A/CONF.10/7

PAPERS PRESENTED
at the
INTERNATIONAL TECHNICAL CONFERENCE
on the
CONSERVATION OF THE LIVING RESOURCES OF THE SEA

Rome, 18 April to 10 May 1955

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NEW YORK, 1956

A/CONF.10/7
January 1956

UNITED NATIONS PUBLICATION
SALES NO.: 1956.II.B.1

Price: $3.00 (U.S.A.); 22/6 stg.; Swiss francs 13.00
(or equivalent in other currencies)

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CORRIGENDUM

1. On page 139, delete the third paragraph, starting "A biological appraisal..." and ending "...no significant difference to the figures adduced." and substitute the following:

    A biological appraisal of this kind should be made for the entire ocean; it will then be possible to classify the various zones of the ocean. Purely as a guide, the quantity of living matter on the floor of the continental shelf may be considered 0.3 times 10^{10} tons and the quantity of plankton 0.03 times 10^{10} tons. These figures must, however, of necessity be corrected by the index of productiveness, which may vary by as much as 50 to 60 times from one part of the ocean to another. The quantity of plankton outside the continental shelf may be estimated, even more approximately, at 1.2 times 10^{10} tons and the quantity of benthos on the ocean floor at 0.1 times 10^{10} tons. By adding all these figures together, the weight of the animal population of the whole ocean may be estimated at between 1.63 times 10^{10} tons, excluding fish and sea mammals, which would, however, make no significant difference to the figures adduced.

2. In the third line of the following paragraph, for "temperature" read "temperate."

FOREWORD

The International Technical Conference on the Conservation of the Living Resources of the Sea which was held in 1955 marked the second occasion on which a United Nations conference discussed the conservation of fish and other marine resources. The earlier occasion was in 1949, when this subject was among those discussed at the United Nations Scientific Conference on the Conservation and Utilization of Resources.[1]

The 1955 conference was confined to problems of conservation of living marine resources. It was attended by delegations from forty-five countries, including all the major fishing countries of the world, and observers from six countries and from specialized agencies and inter-governmental fishery organizations.

The Conference was called by the Secretary-General of the United Nations at the request of the General Assembly,[2] to assist the International Law Commission in the preparation of draft articles on certain basic aspects of the international regulation of fisheries. In view of the technical nature of many of the problems involved in the conservation of fisheries, the General Assembly thought it desirable that the problems should be discussed on a wide international basis by qualified experts, who would prepare a report embodying appropriate scientific and technial recommendations to be taken into account in the further studies of the International Law Commission. It was emphasized that the Conference should not discuss matters of a legal or political nature, to avoid prejudging related problems awaiting consideration by the General Assembly.

The Conference was held in Rome at the headquarters of the Food and Agriculture Organization of the United Nations (FAO) from 18 April to 10 May 1955, and its report was presented to the International Law Commission at the latter's meetings in June 1955.[3] At the Conference, twenty-five

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[1] See Proceedings, vol. VII, "Wildlife and Fish Resources" (sales number: 1950.II.B.8).

[2] Resolution 900 (IX) of 14 December 1954.

[3] See Report of the International Technical Conference on the Living Resources of the Sea (A/CONF.10/6; sales number: 1955.II.B.2) and Official Records of the General Assembly, Tenth Session, Supplement No. 9, A/2934.

technical papers were presented, of which six[4] had been prepared by individual experts or organizations on subjects suggested by the Secretary-General, acting on the advice of a group of experts who assisted him in preparations for the Conference. The following were members of the advisory group of experts: U. d'Ancona, Chairman, General Fisheries Council for the Mediterranean, Rome; N.B. Cacciapuoti, Deputy Director, Natural Sciences Department, United Nations Educational, Scientific and Cultural Organization, Paris; E. del Solar, Technical Adviser to the Peruvian Fishery Society, Lima; D.B. Finn, Director, FAO Fisheries Division, Rome; A. Fridriksson, General Secretary, International Council for the Exploration of the Sea, Charlottenlund, Denmark; J.L. Kask, Chairman, Fisheries Research Board of Canada, Ottawa; C. Miles, Secretary, Indo-Pacific Fisheries Council, Bangkok; and M.B. Schaefer, Director of Investigations, Inter-American Tropical Tuna Commission, La Jolla, California.

Apart from the six papers requested by the Secretary-General, papers were presented in response to his invitation to Governments, specialized agencies and inter-governmental fishery organizations to submit papers on matters within the terms of reference of the Conference and of special interest to them.

With the exception of two papers which have already been published elsewhere, the present volume contains all that were presented at the Conference.[5] Following an introductory paper on the historical development

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4/ "Concepts of Conservation" by Mr. Graham; "The Scientific Basis for a Conservation Programme" by M.B. Schaefer; "Aspects of the Life History of Certain Resources of the Sea in Relation to the Physical Environment" by the United Nations Educational, Scientific and Cultural Organization; "International Conservation Problems, and Solutions in Existing Conventions" by W.C. Herrington and J.L. Kask; "Regulation of North Sea Fisheries under the Convention of 1946" by C.E. Lucas; and "Classification of International Conservation Problems" by G.L. Kesteven and S.J. Holt.

5/ The two previously published papers were "The Contribution of Oceanographic Research to Fisheries Science" by G.L. Kesteven, which was distributed to conference participants as document A/CONF.10/L.9 and was published in FAO Fisheries Bulletin, vol. VIII, No. 2, April-June 1955 (Rome); and "Stock and Recruitment" by W.E. Ricker, distributed as document A/CONF.10/L.10, which was an abridged version of an article of the same title published in the Journal of the Fisheries Research Board of Canada, vol. XI, No. 5, September 1954 (Ottawa).

of concepts of conservation, the papers in the volume are grouped into the following general categories: broad scientific and theoretical aspects of conservation; operations under existing international conventions; and specific regional resources or problems. Finally, there are two papers dealing in more neral terms with the identification of conservation problems and suggestions for their solution.

EXPLANATORY NOTE

The following symbols have been used in the tables throughout the report:

Three dots (...) indicate that data are not available or are not separately reported.

A dash (-) indicates that the amount is nil or negligible.

A blank in a table indicates that the item is not applicable

A full stop (.) is used to indicate decimals.

A comma (,) is used to distinguish thousands and millions.

A slash (/) indicates a crop year or financial year, e.g., 1953/54.

Use of a hyphen (-) between dates representing years, e.g., 1950-54, normally signifies an annual average for the calendar years involved, including the beginning and end years. "To" between the years indicates the full period, e.g., 1950 to 1954 means 1950 to 1954, inclusive.

References to "tons" indicate metric tons, and to "dollars" United States dollars, unless otherwise stated.

The term "billion" signifies a thousand million.

Details and percentages in tables do not necessarily add to totals, because of rounding.

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CONCEPTS OF CONSERVATION

by

Michael Graham, Director, Fishery Research
United Kingdom Ministry of Agriculture and Fisheries

(The mimeographed text of this paper appeared as
document A/CONF.10/L.2)

From early times men have realized that enough mature fish must be allowed to spawn and sufficient young fish must be allowed to grow to a satisfactory size. Often, indeed, men have legislated quite prematurely when neither process was yet in danger. On the high seas, the salmon and halibut off the western seaboard of North America have provided object lessons in conservation. These two examples are not necessarily to be followed blindly, but it is noteworthy that experience of them has led in the New World to emphasis on the maximum sustainable yield as the primary aim of conservation. Historically, the ills that have called for conservation have usually been a decline in catch per unit effort, and smaller average size of fish. Clearly, remedying of these ills is expected to be incidental to increasing or maintaining the total yield.

Some early history

A philosophy of conservation of fisheries is not the monopoly of any single country, but it is convenient to trace the early history of the concepts in one country where it is well documented, namely England, using that history as an example of what doubtless developed in many other parts of the world. Only a few selected examples are needed, beginning with what is possibly the earliest example of regulation of fisheries in England, namely, the regulations for salmon fishing submitted to the king by the county of Cumberland in 1278, and approved. These regulations included closed times, restrictions on the use of nets and provision for a gap between nets in the river big enough to allow a sow and her pigs to pass - later colloquially called "the king's gap". The preamble to the regulations has been translated as follows:

> "The jurors of Lyth and Eskdale and the jurors of Cumberland and Allerdale have reported that serious destruction has been wrought in the River Eden and the River Esk, and in other rivers

> of that county, to salmon ascending to spawn and to salmunculi, descending to the sea, whereby that county and all the adjacent counties have suffered grievous harm" 1/ (Moore and Moore, 1903, page 172). 2/

In 1376 the Commons petitioned the king of England, complaining that

> "where in creeks and havens of the sea there used to be plenteous fishing, to the profit of the kingdom, certain fishermen for seven years past have subtily contrived an instrument which they called 'wondyrchoun', made in the manner of an oyster dredge but which is considerably longer, upon which instrument is attached a net so close meshed that no kind of fish, be it ever so small, which enters therein can escape, but must stay and be taken. And that the great and long iron of the wondyrchoun runs so heavily and hardly over the ground when fishing that it destroys the flowers of the land below water there, and also the spat of oysters, mussels and other fish upon which the great fish are accustomed to be fed and nourished. By which instrument in many places the fishermen take such quantity of small fish that they do not know what to do with them; and that they feed and fat their pigs with them, to the great damage of the Commons of the Realm and destruction of the fisheries, and they pray for a remedy".

According to Moore and Moore (page 174), a commission was appointed to enquire into the matter. The commissioners met at Colchester, and reported, among other things, that the net called "wondyrchoun" had meshes ("maskes") of the length and breadth of two thumbs. It is not recorded that there was any legislation resulting from this report.

The Act of 1558 is concerned with "the preservation hereafter of spawn, fry and young breed of eels, salmons, pikes, and of all other fish which heretofore hath been much destroyed in rivers and streams, salt and fresh, within this Realm insomuch that in divers places they feed swine and dogs with the fry and spawn of fish and otherwise, lamentable and horrible to be reported, destroy the same, to the hindrance and decay of the Commonwealth".

1/ "Juratores de Lyth et Eskedale et Juratores de Cumberland et Allerdale presentaverunt quod magna destructio fit in aquis de Edene et Esk et in aliis aquis in Comitatu isto de salmonibus tempore quo salmones ascendunt ad friandum et similiter de salmunculis tempore quo descendunt ad mare ad magnum detrimentum totius Comitatus et omnium Comitatuum adjacentium."

2/ For full references, see bibliography at the end of this paper.

According to Moore and Moore (page 179), the Act of 1714 stated that, "as the breed and fry of sea fish has been of late years greatly prejudiced and destroyed by the using of too small size of mesh, and by other illegal and unwarrantable practices, no one shall use at sea, upon the coast of England, any trawl net, drag net, or set net for catching any kind of fish except herrings, pilchards, sprats or lavidnian /sand eel or Ammodytes7, which has any mesh of less size than three and half inches from knot to knot, or which has any false or double bottom, cod or pouch". The act also specifies, for several species, sizes below which fish might not be sold.

The Act of 1791 was concerned with maintaining or preserving "the several oyster fisheries within this kingdom" as a great national object, "and whereas the laws now in being are not sufficient effectually to maintain and preserve the said fisheries and to prevent the destroying of the oyster brood".

The Act of 1843 was to carry into effect a convention made between Great Britain and France. One of its aims was to prevent contention between fishermen of the two countries, but there were a great many articles prescribing details of the fishing gears (Moore and Moore, page 240). These included mesh regulations: for trawls, one and three-quarter inches bar - that is, along one of the four sides of a mesh - for herring fishing, one inch and for mackerel, one and one-sixth inches, with corresponding French dimensions. Meshes were also prescribed for other kinds of nets. Johnstone (1905, page 9) states that these regulations were never enforced.

In 1868 a great deal of previous legislation was repealed; Johnstone says fifty acts in all. The ideal of unrestricted fishing was realized, and a fisherman was able to pursue his calling on the high seas "how, when and where he pleased," in the words of the late T. H. Huxley. At the International Fisheries Exhibition in 1883, Huxley stated the doctrine that he and others of his generation had been successful in promulgating and which, indeed, has guided fishery biologists ever since:

> "Every legislative restriction means the creation of a new offence. In the case of fishery, it means that a simple man of the people, earning a scanty livelihood by hard toil, shall be liable to fine or imprisonment for doing that which he and his fathers before him have, up to that time, been free to do.

> "If the general interest clearly requires that this burden should be put upon the fishermen - well and good. But if it does not - if, indeed, there is any doubt about the matter - I think that the man who has made the unnecessary law deserves a heavier punishment than the man who breaks it" (Huxley, 1884, page 18).

Development of modern theory and practice

A Royal Commission meeting in the same year as Huxley's dictum, 1883, listened to arguments in favour of conservation measures. The evidence, for example, of A.W. Ansell dealt with a reduction in average catch per trawler of soles and turbots, comparing the eighteen sixties with the eighteen seventies and eighteen eighties. The report of the commission was to the effect that it could not decide what amount of truth there was in the evidence that had been put to it, namely, that although there might be an increase in the total amount of fish brought to market, the takes of each vessel were smaller in spite of improved fishing gear, and that fish were really scarcer than formerly (United Kingdom Royal Commission on Trawling, 1885, page xxvii).

By 1893, however, a Select Committee of the British House of Commons was convinced by the evidence of the fall in catch per vessel, especially of sole and plaice, and a great falling off, too, in the size of the flatfish caught on the older grounds of the North Sea. This was in spite of an admitted increase in the total catch of all kinds of fish landed in England and Wales, for which, however, the fishing craft had to go further afield. (United Kingdom Select Committee on Sea Fisheries, 1893, page iv).

Bompas (1885, page 423) reports that in 1880 Frank Buckland, two days before his death, wrote in the preface to his Natural History of British Fishes (page ix), "How are we to devise a mesh of net that shall let go the small sole and undersized fry of other fish, keeping the marketable fish only, allowing the others to escape and grow?"

In 1894 C.G.J. Petersen wrote about the decrease in the catch of flatfish in Danish waters (page 58), "For it cannot well be doubted that the same area of sea would be able to give a quantitively greater profit as a constancy, when we suffered the stock of fish to be as fully developed, as in the years before the too eager fishing commenced - and then took exactly so much as the stock could reproduce by new growth".

In 1918 Baranov published the first mathematical model of the relation of vital processes (reproduction, growth and mortality) to the yield of the fishery. In 1931 Russell's theoretical consideration paid attention to "C", the total quantity taken from the fishery during a year, or "yield". Russell did not thereby mean that the catch per unit of effort had to be excluded, as he often made plain to me in conversation. It happens that all theoretical study of fisheries must use the yield as the main variable to be determined; this tended to give it prominence as if it were the sole object of conservation. The conception of "optimum catch" (Hjort and others, 1933) reinforced this emphasis, and in the New World there was a gradual crystallization of opinion in favour of total yield as the primary objective of conservation.

In 1926, Canada and the United States agreed to regulate the halibut fishery, and in 1932 they did so by holding the total catch at the low level which it had reached in the depression of 1931. Since that date, an increase has been allowed in total catch, but there have been several other results, including an increase in the catch per unit fishing effort, relatively greater than the increase in yield.

In Europe, at about that time, the International Council for the Exploration of the Sea was renewing its effort to solve the problem of chronically depressed fishing. As Andersson wrote in the introduction to the jubilee volume of the Council's report (1952): "The Council has always upheld its original intention that the main object of its activity should be the benefit of the fishery ... Here the Council has obtained very positive results, the outcome of which is a convention for the protection of fish in the North Sea and the North Atlantic". In the same volume, Graham (page 75) mentions the measures adopted and notes the lack of definition of objective:

> "The Convention of 1937 was superseded by that of 1946, in which the mesh for distant waters, now including Icelandic grounds, was raised to 110 millimetres and in all other waters covered by the convention, that is from 48° northwards and from Cape Farewell to Vardø, the mesh was to be 80 millimetres on the gauge. In addition a permanent commission was constituted for consideration of extensions or alterations of the provisions of the convention. Size limits were also raised, and two more species (Gadus merlangus and Pleuronectes limanda) were added to the list, which now included hake of 30 centimetres, haddock of 27 centimetres and plaice of 25 centimetres.

"It is evident that such advances in comprehensive thinking as were being made between 1930 and 1935 were accompanied by vigorous prosecution of conservation policy, based on partial assessment of the situation, but nevertheless sound. The overfished condition of the North Sea was indeed so obvious that no very advanced theory was required to justify the first modest measure of conservation. In somewhat the same way, on the other side of the globe, the beginning of the period under review saw the outstanding, indeed the classical, example of regulation somewhat in advance of full mathematical theory undertaken on a large scale. This was the regulation of the halibut fishery of the Pacific, which began effectively in 1930 with the simple ordinance that the annual catch in future should not exceed two specified quantities for two different areas."

On the Pacific halibut fishery, Thompson (1936, page 380) wrote:

"On the walls of the Commission laboratories are kept charts showing the changing abundance of the halibut in its different areas; the great decline in abundance from the earliest days until the year 1930 is shown; where once 300 pounds of fish were taken on the standard unit of gear it is shown that on the southern grounds the yield had fallen to 35 pounds and on the western to 65 pounds, while the total catch on the southern grounds had fallen from 60 million to 22 million. The Commission was organized in 1924. Under the observation of its staff the later part of this decline, from 1925 to 1930, occurred. At that time the Commission had no powers of regulation. It could merely study and analyse, but in 1930 it submitted recommendations to the two governments, and a new treaty was adopted giving the Commission proper regulatory powers. The result is shown on the charts kept by the Commission. Beginning with 1931 the abundance has risen steadily: on the banks to the south, from 35 pounds to 60; on the banks to the west, from 65 pounds to 90. The Commission has made good use of the scientific instruments placed at its disposal by its staff ...

"It may seem to the fisherman somewhat like magic; that by fishing less he can obtain as much from the sea as before, or more. But to the Commission, interested in increasing the number of young as well as making better use of what we have, the results are profoundly interesting. They see the commercial catches becoming to a greater extent composed of mature spawning fish. They see the number of floating eggs and larvae increasing, and they await with eagerness the time when these increased young commence to show in the commercial catch as a real increase of the available stock - an increase that may be used, not simply an accumulated reserve. Justifying each step by its practical success, a great biological experiment is in progress, testing the ability of men to perpetuate and exploit rationally the vitally important resources of marine fish."

It is apparent that in 1935 those watching the regulated halibut fishery were clearly distinguishing the catch per unit effort, which had already risen greatly, and the yield, which it was hoped to raise later. In the ensuing ten years, general policy in the United States was firmly in favour of raising the sustained yield as high as possible. In November 1945, Dr. Ira N. Gabrielson, then Director of the Fish and Wildlife Service, when discussing the conservation of fur seals, halibut, blue crab, trout and black bass, Alaskan salmon, deer and elk, and waterfowl, said: "The purpose of the conservation programme of the Government of the United States of America is to insure a maximum sustained yield from our natural resources".

The United States Sockeye Salmon Fishery Act of 1947 did not appear to go beyond "the protection, preservation and extension" of the fishery concerned, which does not tie the promoters down to the maximum yield. That was, however, closely followed by the International Convention for the Northwest Atlantic Fisheries, 1949, which explicitly aimed "to make possible the maintenance of a maximum sustained catch from those fisheries".

Dunlop and Bell (1952) find new problems in this fishery, and seek for solutions giving greater yield. They write (page 167):

> "Under regulation by the International Fisheries Commission, the abundance of halibut on the Pacific coast has increased almost 150 per cent since 1931 and annual catches have been increased to over 56 million pounds, 3/ about 12 million pounds more annually 4/ than immediately before regulation. This additional poundage has added about $3 million to the fleets' earnings in each recent year. 5/ Though the annual catch is larger, the amount of fishing effort has been reduced about one-third because of greatly increased abundance.

3/ The unpublished figure for 1954 is 70 million pounds.

4/ It was 25 million pounds in 1954.

5/ Approximately double this figure in 1954.

> "The success of regulation has created new regulatory problems. The improved condition of the stocks and a doubling in the size of the fishing fleets have greatly increased the rate of landing and sharply reduced the length of the authorized fishing season, in spite of the greater total catch allowed. The fishing season, which was eight and one-half months long in 1932, has progressively declined to only 28 days in Area 2 and 56 days in Area 3 in 1951. 6/ In present conditions, some sections of the stocks are not yielding the poundage of which they are capable. Other sections of the stocks appear to be subjected to too much fishing.
>
> "When fishing was conducted over a longer period of the year, the fishermen, guided by experience, fished each ground at the best time from the standpoint of availability of fish, value of the catches and weather conditions. With the present season the fishery tends to concentrate on those grounds where the fish are most available at that time of the year."

They conclude (page 171), "Some modification of the system of management, applied so successfully by the International Fisheries Commission since 1932, will be necessary if the maximum productive capacity of the Pacific halibut stocks is to be reached".

Review

It seems that conservation of fisheries commends itself naturally to peoples who are used to husbanding the resources of agriculture. They need the eloquence of a Huxley to remind them that there may be fisheries where no conservation is required. A good historical example is that of the European herring fishery, which from the year 900 or earlier has provided a fluctuating but not diminished harvest for at least ten centuries, in spite of a generally increasing toll by fishing.

In many other fisheries, the fall in the catch per unit effort has prematurely convinced people that conservation is necessary. When a fall in the catch per unit effort is recognized, it is not always easy to convince the fisherman that all is well because the total catch is still rising. Nor can he obtain the same living as previously. It may be necessary for him to risk greater capital expenditure, or to undertake longer voyages, or even to hire himself to a master

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6/ Areas 2 and 3 account for over 98 per cent of the fishery.

when formerly he could be his own master. At this stage, it is usual to hear complaints about some new and more efficient way of catching fish. In the United Kingdom, the classical example was a complaint, mainly from the Scottish liners, that trawls destroyed the spawn of sea fish, whereas all the staple demersal fishes have pelagic eggs, which the trawl cannot touch (Johnstone, 1905, pages 22, 23).

It is, however, evident that all those in the past who have conceived of conservation have had in mind what Petersen meant by his phrase "as a constancy". That is to say, they looked to a continuing fishery, not to one getting worse for the operators or for the consumers as the decades went by. But nobody familiar with fisheries could possibly hope to avoid fluctuations from year to year.

The qualities that have been in men's minds as objectives of conservation measures seem to be one or more of three: (i) the catch per unit of effort; (ii) the total annual yield of fish; and (iii) the average size and quality of fish.

The price of fish has also doubtless entered into the minds of those concerned, who may sometimes have seen possibilities of better prices through some direct or indirect restrictive effect of a conservation measure. This is, as it were, a contamination of concepts of conservation. Another is the desire to favour some sectional interest, and the advocacy of a particular conservation measure that would have that effect. Thus, a closed area or season can be made to favour in practice fishermen living nearest the fishing ground, because they are most likely to be able to break the regulation with impunity; they can often reach the ground and return to their homes within the span of one night. Regulation against a particular gear, for example the "wondyrchoun", is often advocated for sectional motives, and assertions are made of its peculiar destructiveness, as in the passage quoted above.

The foregoing account may be taken as broadly applicable to the class of animals called <u>pisces</u>, or fish in the strictly biological sense. It is probably also sufficiently good to cover the cases of conservation of crustaceans, such as crabs and lobsters.

When, however, one considers molluscs, such as the oyster and mussel, which are static on the bed of the sea or on rocks or structures arising from the sea bed, it may be noted that the concept of private property has often been injected into the general concept of conservation. Such animals are subject to cultivation resembling in some ways agriculture rather than fisheries, and it has evidently seemed reasonable to give the cultivators rights over them similar to those enjoyed in husbandry. Nevertheless, in England some oyster fisheries have remained public property. Those have not, in general, survived as successful fisheries in spite of legislation prescribing the form and manner of fishing.

Another group of marine animals requiring special consideration is formed by the whales. It is well known that in the Northern Hemisphere and in equatorial seas, great fisheries for whales that once flourished (Clark, 1887) have died out, because the number of whales was reduced to such a low level as to provide a living only for relatively cheap enterprises close to favourite grounds for example the Azores (Clarke, 1954). The efforts at international regulation of the remaining whale fisheries have been based, at least partly, on the concept of maintaining the catch per unit effort at a profitable commercial level. This is evident in the preamble of the International Agreement for the Regulation of Whaling, signed in London on 8 June 1937, by representatives of nine governments "desiring to secure the prosperity of the whaling industry and, for that purpose, to maintain the stock of whales". A change towards yield is found in the preamble of the International Convention for the Regulation of Whaling which was signed in Washington on 2 December 1946 by the representatives of fourteen governments, "recognizing that the whale stocks are susceptible of natural increases if whaling is properly regulated, and that increases in the size of whale stocks will permit increases in the numbers of whales which may be captured without endangering these natural resources ...".

Hjort, in his introductory remarks on whales and whaling (1933, page 28), had written:

> "What, then, is our chief need? Security for the future. Common to all human enterprise is the peculiarity that a remunerative undertaking tends to expand until it becomes unremunerative for everybody. The greatest problem of organization to be solved by modern socieity is this: how can a remunerative undertakening be maintained at a high level without

sacrificing freedom, personal initiative and individual inventiveness? It is a problem altogether different from what is commonly termed technical rationalization.

"In the case of whaling the dilemma is particularly difficult, because this industry is above all others an occupation of the open, free, international seas. A voluntary restriction of the size of the industry, i.e., the size of the whaling fleet, in deference to what is necessary at any time with a view to preserving the stock of whales, would mean the voluntary acceptance of this ideal by all nations. If a country declares itself willing to restrict the expansion of its own industry in conformity with this ideal, as the Norwegian industry did for the present whaling season, such a step ought to strengthen its credit all over the world. But it is also understandable that a country may feel a certain anxiety lest an offer of this kind should fail to receive adequate recognition and support. Not unreasonably it may fear that advantage might be taken of the offer by people who have so far shown no enterprise and made no sacrifices to promote the development of whaling, but who would manoeuvre themselves into a position based on power rather than honest work."

In that passage from a noted Norwegian scientist there is the expression of an idea that many fishermen tend to have - and which is usually admitted as correct for molluscs - namely of a proprietary right in a fishery that they have developed.

Conclusion

It is possible to generalize simply but truthfully about the attitude of men towards marine resources. At first, there are the few adventurers who obtain a living where few men wish to follow them, and so long as fishing is conducted in that way no question of conservation arises. Later follow the organizers, who may or may not reduce the catch per unit effort. If they do reduce it, the concept of conservation arises as one of maintaining or restoring the catch per unit effort. This, however, does not appeal to governments as a suitable objective, so long as the total yield per annum continues to rise or at least is not reduced. When, however, the catch per unit effort falls so low as to endanger the continuance of the fishery, because boys no longer wish to engage in it, or when the average size of the fish falls so as to endanger the market because consumers are not interested in such small fish, then governing authorities are willing to take action. In the Old World they have not as yet made any explicit choice among the possible qualities of the fishery - annual yield, catch per unit effort and average size of fish - but in the New World, the choice of maximum yield has been explicit in all recent international conventions.

As to the means of maintaining the yield, and so of other desirable qualities, it is evident from the history that later men have agreed with those of the country of Cumberland in 1278, who were anxious that the ascending salmon should be allowed to spawn and the descending salmunculi to grow larger. By fostering breeding and growth, all men have sensed that they could increase annual yield, catch per unit effort and average size of the fish.

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THE SCIENTIFIC BASIS FOR A CONSERVATION PROGRAMME

by

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(The mimeographed text of this paper appeared as A/CONF.10/L.1, under the title "Types of Scientific Information Required for a Fishery Conservation Programme, and Types of Conservation Measures Applicable in a Conservation Programme")

Contents

Types of Scientific Information Required for a Fishery Conservation Programme

The natural resources upon which mankind depends are of two kinds. In one category are such resources as mineral deposits and fossil fuels, of which there is only a fixed amount on this planet. The amounts of such resources are irreversibly diminished by exploitation. The conservation of such resources consists in using them as carefully and with as little waste as possible so as to secure the greatest current benefits to mankind, and to save as much as possible against future needs.

The second category of resources consists of those which renew themselves. Such resources may be exploited by man without reducing their maximum usefulness in the future. To preserve such resources it is not necessary to refrain from using them, but only to use them in such fashion that they remain capable of continuing to yield maximum benefits to man in the future. Of this category of resources, the living resources of the sea are outstanding examples.

Populations of fishes and other organisms tend to remain in balance with their environments. Over a reasonably long period of time, the losses from the population must be balanced by accessions to the population, otherwise it would become extinct. When, however, the percentage rate of loss is increased, by whatever means, the percentage rate of accession to the population changes also, so that the population again tends to come into balance.

It is the resiliency of a population of organisms, its ability to compensate for increased mortality, which makes it possible for it to survive increases in the populations of its predators. This same phenomenon is the biological basis of fisheries since, from the standpoint of the fish, a fishery is simply an increase in the predation rate. It is the compensatory reaction of the fish population to the mortality produced by fishing which makes a fishery possible, so that the population comes into balance under the environmental conditions which include this predation by man. It is theoretically possible to impose so much fishing on a population as to drive it down below the magnitude at which such compensatory reaction can bring it into balance again - to drive it below its threshold magnitude for survival. I know, however, of no instance where this has been accomplished in a purely marine fishery. It appears that the threshold magnitude is almost always well below the population size to which it is economically possible to fish.

It may be agreed that for nearly all populations of organisms in the sea there need not be concern with protecting them against being driven to such low levels that they can never recover. The question is, rather, from among the wide range of fishing intensities between zero and the maximum that is economically possible, to choose that which is most desirable, both in the sense of being most beneficial to mankind at present and of avoiding any diminution of the benefits which will be obtainable, on a sustained basis, in the future. A conservation programme consists, therefore, in controlling man's predation in such a fashion as to continue to maintain man's benefits from the resources at the highest sustainable level.

It is, in general, considered desirable to maximize total production in a form useful to man, or, in other terms, to maximize the total catch of commercial sizes of fish. This general objective must, however, be subject to modification in some degree in particular fisheries. One of the results of increased fishing intensity is the decreased average age and size of the individuals of the fish population, so that an increased total catch is accompanied by a greater share of smaller fish. Since different sizes of fish are, in some fisheries, not equally desirable in the market, a compromise must be reached between maximum total poundage and the most desirable size composition of the catch. In some fisheries, of course, it is possible to control the sizes of fish captured, independently of the intensity of fishing; but in others this is not practicable, and in these cases changes in the quality of the catch go hand in hand with changes in the level of the average total catch.

Other economic considerations must also sometimes be taken into account. Where, as in the case of a number of clupeids, fish may be used by man in different forms (for example, as human food, or as fish meal for animal feed), the relative desirability of such uses needs to be considered. Further, it is not always desirable to maximize the sustainable total yield regardless of the effort expended in making the harvest. In some cases, economy of fishing effort may be of at least temporary importance, even though the total yield is thereby somewhat diminished. Indeed, it has been asserted by Gordon (1953),[1]

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[1] See bibliography at the end of this paper for this and subsequent references.

and implied by Burkenroad (1951), Beverton (1953) and others, that it may be more desirable to maximize the net economic yield, rather than the sustainable total production.

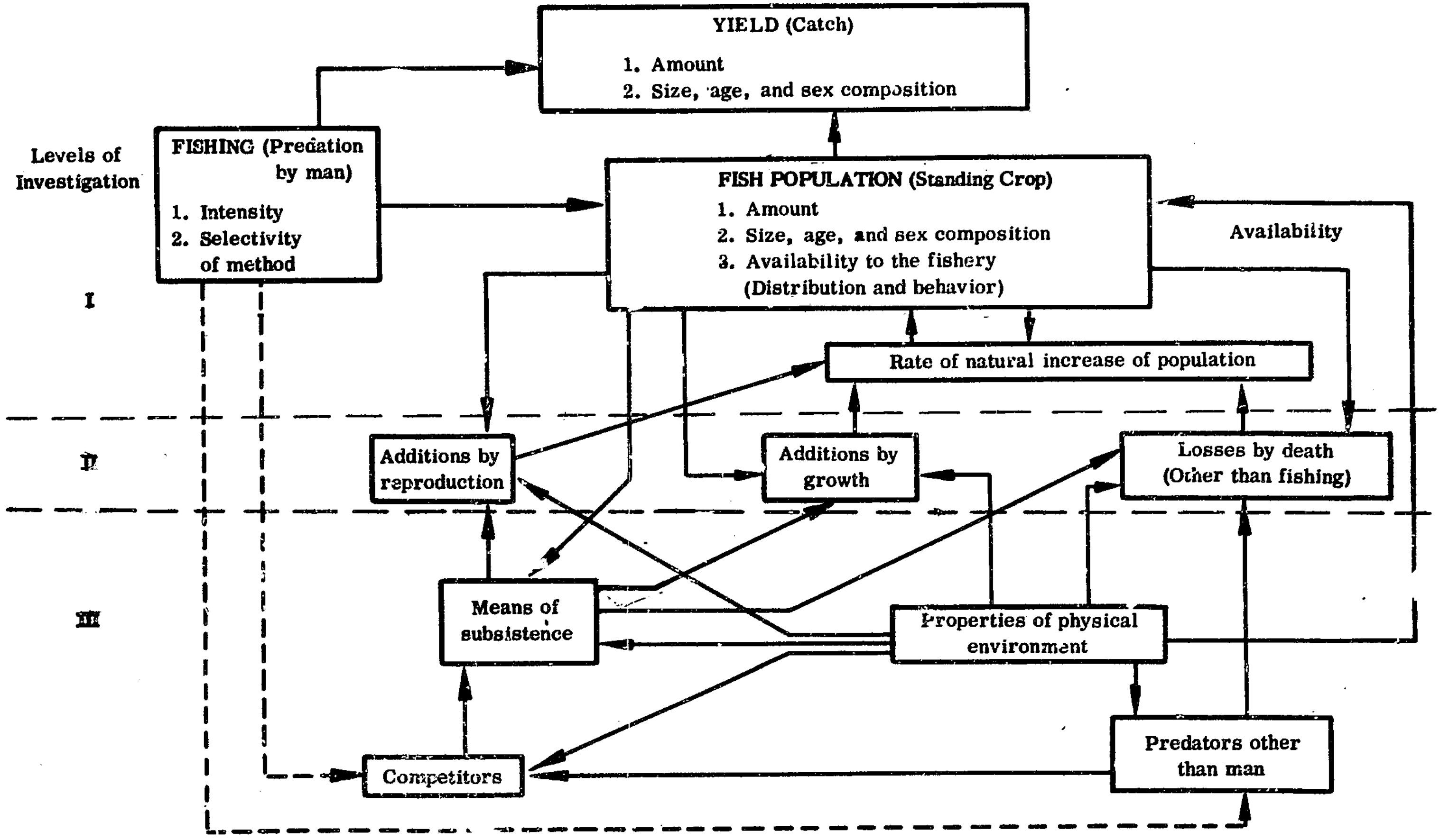
Scientific investigation for conservation purposes should provide information needed to modify fishing practice or intensity in order to maximize the quantity and quality of the catch, or otherwise to regulate the harvest for desirable ends. This involves determination of the effects of man's predation on the abundance and composition of the populations of fish, and on the resulting quantity and quality of the catch. It is also necessary to determine what courses of action may be taken to control the activities of fishermen so as to produce desired changes in the fish populations and in the catch.

These, as will be seen, are matters of some complexity. One of the principal complicating factors is that changes in man's predation are not the only causes of changes in fish populations. Variations in natural environment operate simultaneously, affecting the abundance and composition of the populations, and also the ease of capture, or availability to the fishermen. One of the important and difficult tasks of the fisheries scientist is to take account of such effects arising from "natural" causes, and so reach a correct estimate of the effects of fishing alone.

The factors determining the standing crop and harvest of a fish population under exploitation by man, and their interrelationships, have been diagrammed on the accompanying chart, figure 1. It may be seen that it is concerned with the mutual interactions of a large number of factors. To control a fishery completely it would be necessary to understand all of these interrelationships in their entirety. However, it is possible to achieve a useful measure of control with less than perfect understanding.

Figure 1. Interrelationships of factors determining standing crop and yield

(Arrows indicate direction of cause-effect relationships)



As indicated in the diagram, and as will be developed in more detail below, the understanding of a fishery and the ability to manage it may be considered at three levels. At the first level (level I in figure 1) are simply the relationships between the amount of fishing, the quantity and quality of the catch, the quantity and quality of the fish population, and the rate of natural increase of the population, which may be taken as the harvest on a continuing basis. This treats all the environmental factors as random variables, and so lacks precision. It also gives no insight into the factors making up the natural rate of increase. This procedure is, however, often adequate to determine whether a greater average harvest may be obtained by restrictions on fishing, and so to indicate when conservation management is required.

At the second level, separate measurements are undertaken of the three components - reproduction, growth and natural mortality - which determine the rate of natural increase, and how each of these is related to the abundance and age composition of the population. This provides an improved understanding of the fundamental nature of the fish population and so makes possible more precise management of the fishery. The environmental factors are, again, treated as random variables, so that regulation is possible only for average environmental conditions.

Finally, at the third level, a full understanding would be obtained of the environmental factors - both physical and biological - influencing the population, and so capacity for full management of the fishery would be achieved. This ideal stage is far from being realized for any fishery, but is an ultimate goal of fishery science.

Extent to which the fishery resource is divided into independent populations

One of the important aspects of a fishery resource is the natural biological units into which it is divided. Characteristically, a species of animal consists of groups of lower taxonomic order, which are the basic units from the standpoint of conservation. These basic units are not always capable of clear definition, since the extent of separation into such units is not always clear in the species itself. However, these units, referred to here as populations or stocks, have certain properties by which they may be characterized.

A population of organisms is a homogeneous group of members of the same species, which interbreed freely among themselves and which occupy a continuous environment and so are able freely to intermix and thus maintain their homogeneity. As a result of inbreeding, the members of the population are genetically more similar to each other than to members of other populations of the same species. Since there is this high degree of genetic similarity, and since the population lives in a continuous environment, which is often to some degree different from that of other populations, there commonly occur anatomical differences of either genotypic or phenotypic origin by means of which the members of the population may be identified.

These divisions of a species into populations are not always complete and clear-cut. It frequently happens that there are biological barriers (regions not suitable for the existence of the members of the species) geographically separating regions of suitable environment. The members of the species within one such region are clearly independent of those of other regions. Within such a region, however, there often exist populations of the same species which are only partially independent, since, though they tend to intermix and interbreed with the other members of their own population, they do so to a greater or lesser extent with members of other populations. In such a situation the populations are only semi-independent. D'Ancona (1954, chapter 2) contains an excellent review of these matters.

One of the important characteristics of a population is that it tends to respond as a unit to changes in population magnitude, whether induced by natural causes or by fishing. To the extent that the population is independent of other populations, therefore, its responses to exploitation by man are independent of those of other populations. It is quite obvious that knowledge of the extent of separation of a resource into independent or semi-independent populations is one of the important categories of scientific information with respect to conservation. Conservation is, essentially, applied population dynamics, and the basic unit in population dynamics is the population.

Conservation measures will be most efficient if applied to each population individually. This, however, is not always possible, either because of lack of knowledge of the detailed population structure of a resource, or because it is not always feasible, in practice, to regulate each of many populations separately, particularly if they are not very discreet in their distribution in space or time. In these circumstances, an aggregation of population units may be successfully treated as a conservation management unit. An example of such a situation is offered by the North Pacific halibut (*Hippoglossus stenolepis*). The members of this species along the American coast to the north and west of Cape Spencer were shown by the scientists of the International Fisheries Commission to be distinct from the stocks to the south of Cape Spencer, and successful management regulations were established, based on this geographical division. Subsequently, it has been discovered that, within each region, there are sub-populations which appear on the fishing banks at different times of year, and improved harvesting of the resource has begun, based on this improved knowledge of the population structure (Dunlop and Bell, 1952).

In the case of the Pacific salmons of the genus *Oncorhynchus*, which spawn in rivers and streams, the fish tend to return for spawning to the streams in which they were born; thus for each stream there is a corresponding population. During the period of time spent in the sea, however, several populations of the same species are present in the same sea region. Most fishing is for adults as they return towards their spawning rivers, and it has been found that in some cases different populations pass through the fishery at different times, making it possible to control the amount of fishing affecting separate populations.

For the most effective management of a resource, it is necessary to know, in as much detail as possible, and for a number of reasons, the populations into which it is separated, and also the distribution of these populations in space and in time; and to be able to refer the catches obtained by fishermen to the populations from which they are taken. To elucidate the effects of various physical and biological environmental factors on the size and quality of the populations, pertinent data are needed on the geographical location of the populations at various stages of their lives. Investigations of the life history and ecology of fishes, which will be discussed subsequently, need to be related to particular populations. Finally, in order to obtain the maximum harvest from the resource, management measures need to be applied, as far as practicable, to the separate populations, so as to maximize the harvest from each of them.

Geographical ranges and magnitudes of the populations constituting the resource

As has been pointed out above, the basic unit for conservation management is the population. A fishery for a given species may depend on several populations which are independently affected by man's predation and may also be independently affected by other (environmental) factors. The quantitative scientific investigation of a fishery resource, needs, therefore, to be conducted so as to provide the information needed for the conservation of each of the populations constituting the resource.

It is necessary to know, first of all, the geographical range of the resource, and the ranges of any populations into which it may be separated. Such knowledge is needed in the first instance in order to determine the region of the sea within which it is necessary to conduct scientific investigations. This is of great practical importance: in determining the requirements of ships, men and money needed for investigations; in determining to what extent the fisheries of more than one nation may be involved, which will have an important bearing on the arrangements for scientific investigations; and in the detailed planning and execution of research. This kind of knowledge becomes equally important, of course, in determining over what area of jurisdiction regulations need to be applied to control man's predation on the resource effectively in order to reap the maximum sustainable harvest. It must be understood that both the scientific investigations and the subsequent management measures need to be extended over whatever area of the sea corresponds to the range of the populations in question. Since the ranges of the populations of different species of animals supporting the commercial fisheries are not coextensive, it will, in general, be found that the jurisdictional areas must differ for different fisheries.

The situation in the North Pacific with respect to halibut, salmon and albacore tuna is a fairly good illustration. The range of the halibut populations of the American west coast extends northward and westward from California along the coasts of the United States, British Columbia and Alaska, out along the Aleutian Islands and into the Bering Sea. There is, apparently, no intermixing with the halibut populations on the Asian side in the vicinity of Hokkaido and the Kuril Islands. Investigation and management of the American halibut fishery involves, therefore, only an area of jurisdiction off the coasts of the United States, British Columbia and Alaska. On the other hand, the several species of Pacific salmon spawning in streams on the American continent range far offshore from their home streams - just how far not being known at present - and presumably intermingle in the offshore feeding areas with members of populations of Asian origin. Even more far-ranging are the albacore tuna of the North Pacific. Recent studies indicate that some of the fish subject to capture along the United States west coast migrate completely across the ocean to Japanese waters, and are fished in mid-ocean and in the coastal waters of Japan. Competent investigation and management of this resource will, of necessity, cover the entire North Pacific Ocean.

It is, of course, of the utmost importance to determine the magnitudes of the populations constituting the resource, in relation to the amount being harvested, in order to determine whether or not the current rate of fishing is large or small, and thus to have a basis for judging whether any conservation action is required. Where the degree of predation by man is so low that the losses from the stock of commercial sizes due to fishing are small in relation to the losses due to natural causes, there is no need for conservation measures. Where, on the contrary, the rate of fishing is high, it becomes important to proceed further to determine whether it may have exceeded or may be about to exceed the fishing intensity corresponding to the maximum sustainable yield.

It is important to note the distinction between the magnitude of the standing crop of commercial sizes of fish - that is, the total amount of fish of commercial sizes in the sea at any time - and the productivity of the fish population - that is, the amount which can be harvested on a sustainable basis. "Productivity" as used here is equivalent to the "rate of natural increase of population" on the diagram (figure 1), and also to the term "equilibrium catch" employed in a later section. The maximum standing crop will, on the average, exist in a virgin population on which there is no fishing, and for which productivity, in the sense employed here, is zero. When fishing is first begun, the standing crop, on the average, decreases and the productivity increases.

With increasing intensity of fishing, productivity increases for a time as the standing crop decreases. Eventually a point is reached, at some intermediate level of fishing intensity, where the productivity is maximum, after which it falls off with increasing intensity of fishing.

The relationship between size of standing crop and rate of natural increase, or productivity, is different for different kinds of organisms. Some species, such as the dogfish shark (Squalus suckleyi) of the North Pacific, are very long-lived and slow growing, and have a low fecundity, so that productivity is always small in relation to the size of the standing crop. The opposite extreme is exemplified by many tropical species, as, for example, the tropical anchovy (Cetengraulis mysticetus) used for tuna bait in the eastern tropical Pacific, which grows very rapidly, has a high rate of reproduction and a short life, nearly all the members of the population being in their first and second years of life. In such species the productivity is large in relation to the size of the standing crop.

Consideration of the magnitude of the populations constituting the resource concerns both the size of the standing crop and the productivity. As discussed further in a later section, determination of the effect of fishing on the resource rests largely on study of the relationships between intensity of fishing, population abundance (size of standing crop) and its productivity.

Pertinent facts respecting life history, ecology and behaviour

The purpose of scientific investigation of a commercial fish population is to evaluate quantitatively the effects of man's exploitation on the amount and quality of the population, and of the catch, and also to provide a factual basis for effective conservation action, if such action is found to be required. Since changes in the size and composition of the population, and of the catch, are caused not only by the amount of fishing, but also by variations in different features of the physical and biological environment, it is desirable to obtain some understanding of all causes of changes in the population, and in the catch, and of the manner in which such changes are produced. This should make possible estimates of the effects of exploitation on the resource, and determination of what changes in the fish populations are not due to exploitation.

Research on these matters requires study of a number of aspects of the biology, ecology and behaviour of the fish constituting the resource. The diagram (figure 1) indicates the interrelationships of factors which determine the standing crop and yield of a population under exploitation by man. To each of the several factors indicated on this diagram correspond categories of information which must be known in order to determine their inter-relationships on a quantitative basis. This method of categorizing the information required may serve as a basis of more detailed discussion of the pertinent biological facts.

Composition of the population and the catch

The hield of a fishery at any time is dependent on (a) the magnitude and composition of the population of fish of commercial sizes, also called the "stock"; (b) the intensity of fishing, or quantity of fishing effort employed; and (c) the availability of the fish to the fishermen, that is, the relative share of the stock which can be captured by an average unit of fishing effort. It is obviously important to obtain, on a continuing basis, measurements of the amount of fishing effort employed, the magnitude of the catch and the magnitude - at least the relative magnitude - of the stock.

Fishery scientists have also found it very useful to determine on a continuing basis the size and age composition, and sometimes the sex composition, of the stock, for a number of reasons, among which are the following:

(a) Fishing, even if not selective, affects not only the magnitude of the stock but also its size and age composition, since, by increasing the mortality rate, the longevity and, therefore, the average age and size of the fish in the stock are reduced.

(b) Continuing data on the age and size composition of the stock provide part of the information for inferring certain vital statistics of the population - the rates of mortality, rates of growth and relative rate of recruitment, that is, the relative magnitude of year-classes entering the stock.

(c) Evidence of changes in the stock due to variable success of reproduction, aside from changes arising from the fishery, is obtainable from the variation in year-class strength - the occurrence of the so-called "dominant" year-classes.

The composition of the stock is usually inferred from the composition of the catch by the application of ancillary information as to the intensity of fishing and the selectivity of fishing, by size, age and sex, which may be due to the selective action of the type of fishing gear used, the differential distribution of the fish on the fishing grounds or other "availability" factors.

Availability of the fish to the fishermen

In order to infer the magnitude and composition of the stock from the success of fishing (catch per unit of fishing effort) and the composition of the catch, one must apply adjustments for variations in the "availability" of different categories of fish to the fishing effort. "Availability" is employed here, as by Marr (1951), to mean the degree, in percentage terms, to which a group of fish is accessible to the efforts of the fishery. It is well known that availability varies from time to time, place to place, and among different components of the population. Various statistical devices may be employed to discount the effects of availability in the absence of sufficient information to apply correction factors. This, however, causes a loss of precision in the results, and it is therefore of value to obtain knowledge of those facts respecting the biology and behaviour of the fish which are important in this connexion.

The availability of the fish is dependent to a considerable degree on the geographical distribution of the fish with relation to the location of the fishery. It is therefore important to determine the seasonal changes in distribution due to migration. Such migrations often differ for different age, size and sex categories of the population. In the case of the sardine of the American west coast, for example, the larger and older fish carry out extensive feeding migrations northward from the spawning centres off California, while the smaller and younger fish do not. Many species of fish migrate to particular areas during their spawning season, so that the sexually maturing adults are removed from the fishing area (as in the case of the Pacific sardine), or come into it (as in the case of the North Pacific herring). Some kinds of fish do not perform any large migrations causing major shifts in the geographic distribution of the population, but they do move about to a greater or lesser degree in a "random" manner, in search of food, or for other purposes. The immature halibut of the southern fishing grounds off Canada and the United States offers one example of this sort of movement (Thompson and Herrington, 1930). In such cases the extent of such "random" movements may be an important factor in availability.

The bathymetric distribution of the members of the population is important to fisheries which operate at fixed depths in the sea, and this distribution is sometimes subject to variation with age, size or sex of fish, and with the season of the year. The smaller sizes of yellowfin tuna (Neothunnus macropterus), for example, occur near the surface of the sea and are thus accessible to capture by surface fishing methods, while the larger sizes occur to a lesser extent near the surface and are found at depths down to at least eighty fathoms, where an entirely different kind of gear is required to capture them. An example of seasonal variation in bathymetric distribution is offered by the cod in Greenland waters. Rasmussen (1954) reports that during July and August the cod leave the bottom and form shoals in the upper strata of the sea.

The capture of a number of species of fish, such as herrings, sardines, anchovies and mackerels, by the use of surrounding nets of various kinds depends on the aggregation of the fish into compact schools which can be surrounded by the net. Variations in the aggregation habits of the fish, that is, the sizes of the schools and their compactness, have important effects on the degree of success of capture. Commonly, the aggregation habits change with the age and size of the fish, with the state of sexual maturity and with seasonal changes in the physical and biological factors of the environment. It is less clear whether the amount of fish in the stock - the population density - also influences the aggregation habits.

The capture of many kinds of fish is accomplished by the use of baits or lures, and thus the success of capture depends to a great extent on the feeding habits of the fish, which vary with age, state of sexual maturity and physical conditions, such as temperature.

Variations in the physical environment have been shown, in one fishery or another, to influence, directly or indirectly, all of the above-mentioned factors involved in making stocks of fish more or less available to fishermen. Investigation of the influence of changes in the physical environment on the distribution, migration, aggregation, behaviour patterns and so on, of commercial fish species is, therefore, an important aspect of the scientific investigation of fisheries, as illustrated, for example, by several papers in the symposium of the International Council for the Exploration of the Sea (ICES) on "Fisheries Hydrography" (Lucas and others, 1952).

Components of the natural increase of the population

As noted previously, the catch from a fish population during any year depends on the size of the population and on the amount and effectiveness of the fishing effort applied. The amount of the catch which can be taken without changing the size of the population depends, however, on the amount of the natural increase of the population. If a fishery takes annually only that amount of fish which represents the excess of increases due to reproduction and growth over losses due to deaths from natural causes, the net change in the stock is zero. The excess of increase due to reproduction and growth over loss due to natural deaths, per unit of time (usually a year), is termed the rate of natural increase. What is sought in a conservation programme is to balance the rate of catch with the rate of natural increase, averaged over a suitable period of years, and further to establish this balance at the level most beneficial to man - in general, the balance which will provide the maximum average catch.

For the most effective conservation management of a population, it is desirable to have knowledge concerning the biology and ecology of the fish pertinent to each of the three components (reproduction, growth, natural mortality) making up the rate of natural increase.

Additions by reproduction (recruitment)

Basic information in this category includes facts on the spawning habits of the fish. It is desirable to know the age and size at first maturity in order to determine to what extent the fishery operates on sexually immature members of the population. The type of reproduction, particularly with reference to the protection afforded the eggs and young, is important. This ranges from ovovivaparous reproduction, in which the young are protected until some time after hatching, to completely pelagic spawning, where the eggs drift freely in the sea and are at the mercy of the environment and of predators from the instant of deposition. Determinations of the fecundity (number of eggs spawned by females of different sizes) and frequency of spawning (number of spawnings per female per year) are valuable in assessing the reproductive potential of the population; they are also of value in estimating the absolute size of the adult population by determining the total eggs spawned, from net hauls, and dividing by the mean number of eggs spawned per adult. Determination of the areas of spawning and the season of spawning is of importance, both as a basis for the quantitative estimation of the adult population by the method noted above, and as a basis for studying the effects of environmental factors on the survival of eggs and larvae.

The importance in fisheries management of studying the early life history of marine fishes rests on the observation, made many years ago by Johan Hjort and his co-workers in Norway, that the success or failure of most broods of such species is determined very early in their life. The phenomenon of large variations in success of reproduction exhibited by many marine fishes has been demonstrated to be very often due to variations in their environment during early life, before reaching commercial size. Understanding of these relationships requires rather comprehensive knowledge of the biology of the fishes during their larval and juvenile stages. Pertinent aspects of the early life history include the following: rates of development and growth of larvae and juveniles; food and feeding habits of larvae and juveniles; behaviour, including aggregation habits and tropisms, of larvae and juveniles; spatial and temporal distribution of larvae and juveniles; migrations of juveniles.

Important also in conservation regulation is the determination of "nursery" areas - regions of the sea inhabited by the sub-commercial sizes which may profitably be afforded protection from the predation incidental to fishing for commercial sizes of the same or other species.

Of special relevance to the problem of conservation management is the determination of population density effects on the amount of recruitment to the commercial stock or, in other words, the relationship between the size of the spawning population and the number of their progeny which survive to commercial size. The importance of mortality dependent on density in young stages of fishes, in comparison with mortality independent of density, and the relationship between spawning stock and number of recruits, are among the more controversial and difficult aspects of current fishery research. Ricker (1954) has recently published an illuminating dissertation on this problem.

Interpretation of the relationship between the properties of the environment and the success of reproduction is an important line of study for fish populations (such as the herrings of the North Atlantic and North Pacific) in which there are large year-to-year variations in recruitment, little related to the size of the spawning stock. Such variations are apparently due to variations in the properties of the environment operating in several ways. It is believed that for many fishes, at least, there are critical stages in their development when the lack of some element - such as suitable food when first starting to feed - may result in very high mortality. This need not, however, be always true, or even true in general, since slight changes in mortality rates over a long period of development can produce the same result.

Physical environmental factors may affect the strength of year-classes, either through direct effects on spawning and survival or through indirect effects on food and other means of existence. Direct effects of the physical environment include the effect of temperature and salinity on the location and amount of spawning, the deaths of eggs, larvae or juveniles due to lethal temperature conditions, and their transport by currents to sea areas adverse for survival. Indirectly, the physical environment may affect the survival of young by affecting the production of suitable food, by limiting the space containing suitable temperature or oxygen, or by other factors generally included in the term "means of subsistence". Such effects may be even more indirect, acting through the encouragement of the development of populations of competitors or predators upon the young, or through the provision of conditions for the favourable growth of pathogenic organisms.

Additions by growth

The number of fish in a population is added to only by reproduction. The weight of the stock is, however, also increased by the growth of its individual members. It is desirable to learn how much weight is added per unit of time to the members of the stock at different ages - the age-growth relationships - because this information is important for the determination of the most profitable size at which to harvest the fish in fisheries where the size at capture is amenable to direct control. It is also important in fisheries where such control is not possible because, even then, there may be a most profitable average size, related in turn to the intensity of fishing, which can be controlled.

The rate of growth of fishes is a function not only of the age of the fish but also, when there is competition for food, of the density of the population. This has been rather well demonstrated for some fresh water fishes (see, for example, Beckman, 1941, 1948). It has also been indicated that for some, at least, of the demersal fishes of the North Sea and North Atlantic, the growth among the youngest age groups is greater at lower population densities. It is to be noted, however, that the gain in growth is not sufficient to compensate for losses caused by catching undersized fish of these species (Maurice and others, 1932).

The growth of fishes is directly affected by other properties of the physical environment. It has been shown both by statistical studies and by laboratory experiments, for example, that temperature has a direct effect on the rate of growth.

Variations in the physical environment may also affect the growth of members of a fish population by affecting the food supply. In order to investigate this for a particular species of fish it is necessary first to obtain information on what the fish eat, that is, the kinds of organism the fish feed on and any changes in feeding habits with size and age. It is further necessary to determine whether food is, in fact, a limiting factor in the growth of the members of the population, that is, whether there is ever any shortage of food.

In the event that it is shown that the supply of food does become a limiting factor in the growth of the population, it is of further interest to determine whether the food supply is also related to the density of the population, that is, to determine whether grazing by the fish population effectively modifies the standing crops of food organisms. The above-cited examples of an inverse relationship between growth and population density would lead one to infer that such grazing effects are sometimes of importance, but direct measurements would be desirable.

Where several species of fish feed on the same food, the sizes of the populations of competing species may affect the food supply, and thus the growth of the members of the fish population. Whether this occurs to any important degree in the sea is, perhaps, a moot question.

Decreases by deaths from causes other than fishing

The balance between additions due to reproduction and growth, and losses due to "natural" deaths, determines the rate of natural increase of the population. It is necessary, first of all, to determine the general level of natural mortality, or its inverse, the longevity, of the commercial sizes of fish in the population because this, with similar knowledge of the reproduction and growth rates, gives a first approximation to the rate of natural increase.

For most kinds of animals, including fishes, the mortality rate is not constant, but changes with age. The measurement of the age-specific mortality rates is difficult for populations of sea fishes but, where possible to measure, is of great value, because, together with the age-specific growth rates, it determines whether it is more profitable to leave fishes of a given age in the sea or to harvest them. So long as the gain by growth is greater than the loss by death, poundage will be gained by deferring their capture, but beyond this age, poundage will be gained by harvesting them.

Variations in the mortality of adult sea fishes related to environmental factors are probably, in general, of less importance than those which occur during the early stages of life, when the young fish are more at the mercy of their environments. Such effects may, however, be important in some instances. It appears, for example, in the case of the California sardine, that there are rather significant differences in the natural mortality rates of adults in different years. The properties of the environment can presumably cause mortality of adults either directly or indirectly, as indicated in figure 1. Little data on these matters are available for the sea fishes.

Discounting environmental effects

It has been indicated in the foregoing that changes in the properties of the environment can have noticeable effects on the rate of natural increase of the population and can also, by affecting the availability of the stock to the fishing gear, influence measurements of the relative abundance and quality of the population, based on the commercial catch.

Interest centres, primarily, on determining the effects of man's predation under average environmental conditions, and it is therefore necessary to take suitable account of variations in environmental factors. Short-term environmental effects which may be considered random variables may be averaged out by statistical methods if there is a sufficiently long series of measurements. For this purpose, the series of data being considered must be long relative to the length of the periods of environmental changes. This condition is often encountered in practice.

On the other hand, there sometimes exist long-term environmental changes which influence the commercially important marine fishes. In such cases, where the series of data is short in comparison with the period of such changes, they cannot be regarded as random variables, and some understanding of their effects is required so that they may be suitably discounted in getting at the effects of man's predation. Such long-term effects of changes in the environment have been shown, for example, to be of importance in fisheries for North Atlantic cod, mackerel, lobster, capelin and other species (Tåning, 1953; Templeman and Fleming, 1953).

Effects of intensity and kind of exploitation on the resource, and current status

The foregoing section has considered the kinds of biological and ecological information required for evaluating the effects of man's exploitation on the fish population and on the sustainable catch. This section reviews some of the methods which have been employed in making quantitative estimates of these effects, with particular reference to determining whether or not in a particular fishery the catch could be increased by measures to control man's predation.

An outstanding common characteristic of populations of organisms is that they are self-regulating; they remain at some more or less fluctuating level of abundance over hundreds, or thousands, of years, neither increasing without limit nor declining to zero, in spite of substantial changes in their surroundings. This obviously requires that a population react to changes in its environment in such fashion that losses from the population and accessions to it come into balance under changing conditions. As noted earlier, this resiliency of population is the biological basis of any sustained fishery.

It has been pointed out by Nicholson (1933, 1954a, 1954b), Ricker (1954) and others that, though the level of abundance of a population can be affected by any element of its environment, only those elements which are responsive to changes in population density, and in turn modify the population change, are involved in the self-governing mechanism of the population. The elements involved in this self-regulating system may be conveniently designated as controlling elements and the remainder as modifying elements. The reactions of a fish population which compensate for the mortality due to man's predation, and make a sustained fishery possible, must, of course, involve controlling elements.

It is not necessary to isolate the elements involved, but only to determine quantitatively the relationships between intensity of fishing, the size and composition of the population, and the amount and quality of the catch that the population will sustain, though an understanding of the mechanisms concerned is of obvious value, both in understanding the dynamics of the fishery and in applying conservation measures.

The concept of equilibrium catch and maximum equilibrium catch

The basic problem of fishery management has been very simply and clearly formulated by Russell (1931), who stated the matter essentially as follows:

If P_1 represents the weight of the population of catchable sizes of fish at the beginning of some period of time (a year, for example) and P_2 represents the weight of the population of catchable sizes of fish at the end of the period,

$$(1) \quad P_2 = P_1 + A + G - M - C$$

where A is the amount by which the stock of catchable sizes of fish is increased in weight by recruitment of new individuals during the year (additions by reproduction); G is the increase in weight of the stock by growth during the year; M is the loss of stock by natural deaths during the year; and C is the weight of the annual catch.

In slightly different form:

$$(2)\quad P_2 - P_1 = A + G - M - C$$

This states the obvious fact that the change in weight of the stock is equal to additions to the stock by recruitment and growth, less subtractions by natural mortality and fishing. Obviously, when C is greater than A + G - M, the stock decreases; when C is less than A + G - M, the stock increases; and when C is exactly equal to A + G - M, the net change is zero.

The sum of the three terms (A + G - M) is referred to above as the rate of natural increase. The catch when C = A + G - M, may be called the equilibrium catch, because it is the size of the catch when the population is in equilibrium with its environment, including predation by fishing.

It is clear that under the same environmental conditions, except for the amount of fishing, equilibrium may be established at various levels of stock. Indeed it may be established at any level of stock between the maximum possible stock (when there is no fishing) and the threshold level for survival. The problem, then, is reduced to estimating A + G - M, the rate of natural increase (which equals the equilibrium catch) for various values of P (and corresponding values of fishing intensity). Since the several terms are interconnected biologically, and some or all of them are determined by the density-connected controlling elements of the environment, there will, in general, be some maximum value for the equilibrium catch, the establishment of which is the primary objective of fishery conservation.

Because both the controlling and modifying elements of the environment are subject to variations unrelated to the magnitude of the fish population, the stock, even under constant fishing intensity, is never in practice in equilibrium, but fluctuates about some average level corresponding to average environmental conditions. By taking a suitably long series of observations, however, it is possible to deal with the average condition and to estimate the average maximum equilibrium catch and the fishing intensity corresponding thereto, in the absence of sufficiently detailed knowledge of the operation of all environmental factors to permit them to be taken into account by other than statistical procedures.

Although the estimation of the fishing intensity which will produce the maximum equilibrium catch is a central objective, a somewhat lesser objective may be more easily attained and may be of great immediate importance, that is, the determination of whether the intensity of fishing is above or below the level corresponding to maximum equilibrium catch. This does not necessitate estimating the equilibrium catch over a wide range of fishing intensities, but only determining whether an increase from the existing intensity will result in a decrease or an increase in the equilibrium catch. In the latter case, the population is being underfished (so far as maximum sustainable yield is concerned), while in the former it is being overfished, and conservation action is indicated.

The preceding discussion has been predicated on the assumption that under uniform conditions of environment - including fishing - the fish population tends to stability, that is, in a given set of environmental circumstances the population tends to remain at a fixed level. Most populations of sea fishes are believed to be of this sort. There are, however, some kinds of organisms - notably certain kinds of insects - where the nature of the competition between the members of the same species leads to sustained oscillations in the size of the population, that is, the rate of natural increase tends to be some periodic function (Nicholson, 1950, 1954b). It appears that this type of population may sometimes occur among fishes, for example, some of the population of salmon of the genus *Oncorhynchus*. It has been shown by Nicholson (1954a, 1954b) that this type of population, in a given set of conditions, oscillates periodically about a constant mean value which is determined by the conditions of the environment. Therefore, in terms of the mean values, averaged over one or more cycles of the population and of the factors making up the natural rate of increase, equation 2, above, and the subsequent treatment, apply. In this case there still exists some level of sustained fishing intensity and corresponding mean population which conforms with the maximum sustainable mean catch.

There is, however, the possibility that for oscillating populations the sustainable mean catch might be greater if the fishing intensity were continuously varied than if held at some constant level; on the other hand, it might be less. I do not believe this has been investigated for any marine organisms, and, indeed, I am not acquainted with any literature bearing on this matter for any organism. In the absence of information regarding oscillatory fish populations, this paper deals only with the kinds of populations which may be regarded as tending to stability. As noted above, most, at least of the sea fish populations, are believed to be of this kind.

As noted earlier and as indicated in figure 1, investigation of the effects of man's predation may be made at three levels, of increasing complexity, but leading to increasing understanding of the dynamics of the fishery and consequently to increasing possibility of efficient conservation management.

Investigations at the first level

The first level of investigation (level I in figure 1) may simply obtain, over a series of years which encompasses various degrees of fishing intensity, measurements of fishing intensity, size and composition of the population, and size and composition of the catch, and, on the basis of these, inferences as to the effects of fishing on the stock and catch, and an estimate of the current status of the fishery in comparison with the condition corresponding to maximum sustainable yield.

The amount of the catch may be determined from landing statistics, and its composition from examination of representative samples of the landings. The relative abundance of the stock can be measured by the catch per unit of fishing effort, properly corrected for differences in gear which may be employed. The most precise estimates of this sort also require corrections for variations in availability, but where these are lacking the factor of availability may be treated as a random variable, if the series of data is sufficiently long and if there is, in fact, no systematic, long-term change unconnected with the fishery activities. To compute absolute abundance from relative abundance usually requires data from marking experiments, though this can also sometimes be inferred from changes in catch and relative abundance.

In addition to the measurement problem resulting from variations in availability to the fishing gear, there may also arise a problem in changing efficiency of gear, owing to improvements of existing gear or shifts to new kinds of gear over a period of years. Various statistical devices for taking these into account have been developed and are sufficiently well known to require no detailed discussion here.

Inferences of effects of fishing on the stock and catch, and the current status of the fishery, from the evidence of historical records of changes in relative abundance and catch in relation to changes in fishing effort, have proven most useful in practice. Several good examples come immediately to mind.

The data on the plaice fishery of the North Sea, summarized in several publications of the International Council for the Exploration of the Sea (for instance, Graham, 1954a, figure 3) indicate clearly that the intensity of fishing is sufficiently great to have had a marked effect on the stock, and that the intensity reached before the Second World War was above that corresponding to the maximum yield. For this, and some other North Sea and North Atlantic fish populations, the respites from fishing during the two world wars provided a wide variation in fishing intensity, the effects of which on the stock are unmistakable (Clark and others, 1948). A similar series of data on the Icelandic cod (Graham, 1954a) indicated that this stock, on the contrary, showed no signs of approaching the maximum desirable level of exploitation.

In the well-known example of the Pacific halibut (Thompson and Bell, 1934; Thompson, 1952), the historical series to 1930 indicated that the intensity of fishing had reached, particularly on the oldest fishing grounds, a level well above the maximum desirable, and that the stock had declined to a point where the sustainable harvest was well below the maximum. Acting on this information, the harvest was regulated by the International Fisheries Commission, with subsequent rebuilding of the stocks, and eventually some increase in total harvest as well.

The simple examination of such time series is, in many cases, adequate to indicate whether a stock is underfished or overfished, and thus whether conservation measures are required. It is also possible, however, from a reasonably long historical series of data on abundance, catch and fishing intensity to make quantitative estimates of the effect of changes in fishing intensity on the stock, and to estimate the equilibrium catch at various levels of population and the maximum equilibrium catch. The method employed here consists, essentially, of considering the rate of natural increase, that is, the sum of the terms (A + G - M) to be some single-valued function of the mean population.

$$A + G - M = f(\bar{P})$$

and (from equation 2, above)

$$(3)\ P_2 - P_1 - \Delta P = f(\bar{P}) - C$$

If it is further assumed, as is usual in fisheries research, that the catch per unit of fishing effort is proportional to the mean population encountered by the fishery during the year (as a measure of the relative abundance of the fish), and that the instantaneous rate of fishing mortality is proportional to the number of units of fishing effort, the result is

$$(4)\ \Delta P = f(\bar{P}) - k_1 F \bar{P}$$

and

$$k_1 \bar{P} = U$$

where F is the total number of units of effort applied during the year; $\bar{P}$ is the mean population; U is the catch per unit of effort; and k_1 is a constant.

If on theoretical grounds or on a sufficient basis of empirical experience, the form of $f(\bar{P})$ can be specified, equation 4 or an equivalent formulation can be employed to estimate **quantitatively the relationship between fishing, population** and sustainable catch. Bückmann (1938) and Graham (1939) have discussed part of the theory of this approach. Graham (1935) has applied it in a rough way to the estimation of the equilibrium catch of the demersal fish stocks of the North Sea, as has Baerends (1947). Recently the writer (Schaefer, 1954a, 1954b) has further developed the theory and methodology, and shown applications to the Pacific halibut and sardine fisheries.

In the interpretation of historical series by the foregoing methods, it is assumed that all of the influences of environmental factors other than fishing, as well as measurement errors, may be regarded as random variables. It is necessary, therefore, to employ fairly long series of data for such investigations, for two reasons: (a) Even if the environmental effects mentioned are truly random, the greater the amount of data, the greater the precision of the statistical estimates, and (b) if there exist cyclic variations, it is necessary that the series of data be long enough with respect to the period of significant cycles for such variations to be treated as quasi-random. If there do exist, unknown to the investigator, long-term trends or long-term cycles in the environmental influences, there is the possibility that the changes in population due to such trends or cycles may be attributed to changes in fishing effort, whereas they may not in truth be so. Certainly some caution needs to be exercised in this direction.

Determination of the size and age composition of the catch, and stock, over the same series of years offers one means of determining whether the observed changes may be due to factors independent of the fishery. Where the controlling factor is the intensity of fishing, there occur, along with changes in the magnitude of the stock, changes in the age composition systematically related to changes in fishing intensity (see, for example, Clark and others, 1948). Such a series also makes possible the empirical determination of the relationships between intensity of fishing and quality of the catch which, as pointed out before, may be an important secondary consideration in a conservation programme.

Investigations at the second level

An alternative approach to applying equation 4, or an equivalent formulation, to the determination of the relationship between intensity of fishing and equilibrium catch is to estimate the individual terms for recruitment, growth and mortality, and combine them to estimate equilibrium catch. The pioneer worker Baranov (1918) was the first, so far as I know, to employ this method. He assumed that the number of fish recruited annually to the population is constant for all sizes of population. He assumed growth to be age-specific but independent of size of population (the length directly proportional to the age and the weight proportional to the cube of the length). He assumed the percentage of natural mortality to be constant, and the instantaneous rate of fishing mortality to be proportional to the fishing intensity. Under these assumptions, he computed the equilibrium catch for populations of fish having a specified rate of increase of length with age, for various values of natural mortality rate and fishing intensity.

Thompson and Bell (1934) computed the equilibrium catch in a fishery for various rates of fishing mortality, assuming numbers of recruits constant and percentage rates of growth and mortality constant. They also computed the changes in the population and yield which would occur in the halibut fishery, assuming numbers of recruits to be constant, percentage rate of natural mortality to be constant, growth to be age-specific (using average age-weight data from samples of the catch) but constant at each age, and the instantaneous fishing mortality rate to be proportional to number of units of gear actually fished. The mortality rates employed in the calculations were in the vicinity of those inferred from tagging experiments. With these simplifying assumptions, they found the calculated changes in abundance and catch corresponded rather well with the actual changes over the period of years examined.

Parrish and Jones (1953), studying the haddock of the Faeroes and the North Sea, have computed equilibrium catch, assuming numbers of recruits constant; percentage rate of natural mortality constant (using in different calculations a range of rates within which falls the average value for the fishery in question, inferred from the available data); growth rate age - specific, following a mathematical form due to Bertalanffy, but constant at each age for all population densities (curve fitted to average data from samples of the catch) and the instantaneous fishing mortality rate proportional to the amount of gear fished. It is shown that the present fishing intensity in both areas is above that corresponding to maximum equilibrium catch.

Beverton (1953) made similar calculations, based on the same assumptions and on methodology similar to that of Parrish and Jones, for the plaice and haddock fisheries of the North Sea. He also made calculations of the variations in yield of this fishery, taking into account the effect of variation in age of recruitment due to regulation of size of net mesh. He showed that the equilibrium yield might be increased from the present state by a decrease in intensity of fishing, an increase in mesh of net, or both.

This approach, combining the estimates from current data on recruitment, growth rates and natural mortality rate, is adequate to indicate when a fishery has been overfished, and to indicate the direction regulation needs to take.

Since this does not take into full account the density effects on these factors, and also neglects the age-specificity of natural mortality rates, the estimate of equilibrium catch at fishing intensities very different from the current one becomes increasingly poor. This has been recognized by some authors. Ricker (1944) points out that this assumption, that certain of the rates remain constant when the fishing effort changes, does not correspond to reality, so that such calculations cannot be valid over a very large range of population sizes. Parrish and Jones (1953) say, "Of course, these curves are not valid over their whole range, since with increase in stock density, there will possibly be some decrease in growth rate and increase in natural mortality rate, so that the ordinates to the left of the curve /lower fishing intensity/ are probably over-estimates".

Since recruitment must also decrease at very low levels of population, the values computed for very high fishing rates are, doubtless, also over-estimates. Beverton (1953) notes that

> "... the model can establish the main dynamic properties of a fishery and can indicate the first steps which are required to regulate it, but for making accurate predictions of the regulation required and of its probable effects, it is necessary to take other factors into account. Of particular importance here is the variation of the parameters with population density... Introducing phenomena of this kind makes the model more realistic and gives it the properties of 'self-compensation' which are characteristic of natural populations..."

He has made, for both haddock and plaice, calculations showing the effect of taking into account density effects on the growth rate and natural mortality rat

In determining the average values of recruitment, growth and natural mortality, fishery scientists normally employ data from the catch and from tagging experiments over a series of years. It is implicitly assumed that any environmental influences behave as random variables, which will average out over the series. This, as in the investigations at the first level, is a possible source of error if in truth there is a non-random trend in such factors. The measurement of the elemental rates, however, makes it easier to detect such environmental effects than the simple consideration of the statistical data on catch alone.

Calculations disregarding age-specificity of natural mortality, and disregarding density effects on recruitment, growth and natural mortality, limit the usefulness of the calculations to fishing intensities and population sizes near those for which the rates have been measured. It is desirable, therefore, that where possible the changes of natural mortality with age, and the density effects on all three factors, be determined and incorporated into the calculations. The age-specific mortality rates can be calculated from sufficiently detailed samples of age composition in several successive years. The determination of density effects, however, requires determination of rates at different population densities, which are often difficult to obtain, since the fishery tends to maintain the population density at some rather constant level, depending on economic factors. Such changes in population density as those resulting from respites from fishing during the major wars offer one sort of opportunity for such determinations. Lacking this, as a practical procedure it is probably necessary to proceed step-by-step with management regulation, approaching the condition of maximum sustainable yield by a series of successive changes in regulations.

Investigations at the third level

Investigations at the first and second levels result primarily in information for controlling the fishery so as to give the greatest sustainable yield under average environmental conditions, and the methodology of investigation treats variations of such conditions as random variables to be eliminated by suitable statistical procedures. Understanding of the dynamics of the fishery will, obviously, be more precise, and therefore more useful to effective conservation action, if the effects of the environment on the population and catch are understood and measured along the lines indicated in an earlier section. Such knowledge will also make it possible to establish a regulation of the fishery under which the harvest would be increased during periods of abnormally high rate of natural increase, and decreased during periods of abnormally low rate of natural increase, thus obtaining a greater total production than is possible under regulations based on average conditions.

The necessary quantitative knowledge of the influence of variations of elements of the physical environment on the fish stocks is not available for such ideal management of any of the sea fisheries, but is the ideal which fishery research should hope to attain eventual . This must involve, however, measurements of all important factors in the ecological system, as shown schematically in figure 1. The direct effects of the physical environment on recruitment, growth, mortality and availability of the stock to the fishery must be measured quantitatively. The indirect effects through the modification of the food supply and the living space must also be measured. Since the population of a given fish species is part of an ecological system including populations of other species which compete with it, or prey upon it, the environmental effects on such other populations will affect the survival and growth of the population of the species harvested by man. Finally, in some instances, the fishery may catch members of competing and predatory fish populations because they are of commercial value, or they may be captured and killed incidentally, even if not landed. The study of the effects of fishing on predators and competitors is thus an important kind of investigation in such circumstances.

Since the ecological system is exceedingly complex, the investigations at the third level usually become complex also. Only in a few places have such detailed studies been attempted on an adequate scale. The investigations of the demersal fishes of the North Sea, and the investigations of sardines and related pelagic species off California, are perhaps two of the best examples of progress along this line. In both of these cases a great deal has been learned, serving partly to show how much more needs to be found out. The information developed by investigations at this level is, however, of use in the conservation programme even though it may be imcomplete. Partial information of the relationships indicated at the third level is of value to analyses at the first and second levels.

Relationship to other species being exploited simultaneously

Very often a fishery does not depend on a single species of fish, but is supported by two or more species which are captured in the same areas at the same seasons, sometimes even being taken simultaneously from shoals composed of a mixture of species. For example, trawl fisheries commonly capture a mixture of marketable species. Again, in the tuna fishery of the tropical eastern Pacific (Schaefer 1954c) two species of tuna are taken in the same areas and seasons with the same gear.

In such circumstances it would, of course, be desirable to maximize the sustainable catch of each of the species. Whether this is capable of attainment depends upon the effects of a given amount of fishing on the stock and yield of each species, and upon whether selectivity of species can, in fact, be practised in the fishery.

First of all, it is desirable to determine the effects of fishing on the stock and yield of each species, and its current status in relation to the maximum equilibrium catch. If, as may often occur, some species are being underfished while others are overfished, it is desirable to curtail fishing on the overfished species while allowing it to increase on those that are underfished, if this is possible.

The possibility of selective control depends on the biology and behaviour of the several species. Investigation may show that the various species are differently distributed in area or time, and the pattern of fishing can be modified accordingly. For those species, such as the tunas, which are located by visual means, it is important to determine to what extent the different species school, each according to its own kind, because if mixed schools are of infrequent occurrence selectivity may be exercised in the fishing operation. It may also happen that gear modifications (such as regulation of mesh size of trawls) will make possible the selective escape of one species.

