INTERNATIONAL COUNCIL FOR
THE EXPLORATION OF THE SEA

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Demersal Fish Committee/
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EGG PRODUCTION OF NORTH SEA SOLE IN 1988.

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F.A. van Beek
Netherlands Institute for Fishery Investigations
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ABSTRACT

In 1988 the Netherlands carried out five sole egg surveys in the North Sea. The major aim of the surveys was to estimate the egg production. As a consequence of a very mild 1987 -1988 winter the spawning season was advanced. Spawning started and stopped earlier than in normal years. The estimate of the egg production in 1988 is 4.8 10^{12} compared to 15.5 10^{12} in 1984. Although this estimate must be considered as an underestimate, it indicates a reduction in the spawning biomass of sole in the North Sea in recent years. This indication is supported by the VPA and by a beam trawl survey.

INTRODUCTION

The advice, given by fishery biologists, on TAC levels for important commercial fish stocks is predominantly based on stock assessments using commercial catch data and mathematical models as VPA or length cohort analysis. The quality of the advice will often improve when additional information on the level of recruitment or trends in stock biomass is available from independent sources as young fish surveys, surveys on adult fish, acoustic surveys or egg surveys.

In recent years assessment working experienced difficulties in assessing the state of some stocks because of a detoriation in landing statistics (unreported landings, unsampled landings, no reliable effort data). Also the stock assessment of North Sea sole (*Solea solea* L.) suffers from these problems and now leans heavily on independent information from beam trawl surveys and egg surveys.

In 1984 international sole egg surveys were carried out in the North Sea and English Channel. The main purpose of these surveys was to study the spatial distribution of spawning areas and to estimate the egg production in both areas (ANON. 1986). For 1988 an international egg survey on mackerel and horse mackerel was planned in the second quarter in the North Sea (IVERSEN et al, 1989). The Dutch contribution to this survey covered a major part of the sole spawning areas in spawning time in the southern North Sea and offered the opportunity to combine this survey with a sole egg survey. For this purpose the station grid was extended to the coastal areas and an extra survey was added at the end or March in order to cover the beginning of spawning.

This paper summarizes the results of the 1988 sole egg surveys and compares these with those of the 1984 surveys.

STATION GRIDS AND SAMPLING PROCEDURES

Five surveys were carried out in the period 5 April - 29 July by R.V. "ISIS", R.V. "TRIDENS" and the charter "KW 34". The sampling periods and number of hauls in each survey are given in Table 1. The surveys were directed to sole, mackerel and horse mackerel eggs. The survey week numbers are the same as in the 1984 sole egg survey, except for the 1st survey, which started one week later. The last survey was carried out mainly for mackerel and horse mackerel as sole spawning ceased. As the surveys were a combined species surveys a larger area was covered than was necessary for sole. At least one sample in each half statistical rectangle was planned. Based on the distribution of sole eggs found in the 1984 survey the station grid was intensified to 4 or 8 subrectangles per rectangle in the areas and periods were sole eggs were expected. Therefore the station grid differs between surveys. As the estuaries (Scheldt, Wadden Sea) had a minor contribution in the total egg production in 1984 these areas were not included in the 1988 survey. The English coast was not included in the 1st survey. In 1984 only in the Thames area sole eggs were found in the 1st survey. Figures 1a-e show the station grids.

The plankton sampler used in the surveys was the Dutch Gulf III torpedo with an internal diameter of 50 cm and a 19 cm conical nose cone, equipped with a mechanical flow meter. This gear has been calibrated by WOOD and NICHOLS (1983).

The planning group for the 1984 sole egg survey (ANON, 1984) recommended that a water volume of at least 50 m^3 should be filtered each haul. This value coincides with a haul duration of 10 minutes, fishing 3 minutes per 10 meter depth with a speed of 5 miles through the water. In order to avoid clogging of the net, the maximum recommended mesh size for sole eggs of 500μ was used.

Each sample consisted of a (single or multiple) oblique haul from the surface to 5 meter from the sea bed. In total 543 samples were taken. The mean sampled depth was 22.7 m compared with the mean water depth of 27.7 m. Haul duration varied between 9.5 and 15 minutes. The average haul duration was 11.5 minutes. Samples were taken throughout 24 hour of the day and night.

The mean volume filtered in a haul was 56.95 m^3. In 30% of the hauls less than 50 m^3 was filtered. Most of these hauls were situated near the coast where tidal currents are strong. In these areas it is difficult in keeping the exact fishing speed through the water as the strength and direction of the tidal currents within the water column can differ considerable. *Phaeocystis* bloom was observed in the first survey in the stations closest to the coast. Clogging of the net, however, by *Phaeocystis* was not experienced.

Temperatures were taken from the surface and at the bottom. Due to technical problems the latter temperature could not be taken in the second survey.

All samples were preserved in 4% formaldehyde in fresh water buffered with NaH_2PO_4. Sole eggs were identified according to RUSSEL (1976) and staged using RILEY's (1974) criteria.

DATA PROCESSING

The data were stored and processed in spreadsheets using SUPERCALC4 and EXCEL on a microcomputer. The area sizes of the subrectangles were taken from the 1984 sole egg survey data base.

The duration of the various egg stages were calculated from the average temperature on each station using the following formulae:

$$d_n = \exp(b_n T + a_n)$$

where d_n is the duration in days of stage n and T is the average sea water temperature calculated from surface and bottom temperature. If either was absent, the other temperature was taken. The coefficients a and b for each stage n were taken from the 1986 report.

For each survey, egg stage and subrectangle, the density (numbers under 1 m^2) was calculated as:

$$\frac{\text{numbers counted} * \text{depth}}{\text{volume filtered}}$$

The numbers produced per m^2 per day is then:

$$\frac{\text{density}}{\text{stage duration}}$$

and the production in the subrectangle is then

$$\frac{\text{area size} * \text{density}}{\text{stage duration}}$$

The total production per day for each survey was calculated as the sum of the production per day in each subrectangle. To provide production estimates for small gaps in the station grid and on the edges of the survey area the geometric mean value of the numbers produced per m^2 in the adjacent subrectangles for the unsampled subrectangle was used.

