International Council for the
Exploration of the Sea

C.M. 1963
Comparative Fishing Committee
No. 118

The methods used by the Co-opted Members of the Liaison Committee to determine mortality rates of sole

by

L. K. Boerema, J. A. Gulland and J. J. Zijlstra

I. Introduction

The Lienesch Committee of the Permanent Commission reported in 1958 on the expected effects of mesh increase upon the sole fisheries. Among other things, these estimates were based upon the assumption that young sole, escaping through the meshes in one area, might be caught later in fisheries catching mainly older soles in other areas. The report of the Sole Working Group, submitted in 1962, showed, however, that the sole population in the Southern North Sea consists of various groups, each with their own migration pattern. The results indicated that these groups either do not mix, or mix only to a limited extent, although in some seasons their areas of distribution overlap.

These findings necessitated a revision of the mesh assessments for sole. After the 1962 I.C.E.S. meeting, Möller Christensen developed a new method of age-determination in sole, from the burned otoliths. The Working Group on Sole Age Determination agreed that this method gave reliable results (Report to this meeting). Growth data obtained from the new age-readings were different from previous growth estimates, which fact added to importance of the re-assessments.

The co-opted members of the Liaison Committee (L. K. Boerema, secretary of the Liaison Committee, St. Olsen, D. Sahrhage and J. J. Zijlstra), carried out the re-assessments, with the assistance of J. A. Gulland, during their meeting at IJmuiden in the period 29th April-5th May 1963. This report deals with the methods used by them to determine the mortality rates in sole.

II. Determination of total mortality

The mortality rates had to be calculated for each of the sole groups separately. On the basis of the Sole Working Group Report, and in consultation with the former members of that Working Group, for each quarter of the year the North Sea was divided into areas more or less covering the area of distribution of each group (see fig. 1). Data on total quantity landed, effort, and on length composition of the sole landings by quarter and area were collected from the various countries. Because of the short period elapsed since the meeting of the Working Group on Sole Age Determination, nearly the only length-age data available were those from the Netherlands, from samples collected of the sole in areas 1, 2, 3 and 4, in the second quarter of the years 1958-1961.

In each quarter, 6 or 7 samples had been collected, each sample consisting of 50 fish (10 fish from each of the 5 market size categories). Because of the small number of samples, some grouping was necessary. It appeared that when the data of all years were pooled per sole area, the length-age relationship showed no significant difference between the groups. For this reason, one single length-age key was determined for each year from all available length-age data of that year. These data, referring to the second quarter only, were applied to the data on length-composition of the landings per 100 hours fishing in that quarter of the year, and age-distributions were calculated.

The data on numbers by age-group, caught per 100 hours fishing in the second quarter of the year by the Netherlands' fleet in area 2, and the estimates of total mortality obtained from them, are shown in table 1.

- table 1 -

Numbers by age-group per 100 hours fishing caught in area 2 in the second quarter of the year by the Netherlands' fleet and the total mortality estimates obtained from them

Numbers

Year	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XI	XII
1958	665	1811	1395	465	364	967	260	247	606	6	85	79
1959	2582	1950	1558	1216	191	447	593	163	172	463	533	70
1960	1400	1929	1360	1381	1079	235	99	527	162	130	690	560
1961	10520	1737	1989	1460	1138	1103	277	256	411	157	731	574

Z

Year	III/IV	IV/V	V/VI	VI/VII	VII/VIII	VIII/IX	IX/X	X/XI	XI/XII	XI/ XII	Average IV- XII
1959/ 1958	-1.075	0.15	0.14	0.89	-0.29	0.49	0.47	0.36	0.27	0.19	0.30
1960/ 1959	0.29	0.36	0.12	0.12	-0.21	1.51	0.12	0.006	0.28	-0.05	0.25
1961/ 1960	-0.22	-0.03	-0.07	0.19	-0.02	-0.17	-0.95	0.25	0.031	0.18	-0.065
Average	-0.335	0.16	0.06	0.40	-0.17	0.61	-0.12	0.21	0.19	0.11	0.16

The Netherlands' length-age key has, by lack of better data, also been applied to the length-composition of the English landings of sole of area 2 in the second quarter. These results are shown in table 2.

The fairly constant catch per unit effort of small sole in the period 1954-1959, which did not indicate a trend in the strength of the successive yearclasses, justified an attempt to obtain an estimate of total mortality also from the slope of the curve of the average age-composition of sole of area 2 in the sampled years. The curves are shown in fig. 2.

The average mortality figures obtained in both ways from the English and Netherlands' data (and, as described, using for all conversions from length to age the Netherlands' length-age keys), are given in table 3 (corrected figures).

