

The Reliability of the Catch per Unit Effort as a Measure of Abundance
in North Sea Trawl Fisheries

by

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During the past thirty years the c.p.e. of plaice by English trawlers has changed appreciably, especially during and just after the war; some of these changes can be shown to be almost exactly proportional to the changes in the stock, but at other times the c.p.e. has not remained proportional to the population. In two periods of relatively steady fishing in 1930-38 and 1950-58, the total mortality coefficients were 0.83 and 0.58 respectively (corresponding closely to the difference in the fishing efforts in the two periods). The average total annual catches by all countries in the two periods were 54,200 tons and 69,200 tons respectively. Taking the natural mortality as 0.1 (and the precise value will not alter the result much), the fishing mortality can be obtained at once by subtraction, and the average size of the exploited stock in the two periods estimated as $54,200/0.73 = 74,300$ tons and $69,200/0.48 = 144,200$ tons, a ratio of 1:1.941. The average catches per hours' fishing by English steam trawlers in the two periods were 18.17 and 35.22 cwt, a ratio of 1:1.939. The extremely close agreement between the two figures is no doubt chance, but it does show that the catch per unit effort gives a very good measure of how much the stock has increased between the 1930s and 1950s. (Much of this increase is due directly to the reduced fishing and hence better survival, but this cannot account for all of the increase, and some is probably due to shift of fishing onto the central parts of the North Sea where fewer very small fish are found).

Between these two periods there were more marked changes in the stock due to the cessation of fishing, at least in the western part of the North Sea, during the war. There was a very large increase in catch per unit effort, but it appears that this increase overestimates the true increase in stocks. This is not the place for a full analysis of the data, but some discrepancies may be shown. Two indices of catch per unit effort have been used, firstly the total catch of plaice by English steam trawlers divided by their total hours' fishing. This is unlikely to be entirely reliable because the distribution of fishing just after the war was not the usual pre-war pattern. An estimate that should be free from distortion due to this difference in distribution is obtained by calculating the c.p.e. in individual statistical rectangles (roughly thirty miles square) and taking the mean of these over the main fished area. The area chosen comprised rectangles D8, E 5-8, F 5-8, G 2-7, H 3-6, J 5 and F 1.

More than 85% of the total English plaice catch was taken from this area in 1946, and the area roughly corresponds to that inhabited by the plaice spawning in the Southern Bight. Even though this is a heavily fished area there were in any particular month some rectangles in which no fishing was done so that no c.p.e. could be directly calculated. For these the c.p.e. was taken as that in the same rectangle in the following month, or estimated as the mean of adjacent rectangles. The latter index is similar to the two indices obtained by Margetts and Holt (1948), Table 20, for the whole of the central and southern North Sea (Region IVb and c) in 1946. It is closer to their 'high' index, as their 'low' index is very much a lower limit, being based on the assumption that in those rectangles where there had been no fishing in any month the c.p.e. was no higher than before the war.

Both indices were then expressed as a ratio of the average of the corresponding indices in 1936-38. These ratios are plotted in Figure 1 for the period from June, 1945, when fishing started again, to December, 1946. Both start at a very high level and thereafter declined rapidly. In June, 1945, the total catch divided by the total effort was some eighteen times higher than in 1936-38,

but some of this increase was due to relatively more fishing being done in the more productive rectangles, as shown by the fact that the better index obtained as the mean of the c.p.e.s in individual rectangles was only a little over nine times the pre-war value. This latter is the best available index of stock abundance based on catch and effort data, and suggests that the stock fell from 9.5 times pre-war in June, 1945 to about five times pre-war at the end of 1945, to barely two times pre-war at the end of 1946. (For comparison Margetts and Holt's 'high' index declined during 1946 from c 6.6 to 2.2, and their low index from 3.1 to 1.6). That is, something like 4.5 times the pre-war stock disappeared in 1945, and three times the pre-war stock in 1946.

