Second Progress Report of the Working Group on Arctic Fisheries

Copenhagen, September 28 - October 4, 1959.

1) Participants:

England: R.J.H. Beverton, Fisheries Laboratory, Lowestoft
L. Birkett, " " "

Germany: Arno Meyer, Institute for Seafisheries, Hamburg

Norway: G. Saetersdal, Institute of Marine Research, Bergen
A. Hylen, " " " " "

U.S.S.R.: Yu.Yu. Marty, Research Institute of Marine Fisheries and Oceanography
A.I. Treschev, " " " " " "
Miss L.G. Nazarova, " " " " " "
V.I. Travin, Polar Research Institute of Marine Fisheries and Oceanography, Murmansk.

G. Rollefsen (Norway) joined the group on October 2, and J.S. Joensen (Denmark) was present for some of the time as observer.

2) Scope of this report

This report presents a summary of the data relating to the Arctic cod and haddock fisheries which were presented and processed at the first meeting of the Working Group in Bergen (May), and also the main conclusions reached at the present meeting from an analysis of these data.

The first objective of the present meeting has been to examine and interpret the changes that have occurred in these fisheries over the last thirty years. We have tried as far as possible to establish what has been the effect of fishing on the stocks of Arctic cod and haddock, both from a study of long-term trends in stock abundance and by estimation of fishing and natural mortality where the data permitted, and to distinguish between changes due to fishing and those due to natural fluctuations in stock abundance. The second objective has been to use these results to make some preliminary assessments of the effects on the fisheries of increasing the size of trawl mesh above the present minimum legal size of 110 mm.

PART I. COD.

A. Trends in landings, fishing effort and catch per unit effort.

A.1. Landings

Statistics of the landings of cod since 1930 are given in Tables I to V; these data are plotted in Figs. C.1 to C.5 (corresponding to these tables) to show the trends that have occurred since that time.

Fig. C.1 shows the total landings by all countries in each of the three regions, viz: Region I (Barents Sea), Region IIA (Norwegian coast) and Region IIB (Bear Island and Spitzbergen), and also the total landings from all regions combined. It will be noted that the landings increased in all three regions after 1934 but decreased during the war period owing to the partial or complete cessation of fishing. Since 1946, the landings have not shown any significant increase above the pre-war peak levels except in Region I; here the landings increased steadily to a peak in 1955 but have fallen again sharply in 1957 and 1958. In Region IIA the landings have declined since 1947. As a consequence of these opposing trends, the total landings from all regions have remained at roughly the same level since 1946, apart from a transitory increase in 1955 and 1956.

The trends in total landings shown in Fig. C.1 can be better understood by seeing how the total landings have been partitioned among the four main fishing countries in the Arctic, viz: England, Germany, Norway and the U.S.S.R. Fig. C.2 shows the total landings in all three regions by countries, and Figs. C.3, C.4 and C.5 show the landings by countries in each region separately.

These diagrams are self-explanatory, the main features being the increase in Norwegian and Soviet landings, and the decrease in English landings, since 1946 in Region I, and the decline in Norwegian landings from Region IIA over the same period.

A.2. Fishing effort

It is well known that in the period since 1930 there has been a marked increase in the amount of fishing in the Arctic, especially in the trawl fisheries. The first step in interpreting the trends that have occurred in the landings is therefore to see how the amount of fishing, that is, the fishing effort, has changed.

In a trawl fishery a fairly reliable measure of fishing effort is the total time spent fishing per year by all vessels. It may be necessary to adjust this to allow for a tendency for the fishing power of trawlers to increase over a long period of years. Thus in the English distant water trawler fleet the average gross tonnage of the trawlers has increased by something in the region of 75% since 1930, and it has been found that the fishing power of these trawlers is roughly in proportion to their tonnage. Therefore, a better measure of fishing effort for English trawlers is the product of fishing time and average gross tonnage, i.e. the "ton-hour". A similar relation has been reported for German trawlers, but in the Soviet trawler fleet fishing power and tonnage are not so closely related, and the simple " fishing hour " is taken as the unit of effort. It might be expected that apart from any increase in size of vessel, modern navigational and fish-detecting aids would also have increased the fishing power of the trawler fleets, especially in recent years. This has not been allowed for in this report, and as a consequence it is possible that the true increase in fishing effort may have been even greater than is recorded below.

For the present purposes it is necessary to arrive at an estimate of the total fishing effort on the stocks in each region, including not only that due to trawling but also due to other methods of capture such as long-line, gill-net and purse-seine. It is difficult to obtain a reliable measure of fishing effort for these years, and in any case it would be in quite different units to trawl effort and so could not be simply added up to give total effort. The procedure in such a case is to take the fishing effort by a trawl fleet as a reference, and obtain the total effort by increasing the trawl effort by the ratio of the total catch by all gears to that by trawl. This gives total effort in trawler effort units, and can be regarded as the amount of fishing that would have been needed by trawlers to obtain the total amount of fish actually caught. Expressed symbolically, we can suppose that in a certain year the trawler effort by a particular country was E_T and that the catch thus obtained was C_T; if the total catch by all other countries and gears from the same region in the same year was C, then the total effort (in trawler units) expended on the stock in that year was

$$E = E_T \times \frac{C}{C_T}$$

Tables VI, VII and VIII give the statistics of fishing effort by the English, German and Soviet trawler fleets in each region since 1930, and of the number of men fishing at Lofoten in the Norwegian fishery (Region IIA). For Region I (Table C.6) it was agreed that the English and Soviet effort units were the best to take as references for computing a total effort on cod in that region, and columns F and G show two sets of estimates of total effort calculated in the way described above, column F in English "ton-hour fishing" units and column G in Soviet " fishing hour " units. Because they are not in the same units, the numerical values of these two sets of total effort figures are not directly comparable, but it can be seen from inspection that both shown an increasing total effort over the period in question. This is shown better in Fig. C.6, where each set of figures has been adjusted to its mean value to make the sets comparable; it is important to note that the relative increase in total effort is very much the same whether English or Soviet effort units are taken as reference, and is about five-fold since 1946. The total effort during the war period could not be estimated precisely, but is certainly below the 1946 level. In Region IIA, total effort is shown in relative units since 1946 in Fig. C.4, taking English effort as reference; for pre-war years the English fishing here was not thought to be reliable enough to use for calculating a total effort. The total effort in Region IIA increased up to 1952, but thereafter has not changed greatly. English effort is also taken as the reference effort in Region IIB (Fig. C.8) since the English fleet has fished consistently here since 1930; the total effort in this region has increased very greatly since 1946, especially in the last three years. There was no fishing in Region IIB during the war period.

It is evident from these diagrams that the fishing effort in the Arctic cod fisheries has changed very greatly since 1930, with a substantial decrease during the war period and a subsequent rise to a high level in the last three years.

Such a situation is favourable for examining the effect of changes in the amount of fishing on the abundance of the stocks, which is the next question to be considered.

A.3. Catch[x] per unit effort

In a trawl fishery the weight or number of fish caught per unit of fishing effort can be taken as a fairly reliable index of the stock abundance, provided certain possible complicating factors are born in mind. For example, it is necessary that in comparing values of catch per unit effort of a particular species over a long period the fleet should have fished consistently for that species throughout, and preferably should have been a substantial part of the total fishing effort, since a small fleet might not have been able to fish representatively over the area occupied by the stock. It is also necessary that the fleet should be one in which the unit of effort can be evaluated as reliably as possible.

Tables IX, X and XI give values of catch (weight) per unit effort by various countries in each of the three regions since 1930. They are in different units because the efforts are different, but they can be compared by adjusting each series of figures relative to its average; these are given in the last columns of each table.

For Region I it was agreed that the most reliable measures of stock abundance would be provided by the catch per unit effort of the English and Soviet trawler fleets, and these are shown for comparison in relative units in Fig. C9. Both sets of data agree in showing a rise in the period 1934 to 1937 when the very strong 1929 year-class was at its peak in the immature stock. In 1946 the English catch per unit effort was much higher than in 1938 and has fallen ever since except for a temporary rise in 1954 and 1955. The Soviet catch per unit effort also fell until 1951 but then increased to a peak in 1955 as did the English catch per unit effort, although the increase was greater and started two years earlier. This difference is due to the somewhat different fishing areas of the two fleets at this time, when the good 1948 and 1950 year-classes were first becoming of catchable size, and to the fact that the smaller fish are not landed by the English trawlers. Thus the increase in the Soviet catch per unit effort reflects the abundance of these good year classes earlier and to a greater extent than does that of the English fleet; for the same reason the Soviet catch per unit effort showed a more marked fall in 1957 and 1958 when the fish had become older and moved further westward. The English catch per unit effort data refer mainly to the somewhat older fish throughout the period since 1946, and give a picture of the decline in their abundance over that period which is less influenced by year-class fluctuations. In the period from 1930 to 1938, on the other hand, the English fleet in Region I concentrated more on haddock than it did in later years, and the English catch per unit effort data for cod may not be truly comparable with post-war data.

There was very little English trawling in Region IIA before 1935, but after that year the English catch per unit effort can be taken as a reasonably good index of stock abundance, and the changes that have occurred are shown in Fig. C.10. Particularly striking is the high value in 1946 and the sharp decline since then to about one seventh of the 1946 value.

[x] Strictly, this should be called "landings" per unit effort, but it was thought preferable to retain the term "catch" which is still in general usage.

Very similar changes are seen in the English catch per unit effort values in Region IIB, the post-war peak being followed by a steep decline to a level in 1958 which was less than one-half of the pre-war average and about one-seventh of the 1946 value. A slight rise is seen in 1955 due to the good 1948 and 1950 year-classes which appeared here as well as in Region I, but the decline continued in 1957 and 1958. An even more pronounced decline is seen in the U.S.S.R. catch per unit effort values since 1950.

When these general trends in catch per unit effort are set against the changes in total fishing effort that have occurred during the same period, it is difficult to avoid the conclusion that increased fishing has been the main cause of the post-war decline in catch per unit effort in all three regions. Only in Region I is the picture complicated by changes in the concentration of fishing on the young fish of especially good year-classes, but when allowance is made for this and all the available catch per unit effort data are used, a similar conclusion is reached. In order to assess the effect of change in mesh size as is attempted later in this report, it is necessary to take this kind of analysis further and to obtain a more precise evaluation of the influence of fishing. This requires estimation of the mortality rate in the stock caused by fishing and that due to all other causes which together are called natural mortality.

B.1. Estimation of the relative magnitude of fishing and natural mortality rates from the relation between stock and effort

To develop the techniques for this analysis a brief theoretical introduction is needed. Suppose the recruitment of young fish to a stock has been fairly constant for a period of years and that the total fishing effort has also remained steady. The stock will then be in equilibrium with the fishing effort applied to it, and the total number of fish in the stock-measured from the age of recruitment upwards - will be determined by the number recruited each year and by the magnitude of the fishing and natural mortality rates. If, now, the fishing effort increases to a higher level, the number of fish in the stock will decrease for a few years until a new equilibrium is reached. There is, in fact, a simple relation between stock numbers and fishing effort under equilibrium conditions, namely that stock size varies inversely with the total mortality rate expressed as an instantaneous coefficient. Thus if the number of fish in the stock is denoted by S_N, and the number of fish recruited annually by R, the equilibrium relation between stock and fishing effort can be expressed as

$$S_N = \frac{R}{F + M} \qquad \ldots\ldots (1)$$

where F and M are the instantaneous coefficients of fishing and natural mortality respectively. The mathematical derivation of an instantaneous coefficient of mortality is given in Appendix I; here it is sufficient to note that the numerical value of such a coefficient is proportional to the magnitude of the cause of that mortality. In equation (1), for example, F is proportional to the total fishing effort, and can be replaced by the quantity cf, where f is the total fishing effort, and c is the constant of proportionality, the numerical value of which depends on the unit of effort employed. It is convenient also to express the number of fish in the stock relative to the number recruited annually, so that the equation can be written

$$\frac{S_N}{R} = \frac{1}{cf + M} \qquad \ldots\ldots (2)$$

This equation predicts that with increasing fishing effort (f) values of stock numbers should lie on a descending curve, and from the extent of the stock decrease compared with the increase in effort it is possible to deduce how much of the total mortality is due to fishing. Thus if there were no natural mortality at all, M in equation (2) would be zero, and stock would vary inversely with fishing effort (as a rectangular hyperbola); if, on the other hand, most of the total mortality were due to natural causes, M would be large compared with cf and stock size would not change much even with quite large changes in effort. Since it is easier to interpret data which lie on a straight line rather than on a curve, it is convenient to transform equation (2) by taking reciprocals of both sides, giving

$$\frac{1}{S_{N/R}} = cf + M \qquad \ldots\ldots (3)$$

Thus the reciprocal of stock numbers is seen to increase linearly with effort.

To apply this equation it is necessary to have data on the total fishing effort and on the catch by numbers per unit effort which can be taken as a reliable index of stock numbers. The former have been given in Table VI for Region I and Table VIII for Region IIB. The data of catch by weight per unit effort of Tables IV, X and XI can be converted to numbers from the extensive measurements of the lenght composition of the catches which are available. Since the relationship expressed by equations (2) and (3) applies only to equilibrium conditions, it is necessary to plot the catch per unit effort in each year against the total fishing effort in that year and in the two preceeding years; this procedure has been found to give the closest approximation to what would be expected in equilibrium conditions.

Table XII gives data of catch by numbers per unit effort and of 3-year sums of total effort in Region I since 1946; English units of catch per unit effort are used since for the reasons given in para A.3 it is thought that these give the most comparable series of indices of stock abundance over this period. Stock is plotted against effort in Fig. C.12.A, and reciprocal of stock against effort in Fig. C.12.B. The points are rather scattered, primarily because in practice the annual recruitment is not constant (as is assumed in equations (2) and (3); nevertheless, both diagrams show a clear tendency for stock and reciprocal of stock to vary with effort as would be expected theoretically. Values for 1957 and 1958 are indicated in both diagrams.

It will be noted that the straight line which represents the data in Fig. C.12.B does not pass through the origin but gives a small positive intercept on the stock axis, where effort is zero. If it were possible to measure the true number of fish in the stock per recruit, this intercept would give an estimate of the natural mortality coefficient M, since from equation (3) when there is no fishing (cf = 0), we have

$$\frac{1}{S_{N/R}} = M$$

Since we have only a proportional index of stock, i.e. catch per unit effort, the intercept (a) of Fig. C.12.B is itself only proportional to the natural mortality coefficient M. However, at the level of effort in 1958 (about 1500 units) the reciprocal of stock has increased by the amount (b), shown in Fig. C.12.B, which is proportional to the fishing mortality coefficient in that year. Therefore, we can say that in 1958 the ratio of the fishing mortality coefficient to the natural mortality coefficient was b/a, and from Fig. C.12.B this ratio is seen to be about 5 to 1. In other words, the conclusion from Fig. C.12.B is that in Region I in 1958 something in the region of 5/6 or about 85% of the total mortality in the stock was due to fishing.

Table XIII gives data of catch per unit effort for Region IIB and total effort in English units since 1935, by which time the exploratory period was over and fishing had become considerable. These data are plotted in Figs. C.13.A and C.13.B in the same way as before. Again a clear relation is seen between stock and effort; in this case the intercept is about one-quarter of the value at the 1958 level of effort, giving the conclusion that in this year about three-quarters of the total mortality in the stock was due to fishing.

A pronounced relation between stock and effort is found also in Region IIA. Although this demonstrates that fishing has had a marked effect on the stock, the data cannot be used to estimate the relative magnitude of fishing and natural mortality as in Regions I and IIB. This is because the stock in Region IIA is composed primarily of old mature fish, and the recruitment to it is itself affected by fishing in Regions I and IIB where the same fish are immature.

To summarize, it can be said that the relations between stock and effort in Regions I and IIB lead to the conclusion that in both regions the total fishing effort in recent years has been responsible for between 75% and 85% of the total mortality in the stock. It is now necessary to attempt to measure the actual magnitude of these mortality coefficients, both in these two regions and also in Region IIA. This requires data on the age-composition of the stocks.

B.2. Estimation of fishing and natural mortality coefficients from data of age-composition and fishing effort.

Although the procedure of relating total stock numbers to fishing effort described above has given a reasonably conclusive result, it has certain limitations. Apart from the scatter of the points caused by year-class fluctuation, the method depends on the comparison of catch per unit effort data over a long period of years; this may involve some error due to factors such as increased fishing power of vessels and gear which cannot easily be allowed for. Those difficulties are largely overcome if the age-composition of the stock is known and the abundance of particular year-classes can be compared from one year to the next to give an estimate of the total mortality rate in those two years which can be related to the total fishing effort at that time. It is fortunate that age and length compositions of Arctic cod are available from all four countries, the data collected by the USSR in Region I and by Norway in Region IIA being particular extensive.

Before analysing these data in detail , it is of interest to see the general changes in the age-composition of the total landings that have occurred since 1930 in the three regions. For this purpose the data are grouped into three periods; (a) 1932/1938, (b) 1946/1950 and (c) 1951/1958. The number of fish at each age per unit effort are shown in the lower half of Figs. C.14.A, C.14.B and C.14.C for each region, respectively. It will be seen that in each region the older fish are particularly abundant in period (b) after the war when fishing was much reduced in Regions I and IIA, and absent in Region IIB. It will be noticed also that there are relatively fewer old fish compared with young ones in the most recent period (c) when the fishing effort was greatest, the contrast with the pre-war period (a) being especially marked in Region IIB. Changes such as these in the age-structure of the population are what would be expected if the changes in fishing effort had influenced to a marked degree the mortality rate in the stocks.

B.2.2. Before proceeding to a more detailed analysis of the age-composition data it is necessary to derive the relation between total mortality coefficient and fishing effort.

Suppose the abundance of a certain year-class in one year is N_1, and in the next year the abundance is N_2. The survival rate from the first year to the second is then N_2/N_1, and this is related to the total mortality coefficient by the expression

$$\frac{N_2}{N_1} = e^{-(F + M)} \qquad \text{..... (4)}$$

where e is the base of the natural logarithms.

Taking reciprocals of each side of this equation gives

$$\frac{N_1}{N_2} = e^{+(F + M)} \qquad \text{..... (5)}$$

and taking natural logarithms of both sides gives

$$\log_e (N_1/N_2) = F + M \qquad \text{..... (6)}$$

Thus the logarithm of the ratio of the abundance of the year-class in two successive years of life gives an estimate of the total mortality coefficient F + M. As set out in para B.1., F is proportional to fishing effort, so that

$$F + M = \log_e (N_1/N_2) = cf + M \qquad \text{..... (7)}$$

This equation shows that estimates of total mortality coefficients from age-composition data when plotted against fishing effort would be expected to follow a linear relation. The intercept of the line (where effort is zero) gives an estimate of the natural mortality coefficient, and the slope of the line gives an estimate of the constant c relating fishing effort (in whatever units are used) to the fishing mortality coefficient F.

It will be realized that the principle underlying this technique has much in common with that described above for interpreting the relation between stock and fishing effort. In this case the procedure is to examine how the total mortality coefficient changes with effort; if the two increase strictly in proportion to each other it means that the observed change in total mortality can be fully accounted for by the change in effort, so that there can be no natural mortality. If, on the other hand, large relative changes in fishing effort produce only a small change in the total mortality coefficient, then it must be that most of the observed total mortality is due to natural causes. With this method, unlike the former, only ratios of abundance are needed, and these ratios do not depend on the units in which the catch per unit effort is measured; thus absolute values of the coefficients F and M can be determined, whereas before only their ratio could be obtained.

B.2.3. The relation between total mortality coefficient and fishing effort in Region I

The longest series of age-composition data for cod in Region I are those of the USSR. These are tabulated for years since 1932 in Table XV A as numbers of fish of each age per 1 hour trawling. It was found that over the period as a whole, age-groups VII, VIII and IX were fully represented and gave the best estimates of total mortality. The average mortality over these three years of life is shown for each pair of years both as annual percentage rates and as instantaneous coefficients below the age-composition data. The last row of the table gives the total fishing effort in USSR units.

The total mortality coefficients and total effort are plotted in Fig. C.15.A. Despite the scatter of the points there is a tendency for the higher mortality coefficients to be associated with the higher values of fishing effort. This is particularly noticeable when the pre-war values (hollow circles) are compared with those of recent years (solid circles). The mortality values are seen to be unexpectedly high in 1950/51 and 1952/53, but 1951 and 1953 were the years in which the 1948 - 1950 year-classes first appeared in quantity in the catches, and it is probable that the change in distribution of the fleet caused the abundance of older fish to be underestimated in those years. This would result in an apparently high mortality rate in fish of 7 to 9 years of age in the two pairs of years in question. It is not possible to make a precise allowance for this complication, but it was thought that the broken line shown in Fig. C.15.A gave a reasonable representation of the data. This line has a slightly negative intercept, but this is not significant bearing in mind the scatter the points; it can, however, be concluded that the natural mortality coefficient is small compared with the total mortality coefficient of about 1.0 in the last few years (about 65% per year).

Another set of age-composition data for Region I was prepared by combining all the available length and age-compositions from all four countries raised to catch per unit effort in English ton-hour units. These are given in Table XV B and plotted against total effort in English ton-hour units in Fig. C.15.B. As before the pre-war points are shown by hollow circles and post-war points by solid circles. The apparently high mortality rate in years 1950/51 and 1952/53 does not now appear, and the trend of mortality with effort is clearer although still similar to that of Fig. C.15.A. The intercept shown has a value of 0.2 (about 20% per year), which can be taken as an estimate of the natural mortality coefficient of cod in Region I over the age-range 7 to 9 years.

It should be mentioned at this point that although this estimate is called "natural mortality" it does, in fact, include all causes other than fishing which are responsible for the observed decrease in catch per unit effort of the year-class with age. For example, fish of 7 to 9 years of age are approaching maturity, and are beginning to emigrate each winter to Lofoten, and this may reduce their availability to capture in the Region I trawl fisheries. To the extent that this happens it is included in the estimate of M obtained from the intercepts of the regressions of Figs. C.15.A and C.15.B. The observed intercept is what is needed for making assessment for Region I fisheries, but it is possible that the true mortality rate from natural death alone may be somewhat smaller.

B.2.3. Total mortality and effort in Region IIB.

A similar analysis can be attempted for Region IIB although here the age-composition data are less extensive than in Region I.

Table XVIA shows the English age-composition data since 1950, in units of "number caught per 100-ton hours fishing", together with estimates of total mortality coefficient over ages 7 to 9 and total effort in English units. These are plotted in Fig.. C.16.A together with an average value for the years 1947 to 1949 calculated from USSR age data converted to English catch per unit effort units (solid circle). The values for 1953/54 and 1954/55 are probably too high owing to the strong 1950 year-class which entered the English landings at about this time and probably caused some diversion of fishing from the grounds where the older fish are normally caught. Bearing this in mind there is some indication of a trend as shown by the broken line, but on so few data no precision can be attached to the value of the intercept.

The picture becomes rather clearer when Soviet age-composition data and total effort in USSR units are used. These are given in Table XVI B, the mortality coefficients being plotted against effort in Fig. C.16.B. The regression line shown provides a reasonable representation of the points and gives a small intercept in the region of 0.2.

It is evident that the relation between total mortality coefficient and fishing effort cannot be established as reliably in Region IIB as it can in Region I. This is partly because the data cover a shorter span of years but also because from 1949 until 1955 the total effort remained nearly constant. It was not until 1956 that the effort increased sharply, and it is significant that the English and the Soviet data agree in showing a high total mortality coefficient since then. In 1957/58 it appeared from the English data to be about 1.3, and about 1.6 from the Soviet data; this is equivalent to a mortality rate in the region of 75-80% per year. From such trends as can be distinguished from Figs. C.16.A and C.16.B, together with the results of the analysis of stock and effort for Region IIB given earlier, it is concluded that much the greater part of this mortality was due to fishing.

B.2.4. The relation between total mortality coefficient and fishing effort from data of the Lofoten Skrei fishery (Region IIA).

A long series of age-composition data for the Norwegian Skrei fishery at Lofoten are available. These refer to the mature fish from 7 years old upwards, which during their earlier years of life constitute the immature stocks in Regions I and IIb.

An analysis of these data is complicated by the fact that the gears used and the characteristics of the fishery generally make it difficult to express the age-composition in terms of catch per unit effort. The procedure adopted has therefore been first to convert the data to spawning group compositions, giving in each year the number of first time spawners, second time spawners, and so on. Since the second time spawners in one year are the survivors from the first time spawners of the previous year, such data can be treated for mortality estimation just as can age-compositions; the advantage is that the influence of year-class variation is thereby diminished, since each spawning group consists of fish of various ages and hence of several different year-classes. Secondly, the data have been grouped into two periods, the first from 1946 to 1951, and the second from 1951 to 1958, and the average total mortality coefficient calculated for each period; this procedure was adopted to overcome as far as possible the lack of reliable catch per unit effort data for this fishery.

The spawning group data for each of these periods, males and females separately, are given in Table XVII. The logarithms of the numbers are plotted against spawning group number in Fig. C.17.A; from equation (6) it follows that the slope of the lines fitted to these plots is an estimate of the total mortality coefficient (F + M). It will be seen at once that the slope of the spawning group compositions of both males and females is steeper in the second period[x)] than in the first, the total mortality coefficients being:

	Males	Females	Mean
Period 1946/1950	0.62	0.62	0.62
Period 1951/1958	1.10	0.97	0.99

To estimate how much of the total mortality coefficient is due to natural mortality it is necessary to determine the total fishing effort on these mature fish in the two periods. After spawning, the mature fish migrate back to the feeding grounds in Regions I and IIB, so that the fishing effort applied to them must include not only that during the spawning season at Lofoten, but also that in the fisheries in Regions I and IIB for the rest of the year. An effective total effort can most simply be calculated in such a case by dividing the total annual catch of mature fish in all regions and from all gears by an index of the abundance of these fish in that year. Thus, if the catch per unit effort by a certain fleet x is C_x/E_x and can be taken as a reliable index of abundance, and the total catch is C, we have

$$\frac{C}{C_x/E_x} = \text{total effort}$$

in the units in which reference effort E_x happens to be measured. It will be appreciated that this method is precisely equivalent to that used in para A.2 for calculating total effort by regions.

