FISHERIES OCEANOGRAPHY IN EUROPE

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Any review of the status and accomplishments of fisheries oceanography would be incomplete without an account of fisheries oceanography in Europe, where the science began and is still vigorous after more than 50 years.

Fisheries oceanography may be said to have begun with the establishment in 1902 of the International Council for the Exploration of the Sea, by representatives of north-west European governments. The form that fisheries oceanography was to take was foreseen and described by the Council in its first Administrative Report (1903), in the following words:

"It was thereby shown that the research work might best be divided into two main divisions, of which the one had in view the physical conditions of the sea, the other the biological—more especially in regard to the animals most useful as human food. Naturally it was seen from the beginning that the study of the physical conditions, of the chemical nature of the ocean waters, of the currents, etc., was of the greatest importance for the investigation of the problems connected with life, that on the other hand, the study of the floating organisms had particular worth for the solution of hydrographic problems, and consequently that a sharp line should never be drawn between these two main divisions . . ."

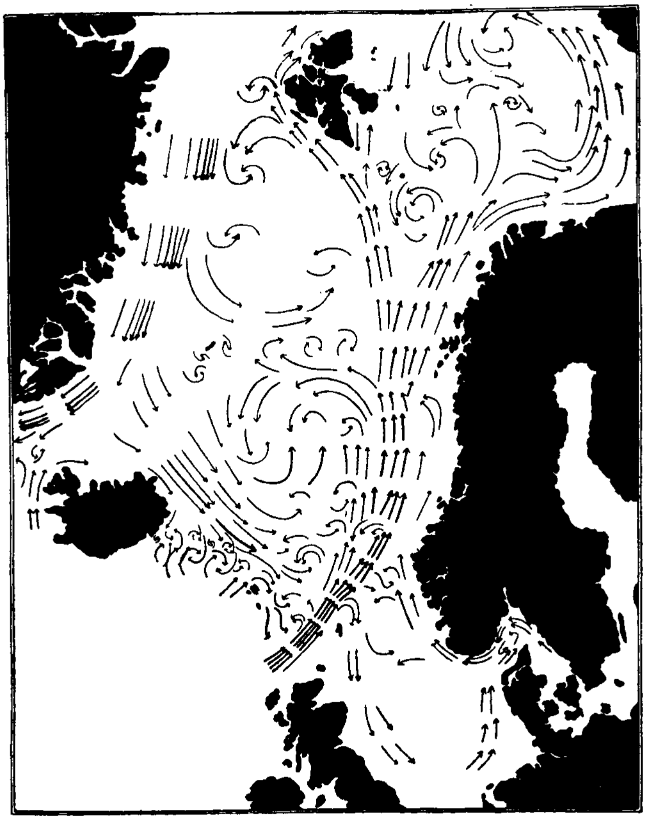

FIGURE 1. Surface currents in the Norwegian Sea (from Helland-Hansen and Nansen 1909).

Most marine scientists know in a general way how, mainly under the aegis of this Council, the north-west European countries have co-operatively and individually planned, performed, discussed, and published an immense amount of oceanographic work which was, or was hoped to be, pertinent to fisheries problems. The remarks in this paper will be confined to the investigations in the region between the English Channel, the Barents Sea, and Greenland. There has, of course, been much work also off the Atlantic coasts of France, Spain, and Portugal, which are in the International Council's area, and in the Mediterranean and Black Seas, which are not.

Figure 1, the well-known surface current chart of Helland-Hansen and Nansen (1909), shows how the warmer more saline North Atlantic water enters the region, mainly through the Faroe-Shetland Channel, as the Norwegian Current, while colder less saline Arctic water flows out, between Greenland and Iceland, as the East Greenland Current. An outflow of low-salinity water from the Baltic contributes to the Norwegian Current. The shallow North Sea receives Atlantic water from the north, around Shetland; and to a less extent from the south, through the English Channel, as indicated in Figure 3.

Another kind of summary of the hydrography of part of this region is the chart of Dietrich (1950) showing natural regions based on distribution of salinity and temperature (Fig. 2).

