr. Charles E. Fryer, Superintending Inspector of the Board of Agriculture and Fisheries, London, made the following statement:

"The Fisheries carried on in the high seas are to a large extent concerned with fish of whose habits we know very little. Notwithstanding all that has been done here in this great country — probably more than

in the rest of the world put together, we still find that we are exceedingly ignorant of the minutiae of the habits and of the habitat of the fish which constitute the great harvest of the sea. The more we know, the more I think we find we need to know, and there is an enormous field of research to be exploited before we can decide whether any protective measures should be adopted for the furtherance of the fisheries carried on in the high seas, more particularly with reference to those fish which are classed as pelagic rather than those which are more local in their habits. The first consideration, therefore, would be to decide upon a method of investigation. . . . We have found that we have made regulations in many cases — in most cases — without sufficient information; and then, having made regulations, we have had to set to work to a very much larger extent to find out whether they are justified by the facts before us."

In a formal report later made to the Congress, Mr. Fryer also stated:

"The further afield the fishermen of any State go, the more certainly will they be brought into closer relations with the fishermen of fresh nationalities, and the longer will be the list of States which find that they have interests in common — interests which will, sooner or later, call for combined action in the direction of international regulation of the fisheries on the high seas. Whether such regulations should aim at the protection of the fishermen — either in their lives, their property, or their morals — or at the protection of the fisheries against overfishing, must depend on circumstances. . . . It is far easier to prove that the lives or property of fishermen are in danger than it is to establish any connection between the fishing operations of the fishing fleets and the fluctuations in the yield of the fisheries, especially in the deep seas; and as a preliminary to any effective steps for the protection of the fisheries on the high seas by way of international regulations, it will be found necessary to provide for international agreement as to the nature and extent of the statistical records to be kept and as to the method and scope of research into those natural phenomena which affect the productiveness of such fisheries more extensively than the combined operations of all the fishing fleets."

In the same discussions, Mr. Charles Hughes Stevenson, of the United States Bureau of Fisheries, expressed the following opinions:

"So far as regards the demersal or bottom fishes — the cod, haddock, halibut, flatfish, etc. — our present knowledge of the remedial effects of fishery restriction is so slight as scarcely to furnish a satisfactory basis for even national legislation in territorial waters, much less for complicated international regulations."

Finally, Dr. David Starr Jordan, Commissioner of the International Fisheries Commission of Great Britain and the United States (covering fisheries of the Great Lakes and other boundary waters of the United States and Canada) commented as follows on the problems to be considered under this Commission:

"In nearly all cases the final key to the situation is found in artificial propagation — the development of the hatchery. This demands, however, men who are willing to study their business and to learn thoroughly the nature of the fishes concerned — the egg, the fry, and the adult. Artificial hatching is not a process. It is an art, and like all arts it must rest on science. How much of the money spent on hatcheries has been wholly wasted no one can tell, but the amount is considerable."

The above quotations give a glimpse of the state of fishery science and fishery knowledge in 1908, although some of them could easily be contemporary. In general they indicate some qualitative knowledge of the fish but an almost complete lack of quantitative knowledge of fish stocks. This is further illustrated by reference to other reports at the Congress. In the discussions on menhaden, Professor Goode was quoted to the effect that he estimated approximately a million million of millions of menhaden (10^{18}) were killed annually by natural enemies. W. F. Hathaway's paper, read at the same meeting, indicated that Dr. Hugh M. Smith and Professor Baird, both noted figures in fisheries, approved of this general estimate and the reasoning by which it was deduced. Some rough calculations can be made using Goode's estimate. At one pound each, 10^{18} menhaden weighing 70 pounds per cubic foot would occupy about 1.4×10^{16} cubic feet of space. This is roughly equal to the volume of 1,400,000 square miles of ocean with an average depth of 50 fathoms. The total area of the continental shelf inside the 100 fathom curve, probably averaging 50 fathoms or less in depth, from the Gulf of Maine to the southern tip of Florida, is much less than 100,000 square miles. Thus, it would take more than 14 times the total space available out to the edge of the continental shelf, to provide room for the menhaden packed solid, "estimated" by Professor Goode.

With this as a background a conclusion can now be risked that we have made considerable progress in the science of fishery biology during the past 50 years, but probably less than one might off-hand assume. In the course of this progress it is likely we have disproved more than we have proved, and we can still look with the greatest sympathy upon Mr. Fryer's comments on the complexities of the ocean.