The average age at first spawning is about 8 years, and three measures of the abundance of fish of 8 years and older are available, viz. the English catch per 100 ton-hours in Region IIA and in Region I, and the Soviet catch per hour in Region I. These are given in Table XVII, each being expressed relative to its respective mean value for comparison; it will be seen that all three sets of catch per unit values show a similar degree of increase over the period, and the average of the three has been taken as the best available estimate. This is divided into total catch of mature fish to give the estimate of total effort on mature fish from 1946 to 1958 in the last columns of the table. For the period 1946 to 1950 the total effort was 6.4 units and from 1951 to 1958 it was 12.1 units.

Fig. C.17.B shows the estimate of total mortality coefficient for the two periods plotted against the corresponding fishing effort. The line joining them gives an intercept of about 0.2, which is an estimate of the natural mortality coefficient in mature fish.

B.2.5. Mortality estimation from a comparison of the abundance of immature and mature fish of the same year-classes.

The analyses described above have been concerned with mortality estimation of the stocks in each of the three regions separately. One further possible use of the data was examined, namely to compare indices of the abundance of certain year-classes as immature fish in Region I and of the same year-classes as mature fish in the Lofoten fishery four years later.

x) The data for the second period are not as closely linear as are those for the first, the fish in the oldest spawning groups being relatively more abundant than would be expected. This is because these few very old fish are survivors from the earlier years when the fishing effort was lower, and the lines shown have therefore been fitted to the first six spawning groups.

Soviet catch per unit effort data for age-groups IV, V, VI and VII combined were taken as indices of abundance of the immature year-classes in Region I each year from 1946 to 1954. Estimates of the combined abundance of age-groups VIII, IX, X and XI were taken from Norwegian Lofoten data in years 1950 to 1958, so that they referred to the same year-classes when they had reached maturity. These data are given in columns A and B of Table XVII. The two sets of data are in different catch per unit effort units and so cannot be used to estimate mortality coefficients directly; the ratio of the two sets of data (Region IIA values divided by Region I values) is however proportional to the average survival rate over the span of age-groups in question. These "survival ratios" for each four-year period are plotted in Fig. C.18.A, and it is seen that over the period from 1946/1950 to 1954/1958 they have decreased steadily to less than one-third of their initial level.

Taking natural logarithms of these "survival ratios" gives values which are proportional indices of the total mortality coefficient, and in Fig. C.18.C these are plotted against estimates of total fishing effort in Region I in USSR units for each 4-year period. The data fall closely on a straight line and give an intercept which is about one-quarter of the index for the last two periods 1953/1957 and 1954/1958. Since it has been estimated in the two preceeding sections that the total mortality coefficient of fish from 7 years upwards in both Regions I and IIa was about 1.0, it follows that the intercept of Fig. C.18.B corresponds to a natural mortality coefficient of about 0.25.

It is of interest to see that the points of Fig. C.18.B show the least scatter of all the plots of mortality coefficient against effort that have been presented. This is because the catch per unit effort data are pooled estimates of the four most abundant age-groups in the two fisheries, and mortality is measured over a span of four years of life, thus minimising errors in age-determination and other factors which influence estimates of the abundance of a single year-class in a particular year.

B.3. Conclusions on the magnitude of fishing and natural mortality in the Arctic cod.

In the preceeding sections a number of attempts to separate and measure the mortality rates due to fishing and to natural causes in the Arctic cod have been presented. Two main techniques have been used, one based on changes in the total abundance of the stocks in response to fishing, and the other on more detailed estimation of mortality rates and their change with fishing effort. All, or nearly all, the available data have been used, in some cases those from one country alone and in others by pooling information from two or more countries according to which was thought to give the most reliable indices of abundance or age-composition and so forth. Probably other ways of treating the data could be devised if more time had been available; but the Working Group were agreed that the results obtained and presented here, although not in every case conclusive when considered in isolation, together give a picture which leaves no doubt as to the effect that fishing has had on the Arctic cod.

The main conclusions can be summarized as follows:-

(i) The natural mortality in Arctic cod is low, and probably averaging not greater than 20% per year ($M = 0.2$). This result has been obtained from several estimates based on sets of data and techniques of analysis which are partially or wholly independent of each other. It has been measured in both mature fish and in immature fish down to the age of about 5 years. No significant difference in natural mortality rate of stocks in the various regions could be distinguished from the data available.

(ii) The increase in the amount of fishing which has taken place in the last 15 years has increased the total mortality rate to about 65% in Regions I and IIA, and to an even higher level (probably about 75%) in Region IIB. This mortality rate has been measured for fish from 5 to 6 years of age and upwards. From the estimate of the natural mortality rate given above, it follows that something in the region of three-quarters to five-sixths of this total mortality is due to fishing.

C. Assessment of the effects of increase of mesh size in the Arctic cod fisheries.

C.1. Some general considerations

The principle underlying the regulation of mesh size as a conservation measure is to reduce the capture of the younger and smaller fish and so allow greater numbers to survive to enter the catches when they are older and larger.

It follows that if this procedure is to be effective in causing the catches to increase, two main requirements must be satisfied. One is that the fishing rate on the older fish must be high enough compared with the natural mortality rate to ensure that a sufficiently high proportion of the young fish released by a larger mesh will, in fact, be caught again during their later life and that not too many will die from natural causes. The other requirement is that the individual fish must be able to increase substantially its weight by growth as it becomes older, so that when the fish released by a larger mesh are recaught later in life, their total weight exceeds that when they were released, even although their numbers are fewer. In these circumstances it follows that the larger mesh would cause the total long-term catch by weight to increase.

In the preceeding section it has been established that at the present time about four-fifths of the total mortality of Arctic cod is due to fishing. This means that after a year-class has been recruited to the fisheries about four-fifths of it will be caught over the rest of its life-span and only one-fifth will die from natural causes. The average growth in weight of Arctic cod is shown graphically in Fig. C.19, where it can be seen that the weight of a fish increases steadily over the whole of its life-span in the commercial fisheries. From 3 years of age, when fish begin to enter the commercial catches in quantity, to 10 years of age, the cod increases its weight by about 15 times. Even before the question is examined in more detail, such a high growth potential as this indicates that it might very well be beneficial to allow all fish of 3 years old to escape capture even if only quite a small fraction could be caught again later in life; with a fraction as high as four-fifths, the likelihood of a gain is even stronger.

It is of interest to note at this point that the reduction of fishing during the war period, which was most pronounced on immature fish, produced a situation in the immediate post-war years not unlike that which would result from a major increase in mesh size. The number of fish at each age in the catches per unit effort in the immediate post-war years compared with both the pre-war period and recent years has been shown in Fig. C.14. In Fig. C.20 the number of fish at each age has been multiplied by their average weight to show the total weight of fish in the catches at each age. The contrast between the three periods is now even more marked than before, and serves to demonstrate the capacity of the Arctic cod stock to increase in total weight when the fishing mortality rate in the younger fish is much reduced.

C.2. The relation between steady catch and age at first capture for Arctic cod.

More definitive assessments of the gain in long-term yield to be expected from allowing the younger fish to escape capture can be made using the estimates of the fishing and natural mortality coefficient and growth in weight given above.

Calculation proceeds by supposing that a year-class becomes fully available to capture on reaching a certain age, after which the number surviving to each successive year af life, and the number caught at each age, are calculated by applying the natural and fishing mortality coefficients as described in Appendix I. The number caught at each age is then multiplied by the average weight of the individual fish to give the total weight caught at each age. These total weights are then added up for all age-groups to give the total catch by weight from the year-class throughout its life in the fishery.

Four pairs of values of fishing and natural mortality coefficients have been used, which it is thought cover the range which the actual values might have at the present time. These are:

(a) F = 1.0, M = 0.2

(b) F = 0.8, M = 0.2

(c) F = 0.7, M = 0.3

(d) F = 0.8, M = 0.3

From what has been said earlier, it is thought that the values (a) and (b) are most likely to accord with reality and (c), (d) can be regarded as a limiting cases. The lowest age at first capture was taken as four years of age, at which the fish have a length of about 40 cm; it was thought that down to at least this size of fish the natural mortality coefficient would not be greater than the values above. Having calculated the total catch of all age-groups, this was divided into the catch of fish of 8 years and younger and the catch of fish 9 years and older, which corresponds roughly to the immature and mature spans of life.

Fig. C.21 shows the relation between total catch, "immature" catch and "mature" catch, with age at first capture from 4 to 8 years. In both cases in which a value of M of 0.2 is used the total catch curve increases steadily up to the limit of the age range considered; with M = 0.3 the total catch also rises throughout, but the increase is less. The immature catch increases up to an age at first capture of 7 years when M = 0.2, and up to 6 years when M = 0.3. The mature catch rises throughout for both values of M.

C.3. Assessment of increases in mesh size

The calculations shown graphically in Fig. C.21 demonstrate that at the present high level of fishing intensity the best use of the growth potential of Arctic cod would be obtained by allowing each year-class to escape capture until it was at least 6 years of age. This conclusion holds true even if the natural mortality coefficient should be as high as 0.3, which is unlikely from the results given earlier in this report. Some idea of what this means in terms of length of fish can be gained from the fact that the average length of fish of six years of age is about 60 cm.

However, the selectivity of a net is not sharp, and even if it were, the variation in size among fish of a given age means that, in practice, it is not possible to allow the fish of a year-class completely to escape capture until they reach a certain age or length and then to fish them at the full intensity. Furthermore, the younger fish tend to occupy somewhat different grounds to older fish and are less heavily fished even within the immature range of age. As a consequence, the fishing mortality coefficient is somewhat lower among the youngest age-groups and smallest sizes than it is among those which are fully recruited, and does not increase abruptly from zero to the full amount when a certain age is reached, as is supposed in Fig. 21.

To refine these assessments so that the actual gain in yield from a year-class which would result from a given increase in size of mesh can be predicted accurately, it is therefore necessary to use additional information relating to length of fish. Specifically, it is necessary to know how selection range varies with size of mesh, and also the true length compositions of the commercial catches over the smaller sizes of fish. A large amount of data on mesh selection of cod were obtained during the International Mesh Experiment carried out during August and September of this year, but in the time available it has not been possible to analyse these data fully. Information on the true length composition of the commercial catches is, however, not at present available from any of the trawl fisheries in the Arctic. Thus it is known that considerable quantities of small fish are at time discarded at sea by English and German trawlers, while the available Soviet data refer to catches of searching trawlers which were taken with smaller meshes and sometimes on grounds containing more small fish than those which would be fished by the main commercial fleet. Therefore the Working Group was unable on this occasion to proceed to the final step of estimating the long-term gain in total catch that would result from specific increases in mesh above 110 mm. It can be said, however, that even with a mesh of 110 mm, large quantities of fish in the length range 35 cm to 45 cm are caught; from the growth in length of cod it is known that few, if any, of these would be as old as 6 years, the large majority being 3 and 4 year-old fish. It is therefore concluded that further increase of mesh above 110 mm is certain to increase the weight of the catch taken from each year-class during its life in the fishery.

PART II HADDOCK

D.1. During the present meeting of the Working Group it has been possible to process and present the data on landings and catch per unit effort of haddock. Compared with cod, the data for haddock, both as regards the commercial statistics and the research data, are less extensive and less reliable; it has nevertheless been possible to make some appreciation of the effects that fishing has had on the stocks. Owing to the shortage of time for preparing this report, it has been necessary to restrict this section on haddock to a brief reference to the tables and figures presented and a summary of the conclusions reached.

D.2. Total landings of haddock since 1930 by regions and by countries are given in Tables H.1 to H.5 and illustrated in Figs. H.1 to H.5, following as far as possible the same scheme as has been adopted for cod.

The landings show considerable fluctuations, which is partly due to the large variation in year-class strength which occurs in these stocks. A better idea of the changes that have occurred in stock abundance can be gained from Fig. H.6, which shows the trends in catch per unit effort in English ton-hour units in each region. It will be seen that in all three regions the catch per unit effort was high immediately after the war and has subsequently declined, the fall being particularly pronounced in Region IIA where, as in cod, the stock consists of older fish than in Regions I and IIB. Having regard to the changes in fishing effort which have occurred, these trends in catch per unit effort indicate that fishing has had a marked effect on the abundance of the haddock stocks. Indeed, the coincidence between the post-war increase and subsequent decline of haddock and of cod is strong confirmation of the effects of fishing.

D.3. Some age-composition data for haddock are available for the trawl fisheries from both Germany and the USSR, but owing to the difficulty of obtaining reliable catch per unit effort data over a long period and of uncertainties in the earlier age-determination methods, it has not proved possible so far to employ successfully the methods of analysis used for cod. The most that can be said at the present time is that judging by the rapidity with which good year-classes have declined in the catches with increasing age, the total mortality rate appears to have been similar in recent years to that of cod.

Length compositions of commercial landings are, however, available for Region I since 1932, and show that significant changes have occurred in the size composition of the stocks since that time. Fig. H.7 shows the length composition of the landings (English and German data) grouped into four periods: 1929-1933, 1934-1939, 1947-1951 and 1952-1958. It will be seen that in the earliest period when the amount of fishing was relatively small the stock consisted of a high proportion of large fish with a modal length of nearly 70 cm. This length composition is indeed characteristic of a virtually unfished stock where the mortality rate is low and a large proportion of each year-class can survive to become nearly fully grown. By the second period, 1934-1939, when the fishing effort had increased substantially, the oldest fish had nearly disappeared from the stock, the modal length had been reduced to below 40 cm, and the structure of the stock had become typical of a heavily fished stock. After the reduced war-time fishing (period 1947/1951) the length composition had returned to something approaching that in the earliest period, but by the last period (1952/1958) the larger fish had again disappeared and the stock once again showed the symptoms of heavy fishing. This coincidence in two separate periods between changes in size composition and increase in fishing effort makes it unlikely that the changes have been due only to year-class fluctuations.

The USSR data for the two periods after 1947 show very similar changes, as can be seen from the middle diagram of Fig. H.7. Here the proportion of smaller fish in the USSR data has been adjusted to correspond with the English and German landings so that the composition of the larger fish in the two sets of data may better be compared.

The bottom diagram of Fig. 34 shows the changes that have occurred in the average weight of fish in the catch. In both the post-war and pre-war periods the average weight has fallen from an initially high value while the fishing effort has been increasing.

D.4. Although the Working Group was unable during the present meeting to make definite estimates of the fishing and natural mortality coefficients for Arctic haddock, it was agreed that the available evidence indicated that fishing mortality was the major component of the total mortality rate at the present time. From what is known of the biology of Arctic haddock it was thought that the natural mortality coefficient would be similar to that of cod.

On this basis some trial calculations of the relation between equilibrium yield and age at first capture were made for haddock, taking the first three pairs of values of fishing and natural mortality as for cod but using the growth in weight of haddock (see Fig. C.19). These showed that even with a natural mortality coefficient as high as 0.3 the total catch would be expected to increase up to an age at first capture of about 6 years, corresponding to a length of fish of about 50 cms. The results which have been reported for the selectivity of trawl meshes for Arctic haddock show that a given size of mesh retains rather smaller haddock than it does cod, owing to the greater girth of haddock. It is, therefore, concluded that for haddock, as for cod, mesh size above 110 mm would result in an increase in the weight of catch which could be obtained from each year-class.

PART III SUMMARY AND CONCLUSIONS

E.1. Having reviewed and analysed the available data for cod, the working group concluded that the changes which have occurred in the abundance of the stocks since 1930 have been caused mainly by changes in the amount of fishing during that time. This is true especially for the increased abundance of the stocks in the immediate post-war years after the reduced war-time fishing, and for the subsequent decline as fishing has intensified.

E.2. From the extensive age-composition data which are available, it has been possible to estimate the total mortality rate in the stocks at the present time, and to determine how much of this is due to fishing and how much to natural causes. The total mortality rate is about 65% per year for both immature fish above 5 years of age and for mature fish in Regions I and IIA; in Region IIB the total mortality rate appears to be higher still, probably in the region of 75% per year. Of this total mortality it was concluded that about 4/5ths was due to fishing and only 1/5th to natural causes.

E.3. The fact that the number of fish of a year-class decreases by as much as 65% during each year of life after the year-class has entered the fisheries, provides a satisfactory explanation for the failure of the good 1948 - 1950 year-classes to cause more than a temporary increase in the abundance of the immature stocks and to have had relatively little influence on the mature stocks in Region IIA, even when allowance is made for the hydrographic changes which have occurred in Region I in recent years.

E.4. From a knowledge of the mortality and growth rates of Arctic cod, and from the provisional results obtained from the International Mesh Experiment which has recently been carried out, it has been possible to make some preliminary assessments of the effect of increasing the size of trawl mesh in the Arctic fisheries. It was concluded that there would certainly be a gain in catch from increase in mesh above the present minimum legal size of 110 mm, but the Working Group were unable on this occasion to assess the effect of specific increases in mesh size.

E.5. The urgency of the need to take some step towards increasing the size of mesh is enhanced by the recent increases in fishing effort, the effects of which on the stocks may not yet be fully apparent. In all probability the relative abundance of larger fish must be expected to decline still further; this itself will tend to make the fishing fleets search more intensively for the smaller and younger fish and so in the long run reduce the productivity of the stocks even more.

E.6. The Working Group agreed that, on the available evidence, the effects of fishing on the stocks of Arctic haddock have been broadly similar to those on cod. While it has not been possible to assess the effects of increase in mesh size on haddock with as much confidence as for cod, it was concluded that to increase the mesh size above 110 mm would also increase the catch that could be obtained from each year-class of haddock.

E.7. The Working Group wish to emphasize that in the time available during the present meeting it has not been possible to investigate all the aspects of the dynamics of the Arctic fisheries which are relevant to its conservation, nor to prepare a report with such care and in as much detail as will ultimately be called for.

Accordingly, the Working Group decided that to complete the task allotted to it a final meeting would be required, of about ten days duration, before the next meeting of the Permanent Commission, preferably early in 1960, at which the following items would be among those to be dealt with:-

(i) To include in the analyses described in this report the data for 1959, which will be of critical importance in confirming and making more precise many of the estimates and conclusions arrived at here.

(ii) To attempt to make assessments of the actual gains, relative to the present level of catches, that are to be expected from specified increases in mesh size. This will require, in particular, a fuller analysis of the results of the International Mesh Experiment than has been possible so far, and as much information on the true length composition of the commercial catches as can be assembled in the time available.

(iii) To put these assessments into a more general perspective by investigating the effects on the long-term catch of changes both in size of mesh and in fishing effort.

(iv) To examine in more detail the data for haddock, and to attempt to make more precise assessments of the effects of increase of mesh size in this species.

(v) To make plans for the coordination of future research between the countries concerned, so that scientific advice can continue to be provided to the Permanent Commission and so assist in achieving the best possible utilization of the Arctic fisheries.

(vi) To prepare and agree a final report for submission to the Permanent Commission at its next meeting in May, 1960.

Copenhagen, September, 1959.

APPENDIX I

Derivation of instantaneous mortality coefficients

Consider a group of fish whose numbers are being continuously reduced by natural and fishing mortality. In the notation of the differential calculus, the instantaneous rate of decrease in numbers at a moment in time can be written as

$$\frac{dN}{dt} = -(F + M)\,N \qquad (1)$$

where F and M are the instantaneous coefficients of fishing and natural mortality.

Suppose the number of fish, present at the beginning of a certain period of time is N_o, and that during that period the two coefficients F and M can be regarded as effectively constant, that is, the relative rate of decrease of the population is constant. The solution of equation (1) gives the number of fish remaining after any subsequent time t as

$$N_1 = N_o\, e^{-(F+M)t} \qquad (2)$$

where e is the base of the natural logarithms. If the unit of time is one year, then the number surviving after one year has elapsed is

$$N_1 = N_o\, e^{-(F+M)}$$

Then the annual survival rate is N_1/N_o, where

$$\frac{N_1}{N_o} = e^{-(F+M)} \qquad (3)$$

and the annual mortality rate is

$$\frac{N_o - N_1}{N_o} = 1 - e^{-(F+M)} \qquad (4)$$

The rate at which fish are being caught at time t during the year is

$$\frac{dC}{dt} = FN_t$$

and from (2)

$$\frac{dC}{dt} = FN_o\, e^{-(F+M)t}$$

The total catch during the whole year is

$$C = FN_o \int_o^1 e^{-(F+M)}\,dt \qquad (5)$$

which after performing the integration becomes

$$C = \frac{FN_o}{F + M}\left(1 - e^{-(F+M)}\right) \qquad (6)$$

Since from (4) the expression $N_o\left(1 - e^{-(F+M)}\right)$ is the total number of fish which have either been caught or have died from natural causes during the year, equation (6) show that of these the fraction f/F+M have been caught. Similarly, the fraction M/F+M have died naturally.

If the coefficients F and M can be taken as remaining effectively constant throughout the life-span of the year-class in the fishery, then the total catch obtained from the year-class during this whole period is

$$C = FN_o \int_o^{\infty} e^{-(F+M)t}dt = \frac{FN_o}{F + M} \qquad (7)$$

In other words the total catch obtained from the year-class is the ratio F/F+M of its initial abundance on entering the fishery.

The use of instantaneous coefficients in the analysis of mortalities of fish stocks has two advantages compared with annual mortality rates. One is that the magnitude of the instantaneous coefficient is proportional to the magnitude of the cause of the mortality which is not the case with annual rates; this is especially important when attempting to relate fishing effort to fishing mortality.

The other is that if two or more causes of mortality are operating simultaneously, the instantaneous coefficient of the total mortality is the sum of the coefficients for the two causes active independently; whereas the total annual mortality rate is not the sum of the two independent annual mortality rates. Thus if the total mortality due to fishing and to natural causes is expressed in terms of the sum of the two instantaneous coefficients (F + M), the relation between the component due to fishing (F) and fishing effort can be investigated independently of the magnitude of the natural mortality coefficient M.

Table I. Arctic cod. Total catch for each region 1930 - 1958.

Metric tons round fresh weight.

Year	Region I	Region II b	Region II a	Total
1930	83 466	72 013	282 163	437 642
1931	96 884	64 266	172 010	333 160
1932	118 681	52 761	220 922	392 364
1933	133 118	53 270	172 448	358 836
1934	183 977	58 773	188 134	430 884
1935	223 253	116 778	151 801	491 832
1936	369 574	186 182	190 148	745 904
1937	431 514	167 960	285 847	885 321
1938	314 075	215 913	259 309	789 297
1939		137 133	352 282	
1940	137 394	20	244 699	382 113
1941	102 714	-	207 498	310 212
1942	25 462	-	177 814	203 276
1943	32 506	-	136 118	168 624
1944	39 281	-	180 094	219 375
1945		50 000	151 958	
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	1 147 841
1956	787 070	323 834	232 164	1 343 068
1957	396 195	261 704	136 458	794 357
1958	345 420	254 232	152 131	751 783

For notes see tables III - V.

Table II. Arctic cod. Total catch by countries 1930 - 1958.

	England	Germany	Norway	USSR	Others
1930	72 034	23 445	325 459	16 625	79
1931	59 905	26 079	211 443	35 685	48
1932	53 012	24 114	272 948	41 268	1 022
1933	57 718	31 441	231 365	37 393	919
1934	82 946	42 470	235 126	68 780	1 562
1935	119 681	65 374	207 167	95 770	3 840
1936	192 944	99 453	242 787	194 670	16 050
1937	225 917	113 903	303 414	234 560	7 527
1938	213 043	107 037	309 397	150 200	9 620
1939		95 759	379 207	163 390	11 277
1940	-	4 060	264 603	113 450	-
1941	-	-	229 822	80 390	-
1942	-	-	193 266	10 010	-
1943	-	-	153 754	14 870	-
1944	-	-	194 825	24 550	-
1945		-	164 233	64 720	-
1946	260 046	19 111	308 834	117 980	29
1947	309 171	21 913	392 415	155 820	2 698
1948	316 103	38 049	248 973	167 930	3 240
1949	361 602	38 038	219 477	168 230	12 775
1950	248 711	28 556	247 741	189 080	17 894
1951	255 654	36 212	315 058	210 840	9 416
1952	224 983	24 933	297 279	284 630	44 970
1953	133 394	19 221	218 882	295 780	28 269
1954	148 185	20 732	196 020	434 990	26 094
1955	214 968	32 555	268 388	552 420	79 510
1956	260 209	69 067	335 950	581 490	96 352
1957	154 634	45 177	249 706	282 840	62 000
1958	149 513	20 480	272 670	267 120	42 000

Table III. Arctic cod. Catch by countries in Region I 1930 - 1958.
Metric tons round fresh weight.

Year	England	Germany	Norway	USSR	Others	Total
1930	11 993	18 889	35 925	16 625	34	83 466
1931	9 444	13 300	38 419	35 685	36	96 884
1932	14 936	8 636	52 832	41 268	1 009	118 681
1933	21 031	14 702	59 080	37 393	912	133 118
1934	35 570	25 225	54 268	67 990	924	183 977
1935	29 952	22 040	72 397	95 770	3 094	223 253
1936	53 790	27 230	90 805	194 100	3 649	369 574
1937	77 120	32 600	85 281	233 260	3 253	431 514
1938	52 907	34 230	76 101	148 980	1 857 x)	314 075
1939		19 788	66 639	163 200	3 591	
1940	-	3 460	20 504	113 430	-	137 394
1941	-	-	22 324	80 390	-	102 714
1942	-	-	15 452	10 010	-	25 462
1943	-	-	17 636	14 870	-	32 506
1944	-	-	14 731	24 550	-	39 281
1945		-	12 275	64 720	-	
1946	53 835	-	28 676	117 100	29	199 640
1947	127 242	5 980	53 119	151 970	2 447	340 758
1948	164 794	17 000	63 386	158 650	2 790	406 620
1949	226 450	17 210	67 816	162 340	11 126	484 942
1950	136 790	13 500	66 230	135 410	4 544	356 474
1951	129 030	16 160	66 854	189 580	6 365	407 989
1952	130 546	8 220	92 019	258 830	34 545	524 160
1953	59 445	2 340	101 423	261 400	18 231	442 839
1954	72 347	12 440	86 759	404 650	21 338	597 534
1955	91 379	14 890	126 042	530 280	68 103	830 694
1956	67 787	11 640	113 686	512 170	81 787	787 070
1957	38 488	7 590	117 117	183 000	50 000 4)	396 195
1958	46 225	1 181	121 444	146 570	30 000 4)	345 420

Note 1. All weights converted to round fresh weight by means of conversion factors (k) : for Germany K = 1.2
for Norway K = 1.4

Note 2. Since 1949 Soviet data for catches of cod include small quantities of haddock.

x) Note 3. Includes small quantity of flounders.

