International Council for the Exploration of the Sea

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Pelagic Fish Committee

REPORT OF THE MACKEREL/HORSE MACKEREL EGG PRODUCTION WORKSHOP

Lowestoft, 29 January - 2 February 1990

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TABLE OF CONTENTS

TABLE OF CONTENTS

Mackerel / Horse Mackerel Egg Production Workshop

Lowestoft 29 January - 2 February 1990

1. INTRODUCTION

1.1 Terms of reference

At the ICES Statutory Meeting in the Hague (the Netherlands) in October 1989 it was decided (C. Res. 1989 / 2:16) that the Mackerel/Horse Mackerel Egg Production Workshop (Chairman: Mr A Eltink, Netherlands) will be held at the Fisheries Laboratory in Lowestoft, England from 29 January - 2 February 1990 to:

a) complete the analysis of the Western mackerel/horse mackerel egg survey data for 1989;
b) compare the methodology used to estimate the spawning stock size from total fecundity and from batch fecundity;
c) estimate the rate of atresia;
d) prepare estimates of spawning stock size of mackerel and horse mackerel for the appropriate assessment Working Groups.

1.2 Important information, which became available after this workshop meeting

An unusually high production of stage I eggs of about eight times the expected level occurred on the first survey of the Western Egg Survey in 1989. The workshop regarded this as suspect and decided to present the data in this report in two ways by including and excluding the first survey, because no reason was found to reject the data provided. However, important information concerning the invalidity of the egg production estimate of the first coverage became available after this workshop meeting.
On the 6th of March 1990, when most participants of this workshop were meeting in Aberdeen for the "EC Batch Fecundity Method for mackerel", it was agreed that the **egg production of the first coverage should be rejected** based on the information presented. Agreement on the rejection of the first coverage by the Norwegian and German participants was obtained by correspondence. The working document containing the arguments for rejecting the first survey is attached to this report as an **appendix**.

1.3 Participation

The workshop met in Lowestoft from 29 January - 2 February 1990 with the following participants:

E Barnwall	Ireland
W A Dawson	UK (England and Wales)
A Eltink (Chairman)	Netherlands
P Hopkins	UK (Scotland)
S A Iversen	Norway
J Massé	France
J Molloy	Ireland
L Motos	Spain
J H Nichols	UK (England and Wales)
M N Pérez	Spain
C Porteiro	Spain
I G Priede	UK (University of Aberdeen)
A Solá	Spain
M G Walker	UK (England and Wales)
M Walsh	UK (Scotland)
J J Watson	UK (University of Aberdeen)

Observers who sat in on the meeting were:

M F Borges	Portugal
M Castonguay	Canada
B W Jones	UK (England)

In addition, contributions to the proceedings were made by L Woolner, P Witthames, S Milligan and A Thompson all of the Fisheries Laboratory Lowestoft.

2. PROVISIONAL ADVICE TO ACFM

Western mackerel and horse mackerel

Individual national contributions to the western area plankton survey were completed before this Workshop met. As agreed beforehand, all results were sent to the Fisheries Laboratory, Lowestoft and a preliminary assessment was made following methods of data analysis agreed earlier (Anon., 1988a). No survey results from the Federal Republic of Germany of the first coverage were reported in time to be included in the preliminary assessment to be sent to ACFM. The daily egg production of mackerel for this first coverage was assumed to be the same as in 1986, while the daily egg production of horse mackerel for this coverage was assumed to be zero, because of later spawning by horse mackerel.

Due to an error in the use of the flowmeter conversion factor by one country during the fourth coverage, a revision of the preliminary assessment was sent to ACFM during their meeting in November 1989. This increased the mackerel egg production by 11% and the horse mackerel egg production by 29%. This increase was higher for horse mackerel, because the fourth coverage coincided with the peak of spawning for horse mackerel. The following provisional total egg productions were reported to ACFM:

For mackerel: 1.37×10^{15} eggs (stage I)

For horse mackerel: 1.42×10^{15} eggs (stage I)

The total egg production estimates of mackerel and horse mackerel could be converted to spawning stock biomasses using the following fecundity-weight relationships:

Mackerel: 1457 eggs per gram pre-spawning female at maturity stage 4. The conversion to the biomass of fish at spawning time increased the regression estimate by 8%. (Anon., 1987b page 3).

Horse mackerel: 1655 eggs per gram pre-spawning female at maturity stage 4. The conversion to the biomass of fish at spawning time increased the regression estimate by 5% (Eltink and Vingerhoed, 1989).

These provisional egg productions corresponded to a spawning stock biomass estimate of 2.0 million tonnes of mackerel and 1.8 million tonnes of horse mackerel.

North Sea mackerel

During the period which usually represents the peak of the spawning period of North Sea mackerel a single coverage of the spawning area was carried out by Norway in 1989. The daily egg production during this period was estimated at 1.3×10^{12} eggs.

Assuming that the egg production curve in 1989 followed the same pattern as in 1988 the total egg production was estimated at 36×10^{12} eggs. This corresponds to a spawning stock biomass of 53 000 tonnes using a sex ratio of 1:1 and the fecundity weight relation as given in Iversen and Adoff (1983). These estimates were given to the ACFM meeting in November 1989 (Iversen, WD 1989).

3. GENERAL ASPECTS

3.1 Mackerel egg stage duration

Experiments have been conducted by England, Scotland and Norway to check the relationship between development rate and temperature established by Lockwood et al. (1981). All the experiments have confirmed that the relationship for stage I eggs remains valid.

In order to resolve the anomalous production values for later stage eggs a total of 13 samples of mackerel eggs were examined and staged fresh at sea during the RV CIROLANA 5/89 cruise. These samples were then fixed in 4% formalin and restaged back in the laboratory.

No change in numbers of eggs identified as stage 1 eggs occurred following fixation, however the proportions of stages 2, 3, 4 and 5 altered (Table 3.1) (Thompson, WD 1990a). This was especially the case in the latter three stages where fixed eggs were assigned to later stages. This is shown by the higher counts of stage 4 and 5 eggs in the fixed state. This can be explained if fixation causes larvae to coil further round in the egg. No correction need be applied when only using stage 1 eggs. However, if later stages are used then a factor is required to correct for fixation artifacts that change egg stage assignment.

3.2 Spawning periodicity

Mackerel

Conclusive evidence was presented from the three following independent sources that mackerel spawning may occur throughout the 24 hour period. It is not confined to any time of the night or day.

Evidence from the captive mackerel experiments in Scotland (Figure 3.1) shows that whilst there was some increased activity at night there was still a significant spawning during the day. (Walsh, pers. comm.).

The mean percentage of daily egg production of captive mackerel within each 6 hour period over 63 days is shown in the text table below.

Time period	%
0000h-0600h	33.6
0600h-1200h	19.6
1200h-1800h	19.5
1800h-2400h	27.5

During survey period 3 some sampling was done by England over a 27 hour period at a single station to examine diel periodicity of spawning. Eggs taken on each of the 15 hauls were examined fresh and sorted microscopically into 2 cell, 4 cell, 8 cell, 16 cell, 32 cell and 64 cell stages. These eggs were then back calculated to their spawned time using detailed development data obtained concurrently. The data were obtained using artificially fertilised eggs reared over a range of temperature (Figure 3.2). The methods of rearing and subsequent back calculation was the same as that described for plaice by Nichols (1989). The data as numbers per m^3 for each of the stages back calculated to spawned time is shown in Figure 3.3. This shows that spawning may occur at any time of the day or night. However, a quadratic equation fitted to numbers of eggs, m^{-3} against time of day using GLIM, shows a significant increase in the production of eggs during the middle of the day, $F = 7.1$, $P<0.025$. If the two highest values are omitted the relationship remains significant. (Nichols, pers. comm.)

During sampling by Spain in southern Biscay fixed egg samples at two stations were examined and staged in detail, up to the 16 cell stage. This stage occurred in the samples at all times of the day and night (Figure 3.4). (Motos et al., WD 1990).

Horse mackerel

Two observations were presented both of which suggested that spawning may be synchronised. However the two data sets were not in agreement on the specific time of day and therefore further experiments need to be carried out to clarify this.

From the egg surveys by Spain in southern Biscay two detailed observations of the occurrence of early blastodisc stage eggs were made. The data are shown in Figures 3.5 and 3.6 and indicate a peak spawning between 1500h and 2400h. (Motos et al., WD 1990).

In a further experiment ovaries from fish taken off the NW coast of Spain were examined histologically. The occurrence of oocytes with migratory nuclei, hydrated oocytes and post-ovulatory follicles suggest that spawning is synchronised, but to a later period of the night. (Pérez and Porteiro, WD 1990).

3.3 Comparison of egg staging

The results of a comparison of egg staging were presented in a working document (Thompson, WD 1990b). Ten samples of mackerel eggs obtained from Biscay during May 1989 were fixed in 4% formalin. The same samples were staged and counted by England, Scotland, France, Ireland, the Netherlands and Spain. The total number of mackerel eggs in the samples ranged from 93 to 184, with a between-country error of ± 3 eggs per sample. Percentage deviations, by country, from the overall average number of eggs counted in each stage was used to identify differences in stage identification among the countries (Table 3.2). There is a wide variation in stage identification of stages 1a, 1b, 3, 4 and 5, with less variation for stage 2. The most important result was stage 1 eggs (i.e. stages 1a and 1b combined), which are currently used by the working group for the determination of total egg production, were fairly accurately identified by all countries, with a variation of -7 to +10% from the overall mean. The coefficient of variation (s/x) in counts of the various stages arising from errors in stage identification was 9% for stage 1 eggs and 5% for stage 2-5 eggs combined (Table 3.3). The coefficient of variation for stages 1a, 1b, 2, 3, 4 and 5 ranged from 23% to 81%, values which are too high to be acceptable for the estimation of egg production. These conclusions are in agreement with a similar study undertaken in 1986 (Anon., 1987a).

3.4 Collection of other fish eggs and larvae

At the planning workshop in 1988 England asked for all other eggs to be sent to them for identification. There are potentially useful data in these surveys on other species which are not being utilised. In particular hake and megrim egg abundances could probably be used for stock size estimates. MAFF Lowestoft at present do not have personnel available to analyse samples in the immediate future, however, it is hoped that the tubes of sorted eggs can still be sent to Lowestoft. A review of the position should be made at any subsequent survey planning workshop.

The request for anchovy and pilchard eggs from the area south of 47°N to be sent to Spain, has been complied with for survey periods 2 to 5. No eggs have been received from the Federal Republic of Germany from period 1.

3.5 Plankton sampler

Efficiency of samplers

Calibrated flowmeters were used in the national versions of the Gulf III sampler and the CalVet net used by Spain. The basic design of the various flowmeters was different and the methods of calibration also differed. Some flowmeters were calibrated in a flume or towing tank *in situ* within the sampler, whilst others were calibrated in free stream. Recent experiments by the Netherlands with their own Gulf III have cast some doubts upon earlier flume and towing tank calibrations of their net conducted by England. The Dutch experiments show that up to 120% of the theoretical volume offered to the nose cone of a Gulf III may be filtered by the net. This compares with values of 90% to 95% at present used for this type of sampler. Clearly there is a large potential source of error which must be investigated. To this end towing tank trials will be conducted on 19 February 1990 in the Netherlands using the encased Dutch sampler and the German Nackthai. Representatives from a number of ICES member countries will be present as observers at these trials. The results of recent English calibrations and a description of the method will be published as soon as possible in the MAFF Technical Report Series.

Variability in sampled volumes

Flowmeter readings from similar hauls were sometimes very variable. It is recommended that further attention is given to the problem at the next workshop meeting.

3.6 Historical data base

All mackerel and horse mackerel data for the five survey years since 1977 are available to all ICES member countries. These data are on an INGRES database on a

VAXCLUSTER, running a VMS operating system. They are held as numbers per m^3 together with station positions and the physical data where available, usually surface temperature and salinity, volumes of water filtered, depth and sampler depth. The egg data can be readily converted to numbers per m^2 and numbers produced per m^2 per day using egg development equations for both species also held on the data base. This is achieved using various INGRES systems applications.

Data processing for the 1989 surveys has taken approximately four person months work. In future this could be speeded up if more consideration could be given at the planning stage to how data can be transferred between countries. Because of the heavy staff commitment, it is unlikely that Lowestoft will be able to take full responsibility for data processing for any surveys proposed in the future. In this context consideration must be given to finding an alternative arrangement at the next workshop meeting.

3.7 Proposal for a new paper on the Western Egg Surveys 1977 - 1989

The Workshop agreed that the results from all five western egg surveys since 1977 should be published in an appropriate journal. It was not possible to finalise the details, including authorship, during the meeting. An acceptable suggestion was that individuals involved in the surveys over a long period should be authors whilst the contribution of others should be recognised in the acknowledgements.

4. NORTH SEA EGG SURVEYS IN 1989, 1990 AND 1991

4.1 Egg Surveys in 1989

Mackerel

During the period 16-27 June 1989 the spawning area of mackerel in the North Sea was covered once by the Norwegian research vessel "MICHAEL SARS". This period usually represents the peak of the spawning period. The methods for sampling, data handling and calculations were the same as in previous years (Anon., 1988a, Iversen et al., 1989).

The distribution of mackerel eggs which are up to one day old is shown in Figure 4.1. The daily egg production obtained from the survey was 1.3×10^{12} eggs (Iversen, WD 1989). If this represents the peak of the spawning period and the shape of the production curve was the same as the ones calculated for either 1981-1984 or 1986 the estimated egg production is in the range of $34\text{-}56 \times 10^{12}$ eggs. If the spawning curve in 1989 had the same shape as in 1988 (Figure 4.2) then the egg production is estimated at

36×10^{12} eggs. If the sex ratio of 1:1 and the weight fecundity relation given by Iversen and Adoff (1983) are applied to this estimate of egg production then the spawning stock biomass must have been about 53 000 tonnes. This indicates an increase in the spawning stock since 1988 when it was estimated at 37 000 tonnes (Iversen et al., 1989). However, the spawning stock in the North Sea must be considered to be still at a very low level.

Horse mackerel

Five coverages of the spawning area of horse mackerel (and sole) in the southern and eastern central North Sea were carried out by the Netherlands from mid April to late July 1989. The horse mackerel data are not fully analyzed yet. An estimate of the spawning stock will be given in a separate report to the ACFM meeting in May this year.

4.2 Egg surveys in 1990

Since 1984 an international mackerel egg survey has been carried out every second year in the North Sea. The last one was carried out in 1988 and for this survey horse mackerel was included on an international basis for the first time.

In 1990 the Netherlands, Denmark and Norway will carry out the investigations according to a time schedule given in Table 4.1. As in 1988 the investigations will cover both mackerel and horse mackerel. The Dutch survey will cover the area and season of the main sole egg production. Horse mackerel spawn mainly in the southern and south eastern part of the North Sea (Iversen et al., 1989). This area (Figure 4.3) will be covered by two Dutch research vessels "ISIS" and "TRIDENS".

The first Dutch survey in March is assigned to sole because both mackerel and horse mackerel start spawning later. In 1988 the horse mackerel started spawning during late April early May with the peak spawning in June (Iversen et al., 1989). The spawning ended in late July. The spawning period for horse mackerel seems therefore to be rather similar to that of mackerel which starts spawning in mid May with peak spawning in mid or late June and the spawning is finished late July.

The rest of the area (Figure 4.3) which is the main mackerel spawning area will be covered by the Danish ("DANA") and Norwegian ("MICHAEL SARS") research vessels.

The main mackerel spawning area is usually between 55° and 58° N and between 1° and 5°E. This part will be covered more intensively than the rest of the area. Plankton samples will be sorted on board and the surveyed area will be adjusted according to these results.

Skagerrak which normally is not part of the main spawning area will be partly covered during second half of June.

The 1990 mackerel egg survey in the North Sea will be carried out following the standard procedure described by Iversen and Westgaard (1984) and Iversen et al. (1985).

The Danish and Dutch vessels will use a modified Gulf III type sampler while the Norwegian vessel will use a 20 cm Bongo net. Based on the previous surveys there are no indications of any differences in the catch efficiency between the two samplers. Therefore the choice of gear type is not expected to have any effect on the results.

It is recommended that a mesh size of 500 µm is used for sampling mackerel, horse mackerel and sole eggs as nets with a smaller mesh size will be easily clogged.

The Danish and Norwegian vessels should operate the samples as in previous years, which means stepwise in depths 20m, 15m, 10m, 5m and 0.5m. The Gulf III sampler should be towed at a speed of 5 knots, 2.5 minutes at each depth and the Bongo net at 2.5 knots, 5 minutes at each depth. The Dutch vessel, which will also be sampling sole eggs, should operate the sampler as in 1988, which means that the Gulf III should be towed in oblique hauls at a speed of 5 knots from the surface to as close to the bottom as possible.

The samples should be placed in a standard fixative of 4% buffered formaldehyde in distilled water.

For the purpose of estimating the age of the mackerel and horse mackerel eggs the temperature in the surface layer at 5m is required. It is recommended that a temperature depth profile be recorded at each station.

The samplers should be equipped with calibrated flowmeters. For each station information about number of stage 1 mackerel and horse mackerel eggs, filtered volume and temperature at 5m should be given to the coordinator S. A. Iversen, before the end of September 1990.

To obtain information on the composition of the spawning stock of mackerel the vessels should fish during the egg surveys.

It is recommended that the participants meet at the Institute of Marine Research, Bergen before the ACFM November meeting 1990 to assess the results and write a final report. This report should then be presented to the ACFM meeting.

Egg stage duration

Numbers of eggs produced per day will be calculated using the formula for stage 1 eggs as given below:

Mackerel:

$$\ln \text{Time} = -1.61 \ln \text{Temperature} + 7.76$$
(Lockwood et al., 1981)

Horse mackerel:

$$\ln \text{Time} = -1.61 \ln \text{Temperature} + 7.71$$
(Pipe and Walker, 1987)

Fecundity

Fecundity estimates to be applied in 1990 are the same as used in previous years.

North Sea mackerel (Iversen and Adoff, 1983):

$$\text{Fecundity} = 560\ (\text{weight in g})^{1.14}$$

$$\text{Fecundity} = 1.35\ (\text{length in cm})^{3.6}$$

Both these relationships are similar to that accepted for the Western stock in 1989 (Walsh et al., WD 1990).

Horse mackerel (Eltink and Vingerhoed, 1989):

Fecundity = 1655 eggs/gram female horse mackerel in maturity stage 4.

4.3 Egg surveys in 1991

At present egg surveys in 1991 on sole and horse mackerel are planned by the Netherlands for the southern central North Sea and sole surveys in the English Channel are planned by England and France. These surveys will take place from March to July 1991. For the time being there are no plans for mackerel egg surveys in the North Sea in 1991.

However it should be recommended that horse mackerel and mackerel eggs sampled during the 1991 surveys should be classified and staged. It is of great interest to follow the development of spawning in this border area between the spawning areas for the North Sea and the Western mackerel. This is particularly important at present when there are indications that the main spawning area for the western stock may have shifted slightly.

5. THE WESTERN MACKEREL AND HORSE MACKEREL EGG SURVEY 1989

5.1 The western area plankton survey; sample and data analysis

The survey was conducted in accordance with the strategy planned at the workshop in 1988 (Anon., 1988a). At that meeting it was agreed that spatial and temporal distribution of sampling would be directed at an adequate coverage for both mackerel and horse mackerel. The eastern and western boundaries of the survey area were retained whilst the northern and southern boundaries were extended to latitude 56°N and 44°30'N respectively. It was also accepted that both Ireland and Scotland would sample north of 56°N on an opportunistic basis and that Spain would sample south of 44°30'N.

The deployment of research vessel effort in 1989 is shown in Table 5.1. These surveys were split into five sampling periods for subsequent analysis. The periods which are shown in Table 5.1 are: 1 - 20 April, 23 April - 20 May, 21 May - 6 June, 7 - 24 June and 4 - 19 July. At the 1988 planning meeting it was decided to adopt a flexible approach to stratified sampling. The number of samples taken per rectangle during each survey period are shown in Figures 5.1 to 5.5 and the abundance of stage I mackerel and horse mackerel eggs are shown in Figures 5.6 to 5.10 and 5.11 to 5.14.

Samples were again taken at the centre of standard 0.5° x 0.5° rectangles using various national versions of the Gulf III high speed sampler. This was with the exception of the Spanish sampling which was achieved with a vertically-hauled CalVet net, which sampled from 100m depth to the surface. In the presence of a thermocline of at least 2°C in 10 m the maximum sampling depth was limited to 20 m below the thermocline. In the absence of a thermocline sampling was to the bottom or to 200 m or in the case of France and Ireland to 150 m, and in the case of Spain it was always 100m.

Samples, or where necessary sub-samples, were subsequently sorted for all fish eggs and the mackerel and horse mackerel eggs identified counted and staged. At least 100 mackerel and horse mackerel eggs had to be present before a sub-sample was accepted as valid. Using calibrated flowmeter readings to assess volumes filtered per haul, the number of eggs in each stage was raised to numbers per m^3 and converted to numbers per m^2 by multiplying by the maximum sampler depth at each station. Numbers of eggs per m^2 were then raised to numbers produced per m^2 per day using the development equations given by Lockwood et al. (1981) for mackerel and for horse mackerel (Pipe and Walker, 1987). They were then raised by the area of the rectangle they represented and summed to give numbers in each stage produced over the survey area for each of the five sampling periods. Rectangle areas are calculated by 0.5 degree rows of latitude using the formulae:

Area in m^2 = (Cosine latitude x 30 x 1853.2) x (30 x 1853.2)

Where there was more than one observation per rectangle within a sampling period, the arithmetic mean of the observed values was used. For unsampled rectangles within the designated survey area the convention for extrapolation used on all previous surveys was used. A minimum of two immediately adjacent sampled rectangles were required before an extrapolation could be made. Then the geometric mean of all adjacent (both immediate and diagonally) rectangle values were used to provide a value for the unsampled rectangle. Once determined extrapolated values were not used to calculate values for other unsampled rectangles. The extrapolated rectangles are shown in Figures 5.1 to 5.5.

Some samples were taken along the margins of rectangles. The convention adopted for allocating such samples to a specific rectangle was:

Latitude - the rectangle allocated was to the north of the line.
Longitude - the rectangle allocated was to the west of the line.

For each of the five time periods a program then determined:

i) sampling grid - indicating the number of samples per rectangle;
ii) breakdown of rectangle numbers m^{-2} d^{-1} by the three regions North (>51°30'N), Central and South (<48°00'N), as defined by Pope and Woolner (1984);
iii) frequency distribution of numbers m^{-2} d^{-1} by region and survey area;
iv) rectangle temperatures by region;
v) extrapolation for unsampled rectangles;
vi) daily production and variance estimates - broken down into contributions from sampled and extrapolated rectangles by row, region and survey area.

[Detailed results of these analyses are available to participants if required.]

Total production was estimated by summing the production estimates for each rectangle (sampled or extrapolated) in the survey grid. Rectangles with replicate samples - whether from the same day or not - during the time period were represented by the arithmetic mean of <u>all</u> values.

Variance was estimated on the assumption of a constant coefficient of variation (c.v.) for each sampled rectangle (Pope and Woolner, 1984). The estimate of c.v. for 1986 survey data, derived from 118 replicated rectangles within cruises, was 1.3. The 1989 survey had 110 such rectangles and the c.v. was also 1.3. The variance from sampled rectangles was obtained by summing the squares of rectangle production and multiplying it by the c.v. squared. For extrapolated rectangles the procedure was the same except that the value of c.v. will be dependent on the number of rectangles used to determine the extrapolated values.

5.2 Egg production within the standard area

Mackerel

The distribution and abundance of stage I mackerel eggs on each survey is shown in Figure 5.6 to 5.10. Only stage I eggs were used to estimate egg production and spawning stock biomass.

On the first survey production south of 48°N was approximately eight times higher than in previous years (Figure 5.6). Counting and identification checks were made on 12 of the samples representing most of the high rectangle values. These checks revealed differences mainly related to sub-sampling and some misidentification of horse mackerel eggs as mackerel eggs. However it was not possible to quantify this error. Production of mackerel eggs on the second and third surveys was two to three times higher than previous years for the area south of 48°N. Most of the increased production occurred along the shelfedge between 45°N and 47°30'N where in previous years spawning has also been concentrated. With the exception of this unusual result on the first survey the major features of mackerel egg distribution are similar to previous years (Figures 5.6 - 5.10). However analysis of production in southern, central and northern regions from 1980 onwards does indicate a slight shift in spawning to the north. In 1989 the production north of 51°30'N on the third and fourth surveys is much higher than in previous years (Figures 5.8 - 5.9). Some of this increase is generated by high values on, and to the south of, the Porcupine Bank a feature not noted in previous years. Egg production values in excess of 100 $m^{-2}d^{-1}$ were detected on the edge of the survey area suggesting further spawning west of 15°W. By the final survey period in July production had as in previous years declined to a very low level. These differences are shown in the text table below.

Stage I Mackerel egg production x 10^{-15}

	Northern Row Z-T	%	Central Row S-K	%	Southern Row J-C	%	
1980	0.182	13.4	1.048	77.5	0.123	9.1	
1983	0.284	18.3	1.093	70.2	0.179	11.5	
1986	0.228	21.5	0.683	64.6	0.147	13.9	
1989	0.442	20.1	0.849	38.5	0.912	41.3	with FRG data
1989	0.443*	31.7*	0.647*	46.3*	0.308*	22.0*	without FRG data

* = excluding the anomalous value on survey period 1.

