Serial No. 232.

INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES

Document No. 15

ANNUAL MEETING - JUNE 1955

GROUNDFISH STOCKS OF THE WESTERN NORTH ATLANTIC

By WILFRED TEMPLEMAN

Fisheries Research Board of Canada. Newfoundland Fisheries Research Station, St. John's.

ABSTRACT

The past, present and potential fishing levels of the stocks of cod, haddock, American plaice, halibut and redfish in Subareas 1, 2, 3, 4 and 5 of the International Commission for the Northwest Atlantic Fisheries (ICNAF) are discussed.

It is concluded that for the area as a whole the cod is in least danger of being overfished and that the haddock, American plaice, halibut and redfish of the ICNAF area have less ability than the cod to maintain their populations under unrestricted exploitation.

There have been some recent successful exploratory efforts resulting in the discovery of virgin populations of cod, redfish and American plaice in the central part of the ICNAF area.

Assessments are made of the value of mesh regulations for haddock and of the possibilities and needs for conservation measures for the various species under consideration.

INTRODUCTION

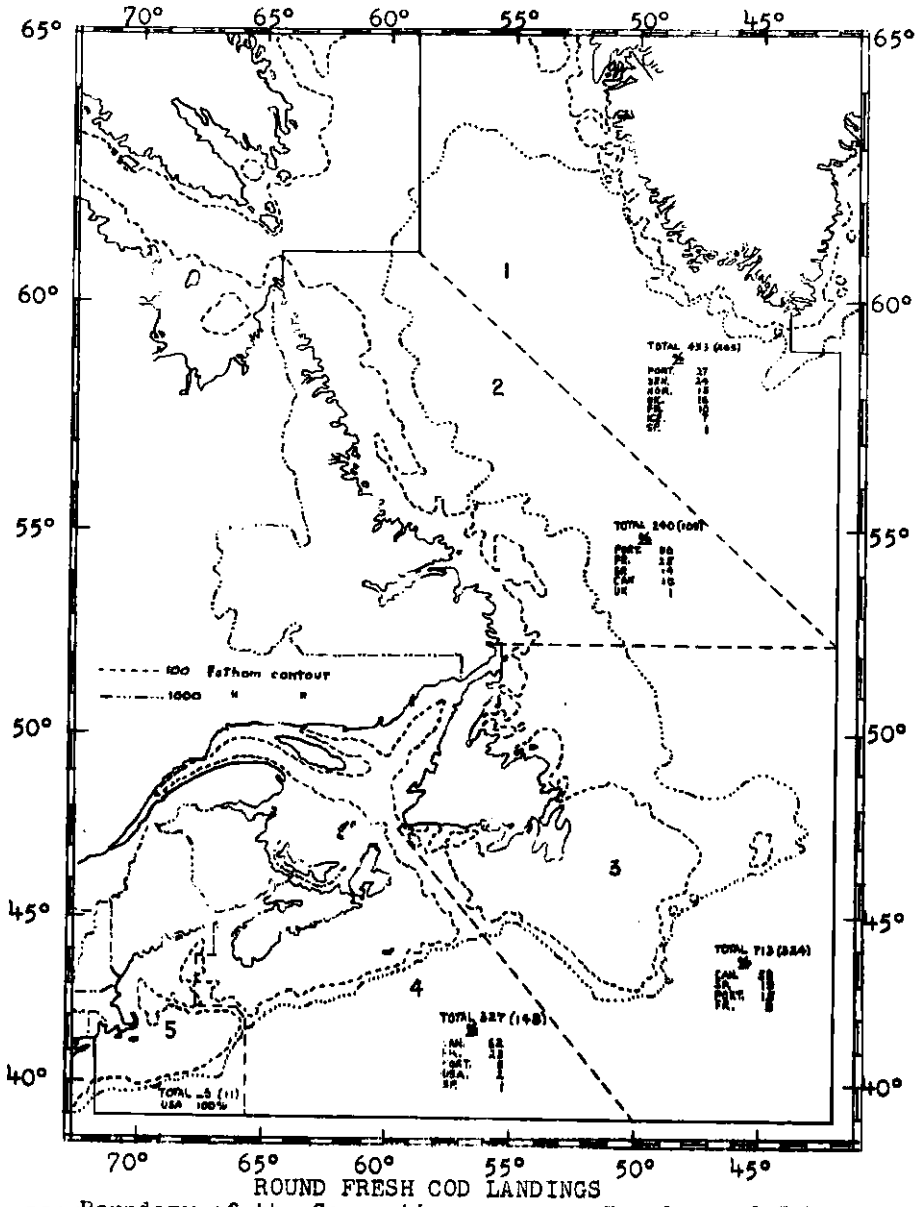
This paper gives an account of some of the chief groundfish populations of the Western North Atlantic and discusses the status of the stocks, some exploratory efforts and the conservation of these fish stocks.

The area under discussion is the Western North Atlantic from West Greenland to south of Cape Cod at Latitude 39°00'N. The divisions mentioned are the Subareas 1, 2, 3, 4 and 5 of the Northwest Atlantic as defined by the International Commission for the Northwest Atlantic Fisheries (ICNAF), Figure 1.

The Canadian groundfish catches include the Newfoundland catches. Cod, haddock, redfish, American plaice and halibut populations only, will be considered. There will inevitably be somewhat more data and greater coverage from the central areas which are best known to the author.

It is not convenient to give in each case the sources of the statistics quoted but the chief sources have been the many unpublished, mimeographed papers prepared in recent years by or for ICNAF, 1952-54, and in addition Sette (1928), Needler (1930a), the statistical portion of the Second Annual Report of ICNAF (1952) and Statistical Bulletin, Vol. 2 of ICNAF (1954).

In addition to the countries mentioned elsewhere in this paper and in Figure 1, a small amount of fishing has been carried out in recent years in the ICNAF area by Germany and Russia.



ROUND FRESH COD LANDINGS

——Boundary of the Convention area ----Boundary of Subarea
Landings are in millions of pounds with thousands of metric tons shown in brackets.

Figure 1. Total landings of fresh round cod from each subarea of ICANF in 1953 and the percentage in each subarea captured by each country. (The catch of a country obtaining less than one per cent of the catch in a subarea is omitted. Only the southern part of the Greenland subarea (1) has been shown, although the whole reported cod catch in Subarea 1 has been included. Catches by Italy of 19 million pounds from Subareas 1 and 2 and 12 million pounds from Subareas 3 and 4 are not included. About 11 million pounds caught by St. Pierre and Miquelon presumably in Subarea 3 are not included in either Figure 1 or Figure 2. The data used are the latest available, but are from ICNAF mimeographed statistics and while generally correct may not be in their final form.)

