International Council for the Exploration of the Sea.

CM 1955
Near Northern Seas Committee
No. 60.

A Note on Mortality and Mesh Regulation of North Sea Sole

by

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1) Introduction

For the I.C.E.S. Special Meeting of 1947 on the effect of the war on the stocks of North Sea fish, Margetts and Holt (1948) gave English catch per unit effort data for sole for each month of 1946 and compared them with the corresponding figures for 1938. They concluded that "... the very considerable increase in density by weight of this fish, in the area from which the vast majority were taken in 1946, was directly attributable to the protection from fishing afforded by the closure of these grounds."

The post-war trends in abundance of sole have since been examined in more detail, using data not available earlier and supplementing with market measurements of length distribution since 1946. Age sampling has been carried out since 1950 by my colleague Mr. Margetts, but as this material has not yet been fully worked up, this preliminary note deals only with the period from the resumption of fishing in 1945 until the end of 1949.

2) Total mortality from the post-war decline in abundance

The catch of sole per 100 hours fishing by English steam trawlers was used as the basic index of abundance, but it was desirable to reduce as far as possible the effect of seasonal fluctuations, and to allow for the fact that the area fished immediately after the war increased month by month and was not identical to the pre-war fishing area. Seasonal fluctuations were minimised by taking the ratio of the post-war figure for each month to the average for the same month in years 1931-38. Area differences were allowed for by summing the catch per 100 hours over the statistical rectangles that happened to be fished in each post-war month and calculating the pre-war figure for those same rectangles.

Figure 1. shows abundance ratios calculated in this way for each month from 1945 to 1949 and expressed as natural logarithms. In the first half of 1945 (shown shaded in Figure 1) fishing was virtually "inshore" in character and of no comparative value. By September, the rectangles fished covered the main area of the English sole fishery (see Wimpenny, 1949) apart from the most easterly grounds; indeed the same rectangles supplied, in September 1938, over 90% of the English sole catch. In this month the density was some eight times the average pre-war level; it thereafter steadily declined until by 1948 the pre-war average (shown by the continuous horizontal line) was effectively reached. The oscillations apparent in the data show that the catch per 100 hours fluctuated more widely than before the war. This is probably the result of a tendency for relatively fewer vessels to fish specially for sole after the war except at the peak of the sole fishing season, owing to the great contemporary abundance of plaice.

The decline in abundance has been represented approximately in Figure 1 by the broken line. This has a slope of 0.75 and because the population is receiving recruits each year and survivors are increasing in weight this has to be regarded as a minimum estimate of the total mortality coefficient. A better estimate could, of course, be made if age-determinations were available for the period, but failing these use has been made of growth data for sole published by Bückmann (1935), viz.:

Age group	Length (cm.)
IV	31.0
V	33.5
VI	35.0
VII	36.0

The procedure adopted was first to calculate, from a knowledge of the length composition, an index of the total abundance (as before, but in numbers instead of weight) of all fish of length 31 cm. and above in 1946; fish of this size range being fully recruited and beyond the influence of gear selectivity. From Bückmann's data a fish of 31 cm. would grow to 33.5 cm. a year later; hence the fish of length 33.5 and upwards in 1947 can be regarded as the survivors of those of 31 cm. and above in 1946. Similarly, the same group can be identified as comprising fish of 35 cm. and above in 1948 and 36 cm. upwards in 1949. Indices of the numerical abundance of these sections of the population in the years in question, together with the values for the whole fished population, are as follows:-

Year		
1946	(a) Total abundance index = 658	(b) Index for fish of 31 cm. and above = 524
1947	(a) Total = 475	(b) 33.5 cm. and above = 223
1948	(a) Total = 163	(b) 35 cm. and above = 63
1949	(a) Total = 196	(b) 36 cm. and above = 25

Natural logarithms of the (b) numbers are plotted in Figure 2, and are fitted closely by a straight line having a slope of 1.04. No great accuracy can be attached to this figure, if only because the growth rate after the war may have differed from that found earlier by Bückmann. Nevertheless, it is, as expected, rather greater than that of Figure 1, and it seems reasonable to conclude that the total mortality coefficient at that time was between 0.7 and 1.0, corresponding to a rate of between 50% and 63% per year.

