# REPORT OF THE
# WORKING GROUP ON MACKEREL AND HORSE MACKEREL EGG SURVEYS

Aberdeen, Scotland, UK

25–29 March 1996



International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

Palægade 2–4 DK–1261 Copenhagen K Denmark

## TABLE OF CONTENTS

# 1 INTRODUCTION

## 1.1 Terms of Reference

a) Plan, coordinate and conduct mackerel and horse mackerel egg surveys;

b) Continue to evaluate and improve egg survey methodologies to estimate spawning stocks;

c) Analyse the results of mackerel and horse mackerel egg surveys and report to the Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy;

d) Report to the Advisory Committee on Fishery Management well in advance of the Advisory Committee on Fishery Management meeting in May 1996.

In addition to the above terms of reference the Mackerel, Horse Mackerel, Sardine and Anchovy Working Group recommended, at their meeting in October 1995 that the Working Group - **"examines the basis for the assumptions about the maturity at age for the western mackerel"**.

## 1.2 Participants

The Working Group met in Aberdeen, Scotland from 25 March to 29 March 1996 with the following participants:

| | |
|---|---|
| Augustin, Nicole | UK (Scotland) |
| Borges, Fatima | Portugal |
| Eltink, Guus | Netherlands |
| Farinha, Anabela | Portugal |
| Fryer, Rob | UK (Scotland) |
| Gregoire, Francois | Canada |
| Joakimsson, Gunnar | Germany |
| Iversen, Svein | Norway |
| Mc Millan, Julie | UK (Scotland) |
| Milligan, Steve | UK (E&W) |
| Molloy, John | Ireland |
| Motos, Lorenzo | Spain |
| Newby, Justine | UK (Scotland) |
| Nichols, John (Chair) | UK (E&W) |
| O'Brien, Carl | UK (E&W) |
| Patterson, Ken | UK (Scotland) |
| Perez, Jose-Ramon | Spain |
| Reid, Dave | UK (Scotland) |
| Sola, Amor | Spain |
| Stœhr, Karl-Johan | Denmark |
| Valdez, Luis | Spain |
| Vingerhoed, Bas | Netherlands |
| Walsh, Martin | UK (Scotland) |
| Watson, Jennifer | UK (Scotland) |
| Witthames, Peter | UK (E&W) |

**Observer**

| | |
|---|---|
| Maravelias, Christos | Greece |

In addition the following attended for a half day on 25 March in order to provide an update on the ICES Cooperative Research Report on the Western area egg surveys;

| | |
|---|---|
| Jones, Sarah | AURIS Environmental, Aberdeen |
| Priede, Monty | University of Aberdeen |

The following attended on 27 March in order to present and discuss the results of the western area mackerel and horse mackerel egg production estimates for 1989, 1992 and 1995, derived from the application of Generalized Additive Models;

| | |
|---|---|
| Borchers, Dave | University of St Andrews |
| Buckland, Steve | University of St Andrews |

## 2 PROVISIONAL ADVICE TO ACFM NOVEMBER 1995 MEETING

For previous triennial surveys the provisional egg production estimates have been provided direct to ACFM for consideration at their November meeting. In 1995 the Mackerel, Horse Mackerel, Sardine and Anchovy Working Group (MHMS&A,WG) meeting was deliberately delayed until October in order that they could use the provisional spawning stock biomass estimates from the egg survey.

Working Documents were produced for the mackerel and horse mackerel egg surveys of the western area and for the southern area and presented to the MHMS&A,WG in October (Anon, 1996). After consideration of the results some changes were made to the calculated egg production estimates by the Working Group. The resultant provisional SSB's for mackerel and horse mackerel, in both the western and southern areas, (Anon, 1996), were used in the provision of their advice to ACFM.

The MHMS&A,WG provided ACFM with separate estimates of mackerel SSB for the western and southern areas and also a combined estimate for both areas.

For the western area most of the data were available and the spatial and temporal survey coverage was good.

### 2.1 Western Area Mackerel

Details of the mean daily egg production for mackerel, calculated for each survey period, and the interpolations for unsampled periods are given in the text table below.

| Period | Dates | Mean egg prod: x $10^{-13}$ | Days | Total egg prod: x $10^{-15}$ |
|---|---|---|---|---|
| * | 16-25 March | (0.170)* | 10 | (0.017)* |
| 3 | 26 March - 14 April | 0.62 | 20 | 0.124 |
| * | 15-21 April | (0.986)* | 7 | (0.069)* |
| 4 | 22 April - 16 May | 1.42 | 25 | 0.354 |
| 5 | 17 May - 8 June | 2.62 | 23 | 0.603 |
| 6 | 9-29 June | 0.51 | 21 | 0.107 |
| 7 | 30 June - 16 July | 0.19 | 17 | 0.032 |
| | | **Total** | 123 | **1.305** |

Note: * interpolated periods and (values).

Using a provisional estimate of fecundity of 1566 eggs/g. female, adjusting by a factor of x1.08 for the difference in weight between pre-spawning and spawning fish and using an atresia value of 8.8% (Anon, 1993a), a provisional spawning stock biomass of 1.97 million tonnes was calculated. This is the lowest estimate for the western area since the egg surveys began.

## 2.2 Western Area Horse Mackerel

Details of the mean daily egg production for horse mackerel, calculated for each survey period, and the interpolations for unsampled periods are given in the text table below.

| Period | Dates | Mean egg prod: x $10^{-13}$ | Days | Total egg prod: x $10^{-15}$ |
|---|---|---|---|---|
| * | 16-25 March | (0.095)* | 10 | (0.010)* |
| 3 | 2 March - 14 April | 0.38 | 20 | 0.077 |
| * | 15-21 April | (0.295)* | 7 | (0.021)* |
| 4 | 22 April - 16 May | 0.19 | 25 | 0.047 |
| 5 | 17 May - 8 June | 2.32 | 23 | 0.533 |
| 6 | 9-29 June | 1.33 | 21 | 0.277 |
| 7 | 30 June - 16 July | 0.87 | 17 | 0.148 |
| | | **Total** | 123 | **1.114** |

Note: * interpolated periods and (values).

No new estimates of fecundity or atresia were available for this area. Therefore the 1992 values of 1430 eggs/g female and 10% atresia were used. Using these values and a conversion factor of x 1.05 to correct from pre-spawning weight, a provisional spawning stock biomass of 1.64 million tonnes was calculated.

## 2.3 Southern Area Mackerel

Data were only available for survey periods 3, 4 and 5. Coverage in periods 4 and 5 was limited to the Cantabrian coast east of 8°W and some data from this area were missing. Using the data available, the mean daily egg production for mackerel was calculated for each survey period. These are given in the text table below together with the interpolations for unsampled periods.

| Period | Dates | Mean egg prod: x $10^{-12}$ | Days | Total egg prod: x $10^{-12}$ |
|---|---|---|---|---|
| * | 15-25 March | (1.194)* | 11 | (13.13)* |
| 3 | 26 March - 13 April | 4.34 | 19 | 82.46 |
| * | 14 April - 7 May | (2.11)* | 24 | (50.64)* $ |
| 4 | 8-12 May | 0.55 | 5 | 2.75 $ |
| * | 13-29 May | (0.354)* | 17 | (6.01)* $ |
| 5 | 30 May - 5 June | 0.14 | 7 | 0.98 $ |
| * | 6-8 June | (0.03)* | 3 | (0.09)* $ |
| | | **Total** | 86 | **156.07** |

Note: * interpolated periods and (values); $ see text below

Highest production occurred on the first survey and the MHMS&A,WG decided to make an adjustment to the egg production estimate to take account of missed production at the start. This was done by taking period 3 as the peak and assuming the same distribution of production on either side of it. Effectively the production in the periods marked $ in the above table were doubled to give a total egg production of 216.54 x $10^{12}$ eggs.

No data were available for fecundity or atresia for this area and the same values as for the western area were used. Using the higher figure for egg production gave a provisional spawning stock biomass estimate of 327,500 tonnes, which represents about 14% of the combined western and southern area estimates.

### 2.4 Southern Area Horse Mackerel

Data were available at the Working Group from periods 2 (Portugal) and 3,4 and 5 (Spain) but nothing from period 1. Details of the survey coverage and the mean daily egg production from sampled and interpolated periods are given in the text table below.

| Period | Dates | Mean egg prod: x $10^{-12}$ | Days | Total egg prod: x $10^{-12}$ |
|---|---|---|---|---|
| 1 | 16 February - 6 March | not available | 18 | not available |
| * | 4-13 March | (0.023)* | 10 | (0.23)* |
| 2 | 14-23 March | 0.068 | 10 | 0.68 |
| * | 24-25 March | (0.186)* | 2 | (0.372)* |
| 3 | 26 March - 13 April | 0.580 | 19 | 11.02 |
| * | 14 April - 7 May | (0.290)* | 24 | (6.96)* |
| 4 | 8-12 May | 0.090 | 5 | 0.455 |
| * | 13-29 May | (0.340)* | 17 | (5.78)* |
| 5 | 30 May - 5 June | 0.800 | 7 | 5.6 |
| * | 6-8 June | (0.180)* | 3 | (0.54)* |
| | | **Total** | 115 | **31.63** |

Note: *interpolated periods and (values).

The production estimate was lower than expected but was thought likely to increase once the data from period 1 became available. Peak production in the Cantabrian area occurred in the final sampled period and it is likely that some production was missed. Fecundity and atresia data from the western area in 1992 were used to calculate the spawning stock biomass. This gave a provisional estimate of 46,450 tonnes after correction from pre-spawning weight.

# 3 GENERAL ASPECTS

## 3.1 Comparison of Egg Staging

A sample of mackerel eggs, collected from the Celtic Sea area during May 1995, was sent to each institute in turn. The egg stages were identified and counted, and the results collated (Table 3.1.1).

The total number of eggs decreased (due to loss and damage in during the analysis) as the sample was passed from institute to institute. Consequently the percentage numbers of eggs in each stage was calculated to enable more direct comparisons to be made (Table 3.1.2).

The results show a reasonable consistency of staging with a few exceptions. Both Spain (IEO) and Germany identified low numbers of stage 1A eggs but this was compensated by the fact that both institutes identified greater than average numbers of stage 1B eggs. Norway and Ireland identified fewer than average stage 1B eggs but higher than average numbers of stage 1A eggs. Similar numbers of eggs were allocated to "total stage 1" by each institute, with between 32% and 48% of eggs being allocated to this stage. This was reassuring as the annual egg production is based upon the abundance of eggs in this stage.

There were also some differences in the allocation of eggs to stages 2 and 3. Both Scotland and Norway identified low numbers of stage 2 eggs which seem to have been allocated to stage 3. When the counts for these stages are combined, similar numbers (of stage 2 + 3) eggs are obtained for each institute.

Similar numbers of eggs were allocated to stages 4 and 5 by all the institutes. There appears to be little problem with the staging of later stage eggs.

Figure 3.1a shows the variation between institutes when eggs are allocated to six development stages. This variation may be decreased if eggs are allocated to only four stages (Fig. 3.1b). When this is carried out only two countries seem to have results different from the rest. Ireland and Germany identified fewer "total stage 1" eggs than other participants but higher numbers of stage 2 +3 combined.

Some institutes experienced problems when staging the eggs in the "exchange" sample because of the dark, opaque nature of the yolk in some eggs. It was noted that it is possible to "clear" eggs which have become affected in this way by pipetting a few drops of 2-5% sodium hydroxide solution (Gurr, 1963) into the sample for a few minutes.

Some institutes experienced difficulties distinguishing between mackerel and horse mackerel eggs in some of their survey samples. It is recommended that the egg sample for the comparison experiment for the next survey should include eggs of both species in all stages of development.

## 3.2 Between Country Variation

During the previous survey in 1992 rescheduling of cruises resulted in substantial temporal and spatial overlap between two different vessels originally intended to sample different time periods (Anon., 1993a). Since there were significant differences in the results between these vessels it was necessary to investigate the possibility of between-country bias. The conclusion of this investigation was that the differences in results could be explained by an early season peak in spawning during the period surveyed by the two vessels. This resulted in a higher production estimate from the vessel starting and finishing its survey first and the conclusion that between-country differences were probably not implicated.

In 1995 there was little sampling of the same area in the same time period by more than one vessel. On the few occasions where this did occur sampling dates were not sufficiently close together to make any valid comparisons and therefore this question was not an issue in 1995.

## 3.3 Spatial and Vertical Distribution of Spawning

### 3.3.1 Spatial distribution of mackerel eggs

Distribution maps of daily stage I egg production per $m^2$ surface are given for the 7 time periods (Figs 3.3a-g). For the first time the surveys were coordinated over both western and southern areas.

During period 1 (Fig 3.3a), only the southern part of the southern area (36°-42°N) was scheduled to be surveyed but an additional non ICES survey for hake eggs was carried out by AZTI in the Bay of Biscay. This survey used compatible methods and strategy and the results have therefore been included in this analysis. The southern area survey was delayed by poor weather and survey coverage was only achieved as far north as 39°30'N. Within the two separate areas covered only very low abundances of stage I eggs were found. Their presence in Biscay was much earlier (mid February) than previously thought, indicating that even in the western area spawning commenced in period 1.

During period 2 (Fig 3.3b) only the southern part of the southern area (36°-42°N) was scheduled to be surveyed. This was successfully achieved, with mackerel eggs found only in low abundance and only between 37°N and 41°N with zero values to the north and south. The commencement of spawning in the Bay of Biscay in the previous survey period and the distribution in period 3 however suggests that there would have been spawning along the north coast of Spain and in the Bay of Biscay during this period.

Distribution in period 3 is shown in Figure 3.3c and indicates good coverage of the spawning area. High abundances of eggs were concentrated in a relatively narrow strip straddling the 200 m contour from the western end of the northern Spanish coast up through Biscay to 49°N with abundance decreasing northwards from here to low levels by 52°N - the northern extremity of the area surveyed. Compared to previous years the distribution pattern was typical for the period.

Distribution during period 4 (Fig. 3.3d) indicated an extension in the main area of spawning towards the north and west compared to period 3. The spawning area appeared to be well covered by the surveys with only very low abundances at the northern and southern extremities of the survey area. Patches of high egg abundances ($>100/m^2d^{-1}$) were found over a broad area between 43°N and 53°N either close to the 200 m contour or to the west with only low abundance on the shelf. In two locations (latitudes 46°30 - 48°N and 51°-53°N) patches of high egg abundance were found well to the west of the 200 m contour. Such westerly patches have been a feature of recent years surveys but their development appears to have taken place slightly earlier than usual, as in 1992.

During period 5 (Fig. 3.3e) which marked the peak of spawning, both the southern and northern limits of the main spawning area shifted northwards as in previous years. The two westerly patches which had begun to develop in the previous period were again in evidence but with even higher abundances. The appearance of such westerly patches has been more frequent in recent surveys (1989-1995) than in earlier years but their locations appear to be relatively constant whenever they do occur. Between these two patches and to the north of them the highest abundances of eggs were largely confined to the shelf edge. A feature of the distribution of the northern patch was the very sharp cut off in abundance west of 15°W. During the same period in 1992, when distribution had been further west than in any previous survey, very high abundances were also found just east of 15°W. No sampling was carried out further west so that outer limits of spawning were unknown in that year. A preliminary comparison between the two

years over the sampling area as a whole indicates that spawning in 1995 may not have been quite so far west as in 1992. In the southern area only low abundances of eggs were found, these being distributed in a narrow strip from the shelf edge towards the coast.

Period 6 (Fig. 3.3f) was marked by a sharp drop in abundance and a reduction of the spawning area. Whilst some spawning took place over the entire north-south extent of the sampling area it was mainly confined to the shelf and shelf-edge with very little over the deeper waters to the west. This was again typical of previous years.

In Period 7 (Fig. 3.3g) there was a continued reduction of the spawning area. The distribution pattern was similar to that of period 6 but with little very spawning at the southern end of the survey area. The highest concentration of eggs was in the centre of the survey area and the pattern typical of previous years.

### 3.3.2 Spatial distribution of horse mackerel eggs

Distribution maps of daily stage I egg production per $m^2$ surface are given for the 7 time periods (Figs 3.3h-n). For the first time the surveys were coordinated over both western and southern areas.

During period 1 (Fig 3.3h), only the southern part of the southern area (36°-42°N) was scheduled to be surveyed but an additional non ICES survey for hake eggs was carried out by AZTI in the bay of Biscay. This survey used compatible methods and strategy (see Section 5.3.1) and the results have therefore been included in this analysis. The southern area survey was delayed by poor weather and survey coverage was only achieved as far north as 39°30'N. In this area very high abundances of eggs were found along the shelf edge between 36°N and 38°N. Only very low abundances of stage I eggs were found in Biscay but their presence here was much earlier (mid February) than predicted by the survey planning group (Anon, 1994) indicating that even in the western area spawning commenced in period 1. The presence of eggs in both the areas sampled suggests a likely continuous distribution between them.

During period 2 (Fig 3.3i) only the southern part of the southern area (36°-42°N) was scheduled to be surveyed. This was successfully carried out with horse mackerel eggs found along most of the shelf edge and in high abundance in two patches one in the same place as in period 1, the other to the north at latitude 39°45'N. The commencement of spawning in the Bay of Biscay in the previous survey period and the egg distribution in period 3 suggests that there would probably have been spawning along the north coast of Spain and in the bay of Biscay during this period.

Distribution in period 3 is shown in Figure 3.3j and indicates good coverage of the spawning area. In the western area eggs were found from the southern end of the survey area as far north as 51°30'N with highest abundance between 47°30'N and 49°30'N not far from the shelf-edge. Proximity of eggs to the 200 m contour was less pronounced than in the case of mackerel and there appeared to be some regional differences. Peak abundances occurred west of the shelf break south of 49°N and east of the shelf break, north of 49°N. In the southern area abundance was highest along the Cantabrian coast with only low and patchy abundance along the western Iberian shelf.

In period 4 (Fig. 3.3k) eggs were found from the southern end of the survey area to 56°N indicating a northward shift in spawning since period 3. Overall abundance was lower than in period 3 and peak abundances were found further south, in the Biscay area. Although the abundances were much lower than mackerel there were some similarities in their distributions with two patches of higher than average abundance well to the west of the shelf edge in the same locations as for mackerel.

In period 5 (Fig. 3.3l) there was no increase in the northward extent of spawning compared to period 4 but there was a marked increase in the abundance of eggs between 49°30'N and the southern boundary of the western survey area. In southern Biscay, south of 46°30'N, the highest abundances were found close to the shelf edge with one patch at the western boundary of the sampled area off Galicia. In the western area between 46°30'N and 48°N patches were found both at the shelf-edge and beyond the western boundary of the standard area. The westerly patches overlapped those observed for mackerel. Further north, between latitudes 49°N and 49°30'N there was a single high abundance patch well inshore of the shelf-edge.

In period 6 (Fig. 3.3n) there was a marked northward shift in distribution compared to period 5. The highest abundances were found in the central part of the survey area between 47°N and 53°N mainly associated with the shelf-edge. Eggs were scarce west of the shelf-edge south of 50°30'N. This was similar to the mackerel egg distribution in the same period.

In period 7 (Fig. 3.4.l) distribution was similar to period 6 but the abundance as expected., was lower. From monthly sampling of ichthyoplankton, off the north coast of Spain, there was evidence that horse mackerel spawning continued to the end of July off the Cantabrian Coast (see Section 6.7).

### 3.3.3 Vertical distribution of mackerel eggs

The vertical distribution of mackerel eggs and larvae is described by Coombs *et al.* (a) (in press). Samples were collected using an LHPR (Longhurst-Hardy Plankton Recorder) in the area to the west of the British Isles and in the Bay of Biscay in the years 1974-1995. Early in the spawning season, when there was no temperature stratification, mackerel eggs were found down to a depth of 400 m. During the main period of spawning, in May and June, eggs were mostly above the thermocline in the upper 50 m of the water column.

The current recommended procedure (Anon., 1994) is to sample to 200 m depth or to 20 m below a thermocline of 2.5°C or more. Based on the results of Coombs *et al.* (a) (in press) this procedure does not lead to any significant under-sampling of eggs.

### 3.3.4 Vertical distribution of horse mackerel eggs

The vertical distribution of horse mackerel eggs and larvae is described by Coombs *et al.* (b) (in press). The results show that both eggs and larvae occur predominantly above the thermocline in the upper 80 m of the water column. As the thermocline developed there was a progressive reduction in the mean depth of both eggs and larvae. In June 1995, where a strong thermocline had developed, 97% of eggs and 95% of larvae were found in the upper 40 m of the water column. As, in the case of the mackerel, the current procedure does not result in any significant under-sampling of eggs.

## 3.4 Sampler Calibration

As a result of an EU funded Concerted Action programme the performance of Gulf III samplers currently used in the mackerel egg surveys has been examined. Previous calibration methods and assumptions have been scrutinised and problem areas highlighted. The Dutch, German and English samplers were all re-calibrated in a towing tank using mini-flowmeters transected across the opening plane of the nose cone. The English sampler and a 20 cm Bongo net were calibrated in a flume tank using a Laser/Doppler system. This system is considered to be the most precise measuring device available for the primary calibration of the samplers. From the combined results of all the trials it was concluded that the Gulf III samplers are between 100% and 105% efficient. The 20 cm Bongo sampler calibrated in the flume was 85% efficient.

Historically there has been little consistency of approach in the way that flowmeters have been calibrated and subsequently used in the field to calculate volume filtered. Ideally they should be calibrated *in situ* in a flume or towing tank against a precise measure of the volume of water entering the sampler. This problem has been addressed and now retrospective calibrations have been carried out on the Dutch and German flowmeters. Following on from this there has been some confusion regarding the basic assumptions made in the past about efficiency during the calculation of volume filtered. Since 1983 English sampler was calibrated in a towing tank with electronic flowmeters *in situ*. However, the mini-flowmeters were transected 2.5 cm in front of the entry plane and an efficiency of only 90-95% was observed. This means that the volume filtered by the English samplers has been underestimated by *ca* 10% with a consequent overestimate of the abundance of plankton.

The Dutch, German and Scottish flowmeter calibration systems have all assumed that the sampler was 100% efficient. Although there are still some uncertainties about the interpretations of flowmeter calibrations done at sea, the Concerted Action group concluded that it was unlikely that any corrections to these data sets could be recommended until the Concerted Action report has been produced. It is proposed that no corrections are made to the database at present.

### 3.5 Examination of the Basis for the Assumption about Maturity at Age in Western Mackerel

Fish which are at maturity stages III-VIII (early developing to recovering spent (Macer, 1976) were assumed to be either maturing prior to spawning, to be spawning or to have spawned in the current spawning season (Anon, 1985). Fish in maturity stages I and II were assumed to be immature.

The ICES Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy requested a further examination of the basis for the assumption about maturity of mackerel, since both the maturity ogive and the mean weights at age in the stock have a major effect on the mackerel assessment (Anon, 1996).

A maturity ogive was constructed in 1985 (Anon., 1985) based on Dutch commercial and research vessel samples taken in April, May, June, July and August in Division VIa south of 57°N and Divisions VIIb,e,f,g,h,j during the period 1977-1984. These Dutch data were accepted as the most representative samples, because they were well distributed throughout both the spawning ground and the juvenile area. However, the shortcoming of this maturity ogive is that no weighting factors have been applied to the samples, depending on how many fish of a certain age group were distributed in the juvenile areas and how many in the spawning area. For the 1-group fish most of the samples should be obtained from the juvenile area and for 2-group fish less samples should be taken from the juvenile area. Relatively more samples should be taken from the adult area when fish are older. Since this information on the relative distribution in the juvenile and adult areas is not available, it is impossible to apply these weighting factors by age group to improve the maturity ogive. The maturity ogive should be estimated for each year to take into account possible differences in growth rates. The mean weights at age in the stock are estimated annually, but up to now a constant maturity ogive has been assumed except for 1986. The percentage mature of 60% for the two year olds (strong 1984 year class) has been reduced to 17% because of the low proportion mature of two year old fish as estimated from biological samples taken during the 1986 surveys (Anon, 1987). Changes in mean weights at age in the catch are expected to be related to changes in the maturity ogive. However, the Working Group considered that it was not possible to estimate annual maturity ogives because of the difficulties mentioned before.

The maturity ogive used up to now was based on mackerel samples from Dutch commercial freezer trawlers and the research vessel Tridens taken during the period 1977-1984 in April-August in ICES Division VIa south of 57°N and Divisions VIIa-c,e-k and VIIIa (Anon, 1986). A new maturity ogive was constructed based on samples taken in years 1985-1995 during the same months and in the same

areas however the samples were mainly taken from adult areas in recent years (Table 3.5.1). The difference between the maturity ogives of both periods is not large despite the fact that in recent years the samples were mainly taken from the adult area. The differences become even smaller when a maturity ogive is constructed over the whole period 1977-1995. The Working Group decided not to change the existing maturity ogive based on the available information and because of the uncertainties in estimating a maturity ogive. The Working Group recommended that a maturity ogive be estimated from the biological samples collected during the surveys of the Daily Egg Production Method in 1992, when many trawl hauls were carried out in the main distribution area of the adult mackerel at peak spawning time. Unfortunately a large part of the juvenile distribution area is not covered by these surveys.

The existing maturity ogive is based on macroscopically estimated maturity stages. However, histological analysis of the ovaries of younger fish shows that the macroscopically estimated proportion mature might be overestimated.

Before adopting an unchanged maturity ogive based on this traditional method a review of other literature and recent work is presented for both sexes.

No data is available for male mackerel but in plaice the youngest fish produce semen which has a similar spermatocrit compared to older fish providing they are caught in an area where spawning is taking place (Witthames, pers comm). The conclusion is that if they are running they are functionally mature.

In the case of females several reports have found that some ovaries, classed macroscopically as maturity stage three, were undergoing abortive maturation and contained many atretic oocytes when examined histologically (Maridueña, 1984; Greer Walker *et al.*, 1987; Coello *et al.*, 1989). The latter authors estimated that although 91% of age two females and almost all age 3 fish were classed as mature macroscopically only 51% and 90% respectively of the population in 1987 actually spawned. However, because the histological sampling was carried out in March and early May in Division VIIj (before peak spawning) and the end of June in Division VIIe the results probably underestimates the amount of abortive maturation. An alternative approach to estimating abortive maturation is to use a histological examination to determine past spawning history and the maximum oocyte diameter found in the ovary as a forward indicator of the likely spawning success. Previous studies have used measurements of maximum oocyte diameter as a general indicator of maturity (West, 1990), in sole (Ramsay and Witthames, in press) and to predict onset of spawning in cod (Kjesbu, 1994). The analysis was restricted to two and three year old fish because previous analyses (above) have shown that these ages contain by far the majority of recruitment in the population. The results are presented in Figure 3.5.1 and Table 3.5.2 and compare fish from Division VIIj (ICES rectangle 28D9 collected in the last week of May 1989) and Division VIIe (ICES rectangle 29E5 collected on 21 May and 10 June) sampled by rod and line from RV *Cirolana* at or just after peak spawning (Anona, 1993). None of the two year olds (19 fish), or three year olds (2 fish) in Division VIIe showed any previous spawning activity (indicated by the absence of post ovulatory follicles, hydrated oocytes and migratory nuclei stages in the ovary). In Division VIIj a low proportion of two year old fish did show evidence of spawning (23% out of 56 fish) whilst an even greater proportion of three year olds (63% from 11) contained these structures. It was also apparent that atresia was more prevalent in the ovaries where the maximum oocyte diameter was <400 µm (55% of 11 fish with oocytes <200 µm, 63% of 16 fish with oocytes between 201-300, 29% of 17 fish with oocytes between 301 and 400) compared with the most advanced group (>400 µm, 8% of 12 fish respectively). The high prevalence of atresia in fish with maximum oocytes size <400 µm suggest they probably fail to spawn and this view is further reinforced when data on oocyte growth rate (Greer Walker *et al.*, 1994) is used to determine whether a particular size of oocyte could mature in the remaining part of the spawning season. It is estimated that it takes 30 days for an oocyte to grow from 400 to 523 µm.

In the case of three year olds from Division VIIj their ovaries all had a maximum oocyte size >400 μm (the smallest was 437 μm) which suggests they may spawn successfully.

In conclusion this review shows that macroscopic maturity assessment substantially overestimates maturity at age and a histologiacl method would give greater precision. A reduction from 59% to 51% (age 2) and from 97% to 90% (age 3) was recommended by Coello *et al.*, (1989) sampling in early May. This study, based on later sampling in ICES Division VIIj (peak spawning was at end of May 1989) suggests an even greater reduction from 59% to 23% (age 2) whilst most age 3 fish in Division VIIj are mature. Neither age group appeared to mature in Division VIIe.

### 3.6 Generalized Additive Models for the Annual Egg Production Method

#### 3.6.1 Generalized additive model methods

The AEPM requires an egg production curve to be estimated as a function of time. The traditional method of estimating these curves involves assigning an estimate of egg abundance from each of a number of survey periods to a single point in time, and interpolating linearly between these point estimates. Each of the individual point estimates is obtained after stratifying the survey region spatially. In contrast, generalized additive models (GAMs) estimate egg density as a smooth function of space, time and oceanographic variables, using the data from a full season of egg surveys. Unlike the traditional method, this method allows quantification of the uncertainty in estimating the shape of the egg production curve to be incorporated in estimation, and it yields estimates of the egg distribution continuously throughout the spawning season. GAMs provide a powerful and flexible statistical tool for modelling egg density, although application of the methods is complicated by the fact that sampling for western mackerel and horse mackerel eggs has been confounded in space and time to varying degrees.

GAMs are an extension of generalized linear models (GLMs) (McCullagh and Nelder, 1989). Both GLMs and GAMs accommodate a variety of distributions for the response, but unlike GLMs, GAMs allow flexible non-linear effects of the explanatory variables on the response to be estimated from the data. Potentially, they allow greater flexibility for modelling spatial and temporal heterogeneity than GLMs. GAMs have the following general form (Hastie and Tibshirani, 1990):

$$E[y] = g^{-1}\left(\beta_0 + \sum_k S_k(x_k)\right)$$

The function $g()$ is the link function, which defines the relationship between the response and the linear predictor, $\beta_0 + \sum_k S_k(x)$ and E[.] denotes expectation. The response, $y$, is assumed to be distributed according to one of a wide family of statistical distributions. Here $y$ is either egg counts or egg presence/absence in a sample, $x_k$ is the value of the $k$th spatial covariate, $\beta_0$ is an intercept term, and $S_k()$ is a smoothing function for the $k$th spatial covariate. We use spline smoothers for $S_k()$. Ordinary linear regression corresponds to using an identity link function in $x$ and assuming $y$ to be normally distributed. Other common combinations are a Poisson error distribution with a logarithmic link function (for counts), and a binomial error distribution with a log link function (for binary data).

The degree of smoothing performed by $S_k()$ is determined by the degrees of freedom (*df*) associated with the smooth; the fewer the degrees of freedom, the less flexible the function. For example, $df=1$ corresponds to a linear effect of the associated explanatory variable. GLMs assume $df=1$ for all explanatory variables. Here we determine the degree of smoothness on the basis of the observed data.

Constraining the distribution in space and time

Sampling for western mackerel and horse mackerel seldom spanned the entire spawning area (ie the observed egg densities at the outer limits of the sampled area were often substantially greater than zero), and sampling never spanned the entire temporal range of spawning (ie the observed densities at the earliest and/or latest sample times were substantially greater than zero). In order to avoid bias being introduced by spatial and temporal extrapolation into unsampled regions of the spawning area, the outer boundaries of spawning were defined prior to fitting the GAMs. The fitted models were constrained to be close to zero at these outer boundaries by inserting artificial zero observations (so-called "structural zeros") at the boundaries. The contribution to the deviance from these structural zeros was removed prior to comparing models. The spatial boundaries varied over time, in accordance with what are believed to be conservative estimates of the true outer boundary of spawning at various times through the spawning season (ie erring on the side of being too wide, if at all).

Figure 3.6.1a shows the limits assumed for mackerel and Figure 3.6.1b shows those for horse mackerel. These limits are based on data from all surveys of the western area conducted to date, and were constructed as follows:

1. The spawning season was divided into five monthly periods (March-July).

2. Data from the ICES survey database were pooled across years (1977-1995). The maximum observed egg densities per survey square (0.5° latitude by 0.5° longitude) and month were plotted. Squares with either zero observed egg density across years, or with very low observed egg densities (when no zero was available) were used to define the outer boundary of spawning in east/west direction, as follows. The extreme outer limits of spawning for each row of survey squares was defined as the first square that lies at least 0.5° longitude beyond the zero or very low observed egg densities. These rules were not always rigidly adhered to, but were adjusted in the light of additional data from other sources. For example data from the Kings Cross survey in 1992 were used to adjust the assumed spawning area boundaries obtained from the above algorithm. In some cases where data were scarce or the outer boundary irregular, some *ad hoc* smoothing was also used.

A temporal limit at which it is assumed that spawning had not yet begun, and a temporal limit at which it is assumed spawning had ended, were defined and used similarly. The start and finish dates for spawning for all years were assumed to be those used for the traditional method in 1995. The start date was assumed to be 10 February and the finish date was assumed to be 31 July. These dates are based on data from all surveys of the western area conducted to date.

One-stage models

In a one-stage model no qualitative distinction is made between zero and non-zero responses. In the one-stage model used here, the count of the number of eggs observed in the sample from location $i$ and at day $j$ ($y_{ij}$ ; $j=1,...,365$) is modelled using a GAM with a logarithmic link function and a Poisson error distribution with an estimated dispersion parameter, as described below. This model assumes that the variance in the response is proportional to the mean at that point. The logarithmic link function implies that the explanatory variables have a multiplicative effect on expected egg counts. To be more explicit:

$$E[y_{ij}] = \exp\left( \text{offset}_{ij} + \beta_0 + \sum_k S_k(x_{kij}) + \sum_{k=1}^{K} \sum_{l>k}^{K} S_{kl}(x_{kij} \cdot x_{lij}) \right)$$

where $x_{kij}$ represents the $k$th explanatory variable at the $i$th location on day $j$,
the $\beta_0$ is an "intercept" parameter,
$S_k(.)$ is the smoothing spline for the $k$th explanatory variable,
$S_{kl}(.)$ is the smoothing spline for the interaction term of the $k$th and $l$th explanatory variables,
$offset_{ij}$ is the (negative) logarithm of the correction factor used to convert observed egg numbers to egg density at the $i$th location on day $j$.

Given estimates $\hat{\beta}_0$, $\hat{S}_k(.)$, $\hat{S}_{kl}(.)$ $(k=1,...,K;\ l=1,...,K)$ , the expected egg density at a point with explanatory variables $x_k$ $(k=1,...,K)$ is given by

$$\hat{E}[\text{density}] = \exp\left( \hat{\beta}_0 + \sum_{k=1}^{K} \hat{S}_k(x_k) + \sum_{k=1}^{K} \sum_{l>k}^{K} \hat{S}_{kl}(x_k \cdot x_l) \right)$$

One-stage models were thought to be adequate for the mackerel data in all three surveys.

Two-stage models

When zero eggs are observed over a large part of the survey area, the one-stage model was found to be inadequate. In this case, egg density was modelled in two stages. In the first stage the presence/absence of eggs was modelled using a Binomial error distribution with a logit link function. The probability of eggs being present is therefore

$$p_{ij} = \frac{\exp\left( \beta_0 + \sum_{k=1}^{K} S_k(x_{kij}) + \sum_{k=1}^{K} \sum_{l>k}^{K} S_{kl}(x_{kij} \cdot x_{lij}) \right)}{1 + \exp\left( \beta_0 + \sum_{k=1}^{K} S_k(x_{kij}) + \sum_{k=1}^{K} \sum_{l>k}^{K} S_{kl}(x_{kij} \cdot x_{lij}) \right)}$$

where parameters are defined as for the one-stage model described above. In the second stage, egg density was modelled after conditioning on the presence of eggs. We found a Gamma error distribution and a logarithmic link function to be adequate in this case. That is, given that there are some eggs present, the number of eggs counted ($y$) is modelled as a Gamma random variable with expectation

$$E[y_{ij}] = \exp\left( \text{offset}_{ij} + \beta_0 + \sum_{k=1}^{K} S_k(x_{kij}) + \sum_{k=1}^{K} \sum_{l>k}^{K} S_{kl}(x_{kij} \cdot x_{lij}) \right)$$

where parameters are as defined earlier. Total egg production was estimated by integrating over the product of the estimated presence probability surface and the estimated egg density surface, given presence.

One-stage models were found to be inadequate for the horse mackerel data and two-stage models were used for all three years.

Integration over space and time

Once a model has been selected, the GAM provides a smooth expected egg density surface which is integrated numerically over a grid in space (within the survey area) and time (within the predefined spawning period) to provide an estimate of the total egg production in the survey area. By integrating over the appropriate spatial and temporal limits, egg production may be estimated at any spatial and/or temporal resolution. In particular, the method can provide estimates of daily egg production at any given day in the spawning period over the whole spawning area ($E_d$), as well as an estimate of annual egg production ($E_a$).

