ASSESSMENTS OF THE EFFECTS OF FISHING AND OF INCREASES IN THE MESH SIZE OF TRAWLS ON THE MAJOR COMMERCIAL FISHERIES OF THE NEWFOUNDLAND AREA (ICNAF SUBAREA 3)

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by

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A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science at the Memorial University of Newfoundland.

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1962

ABSTRACT

A method, described by Gulland(1961), for estimating the effects on fisheries of changes in gear selectivity is reviewed and applied to data of the major commercial fisheries of the Newfoundland Area (ICNAF Subarea 3). Methods of estimating the essential parameters are also briefly described. The changes in gear considered are in reality increases in the mesh size of trawls, the other gear components remaining unchanged.

For assessment purposes the subarea has been divided into several regions, largely on the basis of a knowledge of the cod stocks, and the fisheries in them have been considered separately. Some evaluation of the effects of fishing on the cod and haddock stocks has been made, and for these fisheries both immediate and long-term assessments of increases in the mesh size of trawls have been computed. Also given are the effects of such mesh size changes on the landings by gears other than trawls. Because of the recent development of the redfish fisheries in most regions and of the scarcity of adequate data from the major redfish-producing countries, the assessments that can be made are restricted largely to the calculation of the immediate losses.

The assessments indicate that the mesh sizes required to produce the optimum long-term yields vary greatly between regions for the different species. Since two or more species

are often present on the same fishing grounds and caught by trawlers, for practical reasons a uniform mesh-size regulation must be considered for the subarea as a whole. A 4½-inch mesh size in trawls is shown to be the optimum for the cod and haddock fisheries considered together. Despite the lack of long-term assessments for the redfish fisheries, the available information suggests that long-term benefits are unlikely from any increase in mesh size, although an increase to 4 inches would result in only slight immediate losses for most regions. No long-term assessments were made for the flounder fishery, but cursory examination of selection ogives and length composition data indicates that an increase in mesh size to 6 inches would not affect the commercial landings. Since it is not practical to have different mesh sizes throughout the subarea, it is concluded that a minimum mesh size of 4½ inches might be a fair choice for the regulation of the trawl fisheries on all species.

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SECTION 1. INTRODUCTION

The need for conservation arises at some time or other in nearly all fisheries which are intensively exploited. When the fishing intensity increases on a virgin or unexploited stock, the annual catches rise rapidly to a peak, but after a few years they decline almost as rapidly as they increased and gradually attain an equilibrium at a level somewhere below that of the best years of the fishery. During the decline from the peak level the demand for regulation usually arises, particularly if a new and more efficient method of fishing is introduced. The conception that the stock is being overfished, because it now yields less than it originally did, is a false one, for the catches during the peak years were not the yields of those years but the withdrawal of reserves built up in previous years. In fact, the thinning out of the population may be of great benefit to man, for the removal of the old slow-growing fish that add very little to their individual weights in the consumption of large quantities of food may result in their replacement by many more young fast-growing fish that use their food mainly in adding to their weight. However, it is inevitable that, as the fishing pressure continues to increase, the need for conservation measures becomes significant. The purpose of conservation is to control man's predation in such a way as to maintain the crop available for harvesting at the highest sustainable level.

The fisheries of the Northwest Atlantic Ocean are the oldest in the Western Hemisphere (with the exception of any fishing carried on by the original inhabitants of the Americas), having been prosecuted by European fishermen for more than 450 years. Their methods of finding and catching fish were crude when compared with the efficient fish-finding apparatus and fishing gears of today. In recent years grave concern has been felt for the fisheries because of the rapidly expanding fleets of large trawlers which frequent the offshore banks off the East Coast of Canada all the year round. With their modern navigational aids, echo-sounders, fish-finding apparatus and large bag-like nets which are dragged over the bottom, they are very efficient in finding and catching fish, but they are equally as efficient in destroying large quantities of small unmarketable fish, unless the meshes of the nets are large enough to permit their escape.

Recognition of the problem of wastage of small fish as well as that of reduced abundance and possible depletion of the fishery resources of the Northwest Atlantic Ocean led to the formation in 1950 of the International Commission for the Northwest Atlantic Fisheries, commonly referred to as ICNAF. The boundries of the ICNAF Area are shown in Figure 1. At present the participating nations are Canada, Denmark, France, Germany, Iceland, Italy, Norway, Portugal, Spain, the Union of Soviet Socialist Republics, the United Kingdom, and the United States of America. The purpose of the Commission is contained in the preamble to the Articles of the Convention (Appendix 1 of the Report of the First Annual Meeting of the Commission held at Washington in 1951) and reads as follows : "The Governments whose duly authorized representatives have subscribed hereto, sharing a substantial interest in the conservation of the fishery resources of the Northwest Atlantic Ocean, have resolved to conclude a convention for the investigation, protection and conservation of the fisheries of the Northwest Atlantic Ocean in order to make possible the maintenance of a maximum sustained catch from those fisheries ... ".

One of the first duties of the Commission was to institute an efficient and detailed study of the various fisheries from the viewpoint of determining the landings with regard to a breakdown by gear and season into the smallest statistical areas considered feasible. In addition, the participating countries were urged to intensify their biological research programs on the various fisheries in order that the necessary biological information might become available as soon as possible. All the statistical and biological data, submitted to ICNAF, are made available to research workers in three annual publications : the ICNAF Statistical Bulletin, the ICNAF Sampling Yearbook, and the ICNAF Annual Proceedings. It was from these publications that the author extracted a very large part of the information necessary to effect this study of the immediate and long-term effects of regulating the trawl component of the major fisheries carried on in ICNAF Subarea 3.

The first objective of such a study must be the examination and interpretation of the changes that have probably occurred throughout the history of the fisheries with a view to establishing the effects of fishing on the stocks, both from a study of long-term trends in stock abundance and by the estimation of mortality rates, and to distinguishing between the changes that may have been due to fishing and those resulting from natural fluctuations in stock abundance. The second objective is to utilize these results in an effort to make some assessment of the effects on the fisheries of introducing regulations in order to eliminate as much wastage of small fish as possible, to avoid possible depletion in the future and to maximize the yield from the fisheries. With these objectives in mind this study is a preliminary attempt to assess the major commercial fisheries of the Newfoundland area (ICNAF Subarea 3), insofar as assessments are possible from the data available at the present time.

Since the end of World War II there has been a very rapid increase in the fishing effort of the relatively modern method of fishing with trawls, which involves dragging over the bottom a bag-like net capturing both large and small fish in its path, as distinct from the more ancient method of hook and line fishing, which is dependent on how hungry the fish are. For many decades Newfoundland fishermen have depended on the migration of cod into the shallow coastal waters during the summer months. These fish belong to stocks of cod which in the autumn, winter and spring live in deep water on the offshore slope and bank areas and are there fished extensively by large trawlers from a dozen or more countries. Depletion of these offshore concentrations would have a detrimental effect on the inshore fishery of Newfoundland. In recent years much concern has been expressed for the future of the fisheries, and much study has been devoted to methods of controlling the devastation of small fish by trawlers and to methods of regulating the fisheries such that the maximum sustained yield may be obtained from them. The present assessments for the various increases of mesh size in trawls do not so much compare present yields with future yields, but rather they compare the yields by small-meshed trawls with the yields that probably would have been obtained had larger-meshed trawls been used during the period under consideration.

For the cod and haddock fisheries of Subarea 3 it has been possible in some instances to show that fishing is having an effect on the stocks, and for these fisheries calculations have been made of the possible long-term effects of increasing the mesh size of trawls. For the redfish fisheries, on the other hand, existing data are for the most part inadequate and the assessments that can be made are limited. Since the haddock, redfish and flounder fisheries are carried on offshore only by trawlers, no other gear components will be affected by any regulation of the mesh size in trawls. The cod fisheries are prosecuted largely by trawlers on the offshore banks, but a large segment of the annual yield is caught in the inshore coastal waters of Newfoundland by such gears as codtraps, handlines, linetrawls, jiggers, gillnets, etc., which throughout this study are classed together as inshore gears. Consequently, any regulation of the mesh size in trawls will produce different long-term effects on the landings of the unregulated gears. Therefore, insofar as it was possible from the data available, assessments have been made to demonstrate the effects that a regulated trawl fishery would have on each important unregulated gear component of the fishery. The assessments are based for the most part on research and statistical data up to and including the year 1958. Except when indicated otherwise, the mesh sizes referred to throughout this paper are internal measurements of the trawl meshes in the wet condition, made by an ICNAF standard longitudinal wedge-shaped gauge inserted in the mesh under a pressure of 10-15 pounds.

In order to illustrate the significance in the Northwest Atlantic of the rich fishing grounds of Subarea 3, the recent average annual landings of the four major commercial fisheries in each ICNAF subarea are shown in Figure 1. In Figure 2 are given the recent average annual landings of these same four fisheries by trawlers and by other gears for the divisions of Subarea 3. All references in this paper to landings of fish, given in tons, refer to metric tons of round fresh fish.

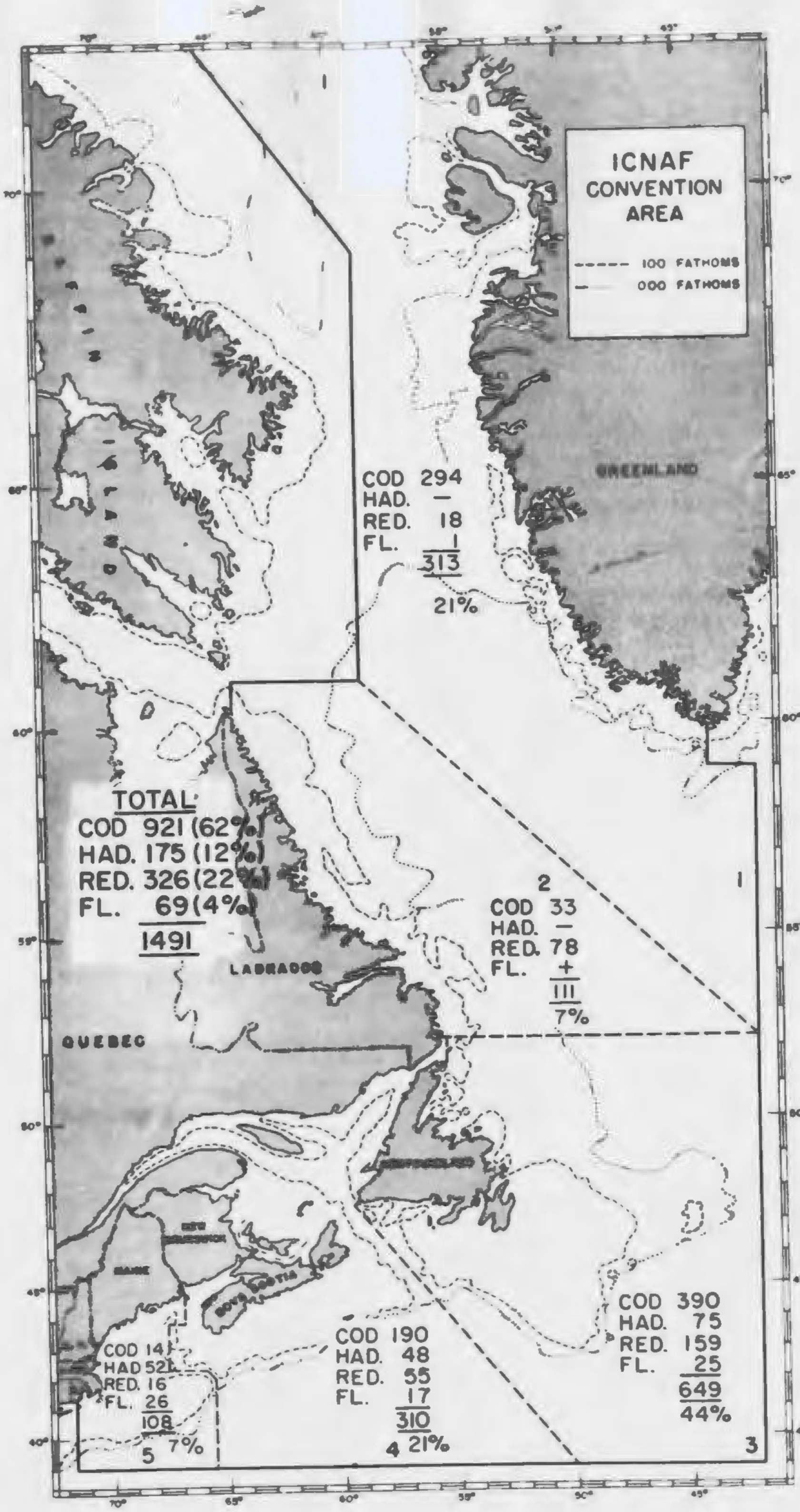

Figure 1. Chart of the ICNAF Area showing by subareas the average annual landings of cod and haddock for 1955-58, and of redfish and flounder in 1958 (thousands of metric tons).

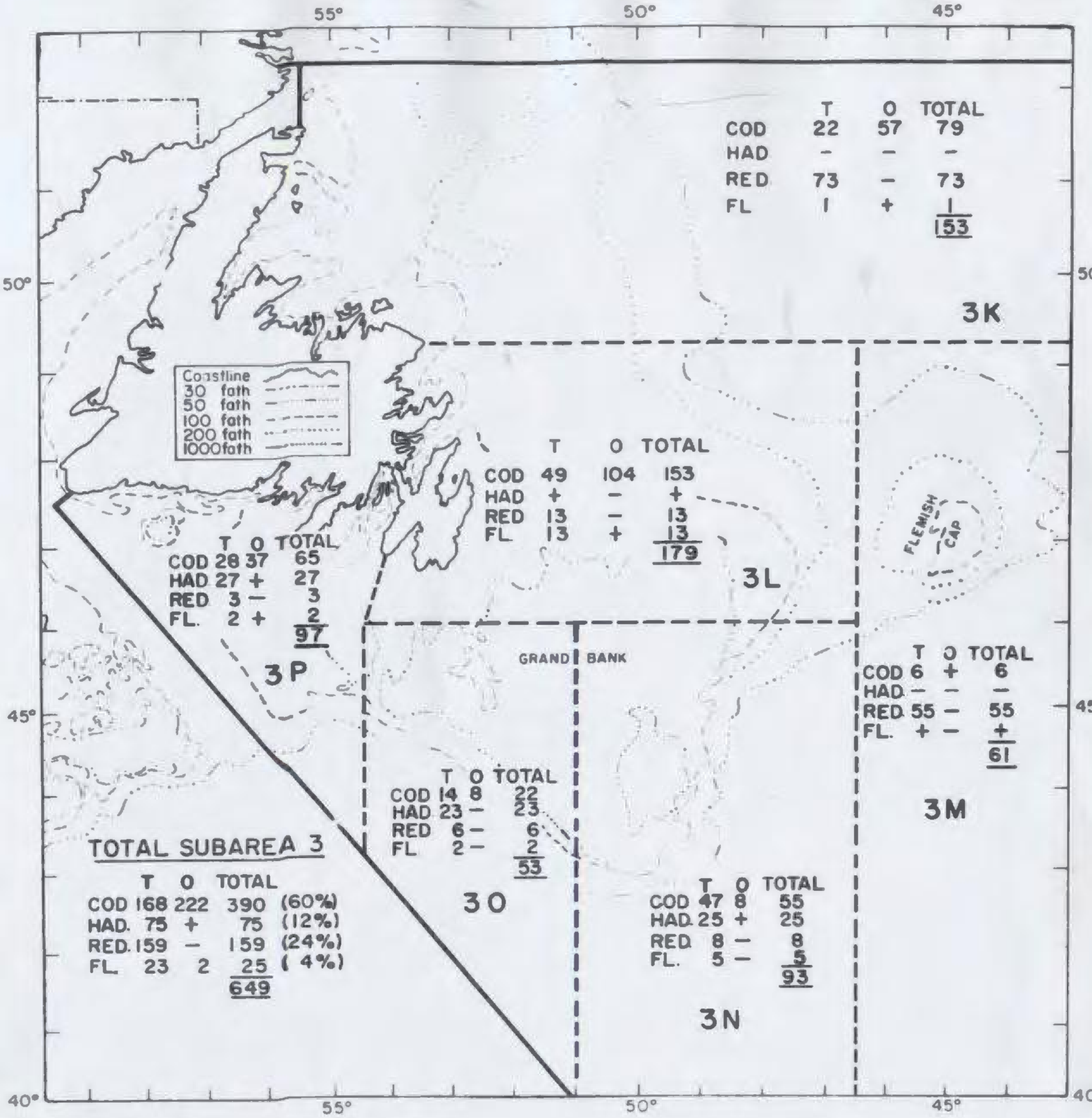

Figure 2. Chart of ICNAF Subarea 3 showing by divisions the average annual landings of cod and haddock for 1955-58, and of redfish and flounder in 1958 (thousands of metric tons).

SECTION 2. METHODS OF ASSESSMENT

A. Data Requirements and the Methods Used

When the size of mesh is increased beyond that at present in use by trawlers, a certain number of small fish that would have been retained by the small-meshed gear will escape capture. Most of these will survive and grow to a larger size at which they can be later retained by a larger mesh. A certain proportion of them will eventually be caught and their average size when they are caught will be the same as that of the rest of the fish in the catch by the larger mesh. If this proportion is high enough and if considerable growth has occurred in the interim, their total weight will exceed the weight of the fish released, and so there will be a long-term gain to the fishery. In order to assess the long-term effects on a fishery of an increase in the mesh size of trawls, the basic requirements are: (a) the present size compositions of the catches by all gears, (b) the recent annual landings by gears, (c) the selection curves for the various trawl mesh sizes under consideration, (d) an estimate of the proportion of the released fish that will eventually be caught, and (e) information on the growth rate of the species. If precise assessments are to be made, fairly reliable estimates of the natural and fishing mortality rates are required.

A very efficient method of making an assessment of a fishery when such data are available has recently been developed by Gulland (1961). The more conventional methods, particularly that of Beverton and Holt (1957), require the use of age-length data, by which the length compositions of the released fish are converted to length-at-age frequencies by year-classes, and each year-class has to be dealt with separately in a complex yield equation. Gulland's method, on the other hand, does not require the use of age compositions, which are often inadequate or not available, but treats the length composition of the catch directly and requires only a fairly reliable growth curve embracing the selection range of the gear. As well as being more efficient in treating data, Gulland's method is much quicker to apply when the essential parameters are known, and it is especially useful in assessing complex fisheries, in which a number of different gears are operating, the size compositions of the catches of which are very different. Gulland's method has therefore been used throughout this study, but in view of its very recent development and limited distribution (a detailed description of the method was still in press at the time of writing this paper) it is necessary to outline the theory of the method as it pertains to the calculation of the long-term changes in the yield for fisheries in which a single trawl gear is operating, and also for fisheries in which several different gears are used.

B. Gulland's Method of Assessment

1. Symbols and definitions

In order to avoid the repetition of definitions throughout this section, the principal symbols with their definitions are as follows:

$_TN_R$ the number of fish released by an increase in the mesh size of trawls.

$_TW_R$ the weight of the $_TN_R$ fish.

$_TN_K$ the number of fish in the immediate kept catch of the large-meshed trawls (i.e. the number that would have been retained if the larger mesh had been used).

$_TW_K$ the weight of the immediate kept catch ($_TN_K$).

$_TW$ the weight of the fish caught by the small-meshed gear.

$_TW_L$ the weight of the fish landed from the catch by the small-meshed trawls.

$(_TW_K)_L$ the weight of the fish landed from the immediate kept catch by the large mesh

$_TL$ the percentage immediate loss to the trawl catch as a result of an increase in the mesh size.

$_TL_L$ the percentage immediate loss to the trawl landing as a result of an increase in the mesh size.

$_ON$ the number of fish landed by an unregulated gear.

$_OW$ the weight of the $_ON$ fish.

$_ON'$ the number of fish landed by an unregulated gear, of sizes greater than the maximum length of the fish released by trawls with the large mesh size.

$_OW'$ the weight of the $_ON'$ fish.

$_ON''$ the weighted portion of that part of the landings of the unregulated gear whose fish are within the length range of fish released by the large-meshed trawls.

$_OW''$ the weight of the $_ON''$ fish.

E the proportion of the released fish that will eventually be caught ($= F/(F+M) = F/Z$).

M the instantaneous rate of natural mortality due to the death of fish by all causes except man's fishing, commonly called the natural mortality coefficient.

F the instantaneous rate of fishing mortality, commonly called the fishing mortality coefficient.

Z the instantaneous total mortality coefficient ($Z = F + M$).

Δt the increase in the mean age at first capture resulting from an increase in the mesh size.

e the base of natural logarithms.

2. Calculation of the immediate loss

Any increase in the mesh size of trawling gear must result in an immediate loss to the trawl catch. This parameter ($_TL$) is simply the ratio of the weight of the released fish to the weight of the fish caught by the initial small-meshed gear, viz,

$$_TL = \frac{\text{old catch}(_TW) - \text{immediate kept catch}(_TW_K)}{\text{old catch }(_TW)} = \frac{_TW_R}{_TW} \quad \ldots\ldots(1)$$

3. Calculation of the long-term change for a single trawling gear operating on a fish stock

In applying the method proposed by Gulland, we must consider the fate of the $_TN_R$ fish that would have been released, had the larger mesh size been in use at the time during which the length composition is considered representative of the catch. They will be subjected to natural mortality (M) for a period before they become liable to capture by trawls with the larger mesh size. This period (Δt) is the time between the mean selection ages of fish caught by the small and large mesh sizes. Some of the ${}_TN_R$ fish, which are only just large enough to be caught by the small mesh, will with the introduction of a larger mesh size be subjected to M for the whole of the period Δt. Others, which would have been captured by the small mesh only just before they reached a size at which they would become liable to capture by the larger mesh, will be subjected to M for only a very short time. On an average the ${}_TN_R$ fish will be subjected to M for a period of about $\frac{1}{2}\Delta t$.

The rate of natural mortality at any time t depends on the number present at that time and can be written as

$$\frac{dN}{dt} = -MN \quad \text{.............................} \quad (2)$$

This form of expressing the rate of decrease of a population (N) has been used by many authors, among them being Baranov (1918), Graham (1935), Schaefer (1943), Ricker (1944), and more recently Beverton and Holt (1957). The solution of this differential equation gives the number remaining in the population at any time t as

$$N_t = (\text{constant}).\ e^{-Mt} \quad \text{..................} (3)$$

where the constant of integration referred to is the initial number in the population at time $t = 0$. Since we are interested only in integrating (2) over the period $\frac{1}{2}\Delta t$, using the ${}_TN_R$ released fish as the initial number, by substitution in (3) we have

$${}_TN_{R'} = {}_TN_R.e^{-\frac{1}{2}M\Delta t} \quad \text{......................} \quad (4)$$

which is an expression for the number of the released fish that will be expected to survive and to become liable to capture by the larger mesh. Some of these will be caught at an early age as soon as they are large enough to be retained by the larger mesh, but others will escape the large-meshed gear initially and might live to an old age before being caught. If <u>E</u> is the proportion of these ${}_TN_{R'}$ fish that will eventually be caught, the actual number that will be caught in the long-term is

$$ {}_TN_{R''} = E.{}_TN_{R'} = E.{}_TN_R.e^{-\frac{1}{2}M\Delta t} \quad \text{............} \quad (5)$$

and the immediate kept catch (${}_TN_K$) will therefore increase by the proportion <u>Q</u>, where

$$ Q = \frac{{}_TN_{R''}}{{}_TN_K} = \frac{{}_TN_R}{{}_TN_K}.E.e^{-\frac{1}{2}M\Delta t} \quad \text{............} \quad (6)$$

In actual weight units the immediate kept catch (${}_TW_K$) will increase by an amount ($Q.{}_TW_K$), which is the <u>expected gross gain</u>. Remembering that any increase in the mesh size will result in an immediate loss to the trawl catch of ${}_TN_R$ fish whose weight is ${}_TW_R$, the <u>net</u> long-term change will be $Q.{}_TW_K - {}_TW_R$. Expressing this change relative to the catch (${}_TW$) by the small mesh gives the long-term change in the yield by trawlers as

$$ {}_TG = \frac{Q.{}_TW_K - {}_TW_R}{{}_TW} \quad \text{....................} \quad (7)$$

and, since ${}_TL = {}_TW_R/{}_TW$, and $1 - {}_TL = {}_TW_K/{}_TW$ from equation (1), we may write (7) as

$$ {}_TG = (1 - {}_TL)Q - {}_TL \quad \text{..................} \quad (8)$$

which is an expression for the change in yield relative to the catch by the small-meshed trawls. If $_TG$ is positive, an increase in the mesh size would eventually be beneficial, but a negative $_TG$ means that a long-term loss would result. It must be remembered here that the whole analysis is based on the assumptions that the stock of fish is in equilibrium with the environment and that future levels of fishing intensity will be approximately the same as at present.

4. Treatment of discards

For fisheries in which considerable quantities of fish are discarded at sea as being too small for the market, any assessments based entirely on catch data would not give a very realistic picture of the changes in yield resulting from an increase in mesh size, because the quantity landed rather than that caught is the more important. Therefore, account must be taken of this factor when making assessments of such fisheries. The ideal situation would be to have available length compositions of both catches and landings, from which data a "cull" or discard curve can be calculated. However, even if only the proportion by weight of the catch discarded is known, it is better to estimate a length composition for these discards rather than disregard them altogether.

Taking discards into consideration, the immediate loss to the landings as a result of an increase in the mesh size of trawls is now calculated from landing data only as

$$_TL_L = \frac{_TW_L - (_TW_K)_L}{_TW_L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

As before in equation (6), the value of $\underline{Q}$ is calculated from catch data only.

Using the value obtained for $\underline{Q}$ from equation (6) and the value for ${}_TL_L$ from equation (9), the long-term change in the landings of trawlers can now be written as

$$ {}_TG_L = (1 - {}_TL_L)Q - {}_TL_L \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10) $$

5. Calculation of the long-term changes when several gears are operating on a fish stock

So far the case in which a fishery is carried on by a single gear (i.e. trawls, the mesh size of which is increased) has been considered. Most fisheries, however, are carried on by several types of gear: for example, the cod fisheries of the Newfoundland area (ICNAF Subarea 3) are prosecuted on the offshore banks by trawls and lines, whereas in the coastal waters Newfoundland fishermen use a variety of gears. In such areas, where several types of gear are used, the fish that are released by an increase in the mesh size of trawls would most certainly benefit the landings by those gears which are not regulated, since some of the fish released by the large-meshed trawls would survive and eventually be caught by the unregulated gears. Consequently, any assessment of such fisheries must also take into account not only the predicted gain or loss to the trawl fishery but also the benefits that would accrue to these unregulated gears which operate in the same area or on the same fish stocks.

The calculation of the immediate loss to the trawl catch is the same as before in equation (1), or if the assessments are being made in terms of landings equation (9) must be used.

In order to assess the long-term changes, it is now necessary to make adjustments for the total number of fish caught by all the unregulated gears. For example, suppose an unregulated gear operates on that part of a fish stock whose length composition is completely below the selection range of the small-meshed trawls; the landings from such a fishery cannot be considered in the assessments, for no matter how many fish were released by large-meshed trawls the fishery by the unregulated gear would not be affected, since none of the trawl released fish would subsequently be caught by this gear. If, on the other hand, all the fish caught by the unregulated gear were of greater length than the maximum length of fish released by the large-meshed trawls, the fishery by the unregulated gear would receive its share of the benefit, proportional to the ratio of the catch by the unregulated gear to the total catch of this gear and the trawling gear combined. If, however, an appreciable part of the catch by the unregulated gear consists of fish within the length range of the fish released by an increase in the mesh size of trawls, the total catch of the unregulated gear must be adjusted before it can be used in the assessments. The procedure, as proposed by Gulland, is to calculate the total number ($_ON'$) of fish caught by the unregulated gear of lengths greater than the maximum length of the fish released by the large-meshed trawls. To this quantity must be added a weighted fraction ($_ON''$) of that part of the catch by the unregulated gear whose fish are within the length range (L_1 to L_2) of fish released by an increase in the mesh size of trawls. This weighted portion is found by the relationship

$$_ON'' = \sum_{L_1}^{L_2} {_ON_i''} = \sum_{L_1}^{L_2} p_i \cdot {_ON_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

where p_i = the proportion of fish released by trawls that are smaller than length $\underline{i}$,

and $_ON_i$ = the number of fish of length $\underline{i}$ caught by the unregulated gear.

For each unregulated gear, the number $({}_ON' + {}_ON'')$ must be calculated and also the corresponding weight $({}_OW' + {}_OW'')$. If there are several unregulated gears in addition to trawls, the value of $\underline{Q}$ in this case (compare with equation (6)) is

$$Q = \frac{{}_TN_R}{{}_TN_K + \Sigma({}_ON' + {}_ON'')} \cdot E \cdot e^{-\frac{1}{2}M\Delta t} \quad \ldots\ldots\ldots\ldots \quad (12)$$

It must be noted that, in cases where the size composition of the catches of the unregulated gears is wholly above the range of sizes of fish released by large-meshed trawls, $_ON''$ will be equal to zero. Also, any part of the catches by the unregulated wholly below the smallest of the trawl-released fish must be disregarded completely in calculating the term $({}_ON' + {}_ON'')$.

As before, the long-term change in yield for the trawl fishery is given by equation (8) for catch data and by equation (10) for data of landings, but we must use the value of $\underline{Q}$ obtained from equation (12).

For any particular unregulated gear $\underline{O}$, the long-term change in its catch (or landing, if such data are used) will be

$$_OG = Q\left\{\frac{{}_OW' + {}_OW''}{{}_OW}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

If the whole of the catch of the unregulated gear is above the maximum size of fish released by the large-meshed trawls,

then $$_OG = Q \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

since $_OW''$ would be equal to zero and $_OW'$ would be equal to $_OW$.

SECTION 3. ESTIMATION OF THE PARAMETERS

In order to illustrate the application of the Gulland method of assessing a fishery, we shall utilize the data for the cod fishery of one of the regions considered in Section 5. Before doing this, however, the methods of estimating certain basic parameters, apart from those obtained from the length-composition data, must be discussed. These parameters are the total mortality coefficient (Z), the selection ogives for the various mesh sizes, the ratio of fishing to total mortality (E), and the estimation of Δt.

A. Estimation of the Total Mortality Coefficient (Z)

Throughout this study the total mortality coefficients have been estimated by the standard method of determining the rate of decrease in abundance of age-groups with increasing age from age-composition data of the catches. It is customary to combine age-composition data for several years in order to eliminate or reduce the effects of fluctuations in recruitment of fish to the exploited phase of the population.

The theory underlying the determination of total mortality rates from age-composition data has been reviewed by Beverton and Holt (1957), and it is sufficient here to give only the basic relationships representing the decrease in abundance of an age-group with increasing age. If N_t represents the number present at age <u>t</u>, the numbers at successive ages, $t+1$, $t+2$, ... $t+r$, are given by the relationships:-

$$N_{t+1} = N_t e^{-(F+M)}$$

$$N_{t+2} = N_t e^{-2(F+M)}$$

and

$$N_{t+r} = N_t e^{-r(F+M)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

By taking the natural logarithms of (15) and rearranging the terms, we obtain

$$F+M = \frac{1}{r} \log \left\{\frac{N_t}{N_{t+r}}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (16)$$

General experience in fisheries research has shown that, when age-composition data are plotted on semi-log paper (see Figure 7), the descending right limb of the resulting catch curve will generally be linear, and the slope of this line can be used as an indication of the magnitude of the total mortality coefficient (Z). The estimates of Z, used in the cod and haddock assessments, have therefore been found by plotting the age-composition data on semi-log paper, by drawing the best-fitting straight line through the points of the descending right limb of the curve, and then by calculating the slope from equation (16) using values of N_t and N_{t+r} taken from the line.

B. Estimation of the Ratio of Fishing to Total Mortality (E)

In none of the regions considered in this paper was it possible with the limited data available to divide Z into its natural and fishing components (M and F) from which a reliable value of E (= F/Z) could be obtained. It was therefore necessary to use a range of E values, which was thought to embrace the true value at present (1955-58) levels of fishing intensity. However, some assurance that the lower limit of the range is a minimum value can be obtained from tagging data, when the percentage of tag returns from a given experiment over a period is known.

Without reviewing the theory underlying the use of tagging data in estimating mortality rates, which problem has been discussed in detail by Beverton and Holt (1957), it is only necessary here to give one of their equations (page 189 of their paper) and show how an estimate of the minimum value of E can be obtained. The equation referred to gives the relationship between the total recaptures over a period of time and the number of fish initially tagged, viz.,

$$\sum_{x=1}^{r} n_x = \frac{FN_0}{F+X}(1 - e^{-r(F+X)}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (17)$$

where $\sum_{x=1}^{r} n_x$ = $n_1 + n_2 + n_3 + \ldots\ldots + n_r$, which represents the total recaptures over a period of r years for the case where recaptures are considered on an annual basis;

N_0 = the initial number of fish liberated;

F = the rate of reduction of tagged fish due to fishing (the fishing mortality coefficient);

and X = the rate of reduction of tagged fish due to all other causes (the other-loss coefficient), including natural deaths, mortality of tagged fish due to tagging, and the detachment of tags from living fish prior to recapture.

