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INTERNATIONAL TECHNICAL CONFERENCE ON THE CONSERVATION OF THE LIVING RESOURCES OF THE SEA

Types of scientific information required for a fishery conservation programme

In accordance with the advice of experts consulted by the Secretary-General, technical papers on certain items of the provisional agenda were invited from a number of authorities. The Secretary-General has the honour to communicate the following paper by Chief Biologist, Mr. G.L. Kesteven, of the Fisheries Division of the Food and Agriculture Organization of the United Nations. Summaries of this paper in English, French and Spanish will be issued as A/CONF.10/L.9 (Summary).

THE CONTRIBUTION OF OCEANOGRAPHIC RESEARCH TO FISHERIES SCIENCE

by

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I. INTRODUCTORY

1. The contribution of oceanography to fisheries research (which means research in economic and technical fields as well as in biological fields) is to be understood only in terms of the applied character of fisheries science. An effort is made in the following paragraphs to review the implications of this statement. However, one principal consequence should be stressed, namely, that it obliges the fisheries scientist to discriminate keenly, and frequently to scrutinize his activities to determine whether they will stand the test of their application to practical fishery problems.

II. SOME DEFINITIONS

2. The term "oceanography" is taken to be a correlate of "limnology" and thus, like that term, to comprehend the whole of the scientific work with a biological objective or of biological use, bearing upon the hydrosphere. This definition derives authority from many works from among which the monumental, and already classical work, The Oceans by Sverdrup, Johnson and Fleming (1942), may be chosen for citation. The value of regarding oceanography as a correlate of limnology may be judged from the success of the comprehensive treatment of freshwater problems in such standard periodicals as the Internationale Revue der gesamten Hydrobiologie u. Hydrographie, and the standard text by Welch (1935) for which Limnology is the title. There appear to be no adequate reasons for the restrictions imposed upon the term by some workers, who regard it as being concerned only with physical and chemical features of the oceans, and even as the special preoccupation of naval research establishments.

3. Oceanography should signify the study of the oceans as water masses and of the biota which inhabit them. If not qualified, as it is in expressions such as "fisheries biology", it is a pure science with no limitations upon the range or detail of the subject-matter of its enquiry. A qualifying term, such as "fishery" signifies an orientation of the enquiries and a limitation of the field, rather than a specialized extension; thus, fisheries oceanography is the investigation of the physico-chemical and biotic properties of the oceans required by fisheries

science - it does not mean all the technical aspects of fisheries research. It has a correspondence to terms such as "agricultural botany".

III. GENERAL CONSIDERATIONS

4. As a beginning we may say that oceanography holds a relationship to fisheries corresponding to that which meteorology holds to agriculture. But we must go further and describe it also as the "soil-science" of fisheries. These two aspects were discussed by Tait (1952) in his Buckland lectures, from the points of view of physical and chemical properties of the sea, respectively, in relation to fishes. The two relationships include the more general, as well as the more particular, aspects of relations of aquatic organisms to the physical and chemical factors of their environment, as described in the now voluminous literature on ecology, as well as in classical studies of animal physiology and ecology.

5. Fisheries biology has the task of describing fishery resources. Its programme traverses, in a general sense, six principal phases:

a. If the area in which the biologist is working is virgin, a survey must be made to determine the general characteristics of the area and of its fish stocks; the principal compositional features of the stocks must be described. For most of the present fishable areas, such information has been accumulated in the course of fishing operations and from work in marine biology; a programme in fishery biology which starts when the industry is already well developed, must first collate all this information.

b. The general features of the stocks of the species to be investigated must be determined. The species must be correctly identified, and the continuity and taxonomic homogeneity of these stocks must be examined. This work may or may not require the refined taxonomic study known as racial investigation, but it is in any case a distribution study which must concern itself with details in the bionomics of the species.

c. The bionomics of the species must be discovered, that is, the general life-history, ontogenology (embryology, growth and gerontology), including feeding habits, reproduction and migratory habits.

d. The composition of the stocks is to be determined, and if they exist in separate units, this determination must be made for each separately. This compositional study concerns the age, sex, size, maturity and other groupings of the population.

