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R. M. Johnston Memorial Lecture

Science and Sea Fisheries with special reference to Australia

BY

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With 2 Plates and 3 Text Figures

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FOREWORD

One of my very worthy predecessors has indicated in his inimitable way the difficulties which face anyone honoured by election to deliver a lecture which has been instituted to bear memory to a great pioneer. There is to my mind always much difficulty in framing those lectures which are expected to do justice to a seat of office. The task is, however, immeasurably greater when a lecture is to serve as an offering in memory of a great man. The best I can do is to choose a subject close to my heart and I have selected one associated with the sea for I was first trained in a school of Marine Zoology at a University in a great seaport—that of Liverpool in England, and since I was by nature fond of the sea, my investigations have practically always been associated with marine problems. Whether the work was what some would call of pure scientific value or not, it has almost always been intimately connected with fishermen and fishery problems.

I make no apology, however, for selecting a subject associated with the sea and its products. The history of Hobart Town itself, its early pre-eminence in whaling and shipbuilding, is fortunately somewhat familiar to me. Is not this the obvious place for discoursing on sea products? But that is only to provide the background. The man whose memory we honour this evening was one of Tasmania's pioneers in the fishery problems. For several years he was a member of the fishery boards. He was the author of a number of papers on fishes. Moreover, if it were Johnston's hobbies—geology, zoology, and botany—which claimed the attention of his brother scientists, may I say that Biological Science to-day is becoming in many fields a statistical science, as you will see tonight. R. M. Johnston's life work was that carried out as the pioneer Government Statistician for Tasmania.

I render my homage gladly and humbly to his name. Australia has urgent need to-day of servants with such broad outlooks.

INTRODUCTION

I need not labour the point that Applied Science has changed the world completely in the last century. There are some who say for the worse. It is very difficult to see how that idea can be upheld if even a cursory observation of current economic problems is made. Any discoveries reducing the demands for labour in one field are, or should be, balanced by discoveries and inventions which have required more labour in other fields. The increased production in wheat and other foodstuffs cannot honestly be claimed to have resulted in over-production whilst thousands remain underfed. Again, the discoveries of medical science have removed altogether many horrors of life; and it would almost be ridiculous for me to try and tabulate the results of discoveries in, say, the field of electricity. Rather would I suggest that it is man's business organization that is at fault in these hours of trial, and especially his political systems. The world is almost controlled as if modern science had never existed, and by those who are still the products of an ancient educational system, ignorant of scientific method, although every day the effects of science lie plainly before our eyes.

In no branch of modern life has science played a more important part than in its relations with our food supplies. It has enabled the farmer to grow far more than two ears of corn where only one grew before and in addition has aided him in battling with drought and crop diseases. We have discovered the mechanism of heredity and the laws to be observed in breeding animals. We have learnt how to preserve our food, to convey it from one end of the earth to the other. We can make up the deficiencies in the soil by chemical products, so that there is food enough for richer plant growth, and we are still seeking better and better means of economically nourishing our live stock. The great science of Agriculture with its sister branches of knowledge is now represented in our universities and farm schools.

There is one great area of the earth's surface, however, where we reap without sowing, indeed in most places without knowing how best to reap, and whether we do it wisely or dangerously. That area is represented by the Sea.

There was a time when man neither cultivated crops nor worried overmuch about the extent of his hunting. But long before history left us anything in the way of records, the culture of plants and the domestication of animals had been practised. Before the dawn of modern science man had obtained much knowledge along these paths.

As concerns a similar investigation of the sea we are still only moving out of the primitive stages. We in Australia are particularly backward and in many respects scarcely out of an unusually primitive hunting stage.

It has been carelessly said that Australia has the greatest fishing coast in the world. In what way is this true? Taking the whole of our coast into consideration and estimating the area between it and the 200-fathom line, the result is 644,000 square miles. Of this probably 65 per cent. lies north of the latitude of Rockhampton, 23½° S. (in Queensland.) We are left with 145,385 square miles if we take the fishing area off the coasts of New South Wales, Victoria, Tasmania and South Australia. Now the trawling grounds alone of Europe are well over 680,000 square miles in area, that is to say, greater than our whole total, and these are all proved fishing areas. (The Mediterranean is completely left out in this calculation.)

As regards Australian production we have been told (Reports of the Australian Fisheries Commission, 1929) that the fishery of Victoria is confined almost solely to the bays and inlets along the coast and that these are now fished to capacity. Yet there is practically no deep water fishery off the East Victorian coast except what is carried on by a few Sydney trawlers. The fishery of South Australia again is chiefly in the St. Vincent's and Spencer's Gulfs and is equally the result of small scale fishing. The Great Bight remains more or less a *mare incognitum*. The Tasmanian fisheries are mainly those of the south-east, extending from Recherche Bay to Schouten Island, based on Hobart, and the other regions such as the west and north-east are said to be hindered by bad weather or lack of transport facilities. That excellently situated region of sea, the Bass Strait, is supposed to be relatively unproductive. Like most other areas the Tasmanian fisheries are also mainly served by hand lines and seine nets.

The fishing industry of Western Australia is as primitive as those of the States mentioned above and even more localized. Only in New South Wales has an effort been made to use the methods of large scale commercial fishing, but even here as much fish comes from the estuaries and other land-locked waters as from the ocean fisheries and the inshore fisheries employ about one thousand eight hundred persons directly as against say 200 on the deep sea trawlers.

Now the N.S.W. trawlers have only been at work 19 years, yet during the past five years the captains have complained of scarcity of fish and the voyages have increased from three or four days to seven or eight days. Are the complaints justified? If they are, can the matter be explained? Has over-fishing already resulted in depletion? I bring this last query into my introduction because the first stimulus for the application of science to Sea Fisheries may be traced to the origin of a similar fear of *depletion* in other parts of the world where catches appeared to be falling off. The initiation of a scientific study was not due to a desire to *increase* the yield of the sea beyond its previous fertility, but to explain diminutions and then, if possible, to bring the fertility back to that which was supposed to be the original state.

In Australia we are in the position that most of our fishing areas are still unknown and rest almost in the virgin state, crying for exploration. Yet, as if to emphasize the need from the outset for information along scientific lines, the only sea area which has been seriously worked already presents problems and alarums.

I do not intend to trace the history of the world's *great* fisheries here. It will be sufficient to note that the dawn of a new era came with the application of steam to fishing vessels and the tremendous development of trawling in the nineteenth century. Trawling as a well-defined mode of fishing in the North Sea expanded gradually during the years between 1800 and 1860 but it was after 1880 with the utilization of steam trawlers, that events moved faster, to culminate with the discovery and adoption of the otter trawl after 1895.

Of course biological discoveries of some importance in regard to fisheries were made before the comparatively recent dates I have given here, because there were zoologists interested in the sea and its life from the time of that great pioneer Aristotle. Indeed one of the outstanding scientific discoveries bearing upon fisheries was that of Professor G. O. Sars of the University of Christiania, who discovered in 1864 that the eggs of the cod fish, and other important food fishes floated in the surface waters of the sea after extrusion and fertilization, and underwent their development until hatching took place in these surface waters. Yet even now it is a popular belief on the part of fishermen that the sea fish lay their eggs on the sea bottom where they are destroyed by trawlers.

Complaints about over-fishing in the North Sea came to be potent about 1863 when the English Government appointed a commission to enquire 'whether or not the value of the fisheries was increasing, stationary, or decreasing; whether or not the existing methods of fishing caused permanent injury to the fishing grounds, and whether an extension of existing legislation was necessary.'

Allegations that trawls destroyed the eggs of sea fish and that depletion was occurring were again brought before an English commission in 1878. Between these dates, however, German scientists became more directly interested in sea-fisheries, and in 1870 the Royal Prussian Commission for the Scientific Investigation of the German Seas was established—the first definite organization of science in its application to sea fisheries. Other countries were close together in this evolution of interest in sea fisheries. Supposed depletion had just occasioned the appointment of a Fisheries Commission in the United States and a Report was issued in 1871 on the decrease of food fishes on the Coast and in the Lakes of U.S.A. This Report is particularly interesting for the consequences which led to the formation of the United States Bureau of Fisheries and the application of science on a larger and better organized scale than anywhere else.

The wave of inquiry seems almost to have been world-wide about 1865-1875, and even in 1870 it is said that Dutch herring boats were supplied with thermometers and notes relating to their use, because it had been discovered that more herring were caught at temperatures between 12° and 14° C. than under other conditions. The Russians, too, were making researches in the Baltic and the White Seas. The first British effort on a serious scale came with the Scottish Fishery Board's inquiry in regard to Herring towards the end of the 'seventies.

Fishery Boards in Scotland were years ahead of England in their activities. Scotland was not only collecting information as far back as 1850-1860 but was encouraging scientific investigations. (Natural History of Herring 1843-47 by Goodsir and Wilson. Herring Eggs, Dr. Walker 1803.) Huxley himself devised forms for the tabulation of fishery observations in 1856. All this was desultory, however, until the reconstituted Board of 1882 stated that 'without further information as to the habits and life history of the food fishes, it would be impossible to submit satisfactory Reports to Parliament, either as to the improvement or as to the regulation of Fisheries.'

England had no fisheries department at all until 1886 and its activities were scarcely worthy of note for many years. Scientific investigation was developed, however, sporadically by certain of the Fishery Committees which were responsible for the control of different parts of the English coast. It was practically dependent on the private interest of a few scientists of note, one or two semi-private biological stations, and the Marine Biological Station of Plymouth whose fine record of work from 1884 onwards is well worthy of mention. The English Marine Biological Association might be regarded as the official advisor to the Government during that period.

In the year 1899 the Swedish Government invited Government representatives from Great Britain, Germany, Denmark and other European countries to meet at Stockholm for the elaboration of a joint scheme of exploration of the seas in the interest of sea fisheries. Out of this arose the *Permanent Council for the Investigation of the Sea* which has instituted many researches into hydrography and marine biology and whose publications are of the greatest value. In these works the shading of so-called pure and applied science into each other is very evident.

Anyone interested must look elsewhere for the history of all these and other organizations. My purpose in this brief account is merely to suggest the atmosphere in which the need for inquiry arose. To a considerable extent this enveloped a demand from one section of fishermen for legislation against another; the conflict of those pursuing one kind of fishing against some method of fishing used by their brethren, which was supposed to be causing depletion. A unifying feeling if present in the fishing fraternity was due to a rooted objection to legislation of any kind on the grounds that it was wrong or useless to interfere. And boards of enquiry had often to admit that they knew little or nothing on which to base the laws.

In these ways, then, our history of Fishery Science commenced 64 years ago. It was a lucky chance that in those happy pre-war years I met at Kiel, and Heligoland, all the German commissioners, Hensen, Brandt, Reinke, Krümmel and Heincke, the members of the very first organized body for the development of fisheries science. Their work was well and truly aimed at the fundamentals.

