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North-East Arctic Fisheries Working Group

Report of the Meeting at Copenhagen, December 4th-14th 1967

1. Participants

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2. Introduction

At its fifth meeting in Paris 1967 NEAFC asked the Arctic Working Group 'to consider .... what statistics it would require to make assessments of the state of the stocks from time to time' (NEAFC NC5/79).

The North-East Arctic Fisheries Working Group had earlier been requested by ICES to update its assessments carried out at a meeting in Hamburg in 1965 (ICES, CM 1965, Doc.No. 3, Gadoid Fish Cttee.) and this had been arranged for a meeting in April 1967. That meeting was postponed. The present meeting was reconvened by the Liaison Committee to carry out these assessments as an essential preliminary to the consideration of the specific request given by NEAFC to the Arctic Fisheries Working Group which met on December 14-15th 1967. These requests from ICES and NEAFC to the Liaison Committee required the Working Group to make a general assessment of the current state of the fishery, and the effect upon it of changes in the amount of fishing, or of changes in mesh-size.

The 1965 assessments had led to the conclusions:

i) that a long-term gain in catch might be expected by releasing fish very much larger than those in the selection range of the mesh in use at that time, and

ii) that any moderate reduction of effort would give an increase in the total catch, and a substantial increase in the catch per unit effort.

The report of the Hamburg Meeting also drew attention to some of the technical difficulties in preparing detailed assessments, in particular the uncertainty of the length composition of catches as opposed to landings for the different countries, and the effective mesh-size of the gear currently in use. Subsequent research and data made available at the present meeting have clarified these points and enabled the Group to prepare a more comprehensive assessment of these fisheries.

The recent history of regulation of these fisheries (NEAFC Region I, Sub-area I and Divisions IIA and IIB - hereafter referred to as Divisions) has been of mesh changes from 110 mm to 120 mm manila on 1.1. 1963, and from 120 mm to 130 mm on 1.1. 1967. Some comment on the effect of the former change is given in Section 4e, but no data were available at the present meeting to examine any effect of the most recent measure on the length composition of the catches.

3. COD: State of the Fishery

a) Landings and fishing effort

The total landings by all countries are summarised by ICES Divisions in Table 1 for the period 1946-1966. These had fluctuated about a mean level of 800,000 tons throughout the period 1946-1963 apart from two exceptional years in 1955 and 1956 when landings exceeded 1,100,000 tons. In the period 1961-1963 the average annual catch was 820,000 tons. In the last three years 1964-1966 this average has fallen by 45 per cent to 450,000 tons. In the fisheries of Divisions I and IIB which are based upon both the immature and mature cod the landings have fallen by 50 per cent, but in Division IIA, where the fishery is based predominantly upon mature cod during the spring spawning season, the decline in landings has been rather less, 15 per cent.

This decline is evident in the catches of each of the principal countries fishing in the area:

U.S.S.R.	59%
Norway	22%
U.K.	40%
Germany	39%

The catch taken by these countries in recent years are given in Table 2.

Fishing effort was known to have been reduced in Divisions I and IIB since 1963 and the detailed estimates now available are summarised in Table 3. In Division I the total fishing effort of all countries together has been reduced by approximately 40 per cent. The estimates for Division IIB are less conclusive but they do indicate a decrease of at least 10 per cent and probably more. Estimates from Norwegian and U.K. data also indicate a decrease of 20 per cent in effort in Division IIA. In total these changes represent a decrease of some 25 per cent in the total effective fishing effort on the Arcto-Norwegian cod stock as a whole, thus returning to the level of effort recorded in the late 1950's.

b) Size and composition of the stock

Estimates of abundance, as catch per unit effort, are given for each Division in Table 4. These show that although the catch per unit effort in Division I is less than in the period 1961-1963, it has increased from the low level of 1964. In Division IIB the abundance has remained at its lowest level since 1946, in Division IIA also the catch per unit effort has remained almost steady in recent years though the true changes continue to be masked by possible changes of availability to the Norwegian fisheries, and by the tendency of U.K. trawlers to fish further north on slightly different grounds from former years.

The age-composition of the stocks in Divisions I and IIB shows that the currently low catch per unit effort in these areas has followed from the continued low abundance of older age-groups, mainly as a consequence of the high level of fishing effort in 1960-1963, and the recruitment of poor year-classes spawned in the period 1960-1962 which would normally have provided the main proportion of the catches as medium cod in 1965 and 1966. However, in the last year 1966 there is evidence of increased numbers of codling from the 1963/64 year-classes which are above average.

The catch per unit effort in Division IIA has been maintained largely by the recruitment to the spawning stock of the 1958 year-class; this was the largest year-class of the last ten years.

The age-composition of the stocks in Division I and IIA are reflected by a low mean length and age in the landings in 1966. It was also noted that landings by USSR from these Divisions contained a greater proportion of small fish than these of other countries. However, data collected aboard Norwegian and U.K. vessels in 1966 showed that in this year an average of 6 per cent by weight and 20 per cent by number of the catches were rejected at sea and the appropriate correction showed that the length composition of the catches was closely comparable for all countries.

c) Estimate of total mortality

Estimates of total mortality (Z) have been calculated for the catch per unit effort data and by the 'virtual population' method (Gulland 1965) and are given in Table 5. These results can be summarised as followe for the periods 1962-1964 and 1964-1966:

	Catch per Unit Effort		'Virtual Population'	
	1962-1964	1964-1966	1962/63	1964/65
Division I	Z = 1.38(75%)	0.81(55%)	0.98(62%)	0.79(55%)
Division IIB	1.20(70%)	0.75(53%)		
Division IIA	-	-		

The estimate of total mortality in Division IIB for the years 1964-1966 excludes that of 1965/66 when the apparent mortality increased very sharply again owing to a low availability of cod in that year caused by atypical environmental conditions. The estimates of catch per unit effort for Division IIA which we have been able to calculate at this meeting were not thought sufficiently accurate to present an estimate of Z by this method for the reasons referred to in Section 3b.

These figures show clearly that there has been a detectable reduction in total mortality rate since the reduction in fishing effort took place in 1964.

Summarising the present state of the cod fishery it is clear that the sharp decline in catches is mainly attributable to the reduction in fishing effort. However, this has led to a decrease in total mortality which will, if maintained, lead to some recovery of the stock. Although there has been some increase in abundance in Division I, at the present time the effect of the reduction in effort is not obvious in the actual catches, owing to the aftermath of the effects of previously high fishing upon age-groups now contributing to the 'large' cod and the recruitment of a series of poor year-classes in recent years. It is expected that the benefits following the reduction in effort and the recent introduction of an increased mesh-size will become clearer as the much stronger 1963 year-class passes through the fisheries.

4. COD: Assessments

a) Present selectivity

i) Mesh-size in use.

Data on the mesh-sizes of cod-ends in use received from member countries of NEAFC during 1965-1966 show that although some cod-ends measured had mean mesh-sizes below the prescribed minimum, they were in general conformity with the regulations. This was due to a number of cod-ends having mesh-sizes substantially above minimum and to the mesh-sizes of the majority of those below it being less than 5 mm below minimum.

ii) Net materials.

Data on net materials in use have shown that the use of natural fibres in commercial fisheries has decreased during 1964-67. The cod-end materials in most common use are now polyamide and polypropylene, and to some extent manila. The Convention mesh-sizes for these materials were 120 mm for manila/polypropylene and 110 mm for polyamide until 1st January 1967 when they were increased to 130 mm and 120 mm respectively.

iii) Topside chafers.