Note 4. Estimated.

Table IV. Arctic cod. Catch by countries in Region II a 1930 - 1958.
Metric tons round fresh weight.

Year	England	Germany	Norway	Others	Total
1930	222	-	281 896	45	282 163
1931	1 064	-	170 934	12	172 010
1932	2 138	-	218 771	13	220 922
1933	2 003	-	170 438	7	172 448
1934	2 700	8 215	177 219	-	188 134
1935	9 305	21 280	121 162	54	151 801
1936	16 594	43 892	129 662	-	190 148
1937	27 490	58 681	199 582	94	285 847
1938	12 326	39 761	207 070	152	259 309
1939	16 000 x	43 570	292 712	-	352 282
1940		600	244 099	-	244 699
1941	-	-	207 498	-	207 498
1942	-	-	177 814	-	177 814
1943	-	-	136 118	-	136 118
1944	-	-	180 094	-	180 094
1945	-	-	151 958	-	151 958
1946	20 413	-	275 504	-	295 917
1947	45 302	1 187	329 640	251	376 380
1948	43 771	15 740	176 883	450	236 844
1949	30 483	11 276	145 515	803	188 077
1950	15 483	14 316	173 779	8 147	211 725
1951	22 990	17 002	238 512	194	278 698
1952	33 891	16 418	195 517	949	246 775
1953	23 297	12 490	113 304	-	149 091
1954	17 333	8 005	104 486	-	129 824
1955	19 172	14 802	129 736	-	163 710
1956	28 381	27 144	176 561	78	232 164
1957	26 819	14 444	95 195	-	136 458
1958	23 200	15 989	112 942	-	152 131

Note: Landed weights converted to round fresh weights by means of conversion factors

for England and Germany 1.2

for Norway 1.6

x : estimated.

Table V. Arctic cod. Catch by countries in Region II b 1930 - 1958.
Metric tons round fresh weight.

Year	England	Germany	Norway	USSR	Others	Total
1930	59 819	4 556	7 638	-	-	72 013
1931	49 397	12 779	2 090	-	-	64 266
1932	35 938	15 478	1 345	-	-	52 761
1933	34 684	16 739	1 847	-	-	53 270
1934	44 676	9 030	3 639	790	638	58 773
1935	80 424	22 054	13 608	-	692	116 778
1936	122 560	28 331	22 320	570	12 401	186 182
1937	121 307	22 622	18 551	1 300	4 180	167 960
1938	147 810	33 046	26 226	1 220	7 611	215 913
1939	77 000	32 401	19 856	190	7 686	137 133 x^1
1940	-	-	-	20	-	20
1945	50 000	-	-	-	-	50 000 x^1
1946	185 798	19 111	4 654	880	-	210 443
1947	136 627	14 746	9 656	3 850	-	164 879
1948	107 538	5 309	8 704	9 280	-	130 831
1949	104 669	9 552	6 146	5 890	846	127 103
1950	96 438	740	7 732	53 670	5 203	163 783
1951	103 634	3 050	9 692	21 260	2 857	140 493
1952	60 546	295	9 743	25 800	9 476	105 860
1953	50 652	4 391	4 155	34 380	10 038	103 616
1954	58 505	287	4 775	30 340	4 756	98 663
1955	104 417	2 863	12 610	22 140	11 407	153 437
1956	164 041	30 283	45 703	69 320	14 487	323 834
1957	89 327	23 143	37 394	99 840	12 000	261 704 x^2
1958	80 088	3 310	38 284	120 550	12 000	254 232 x^2

Notes:

(i) ENGLISH, GERMAN and (probably "OTHERS") data refer to landings, not catch; RUSSIAN data are of catch.

(ii) GERMAN data compiled from monthly figures and increased by factor of 1.2 to convert from gutted to whole weight.

(iii) "OTHERS" for 1937 probably includes other gadoid species.

(iv) From 1952 onwards, the Faroe catch in the NE area is split half in each of regions I and II b to arrive at a total for "OTHERS".

x^1 Estimated for English landings.

x^2 In the absence of statistics, the catch of "OTHERS" is taken as 12 000 tons in 1957 and 1958 for the purpose of obtaining on approximation to the total catch in these years.

Table VI. Arctic cod. Fishing effort in Region I 1930 - 1958.

	A	B	C	D	E	F	G
Year	England	Germany	USSR	Total catch / English catch	Total catch / USSR catch	English effort x D	USSR effort x E
1930	16.30	5617	47500	6.96	5.02	113.45	238.45
1931	16.04	5245	89213	10.26	2.72	164.57	242.65
1932	21.89	3029	98257	7.95	2.88	174.03	282.99
1933	29.17	3644	98403	6.33	3.56	184.65	350.30
1934	31.47	3050	128283	5.17	2.71	164.10	347.64
1935	24.72	3178	102978	7.45	2.33	184.16	239.94
1936	36.72	2526	190294	6.87	1.90	252.27	361.55
1937	57.37	3247	206425	5.60	1.85	321.27	381.90
1938	42.59	2971	196026	5.94	2.11	252.98	413.62
1944						11.0	28.0
1945						44.0	110.0
1946	17.6	-	103628	3.71	1.71	65.5	177.21
1947	38.4	272	148990	2.68	2.24	103.0	333.74
1948	63.1	851	161888	2.47	2.56	155.7	414.44
1949	80.0	1013	170884	2.14	2.99	171.2	510.93
1950	93.2	857	161202	2.61	2.63	248.0	423.96
1951	98.93	1461	231195	3.16	2.15	312.62	497.07
1952	102.60	1524	246505	4.02	2.03	412.45	500.42
1953	53.12	334	275158	7.45	1.69	395.74	465.02
1954	51.47	851	340042	8.26	1.48	425.14	503.26
1955	60.65	1050	373437	9.09	1.57	551.31	586.30
1956	54.28	856	492471	11.61	1.54	630.19	758.40
1957	44.46	616		10.29	2.17	457.49	778.64
1958	55.57	-		7.47	2.36	415.11	751.97

Notes:

A Hours fishing x average tonnage x 10^{-6} = millions of ton-hours. Data for 1946-1950 adjusted for distribution of effort on main cod grounds.

B Fishing days.

C Estimated Hours fishing (obtained as ratio $\frac{\text{catch (tons)}}{\text{catch/hr}}$).

F = Estimated total effort in English units.

G = Estimated total effort in Russian units (as 1000 Hours fishing).

Table VII. Arctic cod. Fishing effort in Region II a 1930 - 1958.

	A	B	C	D	E	F	G	H	I
Year	England	Germany	Norway	Total catch / English catch	Total catch / German catch	Total catch / Lofoten catch	English effort x D	German effort x E	Norwegian effort x F
1930	0.34		28 356	1 271.00		1.39	4.32		39 415
1931	2.15		26 508	161.66		1.65	347.57		43 738
1932	2.53		26 608	103.33		1.31	261.42		34 856
1933	3.68		31 905	86.09		1.34	316.81		42 753
1934	3.09	865	28 336	69.68	22.90	1.35	215.31	19.81	38 254
1935	5.07	3 759	28 772	16.31	7.13	1.72	82.69	26.80	49 488
1936	4.92	4 568	25 043	11.46	4.33	2.25	56.38	19.78	56 347
1937	9.92	6 508	23 559	10.40	4.87	2.17	103.17	31.69	51 123
1938	4.91	5 638	22 548	21.04	6.52	1.81	103.31	36.76	40 812
1939									
1945									
1946	3.16	-	21 517	14.50	-	1.44	45.82	-	30 984
1947	11.89	523	20 541	8.31	317.09	1.61	98.91	165.84	33 071
1948	15.09	2 535	19 247	5.41	15.05	1.34	81.64	38.15	25 791
1949	10.29	2 598	18 552	6.17	16.68	1.76	63.49	43.33	32 652
1950	11.03	3 973	16 514	13.67	14.79	1.84	150.78	58.76	30 386
1951	16.04	3 757	21 981	12.12	16.39	1.50	194.40	61.38	32 972
1952	29.32	4 320	23 645	7.28	15.03	1.70	213.45	64.93	40 197
1953	19.92	3 074	23 192	6.40	11.94	1.80	127.49	36.70	41 746
1954	17.52	2 732	20 441	7.49	16.22	1.77	131.22	44.31	36 181
1955	18.42	4 191	14 437	8.54	11.06	2.21	157.31	46.35	31 906
1956	20.40	4 197	18 033	8.18	8.55	2.20	166.87	35.88	39 673
1957	23.86	3 878	10 812	5.09	9.45	3.70	121.45	36.65	40 004
1958	26.70		12 125	6.56	9.51	2.81	175.15		34 071

Notes:

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

B Fishing days.

C Number of men fishing in Lofoten.

G = Estimated total effort in English units.

H = Estimated total effort in German units.

I = Estimated total effort in Norwegian units.

Table VIII. Arctic cod. Fishing effort in Region II b 1930 - 1958.

	1	2	3	A	B	C	D
Year	England	Germany	USSR	Total catch of cod (tons)	English catch	A/B	English effort x C
1930	17.51	596		72 013	59 819	1.20	21.01
1931	16.14	1 239		64 266	49 397	1.30	20.98
1932	18.61	1 227		52 761	35 938	1.47	27.36
1933	14.48	1 637		53 270	34 684	1.54	22.30
1934	21.80	1 337	1 145	58 773	44 676	1.32	28.78
1935	19.79	1 707	-	116 778	80 424	1.45	28.70
1936	24.06	2 043	687	186 182	122 560	1.52	36.57
1937	35.51	1 311	1 287	167 960	121 307	1.38	49.00
1938	50.71	1 813	2 068	215 913	147 810	1.46	74.04
1939	(?)	1 815	452				
1940			105				
1945	5.59						
1946	20.33	866	518	210 443	185 798	1.13	22.97
1947	31.29	1 099	4 425	164 879	136 627	1.21	37.86
1948	31.73	300	8 360	130 831	107 538	1.22	38.71
1949	27.60	7 960	6 402	127 103	104 669	1.21	33.40
1950	36.91	49	41 605	163 783	96 438	1.70	62.75
1951	54.23	169	17 008	140 493	103 634	1.36	73.75
1952	30.98	123	26 327	105 860	60 546	1.75	54.22
1953	27.48	319	31 255	103 616	50 652	2.05	56.33
1954	32.12	71	27 835	98 663	58 505	1.69	54.28
1955	44.32	137	19 593	153 437	104 417	1.47	65.15
1956	68.12	1 623	48 139	323 834	164 041	1.97	134.20
1957	65.56	2 196	151 273	261 704	89 327	2.93	192.09
1958	66.39	585	215 268	254 232	80 088	3.17	210.46

NOTES:

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

B 2 Fishing days.

C 3 Estimated Hours fishing (obtained as ratio $\frac{\text{catch (tons)}}{\text{catch/hr}}$)

D = Estimated total effort in English units.

Table IX. Arctic cod. Catch per unit effort for trawl fisheries in Region I 1930-58. Metric tons round fresh weight.

Year	England	Germany	USSR	Relative C.P.U.E. England	Relative C.P.U.E. USSR
1930	0.074	3.36	0.35	0.510	0.422
1931	0.059	2.54	0.40	0.407	0.482
1932	0.068	2.85	0.42	0.469	0.506
1933	0.072	4.03	0.38	0.497	0.458
1934	0.112	8.27	0.53	0.772	0.639
1935	0.121	7.80	0.93	0.834	1.120
1936	0.146	11.30	1.02	1.007	1.229
1937	0.134	9.47	1.13	0.924	1.361
1938	0.124	10.60	0.76	0.855	0.916
1939					
1945					
1946	0.305	-	1.13	2.104	1.361
1947	0.335	22.50	1.02	2.310	1.229
1948	0.261	19.90	0.98	1.800	1.181
1949	0.283	17.00	0.95	1.950	1.145
1950	0.147	15.85	0.84	1.014	1.012
1951	0.130	10.80	0.82	0.897	0.988
1952	0.127	5.04	1.05	0.876	1.265
1953	0.112	6.82	0.95	0.773	1.145
1954	0.141	14.75 x)	1.19	0.972	1.434
1955	0.151	14.00 x)	1.42	1.041	1.711
1956	0.125	14.00 x)	1.04	0.862	1.253
1957	0.087	13.95 x)	0.51	0.600	0.614
1958	0.083	-	0.46	0.572	0.554
Average	0.145		0.83		

Notes:

(I) English figures are $\frac{\text{tons (fish landed)}}{\text{100 hours fishing x average tonnage (ships)}}$
Data for 1946-1950 adjusted for distribution of fishing on the main cod grounds.

(II) German figures are tons per fishing day.

(III) Russian figures are tons per 1 hour trawling.

(IV) Relative C.P.U.E. = $\frac{\text{Annual values}}{\text{Average}}$

x) Fishing mainly in April, May, November, December and January.

Table X. Arctic cod. Catch per unit effort for fisheries in Region II a 1930 - 1958.
Metric tons round fresh weight.

				Relative C.P.U.E.	
Year	England	Germany	Norway	England	Lofoten
1930	0.065	-	7.18	0.351	1.264
1931	0.049	-	3.93	0.265	0.692
1932	0.084	-	6.32	0.454	1.113
1933	0.054	-	4.05	0.292	0.713
1934	0.087	9.50	4.92	0.470	0.866
1935	0.184	5.66	3.06	0.995	0.539
1936	0.337	9.61	3.37	1.822	0.593
1937	0.277	9.02	5.60	1.497	0.986
1938	0.251	7.05	6.35	1.357	1.118
1939					
1946	0.647	-	9.58	3.497	1.687
1947	0.381	2.27	11.36	2.059	2.000
1948	0.290	6.21	5.90	1.568	1.039
1949	0.296	4.34	5.75	1.600	1.013
1950	0.140	3.60	6.96	0.757	1.226
1951	0.143	4.53	8.44	0.773	1.486
1952	0.116	3.80	6.14	0.627	1.081
1953	0.117	4.06	3.57	0.632	0.629
1954	0.099	2.93	3.58	0.535	0.630
1955	0.104	3.53	5.14	0.562	0.905
1956	0.139	6.47	5.85	0.751	1.030
1957	0.112	3.72	3.41	0.605	0.600
1958	0.087		4.47	0.470	0.787
Average	0.185		5.679		

Notes:

(i) English figures are $\frac{\text{tons (fish landed)}}{\text{100 hours fishing x average tonnage (ships)}}$

(ii) German figures are tons per fishing days.

(iii) Norwegian figures are tons per man in Lofoten.

(iv) Relative C.P.U.E. = $\frac{\text{Annual values}}{\text{Average}}$

Table XI. Arctic cod. Catch per unit effort for trawl fisheries in Region IIb 1930-58. Metric tons round fresh weight.

				Relative C.P.U.E.	
Year	England	Germany	USSR	England	USSR
1930	0.342	7.64	-	1.131	-
1931	0.306	10.31	-	1.012	-
1932	0.193	12.62	-	0.638	-
1933	0.240	9.12	-	0.794	-
1934	0.205	6.76	0.69	0.678	0.736
1935	0.406	12.94	-	1.343	-
1936	0.510	13.87	0.83	1.687	0.885
1937	0.342	17.26	1.01	1.131	1.077
1938	0.292	18.23	0.59	0.966	0.629
1939	-	17.86	0.42	-	0.448
1940	-	-	0.19	-	0.203
1946	0.915	22.06	1.70	3.026	1.812
1947	0.437	13.42	0.87	1.445	0.928
1948	0.339	17.70	1.11	1.121	1.183
1949	0.379	20.76	0.92	1.253	0.981
1950	0.261	15.12	1.29	0.863	1.375
1951	0.191	18.06	1.25	0.632	1.333
1952	0.195	2.40	0.98	0.645	1.045
1953	0.184	13.78	1.10	0.608	1.173
1954	0.182	4.04	1.09	0.602	1.162
1955	0.236	20.90	1.13	0.780	1.205
1956	0.241	18.99	1.44	0.797	1.536
1957	0.136	10.54	0.66	0.450	0.704
1958	0.121	5.31	0.56	0.400	0.597
Average	0.3024		0.938		

Notes: (i) English figures are $\frac{\text{tons (fish landed)}}{\text{100 hours fishing x average tonnage (ships)}}$

(ii) German figures are tons per fishing day.

(iii) Russian figures are tons per 1 hour trawling.

(iv) Relative C.P.U.E. $= \frac{\text{Annual values}}{\text{Average}}$

Table XII Region I Cod. Stock and Effort (see Fig. 12)

	A	B	C
Year	Number per 100 ton-hours	$\frac{1}{A}$	3-year sums of total effort (ton-hours x 10^{-6})
1946	125	0.80	120
1947	139	0.72	212
1948	126	0.79	324
1949	113	0.88	430
1950	37	2.72	569
1951	50	2.02	727
1952	56	1.80	967
1953	48	2.07	1,121
1954	64	1.57	1,233
1955	64	1.57	1,372
1956	51	1.97	1,606
1957	34	2.95	1,639
1958	38	2.66	1,503

Note: Col. A Based on English catch per unit effort data.

Col. C Estimates of total effort in English ton-hour units raised to total catch ratio.

Table XIII   Region II B Cod.   Stock and Effort (see Fig. 13)

Year	A Numbers caught per 100 ton-hours	B $\frac{1}{A}$ x 100 = Reciprocal of CPUE	C 3-year sums of total effort millions of ton-hours
1935	194.1	0.52	80
1936	154.6	0.65	94
1937	123.1	0.81	114
1938	102.5	0.98	160
1946	186.7	0.54	28
1947	108.7	0.92	66
1948	89.8	1.11	100
1949	150.5	0.66	110
1950	72.0	1.39	135
1951	79.1	1.26	170
1952	90.0	1.11	191
1953	79.5	1.26	184
1954	90.0	1.11	165
1955	114.8	0.87	176
1956	103.9	0.96	254
1957	48.8	2.05	392
1958	60.2	1.66	537

Note: Col.A. Estimates based on English catch per 100 ton-hours fishing.

Col.C. Estimates of total fishing effort in English ton-hour units raised to total catch ratio.

Table XVa. Region I Cod. Age-composition, number of fish per 1 hour's fishing from USSR age data and catch per unit effort.

Year / Age	1932	1933	1934	1935	1936	1937	1938	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
2	17	8	7	13	4	11	1	-	-	2	-	-	4	4	1	-	1	2	6	2
3	43	60	42	35	44	24	12	27	7	3	2	2	87	86	139	25	10	20	15	13
4	61	49	97	77	53	73	24	43	58	6	10	23	182	326	321	351	79	40	47	58
5	53	48	95	205	54	36	52	42	90	53	51	52	136	287	209	312	330	163	29	69
6	34	28	51	96	180	67	30	70	90	114	149	71	70	145	82	171	251	233	59	39
7	27	23	28	44	78	130	55	51	72	160	154	105	42	84	26	66	95	81	57	28
8	13	14	27	20	36	69	60	43	19	39	54	55	18	20	15	25	36	28	36	31
9	8	6	8	8	9	24	26	90	23	24	20	24	7	10	4	10	12	6	7	10
10+	19	11	8	11	10	11	10	96	84	29	24	24	4	6	4	9	10	4	6	9
% total mortality rate, ages 7 to 9	51	18	54	40	23	58		56	17	59	60	85	49	82	20	49	78	67	61	
Total mortality coefficient ages 7 to 9	0,72	0.20	0.78	0.50	0.26	0.87		0.81	0.19	0.88	0.92	1.91	0.67	1.67	0.22	0.67	1.51	1.10	0.95	
Total fishing effort USSR units	317	349	294	301	372	398		256	375	463	467	461	499	483	484	544	671	767	764	

Note: Total effort values in bottom row are in units of thousands of hours fishing.

Table XVb Region I. Cod. Estimated age-composition of total catch by all countries, raised by English catch per unit effort.

Year / Age	1932	1933	1934	1935	1936	1937	1938	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
3	0.02	-	-	0.03	0.10	0.02	0.37	7.26	2.09	0.88	4.42	-	0.04	0.15	0.02	0.07	-	0.02	0.08	0.56
4	0.38	0.37	0.43	0.56	0.58	1.89	1.87	11.52	18.25	1.89	12.92	0.49	1.41	4.65	2.02	5.33	0.73	0.50	1.98	4.44
5	1.49	2.12	3.18	7.85	1.75	2.91	7.09	11.39	28.42	15.59	18.38	1.15	8.61	11.84	13.77	19.03	10.83	6.29	3.40	9.98
6	3.16	3.37	6.18	13.97	8.61	7.66	5.73	18.91	28.42	33.19	34.83	5.49	13.58	16.26	16.41	21.76	26.82	22.76	9.81	8.31
7	3.81	4.62	5.47	10.04	7.96	17.05	9.46	13.77	22.57	46.77	20.08	12.89	11.52	13.14	7.20	10.25	15.70	13.51	9.70	5.81
8	2.16	3.37	8.69	5.82	9.28	8.65	9.54	11.77	5.99	11.31	9.08	9.32	6.62	4.09	5.49	3.99	5.44	5.59	6.55	5.53
9	1.55	1.60	2.59	2.82	3.50	2.53	4.30	24.29	7.10	7.17	6.58	4.28	4.11	2.11	1.62	1.62	1.93	1.20	1.29	1.56
10	2.20	1.37	0.75	0.88	0.93	0.38	1.24	17.65	10.45	2.01	2.94	1.76	1.76	1.52	0.70	0.48	1.30	0.61	0.58	0.91
11	1.48	0.64	0.56	0.29	0.19	0.26	0.48	5.26	11.01	3.65	1.59	1.01	1.96	0.91	0.15	0.67	0.57	0.24	0.38	0.42
12+	2.80	2.18	1.98	1.22	1.13	0.33	0.13	3.13	4.74	2.76	2.50	0.37	0.02	0.93	0.25	0.13	0.19	0.08	0.10	0.20
% total mortality rate, 7 to 9	19	-20	41	25	46	47		49	23	66	53	52	66	59	61	49	72	67	63	
total mortality coefficient, ages 7 to 9	0.21	-0.18	0.53	0.29	0.61	0.64		0.67	0.26	1.09	0.76	0.74	1.09	0.90	0.94	0.67	1.27	1.10	1.00	
Total fishing effort English units	79	174	174	218	287	287		84	130	163	210	280	363	404	410	488	591	544	436	

Note: Total effort values in bottom row are in units of millions of ton-hours fishing.

Table 16a. Region IIB Cod. Age-composition, number per 100 ton-hours fishing, and total effort.

Year / Age	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
3	1.0	-	-	-	0.2	1.7	1.5	2.1	1.7	0.3	-	0.2	1.2
4	11.1	9.4	2.7	9.5	2.6	9.0	36.1	10.7	19.6	10.8	1.1	2.7	25.1
5	24.6	40.9	20.5	43.3	12.4	11.1	23.8	38.8	25.4	60.2	22.1	4.7	14.1
6	15.8	14.1	22.9	65.4	26.5	20.4	7.7	15.6	35.3	26.4	60.4	16.1	6.0
7	9.2	1.6	19.7	26.4	19.7	18.7	8.6	3.9	4.8	14.2	11.9	18.6	8.2
8	14.6	1.8	5.5	4.0	7.8	13.4	4.7	4.4	1.7	1.6	7.2	4.5	4.5
9	71.1	13.6	3.9	1.3	2.3	3.4	6.7	2.7	0.8	0.4	0.8	1.7	0.8
10+	38.9	27.3	13.6	0.6	0.5	0.8	0.9	1.3	0.7	0.9	0.4	0.3	0.3
Mean % total mortality rate, ages 6/7, 7/8 and 8/9					41	63	47	71	68	51	70	72	
Mean total mortality coefficient					0.52	0.99	0.63	1.24	1.15	0.72	1.20	1.27	
Total fishing effort, English units					68	64	55	55	60	99	163	201	

Note (i) English age data and catch/unit effort from 1950 - 1958

(ii) USSR age data converted to equivalent English age-composition for 1946 - 1949.

Table XVIb

Region II B Cod.

Age-composition, number per hours fishing, based on U.S.S.R. data

Age / Year	3	4	5	6	7	8	9	10+	A: % mortality rate; 6-8/7-9	B: Mortality coefficient
1949	+	41	117	174	70	11	4	1	- 11	- 0.10
1950	10	21	82	126	175	78	29	26	55	0.80
1951	40	162	187	254	131	38	3	+	61	0.92
1952	65	388	161	57	68	51	47	52	58	0.87
1953	146	117	325	146	37	26	11	5	50	0.69
1954	9	204	167	183	61	25	17	36	50	0.69
1955	8	114	251	134	105	23	6	6	42	0.54
1956	2	33	232	346	110	40	2	1	74	1.35
1957	53	27	28	87	87	35	9	3	81	1.66
1958	54	234	48	22	29	10	1	+		

Note: Col. A = % Mortality rate = $\frac{N_2 - N_1}{N_1} \times 100$

Col. B = $1 - e^{-A}$

Table XVII

Spawning group composition of skrei 1946-1950 and 1951-1958 and corresponding effort of mature fish.