The survey periods were used to calculate the beginning and end of the seasonal production and the survey midpoints. The start and ending of the spawning season was arbitrarily set at March 14th and July 31th. For each survey the total production for each stage was plotted against survey midpoint to produce the seasonal production curves from which the total seasonal production of each stage was calculated by trapezoidal integration.

The instantaneous daily mortality rate is calculated from the equation:

$$N_{x+1} / N_x = e^{-Zt}$$

where t is the time (or age difference) in days between the successive stages.

DISTRIBUTION OF SOLE EGGS

The abundance of stage 1 eggs as numbers per m2 is given for each survey in Figures 1a-e. Spawning of sole in the North Sea starts in March in the Southern Bight. In the first survey the highest concentrations of eggs are found along the Belgian coast (Figure 1a). However, also off the Dutch coast and along the Dutch Wadden Islands on the edges of the survey limits stage 1 eggs occurred. This is in contrast with the 1984 survey where during the 1st survey spawning was restricted mainly south of 51°45'N. The occurrence of significant amounts of eggs along the edges of the survey area indicates that the first survey did not fully covered the spawning areas of sole in this period and soles were spawning earlier than expected in other areas. The 1988 spawning season was preceded by an abnormal mild winter, while the 1984 season followed a "normal" winter. As temperature increase is the main trigger to start spawning (DE VEEN, 1970), spawning must have started earlier in 1988. The occurrence of already fully metamorphosed sole larvae in the 1st survey but also in preceding cod and plaice egg surveys (Rijnsdorp, personal communication) in 1988 and the occurrence in early April of partly spent females in fish samples bought in Dutch fish markets, support this explanation.

As the season progressed, concentrations of newly spawned eggs developed in more northern areas along the English, Dutch, German and Danish coast and in the Thames. Spatial distribution patterns of the sole eggs corresponds to those of the 1984 surveys. However, not only spawning started earlier in 1988, it also stopped earlier compared to 1984. At the end of June sole eggs were absent in the survey area except a small number along the German coast of Schleswig Holstein and the Danish coast (Figure 1d). In the same period in 1984 stage I eggs declined during June but considerable numbers were present in most of the survey area.

The spatial distribution of stages II to IV eggs closely follow that of stage I as in the 1984 survey and are not given in this report.

EGG PRODUCTION AND MORTALITY

The total egg production per day of each stage in each survey is given in Table 2. The extrapolated production in unsampled areas is given separately. Figure 2 shows the seasonal production curves. In Table 3 the total seasonal egg production and the instantaneous daily mortality rate in 1988 is compared with the results of the 1984 survey. The plot of ln of production of each stage against age is shown in Figure 3.

The number of fertilized eggs at the time of spawning was estimated from the production figures of stage I and the mortality between stages I and II ($Z = 0.0899$). This mortality was about half of the mortality in 1984. The low mortality between stage I and II originates from the fact that the production of stage I and II eggs were almost the same in the 1988 survey. However, this does not cause the difference in magnitude of production in both years. The production of all stages in all surveys in 1988 was considerable lower compared to 1984. The estimated production of unfertilized eggs in 1988 is $4.8\ 10^{12}$. This estimate is about one third of the estimated production in 1984 of $15.5\ 10^{12}$.

The extrapolated areas account for 3% in the estimate of the total production in 1988. Taking into account the advanced spawning of sole in 1988, the start of the spawning season was arbitrarily set at March 14th, 22 days before the start of the first survey compared to March 25th in 1984. However, the incomplete coverage of the spawning areas in the first survey certainly underestimate the egg production in 1988. However, this can not be substantial as the estimated production of fertilized eggs will increase by only 14% to 5.5 10^{12}, still about one third of the estimated production in 1984, if the egg production in the first survey was underestimated by a factor 3.

A comparison of the percentage mortality per day is given in the table below

mortality	1984	1988
stage I-II	16	9
stage II-III	52	61
stage III-IV	54	31
stage I-IV	44	38

As the first survey will mainly underestimates the stage I eggs also the calculated mortality between stage I and II and the total mortality between stage I and IV will be underestimates.

DISCUSSION

Taking into account that the 1988 surveys have underestimated the egg production of sole, they indicate a level of egg production in the order of about one third of the production in 1984, suggesting a similar reduction in spawning stock biomass. Confidence limits on the production estimates were not calculated but are usually wide. Therefore the survey results should be used with caution. However, the signal of a significant reduction in spawning stock biomass is clear and is supported by the signals from the VPA and a beam trawl survey, carried out by the Netherlands since 1985 in the southern North Sea (ANON. 1989).

A sexes separated VPA, using the most recent working group data (ANON. 1989 revised figure) shows a decline in female spawning stock biomass in the period 1984 - 1988 from 29 thousand tonnes to 24 thousand tonnes (Figure 4). The decline in female spawning stock biomass is less drastic as the egg surveys may indicate. However, the detoriation of the quality of the data used in the assessment, makes the results of the assessment in recent years uncertain.

Available fecundity data for North Sea sole (ROSENBOOM, 1985; ANON. 1986) are in contradiction and therefore makes a calculation of female spawning stock biomass from the egg production uncertain.

At present there is disagreement about the question whether sole is a determinate or an indeterminate spawner. URBAN and ALHEIT (1988) state sole is an indeterminate spawner because the number of reserve oocytes to be matured and spawned during spawning season probably depends on the feeding conditions during the spawning season. Fecundity estimates determined before the onset of spawning could then not be correct and would lead to erroneous estimates of spawning stock. However recent unpublished fecundity data for North Sea sole (Millner, personal communication) show a distinct break in the size distribution of the oocytes at 200 μ, differentiating the previtellogenic oocytes from the population of vitellogenic oocytes destined for spawning in the current year. This may indicate that sole is a determinate spawner. Also LE BEC (1983) and DENIEL (1981) conclude that sole in the Gulf of Biscay is a determinate spawner based on the development of the size distribution of the oocytes larger than 240μ during the spawning season. They found that all oocytes larger than 240μ will be spawned in one spawning season. However, they did not measure oocytes smaller than 240μ and it remains possible that part of these oocytes migrate in the same season to the population of vitellogenic oocytes.