Where it is not possible, on these or other bases, to fish selectively, it will, in general, still be possible to control the fishing to obtain the maximum sustainable aggregate catch of all the species. Beverton (1953), for example, has noted that for the trawl fishery of the North Sea "for any given fishing intensity there is a mesh size which enables the greatest combined yield to be obtained, although this combination of fishing intensity and mesh size might not be eumetric for any one of those species alone".

Here, again, it will sometimes also be necessary to consider some of the economic aspects of the fishery. Where several species are caught simultaneously, and they have quite different values in the market, it may be desirable to manage the fishery so as to obtain somewhat less than the maximum sustainable aggregate catch in order to secure a more desirable species composition. The same types of biological information are, however, required for both purposes; in either case the necessary conservation measures must be based on scientific knowledge of the dynamics of the fish populations concerned.

Types of Applicable Conservation Measures

When scientific investigations of the types discussed above have shown that curtailment or modification of man's predation on the fish population will increase the quantity or quality of the catch, various kinds of regulatory measures may be put into effect. The kind of regulation imposed will depend on the effects which it is desired to obtain, the nature of the fish population, the characteristics of the fishery, and economic and social factors pertinent to the particular circumstances.

Control of level of fishing intensity to obtain maximum average sustainable catch

When the investigations have shown that there exists, or is imminent, a condition of overfishing (that is, an intensity of fishing such that the sustainable catch is less than it would be at a lower intensity), the sustainable catch may be increased by curtailing the amount of fishing. This may be accomplished in several ways.

The most straightforward method is to limit directly the amount of fishing effort employed in the fishery. This may be accomplished by limiting the number of fishermen or vessels which are permitted to engage in fishing, or by allowing all who wish to do so to fish, but limiting the amount of fishing time or amount of fishing gear per person or vessel. Limiting the number of persons or vessels permitted to fish has the effect of giving a property right to those who are so permitted, which is contrary to public policy in many countries. Limiting the total fishing intensity by regulating the amount of fishing of each person who wishes to engage in the fishery has the same effect on the fish population and the catch, but has the possible disadvantage that the total cost of harvesting the yield is greater, so that the net economic yield is less.

Administratively, it is usually easier to limit the amount of fish which is permitted to be caught and landed than to limit the amount of fishing effort directly. Limitation on fishing intensity is, therefore, often obtained indirectly by means of quotas or limits on the permitted landings. This technique has been employed successfully in the Pacific halibut fishery, among others. Where a single annual quota is imposed for a given geographical region, the permitted catch will be obtained in a shorter and shorter time as the abundance of fish is rebuilt, so that the fishery will tend to be concentrated in a short season. If within the region there are several sub-populations which become available to the fishery at different times of the year, this results in the fishery's bearing on them unequally. Such a condition is apparently the case for the Pacific halibut (Dunlop and Bell, 1952). In this event, it becomes necessary to establish separate catch quotas for different time intervals in order to obtain full utilization of all the sub-populations. The Pacific salmons offer other examples of resources composed of several populations that are available to capture at different times in the same fishing area, and for which limitations on permitted catch need to be applied separately for different time periods to obtain the desired fishing intensity for each of the several populations.

Limitation on fishing intensity is also often obtained by establishing closed seasons during which no fishing is permitted, usually choosing seasons when the fish are most amenable to capture. This seems, of course, to be economically inefficient. A similar type of indirect limitation on fishing intensity may be obtained by closing to fishing certain areas where fish are most amenable to capture. Where closed areas have the sole object of curtailing fishing intensity, and not of protecting certain classes of fish, this type of control may, again, be less economically desirable than others, if the areas chosen are those where fish are particularly amenable to capture.

A popular method of controlling intensity of fishing without limiting the number of persons engaged in fishing, or establishing direct catch limitations, is to employ regulations to limit the efficiency of the fishing gear. This may involve complete prohibition of certain kinds of gear; prohibition of the use of ancillary equipment, such as electronic devices for locating fish shoals, or the addition of power to sailing craft; limitations on the size of vessels permitted to engage in the fishery; or restrictions on the fishing gear itself, such as limits on the length of gill nets or purse-seiners or on the maximum breadth of trawl nets.

Protection of fish whose conservation would result in greater average catch or more desirable quality

As noted earlier, the total sustainable yield from a fish population may be increased by permitting the fish to remain in the sea so long as the increase in weight by growth exceeds the loss in weight by natural deaths. Harvesting fish of larger sizes will, in some cases, also produce fish of more value in the market. In such cases, and where it is practicable to do so, regulations to protect the smaller sizes of fish are desirable. This may be accomplished in several ways.

Regulation of fishing gear to permit differential capture of specified sizes of fish is a practical method in fisheries employing gill nets, trawl nets and similar gear, since regulating the size of mesh of the nets allows fishes below specified sizes to escape capture. This type of regulation is being used, for example, in the trawl fisheries of the North Sea and certain parts of the north-west Atlantic.

It is also practical in some instances simply to prohibit the landing of fish below a specified size. For this to be practicable, the nature of the fish and the fishing method must be such that (a) the fishermen can avoid capturing the small fish, or (b) the small fish can be returned to the sea after capture without a large percentage of deaths. Where the small fish occur in different geographical areas (often called "nursery" grounds) than the large fish, the small fish may be protected from capture by closing such areas to all fishing.

It may happen that, within the area where fish are available to the fishing gear, small fish occur in certain seasons of the year and large fish at others. In such cases, closure of the fishery during the season when the small fish predominate is an effective means of achieving this kind of control.

Differential harvesting of sexes

It may happen that the ratio of sexes occurring in nature is such that there is a surplus of one sex in relation to the requirements for reproduction. In this event, the fishery may be managed so as to fish one sex more intensively than the other, by taking advantage of differential distribution, behaviour or morphology of sexes. It may also happen, conversely, that the unregulated fishery bears unequally on the sexes, disturbing the normal sex ratio necessary for efficient reproduction. In this case regulations to correct the imbalance are in order.

The only example which comes readily to mind is the sockeye salmon. For some populations of this species in Alaska, it has been indicated (Pacific Fisherman, 1950) that there is a normal surplus of males, and that these may be differentially captured by regulation of the mesh sizes of the gill nets used to catch them. It has been shown, likewise, that the gill net fishery for Fraser River sockeye salmon (Peterson, 1954) is selective towards the males, the degree of selection being related to the mesh size of the nets; here it has not been indicated whether or not this is desirable.

Regulations designed to ensure adequate recruitment

Regulatory measures are frequently employed with the object of ensuring that recruitment to the fishable stock is maintained. For some populations, of which, again, the Pacific salmon offer a ready example, it has been indicated by research that there is an optimum size of the spawning population which will produce the maximum resulting harvest, so that regulation takes the form of restrictions on fishing to permit the optimum number of fish to escape to the spawning grounds. This type of regulation, which depends on the premise that the relationship between spawning stock and resulting recruitment is the predominantly important factor determining the rate of natural increase, has little application to most purely marine populations.

Minimum size at first capture, obtained by any one of the means mentioned above, chosen so as to minimize the capture of sexually immature fish, has been justified on the basis that so long as the fish are given maximum opportunity to spawn at least once, adequate recruitment will be assured.

Protection of young fish by closure of nursery areas is also sometimes considered a means of assuring increased recruitment to the stock of adult fish, quite aside from the augmented weight of catch to be obtained by allowing the small fish to gain additional weight by the excess of growth over natural mortality, when such exists.

Protection of adult spawning fish by prohibition of fishing in spawning areas or during spawning seasons, with the aim of thereby increasing the number of progeny, is a widely practised type of regulation which, except in special circumstances, has little or no inherent advantage over restriction on fishing at any other period. The widespread belief in the effectiveness of this type of regulation probably arises from a presumed analogy with the conservation of various land animals which care for their young during a protracted time and whose protection, therefore, is necessary to the survival of their young. Since the majority of commercially important fishes give their young little or no post-natal care, refraining from catching them during the spawning season will produce but few more progeny than refraining from catching an equal number some months earlier. The only net increase will be due to the spawners having survived a certain natural mortality in the intervening period. If the stock is equally accessible to capture during both periods (that is, if a unit of fishing effort catches the same percentage of the existing total adult stock during the spawning period and during the non-spawning period), there will be no gain at all, in eggs produced, from applying the same fishing effort during the non-spawning period rather than the spawning period, because the percentage of the initial stock surviving to spawning will be exactly the same, whatever the time.

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A FIRST APPROXIMATION TO A MODERN THEORY OF FISHING

by

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(The mimeographed text of this paper appeared as document A/CONF.10/L.7)

In 1930, Meek published a diagram on the relationships of growth and mortality to age in a stock of fish and almost simultaneously others developed the same line of thought, which was indeed Petersen's (1894) and Baranov's (1918).[1] New work in the nineteen thirties contained a new lesson, namely, that the possibility had arrived of continually controlling the yield of a fishery by controlling the rate of fishing. Any difficulty thus became one not of uncontrollable fish but of unco-operative men.

The new theory, with much evidence bearing on it, has been worked out in detail by Beverton and Holt, whose main equation was quoted by Graham (1952) and whose book is in preparation. Parrish and Jones (1952) have already used some of Beverton and Holt's methods, which are mentioned by Schaefer in his background paper for the present conference.[2] Dr. Schaefer has very ably and elegantly expounded the whole subject. Perhaps there might also be some use for a short paper with an arithmetical example, which a reader could easily follow through himself, provided we are content with a first approximation. There is no reason to despise the first approximation, because it is sufficient to demonstrate the main lesson, and none of the many deeper studies have, in fact, disturbed it.

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[1] See bibliography at the end of this paper.

[2] See paper entitled "The Scientific Basis for a Conservation Programme".

Mortality and average age

Death fosters youth. At school, I was told that in the Middle Ages a forty-year old European would be a senior among his fellows, because death by violence or disease was more common in a man's lifetime then than in modern times. Although I have since learnt to be uncertain about the Middle Ages, I do not doubt the explanation, which is confirmed by actuarial algebra and practice: a high rate of mortality goes with a low average age, and vice versa.

Man, nowadays, rarely meets his death by being eaten, which is the usual fate of other members of the organic world. Most fish can be eaten by many kinds of animals, and sometimes by parasites or other organisms of disease. If, however, one agent of death becomes so active as to claim more fish than die by all other agencies put together, then that agent has control of the average age of the stock of fish. Until man attains that relation to the fish, the example given in this paper does not apply. Instead, Huxley's dictum 3/ is the appropriate guide: let the fisherman be free.

The theory of fishing therefore begins thus: When the rate of fishing effectively governs the average age of a stock of fish...

Theoretical examples

Having agreed that the rate of fishing could control the average age, consider that twenty fish represent a stock - which might really number 200 million - with young fish coming in and old ones dying or being caught, but the level remaining the same, just as, in even a swift stream, a pool can retain the same level. In this case, which is quite realistic for hard-fished stocks, suppose that a rate of

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3/ See the author's paper entitled "Concepts of Conservation".

fishing of 0.80 holds the stock level, that is, the average annual catch is 80 per cent of the average stock. The resulting age census might be as follows, with average weights of fish also shown.

Age	Number	Average weight (kilogrammes)	Weight of stock (kilogrammes)
I	6	0.17	1
II	4	1	4
III	3	2	6
IV	3	3	9
V	2	5	10
VI	1	7	7
VII	1	9	9
Total	20		46

The catch would be 80 per cent of the twenty fish, of an average weight of $\frac{46}{20}$ kilogrammes, which is 0.8 of 46 kilogrammes, namely 36.8 kilogrammes.

Assume that a rate of 0.70 would allow the census to alter to the following steady level:

Age	I	II	III	IV	V	VI	VII	VIII	Total
Number	6	5	4	4	3	2	1	1	26

Using the same average weights, and one extra for the oldest fish, the result would be:

Age.............	I	II	III	IV	V	VI	VII	VIII	Total
Weight of stock	1	5	8	12	15	14	9	10	74

and the new catch would be 0.7 times 74 or 51.8 kilogrammes. That is a gain in yield, and shows how fishing less can catch a greater weight.

If one looks closely at the comparison, one can see that the gain is not automatic. The lower fishing rate, which allows greater survival to form a heavier stock, also takes less of that stock, and the gain cannot continue indefinitely. For example it is difficult to conceive of a one per cent rate of fishing giving a high annual catch; and a zero rate certainly could not.

Conclusion

In order that the arithmetic in the example might be followed easily, I have used convenient imaginary data. Here, however, are real values for some North Sea species (from the Beverton and Holt manuscript, for a fishery using a trawl mesh 70 millimetres on the gauge):

Species and rate of fishing	Relative yield
Plaice:	
0.70	196
0.50	212
0.30	217
0.20	197
Haddock:	
0.70	134
0.50	137
0.30	125
0.20	112
Cod:	
0.70	1,030
0.50	1,440
0.30	2,100
0.20	2,450

These figures are not first, but close, approximations, using, as well as possible, all the available information. First approximations would, however, be sufficient to illustrate the modern theory, which might be put into words such as these: When the rate of fishing effectively governs the average age of a stock of fish, then varying the rate of fishing would control the yield of the fishery.

Great benefits of several kinds are therefore obtainable if the rate of fishing can be controlled, especially when, as often is the case, an intermediate rate of fishing gives the best results.

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ASPECTS OF THE LIFE HISTORY OF CERTAIN RESOURCES OF THE SEA IN RELATION TO THE PHYSICAL ENVIRONMENT

by

United Nations Educational, Scientific and Cultural Organization

(The mimeographed text of this paper appeared as A/CONF.10/L.3 under the title "Pertinent Aspects of the Life History of Given Resources of the Sea in Relation to the Physical Environment")

Contents

Examples of Reaction of Specific Marine Species to their Environment

ROLE OF THE ENVIRONMENT IN THE BIOLOGY OF ECONOMICALLY VALUABLE STOCKS [1]

by

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The majority of economically valuable marine stocks belong to the phylum of vertebrate animals. They are principally the fishes and, among these, essentially the so-called food fishes of commercial importance at the present time. There are doubtless other fishes, as well as some invertebrates, which, although not now of commercial significance as human food, will one day become so by virtue of development in processing techniques.

In the evolutionary scale of vertebrates at the supreme head of which is man, fishes occupy the lowliest position, after mammals, birds, reptiles and amphibians. In the case of man, his environment comprises many and various factors, but above all living creatures he possesses unique powers of will, self-determination and adaptation, tending to render him independent of his environment. Nevertheless, one of the most significant trends in the scientific study of man has been the increasing understanding of the extent to which the conditions of his environment affect, and to some extent control, the life and habits of the individual, of the social or national group, and even of the race.

On the descending scale from man to fishes, not only the scope of environmental conditions rapidly narrows, but reactionary powers and powers of adaptation also diminish; a priori relationships between the life and habits of the animal and the conditions of its environment become the more intimate; the animal becomes increasingly dependent upon environmental factors for its welfare, and indeed its survival. With particular reference to fishes, therefore, such relationships may logically be expected to be of quite fundamental importance.

The whole environment of fishes, excluding man's activities towards them, comprises biological as well as physical factors - that is - food and enemies, as

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[1] In substantial measure this section is a summary of the author's Hydrography in Relation to Fisheries (Edward Arnold and Company, London, 1952).

well as the sea floor, the sea itself, and to some extent the atmosphere. While on occasions food or predators may at one time or another assume major significance as environmental factors, the aggregate of evidence goes to show that, in general, this is only in virtue of their more immediate but temporary importance relative to physical and chemical factors in and of the sea. Scientific investigation increasingly points to the conclusion that fishes and their food ultimately depend upon the varying physico-chemical conditions of the sea itself.

Physical Conditions in the Sea in Relation to Fishes

The temperature of the sea exerts marked and often decisive influence on all fishes throughout their lives. Temperature is unquestionably the governing factor in spawning, as shown by the comprehensive works of Schmidt (1909)[2/] and of Damas (1909) on gadoids, and by other investigators in respect of herring (Fulton, 1902), mackerel (Allen, 1920; Nilsson, 1914) and other species (Fulton, 1902; Orton, 1927). It is clear from experimental and natural evidence that the temperature limits within which spawning takes place - and only within which it will take place - are narrow, relatively precise, and specific for each species.

Numerous experiments also have proved the correlation between temperature and the rate of development of fish eggs (Dannevig, 1895; Tait, 1952). Within limits which are sometimes surpassed in the sea low temperatures retard and high temperatures accelerate development. Natural evidence of the phenomenon is contained in the different rates of development of spring and autumn herring ova, respectively, and in the differential development of early and late ova of the same species, even from the same fish, during a spawning season. Undue thermal retardation or acceleration of the hatching process of fish eggs entails the risk of infirmity in the resulting hatch, or even of mortality (Johansen and Krogh, 1914).

Temperature differences during the hatching period have at least another consequence. Tåning (1946) has shown for the sea trout that the subsequent vertebral structure of the embryo is conditioned by temperature during the

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[2/] Numbers in parentheses refer to the references at the end of this section.

period of development of the egg. Herein probably lies the explanation of the fact that fishes of the same species are found to be larger, age for age, in cold than in warm water regions.

Development and growth of larval and baby fishes have also been shown to be directly influenced by temperature (Dawes, 1930/31) independently of the influence of food. Sea temperature is further directly connected with the physical activity of fishes, with their respiratory rate, rate of heart beat, and rate of metabolism. Numerous experiments have shown that a temperature increase of only one degree centigrade increases the rate of metabolism by about 10 per cent (Harvey, 1928). Temperature, too, influences in greater or less degree the migrations of fishes, apart from that which is associated with the spawning urge (Bull, 1952).

Salinity

The salinity or aggregate salt content of the sea, which in this context may be regarded as a physical quantity, is of direct consequence, particularly in its space-time variations, to those marine organisms - even though they may not in the main be fishes or fish eggs, but organisms which constitute the food of fishes - which must adjust their internal osmotic pressures to that of the surrounding medium. Indirectly, also, salinity in association with temperature determines the internal friction or viscosity of the sea, which bears immediately on the suspension of marine organisms. Associations which are not in themselves conclusive of direct or essential connexion between salinity *per se* and the phenomena concerned have been demonstrated in relation to spawning (Damas, 1909; Schmidt, 1909), the abundance of fry (Johansen, 1927), the rate of growth of fishes and - for certain species at least - the distribution. The greater likelihood, however, is that, in reality, the associations are with one or another of the typical water masses present, of which the salinity is an index. On the other hand, recognition must be made of Bull's experimental demonstration (Bull, 1952) of certain fishes' conditioned responses to a minimal change in salinity of as little as 0.2 per thousand.

Light

Differential penetration of light into the sea has several consequences of significance to fishes as witness the diurnal vertical migrations of some pelagic fishes and of plankton organisms generally. Too strong sunlight is lethal to some marine creatures. Again, physical activity, respiratory, cardiac, and metabolic rates are affected by light intensity (Harvey, 1928). Respiration in bright daylight has been found among plankton animals to be as much as double that in the dark (Marshall, Nicolls and Orr, 1935). Different parts of the spectrum also have been found to be injurious to various organisms (Clarke and Ostler, 1934).

Currents

The currents of the sea, both horizontal and vertical, as manifestations of probably the most fundamental and universal characteristic of the sea, namely its constant movement, to which practically all questions relating either to the sea itself or to its inhabitants must sooner or later be referred, play, at one and the same time, intimate and over-all roles in the lives and habits of fishes. In their merely mechanical effects, many examples can be cited of plankton distributions conforming to the pattern of the horizontal currents in a region like the North Sea for instance (Tait, 1937; Orton, 1937; Braarud and others, 1953). Bowman (1953), with particular reference to plaice, worked out a striking example of the close interdependence of fish migrations and the prevailing current system. Together with these, the remarkable demonstration (by Carruthers, Lawford, Veley and Parrish, 1951) of the apparent coincidence between the distribution of haddock in the northern North Sea and the shape of the Great Eddy in that region (Tait, 1937) are strong pointers to the actual and potential importance, indeed the indispensability to fishery investigators, of the most detailed knowledge of currents.

In brief, however, currents and water movements generally are of supreme importance - because they are most fundamental - in all aspects of marine investigations directed towards an understanding of the living resources of the sea. They control the distribution of temperature and other physical and chemical properties of the sea on which all marine life depends; they control the distribution of the ultimate food organisms of the fishes and other forms; they control the dispersal of fish eggs and of the youngest fishes prior to their acquiring motive power of their own; and, in the reproductive stage, they must at least be closely involved in the migrations of fishes towards those places where the physical conditions exist in which alone spawning will take place.

Depth of water

The fact that different species, often of the same genus, evidently find optimum spawning conditions in different depths of water (Tait, 1952) would appear to carry the further implication of pressure as a material factor in the process. The classical instance of depth as an apparently significant factor in spawning is associated with Schmidt's solution of the eel problem (Schmidt, 1928) when, in 1922, he literally tracked down the smallest baby eels ever captured to a restricted region of the Sargasso Sea, southeast of Bermuda, and deduced therefrom that the eggs from which they had obviously very recently hatched were spawned in relatively great depth in this region in temperatures 18° to 20° centigrade. Eel eggs have in fact since been taken from the region in question (Russell and Yonge, 1936).

Sea floor

There is another important physical factor in the inanimate environment of demersal fishes, particularly, which influences them to a greater or less extent, and that is the sea floor, in its structure and topography, in its food content and in relation to water movement immediately above it. Different species favour mud bottoms, sandy bottoms and gravel bottoms, respectively, but on account of technical difficulties mainly probably less attention on the whole has been paid scientifically and to date to this aspect of environment than to others. Modern developments in underwater photography and television, however, hold promise of greater interest and progress in this aspect of marine investigation.

The Chemistry of the Sea in Relation to Fishes

Water is fundamentally necessary to all forms of life, and being the universal solvent, par excellence, it is to be expected that all of the other substances which are necessary to marine life will be found in sea water. Sea water almost certainly does contain, even if only in extremely minute and so far undetectable quantity in some cases, all of the elements now known to science. Only some fifty of these have actually been detected in solution in it, the presence of others being inferred from the fact of their occurrence in the ashes of marine plants and animals. There would also appear to be substances of the nature of vitamins or other metabolites in sea water.

Salinity, arbitrarily expressing the total salt content of sea water, has already been treated as a physical quantity. The essential hyrochemical factors from a biological standpoint, however, are the particular substances dissolved in sea water rather than their aggregation as expressed by salinity. There is nevertheless another property of sea water of an inclusive chemical nature which is connected with certain forms of biological activity. This is its degree of acidity or alkalinity, scientifically expressed and measured in terms of hydrogen-ion concentration. Sea water is only under exceptional circumstances acid, being normally slightly alkaline in reaction on account mainly of carbonate and bicarbonate in solution.

Low hydrogen-ion concentration in the sea is usually accompanied by high oxygen concentration and is indicative of relatively intense biological activity among marine plant organisms, which are the basic source of nourishment in the sea as on land. The primary condition of existence of these organisms is adequate sunlight, from which they derive energy to break down the dissolved carbon dioxide in the sea, utilizing the carbon to build up starches and sugars. In withdrawing carbon dioxide from the sea, plants thus diminish its acidity, and measurement of this change in hydrogen-ion concentration enables estimates to be made of the intensity of the above biological process of photosynthesis and also of the abundance of organisms engaged in the process. Atkins (1926) made such estimates of what is now termed "productivity" in the English Channel off Plymouth and calculated this to be approximately three pounds weight of vegetable matter under each square metre of sea surface area.

Fishes congregating in shoals, by their respiration, increase the hydrogen-ion concentration in their neighbourhood, and American investigators have claimed that herring and others of the more active fishes are particularly sensitive to small changes in hydrogen-ion concentration (Powers, 1921). It is a fact well known to fishermen in an empirical sense that herring avoid water of which the hydrogen-ion concentration has been appreciably diminished by the presence of much microscopical plant life. Apparently, therefore, although changes in hydrogen-ion concentration are generally small, these may nevertheless be significant as regards the well-being of fishes, besides affording indication of the amount of fish food which will subsequently be available.

In respect of sea water chemistry in relation to marine life, so far as fishes are concerned, and apart from their food, oxygen is their staple requirement. Compared with land animals, fishes demand surprisingly little oxygen to sustain life. As little as one-third of one per cent may suffice, and except in regions where the water circulation is especially weak, sufficient oxygen is usually found dissolved in sea water to satisfy respiratory needs. This is true also of many inorganic constituents of sea water, present in solution in extremely small amounts; there is evidently always a sufficiency to meet the needs of marine plants and animals for these.

Many marine animals appear to be able to draw directly upon a number of the inorganic materials in the sea - especially sodium, magnesium and calcium - to build their bodies. A number of elements such as strontium, vanadium, nickel, cobalt, lead, boron and manganese have been detected in the body structure and fluids of marine animals, but the "reasons" for their being present are still obscure, except perhaps in the case of strontium. This element, chemically allied to calcium, evidently replaces the latter under certain circumstances as the main constituent of the shells of some marine animals, the reason being that calcium carbonate (the form in which calcium mostly exists in the sea) is more soluble in cold than in warm water and on that account is less easily withdrawn from cold water, say, in polar regions. Strontium carbonate has the opposite characteristic, being more soluble in warm water than in cold water, from which it will therefore more easily be deposited. The discovery of a radiolarian in the Antarctic whose shell is almost completely made of strontium carbonate appears in support of these facts. In very warm waters calcium is almost the only constituent of marine shells.

Copper, which is generally poisonous to living organisms, does, in minute amount fulfil a necessary function in the lives of oysters and of a number of other marine animals in whose bodies it has been found (Marks, 1938). Cobalt, too, occurs in lobsters and mussels, arsenic in the tissues of many marine forms, while barium, boron, cadmium, chromium, iodine, lead, manganese, nickel, potassium, tin and even radioactive elements, from their occurrence in the remains of living organisms, evidently play a part in the life of the sea. All of these except potassium occur only in minute quantities in solution in the sea. Some of them - like cadmium, chromium, cobalt and tin - have not so far been specifically identified in sea water itself.

Iron is another metal which occurs in minute concentration in the sea in combination with other elements which render its absorption by plants and animals possible. Iron, however, along with certain other substances, has a special significance in the vital economy of the sea. Only a few substances have this particular significance.

Brandt in 1899 formulated the conditions necessary for plant growth in the sea, specifying certain materials as indispensable. In their elemental form these are carbon, oxygen, hydrogen, nitrogen, sulphur, phosphorus, calcium potassium, magnesium, iron and silicon. By analogy with Liebig's Law of the Minimum in regard to land plants, Brandt further affirmed that each of these indispensable substances must be present in at least minimum amount, and he indicated nitrogen, phosphorus, and perhaps silicon and iron, as the substances most likely to occur in less than vitally minimum concentrations. In the forms in which they occur in the sea and in which they are of service to marine plants - nitrogen and phosphorus to build up protein, and silicon for structural purposes - it is the two former elements, as nitrate and phosphate, but particularly the latter (the ratio of nitrate-nitrogen to phosphate-phosphorus (Cooper, 1937) in the sea being of the order of about fifteen to one), which in fact first fall below the minimum requirement. This is due to their rapid assimilation by marine plants immediately following the intense photosynthetic activity which is characteristic of the upper sea layers in spring. Further plant proliferation depends on the renewal of phosphate by vertical circulation of the waters so as to bring nutrient rich bottom waters into the photosynthetic layers. Where the entire water column is denuded of phosphate, as in many of the shallower shelf regions around continents, renewal of phosphate depends upon current activity from oceanic regions, both vertical and horizontal currents, the former to bring up nutrient-rich deep waters on to the continental shelf by upwelling process, and the latter to distribute these upwelled waters over the shelf region. Renewal of the phytoplankton-bearing upper layers in phosphate thus frequently occurs towards autumn in temperate latitudes mainly, leading to a secondary outcrop of vegetable matter generally of smaller magnitude than the spring phenomenon.

Again, the fact of the total utilization of phosphate-phosphorus by marine plants in the photosynthetic zone may be used as a basis for calculating the approximate productivity of a region, first in vegetable matter, and, second, prospectively, in weight of fish. Atkins made such calculations in the English Channel (Atkins, 1926, page 197), and although he expressly states that the coincidence is fortuitous, he did, in respect of vegetable matter, obtain the same approximate figure, namely, three pounds weight per square metre of sea surface, as that which he derived from his calculation based on differential hydrogen-ion concentrations. For the weight of fish that might accrue from this production of vegetable matter, and having regard to various contingencies which are not yet measurable, his estimate was from one to seven tons of fish per square mile of sea surface in water of forty fathoms depth.

While phosphates and nitrates are almost certainly under normal circumstances the determining factors for the development of marine plants, they may not be so under all circumstances. Silicon, for instance, is required by diatoms in the construction of their skeletons, and silica occurs in only very small amount in the sea and is subject to well marked space-time variations similar to those undergone by nitrate and phosphate. Provided, however, that diatoms can utilize the most minute amounts of silicate, the evidence is that its scarcity can hardly be held to limit diatom growth. But, as implied in the proviso, it is not unlikely that the diatom cannot fabricate its siliceous shell in water below a certain concentration in silicate.

Iron, an essential constituent of vegetable organisms, has assumed this aspect of minimal occurrence despite the fact that it is excreted by zooplankton more rapidly than phosphorus, and probably therefore returns into circulation more quickly. However, most of the iron in the sea is present in a form not directly usable by organisms, less than 10 per cent (Cooper, 1937b) being in true solution. The position therefore seems to be that plant development may sometimes be delayed by a deficiency of available and usable iron.

In conclusion, as already stated, there is evidence of the existence in solution in the sea of certain growth-promoting substances apparently of the nature of vitamins. It is well known, for instance, that marine organisms are more easily reared and show much better development in natural than in artificial sea water, suggesting that some organic substance, or group of substances, occurring widely perhaps among the breakdown products of living organisms and dissolved in sea water, act as growth-promoting factors. From existing knowledge of the nature of such breakdown products, not all of which are beneficial to marine organisms, it seems almost certain that their action is essentially chemical. Lucas puts the modern viewpoint on this question comprehensively in two recent essays (Lucas, 1947 and 1949).

Conclusions

In the light of the preceding discussion, it is clear that the relationships of fishes with the many and various factors in their inanimate environment are of a fundamental character. The foregoing considerations, exemplified and supported by reports on pages citing particular examples, demonstrate with some cogency the almost constant and, for the most part, intimate, dependence of fishes on environmental factors; in other words, that, directly and indirectly, the growth and even the survival of fishes are closely bound up with these factors, the most essential and vital of which vary seasonally and fluctuate annually. There is evidence also of still longer-term fluctuations to which they are subject (Tait, 1956).

In these circumstances it is legitimate and reasonable to look to these factors, separately and together, for at least part - probably a most significant part - of the explanation of fluctuations in space-time occurrence in abundance, and in quality, to which all commercial fisheries are subject. Until these phenomena of fluctuations are much better understood than at present, understood to the extent of being able to anticipate them, measures of conservation of valuable food fish stocks can scarcely be other than empirical, more or less tentative, and in the long run probably only palliative. Fortunately, in at least one fishery region scientific research has gone far enough to point the moral.

The crux of the matter of fluctuations in the stocks of fishes is believed, as the result of biological investigations, to reside in an extremely restricted period of a fish's life, when it seems to depend almost entirely for survival upon a chain of inanimate environmental factors, culminating in the inclusive biological environmental factor of food. The stock of a particular species comprises fishes of different ages, the proportion of these age groups, or year-classes, fluctuating from year to year. Normally, one or two, sometimes three, age groups dominate the fishery of a species for one or more years. The strength or abundance of a given year-class is evidently determined at an early, critical stage in its existence, and this crucial stage in the lives of individual fishes falls within the first two to three or four days immediately following the consumption of the yolk sac with which the baby fish is hatched from the egg (Woborg, 1948). At this stage, survival depends essentially upon the presence in its immediate vicinity of the minute animal and plant life on which it must feed. The latter, as the basic requirement, depends, as has been pointed out, on a sufficiency of dissolved nutrient salt, principally phosphate, in the sea. This, in turn, in the relatively shallow continental shelf regions where up to the present the bulk of the world's food fisheries are to be found, and where the basic marine vegetable organisms are most prolific, after its first rapid and total abstraction from the sea by the vernal outcrop of plant life, depends for replenishment on vertical and horizontal current activity generating water displacement from the deep oceanic regions on to the shallower shelf areas.

This primary significance of the oceanic water masses to the health of fish stocks seems to be well illustrated by the following example. The most outstanding case of a particular year-class which dominated a fishery for many years is that of the 1904 year-class in the Norwegian spring herring fishery (Hjort, 1926). In 1907 there were five fairly rich, evenly represented year-classes in this herring stock. These were fishes four to eight years old. In 1908, this even proportion was broken by the appearance of the 1904 year-class, which in the following years exceeded all other year-classes. In 1910, when six years old, it formed almost 77.5 per cent of the Norwegian herring stock. Four years later it was still above 50 per cent. Even in 1919, when it was fifteen years old, this 1904 year-class was still numerically the strongest. It only petered out in 1922 and 1923 when the 1918 brood of herrings, entering the catches in 1922 as four-year-old fishes, began to displace it. The 1904 year-class not only contributed strongly to the Norwegian herring fishery for many years, but also dominated the Norwegian cod fishery until the next most abundant year-class came along in 1912.

The physical data relative to the sea which were collected in the first decade of the present century were much more meagre than current data. None the less, the records of temperature and salinity - particularly the latter - for the years

1903 and 1904 pertaining to the northern North Sea and neighbouring waters are sufficient to justify the inference that oceanic influence in these regions was abnormally strong in these two years, especially perhaps the former.

In extension of the above classic case, and apparently adding further significance to the influence of oceanic water masses, Hjort, in the winter of 1914/15, when he was working in Canadian waters, found that the majority of mature Newfoundland herrings belonged also to the 1904 year-class (Hjort, 1919). On the other hand, he found that herrings off the coast of Nova Scotia, and off the southern shores of the Gulf of St. Lawrence, were quite different in age composition from the Newfoundland stock. The significance of the difference almost certainly lay in the fact that the Newfoundland population was more closely associated with the oceanic Gulf Stream water than were the Nova Scotian and Laurentian stocks.

An example of more recent date, which incorporates practically all the environmental factors concerned, adduces still stronger evidence of the highly significant role of inanimate environmental factors on stocks of fishes, and focuses attention in this regard on the apparently preponderant influence of the ocean water mass, in its variations and fluctuations, on the fauna of the shelf regions which are of such importance to fisheries. From the year 1930, the flow of Atlantic Ocean water towards and into the English Channel at the period of its maximum annual intensity declined almost year by year for eight years. This important finding was not obtained from actual physical observations in the sea, but by deduction from the numbers taken of certain animal fish food species which, on the basis of Russell's plankton indicator theory (Russell, 1939), denote oceanic water environment. However, certain quantitative dynamic computational figures are now available (Tait, 1956), relative to the Atlantic current in the Faeroe-Shetland Channel north of Scotland, which may be assumed to be in at least approximate correspondence with the English Channel as regards the flow of oceanic water towards it, which confirm the above deductions relative to the years from 1930 on.

In this same period of eight years both nitrate and phosphate in the English Channel declined in amount at the time of their maximum concentrations before the spring outcrop of plant life. Comparison of phosphate records for the two periods 1924 to 1927 and 1934 to 1937 show that the decrease in the latter period as a whole compared with the former was about 35 per cent.

As the result prima facie of these declinations the annual amount of planktonic life, plant and animal, in the English Channel region diminished correspondingly after the year 1930, and again, from 1931 onwards, there was a remarkable decrease in the abundance of larval fishes in the Channel.[3/] This decrease at first occurred only in the comparatively small number of summer spawning fishes, but it extended subsequently to the more numerous spring spawning species also. If average numbers for the four-year period 1934 to 1937 are compared with those for the same period ten years before, namely, 1924 to 1927, it is found that the larvae of the summer spawning fish in the later period were reduced to little more than one-fifth of their former abundance, while the numbers of the young of spring spawners dropped to one-third. What is especially significant is that practically all species were similarly affected, indicating that the decrease was not due to a chance coincidence in annual fluctuations, but was probably correlated with, and the outcome of, reduced plant crops due to marked decline in phosphate and nitrate concentrations, which, in turn, failed to be replenished at least in sufficient quantity on account of diminution or of some form of deterioration in the indraught of deep oceanic water masses by the prevailing currents.

These very practical researches in the English Channel go even further. They cite concrete evidence of an actual fishery fluctuation associated with the changes mentioned. By the year 1938, the herring fishery of Plymouth had declined to such an extent as to be practically non-existent. The most significant feature in the trend was a marked change in the composition of the catches which began in 1931/32, in the winter of the year in which the larvae of summer spawning fishes first showed signs of decline. Prior to 1931/32, the younger herrings of six years and under formed at least two-thirds of the catches. In that season, however, they

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[3/] One must here note, however, that phosphate rich water may not always lead to a good survival of larval fishes (Russell, 1951). "In 1929", to quote Russell "when there was fertile water in the area (the English Channel off Plymouth) the usual peak of young of spring spawning fish was missing," owing, it is thought, "to a great abundance at the time of voracious ctenophores".

were only 52 per cent of the total, and from then on there was a progressive and rapid change in the composition of catches until they comprised in 1938 less than 20 per cent of the younger, and more than 80 per cent of the older, fishes. It is germane to note that this change in the age composition of the herring shoals was not immediately reflected in the bulk sizes of the catches, which for some years were maintained at a good level by the considerable stocks of older fish; but as these passed out of circulation they were not replaced by adequate numbers of the younger year-classes.

It certainly appears, therefore, that not only do the main and probably the essential causes of fishery fluctuations lie in the physical and chemical factors of the inanimate environment, in the varying amounts and composition of typical water masses - probably for the most part of a particular water mass - pervading the fishery regions, but also adequate observation of these factors would afford at least a substantial means of anticipating such fluctuations. As the writer has formerly pointed out, and Deacon and Kesteven have endorsed, physical, including chemical, oceanography is, by analogy with agriculture and similar pursuits on land, at once the meteorology, the climatology, and the soil science of fisheries, and something approaching the pattern, perhaps also the scale of observations taken in these sciences, would seem to be a sine qua non for the solution of some of the most pressing problems concerning the living resources of the sea.

At the same time, since the comparatively short treatment in this section of highly complex phenomena of environmental relationships in the sea must inevitably tend to some over-simplification of the issues, it must be emphasized that the fruits of the implied recommendation in the foregoing paragraph are probably only realizable in proportion as the biological phenomena concerned are likewise accurately specified and assessed in something like quantitative terms.

These suggestions and recommendations demand for their execution operations of two broad categories: field operations and laboratory, including aquarium, operations, each category subdivisible under a number of heads. Field operations range from local to lesser or greater regional surveys - the former probably more systematically intensive than the latter - designed to collect the bionomic, physical and chemical data for evaluation of both the static and the dynamic factors above specified. Regional institutional resources, existing or to be established,[4/] would be necessary to supplement those of national and local institutions and laboratories.

Laboratory and aquarium operations would take care of fundamental research on the methods and measurement techniques, physical, chemical and biological, to be used in field operations, and on various aspects of the physiology of marine creatures, knowledge of which is necessary to the proper appreciation and interpretation of field survey data. Research of this kind is at present carried out at the marine biological stations of the world and at such institutions as, for example, the Scripps and the Woods Hole Oceanographic Institutions in the United States, the British National Institute of Oceanography, the Geophysical Institute of Bergen University, that at Göthenburg, Sweden, and the former Institut für Meereskünde in Berlin.

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[4/] Establishment need not necessarily be de novo, but might conveniently accompany expansion of present more or less cognate organizations or institutions.

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OUTSTANDING QUESTIONS

by

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Basic Questions

Fluctuations in food fish stocks

The greatest and most comprehensive need towards that understanding of the living resources of the sea which is indispensable to their rational utilization, and consequently to the formulation of scientifically sound measures of conservation in respect of any given species, or group of species, would seem to be systematic and, in particular regions, intensive and detailed observation of those characteristics of the sea - its movements, its conservative and non-conservative properties - which have obvious and profound influences on fishes and other marine creatures on which fishes depend. The great problem of discovering the causes of natural fluctuations in the incidence, abundance, and quality of fish stocks seems fundamentally to depend for its solution on such observation. From knowledge of the causes to anticipation of such fluctuations, and hence to prediction of their effects upon the stocks of economically valuable species, is of course the supreme objective, and the immediate modus operandi would seem to be through world-wide, co-ordinated, physical (including chemical) oceanographical services after the pattern of the meteorological organizations.

Conjointly, and with the same problem in view, there is almost equally great need on the biological side for accurate, quantitative assessments of local and regional fish stocks, the age composition of each and the annual recruitment thereto; of predator species; of the abundance and composition of fish food as well as of inimically non-fish-food organisms; of the exact

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[5] Based on suggestions received from experts.

nature of the contribution of the former to the development, growth and maintenance of fishes under varying physical conditions, and, on a uniform basis of inter-comparability, of the intensities and magnitudes of man's predatory activities towards economically valuable food fish stocks. The desiderata here are: comprehensive vital statistics from the field, and controlled laboratory or aquarium researches on various aspects of the physiology of fishes.

Save perhaps that improvement of existing methods, or development of new methods, might be expected to facilitate and accelerate the collection and processing of observational data, the acquisition of the necessary information on the inanimate environment presents no undue technical difficulty. For the collection of the basic materials of marine vital statistics, on the other hand, new and improved methods of capture of the creatures are necessary in at least a number of cases, and in some respects also the necessary biological knowledge is lacking.

Nutrition of fish

Nutrition, as a biological environmental factor affecting food fish stocks, assumes significance chiefly in relation to the development and rate of growth of fishes, but also in the matter of their quality. In the first instance, however, for some important food fishes there is still a lack of field knowledge of the actual organisms which constitute their food. In the main this is fairly well known for North Atlantic commercial species, but for other regions (see below) the information is at least deficient if not entirely lacking.

Knowledge of the rate of growth of various fishes maximally nourished under varying conditions of temperature, salinity, light, and possibly other factors, which is to be gained by experimental research in aquaria, is for the most part scanty, and sometimes completely lacking. The existence of "standard" knowledge of this kind is required as a basis for information on the relation of the amount of food available to stock size and quality; this affords an indication of the optimum or safe displenishment of stocks by capture without incurring risk of overfishing. Another important application of such basic knowledge would be the offsetting of a region of poor growth rate by transplantation of species, if practicable, as in the case of North Sea plaice, to a region of maximal growth.

Concurrently with experimental research on growth rate in relation to nourishment by weight, an investigation could also be made of the question of quality judged by fat content, in relation to the fat content of the nourishment supplied, having in view the relationship of the fat content of plankton organisms to the quality of fishes which feed upon them.

Although probably more closely connected with the nourishment of the food organisms of fishes than with the fishes themselves, the long-debated question of organic solutes in the sea, recently revived since the discovery of the new chemistry skill of identification of trace substances by paper chromatography, deserves further investigation as a possibly significant environmental factor.

The question of disease in fishes, about which very little is known, has possibly some relation to nutrition. The question of why herring, for instance, avoid certain plankton organisms and the regions wherein they are to be found, might be more meticulously examined. It is known that lymphocystosis, probably caused by a virus, produces some striking symptoms in plaice, for instance, such as tumour-like swellings in connective tissues, especially in fins and tail. Halibut not infrequently come to market with more or less obvious signs of disease. Experiments in aquaria, in which deadly infections with microsporidia and Vibrio anguillarum were used, show that in certain circumstances they may increase the normal mortality of a species.

Tropisms of fish

As regards the difficult and complex problem of the various tropisms of fish and their responses to currents, temperature, salinity, light and other physical and chemical properties of the sea, the following quotation from the concluding section of a recent publication (Bull, 1952)[6] seems appropriate:

> "Individual teleosts perceive, and react purposively to -- as shown by their ability to form conditioned responses -- these minimal changes in the water immediately surrounding them:
> (a) 0.03° centigrade of temperature
> (b) 0.2 per thousand of salinity
> (c) 0.05 pH (hydrogen-ion concentration)."

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[6] See bibliography at end of preceding section.

Whether they are capable of similarly perceiving changes in rate of current flow has not yet been resolved. So far, the evidence is that they do not perceive such changes when the rate of change is very slow. There are, however, great practical difficulties in carrying out the work using rates of flow, and other factors corresponding to the normal tidal flows or oceanographic currents.

The experiments, like other conditioned response experiments, whether yielding positive conclusions or not, permit no statement on their "psychological" meaning. But the way in which the responses are carried out suggests that they are different in character from typically non-voluntary acts, such as the maintenance of equilibrium. In nature, reactions based on these perceptual abilities would probably be both voluntary and intentional.

The physical distribution of these properties of sea water is such that they might well serve as directive stimuli, the more so since the perceptual ability of the fish lies close to the limits of accuracy of the hydrographer's estimations.

In considering these problems as a whole, Bull states, he was "struck by the complete absence of accurate, compendious studies of the normal behaviour of even our commonest food fishes... The preparation of such monographs - based on direct observation and laboratory experiments - would certainly produce facts, and very likely also new ideas." Obviously, according to this expert, much valuable work needs to be done in this field, so contingent upon the problems of fish migrations and of causes of stock fluctuations.

The evaluation of productivity in the sea, including the problem of measurement techniques, is now attracting greater attention than before. The question is not yet answered, for instance, whether the determination of plankton production by the aid of carbon 14, as developed in recent years, which appears to give valuable information on the basic nourishment for life in the sea, is superior - in assessment of the influence of plankton on the distribution, density, and quality of pelagic fish - to the much simpler, more straightforward method of instrumental plankton collection. Whichever method is finally proved to be most reliable, the objective is the registration of the productivity in food fishes of various parts of the sea, thus contributing also from this angle to the solution of the problem of optimum yields from fisheries.

Investigation of assimilation phenomena by means of other tracer elements, phosphorus 32 for example, is advocated. Likewise, the development of a serial method is needed for determining the quantities of dissolved and particular carbon, and the development also of indicators for the levels of assimilation and remineralization processes in the sea, for example, components of the total phosphate, manganese, nitrogen components, chlorophyll, proteins and reduction potential.

Regional Problems

Pacific and Atlantic Ocean areas

Among regional problems there is one which is both a basic subject and regional, the latter in almost a world-wide sense. The tunas, as pointed out by Royce,[7] may on the one hand "comprise ultimately the most important food fishery in the world", yet, on the other, despite their "present and potential importance ... very little is known of their biology". Associated with the biological problem are the technical ones of development and improvement of instruments for locating, identifying and delineating oceanic pelagic fish shoals and planning proper oceanic fishing vessels and gear.

Mediterranean Sea

In respect of Mediterranean tunas, at present so little is known of their ecology that it cannot even be said whether or not the Mediterranean stocks are being sufficiently exploited as human food. Here would seem to be a question with preliminary technical problems and doubtless other associated problems, which, notwithstanding its vastness and intricacy, is so outstanding as to call for immediate and concerted attack: the ecology of the tunas, which have almost world-wide distribution. Of these there are at least six groups of species, which, besides being a potentially invaluable human food resource, are, in some cases at all events, also voracious predators on other valuable pelagic food fish species, such as herring, mackerel and sardines.

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[7] See "A Statement on the Ecology of Tunas" in this series.

The scientific, efficient utilization of European stocks of the sardine is also hindered because of certain deficiencies in both field and laboratory knowledge. Muzinić[8] and other experts imply that the whole ecology of the sardine (both Mediterranean and Atlantic stocks) needs to be put upon firmer bases. Statistics of the sardine fisheries relating to fishing effort and catch appear to be seriously inadequate, while adequate assessments of stock and brood strengths evidently await a reliable method of determining the age of a sardine. Apparently considerable difficulty in this respect is encountered in the Mediterranean.

South-eastern Asia

From south-eastern Asia, Tham Ah Kow, of Malaya, submits a problem as a matter essential to the food fisheries of this region. This is the distribution and ecology of some five species of the genus Stolephorus Lacépède,[9] inhabiting the Straits of Malacca, the South China, Java and Andaman Seas, with questions involving the food and feeding relationships of the different species, and the responses to environmental factors of those caught in large quantities.

ORGANIZATIONAL PROBLEMS

by

The secretariat of the United Nations Educational,
Scientific and Cultural Organization

International co-operation in the field of oceanographic research, both fundamental and as specifically applied to fish, is at present being carried on through organizations which may be broadly classified into the following two groups:

(1) International scientific societies such as those concerned with geodesy and geophysics or with the biological sciences, comprising such

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[8] See "Some Observations on the Habits of the Sardine" in this series.

[9] See "Response of Stolephorus pseudoheterolobus Hardenberg to Environmental Factors" in this series.

specialist organizations as the Association d'Océanographie physique (Association for Physical Oceanography). These societies are of the non-governmental type. Their basic purpose is to develop contacts among experts by means of congresses, exchanges of publications and the like. For example, an international conference on marine biology laboratories was held in April 1955 at Rome under the auspices of the International Union of Biological Sciences.

(2) Regional bodies, which systematically collect data likely to be of value in utilizing the resources of the sea and, as necessary, propose administrative measures for the conservation of these resources. These bodies are usually inter-governmental. A typical example is the International Council for the Exploration of the Sea, which was set up at the beginning of the present century. Other such bodies that may be mentioned, without attempting to give a complete list, are the General Fisheries Council for the Mediterranean, the International Commission for the Northwest Atlantic Fisheries and the Indo-Pacific Fisheries Council. These bodies maintain relations with the Food and Agriculture Organization of the United Nations, which in some instances (as, for example, in the Indo-Pacific region) even handles their administrative work.

There thus exists already a large network of bodies concerned either with the advancement and dissemination of basic knowledge or with the study of measures to promote the rational utilization of the resources of the sea. The previous sections have clearly shown, however, that there is a need for co-ordinated research on a world scale, and it appears that further improvement in this direction can be anticipated.

In the first place, it seems essential that the results of oceanographic observations should be systematically collected so that synoptic data might be provided for use by the regional and local bodies. This procedure has already been adopted in meteorology. With particular regard to the habits of economically useful species, the necessary data - such as are at present lacking on the biology of the various species of tuna - can only be obtained through research directed and co-ordinated on a world scale.

Furthermore, study of the phenomena of the ocean involves several distinct branches of sciences, all of which must be co-ordinated if science is to be placed at the service of the fisheries and if information of value for rational utilization of the resources of the sea is to be obtained.

The Food and Agriculture Organization and UNESCO have for some years been jointly considering means to achieve this purpose. At its eighth General Conference, held at Montevideo at the end of 1954, UNESCO approved its Director-General's proposals in this matter.[10/] The UNESCO programme for 1956/57, for which the Conference appropriated a total sum of $54,000, provides for establishment of an International Advisory Committee on Marine Sciences, with functions similar to those which the Advisory Committee on Arid Zone Research has in its own field. The duties of this committee will be made to make recommendations concerning the stimulation and co-ordination of fundamental research in physical oceanography and marine biology and to mobilize scientific knowledge with a view to solving specific problems encountered in the utilization of marine resources in various parts of the world. This means in effect that the committee will have to take steps for co-ordinating relations: (a) among the various branches of science concerned with aquatic phenomena (including limnology, which has valuable experimental data to offer); (b) between scientific knowledge and rational utilization - in other words between theory and practice; (c) between under-developed countries and the most advanced research institutions.

At the conclusion of the International Technical Conference on the Conservation of the Living Resources of the Sea, a meeting of experts is to be held at Rome to consider this committee's programme and mode of operation, particularly in the light of the results of that conference.

The importance of international co-operation in oceanography was stressed in the course of studies carried out between 1946 and 1948 by the United Nations on the possibility of establishing international laboratories. These studies were made by various authorities, including Professor J.A. Fleming, who at that time headed the International Council of Scientific Unions, and Professor H.U Svetdrup, who was then directing the Scripps Institution of Oceanography in the United States. A booklet entitled "The Question of Establishing United Nations Research Laboratories" [11/] was published.

[10/] Cf. document UNESCO/8C/PRG/22.

[11/] Sales No.: 1949.IV.1.

With regard to the Indo-Pacific region, the following documents are of interest: "Report on International Oceanographic Requirements", adopted by the Indo-Pacific Fisheries Council at its fourth session (Quezon City, Philippines, October 1952; the UNESCO report on the meeting of consultants to consider the possible creation of an oceanographic organization for the Indo-Pacific Region, held at Manila in October 1953 (UNESCO/NS/113); the circular letter ML/997 sent by the Director-General of UNESCO to UNESCO national commissions in June 1954.

With regard to Latin America, an expert committee convened at Concepción, Chile, in November 1954 by the Field Science Co-operation Office of UNESCO made a number of recommendations (UNESCO/SC/DIV/29), some of which are now being carried out.

The UNESCO programme on marine sciences was the subject of a report adopted by the General Conference at its eighth session, held at Montevideo at the end of 1954 (UNESCO/8C/PRG/22). UNESCO's methods of action in the field of scientific research in general are described in the report UNESCO/NS/114 (rev.).

Reference is also made to the report entitled Oceanography and Fisheries by G.L. Kesteven, Chief of the Marine Fisheries Section of the Food and Agriculture Organization of the United Nations.

LIFE HISTORY OF *Penaeus japonicus*

by

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Research Department, Fisheries Agency of Japan

In Japan the study of the life history of kurumaebi (*Penaeus japonicus*), which is the representative species of the peneids in the waters around Japan is more thorough and complete than that of other fishes. Generally speaking, the shrimp or prawn lives along or near the coast, and the range of its migration does not exceed fifty nautical miles. *Penaeus orientalis*, on the other hand, migrate as much as several hundred nautical miles. Shrimps (*peneids*) are one of the most important marine resources of all crustaceans, with geographical distribution extending to waters in temperate and torrid zones all over the world.

Spawning habits and seasons

The spawning season of the shrimp is between the middle of April and the beginning of October, the high season being from the middle of June to the end of August. In other words, the best season for spawning is summer, when the temperature of the sea is highest. Spawning takes place during the night, while the shrimp are swimming. The number of eggs laid by a single shrimp of 20-centimetre body length is approximately 700,000.

Development

The eggs hatch out in fourteen hours if the water temperature is between 27° centigrade and 29°. The newly hatched larvae are called nauplius. These moult six times and after the sixth moult pass into the zoea stage. The time necessary for six moults, in water of 27° to 29°, is between thirty-seven and thirty-eight hours. Larvae in the zoea stage experience three moults, and after the third moult pass into the mysis stage. The time required is about five days when the water temperature is between 27° and 29°. Larvae in the mysis stage also go through three moults in five days. After the third moult they are then in the post-larval stage. Larvae in the post-larval stage moult every two or three days and gradually assume the shape of adult shrimp.

The nauplius, zoea and mysis stages are completely planktonic. The beginning of the post-larval stage is still planktonic, but after ten or twelve moults the mature life of the adult begins, the creatures remaining in the sand during the daytime and coming up into the water at night. Nauplius stage larvae can go without food from outside as they have a store of yolk within the body; but in the zoea stage this store is exhausted and food from outside is then necessary. Therefore, unless the proper food is then available, the larvae perish. Actually, very few larvae survive the zoea stage, in which their food is phytoplanktonic. Only in the mysis stage do they begin to take zooplankton. Thereafter their food is primarily animal.

Since spawning takes place in water deeper than ten metres, eggs and larvae in the initial stage are not usually found near the seashore. It is not until they enter the post-larval stage that they congregate close to the seashore, where they grow to a body length of four to five centimetres. After that they gradually move offshore.

The growth of the larvae is so rapid that those which hatched in April or May become parent shrimp in October of the same year. Their life is between one and two years, with very few living longer than two years. Of all peneids in the waters around Japan, it is only the shrimp which lives longer than a year; the life of the others is mostly one year. Even in the case of shrimp of a larger size, such as Penaeus orientalis, it takes no more than six months for them to mature; their span of life, too, is a year. Shrimps belonging to peneids in other waters are presumed also to live only for one year.

Conservation

Fluctuations of shrimp resources are almost entirely dependent upon changes in the physical environment such as changes in temperature, in other sea water conditions and in the amount of sunshine; the intensity of catch has hardly any effect upon the condition of the resources. The most that can be done to control the effect of the environment is to prevent the pollution of sea water. Even this, however, would be almost nothing compared with the influence of the natural physical circumstances.

THE ATLANTIC SARDINE

by

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Although the details of the morphology and biology of the Atlantic sardine are well known, there has seldom been any attempt to synthesize them. The basic facts about the habits of this fish and its reactions to its environment have not been studied to the same extent, and for the most part are not known. The main features of its ecology have, however, been determined from exact observations and from hypotheses based on a large body of compatible data.

Habits in a Normal Environment

Effect of temperature

This is the most important factor, for the distribution of the species is strictly limited in the Atlantic and elsewhere by the annual isotherms of 10° and 20° centigrade. This allows a very extensive habitat, from the coast of Mauritania to Northumberland.

Temperature also determines the periodical concentrations and principal migrations. This clupeid requires high temperatures - varying with the strain - for its larval and fry stages and then more moderate temperatures for spawning, after which it looks for colder waters. Since this process repeats itself after each sexual maturing, the sardine tends to move towards colder and colder water as it grows older.

This is the case with the sardines in the Bay of Biscay. The fry hatch out in the south from winter to spring (10° to 16°) and remain there until they reach their first sexual maturing at the end of two years. After spawning, the fish, now adult, leave these waters, which become warmer with the spring; they proceed to the coasts of La Vendée and Brittany.

At the end of their third year, during which they spawn again, they seek out still colder waters to the north. The fry from these northern spawnings spend the winter south of the area where they were hatched and return there later, repeating the process described above.

Their first migration will not, however, bring them to the southernmost part of the Bay of Biscay in every case. The southern limit of this migration depends on the winter temperature and varies from year to year; it is the isotherm of 10° to 11° centigrade.

The life cycle of the Moroccan strain is similar but with modifications which reflect the environmental differences. Certain hydrological phenomena (upwellings) have the effect of making the northern zone of the Moroccan waters warmer (20° to 25°), especially in summer, than the middle zone, where the water is from 14° to 16°. The sardine's migration is thus "physiologically" in the same direction as in Europe, that is towards the colder waters, but geographically it is in the reverse direction, towards the south.

In the northern sector, the fry hatch out in winter and spring and go through their early stages in the warm waters off Casablanca. They mature more quickly than in Europe and reproduce themselves at the end of their first year in the spawning ground in which they were hatched.

At the onset of spring, however, this sector becomes too warm for them, and they are forced to migrate southwards into waters having a temperature which now suits them (14° to 16°). As the cold of the following winter brings the temperature in the original spawning area down to the moderate level (18°) that suits the spawners, they return there for spawning and afterwards leave again for the cold waters of Safi.

An identical situation occurs near Agadir, where the warm zone of Ghir and the cold zone of Ifni have the same effect on the reproduction of sardines in that region.

Effect of currents

Currents also affect the movements of sardines, which prefer the calm waters in the lee of headlands. If they are unable to stay there, however, they follow the current, which sometimes takes them very long distances. This is often observed in the Bay of Agadir, where the migrations are speeded up or slowed down by the combined effect of currents and temperature.

A tagging experiment has shown that sardines can be carried as far as fifty kilometres in a few days, or even a few hours, either northwards or southwards.

Day and night habits

It is difficult to deduce any general law in regard to these. Two facts do, however, emerge from regular ultrasonic observation: (1) the sardines often congregate in large schools at night; (2) subject to thermal conditions tending to encourage or discourage their rising to the surface, they usually remain near the bottom by day and near the surface by night.

Habits in a Confined Environment

The development of tuna fishing with live bait has led to a study of the survival of sardines in tanks. Although these experiments do not exactly reproduce the natural conditions of life, since they involve a previous domestication process which alters the reactions of the organisms quite considerably, they are nevertheless of interest.

Reaction to currents

The first tank experiments failed because the water came in with some turbidity. As soon as the inflow and outflow of water were rendered imperceptible the results improved considerably. This agrees with marine observations, which show that the sardine, in contrast with other clupeids, prefers calm waters.

Reaction to light

Fishing with lamps, as often practiced along the shore, shows clearly that the sardine is very sensitive to light and has a positive phototropism. In the tank, this phototropism is very pronounced, and if a light is kept constantly shining over the tank the sardines stay at the surface, their activity increases and they live longer.

Reaction to food

Sardines quickly become accustomed to food different from what they find in the sea. They are always greedy, and in a few days they develop the habit of coming to the surface as soon as the "roe" is scattered on it. This is, of course, well known to fishermen, who broadcast bait to attract the fish.

If these three conditions exist - calm water, light and plenty of food - sardines in captivity can quickly recover from the radical change in their environment and can survive in large numbers in a confined space for over two weeks.

These data are clearly somewhat incomplete. They have been obtained partly by methods which can properly be termed scientific and partly from the pure practical lore of fishing. To improve our knowledge of the ecology of this fish, a combination of the two methods is recommended, and the biologist will always find it valuable to do more marine research on the actual fishing grounds.

SOME OBSERVATIONS ON THE HABITS OF THE SARDINE

by

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The habits of the Mediterranean sardine (Sardina pilchardus Walbaum) have not thus far been the subject of any systematic research. As far as is known, there has not even been any study under experimental conditions. That is why the literature concerning the Mediterranean sardine contains only indirect information on this clupeid's habits.

In the course of tagging experiments in the eastern Adriatic, there has been opportunity to make some direct observations on the sardine, especially the adult sardine. It should be noted that these observations were made solely for the purpose of the work in hand and are thus of value for guidance only.

Before the observations are described, the conditions in which they were made must be considered. The preliminary tagging experiment was made in winter in a wooden tank with partitions, some of which were replaced by metal netting so that the water could circulate. During the definitive tagging operations, which took place during the fishing season,[12] a rectangular tank (four metres by one metre by one metre) was used, with sides of cotton netting.

The fish to be tagged were selected during lamp-fishing expeditions. The tank was then towed by motorboat to a sheltered spot where the tagging operations began, usually between 4.00 and 6.00 a.m. The tagged fish were placed in one of the two compartments of the tank or in a separate tank.

The sardines seemed to tolerate captivity well. The experiment was made on several occasions of giving them maize semolina. They swallowed the semolina, and its presence was afterwards established in their digestive tracts.

The sardines stayed grouped inside the tank, forming a single school. This was also true of the tagged fish. The only exceptions were injured fish, which remained apart, usually nearer the surface. Even when leaving the tank,

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[12] In the eastern Adriatic, sardine fishing goes on mainly between April and October, that is, outside the spawning season.

the fish still formed a school which did not include those in poor condition. These stayed in the tank or wandered about near it in a confused manner. The better the quality of fish, the more the school would be coherent and would tend to move off in a definite direction. In only one experiment was the regular movement of the tagged fish upon departure disturbed, and this was due to the presence of very aggressive predatory species (*Lichia* sp.) in the immediate neighbourhood. The alarmed sardines were unwilling to leave the tank, and even when driven out of it came back in or remained as close to it as possible.

While in the tank, the sardines moved continuously from one end of the tank to the other. Their motion was never circular, as is the case with mackerel.

There were no significant variations of temperature while this work was in progress. The lowest surface temperature, which was recorded towards the end of the operations, at the place where the marking was being carried out, was 17.0° centigrade, and the highest temperature was 25.1°. We were, however, in a position to observe that temperature could have a remarkable effect on the habits of the sardine. For instance, when the surface temperature was 22.5° or over, the tagged fish dived into deep water on leaving the tank. It was even observed that in these conditions the high temperature had a lethal effect on them. On several occasions a fairly high mortality among the fish before tagging was noted during the hot months, or, to be more precise, when the surface temperature was 23.0° or over.[13] The survivors appeared to be limp and had a strong tendency to lose their scales. Despite all the precautions taken, this high mortality continued to hinder the work and even forced a suspension of tagging operations during part of the fishing season, especially as the fish tagged at such times were being recaptured only rarely or not at all, which suggested a higher mortality rate after tagging. The number of deaths seemed to be especially large when the fish had been caught early in the morning. On two occasions a fairly high mortality was observed even below 23.0° (22.0° and 22.5°), but other factors may also have been operative. In any case there were

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[13] K. Muzinić, "Tagging of Sardines (*Clupea pilchardus* Walbaum) in the Adriatic in 1950 and 1951", *Acta Adriatica*, vol. IV, No. 11 (Split), 1952; and "Research on Movements of the Sardine (*Sardina pilchardus* Walbaum) in the Eastern Adriatic", General Fisheries Council for the Mediterranean, *Technical Report*, No. 3 (Rome, 1954).

still some deaths at 20.5° and 21.0°, while there were none or very few between 17.0° and 18.5°. It may be pointed out in this regard that in the eastern Adriatic a reduced sardine catch seems to coincide with the highest annual temperature.

Pending the results of research under experimental conditions on the effect of temperature and temperature changes, the temperature factor can be assumed to be one of the most important affecting the habits of the sardine.

We are unable to say how the habits of the fish are affected by temperatures lower than those mentioned above. It may be mentioned that the temperature recorded in winter at the places where sardines were being caught by trawling from near the bottom ranged from 13.2° to 15.4°. All the fish caught were in process of reproduction.

Light must also be included as one of the factors determining the sardine's habits. An attempt to tag fish at night by artificial light showed that the fish were unwilling to leave the tank even though the lamp had been previously masked. This hypothesis is strengthened by the observation, made in analysing the stomach content of Adriatic sardines, that the sardine does not feed at night[14/] and by the fact that artificial light is used in sardine fishing.

It was also observed during our operations that rough seas have a harmful effect on this clupeid.

It seems, therefore, that the habits of the sardine are governed by a number of factors, which deserve thorough study.

REACTIONS OF MACKEREL TO ENVIRONMENTAL FACTORS

by

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The North Atlantic mackerel (Scomber scombris) during its spawning, which takes place in surface waters, seeks temperatures of 10° to 15° centigrade

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[14/] T. Vucětić, "On the Feeding Cycle of the Adult Sardine (Clupea pilchardus Walbaum)", General Fisheries Council for the Mediterranean, Technical Report, No. 3 (Rome, 1954).

with the temperature rising, and it spawns therefore in the Marmara Sea about April and May (H. Lissner), in the Mediterranean from January to March (E. Sella and O. Giacchi), at the western entrance to the English Channel and south of Ireland from March to July, and in the northern North Sea, Skagerrak and Kattegat, partly also in the Belt Sea, in June and July. It had been thought by scientists who have investigated the mackerel in the last-named area that it also favoured a rather narrow range of salinity of between 26 per thousand and 33 per thousand, but in recent years mackerel eggs have been found in considerable numbers (by I. Fraser) in the Faeroe Channel, where the salinity is about 35 per thousand, and where they cannot possibly have been carried by the currents from areas with lower salinity. Furthermore, off the English Channel in some years mackerel eggs are found in largest quantities where the salinity is about 35 per thousand (G.P. Farran), or even over 35.5 per thousand (J. Furnestin). The stock west of the British Isles and France may be distinct from that of the North Sea (as supposed by J. Le Gall), but no racial differences have so far been found between them.

On the other hand, there is lower salinity spawning limit for mackerel a little below 20 per thousand. A few mackerel eggs have been found in the western Baltic floating in water of 16 per thousand salinity, but they may have been carried there from water of about 20 per thousand. The eggs can be fertilized in these low salinities and larvae can develop, but it is still uncertain whether they can grow up to young fish in these waters (R. Kändler).

It seems that the spawning of the mackerel may be bound also to places wit large amounts of such plankton as is fit for the food of the larvae, but this question requires further investigation.

In the Skagerrak and northernmost Kattegat where the temperature in most years rises quickly to the upper limit for spawning mackerel, it has been shown (A.C. Johansen) that the yield of the mackerel fishery or the stock of spawning fish during the spawning season is least in those years when the temperature of the water is highest during the spawning months. In such years the water temperature is generally also higher than normal in the months preceding, and this connexion can be used for predicting the yield of the mackerel fishery.

Figure 2 shows the connexion between the mean sea surface temperature in June and July and the average catch per boat of the Swedish drift net fishery, which is carried on only for spawning mackerels. Averages were calculated for the period from 1919, when statistics for this fishery were started, to 1945. After that year the catch per boat increased considerably, owing partly to changed fishery methods and partly to an increase in the stock on account of stronger year-classes.

Figure 3 shows the connexion between the average surface temperature in April, May and June, that is, just before the fishery starts, and when it has started.

The mackerels of north-western Europe come to the spawning places from about 150 to 200 metres depth; most of them coming to the Skagerrak and Kattegat arrive from the North Sea. Although the mackerel is a very strong swimmer, this migration seems to be influenced by currents. The influence of currents on the distribution of all fish which do not keep strictly to the bottom is great, because the fish cannot feel the direction of the current and therefore are transported by it. The stronger the current in the lower layer, the higher becomes the yield of the fishery in the Skagerrak and the northern Kattegat. The strength of the current can be measured by the salinity at the bottom in the Kattegat, where the salinity is measured each day at different depths at the light vessels. There is a pronounced correlation between the annual fluctuations of the catch of mackerel during the first months of the fishery and the bottom salinity when the mackerels arrive. The mackerels come to the surface when the surface temperature in spring is at least as high as in the lower layer, and when an intermediate colder layer does not prevent them from rising (A. Dannevig).

The yield of the fishery during the spawning season can be predicted because the ingoing current is mostly generated as a reaction to the current of brackish water which flows from the Baltic in the surface layers. The current can be measured by the surface salinity in the Kattegat - measured at the light vessels - but it can also be measured by the force of the east-west component of the wind, which very much influences the surface current. The best measure for the wind is the gradient of (the difference in) barometric

Figure 2. Correlation between average catch per boat and mean temperature of the surface water in June and July in the Skagerrak and northern Kattegat, 1919-45 (Swedish drift net fishery for mackerel)

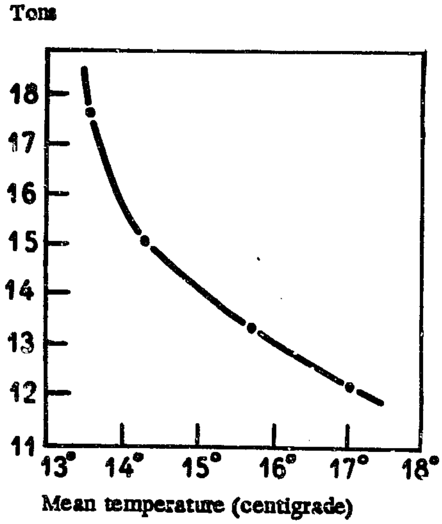


Figure 3. Correlation between average catch per boat and mean temperature of the surface water in the same area, in April, May and June, 191

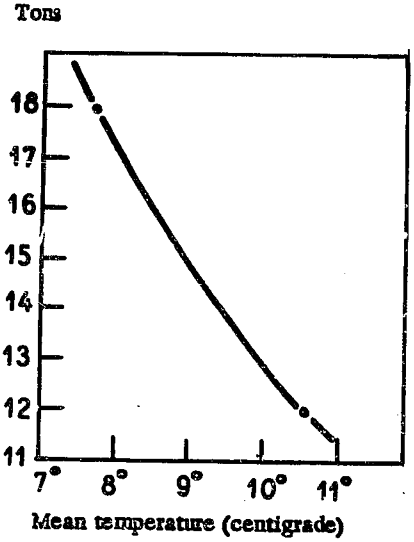


Figure 4. Correlation between difference in barometric pressure between southern and northern Jutland (Fanö-Skagen) — measuring the strength of the westerly winds in January, February, March — and deviation from five-year moving averages of the catch per boat in the Skagerrak and northern Kattegat, 1919-52

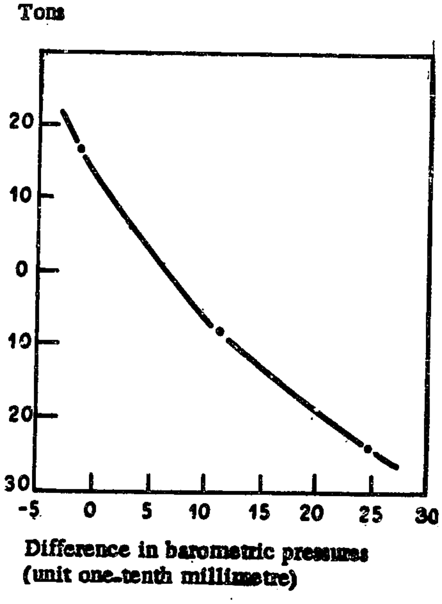
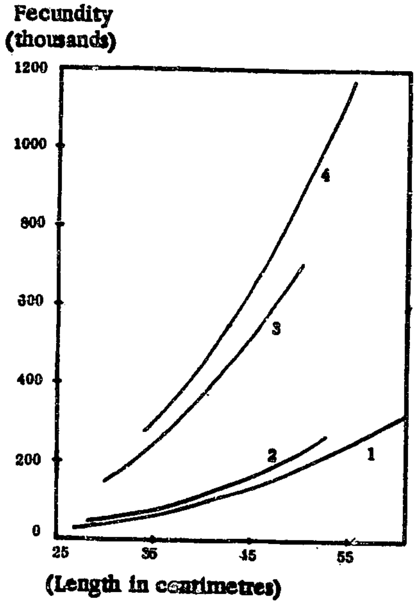


Figure 5. Relation between fecundity and total length of plaice



(1) North Sea, southern bay; (2) North Sea, Flamborough area; (3) Western Baltic; (4) Baltic, Bornholm area. Data on North Sea plaice from A. C. Simpson, 1951

pressure on a line at a right angle to the wind direction, in this case by the pressure in a north-south direction. The current from the North Sea carrying the mackerel to the Skagerrak is generated by the current in the surface water layer. This correlation, which is used also for predicting the yield, is shown in figure 4.

During recent years the mackerels have become more frequent in these waters and have spread more towards the Baltic during the spawning season. The number of eggs in the southern North Sea has increased (H.J. Aurich), and a little spawning takes place now also in the western Baltic (R. Kändler). This change is due to a great climatic change.

After spawning, the mackerel spreads out over other areas in order to feed. West of the English Channel they migrate in a coastal direction (J. Furnestin), and from the Skagerrak and the northern Kattegat most of them go south through the Kattegat. Also many young mackerels which have not spawned go this way. During the summer these keep to the surface, and therefore the quantity of mackerel in the inner Danish water is influenced by the wind, which carries the surface water and the mackerel southwards. Although correlations here can be proved statistically, they are not generally so pronounced that they can be used for prediction.

During the summer the quantity of mackerel at the surface, and therefore the catch, may also be influenced indirectly by the number of sunshine hours, as, for example, in the English Channel (E.J. Allen, E.S. Russell).

In the Black Sea, the southern North Sea, the Skagerrak, Kattegat, Great Belt and Little Belt, and Baltic, the temperature during the autumn becomes too low for the mackerel, which then move away from the colder waters towards deeper layers and warmer areas, where they remain until the following spring. Some few may stay behind in the deeper layers of the Baltic and some in the Skagerrak, but most of the stock migrates to the deeper layers of the northern North Sea. The migration from the Baltic is the more intensive the lower the temperature is during the autumn months.

Fluctuations in the strength of the year-classes are also of importance in annual fluctuations in the density of the commercial stock, and this variation is also used for predictions of the Skagerrak-Kattegat fishery. The North

Atlantic mackerel is found also on the Atlantic coast of North America, and here predictions for yield are given exclusively from the strength of the year-classes and the length-composition of the stock (O.E. Sette). The connexions between the strengths of the year-classes and environmental factors have not been stated.

RESPONSE OF THE PLAICE TO ENVIRONMENTAL FACTORS

by

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Knowledge about the response of the plaice to environmental factors is based almost entirely on observations made in the sea and only to a small extent on experiments in aquaria, since the apparatus required for the latter is available in only a few laboratories.

The influence of the salinity of the water is clear from the behaviour of the species in the Baltic, where its propagation and distribution are limited by decreasing salinity towards the eastern end of the sea. There the pelagic eggs, owing to their lower specific gravity because of increased absorption of water in the ovary, are adapted to the lesser buoyancy of the Baltic waters, with salinity as low as 12 per thousand. In the older larval stages, a further reduction of the salt content can be tolerated, so that they can move from the more saline lower levels of the deeps to the less saline upper levels, where the species is found in shallow coastal waters with salinity as low as 7 per thousand. It is enabled to live in these waters by osmotic pressure regulation, on which experimental investigations have been carried out, which have made a most important contribution to knowledge of the environmental adjustment of sea fish. Osmotic pressure regulation fails when the salinity is very low (under 5 per thousand), when the normal concentration of the blood serum cannot be maintained, and the fish dies, showing symptoms of paralysis and suffocation. In this respect, the North Sea plaice seems to be more resistant than the Baltic plaice, which lives on the borders of the former's normal habitat.

Little work has been done on the effects of salinity, of oxygen and carbon dioxide pressures and of hydrogen-ion concentration on the fertilization and development of plaice eggs. The species has adjusted itself to the greater perils menacing the progeny in the unfavourable conditions of the Baltic by developing earlier sexual maturity and higher fertility (figure 5). The Baltic plaice produces four times as many eggs as the North Sea plaice of the same size, a consequence of natural selection which is of the greatest importance from the point of view of the productivity of the strain.

As the plaice, at spawning time, resorts to the waters with the highest salt content that it can reach in the surrounding area, it may be assumed that it is guided in this also by the degree of salinity. But no detailed knowledge is available on the plaice's capacity to distinguish differences in salinity; nor has any sensory physiological research been done on their sensitivity to differences in temperature, which also play a considerable part in their migrations to and from the spawning grounds. The plaice, which spawns in winter, prefers a water temperature of between 4° and 7° centigrade. Abnormal hydrographic conditions may bring about changes in the spawning grounds or in the spawning season. For instance, an increased inflow of warmer water of high salinity produces heavier spawning in the south-eastern region of the North Sea. In the western Baltic, hard winters, with water temperatures in the region of 0° centigrade cause an interruption and prolongation of spawning. In such cases, the spawning season of the plaice coincides in part with that of the flounder (Pleuronectes flesus L.) and sometimes large numbers of hybrids of the two closely related species are produced. These hybrids are capable of living but do not reproduce to any great extent.