Horse mackerel

Eggs were sorted and staged from survey periods two to five but not from period 1. The distribution and abundance of stage I eggs for these periods is shown in Figures 5.11 - 5.14. As in previous years spawning is concentrated along the shelf edge. Production builds up slowly from the south on periods two and three to a peak production in the central and northern sections during June (period 4). The highest values of stage I egg production, up to 900 m^{-2} d^{-1} occurred within survey period 4 both south west of Ireland and to the south of the Porcupine Bank.

5.3 Egg production north of the standard area

The only full coverage north of 56°N was done by Ireland in period three. Some sporadic sampling along the shelf edge was done by Scotland but these data have not been used.

Abundance of mackerel eggs north of 57°N was very low, but there was a significant production in the two rectangles off the shelf edge at latitude 56°15'N (Figure 5.15).

No horse mackerel eggs were found on this survey.

5.4 Egg production east of the standard area

The eastern Celtic Sea and Western Channel was surveyed by RV Corystes in June 1988. The egg production of western mackerel and horse mackerel spawning east of the international survey grid was estimated by calculating the nos/m^2/day of stage 1 mackerel and horse mackerel eggs for those rectangles unsampled during the relevant period in 1989 (Figures 5.16 and 5.17). A triangular egg production curve was drawn with this estimate at the peak and the total egg production under the curve was calculated (Figure 5.18 and 5.19). The total egg production for the eastern part of the survey grid is given for mackerel and horse mackerel in Tables 6.4 and 6.6 respectively. The proportion of mackerel spawning to the east of the survey grid compared with the main 1989 survey grid was estimated to be less than 3%. However, for horse mackerel it was much higher, approximately 8%.

5.5 Egg production south of the standard area

To the south of 44°30'N sampling occurred along the north coast of Spain in periods two and four only. These samples were taken by Spain using the vertically hauled CalVet net. (Motos et al., WD 1990).

There was some stage I mackerel egg production in this area during period two but the mean rectangle values were low ($<35\ m^{-2}\ d^{-1}$) compared with those in the standard area (up to $650\ m^{-2}\ d^{-1}$). Production during the fourth period was very low (Table 5.2).

Production of horse mackerel eggs in this area was more significant. During period two, production of stage I horse mackerel eggs reached $141\ m^{-2}\ d^{-1}$ in rectangle A5 and in period four a similar production was observed in a rectangle close to the Spanish coast south of 43°30'N. Production of stage I horse mackerel eggs reached $440\ m^{-2}\ d^{-1}$ in the standard area during period four.

5.6 Total seasonal egg production

The total stage I egg production estimate for each survey period was plotted against the mid cruise date to give a production curve based on five points for mackerel (Figure 5.18) and four points for horse mackerel (Figure 5.19). The total stage I egg production for the spawning season throughout the standard area was then calculated by integrating the area under the curves.

In addition to the production curves for the standard area (Figure 5.18), a production curve for mackerel eggs north of 56°N was also drawn from the single point obtained for period three. Similarly a curve based on points for periods two and four was obtained both for mackerel and horse mackerel in the area south of 44°30'N. The resulting estimates of total seasonal production in these areas are presented separately. The individual survey values for each area are presented separately for mackerel and for horse mackerel (Table 5.2). A production curve for the western Channel is also included.

Mackerel

Because of the unusually high production of stage I eggs on the first survey, the workshop decided to present two seasonal production curves one including and the other excluding this high value (Figure 5.18). It was not possible to examine all the evidence in detail, which might have helped to explain this unusually high value, neither was it possible to complete all the necessary sample validation. Until a satisfactory explanation for the apparent anomaly can be found, the validity of this point, in the context of a western spawning stock must be questioned.

Using the period one data point, a total seasonal production of 2.22×10^{15} stage I eggs is obtained. By excluding the first data point, the total seasonal production drops to 1.41×10^{15} stage I eggs.

Both values show an increase in production over the 1986 figure, but the first value generates the highest egg production found since the surveys began in 1977. The estimated 95% confidence limits for these values are ± 22% compared with a figure of ± 23% obtained in 1983 and in 1986.

Once again a small contribution to the total seasonal egg production was made from sampling by Ireland north of the standard area. The area under the production curve (Figure 5.18) represents 4.06×10^{13} stage I eggs produced. This contributes approximately 3% to the production for that period, compared with 4% calculated for the area north of 55°N in 1986.

The production curve for the area south of 44°30'N, also shown in Figure 5.18, represents a total seasonal production of 1.36 x 10^{13} stage I eggs in this area. This amounts to 1.8% of the total estimate for period two, and 0.2% for period four.

A single survey in 1988 was used to provide an estimate of egg production east of the standard area in particular in the western English Channel. This single point estimate, for June of 64.82 x 10^{10} stage I eggs per day, generates a total egg production of 0.039 x 10^{15} stage I eggs for this eastern area.

Horse mackerel

No data were available for period one although it is known that horse mackerel eggs were present in some of the samples on this survey.

Production of horse mackerel eggs in periods two, three and four is considerably higher than any values recorded in previous survey years (Table 5.2). The value for the peak period in June of 3.47 x 10^{13} is approximately three times greater than the high value recorded in 1980 (Eaton, 1989). In previous years the production curves have been calculated for two areas north and south of 48°N. For 1989, the production curve (Figure 5.19) and total seasonal production estimate of 1.51 x 10^{15} is presented for the whole of the standard survey area.

There was no production of horse mackerel eggs in the one survey north of 56°N in period three. However there was a significant production south of 44°30'N recorded in the Spanish surveys in periods two and four. The contribution from this area is also shown in Figure 5.19. The area under that curve represents a production of 5.5 x 10^{13} which adds approximately 4% to the total stage I egg production within the standard area.

An estimate of stage I egg production to the east of the standard area was obtained from a single survey in 1988. The estimate of 0.202 x 10^{13} stage I eggs per day in June, generates a total stage I egg production of 0.121 x 10^{15} eggs for this area.

5.7 Changes in the egg distribution and the time of spawning

If the egg production estimate for the first period is included, the resulting egg production curve (split into three regions: norths, central and south) is markedly different from those of previous years (Figure 5.20, 5.21 and 5.22). Production during April was about 8 times the expected level, and produced a total egg production estimate which is the highest observed since the surveys began. Re-examination of small numbers of samples from the first period confirmed the high abundance of mackerel eggs, and no reason was found to reject the data provided. A number of possible explanations for the anomaly were discussed.

i) The production of eggs in the first period could be accounted for by early spawning activity. The higher production in periods 2 and 3 in 1989 compared with 1986 supports this (Figure 5.20). The temperatures observed over the whole spawning area in April 1989 were about 1°C higher than those of the same period in 1986, but it is not known whether this would induce a change in the timing of spawning. Accounting for the production in this way would require that almost all of the western spawning stock, as estimated by the latest VPA (Anon, 1989), released batches of average size every 24 hours during the first period, and then subsequently spawned a comparable number of eggs to that observed in previous years. Although there is some evidence of an increase in fecundity in 1989, this would be no more than about 10% (Walsh et al., WD 1990). If the increase in fecundity was because of "de novo" vitellogenesis during spawning, it would be on a scale never before observed for this stock and would undermine the validity of the total egg production method of assessment. The explanation that there was early spawning activity of the western stock would be more plausible if there was evidence of large adult fish in the southern area during period 1. Samples taken at the time of the survey however, indicate that the mean size of fish was only 34cm (Figure 5.23A).

ii) Another possibility is that there has been massive immigration from another stock into the western area. The most likely migration would be from the southern stock in ICES divisions VIIIc and IXa. It is possible that such a migration was caused by the warmer temperature observed in Biscay during 1989, but there is no evidence to support this. It would require an immigration of approximately 1 million tonnes to account for the spawning peak in April, but there is no evidence that the southern stock is this large.

The workshop remained unconvinced by these explanations. Until a satisfactory explanation is found the egg production estimate for the first period in 1989 must be regarded as suspect. The workshop asked that all available age, length and maturity data be collated for the 1989 spawning period and asked that this data be presented at the Mackerel Assessment Working Group which is scheduled to meet in April of this year. It also requested that any relevant data from the southern area, ICES Divisions VIIIc and IXa be made available to the Mackerel Working Group.

6. TRADITIONAL TOTAL FECUNDITY METHOD FOR ESTIMATING SPAWNING STOCK SIZE OF MACKEREL AND HORSE MACKEREL

6.1 General Principles

The spawning biomass of mackerel has been estimated on a triennial basis since 1977 whereas the biomass of horse mackerel was estimated for the first time by this workshop in 1989. Prior to this Eaton (1989) calculated the horse mackerel biomasses for the years 1977, 1980, 1983 and 1986. The traditional method of assessment used in these estimates employs a series of 4 or 5 egg surveys spread evenly throughout the spawning season. An egg production curve is then constructed and by integration the total egg production during the spawning season is obtained (eg Figure 5.18 and 5.19). This is divided by the total potential fecundity (expressed as eggs per gram female), which is determined immediately prior to spawning, in order to obtain the biomass of pre-spawning females. By applying the sex ratio the biomass of pre-spawning fish can be obtained. By applying a conversion factor this pre-spawning biomass can be converted into biomass at spawning time.

The total potential fecundity is estimated by counting the total number of eggs above a certain size threshold in individual fish over a length range. The threshold is the size at which eggs become vitellogenic and is calculated as the maximum size of the previtellogenic eggs at the end of spawning. There are two potential sources of error in this method. Firstly, some of the eggs subsequently become atretic and are resorbed and, secondly, previtellogenic eggs may become vitellogenic after spawning has commenced thus increasing the fecundity.

6.2 Age and length composition

In the past, length data were required for each survey period to calculate the number of spawning females in the population from the egg production estimates and a fecundity-length relationship. This data is no longer required because spawning stock biomass is now calculated directly from total egg production and fecundity/g fish weight.

In view of the apparent occurrence of an early spawning peak in April, however, a review of available biological data may help to provide some evidence as to whether or not this early spawning peak was real. A summary of available data is given in Table 6.1.

A detailed analysis of all biological data was not possible at the workshop but a brief investigation of mackerel length data from the Biscay area was made. Length data from this area in 4 different survey periods are shown in

Figures 5.23a-d and from a previous egg survey in April 1986 (Figure 6.1).

Taken together Figures 5.23a-d indicate no consistent trend between survey periods. This differs from the pattern of previous years where there was a decrease in fish size as the season progressed (Dawson, 1986, Eltink, 1987). The size of mackerel during the first survey were slightly smaller than during the same period in 1986.

It is recommended that biological data from all available sources be reviewed to see if there are any unusual features in 1989 which might account for the anomalous egg production curve.

6.3 Sex ratio

Mackerel

The sex ratio of mature mackerel in the spawning area (ICES Division VIIj) was estimated at 0.49 females from samples of the Dutch commercial freezer trawlers, which were taken during the months March to July in 1982 - 1989 (Eltink, pers. comm.).

A sex ratio of one male per female was used to convert the biomass of female mackerel into the biomass of spawning mackerel. This sex ratio was also used for the earlier Western Mackerel Egg Survey of 1986 (Anon., 1987a).

Horse mackerel

The sex ratio of mature horse mackerel in the spawning area (ICES Division VIIj) was estimated at one male per female from samples of the Dutch commercial freezer trawlers, which were taken during the months March to July in 1982 - 1988 (Eltink, pers. comm.). This sex ratio will be used to convert the biomass of female horse mackerel into the biomass of spawning horse mackerel.

6.4 Total fecundity

Mackerel

Two previous estimates of total potential fecundity have been made for the western mackerel stock in 1977 (Lockwood, 1978) and in 1986 (Greer-Walker et al., 1987). In 1989 a similar exercise was undertaken jointly by MAFF and DAFS in conjunction with Aberdeen University (Walsh et al., WD 1990). As recommended by a previous workshop (Anon., 1987a and Anon., 1988a) further work was carried out to estimate atresia (section 6.5) and to determine the appropriate size threshold above which oocyte counts were made.

For estimation of total fecundity, ovaries from 100 late pre-spawning fish, stratified by length to cover the length range of spawners, were examined. These were obtained from the main spawning area and screened histologically to ensure that spawning had not started. As in previous years fecundity was estimated volumetrically after digestion of one ovary per fish in Gilsons fluid. The sub-sampling techniques used by DAFS and MAFF differed only in minor detail from those used in 1986 (Greer Walker et al. 1987). For estimation of the size threshold above which to make oocyte counts, 36 ovaries, in fish close to the end of spawning, were examined histologically to determine the maximum size of previtelline oocytes (pvo's) and the vitellogenesis size threshold.

Results from the latter investigations indicate that maximum pvo size decreases through spawning and confirm the conclusions made in 1986 (Greer Walker et al. 1987) that using a size threshold measured in pre-spawning fish for making oocyte counts would result in a considerable underestimate of total potential fecundity. Measurements of maximum pvo size and of the 50% vitellogenic size threshold in fish close to the end of spawning gave values between 132 µm and 135 µm (corrected for shrinkage in Gilsons fluid). These values are very close to the value of 130 µm used in previous fecundity estimates and suggest no change in this parameter between years. For the purpose of between years consistency a value of 130 µm was again used in 1989.

In contrast to 1986, fecundity/length and fecundity/weight relationships calculated by DAFS and MAFF in 1989 showed significant differences. The two 1989 length/fecundity relationships are shown in Figure 6.2 together with data from previous years. The slopes of the DAFS and MAFF data are not significantly different but the DAFS data give fecundity values about 30% higher than those of MAFF. The MAFF length/fecundity relationship in 1989 was much closer to that of 1986 than the DAFS one. This could indicate a positive bias in the DAFS data. In 1989, however, ovary weights were greater than in 1986. When this is taken into account the DAFS data for 1989 are closer to those of 1986 than are the MAFF data as shown below:

YEAR	INVESTIGATOR	SAMPLE SIZE	NOS MATURING OOCYTE/g (ovary)	% DIFFERENCE FROM 1986
1986	DAFS & MAFF	53	20944	-
1989	DAFS	50	22534	+8
1989	MAFF	50	17096	-19

On the basis of these rather conflicting results it was decided that the MAFF and DAFS data should be combined for the purpose of calculating a preliminary stock size estimate. A further analysis of the between-laboratory difference will be undertaken to estimate any possible source of bias with a view to producing a better estimate before the mackerel working group meeting in April.

The combined MAFF/DAFS value for fecundity/g of total fish weight in 1989 was 1626. This value has been used in the estimation of spawning stock biomass in 1989 and is 11% higher than the 1986 estimate.

Horse mackerel

In accordance with the terms of a contract with the Commission of the European Communities, the Netherlands Institute for Fisheries Investigations at IJmuiden, started a study on the total fecundity of Western Horse Mackerel (*Trachurus trachurus* L.).

In these investigations (Eltink and Vingerhoed, 1989) the potential total fecundity of horse mackerel was estimated, using both a volumetric and histometric method. The traditional standard volumetric method was used for estimating the total fecundity and ovaries in pre-spawning condition were digested in Gilsons fluid. The histometric method has a number of advantages. The use of Gilsons fluid, a persistent poison, is avoided and maturity stages can be confirmed by identifying post-ovulatory follicles. In addition, the size at which oocytes become vitellogenic can be measured. The results of the histometric method were not significantly different from those of the volumetric method. The total fecundity of Western Horse Mackerel was estimated at 1478 eggs per gram female fish in maturity stage 4 for the volumetric method and 1655 eggs per gram female for the histometric method. There is an increase in weight of about 5% from fish in maturity stage 4 to fish in maturity stage 6. The use of the histometric fecundity estimate is preferable, because it is more likely that this method will be used in future. The spawning stock biomass estimates will therefore be more comparable in future when the histometric value is used.

The total fecundity estimate of Nazarov (1977) used in earlier biomass estimates (Anon., 1987a) was about half the recent estimate. The biomass estimates were therefore doubled. This low fecundity estimate of Nazarov was probably caused by a relatively high size threshold of 175 µm above which he counted the oocytes to be spawned in the current spawning season. This size threshold is much higher than the one of 101 µm estimated by Eltink and Vingerhoed (1989), which was close to the estimated by Macer (1974) at 96 µm.

French research on the total fecundity of horse mackerel (Deniel, 1989) resulted in a rather low fecundity estimate, because a size threshold of 160 µm was used. It was not clear how Deniel arrived at this threshold, but he reported the maximum size of previtellogenic oocytes in spent fish to be 105 µm. This confirms that the size threshold above which oocytes should be counted for the total fecundity should be around 100 µm.

It was decided that the fecundity of 1655 eggs per gram female horse mackerel (Eltink and Vingerhoed, 1989) should be used to convert total egg production to biomass of pre-spawning females.

6.5 Atresia estimates

Mackerel

Random samples of mature female fish were collected from four cruises occurring between April and July 1989 (Greer Walker et al., WD 1990). Ovaries were fixed in formalin, dehydrated, sectioned and stained. The slides were then scored to establish the prevalence (the number of female fish with atretic oocytes) and intensity (the number of atretic oocytes found in an individual ovary) of atresia within the population. Approximately one third of all ovaries examined contained atretic eggs (Table 6.2) and the relative intensity, which is defined as the number of atretic eggs divided by the predicted fecundity, varied between and 0 and 0.2 at the beginning of the spawning season and 0 and 0.6 towards the end (Table 6.3). Figure 6.3 shows the relative intensity by prevalence for each survey period. The correction required for the biomass estimate is given in section 6.6.

Horse mackerel

Ovaries were collected between February - June 1989 from the northwestern Cantabrian Sea during the spawning period. Alpha atresia occurred in 40 per cent of the ovaries containing yolked oocytes. The incidence of atresia appeared to decline at the peak of the spawning season. Lower levels of atresia occurred in spawning fish with postovulatory follicles in the ovaries. Atresia in hydrated oocytes were noted (Pérez and Porteiro, WD 1990).

6.6 Estimation of the spawning stock biomass

Mackerel

Total egg production is given for the standard survey grid both including and excluding the first period data. Egg production outside the standard area is given separately for north of 56°N, the Western Channel and south of 44°30'N. These data are summarized in Table 6.4.

The 1989 fecundity/weight relationship was used to calculate the number of eggs per gram of late pre-spawning females. This was estimated to be 1626 eggs per gram, (Walsh et al., WD 1990). This was applied to the total egg production estimate to obtain the spawning stock biomass of late pre-spawning fish. The conversion to the biomass of fish at spawning time (Anon., 1987b page 3) increased the estimate by 8%. The spawning stock biomass estimates are also given in Table 6.4.

Correction for atresia.

Vitellogenic oocytes in the ovary are either spawned or they become atretic, so that adding a production curve of atretic oocytes to the egg production curve accounts for all of the potential fecundity of the stock.

Let

T_i = duration of period i

E_i = egg production during period i

f = potential fecundity per gram female

a_i = daily production rate of atretic oocytes per gram female during period i

The biomass of spawning females B_i corresponding to the egg production E_i is given by

$$B_i = E_i / (f - a_i T_i)$$

So that the production of atretic oocytes A_i during period i is

$$A_i = a_i \, T_i \, B_i$$

Total female SSB is then calculated as $\sum B_i$ or, equivalently, $\sum (A_i + E_i) f$.

Note that B_i is the biomass of females required to spawn all their eggs during time period i to account for the observed production. In fact, a larger biomass would spawn a proportion of their eggs during this time period. The method must therefore be regarded as an approximation.

The rate of production of atretic oocytes per gram female depends on the prevalence and intensity of atresia and on the duration of the atretic stage in the ovary. Prevalence and intensity were determined histologically (see section 6.5) and the mean intensity calculated after log transformation of the distribution of prevalence against intensity for fish with atretic oocytes. These are summarised in the text table below.

Period examined	No.ovaries	% with atretic oocytes	Mean number of atretic oocytes per gm for fish with atresia
2	26	46	78
3	23	26	224
4	25	32	198
5	30	30	104

The mean number of atretic oocytes per gram female in the population is calculated by multiplying the last column in the table by the percentage of females with atretic oocytes. In the absence of reliable information, the daily production rates of atretic oocytes per gram female were calculated using assumed durations of the atretic stage of 5 days (Hunter and Macewicz, 1985) and of 10 days.

The results are summarised in table 6.5. Assuming durations of atretic oocytes of 5 days and of 10 days increases the estimate of female SSB by 16% and 7.5% respectively.

Horse mackerel

Total Egg production is given for the standard grid, Western Channel and south of 44°30'N in Table 6.6. No egg production was found north of 56°N.

The fecundity/weight relationship given by Eltink and Vingerhoed (1989) was used to calculate the number of eggs per gram of late pre-spawning females. This was based on samples collected in 1987 and 1988 and was estimated to be 1655 eggs per gram. This was applied to the total egg production estimate to obtain the spawning stock biomass of maturity stage 4 fish. The conversion to the biomass of fish at spawning time increased the estimate by 5% (Eltink and Vingerhoed, 1989) The biomasses of horse mackerel in pre-spawning condition and at spawning time are listed in Table 6.6 for both inside and outside the standard area.

7. NEW BATCH FECUNDITY METHOD FOR ESTIMATING SPAWNING STOCK SIZE OF MACKEREL

According to the terms of study contract No DG XIV/B/1-1989/2 between the Commission of the European Communities and the University of Aberdeen, research on mackerel batch fecundity and fraction of females spawning is being carried out. The preliminary results of this research are presented in thes section, but do not necessarily reflect the opinion of the Commission of the European Communities and do not prejudice its future attitude in this field. The text in this section may be reproduced, in whole or in part, quoting the source.

7.1 General Principles

The batch fecundity method is an alternative means of calculating spawning stock biomass from egg production data (Lasker, 1985). The basic principle is that instead of integrating egg production over the whole spawning season, a single estimate of daily egg production at some time during the middle of the spawning season is obtained (Figure 7.1) (Priede & Watson, WD 1990). The number of female fish is then calculated:

$$N_f = E_d / F_b \cdot S$$

Where:

N_f is the number of female mackerel in the spawning area.
E_d is the daily egg production in the spawning area.
F_b is the batch fecundity.
S is the daily spawning fraction.

7.2 EC Study contract. Application of the Batch Fecundity method to the Western Mackerel Stock

In 1989 it was decided to undertake a trial of this new method on the western mackerel stock taking advantage of the fact that the ICES was coordinating extensive egg production surveys for the purposes of the total fecundity egg production method. The work is being carried out as a study contract for the Commission of the European Communities. The University of Aberdeen is responsible for coordination of the contractors who are The University of Aberdeen in Association with, DAFS, Marine Laboratory, Aberdeen, MAFF, Lowestoft, Dept. of the Marine Dublin, and IFREMER, Nantes (Figure 7.2).

The value for daily egg production (E_d) has been derived as a subset of the egg survey data for the total fecundity method. This deviates from the original practice in applying the batch fecundity method (Lasker, 1985) in that early egg mortality in stage I is not accounted for. In comparing the two methods applied to the western mackerel stock it has been decided to use the same egg production estimates for both biomass estimates. In order to estimate the batch fecundity (F_b) and spawning fraction (S) a ship was chartered to undertake a trawl survey during the middle of the spawning season. The MFV KING'S CROSS was chartered by the University of Aberdeen from 23 May to 12 June 1989 and trawled for mackerel between 47°30'N and 60°N along the continental shelf margin (Figure 7.3). From 51 trawl (pelagic trawl with vertical opening of about 80-100m) hauls 1330 ovaries were fixed for histological sectioning and analysis for estimation of spawning fraction. These samples were also used for estimation of batch fecundity.

The overall organisation of the batch fecundity programme is described in an Interim Report to the European Commission, November 1989 (Watson (Editor), WD 1989) and a working document (Priede & Watson, WD 1990) summarising progress since November. The Lowestoft Laboratory has collated data for egg production for 23 May to 12 June (Figure 7.4). The batch fecundity data have been fully analysed (Watson & Priede, WD 1990) (Figure 7.5). All data necessary for the estimation of spawning fraction have been collected and preliminary results were presented to the working group (Watson, Priede & Walsh, WD 1990; Watson & Priede, WD 1990). The observation that mackerel spawn throughout the daily 24h cycle means that estimation of spawning fraction requires data on duration of oocyte maturity stages and durations of post-ovulatory follicles.

A working group of the EC Mackerel Batch Fecundity group will be convened in Aberdeen on 5-7 March 1990 to agree on the spawning stock biomass estimate and to begin drafting of the final report to the European Commission (Figure 7.2). Results from that group may be made available for discussion at the ICES Mackerel Working Group 24 April-2 May 1990, in Copenhagen. A final report to the European Commission is required by the end of May 1990 detailing the work carried out and comparing the results of the Total Fecundity method and the Batch Fecundity method.

7.3 Preliminary estimates of stock biomass

The batch fecundity method is a practical method for estimation of biomass of the Western mackerel stock. At the time of this workshop estimates of egg production, and batch fecundity were complete. Final estimates of spawning fraction were not available. Estimates of the biomass will be available after the Aberdeen Working Group in March 1990.