Suppose, however, one glances through the whole mass of literature which has resulted from the development of the various bodies to which reference has been made—what is the general impression of the condition of Fisheries Science, of its aims and its achievements, of its methods and its requirements? How do we stand in Australia and what attitude should we take to this sort of research? It is to find the answers to these questions that I have set myself in this address.

The first impression made by much perusal of Government and other documents is that, considering the amount of research which has been conducted under the auspices of fishery commissions, a considerable amount of energy has been wasted on non-essential work. I must be careful about this criticism because no one realizes better than myself how exceedingly difficult it is to draw the line between pure and applied science. This was recognized at the very initiation of the United States Fish Commission when it was asserted that the life histories of the fish could not be complete without a thorough knowledge of their associates in the sea, especially of those which form the prey of, or which prey upon, the fish population. Unfortunately fishermen, pseudo-experts and politicians have all been far too ready to step in with criticism somewhat similar to that of mine above—albeit far more embracing, and with nothing to support it.

Fisheries science involves very adequate knowledge of many cognate sciences. To understand the phenomena of growth, migration and reproduction of any particular species of fish, necessitates the co-operation of biologists, physicists, chemists and hydrographers. It is quite easy to understand why the fisherman or the man in the street cannot see the necessity for investigating, say, the minute floating life (the plankton) of the sea so long as he is altogether ignorant of the elementary facts about such work. Yet, whilst impatient of general criticisms, and of the lack of understanding on the part of these people, I feel bound to stress the fact that *experiment* has lagged far too much behind *description* in zoology. Elaborate descriptive catalogues of starfish and medusae *may* at some time play a part in our control or understanding of the marine environment, but the enormous output of purely taxonomic zoology has overshadowed other work of fundamental importance. Fortunately there is a new spirit in zoological science amongst the younger school today.

Sea fishery does not at present bear any resemblance to Agriculture for it only represents the harvesting. And the first prime essential, which has been recognized by Governments everywhere—even by the Governments of Australian States—is that Fisheries must be conserved. That word '*con*served' I shall suggest means something a little different from the more frequent term '*pre*served'. I suggest that it implies that whilst fishing shall take place and full use be made of the natural produce of the sea, it should be regulated in such manner that the natural yield is at least upheld. If methods of increasing the yield can be discovered, so much the better.

And here I may suggest that the fishing industry above all others requires the attention of Government. It is most akin to agriculture but its claim for help is even greater, for the farmer may at least hope to own his land, and what he does with it does result in benefit, (or the converse), to himself, as well as perhaps to the country. But the sea fishermen have no claim either to the sea floors, or the surface waters. Force of circumstance in the past has driven the hardy fisher folk of the northern hemisphere to invent their own gear and even to explore remote icy seas to obtain their profits. But in a country like Australia (where there is no time for this century-long growing-up process, and the slow evolution of older populations), I can scarcely visualize a public company spending large sums on the exploration of new fishing grounds when they know that the results are going to be available to anyone else who likes to use them.

THE METHODS OF FISHERIES SCIENCE

Biometrical methods

As I have indicated above, the first step in the application of science to fisheries is the obtaining of knowledge of the fishery stock and something definite about its productivity. Starting off from this point we are at once faced with the following questions when taking stock of the fish production of the sea.

(1) Is there over-fishing?

(2) If over-fishing is taking place how can it be avoided?

Round about these two questions revolve many different branches of Fisheries science.

In order to answer the first question, methods must be devised to determine:—

(*a*) Some idea of the natural resources of the region of the sea under consideration and the proportion of the fish caught to the natural production in the same time.

(*b*) Whether *natural fluctuations* in yield occur quite apart from anything which may be due to human influence, and what may be the relative force of nature as compared with human interference.

(*c*) Whether definite reduction in the number in the sea of one type of fish—either species or size class—is really a bad feature.

(It has been said, for example, that overfishing of large sizes may result in more fish food and consequently faster growth and greater production on the part of the smaller sizes.)

The second question set out above involves firstly the problems of fish hatching and fish-rearing. Is it possible to perform such operations commercially and can over-fishing be balanced by such means? Another possibility of enrichment also exists by the transplantation of small fish from one area relatively rich in small fish but poor in food supplies to another area rich in the latter but removed from the breeding grounds of the species. These lines of investigation bring along in their train the following necessary studies:

(1) The acquirement of a full knowledge of the life histories of the species of commercial fish involved, from the egg stage to the adult, their feeding and breeding habits, and their migrations.

(2) A knowledge of the marine environment—its physical, chemical, and biological characteristics.

The difficulties of the biological problems are extremely great, however, and the fishermen and others interested must realize this at the outset and properly evaluate the work of the scientist—an attitude which is rare, except possibly in Japan and the United States. It has taken a very considerable expenditure to date to determine the exact habits of the Australian blowflies and the best methods of restricting them, yet unfortunately with little practical success so far as the latter object is concerned. Living things are not so easy to control or remodel as machines, or articles of wood and iron. And living things in the sea present the additional difficulty that usually they cannot be seen until caught. Their very capture involves difficulties and increased expense. The area of the earth involved in sea fisheries brings further trouble—fisheries are not usually tied down to a small district; and eggs spawned in one region may drift far and grow up in another quite distant place.

There is no doubt that the first step in the general investigation of a fishery involves the institution of methods for capturing fair samples of fish from the sea and the establishment of statistical methods for dealing with these samples. By the application of the correct methods, information can and should be obtained regarding (1) the number of fish of any particular species in a catch of definite duration—time and locality being accurately noted; (2) weight of fish; (3) lengths of fish for age determinations, also scale samples; (4) sex and degree of development (to be correlated with length, age, and season); (5) contents of alimentary canal.

Fishery statistics devised for operating on such information are, however, not by any means simple. Commercial statistics may, if taken honestly, supply some valuable information indicative of the fluctuations in the sea. For this purpose, however, information is necessary regarding the source of the captures (which very often trawling captains or owners refuse to divulge) *and the duration of the hauls*, so that eventually one can determine a most important figure—the catch per a unit of time—sometimes set out as the catch per day's absence, better and more definitely worked out as the catch per 100 hours fishing.

For example, in 1924 the catches of English trawlers worked out as follows for 100 hours of trawling:

In the North Sea 122 cwt.; in the English Channel 101 cwt.; South of Ireland 246 cwt.; but the Barents Sea gave 890 cwt. and Iceland 1027 cwt. New South Wales trawlers have never reached such high figures as are reported for the Barents Sea and Iceland, but occupy an intermediate position, with 430 cwt. in 1919, 443 cwt. in 1921, and 470 cwt. (probably the highest average reached) in 1922. Unfortunately the present figures which will be referred to later give yields which are only 290 cwts. or thereabouts.

A serious difficulty in addition to those raised above is that in any long period of yearly comparisons the catch per 100 hours may be invalidated owing to changes in types of fishing gear or methods of fishing. Yet it is these long series of statistics which are valuable. The statistics of the northern hemisphere which go back some years before the war are not altogether comparable with ease because the types of fishing gear have changed. This difficulty may be allowed for with care. For the greatest accuracy there is no possibility of working other than with special research vessels whose gear can be controlled for the special purposes in view, but this makes investigation costly and limited. There has been considerable difficulty in obtaining fishery statistics which can be utilized for the purposes indicated above and from which observers can deduce all that science has shown possible. It is obvious that the taking of length measurements may often necessitate scientists or trained observers working at sea on research or commercial vessels. The catches brought to market by commercial vessels do not even represent fair samples of the catch taken—all small fish having been thrown overboard.

At the Pan Pacific Conference held in Honolulu in August 1920 the Government of Australia (with Japan, New Zealand, Canada, U.S.A. and Hawaii) was recommended to collect systematic statistics of the fisheries and publish them annually. Nothing has been done and fourteen very important years have gone since then. At present we lack valuable fundamental information as a result of this for the Australian statistics indicate merely the amount and value of fish landed. And they do not even allow any attempt at discovering the catch per 100 hours fishing or the catch per day's absence from port.

Now let us see what biometrical work may accomplish. The statistics of the Plaice Fishery of the North Sea form probably one of the best examples the world can provide of the difficulties have demonstrated sufficiently well the accuracy and usefulness of scale readings.

Up to date, however, most of the scale reading methods have been used in the cooler temperate seas and whilst they are clearly applicable to fish of Tasmanian waters (I have had scales of

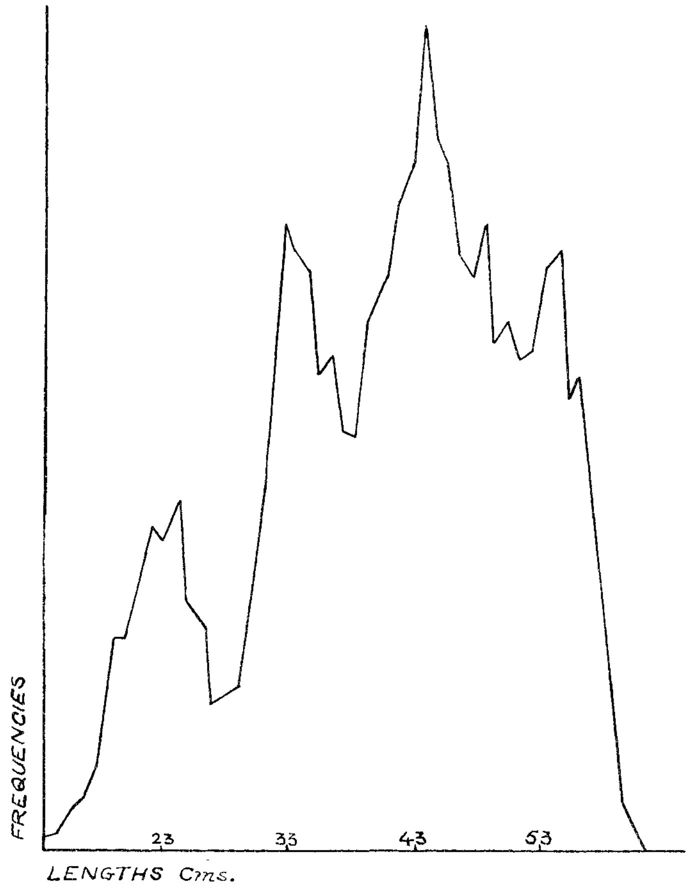


Fig. 1.—Curve depicting frequencies of Tiger Flathead of lengths between 14 and 62 cms. taken on three cruises during Sept.-Oct., 1931. (From data of A. Colefax).

Trumpeter and other species sent me by the late Mr. Clive Lord) and I have reason to believe are probably applicable to certain fish species of New South Wales waters, they may be altogether uncertain in our more tropical waters.

We can now return to our North Sea example of fishery statistics. The results of scale readings not only showed that the large post-war plaice were *old* fish, but that *the smaller sized fish did not correspond in age to pre-war fish of the same length. They were older.* In other words the post-war plaice were growing more slowly than the pre-war plaice.

