INTERNATIONAL COUNCIL FOR THE
EXPLORATION OF THE SEA

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Pelagic Fish Committee

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Introduction

This paper presents some further results of the analysis of North Sea herring larval surveys according to the method described earlier by this author (Corten, 1978). The main aspect in which this method differs from other studies on the same material (Anon. 1977, 1979, Saville 1979) is that the relationship between spawning stock and larval production is studied for the North Sea as a whole, and not for the various subpopulations separately. This approach has the advantage that independant stock estimates for the years prior to 1977 can be obtained from a Virtual Population Analysis of all catches taken in the North Sea. Stock estimates for individual subpopulations are much harder to obtain by this method, because a VPA on subpopulations basis requires that all herring catches in the North Sea are split into their racial components.

For later years (after the introduction of the ban on herring fishing in 1977) VPA-estimates of stock size are no longer available. Still, it is possible to obtain other estimates of spawning stock size, and compare these with larval production data. These other estimates are stock projections, based on the VPA estimate for the stock in 1976, and on recruitment estimates for later years from the International Young Fish Surveys.

The possibility to compare larval production for the whole North Sea with projected stock sizes is an important advantage of the present method. In this way, larval production estimates can be used as a continuous check on stock projections. As will be shown in the following section, this is really the only appropriate way to use larval data at the moment.

Limitations of the use of larval production data in the present situation

In the first paper by this author (Corten, 1978), no significant correlation could be obtained between larval production and stock size from VPA for the period 1972 - 1976. This was hardly surprising considering the limited number of years for which data were available. In the meantime, new data on larval production for the years 1977 - 1979 have become available. The series of VPA estimates, however, cannot be extended as catches of herring have been negligable since 1977, due to the ban on directed fishing for herring. On the basis of our present material, it is still not possible therefore to follow the procedure taken by other authors (Anon. 1977, Saville, 1979), that is to correlate larval production with VPA stock estimates, and then calculate a regression line which can be used to predict stock size from larval production in years for which no VPA estimate is available.

It is questionable, however, whether the procedure mentioned above is at all valid in the present situation. The regression lines used by the authors mentioned above are all based on a period in which the total North Sea stock was below a level of 300 000 tonnes. It is very dangerous to use these regression lines for prediction at a time when the North Sea stock is expanding beyond this level. Firstly, there is an increasing uncertainty about the true position of the regression line at higher values of X, which can be illustrated by calculating the confidence belts around the regression line. In the second place, it is not certain whether the relationship between stock and larval production will remain linear also at higher levels of stock size.

So it is obvious that the regression lines based on a period in which the total North Sea stock was below 300 000 tonnes, cannot be used to find out at what moment the stock will have reached a level of 800 000 tons, the aim of the present management policy. This fact is a major limitation in the use of herring larval data today; a limitation which perhaps has not yet been fully appreciated by the Herring Assessment Working Group (Anon. 1980).

The limitation mentioned above doesnot mean that larval data are completely useless at the moment. Of course they still are a most valuable source of information on the development of the North Sea stock as a whole, and the development of the individual subpopulations in particular. The point is, however, that larval surveys cannot be used on their own, ignoring other sources of information on the present stock size, and just extrapolating a regression line that was calculated for a different range of stock sizes. The only way to use larval data at this time is to compare them with our best estimates of present stock size (see below), and to investigate whether both parameters follow the same trend. If this is the case, the hypothesis is supported that the stock estimates used are indeed good indices of the actual spawning stock.

Estimates of spawning stock in 1977 - 1979

As mentioned above, the series of VPA estimates used in the earlier paper (Corten 1978) cannot be extended for the years after 1976, due to the absence of sufficient herring catches. The only possible way to extend the series of stock estimates beyond 1976 is to include projected values, which are based on a VPA estimate for the adult stock in 1976, and on estimates of recruiting year-classes in later years from the International Young Fish Surveys. The VPA estimate for the adult stock in 1976 is admittedly rather uncertain, but the projected stock sizes for later years depend to an increasing extend on newly recruited year classes, which have been estimated with a reasonable degree of accuracy in the IYHS.

