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

Pertinent facts respecting the life history, ecology and behaviour of the species constituting the resource

In accordance with the advice of the group of experts convened by the Secretary-General to assist him in the preparation of this Conference, technical papers on certain items of the provisional agenda were invited from a number of authorities. The Secretary-General accordingly has the honour to communicate the following paper by the United Nations Educational, Scientific and Cultural Organization, of which a summary is available in English, French and Spanish as A/CONF.10/L.3 (Summary)

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

by

UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

55-07022

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Appendices

I. THE ROLE OF THE ENVIRONMENT IN THE BIOLOGY OF THE ECONOMICALLY VALUABLE STOCKS 1/

by

JOHN B. TAIT

A. Introductory

1. 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 commercial significance as human food, will one day become so by virtue of development in processing techniques.

2. 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 revelation of the enormous 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.

3. Descending the 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 are logically to be expected to be of quite fundamental importance.

4. The whole environment of fishes, excluding man's activities towards them, comprises biological as well as physical factors, i.e. food and enemies, as well as the sea floor, the sea itself, and to some extent the atmosphere. While on occasions

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1/ In substantial measure this section is a summary of the writer's book "Hydrography in Relation to Fisheries". London: Edward Arnold and Co., 1952.

9. 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 1°C increases the rate of metabolism by about ten per cent (14).

10. Temperature too influences in greater or less degree the migrations of fishes, apart from that which is associated with the spawning urge (6).

11. 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 requir to 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 <u>per se</u> and the phenomena concerned, have been demonstrated in relation to spawning (10,28a), the abundance of fry (17), the rate of growth of fishes (46), and at least certain species distributions. 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 index. On the other hand, recognition must be made of Bull's (6) experimental demonstration of certain fishes' conditioned responses to a minimal change in salinity of as little as 0.2 per mille.

12. 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 (14). Respiration in bright daylight has been found among plankton animals to be as much as double that in the dark (21). Different parts of the spectrum also have been found to be injurious to various organisms (8).

13. 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 its inhabitants must sooner or later be referred, play, at one and the same time, intimate and over-all rôles in the lives and habits of fishes. In their merel

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 (30b,24b,4). Bowman (3), 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 (7) of the apparent coincidence between the distribution of haddock in the northern North Sea and the shape of the Great Eddy in that region (30b) are strong pointers to the actual and potential importance, indeed the indispensability to fishery investigators, of the most detailed knowledge of currents.

14. In brief, however, currents and water movements generally are of supreme, because they are of the most fundamental, importance in all aspects of marine investigations directed towards the understanding of the living resources of the sea. They control the distribution of temperature and other physical and, as will be seen below, 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 concerned in the migrations of fishes towards those places where the physical conditions exist in which alone spawning will take place.

15. The fact that different species, often of the same genus, evidently find optimum spawning conditions in different DEPTHS of water (30a) 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 (28b) 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 of 18° to 20°C. Eel eggs have in fact since been taken from the region in question (27).

16. There is still an 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.

C. The chemistry of the sea in relation to fishes

17. WATER is fundamentally necessary to all forms of life, and being the universal solvent, par excellence, it is to be expected that all of those other substances which are necessary to marine life will be found in sea water.

18. Sea water almost certainly does contain, even if only in extremely minute and so far undetectable quantity in some cases, all of the ninety-odd "elements" now known to science. Only some fifty of these, however, have actually been detected in solution in the sea, 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.

19. Salinity, arbitrarily expressing the total salt content of sea water, has already been treated as a physical quantity. The essential hydrochemical 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.

20. 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 the existence of these organisms is adequate SUNLIGHT from which they derive the 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, the plants thus diminish its acidity, and measurement of this change in hydrogen-ion concentration enables estimates to be made (i) of the intensity of the

above biological process of photosynthesis and (ii) of the abundance of the organisms engaged in the process. Atkins (2) 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.

21. 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 (25). 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.

22. 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.

23. Coming now to the details 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.

24. Likewise with many of the inorganic constituents of sea water present in solution in extremely small amounts; there is evidently always a sufficiency to meet the needs in these substances of marine plants and animals.

25. 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 than in cold water from which it will therefore the 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.

26. COPPER, which is generally poisonous to living organisms does, however, 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 (20). 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.

27. IRON is another metal which occurs in minute concentration in the sea in combination with other elements which renders 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.

28. Brandt, in 1899 (5), formulated the conditions necessary for plant growth in the sea, specifying certain materials as being 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 whic 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 th two former elements, as NITRATE and PHOSPHATE, but particularly the latter (the ratio of nitrate-nitrogen to phosphate-phosphorus (9a) in the sea being of the ordc

of about 15:1), 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 on 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.

29. 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 (2) made such calculations in the English Channel, 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.

30. 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, practically to denude the water of this salt, the evidence is that lack of it can scarcely 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 certain concentration in silicate.

31. Finally, iron, an essential constituent of vegetable organisms, has assumed this aspect of minimal occurrence despite the fact that iron is excreted by zooplankton more rapidly than phosphorus, and probably therefore returns into circulation more quickly. On the other hand, most of the iron in the sea is present in a form not directly usable by organisms, less than ten per cent, according to Cooper (9b), being in true solution. The position therefore seems to be that plant development may sometimes be delayed by a deficiency of available, usable, iron.

32. In conclusion, as already mentioned, there is evidence of the existence in solution in the sea of certain growth-promoting substances of the nature, apparently, 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 will be beneficial to marine organisms, it seems almost certain that their action is essentially chemical. They are appropriately mentioned therefore under the present head. Lucas puts the modern viewpoint on this question comprehensively and perspectively in two recent essays (19a,b).

D. Conclusions

33. In the light of the above, the relationships of fishes with many and various factors in their inanimate environment, are clearly of a very fundamental character. The foregoing considerations, exemplified and supported by reports submitted as appendices, 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, and above all in the ultimate, the welfare and livelihood of fishes, and often their survival, 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 (30c).

34. In these circumstances it is legitimate and reasonable to look to these factors, severally and in aggregation, for at least part - probably a most significant part - of the explanation of those fluctuations in space-time occurrence in abundance, and in quality, to which all commerical 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.

35. 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 its almost entire dependence for survival upon a chain of inanimate environmental factors, culminating in the inclusive biological environmental factor of food, would seem to be undeniable.

36. 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.

37. 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 <u>two to three or four days</u> immediately following the consumption of the yolk sac with which the baby fish is hatched from the egg (32). 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 requirements, 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 originate and are carried out, 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 its replenishment on vertical and horizontal current activity generating water displacement from the deep oceanic regions on to the shallower shelf areas.

38. This primary significance of the oceanic water-masses to the health of fish stocks, through one or more year-classes generated and established under favourable environmental conditions, seems to be well illustrated by the following classic example.

39. The most outstanding case of a particular year-class dominating a fishery for many years is that of the 1904 year-class in the Norwegian Spring Herring Fishery (15b). In 1907 there were five fairly rich, evenly represented year-classes in this herring stock. These were the four to eight years old fishes. 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 77-1/2 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.

40. Not only, however, did the 1904 year-class contribute so strongly to the Norwegian herring fishery for so many years, but the same year-class dominated also the Norwegian cod fishery until the next most abundant year-class came along in 1912.

41. The physical data relative to the sea which were collected in the first decade of the present century were very much fewer than they are now. 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.

42. In extension of the above classic case, and apparently adding further significance to the influence of oceanic water-masses, Hjort (15a) in the winter of 1914-1915, when he was working in Canadian waters, found that the majority of mature Newfoundland herrings belonged also to the 1904 year-class. But on the other hand, he found that the herrings off the coast of Nova Scotia, and off the southern shores of the Gulf of St. Lawrence, were quite different as regards their age composition from the Newfoundland stock. The significance of the difference almost certainly lay in the fact of the Newfoundland population being more closely associated with the oceanic Gulf Stream water than were the Nova Scotian and Laurentian stocks.

43. An example of more recent date, however, which incorporates practically all the environmental factors concerned, adduces still stronger evidence of the highly significant role of inanimate environmental factors on the stocks of fishes, and focuses attention in this regard on the apparently preponderating 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.

44. From the year 1930, the flow of Atlantic Oceanic 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 did not accrue 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 (26a), denote oceanic water environment. Certain quantitative dynamic computational figures are now available, however, (30c) relative to the Atlantic Current in the Faroe-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 1930 onwards.

45. 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 1924-1927 and 1934-1937 show that the decrease in the latter period as a whole as compared with the former was about 35 per cent.

46. Prima facie as the result 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.[1/] This

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1/ One must here note, however, from Russell (26b) that phosphate rich water may not always lead to a good survival of larval fishes. "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".

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. Comparing average numbers for the four-year period 1934 to 1937 with those for the same period ten years before, namely, 1924 to 1927, 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.

47. These very practical researches in the English Channel go even further. They cite concrete evidence of an actual fishery fluctuation associated with the changes above-mentioned.