The cod and haddock populations in different subareas have been shown to be essentially separate and distinct. (Cod: Schmidt, 1930; Schroeder, 1930; Thompson, 1943; Hansen, 1949. Haddock: Needler, 1930b; Vladykov, 1935; Thompson, 1939.) The few individuals that pass the deep water barriers between subareas are insufficient to change in any measurable way the racial characteristics or abundance of the subarea populations. An exception must be made for Subareas 2 and 3 between which there is no barrier except that of distance and where there is evidently more intermigration of cod than between the other subareas. The west coast of Newfoundland section of Subarea 4 also has a stock of cod, a large part of which spends the winter in Subarea 3 and some part doubtless also in Subarea 2. Only a small proportion of Subarea 4 cod, however, are caught on the west coast of Newfoundland.

Redfish population apparently migrate little and for both redfish and American plaice, although no tagging has been done on redfish and little on plaice, evidence from size at sexual maturity and from other phases of the life-history indicate no very significant degree of movement between subareas. Probably in redfish there is some movement in the deep water between subareas but if such movements exist they are unlikely to be great enough to render invalid conclusions regarding trends of catch within subareas.

COD

Exploitation. By far the greatest fishery in the ICNAF area is for cod, Gadus callarias L. The cod fishery in the Northwest Atlantic began very shortly after Cabot's discovery of Newfoundland in 1497 and has continued for over four hundred years. Traditionally from the beginning, the fishery has been an international one in the Newfoundland area, Subarea 3 of ICNAF, which is the greatest cod area. The fishery is also international in Subareas 1, 2 and 4. In Subarea 4 Canada obtains the greatest share of the catch (62% in 1953). In this year France obtained 29% of the catch in Subarea 4. In Subarea 5 almost the whole catch is taken by the United States.

At the present time the most important cod fishing countries of the Western North Atlantic area are Canada, Portugal, France and Spain. The total of the cod catches by other European countries fishing in this area, namely, Denmark (including also West Greenland and the Faroes), Norway, the United Kingdom, Iceland and Italy, is rapidly increasing.

The total cod catch for the whole area has averaged more than 1850 million pounds per year from 1950 to 1953.

Over the ICNAF area as a whole from Greenland to Cape Cod the cod catch has been increasing considerably since the early 1930's and there has been a considerable increase since the end of World War II after a decrease in effort and in catch during the war. There is as yet no indication that the catch of cod in the area has reached its peak. Traditionally in Subareas 2, 3 and 4 Canada has caught by far the greatest amounts of cod. The Canadian proportion of the catch, however, has been decreasing and that of the European nations increasing (Figure 2). This has partly been due to the increased catches in Greenland, almost entirely by European ships, but also there has been a decreased Canadian catch relative to the European in Subareas 2 and 3. From lack of statistics on the European catch in Subarea 4, the proportions of the catch caught

by European and by North American fishermen in this subarea are in doubt except for 1953. The United States cod catch has decreased very greatly since 1880 when many of her dory-vessels fished for cod on the Grand Bank and other northern areas.

The total catch and the percentage of the cod catch in each subarea obtained by various countries in 1953 are shown in Figure 1.

In the northern Subareas, 1 and 3, West Greenland and Newfoundland, respectively, there is as yet no indication of overfishing for cod, and the Labrador area, Subarea 2, is almost certainly underfished for this species.

In Subarea 4, the Nova Scotian Banks and the Gulf of St. Lawrence, the larger part of the catch (62% in 1953) is obtained by Canada. In this area there has been some decline in Canadian and U.S. cod catches in recent years from peak landings in 1945-46 and the proportion of large cod in the landings has decreased. The available statistics of catch and effort, however, are for too short a period and the data on the European catch in Subarea 4 is too incomplete to indicate clearly a depletion in the cod population. The 1953 statistics, which for the first time show the apparently large (29% in 1953) catches by France in Subarea 4 leave us in doubt of the magnitude of the downward trend and render it imperative that attempts be made to obtain better subarea statistics and to ascribe past catches, if such is possible on the basis of existing information such as vessel logs, to the appropriate subarea.

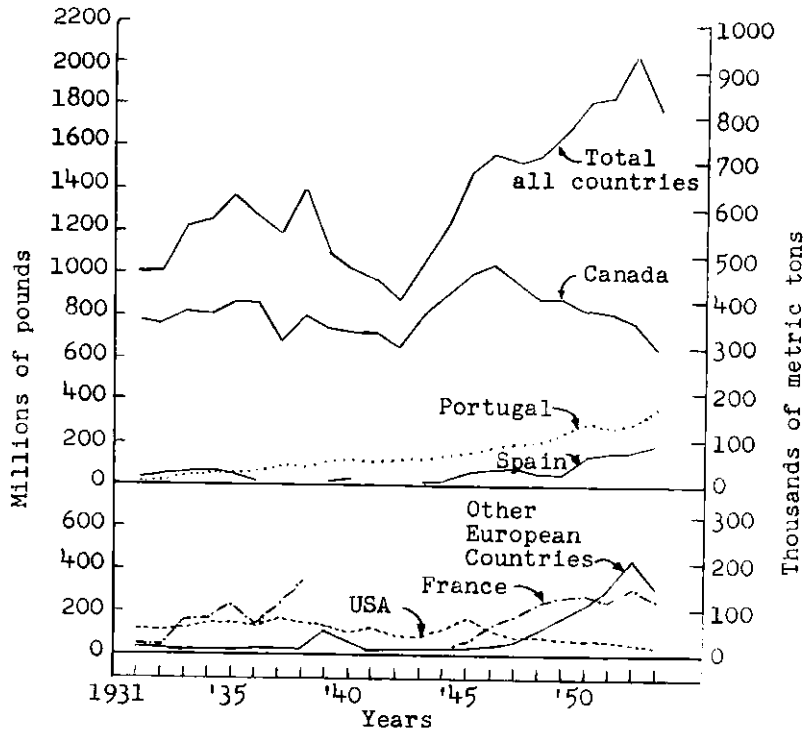


Figure 2. Landings in millions of pounds of round fresh cod, from all five ICNAF subareas, 1931-1953. ("Other European countries" include Denmark, Norway, United Kingdom, Italy and Iceland.)