Such analysis generally reveals a fluctuation from year to year in composition of the stocks. Frequently, there is also considerable variation from area to area and between distinct segments of the stock. The study should seek, not only to describe the composition and its fluctuation, but also to discover the causes of these fluctuations and, if possible, to evolve a method of predicting the appearance of the fluctuations.

e. Following directly from stage d., we require the measurement of the properties of the population. These properties are potentials for growth and reproduction, and represent viability as a complement to the mortality which the stock sustains. In this stage there is effected a considerable concentration of information because, not only must data on the bionomics and composition of the stocks be reduced to expressions summarizing the consequence of these structural features, but there must also be a reference to the physiological, physical and other data concerning the factors which determine the properties of the population as a whole. This work should also aim at prediction.

f. The fishery biologist must then collaborate with the fishery economist and the fishery technologist in applying the general theory of fishing, to give precise expression to the relations between the properties of the population and the effect of fishing operations.

6. The essential feature of this programme is that it is concerned with populations: its purpose is to develop an embracing description of the population as a whole and of its response to changes in the environment, including among such changes those in fishing intensity.

7. The fishery biologist's responsibility in respect of these populations is one of two kinds, which may be summed up in two questions. Firstly, what type of population, and where? And secondly, of what abundance? The first question belongs, in the main, to the exploratory stage, the second to the management stage. In a way, also, these questions are concerned with different kinds of abundance:

those which relate to the availability of the fish to fishing operations, and those which relate to the real abundance of the stock; these are covered respectively by the first three and the last three of the stages listed above.

8. In the following paragraphs we give a brief account of the role played by oceanography in assisting fisheries biology in describing fishery resources, in each of the principal divisions of its work.

IV. OCEANOGRAPHY AND THE DISTRIBUTION OF FISH

9. In its broadest sense, this is marine zoogeography, but the fishery biologist has to press his enquiry far deeper because he seeks to establish the ontogenetic distribution patterns, and, moreover, the seasonal, annual and even secular modulations, for each species of commercial importance. The great oceanographic cruises, of the Challenger and others since, have established the major features of our picture of marine zoogeography and yet there remains much to be done to enable us to evaluate unexploited areas in a way that will give fishermen the information they need to plan the development of fishing operations.

10. The zoogeographic account of the distribution of marine faunas is, in effect, a generalized one referring to groups of species and to individual species where these characterize the fauna and serve as indicators of identified conditions. The distribution patterns usually referred to in zoogeography indicate the broadest limits within which the faunas are seen to occur. The more restricted limits, within which the various ontogenetic stages move, are not so important to zoogeography as they and their seasonal and other modulations are to fisheries. But the greater pattern, as well as its component parts, is the grosser manifestation of the reaction of the individual organisms to the various elements of their environment at the behest of their own physiology. The general adjustment of the organism to its medium, in respect of its respiratory and osmo-respiratory requirements, set the general limits within which it can move; differences in these requirements, between ontogenetic stages, may give separate distributions to these stages. The nutritional requirements and peculiar needs in respect of reproductive habits further complicate the picture, as the organisms

undertake feeding and reproduction migrations in search of the situations where the necessary conditions are satisfied. It is, perhaps, no misrepresentation to say that the objects of this enquiry are, firstly, to describe the distribution of the fish and the conditions in which they are found and, secondly, to find a means of predicting where such conditions will be found - as a means to predicting where the fish will be. It must be stressed, however, that the accurate account of distribution requires detailed elucidation of the life history of the species.

11. At present we are concerned mainly with the types of fauna found in various situations, with the task of characterizing an area in respect of the composition of its fauna and, in regions where the fauna is known, with evolving means of predicting the variations in the distribution of elements of that fauna and of ontogenetic stages of those elements.

