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Exploration of the Sea

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Demersal Fish (Northern) Committee

North-East Arctic Fisheries Working Group

Report of the Meeting at Copenhagen, January 13th-17th 1969

1. Participants

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2. Introduction

After consideration of the Report of the 1967 Meeting of this Group, ICES, at its 56th Statutory Meeting, passed the Resolution that the Group should meet to complete their assessments of the haddock and redfish stocks of this area, and to consider any new evidence that may be presented relating to the cod stocks of this area (C.Res.1968/2:6). The area in question comprises Sub-area 1 (Barents Sea), Division IIA (Norway coast) and Division IIB (Bear Island/Spitsbergen). Accordingly the Group met in Copenhagen in January 1969, and in their preliminary discussion of the work before them the Group also agreed to review the catch statistics for the coalfish fishery within the area.

3. COD

a) State of the fishery (Tables 1-4)

The Group noted that recruitment of the strong 1963 and 1964 year-classes has led to an improvement in the fishery. In Sub-area I and Division IIB both the catch and the catch per unit effort have increased in 1967, especially at Bear Island, but there is no clear indication that the fishing effort has changed from its 1964-1966 level. In Division IIA, the abundance of the stock decreased in 1967 and the fishing effort increased. Although statistics for 1968 are not yet available, it is expected that further increases in stock abundance will have been followed by increasing fishing, and hence higher catches in Sub-area I and Division IIB.

b) Assessment of the fishery

In view of the short time that has elapsed since the previous meeting, the Group did not revise earlier assessments for the cod fishery. However, new information was presented concerning density-dependent variations in growth, and a consequent effect upon the selection factor for cod which should be taken into account when interpreting the assessment presented in the last report.

b) (i) Density-dependent growth

Research by U.S.S.R. has shown a high correlation ($r = -0.67$) between the mean abundance of 2-3 year old cod in the Barents Sea during the first four years of growth of a year-class, and its mean length at three years of age. As the abundance of young cod has declined so the mean length of 3 year old cod has increased from about 32 cm to about 40 cm during the period 1946-1963. Moreover there has been no significant increase in the mean increment of 5-9 year old cod during the same period. This indicates that the higher mean length for age noted in the previous report (para.5) can be attributed to increased growth of juvenile phase of the life-history alone.

b) (ii) Selectivity

Recent selectivity experiments in the Bear Island area indicate that the selection factor for manila for cod may now be lower (3.3) than indicated by earlier work (3.7) (Bohl, 1968). This would follow from the increased growth which has at the same time been accompanied by an increase in the mean girth of fish of a given length. It is expected that the new data will be evaluated by the Joint ICES/ICNAF Working Group on Selectivity Analysis, but, pending their conclusion, the relation between mean age of recruitment and effective mesh-size used in the previous assessment has been recalibrated in Figure 1.

b) (iii) The effect of changes in growth and selectivity upon earlier assessments

The previous assessment was based upon the estimates of current growth rate (in 1960-1966) and, therefore, reflects accurately the present yield per recruit. However, if lower levels of fishing increase the abundance of all age groups (and especially that of 0-4 year old cod as a result of a stock and recruitment relationship), growth would be reduced. The previous assessment would then overestimate slightly the yield per recruit that would follow a reduction in fishing effort. Similarly, the yield at higher levels of fishing mortality may be slightly underestimated.

The reduction in selectivity increases slightly the potential benefits in yield per recruit of further increases in mesh-size.

In this context it is worth noting that the increases in mesh-size from 110 mm - 130 mm (manila), authorised by NEAFC in recent years, have not increased the age of first capture as much as had been intended, owing to the increase in growth. It is even possible that when the present selection factor is determined by the Selectivity Working Group it will be found that the age of first recruitment has decreased slightly. In the event, the yield per recruit has increased owing to the growth change, and it follows that, for cod, the benefits of further increases in mesh-size would be slightly higher than in previous estimates.

Cod. Variations in year-class strength

The last Report drew attention to the recent decline in recruitment to this stock, and the relationship between this and trends in both the size of the spawning stock and in the 'environment' as measured by the variation in temperature at the Kola Meridian. At that time the Group was not able to conclude a causal relationship between these variables. Further evidence on this subject was presented to the Council Meeting in 1968 (Garrod, 1968).

This most recent analysis assumes that in the absence of any climatic trend that might influence density-independent variation in recruitment, the spawning stock of an unexploited population would, on average, replace its own initial number of recruits, so that, when R_{sp} denotes the mean number of 3 year old recruits to the spawning stock, and R_3 the number of 3 year old recruits from the filial generation, $R_3/R_{sp} = 1$. Using the year-classes of the age groups 7-13 to represent the spawning stock in any year it was shown that the replacement rate has declined in recent years (Figure 2). As in previous analyses this decline in replacement might be a function of both spawning stock size and environmental effects. However, the influence of density-independent mortality upon year-class strength would be expected to influence only the proportion of eggs which survive to three years of age (survival) as distinct from the effect of spawning stock size which determines the absolute number of eggs spawned. The changes in survival (S) in the stock in the period 1944-1962 were then examined using the index

$$S = R_3/R_{sp}\ e^F$$

where e^F represents the proportional increase in survival of eggs that must take place to offset the decline in spawning capacity caused by fishing, F being the mean fishing mortality per year-class summed over the period from 3-9 years of age in this stock[x]. Then

$$\log_e S = \log_e R_3/R_{sp} + F$$

x) For simplicity this formulation excludes changes in the mean weight of fish in the spawning stock.

The plot of $\log_e S$ against F for the Arcto-Norwegian cod is shown in Figure 3 together with two hypothetical relationships.

(1) $R_3/R_{sp} = 1$ and hence $\log_e S = F$. This relation represents the basic assumption of previous assessments, that the recruitment is independent of the effect of fishing and held constant by improvement in the rate of survival of eggs or larvae as the spawning stock is reduced.

(2) $R_3 = c\ R_{sp}\ e^{-F}$ where c is a constant, then $\log_e R_3/R_{sp} + F = \log_e c$:

survival is constant and hence recruitment is proportional to spawning stock size. Variations in survival that do occur would then be determined by density-independent factors.

Statistically the regression of the unsmoothed data used as a basis for Figure 3 is significantly different from the first hypothesis $\log_e S = F$ ($p = < 0.01$). However, because the biological mechanisms involved in this relationship are not understood, it cannot be concluded that the regression represents the real relation between these variables. There are indications that at least over a part of its range the index $\log_e R_3/R_{sp} + F$ tends to the constant level $\log_e c$. This would mean that variations in survival within this upper part of the relation could be associated with fluctuations in density - independent causes of juvenile mortality. Data were presented showing an association between survival and variations in the Atlantic inflow in the period 1950-1962, the period when survival has fluctuated around a constant level (Figure 4). The Group also noted that the provisional value of survival for the 1963 year-class, the last very rich group is $\log_e S = 2.63$ when $F = 2.57$ so that this very good year-calss has just replaced the initial average recruitment to the year-classes in the spawning stock in that year.

From the examination of these data the Working Group concluded that the present basic assumption of assessments, that recruitment is independent of spawning stock size, is no longer tenable if the statistically significant difference from the relation $\log_e S = F$ is valid. The use of this criterion would be suspect if the value $\log_e S$ has been overestimated in early years. This is improbable since the estimates of recruitment used to determine the survival index are derived by virtual population analysis and in the last Report it was shown that the method gave estimates for recruitment which were closely correlated with comparable data from independent pre-recruit surveys over the period 1946-1962. Alternatively the conclusion would be invalidated if the most recent points had been depressed by some trend in factors causing density-independent mortality. However, it is thought probable that these factors would be directly or indirectly related to the physical environment and it was shown that the observed variations in survival already fit well the chronological series of indices of environment that are available: there has been no consistent trend in the period examined.

Thus, although the Working Group was unable to define accurately its true form, it concluded (i) that there is a stock recruitment relationship in this stock which reduces the probability of rich year-classes being spawned at high levels of fishing mortality, and (ii) that at the present level of fishing mortality and conditions determining density independent mortality of eggs and larvae, the depleted spawning stock is unable to replace itself.

In discussing the biological mechanisms of stock and recruitment relationships the Group noted that the composition of the spawning stock may have an especially important influence on its reproductive potential. At the present high level of fishing mortality on the mature stock (Annual $F = 0.8$) relatively young first time spawners constitute some 85% of the spawning stock. Although the potentially lower fecundity of these young spawners may have been offset by recent increases in growth the Group also noted that the reduction in spawning stock has also led to a restriction of the spawning in time which might also influence the size of recruitment. It was noted too that for Arcto-Norwegian cod, because of the late onset of maturity (50% part of maturity = 10.5 year) the stock is exposed to fishing for a longer period prior to spawning than any other major stocks. Therefore a given level of fishing mortality will reduce the spawning stock to a smaller proportion of its original potential compared to other stocks.

Thus, although the biological mechanisms are not understood, circumstantial evidence supports the view that at high levels of fishing this stock will be especially vulnerable to the reduction of recruitment caused by reduced spawning stock which must occur in all stocks at some level of fishing mortality.

As a result the Group viewed with some misgiving the recent scarcity of recruits to the year-classes 1965-1968, as indicated by both the U.S.S.R. and international young fish surveys. The data from the U.S.S.R. surveys are reproduced in Table 5. This decline is a function of the reduced spawning stock, in addition to adverse environmental effects that may exist at present, when viewed over the longer term of the recorded history of this fishery. Good year-classes will occur from time to time but the probability of the succession of rich broods necessary to rebuild the stock has been seriously reduced by the degree of depletion of the spawning stock. With the recruitment known to be available up to 1972/73 it is unavoidable that this fishery will collapse in the early 1970's. Catches are expected to fall to a lower level than in 1964-1965, especially in Sub-area I and Division IIB and to decline later in Division IIA; and, in view of the stock and recruitment relation, there is no certainty that exceptionally favourable environmental conditions would lead to its rapid recovery.

4. HADDOCK

a) State of the fishery (Tables 6-8)

The previous report noted the influence of two good year-classes of 1960 and 1961 upon landings in recent years. These were still strongly represented in 1967 but total catches fell slightly.