As a grid of values for each selected covariate must be prepared for integration, explanatory variables which are not well defined except at sampled points and times (duration of haul and sampling depth, for example) present difficulties and were excluded as candidate explanatory variables. Time-dependent explanatory variables are also only available at the sampled points and times. In order to use these variables in integrating the egg production surface to obtain the egg production curve, they would have to be modelled as functions of space and time. Temperature is one such variable. Investigation showed temperature to be highly correlated with date so that we have chosen to omit temperature from the model, and to include date. Obtaining a grid for integration with respect to explanatory variables which are not time dependent is straightforward. For bottom depth a digitised bathometry data set from the British Oceanographic Data Centre has been used.

Bootstrap variance estimation for the one-stage modelling process

The variance of $E_a$ (and the daily egg production on any given day, $E_\phi$ if desired) can be estimated using parametric bootstrap procedures. This involves generating *b* pseudo-samples of the egg survey data using the fitted model, and refitting the GAM to each of these pseudo-samples. Integrating each refit over space and time yields *b* bootstrap estimates for $E_a$ (and $E_d$, if desired). The cv of these bootstrap estimates is our estimate of the cv for the GAM estimate. Confidence intervals can also be constructed from the *b* bootstrap estimates. In order to generate pseudo-samples from an over-dispersed Poisson distribution, we use a method proposed by Bravington (1993) and described by Borchers *et al.*, (1994, 1995) in the context of the western mackerel survey data.

Bootstrap variance estimation for the two-stage modelling process

Borchers *et al.*, (1994, 1995) describe in detail the two-level bootstrap procedure used for the two-stage GAM models. The first level of the procedure parametrically generates pseudo-samples of presence/absence data, and the second level parametrically generates pseudo-samples of egg numbers at those points at which the first level generated egg presence.

In both cases, the bootstrap procedures can generate variance estimates for egg production estimates at any spatial and/or temporal resolution.

Model selection

Model selection with GAMs involves choosing an appropriate link function and error distribution, as well as choosing both explanatory variables and the appropriate degree of smoothness with which they enter the model.

While no formal tests of model adequacy were performed, plots of deviance residuals versus date, and the spatial distribution of residuals summarised by months, were examined in order to check the suitability of the models.

In order to simplify the model selection process, we adopted the approach taken by Borchers *et al.* (1994) for model selection and considered only smoothing splines with either 4 degrees of freedom (*df=4*) or one degree of freedom (*df=1*). Covariates first entered the model with *df=4*, and backward stepwise elimination was used to select a set of covariates. Selection between smooths with *df=4* and smooths with *df=1* was performed in the next step. However, when it was found that this selection step very seldom resulted in variables entering the model linearly, the step was omitted. Finally, first order interactions of the previously selected covariates were selected, again using backward stepwise elimination. Comparisons between models were made on the basis of approximate F-tests (Hastie and Tibshirani, 1990), after adjusting for the change in deviance due to the structural zeros. The explanatory variables ($x_k$) used in the GAMs are as follows:

date (*date*),
longitude (*lon*),
distance to the 200 m contour line (*cdist;* negative if *tdepth>200*) in nautical miles,
distance along the 200 m contour line in a north-south direction (*gdist*) in nautical miles, and
logarithm of bottom depth (log(*tdepth*)) in metres.

Attempts to include a vessel factor were unsuccessful as a result of substantial confounding between position, time and vessel.

Bias in GAMs

Initial model fits using *df=4* resulted in egg production curves which, while being similar in shape to those previously estimated using the traditional method, were uniformly lower - by as much as 40% in one case.

After considering the possible sources of bias in each of the methods, it was concluded that the GAM method estimates were substantially negatively biased as a consequence of using a non-linear link function together with an error distribution in which the variance depends on the mean, and that bias correction was necessary. The bias is a consequence of the fact that points with higher means (and hence higher variances) are assigned less weight in the fitting procedure than points with lower means. This inherent bias in GAMs is too large to be ignored in the case of these data.

Bias in GAM predictions can be reduced by increasing the *df* of the smoothers at the expense of decreasing the precision. Generalized cross-validation (GCV) suggested that smoothers with *df=32* might be appropriate, but Hastie and Tibshirani (1990) and Wood and Horwood (1995) note that GCV tends to result in undersmoothing when used with the kind of models we are using. On the bases of estimation at a limited number of different *df*, the point estimate of annual egg production appeared to stabilise somewhat in the region of *df=12*. We therefore used fits with *df=12* to evaluate the effectiveness of increasing the *df* of the smooths in removing the apparent bias.

While increasing the *df* in this way was successful at reducing the discrepancy between the traditional point estimate and the GAM production curve evaluated at the corresponding point in time, it also resulted in surprisingly low density estimates at other points in time. Examination of the data in these regions suggested that a combination of little or no sampling effort, and some confounding of sampling in space and time in the vicinity was causing local negative bias in egg density. The net effect was that while the estimate of annual egg production from the GAM method with *df=12* was higher than that with *df=4*, it usually remained substantially below that from the traditional method.

GAMs with *df=4* are able to interpolate effectively over the regions of low or no sample effort, but they appear to be negatively biased, as described above. Methods for correcting this bias inherent in GAMs

have received little attention in the literature to date. Here we have used a bootstrap bias-correction method similar to that of Efron and Tibshirani (1993; pp138-139). Our method differs from theirs in that we use a multiplicative correction while they use an additive correction. Limited time has precluded use of this method for all six datasets. It has been applied only to the 1995 mackerel and horse mackerel surveys and the 1992 horse mackerel survey. In addition, the following *ad hoc* bias-correction method has been used for all surveys. The estimated GAM egg production curve has been multiplicatively scaled up so that the predictions of egg production at the points in time corresponding to the point estimates from the traditional method have the same average value as those estimates. Even with this *ad hoc* correction method, estimates of total egg production differ between the methods because the piecewise linear sections of the traditional egg production curve are ignored by the scaling procedure.

### 3.6.2 Results and comparison of methods

Figures 3.6.2a, b and c show the mackerel/horse mackerel survey coverage over intervals of 20 days spanning the sampling period for the 1995, 1992 and 1989 surveys, respectively. Note that there is only partial spatial coverage of the survey area during any time period and that there is some confounding in time and space. In 1995 the survey area was extended westwards compared to the earlier years, and an adaptive sampling strategy in the east-west direction was used for the first time. The 1995 survey has the most complete coverage in space and time.

Figures 3.6.2d, e and f show the average mackerel densities in each of the three surveys, while Figures 3.6.2g, h and j show the corresponding mackerel densities estimated by the GAMs. Figures 3.6.2k, l and m show the average horse mackerel densities in each of the three surveys, while Figures 3.6.2n, o and p show the corresponding horse mackerel densities estimated by the GAMs.

A comparison of the uncorrected GAM method and the traditional method reveals substantial differences in estimates. In all cases the GAM estimate is lower than that from the traditional method. In interpreting Table 3.6.1, it should be borne in mind that in the cases of the 1992 and 1989 estimates the GAM method is estimating egg abundance over a wider area than the traditional method. The GAM estimates for the 1992 and 1989 survey areas only would be somewhat lower than the estimates shown in Table 3.6.1 for these years, although preliminary calculations indicate that they would not be substantially lower.

The primary reason for this discrepancy is believed to be the bias inherent in GAM methods. GAMs to estimate the abundance of Bering sea groundfish from trawl survey data, Swartzman *et al.* (1992) obtained abundance estimates which were consistently between 30% and 50% lower than estimates derived using a method which is broadly similar to the traditional method of this paper.

Bootstrap bias correction was performed for the 1995 survey data and the 1992 horse mackerel survey data. These bias-corrected estimates are presented in Table 3.6.2, together with the *ad hoc* bias corrected estimates and the estimates from the traditional method, for all years. It has not been possible to estimate the variance for the correction factor in the limited time available, and variance estimates are therefore omitted at this stage. The cv's appearing in Table 3.6.1 are negatively biased estimates of the cv's of the bias-corrected estimators of egg abundance.

Except in the case of mackerel in 1989, the *ad hoc* bias correction results in GAM estimates which agree well with the estimates from the traditional methods (not surprisingly). The bootstrap method bias-corrected estimates for horse mackerel in 1995 and 1992 agree well with the traditional method estimates, while the estimate for mackerel in 1995 remains substantially below that from the traditional method. It is not clear at this stage what the reason for this is, but it would be premature to conclude

either that the bootstrap bias-correction has failed, or that the traditional method estimate is positively biased in this case.

Unlike the *ad hoc* bias correction method, the bootstrap bias-correction method is independent of the traditional method estimate. However, it is not possible to reach a reliable conclusion regarding the efficacy of the bias-correction method on the basis of only three bootstrap bias-corrected estimates. Further work needs to be done with respect to determining the efficacy of bias-correction methods, and developing methods for estimating the variance due to the bias-correction factor.

Plots of the egg production curves for both species in each of the three years are shown in Figure 3.6.2q. The curves are similar for the traditional and the GAM methods in all cases except the 1989 mackerel survey. A substantial part of the difference between the plots is due to the dates assumed for the onset and end of spawning. (Remember that the GAM method uses the same dates over all years, while different dates were used in different years for the traditional method). Unlike the traditional method, the GAM method egg production curve is not strongly determined by the start and end dates assumed for spawning. In the case of horse mackerel in 1989, for example, the GAM curve rises substantially above zero only around day 80 (some 40 days after the date at which the curve is constrained to be zero) while in other cases it rises substantially above zero at a much earlier date. The GAM method allows the data to determine the egg production curve to a much greater degree than does the traditional method.

The 1989 mackerel survey provides an illustration of both the power of the GAM method and the need for careful modelling when using the method. Because it can use data from later in the survey to predict the trend of egg density in space at the time of the early German survey, the GAM method is able to incorporate the German data reliably, despite the concentration of survey effort about the 200 m contour line, unlike the traditional method (Anon, 1990). However, in order to use the data from later in the survey to extrapolate the early German survey data over the whole survey area, the flexibility of the GAM model needs to be restricted. In particular, interactions between date and distance from the 200 m contour, and between date and bottom depth were excluded.

The GAM method has a number of advantages over the traditional method. Primary among these are:

- It is able to model complex trends in density with respect to space, time, and other explanatory variables, without *ad hoc* assumptions about the form of the trends. In addition, the method provides information on the nature of these trends with respect to a wide variety of explanatory variables, and this at a resolution which is likely to provide useful insights into the underlying mechanisms driving spawning distribution.

- It provides a reliable means of extrapolating beyond the sampled region, to the boundaries of the spawning area.

- It is comparatively insensitive to the assumed start and end times of spawning.

The method is computationally intensive, but this is not seen as a serious drawback. Currently the method's primary drawbacks are:

- Considerable care needs to be taken in model selection, and automated model selection is likely to be inadequate in many cases. This is particularly the case when sampling is confounded in space and time, as is the case (to varying degrees) with the western mackerel and horse mackerel survey data. In this context, it should be remembered that only stage I eggs are used in the estimation of the egg production curve. In principle GAMs provide a powerful means of incorporating data from other stages in the estimation process. Data on the density of stages I

through V are gathered on the surveys. With stage V eggs in the region of eight days old, use of these data are potentially useful in so far as they allow the estimation procedure to "look back" in time and so fill some of the gaps in sampling in space and time. While movement of eggs between spawning and later stages complicates spatial models which incorporate stages II through V, there are potential gains from the use of these stages.

- The reliability of the bias-correction method has not been demonstrated conclusively. While the results to date are promising, further work remains to be done both in testing the method, and in estimating the variance due to bias-correction.

A comparison of the features of the traditional method with the GAM method, as applied to the annual egg production method of assessment, is made in Table 3.6.3.

It has not been possible to address the issues of bias precision and accuracy (mean squared error) of the two methods fully in the time available, and it is therefore too early to draw conclusions about the relative precision of the two methods, and the relative usefuless in stock assessment procedures. These issues will be fully addressed in a Working Document (WD) to be presented at the next meeting of the MHMS and A WG. This WD will also include the results of the analysis of the southern area, mackerel and horse mackerel egg production by GAM.

### 3.7 ICES Cooperative Research Report

At the meeting of the Mackerel and Horse Mackerel Egg Production Workshop, in Vigo, in 1994 it was recommended that the results of comparisons between the DEPM and AEPM for mackerel and horse mackerel in the western area should be published as an ICES Cooperative Research Report (Anon., 1994).

Progress to date on this report has been slow. The Working Group accepted a proposal, put forward by the joint editors, to expedite the publication by engaging professional support. Through the University of Aberdeen, Ms Sarah Jones is now under contract from March to June 1996 to assist in the preparation of the report. A list of all the proposed chapters and the authors has been circulated. During the coming weeks authors of sections will receive draft text based on what has been written previously in the two EU reports to DG XIV describing the 1989 and 1992 AEPM/DEPM surveys. These will be revised as necessary by the authors and returned to the editors. The report will be delivered to ICES at the end of June 1996.

| Table 3.1.1 The number of mackerel eggs allocated to each development stage by country | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Country** | **Development stage** | | | | | | | |
| | **1A** | **1B** | **Total 1** | **2** | **3** | **4** | **5** | **Total** |
| England | 33 | 14 | 47 | 34 | 18 | 9 | 4 | 112 |
| Ireland | 32 | 7 | 39 | 35 | 24 | 7 | 6 | 111 |
| Spain (AZTI) | 30 | 15 | 45 | 28 | 23 | 6 | 7 | 109 |
| Spain (IEO) | 6 | 36 | 42 | 27 | 19 | 6 | 7 | 101 |
| Portugal | 20 | 26 | 46 | 19 | 22 | 4 | 6 | 97 |
| Scotland | 30 | 18 | 48 | 10 | 28 | 9 | 6 | 101 |
| Norway | 39 | 6 | 45 | 3 | 36 | 9 | 7 | 100 |
| Germany | 9 | 23 | 32 | 30 | 23 | 9 | 5 | 99 |
| Netherlands | 18 | 22 | 40 | 30 | 12 | 7 | 4 | 93 |

| Table 3.1.2 The percentage of mackerel eggs allocated to each development stage by country | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Country** | **Development stage** | | | | | | | |
| | **1A** | **1B** | **Total 1** | **2** | **3** | **4** | **5** | **Total** |
| England | 29.5 | 12.5 | 42.0 | 30.4 | 16.1 | 8.0 | 3.6 | 100 |
| Ireland | 28.8 | 6.3 | 35.1 | 31.5 | 21.6 | 6.3 | 5.4 | 100 |
| Spain (AZTI) | 27.5 | 13.8 | 41.3 | 25.7 | 21.1 | 5.5 | 6.4 | 100 |
| Spain (IEO) | 5.9 | 35.6 | 41.6 | 26.7 | 18.8 | 5.9 | 6.9 | 100 |
| Portugal | 20.6 | 26.8 | 47.4 | 19.6 | 22.7 | 4.1 | 6.2 | 100 |
| Scotland | 29.7 | 17.8 | 47.5 | 9.9 | 27.7 | 8.9 | 5.9 | 100 |
| Norway | 39.0 | 6.0 | 45.0 | 3.0 | 36.0 | 9.0 | 7.0 | 100 |
| Germany | 9.1 | 23.2 | 32.3 | 30.3 | 23.2 | 9.1 | 5.1 | 100 |
| Netherlands | 19.4 | 23.7 | 43.0 | 32.3 | 12.9 | 7.5 | 4.3 | 100 |

**Table 3.5.1: The number of immature and mature mackerel by sex and sexes combined by age according Dutch samples from mainly commercial freezer trawlers and some from research vessel *Tridens* taken in April, May, June, July and August in ICES Divisons VIa south of 57°N, VIa-c, e-k and VIIIa for the periods 1977-1984, 1985-1995 and 1977-1995. The maturity ogive as used by the ICES Mackerel Working Group from 1986 onwards is given as well (bold)**

| | 1997-1984 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Age 1 | Age 1 | Age 1 | Age 2 | Age 2 | Age 2 | Age 3 | Age 3 | Age 3 | Age 4 | Age 4 | Age 4 | Age 5 | Age 5 | Age 5 |
| **SexÕ** | F | M | F+M | F | M | F+M | F | M | F+M | F | M | F+M | F | M | F+M |
| **Number immatures** | 92 | 122 | 214 | 161 | 133 | 294 | 36 | 78 | 114 | 9 | 18 | 27 | 5 | 15 | 20 |
| **Number matures** | 7 | 11 | 18 | 176 | 256 | 432 | 481 | 570 | 1051 | 402 | 433 | 835 | 340 | 358 | 698 |
| **% Mature** | 7% | 8% | 8% | 52% | 66% | 60% | 93% | 88% | 90% | 98% | 96% | 97% | 99% | 96% | 97% |
| **Maturity ogive WG** | | | 8% | | | 60% | | | 90% | | | 97% | | | 97% |

| | 1985-1995 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Age 1 | Age 1 | Age 1 | Age 2 | Age 2 | Age 2 | Age 3 | Age 3 | Age 3 | Age 4 | Age 4 | Age 4 | Age 5 | Age 5 | Age 5 |
| **SexÕ** | F | M | F+M | F | M | F+M | F | M | F+M | F | M | F+M | F | M | F+M |
| **Number immatures** | 53 | 58 | 111 | 60 | 40 | 100 | 6 | 1 | 7 | 0 | 1 | 1 | 0 | 1 | 1 |
| **Number matures** | 5 | 7 | 12 | 72 | 53 | 125 | 176 | 203 | 379 | 377 | 419 | 796 | 393 | 354 | 747 |
| **% Mature** | 9% | 11% | 10% | 55% | 57% | 56% | 97% | 100% | 98% | 100% | 100% | 100% | 100% | 100% | 100% |

| | 1977-1995 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Age 1 | Age 1 | Age 1 | Age 2 | Age 2 | Age 2 | Age 3 | Age 3 | Age 3 | Age 4 | Age 4 | Age 4 | Age 5 | Age 5 | Age 5 |
| **SexÕ** | F | M | F+M | F | M | F+M | F | M | F+M | F | M | F+M | F | M | F+M |
| **Number immatures** | 145 | 180 | 325 | 221 | 173 | 394 | 42 | 79 | 121 | 9 | 19 | 28 | 5 | 16 | 21 |
| **Number matures** | 12 | 18 | 30 | 248 | 309 | 557 | 657 | 773 | 1430 | 779 | 852 | 1631 | 733 | 712 | 1445 |
| **% Mature** | 8% | 9% | 8% | 53% | 64% | 59% | 94% | 91% | 92% | 99% | 98% | 98% | 99% | 98% | 99% |

**Note:** During the period 1985-1995 there are relatively less immature fish in the samples, because the fishery mainly took place in the adult area and not in the juvenile areas. The maturity ogive is not that much different over the period 1977-1995. I suggest not to change the maturity ogive. However, the maturity ogive might need to be changed for 1- and 2- year olds based on histological results.

**Table 3.5.2: Prevalence of spawning in two and three year old fish (indicated by the presence of migratory nuclei, post ovulatory follices or hydrated oocytes in the ovaries of rod and line caught fish from 107E (rectangle 29E5) and 107J (rectangle 28D9) classified by the maximum oocyte diameter (100 μm intervals) found in histological section**

| Sample area | Classification based on the maximum diameter oocyte (μm) found in the ovary | Total number of fish within each class | Number of fish spawning | Number of fish with atresia | % mature |
|---|---|---|---|---|---|
| **Two year olds** | | | | | |
| Area 7J | <200 | 11 | 0 | 2 | 23 |
| | 201-300 | 16 | 1 | 11 | |
| | 301-400 | 17 | 0 | 3 | |
| | >401 | 12 | 6 | 1 | |
| Area 7 E | <200 | 9 | 0 | 5 | 0 |
| | 201-300 | 8 | 0 | 6 | |
| | 301-400 | 2 | 0 | 0 | |
| | >401 | 0 | 0 | 0 | |
| **Three year olds** | | | | | |
| Area 7J | <200 | 0 | 0 | 0 | 100 |
| | 201-300 | 0 | 0 | 0 | |
| | 301-400 | 0 | 0 | 0 | |
| | >401 | 11 | 7 | 2 | |
| Area 7E | <200 | 2 | 0 | 0 | 0 |
| | 201-300 | 0 | 0 | 0 | |
| | 301-400 | 0 | 0 | 0 | |
| | >401 | 0 | 0 | 0 | |

**Table 3.6.1 Comparison of estimates of total annual egg production ($\hat{E}_a$) from the GAM method (df=4) without bias correction, and the traditional method. Standard errors are shown in round brackets, %cv's are shown in square brackets**

| Year | $\hat{E}_a$ x $10^{15}$ | | | |
|---|---|---|---|---|
| | Western mackerel | | Horse mackerel | |
| | GAM | traditional method | GAM | traditional method |
| 1995* | 0.841*<br>(0.02)<br>[ 2.6] | 1.487*<br>( 0.17)<br>[11.5] | 0.850*<br>(0.027)<br>[ 3.2] | 1.226*<br>( 0.23)<br>[19.0] |
| 1992 | 1.743* | 1.94 †<br>(0.17)<br>[ 8.8] | 1.390*<br>(0.09)<br>[ 5.4] | 1.58†<br>(0.20)<br>[12.7] |
| 1989 | 1.373* | 1.52# | 1.204* | 1.63# |

* based on integrating within the 1995 survey area.
† based on integrating within the 1992 survey area.
# based on integrating within the 1989 survey area.

**Table 3.6.2 Comparison of estimates of total annual egg production ($\hat{E}_a$) for the bootstrap and *ad hoc* bias-corrected GAM methods, and the traditional method. The %cv's are identical to those in Table 3.6.1 (variance due to estimation of the correction factor is ignored). "Bias-corrected" is abbreviated to "bc"**

| Year | $\hat{E}_a$ x $10^{15}$ | | | | | |
|---|---|---|---|---|---|---|
| | Mackerel | | | Horse Mackerel | | |
| | GAM bootstrap bc | GAM *ad hoc* bc | traditional method | GAM bootstrap bc | GAM *ad hoc* bc | traditional method |
| 1995* | 0.950* | 1.393* | 1.487* | 1.202* | 1.246* | 1.226* |
| 1992 | | 2.088* | 1.94† | 1.650* | 1.591* | 1.580† |
| 1989 | | 1.952* | 1.52# | | 1.470* | 1.63# |

* based on integrating within the 1995 survey area.
† based on integrating within the 1992 survey area.
# based on integrating within the 1989 survey area.

| Table 3.6.3 Comparison of the features of the traditional method with the GAM method for AEPM assessment | | |
|---|---|---|
| **Issue** | **Traditional method** | **GAM method** |
| Model assumptions and selection | Models egg density as a step function of survey square position alone. | Able to choose appropriate link function on the basis of the data. Able to model egg density as a function of many explanatory variables. |
| | Relatively weak assumptions about error distribution (independence within and across survey squares; constant cv across squares). | Able to choose appropriate error distribution. Assumes independence. Conditions more heavily on error distribution in estimating variance. |
| | Strong prior assumption about the (linear) form of the egg production curve. | Weak prior assumptions about the form of the egg production curve. Able to select appropriate form. |
| | Model selection is trivial. | Model selection is non-trivial and requires statistical expertise. |
| Survey strategy | Method is less sensitive to confounding of sampling in space and time within a single period. | Requires sampling to span spawning area adequately throughout spawning period. Modelling is sensitive to confounding of sampling in space and time. |
| | Important to determine the boundaries of the spawning area. Extrapolation from sampled area to boundaries can introduce bias. All extrapolation is essentially *ad hoc*. | Important to determine the boundaries of the spawning area. Extrapolation can result in large bias if model is not constrained at the boundaries. Can use information on boundaries from other sources together with GAM to give a consistent, objective means of extrapolating. |
| Variance estimation | Limited models available for error distribution. | Wide variety of models available for error distribution. |
| | Variance arising from estimation of the shape of the egg production curve is neglected. | Incorporates the variance due to estimating the shape of the egg production curve. |
| | Correlated residuals lead to biased variance estimation unless sampling is random. | If the GAM does not succeed in modelling the correlation in residuals, variance estimates will be biased. |
| Insight provided into biological issues | Only very substantial changes in distribution with time are visible, and only between a few time points. | Method provides detailed information on the spatio-temporal distribution of eggs throughout the spawning season. |
| | No insight provided into non-spatial determinants of egg distribution. | The selected explanatory terms and interactions give insight into the underlying processes governing egg distribution. |

| Table 3.6.3 Comparison of the features of the traditional method with the GAM method for AEPM assessment | | |
|---|---|---|
| **Issue** | **Traditional method** | **GAM method** |
| Bias | The *ad hoc* extrapolation can lead to substantial bias. | With reasonable outer bounds for the spawning area, the method provides a consistent method for extrapolation. |
| | The piecewise linear approximation to the egg production curve can lead to substantial bias. | GAM method is able to model the shape of the egg production curve with little or no bias. |
| | Substantially non-uniform sampling time within a survey period results in biased egg production estimates for the period. | Robust to non-uniform sampling in time, provided there is sufficient wide spatial coverage throughout the spawning period. |
| | With appropriate sampling design and analysis, no bias correction to the point estimates of egg production is necessary. | GAM estimates are inherently biased, but the bootstrap bias-correction method appears to show promise. Little work has been done to address the problem of bias in GAM estimates to date. |
| | Sensitive to start and finish dates assumed for spawning. | Relatively insensitive to start and finish dates assumed for spawning. |

