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Report of Working Group of Scientists on Fishery Assessment in relation to Regulation Problems

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International Commission for the
Northwest Atlantic Fisheries.

Report of Working Group of Scientists on Fishery Assessment in relation to Regulation Problems

SECTION 1. MEETINGS AND PARTICIPANTS

1.1 The first stages in assembling and processing the available data followed the general plan drawn up at the Ninth Annual Meeting of ICNAF at Montreal in 1959. Those scientists concerned with sub-areas 1 and 2 had some discussions during the 1959 ICES meeting. Compilations of data and some preliminary assessments for sub-areas 3,4 and 5 were examined in December, 1959 at the Meeting of scientific advisers to these panels, and detailed plans were drawn up for the next stage of the work. A report of this meeting was presented at the Tenth Annual Meeting of ICNAF. (Doc. 3, App. II).

1.2 Thereafter, three full meetings of the Working Group have been held,

(a) Lowestoft, March 17-26, 1960
(b) Bergen, May 19-22, 1960, and during the following two weeks
(c) Lowestoft, March 20-30, 1961

Plans for the final meeting (c) were worked out during the meeting of scientific advisers to Panels 3, 4 and 5 during their meeting in Woods Hole in December, 1960, which the Convenor also attended.

1.3 Participants at all three full meetings were as follows:-

R.J.H. Beverton (U.K.) (Convenor)
L.M. Dickie (Canada)
V. Hodder (Canada)
E. Cadima (Portugal)
S.J. Holt (F.A.O.)
B.B. Parrish (U.K.)
J.A. Gulland (U.K.)

The following attended some but not all meetings:-

G. Saetersdal (Norway) 1st and 2nd meeting)
A. Hylen (Norway) (3rd meeting)
R.P. Silliman (U.S.S.) (1st and 2nd meetings)
R. Hennemuth (U.S.A.) (3rd meeting)
V Travin) (U.S.S.R.) (1st meeting)
L.G. Nazarova)
Ju, Ju. Marty) (U.S.S.R.) (3rd meeting)
S.S. Baranov)
R. Jones (U.K.) (1st meeting)

SECTION 2 - SCOPE OF REPORT

2.1 The tasks set to the Working Group were as follows:-
To complete the processing and evaluation of studies made on an area basis by groups of scientific advisors to panels. In each of the five sub-areas ".... the prime objectives would be to obtain the best estimates of the immediate and long-term effects of enforcing minimum meshes of, say, between 4 inches and 6 inches, on a per-recruit basis for each of the three species (cod, haddock and redfish...) including determinations of the minimum fish sizes appro-iate to the minimum mesh sizes postulated.

These estimates should be made first in relation to the present rate of fishing, and preferably also in relation to a hypothetical (or, if possible, "expected", as determined by national forecasts) furture rate of fishing. The results should be formulated so as to permit comparison of the individual values with the results of applying overall any particular minimum mesh and ... include... preliminary evaluations of greater benefits to be expected in any instance where the data suggested that increases beyond 6 inches were likely to be more beneficial for that stock. The possible consequences ...for other fisheries should be borne in mind". The sub-area reports, and subsequently therefore, that of the Working Group" ... should refer to the possible benefits to be obtained by other conservation methods. "(Quotations from Report of the Standing Committee on Research and Statistics, Annual Meeting, June 1959, Proceedings No. 4, ICNAF Serial No. 643).

2.2 An evaluation of the influence of fishing on the stocks is fundamental to assessing the effect of applying a regulative measure. This report sets out in summary form the conclusions reached by the Working Group on the effects of fishing on the stocks in the ICNAF area. Conclusions are based for the most part on research and statistical data up to and includir the year 1958, but some 1959 data have been used where availa...e.

2.3 For most of the main cod and haddock fisheries it has been possible to establish that fishing is having an effect on the stocks, and for these fisheries calculations have been made of the probable long-term effects of increase of mesh size at present levels of fishing intensity. The accuracy of the assessments is seldom high, however, and the procedure is adopted of giving a range of possible effects according to the reliability of the data. In some fisheries, including most of those for redfish, it has not been possible to determine from existing data whether or not the stocks have yet been affected by fishing, and so the kind of assessments that can be made are even more restricted. Of the minor species, some appreciation has been made for halibut in the whole area and for Yellowtail flounder in Sub-area 5. Effects of fishing and assessments of mesh increase at present levels of fishing intensity are presented on a sub-area basis in Sections 4-8 (for Sub-areas 1 to 5 respectively). Halibut is treated separately in Section 9. Conclusions on mesh effects are summarized in Section 10, which also includes a considering of the consequences of adopting a uniform mesh throughout the Convention area compared with differential mesh sizes.

2.4 It has not been possible to make a comprehensive study of the effects of mesh increase at levels of fishing intensity other than the present one. Some general remarks on this question, together with certain illustrative examples are, however, given in Section 11. Comments on other methods of regulation are offered in Section 12.

2.5 Although not specifically mentioned in the tasks given to the Working Group as set out above, reference was made in the proceedings of the Ninth Annual Meeting to the question of the adoption of a uniform mesh for the North Atlantic region. The Working Group has not considered fisheries outside the ICNAF area, but wishes to draw the attention of the Committee to recent developments concerning the northern part of the Permanent Commission area. These are that a scientific report on the state of the cod and haddock fisheries of the North-east Arctic, and an assessment of the probable effects on them of further increases in mesh above the present regulation si: of 110 mm(= approx. $4\frac{1}{4}$"), was submitted to the Eighth Meeting of the Permanent Commission in May, 1960 by the Arctic Fisheries Working Group of ICES. Further, at the request of the Permanent Commission, ICES has set up another working group (the North Western Working Group) to make a similar appraisal for the remainder of the northern part of the Permanent Commission area, which includes Iceland and East Greenland.

The report of this latter group is due to be presented at the Ninth Meeting of the Permanent Commission in May, 1961. Thus, by June 1961, the two ICES Working Groups and the present ICNAF Group will, between them, have reported on the fisheries in the whole of the Northern part of the North Atlantic. It is suggested that it might then be desirable to make a joint scientific appraisal of the stocks of its fisheries in the two Commission areas. Such a joint study is particularly appropriate where (as at Greenland) there is significant movement of fish between the ICNAF and Permanent Commission areas. It is also important in so far as changes of fishing effort in the two areas are inter-related.

2.6 During the course of its work, the Group paid attention to locating gaps in existing information and to delimiting the needs for future research which might lead to a better understanding of the effects of fishing on the stocks. The suggestions of the Group are listed for the consideration of the Committee in Section 13.

SECTION 3. MESH ASSESSMENTS - SOME GENERAL COMMENTS ON METHODS AND INTERPRETATION

3.1 When the size of mesh is increased it will allow a certain number of small fish to be released which would have been caught with the original mesh. The number thus released can be calculated from a knowledge of the size composition of the original catches taken by the old mesh and the retention curves of the old and new meshes. The total weight of these released fish, expressed as a percentage of the original catch, is the <u>immediate loss</u>. A proportion of these released fish will die before they have grown large enough to be retained by the new mesh, but in most of the assessments considered here the time taken by the fish to grow into the retention range of the new mesh is not great, and the majority of the released fish will survive to increase the stock of larger fish. The fraction of these survivors that will eventually be caught during the remainder of their life is determined by the ratio of fishing mortality to total mortality in the stock (denoted by E); their average weight when caught can be estimated from observed size composition of the catches after applying the selection curve of the new mesh. Thus, the <u>long-term effect</u> of the mesh increase can be calculated as the difference between the total weight of the fish when released to the total weight of the survivors when caught later in their life. If the latter exceeds the former, there will be a long-term gain from the mesh increase, and vice-versa; in the assessments given below the long-term change (gain or loss) is expressed as a percentage of the original catches. In some fisheries a porportion of the catch as taken by the present mesh sizes is discarded at sea. Although this discarding does not influence the actual quantity of fish released by a given increase of mesh, it means that the effect, both immediate and long-term, on the <u>landings</u> is different from that on the catches. Wherever discarding is known to occur and can be estimated, assessments are given in terms of the percentage effect on <u>landings</u>.

3.2 The information required to make an assessment of the long-term effect of mesh increase is therefore the present quantity and size-composition of the fish caught by each component of the fishery (and of fish landed, if these differ from the catches), the selectivity of the fear for various mesh sizes, the ratio of fishing to total mortality in the stock (E), and the growth and natural mortality rate of fish in the selection ranges of the meshes considered. The method generally adopted for making assessments from such data is that developed by Gulland (1961), but for haddock in Sub-area 5 assessments have been made by an extension developed by Silliman of the more conventional methods based directly on age-composition and length -at-age data.

3.3 The long-term assessments calculated by these methods show how a given increase in mesh size would be expected to influence the average future level of landings compared with what would have been obtained had no change in mesh size been made.

Except in Section 11, the assessments are based on the propostion that the present amounts of fishing by the various gears, and the distribution of fishing on fish of various sizes, remain unchanged In reality, even if the amount of fishing does not alter, it would be expected that an increase of mesh would have the ancillary effect of tending to encourage vessals to fish more on grounds containing larger fish. While neither the extent or detailed effect of this can be predicted, it would certainly tend to improve the general exploitation of the stocks and increase the share taken by trawlers compared with other gears.

3.4 It has been supposed for the assessments of this report that the selectivity of trawl gear only is regulated. For this reason, and also because there are often differences in the size compositions of catches and landings by the various trawl fleets even when they are fishing the same stock, a given increase in mesh size will produce different long-term effects on the landings by the various gears and fleets. Assessments have therefore been made, so far as was possible from the information available, for the effects on each major component of the fisheries.

3.5 General experience in fishery research is that of the quantities required for long-term assessment, the ratio of fishing to total mortality (E) is the most difficult to estimate and may critically affect the conclusions reached. The procedure has therefore been adopted of calculating long-term assessments for a range of values of E within which the true value is thought to lie. In most of the fisheries considered here it has been possible to obtain only very approximate estimates of E, and the range of values used in assessment is correspondingly wide. This sometimes results in a rather wide range of assessments, but in certain circumstances useful conclusions can nevertheless be drawn. In some fisheries (e.g. most redfish fisheries) no estimate of E can be obtained from present data and so no long-term assessments are yet possible. In such cases the value of E can be calculated which, for a given increase in mesh size, would leave the long-term landings unchanged; this critical value of E (called the "break-even" value) serves to indicate in a general sense how intense the fishing would have to be to enable the mesh increase in question to result in a long-term gain.

3.6 It is a feature of the stocks in the ICNAF area that they are in many cases sub-divided into local "groups" between which there is little or no mixing. In some instances a particular group has a clearly definable fishery associated with it, in which case assessments have been made in the first instance for that particular group and its fishery, if sufficient data are available. In others, the fishery extends over two or more groups; the procedure has then been to combine data for these groups, weighted as necessary by the catches from each, thus giving assessments which relate as nearly as possible to the effective exploitation of the component groups as a unit.

3.7 Some comment is also required on the significance of the assessments of immediate loss given in this report. They have been calculated directly from the size compositions of catches and selectivity of the gear, but in interpreting them the following points should be borne in mind:-

(a) There is substantial evidence that an increase in mesh size increases the fishing power of the gear and results in greater catches of larger fish beyond the selection range of the mesh.

(b) The reduced catches of smaller fish caused by an increase in mesh size might result in vessals fishing more on grounds where larger fish are relatively more abundant.

(c) There may have been discarding with the smaller mesh in use. It is to be expected that with the larger mesh proportionally fewer of the small fish caught would be discarded.

(d) The figures quoted are of the losses at the moment the large mesh is introduced, but from then on the fish released grow into the retention range. The losses over the first full year of fishing with the larger mesh will therefore be less than the rate experienced initially; in later years the landings approach the figures given for the long-term effects.

All the above points mean that the figures given in the tables give an exaggerated impression of what the true effect on the landings might be. In addition the practical significance of the calculated immediate losses must be judged against the normal seasonal and year-to-year variation in catches which is encountered in each fishery, which is often much larger than the estimated immediate loss.

3.8 As a guide to the various divisions of the ICNAF area, to which frequent reference is made in this report, Figs. A, B and C are charts of the ICNAF area showing the 1958 landings by divisions of the three main species, (cod, haddock and redfish), distinguishing trawl, other gears and total landings.

SECTION 4 - SUBAREA 1

4.1 <u>The Fisheries</u>

The principal species exploited in Sub-area 1 are cod, yielding about 300 thousand tons annually, and redfish yielding about 20 thousand tons. A relatively small halibut fishery, yielding about one thousand tons, also operates in the area, but no other species are of major commercial importance. The average landings of cod, redfish and other species in 1957 and 1958, by countries and gears, are given in Table 4A.

<u>Table 4A.</u> Subarea 1: Average landings for 1957/58 by countries and gears (thousands of metric tons)

ountry	DENMARK Green-land	DENMARK Faroes		FRANCE	GERMANY	ICE-LAND	NORWAY		PORT-UGAL		SPAIN	U.K.	TOTAL
ar	L	L	OT	OT	OT	OT	L	OT	DL	OT	OT	OT	
Cod	26	16	22	25	20	10	26	2	72	40	25	10	294
edfish	+	-	-	-	14	8	-	+	-	-	-	+	22
hers	3	+	+	-	1	+	1	-	-	-	+	+	5
TAL	29	16	22	25	35	18	27	2	72	40	25	10	321

L = Line (Long and handline)
DL = Line (Dory)
OT = Otter trawl

Cod were first exploited by line in the southern part of the area, but with the spread northwards of the cod stocks in the 1920's, following climatic changes in the area, this fishery became more widespread, extending northwards along the west coast of Greenland, to as far north as latitude 70°N (Division 1A). At the same time, trawling developed over a wide area, especially on the offshore banks, and in the postwar years the trawl fisheries have spread to all Divisions of the Subarea, and have taken approximately half of the total cod catch.

The line fishery can be divided into two components; a long line and dory fishery, undertaken principally in the offshore regions by Portuguese, Danish and Norwegian vessels, and an inshore handline fishery, conducted by Danish and Greenland vessels. The trawl fishery, since the war has been conducted by a number of countries, principally Portugal, Spain, France, Denmark and Germany.

Although small quantities of redfish were landed from the Subarea by long liners and trawlers in prewar years, a major fishery for this species did not develop until 1953, when it became fished by Icelandic and German trawlers on the continental slope, principally in the southern Divisions 1F - 1D.

Fishing for halibut in Subarea 1 dates back to the beginning of the century. The period of greatest fishing was during the inter-war years, when annual landings from United Kingdom long liners ranged between one thousand to five thousand tons. Since the war, however annual landings have been around one thousand tons, taken principally by Norwegian long liners and trawlers.

4.2 Cod

4.2.1 Division of stocks

The biology of the cod in the Subarea has been studied by Danish workers (e.g. Hansen (1949), Tåning (1937). The results of tagging experiments and other studies indicate that the cod population in the West Greenland area does not form a single homogeneous unit (Wise and Jensen, 1960). The results suggest that: (a) there is relatively little interchange between the inshore concentrations and those on the offshore banks; (b) the offshore concentrations do not mix freely over the whole of their range, but tend to form two groups; a smaller northern group in Divisions 1A and B, and a larger southern one in Divisions 1C-F, which is closely related to the East Greenland and Iceland cod stocks, with which mixing takes place to a varying extent from year to year; (c) there is relatively little exchange of adult cod between Subareas 1 and 2. Because of the present uncertainty concerning the actual degree of mixing between the offshore groups inhabiting the northern and southern parts of the area, for the purpose of the present mesh assessment all the offshore fisheries have been taken together. It is also assumed that no appreciable quantity of fish move from the offshore fisheries into the inshore region fished by the Greenland handline fishery. The latter is therefore regarded as being unaffected by changes in the trawler mesh size.

4.2.2. The total landings of cod from the Subarea, the landings from the inshore Greenland fishery, and those from the offshore line and trawl fisheries are given in Fig. 4.1. The data are also given in App. 1,Table 4.1, and more detailed statistics of landings by country, gear and statistical division are also given for the more recent years in App. 1,Table 4.2. These figures show that whereas the total cod landings during prewar and war years fluctuated about a mean annual level of about 60 thousand tons, they increased rapidly after the war to a more steady level of about 300 thousand tons in the period 1954-58. This increase was due principally to the offshore trawl fishery, which increased to over 150 thousand tons after 1950.

4.2.3 For most of the cod fisheries, catch per unit effort data are available only since 1951. The longest series are for the UK trawl fishery, conducted principally in Divisions 1F. These, and Portuguese trawl and line data since 1951 are given in Fig. 4.2. The data of catch per unit effort for all countries, gears and Divisions for the years after 1951 are given in App. 1, Table 4.3. Corresponding estimates of total <u>effort</u>, for each Division, and for the Subarea as a whole, are given by country and gear in App. 1, Table 4.4.

These data show that the catches per unit effort for the main trawl and line fisheries since 1951 fluctuate widely from year to year, although in several of them the values follow the same general pattern of increase up to 1954-56, followed by a decrease. The estimates of total effort show a similar wide variation and, from the limited series of effort data available, it is not possible to establish that the decline in catch per unit effort after 1956 is due to increased fishing.

4.2.4 Assessment of Mesh changes

Sample data collected during recent years reveal consistent differences between the size compositions of the catches taken by the trawl fisheries of the different countries. They may be taken in three main groups, as follows:-

(a) Portugal, Spain, France
(b) UK, Iceland
(c) Germany

The available data for these three groups in 1958 are given in Fig. 4.3. The data for the countries in the first group are of catches, while those for Germany and the U.K. are of landings. Information on the proportions of the catch discarded by U.K. trawlers in recent years gives an estimate of 5% by weight. For the assessments it was assumed that equal numbers were discarded by the German fishery, and that for both countries all of the discards would be released by the larger meshes. Discards by Portuguese trawlers in 1956-58 were 1-2% by weight and for the assessment it was assumed that Spanish and French trawlers discarded the same proportions.

Because of the substantial differences between these size compositions, assessments of the immediate and long-term changes in mesh size were made separately for these three groups, as well as for the line and total fishery.

Estimates of total mortality rate (Z) and of its two components, fishing and natural mortality, for the assessments were made from series of age composition data for the fishery. The average percentage age composition for 1952-1957 is plotted in Fig. 4.4, and the data for individual years is given in Table 4.5. These data and the analysis of Danish tag recaptures (Poulsen, 1957), corrected for efficiency of recovery, gave a value of Z of about 0.35, and of E of about 0.5. Therefore, values of E of 0.4 and 0.6 have been used in the assessments.

Selection curves were drawn up for each mesh size from data obtained from a single set of selectivity experiments in the southern part of the Subarea, together with selectivity and weight-length data from the north-east Atlantic. These data gave selection factor of 3.7 and a selection range of 10 cm. No corrections were made for possible seasonal changes in selectivity, though it is known that there are marked seasonal changes in weight at length in this region. The selection curves are given in Appendix II.

Because of uncertainty about the mesh size currently in use in the trawl fisheries in the Subarea, assessments were made first on the basis of a small current mesh size, such that the left-hand side of the length catch curve is not influenced by mesh selection; and secondly of a current mesh size of 4¼ inches. These assessments gave very similar results, so that only those for the second assumption are presented here.

The estimated immediate and long-term changes in landings of the three trawl groups, the line fisheries, and for all fisheries combined, for mesh sizes between 4½ to 6 inches are presented in Table 4B.

Table 4B. Subarea 1: Mesh assessments of Cod

Mesh size change (inches)	l_c (cm)	t_c (yrs)	Gear Group	% changes in 1957-58 landings: Immediate	Long term changes for			
From 4¼ to	52	5.2			0.4 0.14 0.21	0.5 0.175 0.175	0.6 0.21 0.14	E F M
4½	53	5.3	Trawl A	-0.5	-0.3	-0.1	+0.1	
			Trawl B	-0.2	+0.3	+0.5	+0.6	
			Trawl C	0	+0.3	+0.5	+0.6	
			Trawl D*	-0.3	0	-0.1	+0.2	
			Line	-	+0.4	+0.5	+0.8	
			Total	-0.2	+0.1	+0.2	+0.3	
5	54	5.4	Trawl A	-4	-1.8	-1.1	-0.4	
			Trawl B	-2	+0.5	+1.2	+1.8	
			Trawl C	-0.8	+1.6	+2.3	+2.9	
			Trawl D*	-3.2	-1.0	-0.4	-0.2	
			Line	-	+2.3	+3.0	+3.5	
			Total	-1.7	+0.5	+1.2	+1.8	
5½	55	5.5	Trawl A	-9.7	-4.6	-3.3	-2.0	
			Trawl B	-5.3	-0.7	+0.6	+2.0	
			Trawl C	-2.8	+2.5	+3.0	+5.3	
			Trawl D*	-8.3	-3.1	-1.8	-0.5	
			Line	-	+5.3	+6.6	+8.0	
			Total	-4.4	+0.9	+2.2	+3.6	
6	56	5.7	Trawl A	-18.0	-8.7	-6.6	-4.6	
			Trawl B	-11.0	-2.7	-0.6	+1.7	
			Trawl C	-5.5	+3.3	+5.5	+7.8	
			Trawl D*	-14.0	-6.0	-4.0	-1.9	
			Line	-	+9.5	+11.5	+13.6	
			Total	-7.3	+1.3	+3.4	+5.6	

A = Portugal, Spain, France
B = U.K.
C = Germany
D = Norway, Denmark, Iceland

* Estimated.