The influence of the temperature of the water on the rate at which the plaice eggs develop has been known for a long time, and it is possible by this means to determine the age of eggs found in the sea. According to van't Hoff's law, all other metabolic processes are also quicker at higher temperatures, so that the growth of the plaice is also very largely dependent on temperature. The effect of this factor can indeed be seen clearly even when temperature differences are small, as in the Faeroes-Iceland region, where cold and warm bodies of water intermingle, the growth of the plaice being quicker in the warmer areas than in the cold. At temperatures of about 1° to 2° centigrade,

Figure 6. Correlation between temperature and monthly growth of transplanted North Sea plaice in the Sejerö Bay (curve marked S) and the southern Little Belt (curve marked L), respectively (from A. J. C. Jensen, 1938)

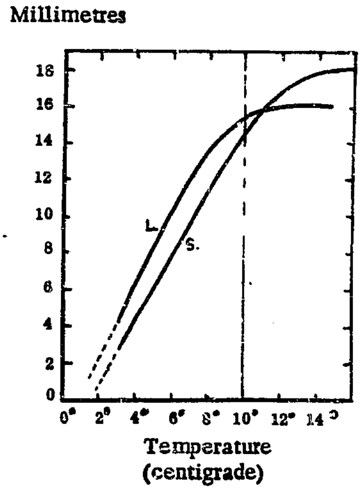


Figure 8. Growth of the plaice. Data on North Sea plaice from A. Bückmann, 1938

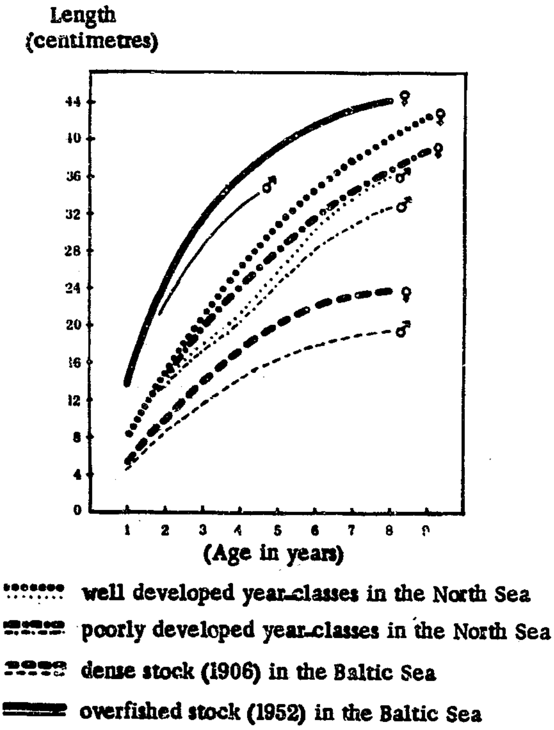


Figure 7. Association between plaice brood strengths and winds from south-west quadrant (from Carruthers, Lawford and Veley, 1951)

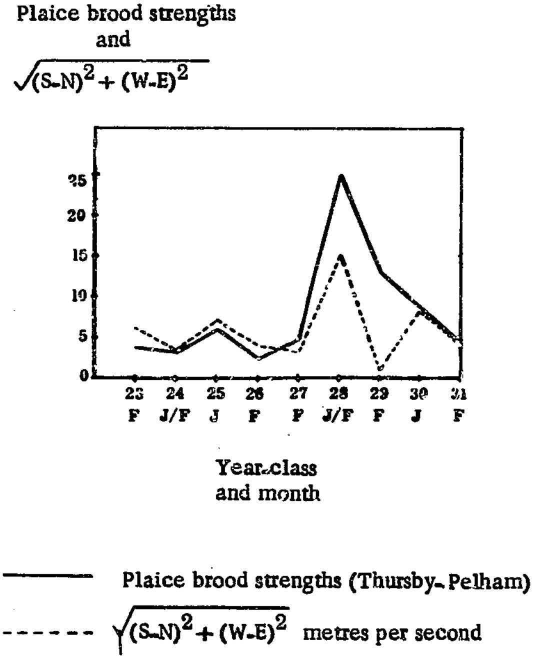
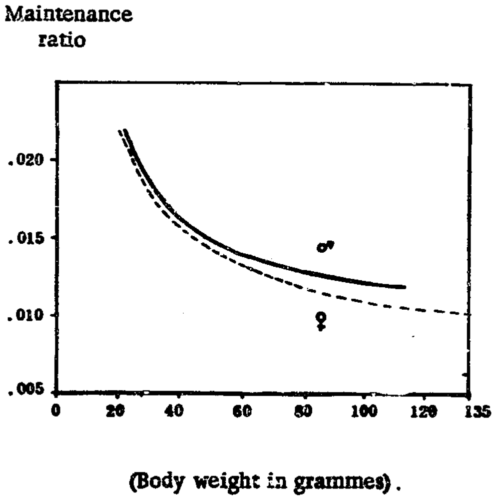


Figure 9. Relationship between maintenance ratio and body weight of male and female plaice between two and three years old (from B. Dawes, 1931-32)



and in the English Channel at temperatures of less than 10°, growth is arrested, while the optimum is attained at about 13° to 15° (figure 6). Acceleration of growth by raising the temperature is possible only to a certain point, owing to the limited capacity of the plaice, which is a member of the northern fauna, to tolerate a wide range of temperatures. No reliable information, based on observations in aquaria, exists on the minimum temperature at which assimilation of food is still possible. When the temperature of the water is low, the plaice shows little activity and young plaice, in particular, burrow deep into the sand during the winter so that they escape the trawl. The annual variations in temperature of water in coastal areas govern the appearance of the plaice there in the spring, when the water begins to warm up, and their disappearance into deeper waters in the summer when the temperature rises above the optimum.

Little is known, either, about the influence of light and the activity of the plaice at different intensities of light. From recent observations in aquaria, it appears to swim about energetically at night but little during the day. Visual stimuli may perhaps have some influence on the movement of the plaice from deeper to shallower water and vice versa. Only the youngest bottom stages are found in shallow water where they are exposed to bright daylight, while older fish seek the more subdued light of the deeper waters. This may also be a reason for the distribution of plaice in depth according to age, which is of such importance from the fisheries' point of view. As the plaice grow, they move off into deeper water. They possibly have a eurybathic sense which enables them to find the optimum depth for their own size. Sight as well as touch certainly plays an important part in their search for food, as plaice eat almost exclusively during the day.

The currents in the sea are extremely important both with regard to the passive transport of the fry and to the independent movement of the grown fishes. The relative positions of spawning grounds and feeding grounds can be explained only by the direction of the currents prevailing during the development of the spawn. Changes in hydrographic conditions and currents due to weather phenomena have considerable repercussion on the distribution of the fry and therefore on the number of progeny found in the nursery grounds. A correspondence has been noted between the size of the new generation for any year and the winds prevailing in the southern part of the North Sea during the pelagic phase of the plaice's development (figure 7), but further investigations are necessary to prove the reliability of these observations. In view of the absence of constant currents at the time, it seems doubtful whether rheotaxis is responsible for the movement of the fish to the spawning grounds at the spawning season. The migrating fishes are probably instinctively influenced by the sense stimuli to which they are exposed and accordingly reach an environment appropriate to their requirements at the time.

The density of the population and the amount of food available have decisive effects on the rate of growth of the plaice. In the nursery grounds in the south-eastern part of the North Sea, the rate of growth falls when the brood is large and rises when it is small (figure 8). Accordingly, in years when there is a large brood the fishes are generally smaller, and when the brood is small, the fishes are larger. It may, therefore, be advantageous to "thin out" young fishes in areas where they congregate in large numbers. This increases the fishery yield, as has been found, for instance, in the Kattegat and the Baltic. In the Baltic, in particular, this has led to an enormous acceleration of the rate of growth, which before was extremely slow. Fluctuations in the availability of the species on which the plaice feed also influence the rate of growth, which is favoured by the large-scale production of certain species.

When feeding, the plaice often shows a preference for certain species. It has been found that moluscs are preferred in summer and polychaetes in winter, which can be plausibly explained by the recently established fact that adult plaice grow new teeth periodically and that this process takes place in winter. During this period they avoid eating animals with hard shells. From the results of experiments carried out in tanks and aquaria, it appears that the plaice needs a daily intake of 0.01 per cent to 0.02 per cent of its own weight, in the form of shellfish, for the maintenance of its body weight (figure 9). The quantity required falls at lower temperatures and as the fish grows larger. When there is an abundant supply of food, one-year-old plaice absorb from 3 per cent to 6 per cent of their own weight in food daily. When conditions are good, the feeding quotient is as high as 5.8.

Considering the generally large numbers of plaice, their only serious competitors for food, in addition to a few invertebrates, are those species of fish which have a similar diet and are equally numerous. The most important of these is the common dab (*Pleuronectes limanda* L.) which is found in large quantities in the southern part of the North Sea, to the detriment of the plaice. This species is considerably more fertile than the plaice, grows very slowly and is of little economic importance. It is therefore advisable not to set too high a level for the protection of this competitor, to the detriment of the more valuable plaice, but on the contrary to keept it down as far as possible by intensive fishing. The plaice has many enemies, which decimate its progeny. In the southern part of the North Sea, only about a sixth of the eggs hatch out. A large proportion of the pelagic eggs and larvae fall a prey to jellyfish, sagitta and others. The bottom stages and growing fishes are devoured by predatory species such as the cod and turbot. On the other hand, the numbers of marketable plaice are not substantially reduced by the depredations of the larger fish of prey.

No evidence is available of serious injury to plaice from parasitic worms and crustaceans. Lymphocystosis, probably caused by a virus, produces some striking symptoms - a tumour-like swelling of the connective tissues, especially in the fins and tail. Very little is known about infectious diseases in sea fish. Experiments in aquaria, in which deadly infections with microsporidia and *Vibrio anguillarum* were used, show that in certain circumstances they may increase the normal mortality.

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RESPONSE OF *Stolephorus pseudoheterolobus* HARDENBERG TO ENVIRONMENTAL FACTORS

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The genus *Stolephorus* Lacépède is well represented in the waters of the Indo-Australian Archipelago by no less than eight species.[15] In the Straits of Singapore four species - *Stolephorus pseudoheterolobus* Hardenberg, *Stolephorus heterolobus* Rupp, *Stolephorus indicus* (von Hasselt) and *Stolephorus insularis* Hardenberg - form a substantial portion of the fish catch. Among these, *Stolephorus pseudoheterolobus* is by far the most common. The most common type of gear used in Singapore Straits for the exploitation of this genus is the "kelong", a fixed trap built generally between the three-fathom and five-fathom lines.[16] A smaller modified version of the "kelong" known as the

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[15] J.D.F. Hardenberg, "Some Remarks on the Genus *Stolephorus* Lacépède in the Indo-Australian Archipelago", *Treubia*, vol. 14, No. 1 (Bogor /Buitenzorg/, Java, 1932), pp. 299-312.

[16] D.W. Le Mare and Tham Ah Kow, "The Kelong Fishing Method", paper prepared for the Fishery Conference convened by the United Kingdom Special Commissioner for South-East Asia at Singapore, 1947 (mimeographed).

"blat" and the ordinary beach seine are also used to a much smaller extent to exploit this genus.

The fishermen in Singapore Straits are aware that Stolephorus pseudoheterolobus may, generally speaking, be expected in their catch during certain months of the year and that the quantity of catch of this species varies from year to year. They believe that these phenomena are the result of varying conditions of sea water and weather, including wind and rainfall. They believe that certain currents and wind conditions are responsible for good catches, that poor catches are due to the water being too cool or too turbid and that failure of the fish to appear altogether at the proper season is due to unfavourable wind conditions.

It was decided that these observations of the fishermen should be tested on a quantitative basis by means normally at the disposal of the fisheries' scientist and that, at the same time, data should be obtained with a view to elaborating a more precise basis for prediction. The kelong, which is operated daily throughout the year in all conditions of weather and is responsible for the bulk of the catch of Stolephorus pseudoheterolobus in Singapore Straits, appears to be the ideal gear to use to assess the level of availability of this species in Singapore Straits at any one time. Moreover, Singapore Straits by its geographical position is sufficiently protected to enable observations on the physical, chemical and biological factors of the environment to be carried out throughout the year in all conditions of weather. An investigation was therefore started in Singapore Straits during which a qualitative and rough quantitative study was made of the food[17/] of Stolephorus pseudoheterolobus, and observations on temperature and quantitative determinations of salinity, phytoplankton and zooplankton were made, at fortnightly intervals throughout two full years.[18/] At the same time daily observations on rainfall, wind direction and wind force were made available for this study by the Malaya Meteorological Service and daily records of catches of Stolephorus pseudoheterolobus and other species were kept.

[17/] Tham Ah Kow, "The Food and Feeding Relationships of the Fishes of Singapore Straits", Colonial Office, Fisheries Publications, vol. 1, No. 1 (London 1950).

[18/] Tham Ah Kow, "A Preliminary Study of the Physical, Chemical and Biological Characteristics of Singapore Straits", Colonial Office, Fisheries Publications, vol. 1, No. 4 (London, 1953).

It was found that *Stolephorus pseudoheterolobus* fed mainly on diatoms and copepods. However, it was also found that this species, in turn, served as the food of the Spanish mackerel, three species of which - *Scomberomorus commerson* Lacepede, *Scomberomorus guttatus* Schneider and *Scomberomorus lineolatus* Cuvier - are commonly found in Singapore Straits. The results of the investigation indicated, among other things, the following relationships between *Stolephorus pseudoheterolobus* and the various factors of the environment:

Within the limits of the physical and chemical environment obtaining in Singapore Straits during the two years (1948 and 1949) of the investigation, that is, a range of 27° to 30.5° centigrade for temperature of sea water and 28.47 to 31.87 per thousand for salinity,

(a) Food availability appeared to be a dominant factor in determining the level of maximum availability of this species. Whenever this species was abundant in the catches, it was invariably found that either diatoms or copepods or both were abundant.

(b) Temperature and salinity did not appear to have any effect on the availability.

(c) Exceptionally heavy and continued rainfall appeared to affect catches and, since decreased salinity due to heavy rainfall did not affect them, the high turbidity resulting from the heavy drainage from land would appear to be an adverse environmental factor for *Stolephorus pseudoheterolobus*.

(d) In the absence of heavy continued rainfall, high wind force under certain circumstances would appear to be a favourable environmental factor in the aggregation of *Stolephorus pseudoheterolobus* in Singapore Straits. When the west wind has been blowing strongly for more than two days and there has been no heavy rainfall, it is almost certain that there will be glut catches for the kelongs situated in the western portion of Singapore Straits. In the eastern portion of Singapore Straits, when there are strong north-east, east and south-east winds with no heavy continued rainfall along the east coast of Malaya and Singapore, heavy catches of this species may be expected from the kelongs situated there. These phenomena indicate clearly the role which wind force plays in the aggregation of surface living species such as *Stolephorus pseudoheterolobus* in regions where the currents are mainly monsoon currents.

(e) It was observed that when heavy catches of *Scomberomorus* spp. were made, *Stolephorus pseudoheterolobus* was also abundant. Since *Stolephorus pseudoheterolobus* forms the main food of these species in Singapore Straits, it would appear that the presence of *Stolephorus pseudoheterolobus* in Singapore Straits was one of the factors which induced the aggregation of the *Scomberomorus* species.

These ecological relationships were tested and found to be statistically significant. It would appear, therefore, that with a sustained study of environmental factors over a period of years sufficient data could be accumulated to render the formulation of a basis for prediction of fish availability a distinct possibility.

OBSERVATIONS ON THE HABITS OF THE PEARL OYSTER (*Pinctada margaritifera L.*) IN RELATION TO ITS ENVIRONMENT

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This species of lamellibranch mollusc is distributed throughout the Indo-Pacific coral zone. Although individual specimens are as a rule fairly widely separated, in the lagoons of the Tuamotu Archipelago they occur in quite large numbers in a limited area, as is shown by the fact that divers can harvest as much as 100 tons of shell in three months in one-third of the lagoon of Hikuoru Island alone. Lagoons are accordingly well suited for the propagation of oysters. The larvae live in the lagoons throughout their planktonic life and are brought outside only by accident. They attach themselves in large numbers to the natural objects to be found in the lagoons. What conditions are necessary for the growth and reproduction of this species of pearl oyster?

For its growth it requires suitable salinity, temperature and food. These conditions are apparently present in most of the lagoons, since in three years the oyster attains the marketable size of thirteen centimetres or over, a fact which indicates a fairly high rate of shell secretion. The water density is normally 1.025, and the temperature range is approximately from 25° to 30° centigrade. The oyster's main food, plankton, is especially abundant in summer when all marine organisms are reproducing themselves. In the Takapoto lagoon the water density is 1.030 and the temperature from 25° to 30°. The pearl oyster, though in good physical condition, does not grow a very large shell and in three years does not exceed eight centimetres.

There can be no doubt that the salinity of the water plays an important part in the development of the egg and the growth of the adult oyster. The dwarfed character of the pearl oysters in the Takapoto lagoon is due to the high salinity of the water. The lagoon has only slight communication with the ocean as it is almost completely surrounded by the island. Plankton is less plentiful there.

In water up to fifteen metres in depth the oyster grows slowly, the shell remains short and thickens, and the organism is in poor physical condition. It is most often in this zone and in such individual specimens that pearls are found. High temperature, excessive light, high salinity and lack of sufficient food are the probable causes of this deficiency.

At depths between fifteen and forty-five metres growth is normal. The organism is in good physical condition and secretes a mother-of-pearl of good quality.

The pearl oyster reproduces between October and February in the Southern Hemisphere. The genital glands develop from October onwards, and spawning takes place in December, January and February. The water temperature then reaches about 30°. An astronomical quantity (some billions) of ova and spermatozoids are ejected by the females and males. They fall to the bottom and are moved about by the currents. The ova are quickly fertilized. Within twenty-four hours a properly formed ovum (only half or three-quarters of the ova are properly formed) turns into a ciliated larva. The larva can move vertically for short distances and remains close to the surface. It is unable, however, to resist the slightest current that it encounters. It is food for all other animal organisms. If they are to develop properly, the surviving larvae must have favourable temperature conditions (30°) and, as they have very narrow stomata, must have access to a plentiful food supply in the form of very small microscopic algae or protozoans. For twenty-one to twenty-five days, drifting at the mercy of the currents, the larva grows and undergoes anatomical transformations ending with a complete internal metamorphosis. It then falls to the bottom and secretes a new shell. If it finds a suitable support to which it can adhere, it continues to live; otherwise it dies or falls prey to the innumerable enemies lurking at the bottom. Large numbers perish in this way, and in addition the winds and currents will already have cast up large quantities on to the shore to die.

To attach themselves, however, the larvae need stones or shells. Sand is fatal to them. The stones and shells must be clean and be free of animal life. A stone covered with living corals or various organisms cannot be used as a support, as the byssus filaments cannot adhere to them. In the course of time the sea deposits sand in the lagoon. As the thickness and surface area of the sand increase, the lagoon gradually becomes shallower. Shallow lagoons are the first to be affected. At the bottom of the others are to be found areas of sand among rocks of varying size. If there is a clam shell or a pebble (such as a piece of dead coral) lying on an area of sand, a pearl oyster will almost always be found adhering to it. The cyclone of 1906, which devastated some of the islands, uprooted many trees and set them down in the bottoms of the lagoons. These trees served as supports or collectors and quickly became covered with pearl oysters.

At present the oysters are mainly attached to rocks which have not been silted up in the lagoon bottoms. As these rocks, however, are becoming progressively covered with various kinds of animal matter, there are not many free spaces left.

Once they have attached themselves, the young oysters have to face many new enemies, such as fish, crustaceans, molluscs, echinoderms and others. Very many oysters will perish and very few reach maturity. Out of each million ova laid, it may be said that only between one and ten will carry on the species. Thus, female oysters are required in great numbers to ensure the continuance of the species in a given place. When the reproductive stock falls below a certain point, it can be taken as certain that sooner or later the population will become totally extinct. That is the critical factor for the prosperity of a lagoon. Tens of thousands of spawners concentrated in a relatively small area are required to secure the continuance of the species.

Excessive pearling inevitably results in a dangerous diminution of the stock. The male and female oysters which have escaped the divers are often at long distances from each other, which makes it difficult to fertilize the ova.

The larvae, dispersed by the currents, adhere wherever they can, even in places where the adults are to vegetate for the remainder of their existence. The adult can resist severe conditions, such as excessive heat and light, but only individuals living under very favourable conditions can produce viable offspring, because their ova are properly formed. The areas where these conditions are fulfilled may be regarded as the cradle of the race, and in the case of the pearl oyster of Oceania, the great lagoon bottoms constitute such areas.

THE ARCTIC COD

by

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In February each year enormous shoals of spawning cod appear on the northen coast of Norway and give rise to the famous Lofoten Fishery. This fishery lasts for a few months only until the cod disappears after the completed spawning. From historic sources it is known that the fishery, although fluctuating, must have existed for more than a thousand years. As it is of fundamental importance for Norway, it has been regulated for centuries.

Scientific investigations of the Lofoten cod and its environments were started about a hundred years ago. Such investigations have revealed the main features of the biology of the Arctic cod.

The "home" of the Arctic cod is the vast areas of the Barents Sea, where both the old and the young fish spend most of the year feeding. But in October and November each year ever increasing numbers of the sexually mature cod start moving southwards on their annual migration to the spawning grounds off the Norwegian coast. During this migration the cod can be found at depths of 200 to 400 metres, following the continental shelf along the coast. On their way the fish shoals have to cross several submarine valleys, which may divert some of the cod. But most of the shoals penetrate southwards to the great submarine valley in the continental shelf outside the Westfjord. They enter the Westfjord and congregate on the spawning banks on the landward side of the Lofoten Islands. For a couple of weeks the cod remains here while the roe and the milt ripen and attain the spawning stage. When the spawning has been accomplished the cod starts the return migration to the feeding areas of the Barents Sea.

The distance from the central part of the Barents Sea to the Lofoten Banks amounts to about 800 nautical miles. This means that the "average" cod has to cover 1,600 nautical miles each year in order to deposit its pelagic eggs in one particular area on the Norwegian coast. It is not known why this enormous effort is demanded of spawning cod. It can only be assumed that migration to this locality is a necessary measure arranged by nature in order to ensure successful propagation. Nor is much known about how the fish is able to find its way to the spawning banks. It must be assumed that this is an hereditary ability, which, however, according to our observations seems to be connected with temperature differences in the sea.

In respect of the hydrographical conditions of the waters in which the Arctic cod lives and migrates, it may be stated that the Barents Sea is a shallow part of the North Polar Sea, where in north Arctic waters temperatures below 0° centigrade prevail, while in the south there is relatively warm water of Atlantic origin. As is indicated later, the pronounced temperature gradients found here have a decisive influence on the distribution of the fish, which on the whole seek to avoid the cold Arctic water.

The first southward part of the spawning migration takes place towards increasing temperature. For the actual spawning process the cod seem to prefer temperatures around 6° to 7° centigrade. A closer study of the behaviour of the cod on the spawning banks demonstrates the clear correlation which here exists between the temperature distribution of the sea and the occurrence of the cod.

In a hydrographical cross-section of the Westfjord in winter it is found that the warmest water is located in the deepest layers. This water is of Atlantic origin and is heavy due to its high salinity. On top is a layer of cold coastal low salinity water. The stratification of the two types of water is very pronounced. Between them an intermediate layer is formed through mixing. Here the temperature increases rapidly from 3° to 6° (the thermocline).

The cod arrives in the Westfjord in the warm water below the intermediate layer and mainly close to the bottom. As the fish aggregate, large continuous shoals are formed in the intermediate layer, stretching out horizontally for several nautical miles sometimes. Here the shoals will remain until after the spawning. Heavy storms may sometimes disturb the stratification of the water and push the cold water towards the bottom. In such cases the cod has been found to withdraw until normal conditions are again established.

It thus seems obvious that the temperature has a direct effect upon the behaviour of the cod. This is furthermore sustained by observations of annual variations in various qualities of the intermediate layer and corresponding variations in the behaviour of the fish. Thus, the layer preferred by the cod may in some seasons be quite narrow, resulting in a narrow vertical distribution of the shoals. In other seasons the intermediate layer may be thicker, allowing much thicker formations of cod. The critical layer may also be found at greatly different depths in the various seasons with corresponding variations in the vertical occurrence of the cod.

These variations in the qualities of the "fish-carrying" layer are accordingly of very great importance for the practical fishery. Certain conditions will favour the fishery by making the fish easier to catch, while others will impede fishing activity.

While the cod is very sensitive to temperature in spawning, the temperature limits between which it may thrive and grow in the vegetative stage of its life are much greater. Nevertheless, the extreme conditions of the Barents Sea demonstrate clearly the temperature dependence of the cod. The minimum temperature tolerated by it probably lies around minus 1° centigrade. Occasionally profitable catches may be taken in temperatures below zero, but generally temperatures below 2° seem to be unfavourable to it and seldom allow large concentrations of fish. Such concentrations can, however, often be found in temperatures of 2° to 4° in areas where the Atlantic and the Arctic water converge, and where accordingly the bottom temperature gradients are well defined. Seasonal and other variations in the temperature of parts of the Barents Sea will thus have a most direct influence on the occurrence of the fish, and observations of this temperature are of prime importance for the fishery.

A STATEMENT ON THE ECOLOGY OF TUNAS

by

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Tunas are unique among the important food fishes of the world in that they are truly oceanic fishes, which live, spawn, and die on the high seas without regard to the nearness of land. Thus, they differ from the herrings, cod-like fishes, flatfishes, salmon, and even the closely related mackerel, all of which inhabit waters over or near continental shelves.

Six groups of tuna species comprise the major tuna fisheries of the world. These are: (1) the bluefin tunas of the genus Thunnus, for which there are major[19/] fisheries in the Mediterranean, north-eastern Atlantic, eastern and western Pacific; (2) the yellowfin tunas of the genus Neothunnus, for which there are major fisheries over much of the tropical Pacific; (3) the bigeye tunas of the genus Parathunnus, which are fished extensively only in the western Pacific; (4) the albacore of the genus Germo, caught in major quantities on both sides of the north Pacific and in the north-eastern Atlantic, and more recently in the tropical Pacific; (5) the skipjack of the genus Katsuwonus, taken in greatest quantities in the eastern and western Pacific; and lastly (6) the bonito of the genus Sarda, important in the Mediterranean and in the south-eastern Pacific. In addition to these established fisheries others are rapidly developing, especially in the Indian Ocean, south-eastern Atlantic, and south-western Pacific.

Despite the present and potential importance of the tunas, very little is known of their biology. Intensive studies of their habits have only recently begun. Furthermore, it has been found difficult to domesticate and study them in captivity. Consequently, it is not possible to find generalizations which apply certainly to all species but only to point out facts ascertained for certain species which may be thought to apply generally.

[19/] Here defined as a recorded catch of more than 10,000 tons in any year since 1930.

Quite naturally these fishes are best known from the experience of the coastal fisheries, which of course always fish the nearest available stocks, and therefore records of occurrence of tunas have come mostly from the coasts of the continents or the vicinity of islands. However, the explorations by Japan during the past two decades and the more recent explorations of the United States show clearly that yellowfin, bigeye, skipjack and albacore occur over an immense area of the tropical, subtropical and some of the temperate Pacific Ocean. These researches, together with previous records of occurrence, suggest that one or more of the species can be found almost anywhere in the Pacific between 40° north and 40° south latitude, and indeed some of them may at times extend poleward from these limits.

Within this vast area these tunas are not, of course, uniformly distributed. The yellowfin and skipjack tuna have been found in greatest abundance near the equator and in the warm Kuroshio current, whereas the bigeye tuna and the albacore prefer the slightly cooler waters of more temperate latitudes. The bluefin also like the cooler waters but are abundant only near the coasts of the continents.

The broad range over which many of the tunas are found and special studies of Japanese scientists suggest that all species tolerate a considerable range of water temperatures. The skipjack has been reported from 15° to 32° centigrade, albacore from 14° to 32° and bluefin from 5° to 29°; however, in specific areas, as for example off the coasts of Japan and Australia, a species may be found within very narrow temperature limits and may appear to follow a temperature zone which advances poleward and then retreats with the seasons.

The rate of growth of these large, very active, and rapidly swimming fishes is generally high. Studies of skipjack suggest that they reach the common commercial size of three to ten kilogrammes in one to three years, whereas the yellowfin reaches the common commercial sizes of twenty to eighty kilogrammes in from two to five years. Bluefin have been reported to grow more slowly. Little is known of the growth rates of the other species and indeed, even the methods of determining age are not thoroughly proved.

All of these species of tunas are voracious and eat a great variety of fish, cephalopods and crustaceans, some of which they apparently catch as deep as 100 fathoms. Quite surprisingly, even large tunas occasionally feed on tiny crustaceans, but on the other hand they will gorge themselves on fish up to half their own length when they can.

Almost nothing is known of the migration of the tunas because these active animals are extremely difficult to catch, tag and release without injury. However, the small amount of tagging which has been done off the western coast of the Americas by scientists from California has provided an example of the most remarkable migration known among fishes. An albacore tagged off the coast of California was recaptured about a year later off the coast of Japan, more than 5,000 miles distant from the point of release. Others tagged close to the American coast were recaptured in the middle of the north Pacific, about midway between the United States and Japan. For the bluefin group, the summer fishing seasons on both sides of the north Atlantic and Pacific and in the Mediterranean suggest a definite seasonal migration. Too little is known of the other species to make any general comments.

The spawning adults of yellowfin, bigeye and skipjack have been found over enormous areas of the Pacific and throughout a great portion of the year. In addition, the helpless eggs and larvae of the tunas may be caught in fine mesh plankton nets over an immense area of the ocean. On the other hand, the bluefin apparently seek particular spawning areas at certain seasons, as in the Mediterranean.

A close relationship of tuna fisheries and ocean current boundaries has been noted in several areas. However, the common factor in the occurrence of most tunas appears to be the total quantity of food, which in turn depends primarily on the nutrients of the surface layer of the ocean. These must come from rivers or from water upwelled from the rich depths of the ocean. Enrichment from such upwelling occurs along the equator, where currents impinge on land, and in the great eddies or gyres of the ocean. Then, too, concentrations of tuna food without an increase in nutrients may occur between converging currents, where surface waters sink and leave behind the food animals.

This knowledge concerning tunas suggests that here is a group which may comprise ultimately the most important food fishery in the world. Already they are known to be distributed in commercially important quantities over a greater area of the oceans than any other group of food fishes. Further studies of the basic biology of each stock of each species will show how much tuna can be made available to feed the people of the world.

THE CONSERVATION OF BIOLOGICAL RESOURCES IN COASTAL WATERS

by

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(The mimeographed text of this paper appeared in French as document A/CONF.10/L.12 under the title "La conservation des ressources biologiques dans la zone littorale")

As long ago as 1921, in a paper which remained unpublished for some time until, through the good offices of Commandant Rouch, Director of the Musée Océanographique, it appeared in the Bulletin des Amis du Musée Océanographique, Price Albert I of Monaco drew attention to the urgent necessity of holding a meeting such as the international technical conference we are now attending. "The protection of maritime fisheries," wrote the Prince, "raises very serious questions, for they sustain, directly or indirectly, a large part of the human race."

> "The destruction which overfishing is bound to cause among sedentary species has long been a matter of concern; attempts have been made to remedy the situation by the regulation of fishing methods and especially by efforts to protect undersized creatures. However, the rise in fishing abuses in most of Europe's seas, difficulties in enforcing certain restrictions and the failure to punish offenders will surely lead to a most serious crisis in the fishing industry unless steps are taken in good time to adopt an international convention having as its object a wiser and stricter organization of the exploitation of so important a food resource.
>
> "No time should be lost in introducing certain rigorous laws and strict penalties based on an international agreement, for the marine world knows no boundaries other than those formed by currents, temperature, the nature of the waters and the bottom of the sea. Its inhabitants are subject only to certain physiological conditions; they are seriously affected only by powerful influences such as mighty geological phenomena which cause some disturbance in those conditions, or else by the actions of man, who with the ever-growing efficiency of his equipment, eventually exhausts the most productive sources of his wealth.
>
> "That is why the riches of Europe's seas are beginning to show signs that they are not inexhaustible and we shall have proof before long that only oceanography can teach us how to go about the cultivation of the marine world, where, by virtue of a biological heredity which is stronger than all of life's others forces, man's chief food grows."

In that paper, which may be said to have been his last scientific work, Prince Albert I, pioneer in so many fields, touched on most of the questions with which this Conference is concerned.

He emphasized the importance of plankton, the basic food of marine animals, since creatures that do not actually consume it themselves eat those that do. He recommended the study of plankton, of its density and distribution, so essential for a knowledge of the life history of migratory fish.

He protested against the mass destruction of immature fish all along the Mediterranean coast, "where fishermen catch the smallest fry sheltering in the under-water vegetation". He drew attention to the progressive impoverishment resulting from such practices and to the increasing dissatisfaction of fishermen with their occupation, which they themselves had ruined, and he deplored the ineffectiveness of penal measures that are not seriously enforced.

Unfortunately, this destruction of young fish is not confined to the coasts of France and Monaco. In June 1947, I pointed out in my Rapport sur la pêche en Grèce the pressing need for action against this deplorable and far too widespread practice, encountered along all the shores of the Mediterranean. I have also found the same thing in the Caribbean and along the west African coast, where, if the tiny fish are not sold, they are left lying on the beach to be devoured by scavengers. Most of these fish are of species which grow to a large size fairly rapidly and which could therefore be of considerable nutritional and economic value.

Accordingly, we should have an international convention which would prevent the catching of fish below marketable size; the regulations would have to be firmly applied, and would include rigorous measures to prohibit the sale of such fish, to supervise fishing grounds, to inspect gear and to establish preserves where fishing would be forbidden.

Minimum marketable size

This term means the size which a fish has to reach in order to reproduce itself at least once. We hope to be able shortly, on the basis of observations along the coasts of North Africa, France, Greece, Monaco, Turkey and the Gulf of Genoa, to indicate what this size would be for most of the edible species in the

Mediterranean. It is already known that, with the exception of tunny, some rays and certain kinds of dogfish, fish grow very slowly in the Mediterranean, where at any given age they are smaller than in the Atlantic.

If the sale of fish below marketable size is strictly prohibited, the fishermen, no longer able to dispose of them, will throw them back into the sea at once and, what is more, discontinue fishing in areas where the average size is below the legal limit.

Fishing methods and gear

Certain practices should be strictly prohibited: the use of stupefying materials, lime, copper sulphate, dynamite and saw-toothed dragnets.

Other coastal fishing practices, often criticized and even prohibited in certain places, are not as harmful as they are thought to be; fishing by torchlight, for example, is practiced only with very small craft in exceptionally calm weather on moonless nights and is therefore of very limited scope. In any case, the fish brought in are rather large. The same is true of deep-sea searchlight fishing when practised with revolving nets of suitable mesh size and confined to migratory species.

On the other hand, fishing for *poutine* (whitebait) is, as F. de la Tourrasse points out in his *Observations sur la poutine de sardine dans la région de Monaco*, a real heresy from the economic point of view. It is permitted from Nice to the Italian border, apparently because it is allowed at Ventimiglia and beyond. It is responsible for the destruction of billions of sardines and anchovies as small fry, with the result that now fishermen seldom encounter the full-grown fish in the waters of the Principality of Monaco, and most of the sardines marketed in Monaco are caught far from the coast, where fishing for *poutine* is prohibited. Fishing for *poutine rose* (pink whitebait) is not harmful because it is confined almost exclusively to *Aphya*, which, in spite of their tiny size, are full grown.

Meshes of fishing nets

In fishing with dragnets, the dragging exercises a pull on the diagonal of the meshes, which sooner or later either close completely or, at best, are so reduced in size as to retain only a small part of their straining capacity, particularly when the nets are used in shallow water or inshore over under-water vegetation, or even in deep-sea fishing if there is soft and sticky mud on the bottom, as is so often the case in the Mediterranean.

Again and again improvident fishery people have been reluctant to admit this fact, and the terms of the London convention, to which a dozen European States are parties, are not always observed. However, it has been found that small fish can escape from nets which have sufficiently large meshes provided that the cod-end of the trawl is not soon filled with algae or kelp and the mud is not too sticky.

Experiments with a "trouser net", one "leg" of which had meshes of thirty-seven square millimetres, and the other meshes half as large, showed that small fish were able to pass through the leg with the larger meshes, whereas a large number were caught by the other. Some will say that those which escaped suffered serious shock and cannot have survived. I do not share that view. Abroad the "George Bligh", I have taken live hake found in a regulation English trawl between the cod-end and its cover of small mesh netting, kept them in a tank on the trawler after puncturing their swim bladders, banded them, measured them and returned them to the sea. Nine months later, one of them (which had measured twenty-eight centimetres when first caught) was caught again, and its growth for the period had been quite normal.

The closing of the meshes of dragnets is due to the pull exercised along the diagonal. Would it not be possible, by special weaving or mounting, to produce meshes less likely to lose their shape when the net is dragged and then make the use of such netting compulsory, at least in the cod-end of trawls?

Protection of certain coastal waters (isolation zones)

Most species of fish, except for rays, certain kinds of dogfish and small coastal species like gobies, do not lay their eggs on the bottom. Their eggs are pelagic; as soon as they are laid, they rise towards the surface and it is near the surface that they hatch. Consequently, the danger of egg destruction from trawling devices is sometimes needlessly exaggerated, and the term "spawning ground" is very often misused to designate the places on the bottom, inshore, where the fry live after completing the pelagic phase of their existence. The

English word "nursery" is much more accurate and these nurseries, which quite often consist of under-water vegetation, should be protected.

Many species of fish come close to the shore to lay their eggs; they could be protected very effectively by the establishment of suitably selected coastal isolation zones, or by the introduction of closed seasons in certain areas.

Educating the fisherman

Fishermen would be more inclined to accept and observe regulations if they understood their purpose. In addition to their research work, the biologists of fishery institutes also have a duty to enlighten fishermen. They should have direct contacts with fishermen to make them realize the dangers of some of their practices and of the use of fishing devices and methods which are responsible for the already alarming impoverishment of the waters and which will eventually depopulate the sea. The fishermen will then be more inclined to accept regulation, and will even themselves request it.

Thus, sensible men in some areas prohibit fishing methods that are considered harmful. Before the war, the fishermen of Les Sables d'Olonne realized that the facts brought to their attention by experts of the Fisheries Office were true, and asked the Minister of Merchant Shipping to establish a coastal isolation zone - to which they had previously been opposed - in order to protect the reproduction of soles and cetaceans, which they had found increasingly scarce. Never was such a regulation better observed, for the fishermen themselves enforced it.

The protective measures that are necessary will, of course, have to be determined in the light of information provided by biological oceanography. Studies relating more specifically to fishery, stocking and seasonal variations are in progress in Monaco, where His Highness Prince Rainier III has long been giving his attention to this problem of the destruction of coastal fauna. These studies have been the subject of communications to the General Fisheries Council for the Mediterranean and to the International Commission for the Scientific Exploration of the Mediterranean Sea.

BIOLOGICAL APPRAISAL OF THE OCEAN, AND THE PROBLEM OF TRANSOCEANIC ACCLIMATIZATION

by

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(The mimeographed text of this paper appeared as document A/CONF.10/L.15; original in Russian)

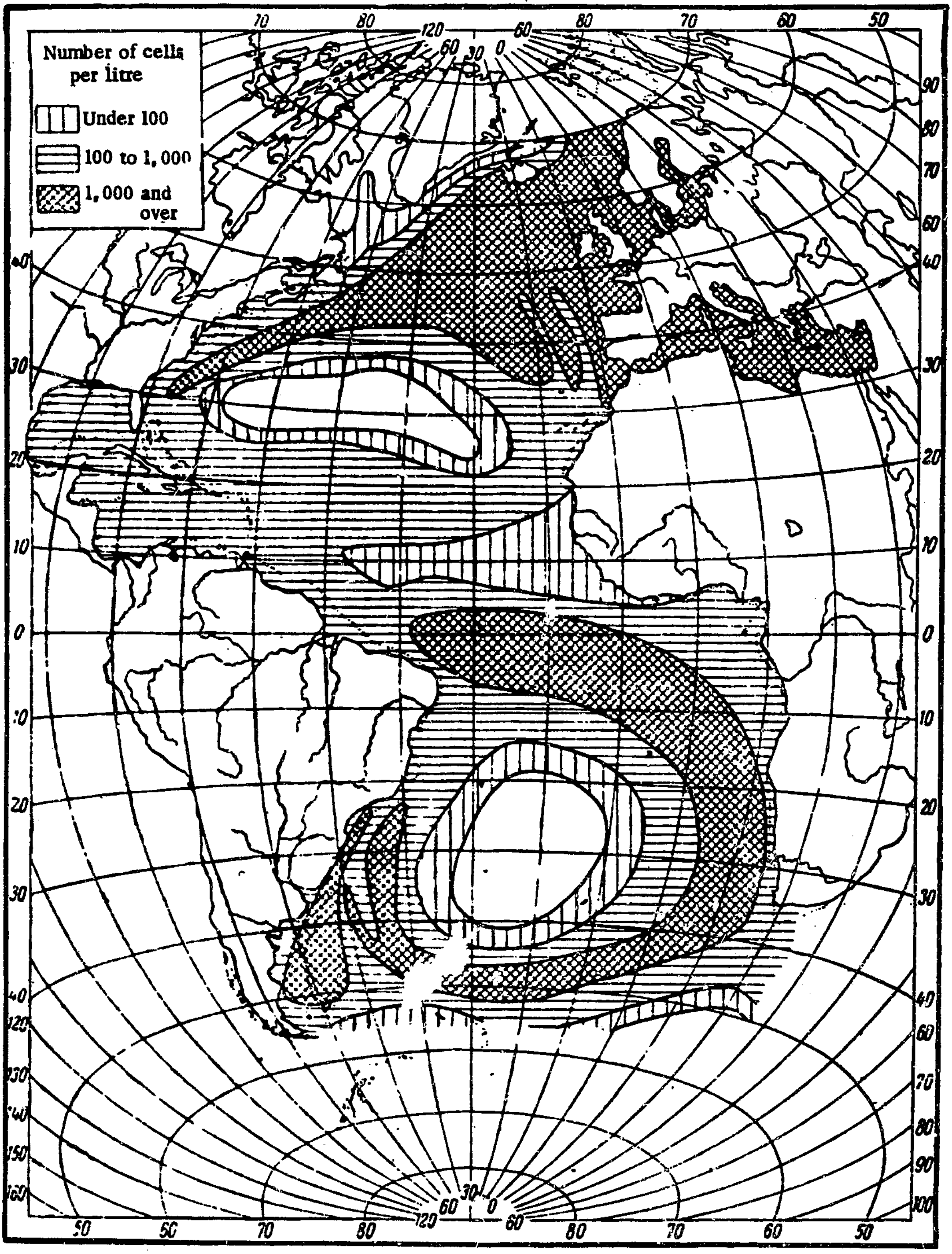
To control the use of the resources of any body of water it is necessary: (a) to record the composition, quantitative distribution and movements of stocks of the organisms concerned; (b) to ascertain to what extent the qualitative and quantitative distribution is dependent, both statically and dynamically, on the biotic and abiotic factors of the environment; (c) to develop fishing and utilization techniques; (d) to take steps to conserve resources; and (e) to take steps to expand and improve primary resources. This paper is concerned with some questions bearing on aspects (a), (b) and (c). Rational use of the animal and vegetable resources of the ocean must be based on biological appraisal, both qualitative and quantitative, of the inhabitants of the pelagic zone and of the ocean floor.

The fundamental elements of biological appraisal are the occurrence of these living species in the mass, their quantitative distribution and degree of productiveness. The concentration of commercially useful organisms is merely one aspect of the general picture of the distribution of living organisms in the world's waters.

Living organisms in the ocean are distributed very unevenly, both qualitatively and quantitatively. This unevenness is the result of three main determining elements: (a) latitudinal distribution; (b) distance from the coast; and (c) the horizontal and vertical flow of ocean water masses, which changes the latitudinal distribution.

A quantitative appreciation of the distribution of pelagic life, based on the Pontosphaera huxleyi, was first made fifty-three years ago by H. Lomann for the Atlantic Ocean (figure 10). In 1929, Lomann's map was corrected for all the plankton by E. Hentschel (figure 11). Unfortunately, these maps were

Figure 10. Map showing quantitative distribution of Coccolithophorid (Pontosphaera huxleyi) in the Atlantic Ocean (after H. Lomann)



constructed on the basis of the number of specimens and not the average weight of living matter, so that they are not easily comparable with data obtained for other regions of the ocean and for other organisms. However, even such maps as these are not yet available for the Pacific Ocean.

The first estimates of the quantitative distribution of marine benthos were made by Danish investigators almost half a century ago (C.G.J. Petersen, H. Blegvad, R. Spärck, G. Thorson and others) but only for limited areas of the ocean. These scientists showed that the various species of fish did not use all the fauna of the sea floor, and that the fauna should be classified as those that served as food and those that did not. Hence, no simple relationship should be looked for between phytoplankton and zooplankton or between zoobenthos and fish; these interrelationships are vastly more complicated.

The variations, according to latitude, of the quantitative distribution of pelagic organisms are shown in figure 12. The zones, from the poorer sub-polar regions towards the equator, first increase in productiveness but then yield exceptionally low average weights of living matter in the oceanic regions of low salinity. Not until the line of junction of the equatorial current and counter-current is reached does the average weight of living matter increase slightly.

Significant qualitative changes are also observable over the same area, as indicated by the following figures giving the number of species of green, brown and red seaweed, and of animals, in various ocean latitudes (after Schapova):

Region	Number of species	
	Seaweed	Animals
Kara Sea	55	1,200
Barents Sea	172	1,800
Mediterranean Sea	423	6,000 to 7,000
Malay Archipelago	860	40,000
Southern South America	309	
Antarctic region	63	

The number of species of macrophytes and animals living on the ocean floor greatly increases in the equatorial region. It is the mobile species of marine life, such as fish, cetaceans and some squids, that react most markedly to the

Figure 11. Map showing quantitative distribution of plankton in the Atlantic Ocean (after Hentschel)

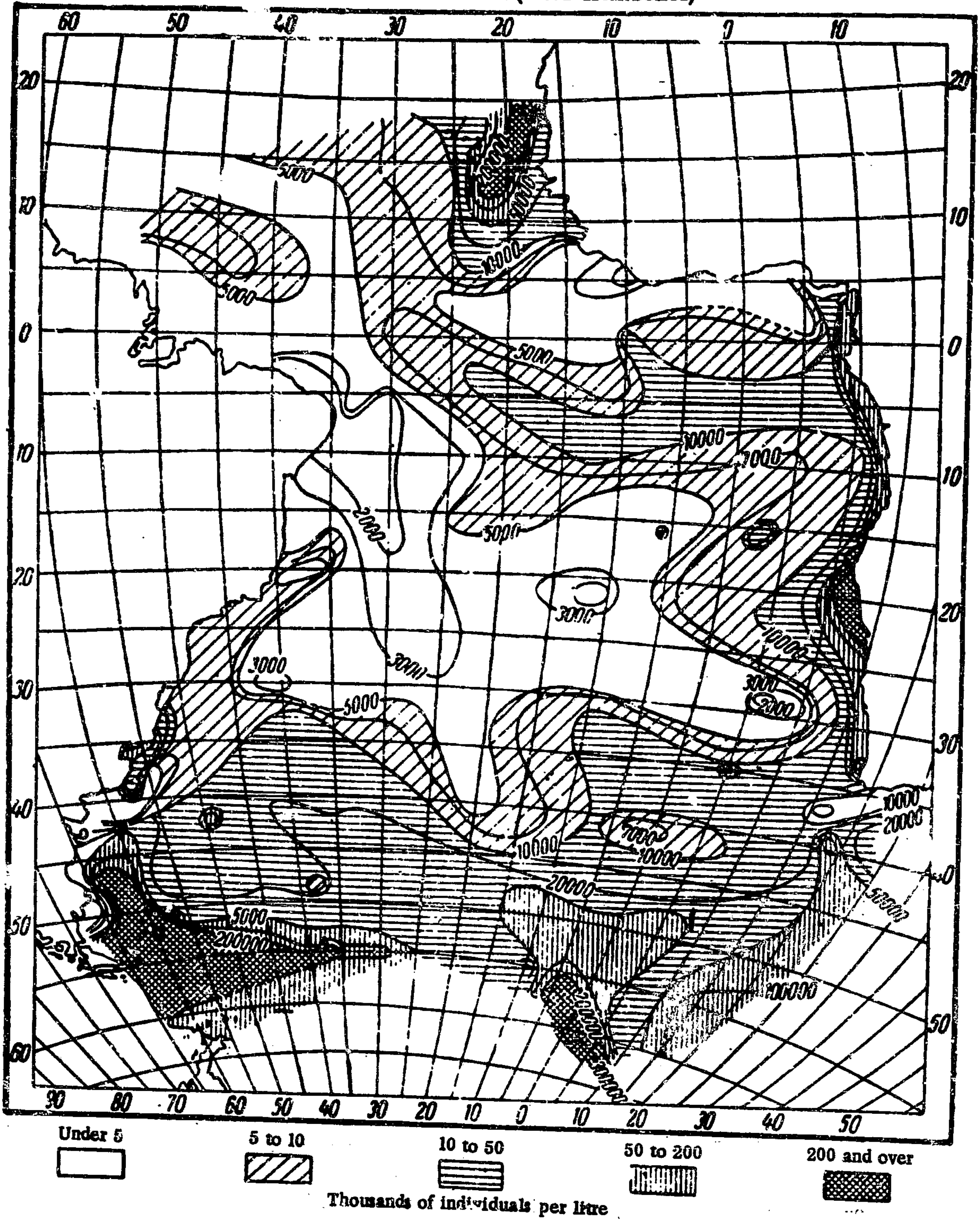
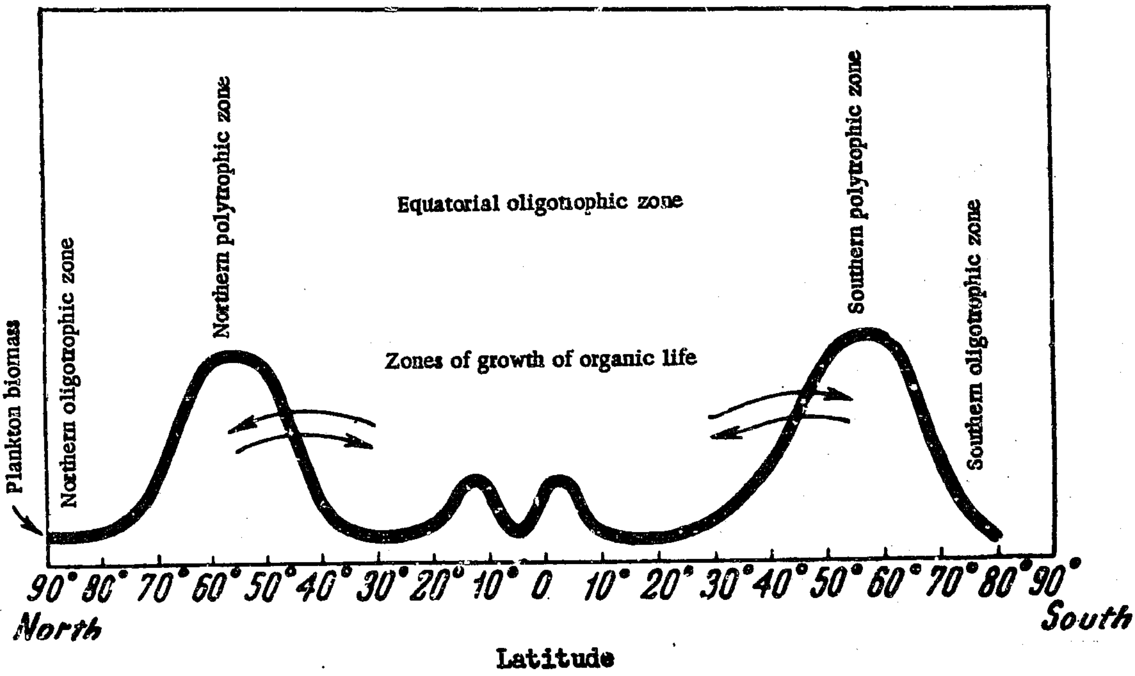


Figure 12. Distribution of ocean plankton biomass, by latitude
(after Zenkevich)



peculiarities of the quantitative distribution of nutritional fauna and seasonal changes of climate; they move about in their search for food, going to colder waters in summer and to warmer zones for breeding in winter.

Reasonably accurate maps of the quantitative distribution of the fauna of the pelagic zone and of the ocean floor exist for only a few regions of the ocean. They exist for the northern waters of Europe and Asia (figures 13 and 14), for the seas of southern Europe (figure 15) and for some Far Eastern seas (figures 16, 17, 18 and 19), and the work has been done in great detail for the fauna of the Sea of Azov (figures 20 and 21) and the Caspian Sea (figures 22 and 23).

Figure 13. Map showing distribution of benthos biomass in the northern seas of the Union of Soviet Socialist Republics (after Zenkevich)

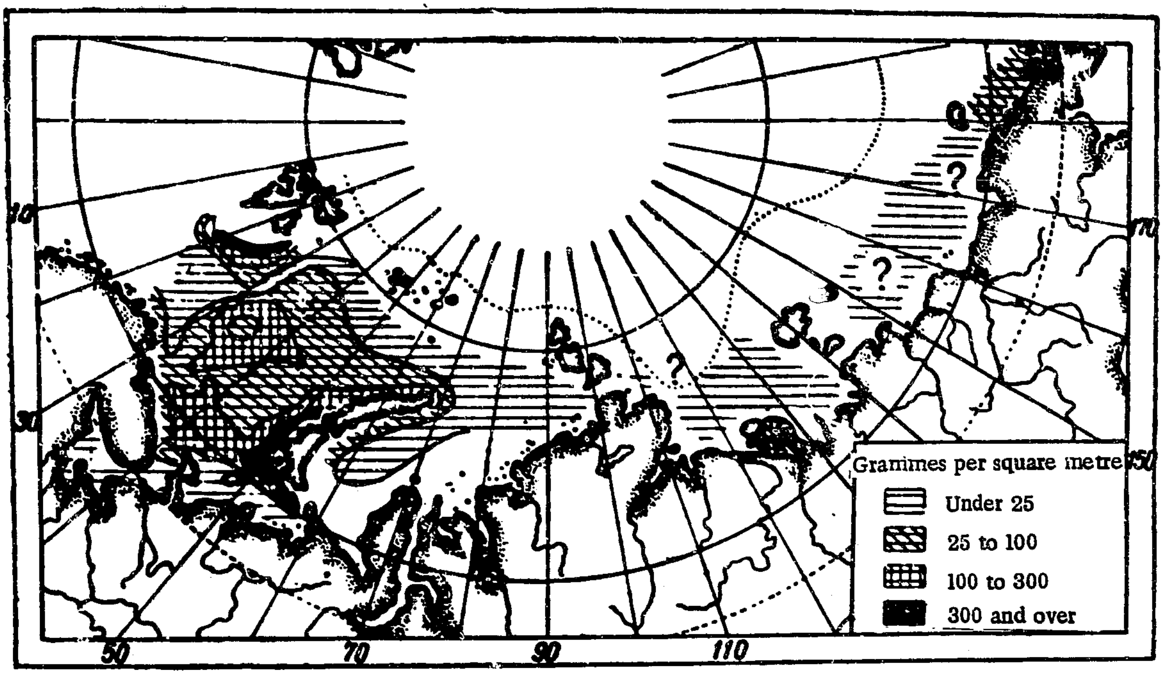


Figure 14. Map showing distribution of plankton biomass in the northern seas of the Union of Soviet Socialist Republics (after Zenkevich)

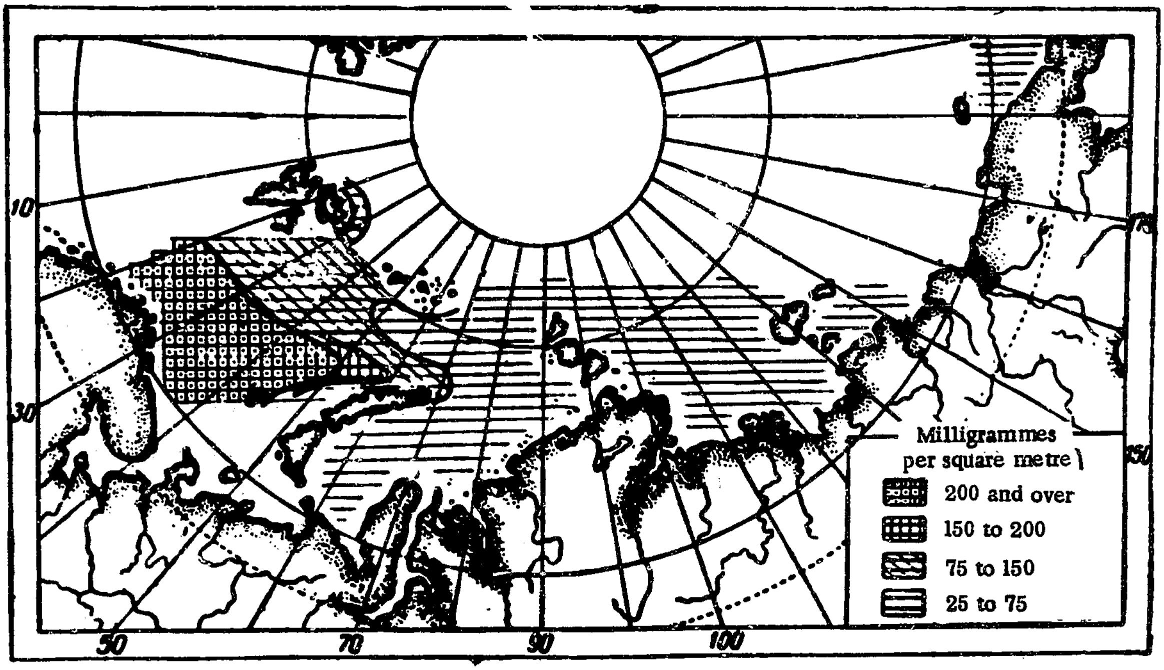


Figure 15. Map showing distribution of benthos biomass in southern European seas (after Zenkevich)

(Grammes per square metre)

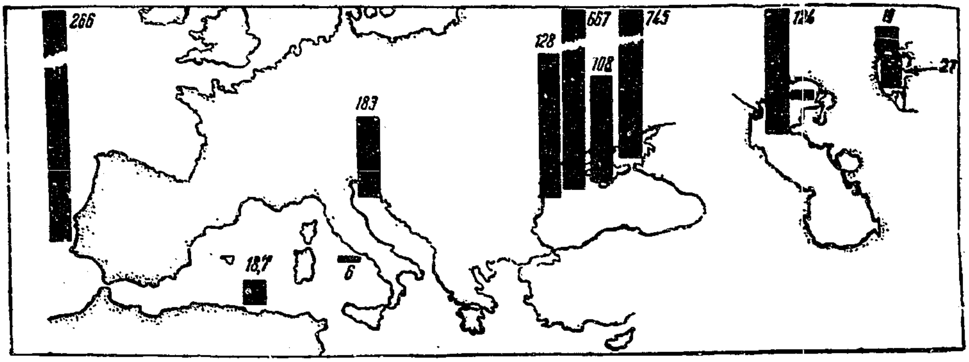


Figure 16. Map showing distribution of benthos biomass in the Sea of Okhotsk (after Savilov)

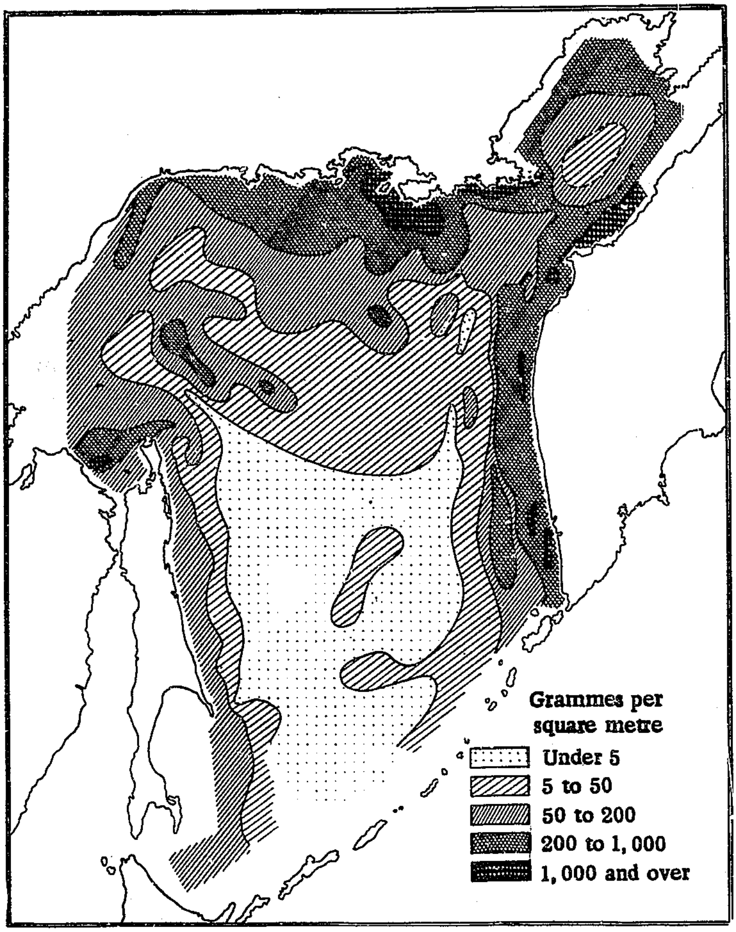


Figure 17. Map showing distribution of communities of benthic fauna in the Sea of Okhotsk (after Savilov)

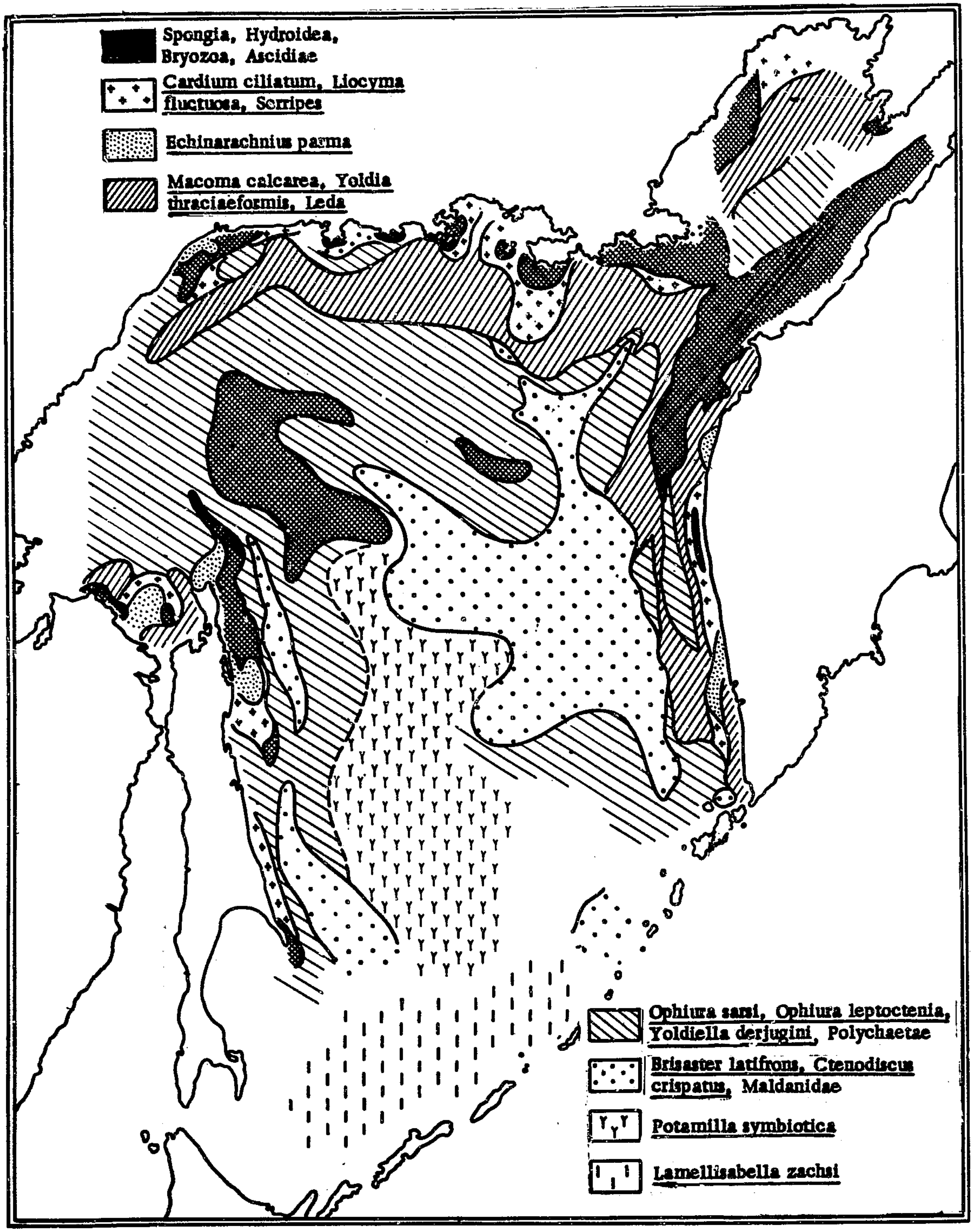


Figure 18. Map showing distribution of benthos biomass in the western part of the Bering Sea (after Belyaev)

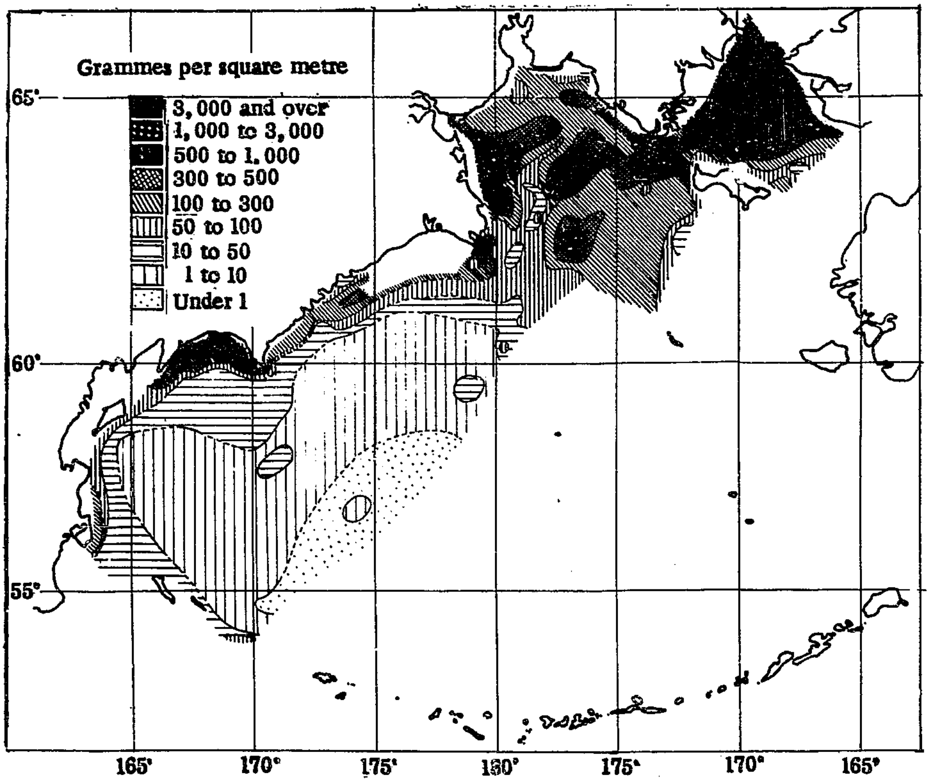


Figure 19. Map showing distribution of plankton biomass in the western part of the Bering Sea in June (after Vinogradov)

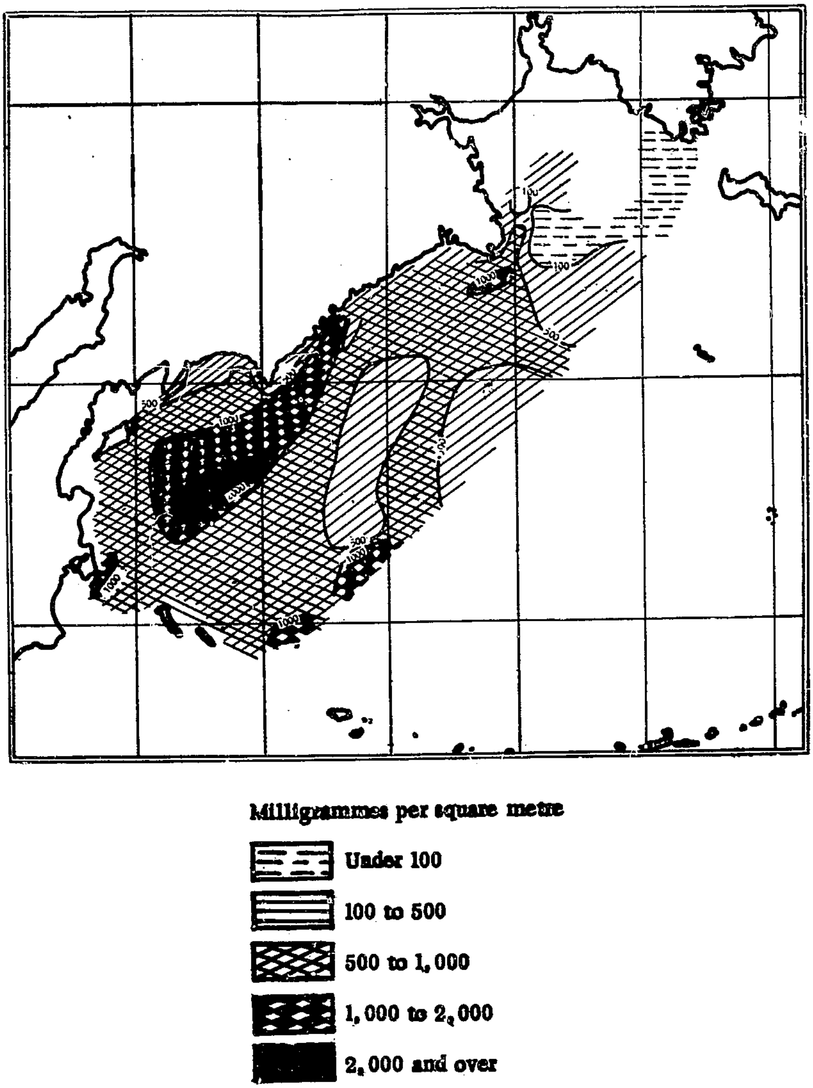


Figure 20. Map showing distribution of benthos biomass in the Sea of Azov in spring (after Vorobyov)

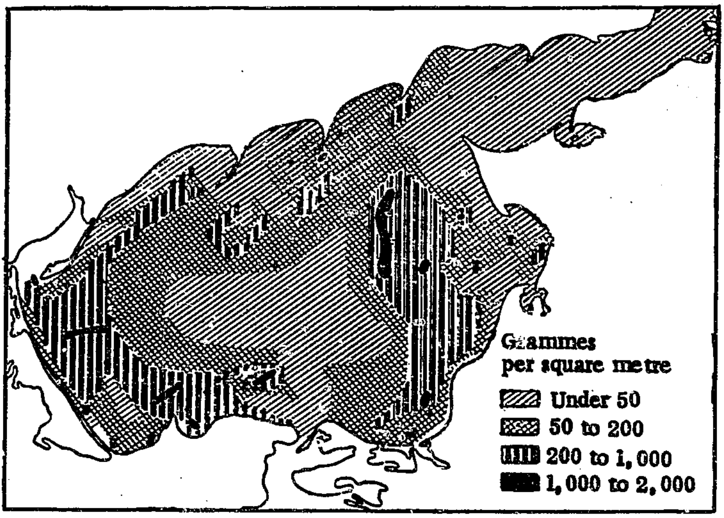
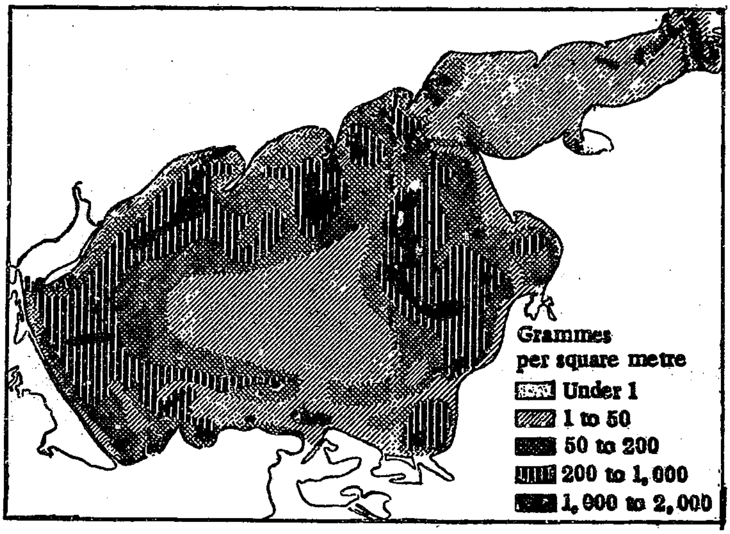


Figure 21. Map showing distribution of benthos biomass in the Sea of Azov in summer (after Vorobyov)



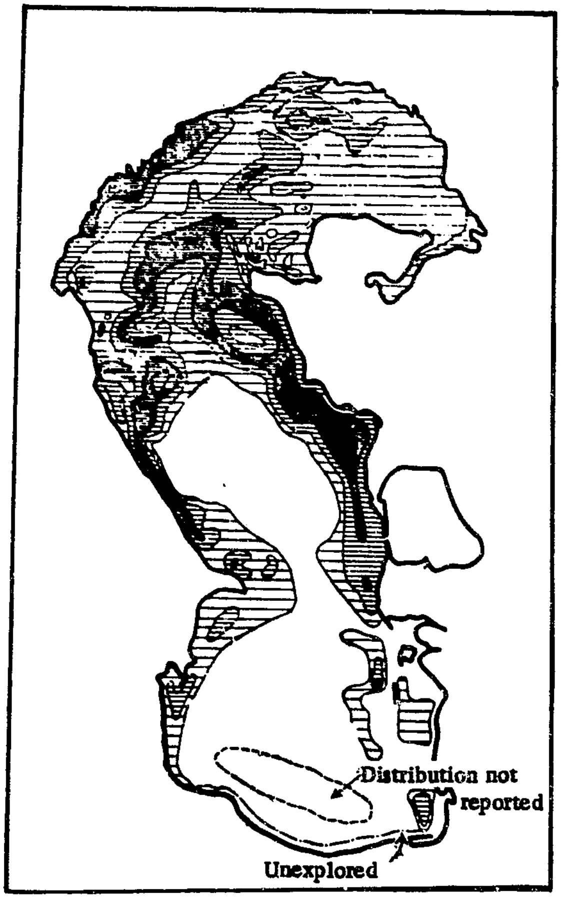


Figure 22. Map showing distribution of benthos biomass in the Caspian Sea (after Ryabchikov and Yashnov)

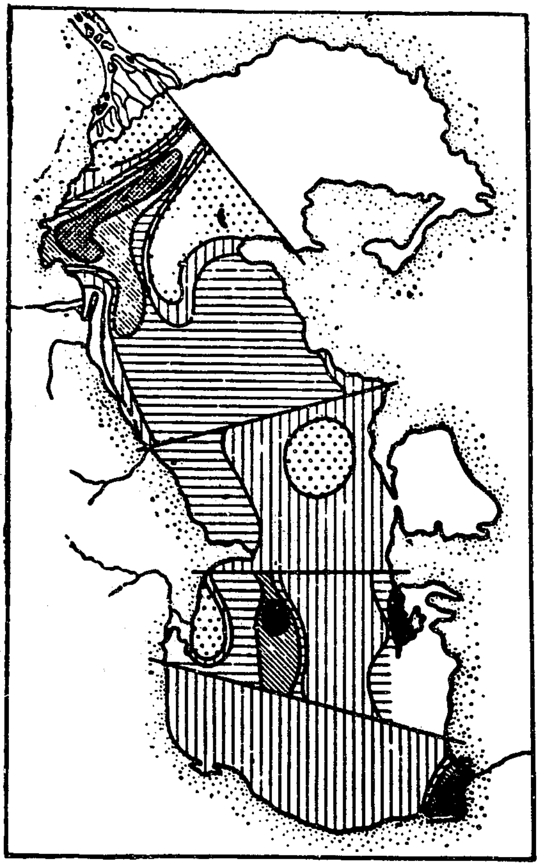
Grammes per square metre

■ 1,000 and over
▩ 500 to 1,000
■ 100 to 500
▤ 25 to 100
▭ 1 to 25
□ Under 1

Figure 23. Map showing distribution of autumn plankton in the Caspian Sea (after Ryabchikov and Yashnov)

Milligrammes per cubic metre

▩ 200 and over
▧ 100 to 200
▤ 50 to 100
▥ 25 to 50
⬚ Under 25



PAPERS PRESENTED AT THE INTERNATIONAL TECHNICAL CONFERENCE ON THE CONSERVATION OF THE LIVING RESOURCES OF THE SEA

Rome, 18 April to 10 May 1955

A/CONF.10/7

Sales no. 1956.II.B.1

CORRIGENDUM

1. On page 139, delete the third paragraph, starting "A biological appraisal..." and ending "...no significant difference to the figures adduced." and substitute the following:

> A biological appraisal of this kind should be made for the entire ocean; it will then be possible to classify the various zones of the ocean. Purely as a guide, the quantity of living matter on the floor of the continental shelf may be considered 0.3 times 10^{10} tons and the quantity of plankton 0.03 times 10^{10} tons. These figures must, however, of necessity be corrected by the index of productiveness, which may vary by as much as 50 to 60 times from one part of the ocean to another. The quantity of plankton outside the continental shelf may be estimated, even more approximately, at 1.2 times 10^{10} tons and the quantity of benthos on the ocean floor at 0.1 times 10^{10} tons. By adding all these figures together, the weight of the animal population of the whole ocean may be estimated at between 1.63 times 10^{10} tons, excluding fish and sea mammals, which would, however, make no significant difference to the figures adduced.