By rearranging the terms of equation (17) , we have

$$\frac{F}{F+X} = \frac{n_1 + n_2 + \ldots\ldots + n_r}{N_0} \cdot \left(\frac{1}{(1 - e^{-r(F+X)})}\right) \quad \ldots\ldots\ldots \quad (18)$$

In cases where r represents a number of years and F+X is a value not greatly different from the general order of magnitude of the values of Z considered in this paper for the cod assessments, the last term (in brackets) of equation (18) will be sufficiently close to the value of one that we may write the approximation

$$\frac{F}{F+X} = \frac{n_1 + n_2 + \ldots + n_r}{N_o} \quad \ldots\ldots\ldots\ldots\ldots (19)$$

(For example, if r = 6 years and F + X = 0.8, say, then from e^{-x} tables we find that the last term of (18) equals 1.008.)

The right hand side of (19) is simply the ratio of total recaptures over a period of r years to the total number of fish initially liberated. The denominator of the left hand side can be considered to have the same significance as the total mortality coefficient (F+M), which we have discussed previously; but it will always be greater than F+M, because X is greater than M. Consequently the ratio $\frac{F}{F+X}$ will always be less than $\frac{F}{F+M} = E$, but it serves the purpose of establishing a lower limit for the range of E. Tagging data have been used for this purpose in the cod assessments of Divisions 3K, 3L and 3P.

C. The Selection Ogives

Experiments carried out by many workers in the field of fisheries research have shown that the selective action of trawls does not cause all fish to have the maximum probability of being caught upon reaching a certain critical size; rather the probability of individuals being caught by trawls of given selective properties varies over a certain size range of fish, known as the "selection range". Typically the probability of retention by trawls of fish in the selection range can be described by a

S-shaped or sigmoid curve as in Figure 17. It is also common knowledge that the main selective action of a trawl takes place in the cod-end, and throughout this study the mesh sizes refer to the cod-end of the trawl.

The properties that usually define the selectivity of trawls are the 25, 50 and 75% retention lengths of fish, or often only the 50% retention length and the "selection span" (distance between the 25 and 75% retention lengths) are given. Jensen (1949) and others have shown that for many species of fish there is an approximate proportional relationship between the 50% retention length (l_r) and the cod-end mesh size, given by

$$l_r = b.(\text{mesh size}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (20)$$

where <u>b</u> is a constant called the "selection factor". Consequently, when for a particular species the selection factor and the selection span are known, it is possible to determine the 25, 50 and 75% retention lengths for each mesh size. When these are plotted on probability paper and a straight line drawn through them, the percentage retained for each length-group over the selection range can simply be read off from the straight line. Figure 3 shows on probability paper the lines for the 4-inch and the 6-inch mesh sizes, from which the corresponding selection ogives for cod have been prepared (see Appendix II). The data used refer to cod-end meshes of double manila twine, and are from a summary of trawl selectivity data for the Northwest Atlantic Ocean by Clark, McCracken and Templeman (1958).

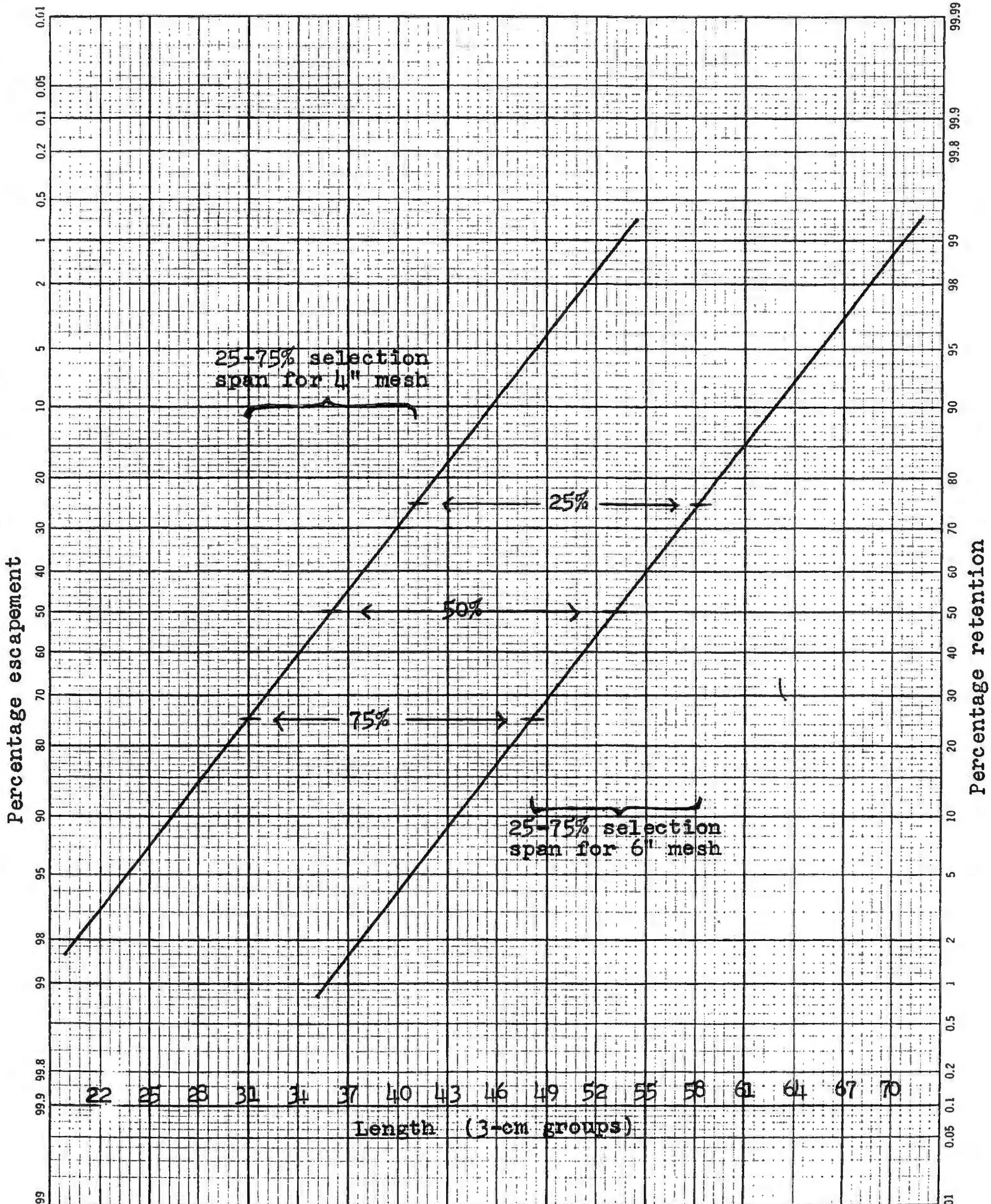

Figure 3. Selection curves of the 4 and 6-inch mesh sizes for cod as illustrated on probability paper.

D. Estimation of Δt

The value of Δt, required for the calculation of the long-term changes in yield of a fishery, is the difference between the mean ages at first capture for the large and the small mesh sizes. This is best found by estimating the mean retention lengths from the ascending left limbs of the curves obtained when the length composition of the small-meshed trawl catch and that of the immediate kept catch of the large mesh are plotted on graph paper. The mean retention lengths (l_c) are then converted to mean ages at first capture (t_c) by the relationship

$$t_c = t_o - \frac{1}{K} \log \left\{ 1 - \frac{l_c}{L_\infty} \right\} \quad \ldots\ldots\ldots\ldots\ldots \quad (21)$$

where t_o, K and L_∞ are the parameters of the appropriate growth curve (see Figure 8). This relationship (21) is a rearrangement of the von Bertalanffy* growth equation, which has been discussed in detail by Beverton and Holt (1957).

The method of estimating the mean retention lengths is shown in Table 1. These are then converted to mean ages at first capture, and the difference between them is an estimate of Δt.

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* von Bertalanffy produced a number of papers on the theory of organic growth, but the mathematical representation of growth discussed by Beverton and Holt is based largely on his 1938 paper.

E. Example of Computations Involved in Making the Assessments

The first essential for an assessment of this kind is a representative set of catch (or landing) length composition for each major gear component of the fishery. We shall consider here the data for cod from ICNAF Division 3P, which encompasses the coastal waters along the south coast of Newfoundland and also the offshore banks. The cod fishery in this region, discussed in detail in Section 5, has been divided into three major components by types of gear - trawl, offshore line, and inshore gears - and the length compositions of these gear components are given in Appendix I, Table 5. In view of the importance of the inshore fishery, which would obviously receive some benefits from any mesh size regulation that might be imposed on the offshore trawl fishery, we must apply the data to the case of multiple gears (see pages 20-22). In order that we may obtain a more realistic picture of the results, we must take into account the discarding of small unmarketable fish.

From a knowledge of the offshore trawl fishery during the 1955-58 period, gained by the author in reviewing many of the research reports presented annually to ICNAF by the various countries fishing in the Newfoundland area and by his attendance at a number of ICNAF Annual Meetings, the effective trawl mesh size in use was considered to be about 3 inches. Also it was generally customary for trawlers to discard, as too small, cod below a length of about 45 centimeters. Lacking adequate data of discards, therefore, "knife-edge" discarding was taken as lying between the 42-44 and 45-47 centimeter length-groups.

In Table 2 is given an example of the worksheet for the computations involved in determining the immediate effect of an increase in the mesh size of trawls from an initial 3 inches to a larger mesh size of 5 inches. The 3-centimeter length-groups of column A are standard for the reporting of cod length frequencies. The mean weights of column B were obtained from the measurement at the St. John's Biological Station, Newfoundland, of several thousand cod taken by research vessels over all seasons and during a period of several years (Appendix III). In column C is the length composition of the trawl catch by the small mesh. Columns D and E are the selection ogives of the small and the large mesh sizes respectively, and column F the ratios of the large to the small mesh retention factors. In column G is the length composition of the immediate kept catch, that is, the catch by numbers that would have been obtained had a 5-inch mesh size been used instead of the small mesh. In column H are the numbers that would have escaped the large-meshed trawls to grow larger and become liable to capture at some later time. Column I gives the weight of the trawl catch that was landed while the small mesh size was used, and column J gives the weight of the immediate kept catch that would have been landed had the large mesh been used, assuming that there would have been no change in the practice of discarding small fish at sea. Using the weight totals of columns I and J, the immediate change relative to the small-meshed trawl landings is computed from equation (9) as -4.32%.

Since the length composition of the landings of the inshore gears overlaps considerably the selection range of the trawling gear, it is necessary to adjust these landings (note that we consider landings instead of catches for the gears not being regulated, since any discards that they might have does not matter in the case where only the mesh size of trawls is being regulated). The procedure for adjusting these landings is given on pages 21-22, and a worksheet showing the necessary calculations for the inshore fishery is given in Table 3. The length composition of the inshore landings is given in column C. Columns D, E and F show how the weighting factors over the trawl selection range are obtained, and column G is the adjusted length frequency, the total of which we must use in equation (12). Column H is the weight of this adjusted frequency, and column I the weight of the original frequency of the landings.

Actually we should also adjust the length frequency of the offshore line fishery in the same manner, but it will be noted from Appendix I, Table 5, that this fishery makes only a very minor contribution to the total cod landings from this region, and also that the greater part of the length composition lies above 61 centimeters (the upper limit of the trawl selection range for the 5-inch mesh). Therefore, any adjustment would have only a very slight, if any, effect on the final results.

For the long-term assessments an estimate of Δt is needed, and the value that we shall use is $\Delta t = 0.4$ years from Table 1, representing the difference between the mean selection ages of fish caught by the 5-inch and 3-inch mesh sizes.

The only remaining parameter, $E = F/(F+M)$, is usually the most difficult to estimate. However, a fairly consistent value for the total mortality coefficient, $Z = 0.6$, has been estimated for this region from age-composition data (see Figure 7), and by considering a range of values for the natural mortality coefficient (M) , within which the true value is thought to lie, some appreciation of the possible effects of an increase in the mesh size may be obtained. A wide range of $\underline{M}$ from 0.10 to 0.30 has been used, giving corresponding values of $\underline{E}$ from 0.83 to 0.50 respectively. In Section 5 it is shown from tagging data that the lower limit of this range of $\underline{E}$ values is not unreasonable.

Having obtained values for all the necessary parameters, we can now proceed with the calculation of the long-term effects of an increase in the mesh size of trawls, using equations (10), (12), (13) and (14) of the previous section. Table 4 is a worksheet of the computations. Since we have not adjusted the length composition of the offshore line fishery, the values of $\underline{Q}$ represent the changes in the yield of this fishery directly from equation (14), and the values of $\underline{Q}$ multiplied by 100 represent the percentage changes. With regard to the inshore fishery, there is reason to believe that this fishery would not benefit fully from an increase in the mesh size of trawls, since some of the fish that would be released by the large-meshed trawls might remain on the offshore banks where they would not be liable to capture by the inshore gears. It was assumed, therefore, that about one-half of the released fish would subsequently become liable to capture by the inshore gears, and the effects of this assumption can be achieved in the computations simply by considering only one-half of the values for $_{O}N' + _{O}N''$ and $_{O}W' + _{O}W''$ from Table 3. The percentage changes in the yield of the inshore fishery over the range of E considered are represented by the values of $_{O}G$ multiplied by 100, where $_{O}G$ is obtained from equation (13). The percentage changes in the yield of the trawl fishery are represented by the values of $_{T}G_{L}$ multiplied by 100, where $_{T}G_{L}$ is obtained from equation (10). It will be noted that the values for the changes in both the inshore fishery and the offshore line fishery are all positive, since any increase in the mesh size of trawls will always provide some long-term benefits to these unregulated fisheries. For the trawl fishery, however, the first value of $_{T}G_{L}$ under $M = 0.30$ is negative, indicating that if the natural mortality rate is as high as this it would be detrimental at least for the trawl fishery to increase the mesh size. For M values of 0.20 and 0.10 the values of $_{T}G_{L}$ are positive and an increase in mesh size would be beneficial.

Table 1. Method of estimating the mean ages at first capture (t_c) from the left limbs of length-composition catch curves. (Worksheet refers to catch curves of 3-inch and 5-inch mesh sizes of trawls for cod in Division 3P.)

Length	Left limb of catch curve	r_2/r_1	Resultant catch curve	First differences, d_i	
3-cm groups	3-inch mesh	Col. F, Table 2	5-inch mesh	3-inch mesh	5-inch mesh
28	10	0.017		10	
31	22	0.053	1	12	1
34	43	0.105	4	21	3
37	108	0.183	20	65	16
40	285	0.309	88	177	68
43	657	0.455	299	372	211
46	1033	0.610	630	376	331
49	1444	0.760	1097	411	467
52	1695	0.870	1475	251	378
55	1781	0.940	1674	86	199
58	1781*	0.980	1745		71
61	1781	0.990	1763		18
64	1781	1.000	1781		18
			Σd_i =	1781	1781
			$\Sigma d_i l_i$ =	82064	87596

The mean selection length is found from the relationship:

$$l_c = \frac{\Sigma d_i l_i}{\Sigma d_i} - 1.5 \text{ cm.}$$

For the 3-inch mesh, $l_c = \frac{82064}{1781} - 1.5 = 44.6$ cm.

For the 5-inch mesh, $l_c = \frac{87596}{1781} - 1.5 = 47.7$ cm.

From the growth curve of Figure 8, the corresponding mean selection ages by equation (21) are: $t_c = 3.9$ years for the 3-inch mesh,

and $t_c = 4.3$ years for the 5-inch mesh.

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* In cases where the selection range for the large mesh size extends beyond the mode of the length-composition curve for the small mesh, it is customary to apply the retention factors beyond the mode to the value of the mode itself rather than to the decreasing values beyond the mode.

Table 2. Method of computing the immediate effects of an increase in the mesh size of trawls. (Worksheet refers to trawl-caught cod in Division 3P.)

A	B	C	D	E	F= E/D	G= C.F	H= C-G	I= B.C	J= B.G
l	w	$_TN$	r_1	r_2	r	$_TN_K$	$_TN_R$	$_TW_L$	$(_TW_K)_L$
3-cm groups	kg	('000)	3-in mesh	5-in mesh	r_2/r_1	('000)	('000)	tons	tons
28	0.18	10	0.60	0.01	0.017	-	10		
31	0.25	22	0.75	0.04	0.053	1	21		
34	0.33	43	0.86	0.09	0.105	4	39		
37	0.43	108	0.93	0.17	0.183	20	88		
40	0.54	285	0.97	0.30	0.309	88	197		
43	0.68	657	0.99	0.45	0.455	299	358		
46	0.84	1033	1.00	0.61	0.610	630	403	868	529
49	1.02	1444		0.76	0.760	1097	347	1473	1119
52	1.23	1695		0.87	0.870	1475	220	2085	1814
55	1.46	1781		0.94	0.940	1674	107	2600	2444
58	1.72	1755		0.98	0.980	1720	35	3019	2958
61	2.01	1504		0.99	0.990	1489	15	3023	2993
64	2.32	1197		1.00	1.000	1197		2777	2777
67	2.68	804				804		2155	2155
70	3.07	584				584		1793	1793
73	3.49	510				510		1780	1780
76	3.95	415				415		1639	1639
79	4.45	367				367		1633	1633
82	4.99	264				264		1317	1317
85	5.58	125				125		698	698
88	6.22	56				56		348	348
91	6.89	39				39		269	269
94	7.62	27				27		206	206
97	8.40	13				13		109	109
100	9.22	13				13		120	120
103	10.11	9				9		91	91
Totals		14760 $_TN$				12920 $_TN_K$	1840 $_TN_R$	28003 $_TW_L$	26792 $(_TW_K)_L$

From equation (9) the immediate change in the trawl landing would be:

$$_TL_L = \frac{_TW_L - (_TW_K)_L}{_TW_L} = \frac{28003 - 26792}{28003} = 0.0432 = 4.32\%$$

Table 3. Method of adjusting the length composition of gears which are not being regulated. (Worksheet refers to inshore cod of Division 3P.)

A	B	C	D	E	F = n_i / N_R	G = F.C	H = G.B	I = C.B
l	w	$_ON$	$_TN_R$	n_i^*	p_i	$_ON'+_ON''$	$_OW'+_OW''$	$_OW$
3-cm groups	kg	('000)	('000)			('000)	tons	tons
28	0.18		10	10	0.005			
31	0.25		21	31	0.017			
34	0.33	7	39	70	0.038			2
37	0.43	69	88	158	0.086	6	3	30
40	0.54	336	197	355	0.193	65	35	182
43	0.68	798	358	713	0.387	309	210	544
46	0.84	1167	403	1116	0.607	708	595	980
49	1.02	1524	347	1463	0.795	1212	1236	1555
52	1.23	1689	220	1683	0.915	1545	1900	2077
55	1.46	1709	107	1790	0.973	1663	2428	2496
58	1.72	1546	35	1825	0.992	1534	2638	2660
61	2.01	1340	15	1840	1.000	1340	2693	2693
64	2.32	1218				1218	2826	2826
67	2.68	1015				1015	2720	2720
70	3.07	818				818	2511	2511
73	3.49	647				647	2258	2258
76	3.95	459				459	1813	1813
79	4.45	339				339	1509	1509
82	4.99	230				230	1148	1148
85	5.58	157				157	876	876
88	6.22	110				110	684	684
91	6.89	88				88	606	606
94	7.62	61				61	465	465
97	8.40	49				49	412	412
100	9.22	28				28	258	258
103	10.11	21				21	212	212
106	11.05	13				13	144	144
109	12.04	11				11	132	132
112	13.09	13				13	170	170
115	14.21	6				6	85	85
118	15.39	4				4	62	62
121	16.63	6				6	100	100
124	17.93	5				5	90	90
124	20.78	3				3	62	62
Totals		15486 $_ON$				13683 $_ON'+_ON''$	30884 $_OW'+_OW''$	32362 $_OW$

* This column is simply the accumulated sum of column D.

Table 4. Method of calculating the long-term changes resulting from an increase in the mesh size of trawls. (Worksheet refers to an increase in mesh size from 3 to 5 inches for cod in Division 3P.)

PARAMETERS

From Table 2,	${}_T N_R$	= 1840	
From Table 2,	${}_T N_K$	= 12929	
From Appendix I, Table 5,	${}_0 N$ (offshore)	= 1127	(not adjusted)
From Table 3,	$\frac{1}{2}({}_0 N' + {}_0 N'')$ (inshore)	= 6842	(adjusted)
For equation (12),	$\frac{{}_T N_R}{\text{Total } N_K \text{ (adjusted)}}$	$= \frac{{}_T N_R}{{}_T N_K + {}_0 N + \frac{1}{2}({}_0 N' + {}_0 N'')}$	
	$= \frac{1840}{12920 + 1127 + 6842}$	= 0.08808	
From Table 3,	$\frac{\frac{1}{2}({}_0 W' + {}_0 W'')}{{}_0 W}$	$= \frac{15442}{32362} = 0.47716$	
From Table 2,	${}_T L_L$	= 0.0432	
and	$1 - {}_T L_L$	= 0.9568	
From Table 1,	Δt	= 0.4 years	
From Figure 7 for Division 3P,	$Z = F + M$	= 0.6	

Range of M considered	0.30	0.20	0.10
Corresponding range of $E = F/Z$	0.50	0.67	0.83
$\frac{1}{2}M\Delta t$	0.06	0.04	0.02
$e^{-\frac{1}{2}M\Delta t}$	0.9418	0.9608	0.9802
$E \cdot e^{-\frac{1}{2}M\Delta t}$	0.47090	0.64374	0.81357
$Q = \frac{{}_T N_R}{{}_T N_K + {}_0 N + \frac{1}{2}({}_0 N' + {}_0 N'')} \cdot E \cdot e^{-\frac{1}{2}M\Delta t}$	0.04148	0.05670	0.07166
${}_0 G = Q\left(\frac{\frac{1}{2}({}_0 W' + {}_0 W'')}{{}_0 W}\right)$ (inshore)	0.0198	0.0271	0.0342
${}_T G_L = Q(1 - {}_T L_L) - {}_T L_L$ (trawl)	-0.0035	0.0110	0.0254

SECTION 4. COMMENTS ON INTERPRETATION OF RESULTS

The long-term assessments, calculated by the methods of the preceding sections, indicate how a given increase in the mesh size of trawls would be expected to affect the average annual level of the 1955-58 landings compared with what was actually the case during this period, throughout most of which the effective mesh size of trawls was assumed to be about 3 inches. The assessments are based on the supposition that present levels of fishing intensity will remain unchanged. It is also supposed that there would be no change in the distribution of fishing on the stocks. However, even if no change in the amount of fishing occurred, it would be expected that an increase in the mesh size of trawls might in reality have the useful effect of encouraging trawlers to fish more on grounds containing larger fish. While it is not possible tompredict the extent or the effect of this, such a tendency would certainly improve the overall general exploitation of the stocks.

For this study it has been assumed that the selectivity of trawling gear only is regulated. The trawl selectivity data, from which the selection ogives were prepared (Appendix II), have been obtained from experiments carried out largely by small research vessels in the New England, Nova Scotia and Newfoundland areas and reported by Clark, McCracken and Templeman (1958). No selectivity data are available for large trawlers of the types used by the European countries, and no critical evaluation of the existing data has been attempted. Although it is known that selection curves obtained from research vessel experiments, generally from relatively small catches, tend to yield higher selection factors than those obtained from large catches, the assessments would probably not be significantly affected, since any differences would be relative.

For the cod and haddock fisheries of Subarea 3 calculations have been made of the probable long-term effects of increases in the mesh size of trawls at present (1955-58) levels of fishing intensity. Of the parameters required for long-term assessments, the ratio of fishing mortality to total mortality ($E = F/Z$) is generally the most difficult to estimate and this parameter may critically affect the results of the computations. In this study, therefore, the procedure has been adopted of calculating long-term assessments for a range of $\underline{E}$ values. The wide range of $\underline{E}$ used has generally resulted in a rather wide range of predicted long-term changes in yield for the various mesh sizes. However, useful conclusions can nevertheless be drawn from them.

For the redfish fisheries the existing data are generally inadequate and the assessments that can be made are even more restricted than those for cod and haddock. The lack of age-composition data does not permit the estimation of a total mortality coefficient (Z) much less the separation of $\underline{Z}$ into its natural and fishing components, and no long-term assessments can be made. In such cases, however, it is possible to estimate a value of E which, for a given increase in mesh size, would leave the long-term yield unchanged. This value of E is derived as follows: By equating the net long-term change in yield (page 17) to zero, we have

$$Q \cdot {}_T W_K - {}_T W_R = 0$$

and by rearranging the terms

$$Q = \frac{{}_T W_R}{{}_T W_K} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

By substituting for Q from equation (6) we obtain

$$\frac{{}_T N_R}{{}_T N_K} \cdot E \cdot e^{-\frac{1}{2}M\Delta t} = \frac{{}_T W_R}{{}_T W_K}$$

from which $$E = \frac{{}_T N_K \cdot {}_T W_R}{{}_T N_R \cdot {}_T W_K} \cdot \left(\frac{1}{e^{-\frac{1}{2}M\Delta t}}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

Considering the possible ranges of M and $\frac{1}{2}\Delta t$, the term $(-\frac{1}{2}M\Delta t)$ is small and hence $e^{-\frac{1}{2}M\Delta t}$ is not greatly different from the value of one. Consequently the value of $\frac{1}{e^{-\frac{1}{2}M\Delta t}}$ will be sufficiently close to one that it can be disregarded in equation (23). (For example, suppose that $M = 0.20$ and $\Delta t = 1.0$ years, then $\frac{1}{e^{-\frac{1}{2}M\Delta t}} = \frac{1}{e^{-0.1}} = \frac{1}{0.9048} = 1.105$.)

Disregarding, therefore, the last term in equatinn (23), we may write an expression for the minimum value of E, viz,

$$E' = \frac{{}_T N_K \cdot {}_T W_R}{{}_T N_R \cdot {}_T W_K} = \frac{{}_T \bar{W}_R}{{}_T \bar{W}_K} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (24)$$

where ${}_T \bar{W}_R$ = the mean weight of the fish released by an increase in the mesh size of trawls,

and $_{T}\overline{W}_{K}$ = the mean weight of the fish in the immediate kept catches of the large-meshed trawls.

This critical value of $\underline{E}'$ (called the minimum "break-even" value) serves to indicate how intense the fishing would have to be in order for an increase of mesh size to result in long-term gain.

Some consideration must also be given to the significance of the immediate losses to trawls indicated in Section 5. They have been calculated directly from the size compositions of catches and the selection ogives for the various mesh sizes, taking discards into account where possible, but in interpreting these immediate losses several points should be borne in mind:

(a) There is substantial evidence (Clark, McCracken and Templeman, 1958) that an increase in the mesh size of trawls increases the fishing power of the gear and results in bigger catches of larger fish above the selection range of the mesh size.

(b) The reduced catches of smaller fish caused by an increase in the mesh size might encourage trawlers to fish less on concentrations of small and medium-sized fish and more on grounds where larger fish are abundant in sufficient quantities to still make fishing worthwhile.

(c) In fisheries where the discarding of small fish has been a general practice, it would be expected that with a larger mesh size proportionately fewer of the small fish caught would be discarded.

(d) The values of the immediate losses, quoted in the assessment tables of the next section, represent the losses at the moment the large mesh size is introduced. From that time onward the fish released by the larger mesh would grow into the selection range and the immediate losses would become progressively less. The losses over the first full year of fishing by trawls with the larger mesh size would, therefore, be considerably less than those experienced initially. In later years the changes in landings would approach the values given for the long-term effects.

All the above points indicate that the true immediate losses may well be less than the values given in the assessment tables, and consequently the long-term changes may be more favourable.

SECTION 5. THE ASSESSMENTS

A. Cod

1. Brief review of the fisheries

From its beginning in the early sixteenth century, shortly after Cabot's discovery of Newfoundland, the cod fishery on the Newfoundland banks has been the greatest fishery in the Northwest Atlantic Ocean. It has traditionally been an international one, the principal competitors during the first three centuries after the discovery being Britain and France. Canadian and USA dory-vessel fleets carried on extensive line fisheries on the offshore banks during the second half of the nineteenth century, but since 1900 these have declined rapidly and are now negligible. Although Portuguese and Spanish vessels fished on the Newfoundland banks before the present century, it has only been since 1930 that their cod landings have formed a significant part of the annual cod yields.

The Newfoundland cod fishery has always been almost entirely an inshore fishery, carried on with a great variety of gears. It is prosecuted largely during the summer months when the cod are attracted towards the coast by the onshore spawning migration of capelin. Prior to about 1930 the traditional methods of fishing by the European fishermen on the offshore banks have been handline and linetrawl fishing from dories, which operated from vessels called "dory schooners". Following the introduction of trawling in the 1920's, the once very extensive offshore line fishery rapidly declined. Except for Portugal, which still has a large dory-vessel fleet, most of the offshore cod fishery is carried on at present by large trawlers.

The earliest available statistics of the cod fishery are those of Newfoundland landings from 1804 and of French landings from 1874 (ICNAF Annual Report for the Year 1951-52). During the period from 1804 to about 1880 the Newfoundland annual cod landings show an upward trend from about 100 thousand to 250 thousand tons; between 1885 and 1900 the landings were fairly steady at about 200 thousand tons; and the period since 1905 is characterized by a stabilization of the landings at a level between 220 thousand and 300 thousand tons annually. From 1874 the French landings fluctuated greatly between 20 thousand and 190 thousand tons annually, the low levels having occurred in periods of depression and war-time (Figure 4).

Since about 1935, for most of the countries fishing in the Northwest Atlantic, statistics of cod landings are available by ICNAF subareas and by methods of fishing. These are given in Appendix I, Table 1, for Subarea 3. During this more recent period (1935-58) annual landings have increased from less than 250 thousand tons prior to 1945 to more than 400 thousand tons in the 1950's (Figure 5). Newfoundland inshore landings (excluding those of Labrador in Subarea 2) fluctuated between 125 thousand tons just prior to World War II and 230 thousand tons immediately after the war; in recent years the annual

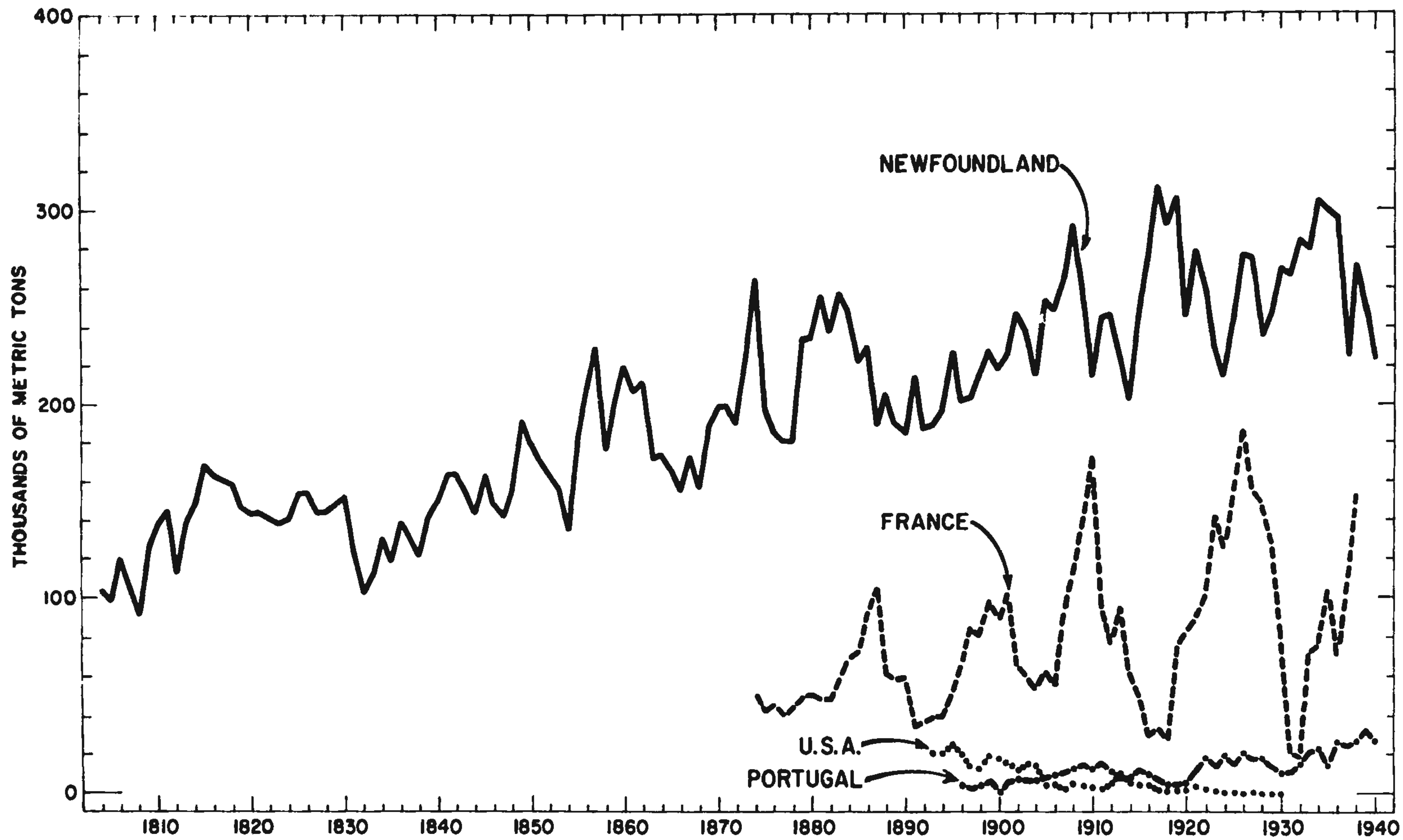

Figure 4. Landings of cod from Newfoundland waters and adjacent banks by countries from which statistics are available prior to 1930. (Drawn from statistics reported in ICNAF Annual Report for the Year 1951-52.)