Despite uncertainties concerning the biology of the cod in this Subarea, and the lack of long series of population data for the offshore stocks, it is possible to conclude from these results that, with meshes up to 5 to 5½ inches, long term changes in landings would be small for the total fishery and for its trawl and line components. However, with a 6 inch mesh, long term losses to at least some components of the trawl fisheries might be substantial. It should be mentioned that, as a result of these changes, some small benefits should accrue to neighbouring fisheries outside the ICNAF Area (East Greenland and Iceland), due to a greater weight of immigrants from Subarea 1.

4.3 Redfish

4.3.1 Division of Stocks

Little is known at present of the biology of the redfish in Subarea 1. The main concentrations of this species, on which the principal trawl fisheries are based, are located on the continental slope in Divisions 1C, D, E and F. The available length composition data from these Divisions show no major geographical differences, and are similar for the two principal fisheries (Germany and Iceland). Therefore, in the absence of other biological evidence, the offshore concentrations in all Divisions have been treated as one unit. Danish data indicate the presence of concentrations of redfish, of smaller size, in certain of the West Greenland fjords, but it is not clear whether they are the younger members of the stock fished offshore, or members of another, slower growing form. These concentrations are not subject to exploitation, and so no account has been taken of them in the mesh assessments.

4.3.2 Prior to 1953, landings of redfish from Subarea 1 were very small, not exceeding 150 tons annually. In 1953, however, Icelandic trawlers began fishing the species in this region,and Germany in 1954, and landings have ranged from 14 to 30 thousand tons since then. The available data are given in Figure 4.5 and App. I, Table 4.6.

4.3.3 The available effort and catch per unit effort data, for U.K., Icelandic and German trawlers respectively, are given in App. I, Table 4.7.

These data reveal wide annual fluctuations in catch per unit effort and it is not possible to detect any significant trends during the period. A factor contributing to these fluctuations was undoubtedly the varying proportions of the total fishery devoted specifically to redfish, especially during the earlier years. This factor may account for the sharp drop in catch per unit effort in both the German and Icelandic fisheries in 1956.

4.3.4 Assessments of Mesh Changes

The most extensive series of length compositions of catches are for the German fishery, which are available for the years 1955-59. These reveal little variation from year to year, and are very similar to Icelandic data for the years 1954-56. The combined data for the German fishery, for the years 1955-59, on which the assessments of the mesh changes have been made, are shown in Fig. 4.6.

In the absence of age composition data for the redfish from this Subarea, no estimates of total mortality rate (Z) or of its components can be made. Further, with the short series of data available, it is not possible to establish an effect of fishing on the stock. The assessment of long term effects has therefore been confined to estimating the minimum value of E (break-even value) necessary to produce a long term gain at each mesh size. Since the mesh size currently in use in the redfish fishery is not known, the calculations have been made on the assumption that it is not greater than 4 inches, so that the left-hand side of the catch curve is not affected by mesh selection.

Selectivity data are not available for redfish in Subarea 1. Therefore, selection curves were drawn up from published data for other parts of the north Atlantic. The selection values used are given in Appendix II. In the absence of length-weight data for redfish in this area, a cubic relation was used for expressing the length in terms of relative weight.

It is important to note that the selectivity values for redfish used in these and other assessments in this report are based on data from experimental hauls in which the average quantity of fish caught was probably less than is typical of the commerc fisheries (especially those in the northern Subareas 1, 2, 3 KL. As there is evidence that the selectivity of redfish varies inversely with size catch (von Brandt, 1960), it is possible that the selectivity values for redfish used in this report, and hence also the assessments of immediate loss calculated from them, are somewhat too high.

The estimated immediate losses, and the minimum value of E, necessary to produce a long term gain, are given in Table 4C.

Table 4C. Subarea 1: Mesh Assessments for redfish

Mesh size change (inches) From 4 or smaller to	Gear Group	% change in 1955 - 59 landings: Immediate	% change in 1955 - 59 landings: Long term Break-even values of E at least
4½	Trawl	-7	0.4
5		-14	0.5
5½		-25	0.6
6		-32	0.7

Having regard to the relatively small size and recent origin of the redfish fishery in this area, the possible existence of large oceanic reserves and the values of E observed in other fisheries, it is likely that the present value of E is lower than the estimated minimum values for meshes above 4½ inches. Therefore, it is expected that, with the present level of exploitation in this area, no long term gains would result from increases in mesh size above 4½ inches, and with meshes above 5 inches, losses would probably be considerable.

(5.1)

SECTION 5 - SUBAREA 2

5.1 The Fisheries

The fisheries in Subarea 2 are a Newfoundland inshore trap and line fishery for cod, and more recent offshore trawl fisheries for cod and redfish (see Table 5A). The offshore cod trawl fishery was negligible before 1952 and increased sharply to about 100 thousand tons in 1953; it has since decreased to less than 30 thousand tons. The landings from the inshore cod fishery dropped from a level of 60-80 thousand tons in the period 1930-38 to about 10 thousand tons since 1955 (see appendix Table 5.1). The redfish fishery did not begin until 1958.

Table 5A. Subarea 2: Recent landings ('000 metric tons round fresh)

ountry	Canada			France	Germany	Iceland	Portugal	Spain	USSR	UK	USA	Tota
Gear	M OT	OT	N TRAP	OT	OT	OT	OT	OT	OT	OT	OT	
Cod	+	-	12	15	+	+	8	1	+	-	-	6
dfish	3	1	-	-	12	33	-	-	13	-	2	64
hers	+	+	+	-	+	-	-	-	+	-	+	+
tal	3	1	12	15	12	33	8	1	13	-	2	100

5.2 Cod

5.2.1 Canadian data show that cod are distributed along the whole Labrador coast and on the offshore banks. No sharp stock divisions are evident either as between the inshore and offshore grounds or from north to south. There is probably some mixing of these fish with those off north-east Newfoundland (subdivision 3 K) but there appears to be a clear distinction between stocks of Subarea 2 and of west Greenland. (Templeman and Fleming 1953, Wise and Jensen 1960).

5.2.2 Landings of cod from Subarea 2 before 1953 were almost entirely by Canadian inshore gears (see App.I, Table 5.1). The decline in these annual landings from a peak of 70 thousand tons in the 1930's to the present level of about 10 thousand tons is believed to be due to a reduction in fishing effort. Offshore fishing by large otter trawlers started in 1952, and after a peak of 100 thousand tons in 1953, there has been a fall in both catch, and catch per unit effort (see Fig. 5.1). This fall does not, however, bear any obvious close relation to changes in effort. At present, Canadian inshore gears take about one third of the total cod landings, and the offshore trawl catch is shared mainly between France (60%) and Portugal (30%) with Spain, Germany, U.K. U.S.S.R. and Iceland taking smaller quantities.

5.2.3 Age compositions data for 1956-58 given in the ICNAF Sampling Year-books, and unpublished Russian data for 1957 and 1958, have been combined to give an average percentage age distribution (Fig. 5.2.). The log catch curve is approximately linear only for ages 13 and above, and for these ages gives an estimate for Z of 0.5. The Z for younger fish (which form over 85% of the catch) is, however, probably less than this.

5.2.4 Length composition data for the Portuguese and Spanish trawl catches for 1957 and 1958 (from the ICNAF Sampling Year-book) have been used to estimate the immediate effects of a mesh change. These are shown in Fig. 5.3. No mesh selection data are available for this subarea, so the values used for the Subarea 1 assessments have been adopted. No account has been taken of possible discards, so the immediate losses as calculated tend to be overestimates. The immediate effects for mesh sizes between 4½ inches and 6 inches are given in Table 5B.

Table 5B. Subarea 2: Mesh assessments for cod

Mesh size change from 4¼ to	Gear	% change in 1957/58 landings	
		Immediate	Break-even values of E
			At least
4½	Otter Trawl	-2	0.5
5		-8	0.5
5½		-16	0.6
6		-35	0.6

5.2.5 Because there is no evidence on the effect of fishing from which a value or probable range of values of E may be estimated - nor indeed any very good estimate of Z - no long-term assessments have been attempted. Break-even values of E have, however, been calculated, and the results are shown in Table 5B. These range from 0.5 for 4½ inches up to 0.6 for a 6 inch mesh, and are of the same magnitude as the estimates of E for other subareas in which the intensity of exploitation would be expected to be high as, or higher than, in Subarea 2. Long-term gains to the landings as a whole are therefore unlikely, though there would be some gains (their magnitude being dependent on the degree of in-shore-offshore mixing) to the non-regulating inshore gears.

5.3 Redfish

5.3.1 The redfish fishery in Subarea 2 is of very recent origi Landings before 1958 were negligible, but in that year a major fishery by otter trawlers developed, over 60 thousand tons being taken mainly from the southern part of the area. The main redfish concentrations exploited in the subarea are thought to be parts of a stock extending from the northern Grand Bank and the east coast of Newfoundland (division 3K and L) northwards along the Labrador shelf, (Templeman 1959).

5.3.2 Length data are available for German catches in 1958 and 1959 and for Russian catches in 1957 and 1958 of Sebastes marinus and S. mentella separately (the latter comprises about 90% of the catches). These are shown in Fig. 5.4. Assessments of the immediate effect of increases of mesh size have been made using the same selection curve as in Subarea 1 (selection factor 2.6) assuming that the present gear is non-selective (see, however, Para. 4.3.4). There were no substantial differences between the results obtained using the three different length compositions, and the mean values are shown in Table 5C.

Table 5C. Subarea 2: Mesh assessments for redfish

Mesh size changes from small to	Gear	% change in 1958 landings	
		Immediate	Break-even value of E
			at least
4½	Otter trawl	-6	0.4
5		-18	0.6
5½		-28	0.7
6		-38	0.8

5.3.3 No data are available for determining the magnitude of E, and in view of the very recent development of the fishery in this area, the Group considers that for the present no useful long-term quantitative assessments can be made. However, the break-even values of E which are given in Table 5C appear high, particularly for 5" and 6" meshes.

SECTION 6 - SUBAREA 3

6.1 The Fisheries

6.1.1 From its beginning in the early 16th century the cod-fishery on the Newfoundland Banks (Subarea 3 mainly) has been the greatest fishery in the Northwest Atlantic. It has traditionally been an international one with Canada, France, Spain and Portugal being now the principal cod-fishing countries. At present the Canadian fishery is almost purely an inshore one, with a great variety of gears, such as codtraps, handlines, longlines, gill nets, jiggers, etc. France, Spain and Portugal operate on the off-shore banks with large trawlers; Portugal also has a fleet of dory vessels which carry on an extensive line fishery.

Since 1935 annual total landings have increased from an average of about 250 thousand tons to more than 400 thousand tons in the mid 1950's. A subsequent sharp decline from 450 thousand tons in 1957 to 300 thousand tons in 1958 has been attributed to unusually high temperature conditions throughout most of the area in 1958 (Templeman, 1959a). During the period under considerati the Canadian inshore landings fluctuated between 125 thousand tons during the pre-war years and 230 thousand tons immediately after the war; in recent years the average annual landing has been just under 200 thousand tons.

The landings from the offshore trawl fishery have increased from less than 25 thousand tons during the war years to an average annual level of about 200 thousand toms in the 1950's. The offshore line fishery, mainly by Portuguese dory vessels has fluctuated between 30 and 80 thousand tons over the period. (Fig. 6.1 and App. Table 6.1).

6.1.2 Although haddock were abundant on the southern part of the Grand Bank (Division 3N and O) in the 1930's (Thompson, 1939), the haddock fishery did not begin until 1946 and the landings increased rapidly to nearly 80 thousand tons in 1949. Following a decrease to 43 thousand tons in 1953, a peak landing of 105 thousand tons occurred in 1955, due to the presence of the very abundant 1949 year-class which by then had grown to commercial size. There has subsequently been a steady decline to 44 thousand tons in 1958. The haddock fishery is strictly an offshore trawl fishery and is carried on almost exclusively by Canada and Spain. (Fig. 6.4 and App. I, Tables 6.4 and 6.5).

6.1.3 The redfish fishery was begun by Canada in 1947 and by the U.S.A. in 1951. In the early 1950's landings rose to about 45 thousand tons. In 1956 the USSR began in Division 3M a substantial redfish fishery which subsequently expanded into Divisions 3K and 3L; and the landings by that country increased from an initial 13 thousand tons to 96 thousand tons in 1958. Icelandic trawlers entered the area in 1958 and landed 44 thousand tons of redfish from it in that year. (Fig. 6.6 and App. I, Tables 6.6 and 6.7). There is every indication of a continuing increase in the redfish fishery. In 1958 when nearly 160 thousand tons were landed, redfish surpassed haddock to become the second most important species in the Subarea.

6.1.4 The total annual yield of cod, haddock and redfish in recent years has been almost 630 thousand tons, of which cod represents 63% (Table 6A).

6.2 Cod

6.2.1 Landing and Effort Data

The only long series of landing and effort data available are those of the Portuguese otter trawl and dory vessel fleets from 1935 onwards, and prior to 1952 these data are reported as pertaining to the Newfoundland Banks generally.

Fig 6.1 shows the landings per day fished for Portuguese trawlers, the calculated total trawl effort and the calculated total effort in trawler units. 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 trawl fleets during the post-war years, resulting in an increase in fishing effort in the Subarea from a level of less than 1,000 days fished to nearly 10,000 in the 1950's, the landing per day fished has decreased to about 20-25 tons.

Prior to the introduction of trawlers in the 1920's, the Grand Banks attracted hundreds of dory vessels, particularly French and Canadian, which carried on an extensive line fishery. For example, in the first decade of this century French landings from the Convention Area fluctuated between 50 and 175 thousand tons, most of which were probably caught in Subarea 3; and the landings by Newfoundland and Nova Scotia n dory vessels 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. In 1946 and subsequently, when fishing conditions returned to normal, the landing per unit effort stabilized at about 35 tons per 100 dory days fished.

Table 6A. Subarea 3: average annual groundfish landings ('000 metric tons) by species, divisions and gears, for the period 1955-58 (redfish for 1958 only)

Species	Divisions	TRAWL														LINE					INSHORE			GRAND TOTAL
		Canada (M)	Canada Nfld.	France (M)	France St.P	Germany E	Germany W	Ice-land	Port-ugal	Spain OT	Spain PT	USSR	UK	US	Tot-al	Can. (M)	Den. (F)	Nor-way	Port-ugal	Total	Can. Nfld.	France St.P	Total	
Cod	3K-L	2.4	1.8	30.0	–	–	–	+	23.8	9.5	2.5	0.7	+	–	70.9	4.0	–	+	18.0	22.0	139.4	–	139.4	232.3
	3M	–	–	+	–	+	–	–	+	–	+	5.9	–	–	6.2	–	–	+	+	0.3	–	–	–	6.5
	3N-O	3.1	2.5	4.0	–	–	+	–	4.0	16.7	30.6	–	0.4	–	61.3	0.9	–	–	15.2	16.1	–	–	–	77.4
	3P	2.0	1.7	10.2	–	–	+	–	4.7	8.3	0.4	–	0.6	–	28.0	4.0	–	–	0.8	4.8	28.7	3.6	32.3	65.1
	3NK	–	–	+	0.9	–	+	–	–	–	–	–	0.4	–	1.4	–	1.7	5.6	–	7.3	–	–	–	8.7
	Total	7.5	6.0	44.5	0.9	+	+	+	32.5	34.4	33.5	6.6	1.5	–	167.7	9.0	1.7	5.9	34.0	50.6	168.1	3.6	171.7	390.0
Haddock	3N-O	5.1	14.8	–	–	–	+	–	+	23.0	4.8	–	+	+	48.3	–	–	–	–	–	–	–	–	48.3
	3P	5.8	11.3	–	–	–	+	–	+	5.2	+	–	0.8	+	23.3	+	–	–	–	+	+	+	+	23.7
	3NK	–	–	–	3.2	–	+	–	+	–	–	–	+	–	3.3	–	–	–	–	–	–	–	–	3.3
	Total	10.9	26.1	–	3.2	–	+	–	+	28.2	4.9	–	1.1	+	74.9	+	–	–	–	+	+	+	+	75.3
Redfish (1958 only)	3K-L	+	+	–	–	–	–	43.7	–	–	–	42.2	–	–	86.2	–	–	–	–	–	–	–	–	86.2
	3M	–	+	–	–	0.6	–	–	–	–	–	53.9	–	+	54.5	–	–	–	–	–	–	–	–	54.5
	3N-O	0.5	3.3	–	–	–	+	–	–	–	–	–	–	10.0	13.8	–	–	–	–	–	–	–	–	13.8
	3P	+	3.1	–	0.6	–	+	–	–	–	–	–	–	+	4.2	–	–	–	–	–	–	–	–	4.2
	Total	0.8	6.8	–	0.6	0.6	+	43.7	–	–	–	96.0	–	10.2	158.7	–	–	–	–	–	–	–	–	158.7
TOTAL		19.2	38.9	44.5	4.7	0.6	+	43.7	32.5	62.6	38.4	102.6	2.6	10.2	401.3	9.0	1.7	5.9	34.0	50.6	168.1	3.6	171.7	624.0

During 1955-57 the landing per unit effort of the Portuguese line fishery increased to nearly 40 tons. This 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 Canadian (Nfld.) 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 as any other commonly used bait (Templeman and Fleming, MS). The poor fishing in 1958 has been attributed largely to unusually high tempature conditions resulting in cod being much less concentrated in the fishing areas than normally (Templeman, 1959a).

Although there are some inconsistencies in the available data, it appears that the cod stocks have responded to increases and decreases in fishing intensity. As the stocks in one area are reduced to a low level, other areas with better concentrations are exploited. Thus the increase in fishing intensity, particularly by the trawl fleets, has in recent years resulted in hitherto unexploited cod stocks being fished. This process is continuing, so that the decline in landings per unit effort from the Subarea as a whole is less marked than might be expexted from consideration of the rates of local depletion.

Examination of data by Divisions since 1953 (App. Table 6.3) shows that in 3N and O (the southern Grand Bank), where the bottom is best for trawl fishing, the landing per unit effort of the Spanish, Portuguese and Canadian fleets has decreased significantly, and as a result a considerable decrease in fishing effort subsequently occurred. During the early 1950's the fleets had already moved into 3L, and by 1957 and 1958 a decrease in landings per unit effort from that Division is apparent, though small. The northward expansion of the trawl fishery into 3K and westward into 3P is taking place at present, but there is no clear indication that the stock is yet being reduced in those Divisions.

6.2.2 Division of Stocks

According to Templeman (1953), studies of vertebral averages, growth rates and tagging returns indicate three well-defined stocks of cod in Subarea 3: (a) the east coast of Newfoundland stock (3K and L) which extends from the northern edge of the Grand Bank northward into the Labrador area; (b) the central and southern GrandBank stock (3N and O); and (c) the south and west coast of Newfoundland stock (3P and 4R). From more recent tagging studies (Templeman, unpublished MS) and from studies on nematode infestation (Templeman, Squires and Fleming, 1957) there are at least three divisions of the cod population in 3P and 4R, but these are here considered as a unit because of the inadequate separation of catch statistics for the indivdual stocks. A relatively small but distinct stock exists on the Flemish Cap (3M). Accordingly for purposes of assessments these four divisions of cod stocks in the Subarea have been treated separately.

6.2.3 General Notes on Data Used in Making the Assessments

The assessments were made by Gulland's method using length compositions of catches. All available data from the ICNAF Sampling Year-books covering the period 1955-58 were considered, to obtain an adequate set of length compositions for the offshore trawl fisheries in recent years. In some cases the length compositions were stated to pertain to catches and in other cases to landings. Where necessary, data for landings were converted to catches by adjusting for discards before being used. The adjustments were, however, sometimes rather arbitrary, particularly for 3P data, which were scanty for the trawl fishery. By combining length compositions, weighted to the catches by the various countries for which data were available, sets of length compositions of trawl catches for individual years were obtained. These were averaged to give a set of length compositions of the average annual trawl catches for the period under consideration.

For 3P, however, the few available length compositions of trawl landings were first combined and then adjusted to the average annual landing for the 1955-58 period. Representative length compositions of the offshore line and the inshore fisheries were obtained in the same manner, except that no account was taken of discards. The length-weight relationships used were based on unpublished measurements, at the St. John's Biological Station, of several thousand cod collected over a number of years from many parts of the Subarea. The representative length compositions by regions and gears are illustrated in Fig. 6.2.

The selection ogives (Appendix II) were prepared by McCracken from data published by Clark, McCracken and Templeman (1958).

Since, in such a cosmopolitan fishery as that for cod in Subarea 3, there is likely to be considerable variation in the mesh size of codends and in the use of chafing gear, two sets of assessments were made, one assuming that the mesh size currently used is 4" and the other that it is 3", with the presumption that the actual effective mesh size may be within this range. The results were essentially the same, and therefore only those for the 4" mesh are given in the assessment Tables 6B to 6E.

The values of the total mortality coefficient (Z) for the various areas were estimated by inspection of the right-hand limbs of the catch curves obtained by plotting age composition data on semi-log paper (Fig. 6.3).

6.2.4 <u>Divisions 3K and L</u>

6.2.4.1 This area is by far the most important of the cod-fishing areas of Subarea 3, accounting in recent years for about 60% of the total Subarea 3 cod landings. Of this quantity the Canadian inshore fishery took 60%, Portuguese otter trawl and dory vessel fleets 18%, French trawlers 13%, and Spanish otter and pair trawlers about 5%. The trawl fishery as a whole accounted for 31% of the total landings from this area, which for the period 1955-58 averaged 232 thousand tons annually. (Table 6A).