Members of the Group have from their personal knowledge of the fisheries noted that topside chafers are commonly used by many trawlers but the data available were not sufficient to decide what design these are although the double cod-end is known to be amongst them.

The effective mesh-sizes of the international fleets as a whole have therefore not been the Convention's legal size during the period 1962-66 and in the absence of a precise measure it has to be assumed to lie between the limits of 120 mm (manila) and a lower limit determined as though the entire fleets were using a double cod-end.

Selection experiments with a double cod-end, or modified double cod-end, carried out in the north-east Arctic fisheries indicate that they reduce selectivity by 10-20 per cent. Taking the lower limit of 10% reduction to allow for the fact that some trawlers are not using chafers, the effective mesh-size would in 1962-1966 have been about 110 mm for manila/polypropylene and 100 mm for polyamide. For cod these correspond to mean retention lengths of 45 cm for cod-ends without chafer, and 41 cm for cod-ends with chafer.

On this basis the introduction of the 130 mm manila minimum at 1.1. 1967 would indicate current mean effective mesh-sizes of 120 mm manila/propylene and 110 mm polyamide. However, the more widespread introduction of the 'Polish type' topside chafer, would raise this effective mesh-size to 125 mm manila/polypropylene and 115 mm polyamide according to the results of the most recent experiments as to this type of chafer. The mean length/age of retention would then be increased.

b) The estimates of fishing mortality. F.

In its last report the Working Group noted that the ratios of the catches of particular age-groups in the three Divisions of the fishery must indicate some variation of fishing mortality with age. In particular the effect of fishing upon the mature age-groups was expected to be greater than that on the immature age-groups because these are not exposed to the fishing in Division IIA. In the catch per unit effort analysis used by the Group at that meeting these changes in mortality were obscured by the variability of the data. A modified technique of 'virtual population' analysis was developed to overcome this problem and it has been used by this Working Group to give estimates of total mortality and fishing mortality. Details of this method are given in the Annex to the Report of the Hamburg Meeting (Gulland 1965).

The data used in this method are the numbers of fish of each age-group in the catch in successive years and an estimate of natural mortality (M.). In previous work the level of natural mortality on 6 year-old cod has been estimated at 0.15-0.27 and for 7 year-olds as 0.30-0.50. In the absence of a more precise estimate to show whether or not natural mortality might vary with age, as seems probable, a median value of 0.30 was assumed constant for all ages in the current 'virtual population' analysis. This value also corresponds with the mean of estimates of M taken from catch/effort analysis. The estimates of total and fishing mortality obtained in this way are summarised in Table 5.

In these results two phases in the increase of mortality can be discerned, an increase over the age range 3 to 5 as fish are recruited to the exploited stock through the selection range of the fishing gear, followed by a further increase in fish of 8 years and older as they mature and their annual migration cycle takes them to the Norway Coast fishery. The proportion of this mortality occurring in each of the Divisions has been determined by the ratios of the catches of each age-group.

The method cannot give an estimate of mortality for 1966 so the level for 1965 has been taken as the best estimate of the current rate of mortality in subsequent assessments.

c) Method of assessment

As outlined in the introduction the Group carried out assessments of the effect upon these fisheries of changes in fishing effort and mesh-size. These have been carried out for the fishery as a whole without identifying the implications of such changes to particular national or gear type sectors of the fisheries.

The variation of fishing mortality with age precludes methods of assessment depending upon the constancy of this parameter throughout the life of the fish.

Instead potential yields have been assessed by reconstructing the exploited life-history of a given number of recruits assuming that the pattern of variation of F with age remains close to that determined for the fishery in 1965. The effect of changes in fishing mortality have then been determined as the yield per recruit at four levels of fishing effort relative to the present situation, the effect of one-third and two-thirds reduction of effort and one-third and two-thirds increase in effort applied uniformly throughout all three Divisions. In this we assumed natural mortality M = 0.3 with sample calculation at M = 0.20.

In assessing the effect of changes in mesh-size we assumed fishing mortality remained at its 1965 level and calculated the yield per recruit for a range of ages at first recruitment which was itself calibrated to the effective mesh-size in use.

The relative changes in catch per unit effort corresponding to each of these possibilities have also been calculated.

It has not been possible in the time available to assess the effect of simultaneous variations in fishing effort and mesh-size.

d) The effect of changes in fishing effort (Table 6, Figures 1 and 2).

The relationships illustrated in Figure 1 show that with the current pattern of variation of mortality with age (i.e. the current mesh-size) the maximum yield per recruit would be obtained with a level of effort one third less than at present. However, the curve is very 'flat-topped' and such a reduction of effort would give less than 5 per cent increase in yield. At the same time the reduction in effort would enable fish to survive longer and so it would increase the numbers of fish recruiting to the fishery in Division IIA in the later years of their lives. Consequently the catch would be distributed in a different way, decreasing in Divisions I and IIB and increasing in Division IIA. Conversely if fishing effort increased the total yield per recruit would decrease but a greater proportion of this yield would be caught in Divisions I and IIB. Calculations using the value M = 0.20 did not materially alter these conclusions.

The trends in catch per unit effort implied by these changes in fishing effort have been expressed as percentages relative to the present level because there is no strict comparison between this index and the actual catch per unit effort in any one type of gear. A one-third reduction of effort would increase stock abundance by 50 per cent in Divisions I and IIB, and double it in Division IIA. The general relationship between the Divisions follows the same pattern as the distribution of yield: the higher the fishing effort the lower the expectation of survival and hence the relatively greater effect on the fisheries in Division IIA which depend upon the survival to older ages.

e) The effect of changes in mesh-size (Table 7, Figure 2).

Ideally this assessment depends upon an accurate knowledge of the mean age or mean length at recruitment. This cannot be determined because the observed recruitment to the fishery is compounded not only of recruitment to the gear, by its selection pattern, but also by biological recruitment to the area fished. We have therefore taken the pattern of calculated mortality (Table 9) and examined the effect upon yield when the initial recruitment begins at different ages. This will underestimate the mean age of recruitment by approximately 1.5 years since it takes about 3 years for the slowest growing fish to pass through the selection range of the gear. Thus the onset of measurable fishing effort at 3.0 years at the present mesh-size reflects a mean age of recruitment of abt. 4.5 years.

The results of the assessments have been recorded in the yield per recruit and catch per unit effort at different ages of initial recruitment. (See Table 7 and Figure 2). These ages have also been adjusted to the mean age of recruitment and calibrated against mesh-sizes of manila and polyamide fibres, with and without chafers in Table 8. For example although its effect was not detectable the age of fish in the catch showed that in 1966 initial recruitment to the fishery took place at 2.5 to 3 years of age. This corresponds to a mean age of recruitment of between 4.0 and 4.5 years and an effective mesh-size of 110-120mm manila (without chafer). These values conform to the data available on the effective mesh-size in use. Fron the results the total yield per recruit will increase with mesh-size throughout the range considered, but the gains become progressively less. However, the yield in Divisions I and IIB does not increase beyond an age of initial recruitment of 3 years old;

as in the assessment of the effects of changes in effort, the increase in yield from the total fishery would be drawn from improved catches in Division IIA. Since, as stated, the current age of initial recruitment is less than 3 years it appears that the current regulation if enforced is close to the limit that will give increases in yield of cod in all Divisions.

The assessment of changes in catch per unit effort show that changes in mesh-size will have no detectable effect upon that in Divisions I and IIB but there would be very considerable increases for Division IIA.