These figures demonstrate the great differences in the environment of the fishes of the region. Much of the early fisheries oceanographic work consisted of collection, description, and analysis of material in sufficient mass to show what species or populations of fish reacted to what properties of the environment and in what ways. The results have been summarized by Tait (1952, Chapters 1, 2). They gave rise, among other things, to a few rather useful, though not entirely dependable, rules; e.g. that fish populations breed at particular temperatures (Orton 1920) and that breeding migrations are contranatant (E. S. Russell 1937). Mention must be made at this point of the aquarium experiments of Bull (1952), which demonstrated the ability of fishes to perceive and act purposively to changes as low as 0.03° C., 0.2 ‰ of salinity, and 0.05 units of pH, in the water around them; this made the conclusions from the field work more acceptable.

[1] Contribution from the Scripps Institution of Oceanography.

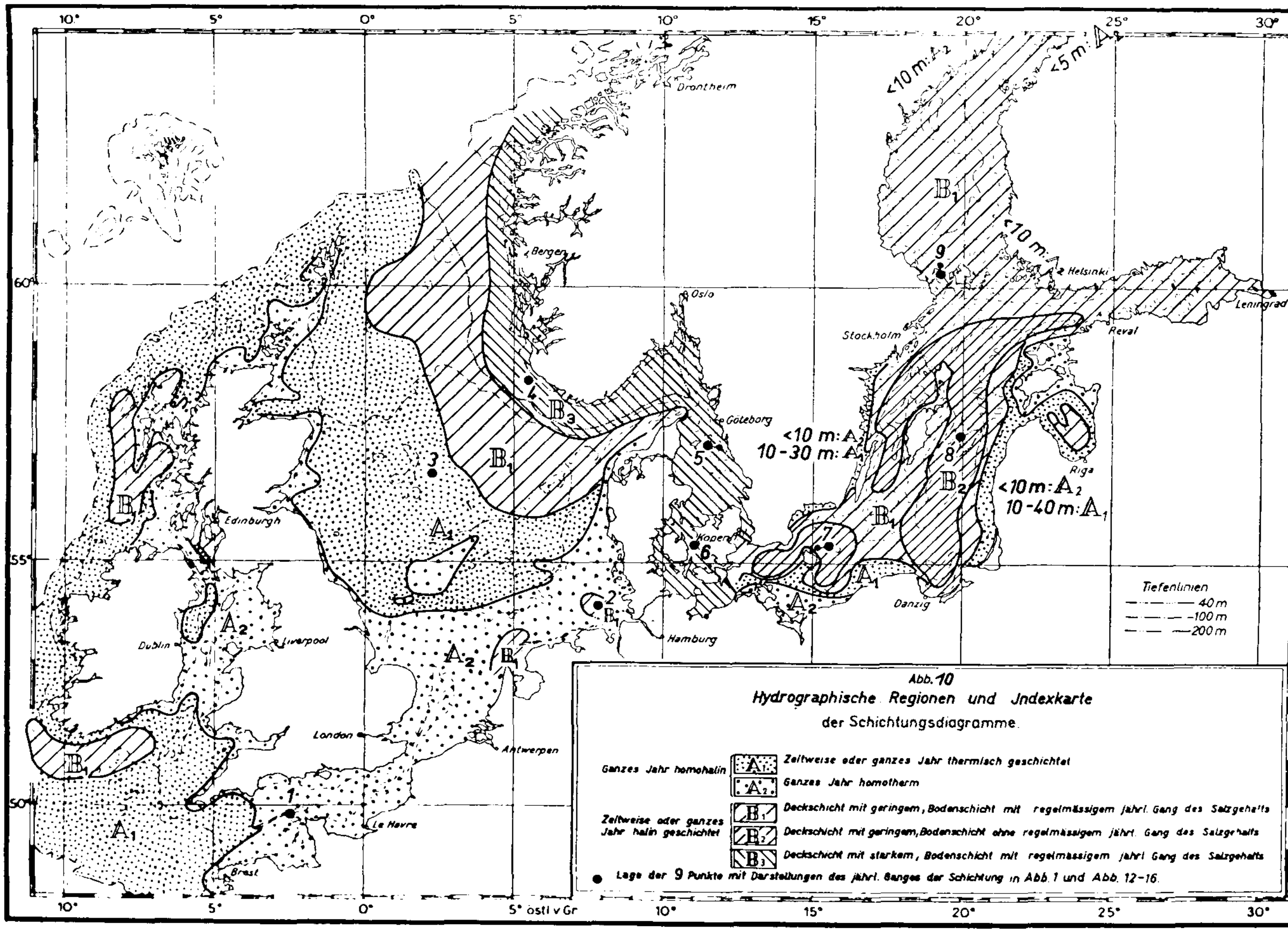

FIGURE 2. Hydrographic regions in the North and Baltic Seas (from Dietrich 1950).