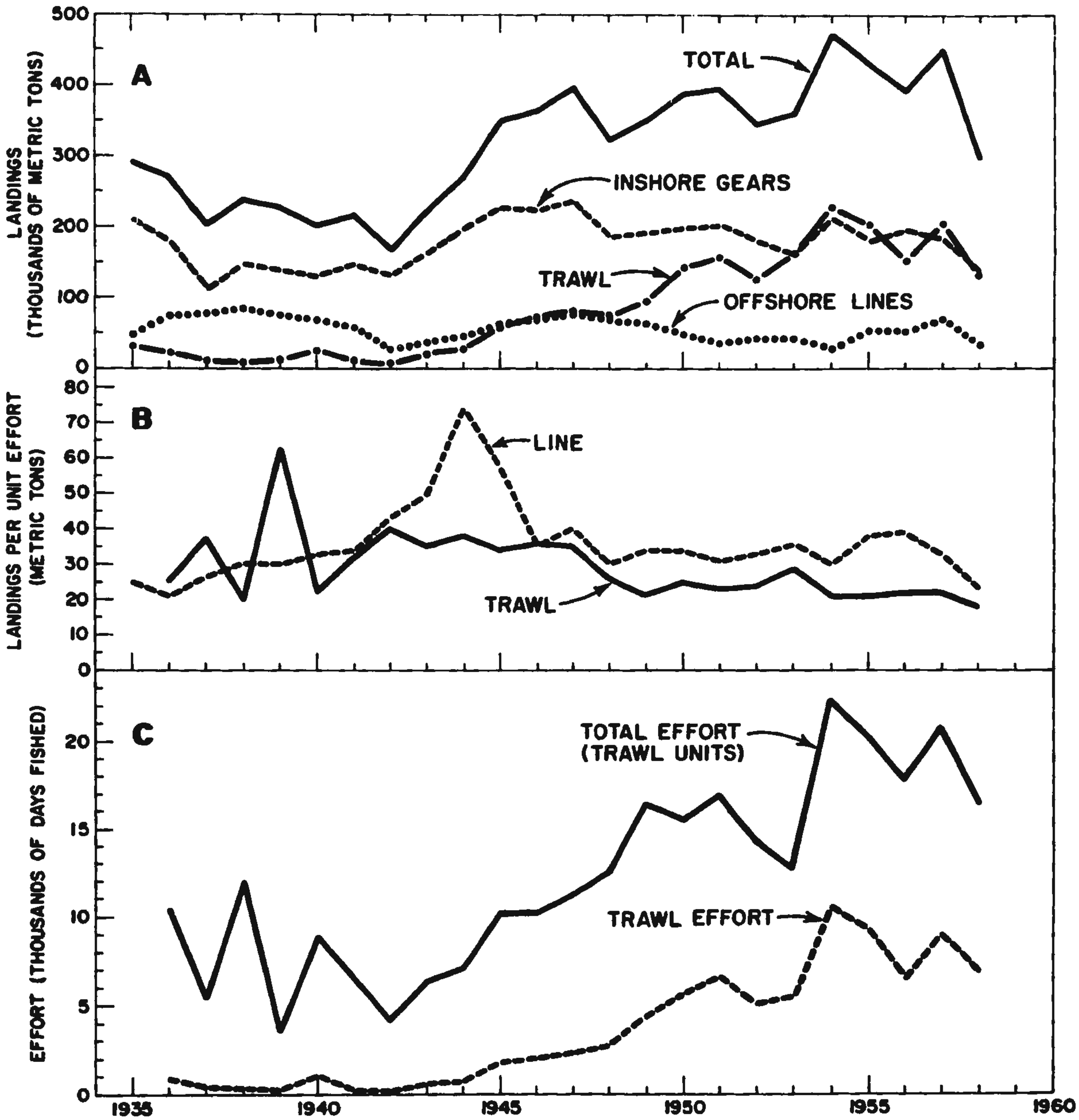

Figure 5. Subarea 3 cod: A, landings by gears and total annual landings for the period 1935-58; B, landings per unit effort for Portuguese trawlers and dory vessels fishing on the Newfoundland Banks (mainly Subarea 3); C, calculated trawler effort and total effort (in trawl units), based on the landings per unit effort of Portuguese trawlers. (Appendix I, Tables 1 and 2.)

landings have been just less than 200 thousand tons. The landings from the offshore line fishery, mainly by Portuguese dory vessels, have varied between 30 thousand and 80 thousand tons over the same period. The offshore trawl fishery, carried on largely by France, Spain, Portugal, and more recently by the USSR, has developed rapidly, and landings have increased from less than 30 thousand tons prior to World War II to an annual average level of about 200 thousand tons in the 1950's.

2. The effect of fishing on the cod stocks

The only long series of landing and effort data available are those of the Portuguese dory-vessel and trawl fleets from 1935 to the present time, but prior to 1952 these data are reported as pertaining generally to the Newfoundland banks, probably including small amounts of fishing off Labrador (Subarea 2) and in the Gulf of St. Lawrence (Subarea 4). These data have not been published but were obtained on request from the ICNAF Secretariat, Halifax, Nova Scotia; a summary of these data is given in Appendix I, Table 2.

The landings per day fished by Portuguese trawlers, the calculated total trawl effort and the calculated total effort in Portuguese trawler units are shown in Figure 5. From 1936, when the first Portuguese trawler operated in the area, until 1940 only one or two Portuguese trawlers were fishing, and the landings per day fished fluctuated considerably; however, for the period 1936-47 they averaged about 35 tons. With the rapid expansion of the trawling fleets during the post-war years, resulting in an increase in fishing effort in the subarea from a level of less than 1000 days fished to nearly 10,000 in the 1950's, the landings per day fished have decreased to a level of 20-25 tons.

Prior to the introduction of trawlers in the 1920's, the Grand Banks attracted hundreds of dory schooners, particularly French and Canadian, which carried on an extensive line fishery; for example, in the first decade of this century French landings from the ICNAF Area ranged between 50 thousand and 175 thousand tons, most of which were probably caught in Subarea 3, and the landings of Newfoundland and Nova Scotian dory schooners were together 50 thousand tons or more. During the war years, 1940-45, the line fishery on the offshore banks dropped to a very low level, and the landings per unit effort increased (Figure 5). In 1946 and subsequently, when fishing conditions returned to normal, the landings per unit effort tended to stabilize at a level of about 35 tons per 100 dory days fished. During 1955-57, however, the landings per unit effort increased to nearly 40 tons instead of decreasing as would be expected when fishing on a stock intensifies; but this increase is believed to be due mainly to a very recent practice by the Portuguese dory fishermen of obtaining large quantities of frozen squid bait at Newfoundland ports. Squid were very abundant in Newfoundland waters during 1953-57 (Squires, 1959), and it is known that squid bait is almost twice as effective in catching cod as any other commonly used bait (Templeman and Fleming, MS). The poor fishing in 1958 is largely attributed to higher than normal temperature conditions throughout much of the area, causing the cod to have been much less concentrated in the fishing areas than normally (Templeman, 1959a).

Although there are inconsistencies in the available data, it appears that the cod stocks have responded to changes in fishing intensity. As the stocks in one area are reduced to a low level, other areas with better concentrations are discovered and undergo exploitation. Thus the increase in fishing intensity, particularly by the trawling fleets, has in recent years resulted in hitherto unexploited cod stocks being fished. This process is still continuing, so that the decline in landings per unit effort from the subarea as a whole is less marked than might be expected from a consideration of the rates of local depletion (see page 59).

Examination of data by ICNAF divisions since 1953 reveals that in 3N and 3O (the southern part of the Grand Bank), where the bottom is best for trawl fishing, the landings per unit effort of the Spanish, Portuguese and Canadian fleets have decreased significantly, and as a result a considerable decrease in fishing effort has subsequently occurred (Appendix I, Tables 3 and 4). During the early 1950's the fleets had already moved into Division 3L, and by 1957 and 1958 a decrease in the landings per unit effort in that division was apparent but small. The northward expansion of the trawl fishery into Division 3K and westward into Division 3P is taking place at present, but there is no clear indication that the stocks in those divisions are as yet being reduced.

3. Survival and nature of the cod stocks in Subarea 3

Considering that they have withstood more than four centuries of exploitation, the cod stocks show great ability to withstand relatively constant but heavy fishing pressure. Many factors favour the abundance and survival of cod in the area. They feed equally well on the bottom and in mid-water and they can accommodate themselves to a wide range of depth and temperature conditions, although preferring cold water near 0°C. The great abundance of plankton as well as capelin and other food fishes provide vast quantities of food, suitable for their survival and growth throughout all stages of their lives. During and after spawning adult cod may spend several weeks in the upper water levels where they are not available to the ordinary trawling gear. Also some relief from fishing pressure often occurs in the winter and spring when the stocks off the east coast of Newfoundland cannot be fished on account of ice conditions. Young cod during the first two or three years of life are not strictly bottom feeders but tend to live farther off the bottom than the adults; thus their premature destruction by trawls is probably not a serious problem. The great expanse of Subarea 3 alone, more than 100,000 square miles, provides many suitable areas for the settling of the pelagic post-larval stages and renders the complete failure of year-classes unlikely.

Because of the resiliency of cod to adapt themselves to a wide range of environmental conditions, it is inevitable that there must be great variation in the biological characteristics of cod throughout the area. According to Templeman (1953), three well-defined stocks of cod may be distinguished in the subarea from studies of vertebral averages, tagging returns, growth rates and the incidence of cod parasites. These are (a) the east coast of Newfoundland stock (Divisions 3K and 3L) which extends from the northern edge of the Grand Bank northward into the Labrador area, (b) the central and southern Grand Bank stock (Divisions 3N and 3O), and (c) the south and west coast of Newfoundland stock (Divisions 3P and 4R). In addition, the Flemish Cap (Division 3M) appears to have a small stock of its own as indicated by USSR catch statistics since 1956.

All four stocks are well separated from each other and hindered to some extent from mixing by such natural barriers as deep channels and water masses of low temperature. Within the 3K and 3L stock, which extends over a wide area, there are no real barriers and the cod may mix freely, but this does not seem to be the case. Although there appears to be no distinct difference in vertebral numbers, growth rate studies indicate that complete mixing does not occur (Templeman, 1953); rather, the differences in growth rate are considerable from north to south in the region, and such evidence seems to indicate that each submarine shelf off the headlands along the east coast of Newfoundland has its own local population of cod which tends to follow an inshore-offshore migratory pattern rather than extensive north-south movements. The southern and central Grand Bank stock (3N and 3O) is considered to be distinct because of its low vertebral average and very fast growth rate. Tagging studies reveal that this stock has very little association with the coast or with the adjoining stocks. In 3P and 4R there are two or more divisions of the cod population as indicated from more recent tagging studies (unpublished data of the St. John's Biological Station, Newfoundland) and from studies on nematode infestation (Templeman, Squires and Fleming, 1957), but those of Division 3P are here considered as a unit because of the inadequate separation of catch and effort statistics for the individual stocks.

For purposes of the assessments, therefore, the subarea has been divided into the four major regions given above and the stocks in them are treated separately.

4. General notes on data used in making the assessments

The assessments were made by Gulland's (1961) method using length compositions of catches (or sometimes landings). All available length data from the ICNAF Sampling Yearbooks covering the period 1955-58 were considered in order to obtain adequate sets of length compositions for the offshore trawl fisheries in recent years. In some cases the length compositions were stated as pertaining to catches and in other cases to landings. Where necessary, data of landings were converted to catches by adjusting for discards before being used. The adjustments were, however, sometimes rather arbitrary, particularly for the 3P data which were scanty for the offshore trawl fishery. By combining length compositions, weighted to the catches of the various countries for which data were available, sets of length compositions of all trawl catches were obtained on an annual basis. These were averaged to give for each region a representative length composition of the average annual trawl catch for the period under consideration (i.e. 1955-58). Representative length compositions of the offshore line fishery and the inshore fishery were obtained in the same manner, except that no account was taken of discards. The length compositions by gears for the various regions are given in Appendix I, Table 5, with notes showing how they were obtained, and they are illustrated in Figure 6.

The length-weight relationships used in the assessments are based on data collected by research vessels of the St. John's Biological Station, Newfoundland, and are given in Appendix III. The immediate and long-term assessments were made for increases in mesh size from an initial 3 inches to 4 inches and thereafter by ½-inch intervals to 6 inches. The selection ogives for the various mesh sizes are given in Appendix II.

The average annual cod landings, on which the assessments are based, by countries, gears and regions for the period 1955-58 are given in Table 5.

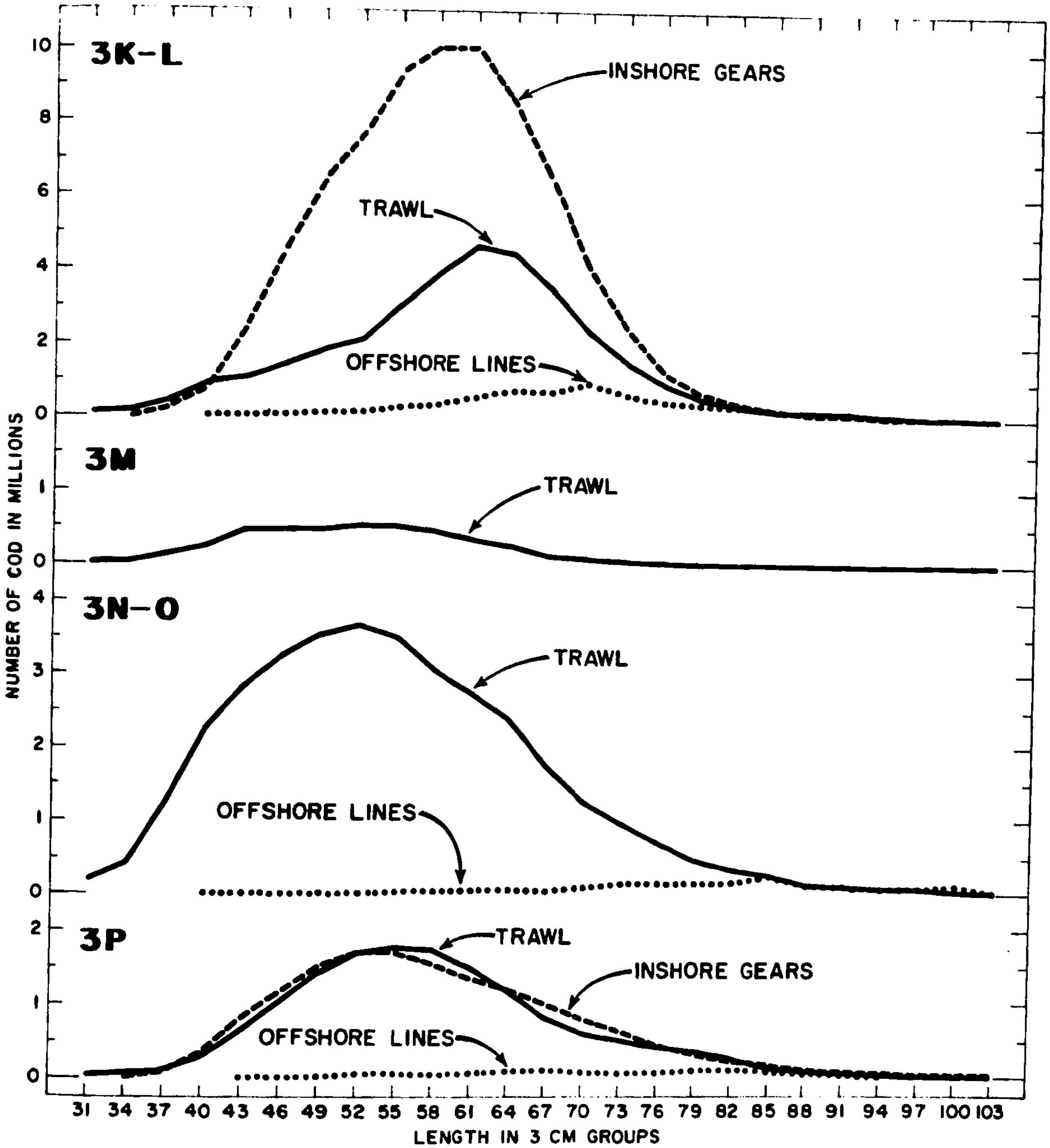

Figure 6. Subarea 3 cod: size composition of catches by trawls and of landings by other gears for the various regions, based on length composition of samples for the period 1955-58 anda djusted to the average annual landings for that period (see Appendix I, Table 5).

5. Divisions 3K and 3L assessments for cod

This region is by far the most important of the cod-fishing areas of Subarea 3, accounting in recent years for about 60% of the total cod landings from the subarea. Of this quantity the Newfoundland inshore fishery took 60%, Portuguese dory-vessel and trawl fleets 18%, French trawlers 13% and Spanish trawlers about 5%. The trawl fishery as a whole in this region accounted for 31% of the cod landings, which for the period 1955-58 averaged 232 thousand tons annually (see Table 5).

This stock demonstrates a seasonal inshore-offshore migratory pattern, the degree of concentration both in the coastal waters and offshore depending largely on the temperature conditions of the Labrador Current. During late autumn, winter and spring, when the shallow water near the coast is too cold, the cod live in deeper water offshore, where they are available to the offshore trawl and line fisheries. In late spring, when the coastal water has become sufficiently warm, large numbers of cod move inshore in conjunction with the spawning migration of capelin, and for about three or four months during the summer they are fished extensively by Newfoundland inshore fishermen. Templeman and Fleming (1956) have shown that the cod caught by inshore gears in shallow water near the coast are considerably smaller than those caught by longlines in the deeper water at the edges of the coastal shelves during the summer and in other seasons.

Table 5. Subarea 3 cod: average annual cod landings by gear, country and region for the period 1955-58.

Gear	Country	Landings in thousands of tons(1)					
		3K-L	3M	3N-O	3P	3NK(2)	Total
Trawl	Canada (M)	2.4	-	3.1	2.0	-	7.5
	Canada (Nfld)	1.8	-	2.5	1.7	-	6.0
	France (M)	30.0	+	4.0	10.2	+	44.5
	France (St.P)	-	-	-	-	0.9	0.9
	Germany (E)	-	+	-	-	-	+
	Germany (W)	-	-	+	+	+	+
	Iceland	+	-	-	-	-	+
	Portugal	23.8	+	4.0	4.7	-	32.5
	Spain (OT)(3)	9.5	-	16.7	8.3	-	34.4
	Spain (PT)	2.5	+	30.6	0.4	-	33.5
	USSR	0.7	5.9	-	-	-	6.6
	UK	+	-	0.4	0.6	0.4	1.5
	Total	70.9	6.2	61.3	28.0	1.4	167.7
Line	Canada (M)	4.0	-	0.9	4.0	-	9.0
	Denmark (F)	-	-	-	-	1.7	1.7
	Norway	+	+	-	-	5.6	5.9
	Portugal	18.0	+	15.2	0.8	-	34.0
	Total	22.0	0.3	16.1	4.8	7.3	50.6
Inshore	Canada (Nfld)	139.4	-	-	28.7	-	168.1
	France (St.P)	-	-	-	3.6	-	3.6
	Total	139.4	-	-	32.3	-	171.7
GRAND TOTAL		232.3	6.5	77.4	65.1	8.7	390.0

(1) From Appendix I, Table 3.

(2) 3NK = Subarea 3, division not known.

(3) Spain (OT) = Spanish otter trawl; Spain (PT) = Spanish pair trawl.

The foregoing description of the migratory pattern is generally true for the northern part of the region (3K), where the deep water fishing grounds are adjacent to the coastal waters of the east coast of Newfoundland. The southern part of this region (3L) includes the northern half of the Grand Bank, the northwestern slope of which is directly continuous with the coastal shelf in the Baccalieu area, and presumably there is a gradual lessening of the coastal migratory tendency as one moves offshore along the northern and northeastern slope of the Grand Bank, since some of the cod move in summer from the deep water slope onto the shallow bank areas rather than to the coast. Along the western slope of the Grand Bank facing the Avalon Peninsula, tagging studies show strong shoreward movement of cod at capelin spawning time but some tendency also for cod to move eastward onto the bank during the summer and stay in the vicinity of the Virgin Rocks.

The above conclusions are based on tagging experiments and experimental fishing carried out in recent years by the St. John's Biological Station (unpublished data).

The series of landing and effort data available for this region is not long (Appendix I, Table 4), but examination of annual landing per unit effort data by trawlers since 1954 gives no clear indication of a relation between effort and abundance. Although there has been since 1956 a decline in the landings per unit effort of all trawl fleets in Division 3L, it is not possible to conclude from such a short series of data that this has been caused by fishing. However, a continuing study of the Newfoundland inshore fishery since 1951 in the waters of the Bonavista Shelf area of Division 3L indicates that this local fishery has been seriously affected (Templeman, 1959a and 1960). In 1950 and 1951 large unexploited concentrations of cod were discovered in the deep water parts of the shelf 15 to 20 miles from shore and an appreciable long-line fishery subsequently developed. Up to 1956 the catch per day's fishing was about 4.3 tons per boat. In 1956 a few large trawlers began fishing in the area, and in 1957 and 1958 a much larger concentration of effort by a large number of foreign trawlers and fleets of Faroese and Norwegian longliners occurred. Subsequently the catch per day's fishing by Newfoundland long-liners has decreased rapidly, averaging less than 2.0 tons per boat by 1960. The inshore handline fishery in the area decreased from a pre-1956 level of more than 1.5 tons per boat per day to less than 0.9 tons in 1960, and the codtrap catches declined from about 3.0 tons per haul to 1.5 tons over the same period. Furthermore, the average size of cod caught by longlines and other gears has decreased by about 10 centimeters between 1952 and 1959, and the cod landings from the inshore Bonavista Shelf area are now not much more than one-half the pre-1956 level, although there has not been any appreciable change in the inshore fishing effort (Fleming, 1960b and 1961).

Scanty age-composition data from Newfoundland research vessel catches for the period 1948-53, when the offshore trawl fishery was somewhat less intense than at present, indicate that the total mortality coefficient (Z) was about 0.35, while age compositions of the Newfoundland inshore fishery during 1947-50 give a Z of about 0.6. Data of the inshore fishery for the period 1955-58 indicate that Z was about 0.7, with individual estimates for the four years ranging between 0.65 and 0.75. For the offshore trawl fishery age compositions of Portuguese samples in 1955 and of Spanish and Portuguese samples in 1957 both give estimates of Z of about 0.5 (Figure 7). The difference between the estimates of Z for the inshore and the offshore fisheries is probably reflected in the difference between the inshore and the offshore length compositions, since the larger fish tend to remain offshore in the deep water and to be more available to the trawl fishery than to the inshore fishery (Templeman and Fleming, 1956). This is also evident from the length compositions illustrated in Figure 6. Considering the total mortality estimates of 0.7 and 0.5 for the inshore and the offshore fisheries respectively during the 1955-58 period, an intermediate value for Z of 0.6 was used for the assessments of the cod fisheries in this region.

No direct separation of Z into its natural and fishing components, by analysis of changes in effort and abundance, can be made from the present data. However, from cod-tagging experiments carried out in 1950 at two inshore locations (Fogo in Division 3K and St. John's in 3L), total returns to the end of 1960 were 38% for a 5-inch internal tag and 47% for a small

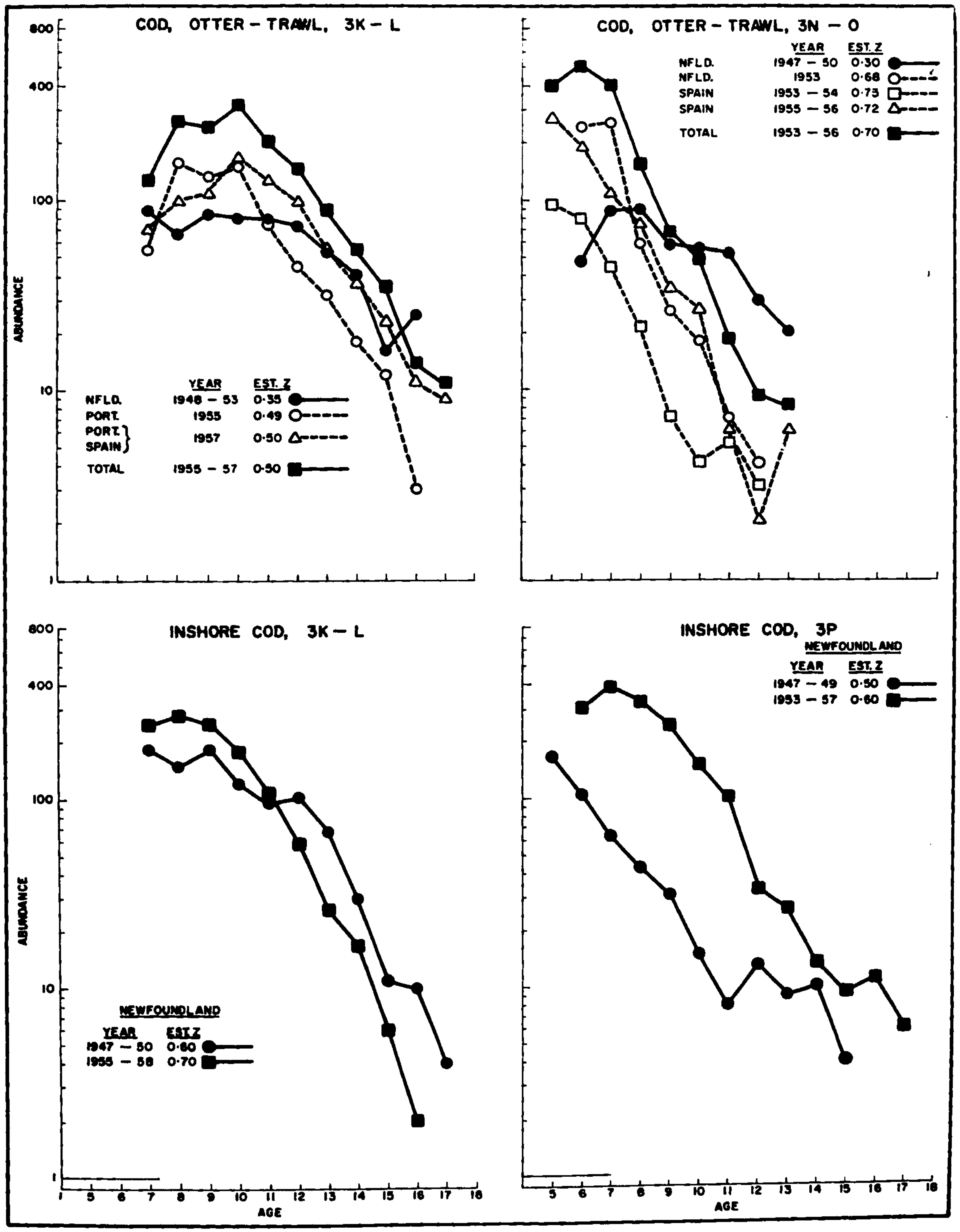

Figure 7. Subarea 3 cod: logarithmic plots of the age composition data used in estimating the total mortality coefficients (see Appendix I, Table 6).

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2-inch red pre-opercular tag (Templeman and Pitt, 1961). Furthermore, tagging experiments carried out in 1954 at various locations produced during the 6½-year period to November 1, 1960, a total return of 33% (Templeman, 1961). These results indicate that the ratio of fishing mortality to total mortality (E) is probably not less than 0.5 and could be considerably larger. A range of E values from 0.83 to 0.50, corresponding to values of M from 0.10 to 0.30 for a Z of 0.6, is therefore considered reasonable for assessment purposes.

The cod along the east coast of Newfoundland tend to remain offshore in the deep water as they become older, and a large portion of the cod along the western, northern and north-eastern slope of the Grand Bank migrates during the summer onto the bank itself rather than inshore. Because of this, it has been assumed for these assessments that fish released as a result of increases in the mesh size of trawls would subsequently be relatively only about one-half as available to the inshore fishery as to the offshore trawl and line fisheries.

Figure 6 shows, for the period 1955-58, the length composition of the average annual trawl catch used in making the assessments for this region (3K and 3L). The length compositions of the average annual landings of the Newfoundland inshore fishery and the offshore line fishery for the same period are also shown. In this region, where cod tend to be large, the quantities discarded appear to be small. Estimates of the proportion discarded by weight are 1.6% for Portuguese trawlers in 1957 and 2.8% in 1958 (communication to the ICNAF Secretariat in 1960 from Capt. T. de Almeida, Lisbon, Portugal). For the trawl fishery, therefore, it was assumed that all fish below 45 centimeters were discarded, this being consistent with an average discarding of about 2% by weight.

Age-length data used for the estimation of t_c are a combination of Newfoundland data for 3K and 3L in 1947-50 (Fleming, 1960a) and Portuguese and Spanish data for 1956-57 (ICNAF Sampling Yearbooks). The growth curve is illustrated in Figure 8.

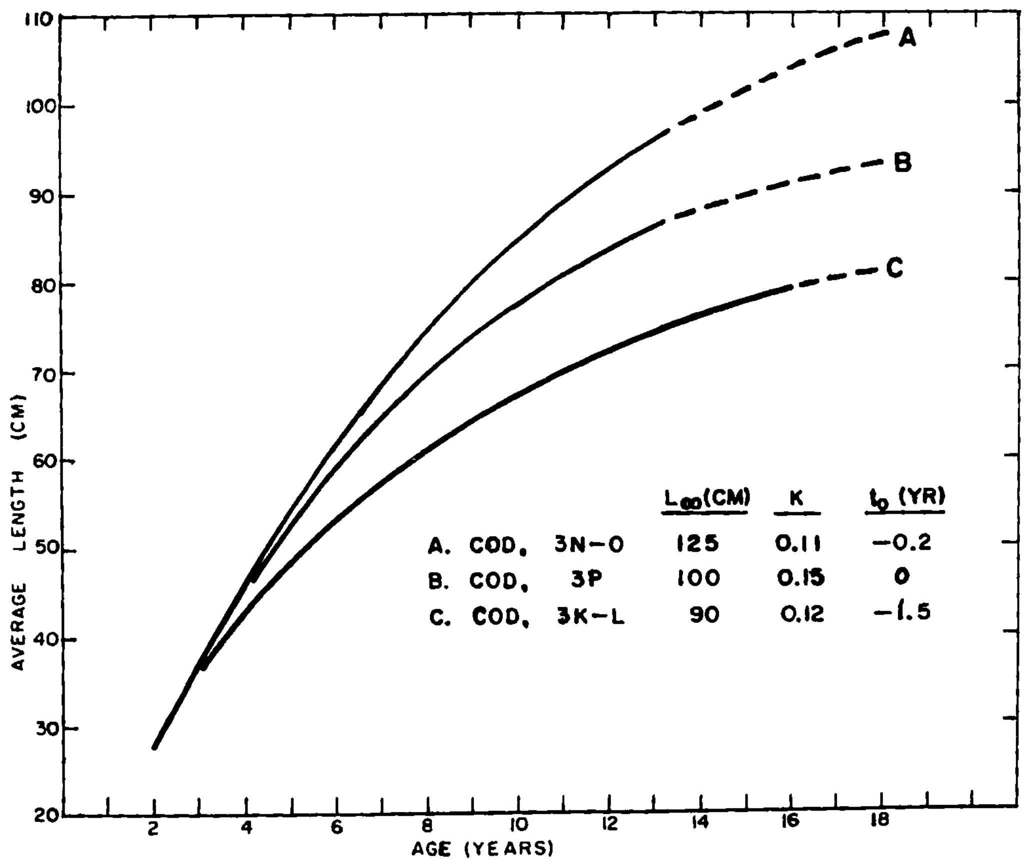

Figure 8. Subarea 3 cod: growth curves obtained from the Bertalanffy growth equations fitted to the age-length data of Appendix I, Table 7.