In Sub-area I the abundance of the stock remained steady but fishing effort fell, whereas in Division IIA, which together with Sub-area I provides over 95% of the total catch, the recorded abundance of haddock declined. There was no significant change in the level of the total international fishing effort.

b) Estimates of mortality

In this fishery haddock are not fully recruited to the exploited stock until 5-6 years of age and in recent years the low abundance of older age-groups has led to a high variability in estimates of total mortality based on catch per unit effort statistics. Change in the degree of concentration on haddock by various fleets has also contributed to this variation. In order to overcome the limitations of this approach the Group placed more emphasis on the determination of the mortality estimates by virtual population analysis using a value of natural mortality, $M = 0.2$ taken from the catch per unit effort analysis.

The basic data of numbers caught at each age in successive years used in the analysis were compiled independently by two countries before the meeting and, in reviewing these, it was noted that in some years numbers of old haddock have been recorded by some countries fishing in Sub-area I. It is known from observation that haddock over 8 years of age have not been widely distributed in this area in recent decades, even taking into account their reduced abundance. The Group concluded that these catches must have been taken near the western margins of the Sub-area and might be more closely associated with the age composition of the stock in Division IIA.

Some further discrepancies between the two sets of data were noted which could not be reconciled with the data at hand. In particular the basic data may underestimate slightly the total numbers of young fish (2-4 year old) in the landings with a consequent underestimate of the total mortality for these age groups. Given this limitation estimates of total and fishing mortality are shown in Table 9. The variation of mortality with age has been determined from the mean mortality per age group for the calendar years 1956-1963, the year for which Z can be estimated with confidence for each of the age groups 2-10. The fishing mortality for 1964-1965 has been calculated for age groups 6-10 and interpolated for age groups 2-5 using the appropriate proportion of F (maximum) determined from the years 1956-1963.

These results are close to the estimates of fishing mortality from the catch per unit effort analysis given in the previous Report. A value of fishing mortality $F = 0.8$ for fully recruited age groups has been taken from the virtual population analysis as a basis for assessment of the fishery.

c) Assessments

The Working Group examined the effect upon the yield per recruit of changes in both fishing effort and age at recruitment. Assessments were carried out by the method described in para. 4(c) of the last Report.

c) (i) Effort (Table 10, Figure 5)

We considered the effect of changes in fishing mortality to 0.33, 0.67, 1.33 and 1.67 of the present level, the change in mortality being equally distributed between the statistical divisions of the fishery and according to the variation of fishing mortality with age. These confirm the previous results, that a reduction of fishing mortality would increase the yield per recruit to a maximum approximately 20 per cent higher than the current yield per recruit at one third the present level of fishing mortality. The major part of this increased yield would be taken in Division IIA. Catch per unit effort would also be increased. Increases in fishing mortality will decrease both yield per recruit and catch per unit effort.

During their examination of the estimates of mortality used as the basis for this assessment the Group noted that the known decline in actual fishing effort in the area of the fishery since 1964 has not been clearly reflected in the estimates of total international fishing effort (Table 8), nor has it been accompanied by a detectable decrease in fishing mortality in haddock. We are therefore not able to specify what reduction in actual effort might be required to secure a particular reduction in fishing mortality. In general we would expect any reduction in effort to overestimate the consequential decrease in fishing mortality because of differences in the degree of concentrations on the two species, cod and haddock.

c) (ii) Mesh assessments (Table 11, Figure 6)

Using the methods described in the last report the Group examined the effect upon yield per recruit of increases in the age of initial recruitment from the present 2.0 years to an upper limit of 5.0 years.

Those results show that the total yield per recruit of haddock would increase with further increases in mesh-size, up to the limit of the range calculated, where the yield per recruit would be some 20 per cent higher than its current level. This agrees with the conclusion given in the previous Report. the effect of increases in mesh-size on the haddock fisheries in Sub-area I and Division IIB was separated from the effect in Division IIA showing that the yield per recruit would be increased in all areas, but proportionately more so in Division IIA where the fishery depends on older haddock. However, this does not mean to say that the catches of national fleets within each area will be affected to the same extent. (See para. 5(b)).

In order to interpret these changes in yield per recruit with increasing age of initial recruitment, a calibration has been given in Figure 1 relating this age, and the mean age of recruitment, to the mesh-size. However, the most recent data on selectivity are being reviewed by the ICES/ICNAF Working Group on Selectivity Analysis. It is probable that the change in growth rate noted below has also influenced the girth and so reduced the selection factor as for the cod, so it is not possible at present to specify an accurate selection factor for haddock. The illustration therefore shows the initial and mean age and length of recruitment of haddock for a given mesh-size over a range of selection factors. The most probable range of the present effective mesh-size in the north-east Arctic is indicated. Thus, with the present mesh of 130 mm manila it is probable that the selection factor for haddock lies in the range of 2.9-3.6, depending on the incidence of the use of topside chafers, and at present this range corresponds to a range of initial age of recruitment of 2.0-3.0 years. An increase in mesh would increase the initial age of recruitment. The resulting change in yield per recruit can be determined from Figure 6.

d) Changes in growth rate

Sonina (1965,1967) has shown that the growth rate of haddock in the Barents Sea has changed during the last twenty years. These changes are summarised in Table 12 in terms of the mean fresh weight for different age groups. During the period 1952-1964 the average weight of the age groups 2-6 has shown an increase followed by a decrease to its original level during recent years. For older age groups there has been a progressive increase in weight at age, the present increased weight perhaps reflecting the enhanced growth of young fish in the years 1959-1962. This change has been associated with the preferred diet of capelin (*Mallotus villosus*) during these years which have a higher calorific content than the diet of benthic organisms more typical of earlier years.

In view of transitional state of the growth pattern the Working Group did not consider that an approximation by the von Bertalanffy formula would be justified and instead took the mean weight at age for the period 1963-1964 when preparing the assessments. This gives a slightly 'unconventional' growth pattern which accounts for the atypical form of the assessments of changes in yield per recruit; the yield per recruit continues to increase at increasing ages of initial recruitment. This is generated by the relatively high weight at age of the older fish which may not exist in a fishery under stable conditions. The increasing yield per recruit at high ages of recruitment is therefore not reliable but the general conclusion that an increase in the age of recruitment would give some small benefits in yield per recruit remains valid.

This same effect may have led to an overestimate of the yield per recruit at low levels of fishing effort (Figure 5) especially if the consequent increase in stock size also led to a density-dependent reduction in growth. However, again the general conclusion of the effort assessment remains valid.

e) Fluctuations in year-class strength

Table 13 gives estimates of the relative strength of recent year-classes determined from U.S.S.R. young fish surveys. These agree with the results of other surveys in showing that the year-classes 1962-1964 are relatively poor, and those for 1965-1968 extremely weak. Provisional examination of the $\log_e S$ values, as defined in para. 4, indicates that the stock was on average replacing itself up to 1960. Clearly this has not been the case in recent years but at present there are no grounds for supposing this might be influenced by a reduction in spawning stock size caused by fishing.

5. REDFISH

a) The state of the fishery (Tables 14-19 and Figure 7)

Redfish landings of all species from this area reached a peak of 109 thousand tons in 1959 but, after a temporary recovery in 1964, landings had declined to 24.000 tons by 1967. The major part of this decline can be seen in catches by Germany and U.S.S.R., the two countries that have the predominant interest in redfish. Landings by U.K. and Norway having remained more stable since redfish is only a by-catch of fisheries for other species. The division of the catch between statistical areas has been obscured by the adjustment of the sub-area boundaries which took place in 1964. As a result of this change the important redfish grounds in the Kopytov area fell into Division IIA instead of IIB so that the apparent trends in catches in these two divisions since 1964 are artefacts. It seems clear that landings of redfish have decreased in all areas.

The only reliable catch per unit effort data refer to the U.S.S.R. fishery for Sebastes mentella in the Kopytov area; these are illustrated in Figure 7 showing how closely this decline reflects the decline in landings. This implies that total effort has remained fairly steady although the Working Group did not compute this statistic because the landings group all species and do not refer to S. mentella alone. However, correspondence between the landings and trends in abundance does imply that this species contributed the major part of the peak catches in 1959-1960 and it is known that the fishery for the other species, S. marinus, has remained stable at a low level of landings for many years. The conclusion that the stock of S. mentella has shown a sharp decline in the last ten years agrees with the researches of Sorokin and Shafran (1968).

b) Identity of the stocks and their composition

To the knowledge of the Working Group the geographical extent of the redfish stocks in the north-east Arctic has not yet been successfully determined. The decline in catches and abundance might suggest that their range is limited but an alternative theory cannot be excluded that the occurrence of fishable concentrations of redfish has been reduced by the physical effect of trawling on their characteristic habitat. Age compositions of S. mentella presented by U.S.S.R. could not clarify this problem. These showed the range of age from 7-24 years within the length range 25-45 cm, and the variations in size and sex ratio between samples which are characteristic of redfish fisheries.

c) Assessments

The ages of the redfish samples presented were determined from scale readings. Research workers in other areas are also using otoliths for this purpose and the Group considered some validation study was necessary before the recorded age structure of this S. mentella stock could be used in mortality studies. The frequency of older age groups in the samples was reduced beyond an apparent peak in abundance (= full recruitment?) at 13-16 years of age but, because of the sampling problems, this does not necessarily reflect the effect of fishing. In the context of recruitment to the stock, 0-group redfish have been relatively numerous in some recent international surveys of 0-group fish in this area, but the Group noted that these may not provide a reliable guide to future prospects in a species which is not recruited to the exploited stock until it is about 10 years old.

The Group was therefore unable to make even provisional assessments of the effect of fishing and could not progress beyond the conclusions of other workers, that slow rate of growth and apprently low rate of recruitment imply that these stocks of redfish cannot maintain a high yield. It was, however, clear that all member countries fishing the area must increase their research and sampling effort in all aspects of the biology of these species if the problems are to be overcome.