6.2.4.2 This stock shows a seasonal inshore-offshore migratory pattern and the extent of concentration both in the coastal waters and offshore depends largely on the tempature conditions of the cold Labrador current. The cod live in deep water offsho.. during th autumn and winter months, when they are available to the offshore trawls and lines, but in late spring they move inshore in conjunction with the spawning migration of capelin. 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 inshore are considerably smaller than those caught on the offshore banks in deep water both during the summer and in other seasons.

The above description of the migratory pattern holds for the northern part of the area where the deep water fishing grounds are adjacent to the coastal waters of Newfoundland. The southern part of this area (3L) includes the northern half of the Grand Bank, and most of the cod on the northern and northeastern parts of the bank move, in summer, from the deep water onto the shallow bank areas rather than to the coast. Further, most of the cod wintering in the deep water areas of the Avalon Channel and northwest Grand Bank do not come inshore in summer but stay in the vicinity of the Virgin Rocks.

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

6.2.4.3 The series of effort data available for this area is not long, but examination of landings per unit effort by trawlers since 1954 gives no clear indication of a relation between the effort and abundance. Although there has since 1956 been a decline in the landings per unit effort of all trawl fleets in 3L (App.I, Table 6.3), it is not possible to conclude from such a short series that this has been caused by fishing. A continuing study of the Canadian inshore fishery since 1951 on the Bonavista Shelf area of 3L indicates, however, that this local fishery has been seriously affected (Templeman, 1959a and 1960). In 1950-51 large unexploited concentrations of cod were discovered in the deep water parts of the Shelf 15-20 miles from shore and an appreciable longline fishery subsequently developed. Up to 1956 the catch per day's fishing was about 4.3 tons. 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 trawlers and fleets of longliners from the Faroe Islands and Norway occurred. Subsequently, the catch per day's fishing by Canadian longliners has decreased rapidly, reaching less tha n 2.0 tons by 1960. The Canadian inshore handline catches in the area decreased from a pre-1956 level of over 1.5 tons per boat per day to less than o.9 in 1960, and the codtrap catches declined from about 3.0 tons per haul to about 1.5 tons over the same period. Furthermore, the average size of cod caught by longlines and other gears has decreased by about 10 cm between 1952 and 1958, and the cod landings from the inshore Bonavista Shelf area are now not much more than half the pre-1956 level without there having been any appreciable change in the inshore fishing effort (Fleming, MS, 1960b and 1961.).

6.2.4.3 Scanty age composition data from Canadian research vessel catches for the period 1948-53, when the offshore trawl fishery was somewhat less intense than at present, gave an estimate for Z of about 0.35. Portuguese samples in 1955 and Spanish and Portuguese in 1957 both give estimates for Z of about 0.5. Age compositions from the Canadian inshore fishery for 1947-50 give a Z about 0.6 and for 1955-58 about 0.7 (Fig. 6.3), with individual estimates for the four recent years ranging between 0.65 and 0.75. The differences between the estimates of Z for the inshore and for the offshore fisheries are probably reflected in the difference between the inshore and 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 Fig. 6.2. Consequently an intermediate value of Z of 0.6 was used for the assessments of the cod fishery as a whole in this area.

6.2.4.5 No direct separation of Z into its components, by analysis of changes in catches and effort, can be made from present data . However, total returns to the end of 1960 from tagging experiments in 1950 at two inshore locations (Fogo in 3K and St. John's in 3L) were 38% for a 5 inch internal tag and 47% for a small 2 -inch red preopercular tag (Templeman and Pitt, MS, 1961). Further experiments carried out in 1954 at various locations gave during the 6½-year period ending 1st November, 1960 a total return of 33% (Templeman, MS, 1961). These results show that E is not less than 0.4 and could be considerably larger. A range of E from 0.75 to 0.42, corresponding to values of M from 0.15 to 0.35, is therefore considered reasonable for assessment purposes.

The cod tend, as they become older, to remain offshore in deep water along the east coast of Newfoundland (3K), and along the western, northern and northeastern Grand Bank (3L) a large proportion of the cod migrate during the summer onto the Grand Bank itself rather than inshore. It has therefore been assumed for these assessments that fish released as a result of increases in mesh size of trawls would subsequently be relatively only half as available to the inshore fishery as to the offshore trawl and line fisheries.

6.2.4.6 Fig 6.2 gives, for the period 1955-58, length compositions of the average annual trawl catches which have been used in making the assessments for 3K and L. The length compositions of the average annual landings of the Canadian inshore fishery and the offshore line fisheries are also shown. In this region, where cod tend to be large, the quantities discarded appear to to be small. Estimates of the proportion discarded, by weight, are 1.6% for Portuguese trawlers in this region in 1957 and 2.8% in 1958 (private communication to ICNAF Secretariat from Capt. T. de Almeida, 1960). It was therefore assumed that for the trawl fishery all fish below 45 cm were discarded, this being consistent with an average discard of about 2% by weight.

Age-length data used in the estimation of t_c are a combination of Canadian data for 3K and L in 1947-50 (Fleming, 1960a) and Portuguese and Spanish data for 1956 and 1957 (ICNAF Sampling Year-books). The results of the assessments are given in Table 6B.

Table 6B. Divisions 3K and L: mesh assessments for cod

Mesh size change (inches)	l_c (cm)	t_c (yr)	Gear Groups*	% change in 1955 - 8 landings				
				Immediate	Long term change for			
From 4 to	43.0	4.0			0.42	0.58	0.75	E
					0.25	0.35	0.45	F
					0.35	0.25	0.15	M
4½	45.0	4.3	Trawl	-0.7	-0.1	+0.2	+0.5	
			Offshore line	0	+0.6	+0.9	+1.1	
			Inshore gears	0	+0.3	+0.4	+0.5	
			Total	-0.2	+0.2	+0.4	+0.6	
5	47.0	4.7	Trawl	-2.1	-0.8	-0.2	+0.5	
			Offshore line	0	+1.4	+2.0	+2.7	
			Inshore gears	0	+0.7	+1.0	+1.3	
			Total	-0.6	+0.3	+0.7	+1.2	
5½	49.5	5.2	Trawl	-6.8	-4.1	-2.8	-1.3	
			Offshore line	0	+2.9	+4.3	+5.9	
			Inshore gears	0	+1.4	+2.0	+2.7	
			Total	-2.1	-0.1	+0.8	+1.8	
6	52.0	5.7	Trawl	-13.3	-9.3	-7.3	-4.8	
			Offshore line	0	+4.5	+6.8	+9.6	
			Inshore gears	0	+2.0	+3.0	+4.3	
			Total	-4.0	-1.2	+0.2	+2.0	

* Trawl group - France (42%), Portugal (34%), Spain (17%), Canada (6%), USSR (1%).
Offshore line group - Portugal (82%), Canada (18%).
Inshore gears group - Canada (Nfld.) only.

6.2.4.7 For all values of E considered there would be only slight changes in total landings for all mesh sizes up to 6 inches. This is mainly because the number of fish that would be released (N_R) is very small relative to the total number of fish that would be kept (N_K). The trawl fishery would gain slightly with an increase in mesh to 4½ inches; losses would be slight with a mesh of 5 inches but become rather greater for a 6 inch mesh. The offshore line and the inshore fisheries show increasing gains throughout.

6.2.5 Division 3M

6.2.5.1 This stock, separated from the others in 3K and L and in 3N and O by a very deep channel, was not exploited to any great extent prior to 1956, but since then most of the cod caught there has 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 (Table 6A). The cod here are generally smaller than those of 3K and L and are believed not to migrate or to mix to any great degree with those in neighbouring areas.

6.2.5.2 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, nor its fishing and natural components.

6.2.5.3 The immediate losses for increases of mesh size above an initial 4 inch and also above an initial 3 inch have been calculated from USSR length compositions for 1958 (Fig. 6.2). The results in both cases are very similar, and only those for the former are shown in Table 6C.

Table 6C. Division 3M: mesh assessments for cod

Mesh size change (inches)	Gear/ country	% change in 1955-58 landings	
		Immediate	Long term
From 4 to			Break-even value of E at least:
4½	Trawl-USSR	-4.2	0.5
5	" "	-10.3	
5½	" "	-22.5	
6	" "	-34.4	

6.2.5.4 The break-even values of E, calculated from these length data, are in the region of 0.5 for all mesh sizes, and this suggests that fishing would not have to be particularly intense for an increase in mesh size to produce long-term gains.

6.2.6 Division 3N and O

6.2.6.1 This entirely offshore fishery, conducted mainly by Spanish otter and pair 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 (Table 6A).

6.2.6.2 This stock is considered to be relatively distinct from fish 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, 1955). Like the cod of 3K and L a seasonal migratory pattern is evident. During summer and autumn the cod are generally concentrated on the shallow parts of the banks where temperature conditions are most suitable. In the winter months the shallow water areas are covered with very cold (<0°C) water and the cod are found in the deep water areas of the slopes. Cod also tend, as they grow older, to remain in the deeper water.

6.2.6.3 No long series of effort data is available for this area, but landings per unit effort since 1954 show steady decreases for all fleets, and the fishing effort by otter trawlers has declined considerably as the fleets moved northward into 3K and L and westward into 3P and Subarea 4 (App. I, Table 6.3). The effort for pair trawlers remained about the same during the 1954-58 period, mainly because the bottom of this area is most suitable for this type of fishing.

6.2.6.4 Age composition data from Canadian research vessel catches in 1953 (unpublished) and from the catches of Spanish trawlers in 1953-56 (ICNAF Sampling Yearbooks, Vols. 1 and 2) both give estimates for Z of 0.7 (Fig. 6.3), and this value was used in making the assessments.

6.2.6.5 No direct separation of Z into its components was possible from the very short series of landing and effort data available. However, Canadian research vessel age compositions (unpublished) collected during 1947-50 gave a Z of about 0.3 for age groups VIII to XII, which lived through a wartime and pre-war period of relatively low fishing intensity (Fig. 6.3). Consequently, the values of M adopted for area 3K and L (0.35, 0.25 and 0.15) were used also for this area, giving corresponding E values of 0.50, 0.64 and 0.79 respectively. It is considered that the lower values of M (and hence the higher values of E) are the more probable ones.

6.2.6.6 Representative length compositions of the average annual catch by the trawl fisheries for the period 1955-58 are illustrated in Fig 6.2. Representative length compositions of the average annual landing by Portuguese dory vessels are also given. Since most of the fish are smaller in this region than in 3K and L and since the Spanish Research Reports to ICNAF indicate that the minimum commercial size is about 40 cm, it was assumed that for the trawl length compositions all cod below 42 cm had been discarded as too small, the quantity amounting to 3.3% of the catch by weight and 14% by number. Rojo (1957 and 1958) states that in catches the percentages of cod below commercial size vary considerably with the season and with the area: in 1955 discards by number were 0.48% during the spring in Division 3O and 16% during the summer in 3N; in 1956 during the summer 8.7% were discarded in 3N; also from samples taken in August and September of 1957 discards were 22.3% and 11.7% respectively. All of these percentages refer to cod smaller than 40 cm in the samples. The age-length data used for the estimation of t_0 represent a combination of Canadian (Nfld.) data for 3N and O in 1947-50 (Fleming, 1960a) and Spanish data for 1953-56 (ICNAF Sampling Yearbooks).

The assessments for an initial 4-inch mesh are given in Table 6D. They were calculated also for an initial 3-inch mesh, with essentially the same results except that both immediate losses and longer term gains for the increase to 4½ inch mesh were about 50% greater.

Table 6D. Divisions 3N and O: mesh assessments for cod

Mesh size change (inches	l_c (cm)	t_c (yr)	Gear groups*	% change in 1955-8 landings Immediate	Long-term for			
					0.50	0.64	0.79	E
					0.35	0.45	0.55	F
From 4 to	39.5	3.1			0.35	0.25	0.15	M
4½	41.9	3.4	Trawl	-1.9	+2.0	+3.2	+4.5	
			Offshore line	0	+4.0	+5.2	+6.6	
			Total	-1.5	+2.4	+3.6	+4.9	
5	44.7	3.8	Trawl	-5.5	+3.2	+6.1	+9.3	
			Offshore line	0	+9.2	+12.2	+15.6	
			Total	-4.4	+4.4	+7.4	+10.6	
5½	49.3	4.4	Trawl	-13.6	+2.4	+8.3	+15.2	
			Offshore line	0	+18.5	+25.2	+33.2	
			Total	-10.7	+5.7	+11.8	+18.9	
6	53.1	5.0	Trawl	-22.0	-0.7	+8.1	+18.8	
			Offshore line	0	+27.3	+38.4	+52.2	
			Total	-17.4	+5.1	+14.4	+25.7	

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

6.2.6.7 Long-term gains in total landings are to be expected for all mesh sizes up to 6 inches. These are substantial for the higher values of E. The trawl fisheries would benefit from increases to 5½ inches and even 6 inches provided that M is not higher than 0.30-0.35; if M is smaller the long-term gain to this fishery would be substantial for meshes up to 6 inches, even though the immediate loss would be high. The line fisheries 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 3N and O and those for 3K and L are: (a) the number of fish that would be released by trawl relative to the total retained by all gears is large for the former area, and (b) the cod there grow considerably faster than in any other part of the Subarea.

6.2.7 <u>Division 3P</u>

6.2.7.1 This Division accounted for 17% of the Subarea landings during the 1955-58 period, 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% (Table 6A).

6.2.7.2 The composition of this stock unit is more complex th- those considered previously in that it consists of two or mor groups of cod. Tagging studies (Thompson, 1943, and Templeman, unpublished data) indicate that cod in the eastern and south-eastern parts of this Division move freely between the offshore banks and inshore waters along the eastern half of Newfoundland's south coast. These fish are known not to mix much with the concentrations of cod which winter in the western part of the Division, 3P (north), providing a substantial winter and spring inshore fishery there, and which then migrate into 4R to provide an inshore summer fishery along the west coast of Newfoundland. French, Portuguese and Spanish trawlers carry on an intense 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 4R. Because the decision by ICNAF to divide Division 3P into 3P (north) and 3P (south) is very recent (1957) it has not been possible to consider these separately in this report.

6.2.7.3 No consistent trend is detectable in the landing per unit effort data for trawlers during the period 1954-58 (App. Table 6.3). The scanty age composition data from trawl catche are inadequate to give an estimate of Z, but returns from tagging experiments carried out in 1954 on St. Pierre Bank and Burgeo Bank in this Division (Templeman, MS, 1961) gave a Z of 0.65. Age compositions from the Newfoundland inshore fishery in 1947-49 give a Z of o.5, and for the years 1953 to 1957 individually gave estimates ranging from 0.5 to 0.7, with an average of about 0.6 (Fig. 6.3). This latter value of Z was used in making the assessments for this Division.

6.2.7.4 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 the 6½ year period ending 1st November, 1960 (Templeman, MS, 1961), indicating that the values of E of 0.42, 0.58 and 0.75 used in making the assessments are not unreasonable.

6.2.7.5 Length composition data of trawl catches from this Division are scanty. Some Canadian (Nfld.) landings in 1955 and 1958, Spanish in 1957 and German in 1958 were combined and then adjusted for discards somewhat arbitrarily. Fish below 45 cm were considered discarded and this amounted to about 2.3% of the catch, a figure in agreement with estimates of discards by Portuguese trawlers in 3P: viz. 3.9% in 1957 and 1.7% in 1958 (private communication to ICNAF Secretariat from Capt. T. de Almeida, 1960). The age-length data used for the assessments are Canadian (Nfld,) data for 1947-50 (Fleming 1960a). The assessments for mesh changes from an initial 4 inches are given in Table 6E below; corresponding calculations were made for an initial mesh size of 3 inches, giving essentially the same results.

6.2.7.6 Long-term gains in total landings are predicted for all increases in mesh size up to 5½ inches, and up to 6 inches for the higher values of E. For the trawl fisheries changes in landings would be slight up to 5 inches and for larger mesh sizes greater losses would result. The offshore line fisheries and the inshore fishery would gain from any increase in mesh size.

6.3 Haddock

6.3.1 The haddock fishery in Subarea 3 is essentially an offshore trawl fishery, and the average annual landing during the period 1955-58 was 75 thousand tons. Of this Canadian trawlers landed 50% and the Spanish fleet 45%. About 65% of the total landing cane from the Grand Bank part of Subarea 3 (3N and O) and the remainder from St. Pierre Bank (3P), mainly during 1955 and 1956 (Table 6A).

Table 6E. Division 3P: mesh assessments for cod

Mesh size change (inches)	l_c (cm)	t_c (yr)	Gear groups*	% change in 1955-58 landings				
				Immediate	Long-term for			
					0.42	0.58	0.75	E
					0.25	0.35	0.45	F
From 4 to	44.6	3.9			0.35	0.25	0.15	M
4½	45.7	4.0	Trawl	-1.3	-0.5	-0.1	+0.3	
			Offshore line	0	+0.9	+1.2	+1.6	
			Inshore gears	0	+0.9	+1.2	+1.6	
			Total	-0.6	+0.3	+0.6	+1.0	
5	47.3	4.2	Trawl	-3.9	-1.7	-0.8	+0.1	
			Offshore line	0	+2.3	+3.2	+4.1	
			Inshore gears	0	+2.1	+3.0	+3.9	
			Total	-1.6	+0.5	+1.4	+2.3	
5½	50.5	4.6	Trawl	-10.9	-6.3	-4.4	-2.2	
			Offshore line	0	+5.1	+7.3	+9.8	
			Inshore gears	0	+4.7	+6.7	+9.0	
			Total	-4.7	0.0	+2.0	+4.2	
6	53.7	5.0	Trawl	-19.2	-12.7	-9.7	-6.3	
			Offshore line	0	+8.0	+11.7	+16.0	
			Inshore gears	0	+7.2	+10.5	+14.4	
			Total	-8.2	-1.3	+1.9	+5.6	

* Trawl group - France (36%), Spain (31%), Portugal (17%), Canada (13%).
Offshore line- Canada (83%), Portugal (17%).
Inshore gears- Canada (89%), France (11%).

6.3.2 In Subarea 3 the main haddock fishery is normally on the southern part of the Grand Bank (3N and O), but during the period 1954-56 there was a substantial Canadian haddock fishery on St. Pierre Bank in 3P (App. I, Table 6.5), almost exclusively on the very abundant 1949 year-class. Only small quantities of haddock were landed from there before 1953 and no significant quantities since 1957. Growth and otolith studies indicate that the haddock on the Grand Bank and on St. Pierre Bank are relatively distinct groups. Some mixing may occur on the slope in the deep water area between the two banks, but the unusually low tempature of the water in the channel between the banks tends to limit the extent of mixing. Because there has been no significant survival of year-classes on St. Pierre Bank since the very successful year-class of 1949, and no fishing for haddock since 1957, the present analysis will not be concerned with the transitory fishery there during the period 1954-56. Most of the observations concernin- the biological features of the haddock stocks in Subarea 3 made above and in subsequent paragraphs are based on unpublished records of the St. John's Biological Station.

6.3.3 The Grand Bank (3N and O) stock, which has been the mainstay of the haddock fishery since 1957, is concentrated along the southwest slope (in Division 3O) during the winter and spring months when the shallow areas of the bank are covered with water below $0^{o}C$. This is the time when most of the Canadian otter trawl catches are taken. Usually by June, when the shallow bank water has warmed up sufficiently, the haddock disperse and move eastward across the bank. By mid-summer and later they are concentrated again, but now on the Southeast Shoal (3N) in shallow water of 20-25 fathoms, and are there fished mainly by the Spanish trawlers.

6.3.4 Considerable differences in the survival of year-classes occur in all haddock stocks, but these variations are much more extreme in the northern than in the southern parts of the range of haddock in the ICNAF Area. Thus 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 outstandi year-classes were those of 1946,1949,1952 and 1955, the intermediate year-classes being almost complete failures except for moderate ones in 1953 and 1956. There is no evidence of any significant survival of 1957,1958 or 1959 year-classes. During the 1955-58 period, on which these assessments are based, the 1949 year-class to a large degree, and the 1952 to a much lesser extent, were dominant in the landings. The growth rate of the 1949, and of all the more recent year-classes is considerably slower than that of year-classes present during the early years of the fishery.

6.3.5 The only landing per unit effort data available are those for Canadian trawlers since 1954 (Fig. 6.4). On St. Pierre Bank, where haddock appear to grow faster, the landing per hour fished was at a high level in 1954 and 1955 but it decreased rapidly to almost nothing in 1958 and at present the fishery is negligible. On the Grand Bank the best catches occurred in 1955 and 1956. These years were followed by a rapid decline in the landing per unit effort, which by 1958 was little more than half the 1956 level, total trawl effort having increased by as much as 50% during the same period. More rec... observations indicate that there has been some improvement in the landing per unit effort for 1959 as the 1955 year-class began to dominate in the catches.

6.3.6 Age composition data from research vessel surveys in the area, conducted by the St. John's Biological Station, indicate that for the three main year-classes for which sufficient data exist - 1942, 1946 and 1949 - 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 ages. Another independent estimate of 0.75 was obtained from the slope of the curve of numbers per unit effort at successive ages of the 1949 year-class during the period 1954-59, the data being obtained from the catches of Newfoundland trawlers. A Z of 0.75 was therefore used for the assessments.

6.3.7 Some age-composition data exist for an earlier period (1931-35) when there was very little haddock fishing (Thompson, 1939), but these are not sufficient to enable a firm estimat 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 of any direct separation of total mortality into its components, a range of values of M of 0.15, 0.25 and 0.35 have been taken, corresponding to values of E of 0.80, 0.67 and 0.53 respectively.

