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Extracts from Report of ICES Liaison Committee to North-East Atlantic Fisheries Commission[1] 1968

A. REGION 1 FISHERIES

A.1 Assessment of state of Arctic cod and haddock fisheries

In reports presented at recent meetings of this Commission and of ICNAF[2)], it has been shown that in addition to the enforcement of the minimum legal size and mesh-size regulations already employed in the Convention area, there are two main types of regulatory measure by which control of the fishing mortality rate (as distinct from the age at which they recruit to the fishery) in fish stocks exploited in international fisheries may be achieved. These are (a) by controlling the total catch taken from the exploited stock (catch quotas), (b) by limiting the total amount of fishing effort expended by the fishery.

At its last meeting the Commission requested advice on the statistics required to make assessments of the state of the fish stocks from time to time in view of the possible introduction of such measures. In its consideration of this request the Liaison Committee took as its main tasks:-

(1) to assess the present state of the exploited stocks of cod and haddock in Region I of the Convention Area, relative to the amount of fishing effort and to estimate the immediate and long-term effects on catch and catch-per-unit-effort of changes in fishing mortality rate, and at the same time to bring up to date earlier assessments of the effects of changes in mesh size,

(2) to examine what statistics and biological data and knowledge would be necessary for the establishment

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The full Report was presented to the 6th Meeting of NEAFC as Document NC6/80.

2) The following reports are of special relevance:

(a) "Review of Possible Conservation Actions for the ICNAF Area". ICNAF, Comm. Doc. 65-12.

(b) "Regulation of Fishing Effort. Memorandum by the United Kingdom Delegation". NEAFC Doc., N.C. 4/51. ICNAF Comm. Doc. 66-17.

(c) "Report of the Working Group on Joint Biological and Economic Assessment of Conservation Actions". ICNAF Comm. Doc. 67/19.

of effective regulations controlling fishing mortality rate and to assess their current availability for the fisheries on cod and haddock in Region 1.

Arrangements were made for the first of these tasks to be dealt with by the North-eastern and North-western Arctic Working Groups for the north-east Arctic and north-west Arctic (Iceland) cod and haddock stocks respectively. The results of these assessments are summarised in Sections A.1.1 and A.1.2 while the detailed reports of the working groups are attached as Appendices I and II. The second task was considered afterwards at a short, joint meeting of these Working Groups, and the results of these considerations are set out in Section A.1.3.

A.1.1 North-east Arctic fisheries (Appendix I)

Arctic cod

Landings and fishing effort (App. I, Tables 1-3)

In the period 1946-1963 the total landings of cod from the north-east Arctic fluctuated about a mean of about 800,000 tons. In the years 1964-1966 however the average decreased by 45% from the 1961-63 level to 450,000 tons. The decrease was greatest in Subarea I and Division IIb, where the fisheries are based upon both immature and mature fish, the landings decreasing by 50%. In Division IIa, where the fishery is based predominantly on mature fish the landings decreased by only 15%.

In the period 1964-66 the total fishing effort decreased from the 1961-63 level in each of the main fishing areas. In Subarea I it decreased by approximately 40%, and in Division IIb by at least 10%. The available data indicate a decrease of 20% in Division IIa. These changes represent a decrease of 25% in the effective fishing effort for the north-east Arctic cod fishery as a whole, bringing it to the level of the late 1950's. The sharp drop in landings since 1963 is mainly attributable to this decrease, which, if maintained will lead to some recovery of the stock, although the actual yields during the next few years will be governed by the strength of the recruit year-classes, which are known to be poor.

Size and composition of the stock (App. I, Table 4)

Estimates of catch per unit effort show that the stock abundance in Subarea I was less in 1964-1966 than in the period 1961-1963, and that in Division IIb it remained at its lowest level since 1946. In Division IIa the catch-per-unit-effort has remained almost steady in recent years, largely due to the recruitment to the spawning stock of the strong 1958 year-class. The mean age and length of the landings in 1966 were very low. USSR landings from Subarea I and Division IIb contained a greater proportion of small fish than those for Norway and the U.K. from these fishing areas. However, when allowance is made for differences in the rejection rates for the different countries the length compositions of the catches from these areas were closely comparable for all countries.

Estimates of total mortality rate (App. I, Table 5)

Estimates of total annual mortality rate were obtained from catch-per-unit-effort and age composition data for the fisheries in Subarea I and Division IIb for the periods 1962-1964 and 1964-1966. Values of approximately 70% (instantaneous rate = 1.2) for the earlier period and 55% (instantaneous rate 0.7) for the later one, were obtained. This decrease reflected the decrease in fishing effort since 1963. In the assessments of the effects of changes in fishing mortality rate, value of instantaneous natural mortality rate of 0.3 for all age-groups and instantaneous fishing mortality rates, varying with age between 0.02 for age 3 and 1.13 for age 10, were used.