Transitional stages

One might maintain that we have gone through certain transitional stages in reaching our present position. We have passed through a period which might be designated as the age of the "Philosopher's Stone" — a period during which it was frequently hoped and believed by many that man had discovered some one magic operation or regulation which would ensure the continued productivity of the stocks of fish. Judging by the quotation from Dr. Jordan, many believed in 1908 that artificial propagation was the answer to our dilemma. Then and later many believed that through some specific regulation, such as the widely advocated proposal that all fish should be protected until they had completed one spawning, the continued abundance of fish would be ensured. Some years after 1908 a considerable group convinced themselves that the newly discovered phenomenon of increased growth rate with decreased density of fish, would ensure the productivity of the fisheries. This latter philosophy was championed at one time by Professor Garstang, and in my notes it is listed as the "Fairy Godmother Concept." These and other beliefs from time to time have held an important place in the thinking of fishery conservationists, but now are generally discredited as magic cure-alls by the current group of professional thinkers and workers in this field, although relics of such beliefs may still persist in some quarters.

As a matter of fact none of these contentions is completely wrong. Artificial propagation, minimum age or size limits, and increased growth rate under intensive fishing, all play their part in the solution to the problem

of maximum sustained productivity of the fish stocks. It is the job of fishery biology to evaluate this part and see that each measure or characteristic is made use of in situations where it will contribute most to the solution—and contrariwise, see that it is not used where it is useless or worse. They are items in the fishery administrator's kit of tools which the fishery biologist must help him to understand and use properly. The more such tools the fishery biologist can master and add to the kit, the nearer will we be to the solution of our problem.

During the past 50 years it has become generally accepted among professional fishery workers that there is no single simple solution to our fish productivity problems. These problems are highly complex, require thorough study of their many aspects, and usually require use of complex management programs. In very few cases can we claim to have achieved even partial solutions.

Two approaches to the study of certain fishery problems

The approaches to the study of these fishery problems can perhaps be divided into two general types. The first might be called the synthetic approach. This holds that we should begin with a quantitative study of the basic nutrients, their seasonal variation and distribution, and build up from these to quantitative knowledge of the plankton and the dependent food chain, to reach an adequate understanding of the quantities of useful fish and the factors which control their productivity. The second approach might be called the analytical approach. This, in general, proposes that studies begin with the fish which are being utilized, with their abundance and productivity, and follow from there down or out, to determine and evaluate the principal factors which control their productivity.

Proponents of each of the two approaches have held forth in the past and continue at present. Let us quote again from Mr. Fryer at the International Fishery Congress, concerning the International Council for the Study of the Sea:

> "That council started with a very large programme of research, involving many matters, which those who are interested in fisheries know are concerned with fishery development, and which influence the movements of fish, such as temperatures, currents, depths, salinity, and generally what is summed up in the word 'oceanography'. But, while all these matters are necessarily involved in the great question of fishing and fisheries, they are not necessarily essential to the study of some of the more important problems that we have to deal with, and the International Council which has been established with regard to the North Sea is finding that it has to limit its programme and to take up some of the more pressing and urgent questions, rather than to deal with the study of fish and fisheries of the ocean at large."

This experience of the Council is not unique. Continuing after the time of the Fishery Congress, many fishery workers held optimistic hopes that the basic productivity of the sea could be determined through development and application of quantitative methods for studying plankton, initiated by Henson and other workers some years earlier. However, by 1920 it began to be apparent that the complexities and magnitude of the sea were so great, and the errors of observation so considerable, that the precision of observation and extent of facilities were still far short of being adequate

to justify much hope that this synthetic approach could soon provide answers to the practical problems of the fisheries.

Since that time the science of fishery biology has developed, assisted in the development, or in some cases simply benefited, by new methods and tools which enable us to go far beyond the practical limits of 50 or even 25 years ago. The deficient statistical records, referred to by Mr. Fryer in 1908, have since been greatly improved and expanded so that for many of our fisheries we now have a fairly accurate record of the quantities of fish annually landed. In some fewer cases we have further information on the amount of fishing effort which has been expended in their capture. These two series of records together make it possible to obtain a measure of the availability of fish to the fishing gear, which reveals with more or less accuracy the changing density of the fish stocks. We have developed devices which provide us with accurate quantitative measures of various characteristics of the fishes' environment and it is possible to operate these rapidly, so that better and greatly increased quantities of data can be obtained by expenditure of the same time and effort. We have greatly improved and developed statistical procedures which make it possible to extract comprehensible information and conclusions from these tremendous bodies of statistical and other data and to test the significance of these conclusions. We also now have available efficient and complicated calculating machines with which to handle the masses of data which heretofore would require the services of such extensive manpower as to make the cost and time prohibitive.