Spawning group	1946 - 50		1951 - 58		Year	Relative catch/unit effort England IIa	Relative catch/unit effort England I	Relative catch/unit effort USSR I	A Mean relative catch/unit effort	B Total catch of Mature fish Region I, IIa, IIb	Total effort B/A	Mean effort for period
1	451	466	597	614	1946	3.057	3.340	3.053	3.150	131812	41845	67,735 (1946-1950)
2	282	241	293	258	1947	1.715	2.111	1.680	1.835	138629	75547	
3	136	141	77	80	1948	1.258	1.445	1.227	1.310	92737	70792	
4	66	71	18	22	1949	1.369	1.214	1.307	1.297	78131	60240	
5	32	38	7	11	1950	0.600	0.889	1.373	0.954	86090	90241	
6	15	19	4	7	1951	0.747	0.838	0.387	0.657	86050	130974	121,360 (1951-1958)
7	10	10	3	4	1952	0.600	0.514	0.480	0.531	77121	145237	
8	5	6	1	2	1953	0.600	0.441	0.307	0.449	46489	103543	
9	3	4	-	1	1954	0.515	0.397	0.587	0.499	50186	100573	
10	1	2	-	-	1955	0.542	0.507	0.773	0.607	61668	101595	
1	1	1	-	-	1956	0.772	0.415	0.507	0.564	81652	144773	
2	-	-	-	-	1957	0.656	0.484	0.653	0.597	70257	117684	
F + M	0.62	0.62	1.10	0.97	1958	0.515	0.460	0.667	0.537	67772	126205	
Mean	0.62		1.04									

Notes:

Mature fish are 8 years and older.

Table 18 Comparison of abundance of certain year-classes in Region I and four years later in Region IIA, and total fishing effort.

Year	A	Year	B	C	D	Year	E
1946	206	1950	528	2.56	1.36	1946/49	1.77
1947	300	1951	1022	3.41	1.07	1947/50	2.41
1948	333	1952	795	2.39	1.43	1948/51	3.17
1949	364	1953	470	1.29	2.05	1949/52	4.09
1950	251	1954	412	1.64	1.81	1950/53	4.90
1951	430	1955	577	1.34	2.01	1951/54	5.55
1952	842	1956	795	.94	2.36	1952/55	6.39
1953	638	1957	418	.66	2.72	1953/56	7.17
1954	900	1958	642	.71	2.65	1954/57	7.38

Col.A. Catch per unit effort of age-groups 4 to 7; hos. per hour's trawling, USSR data.

Col.B. Catch per unit effort of age-groups 8 to 11 four years later;

Col.C. Ratios Col.B to Col.A. (proportional to survival rate)

Col.D. Natural logarithms of reciprocals of Col.D (proportional to total mortality coefficient).

Col.E. Total fishing effort in Region I, in relative units.

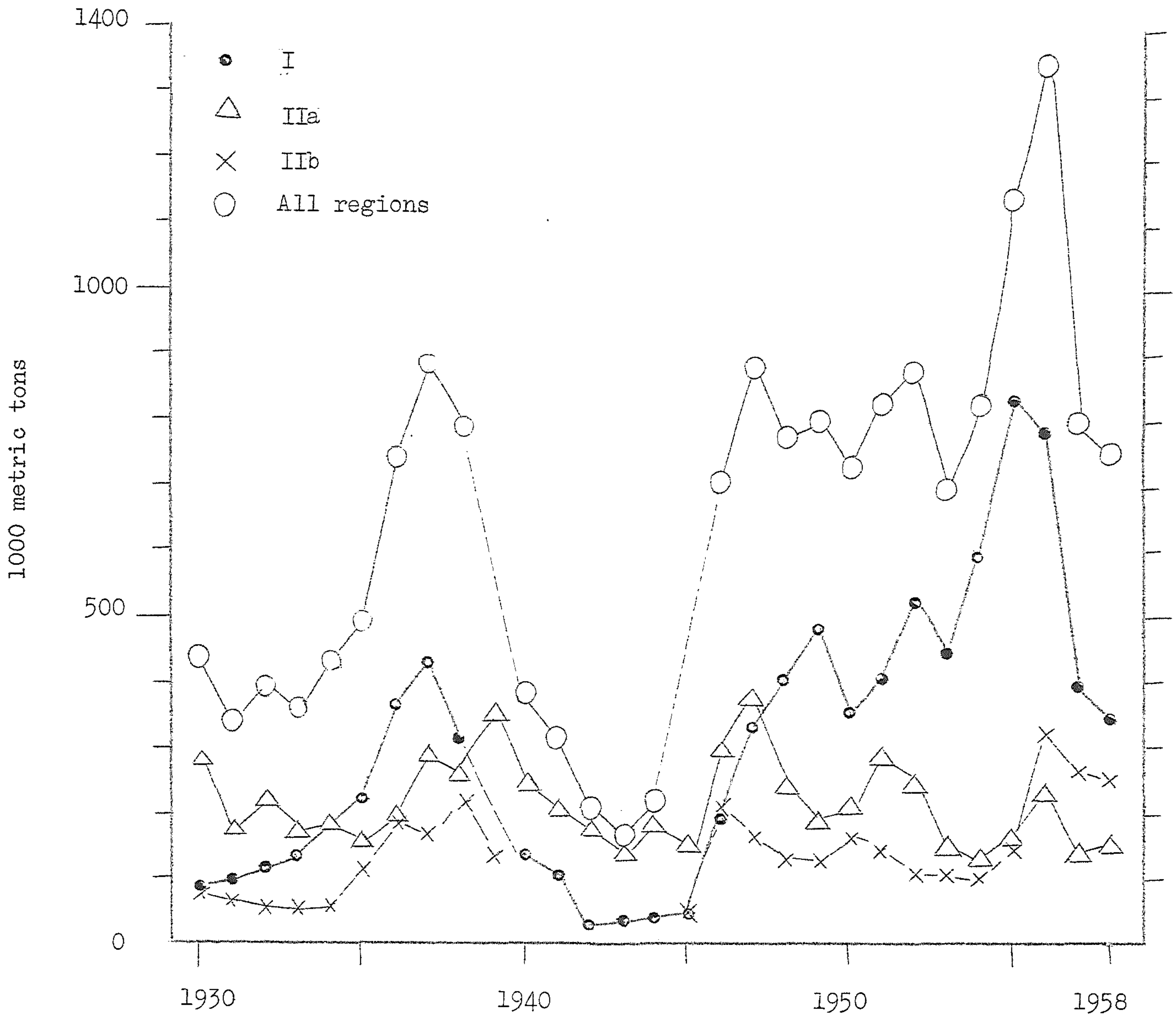


Figure C1. Arctic cod. Total landings from each region. (See Table I).

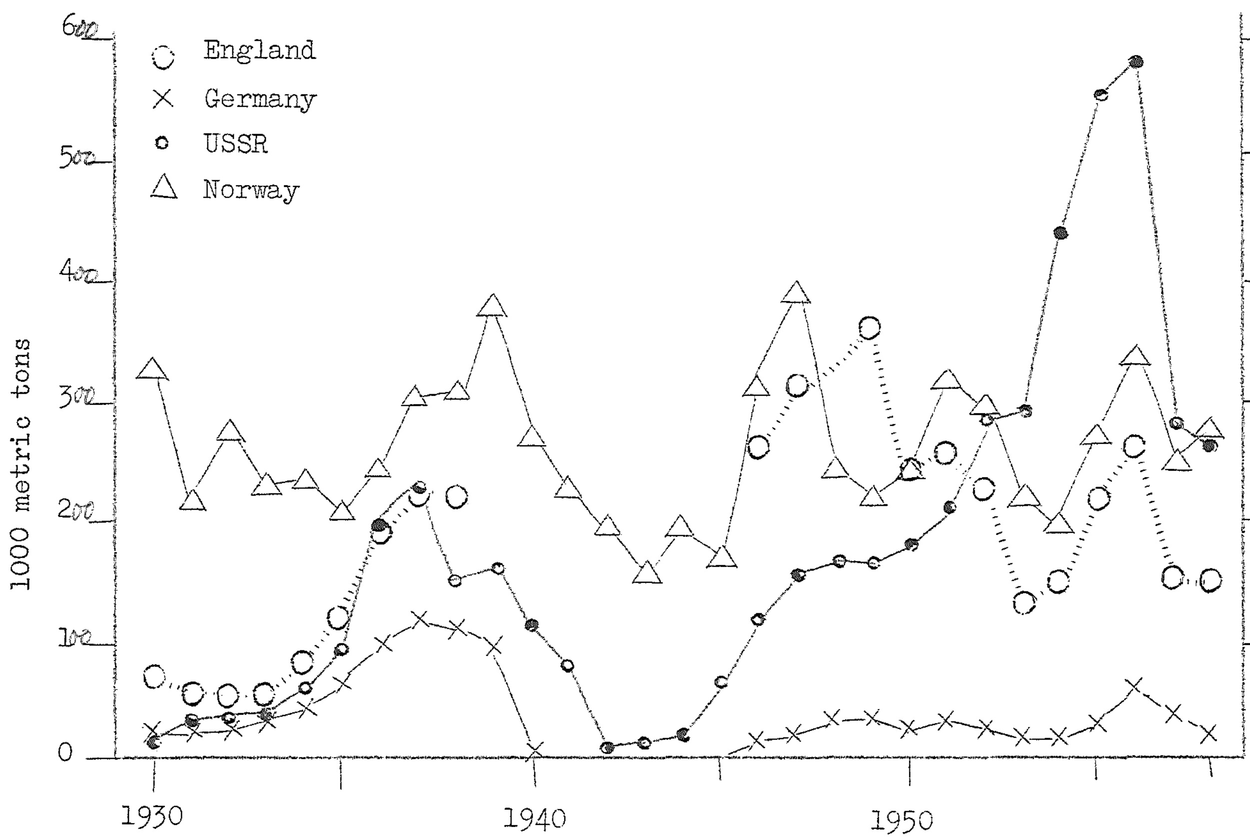


Figure C2. Arctic cod. Total landings by countries. All regions (See Table II).

Figure C.3. Arctic cod. Region I. Landings by countries (See Table III).

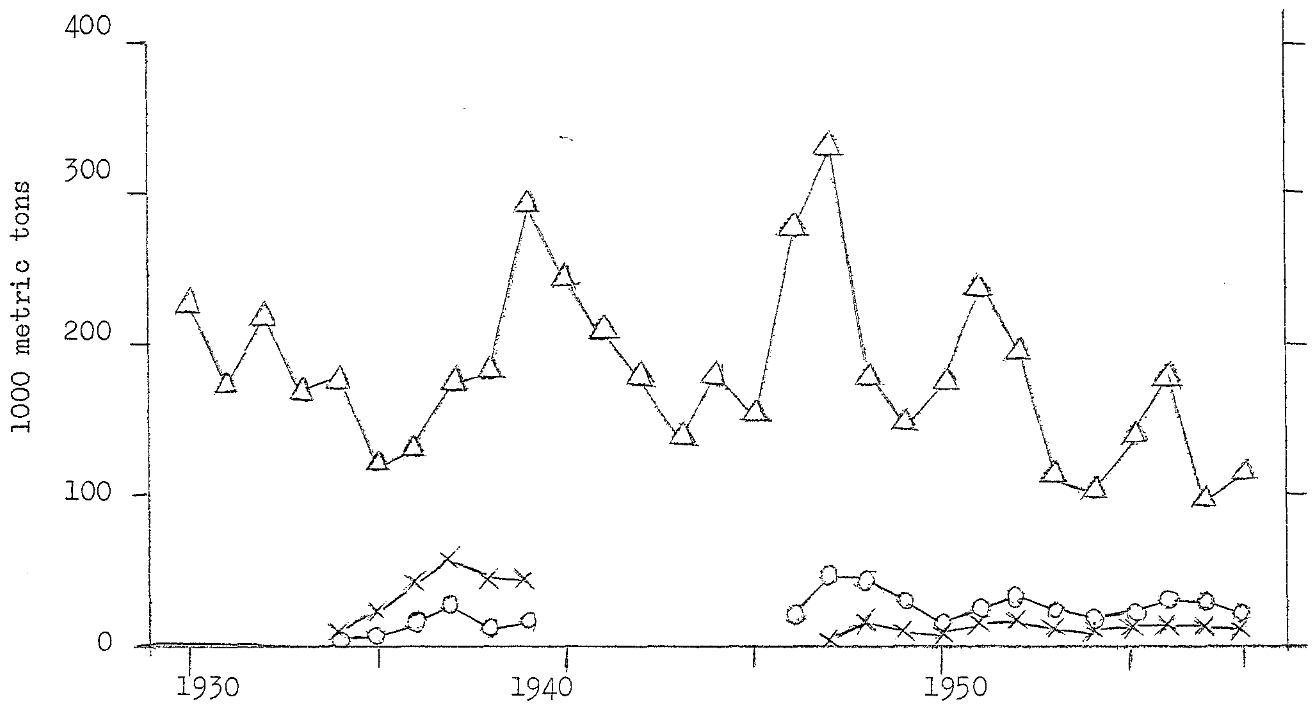


Figure C.4. Arctic cod. Region IIa. Landings by countries (See Table IV).

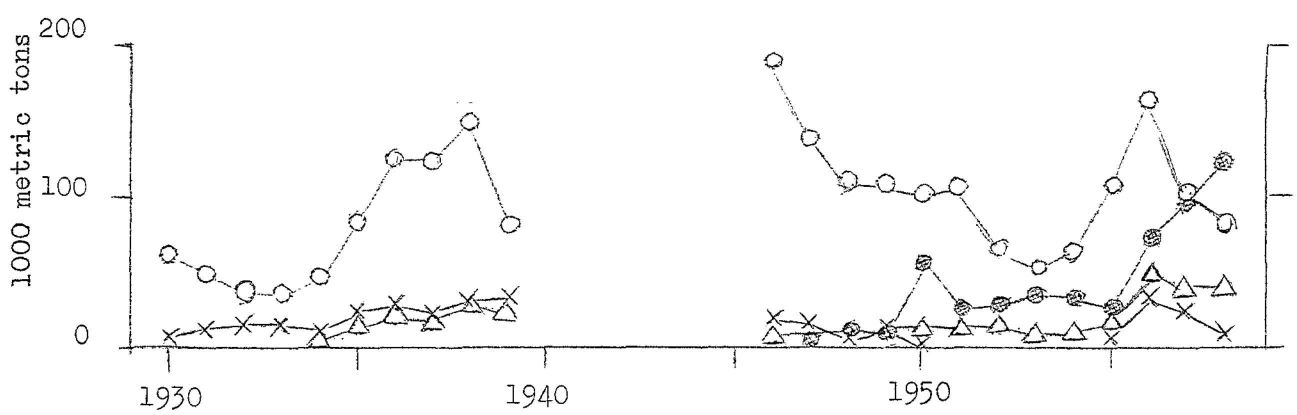


Figure C.5. Arctic cod. Region IIb. Landings by countries (See Table V).

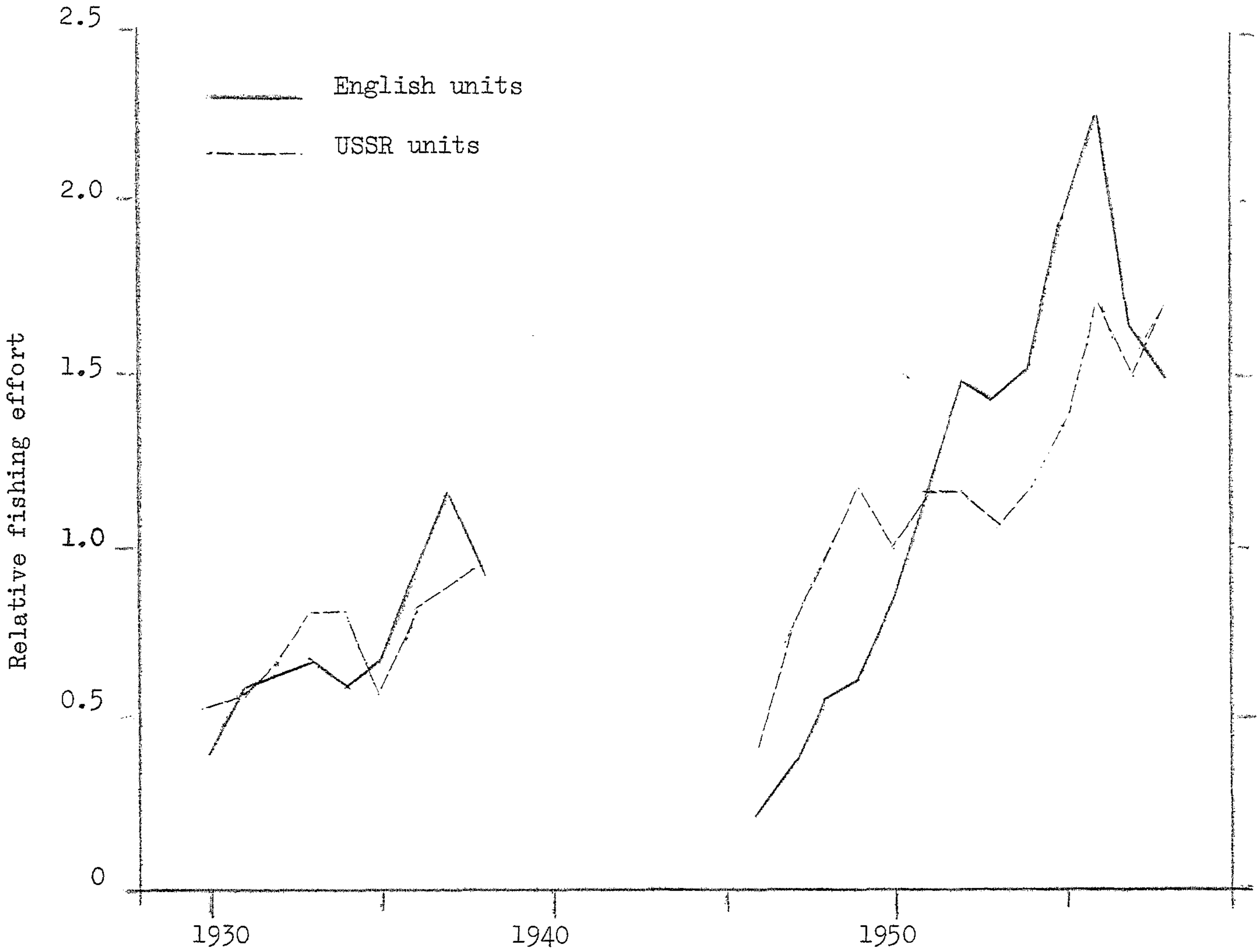


Figure C6. Arctic cod. Region I. Total fishing effort, relative to the mean in a) English units and b) USSR units. (See Table VI).

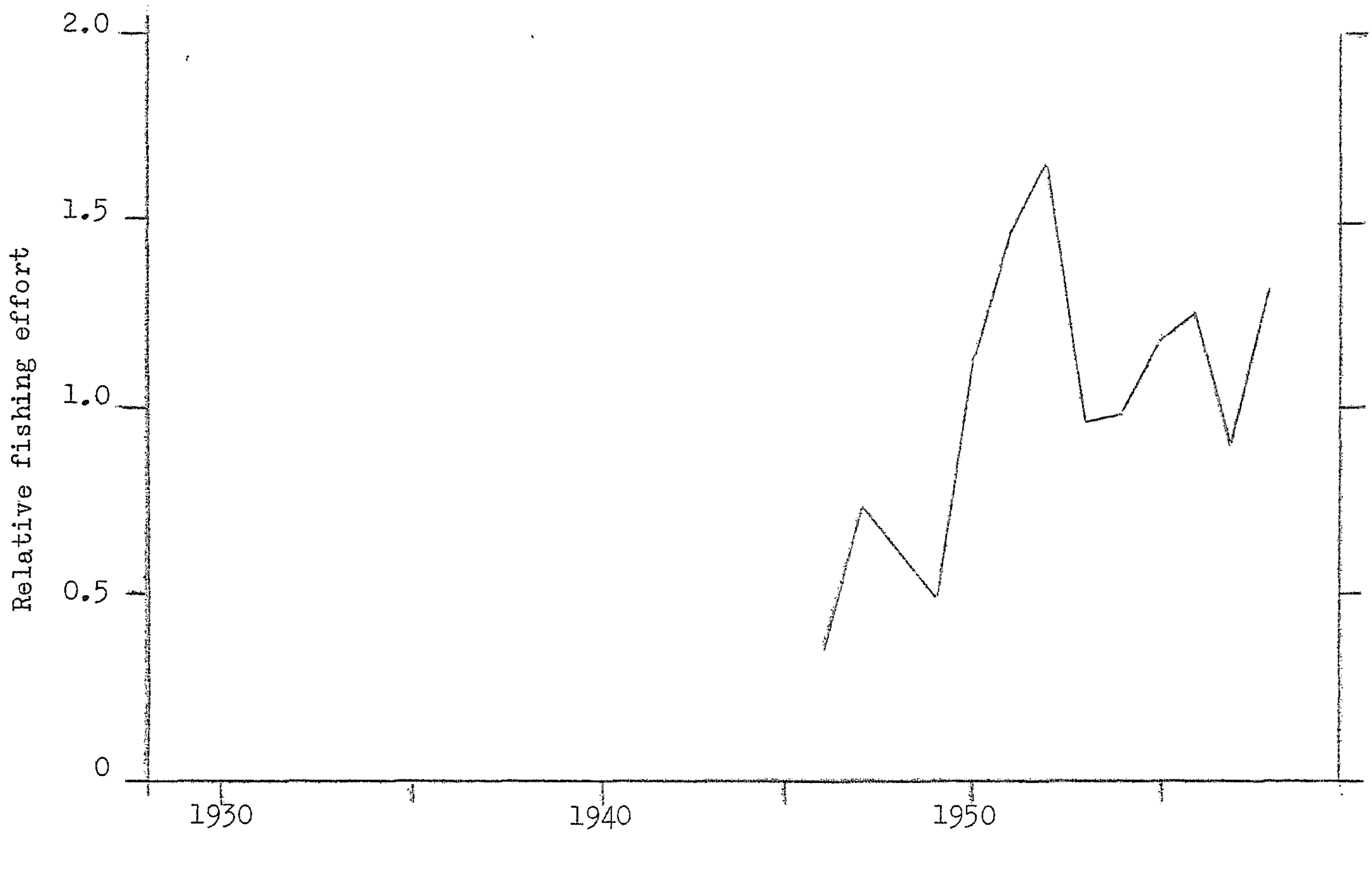


Figure C7. Arctic cod. Region IIa. Total fishing effort, relative to the mean in English units. (See Table VII).

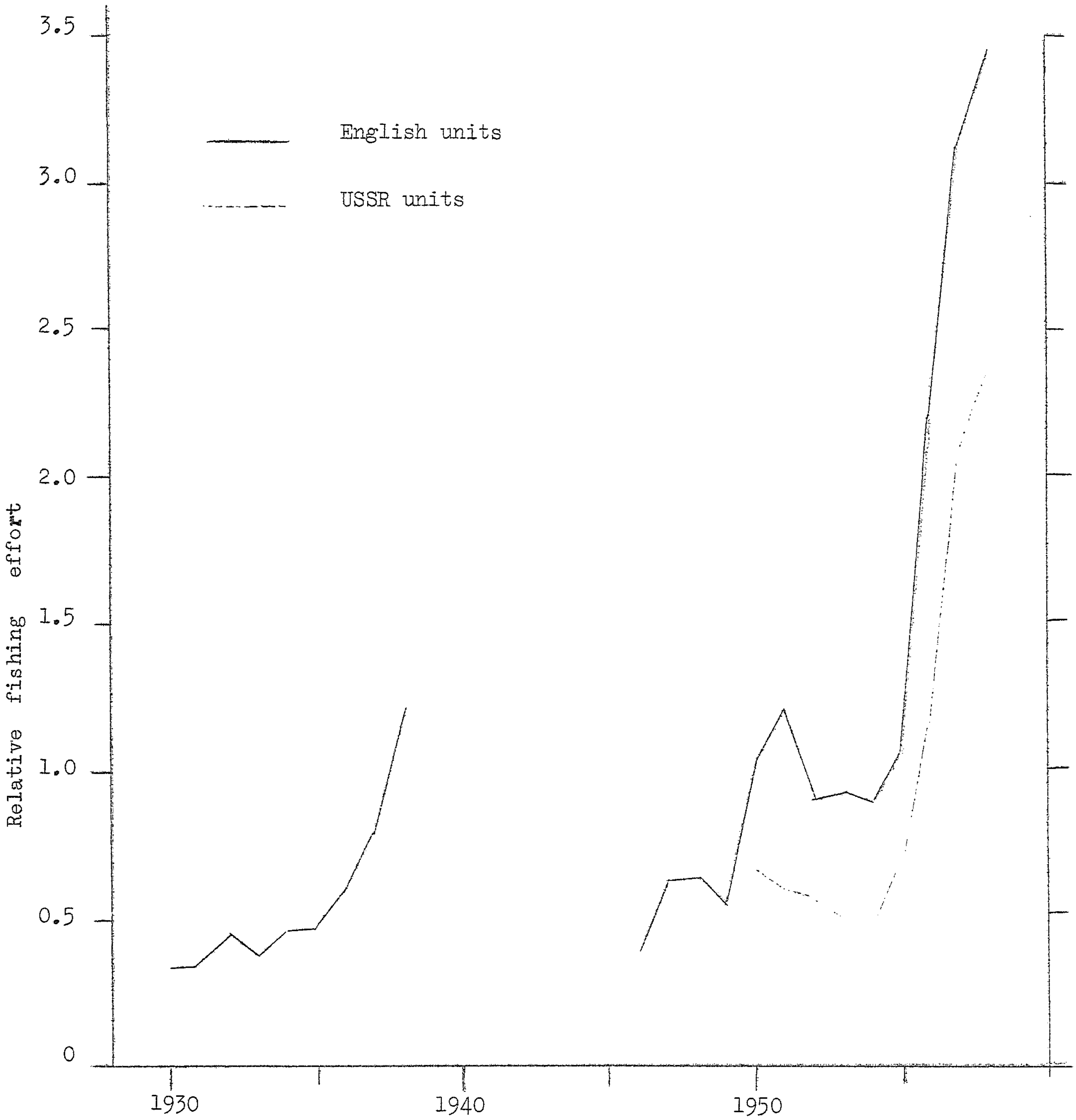


Figure C8. Arctic cod. Region IIb. Total fishing effort, relative to the mean in English units. (See Table VIII).