The following spawning stocks have been calculated for the years after 1976:

1977 :	180 000 tonnes
1978 :	271 000 tonnes
1979 :	442 000 tonnes.

The figures for 1978 and 1979 are also given in the latest report of the Herring Assessment Working Group (Anon., 1980).

The projected stock sizes given above may contain certain random errors, due to a variety of causes. The survey mean for the IYHS has a rather high variance (see for example Corten, 1979), and this will give rise to a random error in the abundance estimate for the year class at an age of $1\frac{1}{2}$ years. Furthermore, some unexpected things may happen to the year class between the time of the IYHS and the moment of recruitment to the spawning stock. An unusually high proportion of the year class may be destroyed in the industrial fisheries, or may migrate out of the North Sea and into Division VIa. Still, despite all these possible errors, the abundance indices from the IYFS have been proven to be good indices of final year class strength (Anon., 1978), and the projected stock sizes based on these recruitment indices should therefore be regarded as the best estimates of adult stock size available at present.

Larval production estimates for 1977 - 1979

In the earlier paper by this author (Corten, 1978), larval production on the various spawning grounds was calculated by the method first described by Van de Kamp (1976). By this method, the hatching period is divided into 15 day intervals and the means of larval abundances in each 15-day interval are summed over the whole hatching period to arrive at an estimate of the total larval production. In this way, larval production on different spawning grounds can be directly compared and even summed (after correction for differences in fecundity). For details on this method, the reader is referred to the earlier papers.

The series of production estimates for small larvae, given by Corten (1978) have now been extended with data for 1977 - 1979. Table I presents figures for total larval production on the different spawning grounds, and table II shows the conversion of larval production estimates for different spawning grounds into one index of larval production for the total North Sea. First, larval production for each subpopulation is divided by its specific fecundity (expressed in thousands of eggs per kg fish), and the indices thus obtained are summed to arrive at one index of larval production for the total North Sea. Basic data used were taken from the annual survey reports (Wood, 1978; McKay, 1979) and from the preliminary results of the surveys in 1979.

Medium size larvae, which were also used by Corten (1978) are not being further considered in this paper. Data on this size-group are still regarded as a useful complement to the data on small larvae. However, the use of medium size larvae presents some special problems, the discussion of which would confuse the main argument in the present paper.

The relationship between larval production and estimates of spawning stock.

Table III compares data on larval production for the years 1967 - 1979 with stock estimates from VPA (before 1977) and projected stock sizes (since 1977). A graphical representation of the same data is given in figure 1.

It is seen that there is a large discrepancy between larval production and stock estimates in the earlier years of the surveys, but that both parameters follow the same trend in recent years. In the years 1967 - 1972, larval production showed an increasing trend while stock estimates from VPA were declining. It has been suggested (Anon., 1977) that the sampling efficiency may have been low in the earlier years of the programme and that the real abundance of larvae may have been underestimated in those years. For a comparison of stock estimates and larval production, it seems advisable therefore to concentrate only on the more recent years and to leave out the data for the first 5 years.

The close relationship between stock estimates for the years 1972 - 1979 and the corresponding larval productions, which appeared already in figure 1, is confirmed by a regression analysis. It is found that both parameters are significantly correlated ($r = 0.76$) and the predictive regression of Y (stock size) on X (larval production is given by:

$$Y = 4.06X + 82.60$$

in which Y = spawning stock in '000 tonnes
and X = index of total larval production.

However, the purpose of our regression analysis was not to find a regression line that can be used to predict one variable from the other, but to obtain a line that best describes the relationship between both variables. For this purpose, it is better to use a functional regression line than a predictive one (Ricker, 1973). The functional regression line is described by:

$Y - \overline{Y} = \frac{b}{r} (X - \overline{X})$ in which $\overline{X}$ and $\overline{Y}$ are the means of all observations

b = first regression coefficient in the predictive regression above,

r = correlation coefficient.

Substituting the appropriate values, we find the following formula for the functional regression line:

$$Y = 5.34X + 38.15.$$

This regression line is shown in figure 2.