The assessments of the immediate and long-term effects of increases in mesh size, based on an initial mesh size of 3 inches, are given in Table 6. For all values of E considered there would only be slight changes in total landings for all mesh sizes up to 6 inches. This is mainly because the number of fish

Table 6. Divisions 3K and 3L assessments for cod

Mesh size change (inches)	l_c (cm)	t_c (yr)	Gear group*	Percentage change in 1955-58 landings: Immediate loss	Long-term change for			
					0.50	0.67	0.83	E
					0.30	0.40	0.50	F
From 3 to	49.8	5.3			0.30	0.20	0.10	M
4	50.4	5.4	Trawl	-0.3	+0.3	+0.5	+0.7	
			Offsh. line	0	+0.6	+0.8	+1.1	
			Insh. gears	0	+0.3	+0.4	+0.5	
			Total	-0.1	+0.3	+0.5	+0.6	
4½	51.1	5.5	Trawl	-1.0	+0.2	+0.7	+1.1	
			Offsh. line	0	+1.3	+1.7	+2.2	
			Insh. gears	0	+0.6	+0.8	+1.1	
			Total	-0.3	+0.6	+0.9	+1.2	
5	52.0	5.7	Trawl	-2.5	-0.3	+0.5	+1.3	
			Offsh. line	0	+2.2	+3.0	+3.8	
			Insh. gears	0	+1.1	+1.5	+1.9	
			Total	-0.7	+0.8	+1.3	+1.9	
5½	53.9	6.1	Trawl	-7.1	-3.0	-1.6	+0.1	
			Offsh. line	0	+4.2	+5.9	+7.7	
			Insh. gears	0	+2.0	+2.7	+3.6	
			Total	-2.2	+0.6	+1.7	+2.9	
6	56.0	6.6	Trawl	-13.5	-7.9	-5.5	-2.9	
			Offsh. line	0	+6.4	+9.1	+12.1	
			Insh. gears	0	+2.9	+4.1	+5.5	
			Total	-4.1	-0.1	+1.6	+3.6	

*Trawl group - France (42%), Portugal (34%), Spain (17%), Canada (6%) and USSR (1%).

Offshore line - Portugal (82%) and Canada (18%).

Inshore gears - Canada (Newfoundland) (100%).

that would be released ($_TN_R$) is very small relative to the total number of fish that would be kept ($_TN_K$). For the intermediate value of E (= 0.67) the optimum mesh size is about 4½ inches for the trawl fishery, but if E is as high as 0.8 a mesh size of 5 inches would produce the optimum long-term yield; mesh size increases beyond 5 inches would not likely be beneficial. The offshore line and the inshore fisheries would benefit from any increase in mesh size of trawls, the long-term benefits becoming greater as the mesh size is increased.

6. Division 3M assessments for cod

This stock, separated from the others in 3K and 3L and in 3N and 3O by a very deep channel, was not exploited to any great extent prior to 1956 (Appendix I, Table 3), but since then most of the cod caught there have been taken by USSR trawlers in conjunction with their very extensive redfish fishery in the region. The average annual landing for the period 1955-58 was 6.5 thousand tons, which represents less than 2% of the Subarea 3 cod total (see Table 5). The cod are generally smaller than those of 3K and 3L and are believed not to migrate nor to mix to any great degree with those in neighbouring regions.

Because of the very recent development of this cod fishery and the lack of age-composition data, it is not possible at present to estimate Z or its fishing and natural components.

The immediate losses for increases of mesh size above an initial 3 inches have been calculated from USSR length compositions of catches in 1958 (Figure 6), and the results are given in Table 7. With regard to long-term changes it is not possible to calculate more than the break-even values of E. Using the growth curve for cod of Divisions 3K and 3L to convert the mean retention lengths (l_c) to mean retention ages (t_c), and taking an M value of 0.2 (the intermediate value used in the assessments for cod of the other regions of Subarea 3), approximate break-even values of E have been computed from equation (23). They range between 0.4 and 0.6 for the various increases of mesh size considered, suggesting that fishing might not have to be particularly intense for any increase of mesh size up to 6 inches to produce long-term benefits. Should the growth rate of this stock be faster than that for cod of Divisions 3K and 3L, the break-even values of E would be correspondingly

Table 7. Division 3M assessments for cod

Mesh size change (inches)	l_c (cm)	t_c (yr)	Gear group*	Percentage change in 1955-58 landings: Immediate loss	Percentage change in 1955-58 landings: Long-term — Minimum break-even value of E
From 3 to	40.6	3.6			
4	42.3	3.9	Trawl	-3.2	0.44
4½	43.8	4.1	"	-6.6	0.48
5	45.0	4.4	"	-12.0	0.51
5½	49.0	5.0	"	-23.4	0.56
6	53.4	6.0	"	-34.8	0.62

*Trawl group - USSR (95% of 3M cod landings) lower than those indicated in Table 7. Lacking an estimate of Z (and hence E) for this region, it is not possible to predict which mesh size would likely provide the optimum long-term benefits. However, the immediate losses would be substantial for increases of mesh size beyond 5 inches.

7. Divisions 3N and 30 assessments for cod

This entirely offshore fishery, prosecuted mainly by Spanish trawlers and Portuguese dory vessels, accounts for about 20% of the Subarea 3 cod landings. Of an annual average of 77 thousand tons landed during the 1955-58 period, 61% was taken by Spain, 25% by Portugal and 8% by Canada. The trawl fishery took 79% of the cod total (see Table 5).

This stock is considered to be relatively distinct from stocks in neighbouring areas because of marked differences in growth rate and vertebral numbers. Tagging studies also indicate very little mixing with cod of adjoining areas mainly because of surrounding temperature barriers (Templeman, 1953). Like the cod of 3K and 3L a seasonal migratory pattern is evident. During the summer and autumn the cod are generally concentrated on the shallow parts of the Grand Bank where temperature conditions are most suitable. In the winter months the shallow water areas are usually covered with very cold water and the cod are found on the deep water areas of the slopes. Also there appears to be a tendency for cod as they grow older to remain in the deeper water.

No long series of effort data is available for this region, but landings per unit effort since 1954 show steady decreases for all fleets (Appendix I, Table 4). The fishing effort by trawlers has declined considerably as the fleets moved northward into Divisions 3K and 3L and westward into 3P and Subarea 4. The effort for pair-trawling has remained about the same during the 1954-58 period, mainly because the bottom in the region is most suitable for this type of fishing.

Age-composition data from Newfoundland research vessel catches in 1953 (unpublished data of the St. John's Biological Station, Newfoundland) and from the catches of Spanish trawlers during 1953-56 (ICNAF Sampling Yearbooks) both give estimates for $\underline{Z}$ of about 0.7 (see Figure 7), and this value was used in making the assessments.

No direct separation of $\underline{Z}$ into its natural and fishing components is possible at present from the very short series of landing and effort data available. However, Newfoundland research vessel age compositions of catches, collected during the period 1947-50, give a $\underline{Z}$ of about 0.3 for age-groups VIII to XII, which lived through a war-time and pre-war period of relatively low fishing intensity (Figure 7). Consequently, the values of $\underline{M}$ used in the assessments for region 3K and 3L (i.e. 0.30, 0.20 and 0.10) were used also for this region, giving corresponding $\underline{E}$ values of 0.57, 0.71 and 0.86 respectively. In view of the low value of $\underline{Z}$ indicated above for the war years, it is believed that $\underline{M}$ for this region may be in the lower part of the range used.

A representative length composition of the average annual catch by trawlers for the period 1955-58 is illustrated in Figure 6. The length composition of the average annual landing by Portuguese dory vessels is also shown. Since most of the fish caught in this region are smaller than those caught in 3K and 3L, and since the Spanish research reports to ICNAF indicate that the minimum commercial size is about 40 centimeters, for the trawl fishery it was assumed that all cod below 42 centimeters had been discarded as being too small, the amount being 3.3% of the catch by weight and 14% by number. Rojo (1957 and 1958) states that in Spanish trawler catches the percentages of cod below commercial size vary considerably with the season and with the area: in 1955 discards by number were 0.5% during the spring in Division 30 and 16% during the summer in 3N; in 1956 during the summer 8.7% were discarded in 3N; and from samples taken in August and September of 1957 discards were 22.3% and 11.7% respectively. All these percentages refer to cod smaller than 40 centimeters in the samples.

The growth curve used for the estimation of t_c represents a combination of Newfoundland data from 3N and 30 in 1947-50 (Fleming, 1960a) and Spanish data for 1953-56 (ICNAF Sampling Yearbooks), and it is illustrated in Figure 8.

The assessments of the immediate and long-term effects of increases in mesh size, based on an initial mesh size of 3 inches, are given in Table 8. Long-term gains to total landings

Table 8. Divisions 3N and 30 assessments for cod

Mesh size change (inches)	l_c (cm)	t_c (yr)	Gear group*	Percentage change in 1955-58 landings: Immediate loss	Long-term change for E 0.57 / F 0.40 / M 0.30	E 0.71 / F 0.50 / M 0.20	E 0.87 / F 0.60 / M 0.10
From 3 to	39.2	3.2					
4	41.3	3.4	Trawl	-1.3	+2.7	+3.7	+4.8
			Line	0	+4.0	+5.0	+6.1
			Total	-1.0	+3.0	+4.0	+5.1
4½	43.1	3.6	Trawl	-3.2	+4.3	+6.3	+8.5
			Line	0	+7.5	+9.5	+11.8
			Total	-2.5	+5.0	+7.0	+9.2
5	45.5	3.9	Trawl	-6.6	+5.6	+9.1	+13.1
			Line	0	+12.2	+15.7	+19.7
			Total	-5.2	+7.0	+10.5	+14.5
5½	49.6	4.3	Trawl	-14.3	+6.2	+12.7	+20.2
			Line	0	+20.5	+26.9	+34.4
			Total	-11.3	+9.2	+15.7	+23.3
6	53.3	4.8	Trawl	-22.5	+4.7	+14.2	+25.7
			Line	0	+27.2	+36.7	+48.1
			Total	-17.8	+9.4	+18.9	+30.4

*Trawl group - Spain (77%), Canada (9%), France (7%) and Portugal (6%).
Line group - Portugal (94%) and Canada (6%).

are predicted for all increases in mesh size up to 6 inches, and these would be substantial for the higher values of E. The trawl fishery would also benefit from all increases to 6 inches, but the optimum yield for the lowest value of E (= 0.57) would be obtained with a 5½-inch mesh size. The line fishery would benefit from any increase in mesh size and greatly so for mesh sizes above 5 inches. The reasons for the great difference between the predicted benefits for Divisions 3N and 30 and those for 3K and 3L are (a) the number of fish that would be released by large-meshed trawls relative to the total number retained by all gears is large for this region, and (b) the cod in this region grow considerably faster than in any other part of the subarea.

8. Division 3P assessments for cod

This region during the 1955-58 period accounted for 17% of the subarea cod landings or an average annual landing of 65 thousand tons. The Canadian fisheries (mainly Newfoundland inshore) took 56%, while France (mainly trawlers) took 21%, Spain 13% and Portugal 8%. The average annual yield was shared by gears as follows: trawlers 43%, offshore line 7% and inshore gears 50% (see Table 5).

The composition of this stock unit is more complex than those considered previously in that it consists of two or more groups of cod. Tagging studies (Thompson, 1943, and unpublished data of the St. John's Biological Station, Newfoundland) indicate that cod in the eastern and southeastern parts of this division move freely between the offshore banks and the inshore waters along the eastern half of Newfoundland's south coast. These fish are known not to mix much with concentrations of cod which winter in the western part of the division (3P north), providing a substantial winter inshore fishery there, and which in the spring migrate into Division 4R to provide an inshore summer fishery along the west coast of Newfoundland. French, Portuguese and Spanish trawlers often carry on an intensive fishery for a short period in March on a cod concentration in the Halibut Channel just east of St. Pierre Bank (3P south), and during March and April they also fish the 3P (north) concentrations as they move around the southwest corner of Newfoundland into Division 4R. Because the decision by ICNAF to divide Division 3P into 3P (north) and 3P (south) is very recent (ICNAF Annual Meeting, 1957), it has not been possible to consider separately the cod populations in these subdivisions.

No consistent trend is detectable in the landing per unit effort data for trawlers during the period 1954-58 (Appendix I, Table 4). The scanty age-composition data from trawl catches are inadequate to give a reliable estimate of the total mortality coefficient (Z), but returns from tagging experiments carried out in 1954 on St. Pierre Bank and on Burgeo Bank in this division (Templeman, 1961) give a Z of about 0.7. Age-composition data from the Newfoundland inshore fishery for 1947-49 give a Z of 0.5, and for the period 1953-57 individual estimates ranged from 0.5 to 0.7 with the average being about 0.6 (Figure 7). This latter value of Z was used in making the assessments for this region.

No direct separation of Z into its components was possible from the scanty catch and effort data available. However, returns from cod tagged in 1954 on St. Pierre Bank were 26% and on Burgeo Bank were 30% over a period of 6½ years (Templeman, 1961), indicating that the values of E of 0.50, 0.71 and 0.86 used in the assessments are not unreasonable.

Length composition data of trawl catches from this region are meagre; however, some of Newfoundland trawler landings in 1955 and 1958, Spanish in 1957 and German in 1958 were combined and then adjusted for discards (see Figure 6). In the computations cod below 45 centimeters were considered as being discarded, the quantity amounting to 2.3% of the catch by weight, a figure in agreement with estimates of discards by Portuguese trawlers in Division 3P: 3.9% in 1957 and 1.7% in 1958 (communication to the ICNAF Secretariat in 1960 from Capt. T. de Almeida, Lisbon, Portugal). The length composition of the Newfoundland inshore landings for the period 1955-58 are also shown in Figure 6.

The age-length data used for the estimation of t_c are Newfoundland data collected during 1947-50 (Fleming, 1960a). The growth curve is illustrated in Figure 8.

The assessments of the immediate and long-term effects of increases in mesh size beyond an initial 3 inches are given in Table 9. Long-term gains in total landings are predicted for all increases in mesh size up to 6 inches, the optimum size being 5 inches for the lower limit of E and increasing to 6 inches for the highest value of E considered. For the trawl fisheries, however, optimum mesh sizes over the range of E are between 4 and 5 inches, the size most likely to produce the best long-term benefits being 4½ inches. For increases in mesh size beyond 5 inches, the trawl fishery would probably experience long-term losses. The offshore line and the inshore fisheries would gain from any increase in the mesh size of trawls.

Table 9. Division 3P assessments for cod

Mesh size change (inches)	l_c (cm)	t_c (yr)	Gear group*	Percentage change in 1955-58 landings: Immediate loss	Long-term change for: 0.50	0.67	0.83	E
					0.30	0.40	0.50	F
From 3 to	44.6	3.9			0.30	0.20	0.10	M
4	45.4	4.0	Trawl	-0.6	+0.4	+0.7	+1.0	
			Offsh. line	0	+1.0	+1.4	+1.7	
			Insh. gears	0	+0.5	+0.7	+0.8	
			Total	-0.3	+0.5	+0.7	+1.0	
4½	46.3	4.1	Trawl	-1.9	+0.3	+1.0	+1.8	
			Offsh. line	0	+2.2	+3.0	+3.8	
			Insh. gears	0	+1.1	+1.4	+1.8	
			Total	-0.8	+0.8	+1.4	+1.9	
5	47.7	4.3	Trawl	-4.3	-0.3	+1.1	+2.5	
			Offsh. line	0	+4.1	+5.7	+7.2	
			Insh. gears	0	+2.0	+2.7	+3.4	
			Total	-1.9	+1.1	+2.2	+3.3	
5½	50.7	4.7	Trawl	-11.2	-3.6	-0.6	+2.5	
			Offsh. line	0	+8.5	+11.9	+15.4	
			Insh. gears	0	+4.0	+5.5	+7.1	
			Total	-4.8	+1.1	+3.4	+5.7	
6	53.8	5.1	Trawl	-19.3	-8.5	-3.9	+0.9	
			Offsh. line	0	+13.4	+19.1	+25.1	
			Insh. gears	0	+6.1	+8.6	+11.3	
			Total	-8.3	+0.3	+4.0	+7.9	

*Trawl group - France (36%), Spain (31%), Portugal (17%) and Canada (13%).

Offshore line - Canada (83%) and Portugal (17%).

Inshore gears - Canada (Newfoundland) (89%) and France (St. Pierre) (11%).

B. Haddock

1. Brief review of the fisheries

Although haddock were abundant on the southern part of the Grand Bank (Divisions 3N and 30) in the 1930's (Thompson, 1939), the haddock fishery did not begin on a large scale until 1946, and the landings increased rapidly to 80 thousand tons in 1949. The decline in numbers of large fish in the catches and some relaxation in fishing effort resulted in a decline in total landings to 43 thousand tons by 1953. However, a great increase in fishing effort subsequently occurred as a result of the recruitment of the very abundant 1949 year-class and because of the utilization of small haddock by Newfoundland fish plants, and a peak landing of 105 thousand tons occurred in 1955. Since then there has been a steady decline to 35 thousand tons in 1959 (Appendix I, Table 8, and Figure 9).

Except for very insignificant quantities taken inshore along the south coast of Newfoundland, the haddock fishery is strictly an offshore trawl fishery, and up to 1959 was carried on almost exclusively by Canada and Spain. Up to 1953 Spanish trawlers generally took about three-quarters of the annual yields, but since then Canadian trawlers have taken more than one-half of the annual landings.

2. Nature of the haddock stocks

There are three large and essentially independent groups of haddock stocks in the Northwest Atlantic - on Georges Bank

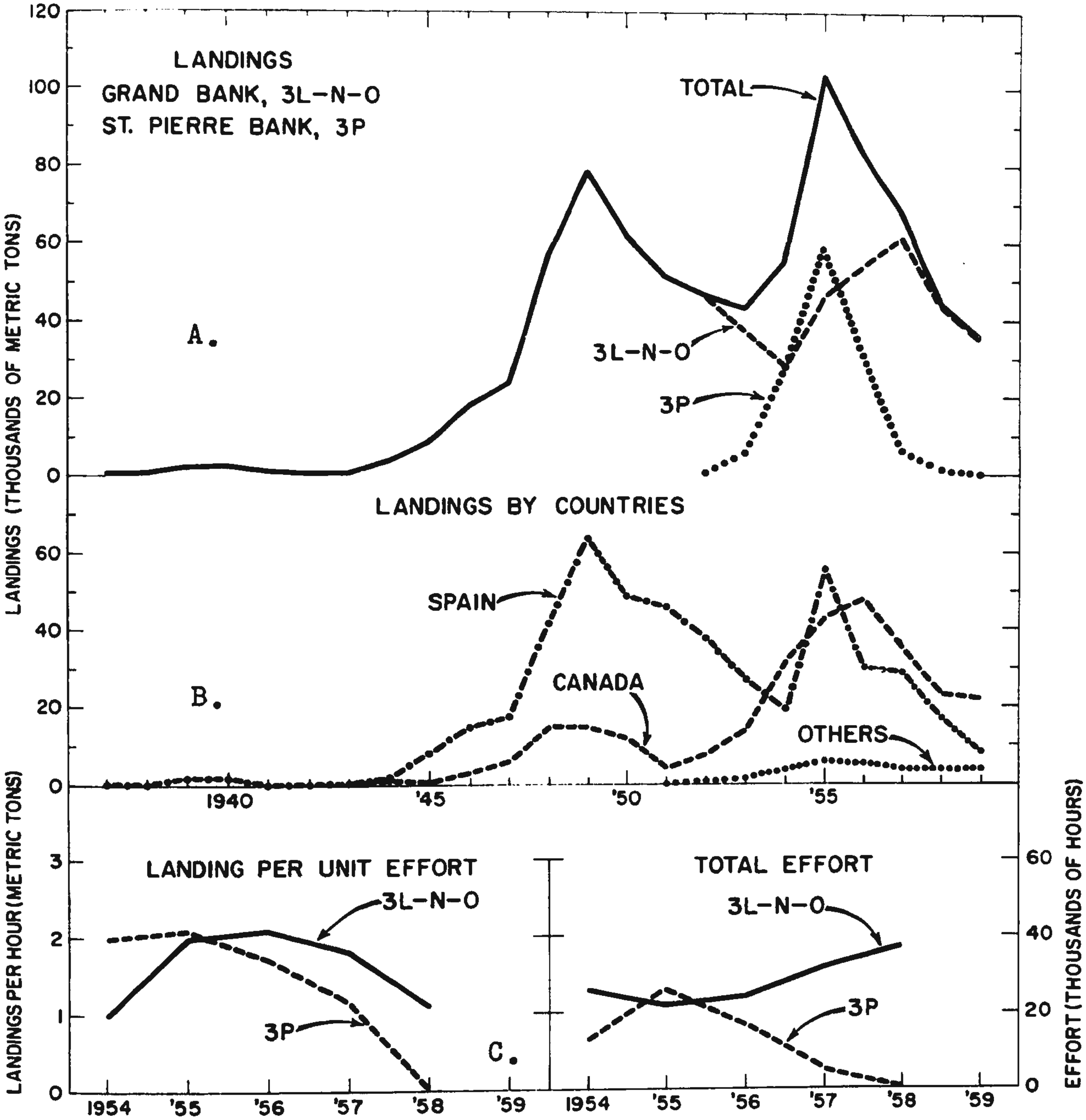

Figure 9. Subarea 3 haddock: A, annual landings for the period 1937-59; B, annual landings by countries for 1937-59; C, landings per unit effort and calculated total effort by regions, based on landing and effort data of Newfoundland trawlers for the period 1954-58.

in Subarea 5, on the Nova Scotian Banks in Subarea 4, and on the Newfoundland Banks in Subarea 3 - separated from each other by deep water channels.

In ICNAF Subarea 3, where the most northern of the stocks is located, the main haddock fishery normally takes place on the southern part of the Grand Bank (Divisions 3N and 3O), but during the period 1954-56 there was a substantial fishery for haddock on St. Pierre Bank in Division 3P as well (Figure 9, and Appendix I Table 9), almost exclusively on the very abundant 1949 year-class. Only very small quantities of haddock were landed from the latter bank before 1953 and no significant fishery for haddock has occurred there since 1957. Growth and otolith studies indicate that the adult haddock on the Grand Bank and on St. Pierre Bank are relatively distinct groups. Some mixing may occur on the slope area in the deep water between the two banks, but the moderately deep channel between the Grand Bank and Green Bank and the generally low temperature of the water in this channel and on Green Bank tend to limit the extent of mixing. Since haddock were not known to exist in abundance on St. Pierre Bank except for the period 1950-56, it may be postulated that the water current pattern, immediately following the Grand Bank haddock spawning in 1949, was such that haddock larvae in great numbers drifted in the general direction of St. Pierre Bank and the young settled on the bottom there in the autumn of 1949, the population subsequently developing its own distinct growth characteristics.

Because there has been poor survival of year-classes on St. Pierre Bank since that of 1949 and no fishery for haddock there since 1957, the present analysis will not be concerned with the transitory fishery there during 1954-56.

The Grand Bank (3N and 3O) stock, which has been the mainstay of the haddock fishery over the course of its short history, is usually located along the southwest slope (in Division 3O) during the winter and spring months when the shallow areas of the bank are covered by cold water of unfavourable temperatures, generally less than 1°C; the haddock are thus concentrated in depths greater than 50 fathoms where the water temperatures are higher and more favourable. At this time most of the Canadian trawl landings are taken. Usually by June, sometimes earlier, when the shallow bank water has warmed up sufficiently, the winter and spring concentrations disperse and the haddock move eastward across the Grand Bank. By mid-summer and later they are concentrated again but now on the Southeast Shoal (Division 3N) in shallow water of about 25 fathoms, and they are there fished (up to 1959) mainly by Spanish trawlers whose catches are split and salted on board ship. Canadian trawlers do not usually fish these summer concentrations because of the greater distances from the fishing ports and the spoilage problems with fresh fish during the warm summer months (the Canadian haddock fishery is a fresh fish industry). As the autumn progresses and the shallow bank water becomes colder, the haddock are gradually forced to return to their winter-quarters in the deeper water along the southwest slope of the bank. The above is generally the picture, but hydrographic conditions are variable and the haddock schools may in an unusually cold year remain concentrated along the slope for a longer than normal period, thus favouring the Canadian trawl fishery for them; in an unusually warm year the haddock may disperse earlier in the spring and remain spread out over the bank for a longer than normal period, thus hampering the fishery.

Considerable differences in the survival of year-classes occur in all the haddock populations of the Northwest Atlantic, but these variations are much more extreme in the northern than in the southern parts of the range of haddock in the ICNAF Area. In Subarea 3 the survival of one year-class may be several hundred times greater than that of another. On the Grand Bank the most recent outstanding year-classes were those of 1946, 1949, 1952 and 1955, the others between 1946 and 1958 being almost complete failures except for moderate survival in 1953 and 1956 (Figure 10). During the period 1955-58, on which these assessments are based, the 1949 year-class to a large degree and the 1952 year-class to a much lesser extent were dominant in the landings. Also it might be of interest to mention here that the growth rates of the 1949 and of all the more recent year-classes were considerably less than those of year-classes that were present during the early years of the fishery.

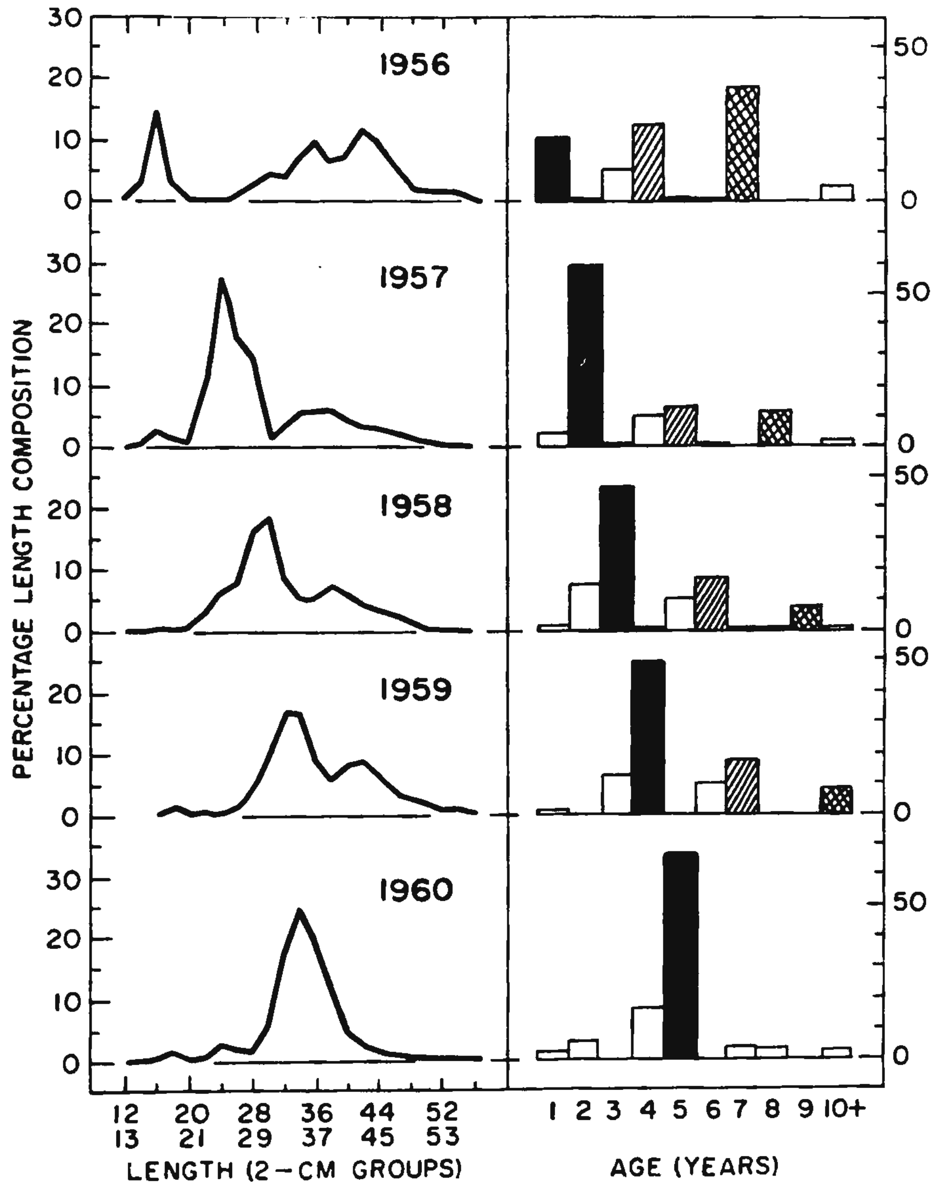

Figure 10. Subarea 3 haddock: length and age composition of research vessel catches on the Grand Bank for the years 1956-60.

3. Divisions 3N and 30 assessments for haddock

During the period 1955-58 the average annual landings from Subarea 3 amounted to 75 thousand tons, of which Canadian trawlers landed 50% and the Spanish fleet 45%. About 64% of the total, or 48 thousand tons, were caught on the Grand Bank (3N and 30) portion of the subarea (Table 10).

Table 10. Subarea 3 haddock; average annual landings by gear, country and region for the period 1955-58

Gear	Country	Landings in thousands of tons[1]		
		3L-N-O	3P	Total
Trawl	Canada (M)	5.1	5.8	10.9
	Canada (Nfld)	14.8	11.3	26.1
	France (St. P)	-	3.2[2]	3.2
	Germany (W)	+	+	+
	Portugal	+	+	+
	Spain (OT)[3]	23.0	5.2	28.2
	Spain (PT)	4.8	+	4.9
	UK	+	0.8	1.1
	USA	+	+	+
	Total	48.3	26.6[2]	74.9
Line	Canada (M)	-	+	+
Inshore	Canada (Nfld)	-	+	+
	France (St. P)	-	+	+
GRAND TOTAL		48.3	27.0	75.3

(1) From Appendix I, Table 9.

(2) 3.2 thousand tons from unknown division included here under 3P.

(3) Spain (OT) = Spanish otter trawl; Spain (PT) = Spanish pair trawl.

The only landing per unit effort data available for haddock are those for Newfoundland trawlers since 1954 (Figure 9, and Appendix I, Table 10). On St. Pierre Bank (Division 3P) the landing per unit effort was at a high level in 1954 and 1955, but it decreased rapidly to almost nothing in 1958 and the fishery is at present negligible. On the Grand Bank the best fishing occurred in 1955 and 1956. These years were followed by a decline in the landing per unit effort, which by 1958 was not much more than half the 1956 level, the total trawl effort having increased by as much as 50% during the same period. More recent observations indicate that there was some improvement in the landing per unit effort in 1959 as the abundant 1955 year-class began to dominate all others in the commercial landings.

Age-composition data from research vessel surveys throughout the area, conducted by the St. John's Biological Station, Newfoundland, indicate that for the three main year-classes for which sufficient data exist (i.e. 1942, 1946 and 1949) the total mortality coefficient (Z) probably lies between 0.7 and 0.8. This estimate was obtained by plotting logarithms of relative catch (in numbers) per unit effort at ages in successive years against age. Another independent estimate for $\underline{Z}$ of 0.75 was obtained from the slope of the descending right limb of the curve representing the logarithms of the numbers per unit effort of the 1949 year-class at successive ages for the years 1954 to 1959, the data having been obtained from samples of the landings by Newfoundland trawlers (Figure 11). Consequently a total mortality coefficient of 0.75 was used in making the assessments.

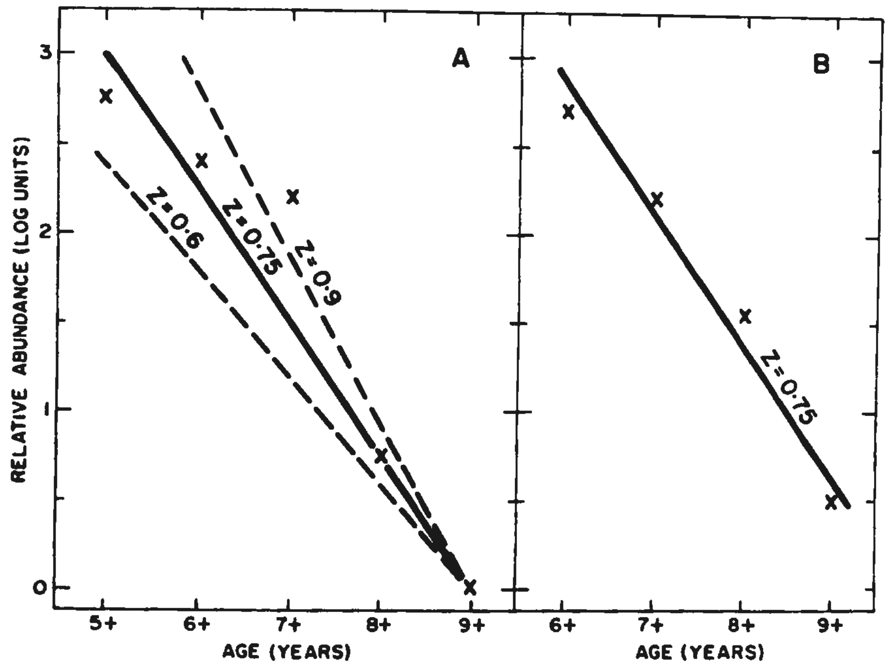

Figure 11. Subarea 3 haddock: estimates of the total mortality coefficient for the Grand Bank (3N and 3O) haddock fishery obtained by plotting the logarithms of relative abundance against ages in successive years: A, research vessel data; B, commercial fishery data. (From unpublished records of the St. John's Biological Station, Newfoundland.)

No direct separation of **Z** into its natural and fishing components is possible at present from the catch and effort data available, nor are there any tagging data to give a direct estimation of **F** or **E**. Some age-composition data exist for an earlier period (1931-35) when there was very little fishing for haddock (Thompson, 1939), but these are not sufficient to enable a firm estimate of mortality to be obtained. They suggest, however, that the relative abundance of older fish at that time was greater than in recent years. In the absence, therefore, of an estimate of natural mortality, an assessment can only be made by choosing arbitrarily a range of values within which the natural mortality (M) is presumed to lie. A value for M of 0.2 has been used in making assessments on haddock stocks in other areas of the North Atlantic. Beverton and Holt (1957) used this value for North Sea haddock, and it was also used by Graham (1952) and Taylor (1957) for the Georges Bank haddock assessments. However, in view of the precarious position that the Grand Bank stock occupies in the most northern part of the range of haddock in the Northwest Atlantic, it is probable that the actual value of M for this stock may be somewhat higher than 0.2. The long-term assessments were computed for M values of 0.15, 0.25 and 0.35, corresponding to values of E of 0.80, 0.67 and 0.53 respectively, but it is thought that the higher values of M (hence the lower values of E) are the more probable ones.