In the field of planning we now have available more advanced hypotheses and theories (mathematical models if you will) concerning the dynamics of fish populations and their productivity, which make it possible to approach our problems in better organized and more effective ways.

Through various of these improved facilities we have advanced our knowledge somewhat with respect to one of the problems to which Mr. Fryer referred: that is, "the establishment of any connections between the fishing operations of the fishing fleets and the fluctuations in the yield of the fisheries."

Some accomplishments

Fishery biologists have demonstrated to the satisfaction of most scientists that there is a real and direct relation between fishing intensity and the sustained yield of some species, including salmon, halibut, haddock, North Sea trawl-caught fish, east China Sea trawl-caught fish, and whales. It has been shown that in some cases this results from capture of the fish before they attain their most productive size, in others through reduction in the spawning stock to levels which affect the production of young, while in others it develops simply from the reduction in the total abundance of marketable fish as a result of intensive fishing.

In some fewer cases it has been demonstrated, again to the satisfaction of most scientists, that through controlling the kind and quantity of fishing effort, a higher continuing yield of some species such as halibut and salmon can be obtained. In the case of stocks of whales off the east coast of Asia, the conservation management program of Japan—the only nation exploiting these stocks on a considerable scale—has resulted in their continued high productivity, in contrast to what has happened to whale stocks elsewhere

on the high seas. Other management programs recently have been undertaken through agreement on the use of large-meshed gear to protect small fish in the Gulf of Maine and the North Sea.

Progress in handling international problems

One of the earlier quotations from Mr. Fryer, among other things, referred as follows to the problem of international regulation of the fisheries on the high seas — "The further afield the fishermen of any State go, the more certainly will they be brought into closer relations with the fishermen of fresh nationalities, and the longer will be the list of States which find that they have interests in common — interests which will, sooner or later, call for combined action in the direction of international regulation of the fisheries on the high seas."

Prior to the 1908 Fishery Congress, various nations had tried from time to time to solve their joint fishery problems by conventions for the regulation of high seas fisheries. Some success was achieved in settling issues concerned with "rules of the road," conflicts in gear, and such operational problems. However, no particular success developed with respect to problems of fish productivity. Probably this resulted from lack of knowledge and techniques of fishery research and management as much as from anything, although the various complications deriving from international action must have played an important part.

Since that time, however, beginning in 1923, the United States, working with Canada and later with other countries, has embarked on a system of fishery research and conservation conventions which are proving brilliantly successful in restoring and safeguarding the productivity of common high-seas fishery resources. Progress has been made through careful step-by-step exploration of practical ways and means for developing and coordinating research, and devising suitable, effective, and practical conservation measures for promoting the sustained maximum productivity of the stocks of fish covered by the conventions. As one step proved itself and convinced an always skeptical fishing industry and public, which watched with a critical eye this increasing delegation of responsibility and authority to an international body, it was possible to move on to development and adoption of additional measures to handle more involved problems of these and other fisheries which have later been covered by fishery conventions. Thus by means of much study, discussion and negotiations, since the first halibut convention in 1923, we have developed and tested a considerable assortment of procedures for handling a variety of international fishery conservation problems.

The success of these conventions has been possible only because of the contributions of the science of fishery biology and some exceptional fishery biologists. The fishery commissions never have had funds or staff adequate to tackle all the direct and related problems of these fisheries — the synthetic approach. Their success, to a considerable extent, has resulted from the ability of their directors and staffs in identifying the most critical problems, getting the answers or a large measure of the answers to these problems, convincing the fishermen and public that these answers justified action, and then progressing onto the management steps in the complex of research and management.

Pacific Halibut Convention

The Halibut Convention between the United States and Canada, negotiated in 1923, was the first example of a successful attempt for international conservation regulation of a high-seas fishery. Several characteristics contributed to its success. First of all, the fishery concerned only two countries. It was confined largely to a single type of fishing operation. The fishery had expanded rapidly and the yields in individual areas had declined with alarming rapidity. However, success was furthered most of all by a realistic and effective research program which determined, then concentrated upon, the lines of research which revealed the relation between the fishery and the stocks of fish, and indicated the management measures which would be most productive. As first negotiated, this Convention provided for an international commission empowered to conduct research but not to regulate. The results of the research were so convincing that the Convention was renegotiated in 1930 to include terms which gave the Commission the authority to regulate the fishery. This Commission has its own research staff and makes use of an advisory committee including representatives from the halibut industry. The Convention provides for equal sharing of the expenses.