As discussed in an earlier paragraph, the fact that larval production in recent years is still following the same trend as projected stock sizes, may be explained as an indication that the stock projections are in the right order of magnitude. This is as far as we can go in interpreting larval data at present. It is not possible to derive from the larval data an independant estimate of stock size, because the relationship between stock and larval production cannot be predicted for the present range of stock sizes.

In the next years, new values for larval production and stock projection can be added to our series of observations. If the now existing correlation is maintained, we can remain confident in the stock projections used. If, on the other hand, the correlation breaks down or the regression line drastically changes position, either the projected stock sizes could be wrong, or larval production might not increase proportionally to stock size anymore. In this case, the only adequate way out of the problem would be to obtain new stock estimates by an independant method (echo-surveys or tagging).

Monitoring the development of stock size for individual subpopulations.

In addition to being used as a check on projected stock sizes for the total North Sea, larval surveys also provide an indication of the different development rates for the various subpopulations in the North Sea. On the basis of this information, different management actions may be taken for different areas within the North Sea, and the total yield from the North Sea in future years may be greater than in a situation where the North Sea herring is treated as one unit stock.

As long as the size of the projected herring stock for the total North Sea is confirmed by the index for total larval production, the larval data can also be used to partition the projected stock size for the total North Sea into segments for the individual subpopulations. This is a side-benefit of the method for calculating larval production used in this paper. The index of larval production for the total North Sea is the sum of production indices for the various subpopulations. These indices (calculated by dividing total larval production of a particular subpopulation by its specific fecundity) are directly proportional to the size of each subpopulation, and may therefore be used as a key to split an estimate for the total North Sea stock into the various racial components.

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TABLE I - Total production estimates of small larvae in numbers x 10^9.

Shetland-Orkneys, larvae < 10 mm.				
Year	01-15 Sept.	16-30 Sept.	01-15 Oct.	Total
1977	2101	206	520	2827
1978	7349	174	422	7945
1979	3197	3007	481 ')	6685

Buchan, larvae < 10 mm				
Year	01-15 Sept.	16-30 Sept.	01-15 Oct.	Total
1977	93 ')	25	3	121
1978	177 ')	198	38 ')	413
1979	187	15	2 ')	204

Central North Sea, larvae < 10 mm					
Year	01-15 Sept.	16-30 Sept.	01-15 Oct.	16-31 Oct.	Total
1977	593	350	116	3	1062
1978	1543	88	402	2	2035
1979	873	329	889	42	2133

Southern Bight and English Channel, larvae < 11 mm					
Year	05-20 Dec.	X-mas correction	01-15 Jan.	16-31 Jan.	Total
1977	2	1	0	10	13
1978	49	13	4	3 ')	69
1979	7	57	219	42	325

') estimated on the basis of neighbouring periods.

TABLE II - Calculation larval production index total North Sea from larval production estimates for individual subpopulations.

P = production of small larvae in numbers x 10^9.

F = specific fecundity in thousands of eggs per kg fish.
(180 for northern and central North Sea; 105 for southern North Sea).

Year	Central and northern N.Sea		Southern North Sea		Total North Sea
	larval production (P_1)	index spawning stock ($\frac{P_1}{F_1}$)	larval production (P_2)	index spawning stock ($\frac{P_2}{F_2}$)	index spawning stock $\Sigma \frac{P}{F}$
1977	4 010	22.28	13	0.12	22.40
1978	10 393	57.74	69	0.66	58.40
1979	9 022	50.12	325	3.10	53.22

<u>TABLE III</u> - Comparison between larval production total North Sea and stock estimates from VPA (before 1977) and stock projection (since 1977).