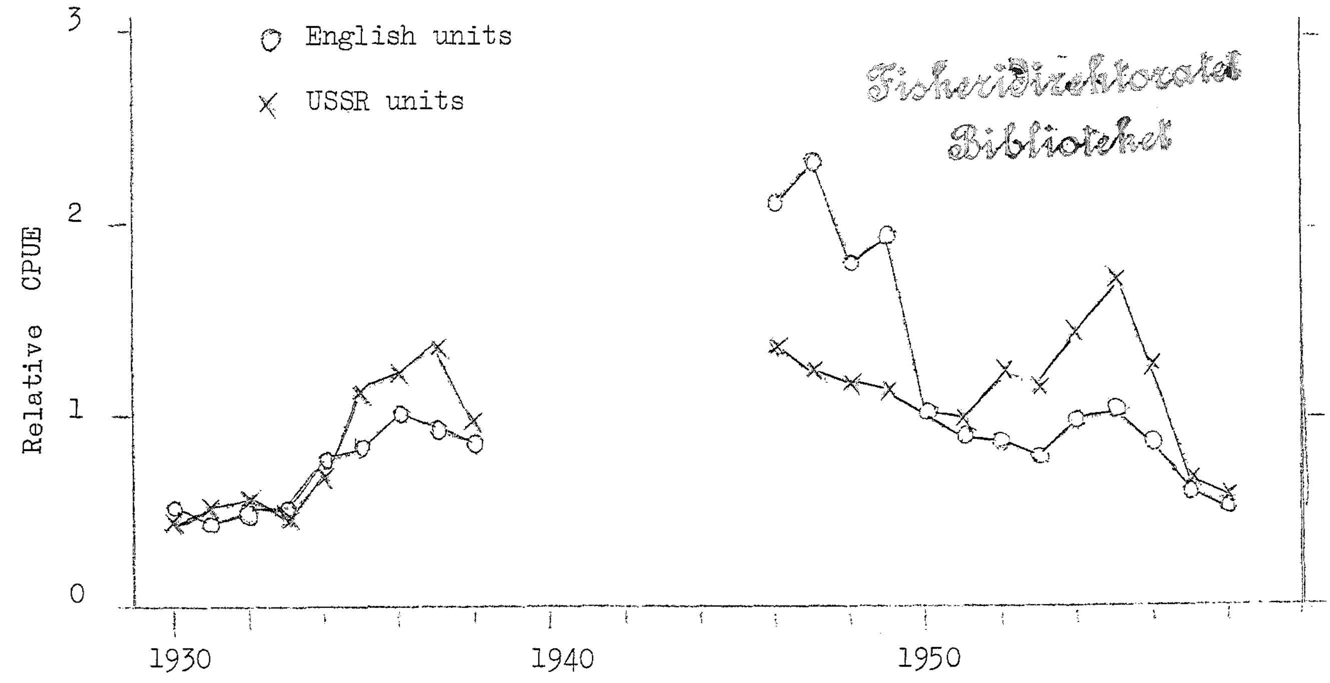


Figure C9. Arctic cod. Region I. Catch per unit effort, relative to the mean in a) English, and b) USSR units. (See Table IX).

Figure C10. Arctic cod. Region IIa. Catch per unit effort, relative to the mean in English units. (See Table X).

Figure C11. Arctic cod. Region IIb. Catch per unit effort, relative to the mean in English units. (See Table XI).

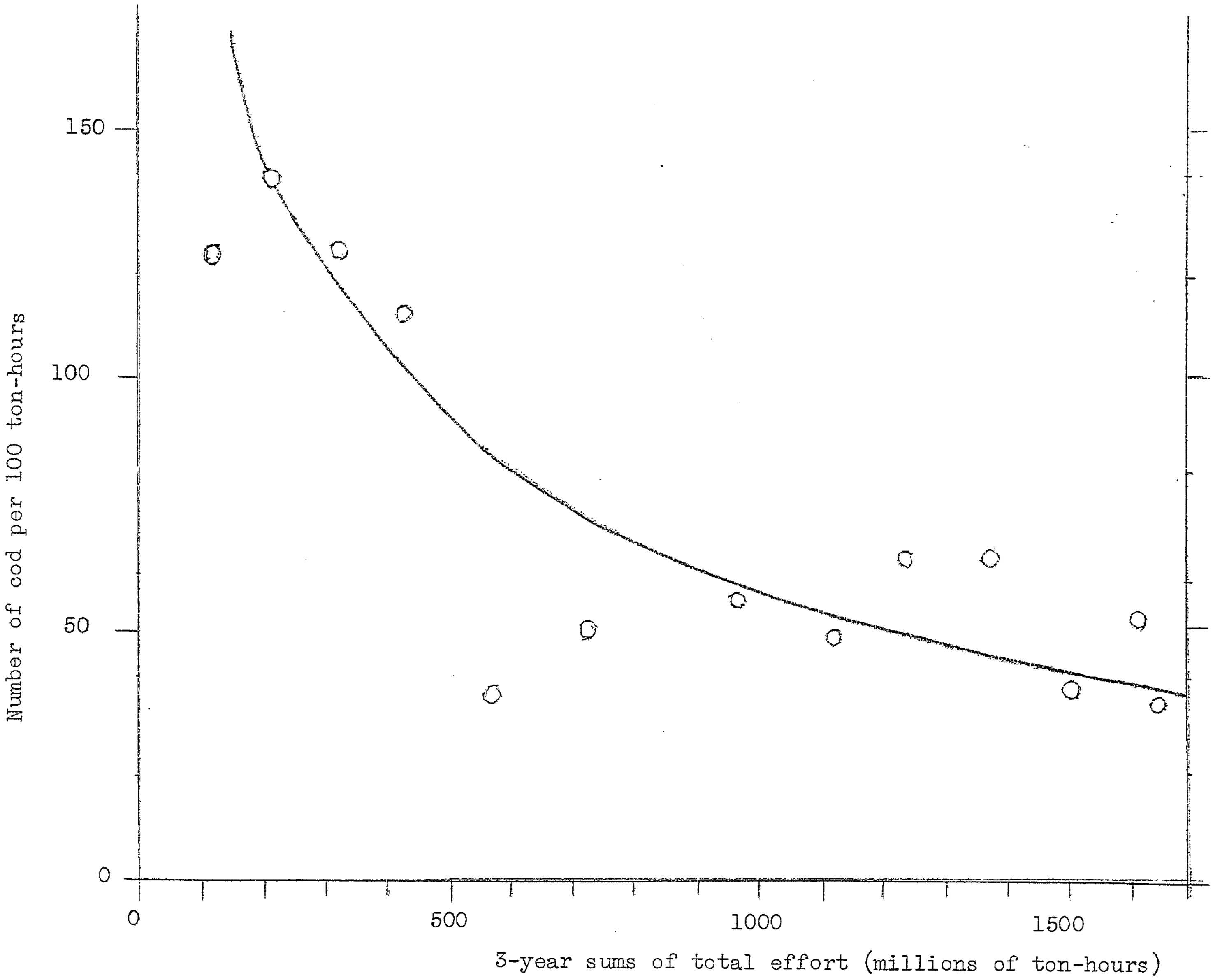


Figure C12a. Arctic cod. Region I. Relation between stock density and fishing effort. (See Table CXII).

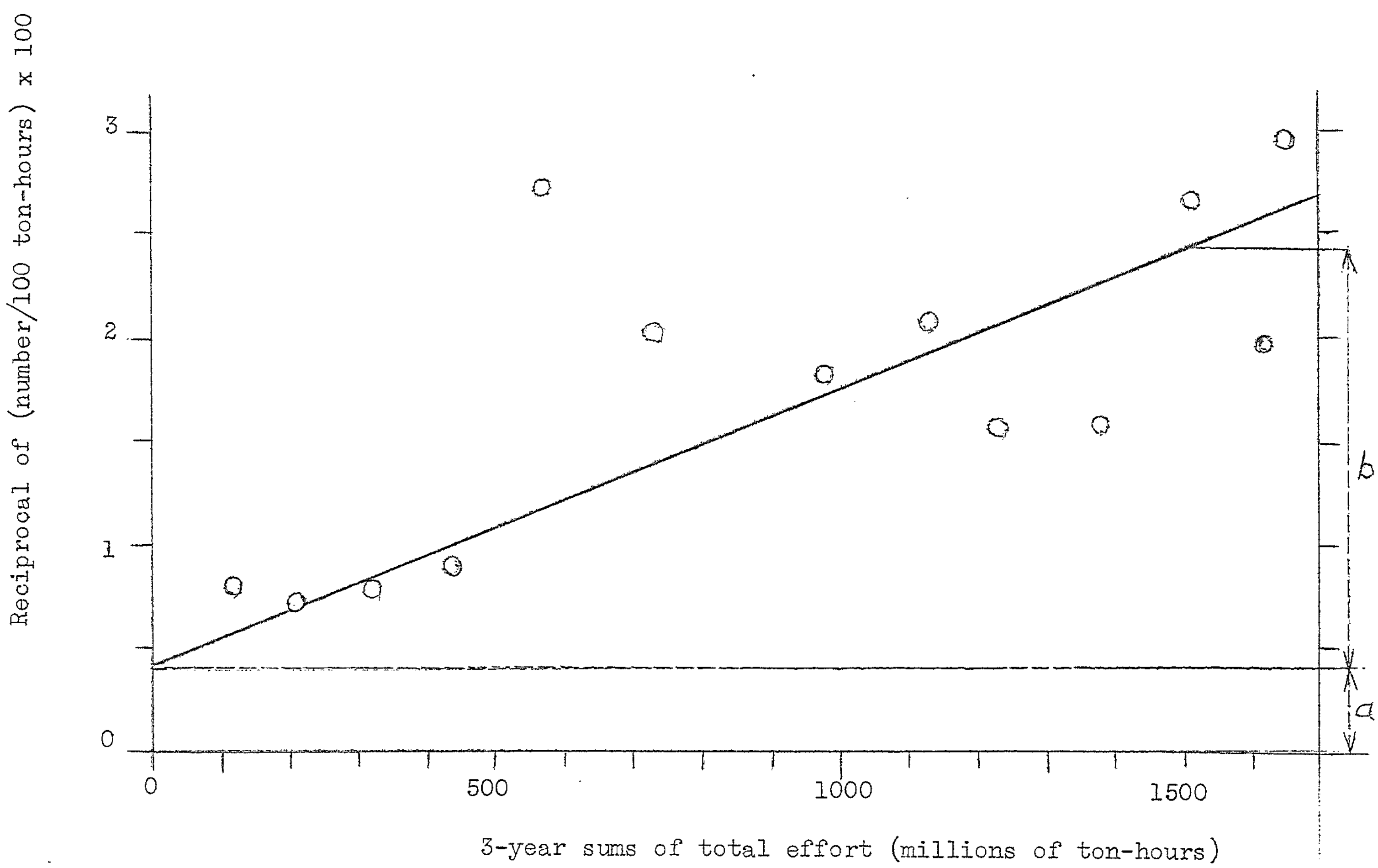


Figure C12b. Arctic cod. Region I. Relation between the reciprocal of the stock density and fishing effort. (See Table CXII).

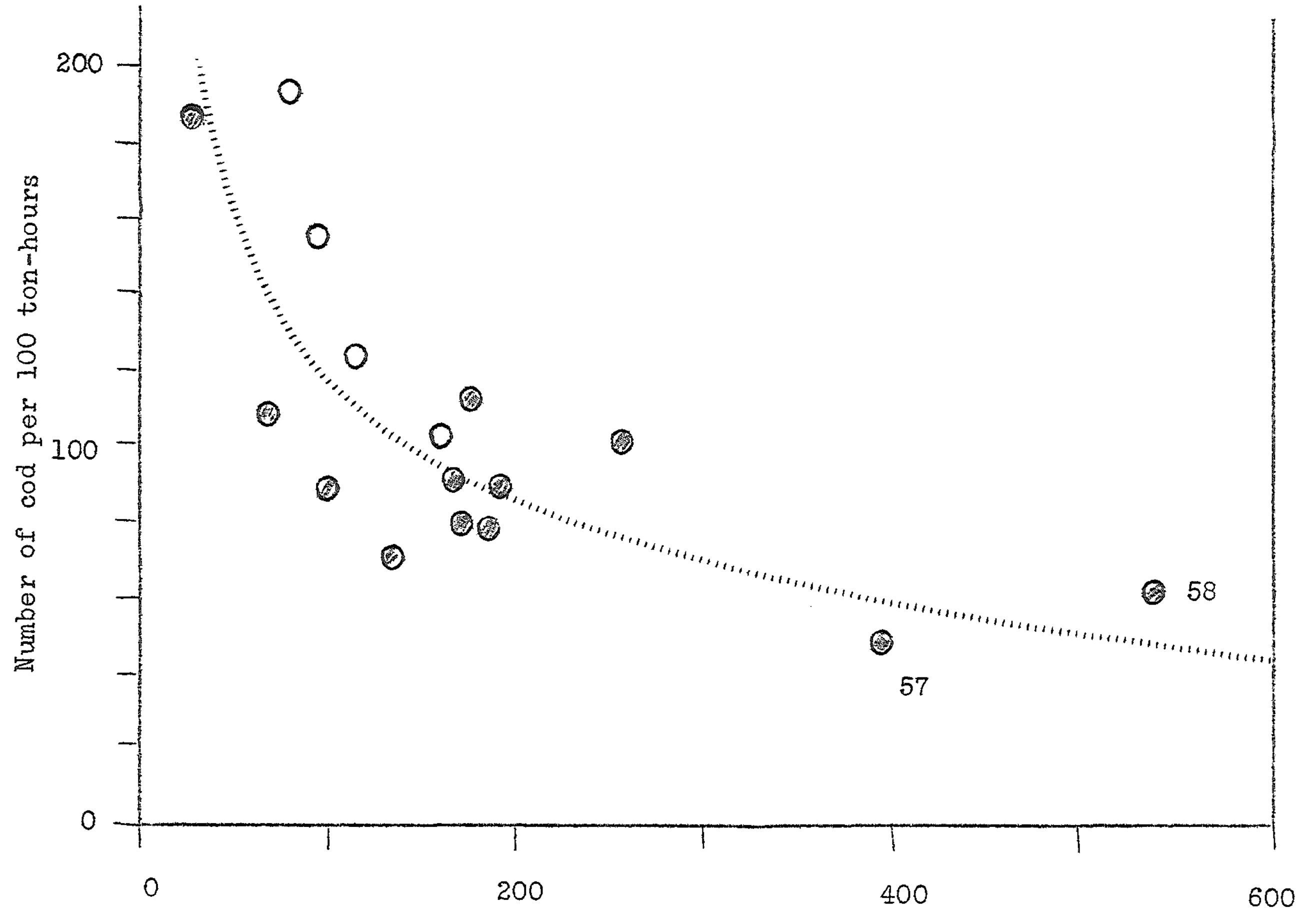


Figure C13a. Arctic cod. Region IIb. Relation between stock density and fishing effort. (See Table XIV).

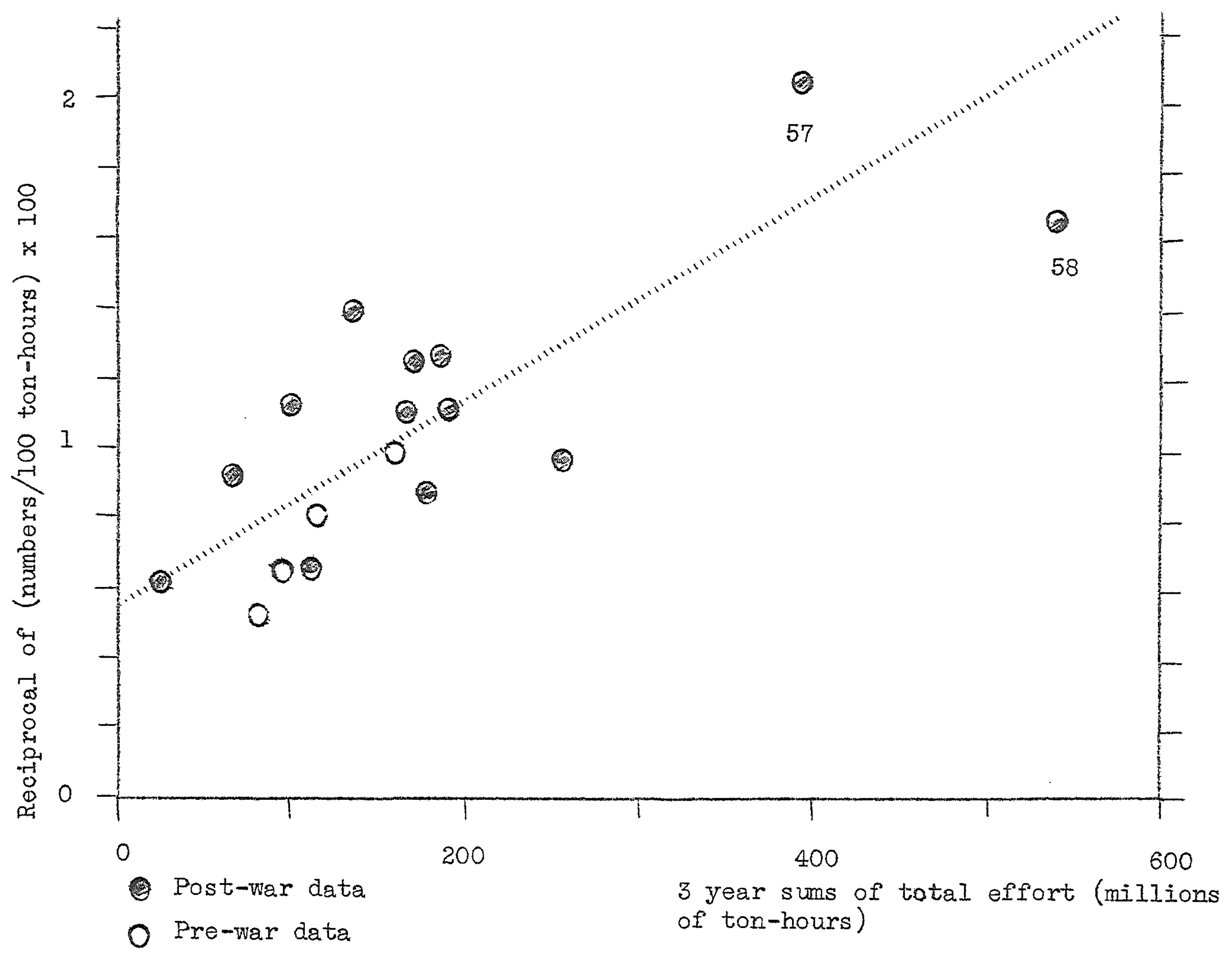


Figure C13b. Arctic cod. Region IIb. Relation between the reciprocal of the stock density and fishing effort. (See Table XIV).

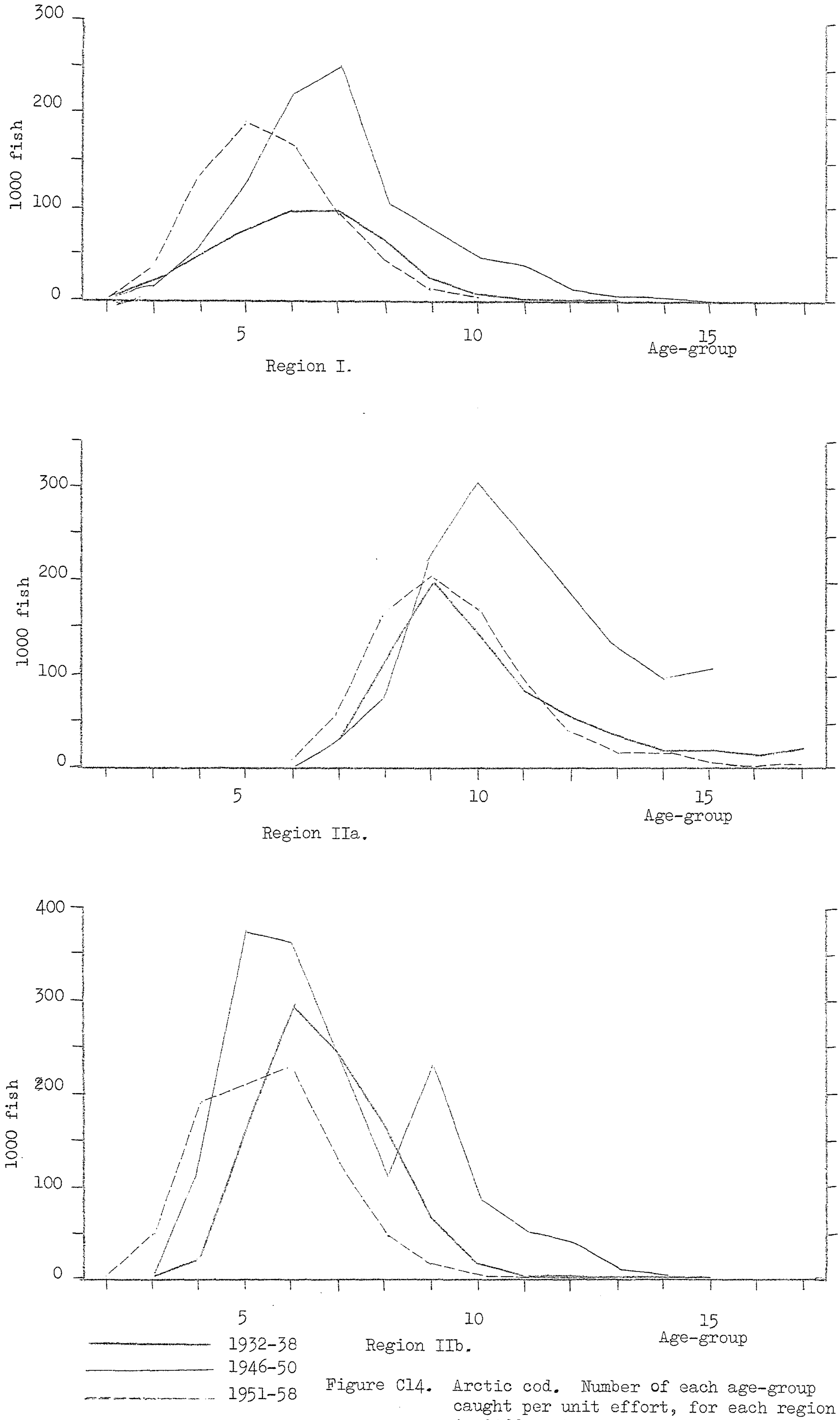


Figure C14. Arctic cod. Number of each age-group caught per unit effort, for each region in different periods.

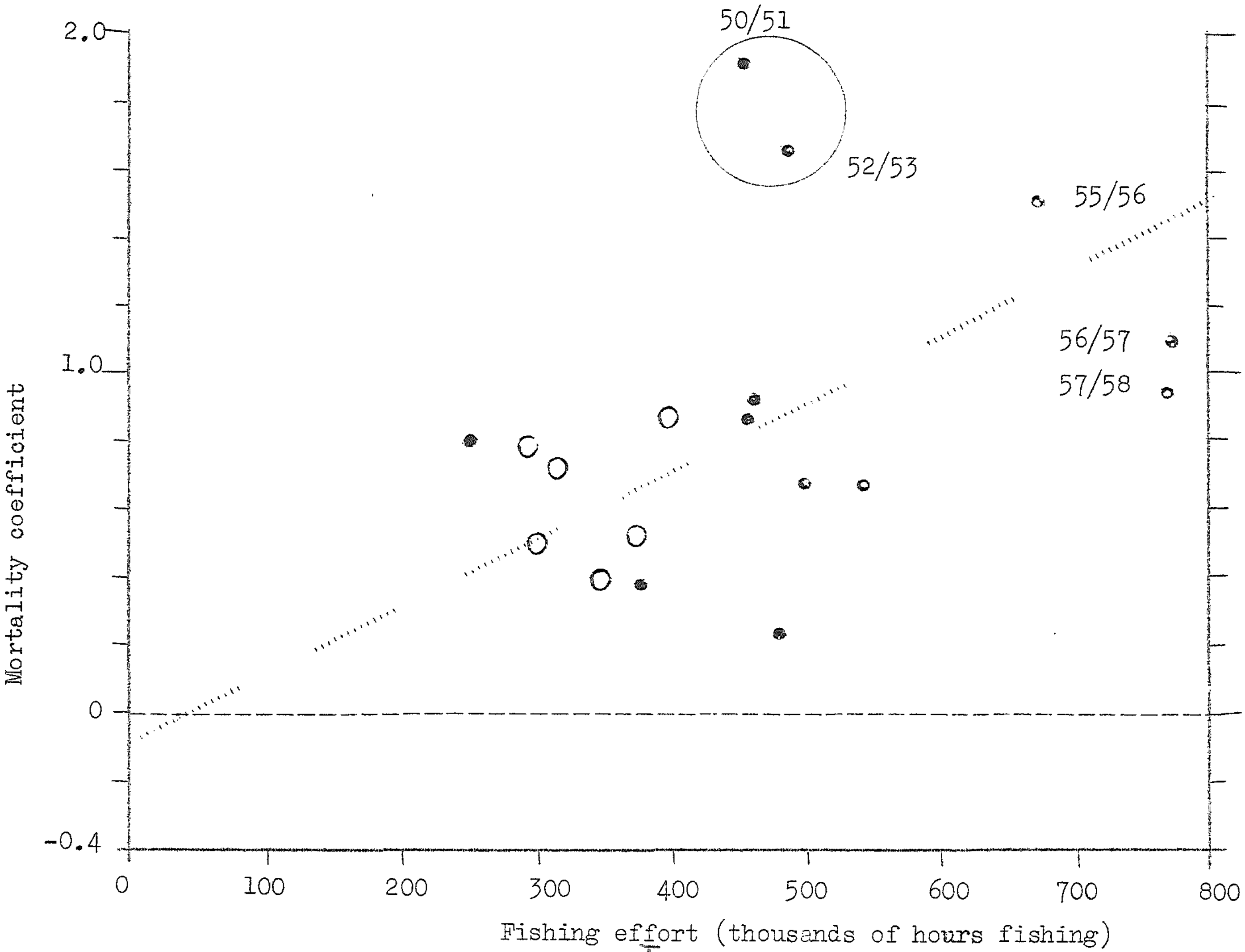


Figure C15a. Arctic cod. Region ~~IIb~~ I. Relation between total mortality coefficient from age 6-9 (USSR) data and total fishing effort in USSR units. (See Table XVb).