In such a fishery, where there have been violent changes not only in year-class strength but also in growth rate and size composition, it is difficult to make assessments of the effects of a mesh size regulation which will generally be applicable. The assessments are further complicated by an inadequate knowledge of the size composition of the fish discarded at sea by Canadian and Spanish trawlers, and, even though rough estimates of the quantities discarded are known, these vary considerably from year to year and even from season to season as a good year-class enters and grows through the selection range of the commercial gear. Unlike the cod fishery, in which the quantities discarded at sea in Subarea 3 are at present insignificant, the discarding of haddock below commercial size has always been a serious problem from the point of view of conservation. Estimates of the quantities discarded annually during the 1955-58 period varied between 6% and 23% for Newfoundland trawlers, giving a weighted average for the period of 15% by weight. No such estimates are available for the Spanish fishery, but references to discards and to minimum commercial size are given in the "Spanish Research Reports" of ICNAF Annual Proceedings as follows: in the Report of 1954 there is one observation of 20% by number discarded, but this occurred at the end of the fishing campaign; in September of 1956 57% of 2242 haddock measured from a catch were discarded as being too small for the industry; in 1957 it is stated that, of two samples taken in August and September, the quantities discarded were large; in all instances the minimum commercial size was given as about 40 centimeters. By assuming for the Spanish length compositions that "knife-edge" discarding occurred between 37 and 38 centimeters, a value of 18% by weight discarded is obtained, which value is similar to that given for Newfoundland trawlers. In view of the variable nature of the quantities discarded, the assessments were made by assuming that discards ranged from 10% to 25% by weight.

The assessments for haddock are based on the average size composition of the catches for the period 1955-58. Because of the similarity of the length composition of the catches by the Newfoundland and by the Spanish trawlers (Figure 12), the calculations are based on the combined data of both fleets. The estimates of t_c were obtained from the growth curve shown in Figure 13, and the length-weight relationships used are given in Appendix III. The selection ogives (Appendix II) were prepared from information published by Clark, McCracken and Templeman (1958).

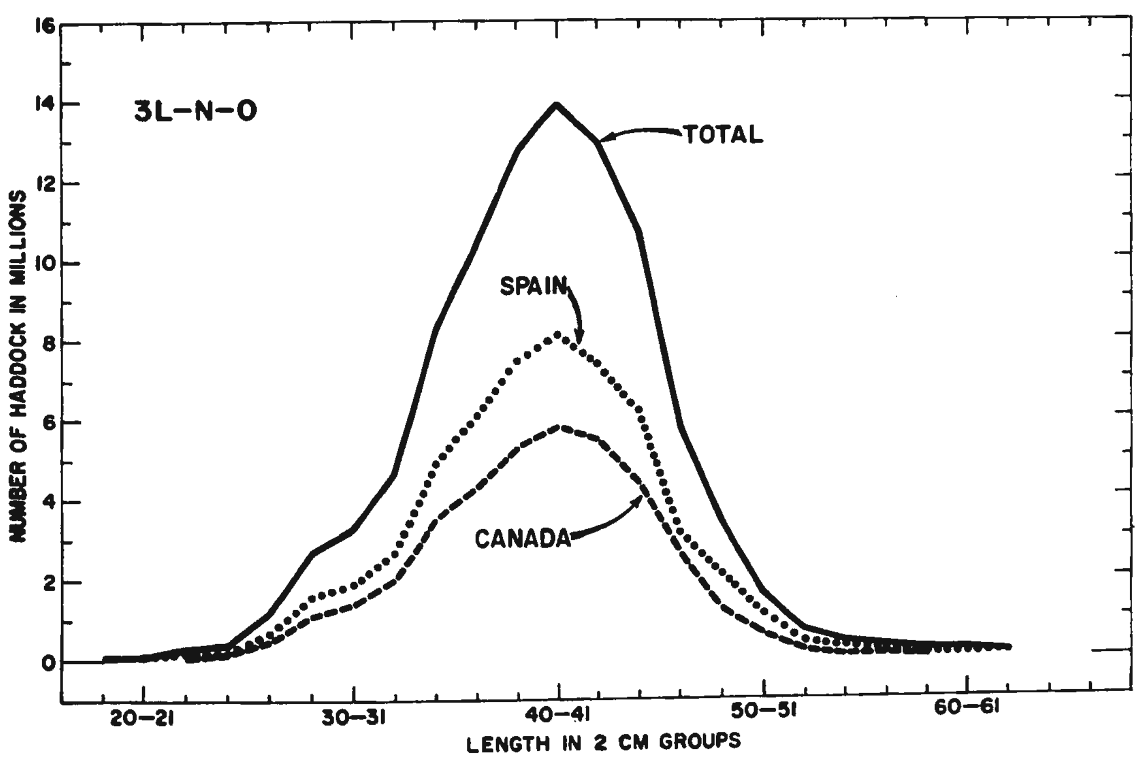

Figure 12. Subarea 3 haddock: length composition of the average annual catches by Canadian and Spanish trawlers for the period 1955-58 in region 3N-O.

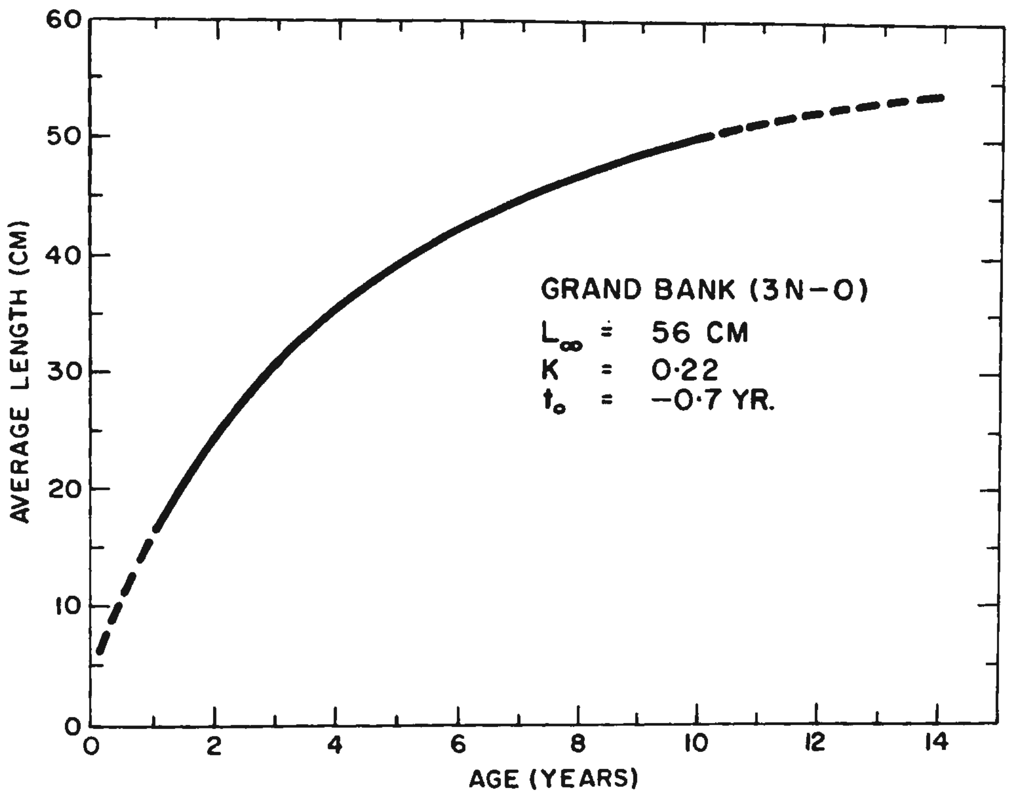

Figure 13. Subarea 3 haddock: growth curve obtained from the Bertalanffy growth equation fitted to age-length data from the Grand Bank stock.

The assessments, based on increases in mesh size from an initial 3 inches by intervals up to 6 inches, are given in Table 11. For increases in the mesh size of trawls to 4½ inches long-term gains would result over the entire ranges of M and of discards considered. For increases above 4½ inches the effect depends very much on the value of M: if M is less than 0.25 the gain for a 5-inch mesh would be substantial, but if M is greater than 0.25 a long-term loss would probably result; for the 5½ and 6-inch mesh sizes the long-term losses would be large except for very low values of M (hence high values of E). If we consider the intermediate values of E and of discards as being on an average the most probable ones, a mesh size of 4½ inches would produce the optimum long-term benefits.

Table 11. Divisions 3N and 3O assessments for haddock*

Percentage discards with 3-inch mesh	Mesh size change (inches) From 3 to	l_c (cm) 31.1	t_c (yr) 3.0	Percentage change in 1955-58 landings: Immediate loss	Long-term change for E 0.53, F 0.40, M 0.35	E 0.67, F 0.50, M 0.25	E 0.80, F 0.60, M 0.15
10%	4	35.4	3.8	-5.8	+2.8	+5.5	+8.3
	4½	37.5	4.3	-15.6	+0.7	+6.4	+12.4
	5	41.4	5.4	-38.5	-11.3	+0.2	+13.6
	5½	46.0	7.1	-64	-32.5	-15.0	+8.0
	6	49.9	9.4	-80	-53	-32.3	-1.2
17%	4	Same as		-4.4	+4.4	+7.2	+10.0
	4½	above		-12.7	+4.1	+10.1	+16.2
	5			-34.6	-5.8	+6.5	+20.7
	5½			-62	-27.0	-8.1	+16.8
	6			-79	-49	-26.3	+7.5
25%	4	Same as		-3.6	+5.2	+8.0	+10.8
	4½	above		-11.1	+6.1	+12.1	+18.4
	5			-32.0	-2.0	+10.8	+25.6
	5½			-59	-22.7	-2.6	+23.8
	6			-77	-45	-21.0	+15.3

*Trawl group - Canada (41%), Spain (58%) and others (1%).

C. Redfish

1. Brief review of the fishery

The redfish fishery of Subarea 3 was begun in 1947 on the southern part of the Grand Bank (Divisions 3N and 30) by Canadian trawlers, and USA trawlers began fishing there in 1951. There was a rapid rise in annual landings to a peak of nearly 46 thousand tons in 1952. By 1955 the landings had declined to 18 thousand tons, due partially to a major shift in fishing effort to redfish in the Gulf of St. Lawrence (Divisions 4R, 4S and 4T) and partly to a diversion of effort by Canadian trawlers to fishing for haddock. In 1956 USSR trawlers started fishing in Division 3M, where the redfish concentrations had not been exploited previously. By 1958 their exploitation of redfish had extended into Divisions 3K and 3L. Icelandic trawlers started fishing in 3K in the autumn of 1958. Consequently there has been a very rapid increase in total redfish landings from Subarea 3 to 158 thousand tons for the year 1958, of which the USSR took 60%, Iceland 28%, USA 6% and Canada 5% (Figure 14, and Appendix I, Tables 12 and 13).

2. Nature of the stocks

Because of the very recent development of the redfish fishery on a major scale in Subarea 3 and because of the scarcity of information on the stocks from the major redfish-producing countries, it is not possible to divide the stocks except perhaps on a very general basis. Templeman (1959b),

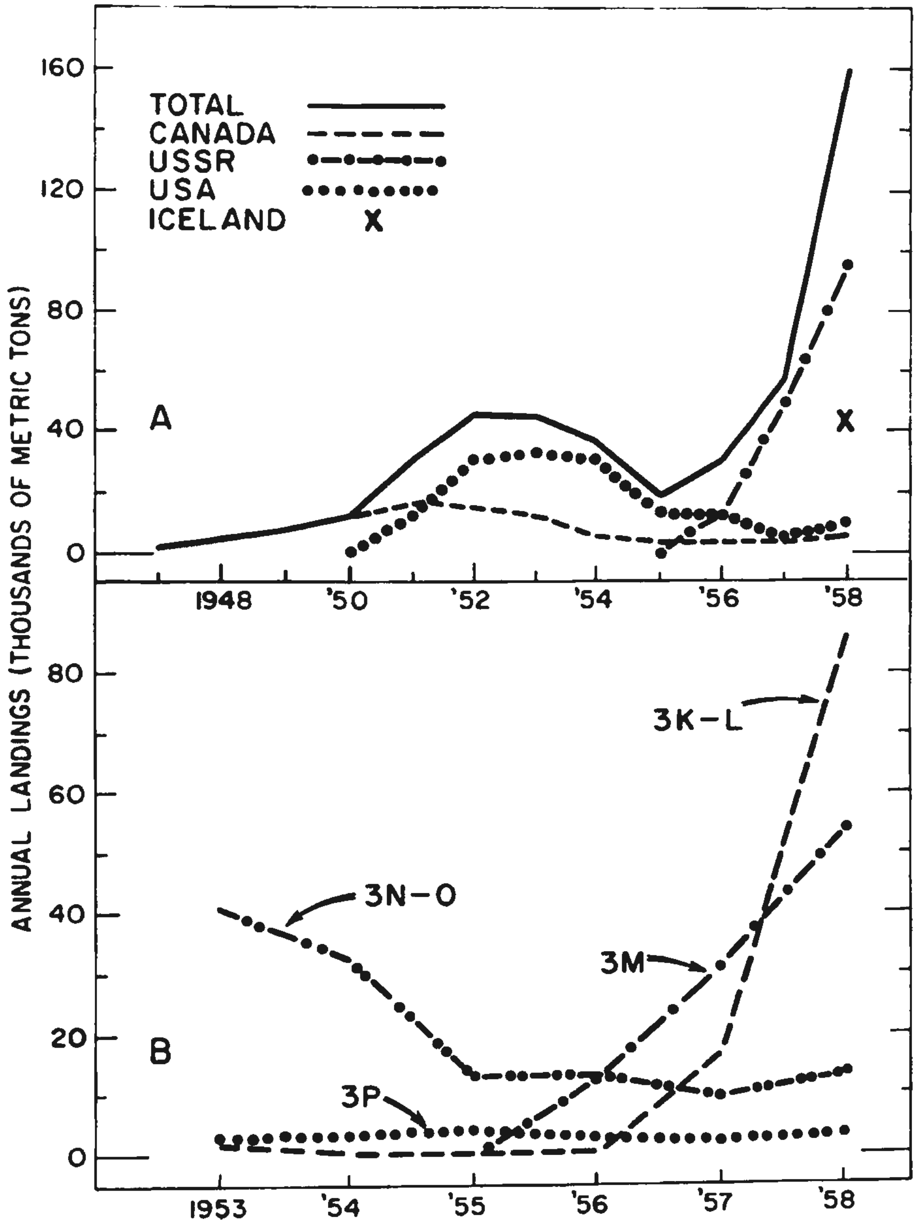

Figure 14. Subarea 3 redfish: landings by countries for the period 1947-58 and by regions for 1953-58.

from exploratory research vessel fishing carried out during the period 1947-54, considers three major divisions of the subarea from the point of view of redfish distribution : the deep water area extending from the southeastern slope of the Grand Bank northward along the east coast of Newfoundland (Divisions 3K and 3L), where the redfish are restricted in their vertical movement by the overlying cold water of the Labrador Current; the Flemish Cap (Division 3M), where there are no such temperature restrictions; and the area along the southwestern slope of the Grand Bank and along the south coast of Newfoundland (Divisions 3N, 3O and 3P), where the redfish are found in shallower water than to the north. The main redfish concentrations of the Northwest Atlantic are found in depths ranging from 100 to 300 fathoms, usually in the neighbourhood of the deep bottom water where the temperatures range between 3 and 6°C. For these assessments Division 3P is considered separately from 3N and 3O, mainly because the former region is the center of a small local Newfoundland fishery and also because the length composition of the catches in 3P is quite different from those of the Canadian and USA catches in 3N and 3O.

3. General notes on data used in making the assessments

Unlike cod and haddock, for which the problem of age determination has been resolved for some time and ageing is relatively simple, redfish combine slow growth and a long life with the fact that they live in deep water where seasonal variation in environmental conditions is not great, so that age determination is very difficult and laborious. Consequently, there are very little age-composition data available, from which estimates of total mortality coefficients for the redfish stocks can be obtained. It is not possible, therefore, to do more than determine the immediate effects of increases in the mesh size of trawls and estimate the minimum break-even values of E.

Length compositions of the catches from the various regions for 1958 are illustrated in Figure 15. Length compositions of USSR catches were considered representative of all redfish catches in Divisions 3K, 3L and 3M by countries not reporting length-composition data. Those for 3K and 3L were combined for the assessments because of their similarity. Likewise Canadian and USA length compositions of catches in 3N and 3O were taken together. The data for the remaining two regions, 3M and 3P, were considered separately. The discarding of small redfish at sea was not taken into account in the assessments, for no estimates of quantities discarded or minimum commercial sizes are available and the discarding of small fish is not thought to be a serious problem in the redfish fishery at present. Although marinus-type redfish are caught in small quantities in some parts of the subarea, the assessments are based entirely on the length compositions of mentella-type redfish.

The selection ogives and the length-weight relationships, used to calculate the immediate effects of increases in mesh size, are given in tabular form in Appendices II and III

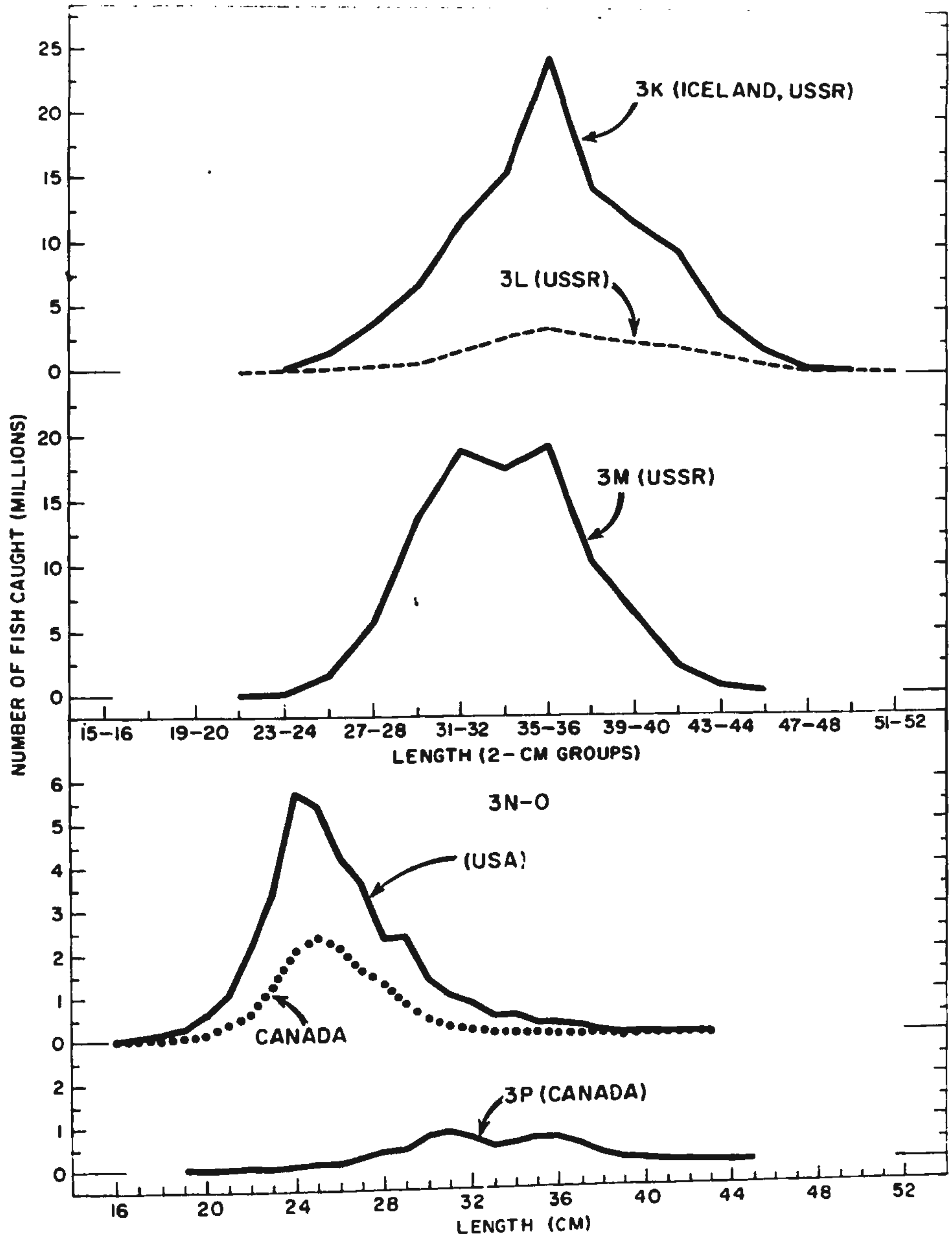

Figure 15. Subarea 3 redfish: length composition of catches by countries and regions for 1958. (Those for 3K, 3L and 3M are given in 2-cm groups.)

respectively. The values of t_c estimated for the various mesh sizes were obtained from the growth curve of Figure 16, which is based on age-length data of redfish from Hermitage Bay on the south coast of Newfoundland (Sandeman, 1959). The effective trawl mesh size in current use was assumed to be 3 inches, and increases by ½-inch intervals to 6 inches were considered.

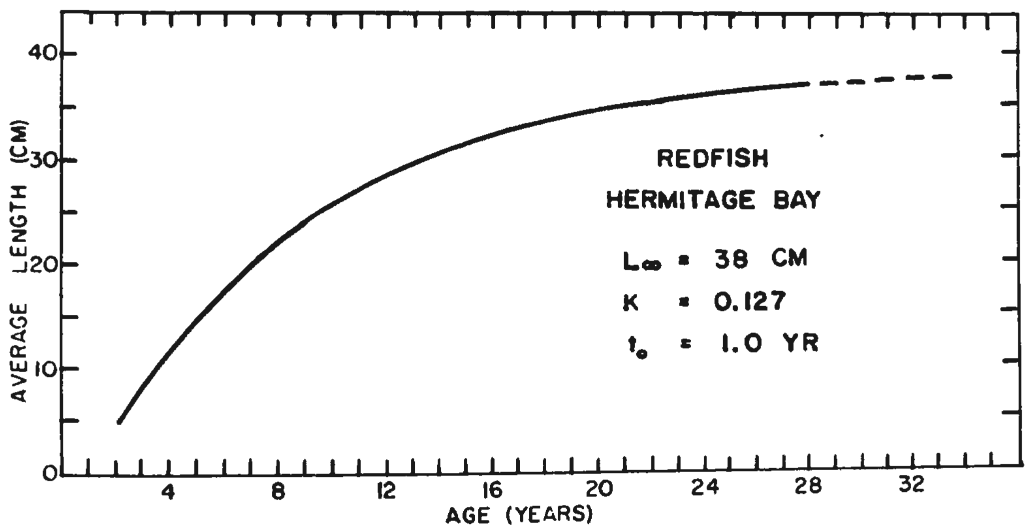

Figure 16. Subarea 3 redfish: growth curve obtained from the Bertalanffy growth equation fitted to the age-length data of Hermitage Bay redfish (from Sandeman, 1959).

4. Divisions 3K and 3L assessments for redfish

This fishery on virgin stocks began only in 1957, and good fishing was experienced by USSR trawlers as is indicated by the landing per unit effort data for 1957 and 1958 (Appendix I, Table 14). From Table 12 it is noted that the USSR and Iceland shared almost equally the total landings of redfish from this region in 1958. As would be expected during the initial exploitation, the fish caught here were considerably larger than those from any other region of the subarea, the mode of the frequency distribution being at 35-36 centimeters and the mean weight being 0.71 kilogram (Appendix I, Table 15).

Table 12. Subarea 3 redfish: annual landings by gear, country and region for 1958.

Gear	Country	Landings in thousands of tons (1)				
		3K-L	3M	3N-O	3P	Total
Trawl	Canada (M)	+	-	0.5	+	0.8
	Canada (Nfld)	+	+	3.3	3.1	6.8
	France (St. P)	-	-	-	0.6	0.6
	Germany (E)	-	0.6	-	-	0.6
	Germany (W)	-	-	+	+	+
	Iceland	43.7	-	-	-	43.7
	USSR	42.2	53.9	-	-	96.1
	USA	-	+	10.0	+	10.1
	Total	86.2	54.5	13.8	4.2	158.7

(1) From Appendix I, Table 13.

The assessments for this region are given in Table 13. From the available length-composition data (and these may not be indicative of the size composition of the stock after several years' exploitation), the immediate losses would be slight for increases in the mesh size to 4½ inches but they would become substantial for larger meshes. Considering the slight immediate losses and the small values of Δt, the minimum break-even value of $\underline{E}$ suggests that the fishing intensity might not have to be particularly high for mesh sizes up to 4½ inches to produce long-term gains, particularly if the natural mortality coefficient (M) is of the order of 0.1 or less, which it is likely to be in a long-living fish as the redfish.

5. Division 3M assessments

The fishery in this region was begun on a virgin stock in 1956 by USSR trawlers, and up to 1958 the annual landings have increased from an initial 13 thousand tons to 55 thousand tons. For 1957 and 1958 the landings per unit effort were below that for 1956 (Appendix I, Table 14), but no conclusions can be drawn at this stage because some of the effort, particularly in 1957, may have been devoted to cod fishing. The length composition of USSR catches in 1958 indicates that the redfish in this region are generally smaller than those in 3K and 3L, having the mode of the frequency distribution at 33-34 centimeters and a mean weight of 0.57 kilograms (Appendix I, Table 15).

The assessments for redfish in this region are given in

Table 13. The immediate losses would be substantial for all increases in mesh size above 4½ inches. The minimum break-even value of E suggests that fishing intensity would have to be relatively higher than in, for example, Divisions 3K and 3L for long-term gains to result from any increase in mesh size beyond 4 inches.

6. Divisions 3N and 3O assessments

Redfish fishing began in this region in 1947 and the annual landings rose rapidly to a peak landing in 1952 of 45 thousand tons, caught entirely by Canadian and USA trawlers (Figure 14). Since then the annual landings have ranged between 6 and 15 thousand tons. Although the landings have fluctuated greatly, no consistent trend is detectable in the landing per unit effort data (Appendix I, Table 14); rather the fluctuations are probably due to major shifts in fishing effort to other areas of redfish concentration and even to fishing for other species, e.g. haddock in 1954-56. Although adequate length compositions of commercial catches are not available for the early years of the fishery, some data collected by the St. John's Biological Station, Newfoundland, indicate that there has been a gradual decrease in the average size of redfish caught by Newfoundland trawlers since the fishery began. This is what would be expected to happen as fishing intensifies on a previously unexploited stock, but a change of this kind can also be exaggerated by a tendency for the fleets to fish concentrations of smaller redfish at shallower depths if the larger fish have become less abundant in deeper water. From exploratory fishing carried out in this region in 1952, Templeman (1959b) shows that a difference of as much as 9 centimeters existed between the modes of the length-frequency distributions of redfish caught in 110 and 200 fathoms. The trawlers now land redfish considerably smaller than they did during the early years of the fishery, despite the fact that the price differential favours the catching of larger fish. Although it cannot be definitely stated that the stocks are being reduced by fishing, there is some indication that redfish are not now as abundant in the depths fished by the trawlers at the start of the fishery. The mode of the length composition of the catches in 1958 was about 25 centimeters and the mean weight about 0.27 kilograms (Appendix I, Table 15).

For all increases in mesh size beyond that at present in use, the immediate losses would be large (see Table 13). The high minimum break-even value of $\underline{E}$ and the large values of Δt indicate that fishing would have to be quite intense for any increase in mesh size to produce long-term gains, bearing in mind especially that the break-even value of $\underline{E}$ of 0.7 is a minimum for an increase in mesh size to 4 inches.

7. Division 3P assessments

The Canadian redfish fishery in this region is carried on by a few small trawlers on local concentrations in the deep

Table 13. Subarea 3 assessments for redfish.

ICNAF Divisions	Mesh size change (inches)	l_c (cm)	t_c (yr)	Percentage change in 1958 landings: Immediate loss	Long-term: Break-even value of E at least
3K-L	From 3 to	31.3	14.8		
	4	31.6	15.4	-1.2	0.5
	4½	32.2	16.0	-6.1	
	5	33.7	18.4	-18	
	5½	36.1	24	-37	
	6	38.9	35	-57	
3M	From 3 to	28.3	12.0		
	4	28.8	12.4	-2.9	0.6
	4½	30.1	13.6	-12.3	
	5	32.3	16.0	-30	
	5½	35.4	22	-54	
	6	38.6	35	-72	
3N-O	From 3 to	21.9	7.8		
	4	25.2	9.6	-31	0.7
	4½	28.1	11.8	-56	
	5	31.6	15.4	-76	
	5½	35.2	21	-89	
	6	38.6	35	-95	
3P	From 3 to	27.6	11.4		
	4	28.3	12.0	-4.4	0.6
	4½	29.8	13.4	-16.3	
	5	32.2	16.0	-36	
	5½	35.4	22	-60	
	6	38.6	35	-77	

water channels just off the south coast of Newfoundland. Small quantities are also obtained from the western slope of St. Pierre Bank. From 1953 to 1958 the annual redfish landings have ranged between 2 thousand and 5 thousand tons (Appendix I, Table 13). Landing per unit effort data, available only since 1954, indicate that there has been more than a 30% decline in the landings per hour fished since 1955 (Appendix I, Table 14). The effort remained relatively steady between 1954 and 1957, but a considerable increase in effort occurred in 1958, probably due to the decline in the haddock fishery on St. Pierre Bank.

The redfish caught in this region during 1958 were larger than those landed from Divisions 3N and 30 (Figure 15), and consequently the immediate losses would be less, but they would still be quite substantial for increases in mesh size beyond 4 inches (Table 13). The minimum break-even value of E is not as high as that calculated for 3N and 30, but nevertheless it indicates that fishing would have to be fairly intense for mesh size increases to produce long-term gains.

D. Flounders (American plaice and witch)

Like the haddock and redfish fisheries, the flounder fishery of Subarea 3 has developed only since the end of World War II, and up to the present time it has been prosecuted mainly by Canadian trawlers. Statistics of landings by countries and ICNAF divisions are available only since 1953 and these are given in Appendix I, Table 16. The annual landings for the period 1953-58 ranged between 11 thousand and 26 thousand tons. The flounder landings consist largely of American plaice (80-90%), the remainder being mostly witch flounder.

Calculations of the immediate and long-term effects of increases in the mesh size of trawls have not been undertaken in this study. However, in Figure 17 are illustrated American plaice length compositions of catches and landings together with the 4-inch and 6-inch selection curves. The data are sufficient to show that, although no great saving of small fish would be realized, an increase in the mesh size of trawls to 6 inches would not significantly affect the landings, the 50% retention length being below the minimum length of fish in the landings.

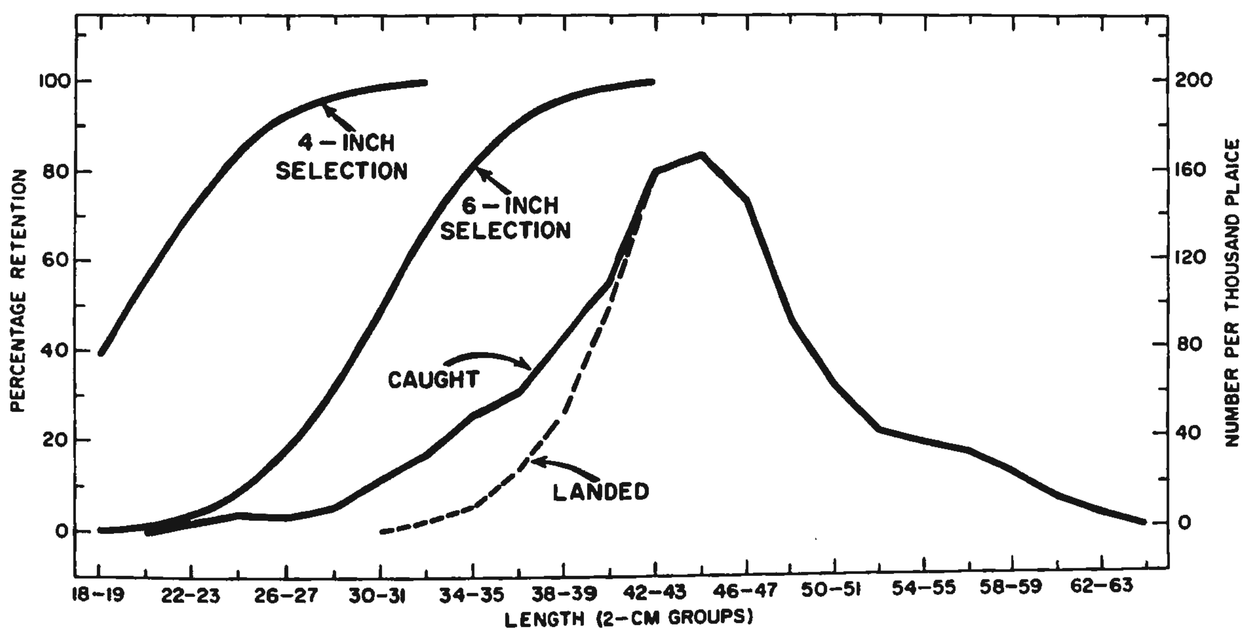

Figure 17. Subarea 3 American plaice: length composition of catches and landings, based on data collected by observers on two trips on Newfoundland trawlers in 1953; and the selection curves for the 4-inch and 6-inch trawl mesh sizes.