The effect of changes in fishing mortality rate (effective fishing effort (App. I, Table 6, Figs. 1 & 2)

Assessments were made of the effects on long term catches of changes in fishing mortality rate applied proportionately in all main sections of the total fishery on north-east Arctic cod. On the assumption that the mesh size in use, the pattern of fishing and the growth rate of cod remain as at present, the results of the assessments showed that the maximum equilibrium catch-per-recruit would be obtained by reducing the effective fishing effort by one third from its present level. At this level of fishing effort, the equilibrium catch-per-recruit would be about 5% greater than at present. Further, if the average level of recruitment remains the same as in the past, the size of the spawning stock in Division IIa would be doubled and the immature and

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non-spawning stocks in Subarea I and Division IIb would increase by 50%, resulting in corresponding increases in the catches-per-unit-effort in the fisheries in these areas.

Variation in year-class strength (App. I, Tables 9 & 10, Figs. 4 & 5)

Estimates of the relative strength of cod year-class prior to their recruitment to the exploited stock are obtained each year from research vessel trawling surveys carried out in Subarea I and Division IIb. The estimates for the 1965, 1966, and 1967 year-classes, on which the fisheries in areas I and IIb in the early 1970's and in area IIa in the mid 1970's will be mainly dependent, show them all to be extremely poor. The prospects for these fisheries are, therefore, not good, and it is expected that the size of the spawning stock of cod will by the mid 1970's decrease, perhaps to as little as 5-10% of its average size during the 1950's.

Effects of mesh changes (App. I, Tables 7-9 and Fig. 2)

Data reported by countries of the mesh sizes in use in the north-east Arctic trawl fisheries in 1965 and 1966 indicated that in general the mean mesh-sizes in cod-ends measured in 1965-1966, were in conformity with the regulations. However, it is known that topside chafers of varying designs are in common use in these fisheries, and that therefore the effective mesh size of the trawl fishery as a whole is probably less than the one prescribed by the convention. In the assessment of the effects of changes in mesh size, a reduction of 10% in overall selectivity was assumed, due to the use of topside chafers, which gave values of 110 mm for manila/polypropylene and 100 mm for polyamide as the effective mesh sizes in use during recent years.

The results of these assessments showed that, assuming the same pattern of fishing and fishing mortality rate as at present, equilibrium catch per recruit and catch-per-unit-effort for the fishery as a whole would increase from the present level with increases in trawl mesh size up to at least 160 mm. The greatest gains would accrue to the spawning fishery in Division IIa, the gains for which would increase over the whole mesh size range, but the trawl fisheries in areas I and IIb would not experience gains beyond an effective mesh size of 130 mm.

Arctic haddock

Landings and fishing effort (App. I, Tables 11-13)

The total landings of haddock from the north-east Arctic dropped from 176,000 tons in 1961-1963 to 125,000 tons in 1964-1966, and as for cod the majority of the decrease took place in Subarea I. As in the cod fishery the estimated total fishing effort in 1964 and 1965 decreased from the previous high level, but it increased again in 1966. This may have been due to a higher proportion of the total effective effort in 1966 being deployed on haddock, because of low cod abundance.

The reduced catch since 1963 was due mainly to the reduction in fishing effort and to relatively poor recruitment to the exploited stock. The latter has also prevented any improvement in catch-per-unit-effort following the reduction in total fishing effort since 1963.

Assessment of effects of changes in fishing mortality rate (effective fishing effort) (App. I, Table 6, Fig. 6)

The results of assessments of the effects of changes in fishing mortality rate in the exploited haddock stock, assuming the same mesh size and natural population parameters (growth and natural mortality rates) as at present, indicate that no decrease, and perhaps a significant increase in equilibrium catch per recruit would result from decreases of up to a half in fishing mortality rate (effective fishing effort) from the present level. Catch-per-unit-effort would increase approximately proportionately.

Fluctuations in year-class strength (App. I, Table 14)

Postwar data on the relative strength of year-classes of north-east Arctic haddock show that their strengths have fluctuated widely. Although no identifiable trend in year-class strength has been observed since 1946, the data show that in recent years there has been an unprecedented run of six poor year-classes, which will have an adverse effect on the fishery in the immediate future.

Assessment of effects of changes in mesh size (App. I, Fig. 7)

Assessments of the effects of increases in effective mesh size on haddock catches and catches-per-unit-effort, using the same estimate of the effective mesh size currently in use as for cod showed that increases in total equilibrium catch and catch-per-unit-effort by the haddock fishery as a whole would result from increases in effective mesh size to 160 mm. The assessments also show that increases in equilibrium catch, perhaps by as much as 15% would be achieved by increasing the effective mesh size currently in use to 130 mm, as prescribed by the convention.