It will be clear that the solution of the above problem is of paramount importance to estimate the female spawning stock biomass from egg surveys. Nevertheless it is believed that egg surveys can give a reliable, through maybe a crude, estimate of trends in spawning stock biomass. Annual variations in the gonad weight - body size relations will be generally smaller than the observed difference in egg production between 1988 and 1984 (VAN BEEK, 1988).

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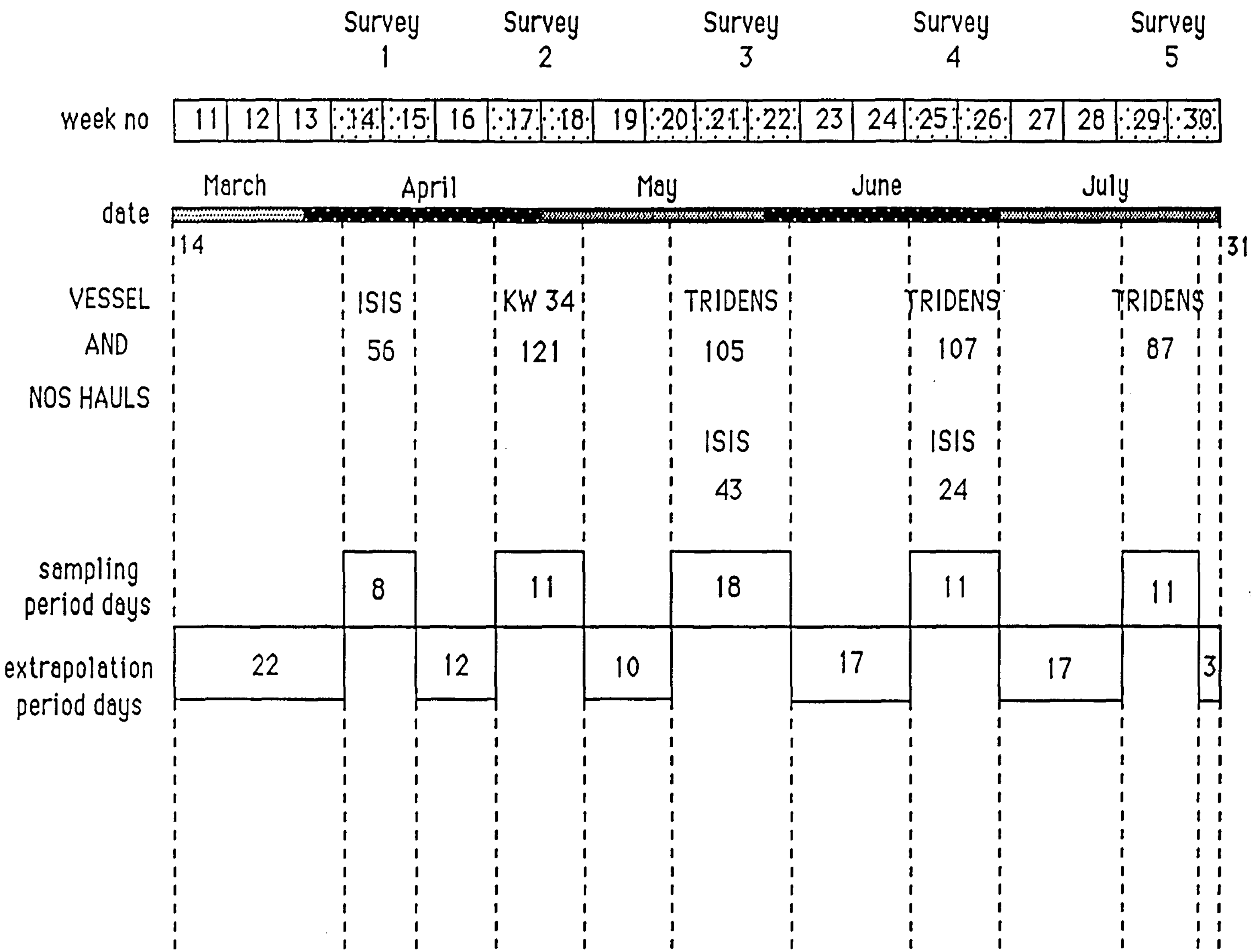

Table 1 Sampling periods, vessel participation in the survey and number of hauls in the 1988 sole egg survey.

Table 2 Sole Egg production per day in the North Sea in 1988 (millions)

	stage 1	2	3	4
observed rectangles				
survey 1	8393.5	2746.9	409.2	0
survey 2	61985.5	66486.5	13472.8	2848.1
survey 3	82805.3	69024.9	10678.1	6038.3
survey 4	1554.8	1684.2	250.4	0
survey 5	709.5	200.7	1348.2	0
extrapolated rectangles				
survey 1	0	0	0	0
survey 2	4123.5	872.7	119.7	192.8
survey 3	1413.6	35.1	61.4	40.5
survey 4	0	0	0	0
survey 5	55.4	47.2	2	0
observed + extrapolated rectangles				
survey 1	8393.5	2746.9	409.2	0
survey 2	66109.0	67359.2	13592.5	3040.9
survey 3	84218.9	69060.1	10739.5	6078.8
survey 4	1554.8	1684.2	250.4	0
survey 5	764.8	247.9	1348.2	0

Table 3 Estimates of production and daily mortality rate of North Sea sole eggs from the 1988 survey. The estimates in 1984 (*in italics*) are given for comparison.