6. COALFISH (Tables 20-23, Figure 8)

The assessment of the coalfish stocks in this area is outside the terms of reference of this Group but in view of the problems under consideration by a Coalfish Working Group at present examining the fishery in the western part of Division IIA, we considered it would be useful to present the fishery statistics for this area. The mean catch per unit effort measured by English steam trawlers, in the period 1960-1967, has been rather lower than those from the previous years 1951-1959, but not very different in the most recent years and indeed fishing effort in Sub-area I has declined. The Group did not examine age composition data but, in the absence of any marked adverse change in the fishery we considered that the conclusions of the Coalfish Working Group (ICES 1965, para. 7) probably remain accurate that 'there is no reason to assume this stock has been seriously depleted by fishing' and 'the output of the coalfish fisheries has been affected by changes in availability and by fluctuation in recruitment, particularly in the Norway coast area'.

7. Conclusions

1. The high level of fishing mortality in recent years, combined with the long-term effect of a number of poor year-classes, has seriously reduced the size of the spawning stock of Arcto-Norwegian cod. This had reduced the probability of strong year-classes in the near future and it is expected that both the stock, and the average recruitment, will remain at an extremely low level for some years owing to the effects of fishing which has already taken place.

2. A decrease in fishing mortality in the haddock stock to one third its present level would be expected to give increased yield per recruit and catch per unit effort with proportionately greater benefit to fisheries in Division IIA.

3. Increases in mesh-size up to c. 150 mm would give increased yield per recruit in the haddock, again with proportionately greater benefit to fisheries in Division IIA.

4. It is not possible to assess the state of the redfish stocks with the data currently available.

RECOMMENDATION

All member countries fishing in the north-east Arctic be urged to intensify their research effort on redfish with particular regard to

(i) the identity of the stocks

(ii) increasing the level of sampling

(iii) establishing the validity of age determinations.

On behalf of the Working Group

D.J. Garrod

References

Bohl, H.J.	1968	"Preliminary results of German mesh selection experiments on cod off Bear Island", ICES, C.M.1968/B:15.
Garrod, D.J.	1968	"Stock and recruitment relationships in four north Atlantic cod stocks". ICES, C.M.1968/F:14.
ICES	1965	"Report of the Coalfish Working Group". Coop.Res.Rep., Ser.A, No.6.
Sonina, M.A.	1965	"A relationship between growth rate and population density for haddock in the Barents Sea". ICNAF, Spec.Publ., No. 6.
Sonina, M.A.	1967	"Some reasons for the change in the age-length composition of the haddock population in the southern Barents Sea in 1950-1965". Mater.otchetn.sessii-uchenogo.soveta.PINRO 8.

Working documents contributed to the meeting:

Konstantinov, K.G. and Sonina, M.A.	"The Share of haddock in Soviet trawl catches in the Barents Sea".(In press. PINRO Murmansk).
Ponomarenko, V.P.	"Factors determining the growth rate of cod at different stages of their life cycle". (In press. PINRO Murmansk).
Sorokin, V.P. and Shafran, I.S.	"An assessment of the absolute abundance of the commercial deepwater redfish stocks in the Barents Sea". (St. Vsesoyuznaya conferentsiya molodykh spetsialistov, Murmansk.)(In Russian, translated for the Working Group).

Table 1. COD. Total landings by divisions (metric tons, round fresh). Revised and additional figures for years 1960-1967.

Year	Sub-area I	Division IIB	Division IIA	Total
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
1967	320,842	115,375	134,838	571,055

Table 2. COD. Landings by countries (Sub-area I and Divisions IIA and IIB combined). Revised and additional figures for years 1960-1967.

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
1967	77,436	3,628	218,910	270,417	664	571,055

Table 3. COD. Estimates of total international fishing effort for Sub-area I and Divisions IIA and IIB.

Year	Sub-area 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 Units	Norway Units
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
1967	51	30	395	61	10	12	110	13	50	5	261	22

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	Sub-area I		Division IIB		Division IIA	
	UK[1)]	USSR[2)]	UK	USSR	UK	Norway[3)]
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
1967	0.081	0.53	0.106	0.87	0.052	3.5

1) UK data - tons per 100 ton hours fishing.

2) USSR data - tons per hous fishing.

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

Table 5. COD. Estimates of year-class strength. (USSR surveys were extended to Division IIB in 1956. The number per hour fishing for USSR surveys is the mean of II and III year old fish).

Year-class	USSR Survey No./hour fishing		Mean for whole area	USSR Assessment	Virtual Population No. x 10^{-8} 2-yr old
	Sub-area I	Division IIB			
1946	5			poor	9
1947	17			+ avge	13
1948	25			rich	20
1949	24			rich	23
1950	82			v.rich	30
1951	13			- avge	12
1952	2			poor	6
1953	11			poor	8
1954	10			- avge	14
1955	4			poor	9
1956	12	24	15	- avge	12
1957	10	15	11	- avge	13
1958	10	20	14	+ avge	15
1959	12	13	12	+ avge	12
1960	6	13	10	poor	7
1961	2	2	2	poor	3
1962	6	5	5	poor	5
1963	14	84	46	rich	(20)
1964	51	39	45	rich	(20)
1965	< 1	< 1	< 1	v.poor	(1)
1966(I+II)	< 1	< 1	< 1	v.poor	
1967(0+I)	< 1	< 1	< 1	v.poor	
1968(0)	< 1	< 1	< 1	v.poor	

See USSR reports to "Annales Biologiques".

Table 6. HADDOCK. Total landings by divisions (metric tons, round fresh). Revised and additional figures for years 1960-1967.

Year	Sub-area 1	Division IIB	Division IIA	Total
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
1967	104,005	2,765	30,668	137,438

Table 7. HADDOCK. Landings by countries (Sub-area I and Divisions IIA and IIB combined). Revised and additional figures for years 1960-1967.

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
1967	22,087	1,705	51,954	60,461	1,231	137,438

Table 8. HADDOCK. Catch per unit effort and estimated total international effort.

	Catch per Effort (UK) Kilos/100 ton hours			Estimated Total Effort UK units $\frac{\text{Total Catch} \times 10^{-6}}{\text{tons/100 t.hours}}$ Region 1
	Sub-area	Division		
Year	I	IIA	IIB	
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
1967	18	25	2.4	7.6

Table 9. HADDOCK. Summary of estimates of mortality.
Estimates using the virtual population technique.

Age group	Variation of Z with age 1956-1963			Mean fishing mortality 1964-1965
	Mean Z	Mean F (M = 0.2)	% of F (max.)	
2	.24	.04	6	.05
3	.35	.15	23	.19
4	.59	.39	60	.49
5	.79	.59	91	.74
6	.88	.68	100	.80
7	.84	.64	100	.80
8	.84	.64	100	.80
9	.82	.62	100	.80
10	.70	.50	100	.80
Mean age groups 6-9		.65		.80

Table 10. Haddock Assessment: The effect of variation in fishing effort.

(A) Yield per recruit (kg)	Change in effort from present level (100)				
	0,33	0,67	1,00	1,33	1,67
Sub-area I and Division IIB	0,363	0,370	0,367	0,353	0,343
Division IIA	0,215	0,141	0,098	0,072	0,058
Total	0,578	0,511	0,465	0,425	0,401
(B) Catch per unit effort					
Sub-area I and Division IIB	3.00	1.51	1,00	0.72	0.56
Division IIA	6.65	2.14	1.00	0.55	0.35

Table 11. Haddock Assessments: The effect of changes in age at recruitment (mesh change).

	Age at initial recruitment						
	2,0	2,5	3,0	3,5	4,0	4,5	5,0
(A) Yield per recruit (kg)							
Sub-area I and Division IIB	0,385	0,388	0,392	0,401	0,409	0,422	0,431
Division IIA	0,099	0,101	0,105	0,111	0,121	0,139	0,165
Total	0,484	0,489	0,497	0,511	0,529	0,561	0,596
(B) Catch per unit effort							
Sub-area I and Division IIB	.99	1.00	1.01	1.03	1.05	1.09	1.11
Division IIA	.98	1.00	1.04	1.10	1.20	1.38	1.63

Table 12. Mean round fresh weight per age of cod and haddock (Kilos) (USSR data).

Age	Cod	Haddock			
	1958/67	1927/37	1952/58	1959/62	1963/64
2		0.17	0.23	0.28	0.25
3	0.59	0.37	0.39	0.59	0.41
4	0.95	0.63	0.60	0.86	0.62
5	1.41	1.02	0.91	1.18	0.97
6	2.14	1.49	1.32	1.63	1.59
7	3.17	1.83	1.76	2.14	2.33
8	4.49	2.16	2.39	2.68	2.72
9	5.73	2.46	3.06	3.34	3.56
10	7.06	2.72	3.46	3.44	4.41
11		2.82	4.32	4.18	

Table 13. 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	10)	5
1952	7)	75	1964	14)	
1953	31)		1965	(< 1)	
1954	5)		1966 (I-II)	(< 1)	
1955	3)	11	1967 (0-I)	(< 1)	
1956	23)		1968 (0)	(< 1)	
1957	12)				

Table 14. REDFISH: Total international landings in Sub-area I and Divisions IIA and IIB (tons).

Year	Sub-area I	Division IIA	Division IIB	Total
1956	11,769	20,211	30,522	62,502
1957	16,989	19,721	60,715	97,425
1958	21,965	19,008	48,946	89,919
1959	26,208	16,920	65,681	108,809
1960	14,788	17,673	54,606	87,067
1961	14,036	18,216	32,043	64,295
1962	8,621	12,198	14,746	35,565
1963	10,753	15,750	15,429	41,932
1964	38,380	14,874	12,923	66,177
1965	6,323	29,055	4,467	39,845
1966	6,383	25,125	3,280	34,788
1967	3,655	18,653	1,323	23,631

Table 15. REDFISH: Landings by countries, in Sub-area I and Divisions IIA and IIB (tons).

Year	England	Germany	Norway	USSR	Others	Total
1956	8,080	22,843	4,674	26,889	16	62,502
1957	6,986	35,621	4,006	50,809	3	97,425
1958	6,348	17,621	4,151	61,799	-	89,919
1959	8,167	10,832	3,971	85,738	101	108,809
1960	9,613	9,748	5,973	61,704	29	87,067
1961	7,438	10,218	4,022	42,564	53	64,295
1962	7,197	4,631	6,102	17,630	5	35,565
1963	6,912	5,568	7,714	18,400	3,338	41,932
1964	6,221	3,859	8,483	44,626	2,988	66,177
1965	4,888	4,766	6,617	22,321	1,253	39,845
1966	6,546	5,389	6,931	15,889	33	34,788
1967	5,607	5,550	5,205	7,269	-	23,631

Table 16. REDFISH: Landings by countries, Sub-area I (tons).