3) Separation of fishing and natural mortality.

The above mortality estimates refer, of course, to deaths from all causes, and there is no way of assessing the magnitude of those due to fishing merely from the rate of decline of stock. It can be done, however, by using, in addition, the observation that the stock level when fishing resumed in 1945 was in the order of $8\frac{1}{2}$ times the average pre-war value. In a paper submitted to the 1954 I.C.E.S. Special Meeting on Sampling I described briefly how the relative increase in stock abundance resulting from cessation of fishing for a known period could be used to estimate the order of magnitude of fishing and natural mortality. Adopting the same method in the present instance and using again Bückmann's growth data, it is found that the observed increase in abundance of sole after six years without fishing could result from any combination of fishing (F) and natural mortality (M) coefficients defined by the full line of Figure 3. If it is assumed, for example, that the total mortality coefficient of 1.0 found from the data of Figure 2 applied also in the period 1931-38, then it can be shown on Figure 3 by a line whose co-ordinates at any point add up to 1.0. This is the broken line of that diagram, and it intersects the full line at F = 0.9, M = 0.1.

It must be emphasized that no great accuracy can be assigned to these figures. The use of the war-time increase in the way described depends on the assumption that the average level of recruitment during the war was not greatly different from that during the pre-war eight years; while both the growth data and the estimates of total mortality were obtained at times other than those to which they have been applied. Nevertheless, the changes in stock abundance during and after the war form a consistent picture which would seem to permit only one kind of interpretation, namely,

(a) That the total mortality coefficient of North Sea sole is high, and probably above 0.7 (= 50% per year)

(b) That the majority of this, probably more than three-quarters, is due to fishing.

4) Mesh regulation and the sole fishery

Some idea of the long-term effect of mesh regulation on the North Sea sole fishery can be obtained from these rough estimates of fishing and natural mortality, using the yield equation developed by S.J. Holt and myself (see Beverton, 1953), and estimates of other parameters given in the Appendix to this paper.

Figure 4 shows two curves of yield per recruit against mesh size. The upper is calculated with a total mortality coefficient of 1.0 made up of $F = 0.9$, $M = 0.1$, and the lower with a total of 0.8 consisting of $F = 0.6$, $M = 0.2$. While these cannot be claimed to be limiting values, the data presented above suggest that the true values of F and M are likely to be within them. The curves are expressed as yield per recruit to enable the effect of mesh regulation to be assessed independently of the large fluctuations in year-class strength which characterise the North Sea sole population. For example, the upper curve predicts a maximum yield per recruit with a mesh of about 100 mm.; if the mesh in use prior to regulation is taken as 65 mm., this represents an increase of more than 50% in the yield per recruit. Therefore, if the level of recruitment after regulation remains unchanged, the average yield could be expected to increase by this percentage. If recruitment happens to increase, the actual yield would increase by a correspondingly greater amount; while if there should happen to be a long series of poor year-classes the yield may even fall below its original level. But whether few or many recruits enter the fishery in the future, the upper curve of Figure 4 predicts that to obtain the greatest yield from them would require a mesh of about 100 mm.

In the lower curve of Figure 4 the effect of increasing the size of mesh is much less, owing primarily to the natural mortality coefficient being twice as large as before. Nevertheless, the maximum of the curve is at a mesh of about 85 mm., and represents an improvement in yield per recruit of some 25% above that for a 65 mm. mesh.

The important conclusion to be drawn from Figure 4 is not, however, a question of exactly how much more yield is to be expected from the use of any particular size of mesh; this clearly cannot be stated from the limited data examined here. What matters at the moment is whether or not a 75 mm. or 80 mm. mesh would be harmful, in the long run. The conclusion from Figure 4 is that the use of a 75 mm. or 80 mm. cod-end mesh is most unlikely to cause any reduction in the average level of yield to any fishery based on the main adult stock of North Sea sole; on the contrary, the available evidence suggests that a definite increase would result.