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 an assessment of the effects of a mesh regulation which will be generally applicable. The assessment is further complicated by inadequate knowledge of the size composition of the discards 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 gear. In view of the variable size composition of the catches from year to year, due to the progression of dominant year-classes through the fishable stock, the assessments for haddock given in this report are based on an average size composition of the catches for the period 1955-58. Combined Spanish length compositions of catches for 1955-57 and Canadian length compositions (landing data adjusted for discards) for 1955-58 were used.

Estimates of quantities discarded annually during the period varied between 6% and 23% for Canadian (Nfld.) 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 minimum commercial size are in the "Spanish Research Reports" of ICNAF Annual Proceedings as follows: in 1954 there is one observation of 20% by number discarded, but this occurred at the end of the fishing campaign; in September 1956, 57% of 2422 fish 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, quantities discarded were large. In all instances the minimum commercial size was given as 40 cm. By assuming for the Spanish data that "knifeedge" discarding of small haddock occurred between 37 and 38 cm, a value of 18% by weight discarded is obtained, which is similar to that given for Canadian (Nfld.) trawlers.

Because of the similarity of the length compositions and estimated quantities discarded by both Canadian and Spanish fleets, the immediate and long-term assessments are based on the combined data for both fleets (Fig. 6.5) In view of the variable nature of quantities discarded the assessments were made assuming that discards range from 10% to 25% by weight.

The growth curve, based on the slow-growing 1949 year-class, and the length-weight relationships used were obtained from unpublished records of the St. John's Biological Station, Canada. The selection ogives for the various mesh sizes are given in Appendix II. The assessments (Table 6F) are based on an initial mesh size of 3 inches.

Table 6F. Divisions 3N and O: mesh assessments for haddock

sh size change ches)	l_c (cm)	t_c (yr)	Gear groups*	% change in 1955-58 landings Immediate	Long-term change for			
					0.53	0.67	0.80	E
					0.40	0.50	0.60	F
om 3 to	31.1	3.4			0.35	0.25	0.15	M
4	35.4	4.0	Trawl	-6	+3	+6	+9	
4 ½	37.5	4.5	Trawl	-16	+1	+7	+13	
5	41.4	6.0	Trawl	-38	-12	-1	+13	
5 ½	46.0	8.4	Trawl	-64	-37	-20	+3	
4	35.4	4.0	Trawl	-4	+6	+8	+11	
4 ½	37.5	4.5	Trawl	-10	+8	+14	+20	
5	41.4	6.0	Trawl	-32	-3	+10	+25	
5 ½	46.0	8.4	Trawl	-59	-28	-8	+19	

* Trawl group - Canada (41%) and Spain (57%).

6.3.9 For increases in mesh size to 4½ inches long-term gains result over the range of M and of discards considered. Above 4½ inches, however, the effect depends very much on the value of M. Thus if M were less than 0.25 the gain for a 5-inch mesh would be substantial, but if M were greater than 0.25 a loss would probably result; for the 5½ and 6-inch mesh sizes the long-term losses would be substantial except for very low values of M. The immediate losses would be large for mesh sizes over 4½ inches.

6.4 Redfish

6.4.1 This fishery was begun in 1947 on the southern part of the Grand Bank (3N and O) by Canadian trawlers, and USA trawlers began fishing there in 1951. There was a rapid rise in 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 the fishing effort to the Gulf of St. Lawrence (4R, 4S and 4T) and partly to a diversion of effort by Canadian trawlers to haddock fishing. In 1956 USSR trawlers started fishing in 3M, where the redfish had not previously been exploited. By 1958 their exploitation of redfish had extended into 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 thousnad tons in 1958, of which USSR took 60%, Iceland 28%, USA 6% and Canada 5%. (App. I, Tables 6.6 and 6.7, Table 6A and Fig. 6.6).

6.4.2 Division of Stocks

Because of the very recent origin of the redfish fishery on a major scale in Subarea 3 and of the scarcity of information on the redfish stocks from the main redfish-producing countries, it is not possible to divide the stocks except perhaps on a general basis. Templeman (1959b), 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 slope extending from the southern tip of the Grand Bank northward along the east coast of Newfoundland (3K and L), where the redfish are restricted in their vertical movement by the overlying cold water of the Labrador Current; the Flemish Cap (3M) where there are no such tempature restrictions; and the area along the southwestern slope of the Grand Bank and the south coast of Newfoundland (3N, O and P), where the redfish are found in shallower water than to the north. For these assessments, however, 3P has been considered separately from 3N and O, mainly because it is the centre of a small local Canadian fishery and the length composition is quite different from those of the USA and Canadian fisheries in 3N and O.

6.4.3 General Notes on Data Used in Making the Assessments

Because of the very recent origin of the redfish fishery and the difficulty in age determination for redfish, estimates of the mortality coefficients cannot at present be made, and consequently it is not possible to do more than determine the immediate effects of mesh increases and the break-even values of E. Length compositions of the landings in the various regions for 1958 are illustrated in Fig. 6.7. In view of the similarity of the Canadian and USA length compositions in 3N and O these were combined for the assessments; the same was done for 3K and L. The assessments are based entirely on the length compositions of Mentella-type redfish. The length-weight relationships used were obtained from unpublished records of the St. John's Biological Station. The selection ogives (Appendix II) were prepared from data published by Clark, McCracken and Templeman (1958, see also para 4.3.4). For the Canadian and USA redfish fisheries the present mesh size was considered to be 3 inches, from information obtained from the Woods Hole Laboratory and the Canadian Biological Stations at St. Andrews and St. John's. The USSR fleets, and presumably the Icelandic, use a 4-inch mesh and the assessment for them relate to this initial size.

6.4.4 Divisions 3K and L

This fishery on virgin stocks began only in 1957 and good fishing was experienced by both the USSR and Icelandic trawlers, as indicated by the catch per unit effort data for those fleets in 1957 and 1958 (App. I, Table 6.8). The redfish caught were considerably larger than in any of the other Divisions, having a mode at 35-36 cm (Fig. 6.7) and a mean weight of 0.71 kg.

The immediate losses to this fishery would be substantial for mesh sizes above 4½ inches. The break-even values of E suggest that fishing intensity might not have to be particularly high for mesh sizes up to 4½ inches to produce long-term gains (Table 6G).

6.4.5 Division 3M

This fishery was begun on a virgin stock in 1956 by the USSR, and by 1958 the redfish landing had increased to four times that of 1956. The redfish caught in 1958 were generally smaller than those from 3K and L, having a mean weight of 0.57 kg. During 1957 and 1958 the landings per hour fished were somewhat below that for 1956, but no conclusions can be drawn at this stage because some of the effort-particularly in 1957 - was probably devoted to cod-fishing.

The immediate losses would be substantial for all increases in mesh above 4½ inches, and the break-even values of E suggest that the fishing intensity would have to be relatively higher than in, for example, Divisions 3K and L for long-term gains to result from any increase in mesh size beyond 4 inches (Table 6G).

Table 6G. Subarea 3: mesh assessments for redfish

Mesh size change (inches	Country (percent of total landings)	Divisions	% change in 1958 landings	
			Immediate	Break-even value of E at least
From 4 to				
4½	Iceland (51%)	3K-L	-5	0.6
5	USSR (49%)		-17	
5½			-37	
6			-56	
4½	USSR (99%)	3M	-10	0.7
5	E Germany (1%)		-29	
5½			-53	
6			-72	
From 3 to				
4	Canada (28%)	3N-O	-31	0.7
4½	USA (72%)		-56	
5			-76	
5½			-89	
6			-95	
4	Canada (95%)	3P	-4	0.6
4½	USA (5%)		-16	
5			-36	
5½			-60	
6			-77	

6.4.6 Division 3N and 0

Redfish fishing began in 1947 and rose rapidly to a peak landing in 1952 of 45 thousand tons, entirely by Canadian and USA trawlers. Since then the annual landings have ranged between 6 and 15 thousand tons. Although adequate length compositions are not available for the early years of this fishery, unpublished data of the St. John's Biological Station indicate that there has been a gradual decrease in the average size of redfish caught 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 fish 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) demonstrated a difference of as much as 9cm between the mode of the length composition of redfish at 110 fathoms and the mode for fish at 184-240 fathoms. Males and females were in equal proportions at 110 and 140 fathoms, but at 170 fathoms and deeper large females were dominant in the catches. Although the price differential favours the catching of larger redfish, the fleets now land redfish considerably smaller than they did during the first years of this fishery.

The immediate losses would be high for all increases in mesh size beyond that at present in use. The break-even values of E indicate that fishing would have to be fairly intense for any mesh increase to result in long-term gains especially bearing in mind the fact that these calculations relate to an initial mesh of 3 inches, rather than of 4½ inches as for 3K-L and 3M (Table 6G).

6.4.7 Division 3P

The Canadian fishery in this area is carried on at present by a few small trawlers on local concentrations in the deep water channels just off the south coast of Newfoundland. Small quantities are also obtained from the western slope of St. Pierre Bank. Landing per unit effort data available only since 1954 (App. I, Table 6.8) indicate that there has been more than a 30% decline in the landing per hour fished since 1955. The effort remained relatively steady between 1954 and 1957 but a considerable increase in effort occurred in 1958.

The fish caught in this area are considerably larger than those landed from 3N-0 and consequently the immediate losses are less, but still substantial, for increase of mesh size beyond 4 inches. Break-even values of E are not so high as those calculated for 3N-0 above, but nevertheless indicate that fishing would have to be fairly heavy for mesh increases to result in long-term gains, (Table 6G).

SECTION 7 - SUB-AREA 4

7.1. The Fisheries

The cod fisheries have always been the most important of Sub-area 4, in recent years making up about 40 percent of the total fish landed, and over 55 percent of the total groundfish landed (Table 7A). The other important groundfish landed are, in order of weight: redfish, haddock, pollock and flounders. Groundfishing is carried out by Canada, France, Portugal, Spain and the United States. Canada lands most, and fishes primarily for cod. Cod also comprises the most important part of landings by France, Portugal and Spain. United States boats fish in the Sub-area primarily for redfish, although they take important quantities of haddock in Division 4X. Countries other than Canada use otter trawls almost exclusively for their fishing in Sub-area 4. In the Canadian fishery, however, hook and line and trap fisheries are more important, these gears accounting for 73 percent of the Canadian cod landings, or about 50 percent of all cod landed from the Sub-area. Important quantities of haddock and most of the pollock are also taken by hook and line and trap.

Table 7A. Sub-area 4: Average annual groundfish landings ('000 metric tons) by main species, divisions, gear and countries. (Average for 1957 and 1958.)

Species	Division	Otter Trawls						Other gear (mainly line Canada)	Total
		Canada	France	Portugal	Spain	U.S	Total		
Cod	4X	+	-	-	-	1	1	12	13
	4VW (except 4V spring)	10	+	-	4	+	14	18	32
	4T (+4V spring)	24	10	3	12	-	49	38	87
	4R	2	22	11	+	-	35	25	60
	4S	+	+	+	-	-	1	6	7
	Total	36	32	14	16	1	100	99	199
Haddock	4X	4	-	-	-	10	14	5	19
	4VW	20	-	-	2	1	23	3	26
	4T	2	-	-	-	-	2	-	2
	4RS	-	-	-	-	-	-	-	-
	Total	26	-	-	2	11	39	8	47
Redfish	4X	-	-	-	-	7	7	-	7
	4VW	1	-	-	-	19	20	-	20
	4RST	16	-	-	-	12	28	-	28
	Total	17	-	-	-	38	55	-	55
Other Ground-fish	4X	3	-	-	-	+	3	23	26
	4VW	9	-	-	-	+	9	6	15
	4T	10	-	-	-	-	10	6	16
	4RS	1	-	-	-	-	1	1	2
	Total	23	-	-	-	-	23	36	59
Total Ground-fish	4X	7	-	-	-	18	25	40	65
	4VW	40	-	-	6	20	66)	27)	112)
	4RST	55	32	14	12	12	126)	76)	183)
	Total	102	32	14	18	50	217	143	360
Total All fish	4X	7	-	-	-	18	25	115	140
	4VW	40	-	-	6	20	66)	62)	147)
	4RST	55	32	14	12	12	126)	112)	219)
	Total	102	32	14	18	50	217	289	506

7.2 Cod

7.2.1. Division of stocks

At least four major stock divisions have been distinguished by tagging experiments (McKenzie 1956; McCracken 1959), research boat surveys and analysis of biological characteristics (McKenzie and Smith 1955). Cod in Division 4X appear to mix little with those of other areas, and have accordingly been treated as a unit. Cod in northeastern 4V in the spring move into 4T in late May. They are fished in both areas, and in keeping with the knowledge of stock identity, fisheries of 4T and 4V (spring) have been treated together as a second unit. Other fisheries in 4V and those in 4W are treated together as a third unit which may reasonably be considered separately from the rest. Assessments for each of these three units are discussed below.

A fourth unit stock appears in Divisions 4R and 3P. This is fished in spring in 3P North and southern 4R by the same vessels fishing 4T and 4V (spring), and in summer in northern 4R by Canadian inshore gears. No separate assessments have been attempted for this relatively important stock unit. However, the pattern of its fisheries is similar to that on the 4T and 4V (spring) unit; length and age compositions of Portuguese catches in the two areas are much alike (Fig. 7.1), and there is evidence of limited mixing between the stocks (McCracken 1959). An indication of the effects of mesh increases on the 4R and 3P landings may therefore be obtained from assessments for 4T and 4V (spring) (para. 7.2.4.4.).

Relatively small landings are made, primarily by traps, from what is probably a fifth stock unit in Division 4S. Since this study is most concerned with regulation of otter trawls, no assessments of this fishery have been attempted.

7.2.2. General data used in making assessments

Assessments have been made using length compositions of catches. Data for length-composition of the landings and of the discards were available in most cases for gears used in the Canadian fishery and for the Portuguese otter trawl fishery. It was assumed that the latter was representative of the entire European fishery. The data from these sources were used in constructing annual length compositions for total catch for each of the important components of the fisheries, and annual averages were prepared for a number of recent years.

Length-weight relationships were taken from unpublished data of the Biological Station, Fisheries Research Board of Canada, St. Andrews, N.B. and are given in the Appendix.

Selection ogives were prepared from the data published by Clark, McCracken and Templeman (1958). (See Appendix II).

In all Sub-area 4 fisheries the effective mesh size currently in use was assumed to be 4½-inch manila, or its equivalent in other materials. Assessments of the effect of a 4-inch mesh were made by extrapolating curves relating mesh size and long-term changes at mesh sizes of 4½inches and greater.

In all Sub-area 4 assessments, the age-length (growth) data, used in estimating the average size, (l_c), and age (t_c), at first capture with different meshes, were taken from commercial samples

In most cases, values of Z were estimated from lines fitted by eye to the right-hand limbs of log catch-curves.

7.2.3. Division 4X

7.2.3.1. Landings of cod from this Division have been made almost wholly by the United States and Canada. They have averaged about 18,000 metric tons per year since 1947, but have declined gradually throughout this period from a high of about 21,000 tons in 1947 to a low of 12,000 metric tons in 1958 (Fig. 7.2).

The Division includes fisheries on a number of local inshore stocks of cod off southwestern Nova Scotia and in the Bay of Fundy. Over 80 percent of the total landings come, however, from the area southwest of Nova Scotia. In view of the importance of this area, the fact that fisheries throughout the Division are similar, and indications (unpublished data) that year-class strengths tend to vary together, biological data from southwestern Nova Scotia have been used in making assessments for the whole Division.

In recent years more than 85 percent of the total cod landed from 4X have been caught by Canadian hook and line (Table 7A). The remainder, totalling less than 2,000 metric tons, are taken by United States and Canadian otter trawlers, mostly incidental to haddock fishing. The scanty length-composition data available from otter trawl catches (U.S.A. unpublished data) indicate that sizes taken do not differ significantly from those taken by the Mustad No. 16 to 17 hooks in common use in the line fishery. Length and age compositions and catch per unit effort data for the line fishery have therefore been used in the analysis.

7.2.3.2. Catch per unit effort (Fig. 7.2) was slightly higher in 1948 than in any other year since 1947; apart from this it has remained rather constant throughout the study period but with a slight downward trend. Changes in total lendings appear therefore to be related primarily to changes in total effort (Fig. 7.2). More detailed interpretation is complicated by seasonal changes in the pattern of fishing.

7.2.3.3. Total mortality rate, $Z = 0.45$, was estimated from the right-hand limb of the average catch curve (age compositions) for the period 1947-1958 (Fig. 7.3). Returns from a tagging experiment begun in 1953 totalled about 50 percent over the first two years (Paloheimo 1958), from which F is approximately 0.35, so that $M = 0.10$, and $E = 0.78$. Assessments of immediate and long-term changes in landings following increases in the otter trawl mesh sizes above the 4½ inches currently in use have been made for $Z = 0.45$ with $M = 0.15, 0.10, 0.05$ ($E = 0.67, 0.78, 0.89$) and using length compositions for 1956 to 1958 shown in Fig. 7.4.

7.2.3.4. The table of assessments (Table 7B) indicates that otter trawl catches would not be increased by increasing the size of mesh used to catch cod. This results from the fact that most of the cod landings are made by hook and line; hence most of the fish released by otter trawls would, if retaken, be retaken by hook and line. As a result, the hook and line catch would probably gain slightly, although the changes would be too small to affect the total landings appreciably.

7.2.4. Divisions 4T and 4V (Spring)

7.2.4.1. The cod fishery of this area has changed rapidly during the twelve-year study period (1947-1958). Initially it was an inshore Canadian hook and line fishery, landing about 40 thousand metric tons from northern 4T during the summer and autumn of each year. In 1947 Canadian small otter trawlers were introduced, and by 1951 they were taking 30 percent of the total. During the same period landings by the line fishery dropped, so that total Canadian landings stayed relatively constant (Fig. 7.5). Otter trawl landings continued to increase steadily until 1957 (App.I, Table 7.1), but have declined since. Line fishery landings continued to

Table 7B. Division 4X. Mesh assessments for cod

Mesh size change (inches)	l_c (cm)	t_c (yr)	Gear Group	% change in 1956 to 1958 landings				
				Immediate	Long term for an			
					0.67	0.78	0.89	E
					0.15	0.10	0.05	M
From 4½ to	42.7	2.00			0.25	0.35	0.45	F
4			OT	+2	0	-1	-1	
			Other	0	-1	-2	-2	
			Total	+1	-1	-2	-2	
5	43.0	2.05	OT	-2	-1	-1	-1	
			Other	0	+1	+1	+1	
			Total	0	+1	+1	+1	
5½	43.5	2.15	OT	-6	-5	-4	-4	
			Other	0	+1	+2	+2	
			Total	0	0	+1	+1	
6	44.6	2.25	OT	-10	-8	-8	-7	
			Other	0	+1	+1	+2	
			Total	-1	0	0	+1	

Trawl group: United States (70%); Canada (30%)
Other group: Canada - hook and line (100%)

decrease to about 20,000 metric tons in 1955, rose sharply in 1956 and 1957 to their earlier level, apparently as a result of a markedly increased cod growth rate accompanied by an increase in abundance (Kohler, unpublished MS), but they have decreased again since.

In the early 1950's a European fleet of large otter trawlers began fishing this stock during the spring in southern 4T and northern 4V. In 1956 they landed over 40,000 metric tons, but their annual landings have dropped subsequently as some of the boats have been diverted to fishing in the neighbouring Division 4R. From 1956 to 1958 total landings from the 4T-4V (spring) stock have averaged 87,000 metric tons, over twice the 1947-51 level.

7.2.4.2. Records of catch per unit effort are available for each of the three major fishery components, and these have been expressed in terms equivalent to metric tons per hour fished by a large otter trawler (Fig. 7.5). Catch per unit effort for small otter trawlers has declined steadily since 1948 except briefly in 1956 and 1957 when the fish taken were unusually large. Catch per unit effort by lines similarly declined from 1947 to 1954, but increased abruptly, reaching an all-time high in 1957, with large catches of large cod. It has decreased abruptly since then. Catch per unit effort by Portuguese and Spanish otter trawlers appears to have decreased since 1955. Taking account of the transitory effects in the late 1950's of a change in growth rate which led to a marked increase in the average size of fish (and a possible increase in their availability to lines), these data indicate a progressive decrease in abundance, associated with the increased landings and effort.

7.2.4.3. Age compositions of both the otter-trawl and line-caught cod are available for the periods 1951 to 1954 and 1956 to 1958. From catch curves for these periods (Fig. 7.6) it appears that mortality rates in recent years have been higher than in the earlier period, for both otter-trawl and line-caught fish. However, changes in year-class strength and the recent large changes in the fishery, combined with sampling errors, make it impossible to use these statistics from commercial sampling to obtain accurate estimates of total mortality, or its components. A provisional estimate of Z = 0.50 has been derived from the average catch curve for all gears from 1956 to 1958, and this has been used as a central value in the assessment calculations. Catch curves plotted from research vessel hauls from 1959 to 1960 (Jean, unpublished data) suggest however that Z may now be about 0.70. (Fig. 7.7).

Returns through 1960 from tags released in 1955 and 1956 have totalled nearly 50 percent, suggesting that F is at least half of the total mortality. Assessments have therefore been made using M = 0.20 and Z = 0.35, 0.50, 0.65 (E = 0.43, 0.60, 0.69) and based on the average length compositions for 1956-58 shown in Fig. 7.4.

7.2.4.4. The table of assessments (Table 7C) indicates that there would be gains to otter trawlers for mesh increases up to 5½ inches, at about which point it appears that they would realise maximum yield per recruit for present fishing levels. At mesh sizes above this, initial losses would be substantial, and these may not be compensated for in the long term. There would be gains to the line trawls for all increases in mesh size, and if line fishing maintains its present relative importance, long-term gains to total landings by all gears would result from all mesh increases considered.