Year	England	Germany	Norway	USSR	Others	Total
1956	2,513	892	589	7,771	4	11,769
1957	2,344	870	1,426	12,349	-	16,989
1958	1,973	861	377	18,754	-	21,965
1959	2,827	121	328	22,901	31	26,208
1960	4,487	2,461	1,408	6,403	29	14,788
1961	3,063	546	19	10,364	44	14,036
1962	2,832	-	896	4,888	5	8,621
1963	1,937	-	918	4,560	3,338	10,753
1964	1,812	-	492	33,246	2,830	38,380
1965	1,016	-	333	4,974	-	6,323
1966	1,705	7	159	4,511	-	6,383
1967	1,419	354	242	1,640	-	3,655

Table 17. REDFISH: Landings by countries, Division IIA (tons).

Year	England	Germany	Norway	USSR	Others	Total
1956	2,087	13,712	4,083	329	-	20,211
1957	2,250	13,681	2,545	1,245	-	19,721
1958	2,531	10,441	3,770	2,446	-	19,008
1959	2,744	10,421	3,478	277	-	16,920
1960	3,846	7,287	4,529	2,011	-	17,673
1961	2,560	9,672	4,003	1,978	3	18,216
1962	2,507	4,631	5,060	-	-	12,198
1963	3,550	5,568	6,632	-	-	15,750
1964	3,014	3,788	7,923	-	149	14,874
1965	2,916	4,766	6,129	13,991	1,253	29,055
1966	4,373	5,382	6,772	8,565	33	25,125
1967	3,781	5,196	4,961	4,715	-	18,653

Table 18. REDFISH: Landings by countries, Division IIB (tons).

Year	England	Germany	Norway	USSR	Others	Total
1956	3,480	8,239	2	18,789	12	30,522
1957	2,392	21,070	35	37,215	3	60,715
1958	2,024	6,319	4	40,599	-	48,946
1959	2,596	290	165	62,560	70	65,681
1960	1,280	-	36	53,290	-	54,606
1961	1,815	-	-	30,222	6	32,043
1962	1,858	-	146	12,742	-	14,746
1963	1,425	-	164	13,840	-	15,429
1964	1,395	71	68	11,380	9	12,923
1965	956	-	155	3,356	+	4,467
1966	467	-	-	2,813	-	3,280
1967	407	-	2	914	-	1,323

Table 19. REDFISH: Catch per unit effort.

Year	Sub-area I	Division IIA		Division IIB
	U.K.	U.K.	U.S.S.R.[1)]	U.K.
	Tons/100hrs	Tons/100hrs	Tons/1hr	Tons/100hrs
1956	2.85	6.49	10.0	3.23
1957	3.34	5.05	5.6	2.34
1958	2.30	5.82	7.4	2.02
1959	3.01	6.95	6.9	2.07
1960	3.02	6.53	6.2	2.05
1961	2.17	5.64	5.4	2.37
1962	2.09	4.98	4.7	2.59
1963	1.69	8.43	4.4	2.23
1964	2.95	5.84	3.9	1.98
1965	1.68	6.30	2.9	1.86
1966	1.74	6.41	2.7	1.39
1967	1.69	5.14	2.5	2.93

1) According to data by Sorokin and Shafran.

Table 20. COALFISH: Total international landings in Sub-area I and Divisions IIA and IIB (tons).

Year	Sub-area I	Division IIA	Division IIB	Total
1960	19,041	113,912	562	133,515
1961	16,360	89,177	414	105,951
1962	10,929	109,375	403	120,707
1963	20,809	127,675	143	148,627
1964	53,968	142,544	994	197,506
1965	16,149	168,567	884	185,600
1966	10,479	191,575	921	202,975
1967	13,358	167,389	275	181,022

Table 21. COALFISH: Landings by countries in Sub-area I and Divisions IIA and IIB (tons).

Year	England	Germany	Norway	France	Others	Total
1960	9,780	25,948	96,050	1,700	37	133,515
1961	4,595	19,757	77,875	3,625	99	105,951
1962	4,699	12,651	101,895	544	918	120,707
1963	4,112	8,108	135,297	1,110	-	148,627
1964	6,591	4,420	184,700	1,525	270	197,506
1965	6,741	11,387	165,531	1,618	323	185,600
1966	13,078	11,269	175,037	2,987	604	202,975
1967	8,379	11,822	150,860	9,472	489	181,022

Table 22. COALFISH: Landings by countries (tons).

Sub-area I.

Year	England	Germany	Norway	France	Others	Total
1960	3,401	1,371	12,532	1,700	37	19,041
1961	1,516	198	10,942	3,625	79	16,360
1962	1,297	-	8,170	544	918	10,929
1963	953	-	18,746	1,110	-	20,809
1964	1,880	-	50,555	1,525	8	53,968
1965	1,599	-	14,461	-	89	16,149
1966	3,024	19	7,366	-	70	10,479
1967	1,485	233	11,640	-	-	13,358

Division IIA.

Year	England	Germany	Norway	France	Others	Total
1960	5,817	24,577	83,518	-	-	113,912
1961	2,727	19,559	66,879	-	12	89,177
1962	3,211	12,651	93,513	-	-	109,375
1963	3,032	8,108	116,535	-	-	127,675
1964	4,088	4,410	133,882	-	164	142,544
1965	4,498	11,387	150,842	1,618	222	168,567
1966	9,418	11,250	167,671	2,987	249	191,575
1967	6,628	11,589	139,211	9,472	489	167,389

Division IIB.

Year	England	Germany	Norway	France	Others	Total
1960	562	-	-	-	-	562
1961	352	-	54	-	8	414
1962	191	-	212	-	-	403
1963	127	-	16	-	-	143
1964	623	10	263	-	98	994
1965	644	-	228	-	12	884
1966	636	-	-	-	285	921
1967	266	-	9	-	-	275

Table 23. COALFISH: Total international fishing effort in Sub-area I and Division IIA derived from the catch per unit effort of English steam trawlers.

	Sub-area I			Division IIA		
Year	Tons/million ton hours	Total international catch	Total fishing effort in million of ton hours	Tons/million ton hours	Total international catch	Total fishing effort in million of ton hours
1960	32	19,041	595	151	113,912	754
1961	15	16,360	1,090	88	89,177	1,013
1962	14	10,929	781	96	109,375	1,139
1963	12	20,809	1,734	110	127,675	1,161
1964	41	53,968	1,316	105	142,544	1,358
1965	37	16,149	436	131	168,567	1,287
1966	43	10,479	244	188	191,575	1,019
1967	28	13,358	477	123	167,389	1,361
1951-1959	35			149		
1960-1967	28			124		

Appendix 1

Estimation of catches at varying levels of fishing mortality in the Arcto-Norwegian cod and haddock stocks

Introduction

The 1968 meeting of NEAFC passed a resolution setting up an ad hoc Committee to discuss a scheme to regulate fishing mortality in the north-east Arctic (NEAFC Resolution NC/68). This Committee met in January 1969 and, as a result of their talks, asked this Working Group for estimates of catches from these stocks at varying levels of fishing mortality to be presented to the 1969 meeting of NEAFC. The Working Group met in Copenhagen on 23rd February 1969; of the countries on the Group all except U.S.S.R. were represented.

Method

The number of fish in each age-group of the cod and haddock stocks at the beginning of 1968 was determined from existing data by an extension of the 'virtual population' analysis used in earlier work. These stocks were then incorporated in a model calculating the stock and yields in 1968 and 1969 which are expected to follow an increase in fishing mortality to a 10% higher level for cod, and 20% higher for haddock, this being an estimate of increased fishing mortality in 1968 owing to the favourable stock situation outlined in the report.

The expected yields from the stocks in 1970 and 1971 were then calculated assuming

(i) fishing mortality continues at its 1969 level

(ii) that it is reduced and stabilised at its 1964-1966 level, this being the 'present' level referred to in the NEAFC Resolution, and

(iii) that it is reduced to specified percentages of the 1964-1966 level.

The construction of these models required estimates of recruitment to the more recent year-classes which could not be deduced from the statistics of the commercial fishery. These have been taken from the pre-recruit surveys discussed elsewhere. The recruitment to year-classes contributing to catches in 1970 and 1971 is listed in Table 1.

Results

The level of catch appropriate to each level of fishing mortality for cod and haddock is given in Tables 2 and 3. Separate estimates for the catch in Division IIA are also given for 1970 bearing in mind the desirability of controlling the fishery in this area separately in the interests of efficiency of the regulation. These estimates for Division IIA should be viewed with caution because they refer only to the catch of mature cod and exclude a proportion of immature cod taken in the northern part of the area. Estimates are not given for 1971 because it is considered that the influence of regulation in 1970, and the change in the fishery limit off Norway in 1970 may have influenced the distribution of fishing in 1971 and so altering the basis upon which this split has been calculated. The percentage changes in fishing mortality given in the tables have been selected to conform with the assessments given in previous reports indicating the level which would secure the maximum yield per recruit and, for cod, the level at which recruitment can be maintained in accordance with the Group's conclusion concerning the stock and recruitment relation in this species. If fishing mortality is regulated to a level in excess of F = 0.37 on fully recruited age-groups then the probability of rich year-classes could be expected to decline slowly and the reduction of effort would not be of substantial benefit to the stock though there would be an increase in catch per unit effort. Conversely regulation to reduce fishing mortality below this level will increase the probability of rich year-classes and enhance the rate of recovery of the stock.

It should be borne in mind that the statistics for 1967 are the most recent data that could be used as a basis for these quota. It is expected that more closely up-to-date information, as would be required in any continuing scheme to regulate fishing mortality, would improve the precision of the estimates but the effect of these errors can be accommodated without loss in catch estimates for subsequent years.

Table 1. Cod and Haddock. Estimates of recruitment used in model.