8. COMPARISON OF THE METHODOLOGY USED TO ESTIMATE THE SPAWNING STOCK SIZE FROM TOTAL FECUNDITY AND BATCH FECUNDITY

The formal comparison of the two alternative egg production methods will be the subject of a report prepared under the terms of EC study contract No XIV/B/1-1989/2. That report is due for completion in May 1990 but a draft will be available resulting from the EC Batch Fecundity meeting to be held in Aberdeen 5-7 March 1990.

Arguments in favour of the total fecundity method.

Sampling is carried out throughout the whole spawning season and therefore variations in the spawning pattern can be detected. In 1989 for example the batch fecundity method would have failed to detect the anomalous early spawning peak.

The total fecundity method has now been used since 1977 and represents a consistent time series index of spawning stock biomass status.

Results of the total fecundity method are in agreement with converged VPA estimates.

It appears that total fecundity does approximate to the potential fecundity estimated from counting oocytes above a size threshold of 130 µm in pre-spawning ovaries.

Arguments against the total fecundity method.

The method is costly, requiring (in 1989) a sequence of 5 egg surveys in order to estimate total egg production during the spawning season. (A total of 180 days).

The method assumes that fecundity in mackerel is determinate. This assumption according to Coello (1989) is not valid. One explanation for the early season spawning anomaly in 1989 is excess early spawning by the resident stock. Such a phenomenon results in errors in the biomass estimate using the total fecundity method.

In order to correct the estimate of total fecundity for loss of eggs through atresia data on duration of atretic stages are required. Coello (1989) by considering different components of the stock suggests a loss of 25% of total potential fecundity in 1987. In section 6.6 the estimate of egg loss through atresia in 1989 is 16%.

There appears to be no means of estimating gain of eggs by de novo vitellogenesis which may compensate for, or exceed egg loss through atresia. The 1989 egg production anomaly could, at least partially, be the result of such a gain of eggs.

Arguments in favour of the Batch Fecundity Method.

No assumptions are made about future or past egg production by fishes; determinate spawning need not be assumed.

The batch fecundity and spawning fraction are determined from samples taken during the period of the egg survey. Biomass estimates are therefore not affected by high or low anomalies in egg production by the resident stock such as may have occurred in 1989.

The batch fecundity method only requires one egg survey during the middle of the spawning season.

The EC study has proved that it is possible to measure batch fecundity to an adequate level of precision.

Arguments against the batch fecundity method.

The method assumes all the adult stock is in the survey area during the survey period.

The observation that mackerel can spawn at any time during the diel 24h cycle means that data is needed on duration of oocyte and post-ovulatory follicle stages in order to obtain precise spawning fraction estimates. Captive spawning experiments can provide that information.

Estimation of spawning fraction requires an extensive trawl survey of the adult stock throughout the survey area.

Conclusion: Difficulties resulting from the anomalous spawning pattern in 1989 may mean that valid comparison of the two methods is not possible and any firm recommendation would be premature.

9. DEFICIENCIES AND RECOMMENDATIONS

Total fecundity/Batch fecundity comparison

Estimates of spawning fraction were not available for this workshop, therefore comparison of the two methods was not possible. The Workshop recommends that the estimate of biomass from the EEC Batch Fecundity Meeting, to be held in March 1990, be made available to the 1990 ICES Mackerel Working Group meeting for comparison.

The batch fecundity method

The workshop recommends that the comparison between the total fecundity method and the batch fecundity method should be repeated for mackerel and investigated for horse mackerel.

Batch fecundity

Reliable data are only available for one year for the western mackerel stock (1989). Further research should be directed to investigate inter-annual variations in batch fecundity.

Spawning fraction

The observation that mackerel spawn throughout the 24 h diel cycle means that to estimate spawning fraction good estimates of oocyte maturation and post-ovulatory follicle durations are necessary. Further experiments on captive mackerel is recommended to improve accuracy of measurement of spawning fraction. Further observations on diel periodicity of spawning are recommended.

Rate of Atresia

Prevalence and intensity of atresia as measured from histological sections can only be used to estimate egg loss through atresia if the duration of atretic stages is known. At present this information is not available. Research on captive mackerel is recommended to determine the duration of atretic stages.

De novo vitellogenesis

There is no clear means of correction of the total fecundity estimate to take into account possible development of new eggs during the course of the spawning season.

Next workshop meeting

If another meeting of the Mackerel/Horse Mackerel egg production workshop is to be held it is recommended to have it in January 1991 (proposed IJmuiden), which is before research vessel time will be firmly scheduled by most countries.

Plankton sampler

Given the variability of the volumes filtered indicated by the flowmeter readings in replicate hauls, further investigations on sampler efficiency and calibration are encouraged.

Data processing by another institute

Due to heavy staff commitment, it is unlikely that Lowestoft will be able to take full responsibility for data processing for future egg surveys. Therefore an alternative arrangement for processing the data has to be found at the next workshop meeting.

Validation of data for first period

The Workshop recommends thorough checking of sample collection, egg identification and data analysis for the first period in order to verify the unusually high anomalous value.
The Workshop recommends that all available age, length, maturity and any other relevant biological data from the Western spawning area be collated for the 1989 spawning period, March through to July and be presented to the 1990 Mackerel Working Group meeting. Data should be given by area: north of $51^{0}30'$N, central between 48^{0} N and $51^{0}30'$N, and south of 48^{0} N.
The Workshop recommends that all relevant data including egg production data from the Southern area, ICES division VIIIa and IXc, be presented to the 1990 Mackerel Working Group meeting.

Total fecundity

It is recommended that further work be carried out to determine and, if possible, to remove the source of the bias between the MAFF the DAFS mackerel fecundity estimates so as to obtain a better estimate of fecundity in time for the 1990 ICES mackerel working group.

Maturity key

It is recommended that the simplified mackerel maturity key used by DAFS and MAFF during the 1989 mackerel egg surveys (Walsh 1990 WD) be adopted for use by all ICES countries in future egg surveys; and for the Mackerel Working Group to coordinate this.

10. WORKING DOCUMENTS

List of discussion papers presented at the *ad hoc* Mackerel / Horse mackerel Egg Production Workshop 1990.

Dawson, W. A. and Milligan, S. P. WD 1990.
The contribution of spawning in the Western Channel to the Western mackerel (*scomber scombrus*) and horse mackerel (*Trachurus trachurus*) stocks.

Greer-Walker, M. WD 1990.
Towards an estimate of atresia in the mackerel (*Scomber scombrus*).

Iversen, S. A. WD 1990.
Preliminary results from a mackerel spawning survey in the North Sea 1989. (Working Doc. for ACFM, November 1989 meeting).

Motos L, Uriarte, A. and Valencia, V. WD 1990.
Preliminary results on Mackerel and Horse Mackerel Eggs from AZT1-S10 1989 Egg Surveys.

Pérez Nelida and Porteiro, C. WD 1990.
Preliminary Results of a histological study of the gonads of the southern horse mackerel (*trachurus trachurus* L.) stock.

Priede, I. G. and Watson, J. WD 1990.
The Batch Fecundity Egg Production Method for Estimation of Spawning Biomass. Application to the Western Mackerel Stock.

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Table 3.1 Changes in counts of mackerel eggs following fixation with formalin.

Egg stage	Average number counted per sample		Ratio
	Fresh	Fixed	fresh/fixed
1	18.92	18.92	1.000
2	16.46	16.00	1.029
3	17.46	13.92	1.254
4	12.31	15.23	0.808
5	10.31	11.46	0.900
Total	75.46	75.54	

Table 3.2 Percentage departure from mean numbers of eggs in each stage by country.

	Stage						Stage 1
	1a	1b	2	3	4	5	(1a+1b)
England	13	-26	12	-21	26	4	- 7
Scotland	- 4	26	-19	- 6	48	-28	6
France	27	-26	4	14	-39	- 6	10
Ireland	26	-51	- 9	- 1	-10	15	1
Netherlands	-54	99	6	28	-20	- 7	- 5
Spain	- 8	- 1	7	-14	- 5	22	- 6

Table 3.3 Mean, variance, and coefficient of variation of egg counts per sample arising from differences in stage identification among countries.

	Stage						Combined stages	
	1a	1b	2	3	4	5	1	2-5
Mean	33.5	15.6	22.2	22.3	19.4	21.9	49.1	85.9
Standard Dev	13.6	12.7	5.0	5.7	7.7	5.7	4.5	4.6
Coeff.of Var (%)	41	81	23	26	40	26	9	5

Table 4.1 The 1990 North Sea egg surveys. Available ship time.

Research Vessel	Period
Tridens & Isis	12 - 16 March 26 March - 6 April 23 April - 4 May 21 May - 1 June 18 - 29 June 9 - 20 July
Dana	9 - 18 June
Michael Sars	16 June - 15 July

Table 5.1 Research vessel deployment during the 1989 Western Egg Surveys.

RESEARCH VESSEL	PERIOD 1	2	3	4	5
WALTHER HERWIG	1/4-20/4				
SCOTIA		23/4-14/5			
IBAIZABAL DOS		10/5-20/5		14/6-24/6	
CIROLANA			21/5-6/6		
EMER MARIE			22/5-6/6		
CRYOS			27/5-4/6	8/6-12/6	
TRIDENS				7/6-21/6	4/7-19/7
LOUGH FOYLE				7/6-22/6	
	1/4-20/4	23/4-20/5	21/5-6/6	7/6-24/6	4/7-19/7

Table 5.2 Summary of Western mackerel and horse mackerel stock Stage I egg production in 1989.

Daily egg production x 10^{13}	Period 1 1-20 April	Period 2 23 April- 20 May	Period 3 21 May- 6 June	Period 4 7-24 June	Period 5 4-19 July
Survey mid point	-10 April-	-3 May-	-29 May-	-15 June-	-11 July-
Mackerel					
Standard area	4.4773*	1.5727	2.1344	1.6532	0.3124
North of 56°N	-	-	0.0677	-	-
South of 44°30'N	-	0.0287	-	0.0032	-
Horse mackerel					
Standard area	-	1.1064	1.4741	3.4747	0.3596
North of 56°N	-	-	Nil	-	-
South of 44°30'N	-	0.0802	-	0.0534	-

*Anamalous point see section 5.2

Table 6.1 Fish sample data available from western mackerel and horse mackerel spawning grounds in 1989.

Vessel	Period	Fishing gear	No. hauls	Mackerel				Horse Mackerel			
				Catch/h	Length distributions	Age	Maturity	Catch/h	Length distributions	Age	Maturity
Cirolana	Mar	B.Tr	40	C	C	C	C	C	C	-	-
Walter Herwig	Apr	B.Tr	14	NCS	NCS	NCS	NCS	?	?	?	?
Scotia	Apr/May	B.Tr/HL	22	NCS	NCS	NCS	NCS	NCS	NCS	-	-
Kings Cross	May/Jun	Pel. Tr	45	NC	NC	NC	NC	NC	NC	NC	NC
Cirolana	May/June	HL	?	C	C	C	C	-	-	-	-
Cryos	May/Jun	Pel.Tr/HL	14	-	CS				CS		
Emer Marie	May/Jun	HL		-	NC	NC	NC	-	-	-	-
Lough Foyle	Jun	HL	9	-	NC	NC	NC	-	-	-	-
Tridens	Jun	B.Tr	11	S	S	(few)		S	S	(few)	
Tridens	July	B.Tr	8	C	C	(few)		C	C	(few)	
Dutch commerical	Mar) Apr) May)	Pel. Tr	?	-	NC	NC	NC	-	NC	NC	

Key: N = North of 51°30'N
C = 48°00'N - 51°30'N
S = South of 48°00'N

B.Tr = bottom trawl
HL = hand lines
Pel.Tr = pelagic trawl

Table 6.2 The prevalence of atresia during the spawning season.

	Cruise			
	SCOTIA	KINGS CROSS	LOUGH FOYLE	TRIDENS
Number of fish in sample	25	41	26	30
	Prevalence as a proportion of 1.0			
Prevalence of alpha atresia	0.36	0.41	0.31	0.30
Prevalence of alpha atresia at the yolk vesicle stage	0.32	0.32	0.19	0.13
Prevalence of alpha atresia at the yolk granule stage	0.20	0.34	0.27	0.27
Prevalence of advanced atresia	0.12	0.05	0.00	0.03
Prevalence of all atresia	0.48	0.46	0.31	0.33
Prevalence of post-ovulatory follicles (spawning fraction)	0.72	0.34	0.77	0.70
Proportion of the predicted fecundity spawned	0.35	0.50	0.44	0.62

Table 6.3 The relative intensity of alpha atresia during the spawning season.

		Cruise			
	Relative intensity	SCOTIA	KINGS CROSS	LOUGH FOYLE	TRIDENS
Number of fish in sample		25	41	26	30
		Relative intensity as a proportion of 1.0			
	0	0.56	0.78	0.69	0.70
Number of atretic eggs / Predicted fecundity	0.1	0.32	0.05	0.12	0.13
	0.2	0.12	0.12	0.08	0.03
	0.3	0	0.02	0.04	0.07
	0.4	0	0.02	0.04	0.03
	0.5	0	0	0	0.03
	0.6	0	0	0.04	0
	0.7	0	0	0	0

Table 6.4 Summary of the Western mackerel stock total egg production and spawning stock size estimate in 1989.

Area	Total egg production x 10^{15}	Spawning stock biomass x 10^6 t of late pre-spawning fish (using 1989 fecundity/ weight relationship)	Spawning stock biomass x 10^6 t at spawning time
Standard area 56°N-44°30'N	2.215# 1.410x	2.725 1.734	2.929 1.864
North of standard area North 56°N	0.041	0.049	0.054
Western Channel East of 7°30'W (See Fig. 5.16)	0.039*	0.048	0.052
South of standard area South 44°30'N	0.014	0.017	0.018

Including anomalous first period value
x Excluding anomalous first period value
* 1988 egg production figures

Table 6.5 Female SSB estimates corrected for atresia.

E_i = egg production during period i (x 10^{13})
T_i = duration of period i in days
a_i = daily egg production of atretic oocytes per gram female
B_i = corresponding female SSB for period i (x 10^3 tonnes)
(Rate at atresia for period 1 assumed to be same as that for period 2)

Period of integration of egg production			Assuming no atresia	Assuming duration of atretic stage			
				5 days		10 days	
	T_i	E_i	B_i	a_i	B_i	a_i	B_i
1. 21 Mar-22 Apr	33	90.0 19.2*	553.5 117.9*	(7.176)	647.9 138.0*	(3.588)	597.1 127.1*
2. 23 Apr-20 May	28	54.9 44.4*	337.5 273.4*	7.176	385.1 311.9*	3.588	359.6 291.4*
3. 21 May-6 Jun	17	35.2	216.5	11.648	246.7	5.824	230.6
4. 7 Jun-29 Jun	23	34.2	210.4	12.672	256.5	6.336	231.2
5. 30 Jun-17 Jul	18	7.9	49.0	6.24	52.6	3.120	50.7
Totals		222.2 140.9*	1366.9 867.2*		1588.8 1005.7*		1469.2 931.0*

Note - Values marked * exclude the data from the first survey.

Table 6.6 Summary of the Western horse mackerel stock total egg production and spawning stock size estimate in 1989.

Area	Total egg production $\times 10^{15}$	Spawning stock biomass $\times 10^{6}$ t of late pre-spawning fish (using fecundity of 1655 eggs per gm female)	Spawning stock biomass $\times 10^{6}$ t at spawning time
Standard area 56°N-44°30'N	1.507#	1.821	1.912
North of standard area North 56°N	0	0	0
Western Channel East of 7°30'W (See Fig. 5.17)	0.121*	0.146	0.153
South of standard area South 44°30'N	0.055	0.066	0.069

No estimate available for the first period
* 1988 egg production figures

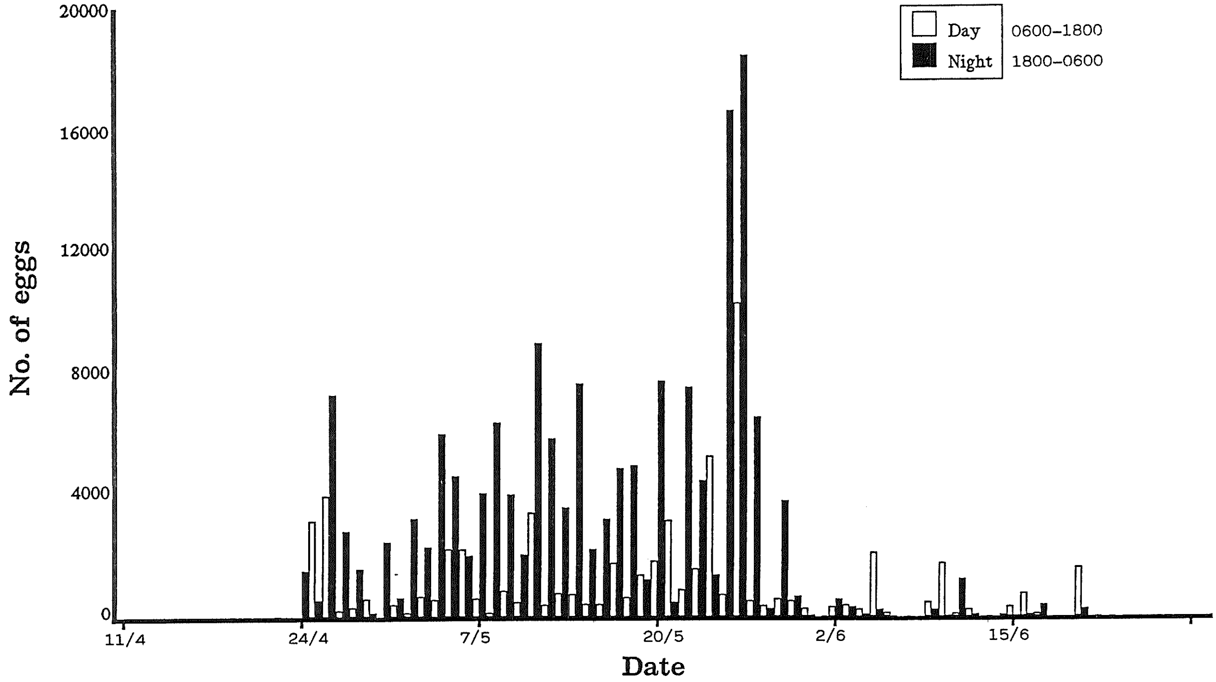


Figure 3.1 The production of mackerel eggs by day and by night, from tank experiments over the period 11 April to 26 June.

Figure 3.2 Duration of seven stages within the blastodis~~k~~c stage of mackerel eggs over the temperature range 8°C to 19°C. The fitted curves are from the equation lnt = AlnT+B (t = time in hours; T = temperature °C)

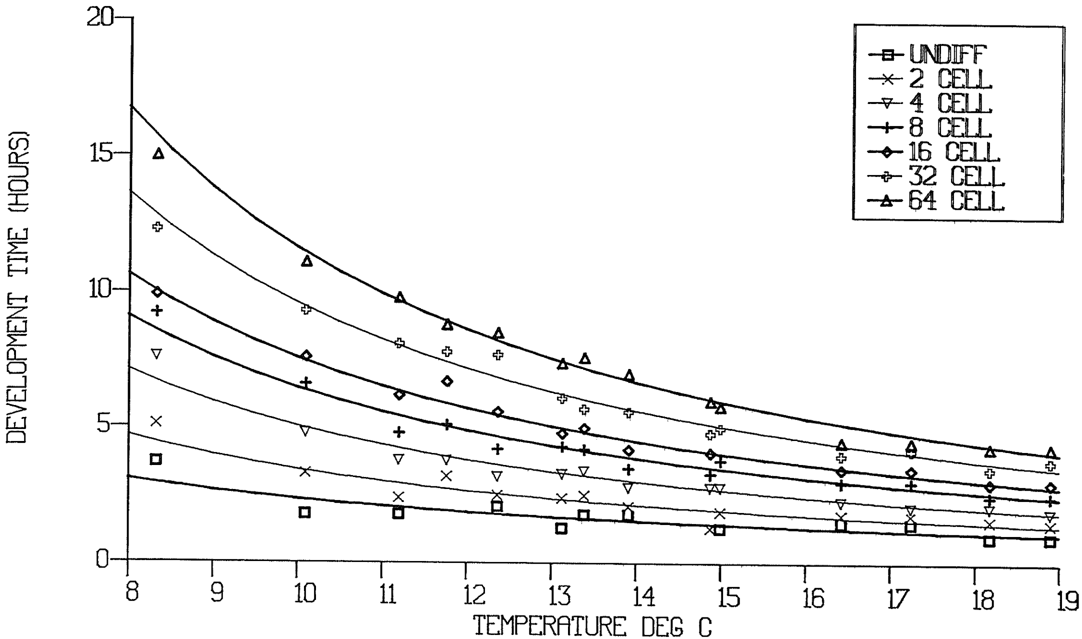
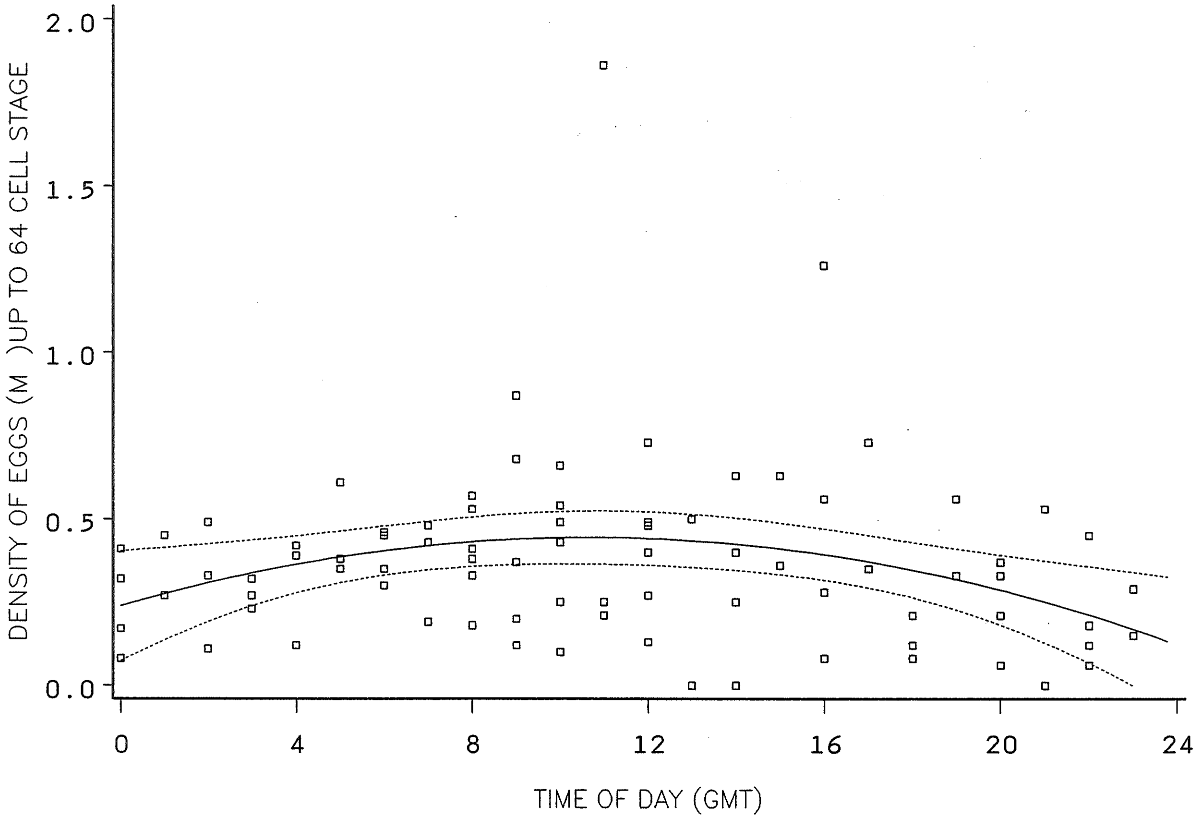


Figure 3.3 Timing of mackerel spawning from thirteen plankton samples taken over a 28 hour period off the SW coast of Ireland, 2/3 June 1990. Using temperature/development rate data, eggs up to 64 cell stage have been back calculated to their spawned time.



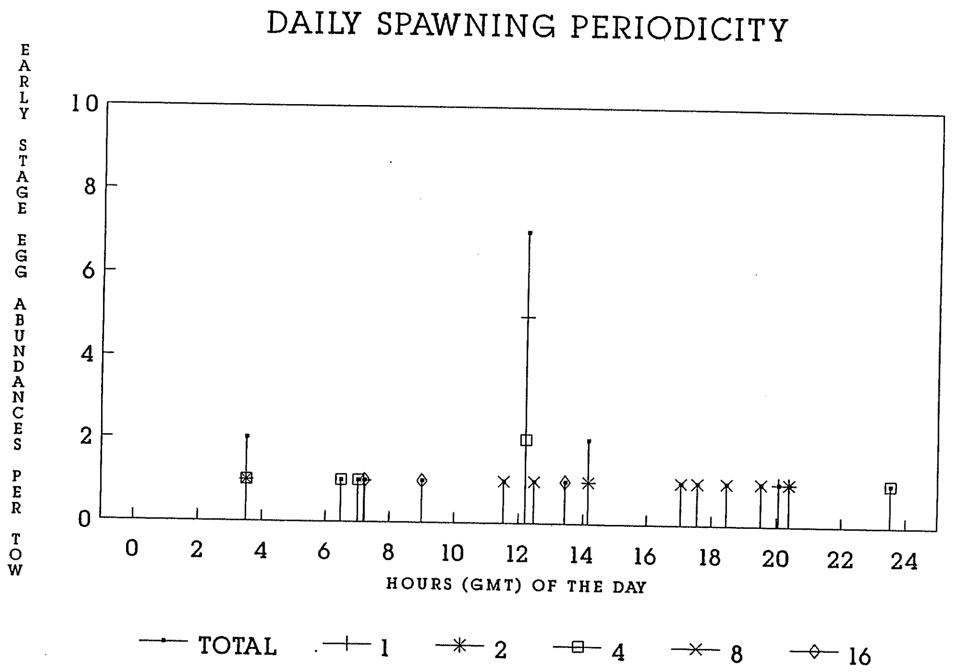


Figure 3.4 The occurrence of early stage mackerel eggs up to 16 cell stage over a 24 hour sampling period in southern Biscay during May 1989.