SECTION 6. SUMMARY OF THE ASSESSMENTS

The assessments of increases in the mesh size of trawls, given in the preceding section, are summarized in Table 14, which gives the immediate and long-term percentage changes in landings by trawlers (T), other gears (O) and by all gears combined (Tot.) for each of the "stock units" or regions of Subarea 3. Only the assessments for a single value of E, the central value which is thought to be the most likely, have been used for each region, and these values of E are given in the last column of the table. Also given are the average annual landings, in thousands of tons, by the two major gear components; these are the same quantities given in the tables of landings of the preceding section. In summary tables of this kind it is unavoidable that space is available for entries that are uncertain or lacking altogether; to meet these situations the following symbols have been used:

- \- no landings
- • no assessments made
- ( ) estimates uncertain.

In Table 14 the last line for each species represents the percentage changes for the subarea as a whole. These values were obtained by weighting the regional percentage changes for each mesh size by the landings given in the left-hand part of the table. For cod, listed from 3NK (division not known) and from Division 3M, no long-term assessments could be made because of inadequate information, but the landings given are so insignificant, relative to the total landings of cod, that the assessments for the subarea as a whole would not be affected. For haddock in Division 3P no assessments were made because of the transitory nature of this fishery, but in considering the total landings for the subarea the 3N and 3O assessments are assumed to be representative of the entire haddock fishery. For redfish in all regions of the subarea only the immediate losses are given because the available data were inadequate for the calculation of long-term effects. The underlined values in Table 14 represent for the trawl fishery and for the total fishery the optimum situations of the various increases in mesh size.

In considering the optimum conditions for a mesh-size regulation of the trawl fishery, it is essential for practical reasons (i.e. the application of a uniform mesh-size regulation throughout the subarea) to combine the effects of mesh-size changes for all species that may be affected. In this study the lack of long-term assessments for redfish does not permit such a combination. It is possible, however, to treat the cod and haddock fisheries in this way. In Table 15, therefore, are given the percentage changes for cod and haddock separately (from Table 14) and for both species combined. For reference the immediate losses to the redfish fishery are given in the last column of the table.

From Table 15 the long-term percentage changes for <u>cod</u> of the subarea as a whole indicate that the total landings would increase steadily with increases in mesh size up to 6 inches. The trawl fishery would also gain from increases in mesh size up to 6 inches, but the optimum benefit would be obtained with a mesh of 5 to 5½ inches. The other unregulated gears would gain increasingly as the mesh size of trawls is increased.

For haddock, the larger part of which was landed from the Grand Bank (3N and 30) part of Subarea 3, long-term gains would result from increases in mesh size to 5 inches, but losses are predicted for the larger mesh sizes. The optimum long-term benefits would probably result from a mesh size of about 4½ inches.

For cod and haddock combined the total landings by all gears would reach an optimum level for a trawl mesh size of 5 inches but would decrease rapidly thereafter. The trawl fishery would gain with a mesh increase to 5 inches and probably to 5½ inches, but a 6-inch mesh would result in long-term losses; the optimum mesh size is indicated as 4½ inches.

For redfish, because there are no long-term assessments, nothing can be said about the mesh sizes which would produce the optimum long-term yields. However, for the subarea as a whole the immediate loss to the landings would probably not be greater than 5% for a mesh-size increase to 4 inches, and this might be compensated for in the long-term in all regions except 3N and 30 where the immediate loss would be substantial. For a mesh size of 4½ inches, however, the immediate loss (-13%) for the subarea is high enough that there is little probability that this could be fully made up in the long-term.

Table 14. Summary of the assessments given in Section 5.

Species	Stock unit area	Annual landings ('000 tons)			Percentage changes in landings resulting from incr[ea]se[s]								
					4 inches				4½ inches				
					Imm.	Long-term			Imm.	Long-term			…n.
		T	O	Tot.	loss	T	O	Tot.	loss	T	O	Tot.	…ss
Cod	3K-L	71	161	232	-0.3	+0.5	+0.5	+0.5	-1.0	+0.7	+0.9	+0.9	…5
	3M	6	+	7	-3.2	.	.	.	-6.6	.	.	.	- …0
	3N-O	61	16	77	-1.3	+3.7	+5.0	+4.0	-3.2	+6.3	+9.5	+7.0	…6
	3P	28	37	65	-0.6	+0.7	+0.7	+0.7	-1.9	+1.0	+1.7	+1.4	…3
	3NK	2	7	9	.	.	.	.	.	.	.	.	…
	Total	168	222	390	-0.8	+1.8	+0.9	+1.3	-2.2	+2.9	+1.7	+2.2	…7
Haddock	3N-O	48	-	48	-4.4	+7.2	-	+7.2	-12.7	+10.0	-	+10.0	-
	3P	27	+	27	.	.	.	.	.	.	.	.	…
	Total	75	+	75	(-4.4)	(+7.2)	-	(+7.2)	(-12.7)	(+10.0)	-	(+10.0)	(- …)
Redfish	3K-L	86	-	86	-1.2	.	-	.	-6.1	.	-	.	-
	3M	55	-	55	-2.9	.	-	.	-12.3	.	-	.	-
	3N-O	14	-	14	-31	.	-	.	-56	.	-	.	-
	3P	4	-	4	-4.4	.	-	.	-16.3	.	-	.	-
	Total	159	-	159	-4.5	.	-	.	-12.9	.	-	.	-

Table 15. Predicted long-term effects of applying a uniform mesh-size regulation t[o] th[e cod] and haddock fisheries of Subarea 3.

Mesh size change in inches from 3 to	Percentage long-term changes in landings for the various mesh sizes								
	Cod			Haddock			Cod and Haddock		
	T	O	Tot.	T	O	Tot.	T	O	Tot.
4	+1.8	+0.9	+1.3	+7.2	-	+7.2	+3.5	+0.9	+2.…
4½	+2.9	+1.7	+2.2	+10.0	-	+10.0	+5.1	+1.7	+3.…
5	+3.9	+3.0	+3.3	+6.5	-	+6.5	+4.7	+3.0	+3.…
5½	+4.0	+5.5	+4.9	-8.1	-	-8.1	+0.3	+5.5	+2.…
6	+2.3	+8.0	+5.5	-26.3	-	-26.3	-6.5	+8.0	+0.…

	ses of mesh size to :											Value of E used
	5 inches			5½ inches				6 inches				
n.	Long-term			Imm.	Long-term			Imm.	Long-term			
ss	T	O	Tot.	loss	T	O	Tot.	loss	T	O	Tot.	
.5	+0.5	+1.7	+1.3	-7.1	-1.6	+3.2	+1.7	-13.5	-5.5	+4.7	+1.6	0.67
.0	.	.	.	-23.4	.	.	.	-34.8	.	.	.	.
.6	+9.1	+15.7	+10.5	-14.3	+12.7	+26.9	+15.7	-22.5	+14.2	+36.7	+18.9	0.71
.3	+1.1	+3.0	+2.2	-11.2	-0.6	+6.4	+3.4	-19.3	-3.9	+10.0	+4.0	0.67
.	.	.	.	.	.	.	.	.	.	.	.	.
.7	+3.9	+3.0	+3.3	-11.0	+4.0	+5.5	+4.9	-18.6	+2.3	+8.0	+5.5	
	+6.5	-	+6.5	-62	-8.1	-	-8.1	-79	-26.3	-	-26.3	0.67
.	.	.	.	.	.	.	.	.	.	.	.	.
)	(+6.5)	-	(+6.5)	(-62)	(-8.1)	-	(-8.1)	(-79)	(-26.3)	-	(-26.3)	
	.	-	.	-37	.	-	.	-57	.	-	.	.
	.	-	.	-54	.	-	.	-72	.	-	.	.
	.	-	.	-89	.	-	.	-95	.	-	.	.
	.	-	.	-60	.	-	.	-77	.	-	.	.
	.	-	.	-48	.	-	.	-66	.	-	.	.

the cod

	Imm. loss
	Redfish
t.	T
.2	-4.5
.5	-12.9
.8	-28
.8	-48
.1	-66

SECTION 7. DISCUSSION AND CONCLUSIONS

The assessments presented in the preceding sections are strictly valid only if such parameters as the amount and the distribution of fishing activity, growth rates, natural mortality rates and recruitment remain unchanged from those estimated as existing during the period 1955-58, on which the data are based. No attempt has been made in this study to calculate in a comprehensive way the effects that changes in these parameters would have on the assessments of changes in mesh size, but some generalizations of the effects that might be expected can be given.

A greater fishing effort will increase the total mortality rate. This will in the long-term reduce the number of large fish in the catches, and consequently the number of small fish will be greater. The immediate loss for a given increase in mesh size will be larger, but so also will be the number of released fish. The long-term gain from the released fish will be higher, since the proportion subsequently caught (E) will also be higher than before. Therefore, the effect of increased fishing effort will, for a given increase in mesh size, generally result in greater long-term gains than those given in the preceding assessment tables. It is also true that the optimum mesh size (i.e. that required to produce the maximum long-term yield) will also increase as fishing effort increases (Beverton and Holt, 1957, p. 318).

It is inevitable that increased fishing effort will result in changes in the distribution of fishing activity on fish of different sizes. The decreases in catch per unit effort, which must follow such increases in fishing effort, may cause trawlers to fish in areas where small fish predominate, once the larger fish have become scarcer on the normal fishing grounds. Also technological improvements in processing may reduce the size of fish acceptable on the market. Consequently, the catches under conditions of increased fishing effort would consist of relatively smaller fish than before, and so the fishery would become much more sensitive to changes in mesh size (compare the length compositions and the long-term assessments for cod in 3K and 3L with those for haddock in 3N and 30).

Changes in the growth rate of a fish stock may greatly influence the long-term assessments, particularly if the changes occur over the selection range of the gear. A slower growth will have the effect of increasing the value of Δt (the difference between the mean retention ages of the large and small mesh sizes), thus reducing the number that will reach the retention size of the larger mesh and diminishing any long-term gain that might be indicated by a faster growth rate. Should such a change in the growth rate occur, a smaller mesh size would be better, even if the larger one is considered best under present conditions of growth. Of course, a faster growth rate on the other hand would enhance the long-term benefits and cause the optimum yield to be obtained with a mesh size larger than that predicted in the assessments.

Changes in natural mortality will greatly affect the assessments, insofar as they affect the number of released fish that will subsequently be caught with the larger mesh and also the number of larger fish in the immediate kept catch. Since it was not possible from the available data to obtain reliable estimates of this parameter, some appreciation of its effect on the long-term assessments for the various mesh sizes is given in the assessment tables of Section 5.

Changes in the recruitment of fish to the exploited stock may in certain cases have a serious effect on the assessments. Insofar as the assessments in this study compare not so much the future yields with present yields but rather present yields by small-meshed trawls with yields that might have been obtained had a larger mesh been used during the same period, recruitment changes will not critically affect these assessments. However, if the amount of fishing on a stock depends largely on the prominence of certain year-classes (e.g. the St. Pierre Bank haddock fishery which is an extreme case), the estimated long-term assessments may not be as reliable as those for a fishery on a stock which exists under more stable conditions. In such a fishery as the St. Pierre Bank haddock fishery, the best theoretical long-term yield from a single year-class might be obtained by a large mesh if fishing extended over the full life-span of the year-class from the time it entered the exploited phase of its life. In practice, however, the yield from the year-class will not be as high as the theoretical yield, because the catch per unit effort will, unless there are other good year-classes following along, become so small during the later years of the life-span that fishing will be unprofitable. The best attainable yield might, therefore, be obtained by the use of a mesh size smaller than that predicted and with intense fishing occurring over a relatively short period of time.

All of the above factors, if operating at once in the same direction on any particular stock of fish, will greatly affect the long-term assessments as calculated from the present data by either greatly enhancing or diminishing the benefits that are predicted to accrue from an increase in mesh size. This is seldom the case, however, certainly for the more stable fisheries such as the cod fisheries throughout the subarea, for changes in some of the parameters in one direction may be balanced by changes of others in the opposite direction. Consequently, if the parameters used for the cod assessments of this study are representative of the stock units throughout the subarea, there is no reason to believe that the predicted long-term changes at present effort levels do not give a fairly dependable indication of what mesh size would be best for the trawl fishery. On the other hand, the long-term changes for the haddock fishery are much more sensitive to mesh size changes, and the predicted long-term changes are less reliable.

The most critical fishery at the present time seems to be the haddock fishery, in which there was great destruction of small haddock during the peak years of the fishery. For comparison, let us digress here to briefly consider a parallel situation for the haddock fishery of ICNAF Subarea 5. The landings from that fishery reached their peak in 1930 as a result of a very rapid rise in fishing effort. Coincident with this rise in effort there was a fourfold decrease in the catch per unit effort to a level about which the catch per unit effort fluctuated only slightly for the next 20 years (Herrington, 1941, and Graham, 1952). Herrington (1935, 1936), in summarizing the available information, reported that the small-meshed trawls were destroying each year very large numbers of small haddock; for example, during the 9-month period from September of 1930 to May of 1931, it was estimated that 63 million small haddock were destroyed, a number equivalent to nearly 100 thousand tons of fish, if they had been permitted to live and grow to a commercially acceptable size. He proposed that four-fifths of this wastage would be eliminated with no serious effects on the commercial landings by the introduction of a minimum legal mesh size in trawls of 4 3/4 inches, new dry measurement between knot centers (equivalent to a mesh size of about 4 inches, internal wet measurement). He warned, "It cannot be assumed that the saving of undersized haddock will restore the fishery to its 1926 to 1928 level; in fact, no one can guarantee that the fishery will be maintained at its present level. But we can be sure that, if the destruction of small fish is prevented, the fishery will be maintained at a higher level than would otherwise be possible." No action was taken on this or other similar proposals to decrease the destruction of small haddock until 1952, when, upon the recommendation of the International Commission for the Northwest Atlantic Fisheries after a special assessment, regulations were introduced to prohibit the taking of haddock in the New England area (ICNAF Subarea 5) with a trawl net having a mesh size less than 4½ inches when measured wet after use.

In 1957 the 4½-inch mesh regulations were extended to the cod and haddock fisheries of Subarea 4, and 4-inch mesh size regulations were introduced for the same two species in Subarea 3. Although no comprehensive long-terms assessments were made as a basis for such a decision, it was apparent from the start of the Subarea 3 haddock fishery, particularly during 1954-56 when the very abundant 1949 year-class was undergoing intensive exploitation and very large quantities of small haddock were discarded at sea as being too small for the market, that there was a need for some form of trawl regulation. As a result of the experience gained from the mesh size regulations for trawls in Subarea 5, it was decided that a 4-inch minimum mesh size for trawls could not be harmful to the haddock fishery but would permit the release of some of the small haddock that normally would be destroyed by the continued use of trawls with a small mesh size (2 3/4 to 3 inches). The present assessments indicate that the minimum 4-inch mesh regulations for cod and haddock were a step in the right direction, but an increase in mesh size to $4\frac{1}{2}$ inches is predicted to further reduce the wastage of small fish and enhance the long-term yields of these fisheries.

Redfish, because of their very different biological characteristics of a long life-span and slow growth, cannot be considered in the same light with the faster-growing cod and haddock. However, despite the lack of long-term assessments, the minimum break-even values of E for the various regions are such that appreciable long-term benefits are unlikely from any increase in the mesh size above that currently in use (a mesh size of 2 3/4 inches is generally used, since the 4-inch mesh regulations do not include redfish). Small increases in the mesh size, e.g. to 4 inches, would probably result in only very slight changes in the immediate and the long-term yields of redfish from most regions, and this may also be true for an increase in mesh size to $4\frac{1}{2}$ inches except in Divisions 3N and 3O. In this region, where the redfish caught and landed are small, a mesh size regulation of $4\frac{1}{2}$ inches (minimum) to include this species might be beneficial, despite the large immediate losses indicated in this study, in encouraging trawlers to fish at greater depths where larger redfish predominate or to fish in other regions, thus enabling the 3N and 3O stock to recover from the effects of past exploitation on small fish.

Although no long-term assessments were made for the flounder fishery in Subarea 3, it can be safely postulated that any increase in the mesh size to 5 or even to 6 inches would not affect the commercial landings of these species, if the present discarding practices remain unchanged.

It is apparent from the foregoing that the mesh sizes required to produce the optimum yields from the four major commercial fisheries are very different. Since two or more of the species are often present on the same fishing grounds and caught by trawlers even when only one species is sought and landed, it would not be realistic to regulate these fisheries with different minimum mesh sizes; but rather a uniform mesh-size regulation should be the aim of the legislators from the practical viewpoint of enforcement and control over the size of mesh required in the manufacture of trawls. The present assessments indicate that a minimum mesh size of 4½ inches would represent a fair medium for the regulation of the trawl fisheries in Subarea 3. However, if the present trend of rapidly increasing fishing effort by trawlers continues, it might be better from the viewpoint of conservation to increase the minimum mesh size to 5 inches.

ACKNOWLEDGEMENTS

This preliminary study of the effects of increasing the mesh size of trawls on the major commercial fisheries of the Newfoundland area (ICNAF Subarea 3) was initiated as a result of the concern that has been expressed in recent years for the conservation of the fish stocks. Much information about the stocks still remains unpublished, and the author gratefully acknowledges the assistance of scientists at the St. John's Biological Station, Fisheries Research Board of Canada, who supplied essential data. The author is particularly indebted to Dr. E. M. Poulsen, Executive Secretary of ICNAF, Halifax, N. S., who patiently responded to the many requests for data which were otherwise not available. Dr. W. Templeman and Mr. A. W. May kindly read the manuscript and offered many suggestions which have been incorporated in the text.

REFERENCES

Baranov, F. I. 1918. On the question of the biological basis of fisheries. Nauchnyi issledovatelskii ikhtiologicheskii Institut, Izvestiia, 1(1): 81-128. [Report Div. Fish Management and Scientific Study of the Fishing Industry.]

von Bertalanffy, L. 1938. A quantitative theory of organic growth. Human Biology, 10(2): 181-213.

Beverton, R. J. H., and S. J. Holt. 1957. On the dynamics of exploited fish populations. U.K. Min. Agr. and Fish., Fish. Invest., Ser. 2, 19, 533 pp.

Clark, J. R., F. D. McCracken and W. Templeman. 1958. Summary of gear selection information for the Commission Area. Int. Comm. NW Atlantic Fish., Ann. Proc., 8: 83-99.

Fleming, A. M. 1960a. Age, growth and sexual maturity of cod (Gadus morhua L.) in the Newfoundland area, 1947-1950. J. Fish. Res. Bd. Canada, 17(6): 775-809.

Fleming, A. M. MS, 1960b. The commercial cod fishery at Bonavista. Fish. Res. Bd. Canada, Rep. Biol. Sta., St. John's, Newfoundland, for 1959-60 (mimeographed), App. No. 13, pp. 53-59.

Fleming, A. M. MS, 1961. The commercial cod fishery at Bonavista. Fish. Res. Bd. Canada, Rep. Biol. Sta., St. John's, Newfoundland, for 1960-61 (mimeographed), App. No. 3, pp. 9-15.

Graham, Herbert W. 1952. Mesh regulation to increase the yield of the Georges Bank haddock fishery. Int. Comm. NW Atlantic Fish., Second Ann. Rep. for the year 1951-52, pp. 23-33.

Graham, M. 1935. Modern theory of exploiting a fishery, and application to North Sea trawling. J. Conseil Expl. Mer, 10: 264-274.

Gulland, J. A. 1961. The estimation of the effect on catches of changes in gear selectivity. J. Conseil Explor. Mer, 25(2): 204-214.

Herrington, W. C. 1935. Modifications in gear to curtail the destruction of undersized fish in otter trawling. U.S. Dept. Commerce, Bur. Fish. Invest. Rep. No. 24, 48 pp.

1936. Decline in haddock abundance on Georges Bank and a practical remedy. U.S. Dept. Commerce, Bur. Fish. Circular No. 23, 22 pp.

1941. A crisis in the haddock fishery. U.S. Fish and Wildlife Serv., Fish. Circular No. 4, 14 pp.

Hodder, V. M. MS, 1961. Length and age composition of Grand Bank haddock from research vessel cruises. Fish. Res. Bd. Canada, Rep. Biol. Sta., St. John's, Newfoundland, for 1960-61 (mimeographed), App. No. 7, pp. 27-29.

International Commission for the Northwest Atlantic Fisheries. 1951. Report of the first annual meeting with appendices, 53 pp.

International Commission for the Northwest Atlantic Fisheries. 1952. Statistics of landings of groundfish from the Convention Area. Second Ann. Rep. for the year 1951-52, Part 4, 68 pp.

1953-1959. Ann. Proc., Vol. 3-9.

1954-1960. Stat. Bull., 1952-58, Vol. 2-8.

1958-1960. Sampling Yearbooks, 1955-58, Vol. 1-3.

1960. Groundfish landings from the Convention Area in 1959 arranged by species, countries and divisions. ICNAF Doc. (mimeographed), Ser. No. 780, 3 pp.

Jensen, A. J. C. 1949. The relation between the size of mesh and the length of fish released. Rapp. Conseil Expl. Mer, 125: 65-69.

Ricker, W. E. 1944. Further notes on fishing mortality and effort. Copeia, 1944(1) : 23-44.

Rojo, A. 1957. Spanish research report for 1956. Int. Comm. NW Atlantic Fish., Ann. Proc., 7 : 58-62.

1958. Spanish research report for 1957. Int. Comm. NW Atlantic Fish., Ann. Proc., 8 : 61-73.

Sandeman, E. J. 1959. A contribution to the problem of the ageing and growth-rate in Sebastes. ICES/ICNAF Redfish Symposium, Copenhagen, 1959, Contr. No. A-11, 17 pp. (mimeo.).

Schaefer, M. B. 1943. The theoretical relationship between fishing effort and mortality. Copeia, 1943(2): 79-82.

Squires, H. J. 1959. Squid inshore in Newfoundland and on the Grand Banks, 1953 to 1958. Fish. Res. Bd. Canada, Atl. Prog. Rept., No. 72, pp. 23-26.

Taylor, C. C. 1957. Natural mortality rate of Georges Bank haddock. U.S. Fish and Wildlife Serv., Fish. Bull., 58(126): 1-7.

Templeman, W. 1953. Knowledge of divisions of stocks of cod, haddock, redfish and American plaice of Subareas 3 and 2 of the Northwest Atlantic Convention Area. Int. Comm. NW Atlantic Fish., Ann. Proc., 3: 62-66.

1959a. Canadian research report for 1958. Int. Comm. NW Atlantic Fish., Ann. Proc., 9: 20-26.

1959b. Redfish distribution in the North Atlantic. Bull. Fish. Res. Bd. Canada, No. 120, 173 pp.

1960. Canadian research report for 1959. Int. Comm. NW Atlantic Fish., Ann. Proc., 10: 19-25.

1961. Comparison of returns from different tags and methods of attachment used in cod tagging in the Newfoundland area, 1954 and 1955. Int. Comm. NW Atlantic Fish., Fish Marking Symposium, Woods Hole, May 1961, Doc. No. 45, Ser. No. 858, 20 pp. (mimeographed).

Templeman, W., and A. M. Fleming. 1956. The Bonavista longlining experiment, 1950-53. Bull. Fish. Res. Bd. Canada, No. 109, 55 pp.

1962. Longlining experiments off the east coast of Newfoundland and southern Labrador, 1950-55. Bull. Fish. Res. Bd. Canada (in press).

Templeman, W., and T. K. Pitt. 1961. Comparison of returns of different tags and from differences in tagging methods for cod tagged in the inshore area, St. John's and Fogo, Newfoundland, 1950. Int. Comm. NW Atlantic Fish., Fish Marking Symposium, Woods Hole, May 1961, Doc. No. 47, Ser. No. 864, 8 pp. (mimeographed).

Templeman, W., H. J. Squires and A. M. Fleming. 1957. Nematodes in the fillets of cod and other fishes in Newfoundland and neighbouring areas. J. Fish. Res. Bd. Canada, 14: 831-897.

Thompson, H. 1939. The occurrence and biological features of haddock in the Newfoundland area. Dept. Nat. Resources, Newfoundland, Res. Bull. No. 6, 31 pp.

1943. A biological and economic study of cod (*Gadus callarias* L.) in the Newfoundland area. Dept. Nat. Res. Newfoundland, Res. Bull. No. 14, 160 pp.

APPENDIX I. BASIC DATA OF LANDINGS, FISHING EFFORT, LENGTH AND AGE COMPOSITIONS, AND GROWTH

Table 1. Subarea 3 cod: landings (metric tons) by countries and gears for the period 1935-59.

Table 2. Landings per unit effort for cod by Portuguese dory vessels and trawlers fishing on the Newfoundland Banks during 1935-58, the calculated total effort by trawls and the calculated total effort by all gears in Portuguese trawler units.

Table 3. Subarea 3 cod: landings (metric tons) by countries, ICNAF divisions and gears for the period 1953-58.

Table 4. Subarea 3 cod: average landings per unit effort and the calculated fishing effort for cod by trawlers of the major cod-fishing countries during the period 1952-58.

Table 5. Subarea 3 cod: length compositions of the average annual catches (trawls) and landings (other gears) by regions for the period 1955-58.

Table 6. Subarea 3 cod: age composition data used in estimating the total mortality coefficients (Z).

Table 7. Subarea 3 cod: age-length data used for the growth curmes of Figure 8.

Table 8. Subarea 3 haddock: landings (metric tons) by countries and gears for the period 1935-59.

Table 9. Subarea 3 haddock: landings (metric tons) by countries, gears and ICNAF divisions for the period 1953-58.

Table 10. Subarea 3 haddock: landings per unit effort of Newfoundland trawlers, and the calculated total fishing effort by the Canadian fleet and by the entire fleets of trawlers during the period 1954-58.

Table 11. Divisions 3N and 30 haddock: length compositions of the average annual trawl catches for the period 1955-58.

Table 12. Subarea 3 redfish: landings (metric tons) by countries for the period 1940-59.

Table 13. Subarea 3 redfish: landings (metric tons) by countries and ICNAF divisions for the period 1953-59.

Table 14. Subarea 3 redfish: landings per unit effort and calculated effort of the trawling fleets for the period 1954-58.

Table 15. Subarea 3 redfish: length compositions of the trawl catches by ICNAF divisions for the year 1958.

Table 16. Subarea 3 flounder: landings (metric tons) by ICNAF divisions and countries for the period 1953-59.

Table 1. Subarea 3 cod: landings (metric tons) by countries and gears for the period1935

Year	Canada (M)		Canada (Nfld)			France (M)	France (St.P)		Denmark (F)	Germany (E)	Germany (W)	Iceland	Norwy	
	OT	DV	OT	DV	Inshore	OT	OT	Insh.	LL	OT	OT	OT	LL	
1935		15252	-	18852	211038	+			-	-	-	-	-	
36		14566	2682	34823	177229	+			-	-	-	-	-	(3
37		19047	7734	37992	112710	+			-	-	-	-	-	(4
38		19724	1449	41162	146827	+			-	-	-	-	-	(2
39		11865	-	36908	138482	+			-	-	-	-	-	(5
40		9960	-	38594	129838	-			-	-	-	-	-	(8
41		13335	-	31438	146232	-			-	-	-	-	-	(10
42		10668	-	9591	131121	-			-	-	-	-	-	(7
43		11158	-	20442	162876	-			-	-	-	-	-	(13
44		17145	-	19707	195924	-			-	-	-	-	-	(17
45		12546	-	21335	226306	+			-	-	-	-	-	(26
46		19223	188	24488	222473	+			-	-	-	-	-	(31
47		22344	490	28850	235284	+			-	-	-	-	-	(37
48		18341	1361	28360	184398	+			-	-	-	-	-	(40
49		22905	2722	24385	191070	+			-	-	-	-	-	(65
50		15425	3266	8671	198507	+			-	-	-	-	-	(67
51		18346	4354	1067	203428	+			-	-	-	-	-	(73
52	5704	19017	4890	315	179427	+			-	-	-	-	-	44
53	9865	16150	6191	-	154432	26898	1045	4327	-	-	705	-	-	40
54	15479	13381	9532	-	208099	44836	864	4760	-	-	-	-	-	50
55	9548	15179	7357	-	173922	60828	415	4430	-	-	-	-	-	43
56	6886	9819	6254	-	189758	27252	804	4198	-	-	-	-	117	31
57	8722	7786	6721	-	178050	54480	1330	3308	2956	-	369	-	1617	35
58	4731	3104	3798	-	130695	35345	923	2572	3939	5	349	374	630	19
59*	8636			186654		38498	4492		7577	17	694	1549	400	

Notes

All statistics of landings prior to 1959 were obtained from ICNAF Statistical Bulletins, Vol. 1 - 8, except for those of Spain prior to 1951 and Portugal prior to 1955 which were obtained from the files of the ICNAF Secretariat, Halifax, Nova Scotia; the 1959 landings, which include 38 tons by Belgium and 7 tons by Poland, were obtained from ICNAF Document Serial No. 780, 1960; the Spanish and French landings prior to 1954 have been increased by a factor 1.2 to compensate for a change in the conversion factor used to convert wet salted cod to round fresh weight. Explanatory notes by countries are as follows:

Canada (M) - 1935-51 landings are not reported by gears, but they are mainly from dory vessels engaged in the salted codfish industry.

Canada (Nfld) - 1935-51 landings are not given by gears in the ICNAF Statistical Bulletins, but these have been estimated from information available at the St. John's Biological Station, Newfoundland.

France (M) - Prior to 1953 the landings from the Convention Area are not available by ICNAF subareas as indicated by the symbol (+).

France (St.P) - No reports prior to 1953.

riod1935-59 (*landings for 1959 are provisional and are not yet available by gears).

Norwy	Portugal		Spain		USSR	UK	USA	Grand Total	Total landings by gears		
LL	OT	DV	OT	PT	OT	OT	OT	All gears	Trawl	Line	Inshore
-	-	14200	(29472)	-	-	605	275	(289694)	(30352)	48304	211038
-	(3031)	22500	(13261)	-	-	-	1414	(269506)	(20388)	71889	177229
-	(4454)	19200	-	-	-	-	1271	(202408)	(13459)	76239	112710
-	(2260)	23500	-	-	-	-	2434	(237356)	(6143)	84386	146827
-	(5267)	26300	(7607)	-	-	-	120	(226549)	(12994)	75073	138482
-	(8669)	18000	(15294)	-	-	-	47	(220402)	(24010)	66554	129838
-	(10298)	13400	-	-	-	-	3	(214706)	(10301)	58173	146232
-	(7244)	5900	-	-	-	-	9	(164533)	(7253)	26159	131121
-	(13218)	6200	(7109)	-	-	-	-	(221003)	(20327)	37800	162876
-	(17134)	8500	(9992)	-	-	-	-	(268402)	(27126)	45352	195924
-	(26575)	28400	(32268)	-	-	-	-	(347430)	(58843)	62281	226306
-	(31570)	25700	(39792)	-	-	-	-	(363434)	(71550)	69411	222473
-	(37430)	26000	(43840)	-	-	-	-	(394238)	(81760)	77194	235284
-	(40151)	20500	(30092)	-	-	567	53	(323823)	(72224)	67201	184398
-	(65468)	15200	(25627)	-	-	444	-	(347821)	(94261)	62490	191070
-	(67812)	23100	(37538)	32585	-	213	35	(387152)	(141449)	47196	198507
-	(73640)	15600	(33558)	44371	-	63	83	(394510)	(156069)	35013	203428
-	44082	21427	(39215)	30054	-	-	64	(344194)	(124008)	40759	179427
-	40485	26514	46832	27307	-	277	116	361144	159721	42664	158759
-	50713	22488	75310	28773	-	948	36	475219	226491	35869	212859
-	43699	34799	48358	29449	-	1053	3	429040	200710	49978	178352
117	31329	40076	30562	37186	3001	1390	15	389708	144679	51073	193956
1617	35451	40763	34690	37715	18041	2239	22	448815	199780	67677	181358
630	19589	20423	24004	29802	5370	1472	-	292796	125762	33767	133267
406	73730		80899		15221	2521	13	424551			

Portugal, OT - Prior to 1952 the landings are bracketed because they are reported as from the Newfoundland area, although it might be assumed that most of the fish were obtained from Subarea 3.

Portugal, DV - Prior to 1952 the dory vessel landings are also reported as from the Newfoundland area, but, since these vessels do not generally fish in Subareas 2 and 4, their landings are considered to have been obtained from Subarea 3.

Spain, OT - 1935-50 landings are not available by ICNAF subareas, but they are considered to have been obtained mainly from Subarea 3; they are bracketed, however, since small quantities were probably obtained in Subareas 1, 2 and 4. The landing for 1951 includes 20625 tons and that for 1952 includes 8424 tons, which were reported as from Subareas 3 and 4 but mainly from 3.