The average lengths and ages for pre- and post-war plaice are given by Fr. Heincke and Ad. Buckmann as follows:—

Age Groups	I	II	III	IV	V	VI	VII
Average Length in Centimetres—							
1905-6	15	19	23	26	30	32	38
1922	14	16	19	22	25	29	32

An explanation of the above figures was offered as follows:[1]

As a result of the war-time cessation in fishing, large numbers of plaice increased in age and consequently in size. The result of this was a crowding of young fish on the bottom in certain areas with a resultant diminution in the rate of growth—possibly through reduction in the food supply available. We might regard the North Sea as having thus returned (more or less) to the original condition of virgin grounds.

The first result of the discoveries given above was that the German experts, and certain English workers, regarded the whole matter as an absolute proof of the need for restriction of fishing in the North Sea and evidence of the necessity for international regulation. Plans for such were put forward.

There were some, however, who interpreted the figures otherwise. The late Professor James Johnstone of Liverpool, for example, claimed that in the Irish Sea the variability in size and abundance of plaice during the years 1892-1920 was something that happened of itself—'Quite apart from the influence of the fishing fleets.' Throughout the period there was good evidence of a natural fluctuation in the abundance of plaice, some series of years being good, while others were relatively bad.

If this explanation were applied to the North Sea we should have to believe that the increase of plaice during the war years was *just* a coincidence and little or nothing more. Those who were most familiar with the North Sea did not accept the probability of such a coincidence.

The next step to be noted was a remarkable falling off in the plaice catches in the North Sea in the successive post war years 1920-23. The war-time accumulation of fish seemed to be removed in an amazingly short time. It could not be explained away simply

[1] See H. M. Kyle. 'Die Statistik der Seefischerei Nord-Europas' *Handbuch der Sec-Fischerei Norde-Europas.* Bd x. Heft. 4. 1928.

There is some evidence, therefore, that a diminution in the available stock of Tiger Flathead has taken place in N.S.W. waters. But not enough, judging from the possibilities outlined above, to make any assured statement possible. The fish may have migrated to new grounds. The falling off may also be the reduction which has been experienced everywhere the world over on working a new and virgin fishing ground. A new equilibrium may be set up which can remain more or less constant according to the influence of natural fluctuations.

There might on the other hand have been over-fishing. We know nothing of the fish stocks of the Australian continental shelf. As I pointed out three years ago the present New South Wales grounds only equal the area of the Irish Sea and we have removed from them in one year four times the quantity obtained from the Irish Sea in a similar time. Anyway, whilst it is now realized that natural fluctuations with rhythms often extending over periods of years are characteristic of fish stocks, and are of fundamental importance in any application of science, so is it realized that the old conceptions of an infinite fecundity of the sea are out of date. The situation discovered in our waters is important enough to indicate that statistical work is very necessary, and that it should be combined with any exploration work that may be carried out on new grounds.

Very much to be desired are more biological studies which will give us information regarding the life history and migrations of the Tiger Flathead, its breeding habits and its rate of growth. All this work involves either the use of a research vessel, or the employment of suitable workers on commercial trawlers, combined with the offer by the latter of details of their catches, which are not at present available. It should be easy by tactful agreement for the latter to be made possible especially since there should be no reason why any information obtained during this work, should be divulged or made public in any way until a year had elapsed. But the Tiger Flathead is only one example of the need for more information regarding our commercially valuable fish.

Let us now return to another aspect of our fishery research which is intimately connected with that we have just touched upon. You have seen from Text fig. 1 that some attempt has been made to apply the system of age determination by length measurements to a New South Wales fish (the Tiger Flathead).

This work was carried out by my colleague Mr. A. N. Colefax, B.Sc. (see Linn. Soc. N.S.W. Vol. 59, 1934) in connexion with a study of our most important trawled fish. A considerable amount of information was gained but unfortunately there has been no possible way of following it all up. The data provides the nucleus for future investigation. Means will have to be provided for capturing the smaller flathead. The life history of the fish between the egg and the smallest stage captured will have to be followed

The significance of the ability to recognize the age groups of fish is brought home by discoveries which may be said to rank amongst some of the most important of fishery science up to date. Both in America and Europe where elaborate statistical investigations have been carried out, it has been found that the natural fluctuations which are now recognized as highly characteristic of the fish stocks of the sea, are bound up with variations in the number of fish present belonging to some particular year group or another. For example, the application of the methods we have described has shown that in the great herring catches of any particularly good year the bulk of the fish caught belonged to a definite year group, i.e. they were all hatched years before in what was either a singularly good reproductive year or one from which an unusual number of fish had survived and developed.

Such a prevalent age group may indeed form the bulk of the valuable herring in the shoals of several successive years (see Text fig. 2). Thus the success of any particular year's herring fisheries may be entirely due to the attainment of maturity of some long antecedent very successful year of reproduction. The discovery of these facts is having two consequences.

(1) It is making it possible to forecast successful fisheries a year or even more beforehand by following the gradual growth and the attainment of commercial size of some successful year class. This forecast may eventually include the date a profitable fishing might be expected to commence, the expected quality of the catches and the estimated yield. It is the *uncertainty* and *variation* in yield in pelagic fishing which is usually most serious to both fishermen and merchants. Removal of a little of this uncertainty would be of the highest value.

(2) It has shown that one of the most important causes of fluctuation in any fish stock is due to causes which operated years before when a breeding season was a success or a failure. It has thus given us a clue to a new line of investigation.

Possibly (nay probably) the causes which determine the success of the breeding season of a species of marine fish may be always beyond our control. At present. however, we do not know what they are and it is certainly worth-while trying to find out. The most favoured assumption is that the environmental conditions prevailing during the period that the eggs are hatching out and during the immediately following weeks are of paramount importance. There is little doubt that this is one of the most hazardous periods in the life history of a marine fish and if the planktonic conditions at the time the young larva is hatched are unfavourable for it, there may be no food suitable for these delicate stages.

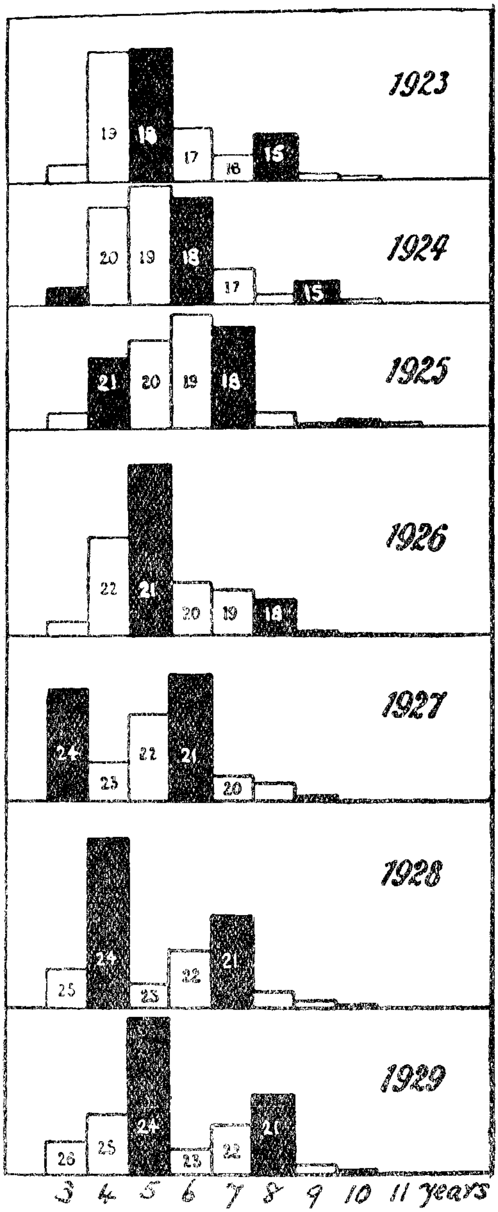


Fig. 2.—The fluctuations in the composition and abundance of herring in the East Anglian fishery from 1923 to 1929.

The figures at the bottom indicate the age of the fish in each year group. The height of the columns indicates the abundance in the catches of the particular year group, and the figure on the columns indicates year of hatching. "Black" columns represent successful year groups. (From W. G. Hodgson).

Studies of Life Histories

At the present moment we know next to nothing about the eggs or the larval stages of our Australian marine fish. There is a gap in our knowledge that must be filled up and here let me describe some of our own work in following life histories which has in its small way resulted already in a considerable success during the past few years.

The eggs of most marine fish of commercial importance are pelagic, that is to say they float in the sea. Herring eggs are exceptional, being laid on the bottom on various objects (and of course the reproductive habits of sharks and rays, fishes which sometimes come also within the purview of commercial significance, are very different from the more important teleost fishes.) In order to recognize for the first time the species of the tiny floating eggs of teleost fishes, two methods are available.

A particular fish species may be kept in numbers in ponds attached to a fish hatchery and the eggs, after extrusion from the mature females (and subsequent fertilization) may be scooped up from the water in fine silk nets, placed in hatching boxes and the development gradually followed. In this way there is no doubt at the outset that the eggs belong to the species of fish which we have in the pond. The egg may be examined and the features referred to below noted. If hatching and culture for a time are successful, the different stages from the egg until the definite adult form is reached, may all be examined and illustrated. It should then be possible on future occasions to recognize these eggs or larvae when caught at sea.

A variation of this method is to take the mature fish from a pond or aquarium tank and actually squeeze out the ripe eggs from the female and the ripe sperm from the male and conduct the fertilization in glass vessels. The whole sequence of stages can then be followed as before. This method can be easily adapted for use on board commercial fishing craft and the following simple device was invented and used successfully by us on N.S.W. trawlers. It consists of a small cylinder of celluloid with windows, these windows and the ends are covered with bolting silk. Eggs taken from mature fish captured by the trawler are introduced into the cylinder, the silk replaced and the whole thing immersed in a large bucket or other tank of sea-water which is conveniently changed or kept refilled as required. The motion of the ship keeps the submerged but floating cage, with its eggs, in constant movement, and at least the egg stages and possibly early larvae can be obtained in this way.

The main difficulty about the above methods is the obtaining of mature fish or of keeping members of both sexes until mature. Still, this is frequently accomplished, for it is the practical method of such marine fish hatcheries as are in existence.

The second method applies to the fish eggs which are captured floating in the sea water and which are taken in plankton nets sometimes in abundance, sometimes in isolated numbers.

Hints as to the possible family of fish to which the eggs belong may be obtained by reference to the known fish eggs of other parts of the world. For example, it is common in the herring group (note that although the herring lays its eggs on the sea bottom, its near relatives the sprats, pilchards, &c. have typical floating eggs), for the egg yolk to be divided up into segments. The eggs of the anchovy are oval (the yolk is also segmented here.)