The Halibut Convention has been revised from time to time to keep it up to date and permit the most effective handling of its responsibilities. Following inauguration of the management program of the Commission, the decline in the halibut stocks was halted, and there has been a major increase in the productivity since then until at present the total annual production approaches that during the early years when the fishery was drawing heavily upon accumulated stocks.

Pacific Sockeye Salmon Convention

The United States and Canada ratified their second fishery convention in 1937, to cover the sockeye salmon of the Fraser River, which had been practically wiped out as a result of land slides and overfishing. This Convention provides for regulation only after research covering two cycles of the salmon run, or eight years. The costs of the Convention are divided equally between the two Governments, and the Commission is required to regulate the fishery in such a way that the catch is divided as nearly as possible in equal shares to the fishermen of the two countries. After eight years of investigation the Commission proceeded with regulation and the construction of fishways at Hell's Gate, which the Commission's investigations had clearly demonstrated were critical to the rebuilding of the salmon runs. The Commission's work is now showing practical results in the rapid increase in the runs of sockeye. Through the continued operations of this Commission it is confidently expected that the runs, worth many millions of dollars annually, will be restored and maintained at maximum productivity.

Inter-American Tropical Tuna Convention

Encouraged by the results of the Halibut and Salmon Commissions, the United States Government more recently has sought the solution of other international high seas fishery problems, using a similar approach. In 1949 we negotiated with Costa Rica the Inter-American Tropical Tuna Convention. This Convention provides for research on the yellowfin tuna, skipjack and the bait fish found in the waters off the Pacific Coast of the

Americas, and for recommending to the Contracting Parties any conservation measures found necessary. It adds two new features to our fishery conventions: One, the Convention is open-ended—that is, any of the nations concerned with these fisheries can adhere to the Convention at a later date with the consent of the countries then party to the Convention; and it provides that the costs of operation will be divided among the contracting parties in relation to the catch of the fishes covered by the Convention. It is hoped through this Convention to develop the cooperation of all of the coastal States off which tuna are found, in a program of research and, if necessary, regulation. Recently Panama has adhered to this Convention and is now a member.

Northwest Atlantic Fishery Convention

For the past two decades many people interested in New England's high seas fisheries have strongly advocated a fisheries convention among the nations fishing the Northwest Atlantic. This finally led to the negotiations in 1949 of the Northwest Atlantic Fisheries Convention, which Convention includes all ten countries from the two sides of the Atlantic whose vessels fish in the area. Several new features are included in the convention to handle the special problems arising with so many countries fishing in variable degrees in the different parts of the Northwest Atlantic area. The Convention provides for the setting up of separate "panels" for sub-areas, each panel to include only those nations fishing in the sub-area covered. It is possible by this means to bring the many separate problems involving the different groups of countries in each sub-area under one over-all convention. This avoids the necessity of a multiplicity of separate agreements. The operations of the Commission are financed on the basis of $500 annually from each contracting party, with the remaining costs divided among the parties in proportion to the number of panels on which they are members. In the field of research it provides that the Commission set up under this convention shall arrange for the cooperative study of the fisheries problems of the area through preparation of an over-all research program, and coordinating the work of the several countries party to the Convention, rather than by operating its own research staff, as do the halibut, salmon and tuna commissions.

North Pacific Fisheries Commission

The most recent fishery agreement to which the United States is a party is the North Pacific Fisheries Convention, negotiated between the United States, Canada and Japan, to resolve their serious and persistent fisheries problems in the North Pacific. In this convention several important procedures and concepts were introduced to provide for suitable handling of a number of new problems not covered by previous agreements. Probably the foremost is the concept of abstention. This concept sets forth the principle that when a stock of fish is being completely utilized and regulated, on the basis of extensive scientific research, to provide for the maximum sustained productivity of this stock, the entry into this fishery of the fishermen of other countries not previously participating in the fishery and in the related research and management program, could not increase the over-all sustained production but would serve principally to discourage such research and management programs as had preserved the productivity of the fishery.