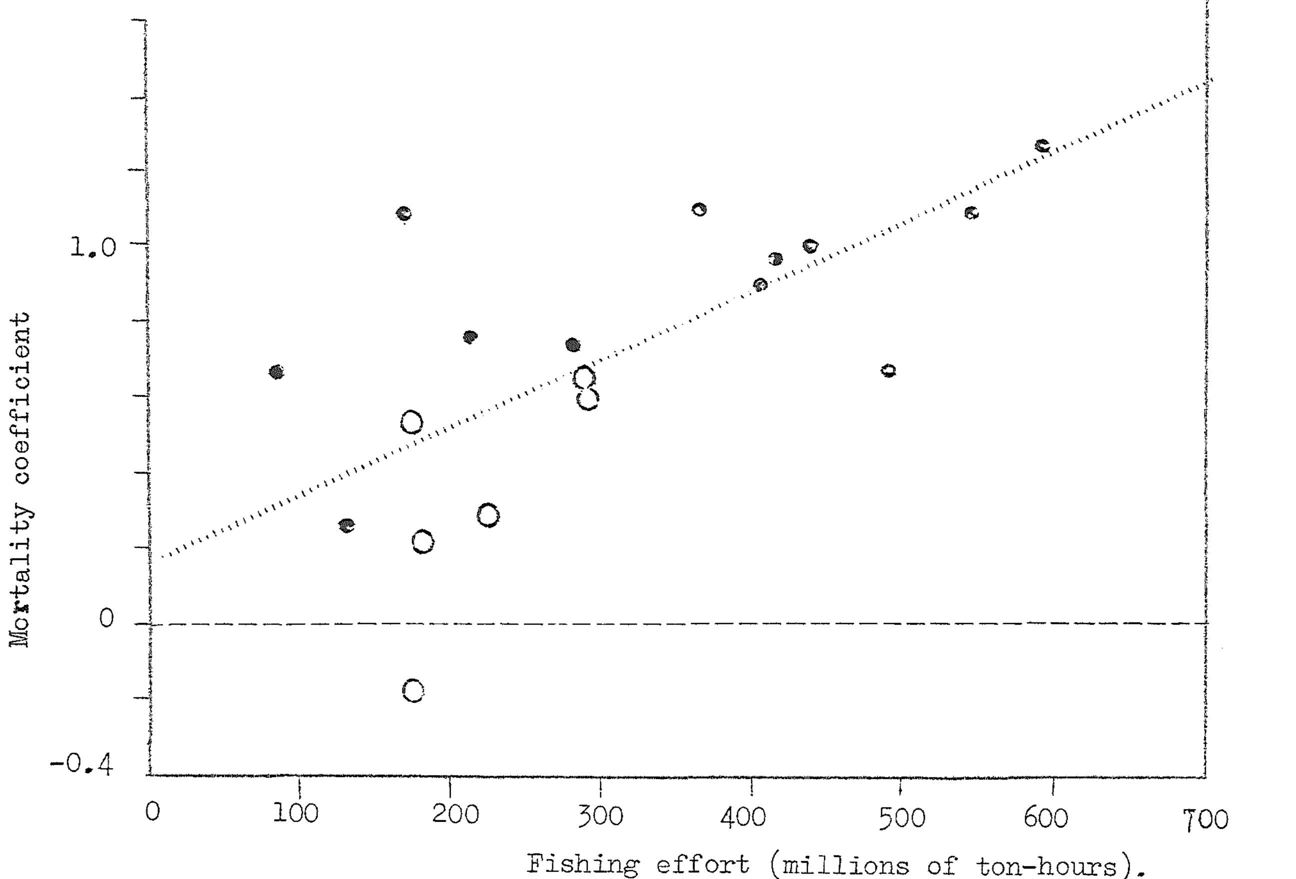


Figure C15b. Arctic cod. Region ~~IIb~~ I. Relation between total mortality coefficient from age 6-9 (English data) and total fishing effort in English units. (See Table XVa).

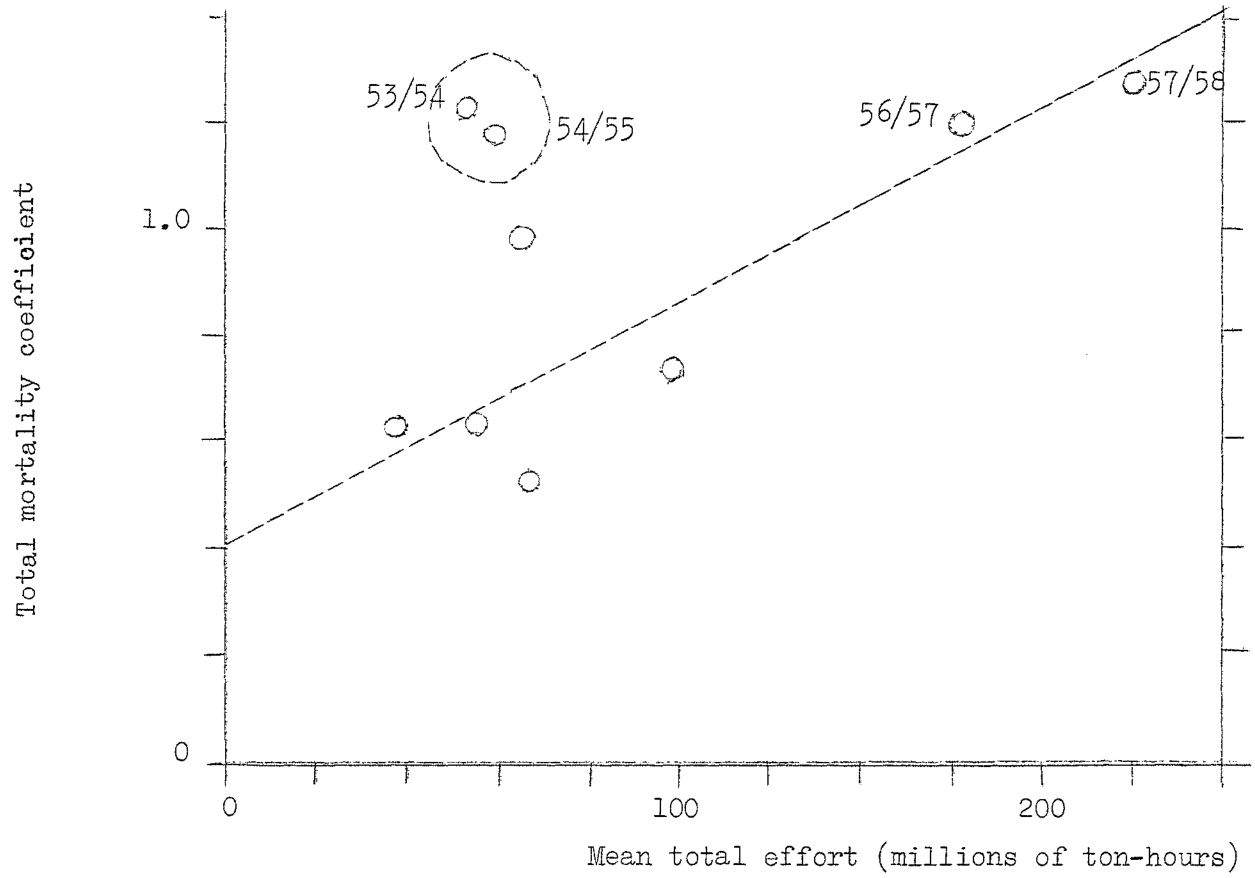


Figure C16a. Arctic cod. Region IIb. Relation between total mortality coefficient from age 7 to 9 and total fishing effort in English units. (See Table XIIIa).

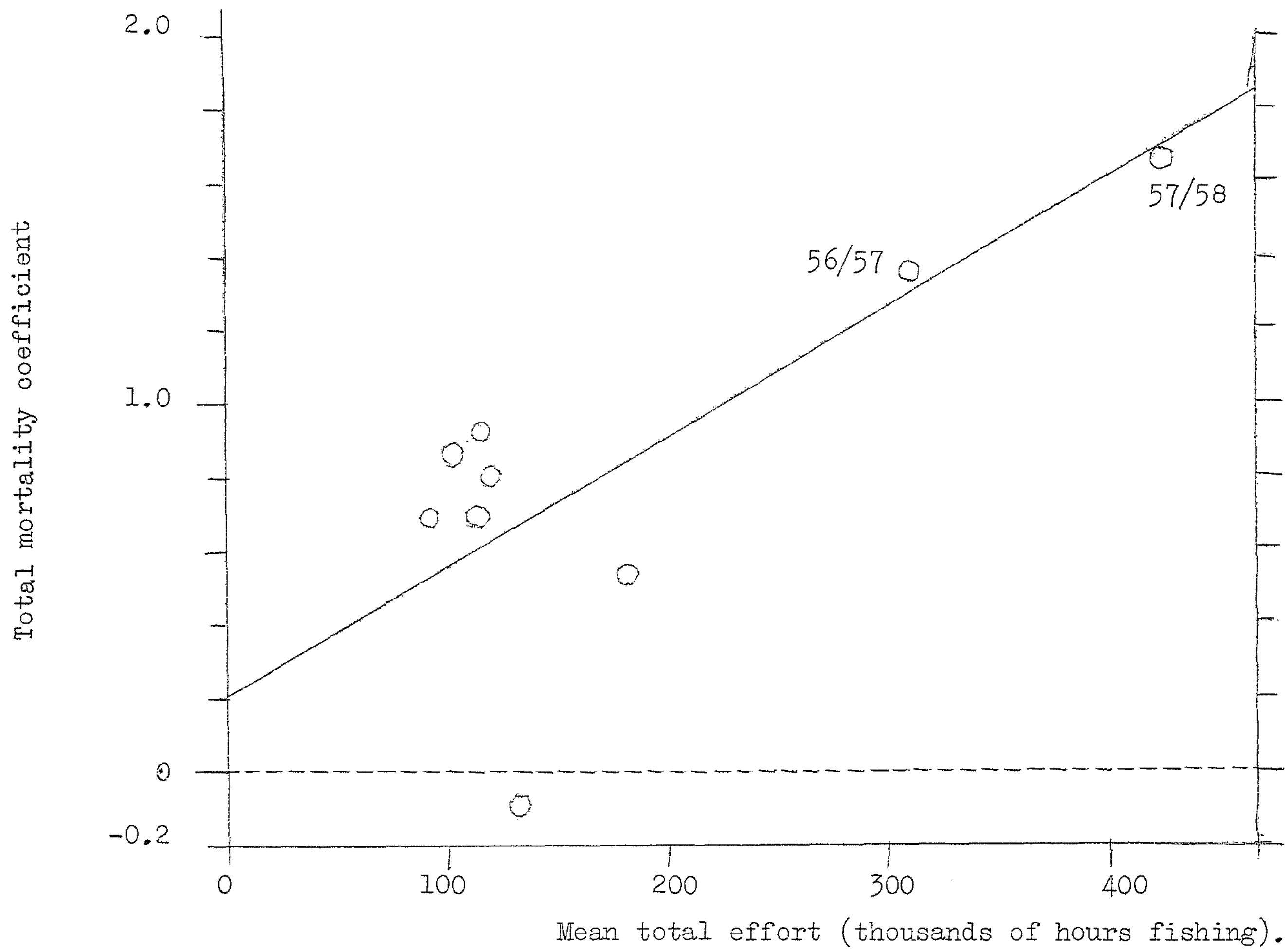


Figure C16b. Arctic cod. Region IIb. Relation between total mortality coefficient from age 7 to 9 and the total fishing effort in USSR units. (See Table XIIIb).

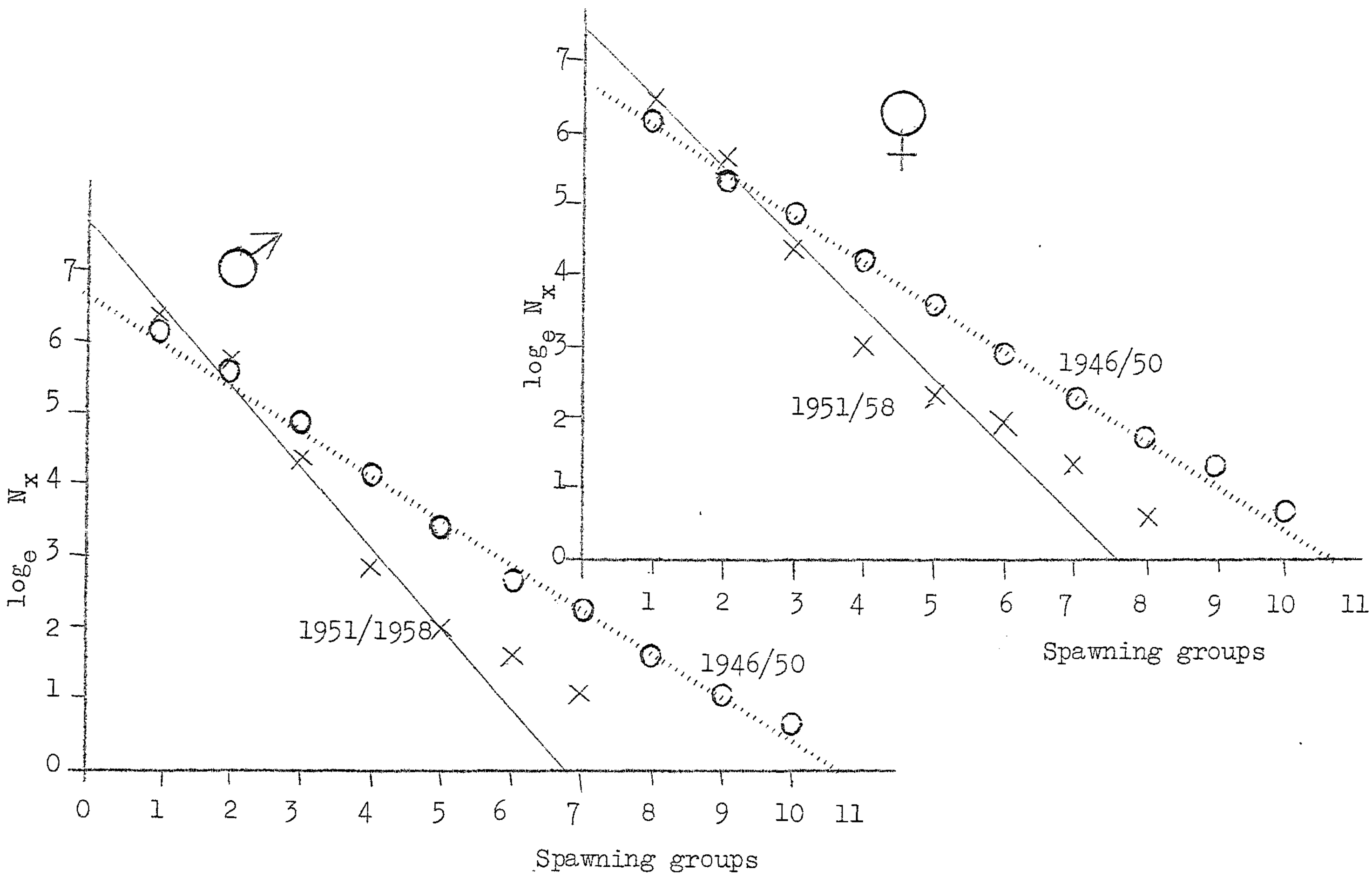


Figure 17a. Arctic cod. Region I[I]a. Spawning group composition of skrei 1946-1950 and 1951-1958, males and females. (See Table XVII).

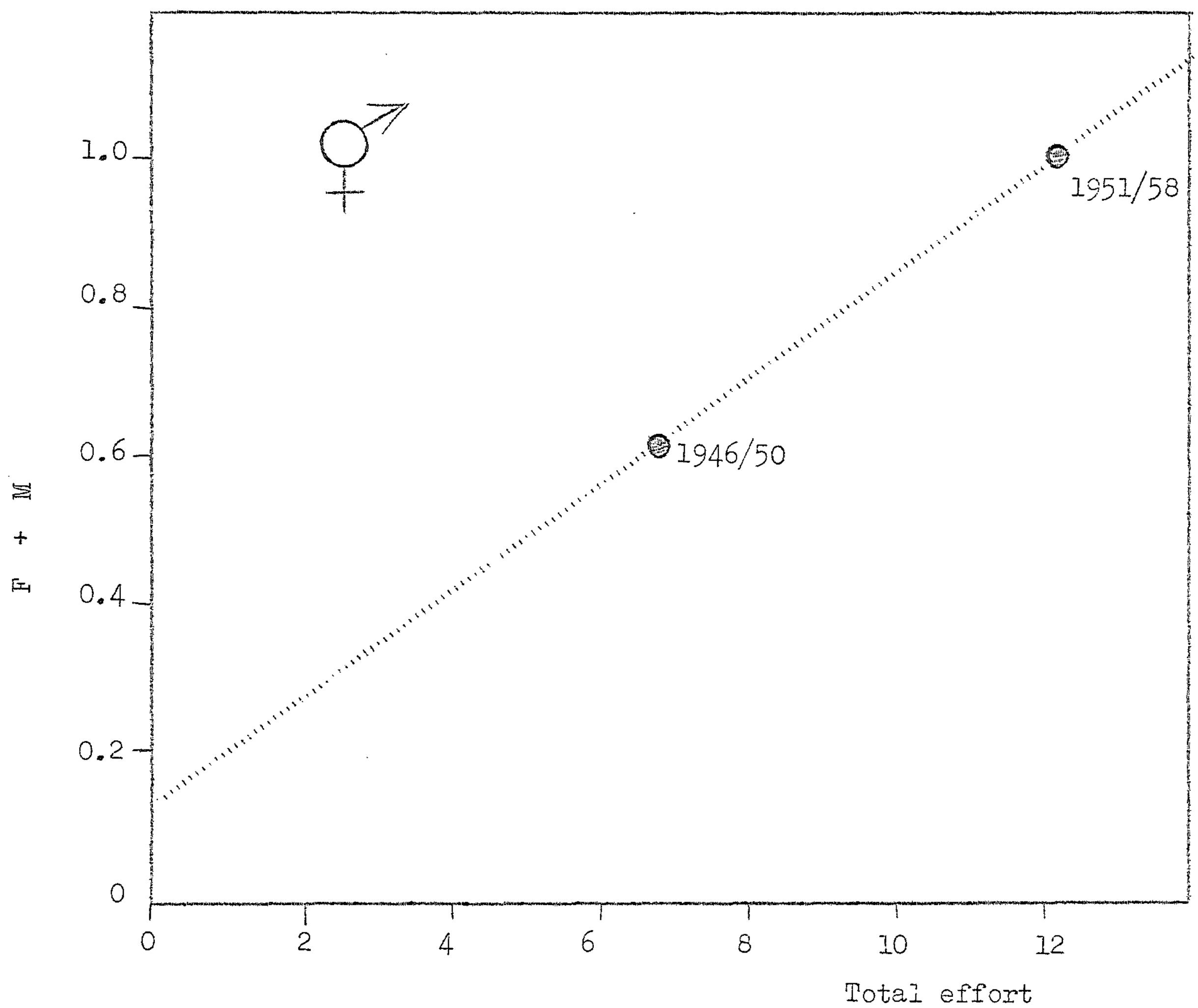


Figure C17b. Arctic cod. Relation between total mortality coefficient and total fishing effort on mature fish (8 years and older). (See Table XVII).

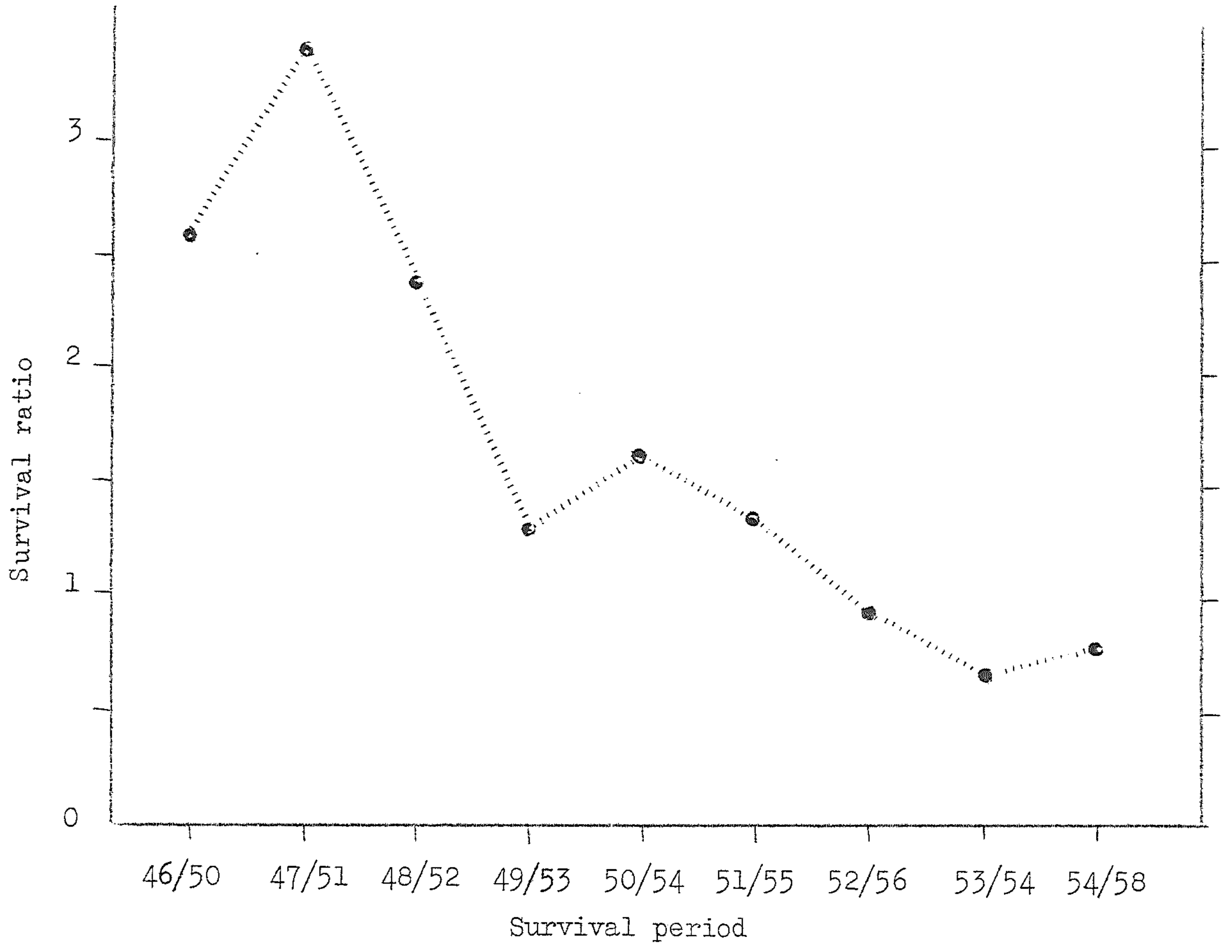


Figure C18a. Arctic cod. Ratios of the abundance of certain year-classes in Region I (USSR data) and four years later in Region IIa (Norwegian data) during the post-war period, to show decrease in survival ratio. (See Table CXVI)

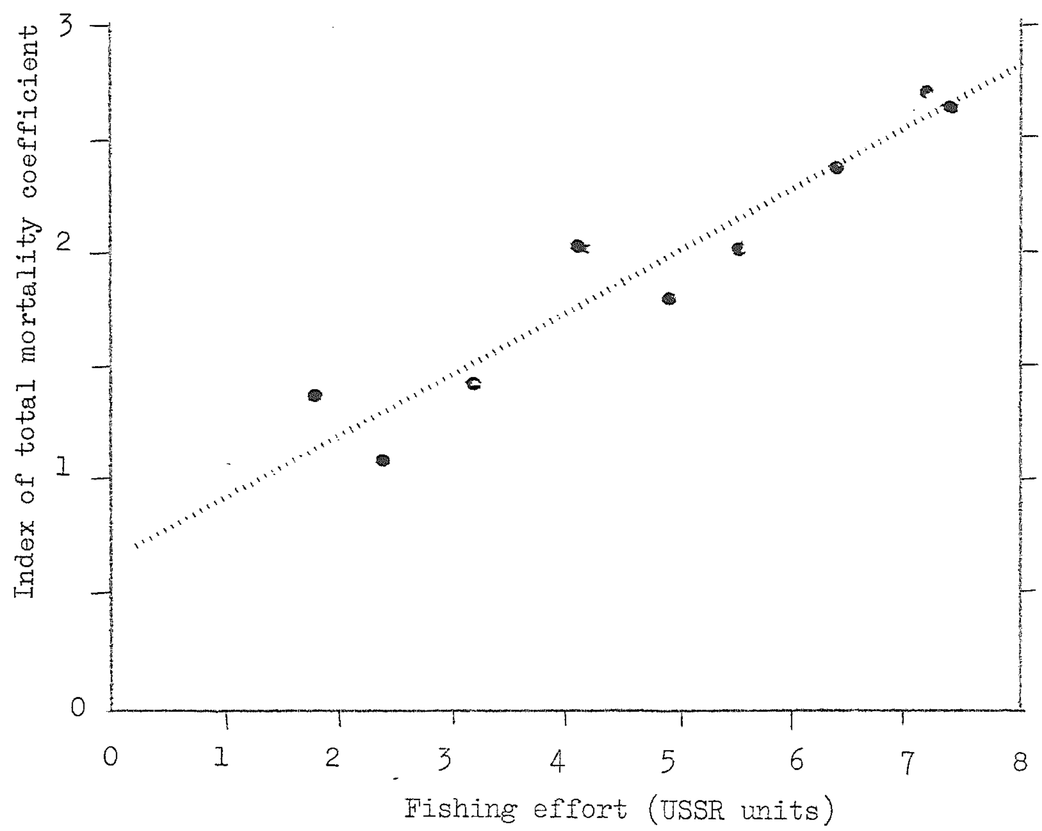


Figure C18b. Arctic cod. Survival ratios of Fig C18a expressed as indices of total mortality coefficient and plotted against total fishing effort in Region I (English units).