2. In the third line of the following paragraph, for "temperature" read "temperate."

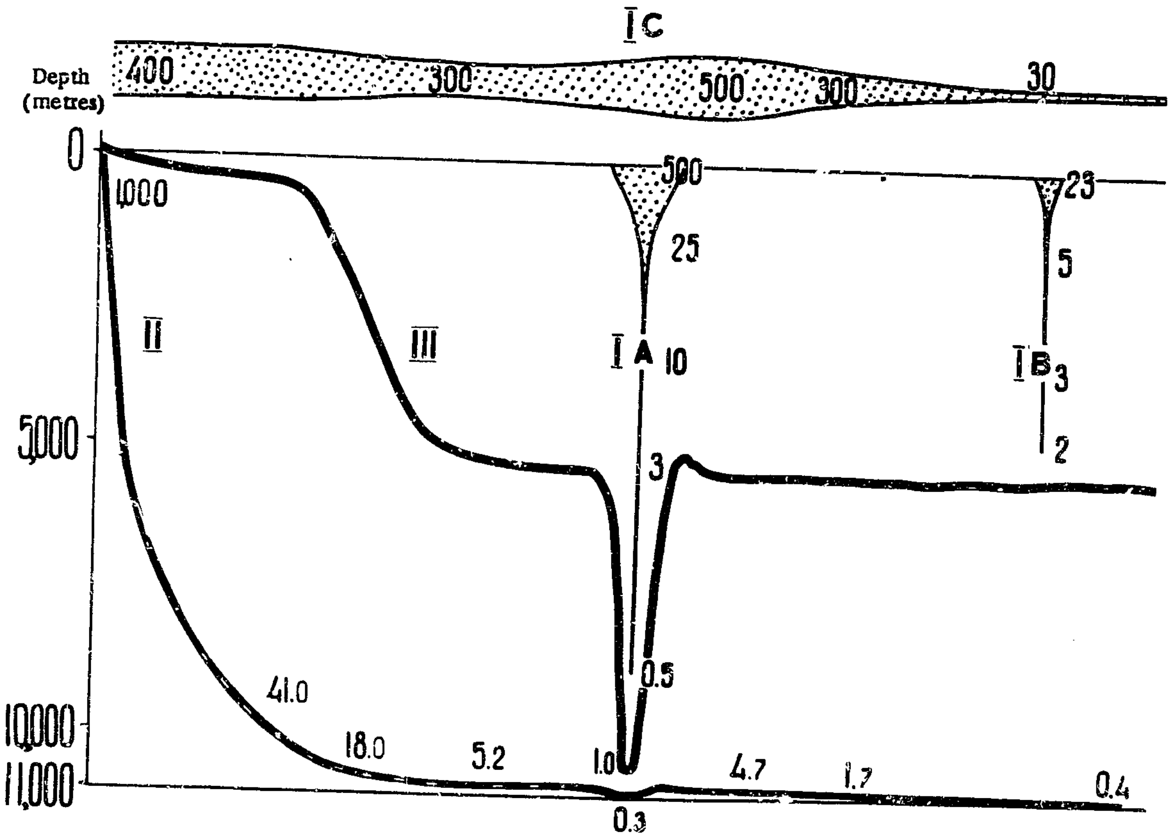
After observations over many years, it is now possible to construct a diagram showing the general character of the quantitative changes of benthos an plankton observed in moving from the coast towards the deep ocean in the north-western part of the Pacific Ocean (figure 24). The Soviet expedition ship "Vityaz", by a six-year investigation of the distribution of living matter in t north-west Pacific, showed that in general terms the average weight of benthos per square metre falls from one kilogramme at the shore to 0.4 gramme at a distance of 1,000 sea miles from the Kuril Islands. Over the same stretch of water, the average weight of plankton per cubic metre of water falls from 400 milligrammes to between 20 and 30 milligrammes. The average weight of plankton per cubic metre falls to two milligrammes at a depth of five kilometre and to 0.5 milligramme at ten kilometres.

According to the Danish research worker, R. Spärck, who used material collected during the remarkable voyage of the "Galathea", the average weight of benthos per square metre in typical ocean regions is of the order of one or two grammes.

A biological appraisal of this kind should be made for the entire ocean; it will then be possible to classify the various zones of the ocean. Purely as a guide, the quantity of living matter on the floor of the continental shelf ma be considered 14 times 10^{11} tons and the quantity of plankton 8 by 10^{11} tons. These figures must, however, of necessity be corrected by the index of productiveness, which may vary by as much as 50 to 60 times from one part of the ocean to another. The quantity of plankton outside the continental shelf may be estimated, even more approximately, at 4 by 10^{11} tons and the quantity of benth on the ocean floor at 0.27 by 10^{11} tons. By adding all these figures together, the weight of the animal population of the whole ocean may be estimated at betwe 25 to 30 times 10^{11} tons, excluding fish and sea mammals, which would, however, make no significant difference to the figures adduced.

By taking account of all the characteristics of physical geography and biology, it becomes possible to proceed to classify the zones of the ocean. The frigid, temperature and tropical zones of both the Atlantic Ocean and the Pacifi Ocean can be divided, as a first approximation, into eight neritic faunas of the

Figure 24. Quantitative changes in plankton and benthos biomass in north-western Pacific Ocean (after Zenkevich), measured from the coast outwards in a south-easterly direction to a distance of 1,000 miles



I. Plankton (milligrammes per cubic metre)

- A. Vertical distribution over the Kuril-Kamchatka trench
- B. Vertical distribution farther offshore
- C. Variation in near-surface plankton with distance from coast

II. Relation between quantity of benthos biomass (in grammes per square metre) and distance from shore

III. Topography of sea bottom, showing crossing of Kuril-Kamchatka trench temperate zone, four of the tropical and two of the frigid zones (figure 25). The faunas of these regions are now distinct and they have passed through a protracted period of separate development, but in the remote geological past, the faunas of the tropical and temperate zones had a common genetic origin. The faunas of the frigid zones are particularly divergent in form, yet they show a certain degree of unity at both poles.

Though they may now be separated from each other by open stretches of ocean or by continents, all regions belonging to the same zone show the same characteristic development of large numbers of similar species, analogous biological phenomena, analogous trophic relationships, and so on. The development of analogous biological phenomena may be illustrated by the feeding cycles of the cod of the North Atlantic and the east Australian flathead (Neoplatycephalus). All the elements of these cycles are different, but the feeding cycles as a whole are generally analogous. Bearing in mind existing experience, it is possible by classifying the oceanic regions to plan large-scale transoceanic acclimatizations.

In this connexion, "potential living areas" and "acclimatization resources" should be sound biogeographical concepts. As a result of the historical development both of marine fauna and of the orography of the ocean, many environmentally similar regions with their various fauna are now prevented from exchanging them. Thus, the actual living areas of the vast majority of marine organisms, particularly those of the sea floor and of the neritic zone, are considerably smaller, and in some cases many times smaller, than the areas which they could inhabit or, in other words, than their potential living areas. This fact places at man's disposal virtually inexhaustible possibilities of acclimatization which he may reasonably turn to his own advantage. Nature itself seems to show the way; it is necessary only to recall the settling of the Chinese crab Eriocheir sinensis in both the salt and fresh waters of north-west Europe, the journeyings of the Caspian hydroid Cordylophora caspia first in the Baltic Sea and then throughout the world, the migration of the American crab Heteropanope tridentata first to the Zuyder Zee and then to the Black Sea and the Sea of Azov, of the gastropod Rapana bezvar from the China Sea to the Black Sea,

Figure 25. Schematic diagram of principal neritic faunas of the Atlantic and Pacific Oceans (after Zenkevich)

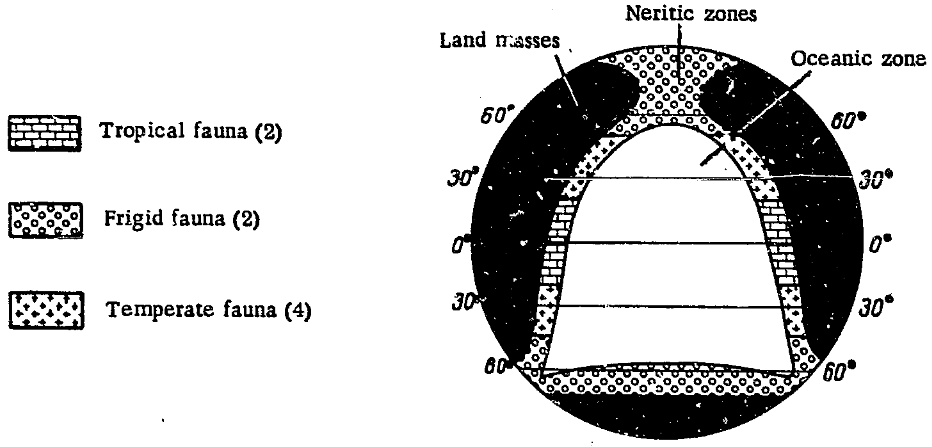
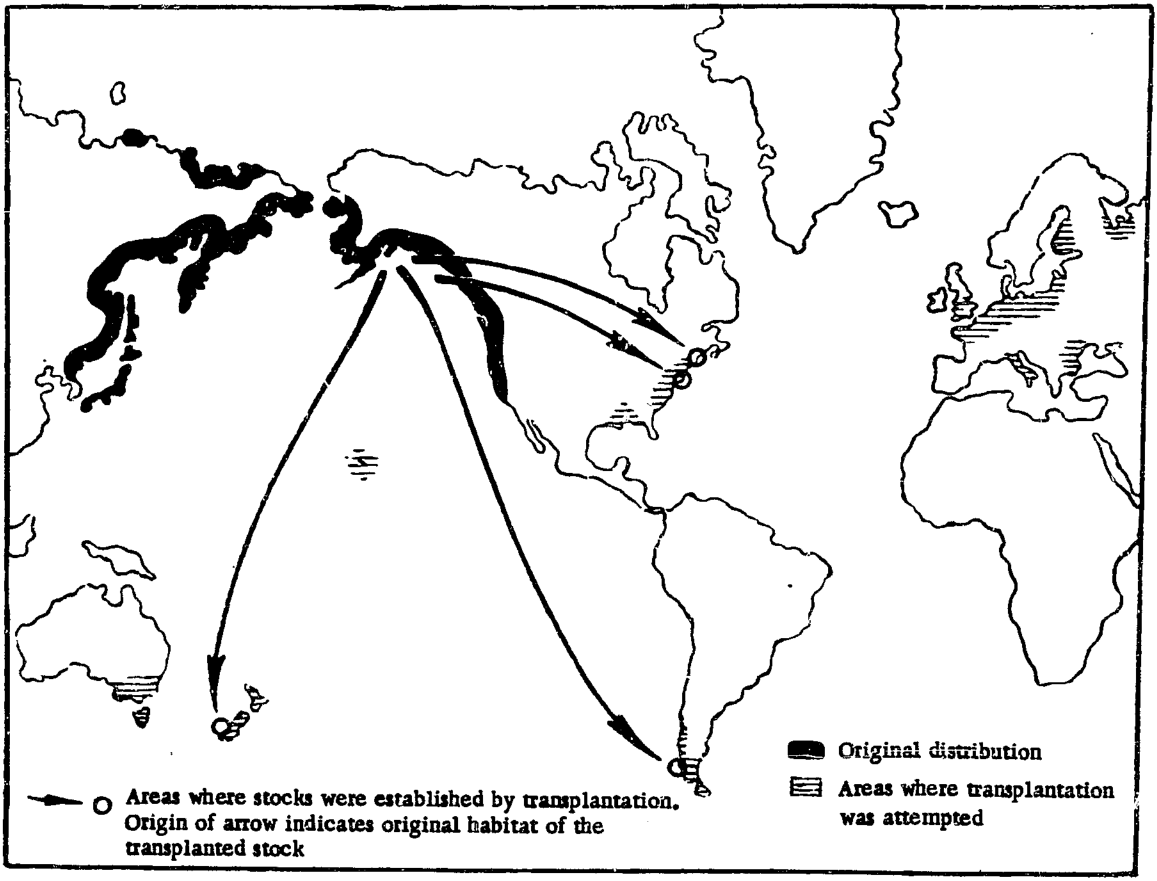


Figure 26. Map showing acclimatization of North Pacific salmons (Oncorhynchus) in the Atlantic Ocean and the Southern Hemisphere (after Zenkevich)



of the diatom *Rhizosolenia calcaravis* and the bivalve *Mytilaster lineatus* from the Black Sea to the Caspian, and many other remarkable examples of self-acclimatization.

Side by side with the concept of potential living area, the concept of an acclimatization resource, that is, of a collection of species from various other oceanic regions which are capable of inhabiting a specific region, must be developed. The actual living area of the overwhelming majority of species living in the ocean is ordinarily circumscribed by insurmountable barriers. It is quite evident that the frigid zone of one hemisphere is a potential living area for very many inhabitants of the frigid zone of the ohter hemisphere. The same situation applies to the eight neritic faunas of the temperate zone and the four tropical faunas. The eight neritic zones and the four tropical zones can provide very rich acclimatization resources for one another and should be most carefully investigated. In these circumstances, sixty-four possible routes of transoceanic acclimatization may be defined and used to find potential living areas for valuable commercial species or for the organisms on which they feed, or for some other useful purpose.

In the past, there have been examples of the very successful use of transoceanic acclimatization. A well-known instance is the successful transplantation of oysters from certain oceanic regions to others, making use of their potential ability to live in eihter ocean of the Northern Hemisphere. Other outstanding examples have been the successful acclimatization in the Pacific of shad (*Alosa sapidissima*) transferred from the Atlantic side of North America, using their potential ability to live in either ocean of the same hemisphere, and the transfer of salmon from the North Pacific to the Southern Hemisphere and to the North Atlantic (figure 26), using their potential ability to live in the equivalent zone of either hemisphere. The fact that there have been specific instances of failure to acclimatize Pacific salmon in no way means that satisfactory results cannot be obtained from the same regions in the future.

Examples of extremely good results obtained from certain acclimatization measures are also to be found in the seas of the Soviet Union. During the nineteen thirties grey mullet from the Black Sea were transferred to the Caspian, and they became a valuable commercial commodity in their new living area. In

1939 and 1940, the sea worm Nereis succinea was introduced into the Caspian Sea, where it is used for food by the sturgeon and stellated sturgeon.

In connexion with the construction of a number of large reservoirs in the Soviet Union, a large-scale plan of acclimatization measures is being carried out in order to secure a planned fishing economy in the reservoirs. Acclimatization measures for these reservoirs are also required in connexion with the controlled drainage of the river systems feeding the Sea of Azov, the Caspian Sea and the Aral Sea. Grey mullet from the Caspian and sprats from the Baltic are being introduced into the Aral Sea, where until now there were no fish of the herring type. Various species of edible invertebrates have also been transferred from the Caspian Sea to the Aral. The Caspian Sea, the Sea of Azov and the Baltic Sea will also need certain further acclimatization measures. It is proposed to acclimatize in the Caspian Sea the mollusc Macoma baltica, which is of very great importance in the Baltic from the nutritional point of view.

If the problem is approached seriously and in a spirit of international co-operation, a very real increase and improvement in the commercial resources of the ocean can be achieved. It should be remembered that the Southern Hemisphere lacks such important commercial fish as cod, sea perch (Sebastes marinus) and herring. The herring of the Black Sea and the Caspian Sea could provide a valuable acclimatization stock for some inshore areas of the ocean. Closely related species or even subspecies might also form a valuable resource for transoceanic acclimatization. The possibility of transferring Atlantic cod to the Pacific and perhaps of transferring fur seals to the Greenland Sea might also be considered.

There can be no doubt that great results may be expected from transoceanic acclimatization, and such acclimatization should be fully considered in investigating means for the planned utilization of the resources of the ocean. In the meantime, research in the field of the biological appraisal of the ocean and the use of the possibilities offered by transoceanic acclimatization is in its infancy. It should be intensified and developed on a much larger scale.

INTERNATIONAL CONSERVATION PROBLEMS, AND SOLUTIONS IN EXISTING CONVENTIONS

by

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(The mimeographed text of this paper appeared as A/CONF.10/L.4 and Corr.1 under the title "International Fishery Conservation Problems and Solutions Developed in Existing Conventions")

Contents

Practical development of international co-operation for effective conservation of the living resources of the sea must, by the very nature of the problem, depend upon progress in two fields of technical and scientific endeavour.[1] First, methods of exploiting resources must develop in efficiency and range to the point where stocks of fish can be materially reduced by man's activities, and the reduction extended to areas and stocks which are being exploited by the nationals of more than one country; second, fishery

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[1] See the end of this paper for definitions of terms used.

science must be developed to the stage where the effect of man's activities on fish stocks can be evaluated, and measures of control can be devised which will limit or control these activities to obtain the desired results. Men began to approach this state of affairs less than a century ago.

The advances of the industrial revolution began to be effectively applied to the fishing industry at about the turn of the present century. Steam and internal combustion power adapted to fishing vessels increased their speed and cruising range; mechanized gear multiplied fishing efficiency; advances in preservation allowed vessels to continue to fish longer; and increases in population augmented the demand for the product. This trend continues today.

Under heavy fishing the strain on known resources became apparent from gradually diminishing returns from the same fishing effort. Fewer fish on older fishing grounds had to be shared by more fishermen from many countries. The generally held view that the seas were inexhaustible was exploded, and the concept of the optimum catch was gradually developed. The question became: to what extent could the quantity and quality of the catch be improved by regulating fishing operations, and how could this be done when fishermen of more than one country worked competitively over the same area on a limited resource?

This problem, as might be expected, first became acute in the north-eastern Atlantic (the North Sea and adjacent waters) where fishing fleets were among the first to be mechanized and where fishing had been heavy for many years. It was in this area, too, that the international nature of the problem was first recognized, and attempts at joint study and suggestions for joint management were first introduced.

Problems of diminishing returns from high seas fishery resources soon developed in other parts of the world. This was particularly true in the North Pacific area, first with respect to fur seals, then halibut and, later, salmon and other species.

Development of Research Councils and Conservation Agreements

Development of the international approach to solving high seas fishery problems occurred in two ways. The first involved co-operative research only. Research was non-contentious and everyone seemed in favour of developing more information regarding a little-known but valuable resource which was beginning to show signs of exhaustion.

In answer to an obvious need in the North Sea area, where the fisheries were of first importance, an International Council for the Exploration of the Sea, composed of western European countries, was organized for the purpose of co-ordinating and advancing ocean research. Led by some of the leading marine scientists of the day, this Council was an almost immediate success. It gave great impetus to fishery research in the eastern North Atlantic area and inspired others in other parts of the world to follow. In 1919 a somewhat similar body, called the International Commission for the Scientific Exploration of the Mediterranean Sea, was formed by countries bordering the Mediterranean for the study of oceanography in general in that body of water; and in 1920 the North American Council on Fishery Investigations, having similar aims and close ties to the parent North Sea council, was organized, with special emphasis on western North Atlantic research.

More than a quarter of a century passed before the next regional fisheries council was organized. This took place in 1948 under the Food and Agriculture Organization of the United Nations (FAO) in the Indo-Pacific area and was followed closely, in 1949, by a new council for the Mediterranean Sea. Some progress also has been made towards organization of a fishery council for Latin American waters.

The other line of development was more controversial, dealing with actual international high seas fisheries management. The terms of reference and objectives were more precise, and the agreements were in the nature of formal treaties.

The first formal international convention was entered into by Canada, Japan, Russia and the United States in 1911 for the purpose of conserving the fur seals of the North Pacific. This convention was successful in restoring the fur seal populations but became inoperative in 1941. The second convention in point of time, the Pacific halibut convention of 1923, between Canada and the United States, deals with the conservation of one species, the Pacific halibut, in one area, the north-eastern Pacific. This convention has achieved a large measure of continuing success. The next convention was the sockeye salmon convention of 1937, between Canada and the United States. It deals with one species and one river system, the Fraser. It, too, is successful in aiding progress towards its objectives. The Baltic convention, signed by Danzig, Denmark, Poland and Sweden in 1929, covering plaice and flounder in the Baltic, functioned until the Second World War. The Skagerrak, Kattegat and Sound convention, signed by Denmark, Norway and Sweden in 1937, provided minimum size limits for plaice and dab. The remaining conventions, on whaling, inter-American tropical tuna, the north-west Atlantic fisheries, overfishing and the North Pacific fisheries, have all been negotiated and became operative within the last decade. The older conventions of this group have already made encouraging progress in the direction of their objectives.

It is the intention of this paper to review briefly the organization of these international research councils and the more formal international fishery conventions and agreements, to point out the problems which they were designed to solve and the procedures used, and to assess their achievements so far as is possible at this early date.

The Research Councils

International Council for the Exploration of the Sea

Although sporadic attempts were made in the North Sea area to get agreement on such measures as minimum mesh size during the first half of the nineteenth century, modern progress dates from late in the century, with the evolution of beam and otter trawling and the extension of fishing offshore. Characteristically, the first moves were steps to develop co-operation in research concerning the sea and its resources through informal co-operation among scientists. This later led to formal co-operation through the organization of the International Council for the Exploration of the Sea. Following organizational meetings held in Stockholm in 1899 and Christiania in 1901, a North Sea Research Council was formed. Its inaugural meeting was held in Copenhagen in 1902.

The purpose of this Council, the Conseil Permanent International pour l'Exploration de la Mer,[2] is the "international investigation of the sea". Its main functions are to encourage study of the sea and to co-ordinate to this end the operations of co-operating governments. It has since served as the inspiration, and to some extent the model, for nearly all co-operative approaches to international oceanographic and fisheries studies. It has helped to lay the basis for the new sciences of hydrography and fisheries. It has survived two world wars. In 1952 it held its fiftieth anniversary meeting in Stockholm, and its jubilee report provides an impressive account of its accomplishment over the preceding twenty-five years.

Functionally, the Council is divided into committees on special topics and on certain areas to carry out its co-operatively planned research. The subject committees, such as the Salmon and Trout Committee, the Statistical Committee, the Plankton Committee, the Hydrographical Committee and, until recently, the Whaling Committee, give special study to the problems indicated by their names. The area committees, such as those for the Baltic area, the transition area, the north-eastern area, the north-western area and the southern North Sea area, deal with common problems in the area designated by the countries most interested. The Council collects and collates fishery statistics and hydrographic information and publishes the results of investigations.

The Council employs a general secretary and a small scientific and clerical staff, who co-ordinate research and organize annual meetings. The Council's operations are supported by modest contributions from member governments.

The Council has played an important role in shaping the various fishery conventions that have been negotiated for the north-eastern Atlantic area. These conventions, without exception, have been developed to put into effect the Council's recommendations respecting certain fisheries or stocks of fish. Furthermore, since it provided facilities for co-ordinating the research work of all interested nations in the area, subsequent conventions provided only for putting the Council's recommendations into effect. They did not provide for separate co-ordination of research or for special research on the problems they covered. This is one of the primary differences between the international conservation organizations developed in this area and those in the North Pacific,

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[2] Formal title; in English translation, the International Council for Exploration of the Sea. The Council is generally referred to as ICES, from the first letters of its English title.

General isheries Council for the Mediterranean

Patterned largely on the Indo-Pacific Fisheries Council, the General Fisheries Council for the Mediterranean was organized at a meeting called by FAO in Rome in September 1949, where an agreement was drawn up similar to the one concluded at Baguio. The inaugural meeting was held at Rhodes, Greece, in July 1952.

Five technical committees have been established; they are concerned with exploration, production, utilization, fresh water fisheries, and research and statistics. This arrangement provides for wider terms of reference than those of the original Mediterranean council, which had ceased to function at the beginning of the Second World War and which this Council was designed to replace.

At the time of the 1954 meeting, eleven Governments - Egypt, Greece, France, Israel, Italy, Monaco, Spain, Tunisia, Turkey, the United Kingdom and Yugoslavia - were full members, participating in the meetings by sending technical delegates.

The Council maintains headquarters in Rome; the secretariat and limited support in publication are supplied by FAO. The secretary of the Council organizes the annual meetings and serves as editor of the proceedings.

The Fisheries Conventions

Fur seals

The fur seal herds of the North Pacific area have their principal rookeries on three island groups, the Pribilof Islands (United States) in the Bering Sea, which are inhabited by the largest herd, the Commander, or Komandorskie, Islands (USSR) off Kamchatka and Robben Island off the southern tip of Sakhalin Island, which was Japanese in 1911.

Intensive pelagic sealing had so reduced the number of seals in these herds that by 1911 Great Britian (for Canada), the United States, Japan and Russia signed a convention providing for protection of the seals. Each country undertook enforcement of this agreement with respect to its owns nationals.

All parties to the convention agreed to prohibit pelagic sealing. In return, the United States undertook to manage the Pribilof seal herd and pay Canada and Japan 15 per cent apiece of the sale price of the skins as their shares of the harvest. Russia undertook to manage the Commander Islands herd and pay Canada and Japan each 15 per cent of the harvest under somewhat the same arrangements, and Japan undertook to manage the Robben Island herd and pay Canada and Russia each 10 per cent of the Robben Island harvest of seal skins.

Within a relatively short time, the beneficial effect of the prohibition of unrestricted pelagic killing became manifest. The downward trend in the seal population was reversed; by 1916 it had nearly doubled, and by 1930 the Pribilof herd had increased to approximately 1.5 million.

There was no provision in the fur seal convention for joint or co-ordinated research on the seal populations or on the effect of the seals on other marine organisms. Little research was done on these problems, even by countries directly concerned with managing the herds.

Operations under the convention were successful until October 1940, when the Japanese Government notified the other signatories of its intention to terminate the convention one year thereafter. It was the Japanese opinion that the fur seals of the North Pacific had become so numerous that the objectives of the convention had been achieved, and that direct and indirect damage inflicted by seals on the fishing industry of Japan was proving more and more serious. In view of the lack of conclusive evidence as to the size of the herd and its effect on commercial fisheries, no agreement on this matter was reached, and the convention was terminated on 23 October 1941.

Protection of fur seals in the eastern and northern Pacific was continued by agreement between Canada and the United States. The Union of Soviet Socialist Republics has not engaged in pelagic sealing on its own account, and Japan, by agreement following the treaty of peace, has refrained from this activity. The four countries party to the 1911 agreement have indicated an interest in negotiating a new fur seal convention, and in recent years research leading to a more precise knowledge of the Pribilof seal population and the effects of the seals on other valuable marine resources has been undertaken both internationally and nationally.

Pacific halibut

The convention for the preservation of the halibut fishery, negotiated between Canada and the United States in 1923, marks the first successful attempt at formal international co-operation in combined research and regulation of a high seas fishery.

Following a heavy increase in halibut fishing after the First World War, yields from some areas began to decline, until by the early nineteen twenties fishing on the older banks was no longer profitable. It was to study the reasons for this rapid decline in halibut stocks that Canada and the United States in 1923 signed a convention to study halibut stocks jointly, with a view to recommending measures to halt the decline.

As first negotiated, the convention provided for an international commission empowered only to conduct research. The results of the research, after a few years, were so convincing that the convention was revised in 1930 to give the Commission authority to regulate the fishery. The Commission has its own research staff and makes use of an advisory committee which it appoints; this includes representatives of the halibut industry and other interested groups in both countries.

The International Pacific Halibut Commission3/ consists of three members from each of the two countries (originally two from each country), appointed by the Governor General of Canada and the President of the United States. The commissioners serve without compensation. One commissioner for each country is usually a senior federal government officer; the other two are public

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3/ The name was changed from International Fisheries Commission in 1953.

members who are well informed concerning the needs of the local industry and are willing to undertake the necessary study and to devote the time required to carry out their responsibilities effectively. All decisions of the Commission are made by a concurring vote of at least two of the commissioners of each contracting party. Almost without exception, decisions and recommendations have been unanimous. The cost of operating the Commission is borne equally by the participating countries, and the amount of money required is recommended by the Commission and voted by the governing bodies of both countries.

Following the inauguration of the management programme of the Commission, the decline in halibut stocks was halted, and there has been a general increase in productivity, from an annual average catch of 45 million pounds in the early nineteen thirties to 70 million pounds in 1954. About 75 per cent of the world supply of halibut is produced from stocks managed by the Commission.

The convention for the preservation of the halibut fishery of the northern Pacific Ocean and the Bering Sea has been kept flexible deliberately. It has been revised from time to time to permit the most effective operation under changing conditions and responsibilities. After nearly thirty years of successful operation, the Commission has come to be considered an almost permanent organization, with both participating governments pointing with justifiable pride to its marked success in carrying out an important international responsibility.

Baltic area

Increasing knowledge of the effect of the fishery on the flatfish of the Baltic led to the negotiation of a convention for the Baltic in 1929. This convention included Danzig, Denmark, Germany, Poland and Sweden. It covered plaice, *Pleuronectes platessa* and flounders, *Platichthys flesus*. It provided for minimum fish sizes for each of three areas, determined by differences in the rate of growth of the fish. Enforcement was carried out by each contracting party with respect to its own nationals. This convention remained in operation until the Second World War.

Plaice and dab in the Skagerrak, Kattegat and Sound fisheries

A convention for this area, signed in 1937 by Denmark, Norway and Sweden, provided nimimum fish sizes for plaice, Pleuronectes platessa, and dab, Limanda limanda.

Sockeye salmon

A fisheries convention negotiated between Canada and the United States deals with one species of salmon (sockeye) originating in the Fraser River system, which lies wholly in Canada. However, the adult salmon on their way to the river to spawn pass through United States and Canadian waters successively and are subjected to intensive fishing by the nationals of the two countries in their respective waters. The occasion for the negotiation of the convention was a sharp reduction in the runs of sockeye salmon to the river system, following landslides which partially blocked the river, and overfishing.

The convention, signed in 1937, provided for setting up a commission which would be given powers to regulate sockeye salmon fishing after a period of research covering two cycles of the salmon run, or eight years. The International Pacific Salmon Fisheries Commission is composed of three Canadian and three United States commissioners appointed in the same way as are the members of the International Pacific Halibut Commission. The convention itself in this case provides for appointment from each country of an advisory committee from the salmon industry and other interested groups. These advisers may attend all non-executive meetings of the Commission. The convention also provides for an independent international research staff under a Director of Investigations, all under the Commission's general supervision. The costs of the Commission are divided equally between the two governments, and the convention requires that the regulatory system provide an equal division of the catch.

After a number of years of research the Commission began construction of a fishway at Hell's Gate, and later at other places, to facilitate the salmon's ascent to their spawning grounds in the river. The Commission undertook regulation of the salmon fishery after the eight years of preliminary research called for by the convention.

The Commission's work is showing practical results in the rapidly increasing runs of sockeye salmon. Through the continued operation of the Commission it is expected that sockeye salmon runs, worth many millions of dollars annually, will be restored and maintained at maximum productivity. During the peak years of the fishery, the catch averaged 20 million fish annually. This was subsequently reduced by obstructions and overfishing to about 2 million fish. Under guidance of the Commission, the run of sockeye salmon was restored to 10 million fish in 1954, and it is anticipated that under continued sound research and management the fish runs can be built up to their original level.

The salmon convention and the halibut convention, mentioned above, are the oldest international conventions that have included both fact-finding and conservation management measures necessary to achieve conservative objectives. They are the only conventions that have been operating for a sufficient number of years to demonstrate effectively the possibilities of international co-operation in rehabilitating and maintaining the productivity of international fisheries.

Whaling

Modern whaling was ushered in with the introduction of the floating factory ship. Experiment with the first ship of this type took place near the Falkland Islands in 1906, and by 1938 there were forty-four large mechanized factory ships operating in the oceans of the world, principally in the Antarctic.

The heavy strain of competitive and unrestricted whale hunting during the decade from 1921 to 1931 reduced the number of whales so precipitously that by 1932 some whaling companies, individually and by agreement with others, undertook to limit their catches voluntarily. Though this provided some relief, other operators would not agree to curb their killing, and the total effect on the stock was not sufficient to halt the decrease.

Aside from a conference in Paris in 1927, joint efforts at conservation of the resource prior to 1931 were limited to relatively ineffective informal agreements between whaling companies and the enactment of whaling regulations by individual governments. In 1931, representatives of twenty-one governments met in Geneva and concluded a convention for the regulation of whaling. This convention was succeeded by another agreement, concluded in 1937 and signed by nine of the signatories to the 1931 agreement. The 1937 agreement was amended in 1938, 1944 and 1945.

Effective whaling was discontinued during the Second World War, but was resumed almost immediately after the cessation of hostilities in Europe. Nine factory ships operated in the Antarctic during the 1945/46 whaling season.

With the long history of ineffectual management of the world's whale resources as an object lesson, a conference was called at Washington, D.C., in November 1946 to discuss the organization of an effective international body before whale hunting should again get out of control with the resumption of antarctic whaling after the war. At this meeting a convention was negotiated and signed, the necessary ratifications were completed and it came into force two years later. The inaugural meeting of the International Whaling Commission was held in London from 30 May to 6 June 1949. Meetings have been held annually since then at various capitals of the world. Seventeen countries - Australia, Brazil, Canada, Denmark, France, Iceland, Japan, Mexico, the Netherlands, New Zealand, Norway, Panama, Sweden, the Union of South Africa, the Union of Soviet Socialist Republics, the United Kingdom and the United States - now adhere to the convention.

This convention for the first time established a commission empowered to fix hunting seasons, restrict whale hunting areas, limit the number of whales which can be caught each season, set size limits, prohibit the catching of scarce species, prohibit waste in processing, supervise and control operations and enforce regulations. The Commission recommends research, reviews and evaluates scientific findings, and may recommend restrictive measures on the basis of these findings.

The Commission employs a part-time secretary-general who arranges for annual meetings and prepares reports on the meetings and recommendations. Each participating government has one commissioner and one vote. Under the auspices of the Commission, catch statistics are collected and analysed by the International Bureau for Whaling Statistics, an organ of the Norwegian Government, and a considerable amount of research is carried on by member governments. The Commission has no scientific staff of its own. Whale research is very expensive; only a modest amount is performed by the scientists of a few whaling countries, and much of this is dependent on the goodwill of the whaling companies.

Contracting governments must indicate their assent in writing to amendments to the whaling schedule or changes in whaling regulations before they become binding on the government concerned.

Tropical tuna

The convention between Costa Rica and the United States for the establishment of an Inter-American Tropical Tuna Commission was negotiated in 1949, and the inaugural meeting was held in July 1950. The convention deals with yellowfin and skipjack, the principal tunas found in the tropical eastern Pacific, and associated bait fisheries. Its principal objectives are to gather, analyse and interpret relevant information concerning the fishes covered by the convention and to recommend to the contracting parties the conservation measures necessary for maintaining the population of fishes at a level which would permit maximum utilization year after year.

Provision was made in the convention for any interested government not signatory to the original convention to adhere by making application to the depository government and by assuming its proper proportion of responsibilities. In accordance with this provision, Panama joined in 1954.

The convention provides for setting up a commission, and for the appointment of commissioners (up to four) by each participating government. The Inter-American Tropical Tuna Commission employs its own staff, which operates under a director of investigations. Funds to operate the Commission are voted by governments on the recommendation of the Commission, with the costs divided according to their catch from the fish stocks covered by the convention.

The Commission has already made notable progress in assessing the size and distribution of fish stocks and the effect of fishing on both the tunas and the bait fishes employed to catch tunas.

North-west Atlantic fisheries

The bank fisheries of the north-west Atlantic Ocean contiguous to the coast of North America are among the oldest and most productive in the Western Hemisphere and are fished by many European and North American countries. The effects of the great increase in fishing effort in the decades following the turn of the century began to show on some species of fish. Although no crisis was imminent in the north-western Atlantic, there was general recognition that overfishing was a growing possibility. This concern, coupled with the much more critical need for international conservation measures in the North Sea area, prompted the convening of international conferences in London in 1937, 1943 and 1946. These conferences dealt with the whole of the North Atlantic, though the problems on either side of the ocean were different. None of the provisional agreements arrived at was accepted by all governments.

In 1949 a conference was convened in Washington to consider the north-west Atlantic fishing area separately. This conference negotiated the International Convention for the Northwest Atlantic Fisheries, which was signed in 1949 and which entered into force in July 1950 on formal adherence by the fourth government. The inaugural meeting was held in Washington in April 1951.

The convention provides for setting up a commission through the appointment of not more than three commissioners by each contracting government. The International Commission for the Northwest Atlantic Fisheries has a full-time executive secretary with a small staff which collates the scientific programmes of the panels and services the meetings of the Commission and its committees. The operations of the Commission are financed by the payment 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.

The principal features of the convention are the following: The extensive waters under the convention are divided into sub-areas, roughly along the lines of separate biological stocks so far as these are known. A separate panel is established for each sub-area, each panel including the governments whose nationals are actively fishing in the sub-area or whose shores are contiguous to it. Each panel is responsible for co-ordinating research and recommending conservation measures for its sub-area. The Commission co-ordinates the work of the panels and receives their recommendations for appropriate action concerning research programmes or regulatory measures.

The Commission is responsible for programming research, and collecting and disseminating information necessary for maintaining the productivity of stocks of fish which support international fisheries. Research work generally is done by member governments, not by its own staff of scientists, as is the case with the halibut, salmon and tuna commissions. Provision is made, however, for the Commission itself to carry out needed research when it is not feasible to have it done by separate governments and for the Commission to employ such personnel as it requires for this purpose. Neither the Commission nor any special panel has authority to take direct regulatory action. Normally, recommendations for conservation measures originate with the panels. The Commission reviews the recommendations and, if they are approved, recommends them to member governments for joint action. If the Commission's recommendations are accepted by the governments which are members of the panel covering the sub-area to which the recommendations apply, the regulations then become binding on all contracting governments when their nationals fish in these sub-areas.

Provision is made for non-signatory governments whose nationals participate in the fishery to adhere to the convention. Such governments become members when their applications to the depository government are agreed to by member governments.

In spite of its short life the Commission has made encouraging progress. Regulation of mesh sizes has been recommended and adopted for one sub-area. Striking benefits to the haddock fishery are already evident. Recommendations by other panels for other sub-areas are under active study.

North Sea fisheries

In the nineteen thirties the intensification of fishing in the North Sea and the decreasing catch, particularly of the more desirable species, stimulated efforts to reach agreement on conservation measures. A convention to control mesh measurements and the sizes of fish taken was negotiated and signed in 1937 by ten North Sea countries. For various reasons this convention never was ratified by all the governments.

After the Second World War, in view of the graphic example of the effects of reduced fishing intensity, a new fishery convention, the Convention for the Regulation of the Meshes of Fishing Nets and the Size Limits of Fish, was negotiated and signed by twelve countries in 1946; it became effective in 1954. Present membership includes Belgium, Denmark, Western Germany, France, Iceland, Ireland, the Netherlands, Norway, Poland, Portugal, Spain, Sweden and the United Kingdom.

This convention provides for minimum sizes of trawl mesh in fishing for bottom fish and minimum lengths for the twelve principal species of bottom fish. Each government undertakes to employ appropriate measures to ensure application of the provisions of the convention to its own vessels. The convention provides for a permanent commission made up of one or two representatives from each government (with only one vote for each delegation), to meet at least once each three years, with the duty of considering whether the provisions of the convention should be extended or altered. The Commission, where practicable, is to consult with the International Council for the Exploration of the Sea[4/] on this matter. The contracting governments agree to give effect to any recommendations to extend or alter the convention which are unanimously approved by governments represented at a meeting of the Commission and by all contracting governments not represented at the meeting. The convention has a minimum life of three years and may be acceded to by any government upon notification to the depository government.

This convention differs from most of the others in that it provides for no special research or research co-ordinating body, and it specifies certain conservation measures. The duty of the Commission is to consider extensions or alterations of the provisions of the convention after consultations with ICES. The latter organization serves as the scientific fact-finding agency of the Commission. Liaison is provided through a Liaison Committee made up of the five chairmen of ICES committees which deal with areas and species of concern to the Commission. This has provided an effective procedure for utlization of the services of ICES. Perhaps its chief limitation arises from the time required to transmit requests and problems to ICES and receive the latter's recommendations or comments in reply.

[4/] See section on research councils, above.

North Pacific fisheries

The International Convention for the High Seas Fisheries of the North Pacific Ocean is the most recent international fishery convention for the high seas; the inaugural meeting was held in January 1954, and the convention has been in operation over a year. The convention area includes all waters, except the territorial waters, of the North Pacific and its adjacent seas. The three signatory governments, Canada, Japan and the United States, undertake to handle under this convention all their mutual fishery problems in the area, whether bilateral or trilateral, except for those covered by existing conventions. The convention covers all stocks of fish under substantial exploitation by two or more of the contracting parties; decisions and recommendations concerning regulation of fishing on such stocks are confined to the contracting countries engaged in their exploitation on a substantial scale.

The convention recognizes that the continued productivity of some North Pacific resources is the direct result of the long continued conservation efforts of certain contiguous countries. These efforts include research and management involving expenditure of extensive time, effort and money, as well as restraints and sacrifices on the part of the fishermen. Without such efforts these fisheries would not continue as productive resources. The convention therefore provides that where it can be demonstrated that a stock of fish is being fully utilized by one or more of the contracting parties and where the fishery in question is under scientific management and regulation, the principle of abstention should be applied. Contracting parties which have not historically fished these stocks agree not to engage in fishing the stocks, and the contracting parties fishing them agree to continue to carry out necessary conservation measures. Fishing in the same area for other stocks of fish is not affected.

To facilitate the administration of these abstention principles so far as salmon fisheries are concerned, a provisional line was adopted on the basis of the best information available; it is designed to separate areas containing salmon of North American origin from areas in which salmon of Asian origin are found. Provision is made in the protocol of the convention to initiate investigations "as expeditiously as practicable" for the purpose of either confirming or improving this provisional line. Because of the importance of the line, with respect to abstention, the convention also provides, in the event that unanimous agreement cannot be reached in a reasonable time on the location of the line, for the appointment of a committee of three competent scientists, not nationals of the contracting parties, by mutual agreement of all parties. Majority decision by this committtee would determine the recommendations to be made by the International North Pacific Fisheries Commission, established under the convention.

The convention provides for action by the authorized officers of any contracting party when a person or fishing vessel of any party is engaged in operations in violation of the provisions of the convention or where there is reasonable ground to believe it was so engaged immediately prior to boarding by the officer. Under these conditions the officer may arrest or seize the person or vessel and deliver such person or vessel as promptly as practicable to the authorized officials of the contracting party to which the person or vessel belongs, at a place to be agreed upon by both parties. To ensure the satisfactory operation of the enforcement provisions of the convention, it provides that in the sixth year of its operation the contracting parties shall meet to review the effectiveness of the enforcement provisions and to consider means by which they might more effectively be carried out.

The Commission provided for in the convention consists of not more than four commissioners to be appointed by each contracting government. Research, though planned and reviewed co-operatively, is generally to be carried out by the contracting governments. However, when this is not feasible, the Commission may employ its own staff to perform such research.

The convention authorizes the appointment of advisory committees from the fishing industry and other interested groups in each country and provides that the members may attend all except closed meetings of the Commission.

The Commission maintains an executive director with a small scientific and clerical staff. The present duties of the staff are to help plan and co-ordinate research carried out by the agencies of the contracting parties and to organize and service the annual meetings and the meetings of the committees.

South Pacific fisheries

Latin American countries have in recent years shown keen interest in the fishery resources off their shores. One manifestation of this interest was the organization in August 1952 of the Permanent Commission for the Exploitation and Conservation of the Maritime Resources of the South Pacific, by the Governments of Chile, Ecuador and Peru. The inaugural meeting took place in December 1954. The objectives of the Commission are "to secure a better exploitation and conservation of the maritime resources of the South Pacific".

Three committees, or sub-commissions, have been established to achieve these objectives; these deal with treaties, diplomatic matters and technical subjects. The Commission has very wide terms of reference but, aside from the promulgation of regulations to control whaling, no technical or conservation programme has been announced.

Definitions

For the purpose of this paper the following terms have been used with the meanings indicated:

Population or stocks of fish. A collection of individual fish of the same species forming a homogeneous group living in a continuous environment, capable of separate identification, which responds as a unit to fishing or other causes of changes in population density. Such populations, or aggregates of populations, constitute the units of the resource, dealt with in conservation management.

Fishery resource. A population or group of populations of any species of marine organism which is or may be exploited by man.

Exploitation. The use of a resource by man; utilization.

Fishery management. Vigilant overseeing of resource exploitation. It includes the application of conservation measures and procedures, and the research required to develop them.

Conservation. Control of man's fishing activities in such a way as to produce the maximum sustainable yield of fishery products in the form most useful to man.

Conservation measures. These include such technical devices as limitations on catching effort, limitations on total catch, gear restrictions and closed areas, as distinct from "procedures", which relate to ways of applying and administering such devices.

REGULATION OF NORTH SEA FISHERIES UNDER THE CONVENTION OF 1946

by

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(The mimeographed text of this paper appeared as A/CONF.10/L.5 under the title "International Fisheries Convention, 1946")

Contents

North Sea Fishery Conditions Prior to 1946

The North Sea overfishing problem is one of the oldest and the best-known. The symptoms took the form of (1) diminishing average size of important commercial fish; (2) diminishing catch per unit of fishing (per trawler/ton/day, for example); and (3) diminishing total yield. As is usual, the first two were noticed ahead of the third and indeed they long preceded it, for these are the first effects of fishing. From the moment a virgin stock is fished, the average length of life of its members begins to fall, and the average catch per haul tends to diminish. Although these signs are not of themselves reliable signs of biological overfishing,1/ they were causing considerable concern even before 1900. As the industry developed, there was increasing concern by 1913 for several species. For all that, these changes, which most directly affect the fishermen themselves, and the profit for their work, were at first fairly easily countered by fishing new grounds outside the North Sea and by improving boats and gear, but this was not the case with the third symptom - decreasing total yields - which was felt by all.

The First World War gave a substantial respite from 1914 to 1918 to most of the North Sea fisheries, and fishermen in 1919 again found large prime fish and a profitable catch per fishing unit. Total yield was also up, and the industry exploited the grounds to the utmost, with the result that average sizes and catch per unit had diminished remarkably by 1922; a decrease in the total yield of haddock, plaice and hake and other fish followed. The introduction of the more efficient VD trawl gear in 1925, which no progressive trawl skipper could ignore, served initially to increase the catch per unit effort, but, after initial profit, the three important criteria fell even further. The depressing years of the nineteen thirties, when North Sea fishermen worked hard and dangerously for poor returns, were the inevitable consequence.

All concerned knew that some solution must be found, but agreement about its nature was difficult to reach and seeking for the right answer was a slow process. Various solutions were proposed from restriction of fishing by area or season to direct limitation of the catch, but regulation of minimum landing sizes of fish and of mesh size were those most favoured, representing as it were the lowest common factor of agreement. The emphasis was on raising the average size of fish in the population by enabling small, unmarketable fish to escape and grow more

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1/ "The productiveness of a fish stock depends on the effort used to exploit it, the productiveness first increasing and then decreasing as the effort increases" (M. Graham, "The Sigmoid Curve and the Overfishing Problem" in Rapports et Procès-Verbaux des Réunions of the Conseil Permanent International pour L'Exploration de la Mer, vol. 110, Copenhagen, 1939).

"The detection of biological overfishing from the statistics of a commercial fishery is possible when, over a period of years during which there has been a steady growth of exploitation, the yield is observed to decrease steadily after an initial rise"(B.B. Parrish and R. Jones, "Haddock Bionomics: 1. The State of the Haddock Stocks in the North Sea, 1946-1950 and at Faroe, 1914-1950" in Marine Research, 1952, No. 4 of the Scottish Home Department HMSO, Edinburgh, 1953).

before they were caught again. Fisheries' scientists and administrators had rightly convinced their governments that small fish could be saved to grow larger by increasing the size of the mesh, and that it would profit the fisheries to do this. The United Kingdom introduced minimum mesh and size regulations in 1933 and, following unanimous recommendation from the International Council for the Exploration of the Sea (Conseil Permanent International pour l'Exploration de la Mer) in 1934, all the countries concerned resolved in 1937 to introduce similar regulations. But war broke out again, and no more could be done until representatives of the countries were able to meet again in 1946.

The rest afforded the North Sea fisheries by the Second World War provided, if such were needed, a second gigantic demonstration of the effects of reducing the fishing effort in a complex fishery, with results very similar to those following the First World War. Average sizes and catch per unit were well up again in 1945, and, in relation to the reduced fishing effort, so was the yield. Indeed, a special survey by the Council demonstrated an increase of stock density, up to threefold and more, in most of the North Sea fisheries, as a result mainly of reduced fishing mortality. But all too soon these diminished again as the renewed fishing effort made itself felt.

Major Provisions of 1946 Convention

In 1946 the fisheries' administrators and scientists of European nations drew up an International Convention for the Regulation of the Meshes of Fishing Nets and the Size Limits of Fish. This prescribed minimum sizes of fish and trawl meshes for two great areas: that of the distant fisheries, from the Barents Sea to Greenland, and that of the nearer and middle water fisheries, covering most of the remaining area of the Atlantic north of latitude 48° north and east of longitude 42° west. Essential features for the North Sea are as follows:

Article 5

> "No vessel shall carry on board or use any trawl, seine, or other net towed or hauled at or near the bottom of the sea, which has in any part of the net meshes of less dimensions than those specified in the first annex to this Convention."

Article 6

"Notwithstanding the provisions of article 5, vessels fishing for mackerel, clupeoid fishes, smelts, eels, great weevers (*Trachinus draco*), shrimps, prawns, nephrops or molluscs, may carry on board and use nets having meshes of dimensions less than those so specified: provided that (a) any fishing instruments used by such vessels for the capture of any of the fish described in this article shall not be used for the purpose of capturing other kinds of fish; and (b) any fish of the descriptions set out in the second annex to this Convention which may be captured by such instruments and are of less than the minimum sizes prescribed therein shall be returned to the sea immediately after capture."

Article 7

"(1) No vessel while operating shall use any device by means of which the mesh in any part of a fishing net to which article 5 of this Convention applies is obstructed or otherwise in effect diminished.

"(2) Notwithstanding the provisions of the foregoing paragraph, it shall not be deemed to be unlawful to attach to the underside of the cod-end of a trawl net any canvas, netting, or other material, for the purpose of preventing or reducing wear and tear."

Article 8

"No vessel shall retain on board any sea fish of the descriptions set out in the second annex to this Convention, of a less size than the size prescribed therein for each fish, and all such fish shall be returned immediately to the sea; provided that they may be retained on board for the purpose of transplantation to other fishing grounds."

Article 9

"Each Contracting Government undertakes to prohibit by regulations the landing, sale, exposure or offer for sale, in its territories, of any sea fish of the descriptions set out in the second annex to this Convention which are of a less size than the size prescribed therein for each fish and have been caught in the waters defined in article 1 of this Convention, whether such fish are whole or have had their heads or any other part removed."

Article 10

"The provisions of this Convention shall not apply to fishing operations conducted for the purposes of scientific investigation, or to fish taken in the course of such operations, but fish so taken shall not be sold, or exposed or offered for sale in contravention of the provisions of article 9."

Article 11

"The Contracting Governments agree to take, in their territories and in regard to their vessels, to which this Convention applies, appropriate measures to ensure the application of the provisions of this Convention and the punishment of infractions of the said provisions."

Annex I

"(1) In all waters covered by the Convention, as defined in article 1 and article 4, except as provided in paragraph (2) below, the minimum size of mesh for nets referred to in article 5 shall be such that when the mesh is stretched diagonally lengthwise of the net a flat gauge 80 mm. broad and 2 mm. thick shall pass through it easily when the net is wet."

Annex II

"The fish to which articles 6, 8 and 9 of this Convention apply and the sizes below which such fish may not be retained on board, landed, or sold and exposed or offered for sale are as follows:

Fish	Size limit for whole fish measured from tip of snout to extreme end of tail fin (Centimetres)
Cod (<u>Gadus callarias</u>)	30
Haddock (<u>Gadus aeglefinus</u>)	27
Hake (<u>Merluccius merluccius</u>)	30
Plaice (<u>Pleuronectes platessa</u>)	25
Witches (<u>Glyptocephalus cynoglossus</u>)	28
Lemon soles (<u>Microstomus kitt</u>)	25
Soles (<u>Solea solea</u>)	24
Turbot (<u>Scophthalmus maximus</u>)	30
Brill (<u>Scophthalmus rhombus</u>)	30
Megrims (<u>Lepidorhombus whiff</u>)	25
Whitings (<u>Gadus merlangus</u>)	20
Dabs (<u>Pleuronectes limanda</u>)	20 "

Particularly in the North Sea area, the prescribed measures were necessarily less stringent than some countries would have desired, and the convention did not include certain measures that some felt were already necessary. There was, however, a sense of urgency and common endeavour, which might have secured speedily a vital measure of conservation. It remained merely for the convention to be ratified, but ratification was not completed until 1953, and the convention was not made effective until 1954, when the fisheries had again become severely overfished.

Application of Provisions and Review of their Effects

It is necessary to see first just what benefits were to be expected from this international agreement, and, to understand them clearly, a word or two about the fishery is necessary. The essential feature is the mixed nature of the North Sea fishery. Most of the commercial fish communities are made up of more than one species; all may be edible, but in many parts of the world there is a market only for one or two members of the community. They may be sufficiently different in size or habit to require capture mainly by different methods. It is a reflection of its long history that the North Sea fishery has to meet a very wide demand.[2] Human tastes thus make conservation difficult, and no foreseeable regulation can benefit all stocks equally even if there were no ecological reactions between them. For this reason, mesh regulations can meet only the major demand, while some size limits may in the end be governed by the market for a specific size, and not necessarily match the selection value of the regulation mesh.

The estimated benefits to be derived from the regulations were that, if the fishing effort were not increased, in the course of a few years the yield of haddock might be expected to attain 15 per cent more than it would have in the absence of international regulation and that of hake about 10 per cent, with the yield of cod 5 per cent more. Since the minimum size of mesh then prescribed necessarily had the roundfish chiefly in view, only a very small benefit could be anticipated for the valuable plaice fishery - perhaps 3 per cent - for it could be effectively conserved in this manner only by much larger minimal meshes. The sole, however, should benefit more than the plaice. Clearly, the chief result would be an improvement in the important haddock fishery, although it is an essential that the over-all fishing intensity should not be increased. But the mere fact that the countries had reached an agreement was of tremendous value, and it could only be hoped that on this foundation more thorough-going conservation could be built.

2/ The Bulletin Statistique of the International Council for the Exploration of the Sea records catches of more than a score of demersal species, of which twelve are of sufficient importance to be scheduled in the convention.

These estimated benefits arise directly from the escape of young fish through the wider meshes so that they may grow to a more valuable size before they are caught again. The minimum size limits of the fish themselves have no value in conservation - all the roundfish rejected as being undersized would be dead before they could be thrown back into the sea. But in so far as these sizes were closely related to the effective mesh selection, they were valuable in ensuring that the regulations were being observed. If the chosen minimum fish size is correct, then it will not be profitable to use an illegal mesh in order to catch illegal sizes in substantial numbers, for they are liable to be confiscated on landing, with the possibility of prosecution.

One very practical problem arises from the need to convince fishermen that the regulations are reasonable; many fishermen were until recently convinced that the strain undergone by the net while trawling - particularly with a large catch of fish - would effectively lengthen and thus close the meshes so that small fish could not escape. Ingenious experiments as long ago as 1932 demonstrated clearly to scientists that this was not the case, but it was not until under-water films obtained by scientists a year or two ago showed clearly that the meshes remain open and that fish escape, in good condition, that the majority of fishermen were convinced. Two films "The Trawl in Action" and "Fish and the Seine Net" have provided valuable publicity on both sides of the Atlantic and are being shown around the world.

Despite these benefits, however, it was expected that some losses might occur, particularly for certain types of fishermen, during the first two or three years after the regulations were introduced because of the inevitable loss of the smaller fish; this would particularly apply to the whiting, for example. For most, the loss was not expected to be heavy, and it was regarded as an investment for the benefits to come. But there was also an indication from research in the North Sea that even this loss might prove much less than was feared, because the larger meshes might be expected to increase the flow of water through the net and so increase its efficiency in the capture of larger fish. It is too early yet to be certain that this will be so in the North Sea, but there is already good evidence from elsewhere, particularly on the other side of the Atlantic where another haddock regulation has been introduced. This has resulted, even during the first year or two, in heavier catches of the larger fish being caught by the large-meshed nets of the "regulation" fleet than are being caught by a few commercial vessels selected to fish experimentally with the smaller "pre-regulation" meshes. So much is this the case that it is said to be difficult now to persuade the selected boats to use the original - smaller - meshes for experimental purposes; their skippers have decided that the larger mesh pays!

Quite apart from the third progressive overfishing of the North Sea stocks, during the interval between 1946 and 1954, other things had been happening. It was becoming increasingly obvious that mesh and size regulations alone could not completely prevent the overfishing and that, while even greater benefits could be sought by agreeing on larger minimum meshes, this course would prove particularly difficult for those countries which had traditionally fished for the smaller marketable fish, with smaller boats and gear, often along the coasts. This became even clearer at a second post-war fishing conference in 1947. A further control was urgently needed because of two facts: (1) mesh regulation would only be valuable if the fishing effort were not increased under the combined attraction of more and larger fish on the grounds and (2) the most profit would in any event only be obtained if the fishing effort were adjusted to take just as "much as the stock could reproduce by new growth". Petersen had realized this as early as 1894 and Baranov in 1918. Russell in 1931, Thompson and Bell in 1934 and Graham in 1935 followed, along rather different lines, but it remained for Hulme, Beverton and Holt, after the war, to formulate the relationship in modern mathematical terms, with the benefit of a much longer series of fishery statistics than their predecessors had. Valuable accounts of the development of the theory are given by Graham (1952)[3/] in the jubilee volume of the Council,[4/] and of the elements of the modern theory by Beverton (1953).

The primary fact is that it is now possible to calculate the maximum yield which a fishery can be expected to sustain, theoretically, over a term of years in which the essential variables remain constant or average out. Long series of

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[3/] For the references in this paragraph, and others, see the bibliography at the end of this paper.

[4/] Conseil Permanent International pour l'Exploration de la Mer, <u>Rapports et Procès-Verbaux des Réunions</u>.

statistics are helpful; only for a few fisheries can this be measured at present with any precision. For the North Sea this "maximum sustainable yield" would be much higher than that now taken of several individual species of commercial value. It may in some circumstances be only a theoretical maximum, or one to be attained only at an inordinate cost. "Thus the presence of a maximum in a curve of yield as a function of fishing intensity with the mesh size held constant is not a general feature, but depends on the size of mesh in question" (Beverton 1953, page 62). For all that, "there exists a wide range of combination of fishing intensities and mesh sizes which could have produced a greater yield"5/ than the pre-war or present fishing intensity in the North Sea, so that it is possible to get much nearer to the ideal than is now the case, under the present regulations.

The best or optimum yield for any one species can only be gauged by a mixture of biology and economics. To secure it consistently, either the minimum mesh would need to be much bigger (with considerable losses of some smaller fish such as whiting), and the total effort controlled at its present level, or the present (or perhaps a slightly larger) mesh might be retained with a considerably decreased effort. What is needed, in fact, is the most economical combination of both. One important corollary is that this concept "can also be applied to a fishery based on two or more species of fish of commercial importance which are caught simultaneously by the same gear, as is the case in the North Sea. Thus for any given fishing intensity there is a mesh size which enables the greatest combined yield to be obtained, although this combination of fishing intensity and mesh size might not be eumetric6/ for any one of those species alone" (Beverton 1953, page 65).

At its simplest, the fishing effort could be evenly spread over the whole year, or a greater effort concentrated - by a competitive scramble - into a few months, with an identical yield. We are seeing the latter happen in the Pacific halibut fishery, and in the whale fishery the agreed yield is probably not being

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5/ Loc. cit.

6/ That is, well-balanced, "because for any fishing intensity it defines the mesh size which will enable the greatest yield to be obtained at that intensity" (Beverton, page 63).

obtained in the most economic way. By the same token, the present North Sea yield could be obtained, under the present mesh restriction, with a smaller over-all effort spread economically, at much greater profit per fishing unit. It has been estimated that, using the 80-millimetre mesh, the vessels now fishing the North Sea could, by staying in port for about one week in every two, land rather more fish of a larger size (a value increase of about 25 per cent) once the full benefit of the larger mesh was reached, in six to seven years. They would take more than twice the catch per unit effort - no small profit! This relation between the yield obtainable and the effort applied (at the appropriate minimum mesh) is one of the problems which the European nations now have to consider, and other nations will be concerned in such matters sooner or later.

When the convention was drawn up, it provided for regular sittings of a permanent commission to review the working of the convention, and this Commission has sat regularly since 1953, dealing with a number of problems. Perhaps the greatest problem was that the articles had been worded in such a manner that it was not possible to agree easily on the proper way of amending the regulations. While representatives of one group of nations felt that amendments could, in effect, include any unanimously desired regulations for improving conservation, another group felt that amendments could only concern the two types of provision already specified, that is, those on minimum mesh size and on minimum fish sizes (and, of course, areas). Clearly, the only thing to do was for all to agree on the narrower interpretation, although the representatives of most countries recognized that these two types of regulation alone could not afford anything like the maximum benefit to the North Sea fisheries. This could only be achieved by measures directed towards ensuring the maximum yield securable, at fishing rates which would be economic to all concerned. The present convention does not allow for such control either of yield or effort, but a new convention or a suitably amended one could do so, subject to safeguards.

Such decisions are not easily reached, although in simpler circumstances there are precedents for them. For example, the conventions dealing with Pacific halibut and salmon (between the United States and Canada) have prescribed and enforced catch limits. The International Commission for the Northwest Atlantic Fisheries allows for such a prescription although it has not yet been enforced.

The International Whaling Commission uses this method as its chief means of regulation to date. It may well be useful to provide in future conventions for the possible application of any measure needed to conserve the stocks and supported by scientific evidence, even if some measures could scarcely receive general agreement at the time of drafting a convention.

There lies before the fishing nations of Europe, therefore, a very important decision. Ultimately, control is concerned, but in the first place statistics are concerned, in making assessments. It is a matter of history that, for the best-known and most studied fishery in the world, it has taken approximately fifty years to introduce its first international regulation, only to find that there are still many problems to solve. What is important, however, is that it is now possible to foresee some of the dangers as well as to predict with some certainty the prospective benefits. This is only because there are now available long series of statistics, steadily improving in precision for conservation purposes, albeit still not entirely adequate. These are maintained by the various countries and collected and summarized by the International Council for the Exploration of the Sea. They have provided the basis for research in the area and in this way have perhaps helped to make prediction, and then legislation, simpler and speedier than it might have been. They now provide the means for assessing the results of predictions and regulations and the only basis for further conservation studies. One of the most important essentials for any fishery is the compilation from its origin of all those statistics (catch, date, place, effort, and so on, all to the required detail) which alone make assessment and then prediction possible.

Another problem before the Commission set up under the 1946 Convention for the Regulation of Meshes of Fishing Nets and the Size Limits of Fish concerned the trawl and the seine net. Extensive scientific investigations in several countries, which had provided the evidence for the selective effect of meshes, had mainly been done with the trawl but, not unreasonably, the convention had prescribed for all such nets. Work which only matured in 1953, however, convinced the fisheries' scientists, and in due course the Commission agreed, that the seine net was a more selective instrument than the trawl, permitting more and larger fish to escape (see, for example, Lucas, Ritchie, Parrish and

Pope, 1954). A mesh approximately 10 millimetres smaller between knots secured the same selection as the larger trawl mesh, and the regulation was altered accordingly. At the same time, in order to introduce the major regulation more gradually in those fisheries where its immediate effects would be most severe, the minimum mesh size for trawl nets was reduced from 80 millimetres to 75 millimetres for the first two years - so that the North Sea regulation at present in force provides for a minimum of 75 millimetres in the trawl and 70 millimetres in the seine. Further, the under-water films and other available evidence suggest that this problem concerns the thickness and flexibility of net twine as well, and it may yet prove that trawls of thin twine, for example, are more selective than those of thicker twine, mesh for mesh.

When the national representatives came together to discuss the actual application and enforcement of the regulations, it became clear that enforcement might well not prove so simple as it had seemed at first. The meshes, for example, were to be tested by means of a flat gauge of the prescribed size, passing easily through the meshes when wet. But how is one to ensure that the officers and the fishermen of many countries have the same idea of a "minimum of pressure" - or that nets are equally wet when tested? Good will and common sense are needed in local enforcement of the regulations, tempered with a modicum of science.

Again, not only should justice be done, but it is even better if it is seen to be done. With the best will in the world, can the fishermen of one country be sure that the regulations are being enforced as strongly elsewhere as they feel they are being applied by their own government? And what if the apparent severity of the penalties is not the same in all countries? Is an international inspection force required, with complete standardization in enforcement and penalty for offence? These are notions which necessarily conflict with national sovereignty and tradition. As the convention has only been in force for a year, it is necessary to see how it works out in practice before attempting to resolve the problems set forth in this paragraph.

Just as the convention was going into effect, attention was drawn to another type of problem. The present convention concerns demersal fish and not pelagic fish, so that the familiar herring fisheries had properly been excluded from the regulations. However, the rapidly increasing industrial fishery for small herring and sprat was the incidental means of catching the young of species which came within the scope of the convention. Now the convention prescribes minimum sizes for various fish, including whiting, so that it was an offence to land them below these sizes. Yet large numbers were being landed along with the young clupeoids. Indeed, during 1953 a quantity of undersized whiting was landed in this way which was about one-third that of the total landings of legal size whiting by all European countries! There was in fact a legal problem and a biological one. A preliminary biological assessment suggested that, if not already dangerous to the stock, the increasing size of this fishery would soon become dangerous. The regulations were therefore adjusted so that in such industrial fisheries not more than 10 per cent of undersized fish in the convention schedule could legally be landed. Attempts are also being made to avoid, for the industrial fishery, those shoals in which many whiting are mingled with the herring community.

It is important that in reaching decisions on such matters the Commission was able and willing to take its scientific advice from the International Council for the Exploration of the Sea, and a final word should be said about the relationship between these two bodies, for they are not exactly matched anywhere else in the world. Again it is a matter of history. Regulations have all too often been formulated before research but in this case they were not. Some fifty years ago the governments of Europe began to send their delegates and their fisheries' experts to meet yearly under the auspices of the Council, among other things for the very good purpose of securing "the rational exploitation of the sea". It is important to note these words. They represented an ideal fifty years ago, but a practical ideal. They do so now, and probably none serve better for that objective of economic maximum catch to which all aspire. As the scientists' investigations and their judgements matured, they were able, through the Council, to bring to the attention of the respective governments more and more precise information about the nature of some fishery problems and ways of resolving them. In this way the Council stimulated the formulation of some minor conventions and in due course the major one of 1946. But the Council still remained completely separate from the Commission, which it might be said to have evolved, whereas in most other fishery conservation schemes, research and international administration have in one way or another been closer from the start. However, the Convention specified that the Commission should "where practicable consult the International Council for the Exploration of the Sea", and the Council in due course set up a Liaison Committee composed of the chairmen of certain of its committees, to which problems from the Commission could be submitted for consideration and recommendation. This mechanism has been welcomed by the Commission and it has already been used with advantage to both organizations; it seems likely that it will continue for some time to meet the foreseeable scientific requirements of the Commission. Last, but not least, mention should be made once more of the service the Council has, long provided and will maintain in its international collection of statistics (*Bulletins Statistiques*). They have been invaluable in the past and will be even more so in the future, as they are remodelled, and their publication advanced, in order to meet the growing requirements of a conservation scheme in process of development.

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CONSERVATION PROBLEMS IN THE NORTHWESTERN ATLANTIC

by

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(The mimeographed text of this paper appeared as A/CONF.10/L.8 under the title "Conservation Problems in the Northwestern Atlantic and Related Activity of the International Commission for the Northwest Atlantic Fisheries (ICNAF)")

Contents

The problem of conservation arises in nearly all cases where an extensive fishery is carried on. When a new and more effective fishing method is introduced, the demand for conservation regulations can be especially strong, often from already established, less effective fishing industries. Too often such demands have been met too willingly by the authorities, and it might well be that more regulations have been ineffective, or even injurious, than effective and profitable. An intense fishery need not be injurious to a fish population, that is, injurious to the returns from that resource over a series of years.

When a new fishery operates on a virgin or little exploited population, the catches rise rapidly to a peak, maintain that peak for a few years and then decline nearly as quickly as they rose until gradually the fishery establishes itself on a level somewhere between the original low landings and peak landings. Our concern is to manage the fishery so that this level is as high as possible.

During the decline from the peak fishing operations, the demand for regulations arises: "A few years ago the catch was so high, now it is so low, the intense fishing, the 'overfishing' has depleted the stock so that it yields less than it formerly did". This conception, however, is false, for the population does not yield less; it may even yield more. The catch during the peak years was not the yield of those years but the withdrawal of a capital hoarded in earlier years.

In the management of a fishery, the aim is to maintain the crop available for yearly harvesting at as high a level as possible. It is not the size or the weight of the population that matters, but the weight of the fish meat produced yearly.

In a dense population the fishes are slow-growing and old. They are using their food supply in milling around searching for food, in spawning migration, in producing roe and milt, adding very little to their individual weight; thus, the yearly crop of fish for food is small. In such a population a thinning out by an intense fishery is a great benefit - from our point of view - causing the old, slow-growing individuals to be replaced by young, fast-growing individuals, who use their food in adding to their size and weight, thus increasing the yearly crop. Many examples of this are known, fully supported by evidence.

In the history of a fishery, it is dangerous to postpone conservation measures to a date too late, but is just as dangerous, perhaps even more so, to introduce them too early. Conservation efforts must aim at controlling the population or populations in question at such a level of abundance that the individuals, in as short a time as possible, reach optimum size, and then at catching these as soon as possible, before natural mortality has claimed too large a part. By optimum size is understood the size of the individual at the time when the year-class is of maximum weight. This definition may be qualified if there is a price differential based on cullings.

To achieve this a tremendous amount of research work is needed along the lines defined by M. B. Schaefer in his paper above, "The Scientific Basis for a Conservation Programme". The problem of determining the period of individual life when fishing should start, of fixing the most profitable state of density or rather of "thinning out", and of defining the most advisable regulation measures is a vast one. These problems are further complicated by the fact that regulation of the fishery of a certain species also acts upon other species in the same habitat and through these reacts on the former.

Aims of Conservation

The two main aims of fish conservation are: (1) to secure to mankind a continued supply of fish sufficiently large to meet the demand, and (2) to maintain a paying fishing industry. In many cases these two aims can be achieved through the same measures of conservation. In some cases, however, and perhaps in more cases than is generally realized, this is not so. A conservation measure may cause a lesser quantity to be caught, with the result that, through improved quality, the fishing industry pays better, but a decrease in the amount of food made available for man results.

Thus, in considering conservation, in each case it must be decided which of the two aims should be given priority. With the steadily increasing need for food, obviously the first aim - supply - is to be given priority. The problem is to produce more food from the sea, at a price low enough to make it available to those who need it most. However, no fishery - without support - can be carried on over a long period if it does not yield a profit for the fishing industry. Therefore the second aim must be considered, not only for its own sake but also for the sake of achieving the supply needed.

Discussion of Specific Items of the Conference Agenda

Magnitude and geographical range of the population constituting the resource

In considering this item, it must be borne in mind that in some cases the population constituting the resource - that is, the population fished - is not identical with the population sustaining that fishery. It may be that the fishing is carried out only in part of the area over which the resource, the species in question, is distributed. If one tries to judge the magnitude of such a resource through statistics of the fishery, or through research work in the area "threatened", one comes to a wrong conception of the size of the resource and of its ability to endure fishing. A species fished in only part of its range will be able to endure in that area a much stronger fishery than a species fished over its whole range. This fact is, of course, most obvious; however, it has often been overlooked or not sufficiently considered. When contemplating the introduction of regulations for a fishery, the research work on the species in question must be carried out not only in the area where it is fished but in the whole area where the species is distributed, provided that it is connected with the fishing area.

Effects of intensity and type of exploitation on the resource

It is obvious that study of the effects of intensity and type of exploitation must be based on study of these two elements themselves, that is, of the statistical information that can be collected on them from the commercial fishery. When the International Commission for the Northwest Atlantic Fisheries (ICNAF) started work in 1951, it was recognized from the beginning that one of the principal aims of its work would be compilation of reliable statistical data, as extensive and as refined as possible, from all ten member countries which have fishermen in the area.

The main international fisheries in this area are fisheries for cod, haddock and redfish. The principal cod fisheries are on the Grand Banks of Newfoundland and in West Greenland waters. The haddock fishery is centred off the coasts of Nova Scotia and New England. The fishery for redfish, which is a fairly new one, mainly takes place on the Grand Banks, off Nova Scotia, -

in the Gulf of St. Lawrence and in New England waters. In the waters off the southwestern coast of Greenland, a fishery for redfish has started during the past two years.

The following ten nations, which are members of the Commission, carry on fishing in the area: Canada, Denmark, France, Iceland, Italy, Norway, Portugal, Spain, United Kingdom and United States. During recent years, Germany has started fishing on the Grand Banks and in West Greenland waters, and the Union of Soviet Socialist Republics has carried out a little experimental fishing on the Grand Banks. The total landings of groundfish from the area amounted in 1953 to 1.2 million metric tons, round fresh.[1]

As statistics on the commercial fishery are the primary basis for deciding whether regulations are needed, and, if so, what kinds of regulations are desirable, a short survey of the Commission's statistical requirements and of the use made of them is given here.

The area dealt with by the Commission is that part of the northwestern Atlantic which stretches north from latitude 39° north and west from longitude 42° west to the coasts of New England, the maritime provinces of Canada, Quebec, Newfoundland and Greenland. In order that the more or less independent populations may be dealt with separately, the area has for statistical purposes been divided into twenty-three sub-divisions. In defining the borders of these sub-divisions, stress was laid upon the using of natural borders, such as deep channels and known borders of distribution of stocks, with the effect that the sub-divisions to some degree correspond to natural habitats of the various stocks of fishes.

Statistical data on landings and efforts from these sub-divisions are collected by months. Data on landings cover only the principal species of groundfish (the pelagic species play a small part in the international fisheries in the area). Statistics on landings are collected according to commercial size categories in use by the industry. Definitions of such categories are reported annually.

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[1] Whole fish, weight before cleaning.

Statistics of efforts comprise:

(a) Number and tonnage of fishing vessels in use;

(b) Manpower on the vessels;

(c) Gear used;

(d) Such data on the time factor as: days absent from port, days on fishing grounds, days fished and hours trawled, this latter for trawl fishing, with corresponding data for the various kinds of hook fishing.

Based on landings and efforts, calculations of the yield per unit of effort are made with the aim of measuring the efficiency of the various fishing methods and also of achieving measurements of abundance of fish and variations in abundance in time and space.

As the Commission has only been at work for three to four years, not all of its statistical requirements as stated above are completely met by all countries. However, each year sees a marked improvement in the quantity and quality of statistical data obtained. The statistics on landings are given in metric tons and round fresh after application of conversion factors. It is recognized that the conversion factors in use in this area, as in others, are not so accurate as could be wished. Extensive experiments on conversion factors recommended by the Commission are being carried out by the participating countries.

Problems in respect of which international conservation measures and procedures have been instituted in the northwestern Atlantic

In the waters off the New England coast, a certain decline in the yield of the haddock fishery was observed in the late nineteen forties. This in connexion with the great waste of small haddock caught by otter trawlers was of great concern to the fishing industries, the fisheries' authorities and the biologists.

At the first annual meeting of the International Commission for the Northwest Atlantic Fisheries in 1951, the problem and proposals for regulations were presented. After further studies an international regulation introducing a 4-1/2 inch mesh for otter trawls was introduced in the summer of 1953 for the area off the New England coast. The 4-1/2 inch mesh is measured stretched, wet and after use.

The introduction of this conservation measure was based on the following observations:[2] (a) a general decline of catches from a peak, reached around 1930, to a rather low, stable level over the years; (b) a decline in index of abundance[3] during the late nineteen forties; (c) a decrease in individual size for the years after 1947. It was, however, recognized that this decrease could be due to a dominance of rich young year-classes. From these observations, it was considered evident that the haddock fishery of the area had come to a stage where the degree of fishing was determined mainly by the abundance of fish. The problem was not that of rehabilitating a depleted stock but rather of increasing the production of a productive population by proper management of the fishery.

Extensive studies of distribution, migrations, growth differences and racial characters showed that the post-larval population of haddock within the area did not to any appreciable degree intermingle with stocks of haddock in adjacent areas. This fact ensured that the fishing industry that had to undergo regulation would be the one to benefit from it.

Other studies were concerned with fishing practices. It was found that the mesh then used (2-7/8 inches) had its 50 per cent selection point at 25 centimetres, and that the fishery discarded all haddock below 27 centimetres. The amount of haddock annually discarded in the area was estimated at around 7 million kilogrammes.

Through these studies and studies of growth rate and mortality rates, the question of optimum age of first capture was approached. The most difficult problem was to determine the natural mortality; this is a problem in all stocks, and one not yet satisfactorily solved Total mortality was calculated to be 45 per cent, and natural mortality - based on experience - was estimated to be 15 per cent at its highest.

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[2] Herbert W. Graham, "Mesh Regulation to Increase the Yield of the Georges Bank Haddock Fishery", International Commission for the Northwest Atlantic Fisheries, Second Annual Report, for 1951/52 (St. Andrews, New Brunswick, 1952).

[3] The index is in thousands of pounds landed per day's trawling by a standard trawler.

Fishing experiments showed that, in order to avoid discarding appreciable quantities of undersized haddock, a mesh securing a 50 per cent selection at 40 centimetres was needed, and a 4-1/2 inch mesh was found to be the one to recommend. In 1953 this mesh size was introduced internationally for the area concerned, as already mentioned.

The Commission found it desirable to study the effects of the regulation very closely, partly to gain some general experience in conservation procedures and partly to find out whether the mesh size introduced was the one to obtain over the years the highest possible level of catches. Therefore, the Commission recommended a plan for research, carried out since 1953 and still in progress, which is based on a comparison of catches from trawlers using the new regulation mesh size with other trawlers licensed to use the previous small mesh size. This research has yielded the following results:[4/] The quantity of discarded fish (less than 30 centimetres, approximately) was reduced to a negligible amount. Landings of haddock between that size and 40 centimetres were somewhat reduced. This latter loss was, however, compensated by greater numbers of larger fish caught. It must be borne in mind that the benefit in this early period arises only from the greater catches of larger fish which are a result of the increased efficiency of the larger mesh. To this will be added in coming years the benefit arising from the returns from the large quantities of smaller haddock saved, which gradually enter the fishery.

A most obvious indication of the advantages to the fishing industry of the regulation is that many fishermen in the neighbouring Nova Scotian area have voluntarily introduced the same mesh size.

International conservation problems under study in this area

Cod. During recent years a decrease in the yield of the cod fishery in Nova Scotian waters, especially in the amount of larger cod, has been observed. It has therefore been found advisable to introduce conservation measures in that region for the cod as well as for the haddock. Regulations are now being considered for these two species. The problems in this area are more involved

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[4/] Herbert W. Graham, "United States Research in Convention Area during 1953", International Commission for the Northwest Atlantic Fisheries, Annual Proceedings, vol. 4 (Halifax, Nova Scotia, 1954).

than in the New England region, as a greater variety of fishing methods are in use by a greater number of countries. The fact that fishing vessels frequently pass from the Nova Scotian area to the Newfoundland Banks means that it will possibly be necessary to include this latter area, one of the most important areas for international cod fishing in the world, in the conservation procedure. This vast problem is now being studied by the countries concerned according to planning carried out by the International Commission for the Northwest Atlantic Fisheries, and it will be one of the main problems dealt with in the coming meeting of the Commission.