Appendix

Values of parameters used in calculating the curves of Figure 4 (other than those of fishing and natural mortality) are as follows:-

1) Parameters of the von Bertalanffy growth equation:

$W_\infty = 482$ gm.
$K = 0.42$
$t_o = 0.3$ yrs.
) fitted to Bückmann's data

2) Mean length at recruitment = 20 cms.

This is the average size at which fish become fully exposed to fishing. It is not known accurately, but the above figure is not thought to be far wrong. If the true value should be higher than 20 cm., the effect would be to reduce the amount by which the yield is predicted to increase for a given increase in mesh. The mesh sizes giving the greatest yields (i.e. the maxima of the curves of Figure 4) would, however, remain unchanged, so that the main conclusion of this paper - that meshes up to 80 mm. would not be detrimental - is unaffected.

3) Selection factor = 3.4

This is the constant of proportionality in the equation

50% length = 3.4 x cod-end mesh size

and is based on recent data from several sources

4) Range of selection ogive

The span of length between the 25% and 75% points, which is a convenient measure of the spread of the selection ogive, is taken as 3 cm., this figure again coming from recent experiments. A knowledge of the spread of the selection ogive is needed when computing the proportion of undersized fish in the catch resulting from the use of any particular mesh size.

References

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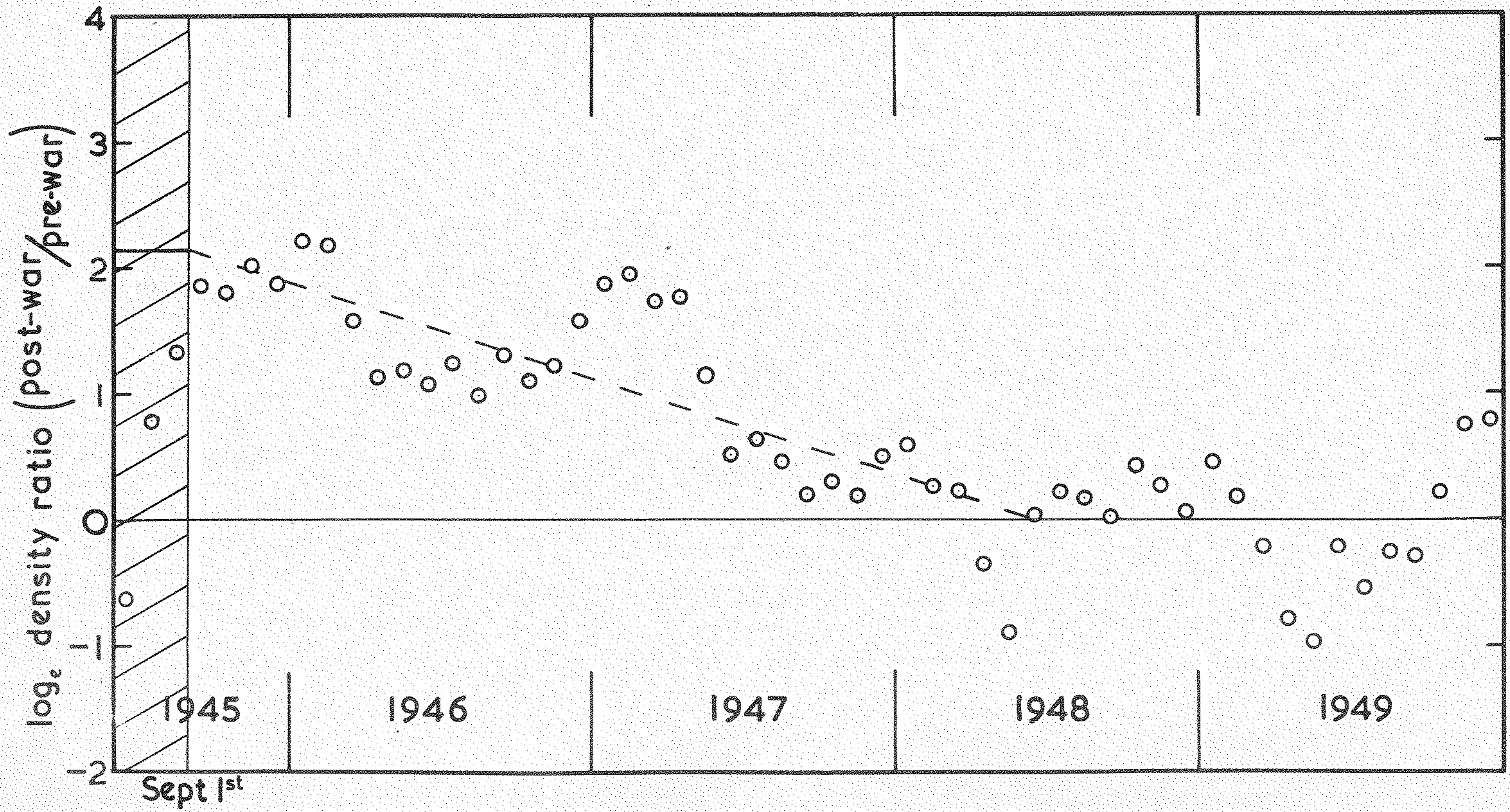
Fig. 1 Decline in density of N. Sea sole after resumption of fishing in 1945.