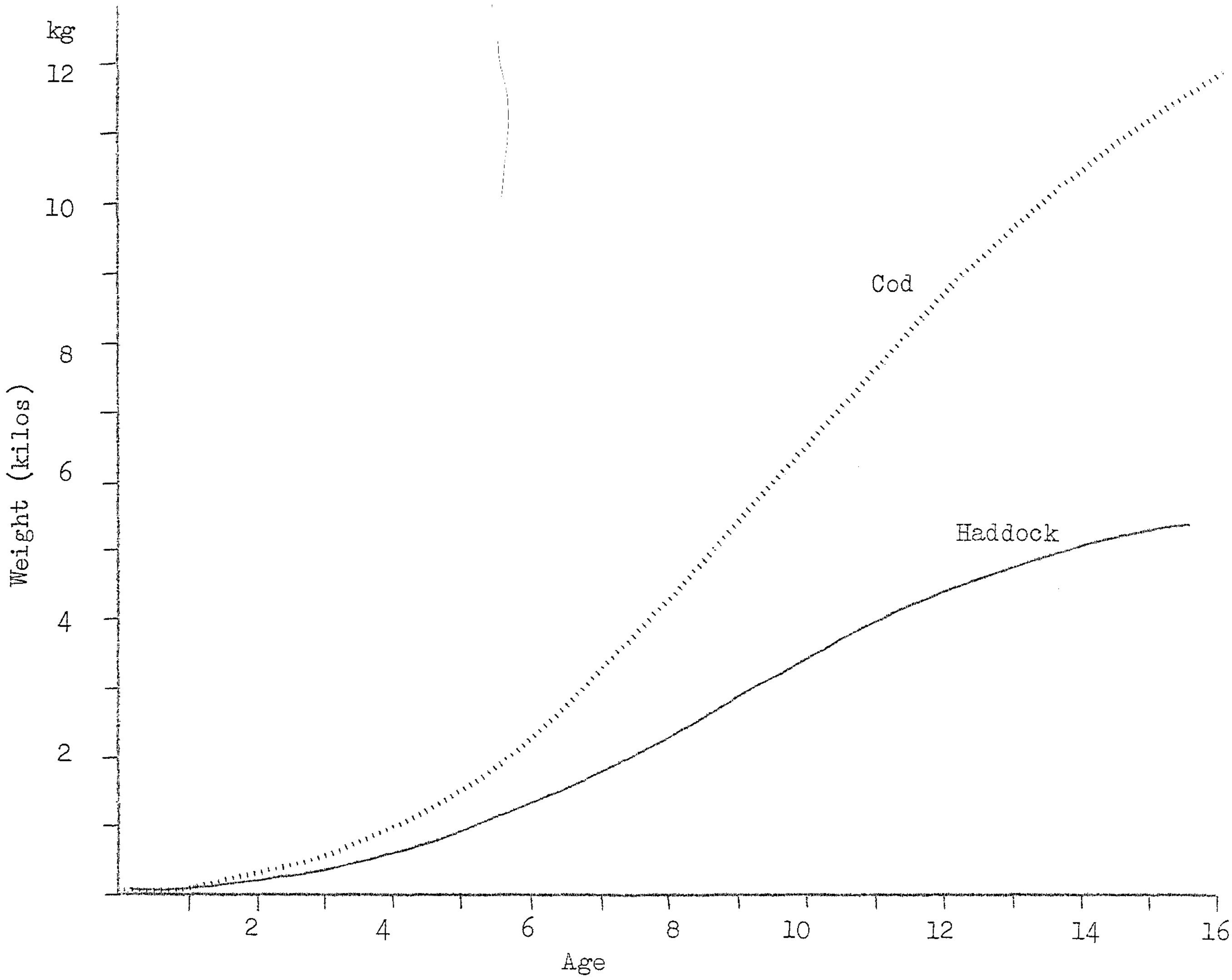


Figure C19. Arctic cod and haddock. Growth in weight of each species.

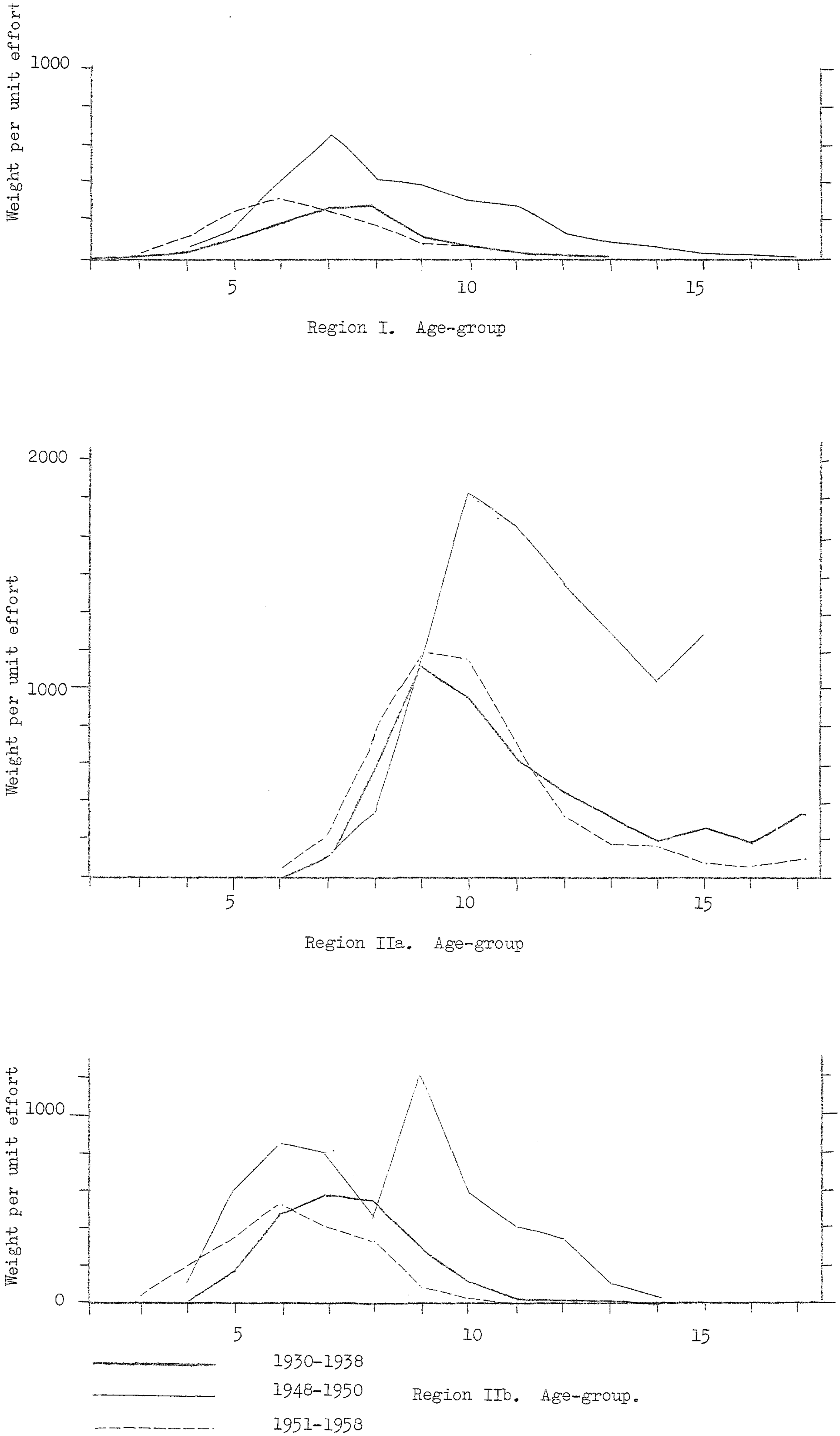


Figure C20. Arctic cod. Total weight of each age-group caught per unit effort for each region in different periods.

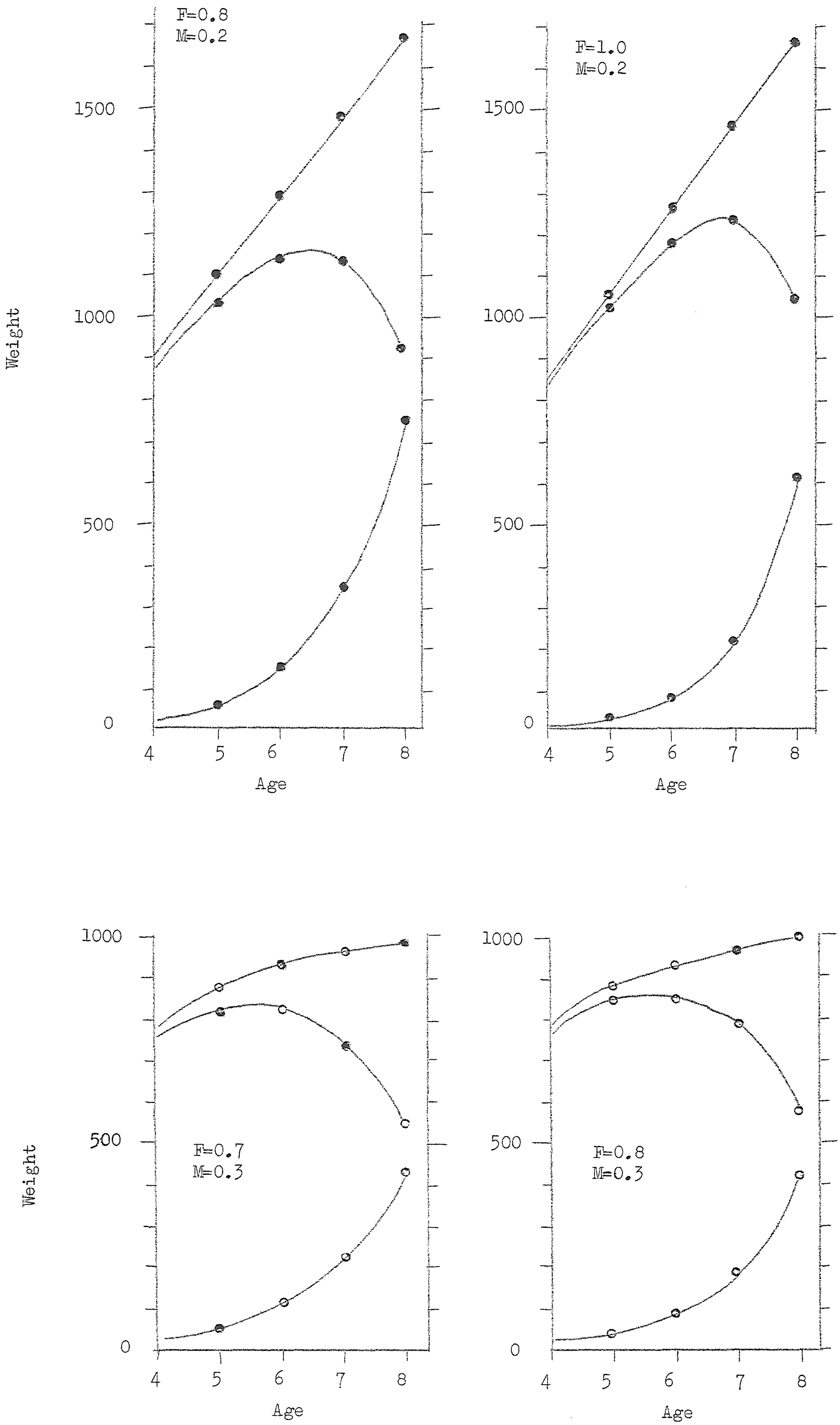


Figure C21. Arctic cod. Relation between total catch, "immature" catch and "mature" catch, with different age at first capture.

Table H.I. Arctic haddock: Total landings for each region 1930-1958 in metric tons round fresh weight

Year	Region I	Region IIa	Region IIb	Total
1930	91.042	2.834	8.479	102.355
1931	69.958	4.596	6.162	80.716
1932	40.912	4.910	8.432	54.254
1933	41.399	3.434	3.497	48.330
1934	44.658	10.062	4.596	59.316
1935	52.667	18.411	5.388	76.466
1936	73.046	21.462	3.924	98.432
1937	102.583	27.973	7.391	137.947
1938	167.741	30.384	14.202	212.327
1939	106.139	17.050	5.748	128.937
1940	88.835	1.981	15	90.831
1941	68.115	2.577	-	70.692
1942	21.030	2.191	-	23.221
1943	47.798	1.747	-	49.545
1944	55.734	1.145	-	56.879
1945	21.171	1.023	-	22.194
1946	59.166	26.799	8.245	94.210
1947	94.329	36.258	5.603	136.190
1948	79.423	37.785	7.373	124.581
1949	115.574	24.953	9.626	150.153
1950	90.517	30.010	11.206	131.733
1951	86.735	27.758	5.564	120.057
1952	103.662	20.334	3.664	127.660
1953	105.416	15.605	2.426	123.447
1954	125.681	22.096	8.671	156.448
1955	157.098	34.693	10.954	202.745
1956	163.720	40.935	8.624	213.279
1957	86.986	24.658	11.061	122.705
1958	78.065	28.613	5.121	111.799

Note 1: All weights converted to round fresh weight by means of conversion factors:

England 1930 - 38 and 1951-58	1.2
" 1946 - 1950	1.6
Germany	1.2
Norway	1.4

Table H II Arctic Haddock: Total landings by countries, 1930 - 1958 in metric tons round fresh weight.

Year	England	Germany	Norway	U.S.S.R.	Others
1930	29.731	41.527	30.937	-	160
1931	18.899	34.836	26.854	-	127
1932	18.881	20.830	14.387	-	156
1933	16.602	21.277	10.393	-	58
1934	16.425	15.497	13.277	14.080	37
1935	23.887	28.380	13.226	10.910	63
1936	36.450	20.432	19.190	22.300	60
1937	50.546	30.900	22.813	33.440	248
1938	46.982	46.824	20.412	97.300	809
1939	-	33.972	20.056	74.680	229
1940	-	2.764	11.606	76.400	61
1941	-	-	11.677	58.660	355
1942	-	-	11.841	11.380	-
1943	-	-	8.445	41.100	-
1944	-	-	2.349	54.530	-
1945	-	-	1.344	20.850	-
1946	72.733	58	8.199	13.210	10
1947	82.957	655	14.682	37.210	686
1948	62.777	12.900	30.652	17.800	452
1949	80.757	12.455	25.803	29.320	1.818
1950	70.684	13.993	21.805	24.764	487
1951	52.367	11.785	21.405	34.144	356
1952	46.351	7.536	26.940	46.589	244
1953	30.084	6.544	39.176	47.442	201
1954	32.208	9.993	41.004	73.147	96
1955	44.085	18.462	44.641	95.450	107
1956	43.072	26.258	51.255	92.551	143
1957	32.634	8.449	47.748	33.780	94
1958	27.317	7.622	50.377	26.383	100

Table H III Arctic haddock: Total landings from Region I, 1930 - 1958 in metric tons round fresh weight.

Year	England	Germany	Norway	U.S.S.R.	Others	Total
1930	21.846	40.765	28.431	-	-	91.042
1931	13.781	32.750	23.362	-	65	69.958
1932	12.430	17.828	10.562	-	92	40.912
1933	14.062	19.424	7.902	-	11	41.399
1934	12.834	8.322	9.395	14.070	37	44.658
1935	16.036	15.404	10.296	10.910	21	52.667
1936	25.956	8.767	15.981	22.300	42	73.046
1937	34.716	14.482	19.727	33.410	248	102.583
1938	30.281	22.666	17.632	96.500	662	167.741
1939	-	13.835	17.462	74.650	192	106.139
1940	-	2.616	9.768	76.390	61	88.835
1941	-	-	9.100	58.660	355	68.115
1942	-	-	9.650	11.380	-	21.030
1943	-	-	6.698	41.100	-	47.798
1944	-	-	1.204	54.530	-	55.734
1945	-	-	321	20.850	-	21.171
1946	39.752	-	6.194	13.210	10	59.166
1947	44.797	325	11.514	37.200	493	94.329
1948	34.954	349	26.113	17.680	327	79.423
1949	62.488	2.526	19.845	29.220	1495	115.574
1950	47.923	1.351	16.453	24.374	416	90.517
1951	33.259	2.105	17.048	34.124	199	86.735
1952	33.441	1.904	21.491	46.589	237	103.662
1953	21.761	1.217	35.261	47.052	125	105.416
1954	15.752	2.218	34.805	72.837	69	125.681
1955	19.356	3.402	38.829	95.450	61	157.098
1956	23.182	4.028	44.259	92.191	60	163.720
1957	14.986	1.134	37.883	32.940	43	86.986
1958	10.012	172	41.448	26.383	50	78.065

Note 1: All weights converted to round fresh weight by means of the same conversion factors (see Note 1 in table H.I.)

Note 2: Figures for "others" taken direct from Bulletin Statistique.

Note 3: From 1953 onwards the Faroe landings from the NE-area are split in half region I and half region IIb.

Note 4: Soviet data from 1949 onwards, as presented, included small quantities of haddock in with cod. Haddock landings for these years were estimated as 0.18 x cod, the average proportion in the years 1945 - 1948.

Note 5: "Others" in 1958 estimated.

Table H IV **Arctic haddock:** Total landings from Region IIa, 1930 - 1958 in metric tons round fresh weight.

Year	England	Germany	Norway	Others	Total
1930	168	-	2.506	160	2.834
1931	1,042	-	3.492	62	4.596
1932	1,021	-	3.825	64	4.910
1933	896	-	2.491	47	3.434
1934	1.736	4.444	3.882	-	10.062
1935	4.421	11.018	2.930	42	18.411
1936	7.388	10.865	3.209	-	21,462
1937	9.964	14.923	3.086	-	27,973
1938	7.408	20.149	2.780	47	30,384
1939	-	14.456	2.594	-	17,050
1940	-	143	1.838	-	1.981
1941	-	-	2.577	-	2.577
1942	-	-	2.191	-	2.191
1943	-	-	1.747	-	1.747
1944	-	-	1.145	-	1.145
1945	-	-	1.023	-	1.023
1946	24.794	-	2.005	-	26.799
1947	32.819	78	3.168	193	36.258
1948	20.618	12.503	4.539	125	37.785
1949	8.978	9.730	5.958	287	24.953
1950	11.958	12.629	5.352	71	30.010
1951	13.601	9.643	4.357	157	27.758
1952	9.270	5.615	5.449	-	20.334
1953	6.492	5.261	3.852	-	15.605
1954	8.231	7.740	6.125	-	22.096
1955	14.237	14.875	5.581	-	34.693
1956	13.401	21.439	6.070	25	40.935
1957	8.670	6.719	9.269	-	24.658
1958	13.003	7.301	8.309	-	28.613

Note 1: All weights converted to round fresh weight by means of the same conversion factors (see note 1 in table H.I.)

Note 2: Figures for "Others" taken direct from Bulletin Stastique.

Note 3: From 1953 onwards the Faroe landings from the NE area are split in half region I and half region IIb.

Note 4: From 1953 onwards the German landings from Svinøy are not included.

Table H V, Arctic Haddock: Total landings from Region IIb, 1930 - 1958 in metric tons round fresh weight

Year	England	Germany	Norway	U.S.S.R.	Others	Total
1930	7.717	762	-	-	-	8.479
1931	4.076	2.086	-	-	-	6.162
1932	5.430	3.002	-	-	-	8.432
1933	1.644	1.853	-	-	-	3.497
1934	1.855	2.731	-	10	-	4.596
1935	3.430	1.958	-	-	-	5.388
1936	3.106	800	-	-	18	3.924
1937	5.866	1.495	-	30	-	7.391
1938	9.293	4.009	-	800	100	14.202
1939	-	5.681	-	30	37	5.748
1940	-	5	-	10	-	15
1941	-	-	-	-	-	-
1942	-	-	-	-	-	-
1943	-	-	-	-	-	-
1944	-	-	-	-	-	-
1945	-	-	-	-	-	-
1946	8.187	58	-	-	-	8.245
1947	5.341	252	-	10	-	5.603
1948	7.205	48	-	120	-	7.373
1949	9.291	199	-	100	36	9.626
1950	10.803	13	-	390	-	11.206
1951	5.507	37	-	20	-	5.564
1952	3.640	17	-	-	7	3.664
1953	1.831	66	63	390	76	2.426
1954	8.225	35	74	310	27	8.671
1955	10.492	185	231	-	46	10.954
1956	6.489	791	926	360	58	8.624
1957	8.978	596	596	840	51	11.061
1958	4.302	149	620	-	50	5.121

Note 1: All weight converted to round fresh weight by means of the same conversion factors (see Note 1 in table H.I.).

Note 2: Figures for "Others" taken direct from Bulletin Statistique.

Note 3: For years prior to 1953 the Norwegian landings of haddock in region IIb are partly included in the catch from region I and partly region IIa.

Note 4: From 1953 onwards the Faroe landings from the NE-area are split in half region I and half region IIb.

Note 5: "Others" in 1958 estimated.

Table H.6. Arctic haddock. Catch per unit effort, expressed as kilos per 100 ton-hours fishing.

Year	Region I	Region II a	Region II b
1930	134	-	43.0
1931	86	-	25.0
1932	56	-	28.0
1933	49	-	11.5
1934	41	-	8.6
1935	66	0.95	17.3
1936	71	1.5	13.0
1937	59	1.0	16.5
1938	71	1.5	18.2
1946	97	7.9	41.0
1947	61	2.8	17.1
1948	52	1.4	23.4
1949	67	0.87	34.2
1950	41	1.1	28.6
1951	33	0.84	10.2
1952	32	0.32	11.8
1953	41	0.32	6.7
1954	30	0.46	25.8
1955	31	0.77	24.4
1956	42	0.66	9.5
1957	33	0.30	13.7
1958	19	0.48	6.5