- table 2 -

Numbers by age-group per 100 hours fishing caught in area 2 in the second quarter of the year by the English fleet and the total mortality estimates obtained from them

Numbers

Year	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XI	XII
1959	169	263	314	268	32	107	140	53	53	129	149	20
1960	100	210	153	172	147	31	21	84	29	23	108	85
1961	211	133	159	122	115	92	30	29	50	23	101	78

Z

Year	III/IV	IV/V	V/VI	VI/VII	VII/VIII	VIII/IX	IX/X	X/XI	XI/XII	XI/ XII	Average IV- XII
1960/ 1959	-0.22	0.54	0.60	0.60	0.032	1.63	0.51	0.60	0.83	0.56	0.66
1961/ 1960	-0.29	0.28	0.23	0.40	0.47	0.033	-0.32	0.52	0.23	0.33	0.24
Average	-0.26	0.41	0.42	0.50	0.25	0.83	0.10	0.56	0.53	0.45	0.45

- table 3 -

Estimates of total mortality coefficient (sole, area 2)

	Netherlands' data	English data
From annual decline in catch per unit effort per yearclass	0.16	0.45
From catch curves	0.30	0.21

All these estimates, the mean value of which amounts to about 0.3, are very much lower than the values obtained in the assessments of the Lienesch Committee (0.9).

A few other considerations support the likelihood of the new estimates being the more correct ones. In the case of a low total mortality, one should expect the catches to include relatively many old fish, and in fact the landings in 1958 to 1961 did contain a fair number of old soles up to about 15 years in age. Furthermore, back-calculations of relative yearclass strength at the time of recruitment by applying different mortality rates to recent age-compositions, and comparing these estimates with catch per unit effort estimates of small soles in previous years, provide another method of finding the order of magnitude of the total mortality (method from and applied by J. F. de Veen). For this analysis Netherlands' data of catch per unit effort per yearclass in 1958-1961 were combined with catch per unit effort data of small soles landed by Dutch cutters in 1946-1960 (fig. 3). If a total mortality rate of 0.2 was used for the calculation of original yearclass

strengths, the 1947 yearclass would have been of about the same level as the yearclasses 1953-1956, whereas if a mortality rate of 0.5 is applied, the 1947 yearclass would have been about 10 times as abundant as those of 1953-1956. The catch data show that neither can be correct. The catch data indicate that the total mortality must be between 0.3 and 0.4.

Considering all the evidence, taking into account that some increase in fishing efficiency of the Dutch vessels took place throughout the period, and realizing that the highest landings came from soles of area 2 which show the highest mortality rate, a total mortality coefficient of 0.35 has been accepted as the most likely for this group.

Because of lack of time for more elaborate calculations the mortality coefficients of the soles of areas 1, 3 and 4 have now been calculated from a comparison of the slopes of the length distributions with that of area 2. For this purpose, graphs have been made of the length compositions, plotted on a logarithmic scale, and straight lines have been drawn through the points between 35 and 45 cm (lines fitted by eye, fig. 4). The decrease in numbers from 35 to 45 cm, determined from this straight line, has been expressed as the exponential of e. As far as the growth rate is the same, this value "Z" is an estimate proportional to Z. As has been explained above, no appreciable difference could be shown to exist between the growth rates of the soles belonging to the areas 1, 2, 3 and 4. Insufficient information is available on the areas 5 and 6, but here growth might well be different.

The following values of "Z" were obtained:

- table 4 -

Netherlands' length distributions
"Z"

Area (sole group)	1959	1960	1961	Average	In % of area 2
1	4.2	3.8	3.6	3.86	95
2	3.9	4.4	3.9	4.06	100
3	3.3	3.1	2.9	3.10	76
4	3.3	3.8	3.3	3.46	85

English length distributions

Area (sole group)	1959	1960	1961	Average	In % of area 2
1	3.5	2.9	3.1	3.16	96
2	3.3	3.2	3.4	3.30	100
3	3.1	2.5	2.6	2.73	80
4	?	?	?	?	?

Although the slope in the English length distribution is less than in the Dutch figures (which also was apparent from table 1) the differences in slope between the areas is very similar.

Applying the Netherlands' data to the mortality rate of 0.35 for area 2, the following estimates of the areas 1-4 are obtained.