Summary of Assessments

It is evident from the above that despite a significant decrease in fishing effort since 1963, both the immature and adult members of the north-east Arctic cod stock are heavily exploited, and the number of age-groups in the exploited stock has been severely reduced, making the fishery more sensitive to changes in year-class strength. As indicated above, the available evidence indicates that the three most recent year-classes are very weak ones, with the result that at the present level of fishing mortality rate, the spawning stock will be reduced to a very low level by the mid 1970's. Since on theoretical grounds one has to accept that at least at some very low level of spawning stock, recruitment becomes directly dependent on spawning stock size, this raises the important question whether, at this low level of spawning stock the level of recruitment will be directly affected. Unfortunately, very little is known about the relationship between spawning stock size and the number of recruits in fish, and particularly in cod, but one might wonder whether the expected, exceptionally low level of spawning stock size in the 1970's might lead to another series of poor year-classes. The Committee wishes to stress that effective regulations introduced now would lessen the dangers of these possible serious consequences being realised.

The prospects in the immediate future for the haddock fishery is similar to that for the cod. A succession of six poor year-classes will lead to a reduction in catch and catch-per-unit-effort during the next few years, but regulations introduced now would result in higher catches than would be obtained with the continuation of the present high rate of exploitation in the absence of regulation.

A.1.2 North-west Arctic Fisheries (Appendix 2)

Iceland cod

Landings, fishing effort and catch-per-unit-effort (App. 2, Tables 1-3)

Total landings of cod from Iceland grounds have shown a declining trend since the mid 50's to reach 357,000 tons in 1966, compared with an average of 483,000 tons in the period 1955-1960. Similarly, the average catch-per-unit-effort of the trawl fisheries also declined during this period while the total fishing effort increased, although it declined somewhat in 1966 from the previous high level. While the decrease in catch-per-unit-effort and total yield can be attributed in part to the increase in the rate of exploitation of the cod stock, it is also partly due to a decrease in the level of recruitment to the stock as a result of a series of poor year-classes.

Mortality rates (App. 2, Tables 7-9)

In the previous assessments made by the North-western Working Group (Coop. Res. Rep. Ser. B. 1966), total annual mortality rates of about 60% for immature cod and 70% for the mature stock (instantaneous rates = 0.92 and 1.2) were estimated. A further study of these and more recent data has shown, however, that for a stock which experiences a 60% annual mortality rate (and has a constant natural mortality rate) the numbers of 3-6 year-olds (immature) and mature 7 year-olds and older (mostly mature) fish caught should be in the ratio: 1:0.026. The observed ratio of the numbers for Iceland cod in recent years has, however, been 1:0.5, indicating a much larger number of mature cod than expected, on the basis of a constant mortality rate of 60%. This discrepancy could by explained in either of the following ways:-

(a) the stock of immature cod fished at Iceland forms the main body of pre-recruits to the mature stock and their annual mortality rate is, in fact, substantially less than that of the adults,

(b) the part of the immature stock exploited at Iceland experiences a mortality rate of about 60%, but this does not constitute the whole of the immature stock which subsequently recruits to the mature stock.

While it is known that, at least in some years mature cod migrate from Greenland to Iceland at the onset of spawning, thereby providing in these years, at least part of the additional supply, its magnitude, and the variations in it are not known; nor is it known whether there are stocks of immature cod at Iceland which are not exploited by the trawl fisheries. In view of these uncertainties, and in the absence of sufficient evidence to the contrary, the assessments of the effects on long term catch and catch-per-unit-effort in the cod fishery of changes in fishing mortality rate and of mesh size were made on the basis of the first of the above alternatives, but the effects of the second alternative on the results of these assessments were also considered especially where they were likely to be substantially changed in direction or magnitude.

The assessments were made for three values of natural mortality rate for all age groups (0.05, 0.15 and 0.3) of which the central value of 0.15 is considered to be nearest to the true average value.

<u>Assessment of effects of changes in fishing mortality rate (effective fishing effort)</u> (App. 2, Tables 10-13 & Fig. 3).

Different age-groups in the exploited cod stock at Iceland are fished by different components of the total fishery. The immature members (mainly age groups 3-6) are fished principally by the trawl fisheries (mainly UK and Germany), while the mature members (mainly age groups 7 and older) are fished principally in the spawning fishery, almost exclusively by Iceland. Since the effects of changes in fishing mortality rate (effective fishing effort) will differ according to which component of the total fishery is changed, the assessments were made on the following three bases:

(a) proportionate changes in both the immature and mature (spawning) fisheries,

(b) changes in the spawning fishery only, the fishery on immatures remaining unchanged,

(c) changes in the fishery on immatures only, the spawning fishery remaining unchanged.

The results of these assessments, which are set out in detail in Appendix 2, Tables 10-12, are summarised below, on the assumption that the average level of recruitment remains approximately the same as in the past, and that a constant natural mortality rate of 0.15-0.2 applies throughout the exploited life-span.

(a) Proportionate changes in immature and mature fisheries

A smaller increase in long-term average, total catch for all fisheries combined would be expected to result from a decrease of up to 60% in effective fishing effort, while it would decrease with increase in fishing effort. Large gains in average catch and catch-per-unit-effort would accrue to the fishery on mature cod, but the fishery on immature cod would experience substantial losses in average catch, although catch-per-unit-effort would increase.