In Subarea 5, including Georges Bank and most of the Gulf of Maine, and fished entirely by United States vessels, the cod landings have decreased gradually since 1930 and more rapidly since 1946. It does not appear to be certain whether this decrease is a natural one or whether it resulted from a decrease in effort by line vessels specifically directed toward cod, with an increasing proportion of the effort by trawlers devoted to catching haddock and redfish. There is a possibility that the decrease is due to increasing water temperatures which in the long run are unfavourable to the cod near its southern limits but this should not be too readily assumed until the question of the diversion of effort from cod grounds and from methods such as line fishing, especially suited to cod, is examined closely.

Exploration. It would seem to be almost an impossibility, after four centuries of intensive exploitation by many nations, that any large unfished grounds and virgin stocks of cod remain in the Newfoundland area. Such fishing grounds and stocks, however, have been discovered recently. During its long history the Newfoundland shore fishery for cod has been typically a fishery of the very shallow waters. The cod, attracted to the very shore by the onshore spawning migration of the capelin, are readily captured in June in five or ten fathoms and progressively deeper as the summer and autumn advance. These inshore cod are generally small and young. The usual gear has been the trap, the hand-line and the longline pulled by hand.

On the northeast coast of Newfoundland where these inshore cod are so abundant, fishermen in the main cod-fishing areas, which are near the headlands, have occasionally tried fishing a short distance outward from their regular fishing grounds and finding cod scarce or absent proceeded no further. Their small boats of 30 feet or less in length were unsuitable for offshore voyages and their gear was unsuitable for deepwater fishing. They also had a firm belief that there were no cod available beyond the immediate inshore area. Their fishing was thus restricted to the fishing grounds out to about six miles offshore. Here the cod were typically small and there were violent fluctuations in numbers.

By its exploratory work since 1950 the Department of Fisheries of Canada working through the Fisheries Research Board and the Board's Newfoundland Fisheries Research Station has changed completely the mental outlook toward this fishery.

Using 55-foot longliners with longline gear worked by mechanical gurdy, the area from ten to forty miles offshore has been explored systematically. In the area along the northeast coast of Newfoundland and extending northwards to Labrador the coastal water deepens rapidly to one hundred and fifty fathoms or more. The Labrador Current hugs the coast and is deepest near the coast. This current has a central core of cold water usually -1.0° to -1.5°C. or even lower in temperature and extends in the early spring from the surface to 120 fathoms or deeper. In late spring and early summer the shallow layers warm up and the traditional early summer fishery is for small cod which follow the capelin into this shallow layer of newly warmed water.

In this northern region the bigger and older cod do not usually come inshore, but remain, where all the cod both large and small have spent the winter, in the deep water typically below 120 fathoms. This deep water is Atlantic water connected with the deeper waters of the Atlantic Ocean and is warmer, more saline and heavier than the more superficial waters of the Labrador Current

These large cod were found to be very abundant in the water near and below the depth where the lower border of the below 0°C. layer meets the underlying warmer deep Atlantic layer. Once this relationship had been determined by experimental fishing off Bonavista in 1950 and 1951 the search for deepwater cod was concentrated along the deeper borders of the Labrador Current mostly 10 to 60 miles offshore and abundant supplies of large cod were found. Thus new fishing grounds with abundant large cod were found along a several hundred mile stretch of coastal shelf from Trinity Bay to Southern Labrador. Except in a very few places where the deep water came very close to the coast or where, further offshore, European trawlers had made an occasional set, these deepwater cod had not been fished. The best of the new fishing grounds, which were in deep water twenty to sixty miles off bold headlands, had apparently never been previously fished.

Here was a great reserve of large cod which as they grew older and larger and became less and less likely to visit the shallow water, were relatively safe from the effects of the fishery.

A new fishery by mechanical longline is rapidly developing for these large cod, and these newly discovered grounds and cod populations appear likely to be able to provide a catch of over a hundred million pounds of large cod per year.

REDFISH

Exploitation. The North American fishery for the redfish, Sebastes marinus (L.) began to increase rapidly in 1935 when seventeen million pounds were landed in the United States as compared with less than two million pounds in 1934 and less than three hundred thousand pounds in 1933. The redfish fishery is in deep water and until recent years has been almost entirely and even now is chiefly prosecuted by United States vessels. The chief area fished at first was the Gulf of Maine but there were some catches on the Nova Scotian Banks. As the local supply became reduced the American fishery on the Nova Scotian Banks increased and gradually spread northward.

From the Fisheries Statistics of the United States (1954) the record American redfish catch of 258 million pounds was obtained in 1951. For the whole Western North Atlantic the highest catch was about two hundred and ninety-eight million pounds in 1951. Eighty-seven per cent of this catch was by U.S. and almost all the remainder by Canadian vessels. The catch in 1953 was about two hundred and thirty million pounds. The landings are declining in Subarea 5 and in the Nova Scotian Bank areas of Subarea 4, and redfishing is gradually spreading northward. This involves the building of larger and faster redfishing vessels by the United States, to fish the Gulf of St. Lawrence and the Grand Bank areas. Beginning in 1953 the redfish in the West Greenland area, Subarea 1, began to be exploited in quantity, particularly by Icelandic trawlers.

Exploration. Since 1947 the fisheries research ship "Investigator II", operated by the Newfoundland Station of the Fisheries Research Board of Canada, has explored the abode of the redfish in the deep water between one hundred and four hundred fathoms. Some large virgin populations of redfish were found in the Gulf of St. Lawrence, on the South Coast of Newfoundland, on the southwestern and the eastern Grand Bank, on Flemish Cap, north of the Grand Bank and east of Hamilton Inlet Bank in Labrador.

In the warmer more southern parts of the area, such as on the southwestern slope of the Grand Bank, redfish are plentiful from eighty to two hundred fathoms, while off Labrador commercial quantities occur only deeper down, from about one hundred and sixty to three hundred fathoms. The northern redfish are considerably larger than the southern and the deep water redfish are larger than those of the shallow water.

In the past few years Canadian trawlers have begun to exploit in quantity these newly discovered redfish populations and American trawlers also have moved into the Gulf of St. Lawrence and to the Grand Bank areas and are landing yearly from these areas a catch several times as great as the Canadian catch. The redfish populations off the northeast coast of Newfoundland and east of Hamilton Inlet Bank have not yet been exploited commercially.

AMERICAN PLAICE

There is a small fishery for American plaice, Hippoglossoides platessoides(Fabr.), in the New England area, Subarea 5. This is of the order of three or four million pounds yearly. The American plaice, however, is more abundant in colder water in the northern Subareas 3 and 4.