**Figure 3.1.a.** Comparison between institutes when allocating a sample of Mackerel eggs to six development stages.

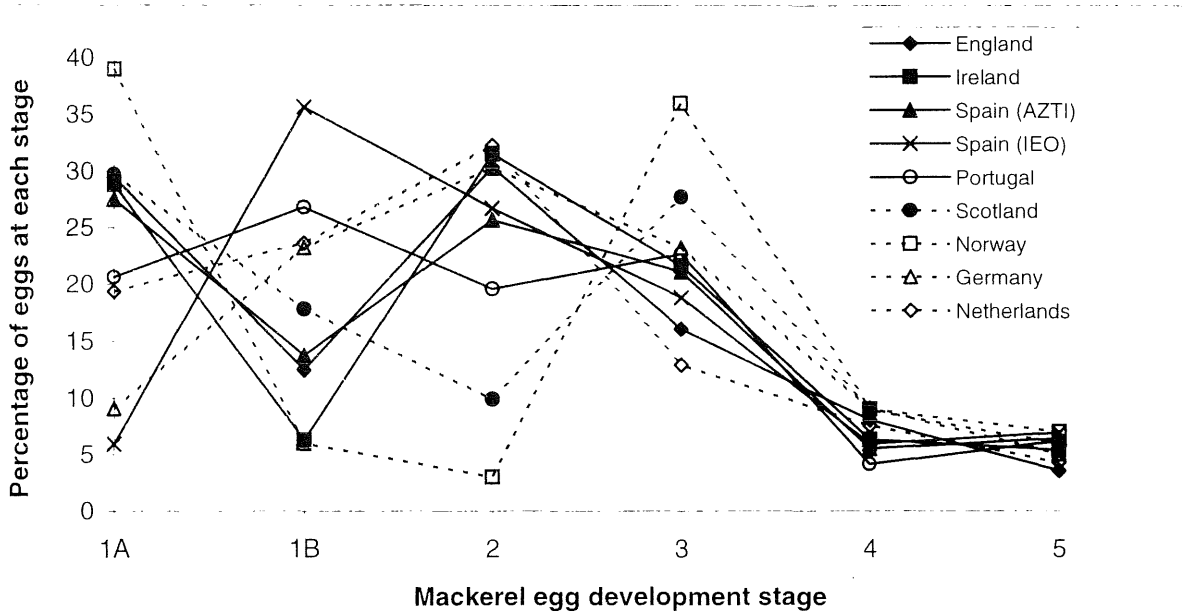



**Figure 3.1.b.** Comparison between institutes when allocating a sample of Mackerel eggs into four development stages.

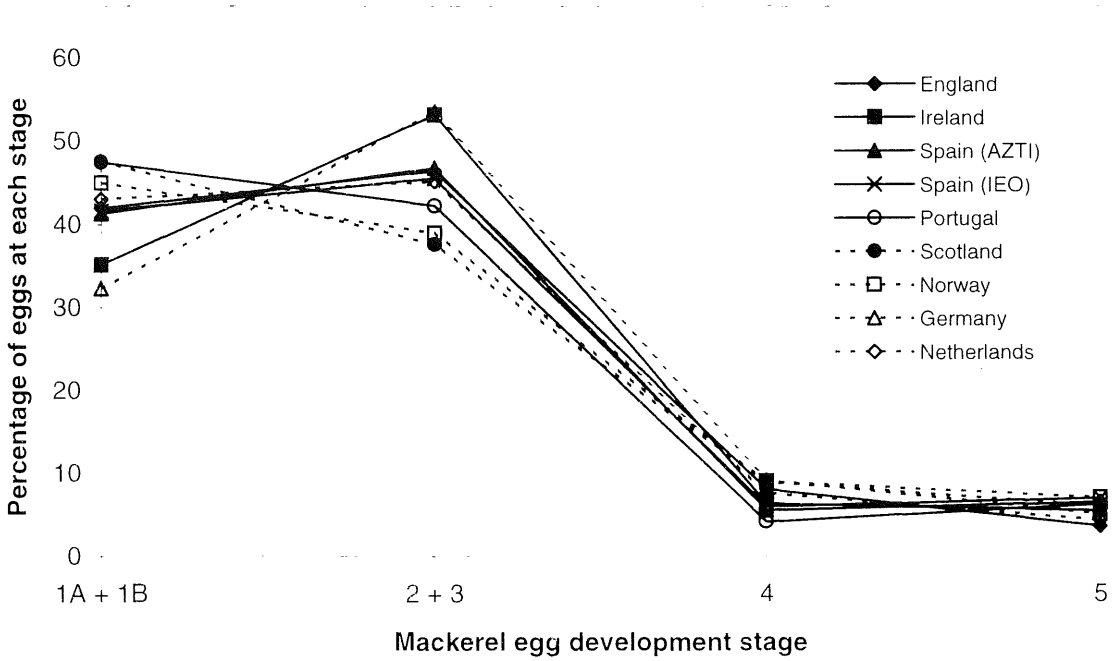


**Figure 3.3a** Period 1

Mackerel Nos/sq m/day by rectangle from 120295 to 060395

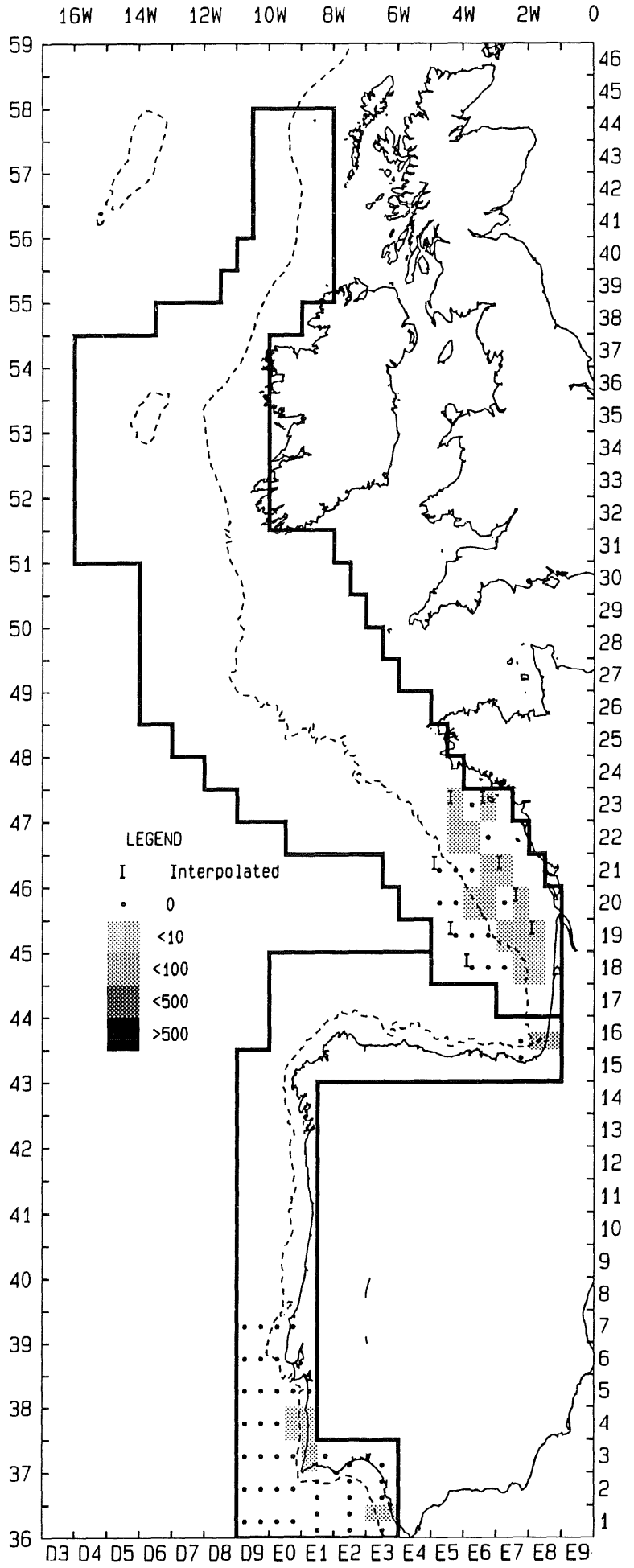


**Figure 3.3b** Period 2

Mackerel Nos/sq m/day by rectangle from 140395 to 240395

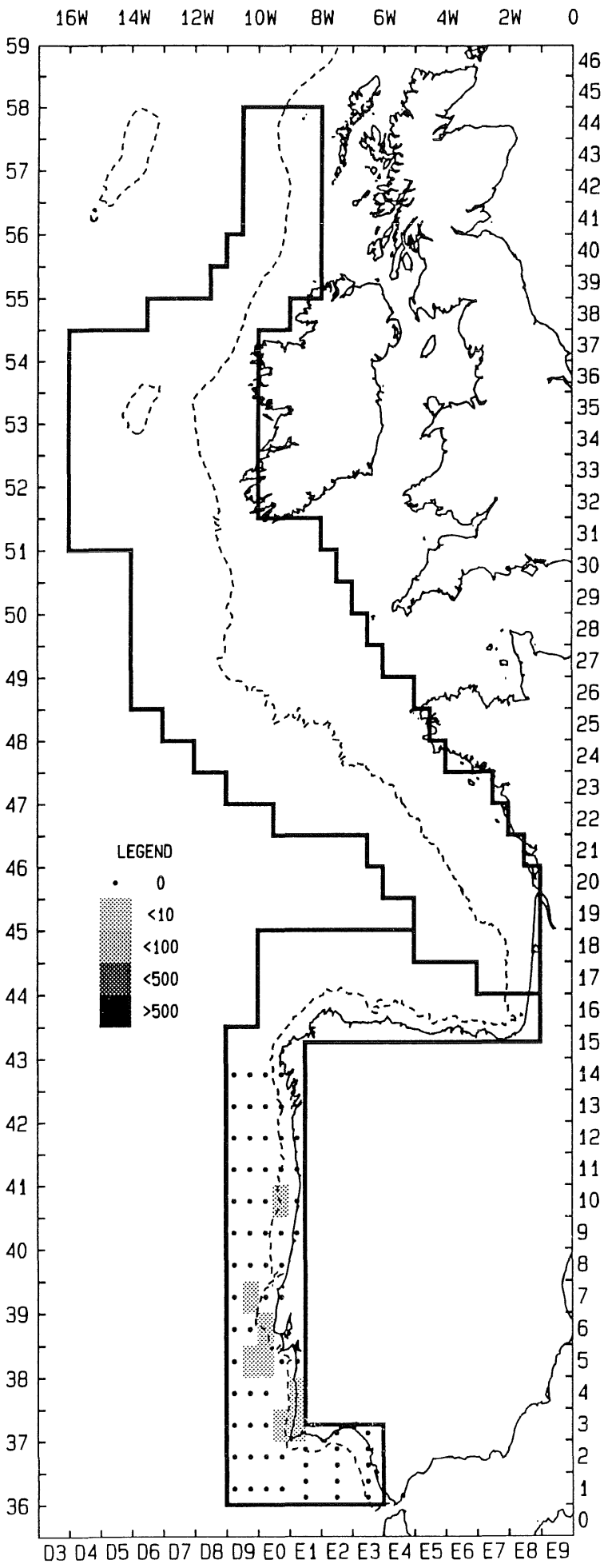


**Figure 3.3c** Period 3

Mackerel Nos/sq m/day by rectangle from 230395 to 150495

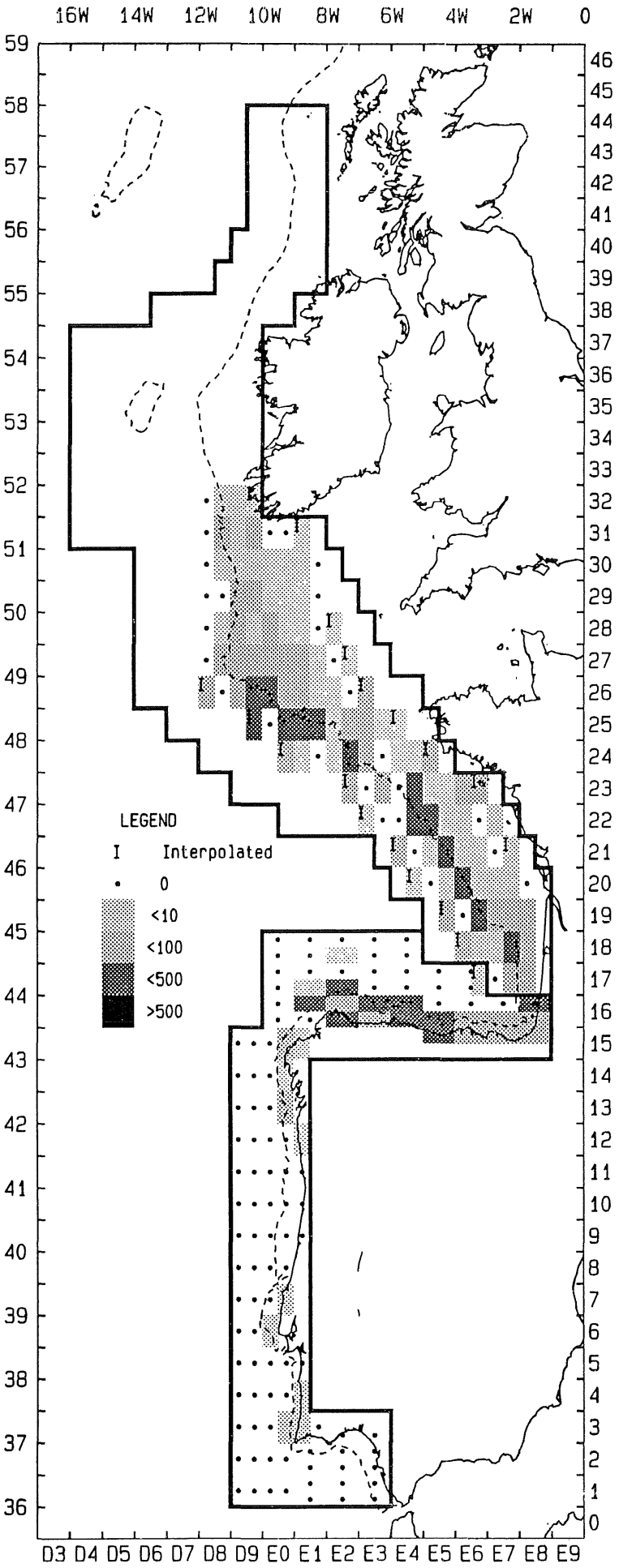


**Figure 3.3d** Period 4

Mackerel Nos/sq m/day by rectangle from 220495 to 180595

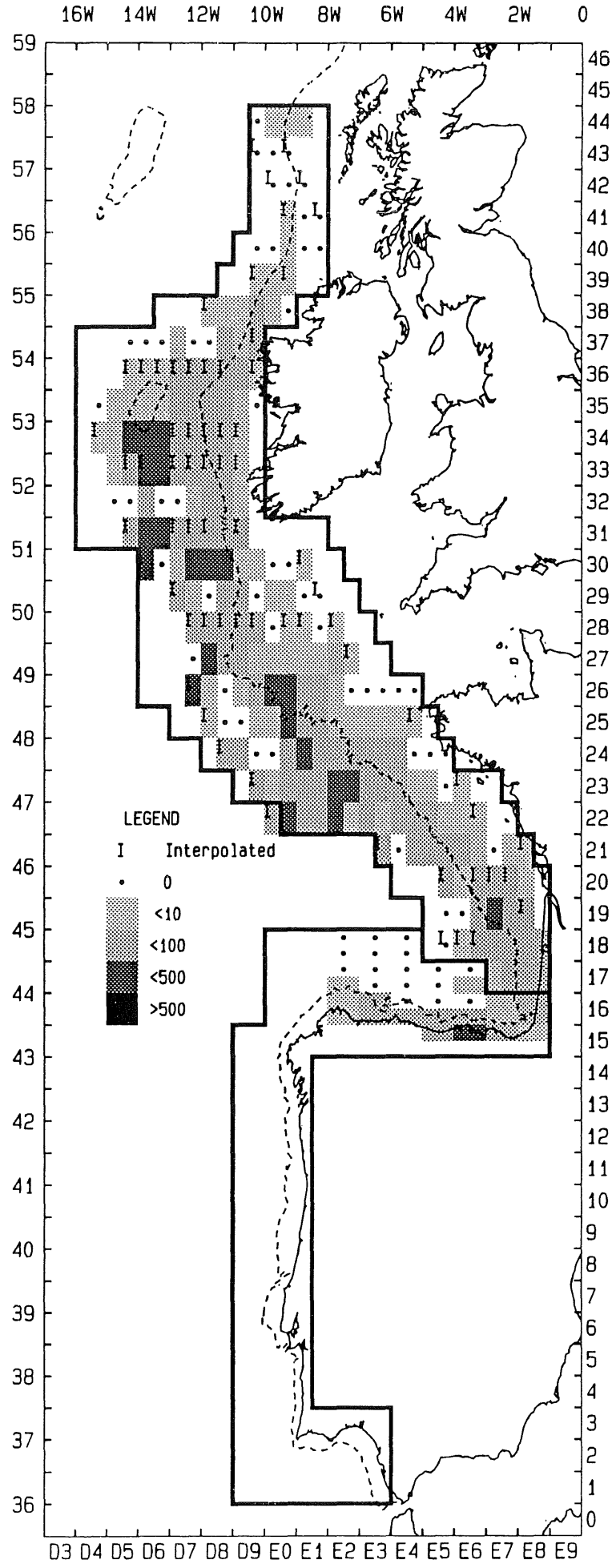


**Figure 3.3e** Period 5

Mackerel Nos/sq m/day by rectangle from 170595 to 200695

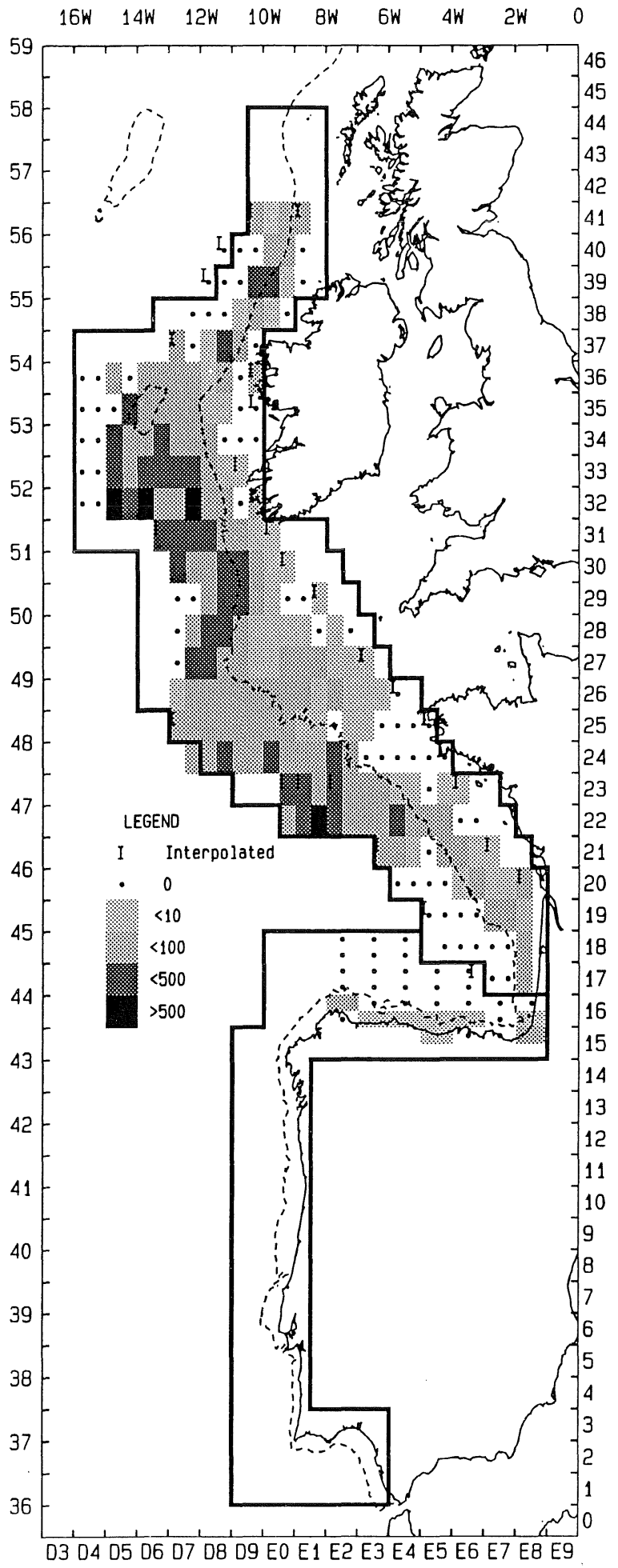


**Figure 3.3f** Period 6

Mackerel Nos/sq m/day by rectangle from 070695 to 020795

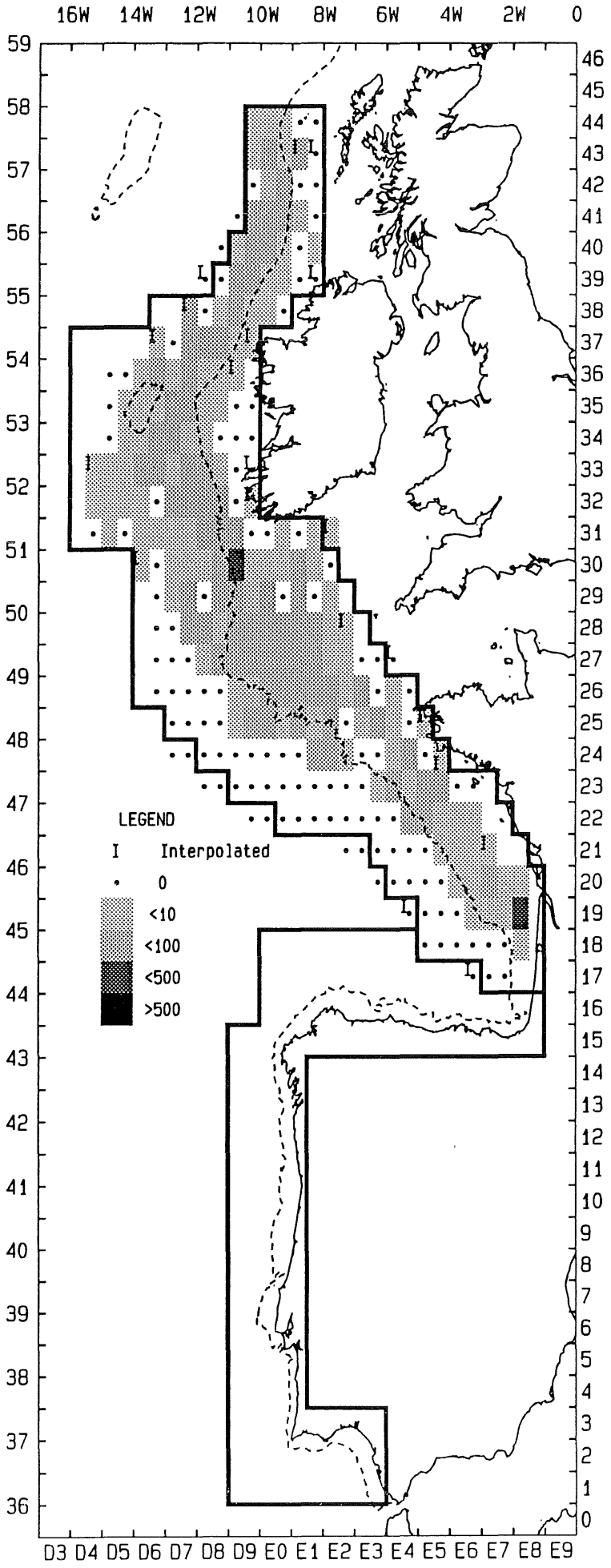


**Figure 3.3g** Period 7

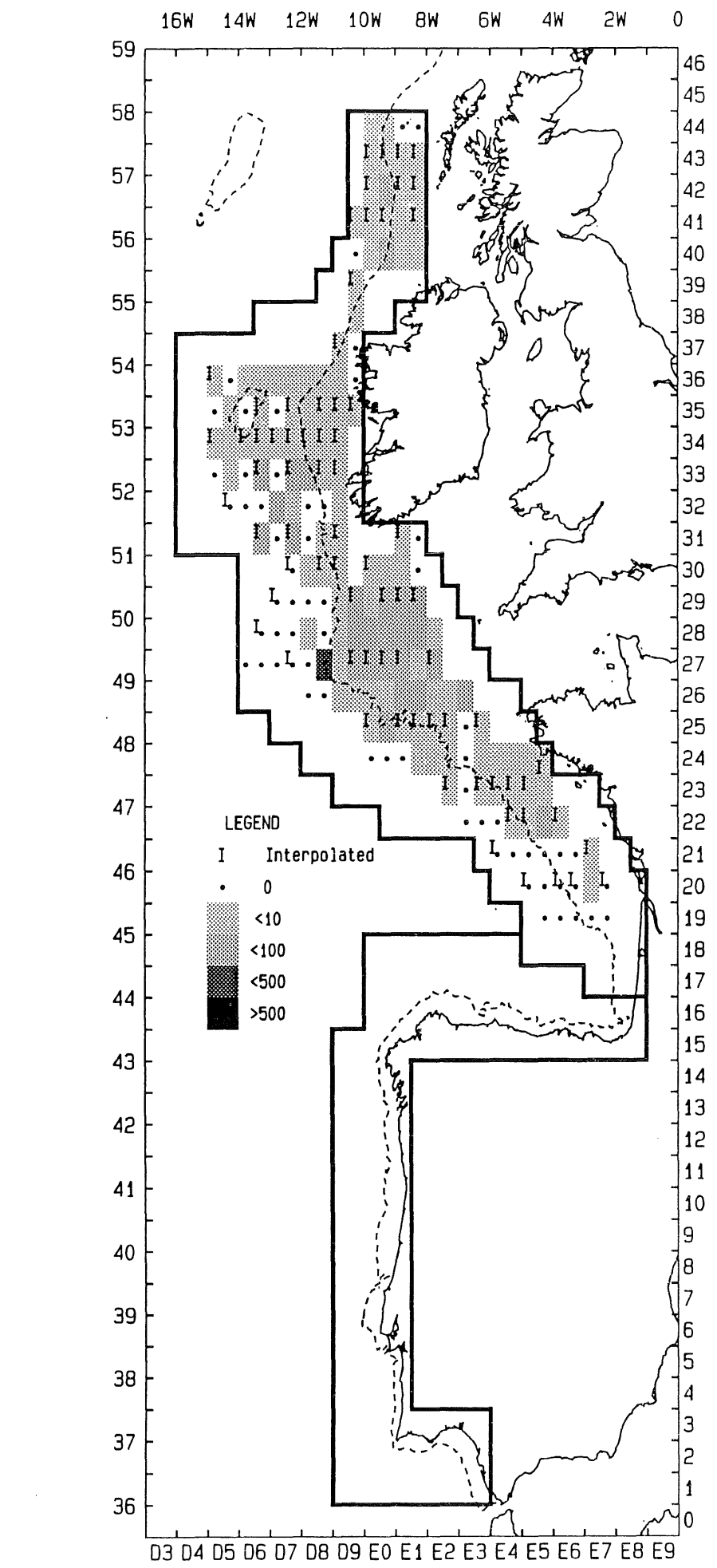


**Figure 3.3h** Period 1

Horse Mackerel Nos/sq m/day by rectangle from 120295 to 060395

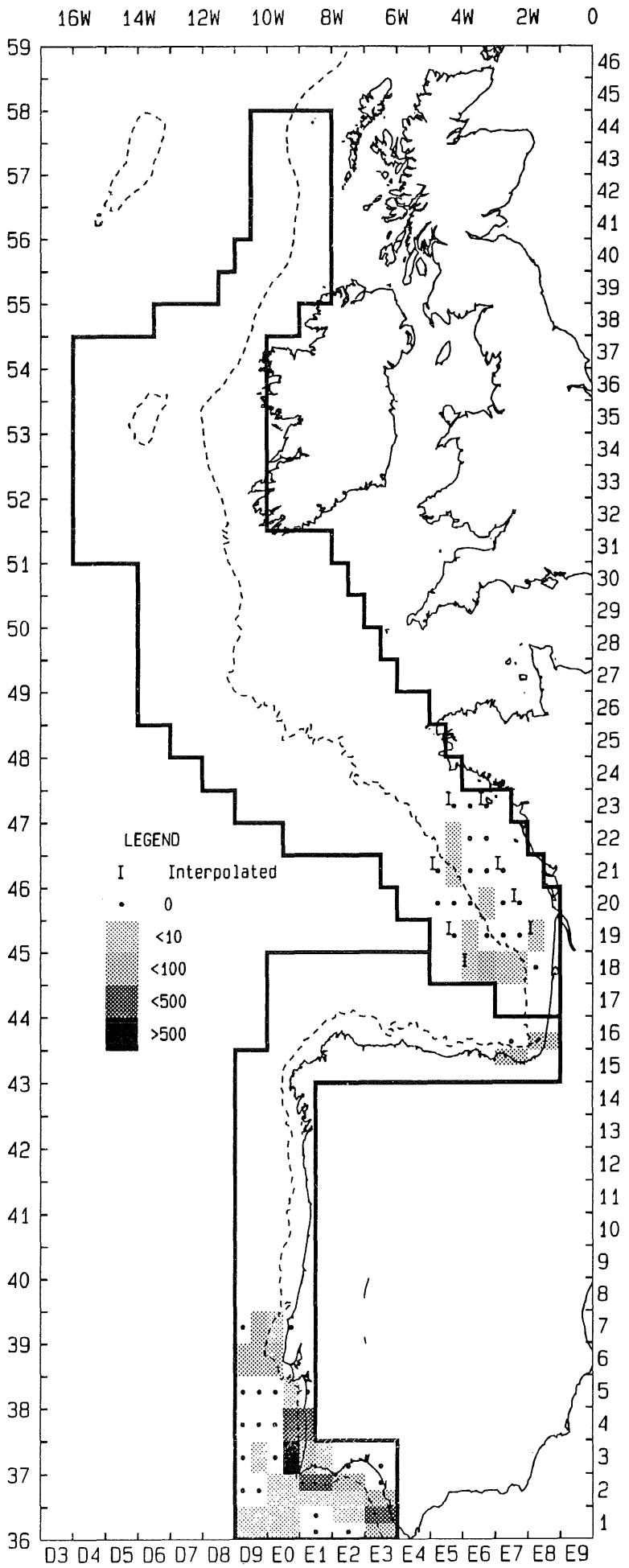


**Figure 3.3i** Period 2

Horse Mackerel Nos/sq m/day by rectangle from 140395 to 240395

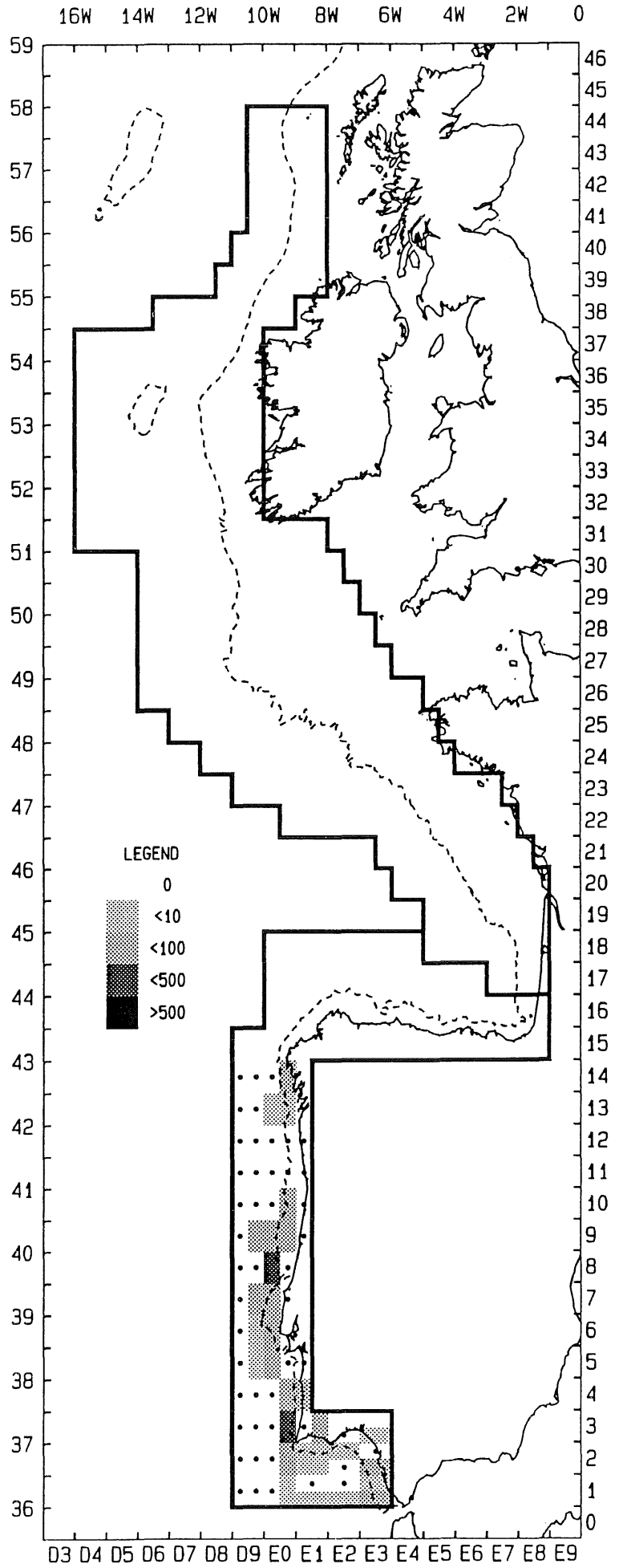


**Figure 3.3j** Period 3

Horse Mackerel Nos/sq m/day by rectangle from 230395 to 150495

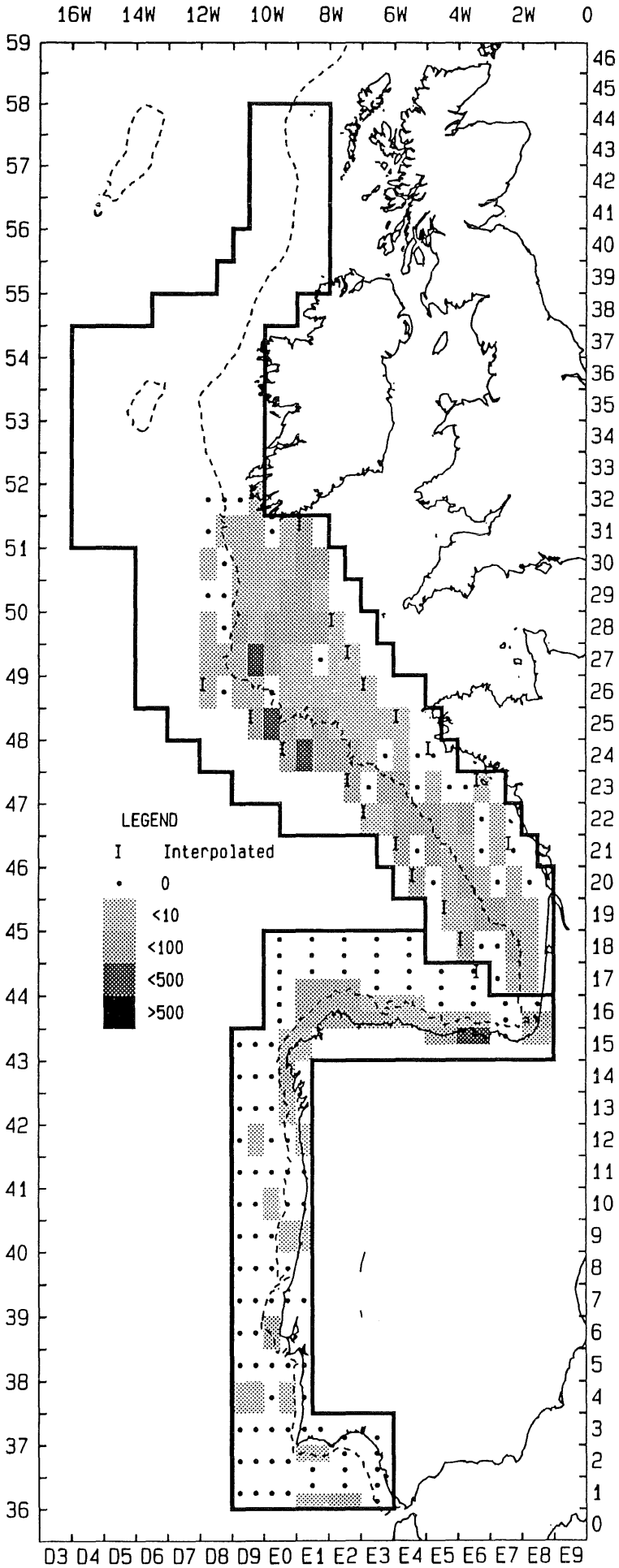


**Figure 3.3k** Period 4

Horse Mackerel Nos/sq m/day by rectangle from 220495 to 180595

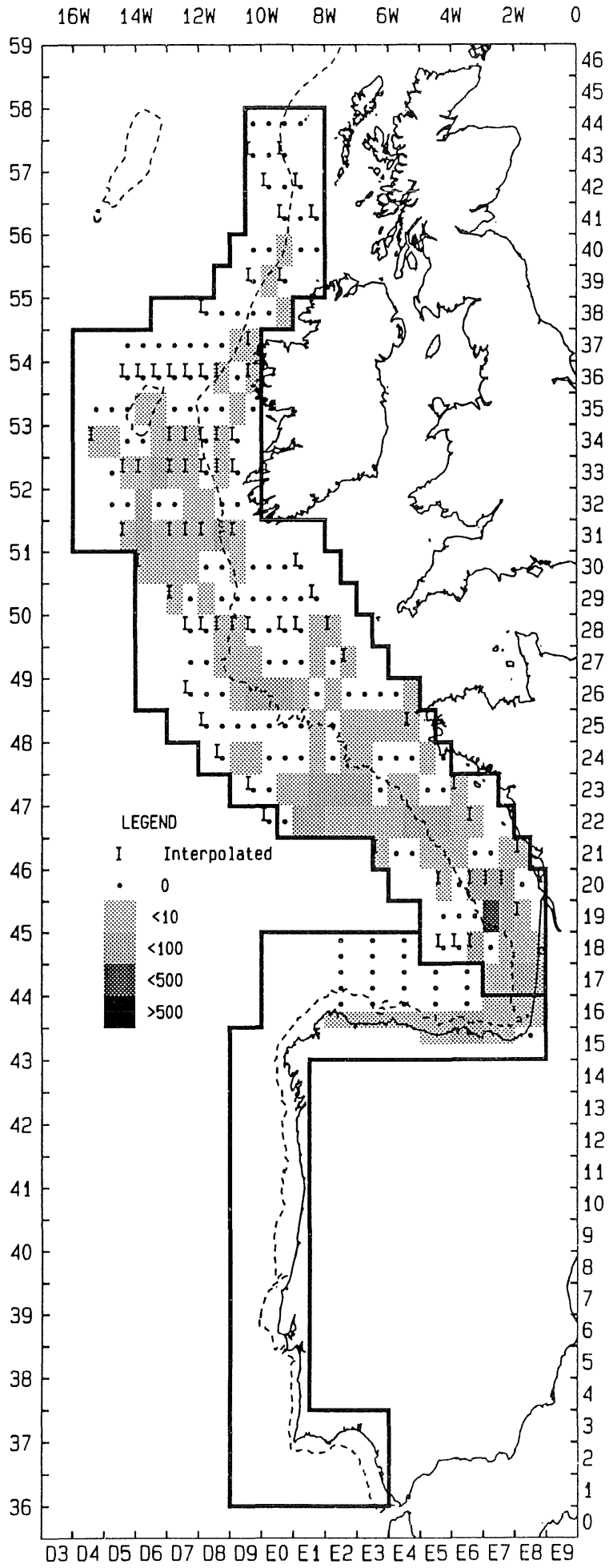


**Figure 3.31** Period 5

Horse Mackerel Nos/sq m/day by rectangle from 170595 to 080695

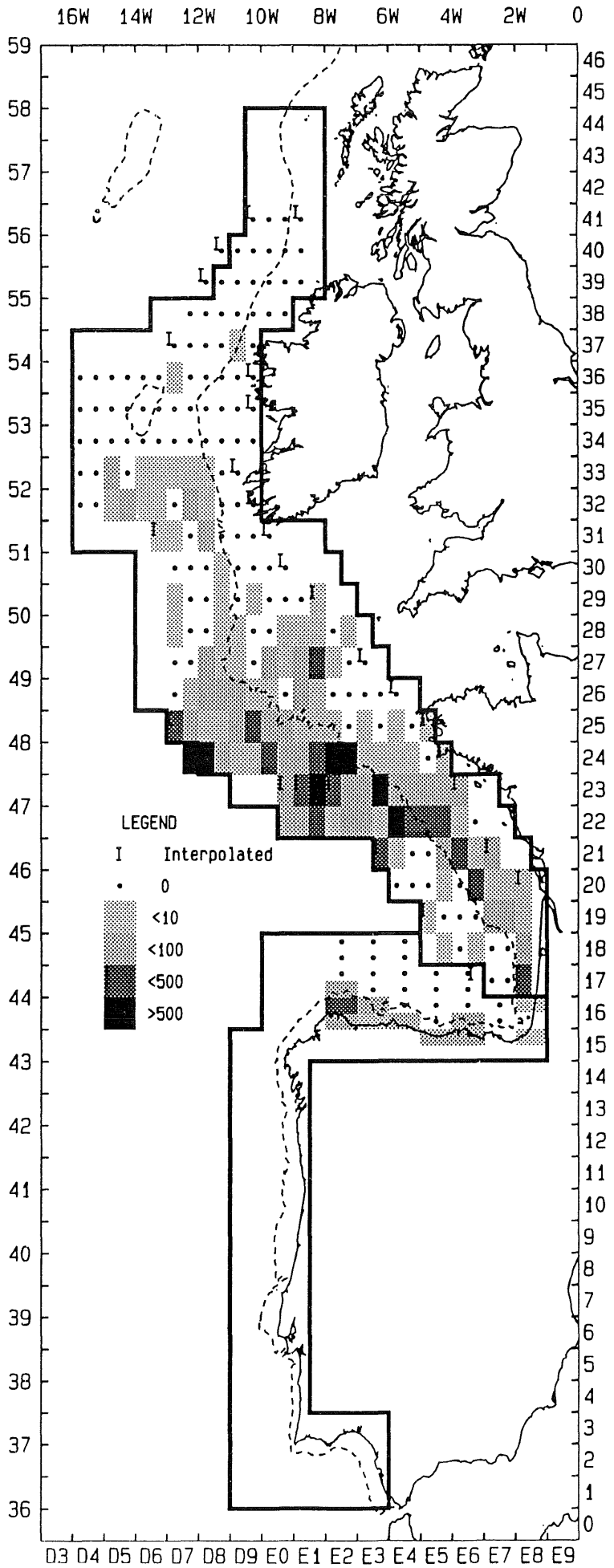


**Figure 3.3m** Period 6

Horse Mackerel Nos/sq m/day by rectangle from 070695 to 020795

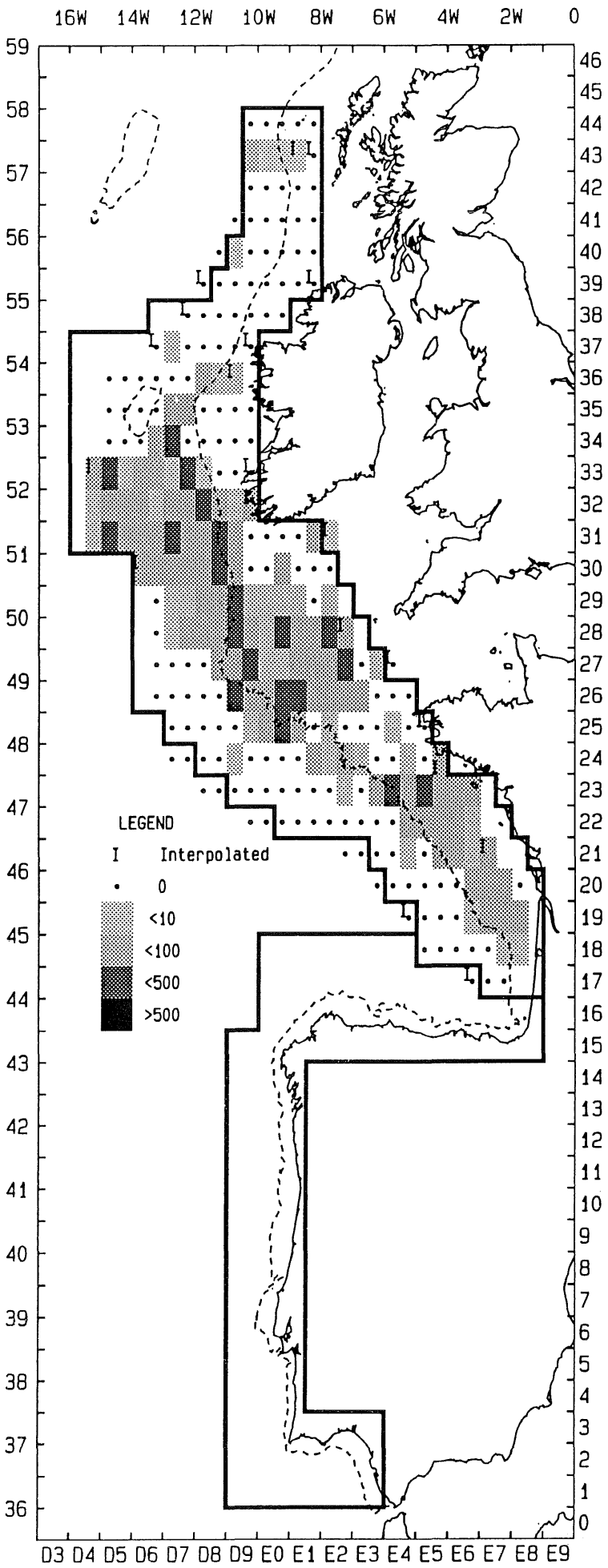


**Figure 3.3n** Period 7

Horse Mackerel Nos/sq m/day by rectangle from 270695 to 160795

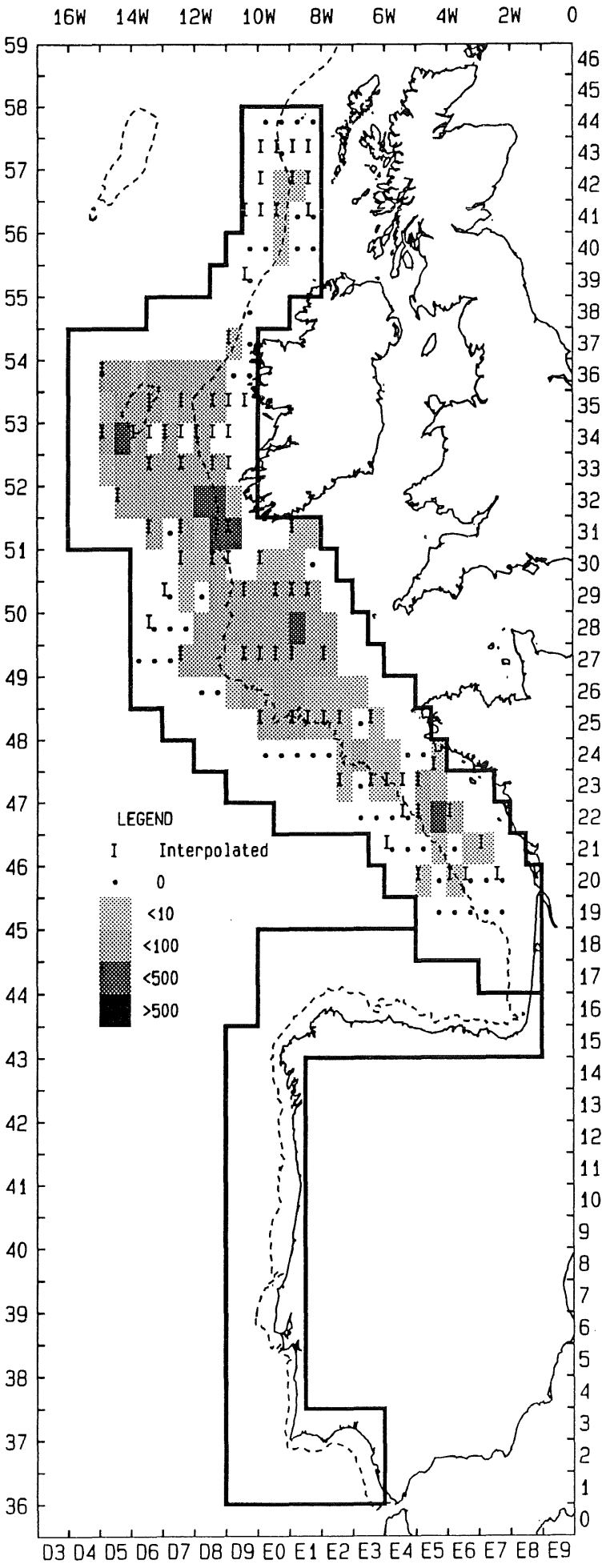


**Figure 3.5.1**

Maximum oocyte diameter found in ovary sections from fish caught by rod and line in relation to fish length and sample area during 1989.