stage	I		II		III		IV
1988 survey							
production * E-12	4.3767		3.7767		0.6288		0.2583
ln(production)	1.4763		1.3289		-.4639		-1.3536
stage duration	2.28		1.00		2.84		2.03
age	1.14		2.78		4.70		7.14
stage interval		1.64		1.92		2.44	
-Z		-.0899		-.9337		-.3654	
exp(-Z)		.9140		.3931		.6939	
1-exp(-Z)		.0860		.6069		.3061	
					No of fertilized eggs * E-12		4.849070
1984 survey							
*production * E-12*	*12.9154*		*9.9529*		*3.0899*		*0.6119*
ln(production)	*2.5584*		*2.2979*		*1.1281*		*-0.4912*
stage duration	*2.07*		*0.88*		*2.31*		*1.91*
age	*1.04*		*2.51*		*4.11*		*6.22*
stage interval		*1.48*		*1.60*		*2.11*	
-Z		*-.1766*		*-.7334*		*-.7675*	
exp(-Z)		*.8381*		*.4803*		*.4642*	
1-exp(-Z)		*.1619*		*.5197*		*.5358*	
					*No of fertilized eggs * E-12*		*15.50638*

Table 4. Average temperatures and stage duration by survey. The average temperatures are calculated from the stations were sole eggs were caught.

	temperature °C	stage duration I	II	IIII	IV
survey 1	7.2	3.1	1.5	4.2	2.5
survey 2	8.6	2.7	1.2	3.4	2.3
survey 3	11.4	1.9	.8	2.2	1.9
survey 4	13.0	1.6	.6	1.8	1.7
survey 5	15.6	1.1	.4	1.2	1.4
average		2.1	.9	2.6	2.0
weighted average		2.3	1.0	2.7	2.0

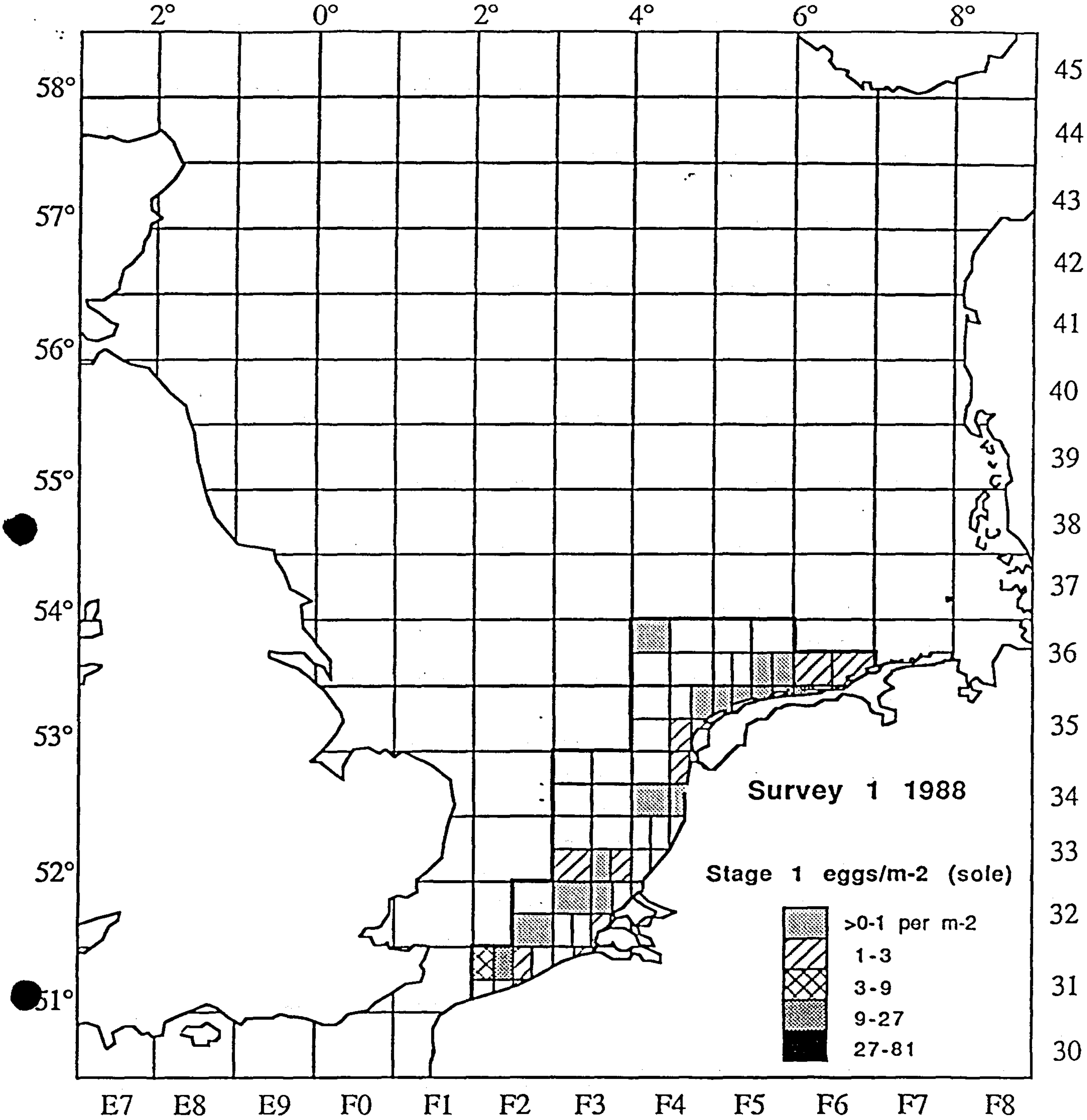

Figure 1a Station grid and abundance of stage I sole eggs measured during the 1988 surveys (nos m2). The fat line gives the limits of the survey.