This kind of work was more straightforward than that which came later. In the period between the wars several lines of fisheries work were progressing in a way that seemed to leave the hydrographers and planktologists with a minor role to play as far as practical fisheries problems were concerned. The hydrographers and planktologists found plenty to do on their own account, but their connection with fisheries biology was temporarily weakened.

One reason was that it had become clear that the condition of many important fish populations, especially demersal populations, could be improved by restricting man's fishing (E. S. Russell 1942). This meant: that there was no need of oceanography to help fishermen find these fish, since the fishermen were already too efficient at that for their own good; and that oceanography's promise to understand and predict changes, nothing more, seemed less attractive than the promise of fisheries biology to control changes by regulating fishing. This affected the work on plaice, haddock, hake and other species, and the programs of the countries concerned—especially England, Holland, Belgium, Denmark, and Germany—and continues to do so. The work on the pelagic herring and the semi-pelagic cod was not greatly affected.

Another reason was the well-merited popularity of the theory of natural fluctuations in fish populations according to Hjort (1914). The essential points of the theory were: that year-classes may vary greatly in size because of differing natalities and mortalities of young from year to year; that the progression of these rich, medium, and poor year-classes through the older fishable part of the population has a decisive effect upon the numbers present and catchable each year; and that this effect is predictable in detail if the initial year-class strengths, and average growth-rate of the fish, are known. Although Hjort perceived the probable significance of environmental factors in causing the differences in the year-classes, he pointed out that the causes would have no great importance for practical forecasting if one could measure the differences themselves before the year-classes became important in the fishable segment of the population. It turned out that the differences could be so measured in several populations, by study of age-composition of numerous samples of fish taken before or just at their entry into the fishery, and that useful predictions could be made. This was done particularly for herring, in south-east England (Hodgson 1932) and elsewhere.

In proposing his theory of natural fluctuations, Hjort (1914) had considered and virtually rejected the idea that the coastal food-fish penetrate the ocean waters. Coastal fishermen everywhere tend to believe that fish must be offshore when they cannot be found inshore, and persistently ask their scientists to investigate these waters for them. We will see later that the

Norwegian fishermen were partly right in this belief, and that Hjort was wrong when he disagreed with it. However his conclusion was reasonable in the light of the evidence available to him, and it is salutary to give his words:

"In the course of the Norwegian fishery investigations carried out under my supervision, I have endeavoured in various ways to discover whether any fish move out beyond the coastal banks . . . Numerous experiments have been made with drift net and floating lines, for the most part, however, with negative result."

He then explains that he did find *Sebastes*, the redfish, in many places; some herring in deep water between the North Sea and the Faroe area, but virtually none in the main part of the Norwegian Sea; and little or nothing in the way of cod, haddock, coalfish, and catfish; and he continues:

"Experiments of this nature are, however, by no means easy to carry out, and negative or mainly negative results are scarcely sufficient to warrant the conclusion that the species in question do not occur in any quantity in the waters investigated; there is always the possibility that the fish might occur in shoals, which it would be a matter of merest chance to encounter in so great an expanse of sea. One thing at least is certain; we have no other grounds for supposing the existence, in any considerable numbers, of coastal fish in the deeper parts of the Norwegian Sea, beyond (occurrences of *Sebastes* and restricted occurrences of herring noted above)."

This helped to divert attention from the ocean waters, and was another disservice to the kind of fisheries oceanography that the founders of the International Council had envisaged.

We now turn to what some fisheries oceanographers, physical and biological, did while some fisheries biologists were specializing in the above-mentioned ways; and how some common ground has now been reached again, especially in herring and cod research.

There were workers in England and Scotland who believed that the varying influx of Atlantic water to the North Sea and English Channel was the key to many fluctuations in fish populations.