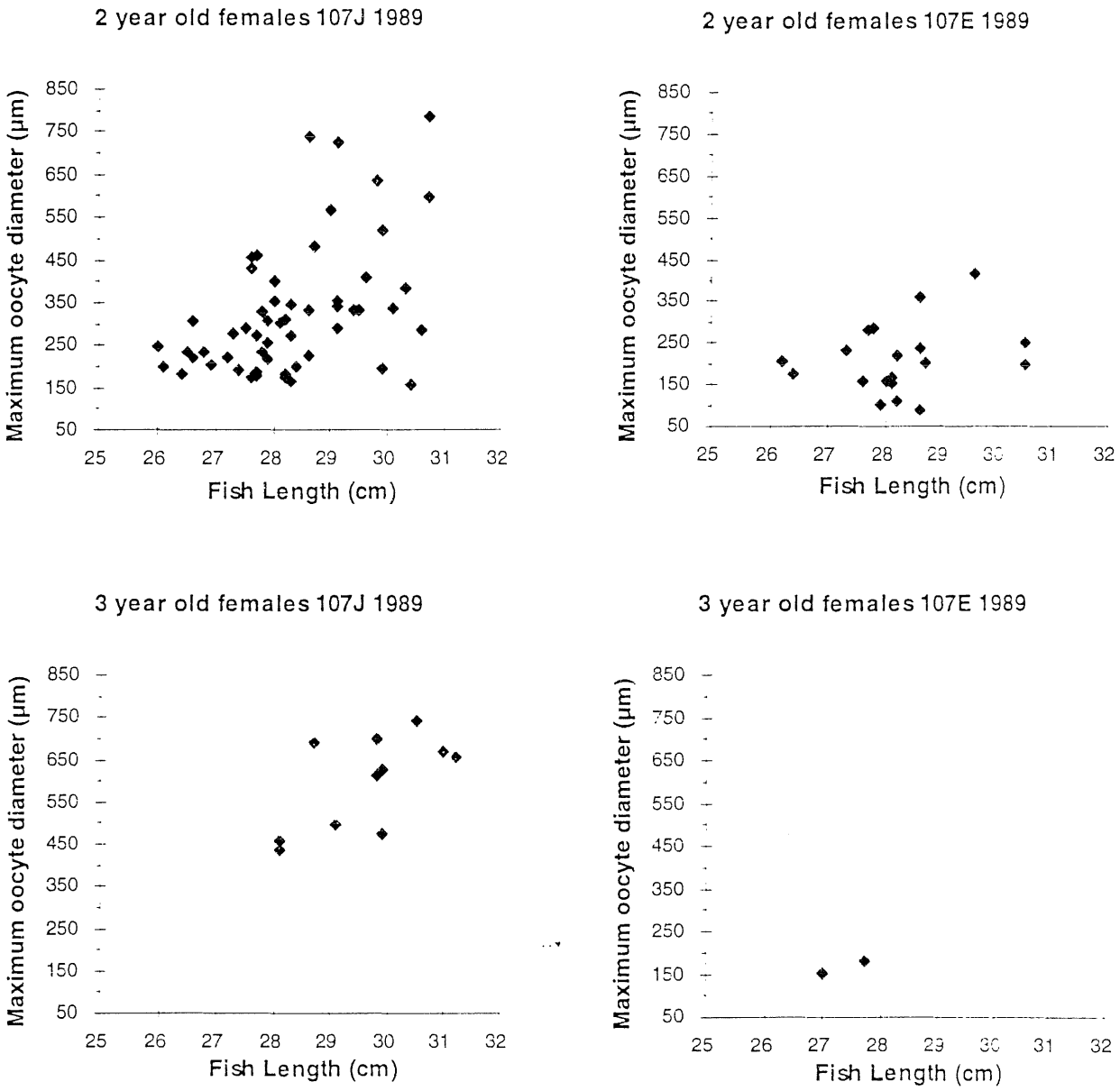


**Figure 3.6.1a:** Assumed outer limits of spawning for western mackerel

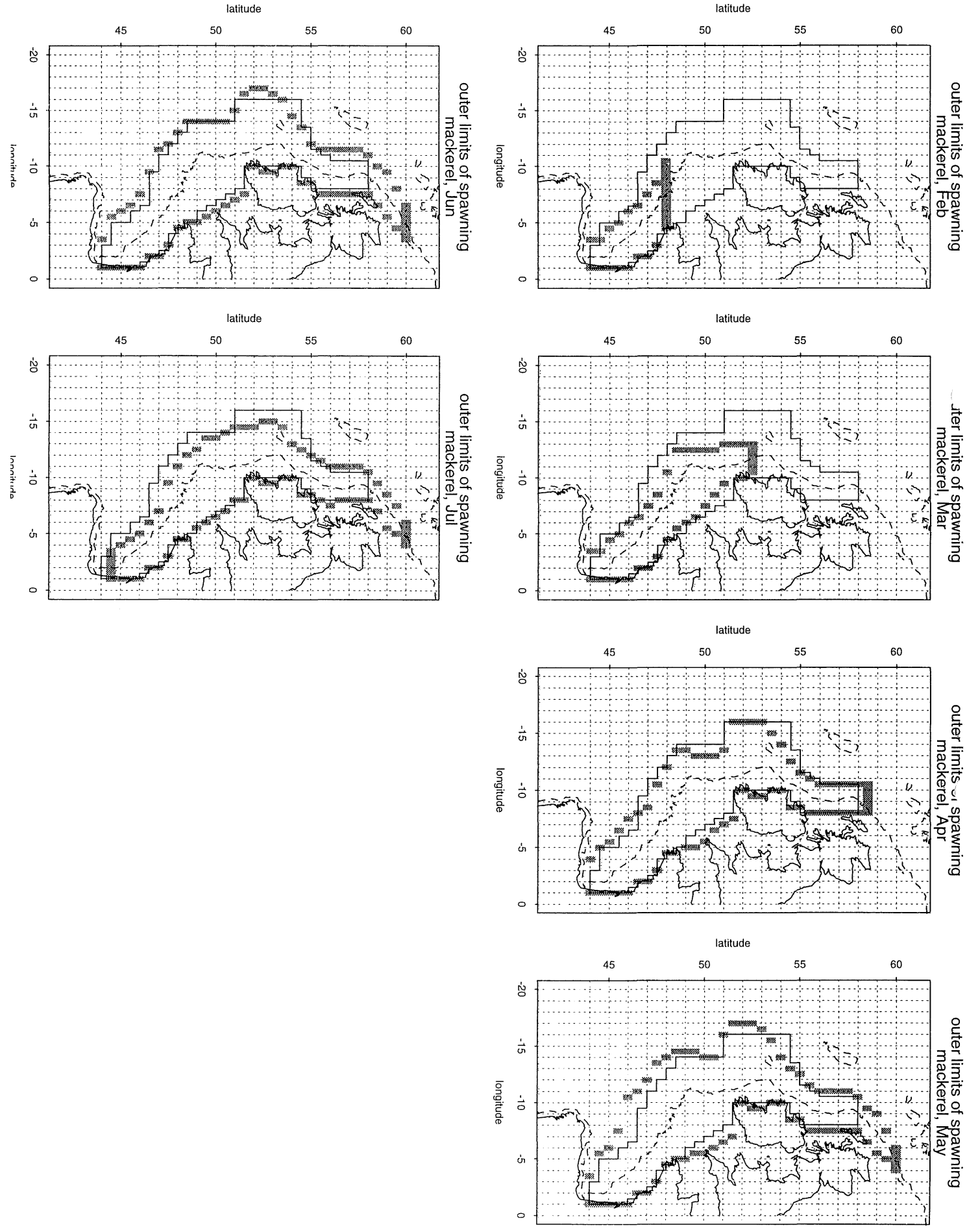


**Figure 3.6.1b:** Assumed outer limits of spawning for western horse mackerel

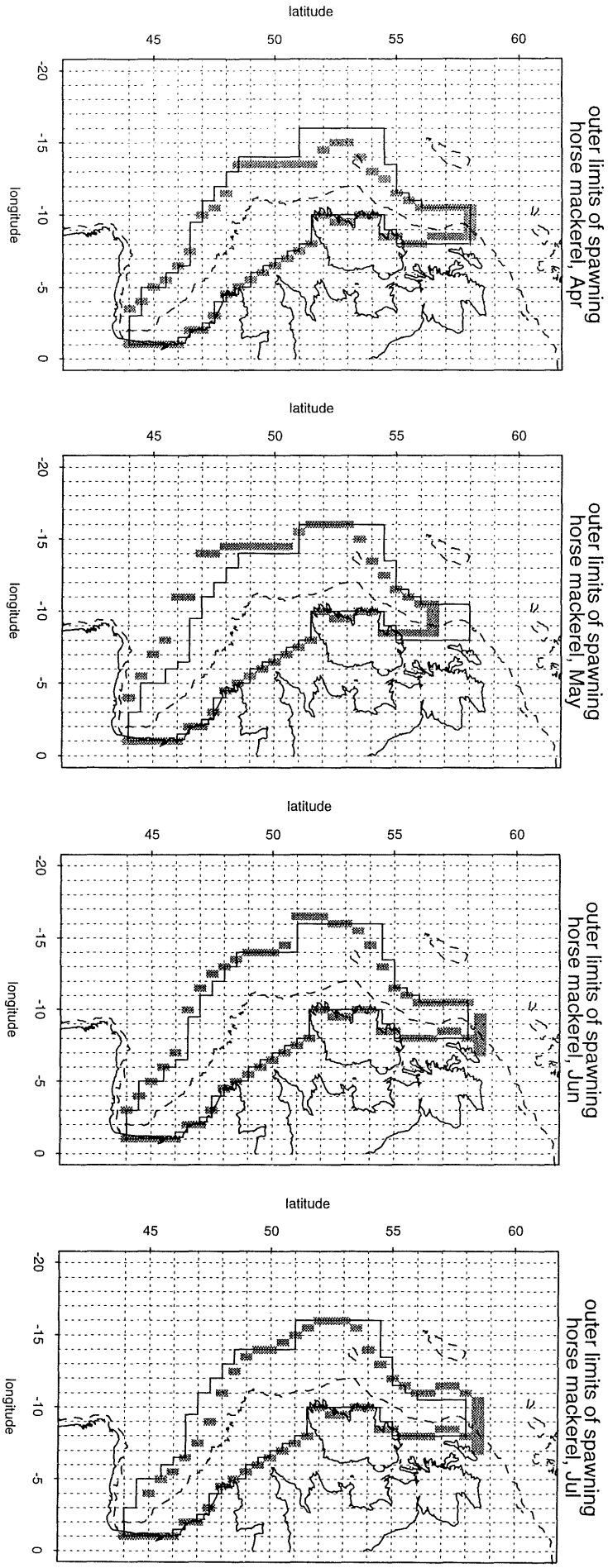


**Figure 3.6.2a:** Locations of egg samples taken during the 1995 mackerel/horse mackerel egg survey. Samples are shown summarised in 20 day intervals. Day 1 is 1 January.

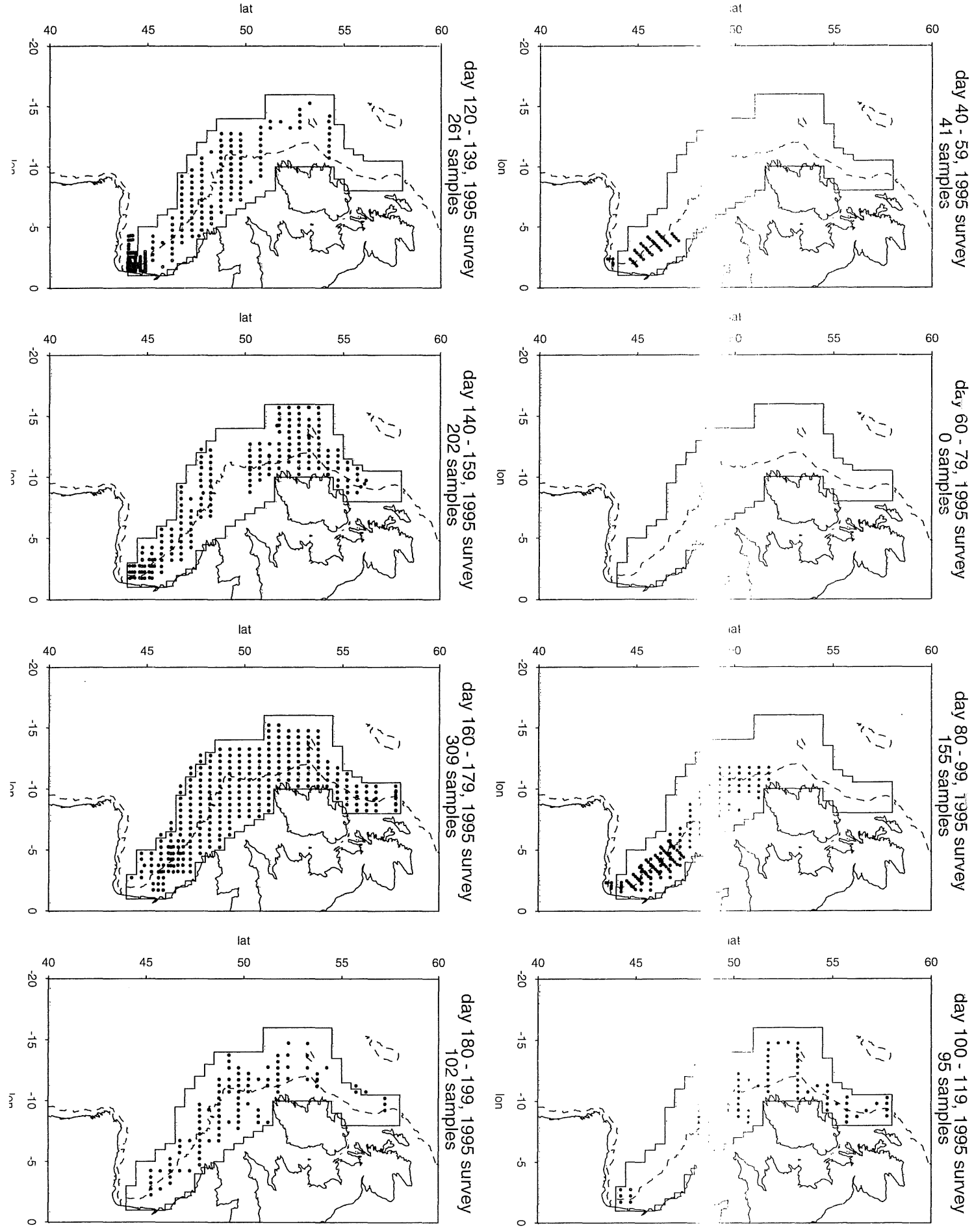


**Figure 3.6.2b:** Locations of egg samples taken during the 1992 mackerel/horse mackerel egg survey. Samples are shown summarised in 20 day intervals. Day 1 is 1 January.

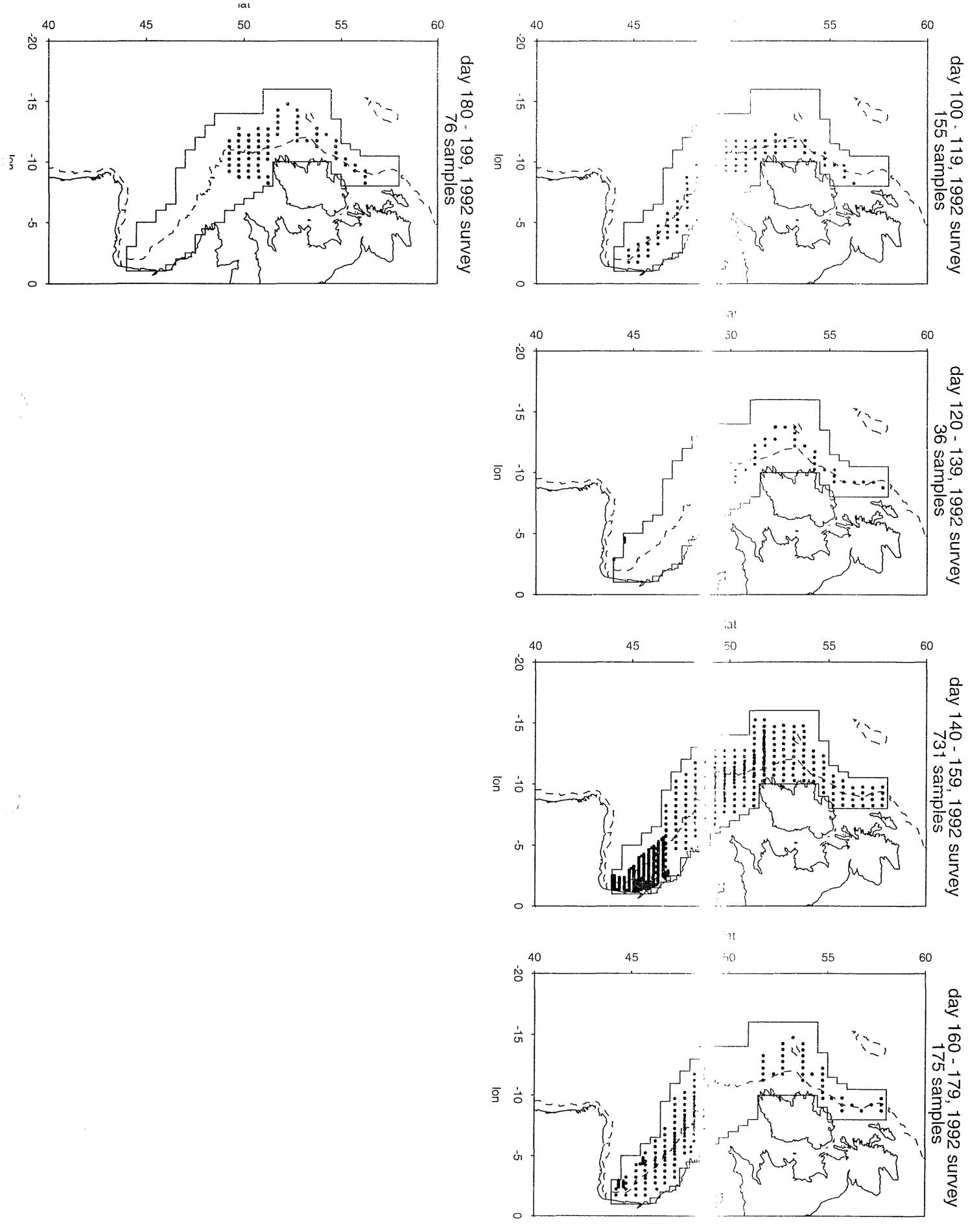


**Figure 3.6.2c:** Locations of egg samples taken during the 1989 mackerel/horse mackerel egg survey. Samples are shown summarised in 20 day intervals. Day 1 is 1 January.

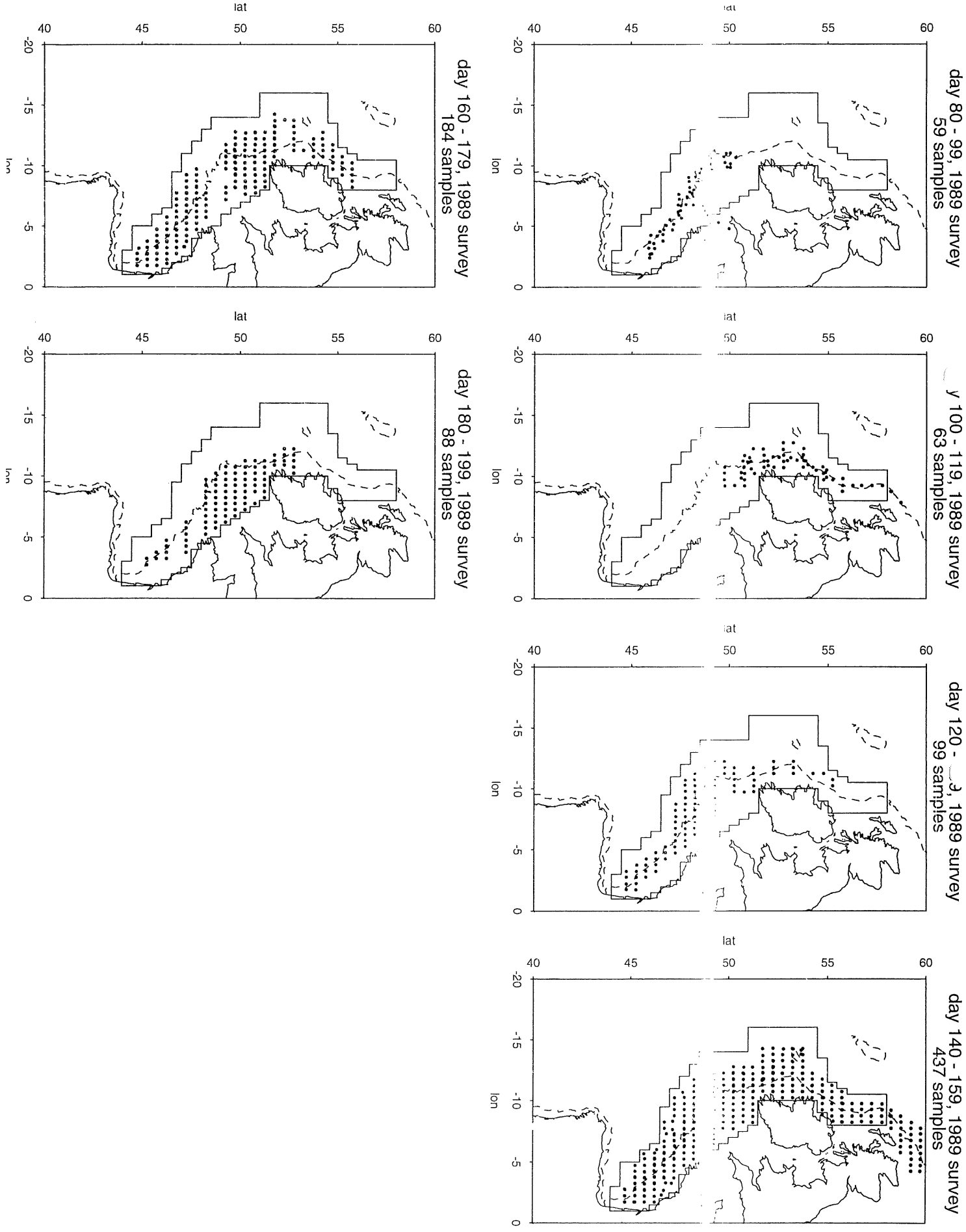


**Figure 3.6.2d:** 1995 survey: Observed mackerel egg densities (eggs per $m^2$) averaged within each half-degree block in the survey area. Unshaded half-degree blocks were not sampled.

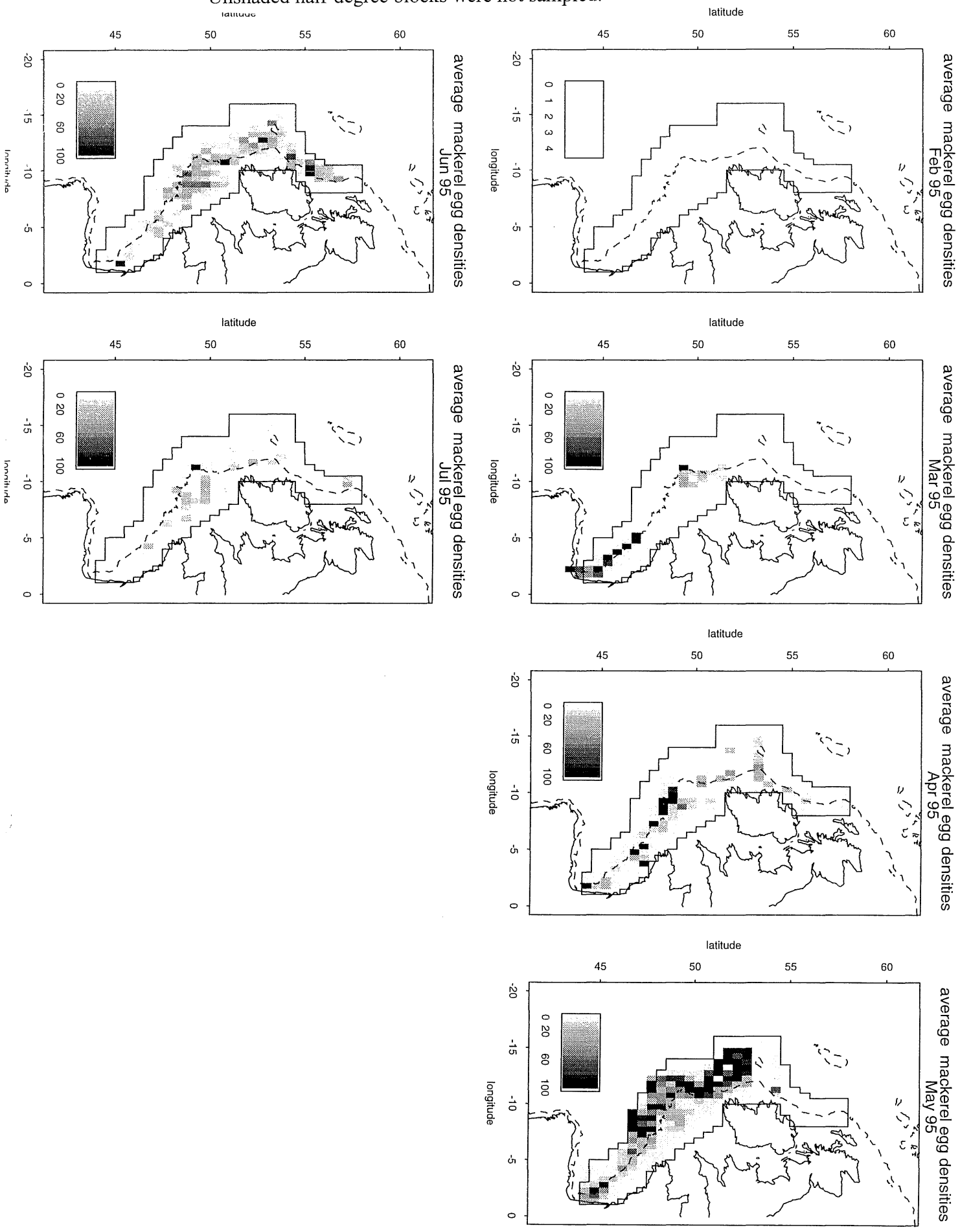


**Figure 3.6.2e:** 1992 survey: Observed mackerel egg densities (eggs per $m^2$) averaged within each half-degree block in the survey area. Unshaded half-degree blocks were not sampled.

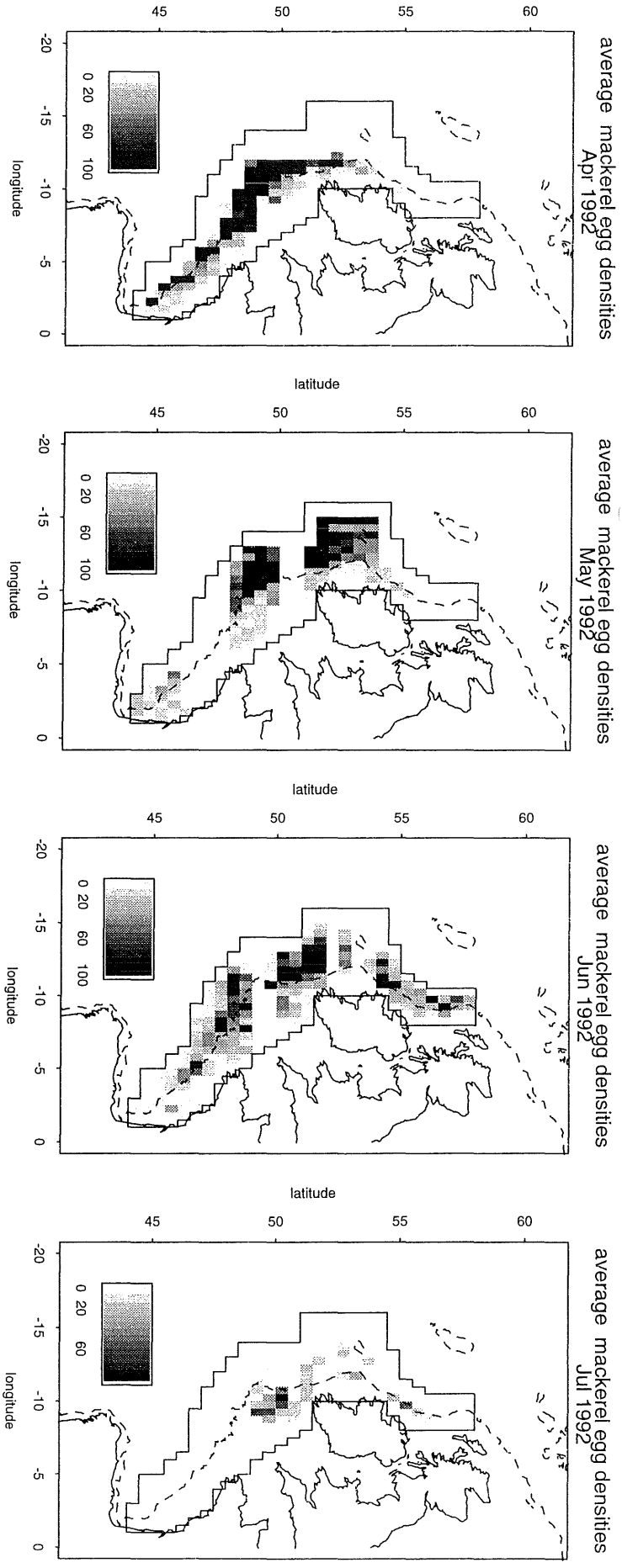


**Figure 3.6.2f:** 1989 survey: Observed mackerel egg densities (eggs per $m^2$) averaged within each half-degree block in the survey area. Unshaded half-degree blocks were not sampled.

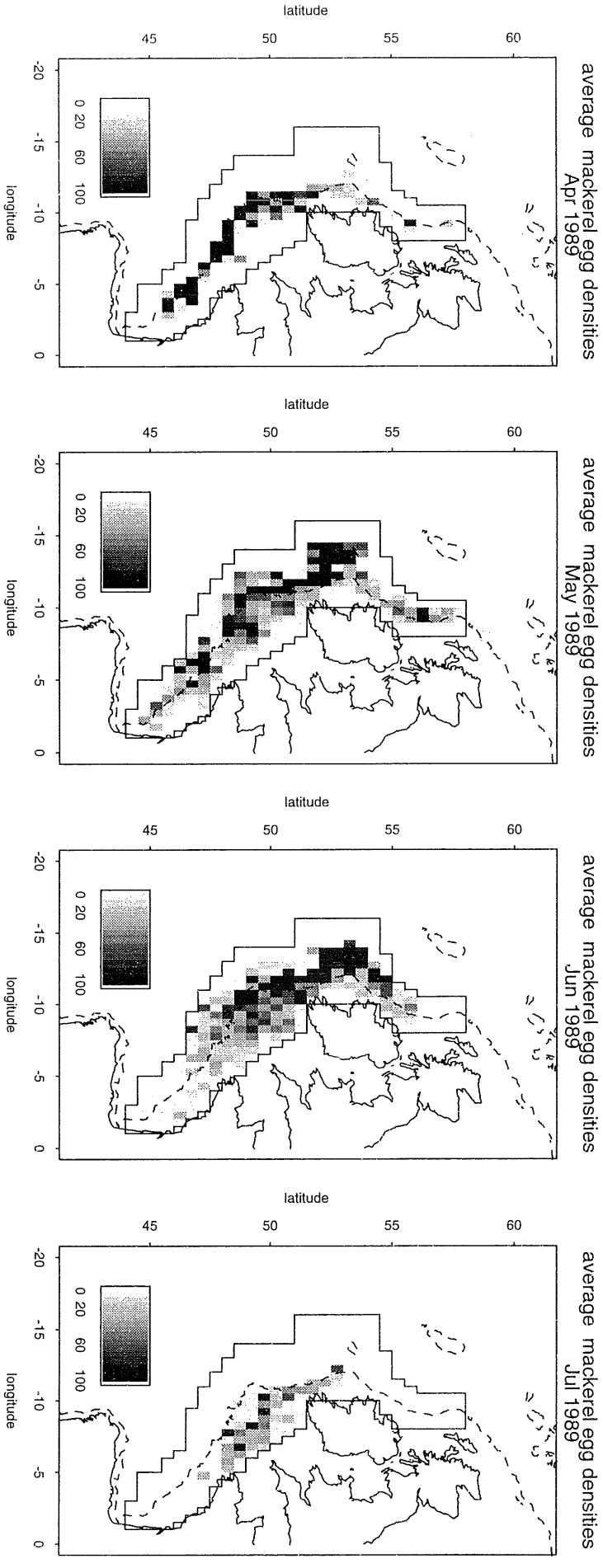


**Figure 3.6.2g:** 1995 survey: Spatial distribution of estimated mackerel egg density (eggs per $m^2$) at selected dates: **60**:1.3.95, **80**: 20.3.95, **100**:10.4.95, **120**:30.4.95, **140**: 20.5.95, **160**: 9.6.95, **180**: 29.6.95, **200**: 19.7.95. Egg densities greater or equal to 100 are shown with the same level of shading. The 200 m contour line is shown as a dotted line.

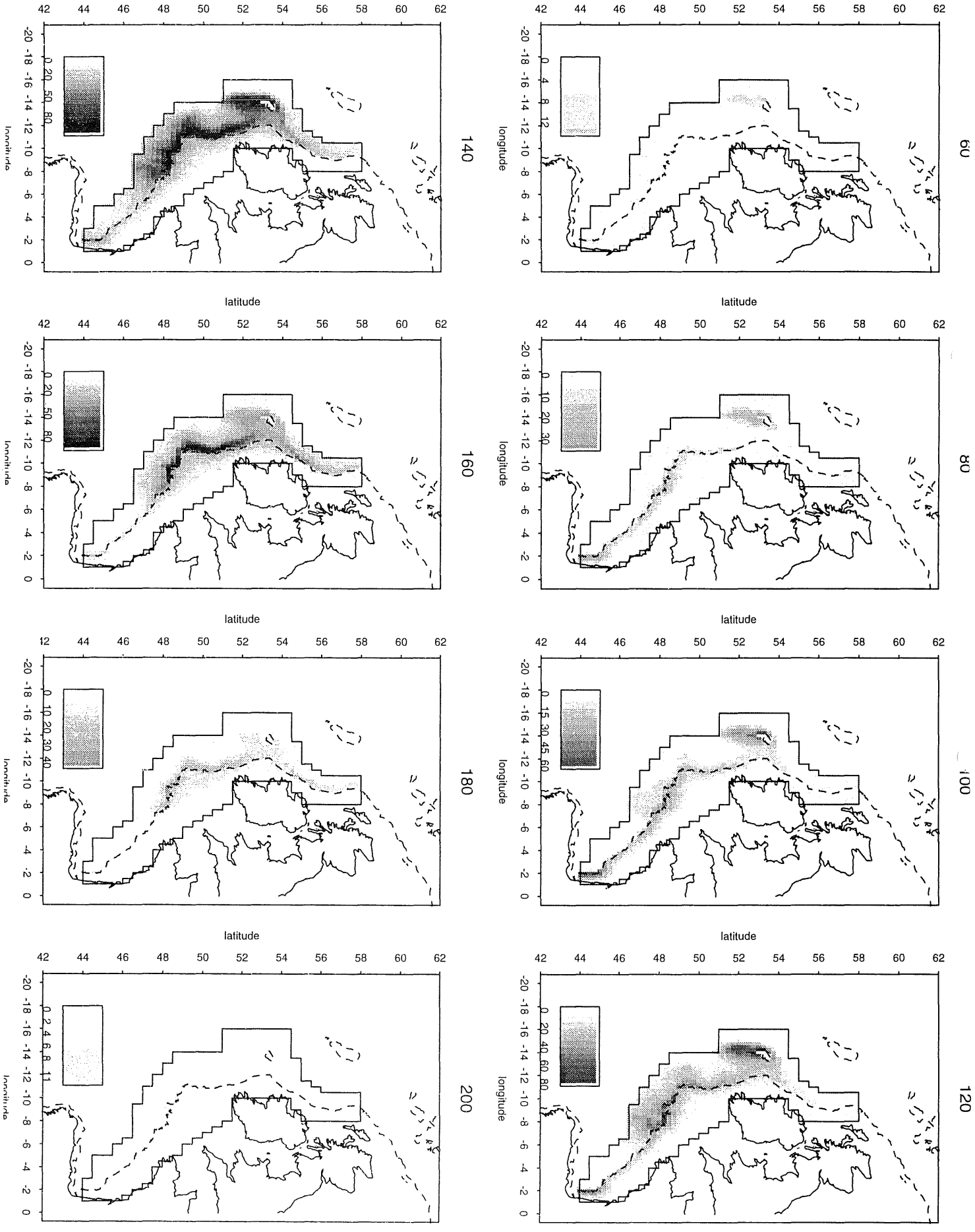


**Figure 3.6.2h:** 1992 survey: Spatial distribution of estimated mackerel egg density (eggs per $m^2$) at selected dates: **60**:1.3.95, **80**: 20.3.95, **100**:10.4.95, **120**:30.4.95, **140**: 20.5.95, **160**: 9.6.95, **180**: 29.6.95, **200**: 19.7.95. Egg densities greater or equal to 100 are shown with the same level of shading. The 200 m contour line is shown as a dotted line.