The changes in catches on the basis of the alternative hypothesis regarding the distribution of immature fish cannot be estimated accurately in the absence of more precise information of the relative sizes of the exploited and unexploited parts of the stock of immatures, but the gains to the spawning fishery would be less than on the basis of the hypotheses used above.

(b) Changes in spawning fishery only

A decrease in effective fishing effort in the fishery on mature cod, by up to 60% from its present level, would lead to gains in long term average catch and catch-per-unit-effort in the fishery on immatures, but the catch in the fishery on mature cod would decrease. In fact, the catch in the latter would increase with an ancrease in fishing effort, although in that event, the catch in the fishery on immatures would decrease. There would be little change in the average total catch of all fisheries combined with either a moderate increase or decrease in fishing effort.

These expected changes would be broadly the same on the basis of the alternative hypothesis regarding the distribution of immature fish.

(c) Changes in the immature fishery only

Decreases in effective fishing effort in the immature cod fishery would lead to large gains in long-term average catch and catch-per-unit-effort in the fishery on mature cod, but the average catch in the fishery on the immatures would decrease significantly, although its catch-per-unit-effort would increase. The average total catch of all fisheries combined would increase. An increase in effective fishing effort would result in a decrease in average total catch of all fisheries combined and to the fishery on mature cod, but an increase in the catch of the fishery on immatures.

The alternative hypothesis regarding the distribution of immature fish would result in smaller losses to the immature cod fishery and also smaller gains to the mature cod fishery than on the basis of the hypothesis used in the above assessment. However, the direction of the changes would be expected to be the same.

In summary, therefore, these assessments indicate that gains in long-term total average catch for all fisheries combined and in catch-per-unit-effort would be likely to result from moderate proportionate decreases in effective fishing effort in all fisheries exploiting Iceland cod, or from a decrease in the fishery on immature cod only. However, the gains would not be shared equally by all components of the total fishery. Indeed, they would accrue solely to the mature cod fishery, which would experience large gains, while the fishery on immatures would suffer losses in total catch (although not in catch-per-unit-effort). The catch in the latter fishery would increase from a decrease in fishing effort in the spawning fishery, but this would be at the expense of larger losses to that fishery and a small overall loss in the total catch of all fisheries combined.

In presenting the results of these assessments, the Liaison Committee wishes to draw the Commission's attention once more to the present uncertainty regarding the distribution and movements of immature cod, which subsequently recruit to the mature stock exploited at Iceland. While new information, following further research, may alter the estimated magnitude of the effects of changes in effective fishing effort, the Committee considers that it would be unlikely to change the direction of changes in average catch given above.

In relation to further scientific study and assessment of the cod stock at Iceland, the Liaison Committee endorses the recommendations of the North-Western Working Group (App. 2, p.7) and those of the "Icelandic proposal" Working Party set up by the Commission at its last annual meeting.

Assessment of effects of changes in mesh size (App. 2, Table 14)

The earlier assessments made by the North-western Working Group (Coop. Res. Rep. Ser. B 1966) on the immediate and long-term effects of changes in mesh size in the cod fishery at Iceland showed that long-term gains in total catch would be achieved with increases in effective mesh size up to, at least 160 mm (manila); the gains would be greatest for the fishery for mature cod, pursued principally by non-trawl gears and least for the UK trawl fishery based mainly on immature fish for which no gains would be achieved at effective mesh sizes above 130 mm (manila). On the basis of the lower estimates of fishing mortality rate for the immature cod stock, used in the most recent assessment, the expected gains in catch for increases in mesh size would be somewhat lower than those estimated previously, so that, while small gains in total catch would be expected to accrue to the fishery for mature cod and the total fishery with increases in effective mesh size up to 160 mm, the trawl fishery for immature cod would be expected to suffer losses in long term catch for effective mesh sizes above 130 mm.

As in the northeast Arctic the use of topside chafers is known to be widespread in the trawl fisheries at Iceland, which therefore reduces the effective mesh size in use at the present to below the convention minimum of 130 mm (manila).

Iceland haddock

Landings and catch-per-unit-effort (App. 2, Tables 15 & 16)

During the years 1960-1965, haddock landings from Iceland were the highest on record, averaging 103,000 tons, compared with 62,500 tons for the period 1950-1959. In 1966, however, the landings decreased sharply to 60,000 tons, the lowest recorded since 1963. A steady decrease in catch-per-unit-effort in the English, German and Icelandic trawl fisheries has taken place since 1962, to reach its lowest recorded level in 1966.

The relatively very high landings in the years 1961-

1963 were due mainly to good recruitment from the strong 1957 year-class, and the decrease since then, and especially in 1966, was due principally to the reduction in its number. During the years 1960-1965, the total fishing effort on haddock remained at a high level.