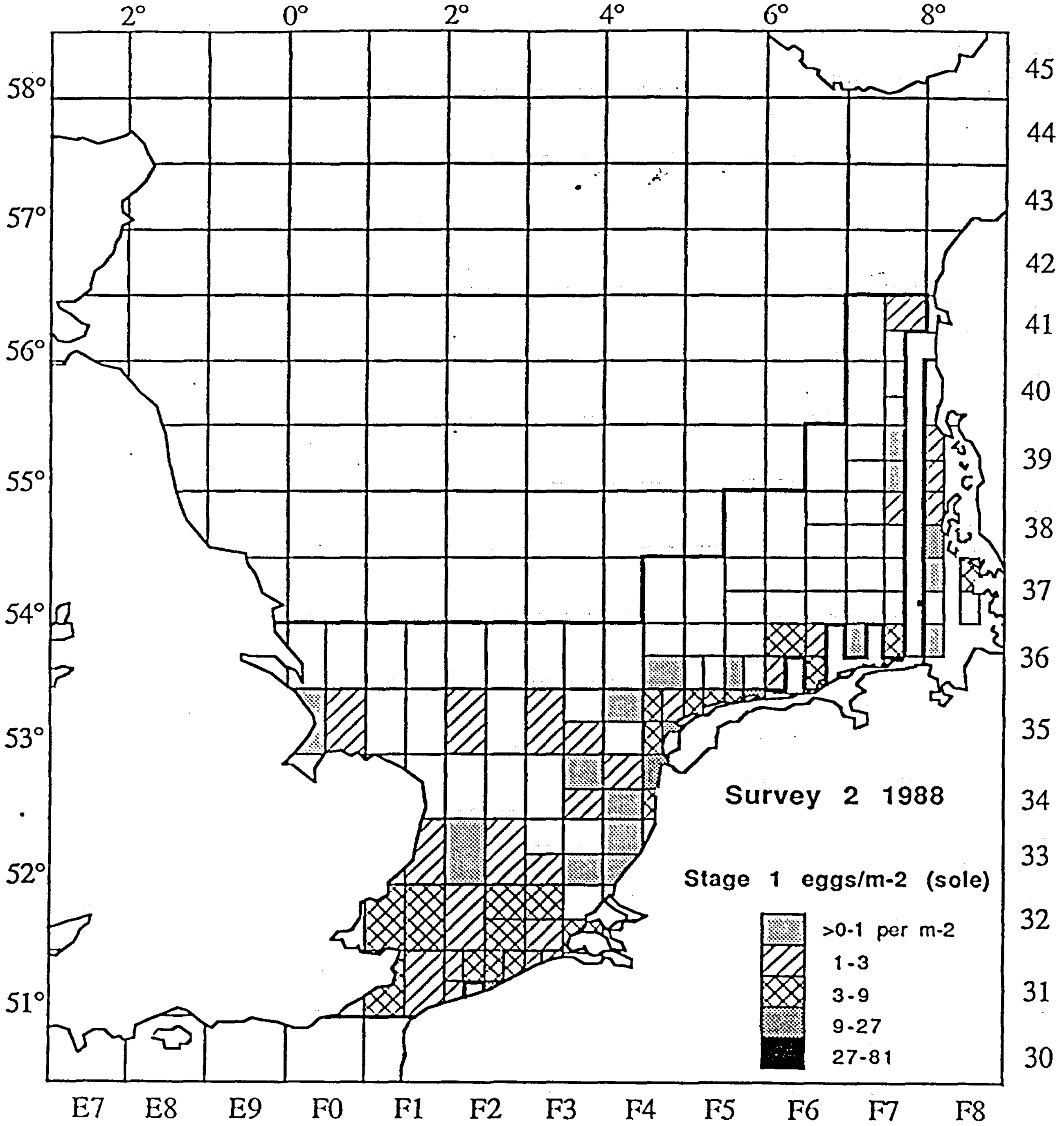

Figure 1b Station grid and abundance of stage I sole eggs measured during the 1988 surveys (nos m²). The fat line gives the limits of the survey.