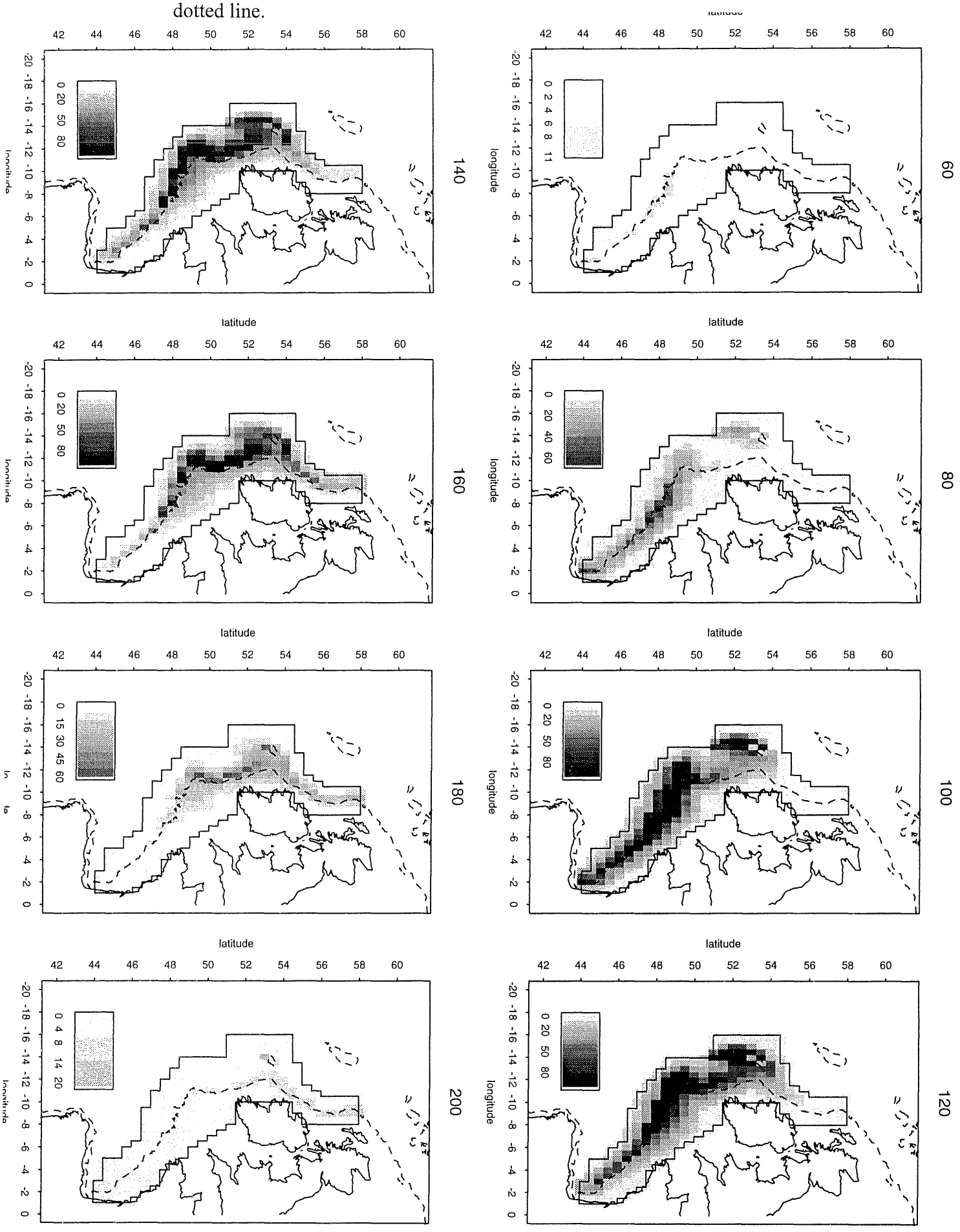


**Figure 3.6.2j:** 1989 survey: Spatial distribution of estimated mackerel egg density (eggs per $m^2$) at selected dates: **60**:1.3.95, **80**: 20.3.95, **100**:10.4.95, **120**:30.4.95, **140**: 20.5.95, **160**: 9.6.95, **180**: 29.6.95, **200**: 19.7.95. Egg densities greater or equal to 100 are shown with the same level of shading. The 200 m contour line is shown as a dotted line.

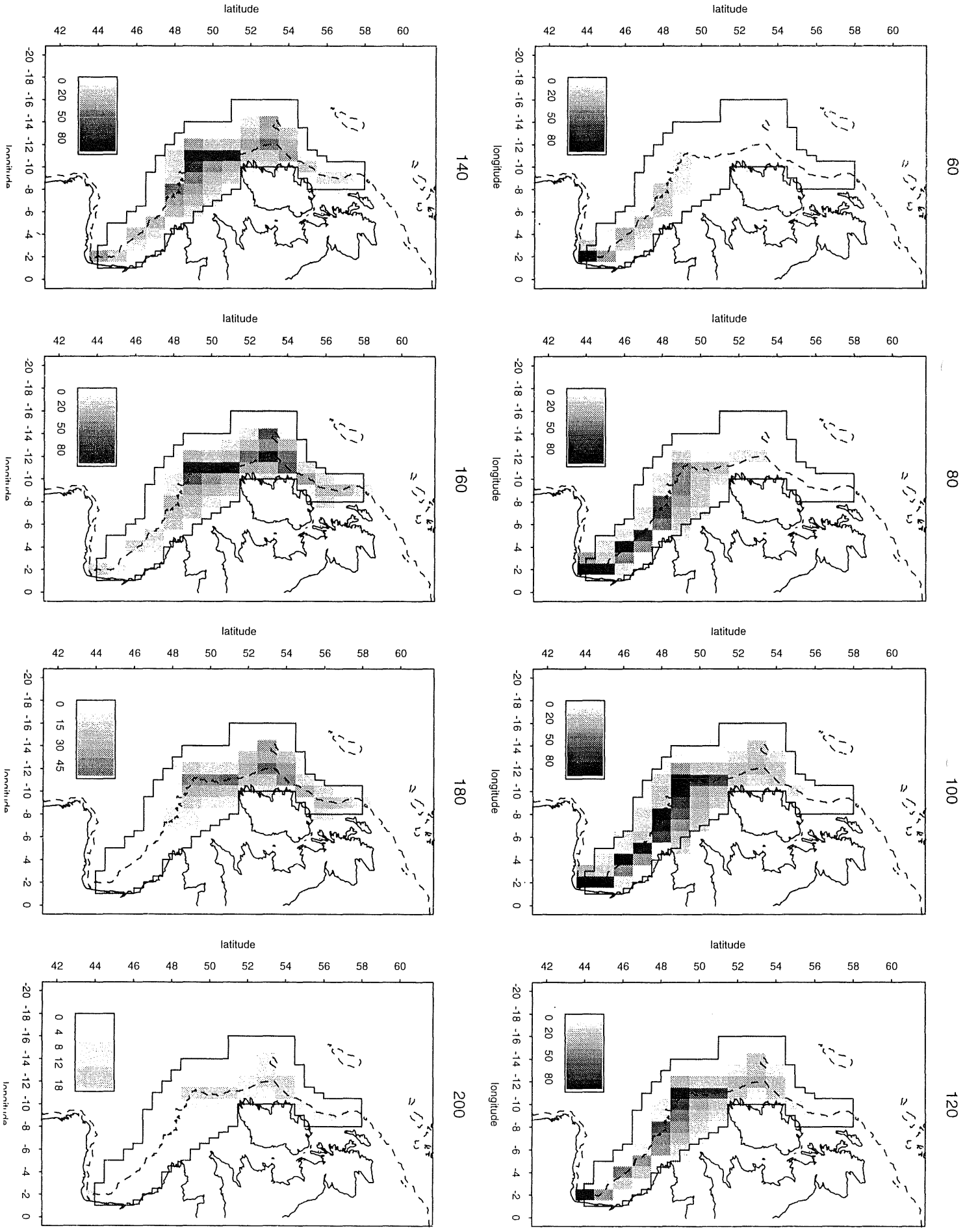


**Figure 3.6.2k:** 1995 survey: Observed horse mackerel egg densities (eggs per $m^2$) averaged within each half-degree block in the survey area. Unshaded half-degree blocks were not sampled.

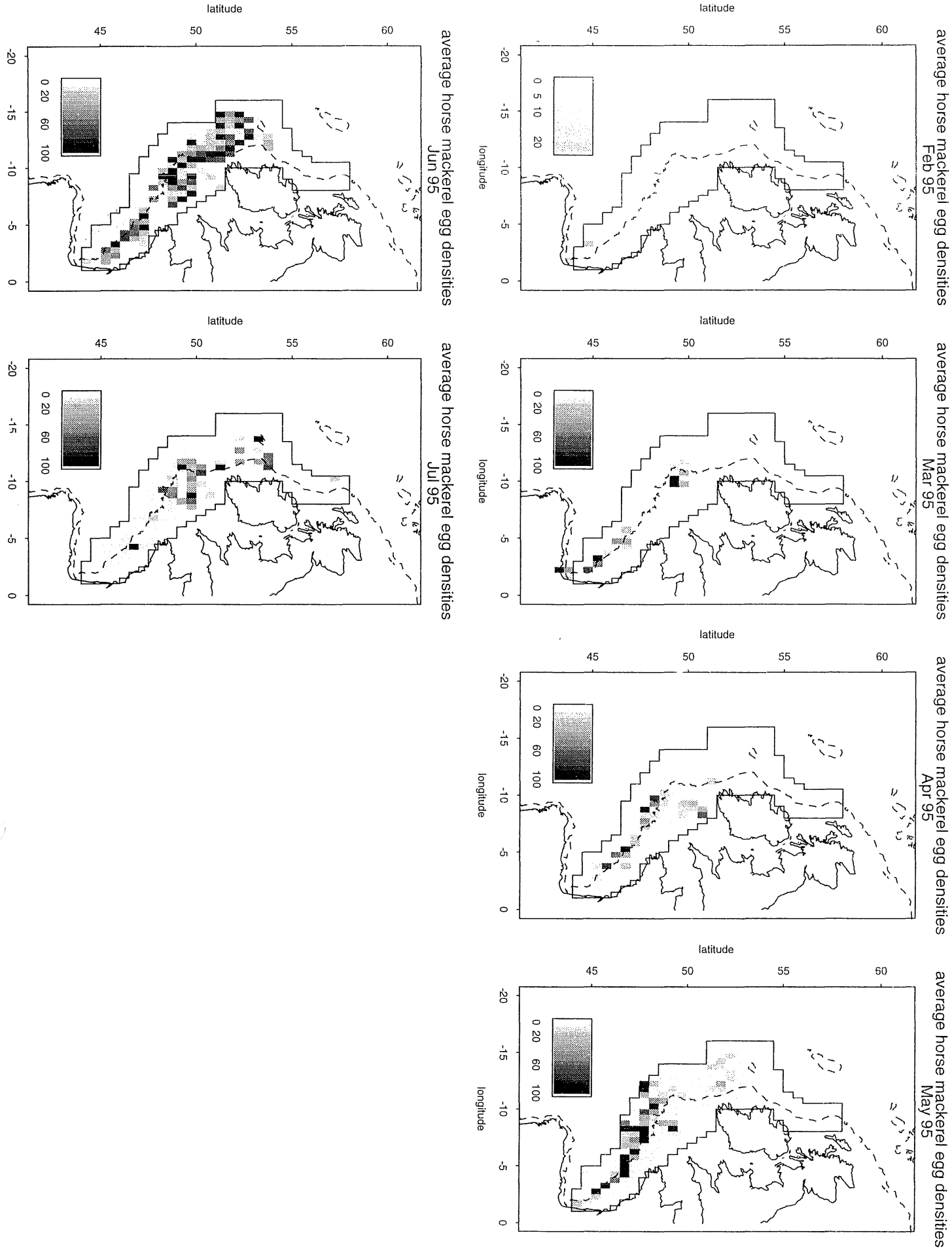


**Figure 3.6.2l:** 1992 survey: Observed horse mackerel egg densities (eggs per $m^2$) averaged within each half-degree block in the survey area. Unshaded half-degree blocks were not sampled.

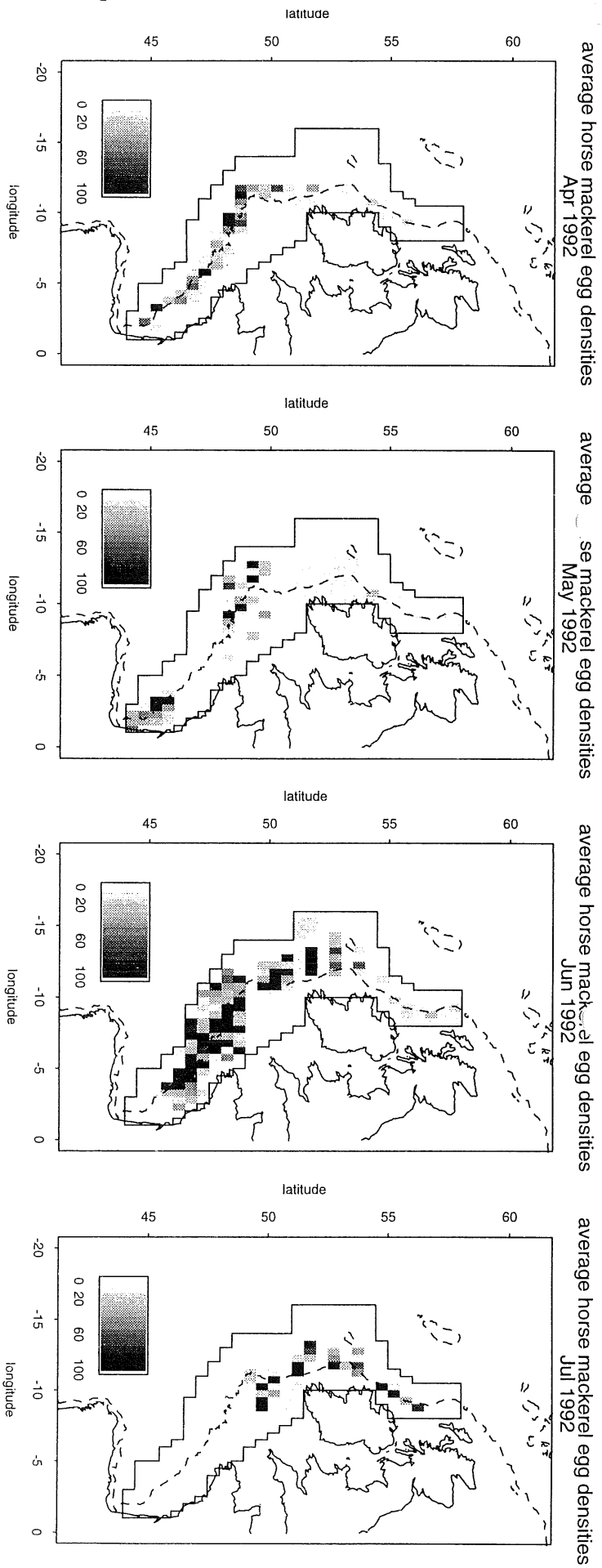


**Figure 3.6.2m:** 1989 survey: Observed horse mackerel egg densities (eggs per $m^2$) averaged within each half-degree block in the survey area. Unshaded half-degree blocks were not sampled.

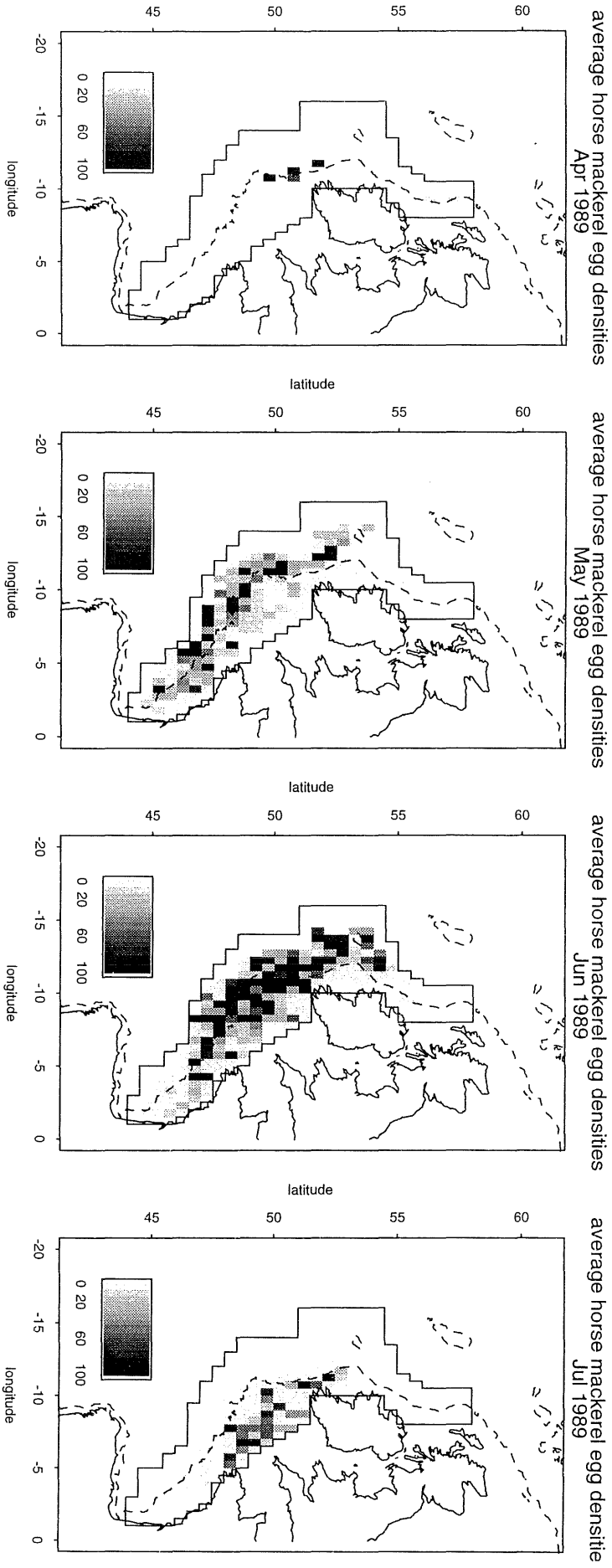


**Figure 3.6.2n:** 1995 survey: Spatial distribution of estimated horse mackerel egg density (eggs per $m^2$) at selected dates: **60**:1.3.95, **80**: 20.3.95, **100**:10.4.95, **120**:30.4.95, **140**: 20.5.95, **160**: 9.6.95, **180**: 29.6.95, **200**: 19.7.95. The 200m contour line is shown as a dotted line.

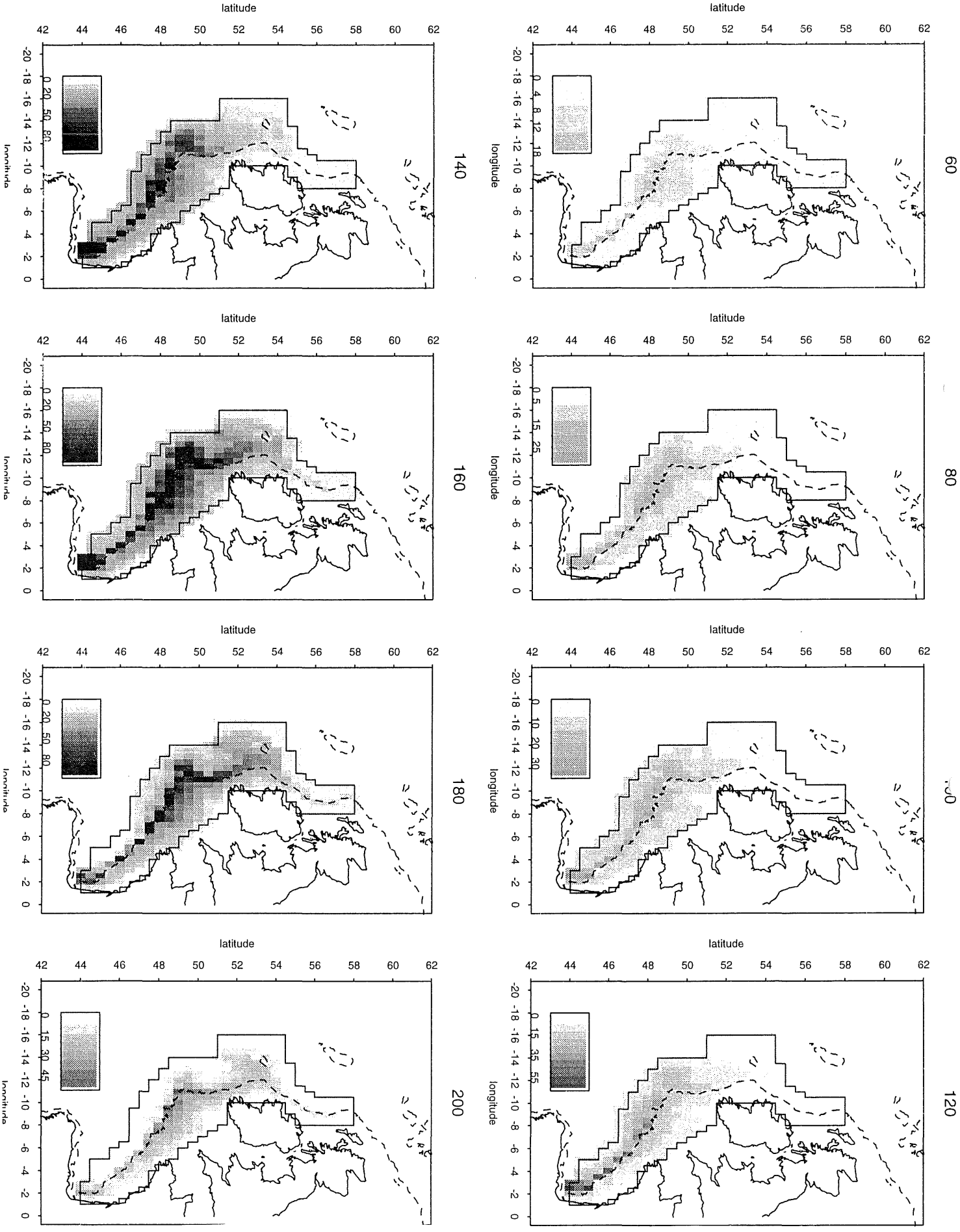


**Figure 3.6.2o:** 1992 survey: Observed horse mackerel egg densities (eggs per $m^2$) averaged within each half-degree block in the survey area. Unshaded half-degree blocks were not sampled.

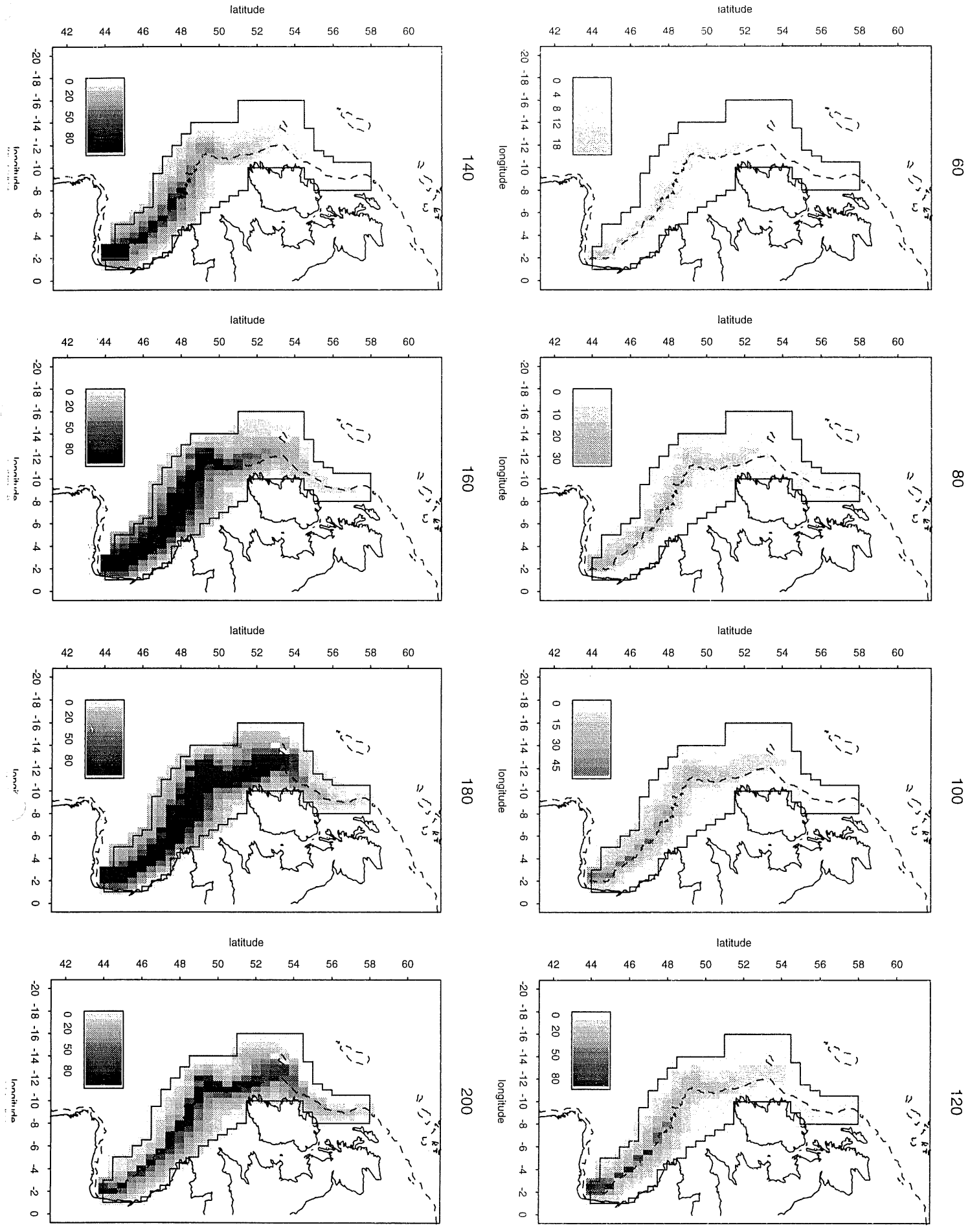


**Figure 3.6.2p:** 1989 survey: Observed horse mackerel egg densities (eggs per $m^2$) averaged within each half-degree block in the survey area. Unshaded half-degree blocks were not sampled.

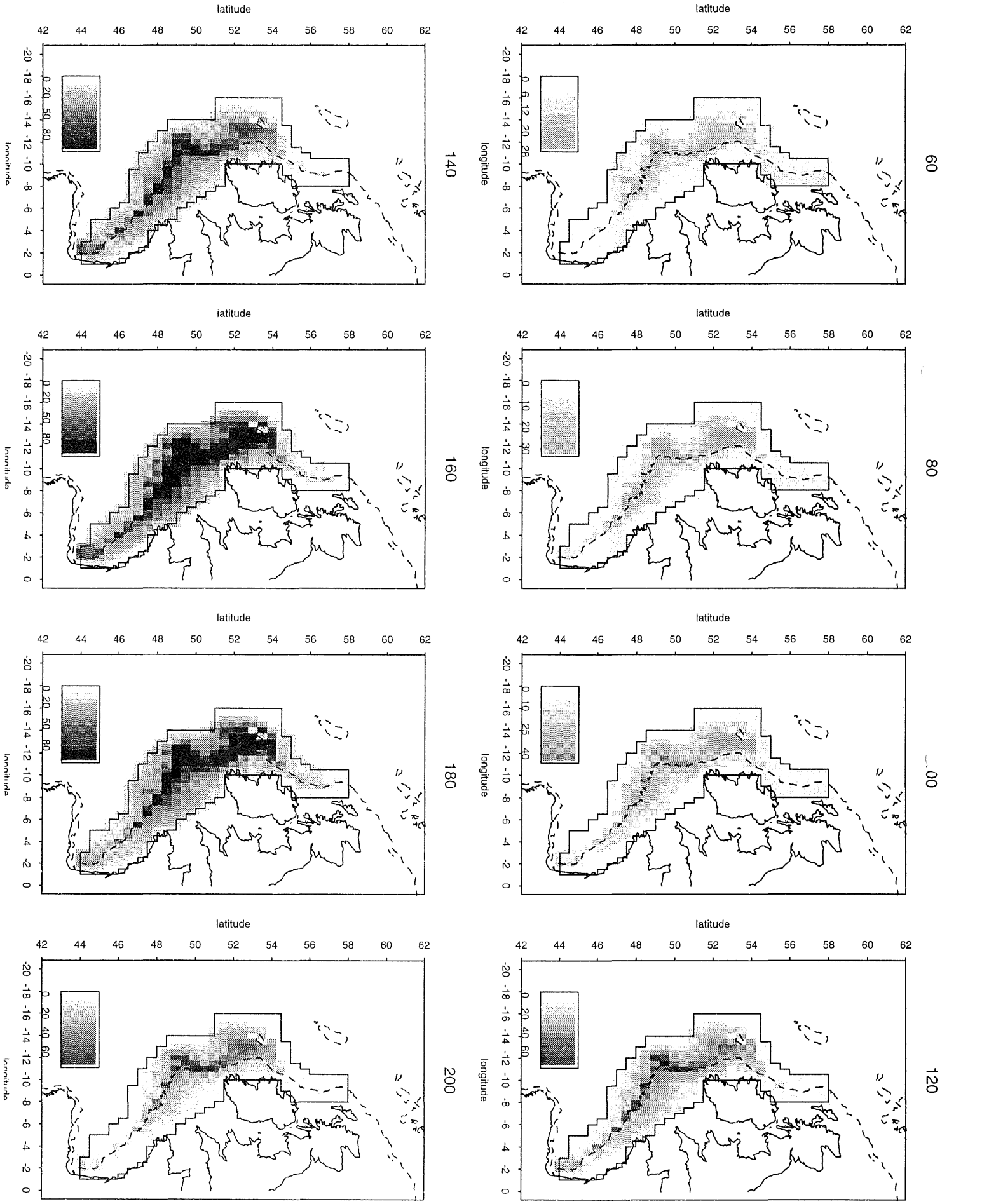
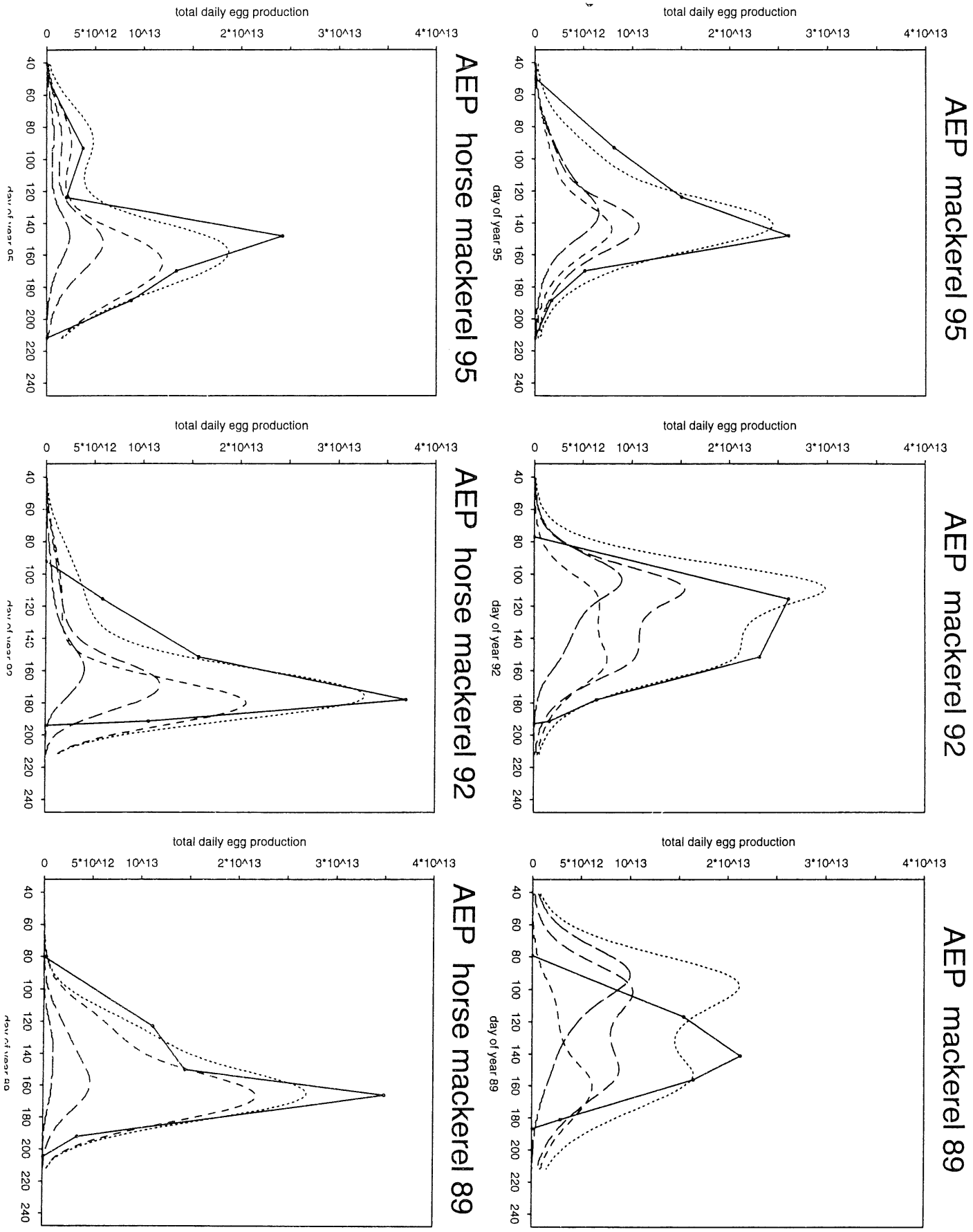


**Figure 3.6.2q:** Plots of estimated egg production curves for mackerel and horse mackerel for 1995, 1992, and 1989. Solid lines are the traditional method estimates. Dotted lines are the *ad hoc* bias-corrected GAM method estimates. Dashed lines are the *ad hoc* bias-corrected GAM method estimates in the southern stratum (longest dashes), middle stratum (medium length dashes), and northern stratum (shortest dashes).



# 4 NORTH SEA EGG SURVEYS IN 1996

## 4.1 Countries and Ships Participating

The last time that the size of the spawning stock in the North Sea was estimated, based on the Annual Egg Production method was in 1990 (Iversen *et al.*, 1991). In Anon (1993a) it was recommended that a new egg survey in the North Sea be carried out in 1996. In 1990 the spawning stock was estimated at 78,000 tonnes (Iversen *et al.*, 1991). Single coverages of the spawning area in 1991 and 1992 indicated that the spawning stock was still at a very low level (Anon., 1993a).