These results are in close agreement with those reached at the Hamburg Meeting. Calculations made at that time indicated that for cod 'halving the effort would result in a long-term increase in catch to a maximum around 10% higher than at present'. Since that time fishing effort has been reduced by one quarter, a further reduction of an equivalent amount (one third the present level) would bring the fishery to the level of fishing effort generating the maximum yield per recruit. The mesh assessments also showed potential benefits to the total yield of releasing fish considerably larger than at present. The benefits to the fishery of the increase in mesh-size from 110 mm to 120 mm manila in 1963 can only be inferred from the evident increase in effective mesh-size. It might have been expected to show a detectable effect upon the numbers of the youngest age-groups in the catches but this is obscured by short-term fluctuations in recruitment and by recent changes in fishing effort. Indeed the first year-class recruiting immediately following the mesh-change, the 1960 class, only became fully recruited as 6 year olds in 1965/66 so that insufficient time has elapsed since the introduction of the measure for it to have had a marked influence upon catches.

5. Cod: Density Dependent Growth.

Research recently carried out in USSR has examined the longer term changes in growth-rate of cod in this area. In Figure 3 the mean weight of 10 year old cod is taken to represent these changes and plotted against the mean catch per unit effort for the same years taken from USSR and U.K. data as the best estimates of stock density during the feeding periods of the fish. There would be a significant correlation between these variables but growth may be influenced by a large number of factors e.g. hydrographic conditions, and in the time available it was not possible to estimate the true effect upon growth of variations in stock density alone. However, it must be recognised that such changes probably have occurred. Bearing in mind the changes in catch per unit effort consequent upon changes in fishing effort or mesh-size, if the density dependent changes in growth were repeated then all the relationships in Figures 2 and 3 would be slightly flattened.

6. Cod: Variations in Year-class Strength.

Estimates of year-class strength are now available from two sources for the period of years being considered, the young fish surveys carried out by the USSR and the virtual population analysis which gives estimates of the absolute number of recruits entering the commercial fishery each year. These two sets of data are summarised in Table 9. For recent years these data are amplified by the Norwegian cod larval surveys and by the USSR/Norwegian/U.K. 0-group fish surveys.

The USSR has combined its young fish survey data with an assessment of the 'performance' of each year-class in the fishery to give an index of each year-class as very rich, rich, above or below average, poor and very poor. In Figure 4 these are compared with the virtual population estimate, justifying the use of this latter as an accurate measure of the absolute level of recruitment. These are then given in Table 10 as the mean value of four year-class periods as millions of 2-year old cod. Thus the 1946-1949 year-classes averaged 1,630 million fish and would have recruited to the fisheries as 3-year olds in the years 1949-1952. The figure for the last four years is based on the survey data alone since these year-classes have not yet appeared in the commercial fishery in sufficient numbers to permit an estimate.

The average for an alternative grouping of the years was also calculated to show that the overall decline is not spurious. The trend in recruitment is illustrated in Figure 5. By taking these averages in conjunction with the yield per recruit at the present level of fishing effort and mesh size (0.53 kg - see Tables 6 and 7) it is possible to calculate a comparable potential yield from the average recruitment in these years. Thus, for the 1946-49 group the mean annual year class size was 1630 million 2 year old cod. The yield from this group could have averaged 0.53 kg per fish if they had been exploited at the conditions obtaining in 1966, giving a potential yield of 1630 million x 0.53 kg or about 860,000 tons. Each year class makes its major contribution to the landings as 5-8 year olds so that this catch for the 1946-49 year classes would have been taken mainly in the period 1951-54. The potential yield from each group of year classes in Table 10 can be summarised as follows:-

Year classes	Millions of recruits per year	Potential yield (tons round fresh)	Calendar years of main contribution to landings
1946-49	1630	860,000	1951-54
1950-53	1420	750,000	1955-58
1954-57	1180	625,000	1959-62
1958-61	950	500,000	1963-66
1962-65	(1100)	583,000	1967-71

During the period 1950-1963, up to the sudden decline in fishing effort, the actual yield had been slightly higher than the potential owing to the progressive erosion of the standing crop of the stock which gave benefits over and above the true production in any one year.

There is a wide variety of factors which might have influenced the success of recruitment in this period. Wiborg (1957) has shown that the hydrographic conditions at spawning, and its timing, location and duration, may influence survival. So also may the actual number and quality/viability of the eggs spawned and the conditions encountered by the juvenile fish in Divisions I and IIB. It is impossible to obtain comprehensive quantitative estimates of all these variables at present but an index of the mean annual temperature of the 0-200 m layers on the Kola Meridian has been taken as a broad measure of the environmental conditions in the general area. This is given in Table 10 together with three estimates of spawning stock size. Of these the Norwegian data are believed to overestimate stock size since the mid 1950's owing to changes in some characteristics of the fishery, and the virtual population estimate is of cod of 7 years and older irrespective of their maturity.

The changes are plotted in Figure 5. As with the relation between growth rate and stock density, there would be significant correlation between these variables but this would not necessarily reflect a causal relation and the contribution of each variable to the trend in recruitment cannot be resolved from the existing data with the methods at present available. Nor do we envisage an unequivocal solution to this problem within the next few years. However, members of this Group consider that all the factors mentioned will have had some influence upon recruitment and we therefore wish to draw attention to the immediate situation in this fishery.

The year classes of 1965, 1966 and 1967 have been shown to be extremely poor in all surveys. Taking an optimistic view that they will have an average level of equal to the 1962 year class their average potential yield will be about 250,000 tons. The main part of the first of these poor year classes, 1965, will mature in 1973 and at some time in the mid 1970's the spawning stock will be almost entirely dependent on recruits from these year classes. The spawning stock will then be very small, even taking into account the improved survival that has followed the recent reduction in fishing effort. Fundamental biology demands that a stock recruitment relationship must exist at some critical low level of spawning stock size and in the opinion of the Working Group this level will be approached, if not reached, during the next decade. The prospects will then be black indeed unless a new strong year class is spawned during the period 1968-1970 and permitted to grow to maturity in significant numbers.

7. Haddock.

a) Total catch and fishing effort (Tables 11, 12 and 13)

Table 11 of the changes in catch shows the drop from 176,000 tons in 1961-63 to 125,000 tons in 1964-66. The greater part of these catches is taken in Divisions I and IIA reflecting the same trend seen in the cod catches, the majority of the decrease taking place in Division I.

The fishing effort recorded by the different countries is the same as that recorded for cod (see Table 3) and for haddock the estimate of total fishing effort in Table 12 also reflect the decrease in 1964/65 from the previously recorded high level. In 1966, however, it will be seen that there was a recovery in fishing effort, rather larger than that for the cod fishery. For the English fleet the catch per unit effort decreased, but there was a slight increase in these data for the USSR fleet, and for Norway. These discrepances may be related to changes in the proportion of effective effort deployed on haddock in view of the low abundance of cod and so the estimate of total effort based on English data may be too high.

b) Stock composition

The abundance of haddock in Division I has remained relatively very low since 1963. However, any improvement in the abundance of the stock since that time, owing to the reduced effort in 1964 and 1965 has been masked by the changes in recruitment. The fishery during the past three years has been heavily dependent upon the 1960 and 1961 year-classes which were rather rich, but, though they did give rise to exceptionally good fishing in Division IIA in 1966, they have not been large enough to do more than offset the effects of previously high fishing and poorer recruitment in very recent years.

c) The estimation of mortality

It has not been possible in the time available to carry out the more discriminating 'virtual population' analysis and estimates of total mortality have been based on the catch per unit effort analysis. This gives an extremely high value of total mortality Z = 1.70 compared with a mean value Z = 1.20 estimated at the Hamburg meeting for the years 1960/61-1962/63. We concluded that the value for 1964/66 may be an over-estimate owing to recent changes in the availability, or in the 'efficiency' of fishing for haddock, but that the total mortality appears to have remained at or above the high level of the early 1960's.