Assessment of the effects of changes in fishing mortality rate (effective fishing effort) (App. 2, Table 22 and Fig. 5)

Assessments were made of the effects on the long-term average catch of haddock, of changes in fishing mortality rate (effective fishing effort), using values of instantaneous natural mortality rate of 0.15 and 0.3, whithin which range the average value for haddock is considered likely to lie. The results of these assessments showed that for the present mesh size in use in the trawl fleets, the fishing mortality rate is close to that giving the maximum, long-term catch per recruit and, assuming the same average level of recruitment as in the past, only small changes in long-term average catch would result from moderate decreases, of up to 40% in effective fishing effort. This indicates that approximately the same average annual catch could be obtained at a substantially lower level of fishing effort than at present, with an associated increase in the catch-per-unit-effort.

Assessment of the effects of changes in mesh size (App. 2, Table 23)

New assessments of the effects of changes in mesh size in the trawl and Danish seine fishery for Iceland haddock, in the light of the most recent stock composition data and results, indicated that no gains in total catch for the haddock fishery as a whole would accrue from increases in effective mesh size above the prescribed minimum of 130 mm (manila) in the Iceland area. While any increase above this level would result in gains to the fishery by gears other than trawl and Danish seine, the trawl and Danish seine fisheries of most countries would suffer small losses.

A.1.3 Data required for regulations controlling fishing mortality rate

A. Catch quota regulations

The success with which a catch quota regulation

(assuming it is properly enforced) can achieve the control of fishing mortality rate on an exploited stock at any desired level is determined by the accuracy with which the values of its biological parameters, governing its abundance and hence the catch which it can yield at the chosen level of fishing mortality rate, can be determined.
The biological parameters concerned are:-

a) the magnitude and pattern of recruitment
b) growth rate
c) natural mortality rate.

Average values of growth and natural mortality rate for a recent period of years during which the fishing mortality rate is known, provide the necessary data for determining the difference between the present catch per recruit and the maximum achievable at a lower or higher value of fishing mortality rate, and hence the reduction in fishing mortality rate necessary to achieve the maximum (or any other catch level). However, the actual catch which can be taken from the stock in any year at the desired fishing mortality is subject to variations due to annual variations in the biological parameters, aspecially the magnitude of recruitment, which must therefore be allowed for when setting catch quotas. The importance of these factors and the current state of knowledge regarding them for the Northeast and Northwest Arctic cod and haddock stocks are summarised below.

Fluctuations in recruitment

It is well known that the total abundance of the stocks of cod and haddock axploited in Region I varies from year to year due to short-term fluctuations in the strength of successive year-classes recruiting to the exploited stock. This is illustrated in Appendices 1 and 2 for the cod and haddock fisheries in the northeast Arctic and at Iceland respectively. They show that annual changes in stock density and catch-per-unit-effort of up to 25-30 per cent, due to this cause, often occur. A knowledge of the year-by-year fluctuations in recruitment in advance of the entry of the new year-class into the exploited stock is therefore essential to allow estimates to be made of annual changes in total stock abundance resulting from them and hence of the adjustments to be made to the total catch quotas. With a regulatory system based on catch quotas alone, failure to make such adjustments to the total quotas during periods of below average recruitment would result in the fishing mortality rate increasing above the desired level and the stock to return towards its pre-regulated state.

Detailed consideration was therefore given to the information available at present on the variations in recruitment to the cod and haddock stocks in the north-east Arctic, and at Iceland, and for the cod stock at East Greenland.

(a) <u>North-east Arctic cod</u>

Three surveys of O-group cod and haddock are carried out in the north-east Arctic each year at the present time. One of these, the USSR trawling surveys, includes data on all pre-recruit agegroups of cod and haddock. A comparison of the relative abundance of 2 and 3 year old fish of successive year classes from this USSR survey with the observed relative abundance of year-classes after recruitment to the fishery shows that agreement is quite good (Appendix 1, Section 6). Thus, data on relative year-class strengths are available at least a year before the cod recruit in abundance to the commercial trawl fishery in the Barents Sea and the Bear Island-Spitsbergen area, and four to five years before they recruit to the spawning fishery off the Norwegian coast.

(b) <u>North-east Arctic haddock</u>

As with the cod, data on the relative abundance of 2 and 3 year old pre-recruit haddock are collected in trawling surveys over the nursery areas in the north-east Arctic by the USSR, and comparison of these estimates with the subsequent observed relative strengths of the same year-classes in the commercial catches shows reasonably good agreement (Appendix 1, Section 9). Again, therefore, data on the strength of a year class are available a year in advance of its entry into the commercial fishery.

(c) <u>Iceland cod and haddock</u>

Trawling surveys have been made by Iceland on the distribution and abundance of young cod and haddock and they give evidence of year-by-year changes in recruitment.

(d) East Greenland cod

No data on the abundance of the year-classes in cod stocks off East Greenland are collected for the period prior to their entry into the fishery, but commercial catch sampling provides estimates of their relative strengths following their recruitment to it.

