INTERNATIONAL COUNCIL FOR THE
EXPLORATION OF THE SEA.

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THE USE OF LARVAL ABUNDANCE DATA FOR ESTIMATING THE STOCK SIZE OF NORTH SEA HERRING.

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1. Introduction

An ICES programme of international herring larval surveys in the North Sea has been in operation since 1967. The main purpose of this programme has been to obtain independant estimates of the spawning stock size of North Sea herring (ICES 1971). At the present time, such independant estimates of stock size are urgently needed in order to gauge the recovery of the herring stock after the introduction of a total ban on herring fishing in the North Sea in March 1977.

Although a considerable amount of data from larval surveys has been collected by now, there have been serious problems in translating larval abundance figures into estimates of spawning stock size. One problem is the fact that larval surveys produce separate indices of spawning stock size for each of the subpopulations of which the North Sea stock is composed, whereas the Virtual Population Analysis (the only other source of stock estimates) produces estimates for the North Sea stock as a whole.

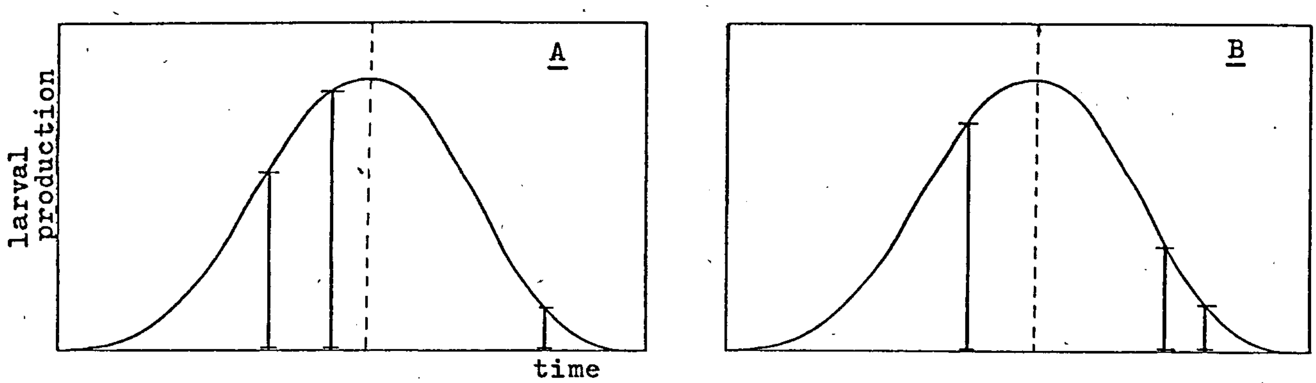
The Working Group on North Sea Herring Larval Surveys has tried to overcome this problem by making separate VPA's for the various divisions of the North Sea. Larval abundance figures for each division were then compared to estimates of stock size for these areas from VPA (ICES 1977a). A great drawback of this method, however, is that VPA estimates of spawning stock for separate North Sea divisions cannot be very accurate. VPA estimates are based on historical catches in the areas concerned, and it is well known that not all fish caught in a certain division belongs to the spawning stock of that division.

An alternative solution is to combine larval production estimates of the various spawning areas into one overall figure for the North Sea, and to compare this total larval production to the VPA estimates of total North Sea stock. This approach was recently recommended by the Herring Assessment Working Group for the area south of 62 °N (ICES 1978), and the present report gives the results of a first attempt at such an analysis.

2. Estimates of integrated larval production for individual spawning grounds.

a. Principle of estimating integrated larval production

The ICES Working Group on North Sea Herring Larval Surveys has estimated larval production from individual spawning areas by taking the mean of all reliable cruise estimates during the entire sampling period (ICES 1977a). This method has certain drawbacks, which have been pointed out previously by Van de Kamp (1976). If the majority of the surveys are made in the peak spawning period, the estimated production will be much higher than when most of the surveys are held at the beginning or end of the spawning period. The figure below illustrates this problem.



Curves A and B represent two spawning areas with exactly the same larval production. In both areas, 3 larval surveys have been made to estimate larval production. In area A two of the surveys by chance coincided with the peak larval abundance, whereas in area B only one survey hit the peak production period. If total production is estimated from the mean of all surveys, the estimate for area A will be higher than the estimate for area B.

The problem can be overcome by dividing the whole spawning season into shorter periods, calculating the mean abundance for each short period, and then integrating over the whole spawning season. If the spawning season in the example above had been divided into 2 periods, the sum of the means for both periods would not have been very different for area A and B.

Such an approach was taken by VAN DE KAMP (1976), who divided the spawning season of herring in the central and southern North Sea into 15-day periods, and then summed the abundance of larvae < 10 mm over the various periods. The period of 15 days was chosen because this was considered to be the maximum time span between hatching and the moment when the larvae reached a length of 10 mm. After each 15-day period, therefore, the size class < 10 mm would contain a completely new generation of larvae, and the sum of the abundances over successive 15-day periods would provide a good index of total larval production.

In the present report, the same division into 15-day periods has been used. Fig. 1 a-d show the surveys that have been considered in this report together with the division into 15-day periods. Results of the surveys were taken from the annual reports to the ICES Council Meeting. In cases where the results had not been reported to ICES, use was made of the original data sheets that had been exchanged between the participating countries after each survey.

To find the total larval production within a 15-day period, first the mean density of larvae per m2 was calculated for each statistical rectangle in the survey area. This was done by averaging all station values within a rectangle, including those on the border line. Subsequently, the mean density of the rectangle was multiplied by its surface area to find the total number of larvae within that rectangle. Fig. 2 shows the surface areas in square meters for all statistical rectangles in the various areas. Finally, the total abundance of larvae for the whole spawning area was found by summing the values for individual rectangles.

b. <u>Correction for incomplete sampling in area and in time.</u>

In case a certain spawning area had not been covered completely within a certain period, a correction was applied to compensate for the missed statistical rectangles. The correction factor was derived from the mean contribution (expressed in a percentage) that the rectangle concerned had made to the overall abundance during that particular 15-day period in years with complete coverage.

Larval production in 15-day periods without any sampling was estimated from the production in neighbouring periods, using the mean ratio between larval production in neighbouring periods in years with complete sampling.

c. Production estimates for small and medium sized larvae.

Total larval production for the whole spawning season was calculated by summing the abundance figures for successive 15-day periods. Tables I a-d give this calculation both for the smallest size categorie (< 10 mm) and for the medium sized larvae (10-15 mm). For the southern North Sea, these categories have been increased by 1 mm to account for the larger size of the larvae at the moment of hatching.

The ICES Herring Larvae Working Group has used so far only the abundance figures for larvae < 10 mm to estimate larval production and parent stock size. However, the abundance of larvae in the 10-15 mm category may provide a second estimate of larval production, possibly just as good as the first one. Although larvae of 10-15 mm will have sustained a higher (and variable) mortality than the smallest size category, their distribution is generally more even and sampling errors due to the patchiness of the larval distribution will be smaller.

3. Combination of larval production estimates for individual spawning grounds into one index of total North Sea spawning stock.

In order to arrive at an index of total North Sea spawning stock, the larval production estimates for individual spawning grounds, calculated in the previous paragraph, have somehow to be summed. However, it is known that herring in different parts of the North Sea have a different fecundity, and a certain amount of herring larvae will not always correspond to the same number of parent fish. Before the larval production figures can be summed, a correction should therefore be made for the mean fecundity of the fish on each spawning ground.