Cod				Haddock			
No. of 3 year olds x 10^{-6}				No. of 3 year olds x 10^{-6}			
1953	620	1961	198	1957	244	1963	192
1954	942	1962	439	1958	102	1964	128
1955	674	1963	2,141	1959	230	1965	40
1956	859	1964	1,499	1960	248	1966	40
1957	1,100	1965	100	1961	188	1967	40
1958	1,185	1966	100	1962	53	1968	40
1959	873	1967	100				
1960	425						

Table 2. Cod: Estimates of catch at specified levels of fishing mortality.

					1967	1968	1969	1970 I+IIA+IIB(IIA only)	1971
a)	Fishing Mortality Constant following 10% increase expected in 1968			F=	0.79	0.87	0.87	0.87	0.87
					Yield in thousand tons round fresh				
					571	802	723	460	277
b)	Fishing Mortality Regulated from 1970 to								
	F	% of F 1964/66	% of F 1968/69						
(i)	0.79	100	91					430 (36.5)	274
(ii)	0.63	80	72					363 (30.9)	261
(iii)	0.53	67	61					316 (26.9)	246
(iv)	0.37	47	42					234 (19.9)	204
(v)	0.26	33	30					170 (14.4)	160

(i) Fishing mortality stabilised at 1964-1966 level.

N.B. (iii) Fishing mortality giving maximum yield per recruit in a constant recruitment model.

(iv) Fishing mortality at which recruitment can be maintained; it does not provide for an increase in recruitment.

Table 3. Haddock: Estimates of catch at specified levels of fishing mortality.

						1967	1968	1969	1970 I+IIA+IIB (IIA only)	1971
a) Fishing Mortality Constant following 20% increase expected in 1968										
	F =					0.77	0.92	0.92	0.91	0.91
							Yield in thousand tons round fresh			
						137.4	86.4	65.6	43.4	30.4
b) Fishing Mortality Regulated from 1970										
	F	% of 1965/66	% of 1968/69							
(i)	0.77	100	85						38.5 (10.8)	30.0
(ii)	0.62	80	68						32.9 (9.2)	29.5
(iii)	0.52	67	57						28.7 (8.0)	27.0
(iv)	0.39	50	43						22.8 (6.4)	23.7
(v)	0.25	33	27						16.0 (4.5)	18.5

NB. (i) Fishing mortality stabilised at 1965-1966 level.

(iv) - (v) Fishing mortality giving maximum yield per recruit in constant recruitment model.

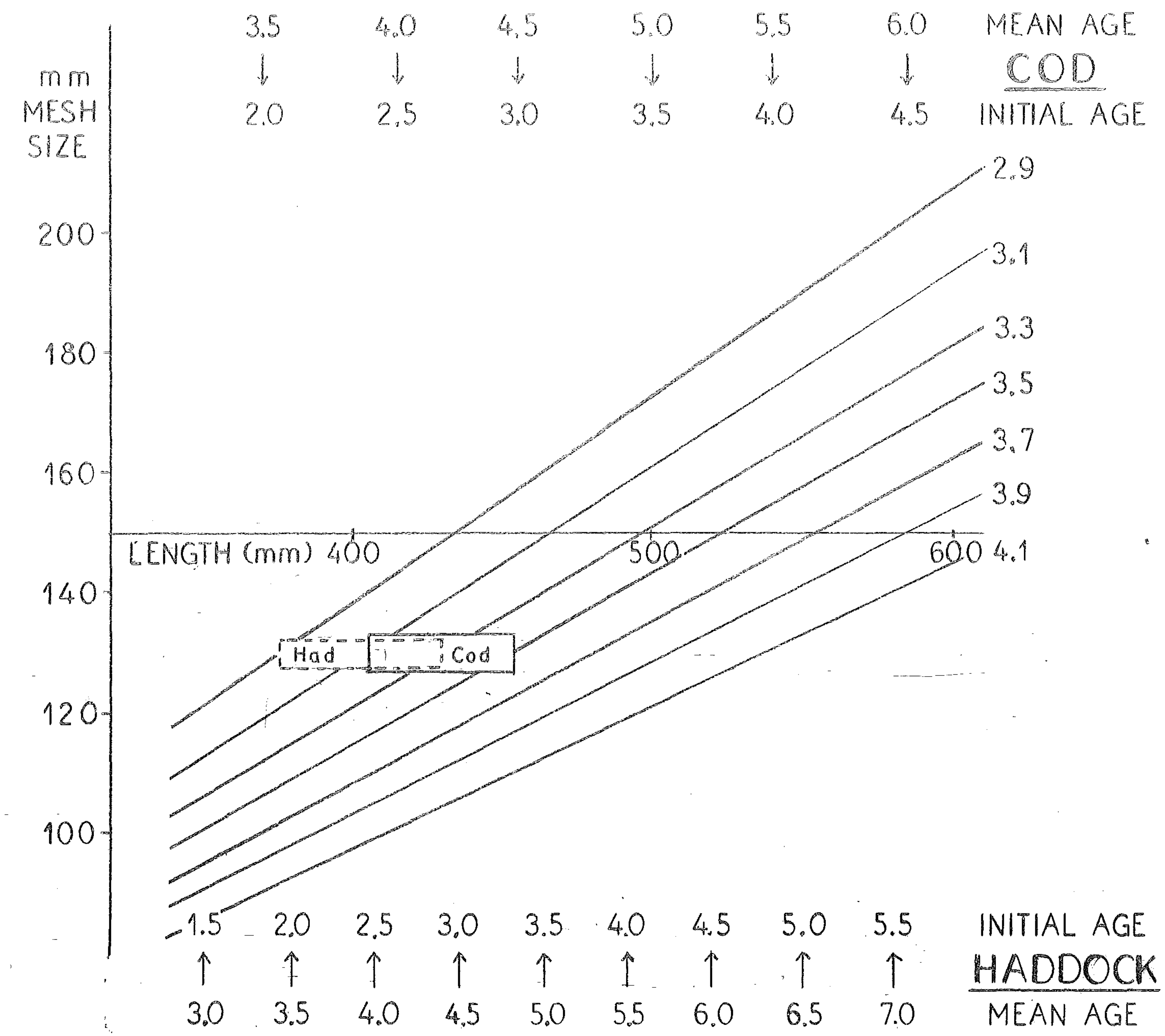


Figure 1. The calibration of mean age of recruitment for cod and haddock against mesh-size.

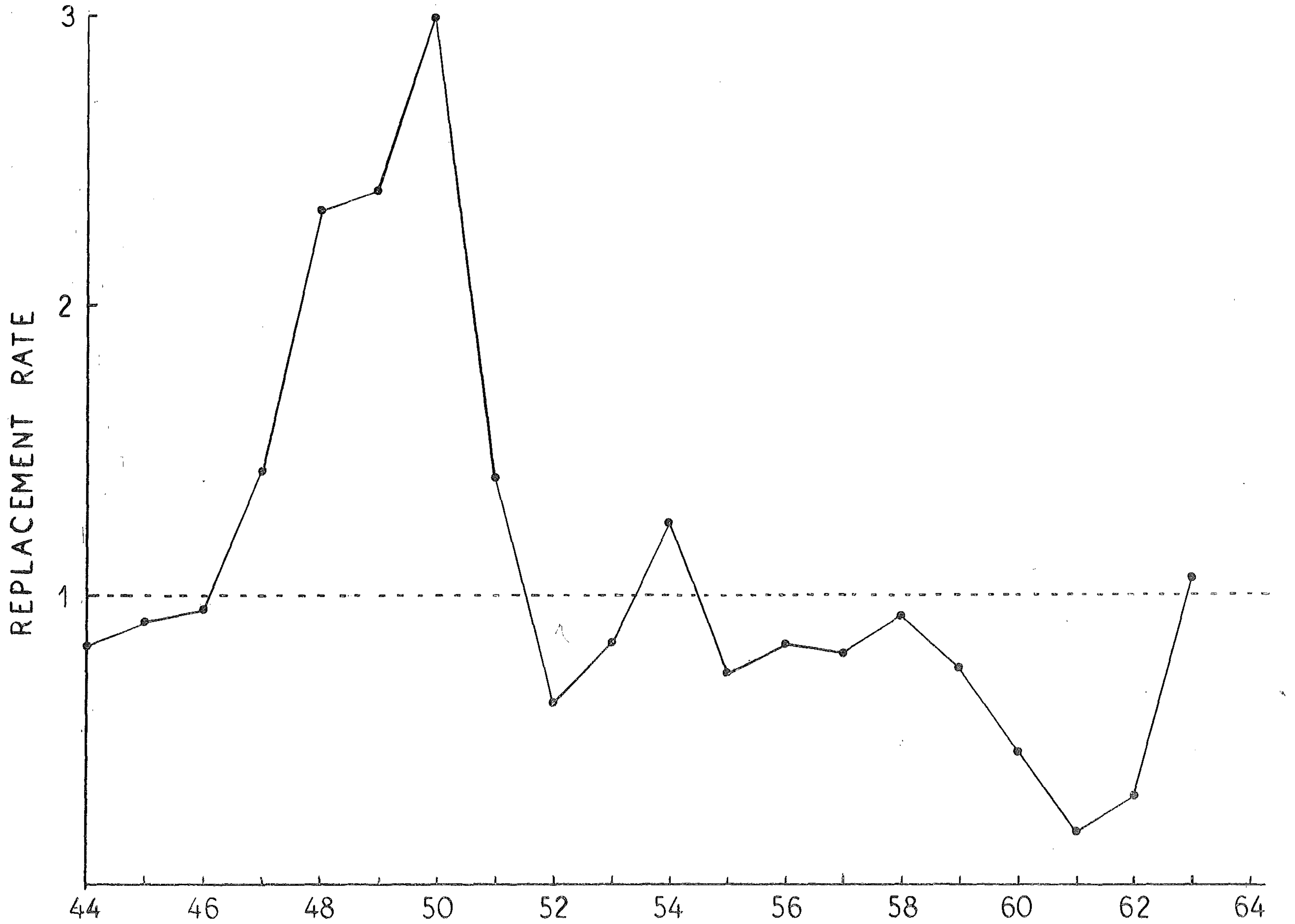


Figure 2. The variation in replacement rate of Arcto-Norwegian cod in chronological series.