48. 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 of events was a marked change in the composition of the catches which began in 1931-1932, in the winter of the year in which the larvae of summer spawning fishes first showed signs of decline. Prior to 1931-1932, the younger herrings of six years and under formed at least two-thirds of the catches. In that season, however, they 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.

49. 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 that adequate observation of these factors would afford at least a substantial means of anticipating such fluctutations. As the writer has formerly pointed out, and Deacon and Kesteven in their report have recently 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.

50. At the same time, and because the above comparatively short treatment 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.

51. These suggestions and recommendations demand for their execution operations of two broad categories, namely, field, and laboratory, including aquarium, operations, each category subdivisible under a number of heads.

52. 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,[1/] would be necessary to supplement those of national and local institutions and laboratories.

53. Laboratory and aquarium operations would take care of fundamental researches of the kind carried out at the marine biological stations of the world, governmental and other, 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

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1/ Establishment need not necessarily be *de novo*, but might conveniently follow by expansion of present more or less cognate organizations or institutions.

Göthenburg, Sweden, and the former Institute für Meereskunde in Berlin, on the methods and measurement techniques, physical, chemical, and biological, to be used in field operations, on various apsects of the physiology of marine creatures, knowledge of which is necessary to the proper appreciation and interpretation of field survey data.

ANNEX

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II. OUTSTANDING QUESTIONS

by

J.B. Tait, based on suggestions
received from experts

A. Subject Questions

1. Fluctuations in Food-Fish Stocks

55. 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 more or less obvious and profound influences on fishes and other marine creatures on which fishes depend. The great problem of the causes of natural fluctuations in the incidence, abundance, and quality of fish-stocks, seems fundamentally to depend for its solution on the implementation of this need. From knowledge of the causes to their anticipation, 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.

56. 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, their age compositions and the annual recruitments thereto, of predator species, of the abundance and composition of fish-food as well as of inimically non-fish-food organisms, of the exact 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 field vital statistics, and controlled laboratory or aquarium researches on various aspects of the physiology of fishes.

57. Save perhaps that improvement of existing, or development of new methods, might be expected to facilitate and accelerate the collection and processing of observational data, the acquisition of the necessary inanimate environmental information 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 meantime lacking.

2. Nutrition of Fish

58. 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, there is lacking still for some important food-fishes the 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 quite absent.

59. Knowledge on 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 meantime 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 relationship of the amount of food available to stock-size and quality, this affording 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 towards offsetting a region of poor growth rate by transplantation of species, if practicably feasible, as in the case of North Sea plaice, to a region of maximal growth.

60. Concurrently with experimental research on growth rate in relation to nourishment by weight, could be investigated also the question of quality 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.

61. 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.

62. Possibly with some relation to the question of nutrition, as well as a question apart, is that of disease in fishes about which very little is known. 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 the market with more or less obvious signs of disease. Experiments in aquaria also, 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.

3. Tropisms of Fishes

63. As regards the difficult and complex problem of the various tropisms of fishes 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 (1952) publication on the results of his work by Bull (see reference in Selected List attached to Chapter I) seems appropriate:

64. "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°C of temperature

(b) 0.2 o/oo of salinity

(c) 0.05 /oH."

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

66. 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 to typically unvoluntary acts, such as the maintenance of equilibrium. In nature, reactions based on these perceptual abilities would probably be both voluntary and intentional.

67. 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.

68. In considering these problems as a whole, Bull says, 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."

69. Obviously, according to this expert there is much valuable work calling to be done in this field, so contingent upon the problems of fish migrations and of cause of stock fluctuations.

70. The question of 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 C_{14}, as developed in recent years and which appears to give most valuable information on the basic nourishment for life in the sea, is superior in assessment of the influence of the plankton on the distribution, density, and quality of pelagic fish than 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 also from this angle contributing to the solution of the problem of optimum yields from fisheries.

71. Investigation of assimilation phenomena by means of other tracer elements, P_{32} for example, is advocated, as well as the development of a serial method 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, e.g. components of the total phosphate, manganese, nitrogen components, chlorophyll, proteins, reduction-potential.

B. Regional Problems

Pacific and Atlantic Oceans

72. Turning to regional problems there is one which is both subject and regional, the latter in almost a world-wide sense. The tunas, as pointed out by Royce[1/] 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 of oceanic fishing vessels and gear for their catchment.

Mediterranean Sea

73. Muzinic also raises the question in respect of the Mediterranean tunas, of their ecology, in regard to which at present so little is known that the question cannot be answered as to whether the Mediterranean stocks are being sufficiently exploited as human food.

74. Here would seem to be a problem with preliminary technical and doubtless other problems associated, which, notwithstanding its vastness and intricacy, is so outstanding as to call for immediate and concerted attack, namely, the problem of the ecology of the almost world-widely distributed tunas of which there are at least six groups of species and 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 sardine.

75. Presently deterring also the scientifically efficient utilization of European stocks of sardine, there are certain deficiencies in both field and laboratory knowledge. Muzinic again says that the whole ecology of the sardine (the Mediterranean and Atlantic stocks) requires to be put upon firmer bases. Statistics of the sardine fisheries relating to fishing effort and catch appear to be seriously short, while adequate assessments of stock and brood strengths evidently await a reliable method of determining the age of a sardine. Considerable difficulties in this regard are encountered apparently in the Mediterranean.

1/ See Appendix 9.

South-East Asia

76. From South-East Asia, Than Ah Kow (Malaya) submits the regional problem of the distribution and ecology of some five species inhabiting the Straits of Malacca, the South China, Java and Andaman Seas, with subject questions involving the food and feeding relationships of the different species, and the reponses to environmental factors of those caught in large quantities, as matters for attention in aid of the food fisheries of this region.

III. PROBLEMES D'ORGANISATION

77. La collaboration internationale dans le domaine des recherches océanographiques, fondamentales ou appliquées aux pêches, s'effectue actuellement par le canal d'un certain nombre d'organisations que l'on peut classer en deux principales catégories:

a) les Unions scientifiques internationales telles que celles de géodésie et de géophysique et des sciences biologiques, qui comportent des groupements spécialisés tels que l'Association d'Océanographie physique. Ces Unions sont de type non gouvernemental. Elles se proposent essentiellement de développer les contacts entre spécialistes à l'aide de congrès, d'échanges de publications, etc... Ainsi, une Conférence internationale des Laboratoires de Biologie marine doit se tenir à Rome en avril 1955 sous les auspices de l'Union internationale des Sciences biologiques.

b) les organismes régionaux qui ont pour tâche de rassembler systématiquement les données utiles à l'exploitation des ressources sous-marines et, le cas échéant, de proposer des mesures administratives pour la protection de ces ressources. Ces organismes sont généralement de caractère intergouvernemental. Le Conseil international pour l'Exploration de la Mer, créé dès le début du 20ème siècle, en constitue l'exemple classique. Sans vouloir en donner une liste complète, on peut citer également le Conseil général des Pêches pour la Méditerranée, la Commission internationale des Pêches dans l'Atlantique nord, le Conseil indo-pacifique des Pêches, etc... Ces organismes sont en contact avec l'Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO), qui, dans certains cas, (par exemple dans la région indo-pacifique) en assure même le fonctionnement administratif.

78. Il existe donc dès à présent un réseau important d'organismes consacrés soit au progrès et à la diffusion des connaissances fondamentales, soit à l'étude des mesures propres à assurer une exploitation rationnelle des ressources de la mer. Toutefois, la nécessité de procéder à des recherches coordonnées à l'échelle mondiale ressort clairement des chapitres précédents et il semble que des progrès peuvent encore être envisagés dans ce domaine.

79. En premier lieu, il apparaît indispensable de rassembler systématiquement les données résultant d'observations océanographiques, afin d'établir, à l'usage des organismes régionaux ou locaux, des renseignements synoptiques. Cette méthode de diffusion est déjà utilisée en météorologie.

80. En ce qui concerne plus particulièrement le comportement des espèces d'intérêt économique, seules des recherches dirigées et coordonnées à l'échelle mondiale permettront d'apporter, pour prendre un exemple particulièrement important, les données qui manquent actuellement sur la biologie des différentes espèces de thon.

81. Enfin, l'étude des phénomèmes de l'océan met en jeu différentes disciplines scientifiques, entre lesquelles il est nécessaire d'établir un lien si l'on veut obtenir des renseignements susceptibles d'assurer une exploitation rationnelle des ressources de la mer, mettant ainsi la science au service des pêcheries.

82. Depuis quelques années, la FAO et l'UNESCO ont étudié ensemble les moyens d'atteindre ce but. Lors de sa 8ème session, tenue à Montevideo à la fin de 1954, la Conférence générale de l'UNESCO a approuvé les propositions du Directeur général sur cette question[1/].