Denmark (RV *Dana*) and Norway (RV *Johan Hjort*) will carry out mackerel egg surveys between 7 June and 2 July 1996. The allocated survey time is poor, but the main spawning area should be covered three times as indicated below.

| Vessel | 1 | 2 | 3 |
|---|---|---|---|
| *Dana* | 7 - 16 June | 16 -21 June | |
| *Johan Hjort* | | 16 - 21 June | 21 June -2 July |

Usually the peak period of spawning is during the second half of June and will therefore probably be sampled during the second period coverage.

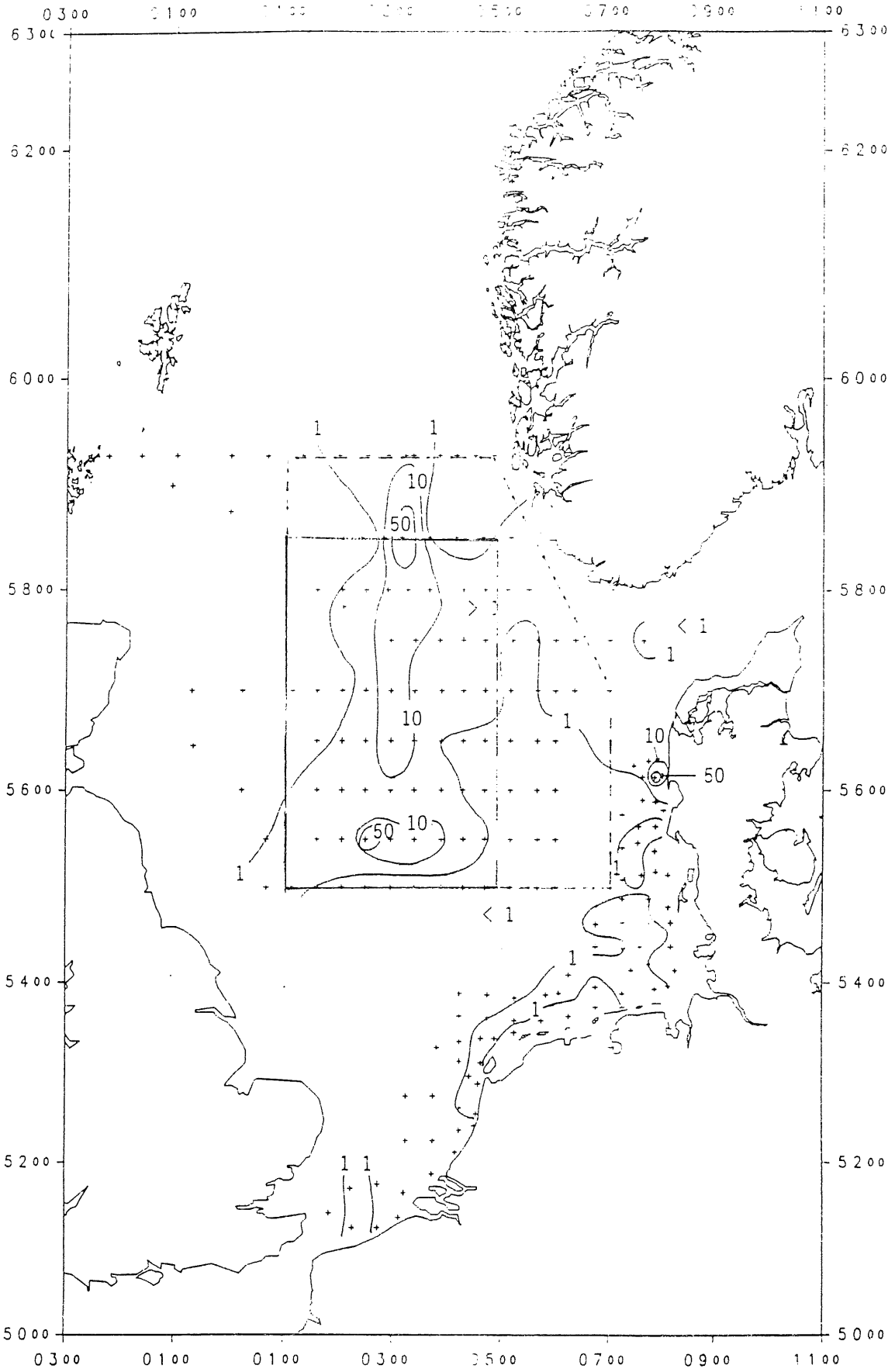
## 4.2 Sampling Area and Survey Design

The main spawning area is usually located between 55°N and 58°N and between 1°E and 5°E. The plankton samples will be roughly examined on board and the survey area will be adjusted according to the results of that examination. Figure 4.1 gives the survey grid used in the second half of June 1990. The stations close to the coast west of Denmark and the Netherlands were sampled in 1990 for horse mackerel and sole eggs and therefore will not be sampled in 1996. Due to the tight time schedule, RV *Dana* will concentrate on the smaller area during the first period indicated in Figure 4.1, while the second and third coverages will target the wider area.

## 4.3 Sampling and Data Analysis

The procedure is fully described in Anon., (1994). For each sampling station information about the number of stage I mackerel eggs, volume filtered and the temperature at 5 m depth will be sent to the coordinator S.A. Iversen by 31 August 1996. Subsequently, S.A. Iversen and K.J. Staehr will prepare a report for the ACFM autumn meeting in 1996.

**Figure 4.1** The distribution of daily production of mackerel eggs per $m^{-2}$ during the fifth coverage, 17 - 30 June 1990 and the stations sampled. The proposed sampling areas for 1996 are shown with solid lines for the first coverage and a broken line for the additional area for the second and third coverages.



# 5 WESTERN MACKEREL AND HORSE MACKEREL EGG SURVEYS IN 1995

Estimation of biomass from the egg surveys - annual egg production method

## 5.1 Countries and Ships Participating

The deployment of research vessel effort in the western mackerel/horse mackerel 1995 egg survey is shown in Table 5.1.

## 5.2 Sampling Areas and Sampling Effort

### 5.2.1 Egg surveys

The standard sampling area used for the western mackerel and horse mackerel egg surveys in 1995 is shown in Figure 5.2.1a. Also superimposed on this figure is the area used in the previous survey in 1992. In contrast to all previous surveys it was decided at the last ICES Workshop (Anon, 1994) that sampling in 1995 would not be constrained by the standard survey boundary where spawning was clearly indicated at or beyond it. The extent to which sampling took place outside the standard area may be seen in Figures 5.2.1b-g. Whilst the use of a standard area is no longer strictly essential it has remained helpful both as a good general guide to cruise leaders in planning and carrying out cruises and more importantly for comparing egg production estimates by different methods and in different years.

The numbers of hauls made per half ICES rectangle per survey period are shown in Figures 5.2.1b-g. Also shown in these figures are the rectangles in which egg production values have been interpolated.

Area and temporal coverage were more comprehensive than in any previous year. With regard to the latter, the provision of additional data from two Spanish (AZTI) hake surveys, prior to the commencement of the ICES surveys of the western area, were extremely useful both in providing better information on timing of the commencement of spawning and in providing additional egg production data at the start of spawning. These surveys indicate that, in future, sampling should start earlier in the western area. They also highlight the lack of data between periods 1 and 3 in 1995. Additional data were also provided from a combined AZTI/IMA anchovy survey to fill in two unsampled rows of rectangles during period 4.

With regard to area coverage, difficulties encountered in 1992 were largely overcome in 1995. In 1992 an unexpectedly westerly distribution of spawning coupled with a sampling strategy which did not always sample to the edge of the distributions resulted in a likely underestimation of egg production around the peak of spawning. Only in two periods and a small number of rows were high egg abundances encountered on the outermost stations in 1995. The extent of this may be evaluated by reference to Figures 3.3a-g (mackerel) and Figures 3.3h-n (horse mackerel).

## 5.3 Sampling and Data Analysis (Traditional Method)

The 1995 survey was conducted in accordance with the sampling strategy described in Anon (1994). The report also provides a detailed description of its evolution over the previous 15 years of its history. Relevant aspects are summarised below.

### 5.3.1 Sampling strategy

The current sampling strategy has evolved over a period of 18 years as a result of experience, increased knowledge and changes in survey requirements and availability of resources.

Throughout the time series the aim has been to carry out a number of surveys over the spawning season with a view to producing an annual egg production "curve". Each survey generates a single point on the "curve" representing the mean daily egg production for that period. Historically the western area has been surveyed over four or five time periods during a spawning season. In 1995 the plan was to carry out five surveys between about mid March and July. For the first time in the history of the surveys these were to be part of a more integrated approach bringing together both the southern and western areas. For the two areas combined, the spawning season was to be surveyed over seven time periods, with sampling of the southern area in the first five periods and of the western area in the last five periods.

Since the start of the series the basic sampling unit has been the ICES 1/2° x 1/2° rectangle. This has remained constant throughout the time series, while the "standard area" surveyed has been expanded with each successive survey as knowledge increased and inter-annual variations in spawning distribution had to be taken into account. In order to ensure that cruise leaders were able to direct their efforts to the expected distributional areas in each time period it has been the practice since 1983 to provide updated historical distribution charts in the preceding planning workshop. This was also the case in 1995.

Over the course of the surveys, efforts have been made to improve the spatial distribution of sampling both to ensure that it was directed towards the most appropriate areas and to improve variance estimation. To this end various forms of stratified sampling, described in detail in Anon (1994), have been in operation since 1986. In 1986 the standard area was divided into high and low sampling strata based on distributions from historic surveys. The aim was to sample at a ratio of two samples to one in high egg density strata in the period of peak spawning. Replicate sampling was achieved either with two consecutive samples in the same rectangle or by sampling twice during a survey with an interval between.

In 1989 a more flexible strategy was adopted, based upon shipboard enumeration of samples to determine where to undertake replicate sampling rather than using a rigid designation of high and low abundance strata. A similar approach was adopted in 1992 but with a slight modification with a view to improving spatial resolution. In this year replicate samples were taken at evenly spaced positions in an east-west direction rather than in the centre of rectangles.

In 1992 the distribution of spawning in mid season was further to the west than in previous years and beyond the standard area. This resulted in some undersampling of egg production.

In 1995 an adaptive sampling scheme was used to overcome such problems. This was also required to meet the needs of a new and potentially more precise method of estimating egg production - a spatio-temporal generalized additive model (GAM).

The main change in 1995 was the adoption of a strategy to sample to the outer boundaries of spawning even if this extended beyond the enlarged "standard" sampling area. This was to be achieved by shipboard evaluation of egg abundance towards the end of each row. Sampling along a row could be terminated after a single zero (or near zero) value or two consecutive low values, ie < about 20 stage I eggs of either species. To meet the additional sampling possibly required by this strategy it was recognised that it might prove necessary during certain periods to reduce the number of rows sampled leaving either two or three row gaps between sampled transects while nonetheless attempting a complete north-south cover. Such a strategy is amenable to the GAM but could leave unsampled areas, which under previous survey protocol, are not allowed to be interpolated. Under these circumstances therefore, it was decided to allow additional interpolation where the distributional data justified it. An example is given under Section 5.3.3. In practice survey cover was sufficient in all but two periods not to require this and in these periods very few additional rectangles were interpolated (see Figs 5.2.1d and g).

The adaptive strategy adopted in 1995 resulted in a reduction in the number of replicate samples taken compared to previous years with only Spain (IEO and AZTI) and England in period 4 able to take replicates.

Sampling was carried out in the centre of rectangles as in all previous years except where consecutive replicate samples were taken. In these cases they were spread at regular intervals within the rectangle. In the ICES surveys Spain (IEO) took replicate samples along a north-south axis while England took them in an east-west direction along the rows as in 1992. In the non-ICES hake and anchovy surveys they were taken along rows which ran perpendicular to the shelf edge in a NE-SW direction.

### 5.3.2 Sampling gears and procedures

In the western area plankton sampling was carried out using national versions of a Gulf III type sampler with the exception of Spain (Table 5.3.1).

Each Gulf III type sampler was fitted with a conical nosecone with either an aperture diameter of 19.5 cm (Netherlands and Scotland) or 20 cm. The Gulf III type samplers were deployed to within 3 m of the bottom or to a maximum of 200 m in deeper water. A double-oblique haul was carried out at each sampling position at a ships speed of approximately five knots. Calibrated flowmeters, mounted both inside the nosecone and externally on the body of each sampler, were used to provide an estimate of the volume of water filtered on each deployment.

The presence or absence of a thermocline on each survey is shown in Table 5.3. Only the Netherlands changed their sampling strategy in the presence of a thermocline. Where the temperature difference was greater than 2.5°C in a 10 m depth band sampling continued to 20 m below the thermocline before hauling began.

In periods one and three Spain (AZTI) used a 60 cm diameter aperture bongo. It was deployed on a double oblique haul to a maximum depth of 200 m or to within 3 m of the bottom in shallower water.

In period four Spain (AZTI) used a Pairovet net (a double calvet net) which had an aperture of 0.05 $m^2$ (≈25 cm diameter aperture). This was deployed to a maximum depth of 100 m and hauled vertically.

In periods three and six Spain (IEO) used a 20 cm diameter aperture bongo. This was deployed on a double oblique haul to a maximum depth of 200 m at a ships speed of 2-3 knots.

On all the surveys a full temperature profile was recorded of the water column sampled and the temperature (°C) at 20 m on each deployment was used as a parameter in the calculation of production of eggs per day in each rectangle.

### 5.3.3 Data analysis by the traditional method

To convert the number of eggs counted in each sample or sub-sample to the number of eggs per $m^2$, the following calculations were made. Firstly the volume of sea water filtered by the sampler during the haul was calculated.

Volume filtered ($m^3$):

$$\frac{\text{Flowm-revs x Aperture}}{\text{Flowm-calib}} \text{ x Efficiency factor}$$

The number of eggs/$m^2$ was calculated from the formula:

$$\text{Eggs/m}^2 = \frac{\text{Eggs counted x factor}}{\text{Volume filtered}} \text{ x Depth sampled}$$

where Flowm-revs = Number of revolutions of the flow meter during a tow
Aperture = The area of the mouth opening of the sampler in $m^2$.
Flowm-calib = The number of flow meter revolutions per metre towed, obtained from the flume or sea calibration in free flow
Eggs counted = number of eggs in the sub-sample
Factor = Raising factor from the sub-sample to the whole sample
Depth sampled = The maximum depth of the sampler during the tow in metres
Efficiency factor = Proportion accepted by the sampler in free flow.

Number of eggs per $m^2$ were raised to numbers per $m^2$ per day using development equations for both species in the following way.

For stage I **mackerel** eggs:

$$\text{Eggs/m}^2\text{/day} = \frac{24 \text{ x eggs/m}^2}{\exp\,[-1.61 \log_e (T^\circ C) + 7.76]}$$

reference Lockwood *et al.* (1981).

For stage I **horse mackerel** eggs:

$$\text{Eggs/m}^2\text{/day} = \frac{24 \text{ x Eggs/m}^2}{\exp\,[-1.608 \log_e (T^\circ C) + 7.713]}$$

Reference Pipe and Walker (1987).

Eggs/$m^2$/day were then raised to the area of the rectangle they represent. The rectangle values were summed to give numbers of eggs per day in each stage over the survey area for each sampling period. Rectangle areas were calculated by each ½° row of latitude using the formula:

$$\text{Area } (m^2) = (\cos \text{ latitude}) \text{ x } 30 \text{ x } 1853.2) \text{ x } (30 \text{ x } 1853.2)$$

When there was more than one observation per rectangle within a sampling period, the arithmetic mean of the observed values were used.

For unsampled rectangles within the designated survey areas the convention for extrapolation used on all previous surveys has been used. A minimum of two immediately adjacent sampled rectangles were required before an extrapolation could be made. This was done by taking the mean of all adjacent rectangle values (both immediately and diagonally adjacent) including zeros. If extrapolation was not valid by this rule the rectangle was excluded from the survey area except under circumstances described below.

In contrast to all previous years it was decided in 1995 to allow additional extrapolation where the distributional data was appropriate to do so. This was only undertaken in periods 4 (Fig. 5.2.1d) and 7 (Fig. 5.2.1g) and applied to a minority of rectangles. These are labelled on the charts as manual fill-ins. The values were all calculated by taking the arithmetic mean of the nearest sampled rectangle directly north and south of the rectangle to be extrapolated.

Once determined, extrapolated values have not been used to estimate values for other unsampled rectangles.

The next stages in estimation of annual egg production by the "traditional" method proceed by:

- estimating daily egg production for each survey period in turn,
- integrating the daily egg production histogram, to give annual egg production.

Daily egg production in each survey period

Let $s$ denote a sampled rectangle, and let:

- $A_s$ be the area of rectangle $s$,
- $n_s$ be the number of hauls in rectangle $s$,
- $x_{sh}$ be the number of stage 1 eggs/m$^2$/day in haul $h$ in rectangle $s$.

Daily egg production/m$^2$ in rectangle $s$ is estimated to be the arithmetic mean of the observations in that rectangle

$$\bar{x}_s = \frac{1}{n_s} \sum_{h=1}^{n_s} x_{sh}$$

Raising by the area of the rectangle then gives the daily egg production in rectangle $s$:

$$A_s \bar{x}_s$$

Arithmetic extrapolation is used to estimate daily egg production in rectangles that are unsampled, but are immediately adjacent to at least two sampled rectangles. Let $u$ denote such an unsampled rectangle, and let $\delta_{us} = 1$ if rectangle $s$ is adjacent (immediately or diagonally) to rectangle $u$, and 0 otherwise. Daily egg production/m$^2$ in rectangle $u$ is then estimated to be

$$\bar{x}_u = \frac{1}{\delta_{u.}} \sum_s \delta_{us} \bar{x}_s$$

where:

$$\delta_{u.} = \sum_s \delta_{us}$$

is the number of sampled rectangles adjacent to $u$. Raising by the area of the rectangle then gives the daily egg production in rectangle $u$:

$$A_u \bar{x}_u$$

Summing egg production over rectangles gives the daily egg production in the survey period:

$$E_D = \sum_s A_s \bar{x}_s + \sum_u A_u \bar{x}_u .$$

Assuming the $x_{sh}$ are distributed with constant coefficient of variation σ, the variance of $_DE$ is then estimated to be

$$\mathrm{Var}[E_D] = \sigma^2 \sum_s \left( A_s + \sum_u \frac{\delta_{us}}{\delta_u} A_u \right)^2 \frac{\bar{x}_s^2}{n_s}$$

The coefficient of variation σ is estimated by the residual standard deviation from an analysis of variance of $\log(x_{sh})$ by rectangle. To avoid the influence of zero egg counts, any rectangles with any zero counts are excluded. In practice, there are too few rectangles with replicate hauls to estimate σ reliably for each period, so the estimates for each period are pooled.

Annual egg production

Annual egg production is estimated by integrating the daily egg production histogram. This involves calculating the egg production in each sampling period and then interpolating or extrapolating the unsampled periods to calculate the egg production in these. This is equivalent to taking a weighted sum of the daily egg production estimates in each survey period.

We can write this formally as follows. Suppose there are $P$ periods, and let:

- $E_{Dp}$ be the daily egg production in period $p$,
- $t_{p1}$, $t_{p2}$ be the start- and end-times of period $p$,
- $t_{01}$, $t_{02}$ both denote the start-time of spawning,
- $t_{P+1,1}$, $t_{P+1,2}$ both denote the end-time of spawning.

Annual egg production is then estimated to be:

$$E_A = \sum_{p=1}^{P} \lambda_p E_{Dp},$$

where:

$$\lambda_p = t_{p2} - t_{p1} + \frac{(t_{p1} - t_{p-1,2})(t_{p1} - t_{p-1,1})}{t_{p2} + t_{p1} - t_{p-1,2} - t_{p-1,1}} + \frac{(t_{p+1,1} - t_{p2})(t_{p+1,2} - t_{p2})}{t_{p+1,2} + t_{p+1,1} - t_{p2} - t_{p1}}.$$

Note that when no interpolation is needed (because sampling periods follow on immediatley) this expression reduces to

$$\lambda_p = tp_2 - tp_1$$

The variance of $E_A$ is estimated to be:

$$\mathrm{Var}[E_A] = \sum_{p=1}^{P} \lambda_p^2 \mathrm{Var}[E_{Dp}].$$

Biomass estimation

Total fecundity per gram fish ($F_{TW}$ )was estimated to be the slope of a weighted regression of annual potential fecundity on fish weight forced through the origin; statistical weights equal to the inverse of fish weight were assigned to each observation to allow for the greater variability in fecundity of larger fish. This is equivalent to using the ratio of the arithmetic mean fecundity to the arithmetic mean fish weight. The variance of the annual potential fecundity per gram fish weight was given by the variance of the regression slope.

The number of atretic eggs per gram female produced during the spawning season (A) was estimated to be:

$$A = GM\left[\frac{i}{w}\right] p \frac{s}{d}$$

where i is the intensity, ie the number of atretic oocytes in a female with atresia in spawning condition (see Section 5.5 for full definition).
w is the total fish weight in grams.
p is the prevalence of females in spawning condition with atresia.
s is the assumed spawning duration (60 days for mackerel, 70 days for horse mackerel)
d is the estimated duration of the atresia stage (7.5 days for mackerel, 15 days for horse mackerel).
GM denotes the geometric mean

The geometric mean of i was used because individual values as high as 37% of the potential annual fecundity were found. Such values would almost certainly be associated with a shorter spawning season than 60 days. For example in some fish total resorption of the fecundity can occur without spawning taking place (Walsh *et al.*, 1990). Use of a geometric mean reduces the effect of these unrealistically high individual values of i.

Three methods were investigated to correct intensity for fish size:

1. $GM(i/w_{stages\ 3\text{-}6})$
2. $GM(i/w_{stage3})$
3. $Fg\ GM[i/F_{lt}]$

where $F_{lt}$ is potential annual fecundity predicted from the length of the fish and derived from the fecundity length regression in Table 5.5.1
$F_g$ is mean fecundity per gram for 1995 (1473 Table 5.5.2)
$w_{stage\ 3}$ is fish weight calculated from the observed fish length using a weight length relationship derived from stage three fish sampled for the fecundity weight length data set.

Each method was used to calculate GM (i/w). These gave very similar results (78.43, 79.22, 79.98 respectively), therefore method one was adopted for its greater simplicity.

The variance of A was estimated using a bootstrap approach which involved resampling from the atresia data (ie values of i and w) and from the presence/absence data to estimate prevalence.

Total fecundity per gramme fish corrected for atresia was estimated to be:

$$F_{TW} - A \text{ with variance } Var[F_{TW}] + Var[A]$$

Total spawning stock biomass (B) was estimated to be:

$$B = \frac{\text{Total annual egg prod}}{\text{Fec per g fish weight}} \times \frac{1}{\text{Fract females}} \times \text{corr f}$$

The correction factor is the value used to adjust pre-spawning to average spawning fish weight.

The variance of the spawning stock biomass was given by:

$$\text{Variance (biomass)} = \text{Biomass}^2 \times (CV(e)^2 + CV(F)^2$$

where CV(E) is the coefficient of variation of total annual egg production and CV(F) is the coefficient of variation of fecundity per gramme fish weight.

Total spawning stock biomass corrected for atresia (and its variance) was estimated by using annual potential fecundity per gramme fish weight corrected for atresia (and its variance) in the formulae above.

## 5.4 Egg production of mackerel

The mean daily stage I egg production estimates for each survey period were plotted against the mid cruise dates to give a production 'curve' (Fig. 5.4a) as in previous years. The associated values are given in Table 5.4.1.

The start date of spawning was assumed to be 10 February. This is much earlier than assumed in previous years (generally around mid March) but is based on results from the spanish (AZTI) hake egg survey which indicated the presence of small numbers of stage IV mackerel eggs in southern Biscay on 17 February. The 10 February is probably close to the real start date in previous years when sampling was not carried out so early in the season. The end point of spawning was assumed to be 31 July. This differed from the procedure followed in previous years when the date of the last sample containing stage I eggs was used. This would have been 16 July in 1995. The later date was adopted as a more realistic date for the end of spawning and because such a date is required for the GAM with which the traditional method needs to be compared.

In all previous years some individual period production estimates considered to have been minimum values because it had never been possible to sample the entire spawning area. In 1995, with the altered sampling strategy and better area coverage, the extent of the underestimation is likely to have been considerably reduced. Thus only in periods 4 and 5 was there an indication that sampling had not reached to the edge of the main spawning area. In period 4 (Fig. 3.3d) the data indicate some possible underestimation west and south of row 22 and west of row 31. In period 5 a similar situation pertained (Fig. 3.3e). Production estimates for the individual time periods are given in Table 5.4.2.

It should be noted that the dates in Table 5.4.2 do not exactly match those of Table 5.4.1 for periods 4, 6 and 7. This is because in order to achieve maximum spatial coverage in each period there was some temporal overlap (Table 5.4.1). For the calculation of period production estimates (Table 5.4.2) there can be no overlap in dates and therefore in this table the beginning of each sampled or interpolated period is always the day after the last day of the preceding period. On those occasions when temporal overlap did occur, no rectangle egg production estimates were used in more than one period.

The estimated CVs given in Tabel 5.4.2 were very close to those of previous years despite the reduced number of replicate samples.

In order to compare the 1995 results with those of previous years and with estimates from the GAM it is necessary to adjust these estimates. For the former comparison only those data within the 1992 standard survey area have been used and the start and finish dates have been adjusted to correspond to those used in that year. For comparison with the GAM, only rectangles inside the 1995 standard survey area have been used. This estimate, however, is not included here since the best estimate for the GAM has not yet been finalised. The two production estimates described are summarised in the text table below.

**Comparative estimates of total egg production in 1995 using different sampling areas and spawning season length**

| | Annual stage 1 egg production $\times 10^{-15}$ | | | |
|---|---|---|---|---|
| | Mackerel | | Horse mackerel | |
| | estimate | se | estimate | se |
| 1995 extended survey area | 1.487 | 0.170 | 1.226 | 0.232 |
| 1992 survey area and start/end times | 1.268 | 0.150 | 0.957 | 0.205 |

Of these two estimates, the 1995 extended area one is considered to be the better approximation to true egg production in 1995, while the lower value is the more appropriate one for comparison with historic data. An investigation of sources of error in these estimates (Walsh Working Document 1995) suggests a possible positive bias in the extended area estimate. This tentative conclusion was drawn as a result of investigating changes in egg production within and between survey periods and comparing those with the temporal distribution of sampling effort. To test the effect of the latter on the period egg production estimates, the median dates of sampling in each period were calculated and these dates used as the new mid-point dates for each period. This resulted in some reduction in the duration of the sampled periods and an increase in duration of the interpolated periods. The results of this analysis gave a reduction in egg production of 4% in the case of mackerel from 1.487 (E+15) to 1.429 (E+15). Other possible sources of error cannot be easily quantified. A qualitative investigation of egg production in the interpolated rectangles (14% of total production) suggests that this may have been overestiamted in 1995. Some underestimates of egg production will, however, have resulted from not sampling to the outer edges of the spawning area in some rows in periods 4 and 5. In view of the above considerations and their implications for the stock it is recommended that the calculated value of 1.487 (E+15) be regarded as a maximum estimate.

Comparisons with previous survey results are summarised in Figure 5.4b and Table 5.4.3. The shape of the production "curve" in 1995 appeared to be typical of previous years while total egg production was approximately 35% lower than in 1992.

## 5.5 Total Fecundity and Atresia of Mackerel

Total annual potential fecundity (fecundity) estimates have previously been made for the western stock in 1977 (Lockwood, 1978), 1986 (Greer Walker *et al.*, 1987), 1989 (Walsh *et al.*, 1990) and 1992 (Anon, 1993). In 1995 a similar excercise was undertaken by the Fisheries Laboratory in Lowestoft and the Marine Laboratory in Aberdeen in conjunction with Aberdeen University.

Ovaries from over 100 pre-spawning mackerel, stratifed by length to cover the range of spawning fish, were collected from trawl catches (RV *Cirolana*) close to the continental shelf edge between latitudes 48 to 51.5°N and 7.7 to 11°W between 16 March and 1 April. Each mackerel was screened to eliminate spawning fish indicated by the presence of post-ovulatory follicles. As in 1989 and 1992 (Walsh *et al.*, 1990) the fecundity was estimated gravimetically, counting oocytes >130 µm after digesting one ovary in Gilson's fixative and correcting for the weight of the other ovary (used in the histological screening).

Prior to working up the full set of samples, SOAEFD and MAFF undertook an intercalibration excercise on 10 fish to test for any possible differences. No significant differences were found. However, on completion of the full set of samples small inter-laboratory differences were found between fecundity/weight and fecundity/length relationships (P>0.5). Mean values of fecundity/g are given below:

| Laboratory | Mean fecundity $g^{-1}$ total weight | s.e. | n |
|---|---|---|---|
| SOAEFD | 1,407 | 41.7 | 50 |
| MAFF | 1,523 | 34.5 | 45 |
| SOAEFD/MAFF 0.9241 | | | |

The data were carefully screened for outliers and possible errors but none could be detected. In the absence of any grounds for rejecting either data set therefore the two were combined and composite fecundity/wt, fecundity/length relationships derived. These, together with comparable data from 1989 and 1992, are given in Table 5.5.1. The historical series from 1989 for these fecundity relationships are shown in Figure 5.5.a and was tested for between year variation by analysis of covarince. No significant heterogeneity was found in the regression comparing 1992 with 1995 (p>.05 n= 195) but the latter was significantly lower than 1989 (p<.05 n=174). Compared to both previous years the intercept on the fecundity/weight regression in 1995 (-37755) was closest to the zero intercept and was not significantly different from it, as in 1989 but in contrast to 1992. The relationship between oocytes per g total weight and fish weight is shown in Table 5.5.2.

The lower fecundity measured in 1995 is consistent with observations made during the sample collection at sea where suitable fish were sparse in the trawl catches. Many fish were opened and rejected because the ovary appear poorly developed and had not advanced to late maturity stage three.

Conversion of Egg Production into Biomass

A conversion factor was derived from the annual potential fecundity per gram fish weight and was estimated to be the slope of the fecundity total weight regression forced through the origin as in 1989 and earlier assessments (the procedure in 1992 was slightly different because the intercept was significantly different from zero). The regression was weighted to allow for greater variability in the fecundity of heavier fish, with the statistical weight taken to be the inverse of the corresponding fish weight. For mackerel the estimate was 1,473 eggs per gramme with a standard error of 29.

Estimation of the Number of Oocytes Lost From the Potential Annual Fecundity by Atresia

Estimates of atresia based on the prevalence and intensity of the early α atresia stage (atresia) in spawning fish were produced for the 1989 (Walsh *et al.*, 1990) and 1992 surveys (Anon, 1993) and used to correct the potential annual fecundity on the latter. The University of Aberdeen and MAFF used the same method in 1995 as 1992 to estimate atresia but some modification was made to estimate the atresia correction for the predicted annual potential fecundity (see data analysis 5.3.3).

Ovary samples were collected from fish caught by research vessels using either trawl or handline and prepared for stereometric analysis (Anon, 1990). The numbers of fish in spawning condition, identified by the presence of any of the following histological stages (migratory nuclei oocyte, hydrated oocyte or post ovulatory follicle) were selected for estimation of atresia as detailed in Table 5.5.3.

The fish samples from each research vessel (Table 5.5.3) were aggregated by month because the collections made on the various cruises had substantial overlap in time. The results are shown for each institute in Table 5.5.4 and show the highest levels of atresia loss during the first two months of spawning peaking in May (39.2-69.4, 41.3-130.7, 29.3-175.3, 33.1-125.7 by month and institute MAFF-University respectively). Although the trends in prevalence and intensity are similar the University values, especially for intensity, are higher than MAFF. At this stage there is no reason to reject either data set especially as the sample allocation was biased in favour of the latter (samples from *Lough Foyle* and *Johan Hjort* were not sent to MAFF).

Samples collected on the 31 May by *Tridens* showed particularly high prevalence and intensity of atresia (0.542-0.667, 41.3-108.5 respectively) for reasons unknown but future assessments must try to increase the number of trawl hauls and randomly select a fixed number of fish randomly selected at each site. An overall number of oocytes per gramme female during the spawning season was calculated (171s.e.26) which showed a 50% increase from 1992. This observation is consistent with the observations made at the time of collecting the fecundity samples in that overall individual egg production was depressed relative to 1992.

## 5.6 Biomass Estimate of Mackerel

Total stage I egg production using all data both within and beyond the 1995 standard sampling area is given in Table 5.4.2. Total spawning stock biomass (SSB) was estimated using the fecundity estimate of 1.302 oocytes/gram female adjusted for atresia (Section 5.5), a sex ratio of 1:1 and a raising factor of 1.08 (Anon, 1987) to convert pre-spawning to spawning fish. This gave an estimate of spawning stock biomass for 1995 of 2.47 million tonnes adjusted for atresia and with a standard error of 0.29 million tonnes. In this estimate 97% of the variance is attributable to the egg survey and 3% to the fecundity estimate. As mentioned in Section 5.4 the egg production value used to calculate the SSB is considered to be a maximum value and the same comment therefore applies to the biomass estimate.

For the purpose of comparing biomass in 1995 with historic estimates it is better to use data collected from a comparable area and time period. To this end an estimate using the 1992 standard survey area and the same start and finish dates as in 1992 has been calculated. This gave a spawning stock biomass estimate, adjusted for atresia of 2.10 million tonnes (Table 5.4.3) with a standard error of 0.26 million tonnes.

This estimate indicates a 28% drop in biomass compared to 1992. This is lower than the drop in egg production because of lower fecundity and higher atresia in 1995.

## 5.7 Egg Production of Horse Mackerel

The mean daily egg production estimates for each survey period were plotted against the mid cruise dates to give a production curve (Fig. 5.7a) as in previous years. The associated values are given in Table 5.4.1.

The start date of spawning was assumed to be 10 February. This is much earlier than assumed in previous years (generally around mid March) but is based on results from the spanish (AZTI) hake egg survey which indicated the presence of small numbers of stage IV horse mackerel eggs in southern Biscay on 17 February. The 10 February's probably close to the real start date in previous years when sampling was not carried out so early in the season. The end point of spawning was assumed to be 31 July. This differed from the procedure followed in previous years when the date of the last sample containing stage I eggs was used. This would have been 16 July in 1995. The later date was adopted as a more realistic date for the end of spawning and because such a date is required for the GAM with which the traditional method needs to be compared.

In all previous years some individual period production estimates are considered to have been minimum values because it had never been possible to sample the entire spawning area. In 1995, with the altered sampling strategy and better area coverage, the extent of the underestimation is likely to have been considerably reduced. Thus only in period 5 was there an indication that sampling had not reached to the edge of the main spawning area. In period 5 (Fig. 3.3l) the data indicate some possible underestimation west and south of row 24. Production estimates for the individual time periods are given in Table 5.4.2.

In order to compare the 1995 results with those of previous years and with estimates from the GAM it is necessary to adjust these estimates. For the former comparison only those data within the 1992 standard survey area have been used and the start and finish dates have been adjusted to correspond to those used in that year. For comparison with the GAM, rectangles outside the 1995 standard survey area need to be excluded. This comparison is not, however, made here as the best estimate from the GAM has yet to be finalised. As in the case of mackerel the 1995 extended area estimate should be considered as a maximum value. Calculation of egg production based on median dates of sampling periods reduces the estimate by 3% but other possible sources of error cannot be quantified. The two alternative production estimates are summarised in the text table in section 5.4.

Comparisons with previous survey results are summarised in Figure 5.7b and Table 5.4.3. The shape of the production "curve" in 1995 differed from that of previous years with peak production apparently one period earlier than in the previous two survey years. Total egg production was approximately 39% lower than in 1992.

## 5.8 Total Fecundity and Atresia of Horse Mackerel

Total Fecundity

Following the recommendation of the planning meeting in 1994 (Anon, 1994) 10 ovaries per cm group of horse mackerel in late pre-spawning stage 3 should be collected for fecundity estimation and 90 randomly selected adult females should be collected for atresia estimation during period 3. In April 1995 150 horse mackerel ovaries were collected for fecundity estimation in ICES Divisions VIIb,g,h,j and VIIIa, but unfortunately none were collected for atresia estimation. The fish collected were within a length range of 25-43 cm and the ovaries were sent to RIVO-DLO, Netherlands for further analysis. The histometric method to estimate the annual potential fecundity is described in Eltink and Vingerhoed (1989) and Emerson *et al.* (1990). Only 99 ovaries were used to make histological slides, because many

ovaries were damaged during collection. From these slides 87 were good enough for scoring presence of atresia and post-ovulatory follicles, but only 34 were good enough for fecundity and atresia estimation. The histological sections were examined: i) to ensure that spawning had not yet commenced (spawning is indicated by the presence of post-ovulatory follicles); and ii) to determine the annual potential fecundity by raising the counts of vitellogenic and atretic oocytes to the total volume of the ovary. Out of the 34 histological sections only 12 could be used for further analysis, because 22 showed obvious presence of post-ovulatory follicles. Some of these 12 fish might have been spawning because of the possible presence of undetected post-ovulatory follicles in a very late stage. These stages are difficult to distinguish from atretic oocytes because of the presence of blood cells in several parts of the ovary, which also indicates spawning activity. Figure 5.8a shows the plot of the fecundity against fish weight from fish collected in period 3, which corresponds to an estimated fecundity of 1,136 eggs per gram pre-spawning female based on these fish in a length range of 26-38 cm (Table 5.8.1).