In the Newfoundland area, Subarea 3, the fishery for American plaice has developed rapidly within the past few years from a catch of less than half a million pounds previous to 1948, to about thirty million pounds a year in 1951-53. Almost all this fishery is on the eastern and northern Grand Bank. Also in the Nova Scotian and Gulf of St. Lawrence areas, Subarea 4, the catch of plaice has increased from two to three million pounds a year previous to 1948, to about fifteen million pounds a year in 1952 and 1953. About twelve of these fifteen million pounds were caught on fishing grounds of the Gulf of St. Lawrence which are in the northern colder water parts of the southern half of the Gulf.

The plaice is abundant and large in the very cold water areas with bottom water close to 0°C. for most of the year. The Grand Bank areas were discovered largely through the efforts of the "Investigator II" and of Newfoundland otter-trawlers.

The Gulf of St. Lawrence fishery for plaice developed with the recent introduction of large numbers of small 55-60 foot otter-trawlers particularly in the Caraquet area of northern New Brunswick.

The "Investigator II" has found a small area on Hamilton Inlet Bank in Subarea 2, where American plaice are plentiful, but as yet there is no commercial fishery for plaice in Subarea 2.

It is a little uncertain at the present time whether or not the catch of American plaice in Subareas 3 and 4 is reaching its peak. Doubtless a greater quantity could be caught, at least for a few years, by more intensive fishing.

HALIBUT

The Atlantic halibut, Hippoglossus hippoglossus (L.), is less abundant than its Pacific relative Hippoglossus stenolepis. On the Atlantic Coast most of the halibut catch is landed by vessels using longline fishing gear. Quantities are, however, landed by otter-trawlers, particularly from the warmer slopes of the banks. These otter-trawl fish are mostly small, young halibut caught in shallower water than the line-caught larger halibut. European vessels fishing in the slope areas of St. Pierre, Green and Southwest Grand Banks for cod and haddock for salting, must catch considerable quantities of these halibut and usually discard them.

Although of lesser magnitude than the halibut population on the Pacific Coast, the halibut catch in the ICNAF area on the Atlantic Coast of North America and West Greenland might be one-quarter to one-third that on the Pacific Coast if protection could be given to the young fish. The United States catch alone was 20 million pounds gutted weight in 1896 and was over 10 million pounds in each of the years 1893 to 1900. Even in 1921 the United States catch was 6 million pounds, while the United States catch per year, in recent years, has been only about four hundred thousand pounds. The U.S. catches were made chiefly in Subareas 3, 4 and 5 of ICNAF and small amounts were taken, in the earlier years, from Subareas 1 and 2 and even from the Iceland area. A considerable decrease would have occurred in any case but the rapidity and extent of the decrease has been largely due to the decline in the United States line fishery for halibut.

The Canadian halibut catch between 1933 and 1939 ranged between three and five million pounds head-off gutted weight per year. In the period from 1940 to 1948 the average yearly catch was less than two million pounds. The low catch was due to reduced effort in halibut fishing during the war years. This led to an increase in weight of the halibut population, which when line fishing effort for halibut rose again, resulted in a catch of over ten million pounds in 1950, eight million in 1951, five and three-quarter million pounds in 1952 and six million pounds in 1953.

The United Kingdom landed over eleven million pounds of gutted halibut from the Greenland area (Subarea 1) in 1929, nine million pounds in 1930, eleven million in 1931 and over five million pounds, mostly from Subarea 1 with smaller amounts from the Labrador subarea, in each of the years 1928 to 1935. The United Kingdom halibut catch had fallen to seven hundred thousand pounds by 1938.

At present European countries land small amounts of halibut almost entirely from the Greenland area. Complete statistics are not available but the European catch in Subarea 1 in 1953 was approximately two and a half million pounds.

HADDOCK

There are three large and essentially independent groups of haddock populations on the North American Banks. These have their main winter and spawning abodes on Georges Bank, the Nova Scotian Banks and on the Newfoundland Banks respectively. These main population groupings, each of which in the two northern subareas, at least, include some relatively independent sub-groups, are separated by deep channels.

The New England stock in Subarea 5 is caught entirely by American vessels and had a peak catch of 278 million pounds of round fresh haddock in 1929. During the past twenty years the catch has stabilized at about a hundred to a hundred and twenty million pounds.

The landings of haddock in the Nova Scotian area, Subarea 4, reached their peak in 1935 when the landed catch in the United States and Canada from this area was 148 million pounds of round haddock. In 1953 the catch was about a hundred million pounds, approximately the same amount as in the New England area. In 1953 Canada obtained 56% of the haddock catch in Subarea 4, the United States 43% and Spain 1%.

Haddock populations on the Newfoundland Banks, Subarea 3, were first explored by the research trawler "Cape Agulhas" of the Newfoundland Fisheries Research Station in the years 1931-35 (Thompson, 1939). Haddock fishing on these banks was negligible before 1946 and the peak catch was in 1949 - about a hundred and fifty million pounds of round fish. Since that year there has been a decline in the catch which in 1953 was 77 million pounds. Omitting other countries which land only very small amounts of haddock, in the ten years between 1944 and 1953 about three-quarters of the haddock catch in the Newfoundland area (Subarea 3) was landed by Spain and one-quarter by Canada. In 1953 in this Subarea, Spain obtained 58% and Canada 40% of the haddock catch.

CONSERVATION

Cod. In considering the general picture of these great fisheries for groundfish in the entire ICNAF area, it is obvious that the cod fishery, after more than four centuries of heavy exploitation, shows by far the greatest resilience and ability to withstand a very heavy fishery. The actual and the potential volumes of production are also apparently very much greater for the cod than for the other groundfish.

There are many features favouring the abundance and survival of cod in the area under consideration. The cod has equally projecting upper and lower jaws and can feed at will on the bottom or in midwater. It can range and feed from the surface to two hundred fathoms although it is normally not plentiful below 160 fathoms. With its wide vertical and horizontal range the cod can accommodate itself also to a wide range of temperatures.