Any effective program of research and regulation restricting the operations of a nation's fishermen, to promote maximum productivity, would be virtually impossible to maintain if the gains in productivity thus produced could be harvested by fishermen of other countries which had not participated in the research and regulation nor submitted to the restraints. It therefore follows that under such conditions non-participating countries should agree to abstain. This principle is observed in the Convention. The Convention also deals with stocks of fish rather than areas as management units, a sound biological concept which follows our actual practice in the halibut and salmon conventions. It also provides for the setting up of a committee to decide on a possible point of dispute concerning the line provisionally agreed upon for separating stocks of salmon of North American and Asian origin.

The Convention provides for the coordination of the research of the several countries, with the Commission itself carrying on research only where it is not feasible to use established research agencies. It provides for either trilateral or bilateral action on research and necessary conservation measures, with participation in decisions and recommendations limited to the Commissioners from the countries engaged in substantial exploitation of the stock concerned. Joint expenses are to be paid in proportions recommended by the Commission and approved by the Governments. This provides for the division of costs in relation to the fields of activity of the Commission and the countries chiefly benefited by its activities. These provisions give the Convention a flexibility which makes possible the handling of any fishery conservation problem in the area, whether it involves any two or all three countries.

There are other international fishery problems with which the United States is much concerned. They are being studied to determine whether ways and means can be developed for their handling. I am optimistic that with the continued progress of the science of fishery biology, information and procedures can be developed to a point where these problems can be handled with a success equal to that which has characterized our past activities in this field.

Conclusion

What light does this brief review of the past 50 years throw on the future? First of all, it indicates that our progress in handling problems related to maximizing the productivity of stocks of fish has been handicapped chiefly by lack of information and by mis-information. To correct this situation is the primary task of fishery biology. How can this best be done? One thing we can do is stress the development of more precise data. Unless we can attain a much higher degree of precision in our evaluation of the essential parameters of fish stocks, our conclusions must continue to be guesses. Another productive move would be to concentrate further attention on determining and evaluating the controllable factors affecting fish populations. An understanding of other uncontrollable factors is very useful in predicting changes in the availability of fish stocks and sometimes in enabling us to avoid fruitless regulations, but in the final analysis we will not be able to control these factors to produce the results in which we are most interested.

Of the controllable factors, probably the most important is the intensity

of fishing. Present work shows that, at least in many species, this intensity affects the abundance level of fish stocks. We know, as a biological truism, that in general as a stock of fish increases in numbers natural mortality increases until the number of fish is brought into uneasy equilibrium with the environment. The actual level may vary from year to year but to the best of our knowledge it maintains some long-time over-all average (if we can ignore the climatic cycles stretching over hundreds or thousands of years.) Such a balance is developed through increasing intra-specific competition for food and space, increased cannibalism and predation, or other factors related to increasing density of population. We know also that as a population is reduced in abundance a level eventually must be reached where the production of eggs and young is insufficient to make full use of the environment. At some level or levels between these extremes, the optimum conditions must exist with respect to adequacy of spawning and minimum mortality rates. It may be that the level required for adequate spawning is so low as to enable us to disregard it as a practical matter. It may also be that significantly increased mortality rates develop at abundance levels sufficiently high that we may disregard them in a reasonably intensive fishery. However, results of some investigations such as those on haddock, indicate that these factors can be of considerable importance, at least at some of the abundance levels actually observed. Where this is so, an understanding and evaluation of these factors would provide some of the most promising tools for the fishery investigator and administrator.

DISCUSSION

BIOLOGICAL SESSION

Discussion Leader: PAUL GALTSOFF

Discussion Panel: J. L. MCHUGH, THOMAS H. LANGLOIS, HARDEN TAYLOR

Galtsoff: You have heard the papers given this morning by Dr. Hile, Dr. Graham, Mr. Herrington and Dr. Schaefer. A certain emphasis has been placed on the use of mathematical analysis to reveal the mysteries of the population fluctuations in the sea. I would like the audience to inject their ideas in relation to these annual fluctuations and the social, political and economic disturbances caused by changes in the ecological situation in the fisheries. The first paper we will have in our discussion on will be Dr. Hile's paper and the problems of the fisheries in the Great Lakes.

Langlois: I am in substantial agreement with Dr. Hile's paper. I do think that several points should be carried further to take in the fluctuations in the fisheries. The variability found here is a function of environment and is apart from fishing activity.

Lake Erie is a pool in the Great Lakes system, besides being considered a separate entity. All of the lakes except Lake Erie are below sea level. Lake Erie