Table 7C. Division 4T and 4V (Spring). Mesh Assessments for cod

Mesh Size change (inches)	l_c (cm)	t_c (yr)	Gear Group	% change in av. 1956 and 1958 landings				
				Immediate	Long-term for an			
					0.43	0.60	0.69	E
					0.15	0.30	0.45	F
From 4½ to	43.0	2.92			0.20	0.20	0.20	M
4			OT	+1	-3	-6	-8	
			Other	0	-1	-4	-5	
			Total	+1	-2	-5	-7	
5	45.9	3.34	OT	-2	1	3	3	
			Other	0	3	5	5	
			Total	-1	2	4	4	
5½	49.8	3.94	OT	-8	-1	2	4	
			Other	0	8	11	13	
			Total	-5	3	6	8	
6	53.1	4.50	OT	-14	-4	1	3	
			Other	0	12	17	20	
			Total	-8	1	7	14	

Trawl Group: Canada (37%); France (32%); Portugal (14%); Spain (16%); United States (1%).

Other Group: Canada - mainly hook and line (100%).

7.2.5. Divisions 4V (except spring) and 4W

7.2.5.1. Total cod landings from this area have decreased from 57,000 metric tons in 1948 to about 30,000 metric tons by 1953, and have been relatively constant since then (Fig. 7.8). The decline is a result primarily of a decrease in landings by the dory-vessel component of the important hook and line fishery. Hooks and lines took about two-thirds of the total during the earlier years, although in recent years they have accounted for only about half of it (Table 7A). Annual landings by otter trawl have remained relatively constant at about 15,000 metric tons.

7.2.5.2. There is some evidence from tag returns and biological studies (McKenzie 1956; McKenzie and Smith 1955; McCracken 1959) that there are several stock-units within these divisions. However, offshore line and otter trawl vessels often fish several of these stocks on a single trip, making assignment of sample data to a particular stock difficult. Because of this, and the evidence from tagging of some mixing among them, they have been treated as a unit. Such a treatment is adequate for the early years when the important dory-vessel component fished in the same areas as otter trawls, but does not fully represent the recent situation when a large proportion of the line fishing is done by inshore gears on stocks which are incompletely mixed with those fished by otter trawls. This limitation has to be borne in mind in interpreting the assessments.

7.2.5.3. Catch per unit effort records are available for otter-trawl and dory-vessel components throughout the study period. They show fluctuations in abundance, but indicate that its average level has not changed appreciably (Fig. 7.8). Decrease in landings is therefore essentially a result of the decrease in total effort. Otter trawl and small line and long-line effort have been relatively constant, but dory-vessel fishing has decreased steadily and is expected to stop completely in the near future.

7.2.5.4. Age compositions have been determined from both otter-trawl and dory-vessel catches and average catch curves for the whole period give a Z estimate of 0.50 (Fig. 7.9). Returns from tags released inshore in 1954 totalled 36 percent for the first two years, from which F = 0.30. Assessments, based on length compositions in Fig. 7.4, have been made using M = 0.20 and Z = 0.40, 0.50, 0.60 (E = 0.50, 0.60, 0.67) and show immediate and long-term changes following increases in mesh size above the 4½ inches currently in use.

7.2.5.5. The table of assessments (Table 7D) shows that there would be long-term gains to the whole fishery from increases in mesh size up to 6 inches. However, because all fish are released by otter trawls but a high proportion will be recaptured by hook and line, benefits to the otter trawlers reach a maximum at about 5½ inches. If discarding practices remained the same as at present immediate losses to otter trawls would be about 7 percent at 5½ inches but would be double this for an increase to a 6-inch mesh.

These conclusions are based on the assumption that the whole stock is fished by both otter trawls and line gears. It is pointed out above, however, that there is some separation of the two types of fishing. In these calculations we have therefore probably assigned too high a proportion of otter-trawl releases to recapture by lines. The long-term gains to the otter-trawl component are therefore slightly underestimated, while gains to the inshore component of the other gears are slightly overestimated.

7.3. Haddock

7.3.1. Division of stocks

Tagging experiments and biological studies (Needler 1930, Clark and Vladykov 1960) indicate that there are at least three and perhaps four major stock-units in Sub-area 4. Haddock occurring in northwest 4X in summer appear to be a migratory part of the stocks of Sub-area 5. The remaining stocks of 4X consist of an offshore group in the area of Browns Bank which probably mixes with fish from the Bay of Fundy area, and a partially separate stock in eastern 4X (Martin 1953). Within Division 4X, the United States otter trawlers fish primarily on Browns Bank, and the Canadian lines fish the banks to the east. Because of this separation of stocks and fisheries, it appears that the yield of the otter trawl fishery alone would be affected by a change in mesh size. Therefore for Division 4X assessments have been made

Table 7D. Division 4VW (except 4V (spring)). Mesh assessments for cod

Mesh size change (inches)	l_c (cm)	t_c (yr)	Gear Group	% change in 1957 to 1958 landings				
				Immediate	Long-term for an			
					0.50	0.60	0.67	E
					0.20	0.30	0.40	F
From 4½ to	45.6	2.78			0.20	0.20	0.20	M
4			OT Other Total	+1 0 +1	-3 -1 -2	-5 -2 -3	-7 -2 -4	
5	47.7	3.08	OT Other Total	-2 0 -1	1 3 2	2 4 3	3 4 4	
5½	50.5	3.38	OT Other Total	-7 0 -3	1 7 4	2 8 5	3 9 6	
6	52.9	3.70	OT Other Total	-14 0 -7	-3 10 3	0 12 6	2 14 8	

only for the otter trawl fishery. The stocks of 4X appear to be separate from those of 4VW, within which there may be a division into a more or less resident inshore stock and a migratory stock, part of which moves into 4T in summer. Haddock caught in 4V and 4W are treated in this report as coming from a single stock unit.

7.3.2. Division 4X

The otter trawl landings (Fig. 7.10) have increased since 1947, when they were about 9,000 tons, while landings by other gears (mainly line) have decreased from a high of 11,000 tons in 1951.

In 1956, 1957 and 1958 about 14,000 tons per year were taken by otter trawls (principally those of the United States), and about 5,000 tons per year by hook and lines (principally by Canada) (see Table 7A).

A value of Z = 0.45 was calculated from average weight frequency of the 1956-58 landings (method of Ricker, 1948). The values of M and F are not known. For the calculations, values of M of 0.3, 0.2 and 0.1 (E = 0.33, 0.56 and 0.78, respectively) were assumed to encompass the effective value (see other haddock assessments). Predicted changes in otter trawl landings alone (see para. 7.3.1.) for changes in mesh size are given in Table 7E, and are based on OT length-compositions for 1956 to 1958 (Fig. 7.11). For any increase in mesh size above the present 4.5 inches, there would be a loss even for the highest values of E (.78). A reduction of mesh below the regulation 4½ inches would increase the landings somewhat, but this would probably be lost through a resumption of discarding.

Table 7E. Haddock, Division 4X. Mesh assessments. U.S. otter trawls

Mesh size (inches)	l_c (cm)	t_c (yr)	% change in landings				
			Immediate	0.33	0.56	0.78	E
				0.15	0.25	0.35	F
				0.30	0.20	0.10	M
			+2	+5	+3	+2	
4.5 (initial)	37.7	1.1	-	-	-	-	
5.0	41.9	2.1	-7	-6	-3	-2	
5.5	46.1	2.7	-21	-14	-10	-4	
6.0	50.3	3.3	-36	-26	-17	-6	

7.3.3. Divisions 4V and 4W

7.3.3.1. Landings from 1947 to 1958 have fluctuated about an annual average of 23,000 metric tons (Fig. 7.12). Within this period there have, however, been important changes in the fishery. Initially about half of the total was taken by United States otter trawlers, but their landings have fallen sharply since 1953 to less than 5 percent of the total. At the same time Canadian landings have increased to 90 percent of the total. Spanish otter trawlers have landed a little over one thousand metric tons annually since about 1952. Otter trawlers have always taken the major share of the catch, but Canadian lines landed about 25 percent of the total in the early years. Line fishing has, however, been steadily decreasing in importance, and now accounts for only about 10 percent of the total.

7.3.3.2. Catch per unit effort is available for Canadian otter trawlers of 151-500 gross tons (Fig. 7.12) and indicates a rather steady increase until 1955, with a more abrupt increase in 1956 and 1957 associated with the successive appearance of several strong year-classes. Thus, the level of landings has been maintained throughout the period, despite a drop in total effort.

7.3.3.3. Age compositions of the catch have been determined from samples of the otter trawl catch, and a combined catch curve for the whole period (Fig. 7.13) gives a total mortality estimate of $Z = 0.70$. Now, if these catch curves had been influenced appreciably by the recent appearance of strong year-classes, this estimate of mortality rate would be too high. Mortality rates were therefore calculated from the average annual year-class abundance of the six to eleven year old haddock. The results confirmed that the average total mortality for the entire period was of the order of $Z = 0.70$. Annual mortalities plotted against estimates of the average total effort (Fig. 7.14) using a method suggested by Paloheimo (in press) indicate, however, that total mortalities have been decreasing significantly during the recent period of decreasing efforts, and during the period 1955-58 were of the order $Z = 0.50$. The data further suggest that natural mortality is about $M = 0.20$. Assessments based on length compositions given in Fig. 7.11 have been made using $M = 0.20$ with $Z = 0.40$, 0.50, 0.60 ($E = 0.50$, 0.60, 0.67) and show immediate and long-term changes for increases in mesh size above the 4½ inch mesh now in use.

7.3.3.4. The <u>table of assessments</u> (Table 7F) indicates that the present mesh size gives nearly the maximum yield per recruit for the otter trawl fishery at present levels of fishing effort. Increases in the mesh to 5 inches may result in small gains, but increases beyond this would probably result in losses. The line fishery would, of course, benefit from any mesh size increase; however, since it accounts for a relatively small proportion of the total, gains to it would only partly compensate for otter trawl losses. Maximum total landings by all gears would probably be realised at a mesh size no higher than 5 inches.

These assessments depend critically on the estimate of natural mortality rate. If this is less than the 0.20 assumed in Table 7F, maximum yield per recruit at present levels of fishing may be realised at mesh sizes up to 5½ inches. However, if M is higher, losses would result from any increase beyond the present 4½ inches. In this last case there may even be small gains from a reduction in the mesh to 4 inches. In all other cases, however, meshes smaller than those currently in use would result in long-term losses to the fishery.

Table 7F. Division 4VW. Mesh assessments for haddock

Mesh size change (inches) From $4\frac{1}{2}$ to	l_c (cm) 41.7	t_c (yr) 2.80	Gear Group	% change in 1955 to 1958 landings				
				Immediate	Long-term for an			
					0.50	0.60	0.67	E
					0.20	0.30	0.40	F
					0.20	0.20	0.20	M
4			OT	+6	-2	-4	-8	
			Other	0	-4	-7	-11	
			Total	+5	-2	-5	-9	
5	43.8	3.45	OT	-8	-1	1	2	
			Other	0	5	6	6	
			Total	-7	0	2	3	
$5\frac{1}{2}$	46.9	4.35	OT	-25	-6	-2	1	
			Other	0	8	9	10	
			Total	-20	-4	0	2	
6	50.0	5.20	OT	-43	-15	-10	-6	
			Other	0	14	16	18	
			Total	-37	-11	-6	2	

7.4. Redfish

(For Divisions 4V, W, X see Section 8.4).

7.4.1. Divisions 4R, S and T

This redfish fishery, carried on only by Canada and the U.S.A., was begun in the early 1950's. The landings increased rapidly to a peak of 50,000 tons in 1955 and thereafter declined to 23,000 tons in 1958 (App. I, Table 7.3). Of an average annual landing of 38,000 tons during the period 1955-58, Canada took 45 percent and the U.S.A. 55 percent (Table 7G).

Table 7G. Divisions 4R-S-T: average annual redfish landings ('000 metric tons) for the period 1955-58.

Canada (M)	Canada (Nfld.)	U.S.A.	Total
12.4	4.9	21.1	38.4

7.4.2. In the absence of sufficient age composition data, an estimate of Z was obtained from length compositions. In Fig. 7.15 are shown the length compositions by sex of the redfish landings per ten hours fishing by Canadian trawlers in Divisions 4R and S for the years 1954 to 1958. For all years and for both sexes two modal groups of redfish are evident, namely, a group of large males and females which formed the basis of the fishery during its early years, and a group of smaller fish which first became important in the landings in 1955. An analysis of the relative decrease from year to year in numbers of these groups gave estimates for Z of about 0.4 for each sex and each group (Fig. 7.16) and this value was used in making the assessments.

7.4.3. Up to 1955 there was very little fishing on this stock and the catch per unit effort for both Canadian and U.S.A. trawlers was high. Subsequently there has been a gradual decrease in landing per unit effort to about one-half the 1953-55 level by 1958 (App. I, Table 7.4). From 1956 to 1958 there has been a 25 percent reduction in total effort. This series of catch and effort data is not adequate for separation of Z into its components and long-term assessments can only be made by taking a range of M. For these assessments values of M of 0.1, 0.2 and 0.3 were used (E = 0.75, 0.50 and 0.25, respectively).

7.4.4. Annual length compositions of landings by Canadian and U.S.A. trawlers were averaged for the period 1955-58 and combined for use in making the assessments (Fig. 7.17). The length-weight relationships are from unpublished data of the St. John's Biological Station. The growth curve (sexes combined) is that of Sandeman (1959). The selection ogives are given in Appendix II. The assessments are given in Table 7H.

Table 7H. Divisions 4R, S, T: Mesh Assessments for Redfish

Mesh size change (inches)	l_c (cm)	t_c (yr)	Country (percent of total landing)	% change in 1955-58 landings				
				Immediate	Long term for			
					0.25	0.50	0.75	E
					0.10	0.20	0.30	F
From 3 to	27.4	11.2			0.30	0.20	0.10	M
4	28.3	11.8	Canada (45%) U.S.A. (55%)	-4.6	-2.7	-0.6	+1.6	
4½	29.8	13.2		-15	-10.5	-5.1	+1.6	
5	32.2	16.0		-33	-27	-17	-3	
5½	35.4	22.2		-55	-51	-41	-19	
6	38.6	>30		-73	Not calculated			

It appears that an increase in mesh size to four inches would cause only a slight long-term change in landings for a wide range of the E values. For a 4½-inch mesh there would be appreciable long-term losses unless E was about 0.7 or higher. For mesh sizes of 5 inches and larger there would be moderate or substantial long-term losses for all values of E considered.

7.5 Plaice

The Canadian otter trawl fishery of Division 4T takes important quantities of plaice. In recent years annual landings have averaged about 5,000 metric tons, equal to about one-fifth of the otter trawl landings of cod from the Division (Table 7A). The data available are insufficient for calculations of mortality rates, but Fig. 7.18 shows the length composition of recent catches and landings, together with selection curves for 4½ and 6-inch meshes. It is apparent that in the present fishery very large numbers of plaice are discarded, many of which may be killed. Increases of the mesh size up to 6 inches would, however, not lead to significant immediate losses to landings. If discarding practices remained as they are at present, any increase in mesh size would evidently result in long-term gains at present levels of fishing.

SECTION 8 - SUBAREA 5

8.1. The Fisheries

8.1.1. The fishery in this subarea has been carried on for hundreds of years, almost exclusively by New England fishermen. It was not until about 1830, however, that any considerable quantities of groundfish were landed. In the early days, the fishermen were primarily seeking cod, but haddock were always found in great numbers, particularly on Georges Bank, and supported a good winter fishery. At first, hand lines, fished from the decks of the schooners, were used to catch most of the codfish, but hand lining from dories proved more efficient and became the principal gear. Trawl lines, set from dories, were the most common gear for haddock and white hake. Later, line trawling from schooners was developed, and a few small inshore line trawlers are still in use. Landings of haddock increased through the early 1900's, while those of cod declined so that by 1910 the two were about equal. The fishery for white hake declined, while pollock landings gradually increased. About 1924, the packaging of fresh and frozen haddock fillets was developed, and there followed, within six years, an almost threefold increase in landings. They declined just as rapidly in the next six years, but then stabilised near the level of present landings. Cod landings continued to decline. The whiting and redfish fisheries developed rapidly after 1935. In 1905, the otter trawl was introduced into New England, and by 1929 this type of gear had become the primary component of the fishing fleet.

8.1.2. Landings in recent years (Table 8A) have been taken almost exclusively by United States otter trawlers. The fishery for cod and haddock is concentrated on Georges Bank. Redfish are caught in deep waters, primarily in the Gulf of Maine. Silver hake form an inshore fishery. Haddock, redfish, cod, yellowtail flounder, and pollock are the principal species.

Table 8A. Subarea 5. Average of 1956-1958 annual landings, by gears and species (thousands of metric tons).

Species \ Gear	Otter trawl	Line trawl	Sink gill nets	Total
Cod	13	1	1	15
Haddock	52	1	+	53
Redfish	20	0	0	20
Witch	1	0	0	1
Yellowtail	10	0	+	10
Lemon sole[1)]	1	+	0	1
Blackback[2)]	6	+	+	6
American plaice	2	+	0	2
Fluke	3	0	0	3
Pollock	9	+	1	10
White hake	1	1	+	2
Red hake	2	0	+	2
Silver hake	48	+	+	48
Total	168	3	2	173

1) Large winter flounder. 2) Small winter flounder.

8.2. Cod

8.2.1. Annual landings of cod fluctuated between 35 and 65 thousand metric tons in the period 1893-1910, dropping to about 20 thousand metric tons in 1915-16. Landings rose again to about

40 thousand tons in 1930, after which there was a gradual decrease to 11 thousand tons in 1953, the lowest on record. The present level of catch is about 15 thousand tons (Fig. 8.1). Since about 1930, almost all cod have been caught by otter trawlers, which, since 1953, have been required by law to use a cod-end of not less than 4½-inch mesh. Discarding is not prevalent.

8.2.2. Tagging studies (Schroeder, 1930; Wise, MS) have indicated that the Subarea 5 cod stocks do migrate into southern coastal waters to some extent. There is no evidence of any significant mixing with stocks in Subarea 4 and a large enough degree of autonomy seems to be maintained so that a separate assessment of these stocks is warranted.

8.2.3. Fishing effort for cod was derived from the fleet of otter trawlers fishing primarily for haddock on Georges Bank, the same as was used for haddock in section 8.3. About two-thirds of the cod are caught by this fleet. Estimates of effort and landings per unit effort have been obtained since 1931 in the same manner as for haddock (Rounsefell, 1957) (Fig. 8.1). The average annual landing per days fishing (by weight) was found to be negatively correlated with a three-year moving total of effort (the annual total effort plus that of the previous two years) over the period 1933-1958 ($R = .73$, $P = 0.01$, Fig. 8.2). This indicates that fishing has had a significant effect on the stock abundance; and from Fig. 8.2 it appears that the range of effort experienced has reduced the stock to about   of its unfished abundance.

8.2.4. Assessments were based on data of length and weight composition of otter-trawl landings for the years 1956-1958 (Fig. 8.3). Discards of cod were negligible. The growth rate was taken from the curve published by Schroeder (1930). Selection curves (Appendix II) were taken from Clark, McCracken, and Templeman (1958); the selection factor is 3.5 for all mesh sizes. An estimate of $Z = 0.55$ was obtained by an iterative method utilising the instantaneous growth rate and average weights of the exploited and pre-recruit stocks (Ricker, 1958, p. 203). Suitable data are not available for estimating either M or F. Three combinations of F and M, $F = 0.25$; $M = 0.3$; $F = 0.35$, $M = 0.2$; and $F = 0.45$, $M = 0.1$ ($E = 0.45$, 0.64, and 0.82, respectively), were used in making assessments, it being likely that the true values are within this range. From the slope of the regression of Fig. 8.2, E may be considered to be near the upper limit of this range.

8.2.5. Immediate and long-term changes in landings, calculated by Gulland's method, are given in Table 8B. Increasing mesh size to 5 inches would result in negligible long-term changes in landings for any of the E values, but with a mesh size of 6.0 inches predictions range from moderate losses to moderate gains.

Table 8B. Subarea 5. Mesh assessments for cod. OT, U.S.A.

Mesh size change (inches)	l_c	t_c	% change from 1956-58 landings				
	(cm)	(yr)	Immediate	0.45	0.64	0.82	E
				0.25	0.35	0.45	F
From 4.5 to	44.7	2.28		0.30	0.20	0.10	M
5.0	45.5	2.33	-5	-2	0	0	
5.5	46.7	2.42	-15	-4	+1	+5	
6.0	47.5	2.47	-25	-6	+3	+11	

8.3. Haddock

8.3.1. Landings gradually increased through the late 1800's and early 1900's, totalling about 40 thousand tons annually by 1920. There was a tremendous increase in landings during the 1920's, reaching 133 thousand metric tons in 1929, followed by a rapid decrease to about 35 thousand tons in 1934. Since then, the effort has stabilised and landings have fluctuated between 45 and 65 thousand metric tons (Fig. 8.4). Since about 1930, the fishing fleet has consisted almost entirely of otter trawlers, with only a few line trawlers still in operation. The Georges Bank fishery contributes by far the majority of the catch. Since mid-1953, otter trawlers fishing for haddock have been required by low to use cod-ends with a mesh not less than 4½ inches. This has effectively eliminated the discarding of small fish by this fleet.