In the northern subareas the great abundance of the plankton feeding and pelagic capelin, Mallotus villosus, provides vast quantities of cod food and is the greatest single food factor in the maintenance of the great mass of the enormous northern cod populations. As the cod grows older and larger it favours deeper waters where it is not so readily fished. While, if food is plentiful, it may at times be present over any type of bottom, the cod, especially at the larger sizes, favours rough rocky bottom which is not readily trawled. In the adult stages cod migrate far and change their abode rapidly. In the colder areas the cod may spend a month or more, during and after spawning, largely in the upper layers of water where they are not available to ordinary otter-trawl gear. The greater and more northern portion of the cod population cannot be fished in the winter and early spring. The cod grows rapidly to a large size and this reduces the number of predatory enemies. Over most of its range, neglecting the relatively scarce sharks, the cod is the dominant large fish. The presumably predatory pollock and silver-hake and young dogfish generally live south of the main cod areas. The cod is not purely a bottom fish and the younger stages are typically further above the bottom than the larger fish, consequently the destruction of young cod by otter-trawlers is not generally nearly as great as with young haddock. (There are some exceptions to this statement in certain shallow water bank areas where young cod are abundant.) By far the greatest factor, however, is probably that especially in the northern Subareas 1, 2 and 3 of ICNAF, Greenland to Newfoundland, the rough bottom and the very large area covered by low temperature water of minus 0.5° to 3°C. favour the cod more than any other groundfish and render more likely its survival on settling from the pelagic post-larval stage. The large expanse of suitable area also, probably close to a hundred thousand square miles in Subarea 3 alone, renders failures of year-classes

unlikely and unusual in this central part of the cod range. Also the inshore waters of the east coast of Newfoundland are nurseries for young cod and the shoreward set of the Labrador Current in this area ensures an abundant supply of young cod to settle in these favourable waters. To the northward, however, in the Greenland area there are great fluctuations in year-class survival.

While, doubtless, the cod population could be managed for greater economy of effort and the sizes at capture could be increased and while through natural changes in the sea environment or through very greatly increased exploitation the situation could change rapidly, there is at present no obvious need for repressive efforts to protect cod from over-exploitation in the three northern subareas. The situations in the New England area and in the southern Nova Scotia area are more uncertain and should be studied carefully. A number of essentially separate populations of cod, however, exist in the northern subareas as well as in the southern. In Subarea 3, for example, there are at least three essentially separate populations. Some of these populations may be over-exploited while others are under-exploited and the total for the whole area or subarea may not reveal the true picture. It is wise, therefore, to study in detail each population and the effects of the fishery on it. Many countries are carrying out studies on various populations of cod in the ICNAF area.

Redfish. The redfish is a very slow-growing fish, attaining in many areas a size of less than ten inches in ten years (Perlmutter and Clarke, 1949). It is usually fished over very rough bottom, in deep water on the slopes of the banks. It is landed round at a low price, and to produce a paying trip, redfish must be caught in large quantities per day's fishing. This species, because of its slow growth and concentrated abundance in very narrow slope areas, suffers quickly under intensive fishing and each new population fished is quickly reduced in numbers. Only recently has very much been discovered on the life-history of the redfish and even now the information is so recent that most of it is unpublished.

The slow-growing redfish forms a concentrated fringe on the slope areas especially on the seaward edges of the banks and in deep depressions and channels. In all these situations it can readily be found and fished in quantity. From its slow growth and concentration and relative lack of migration it is probably continually in danger of being over-fished, and once over-fished, recovery is bound to be slower than in the case of the haddock or cod. At present prices, however, the depletion is likely to be usually more economic than biological, since, especially in distant waters, redfishing must cease when heavy concentrations are no longer available. At this population level the redfish will still have great reproductive potential.

The redfish feeds on pelagic organisms and in Europe has been caught on longlines over very deep water. Thus, there is the possibility that there are great pelagic populations of redfish, generally unrelated to the bottom, of which the schools presently fished are only a fringe where the pelagic populations impinge on the slope areas. Apart from larval distribution, (Tåning, 1949), however, there is no evidence as yet for the Western Atlantic that these great pelagic populations exist. The evidence from the experimental fishing of the "Investigator II" in deep water between 200 and 400 fathoms has been opposed to the existence of large pelagic populations of redfish. Also the quick decline in the catch per unit of effort and in the abundance of the larger sizes of female redfish in the newly

fished redfish populations of the Grand Bank and other areas, does not give any indication of replenishment of exploited slope and bottom related populations from pelagic populations. The question, however, needs much more research before an adequate answer can be given.

Suitable methods of protection which will also allow a large and profitable fishery for redfish to proceed are not yet obvious to the fisheries scientist. Mesh regulations may be possible but there are considerable difficulties. Among these are the traditional practice of capturing and filleting redfish down to a very small size and the spiny nature of the redfish which causes them to mesh readily. The very slow growth of the redfish, if natural mortality is at all large, may prevent increase in population mass from the smaller to the larger sizes at present utilized. Also, owing to the limited fishing period per day (usually in daylight only), the low price of redfish and the practice of landing them round, it is necessary to catch redfish in large quantities per hour's fishing. Thus a mesh which would liberate a very significant portion of the catch might be uneconomical. On the otherhand, on some fishing grounds there might be some increase in efficiency from the larger mesh. Also in many areas during certain months at least commercial quantities of larger redfish may be obtained by fishing more deeply.

American plaice. The very slow-growing American plaice is a bottom-living species, readily caught by otter-trawlers. In northern areas it is especially related to water of about 40 to 120 fathoms in depth. In the most heavily fished plaice areas the bottom is moderately smooth. Also on the Grand Bank, at least, a considerable reserve of plaice exists where the bottom is rough and the plaice population apparently is less concentrated and less available to trawlers.

The plaice in their cold water areas of abundance, in Subareas 3 and 4, grow to a large size but are also very slow-growing. In the commercial catches from the Grand Bank (according to Mr. R.S. Keir's age determinations at the Newfoundland Fisheries Research Station), plaice are on the average more than twenty years of age.

These concentrated populations of plaice are newly fished, slow-growing, and readily exploited from their consistent location on or near the bottom in the same areas. The fishery is too new to supply adequate evidence on whether or not the catch has reached its greatest yearly amount and what the maximum sustained yield will be. It is to be expected, however, that a considerable reduction will occur in the catch per unit effort and in the total catch when the accumulated virgin stocks of plaice are reduced by the fishery to the point where the catch must depend on the annual growth of the plaice population.

There is at present no specific plan for protecting American plaice in the ICNAF area. The 4½-inch mesh trawl-net regulations, if applied for cod, will in certain areas be a protection for young plaice. Owing to their preference for even lower temperatures than cod, quantities of plaice are encountered during many cod trips but not usually during haddock trips. For the same mesh size, due to the depth of the body in the plaice, the 50 per cent selection point for plaice is at a considerably smaller length than for haddock or cod.

Halibut. The halibut of the Northwestern Atlantic live chiefly in the waters of intermediate temperatures, particularly on the seaward slopes of the banks and in the deep channels. The deep water distribution parallels that of the redfish which is one of the chief foods of the halibut (McIntyre, 1953).