Spain, PT - Pair trawlers started fishing in the ICNAF Convention Area in 1950 and then only in Subarea 3.

Italy - Landings for 1948-59 ranged from about 2000 to 13000 tons from the Convention Area, but these have not been allocated by subareas and consequently are not given in the table.

Table 2. Landings per unit effort for cod by Portuguese dory vessels and trawlers fishing on the Newfoundland Banks during 1935-58, the calculated total effort by trawls and the calculated total effort by all gears in Portuguese trawler units.

Year	Landings per unit effort (tons) by Portuguese fleets		Calculated effort (thousands of days fished) based on Portuguese trawler units	
	Dory vessel landings per 100 dory days fished	Trawler landings per day fished	Total effort by trawlers	Total effort by all gears
1935	24.8			
1936	21.1	25.3	0.81	10.7
1937	26.1	37.7	0.36	5.4
1938	30.2	19.5	0.32	12.2
1939	29.6	63.4	0.21	3.6
1940	32.9	22.2	1.08	9.9
1941	34.2	32.3	0.32	6.6
1942	43.4	39.7	0.18	4.1
1943	49.4	34.7	0.59	6.4
1944	74.5	38.0	0.71	7.1
1945	58.4	33.6	1.75	10.3
1946	34.7	35.2	2.03	10.3
1947	39.6	34.9	2.34	11.3
1948	30.0	25.9	2.79	12.5
1949	34.0	21.2	4.45	16.4
1950	34.0	24.8	5.70	15.6
1951	30.7	23.2	6.73	17.0
1952	33.4	24.1	5.15	14.3
1953	36.1	28.5	5.60	12.7
1954	30.4	21.3	10.63	22.3
1955	38.3	21.2	9.47	20.2
1956	39.0	22.0	6.58	17.7
1957	32.8	21.7	9.21	20.7
1958	22.5	17.8	7.07	16.4

Notes

The Portuguese landing and effort data, from which the estimates of landings per unit effort for 1935-55 were derived, were obtained from the ICNAF Secretariat, Halifax, N.S.; the 1956-58 data were obtained from the ICNAF Statistical Bulletins, Vol. 6 - 8.

The calculated fishing effort values by trawlers and by all gears were obtained by dividing the quantities landed (from Table 1) by the corresponding landing per unit effort values for trawlers given in the above table.

In 1935 no Portuguese trawlers fished in the ICNAF Area.

Table 3. Subarea 3 cod: landings (metric tons) by countries, ICNAF divisions and gea

ICNAF Div.	Year	Trawl: Canada (M)	Canada (Nfld)	France (M)	France (St.P)	Germany (E)	Germany (W)	Iceland	Portugal	Spain OT	Spain PT	UK	USA	USSR
3K	1953	-	-	+	-	-	+	-	1050	+	+	+	-	-
	54	-	-	18530	-	-	-	-	5414	659	-	-	-	-
	55	-	1	15837	-	-	-	-	5906	13	11	-	-	-
	56	-	-	6595	-	-	-	-	2203	3	281	-	-	-
	57	-	-	13589	-	-	-	-	1701	62	-	-	-	-
	58	-	-	22200	-	-	-	374	7168	9268	6	+	-	74
3L	1953	2060	945	+	-	-	+	-	39121	+	+	+	-	-
	54	4198	1822	19724	-	-	-	-	29365	9860	1	948	-	-
	55	4145	2643	15945	-	-	-	-	15300	3679	1291	-	-	-
	56	2401	2289	17433	-	-	-	-	25427	9152	5881	-	-	-
	57	1060	1574	19421	-	-	-	-	26115	9654	578	666	-	160
	58	1811	903	8828	-	-	-	-	11262	6070	1996	+	-	48
3M	1953	-	-	+	-	-	+	-	54	+	+	+	-	-
	54	-	-	189	-	-	-	-	-	-	31	-	-	-
	55	-	-	780	-	-	-	-	-	-	12	-	-	-
	56	-	-	-	-	-	-	-	-	1	5	-	-	300
	57	-	1	12	-	-	-	-	298	-	52	-	-	1643
	58	-	-	-	-	5	-	-	59	-	-	+	-	413
3N	1953	1169	590	+	+	-	+	-	226	+	+	+	+	-
	54	888	1314	574	+	-	-	-	3517	38044	28706	-	+	-
	55	212	355	8052	+	-	-	-	10240	27373	27873	-	-	-
	56	282	210	109	+	-	-	-	116	8069	30906	971	1	-
	57	150	378	136	+	-	-	-	577	11296	35408	-	-	-
	58	316	932	11	+	-	-	-	28	1680	23240	+	-	-
3O	1953	5075	3504	+	+	-	+	-	34	+	+	+	+	-
	54	7568	4216	2459	+	-	-	-	12393	21889	35	-	+	-
	55	1886	1156	5606	+	-	-	-	4542	9487	254	595	3	-
	56	2938	1598	308	+	-	-	-	60	3609	40	-	1	-
	57	4762	3774	1849	+	-	-	-	333	3871	1415	219	-	-
	58	1693	1449	42	+	-	65	-	9	1304	3212	+	-	-

; and gears for the period 1953-58.

			Offshore line gears					Inshore gears			TOTAL
SA	USSR	Trawl Total	Can. (M)	Den-mark	Nor-way	Port-ugal	Line Total	Can. (Nfld)	France (St.P)	Inshore Total	ALL GEARS
-	-	1050	-	-	-	-	-	52292	-	52292	53342
-	-	24603	-	-	-	-	-	82594	-	82594	107197
-	-	21768	-	-	-	-	-	59237	-	59237	81005
-	-	9082	23	-	+	-	23	70281	-	70281	79386
-	-	15352	-	+	108	376	484	67524	-	67524	83360
-	746	39762	-	+	+	42	42	33711	-	33711	73515
-	-	42126	7092	-	-	13794	20886	76600	-	76600	139612
-	-	65918	7354	-	-	12107	19461	93153	-	93153	178532
-	-	43003	8434	-	-	21325	29759	85075	-	85075	157837
-	-	62583	6333	-	95	24711	31139	93322	-	93322	187044
-	1609	60677	1179	+	+	19036	20215	80297	-	80297	161189
-	486	31356	37	+	+	6466	6503	68038	-	68038	105897
-	-	54	-	-	-	-	-	-	-	-	54
-	-	220	-	-	-	378	378	-	-	-	598
-	-	792	-	-	-	-	-	-	-	-	792
-	3001	3007	-	-	+	-	+	-	-	-	3007
-	16432	16795	-	-	969	35	1004	-	-	-	17799
-	4138	4202	-	-	73	340	413	-	-	-	4615
+	-	1985	3727	-	-	12261	15988	-	-	-	17973
+	-	73043	291	-	-	7087	7378	-	-	-	80421
-	-	74105	222	-	-	8447	8669	-	-	-	82774
1	-	40664	-	-	-	9722	9722	-	-	-	50386
-	-	47945	2	-	-	10235	10237	-	-	-	58182
-	-	26207	53	-	-	5157	5210	-	-	-	31417
+	-	8613	4930	-	-	22	4952	-	-	-	13565
+	-	48560	3110	-	-	2773	5883	-	-	-	54443
3	-	23529	2222	-	-	4482	6704	-	-	-	30233
1	-	8554	335	-	-	5607	5942	-	-	-	14496
-	-	16223	575	-	-	10595	11170	-	-	-	27393
-	-	7774	369	-	-	6414	6783	-	-	-	14557

Table 3. (Continued)

ICNAF Div.	Year	Trawl												(
		Canada		France		Germany		Ice-land	Port-ugal	Spain OT	Spain PT	UK	USA	U
		(M)	(Nfld)	(M)	(St.P)	(E)	(W)							
3P	1953	1561	1129	+	+	-	+	-	-	+	+	+	+	
	54	2825	2170	3360	+	-	-	-	24	4858	-	-	+	
	55	3305	3202	14391	+	-	-	-	7711	7806	8	458	+	
	56	1265	2157	2807	+	-	-	-	3523	9728	73	419	13	
	57	2750	994	19192	+	-	369	-	6427	9807	262	1354	22	
	58	911	514	4264	+	-	125	-	1063	5682	1348	64	-	
3NK	1953	-	23	26898	1045	-	705	-	-	46832	27307	277	116	
	54	-	10	-	864	-	-	-	-	-	-	-	36	
	55	-	-	217	415	-	-	-	-	-	-	-	-	
	56	-	-	-	804	-	-	-	-	-	-	-	-	
	57	-	-	281	1330	-	-	-	-	-	-	-	-	
	58	-	-	-	923	-	159	-	-	-	-	1408	-	
Total Sub-area 3	1953	9865	6191	26898	1045	-	705	-	40485	46832	27307	277	116	
	54	15479	9532	44836	864	-	-	-	50713	75310	28773	948	36	
	55	9548	7357	60828	415	-	-	-	43699	48358	29449	1053	3	
	56	6886	6254	27252	804	-	-	-	31329	30562	37186	1390	15	3
	57	8722	6721	54480	1330	-	369	-	35451	34690	37715	2239	22	18
	58	4731	3798	35345	923	5	349	374	19589	24004	29802	1472	-	5

Notes

Trawl

France (M) - Landings for 1953 are not reported by ICNAF divisions.

France (St.P) - Landings are not reported by ICNAF divisions, but they presumably were obtained in Divisions 3N, 30 and 3P.

Germany (W) - Landings for 1953 not reported by ICNAF divisions, and a small quantity in 1958 has not been allocated by ICNAF divisions.

Spain, OT, PT - Landings for 1953 not reported by ICNAF divisions.

USA - Landings for 1953 and 1954 not reported by ICNAF divisions, but they presumably were obtained in 3N, 30 and 3P.

Offshore line

Canada (M) - Landings mainly by dory vessels but they include the following: longliners - 1954, Division 30, 1 ton, and Division 3P, 26 tons; 1955, 3P, 32 tons; 1956, 30, 2 tons, and 3P, 67 tons; 1957, 3N, 2 tons, and 3P, 168 tons; 1958, 3L, 37 tons, 3N, 29 tons, 30, 4 tons, and 3P, 379 tons; Danish seiners, 1958, 3P, 1 ton.

K	USA	USSR	Trawl Total	Offshore line gears: Can. (M)	Denmark	Norway	Portugal	Line Total	Inshore gears: Can. (Nfld)	France (St.P)	Inshore Total	TOTAL ALL GEARS
+	+	-	2690	401	-	-	437	838	25540	4327	29867	33395
-	+	-	13237	2626	-	-	143	2769	32350	4760	37110	53116
58	+	-	36881	4301	-	-	545	4846	29610	4430	34040	75767
19	13	-	19985	3128	-	-	36	3164	26155	4198	30353	53502
54	22	-	41177	6030	-	-	486	6516	30229	3308	33537	81230
64	-	-	13971	2645	-	-	2004	4649	28946	2572	31518	50138
77	116	-	103203	-	-	-	-	-	-	-	-	103203
-	36	-	910	-	-	-	-	-	-	-	-	910
-	-	-	632	-	-	-	-	-	-	-	-	632
-	-	-	804	-	-	1083	-	1083	-	-	-	1887
-	-	-	1611	-	2956	15095	-	18051	-	-	-	19662
08	-	-	2490	-	3939	6228	-	10167	-	-	-	12657
77	116	-	159721	16150	-	-	26514	42664	154432	4327	158759	361144
48	36	-	226491	13381	-	-	22488	35869	208097	4760	212857	475217
53	3	-	200710	15179	-	-	34799	49978	173922	4430	178352	429040
90	15	3001	144679	9819	-	1178	40076	51073	189758	4198	193956	389708
39	22	18041	199780	7786	2956	16172	40763	67677	178050	3308	181358	448815
72	-	5370	125762	3104	3939	6301	20423	33767	130695	2572	133267	292796

Denmark - All fishing by Faroese longliners; landings not reported by ICNAF divisions but presumably from Divisions 3K and 3L.

Norway - Landings by longliners, not fully reported by ICNAF divisions, but presumably from Divisions 3K, 3L and 3M.

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Inshore gears

Canada (Nfld) - Landings largely from small boats fishing near the coast, but small quantities from Danish seiners as follows: 1953, 3P, 5 tons; 1954, 3P, 14 tons; 1955, 3P, 14 tons; 1956, 3P, 8 tons; 1958, 3P, 10 tons.

France (St.P) - Landings from inshore fishery by motor dories, not reported by ICNAF divisions, but considered from Division 3P.

;

General - Except where noted for Portugal and Spain in the notes of Table 1, all landings were taken from the ICNAF Statistical Bulletins, Vol. 1 - 8.

- The symbol (+) indicates that fishing presumably occurred, although the landings are not reported by ICNAF divisions but are placed in 3NK (= Subarea 3, division not known).

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2 tons,
ınd 3P,

Table 4. Subarea 3 cod: average landings per unit effort and the calculated fishing effort for cod by trawlers of the major cod-fishing countries during the period 1952-58.

ICNAF Division	Year	Average landings per unit effort (tons)					Calculated fishing effort for cod				
		Canada (Nfld)	France (M)	Portugal	Spain OT	Spain PT	Canada	France (M)	Portugal	Spain OT	Spain PT
		L/hr fished	L/day fished	L/hr fished	L/hr fished	L/hr fished	Hours fished	Days fished	Hours fished	Hours fished	Hours fished
3K	1954	-	+	1.48	1.91	-	-	+	3652	345	-
	55	-	+	1.29	(0.46)	(0.88)	-	+	4564	28	13
	56	-	+	1.39	(0.19)	1.17	-	+	1587	16	240
	57	-	+	1.17	0.61	-	-	+	1457	102	-
	58	-	+	1.34	1.25	(0.67)	-	+	5369	7397	9
3L	1954	1.34	+	1.54	1.46	(0.86)	4506	+	19019	6777	1
	55	1.32	+	1.51	1.22	1.35	5135	+	10146	3020	954
	56	1.54	+	1.72	1.40	1.59	3045	+	14757	6542	3703
	57	0.92	+	1.61	1.24	1.06	2854	+	16220	7811	546
	58	0.95	+	1.23	0.94	0.73	2860	+	9140	6451	2749
3M	1954	-	+	-	-	(3.56)	-	+	-	-	9
	55	-	+	-	-	(1.50)	-	+	-	-	8
	56	-	+	-	(0.33)	(1.25)	-	+	-	3	4
	57	-	+	1.27	-	(1.26)	-	+	235	-	41
	58	-	+	(0.80)	-	-	-	+	74	-	-
3N	1954	1.04	+	1.19	2.14	1.03	2128	+	2958	17811	27816
	55	0.66	+	1.29	2.00	1.05	864	+	7956	13680	26445
	56	0.69	+	0.62	1.80	1.35	715	+	188	4490	22859
	57	0.72	+	1.01	1.48	1.33	735	+	569	7622	26563
	58	0.71	+	(0.90)	1.07	0.91	1750	+	31	1567	25455
3O	1954	0.97	+	1.82	1.69	(1.56)	12148	+	6794	12944	22
	55	1.29	+	1.55	1.72	0.91	2356	+	2934	5509	280
	56	0.95	+	(1.11)	1.55	(1.16)	4775	+	54	2323	35
	57	0.96	+	1.10	1.35	1.70	8892	+	302	2859	831
	58	0.81	+	0.64	1.14	0.91	3893	+	140	1142	3537

	55	1.29	+	1.55	1.72	0.91	2356	+	2934	5509	280
	56	0.95	+	(1.11)	1.55	(1.16)	4775	+	54	2323	35
	57	0.96	+	1.10	1.35	1.70	8892	+	302	2859	831
	58	0.81	+	0.64	1.14	0.91	3893	+	140	1142	3537
3P	1954	1.33	+	(0.97)	1.92	-	3747	+	25	2525	-
	55	1.30	+	2.10	2.28	(0.25)	4998	+	3681	3428	32
	56	0.55	+	1.80	1.42	(4.29)	6177	+	1953	6860	17
	57	1.34	+	2.30	1.59	1.09	2800	+	2797	6164	241
	58	0.89	+	1.28	1.19	0.99	1608	+	829	4779	1358
Sub-area 3	1952	+	+	1.83	+	+	+	+	24047	+	+
	53	+	+	1.88	1.73	1.15	+	+	21550	27071	23642
	54	1.11	30.6	1.56	1.86	1.03	22529	1466	32448	40402	27848
	55	1.27	32.9	1.49	1.88	1.06	13353	1847	29281	25665	27732
	56	0.89	35.2	1.69	1.51	1.38	14712	774	18539	20234	26858
	57	1.01	30.2	1.64	1.41	1.34	15281	1803	21580	24558	28222
	58	0.81	23.6	1.26	1.13	0.90	10111	1495	15584	21336	33108

Notes

All landing per unit effort values, except those for Portugal, are based on statistics of landings and fishing effort obtained from the ICNAF Statistical Bulletins, Vol. 1 - 8; the landing per unit effort values for Portuguese trawlers are based on adjusted landing and effort data obtained from the ICNAF Secretariat, Haxifax, Nova Scotia. Individual explanatory notes are as follows:

Canada (Nfld) - Landing per unit effort values are based on "special effort" data for Newfoundland trawlers.

France (M) - Landing per unit effort values are based on landing and effort data for vessels of the 68-meter class.

Spain - Because the Spanish effort data are not reported for cod and haddock separately, the landing per unit effort values of both otter trawlers and pair trawlers include cod and haddock, but the fishing effort values are those estimated for cod only.

The fishing effort values were calculated by dividing the quantities of cod landed annually (Table 3) by the corresponding landing per unit effort values given in the left-hand part of the above table. The symbol (+) means that no effort data are available; the values in parentheses indicate less than 100 hours fished.

Table 5. Subarea 3 cod: length compositions of the average annual catches (trawls) and landings (other gears) by regions for the period 1955-58.

Length group (cm)	Mid-point of group (cm)	3K-L			3M	3N-O		3P		
		Trawl	Off-shore line	In-shore gears	Trawl	Trawl	Off-shore line	Trawl	Off-shore line	In-shore gears
21-23	22	1			1					
24-26	25	3			1	17				
27-29	28	15			2	149		10		
30-32	31	29			10	187		22		
33-35	34	100		3	13	412	2	43		7
36-38	37	399		132	135	1243		108		69
39-41	40	987	4	693	239	2252	7	285		336
42-44	43	1161	9	2335	453	2817	7	657	2	798
45-47	46	1391	56	4383	468	3231	11	1033	9	1167
48-50	49	1821	94	6201	474	3561	18	1444	23	1524
51-53	52	2152	109	7382	546	3670	16	1695	45	1689
54-56	55	3055	244	8989	517	3523	45	1781	54	1709
57-59	58	3880	338	9609	455	3042	43	1755	42	1546
60-62	61	4639	540	9658	322	2742	47	1504	64	1340
63-65	64	4440	737	8218	256	2412	74	1197	103	1218
66-68	67	3510	692	6176	108	1732	50	804	116	1015
69-71	70	2328	943	3906	88	1270	97	584	63	818
72-74	73	1491	658	2335	50	970	142	510	63	647
75-77	76	927	478	1185	30	714	164	415	63	459
78-80	79	563	388	675	21	462	157	367	92	339
81-83	82	325	317	398	9	347	167	264	104	230
84-86	85	186	186	221	8	223	238	125	66	157
87-89	88	175	105	109	8	146	157	56	74	110
90-92	91	120	189	96	9	110	112	39	29	88
93-95	94	78	99	42	7	86	86	27	27	61
96-98	97	33	32	34	4	71	73	13	16	49
99-101	100	42	51	27	3	55	108	13	18	28
102-104	103	16	71	10	3	58	58	9	7	21
105-107	106	13	21	16	3	67	85		10	13
108-110	109	12	15	3	2	55	68		5	11
111-113	112	6	2	1	1	54	70		7	13
114-116	115	3	3	1		32	67		4	6
117-119	118	2		1		26	38		7	4
120-122	121	2	2	1		15	41		6	6
123-125	124	2	1			1	29		3	5
126-128	127	1	1			1	34		3	1
129-131	130	1					13		2	1
>131							11			1
N_C	('000)	33909			4246	35753		14760		
W_C	(m.t.)	72438			6200	63260		28672		
N_L	('000)	31214	6384	72840		31493	2335	13635	1127	15486
W_L	(m.t.)	70900	22000	139400		61300	16100	28000	4794	32362

Table 5. (Continued)

Notes

All data (except Newfoundland inshore) were obtained from the ICNAF Sampling Yearbooks, Vol. 1 - 3, for the years 1955-58; length composition data of the Newfoundland inshore fishery were obtained from unpublished records of the St. John's Biological Station. Notes on the treatment of the length composition data are as follows:

3K-L

Trawl

1955. (a) Portuguese length compositions (2580 cod measured) and Spanish (1243 cod) both after discarding were combined and adjusted to the total cod landings of France, Portugal and Spain. (b) Newfoundland length compositions (2541 cod) after discarding were adjusted to the total Canadian trawl landing from the region. (a) and (b) were then combined and considered representative of the total trawl landings from 3K-L.

1956. (a) Portuguese length compositions (4097 cod) after discarding were adjusted to the total cod landings of France, Portugal and Spain. (b) Canadian (Mainland and Newfoundland) length compositions (3705 cod) after discarding were adjusted to the total Canadian cod landing from the region. (a) and (b) were combined and considered representative of the total trawl landings of cod from 3K-L.

1955-56. The length compositions of the trawl landings for these years were combined and adjusted for discards by comparison with the catch length compositions for 1957 and 1958.

1957. Portuguese length compositions (1800 cod) and Spanish (6876 cod) both before discarding were combined and adjusted to the estimated total cod catches by trawlers, the quantity discarded having been accounted for by an assumed "cull" curve, which was obtained by comparing the 1955 and 1956 length compositions of landings with the catch length compositions of 1957 and 1958.

1958. (a) Portuguese length compositions (2287 cod) before discarding were adjusted to the total estimated cod catches by trawl of Canada, France, Portugal and Spain. (b) USSR length compositions (678 cod) and Icelandic (309 cod) before discarding were combined and adjusted to the cod catch by these countries. (a) and (b) were combined and considered representative of the total trawl landings of cod from the region.

1955-58. The length composition of the average annual trawl catch was obtained by averaging those of the catches for the four years (see under 3K-L in the foregoing table).

Offshore line

1955-58. Length compositions of Portuguese dory-vessel landings of 2483 cod in 1955 and 498 cod in 1957 were combined and adjusted to the average annual landings of all countries using line gears for the period 1955-58.

Table 5. (Notes continued)

3M

Trawl

1955-58. USSR length compositions of catches in 1958 (6831 cod measured) were adjusted to the average annual trawl landing for 1955-58.

3N-O

Trawl

1955. Portuguese length compositions (242 cod) and Spanish (7834 cod) before discarding were combined and adjusted to the estimated total trawl catch of the various countries (except Canada), discards having been accounted for by assuming "knife-edge" discarding between 41 and 42 cm. Newfoundland length compositions (1522 cod) after discarding were adjusted to the total Canadian landing and then adjusted for discards by a comparison with the Spanish data for this year. Both sets were then combined and considered representative of the catch length composition for 1955.

1956. Spanish length compositions (3499 cod) before discarding were treated in the same manner as 1955 above. Newfoundland length compositions (1000 cod) after discarding were treated as for 1955 above. Both sets were combined and considered representative of the 1956 trawl catch.

1957. Spanish length compositions (8027 cod) before discarding and Newfoundland length compositions (3825 cod) after discarding were treated as for 1955 above.

1958. There being no Portuguese or Spanish data, USSR catch length compositions (1320 cod) before discarding were adjusted to the estimated total cod catch of all countries except Canada and W. Germany. Canadian length compositions (1138 cod) and W. German (518 cod) both after discarding were adjusted to the total cod landing by these countries and then adjusted for discards by comparison with the catch length compositions of USSR trawlers. Both sets were combined and considered representative of the total cod catch from this region in 1958.

1955-58. The adjusted length compositions of the trawl catches for the four years were averaged, and these are given under 3N-O in the table.

Offshore line

1955-58. Length compositions of Portuguese dory-vessel landings of 499 cod in 1957 and 539 cod in 1958 were combined and adjusted to the average annual landing of line gears during 1955-58.

Table 5. (Notes continued)

3P

Trawl

1955-58. Length composition data of cod catches or landings by trawls are scanty. Canadian length compositions (2356 cod) in 1955 and 379 cod in 1958, Spanish data of 2706 cod in 1957, and W. German data of 576 cod in 1958, all considered to be after discarding, were combined and adjusted to the average annual cod landing by trawls for the period 1955-58. Account of discards was then made by using the Canadian inshore length composition data for comparison.

Offshore line

1955-58. Newfoundland length compositions of 600 cod in 1956 and Portuguese of 343 cod in 1958 were combined and adjusted to the average annual landing by line gears for the period.

Table 6. Subarea 3 cod: age composition data* used in estimating the total mortality coefficients (Z).

Age	Trawl									Inshore			
	3K-L				3N-O					3K-L		3P	
	Canada (Nfld)	Portugal	Spain Portugal	Total	Canada (Nfld)		Spain		Total	Canada (Nfld)		Canada (Nfld)	
(yr)	1948-53	1955	1957	1955-57	1947-50	1953	1953-54	1955-56	1953-56	1947-50	1955-58	1947-49	1953-57
2								14	14				
3		1	8	9	2		7	134	141	18	8	42	8
4	3	1	21	22	95	1	49	232	282	132	123	46	100
5	17	2	45	47	58	38	95	272	405	202	280	165	410
6	48	19	52	71	47	241	80	191	512	136	332	104	610
7	87	54	70	124	88	259	44	107	410	188	252	63	797
8	66	156	99	255	89	59	21	72	152	151	281	43	665
9	84	131	108	239	58	26	7	34	67	187	254	31	492
10	80	148	168	316	55	18	4	26	48	122	182	15	303
11	78	74	128	202	52	7	5	6	18	97	109	8	204
12	73	45	98	143	29	4	3	2	9	105	59	13	65
13	54	32	55	87	20		2	6	8	68	26	9	52
14	41	18	37	55	10	3	1	3	7	30	17	10	27
15	16	12	23	35	4	1	1	9	11	11	6	4	19
16	25	3	11	14	3		1	3	4	10	2	1	23
17	5	2	9	11	4	2		2	4	4	1		12
>17	9	2	13	15	2	1		13	14	5	5	1	28
Total	686	700	945	1645	616	660	320	1126	2106	1466	1937	555	3815
Est. Z	0.35	0.50	0.50	0.50	0.30	0.68	0.75	0.70	0.70	0.60	0.70	0.50	0.60

*Canadian (Nfld) data were made available through the courtesy of A. M. Fleming, Fisheries Research Board of Canada, Biological Station, St. John's, Newfoundland; Portuguese and Spanish data were taken from the ICNAF Sampling Yearbooks, Vol. 1 - 3.

Table 7. Subarea 3 cod: age-length data* used for the growth curves of Figure 8 (average lengths are in centimeters, and the figures in parentheses are numbers of cod on which the averages are based).

Age (yr)	3K-L: 1947-50 Can.(Nfld) 3K-L	3K-L: 1957 Portugal 3K	3K-L: 1957 Spain 3L	3K-L: Unweighted average 3K-L	3N-O: 1947-50 Can.(Nfld) 3N-O	3N-O: 1953-54 Spain 3N	3N-O: 1955-56 Spain 3N	3N-O: Unweighted average 3N-O	3P: 1947-50 Can.(Nfld)
2							28.8 (14)	28.8	24.6 (51)
3	37.4 (16)		38.7 (8)	38.0	44.0 (2)	44.0 (7)	39.4 (134)	42.5	36.5 (70)
4	44.4 (115)		43.8 (21)	44.1	49.0 (95)	46.7 (49)	46.2 (232)	47.3	44.9 (95)
5	49.4 (164)	48.2 (5)	47.0 (40)	48.2	51.6 (58)	52.5 (95)	51.5 (272)	51.9	51.3 (197)
6	54.5 (128)	53.5 (10)	52.3 (42)	53.4	59.7 (47)	58.0 (80)	57.5 (191)	58.4	55.7 (94)
7	59.6 (170)	55.8 (22)	54.9 (48)	56.8	69.8 (88)	63.4 (44)	63.8 (107)	65.7	65.6 (67)
8	62.9 (134)	58.7 (31)	58.4 (68)	60.0	76.8 (89)	70.6 (21)	72.1 (72)	73.2	68.9 (49)
9	65.0 (200)	61.8 (38)	64.3 (70)	63.7	83.5 (58)	75.1 (7)	75.6 (34)	78.1	74.1 (34)
10	66.9 (153)	63.6 (68)	64.4 (100)	65.0	87.6 (55)	90.2 (4)	84.6 (26)	87.5	76.7 (24)
11	67.6 (115)	64.8 (51)	65.9 (77)	66.1	90.4 (52)	88.6 (5)	88.9 (6)	89.3	83.8 (8)
12	68.7 (122)	64.0 (36)	66.1 (62)	66.3	91.2 (29)	97.0 (3)	90.4 (2)	92.8	86.5 (15)
13	70.4 (77)	67.3 (15)	67.8 (40)	68.5	91.9 (20)	107.5 (2)	99.0 (3)	95.4	
14	73.5 (45)	69.9 (12)	70.5 (25)	71.3	95.8 (10)		110.9 (3)		
15		74.5 (6)	76.8 (17)	75.6			108.1 (7)		
16	81.4 (21)	85.8 (4)	69.3 (7)	78.8			100.9 (3)		
17		67.0 (1)	86.4 (8)				109.9 (1)		
18			79.0 (3)				110.9 (3)		

*Canadian (Newfoundland) data were obtained from Fleming (1960a); Portuguese and Spanish data were obtained from the ICNAF Sampling Yearbooks, Vol. 1 - 3.

Table 8. Subarea 3 haddock: landings (metric tons) by countries and gears for the period 1935-59.

Year	Canada (M)		Canada (Nfld)		France (St.P)		Germany	Portugal		Spain		UK	USA	GRAND
	OT	Misc.	OT	Misc.	OT	Misc.		OT	DV	OT	PT	OT	OT	TOTAL
1935	-		538					-	-	1385	-	-	-	1923
36	-		473					-	-	235	-	-	3	711
37	-		856					-	-	-	-	-	123	979
38	-		782					-	-	-	-	-	41	823
39	552		-					23	210	1367	-	-	194	2346
40	258		2					61	372	1818	-	-	29	2540
41	155		162					85	439	-	-	-	-	841
42	103		15					-	-	-	-	-	-	118
43	129		24					-	-	425	-	-	-	578
44	1344		239					-	-	2174	-	-	-	3757
45	150		551					-	-	7770	-	-	-	8471
46	616		2642					-	-	14963	-	-	27	18248
47	1507		4756					-	-	17440	-	-	7	23710
48	4406		10187					-	-	41652	-	-	790	57035
49	2282		12573					-	-	63656	-	-	-	78511
50	1586		10598					445	59	47747	1158	-	148	61741
51	939		3214					595	143	43322	3065	-	8	51286
52	2871	77	4504	192			-	347	240	34134	4158	-	4	46527
53	6401	159	7566	-	-	-	309	538	222	22840	4230	236	334	42835
54	9045	245	22044	935	1628	408	-	449	83	16886	2465	757	390	55335
55	13910	230	28570	443	2122	235	-	778	-	51843	3940	2386	14	104471
56	13387	89	34620	300	3846	-	-	307	-	27418	2930	1195	190	84282
57	9866	23	24556	158	3623	-	59	40	-	24747	4382	622	10	68086
58	6456	3	16815	131	3235	-	254	7	-	8949	8289	192	6	44337
59*	6566		15764		3810	-	10	-	-	8560		223	26	35088*

*Statistics for 1959 are provisional; the 1959 total includes 9 tons by Denmark and 120 tons by Belgium.

Table 8. (Continued)

Notes

All statistics of landings prior to 1959 were obtained from ICNAF Statistical Bulletins, Vol. 1 - 8, except those for Spain prior to 1951 which were obtained from the files of the ICNAF Secretariat, Halifax, Nova Scotia; the 1959 landings were obtained from ICNAF Document Serial No. 780, 1960. The Portuguese and Spanish landings prior to 1954 have been increased by a factor 1.2 to compensate for a change in the conversion factor used to convert wet salted haddock to round fresh weight. Explanatory notes by countries are as follows:

Canada (M) - Landings prior to 1952 were not reported by gears, but these were probably largely by trawlers; landings by miscellaneous gears, 1952-58, were mainly by dory schooners, but longliners landed 1 ton in 1955, 6 tons in 1956 and 3 tons in 1958.

Canada (Nfld) - Landings prior to 1952 were not reported by gears, but they were largely by trawlers; landings by miscellaneous gears were by small inshore boats and longliners.

France (St.P) - No reports prior to 1953; misc. landings were by small motor dories fishing inshore.

Germany - No reports of landings prior to 1952.

Portugal, OT - Trawl landing of 173 tons reported from Subarea 2 in 1953, but this quantity is here included in Subarea 3, since haddock are not known to occur in abundance in Subarea 2.

" , DV - Landings of 240 tons in 1952 and 222 tons in 1953 were reported by dory vessels, subarea unknown, but these are here included in Subarea 3, since dory vessels do not fish in other areas where haddock occur.