Plymouth, in the western English Channel, had a herring fishery until about 1938; its extinction began in 1931 when the first of an unbroken series of poor year-classes appeared. The same year marked the beginning of a fall in the standing crop of planktonic young fish generally, and the beginning of a large drop in the winter maximum of inorganic phosphate. It was also the period at which *Sagitta elegans* was replaced in the plankton by *S. setosa.* It was concluded that the influence of Atlantic ocean water upon the Channel, and with it the possibility of renewal of nutrients to the levels of the nineteen-twenties, had receded (F. S. Russell 1939). There has been no definite improvement since that time.

Cooper (1955), noting no evidence that Atlantic surface waters have ever been rich enough to account for the phosphate levels found off Plymouth before 1931, considered various possibilities by which deeper nutrient-rich Atlantic water could have been carried

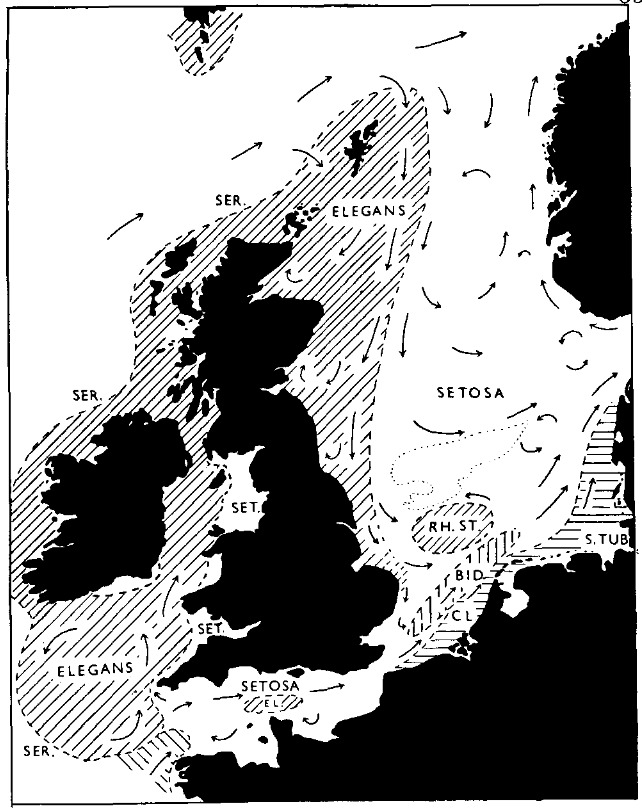

FIGURE 3. Generalized picture of distribution of plankton indicators in the North Sea area: showing occurrence of *Sagitta elegans, S. setosa* (SET.), and other species; arrows indicate general water circulation (from F. S. Russell 1939).

or mixed upwards, in the Channel approaches, during the nineteen-twenties. Observing that this would be facilitated by the elevation of a layer fairly rich in phosphate by a few hundred metres, he supposed the arrival of a suitably large body of water at greater depth, formed by cooling and sinking of water between Faroe and Greenland. Winter temperatures in those regions were particularly low in several years ending about 1921, a year before the beginning of the phosphate record at Plymouth. The effect of the heavy water in keeping the nutrient-rich water elevated in the mouth of the English Channel is supposed to have continued for some years after the recruitment of the heavy water ceased.

Figure 3 shows that *Sagitta elegans,* the plankton-indicator of good conditions for fish in the English Channel, is also distributed in the North Sea in a way that suggests an association with Atlantic water entering through the Faroe-Shetland Channel (F. S. Russell 1939). The idea of plankton organisms as indicators of hydrographic conditions has been so popular in England and Scotland that plankton has been routinely collected, along regular steamship and weathership tracks radiating out from Britain, in most peace-time years since 1932. The convenient Hardy Continuous Plankton Recorder is used. Figure 4 shows the coverage now being obtained (Hardy 1956).