In some parts of its distribution, the northern part of the Gulf of St. Lawrence, on the southwestern portions of the Newfoundland banks, the east coast of Nova Scotia and where warm water impinges on the slopes of the banks, much of the halibut population in spring and summer moves into shallower water near the slopes of the banks or inshore. Elsewhere as on the east coast of Newfoundland and Labrador, where there is a barrier of below $0^{o}C$. water, the halibut remain throughout the year in deep water, usually more than 120 fathoms, and do not approach the shore.

A great deal of otter-trawling for other species occurs on the slopes of the banks and young halibut are particularly vulnerable as incidental catches in these fisheries for cod, haddock and redfish. These young otter-trawl halibut are doubtless caught many years before they have reached their best population weight for capture.

In the halibut areas of the Pacific Coast the halibut is the dominant large fish on the banks and otter-trawling of halibut is regulated to the advantage of the line fishermen. In the Atlantic area, however, the most important fishes on the banks near the halibut areas are the cod, haddock and redfish and the value of the halibut, both actual and potential, is not large compared with the value of the fishery for the other groundfishes. Up to the present time no good method has been found to protect halibut in the Atlantic areas where otter-trawling and line fishing for other species are greatly predominant. The present and the potential values of the Atlantic halibut fishery, however, are by no means negligible, particularly for Canada, since the landed value of halibut per pound is considerably greater than that of cod, haddock or redfish. In spite of the discouraging prospect of success, fishery biologists should occasionally try a little imaginative effort in search of ideas for the protection of the Atlantic halibut.

Haddock. Haddock grow rapidly in comparison with redfish and American plaice. They are, however, considerably faster growing in the southern part of their range on Georges Bank, than in the northern part, on the Newfoundland Banks. Haddock may thus enter the American fishery on Georges Bank at 16 inches in length and less than three years of age, while haddock of the same size on the Grand Bank and St. Pierre Bank are four to six years old. Each population has its own growth and survival characteristics and must be studied independently. Considerable yearly differences in the survival of year-classes occur in all haddock populations. These fluctuations, while always great, are much more extreme in the northern than in the southern parts of the haddock range in the ICNAF area. On the Grand Bank and St. Pierre Bank the survival rate of one haddock year-class may be a hundred times greater than that of another. Under these conditions accurate long-range forecasting of haddock abundance is at present impossible. Short-range predictions, however, are being given by studying the abundance and growth of year-classes of haddock from about one year of age and older.

Compared with the cod, the haddock with its underslung mouth is much more closely realted to bottom living and feeding and to occupancy of smooth bottom areas. All stages from one year of age and upwards are thus more vulnerable to destruction by otter-trawls than are the young of other groundfish species of similar age. In contrast with the cod where the greatest populations live beyond the influence of the Gulf Stream, all the major haddock populations of the Western Atlantic live and spawn on the northern edge of the Gulf Stream. Large eddies exist between the Gulf Stream and the haddock areas of the various banks. These in certain years and months may suck off the water from the neighbouring haddock areas of the banks,

With the water, at any time during their several month-long pelagic existence, the young haddock may be drawn off over oceanic areas with water more than a mile deep (Iselin, 1939). As in the European area, winds are doubtless of great importance in the Northwest Atlantic in the movement to favourable or unfavourable environments of the superficial layers of water containing the haddock larvae (Carruthers, Lawford and Veley, 1951; Carruthers et al, 1952; Carruthers, 1951). In the New England area the widespread nature of the dispersion of haddock eggs and larvae and the importance of currents in producing this dispersion were shown by Walford (1933).

Inevitably, when several months after hatching, these young haddock settle to take on a bottom feeding existence, they must perish if they are not over bank or slope areas preferably less than a hundred and at the most about a hundred and fifty fathoms. All this is somewhat hypothetical but very likely represents the actual case. The haddock in all areas of the Western Atlantic spawn near very deep water and it is unlikely that variations in food or temperature can account for such complete losses of haddock year-classes as occur in the Newfoundland region.

In addition to their dangerous spawning situation, the young haddock have the cod and presumably the pollock, silver hake and other fishes as predators.

In the New England area, Subarea 5, an experiment on using larger meshes in otter-trawls was begun in 1953, following advice from ICNAF. This and other measures of haddock protection were advocated much earlier by Herrington (1932, 1935, 1936 and 1941). It is hoped to prevent the killing of small haddock of sizes which were formerly thrown away at sea, and also to release for further growth some of the small haddock at sizes formerly landed. Thus it is expected that increases will occur in the landed size and in total landed weight. Since the larger fish are more valuable per pound, the values should increase also.

In Subareas 3 and 4, gear and population researches are in progress to study the biological basis for mesh regulations under ICNAF.

From the typically bottom abode of the young as well as of the older haddock a mesh regulation requiring a minimum inner wet measurement of $4\frac{1}{2}$ inches in meshes of otter-trawls should assist the preservation of haddock much more than that of cod. In most areas a larger mesh than $4\frac{1}{2}$ inches would probably be required to have a measurable effect on the cod population.

For areas and degrees of haddock abundance in which the slowing effects of crowding on growth are sufficiently small or not evident, it is possible to say that saving young haddock which are discarded at sea should represent in the future some increase in the landed catch. In the New England area, until recently, an otter-trawl cod-end mesh with internal dimensions of $2\frac{7}{8}$ inches was used. It is possible for this area, to calculate mathematically with some degree of confidence that the gain in weight by growth is probably greater than the loss from natural mortality at the sizes which would escape from a $4\frac{1}{2}$ inch or even somewhat larger mesh (Graham, 1952). Thus it may be argued that greater total catches and larger more valuable fish will be landed by the larger mesh. The expected eventual increase in yearly landings for the Georges Bank area is about 30 per cent if the fishing intensity existing at the time of the change to the larger mesh is maintained (Graham, 1952). Graham and Prometz (1955) state, on the basis of the first year's experience with the mesh regulation and in the light of recent changes in haddock sizes exploited on Georges Bank, that the long-term increase is expected to be greater than 30 per cent.

There are, however, many more unknowns than knowns involved in the argument. There is first of all the fact that the large mesh will protect not only haddock but also cod, silver hake, small dogfish, small flatfishes and other species which either are predators on haddock or compete for food with them at some stage. The effect of the larger population of small haddock below the size of retention by the large mesh, on the survival of members of still younger year-classes is unknown. Herrington (1944) has presented data supporting the idea that the presence of large quantities of older haddock is unfavourable to the survival to the scrod size of large numbers of young. It is also not possible at present to know either the total or the natural mortality rate in the youngest year-classes of haddock. A net, for example, with all its meshes so small that no one-year-old haddock can escape, will doubtless be very inefficient for capturing the larger sizes. Research vessels, also, are probably not numerous nor available enough to cover bank areas adequately for abundance studies. Thus mortality calculations for younger fish are projected back, probably incorrectly, from the older year-classes of haddock which are fully represented in the commercial fishery. While the total yearly mortality of the larger sizes can be estimated with some degree of precision, the natural mortality is in doubt at all ages but especially at the youngest and the greatest ages.