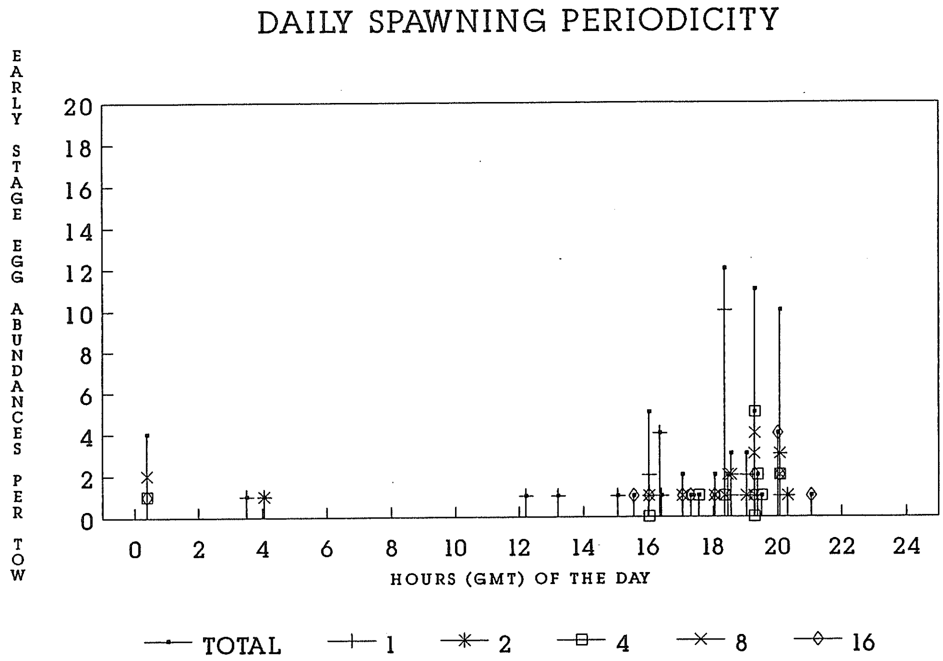


Figure 3.5 The occurrence of early stage horse mackerel eggs up to 16 cell stage over a 24 hour sampling period in southern Biscay during May 1989.

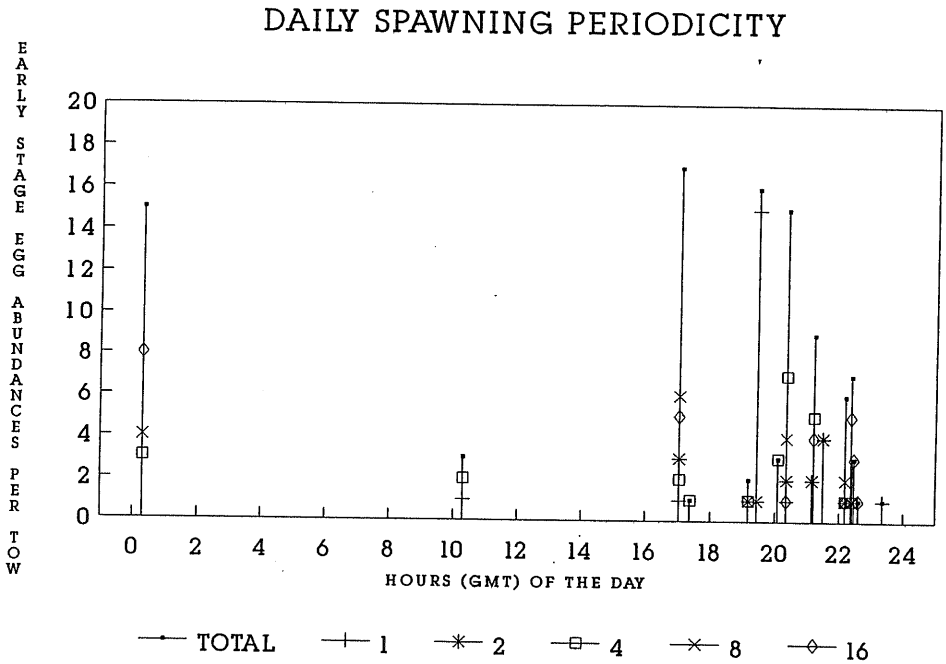


Figure 3.6 The occurrence of early stage horse mackerel eggs up to 16 cell stage over a 24 hour sampling period in southern Biscay during June 1989.

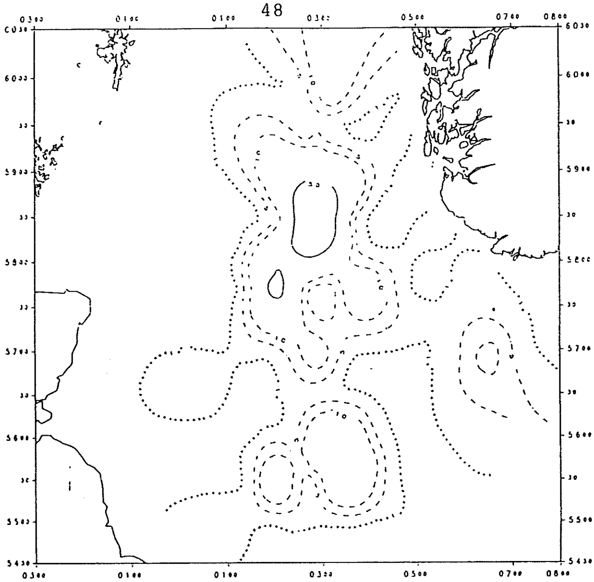


Figure 4.1 The distribution of mackerel eggs less than one day old between 16-27 June 1989 in the North Sea. (numbers/m²/day)

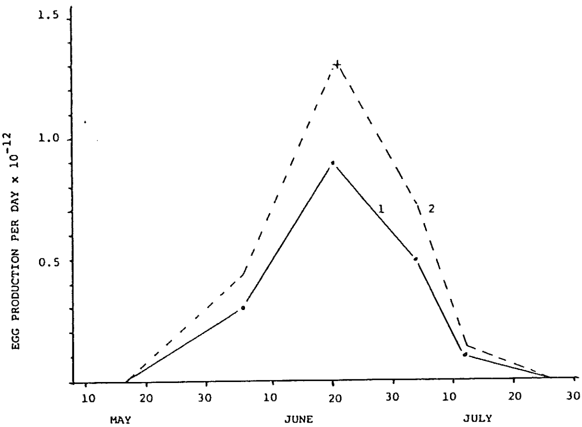


Figure 4.2 The North Sea mackerel egg production curve for 1988(1) and a suggested curve for 1989(2) following the 1988 pattern.

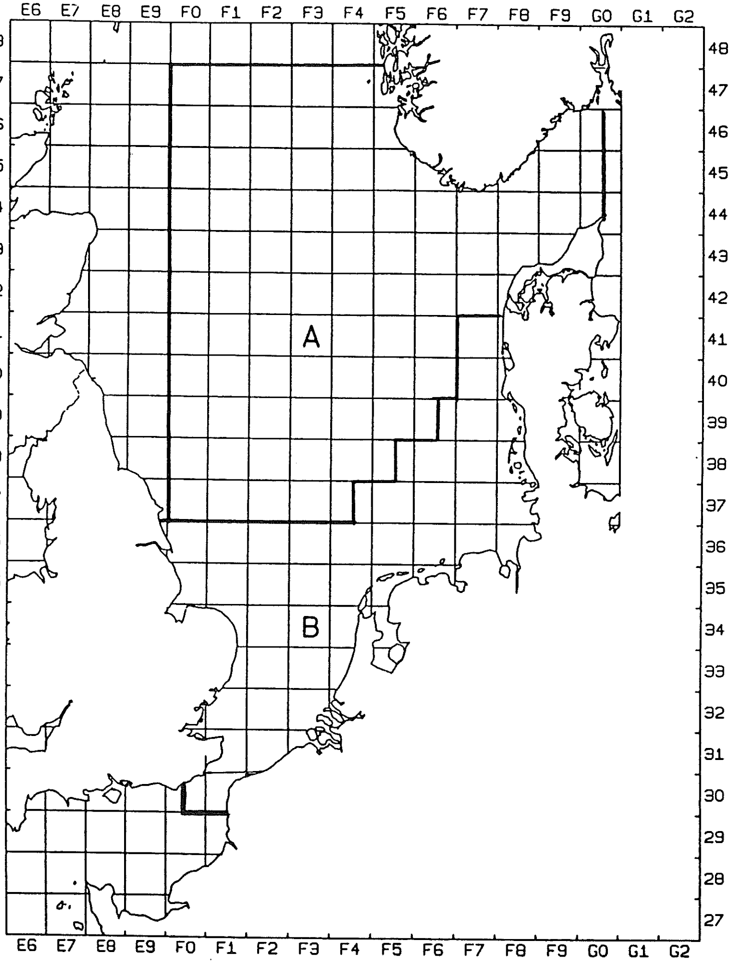


Figure 4.3 The area of the North Sea to be surveyed in 1990 by Denmark and Norway (A) and by the Netherlands (B).

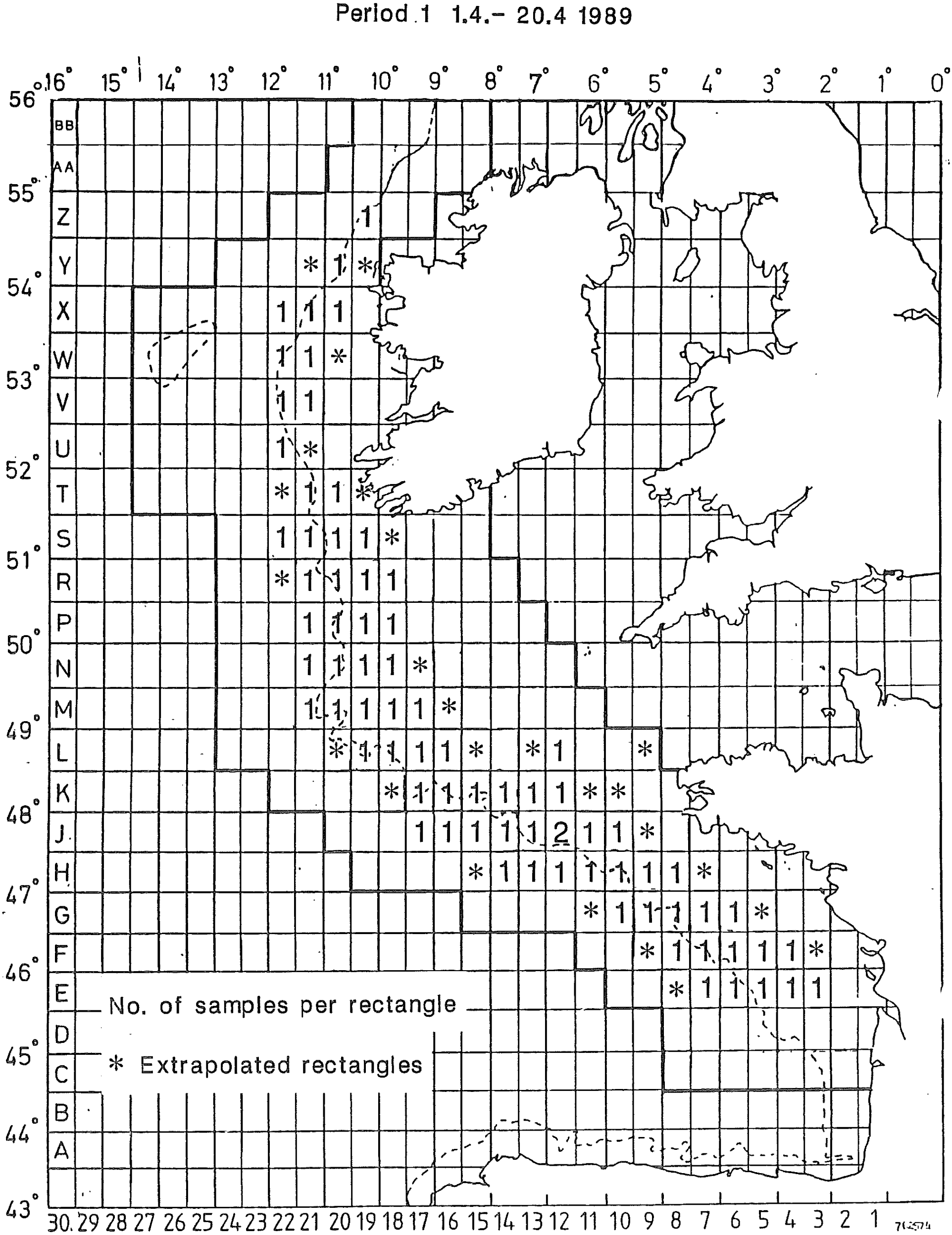


Figure 5.1 The number of observations per rectangle and extrapolated rectangles* for period 1; 1 April to 20 April 1989.

Period 2 23.4. - 20.5.1989

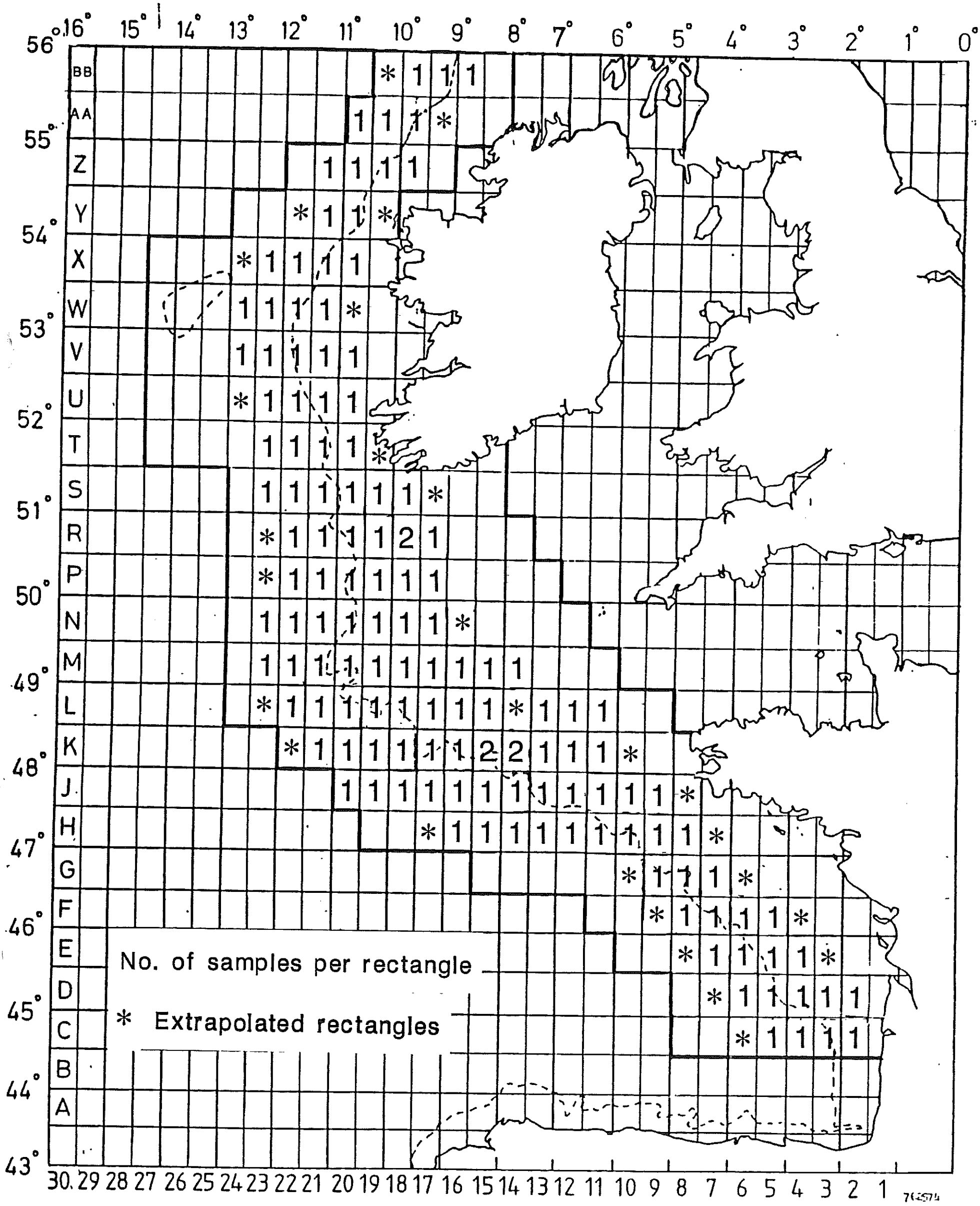


Figure 5.2 The number of observations per rectangle and extrapolated rectangles * for period 2; 23 April to 20 May 1989.

Period 3 21.5. - 6.6.1989

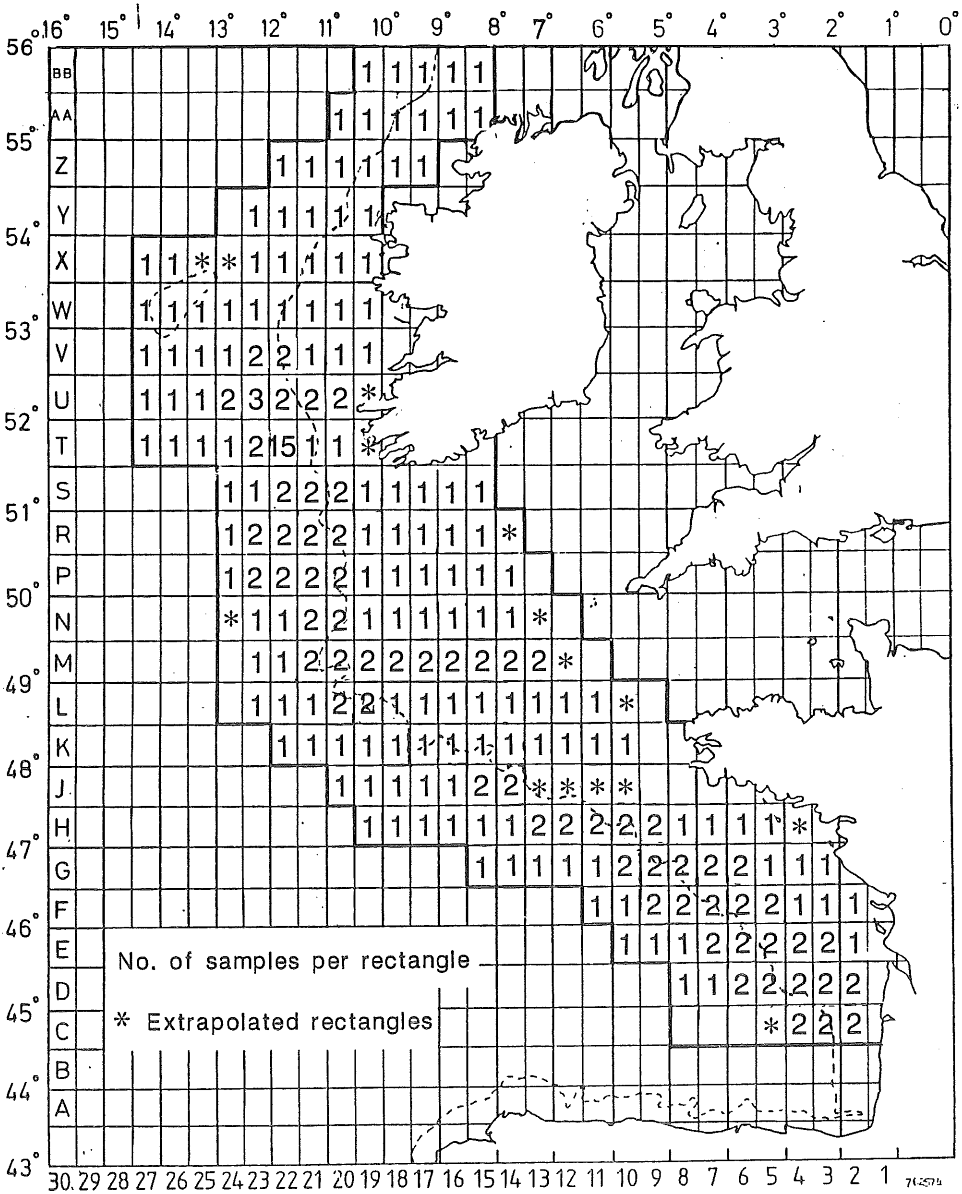


Figure 5.3 The number of observations per rectangle and extrapolated rectangles * for period 3; 21 May to 6 June 1989.

Period 4 7.6.- 24.6.1989

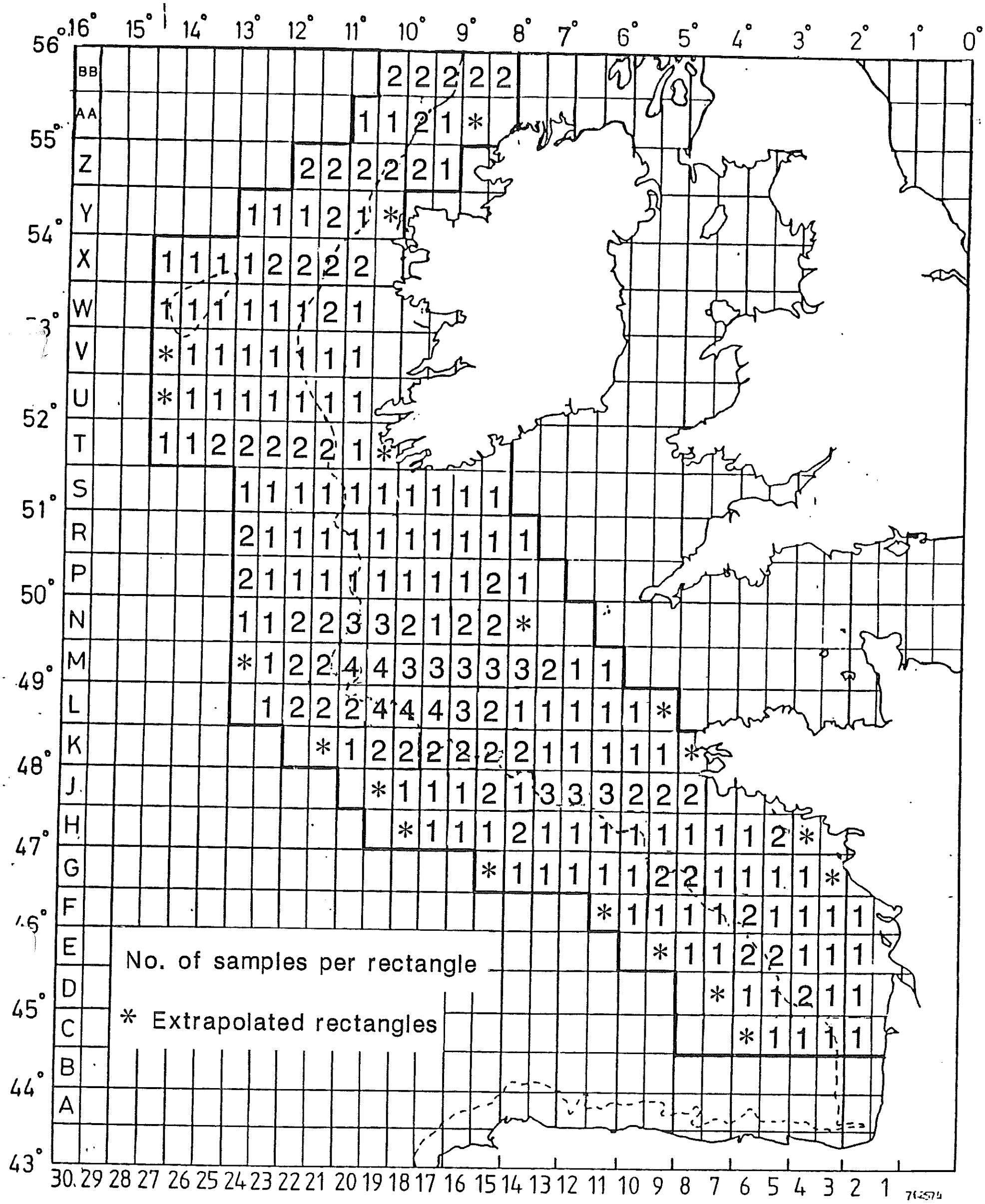


Figure 5.4 The number of observations per rectangle and extrapolated rectangles * for period 4; 7 June to 24 June 1989.