Year	Index of larval production total North Sea	Stock estimates from VPA and stock projection
1967	30.63	767
1968	5.99	361
1969	7.23	348
1970	17.96	309
1971	15.85	223
1972	47.84	265
1973	38.53	220
1974	41.46	161
1975	8.45	95
1976	7.42	155
1977	22.40	180
1978	58.40	271
1979	53.22	442

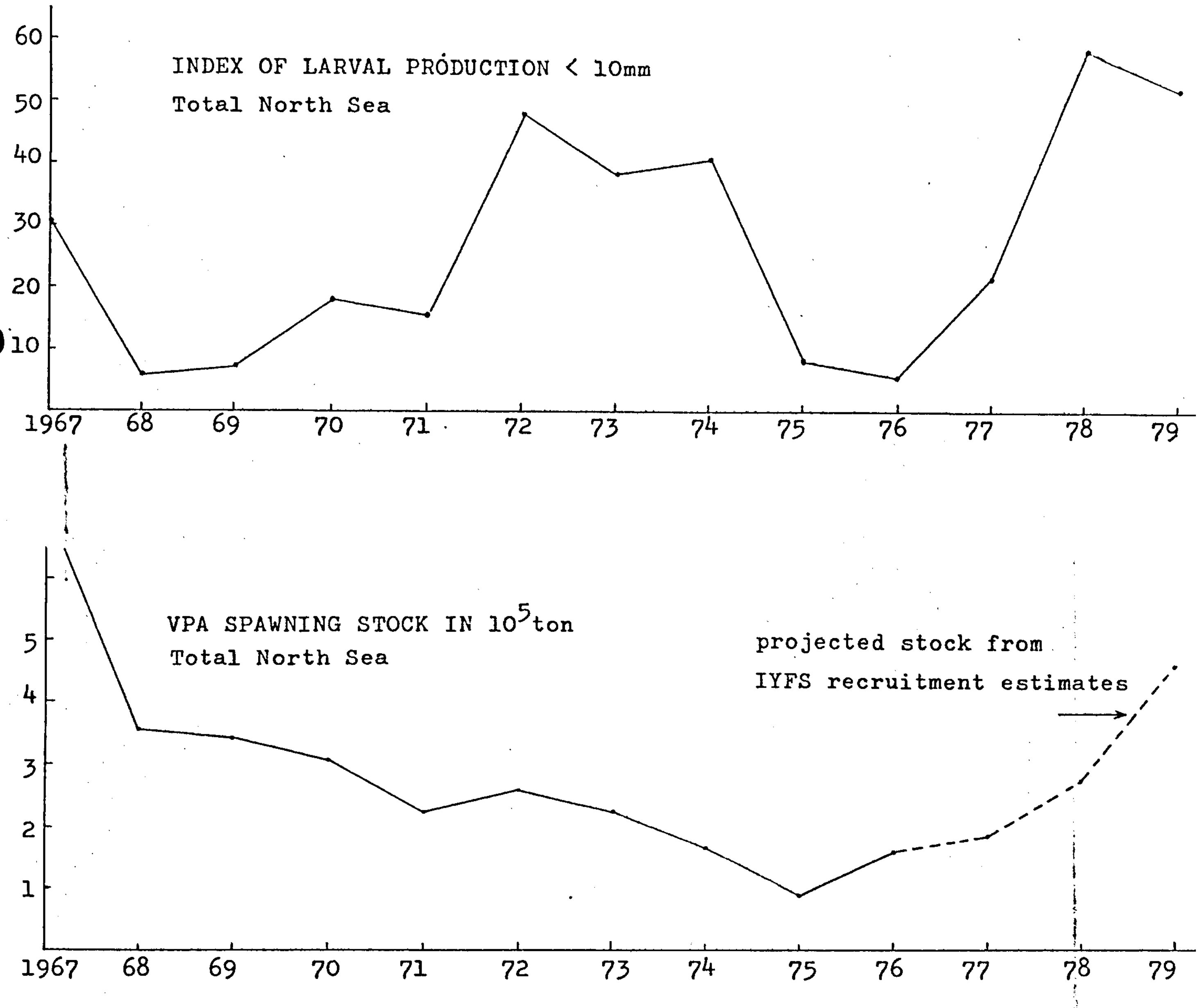

Fig. 1.

Comparison between larval production total North Sea and stock estimates from VPA (before 1977) and stock projection (since 1977).