The large-meshed net is apparently more efficient for catching the larger fish (H.W. Graham, 1954 and Graham and Premetz, 1955) and thus while younger immature fish formerly caught are spared to increase in size, the older fish, from the smallest sizes fully retained, are under greater pressure and consequently should have a greater percentage total mortality than previously. Ships using larger mesh will, when it is economically worthwhile, deliberately fish for larger fish. Even when operating in the same very large and concentrated schools of small haddock as presently exist on the Newfoundland Banks, large-mesh trawlers pull the net for a considerably longer period for each set and doubtless per day's fishing than the trawlers using small mesh. Since the large-meshed net also should move somewhat faster for the same power expenditure and strain water more readily so that less water is pushed ahead of the net, it is inevitable that more fish, of the sizes fully retained by the large-meshed nets, will be caught per day's fishing by the large-mesh than by the small-mesh trawlers. Even the larger sizes below those fully retained by the large-meshed nets should show increased capture rates. If there is an increase in size and numbers and consequently value per trip, the fishing pressure will increase to reduce survival and size (M. Graham, 1954). These situations may be unfavourable only at sizes and ages where the total weight of the population is still increasing rapidly and may be favourable if an age has been reached where natural mortality equals or exceeds increase in weight by growth.

It is becoming apparent that in the Newfoundland area, where the extremes of hydrographic conditions may often concentrate haddock in dense schools over comparatively small bottom areas, the possibility cannot be overlooked that crowding retards growth. It is quite possible that similar crowding effects may be present in the cod of the Greenland and the Labrador subareas. Where such crowding is extreme the use of the large-meshed net and the saving of small haddock, whether previously discarded or retained, may not produce the expected benefits.

Since the older fish, with very much greater numbers of eggs per fish than younger fish, are being reduced in numbers faster by the more efficient large-meshed net, and the younger fish saved to grow toward maturity, it is uncertain whether or not the total number of fertilized eggs produced by the haddock population will be increased

by the large-meshed net. Many biologists will argue that within very large limits the size of the spawning population is of little or no importance. Experiences with Pacific salmon, however, show that while percentage survival of young is greater with small spawnings the total survival is greater with large spawnings, although with still larger spawnings there may be some reduction in total survival of young (Ricker, 1954). With the tendency toward destruction of new haddock year-classes before settling, it may well be important that haddock should spawn in as great a quantity as possible, and especially over as great an area as possible. The latter is obviously more likely to occur when the spawning population is large. Thus the chances are increased that at least some fringes of the floating young will settle in suitable depths and locations.

The institution of a larger mesh in otter-trawls, for groundfish populations with suitably fast growth in relation to the natural mortality, is very likely a step in the right direction but it is not necessarily the only step to be taken. At present it is best to regard the institution of a larger mesh size as a very worth-while and long-range experiment, which, with all the variety in natural survival of young haddock and of fishing intensitites, will take many years to work out. For a considerable time it will be unwise to allow other conservation measures to interfere with the assessment of the mesh experiment. In the Northwest Atlantic the best biological and statistical background for this experiment is for the haddock of the Georges Bank area. Since the area is fished by only one nation, the most complete biological and statistical data and the most efficient control of the enforcement of the mesh regulation should also be possible in this area. Proceeding northward there is less background data available and more nations involved in the cod and haddock fisheries. Thus there is much less likelihood for subareas north of Subarea 5, that if in the near future, larger mesh sizes are established by regulation, it will ever be possible to offer scientific proof of the value of the regulation.

It would be preferable that one subarea be left without mesh regulation, or even better, to have the fishery in one subarea deliberately carried out by the usual type of small-meshed nets, so as to serve as a control to the large-mesh experiment. This, however, may not be possible since ships in one trip may fish several subareas and difficulties of law-enforcement arise.

Climate. Over and above all the considerations discussed is the overriding effect of climate (Rapports et Proces-Verbaux, 1949). Increases in sea temperatures in recent years are credited with the great increase in the cod population in the Greenland area (Jensen, 1939; Dunbar, 1951; Tåning, 1953). Warmer water species such as billfish and mackerel have recently shown a phenomenal increase in the Newfoundland area (Templeman and Fleming, 1953). Recently, pollock have very greatly increased in numbers in Subarea 3. Sea temperatures have increased, also, in the New England area (Taylor and Graham, 1953) and decreases in cod abundance in the southern part of the ICNAF area may be a response to warming waters. By the same token, if water temperatures increased a little more, it is possible that on the Newfoundland Banks the haddock population and the area populated by haddock would increase and the cod population in the whole northern area shift slightly northward. The higher temperatures, however, will also increase, in the northern haddock areas, warm-water predator or competitive species such as pollock, silver hake and dogfish but decrease the predator cod. The resultant effect on the haddock population cannot be predicted adequately.

Slight increases in temperature might favour the growth of the American plaice of which the great commercial populations are in cold waters near 0°C. The lack of large American plaice populations, however, in the New England and the Nova Scotian Bank areas and in the relatively warm Southwest Grand Bank area indicates that a very few degrees temperature increase would probably render the present plaice areas unsuitable for maintaining large populations of plaice. Other flatfish species with higher temperature requirements - the winter flounder and the yellowtail flounder - would increase in numbers in Subarea 3.

Particularly at the northern and southern extremes of the range of a fish, water climate and natural fluctuations in survival of young have usually much more influence on fish numbers in the sea than any interference by human efforts. Our reasoning regarding the effects of mesh and other regulations on the fisheries is based on environmental conditions remaining approximately the same. Unfortunately for our ability to reason accurately in these matters, climatic conditions change continually and at present unpredictably. Continual routine hydrographic observations at the same stations in the fishing areas are a necessity and the biologist must do what he can to understand and assist nature in relation to fish populations. He must be wary of a typical device by which the usefulness of regulations is shown. A common method and often the only safe one politically is to make a regulation at a time when through natural fluctuations or for economic reasons the catch is low and then attribute to the regulation the increase in catch which is inevitable in any case. Fisheries regulations should usually be regarded as experimental. They should be as few as possible. It is my opinion that the fisheries biologist should not as a rule recommend an important fisheries regulation until a serious effort has been made to provide the essential background by which the effect of the new regulation may be assessed.