Now if the planktonic fishery for eggs and larvae is continued on successive days for a period, there is a fair chance that successive stages in the life history may be captured. The following example will illustrate the method. During the months of June, July, and

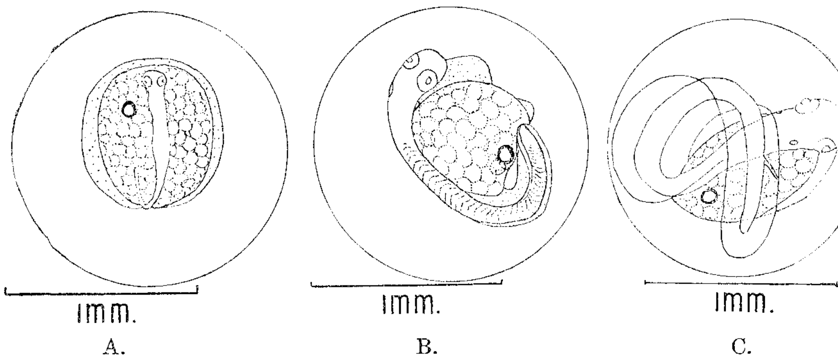


Fig. 3.—Egg of *Sardinia neopilchardus*, Steindachner, diameter 1·4 mm.
A—Early stage of development. B—Later stage of development. C—Ready for hatching. (From Dakin and Colefax.)
[Block lent by courtesy of The Trustees of the Australian Museum.]

August of the three years 1931, 1932, and 1933, numerous eggs were captured off Sydney which were characterized by a wide perivitelline space and a segmented yolk (Text fig. 3). The general resemblance suggested that the egg belonged to a member of the herring group (Clupeidae). But no less than six different species having eggs of this type were found by Delsman off Batavia. It was necessary, therefore, to have further evidence before closer identification could be made. In successive catches in each year eggs had been obtained at different stages of development and we had also taken newly hatched larvae. In 1933 partly as a result of a special effort to settle this particular question, a more concentrated search was conducted for the later and later larvae and as a result we were successful in getting stage after stage which we could link together until finally the size of 28 mm. was reached.

It was not until we had this size that we could be absolutely certain that we were dealing with the Australian pilchard (*Sardinia neopilchardus* Steindachner) but at this size the dorsal and other fins, the general form, the number of vertebrae, left no doubt of the identification. This meant, of course, that for all time we could recognize the eggs or any other early stage of this species if met with in our nets. It also meant the recognition of the breeding season and breeding grounds of the Australian pilchard, at least off the New South Wales Coast, and judging from the number of eggs present in the net, it suggested that the pilchard adults were present in large numbers. Up to the present, however, there has been practically no pelagic fishery around the Australian Coast. The herring family which probably provides the greatest sea wealth in the form of fish, remains almost untouched in Australian waters. California in 1929 took 857,000,000 lbs. of fish from the sea and of this 652,000,000 lbs. were sardines to be used for canning or for reduction purposes (oil and fish meal). The total Australian landings of fish for 1931 were only *62,969,760 lbs.* It is easy to see, therefore, why the exploration of our seas in regard to pelagic fishes is a very desirable experiment.

The search for fish eggs at sea is only part of what is known as Plankton Research. I shall return to other sides of this investigation later.

There is not very much available for purposes of comparison or recognition in fish eggs but, as Ehrenbaum points out, the size, the presence of oil globules, the character of the yolk, the shape, the perivitelline space, the colour, are all features which can be noted. In this respect preservation causes changes all round. It would be advisable to measure considerable numbers of fresh eggs of any particular type in order to determine the range of variability. In respect of the larvae—the shape, the number of the fin rays in particular, and also the number of vertebrae, are important. In addition, the colour, pigmentation, and size, should be noted.

Plankton Studies and the Life History of the Australian Peneid Prawns

There is another life history study in which our plankton work has played a part; it is published for the first time here. On various warmer parts of the Australian coast there is a valuable industry in the fishery for prawns. In New South Wales waters it has averaged about £38,000 during the last ten years. The year 1931 was, however, a peak year. The value reached £76,871 and the quantity obtained was 1,537,420 lbs. This yield is much more startling when it is realized that all this crustacean material came from river estuaries or lagoon-like lakes of relatively little depth which are open to the sea by very narrow and shallow channels (Lake Illawarra and Tuggerah Lakes) and this is in addition to heavy fish yields from the same waters. The prawn fishery is not so important in Victoria, the annual catch being probably little more than 10,000 lbs. from the Lakes of Gippsland. Prawns of the same family are found in the Swan River at Perth but the fishery is only worth about £1200 annually. The Report of the Chief Inspector of Fisheries for Queensland for 1932-33 merely mentions prawns as scarce on the Brisbane market. They should be abundant, however, on the Queensland coast.

Now these commercial prawns of Perth, Gippsland Lakes, Queensland, and above all, of New South Wales waters belong to a Crustacean group—the Peneidae—members of which differ markedly in their mode of reproduction from those of all other groups of the Crustacean order Decapoda. It should be noted in passing that the commercial prawns and shrimps of England and Northern Europe which look superficially very similar to ours, belong to an entirely different group. The Peneid prawns are characteristic of warmer seas. They are elsewhere of commercial importance in Mediterranean countries, in the Southern United States, India, Malaya, and Japan.

Our best known species in New South Wales waters are the King prawn, *(Peneus plebejus)*, and the School prawn *(Penaeopsis macleayi)*. The former is known from Queensland down to the South Coast of New South Wales and occurs again in Western Australia. The school prawn is also known over the whole coast of New South Wales. A third species *(Penaeopsis monoceros)*, less well known on the Eastern Coast of Australia is common again in the Swan River at Perth and has a very wide range being one of the commonest of the Indian prawns and even turning up at Japan and the Philippines.

It is characteristic of our Australian crayfishes and crabs as well as of the shrimps and prawns, lobsters and crabs of Great Britain that the females carry the extruded and fertilized eggs under the abdomen until they hatch out as highly developed larvae. The Peneid life history is very different. The females shed their tiny eggs from the ovaries direct into the sea where they float during their short development until a primitive larval form—the *nauplius*—hatches out. Although this has been known to zoologists for many years it seems to have been singularly unfamiliar even to fishery experts of the countries where Peneid prawns are of commercial importance. In fact little or nothing has been said in their reports about the habits of these prawns notwithstanding the puzzle of their origin.

In New South Wales the problem of the life history of the common prawns aroused my curiosity at once—partly because I had been fortunate enough to catch the eggs and early larval stages of one species in the Swan River, W.A. many years ago. But the stimulus was great enough without this, because to many hundreds of fishermen the prawn was something of a mystery. This was the case at Lake Illawarra (and the same applied to Tuggerah

Lake and Port Jackson harbour with the Parramatta River entering it). During the winter few or no prawns can be taken with nets, and those captured are usually small. There comes a time during the spring when the king prawns become catchable in the Lakes and generally they are first taken at that end of the lake farthest away from the sea and are rather small. During the early summer larger specimens are captured, and then amazing 'outflows' or 'migrations' to the sea take place on dark nights. I have seen two or three of these 'runs' take place. Visitors at the lake entrance, young and old, take hurricane lamps or electric torches, kerosene tins, buckets and hand nets. They flock down to the entrance which connects the lake with the sea, where at low water you can stand with the outstreaming current only up to the knees. Soon there is a semicircle of closely packed people with their lights. It is now, shall we say 7.30 p.m. The water running out to sea is dark blue and clear under the lamps. There are no signs of life except for an occasional crab. The crowd waits. Suddenly someone near the lake cries out 'here they come,' and as suddenly as that, the prawns arrive. Swimming actively, the big prawns come like an army and are rapidly caught as they try to pass by until the buckets are half full and the hunters drift away homeward one by one. Fishermen with nets are at work in the lake itself. A set net at the entrance—naturally not allowed—would make an amazing capture. The moon is quite sufficient to stop the migration which ceases for a number of days at full moon unless the nights are very cloudy.

Every year this story is repeated and millions of large king prawns have been observed leaving the lakes for the sea. But no one ever saw the prawns entering the lakes or estuaries, and since the fishermen looked for eggs on the abdomen as indicative of breeding females they never found any of the latter. Knowing the life history and reproductive habits we naturally adopted the method of dissecting the large females to determine the state of maturity—but curiously enough in most cases there were only mere traces of reproductive organs. Only two theories could be put forward to explain the situation.

(1) The king prawns bred in the lakes and estuaries—this would easily explain the constant supply always moving out to sea and never coming in. But why then did the large prawns go out to sea in such definite masses? And why did one never find a really mature prawn in the lakes? Did they hide away in this condition? One would have to assume too, that the big prawns caught leaving the lake had just spawned in order to account for their small gonads.

(2) The other theory was that the king prawns bred in the ocean and never in the lakes or estuaries and that the lake supplies, enormous as they were, resulted from an early inshore migration of the young at such a small stage that they were never seen by the fishermen. On this theory the lakes would be regarded as specially favourable growing grounds where the prawns gradually increased

in size on the rich food supplies. Finally having attained large size they would leave for the sea in regular armies for their first breeding season. Our largest prawns caught in the lakes and estuaries were, according to this theory, still immature.

We set ourselves to prove one or other of these theories. Prawns were obtained from all the estuaries of New South Wales and at all seasons of the year and dissected for examination of the reproductive organs. And always (with the exception of one species to be referred to later) the reproductive organs were undeveloped. Only when we obtained a few outsized king prawns from near the entrance of Port Jackson in late summer did we find the gonads well developed. But *always* when we obtained large king prawns from the ocean (captured by trawling) the gonads were well developed (see Plate II).

At this stage in our investigation the plankton catches came to the rescue. From the beginning of March the characteristic eggs of the Peneid prawns with the developing nauplius larvae were taken out at sea in our plankton nets. Later on the young stages were also captured. And the converse is true, no eggs of the king prawns were ever taken in inshore waters. I think the life history of the school prawns is exactly the same. The breeding season of the king prawns in the ocean probably extends over at least six months for we have found king prawns at sea developing maturity as late as September.

During the later months of the year in late spring and summer the young of the prawns must stream into the estuaries and lakes, soon to take up their normal habits and grow up.

And now we come to the further surprise. The sizes of the prawns captured by us both at Lake Illawarra and elsewhere, leads indubitably to the conclusion that, with the exception of the very large ones, they are all less than a year old. The largest prawns leaving Lake Illawarra in the summer (size 18 cms.) are not less than 13 months old and no older than 18 months. Our work indicates that the king prawn breeds at about the age of 18 months and the females are then about 21 cms. in size or even more. The rapid growth and attainment of the breeding season in such a short period is not common in commercial marine products. What happens to the prawns in the sea is a very interesting question about which we know absolutely nothing. No studies on the complete life history of Peneid prawns had been made anywhere in the world until recently when the United States Bureau of Fisheries took the matter up. In a recent paper it is stated that probably their prawns never breed again after their first season. If this is the case with our Australian species it will be realised that once again pure science has information of very considerable importance in regard to the proper regulation of a valuable fishery.