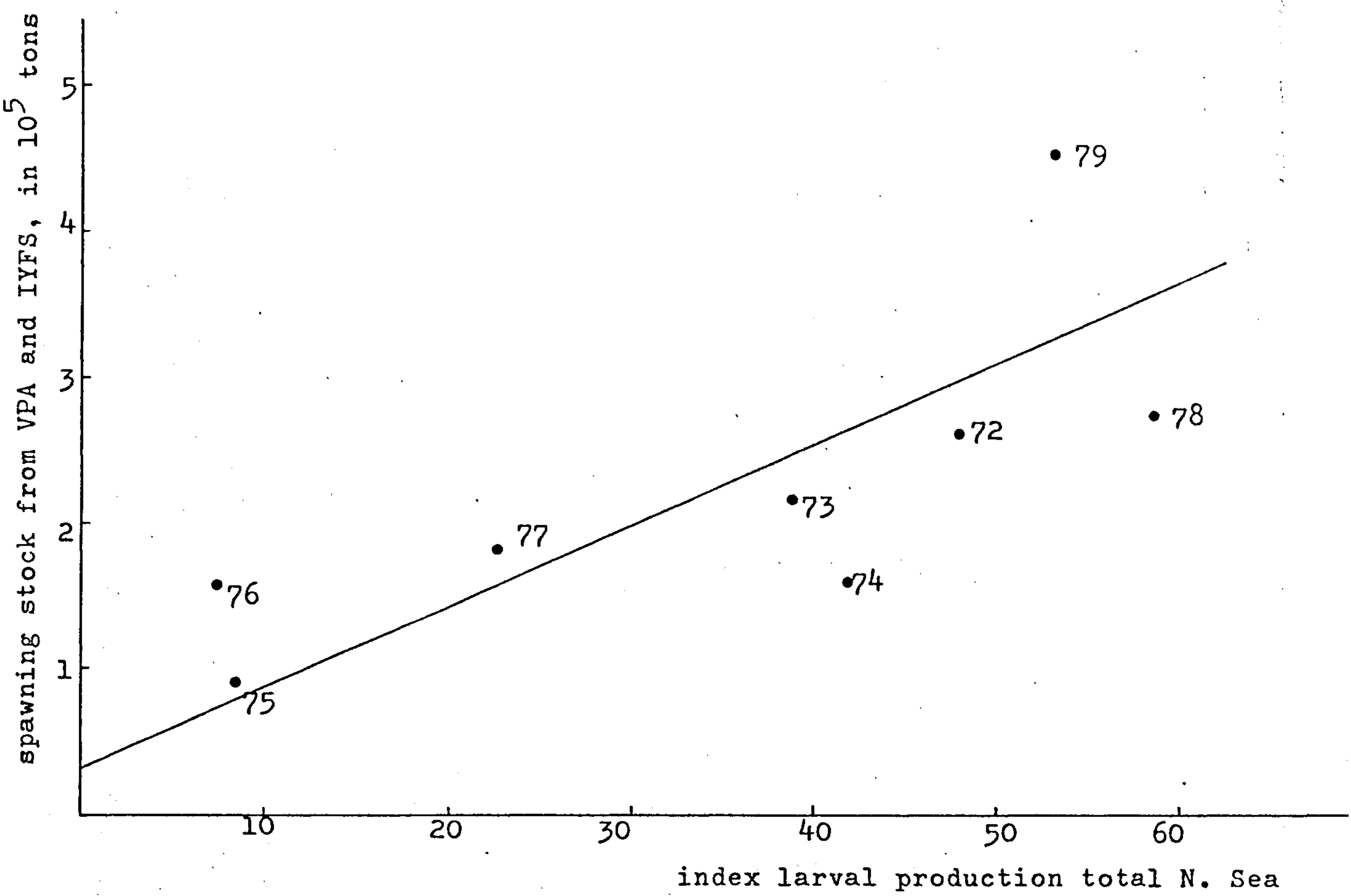

Fig. 2.

Functional regression of stock size on larval production for the total North Sea.