8.3.2. A recent study of vertebral counts (Clark and Vladykov, 1960) and comparison of size composition of catch from Georges and Browns Banks (Schuck and Arnold, 1951) have indicated that the stocks of haddock in Subarea 5 form an autonomous unit.

8.3.3. Collection of landings per unit effort and size composition of landings data began in 1931 (Rounsefell, 1957). The regression of average annual catch per unit on three years' effort for the 1933-1958 period (Fig. 8.5) shows a significant negative correlation ($R = -.57$, $P < .01$) demonstrating that fishing has had a significant effect on the abundance of the stock. A total mortality of $Z = 0.6$ has been estimated from data of average abundance of successive ages in the landings (Graham, 1952). Values for M and F have been quoted as being about 0.2 and 0.4 respectively ($E = 0.67$) for the levels of effort in recent years. Firm estimates of these coefficients have not been obtained, however, and the values of $M = 0.1$ and $M = 0.3$ ($E = 0.83$, $E = 0.50$) have also been used for the assessments.

8.3.4. Immediate changes in landings with changes in mesh size were calculated from data for the average size composition of catch in 1954, 1957 and 1958 (Fig. 8.6). Long-term changes were calculated from these same data by the Gulland method, and from the yields per recruit by the arithmetic method, based on the age composition of catch of the 1952 year-class (an exceptionally strong one). Selection curves were taken from Clark et al. (1958) (Appendix II). Results of these calculations are given in Table 8C.

8.3.5. An increase in mesh size up to 5 inches would cause only small long-term changes in landings. For increases of mesh size up to 6 inches, estimates of changes in landings include both appreciable losses or gains, depending on the value of E; thus predictions of the effects of such increases in mesh size are uncertain.

Table 8C. Subarea 5. Mesh assessments for (U.S. otter trawl) haddock.

Mesh size (inches)	l_c (cm)	t_c (yr)	% change from 1954, 1957, 1958 landings							
			Immediate	Long-term for						
				0.5		0.67		0.83		E
				0.3		0.40		0.50		F
From 4.5 to	38.5	2.03		0.3		0.20		0.10		M
				A	B	A	B	A	B	
5.0	40.0	2.27	-14	0	-2	-1	+1	+2	+5	
5.5	42.2	2.60	-32	-9	-3	0	+4	+9	+14	
6.0	44.7	3.01	-48	-16	-8	-1	+4	+14	+21	

A = "Gulland" method. B = "Arithmetic" method.

8.4. Redfish. Divisions 4V, W and X and Subarea 5

8.4.1. The United States fisheries in these areas, which began in the mid-1930's, include catches from a number of fishing grounds. Fishing in the earliest years was concentrated in the Gulf of Maine (Division 5Y), but later spread to the Nova Scotia Banks (Divisions 4V, W and X). In Subarea 5 (Fig. 8.7) there was a sudden increase of landings in 1941, followed by a decline until the early 1950's, when they became relatively stabilised at a comparatively low level. In contrast, U.S. landings from the Nova Scotia Banks made their greatest increase in the mid-1940's, with a sharp decline in 1952 (Fig. 8.8). There was, at this time, a further shift in effort to the Newfoundland Banks. Landings from the Nova Scotia Banks began to increase again in 1956. The successive shift of fishing effort to more productive grounds after declines in the catches closest to American landing ports suggests that the fishery has been reducing the stocks, at least to the point where it is more profitable to fish more distant virgin stock.

8.4.2. This interpretation of the course of the fishery is not, however, strongly supported by the trends usual for other species in catch-per-unit-effort and size composition of catch. Gulland (1959) points out that there is a rather weak relationship between catch-per-unit-effort and fishing effort in the Gulf of Maine; moreover, the average length of the fish in most areas has not consistently decreased in the manner that might be anticipated if fishing had been the major influence affecting the stock. One of a number of theories developed to explain these anomalies postulates that they may have occurred as the result of successive exploitation of relatively small, self-contained stock-units of redfish within each of the main fishing grounds. In such a case, the course of the fishery reflects a series of segments of histories of individual stocks, which might differ markedly from the history of the exploitation of a single stock.

8.4.3. To test this hypothesis, unpublished length-frequency data of the U.S. Bureau of Commercial Fisheries, Biological Laboratory, Woods Hole, Mass., for the U.S. statistical subdivisions of the Gulf of Maine have been examined. For the years 1938 to 1957, no marked decrease in modal or mean length was revealed, such as might have been expected to occur as a result of the heavy fishing effort from 1942 to 1951. This is true for both the southern (U.S. statistical area XXII G) and the northern (U.S. statistical area XXII B) sect of the Gulf of Maine.

8.4.4. Length frequencies for the western Nova Scotia fishing grounds (unpublished data, U.S. Bureau of Commercial Fisheries, Woods Hole, Mass.) in Division 4X near Cape Sable (U.S. statistical subdivision XXI O) were also examined. In contrast to the Gulf of Maine data, length frequencies of the U.S. catches from this ground do indicate response to fishing pressure, i.e. there was a decrease in modal length from the near-virgin condition of 1936. Before and during the development of the fishery, three different levels of effort were maintained long enough to measure the reactions of the stocks thereto: (1) the near-virgin period prior to 1936, (2) the high effort level from 1948 to 1952, and (3) the lower effort level from 1953 to 1957. Estimates of Z were calculated from the length compositions in each of these periods, and the average growth rate for the entire period (unpublished data, U.S. Bureau of Commercial Fisheries, Woods Hole, Mass.) (method of Ricker, 1958). The following estimates of Z were obtained:

Period:	Z	Effort (boat-days per year)
Before 1936	0.25	25
1948 - 1952	0.40	6,340
1953 - 1957	0.35	1,639

Average values of fishing effort for the corresponding periods are also given above.

Rather small changes in Z are observed despite relatively large changes in effort. An estimate of natural mortality of 0.28 was obtained from the regression of Z on effort. With effort levels of about 2500 days in recent years, the estimates are Z = 0.33 and F = 0.05.

8.4.5. In the Gulf of Maine, area XXII F presents the largest range of effort levels with which to perform an analysis similar to that above. Effort data have been collected since 1943, and three periods of relatively stable effort levels at differing magnitudes have been utilised. The length frequencies of the terminal two years of each period, and the growth curve published by Kelly and Wolf (1959), were used to estimate total mortality; the method outlined by Beverton and Holt (1956) was employed. Different growth rates were used for males and females. The estimated values of Z and average effort (days fished) are listed below:

Period	Z	Average effort
1943 - 1947	0.40	1,790
1948 - 1952	0.52	2,664
1953 - 1959	0.38	1,452

A regression of Z on effort provided an estimate of natural mortality of 0.18. With the recent effort levels of about 3500 days, Z = 0.60 and hence F = 0.42.

8.4.6. Considering the imprecise nature of the calculations and the disparity of the resulting estimates of mortality, assessments were based on values of M of 0.1 and 0.3 and several values of F (see Table 8D). The average length frequencies of the 1957-1959 landings (Figs. 8.9, 8.10) were used; discards were assumed to be negligible. Selection curves were taken from Clark, et al. (1958) (Appendix II).

8.4.7. Assessments of the immediate and long-term effects on the otter trawl catches of increasing mesh size are listed in Table 8D. These suggest that increases of mesh to 4 inches or above in the Nova Scotia fishery are likely to result in long-term losses, and that these would be substantial at mesh sizes larger than 4 inches. A small gain to the Gulf of Maine fishery might result from an increase of mesh to 4 inches, but larger meshes would produce substantial losses here also, unless the true value of M is in the region of 0.1.

Table 8D. **Divisions** 5Y and 4V, W, X. Mesh assessments for redfish. (U.S., otter trawls).

Division	Mesh size change (inches)	l_c (cm)	t_c (yr)	% change in 1957-1959 landings: Immediate	Long-term for			
					0.50	0.67	0.83	E
					0.30	0.40	0.50	F
	From 2.75 to	22.4	7.8		0.30	0.20	0.10	M
5Y (Gulf of Maine)	4.0	25.1	9.0	-24	-6	+2	+9	
	4.5	38.0	11.5	-47	-23	-10	+8	
	5.0	31.5	15.5	-69	-50	-32	-3	
					0.25		0.75	E
					0.10		0.30	F
	From 2.75 to	20.2	8.7		0.30		0.10	M
4VWX (Nova Scotia)	4.0	24.6	11.6	-39	-29		+2	
	4.5	28.0	14.9	-61	-51		-5	
	5.0	31.6	19.4	-79	-72		-17	

8.5. Yellowtail flounder

8.5.1. The yellowtail fishery began to expand in the late 1930's and early 1940's as a result of a decline in abundance of the winter flounder and the demand for food during World War II. Landings reached a peak of 31 thousand metric tons in 1942 and gradually declined to about 6 thousand tons in 1954. Part of the decrease in landings was because of a shift of effort to the industrial fishery. Landings increased to 15 thousand tons in 1958 (Fig. 8.11). Considerable discarding of small fish is believed to occur; however, no information as to the amounts discarded or their length compositions has been obtained. Yellowtail are exploited almost exclusively by a fleet of American otter trawlers, under 75 gross tons, except on Georges Bank, where some vessels up to 100 gross tons participate. Four stocks were identified by Royce et al. (1959). Of these the Southern New England, Georges Bank and Cape Cod stocks lie within Division 5Z; the Nova Scotia stock is in Division 4X.

8.5.2. Comparison of fishing effort with indices of abundance for Division 5Z (Lux, MS) reveals a significant correlation only for Georges Bank. This finding is in accord with Royce et al (1959) who for the Southern New England stock ascribed the observed re tion between fishing effort and total mortality (as deduced from age composition) to the effects of changing availability. They concluded for this stock that "Many of the documented facts about the yellowtail populations are not in accord with theoretical changes caused by heavy fishing".

8.5.3. Since the period covered by the studies of Royce et al. (1942-1949), the relative importance of the Georges Bank fishery has increased greatly, and it now yields about one-third of the total catch of this species in the subarea. The regression of abundance on the 3-year moving average of effort for this area indicates a relation, and the coefficient of correlation is significant at the 0.01 level (Fig. 8.12).

8.5.4. The mortality rate for Subarea 5 was estimated from average weight frequencies of catch in the years 1957-1959 (Fig. 8.13), and the growth curve of Royce (1959) (method of Ricker, 1958), the value of Z = 0.65 being thus obtained. Since the value of M is unknown, calculations were made using values of 0.1, 0.2 and 0.3. covering a range within which it is assumed the true value of th parameter lies, having regard to the low values estimated in oth flatfish fisheries (e.g M = 0.1; North Sea plaice, Beverton and Holt, 1957). Assessments of long-term effects and of immediate effects are given in Table 8E.

Table 8E. Subarea 5. Mesh assessments for Yellowtail flounder.

Mesh size change (inches)	l_c (cm)	t_c (yr)	Gear Country	% change in 1957-1959 landings				
				Immediate	Long-term for			
					0.54	0.69	0.85	E
					0.35	0.45	0.55	F
From 4.5 to	31.3	2.3			0.30	0.20	0.10	M
			Trawl					
5.0	31.3	2.3	(US)	-1	0	0	0	
5.5	31.9	2.4	"	-6	0	+2	+3	
6.0	33.7	2.8	"	-21	-4	+2	+7	

The assessments indicate that there would be little char in the long-term landings for mesh sizes up to 5½ inches, but a 6 inches the direction of predicted changes becomes dependent upon the value of E. Since there is extensive discarding with the 4½-inch mesh in use, benefits of a larger mesh are likely to be greater in fact than here calculated.

8.6. Silver hake

8.6.1. The fishery for silver hake began to expand rapidly about 1935. Landings for food reached a peak of about 57 thousand metric tons in 1957. In addition, a large industrial fishery developed about 1950, landing significant amounts of silver hake which are not separated from other species in the landings statistics. Small and medium otter trawls are the only gears employed in this fishery.

8.6.2. Total mortality was calculated from 1957-1959 (Fig. 8.14) weight compositions (Ricker, 1958). An estimate of $Z = 0.45$ was obtained. There are insufficient data to give any reliable indication of the magnitudes of F and M for this species. The present mesh size is 2½ inches.

Immediate effects of mesh change and break-even values of E were calculated; the results are given in the Table 8F below.

Table 8F. Subarea 5. Mesh assessments for silver hake.

Mesh size change (inches) from 2.5 to	% change in landings (1957-1959) Immediate	Break-even value of E at least
4.0	-40	
4.5	-71	
5.0	-89	0.7
5.5	-96	
6.0	-99	

Break-even value of E is quite high, indicating that a heavy fishing rate would be necessary for larger mesh sizes to provide any long-term gain. With the mean selection length of 32.0 cm for the 4-inch mesh, practically all male silver hake would be eliminated from the catch.

8.7. Minor species

8.7.1. Growth rates are known for only two flounders of this group of species, and estimates for Z for them have been made using weight compositions for two recent years (Figs. 8.15 and 8.16) and are as follows:

Species	Z
Winter flounder	0.80
Summer flounder	0.25

Length composition of landings of the remaining species are portrayed in Figs. 8.17, 8.18, 8.19 and 8.20.

8.7.2. No direct separation of Z into components is possible for any of these species, but immediate effects of a mesh change are given in Table 8G.

Table 8G. Subarea 5. Mesh assessments for minor species.

Species	Present mesh size (inches)	Percentage immediate change for mesh size				
		4.0	4.5	5.0	5.5	6.0
Flounders:						
Winter flounder	4.5	0	0	-1	-3	-7
Summer flounder	4.5	+1	0	-2	-6	-13
Witch	4.5	0	0	0	0	0
Red hake	2.0	-61	-82	-93	-98	-99
Eelpout	2.0	-15	-26	-43	-59	-74
Spiny dogfish	2.0	0	-1	-1	-1	-2

SECTION 9. HALIBUT

9.1. Statistics of landings are available for the U.S. from 1893, for Canada from 1910 and for other countries from about 1930. Several periods of rather high landings are apparent, the first being during the U.S. fishery at the end of the last century in Subareas 3, 4 and 5. A second conspicuous period is during the U.K. special halibut fishery in the Davis Strait around 1930 in which Norway also took some part. At these times the abundance of halibut was probably higher than at present, but there are no data to show whether, or to what degree, such changes have resulted from fishing.

Norwegian long liners now land about one thousand tons annually from Subarea 1. In Subareas 3 and 4 Canadian long-line landings are 2 to 4 thousand tons. Besides these special halibut fisheries, minor quantities are taken as by-catch both in trawl and long-line fishing in all subareas. In Subareas 3 and 4 the incidental landings by trawlers have increased considerably from 1952 to 1957 (113 to 946 tons in Subarea 3; 176 to 307 tons in Subarea 4). This by-catch is more significant than would appear from the landings because the sizes of halibut caught in these fisheries are much smaller than in the special halibut fisheries.

9.2. There is very little information about the biology of halibut in the ICNAF area. Canadian marking experiments do not show many long distance migrations. The results of Norwegian marking experiments at the Davis Strait and Newfoundland indicate that the fishery in Subarea 1 is based on a separate West Greenland stock, while that in Subareas 3 and 4 exploits another stock (or possibly two different local stocks). Although most tagged halibut have been recaptured rather near to the place of tagging, some long migrations of larger fish have been reported, for example, from Subarea 4 (Gulf of St. Lawrence) to Iceland; Subarea 5 (Georges Bank) to the Grand Bank (U.S. data, see Serial No. 743, 1960); Labrador to West Greenland (Norwegian data); and also within the Northeast Atlantic.

9.3. Length compositions of some Norwegian long-line catches are available from Subarea 1. Canadian data are available for compositions of landings by commercial size categories for some years, and for length and age-compositions of research vessel catches.

The upper limit of size of halibut is about 260 cm for females and 170 cm for males. In the special halibut long-line fisheries most fish caught are from 90 to 200 cm and from 10 to 25 years of age. The average weight of the halibut landed from the Canadian offshore fisheries was as estimated from market category data as approximately 52 lb (23.6 kilos) in 1950 and 59 lb (26.8 kilos) in 1952. Average weights in Norwegian long-line catches from West Greenland were 17.7 kilos in 1955, 29.8 kilos in 1956, 22.3 kilos in 1958, and 24.7 kilos in 1959. Halibut caught incidentally in other fisheries seem generally to be of much smaller sizes than these. Thus in 1951 about 40 percent of fish in such landings in Canada from Subareas 3 and 4 weighed less than 12 lb (5.5 kilos). The high vulnerability of small halibut to trawls and cod-lines is partly due to the selectivity of these gears and partly to the tendency for young halibut to move into shallow waters during spring and summer.

9.4. Information on mortality of halibut in the ICNAF area is scanty. If, however, the average weight (24.2 kilos) of halibut in the samples from the Canadian and Norwegian fisheries can be taken to represent the average size of fish caught in the special halibut fisheries as a whole, it is possible to calculate the optimum size of fish at first capture (W_L) which would result in the best long-term yield, depending on the value of E. Thus,

$$W_L = 24.2 \times E$$

Given in Table 9A are values of W_L (and of the corresponding length L_L) for a wide range of values of E:

Table 9A. Halibut: optimum size at first capture corresponding to various values of E.

E	0.75	0.67	0.5	0.33	0.16
W_L (kilos)	18.1	16.2	12.1	8.0	4.0
L_L (cm)	113	109	99	88	72

9.5. The actual value of E probably varies considerably in different areas, but values less than 0.5 seem improbable, especially since natural mortality is likely to be low for the sizes of fish considered here. Thus the few tagging data suggest that fishing mortality coefficient is at least 0.1, and the age-compositions suggest that Z may be about 0.15 (i.e. E . The limiting value of size below which there would be a gain to the special halibut fisheries by releasing fish is thus probably at least as high as 100 cm. For the halibut fisheries as a whole (including incidental ones) the limiting size is somewhat lower because of the smaller average size of the by-catch-halibut.

9.6. No mesh increase of the order that might be contemplated for the other species could be expected to have much effect on halibut landings. The only way of improving the halibut fisheries would seem to be to save the smaller halibut at present taken as by-catch in the cod and haddock fisheries. Whether this is practicable depends critically on achieving an adequate survival of the small fish by discarding those below a minimum size limit. These are questions which need study, and some specific proposals for further work are given in Section 13. In this connection the Group noted that, especially if size limits were contemplated, it would be necessary to consider the halibut fisheries in the Northwest and Northeast Atlantic together.

SECTION 10. SUMMARY OF MESH ASSESSMENTS

10.1 The mesh assessments given in the preceding sections are summarized in Table 10A, which gives the percentage chang[e] in landings by trawl and other gears in each of the "fishery units" used (Sub-areas, groups of divisions or divisions). For compactness, a single value of E, thoughtto be the most probable, has been used, and is shown in the last column of Table 10A; this is usually the central value, but in some cases it does not coincide exactly with any of the particular values quoted earlier which have been taken to cover the likely range. Also shown is the quantity, in thousands of tons, landed annually by each gear in recent years; these are usually the same quantities as those on which the earlier assessments are based. Unavoidably, in summary tables of this kind, space is created for entries which are either uncertain or lacking altogether, and the following conventions have been used to meet these situations:-

( ) estimate uncertain
° no assessment available
- no landings

Further notes on this and other summary tables of this section are given in para. 10.8

10.2 From the data of percentage change and landings given Table 10A, the actual gains or losses (in thousands of tons) have been calculated for each mesh change in each fishery unit. these are given in Table 10B, which can be used as the basis for combining assessments for various mesh sizes, species and regions, as may be required.

10.3 The effects of certain combinations of mesh size which may be of practical relevance are given in Table 10C and 10D. Two areas are considered, (a) the whole I.C.N.A.F. area (Table 10C) and (b) the "southern zone" consisting of division 3NOP and sub-areas 4 and 5 (Table 10D). For redfish immediate losses only are given because long-term assessments are not available for all Sub-areas. Immediate losses only are also given for the minor species in Sub-area 5. The remaining entries in the Table refer to long-term changes, but it must be noted that Sub-area 2 cannot be included as no long-term assessments are available for that Sub-area.

10.4 The top parts of Tables 10C amd 10D show the predicted effects of applying <u>a single mesh size uniformly throughout the area considered</u> (either the whole I.C.N.A.F. area or the southern zone only).

10.4.1 For <u>cod</u>, the total landings increase steadily with mesh size, a mesh of 6" giving a small gain of about 4% in the whole area and a somewhat larger one of about 9% in the southern zone. Trawler landings, however, reach their highest point at intermediate mesh sizes (5" in the whole area; 5½" in the southern zone); and a 6" mesh actually gives a small loss to trawlers in the Convention area as a whole. Other gears, of course, gain increasingly as the mesh size of trawls is increased.

10.4.2 For <u>haddock</u>, nearly all of which is taken by trawl in the southern zone, there is a small gain with both 4½ and 5" meshes; meshes of 5½" and 6", however, give losses which become substantial at 6".

10.4.3 The total landings of <u>cod and haddock</u> combined (by all gears) show small gains for mesh sizes up to 5½" in both the whole area and the southern zone, the loss of haddock at 5½" being more than compensated by the gain of cod. With a mesh size of 6", however, there is an appreciable loss.