For the purpose of this report, a preliminary estimate was made of the mean fecundity in each subpopulation. First the length distribution per unit weight of the adult population was determined for each year, and then a length/fecundity formula was applied, giving the total fecundity of the adult population per unit weight. In this calculation, a sex ratio of 1 : 1 was assumed. Finally, the mean fecundity of the population in a particular year was expressed in number of eggs per kg spawning stock.

Length frequency distributions for the various subpopulations were obtained from the Dutch market sampling system. While this material was rather extensive for the central and southern North Sea, relatively few data were available for the Buchan and Shetland/Orkney area (Table II). For the central and northern North Sea, data from July and August were used, and for the southern North Sea data from October and November. Only fish in maturity stages III, IV and V were considered. Fish in stages VI and VII showed pronounced changes in weight over short periods, resulting in fluctuations in the mean number of fish per kg, and thus in the mean fecundity per kg.

The length/fecundity formulas used were:

Shetland/Orkney) Buchan)	$F = 0.1980\ L^{3.8417}$	(Baxter 1959)
Central North Sea	$F = 5.882\ L^{3} - 51670$	(Zijlstra 1973)
Southern North Sea	$F = 2.826\ L^{3} - 16680$	(Zijlstra 1973)

The formula given by Baxter (1959) refers to fish spawning in the Buchan area. No fecundity data have been published for Shetland/ Orkney spawners, but it is assumed that they resemble the Buchan spawners in this respect (Saville, personal communication). The fecundity formula for Buchan spawners was therefore also applied to the Shetland/Orkney region.

Table II presents the calculation of the mean fecundity/kg for the various subpopulations over the period 1973-1976. It is seen that very similar results were obtained for successive years on the same spawning ground. Apparently, the mean fecundity/kg on a particular spawning ground does not depend very critical on the length (or age) composition of the parent stock. In years with many young fish, the low fecundity of individual fish is counterbalanced by the high number of individuals per kg.

Comparing the various spawning grounds, it is seen that the differences between central North Sea, Buchan,and Shetland/Orkneys are also relatively small. The only major difference in mean fecundity/kg exists between the southern North Sea and the other populations; the southern herring having only little more than half the number of eggs/ kg as compared to the central and northern populations.

In view of other possible errors in larval production estimates (due to sampling errors or variable natural mortality), it was considered unpractical to pay too much attention to minor differences in mean fecundity/kg between populations or from year to year. The only worth while distinction to be made was between the southern North Sea and the other populations. For the calculations in the next paragraph, the rounded mean values for the period 1973-76 were used. These were 105 000 eggs/ kg for the southern North Sea and 180 000 eggs/kg for the central and northern North Sea.

The calculation of an index for total spawning stock from larval production figures was based on the following method.

The larval production from a certain subpopulation can be described by the expression

$P = W.Fec.\ (1 - M)$

in which P = total larval production (expressed as number of larvae reaching a certain length class).

W = weight spawning stock in kg.

Fec = mean fecundity in number of eggs per kg spawning stock.

M = mortality between spawning and the time when the larvae reach the length class defined under P.

The size of the spawning stock can thus be estimated from the larval production:

$$W = \frac{P}{Fec.\ (1 - M)}$$

In most cases, M will not be known, and may even be different from year to year. All we can do is assume M to be constant, and in that way the expression above can be used as a relative index of spawning stock.

If a stock is composed of several subpopulations with a different mean fecundity/kg each, the formula above can be applied to each of the individual subpopulations:

$$W_A = \frac{P_A}{Fec_A \cdot (1 - M_A)} \qquad W_B = \frac{P_B}{Fec_B \cdot (1 - M_B)} \qquad \text{etc.}$$

If we assume M to be constant, the weight of the total spawning stock can be expressed as

$$\frac{1}{(1 - M)} \left(\frac{P_A}{Fec_A} + \frac{P_B}{Fec_B} + \ldots\ldots\ldots \right)$$

Thus, a relative index of the total spawning stock can be obtained by dividing the larval production of each subpopulation by its mean fecundity/kg, and summing the obtained values.

Tables III a and III b show the results of this procedure, applied to the larval production figures for the North Sea in the years 1967-76. Both the size classes < 10 mm and 10-15 mm have been used to estimate the spawning stock.

4. Comparison between estimates of total North Sea spawning stock from larval surveys and from VPA.

The index of spawning stock derived from larval surveys is necessarily a relative one because of the unknown factor M (mortality between spawning and moment of larval survey). There is, however, a method of callibrating these relative indices because we do have estimates of absolute stock size from Virtual Population Analysis. Table III also presents the VPA estimates of spawning stock size for the years 1967-76. These values were calculated by taking the stock sizes at the beginning of the years (from ICES 1977b), and applying to each year class 2/3 of the total mortality which the year class sustained during the whole of the following season.

In figure 3, the indices of stock size derived from larval surveys have been plotted against those from VPA. It can be seen that there is no correlation between the two sets of data, neither for the larvae < 10 mm nor for the 10-15 mm.

An examination of figure 3 shows that the lack of correlation is particularly due to the years 1967, 68 and 69, in which relatively few larvae were found compared to the VPA stock sizes. The Working Group on North Sea Herring Larval Surveys has suggested that sampling of small larvae in the earlier surveys may have been inefficient, particularly in the northern area, due to failure to fish sufficiently close to the bottom (ICES 1977a).

Because of this uncertainty concerning the earlier larval production estimates, it has been examined what the effect would be of leaving out the surveys made during the first 5 years of the programme and only considering the 5 most recent years. If only these 5 most recent years are plotted, a much better correlation is obtained than in the first case. Only the year 1976 stands out as exceptional, having a relatively low larval production compared to its VPA stock size. There may be two explanations to account for the exceptional position of 1976. In the first place, the VPA-estimate of stock size is entirely based on the assumption of fishing mortality for 1976. The Herring Working Group for the area south of 62 °N has admitted that the actual spawning stock size in 1976 could have been substantially below the assumed 155 000 tons (ICES 1977b). On the other hand, the larval production in 1976 may have been affected by exceptionally high water temperatures, especially in the central North Sea. It is known that such exceptional temperatures have a negative effect on the production of herring larvae (Postuma, 1971).

Of the 5 most recent pairs of values, the year 1976 seems a bit doubtful, which leaves only 4 pairs of values as the most reliable data to describe the relationship between larval production and VPA stock size. This number of observations is obviously too low to calculate a regression line in the usual way. Still the data can be used to construct a regression line, because we can make two safe assumptions about the existing relationship. In the first place, the regression line has to go through the origin. It is obvious that if the stock size is zero, larval production will be nil and vice versa. In the second place, the relationship between spawning stock size and larval production should be of a directly proportional nature, at least over the range of low stock sizes that we are dealing with at present. A doubling of spawning stock for instance, should result in a doubling of larval production. The relationship that can be expected between VPA stock estimates, and indices of stock size based on larval surveys should therefore be described by the formula

$$y = a.x$$

In figure 5 such lines have been drawn, both for the set of data based on larvae < 10 mm and for the data based on 10-15 mm larvae. The lines have been drawn through the origin and through the arithmetic mean of the years 1972-75. For the two size categories of larvae, the following relationship was obtained.

larvae < 10 mm	$y = 5.44\ x$
larvae 10-15 mm	$y = 8.72\ x$

in which y = VPA estimate of spawning stock, in 1000 tons
x = index of spawning stock from larval surveys (Table III).