Spain, OT - Landings for 1935-50 were not reported by subareas, but, since Spanish trawlers fished primarily in Subarea 3 and since statistics during 1953-57 indicate that only very small quantities of haddock (less than 3%) were reported from other subareas, it has been assumed that all haddock were landed from Subarea 3; landings of 23348 tons in 1951 and 14357 tons in 1952 were not allocated by subareas, but are here included in Subarea3, since Spanish trawlers did not fish in other subareas where haddock occur; 1953 includes 192 tons reported from Subarea 2.

" , PT - Pair trawlers started fishing in the ICNAF Commission Area in 1950 for the first time, and up to 1953 they fished only in Subarea 3.

USA - Landings not reported by gears prior to 1950, but they were presumably by otter trawlers.

Table 9. Subarea 3 haddock: landings (metric tons) by countries, gears and ICNAF Divisions for the period 1953-58.

ICNAF Div.	Year	Trawl: Canada (M)	Trawl: Canada (Nfld)	Trawl: France (St.P)	Trawl: Germany	Trawl: Portugal	Trawl: Spain OT	Trawl: Spain PT	Trawl: UK	Trawl: USA	Trawl Total	Line: Canada (M)	Line: Canada (Nfld)	Line: France (St.P)	Line: Portugal	Line Total	GRAND TOTAL
3K-L	1953	41	101	-	-	265	+	+	-	-	407	-	-	-	-	-	407
	54	230	23	-	-	13	86	-	757	-	1109	39	-	-	-	39	1148
	55	42	83	-	-	3	65	51	-	-	244	1	-	-	-	1	245
	56	32	60	-	-	16	40	101	-	-	249	1	-	-	-	1	250
	57	65	-	-	-	4	61	113	147	-	390	-	-	-	-	-	390
	58	150	35	-	-	1	234	275	-	-	695	-	-	-	-	-	695
3M	1953	-	-	-	-	-	+	+	-	-	+	-	-	-	-	-	+
	54	-	-	-	-	-	-	33	-	-	33	-	-	-	-	-	33
	55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	57	-	-	-	-	-	-	6	-	-	6	-	-	-	-	-	6
	58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3N	1953	58	42	-	-	-	+	+	+	+	100	-	-	-	+	+	100
	54	66	629	+	-	120	9206	2408	-	+	12429	-	-	-	83	83	12512
	55	50	270	+	-	630	21965	3832	-	6	26753	-	-	-	-	-	26753
	56	179	1484	+	-	-	21046	2812	368	3	25892	-	-	-	-	-	25892
	57	286	1435	+	-	-	20394	4053	-	-	26168	-	-	-	-	-	26168
	58	1765	4752	+	-	-	7923	7159	+	2	21601	-	-	-	-	-	21601
3O	1953	2919	5058	-	+	100	+	+	+	+	8077	1	-	-	+	1	8078
	54	1518	3254	+	-	312	6908	24	-	+	12016	-	-	-	-	-	12016
	55	943	1816	+	-	28	14183	50	291	8	17319	-	-	-	-	-	17319
	56	5866	15597	+	-	-	2801	17	-	73	24354	-	-	-	-	-	24354
	57	6706	21840	+	-	-	2883	145	236	10	31820	-	-	-	-	-	31820
	58	4386	11949	+	140	-	578	573	+	4	17630	-	-	-	-	-	17630
3P	1953	3383	2308	-	+	-	-	-	+	+	5691	158	-	-	+	158	5849
	54	7231	18118	+	-	4	685	-	-	+	26038	206	935	408	-	1549	27587
	55	12875	26401	+	-	117	15630	7	2095	-	57125	229	443	235	-	907	58032
	56	7310	17479	+	-	291	3531	-	827	114	29552	88	300	-	-	388	29940
	57	2809	1281	+	59	36	1409	65	239	-	5898	23	158	-	-	181	6079
	58	155	79	+	19	6	214	282	67	-	822	3	131	-	-	134	956
3NK	1953	-	57	-	309	173	22840	4230	236	334	28179	-	-	-	222	222	28401

	54	7231	18118	+	-	4	685	-	-	+	26038	206	935	408	-	1549	27587
	55	12875	26401	+	-	117	15630	7	2095	-	57125	229	443	235	-	907	58032
	56	7310	17479	+	-	291	3531	-	827	114	29552	88	300	-	-	388	29940
	57	2809	1281	+	59	36	1409	65	239	-	5898	23	158	-	-	181	6079
	58	155	79	+	19	6	214	282	67	-	822	3	131	-	-	134	956
3NK	1953	-	57	-	309	173	22840	4230	236	334	28179	-	-	-	222	222	28401
	54	-	20	1628	-	-	1	-	-	390	2039	-	-	-	-	-	2039
	55	-	-	2122	-	-	-	-	-	-	2122	-	-	-	-	-	2122
	56	-	-	3846	-	-	-	-	-	-	3846	-	-	-	-	-	3846
	57	-	-	3623	-	-	-	-	-	-	3623	-	-	-	-	-	3623
	58	-	-	3235	95	-	-	-	125	-	3455	-	-	-	-	-	3455
Sub-area 3	1953	6401	7566	-	309	538	22840	4230	236	334	42454	159	-	-	222	381	42835
	54	9045	22044	1628	-	449	16886	2465	757	390	53664	245	935	408	83	1671	55335
	55	13910	28570	2122	-	778	51843	3940	2386	14	103563	230	443	235	-	908	104471
	56	13387	34620	3846	-	307	27418	2930	1195	190	83893	89	300	-	-	389	84282
	57	9866	24556	3623	59	40	24747	4382	622	10	67905	23	158	-	-	181	68086
	58	6456	16815	3235	254	7	8949	8289	192	6	44203	3	131	-	-	134	44337

Notes

Canada (M), Line - Landings mainly by dory vessels engaged in halibut fishing and in the salt cod fishery.

Canada (Nfld), Line - Landings mainly by small boats fishing near the coast with codtraps, handlines, etc.

Portugal, Trawl - Landing of 173 tons in 1953 was reported from Subarea 2, but this amount is here included in 3NK, since haddock do not occur in Subarea 2.

Portugal, DV - Landing of 222 tons in 1953 was reported as from an unknown subarea, but the amount is here included in 3NK, since dory vessels fished only in Subareas 1 and 3 and since haddock do not occur in abundance in Subarea 1.

Spain, OT - Landings of 192 tons in 1953 and 1 ton in 1954 were reported from Subarea 2, but these are here included in 3NK, since haddock do not occur in Subarea 2.

General - All statistics of landings were obtained from the ICNAF Statistical Bulletins, Vol. 3 - 8.

- The symbol (+) indicates that fishing probably occurred, but the quantities are given in 3NK (= Subarea 3, division not known).

Table 10. Subarea 3 haddock: landings per unit effort of Newfoundland trawlers, and the calculated total fishing effort by the Canadian fleet and by the entire fleet of trawlers during the period 1954-58.

Region	Year	Landings per hour fished by Newfoundland trawlers (metric tons)	Calculated effort in thousands of hours fished	
			Canadian trawlers	All trawl fleets
Grand Bank, Divisions 3L-N-O	1954	0.99	5.8	25.8
	55	2.02	1.6	21.9
	56	2.08	11.2	24.3
	57	1.83	16.6	31.9
	58	1.08	21.3	36.9
St. Pierre Bank, 3P	1954	1.97	12.9	13.2
	55	2.17	18.1	26.3
	56	1.72	14.4	17.2
	57	1.15	3.5	5.1
	58	+	+	+
Total, Subarea 3	1954	1.67	18.7	39.0
	55	2.16	19.7	48.2
	56	1.88	25.6	41.5
	57	1.71	20.1	37.0
	58	1.08	21.5	37.6

Notes

The landings per unit effort of Newfoundland trawlers were obtained from the "special effort" data of the ICNAF Statistical Bulletins, Vol. 4 - 8.

The fishing effort values were obtained by dividing the landings (from Table 9) by the landings per unit effort of Newfoundland trawlers given above in the table.

The symbols (+) for St. Pierre Bank in 1958 indicate that there was insufficient fishing effort to obtain a reliable landing per unit effort value.

Table 11. Divisions 3N and 30 haddock: length compositions of the average annual trawl catches for the period 1955-58.

Length range (cm)	Mid-point of range (cm)	Number of haddock in thousands*		
		Canada	Spain	Total
18-19	18.5	21	29	50
20-21	20.5	50	70	120
22-23	22.5	119	166	285
24-25	24.5	178	248	426
26-27	26.5	502	701	1203
28-29	28.5	1138	1588	2726
30-31	30.5	1358	1895	3253
32-33	32.5	1955	2729	4684
34-35	34.5	3474	4850	8324
36-37	36.5	4342	6061	10403
38-39	38.5	5341	7456	12797
40-41	40.5	5801	8098	13899
42-43	42.5	5523	7405	12928
44-45	44.5	4367	6184	10551
46-47	46.5	2609	3050	5659
48-49	48.5	1218	2142	3360
50-51	50.5	551	1075	1626
52-53	52.5	247	405	652
54-55	54.5	127	299	426
56-57	56.5	72	233	305
58-59	58.5	52	135	187
60-61	60.5	37	114	151
62-63	62.5	19	110	129
64-65	64.5	8	59	67
66-67	66.5	2	15	17
68-69	68.5	1	13	14
Number caught, N_C	('000)	39112	55130	94242
Weight caught, W_C	(m.t.)	23539	34123	57662
Number landed, N_L	('000)	28995	36793	65788
Weight landed, W_L	(m.t.)	20000	27857	47857
Percentage discards		15.0	18.4	17.0

*Canada and Spain together landed 99% by weight of the haddock landed from catches on the Grand Bank during the period 1955-58.

Table 11. (Continued)

Notes

All data were obtained from the ICNAF Sampling Year-books, Vol. 1 - 3, for the years 1955-58.

The Canadian data represent the measurement of fish in the landings rather than in the catches, but they were adjusted for discards by comparison with the length-composition data of catches by Spanish trawlers. The length compositions of Table 11 are based on the following data:

1955. Canada (Nfld), 19416 haddock measured from the landings of commercial trawlers.

Spain, 7080 haddock measured, before discarding.

1956. Canada (Nfld), 21693 haddock measured, from landings.

Spain, 2422 haddock measured, before discarding.

1957. Canada (Nfld), 35851 haddock measured, from landings.

Spain, 1715 haddock measured before discarding.

1958. Canada (Nfld), 31057 haddock measured, from landings.

Table 12. Subarea 3 redfish: landings (metric tons) by countries for the period 1940-59.

Year	Canada (M)	Canada (Nfld)	France (St.P)	Germany (E)	Germany (W)	Iceland	UK	USA	USSR	GRAND TOTAL
1940	-	-	-	-	-	-	-	-	-	-
41	-	-	-	-	-	-	-	-	-	-
42	-	5	-	-	-	-	-	-	-	5
43	-	12	-	-	-	-	-	-	-	12
44	-	37	-	-	-	-	-	-	-	37
45	-	144	-	-	-	-	-	-	-	144
46	-	264	-	-	-	-	-	-	-	264
47	-	1741	-	-	-	-	-	-	-	1741
48	25	4572	-	-	-	-	2	-	-	4599
49	33	7437	-	-	-	-	-	-	-	7470
50	261	11716	-	-	-	-	-	282	-	12259
51	1096	16211	-	-	-	-	-	13562	-	30869
52	2140	12582	-	-	-	-	-	31464	-	46186
53	2104	10377	-	-	5	-	-	33114	-	45600
54	1918	3999	32	-	-	-	1	31269	-	37219
55	763	3306	128	-	-	-	-	13406	-	17603
56	603	2941	88	-	-	-	3	13304	12908	29847
57	426	3377	273	-	2	-	33	4748	48805	57664
58	772	6751	567	596	87	43668	-	10211	96046	158698
59*	1297	4999	701	1074	8794	25115	34	16483	151936	211974*

*Landings for 1959 are provisional; the total includes 1475 tons by Belgium and 66 tons by Poland.

Notes

All statistics of landings prior to 1959 were obtained from the ICNAF Statistical Bulletins, Vol. 1 - 8; the 1959 landings were obtained from ICNAF Document Serial No. 780, 1960. Explanatory notes by countries are as follows:

Canada (M) - Landing for 1958 includes 2 tons by Danish seiner.

Canada (Nfld) - Landings for 1942-51 were not reported by gears, but they were mainly obtained by trawlers; landings for 1952-58 include the following small quantities by Danish seiners: 26, 297, 26, 81, 62, 31 and 22 tons respectively.

Table 13. Subarea 3 redfish: landings (metric tons) by countries and ICNAF divisions for the period 1953-59.

ICNAF Div.	Year	Canada (M)	Canada (Nfld)	France (St.P)	Germany (E)	Germany (W)	Belgium	Iceland	Poland	UK	USA	USSR	GRAND TOTAL
3K	1953	-	-	-	-	-	-	-	-	-	-	-	-
	1954	-	-	-	-	-	-	-	-	-	-	-	-
	1955	-	-	-	-	-	-	-	-	-	-	-	-
	1956	-	-	-	-	-	-	-	-	-	-	-	-
	1957	-	-	-	-	-	-	-	-	-	-	-	-
	1958	-	-	-	-	-	-	43668	-	-	-	29204	72872
	1959*	-	-	-	-	-	+	23534	66	10	-	78357	101967
3L	1953	25	1751	-	-	-	-	-	-	-	-	-	1776
	1954	4	392	-	-	-	-	-	-	1	-	-	397
	1955	12	5	-	-	-	-	-	-	-	100	-	117
	1956	-	16	-	-	-	-	-	-	-	-	-	16
	1957	13	50	-	-	-	-	-	-	33	-	17232	17328
	1958	42	339	-	-	-	-	-	-	-	-	12947	13328
	1959*	208	32	-	843	8794	+	1581	-	11	287	20347	32103
3M	1953	-	-	-	-	-	-	-	-	-	-	-	-
	1954	-	-	-	-	-	-	-	-	-	-	-	-
	1955	-	-	-	-	-	-	-	-	-	-	-	-
	1956	-	-	-	-	-	-	-	-	-	54	12908	12962
	1957	-	1	-	-	-	-	-	-	-	-	31573	31574
	1958	-	9	-	596	-	-	-	-	-	32	53895	54532
	1959*	-	-	-	231	-	+	-	-	-	-	51977	52208
3N	1953	977	5062	-	-	-	-	-	-	-	+	-	6039
	1954	451	712	+	-	-	-	-	-	-	+	-	1163
	1955	84	258	+	-	-	-	-	-	-	3903	-	4245
	1956	102	160	+	-	-	-	-	-	3	7226	-	7491
	1957	28	1225	+	-	-	-	-	-	-	2502	-	3755
	1958	258	1524	+	+	-	-	-	-	-	5959	-	7741
	1959*	109	1433	+	-	-	-	-	-	9	8083	844	10478
3O	1953	879	632	-	-	+	-	-	-	-	+	-	1511
	1954	719	339	+	-	-	-	-	-	-	+		1088

	1959*	109	1433	+	-	-	-	-	-	9	8083	844	10478
30	1953	879	632	-	-	+	-	-	-	-	+	-	1511
	1954	749	339	+	-	-	-	-	-	-	+	-	1088
	1955	274	68	+	-	-	-	-	-	-	8080	-	8422
	1956	401	50	+	-	-	-	-	-	-	5564	-	6015
	1957	238	78	+	-	-	-	-	-	-	2031	-	2347
	1958	246	1786	+	-	2	-	-	-	-	4037	-	6071
	1959*	745	963	+	-	-	-	-	-	2	7230	328	9268
3P	1953	223	2932	-	-	+	-	-	-	-	+	-	3155
	1954	714	2447	+	-	-	-	-	-	-	+	-	3161
	1955	393	2975	+	-	-	-	-	-	-	1323	-	4691
	1956	100	2715	+	-	-	-	-	-	-	460	-	3275
	1957	147	2003	+	-	2	-	-	-	-	215	-	2387
	1958	226	3093	+	-	8	-	-	-	-	183	-	3510
	1959*	235	2571	+	-	-	-	-	-	2	883	83	3774
3NK	1953	-	-	-	-	5	-	-	-	-	33114	-	33119
	1954	-	109	32	-	-	-	-	-	-	31269	-	31410
	1955	-	-	128	-	-	-	-	-	-	-	-	128
	1956	-	-	88	-	-	-	-	-	-	-	-	88
	1957	-	-	273	-	-	-	-	-	-	-	-	273
	1958	-	-	567	-	77	-	-	-	-	-	-	644
	1959*	-	-	701	-	-	1475	-	-	-	-	-	2176
Sub-area 3	1953	2104	10377	-	-	5	-	-	-	-	33114	-	45600
	1954	1918	3999	32	-	-	-	-	-	1	31269	-	37219
	1955	763	3306	128	-	-	-	-	-	-	13406	-	17603
	1956	603	2941	88	-	-	-	-	-	3	13304	12908	29847
	1957	426	3377	273	-	2	-	-	-	33	4748	48805	57664
	1958	772	6751	567	596	87	-	43668	-	-	10211	96046	158698
	1959*	1297	4999	701	1074	8794	1475	25115	66	34	16483	151936	211974

*Landings for 1959 are provisional

Notes

General - All statistics of landings up to 1958 were obtained from the ICNAF Statistical Bulletins, Vol. 1 - 8; the 1959 landings were taken from ICNAF Document Serial No. 780, 1960.

- The symbol (+) indicates that fishing probably occurred, although the landings have not been reported by ICNAF divisions and are placed in 3NK (= Subarea 3, division not known).

Table 14. Subarea 3 redfish: landings per unit effort and calculated effort of the trawling fleets for the period 1954-58.

ICNAF Div.	Year	Landing per unit effort (m.t.) Canada L/hr fished	USSR L/hr fished	USA L/hr fished	Calculated effort Canada Hours	USSR Iceland Hours	USA Days
3K	1954	-	-	-	-	-	-
	1955	-	-	-	-	-	-
	1956	-	-	-	-	-	-
	1957	-	-	-	-	-	-
	1958	-	2.64	-	-	27603	-
3L	1954	1.87	-	-	212	-	-
	1955	+	-	-	+	-	-
	1956	+	-	-	+	-	-
	1957	1.23	1.72	-	51	10013	-
	1958	1.33	2.56	-	288	5067	-
3M	1954	-	-	-	-	-	-
	1955	-	-	-	-	-	-
	1956	-	2.17	-	-	5943	-
	1957	+	1.53	-	+	20634	-
	1958	+	1.82	-	+	29575	-
3N	1954	1.23	-	+	943	-	+
	1955	1.14	-	+	299	-	+
	1956	1.19	-	+	220	-	+
	1957	1.55	-	+	808	-	+
	1958	1.99	-	+	895	-	+
3O	1954	1.30	-	+	836	-	+
	1955	+	-	+	+	-	+
	1956	+	-	+	+	-	+
	1957	+	-	+	+	-	+
	1958	1.30	-	+	1559	-	+
3P	1954	0.76	-	+	4154	-	+
	1955	0.80	-	+	4205	-	+
	1956	0.68	-	+	4146	-	+
	1957	0.60	-	+	3571	-	+
	1958	0.53	-	+	6322	-	+
Sub-area 3	1954	0.95	-	17.5	6261	-	1786
	1955	0.82	-	11.9	4938	-	1126
	1956	0.71	2.17	14.1	5027	5943	943
	1957	0.78	1.60	16.6	4863	30647	288
	1958	0.83	2.10	15.6	9075	66530	653

Table 14. (Continued)

Notes

The landings per unit effort for Canada were obtained from the "special effort" data of Newfoundland trawlers given in ICNAF Statistical Bulletins, Vol. 4 - 8; those for USSR trawlers were obtained from the landind and effort statistics of ICNAF Statistical Bulletins, Vol. 6 - 8; and those for USA trawlers were obtained from data supplied the author by the Fisheries Laboratory, Woods Hole, Mass.

The fishing effort for redfish by the fleets indicated were obtained by dividing the appropriate landings (from Table 13) by the landing per unit effort values in the foregoing table.

The symbol (+) indicates that effort data were lacking or inadequate.

Table 15. Subarea 3 redfish: length compositions of the trawl catches by ICNAF divisions for the year 1958.

Length range (cm)	Number of redfish in thousands					
	3K	3L	3M	3N-O		3P
	Iceland USSR	USSR Canada	USSR	Canada	USA	Canada USA
15				5		
16				15	9	
17				20	28	
18				19	148	
19				86	316	3
20				180	595	6
21		2	48	368	1077	19
22				632	2211	26
23	162	26	185	1286	3372	23
24				2064	5742	58
25	1138	192	1565	2405	5389	122
26				2140	4209	96
27	3567	409	5736	1589	3614	238
28				1266	2276	369
29	6636	674	13872	800	2397	414
30				460	1375	752
31	11611	1587	18823	283	1003	829
32				215	808	639
33	15241	2667	17420	111	492	482
34				118	511	534
35	24523	3304	19260	99	307	662
36				68	307	626
37	14379	2702	10261	37	279	463
38				38	111	228
39	11668	2264	5947	18	19	103
40				15	28	90
41	9407	1899	2144	4	28	26
42						22
43	4253	1204	590	1	9	6
44						2
45	1724	541	125			2
46						
47	213	133				
48						
49	76	27				
50						
51		7				
52						
N ('000)	104598	17638	95976	14342	36660	6840
W (m.t.)	72872	13328	54532	3814	9996	3510
$\bar{W}$ (kg)	0.70	0.76	0.57	0.27	0.27	0.51

Table 15. (Continued)

Notes

All redfish length-composition data, on which the catch length compositions of the table are based, were obtained from the ICNAF Sampling Yearbook, Vol. 3, for the year 1958. The USSR length compositions for Divisions 3K, 3L and 3M were reported by 2-centimeter groups. Explanatory notes by ICNAF divisions are as follows:

3K - USSR length compositions (36492 redfish were measured) for 1958 were weighted by months and then adjusted to the total quantity of redfish landed by the USSR (40%) and Iceland (60%).

3L --USSR length compositions (32648 redfish were measured) for 1958 were weighted by months and adjusted to the total quantity of redfish landed by the USSR (97%) and Canada (3%).

3M - USSR length compositions (62209 redfish were measured) for 1958 were weighted by months and adjusted to the total quantity of redfish landed by the USSR (99%) and East Germany (1%).

3N-O - Newfoundland length compositions (6655 redfish were measured) for 1958 were adjusted to the total quantity of redfish landed by Canada (28%).

- USA length compositions (3900 redfish were measured) for 1958 were adjusted to the total quantity of redfish landed by the USA (72%).

3P - Newfoundland length compositions (5887 redfish were measured) for 1958 were adjusted to the total quantity of redfish landed by Canada (95%) and the USA (5%).

Table 16. Subarea 3 flounder: landings (metric tons) by ICNAF divisions and countries for the period 1953-59*.

ICNAF Division	Year	Canada (M)	Canada (Nfld)	France (St.P)	Germany	Spain	USSR	UK	USA	Total
3K	1953	-	-	-	-	-	-	-	-	-
	54	-	-	-	-	-	-	-	-	-
	55	-	433	-	-	-	-	-	-	433
	56	-	584	-	-	-	-	-	-	584
	57	-	465	-	-	-	-	-	-	465
	58	-	812	-	-	-	-	-	-	812
	59*	-	2	-	-	-	241	10	-	253
3L	1953	2031	2408	-	-	-	-	-	-	4439
	54	2014	1108	-	-	-	-	22	-	3144
	55	6204	5639	-	-	-	-	-	-	11843
	56	4152	5089	-	-	-	-	-	-	9241
	57	4518	4056	-	-	-	314	24	-	8912
	58	7106	5801	-	-	-	17	-	-	12924
	59*	5020	7605	-	180	-	132	5	-	12942
3M	1953	-	-	-	-	-	-	-	-	-
	54	-	-	-	-	-	-	-	-	-
	55	-	-	-	-	-	-	-	-	-
	56	-	-	-	-	-	12	-	-	12
	57	-	-	-	-	-	505	-	-	505
	58	-	2	-	-	-	150	-	-	152
	59*	-	-	-	-	-	302	-	-	302
3N	1953	3740	4253	-	-	-	-	-	-	7993
	54	1351	1991	-	-	4	-	-	-	3346
	55	1207	1114	-	-	-	-	-	3	2324
	56	829	2390	-	-	-	-	14	5	3238
	57	1058	2835	-	-	-	-	-	-	3893
	58	1277	4161	-	-	-	-	-	1	5439
	59*	401	4180	-	-	-	1	3	1	4586
3O	1953	2768	2205	-	-	-	-	-	-	4973

	57	[illegible]	[illegible]	-	-	-				[illegible]
	58	1277	4161	-	-	-	-	-	1	5439
	59*	401	4180	-	-	-	1	3	1	4586
30	1953	2768	2205	-	-	-	-	-	-	4973
	54	1499	1052	-	-	-	-	-	-	2551
	55	1202	163	-	-	-	-	20	19	1404
	56	1923	1024	-	-	-	-	-	10	2957
	57	5252	2127	-	-	-	-	61	-	7440
	58	816	923	-	8	-	-	-	-	1747
	59*	975	752	-	-	-	-	8	3	1738
3P	1953	851	1086	-	-	-	-	-	-	1937
	54	639	1481	-	-	-	-	-	-	2120
	55	1259	1688	-	-	-	-	17	-	2964
	56	402	1159	457	-	-	-	6	-	2024
	57	2989	1112	-	-	-	-	30	22	4153
	58	1154	1034	-	8	-	-	-	-	2196
	59*	2039	1762	-	-	-	-	10	1	3812
3NK	1953	-	141	-	18	-	-	-	40	199
	54	-	13	95	-	-	-	-	85	193
	55	-	-	410	-	-	-	-	-	410
	56	-	-	-	-	-	-	-	-	-
	57	-	3	953	-	-	-	-	-	956
	58	-	3	1071	13	-	-	10	-	1097
	59*	-	-	701	-	-	-	-	-	701
Sub-area 3	1953	9390	10093	-	18	-	-	-	40	19541
	54	5503	5645	95	-	4	-	22	85	11354
	55	9872	9037	410	-	-	-	-	-	19379
	56	7306	10246	457	-	-	12	20	15	18056
	57	13817	10598	953	-	-	819	115	22	26324
	58	10353	12736	1071	29	-	249	10	1	24449
	59*	8435	14301	701	180	-	676	36	5	24334

*The 1953-58 data were obtained from the ICNAF Statistical Bulletins, Vol. 3 - 8; the 1959 landings were obtained from ICNAF Document Serial No. 780, 1960, and are provisional.

APPENDIX II. SELECTION OGIVES OF THE VARIOUS TRAWL MESH SIZES FOR COD, HADDOCK, REDFISH AND AMERICAN PLAICE *

Table 1. Selection ogives for cod.

Midpoint of 3-cm length group	Percentage retention by					
	3-inch mesh	4-inch mesh	4½-inch mesh	5-inch mesh	5½-inch mesh	6-inch mesh
13	4					
16	9					
19	17	1				
22	30	3	1			
25	44	7	2			
28	60	14	5	1		
31	75	25	11	4	1	
34	86	40	20	9	2	1
37	93	53	34	17	5	2
40	97	70	50	30	11	4
43	99	83	66	45	21	9
46	100	91	79	61	34	17
49		96	89	76	50	30
52		98	95	87	66	44
55		100	98	94	79	60
58			99	98	89	75
61			100	99	95	86
64				100	98	93
67					99	97
70					100	99
73						100

* These selection ogives were prepared from information reported by Clark, McCracken and Templeman (1958).

APPENDIX II. (Continued)

Table 2. Selection ogives for haddock.

Midpoint of 2-cm length group	Percentage retention by					
	3-inch mesh	4-inch mesh	4½-inch mesh	5-inch mesh	5½-inch mesh	6-inch mesh
12.5	5					
14.5	10					
16.5	18					
18.5	28	1				
20.5	40	3				
22.5	54	6	1			
24.5	66	10	3			
26.5	77	18	5	1		
28.5	86	28	11	2		
30.5	92	41	18	4	1	
32.5	96	54	28	8	2	
34.5	98	67	40	14	3	
36.5	99	78	54	22	6	1
38.5	100	87	68	34	11	3
40.5		93	79	47	18	6
42.5		96	87	60	28	11
44.5		98	93	73	40	18
46.5		99	97	83	54	28
48.5		100	98	90	67	41
50.5			99	95	78	54
52.5			100	97	87	67
54.5				99	92	78
56.5				100	96	87
58.5					98	93
60.5					99	96
62.5					100	98
64.5						99
66.5						100

APPENDIX II. (Continued)

Table 3. Selection ogives for redfish.

Length cm	Percentage retention by 3-inch mesh	4-inch mesh	4½-inch mesh	5-inch mesh	5½-inch mesh	6-inch mesh
12	4					
13	8					
14	14					
15	22	1				
16	33	2				
17	45	3				
18	58	5	1			
19	70	8	2			
20	80	12	4			
21	88	18	6	1		
22	93	26	9	2		
23	96	35	13	4		
24	98	44	18	6	1	
25	99	54	25	8	2	1
26	100	64	33	12	3	2
27		73	41	17	5	3
28		81	50	23	7	4
29		87	59	30	10	6
30		92	67	37	15	8
31		95	75	45	20	11
32		97	82	54	26	15
33		98	87	62	33	20
34		99	91	70	40	26
35		100	94	76	48	32
36			96	82	56	39
37			98	87	64	46
38			99	91	71	53
39			100	94	77	60
40				96	83	67
41				98	88	73
42				99	91	79
43				100	94	84
44					96	88
45					97	91
46					98	94
47					99	96
48					100	97
49						98
50						99
51						100
52						

APPENDIX II. (Continued)

Table 4. Selection ogives for American plaice.

Midpoint of 2-cm length group	Percentage retention by	
	4-inch mesh	6-inch mesh
10.5	2	
12.5	5	
14.5	11	
16.5	22	
18.5	38	
20.5	56	1
22.5	72	4
24.5	85	9
26.5	93	19
28.5	98	33
30.5	99	50
32.5	100	67
34.5		81
36.5		91
38.5		96
40.5		99
42.5		100

APPENDIX III. Length-weight Data for Cod, Haddock and Redfish (Round Fresh Fish)

COD		HADDOCK		REDFISH	
3-cm groups	Weight (kg)	2-cm groups	Weight (kg)	1-cm groups	Weight (kg)
15-17	0.04	16-17	0.04	15	0.05
18-20	0.06	18-19	0.05	16	0.06
21-23	0.09	20-21	0.07	17	0.07
24-26	0.13	22-23	0.10	18	0.09
27-29	0.18	24-25	0.13	19	0.10
30-32	0.25	26-27	0.16	20	0.12
33-35	0.33	28-29	0.20	21	0.14
36-38	0.43	30-31	0.25	22	0.15
39-41	0.54	32-33	0.31	23	0.18
42-44	0.68	34-35	0.37	24	0.20
45-47	0.84	36-37	0.44	25	0.23
48-50	1.02	38-39	0.52	26	0.26
51-53	1.23	40-41	0.61	27	0.29
54-56	1.46	42-43	0.71	28	0.32
57-59	1.72	44-45	0.81	29	0.35
60-62	2.01	46-47	0.93	30	0.39
63-65	2.32	48-49	1.06	31	0.44
66-68	2.68	50-51	1.20	32	0.48
69-71	3.07	52-53	1.35	33	0.52
72-74	3.49	54-55	1.51	34	0.57
75-77	3.95	56-57	1.70	35	0.63
78-80	4.45	58-59	1.89	36	0.68
81-83	4.99	60-61	2.10	37	0.74
84-86	5.58	62-63	2.32	38	0.80
87-89	6.22	64-65	2.55	39	0.86
90-92	6.89	66-67	2.80	40	0.93
93-95	7.62	68-69	3.07	41	1.00
96-98	8.40	70-71	3.36	42	1.08
99-101	9.22	72-73	3.67	43	1.16
102-104	10.11			44	1.24
105-107	11.05			45	1.33
108-110	12.04			46	1.42
111-113	13.09			47	1.52
114-116	14.21			48	1.65
117-119	15.39			49	1.72
120-122	16.63			50	1.82
123-125	17.93			51	1.94
126-128	19.31			52	2.06
129-131	20.75			53	2.17

Source: Unpublished data of the St. John's Biological Station, Newfoundland.

APPENDIX IV

Abbreviations Used

Canada (M)	=	Canada Mainland
Canada (Nfld)	=	Canada (Newfoundland)
Denmark (F)	=	Denmark (Faroes)
Denmark (G)	=	Denmark (Greenland)
France (M)	=	France (Mainland)
France (St.P)	=	France (St. Pierre and Miquelon)
Germany (E) or (W)	=	Germany (East) or (West)
UK	=	United Kingdom
USA	=	United States of America
USSR	=	Union of Soviet Socialist Republics
LL	=	Longliner
DV	=	Dory vessel, line fishing
OT	=	Otter trawler
PT	=	Pair trawlers
NK	=	Not known; used when the subarea or division not given for data.

List of Species

Cod	*Gadus morhua* L.
Haddock	*Melanogrammus aeglefinus* (L.)
American plaice	*Hippoglossoides platessoides* (Fab.)
Witch	*Glyptocephalus cynoglossus* (L.)
Redfish (ment.)	*Sebastes marinus mentella* (Travin)
" (mar.)	*Sebastes marinus marinus* (L.)