The present situation in the north-east Arctic haddock fishery therefore shows some similarity to the cod fishery. The catch fell in 1964 owing to the reduction in effort on a stock of relatively poor abundance. The fishery has not changed significantly since that time, except for the transient good fish in Division IIA in 1966 referred to above.

8. Assessment.

The discussion of present mesh-size, mesh regulations and trawl materials with regard to cod fishery in Section 4a applies equally to the haddock fishery. Norwegian and English experiments on the selectivity without chafer have in general confirmed the value of 3.6 for manila used at the Hamburg meeting and this has been used in assessments made at the current meeting. However, selectivity experiments with a manila double cod-end indicate a slightly greater reduction in selectivity for haddock than for cod, 15-25% as opposed to 10-20%, probably as a result of differences in the girth/length relationships for the two species. The available evidence of the effect of a chafer upon the selectivity of polyamide fibres was not adequate to calculate a reliable selection factor for this material. Assuming similar differentials between manila and polyamide and a similar proportion of chafers in use as for cod, the mean effective mesh-size for haddock in 1962-1966 would have been 103 mm for manila/polypropylene, and 95 mm for polyamide, corresponding to a 50 per cent release lengths of 37 cm instead of 43 cm if no chafer had been used.

The recently introduced minimum mesh will increase these effective mesh-sizes to 110 mm manila/polypropylene and 102 mm polyamide.

a) Method of assessment

It has not been possible to identify trends of increasing mortality with age of haddock, though these may occur. It has been necessary to assume this as constant and the potential yield per recruit has been taken from tables of the yield function using the parameters K = 0.10 (determined from growth studies) M = 0.20 (determined by the catch effort analysis) and F = 1.20-1.50. The levels of E = F/F+M therefore lies between 0.80-0.90.

b) Results of assessment (Figures 6 and 7)

The effects of changes in fishing effort are given in Figure 6. The present level of exploitation is beyond that giving the maximum yield per recruit at the current mesh-size with or without chafer. A reduction in effort to one half its present level might reduce the value of E to 0.70 giving a significant improvement in the yield per recruit but it is difficult to be certain that mortality would reduce by this amount because of the partial dependence of the fishery on haddock upon the state of the cod fishery. Moreover the Group noted that no effect of the decrease in effort in 1964 and 1965 could be detected.

The assessment of the effect of changes in mesh-size at the present level of effort (Figure 7) indicates that some further increase in mesh-size to release haddock of up to 60 cm would improve total yield per recruit, perhaps by as much as 15 per cent. However, the effects of such changes upon different sectors of the fishery have not been calculated.

The conclusions from these theoretical calculations are the same as those reached at the Hamburg meeting.

9. Fluctuations in Year-class Strength. (Table 14)

These estimates show the wide fluctuation of year-classes and their passage through the fishery can be traced in the catch statistics in Table 12. The peak catch in 1955/56 is related to the 1950 year-class, and the catch of 1961/62 to the 1956 (1957?) year-classes. Recently improved total catches have contained a large proportion of the 1960/61 year-classes. There has been no clearly identifiable trend since 1946 but in recent years there has been an unprecedented run of six poor year-classes. Inevitably the total yield of haddock must fall as these year-classes pass through the fishery, even though the yield per recruit is held close to its potential.

Conclusions

The assessments carried out at this meeting have confirmed the conclusions reached at the Hamburg meeting. For cod the curve of yield per recruit with changing fishing effort is very flat and the same yield could be obtained with appreciably less effort, about one half its 1963 level and two-thirds its current level. For haddock a reduction of effort is expected to confer some increase in yield but further research is necessary to assess the interaction of fishing for cod and haddock in this area before the actual reduction in mortality on haddock can be predicted for a given reduction of effort.

So far as mesh-sizes are concerned the position has not changed materially since the Hamburg meeting for the period under review. These showed that in principle further increases in yield per recruit would be obtained by releasing fish larger than those released by the mesh-size which recently came into force with or without chafer at the present level of effort.

In both the cod and haddock fisheries a series of very poor year-classes will recruit to the fisheries over the next three years and though the yield per recruit is expected to be maintained the total yield must fall quite considerably.

Recommendation

The Group recommends that all countries should make an especial effort to obtain statistics of haddock catches and landings comparable in scope and quality to the present cod statistics in order to facilitate a more reliable assessment of the haddock fishery in the near future.

On behalf of the Working Group

D.J. Garrod.

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Table 1. COD. Total Catch by Divisions (metric tons, round fresh). Revised and Additional Figures for Years 1946-1966.

Year	Division I	Division IIB	Division IIA	Total
1946	199,640	210,443	295,917	706,000
1947	340,758	164,879	376,380	882,017
1948	406,620	130,831	236,844	774,295
1949	484,942	127,103	188,077	800,122
1950	356,474	163,783	211,725	731,982
1951	407,989	140,493	278,698	827,180
1952	524,160	105,860	246,775	876,795
1953	442,839	103,616	149,091	695,546
1954	597,534	98,663	129,824	826,021
1955	830,694	153,437	163,710	1147,841
1956	787,070	323,834	232,164	1343,068
1957	399,595	256,504	136,458	792,557
1958	388,067	229,115	152,131	769,313
1959	322,798	242,762	179,047	744,607
1960	380,488	101,591	155,654	637,733
1961	407,699	222,451	148,886	779,036
1962	539,785	222,611	138,186	900,582
1963	540,057	116,494	116,788	773,339
1964	202,606	126,029	108,803	437,438
1965	241,489	107,407	99,855	444,751
1966	288,597	55,299	134,312	478,208

Table 2. COD. Catch by Countries (Divisions I, IIA and IIB combined). Revised and Additional Figures for Years 1960-1966.

Year	England	Germany	Norway	U.S.S.R.	Others	Total
1960	141,175	9,866	240,292	213,400	33,000	637,733
1961	157,909	7,865	268,377	325,780	19,105	779,036
1962	174,914	6,293	225,615	476,760	(17,000)	900,528
1963	129,779	4,087	204,509	417,964	(17,000)	773,339
1964	94,549	3,202	149,878	180,550	9,259	437,438
1965	89,874	3,670	197,085	152,780	1,342	444,751
1966	95,752	4,296	203,792	169,300	5,068	478,208

Table 3. COD. Fishing Effort.

YEARS	Division I				Division IIB				Division IIA			
	National Effort		Total Effort		National Effort		Total Effort		National Effort		Total Effort	
	UK[1]	USSR[2]	UK units	USSR units	UK	USSR	UK units	USSR units	UK	Norway[3]	UK	Norway
1946	18	10	65	18	20	+	23	12	3	22	46	31
1947	38	14	103	33	31	+	38	19	12	21	99	33
1948	63	16	156	41	32	1	39	13	15	19	82	26
1949	60	17	171	51	28	1	33	14	10	19	63	33
1950	93	16	248	42	37	4	63	13	11	17	151	30
1951	99	23	312	50	54	2	74	11	16	22	194	33
1952	103	25	412	50	31	3	54	11	29	24	213	40
1953	53	27	396	46	27	3	56	9	20	23	127	42
1954	52	34	425	50	32	2	54	7	18	20	131	36
1955	61	37	551	59	44	1	65	9	18	14	157	32
1956	54	49	630	76	68	4	134	19	20	18	167	40
1957	45	36	462	78	66	12	188	31	24	11	121	40
1958	56	32	467	84	66	18	190	42	27	12	175	34
1959	61	27	356	74	83	21	200	63	26	10	213	25
1960	95	43	512	91	42	11	97	34	39	10	232	26
1961	94	53	518	109	51	22	173	39	30	9	255	20
1962	93	61	590	94	51	16	168	29	34	10	210	21
1963	78	62	635	91	45	9	120	22	29	7	176	19
1964	42	30	351	55	49	17	136	32	36	6	157	17
1965	42	25	367	62	37	11	95	4	33	5	150	16
1966	63	33	387	69	23	16	71	29	46	5	199	15

[1] Hours fishing x average tonnage x 10^{-6} = millions of ton hours.