83. Le programme de l'UNESCO pour 1956-57, pour lequel la Conférence a alloué un crédit total de 54.000 dollars, prévoit la création d'un Comité consultatif international des Sciences de la Mer, doté d'attributions analogues à celles qu'exerce, dans le domaine qui lui est propre, le Comité consultatif de Recherches sur la Zone aride. Ce Comité devra d'une part formuler des recommendations concernant l'encouragement et la coordination des recherches fondamentales dans le domaine de l'océanographie physique et de la biologie marine, d'autre part, mobiliser les connaissances scientifiques pour la solution des problèmes concrets que pose l'exploitation des ressources de la mer dans les différentes régions du globe. Le Comité devra en somme établir un courant d'échanges:

1/ Cf. document UNESCO/8C/PRG/22.

a) entre les différentes disciplines scientifiques concernant les phénomènes aquatiques (y compris la limnologie, source de précieuses observations expérimentales);

b) entre la connaissance scientifique et l'exploitation rationnelle, c'est-à-dire entre la théorie et la pratique;

c) entre les pays sous-développés et les institutions de recherche les plus avancées.

84. Une réunion d'experts doit se tenir à Rome, à la suite de la Conférence technique internationale sur la Conservation des Ressources biologiques de la Mer, afin d'étudier le programme et les modalités de fonctionnement de ce Comité, en tenant compte, notamment, des résultats de la Conférence.

ANNEXE

Notes bibliographiques

85. L'importance de la coopération internationale en océanographie a été soulignée, au cours des études effectuées par les Nations Unies de 1946 à 1948 sur la possibilité de créer des laboratoires internationaux, par différentes personnalités, notamment par les professeurs J.A. Fleming, qui présidait à cette époque le Conseil International des Unions Scientifiques, et H.U. Svetdrup, qui dirigeait à cette époque l'Institut d'Océanographie Scripps (Etats-Unis). On pourra consulter à ce sujet la brochure publiée par les Nations Unies en 1949 sous le titre "Le problème de l'établissement des Laboratoires de recherche des Nations Unies".

86. En ce qui concerne la région indo-pacifique, on pourra consulter les documents suivants:

a. "Report on International Oceanographie Requirements", adopté par le Conseil indo-pacifique des Pêches en sa 4ème Session (Quezon City, Philippines, octobre 1952);

b. Le rapport de l'UNESCO sur la réunion de consultants tenue en octobre 1953 à Manille pour examiner la création éventuelle d'une organisation océanographique régionale (document Unesco/NS/113);

c. La lettre circulaire ML/997 adressée par le Directeur général de l'UNESCO aux commissions nationales de cette Organisation en juin 1954.

87. En ce qui concerne l'Amérique latine, un Comité d'experts, convoqué à Concepcion (Chili) en novembre 1954 par le Poste de Coopération scientifique régional de l'Unesco, a formulé un certain nombre de recommandations (document Unesco/8C/DIV/29), dont certaines sont en voie d'exécution.

88. Le programme de l'UNESCO en ce qui concerne les sciences de la mer a fait l'objet d'un rapport adopté par la Conférence générale en sa 8ème session, tenue à Montevidéo à la fin de 1954 (document Unesco/8C/PRG/22). Les méthodes d'action de l'Unesco dans le domaine de la recherche scientifique en général sont décrites dan le rapport Unesco/NS/114 (rev.).

89. Signalons enfin le rapport "Ocenography and Fisheries" de G.L. Kesteven, Chef de la Section de Biologie des Pêches de la FAO.

APPENDIX 1

Life history of Penaeus japonicus

by

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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 50 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 crustacea, their geographical distribution extending over the waters between the temperate and the torrid zones all over the world.

Habit and season of spawning

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 they are swimming. The number of eggs laid by a single shrimp of 20 cm. body length is approximately 700,000.

Development

The eggs hatch out in 14 hours if the water temperature is between 27° and 29°C. 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° - 29°C, is between 37 and 38 hours. Larvae in the zoea stage experience three moults and after the third moult pass into the mysis stage. The time required is found to be about 5 days when the water temperature is between 27° and 29°C. Larvae in the mysis stage also go through three moults in 5 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 phyto-planktonic. Only in the mysis stage they begin to take zo-plankton. Thereafter their food is primarily animal.

Since spawning takes place in water deeper than 10 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 4-5 cm. body length. 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 and 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 in temperature and other sea water conditions and in the amount of sunshine, etc.; 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 as compared with the influence of the natural physical circumstances.

APPENDIX 2

La Sardine atlantique

par J. Furnestin
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et technique des Pêches, Paris.

La morphologie et la biologie de la sardine atlantique sont bien connues dans le détail, mais rares sont ceux qui ont tenté la synthèse.

Quant à son comportement, soit ses rapports avec le milieu, qui n'a pas fait l'objet d'autant de recherches, on en ignore l'essentiel.

Néanmoins, des observations précises et des hypothèses basées sur des faits nombreux et concordants, permettent de saisir les traits principaux de son oecologie.

1° - Comportement en milieu normal

Effets de la température - C'est le facteur le plus important. En effet, la répartition de l'espèce est étroitement limitée dans l'Atlantique et ailleurs par les isothermes annuelles de 10° et 20°. Ceci lui confère une aire de peuplement fort étendue, de la côte mauritanienne au Northumberland.

La température détermine aussi ses concentrations périodiques et ses principales migrations.

Ce Clupe exige des températures élevées (mais variables suivant la race) pour ses stades larvaires et juvéniles, puis plus modérées pour la ponte, après laquelle il recherche des eaux plus froides. Comme il est ainsi après chaque maturité sexuelle, la sardine, à mesure qu'elle vieillit, tend à gagner des eaux de température toujours plus basse.

Cela se produit pour les sardines du golfe de Gascogne.

Les jeunes éclosent au sud, de l'hiver au printemps (10° à 16°), y restent jusqu'à leur première maturité sexuelle qu'ils atteignent à deux ans révolus.

Après la ponte, devenus adultes, ils fuiront ces eaux que le printemps réchauffe et gagneront les côtes vendéennes et bretonnes.

Au bout de leur troisième année marquée par une nouvelle ponte, ils rechercheront au nord des eaux encore plus froides.

Les jeunes issus de ces pontes septentrionales hiverneront au sud de la zone où ils sont éclos pour y revenir plus tard, suivant les mêmes lois.

Mais leur première migration ne les amènera pas toujours dans la partie la plus méridionale du golfe. Fonction de la température hivernale, sa limite vers le sud, variable suivant les années, sera l'isotherme de 10° - 11°.

La race marocaine évolue pareillement, mais suivant des modalités correspondant aux différences du milieu.

Certains phénomènes hydrologiques (<u>upwellings</u>) font que le nord du Maroc, surtout en été, est plus chaud (20° à 25°) que le centre occupé par des eaux froides (14° à 16°).

De par ces conditions, la migration "physiologique" des sardines demeure de même sens qu'en Europe (vers les eaux froides), mais leur migration géographique est inverse (vers le sud).

Dans le secteur nord, les jeunes naissent en hiver et au printemps et passent leurs premiers stades dans les eaux chaudes aux abords de Casablanca. Plus précoces qu'en Europe, ils se reproduisent dès la fin de leur première année, sur leur frayère natale.

Mais au début du printemps, le réchauffement de ce secteur, excessif pour eux, les oblige à migrer au sud dans les eaux à 14° - 16° qui leur conviennent désormais.

L'hiver suivant, le refroidissement provoquera sur l'aire de ponte originelle la température modérée (18°) favorable aux reproducteurs qui y reviendront pour repartir encore, leur ponte terminée, vers les eaux froides de Safi.

Une situation identique se présente près d'Agadir où la zone chaude de Ghir et la zone froide d'Ifni ont la même influence sur la reproduction des sardines de cette région.

<u>Effets des courants</u> - Les courants agissent aussi sur les déplacements des sardines qui recherchent les eaux calmes à l'abri des caps. Mais si elles ne peuvent s'y maintenir, elles suivent le courant qui parfois les entraîne fort loin, fait souvent remarqué en Baie d'Agadir où l'action des courants s'ajoutant à celle de la température accélère ou ralentit les migrations.

De même, une expérience de marquage a démontré que les sardines peuvent se laisser déporter de 50 km en quelques jours (voire en quelques heures) alternativement vers le nord et le sud.

Comportement diurne et nocturne - Reconnaître là une loi générale est difficile.

Néanmoins, deux faits se dégagent d'observations régulièrement faites au moyen des ultra-sons:

- les sardines se rassemblent souvent en formations considérables, la nuit;
- compte tenu des conditions thermiques favorisant ou contrariant leur montée en surface, elles se tiennent généralement près du fond le jour et de la surface la nuit.

2°- Comportement en milieu confiné

Les progrès de la pêche au thon a l'appât vivant ont amené à étudier le problème de la survie des sardines en vivier.

Ces expériences ne reflètent pas exactement leur manière d'être en milieu naturel, car elles les soumettent à un début de "domestication" qui modifie assez profondément les réactions des organismes. Ces expériences restent néanmoins intéressantes.