12. The role of oceanography in this phase of the programme is, first, to furnish the description of the physical, chemical and biotic properties of the water masses, and, in doing so, it corresponds to soil science coupled with climatology. When the distribution patterns are revealed, the role of oceanography corresponds to that of meteorology in predicting the conditions to be found, and the task of the fishery biologist is then to predict the response of the fish stocks to such conditions.

V. OCEANOGRAPHY AND THE ABUNDANCE OF FISH

13. In this part of the programme we may consider three types of problem having a common basis. We are concerned, (a) with the natural abundance of fish in an area, a problem which has a practical meaning only for unexploited areas, although a method of estimating the potential natural abundance of an exploited stock might solve many of the problems concerning abundance under conditions of exploitation; (b) with the functuations in abundance which have manifested themselves in all exploited stocks, whatever the degree of exploitation; and (c) with the special problem of the effect of fishing operations on the abundance of the stock.

A. Natural abundance

14. The assessment of the natural abundance of stocks in virgin areas is a task of peculiar difficulty which demonstrates, perhaps more than anything else, the special character of the work of fisheries science and the abstruseness of its problems. A simple example will serve to indicate the nature of the problem and the difficulties. Somali fishermen have for many years been catching tunas off the Somali coast, and for some years a few small canneries have been processing this catch for the export market. The canneries would like to expand their operations, but to do so they must increase their catch of tuna. The question is do substantial stocks of tuna, accessible to fishing craft operating from Somalia inhabit the waters of the Arabian Sea east of Somalia, or are the occurrences from which the fishermen have made their catch merely sporadic invasions from a principal area lying remotely from Somalia? This may be a question of ontogenetic distribution pattern, the understanding of which could lead to a method of predicting the times and conditions under which these occurrences take place, and even of the fluctuations in relative numbers of fish appearing from time to time. But this would still be insufficient: the cannery operators must have some indication of the actual numbers likely to be available in order to decide the amount of fishing equipment (craft and gear) which could be used effectively, and of the amount of processing equipment which would be required to handle the catch.

15. There are probably two broad avenues of approach to this problem. One is by way of evaluation of the area in terms of basic productivity and description of food chains. This would be possible only for stocks endemic to the area and not to transients. The other approach is by way of special sampling which, in the case of pelagic stocks, may include aerial observation. It may be noted that in this field of work there is urgent need to elaborate and improve the methodology of searching and sampling and it seems likely that greater use can be made of reference to oceanographic factors as determinants of the behaviour of the fish.

16. In the more general task of measuring the productivity of an area, and relating it to water and meteorological conditions, the oceanographer must take a leading role; the more restricted task of the fishery biologist is to develop the understanding of the nutrition of the economic species so as to be able to use the data on food availability.

B. Fluctuations in abundance, and the effect of fishing operations on abundance

17. The structure of the problem was symbolized by Russell (1942) in his well-known equation, which says that the difference in a stock of fish between one season and another can be represented by the balance between Growth + Reproduction/ Natural Mortality + Fishing Mortality. We may take these four elements as the plan for our enquiry.

1. Growth

18. The growth of any individual may be taken to be the result of the operation of factors which may be considered in three groups, (a) genetic factors, (b) food supply, and (c) the environment affecting food procurement and the subsequent metabolism. Between these arise interactions. In the past, fishery biology has concerned itself chiefly with measuring and describing the ontogenetic manifestations of growth: it has made little analysis of growth itself as a physiological process. The initial approach has, however, furnished a useful description of the grosser features of the problem, and some attempt has been made to measure the relations between rate of growth and food availability and environmental conditions. Whether much further progress can be made along this line before more detailed enquiry is made into the physiology of growth might be questioned, but both types of enquiry require much information from oceanography on the environment of the fish.