5. Discussion

In the previous section, it was mentioned that sampling errors in the earlier years of the programme may have caused a systematic under-estimate of larval production on the northern spawning grounds. This may be one explanation for the lack of correlation between stock indices based on larval surveys, and those based on VPA, especially in the earlier years. In addition to sampling errors during the larval surveys, however, there may be other factors that can disturb this correlation. In this section, both sampling errors and some of these other factors will be considered in a little more detail.

a. Errors in sampling the larvae.

There are a large number of possible errors in the sampling of herring larvae, and although sampling methods have been improved in the past, they may still not be quite perfect yet. The most likely

sources of error are:
- Not fishing close enough to the bottom. Especially in the earlier years of the surveys not all samplers were equiped with real-time depth recorders, and the depth of the sampler was estimated from the amount of warp paid out. This may have resulted in insufficient sampling of the lowest water layer, where the youngest larval stages are thought to be concentrated.
- Incomplete coverage of larval concentrations in time and area. Although the larval data presented in this report have been corrected for missed periods and areas, the corrected figures may still be poor estimates of the actual production. Correction factors are based on average timing and distribution of larval production, and they may not be applicable in years with an abnormal spawning pattern.

  A factor which has not been compensated for is the missed sampling in late August in the Shetland/Orkney area. Judging from the density of small and medium sized larvae in the first half of September during most years, there must have been a substantial larval production in that area already in the second half of August. However, too few observations during this period were available to calculate a correction factor for missed sampling in this period.
- Exclusion of yolk-sac larvae. These larvae have so far been excluded from the abundance estimates because of their patchy distribution. However, this is not a valid reason for not counting these larvae; moreover it is not sure whether all countries have used the same criteria to define the end of the yolk-sac stage.
- Differences in sampling gear and method. During the meeting of the Working Group on North Sea Herring Larval Surveys, it appeared that there was a considerable diversity in the detailed designed of the samplers used (ICES 1977a). Shortly before this meeting, it had been discovered that one country (The Netherlands) had even been using a different mesh size in the samplers.
  Although efforts have been made to standardize further the sampling gear, there is still a variety of samplers in use at this moment. Few comparative fishing experiments have been conducted to compare the actual catch rates of samplers used by different countries.

b. Errors due to exchange of fish and larvae between the North Sea and Division VIa.

The border between North Sea and VIa at 4° West is not a natural boundary, dividing two clearly separated populations. On the contrary, the spawning area of herring north of Scotland extends right across this borderline, with an important production of larvae on both sides of the 4 °W. In addition, there is a continuous migration of juvenile herring across this border (Saville and Bailey, 1978) and probably also of adult herring.

The existence of this boundary at 4°W presents some special problems to the assessment of both VPA stock size and larval production. The VPA estimate of stock size is based on fish caught exclusively in the North Sea. However, part of the population fished during the summer in the northern North Sea may quite well spawn just west of 4 °W, and its larval production may therefore not be included in the larval abundance index for the total North Sea. One can even imagine that the same fish shift their spawning ground back and forth across the 4 °W in successive years, depending on hydrographic conditions.

Another complication is that medium sized larvae in the Shetland/ Orkney area can never be ascribed with absolute certainty to either the North Sea population or the VIa stock. They may have been born in the area, but it is also quite possible that they were born in VIa and crossed the boundary while drifting with the residual current.

For a proper comparison of stock size and larval production, it would be far more convenient if the northern part of Division VIa, say north of 57 °N, would be considered in combination with the North Sea.

c. Variable natural mortality in the egg and early larval stage.

In the analysis of larval production data presented in this report it has been assumed that the natural mortality (M) between spawning and the moment of sampling is constant from year to year, and also between different subpopulations. This is probably not the case. Differences in hydrographic conditions may have a direct or indirect effect on the survival of eggs and larvae. Postuma (1971) found a relationship between bottom temperature on spawning grounds and subsequent recruitment; an indication that hydrographic factors control to some extent the hatching succes and survival of the early larvae.

The question is, however, not whether M is absolutely constant or not, but in what order of magnitude it is fluctuating. If its fluctuations are relatively small, say in the order of ± 10 %, the larval surveys can give an adequate estimate of the spawning stock from year to year.

If the fluctuations are larger, say 25 %, the survey results from an individual year will not provide a reliable stock estimate, but the mean larval production over a period of 2 - 3 years will still be quite meaningful.

In case the fluctuations in M are much larger than 25 %, the larval surveys have little use for the assessment of the spawning stock, unless a method can be found to correct for fluctuations in M. It is possible for instance, that the relationship between M and some abiotic factors can be quantified, and that larval production figures can thus be corrected, at least partly, for fluctuations in M.

At this moment, it is hard to say in what order of magnitude M is fluctuating. In the earlier years of the surveys, larval production estimates changed drastically from year to year, apparently independant of the development of stock size. However, it is not possible to decide whether these apparent fluctuations in larval production were due to vatiations in M, or to any of the sources of error discussed above. For the most recent years, the relationship between larval production and VPA stock size appears to be much better, which would indicate a relatively constant M.

A clear picture of the variation in M, however, can only be obtained after a further reduction of the errors in larval sampling and VPA.

6. Acknowledgements.

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I am also grateful to the various herring experts in Lowestoft, Aberdeen, Hamburg and Reykjavik, who provided me with results from larval surveys that had not been reported to ICES previously.

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/MV/ds

TABLE Ia - Total production estimates small and medium sized larvae x 10^9
Shetland-Orkneys.

	1-15 Sept		16-30 Sept		1-15 Oct		Total	
	<10	10-15	<10	10-15	<10	10-15	<10	10-15
1967	669	1019	668	1225	96*	790*	1433	3034
1968	251	318	44	172	6*	111*	301	601
1969	341	520	241	491	35*	317*	617	1328
1970	1149*	1003*	553	1523	80	786	1782	3312
1971	1393	275	226	580	64	1157	1683	2012
1972	1378	247	5412	2347	780*	1513*	7570	4107
1973	2441	485	955	1260	138*	812*	3534	2557
1974	720	506	450	850	15	176	1185	1532
1975	447	325	108	566	16*	365*	571	1256
1976	972	201	67	184	10*	42*	1049	427

*) estimated.

TABLE Ib - Total production estimates small and medium sized larvae x 10^9.
Buchan.

	1-15 Sept		16-30 Sept		1-15 Oct		Total Sept	
	<10	10-15	<10	10-15	<10	10-15	<10	10-15
1967	12	127	2	69	5	5	19	201
1968	0	2	0	3	0*	0*	0	5
1969	1	2	0	0	0*	0*	1	2
1970	6	2	20	1	2	7	28	10
1971	139	120	110	333	23	28	272	481
1972	195	0	5	25	1*	9*	201	34
1973	3	0	17	24	3	15	23	39
1974	46	36	670	116	10	50	726	202
1975	278	12	311*	40*	2	3	591	55
1976	1	14	1	8	0*	3*	2	25

*) estimated.

TABLE Ic - Total production estimates small and medium sized larvae x 10^9
<u>Central North Sea.</u>

	1-15 Sept		16-30 Sept		1-15 Oct		16-31 Oct		Total	
	<10	10-15	<10	10-15	<10	10-15	<10	10-15	<10	10-15
1967	3132	5	383	65	22	157	341*	37*	1878	264
1968	345	53	0	0	0	0	85	8	430	61
1969	14	6	2	0	14	152	3*	26*	33	184
1970	570	28	315*	180*	182	267	103*	77*	1170	552
1971	118	21	173	156	511	258	70	202	872	637
1972	288	33	143	154	159	425	31	44	621	656
1973	662	50	1175	581	1253	448	161	221	3251	1300
1974	2173*	288*	1484*	452*	1368	452	485*	194*	5510	1386
1975	131*	271*	109	102	83	721	9	209	332	1303
1976	97	22	149	309	4	104	17	6	267	441

*) estimated.