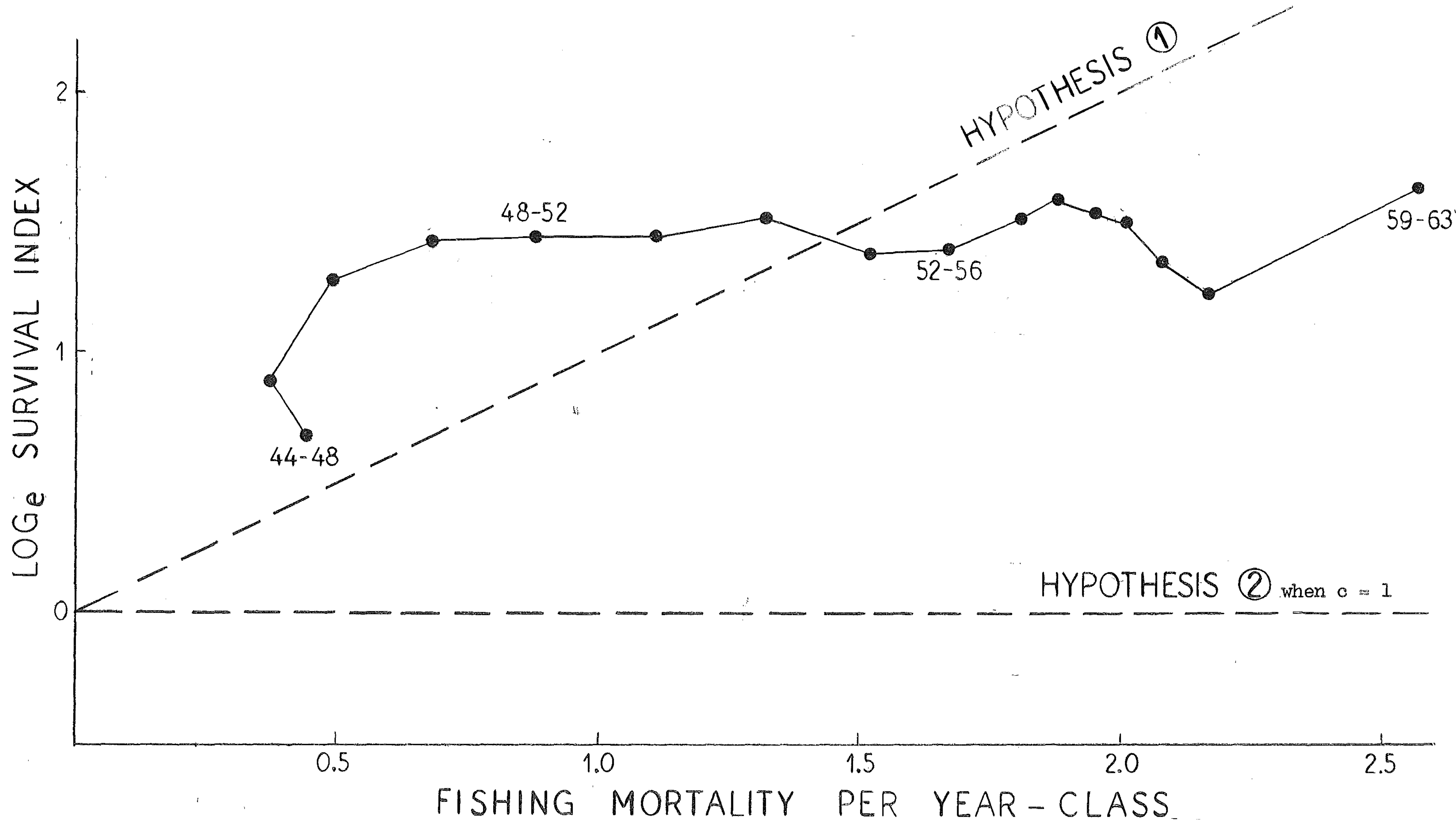


Figure 3. The variation in $\log_e$ S plotted against fishing mortality per year-class.

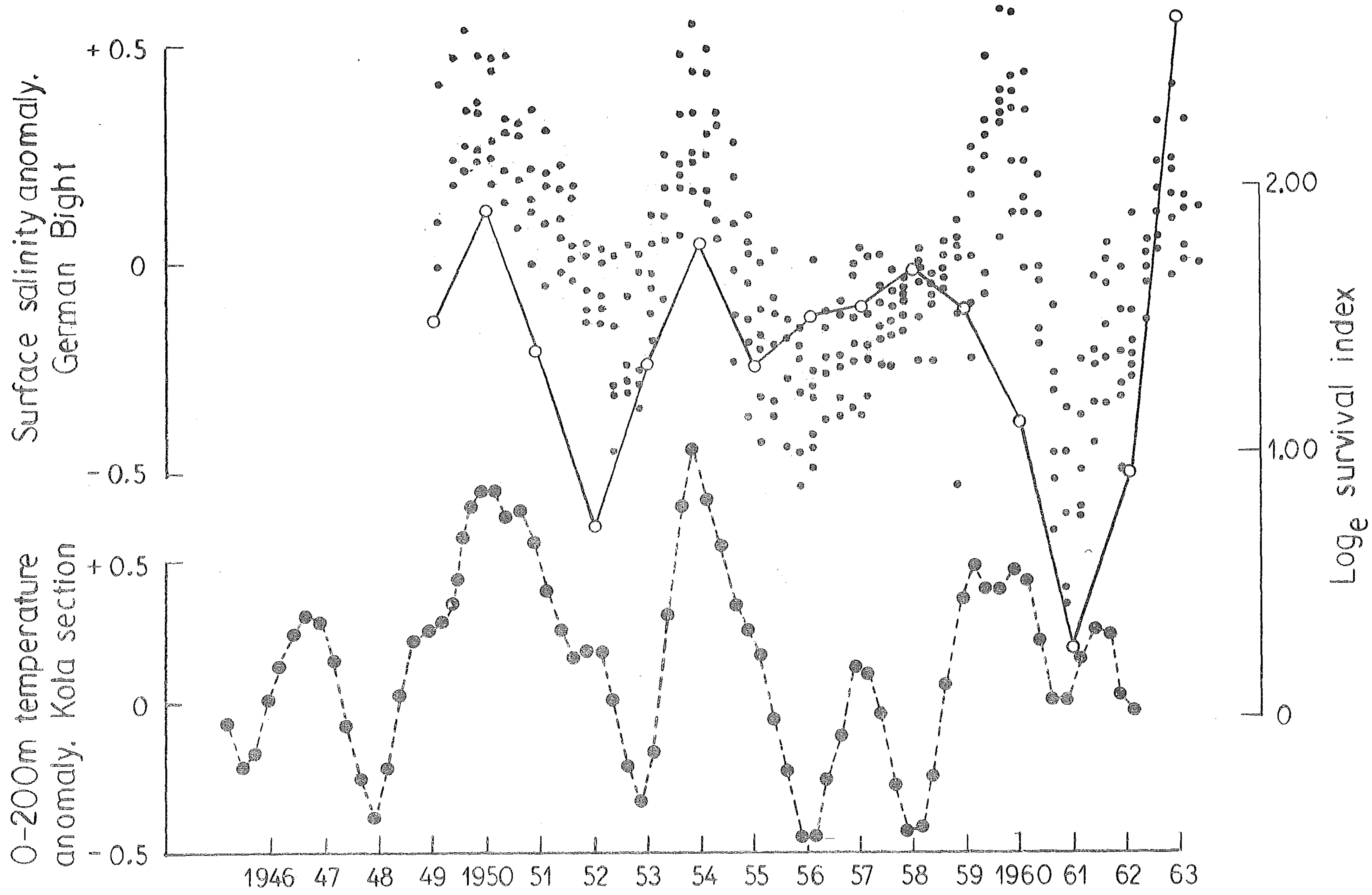
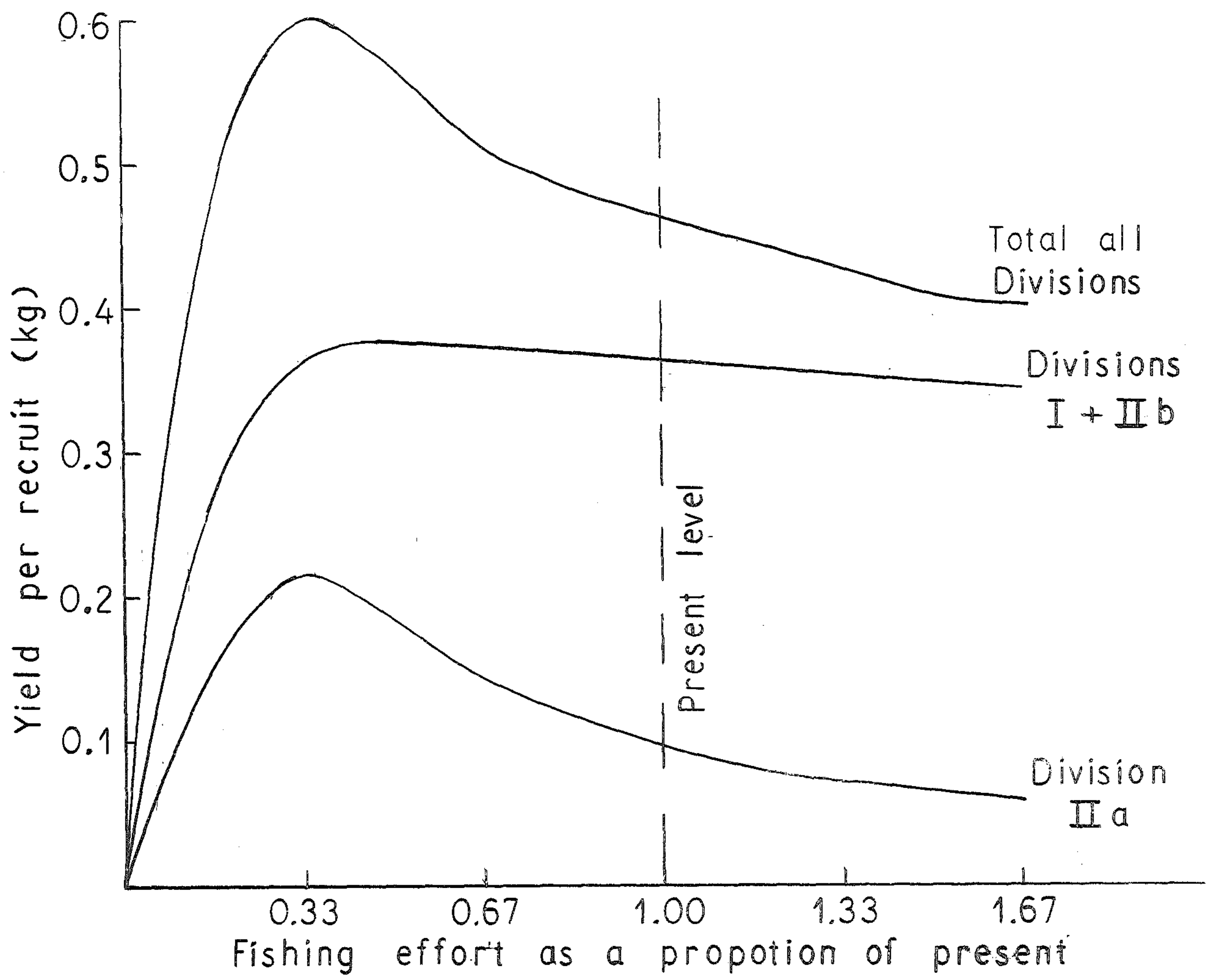
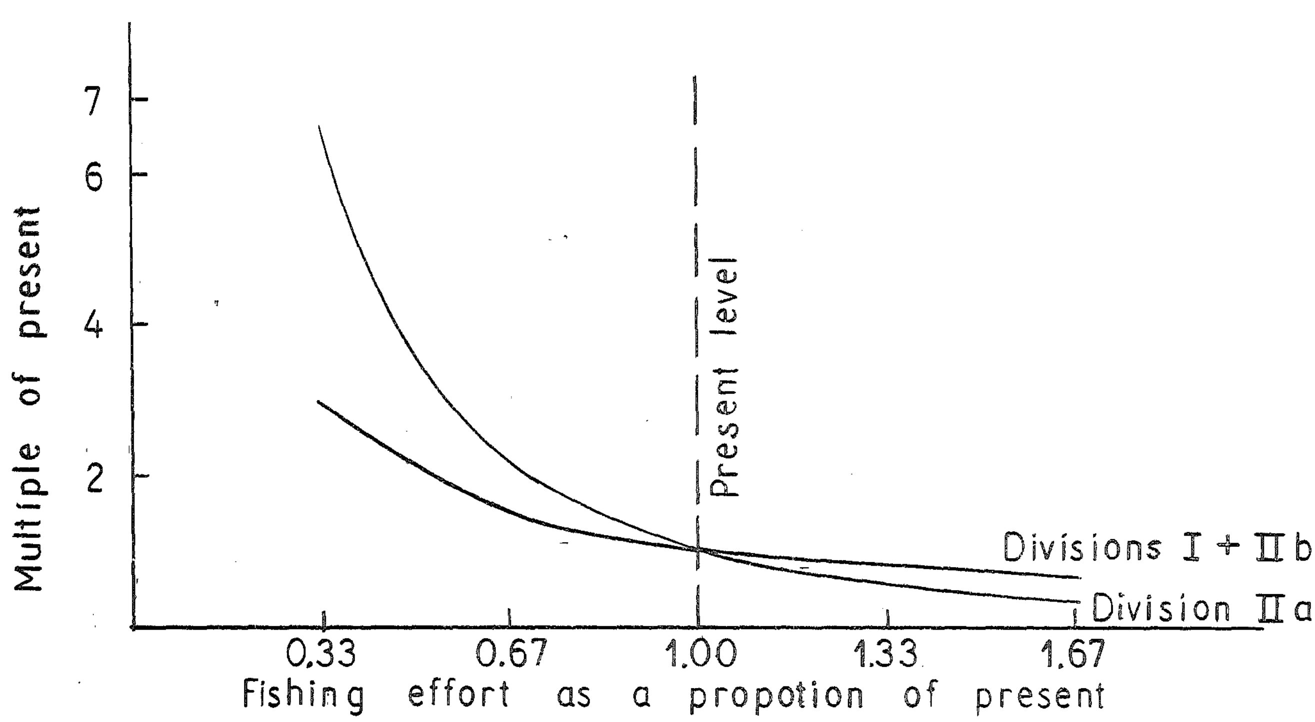