19. The first information required is that concerning food availability; the second is that concerning temperature, salinity, trace elements and biotic factors which influence the procurement of food by the fish and the processes by which it digests and assimilates what it ingests. But the work of fishery biology has been concerned generally with estimates of average growth in populations and with this as a means of characterizing year-classes and the conditions prevailing from year to year. Recent work has carried the theory further to attempt to use such growth as a means of estimating the biomass production of the population as a whole. Such work will accomplish a practical effectiveness, however, only after the underlying physiology of nutrition and growth have been studied further and this will mean, as in the study of nutrition and growth of domestic animals, that there must be controlled experiments in which both food supply and environmental factors are at least precisely measured if not actually controlled.

20. In this field of enquiry, taking it to be the responsibility of fishery biology to measure the growth of the population, the contribution of oceanography is twofold - initially in aiding the description and analysis of these systems, and subsequently in providing data for a prediction system. In the initial phase the contribution is of data on all factors which might directly or indirectly affect the nutrition and growth of the fish. In the prediction phase the data would concern certain critical factors.

2. Reproduction

21. Although in the fishing theory equation this term refers essentially to recruitment into fishable stocks, the fishery biologist has some concern with the whole range of phenomena which lead to the reproductive act, and those which lead from that act to recruitment. That is to say, there is a concern with sex ratios and fecundity, with length and age at first maturity and, within each season, of the maturation of the gonads, with the spawning act itself (including fertilization), with embryonic development and hatching, with larval and post larval development, and with growth and survival through these and the young-fish stages. Some workers consider that the only practicable approach to the problem of replenishment of the stock is to measure recruitment as it is taking place, or the potential recruits shortly before they enter the fishery. Other workers contend that it is possible to enter more deeply into the system and to attempt some measurement of the series which connects spawners with recruits. Among these latter there are some who believe that, although in general the eggs produced at each spawning are always so far in excess in numbers of individuals which survive to be recruits to the fishery, so that little connexion can be found between the number of eggs spawned and the subsequent recruitment, nevertheless the brood strength is determined in the main by one or more critical factors at certain critical points in the life of the brood. Efforts at demonstrating this hypothesis have aroused some controversy. However, it is unquestionable that the sequence described above is closely dependent upon environmental conditions and that any understanding of it, let alone any measurement of it or formulation of a prediction system, must make demands on oceanography.

3. Natural mortality

22. This term is perhaps even more recalcitrant than either "Growth" or "Reproduction". We may argue, a priori, that mortality may be caused by predation, parasitism, disease, lethal genetic characters, malnutrition and physical factors such as temperature and salinity extremes, but there seems to be little prospect yet of measuring the result of the operation of each of these factors separately or, as an antecedent to that result, the intensity of each factor. Nevertheless, again we must look to oceanography to furnish the fishery biologist with some of the information which he will require in this field. At the present stage, natural mortality must be accepted as a sum arrived at after deducting measured fishing mortality from estimated total mortality. It might be possible to correlate variations in natural mortality with variations in environmental factors and thus to approach both analysis of the causes and prediction of intensity.

4. Fishing mortality

23. In this field, oceanography has a small contribution to make in respect of the influence of weather and sea conditions on the intensity of fishing operations and their efficiency, but we defer further consideration of this to section VII of this paper.

5. Fluctuations in abundance

24. A great deal of work has been done in describing the fluctuations in abundance of exploited stocks and analysing these fluctuations in terms chiefly of variations in strength of brood-classes and in recruitment into fishable stocks. This work can proceed at various levels - either with simple description of the fluctuations and elementary correlation with various environmental factors, a course which does not promise much reliability in its results, or with varying degrees of penetration of the analysis into the systems, with the conviction that if relationships are truly identified and relations usefully measured, prediction systems may be evolved which have a practical and reliable value.

C. Fishing theory

25. Perhaps the ultimate objective of fishery science in respect of fishing operations is to prepare for each unit fishery a description of the fish stocks and of the effect on them of the fishing operations, in order to permit the design of a plan of management of the fishing operations which will ensure the best exploitation of the stocks. The description for each unit fishery will be along the lines of the Russell equation, and the dependence of this work upon oceanographic enquiry is clear.