TABLE Id - Total production estimates small and medium sized larvae x 10^9
Southern Bight and English Channel.

	mid December**		1 - 15 Jan		16 - 31 Jan		Christmas ** correction		Total	
	<11	11-16	<11	11-16	<11	11-16	<11	11-16	<11	11-16
1967/68	28	9	46*	16*	3*	8*	19	6	96	39
1968/69	61	12	100*	21*	2	5	40	8	203	46
1969/70	21	9	271	92	14*	34*	73	25	379	160
1970/71	105	63	10	105	3	43	29	42	147	253
1971/72	7	3	4	6	1	2	3	2	15	13
1972/73	22	12	77	70	4	41	25	21	128	144
1973/74	21	87	34*	155*	6	18	14	61	75	321
1974/75	2	13	17	4	0	2	5	4	24	23
1975/76	4	4	8	5	1	7	3	2	16	18
1976/77	3*	3*	5	6	0*	3*	2	2	10	14

*) estimated.

**)The larval surveys in the month December cannot be divided into two 15-day periods, because most surveys have been made in the middle of the month, and none at all during the end of the month because of the Christmas holiday (figure 1d). Therefore all December surveys were ascribed to the period "mid-December", roughly coinciding with the 2nd and 3rd week of December. To compensate for the missed sampling in the 4th week of December, a "Christmas correction" was applied, which was equal to

$$\frac{\text{(abundance mid-December)} + \text{(abundance 1-15 January)}}{4}$$

TABLE II - Calculation of mean fecundity in number of eggs/kg parent stock. Length distributions based on fish in maturity stage III - V.

Area and season	Shetland-Orkney July-Aug				Buchan July-Aug				Central North Sea July-Aug				Southern North Sea Oct-Nov			
year	1973	1974	1975	1976	1973	1974	1975	1976	1973	1974	1975	1976	1973	1974	1975	1976
length distribution																
22.0			1	2								2			1	1
22.5			1	3					1			7		1	1	1
23.0	2		2	6				1	5	2	1	9	1	3	7	3
23.5			1	9			2	5	20	6	7	18	6	5	17	7
24.0	4		2	9		1	1	3	32	14	12	27	9	11	39	13
24.5	8	1	4	5		2	1	5	43	27	10	26	20	9	54	19
25.0	13	2	7	7		3	3	4	77	29	21	28	20	7	45	13
25.5	21	1	7	8		4	4	4	95	32	25	20	21	8	36	12
26.0	18	1	8	9		8	2	1	102	47	27	23	23	7	25	10
26.5	16	2	5.	16		4	3	3	69	48	31	12	19	8	16	7
27.0	12	8	7	6		5	3	3	36	64	48	17	10	11	16	5
27.5	11	13	9	6		9	1	2	23	50	58	13	7	7	10	1
28.0	7	8	4	2	no data	4	1	1	16	36	55	21	1	4	6	
28.5	5	9	9	2		2	1	3	11	22	44	17	4	3	5	
29.0	4	3	7	1		2		2	9	14	32	26	2	1	3	
29.5	1	1	6			1		3	6	3	15	24		1	2	
30.0	2		8						2	3	8	11	1			
30.5	3		6	1		1				3	4	5		1	1	
31.0	2		6								1	2				
31.5	1		3													
32.0			1	2												
32.5			2													
33.0											1					
Weight sample in kg	22.3	9.7	23.1	14.7		8.1	3.4	6.5	84.8	67.5	74.4	52.8	22.7	13.2	42.0	12.4
Tot.fecundity $x10^{3}$	4122	1718	3949	2558		1468	612	1150	14597	12596	14285	9604	2377	1472	4366	1325
Fecundity/kg $x10^{3}$	185	177	171	174		181	180	177	172	187	192	182	105	112	104	107

TABLE IIIa - Indices of total North Sea spawning stock calculated from production of larvae <10 mm (<11 mm in Southern North Sea) on individual spawning grounds.

YEAR	Central and northern North Sea		Southern North Sea			
	total larval production (P) (billions)	index spawning stock ($\frac{P}{Fec}$)	total larval production (P) (billions)	index spawning stock ($\frac{P}{Fec}$)	index total N. Sea spawning stock ($\Sigma \frac{P}{Fec}$)	Spawning stock from VPA in '000 tons
1967	5350	29.72	96	0.91	30.63	767
1968	731	4.06	203	1.93	5.99	361
1969	651	3.62	379	3.61	7.23	348
1970	2980	16.56	147	1.40	17.96	309
1971	2827	15.71	15	0.14	15.85	223
1972	8392	46.62	128	1.22	47.84	265
1973	6808	37.82	75	0.71	38.53	220
1974	7421	41.23	24	0.23	41.46	161
1975	1494	8.30	16	0.15	8.45	95
1976	1318	7.32	10	0.10	7.42	155

TABLE IIIb - Indices of total North Sea spawning stock calculated from production of 10-15 mm larvae (11-16 mm in southern North Sea) on individual spawning grounds.

YEAR	Central and northern North Sea		Southern North Sea			
	total larval production (P) (billions)	index spawning stock ($\frac{P}{Fec}$)	total larval production (P)	index spawning stock ($\frac{P}{Fec}$)	index total N. Sea spawning stock ($\sum \frac{P}{Fec}$)	Spawning stock from VPA in '000 tons
1967	3499	19.44	39	0.37	19.81	767
1968	667	3.71	46	0.44	4.15	361
1969	1514	8.41	160	1.52	9.93	348
1970	3874	21.52	253	2.41	23.93	309
1971	3365	18.69	13	0.12	18.81	223
1972	4797	26.65	144	1.37	28.02	265
1973	3896	21.64	321	3.06	24.70	220
1974	3120	17.33	23	0.22	17.55	161
1975	2614	14.52	18	0.17	14.69	95
1976	893	4.96	14	0.13	5.09	155