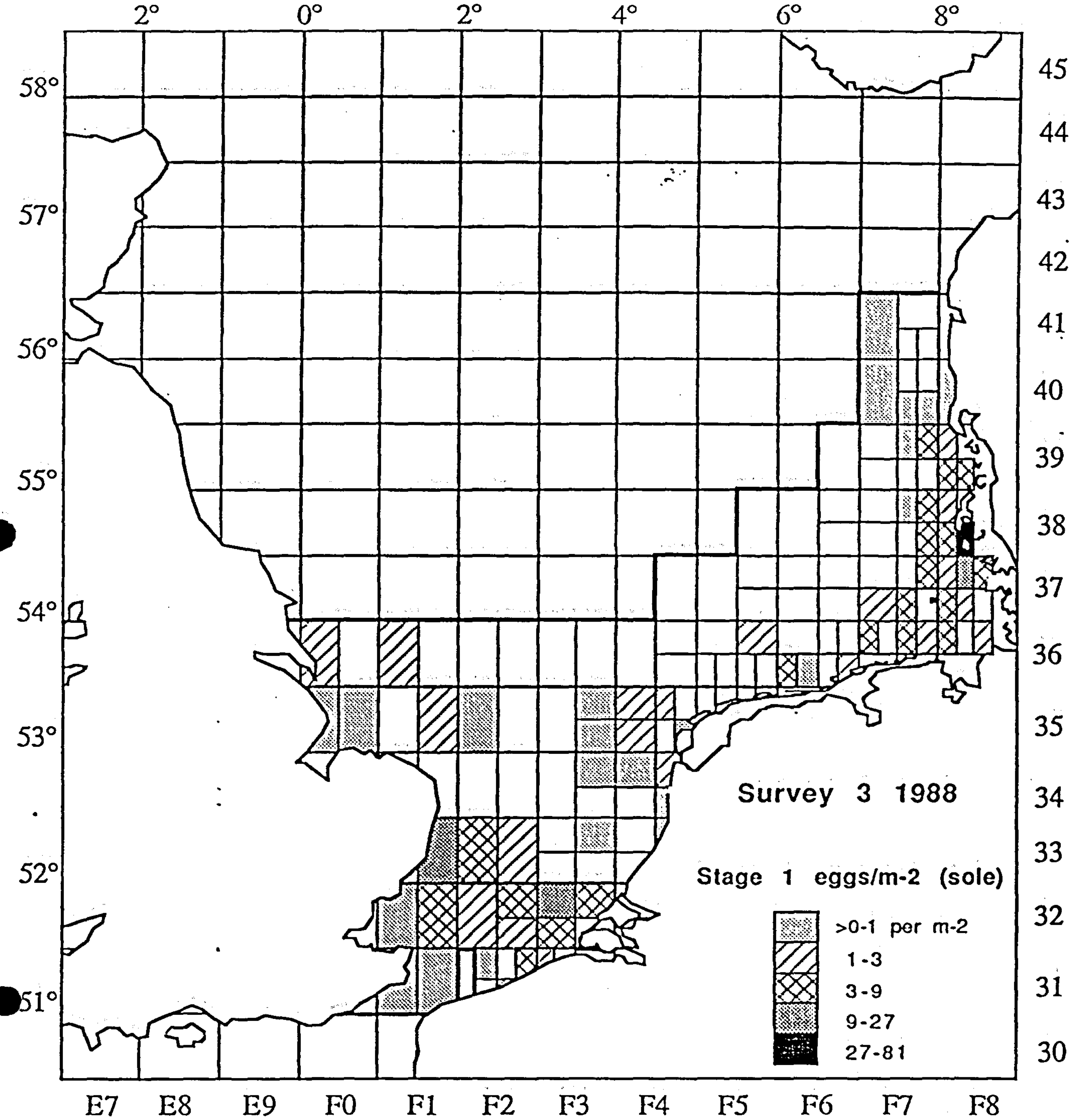

Figure 1c Station grid and abundance of stage I sole eggs measured during the 1988 surveys (nos m^2). The fat line gives the limits of the survey.

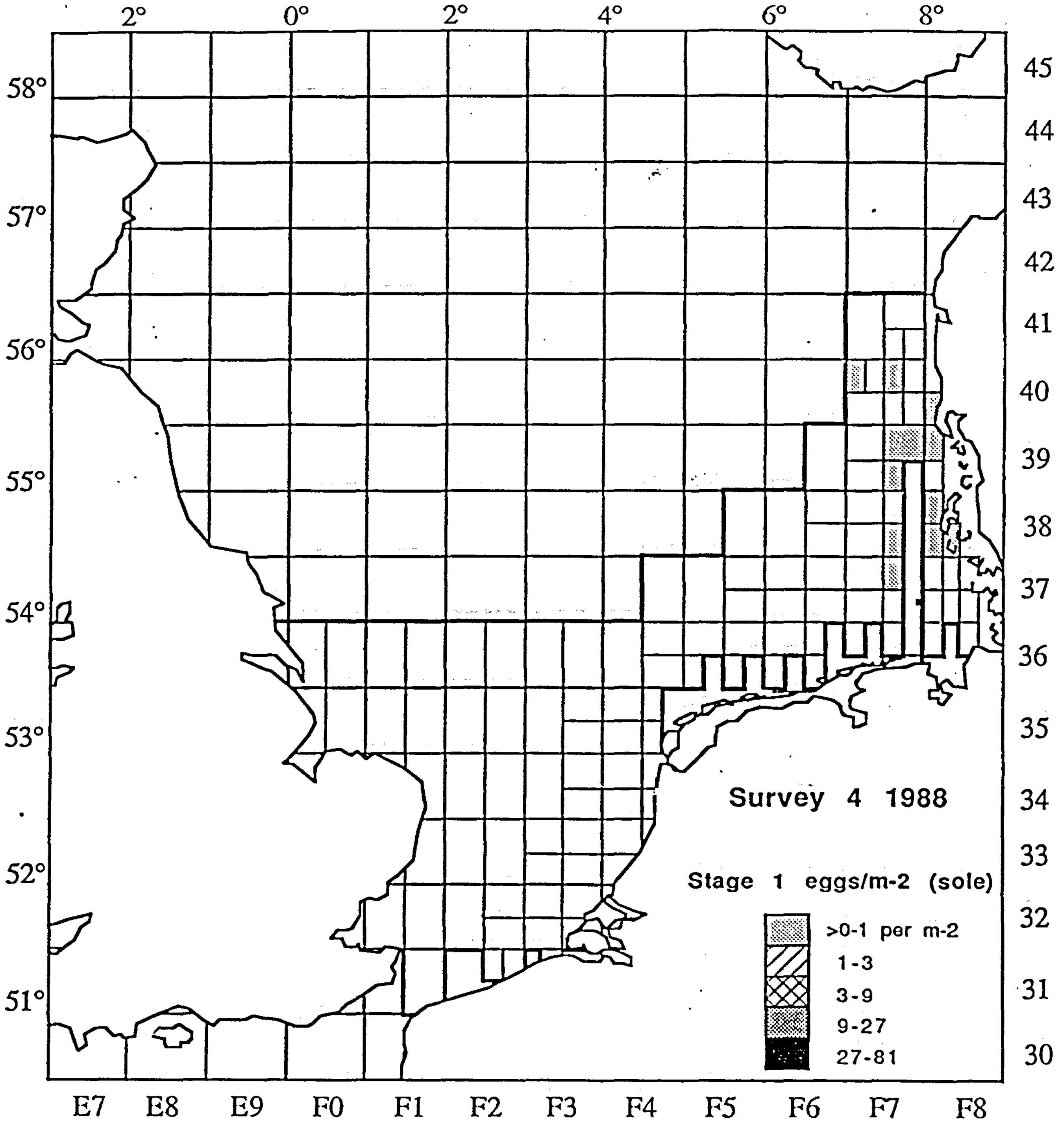

Figure 1d Station grid and abundance of stage I sole eggs measured during the 1988 surveys (nos m^2). The fat line gives the limits of the survey.