The surface currents of the Northern North Sea region are shown, from the drift-bottle work of Tait (1937), in figure 5. Tait (1955) has also studied vol-

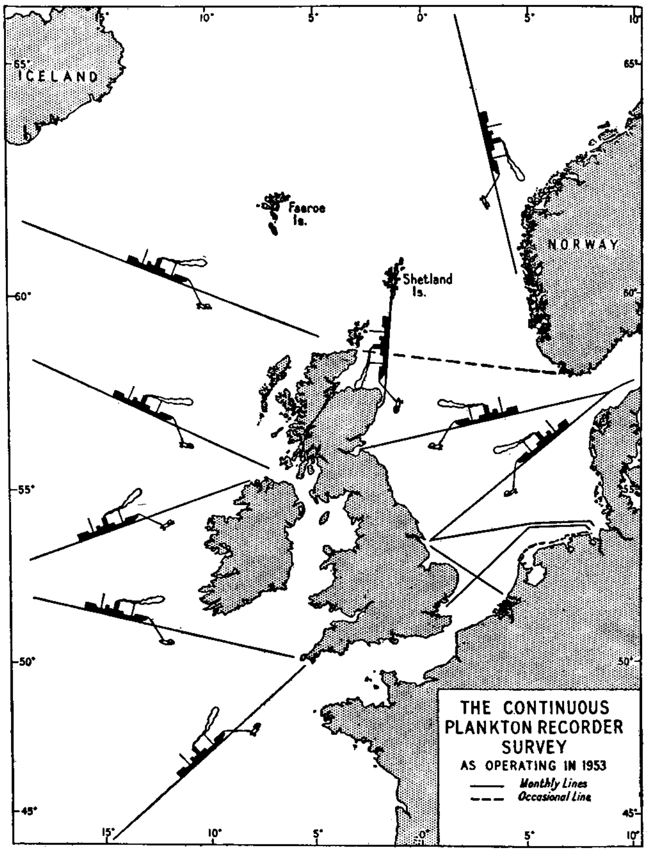

FIGURE 4. Scope of Continuous Plankton Recorder survey in 1953 (from Hardy 1956).

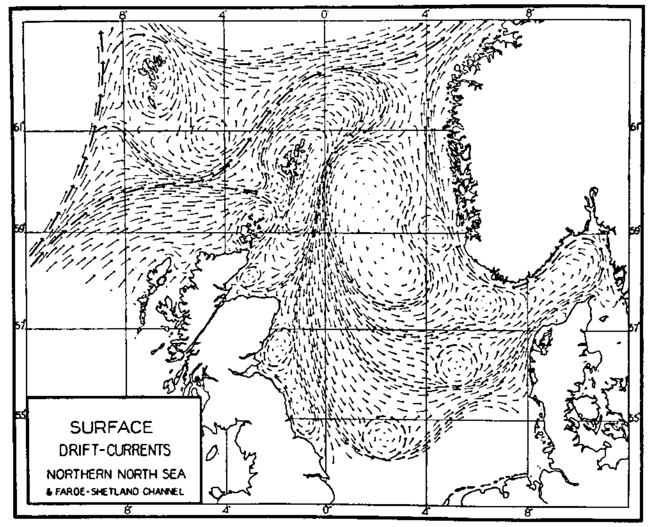

FIGURE 5. Surface currents in the northern North Sea (from Tait 1937).

ume transport of oceanic water (salinity >34.99 ‰) through 68 sections made across the Faroe-Shetland Channel from 1927 through 1952, noting various seasonal and annual changes. Scottish biologists have been trying to link such changes with fluctuations in distribution of plankton organisms on the above-mentioned sampling lines around the north of Britain, and with events in the herring fishery off the northeast coasts of Scotland (Glover 1955).

Another aspect of plankton work related to herring must be mentioned, the aggregation of the herring on to the plankton, especially the copepod *Calanus*, which it eats. This has been investigated several times in different areas, frequently in the hope that the relationship would prove sufficiently close to enable fishermen to locate herring from their own plankton surveys with simple collecting instruments. This has happened sometimes but not always (e.g. Hardy, Lucas, Henderson, and Fraser 1936, in the North Sea). It is now clear that a close positive relationship between herring and food is much more likely to occur in some situations than in others, as shown for example from the work of Manteufel (1941) in the Barents Sea, where the study was simplified by the fact that only one brood of *Calanus* occurs per year. The relationships between this brood and the herring are summarized diagrammatically in figure 6.