[2] Hours fishing (catch/catch per hour fishing) x 10^{-4}

[3] Number of men fishing at Lofoten x 10^{-3}.

Table 4. COD. Catch per Unit Effort. (Metric Tons Round Fresh).

YEAR	Division I		Division IIB		Division IIA	
	U.K.[1]	USSR[2]	U.K.	USSR	U.K.	Norway[3]
1946	0.305	1.13	0.915	1.70	0.647	13.6
1947	0.335	1.02	0.437	0.87	0.381	13.0
1948	0.261	0.98	0.339	1.11	0.290	7.9
1949	0.283	0.95	0.379	0.92	0.296	8.6
1950	0.147	0.84	0.261	1.29	0.140	6.2
1951	0.130	0.82	0.191	1.25	0.143	6.8
1952	0.127	1.05	0.195	0.98	0.116	5.9
1953	0.112	0.95	0.184	1.19	0.117	5.2
1954	0.141	1.19	0.182	1.56	0.099	2.7
1955	0.151	1.42	0.236	1.64	0.104	4.6
1956	0.125	1.04	0.241	1.71	0.139	4.8
1957	0.087	0.51	0.136	0.84	0.112	2.8
1958	0.083	0.46	0.121	0.69	0.087	3.8
1959	0.091	0.44	0.121	0.55	0.084	5.5
1960	0.075	0.42	0.105	0.31	0.067	3.0
1961	0.079	0.38	0.129	0.44	0.058	3.7
1962	0.092	0.59	0.133	0.74	0.066	4.0
1963	0.085	0.60	0.098	0.55	0.066	3.1
1964	0.058	0.37	0.092	0.39	0.070	4.8
1965	0.066	0.39	0.109	0.49	0.066	2.9
1966	0.074	0.42	0.078	0.19	0.067	4.0

[1] U.K. data - tons per 100 ton hours fishing.

[2] USSR data - tons per hour fishing.

[3] Norwegian data - tons per gill net boat week at Lofoten.

Table 5. COD. Summary of Estimates of Total Mortality. (z).

(A) Catch per Unit Effort Analysis.

	1946/47	49/50	54/55	60/61	61/62	62/63	63/64	64/65	65/66
Division I									
Age 7-9 UK	0.67	0.76	0.67	0.12	0.86	1.21	1.92	1.10	0.49
USSR				-0.18	0.90	0.78	1.61	1.12	0.54
Mean						← 1.38 →		←0.81→	
Division IIB									
Age 7-9 UK		0.50	0.96	0.83	0.90	1.31	0.92	0.68	1.39
USSR				1.12	0.08	1.31	1.24	0.83	1.63
Mean						←1.20 →		0.75	

(B) Virtual Population Analysis (M=0.30)

Age	1946	1950	1955	1960	1961	1962	1963	1964	1965	Fishing mortality 1964-65
3			0.31	0.34	0.35	0.37	0.33	0.32	0.32	0.02
4	0.31	0.31	0.37	0.49	0.55	0.55	0.51	0.45	0.44	0.14
5	0.33	0.36	0.75	0.63	0.73	0.88	0.87	0.75	0.76	0.46
6	0.36	0.49	0.76	0.74	0.74	1.06	1.09	0.70	0.75	0.45
7	0.39	0.59	0.88	0.70	0.74	0.91	1.07	0.79	0.69	0.39
8	0.42	0.65	0.89	0.68	0.89	0.95	1.03	0.93	0.90	0.60
9	0.54	0.68	1.12	0.65	0.89	1.24	0.97	1.35	1.11	0.81
10	0.96	0.72	1.50	0.88	1.02	1.02	1.28	1.01	1.43	1.13
Age 5-8	0.37	0.52	0.63	0.69	0.78	0.95	1.01	0.79	0.78	

Table 6. Cod Assessments: The Effect of Variations in Fishing Effort.

(A) Yield per Recruit (kg).

	Change in Effort from Present Level (1.00)				
	0.33	0.67	1.00	1.33	1.67
Divisions I+IIB	0.376	0.447	0.468	0.479	0.474
Division IIA	0.121	0.091	0.064	0.050	0.040
T o t a l	0.497	0.538	0.532	0.529	0.526

(B) Catch per Unit Effort.

Divisions I+IIB	2.32	1.40	1.00	0.76	0.60
Division IIA	5.73	2.14	1.00	0.58	0.38

Table 7. Cod Assessments. The Effect of Changes in Age at Recruitment (= Mesh Change).

(A) Yield per Recruit (kg).							
	Age at Initial Recruitment						
	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Divisions I+IIB	0.456	0.461	0.468	0.466	0.455	0.439	0.409
Division IIA	0.038	0.051	0.064	0.082	0.107	0.135	0.169
T o t a l	0.494	0.512	0.532	0.548	0.562	0.574	0.578
(B) Catch per Unit Effort.							
Divisions I+IIB	0.98	0.99	1.00	1.00	0.98	0.95	0.88
Division IIA	0.59	0.79	1.00	1.28	1.65	2.26	2.63

Table 8. Cod. Calibration of Age at Initial Recruitment to Mesh-size.

Age at Initial R.	Age at Mean R.	Mean Length at Mean R. (mm)	Mesh Without Chafer		Mesh With Chafer	
			Manila	Polyamide	Manila	Polyamide
			S.F.=3.7	S.F.=4.1	S.F.=3.3	S.F.=3.7
2.0	3.5	370	100	90	112	100
2.5	4.0	415	112	101	126	112
3.0	4.5	455	123	111	138	123
3.5	5.0	500	135	122	152	135
4.0	5.5	540	146	132	164	146
4.5	6.0	585	158	143	177	158
5.0	6.5	625	169	152	189	169

Table 9. COD. Estimates of Year-Class Strength.
(USSR surveys were extended to Division IIB in 1956)

Year-class	USSR Survey No./hour fishing			USSR Assessment	Virtual Population
	Total II + III Gp		Mean[1] II + III Gp		No. x 10^{-8} 2 yr old
	Division I	Division IIB			
1946	9		5	poor	9
1947	31		17	+ avge	13
1948	49		25	rich	20
1949	48		24	rich	23
1950	166		82	v.rich	30
1951	28		13	- avge	12
1952	4		2	poor	6
1953	22		11	poor	8
1954	20		10	- avge	14
1955	10		4	poor	9
1956	24	46	15	- avge	12
1957	15	28	11	- avge	13
1958	22	42	14	+ avge	15
1959	22	22	12	+ avge	12
1960	13	31	10	poor	7
1961	5	2	2	poor	3
1962	11	9	5	poor	5
1963	31	159	46	rich	(20)
1964	103	80	45	rich	(20)
1965 (I+II)	<1	<1	<1	v.poor	(1)
1966 (0+I)	<1			v.poor	
1967 (0)	<1			v.poor	

[1]Weighted mean. See USSR Reports to Annales Biologiques.