Period 5 4.7. - 17.7.1989

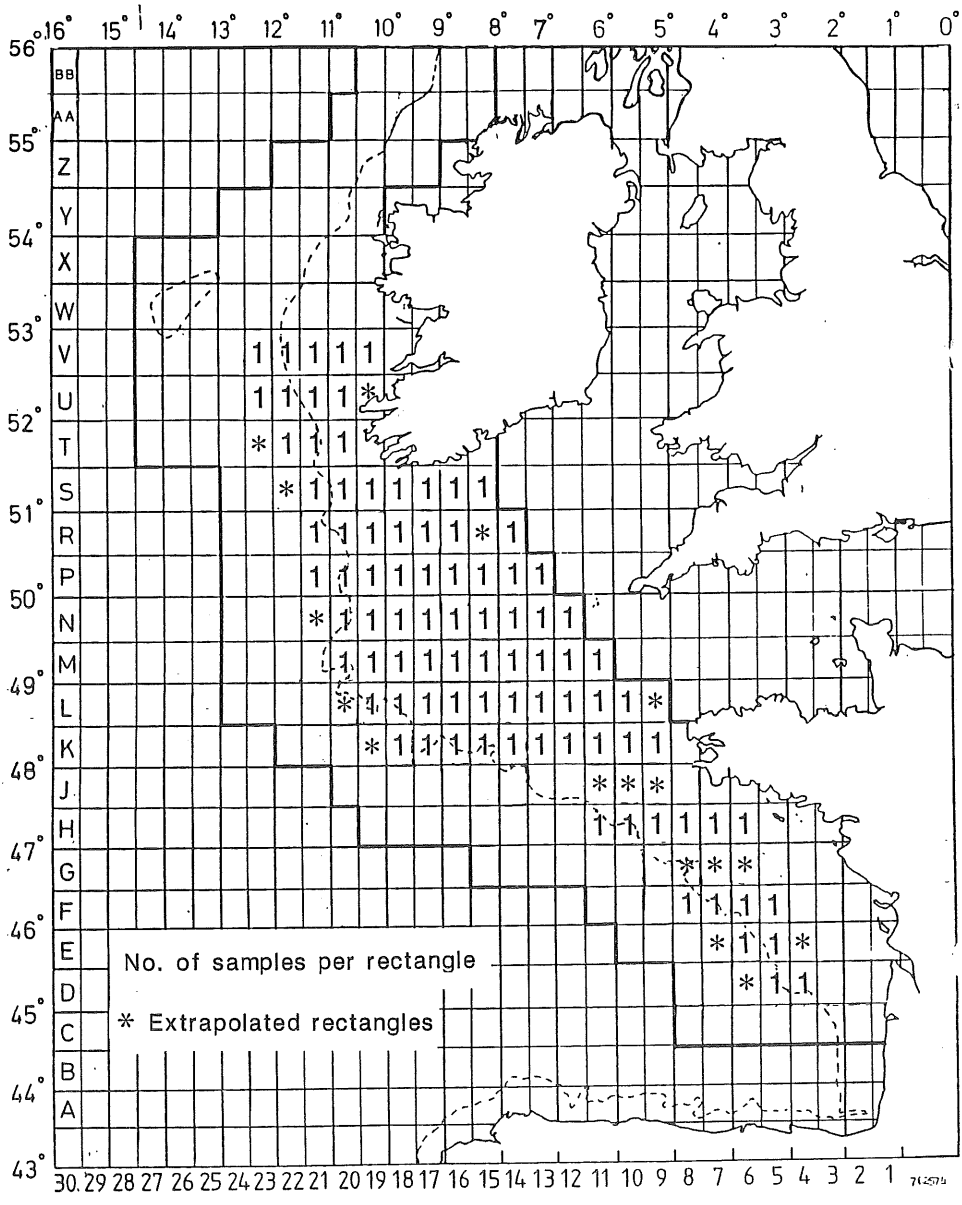


Figure 5.5 The number of observations per rectangle and extrapolated rectangles * for period 5; 4 July to 17 July 1989.

Figure 5.6 The distribution of stage I mackerel eggs as numbers per m^2 per day for survey period 1; 1-20 April 1989.

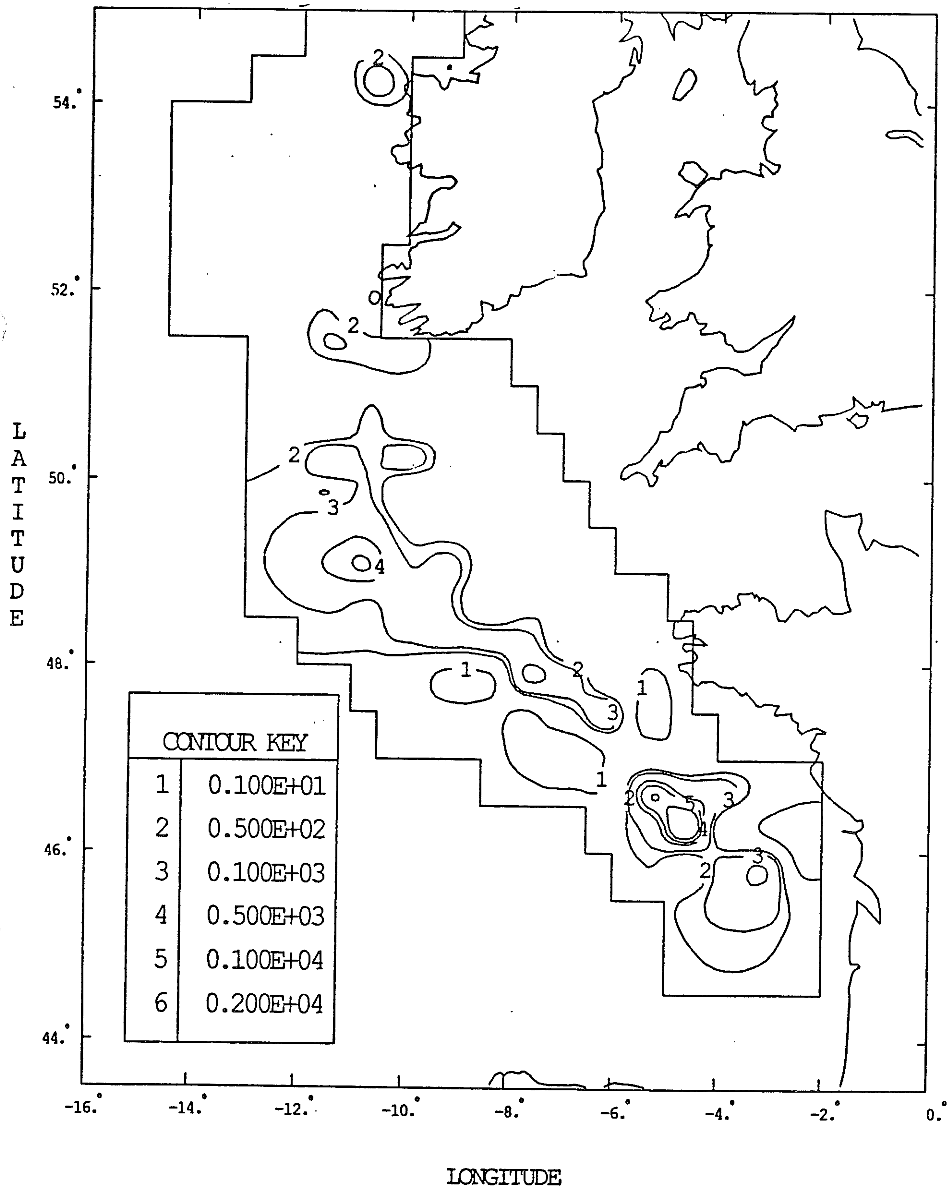


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Figure 5.7 The distribution of stage I mackerel eggs as numbers per m^2 per day for survey period 2; 23 April-20 May 1989.

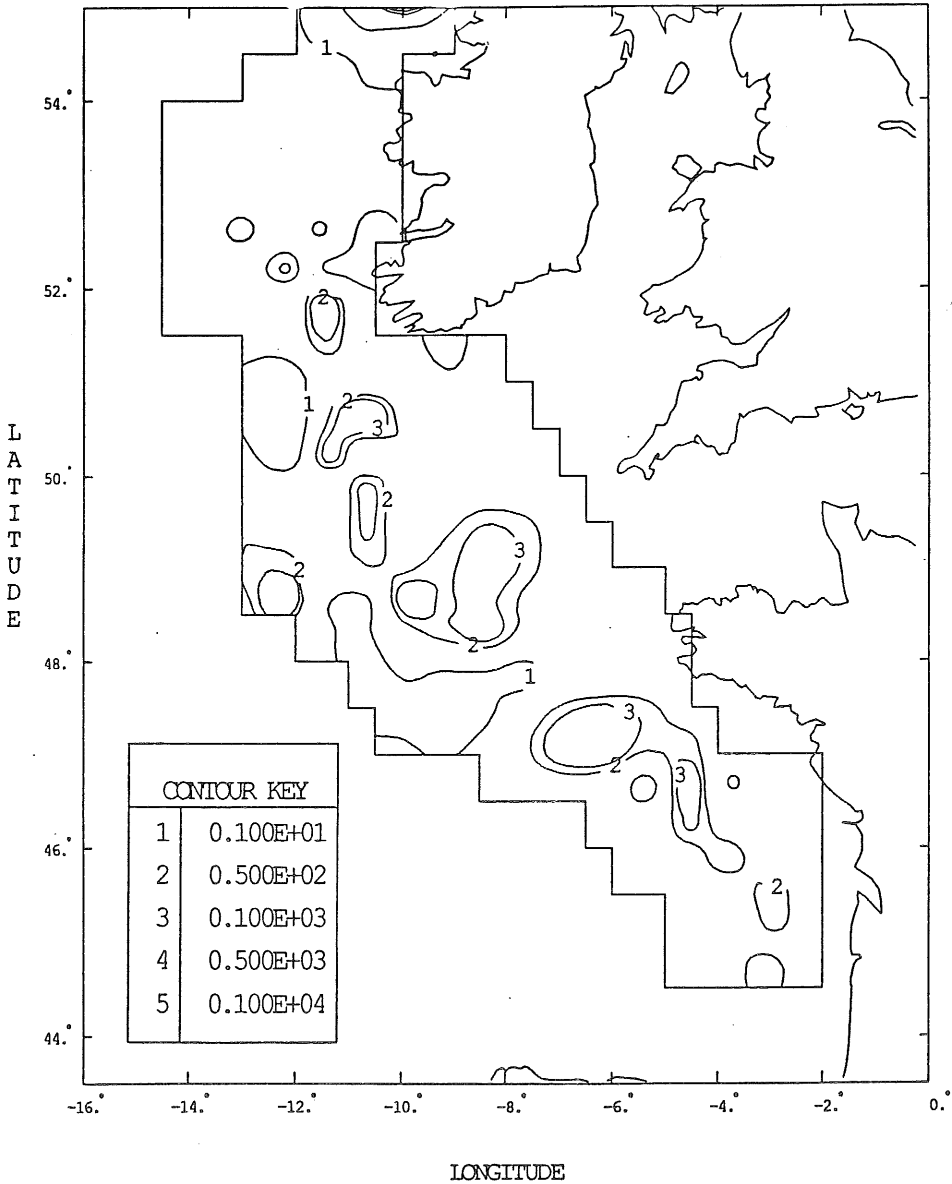


Figure 5.8 The distribution of stage I mackerel eggs as numbers per m^2 per day for survey period 3; 21 May-6 June 1989.

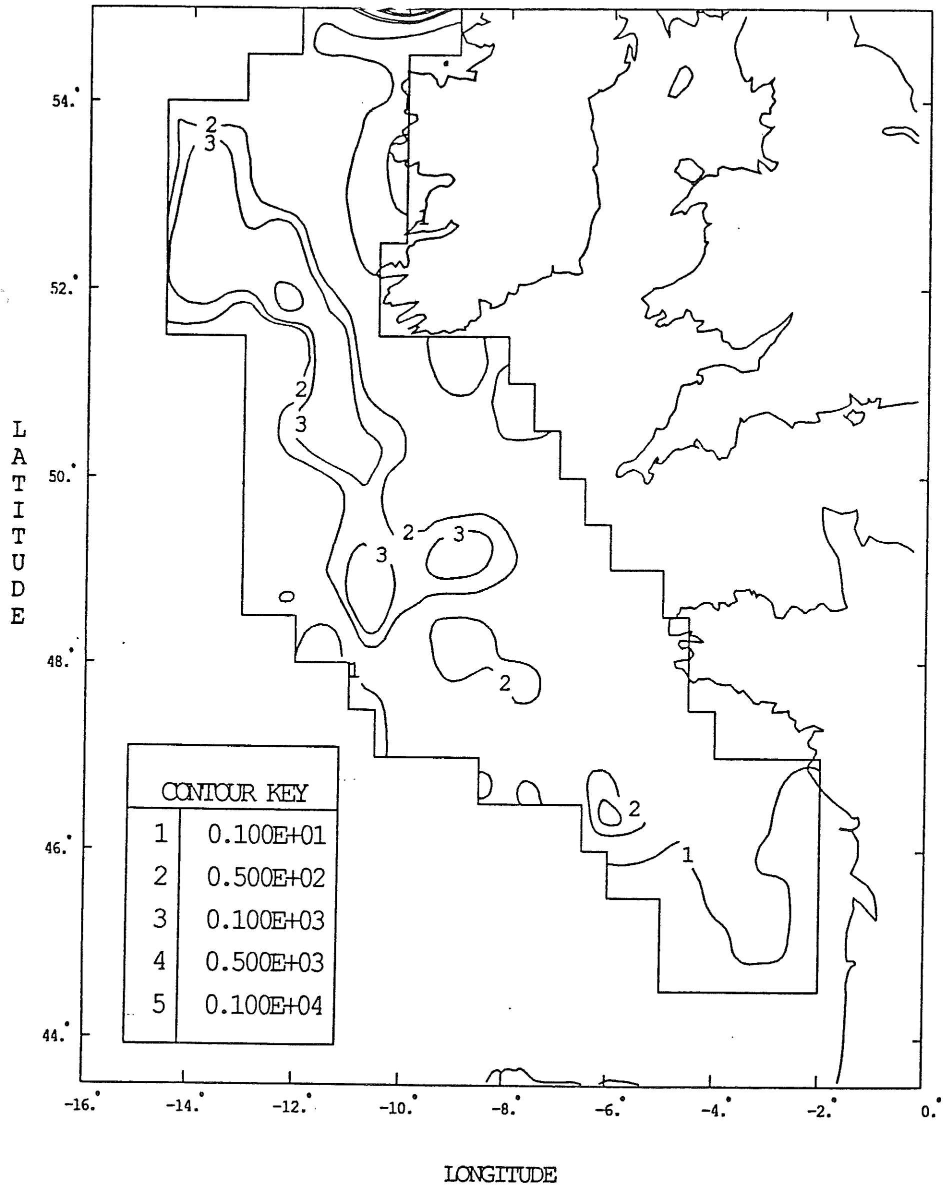


Figure 5.9 The distribution of stage I mackerel eggs as numbers per m^2 per day for survey period 4; 7-24 June 1989.

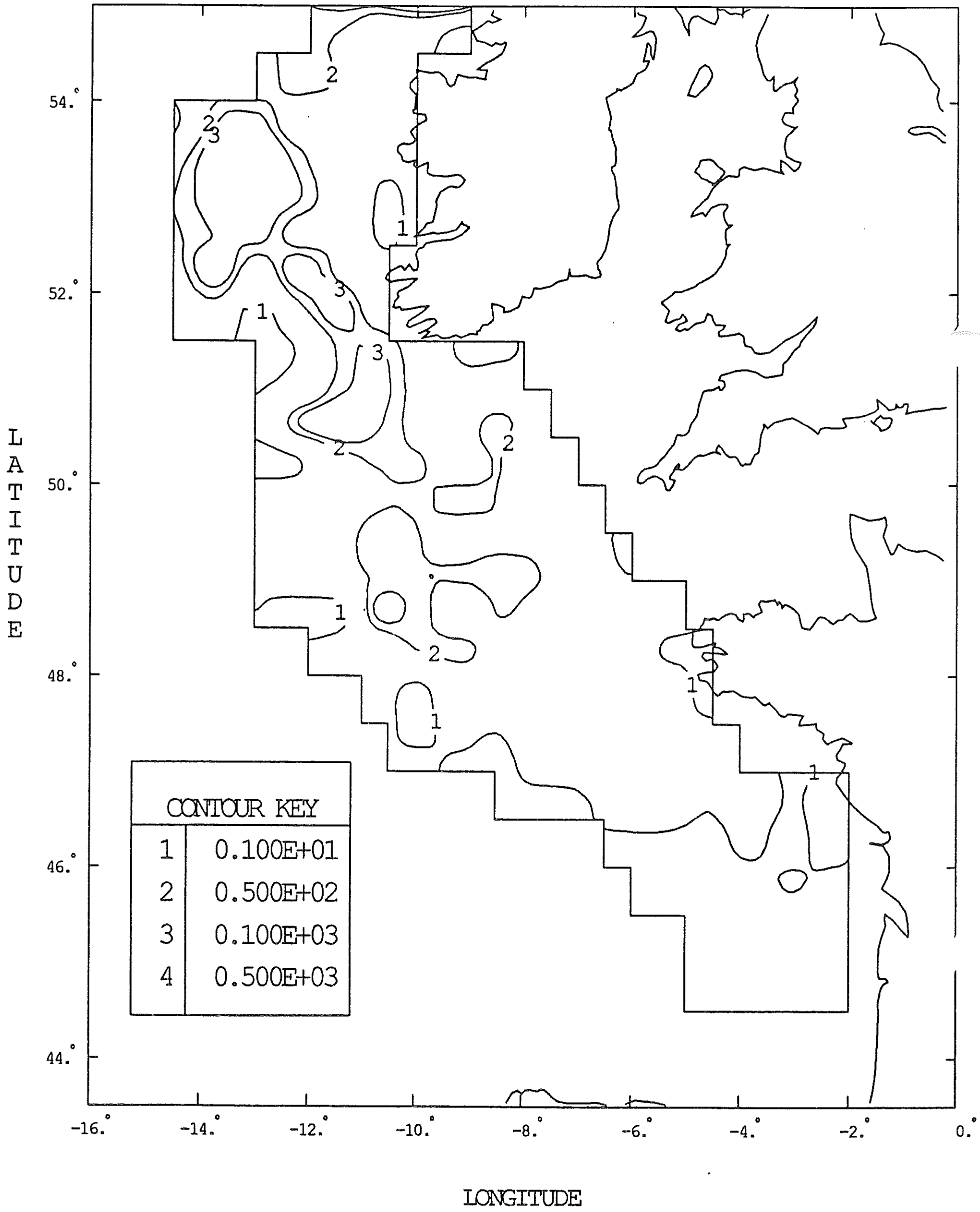


Figure 5.10 The distribution of stage I mackerel eggs as numbers per m^2 per day for survey period 5; 4-17 July 1989.

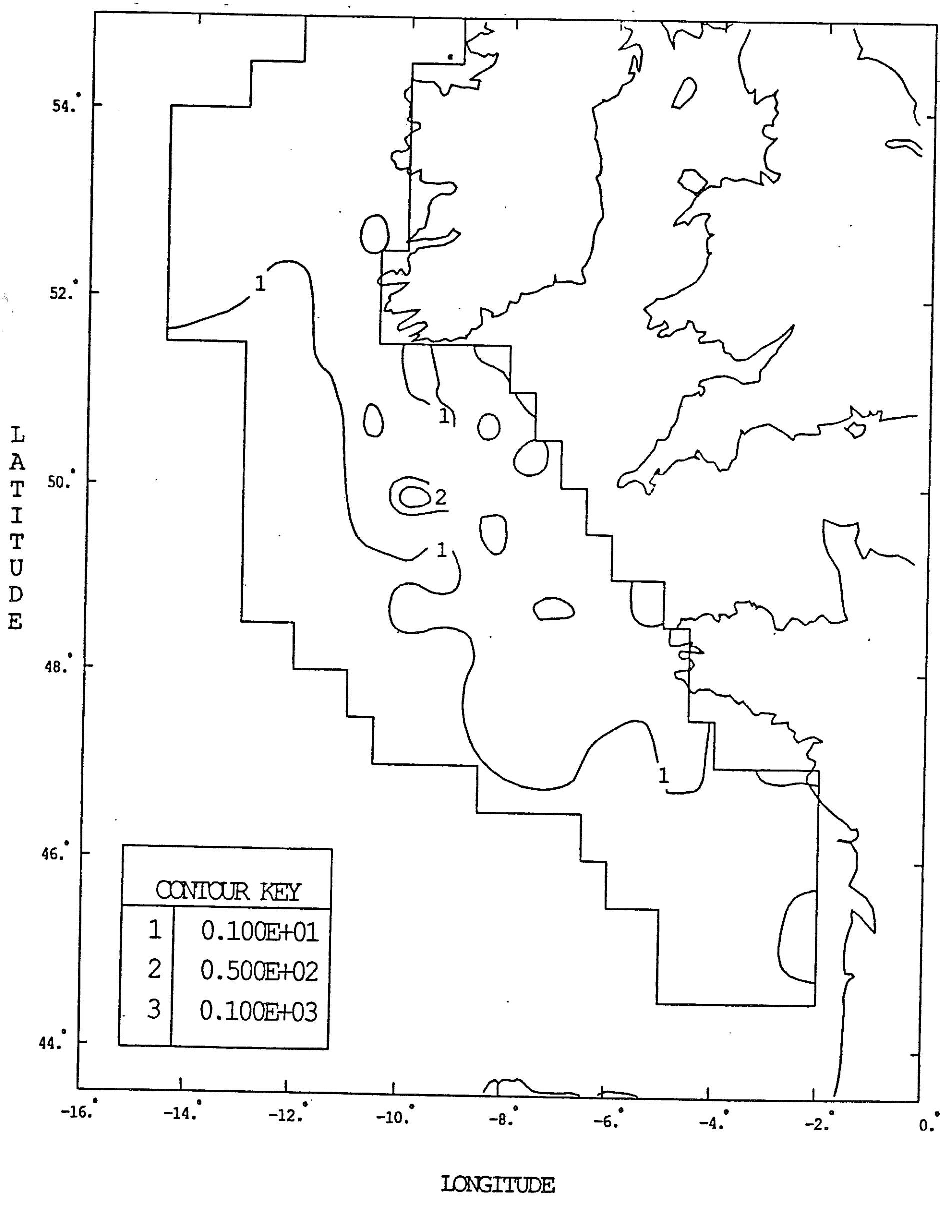


Figure 5.11 The distribution of stage I horse mackerel eggs as numbers per m^2 per day for survey period 2; 23 April-20 May 1989.

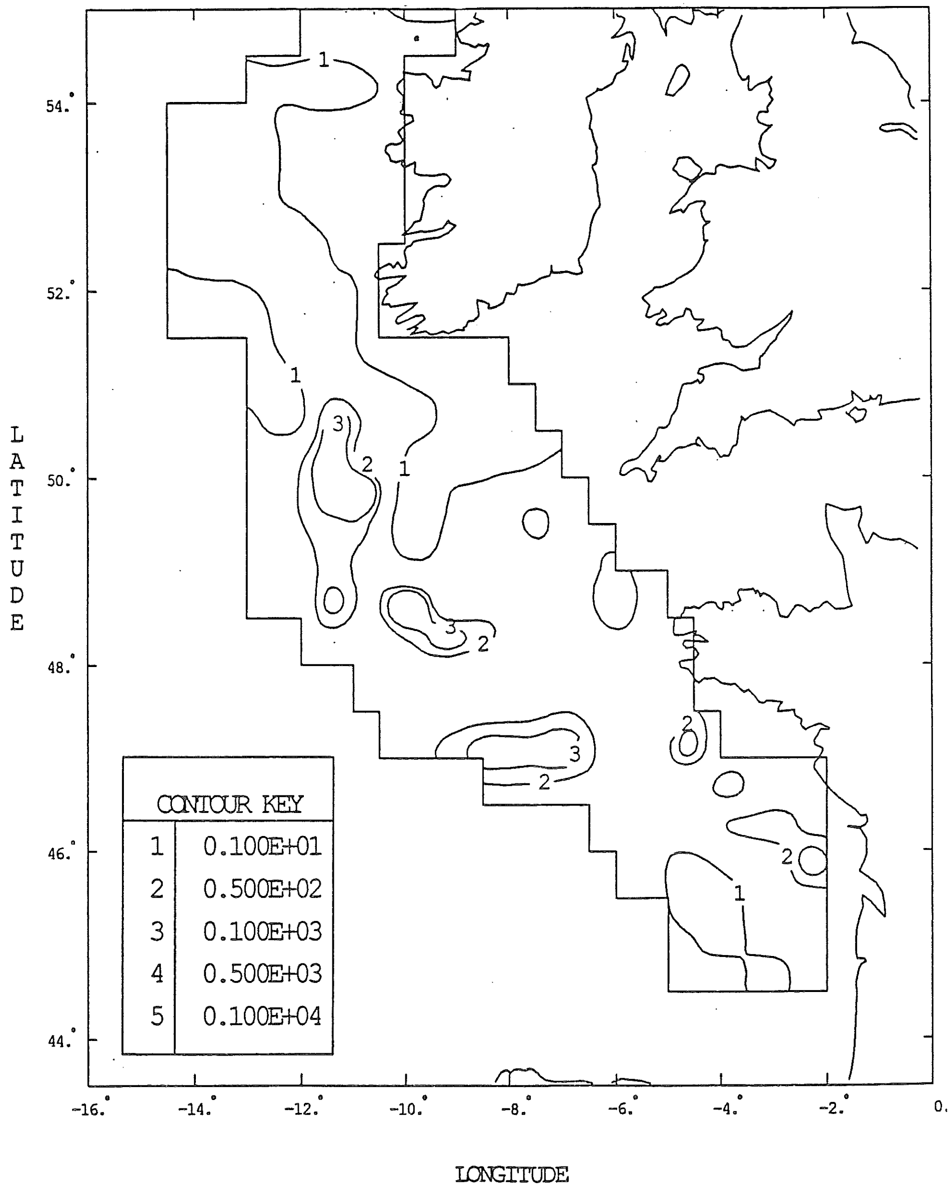


Figure 5.12 The distribution of stage I horse mackerel eggs as numbers per m^2 per day for survey period 3; 21 May-6 June 1989.