- THE END -

References

Carruthers, J.N.

1951. An attitude on "fishery hydrography". Sears Found., Jour. Mar. Res., 10(1): 101-118.

Carruthers, J.N., A.L. Lawford, V.F.C. Veley and B.B. Parrish

1951. Variations in brood-strength in the North Sea haddock in the light of relevant wind conditions. Nature, 168(4269): 317-319.

Carruthers, J.N., A.L. Lawford and V.F.C. Veley

1951. Fishery hydrography: brood-strength fluctuations in various North Sea fish, with suggested methods of prediction. Kieler Meeresforsch., 8(1): 5-15.

Dunbar, M.J.

1951. Eastern Arctic waters. Bull. Fish. Res. Bd. Canada, 88 : 1-131.

Graham, Herbert W.

1952. Mesh regulation to increase the yield of the Georges Bank haddock fishery. Internat. Comm. N.W. Atlantic Fish., 2nd Ann. Rept., (1951-52) : 23-33.

1954. United States research in convention area during 1953. Internat. Comm. N.W. Atlantic Fish., Ann. Proc., 4 (1953-54) : 56-59.

Graham, Herbert W. and Ernest D. Premetz

1955. First year of mesh regulation in the Georges Bank haddock fishery. U.S. Fish and Wildl. Serv., Spec. Sci. Rept. Fish., 142 : 1-26.

Graham, Michael

1954. Half a century of fishery biology in Europe. Proc. Gulf and Carribean Fish. Inst., 6th Ann. Session: 1-11.

Hansen, Paul M.

1949. The biology of cod in Greenland waters. Cons. Perm. Internat. Explor. Mer, Rapp. et Proc.- Verb., 123 : 1-77.

Herrington, William C.

1932. Conservation of immature fish in otter-trawling. Trans. American Fish. Soc., 62 : 57-63.

1935. Modifications in gear to curtail the destruction of undersized fish in otter trawling. U.S. Bur. Fish. Investig. Rept., 24 : 1-48.

1936. Decline in haddock abundance on Georges Bank and a practical remedy. U.S. Bur. Fish. Circ., 23 : 1-22.

Herrington, William C. (cont.)

1941. A crisis in the haddock fishery. U.S. Fish and Wildl. Serv. Circ., 4 : 1-14.

1944. Factors controlling population size. Trans. N. American Wildl. Conf., 9 : 250-263.

International Commission for the Northwest Atlantic Fisheries

1952. Second Ann. Rept. for the year 1951-52 (4) : 35-68.

1954. Statistical Bull., 2, (1952) : 1-52.

Iselin, C. O'D.

1939. Some physical factors which may influence the productivity of New England's coastal waters. Sears Found., Jour. Mar. Res., 2(1) : 74-85.

Jensen, Ad. S.

1939. Concerning a change of climate during recent decades in the Arctic and Subarctic regions, from Greenland in the west to Eurasia in the east, and contemporary biological and geophysical changes. Kgl. Danske Vid. Selsk., Biol. Medd., 14(8) : 1-76.

McIntyre, A.D.

1953. The food of halibut from North Atlantic fishing grounds. Scottish Home Dept. Mar. Res., 1952, No. 3 : 1-20.

Needler, A.W.H.

1930a. Statistics of the haddock fishery in North American waters. U.S. Bur. Fish. Doc., 1074 : 27-40.

1930b. The migrations of haddock and the inter-relationships of haddock populations in North American waters. Contrib. Canadian Biol. and Fish., 6(10) : 243-313.

Perlmutter, Alfred and George M. Clark

1949. Age and growth of immature rosefish (Sebastes marinus) in the Gulf of Maine and off western Nova Scotia. U.S. Fish and Wildl. Serv. Bull., 51(45) : 205-228.

Rapp. et Proc.-Verb. (various authors)

1949. Climatic changes in the Arctic in relation to plants and animals. Cons. Internat. Explor. Mer, Rapp. et Proc.-Verb., 125 : 5-52.

Ricker, W.E.

1954. Stock and recruitment. Jour. Fish. Res. Bd. Canada, 11(5) : 559-623.

Schmidt, Johs.

1930. The Atlantic cod (Gadus callarias L.) and local races of the same. Compt.-Rend. Trav. Lab. Carlsberg, 18(6) : 1-72.

Schroeder, William C.

1930. Migrations and other phases in the life history of the cod off southern New England. U.S. Bur. Fish. Doc., 1081 : 1-136.

Sette, Oscar E.

1928. Statistics of the catch of cod off the east coast of North America to 1926. U S Bur Fish Doc., 1034 : 737-748.

Tåning, Å. Vedel

1949. On the breeding places and abundance of the redfish (Sebastes) in the North Atlantic. Jour. du Cons., 16(1) : 85-95.

1953. Long term changes in hydrography and fluctuations in fish stocks. Internat. Comm. N.W. Atlantic Fish., Ann. Proc., 3 (1952-53) : 69-77.

Taylor, Clyde C. and Herbert W. Graham

1953. Changes in the distribution of marine animals in New England and Middle Atlantic waters in relation to changes in temperature. (Author's abstract). Internat. Comm. N.W. Atlantic Fish., Ann. Proc., 3 (1952-53), p. 68.

Templeman, Wilfred and A.M. Fleming

1953. Long term changes in hydrographic conditions and corresponding changes in the abundance of marine animals. Internat. Comm. N.W. Atlantic Fish., Ann. Proc., 3 (1952-53) : 79-86.

Thompson, Harold

1939. The occurence and biological features of haddock in the Newfoundland area. Res. Bull. Fish., Dept. Nat. Res. Newfoundland, 6 : 1-31.

1943. A biological and economic study of cod (Gadus callarias, L.) in the Newfoundland area. Res. Bull. Fish., Dept. Nat. Res. Newfoundland, 14 : 1-160.

United States

1954. Fishery Statistics of the United States, 1951. Fish and Wildl. Serv., Stat. Dig. 30 : 1-341.

Vladykov, V.D.

1935. Haddock races along the North American Coast. Atlantic Prog. Repts. Biol. Bd. Canada, 14 : 3-7.

Walford, Lionel A.

1938. Effect of currents on distribution and survival of the eggs and larvae of the haddock (Melanogrammus aeglefinus) on Georges Bank. U.S. Bur. Fish. Bull., 29 : 1-73.

--ooOoo--