1 . 10A. SUMMARY OF MESH ASSESSMENTS (% CHANG

Species	Stock Unit Area	Recent Average Annual Landings ('000 metric T.)			% change in landings resulting from an increase of mesh size to:-																Value of E used	Text para. and Table ref.
					4½"				5"				5½"				6"					
						Long-term				Long-term				Long-term				Long-term				
		T	O	Tot.	Imm.	T	O	Tot.	Imm.	T	O	Tot.	Imm.	T	O	Tot.	Imm.	T	O	Tot.		
COD	1	154	140	294	-0.5	0	+0.5	+	-3	-0.5	+3	+1	-8.5	-2	+6.5	+2	-14	-4	+11.5	+3.5	0.5	4.2.4;4B
	2	24	12	36	-2	.	.	.	-8	.	.	.	-16	.	.	.	-35	.	.	.	.	5.2; 5B
	3KL	71	161	232	-1	0	+0.5	+0.5	-2	0	+1	+1	-7	-3	+2.5	+1	-13.5	-7.5	+3.5	0	0.6	6.2.4;6B
	3M	6	+	6	-4	.	.	.	-10	.	.	.	-22.5	.	.	.	-34.5	.	.	.	.	6.2.5;6C
	3NO	61	16	77	-2	+3	+5	+3.5	-5.5	+6	+12	+7.5	-13.5	+8	+2.5	+12	-22	+8	+38.5	+14.5	0.6	6.2.6;6D
	3P	28	37	65	-1.5	0	+1	+0.5	-4	-1	+3	+1.5	-11	-4.5	+6.5	+2	-19	-10	+11	+2	0.6	6.2.7;6E
	4X	1	12	13	0	0	0	0	-2	-1	+1	+1	-6	-4	+2	+1	-10	-8	+1	0	0.8	7.2.3;7B
	4VW	14	18	32	0	0	0	0	-2	+2	+4	+3	-7	+2	+8	+5	-14	0	+12	+6	0.6	7.2.5;7D
	4RST	85	69	154	0	0	0	0	-2	+3	+5	+4	-8	+4	+13	+8	-14	+3	+19.5	+10.5	0.7	7.2.4;7C
	5	13	2	15	0	0	0	0	-5	0	.	(0)	-15	+2	.	(+2)	-25	+4.5	.	(4.5)	0.7	8.2; 8B
HADDOCK	3NO	48	-	48	-13	+10	-	+0	-35	+4	-	+4	-62	-14	-	-14	(-100)	(-100)	-	(-100)	0.7	6.3; 6F
	3P	23	1	24	(-13)	(+10)	.	(+10)	(-35)	(+4)	.	(+4)	(-62)	(-14)	.	(-14)	(-100)	(-100)	-	(-100)	.	as for 3NO
	4X	14	5	19	0	(0)	0	0	-7	-3	(0)	.	-21	-10	(0)	.	-36	-16	(0)	.	0.6	7.3.2;7E
	4VW	23	3	26	0	0	0	0	-8	+1	+6	+2	-25	-2	+9	0	-43	-10	+16	-6	0.6	7.3.3;7F
	4T	2	-	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	5	52	1	53	0	0	0	0	-14	+1	.	(+1)	-32	0	.	(0)	-48		.	(-1)	0.7	8.3; 8C
REDFISH	1	22	-	22	-7	.	-	.	-14	.	-	.	-25	.	-	.	-32	.	-	.	.	4.3.4;4C
	2	64	-	64	-6	.	-	.	-18	.	-	.	-28	.	-	.	-38	.	-	.	.	5.3; 5B
	3KL	86	-	86	-5	.	-	.	-17	.	-	.	-37	.	-	.	-56	.	-	.	.	6.4; 6G
	3M	55	-	55	-10	.	-	.	-29	.	-	.	-53	.	-	.	-72	.	-	.	.	6.4; 6G
	3NO	14	-	14	-56	.	-	.	-76	.	-	.	-89	.	-	.	-95	.	-	.	.	6.4; 6G
	3P	4	-	4	-16	.	-	.	-36	.	-	.	-60	.	-	.	-77	.	-	.	.	6.4; 6G
	4X	7	-	7	-61	-51	-	-51	-79	-72	-	-72	(-95)	.	-	.	(-100)	.	-	.	0.25	8.4; 8D
	4VW	20	-	20	-61	-51	-	-51	-79	-72	-	-72	(-95)	.	-	.	(-100)	.	-	.	0.25	8.4; 8D
	4RST	28	-	28	-15	-5	-	-5	-33	-17	-	-17	-55	-41	-	-41	-73	.	-	.	0.5	7.4; 7H
	5	20	-	20	-47	-10	-	-10	-69	-32	-	-32	(-85)	.	-		(-93)	.	-	.	0.7	8.4; 8D
OTHERS	4X	3	23	26	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.
	4VW	9	6	15	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.
	4RST	11	7	18	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	7.5
	5	83	2	85	(-53)	.	-	.	(-65)	.	.	.	(-72)	.	.	.	(-78)	.	.	.	.	(8.6;8.7 (8F,8B

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TABLE 10B. SUMMARY OF MESH ASSESSMENTS (CHANGES IN ' 000 TONS)

Species	Stock Unit Area	Change in landings ('000 metric tons) resulting from an increase of mesh size to:-															
		4½"				5"				5½"				6"			
			Long-term				Long-term				Long-term				Long-term		
		Imm.	T	O	Tot.	Imm.	T	O	Tot.	Imm.	T	O	Tot.	Imm.	T	O	Tot.
COD	1	-0.5	-0.2	+0.8	+0.6	-4.9	-0.6	+4.2	+3.6	-12.8	-2.8	+9.2	+6.4	-21.6	-6.2	+16.1	+9.9
	2	-0.5	.	.	.	-1.9	.	.	.	-3.8	.	.	.	-8.4	.	.	.
	3KL	-0.5	+0.1	+0.8	+0.9	-1.5	-0.1	+1.8	+1.7	-4.8	-2.0	+3.7	+1.7	-9.4	-5.2	+5.6	+0.4
	3M	-0.2	.	.	.	-0.6	.	.	.	-1.4	.	.	.	-2.1	.	.	.
	3NO	-1.1	+1.9	+0.8	+2.7	-3.3	+3.7	+2.0	+5.7	-8.3	+5.1	+4.0	+9.1	-13.4	+4.9	+6.1	+11.0
	3P	-0.3	0	+0.4	+0.4	-1.1	-0.2	+1.1	+0.9	-3.0	-1.2	+2.5	+1.3	-5.4	-2.7	+3.9	+1.2
	4X	0	0	0	0	0	0	+0.1	+0.1	-0.1	0	+0.2	+0.2	-0.1	-0.1	+0.1	0
	4VW	0	0	0	0	-0.2	+0.2	+0.7	+0.9	-1.0	+0.2	+1.4	+1.6	-2.0	0	+2.2	+2.2
	4RST	0	0	0	0	-1.7	+2.6	+3.5	+6.1	-6.8	+3.4	+8.9	+12.3	-11.9	+2.6	+13.5	+16.1
	5	0	0	0	0	-0.6	0	(0)	(0)	-2.0	+0.3	(0)	(+0.3)	-3.2	+0.6	(0)	(+0.6)
HADDOCK	3NO	-6.2	+4.8	-	+4.8	-16.8	+1.9	-	+1.9	-29.8	-6.7	-	-6.7	(-48.0)	(-48.0)	-	(-48.0)
	3P	(-3.0)	(+2.3)	.	(+2.3)	(-8.1)	(+0.9)	.	(+0.9)	(-14.3)	(-3.2)	.	(-3.2)	(-23.0)	(-23.0)	.	(-23.0)
	4X	0	0	(0)	0	-1.0	-0.4	(0)	-0.4	-2.9	-1.4	(0)	-1.4	-5.0	-2.2	(0)	-2.2
	4VW	0	0	0	0	-1.8	+0.2	+0.2	+0.4	-5.7	-0.5	+0.3	-0.2	-9.9	-2.3	+0.5	-1.8
	4T	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	5	0	0	0	0	-7.3	+0.5	.	(+0.5)	-16.6	0	.	(0)	-25.0	-0.5	.	(-0.5)
REDFISH	1	-1.5	.	-	.	-3.1	.	-	.	-5.5	.	-	.	-7.0	.	-	.
	2	-3.8	.	-	.	-11.5	.	-	.	-17.9	.	-	.	-24.3	.	-	.
	3KL	-4.3	.	-	.	-14.6	.	-	.	-31.8	.	-	.	-48.2	.	-	.
	3M	-5.5	.	-	.	-15.9	.	-	.	-29.1	.	-	.	-39.6	.	-	.
	3NO	-7.8	.	-	.	-10.6	.	-	.	-12.4	.	-	.	-13.3	.	-	.
	3P	-0.6	.	-	.	-1.4	.	-	.	-2.4	.	-	.	-3.1	.	-	.
	4X	-4.3	-3.6	-	-3.6	-5.5	-5.0	-	-5.0	(-6.6)	.	-	.	(-7.0)	.	-	.
	4VW	-12.2	-10.2	-	-10.2	-15.8	-14.4	-	-14.4	(-19.0)	.	-	.	(-20.0)	.	-	.
	4RST	-4.2	-1.4	-	-1.4	-9.2	-4.8	-	-4.8	-15.4	-11.5	-	-11.5	-20.4	.	-	.
	5	-9.4	-0.2	-	-0.2	-13.8	-6.4	-	-6.4	(-17.0)	.	-	.	(-19.0)	.	-	.
OTHERS	4X 4VW 4RST 5	(-45)				(-57)				(-62)				(-66)			

TABLE 10C.

KIND OF REGULATION		MESH SIZE(S) (in)						ICNAF AREA										
								COD (long-term)			HADDOCK (long-term)			COD AND HADDOCK (long-term)			REDFISH (imm)	OTHER SPP (imm) Subarea 5 only
								T	O	Tot.	T	O	Tot.	T	O	Tot.		
UNIFORM MESH THROUGHOUT ICNAF AREA		4½						0	+0.5	+0.5	+4	–	+4	+1.5	+0.5	+1	-17	-53
		5						+1	+3	+2	+2	–	+2	+1.5	+3	+2	-35	-65
		5½						+0.5	+6	+3	-8	–	-7	-1.5	+6	+2	-49	-72
		6						-1.5	+10	+4	-48		-46	-14	+10	-3	-63	-78
		REGION																
DIFFERENT MESH SIZES BY REGIONS, SUCH THAT THEY MAXIMISE:-	TOTAL GAINS OF:	1	3KLM	3NOP	4VWX	4RST	5											
	COD	6	5	6	6	6	6	0	+10	+5	-48	+16	-46	-13	+10	-3	-47	-78
	HADDOCK (a)	–	–	4½	(4½)	.	5	-0.5	+7	+3.5	+4.5	+6.5	+5	+1	+7	+4	-38	-65
	COD AND HADDOCK	6	5	4½	5	(6)	5	-0.5	+7	+3.5	+4.5	+6.5	+5	+1	+7	+4	-38	-65
	GAINS TO TRAWLS OF:	1	3KLM	3NOP	4VWX	4RST	5											
	COD	4½	4½	5½	5½	5½	6	+2	+4	+3	-8	+10	-7	-1	+4	+1	-34	-78
	HADDOCK (a)	–	–	4½	4½	.	5	+1	+2.5	+2	+4.5	+6.5	+5	+2	+2.5	+2	-26	-65
	COD AND HADDOCK	4½	4½	4½	4½	(5½)	5	+1	+2.5	+2	+4.5	+6.5	+5	+2	+2.5	+2	-26	-65

(a) For calculating the % changes of cod, cod and haddock and redfish in these hypotheses the mesh sizes for Subareas 1, 3KLM and 4RST are those required to maximise the gains of cod, since no haddock are caught in these areas.

TABLE 10D.

KIND OF REGULATION		MESH SIZE(S) (in)						SOUTHERN ZONE (3NOP, 4, 5)									
								COD (long-term)			HADDOCK (long-term)			COD AND HADDOCK (long-term)			REDFISH (imm)
								T	O	Tot.	T	O	Tot.	T	O	Tot.	
UNIFORM MESH THROUGHOUT ICNAF AREA		4½						+1	+1	+1	+4	–	+4	+2	+1	+2	–42
		5						+3	+5	+3	+2	–	+2	+2.5	+5	+3	–60
		5½						+4	+11	+7	–8	–	–7	–1	+11	+2.5	–78
		6						+2	+17	+9	–48	–	–46	–20	+17	–9	–89
		REGION															
DIFFERENT MESH SIZES BY REGIONS, SUCH THAT THEY MAXIMISE:–	TOTAL GAINS OF:–	1	3KLM	3NOP	4VWX	4RST	5										
	COD	6	5	6	6	6	6	+3	+17	+9	–48	+16	–46	–20	+17	–9	–89
	HADDOCK (a)	–	–	4½	(4½)	·	5	+2	+10	+5	+4.5	+6.5	+5	+3	+10	+5	–64
	COD AND HADDOCK	6	5	4½	5	(6)	5	+2	+10	+5	+4.5	+6.5	+5	+3	+10	+5	–64
	GAINS TO TRAWLS OF:–	1	3KLM	3NOP	4VWX	4RST	5										
	COD	4½	4½	5½	5½	5½	6	+4	+11	+7	–8	+10	–7	–1	+11	+2.5	–81
	HADDOCK (a)	–	–	4½	4½	·	5	+2	+6	+4	+4.5	+6.5	+5	+3.5	+6.5	+4.5	–58
	COD AND HADDOCK	4½	4½	4½	4½	(5½)	5	+2	+6	+4	+4.5	+6.5	+5	+3.5	+6.5	+4.5	–58

(a) For calculating the % changes of cod, cod and haddock and redfish in these hypotheses the mesh sizes for Subareas 1, 3KLM and 4RST are those required to maximise the gains of cod, since no haddock are caught in these areas.

For trawlers only there is a gain for mesh sizes up to 5", a small loss at 5½" and an appreciable loss at 6".

).5 The lower part of Tables 10C and 10D sets out the predicted effects of applying different mesh sizes in various parts of the Convention area. For this purpose the Convention area has been divided into six regions, on the basis of both stock and fishery divisions, namely:-

Sub-area	1
Division	3, KLM
"	3, NOP
"	4, RST
"	4, VWX
Sub-area	5

It is thought that these probably represent the greatest degree of subdivision of the Convention area which it would be practicable to consider in this context. In each of these regions a mesh size is chosen such that it maximises either the gain in total landings or to trawlers only, and according to whether the landings to be maximised are those of cod, haddock, or cod and haddock combined. As mentioned above, Sub-area 2 is not considered because no long-term assessments can yet be made for this Sub-area.

10.6 The actual mesh sizes which would be adopted in the different regions according to these various criteria are shown in the left-hand columns. They range from 4½", giving the best gain of haddock to trawlers in the less heavily fished regions, to 6", which gives the best gain in total landings of cod in all regions except 3, KLM.

10.7 The resulting landings which determine the mesh size used in each case (i.e. cod, haddock or cod and haddock) are underlined in the table. Thus, the meshes chosen to maximise the total landings of cod are mostly of 6" in size, so the effects are much the same as those shown in the upper part of the table for a uniform mesh of 6" throughout the area in question, i.e. a moderate gain in cod but rather substantial losses of haddock. Correspondingly, if the mesh in each region is determined by the need to maximise the landings of haddock, the size required is smaller.

).8 Meshes chosen to maximise the total landing of cod and haddock combined are more variable (depending on which is the more important species in the region in question). The gain in these circumstances is still not large (because in no one region is the potential gain large from any mesh up to 6", under present conditions), but it is appreciably larger than the best gain which could be obtained by any uniform mesh. Thus, the application of differential mesh sizes in the various regions of the I.C.N.A.F. area could produce a gain of 4% in total landings by all gears, compared with 2% with the best uniform mesh (5" or 5½"); for the southern zone only the difference is 5.5% to 3%. If trawl landings only are maximised, differential mesh sizes could produce gains of 2% and 3.5% in the whole area and the southern zone respectively, compared with 1.5% and 2.5% respectively from the best uniform mesh (5").

Explanatory notes on the summary tables of this section are as follows:-

(a) No long-term assessments have been made for cod in Sub-area 2, (36,000 tons = 3.9% of total cod)
Division 3M (6,000 tons = 0.6% of total cod)
Sub-area 5, caught by other gears (2,000 tons = 0.2% of total cod)

(b) No long-term assessments have been made for fisheries for haddock by other gears in the following areas:-
3P (1,000 tons = 0.6% of total haddock)
4X (5.000 tons = 2.9% of total haddock)

4T (2,000 tons = 1.2% of total haddock)
5 (1,000 tons = 0.6% of total haddock)

(c) Certain changes have been "estimated" although no direct assessments are possible; these are:-

<u>Haddock</u> (3NO -(trawl) changes for a mesh size of 6"
(3P -(trawl), taken as same percentage as for 3NO

<u>Redfish</u> (4X - immediate loss for meshes of $5\frac{1}{2}$" and 6"
(4VW- " " " " " " " "
(5 - " " " " " " " "

<u>Other species in Sub-area 5</u> (- immediate losses are weighted average of values for individual species given in Tables 8B and 8F

SECTION 11. EFFECTS OF CHANGES IN AMOUNT OF FISHING

11.1 The assessments presented in the preceeding sections are strictly valid only if the amount and composition of the fishing activity (e.g. the proportion caught by the various gears, etc) remain unchanged. In this section some appreciation is offered of the effects that might be expected if these conditions do not hold, and particularly if the fishing effort changes.

11.2 Forecasts of future changes in fishing effort from the 1958 level have been made by certain countries and are summarised in Table 11A, together with the corresponding catches taken in that year. As forecasts are lacking from a number of countries, no quantitative estimates of future changes in total fishing can be made, except for Sub-area 5 (fished mainly by the U.S.A.) where no substantial changes in effort are anticipated. Nevertheless, from such national forecasts as are available, and having regard to the probable development of factory and freezing trawlers, it is reasonable to suppose that the fishing effort in most Sub-areas will tend to increase.

11.3 Because of the lack of quantitative estimates of like future changes in fishing effort, and because calculations involving changes in effort are lengthy and make considerable demands on data, no attempt has been made to calculate in a comprehensive way the changes in the mesh assessments given earlier in this report which would be expected to result from changes in effort. Certain general statements can, however, be made for all stocks and these are illustrated by some trial computations for certain fisheries.

11.4 The magnitude of the changes in landings brought about by a paticular mesh increase is governed by the proportion (by numbers) of fish released by the larger mesh compared with those retained. If this proportion is small, then no substantial long-term gain (on a percentage basis) can result, however, intense the fishing or great the benefit from the released fish. Thus it follows that, except where substantial quantities of small fish are discarded at sea, large long-term gains can be obtained only at the expense of appreciable initial losses, at least in terms of numbers of fish. Fisheries in which the initial losses are small (e.g. cod in Sub-area 1 for mesh sizes up to $5\frac{1}{2}$" at least) cannot therefore be expect to show any really substantial changes, even at much higher intensities of fishing.

Table 11A. Summary of expected changes in fishing effort. Upper figure: thousand tons landed in 1958. Lower figure (where given) expected percentage increase over 1958 effort for the years 1961-1970.

Country	Sub-area 1	Sub-area 2	Sub-area 3	Sub-area 4	Sub-area 5
Canada (M and Q)	-	3 + 6 to + 24% in trawling in all areas Other gears: no change	28	355	13
Canada (Nfld)	-	13 +150%	194 No change	28	-
Denmark (F)	44	-	4 No forecast	-	-
Denmark (G)	31	-	- No forecast	-	-
France	24	18	35 No forecast	42	-
France(St. P.&M)	-	-	9 No forecast	-	-
Germany (E)	1	2	1 No forecast		
Germany	45 1961 as 1960; no other forecast	24	2	-	-
Iceland	14 Probably little change	33	44	-	-
Italy	1	-	1 No change	1	-
Norway	37	-	7 No forecast	-	-
Portugal	113	8	40 No forecast	18	-
Spain	27	2	74 No forecast	21	-
U.S.S.R.	-	13	103 No forecast	-	-
U.K.	10 +10% to +40%	- A little fishing	2 +100% to +200%	- A little fishing	-
U.S.A.	-	2 +25%	10 - 10% to -50%	56 -10% to No change	446 -10% to No change

11.5 The direction in which an increase in fishing effort will influence the effect of a mesh change can be generalised. A greater fishing effort will increase the total mortality rate and hence also the proportion of small fish in the landings. The immediate loss resulting from a given increase in mesh size will therefore be greater, but so also will the gain from the released fish, since the proportion subsequently recaptured (E) will also be higher than before. Thus, in general, the effect of increased fishing will be to enhance the long-term gains which result from a given increase of mesh size. It is also true that the optimum mesh size, i.e. that required to obtain the maximum long-term catch, also increases as fishing effort increases.

11.6 The effect of an increase in fishing effort in itself, mesh change apart, cannot be generalised so readily. In a lightly fished stock (E small), increased fishing is likely to increase the long-term catch; in a heavily fished stock (E large) it may decrease it. The catch per unit effort, however, will always decrease as fishing increases. If the fishing effort of only one component of the fishery (e.g. trawlers generally, or the trawl fleet of one country) increases, then the percentage of the total catch taken by that component will always increase, even if the total catch does not.

11.7 To illustrate these general points, assessments have been made of the effect of changes of fishing effort on cod in Sub-area 1 and haddock in Sub-area 5. For Sub-area 1 cod, the trawl effort has been assumed to increase to twice its present level. The new length composition of the catches under these conditions has been calculated, taking three possible divisions of the present total mortality rate into its natural and fishing components. From the new length composition, the effect of an increase of mesh size from 4¼" to 6" was estimated using Gulland's method and compared with the assessments given in Table 4B for the present level of effort. For Sub-area 5 haddock, the expected age-composition of catches corresponding to levels of total effort which are 50%, 75% and 200% of that at present have been calculated, assuming that under present conditions F = 0.4 and M = 0.2. The effect of mesh increase was then calculated by Silliman's method on the basis of these new age-compositions.