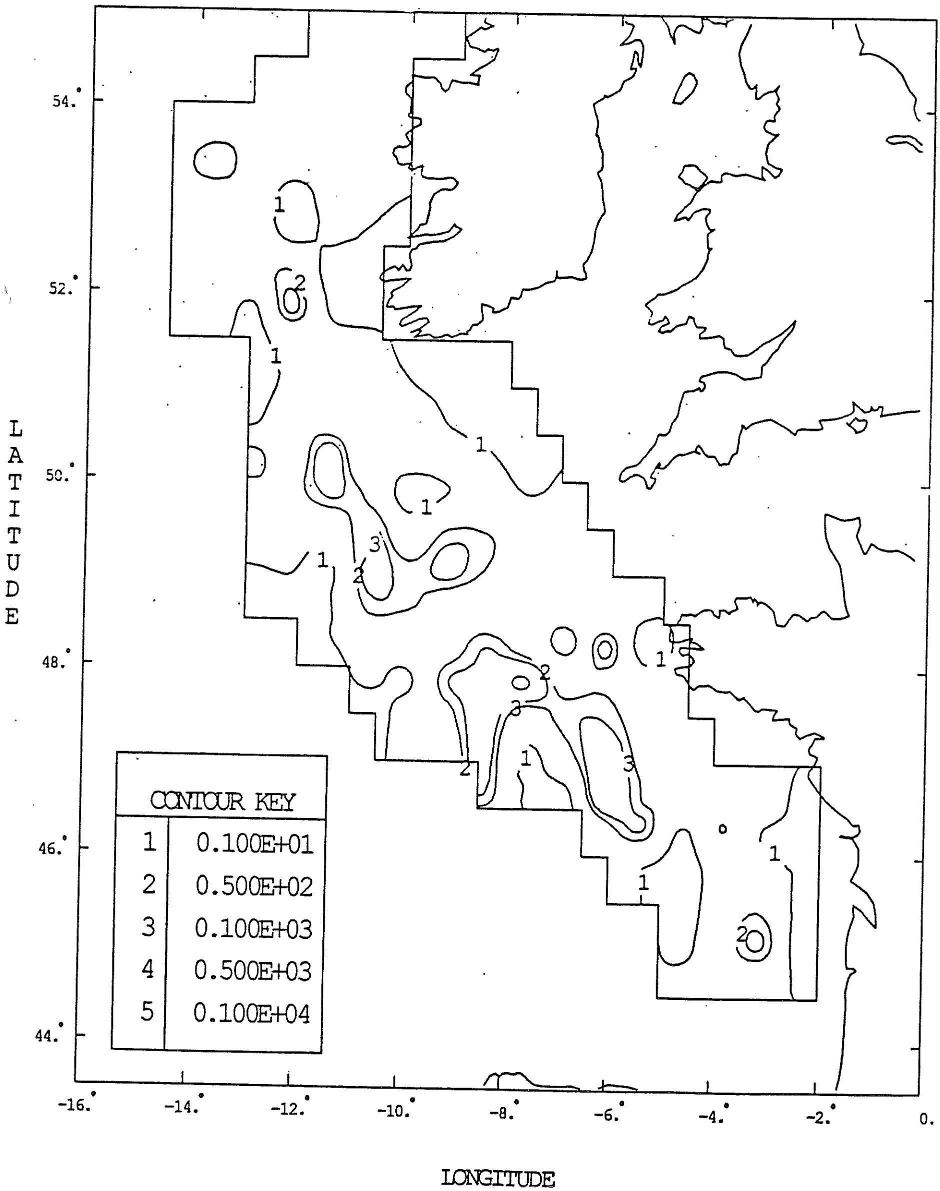


Figure 5.13 The distribution of stage I horse mackerel eggs as numbers per m^2 per day for survey period 4; 7-24 June 1989.

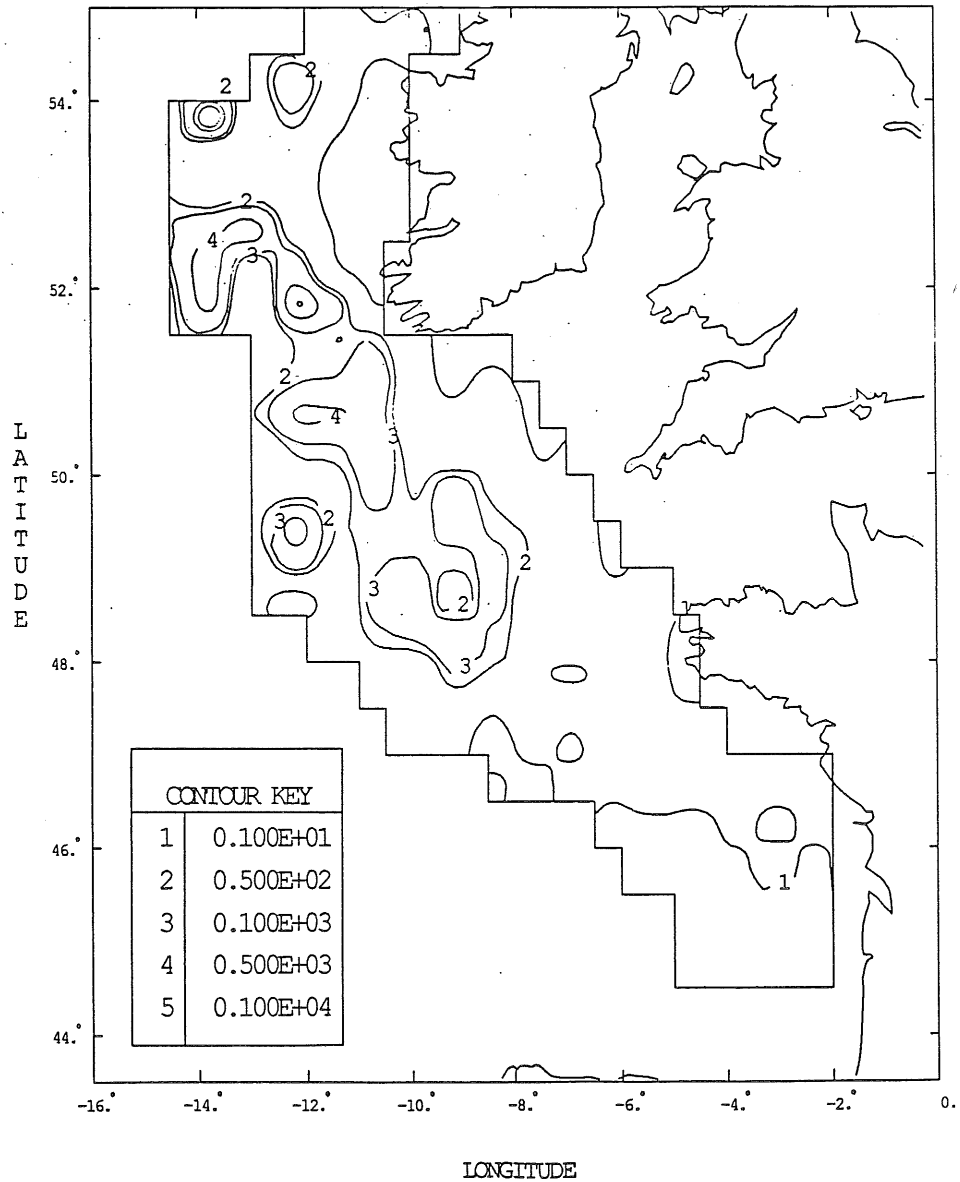


Figure 5.14 The distribution of stage I horse mackerel eggs as numbers per m^2 per day for survey period 5; 4-17 July 1989.

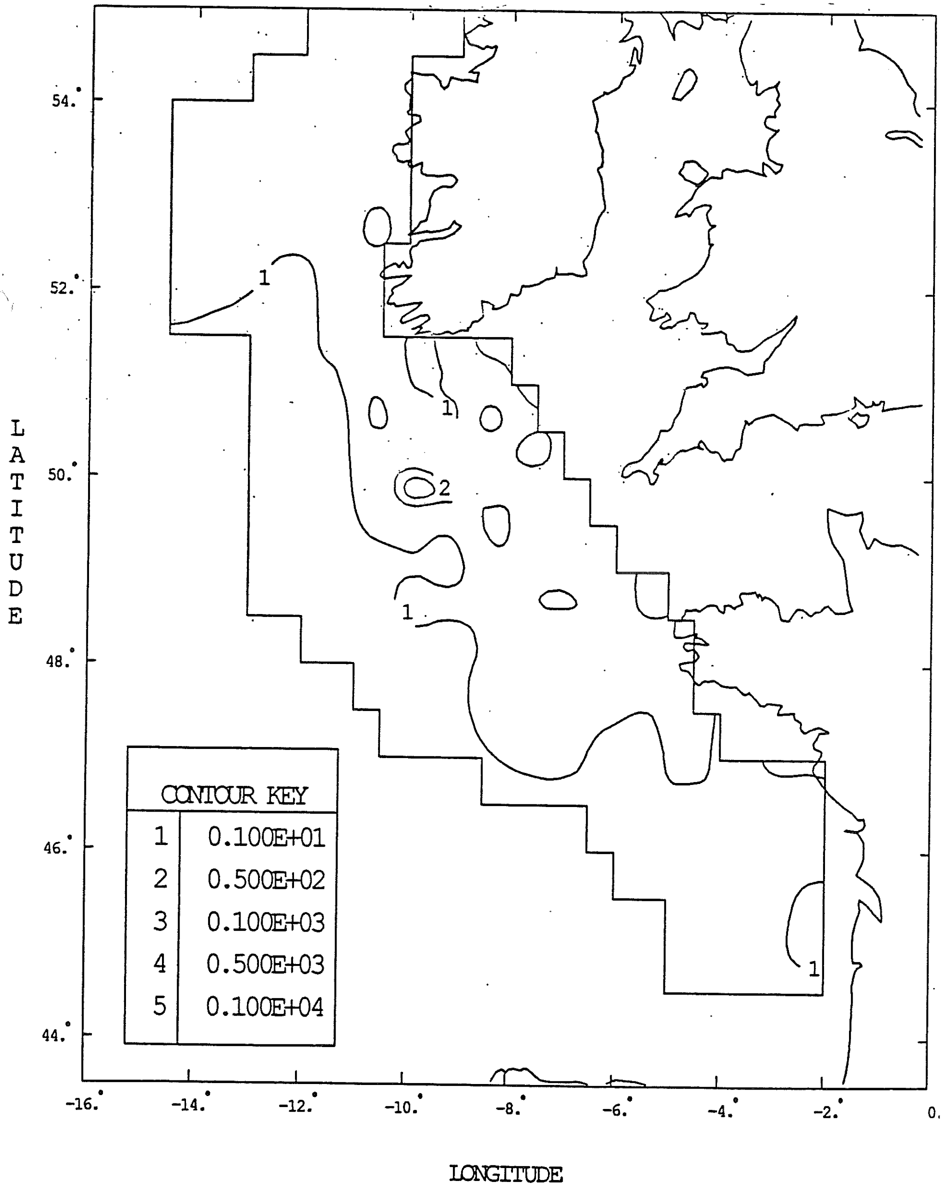
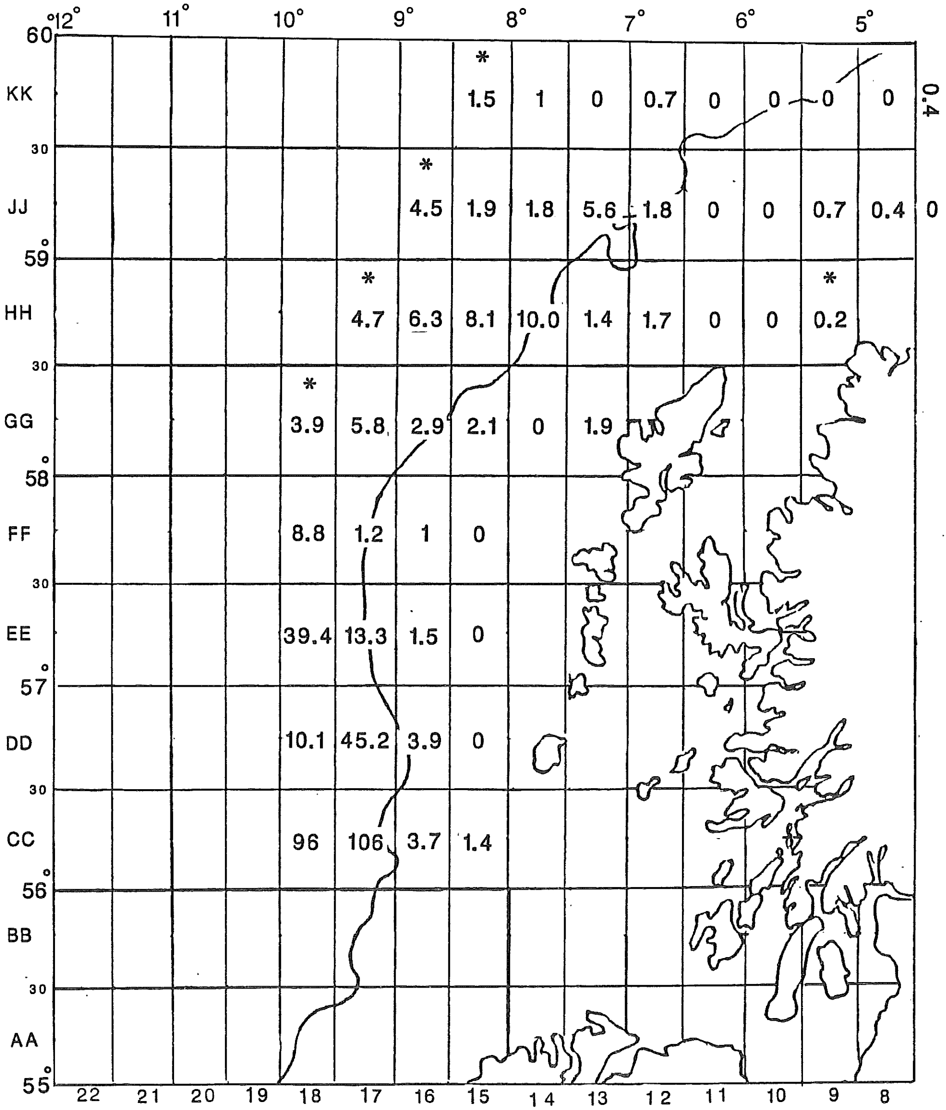


Figure 5.15 The distribution of stage I mackerel eggs as numbers per m^2 per day north of latitude 56°N for the period 22 May-6 June 1989.



Emer Marie 22.5.1989 - 6.6.1989

Figure 5.16 The distribution of stage I mackerel eggs as numbers per m^2 per day from a survey of the western English Channel and Approaches in June 1988. The bold line indicates the eastern boundary of sampling in 1989.

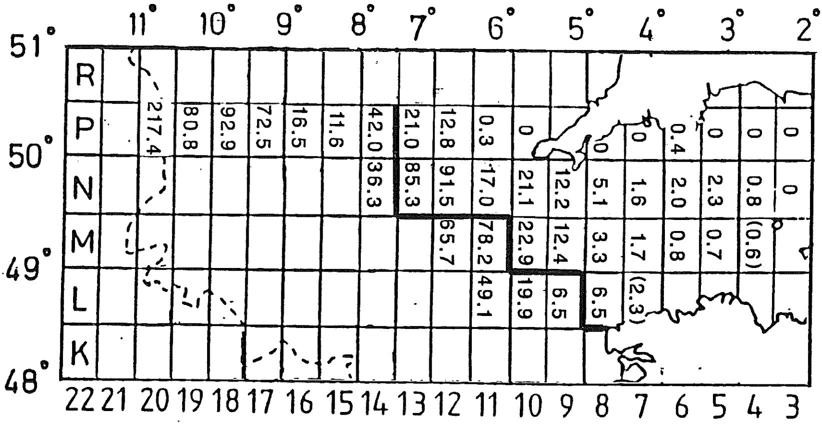
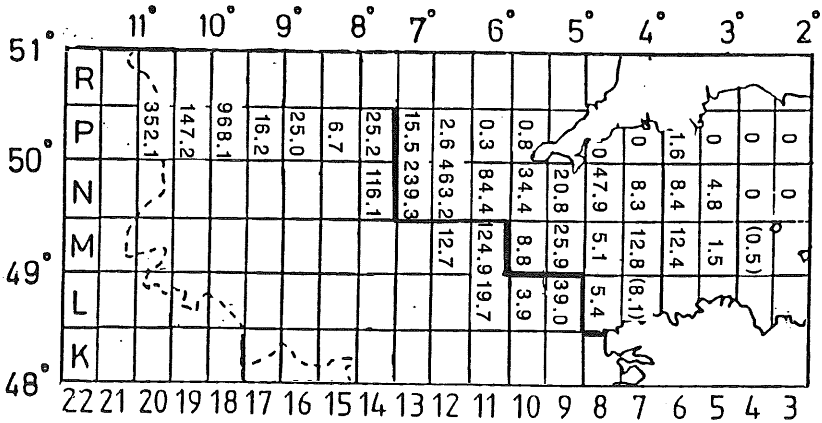


Figure 5.17 The distribution of stage I horse mackerel eggs as numbers per m^2 per day from a survey of the western English Channel and Approaches in June 1988. The bold line indicates the eastern boundary of sampling in 1989.



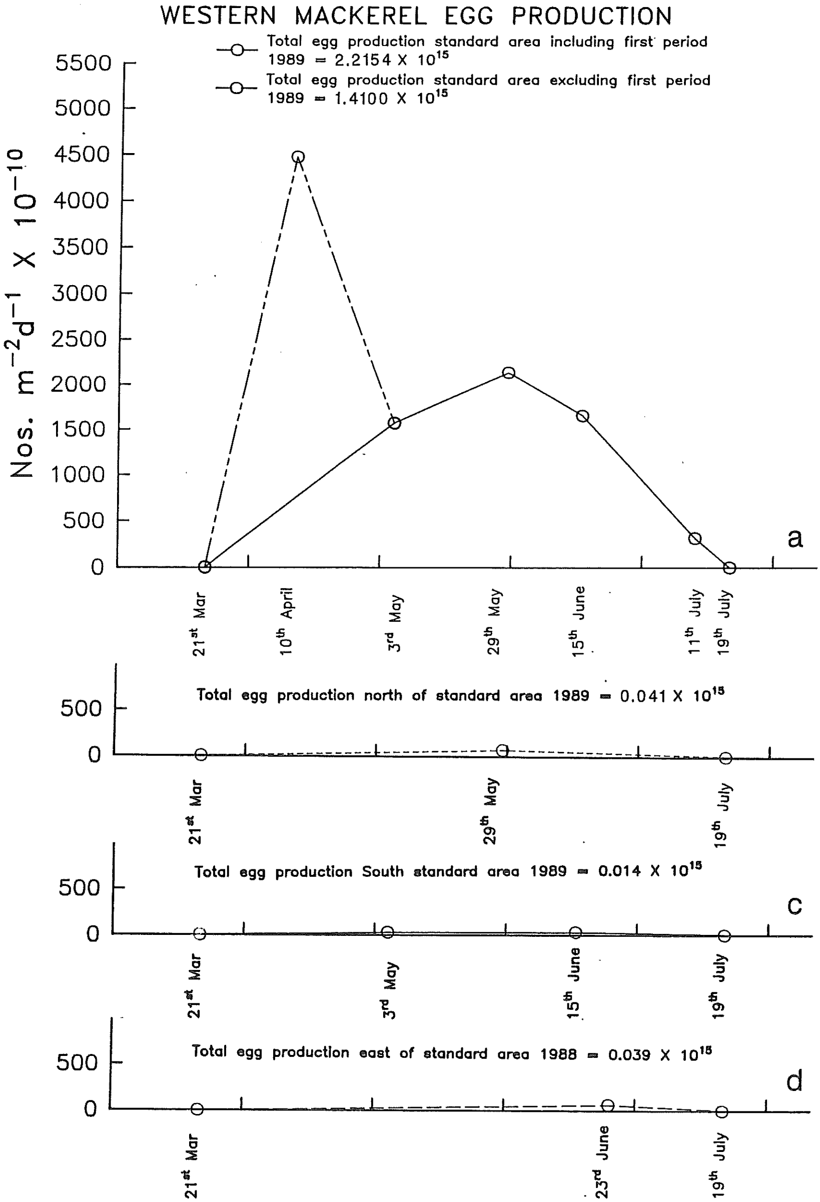


Figure 5.18 Production curves for stage I mackerel eggs for a) the standard survey area in 1989 including and excluding the anomalous first survey point; b) the area north of the standard area (N of 56°N) in 1989; c) the area south of the standard area (S of 44°30'N) in 1989; d) the area east of the 1989 sampled area in 1988.

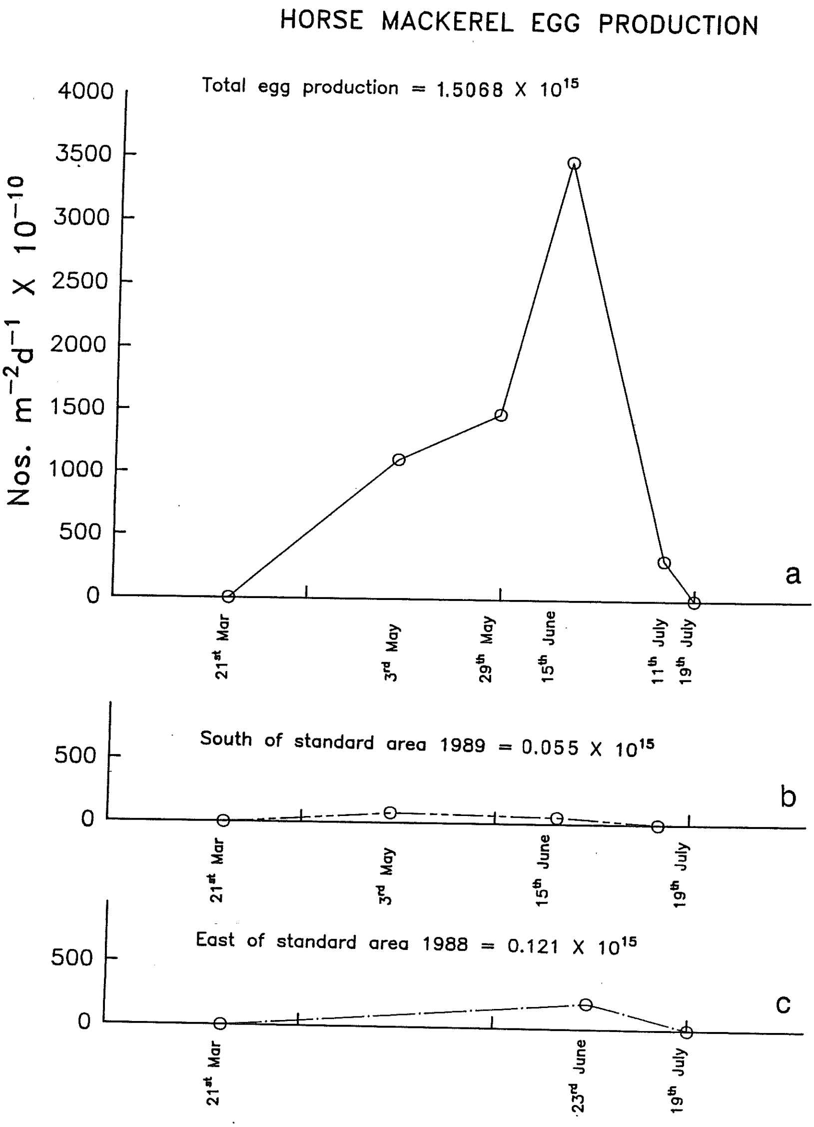


Figure 5.19 Production curves for stage I horse mackerel eggs for a) the standard survey area in 1989; b) the area south of the standard area (S of 44'30'N) in 1989; c) the area east of the 1989 sampled area in 1988.