During the fourth period a random sample of 79 adult horse mackerel was taken for atresia estimation. These 18 fish were in a pre-spawning stage without obvious presence of post-ovulatory follicles. These fish were also taken to estimate the annual potential fecundity (Table 5.8.1). Figure 5.8 shows the plot of fecundity against fish weight during period 4. The estimated fecundity of 1,446 eggs per gramme pre-spawning female in this sample with a length range of 25-38 cm is much higher than that of the sample from the third period. The fecundity estimate from period 3 is 21% lower than that from period 4. A possible explanation for this is that the ovaries collected in period 3 were not taken from fish in a late pre-spawning stage 3. They appeared to be taken from a much later ovary development stage, when spawning had already started. Scoring post-ovulatory follicles showed that 74 out of the 87 fish had spawned (85%). The egg production curve (Figure 5.7a) confirms that spawning actually started in April and then decreased to a lower level in May. Ovaries in a very advanced development stage could have been selected in April for fecundity estimation. Therefore the fecundity results obtained from these ovaries should not be used. The Working Group decided to use the fecundity estimates of the 4th period in 1995 combined with the earlier fecundity estimates from horse mackerel ovaries collected in 1987, 1988 and 1992 (Eltink and Vingerhoed, 1993). The fecundity estimate from the 4th period 1995 covered a restricted weight range and was only based on 18 fish. These fecundity data are shown in Figure 5.8b. The fecundity was estimated at 1,557 eggs per gramme female with a standard error of 42.5 based on 78 fish collected in 1987, 1988, 1992 and 1995.

Atresia

During the third period no atresia sample was collected. During period 4, 5, 6 and 7 respectively 79, 90, 74 and 84 adult female fish were collected for atresia estimation. During the fourth period these fish were taken in ICES rectangles 29E0, 25E0 and 31D8, during the fifth period in 20E6 and 24E3, during the sixth period in 25E3, 26E1 and 27E1, and during the seventh period in 32D8, 25E1.

The results of atresia estimation are presented in Table 5.8.2. The histological slides were scored to estimate the prevalence and relative intensity of atresia and the number of atretic oocytes/gram female within the population. At the beginning of the spawning season (period 4) the prevalence of atresia in horse mackerel was 49% (Table 5.8.3). During period 5, 6 and 7 the prevalence of atresia remained stable (respectively 43%, 45% and 43%). The relative intensity of atresia in horse mackerel ovaries was lowest at peak spawning time (Table 5.8.3).

The proportion of vitellogenic oocytes in the ovary compared to the total potential fecundity decreased during period 4, 5 and 6 from 0.82 to 0.42, but increased again during period 7 to 0.60 (Table 5.8.3). This is probably due to a emigration of spent fish from the spawning area. This leaves the later spawners with a higher residual fecundity in the spawning area.

The method of calculating fecundity and fecundity corrected for atresia is described in section 5.3. A loss of 3.4% of the annual potential fecundity by atresia was estimated. The fecundity corrected for atresia was estimated at 1,504 eggs per gramme female with a standard error of 47.3 (standard error based on both the fecundity and the atresia data). This lower estimate of 3.4% atresia compared to the earlier estimate of 10% (Anon, 1993) is caused by the use of the geometric mean instead of the arithmetic mean to calculate the percentage atresia (see Section 5.3). The Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy used 10% for correcting the fecundity for atresia. This Working Group recommends that the value of 3.4% atresia is used to adjust the historic biomass estimates, since 10% is regarded as an overestimate.

### 5.9 Biomass Estimate of Horse Mackerel

Total stage I egg production using all data both within and beyond the 1995 standard sampling area is given in table 5.4.2. Total spawning stock biomass (SSB) was estimated using the fecundity estimate of 1,504 oocytes/gram female adjusted for 3.4% atresia (see Section 5.8), a sex ratio of 1:1 and a rasing factor of 1.05 (Eltink and Vingerhoed 1989) to convert from pre-spawning to spawning fish. This gave an estimate of SSB for 1995 of 1.71 million tonnes adjusted for atresia and with a standard error of 0.33 million tonnes. As in the case of mackerel the egg production value used to calculate SSB is considered to be a maximum value (see Section 5.7) and the same comment therefore applies to the biomass estimate.

For the purpose of comparing biomass in 1995 with historic estimates it is better to use data collected from a comparable area and time period. To this end an estimate using the 1992 standard survey area and the same start and finnish dates as in 1992, has been calculated. This gave a SSB estimate, adjusted for atreisa of 1.34 million tonnes (Table 5.4.3) with a standard error of if 0.29 million tonnes.This estimate indicates a 42% reduction in biomass compared to 1992.

| Table 5.1.1 The deployment of research vessel effort in the western mackerel/horse mackerel 1995 egg survey | | | | |
|---|---|---|---|---|
| **Period** | **Country** | **Vessel** | **Cruise dates** | **Area coverage** |
| 1 | Spain[1] (AZTI) | *Investigador* | 17 02 - 22 02 | 44°30-47°30'N |
| 3 | Spain[1] (AZTI) | *Investigador* | 23 03 - 27 03 | 44°00-47°30'N |
| | Germany | *W Herwig* | 26 03 - 12 04 | 45°30-52°00'N |
| | Spain (IEO) | *Cornide de Saavedra* | 13 04 - 14 04 | 44°00-45°00'N |
| 4 | Spain[2] (AZTI) | *Explorador* | 14 05 - 17 05 | 44°00-45°00'N |
| | Spain[2] (AZTI/IMA) | *Agorreta* | 15 05 - 17 05 | 44°00-45°00'N |
| | Spain[2] (AZTI/IMA) | *Gamin* | 17 05 | 44°00-45°00'N |
| | England | *Cirolana* | 22 04 - 17 05 | 46°30-49°00'N |
| | Scotland | *Scotia* | 23 04 - 12 05 | 45°00-58°00'N |
| 5 | England | *Cirolana* | 17 05 - 21 05 | 48°30-50°30'N |
| | Netherlands | *Tridens* | 18 05 - 31 05 | 44°00-48°30'N |
| | Ireland | *Lough Foyle* | 23 05 - 08 06 | 50°00-56°30'N |
| 6 | Spain (IEO) | *Cornide de Saavedra* | 07 06 - 16 06 | 44°00-47°00'N |
| | Netherlands | *Tridens* | 13 06 - 27 06 | 44°00-49°00'N |
| | Norway | *Johan Hjort* | 14 06 - 02 07 | 49°30-58°00'N |
| 7 | Scotland | *Heincke* | 27 06 - 16 07 | 45°00-58°00'N |

Notes: [1]Non-ICES surveys for hake eggs
[2]Non-ICES surveys for anchovy eggs

| Table 5.3.1 Sampling gears and procedures adopted during the 1995 western mackerel and horse mackerel egg surveys | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Country** | **Sampling period** | **Sampler** | | **Max depth (m)** | **Thermocline** | | **Temperature (°C)** | | **Comments** |
| | | **Type** | **Aperture diam (cm)** | | **Definition** | **Sampling strategy** | **Measured** | **Use for prod** | |
| England | 4+5 | Gulf III | 20 | 200 | Not found | N/A | Full profile | Temp at 20 m | |
| Ireland | 5 | Gulf III | 20 | 200 | 2.5°C/10 m | 200 m | Full profile | Temp at 20 m | |
| Spain (AZTI) | 1+3 | Bongo | 60 | 200 | Not found | N/A | Full profile | Temp at 20 m | |
| | 4 | Pairovet | 25 (0.05 $m^2$) | 100 | 2.5°C/10 m | 200 m | Full profile | Temp at 20 m | Double calvet net hauled vertically |
| Spain (IEO) | 3+6 | Bongo | 20 | 200 | 2.0°C/10 m | 200 m | Full profile | Temp at 20 m | Thermocline in period 6 only |
| Scotland | 4+7 | Gulf III | 19.5 | 200 | Not found | N/A | Full profile | Temp at 20 m | |
| Norway | 6 | Gulf III | 20 | 200 | 2.5°/10 m | 200 m | Full profile | Temp at 20 m | |
| Germany | 3 | Nackt-hai | 20 | 200 | Not found | N/A | Full profile | Temp at 20 m | |
| Netherlands | 5+6 | Gulf III | 19.5 | 200 | 2.5°C/10 m | 20 m below | Full profile | Temp at 20 m | |

| Table 5.4.1 Western mackerel and horse mackerel mean daily stage I egg production in 1995 ($x10^{-12}$) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Period | Dates | | | Production and standard errors | | | |
| | From | To | Midpoint | Mackerel | | Horse mackerel | |
| | | | | Prodn | se | Prodn | se |
| 1 | 17 02 | 22 02 | 19-20 02 | 0.06 | 0.02 | 0.1 | 0.1 |
| 3 | 23 03 | 14 04 | 03 04 | 8.1 | 2.2 | 3.7 | 1.5 |
| 4 | 22 04 | 17 05 | 04-05 05 | 15.0 | 3.1 | 2.0 | 0.9 |
| 5 | 17 05 | 08 06 | 28 05 | 26.3 | 5.1 | 24.2 | 9.0 |
| 6 | 07 06 | 02 07 | 19-20 06 | 5.1 | 0.8 | 13.3 | 2.8 |
| 7 | 27 06 | 16 07 | 09 07 | 1.7 | 0.1 | 8.7 | 2.7 |

Note: These data apply to the full area surveyed including some rectangles outside the 1995 standard area.

| Table 5.4.2 Western mackerel and horse mackerel total stage I egg production estimates by time period for 1995 | | | | |
|---|---|---|---|---|
| **Dates** | **Period** | **No of days** | **Annual stage 1 egg production × $10^{-15}$** | |
| | | | **Mackerel** | **Horse mackerel** |
| 10 Feb - 16 Feb | - | 7 | <0.001 | <0.001 |
| 17 Feb - 22 Feb | 1 | 6 | <0.001 | <0.001 |
| 23 Feb - 22 Mar | - | 28 | 0.092 | 0.043 |
| 23 Mar - 14 Apr | 3 | 23 | 0.187 | 0.086 |
| 15 Apr - 21 Apr | - | 7 | 0.080 | 0.020 |
| 22 Apr - 16 May | 4 | 25 | 0.375 | 0.050 |
| 17 May - 8 June | 5 | 23 | 0.605 | 0.558 |
| 9 June - 29 June | 6 | 21 | 0.107 | 0.279 |
| 30 June - 16 July | 7 | 17 | 0.032 | 0.148 |
| 17 July - 31 July | - | 15 | 0.009 | 0.042 |
| | Total | 172 | 1.487 | 1.226 |
| | se | | 0.170 | 0.232 |
| | cv | | 1.27 | 1.44 |

Note: The above egg production estimates were made using all sampled and interpolated rectangle data and assumed start and finish dates of 10 February and 31 July respectively.

**Table 5.4.3 Spawning stock biomass for western mackerel and western horse mackerel. Spawing stock biomass estimates are corrected for atresia. A sex ratio 1:1 is assumed. The spawning stock biomass was calculated from the total egg production based on arithmetic mean for unsampled rectangles if available**

| Year | Total egg prod ($x10^{-15}$) mean for unsampled rectangles | | Total fecundity (eggs/g female) | Total fecundity corrected for atresia (eggs/g female) | Pre-spawning stock biomass ($x10^{-6}$ tonnes) | Spawning stock biomass (conv f 1.08) ($x10^{-6}$ tonnes) |
|---|---|---|---|---|---|---|
| | Geom | Arithm | | | | |
| **Annual egg production method - western mackerel** | | | | | | |
| 1977 | 1.98 | | 1,457[1] | 1,329 | 2.98 | 3.22 |
| 1980 | 1.84 | | 1,457[1] | 1,329 | 2.77 | 2.99 |
| 1983 | 1.50 | 1.53 | 1,457[1] | 1,329 | 2.30 | 2.49 |
| 1986 | 1.15 | 1.24 | 1,457[1] | 1,329 | 1.86 | 2.01 |
| 1989 | 1.45 | 1.52 | 1,608[2] | 1,467 | 2.07 | 2.24 |
| 1992 | 1.83 | 1.94 | 1,569 | 1,431 | 2.71 | 2.93 |
| 1995[3] | - | 1.27 | 1,473 | 1,302 | 1.95 | 2.10 |
| Year | Total egg prod ($x10^{-15}$) mean for unsampled rectangles | | Total fecundity (eggs/g female) | Total fecundity corrected for atresia (eggs/g female) | Pre-spawning stock biomass ($x10^{-6}$ tonnes) | Spawning stock biomass (conv f 1.05) ($x10^{-6}$ tonnes) |
| | Geom | Arithm | | | | |
| **Annual egg production method - western horse mackerel** | | | | | | |
| 1977 | 0.533[4] | | 1,589 | 1,430 | 0.75 | 0.78 |
| 1980 | 0.635[4] | | 1,589 | 1,430 | 0.89 | 0.93 |
| 1983 | 0.381[4] | | 1,589 | 1,430 | 0.53 | 0.56 |
| 1986 | 0.508[4] | | 1,589 | 1,430 | 0.71 | 0.75 |
| 1989 | 1.54 | 1.63 | 1,589 | 1,430 | 2.28 | 2.39 |
| 1992 | 1.37 | 1.58 | 1,589 | 1,430 | 2.21 | 2.32 |
| 1995[3] | - | 0.96 | 1,557 | 1,504 | 1.27 | 1.34 |

[1]from Anon (1987), page 3
[2]from Anon (199a)
[3]Estimate using only rectangles within 1992 standard survey area and a survey period similar to 1992
[4]Eaton (1989). I|n 1977 incomplete coverage
[5]Fecundity estimate from Eltink and Vingerhoed (WD 1993)

| Table 5.5.1 Parameters of the fecundity-length and fecundity-weight equation for mackerel in 1989, 1992 and 1995 | | | | | |
|---|---|---|---|---|---|
| **Relationship** | **Year** | **Intercept** | **Slope** | **N** | **R** |
| Fecundity-length (mm) (Ln transformed) | 1989 | -10.6050 | 4.0386 | 100 | 0.93 |
| | 1992 | -13.5589 | 4.5347 | 79 | 0.93 |
| | 1995 | -9.2772 | 3.8049 | 95 | 0.85 |
| Fecundity-weight (g) | 1989 | -67725 | 1777 | 97 | 0.93 |
| | 1992 | -170987 | 2050 | 79 | 0.92 |
| | 1995 | -37755 | 1577 | 95 | 0.84 |

| Table 5.5.2 Relationship of oocytes per gramme female and total weight and the conversion factor used to estimate mackerel biomass in 1989, 1992 and 1995 | | | | | | |
|---|---|---|---|---|---|---|
| **Year** | **Intercept** | **Factor** | **N** | **R** | **Biomass conversion** | **SE** |
| 1989 | 1370 | 0.4880 | 97 | 0.27 | 1608 | |
| 1992 | 1092 | 1.1919 | 79 | 0.49 | 1569 | 36 |
| 1995 | 1345 | 0.3207 | 95 | 0.14 | 1473 | 29 |

**Table 5.5.3 Details of the ships, sample dates and positions used to collect atresia samples. The number of spawning fish (identified by the presence of any one of the following histological stages migratory nuclei or hydrated oocytes and post ovulatory follicles) selected for estimation of population atresia are also shown tabulated by station where available.**

| Vessel | Date | STN | Position | | Number of fish selected |
|---|---|---|---|---|---|
| | | | North | West | |
| *Walther Herwig* | 26 March - 12 April | | 50.4-47.2 | 3.5-11.2 | 48 |
| *Scotia* | 28 April | 119 | 51.1 | 11.1 | 19 |
| | 29 April | 120 | 50.2 | 9.3 | 20 |
| | 30 April | 121 | 48.2 | 16.1 | 15 |
| | 1 May | 122 | 45.5 | 3.4 | 5 |
| *Lough Foyle* | 24 May | 5-6 | 50.2 | 10.3 | 11 |
| | 24 May | 7 | 50.1 | 11.5 | 7 |
| | 26 May | 23 | 51.4 | 14.2 | 6 |
| | 30 May | 41 | 52.2 | 14.4 | 4 |
| *Tridens* | 31 May | | 47.4 | 6.4 | 54 |
| *Lough Foyle* | 5 June | 75 | 53.5 | 12.5 | 5 |
| | 5 June | 77 | 53.5 | 11.5 | 5 |
| | 7 June | 94 | 55.2 | 9.4 | 5 |
| *Johan Hjort* | 15 June | 284 | 55.5 | 9.2 | 23 |
| | 19 June | 285 | 53.2 | 13.2 | 29 |
| *Tridens* | 23 June | | 48.1 | 6.5 | 8 |
| *Johan Hjort* | 25 June | 287 | 49.45 | 11.15 | 7 |
| *Tridens* | 26 June | | 48.45 | 8.49 | 10 |
| | 27 June | | 49.14 | 8.16 | 12 |
| *Heinke* | 29 June | 1 | 54.17 | 11.09 | 1 |
| | 1 July | 2 | 54.17 | 11.09 | 1 |
| *Johan Hjort* | 7 July | 288 | 53.4 | 11.1 | 20 |
| *Heinke* | 10 July | 6 | 52.0 | 8.2 | 18 |

**Table 5.5.4** **A comparison of atresia estimates made by MAFF and Aberdeen University tabulated by month showing the number of sample analysed (n), the prevalence (p) and geometric mean relative intensity GM(i/w) of early α atresia raised to calculate the total spawning production of atretic oocytes(A = GM(i/w)*p/d with the standard error SE calculated by a bootstrap variance approach.**

| Month | MAFF | | | | | University | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | n | p | $GM\left[\frac{i}{w}\right]$ | $GM\left[\frac{i}{w}\right]\frac{p}{d}$ | se | n | p | $GM\left[\frac{i}{w}\right]$ | $GM\left[\frac{i}{w}\right]\frac{p}{d}$ | se |
| April | 46 | 0.239 | 39.2 | 1.25 | 0.41 | 58 | 0.328 | 69.4 | 3.03 | 1.01 |
| May | 24 | 0.542 | 41.3 | 2.98 | 0.81 | 56 | 0.464 | 130.7 | 8.09 | 2.21 |
| June | 15 | 0.133 | 29.3 | 0.52 | 0.35 | 85 | 0.106 | 175.3 | 2.47 | 0.97 |
| July | 5 | 0.600 | 33.1 | 2.65 | 2.05 | 34 | 0.147 | 125.7 | 2.46 | 1.63 |

**Table 5.8.1** The length, weight, annual potential fecundity and its standard error, and the number of atretic oocytes and its standard error from 12 western horse mackerel collected by RV "Walther Herwig" in April 1995 (period 3) and 18 fish collected by RV "Scotia" in May 1995 (period 4). The annual potential fecundities do not include the number of atretic oocytes.
AM = arithmetic mean.

## Annual potential fecundity estimates (period 3)

| Length (cm) | Fish weight (g) | Annual potential fecundity (vitell. oocytes) | SE fecundity | Number of atretic oocytes | SE atresia |
|---|---|---|---|---|---|
| 26 | 145 | 105,189 | 6,740 | 14,089 | 2,285 |
| 27 | 165 | 168,639 | 8,484 | 9,997 | 2,812 |
| 27 | 180 | 197,452 | 19,750 | 0 | 0 |
| 29 | 190 | 200,596 | 15,569 | 0 | 0 |
| 29 | 195 | 199,742 | 14,177 | 22,571 | 2,357 |
| 30 | 230 | 251,801 | 17,864 | 0 | 0 |
| 30 | 270 | 250,239 | 14,735 | 0 | 0 |
| 32 | 310 | 402,943 | 15,892 | 6,956 | 3,312 |
| 32 | 315 | 304,093 | 11,936 | 16,842 | 5,339 |
| 33 | 300 | 411,965 | 19,199 | 1,972 | 1,909 |
| 32 | 310 | 380,630 | 15,570 | 22,430 | 5,239 |
| 38 | 465 | 619,161 | 33,783 | 26,552 | 6,815 |
| **AM** | **256** | **291,038** | | **10,117** | |

## Annual potential fecundity estimates (period 4)

| Length (cm) | Fish weight (g) | Annual potential fecundity (vitell. oocytes) | SE fecundity | Number of atretic oocytes | SE atresia |
|---|---|---|---|---|---|
| 25 | 130 | 169,848 | 15,479 | 13,675 | 3,752 |
| 27 | 157 | 195,587 | 11,938 | 968 | 716 |
| 28 | 168 | 285,466 | 16,283 | 1,929 | 1,167 |
| 28 | 179 | 203,204 | 21,998 | 4,687 | 3,125 |
| 28 | 189 | 288,957 | 20,767 | 0 | 0 |
| 29 | 168 | 184,753 | 7,363 | 34,609 | 3,765 |
| 29 | 209 | 312,905 | 10,984 | 780 | 480 |
| 30 | 215 | 327,688 | 12,375 | 3,387 | 1,514 |
| 30 | 218 | 352,389 | 29,781 | 0 | 0 |
| 30 | 226 | 425,661 | 5,295 | 2,129 | 2,076 |
| 31 | 220 | 291,207 | 16,320 | 0 | 0 |
| 31 | 236 | 288,160 | 22,520 | 2,517 | 2,453 |
| 31 | 261 | 315,922 | 18,920 | 2,966 | 1,537 |
| 32 | 245 | 354,024 | 19,757 | 19,054 | 4,835 |
| 33 | 306 | 517,924 | 30,631 | 5,643 | 2,621 |
| 35 | 314 | 412,002 | 27,672 | 0 | 0 |
| 37 | 460 | 724,381 | 25,921 | 29,548 | 9,546 |
| 38 | 449 | 642,022 | 37,668 | 80,722 | 16,640 |
| AM | 242 | 349,561 | | 11,256 | |

**Table 5.8.2** The length, weight, residual fecundity and its standard error, and the number of atretic oocytes and its standard error from western horse mackerel collected from the third to the seventh period of the 1995 Mackerel / Horse Mackerel Egg Surveys.
AM = Arithmetic mean; GM = Geometic mean.

**Atresia estimates from period 3**

| Length (cm) | Fish weight (g) | Residual fecundity (vitell. oocytes) | SE fecundity | Number of atretic oocytes | SE atresia | No of atretic oocytes/g |
|---|---|---|---|---|---|---|
| 26 | 145 | 105,189 | 6,740 | 14,089 | 2,285 | 97 |
| 27 | 165 | 168,639 | 8,484 | 9,997 | 2,632 | 61 |
| 27 | 180 | 197,452 | 19,750 | | | |
| 29 | 190 | 200,596 | 15,569 | | | |
| 29 | 195 | 199,742 | 14,177 | 22,571 | 2,357 | 116 |
| 30 | 230 | 251,801 | 17,864 | | | |
| 30 | 270 | 211,502 | 17,394 | | | |
| 31 | 270 | 250,239 | 14,735 | | | |
| 32 | 310 | 402,943 | 15,892 | 6,956 | 3,312 | 22 |
| 32 | 315 | 304,093 | 11,936 | 16,842 | 5,339 | 53 |
| 32 | 375 | 310,538 | 13,168 | 17,734 | 6,744 | 47 |
| 33 | 300 | 411,965 | 19,199 | | | |
| 34 | 310 | 380,630 | 15,570 | 22,430 | 5,239 | 72 |
| 34 | 340 | 314,703 | 18,438 | 1,095 | 1,176 | 3 |
| 36 | 395 | 426,019 | 25,436 | 37,446 | 10,070 | 95 |
| 36 | 495 | 555,703 | 63,647 | 13,380 | 4,689 | 27 |
| 38 | 465 | 619,161 | 33,783 | 26,552 | 6,815 | 57 |
| 38 | 510 | 527,536 | 59,737 | 44,470 | 9,339 | 87 |
| **AM** | **303** | **324,358** | **AM** | **19,464** | **GM** | **47** |

**Atresia estimates from period 4**

| Length (cm) | Fish weight (g) | Residual fecundity (vitell. oocytes) | SE fecundity | Number of atretic oocytes | SE atresia | No of atretic oocytes/g |
|---|---|---|---|---|---|---|
| 25 | 130 | 169,848 | 15,479 | 13,675 | 3,752 | 105 |
| 26 | 138 | 142,249 | 8,957 | 352 | 413 | 3 |
| 27 | 157 | 195,587 | 11,938 | 968 | 716 | 6 |
| 28 | 168 | 285,466 | 16,283 | | | |
| 28 | 174 | 86,076 | 5,603 | 824 | 803 | 5 |
| 28 | 179 | 203,204 | 21,998 | 4,687 | 3,125 | 26 |
| 28 | 189 | 288,957 | 20,767 | | | |
| 29 | 168 | 184,753 | 7,363 | 34,609 | 3,765 | 206 |
| 29 | 188 | 230,018 | 27,674 | | | |
| 29 | 209 | 312,905 | 10,984 | 780 | 480 | 4 |
| 30 | 215 | 327,688 | 12,375 | 3,387 | 1,514 | 16 |
| 30 | 218 | 352,389 | 29,781 | | | |
| 30 | 226 | 425,661 | 18,795 | 2,129 | 2,076 | 9 |
| 31 | 220 | 291,207 | 16,320 | | | |
| 31 | 236 | 288,160 | 22,520 | 2,517 | 2,453 | 11 |
| 31 | 239 | 235,497 | 17,622 | 2,795 | 1,512 | 12 |
| 31 | 261 | 315,922 | 18,920 | 2,966 | 1,537 | 11 |
| 31 | 261 | 318,145 | 12,926 | | | |
| 32 | 245 | 354,024 | 19,757 | 19,054 | 4,835 | 78 |
| 33 | 167 | 163,826 | 13,164 | 2,415 | 2,312 | 14 |
| 33 | 258 | 203,730 | 9,739 | 7,070 | 1,959 | 27 |
| 33 | 282 | 297,903 | 19,733 | 34,295 | 4,640 | 122 |
| 33 | 306 | 517,924 | 30,631 | 5,643 | 2,621 | 18 |
| 34 | 291 | 277,704 | 19,405 | 92,038 | 12,626 | 316 |
| 35 | 314 | 412,002 | 27,672 | | | |
| 37 | 460 | 724,381 | 25,921 | 29,548 | 9,546 | 64 |
| 38 | 438 | 428,500 | 25,200 | | | |
| 38 | 449 | 642,022 | 37,668 | 80,722 | 16,640 | 180 |
| AM | 242 | 309,848 | AM | 17,024 | GM | 25 |

Table 5.8.2 Continued

## Atresia estimates from period 5

| Length (cm) | Fish weight (g) | Residual fecundity (vitell. oocytes) | SE fecundity | Number of atretic oocytes | SE atresia | No of atretic oocytes/g |
|---|---|---|---|---|---|---|
| 23 | 96 | 70,728 | 4,370 | | | |
| 23 | 94 | 70,033 | 4,366 | | | |
| 24 | 108 | 71,136 | 22,473 | 1,709 | 681 | 16 |
| 25 | 130 | 120,423 | 7,298 | 4,373 | 2,580 | 34 |
| 25 | 120 | 51,332 | 1,801 | | | |
| 26 | 162 | 137,700 | 5,210 | | | |
| 26 | 142 | 105,406 | 6,429 | 272 | 296 | 2 |
| 26 | 162 | 138,984 | 5,563 | 3,260 | 2,111 | 20 |
| 26 | 128 | 137,192 | 11,632 | | | |
| 26 | 144 | 89,307 | 6,527 | | | |
| 27 | 142 | 160,835 | 12,690 | 1,340 | 840 | 9 |
| 27 | 146 | 74,642 | 6,971 | 6,448 | 1,325 | 44 |
| 27 | 156 | 154,862 | 14,602 | 6,411 | 2,649 | 41 |
| 27 | 144 | 116,548 | 11,301 | | | |
| 27 | 170 | 67,003 | 6,728 | 1,695 | 282 | 10 |
| 28 | 162 | 212,208 | 10,487 | 13,622 | 89,883 | 84 |
| 28 | 166 | 218,565 | 7,809 | | | |
| 28 | 172 | 163,369 | 11,716 | | | |
| 29 | 210 | 124,448 | 6,413 | | | |
| 31 | 206 | 175,378 | 11,711 | | | |
| **AM** | **148** | **123,005** | **AM** | **4,348** | **GM** | **19** |

## Atresia estimates from period 6

| Length (cm) | Fish weight (g) | Residual fecundity (vitell. oocytes) | SE fecundity | Number of atretic oocytes | SE atresia | No of atretic oocytes/g |
|---|---|---|---|---|---|---|
| 23 | 98 | 53,948 | 3,892 | 737 | 630 | 8 |
| 23 | 108 | 79,043 | 5,457 | 7,401 | 1,304 | 69 |
| 23 | 112 | 55,053 | 4,756 | 562 | 439 | 5 |
| 23 | 110 | 74,110 | 5,955 | 4,760 | 1,564 | 43 |
| 24 | 106 | 27,309 | 3,487 | | | |
| 24 | 106 | 44,681 | 3,373 | | | |
| 24 | 124 | 72,267 | 4,779 | | | |
| 24 | 106 | 63,799 | 4,764 | | | |
| 25 | 126 | 63,377 | 3,678 | | | |
| 25 | 130 | 106,035 | 6,943 | 2,035 | 1,067 | 16 |
| 26 | 132 | 88,679 | 3,299 | 1,594 | 993 | 12 |
| 26 | 148 | 80,266 | 4,402 | | | |
| 26 | 128 | 124,916 | 10,736 | 5,844 | 2,080 | 46 |
| 26 | 140 | 37,740 | 2,158 | 25,008 | 4,616 | 179 |
| 26 | 146 | 121,835 | 9,528 | | | |
| 27 | 154 | 59,493 | 4,077 | | | |
| 28 | 166 | 147,700 | 8,649 | 1,276 | 744 | 8 |
| 28 | 180 | 206,319 | 8,449 | 9,437 | 1,882 | 52 |
| 28 | 200 | 152,385 | 7,483 | 25,543 | 2,960 | 128 |
| 29 | 190 | 107,086 | 10,084 | 65,156 | 3,809 | 343 |
| 29 | 192 | 117,984 | 8,703 | 14,145 | 3,818 | 74 |
| 29 | 188 | 99,200 | 4,271 | 816 | 452 | 4 |
| 30 | 198 | 161,306 | 8,003 | 404 | 393 | 2 |
| 30 | 224 | 216,347 | 10,768 | | | |
| 31 | 218 | 53,799 | 2,110 | 57,820 | 6,661 | 265 |
| 32 | 254 | 162,487 | 9,453 | 4,782 | 1,285 | 19 |
| 33 | 326 | 193,949 | 7,325 | | | |
| 37 | 402 | 344,540 | 28,915 | | | |
| AM | 168 | 111,273 | AM | 13,372 | GM | 30 |

Table 5.8.2 Continued

**Atresia estimates from period 7**

| Length (cm) | Fish weight (g) | Residual fecundity (vitell. oocytes) | SE fecundity | Number of atretic oocytes | SE atresia | No of atretic oocytes/g |
|---|---|---|---|---|---|---|
| 25 | 130 | 140,249 | 5,531 | | | |
| 25 | 146 | 112,809 | 9,116 | | | |
| 26 | 142 | 66,461 | 3,469 | | | |
| 26 | 156 | 208,976 | 15,966 | 1,257 | 1,225 | 8 |
| 26 | 156 | 170,032 | 9,982 | | | |
| 26 | 166 | 198,724 | 8,767 | | | |
| 27 | 162 | 195,900 | 13,312 | 11,060 | 9,392 | 68 |
| 27 | 171 | 191,084 | 16,842 | | | |
| 27 | 171 | 136,482 | 8,681 | | | |
| 27 | 172 | 103,005 | 7,170 | 31,209 | 7,114 | 181 |
| 27 | 173 | 212,373 | 25,468 | 5,141 | 1,872 | 30 |
| 27 | 180 | 193,695 | 12,328 | 2,986 | 1,436 | 17 |
| 27 | 281 | 106,631 | 7,475 | | | |
| 28 | 164 | 128,344 | 3,435 | | | |
| 28 | 170 | 115,838 | 6,153 | 502 | 488 | 3 |
| 28 | 172 | 157,216 | 7,027 | | | |
| 28 | 182 | 197,299 | 10,781 | 2,414 | 1,820 | 13 |
| 28 | 182 | 141,886 | 7,061 | 42,964 | 3,500 | 236 |
| 28 | 187 | 124,864 | 7,235 | | | |
| 28 | 191 | 262,976 | 16,114 | | | |
| 28 | 195 | 152,866 | 8,920 | | | |
| 28 | 196 | 192,935 | 12,062 | | | |
| 28 | 196 | 170,255 | 10,139 | | | |
| 28 | 200 | 192,519 | 15,390 | | | |
| 29 | 171 | 112,592 | 10,174 | 81,897 | 4,014 | 479 |
| 29 | 185 | 179,943 | 15,174 | | | |
| 29 | 191 | 163,886 | 9,553 | 1,569 | 726 | 8 |
| 29 | 198 | 209,977 | 11,010 | 872 | 588 | 4 |
| 29 | 221 | 310,599 | 13,177 | | | |
| 29 | 224 | 235,681 | 13,772 | 3,007 | 2,923 | 13 |
| **AM** | **181** | **169,537** | **AM** | **15,407** | **GM** | **26** |

**Table 5.8.3** The number of atretic oocytes per gramme female horse mackerel in the population during the third to seventh survey coverage as obtained from the fraction of females with atresia and the number of atretic oocytes per gramme female with atresia. The proportion of residual fecundity compared to annual potential fecundity and relative intensity are also shown.

| Survey period | Prevalence of atresia # (%) | No of fish for scoring prevalence | No of atretic oocytes/g female with atresia | No of fish for counting atresia | No of atretic oocytes/g female **in the population** | Standard error (SE) | Relative intensity of atresia * (%) | Residual fecundity compared to total fecundity (%) |
|---|---|---|---|---|---|---|---|---|
| 3 @ | (54%) @ | (87) @ | (47) @ | (12) @ | (25) @ | (7.4) @ | (1.6%) @ | (69%) @ |
| 4 | 49% | 45 | 25 | 20 | 12 | 4.7 | 0.8% | 82% |
| 5 | 43% | 54 | 19 | 9 | 8 | 3.5 | 0.5% | 53% |
| 6 | 45% | 47 | 30 | 17 | 13 | 5.7 | 0.9% | 42% |
| 7 | 43% | 49 | 26 | 12 | 11 | 6.9 | 0.7% | 60% |
| **4-7** | 45% | 195 | **27** | 58 | **12** | | | |

# = fraction of fish with atresia (in %)
* = number of atretic oocytes divided by predicted total fecundity (in %)
@ = no ovary sample of 90 randomly taken adult females, but information obtained from the fecundity sample