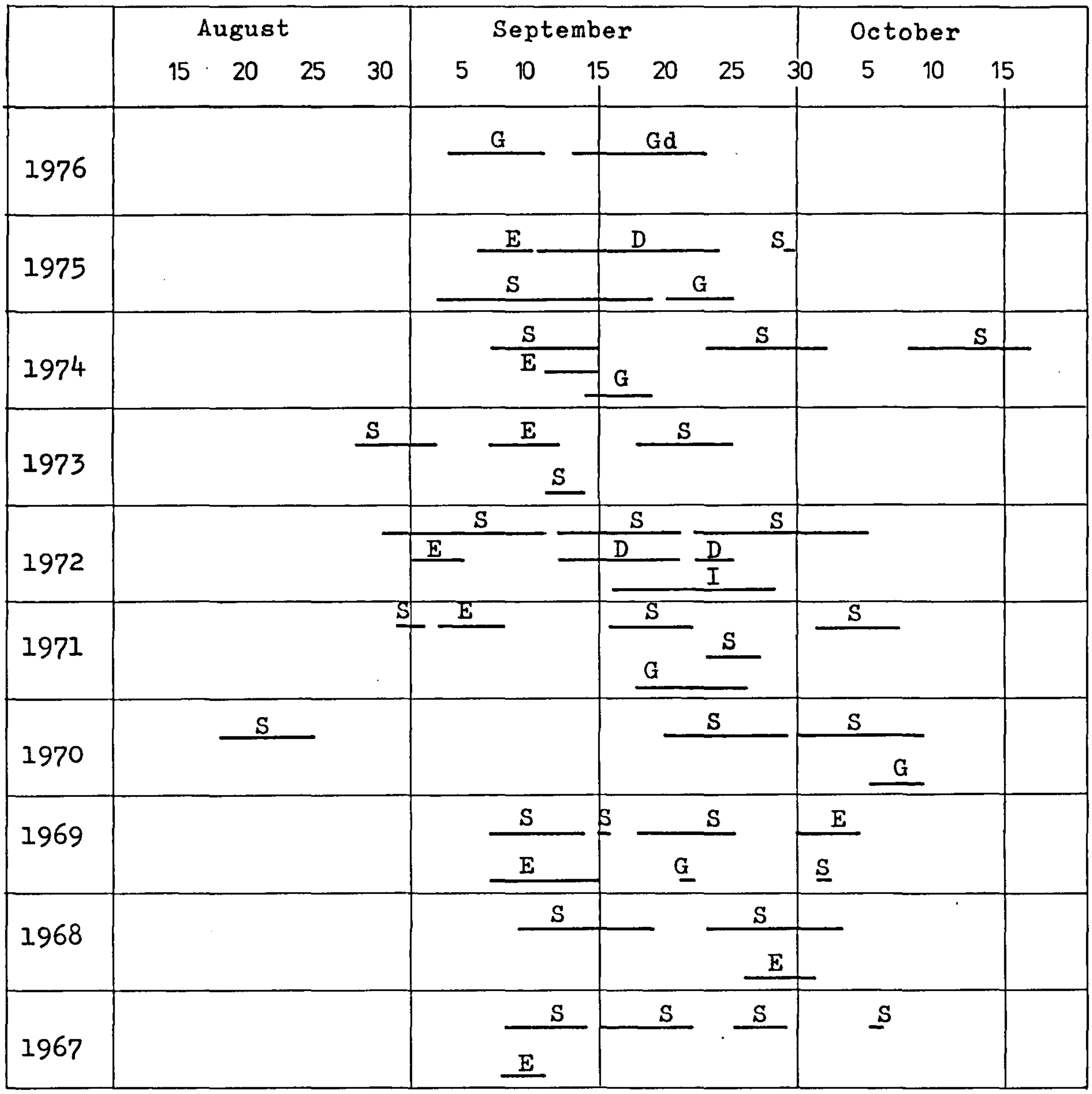


Figure 1a. Surveys used for the calculation of larval production
SHETLAND / ORKNEYS

D - Denmark
E - England
G - Fed. Rep. Germany
Gd - German Dem. Rep.
I - Iceland
S - Scotland

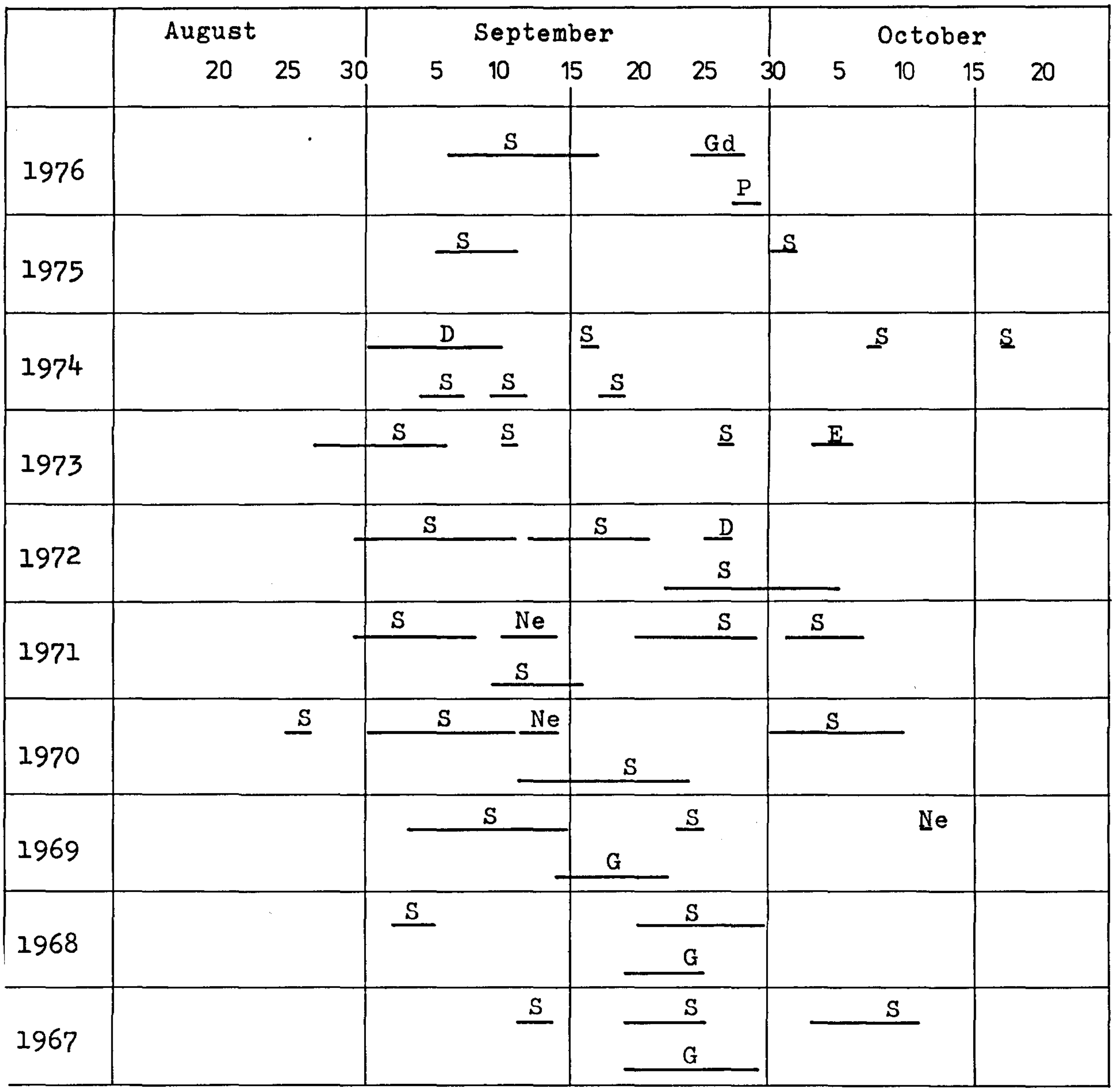


Figure 1b. Surveys used for the calculation of larval production BUCHAN

D - Denmark
E - England
G - Fed. Rep. Germany
Gd - German Dem. Rep.
Ne - Netherlands
P - Poland
S - Scotland