Réaction aux courants - Les premiers essais en vivier où l'eau arrivait avec une certaine turbulence échouèrent. Dès que furent rendus insensibles l'afflux et l'écoulement de l'eau, les résultats s'améliorèrent considèrablement.

Ceci concorde avec les faits observés en mer : contrairement à d'autres clupes, la sardine préfère les eaux calmes.

Réaction à la lumère - La pêche au feu, pratiquée sur maints rivages, prouve bien que la sardine, très sensible à la lumière, a un phototropisme positif. En vivier, ce phototropisme est très affirmé : une lampe éclairant constamment le bassin maintient les sardines en surface, augmente leur activité et prolonge leur vie.

Réaction à la nourriture - Les sardines s'habituent vite à une nourriture différente de celle qu'elles trouvent en mer. Toujours avides, elles prennent en quelques jours l'habitude de monter en surface dès que la "rogue" est répandue. Ce fait, d'ailleurs, est connu des pêcheurs qui jettent l'appât à la volée pour attirer le poisson.

Ces trois conditions réunies (non turbulence de l'eau, éclairage et nourriture abondante) permettent aux sardines captives de surmonter rapidement un changement radical et de survivre nombreuses, plus de deux semaines, en espace confiné.

Ces données, on le voit, sont assez incomplètes. Les unes ont été obtenues par des méthodes proprement scientifiques, les autres par la pratique même de la pêche.

Si on veut parfaire nos connaissances sur l'oecologie de ce poisson, une association des deux méthodes est à préconiser et le biologiste aura toujours intérêt à multiplier les recherches en mer sur les lieux mêmes de pêche.

APPENDIX 3

Account of the present knowledge of the reactions of the mackerel to environmental factors

by

Aage J.C. Jensen

of the Danish Institute of Fisheries and Oceanography, Charlottenlund

The North Atlantic mackerel (Scomber scombrus) during its spawning (which takes place in surface waters) seeks temperatures of 10-15°C with the temperature rising, and it spawns therefore in the Marmara Sea about April-May (H. Lissner), in the Mediterranean in January-March (E. Sella and O. Giacchi), at the western entrance to the English Channel and south of Ireland in March-July, and in the northern North Sea, Skagerrak and Kattegat, partly also in the Belt Sea, in June-July. It has been thought by scientists who have investigated the mackerel in the last-named area, that it also favours a rather narrow range of salinity of between 26 o/oo and 33 o/oo, but in recent years mackerel eggs have been found in considerable numbers (by I. Fraser) in the Faroe Channel where the salinity is ca. 35 o/oo and where they cannot possibly have been carried by the currents from areas with lower salinity; and off the English Channel in some years mackerel eggs are found in largest quantities where the salinity is about 35 o/oo (G.P. Farran), or even over 35.5 o/oo (J. Furnestin). It may be mentioned that 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 these stocks.

On the other hand there is a lower salinity spawning limit for mackerel a little below 20 o/oo. A few mackerel eggs have been found in the western Baltic floating in 16 o/oo salinity water but they may have been carried there from water of about 20 o/oo salinity. 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 with specially 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 these 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.

Fig. 1 shows the connexion between the mean sea surface temperature in June-July and the average catch per boat of the Swedish drift-net fishery, which is carried out only for spawning mackerels. Averages are calculated for the period from 1919, when statistics for this fishery were started, to 1945. After this year the catch per boat has increased very much due partly to changed fishery methods and partly to an increase in the stock on account of stronger year-classes.

Fig. 2 shows the connexion between the average surface temperature in April-May-June, i.e. just before the fishery starts, and when it has started, and the same catch of mackerel as in fig. 1.

The mackerels of north-west Europe come to the spawning places from about 150-200 metres depth; most of them to the Skagerrak and Kattegat come from the North Sea. Although the mackerel is a very strong swimmer, this migration seems to be influenced by the currents. The influence of the 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 co-variation 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 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 mackerels to the Skagerrak is generated by the current in the surface water layer. This co-variation which is used also for predicting the yield is shown in fig. 3.

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 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 amount of mackerels in the inner Danish water is influenced by the wind which carries the surface water and the mackerels 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 amount of mackerels at the surface, and therefore the catch, may also be influenced indirectly by the number of sunshine hours, e.g. in the English Channel (E.J. Allen, E.S. Russell).

In the Black Sea, the southern North Sea, the Skagerrak, Kattegat, Belts and Baltic, the temperature during the autumn becomes too low for the mackerel, which then pass 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 is the temperature during the autumn months.

Fluctuations in the strength of the year-classes are also of importance to annual fluctuations in the density of the commercial stock, and this 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 the yield are given exclusively from the strength of the year-classes and the length-composition of the stock (Oscar E. Sette). The connexions between the strengths of the year-classes and environmental factors have not been stated.

Fig. 1. Co-variation of the temperature of the surface water in June-July and the catch per boat of the Swedish drift-net fishery for mackerel in the Skagerrak and northern Kattegat, 1919-45.

Fig. 2. Co-variation of the temperature in the surface water in April, May, June and the catch per boat of mackerel as in fig. 1.

Fig. 3. Co-variation of the difference in barometric pressure between southern and northern Jutland (Fanø-Skagen), measuring the strength of the westerly winds, in January, February, March, and the anomalies from five-years smoothing of the catch per boat of the Swedish drift-net fishery for mackerel in the Skagerrak and northern Kattegat, 1919-1952.

APPENDIX 3

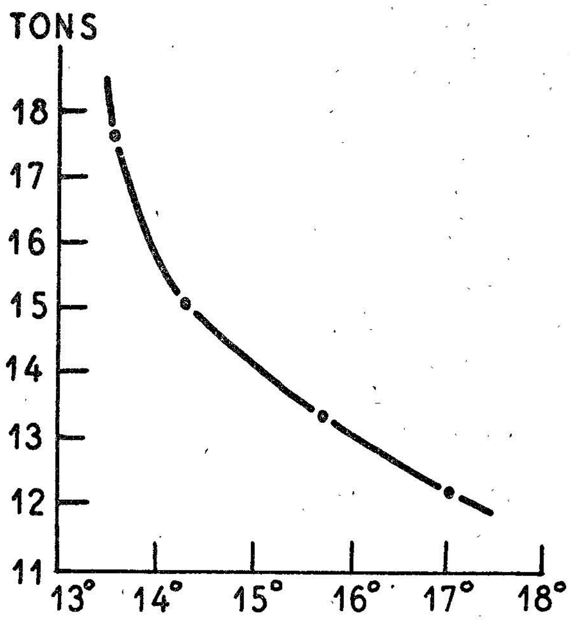

Fig. 1

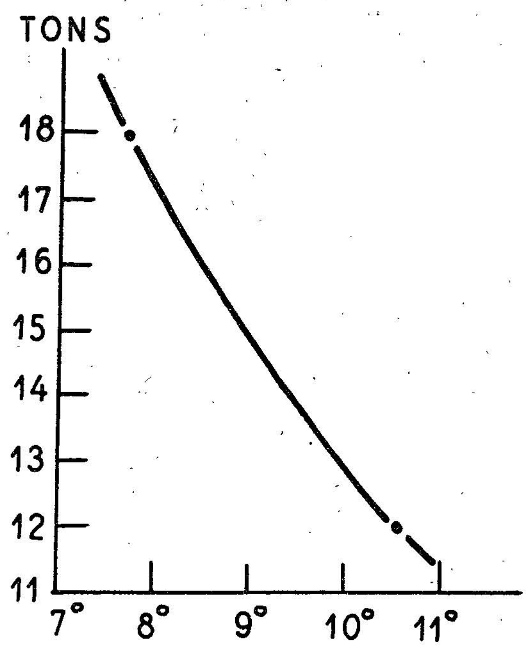

Fig. 2

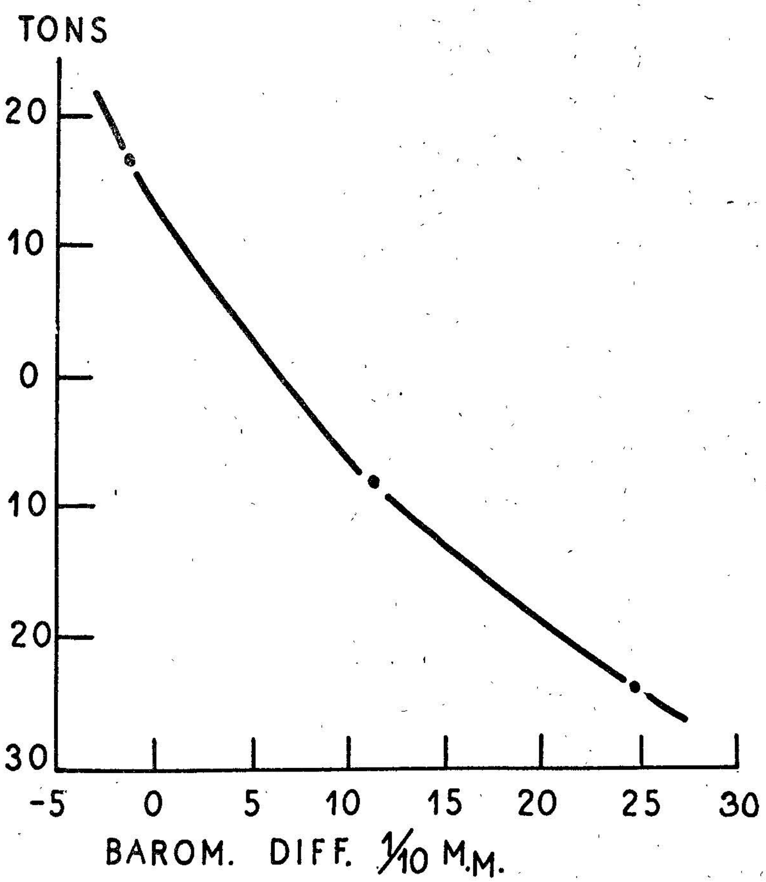

Fig. 3

APPENDIX 4

An account of the knowledge concerning the response of the plaice to environmental factors