I mentioned that there was one exception to the above life history. It is possible to find the adults of *Penaeopsis monoceros* with mature reproductive organs in the inshore waters and once I found their eggs floating in the Swan River at Perth. This species breeds during the late summer months. Curiously enough they have been regarded as school prawns by most of the New South Wales prawn fishers—but school prawns which were not quite as they ought to be. In some districts they are called Greasy Backs.

The Hatching and Rearing of Marine Fish

In my introduction I pointed out that one possible way of increasing the stock of marine fish was by 'artificial' hatching—the rearing of eggs and younger stages in fish hatcheries. Is this feasible and with what possibility of success?

It is difficult to say when the first efforts in fish culture were carried out. The Romans were probably preceded by the Chinese in this respect—the fish being fresh-water fish. So far as we know, however, the eggs were laid by the fish and carefully collected by the 'nurserymen'.

In the fifteenth century (1420) a certain Dom Pinchon cultivated trout at the abbey of Reome near Montbard in France. In 1758 Lieutenant Jacobi of Hoenhausen wrote a manuscript describing how he squeezed the eggs from ripe females and the milt from the males and fertilized the eggs. Artificial fecundation was being practised by the Swiss with trout in 1772 although the function of spermatozoa was not even known at this time. Then this artificial fecundation seems to have been forgotten until it was re-discovered by a simple fisherman, Remy, of Bresse (Vosges). Remy's methods became known to the scientific world through Professor de Quatrefages in 1849. From this time on a great development of fish hatching took place, particularly in France and Germany. When the United States Fisheries Commission was instituted the possibility of counteracting depletion by hatching and rearing was visualized at the outset and such was the vigour with which this side of fisheries technology was pursued, that already in 1872 the United States had gone further almost than anyone else. Since then the United States has led the world in this matter and if one wishes to follow up the types of technique involved, reference should be made to the publications of the United States Bureau of Fisheries. There is, however, an important side of this question for our consideration. The success of fish hatching is certain in so far as it concerns fresh water fish like the carp and its relatives, the trout, the salmon and others. It is quite another matter when one regards the vast fisheries of the sea. The eggs of the trout are about as large as peas—there is an abundance of yolk, the young larvae are hardy and their early life is spent in circumscribed areas which can easily be imitated or found in other places.

One of the most dramatic successes in fish hatching was that of the introduction of the Shad from the Atlantic Coast of the United States (its natural home) to the Pacific Ocean, and its spread and development in the waters of Canada as well as California. This, a fish of the herring family, is also a fish of the anadromous type, i.e. it spends some time in the sea but, like the salmon, leaves it and ascends rivers, to spawn in fresh water. Right at the very beginning of the American Government's attention to fishery investigation, i.e. in 1871, a consignment of shad fry was conveyed from the Atlantic coast (Hudson River) to the Sacramento River, California. This was repeated in 1873 and other years. Adult fish began to turn up within a few years and by 1876 they were getting common in the river where they had been set free. By 1895 the shad fishery of California was of extreme importance to the State and the fish had spread north to the rivers of the Canadian Coast. The species constituted the sixth largest fishery of Northern California in 1928.

This example shows what may be done in the way of introducing a fish to a new area, but it is scarcely a testimonial to the hatching of eggs of typical marine fishes. The spread of the shad in the Pacific may have been due to the occurrence of particularly favourable conditions there. Up to date even the artificial hatching of shad in the Pacific coast rivers has not been able to increase the yield sufficiently to balance human depredation or natural fluctuation.

There is singularly little evidence, then, of success in marine fish hatching. No practical results so far as I know can be put up to support the United States hatcheries for cod, although it must be noted that these are regularly continued; nothing that would be accounted beyond criticism has been put forward to support the British or Norwegian sea-fish hatcheries.

Fifty-eight years ago the United States Fisheries Commissioner said: 'Here the fish culturalist comes in with the proposition "that it is cheaper to make fish so plenty by artificial means, that every fisherman may take all he can catch, than to enforce a code of protection laws." The Salmon rivers of the Pacific slope, and the Shad rivers of the East and the Whitefish fisheries of the lakes are now so thoroughly under control by the fish culturalist that it is doubtful if anyone will venture to contradict his assertion. The question now is whether he can extend his domain to other species'.

That this was an optimistic view is evident from the fact that eight years ago the Assistant in charge of Scientific Enquiry of the United States Fish Commission said that despite 55 years of artificial propagation, the Pacific salmon fishery had declined alarmingly the shad fisheries had declined by 74 per cent. from 1896 to 1923 and the whitefish fisheries, despite an annual distribution of 409,000,000 eggs and fry, had declined in yield from first place in 1880 to fourth place in 1922. Probably in these cases, all being fish with eggs hatching in fresh waters, the results would have been worse without the aid of the culturalist.

So far as sea-fish culture is concerned the summing up by Knut Dahl in 1909 may still be said to hold good. The majority of fresh-water fish possess relatively large and hardy eggs which are hatched resting on the bottom or glued to objects on the bottom. The period of incubation is long. The young when hatched are active, well developed, and hardy creatures. They can easily be reared, can be kept in thousands in a limited space, and fed and reared at no great cost. On the other hand the areas of the sea are so extensive that hatching operations on a tremendous scale would be necessary in order to 'be capable of influencing the enormous quantities of drifting fry which the open waters (of Northern Europe)[1] have been proved to contain.'

The pelagic eggs of marine fish contrast strikingly with those just referred to. They are small and delicate, the period of incubation in our waters may be only a day or two. And all the hatcheries can do when the young are hatched is to 'hurry these larvae into the sea where for many weeks they lead a pelagic life suspended in the waters and subject to their movements'.

I should like, however, to suggest that the last word has not been said in the matter of sea-fish hatching and I would illustrate my point by reference to a case which is almost unknown in the northern hemisphere and which has lately come under my notice in quite a new aspect.

A few months ago I visited the Pacific island of Nauru, (Australian mandated territory). The island is an old coral islet which has been raised so that its highest point is about 200 feet above sea level. In the centre is what is called the lagoon, probably a remnant of an original lagoon, but now a swampy lake cut off from the sea by high ground and very unlike the typical lagoons of coral atolls. At the time of my visit there had been little or no rain for some months. Notwithstanding this, the salinity of the water of the lagoon (which was partially dried up) was only 9 per thousand. The lagoon area is divided up into little ponds and these are crowded with a species of fish, *Chanos chanos* (known to the natives as *Ibya*). The average length of the specimens I saw caught was about 15-18 inches but they grow much larger. These fish are cultivated fish and the lagoon ponds remind one of carp ponds in Europe—highly productive areas of water.

Now the story of the Ibya fishery of Nauru is a surprising one. At a certain time of the year the natives of the lagoon district go down to the ocean coral reefs and look in the rock pools for tiny fish larvae. According to their description these little fish are only about a quarter of an inch in length and extremely difficult to see. They are fished out with a shallow strainer and placed in very ordinary receptacles in the native huts. Apparently the water is changed at intervals but the whole business is most primitive and I should

[1] The same thing will apply in other wide and unrestricted seas.

scarcely imagine that the natives understand much of what they are doing. It is almost an instinct with them. The procedure is something which has been handed down from generation to generation and probably has continued for hundreds of years on the island.

The tiny fish grow rapidly and after a few weeks when they have reached the size of about 2 cm. they are transferred to an outside pond of small size. They do not receive much further attention and gradually grow up. Two months later they are transferred to the big fish ponds of the lagoon where they gradually reach adult size and are ready when required.

Now there are several remarkable things about this business. In the first place the natives collect the larvae of a marine fish at a stage which, in sea fish hatcheries with other fish species, is set free as too difficult to handle further. In the second place, at this difficult stage they change the fish over from sea water to lagoon water which has a very different salinity and constitution. This of itself is a matter which interests me keenly because the osmotic pressure conditions existing between aquatic animals and their environments have been the subject of my researches extending over twenty years.

But let us follow this matter further. The fish (which incidentally the Europeans on Nauru have regarded as something peculiarly Nauruan) is the so-called Milk Fish, *Chanos chanos* (Forskal), (sometimes called the salmon herring), a sea fish related to the herring and of very wide distribution, ranging indeed from the Red Sea where first recorded, the Indian Ocean (on all coasts), to the Pacific Ocean (noted from the East Indies, Samoa, Society Islands, and as far south indeed as New Zealand and Australia). It often enters the fresh waters of rivers and lakes *although it only spawns in the sea.* It is an ocean fish which approaches land at the breeding season and spawns in shallow bays or on coral reef flats.

A specially interesting feature, however, is that this fish above all others is first in commercial importance in the Philippines where the people have from time immemorial cultivated it and now understand many details of the process.[1]

Actually the culture of the fish is highly characteristic of the Indo-Pacific, and is very ancient in origin. Ponds are made and used in the Hawaiian Islands, in Java, Singapore, Madura, and Formosa. But only in Nauru (and possibly at the Gilbert Islands), so far as I am aware, are the larvae cultivated in brackish water.

According to Delsman the eggs of *Chanos chanos,* (called the *Bandeng* in Java), are pelagic. The breeding fish may reach three feet or more in length and the roe contain over 5,000,000 eggs. But

[1] This, by the way, may be of great ethnological importance for it is scarcely likely that the Nauruans have discovered the culture process themselves. I should suggest that it might be evidence of the origin of the Nauruan peoples and might provide evidence that they came from Asia by the Northerly route bringing their habits with them. The early Nauruans probably recognized the fish larvae on the reef shores, having been accustomed elsewhere to looking for them.

the fish never breeds in the culture ponds. There are two spawning seasons in the year and the larvae are scooped up by men, women, and children from floating entanglements of rope set up along the shores.

No attempt seems to have been made at the Philippines (or Java) to remove the eggs from the adult fish, only the young fry are captured in the water, and this itself is a great industry for they are caught and shipped away to the fish cultivators all over Manilla. They are usually about 10 mm. long when captured and quite transparent.

At the Philippines these larvae, in numbers from 1,500 to 2,000 are placed in a 15-litre jar for transport and handled carefully. The jars are kept filled with clean sea-water. The fish larvae are first placed in a nursery pond and apparently after about two or three weeks they should be 3·0 to 3·5 cm. in length, and are then removed to the ordinary ponds. In the Philippines the larvae feed upon a blue-green algal mat (containing other microscopic plants and animals) which develops at the bottom of the pond, but I shall have to omit many of the interesting details which are known of this fish culture in the places where it is carried out.