Finally, for the herring, we must note the appearance in the last decade of an important herring fishery and herring-oceanography program in the middle of the Norwegian Sea, from Iceland to Spitzbergen (Fig. 1), in the very region where Hjort (1914) thought no appreciable amount of herring existed. Location of the resource was primarily the result of equipping a new research ship with asdic (sonar) and using it in regions where a new generation of Norwegian and Icelandic biologists had concluded, from tagging experiments, that herring must occur. But oceanographic work accompanied these surveys from the start, and is producing a picture of herring shoals concentrated, in summer, along the eastern boundary of the cold East Iceland and East Greenland Currents (Devold 1952, Marty 1956). Plankton and productivity (C^{14} method) observations indicate that this is the best part of the region for production of herring food (Berge 1958). Much has been added to our knowledge of currents in the region (Alekseev and Istoshin 1956).

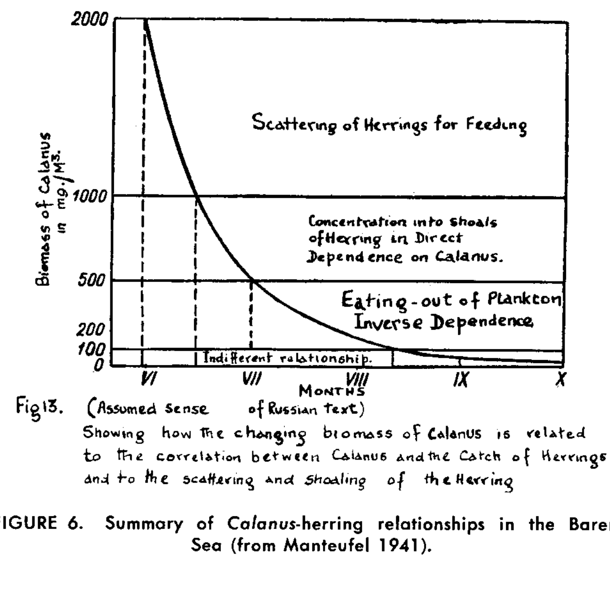

FIGURE 6. Summary of *Calanus*-herring relationships in the Barents Sea (from Manteufel 1941).

The amount of work done on oceanography in relation to cod has likewise been large. Much of it has been planned around the belief that cod are particularly selective about temperature, which arose in part through the work of Thompson (1943) at Newfoundland. The fact that the cod extended its range northwards, from Iceland well into Greenland waters, after the middle nineteen-twenties when the waters of this region were warming, gave further support to the general idea and encouraged the expansion of cod research generally. Biological and hydrographic observations regarding this extension of the cod's range were given by Hansen (1949). Fishery records of the early nineteenth century suggest previous invasions and retreats of cod in Greenland waters. Sea temperature data do not go back quite so far, only to 1876; they show the recent warming very well, of course, and also the preceding cold period about 1920 to which reference has been made (Smed 1949).

There was an unexpected increase in the abundance of cod in the Baltic Sea in the nineteen-forties which Alander (1952) has explained in terms of a series of rich year-classes associated with increased salinity of Baltic water.

Returning to Arctic cod, we note an important investigation by England, commencing in 1949, of the distribution of cod in relation to the environment around Bear Island, between Norway and Spitzbergen. Bear Island lies in the region where the warm Norwegian Current divides and cold water penetrates from the north-east (Fig. 1). The intention was to study relationships of cod to temperature, not so much to predict abundance changes of the whole population through year-class strengths as to predict the location of any payable concentrations of the fish (i.e., similar in motive to some of the herring studies).

The results of this work are still appearing. The results available are somewhat inconclusive on the value of temperature observations to fishermen in the area as a whole, but they point to some situations in which measurement of bottom temperatures would facilitate location of fish (Lee 1952). It was shown that paying quantities are rarely caught in water colder than 1.75°C, except in summer when the fish are feeding heavily to the east of Bear Island and may be found down to –0.5°C. Another finding was that on grounds west of Bear Island, in early summer and in autumn, Atlantic water touching the Bear Island bank can give good catches with bottom temperature between 3° and 5°C. For the area as a whole the range of temperature associated with cod is wide —about –0.5° to 5°C—in the summer feeding season, and narrow—about 2° to 4°C—in the winter nonfeeding season. Even in the winter there may be waters of "suitable" temperature without fish.

Another member of the Bear Island research team has attempted to explain the distribution of cod in the area in a different and more comprehensive way (Trout 1957). The hypothesis, derived from tagging experiments and other biological observations on the cod, is that cod are carried along with currents during summer when they leave the bottom in response to light, and work back against currents in the dark of winter when they have resumed a bottom-living existence.