by

R. Kändler
Professor of the Oceanographic Institute of Kiel University

Our 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 only in 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 due to increased absorption of water in the ovary, are adapted to the lesser buoyancy of the Baltic waters, with salinity as low as 12 o/oo. The older larval stages can tolerate a further reduction of the salt content, 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 o/oo. It is enabled to live in these waters by osmotic pressure regulation, on which searching experimental investigations have been carried out, which have made a most important contribution to our knowledge of the environmental adjustment of sea fish. Osmotic pressure regulation fails when the salinity is very low (under 5 o/oo), 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 the salinity, of O_2 and CO_2 pressures, and of pH-value on the fertilization and development of plaice eggs. The species has adjusted itself to the greater perils menacing the progeny in the unfavourable

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Fig.1 conditions of the Baltic by developing earlier sexual maturity and higher fertility. 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 we have no detailed knowledge of the plaice's capacity to distinguish differences in salinity; nor has any sensory physiological research been carried out into 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^{o} and $7^{o}C$. 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-east region of the North Sea. In the western Baltic, hard winters, with water temperatures in the region of $0^{o}C$ cause the 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 the temperature differences are small, as in the Faroes-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 1-2°C, and in the English Channel at Fig.2 temperatures of less than 10°C, growth is arrested, while the optimum is attained at about 13-15°C. 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. We have no reliable information, based on observations in aquaria, about the minimum temperature at which the assimilation of food is still possible. When the temperature of the water is low, the plaice shows little activity and, in particular, young plaice burrow deep into the sand during the winter so that they escape the trawl. The annual variations in the temperature of the 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.

We also know little 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 time but swims 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 the 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 repercussions on the distribution of the fry and therefore on the numbers of progeny found in the nursery grounds. A correspondence has been noted between the size

Fig.3 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, 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

Fig.4 decisive effects on the rate of growth of the plaice. In the nursery grounds in the south-east of the North Sea, the rate of growth falls when the brood is large and rises when it is small. 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" the 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 of the plaice, which was before 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 molluscs 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 the winter. During this period they avoid eating animals with hard shells. From the results of experiments carried out in tanks

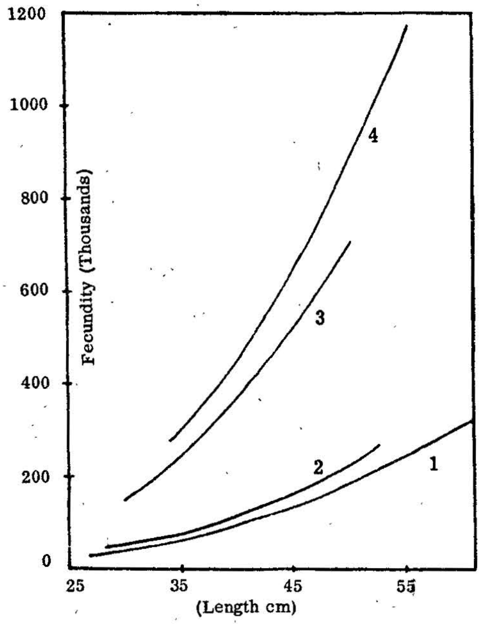
Fig.5 and aquaria, the plaice needs a saily intake of 0.01 per cent to 0.02 per cent of its own weight, in the form of shell fish for the maintenance of its body weight. The quantity required falls at lower temperatures and as the fish grows larger. When there is an abudant supply of food, one-year-old 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 keep 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, etc. 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.

We have no evidence 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. We still know very little 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.

APPENDIX 4

Figure 1

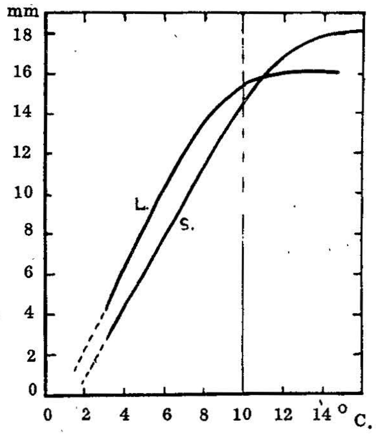


Relation between the fecundity and the total length of the plaice.

1. North Sea, Southern Bay.
2. North Sea, Flamborough Area.
3. Western Baltic.
4. Baltic, Bornholm Area.

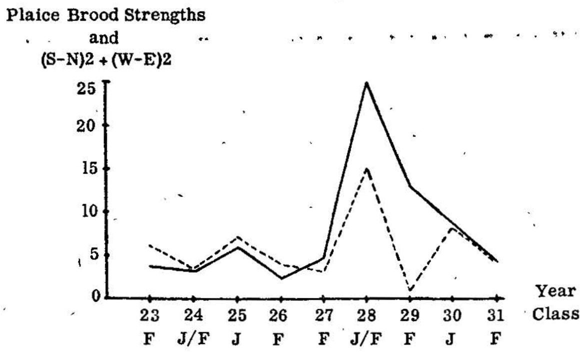
Dates of the North Sea Plaice from A.C. Simpson 1951.

Figure 2



Connexion between temperature and monthly growth of transplanted North Sea Plaice in the Sejrø Bay, (S.)-curve, and the southern Little Belt, (L.)-curve, respectively. (From A. J. C. Jensen)

Figure 3



Association between Plaice Brood Strengths and Winds from SW Quadrant.

——— Plaice Brood Strengths (Thursby-Pelham)

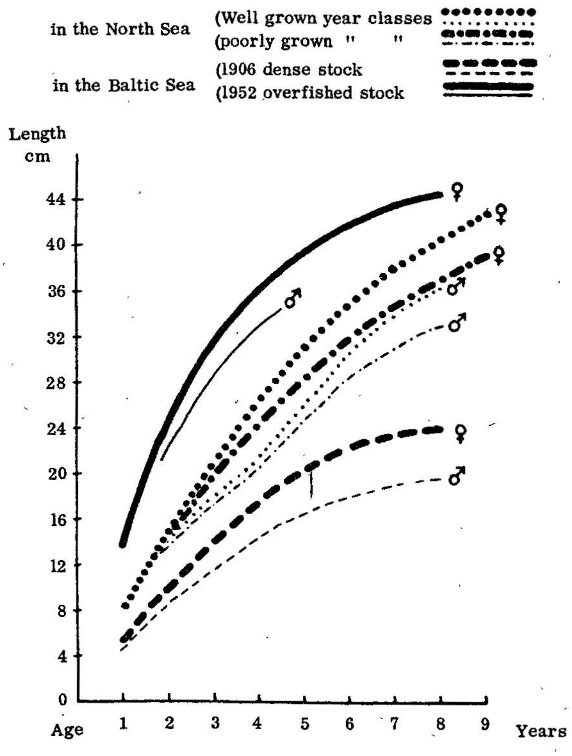
- - - - $\sqrt{(S-N)2 \pm (W-E)2}$ m/sec.

(Months selected shown beneath each year).

From Carruthers, Lawford and Veley 1951.

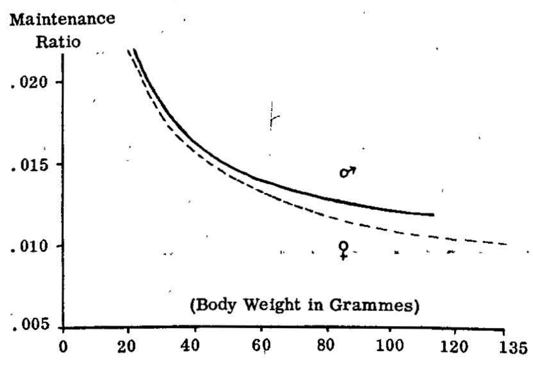
Figure 4

GROWTH OF THE PLAICE



Dates of the North Sea Plaice from A. Buckmann 1938.