Table 10. COD. Fluctuations of Year-Class Strength, Temperature and Spawning Stock Size as Averages of 4-Year Groups.

Years	Year-Class No. x 10^{-8}	Temperature	Spawning Stock Size		
			Norwegian[1]	German[2]	Virtual Population
1946-49 (1948-51)	1630 (2150)	0.38	10.8	2.00(48/49)	35
1950-53 (1952-55)	1420 (920)	0.59	6.0	1.45	27
1954-57 (1956-59)	1180 (1310)	0.46	3.7	1.40	26
1958-61 (1960-63)	950 (875)	0.42	4.0	1.20	16
1962-65 (1964-67)	(1100)	0.14	3.7	0.90	7

[1] Tons/gill net boat week at Lofoten.

[2] Gutted landed tons per day fishing of 1930 standard trawler (200 GRT, 400-500H.P).

Table 11. HADDOCK. Total Catch by Divisions (metric tons, round fresh). Revised and Additional Figures for Years 1946-1966.

Year	Division I	Division IIB	Division IIA	Total
1946	59,166	8,245	26,799	94,210
1947	94,329	5,603	36,258	136,190
1948	79,423	7,373	37,785	124,581
1949	115,574	9,626	24,953	150,153
1950	90,517	11,206	30,010	131,733
1951	86,735	5,564	27,758	120,057
1952	103,662	3,664	20,334	127,660
1953	105,416	2,426	15,605	123,447
1954	125,681	8,671	22,096	156,448
1955	157,098	10,954	34,693	202,745
1956	163,720	8,624	40,935	213,279
1957	86,986	11,061	24,658	122,705
1958	78,112	5,169	29,391	112,672
1959	58,734	3,030	26,415	88,179
1960	121,160	2,336	26,302	149,798
1961	159,728	7,864	25,642	193,234
1962	159,172	3,527	25,189	187,888
1963	123,356	1,091	21,471	145,918
1964	79,056	1,109	18,993	99,158
1965	98,505	934	19,108	118,547
1966	123,438	1,604	35,417	160,459

Table 12. HADDOCK. Catch by Countries (Divisions I, IIA and IIB combined). Revised and Additional Figures for Years 1960-1966.

YEAR	England	Germany	Norway	U.S.S.R.	Others	Total
1960	45,469	5,459	41,745	57,025	100	149,798
1961	39,625	6,304	60,862	85,345	1,098	193,234
1962	37,486	2,895	54,567	91,940	1,000	187,888
1963	19,809	2,554	59,129	63,526	900	145,918
1964	14,653	1,482	38,695	43,870	458	99,158
1965	14,314	1,568	60,447	41,750	468	118,547
1966	26,415	2,098	82,090	48,710	1,146	160,459

Table 13. HADDOCK. Catch per Unit Effort. And Estimated Total Effort.

	Catch per Effort (UK) Kilos/100 ton hours			Estimated Total Effort UK units $\frac{\text{Total Catch}}{\text{tons/100 t. hours}} \times 10^{-6}$ Region I
	Division			
	I	IIA	IIB	
1946	97	790	41	1.0
1947	61	280	17	2.2
1948	52	140	23	2.4
1949	67	87	34	2.2
1950	41	110	29	3.2
1951	33	84	10	3.6
1952	32	32	12	3.9
1953	41	32	7	3.0
1954	30	46	26	5.3
1955	31	77	24	6.6
1956	42	66	9	5.1
1957	33	30	14	3.7
1958	19	48	6.5	5.9
1959	20	37	2.6	4.4
1960	33	34	2.8	9.5
1961	29	36	3.3	6.7
1962	23	42	2.5	8.2
1963	13	33	0.9	11.2
1964	18	18	1.6	5.5
1965	18	18	2.0	6.6
1966	17	34	2.8	9.4

Table 14. HADDOCK. Fluctuations in Year-class Strength. From USSR Surveys.

As Mean Number of 2 and 3 Year Old Fish. Per Hours Fishing.

Year-class	No. of Fish	Mean	Year-class	No. of Fish	Mean
1946	1		1958	4	
1947	1	10	1959	25	32
1948	30		1960	56	
1949	7		1961	42	
1950	256		1962	3	
1951	15		1963	15	5
1952	7	75	1964	(?)	
1953	31		1965 (I+II)	(<1)	
1954	5		1966 (0+I)	(<1)	
1955	3	11	1967 (0)	(<1)	
1956	23				
1957	12				

Figure 1. The effect of changes in fishing effort.