It is evident therefore that data on the abundance of pre-recruits are currently available for the north-east Arctic and Iceland cod and haddock stocks at least a year before they recruit to the exploited stocks, but no pre-recruit data are available for the East Greenland cod stock. In the latter case, adjustments to catch quotas would have to be made in the light of information obtained during the period when a year-class was recruiting to the fishery.

Pattern of recruitment to fisheries

Information is also required of the pattern of recruitment to the different sections of the total fishery, with particular reference to the range of ages between the first appearance of a year-class in the fishery and their becoming fully recruited (termed, "recruitment range"), and their percentage recruitment at each age within this range. This requirement is of major importance for the north-east Arctic and Iceland cod because not only is the "recruitment range" relatively large, but it differs substantially between different sections of the total fishery. Thus, recruitment of cod to the non-spawning, trawl fisheries in both areas takes place at a lower age than to the spawning fishery conducted mainly with other gears, and the "recruitment range" to the latter is larger. Whilst the pattern of recruitment to the trawl fisheries in both areas varies between quite narrow limits from year to year, that of the spawning fisheries, based on the older age-groups is much less well defined, especially as regards the percentage recruitment at successive ages within the "recruitment range". This aplies particularly to the stock of spawning cod at Iceland, which in some years receives recruits from other areas (e.g. Greenland) the quantities of which cannot be predicted in advance.

As a consequence of the marked differences between the age-compositions of the "non-spawning" and "spawning" components of the total cod stock in the north-east Arctic and at Iceland, fished by trawlers and other gears respectively, a catch quota regulation for these fisheries would necessitate the fixing of separate quotas for each of these components of the total fishery. In the absence of separate quotas fishing would, at times of above average recruitment, tend to be directed towards the smaller fish, resulting in a too high fishing mortality rate on them.

A detailed study of the available data on the patterns of recruitment to the main parts of the total cod fisheries in these areas is required. The same holds for the haddock fisheries although the differences in the recruitment patterns to different components of the total fishery are less marked than in the cod fisheries.

Relationship between stock and recruitment

Uncertainty regarding the degree of dependence of recruitment upon spawning stock size may seriously affect the accuracy with which the magnitude of the effects of a regulatory measure can be estimated, but it does not prevent accurate catch-quotas being fixed provided estimates of year-class strength are made during the pre-recruit phase. In fact, the importance of knowing the form of the relationship between stock and recruitment arises in assessing the potential gains in total yield from a catch-quota regulation, rather than in determining the accuracy with which catch quotas can be fixed.

Density-deptendent changes in growth and natural mortality rate

Short-term changes in growth rate and/or natural mortality rate will affect the accuracy with which catch quotas can be set. Density-dependent changes, resulting in a decrease in growth rate or an increase in natural mortality rate, with increase in stock abundance, are of particular importance in this regard in that, unless allowed for, they would tend to lead to overestimation of the global quota for the fish stock in question, resulting in a tendency for the fishing mortality rate to increase above the desired level.

Growth data for the nort-east Arctic cod stock show that the mean weight of adult cod has increased by about 30% between 1950 and 1965 in association with a decrease in stock-desity (see Appendix 1, Section 5). Changes of somewhat similar magnitude have been observed in the Iceland cod stock since the mid-1930's (see Appendix 2, Section 3d). Failure to take account of changes in growth of this magnitude could lead to quite serious errors in the estimation of the total catch quota required to maintain the fishing mortality rate at the desired level.

It is evident, therefore, that the routine collection of data on the mean weight-at-age of the year-classes within the exploited stock would also be required together with detailed studies of the pattern of growth within successive year-classes, to provide a basis for predicting the weight-at-age of the post-recruit phases from the pre-recruits.

No firm evidence is available of density-dependent changes in the natural mortality rate of the Arctic cod and haddock stocks, but the information which is available suggests that they are likely to be small and therefore, if ignored are not likely to result in serious errors in the estimation of catch quotas, based on average values. Of much greater importance is the accuracy of the mean estimates used in arriving at the quotas.

<u>Summary of requirements for setting catch quotas</u>

a) Year-by-year estimates of the relative abundance of recruits entering each distinct component of the total fishery, sufficiently in advance of their entry into the fishery to allow annual quotas to be fixed.

b) The pattern of recruitment of year-classes to each distinct component of the fishery.

c) The fishing and natural mortality rates for each year-class at successive ages within the exploited stock.

d) The increase in weight and the mean weight at age of each year-class from year to year during its passage through the fishery.

At present the available data on these items are most adequate for the north-east Arctic cod, and least for the East Greenland cod stocks.