Figure 5



Graphs showing, for male and female plaice between 2 and 3 years old, the relationship between the maintenance ratio and the body weight. (From B. Dawes 1931)

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APPENDIX 5

An account of the knowledge already available concerning the response of Stolephorus pseudoheterolobus Hardenberg to environmental factors

by

Tham Ah Kow

of the Fisheries Division of Singapore

The genus Stolephorus Lacepede is well represented in the waters of the Indo-Australian Archipelago by no less than eight species.[1/] In the Straits of Singapore four species viz: Stolephorus pseudoheterolobus Hardenberg, Stolephorus heterolobus Rupp, Stolephorus indicus (v. Hass.) 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 and five fathom lines.[2/] A smaller modified version of the "kelong" known as the "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 (1) that Stolephorus pseudoheterolobus may, generally speaking, be expected in their catches during certain months of the year and (2) that the volumes of the catch of this species vary from year to year. They believe that these phenomena are the result of varying conditions of the sea water and the weather such as the 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

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1/ Hardenberg, J.D.F. (1934). "Some Remarks on the Genus Stolephorus Lacepede in the Indo-Australian Archipelago." Treubia, Vol. 14, No. 1, July 1931.

2/ Le Mare, D.W. and Tham Ah Kow (1947). "The Kelong Fishing Method." Fishery Conference convened by the United Kingdom Special Commissioner for South-East Asia at Singapore. Paper No. 1 (Mimeo).

fishermen should be tested on a quantitative basis by means normally at the disposal of the fisheries scientist and that, at the same time, the position should be explored with a view to elaborating a more precise basis for prediction. The "kelong" which is a fixed trap 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 of the food[1] of Stolephorus pseudoheterolobus, observations on temperature and quantitative determinations of salinity, phytoplankton and zooplankton were made at fortnightly intervals throughout two full years.[2] 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.

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, viz: Scomberomorus commerson Lacepede, Scomberomorus guttatus Schneider and Scomberomorus lineolatus Cuvier, are commonly found in Singapore Straits. The results of the investigation indicated, inter alia, 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, viz: $27^{\circ}C - 30.5^{\circ}C$ for temperature of sea water and $28.47^{\circ}/oo$ and $31.87^{\circ}/oo$ for salinity,

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1/ Tham Ah Kow (1950) "The Food and Feeding Relationships of the Fishes of Singapore Straits". Colonial Office Fisheries Publications, Vol. I, No. 1, 1950. H.M.S.O.

2/ Tham Ah Kow (1953) "A Preliminary Study of the Physical, Chemical and Biological Characteristics of Singapore Straits". Colonial Office Fisheries Publications, Vol. I, No. 4, 1953. H.M.S.O.

(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 catches, 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 Stolephorus pseudoheterolobus 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 Scomberomorus spp. 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 Scomberomorus spp.

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.

APPENDIX 6

Quelques observations sur le comportement de la sardine

par R. Muzinic
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Le comportement de la sardine méditerranéenne /Sardina pilchardus W a l b./ n'a pas été, jusqu'à présent, l'objet d'études systématiques. A notre connaissance, elle n'a même pas été soumise aux conditions expérimentales. C'est pour cette raison que, dans la littérature se rapportant à la sardine méditerranéenne, on trouve seulement des indications indirectes concernant le comportement de ce clupéidé, sur lesquelles nous n'insisterons pas ici.

Au cours de nos expériences de marquage, dans l'Adriatique orientale, nous avons eu l'occasion de faire quelques observations directes sur le comportement de la sardine et, en particulier, sur celui de la sardine adulte. Il convient de signaler que celles-ci ont été faites exclusivement dans le but de contribuer à l'efficacité du travail en cours et peuvent, comme telles, représenter seulement des données d'orientation.

Avant d'exposer ces observations, nous devons nous arrêter un peu aux conditions dans lesquelles elles ont été faites.

Notre expérience de marquage préliminaire a été effectuée en hiver dans un vivier en bois à parois partiellement remplacées par du filet métallique assurant la circulation de l'eau. Pour le marquage définitif, auquel on a procédé au cours des raisons de pêche,1/ nous nous sommes servis d'un rectangulaire /4 m x 1 m x 1 m/ dont les parois étaient constituées par du filet en coton.

On prélevait le poisson à marquer sur les pêches à la lumière. Le vivier était ensuite remorqué par un canot à moteur justqu'à un endroit abrité,

1/ Dans l'Adriatique orientale, on pratique la pêche à la sardine surtout d'avril à octobre, c'est-à-dire en dehors de la période de ponte.

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où les opérations commençaient, d'ordinaire, entre 4 et 6 h. Les individus marqués étaient mis dans un des deux compartiments du vivier ou dans un vivier accessoire.

Les sardines semblaient bien supporter cette captivité. Nous avons essayé, à maintes reprises, de leur donner de la semoule de maïs. Elles avalaient les granulés dont nous avons ensuite constaté la présence dans leur tractus digestif.

A l'intérieur du vivier, les sardines demeuraient groupées, formant un banc unique. Ceci était valable également pour les exemplaires qui ont été soumis au marquage. Seulement les individus endommagés faisaient exception à cette règle, en restant isolés et, d'ordinaire, plus près de la surface. Même en sortant du vivier, le poisson formait encore un banc qui n'incorporait pas les sujets en mauvaise condition. Ceux-ci restaient dans le vivier ou erraient désorientés dans son voisinage. Plus le poisson était de bonne qualité, plus le banc était cohérent et s'éloignait dans une direction bien déterminée. Au cours d'une seule expérience, l'éloignement régulier des individus marqués a été dérangé et ce désordre était dû au voisinage immédiat de prédateurs très agressifs /Lichia sp./. Les sardines, effrayées, ne voulaient pas abandonner le vivier et, après en avoir été chassées, elles y rentraient de nouveau ou demeuraient au plus près.

Dans le vivier, la sardine ne cessait de se déplacer d'un bout à l'autre de celui-ci. Son mouvement n'était jamais circulaire, comme c'est le cas pour le maquereau.

Au cours de notre travail, la température n'a pas présenté des variations notables. La température la plus basse qu'on ait pu constater à la surface vers la fin du travail, sur les lieux mêmes des opérations, s'élevait a 17,0°, et la plus haute à 25,1°. Pourtant nous avons eu l'occasion d'observer que la température pouvait avoir une influence remarquable sur le comportement de la sardine. C'est ainsi que les exemplaires marqués plongeaient, en quittant le vivier, vers la profondeur et ceci à partir de 22,5° à la surface. On a même remarqué que, dans les conditions indiquées, la haute température agissait léthalement sur ce clupéidé. Il nous a été donné d'enregistrer, à plusieurs reprises, une mortalité notable chez le poisson, avant le marquage, au cours des mois chauds, plus précisément quand la température de surface s'élevait a 23,0° et au-dessus /R. Muzinic, 1952, 1954/. Les individus survivants semblaient être flasqués et perdaient très facilement leurs écailles. Malgré toutes les précautions prises, cette mortalité continuait à entraver le travail et on a même dû renoncer au marquage durant une partie de la saison de pêche, d'autant plus que les récapturés en résultant ont été très rares ou inexistants, ce qui pourrait déceler une mortalité post-marquage plus élevée. Une mortalité importante semblait surtout se produire dans les cas où le poisson avait été pris de bonne heure. A deux reprises, nous avons observé une mortalité notable même au-dessous de 23,0°/22,0° et 22,5°/, mais d'autres facteurs ont pu intervenir également. En tout cas une certaine mortalité s'est manifestée par des températures de 20,5° et 21,0°, tandis qu'elle était nulle et négligeable entre 17,0° et 18,5°. Il convient de signaler ici que la réduction du rendement de la pêche à la sardine, dans l'Adriatique orientale, semble coïncider avec les températures annuelles les plus hautes.

En attendant que les études dans les conditions expérimentales fournissent des renseignements sur l'action isolée de la température ainsi que sur l'action de ses changements, ce facteur peut quand même être considéré, comme un des plus importants régissant le comportement de la sardine.

Quelle est l'action de températures inférieures à celles indiquées préalablement sur le comportement du poisson, nous ne saurions le dire. On peut mentionner seulement que la température enregistrée pendant l'hiver sur les lieux de la capture des sardines au chalut, un peu au-dessus du fond, a varié de 13,8° a 15,4°. Tous les individus pêchés étaient en cours de reproduction.

Parmi les facteurs pouvant régir le comportement de la sardine, il faut aussi comprendre la lumière. Un essai de marquer le poisson de nuit, sous la lumière artificielle, a montré que celui-ci n'était pas disposé à abandonner le vivier bien que le fanal ait été préalablement masqué. En faveur de cette hypothèse plaide l'observation, faite au cours de l'analyse des contenus stomacaux, chez la sardine adriatique, d'après laquelle elle ne s'alimente pas la nuit/V u c o t i é, 1954/, de même que l'emploi de la lumière artificielle dans la pêche à la sardine.