Figure 5.20 Production curves for stage I mackerel eggs in the standard area south of 48°N, Rows J-C for the years 1980, 1983, 1986 and 1989.

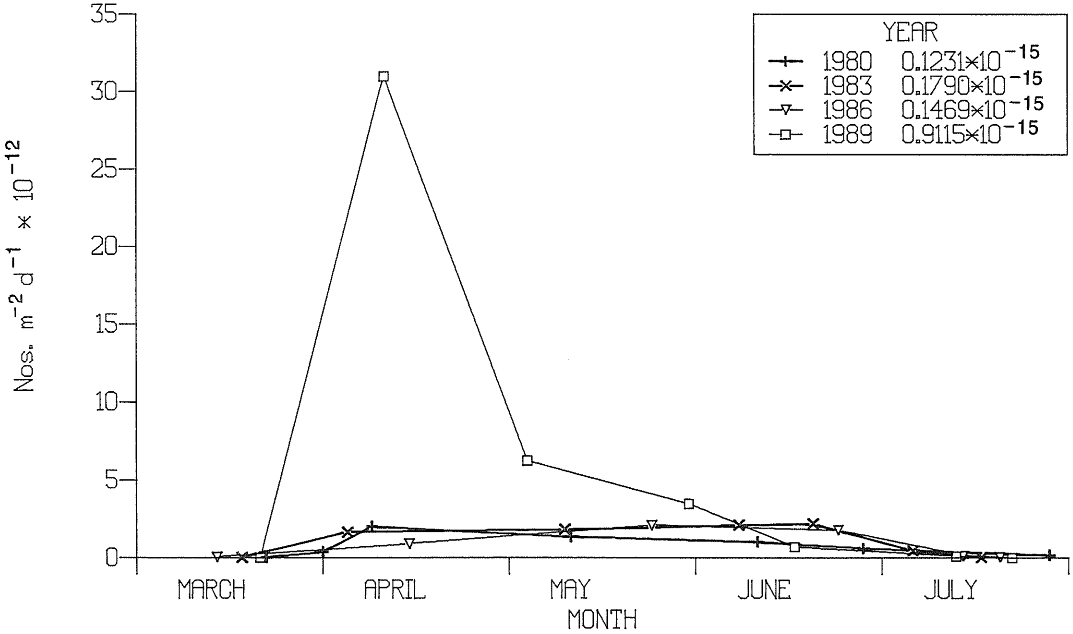


Figure 5.21 Production curves for stage I mackerel eggs in the standard area between latitudes 48°N and 51°30'N Rows S-K for the years 1980, 1983, 1986 and 1989.

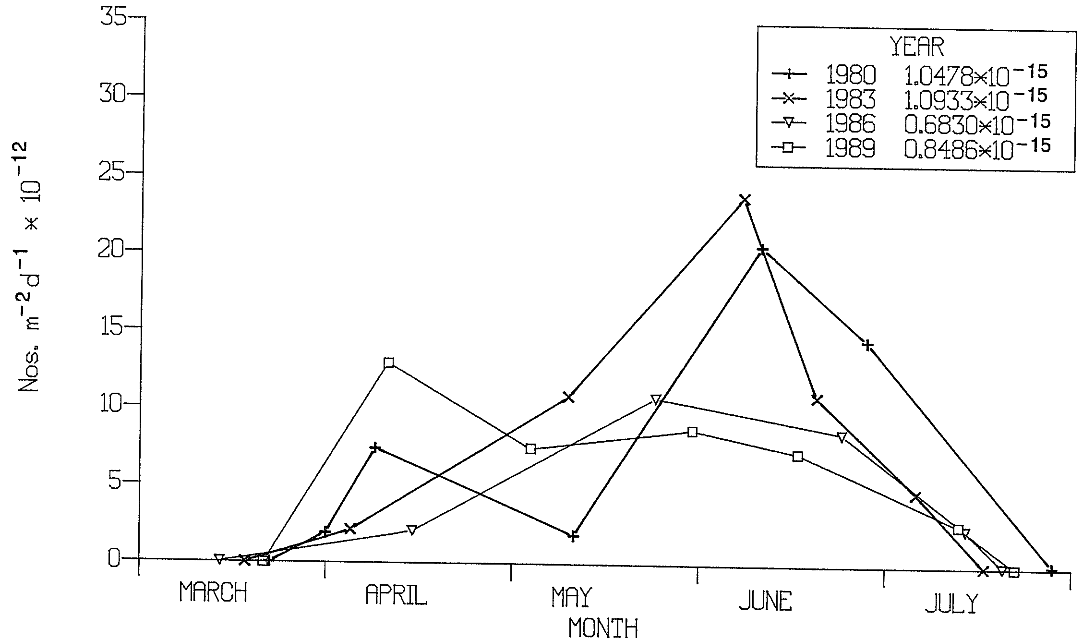


Figure 5.22 Production curves for stage I mackerel eggs in the standard area north of 51°30'N Rows Z-T for the years 1980, 1983, 1986 and 1989.

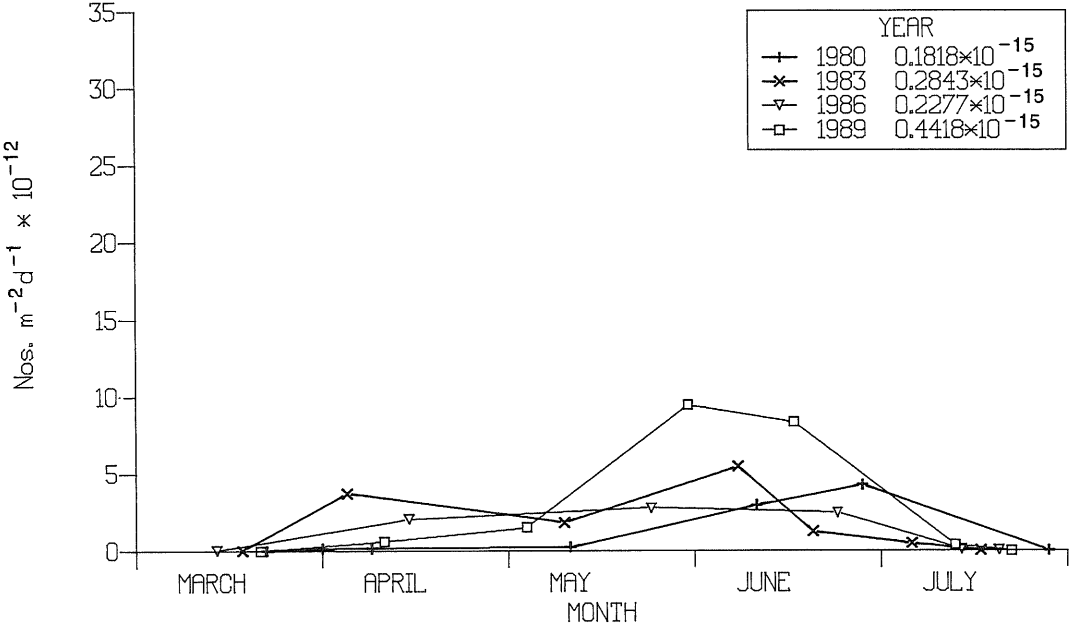


Figure 5.23 Mackerel length compositions in the western area in 1989 from sampling during a) April (Germany) b) May (Scotland) c) May/June (France) d) June (Netherlands).

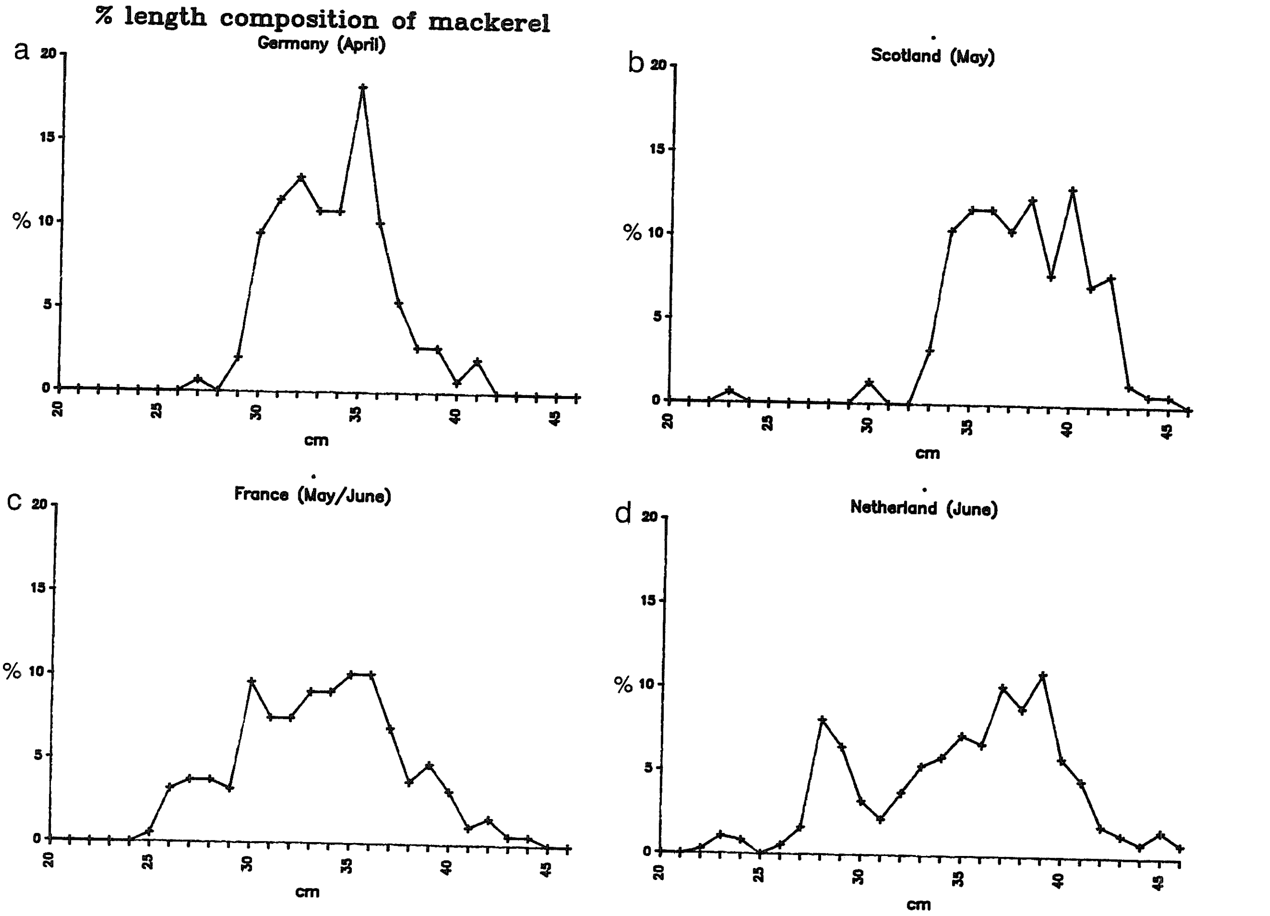


Figure 6.1 Mackerel length compositions from sampling between 2-6 April 1986 by Germany between latitude 46°N and 47°N.

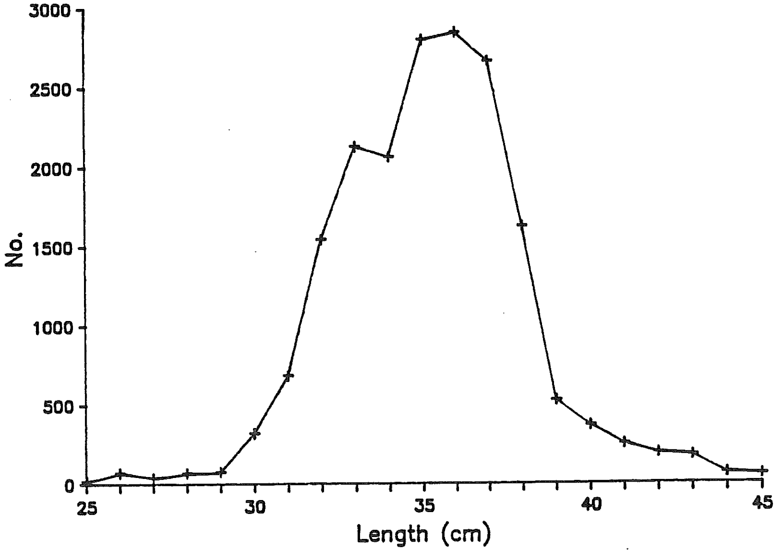


Figure 6.2 Fecundity/length relationships for the western mackerel from four separate analyses.

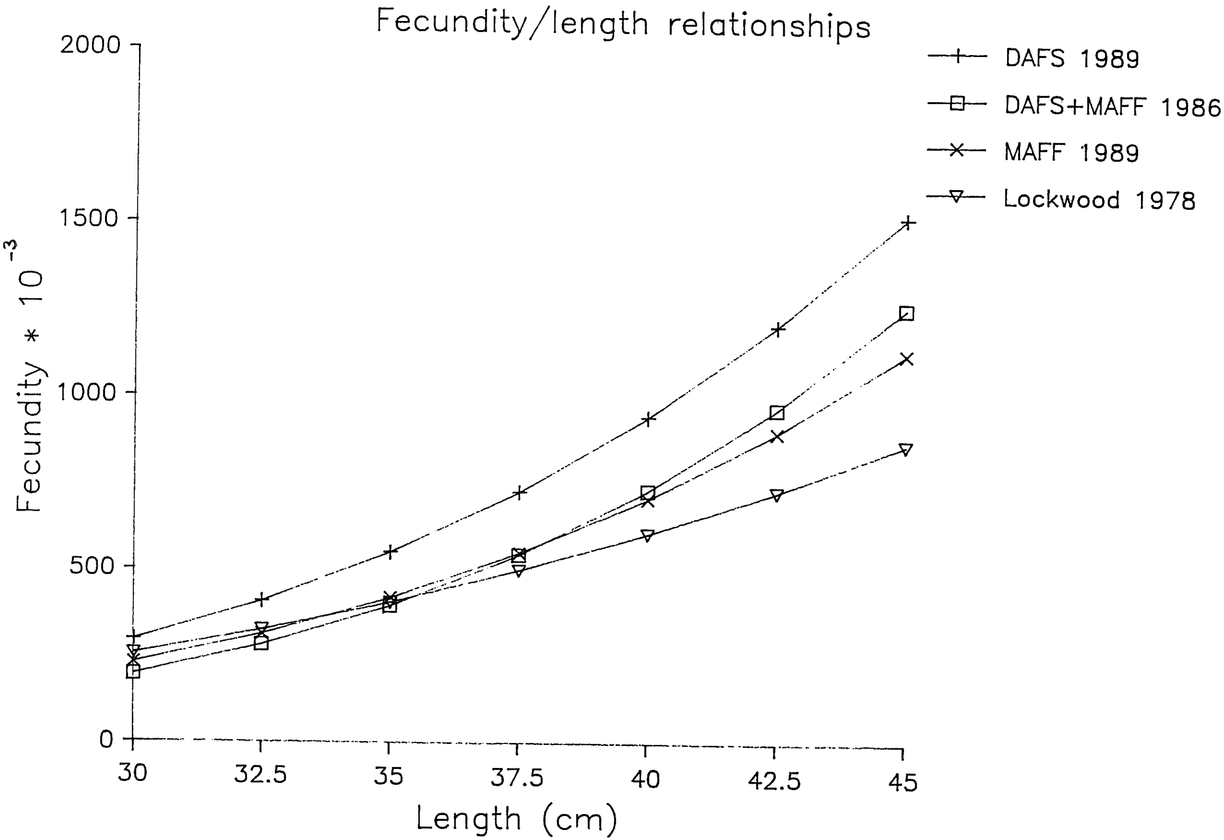
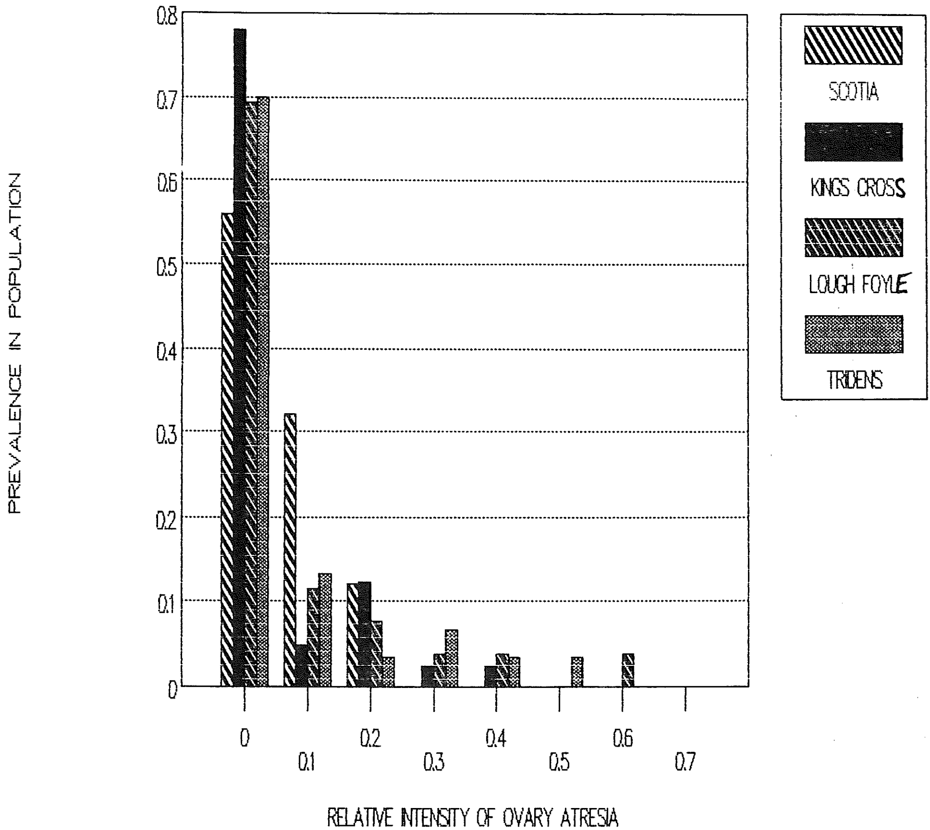


Figure 6.3 The incidence of ovary atresia in mature female mackerel from sampling in the western area in 1989.



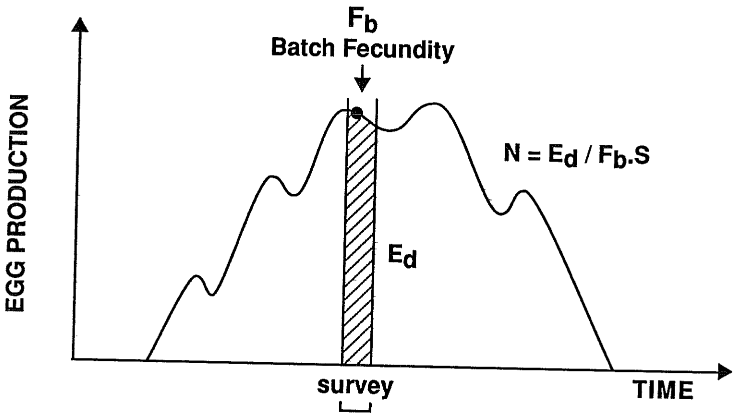


Fig 7.1 THE "BATCH FECUNDITY" EGG PRODUCTION METHOD.
A single estimate of daily egg production (E_d) for the middle of the spawning season is used. Only the batch fecundity (F_b), for fish caught at the same time, and an estimate of spawning fraction (S) are also required to estimate the total number of spawning females (N).

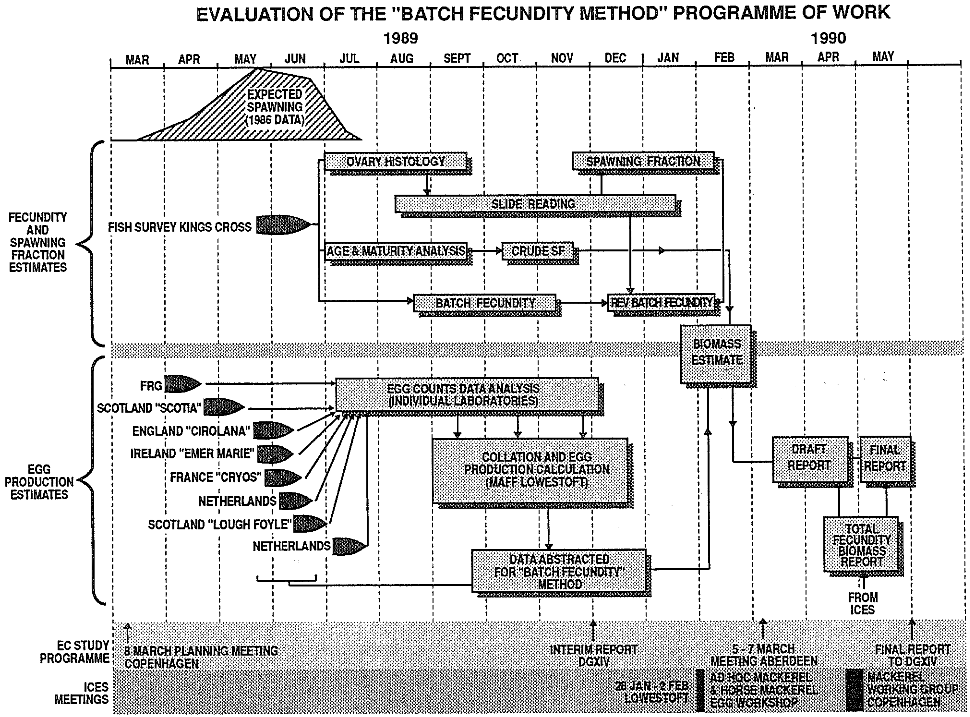


FIG 7.2 Overall organisation of the EC funded programme to evaluate the batch fecundity method for the assessment of stocks of pelagic fishes.

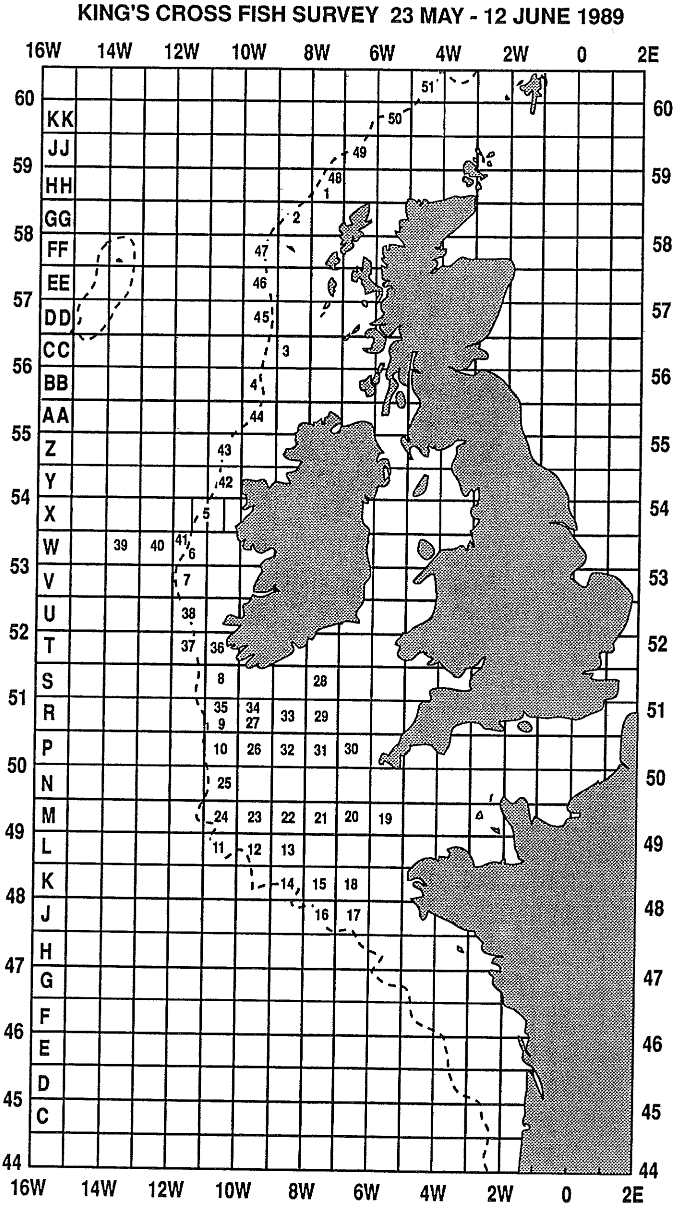


Figure 7.3 Trawl hauls made by the MV KINGS CROSS between 23 May and 12 June 1989 numbered in chronological order.