Variations in catchability

There remains one further source of variation in catch caused by changes in vulnerability, availability, weather conditions etc., all of which may be grouped under the term "catchability". This fluctuates from year to year in a way which is not yet predictable, but changes in it may affect the catch that can be achieved by a given amount of fishing effort. The main effect which variations in this factor would have on a catch quota system would be that

(a) in years of low "catchability" the total annual quota for the fishery in question might not be achieved by the size of fishing fleet operating in the fishery, which would result in the fishing mortality rate in that year falling below the control value, and

(b) in years of high "catchibility", the quota might be achieved more quickly than expected during the year.

B. Fishing effort regulations

The essential item of information required for a regulation based on direct control of fishing effort is a measure of the total amount of effective fishing effort for the fishery as a whole, and the respective contributions to it of the different main components of the fishery.

The following major problems arise in obtaining these estimates:-

(a) in standardising and combining the effort data for the fisheries of different countries and methods of fishing,

(b) in making allowance for changes in the efficiency of a unit of fishing effort for each group of vessels both within a year, due to seasonal changes in the availability of fish and other factors, and from year to year through changes in fishing power due, for example, to changes in technological developments.

At present a complete study of these problems cannot be made because of the absence of information on fishing effort for some of the important components of the total fisheries in the north-east Arctic and at Iceland. This applies especially to fishing by long-line, gill-net and purse-seine. For such a study the following items of information are required for each component (defined in terms of country, method of fishing, size of vessels and, where necessary season) of the total fishery:-

(a) measures of fishing effort in suitable units, for small areas (e.g. fishing grounds or statistical squares) and time intervals (e.g. weeks or months),

(b) corresponding data on the catches associated with the fishing effort for each component in each area and period of time,

(c) data on the size and age composition of the catches.

It is also essential to specify the degree of refinement of the measures of fishing effort subject to regulation, necessary to ensure that the fishing mortality rate in the exploited stock is maintained at the desired level. For the present purpose fishing effort can be defined as the product of the fishing powers of the individual fishing vessels and the time they spend fishing, and it is necessary to determine the appropriate measures of fishing-power and time which are required to effectively control the fishing mortality rate. Analyses of this problem for a number of trawl fisheries have shown that fishing power is associated with a number of factors relating to the fishing vessel, of which its size (tonnage) and engine power are important, and that for trawlers a reasonably efficient index of fishing power within a national fishery is the gross tonnage of the vessels operating. However, no information on fishing power factors is available for the other methods of fishing employed in the fisheries under consideration (e.g. long-line, gill-net and purse-seine). Similarly, whereas for the trawl fisheries, the most efficient measure of time is the number of hours spent fishing, in the case of purse-seine fishing, there is uncertainty regarding the proportion of the total time spent on the fishing grounds which should be included as "fishing time".

In the Liaison Committee's view, the greatest refinement of the fishing effort measures for any method of fishing which could be handled practicably in a regulation of fishing effort, established by the Commission, would probably be the numbers of "days fished". The principal question then is whether, in the fisheries operating in Region 1 of the Convention area, effective control of fishing mortality rate could be achieved by a regulation based on the total number of standard "days fished" by all components of the fishery combined. As mentioned above a full assessment of this question cannot be made until fishing effort, and associated catch data, for appropriate small area and time period, are available for all components of the total fisheries based on the cod and haddock stocks in Region 1. These are required especially for non-trawl fisheries for cod in the north-east Arctic and at Iceland. Periodic re-assessment of the relative efficiencies of their respective fishing-effort units would be necessary in order that account could be taken of the effects of advances in technological efficiency.

C. Concluding remarks

In the preceding paragraphs attention has been confined to the consideration of the kinds of scientific and technical data required, and their current availability, for the establishment of a system of regulations controlling fishing mortality rate, based on either catch-quotas or direct limitation of fishing effort. No attempts have been made at this stage to draw conclusions regarding their relative merits and demerits, which are governed by political, social and economic factors, additional to the scientific and technical ones dealt with above. The latter mainly determine the feasibility and accuracy with which either type of regulatory system can, if properly enforced, achieve efficient control of fishing mortality rate, and the consequent benefits to the fisheries. It is evident that for both types of regulatory measure, the demands on scientific data and particularly on their accuracy are considerable. This applies particularly to a catch quota system applied by itself, in which if the quotas are set only slightly too high (due to errors in estimation) during the transition period and after the new equilibrium stage is reached, no effective reduction in fishing mortality rate is likely to be achieved. In a direct fishing effort regulation, on the other hand, there is a greater degree of tolerance on the accuracy of estimation, provided some reduction in effective fishing effort is achieved. However, it should be noted that the kinds of data required for monitoring the successful application of a fishing effort regulation on the basis of catch are essentially the same as those required for setting catch quotas.