Au cours de nos opérations, on a pu noter aussi une action nuisible de la mer houleuse sur ce clupéidé.

Il semble donc que les facteurs régissant le comportement de la sardine doivent être multipliés. Les observations indiquées démontrent, une fois de plus, qu'ils méritent une étude approfondie.

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APPENDIX 7

Observations sur le comportement de l'huître perlière et nacrière (Pinctada margaritifera L.) par rapport à son milieu

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Cette espèce de "Mollusque Lamellibranche" est dispersée dans toute la zone corallienne de l'Indo-Pacifique. Mais si, en général, les individus sont assez éloignés les uns des autres, au contraire dans les lagons des îles de l'Archipel des Tuamotu ils sont assez nombreux dans un espace restreint, puisque les plongeurs peuvent récolter jusqu'à 100 tonnes de coquilles en trois mois dans le tiers du lagon de l'Ile d'Hikuoru, seulement. Les lagons sont donc des endroits propices à sa propagation. Les larves y vivent tout le temps de leur vie planctonique et ne sont qu'accidentellement entraînées à l'extérieur; elles peuvent donc se fixer en grand nombre sur les collecteurs naturels qui s'y trouvent. Quelles sont les conditions requises pour la croissance et la reproduction de cette espèce d'huître perlière?

La croissance nécessite une salinité, une température et une nourriture appropriées que l'on trouve dans presque tous les lagons puisque en 3 ans l'huître a atteint une taille marchande de 13 centimètres et plus ce qui exprime une vitesse appréciable de sécrétion de la coquille. La densité de l'eau est en général de 1025, la température de 25 à 30°C environ. Le plancton, sa nourriture essentielle, est surtout abondant en été, au moment de la reproduction de tous les organismes marins. Dans le lagon de Takapoto, la densité de l'eau est de 1030, la température est la même que ci-dessus. L'huître perlière reste vivace mais sa coquille n'atteint jamais de grandes dimensions: à 3 ans elle n'a que 8 centimètres.

Sans aucun doute la salinité de l'eau joue un grand rôle dans le développement de l'oeuf et la croissance de l'adulte. Le nanisme des huîtres perlières du lagon de Takapoto est dû a la grande salinité de ses eaux. Le lagon n'a qu'une faible communication avec l'océan, l'île l'enveloppant presque complètement. Le plancton y est plus rare.

De 0 à 15 mètres de profondeur la croissance de l'huître est lente. La coquille reste courte et s'épaissit; l'état physiologique de l'animal est mauvais. C'est le plus souvent dans cette zone et chez ces individus que l'on trouve des perles. Haute température, grande lumière, forte salinité, absence d'une nourriture suffisante sont probablement les causes de cette déficience.

De 15 à 45 mètres la croissance est normale. L'animal est vivace; il secrète une belle nacre.

La reproduction de cette huître perlière a lieu d'octobre à février dans l'hémisphère austral. Les glandes génitales se développent à partir d'octobre; la ponte a lieu en décembre, janvier et février. La température de l'eau atteint alors 30°C environ. Un nombre astronomique (des milliards) d'oeufs et de spermatozoïdes sont rejetés par les femelles et les mâles. Ils tombent sur le fond, où les courants les entraînent. Les oeufs sont rapidement fécondés. Dans l'espace de 24 heures l'oeuf bien conformé (la moitié ou les deux tiers seulement sont tels) se transforme en une larve ciliée. Elle est capable de petits mouvements verticaux et se tient près de la surface de l'eau. Mais elle ne peut vaincre le plus faible courant, à la merci duquel elle se trouve. Tous les animaux s'en repaissent. Pour se développer correctement les larves survivantes doivent se trouver en présence de conditions favorables de température (30°) et avoir à leur disposition une abondante nourriture de très petites Algues microscopiques ou de Protozoaires car leur bouche est très étroite. Pendant 21 à 25 jours, jouet des courants, la larve va croître et subir des transformations anatomiques, puis une véritable métamorphose interne. Elle tombe sur le fond, secrète une nouvelle coquille. Si elle trouve un support convenable sur lequel elle puisse se fixer, elle poursuit sa vie, faute de quoi elle meurt ou est la proie des innombrables ennemis qui la guettent sur le fond. Il en meurt de ce fait des quantités considérables. Les vents et les courants en ont d'ailleurs déjà jeté des grandes quantités à la côte où elles périssent.

Mais pour que les larves se fixent il leur faut des pierres ou des coquilles. Le sable leur est fatal. Les pierres et les coquilles doivent être propres et libres de toute vie animale. Une pierre couverte de coraux vivants ou d'organismes divers ne peut servir à la fixation, les filaments du byssus ne pouvant plus s'y attacher. Or, au cours du temps, la mer rejette du sable dans le lagon. Progressivement, l'épaisseur et la surface du sable augmentent, la profondeur diminue. Les lagons peu profonds sont les premiers menacés. Dans le fond des autres, on ne trouve plus que des surfaces de sable entre des rochers de plus ou moins gros volume. Lorsque, sur une surface de sable s'est trouvée une coquille de bénitier ou un caillou (morceau de corail mort) il est rare de ne pas y trouver une huître perlière fixée. Le cyclone de 1906 qui a dévasté certaines îles, a jeté dans les fonds un grand nombre d'arbres arrachés au sol. Ces arbres ont constitué des supports, des collecteurs et se sont rapidement couverts d'huîtres perlières.

A l'heure actuelle, les huîtres sont surtout fixées sur les rochers non ensablés des fonds des lagons. Mais ces rochers se sont couverts progressivement de productions animales diverses et les espaces libres ne sont plus nombreux.

Les jeunes huîtres une fois fixées ont à affronter des ennemis multiples nouveaux: poissons, crustacés, mollusques, échinodermes, entre autres. De très nombreux sujets vont encore périr. Il en arrivera peu à l'état adulte. Pour un million d'oeufs rejetés, on peut dire que un à dix seulement perpétueront l'espèce. Il faut donc des huîtres mères en très grandes quantités pour assurer la pérennité de l'espèce en un endroit donné. Lorsque le stock de reproduction tombe au-dessous d'une certaine limite, on peut être assuré d'assister, à plus ou moins brève échéance, à l'extinction totale de la population. C'est là le facteur crucial de la prospérité d'un lagon. Il faut des dizaines de milliers de reproducteurs concentrés en un espace relativement restreint pour assurer la continuité de l'espèce.

La pêche excessive aboutit fatalement à réduire le stock d'une manière dangereuse. Les huîtres mâles et femelles qui ont échappé aux plongeurs se trouvent souvent fort éloignées les unes des autres, d'où difficulté de fécondation des oeufs.

Les larves dispersées par les courants se fixent un peu partout, même dans les endroits où les adultes vont végéter tout le reste de leur existence.

L'adulte résiste à des conditions sévères: chaleur excessive, lumière trop forte. Mais seuls les individus vivant dans des conditions très favorables donneront une progéniture viable; leurs oeufs seront bien constitués. La zone où ces conditions seront réalisées peut être considérée comme le "nid de l'espèce". Pour l'huître perlière d'Océanie, les grands fonds des lagons réunissent ces conditions.

APPENDIX 8

The Arctic Cod

by

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of the Institute of Oceanographic Research of Bergen

In February each year enormous shoals of spawning cod appear on the northern 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 we know that the Lofoten Fishery, although fluctuating, must have been of a permanent nature for more than a thousand years. And as it is of fundamental importance for Norway, this fishery 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 on 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 parts of the cod. But the main bulk of the shoals penetrate southwards to the great submarine valley in the continental shelf outside the Westfjord. Here they enter the Westfjord and congregate on the spawning banks inside 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 n.m. each year in order to deposit its pelagic eggs in one particular area on the Norwegian coast. We do not know why this enormous effort is demanded of the spawning cod. We can only assume that the migration to this locality is a necessary measure arranged by nature in order to ensure a successful propagation. Nor do we know much about how the fish is able to find its way to the spawning banks. We must assume that this is a hereditary ability, which, however, according to our observations seems to be connected with temperature differences in the sea.

Turning our attention to the hydrographical conditions of the waters in which the Arctic cod lives and migrates, we find that the Barents Sea is a shallow part of the North Polar Sea, where in the north Arctic waters of temperatures below 0°C prevails, while in the south we find relatively warm water of Atlantic origin. As will be mentioned 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 6-7°C. A closer study of the behaviour of the cod on the spawning banks demonstrates the clear accordance 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 we find that the warmest water is located in the deepest layers. This water is of Atlantic origin and it is heavy due to its high salinity. On top we find 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 process. Here the temperature increases rapidly from 3 to 6°C (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 aggregates, large continuous shoals are formed in the intermediate layer, stretching out horizontally for sometimes several nautical miles. Here the shoals will remain until the spawning has been performed. 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 the annual variations in various qualities of the intermediate layer and the 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 the cod to occur in much thicker formations. 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 "fishcarrying" 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 the fishing activity.