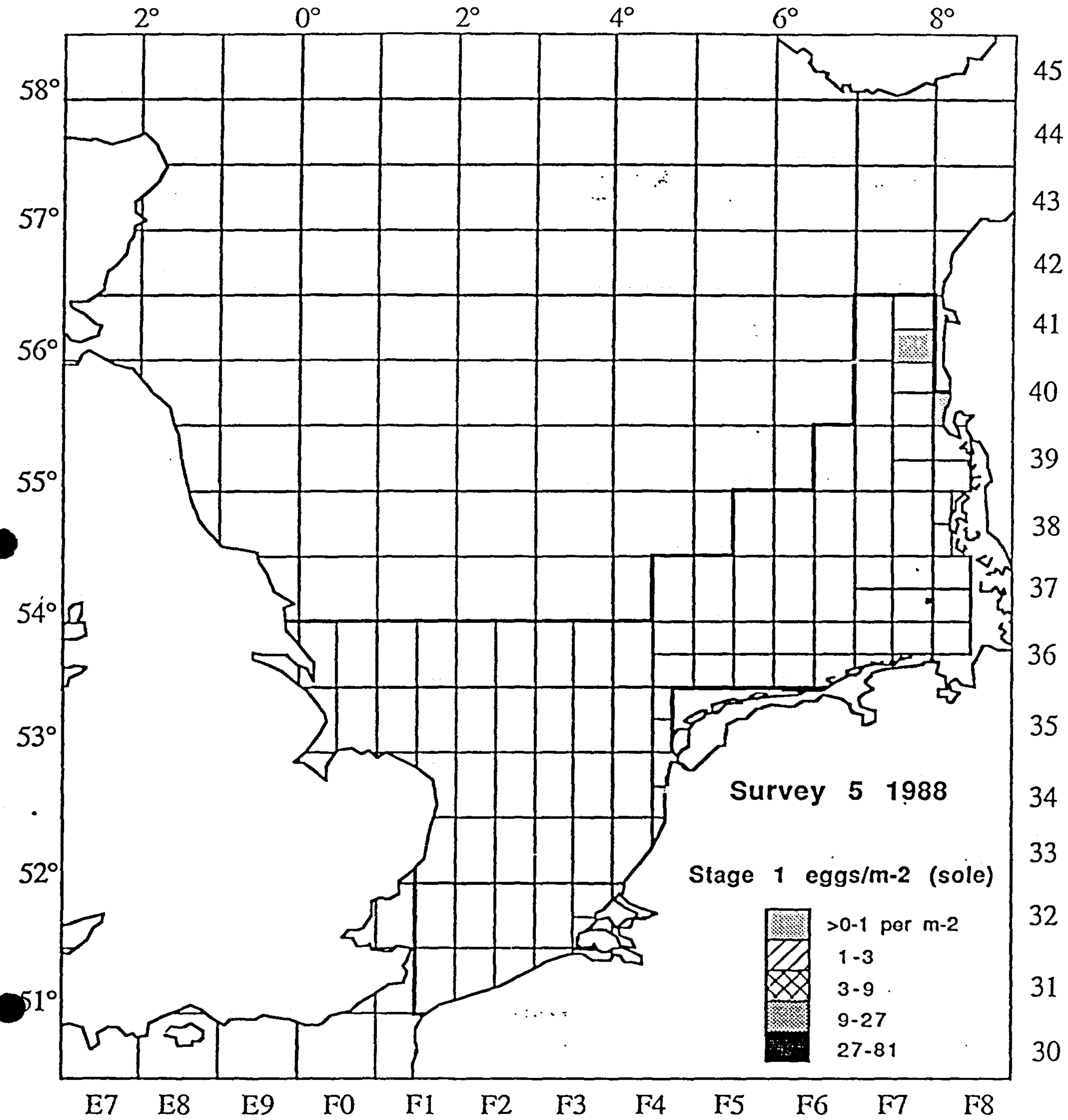

Figure 1e Station grid and abundance of stage I sole eggs measured during the 1988 surveys (nos m2). The fat line gives the limits of the survey.

Figure 2 Production curves for each stage of sole eggs in the 1988 surveys (Day number 0 refers of March 14).