The report of the first two years of this program provides interesting reading for those interested in European fisheries oceanography from the point of view of outlook, organization, facilities, and methods (Graham *et al.* 1954).

There have been many other investigations on the effects of oceanographic variables on European fish, some conclusive and some not. Much of the work has been done in the "Transition Area" at the entrance of the Baltic (Jensen 1952), on many species. Other references to such work, and to oceanographic work less intimately connected with fisheries at the present time, may be found in papers in the International Council's "Rapport Jubilaire" (1952), and in reviews by F. S. Russell (1952) and Fleming and Laevastu (1956). It is proper also to mention the immense contribution made over about 20 years by Britain, to the fisheries oceanography and general oceanography of the Antarctic Ocean, through the "Discovery Committee". The fisheries in this case were for whales, whose relationships to environment have been summarized by Hardy and Gunther (1935). The effort continued as a general oceanographic survey of the Antarctic and adjacent seas, including the Peru and Benguela Currents, and the ships and personnel finally became the nucleus of the National Institute of Oceanography (Mackintosh 1950).

We may return to the matter of whether or not it is important to understand the causes of year-class fluctuations. It is now generally held that they should be known, if only because it is not always possible to measure the changes properly by sampling juvenile fish. Carruthers has for some years approached this problem *ex hypothesi;* he has assumed that the differences are mainly differences in mortality of young and that they occur in the North Sea because of the vagaries of currents that may carry the young into favorable or unfavorable situations; and he has examined the relationships between year-class sizes and measurements of the winds held responsible for the currents, and has found some satisfactory agreements. The idea is shown in figure 7 which is from one of his earlier papers (1938), showing the correspondence over a series of years between the relative size of haddock year-class and sum of east components in the wind, in the North Sea. Since the war he and his colleagues have produced similar arrays

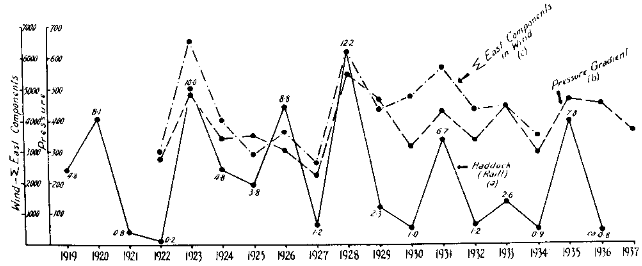

FIGURE 7. Comparison of annual changes in haddock year-class size, pressure gradient, and sum of east components in wind; North Sea data (from Carruthers 1938).

of data, regarding year-class strength and wind, for other species including herring, plaice, cod, and sprat (Carruthers, Lawford, and Veley 1951; other references in Carruthers 1954).

As a result of this work Carruthers (1951) has taken what he calls ''An attitude on fishery hydrography'' which amounts to this: oceanographers who are not obliged to produce practical results may study what they like, but fisheries oceanographers should study winds. Wind data, he emphasizes, are cheap. Warming to this theme in other papers (1953, with Lawford and Veley; 1954) Carruthers asks whether the complex kind of work now thought of as fisheries oceanography, the kind we have been considering, can do the fisheries any good within reasonable time, or ever. He says (1953) of Tait's work:

''Tait is well known of course for the meticulous detail of his work carried out over many years on water movements in the sea areas to which attention has to be paid by those whose task it is to study the fish of the North Sea. Unless the reviewer has got quite a wrong impression, Tait wants more detail still . . . If so, we must wait a goodly time yet before 'Fisheries Hydrography' can pay the dividends which the biologists seem to expect. There is at least the chance, however, that fruitful associations of the kind needed may be worked out between fish fortunes and environmental conditions in a more simple way involving less industry and less cost.''

However, the pattern of fisheries oceanography in Europe has not yet changed much. The work of the last decade has reflected the following recommendation made by the Consultative Committee of the International Council in 1951, after a special scientific meeting on ''Fisheries Hydrography'' which featured many of the above-mentioned papers.

''As the proceedings of this meeting have shown that a combination of biological, hydrographical, meteorological, physiological or statistical researches has furthered our knowledge of biological productivity, of the habits of the fish stocks, and also the fisheries themselves, it is recommended that researches along these lines should be continued.''

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