The actual catches from the area considered in these periods by English steam trawlers were 469,000 cwt in 1945 and 468,000 cwt in 1946, compared with an average of 198,000 cwt in 1936-38. Taking the pre-war fishing mortality as 0.73, the pre-war stock was about $198,000/0.73 = 271,000$ cwt, i.e. the catches in both 1945 and 1946 were about 1.7 times the pre-war stock. The apparent decreases in stock in 1945 and 1946 were therefore greater than the removals by fishing, even without accounting for the nett additions to the stock due to growth and recruitment, less natural mortality. The estimates of the stock at December, 1945, and still more at June, 1945 must therefore be overestimates.

The figures above are only of catches by English steam trawlers, and all the figures, of both catches and estimated stock should be increased by the ratio of English steam trawl to total catch. Unfortunately, the catches of other vessels cannot be allocated so precisely to the area of capture, but there is no reason to suppose that this ratio has changed greatly. In the table below the total North Sea catches of plaice by various groups of vessels have been expressed as a percentage of the English steam trawler catch.

Year	England (S.t.)	England (Others)	Scotland	Belgium	Denmark	Holland	Total
1938	100	14	26	24	140	67	397
1945	100	21	21	29	145	29	353
1946	100	16	23	23	150	63	391

The only appreciable change is in the Dutch catch, which was low in 1945; much of the Dutch fishing is in the area considered, so that the 1945 catches were probably even smaller relative to the 1936-38 stock than has been estimated here.

The stock may be reduced more than suggested by the English steam trawler catches if either there has been more fishing by other vessels, either in the area or just outside - and the table above suggests that this did not happen, or if English steam trawlers did relatively more fishing on the fringes of the area (i.e. which are not included in the catch from the area, but do affect the stock within the area). In fact, the English steam trawler catches within the area in 1946 were 85% of the total, whereas the average catches in the area in 1936-38 were 69% of the total British steam trawl catches (i.e. including Scottish trawlers). Again there does not seem to have been any significant change.

Taking the stock at December, 1946 as being reliably estimated as two times the 1936-38 stock, the upper limits to the abundance in June and December, 1945 (making no allowance for growth and recruitment) are $2 + 1.7 = 3.7$ and $3.7 + 1.7 = 5.4$ times the 1936-38 level respectively. The c.p.e. data therefore overestimate the stock in June and December, 1945 (relative to the steady 1930 and 1950 levels) by factors of at least $9.5/5.4 = 1.76$ and $5/3.7 = 1.35$ respectively.

This overestimation, particularly if the decline to the steady pcece time standard were continued into 1947, would help explain the anomalous high value of 1.30 found by Holt (1949) as the total mortality coefficient between 1946 and 1947. This value, much higher than the 1930-38 value of c 0.83, is inconsistent with the fishing effort during the period which in total was well below the average 1930-38 effort, although more concentrated in the southern North Sea, from which most of the age data were obtained. Not only will the decline in the degree of overestimation result in the decline in numbers, i.e. the mortality, being overestimated, but also the true fishing mortality, for given amount of fishing, will be higher in 1945-46 than in 1930-38, to precisely the extent to which the c.p.e. for a given stock abundance is high.

This discrepancy between the apparent decline in stock in 1945 and 1946 and the actual quantity removed is not confined to plaice. Thus for cod, in the area of twenty-one rectangles (E 5-8, F 5-9, G 4-9 and H 4-9) from which the bulk of English catches came in 1945 and 1946, the best index of stock abundance, based on the mean c.p.e. in the individual rectangles declined from fourteen times the 1931-38 average in June, 1945 to about five to six times pre-war in December, 1946. The catches in both periods were similar, about 2.8 times the pre-war catch. Beverton & Holt (1957) using data of Graham (1938) estimated the total mortality of cod in 1930 as about 0.7, and taking the extreme limit of this being all fishing mortality, the 1945 and 1946 catches were $2.8 \times 0.7 = 2.0$ times the pre-war stock. Therefore, if as for the plaice, the December, 1946 index is taken as correct, and no allowance is made for growth and recruitment, the upper limit to the stock in June, 1945 can be obtained. For cod it is $2.5 + 2.0 + 2.0 = 6.5$ times the pre-war stock, compared with an index of fourteen times based on catch and effort data.