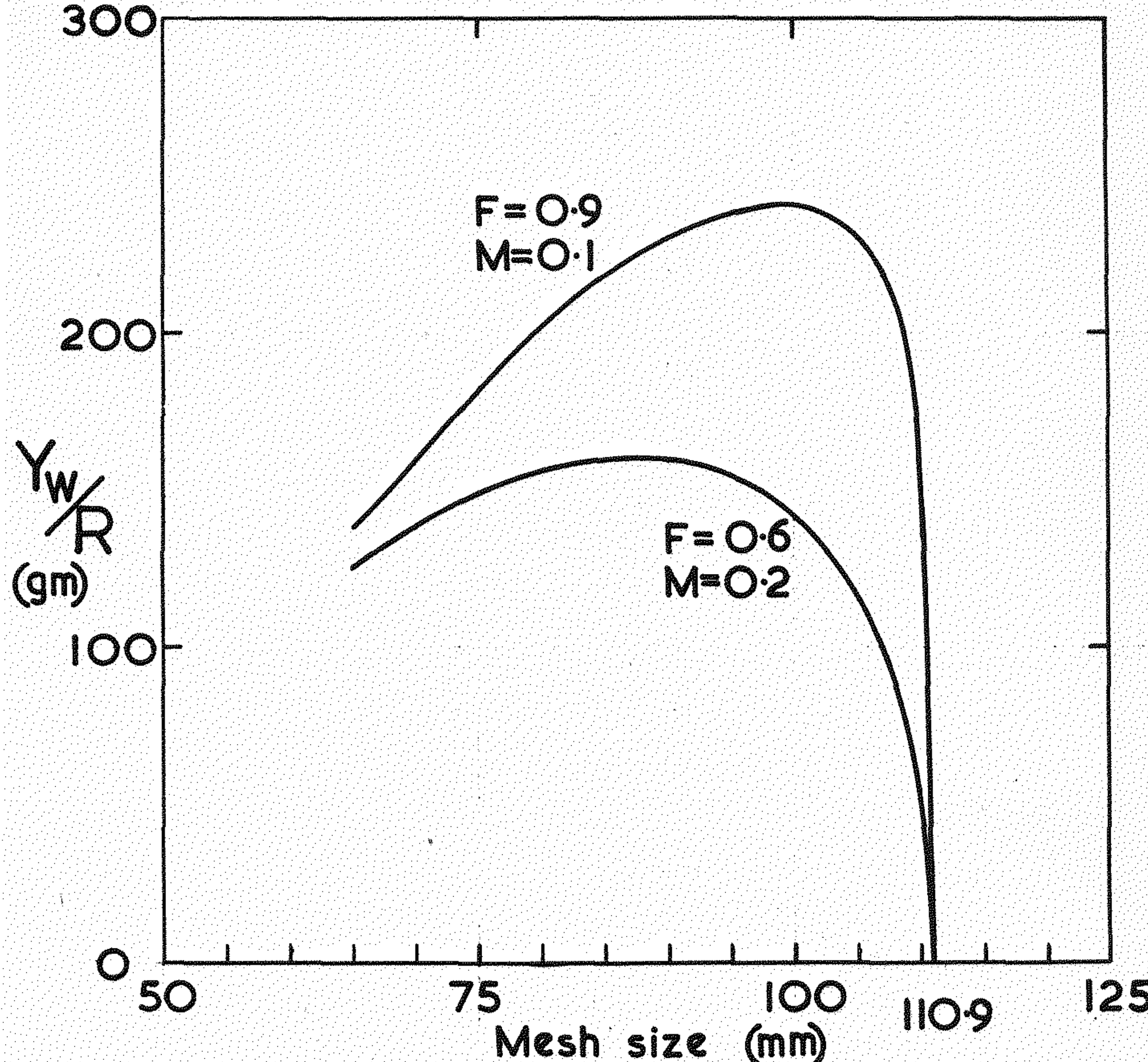


Fig. 4 Relation between steady yield of sole and mesh size.

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