Redfish. The fishery for redfish has grown during recent years to considerable importance for the whole area, from the New England region to the Grand Banks of Newfoundland. There are indications that the stock of redfish within this area cannot support a fishery like the present one. During the past three years the landings from the older fishing grounds off the New England coast and maritime provinces have decreased, amounting in 1953 to less than half of the landings in 1951. In the same years the landings from the Newfoundland area have increased owing to a spreading of the fishing fleet. This search by the fishing fleet for new fishing grounds is a true indication of an insufficiently paying fishery on the old grounds. In its search the fishing industry has made good use of experimental exploration for redfish populations carried out by the Newfoundland Fisheries Research Station. Further research on redfish is planned by the Commission and is under way in the participating countries.

The new redfish fishery off the southwestern cost of Greenland has called for special planning of research. As the fishery here is based on a virgin stock, the information gained is expected to be of special interest. There are not, in the whole North Atlantic, many virgin stocks left for study or exploitation.

Halibut. This is fished from the coast of West Greenland south to New England. There is no doubt that in New England and Nova Scotian waters this species suffered much through a too intensive fishery even in the latter half of the nineteenth century. The returns of the fishery in these areas are now small, and the fishery is only of slight value. However, considering that this area earlier fostered a large stock of this valuable fish, the possibility exists that proper management of the fishery could restore the stock. If conservation has to be introduced for halibut, we are faced not with conserving an existent stock - as is the case with haddock and cod - but with the more difficult problem of rebuilding an utterly depleted stock. In West Greenland waters the halibut has also suffered from too intensive fishing. The problem of conservation of this stock is now being considered. The measure taken will probably be the introduction of an international size limit.

Concluding Remarks

How can it be determined whether a stock (or stocks) in a certain area is being depleted or overfished? Much effort has been directed to defining "depletion", "overfishing", and other terms. When it is remembered that the aims of conservation are to supply the fish needed to cover the demand and to insure the continued existence of a paying fishing industry, the behaviour of that same fishing industry can answer the question.

When fishing vessels in an area are turning their efforts to other, less valuable species, when they spread themselves over the area and beyond it, when they lie rusting in port, then it is evident that the stocks are depleted, are overfished. It is the duty of research organizations to find out, before this occurs, that depletion or overfishing is threatening. To do this, two ways are open:

(1) Complete study of the biology of the stocks and of their changes in abundance and in growth rate, and study of the causes of these changes, whether they are natural, or caused by the fishery.

(2) A close study of statistical information, that is the data which are obtainable from the fishing industry. Annual variations in landings and in effort must be studied simultaneously. The composition of the landings by species, by size categories and by age must be taken into account.

Both ways call for continuous research. The problems will never be solved once and for all. As long as a fishery goes on, conditions for the stock are changing. Long-term climatic changes will also alter conditions from one decade to another.

When planning research work on conservation, it must be clear that it is a perpetual work. The regulations introduced will never be final. They are apt to be changed from time to time or even abolished. Continued vigilance is needed, to keep informed on the stocks, the fishing effort and the way the regulations themselves are working out.

When stocks are about to be depleted, the fishing fleets move around in search of new stocks to be exploited. To the extent that new stocks are being fished, the strain on the old ones is lessened. The shifting of the fishing fleets thus helps the conservation effort. Therefore, the search of the fishing fleets must be supported. Research must be carried out for new species or for new populations to be exploited. This work - the providing of maps showing fish resources and the fishery possibilities of the seas - should go hand in hand with conservation. This work, too, will never be "finished", as conditions will change when exploitation of new stocks starts.

With the mobility of the modern fishing vessels, no stock of fish, however self-contained or discrete, can be regarded as a unity. The exploitation of a new stock of redfish can well influence the haddock stock of the southern Grand Banks by reducing the fishing pressure on the latter stock.

It might even be that the exploitation of, let us say, a hake stock in the Southern Pacific might lessen the strain on the plaice stock of the Southern North Sea. Thus will the exploration for, and exploitation of, new stocks aid the conservation of the old.

The question of conservation and management of fishing is a world-wide question and must be grasped and studied as such.

SCIENTIFIC INVESTIGATION OF THE TROPICAL TUNA RESOURCES OF THE EASTERN PACIFIC

by

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(The mimeographed text of this paper appeared as document A/CONF.10/L.11)

Contents

The tropical tunas which inhabit the high seas off the shores of the Americas from California to Peru and northern Chile constitute the marine resources supporting the most valuable fishery of the eastern Pacific Ocean. These resources consist of populations of two species, the yellowfin tuna, Thunnus (Neothunnus) macropterus, and the skipjack (barrelete), Katsuwonus pelamis. In 1953 there were produced from the eastern Pacific 274 million pounds of these species, consisting of 140 million pounds of yellowfin and 134 million pounds of skipjack.

The preponderant share of the catch is taken by fishing vessels based on the west coast of the United States - very modern, long-range craft forming one of the most specialized fishing fleets in the world. A small but appreciable share of the catch is taken by vessels based in Peru, while smaller quantities are landed in Chile, Ecuador, Panama, Costa Rica and Mexico. Most of the landings in countries other than the United States are trans-shipped frozen to the United States for processing as canned tuna, though small quantities are canned or otherwise consumed in Latin American countries.

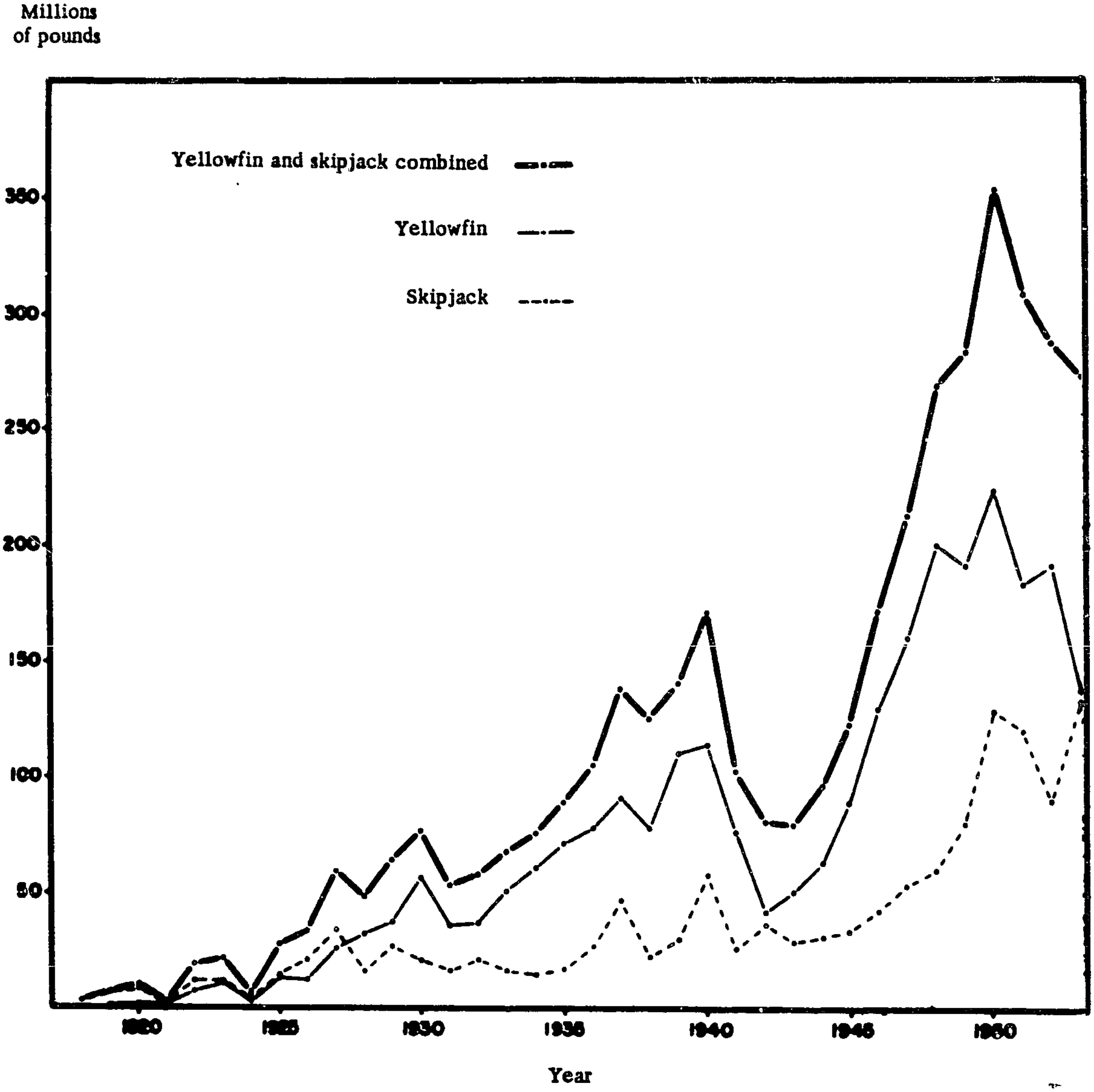
The Inter-American Tropical Tuna Commission is engaged in the scientific investigation of the tuna resources supporting this fishery, and of the resources of bait fishes required for their capture by the pole and line fishing method, which accounts for over 80 per cent of the catch; the remainder is taken by purse-seiners. The tunas inhabit the high seas, in contrast to the bait species which occur primarily in inshore waters, and are, therefore, more pertinent to the subject matter of this conference. This paper is accordingly confined primarily to discussion of the Commission's research on tuna resources.

Development of the Fishery for Tropical Tunas in the Eastern Pacific

Fishing for tunas in the eastern Pacific is of comparatively recent origin. Canned tuna was not produced in the United States or elsewhere in the Americas until 1903, when there was inaugurated in California a new industry based on the canning of albacore (Thunnus germo), a temperate water species of tuna, captured in the seas off southern California during the summer months. The albacore canning industry grew rather slowly, but by 1917 utilized 31 million pounds of these fish. Increased demand for food during the First World War gave impetus to the infant industry. It appears that, simultaneously, about 1918, albacore became somewhat scarcer in California waters than previously, as a result of which fishermen and canners turned to tropical tunas to obtain the required raw material. The northern part of the range of the tropical species reaches to southern California, where they occur only during the warmer months of the year. By 1925, the industry used 22 million pounds of albacore, 13 million pounds of yellowfin tuna and 14 million pounds of skipjack.

In 1926 there occurred a drop in the local albacore supply, owing presumably to some oceanographic variation; this motivated the development of the modern, long-range fishery for tropical tunas. In that year the albacore practically disappeared from California and Lower California, only 2.5 million pounds being captured, and it was not until 1938 that the albacore catch again exceeded 10 million pounds. In order to satisfy the demand for tuna for canning,

Figure 27. Total catch of yellowfin and skipjack tuna from the eastern Pacific, 1918 to 1953



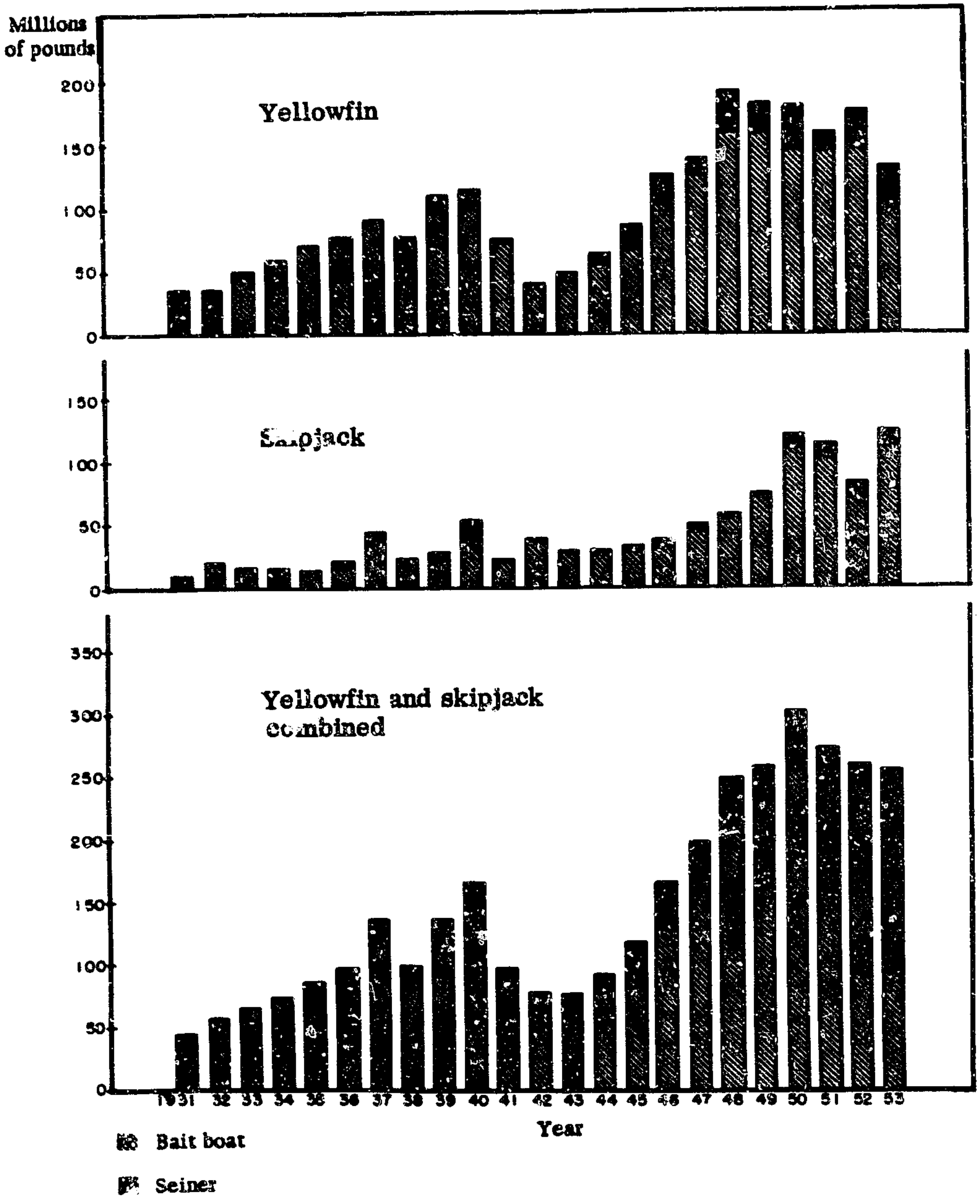
fishermen began to expand the fishing area for yellowfin and skipjack southward along the Mexican coast, and, with the rapid development of long-range craft equipped for refrigerating the cargoes, had expanded the fishing area southward to the equator by 1931. Subsequently, the fishery expanded further southward along the Peruvian coast to almost the southern limit of the distribution, in commercial quantities, of these tropical tuna species.

The increase in the harvest of yellowfin and skipjack tunas from the eastern Pacific is illustrated in figure 27. It may be seen that the fishery enjoyed a sustained growth from its inception until 1941. During the early part of the Second World War, production, especially of yellowfin tuna, decreased considerably, owing to the entry into naval service of most of the long-range tuna clippers and restrictions on the activities of the remainder of the fishing fleet. From 1945 onward, as the fleet was rebuilt, the catch increased very rapidly, attaining a peak production of over 350 million pounds in 1950.

During the years of the modern fishery, the greatest share of the catch has always been taken by tuna clippers, or bait boats, which are vessels equipped to fish for tuna by means of poles and lines, using small live fishes for bait; these are cast into the sea to attract surface-schooling tuna to the boat. A small share of the catch, about 15 per cent, is taken in purse-seine nets by vessels especially built for this sort of fishing. This is illustrated by figure 28, which depicts landings in California - constituting most of the total catch - by species and type of fishing gear.

The bait fishes employed in capturing the tunas are several species of small fishes, mostly of the families Clupeidae and Engraulidae, which occur in quantities in inshore waters near the high seas areas inhabited by the tunas. In the northern bait areas, north of Cape San Lucas or thereabouts, the principal species are California sardines (Sardinops caerulea) and northern anchovies (Engraulis mordax). Similarly, at the southern extremity of the fishery, off Peru, quantities of southern anchovies (Engraulis ringens) are available. Sardines (Sardinops sagax), as well as smaller quantities of a spiny rayed fish of the family Xenicthyidae, which the fishermen call Salima, are taken in the Galápagos Islands. In the tropical seas, approximately between

Figure 28. Landings of tropical tunas in California, by species and type of fishing gear, 1931 to 1953



Lower California and Cape Blanco, Peru, the principal bait species is a deep-bodied tropical anchovy (Cetengraulis mysticetus), called "anchovets" by the tuna fishermen. Small quantities of several species of tropical clupeoid fishes, all known to the fishermen as "herring", are also taken for tuna bait from the tropical areas. Bait is measured by the fishermen in scoops -- the quantity of fish lifted from the bait seine to the bait tanks of the fishing vessel by means of a small dip net, or approximately nine pounds of bait fish. The relative importance of the different kinds of bait is illustrated in figure 29, which depicts the quantity of bait, and the varieties used by United States clippers, for the years 1951, 1952 and 1953.

The Inter-American Tropical Tuna Commission

The very rapid post-war increase in fishing for yellowfin and skipjack tunas in the eastern Pacific gave rise to concern as to the effects of fishing on tuna resources, and also on the bait resources. Very little scientific information was available concerning these species of fish, or about the current status of the fishery with respect to conditions which would provide the maximum sustained yield. In order to make possible the scientific investigation of tunas and bait fishes, and the effects of the fishery on them, there was negotiated in 1949, and ratified in 1950, a convention between Costa Rica and the United States establishing the Inter-American Tropical Tuna Commission.[1/]

Under the terms of the convention, the Commission is to gather and interpret factual information in order to facilitate the maintenance of populations of yellowfin and skipjack tunas, and other kinds of fishes taken by tuna fishing vessels in the eastern Pacific Ocean, at a level which will permit maximum sustained catches year after year. The Commission is directed to undertake necessary scientific investigations for this purpose and, on the basis of these investigations, to recommend proposals for joint action.

The Commission commenced its investigations in 1951 with a small scientific staff, which has since been augmented by additional scientific and technical personnel. This staff has, during the past four years, made progress

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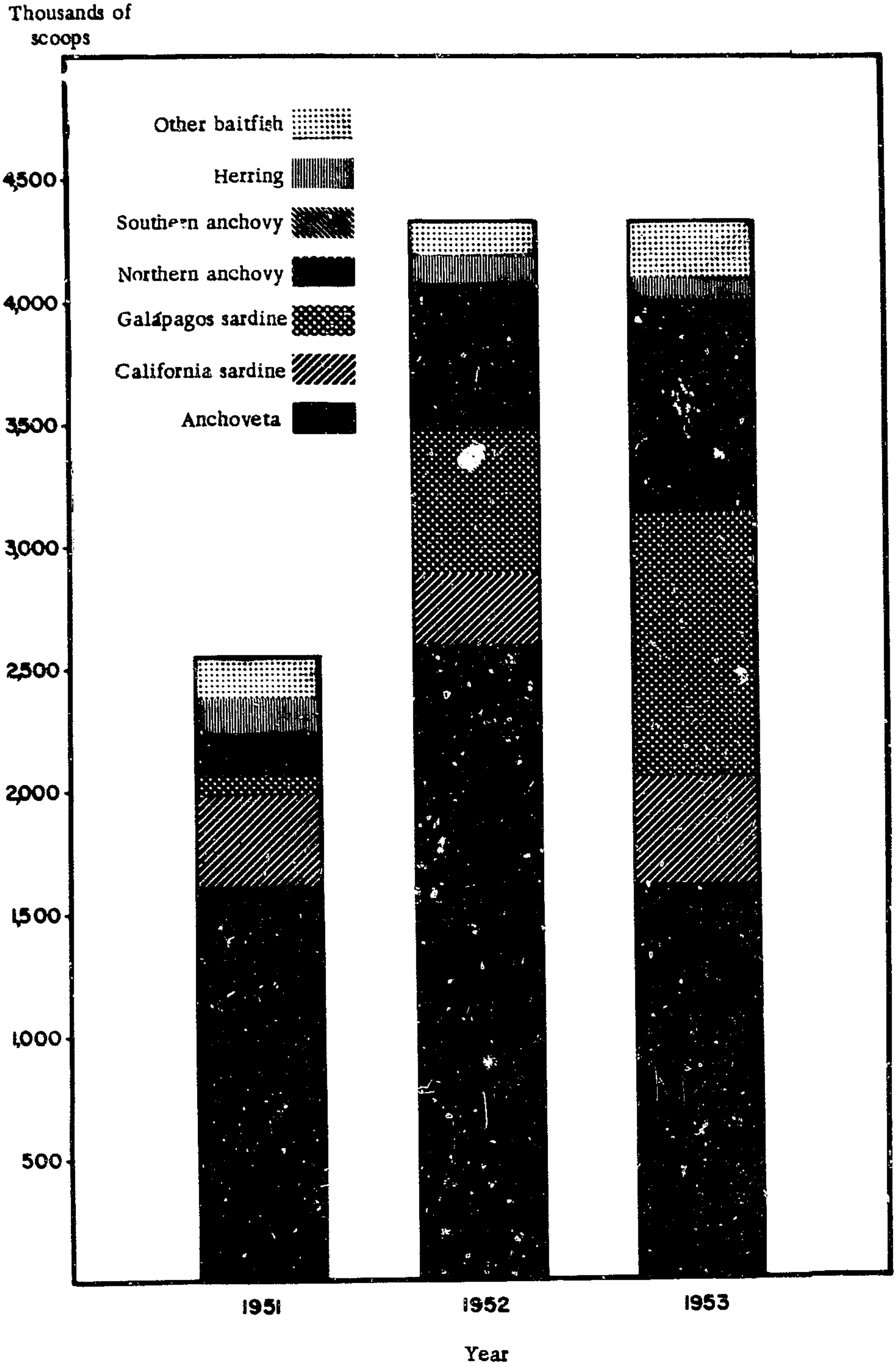
[1/] Panama later adhered to the convention; see paper by W. C. Herrington and J. L. Kask, "International Conservation Problems, and Solutions in Existing Conventions".

Figure 29. Quantities of bait fishes, by variety, taken by United States clippers, 1951 to 1953



in gathering scientific information required for the purposes of the convention. At the outset the biology and ecology of the tunas, and the condition of the stocks, were almost entirely unknown. A great deal remains to be learned, but, as will be seen, sufficient information is being accumulated to assess the general status of the fishery, and to provide a part of the scientific information required as a basis of future conservation action by member governments.

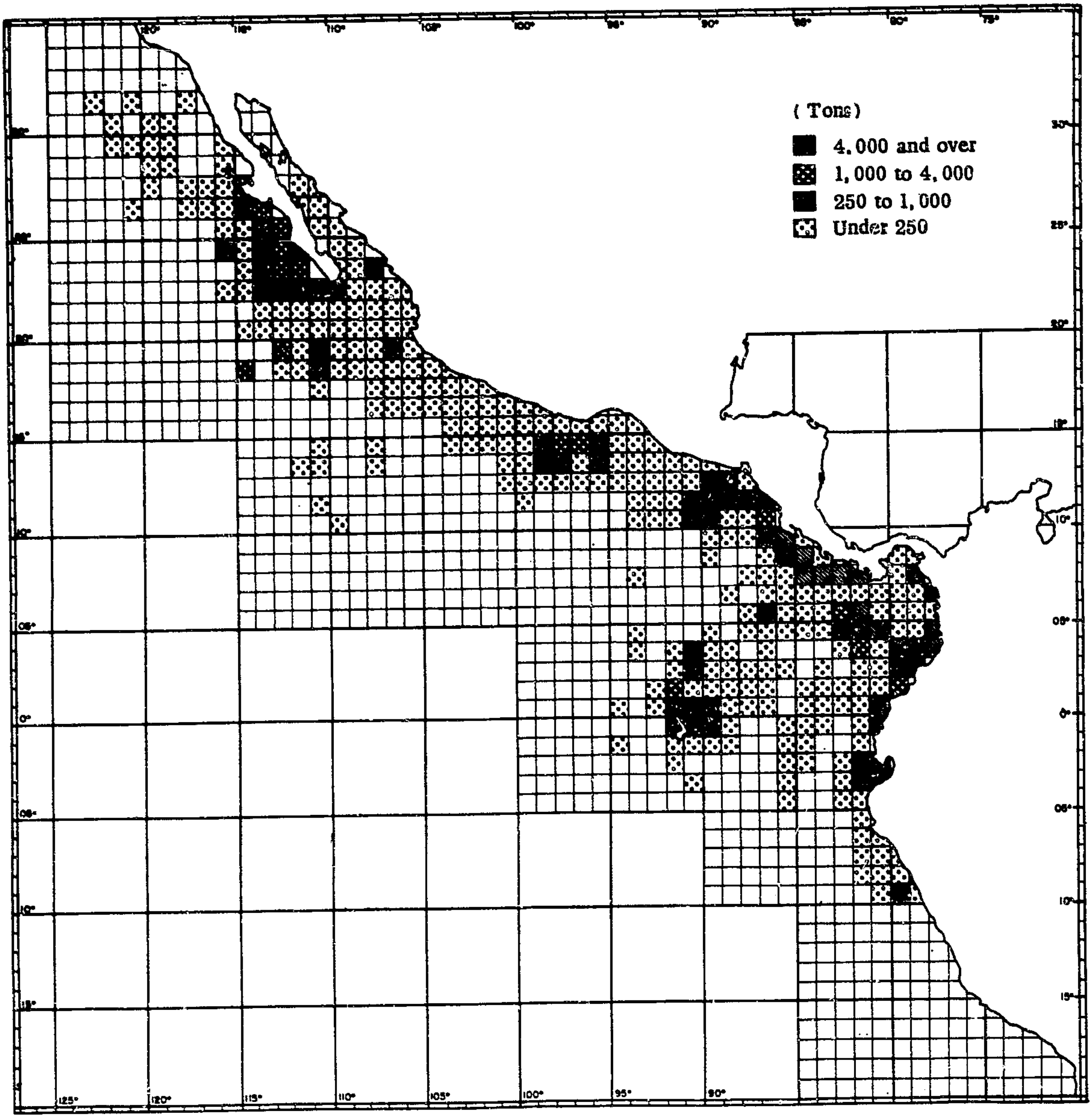
The Inter-American Tropical Tuna Commission is unusual in that it began its investigations at a stage in the development of the fishery when serious overfishing had not yet occurred; often adequate scientific research on a fishery resource is not undertaken until economic distress resulting from overfishing makes such research imperative. The Commission's staff has the opportunity to provide the scientific basis for maintaining the harvest from the resource and preventing serious overfishing before it occurs.

Scientific Information Respecting Tropical Tunas

Geographical distribution

Yellowfin and skipjack tunas are found in the Pacific in a broad band across the ocean extending on either side of the equator, bounded, approximately, by the surface isotherms of 20° centigrade. In addition to the commercial fishery in the eastern Pacific, off the coast of the Americas, there is a sizable amount of fishing, primarily by Japanese fishing craft, on the western side of the Pacific, extending eastward among the islands of the central Pacific to the longitude of Hawaii. Both species, together with the bigeye tuna (*Parathunnus sibi*) are fished commercially in the seas surrounding the Hawaiian Islands, and this fishery is expanding southward along the Line Islands to the vicinity of the equator. They are also known to exist in commercial abundance in the vicinity of the Marquesas Islands and Society Islands. Exploratory fishing by the United States Fish and Wildlife Service has shown that yellowfin tuna occur at various longitudes between the American mainland and the central Pacific.

Figure 30. Map showing geographical distribution of yellowfin and skipjack tuna catches by clippers, 1953 (according to statistical areas of the Inter-American Tropical Tuna Commission)



In the high seas off the shores of the Americas, the yellowfin and skipjack tuna occur in commercial abundance from approximately latitude 32° north to 20° south. At the northern and southern extremes of the range, these fish appear only during the warmer months of the year, but in the middle part of the range they are present at all times. Skipjack apparently tolerate slightly lower temperatures than yellowfin, their range extending slightly farther to the north and south; skipjack are sometimes taken commercially, during the warmest months of the year, off southern California on the north, and off Copiapó, Chile, on the south. The present range of fishing by means of modern high seas fishing craft covers almost the complete span of latitudes, extending from the northern extremity to about Callao, Peru. The commercial fishing area extends offshore from the mainland about 300 miles, except where there are outlying islands (Revillagigedo, Clipperton, Cocos, Galápagos), where it reaches out even farther to include the seas near such islands. Within this range, tunas are not found everywhere in equal abundance but are concentrated in certain localities which, as explained later, appear to be particularly favourable feeding areas, determined by oceanic circulation.

The geographical distribution of the catch from the eastern Pacific, and the areas of concentration, may be illustrated by the catches for 1953 by tuna clippers based in the United States, which keep accurate log-book records of their operations for the Commission. The catches of yellowfin and skipjack tuna by these vessels during that year are shown in figure 30 for each area one degree square in which fishing was done. While there is some variation from year to year, the main centres have remained nearly the same for recent years for which such detailed records are available.

Population relationships

Since yellowfin and skipjack tunas occur all the way across the Pacific, it is important to know whether the fish captured in the eastern Pacific fishery are members of populations confined to that region, or whether they are representatives of larger populations which migrate freely throughout the transoceanic range of each species. Knowledge of whether the members of these species in the eastern Pacific belong to populations distinct from those farther westward is of importance in (a) gauging the magnitude of the catch in relation to the magnitude of the resources; (b) determining the region in which it is necessary to conduct research; and (c) determining the geographical extent of jurisdictional areas for conservation management.

With respect to yellowfin tuna, it has been tentatively concluded that the resource supporting the American fishery is distinct from those farther to the west. Three lines of evidence support this: (1) morphometric comparisons of specimens from the American area with specimens from French Polynesia and with specimens from Hawaii reveal rather large differences in fin lengths and body proportions; (2) tagging by the California State Fisheries Laboratory of yellowfin off the Americas has resulted in no recoveries from the commercial fisheries to the west; and (3) analysis of statistics of fishing intensity and population abundance, discussed below, indicate that changes in fishing intensity have measurably affected abundance, which would be unlikely if the fishery were supported by a large, transoceanic population which is unfished throughout much of its range.

With respect to skipjack tuna, similar conclusions cannot yet be drawn. Morphometric studies do show indications of differentiation between American fish and specimens from farther westward, but the data in hand are not yet adequate for firm conclusions. Tagging has resulted in no recoveries from outside the range of the American fishery, but such negative evidence is not, by itself, a sufficient basis for conclusions. Analysis of statistics of fishing intensity and abundance of skipjack - unlike yellowfin - does not reveal any measurable effect of fishing on abundance. The question, for this species, is therefore still open.

It is, of course, of very great importance also to determine whether within the region of the east Pacific fishery these species are further sub-divided into distinct or semi-distinct populations, or stocks, which should be considered separate biological units in the management of the fishery. Preliminary investigation of this problem by comparison of morphometric data indicates that this technique may not be adequate, because of inability, for technical reasons, to distinguish small anatomical differences. Tagging may indicate the range of migrations of specimens tagged in different locations and so determine the degree of intermingling. During the past two years, the California State Fisheries Laboratory has commenced such tagging experiments, with encouraging results, but it is too soon for definitive conclusions. Migrations up to six hundred and seven hundred miles have been recorded for some specimens at liberty for about a year. Many specimens have, however, shown rather small movement in the same interval of time. It appears that these tunas do not diffuse rapidly throughout the range of the fishery, but this does not preclude complete mixing at a slower rate.

Information from the size composition of catches may also be brought to bear on this problem, since, if the stocks are heterogeneous, consistent differences in size composition persisting in a geographical sub-region may be taken as evidence that separation of populations is being maintained. Here, again, not enough data have yet been gathered along this line for such purpose.

Pending solution to these problems, the Commission is collecting data on fishing effort, yield and tuna abundance by the smallest practicable geographical sub-areas, so that they may be recombined according to such natural boundaries as may exist.

Information on life history, ecology and behaviour

The yellowfin and skipjack tunas are creatures of the high seas. They lead a completely pelagic existence throughout their lives. Owing to their completely oceanic habitat, the study of their biology and life history is technically difficult and expensive, in consequence of which very little has been known concerning them until recent years. During the past decade, however, some fishery scientists of Japan, the United States and other countries have devoted intensive efforts to this group of fishes, so that former ignorance is being replaced by some knowledge of the more important aspects of their biology.

The yellowfin and skipjack tunas, during their early years of life at least, aggregate into schools near the surface. This behaviour is the basis of the fishery in the eastern Pacific, since both the live bait and the purse-seine methods of fishing depend on the occurrence of sizable schools for efficient capture of the fish. Skipjack tuna in commercial catches range in size from about three to thirty-five pounds. Yellowfin tuna in the catch range from about six to two hundred pounds, most of the catch consisting of fish of under forty pounds. Analysis of size frequencies indicates that, for both species, the bulk of the catch consists of members of only three or four age classes, the youngest fish being probably in their first or second years of life.

The smallest sizes are not represented in the catch in proportion to their abundance in the sea, both because of the selectivity of fishing methods at very small sizes, and because of a legal requirement in the State of California, where the bulk of the catch is landed, that skipjack be over 4 pounds (46 centimetres) and yellowfin be over 7-1/2 pounds (57 centimetres). At very large sizes, the yellowfin tuna become partially unavailable to the surface fishing methods in use in the eastern Pacific, owing to vertical migration to greater depths. In the western Pacific and in the vicinity of Hawaii, these large fish are captured commercially by means of pelagic long lines, fishing as deep as 90 fathoms. No commercial fishing by this method has been developed in the eastern Pacific. Experimental fishing by the Inter-American Tropical Tuna Commission, the Scripps Institution of Oceanography, the California State Fisheries Laboratory and other agencies, however, has shown that, particularly in the vicinity of the equator, these large subsurface yellowfin also occur in the eastern Pacific. There is no evidence that the skipjack behave similarl, since this species is not taken, except infrequently, on long-line gear. This, however, may be due to selectivity of the gear rather than absence of the species in subsurface layers of the sea.

It has been shown that the tunas tend to school by sizes, so that the members of a school are more similar in size than in a random sample of the population. Sampling of the landings to obtain a representative sample of the catch therefore involves drawing samples from a sufficiently large number of different schools to average out this source of statistical error. This is done by taking samples from the catch of several different vessels, and for several different fishing days for each vessel, for each geographical area and time period considered. The Commission, in co-operation with the California State

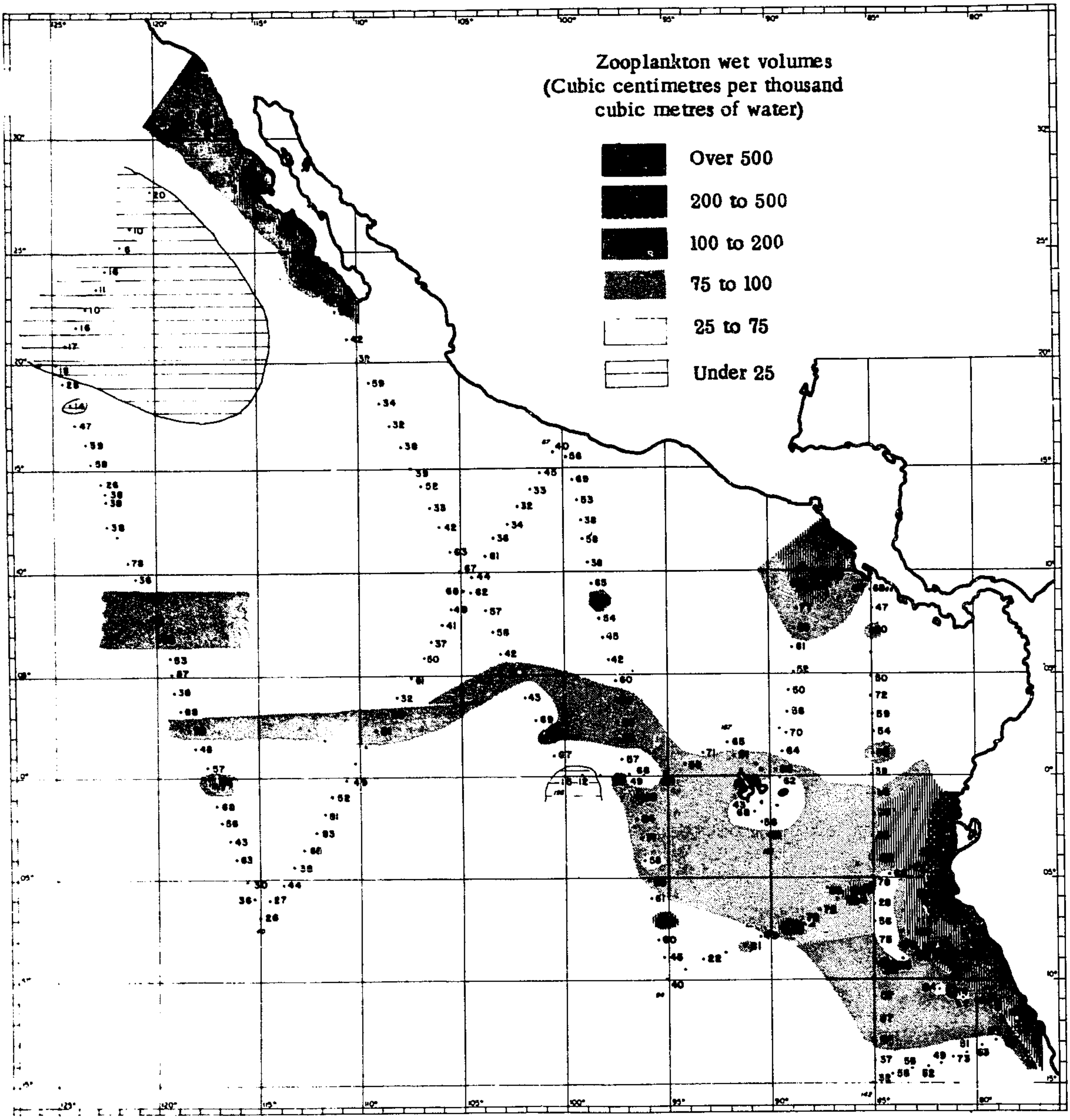
Fisheries Laboratory, has in routine operation a programme of sampling landings to determine the size composition of the catch for each month of the year for six geographical regions of the fishery. These data are expected to yield information on age and growth, on total mortality rates and on the population structure of the resources. The programme has not been in operation long enough to draw conclusions respecting the latter two matters, but some information respecting growth rates is forthcoming.

It appears, from the occurrence and time progression of modes in the length frequencies, that both the yellowfin and the skipjack tunas are relatively rapidly growing species, the commercial catch being composed primarily of only about three age groups in each case. Determination of age is tentative as yet, since checking aging by marks on hard parts has not, so far, proven successful. From the positions of the modes of the size frequencies, however, it appears certain that the youngest age group of yellowfin tuna in the commercial catch cannot be over two years old and is probably but one year old. Determination of age at first capture of skipjack is less certain from presently available data, but it tentatively appears that the youngest age group is two years old. For both species, growth and turnover of population therefore appears to be very rapid.

Spawning of tropical tunas occurs over a wide geographical range, and the spawning season is quite long. Indeed, in the vicinity of the equator, investigations, both by the Commission and by the unit of the United States Fish and Wildlife Service operating from Hawaii, indicate that some spawning takes place throughout the entire year. In these circumstances, large variations in year-class strength are less likely than for species having a restricted spawning area and a short spawning season.

A very large number of eggs are spawned by each female. Investigations in Hawaii have shown, for example, that a 100-pound yellowfin produces over 2 million eggs at a single spawning, and that each fish may spawn more than once during the year. Material for fecundity determinations, for both yellowfin and skipjack from the eastern Pacific, have been collected but have not yet been analysed.

Figure 31. Map showing relative abundance of zooplankton organisms in the eastern tropical Pacific, 17 May to 27 August 1952



Source: Shellback Expedition, Scripps Institution of Oceanography, University of California. Contours off Lower California are based on supplementary data from other cruises.

Numbers represent plankton volumes at stations occupied. Contours of plankton concentrations are shown for regions of high volumes (over 75 cubic centimetres per thousand cubic metres) and for very low volumes (under 25 cubic centimetres per thousand cubic metres).

The pelagic eggs hatch in fewer than forty-eight hours. The eggs and larval stages are taken from the surface to at least 200 metres depth in plankton net hauls. Juveniles from about one to ten centimetres have been collected by light and dip net, at night, at oceanic stations off the Central American coast, and elsewhere, and have also been collected from the stomach contents of adult tunas and other pelagic carnivorous fishes.

With respect to feeding habits, investigations by the Commission's staff in the eastern Pacific, and by investigators of other agencies in other parts of the Pacific, indicate that the tunas feed quite omnivorously on all forms of pelagic animals of suitable size encountered on the high seas, ranging from euphausids and squilla larvae, to fairly large cephalopods and fishes.

Migration patterns of tunas in the eastern Pacific are not yet clear. Extensive tagging experiments have been instituted by the California State Fisheries Laboratory, and these will be augmented by the Commission in the near future. Results as yet are insufficient to determine seasonal migration patterns.

As illustrated in figure 30, above, showing the geographical distribution of catches by tuna clippers during 1953, the tunas are concentrated in certain areas. There are such regions of concentration off Lower California, in the vicinity of the Gulf of Tehuantepec (only during the early part of the year), off the coast of Central America, in the region lying off the coast of the northern part of South America and in the vicinity of the Galápagos Islands. These regions of concentration correspond, in general, with regions of high production of food organisms, as indicated by the volume of zooplankton per unit volume of water. This is illustrated by figure 31, showing the distribution of plankton volumes obtained on a fairly recent oceanographic expedition. The zooplankton is, in major part, a step lower in the food chain than the animals which tuna feed on, but it is expected that the organisms on which the tuna feed would be most abundant in regions with a high standing crop of zooplankton. It further appears that these regions of high production of zooplankton organisms are also regions where the surface waters are enriched by basis nutrients brought up from deeper layers by upwelling, or by mixing along major current boundaries. It seems logical to hypothesize that regions which are fertilized by these physical processes support an abundant growth of primary - plant - producers, which in turn support an abundance of organisms higher in the food chain, culminating in the tunas which are harvested by man. Since the oceanographic régime, to which the tunas seem to be so closely related, is not constant but is subject to variations between seasons and years, it is important to achieve understanding of the details of oceanic circulation, and the causes of its variations. This is, of course, a very large problem, which has just begun to be explored.

Effects of fishing on the resource, and current status

The central problem of the Inter-American Tropical Tuna Commission is determination of the effect of amount of fishing on tuna resources, with particular reference to determining whether the present level of exploitation is above or below the level corresponding to maximum sustainable harvest. Fundamental to the investigation of these matters is the measurement, over a series of years encompassing different levels of fishing intensity, of the abundance of the tunas, the intensity of fishing and the total catch. Such measurements are most conveniently obtained from the detailed records of the fishery itself. A very great part of the labour of the staff has, therefore, been directed towards collection and compilation, on a continuing basis, of detailed information regarding the amount of each species caught, the dates and locations of fishing, and the effort required to make the catches. Since data for a series of years are required for proper analysis and interpretation, the staff has bent its efforts to obtaining pertinent data not only for current years, but also for past years, before the establishment of the Commission.

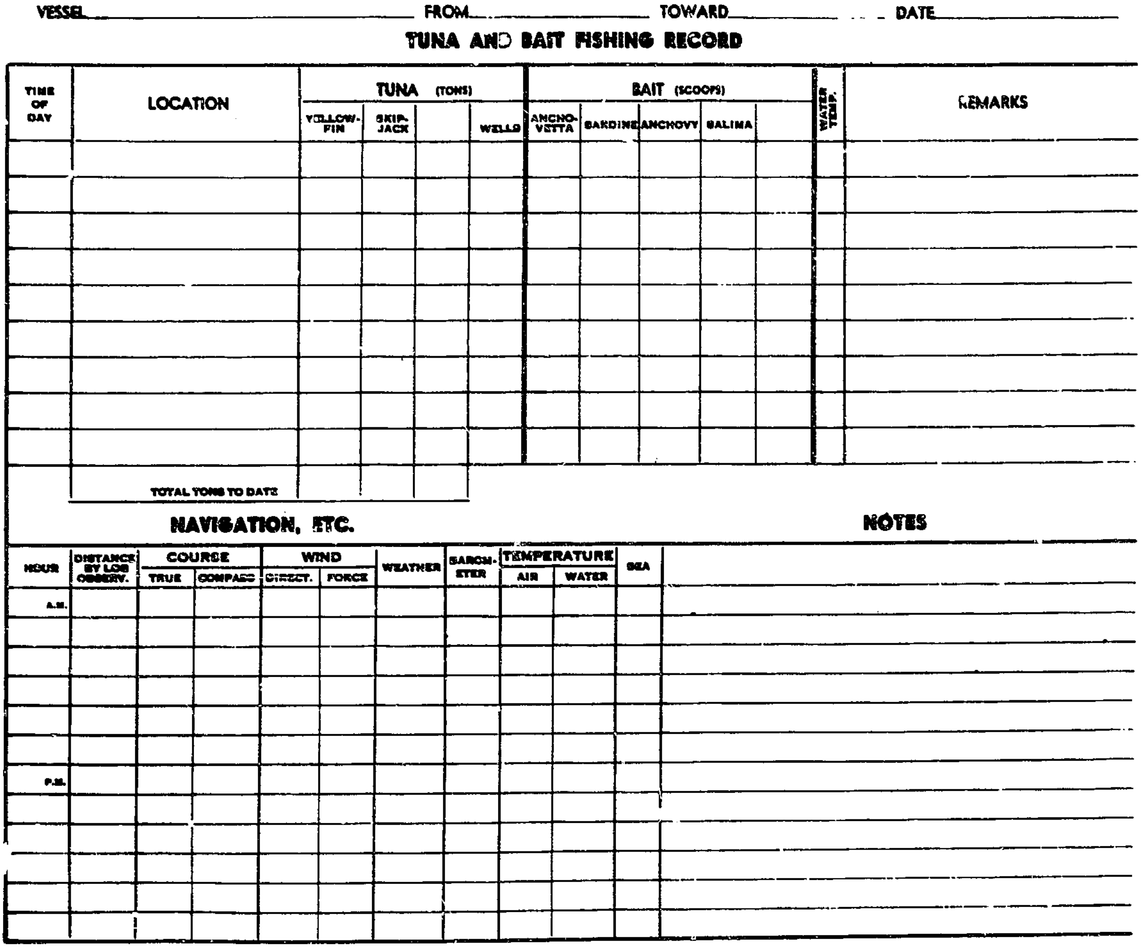
Information respecting the total catch of each species from the eastern Pacific is available since the very early days of the fishery from the records of tuna canners and of government agencies in the United States and other countries where fish are landed. These statistics have been compiled for past years (see figure 27, above) and are collected currently on a continuing basis.

In order to measure the relative abundance of each species of tuna as encountered by fishermen, two kinds of measurement are available, the catch per day's absence from port and the catch per day of tuna fishing. From records of quantities of tuna landed and number of days absent from port, which are obtained from nearly the entire fleet of vessels landing their catches in the United States - accounting currently for about 90 per cent of the total catch - it is possible to compute the average catch per day of absence from port. For seiners this provides a measure of the abundance of the tunas, since they fish for tunas directly with nets. For clippers, however, this measures the combined apparent abundance of tunas and prior success in catching the live bait employed in this fishing method. If, however, the percentage of the time absent from port that is spent in tuna fishing is relatively constant, the catch per day's absence from port measures the apparent abundance of the tunas. Fortunately, as will be shown, this appears to be the case. Measurement of the catch per day's absence from port has the great practical virtue that records are available to compute it for nearly all vessels engaged in the fishery over the past twenty years, so that it may be employed to study major changes which have occurred as the intensity of fishing has changed over that period.

A more exact measurement of average abundance of tunas as encountered by fishermen is provided by the catch per day of tuna fishing. This is computed from log-book records of days actually spent fishing for tunas, and the resulting catch. Current data are gathered by means of specially designed log-books, provided free to fishing captains by the Commission. A specimen page of such a log-book is shown in figure 32. Since 1951, when the Commission commenced its investigations, over 80 per cent of all trips made by vessels landing in the United States have been covered by such log-books. For earlier years, a number of vessel masters had fortunately kept log-book records for their own purposes, and have kindly made them available to the Commission. A fairly adequate sample of the landings is covered by such log-books since 1947, and some log-books are available back to 1930.

Because the efficiency of fishing varies with the size of vessel, the Commission compiles basic data respecting catch per unit of effort by six size categories, based on tuna carrying capacity. From comparison of records

Figure 32. Specimen page from tuna clipper log-book



VESSEL__________ FROM__________ TOWARD__________ DATE__________

TUNA AND BAIT FISHING RECORD

TIME OF DAY	LOCATION	TUNA (TONS)				BAIT (SCOOPS)					WATER TEMP.	REMARKS
		YELLOW-FIN	SKIP-JACK		WELLS	ANCHO-VETTA	SARDINE	ANCHOVY	SALIMA			
	TOTAL TONS TO DATE											

NAVIGATION, ETC. **NOTES**

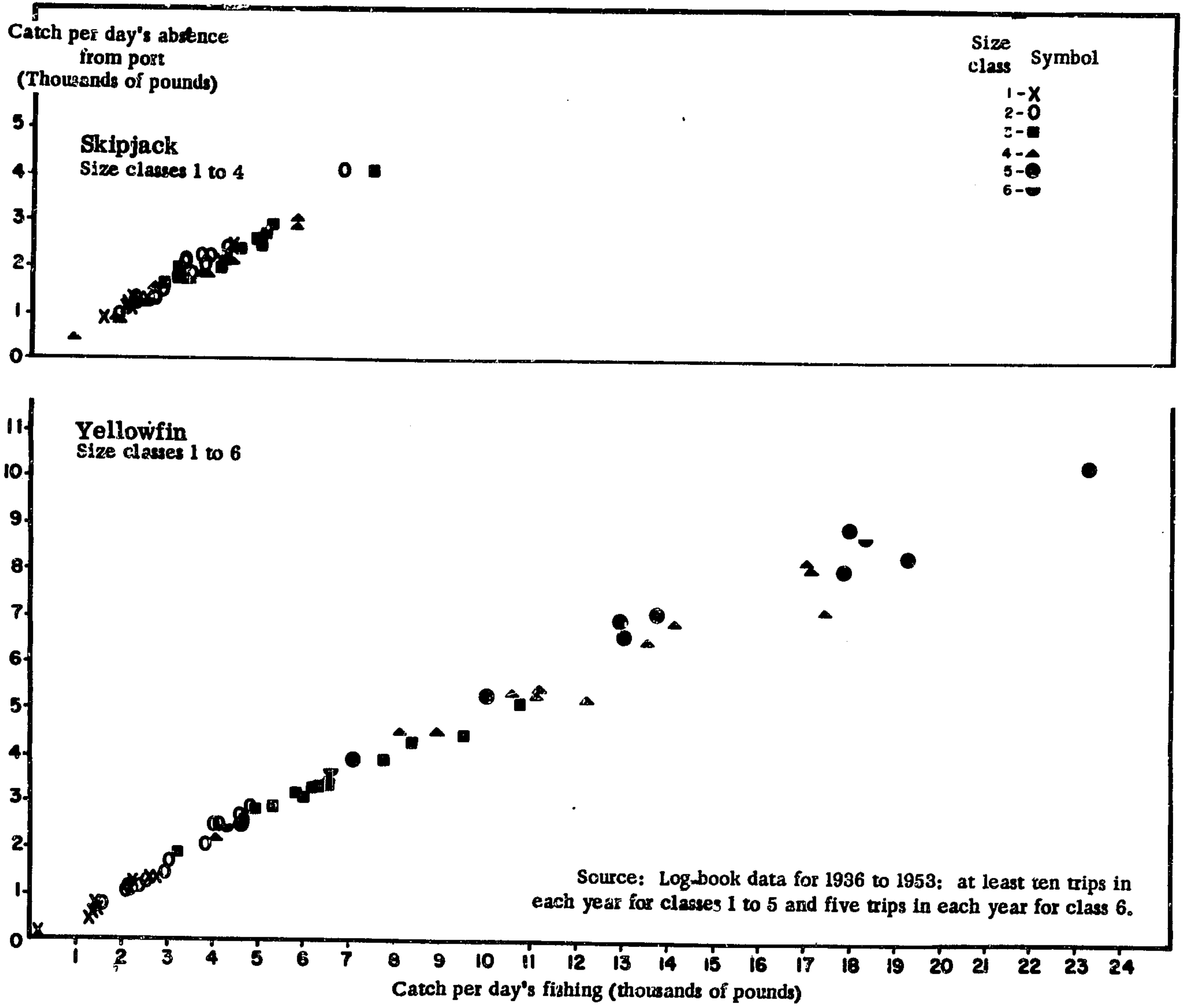
HOUR	DISTANCE BY LOG OBSERV.	COURSE		WIND		WEATHER	BAROMETER	TEMPERATURE		SEA	
		TRUE	COMPASS	DIRECT.	FORCE			AIR	WATER		
A.M.											
P.M.											

of vessels of different size during the same years, it is possible to derive correction factors, so that the catch per unit of effort (catch per day's fishing or catch per day's absence from port) may be expressed in standard units (catch per unit of effort in terms of a given size category taken as standard) to correct for changes in the size composition of the fishing fleet over the years.

In records available from 1[illegible] to 1953, from the catch per day's fishing based on clipper log-book records, compared with the catch per day's absence on the same trips, it has been possible to show that there is a rather constant relationship between the two. This is illustrated in figure 33. The lower panel shows, for yellowfin tuna, the mean catch per day's fishing and the mean catch per day's absence from port for each category of vessel for each year during which data for a specified number of trips were available for calculating both averages. It may be seen that the points cluster fairly closely about a trend line. This indicates that the catch per day's absence from port may be taken as a reasonably good means of estimating the catch per day's fishing and therefore probably also a fairly good method of estimating the apparent abundance of this species as encountered by fishermen. In the upper panel of chart 33, the same sort of information is shown for skipjack tuna, with similar results. For skipjack, only the four smallest size categories of vessels are shown, the two largest classes being omitted because analysis of relationships between landings of the two species has shown that for the two largest classes of vessels, the amount of time spent fishing for skipjack is influenced by the abundance of yellowfin, whereas this does not appear to be true for the smaller size classes of vessels.

Compilation of information has been completed respecting the total catch of both species of tunas from the eastern Pacific, and the catch per day's absence from port for an adequately large sample of the fleet from 1934 to 1953, inclusive. From the catch per day's absence, in standard units, and the total catch, the total relative intensity of fishing for each year may also be computed.

Figure 33. Relationship between tuna catch per day's absence from port and catch per day's fishing, by species, 1936 to 1953



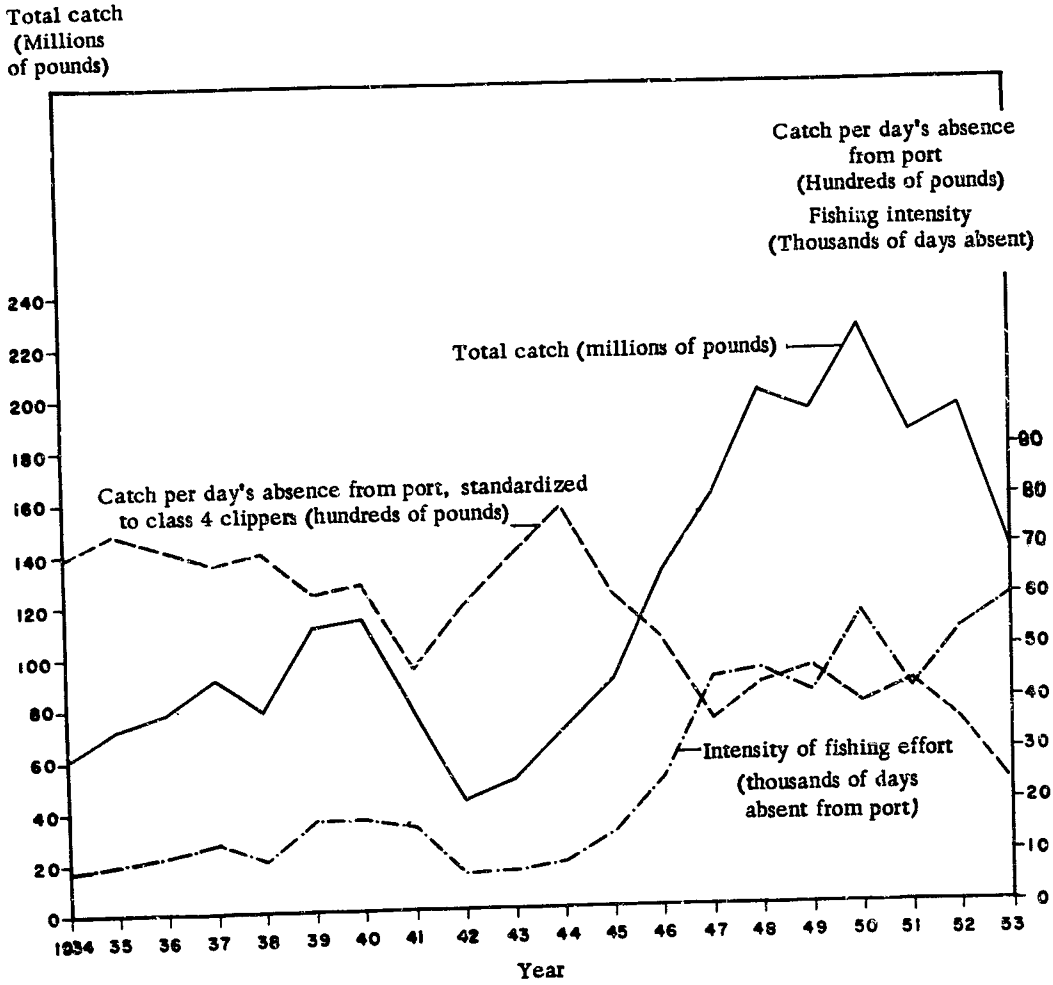
Source: Log-book data for 1936 to 1953: at least ten trips in each year for classes 1 to 5 and five trips in each year for class 6.

This series of statistical measurements of the amount of fishing, yield and apparent abundance for the population of each tuna species as a whole in the entire eastern Pacific gives results of importance. In figure 34 are shown for yellowfin tuna: (a) the total landings by all vessels and all types of gear, a measurement of yield; (b) the catch per day's absence from port of a large sample of United States clippers, standardized to a class 4 clipper, a measure of abundance; and (c) the calculated amount of total fishing effort, in terms of the number of days absent from port of a standard class 4 clipper. It may be seen that as the amount of fishing increased from 1934 to the time of the entry of the United States into the Second World War, the catch increased, but the catch per unit of effort declined rather steadily. With the decrease in fishing effort during the early war years, yield declined but abundance increased sharply. Beginning in 1945, the amount of fishing increased rapidly for a few years, resulting in increased yield but decreased abundance. In recent years, intensity of fishing has exhibited a slight upward trend while the corresponding downward trend of abundance is likewise small. The fishery appears to be stabilizing, with a yield somewhat below the peak yield of 1950.

It seems valid to conclude from these data that the intensity of fishing has been sufficiently great to affect the average abundance of yellowfin tuna. This is, of course, the inevitable result of effective exploitation of a fish population, and indicates only that the rate of catch is at a sufficiently high level measurably to affect the average size of the standing crop. In itself, it tells nothing about the relation of the present level of exploitation to the level of maximum sustainable yield.

To obtain some idea about this latter point, in figure 35 the total catch is plotted against fishing intensity, using the same data as in figure 34. This graph also shows a theoretical curve of equilibrium catch (average sustainable yield) against fishing intensity, based on the assumptions that the yellowfin tuna population aggregate considered here has a population growth curve of the form of the Verhulst-Pearl logistic, and that the mean equilibrium

Figure 34. Yellowfin tuna catch, catch per day's absence from port and fishing intensity in the eastern Pacific, 1934 to 1953



population is in linear relation to the amount of fishing effort. It should be noted that these assumptions may be only approximate, and also that, owing to the rather large variability of catches from 1947 to 1953, the theoretical curve may not prove to be quite correctly fitted. With these reservations, however, it appears that the present level of fishing intensity for yellowfin na in the eastern Pacific is, in the aggregate, near, or perhaps slightly beyond, the level corresponding to maximum sustainable yield. While the foregoing conclusions are valid for the aggregate of all yellowfin in the eastern Pacific, if it turns out that there are, in truth, several separate populations involved, it is possible, and indeed probable, that they may be in quite different stages of exploitation; some of them may be underfished while others are overfished.

Although the fishery for yellowfin in 1953 appears to have reached a level of intensity near the level of maximum sustainable yield, there is no likely imminent danger of serious overfishing. Owing to economic conditions, the intensity of fishing decreased in 1954, and did not promise to increase in 1955. Financial returns from the fishery are such that building new vessels to replace normal losses is not economically attractive, as a result of which the fishing fleet has been shrinking since 1951 (figure 36). In 1952 and 1953 the intensity of fishing was maintained by fuller use of existing vessels, but in 1954 the actual intensity decreased, and no increase was expected in 1955.

Similar statistical data for skipjack present a quite different picture. In figure 37 are charted for this species measurements of yield, fishing effort and apparent abundance, again with the entire eastern Pacific considered as a single unit. It may be seen that, for this species, apparent abundance has exhibited very wide fluctuations not related to the amount of fishing. The general level of catch per day's absence from port in recent years, with very much greater fishing effort and total catch than before the war, is as high as formerly. Biological data are not now adequate to determine whether the variations in apparent abundance are due to variations in avialability to the fishery, or to variations in actual abundance in the sea. Whatever the causes of the variations, it appears from figure 37 that effects of fishing at

Figure 35. Relationship between fishing intensity and total catch of yellowfin tuna in the eastern Pacific, and estimated relation between fishing intensity and average equilibrium catch, 1934 to 1953

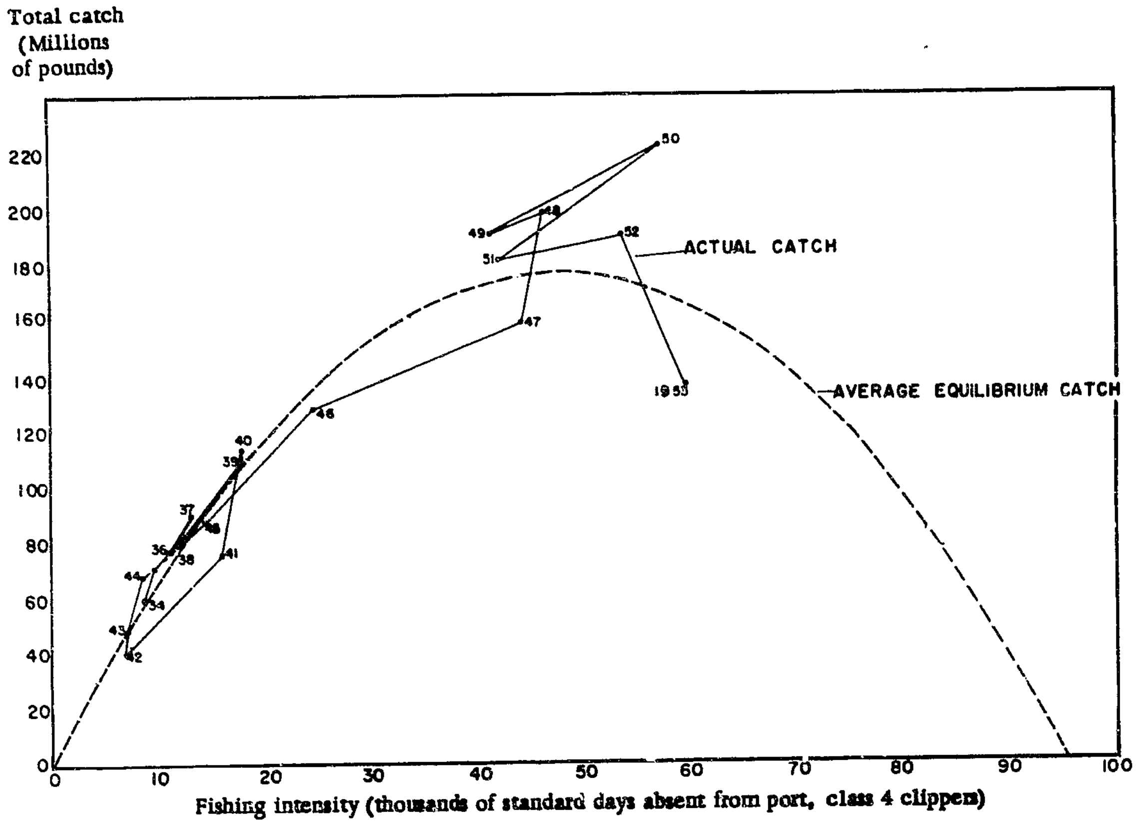


Figure 36. Number of clippers fishing regularly from United States west coast ports, 1932 to 1953

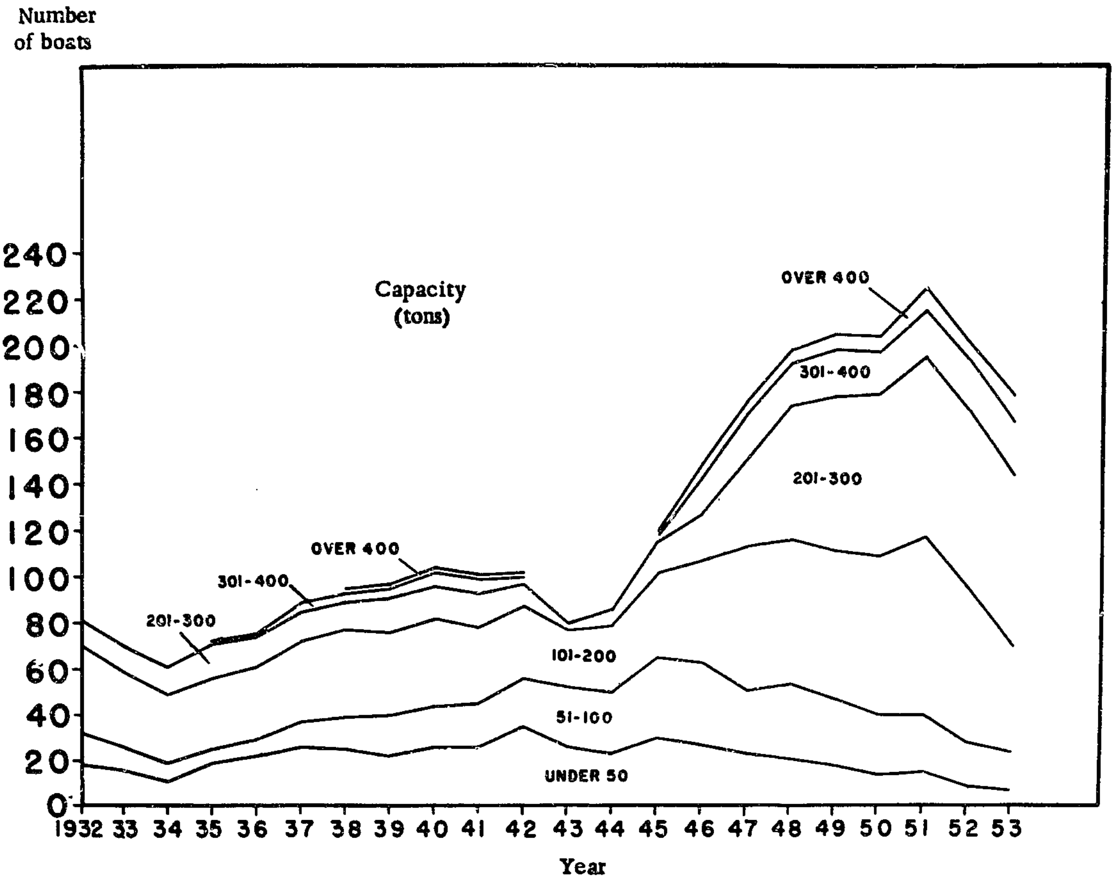
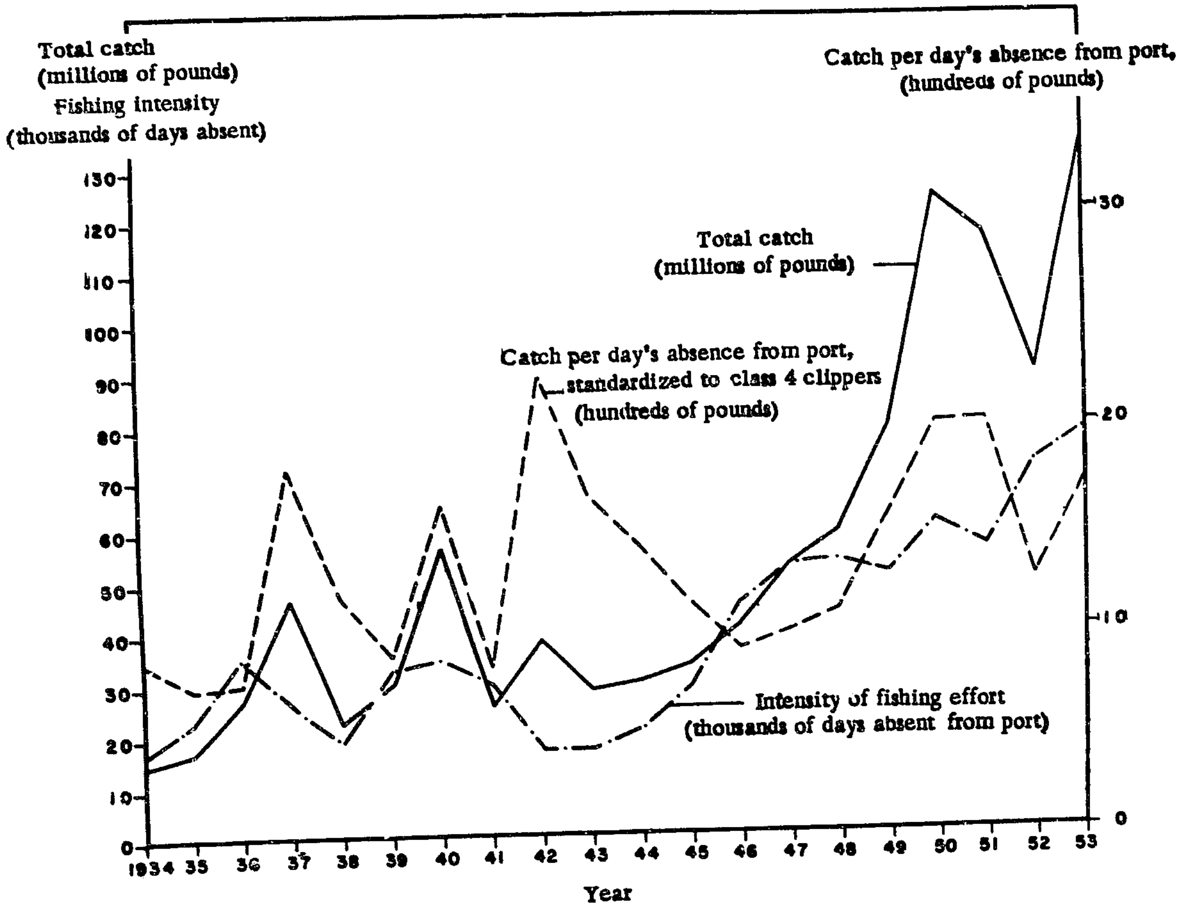


Figure 37. Skipjack tuna catch, catch per day's absence and fishing intensity in the eastern Pacific, 1934 to 1953



present levels on the abundance of skipjack are so small that they cannot be detected in the presence of variations due to other factors. It would appear that the skipjack resource being tapped by the eastern Pacific fishery can support a greater intensity of fishing before reaching the point of maximum average sustained yield.

Simultaneous occurrence of yellowfin and skipjack

The two tuna species occur very generally at the same places at the same times. Sometimes they are found in mixed schools, containing a mixture of members of the two species of similar size. Often, however, the species are schooled separately. It appears likely, from investigations to date, that the yellowfin tuna resource is in a more advanced stage of exploitation than the skipjack resource and that in an unregulated fishery the level of fishing giving maximum sustained yield of yellowfin will therefore be passed before that for skipjack is attained.

Two courses of action are possible at such time as it becomes necessary to establish conservation regulations: (a) action to maximize the sustained average catch of each species individually; or (b) action to maximize the sustained average catch of the aggregate of both species. The first course of action would result in a greater total sustained average catch than the latter, providing that it is possible, in practice, to design regulatory measures that differentiate control of fishing for yellowfin from fishing for skipjack. The practicality of such measures involves considerations of great complexity, both with respect to the behaviour of the fish and with respect to juridical, political and economic matters. The scientific staff of the Commission is not, at this time, prepared to make recommendations on this subject, since the scientific information respecting the behaviour of the fish is as yet inadequate for this purpose.

MANAGEMENT OF THE HALIBUT FISHERY OF THE NORTHEASTERN PACIFIC OCEAN AND BERING SEA

by

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(The mimeographed text of this paper appeared as document A/CONF.10/L.13)

Contents

The experiment of joint international regulation of the halibut fishery in the Northeastern Pacific Ocean by the nations directly involved has been both so unique and so successful as to set a pattern for the management of international coastal fisheries. A fishery which had been disastrously depleted by unrestricted fishing has been so restored as to be one of the best stabilized and most profitable to its fishermen.

When fishermen of the west coast of the United States and Canada despairingly demanded action by their Governments, the International Fisheries Commission (now called the International Pacific Halibut Commission) was established by treaty to investigate the situation. Intensive scientific research convinced the Commission that overfishing was the cause of the depletion and that soundly conducted joint international management by the two nations could restore the abundance of fish and the catch.

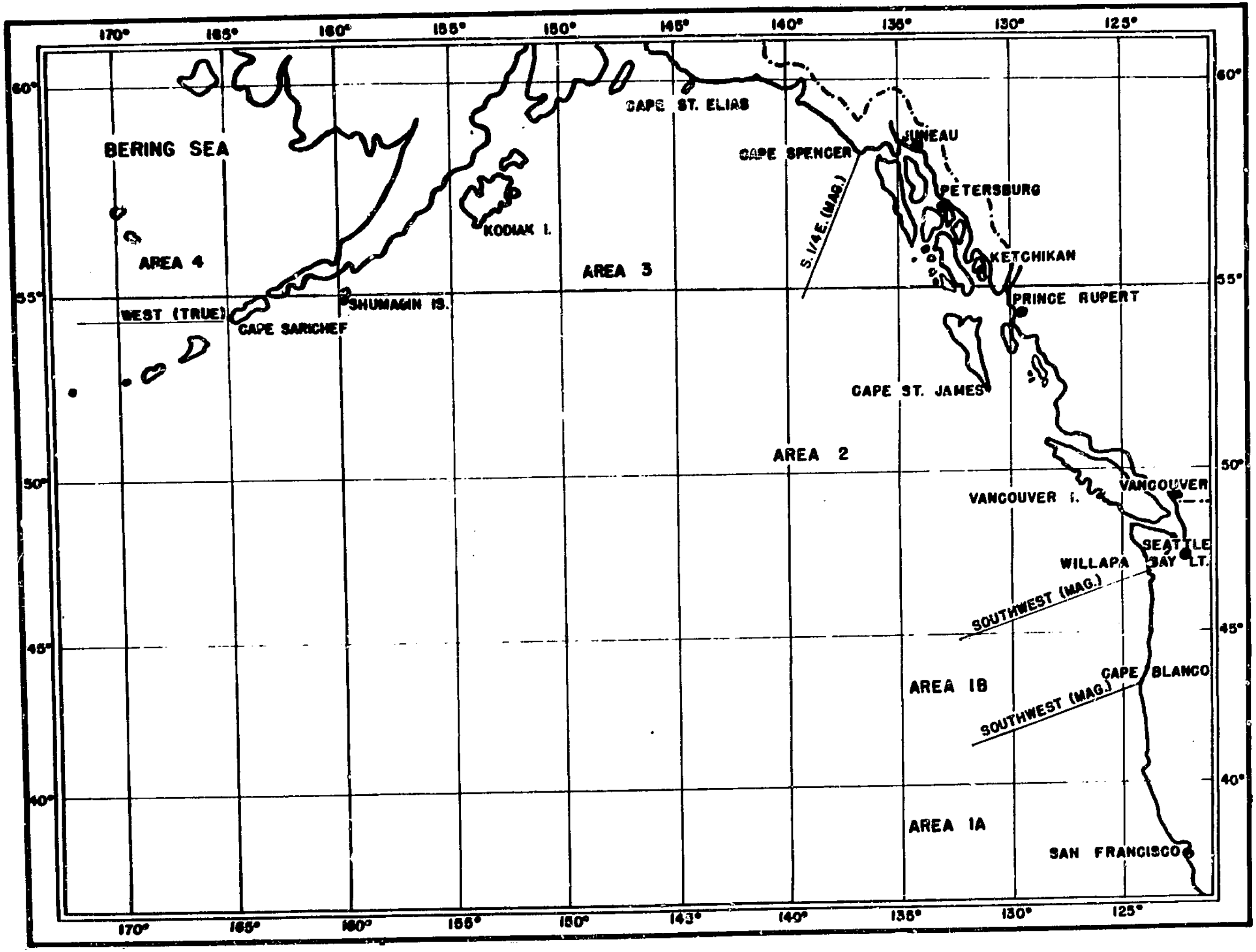
A new treaty then granted regulatory powers to the Commission. These powers have been so effectively exercised that the annual catch has been increased more than fifty per cent, and the entire catch is secured with little more than one-half the fishing effort. In 1954 the catch was the largest in all history.

It is believed that the experience of the Commission can be of value to others concerned with the management of marine fishery resources. The success achieved to date by the joint action of the two countries, each vitally interested in the outcome, may be a source of encouragement to other countries with a joint interest in some resource of the sea. In the following sections a brief summary is given of the condition of the fishery prior to regulation, the methods of regulation used, the results achieved and the new management problems that must be solved in order that maximum sustained yield may be achieved. Detailed information will be found in the references.

Early History of the Fishery

The commercial fishery for halibut in the northeastern Pacific began in 1888 off the southern end of Vancouver Island (figure 38). From the beginning it has been an international deep sea fishery, prosecuted jointly by the nationals of the United States and Canada, principally in extra-territorial waters but within 100 miles of shore.