D. SELECTIVITY AND RELATED ITEMS

D.1 Codend mesh sizes in use

Data on mesh-sizes in use in the trawl and Danish seine-net fisheries of NEAFC Regions 1, 2 and 3 in 1967 have been received from thirteen countries and are summarised in Table 7. As in previous years the interpretation of these data has been complicated by the use of different mesh gauges giving measurements which are not immediately comparable with those taken with an ICES gauge. In countries A, G, H and M measurements were taken with both the wedge and ICES gauges. Their data showed that the wedge gauge did not always give higher readings than the ICES gauge, as has been generally observed in the past, comparative tests with the two gauges. The data reported by country K were in the form of measurements taken with a wedge gauge, converted to an ICES gauge basis, using conversion factors obtained from earlier comparative tests with the two gauges.

Region 1 As from 1st January 1967 the minimum mesh-size of trawls used in Region 1 east of 0° meridian was increased to 120 mm for codends made of polyamide, polyester, cotton and hemp, and to 130 mm for all other materials. This regulation was extended to the part of Region 1 to the west of 0° meridian as from 1st June 1967. The data have, therefore, been divided into those measurements taken before or after 1st June 1967, and the comments below relate to the second half of the year, since it was not always clear from the reports in which part of Region 1 a codend had been used during the first half of the year.

It is evident from the data for the second half of the year that, whereas the mean mesh sizes of polyamide codends were for most countries slightly above the regulation size of 120 mm, those for the polyethylene/polypropylene codends were mostly below the regulation size of 130 mm for these materials. They were, however, for the most part larger than the minimum prescribed for the western part of Region 1 up to 1st June 1967.

Region 2 The data for trawl codends indicate that in most countries a proportion of the codends had mean mesh-sizes below the prescribed minimum for nets used in the fisheries for Annex II species. However, for most countries the overall average mesh size was close to the Convention mesh-size.

The data for seine-nets indicate that in most countries the average mesh-size was greater than the prescribed minimum, although the data for country K, converted from wedge to ICES gauge readings, gave an overall mean mesh size below the regulation mesh size.

Region 3 Only one country submitted mesh size data for fisheries for Annex II species in Region 3, and these indicated a mesh-size near the prescribed minimum of 60 mm.

The Liaison Committee wishes to stress once more the importance of data on mesh-size in use for stock assessment work and reiterates its recommendatioin of last year concerning the need for all countries to report, on a regular basis, data on mesh size in use taken with the ICES gauge, according to the Convention Region, type of fishery and cod-end material. Hitherto the data have been submitted by the countries in different ways, and they are not always comparable. The Committee therefore recommends that the data on mesh-size in use should in future be reported on a standard form, of the type shown in Annex I.

The Committee wishes to point out that, on the basis of the mesh size data for the different materials in use, it is evident that the use of codends made from natural fibres has ceased in most member countries. Synthetic fibres, principally polyamide, polyethylene and polyporpylene are now in general use.

D.2 Codend mesh selectivity

A Norwegian trawl-mesh selection experiment carried out in the north-east Atlantic with a codend made of polypropylene splitfibre resulted in selection factors of 3.7 for cod, 3.4 for haddock and 3.8 for saithe. These values are not significantly different from the selection factors, obtained previously for polypropylene multi-filament. Since similar German experiments reported recently to ICNAF, also showed no significant difference between polypropylene multifilament and polypropylene monofilament the evidence available does not indicate a significant influence of the kind of polypropylene fibre on codend selectivity.

A joint report by France, Spain and Portugal on the selection of hake by trawls with polyamide codends in Region 3 gave selection factors ranging from 3.2 to 4.2 with the covered codend technique. Data from more recent experiments by Spain, submitted to the Liaison Committee gave selection factors of 3.7 and 4.0 for hake and 3.8 for blue whiting for polyamide codends, again using the covered codend method. There is reason to believe that this method underestimates the selection factor for hake, and further research is in progress to give greater precision to the estimates.

The Committee wishes to inform the Commission that ICES decided at its last Annual Meeting to explore the possibility of publishing jointly with ICNAF a summary of codend selectivity data obtained from experiments conducted in the ICNAF and ICES area. The Committee also intends to initiate a comprehensive analysis of selectivity data from past experiments, with particular reference to its variability.

D.3 Topside chafers

Further experiments with a Polish-type chafer, with meshsizes approximately double that of the codend, have been carried out in both the ICNAF area and in Region 1 of the NEAFC area. Data from experiments carried out in the Barents Sea and at Faroe were presented at the ICES meeting in 1966 showing that this type of chafer reduced the selectivity of cod and haddock by less than 10% in both areas. A further English experiment on Faroe haddock in 1967, in which a Polish-type chafer covering the full length of codend was used gave selection factors which were similar to those from earlier experiments without a chafer. These results are in broad agreement with previous observations, that the Polish-type chafer has no large effect on selectivity.

The Committee wishes to point out that it has received very little information on the types of chafers at present in use, in response to the Commission's recommendation at its last Annual Meeting that such information should be reported each year by all member countries. Four countries have reported the use of chafers of an authorized design and it appears from verbal reports that the use of a Polish-type chafer is becoming more widespread. The Commission's attention is drawn to the entry relating to topside chafers in the proposed mesh size and topside chafer reporting forms shown in Annex I.