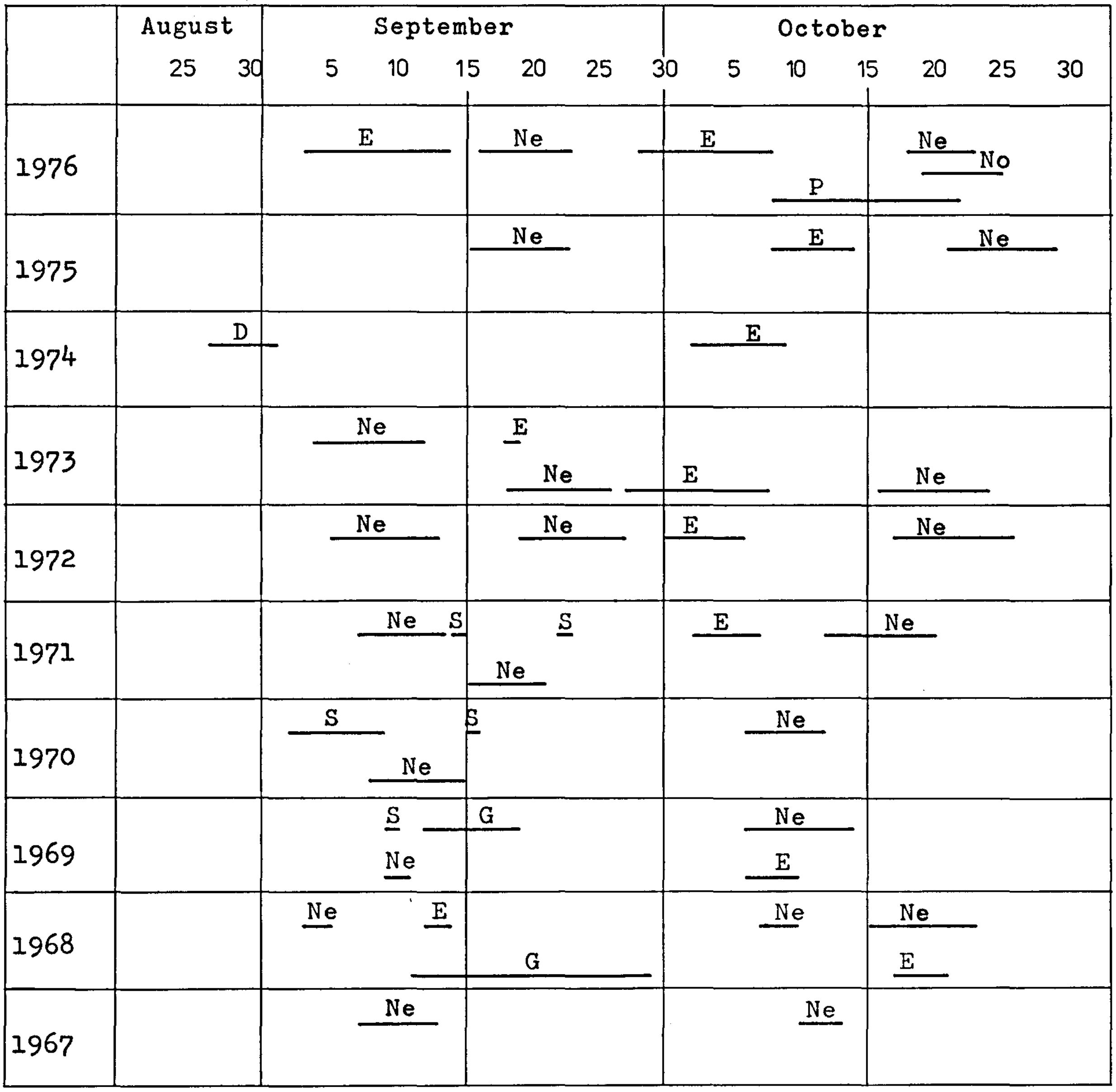


Figure 1c. Surveys used for the calculation of larval production
CENTRAL NORTH SEA

D - Denmark
E - England
G - Fed. Rep. Germany
Ne - Netherlands
No - Norway
S - Scotland

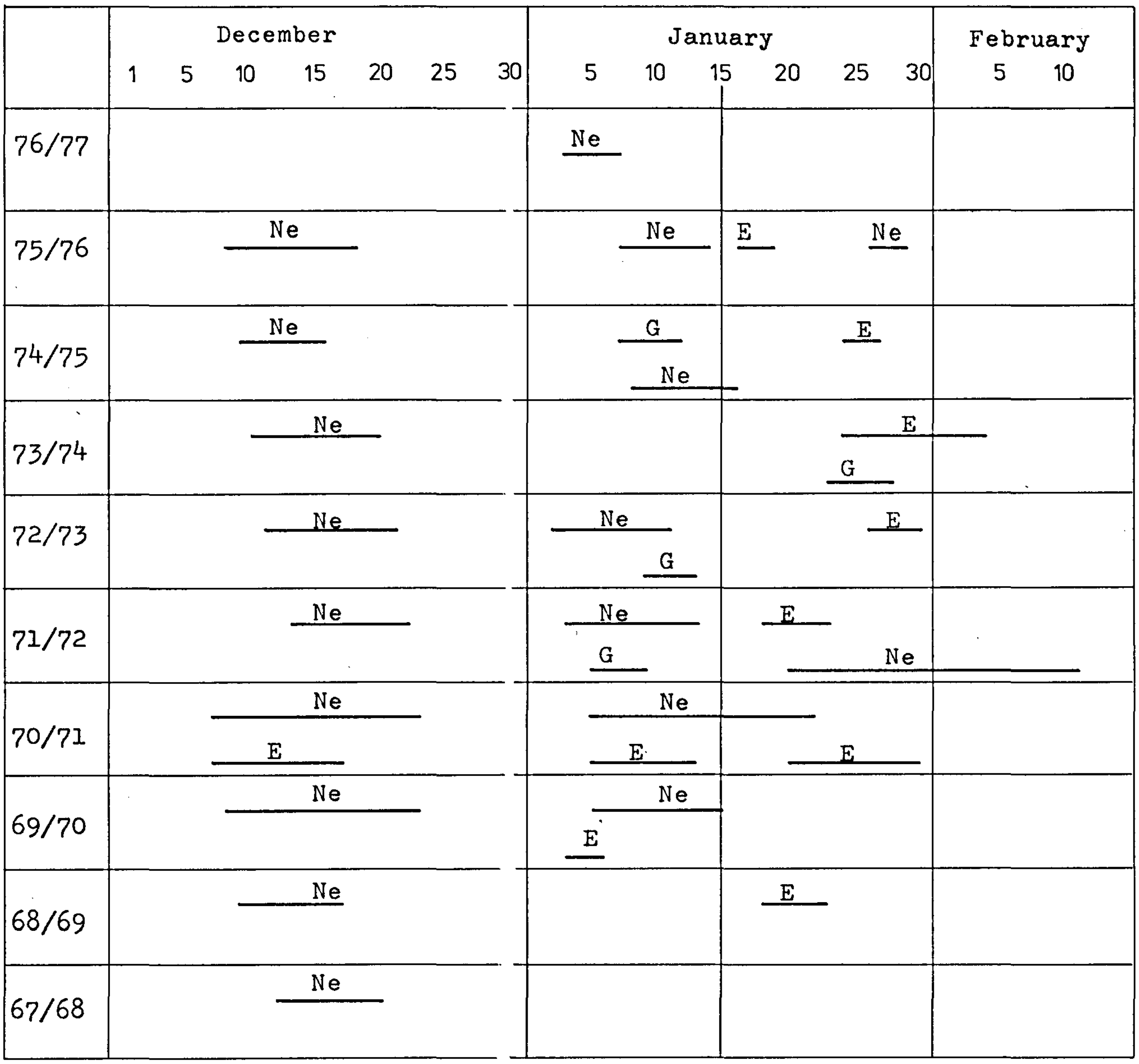


Figure 1d. Surveys used for the calculation of larval production
SOUTHERN BIGHT - ENGLISH CHANNEL