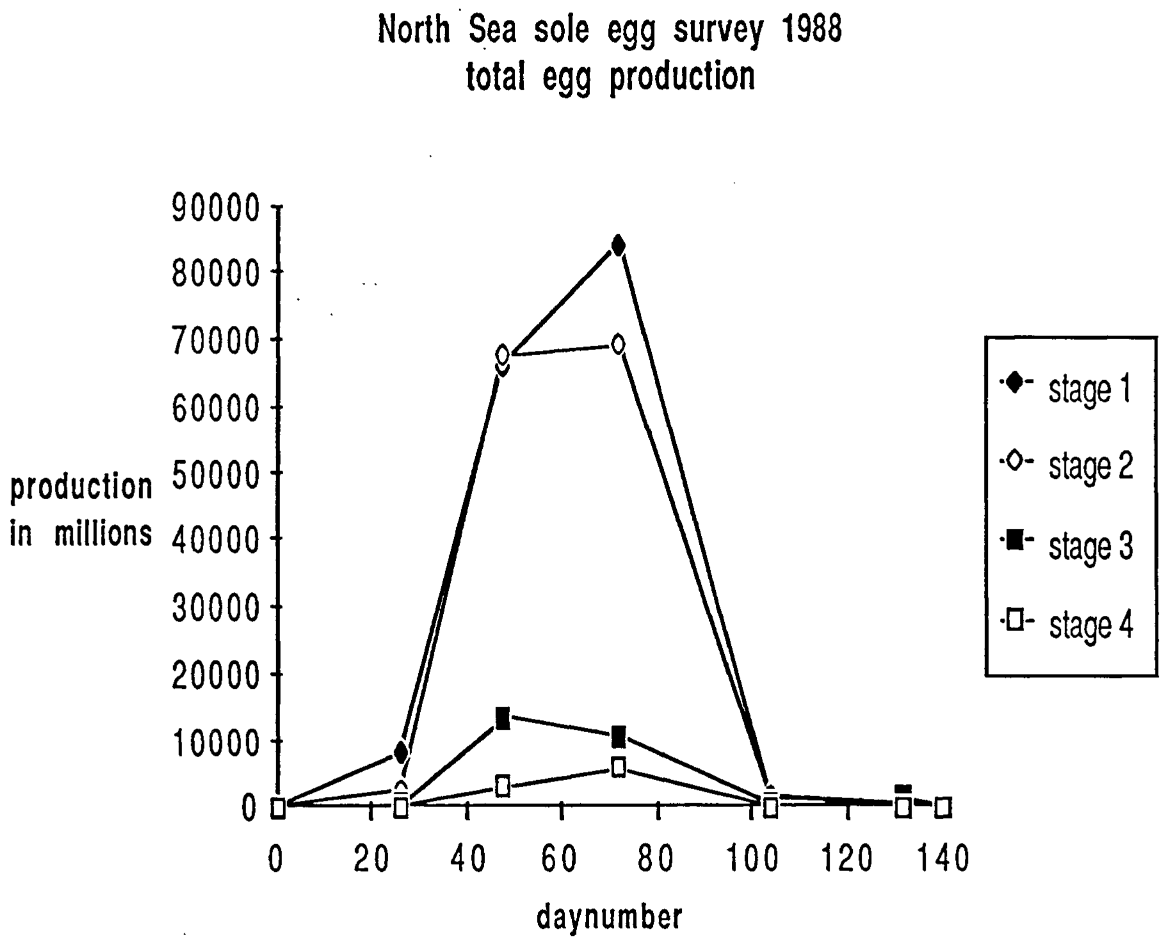

Figure 3 North Sea Sole
Egg survival curves for the 1988 survey

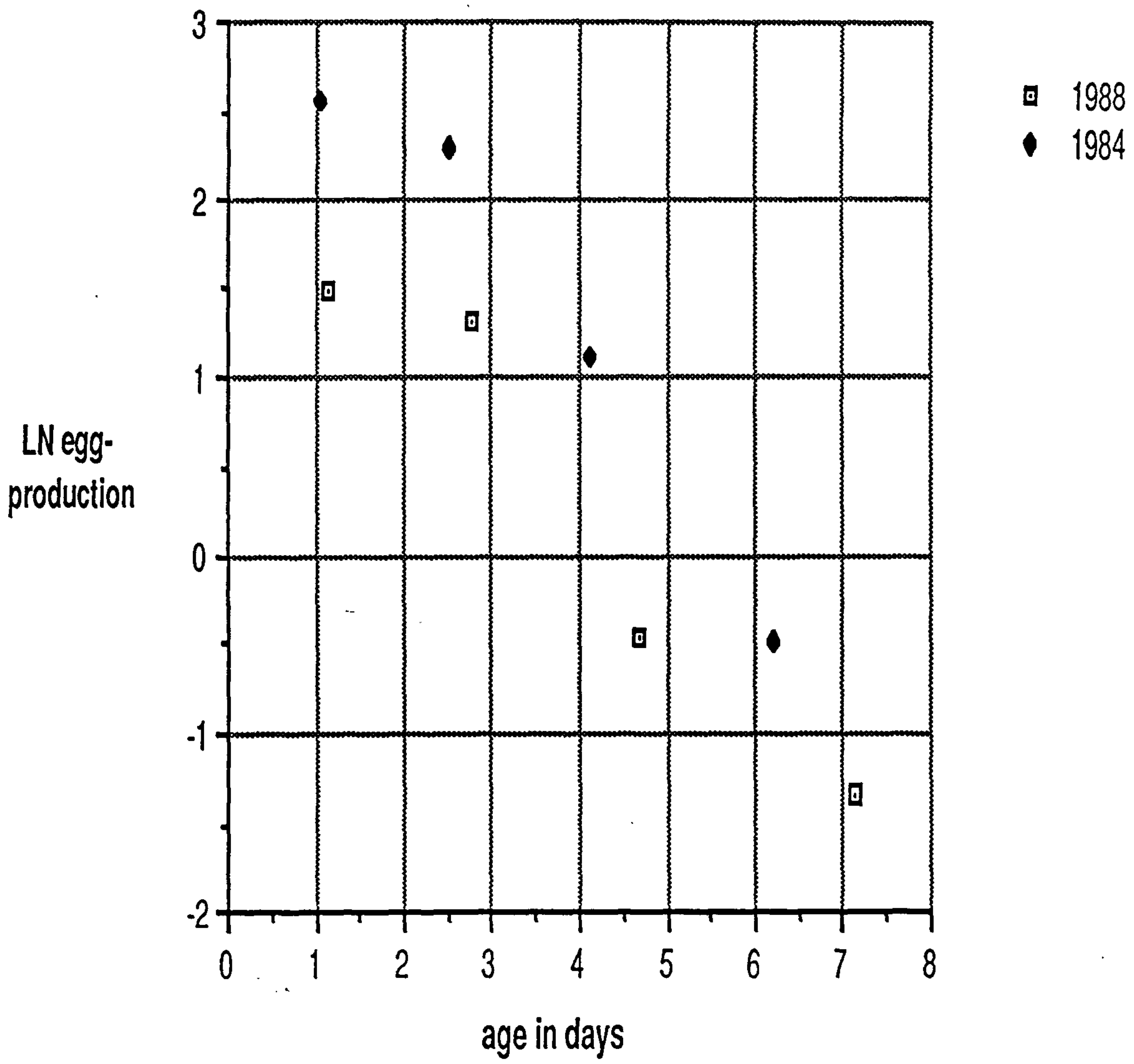

Figure 4 Spawning Stock Biomass of North Sea Sole from VPA for males and females separately (Flatfish Working Group data)