For sole Beverton (1955) found that the instantaneous rate of decrease of the weight landed per 100 hours' fishing during the period 1945-48 was 0.75, and because of recruitment and growth the decrease in numbers of each age-group must be much greater. Even this lower limit is considerably greater than the total mortality determined for the most recent years by the ICES Sole Working Group. Though the period of decline includes the exceptionally cold winter of 1946/47, when mortality was probably high, the rates of decline from June, 1945 to the end of 1946 and again from mid-1947 to the end of 1948 were not very much lower than the overall rate of 0.75 and, as for cod and plaice, it is clear that the immediate post-war decline in c.p.e. is considerably greater than the real decline in stock abundance.

This dramatic fall in catch per unit effort during 1945 and 1946 was not confined to English vessels. Boerema & Cox Heikens (1949) gave data for the Dutch trawl fishery from June, 1945 until the end of 1947. The c.p.e. of both cod and plaice showed the same rapid decrease during 1945 and 1946 (and to a lesser extent in 1947) as did the English c.p.e. The catch of cod for 100 hours' fishing fell from 28,000 kg in June, to 1,500 kg in December, 1946, and that of plaice from 10,000 kg in June, 1945, to 1,500 kg in November, 1946. There are some irregularities; in the winter of 1946/47 the plaice catch had a very pronounced peak (6,000 kg) in January 1947, with slightly lesser values in December and February, while the cod had a peak in March and April, 1947 which was as high as any c.p.e. since the middle of 1945. Despite these irregularities the general trend for both cod and plaice is a very rapid decline during 1945 and 1946 to around 10-15% of the June, 1945 value, which is even more rapid a decline than on the English data, and certainly much more rapid than can be accounted for by the English data, and certainly much more rapid than can be accounted for by the considerably greater amount of fishing in the 1930s.

A possible explanation of the discrepancy between catch per unit effort and abundance, i.e. essentially the variation in the catchability coefficient q , may be in the distribution of the fish and fishing. The catch per unit effort is directly a measure only of the abundance in the area around the fishing gear, and the relation of this to the average density in the whole region may not be constant. The detailed statistical records can correct for this on a large scale, where there are differences between areas of the size of the basic statistical square (about 30 x 30 miles), but cannot distinguish happenings within the smallest statistical area.

In Figure 2 possible distributions of fish within the smallest statistical areas are shown. The lower figure shows the distribution when there is very little fishing; in one favourable place the fish are much more abundant than elsewhere, and fishing is also concentrated there. The average density in the fished area is therefore rather more than twice the average density in the whole area. When the amount of fishing is increased, as shown in the upper figure, the abundance of fish stock in the whole area is reduced, but the reduction will be greatest in the fished part. At the same time the fishing will spread over a larger area. For both reasons the density in the fished area will become closer to that in the area as a whole though still rather greater. This effect could explain the over-estimation of the plaice stock in June, 1945 by a factor of 1.76 relative to the peace-time stock. Suppose, for instance, in the 1930s the density in the fished part of each statistical rectangle was 1.5 times the average density; then the overestimation would be caused if in June, 1945 the density in the fished area was $1.5 \times 1.76 = 2.64$ times the average density - this is a difference which, as suggested by Figure 2, could easily occur.

Another explanation for the variation in q is given by Beverton in a paper to this meeting. He shows that q is different for male and female plaice, and that because of the change in the proportions of males and females immediately after the war the effective mean q for the stock as a whole would be higher just before the war. However, rough quantitative estimates of the magnitude of this effect suggest that it is not sufficient to account for all of the discrepancy observed in the post-war data, and some additional explanation, such as that about the distribution, must also be put forward.

Summary

The abundance of plaice in the North Sea during two periods of sustained fishing (1930-38 and 1950-58) was estimated in two ways - from the catch per 100 hours' fishing by English steam trawlers, and from the total catch and fishing mortality derived from age data. The two methods gave extremely good agreement for the relative abundances in the two periods. The catch per unit effort, however, seems to overestimate quite substantially the increase in abundance when the abundance is very high after a long period of no fishing. It is suggested that this is due to different patterns of fish distribution.