E - England
G - Fed. Rep. Germany
Ne - Netherlands

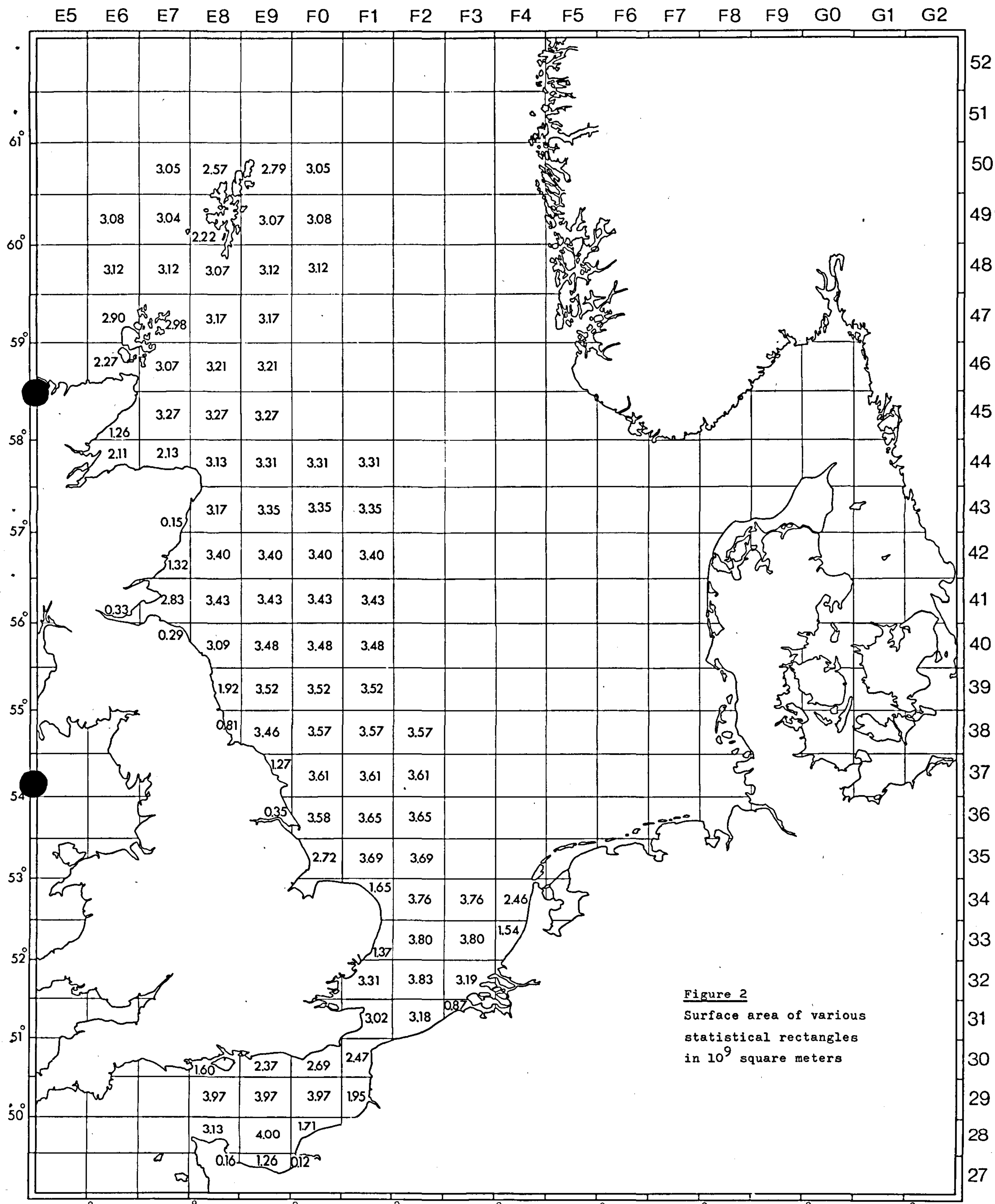
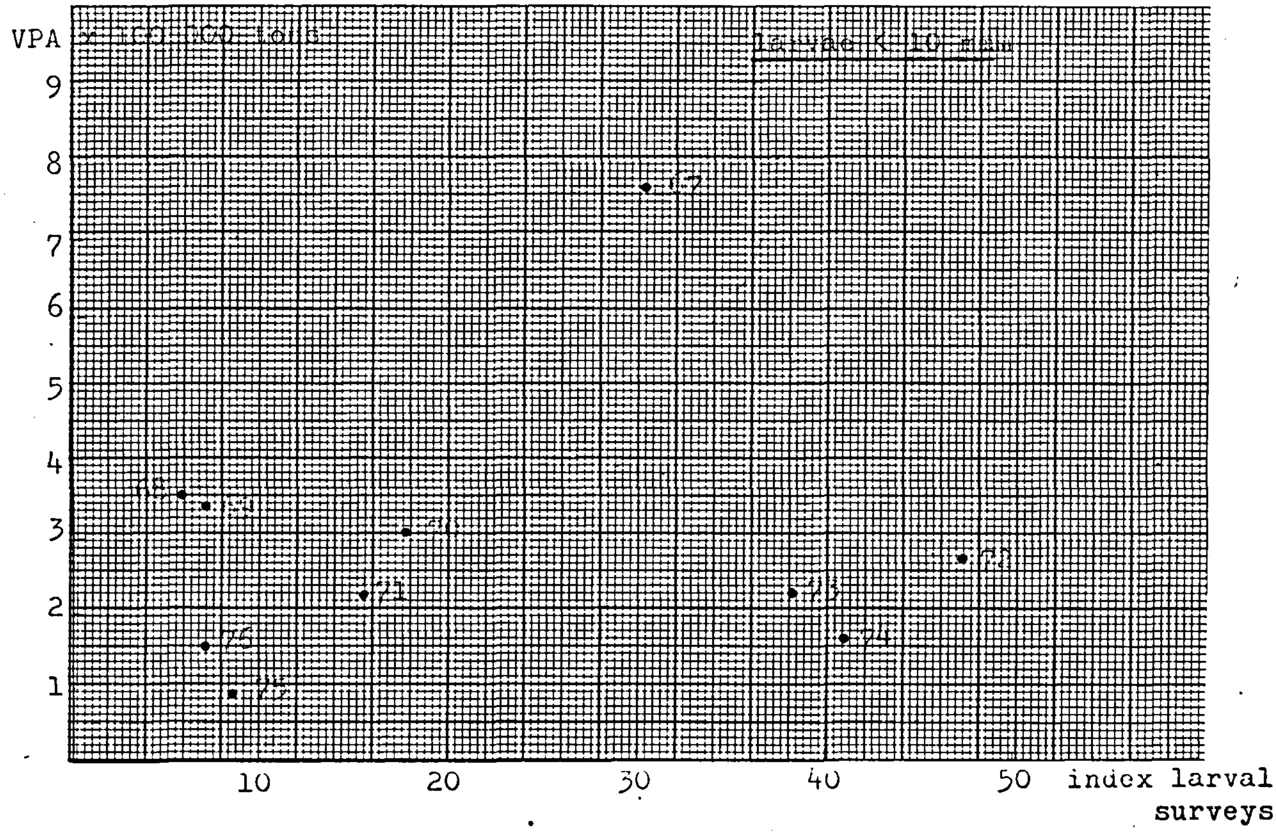