Figure 38. Map of the Pacific coast of North America showing the halibut regulatory areas in effect during 1950



Increasing markets constantly brought about the addition of new and more efficient vessels to the fleet. Improvements in types of construction, in power and in methods of fishing enabled these vessels to extend their operations to more and more distant banks as fishing on the more accessible banks became less profitable.

The fishery expanded rapidly in sheltered waters and by 1910 extended some 700 miles northward to Cape Spencer in southeastern Alaska. Subsequent expansion took the fishery into unsheltered offshore waters, south to Oregon and California and north into the Gulf of Alaska. After 1920, the fishery expanded westward beyond Kodiak Island. By the late nineteen twenties, fishing was being carried on throughout the commercial range of the halibut, from northern California to the Bering Sea, a distance of more than 2,000 miles (Thompson and Freeman, 1930).[1/]

Early in the history of the fishery, it was recognized that the supply of halibut on the older banks was being reduced rapidly, but no general concern was shown. Declines in yield from the older banks were more than offset by gains in yield from the newly exploited ones. Total landings continued to increase until they reached 69 million pounds in 1915.

Events after 1915 changed this complacent attitude. Scientific investigations demonstrated a sharp decline in the abundance of halibut on the older banks (Thompson, 1916). Annual landings declined quickly to about 50 million pounds and were maintained at that level only by increased fishing effort and the exploitation of new banks. The decline led to demands for joint action by the United States and Canada to conserve the fishery, which culminated in the Convention for the Preservation of the Halibut Fishery of the Northern Pacific Ocean and Bering Sea, signed in 1923.

The convention established an annual winter closed season of three months, corresponding to the spawning season of the halibut. It provided for the appointment to the International Fisheries Commission of four non-salaried members, two from each country, to make an investigation of the fishery and to recommend measures for its preservation. Each country undertook to pay the expenses of its own members and one-half of the joint expenses of the Commission. The Commission has always acted as a unit, not as two national sections.

[1/] References in parentheses are to the bibliography at the end of this paper.

At the outset the Commission established the practice, which has been consistently maintained, that thorough scientific investigation shall precede every decision. It assembled a small scientific staff headed by a Director of Investigations and, in 1925, began a programme of statistical and biological research. It undertook the collection and analysis of all available historical information and of all existing statistics of the fishery and made the current collection of such data a part of its continuing programme. Its biological investigations included studies of migrations, racial characteristics, age and growth, age of maturity, fecundity and spawning, and early life history (International Fisheries Commission report, 1928).

Life and Habits of the Halibut

The halibut, Hippoglossus stenolepis Schmidt, is the largest of the flatfishes. It lives principally on the bottom over the continental shelf from very shallow water to depths as great as 1,100 metres. The species occurs in commercial quantities on the coast of North America upon grounds with bottom temperatures ranging from 3° to 8° centigrade, between the southern part of Bering Sea and northern California. It is found in greatest abundance, as indicated by pounds caught per unit effort, at depths ranging from 45 to 450 metres, the depths varying with the season and section of the coast (Thompson and Van Cleve, 1936). The original centre of greatest abundance appears to have been off the coast of British Columbia, but fishing has markedly altered both the absolute and relative levels of abundance throughout its range.

Male halibut mature from five to eleven years of age, with an average of nine years. The females mature from eight to sixteen years of age, with a mean of twelve, and are therefore much more susceptible to overfishing than are the males. Spawning occurs principally in December and January in well-defined spawning areas, at depths from 275 to 400 metres. The number of eggs produced by mature females is large and increases approximately as the weight (Kolloen, 1934).

Larval and post-larval development lasts from six to seven months. The larvae and post-larvae drift passively with the currents at depths down to 750 metres, gradually rising to the upper levels as development progresses. The post-larvae drift with the surface currents into shallow inshore waters where they settle on the bottom (Thompson and Van Cleve, 1936). With increasing size and age, the young move into deeper waters and gradually become available to the commercial fishery.

The fishery on the southern grounds[2/] is dependent mainly upon individuals seven to eleven years of age, with a considerable contribution by individuals up to sixteen years and a small contribution by the six-year olds. On the western grounds[2/] the fishery depends principally upon fish eleven to seventeen years old, with some contribution by older fish and some by fish down to seven years of age (International Pacific Halibut Commission report, 1954).

Growth in weight ranges from 15 to 30 per cent or more annually, depending upon age and grounds and probably other factors. It appears to continue throughout life, though the rate declines with age. The females grow faster than the males upon the same banks, live to an older age and reach a much larger size (Thompson and Bell, 1934).

The halibut is relatively long-lived, individuals over twenty years of age being quite common. Its longevity is a fundamental consideration in the development of any research or management programme. A considerable number of years is required to complete each population cycle, and the populations present at any time are the product or conditions during many earlier years.

Populations

Ascertaining whether the halibut on the numerous banks were a single biological unit or whether they formed several independent units was a prerequisite to determining their condition and what must be done to preserve them (International Fisheries Commission report, 1928). Tagging experiments

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[2/] The "southern grounds" lie between Willapa Bay, Washington, and Cape Spencer in southeastern Alaska and correspond to "Area 2", established by the Commission for regulatory purposes. The "western grounds" extend westward from Cape Spencer to the Aleutian Islands and correspond to "Area 3", recently divided into "Area 3A and Area 3B".

on important fishing grounds, between Vancouver Island and Unalaska Island, where over 98 per cent of the commercial catch was taken, showed that the mature halibut migrated widely within limits whereas the immature migrated very little. They revealed that the halibut to the west of Cape Spencer, Alaska, were practically independent of the halibut to the south of Cape Spencer and that the halibut in the two regions must therefore be considered and treated separately (Thompson and Herrington, 1930). The regions containing these two groups of populations were subsequently established as separate regulatory areas, Areas 3 and 2 respectively, and are so designated hereafter.

It was also found that there were few mature halibut in the southern region, and that the immature ones were divided into a number of smaller population units that were not only independent of the western group but also largely distinct from one another. Some of these population units might have been treated separately but, because they were all in about the same biological condition, could also be considered together (Thompson, 1936). Because it would be advantageous from an administrative standpoint to deal with as few stock units as possible, the smaller units in Area 2 were treated as a group until 1950.

Corroboration was sought and found in other investigations. Age studies revealed that the western stock3/ consisted of slower growing fish and contained more and older age classes. Morphometric studies indicated differences in body proportions and in numbers of vertebrae and fin rays. Studies of the distribution and draft of the eggs and larvae showed that the stock in each region was dependent upon its own spawners for its supply of eggs and young (Thompson and Van Cleve, 1936).

More recently, the small stock of halibut in southern Bering Sea has been studied to ascertain whether it is a distinct unit or part of the large population found south of the Alaska Peninsula. Hydrographic conditions unfavourable to spawning that exist in Bering Sea, the results of tagging

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3/ The term "stock" is used here and elsewhere instead of "population" to avoid the implications of unity and continuity usually associated with the latter term. Recent investigations strongly indicate some lack of unity even among the mature fish in Area 2 and in Area 3.

experiments, and the lack of females beyond the maximum age of immaturity in Bering Sea all indicate that the latter is the case.

Condition of the Stocks Prior to Regulation

Following the definition of the two major stocks of halibut, it became possible to evaluate the condition of each and the effects of unrestricted fishing. From the inception of a significant commercial fishery on the southern stocks in 1888, annual landings from Area 2 increased slowly and were well below the 10-million pound level as late as 1899. Subsequent growth of the fleet brought landings from Area 2 to the 50-million pound level by 1907, and to 59.5 million pounds by 1912, when all important grounds within the area were under exploitation. After 1912 the annual yields fell precipitously, in contrast with the amount of fishing, which declined slightly as a result of war-time conditions. After the First World War, two successive sharp increases in fishing, from 1919 to 1921 and from 1927 to 1929, produced only temporary increases in annual yield and on each occasion the catch declined to lower levels than had prevailed prior to each increase of fishing.

By 1930 the annual catch from Area 2 was only 21.4 million pounds, about 38 million less than in 1912, although all sections of the area were being fished intensively by a large fleet during eight months of the year (Thompson and Bell, 1934; Bell, Dunlop and Freeman, 1952).

The annual catch from the western stocks, in Area 3, increased rapidly from the beginning of that fishery in 1912. It reached 24 million pounds by 1915. Thereafter until 1918 annual landings declined although the amount of fishing remained relatively constant. From 1922 to 1929, continuous growth of the fleet caused a fourfold increase in the amount of fishing. The catch paralleled the increased fishing for the first two years, until 1924, in which year it reached 26.2 million pounds. Subsequent sharp increases in fishing failed to produce any material increase in yield from the area as a whole. On the longer fished grounds in the eastern two-thirds of the area, an active decline in yield occurred after 1925, in spite of successive increases in gear fished. In the entire area the annual take from 1925 to 1930 was maintained at about a 28-million-pound level only by extending the fishery to the most distant grounds.

In 1931, the catch from Area 3 as a whole totalled only 21.5 million pounds, or 4.7 million pounds less than in 1924, although fishing was much more intense and all grounds in the area were being exploited.

It was evident from the statistics for each area that the trends in yield were largely attributable to the changes in the amount of fishing (Thompson and Bell, 1934; Thompson, 1952). In Area 2 a reaction pattern involving a rise in catch with increased fishing and a subsequent decline of catch to a lower level than at the outset was repeated three times, the level of yield decreasing with each successive cycle. In Area 3 as a whole, the same pattern was evident during the 1926 to 1931 period, though not so distinct on account of the expanding range of the fishery. Its continuation after 1931 was prevented by regulation, which reduced and held fishing below the 1925 level.

The combined catch from Areas 2 and 3 reached 68.7 million pounds in 1915 but declined rapidly thereafter to an annual level of approximately 50 million pounds. The precipitous decline after 1915 can be attributed to the combination of unfavourable recruitment, growth and mortality conditions which must have existed in the dense virgin stocks then in Area 3 and to the declining yields resulting from overfishing in Area 2.

The abundance of halibut, as indicated by the catch per unit effort, decreased greatly in both areas with increased fishing. The catch per unit effort decreased about 65 per cent in Area 2 and about 80 per cent in the eastern, first-exploited section of Area 3 during the 1915 to 1928 period. Comparable decreases subsequently occurred in the central and western sections of Area 3 when these were exploited intensively. The decline was sharp during each period of increase in fishing intensity and tended to cease during periods of stable fishing, indicating that the decline was caused by the increase in fishing.

The relative abundance of halibut on different parts of the coast had been markedly altered by the fishery (Thompson, Dunlop and Bell, 1931). The high primeval abundance off the northern British Columbia coast had disappeared and the abundance on each ground from the north end of Vancouver Island in Area 2 to the most distant parts of Area 3 had become graduated according to the distance from port. It was clear that costs of operation, which are reflected in fishing intensity, had been a major factor in determining the relative size of stock from one ground to another and that the impact of the fishery had been great enough to overshadow natural fluctuations, if any occurred.

The annual closed season of three months, established by the reaty of 1923, proved economically desirable. It prevented fishing during the hazardous and often less profitable winter months and eliminated the great landings made when fishing was conducted upon concentrations of mature fish on the spawning grounds in Area 3 (International Fisheries Commission report, 1928). However, the fishery was still at liberty to increase indefinitely during the remainder of the year, which it did, thus largely nullifying the biological benefits of the closure.

With the continued decline in abundance very significant changes occurred within the stocks. The average size of halibut in the catch decreased on all grounds and the percentage of the economically less valuable small and undersized fish increased (International Fisheries Commission report, 1930). Shortly prior to 1930 the landings from Area 2, south of Cape Spencer, consisted largely of small fish under fifteen pounds. In many sections of that area a large halibut over sixty pounds had become a rarity. West of Cape Spencer, fish of large size were still numerous.

On the long and intensively fished southern grounds, few fish were surviving to the age of twelve years, the average age for the onset of maturity in females. The more recently and less intensively fished western grounds still contained many older fish and many mature females, survivors from the primeval stocks that existed prior to fishing. The production of spawn, as indicated by plankton sampling during the spawning season, was at a low level in Area 2 but still considerable in Area 3.

Tagging experiments provided some general estimates of the rate at which the largely immature fish in the southern region and the mature fish in the western region were being removed by fishing and by natural mortality (Thompson and Herrington, 1930). They showed that the removal rate on the long-fished southern grounds was much higher than on the western grounds and explained the observed differences in age composition and spawning. Estimates of growth, based upon age-length studies, indicated that growth rate was higher in Area 2 than in Area 3 and was higher than the natural mortality rate in both areas.

On the basis of general biological knowledge regarding the factors that control the size, composition and yield of fish populations, and of the evidence at hand, the Commission concluded that the stock in Area 2 had long been overfished and was in a very unsound biological condition, and also that the Area 3 stock was rapidly approaching the same condition. It expressed the conviction that the decline in abundance and yield could be stopped and that both could be increased by a proper reduction in the amount of fishing.

The Commission reported its finding to the Governments of Canada and the United States and recommended: control of the amount of fishing, by dividing the coast into areas and applying annual catch limits to the areas according to their individual needs; continuation of the winter closed season, to prevent fishing upon the spawning stocks when they were schooled for spawning; and closure of areas found to be populated by small fish, as well as prevention of the use of destructive gear, to permit more of the small fish to survive to maturity and to secure better economic use of them (International Fisheries Commission report, 1928).

Authority to regulate the halibut fishery by the methods recommended was granted to the Commission by a new treaty signed in 1930 and was broadened by succeeding conventions of 1937 and 1953. Regulations were made subject to the approval of the Governor General of Canada and of the President of the United States. Enforcement of the regulations was made the responsibility of already established enforcement agencies of the United States and Canadian Governments. The first year of actual regulation was 1932.

Biological Principles underlying Investigation and Regulation

In planning investigations and evaluating their results, and in adopting regulations, the Commission has been guided by the following generally accepted biological principles. The density and composition of a population depends primarily upon three variable factors: the number of young produced each year; the rate of growth; and the total mortality rate. Density is determined by the balance between the first two, which increase it, and the third, which reduces it. Composition, or proportion of sizes and ages, depends upon the mortality rate.

The annual production of young is related basically to the abundance of spawners and tends to decrease with reduction in the density of a population, other things being equal. Growth and natural mortality rates tend to decrease with age. Within limits, the growth rate tends to increase and mortality rates to decrease with reduction in the density of a population and vice versa. The mortality rate of commercial sizes increases with the intensity of fishing and decreases with less fishing.

A population subjected to a definite amount of fishing tends to come to stability or equilibrium at a definite density and to yield a definite catch. The density at which the population reaches stability decreases as the amount of fishing is increased and vice versa. The level of yield increases with increased fishing to a maximum at the optimum level of fishing, which gives the optimum density of stock, and decreases progressively thereafter with each further increase of fishing. Conversely, the yield of a population below optimum density increases with decreased fishing until fishing is reduced to the optimum amount to restore the optimum density of stock, and decreases progressively thereafter with further reduction of fishing.

Fishing less than the optimum is underfishing , and fishing more than the optimum is overfishing. Both are equally undesirable inasmuch as each fails to obtain the maximum sustainable yield that a population is capable of producing.

The involved general changes in density and composition of a population and its commercial stock as a result of fishing are complicated by physical changes in the environment which directly affect growth, mortality and the production of young or indirectly affect them by altering the abundance of food or of competitors or predators. They are further complicated by the time required for any change in environment or in the fishery to produce its full effect upon all age classes in the population, twenty or more years in the case of the halibut.

Regulation of the Fishery

Throughout the period of regulation which began in 1932, the Commission has endeavoured to hold the rate of removal by fishing slightly below the rate of replacement from reproduction and growth, without undue interference with commercial fishing. This would allow the halibut to live longer on the average and gradually result in the accumulation of more dense stocks of larger fish, containing a higher proportion of mature ones and capable of sustaining greater annual catches. Increases in the annual catches have been allowed whenever they appeared to be justified by increased stock density.

General control of the rate of removal by fishing has been achieved by establishing regulatory areas, containing independent or closely associated adult populations, in so far as was practicable from an administrative standpoint, and by limiting the annual catch from each area. Annual catch limits with closure upon attainment of those limits have been applied in the more important areas, Areas 2 and 3. Time limits have been used in other areas.

Administering catch limits has necessitated daily collection and tabulation of data regarding the number of boats operating, their size, their efficiency, their future plans and departures, and the area of origin of their catches. From these data the rate of capture has been determined, the date of attainment of each catch limit forecast and the date of closure announced well in advance.

Other measures adopted include: the closure of two nursery areas populated by small fish; the application of a minimum size limit; and prohibition of the use of types of gear known to capture undersized halibut in larger proportion than the setline gear normally used in the halibut fishery. The winter closed season established by the original treaty has been continued.

For administrative purposes, the Commission has required halibut boats over five tons net, to be licensed, to keep log records of their fishing operations and to make statistical returns regarding the amount and area of origin of their catches. It has made the validity of these licences contingent upon compliance with statistical and other provisions of the regulations. It has also required halibut dealers to keep accurate records of their purchases of halibut.

The basic method of regulation - limiting the catch and increasing it conservatively as the density of the stock increased - was a simple, practical method of applying the biological principles of fishing to overfished stocks. According to these principles, if natural mortality and fishing mortality are held below recruitment and growth, the stocks gradually increase toward their optimum density. Should the density of a stock be increased beyond its optimum, where the most favourable biological balance exists, further increases in catch would cause a revealing decline in the catch per unit effort.

With a long fishing season which made all commercial sizes available, the fishery itself could be expected to correct any major lack of balance in stock composition. If large fish become relatively too numerous when the stock approached its optimum density and were competing with the young and hindering recruitment, their higher relative abundance would shift the intensity of fishing to the large sizes and reduce them. If, on the other hand, the large commercial sizes became too scarce, their lower relative abundance would direct more of the fishing to the younger sizes and allow a larger percentage of the older fish to survive. Only when stock density reached the optimum for the natural distribution of fishing would it become necessary to examine the relationship between growth, natural mortality and recruitment to determine whether the yield from the recruits and the number of recruits could be increased by artificial adjustment of the intensity of fishing upon the different size or age classes of fish.

Unfortunately, changes in the fishery after 1940 sharply reduced the length of the fishing season and altered the distribution of fishing. These changes reduced the effectiveness of the regulations and of observations of their effect upon the stocks (International Fisheries Commission report, 1951a). They have made it necessary to modify to some extent the method of regulation, and make a much broader scientific foundation desirable for the future.

The Commission took such corrective regulatory action as it could under the convention of 1937, which permitted only one fishing season per year in each area. In 1951 two small underfished sections of Area 2 were established as separate areas and opened for a brief period at their most productive season after the remainder of Area 2 was closed. In 1952 the same was done with the far western section of Area 3. Some improvement in the utilization of the stocks in the new areas and an increase in yield resulted (International Fisheries Commission report, 1953).

Further regulatory changes were made in 1954 under the convention of 1953, which permits more than one fishing season per year in any area. The regular season in each important area was supplemented by a short season later in the year, when sections of the stocks not available during the regular season may be reached by the fishery. A further increase in yield resulted.

Fluctuations in the strength of year-classes, probably attributable to factors other than fishing, have been observed in some sections of the stocks in Areas 2 and 3. They have produced some short-term changes in the density of the stocks, which have been given due consideration in determining the catch that should be allowed.

Problems and Results of Regulation

Although the halibut regulations have always been based upon sound biological principles, it must be recognized that they have also been influenced in many ways by practical considerations. It has been necessary for practical reasons to control the amount of fishing indirectly, by limiting the catch or the length of the fishing season instead of the number of units of gear, although the latter is the primary determinant. The catch-limit method can be used only in an area where the total catch is sufficiently large and the season sufficiently long to permit determination of the rate of capture during the fishing season and announcement of the date when the catch limit will be attained and the area closed to fishing.

Impracticability of administration as well as the specific need to provide a fishing operation that would be economically profitable without overfishing has prevented general use of special areas and special fishing seasons to increase fishing on small underfished banks. Areas must be large enough to provide the potential fishing fleet with operating space, and the period of fishing long enough to provide the fleet with a profitable trip (International Fisheries Commission report, 1952).

Adjustment of opening dates has been necessary to make the distribution of fishing between areas as normal as possible. Some areas have been opened simultaneously to prevent abnormal concentrations of fishing effort which would have been inimical to successful fishing. Other areas have been opened at different times of the year to induce and maintain fishing in sections along the coast where it would otherwise have declined or practically ceased.

Enforcement problems have also influenced the determination of open seasons and the definition of regulatory areas. Enforceability has been an important determinant in regulating the retention of halibut caught incidentally by other fisheries, even when there appeared to be no biological objection. The retention of halibut caught incidentally by otter trawlers both in open and closed areas has been prohibited in recent years, partly for enforcement reasons, but chiefly on account of biological considerations (International Fisheries Commission report, 1948).

On account of the practical problems which constantly arise, the Commission has found it necessary to maintain close contact with all branches of the halibut fishing industry. The men in the industry have made their special knowledge of it freely available and have thereby made an important contribution to the success of regulation.

Recognizing the experimental nature of regulation, the Commission instituted and has maintained a system of observation of changes in the fishery and in the general density and composition of halibut stocks to ascertain the effect of its control measures. The relative density of the stocks available to the commercial fishery, as indicated by the catch per unit fishing effort, has been increased greatly on all banks. The average catch per unit effort has tripled in Area 2, south of Cape Spencer, and has doubled in Area 3, west of Cape Spencer, since 1931, the last year prior to regulation.

The composition of the stocks, as indicated by length and age samples from commercial landings, has changed markedly with increases in density. Fish of spawning size and age are present in greater numbers and constitute a larger proportion of the catch (International Fisheries Commission report, 1949; International Pacific Halibut Commission report, 1954). Recruitment of young has increased in Area 2, where years of overfishing had caused serious depletion.

Under the original system of regulation the annual catch was gradually increased from 44.2 million pounds in 1931 to 57.5 million in 1950. In 1952 and 1953, by the separate regulation of three small underfished areas, the annual catch was increased to 61.7 million pounds. In 1954, with the institution of short supplementary seasons in important areas, the catch reached 71.2 million pounds (International Pacific Halibut Commission report, 1955).

Economic gains have been as important as the biological ones. The improvement in catch per unit effort after 1932 maintained a profitable fishery in Areas 2 and 3 in spite of the relatively low prices of that period. Fishermen have been assured of profitable trips, and they and the dealers have been provided with an increasing supply of high quality, desirable size fish for their expanding markets.

The amount of fishing required to take the present larger catches has been reduced 50 per cent in Area 2 and 35 per cent in Area 3 from the pre-regulatory levels. The resultant saving in fishing effort and the saving in manpower and capital equipment have been put to other productive use and represent an economic saving as great as the value of the gain in poundage.

New Problems of Regulation

Profound changes have occurred within the halibut fishery as a result of successful regulation. The increases in density of populations have attracted more and more boats into the fishery and drastically reduced the period of fishing, despite the larger catches allowed. The fishing season, which had been nine months long when regulation began in 1932, was less than one month long in Area 2 and less than two months long in Area 3 by 1950.

In the early nineteen forties it became apparent that the shortening of the fishing season was destroying the seasonal balance of fishing that previously existed, and had become a threat to the continued success of regulation. To permit correction of this situation, in 1946 the Commission recommended treaty changes that would permit two or more fishing periods in an area annually - which were not allowed under the 1937 treaty then in effect - as a means of distributing fishing over a longer period of the year.

Statistical and biological studies were undertaken to determine the seriousness of the situation. They demonstrated that, with a single short fishing season, the stocks on some grounds in Areas 2 and 3 were not being exploited as formerly and the catches from them had declined in spite of the greater supply of fish available. The stocks on other grounds were in danger of over-exploitation, if this was not already occurring (International Fisheries Commission report, 1951a and b; Dunlop and Bell, 1952).

The investigations showed that the distribution of fishing which had made all commercial sizes of fish on every bank available to the fishery no longer existed, and that regulation of the distribution of fishing in time and space had become necessary at an earlier stage than would otherwise have been required. Regulation has therefore moved from its original simple stage into a more advanced and complex one. More precise information regarding the availability of the different parts of the stocks on different grounds at different seasons and concerning the effect of each change in distribution of fishing upon the factors which determine the density and productiveness of each stock becomes now of increasing importance.

Future Research

The objective of the halibut convention of 1953 is the attainment of maximum sustainable yield from the halibut populations. Accomplishing this will necessitate the solution of two complex interrelated biological problems: determining the age of capture that will give the maximum yield from recruits and determining the supply of mature ones required to provide optimum recruitment. The application of these biological facts, when secured, will involve the solution of the equally difficult regulatory problem of obtaining the correct amount and distribution of fishing.

Regulation in future will require knowledge of the relationship between growth rate and mortality rate at each age in each stock and of the changes that occur with changes in the density of stock; knowledge of the relationship between the density of spawners and recruitment; and knowledge of the availability of the different age classes on the different banks at different seasons.

To obtain this information the Commission has planned a broad research programme (International Pacific Halibut Commission report, 1955) and will make a beginning upon it during the current year. The programme provides for the following: study of the relationships between intensity of fishing, stock density and annual yield; continuous investigation of the age-composition and growth of the stocks on the more important banks to ascertain the growth and mortality rates at each age, and the density of spawners and recruitment;

repeated tagging experiments on a coastwide basis to determine the relationships between the stocks on different banks, the availability of different sections of the stocks at different seasons, and the general fishing and natural mortality rates; also, study of the factors which influence recruitment, growth and natural mortality.

With the additional basic knowledge that will be derived from its projected research programme, the Commission confidently believes that present and future problems of regulation can be solved and the goal of maximum sustainable yield achieved.

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THE INTERNATIONAL FRASER RIVER SOCKEYE SALMON FISHERY

by

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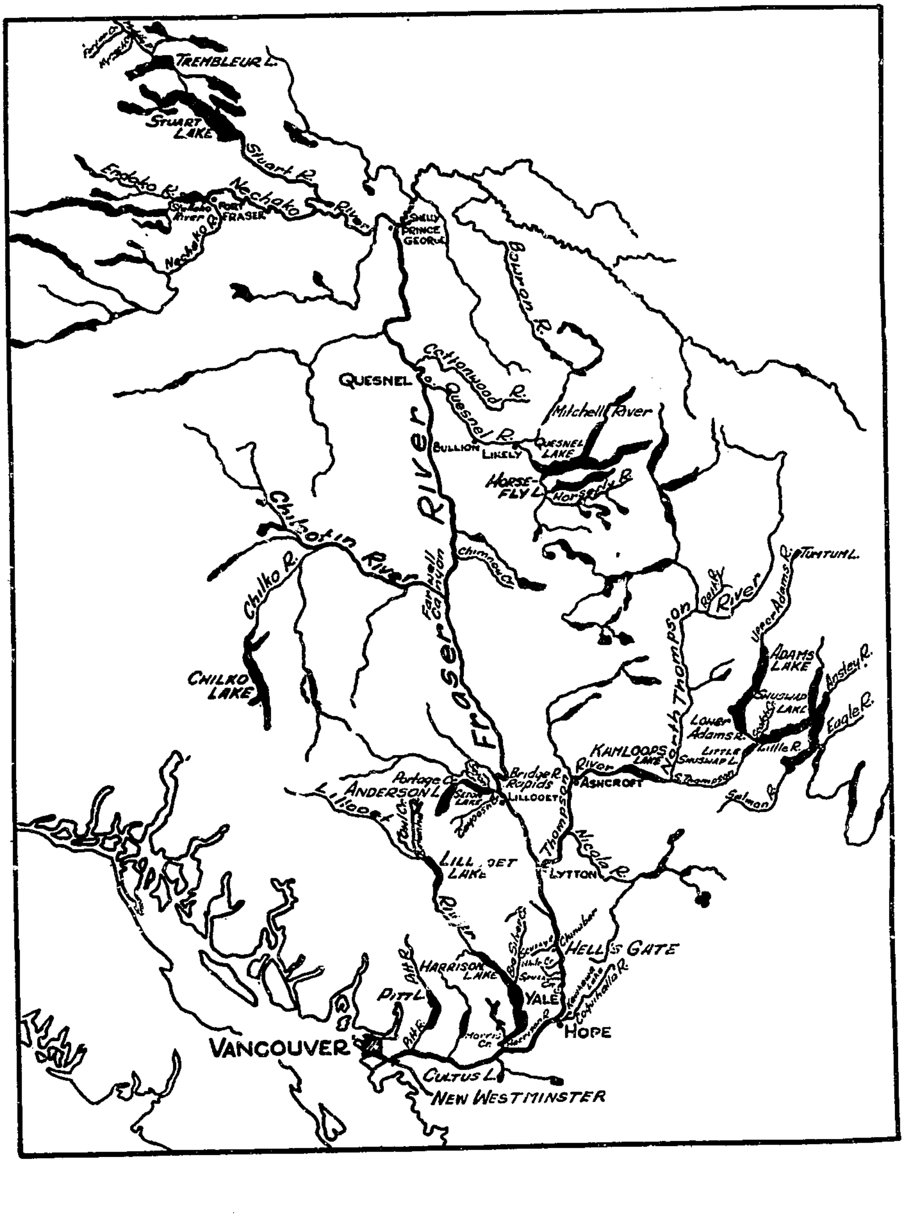
(The mimeographed text of this paper appeared as document A/CONF.10/L.17 and Add.1)

Contents

The Fraser River sockeye salmon fishery is one of the oldest commercial fisheries [illegible] North America. Its history includes a fairly rapid development by the fishermen of both Canada and the United States and then a disastrous decline in production, followed by years of negotiation by imaginative leaders of both countries to obtain international regulation. In 1937 a convention was concluded between Canada and the United States which created the International Pacific Salmon Fisheries Commission. The Commission's purpose was to determine the cause of the "billion dollar decline" in the fishery and then, after eight years of scientific investigation, to regulate the fishery in such a manner as to assist in restoring it while ensuring an equal sharing of the allowable catch by the fishermen of each country.

Figure 39. Watershed of the Fraser River, British Columbia



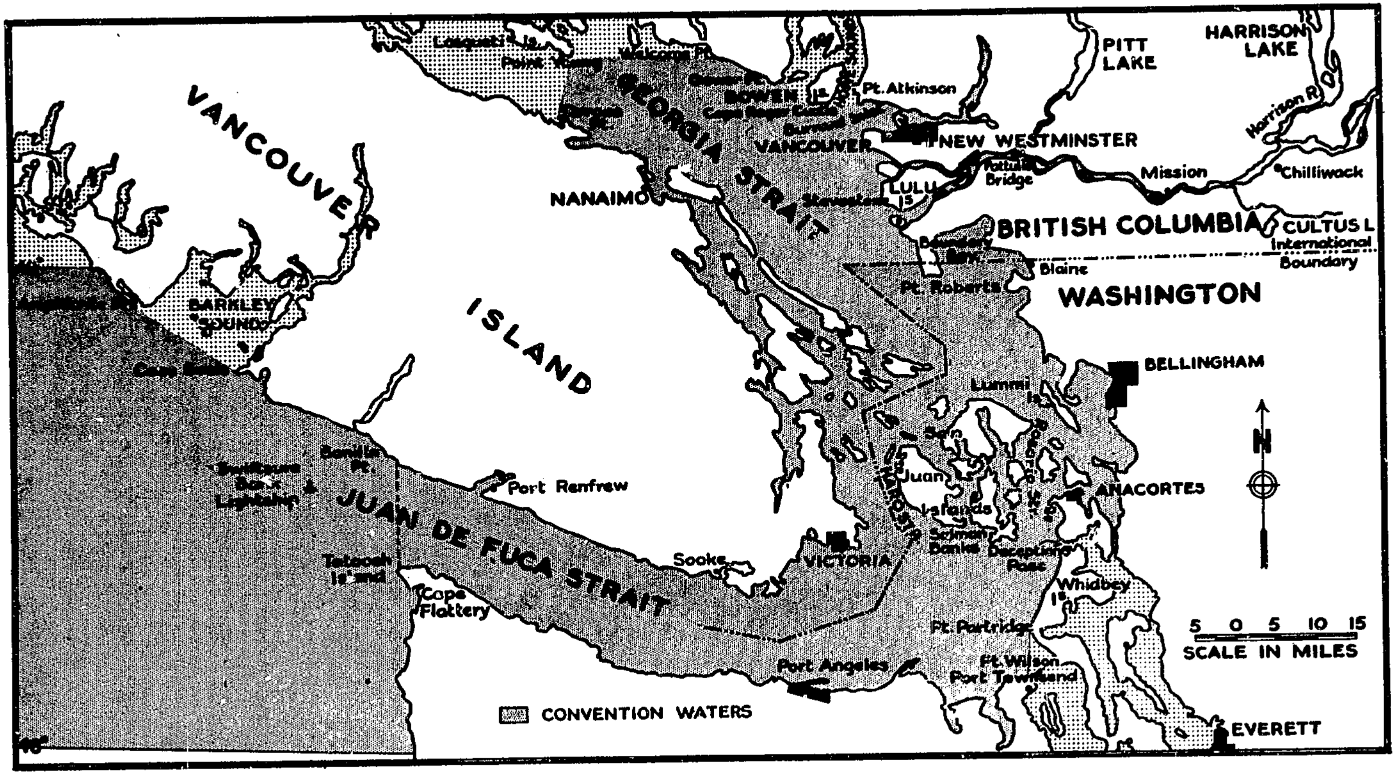
The work of the Commission may be considered as comprising five phases: (1) scientific investigation and determination of the cause of the decline in the fishery; (2) investigation and correction of the chief factor causing the decline; (3) designing regulations to permit rapid rehabilitation without stoppage of fishing; (4) development of effective management policies; (5) scientific investigation and protection of the fishery from the adverse effects of an expanding industrial civilization.

The story of the Commission's operations is one of success; it includes the restoration of millions of dollars to the annual income of the industry and a record of seventeen years of complete harmony in the international control of an international fishery. No treaty of any kind has been more eminently successful than the Sockeye Salmon Fisheries Convention between Canada and the United States. The story of the Fraser River sockeye fishery portrays the benefits to be derived when nations concerned forget their national competitive interests and unite through the media of science and agreement to solve an international fisheries problem.

Description of the Fishery

The Fraser sockeye salmon (Oncorhynchus nerka) reproduce in ten major stream-lake systems of the Fraser River watershed, an area encompassing 90,000 square miles and lying entirely in the Province of British Columbia, Canada (figure 39). The adult sockeye, gregarious and anadromous in nature, approach the west coast of Vancouver Island (figure 40) from the north as they develop maturity and migrate to the Fraser River by either of two routes. A small and variable percentage of the fish follow the east coast of Vancouver Island, thus becoming available exclusively to Canadian fishermen. The majority of fish follow the west coast of Vancouver Island and enter the Strait of Juan de Fuca, where they become available to fishermen from both Canada and the United States, first on the high seas and then in the territorial waters of each country. The last commercial fishing operation they encounter is a large gill net fleet, exclusively Canadian, which is located in the lower fifty miles of the Fraser River proper, below the town of Mission. Beyond this, native Indians residing in the upper watershed have always taken a limited number of sockeye for food,

Figure 40. Map showing commercial fishery waters affected by the Sockeye Salmon Fisheries Convention



drying them on racks for a winter supply. The inherent right of the Indian to take salmon in his accustomed place and manner is recognized by the Governments of both Canada and the United States.

In Canada commercial canning operations began in 1866 and were continued on a limited scale until 1893, when they were greatly expanded and an annual output of several hundred thousand forty-eight-pound cases was attained. The United States sockeye salmon canning industry, which began in 1891, reached full-scale operation by 1897, after which the annual catch of United States fishermen exceeded that of the Canadian fishermen. Over a period of twenty years, from 1894 to 1913, the Fraser River proved itself to be the greatest sockeye salmon river in the world by producing an estimated total catch of 180 million salmon.

The Fraser sockeye salmon do not become available to the fishery until they cease feeding, which is usually when they are in either the high seas area or the territorial waters of Canada immediately adjacent to the entrance of the Strait of Juan de Fuca. As they cease feeding and start their inshore spawning migration, they start to "show" at the surface and become available to such gear as purse-seines and gill nets. A United States purse-seine fleet started operations on the high seas in 1918, but only during the past few years have Canadian purse-seine fishermen begun operations at the entrance to the Strait of Juan de Fuca. Sockeye fishing by United States fishermen has always been carried on by purse-seines, traps and gill nets, with traps being eliminated by the State of Washington in 1934. The Canadian fishery, until the past few years, has been centred off the mouth of the Fraser River and in the lower fifty miles of the Fraser River estuary and has consequently been composed mainly of gill netters. These existing fisheries would be capable of exterminating the sockeye population if no restrictions were placed upon them since the Canadian gill net fishery alone is capable of taking 98 per cent of the annual sockeye run. Periodic closed seasons, both weekly and seasonal, have always been in effect in the fishery of each country, and there is no clearcut evidence of depletion before 1913, even though by that time United States fishermen were taking the major share of the annual catch.

In 1913 rock which was being moved to facilitate railway construction was dumped into a restricted canyon in the lower Fraser River known as Hell's Gate, where it created an almost complete barrier to adult salmon en route to their spawning grounds. This barrier was further increased by a major rock slide in 1914 that was associated with the same railway construction. Vigorous efforts were made by the Canadian Government to remove the rock, and by 1915 the areas was declared clear to migrating salmon. However, the decline in production was almost disastrous: the catch for the four-year period from 1917 to 1921 fell to about 15 per cent of what had previously been considered normal. The relative decline in the areas affected was actually greater than this as a substantial part of the residual production was maintained by unaffected but limited producing areas located below the obstruction.

Investigations and Policies of the International Pacific Salmon Fisheries Commission

Coincident with the decline in production and the declaration that the obstruction no longer existed at Hell's Gate, almost frantic arguments occurred as to whether overfishing or competitive fishing by the fishermen of either or both countries was responsible for the continued low level of the annual runs of Fraser River sockeye. It became increasingly apparent that international action would have to be taken to bring about the restoration of the fishery. On 28 July 1937 an international agreement was ratified by the United States and Canada. Known as the Sockeye Salmon Fisheries Convention, it set up the International Pacific Salmon Fisheries Commission consisting of three members from each country. The Commission was instructed in the convention to protect, preserve and extend the sockeye salmon fishery of the Fraser River and to that end was given authority to investigate the species. The Commission was given eight years to devote to investigations before its powers were expanded to include regulation of the fishermen of both countries, both in territorial waters and on the high seas, with the understanding that the allowable catch should be divided as nearly equally as practical between the fishermen of the two countries.

Chief cause of depletion of stock

Investigations of the Commission, conducted by a carefully selected scientific staff, revealed that the Hell's Gate obstruction still existed, and that whether it constituted a delay or a complete block to salmon en route to their spawning grounds depended on variations in the water level during the year and from year to year. The relationship of conditions at the obstruction and the success of reproduction in terms of returning adults was carefully detailed by Dr. W. F. Thompson in 1945.[1/] On the basis of the available scientific evidence the now famous "hydraulically perfect" and self-operating Hell's Gate fishways and also fishways at Bridge River Rapids and at Farwell Canyon on the Chilcotin River were constructed at a cost of approximately $2 million. The funds were supplied in moiety by the two Governments, in accordance with the terms of the convention.

The beneficial effects of the fishways at Hell's Gate, partially in use by 1945, were not evident until the return in 1949 of the first adult offspring from parents that had used the fishways. Increased escapements to the spawning grounds were known to have occurred in 1945 as a result of the fishways but it was found with surprise that the rate of reproduction of fish using the fishways was 100 per cent higher than the rate of reproduction of those few fish that had managed to overcome the obstruction in previous years. The evidence of increased rate of reproduction of the fish using the fishways proved to be of great importance in leading to a new approach to salmon fishery management. This approach emphasized study of the requirements for sockeye to reproduce successfully.

Ecological investigations and scientific management

A salmon, being a cold blooded animal, is a slave to its environment. Its spawning migration is timed so that the environmental requirments of reproduction are attained at the right moment. Its ability to store energy and go without food is an inherited morphological characteristic arising from the restricted feeding time and lack of available food during its spawning migration in fresh water. The

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[1/] International Pacific Salmon Fisheries Commission, Bulletin, No. 1 (New Westminster, British Columbia, 1945).

amount of energy stored is inherently established and there is sufficient for the purposes of migration, mating, nest-building and spawning before death, which inevitably occurs a few days after spawning. There is little tolerance to cover newly created obstructions or artificial delays in carrying out its reproductive functions. The spawning migration and spawning of the sockeye are therefore timed to meet the requirements of successful survival, which include its arrival on the spawning beds at the proper stage of the annual water temperature cycle. This timing of spawning with the annual temperature cycle also ensures that the feeding fry emerge when the zooplankton upon which they feed are approaching a peak in their abundance. Migration of the fingerlings from their lacustrine environment also takes place in the early spring just after the ice breakup, in order that they may enter the ocean when marine food organisms are approaching their season of abundance. The possible sensitivity of the fish to these relationships is illustrated elsewhere by the tremendous fluctuations in the annual success of reproduction of certain marine species such as the California sardine (Sardinops caerulea).

It is also of considerable biological significance that the annual run of sockeye salmon to the Fraser River is composed of discrete units, each migrating from the sea at its own specific time and spawning in a specific area in accordance with its own individual requirements for survival. Within each unit the numerical frequency of the migrants, spawners or deaths, when related to time, tends to form a normal curve with a range of approximately thirty days. These units are commonly referred to as "populations", "runs" or "races", and since they return each generation to the same spawning area they are commonly identified by the name of the area in which they spawn. Such a unit may be defined as a race if it consists of a homogeneous population with each member spawning in a particular area that offers a generally uniform reproductive environment.

The evidence of increased rate of reproduction of the fish which used the fishways, when considered together with the great mass of miscellaneous data on the character of the migration, reproduction and fresh water environment of the Fraser sockeye, led to an entirely new concept of salmon fishery management. This concept is that "The character of the migration of a race is related to the character of the environmental cycle in the reproductive area, the timing being controlled indirectly by the solar cycle, hence the maintenance of maximum productivity in a fishery depends upon the maintenance of normalcy in the character of the escapement". The failure of early and late arrivals at each spawning area to reproduce at the maximum rate led to the establishment of a second concept which may be considered in part as a modification of the first. It is believed that only the main part of the run is properly related to the normal reproductive cycle and that the tails of the frequency-time curve consist of variants not properly adjusted to the cycle. It may be that the beginning and end portions of the runs have natural functions such as bringing about a genetic adaptation of the population to different adjoining environmental areas, but normally they do not appear to be of value in maintaining a maximum population.

The block at Hell's Gate increased the mortality rate over that caused by the fishery by an amount which resulted in serious depletion. There were two effects of the delay at the obstruction: (1) utilization of stored energy in trying to pass the obstruction resulted in the migrant spawner's either not reaching the spawning ground or else arriving there in such a weakened condition that its spawning was ineffective; (2) delayed arrival on the spawning grounds resulted in improper timing with the normal environmental cycle and therefore a low survival rate among the eggs deposited.

The decline of the racial populations of sockeye salmon reproducing above Hell's Gate brought about a condition which has led to development of another important management principle. The decline completely unbalanced the phenomenon which is commonly referred to as "quadrennial dominance in productivity". Originally all these races had such a marked quadrennial dominance in productivity in the same cycle that far more sockeye were produced in one cycle than in the other three cycles combined. Historical records show that this quadrennial dominance was stable and had existed on the same cycle for at least ninety years. But the Hell's Gate slide was sufficiently severe in its effect to destroy the great runs of every fourth year.

A problem arose when, the dominant year runs having been decimated, the escapements began to increase in every cycle. The problem was to decide whether large racial escapements should be permitted every year regardless of the size of the run, or whether, as a new management principle, fishing pressure should be equal every year regardless of any indicated variability in the annual productivity and escapement. From 1946 through 1950 regulations were formulated on the basis that the few tens, hundreds, or thousands of sockeye on the spawning grounds, if they existed at all, should be allowed to increase in number each year. It was decided, however, that the practice of regulating to exert even fishing pressure should be initiated in 1951. During the period 1946 to 1950 little was known about the cause of quadrennial dominance, and, furthermore, the racial escapements in most instances were less than those recorded for all years prior to 1913. After 1950 the increasing escapements were observed to be producing at a dominant rate each year. Each year-class appeared to be struggling for supremacy in a sense. Two examples of returning quadrennial dominance already existed, each returning on a different annual cycle and each returning on a cycle different from the original one. Thus, evidence was available to show that quadrennial dominance would re-form as the runs approached their original abundance and that it need not occur in all races on the same year. Evidence was also available to indicate that dominance would not re-form until at least one year-class reached a size approaching the reproductive limits of the area.

Data have now been collected for a sufficient period of time to indicate that dominance is caused by an internal cycle in the lake-rearing area and that this internal cycle may not function in exactly the same manner in every case although the result in establishing quadrennial dominant productivity is the same in each case. This internal cycle must be established by the salmon themselves. and for this reason there is a high rate of production each year until the numerical strength of the population approaches normalcy. A period of adjustment then follows, which results in one year-class gaining numerical strength while the productivity of the other three year-classes declines. It is becoming increasingly obvious that the dominant year sets off the internal cycle which controls the sockeye population for the following three years. At the end of these three years the controlling internal cycle will eliminate itself, thus allowing the fourth year run to produce at a maximum rate. Failure to establish even fishing pressure in the off years would extend the internal cycle into the fourth year, and productivity under such circumstances would be below normal.

The Commission's basic management policies are conceived to produce a maximum sustainable catch with a minimum of escapement. These policies can be summarized as follows: (1) Treatment of each "race" or spawning population as a separate -

management problem. (2) Maintenance of normalcy in the escapement and, where possible, the obtaining of the escapement from the peak of the run of each population as it proceeds upstream. (3) Maintenance of even fishing pressure from year to year, regardless of the size of the unit run, unless that particular run has been reduced in size by temporary abnormal reproductive environment or unless reproduction has been unusually good and there is danger of the potential escapement exceeding the requirements of the reproducing area.

Benefits of regulation

The remarkable increase in the annual Fraser River salmon catch for each of the past four years over that obtained in the four preceding parent years, respectively, has completely justified the Sockeye Salmon Fisheries Convention. It is evident, from examination of the magnitude and consistency of the increases in catch, that the purpose of the convention - to protect, preserve and extend the sockeye salmon fishery of the Fraser River system - is being fulfilled. The sockeye catch for 1954 was 9.5 million fish as compared with a catch of 2.1 million for the brood year 1950. The catch in 1953 was 4.02 million fish compared with 2.07 million in 1949. In 1952, some 2.2 million sockeye were taken compared with 1.8 million caught in the brood year 1948. The catch of 2.4 million sockeye in 1951 was a spectacular increase over the 443,000 taken in 1947.

The total catch for the four-year period from 1951 to 1954 was 18.2 million salmon compared with 6.4 million taken in the previous brood years of 1947 to 1950. The current wholesale value of the increase in the catch for the past four years is $42.19 million.

Regulations have been designed to meet the terms of the convention, which specify that the allowable catch be divided equally, as nearly as may be practical, between the fishermen of Canada and those of the United States. These regulations have permitted Canadian fishermen to take 9.15 million sockeye during the past four years while United States fishermen took 9.08 million. The difference - only 68,000 fish - in favour of Canadian fishermen represents practical equality in the catch, or 50.2 per cent for Canada and 49.8 per cent for the United States.

The current annual pack of sockeye salmon represents about 56 per cent of the sockeye packed during the four-year period, 1910 to 1913, preceding the Hells's Gate disaster. Current production is a great increase over the 15 per cent level of production experienced after the disaster but is still considerably below the

100 per cent level of potential production. However, from a biological standpoint, there is reason to believe that the current trend of increased production will continue.

The accomplishments of the Commission have been attained without creating a single controversy between nationals of Canada and the United States in spite of the fact that many emergency restrictive regulations have been imposed on the fishermen of either or both countries.

Future Problems

One of the greatest obstacles facing the Commission's fishery management programme in future years is the possibility of development of new types of fishing gear and expansion of fishing areas, both of which tend to interfere with use of the sensitive management tools developed for dividing the allowable catch and for permitting the maximum catch of the many individual populations which comprise each annual sockeye run to the Fraser River. As the fishery in each area is capable of taking more than its permissible share of the catch and each nation is capable of taking considerably more than its allowable total, it is obvious that sensitive controls for management are required at all times. It is becoming obvious also that the adverse sensitivity of the escapement to the effects of the fishery requires that these controls be used carefully if maximum productivity is to be maintained.

A second major problem threatening the survival of the individual sockeye populations of the Fraser system is the rapid industrial expansion of the region. This expansion necessitates development of large quantities of hydroelectric power with consequent obstructing dams; it is accompanied by denuding of the watershed by logging operations, and by pollution from mining development and manufacturing plants and from the ever-increasing population itself. The adverse effects of industrialization on anadromous fish either have not been prevented or have been only partially prevented when they have occurred elsewhere in the world. The question is whether a proper element of mutual tolerance and respect can be brought about between development of general resources and development of the salmon resource in the case of the Fraser River basin. The successful operation of the Commission is an outstanding example of how such a balanced situation can only exist when action is governed by unbiased assessment of the facts. The Commission is striving, through scientific investigation, carried out in advance of increased use of the natural resources of the Fraser basin, to find ways of harmonizing industrial development with the rapidly improving sockeye fishery.

The Fraser River is a Canadian stream and the natural resources utilized in industrial development are all part of Canada's national economy. Enactment of necessary measures for protecting the international sockeye fishery from industrial development is therefore not primarily an international matter but depends upon a national interpretation of what provides the greatest good to the greatest number of people in Canada. The latter is an entirely fair consideration and that consideration is based to quite an extent on the value of 50 per cent of a rapidly rising sockeye catch. If the cost of maintaining the salmon fisheries exceeds the value received, Canada could hardly be expected to continue to support the necessary fisheries' protection. Fortunately, the current value to Canada of the sockeye resource is sufficiently great to warrant full fisheries' protection, and it is being provided. It is also fortunate that Canada's income from the fishery is destined to increase substantially in the years to come.

The International Pacific Salmon Fisheries Commission will continue to improve its management of the fishery as new facts are obtained and will exert every effort to develop scientific methods for protecting the future of the fishery from dams, diversions and pollution, forms of industrialization which may eventually become so widespread that they may be regarded as potential destroyers of the entire salmon resources. Thus, the fulfilment in the years to come of the terms of reference of a great and successful international treaty will signify that international agreement based on facts is an agreement in principle, and only international harmony can come from such an agreement.

THE INTERNATIONAL WHALING COMMISSION

by

Remington Kellog, Chairman
International Whaling Commission

(The mimeographed text of this paper appeared as document A/CONF.10/L.18)

Historical development

Contracting Governments have at various times agreed to establish international commissions under the provisions of treaties. Some of these commissions are authorized to exercise regulatory powers over the operations of the fishing vessels of the contracting Governments, both inside and outside territorial waters. The authority of other commissions, as for example the International Whaling Commission, is limited to amending, subject to the approval of the contracting Governments, the regulations written into the treaty.

It is now recognized that unrestricted whaling and the ensuring depletion or destruction of world whale stocks will seriously affect the economy of countries dependent on their own facilities for the procurement of edible fats. Conservation of stocks of whales in the oceans of the world, or even those frequenting limited areas of oceanic waters, cannot be promoted successfully by unilateral action on the part of one Government. Many whales make annual migrations from summer feeding grounds in the colder waters to winter calving grounds in the tropics. Conservation of existing whale stocks can be accomplished only by the concerted action of Governments which recognize the necessity of maintaining this natural resource of the sea. International agreements for the regulation of whaling have been in force for more than twenty years; the first was sponsored in 1930 by the Economic Committee of the League of Nations. That convention entered into force on 18 October 1934, but it soon became apparent that its provisions did not adequately restrict the exploitation of whale stocks.

Consequently, Governments that had a major economic interest in whaling were cognizant of the urgency of convening a conference in 1937 to adopt more restrictive regulations and to control further the operations of this industry. The basic agreement of 1937 required the observance of closed operating seasons for both factory ships and land stations; prohibited the taking of whales of certain species already threatened with extinction; prohibited the taking of female whales with calves or suckling whales, and of blue, fin, humpback and sperm whales below the minimum lengths prescribed for each species; required full commercial utilization to be made of every part of every whale taken; and limited the time in which, from the time of catching, whales had to be treated in a factory ship or land station, as the case might be. In general, the purpose of the agreement was to limit the number of whales killed and to prevent the waste of whale material.

While the 1937 conference was aware that the agreement it formulated would not meet the existing situation adequately, it decided that a year should elapse before additional restrictions were imposed on the taking of whales. The protocol formulated by the 1938 conference gave further protection by such additional restrictive measures as (a) prohibition for one year on taking humpback whales by factory ships in the waters south of 40° south latitude; (b) establishment of a sanctuary for baleen whales in the waters south of 40° south latitude, from 70° west longitude westwards as far as 160° west longitude, for a period of two years from 8 December 1938: (c) prohibition of the operation elsewhere within a period of twelve months of factory ships that had operated in the Antarctic; and (d) closing of certain dependent waters to the operations of factory ships.

Although the 1938 conference recognized that an over-all quota would be the only effective method for limiting antarctic whaling, it was not until 1944 that this provision was included in an international agreement. At that conference the quota established for the ensuing antarctic season was 16,000 blue whale units. This quota represented two thirds of the average catch in the antarctic during the six prewar years.

The whaling conference at Washington in 1946 took cognizance of the need to safeguard for future generations the great natural resource represented by whale stocks. Consequently, the codification of existing regulations was undertaken in the light of the necessity for proper conservation of whale resources and orderly development of the whaling industry. At that conference the contracting Governments agreed to establish an International Whaling Commission with a view to devising effective administrative procedures for modifying regulations from time to time without calling other international conferences to conclude a new agreement or protocol in each instance.

The main responsibility of this Commission is to amend from time to time the provisions of the schedule annexed to the 1946 convention, which are, in effect, regulations governing the conduct of whaling by contracting Governments. These regulations relate to the general conservation and utilization of whale resources, including determination of (a) protected and unprotected kinds of whales; (b) open and closed seasons; (c) open and closed waters, including the designation of sanctuary areas; (d) size limits for each kind of whale; (e) time, methods and intensity of whaling, including the maximum catch of whales to be taken in any one season; (f) types and specifications of gear, apparatus and applicances which may be used; (g) methods of measurement; and (h) catch returns and other statistical and biological records.

The Commission is also charged with responsibility for taking action, either independently or in collaboration with other Governments and public or private agencies, to (a) encourage, recommend or, if necessary, organize studies and investigations relating to whales and whaling; (b) collect and analyse statistical information concerning the current condition and trend of whale stocks and the effects of whaling activities thereon; and (c) study, appraise and disseminate information concerning methods of maintaining and increasing whale populations.

Organization

Seventeen countries have become parties to the 1946 International Convention for the Regulation of Whaling and are actively participating in the work of the International Whaling Commission, which was organized in 1949 and held its first meeting in London in that year. Each contracting Government is represented on this Commission by one member, a commissioner, who may be accompanied at annual meetings by one or more advisers.

The Commission, under authority vested by article III of this convention, has set up two committees: a Scientific Committee, to evaluate current scientific and statistical information with respect to whales and whaling, to review current scientific research programmes of Governments, other international organizations and private groups, and to consider such additional matters as may be referred to it by the Commission; and a Technical Committee, to review and consider the laws and regulations of various Governments, annual reports on infractions submitted by Governments, questions involving the time, manner and intensity of whaling operations, and such additional matters as may be referred to it by the Commission.

The International Bureau for Whaling Statistics at Sandefjord, Norway, on the basis of reports submitted by responsible governmental agencies, prepares a statistical summary of the results of whaling operations in the antarctic and elsewhere for each season. These tables indicate the number and sex of each kind of whale taken, average size of sexes, measurements of fetuses (with length of female and date measured) and oil production. This bureau has also submitted charts and tables showing the number and sex of each kind of whale taken, in squares of 10° length and 10° breadth, in the antarctic during the 1937/38 and 1938/39 seasons as well as from 1945/46 to 1951/52, inclusive. These tables also show the mean values per day of work of the catcher, in terms of blue whale units and barrels of oil.

Since all modifications of the whaling regulations are required to be such as are necessary to carry out the objectives and purposes of the 1946 convention, and must be based on scientific findings, these statistical data and special research reports serve as guides to the Scientific Committee in reaching decisions relative to the continuing effect of whaling operations on kinds of whales in specific areas and in making recommendations for appropriate action by the Commission.

The Technical Committee has been chiefly concerned with (a) annual examination of reported infractions and pertinent recommendations thereon; (b) review of the legislation and regulations promulgated by contracting Governments to implement the 1946 convention; (c) adoption of a standard log-book for recording the catch; and (d) questions involving the time, manner and intensity of whaling.

Accomplishments

Pursuant to its assigned responsibility of recommending suitable protective measures for safeguarding whale stocks, the Commission follows closely the effectiveness of regulations in force from year to year. Under the provisions of international agreements in force during the period from 1944 to 1953, the annual catch of whales in the antarctic was limited to 16,000 blue whale units; this represented a reduction by one-third of the catch during six prewar years. The open season for whaling in the antarctic, which during 1944/45 extended from 24 November to 24 March, both dates inclusive, has been shortened, and the opening date advanced in subsequent years, the season authorized for 1954 being limited to 2 January to 7 April, both dates inclusive. Notwithstanding these limitations, the antartic pelagic factories procured about the same amount of oil, or the same number of blue whale units, per day's work of the catcher, as in 1938/39. It should be noted that during the 1938/39 season, the 281 catcher boats which were in operation in antarctic waters, with 34 factory ships and two land stations, captured a total of 38,356 whales, the oil production amounting to 2,820,771 barrels. In 1953/54, however, whaling in the antarctic was carried on by 17 factory ships, three land stations and 227 catcher boats; the 34,831 whales which were taken produced 2,285,526 barrels of oil.

During this ten-year period the length of the antarctic season was shortened by twenty-five days, and, beginning in 1954, the quota for the antarctic was reduced to 15,500 blue whale units. Among the additional recommendations which were made by the International Whaling Commission and subsequently accepted by the contracting Governments, mention may be made of the following: (a) the minimum length of sperm whales permitted to be taken by catcher boats attached to factory ships was raised from thirty-five feet to thirty-eight feet to protect immature males, females being already protected by the thirty-five-foot limit; (b) further protection was accorded the blue whale by advancing the opening date for the permissible taking of this species during the antarctic season; (c) the minke whale was brought under the regulations; (d) restrictions were placed on the taking of humpback whales by factory ships in the antarctic; and (e) the number of inspectors on factory ships was increased from one to two for the purpose of maintaining twenty-four-hour inspection.

Summary

The International Whaling Commission endeavours to conduct its operations with the year-to-year continuity essential to orderly development and management of the whaling industry. It has consistently promoted sound conservation policies. The commissioners appointed by the contracting Governments have a sound concept of their responsibilities and have evinced a genuinely co-operative attitude in dealing with the problems that come within the scope of the Commission. This ability to think and work together to alleviate conditions requiring immediate action, as well as to anticipate problems before they become critical, warrants the conclusion that, with more precise knowledge of the conditions of whale stocks, the Commission is destined to play an increasingly important role in the promotion of conservation policies. The Commission has now established itself as a constructive international entity and is performing with credit the responsibilities delegated to it.

In the exploitation of any natural resource, the practice of obtaining maximum possible returns without regard either to methods employed or to possible irreparable depletion by wasteful procedures is too apt to be followed. Unlike inorganic resources, such as minerals and precious stones, whales are capable of reproducing themselves, and if wisely conserved will yield an adequate return indefinitely. Fortunately, many (but not all) of the Governments whose nationals are engaged in whaling are participating in the work of the International Whaling Commission. The past history of whaling is all too well known; sound judgment dictates that it is in the best interests of all to profit by the mistakes of the past and to regulate effectively the future utilization of this resource.

NOTE ON THE GENERAL FISHERIES COUNCIL FOR THE MEDITERRANEAN

by

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(The mimeographed text of this paper appeared as document A/CONF.10/L.22. It was submitted in French under the title "Note sur le Conseil General des Pêches pour la Meditérranée (CGPM)")

The agreement by which the General Fisheries Council for the Mediterranean (GFCM) was established was drawn up at Rome on 24 September 1949 and came into force on 20 February 1952, upon ratification by five Governments. Under the provisions of the agreement all member States of the Food and Agriculture Organization of the United Nations (FAO) may become members of the Council. States which are not members of FAO may also join upon certain conditions.

The present membership of the Council is composed of the Governments of the following countries: Egypt, France, Greece, Israel, Italy, Monaco, Spain, Tunisia, Turkey, the United Kingdom and Yugoslavia.

The functions of the Council are defined as follows in article III of the agreement by which it was established:

(a) To formulate all oceanographic and technical aspects of the problems of development and proper utilization of aquatic resources;

(b) To encourage and co-ordinate research and the application of improved methods in fisheries and allied industries with a view to the fuller utilization of aquatic resources;

(c) To assemble, publish or otherwise disseminate all oceanographic and technical information relating to aquatic resources;

(d) To recommend to member Governments such national and international research and development projects as may appear necessary or desirable to fill gaps in such knowledge.

(e) To undertake, where appropriate, co-operative research and development projects directed to this end;

(f) To propose, and where necessary to adopt, measures to bring about the standardization of scientific equipment, techniques and nomenclature;

(g) To make comparative studies of the fishery legislation of different countries with a view to making recommendations to member governments respecting the greatest possible co-ordination;

(h) To encourage resdarch into the hygiene and prevention of occupational diseases of fishermen;

(i) To extend the Council's good offices in assisting member governments to secure essential materials and equipment;

(j) To report upon such questions relating to oceanographic and technical problems as may be recommended to it by member governments or by the Food and Agriculture Organization of the United Nations and, if the Council thinks proper to do so, by other international, national or private organizations with related interests; and

(k) To report annually upon its activities to member governments and to the FAO Conference; and to make such other reports to FAO on matters falling within the competence of the Council as may seem to it necessary and desirable.

Plenary sessions of the Council are held every year or every other year. Between sessions, the Executive Committee, which consists of the chairman and the two vice-chairmen, conducts current business in accordance with decisions reached at Council sessions. The secretariat staff is supplied by FAO.

Technical committees have been set up within the Council. Those in existence at present are the Exploration Committee, the Production Committee, the Utilization Committee, the Inland Waters Committee and the Economics and Statistics Committee.

Discussions and technical papers of the Council are published regularly. Three volumes have been issued so far.

The Council's programme of work, adopted at the third session, which was held in Monaco from 14 to 19 October 1954, is shown below, under headings corresponding to the names of the technical committees. The next session of the Council is to be held in October 1956 in Istanbul, Turkey.

Exploration

Clupeids:

Map of quantitative distribution of eggs, showing hydrological conditions.

Critical studies with a view to ascertaining age and growth
Improvement of fishery statistics to obtain precise data on quantities landed and means employed

Tunas:

Bathymetric and geographic distribution of various species
Food and degree of sexual maturity
Migrations

Edible crustaceans:

Breeding grounds and biology, including feeding, reproduction and larval phases of crustaceans belonging to the Peneidae group (*Aristeus aristomorpha*) and to the Pandalidae group

Trawling grounds:

Establishment of a map of trawling grounds for each country
Information concerning demersal fish caught by trawling

Production

Boats, gear, methods: Classification of boats, gear and fishing methods
Fishery administration: Comparative study of fishery regulations
Vocational training of fishermen: Continuation of the study in progress
Regions and fishing seasons: Preparation of a questionnaire with a view to establishing a Mediterranean fishing map and a fishing calendar
Social security and working conditions of fishermen: Comparative study of working conditions and security measures

Utilization

Study of transport and preservation of fish by freezing:

Improvement of the keeping qualities of crustaceans under refrigeration by the use of ascorbic acid, anti-oxydants and preservatives
Comparative study of icing of sardines (fresh water ice or sea water ice)
Economic study of the refrigeration and freezing of sardines (by water or cold air)
Study of technological, technical and economic conditions for the freezing of sardines, mackerel and tunas

- Study of fish meal, oil and by-products:
  - Use of preservatives, anti-oxydants and drying processes so that fish waste can be transported
  - Study of ways of using fish offal (salted sardines) for conversion into by-products
  - Study of an economical method for treatment on board or on land of small quantities of fresh fish or offal
- Canning:
  - Economic and technical comparative analysis of various methods of processing sardines
  - Study of an economic low-capacity plant for fish canning

Inland waters

- Pollution: Effect of pollution by a certain type of factory
- *Valli* culture: Biology of mullet
- Carp culture:
  - Breeding fish in ponds
  - Physiology of food for carp
  - Fertilization of ponds
  - Improvement of the races
  - Diseases (especially ascites)
  - Study of relations between phytoplankton and fish
- Varrage lakes: Effective development
- Salmon culture:
  - Food in ponds
  - Production of fry
  - Transport of fry from hatcheries to fish farms
  - Transport of live fish from fish farms to consumer areas

Economics and statistics

- General economic conditions of fisheries: Order of priority of questions to be studied to be decided by the Executive Committee
- Statistics: Study of statistical methods employed in each country
- Catalogue of names of marine animals:
  - List of names of fish, in process, to be completed
  - List of names of edible molluscs, crustaceans and echinoderms to be prepared.

FLUCTUATIONS IN THE COMMERCIAL FISH POPULATIONS OF THE NORTH-WESTERN PACIFIC IN RELATION TO ENVIRONMENTAL AND OTHER FACTORS

by

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(The mimeographed text of this paper appeared as A/CONF.10/L.14 under the title "Fluctuations in the Commerical Fish Populations of the Northwest Pacific in relation to Meteorological and Oceanographic Conditions, Fishery Operations and Other Factors"; original in Russian)

Contents

The north-western Pacific, including the Bering Sea, the Sea of Okhotsk and the Sea of Japan, is an extensive commercial fishing area (more than 5 million square kilometres) with varied fauna and flora. Approximately 800 species of fish are found there, and more than 100 of them are or could be commercially exploited. Bottom fish are particularly varied, the number of species being considerably higher than in the Atlantic.

Differences in the number of species are largely attributable to the fact that cod and herring are of Atlantic origin (Svetovidov 1948, 1952)[1] and hence there are relatively few varieties of them in the Pacific, while the Pacific origin of the flatfish (Norman, 1934) accounts for the relatively few varieties of flatfish in the Atlantic. At the same time, very similar varieties of the main commercial families - herring, cod, salmon, flatfish, mackerel and others - are found in both the Pacific and the Atlantic. Closely related varieties include: Clupea and Engraulis; Gadus and Eleginus; Limanda, Hippoglossus, Reinhardtius, Hippoglossoides, Pleuronectes and Platessa.

One might expect to find close similarities in the behaviour of these fish and regular fluctuations in populations, particularly as, in most instances, systematic differences are confined to the level of the species or subspecies. Related varieties in both oceans admittedly have certain characteristics of biology and behaviour in common. Nevertheless, recent research into the biology and causes of fluctuation in the fish populations of the northwestern Pacific by the Pacific Research Institute of Fisheries and Oceanography has revealed fundamental differences in the biology of the inhabitants of the Pacific and Atlantic. These differences are largely due to the differing environmental conditions in the two oceans and are the result of adaptation to these conditions At the same time, however, there are very clear indications that the fish population is affected, first, by a number of meteorological and oceanographical factors and, secondly, by intense fishing.

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[1] References in paraentheses are to the bibliography at the end of this paper.

General Environmental Factors

In this connexion, a brief glance at the oceanography of the northwestern Pacific and its specific characteristics is desirable as these have a considerable influence on the biological peculiarities of the fish in that area, and, in many cases, dictate their number.

Deep valleys - 4,000 to 6,000 metres in depth - **forms the** basins of the Sea of Japan and Sea of Okhotsk, and of the Bering Sea, and cover most of their floor. The continental shelf is relatively narrow, generally extending in a narrow band along the north-eastern shore of Asia, and beyond it the ground drops sharply to 3,000 metres or more. These characteristics distinguish the seas of the Far East from the north-eastern Atlantic. As much as 3 million square kilometres of the north-eastern Atlantic consists of broad shoals, whereas only about 1.2 million square kilometres of the north-western Pacific is shallow water. The severe continental climate and the fact that the marginal seas in the Far East are cut off from the open Pacific by a chain of islands are the main **causes** of the intense cooling in winter (to sub-zero temperatures) of large areas of shallow water in certain regions (the north-western part of the Sea of Okhotsk, the eastern off-shore area of the **Gulf** of Sakhalin, the Gulf of Anadyr and others). This cold layer is never warmed through during the warm part of the year; it covers a wide area of shallows, making them unsuitable for the majority of fish living on or near the bottom.

The total area of shallow water in the Far Eastern seas where conditions are suitable for bottom fish is approximately 800,000 to 850,000 square kilometres. Intense cooling (to sub-zero temperatures) in winter and considerable seasonal variation in temperature in the upper layer (particularly in the northern part of the Sea of Okhotsk and Sea of Japan) clearly distinguish the Far Eastern seas from the waters washing the north-western coast of Europe, where annual variations in temperature are negligible and there are virtually no wide areas where the temperature of the water falls to below zero.

Generally speaking, the permanent and tidal currents in the seas of the Far East flow much faster than the currents in the northeastern Atlantic, which are affected by the slow-moving water masses of the Gulf Stream (flowing at not more than 0.1 to 0.3 mile per hour). The majority of the permanent currents in the Bering Sea, the Sea of Okhotsk and the Sea of Japan have a velocity of 0.4 to 0.5 mile an hour or more. Relatively fast currents carrying water masses over shallow water first and then over very deep water or water with sub-zero temperatures create conditions unfavourable to fish and other organisms with pelagic spawn or larvae.

Lastly, vast areas of the Far Eastern seas, and in particular, the shallow areas, are covered for months at a time by floating or stationary ice floes, whereas most of the surface of the north-eastern Atlantic is free from ice the whole year round.

These hydrological differences alone show the substantial differences in the environmental conditions of fish living in comparable areas of the Atlantic and the Pacific.

Other vitally important factors in the environment of many commercial fish also vary, for example the supply of food and the intensity of predation, which frequently determine the size of the fish population. From a comparison of the masses of benthos and zooplankton in the Atlantic and the Pacific it can readily be seen that the benthos and zooplankton indices in many areas of the Far East seas are somewhat higher than those in the seas which wash the shores of northern and north-western Europe. In most of the shallow waters of the Far East the average benthos mass varies from 100 to 500 grammes per square metre, whereas in northern European seas it varies from 20 to 250 grammes per square metre. Approximately the same relation holds good for zooplankton biomass, the figures being 160 to 300 milligrammes per cubic metre and 50 to 140 milligrammes per cubic metre, respectively, as shown in the following table:

Sea	Average mass[a]		Source of data
	Benthos (Grammes per square metre)	Zooplankton (Milligrammes per cubic metre)	
Chukchi (Chukotsk)........	213	160	(Makarov (1937) (Bogorov (1939)
Bering....................	227	...	Makarov (1937)
Okhotsk..................	483[b]	300	(Gordeeva (1948) (Kusmorskaya (1940)
Japan....................	302[c]	240	(Deryugin and (Somova (1941) (Kusmorskaya (1948)
Kara.....................	50	48	(Zenkevich (1947) (Bogorov (1939)
Barents..................	100	140	Zenkevich (1947)
White....................	20	100	Zenkevich (1947)
North....................	244	...	Zernov (1934)
Baltic...................	33	...	Zenkevich (1947)

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[a] To a depth of 200 metres.

[b] West Kamchatka.

[c] Peter the Great Bay.

This substantial difference in favour of the Far Eastern seas would probably be still more marked if the larger zooplankton were taken into account, more particularly the euphausids, which are so abundant in the Sea of Japan and in the Sea of Okhotsk. The greater mass of benthos and zooplankton in the Far Eastern seas accounts for the appearance of large, dense congregations of commercial fish and other creatures in certain areas. The heavy concentrations of flatfish and king crabs off the shores of Kamchatka, pollock in the Korean Gulf, herring off the shores of Sakhalin and Hokkaido and sardines off the southern shores of Japan are well known.

An abundance of benthos or plankton alone, however, is not enough to account for the presence of commercial shoals. For example, although there is in the Gulf of Anadyr an abundance of plankton and benthos for fish food, there are no commercial concentrations of flatfish, nor are there any concentrations of cod, pollock or flat in the northern part of the Bering Sea or in the whole Chukchi Sea, although the types of food eaten by all these fish are found there in especial abundance and the hydrology in summer is particularly suitable (for cod and pollock): the fish do not gc so far from the remote regions where they winter.

A volumetric comparison of the food consumption of a number of the most common commercial fishes indicates that most of them feed a great deal more intensively in the Pacific than in the Atlantic. The average annual index of stomach content[2/] of the Okhotsk Sea cod, for instance, is 225 (Logvinovich, 1949) whereas for the Barents Sea cod it is only 144 (Zatsepin and Petrova, 1939). As a result of the greater abundance of food, the majority of Far Eastern fish have a very limited diet, although there is a wide choice of foods available to them. The Pacific cod, for example, has more than 100 different creatures from which to select its food, but it eats only four or five varieties (Logvinovich, 1949, Gordeeva, 1951). Similarly, the various species of flatfish and halibut, whose range of food includes more than 200 creatures, consistently feed on only a few of these (Mikulich, 1954).

Many Far Eastern fish greatly surpass north-eastern Atlantic fish in their rate of growth, average annual growth in weight and also fleshiness and oiliness. Thus, the average annual growth in weight of the Pacific cod is 1.5 to 3 times that of the Barents Sea cod, and the average weight of the Pacific cod is two to three times that of the Atlantic cod of the same age class.

The inter-specific relations between commercial and non-commercial fish exercise a very real effect on the numbers and behaviour of the commercial fish population, but as yet this factor has been little studied. The number of species - 166 in the Pacific as compared with 48 in the North Atlantic - and the abundance of Cottidae, Agonidae, Hexagrammidae, Liparinae, Blenniidae and other non-commercial bottom fish, which often have a diet similar to that of the commercial fish and feed intensively on the spawn and young of the latter (and sometimes even on mature fish) undoubtedly leave their mark on the biology of many commerical fish and often reduce their stock considerably. The number of species of non-commercial bottom fish in the Pacific and Atlantic Oceans is shown in the following table.

[2/] The ratio, multiplied by 1,000, of the weight of the stomach contents to the weight of the fish.

Family or order	Bering Sea	Sea of Okhotsk	Sea of Japan	Pacific coast of America	Atlantic (Barents Sea)
Cottidae	73	50	36	38	14
Agonidae	16	15	15	15	4
Hexagrammidae	6	5	4	5	--
Cyclopterinae	9	23	10	13	3
Liparinae	22	--	--	--	4
Blenniidae...........	40	55	37	29	23
Total	166	148	102	100	48

Source: For Bering Sea, Andriyashev, 1939; for Sea of Okhotsk, Schmidt, 1950; for Sea of Japan, Lindberg, 1937; for Pacific coast of America, Schulz and de Lacy, 1935; for Atlantic (Barents Sea), Knipovich, 1926.

Other types of fish, too, are known to be affected in this way by natural predation; in the case of salmon, for example, there are instances where up to 80 per cent of the young of the pink salmon are eaten by loaches, young coho salmon and other fishes even before they descend to the sea (Semko, 1953).

These are the fundamental differences in the environment of commercial fish in the north-eastern Atlantic and the north-western Pacific. This specificity of environment is largely responsible for some of the distinguishing biological characteristics of the commercial fish in the North Pacific and it produces sharp fluctuations in the stock of several commercial varieties.

Principal Species of Commercial Fish

Such fishes as the pollock (Theragra chalcogramma), the Pacific herring (Clupea harengus pallasi), the Pacific salmon (Oncorhynchus) and others are extremely widespread and abundant in this area. The pollock is a nekto-benthic rather than a demersal fish; it ranges freely through the middle water and feeds mainly on plankton and nekto-benthic crustacea and much more rarely on benthos. It has little tie with the comparatively narrow continental shelf, withstands low and sometimes sub-zero temperatures relatively well and not infrequently rises to the surface in search of its food.

The Pacific salmon take as their spawning grounds the wide basins of the rivers which empty into the northern Pacific, where the eggs and larvae can develop in conditions most suitable for each species. Later on, when the young salmon migrate to the sea and begin to feed intensively on the concentrated biomasses of the open sea, their environment is particularly favourable and they grow rapidly, ensuring a high level of stock recruitment.

The Pacific herring, which penetrated to the North Pacific from the North Atlantic in one of the interglacial periods, has settled very widely there; it has taken over extensive areas of the offshore shallows as spawning grounds and, feeding on the abundant pelagic food supplies of the Far Eastern seas, has become numerous.

The overwhelming majority of the creatures inhabiting the Far Eastern seas, and particularly the salmon, herring, cod, flatfish, navaga, pollock and king crab, have formed a number of isolated and often independent populations, which have settled in various regions of the Far Eastern seas and adapted themselves to living in varied conditions. The localized nature of the present habitats of the commercial fish, despite their wide distribution throughout these seas, together with the existence of biological and morphological differences in most varieties which have their habitats in several regions, indicates that the fauna is now compartmentalized and isolated in a number of comparatively detached areas, though some are widely scattered all along the north-eastern shores of Asia.

The geological history of the countries of the Far East and, more especially, the distribution of fresh water fauna in north-eastern Asia (Yabe, 1929; Lindberg, 1937, 1948) provide conclusive evidence that successive advances and withdrawals of the sea took place on the shores of eastern Asia during the quaternary period and that enormous upheavals occurred beneath what are now the marginal Far Eastern seas. The distribution and biology of the marine fish carry this theory further and show that not only the fresh water fauna but also the typically marine fauna, and in particular the fish of the Far Eastern seas, which were at one time comparatively uniform, are now split up into local populations.

It may be presumed that the movements of the sea and, more particularly, the chasms which formed in the region of the present marginal Far Eastern seas led to a contraction of the continental shelf, the appearance of large areas of great depth, the development of regions with markedly varying oceanographic conditions, and, perhaps, an increase in the speed of currents. All this led to the breakup of the once continuous populations of fish and other creatures of many kinds which had been inhabiting this area, and to their separation, as indicated, into isolated groups which acquired distinct biological features and, with them, certain related morphological differences.