- table 5 -

Total mortality rates of soles of areas 1-4

Sole area	1	2	3	4
Total mortality rate	0.33	0.35	0.27	0.30

III. Separation of fishing and natural mortality

For the purpose of assessing the effects of mesh increase it is essential to know what fraction of the total mortality is due to fishing and what to natural causes. Little information on this item was available. The Sole Working Group had only very limited time to go into the problems of mortality estimates, and concluded from the overall results that because of the great variation in the numbers of fish reported from the various tagging experiments, no reliable average figure of the fishing mortality could be given. Realizing that estimates of mortality from tagging experiments are subject to numerous errors, most of which - tagging mortality, tag shedding, failure to report tags etc. - tend to reduce the estimate of fishing mortality, the co-opted members hoped that a more detailed analysis of some tagging experiments might at least indicate whether fishing mortality is a substantial part of the total mortality of soles. No former member of the Sole Working Group being present, only data of two groups of experiments could be found in the archives of the Group, summarized in such a form that they could be analysed within the available time. In these experiments the percentage of returns of small sole or of sole in poor condition at tagging was in general rather lower than that of large sole (over 30 cm) in good condition. If only the data of the latter were used, a set of English tagging experiments in the White Bank Area showed a 20% return in the first year after tagging. The corresponding figure from German experiments amounted to 36%, which is even higher than the total mortality rate estimated in the previous section (0.35 or 30% per year). This high percentage is possibly due to variation because of the small numbers concerned, or to tagging having been done in areas of particularly high fishing intensity. Anyway, both the English and the German data indicate that the fishing mortality is a substantial part of the total mortality. /The figure for total mortality, arrived at in the previous section, is rather lower than that estimated by the Sole Working Group (which was estimated at 50% per year or lower). However, as the latter was determined from the decrease in numbers reported in successive years, tag-shedding etc. may have resulted in a considerable over-estimate, and therefore the values of total mortality coefficients obtained from these tagging experiments were not considered to be sufficiently reliable for the present purpose./

Fortunately, an independent estimate of natural mortality could be made from the length distributions of soles landed at Lowestoft in the years immediately after the war. When plotted on a logarithmic scale, the length distributions of fish above the modal length have a rather complex form, with a steep slope for the left hand part, and a much lesser slope for the intermediate range, followed by a steep slope for the largest sizes. The position of the lesser slope changes each year, moving to the right (see fig. 5). This suggests that the two steep parts of the curves correspond to the high total mortality (natural plus fishing) in the periods before the war (for the big fish) and after the war (for the small fish), and that the low slope corresponds to the low mortality (natural mortality, with hardly any fishing) during the war.

Fig. 6 gives the mean lengths of sole per age-group, determined from the samples collected in 1958-1961. If the growth rate has not changed, these data can be applied to the curves in fig. 5. Because of the great difference in growth rate between male and female sole the fish of under 30 cm are a mixture of males of many age-groups, up to about 9 years old, and young females, whereas sole of over 30 cm length consist predominantly of females. Thus, in applying growth data to the English length distributions for sizes of over 30 cm, the figures of female soles should be chosen. On the assumption that the growth rate has remained constant indeed, it appears that the range of the more level part of the length distributions corresponds with the lengths of female sole of the yearclasses which were recruited to the fishery during the war. Therefore, the decrease in numbers over the range between the average length of the 1937 yearclass and that of the 1942 yearclass has been taken to give a measure of the mortality during the war period, and thus of the natural mortality (assuming that the yearclass strength in this period has remained about constant). Because growth is rather variable, so that fish of older ages overlap progressively in size, the differences in the slopes will tend to disappear with time, and the section with level slope will increase in slope, i.e. will gradually give an over-estimate of the natural mortality.

In order to measure the decrease in numbers over the relevant part of the curves in fig. 5, straight lines were fitted by eye. Even although perhaps not too much value should be attached to the figure of the decline of each year separately, the estimates which were obtained, and which are shown in table 6, are very much in agreement and show the expected increase towards 1951.

- table 6 -

Sampling year	Estimated natural mortality
1947	0.08
1948	0.06
1949	0.06
1950	0.09
1951	0.13

With the provisos mentioned above, these data suggest that the natural mortality of sole is very low, almost certainly less than 0.1 and probably around 0.06, or perhaps still less (because even in the war period at least some fishing took place in coastal areas).

Thus, the results of the tagging experiments indicating that fishing mortality is a substantial part of the total mortality, are corroborated and extended by these considerations on the magnitude of the natural mortality.

IV. The values used in the mesh assessments

The values of total and natural mortality arrived at in the previous sections being the best possible estimates for the time being, they were used in mesh assessments in order to determine whether these data would lead to conclusions on the effect of mesh size upon the sole catches which were substantially different from those reported to the Permanent Commission in 1958.

The values used for total mortality were those given in table 5, whereas for natural mortality in each of the sole areas three values were applied (0.035, 0.070, 0.105, giving with a total mortality of 0.35 (area 2) the ratios $\frac{F}{F+M}$ of resp. 0.9, 0.8 and 0.7).

The method followed in the calculations was that described by Gulland (Journal du Conseil XXVI, 2, 1961). The results indicated that mesh increase up to 85 mm would lead to a benefit to the sole fisheries as a whole, and also to the sole fisheries of most countries.