Figure 4. Comparison of variation in $\log_e$ S with indices of the 'environment' for the time series 1950-1963.



A) Yield per recruit



B) Catch per unit effort

Figure 5. Haddock Assessment: A. The effect upon yield per recruit of changes in fishing mortality. B. The effect upon catch per unit effort of changes in fishing mortality.

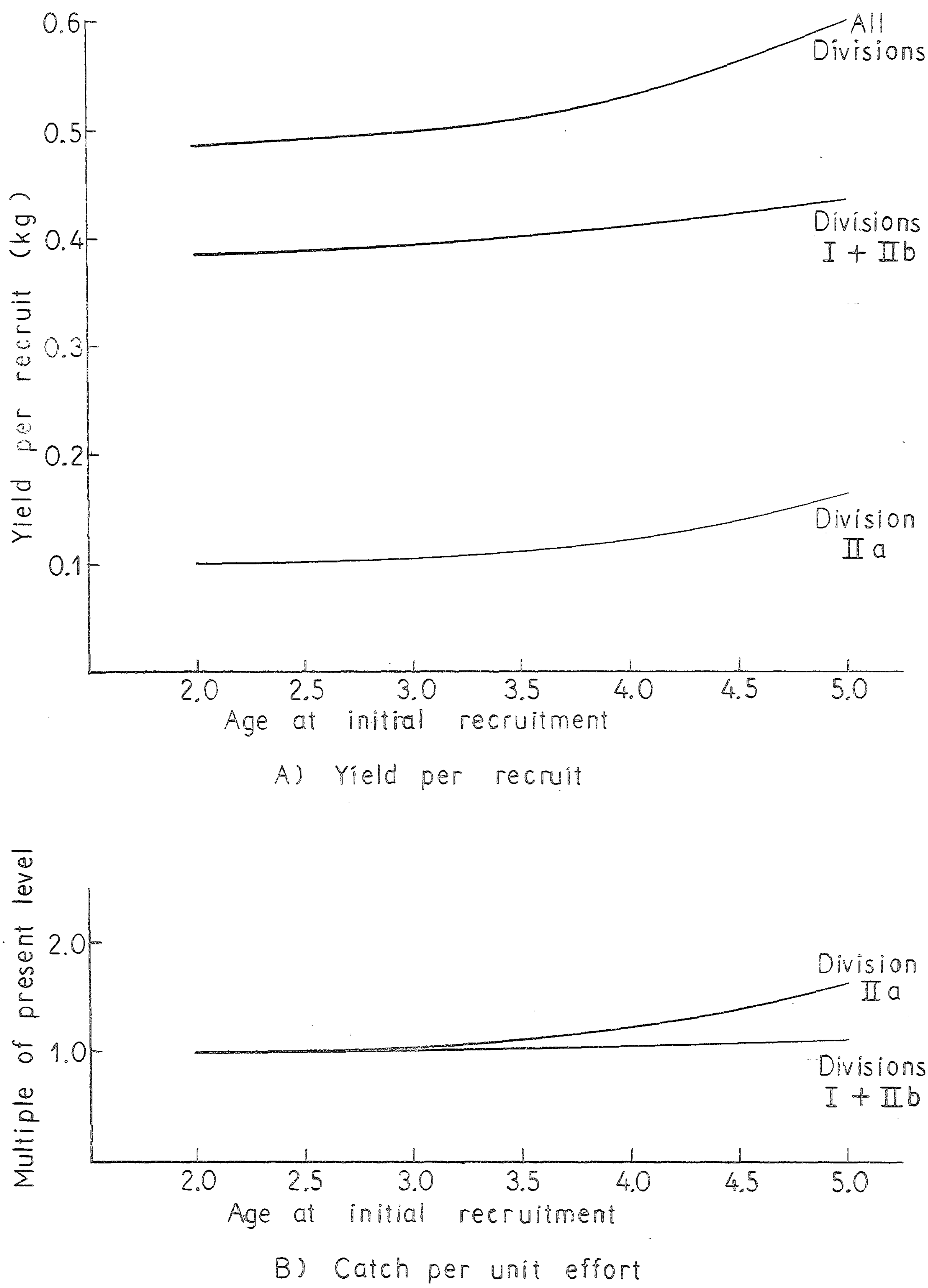
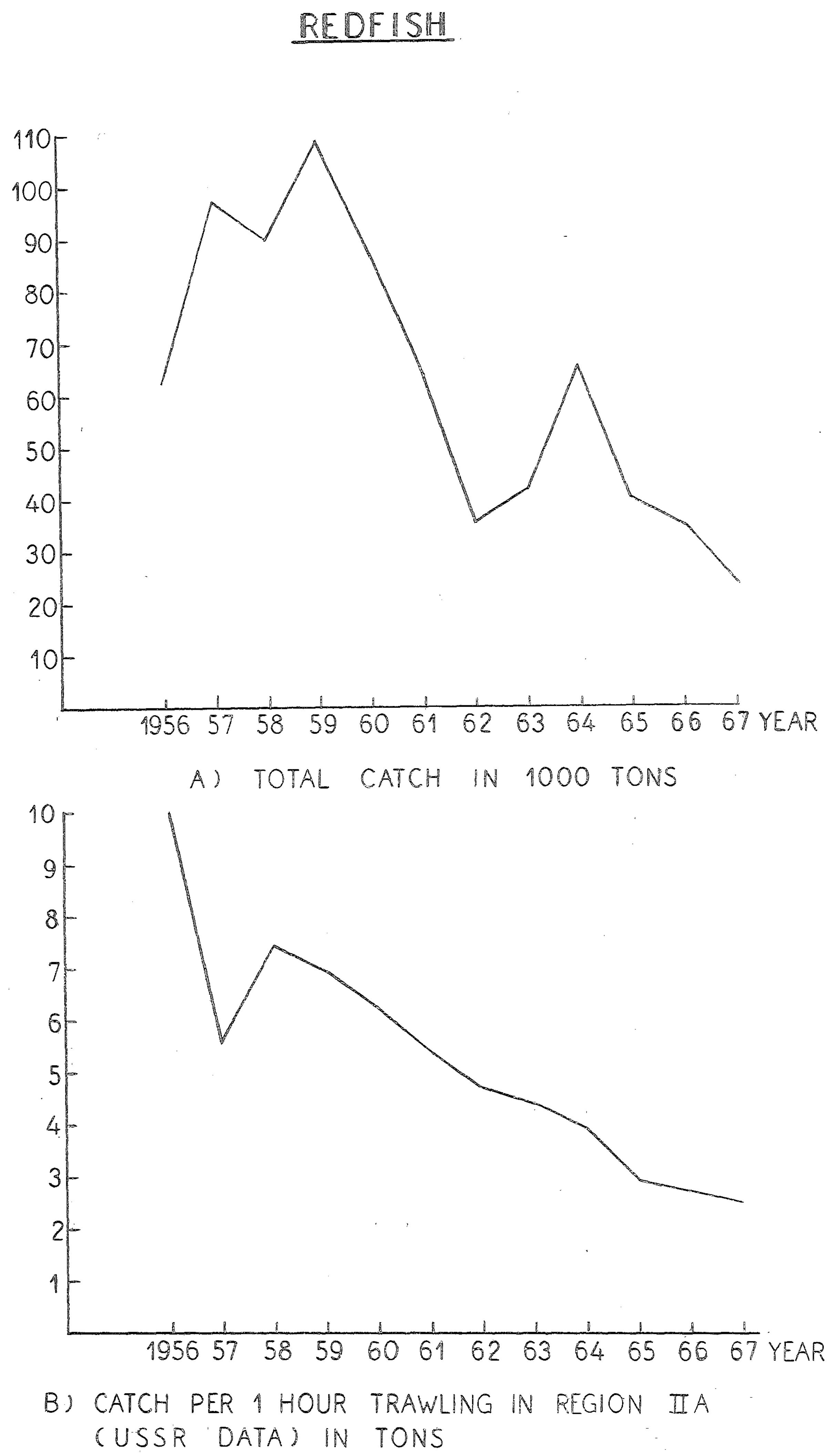
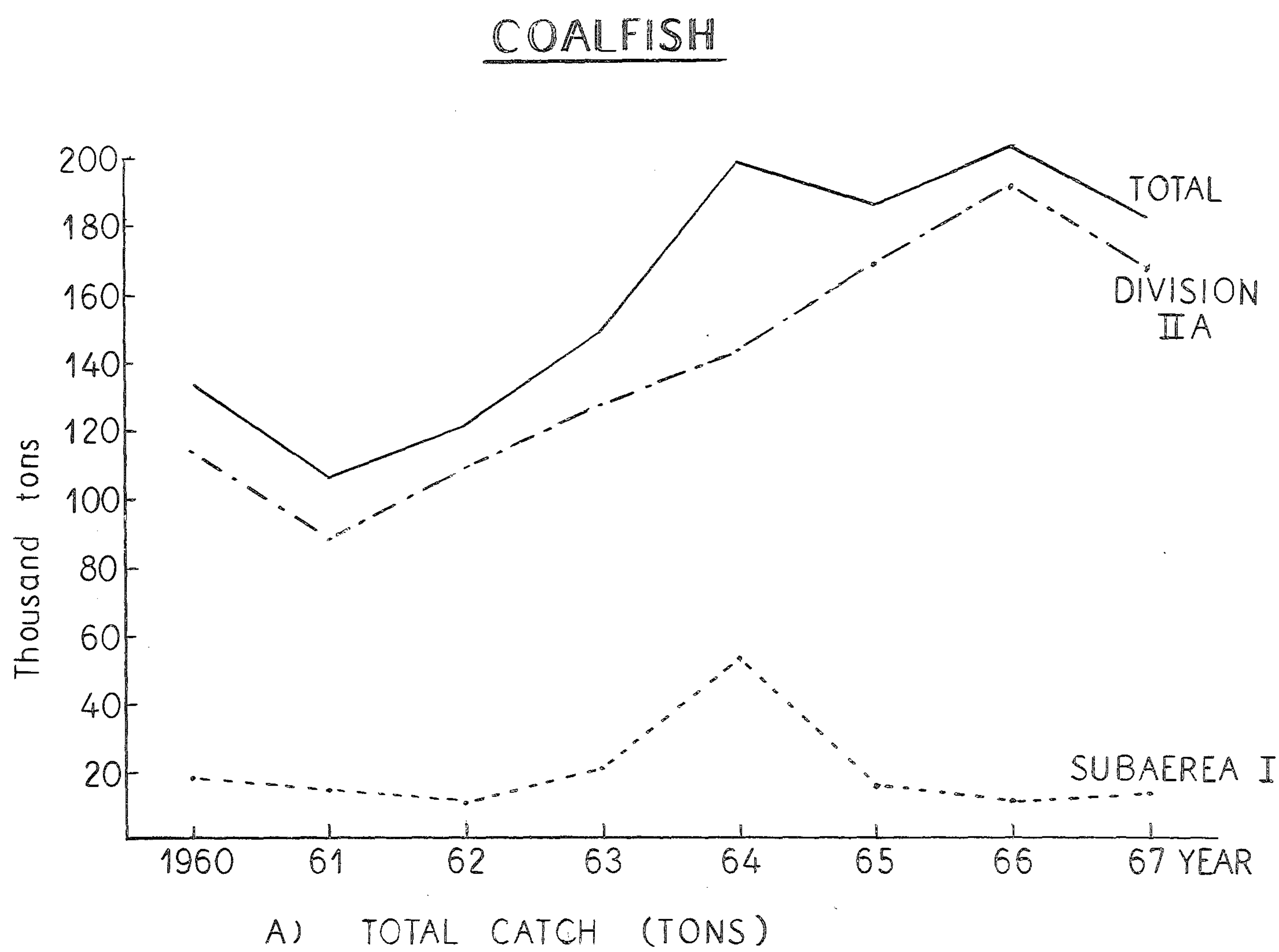