Instead of the very extensive and protracted horizontal migrations of herring, cod, pollock and other fish which occur in the Atlantic Ocean, there occur in the northern Pacific comparatively short seasonal migrations of the majority of fish and other creatures, principally from deep to shallow water and back, which are due both to the sharp seasonal changes in hydrographic conditions in the upper layer of water (to a depth of 200 metres) and to the location of food supplies and other factors (Polutov, 1948, 1951; Moiseev, 1946, 1953). This sharp seasonal change in hydrographic conditions has led in the case of most commercial fish to evolution of single spawning, to a shortened incubation period, to occurrence in a number of fish (flatfish, for instance) of protracted periods of enforced winter fasting (combined with a sharp decline in activity) and so forth. Only a number of pelagic fish, (mackerel, sardine, anchovy, saury and others) in the north-western Pacific undertake fairly lengthy feeding migrations, which are longest during their periods of maximum population density.

As has already been observed, one of the most important characteristics of the Far Eastern seas and one which sets its mark on the nature, the number and, more especially, the biology of the creatures inhabiting them, is the complex of currents which are relatively constant and at the same time fast-moving. In view of the narrowness of the continental shelf, the vast extent of the great depressions and the markedly varying hydrological conditions even in areas situated close to each other, the high speeds of the currents in the Far Eastern seas are extremely unsuitable for many of the creatures living in them which have pelagic spawn. It is easy to see that eggs and larvae - and also later the young fish - which wander into the currents will be carried far away from the spawning area and will then in most cases have to contend with conditions unfavourable for their further development. The simplest reckoning will show that if the eggs and larvae of a fish - for example, the flatfish - remain for fifteen to twenty days in the open sea where the current moves at a speed of 0.5 mile an hour, the young fish will emerge 180 to 240 miles from the spawning ground, which usually means outside the confines of the region which is a suitable habitat for them.

Consequently, fish which have pelagic spawn have evolved ways of avoiding the most harmful effects of fast-moving currents in order to ensure reproduction in sufficient numbers. Flatfish, for example, in regions with very fast-moving currents, come right in to the shore to spawn and deposit their eggs in inlets and bays where there is little water movement. Furthermore, a plaice (pseudopleuronectes yokohamae) has developed a sticky, benthonic spawn (Pertseva-Ostroumova, 1954). It is very probable that certain other types of flatfish (Pleuronectes obscurus and Pleuronectes pinnifasciatus) have developed similar spawn, which is deposited under the ice. No large concentrations of flatfish are found in areas of shallow water with strong currents and only slight indentation of the shoreline, whereas they are being found in greater and greater numbers in regions where there is little movement of the water (western Kamchatka, the Tatar Straits, the south-eastern coast of Sakhalin).

The Atlantic cod has pelagic spawn, but the cod found in Far Eastern waters has benthonic spawn (Uchida, 1936), which is not carried away to any large extent by the currents and is able to develop in areas with the most suitable temperatures. In addition, benthonic spawn is not exposed to the harmful effects of the floating ice which covers much of the spawning areas during the cod's spawning period.

The pollock, which has pelagic spawn, comes close in to the shore, to areas with slow-moving currents, to deposit its eggs (Vedensky, 1949; Gorbunova, 1954). Its main spawning grounds in the Korean Gulf, Peter the Great Bay and off the south-western coast of Kamchatka are in areas of relatively still water.

At the same time, fish with demersal attached eggs (the Pacific herring, and certain members of the Cottidae, Blenniidae, Rajidae and other families) find that the Far Eastern seas offer the most favourable conditions for their development and are found there in great numbers or in a great variety of species. The Pacific herring, unlike the Atlantic herring, deposits its eggs as near the shore as possible, thus ensuring that large numbers survive in regions with extremely strong currents (the Shelekhov Bay and the northern coast of the Okhotsk Sea).

The currents in the Far Eastern seas greatly influence the behaviour and numbers of pelagic fish. Such typical inhabitants of these areas as the sardine (Kaganovsky, 1935), the mackerel (Vedensky, 1951) and the yellowtail Seriola quinqueradiata, and other fish come close in to the shore to spawn and deposit their eggs in inlets and bays.

The foregoing explains why the vast majority of fish with pelagic spawn deposit their eggs near the shore, why fish with benthonic spawn deposit their eggs in their home ground and why fish with demersal attached eggs are found in great numbers and variety of species in the Far Eastern seas.

Owing to the abundance of predators in the north-western Pacific many fish have armed themselves with strong anal rays, well-developed opercular spines and other defences.

The greater fecundity, by comparison with closely related Atlantic varieties, of the majority of the fish inhabiting the Pacific Ocean can be ascribed largely to the gradual reaction of the species to local oceanographic conditions and to the somewhat greater influence of the predators native to Far Eastern waters. The table on page 277 compares several varieties in respect of fecundity (in thousands of eggs).

	Pacific Ocean	Atlantic Ocean
Ground and demersal fish:		
Cod (*Gadus*)[a]	411 to 763	170 to 250
Navaga (*Eleginus*)........................	25 to 210	6.2 to 6.3
Limanda:		
Limanda aspera	626 to 1,133	
Limanda punctatissima................	162 to 528	
Limanda limanda		80 to 140
Hippoglossoides:		
Hippoglossoides elassodon dubuis (37 to 42 centimetres in length)...	211 to 241	
Hippoglossoides platessoides limandoides (47 to 49 centimetres in length)		241 to 336
Pelagic fish:		
Capelin (*Mallotus*)	15.3 to 39.9	6.2 to 13.4
Mackerel:		
Pneumatophorus japonicus	400 to 800	
Scomber scombrus		350 to 450
Anchovy:		
Engraulis encrasicholus		30
Engraulicus japonicus	35	
Herring (*Clupea*)	39.9 to 92.4	14.8 to 23.3

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[a] The number of eggs is for one kilogramme of fish.

The importance of a knowledge of the oceanography of the Far Eastern seas for an understanding of the general principles of the biology of fish common to those seas is evident. Of special importance are the changes which have occurred over a period of years in the Kuroshio current in determing the oceanographical details of the north-west section of the Pacific Ocean and all the Far Eastern seas. The changes observed over the past forty years have led to changes in the distribution of warm and cold masses of water. Two warming periods and one cooling period occurred during that time. Such alternations or disturbances in the Kuroshio considerably affect the oceanographical characteristics of a number of regions in the north-west section of the Pacific Ocean, which in turn influence the distribution and quantity of a number of commercial fishes.

Such are a few of the biological characteristics of the fish populations of the north-western Pacific which, feeding on the highly nutritive benthos and plankton in Far Eastern seas, are found in relatively large numbers notwithstanding the comparatively small area of the continental shelf.

Rational organization of the fisheries for salmon, herring, cod, pollock, flounder, halibut, mackerel and other fish, taking account of the size of the shoals and of conditions of reproduction in the north-western Pacific, may lead to more stable conditions and considerably higher catches. At the same time the fact that commercial fishes are localized, that they spawn near the shore and that the fry remain in shallow waters makes it essential to develop the industry strictly in accordance with the quantity of each commercial species, taking into account its biological characteristics and, at the same time, taking measures to increase its rate of reproduction.

Causes of Fluctuations in Populations

The preceding data concerning the biology of several Far Eastern fish, changes in metereological and oceanographic conditions and the influence of commercial fishing are important factors in causing fluctuations in quantity in the case of a number of commercial fishes in the north-western Pacific. A few of the most characteristic examples of such fluctuations are given.

Pacific salmon

The three main species of Pacific salmon (Oncorhynchus) fished in the Far Eastern waters are the pink salmon, the chum salmon and the sockeye salmon. Before 1940, as much as 400,000 metric tons of salmon was caught along the north-eastern shores of Asia; subsequently, as a result of intensive fishing by the Japanese, who failed to take into account the size of the fish population, and also because of unfavourable meteorological and oceanographic conditions, the size of the catches dropped considerably, amounting at the present time to between 100,000 and 250,000 metric tons.

The current catches of salmon fluctuate in accordance with the intensity of fishing and the productivity of each generation, which depends on a number of natural factors such as the freezing in some years of the spawning grounds, the devouring of the spawn and larvae by predators and changing water level at the spawning grounds. Considerable fluctuation in size of the most numerous species of salmon - the pink salmon - as well as a decline in the populations of other species of Pacific salmon such as the chum and the sockeye salmon - have been noted.

One of the reasons for the marked decline of the salmon population in some areas has been unfavourable climatic conditions. The sharp drop in winter temperatures and the decrease in winter precipitation frequently cause extensive freezing of the spawning grounds. By means of repeated year-round observation of the development of salmon spawn in winter weather in various areas of Kamchatka and in the Amur basin it was possible to establish the effects of hydrometeorological factors on the number of the young with sufficient certainty (Semko, 1953; Krogius, 1954; Birman, 1954, and others).

A typical example is the marked drop in the number of chum in the Amur basin where, as a result of extensive freezing over a period of four years - from 1911 to 1914 - of the spawning grounds of the summer chum salmon in the most sheltered areas, there was a considerable drop in the population, further aggravated by intensive fishing. As a result, the catch, which was 21.4 million fish in 1910, dropped to 0.2 million in 1920 and has remained low since.

The Pacific salmon inhabit different areas at different times and as a rule return for spawning to the basins of the streams where they were hatched. That is why a decreased salmon population in one area cannot be supplemented with salmon from a neighbouring, more productive, area. Once a catch declines, it usually continues to be low for a long time and can be increased only by means of long-term costly measures for the conservation, reclamation and culture of the fish.

Since the commercial salmon fisheries have shrunk, fishing has become more intensive; it has become particularly intensive during recent years as a result of Japanese salmon fishing at sea; the number of salmon reaching the spawning grounds is definitely inadequate in some areas. For example, in 1954, of the main school of sockeye salmon moving to deposit their spawn in Lake Kurile in Kamchatka, only 320,000 fish reached the spawning ground, instead of the 2 million to 2.5 million fish normally needed to fill the spawning ground, while 3.8 million salmon were caught at sea by Japanese vessels. With such intense fishing, the number of Kamchatka sockeye salmon will soon decline disastrously. There is also the example of the population of sockeye salmon in the Kamchatka River basin; as a result of intense fishing, the catch rapidly dropped from 23,000 to 24,000 metric tons, in 1937-39, to 200 or 300 tons; numerous conservation measures have failed to raise it.

With methods developed to forecast the number of Pacific salmon on the basis of data concerning the survival rate of the spawn, larvae and fry, it is possible to predict the nature and number of the spawning runs with some accuracy. The number of fish that may be caught in the different regions should be established in accordance with scientific recommendations for permissible size. The Union of Soviet Socialist Republics is doing extensive work to provide better conditions for the natural spawning of Pacific salmon and to improve the spawning grounds. Fish conservation measures are strictly complied with. The size of the permissible catch is determined each year on the basis of the age composition of the spawning stock. Extensive salmon culture operations are being carried out. In view of the depletion of the Pacific salmon population, even greater efforts are needed to conserve and increase it. Naturally, steps must first be taken to ensure the effective regulation of fishing; otherwise, measures of fish conservation and culture will be of no avail and the number of salmon will rapidly dwindle. It therefore goes without saying that the countries interested in keeping up the Pacific salmon population must participate both in regulation of the size of catch and in the culture of the fish.

Pacific herring

Though Pacific herring occur almost everywhere throughout the coastal waters of the Far Eastern seas, there are several localized stocks which live in limited areas and do not migrate long distances. The largest concentrations are known to exist off the coasts of Sakhalin and Hokkaido and along the north-western shores of the Sea of Okhotsk. Considerably smaller populations occur in the Shelekhov, bays along the north-eastern coast of Kamchatka. Between 1925 and 1935 the total catch of herring in the north-western Pacific was almost one million metric tons, but in recent years it has dropped to 200,000 or 300,000. The number of Pacific herring fluctuates considerably, according to the sizes of the various generations, which are to a large extent determined by oceanographic conditions, and the intensity and nature of the fishing.

It has been observed that the numerous generations of herring that spawn along the north-west shore of the Sea of Okhotsk are those which were hatched in years when there were no ice floes in the littoral zone, while the sizes of the broods are reduced to levels of no practical significance for stock replenishment in years when spawning occurs in an unfavourable ice regime. In view of the fact that not more than two or three age groups are fished, the failure of any one of them materially affects the catch.

The fluctuations in the number of herring in the Sakhalin-Hokkaido stock (in the past twenty years, catches have declined from 900,000 to 100,000 metric tons) are due to somewhat different causes.

The rise in the temperature of the Sea of Japan which began in the years 1922 to 1924 created unfavourable conditions for reproduction of the Sakhalin-Hokkaido herring, especially near Hokkaido, where by 1930 the catches had been reduced by one-half as compared with 1920. Later, in the period 1933 to 1938, the catches also began to decline gradually off the shores of Sakhalin and had fallen to minimum proportions by 1938 (Svetovidov, 1953). When the temperature of the Sea of Japan began to fall (after 1938), the catches gradually began to increase, and high-yield generations appeared in 1939, 1940 and 1942; they constituted the bulk of the catches for nearly twelve years. One generation alone, that of 1939, yielded catches of over 700,000 tons. However, the number of these high-yield generations was substantially reduced and reproduction limited by the intensive fishing of small, sexually immature herring, of which about 150,000 tons a year were caught in 1940 and 1941 (Probatov, 1953).

It is interesting to note that, as a result of the intensive fishing and of an improvement in feeding conditions, some increase is observable in the fecundity of fish of certain sizes, and also a rise in the growth rate (Piskunov, 1952). Owing to the change in oceanographic conditions, however, and to irrational and intense fishing, the numbers of the reproductive population have declined sharply, the area of the spawning grounds has contracted and the catches have fallen. In order to increase the Sakhalin-Hokkaido herring population, the catching of young fish must be completely stopped, offshore fishing regulated and the underwater vegetation in the spawning grounds protected.

Flatfish

There are a large number of species of flatfish (twenty-eight) in the Far Eastern seas, of which only a few, which predominate in the catches, are of primary importance to the fishing industry. Flatfish are scattered in a large number of local, distinct and in some cases relatively small populations living within the confines of a shelf where the oceanographic and feeding conditions are favourable. The largest concentrations are found in the coastal waters of western and south-eastern Kamchatka, near the Kuril Islands, in the Tatar Strait and off the Soviet coast of the Sea of Japan and Sakhalin.

Their migrations are limited to a movement from the relatively deep regions where they winter to the coastal shallows where they breed and feed, the total distance of migration rarely exceeding eighty to one hundred nautical miles, except in the case of halibut.

The specific distribution and biology of flatfish make them particularly vulnerable to fishing, and if this is not regulated a stock may easily be overfished. The effect of intensive fishing may be illustrated by the flatfish stock of Peter the Great Bay (Sea of Japan); study of its influence began simultaneously with the organization of the fishery, a circumstance which has made it possible to verify many changes in the population almost from the first appearance.

The flatfish population of Peter the Great Bay was practically unfished until 1929, but a rapid increase in the catch to 8,000 metric tons, in 1932/33, led to a number of striking consequences. The average catch and the total take declined rapidly in the four years following the organization of intensive fishing, and the areas inhabited by the winter concentrations shrank from 2,000 square kilometres to 150 square kilometres.

At the same time a change occurred in the composition of the catches, through a sharp decline in the number of Limanda aspera, the main species fished. The quantity of the oldest age groups in the population diminished, and the proportion of young, sexually immature fish increased considerably. The average size of flatfish of all ages is increasing; for example, the length of one-year-old males of the species Limanda aspera has increased by 77 per cent (Moiseev, 1946). Sexual maturity also comes earlier in such rapidly growing fish. Statistics show that, on account of the more rapid rate of growth, there was a markedly faster increase in live weight (Moiseev, 1946). In the following years fishery protection measures were adopted: the catching of young fish was prohibited, the mesh sizes of fishing gear were controlled, prohibited fishing areas were defined and a limit was set to the annual catch, which resulted in stable fishery conditions.

The example of the flatfish population of Peter the Great Bay shows that it is relatively easy, if fishing is intelligently regulated, to obtain stable catches and to achieve the most efficient use of the populations for a long time. At the same time it is easy to see that overfishing of flatfish can lead to a sharp decline in the population, and some time is required for its rehabilitation.

It is easy to see that the great isolation of the flatfish populations of the Far Eastern seas makes them much more liable to overfishing than those in the seas of the north-eastern part of the Atlantic Ocean, where the level of flatfish fishing is already too high (Jensen, 1947; Margetts and Holt, 1947).

Cod

Cod are widely distributed in the coastal waters of the north-western Pacific. It is known that there are substantial concentrations off the shores of Kamchatka and in the Anadyr Gulf, near the northern and southern Kurile Islands and off the shores of Sakhalin and in the Sea of Japan. The Pacific cod does not make the extensive migrations peculiar to the Atlantic cod. In various areas it forms local populations which make small seasonal migrations, usually not exceeding 200 to 300 nautical miles. The isolation of the different cod populations makes them highly sensitive to a change in oceanographic conditions and to the effects of commercial fishing. Observations of the cod populations along the eastern coast of Kamchatka have shown beyond a doubt that the size of generations of cod increases in periods of rising temperature, which is explained by the more favourable living conditions for the young fish. A specially marked influence on the numerical strength of the population was noted for the particularly strong brood of 1934, which appeared for ten years in the catch.

On the other hand, very intense commercial fishing of cod in some areas has led to a decrease in the average sizes, and to a sharp decline in the size of the catch. Thus, on the coast of southern Sakhalin in the cod catch amounted to 54,000 metric tons in 1912/13, but the number of cod inhabiting this area then declined markedly, and the catches fell to from 15,000 to 20,000 tons during the period 1931 to 1940 There is no doubt that the fragmentation of Pacific cod into a large number of distinct populations makes them much less resistant to the effects of commercial fishing than, for example, the Arcto-Norwegian stock of cod, which inhabits a wide area, is numerous and offers great resistance to the effects of intense fishing. Major changes in the abundance of cod of the Arcto-Norwegian stock usually occur, not through the effects of commercial fishing, but under the influence of fluctuations in oceanographic factors (Rollefsen, 1949).

The foregoing shows that, in addition to a survey of the oceanographic conditions and the determination of their influence on the numbers of Pacific cod, the particular nature of their biology urgently calls for strict regulation of the intensity of fishing in accordance with stock levels of each population.

Crabs

The king crab (Paralithodes camtschatica) is widely distributed in the northern Pacific, but the most important concentrations are found along the coast of Kamchatka, the northern and southern Kuril Islands, Sakhalin and the Sea of Japan. These concentrations represent separate, isolated populations which make comparatively short migrations. There are no data on the influence of protracted changes in oceanographic conditions on the numerical size of crab populations, but the effect of intense fishing on the supplies of particular, very heavily fished populations has been shown most clearly.

Thus, the crab fishery on the coast of south-western Kamchatka, organized in 1916, from 1922 to 1924 began to land as many as 2.5 to 3 million crabs, which very quickly led to exhaustion of the supplies in this area (Miyake and Matsuro). The rapidly developing crab fishery off the south-western coast of Sakhalin, which yielded over 5 million crabs in 1917, also resulted in a reduction in the population - both a sharp reduction in the size of the crabs caught and a diminution of the catches - after which a number of regulatory measures were adopted. Thereafter the catch became stabilized at 1.5 to 2 million units.

There is no doubt that the specific nature of the biology and distribution of the king crab in the north-western Pacific calls for the same attention to rational exploitation of resources as in the case of most commercial fish inhabiting this basin.

The preceding data on the living conditions of sea fish and animals in the north-western Pacific, which to a considerable extent determine the peculiarities of their biology, distribution and abundance, and the examples given of the effects of too intense fishing on the individual populations of salmon, cod, herring, flatfish and king crab are sufficient proof that all the fish mentioned may soon vanish if fishing is carried on without regard for the biological peculiarity and abundance of each individual population. All this in turn bears witness to the need for agreement between the States concerned on rational exploitation of the natural resources - the populations suitable for commercial fishing - the areas of distribution of which are within the limits of coastal waters and of the high seas adjacent thereto, with a view to securing the largest possible catches while maintaining the populations at a high level.

Without co-ordinated effort on the part of the countries of the north-western Pacific for the conservation and rational exploitation of these natural resources, the resources may be exhausted within a short time. At the same time, there are abundant fishery resources in the extensive open spaces of the north-western Pacific, permitting rapid development of ocean fishing and a substantial increase in the catches. Several species of tunas, sauries, swordfish and many other fish are already being harvested to a great extent, and there is every reason to believe that the catch of these can be considerably increased without any long-term reduction in their number. Their wide area of distribution in the extensive open waters of the Pacific, the great length of their migratory routes, their great number and the fact that they spawn in the open sea make these fish considerably less vulnerable to commercial fishing than those which live in coastal waters and which concentrate for spawning in small areas in the shallows, or in rivers.

While about 9 million metric tons of fish and other marine animals are now being caught in the north Pacific, which is more than in any other basin, there can be no doubt that there are great opportunities for further intensifying the exploitation of the natural resources of this area of the world ocean through development of ocean fishing. This method offers the best prospects from the point of view of proper utilization of the natural resources of the north Pacific.

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FISHERY PROBLEMS AND FISHERY CONSERVATION IN ITALY

presented by

The Italian Delegation to the Conference

(The mimeographed text of this paper appeared as document A/CONF.10/L.20. It was submitted in French under the title "Problèmes de la pêche et de sa protection en Italie")

Italy, with a coastline of 7,500 kilometres - a sizable length when compared with its land area - is deeply concerned with fishery problems, because of the large number of inhabitants engaged in fishing and earning their living by it; because of the high rate of fish consumption, especially in parts of the country which have limited supplies of protein foods; and because of substantial economic interest in fisheries. The importance of these aspects of the question is shown in the following table, which indicates the extent of Italian marine fisheries in 1953.

Fishery area	Fishermen		Type of craft		Catch	
	Total number	Number using sailing craft	Motor ships	Motorboats	Thousands of quintals	Millions of lire
Tyrrhenian Sea:						
Northern area..	5,695	1,238	203	567	108.3	2,018
Central area...	5,240	1,319	138	339	78.1	1,321
Southern area.	21,207	7,758	173	1,451	157.1	2,672
Ligurian Sea...	8,457	2,777	119	575	88.0	1,433
Total, Tyrrhenian Sea..........	40,599	13,092	633	2,832	431.6	7,444
Sardinia	6,409	1,638	36	521	77.2	1,948
Sicily	42,496	10,290	604	705	524.5	9,238
Ionian Sea	4,353	1,346	18	37	92.8	1,409

Fishery area	Fishermen		Type of craft		Catch	
	Total number	Number using sailing craft	Motor ships	Motorboats	Thousands of quintals	Millions of lire
Adriatic Sea:						
Northern area	14,351	4,627	288	443	186.2	3,237
Central area	14,155	2,837	737	322	289.9	4,941
Southern area	17,769	4,989	308	227	191.4	3,562
Total, Adriatic Sea	46,275	12,453	1,333	992	667.5	11,778
Total	140,132	38,819	2,624	5,187	1,793.6	31,778

Italian fishermen carry on their trade in territorial and international waters, namely the Ligurian sea; the Tyrrhenian Sea along the coast of Sardinia; along the southern coast of Sicily and in the Ionian Sea; the Adriatic Sea; and outside the Mediterranean, along the western coast of north Africa and the great Newfoundland banks. The richest areas, where the largest number of fishermen and fishing vessels are found, are the Adriatic, the seas to the sourth of Sicily, and the northern and central areas of the Tyrrhenian Sea.

The most important types of fishery for Italy are trawler fishing, with an annual catch of 1,101,697 quintals; clupeoid and mackerel fishing, with an annual catch of 667,010 quintals; and tuna fishing, with an annual catch of 24,877 quintals. Long-line, coastal and other types of fishing are of less importance.

Migrating clupeoids and scombroids are taken with various types of net: "menaid", lampara and saccoleva nets, or purse-seines. Catches from these fisheries, while very large, are apt to fluctuate widely. They are closely linked to the canning industry. These fisheries are of considerable importance economically, and have a marked influence on the food situation because they add an abundant and popular food.

Tuna fishing, which is traditionally a coastal occupation carried on around Sicily and Sardinia with tunny nets, or madragues, is subject to wide fluctuations and frequent periods of depression. An attempt is being made to introduce purse-seines into tuna fishing. This would make it possible to catch tuna without using madragues and, given necessary controls to avoid overfishing, might bring about a substantial increase in production.

Fishing by trawler, which gives the greatest catches, occupies large numbers of fishermen throughout the year. It is carried out at certain fishing banks by fishermen from a number of localities which have a long tradition of this type of fishing. Among the most important of these are Chioggia, Fano, Ancona, San Benedetto del Tronto, Molfetta, Mazara del Vallo, Porto Santo Stefano and Viareggio.

For some years the fishermen of the west coast of the Italian peninsula, particularly those operating from the harbours of Tuscany and Liguria, have been extending their activities from the shallower waters of the continental shelf to the subjacent slope to a depth of 600 metres. It has thus become possible to catch species hetherto unknown on the market, for example, the "malu" (*Micromesistius (Gadus) poutassou*), the "occhiono" (*Chloropthalmus agassizii*), the red shrimp (*Aristeus aristomorpha*) and others, including the Norway lobster (*Nephrope norvegicus*), hitherto known only in certain small areas, such as the Gulf of Kvarner in the Adriatic.

Thirty-five years ago trawler fishing was carried out almost exclusively by sailing boats working in pairs. From 1921 onwards, motor trawlers began to replace sailing boats and are the only ones used today, with a few exceptions in coastal fishing. The mechanization of fishing boats has resulted in considerably increased catches, an increase which needs to be watched closely in order to avoid overfishing. So far there has been no definite proof of overfishing in Italian waters; as soon as such proof is forthcoming, fishery conservation measures will become necessary.

Italy began to regulate the use of fishing gear as long ago as 1882, with Royal Decree 1090 of 13 November 1882, enforcing the sea fishery chapter of the law on fishing. Trawler fishing is regulated by a ministerial decree of 1 September 1934, while the fishing of fingerlings is regulated by a ministerial decree of 19 October 1939.

The Italian fishing fleet requires further modernization, and several boats must be replaced if maximum yield and security are to be attained. However, increases in the fishing fleet are subject to very strict control. The Italian Government, whose policy it is to ensure a sustained level of production for Italian fishermen, is keenly interested in the protection of fishing in national and extraterritorial waters where the national industry does not compete with that of other countries.

The areas which Italian fishermen share with those of other countries are the Adriatic Sea, the channel between Sicily and Tunisia, and the northern part of the Tyrrhenian Sea. To enable the fishermen to carry on their trade without detriment to the interests of fishermen of neighbouring countries, and also to ensure maximum sustained production, bilateral agreements in respect of these seas are required.

The terms of any agreements covering the Adriatic would have to be drawn with special care. Since Albanian fishing in that area is almost negligible, the two countries chiefly involved are Italy and Yugoslavia. Since biophysically the Adriatic constitutes a single unit, it is not easy, owing to its limited breadth, to delimit the respective territorial waters. Further, the different conformation of the east and west coasts of the sea results in a prevalence of fish in certain areas; these are naturally the most frequented by fishermen. By tradition, fishermen from the Italian coast have trawled the entire Adriatic Sea, and this led to agreements, first between Italy and Austria, and later between Italy and Yugoslavia. Recently, in consequence of political changes, the areas available to Italian fishermen have become more and more restricted, with the result that a crisis of some severity has developed in the Italian Adriatic fishing industry.

The Italian Government is especially concerned with protecting the Adriatic fishery in order to guarantee the livelihood of its fishermen. Consequently, in addition to an agreement on conservation measures which it has concluded with Yugoslavia, negotiations are now proceeding with a view to protecting the economic and social interests of both countries. It must be emphasized that the situation is particularly difficult with respect to the Italian sea fishery, which, despite the availability of equipment and highly skilled fishermen, is confined to a few very limited and normally underproductive fishing grounds. For this reason, the condition of the Italian fisheries is extremely important economically and has serious social aspects as well.

While the Italian Government is concerned with fishery conservation, it is also constrained to provide employment and the means of subsistence for a large section of the coastal population. It must therefore obtain new areas of activity for its fishermen; this might be done by means of international agreements to allocate fishing activities more nearly in accord with the productive capacity of different areas.

The Italian delegation believes that, so far as the Mediterranean is concerned, one of the most effective means of conserving the living resources of the sea would be a better distribution of fishing activity with a view to obviating any undue disparity between overfished and underfished areas.

LIFE HISTORY, ECOLOGY AND BEHAVIOUR OF IMPORTANT SPECIES CONSTITUTING THE FISHERY RESOURCES OF THE SEAS AROUND JAPAN

presented by

The Japanese Delegation to the Conference

COMMENT BY THE KOREAN DELEGATION AND FURTHER COMMENT BY THE JAPANESE DELEGATION

(The mimeographed text of these papers appeared as documents A/CONF.10/L.26, A/CONF.10/L.33 and Corr.1, and A/CONF.10/L.38)

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Japanese Fishery Resources

Sardine

As the unit of conservation management, Japanese sardines, *Sardina melanosticta* Temminck and Schlegel, are deemed to comprise one population. They are caught in all the coastal waters around Japan.

The development of the sexual organs of this sardine begins fully one year after birth, when the body length is twelve to sixteen centimetres, and they are fully mature at two years, with a body length of eighteen centimetres. The number of each sex is about the same, but among the older fish there are more females than males.

The age composition of sardines caught in the Pacific coastal waters of Japan in 1953 is shown below.

Age (years)	Weight (metric tons)	Per cent of total catch
North-eastern coastal waters:		
Under 1	6,873	37.1
1	3,236	17.5
2	8,396	45.2
3	76	0.2
Total	18,547	100.0
Middle coastal waters:		
Under 1	755	30.9
1	532	21.7
2	1,155	47.2
3	5	0.2
Total	2,447	100.0

The most important spawning grounds of the Japanese sardine are located around the Goto Islands off the north-western coast of Kyushu. There are also other spawning grounds in the Sea of Japan, south of the Noto peninsula, and along the Pacific coast, south of the Boso peninsula. The spawning season is in December in the south, and later in the north - in June. The water temperature for spawning is from 13° to 17° centigrade. In the spawning season, the fish remain in deep water during the day but come to the surface in the evening twilight. Spawning takes place from 8 o'clock to 10 o'clock in the evening.

The number of eggs spawned by a one-year-old fish of about 16 centimetres is about 20,000, but a large fish, of over 20 centimetres, spawns approximately 100,000 eggs. Eggs are hatched in about sixty hours, or two to three days. The hatched larvae are 3.2 millimetres in length. In three to four days, they grow to 5 millimetres, and at the time of scale formation, to 35 millimetres; in three months after birth, they are from 50 to 60 millimetres in length; at the time of taking adult form, 75 millimetres; in six to seven months after birth, about 100 millimetres; in one year, 120 to 160 millimetres; in two years, about 180 millimetres; in three years, about 200 millimetres; in four years, about 210 millimetres. Their longevity is estimated at four years or thereabouts.

Eggs spawned and larvae hatched in waters adjacent to the south of Japan are carried along by the current. When the fish are strong enough to swim - five to six centimetres long - they begin to go northward to seek food, until August or September. In autumn and winter they swim southward. When they are more than a year old, they again go northward to seek food in spring and summer, and then swim south to spawn in autumn and winter.

Sardine larvae and juvenile fish feed on zooplankton. When they grow a little older, they eat phytoplankton in addition to zooplankton. The adult fish feed largely on the diatom plankton found in the waters.

The following figures show the sardine catch in 1953 by type of fishing.

	Weight (Metric tons)	Per cent of total
Surrounding nets	417,068	63.19
Beach or boat seines	102,533	15.54
Gill nets	61,541	9.32
Set nets	38,970	5.91
Lift nets	32,441	4.91
Angling and long lines	1,826	0.28
Drag nets	45	0.01
Other types	5,561	0.84
Total	659,985	100.00

The catch of sardines, which reached a peak of 1.6 million tons in 1936, has gradually declined, but since 1945 has shown a rising trend. One reason for this change may be that these fish, which earlier had changed their spawning grounds for more northerly areas, thereby reducing the size of the suitable spawning area, have now again extended their spawning grounds southward and enlarged them. During this period the total catch fell [illegible] to 70 per cent; it has been estimated that 17 per cent of this drop was the result of fishing.

Herring

Herring, *Clupea pallasi* Cuvier and Valenciennes, are found in all waters around Honshu, Hokkaido and southern Sakhalin, but they are considered one population for the purpose of conservation management. In addition, there are two or three small populations which come into lakes to spawn. Herring are caught in the waters around southern Sakhalin and Hokkaido, especially in waters north of Shikotan, Hokkaido. They were formerly caught in the Sea of Japan in waters north of Yamagata prefecture, and in the Pacific in waters north of Miyagi prefecture, and also off the south-eastern part of Korea.

The mature individuals constitute 10 per cent of the three-year age group; 30 to 60 per cent of the four-year age group; and 100 per cent of the five-year and older groups. Their body length in maturity ranges from 26 to 30.5 centimetres.

The spawning season is during March to May - earlier in the south and later in the north. The water temperature for spawning is higher in the south - 5° to 6° - and lower in the north - 3° centigrade. The fishing grounds are also the spawning grounds. As the spawning season approaches, the herring gradually come up to the surface layer of the sea and move towards the shore. In the spawning season they approach the shore in shoals and spawn on seaweed and similar matter. The number of eggs spawned by a four-year fish is about 40,000. However, larger fish generally spawn more eggs than smaller ones, though they may belong to the same year-class.

At water temperatures of 7.3° to 8.4° centigrade, eggs are hatched in twenty to twenty-two days. In five to seven days after birth, their yolk is consumed and they grow nine to ten millimetres in length. They grow to 2.5 centimetres in one month; to 4 centimetres in two months, to 7 centimetres in three months, to 10 centimetres in six months, to 15 centimetres in a full year, to 22 centimetres in two years, to 26 centimetres in three years, to 29 centimetres in four years, to 30.5 centimetres in five years, to 32 centimetres in six years, to 33 centimetres in seven years, [illegible] centimetres in eight years, to 34.5 centimetres in nine years and to 35 centimetres in ten years. Their longevity is generally eight years, but there are a few which are thought to be sixteen years old or thereabouts.

Herring feed chiefly on zooplankton, such as copepods and euphausids. The stomachs of most fish which have come from the bottom and middle layers of the sea are empty; they begin to seek food and eat a great quantity until about six days before spawning. In about sixteen days after spawning, they begin to feed again and become thick, "fat herring". Atka mackerel, greenling and starfish eat the eggs of herring.

The juvenile fish grow in the Sea of Okhotsk, then swim south in autumn along the Pacific coast. The following year they run northward and again enter the Sea of Okhotsk. In autumn, they again migrate south down the Pacific coast along the northern part of Honshu, and then return to the Sea of Okhotsk until the following summer. Some of them - the three-year olds - appear for spawning near the coast of Hokkaido and southern Sakhalin, but most of them stay in the Sea of Okhotsk. After the spawning season they migrate to the northern part of the Sea of Okhotsk, and then go south into the Sea of Japan in January [illegible] February. During the migration, they are caught either as spring, or spawning, herring of three years or over, or as immature summer herring.

The herring catch of 1933, of about 4.5 million metric tons, was the highest on record; one of about 40,000 tons was the lowest. Recent production has ranged from over 100,000 to more than 300,000 tons, as shown in the accompanying table giving the age composition of the catch from 1939 to 1954.

Herring are caught by set nets and gill nets, used in about the proportions shown below. The size of the herring catch depends upon the number of men engaged in fishing and also upon various environmental factors.

	1940	1950
Number of set nets	602	1,025
Number of gill nets (converted)	475	917
Total	1,077	1,942

Year	Age (years) 3	4	5	6	7	8	9	10	11	12	13	14	15	16 and over	Total
Weight (metric tons)															
1939	43,508	49,809	3,296	1,991	883	1,826									101,312
1940	3,395	116,710	35,510	2,940	506	3,050									161,174
1941	1,552	18,096	135,128	9,902	2,099	1,234									168,011
1942	27,601	24,329	18,362	88,504	12,564	46									171,405
1943	650	221,778	22,907	16,521	36,610	713									299,253
1944	311	2,081	314,986	179,150	10,643	17,426									363,345
1945	19,413	505	1,711	289,032	8,459	15,831									334,950
1946	3,386	40,955	2,889	9,258	183,810	16,904	5,724	6,644							269,569
1947	1,219	5,409	28,227	1,900	26,930	117,825	12,509	2,994							197,012
1948	711	11,463	15,200	29,593	2,372	6,413	104,855	7,144							176,250
1949	31,904	13,049	16,400	8,756	18,140	2,381	3,385	84,042							178,056
1950	4,310	59,328	5,117	5,418	4,998	13,163	962	2,269	62,777	1,465					159,806
1951	17,780	10,928	53,399	1,440	4,150	5,367	7,275	3,454	1,556	60,990	1,748				168,088
1952	1,835	163,664	8,447	23,804	1,916	2,903	5,983	5,211	1,675	2,403	49,457	840			268,139
1953	2,510	1,454	186,798	4,251	8,743	1,082	1,013	4,154	2,045	358	158	19,682	300		232,580
1954	1,053	1,826	740	76,998	941	3,651	392	1,103	508	3,443	923	520	19,184	191	111,471
Per cent of total															
1939	42.9	49.1	3.3	2.0	0.9	1.8									100
1940	2.0	72.4	22.0	1.4	0.3	1.9									100
1941	0.9	10.8	80.4	5.9	1.2	0.8									100
1942	16.1	14.1	10.7	51.6	7.3	-									100
1943	0.2	74.1	7.7	5.5	12.2	0.2									100
1944	0.1	0.6	86.7	4.9	2.9	4.7									100
1945	5.8	0.3	0.5	86.3	2.5	4.7									100
1946	1.2	15.2	1.1	3.4	68.2	6.3	2.1	2.5							100
1947	0.6	2.8	14.3	0.9	13.8	59.8	6.4	1.5							100
1948	0.4	6.5	8.6	15.9	1.3	3.6	59.5	4.1							100
1949	17.9	7.4	9.2	4.9	10.2	1.3	1.9	47.2							100
1950	2.7	37.1	3.2	3.4	3.1	8.3	0.6	1.4	39.3	0.9					100
1951	10.6	6.5	31.8	0.9	3.5	3.2	4.3	2.0	0.9	36.3	1.0				100
1952	0.7	61.0	3.2	8.9	0.7	1.1	2.2	1.9	0.6	0.9	18.5	0.3			100
1953	1.1	0.6	80.3	1.8	3.8	0.5	0.4	1.8	0.9	0.1	0.1	8.5	0.1		100
1954	0.9	1.6	0.7	69.1	0.8	3.3	0.3	1.0	0.5	3.1	0.8	0.5	17.2	0.2	100

The recent poor catch is considered a result of a shift to the north of the spawning ground near Hokkaido.

Yellowtail

Yellowtail, Seriola quinqueradiata Temminck and Schlegel, are caught in all coastal waters of Japan. For purposes of conservation management, they are all considered to belong to one population. The age composition of fish caught annually in Sagami Sea is as follows: one-year fish, 16 per cent; two-year, 21 per cent; three-year, 30 per cent; and four-year 25 per cent (Aikawa, 1949).[1] The size of a population in the management unit has been estimated at 129.3 million fish by Tauchi (1940) or 125,615 to 805,625 tons, by Aikawa (1949).

Some yellowtail become mature two years after birth, but most, after three years. Their spawning grounds are located in coastal waters off southern Japan. The spawning season begins in February in the south and ends in June in the north. They reach three centimetres two months after birth, 15 centimetres in four months, 20 centimetres in six months, 30 centimetres (one kilogramme) in one year, 40 to 50 centimetres (three to four kilogrammes) in two years, 60 to 70 centimetres (six to seven kilogrammes) in three years, and 70 to 80 centimetres (eight to nine kilogrammes) in four years.

The optimum water temperature for yellowtail is 14° to 17° centigrade. They swim rapidly when seeking food but move slowly in spawning time. Their highest speed is about forty-nine sea miles a day; in ordinary times they swim about ten sea miles a day.

Yellowtail feed on other fish, the adults on anchovy, sardine, horse mackerel and mackerel. The larvae and juveniles live under floating weeds and are often eaten by other fish. The adults are eaten by porpoises, pilot whales and dolphins.

The total catch of yellowtail in 1890 was 15,000 tons; the recent record was well over 50,000 tons (figure 41). They are caught all year round in southern Japan; in northern Japan, large fish are caught chiefly in summer. They are caught by set nets, trap pockets and long-line and pole-and-line fishing.

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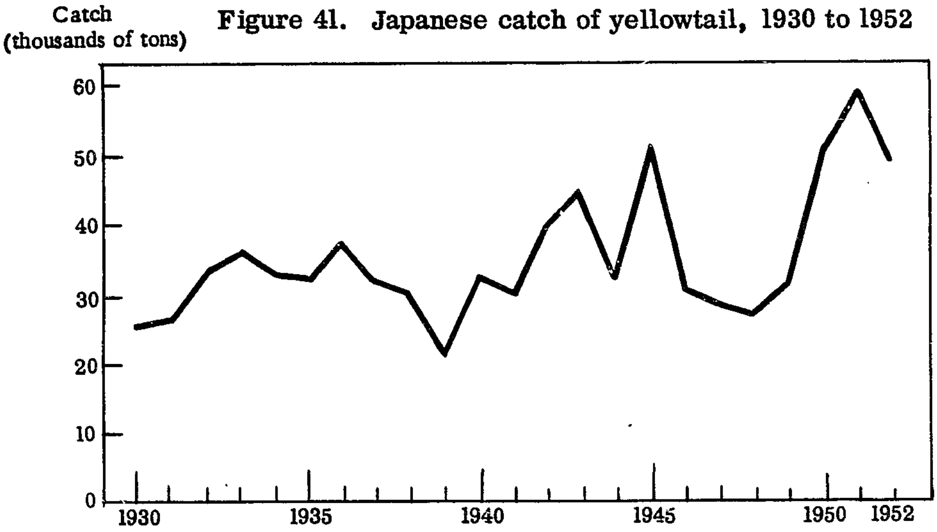
[1] See bibliography for references.

Figure 41. Japanese catch of yellowtail, 1930 to 1952



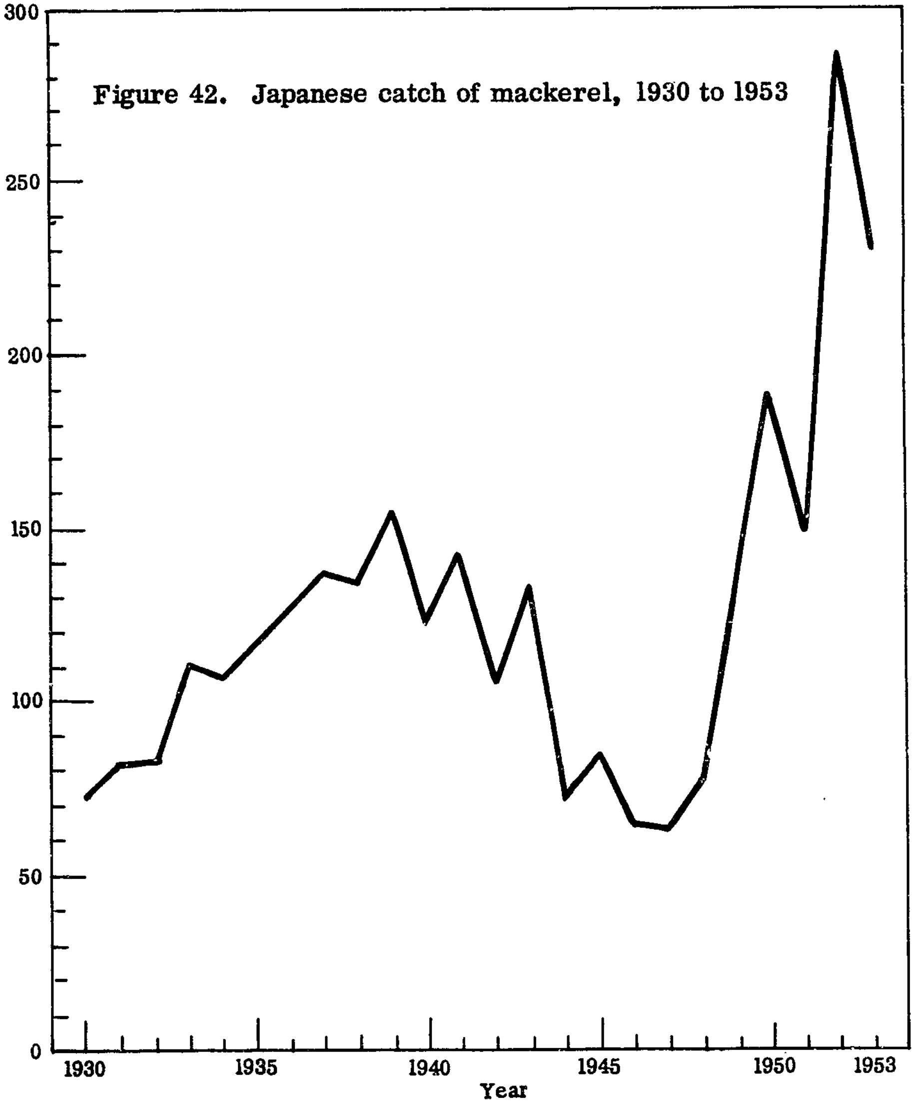


Figure 42. Japanese catch of mackerel, 1930 to 1953

Mackerel

Mackerel caught by Japanese fishermen include two species: Scomber (or Pneumatophorus) japonicus Houttuyn (Japanese mackerel), and Scomber tapeinocephalus Bleeker (Japanese spotted mackerel or southern mackerel). Japanese mackerel are caught in all coastal waters around Japan, in the Yellow sea and in the East China Sea. Japanese spotted mackerel or southern mackerel are abundant in waters around southern Japan. The two species are considered one population and are treated as a unit of conservation management.

Some of the mackerel become mature two years after birth, and the rest after three years. Their spawning area includes all the coastal waters of Japan. The spawning season extends from April to June; it is earlier in the south and later in the north. Spawning water temperature ranges from 13.5° to 21° centigrade, the optimum temperature being 18° centigrade. The number of intra-ovarian eggs of a mackerel is estimated at 300,000 to 400,000 and they are spawned in four or five deposits. At 20° centigrade, the eggs are hatched in about fifty hours. In six months or a year they grow to 12 to 20 centimetres in length; in two years, to 25 to 30 centimetres; in three years, to 30 to 34 centimetres; and in four years, to 34 to 38 centimetres. Most of the commercial fish belong to two-year to four-year age groups; fish of five or six years are very few.

Japanese mackerel live in waters of 7° to 23° centigrade, and their optimum temperature is 10° to 20°. Japanese spotted mackerel live in warmer waters - of 15° to 28°. Young fish of both species live in warmer waters than the adult. When the Japanese mackerel leave southern waters, the spotted mackerel appear there.

Both of these fish migrate in shoals. The youngest class and the one-year group make separate shoals, while the two-year group and older age groups live together. They make especially dense shoals and come up near the surface in the spawning season. Japanese mackerel run northward during spring and summer, swimming through the surface layer of the sea; late in autumn and early in winter they swim southward through the bottom layer, spending the winter in the coastal waters of southern Japan. Most of the spotted mackerel leave Japanese coastal waters in winter and travel southward.

The mackerel feed on pelagic crustaceans, small squid and small fishes, such as sardine and sand launce.

The mackerel catch in pre-war years exceeded 100,000 tons, but it declined after the war, dropping to little over 60,000 tons in 1946 (figure 42). However, this decline was followed by a marked recovery, the catch amounting to about 230,000 tons in 1953. Spotted mackerel represented less than 30 per cent of the total catch.

Formerly commercial dip nets were used for mackerel fishing, but now motor vessels with improved surrounding nets, and with hanezuri (a type of angling equipment), are being used. There is no fear of overfishing with respect to Japanese mackerel. As to Japanese spotted mackerel, it is believed that more fish can be caught without harm to the fishery in the East China Sea and the Yellow Sea.

Skipper

Skipper (Cololabis saira Brevoort), Pacific saury or mackerel pike, are regarded as a single population in Japan for purposes of conservation management. In the Pacific they are caught in waters from the Kuril Islands to the Okinawa Islands (25° north, 136° south). They become mature three years after birth, and fish of over twenty-seven centimetres (three-year to four-year groups) can spawn.

In the spawning season they approach the coast. They spawn 700 to 900 eggs per fish at a time, twice or three times during the season. Their spawning grounds are located in the waters south of central Japan. The spawning season covers a long period, from November to the following June. The fish spawn in November and again in June in the northern part of the spawning ground, and once in March in the southern part. The optimum water temperature for spawning is 15° to 18° centigrade.

At water temperatures of 15° to 16° centigrade, eggs are hatched in ten hours. Juveniles - seven millimetres in length - and young fish are carried northward by the sea current as far as the northern waters of Japan. The youngest fish (under one year) are nearly always found in coastal and off-shore waters; they gradually move northward.

During the southward migration of the adult fish (twenty-five centimetres or more) along the Pacific coast, they are densely crowded. In August they are in northern waters, gradually coming southward to reach the central part of Japan about November. These large shoals are fished commercially to a great extent. In the Sea of Japan, however, the migration of adult fish is very small in scale. The fish are in the southern waters of the Sea of Japan in the spring; they then migrate northward to reach the waters off the west coast of Hokkaido in summer. The optimum water temperature for these fish is 15° to 24° centigrade, They are typical pelagic species, and rarely descend deep into the sea even in the daytime. Adult fish feed on crustaceans and diatoms.

Before the war, the size distribution of the catch showed two modes, at 25 centimetres and at 29 centimetres. Since the war, however, the two modes have disappeared, and there is now a single mode between 26 and 27 centimetres.

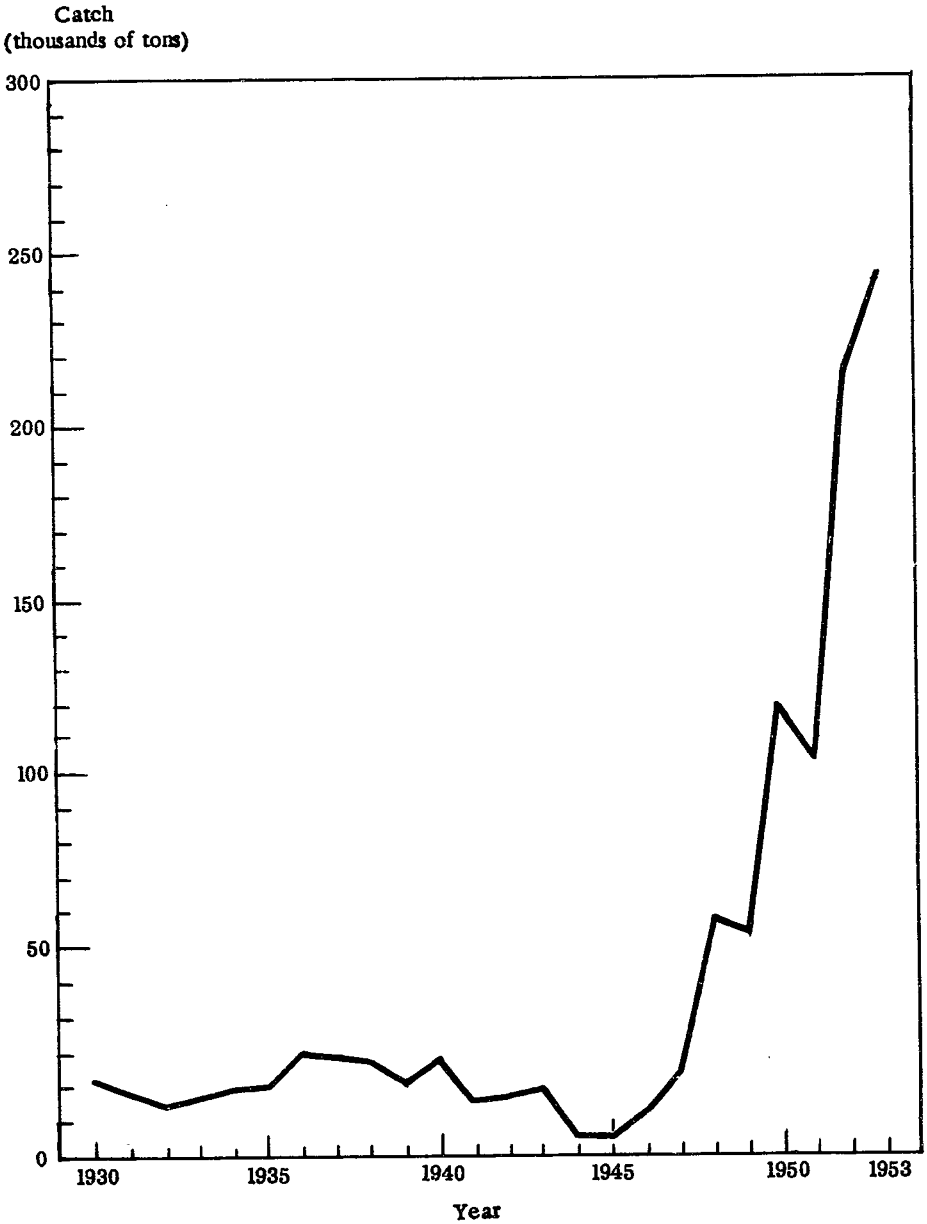
The phototaxis of these fish is strongly positive, but in the spawning season their reaction is weakened to some extent. Before the war, the catch by drift net amounted to 10,000 to 20,000 tons, but after the war the use of commercial dip nets, and of lights because of the strong phototaxis, multiplied the catch tenfold; it reached nearly 250,000 tons in 1953 (figure 43). The amount of the catch per boat by use of drift nets averaged 17.5 tons in 1932, while by newly employed commercial dip nets it averaged 114.6 tons in 1951. Despite increased exploitation by this method, the present fishing rate can be maintained without fear of overfishing.

Tuna

Dominant species among the tunas caught in Japanese waters are the albacore, Germo germo Lacépède, and the bluefin tuna, Thunnus orientalis Temminck and Schlegel. The total catch of tunas in Japanese waters is relatively small. These albacore and bluefin tuna are now considered a single population from the point of view of conservation management.

The albacore are caught in almost all waters between the east coast of Japan and 180° east, and also between 40° and 25° north. The bluefin tuna are caught in all coastal waters of Japan and in the high seas off the coast of the islands of Japan within longitude 150° east and latitude 25° north.

Figure 43. Japanese catch of skipper, 1930 to 1953



In the waters near the Midway Islands, large albacore are caught in November to March, and in Japanese northern waters, small albacore are caught in July and August. Large bluefin tuna are caught off the Pacific coast of Japan, in winter in the waters south of the central part, and in summer in the waters north of the central part. In the Sea of Japan, tuna of medium size are caught in spring and summer. Small tuna are caught in all coastal waters all year round.

Both albacore and bluefin tuna eat many species of fish. In the stomachs of the adult, there can be found a large number of juveniles and young fish of different species.

The body weight of the commercial fish is under ten kilogrammes for the small type of albacore and from ten to thirty kilogrammes for the large type. The small type of bluefin tuna is under twenty kilogrammes; the medium type weighs from 20 to 100 kilogrammes; and the large type is over 100 kilogrammes. The number of intra-ovarian eggs is exceedingly large: the albacore has about 300,000 eggs; the bluefin tuna, about a million. The spawning grounds of the albacore are in the waters off the Midway Islands and those of the bluefin tuna are located in the waters south of the subtropical front.

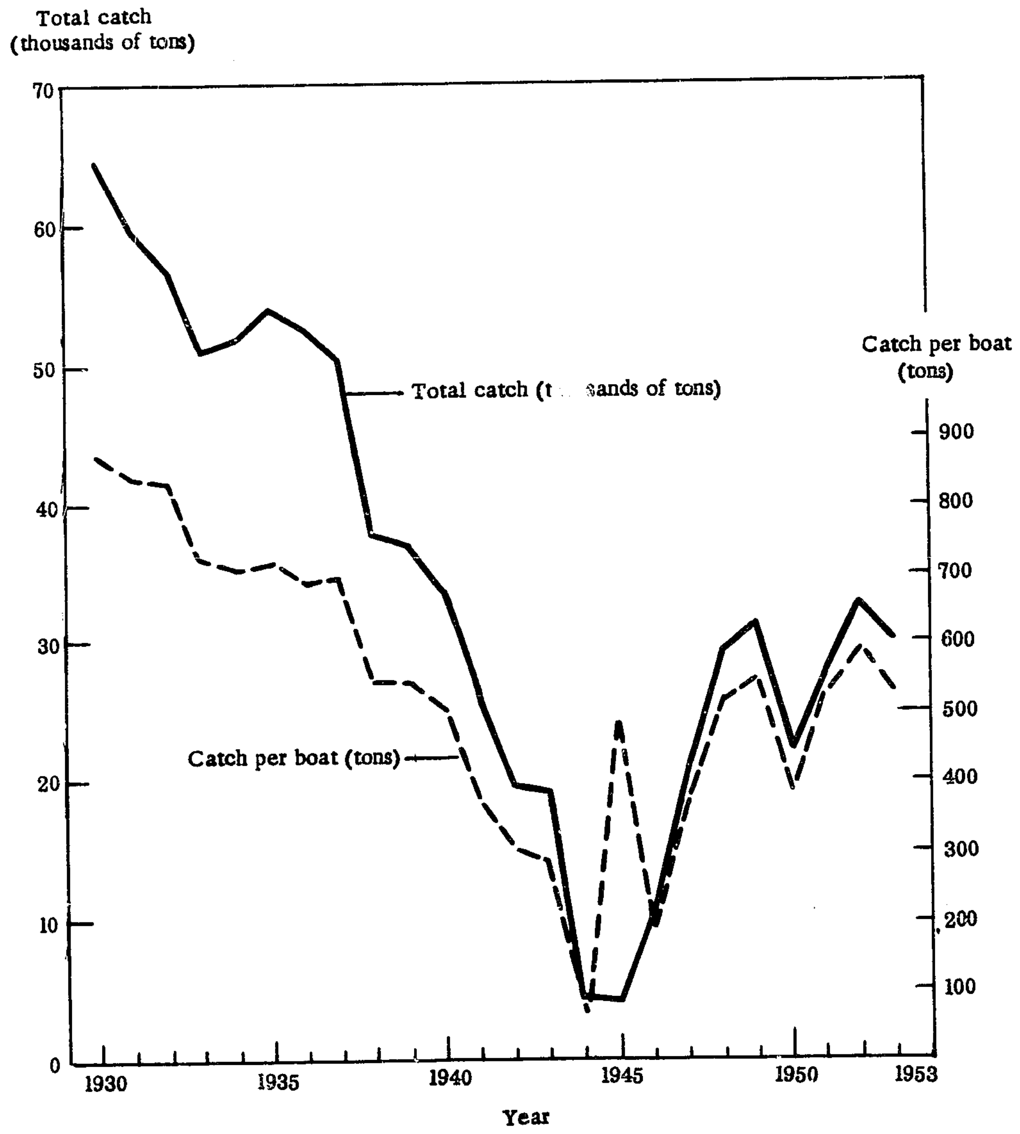
There has been no great increase in the bluefin tuna catch, but with improved techniques and gear for long-line fishing, the catch of albacore has greatly increased in recent years, as the following figures indicate.

	Catch (tons)	
	Average, 1921-25	1953
Albacore	11,250	52,500
Bluefin tuna	22,500	17,250

Bottom fish in the East China Sea and the Yellow Sea

Fishery resources in the East China Sea and the Yellow Sea consist of more than 250 economically important species of bottom fish. They are considered a single unit, however, in conservation management. As a group, bottom fish in these seas behave differently from those in adjacent waters, and rarely intermingle with other fish.

Figure 44. Catch of bottom fish by otter trawler in East China Sea and Yellow Sea, 1930 to 1953

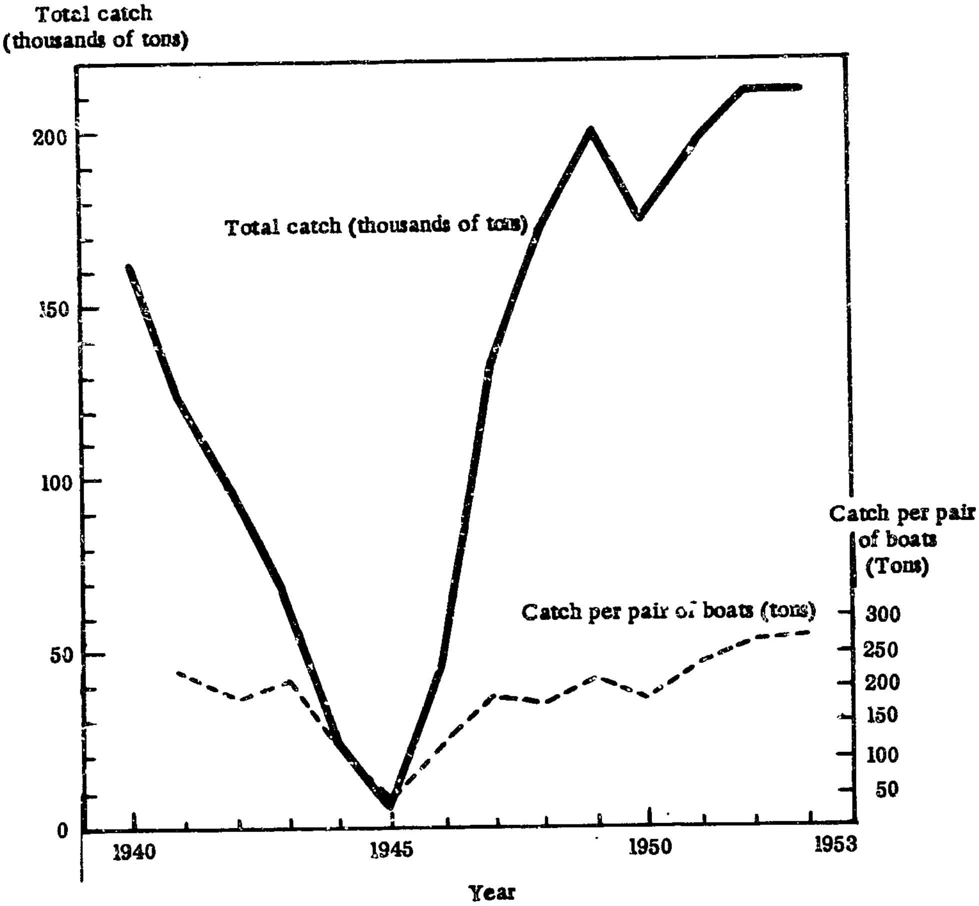


Most of these species spawn in coastal waters, and their larvae and juveniles grow there. The adult fish migrates for feeding towards the open sea, each species taking its own route. Movements of bottom fish as a whole are very complicated; they are caught all year round in all fishing grounds. Most of the bottom fish feed on nekton and benthos and they generally eat other fish. Larvae and juveniles of all species are preyed on by adult fish of other species. Among the bottom fish, the struggle for existence makes the populations closely interdependent.

The Japanese catch of bottom fish in 1940 was 200,000 tons, but it dropped to under 20,000 tons in 1945. At present, production has been restored to the level of pre-war years. The catch by otter trawlers amounted to 34,189 tons in 1953; two-boat trawlers caught 238,000 tons, making a total of over 272,000 tons. The number of licensed boats and the catch per boat in 1953 are given below. Catches for earlier years are shown in figures 44 and 45.

	Number	Catch per boat (kilogrammes)
Otter trawlers	58	707.625
Large trawlers	783	543.75

Figure 45. Catch of bottom fish by two-boat type of trawler, in East China Sea and Yellow Sea, 1940 to 1953



Most of the fishing boats remain in port during July and August. The Japanese fishing fleet operating in these waters is as large as in pre-war years, but despite improved gear and facilities, the annual average catch per net has dropped from 851 kilogrammes in 1947 to 547 kilogrammes. In view of the rising trend in the total catch, however, it is not thought that there is danger of overfishing. Nevertheless, it is considered desirable not to increase further the number of boats in the area. Biological investigations are now being carried on by experts regarding the species of fish constituting the resource.

Bottom fish in Japanese coastal waters

There are many species of fish in Japanese coastal waters, and dominant species vary according to the fishing grounds. For purposes of conservation management, however, they are treated as a single population. They are found around Japan in waters under 200 metres in depth, but in certain regions they may be fished in waters 500 metres in depth.

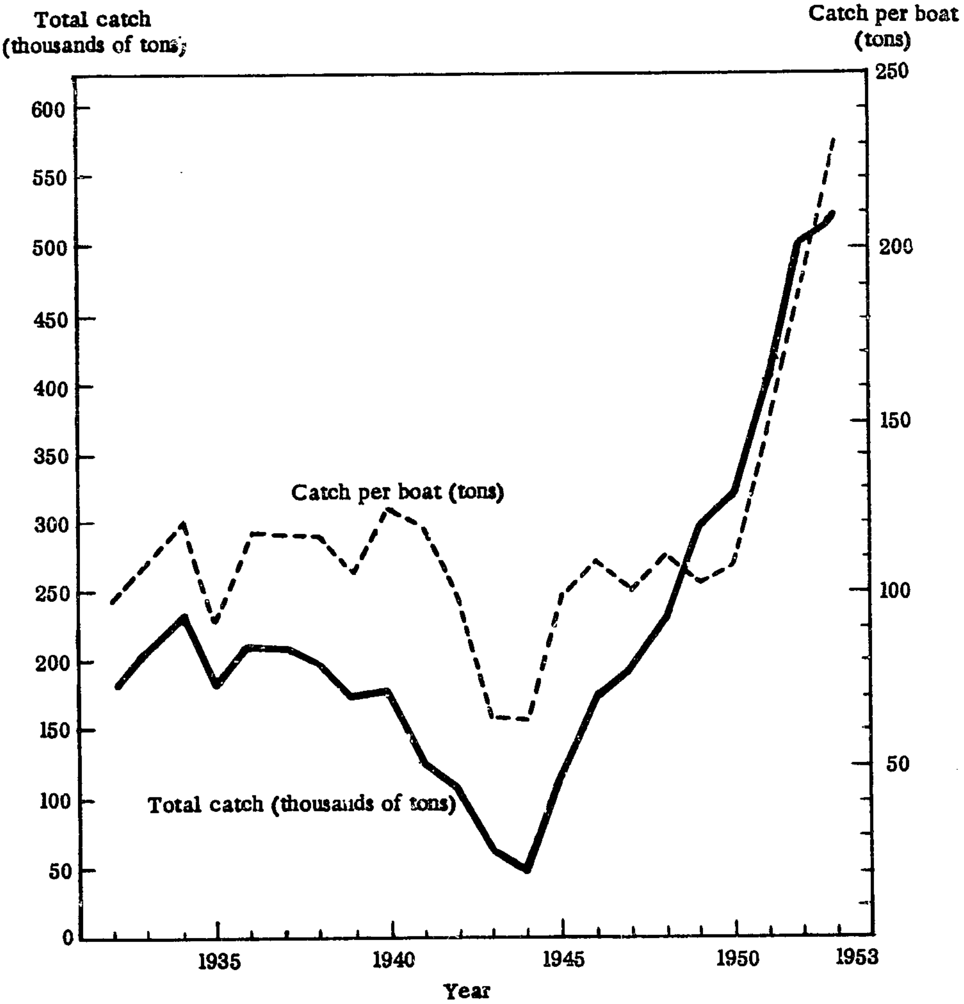
These fish generally come near the shore in their spawning seasons and then leave after spawning. They remain in the same general area, with only small migrations. Most of them become mature in one or two years after birth, and spawn in spring or summer; the catch of the commercial fishery consists largely of one-year-old to three-year-old fish.

The catch in 1944 was 45,000 tons, the lowest recorded in twenty years. Since then, the amount has risen gradually, to more than 500,000 tons in 1953 (see figure 46). As the chart indicates, the rising trend occurred both in total production and in the catch per boat. Because of conservation measures, however, the number of registered fishing boats in Japanese waters, amounting to 2,836 in 1951, was reduced to 1,983 by the end of 1954.

Squid

The squid (Ommastrephes sloani pacifius Steenstrup; flying squid or sagittated calamary) are caught in all coastal waters of Japan. In conservation management they are considered one unit. The unit consists of both the summer and the winter spawning groups, the quantity of the former being only 10 to 20 per cent that of the latter.

Figure 46. Annual catch of bottom fish in Japanese waters, 1932 to 1953



The number of males and of females in the spawning group is almost the same. About 500,000 eggs are spawned per fish. The summer group remains in the south from June to August and is found in the north from July to September. Favourable water temperature is about 23° centigrade. The winter group is found south of central Japan from January to March when the water temperature is over 10° centigrade. They do not spawn in the north.

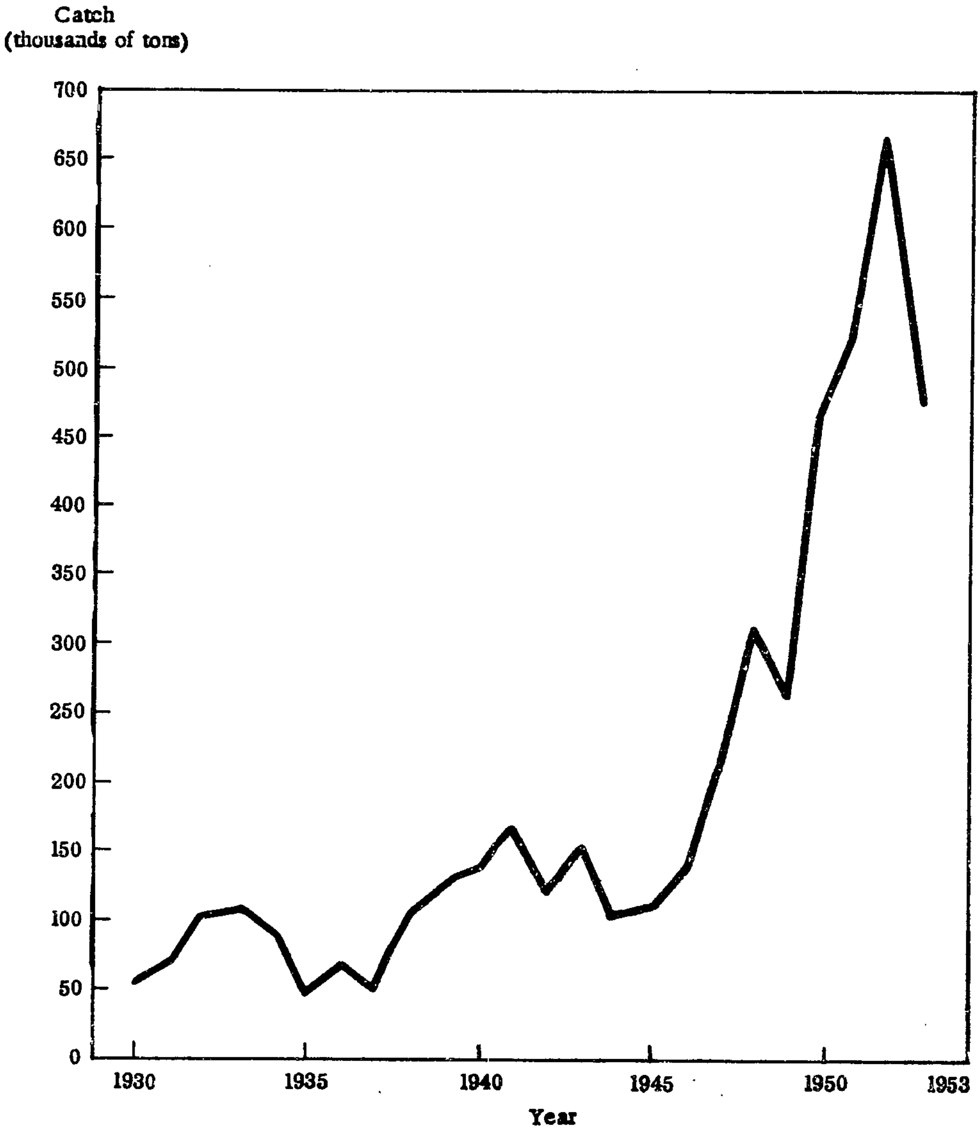
The body (mantle) length of the squid attains 7 centimetres in two months after birth, 15 centimetres in six months, 19 centimetres in seven months, 20 centimetres in eight months, 21 centimetres in nine months, 22 centimetres in ten months, 23 centimetres in eleven months and 25 centimetres in twelve months. They become mature in a year, and die after spawning. The squid feed chiefly on sardines, small mackerel and pelagic crustaceans.

During the day the squid swim in a layer about 100 metres deep; they rise at night to a surface layer. During the autumn and winter they come southward from Hokkaido to Kyrshu. In the spring they move northward from the south and reach Hokkaido in the summer. Some groups remain in one place and do not migrate. The highest speed of the migration of others has been estimated at ten sea miles a day.

The population of squid has increased in recent years. Formerly, the average annual catch was 100,000 tons, but it has recently risen to between 400,000 and 600,000 tons (figure 47), still only 5 to 15 per cent of the estimated total population.

(Bibliography follows on page 315)

Figure 47. Japanese catch of squid, 1928 to 1953



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COMMENT BY THE KOREAN DELEGATION
ON THE
PAPER SUBMITTED BY THE JAPANESE DELEGATION

The Korean delegation wishes to make a few comments with reference to the paper submitted by the Japanese delegation. The paper contains many points which the Korean delegation should like to discuss in detail, but in order to be brief it will limit its comments to a few important ones.

Herring

On the subject of herring (Clupea pallasi Cuvier and Valenciennes), the Japanese paper states that the same species of herring as are found in waters around Japan are also in waters off the south-eastern part of Korea. This is not true. The herring caught in Japanese waters and those found in Korean waters are of two quite different species. The herring caught in waters adjacent to Korea have morphological characteristics distinct from those of the Japanese herring. The Korean herring migrate only between shallow and deep waters, while the Japanese herring migrate over a great range. The Korean herring form an independent population.

The Korean herring spawn on seaweed or other fixed matter in shallow waters during the months of January and February. The maternal herring consist mostly of the four-year, five-year and six-year age groups. Juveniles grow in shallow waters and with the approach of winter migrate to deep waters; they remain in a layer about 200 metres deep during the winter. The following summer, these juveniles move towards the coast and repeat their shallow water and deep water migrations with the change of season. The Korean Government has been taking conservation measures for the protection of herring resources by specifying the permissible body length of the catch (more than nine centimetres) and by establishing a closed period of two to three months in summer, among other measures.

Mackerel

The two species of mackerel, Scomber japonicus Houttuyn and Scomber tapeinocephalus Bleeker, form two distinct populations, with different migrating areas. The Scomber japonicus is an independent population which inhabits the waters around Korea. The fish migrate for feeding in coastal waters where nutrients are rich, and their migration remains within a small range.

They stay in waters adjacent to the Kyung Sang Pukdo, Kyung Sang Namdo, Cholla Namdo archipelago and Cheju Island during winter. In March or April, when the water temperature reaches 13° centigrade they migrate for food, forming a population. As the warm current intensifies, a small part of the population migrates northward along the coasts of Korea to the Ham Kyung Pukdo in the east and to the Pyung An Pukdo in the west. The farther they go northward, the more sparse the population becomes. Most of the population remaining in the south migrates the coastal waters of the Cholla Pukdo, Cholla Namdo, Kyung Sang Pukdo and Kyung Sang Namdo until winter. The density of population is at its highest during the period from June to October, making this period the best fishing season in the area. When the cold current increases and the water temperature is low, the population which had migrated northward returns to the south and remains there during the winter.

When the water temperature is about 15° to 20° centigrade, spawning takes place twice a year in coastal waters ranging from Nam Hae-do to the western coast of Cholla Pukdo (where spawning is most intensive). The spawning period is May and June. The juveniles grow in shallow water and, like the mature fish, are found in all the coastal waters the year round.

As may clearly be seen from the above, the mackerel inhabiting the coastal waters of Korea form an independent population, which neither provides fishing in the waters halfway between Korea and Japan, nor intermingles with other populations. The Scomber tapeinocephalus are rarely seen in waters to the south of Cheju Island in summer and their migration routes differ from those of the Scomber japonicus.

The average catch of Scomber japonicus per unit effort has been decreasing in Korea since the end of the Second World War, demonstrating a serious in the fish population. Should there be no adequate and effective measures for the conservation and protection of the resource, it would eventually face the danger of depletion.

Bottom fish in the East China Sea and the Yellow Sea

Most of the species of bottom fish in the East China Sea and the Yellow Sea make seasonal migrations to the western coastal waters of Korea for spawning and in search of rich nutrients carried from the coast. The coastal waters are thus their spawning grounds and the cradle for their larvae and juveniles. Korea, therefore, has not only a special interest but a duty in protecting them from arbitrary damage by human activity.

However, the fishery resources in the area have been subject to excessive exploitation by Japanese otter trawlers since 1911. The decrease in the resource became apparent by 1921, when large-scale drag nets were introduced into the area. The consequent danger was too evident to be ignored, and by about 1926, the Japanese Government had established measures for fishery control with a view to protecting the resource; they had little success because of the ever-increasing number of fishing boats and their activities.

During the Second World War, the resource was restored to a great extent, owing to the temporary decrease in fishing effort. However, after the war, the intensity of fishing effort greatly increased, causing a large decline in the resource. The Japanese paper does not take account of these historical facts supported by scientific data.

Conservation measures taken by Korea

In view of the importance of fisheries in the national economy, Korea has taken various measures for the conservation and protection of fishery resources in adjacent waters for some time past. The first modern regulations were contained in Law No. 29, the Korean fishery law, promulgated in 1908 by the Korean Government. A series of regulations has been established and enforced since then, including the fishery ordinance of 1911, amended in 1929, the fishery protection regulation of 1929, and fishery regulations issued by several provinces.

Since 1945 the Korean Government has been intensifying its fishery conservation efforts in view of the decrease in resources in adjacent seas because of excessive exploitation by foreign nationals. Whatever small amount of fishery resource remains in the seas adjacent to Korea is the result of conservation, protection and cultivation by Korea at the cost of human toil and financial burdens.

COMMENT BY THE JAPANESE DELEGATION
ON THE
PAPER SUBMITTED BY THE KOREAN DELEGATION

Regarding the first three paragraphs of the comments of the Korean delegation, dealing with herring, the Japanese delegation is well aware of the fact that Asian herring consist of several different races. The Japanese paper, however, did not intend to analyse these races from biological and ecological points of view, but simply stated that they can be and are being treated as one, so far as conservation management is concerned.

As for the paragraphs dealing with the two species of mackerel, in view of a tagging experiment conducted before the war, and from a statistical comparison of morphological characteristics of mackerel in waters near Japan and those in waters near Korea, it cannot be established that the Scomber japonicus inhabiting the waters around Korea are an independent population.