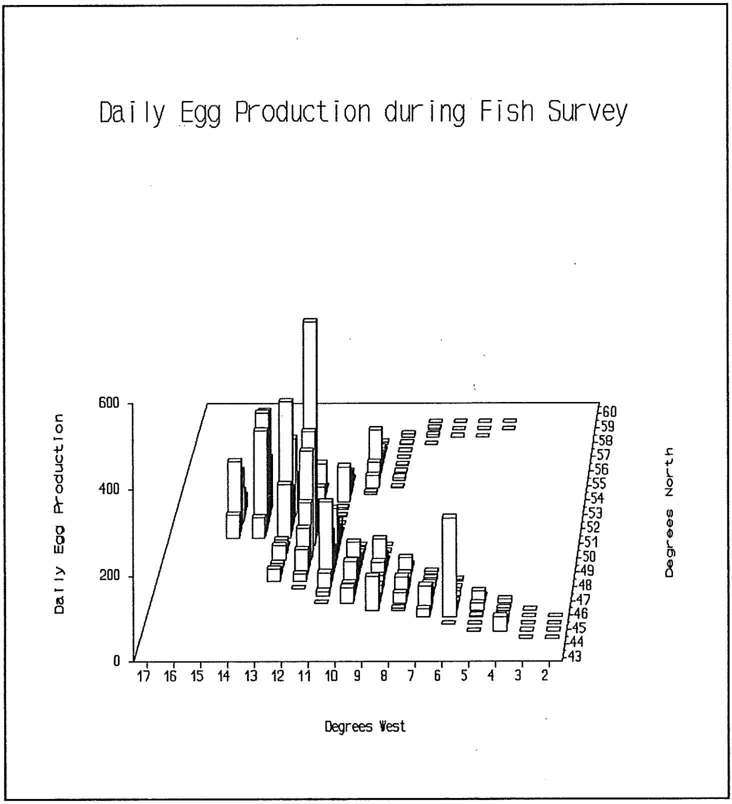


Figure 7.4 Daily egg production (no./m^2/day) over the area and time period covered by the King's Cross fish survey, 23 May - 12 June 1989.

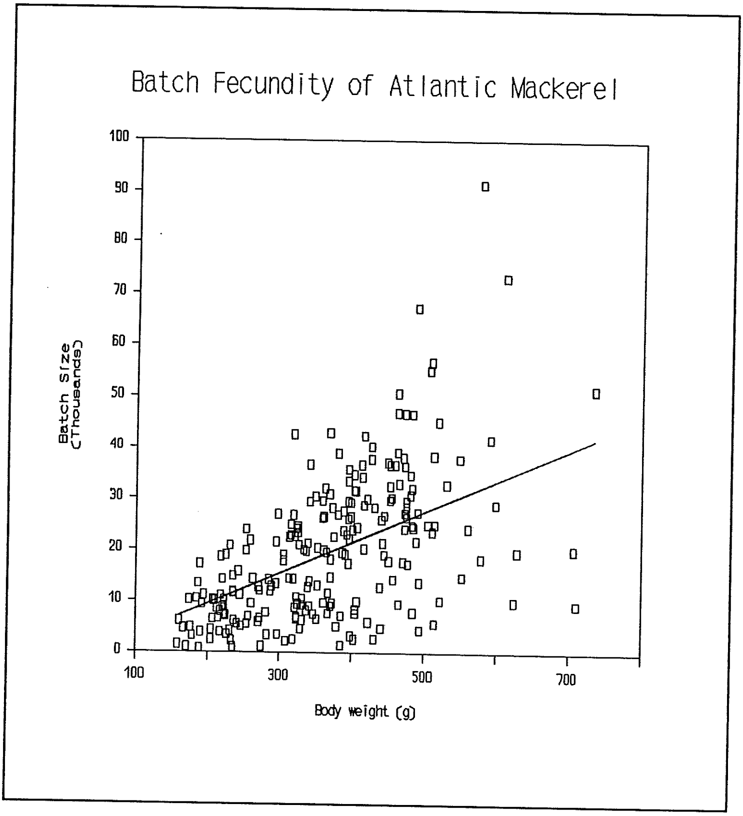


Figure 7.5 Combined Batch Size data from the University of Aberdeen and MAFF, Lowestoft, for spawning mackerel captured during the King's Cross fish survey, 23 May - 12 June 1989. Batch Size (F_b) is given by the equation:

$$F_b = 54.75 \cdot W_s + 1439.0$$

where W_s is ovary-free body weight in grammes.

Appendix

WORKING DOCUMENT

Sources of error in the first period production estimate of the 1989 Mackerel and Horse Mackerel Egg Survey

by Wendy A Dawson, M Walsh, J H Nichols and P Hopkins

INTRODUCTION

Provisional estimates of egg production and SSB were prepared and made available to ACFM at its November 1989 meeting. The FRG data was not submitted by the deadline and as a result the first period value was not included when making the provisional estimate of SSB. Subsequently when FRG data became available they indicated a high anomalous value for egg production. The Mackerel and Horse Mackerel Egg Workshop (Anon. 1990, in prep.) did not succeed in explaining this apparent anomaly and accordingly two alternative mackerel egg production estimates were produced. One included a first period value generated by the FRG suvey which was eight times higher than in the same period in 1986, the other excluded this data point (Fig. 1).

Although the Workshop regarded the first period value as suspect, they could find no valid reason to disregard it. Consequently, they gave two alternative egg production estimates and recommended further checking of the data. This paper presents the results of the data checks and provisional reanalysis of some of the plankton samples.

SOURCES OF ERROR

1. Reanalysis of Plankton Samples

FRG data became available only four weeks before the Workshop, allowing very little time for the data to be checked adequately. Fourteen samples (two of which were broken) were however sent on request to Lowestoft for verification. This indicated that some horse mackerel had been misidentified as mackerel eggs but there was insufficient time to quantify this before the Workshop.

Reanalysis of the 12 samples has subsequently been completed. The numbers of stage I mackerel eggs estimated by FRG and the corrected values together with the percentage differences are given in Table 1. Only the sample from rectangle M21 gave similar results between Lowestoft and FRG. With the exception of one sample, the remainder were all found to have been over-estimated by FRG, some by over 100%. The corrected values have been plotted on a chart and are shown in Figure 2. They fall into two main areas, the southern Celtic Sea (north 48°N) and central Bay of Biscay (south 48°N). The average difference was estimated separately for the two areas and this correction was applied to the remaining unchecked 66 samples within the respective areas. Samples from the north of 48°N were overestimated by an average of 35% and samples from south of 48°N by 61.5%. Applying this correction to the remaining unchecked samples would reduce the first period egg production value by 38%. It should be pointed out however, that reidentification of eggs, previously recorded as mackerel eggs, results in an unexpectedly high production of horse mackerel eggs.

2. Station Positions

In the process of checking the FRG survey data it was observed that some samples were not taken from the centres of rectangles as laid down in the survey procedure. Figure 3 shows that the majority of hauls were in fact taken more than eight miles from the rectangle centre, the average distance was 10.9 miles. Further examination of the station positions revealed that many were directed towards the shelf edge (Fig. 4). The sample positions are shown in Figure 5. This has undoubtedly generated considerable upward bias in the FRG results because spawning is known to be closely linked to the shelf edge (see below), especially at the start of spawning. Examination of the station positions on the same survey in 1986, sampled by FRG, showed that the survey procedure had been followed correctly.

3. Association of Spawning with the Shelf Edge

Figure 6 shows the distribution of stage 1 mackerel eggs in relation to the 200 m contour in the area of highest mackerel egg production (46°N and 47°30'N) during the FRG survey. The data indicate how critical small changes in station position can be to egg production estimates. For the five stations sampled within 2.5 nautical miles of the 200 metre contour daily egg production values ranged from 676 to 1346 while for the eleven stations sampled between 2.5 and 25 nautical miles from this contour the range was 0 to 64.

CONCLUSIONS AND RECOMMENDATIONS

The preceding analysis highlights two major sources of error in the FRG data; mis-identification of eggs and sampling positions biased towards areas of higher egg production.

Provisional calculations of the former error results in overestimation of egg production by approximately a factor of two. Because of wide intersample variation of this error, however, reanalysis of the remaining unchecked samples would be required to quantify this with confidence.

The second source of error is likely to result in an even greater overestimate of egg production given the extent of the bias in station position towards the shelf edge and the concentration of spawning there. It may be possible to re-estimate a production value for the first survey period by an alternative method, eg by using geostatistical techniques. The data could never be directly comparable to those calculated by the current method of sampling in the centre of each rectangle, but maybe useful as an indication of possible higher production for this period than in previous years.

We strongly recommend therefore that the first period survey estimate should not be used for assessment purposes.

In addition we recommend that:

1. The Workshop participants review the evidence either by correspondence or by re-convening the Workshop before the Mackerel Working Group. Their conclusions should be appended to the Workshop report.

3. The remaining 66 unchecked FRG samples be reanalysed.

REFERENCES

Anon, 1990. Report of the Mackerel and Horse Mackerel Egg Workshop, Lowestoft, 29 Jan-2 Feb 1990. In prep.

Table 1

Stage I mackerel egg comparisons - FRG/Lowestoft, March/April 1989

Station	Rect	Stage I mackerel eggs nm^{-2}		Stage I mackerel eggs nm^{-2} d^{-1}			
		Lowestoft	FRG	Lowestoft	FRG/Lt	% difference FRG/Lt	
Biscay (South 48°							
272	F8	1302	3094.4	739.1	1756.0		(138%
274	F7	2045	4766.6	1172.8	2733.8		(133%
276	F6	858	1081.7	492.9	621.2	$\bar{x}$=61.5%	(26%
277	E5	1297	2333.9	726.2	1306.8		(80%
285	G6	488	334.9	267.2	183.3		(-31%
287	G9	2168	2672.0	1208.9	1490.3		(23%
Celtic Sea (North 48°							
301	K15	300	542.6	152.1	275.5		(81%
308	L17	412	666.4	209.0	338.3		(62%
309	L18	382	472.5	191.4	236.8	$\bar{x}$=35%	(24%
312	M19	610	709.6	295.8	343.9		(16%
313	M20	1702	2085.0	838.0	1026.9		(23%
319	M21	1420	1451.2	713.4	729.4		(2%

Figure 1.

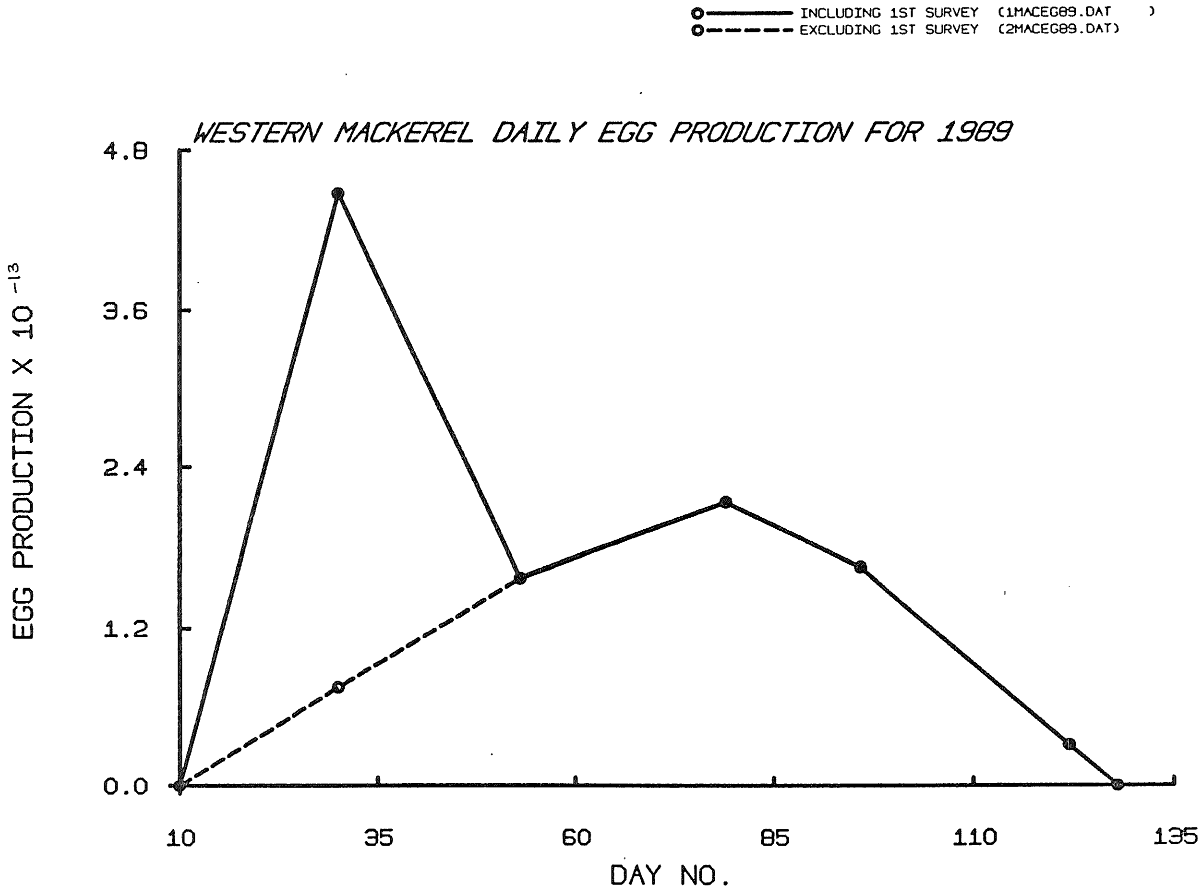

INCLUDING 1ST SURVEY (1MACEG89.DAT)
EXCLUDING 1ST SURVEY (2MACEG89.DAT)
WESTERN MACKEREL DAILY EGG PRODUCTION FOR 1989
EGG PRODUCTION X 10 -13
4.8
3.6
2.4
1.2
0.0
10
35
60
85
110
135
DAY NO.

Figure 2 Corrected values for stage I mackerel eggs $M^{-2}d^{-1}$ during first period survey, April 1989.

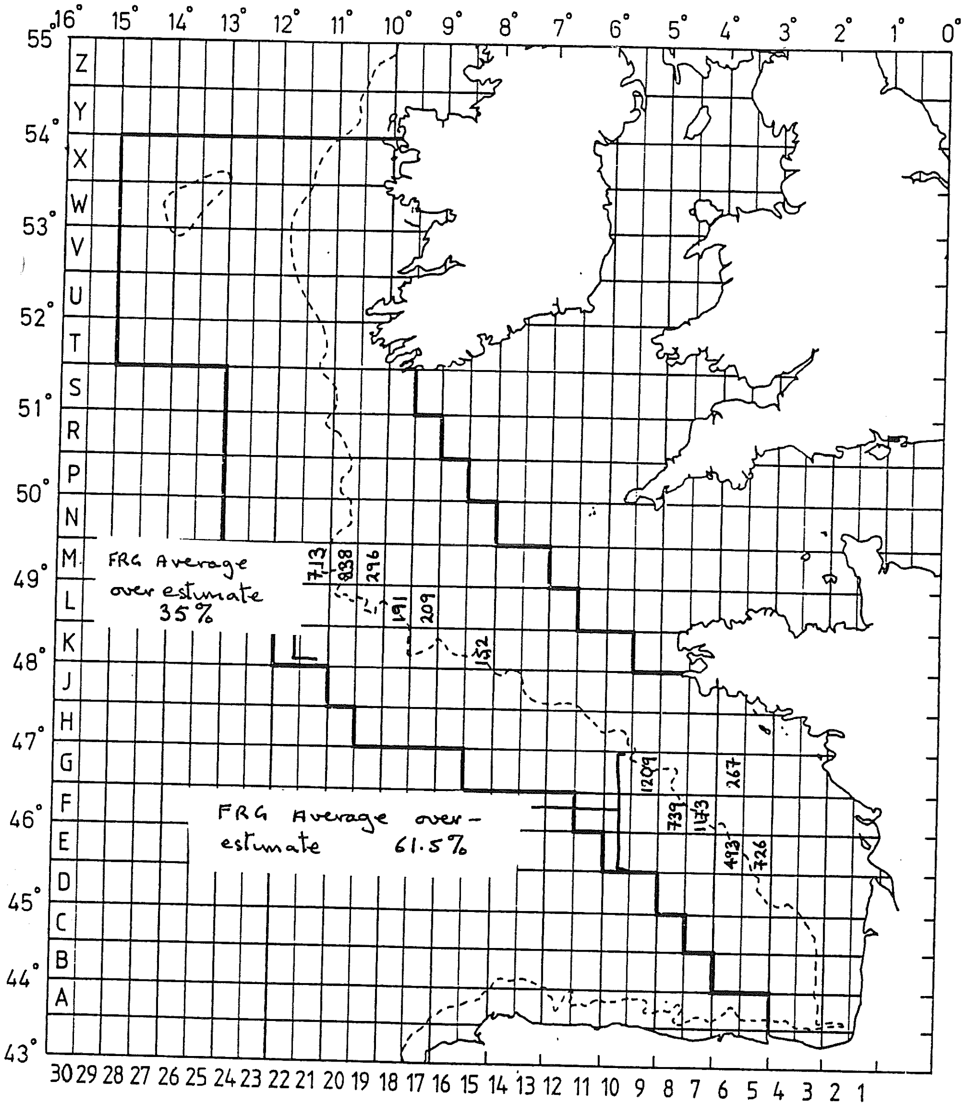


Figure 3. Distance of plankton station from intended postion in centre of rectangle during first survey April 1989

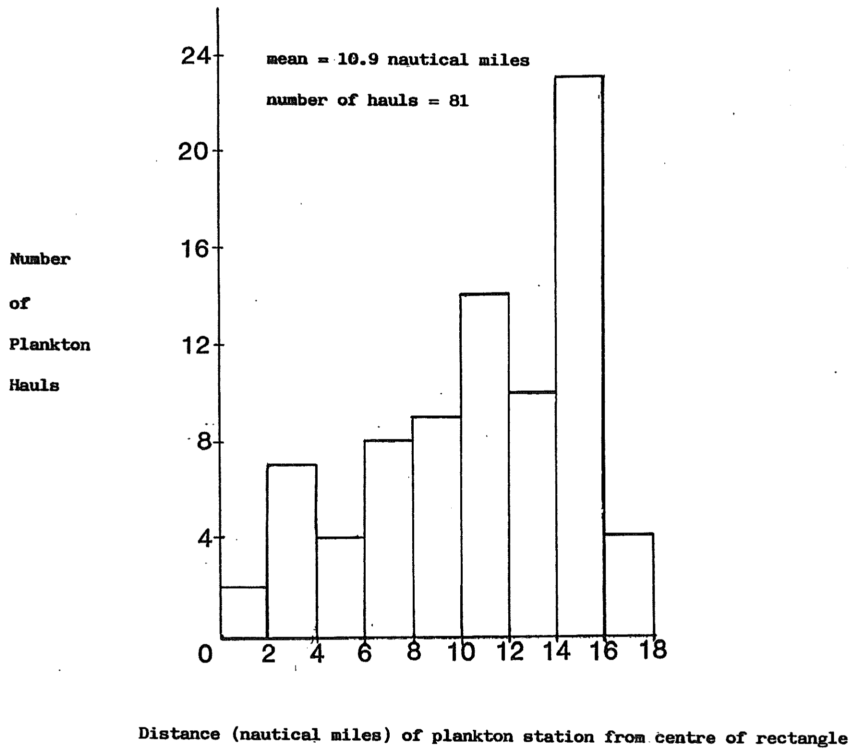
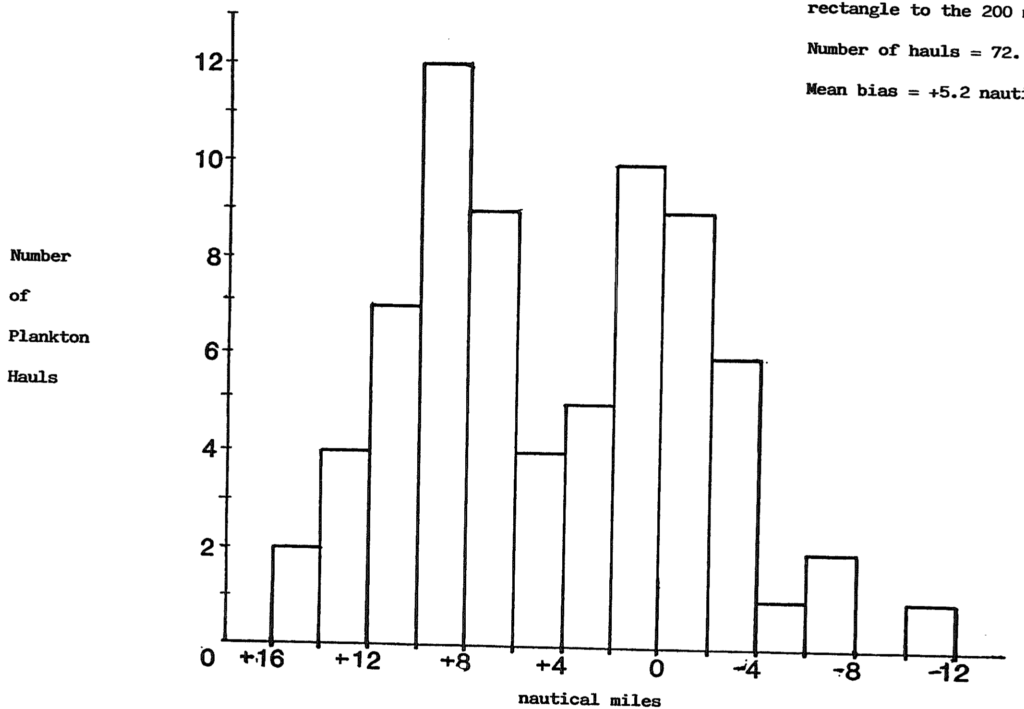


Figure 4. Bias in distance (nautical miles) of sampled position towards 200 metre contour

Note: positive values indicate that sampled position was closer than the centre of the rectangle to the 200 metre contour.

Number of hauls = 72.

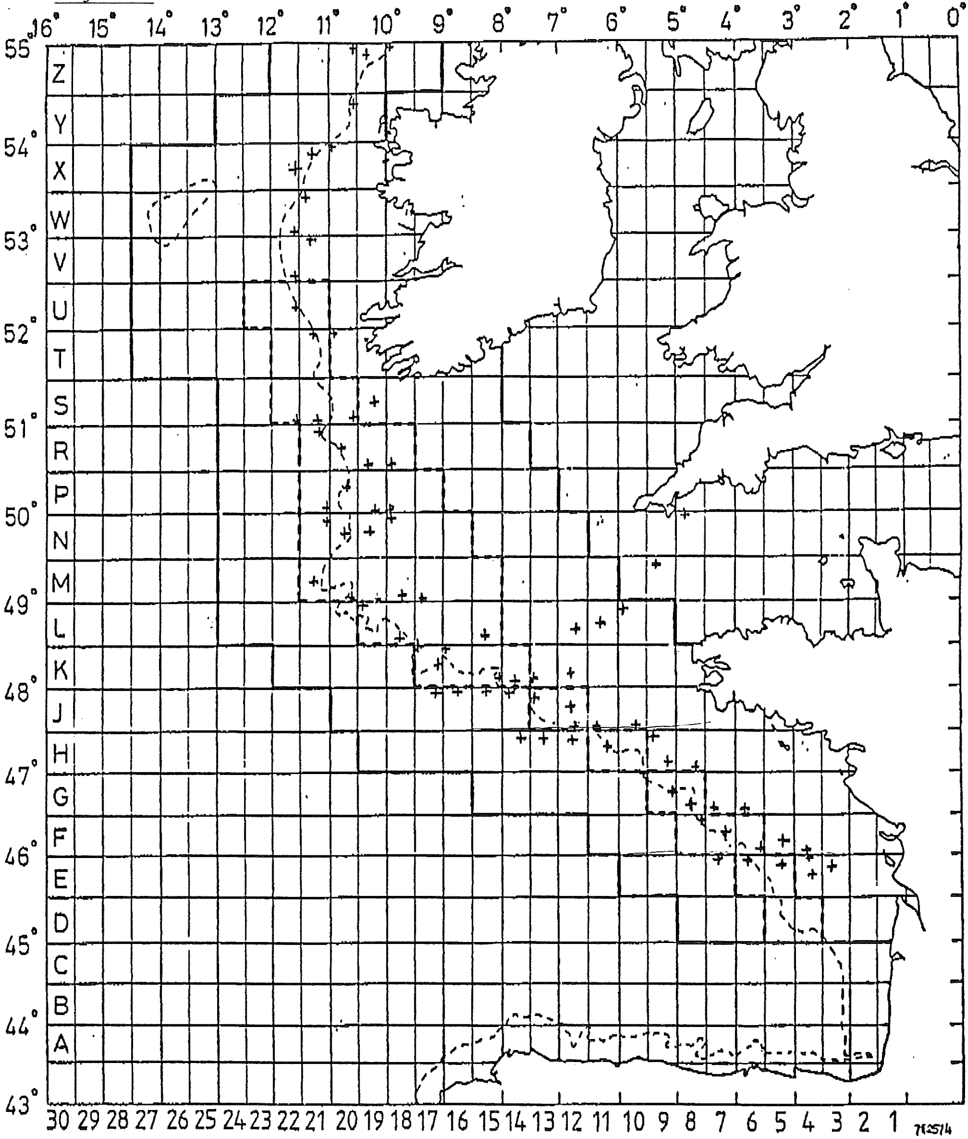
Mean bias = +5.2 nautical miles.



Bias of sampled position towards 200 metre contour

footnote: this analysis was confined to hauls made within 30 n.miles of 200 metre contour

Figure 5



1989 first period station positions. Walther Herwig - April 1990

Figure 6. Distribution of stage 1 mackerel eggs in relation to 200 metre contour between latitudes 46° - 47°30N during first survey April 1989.