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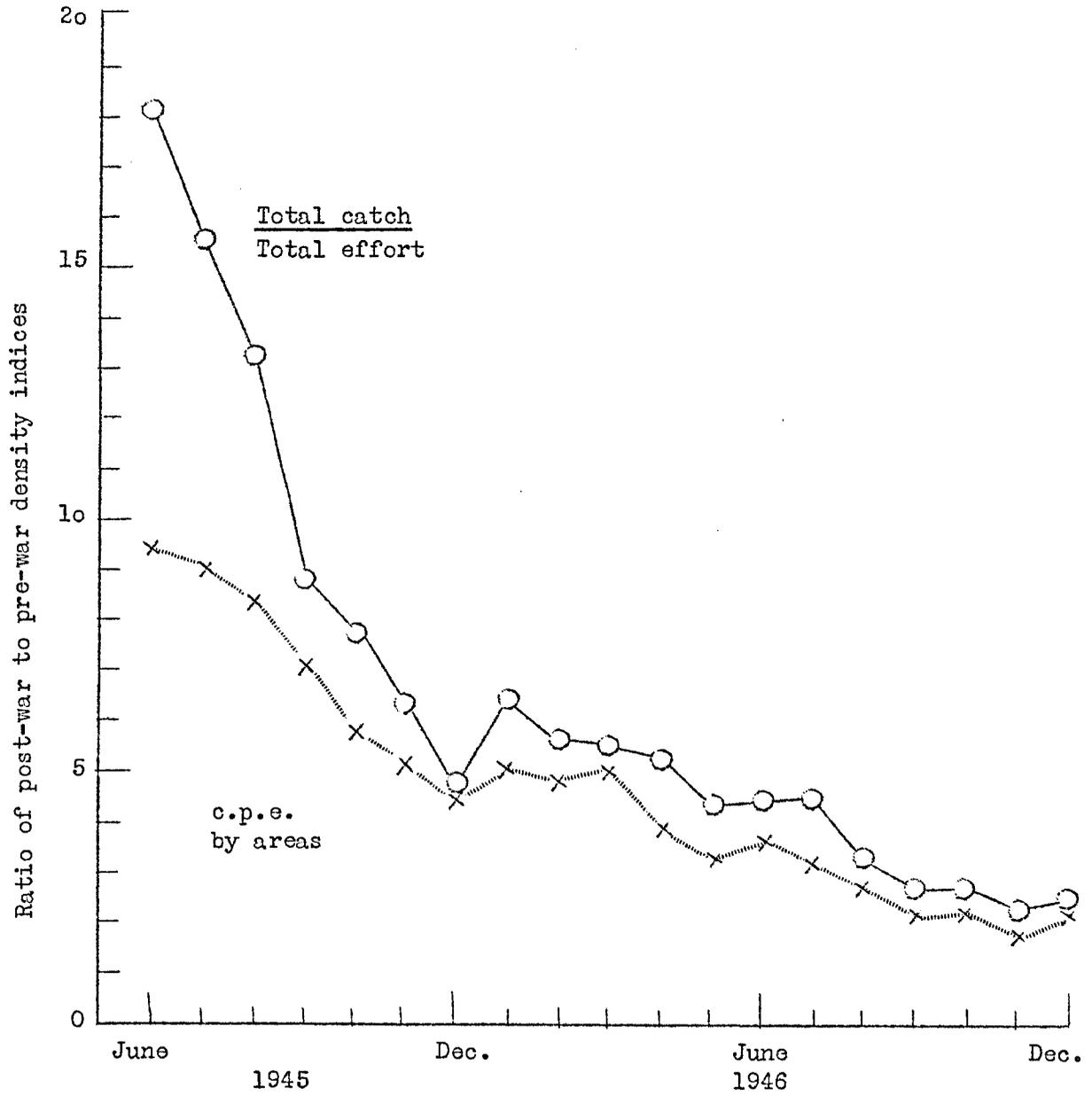


Figure 1. Decline of the catch per unit effort of plaice by English steam trawlers immediately after the War.