The shoals of Scomber japonicus spawn in the East China Sea in spring, then begin a feeding migration to the north; in summer most of them concentrate in the coastal waters of Hokkaido after migrating along the Japanese coast, while some appear in Korean coastal waters. Because of the multiple spawning of mackerel, some of the large-sized individuals spawn in northern grounds while they are there. Towards the middle of autumn, these groups of mackerel return to the south, taking different migration routes. Such extensive dispersion is a general characteristic of mackerel, and, although it is true that farther south more groups can be seen staying for a longer period of time in a given area, it simply means that the groups take different migratory routes, and they certainly cannot be deemed an independent population for that reason.

As to the final paragraph in the comment on mackerel, the decrease in the average catch per unit effort is not necessarily a sign of depletion of stocks. The catch of mackerel by purse-seines and angling is composed largely of large-sized individuals of more than twenty-five to thirty centimetres, belonging to the group which migrates extensively. They have shown hardly any sign of depletion, even in recent years, as can be seen from the Japanese paper. Even if they had, it could be considered a reflection of natural fluctuations in the population.

With regard to bottom fish, Japanese trawlers are not catching larvae and juveniles of bottom fish in the western coastal waters of Korea. The total catch of bottom fish by otter trawlers in the area did not decrease, except during the war years. There have been fluctuations in the catch, however, of certain specific species. But the reason for this was an internal rearrangement of the composition of the species, within the community, as a result of environmental factors.

Furthermore, Japan undertook fishery control measures in the nineteen twenties, not because it felt the need of conservation, but because it was necessary to control competition among trawlers. In fact there was over-production of fishes, rather than under-production, such as might result from depletion of stocks. The measures therefore had hardly anything to do with conservation but were by and large successful in rationalizing fishery enterprises.

In conclusion, Japan is making every effort to further the scientific study of fish resources in the waters around Japan, and is very eager to carry out rational exploitation of these resources through international co-operation, where necessary.

THE IMPORTANCE OF CONSERVATION OF STOCKS OF FISH AND SEA MAMMALS IN ARCTIC WATERS

by

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(The mimeographed text of this paper appeared as A/CONF.10/L.31 and Corr.1, under the title "Information Concerning the Importance of Conservation of Stocks of Fish and Sea Mammals in Arctic Waters")

For more than 230 years Greenland has been under Danish sovereignty, and during that long space of time it has always been the aim of Denmark to help and protect the native population and to develop all possible industries which can be carried out in that remote part of the world, which lies on the boundary of the existence of human beings. With its more than 2 million square kilometres Greenland is the largest island in the world. As the inner part of the island is covered by the inland ice - and enormous icecap 3,000 metres thick - only a small coastal area of about 350,000 square kilometres remains.

The climate is arctic, owing to the northern position of the country, the neighbouring inland ice and the influence of the cold polar current. The country provides no possibilities for economic exploitation except for a modest char fishing industry, some hunting and mining, and some sheep farming in the southernmost areas. The population, amounting to about 24,000 individuals, a mixed population of Eskimo origin, lives in small communities scattered along the west coast, from about 60° to 78° north latitude, and in two districts of the east coast south of 70° north latitude.

All the inhabited places are, without exception, situated on the coast, close to the sea, and the Greenlanders' only resource is the stocks of sea mammals and fish.

Until the climatic change set in during the nineteen twenties, seal hunting was the principal industry. With the increasing temperatures of the sea, cod appeared in greater numbers and over larger areas than before, and a very important cod fishery was gradually developed in the southern and middle part of West Greenland. Seal hunting, however, is still of vital importance to the population of North and East Greenland, where cod are lacking or appear for a very short season. From the seal the Greenlander gets all he needs for existence in the cold Arctic region. The seal's skin is used for clothes and cover for kayaks, umiaks and tents. Its blubber is used for heating the houses, and together with the meat, intestines and all other entrails of the seal, it forms the only procurable nourishing food.

Six species of seals occur in Greenland waters. Four species are stationary or migrate only slightly, while two species, namely the harp seal (Phoca groenlandica) and the grey seal (Cystophora cristata), are migrating seals which have breeding and moulting places in other regions far away from Greenland and only visit Greenland in periods of feeding migration. The most important seals are the harbour seal (Phoca hispida) and the harp seal, but in some localities the grey seal is of importance.

For the polar Eskimo tribe in Thule districts, the walrus is an extremely important animal.

Owing to more unfavourable ice conditions in recent times, caused by the climatic change, and owing to a northward movement of the harbour seal, the catch of that species has decreased. The harp seal and the grey seal have occurred in smaller numbers than before, and the catch of these species has also diminished. Nevertheless, seal hunting is still of great importance to Greenlanders, especially in North Greenland.

Greenlanders look with the greatest anxiety on the exploitation of the stock of harp seal and grey seal which takes place in the breeding places and which they consider to be a menace to the industry.

We are grateful to Canada and Norway for having limited the hunting season for seals, and especially to Norway for having abstained from hunting walrus in recent years. We are, however, convinced that further protection is needed - for instance through refraining from killing mother seals, as these form the most valuable and vulnerable part of the stock, and are of much less value to seal hunters than the pups. Some few years ago Canada, Norway and Denmark started a co-operative scientific study of the seal stock, which included the counting of seals in their breeding places, some marking experiments and investigations into the age composition of the catches of seals in the different regions. By these investigations it is hoped - among other things - to get an idea of the influence of the catch on the seal stock.

No one knows, however, whether other nations will in future participate in seal hunting, and for this reason the Government of Denmark is highly interested that protection of arctic sea mammals should be taken into consideration, when common rules for protection of organisms in the sea are set up by the International Law Commission.

We are aware that our situation is similar to that of countries especially interested in the coastal state question. But there is a difference between Greenland and other countries in this matter. Other countries commonly have other resources upon which they have the possibility of building up industries. For instance, they have in many cases been able to carry on fishing, whaling and seal hunting in waters far away from their home countries. This possibility does not exist for the poor Greenlander, who hunt seals with very primitive gear and has only had the opportunity of developing a fishery for a period of about twenty-five years. In spite of the fact that the Greenland fishing fleet has grown in extent in recent years, the greater part of it still consists of small boats with very weak engines. Only a few are fitted out for operations in offshore waters. It may be many years before a rather primitive and poor population such as this will be able to exploit distant fishing and hunting grounds.

The cod stock for a number of years has been very rich, in Greenland waters. Nevertheless, it must be kept in mind that the cod, like other fish species, has its northern limit off Greenland and that its existence there depends on the relatively high temperatures of the sea in the present period. Very small variations in temperature can be disastrous to the cod population, for fluctuations according to age groups are much more pronounced here than in other waters where cod occur.

From experience over centuries, it is known that the occurrence of cod has been of a periodic character. During the past century only two fairly rich periods are known. Both of them lasted for a few years only. We fear that the rich period which is now occurring will come to an end after a shorter or longer term of years, and if this happens, it will be disastrous to the Greenland population if the very few other possibilities for existence should be diminished by over-exploitation by foreign fishermen and hunters.

In this connexion, we wish to draw attention to the fact that the stock of halibut, which was very rich until the middle of the nineteen twenties, was nearly destroyed in less than ten years by several foreign fishery expeditions carrying out long-lining on the banks and in the deep part of Davis Strait. One of these expeditions fished from more than sixty large motor dories and some other fishing vessels, while the mother ships were very big ships, of 5,000 and 10,000 tons. This single expedition had a yearly output of 3,000 to 4,000 tons of halibut, until in 1935 the halibut stock was diminished to such a degree that the fishery became unprofitable and was given up.

During the same years the modest Greenland halibut fishery decreased very considerably, owing to overfishing of the stock. A plant built in Greenland for the canning of halibut, which had worked quite successfully, had to turn to canning shrimps instead of the decreasing halibut. We know that halibut have been present in Greenland waters also in the cold periods when the cod have been very scarce. It seems that the stock of halibut in recent years has recovered to some degree, but if the same exploitation as in the nineteen twenties and thirties were to be repeated, even on a lesser scale, the stock will once again be destroyed, and the Greenlanders will lose another of their few possibilities for fishing.

From the Danish side, we are very anxious lest the diminution of the stocks of sea mammals and fish in Greenland waters by over-exploitation deprive the poor Greenland population of the possibility of surviving in their rough country. Denmark is a small country without possibilities for transferring the Greenlanders to other, more favourable, places.

Referring to what has been mentioned, we shall once more emphasize that the occurrence of sea mammals and fish in arctic regional waters is a matter of life and death to the small native population. Denmark, which has the responsibility for the welfare of this population, therefore suggests that consideration may be given to our special problems in the report of this Conference to the International Law Commission.

PRODUCTIVITY AND INTENSITY OF EXPLOITATION OF THE ADRIATIC

by

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(The mimeographed text of this paper appeared as document A/CONF.10/L.32)

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Phosphorus content and fertility of water masses:

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When dealing with the exploitation of a fishing region a clear distinction should first be made between the open seas and the enclosed seas and basins. This distinction is particularly necessary if it is intended to examine fully the influence of man on the aquatic biota. In comparison with open marine areas, the enclosed seas or basins are much more influenced by man in this respect, and therefore the regulations required for the purpose of fishery management of various regions should not be standardized. Conclusions as to the degree of exploitation of a sea or basin, and concrete measures needed to protect that particular area (but not other areas which, although similar, do not precisely correspond), can only be drawn on the basis of an analysis of factors influencing the productivity of that sea, analysis of the extent of utilization by man, and similar data.

These arguments must be borne in mind in any comparison of the Adriatic with other more or less exploited seas. In contrast with other European seas, not excluding the branches of the Mediterranean, the Adriatic is notably poor in phosphates and nitrates. This deficiency is the result of a series of factors - for example, insufficient chemical polarization, saturation with oxygen, inadequate liberation of phosphates from the sea bed - which contribute to increasing assumption, by the Adriatic, of the properties of an oligotrophic basin (Buljan, 1953a).[1]

Deficiency in nutrient salts in a sea (by analogy with Liebig's Law of the Minimum) has been found to influence its total productivity. By taking the production of the Adriatic as a function of its amount of phosphorus (Riley and others, 1949; Harvey, 1950) and by comparing it with that of the English Channel, for example, it can bee seen how far these two fishing regions differ in their potential fertility.

Phosphorus Content and Fertility of Water Masses

Adriatic

The Adriatic (figure 48) covers an area of 132,500 square kilometres and has a volume of 31.7 times 10^{12} cubic metres. Its average depth is 239.3 metres. The exploited continental shelf to a depth of 300 metres has an area of 103,717 square kilometres, with a volume of 16.7 times 10^{12} cubic metres.

The amount of phosphorus found in the central Adriatic, along the profile Split-Monte Gargano, in 1952/53 averaged 9.19 milligrammes per ton (Buljan, 1953b). By multiplying this average amount by the total water volume of the Adriatic, we obtain a value of about 291,000 tons of total phosphorus, of which some 153,000 tons occur in the waters over the exploited shelf, the extent of which is explained above.

Since some 74,000 tons of fish were caught in the Adriatic in 1953, this would correspond, for a phosphorus content of 1.2 per thousand, in fish, to

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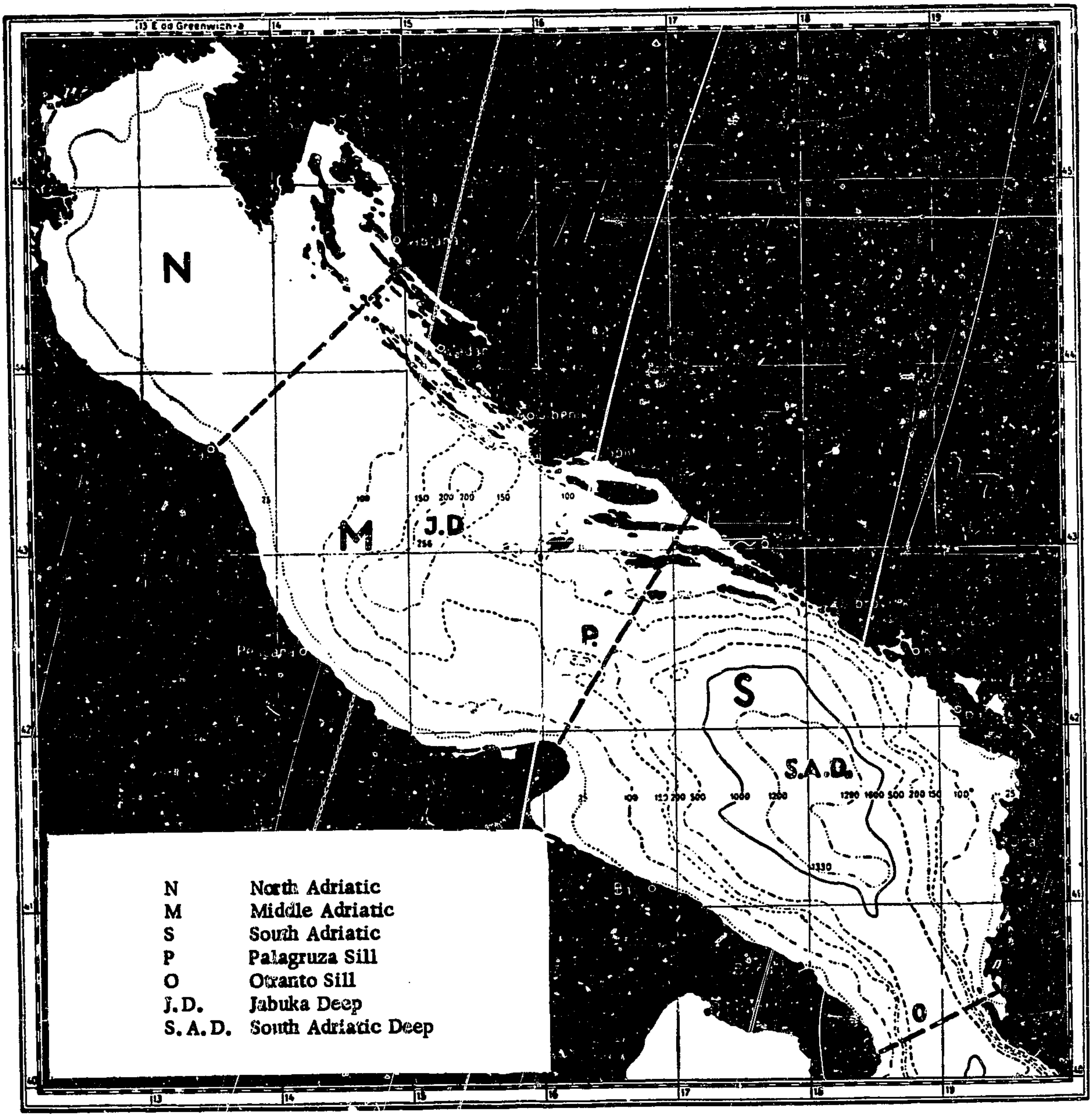
[1] References within parentheses are to items listed in the bibliography at the end of this paper.

Figure 48. Map of the Adriatic showing marine depths



89 tons of phosphorus or 0.03 per cent of the phorphorus in the Adriatic as a whole, and 0.06 per cent of the phosphorus in the waters over the exploited shelf. The value thus obtained represents a crop seventy to eighty times smaller than that of an artificially fertilized lake or lagoon.[2]

English Channel

The English Channel (area VII D and E on the maps of the International Council for the Exploration of the Sea) covers an area of 82,100 square kilometres and has a volume of 5.9 times 10^{12} cubic metres. Its average depth is 72 metres.

The total amount of phosphorus found in the English Channel in 1947/48 averaged 15.0 milligrammes per ton (Armstrong and Harvey, 1950), corresponding to about 88,000 tons of phosphorus computed for that area. The 1948 fish catch amounted to some 56,000 tons, equalling 67.0 tons of phosphorus or 0.08 per cent of the total phosphorus of the area.

The ratio of nutrient salts, in the minimum, is still less favourable in the Adriatic, if, instead of total phosphorus, free phosphates are considered, since these represent about one-third to one-seventh of total phosphorus in the Adriatic, and up to two-thirds in the English Channel (Buljan, 1953b).

Intensity of Exploitation of Fish Resources

Adriatic

According to available data,[3] catches shown on page 330 were taken in the Adriatic after the Second World War (in metric tons).

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[2] "Hier rechnet man bei einer einmaligen Düngungsgabe mit einer Rückgewinnungsquote von nur 0.7% im ersten Jahr, der allerdings in den weiteren Jahren noch weitere, allerdings wesentlich kleinere schnell abfallende Mehrerträge folgen" (Kalle, 1953).

[3] Istituto Centrale di Statistica, Annuario Statistico Italiano, 1949-50, tav. 188, 220, Ser.V., vol. V (Rome, 1953), pages 210-214. Istituto Statistico Italiano, Statistica della Pesca e della Caccia (Rome, 1954), pages 17, 18, 51, 52, 85, 89 and 94. Federal Institute of Statistics, Fish Catch-Distribution and Processing of Sea and Freshwater Fish in 1953, No. 93 (Belgrade, 1953)(data on catches taken in the former Trieste Zone "B" added by the author). Institute of Statistics, Croatia, No. 2/1954, Monthly Statistical Report, III, page 11: "Trawl Fishing in the Waters under Territorial Competence of the P.R. of Croatia"(Zagreb, 1954). J. Basioli, Development of Sea Fishing in the P.R. of Croatia (Institute of Economics, Zagreb, 1952).

Year	Species		Total
	Pelagic	Demersal	
1947	23,945	31,235	55,180
1948	23,927	34,590	58,517
1949	32,442[a]	35,442	67,884
1950	34,833	42,814	77,647
1951	30,558	38,244	68,802
1952	34,318	37,580	71,898
1953	36,667	37,457	74,134
Total (thousands of tons)	30,957	36,766	67,723

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[a] No data for *Thunnus* species are given in Italian statistics.

Of demersal species caught in the Adriatic, 80 per cent are taken by trawlers. The number of trawlers, according to the available data, was as follows: in 1947,[4] 920; in 1951,[4] 1,504; in 1952,[4] 1,683; and in 1953, 2,025.

English Channel

The data on catches in area VII D and E have been taken from the *Bulletin statistique*.[5] For 1947 to 1952 the catches were as follows (in metric tons):

Year	Demersal species	Total (all species)
1947	25,670	41,377
1948	37,246	55,778
1949	44,388	57,942
1950	31,051	67,013
1951	27,193	85,112
1952	40,909	123,171
Total (thousands of tons)	34,410	71,732

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[4] Data on motor trawlers only (motorpescherecci), from 25 horsepower up, were listed in the Italian official statistics for 1947, 1951 and 1952, while the number of vessels for 1953 was determined according to method of work in this sort of fishery for the Adriatic coast as a whole.

[5] Conseil Permanent International pour l'Exploration de la Mer, *Bulletin Statistique*, vol. 32-37 (Copenhagen).

The sudden increase in total catch from 1950 to 1952 may be attributed to more intensive fishing by German trawlers equipped with stronger engines and more up-to-date devices for detection of fish shoals, and to the extension of the herring season (Meyer, 1954). Other species, particularly the demersal, were caught more or less in the same quantities during this period. This fact has been considered when comparing the Adriatic and the English Channel with regard to their utilization and productivity, since it is on the demersal species that the influence of man becomes most manifest. Since natural fluctuations are likely to be less significant in these species, the predatory influence of man is of cardinal significance. It is quite different with the pelagic species, where there are very marked natural fluctuations and the activity of man is hardly felt (Rollefsen, 1951; Tester, 1951). In making a comparison, therefore, between the two fishing regions with regard to intensity of exploitation, it is the demersal fish population that is considered and the size of their catches in relation to the free phosphorus content per unit area.

Exploitation Ratio

The extended shelf of the Adriatic yielded 3[illegible],688 tons of demersal fish, or 363 kilogrammes per square kilometre per year, during the period from 1948 to 1953. The average yield of the English Channel, from 1947 to 1952, was 34,410 tons of all demersal species, or 419 kilogrammes per square kilometre.

The total amount of phosphorus and free phosphates available in the two fishing regions may be compared, as well as the corresponding catches:

	Adriatic	English Channel
Total phosphorus	291,000 tons	88,000 tons
Free phosphates ($P-PO_4$) ...	33,000 tons (291,000 x 0.115)	58,000 tons (88,000 x 0.66)
Catch	38,000 tons	34,000 tons
Phosphorus in total catch .	38 x 1.2	34 x 1.2
Ratio of phosphorus in catch to free phosphates	$\frac{38 \times 1.2}{33,000}$	$\frac{34 \times 1.2}{58,000}$

If one set of figures is divided by the other, it is seen that this ratio is nearly 2:1; that is, the fraction of available phosphorus removed in the catch from the Adriatic is twice the fraction removed in the Channel.

This repeated removal of limiting salts from the Adriatic will probably lead to an unfavourable effect on the balance between the fish and the rest of the biomass within the eco-system. The composition of the ichthyocenosis in warmer shallow waters shows that the biomass of useful animals is kept down, to the advantage of the remaining animals (a larger number of species but a smaller number of individuals, probably linked with a retarded growth and little possibility of regeneration). The fishing process in the sea, particularly when it bears upon demersal species, thus results in gradual diminution of the total biomass of useful animals.

Even though these computations have been made in a somewhat crude way, and may, therefore, involve some error, they still enable one to draw at least some general conclusions as to the productivity and intensity of exploitation of the two fishing regions compared.

Effects of Exploitation

Biological

Restriction of fishing during the Second World War had approximately identical effects on the demersal populations in the Adriatic and in the north European seas (Zupanovic, 1953). An increase in all catches in 1946 by about 50 per cent above the 1939-40 level was reported by D'Ancona (1950) for the north Adriatic, under identical conditions of weather, place and gear. The causes of this increase in fish populations after the war may either be the increase in number of fishes on various fishing grounds, or, more likely, an increase in the average size of fishes in the population owing to diminished mortality and greater probability of survival. This latter hypothesis is confirmed by the 1951 findings in the Bay of Kvarner and in the Podvelebit Channel (along the east coast of the Adriatic). The Bay of Kvarner, owing to unswept mine fields, preserved its virgin stocks until 1951, when trawling was resumed. The average length of Merluccius vulgaris - from the -

economic point of view the most important species of the Adriatic deep sea trawl fishery - was 28.34 centimetres, with 75.3 per cent of specimens above 25 centimetres (according to Zei, 1940, this limit is the border line between the juvenile and adult specimens). The average length of Merluccius caught in the Podvelebit Channel in 1938, when trawling was prohibited there, was 27.3 centimetres, while in 1951, as a consequence of more intensive trawling in that narrow sea during post-war years, the average length of this species dropped to 23.4 centimetres, with only 59.3 per cent of specimens above 25 centimetres. This trend of decrease in the average length of the population of Merluccius is evident in other channels also. The Crikvenica Channel yielded the following average lengths: 1938, 21.0 centimetres; 1947, 27.5 centimetres; 1950, 23.0 centimetres. The Kvarneric Channel had the following averages: 1938/40, 20.2 centimetres; 1947, 29.12 centimetres; 1950, 25.7 centimetres (Zupanovic, 1953).

As regards the open Adriatic, data were available on Merluccius catches, supplied by some commercial trawlers. These data refer to the fishing region lying west of Blitvenica Lighthouse[6] in the direction 270° (43°30' north latitude and 15°13' east longitude). The data are included in the following table.

Year and period	Number of days	Number of trawling vessels	Catch	
			Kg.	Kg. per 100 hours
1951, 3 November to 29 November ...	96	8	8,180	1,065.10
1952, 1 October to 17 October	71	9	4,147	730.10
1953, 4 December to 28 December ...	44	4	2,053	583.23
1954, 3 November to 31 November ...	26	4	1,055	507.21

The decrease in the average size of specimens within populations of economically important species, which is closely connected with the decrease in catch per unit of effort, was until lately considered by the majority of fishery biologists one of the fundamental indications of overfishing. This factor, however, if taken separately, does not prove overfishing (Graham, 1951), and its consequences have rather an economic than biological importance.

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[6] This region is intensively exploited by Yugoslav trawlers.

Further investigations will help to solve the question whether the decrease in the average size of Merluccius in the Adriatic is really caused by activities of man or is the consequence of some as yet unknown natural fluctuations and migrations of adult specimens.

Economic

The fundamental economic problem in which we are here interested is the relation between the catch and its cost. These relations differ widely with regard to various components, and their symbolic formulas may be given in one of the following ways:

$$\text{(i)} \quad T_p > c_v + c_f$$

$$\text{(ii)} \quad T_p = c_v + c_f$$

$$\text{(iii)} \quad T_p < c_v + c_f$$

where T_p stands for the total proceeds from catch, c_v for variable cost, and c_f for fixed cost.

In the first case, the total proceeds (T_p) are much higher than the composite total cost ($c_v + c_f$) and may represent the maximum net return. One could talk here about profit from such a fishery.

But competition among fishing units, particularly in enclosed basins like the Adriatic, does not allow that maximum net return to continue for a long time at the point where "the marginal cost equals marginal production" (Gordon, 1953), and the exploitation goes on to the point where the variable cost rises out of proportion to the catch value. This logically leads to a balance between total proceeds and total composite cost as in the second formula.

In the third case, the catch proceeds do not cover the total cost, and the fisherman is underpaid in comparison with men in similar lines of work. At this exploitation rate the variable cost if particularly high (for fuel, effort and other items) but the total catch remains constant or may even grow smaller owing to decimation of the species or decrease in average size of adult specimens.

If these criteria are applied to trawling in the Adriatic, which involves about 80 per cent of all the catches of demersal species, it may be concluded that today, in some of the zones, the situation is not far from the third case with regard to the economic aspect of exploitation.

Conclusions

In comparison with the English Channel, the Adriatic is 5.4 to 6.0 times poorer in free phosphates ($P\text{-}PO_4$). But the proportion of phosphorus removed from the Adriatic by taking demersal species is twice the proportion removed from the English Channel.

The biological effect of exploitation of the Adriatic manifests itself in a decrease in the average size of Merluccius vulgaris, economically the most important species in the Adriatic deep-sea trawl fishery, and in a reduction in catch per unit of effort. Further investigations may show in what degree these decreases are to be attributed to the activity of man and in what proportion they are the consequence of natural fluctuations and migrations of adult individuals.

The economic effect of exploitation by means of trawls in the Adriatic is reflected in the fact that fishing is unprofitable as a consequence of increased intensity of fishing by a growing number of trawlers in some zones of the Adriatic and decreased weight of the total catch of demersal species.

It would be useful, in my opinion, to make an early attempt to reach a scientific solution to the problem, since this would result in better knowledge of the present status of fish resources in some zones of the Adriatic and clearer ideas about the proper measures for fishery management aimed at improving that status.

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MIGRATIONS OF THE ADRIATIC SARDINE IN RELATION TO ZOOPLANKTON

by

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(The mimeographed text of this paper appeared as document A/CONF.10/L.25. It was submitted in French under the title "Les migrations de la sardine (Sardina pilchardus Walb.) en relation avec le zooplankton")

The sardine (Sardina pilchardus Walbaum) is one of the most important fishes of the Adriatic, accounting for one-half of Yugoslavia's total fishing effort. It is therefore natural that particular attention should have been paid to the study of its ecology.

Sardine fishing along the east coast is carried on exclusively by the night-light method from April to September. Occasionally the fish makes its appearance in small quantities as early as March. It leaves the fisheries again as soon as the bad weather of autumn sets in. Aside from this season, there is practically no sardine fishing; that is why the winter whereabouts of these fish were not known. It was thought that the sardine disappeared into the deep waters of the high seas. The question is not only of scientific interest but is also of practical importance for the fishing industry, since during this period the sardine is not available for fishing.

Until very recently, little was known about the ecology of the sardine in the Adriatic. Since the Second World War extensive research has been carried out, beginning with population studies and continuing with study of spawning periods, embryonic development in relation to external factors and distribution of eggs and larvae throughout the Adriatic. Investigation of external factors, particularly salinity, indicated some connexion between a high annual catch and the flow of Mediterranean waters into the Adriatic. Sardine migrations were studied by analysing catches and by tagging; recently a start has been made on statistical analysis of the intensity of fishing. At present, the renewal rate of the population is being determined on the basis of spawning intensity. It is unnecessary to go into detail in these respects, since a certain amount of information has already been published and more will appear in the near future. The present paper merely draws attention to the scope of the research on plankton, since it is helpful towards a better understanding of the migratory movements of the fish.

The discovery of certain spawning grounds has revealed the whereabouts of the fish in winter, or at any rate during the spawning period. As a general rule, these areas do not lie in the shallow coastal strip where summer sardine fishing takes place, but a little farther out to sea at an approximate depth of between 60 and 120 metres, but never below 200 metres. It is important to note that the spawning grounds are not far distant from the best fishing grounds and may in certain cases lie very close to them. Sardine migrations are therefore not on a very large scale.

The disappearance of the sardine from these fisheries in the autumn and its return in the spring is undoubtedly a complex phenomenon depending on both external and internal factors. It has frequently been said that the search for food is one of the factors governing the movements of fish, particularly pelagic fish. There is, however, no absolute proof of this, a comment which applies to the sardine. Study of the migratory movements of the sardine was therefore undertaken in the light of information on the total biomass of plankton in the sea. The research was concerned merely with zooplankton as a food for the sardine; the observations covered a period of one year.

Difficulties in determining the total biomass of plankton are well known, and no satisfactory method has been evolved so far. However, in order to obtain the desired results, two different methods, considered the most appropriate, were used. To fish large species, nets of coarse muslin and an oblique haul were used, and for small species, silk nets and a vertical haul. The resultant total biomass of plankton was measured in grammes and cubic centimetres. Needless to say, no absolute claim can be made for the data, but the results obtained, though relative, have been of some value in research. Details are not included here; all the data will be published separately. Two zones only are considered in this paper: one, a shallow coastal strip of thirty to forty metres, and the other a deeper strip of seventy to ninety metres in the island zone, stretching out to sea.

The average annual biomass of large species is greater in the farther outlying areas, where the best sardine fisheries and spawning grounds are located, than in the coastal strip, where the sardine is fished in summer.

The opposite is true of the small species, that is, larger quantities are found along the coast and a smaller number out to sea. A study of the path followed throughout the year by the biomass of the two types of zooplankton mentioned above has shown that there are much greater quantities of large plankton in the spawning grounds during winter than during the summer fishing season. On the other hand, during summer the total biomass of small species is greater near the coast than in the spawning grounds.

Thus, the total biomass of these two types of zooplankton gives a remarkably clear picture of sardine migration. In early autumn the sardine leaves the coastal area and fisheries and goes to the spawning grounds. There, and precisely at that period, the biomass of the larger species is greater than along the coast. In April, when the reproduction effort has been completed, the sardine comes nearer the coast. At the same time, the biomass of the larger species diminishes rapidly in the spawning grounds, while that of the small species increases in the coastal area.

The biomass of the large species found in the spawning grounds from January to April contains species of greater nutritive value (mostly large copepods of the Calanidae and Euchaetidae groups, various crustaceans of the larger variety, large sagittae and so on). Thus, at that time of the year, the sardine finds adequate food in the spawning grounds. Since the spawning lasts from November to May, and January or February and May are, in the Adriatic, the two peak periods of the year for phytoplankton, the larvae, both premature and delayed, can develop in satisfactory trophic conditions. It should be added that the migratory movements of the sardine are also influenced by other factors, among them hydrological phenomena.

One of the most important problems of sardine ecology is that of the renewal of the population. Reference has already been made to overfishing of clupeids. That is not yet the case in the Adriatic, but we are nevertheless trying to determine the rate of renewal from that point of view also, on the basis of information about the spawning grounds and their extent, and of accurate data on the intensity of spawning.

SOME OBSERVATIONS ON THE MARINE FISHERIES OF EGYPT

by

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(The mimeographed text of this paper appeared in French as A/CONF.10/L.35 under the title "Quelques aperçus sur la production des pêcheries maritimes en Egypte")

Marine conditions

Relatively warm seas such as those adjacent to Egypt are not generally expected to be very rich in fish. To some extent, however, the entire seaboard of the Nile delta constitutes an exception to this rule. The reasons are, first, the rich flow of nutritive salts brought down by the Nile while the river is in flood, and, second, the formation of shoals in the area facing the delta.

All the fish peculiar to the Mediterranean are found here, including breams, mullets, sea perch, skates and rays, dogfish, bonito, gurnard, bluefish, jack, grouper, lumpfish, umbra and sardine. The sardine is found on the delta coasts from September to December, the bluefish during the summer. The Institute of Hydrobiology at Alexandria is trying to ascertain whence they come and where they migrate. Tunny appear rarely in the Egyptian stretch of the Mediterranean, and this circumstance is largely unexplained.

It is naturally part of the research programme of the Institute of Hydrobiology to determine the fish resources, the spawning grounds, the migration routes and the sources of food, in short, to acquire any data which may have a bearing on the conservation of stocks of salt water fish. No definite conclusions are possible, however, from the data so far collected.

Only that part of the marine area which is adjacent to inhabited regions is exploited by fishermen and familiar to them. The fishing regulations are strict. Fishing with drag nets is absolutely prohibited in certain parts of the west coast (article 57 of the Egyptian fishery regulations). Fishing with the following types of net is also absolutely prohibited: (a) the seine, or garrata, fitted with a bag, if there are more than forty meshes to the bag d more than thirty meshes to the sides to each fifty-centimetre unit; (b) the seine, not fitted with a bag, if there are more than thirty meshes to each fifty-centimetre unit; (c) any kind of seine in the two zones to the north of the temporary barrages which are raised during the dry season at the two mouths of the Nile (article 58).

Furthermore, the gear used by Egyptian fishermen makes it impossible for them to work far from the coast. The use of coast guards ensures strict and effective control. Fish reaching the market are inspected as to size.

Lake conditions

Fishery problems are particularly important in Egyptian lakes, that is, the salt lakes bordering the coast and communicating with the sea by narrow inlets. The bottom of these lakes is formed by deposits from the Nile, with an admixture of sand. They are not generally more than one metre deep, but the navigable channels of Lake Manzala and Lake Burullus have a depth of two to three metres, and the vestigial channels of former arms of the Nile in these two lakes are sometimes as much as four metres deep.

The lakes contain stocks of fish of great importance to Egypt: sea perch, umbra, lumpfish, sole, eel and mullet, as well as certain species of Nilotic origin. These species migrate to the sea during the spawning season.

The Egyptian Government's policy of reclaiming additional land for cultivation through the drainage of the northern delta of the Nile is expected to result in a decrease in the depth of these lakes and a contraction in their surface area - a development which causes some concern to those responsible for fisheries. The consequences of this development, which creates special problems for Egypt, are not yet clear.

The migratory population of the lakes consists mainly of mullets - Mugil cephalus, Mugil capito and Mugil saliens. These are salt water fish which come to feed in the lakes but leave them during the spawning season.

Shoals of almost fully grown fish of the mullet species migrate to the sea during the period from June to September. The Mugil capito migrate in October and November; eels, sea perch and sole, from December to the end of February. It has been shown that a large proportion of the fish which have migrated return after spawning. Fry also head for the lakes as soon as they are strong enough to fight their way against the outward current; they are then between thirteen and eighteen millimetres in length.

The pumping station at Mex, to the west of Alexandria, returns about 4 million cubic metres of water to the sea each day. This water is only slightly saline, and attracts the fry of mullets and eels. When they arrive at the station they cannot continue their journey upstream, and vast numbers therefore concentrate at this point. This season for young mullets lasts from October to the end of March.

The Egyptian service collects a large number of the young mullets and eels which concentrate at the Mex pumping station and throws them into Lake Maryut, a salt lake south of Alexandria which is cut off from the sea. In a period of less than four years the yield from this lake has increased fivefold. Transport centres have been set up, whence glass eels, young fish, mullets and soles are shipped to other inland lakes so that they may benefit from the surplus at Mex.

Egyptian regulations governing fisheries in and around the lakes contain numerous restrictions, which need not be elaborated here, regarding the number of licences, the size of boats, the gear and the methods of fishing. These regulations show the alertness of Egyptian authorities to their responsibilities in the matter of conservation of fisheries. Among the most important provisions are the following: Fishing is absolutely prohibited (a) in the narrow inlet of Lake Burullus and within a radius of one kilometre from this channel, both on the lake and on the seaward side; (b) similarly in Lake Idku, but within a radius of two kilometres; and (c) similarly in Lake Manzala, but within a radius of six kilometres.

COMMENTS ON THE PRINCIPLE OF ABSTENTION

by

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(The mimeographed text of this paper appeared as document A/CONF.10/L.19)

In considering the merits of any system or principle of international law or international procedure regarding fishery conservation, it is probably essential - certainly highly desirable - to have some objective as a basis for evaluation. From the point of view of a world organization, the general objective is found in the preamble of the constitution of the Food and Agriculture Organization of the United Nations: "to promote the common welfare". A natural development from this is expressed in the resolution on the resources of oceanic waters and the continental shelf, adopted at the tenth inter-American conference at Caracas in 1954: "to conserve such wealth and to utilize it properly for the benefit of the riparian State, the continent and the community of nations". This leads to the reasonable conclusion that an important objective of international law or international procedure respecting fishery conservation is to encourage action by nations which will promote the development of the maximum sustainable yield of products from the sea.

There are various ways by which such action can be encouraged. This paper discusses one in particular: laws, principles or procedures which stimulate nations to take necessary action to create or restore the productivity of the living resources of the sea, which without such action would exist at far below the most productive level. It is a necessary concept for utilizing the potential productivity of the resources of the sea.

A country whose fishermen are fully utilizing a resource will hesitate to establish and enforce regulations involving limitation of the current catch (and income) of its fishermen for the purpose of creating or building up stocks of fish to yield higher future production, if this production is freely available to other non-participating countries which might later choose to draw upon it. Neither would you and I deposit funds in a savings account or regularly pay insurance premiums, thereby denying ourselves present luxuries or even necessities, if the resources so built up became available to all our neighbours within easy distance of the bank or insurance company. On the contrary, it is a reasonable certainty that in such conditions we would withdraw our deposits as soon as possible for current use or would reduce the balance to such a level that it would not be worth another person's effort to make the trip to the bank for what was left.

This is a very practical problem which must be faced realistically if effective international procedures are to be developed. The "open savings account" has handicapped the development of effective international fishery conservation programmes for the few decades that fishery science has advanced to a stage where a practical conservation programme is possible.

During the three decades since 1923, Canada and the United States have, through the expenditure of time, talent and money and through restraints on their fishermen, saved two major resources from near extinction. Over a thirty-two year period of intensive research and strict but flexible regulation, the decline in the yield of North Pacific halibut has been halted, and the productivity of the stocks built up, until the catch in 1954 was the highest ever, a 56 per cent increase from the 1930 low. Meanwhile, in other parts of the world, once important halibut fisheries have declined, until about 75 per cent of the world's production of halibut now comes from stocks administered by the International Pacific Halibut Commission.

Through research, construction of expensive fishways, abstention from water-power projects and scientific management, the sockeye salmon stocks of the Fraser River have been restored from an average annual run of about 2 million fish to about 10 million, and appear headed for an average level of 20 million fish or more. The two countries have unilaterally saved and restored other salmon runs along their Pacific coasts in a somewhat similar manner.

To examine these almost unique cases further, the savings account analogy is again useful. How does it happen that Canada and the United States have been able to build up these sustainable high-yielding resources under the traditional world philosophy of open savings accounts? The answer is that in these cases the open savings account existed only in theory. During this period the nearest neighbour who might have been interested in drawing on these accounts lived at a relatively great distance. With the horse and buggy transportation available in the early years, it was not worth his while to make the trip to the bank for the amount of bullion he was able to carry. Consequently, Canada and the United States actually enjoyed closed account conditions during these early years.

Later on, efficient motor transport became available. This made the distant neighbour's trip to the bank practical. However, after discussion with Canada and the United States, creators of the bank account, the interested neighbour recognized the merits of the case and refrained from drawing on the halibut and salmon accounts. This attitude was based on the primary consideration that these accounts existed in a healthy and productive condition as the result of the efforts and restraints exercised by Canada and the United States.

As a result, the accounts continued in a highly productive condition, with Canada and the United States, within the limits of their technical and scientific abilities, making full use of the annual interest and constantly striving through continued research to improve their investment and management practices to increase the returns. In achieving this, the interests of no other country were harmed, and no potential production was being wasted.

Let us turn from this exhibit to another. In the North Sea, some distance off the coast of Denmark, Germany and the Netherlands, there is large shallow area separated from the coast by a deeper channel. This is the famous Dogger Bank. In the North Sea is found the plaice, a flounder viewed by Europe's connoisseurs as one of the choicest products of the sea. The plaice spawns in the south-eastern and southern North Sea, and prevailing currents carry the fry to the coasts of Denmark, Germany and the Netherlands. Shortly thereafter, tremendous numbers of baby plaice swarm in the shoal waters of the area. Because of crowded conditions, food and living space for individual baby plaice are limited, and their growth rate is comparatively slow. This happens with many species but it particularly affects young plaice because they are crowded into a narrow band of shallow water. Relatively few of these small plaice find their way out to the Dogger Bank because of the deep water channel which separates it from the coast. The few which to reach the Dogger Bank encounter highly favourable feeding and growing conditions and rapidly increase in size until they have become fine, marketable fish. Consequently, even though the fish are relatively few in number compared with those in the coastal areas, a vigorous and profitable trawl fishery is maintained.

About fifty years ago one of the pioneers in the field of fishery research, Professor W. Garstang, recognized the potentialities in this combination of circumstances. He proposed that some of the crowded baby plaice on the coastal shallows be collected and transported in well-boats to the Dogger Bank. This proposal was again made to the International Council for the Exploration of the Sea in 1930, by the late Dr. A.C. Johansen. Thinning out the coastal stocks actually would be beneficial since it would result in more rapid growth of the remaining plaice. Meanwhile, the young released on the Dogger Bank would enjoy rapid growth and increase the catch to an extent that would far more than pay the cost of transplantation. Experiments and calculations since then have supported Professor Garstang's and Dr. Johansen's opinions regarding the practical benefits that would accrue from such a project.

Here then is a method of making better use of nature's potentialities. So far as we know, only benefits would come from the operation. But after fifty years the project continues to exist only as an idea; nearby countries continue to lose a large supply of excellent food, their fishermen lose substantial catches and income, and potential resources continue to be wasted.

The causes of this failure to use a potential resource may be several, but I venture the opinion that an important factor is timidity in facing the facts and developing some needed modification of the traditional open banking account concept. The Dogger Bank lacks the early limited accessibility of the halibut and salmon areas; instead, it is located in a crowded neighbourhood.

To return to the analogy, the bank is and was within easy reach of many neighbours, even back in the old horse and buggy days. Evidently few, if any, neighbours were willing to join in making deposits in this open savings account, since they could not afford to build up a bank account upon which the entire community could draw. Result: loss to the countries ready to make the investment and, indirectly, to the world, to the extent that total food supplies were reduced; gain to no one.

In the North Pacific, following the Second World War, with the further increase in efficiency in catching fish and the greater mobility of fishing and processing operations with improved factory ships, it became desirable to develop more formal arrangements than had previously existed for assuring the conservation of fish stocks. This was done by Canada, Japan and the United States in the North Pacific fisheries convention, which entered into force in 1953. In this convention, among other provisions, the principle of "abstention" was first developed and applied.

The provisions concerning abstention are as follows: When the commission set up by the convention determines that any stock of fish in the convention area, the greater part of which is harvested by one or more of the contracting parties, reasonably fulfils the conditions listed below, the commission shall recommend to the contracting parties that the party or parties participating in the fishery of the stock continue to carry out necessary conservation measures and that the other contracting party or parties abstain from fishing such stock.

The following conditions for abstention are given: (1) Evidence based upon scientific research indicates that more intensive exploitation of the stock will not provide a substantial increase in yield which can be sustained year after year; (2) the exploitation of the stock is limited or otherwise regulated through legal measures by each party substantially engaged in its exploitation, for the purpose of maintaining or increasing its maximum sustained productivity, such limitations and regulations being in accordance with conservation programmes based upon scientific research; and (3) the stock is the subject of extensive scientific study designed to discover whether it is being fully utilized and to determine the conditions necessary for maintaining its maximum sustained productivity.

It is provided, however, that no recommendation shall be made for abstention by a contracting party with regard to (a) any stock of fish which at any time during the twenty-five years next preceding the entry into force of the convention has been under substantial exploitation by that party; (b) any stock of fish which is harvested in greater part by a country or countries not party to the convention; and (c) waters in which there is historic intermingling of fishing operations of the parties concerned, intermingling of the stocks of fish exploited by these operations or a long-established history of joint conservation and regulation among the parties concerned so that there it is consequently impracticable to segregate operations and administering control. Abstention from fishing a stock of fish in a given area does not affect the fishing activities of the abstaining party with respect to other stocks of fish in the same area.

The North Pacific fisheries convention embodying these provisions is now in its second year of active operation. The abstention principle appears to be a useful concept which encourages countries to make the investment in talent, time, money and self-denial necessary to derive best use from the present and potential resources of the sea. Lacking this or some similar provision, countries have little incentive to create or restore resources through expensive conservation programmes. In fact, they may even be influenced to abandon such programmes as they have undertaken, in the conviction that when the resources decline to less productive levels they will offer less inducement for distant neighbours to journey far afield to participate in their exploitation.

It would seem that the world has nothing to lose and much to gain by developing the abstention concept, or some more effective variation, to help meet the real and practical conservation problems with which it will increasingly be confronted.

CLASSIFICATION OF INTERNATIONAL CONSERVATION PROBLEMS

by

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(The mimeographed text of this paper appeared as document A/CONF.10/L.6/Rev.1 under the title "Identification of Types of International Fisheries Conservation Problems for the handling of which the Governments concerned have not yet developed or agreed upon Measures or Procedures")

Contents

The purpose of the present paper is to present a brief survey of resources and areas in respect of which no treaty, convention or agreement has been promulgated and to consider the information available concerning these resources[1] in order to know whether a need for conservation is indicated. It is also necessary to learn if there are sufficient data to indicate the type of action that should be taken. Where the information is found to be deficient in this regard, it is necessary to provide a basis for discussing what research ought to be undertaken to supplement existing information so that a plan for conservation may be formulated. In the following pages an attempt is made to examine the conditions under which these purposes may be fulfilled, and to lay the basis for a task that cannot at this point be carried far beyond the preliminary stage.

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[1] The term "resources" here relates to individual species or to groups of species or to the general resources of the seas in a particular area.

There can be no doubt that a survey of available information is desirable at this time, and that some conclusions may be drawn from such a survey, though the conclusion must often be that still more information is required. While any programme of exploitation requires more and more information, it seems desirable to stipulate at the outset that such a survey of the fishery problems of what might be called the "non-treaty" resources and areas must not be taken to indicate that all these problems are of a nature requiring action. A brief discussion is given below of the place of conservation measures in the entire plan of exploitation since, in attempting to identify "conservation problems", it is necessary to be clear about what is meant by conservation and what are the problems.

A major difficulty in identifying conservation problems for which the governments concerned have not developed or agreed upon measures or procedures by which they can be handled is that the already existing agreements are, in their investigational aspect, so extensive and relate to such a large part of the world and its fishery resources. Responsibility for the North Atlantic and adjacent waters is shared by the permanent commission under the Convention for the Regulation of the Meshes of Fishing Nets and the Size Limits of Fish (1946), the International Council for the Exploration of the Sea and the International Commission for the Northwest Atlantic Fisheries. The North Pacific is covered by the International North Pacific Fisheries Commission. The entire Indo-Pacific area, whose limits are not yet precisely defined, is under the Indo-Pacific Fisheries Council. The Mediterranean is covered by the General Fisheries Council for the Mediterranean and by the International Commission for the Scientific Exploration of the Mediteranean Sea. A commission has been proposed for Latin America; a Caribbean commission has certain responsibilities in respect of that area. The Commission for Technical Co-operation in Africa South of the Sahara has certain responsibilities in its area, and the Permanent Commission for the Exploitation and Conservation of the Maritime Resources of the South Pacific in a large sector of the Pacific. There are commissions for all antarctic whale stocks and for halibut, tuna, salmon and seals. In consequence, apart from such areas as the Red Sea and the Persian Gulf, and some uncertainty of jurisdiction in the western Indian

Ocean, the eastern Pacific Ocean and the broad stretches of the South Atlantic, there is, as to area alone, a coverage of a large part of the globe.

If, therefore, the establishment of a fisheries agreement for an area, when entered into by various governments, were mistakenly considered a solution of conservation problems - in the sense that machinery thus exists for gathering information, assessing it and recommending action - there would remain only few areas in respect of which further solutions were yet to be proposed; and even for these there are signs that recommendations for action are already contemplated.

However, the establishment of an agreement, such as that under which the Indo-Pacific Fisheries Council is constituted, can scarcely be held to solve the problems of the fisheries in that region, whether these problems are identified as requiring conservation or as any other kind. Such a step is to be regarded as the preliminary administrative move to make possible the types of international collaboration that will accelerate the gathering of information concerning the resources, improve methods of research and interpretation of data and, eventually, lead to such discussion of the results as may permit realistic conclusions about the fishery and appropriate action. Even in the case of certain other agreements concerned with the regulation of particular resources, as, for example, the convention establishing the International Pacific Halibut Commission, it cannot be held that problems of conserving these resources have been wholly solved by the adoption of a treaty, or even by subsequent work in research and management.

In consequence, it seems to be an unavoidable conclusion that either the treaty areas must be excluded from consideration in this paper, which thereby would be reduced to relatively negligible proportions, or that the majority, if not all, of the resources of these areas must be included within its scope. Moreover, it is important to reject the possible implication that the existence of various treaties and agreements means that the situations to which they refer are definable either as involving conservation problems or as partial solutions of these problems.

Conservation measures and conservation problems

Conservation measures involve control of fishing operations in order that the resources and the catch should continue to possess desired quantitative and qualitative characteristics - especially in the light of other forces affecting such resources. It will be recognized that in this definition the emphasis is upon restraints placed on fishing operations. The purpose of such restraints, however, is to bring about or to maintain certain biologically possible conditions in the resource for reasons based on economic and social grounds.

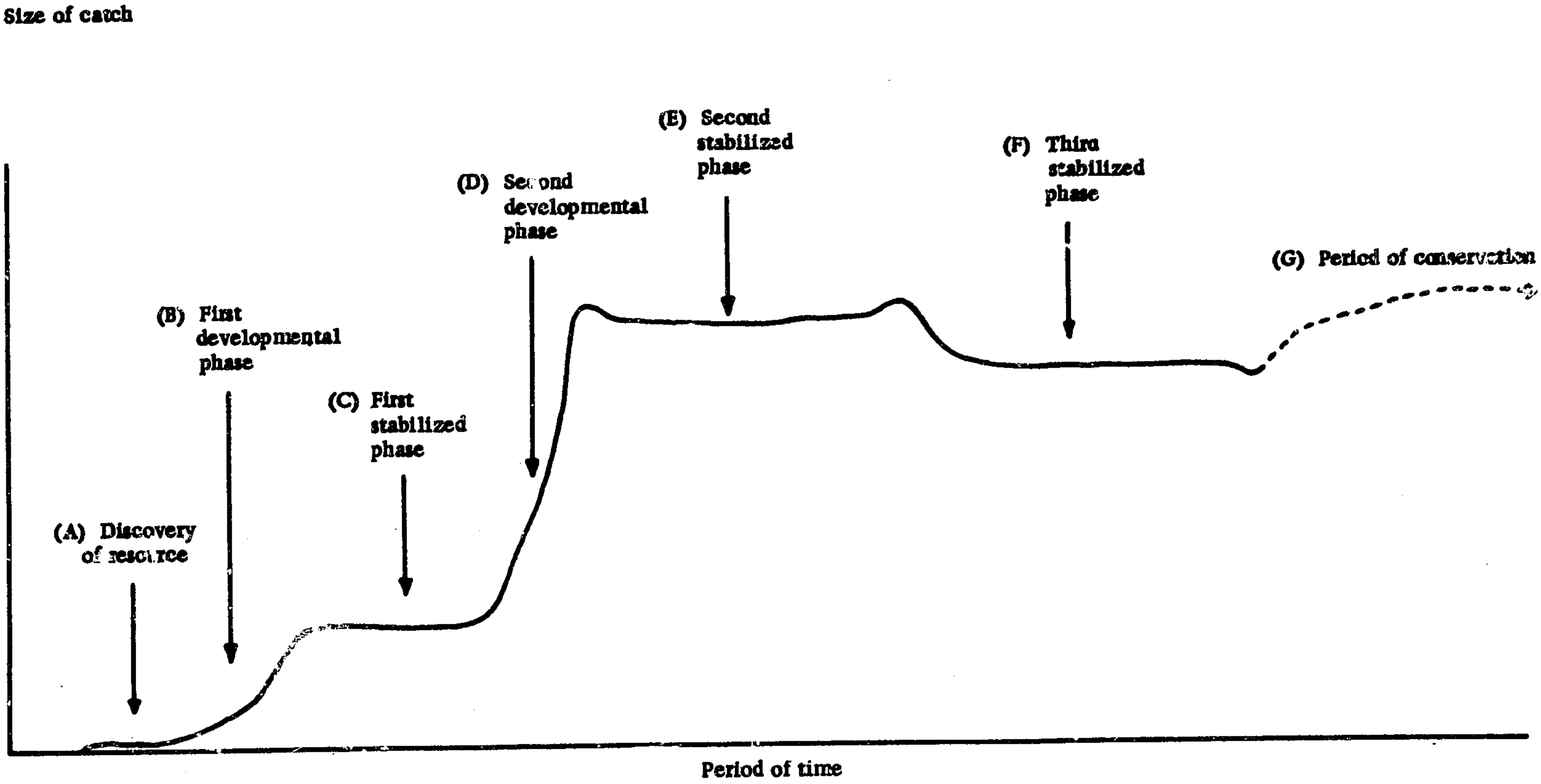
The term "conservation problem" may mean one or more of the following: (a) whether there is need for conservational measures in the sense defined above; (b) where it is established that there is a need for such measures, what kind of measures should be adopted; and (c) the measures having been decided upon, how they can be implemented. Other supplementary problems might be listed, such as the arrangements that should be made to carry out investigations for solving each of the foregoing problems.

It should again be emphasized that both the formulation and the solution of any of these problems, while involving scientific and technical considerations, also include decisions as to the end to be achieved, which involve economic and social judgements. There is no single isolated conservation problem; further, a particular fishery presents conservation problems only in consequence of the factors that determine its situation, including not only biological but also economic and political elements.

Conservation in an exploitation programme

If the general history of fisheries is shown in graphic form (figure 49), with the catch plotted over a period of time, the curve showing its growth has very often a sigmoid shape. When the resource is first discovered, the catch, of course, is small. Thereafter, as experience grows and skill develops and the number of fishing units rises, the catch increases at an accelerating rate, but at some point this rate of increase slows down and, though the catch continues to increase, it does so at a progressively slower rate until the curve begins to flatten out and the catch becomes more or less stabilized. This situation is represented in the accompanying diagram, on which three principal stages in

Figure 49. Hypothetical general curve of historical development of a fishery



Note: After discovery of a resource (A), fishing activity may increase (B), but expansion may be limited (C) by economic and technical factors. Renewed and rapid expansion (D) may be permitted by such factors as the invention of better fishing gear or the opening up of new markets for the catch. Production reaches a peak but then settles down to another steady level (E), higher than the first, but fishing is not necessarily more profitable. It may be that new technical improvements which increase efficiency or reduce costs will encourage further rise in production, but this may only be temporary. The catch settles down to a stable level (F), determined by the capacity of the stock to increase under the particular conditions of exploitation. This level may be no higher, and may perhaps be lower, than the previous one. In this situation, control of the kind and amount of fishing may result in sustained catches (G) equal to the earlier levels, or even higher, obtained with less effort. The problem of evaluation is to distinguish these different kinds of limitation on the catch.

the development of a fishing industry have be[illegible]sed. This diagram, of course, is extremely generalized and the history of no single fishery would precisely follow this pattern. However, in principle it is true that for each individual fishery there is a preliminary exploratory phase, a developmental phase and one or more phases of relative stability. It is obvious that in the first two stages the exploitation programme is concerned with increasing the operations in respect both of their efficiency and of the total catch. For fisheries in these stages there is no immediate question of imposing conservation measures, though it is conceivable that in some situations it might be possible to foresee changes which will presumably take place and to carry out sufficient investigations to be able to propose such measures for the management of the industry as would lead to its most effective development, and yet so to control these operations that, in effect there would be conservation.

Generally speaking, however, conservation measures become necessary only towards the end of a developmental stage or in a stabilized stage of a fishery. Nevertheless, demonstration that a fishery is at either of these stages does not necessarily mean that deliberate restraint upon fishing operations, such as may be [illegible]ribed as a conservation measure, is in fact required. There must at times be doubt as to whether the fishery has actually completed a developmental stage, and there are numerous examples of fisheries which appear to have reached a stabilized condition but which have suddenly expanded far beyond that level. It is therefore again important to emphasize that a fishery's history reflects the play of many factors - economic and social factors not least among them. A fishery history may show stabilization at levels of catch other than the maximum the stock can sustain. This, in fact, is only a special aspect of a more general rule - that none of the features of the historical curve of development may be taken, without adjustment (for which other kinds of information are necessary), as direct evidence concerning the magnitude and productivity of the stocks from which the catch is taken.

Interpretation of the history of a fishery can be achieved only after there has been a biological analysis of the fish stocks - for this purpose also, certain technical and economic data are necessary - and measurement of their properties, combined with an analysis of the technical, economic and social factors involved. After such a study has been made, and it is shown that the catch has approached the level above which no amount of fishing, in practical terms, can be expected to increase it, then that knowledge is sufficient to determine with confidence the nature of the effect which exploitation is producing on the stocks. Some measures for controlling the exploitation may then be proposed, either to maintain certain established features within the stocks, to produce other features or to restore still others. This is the true conservation situation.

Precautionary conservation

From time to time, research workers, administrators and members of the industry have the impression, from certain relatively isolated pieces of evidence, that a fishery has reached its final stage and that the effect of fishing operations is such that it is necessary to exercise some restraint upon them. In these situations resort is had to certain general principles, such as the desirability of ensuring that each fish has the opportunity of spawning at least once, and restrictions are imposed upon fishing in order to observe these principles. In these cases - aside from the fact that the need for conservation is not truly established - there is no certainty that the measures applied will have the effects that are sought or even that the effects themselves are truly desirable.

Of course, such precautionary conservation will not necessarily prove a failure, but, on the other hand, those who impose such measures cannot determine that they are not causing an important and unnecessary economic loss to the industry. Since, however, there appears to be no logical basis for the adoption of such measures and since it is also impossible to predict when such measures may appear desirable, it is not possible in this paper to consider as true conservation problems the situations where precautionary conservation is being or might be practised; certainly no such situations can be anticipated.

Recapitulation

Each fishery normally passes through at least three stages in its history. In the first of these stages, which is exploratory, and generally in the second also, there is no occasion for conservational action. Such action can be considered only in relation to fisheries in or approaching an asymptotic stage of their history. To prove that a fishery is at such a stage, it is necessary to analyse evidence concerning the biological, technical and human elements, and the various factors influencing these. If it can be shown that fishing operations are likely to continue with an intensity endangering the future of the fishery as a whole, measures to restrain these operations should be designed in such a way that they will produce effects on the stocks which will be of economic and social advantage to the countries concerned.[2]

In a schedule of fisheries, conservational problems are present only where the existence of some such characteristics has been recognized and is considered undesirable for one reason or another. Among fisheries for which the conservation problem is recognized, it may be one or more of the three types listed earlier: (a) whether there is need for conservation measures; (b) what kind of measures should be adopted; and (c) how the measures should be implemented.

Schedule of world fisheries

The schedule at the end of this paper presents a list of the unit fisheries of the world, indentified by their common names, with a certain amount of grouping to permit treatment in terms of the foregoing definitions. (Figure 50 provides a key to the numbered areas.) So far as possible, the schedule indicates, for each of the unit fisheries, the species being exploited, the location of the fishery, the gear which is used and the countries participating in the fishery.

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[2] The idea of "endangering" denotes a wide range of possible undesirable consequences. M. Graham in his paper on "Concepts of Conservation", above, mentions declines in total catch, in catch per unit effort and in average size of fish. To this list may be added others, such as undesirable changes in the composition of the species and other variations tending to reduce the value of the catch.

In preparing this schedule, the terms "renewable resources","management unit" and "unit fishery" had to be defined. It is essential to regard a renewable resource broadly, including not merely the size groups of fish of economic value, nor only the entire population of the species which is of present economic interest, but the community of associated living organisms to which this economic species belongs. The importance of this viewpoint derives from the fact that the entire association is affected by fishing operations and, conversely, that fishing operations themselves are in large measure dependent upon forces operating within the entire biological system. The magnitude of the stocks which are of immediate interest and are actually being fished is determined by the magnitude of the entire population of which these stocks are part, and the magnitude of that population is in turn dependent upon the community within which the species lives. The resource, therefore, must be defined as a dynamic system of which one part, the population of the species, is of interest to man who, by his fishing operations, removes a part of this population.

In his paper, "The Scientific Basis for a Conservation Programme", above, M.B. Schaefer has indicated that the unit for management purposes is the separate population of a species. The importance of this unit, its characteristics, and the method of examining and measuring them are described in his paper; the relations of this unit to its environment are discussed by J.B. Tait in his paper on the "Role of the Environment in the Biology of Economically Valuable Stocks".

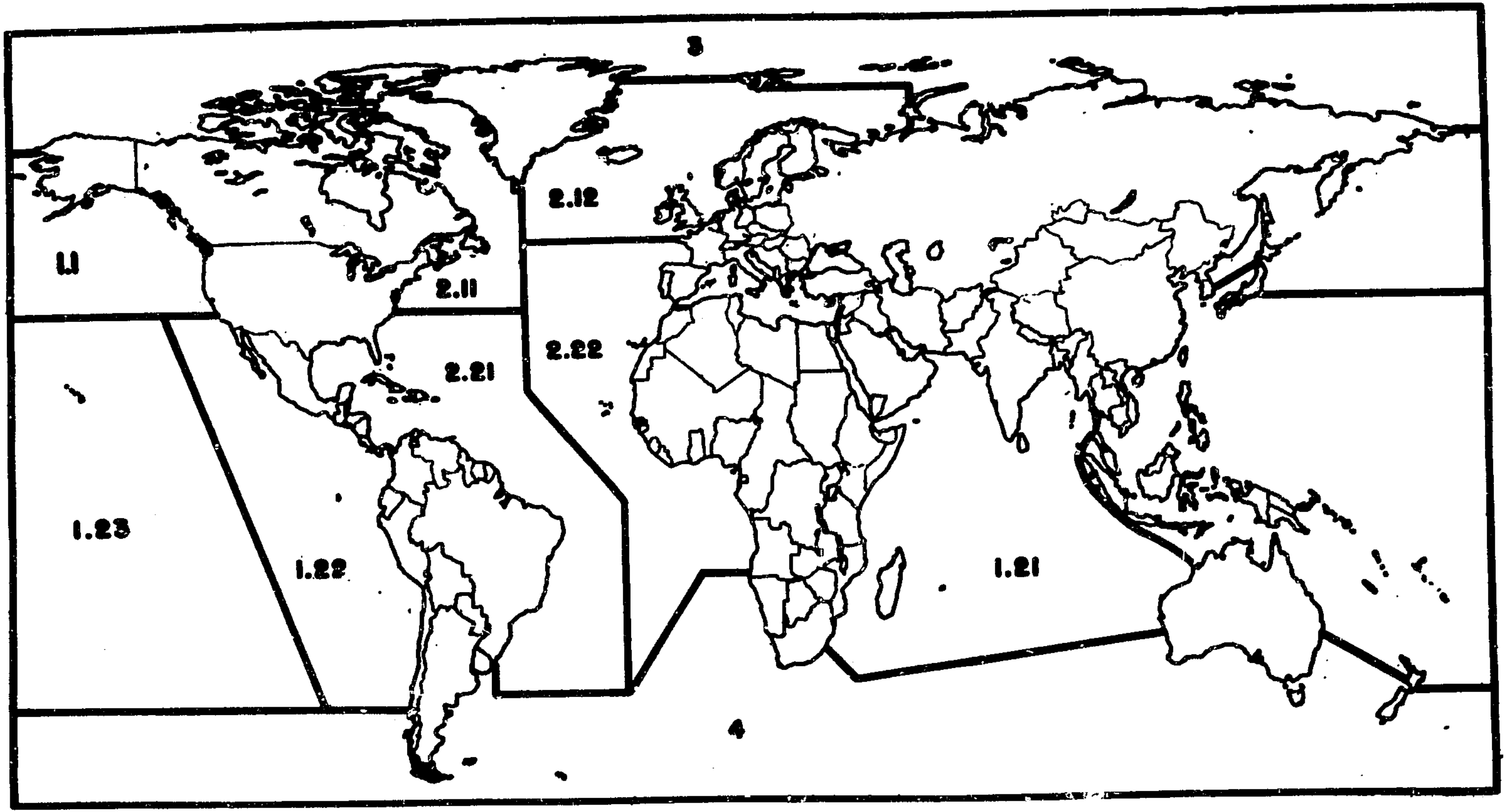
The term "unit fishery" is less amenable to definition. It is best understood in terms of the common names of fisheries, such as trawl fishery, herring fishery, whale fishery and so forth. In some cases, the unit fishery is based upon a single unit stock, and it is of great importance to be able to confirm that the area of the fishery is coextensive with that of the stock. In other cases, the unit fishery is based upon a particular community, for example, in a fishery exploiting demersal stocks, where the gear used may take two or more species simultaneously. Sometimes the fishery is thought of in terms of particular areas, or of particular types or groups of craft or gear, but in many of such cases it is a sub-unit rather than a true unit that is being discussed, since the fishing exploits only a part of a population. From the biological point of view, all fishing upon a particular unit stock must be included within the same unit fishery.

In compiling this list of unit fisheries, a quick review was made of available literature concerning them. This literature is, of course, exceedingly voluminous, and some fisheries are more fully described than others. For example, literature on the resources of the North Sea and the North Atlantic is most extensive; literature on other resources, such as the flying fish of the Celebes, is sparse. From this literature, some attempt was made to summarize available information concerning resources being exploited by each fishery. It was at once apparent that this would take more time than was available and would result in a very bulky document. Moreover, authoritative reduction of these data, from the point of view of determining their reliability and usefulness for formulating conservation programmes, could scarcely be made in a short time from a single office, even if the compilation were complete. In fact, preparation of this compilation is the substantive part of the programme on which the Biology Branch of the Fisheries Division of the Food and Agriculture Organization of the United Nations has now embarked. It is not expected that it will be completed for several years; it is hoped that regional fishery commissions and councils will assist on the project.

Thus, without further studies of the character indicated above, identification cannot be achieved of the types of international fisheries conservation problems for which the governments concerned have not yet developed or agreed upon measures or procedures.

A tentative list of the most important unit fisheries of the world is given below. The information, except perhaps for treaty arrangements, is almost certainly incomplete, but it may provide a basis for discussion and for the compilation of a more comprehensive account. The abbreviations used in this list are shown on page 361.

Figure 50. Map showing division of oceans for classification of unit fisheries



Note: The boundaries shown represent a compromise among several criteria, including oceanographic and zoogeographical factors.

Fur seal agreement, 1942: Provisional fur seal agreement between Canada and the United States, 1942

GFCM: General Fisheries Council for the Mediterranean

Halibut Commission: International Pacific Halibut Commission

ICES: International Council for the Exploration of the Sea

ICNAF: International Commission for the Northwest Atlantic Fisheries

North Pacific Commission: International North Pacific Fisheries Commission

Overfishing convention, 1946: Convention for the Regulation of the Meshes of Fishing Nets and the Size Limits of Fish (Overfishing conference, 1946)

Salmon Commission: International Pacific Salmon Fisheries Commission

South Pacific Commission: Permanent Commission for the Exploitation and Conservation of the Maritime Resources of the South Pacific

Tuna Commission: Inter-American Tropical Tuna Commission

(See pages 362 to 371 for schedule of fisheries)

Area and resource	Gear and method of fishing	Participating countries	Treaty arrangements
WORLD-WIDE:			
Whales	Pelagic whaling	Denmark, Japan, Netherlands, Norway, Panama, USSR, United Kingdom	International Whaling Commission, South Pacific Commission
Whales	Shore-based whaling	Argentina, Australia, Brazil, Canada, Chile, France (for French Equatorial Africa), New Zealand, Peru, Portugal, Union of South Africa	International Whaling Commission, South Pacific Commission
Tunas, other oceanic pelagic species (swordfish, spearfish, sailfish, etc.):			
Central and South American tunas	Lines, purse-seines	Chile, Costa Rica, Ecuador, Mexico, Peru, United States	Tuna Commission
Mediterranean tunas	Traps, lines, purse-seines	Egypt, France (French territories?), Greece, Israel, Italy, Libya, Spain, Turkey	GFCM, International Commission for the Scientific Exploration of the Mediterranean Sea
Pacific tunas	Lines	Australia, China: Taiwan, Japan, Pacific territories, Philippines, United States	Indo-Pacific Fisheries Council
Tunas in other waters, not specifically referred to in treaty arrangements			

Area and resource (cont.)	Gear and method of fishing	Participating countries	Treaty arrangements
1. INDO-PACIFIC:			
1.1 North Pacific			
Salmon (five species, *Oncorhynchus*)	Traps, purse-seines, gill nets, lines	Canada, Japan, Korea, USSR, United States	Salmon Commission, North Pacific Commission
Sardine (*Sardina* or *Sardinops melanosticta*, *Etrumeus micropus*, *Engraulis japonicus*) ...	Nets	Japan, Korea, USSR	North Pacific Commission
Herring (*Clupea pallasi*) .	Purse-seines	Canada, United States	North Pacific Commission
Mackerel (*Scomber japonicus*), jack *Trachurus japonicus*) ...	Lines, nets	Japan	North Pacific Commission
Saury (mackerel), pike (*Cololabis saira*)	Dip nets, lines	Japan	North Pacific Commission
King crab (*Paralithodes camtschatica*)	Tangle nets, trawls	Canada, Japan, USSR, United States	North Pacific Commission
Halibut (*Hippoglossus stenolepis*)	Lines	Canada, United States	Halibut Commission, North Pacific Commission
Groundfish, American coast: Pleuronectids, gadoids (*Sebastes*)	Trawls, some lines	Canada, United States	North Pacific Commission
Shrimp (*Penaeus carinatus*), Yellow Sea	Trawl nets	China, Japan	Indo-Pacific Fisheries Council

Area and resource (cont.)	Gear and method of fishing	Participating countries	Treaty arrangements
Groundfish, East China Sea, Yellow Sea (Pagrosomus major, Paralichthys olivaceus, Nibea argentata)	Trawls	China, Japan, Korea	Indo-Pacific Fisheries Council
Fur seal (Callorhinus ursinus)	Pelagic and island fishing	Canada, Japan, USSR, United States	Fur seal agreement, 1942
1.2 Tropical Indo-Pacific; 1.21 Indian Ocean:			
Reef fish (percomorphs: Lutjanidae, Carangidae, Sciaenidae)	Lines	Madagascar, Mauritius, Réunion, Seychelles	Indo-Pacific Fisheries Council
Stolephorus species	Traps	Most Asian countries	
Groundfish (percomorphs: Lutjanidae, Carangidae, Sciaenidae)	Trawls, lines	Ceylon, India, Japan, Pakistan	Indo-Pacific Fisheries Council
Indian mackerel (Rastrelliger kanagurta)	Traps, surrounding nets	India, Indochina, Malaya, Thailand	Indo-Pacific Fisheries Council
Indian oil sardine (Sardinella longiceps)	Surrounding nets	Southern Arabia, India, Pakistan	Indo-Pacific Fisheries Council
Clupeids, Persian Gulf (Sardinella, Engraulis species)	Various nets	Arabian countries, Iran	Indo-Pacific Fisheries Council

Area and resource (cont.)	Gear and method of fishing	Participating countries	Treaty arrangements
Groundfish, Persian Gulf (percomorphs: Lutjanidae, Carangidae, Sciaenidae)	...	Arabian countries, Iran	Indo-Pacific Fisheries Council
Clupeids, Red Sea	Various nets	Arabian countries, Egypt, Ethiopia, Iran	
Groundfish, Red Sea	...	Arabian countries, Egypt, Ethiopia, Iran	
Reef fish (percomorphs) .	Traps, lines	Australia	
Rock lobster (*Panulirus* species)	Traps, lines	Australia	
1.2 Tropical Indo-Pacific; 1.22 Eastern Pacific:			
Rock lobster (*Jasus* species)	...	Chile	
Sardine (*Sardinops sagax*)[a]	Purse-seines	Chile, Ecuador, Peru	
Shrimp (peneids)	Trawls	Costa Rica, Mexico, Panama	
Groundfish, hake (*Merluccius*), pleuronectids	Trawls, lines, gill nets	Chile	

Area and resource (cont.)	Gear and method of fishing	Participating countries	Treaty arrangements
1.2 Tropical Indo-Pacific; 1.23 Central Pacific:			
Reef fish (percomorphs: Lutjanidae, Carangidae, Sciaenidae)	Lines, traps	All countries	Indo-Pacific Fisheries Council, South Pacific Commission
Flying fish (Exocoetidae)	...	Indonesia	Indo-Pacific Fisheries Council
Mackerel ('Kanbong, pla thu', Rastrelliger kanagurta)	Surrounding nets, traps	Malaya, Thailand	Indo-Pacific Fisheries Council
Groundfish (Sciaenidae, Foriniidae, Stromateus)	Trawls	China, Japan, Korea, USSR	Indo-Pacific Fisheries Council
Pearl oyster	Diving	Australia, Japan	
1.1-1.22 Transition region:			
Pilchard (Sardinops caerulea), anchovies Engraulis mordax, anchoviella species), mackerel, horse mackerel (Pneumatophorus diego, Trachurus symmetricus) .	Purse-seines	United States	

Area and resource (cont.)	Gear and method of fishing	Participating countries	Treaty arrangements
2. ATLANTIC:			
2.11 North-west Atlantic:			
Herring (Clupea harengus), other clupeids	Pelagic gear (weirs, seines, traps)	Canada, United States	ICNAF
Mackerel (Scomber scombrus), chub (Pneumatophorus colias)	Purse-seines	Canada, United States	ICNAF
Lobster (Homarus americanus)	Traps	Canada, France, Spain, United Kingdom, United States	ICNAF
Groundfish on banks (gadiods, pleuronectids, Sebastes)	Trawls, lines	Canada, France, Spain, United Kingdom, United States	ICNAF
Shrimp, prawn (nephrops, etc.)	Trawls	Denmark	ICNAF
2.11-2.12 Transition region:			
Groundfish (gadoids, pleuronectids)	Trawls, lines	Denmark, Iceland, Norway, Portugal, United Kingdom	ICNAF, ICES, Overfishing convention, 1946

Area and resource (cont.)	Gear and method of fishing	Participating countries	Treaty arrangements
2.12 North-eastern Atlantic:			
Groundfish (gadoids, pleuronectids)	Trawls, demersal seines	European countries	ICES, Overfishing convention, 1946
Herring (*Clupea harengus*)	Pelagic and demersal gear (trawls, drift nets, ring nets)	European countries, USSR	ICES, Overfishing convention, 1946
2.12-2.22 Transition region:			
Hake (*Merluccius merluccius*)	Trawls	European countries	ICES
2.11-2.21 Transition region:			
Menhaden (*Brevoortia tyrannus*)	Purse-seines	United States	
2.21 Western central Atlantic:			
Shrimp (*Penaeus* species)	Trawls	Cuba, Mexico, United States	
Reef fish	Lines, traps	Caribbean countries	
Groundfish	Trawls	Argentina, Brazil, Uruguay	
Reef percomorphs	Lines, seines, traps	Brazil	

Area and resource (cont.)	Gear and method of fishing	Participating countries	Treaty arrangements
2.22 Eastern central Atlantic and Mediterranean:			
Groundfish, many species	Trawls	Mediterranean countries	GFCM, ICES, International Commission for the Scientific Exploration of the Mediterranean Sea
Sardine (Sardinella aurita, Sardina pilchardus) ...	Surrounding nets	France, Greece, Italy, Morocco, Portugal, Spain, Yugoslavia	GFCM, ICES, International Commission for the Scientific Exploration of the Mediterranean Sea
Anchovy, horse mackerel (Engraulis encrasicholus, Trachurus trachurus), Black Sea	Ring nets	Turkey, USSR	
Dolphin (Delphinus delphis), Black Sea ...	Ring nets, shooting	Turkey, USSR	
Groundfish (percomorphs)	Lines, trawls	French, Portuguese and United Kingdom territories in Africa and southern Africa	ICES, Commission for Technical Co-operation in Africa South of the Sahara
3. ARCTIC:			
Herring (Clupea harengus)	Seines	USSR	
Groundfish (pleuronectids)	Trawls	USSR	

Area and resource (cont.)	Gear and method of fishing	Participating countries	Treaty arrangements
4. SOUTHERN SEAS:			
4.1 Temperate waters:			
Pilchard (*Sardinops ocellata*), maasbanker (*Trachurus trachurus*) .	Purse-seines	Union of South Africa	
Groundfish (*Merluccius capensis*), pleuronectids (*Austroglossus* species), etc.	Trawls	Union of South Africa	
Snoek (*Thyrsites atun*) ..	Jig lines	South West Africa, Union of South Africa	
Percomorphs (*Atractoscion aequidens*, *Johnius hololepidotus*, *Argyrozona argyrozona*)	Hand lines	Union of South Africa	
Sardine (*Sardinops neopilchardus*)	Nets	Australia	
Groundfish (*Neoplatycephalus richardsoni*)	Trawls	Australia	
Barracouta (*Leionura atun*)	Jig lines	Australia	
Reef fish (*Chrysophrys guttatus*)	Lines, traps	Australia	
Shark	Long lines	Australia	
Groundfish (percomorphs, pleuronectids)	Trawls	New Zealand	

Area and resource (cont.)	Gear and method of fishing	Participating countries	Treaty arrangements
Groundfish	Trawls	Argentina	
4.2 Antarctic:			
Fur seals (Arctophalus pusillus)	...	Union of South Africa	

Note: In addition to the above, there are various diadromous fishes which are not at present caught on the high seas, but they spend an important of their lives at sea. These include:

2.11-2.21 Transition region: Shad (Alosa sapiddissima); North America
1.21 Indian Ocean: Indian shad (Hilsa fish, Hilsa ilisha); India
1.21 Indian Ocean: Hilsa herring (Hilsa reevesii); China and Korea.

a/ Also basis for guano.

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Printed in U. S. A.
0532-Feb. 1956-3625

Price: $3.00 (U. S. A.); 22/6 stg.; Swiss francs 13.00
(or equivalent in other currencies)

United Nations Publication
Sales No.: 1956. II. B. 1