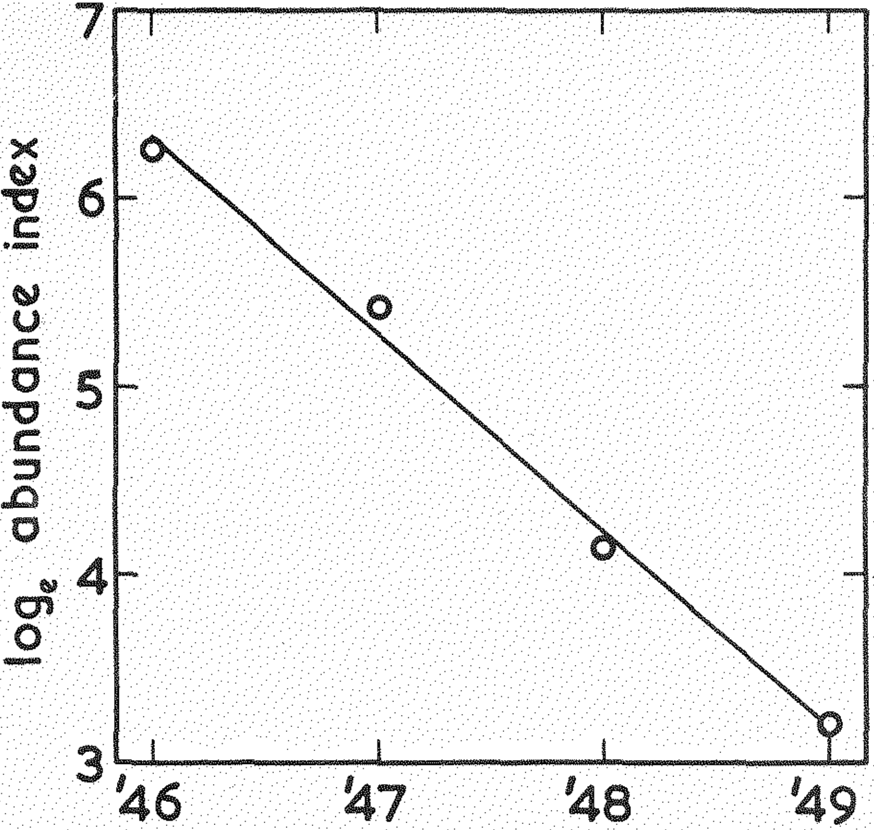

Fig. 2 Estimation of the total mortality coefficient of N. Sea sole.