What I want to point out is that the processes which are now organized on a big scale in the Philippines originated centuries ago as the result of someone's keen observation and experiment. This particular fish species probably lends itself to the almost domestic treatment it receives. But please note—the original Nauruans, probably trying to imitate what they or their fathers had done elsewhere before, appear to have presented it with difficulties in the nature of the salinity of the water, which are equally well surmounted by the fish. One thing is certain and that is that all the stages are able to find suitable food in plenty. One wonders whether this is not the crux of most, if not all, of the problems which have arisen in fish hatching and fish culture. Another important fact (whether dependent on the one just mentioned or not remains unknown) is the ability of the young fish to thrive in limited confining areas.

I have described this Ibya culture of Nauru because I feel that the *culture* of certain fish as well as of other marine organisms of commercial value may have to play a much more important part in the future than it has in the past. There is no branch of marine biology, however, which is more elusive—it requires patience and will probably need the full resources of the biologist and the chemist. Research of this kind should fully satisfy the pure scientist, whilst appealing equally strongly to the applied scientist. I see no reason why pearl oysters and other molluscs should not be cultivated on the northern coasts of Australia—but we know by now that rule of thumb trials can only result in waste of money—possibly biological research on an attenuated scale is not likely to be a bit better. There is of course another view, that the future will see artificial factory products supplanting the natural, (being more cheaply produced and more easily controlled) and the story of the chemists' aniline dyes destroying the indigo industry will be repeated in the waters as in other fields. But biological science is still too far behind its sisters to say what the future has in store in its bearings on the economic production of commercially valuable living things. I have no doubt that wherever and whenever the call comes for Science to aid in this production, methods will be invented that will overcome the difficulties so far experienced.

The General Study of the Plankton

I have already indicated the importance of plankton studies in fisheries research in referring to the capture and study of fish eggs, and prawn larvae and probably in the future our plankton work at Sydney will be chiefly concerned with a search for the eggs and early stages of fish. Our first investigation, however, has naturally been a more general study of the plankton of the New South Wales coastal waters. This work has been continued over four years, and whilst in comparison with the long continued plankton researches at places in the northern hemisphere the time has been short, yet it is the first continuous investigation in the open sea of this part of the world. From the purely systematic point of view one could go on for many years making collections of plankton with varying gear and possibly getting new species—certainly new records geographically. No doubt, too, there is much physiological research of a purely scientific nature to be conducted on planktonic organisms. What interested us, however, was firstly the question whether there existed in our seas any planktonic rhythm (rhythm in production) comparable to that so much discussed in the northern hemisphere, and secondly what the degree of plankton production was in our waters. The first two years of work sufficed to show us that just as in the northern temperate regions there was a very definite rhythm in productivity with two clearly marked seasons of vigorous reproduction—the early spring and the late summer or autumn—and this was the first demonstration of such a rhythm in the *southern* hemisphere.

Now the explanation of the causes which determine the appearance of the microscopic plants and other organisms in the sea at their appointed times, their development of seasons of reproductive energy, and their disappearance or at least their reduction to smaller numbers, has not by any means been found. I have no doubt further light will be thrown on this fundamental problem of the seasons by researches in different parts of the world at different latitudes and in different environments. There is still dispute, however, as to the comparative annual productivity of the seas in plankton at different latitudes, and since this has a very decided relation to the production of the seas in fish it certainly deserves our consideration.

One of the results of that first great plankton expedition—the Kiel Expedition of the Humboldt Stiftung—was the discovery that the catches were very many times greater in the colder northern seas than in the equatorial Atlantic waters. No doubt this was correlated with the well known northern sea fisheries of Newfoundland, the White Sea, and Iceland, and all seemed to strengthen the belief that for some reason the colder seas were more productive than tropical waters despite the converse on land (assuming that climatic conditions are at their best). A theory was indeed put forward very early by Brandt in explanation. It was based on the assumption that nitrates were the mineral substance in the sea determining its ultimate possibility in plant production, and that these were less concentrated in tropical waters owing to the action of denitrifying bacteria. Possibly there may still be room for some doubt in regard to the differential fertility of tropical seas and temperate seas respectively. There is no question, however, that during the summer months in the Antarctic seas there are enormous developments of planktonic plant-life, and that in temperate waters there are outbursts of great productivity in the springtime.

We have never obtained plankton catches off the New South Wales coast at Sydney as rich as those I used to get in the Irish Sea, and I have no doubt whatever that judged by the actual catches the average number or quantity of organisms in a litre of sea water of the Pacific off Sydney is decidedly less than that to be found in the Irish Sea. This cannot be a simple matter of latitude in its bearing on light or temperature, for there are many seawater lagoons of very great area (Lake Illawarra—80 square miles) along the coast of New South Wales in which the plankton content is high in the summer when the water temperature is as high as that of tropical seas.

It is not by any means easy, however, to determine from the observations that have been made up to date that the *actual production* or fertility of open tropical seas is less than that of open temperate seas. The rate of living is faster in the tropical waters, there is a quicker turnover and rate of reproduction. Even frequent plankton catches do not tell the story so simply as was once thought. It is only during the post-war years, as we have seen, and that notwithstanding the elaborate and costly statistical work, that scientists have realised that the presence of large quantities of big fish in an area does not necessarily mean a big production of fish flesh.

Viewed from a similar angle our quantitative plankton estimations still leave much to the imagination. We have only the most meagre information after years of work expended on far less important issues.

It seems reasonable to assume that *if* the raw materials of plant food were as freely available in the tropical seas as in other waters, the amount of annual production in live organic material would be as great in the one area as in the other—both regions would be equally fertile although a standard net catch or other type of plankton catch in the cold area might reveal more actual organic life than one taken in tropical waters. If, for one cause or another, the raw materials of plant food were richly poured into tropical waters, production there might greatly exceed that in a cold area where such nutriment was sparse. This conception seems more likely to fit the observations which have been made. There are places in tropical waters where rich catches have been made. There are places in temperate seas where the plankton can be poor. And so far as we know, the most fertile places of the world's seas are those where a thorough mixing of the waters is constantly taking place either by reason of inflowing water from the land, or the conjunction of two ocean currents or the upwelling of water along coasts.

Quite recently I have instituted the collection of a series of plankton catches off one of the most isolated tropical oceanic islands in the world—Nauru. Thanks to the keen scientific interest of the present Administrator (Commander Garsia) catches will be attempted every three weeks for a year or more. The first catches which I made myself were moderately rich and diatoms were by no means absent. Yet Nauru is in the supposedly semi-barren tropical Pacific Ocean. Time alone will show whether this richness is due to the influence of the island on the immediately surrounding water. If, however, such is the case, Nauru ought to provide one of the best tropical stations in the world for observing this problem. The island is isolated and only about 3½ miles in diameter so that one should not expect it to exert much if any influence on the island water a few miles away from it. It is a very healthy spot with a big white population and all the amenities of life, and it rises so abruptly from the deep ocean that only two or three hundred feet from the edge of the island's narrow reef flat, the depth is 600 feet or so.

The fact is that the fertility of the sea is greatest along sea coasts and over shallow banks. It is just in such places that we already know of rich fisheries. Whether fisheries can be as rich on shallow banks in the tropics as on similar places in the colder regions seems at present very problematic, in any case practically all the intensive fishing countries which have developed the most modern fish catching machinery are in temperate zones. And I think we may say for certain that in no parts of the ocean have the great whales been found in such numbers as in the Antarctic seas. These whales—blue whales, fin whales and humpbacks—are all plankton feeders. They surely serve as testimonies to the fertility of the southern seas in high latitudes.

All this has a bearing upon research work in our own waters. I should like very much to have plankton catches from colder Tasmanian waters for comparison with those taken by us at Sydney. They would need to be taken with a view to quantitative studies. To my mind, the time has gone by for taking plankton catches merely for the sake of listing new species or cataloguing those present.

Pelagic fish like the herring and the pilchard feed upon planktonic organisms and it has been suggested that possibly the use of plankton capturing apparatus by the skippers of drifters might help in telling them when to shoot their nets. Just as I write this, an article written by the skipper of a steam drifter comes to hand in an English fishing journal. He had been using for three years a 'Plankton Indicator' invented by Professor Hardy of Hull. The idea was that where certain species of the Copepod genus, *Calanus*, were present in large numbers, superior catches might be expected; other plankton organisms were known to be deleterious. During three months of one year the nets were shot 69 times, 40 being in water with little or no *Calanus*, and 29 in water containing 'good' or 'fairly good' *Calanus*. The average catch for the 40 in Calanus-free water was only three crans, whilst the average catch for the other 29 was 9·5 crans, an increase of 216 per cent.

Again on an occasion when the herring fishery in the North Sea made a good start the fish deserted the inshore grounds and were next located about 60 to 70 miles to the north-east, in which position they remained for the rest of the season. A research vessel found that there existed a belt of a minute and apparently deleterious plankton organism—*Phaeocystis*—extending one hundred miles east and west. There seemed little doubt that this was an obstruction to the herring.

Lastly there is another very important aspect of plankton work and that is the search to determine whether and how it may be responsible for the great fluctuations in the successful reproduction of our food fishes. There is evidence that in the 'bad years' (i.e. the years which are later on badly represented in the catches) there has been no lack of fertilized eggs produced. The 'poor vintage' may, therefore, be due to these eggs meeting unhealthy physical and chemical conditions in the sea, or maybe the newly hatched young find only a poor development of plankton of the right kind when this is so very essential as food material.

CONCLUSION

I trust my remarks tonight have been sufficient to show that a branch of zoology which may definitely be called Fisheries Science is gradually developing. The progress has been slow. For many years the proper relation of its subdivisions was not realized and certainly those engaged had little notion of the underlying complexities. Many investigators were too well satisfied with their intriguing little problems in marine biology to consider whether their application to fishery problems was obvious enough to balance the expenditure of time and money upon them. And so far as England was concerned, and possibly this is equally true of the

United States, any brilliant investigators in marine zoology probably looked ahead for positions which were not to be found under fishery committees—their association with fishery problems was thus temporary and continuity of research was lacking. This criticism, however, does not apply so much to the Germans and Scandinavians. Times have changed now and the work of the immediate future should be particularly interesting.

Not so very many years ago the opinion was frequently expressed that the yield of the sea was infinite. Did not the females of certain fish species produce 7,000,000 eggs in one spawning season! A simple view, for it is clearly as necessary for such a species to produce its 7,000,000 eggs if the stock is to remain *constant* as it is for the whale to produce its single young each year or the shark its twenty or thirty.

The highly efficient engines of modern fisheries have induced other ideas and from all over the world come stories of fish depletion. I have indicated some in the above account. Let me conclude by referring to another from a country near to us—New Zealand.

Mr. A. E. Hefford, the Chief Inspector of New Zealand Fisheries, in his Report of 1929, was particularly to the point when he said that the

'all important consideration for fishery Administration and for the fishing industry is as to how far the reduction of a stock of fish can proceed before the condition which can be termed positive depletion, has been reached . . .