Figure 2
Surface area of various statistical rectangles in 10^9 square meters



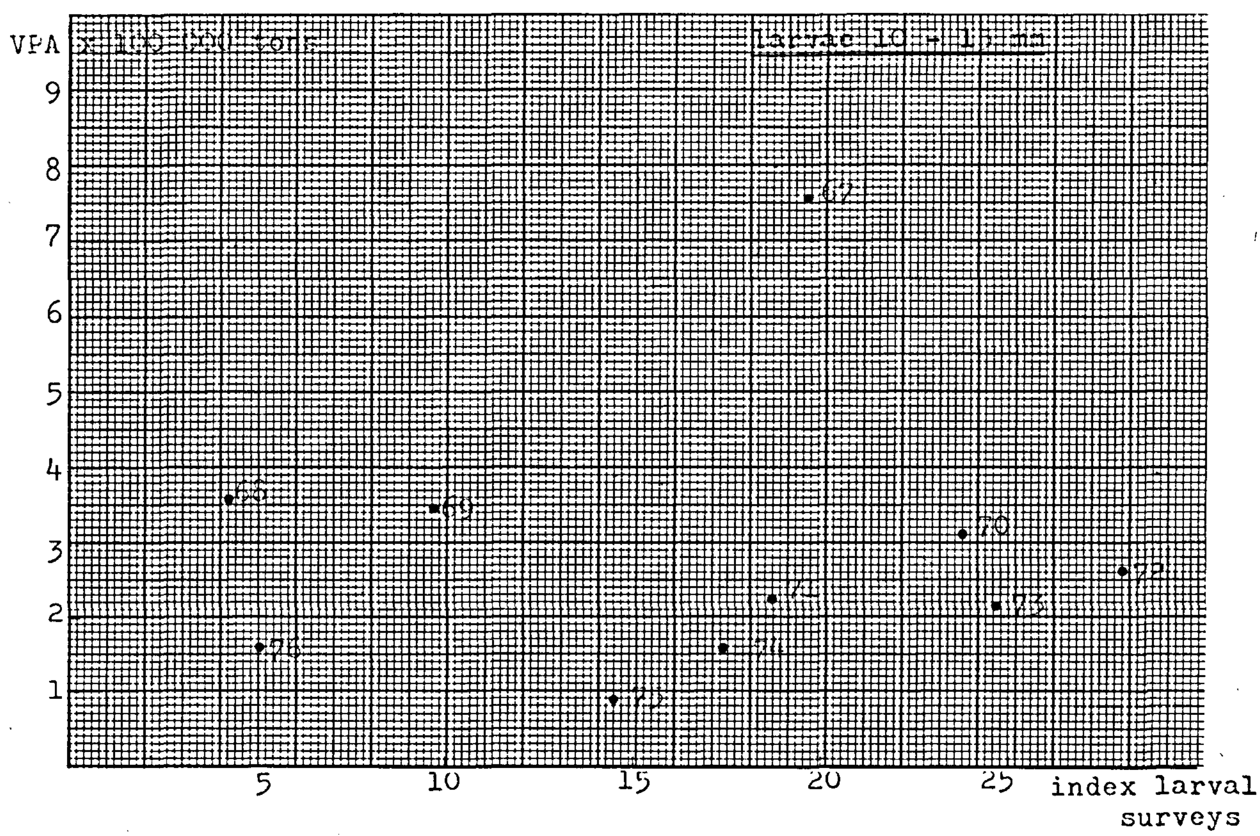


Figure 3. Relationship between estimates of total North Sea spawning stock from larval surveys and from VPA 1967 - 1976

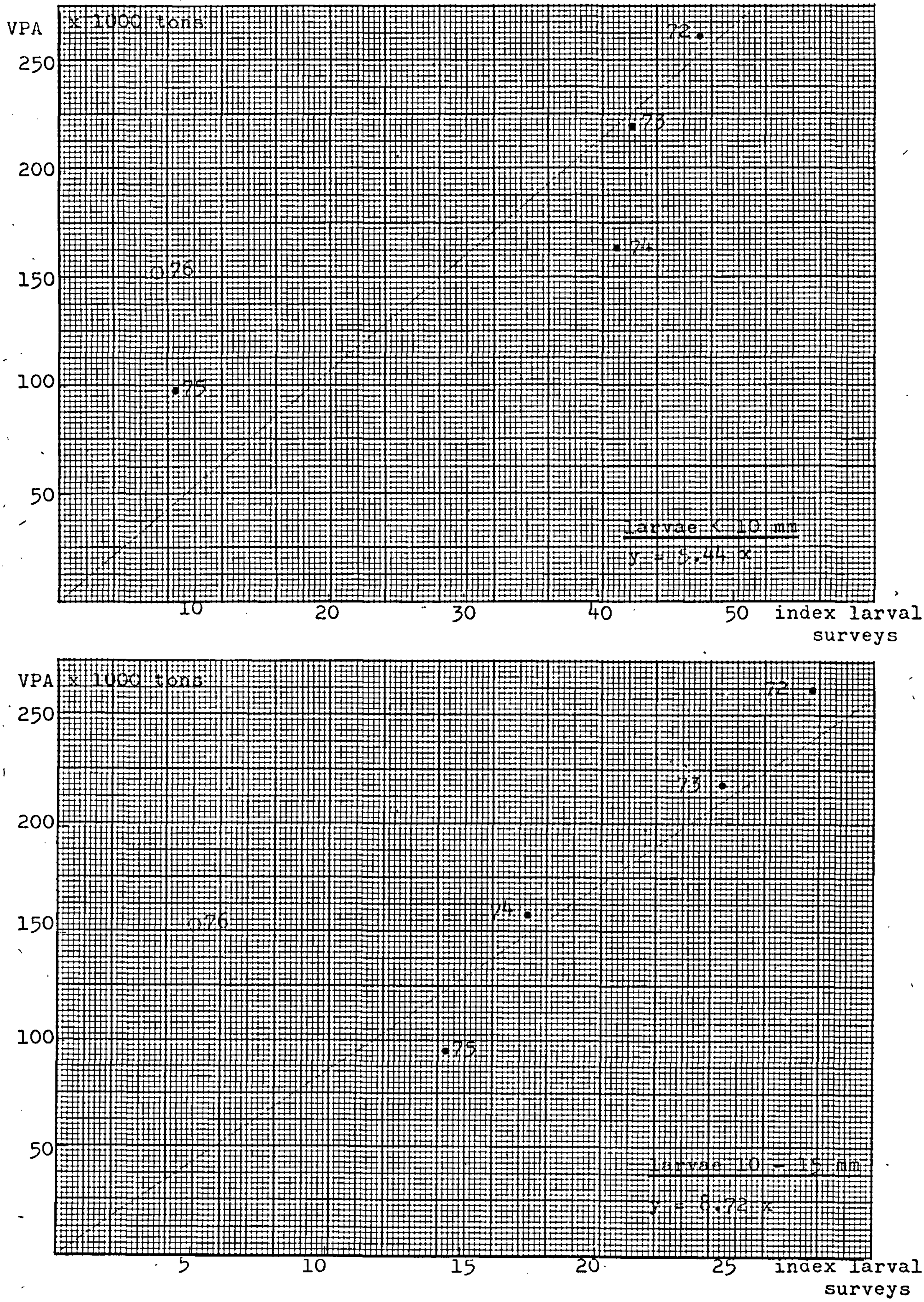


Figure 4. Relationship between estimates of total North Sea spawning stock from larval surveys and from VPA, 1972 - 1975