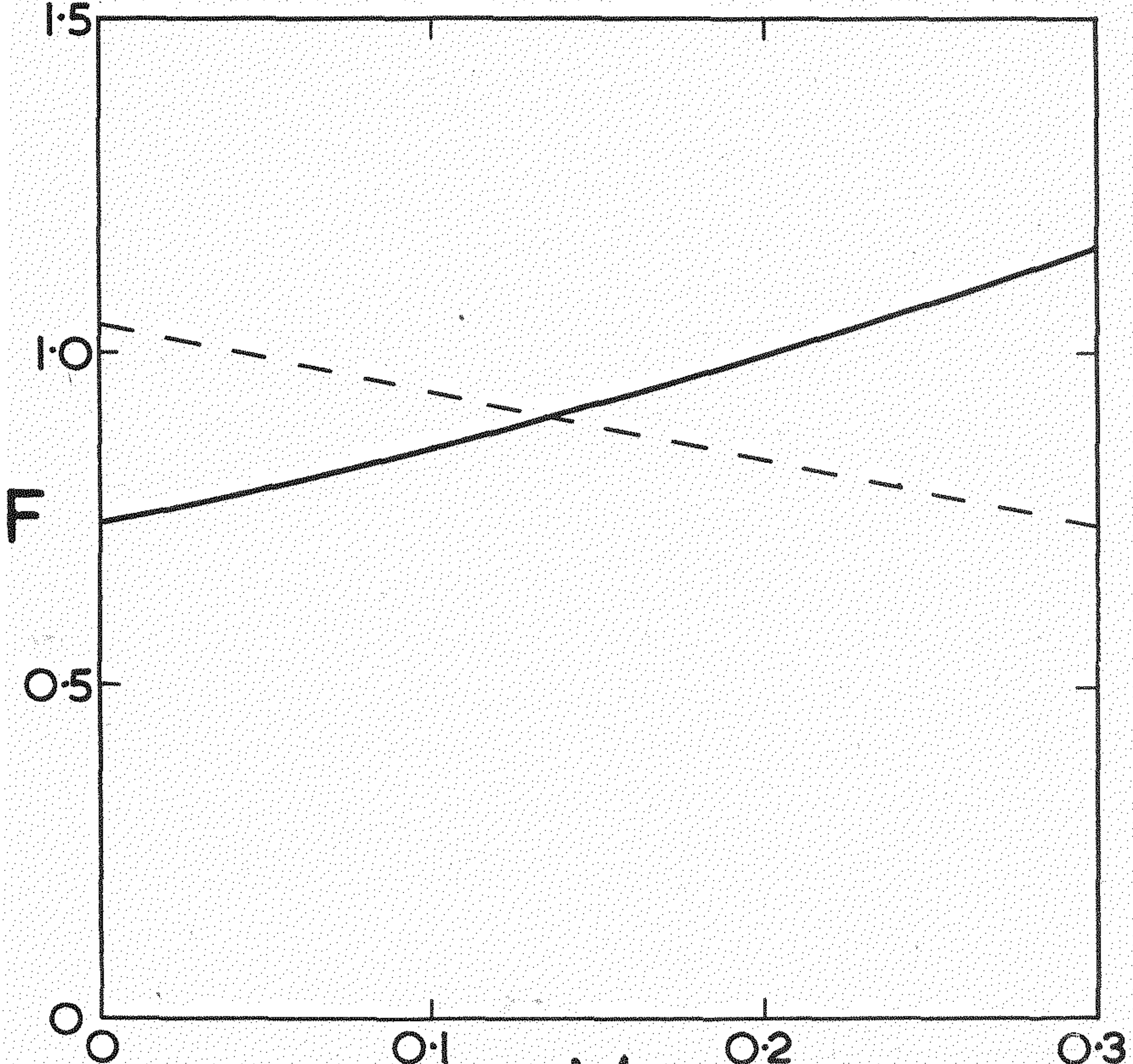

Fig. 3 Estimates of the fishing mortality (F) and natural mortality (M) coefficients of N. Sea sole.