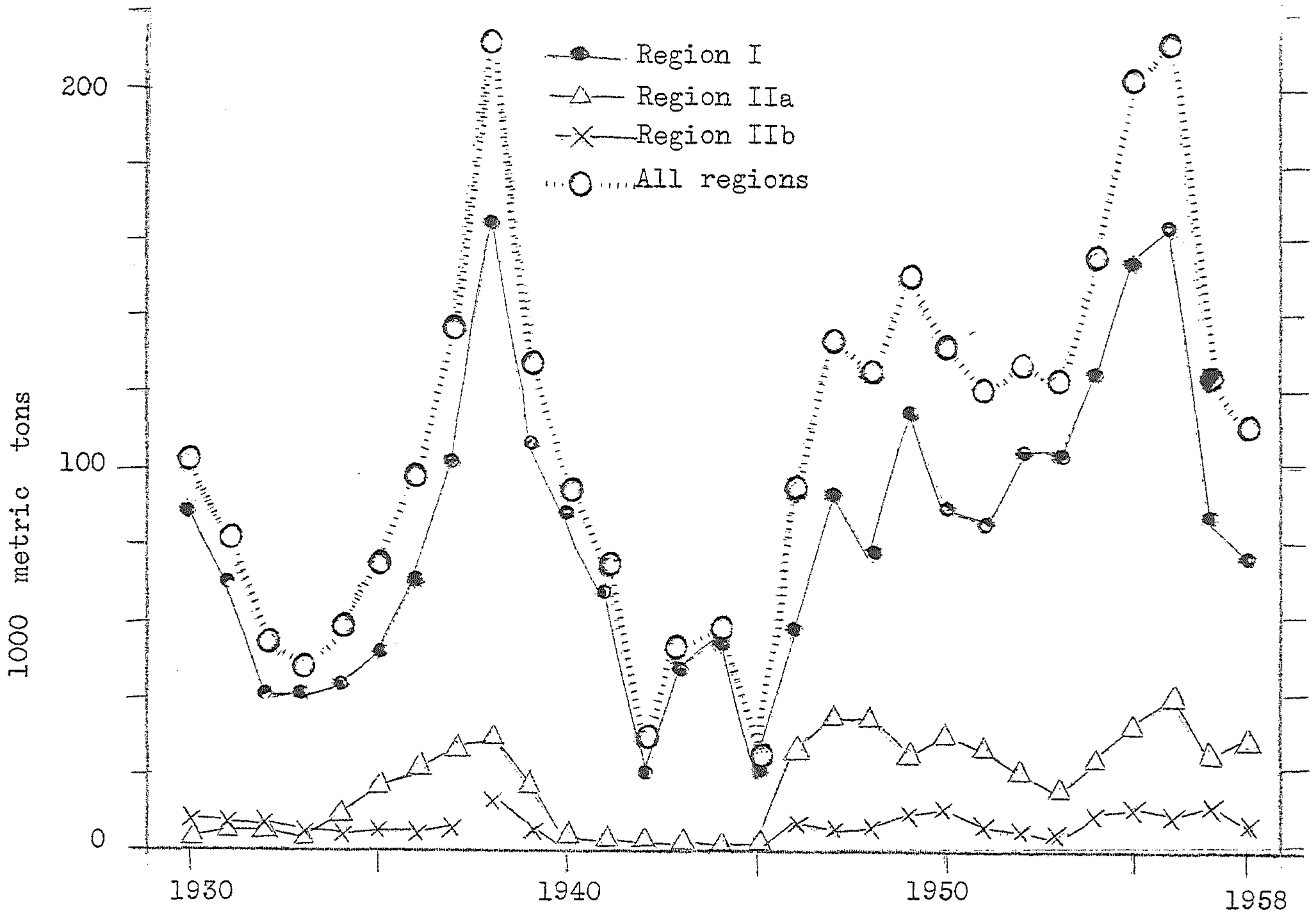


Figure H1. Arctic haddock. Total landings by regions, 1930-1958

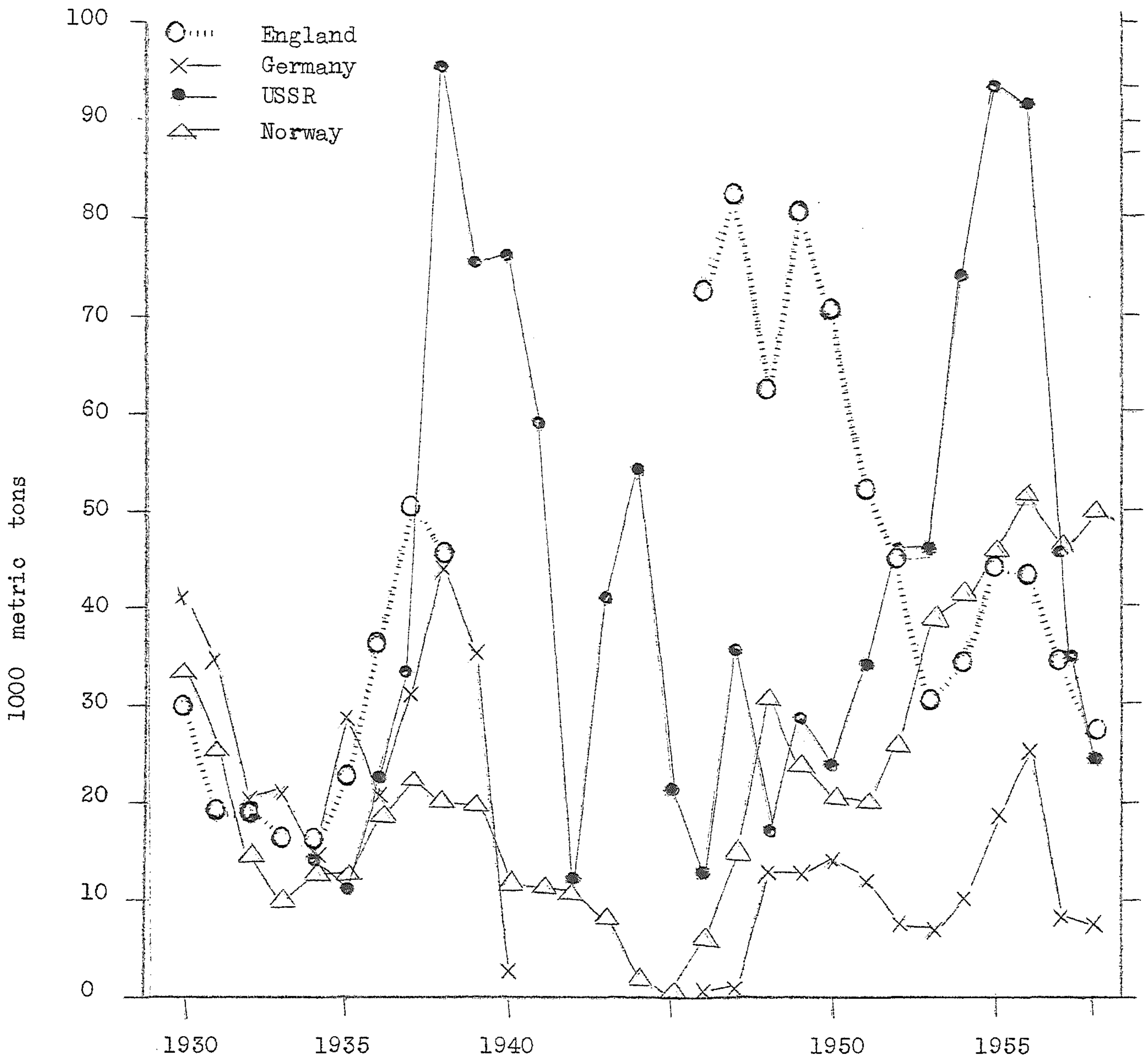


Figure H2. Arctic haddock. Total landings by countries, 1930-1958.

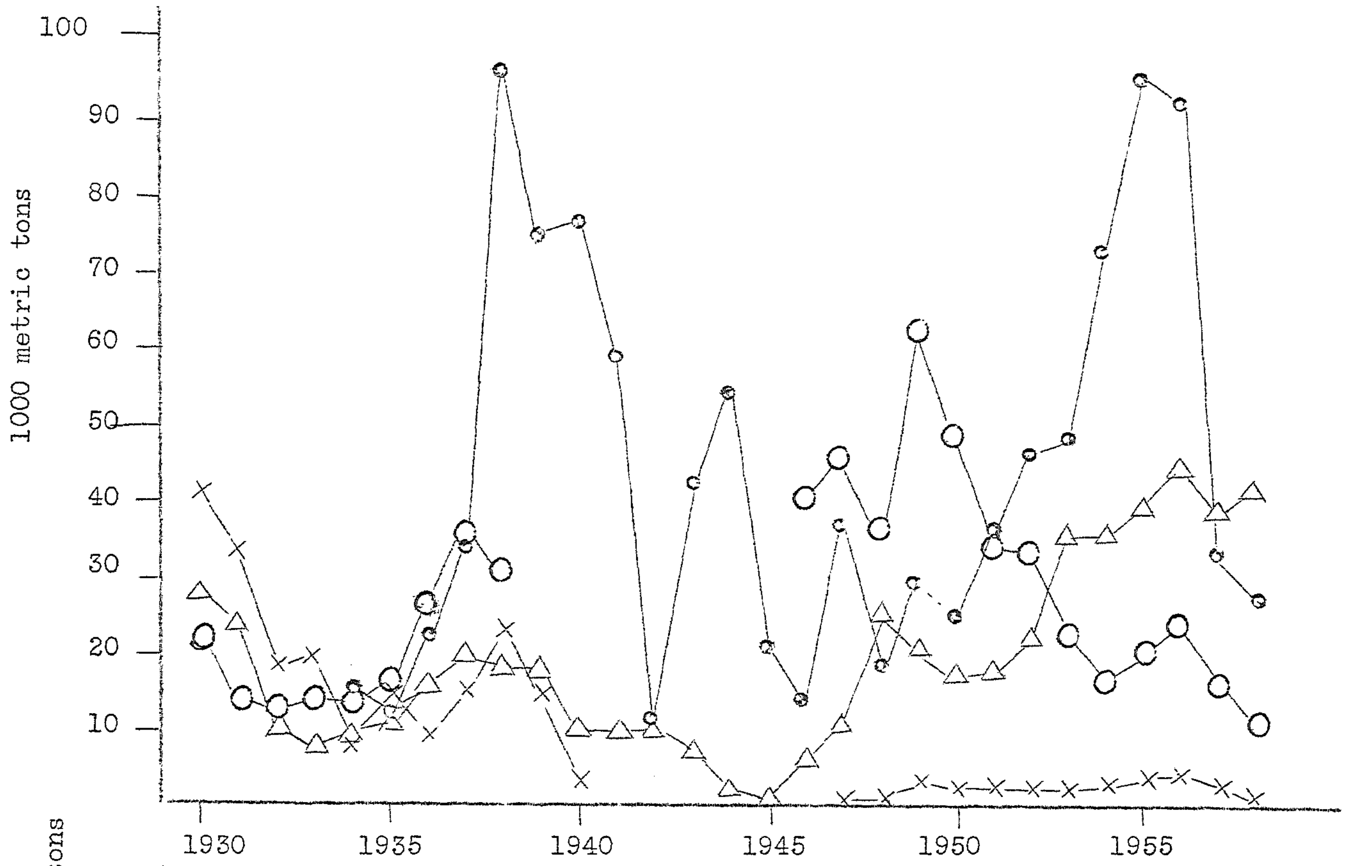


Figure H3. Arctic haddock. Total landings by countries in Region I.

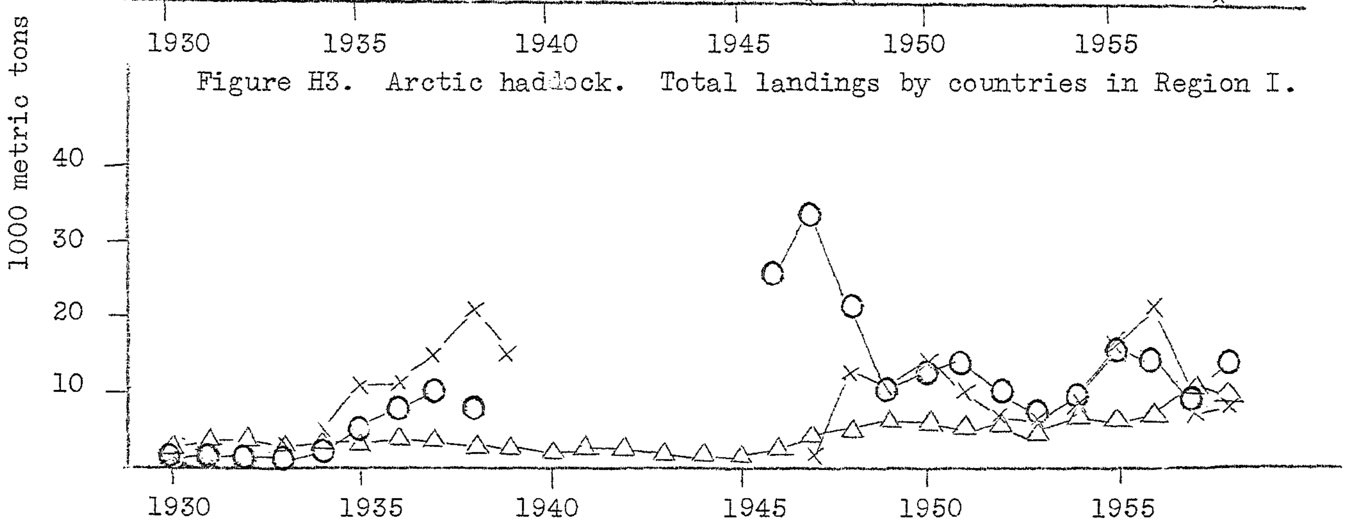
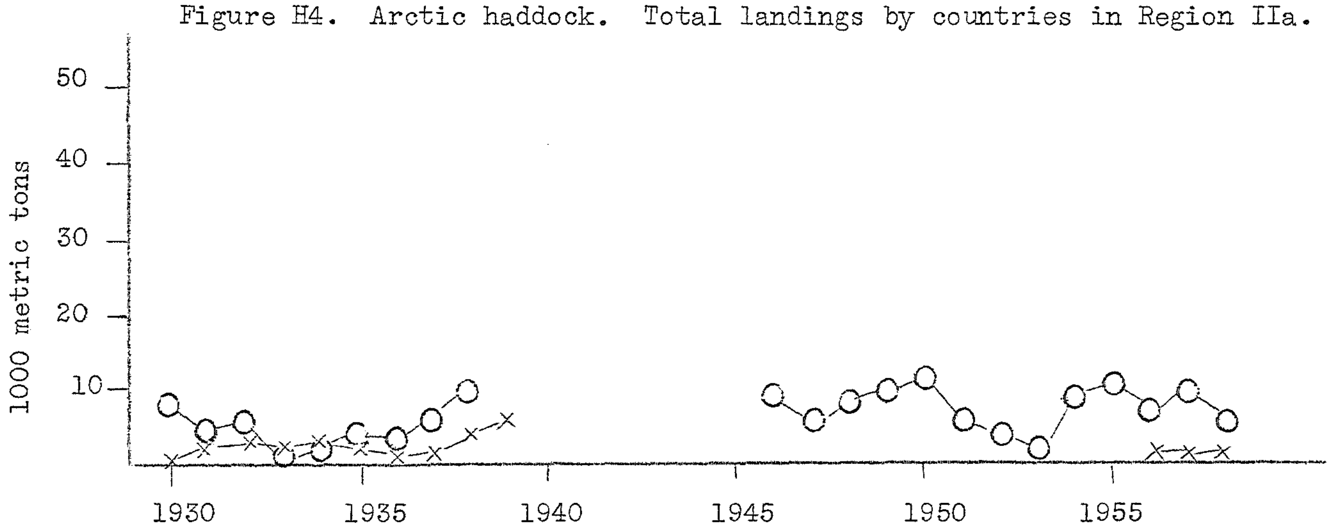
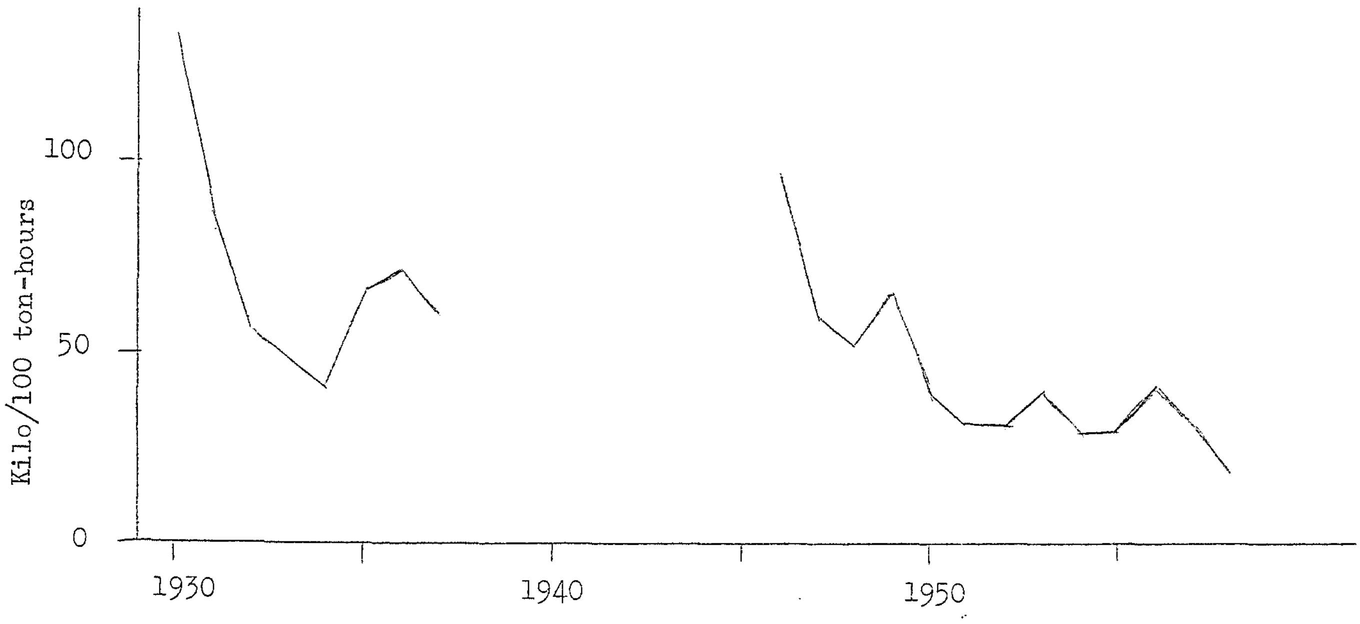


Figure H4. Arctic haddock. Total landings by countries in Region IIa.



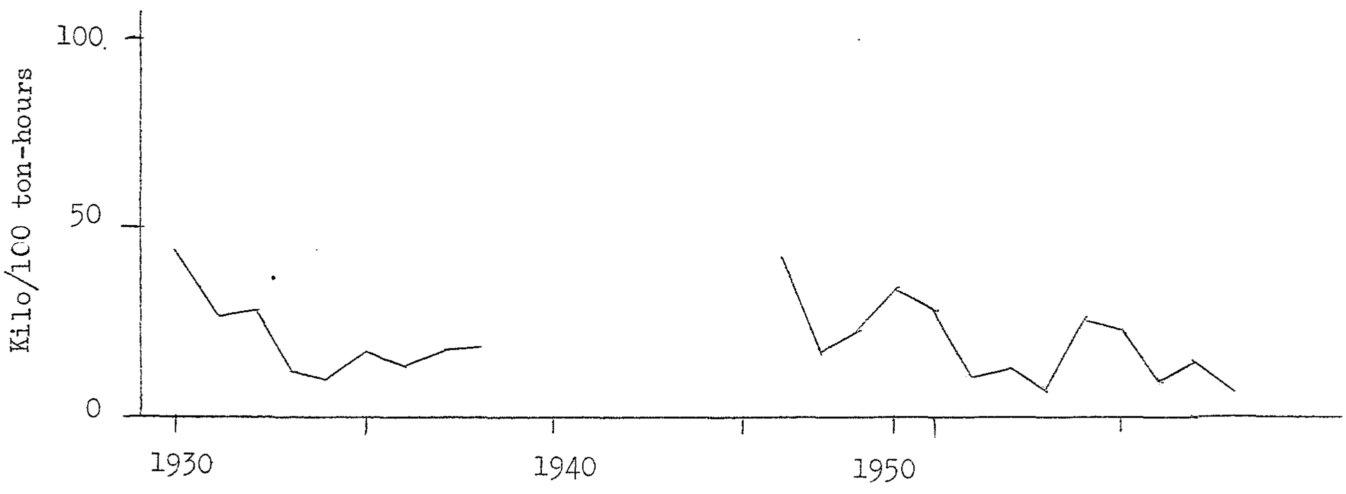
O— England
×— Germany
△— Norway
o— USSR

Figure H5. Arctic haddock. Total landings by countries in Region IIb.



Region I

Region IIa.



Region IIb.

Figure H6. Arctic Haddock. Catch per unit effort, in English units.

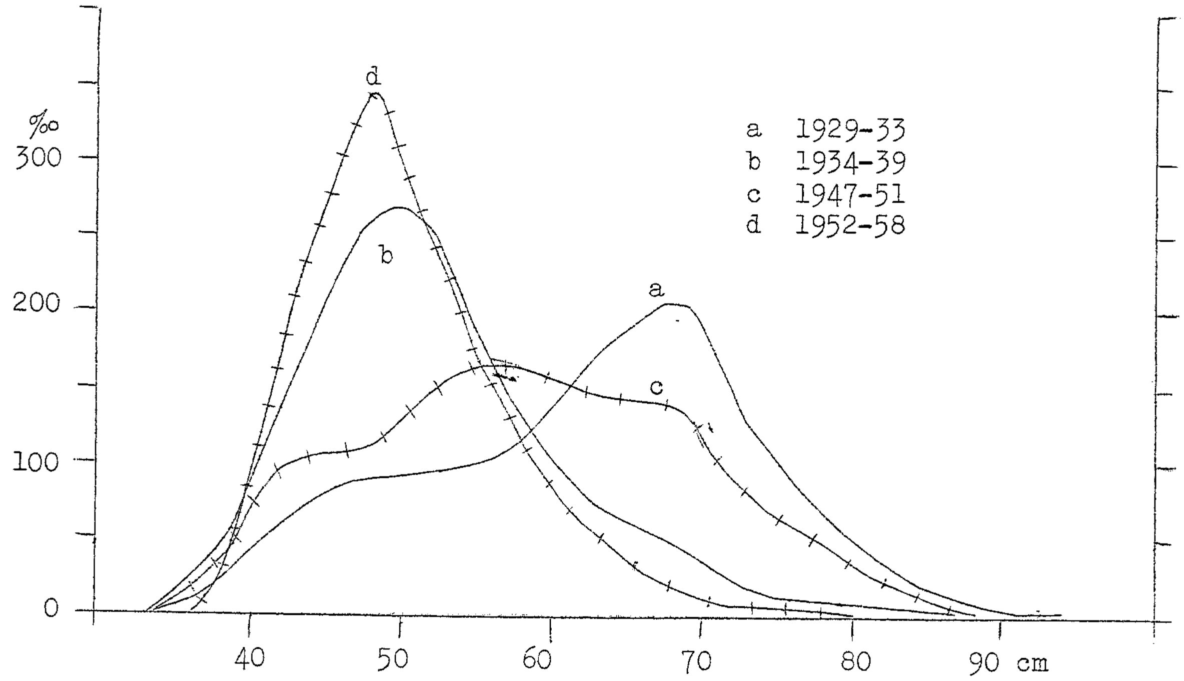


Figure H7a. Arctic Haddock. Region I. Length composition German (1929-55) and English (1956-58)

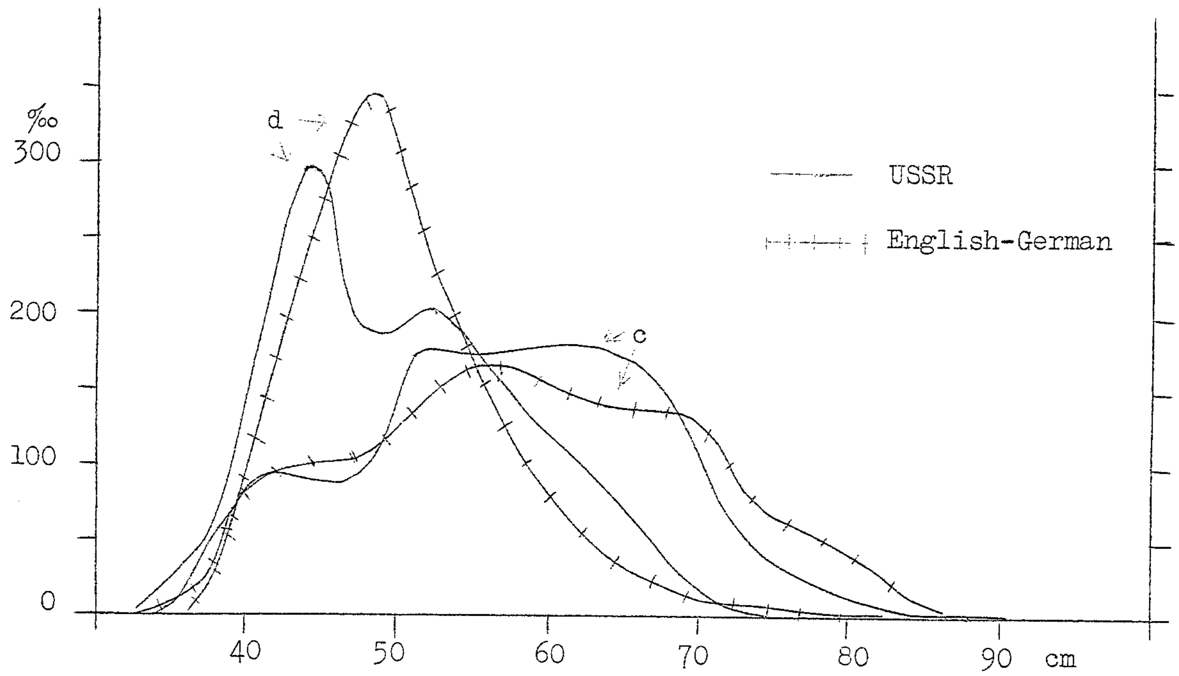


Figure H7b. Arctic Haddock. Region I. Length composition USSR data adjusted to correspond with English and German landings for periods 1947-51 and 1952-58.

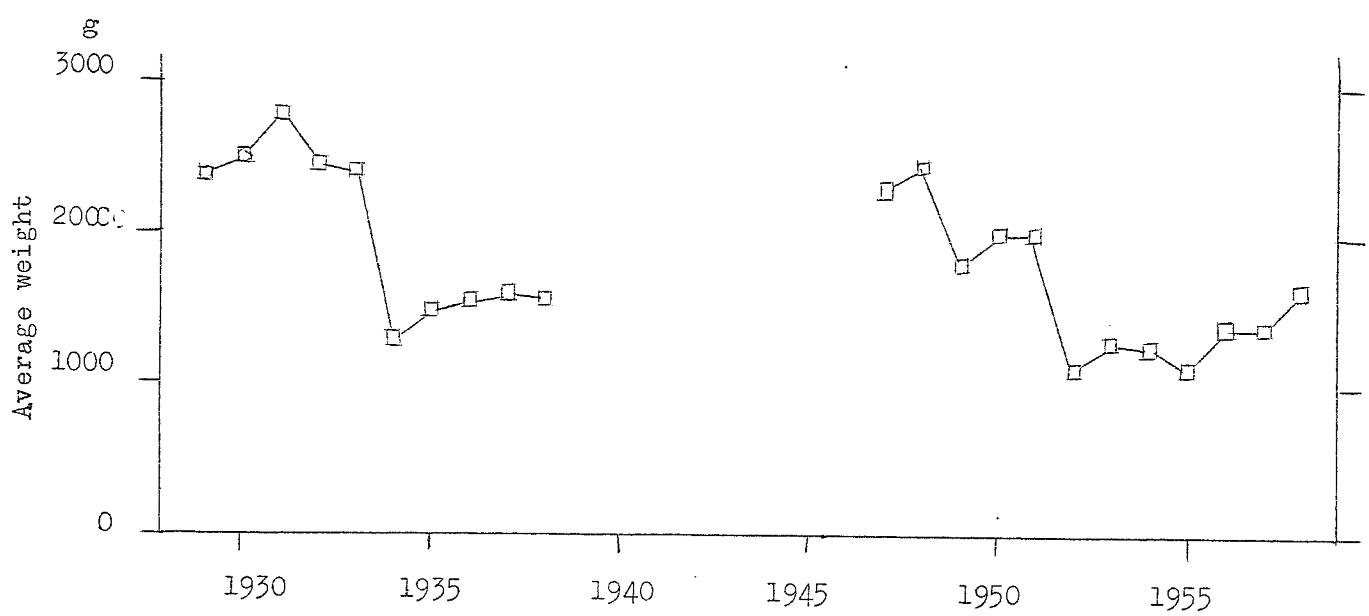


Figure H8. Arctic Haddock. Region I. Average weight of fish landed.