While the cod is very particular about its spawning temperature, the temperature limits between which it may thrive and grow in the vegetative stage of its life is very much greater. Nevertheless the extreme conditions of the Barents Sea demonstrates very clearly the temperature dependence of the cod. The minimum temperature tolerated by the cod probably lies around minus 1°C. Occasionally profitable catches may be taken in temperatures below 0°C, but generally temperatures below 2°C seem to be unfavourable to the cod and seldom allow larger concentrations of fish. Such concentrations can, however, often be found in temperatures of 2-4°C 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 distribution 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.

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APPENDIX 9

A Statement on the Ecology of Tunas

by

William F. Royce

of the Pacific Fishery Investigations, Honolulu

The 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, flat fishes, salmon, and even the closely related mackerels, all of which inhabit the waters over or near the continental shelves.

Six groups of tuna species comprise the major tuna fisheries of the world. These are: (1) the blue fin tunas of the genus Thunnus, for which there are major (here defined as a recorded catch of more than 10,000 tons in any year since 1930) 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, which are caught in major quantities on both sides of the north Pacific and in the north-east Atlantic and more recently in the tropical Pacific; (5) the skipjack of the genus Katsuwonus, which are taken in the greatest quantities in the eastern and western Pacific; and lastly (6) the bonito of the genus Sarda, which are important in the Mediterranean and in the south-east 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 the biology. Intensive studies of their habits have only recently begun. Further, it has been found to be 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.

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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 the records of the occurrence of these tunas have come mostly from the coasts of the continents or the vicinity of islands. However, the explorations by Japan during the past 2 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 the previous records of the occurrence of these fishes, suggest that one or more of the species can be found almost anywhere in the Pacific between 40°N. and 40°S. 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°C., albacore from 14° to 32°C. and bluefin from 5° to 29°C., 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 3 to 10 kilos in 1 to 3 years, whereas the yellowfin reaches the common commercial sizes of 20 to 80 kilos in from 2 to 5 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 proven.

All of these species of tunas are voracious and eat a great variety of fish, cephalopods, and crustacea, some of which they apparently catch as deep as 100 fathoms. Quite surprisingly, even large tunas occasionally feed on tiny crustacea, 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. Turning to 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 the 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.

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libres de toute vie animale. Une pierre couverte de coraux vivants ou d'organismes divers ne peut servir à la fixation, les filaments du byssus ne pouvant plus s'y attacher. Or, au cours du temps, la mer rejette du sable dans le lagon. Progressivement, l'épaisseur et la surface du sable augmentent, la profondeur diminue. Les lagons peu profonds sont les premiers menacés. Dans le fond des autres, on ne trouve plus que des surfaces de sable entre des rochers de plus ou moins gros volume. Lorsque, sur une surface de sable s'est trouvée une coquille de bénitier ou un caillou (morceau de corail mort) il est rare de ne pas y trouver une huître perlière fixée. Le cyclone de 1906 qui a dévasté certaines îles, a jeté dans les fonds un grand nombre d'arbres arrachés au sol. Ces arbres ont constitué des supports, des collecteurs et se sont rapidement couverts d'huîtres perlières.

A l'heure actuelle, les huîtres sont surtout fixées sur les rochers non ensablés des fonds des lagons. Mais ces rochers se sont couverts progressivement de productions animales diverses et les espaces libres ne sont plus nombreux.

Les jeunes huîtres une fois fixées ont à affronter des ennemis multiples nouveaux: poissons, crustacés, mollusques, échinodermes, entre autres. De très nombreux sujets vont encore périr. Il en arrivera peu à l'état adulte. Pour un million d'oeufs rejetés, on peut dire que un à dix seulement perpétueront l'espèce. Il faut donc des huîtres mères en très grandes quantités pour assurer la pérennité de l'espèce en un endroit donné. Lorsque le stock de reproduction tombe au-dessous d'une certaine limite, on peut être assuré d'assister, à plus ou moins brève échéance, à l'extinction totale de la population. C'est là le facteur crucial de la prospérité d'un lagon. Il faut des dizaines de milliers de reproducteurs concentrés en un espace relativement restreint pour assurer la continuité de l'espèce.

La pêche excessive aboutit fatalement à réduire le stock d'une manière dangereuse. Les huîtres mâles et femelles qui ont échappé aux plongeurs se trouvent souvent fort éloignées les unes des autres, d'où difficulté de fécondation des oeufs.

Les larves dispersées par les courants se fixent un peu partout, même dans les endroits où les adultes vont végéter tout le reste de leur existence.

L'adulte résiste à des conditions sévères: chaleur excessive, lumière trop forte. Mais seuls les individus vivant dans des conditions très favorables donneront une progéniture viable; leurs oeufs seront bien constitués. La zone où ces conditions seront réalisées peut être considérée comme le "nid de l'espèce". Pour l'huître perlière d'Océanie, les grands fonds des lagons réunissent ces conditions.

APPENDIX 8

The Arctic Cod

by

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In February each year enormous shoals of spawning cod appear on the northern 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 we know that the Lofoten Fishery, although fluctuating, must have been of a permanent nature for more than a thousand years. And as it is of fundamental importance for Norway, this fishery 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 on 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 parts of the cod. But the main bulk of the shoals penetrate southwards to the great submarine valley in the continental shelf outside the Westfjord. Here they enter the Westfjord and congregate on the spawning banks inside 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 n.m. each year in order to deposit its pelagic eggs in one particular area on the Norwegian coast. We do not know why this enormous effort is demanded of the spawning cod. We can only assume that the migration to this locality is a necessary measure arranged by nature in order to ensure a successful propagation. Nor do we know much about how the fish is able to find its way to the spawning banks. We must assume that this is a hereditary ability, which, however, according to our observations seems to be connected with temperature differences in the sea.

Turning our attention to the hydrographical conditions of the waters in which the Arctic cod lives and migrates, we find that the Barents Sea is a shallow part of the North Polar Sea, where in the north Arctic waters of temperatures below 0°C prevails, while in the south we find relatively warm water of Atlantic origin. As will be mentioned 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 6-7°C. A closer study of the behaviour of the cod on the spawning banks demonstrates the clear accordance 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 we find that the warmest water is located in the deepest layers. This water is of Atlantic origin and it is heavy due to its high salinity. On top we find 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 process. Here the temperature increases rapidly from 3 to 6°C (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 aggregates, large continuous shoals are formed in the intermediate layer, stretching out horizontally for sometimes several nautical miles. Here the shoals will remain until the spawning has been performed. 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 the annual variations in various qualities of the intermediate layer and the 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 the cod to occur in much thicker formations. 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 "fishcarrying" 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 the fishing activity.

While the cod is very particular about its spawning temperature, the temperature limits between which it may thrive and grow in the vegetative stage of its life is very much greater. Nevertheless the extreme conditions of the Barents Sea demonstrates very clearly the temperature dependence of the cod. The minimum temperature tolerated by the cod probably lies around minus 1°C. Occasionally profitable catches may be taken in temperatures below 0°C, but generally temperatures below 2°C seem to be unfavourable to the cod and seldom allow larger concentrations of fish. Such concentrations can, however, often be found in temperatures of 2-4°C 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 distribution 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.

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APPENDIX 9

A Statement on the Ecology of Tunas

by

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The 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, flat fishes, salmon, and even the closely related mackerels, all of which inhabit the waters over or near the continental shelves.

Six groups of tuna species comprise the major tuna fisheries of the world. These are: (1) the blue fin tunas of the genus Thunnus, for which there are major (here defined as a recorded catch of more than 10,000 tons in any year since 1930) 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, which are caught in major quantities on both sides of the north Pacific and in the north-east Atlantic and more recently in the tropical Pacific; (5) the skipjack of the genus Katsuwonus, which are taken in the greatest quantities in the eastern and western Pacific; and lastly (6) the bonito of the genus Sarda, which are important in the Mediterranean and in the south-east 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 the biology. Intensive studies of their habits have only recently begun. Further, it has been found to be 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.

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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 the records of the occurrence of these tunas have come mostly from the coasts of the continents or the vicinity of islands. However, the explorations by Japan during the past 2 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 the previous records of the occurrence of these fishes, suggest that one or more of the species can be found almost anywhere in the Pacific between 40°N. and 40°S. 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°C., albacore from 14° to 32°C. and bluefin from 5° to 29°C., 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 3 to 10 kilos in 1 to 3 years, whereas the yellowfin reaches the common commercial sizes of 20 to 80 kilos in from 2 to 5 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 proven.

All of these species of tunas are voracious and eat a great variety of fish, cephalopods, and crustacea, some of which they apparently catch as deep as 100 fathoms. Quite surprisingly, even large tunas occasionally feed on tiny crustacea, 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. Turning to 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.

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