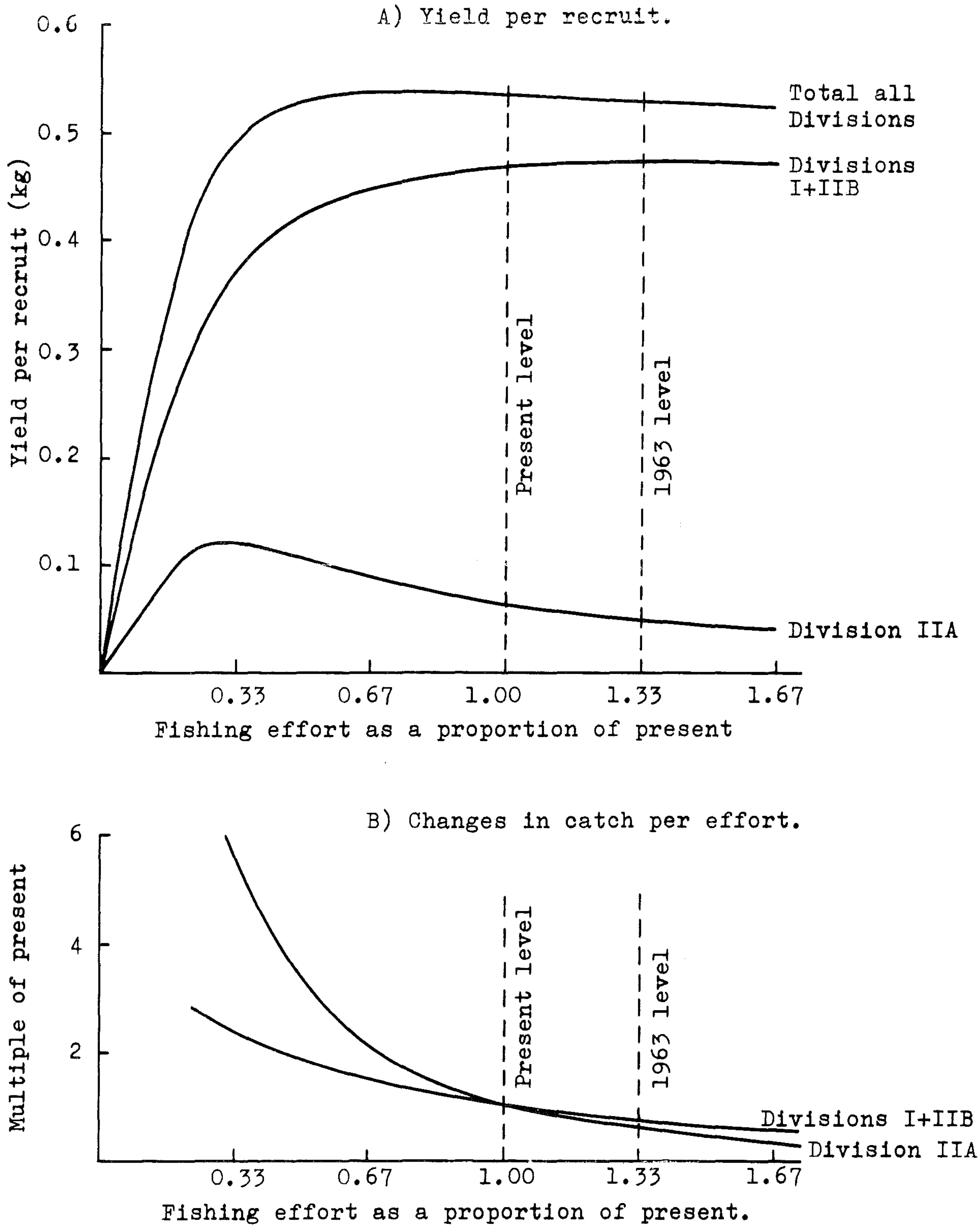

Figure 2. The effect of changes in age at recruitment

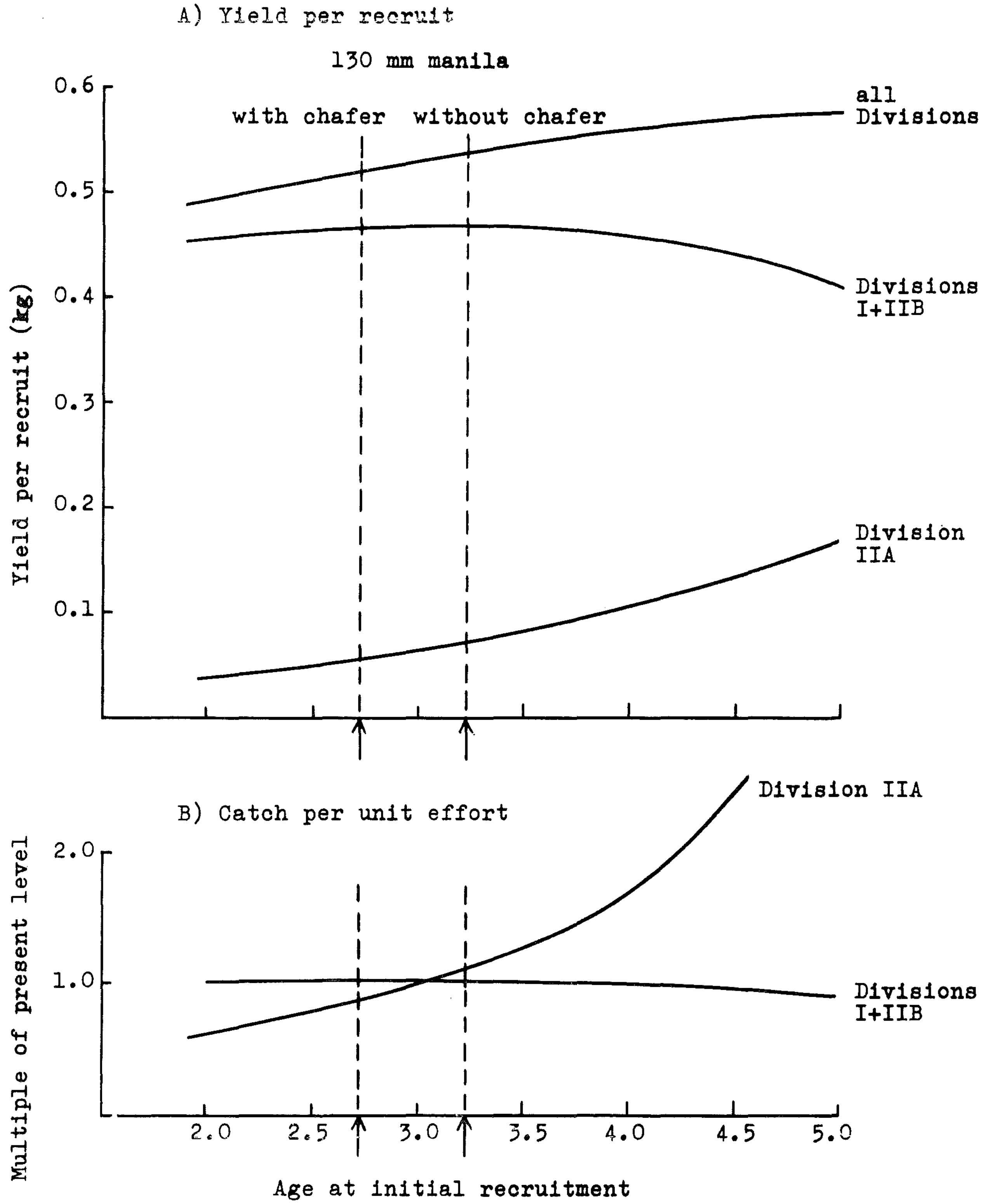

Figure 3. The relation between growth and the catch per unit effort.

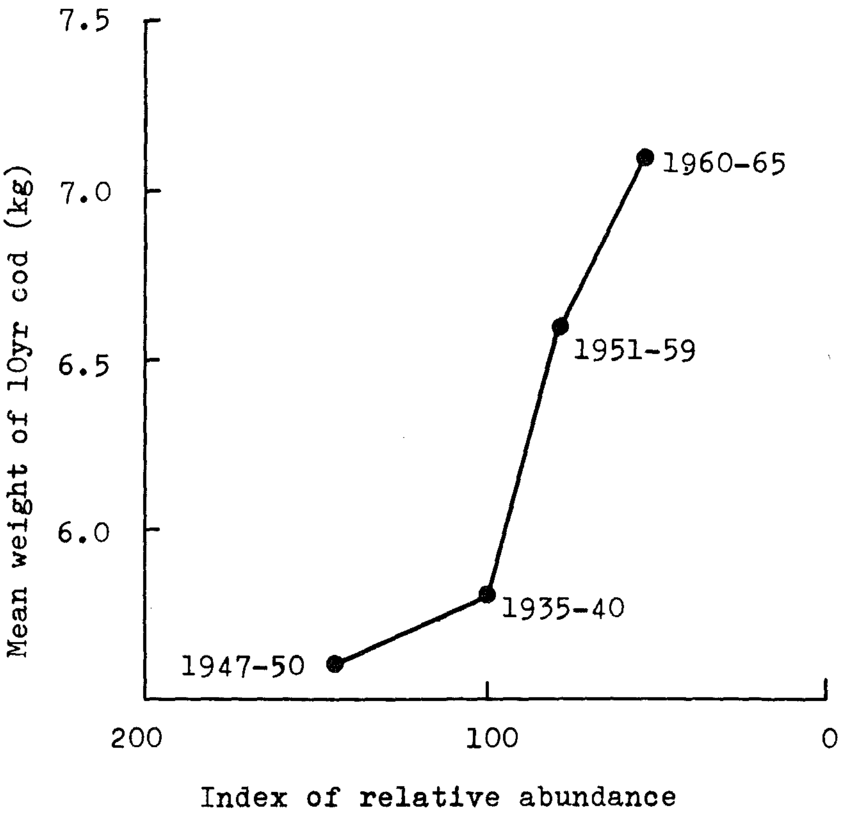

Figure 4. Comparison of USSR assessments with virtual population estimates of year-class size.

Figure 5. Fluctuations in Year-class, Temperature and Spawning Stock.