11.8 Considering first the long-term effect of change in fishing effort with the mesh remaining at its present size, the long-term changes in catch and catch per unit effort for Sub-area 1 cod and Sub-area 5 haddock are shown in Tables 11B and 11C as follows:-

Table 11B. Sub-area 1 cod. Percentage change in landings and landings per unit effort resulting from a doubling of trawler effort.

	Landings			Landings/unit effort		
	(a)	(b)	(c)	(a)	(b)	(c)
Trawl	172	148	127	86	74	63
Other gears	81	66	54	81	66	54
Total	121	102	86	-	-	-

(a) M = 0.3, present F (total) = 0.1
(b) M = 0.2, " " " = 0.2
(c) M = 0.1, " " " = 0.3

Table 11C. Sub-area 5 haddock. Percentage change in landings and landings per unit effort resulting from changes in total effort (as % of present level).

Effort	50	75	100 (present)	200
Landings	86	95	100	102
Landings per unit effort	172	130	100	51

These tables illustrate how, even in a lightly fished stock (case (a) for Sub-area 1 cod), increased effort causes a sharp decrease in landings per unit effort, even when the total landings increase. With a more heavily fished stock than this (e.g. case (c) of Table 11B or Table 11C), doubling the effort can nearly halve the catch per unit effort.

11.9 Table 11D and 11E show the effect of mesh increase on landings under the conditions of increased fishing effort specified in the preceeded tables. The effect of a combined change in both fishing effort and mesh size from the present situation can readily be calculated from these tables and the two preceding.

Table 11D. Sub-area 1 cod. Percentage immediate and long-term changes in landings resulting from an increase of mesh from $4\frac{1}{4}$" to 6", at present effort levels and with the trawler effort doubled

Trawl effort		(a) (M=0.3)		(b) (M=0.2)		(c) (M=0.1)	
		as at Present	Doubled	as at Present	Doubled	as at Present	Doubled
Trawl landings	Immediate	-14	-16	-14	-18	-14	-20
	Long-term	-11	-10	-7	-4	-3	+2
Landings by other gears	Immediate	-	-	-	-	-	-
	Long-term	+4	+8	+8	+17	+13	+27
Total landings	Immediate	-6	-10	-6	-12	-6	-13
	Long-term	-3	-3	+1	+3	+6	+11

Table 11E. Sub-area 5 haddock. Percentage immediate and long-term change in landings resulting from increases of mesh size at levels of effort 50%, 75% and 200% of the present

Mesh change from $4\frac{1}{2}$" to	Immediate change (F=0.4)	Long-term change			
		F=0.2	F=0.3	F=0.4(present)	F=0.8
4"	+5	0	-1	-1	-2
5"	-14	-1	0	+1	+3
$5\frac{1}{2}$"	-32	-2	+2	+4	+9
6"	-48	-4	0	+4	+12

These tables illustrate the generalisations made in paras. 11.4 and 11.5 namely that:-

(a) The greater the fishing effort the greater the gain from a given increase in mesh size.

(b) Where there is a long-term loss at present effort levels this will be reduced, or even become a gain, if effort increases.

(c) The optimum mesh size increases with fishing effort. Thus Table 11E shows that the optimum mesh is at 4" or less at low fishing intensities (F=0.2)and increases up to 6" or more at high intensities (F=0.8).

It is also worth noting from these tables that where there is a long-term gain at present effort levels, it increases roughly in proportion to the increase of trawler effort when the immediate losses are not large, but more rapidly when the immediate losses are higher.

11.10 The above analysis of the effects of increased fishing effort are based on the supposition that the <u>distribution</u> of fishing on fish of various sizes remains unchanged. The decreases in catch per unit effort followi such increases will, however, be much more marked among the larger fish than the smaller, and it is reasonable to suppose that in an attempt to maintain their catch per unit effort as effort increases, vessels will tend to fish more where the smaller fish predominate. In addition to this redistribution of effort which might result indirectly from increases in the amount of fishing, it is also possible that freezing at sea and other developments in fish processing may reduce the minimum size of fish which is commercially acceptable. In either event, the consequence would be that smaller fish would become relatively (and probably absolutely) more numerous in the catches, and so make the fishery much more sensitive to changes in mesh size. Although no quantitative prediction can at present be made of these effects, they may well prove more critical than the direct effect of increases in effort.

SECTION 12. OTHER METHODS OF REGULATION

12.1 In its terms of reference (para 2.1), the Working Group was asked to advise specifically on "... the minimu fish sizes appropriate to the minimum mesh sizes postulated", and also to refer to..." the possible benefits to be obtained by other conservation methods".

12.2 If most or all undersized fish which are caught and then discarded at sea survive, a minimum size limit could be a direct and effective alternative to mesh regulation as a means of increasing the size of first capture. This is probably true for halibut, if handled on board with due care (see Sect. 9), but for the main species of the I.C.N.A.F. area (cod, haddock and redfish) it is most unlikely that any appreciable number of discarded fish would survive, especially if caught by trawl. If a minimum legal size limit is to be of any conservation value for these species, it must therefore serve one or other of the following functions:-

(a) to discourage fishing on grounds which contain only or mainly small fish of sizes it is wished to protect.

(b) To discourage fishermen from reducing their effective mesh size below that prescribed by regulation, by causing the extra catch which they would thereby obtain to consist mainly or wholly of undersized fish which could not be landed.

12.3 To assess properly the first of these possibilities requires detailed information on the catches and catch per unit effort of fish of various sizes, over quite small time intervals, which distinguishes catches by individual vessels or groups of vessels fishing together. It might then be possible to determine whether there are, indeed, particular grounds from which substantial quantities of small fish are taken and, equally important, whether there are alternative grounds containing larger fish to which the same vessels could move at that season without suffering too great a decline in catch. In such cases, an appropiate size limit might well be effective in encouraging vessels to fish less on the small fish grounds and so produce an effect comparable to an increase of mesh. A certain amount of information of this kind is probably available for the I.C.N.A.F. area, but it has not been asked for by the present Working Group and could not, in any event, have been processed or studied in the time available.

12.4 The second possible function of a size limit, that of acting as an adjunct to the enforcement of a mesh regulation, does not, of course, arise unless the mesh regulation could not otherwise be enforced, or enforced only with difficulty. If other means of enforcing a mesh regulation are ineffective, and smaller than legal meshes (either actual or effective, e.g. by the use of "blinders") are in common use, it is presumably because there is a market demand for small fish which are released by the legal mesh. A size limit could, in such a case, eliminate the incentive to use any smaller mesh if it were set high enough to cause most or all the fish released by the legal mesh to be undersized. Unfortunatley, mesh selection is not sharp and fish are released over quite a wide range of size. Consequently, setting a minimum size equal to that of the largest fish released by the legal mesh would result in that mesh unavoidably catching many fish below the legal minimum. All these fish would have to be discarded, and this would cause a wastage which in certain circumstances might well outweigh the gain to be expected from the legal mesh.

12.5 It was considerations such as these which led the Ad Hoc Committee set up by the Permanent Commission in 1955 to conclude that they certainly could not recommend size limit as an alternative to mesh regulation (Ad Hoc Report, 1957). They recommend that if size limits are thought to be essential as an adjunct to the enforcement of a mesh regulation by direct means, they should be set at or near to the 50% selection point of the legal mesh for the species in question. On the assumption that this could result in the legal mesh being used, the Committee gave some examples of the extent to which such a size limit, if rigorously enforced, would reduce the long-term gain which could otherwise have been obtained from that mesh.

12.6 It must be concluded that to rely on a size limit as the sole means of enforcing a mesh regulation is of problematic value, since its effect will depend critically on how fishermen adjust their size of mesh in response to it- which cannot be predicted with any certainty and may result in substantial wastage. Given a reasonably good standard of direct enforcement, however, a size limit set at, or near to, the beginning of the selection range of the legal mesh could have some additional enforcement value without involving much wastage. It would, for example, act as a deterrent against any flagrant breach of the regulations such as might arise from "blinding" of the legal sized codend, a procedure which otherwise might not be easy to detect.

12.7 On other methods of regulation it is possible only to offer some general comments. The conservation effect of any regulatory measure must either be to adjust the size at first capture or to control the amount of fishing, or possibly both. Thus closed seasons and closed areas can, if suitably chosen, have the direct effect of protecting small fish; they could also influence the total amount of fishing in an area, although not necessarily in the most economic way. To evaluate these two methods would require information similar to the kind specified in para. 12.3.

12.8 It is scarcely possible, in the present state of knowledge, to make any detailed statement on the conservation value of, or need for, control of fishing effort in the I.C.N.A.F. area. One general impression does, however, emerge from the investigations on which this report is based, namely that up to 1958 at least, the fishing intensity on most of the stocks of cod and haddock could be described as moderate, and not as heavy as in some other areas of the North Atlantic. Thus it can be taken, as a rough guide, that the long-term catches would be rather insensitive to moderate changes in the amount of fishing, either upwards or downwards, from the 1958 level. The two examples given in Sect. 11 illustrate this point. As a corollary, it follows that the catch per unit effort would be expected to vary roughly inversely with the amount of fishing. As mentioned in Sect. 11, however, assessments of the effect of changes in the amount of fishing make greater demands on data than do those of moderate changes in mesh size, and for many of the stocks in the I.C.N.A.F. area it is not yet possible to draw any definite conclusions on this question.

SECTION 13. RECOMMENDATIONS FOR FUTURE WORK

13.1 While the assessments presented here are as good as can be made with the information and methods at present available, there are many gaps in data and knowledge which need to be filled to make them more precise and reliable. These needs may be divided into three categories.

(a) Collection of basic data (catches, discards, length composition) where these are at present scanty or absent.
(b) Analysis of these basic data and other material to give better estimates of the parameters used in the assessments; in particular, the division of total mortality into fishing and natural mortality.
(c) Study of more complex effects than those considered in the simple models used, e.g. density dependence, and environmental factors.

For the first it is possible to detail certain particular items needing attention but for the others the recommendations are of a more general nature.

13.2 Basic data

13.2.1 Length compositions of landings. For purposes of assessment it is necessary to have some information for every significant component of each fishery. This information is especially critical for: (i) gears other than trawl which may be expected to be catching fish of sizes differing substantially from those caught by trawl, (ii) fisheries in which there are marked seasonal changes in the sizes of fish caught or landed, (iii) trawl fleets among which there are likely to be substantial differences in discarding practice. The following instances have emerged where more data are urgently needed:-

Cod

Inshore lines and traps in sub-area 2,
French trawl catches in all sub-areas,
Spanish otter and pair-trawl catches in sub-areas 3 and 4 (no data for pair-trawl, otter-trawl not reported since 1957 and then only for sub-area 3),
Portuguese dory catches in Sub-area 3 (more continuous coverage needed in all sub-divisions),

Canadian line-fishery (mainland) in Sub-area 4 (fuller coverage needed), U.S. and Canadian otter-trawl in Sub-area 4X (no U.S. data, fuller coverage needed for Canadian).

U.S.S.R. trawl catches in Sub-division 3M: and also age-composition data for this sub-division and for Sub-areas 1 and 2. (This stock is believed to be relatively very lightly fished at present, and hence catch compositions provide an opportunity to estimate M, which should not be lost).

Haddock
Spanish otter-trawl and pair-trawl in Sub-areas 3 and 4 (no pair-trawl data, otter-trawl data reported only until 1957 and for Sub-area 3).

Redfish
Sub-areas 1,2 and 3 (no data for Icelandic catches, U.S.S.R. data needed in 1 cm groups, and more intensive sampling by all countries in Sub-area 1). Sub-divisions 4R, S, T: Canada (mainland).

Halibut
Trawl catches in all sub-areas (length compositions needed to assess possible benefit of size-limits).

Redfish catch and effort data
The Group concluded that to assess the effects of fishing on the redfish stocks it will be necessary to have commercial statistics of catch and effort broken down into the smallest practicable division of time and fishing grounds. It was thought that information on fishing depth is especially important even if it can be collected only on a sample basis.

Mesh sizes in current use

Information is required about the mesh sizes being used in the unregulated trawl fisheries of Sub-areas 1 and 2, and also in those trawl fisheries of Subareas 3,4 and 5 where meshes larger than the regulation size are being used. This information should be accompanied by descriptions of adaptations of the gear which might greatly influence its selectivity, such as the use of double cod-ends and top-side chafers.

13.2.4 Discard data and age-length keys

The Group recognises that I.C.N.A.F. is actively promoting the collection and presentation of these data, and wishes merely to underline the importance of this project and to mention that the data of discards and age-length keys already available have been of great value in their work on assessments. Particular attention is drawn to the continuing importance of obtaining detailed information about discards in all components of the Sub-area 3 haddock fishery (there are, for example, no data available at present for the Spanish fishery) where the culling point is well into the size range of fish in the catches and discarding practice may vary greatly according to the composition of the stock at the time.

13.3 Estimation of parameters

13.3.1 Few of the parameters, particularly natural mortality, used in the assessments have been estimated with very great precision. This lack of precision is particularly important in some regions, either because the degree of uncertainty is large, or because the assessments are critically dependent on the precise value of the parameter concerned.

13.3.2 Stocks where doubt concerning the separation of total mortality into its components seriously affect the assessments as shown by differences in the direction of the long-term change in the assessment tables, include:-

Sub-area 2. Cod: No separation yet possible.
Divisions 3K and L. Cod: For 5½" mesh and larger.
Division 3M. Cod: No separation yet possible.
Division 3P. Cod: For 6" mesh.
Divisions 3N and O. Haddock: 5" mesh and larger.
Divisions 4V and W. Haddock: 5½" mesh and larger.
Sub-area 5. Cod: All meshes.
Sub-area 5. Haddock: All meshes.

as well as redfish in all areas (though it is clear in some that a mesh larger than 5" would involve substantial long-term losses). One method of separating natural and mortality will clearly continue to be the collection and analysis of series of the basic data of catches, fishing efforts and mortality, but this cannot easily be speeded up. Tagging experiments can give fair estimates of fishing mortality within a few years; these are most likely to be useful where no estimate of F is yet available (cod Sub-area 2, Division 3 M), or where the possible values cover a wide range (e.g. two-fold range for haddock in Divisions 4V and W).

13.3.3 Other research projects, specific to particular stocks, which would be useful in improving the assessments include:-

(a) <u>Cod (Sub-area 1).</u> Tagging in Cape Farewell area and East Greenland to improve knowledge of mixing with Icelandic and West Greenland stocks.
(b) <u>Cod (Sub-area 3).</u> Offshore tagging to obtain a measure of the extent of movement onshore.
(c) <u>Cod (Sub-division 4X).</u> Winter tagging to permit a better interpretation of recaptures in relation to age-composition data.
(d) <u>Redfish (S. marinus).</u> Estimation of order of magnitude of the resource, for example by echo sounding and larval abundance surveys.
(e) Redfish (all Sub-areas). Appraisal of whether meshing is likely to become critically important with increases in mesh size, having regard to the greater use of synthetic materials.
(f) <u>Halibut</u>. Measurement on research vessels of the possible survival of small trawl-caught halibut after discarding, and an appraisal of the likelihood of achieving an adequate survival of fish if they were to be discarded from commercial vessels. Further tagging, with the main object of estimating fishing mortality. Exchange of experience of tagging techniques for halibut would be desirable; this point could conveniently be considered during the Tagging Symposium.

(g) <u>Trawl selectivity</u>. The Group has been unable in the time available, to make a critical evaluation of all existing data (see App.II), but certain outstanding needs have emerged. In particular there are still no data for selectivity of large trawlers, pair-trawlers and multiple cod-ends. There are also no selectivity data for redfish in Sub-areas 1 and 2, for cod in Sub-areas 2 and 4X, or for yellowtail in Sub-area 5. In other cases there are limited data, but these are insufficient; thus for cod in Sub-area 1 the only data refer to one season (not the main fishing season) at which it is known that the condition factor is much higher than during the fishing season. Gaps as big as these need to be filled by direct experiment, but it is scarcely practicable to expect that sufficiently accurate experimental data could be obtained for all stocks and areas at all seasons. For a given species, however, knowledge of the variation in the weight-length relation of ungutted fish can be applied to limited experimental data to arrive at a working value for the selection factor which is reasonably representative of the fishery. For this purpose it is proposed that weight-length data be obtained for the important species in all sub-divisions at all seasons.

(h) Selectivity of gears other than trawl. Whilst recognising that studies on this matter are being undertaken, the Group wishes to point out that for the immediate purposes of assessment the need is for comparative data on the length composition of catches taken by hook and trap meshes of various sizes including those in present commercial use.

13.4 Changes in environment

13.4.1 Clearly, changes in the environment might have an appreciable effect on the assessments, which have been made on the basis of unchanged conditions. Environmental changes are only readily taken into account if their effects are expressed in terms of changes in one or more of the basic parameters-recruitment, growth, and natural mortality, and also fishing mortality in so far as the mortality caused by a given fishing effort is altered (availability). Changes in these various parameters are not of equal influence on the assessments. Thus, the assessments given in this report are essentially in terms of "yield per recruit", i.e. they compare not so much future yields with present yields, but future yields with the present mesh with the yields which might be obtained, over the same period, if a larger mesh were used; hence changes in recruitment will not affect these assessments. An exception occurs when the amount of fishing depends critically on the strength of the year-classes in the fishery, there being little or no fishing when year-classes are weak - the St. Pierre Bank haddock fishery is the outstanding example. In such a fishery the best yield per recruit from a single year-class might be taken with a large mesh, with fishing extending over the full life-span of the year-class after it has entered the commercial catches. In the later years of its life, however, the yield from that single year-class would have become low, and unless there were other year-classes following along, fishing would cease because the catch per unit effort it could provide would have become unprofitable. In practice, the best attainable yield per recruit from a single year-class would therefore be taken by using a smaller mesh, and fishing for only a year or two. In such a fishery, but probably only in such a fishery, changes in recruitment affect the results of a mesh change, and some preditction of future year-class strength would be desirable for more accurate assessment.

13.4.2 Growth changes have a greater influence on the assessments. The rate of growth over the selection range affects the numbers reaching the retention size of the new mesh; thus slower growth reduces the long-term gain, though the latter is generally insensitive to small growth changes. However, if the ultimate size which the fish can attain is not much greater than the retention size, a reduction in growth may mean that few fish grow big enough to be caught by the larger mesh. A smaller mesh will then be better, even if the larger is best for the original growth. Again, the St. Pierre Bank haddock provides an example of such growth changes. In this and any other stock in which the ultimate size of fish changes appreciably, and is not well above the mesh selection size, studies, and if possible predictions, of growth changes are most desirable.

Changes in natural mortality could greatly influence the assessments - an increased natural mortality reducing, perhaps critically, the gain in landings from a larger mesh. However, in the I.C.N.A.F. area there have been as yet no clear examples of changes on natural mortality among the adult fish. In some fringe stocks - cod in Sub-area 1, haddock in Sub-area 3, survival of the young stages is most variable giving greatly variable year-classes, but once a good year-class of fish enters the fishery their survival in these fringe areas appears reasonably constant and no worse than that of fish nearer the centre of distribution of the species. Studies of change in natural mortality are therefore not obviously urgent, and so long as it is still difficult to obtain any estimates even of the average level of natural mortality such studies are unlikely to add to the reliability of the assessments in the immediate future.

13.4.4. Changes in "availability", which alter the fishing mortality for a given effort, of course have formally the same effect on mesh assessments as changes in fishing effort. Short-term fluctuations in availability, even though they may critically determine the success of fishing operations from one year to the next, are of less significance in this context than a slow trend, which can only be detected by establishing a change in the fishing mortality rate generated per unit effort.

13.5 Density-dependent effects

13.5.1. Even when the environment is unchanged, the various parameters are liable to be influenced by changes in the stock abundance brought about by fishing effort or mesh changes. Increased stock abundance (e.g. due to a mesh increase) might be expected to increase in some degree the natural mortality rate, reduce growth and increase the number of recruits; it is possible, if unlikely, that increased stock could give a smaller recruitment. These changes act in opposite directions, the first tending to decrease the gain landings from an increase in mesh, and the recruitment effect increasing them. The former have a damping effect and tend to reduce any changes in population abundance caused by fishing.

13.5.2. Estimates of changes in population abundance are therefore likely to be qualitatively correct; however, reduced growth or increased mortality will reduce the proportion of the total population which is within the selection range of the mesh, and may make the assessments incorrect. Such effects are most important either when gains and losses are closely balanced (i.e. when the mesh size is near the maximum of the yield-mesh curve, in which case they will reduce the size of the mesh giving the maximum yield), or when the mesh selection size is close to the ultimate length to which the fish are growing. Because of the difficulty of measuring natural mortality it is likely that studies of density dependent growth will be the more immediately rewarding.

13.5.3. Density-dependent recruitment, though not necessarily more important in any given stock, has potentially a more critical effect, as it tends to exaggerate changes in population size. However, the effect is to make the present assessments conservative, causing them to underestimate both the landings with larger meshes, and the optimum mesh size.

Study of the relation between stocks and recruitment by normal correlation methods is rendered difficult by the variation in the data - both real, and observational - and the fact that each year can give only one pair of observations in each stock. It is suggested that at least the general importance of stock-recruitment dependence on the I.C.N.A.F. area might be more easily determined by considering together all available data from all stocks of each species. The general mechanism underlying the relation may also be profitably studied by intensive research on the early stages of life in one particular stock (preferably one where variations in survival from other causes are not too great).

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