'And especially we must recognise that there is no reason to think that New Zealand Fisheries may be developed to the same degree as those of Europe or North America. *There is no indication of anything approaching the same extent of fishery resources as those of the Northern Hemisphere. There is all the more reason, therefore, for studying what assets we have, with a view to their most economical exploitation*'. (Italics mine).

This is an interesting expression in view of the prevalent opinion in Australia as to the richness of New Zealand waters.

The fundamental problem facing the science of Sea Fisheries is everywhere the same—the valuation of the fishery stocks and the determination of what is going on when man adds his attack to the fluctuations of nature.

I am not going to suggest for a moment that Australia should institute anything on the extensive lines followed by the United States of America, Japan or England. Far from it. I am not at all convinced yet of the supposed enormous richness of our fishery resources. Why should I be in view of the lack of what I call real knowledge. I regard as pure blague the statement that Australia has the greatest fishing coast in the world. Time enough to make comparisons when we know more about it.

It is essential, however, that we should do something, and in a manner that will ensure that what is necessary is done in the most economical way. This implies that it must be efficiently carried out and by people thoroughly qualified to do the work. There is only one body in Australia that is in a position to regard the scientific work in the proper perspective and that is the Commonwealth Council for Scientific and Industrial Research. In their hands I can leave it.

Although it is not altogether to be placed under the head of scientific research, I am quite of the opinion that under the conditions peculiar to Australia, the Government might well undertake to help in the discovery of new fishing grounds and the investigation of the best fishing gear for use on them. The seas are open to all and the industry should benefit many beyond those directly engaged in fishing.

At the present time most of our trawlers are unable to explore beyond the 100-fathom line, although some of the most useful fishing in the world is now carried out at twice that depth. There are now French trawlers with refrigeration plant and storage for 700 to 800 tons of frozen fish, retorts for cooking lobsters, plant for the reduction of fish into oil and scrap, and storage tanks for 26,000 gallons of oil. Trawlers of this kind will travel across the Atlantic to their fishing grounds and remain away for weeks at a time.

The vast field of the pelagic fishes so intensely valuable to other countries has been left altogether unexplored commercially around Australia. The pilchard was worth 3,587,464 dollars to California in 1929, the value of the herring alone landed in Great Britain in one year may be over £5,000,000. How can these pelagic fish be caught best in our waters? Will the drift net, the purse seine, the lampara or other devices prevail? The problem entails a big experiment—it is not exactly one for a private company or individual since the results are for the many. There will be no exclusive licenses.

The Commonwealth Government has now agreed to make these explorations for pelagic fish and in making that decision I think it has done well. Let us not make the mistake of missing the opportunity for conducting statistical and other pure fishery research when these experimental explorations are made. It is cheaper to investigate resources in advance rather than after depletion has taken place.

One of the greatest dangers that Science faces today is that of being expected to produce some great discovery to order, which will bring considerable wealth for an extremely low expenditure. It has been well said that the average individual's interest in science is the hope of getting something for nothing. I regret to say that some of the most sanguine promises have been made to the fishing industry.

I see no reason why scientists should promise the fishing industry easy money. Their work is rather to be regarded as essential to the people for the proper conservation and the utilisation of nature's products. To the fishery industry it might be regarded at least as an insurance although it might turn out a most profitable investment.

I have no doubt that explorations at sea and tests of new fishing gear will show up new grounds and may improve the catching power of the appliances used. This, however, is relatively simple work, involving fishing technique rather than the finer studies of science.

But all this work without the institution of better methods of transportation and marketing would result in worsening the present economic conditions in the industry instead of bettering them. I do not think I can agree with the view that the lack of scientific research up to date has been responsible for the slow development of the Australian fishing industry. There are many other causes. The so-called fresh fish as received by the Australian housewife is, in most localities, a burlesque of the real thing.

The help of the scientist in the development of up-to-date and really modern canning industries, refrigeration methods, the utilization of waste products, the preservation of fishing nets, the propagation of shell-fish, the toxicity of paints and poisons to marine growths, and in the solution of a large number of other problems, is of course, obvious to most.

The use of plankton studies, the study of life histories, of fish eggs, the study of the prevailing hydrographic conditions in the sea and the expenditure of money on the statistical analyses of our fish stocks, are not so obvious. Such researches might result in new culture methods, they might help to discover the secret of the curious fluctuations in the riches of the sea and to make forecasts of the fisheries possible. They will certainly help to an understanding of the conditions upon which fishery legislation must be based, for to have Fishery Acts and Regulations without knowledge cannot be sufficiently condemned.

Unfortunately, so long as neither fishermen nor those who govern us are ever told or instructed as to the reasons why much of the scientific work is conducted, it will never be found possible to enlist the help and sympathy which are so essential to success.

There have been, during the past few years, many cries in the newspapers for Government help in connexion with fisheries. Perhaps if those making most noise had been really altruistically concerned about the general advance of the fishing industry of Australia, something more might have been achieved than the state reached at present.

Unfortunately most of the reproaches have come from interested company promoters whose one idea of Government help was the obtaining of money grants in order to float new concerns, the future of which might be left to unhappy shareholders. This would be a disastrous waste of money and quite against all the advice of the numerous witnesses and experts who attended the meetings of the Commonwealth Fisheries Conference during the years 1927-9.

The only reason the promoters of the projects referred to above have applied to the Governments is because they have met with little response from the investing public. The investing public have probably refrained because they realized that the projects were based on incomplete data.

There are plenty of bonafide fishermen all round the Australian coast and no doubt many business men of standing who would enter into or extend the fishing trade if *shown* that *constant supplies* of fish were available in the sea and markets were forthcoming for their products. To explore every possible line of enquiry might well be regarded as the duty of a Government; to hand over money to any ' Tom, Dick and Harry ' is something which John Citizen would be the first to criticize.

Some years ago a British official from India visited Japan in order to study its fishery methods. In his report he noted that much of the Japanese success was due to the ' Co-operation of Government and people: The Government statesmanlike, resolute in progress on lines systematically thought out and determined, imbued with the scientific spirit, liberal in the necessary expenditure; the people responsible, enterprising, alert to utilise opportunity and to follow example '.

I should like to stress that attitude and to remind you, in conclusion, that it is from a flourishing fishing industry that the great maritime nations have recruited some of the best and most desirable men for the merchant service and the navy.

LITERATURE USED IN THE PREPARATION OF THE LECTURE

General Fisheries Science

Reports of the Commissioner of Fisheries to the Secretary of Commerce, U.S.A.

Bulletins of the United States Bureau of Fisheries.
(Both the above are essential sources of information on fisheries.)

Reports of the Fishery Board for Scotland.

Scientific Reports of the Ministry of Agriculture and Fisheries. England.

Reports of the Lancashire Sea Fisheries Laboratory, Liverpool, England.

Publications of the Conseil Permanent Internationale pour L'Exploration de la Mer. Copenhagen.

Publications of the Ministry of Agriculture and Fisheries. England and Wales.

Wissenschaft. Meeresuntersuch. Kiel and Helgoland.

Meddelelser fra Komm. for Havundersogelser. Copenhagen.

BIGELOW, H. B. & WELCH, W. W. 1925.—Fishes of the Gulf of Maine. *Bull. U.S. Bur. Fish.* Vol. 40, Pt. 1, 1924. pp. 1-567. (Type of general paper referring to Food, Breeding Habits, etc.)

BUCKMANN, A. 1929.—Die Methodik fischerbiologischer Untersuchungen. *Abderhalden Handb. d. biol. Arbeitsmethoden.* Abt. IX, Teil 6, pp. 1-194.

DAVIS, F. M. 1927.—An Account of the Fishing Gear of England and Wales. *Minist. Agr. and Fish.* Fishery Investigations, Ser. II, Sea Fisheries, Vol. IX, No. 6, p. 1—131, 1927.

PETERSEN, C. G. J. 1918.—The Sea Bottom and its production of Fish Food. *Rep. Danish Biol. Station*, Vol. 25, 1918. p. 1—62.

1921.—On the stock of Plaice in relation to intensive fishing—Belt Sea, etc. *Rep. Danish Biol. Station*, Vol. 27, 1920-21. pp. 1-17.

TRESSLER, D. K. 1922.—*Marine Products of Commerce.* Washington, 1922.

Age Determination

DAHL, K. 1907.—Scales of the Herring as a means of determining Age, Growth and Migration. *Rep. Norweg. Fish. Investig.* Vol. II, No. 6, 1907.

GRAHAM, M. 1929.—Studies in Age Determination in Fish. Pt. II. A Survey of the Literature. *Minist. Agr. and Fisheries. Fishery Investigations*, Ser. II, Vol. 11, (Pt. II, pp. 3-50.)

HODGSON, W. C. 1929.—Investigation into the Age, Length and Maturity of the Herring—Composition of Catches from 1923-28. *Minist. Agr. and Fisheries. Fishery Investigations*, 1929.

THOMSON, J. S. 1904.—The Periodic Growth of Scales in Gadidae as an index of Age. *Journ. Marine Biol. Assoc.* (N.S.) Vol. VII, 1904. pp. 1-109.

WINGE, C. 1915.—On the value of the rings on the scales of the Cod as a means of Age Determination. *Medd. fra Komm. f. Havunders. Ser. Fisk.* 4. 8. Copenhagen, 1915.

Fish Hatching

(Fish Eggs, etc.)

DAHL, K. 1909.—The problem of Sea Fish Hatching. *Rapp. Proc. Verb.* Vol. 10, No. 5, 1909. pp. 1-39.

DAKIN, W. J. & COLEFAX, A. N. 1934.—The Eggs and Early Larval Stages of the Australian Pilchard, *Sardinia neopilchardus. Records of the Aust. Museum.* Vol. XIX, No. 2, 1924. pp. 136-140.

EHRENBAUM, E. 1909.—Eier und Larven von fischen. *Nordisches Plankton.* Lief 4. 1 & 2. 1909.

ROULE, L. 1914.—*Traite de la pisciculture et des Peches.* Paris, 1914.

Fluctuations

(See also under Statistics)

Fluctuations in the Abundance of the various year-classes of food fishes. (Series of Reports by various workers.) *Rapp. Proc. Verb.* Vol. LXV, 1930, pp. 5-182. Vol. LXVIII, 1930, pp. 5-115.

HEINCKE, F. AND BUCKMANN, A. 1926.—Die Überfischung der Nordsee und die Wirkungen der Kriegsschonzeit auf ihren Schollenbestand. *Deutsche Fischerbote*, XVIII, Jahr. Heft 3, 1926. pp. 57-101.

JOHNSTONE, J., BIRTWISTLE, W., AND SMITH, W. C. 1922.—The Plaice Fisheries of the Irish Sea. *Reps. Lancs. Sea Fisheries Lab.* Vol. XXX. 1922.

General and Special Subjects

DAKIN, W. J. 1908.—The Osmotic Concentration of the Blood of Fishes. *Biochem. Journal.* Vol. III, No. 5, 1908, pp. 264-

1911.—Notes on the Biology of Fish Eggs and Larvae. *Internat. Rev. Hydrobiol.* Band. III, 1910-1911. pp. 487-495.