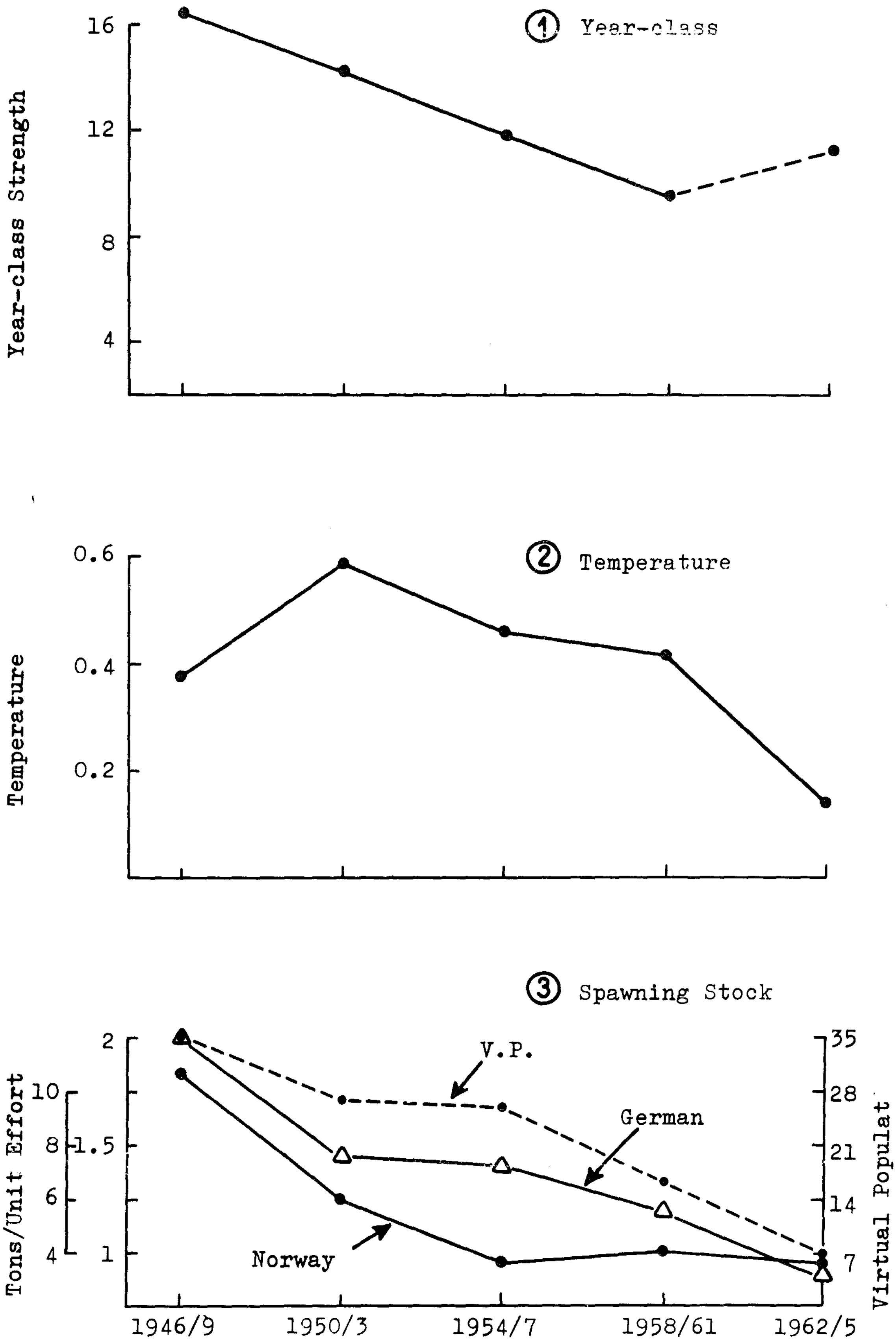

Figure 6. HADDOCK. Yield per recruit and catch per unit effort. Variations with effort.

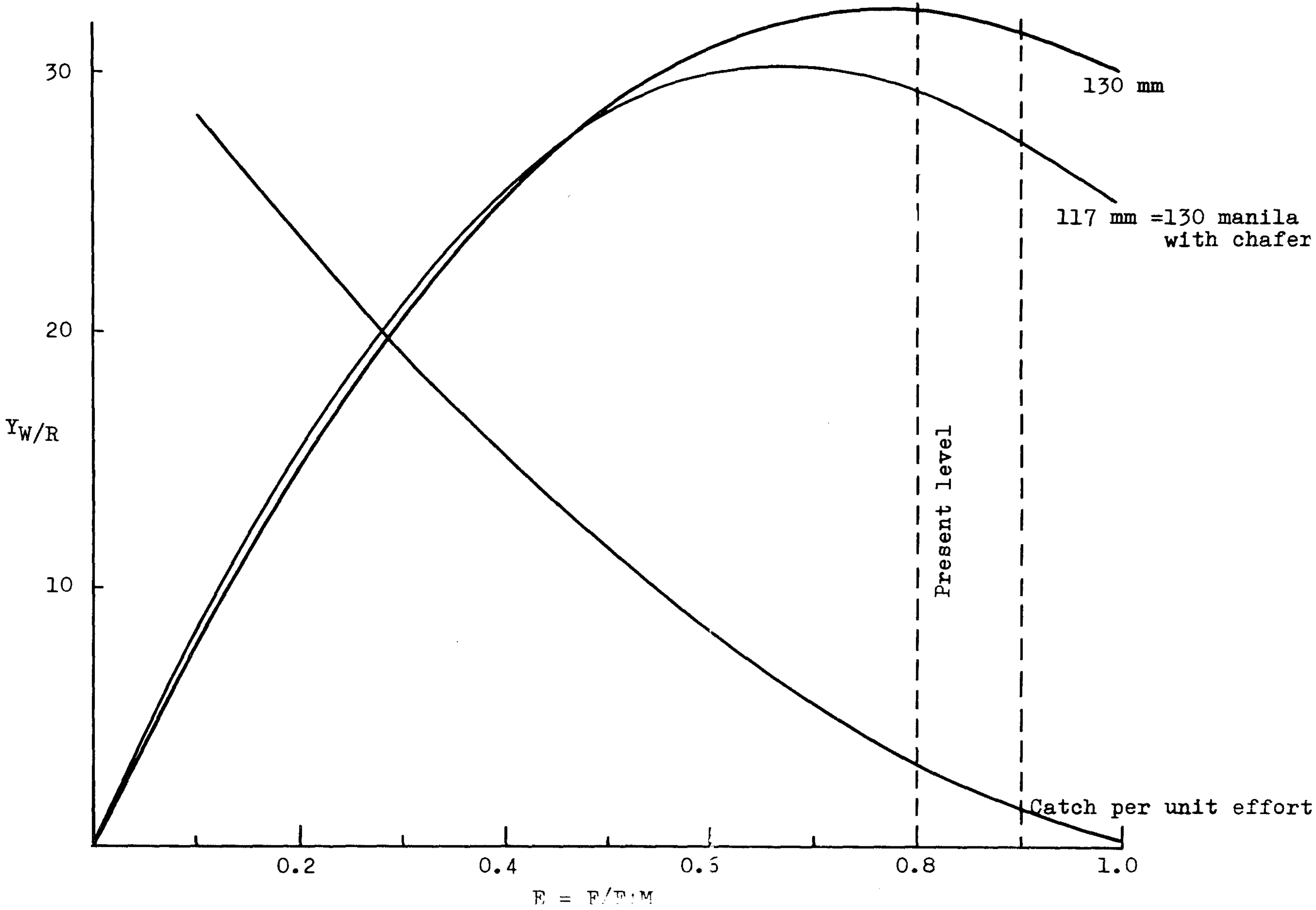

Figure 7. HADDOCK. Changes in yield per recruit with mesh-size.