Figure 6. Haddock Assessment: A. The effect upon yield per recruit of changes in the age of recruitment to the exploited stock. B. The effect upon catch per unit effort of changes in the age of recruitment to the exploited stock.



<u>Figure 7.</u> Total catches of redfish and estimates of catch per unit effort 1956-1967.



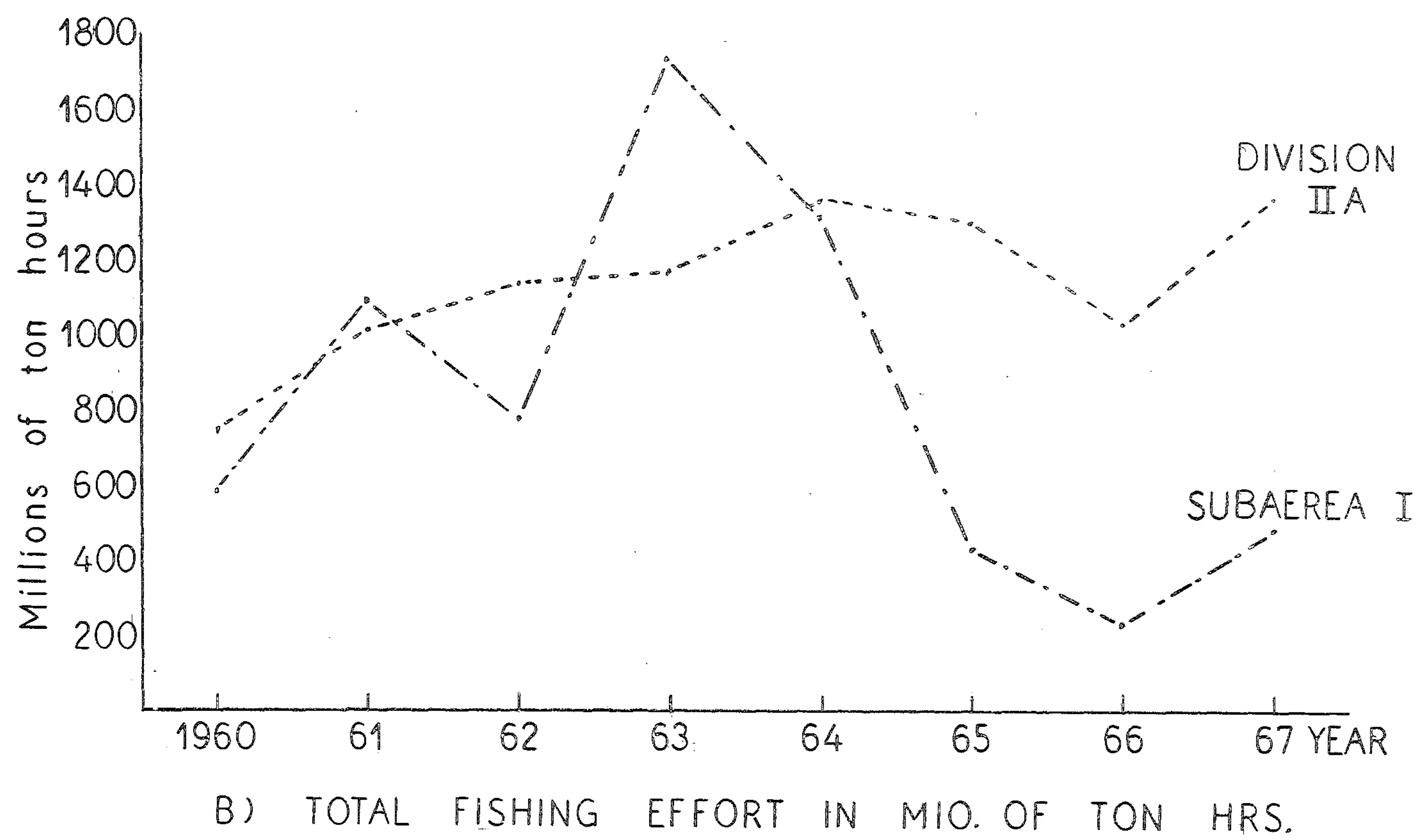


Figure 8. Total c atches of coalfish and estimates of effort 1960-1967.