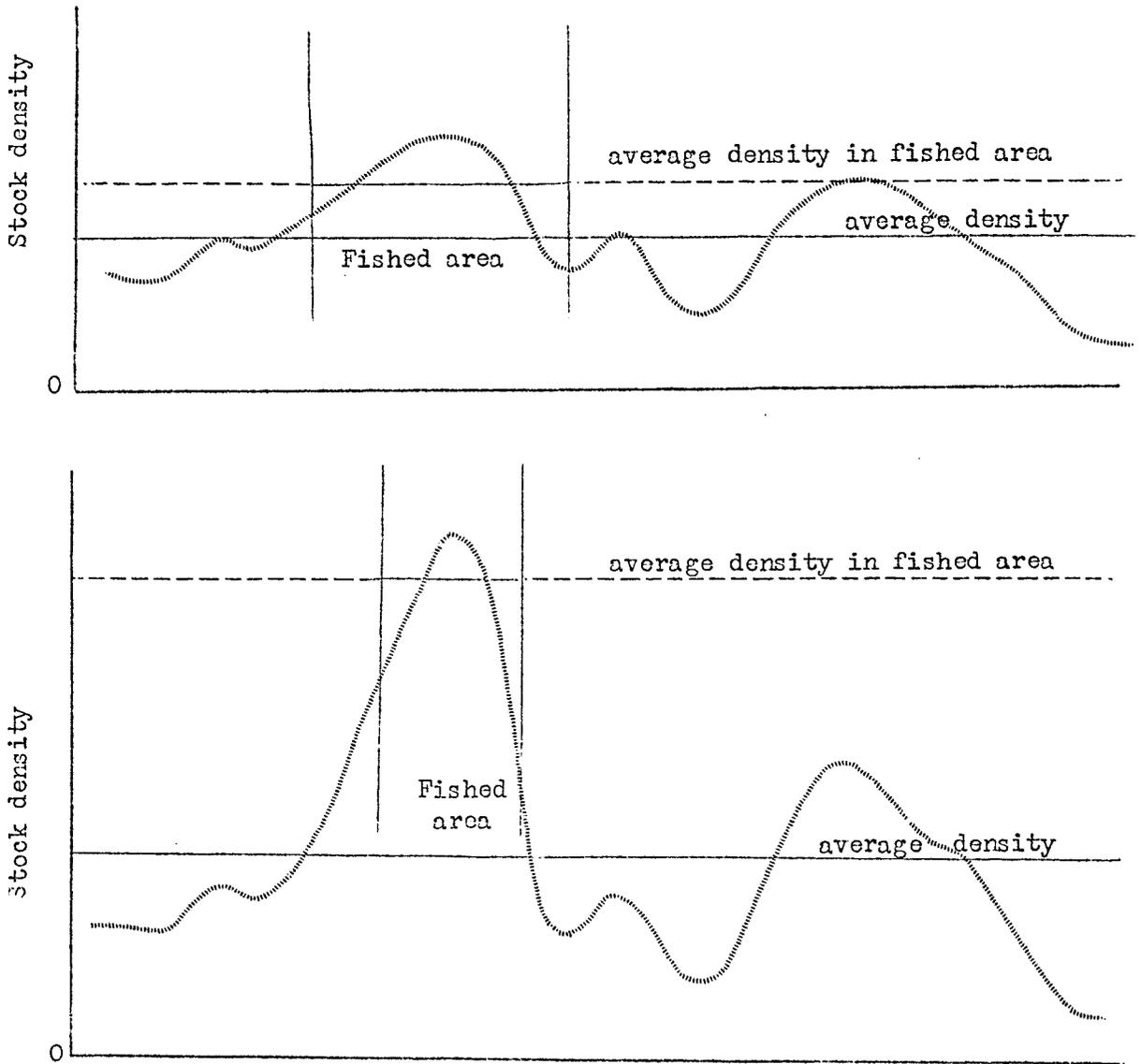


Figure 2. Hypothetical distribution of fish and fishing under heavy fishing (above) and light fishing (below).