1931.—Migrations and Productivity in the Sea. *The Australian Zoologist.* Vol. VII, Pt. I, 1931, pp. 15-33.

Migration

MEEK, A. 1916.—*Migrations of Fishes.* London. 1916.

Plankton

ATKINS, W. R. G. 1924.—On the Vertical Mixing of Sea Water and its Importance for the Algae Plankton. *Jour. Marine Biol. Assoc.* Vol. 13, No. 2, 1924. pp. 319-324.

DAKIN, W. J. & COLEFAX, A. N. 1933.—The Marine Plankton of the Coastal Waters of N.S.W. 1. *Proc. Linn. Soc. N.S.W.* Vol. LVIII, Pts. 3-4, Nos. 247-248, pp. 186-222. 1933.

HARVEY, H. W. 1933.—On the rate of diatom growth. *Journ. Marine Biol. Assoc.* N.S., Vol. XIV, 1927. pp. 837-868.

MARSHALL, S. M. & ORR, A. P. 1927.—The Relation of Plankton to some Chemical and Physical Factors in the Clyde Sea Area. *Jour. Marine Biol. Assoc.* N.S., Vol. XIV, 1927. pp. 837-868.

SAVAGE, R. E. 1930.—The Influence of Phaeocystis on the Migrations of the Herring. *Minist. Agr. and Fish. Fishery Investigations,* Ser. II, Vol. XII, No. 2, 1930.

1931.—The Relation between the Feeding of the Herring off the East Coast of England and the Plankton. *Minist. Agr. and Fish. Fishery Investigations,* Ser. II, Vol. XII, No. 3, 1931.

Statistical Methods

BORLEY, J. O. & COLLABORATORS. 1923.—The Plaice Fishery and the War. *Minist. Agr. and Fisheries. Fishery Investigations,* Ser. II, Vol. V, No. 3, 1923.

BORLEY, J. O. & THURSBY-PELHAM, D. E. 1924.—Report on the English Plaice Investigations in the North Sea, during the years 1921-23. *Minist. Agr. and Fisheries. Fishery Investigations,* Ser. II, Vol. VII, No. 6, 1924.

Bulletin Statistique des Peches Maritimes des Pays du Nord de l'Europe *Cons. Perm. Int. pour l'explor. de la Mer.* Vols. I-XI, 1906-1924.

COLEFAX, A. N. 1934.—A Preliminary Investigation of the Natural History of the Tiger Flathead *(Neoplatycephalus macrodon)* on the South-Eastern Australian Coast. 1. *Proc. Linn. Soc. N.S.W.* Vol. LIX, Pts. 1-2, 1934, pp. 71-91.

EDSER, T. 1925.—A Short Account of the Statistics of the Sea Fisheries of England and Wales. *Rapp. Proc. Verb.* Vol. XXXVI, 1925. pp. 3-27.

HEINCKE, F. 1913.—Investigations on the Plaice. Gen. Report, Pt. 1, Plaice Fishery and Protection Regulations. *Rapp. Proc. Verb.* Vol. XVIIa, 1913. Copenhagen.

1922.—Die Ueberfischung de Nordsee und die Wirkungen den Kriegschanzeit auf ihren Schollenbestand. *Der. Fischerbote.* Jahr. 1922, Nr. 14. pp. 362-389.

JOHANNSEN, W. 1913.—*Elemente der exakten Erblichkeitslehre.* 2 Auf. Jena, 1913.

JOHNSTONE, J., BIRTWISTLE, W., AND SMITH, W. C. 1922.—The Plaice Fisheries of the Irish Sea. *Reps. Lancs. Sea Fish. Lab.* Vol. XXX, 1922. Liverpool.

PETERSEN, C. G. J. 1922.—On the Stock of Plaice and the Plaice Fisheries in Different Waters. A Survey. *Rep. Dan. Biol. Station.* Vol. XXIX, 1922. pp. 1-43.

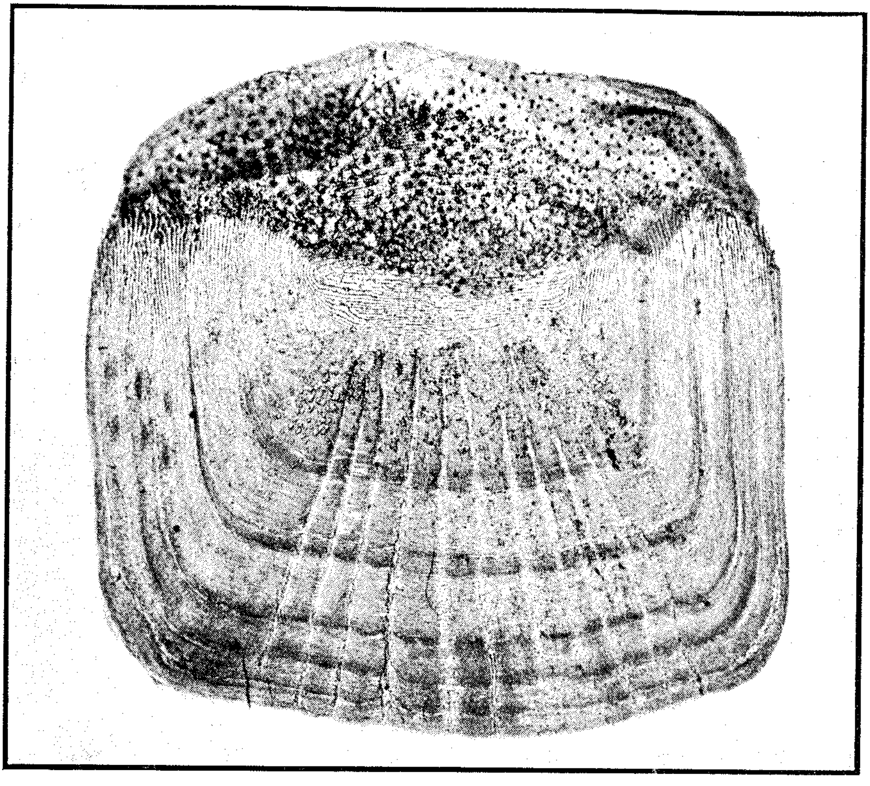
THOMPSON, D'ARCY W. 1908.—On the Statistics of the Aberdeen Trawl-Fishery. 1901-6. *Fishery Board for Scotland Statistical Papers,* 1908. pp. 217-280.

THURSBY-PELHAM, D. E. 1930.—Fluctuations in the Age-Composition of the Plaice Stock in the Southern North Sea during the period 1923-28. *Rapp. Proc. Verb.* Vol. LXV, No. 9, 1929. pp. 67-81.

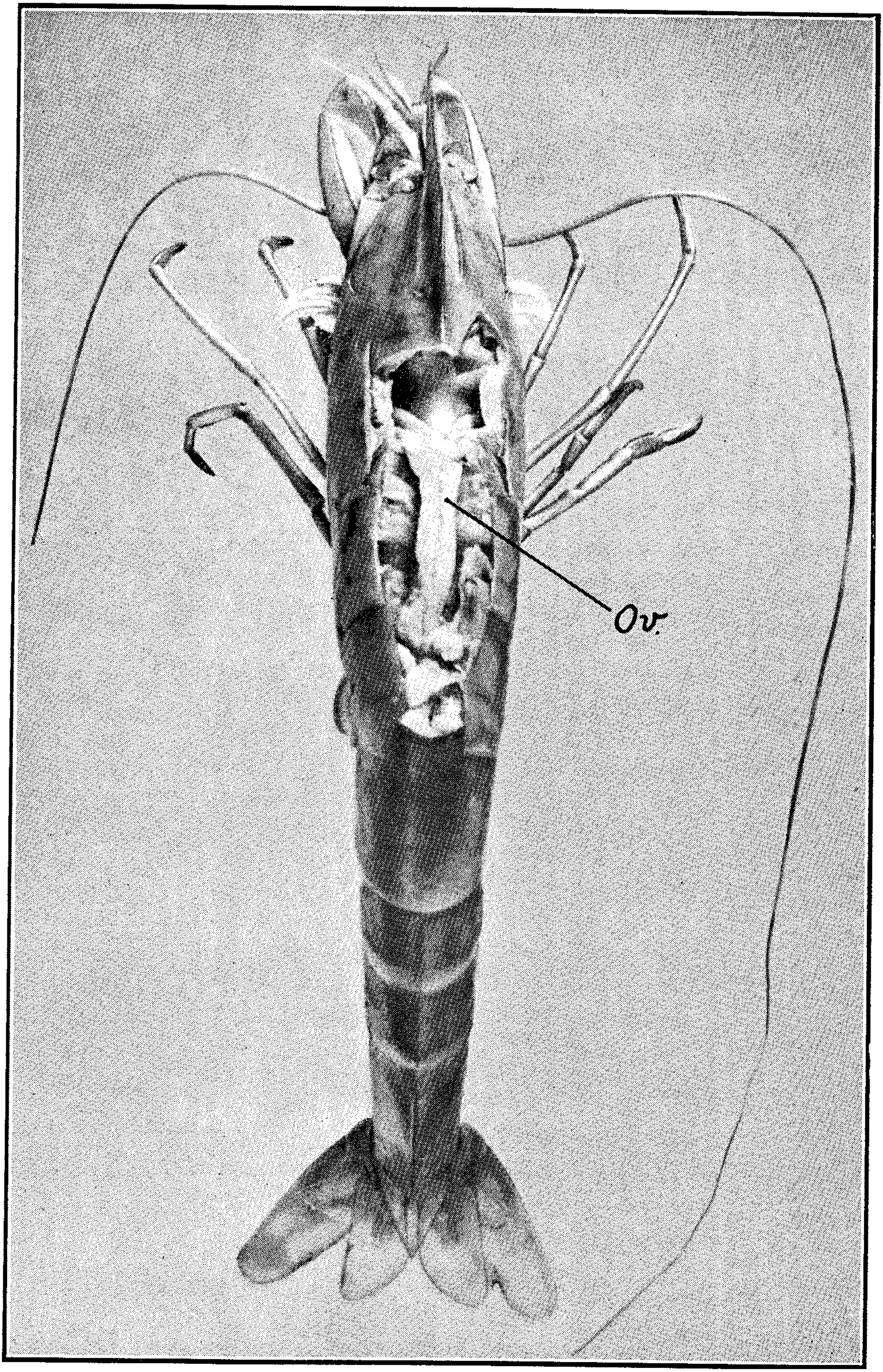
EXPLANATION OF PLATES

PLATE I.—Scale of Tasmanian Trumpeter (low magnification).

PLATE II.—King Prawn *(Peneus plebejus),* female, almost mature, showing ovaries (ov.).



Scale of Tasmanian Trumpeter. (Low magnification).


Ov.