26. Best exploitation clearly means that which will give the best and most sustained yields, and it may be signified by the term "fish husbandry" - a concept which has recently emerged in respect of marine stocks and which deserves consideration though the end-result might not be precisely analogous to snimal husbandry. This touches upon the possibility that there might be other direct intervention in the stocks besides the fishing operations. Some speculative thinking has turned to the possibility of intervening in some of the basic phenomena of the sea, and there have been experiments in fertilization. The realization of artificial upwellings or of control of the movements of marine stocks is probably not feasible as it would usually involve operations quite as ambitious as the fishing potential.

VI. OCEANOGRAPHY AND THE BEHAVIOUR OF FISH

27. Most of those who make their livelihood by fishing, especially perhaps those who do it in a small way, know a good deal about the movements, shoaling and feeding habits of the fish on which they depend. The knowledge is, however, not very accessible or systematic and therefore very susceptible of extension and improvement. It will obviously need a good deal of physical as well as biological study to account for the behaviour of fish shoals, and their changes in density, position and depth with wind, tide and other factors; the experienced fisherman does not expect a complete explanation but any advance which would allow him to improve his gear and methods would be very welcome. Reports have been given of fish moving away from shoal water before the approach of storms and heavy swell,

of voracious feeding just before a storm and even of fish showing awareness of impending earthquakes, but here too, the information is meagre and unsatisfactory. Some experiments have been made on the reactions of fish to light and something is known of the sort of bottom they prefer, but in this too there is much scope for careful observation and record. Fish behaviour might well be a rewarding study and too little attention seems to be paid to it: the collection and sifting of what can be learnt from fishermen would in itself be useful. But it is clear that the tremendous scope of the observations and experiments necessary for a study of these phenomena calls for all the resources of oceanography as well as those of fisheries research.

VII. OCEANOGRAPHY AND FISHING OPERATIONS

28. The dependence of fishing operations on the weather and sea conditions might seem to need little discussion, but as oceanography and fisheries science advance it will always be wise to consider whether more knowledge of the behaviour of the fish, or of the craft and gear, in different weather conditions, can be used to reduce loss or damage and also the time spent on unproductive effort. Methods of predicting waves and swell, and of obtaining warning of their approach, have probably arrived at a stage where they might be used to prevent journeys to offshore banks at a time when the swell found there is too high for fishing; they might also help to prevent damage to moored or beached craft. There is also much to be learnt about the actual operation of underwater gear and the reactions of the fish under different conditions, and fresh opportunities are offered by the new methods of underwater observation, photography, cine-photography and television.

VIII. RELATIONS BETWEEN OCEANOGRAPHY AND FISHERIES SCIENCE

29. There is really no need to emphasize the importance of data on the environment for a study of any organism (or population of organisms) and, as oceanography is defined here, it is the science which will furnish the environmental data required by the fisheries biologist. It is reasonable to argue that fisheries science can no more do without oceanography than agricultural science can do without meteorology. But whereas oceanography (the basic study) has the entire marine hydrosphere as its field of enquiry within limits set only by the interest of the worker and the facilities he can secure, fisheries oceanography is to be defined strictly according to the area of interest and the very practical problems which confront the fisheries biologist.

30. It will be clear from the foregoing, that many types of oceanographic information are required to solve the different problems found in fisheries investigations. Different variables have to be observed, with patterns and intensity of observation suited to the fishery problem. In the determination of general limits of distribution of a fauna, or a species, broad isotherms, isohalines and so forth are sufficient, but for more detailed description of distribution a more precise measurement, with much narrower intervals between the isolines, is required. The oceanographic programme for fisheries must therefore be planned with as clear a view as possible of the factors which influence the biologist's problem and of the use which he hopes to make of the material and data which are collected. It would perhaps not be dogmatic to say that, where resources for oceanographic research are limited, these should be employed in probems which can easily be formulated, rather than in broader fields in which there is only a general hope that the data will prove to be of use at some unspecified time in the future.

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