**Figure 5.2.1a** Standard sampling area for western mackerel and horse mackerel egg survey in 1995

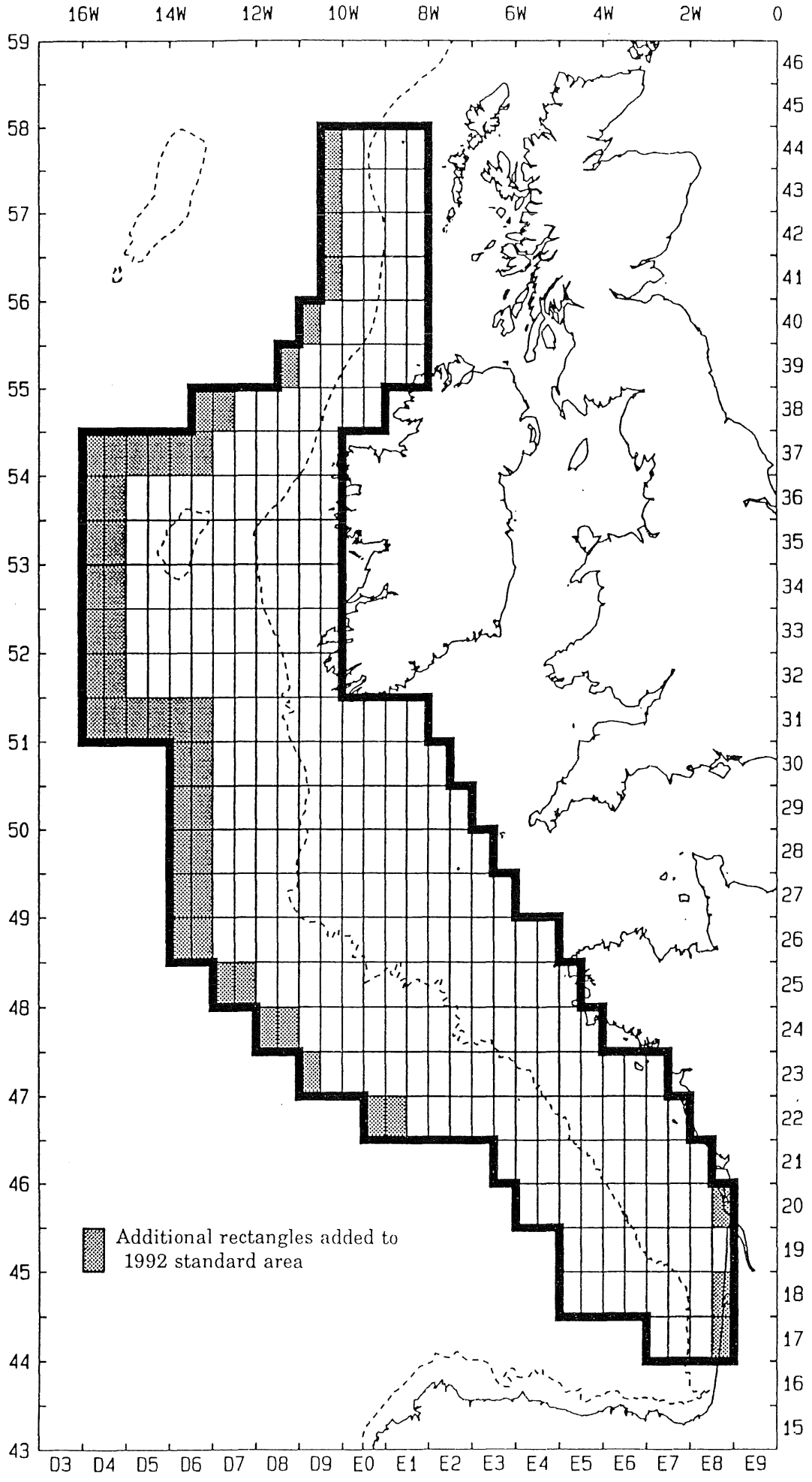


**Figure 5.2.1b** Period 1 No. of obs per rectangle from 170295 220295

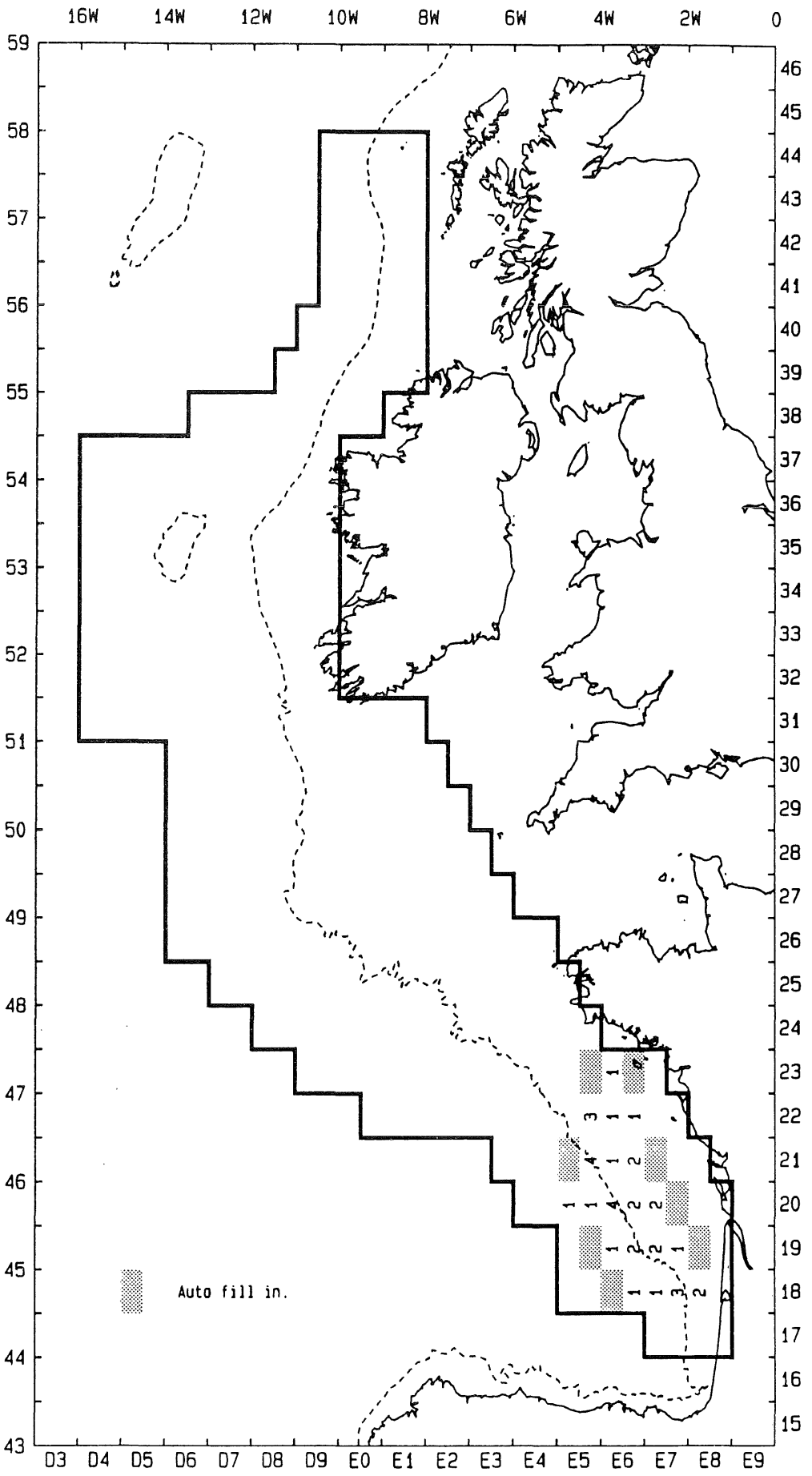


**Figure 5.2.1c** Period 3 No. of obs per rectangle from 230395 to 140495

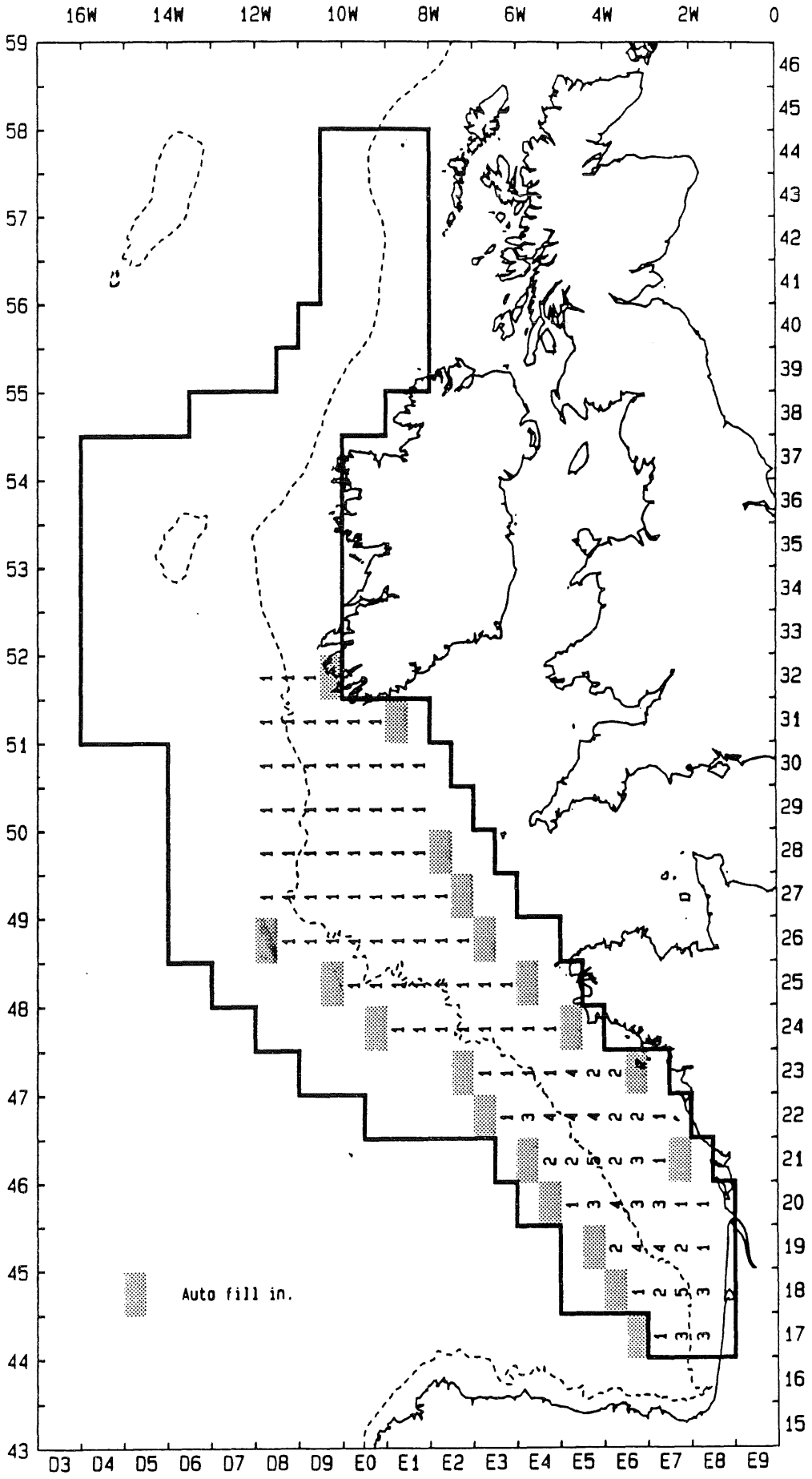


**Figure 5.2.1d** Period 4 No. of obs per rectangle from 220495 to 170595

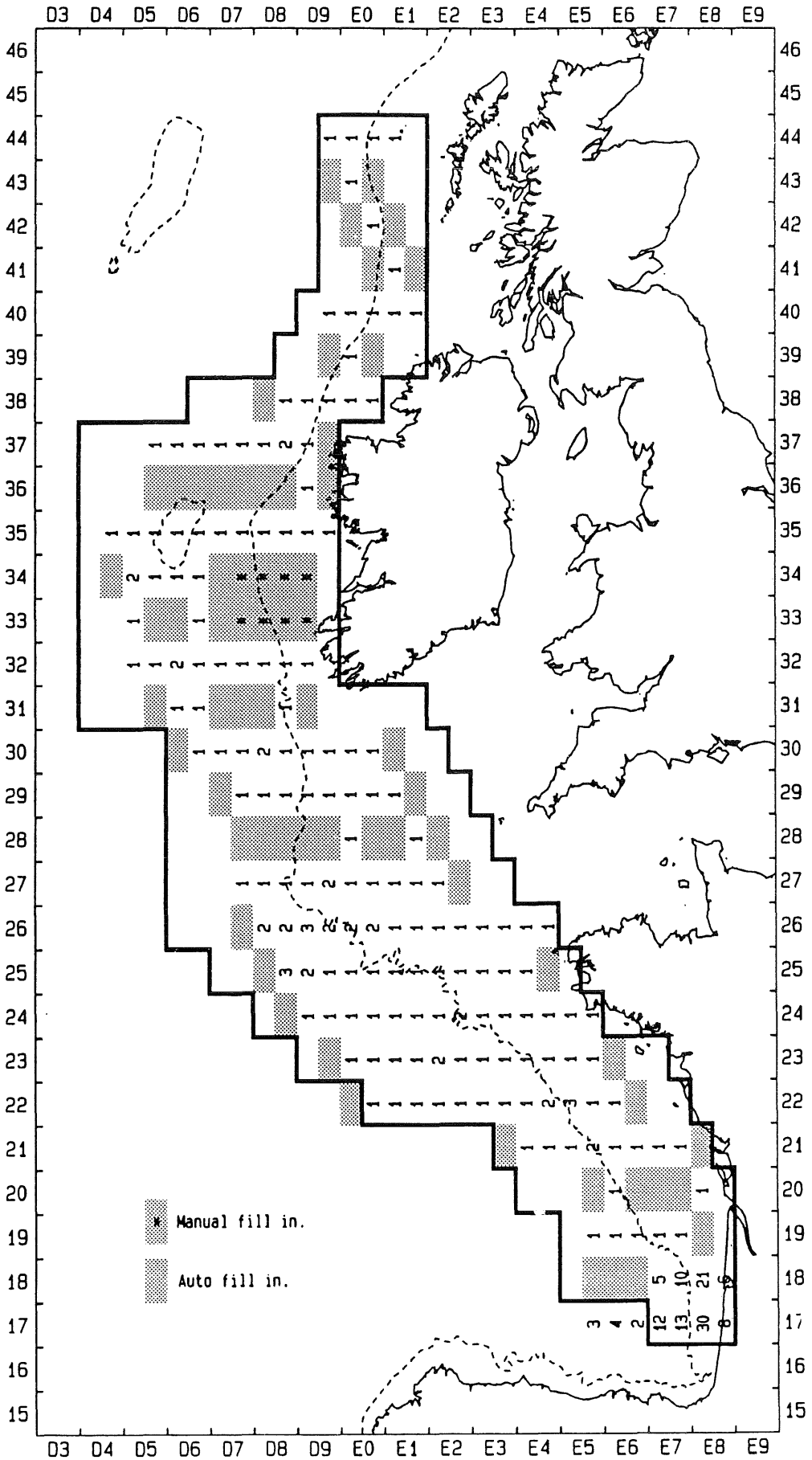


**Figure 5.2.1e** Period 5 No. of obs per rectangle from 170595 to 080695

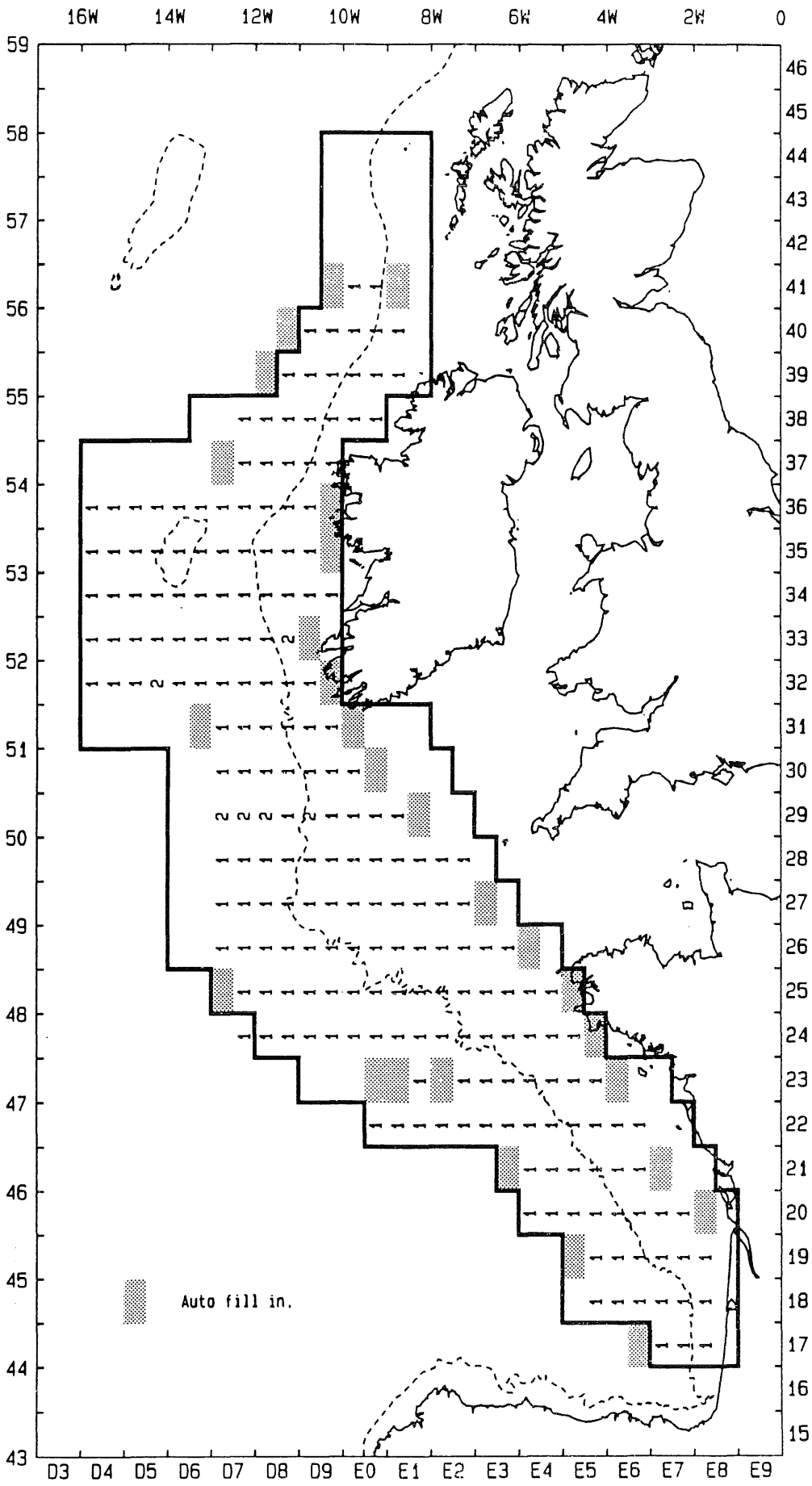


**Figure 5.2.1f** Period 6 No. of obs per rectangle from 070695 to 020795

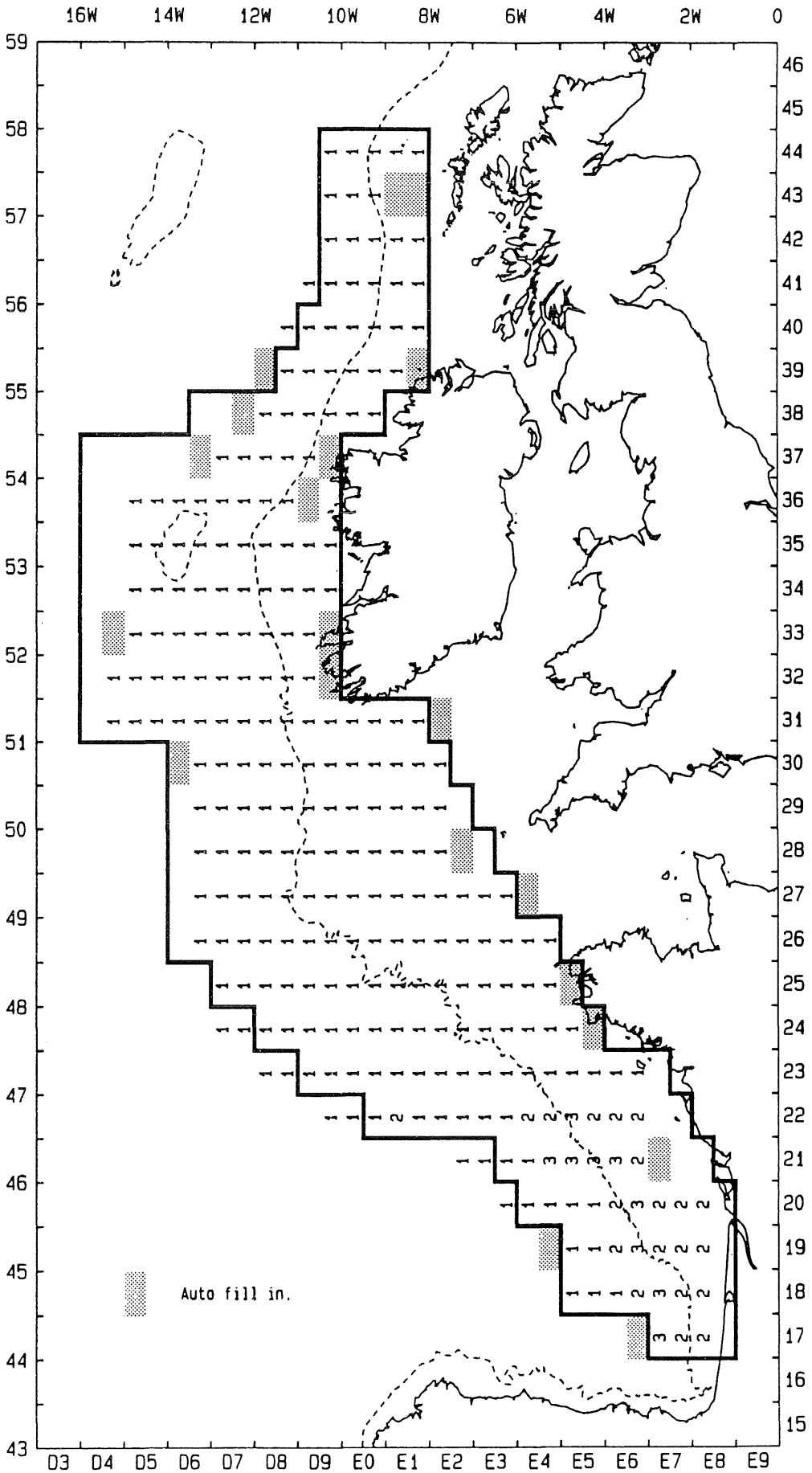


**Figure 5.2.1g** Period 7 No. of obs per rectangle from 270695 to 160795

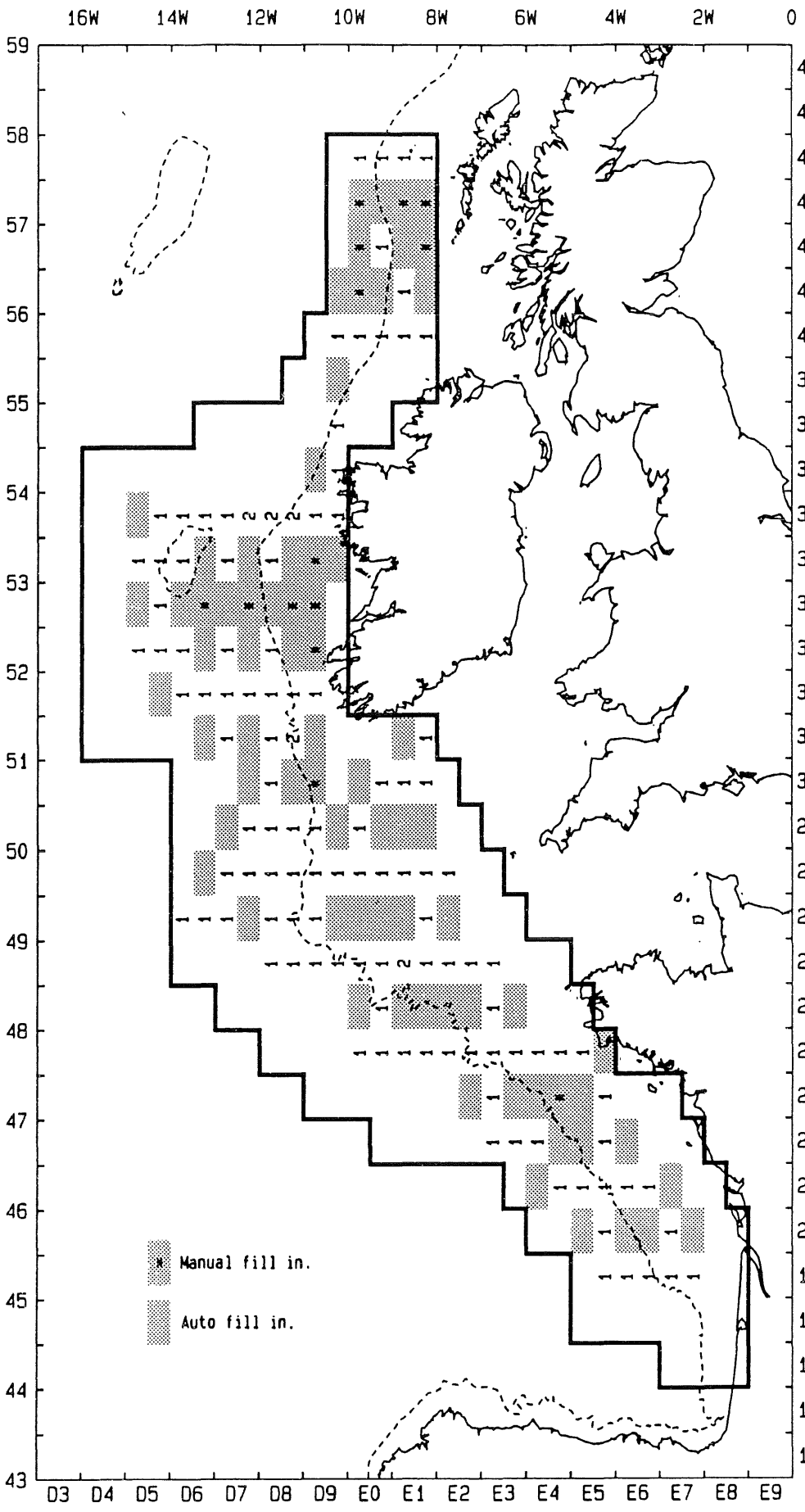


**Figure 5.4a**
Note: Production 'curve' produced using data from all sampled + interpolated rectangles and assumed start and finish date for spawning of 10 February and 13 July respectively.

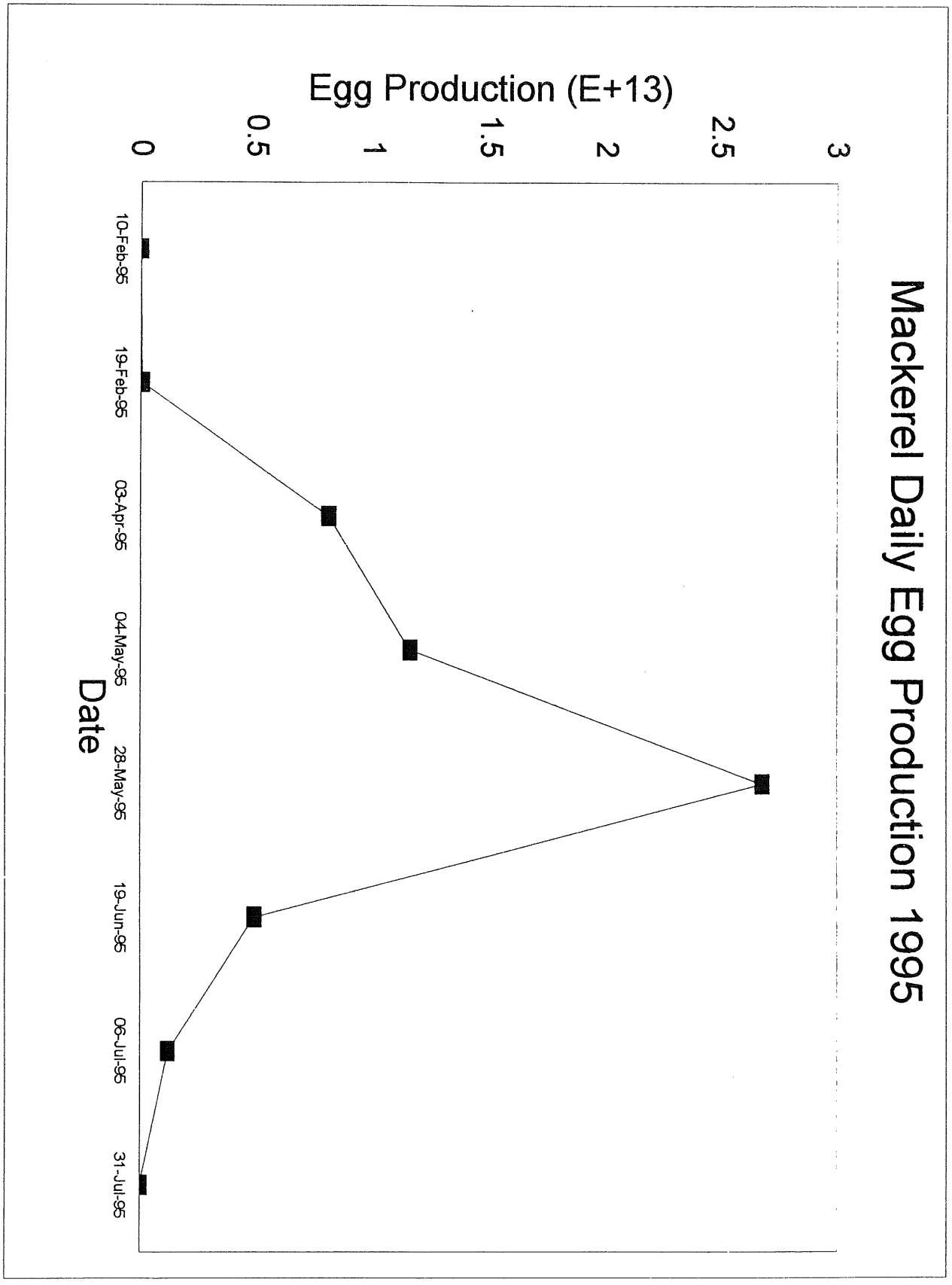
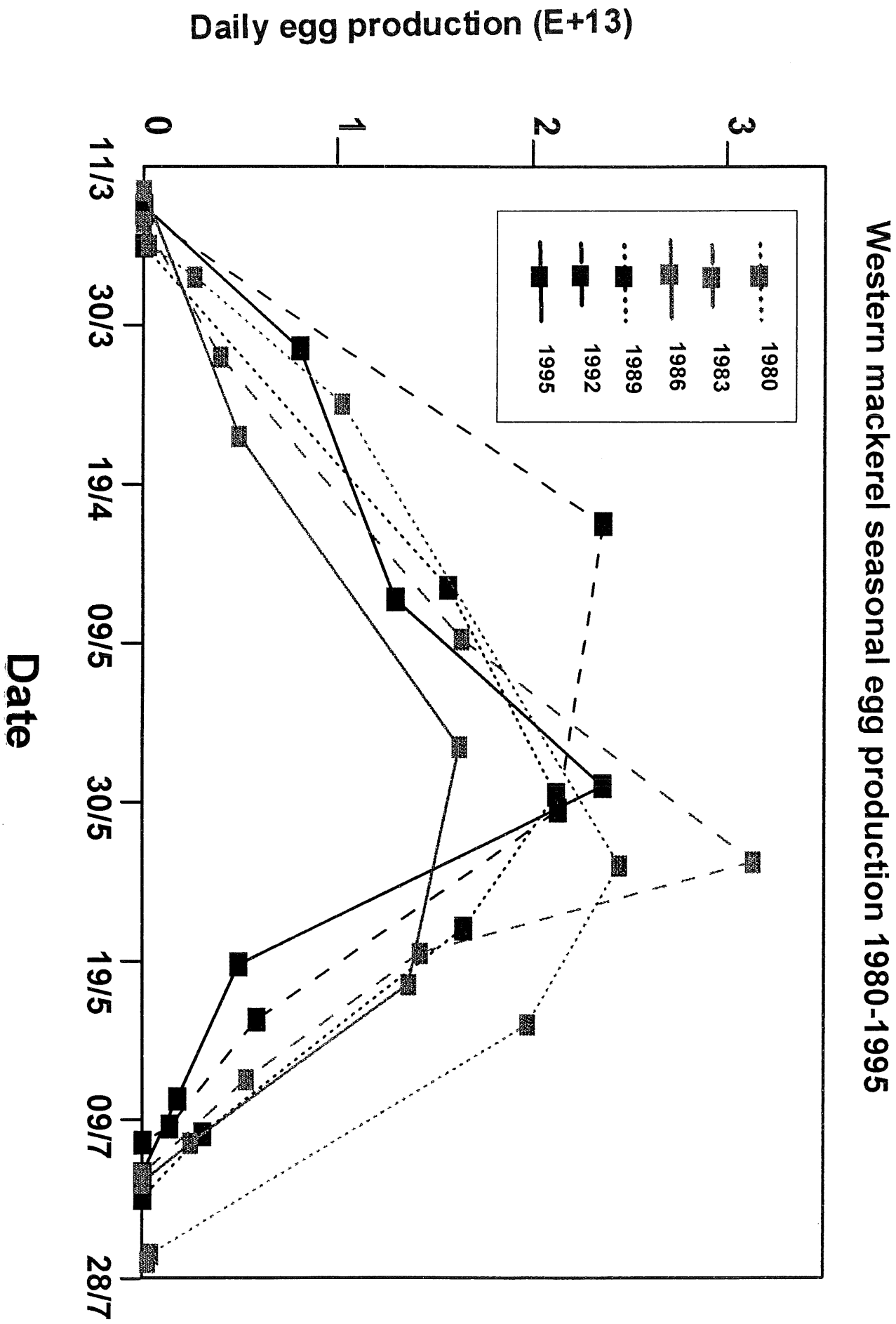


**Figure 5.4b**

Note: Production 'curves' for 1980 - 89 used geometric means for interpolated rectangles. For 1992 & 1995 arithmetic means were used. The 1995 'curve' uses values derived from data within the 1992 standard survey area and the same start and finish dates of spawning as for 1992.



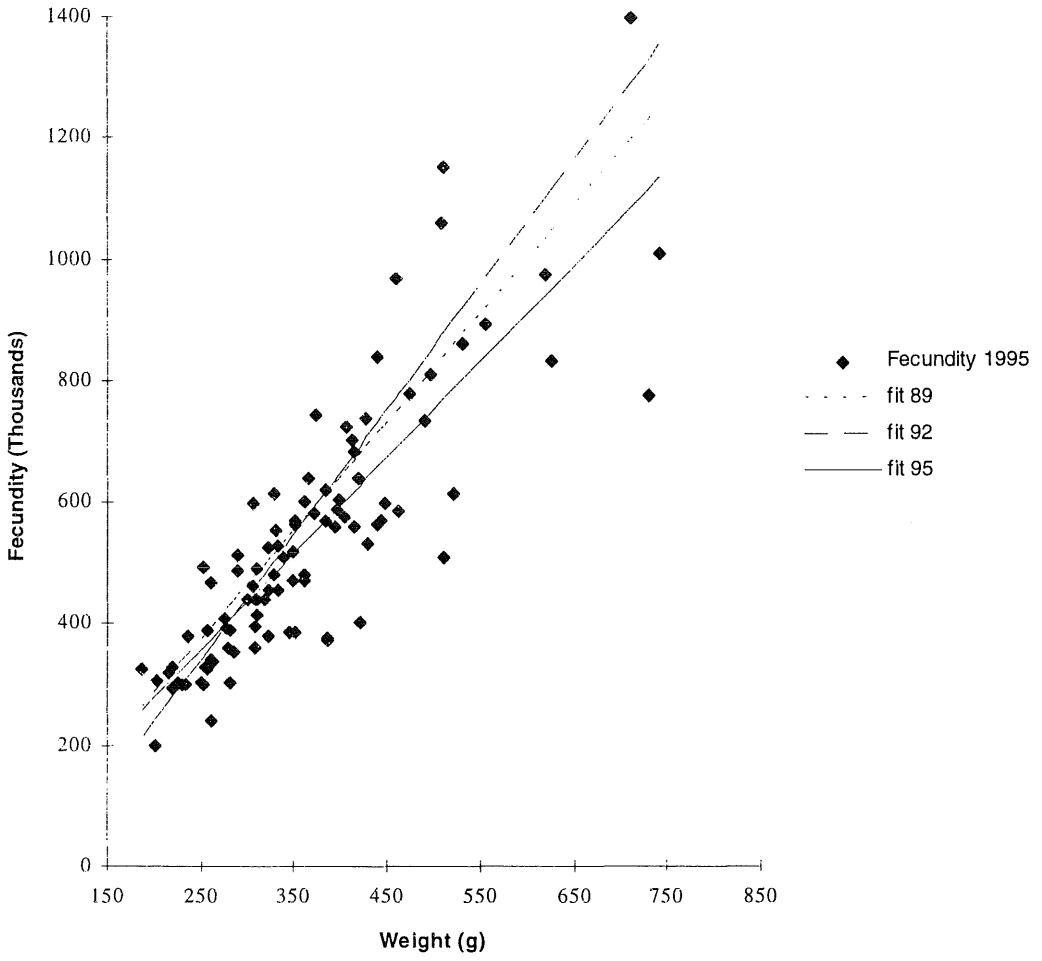



**Figure 5.5a** The total potential annual fecundity-total weight relationship for mackerel collected as part of the triennial mackerel spawning stock estimates since 1989. The data for 1995 is plotted with the fitted regressions from the equation a = mx+ c where a is fecundity, x is total fish weight m is 1777, 2050, 1577 and c is -67725, -170987, -37755 for 1989, 1992 and 1995 respectively.

**Figure 5.7a**
Note: Production 'curve' was produced using data from all sampled + interpolated rectangles and assumed start and finish dates for spawning of 10 February and 13 July respectively.

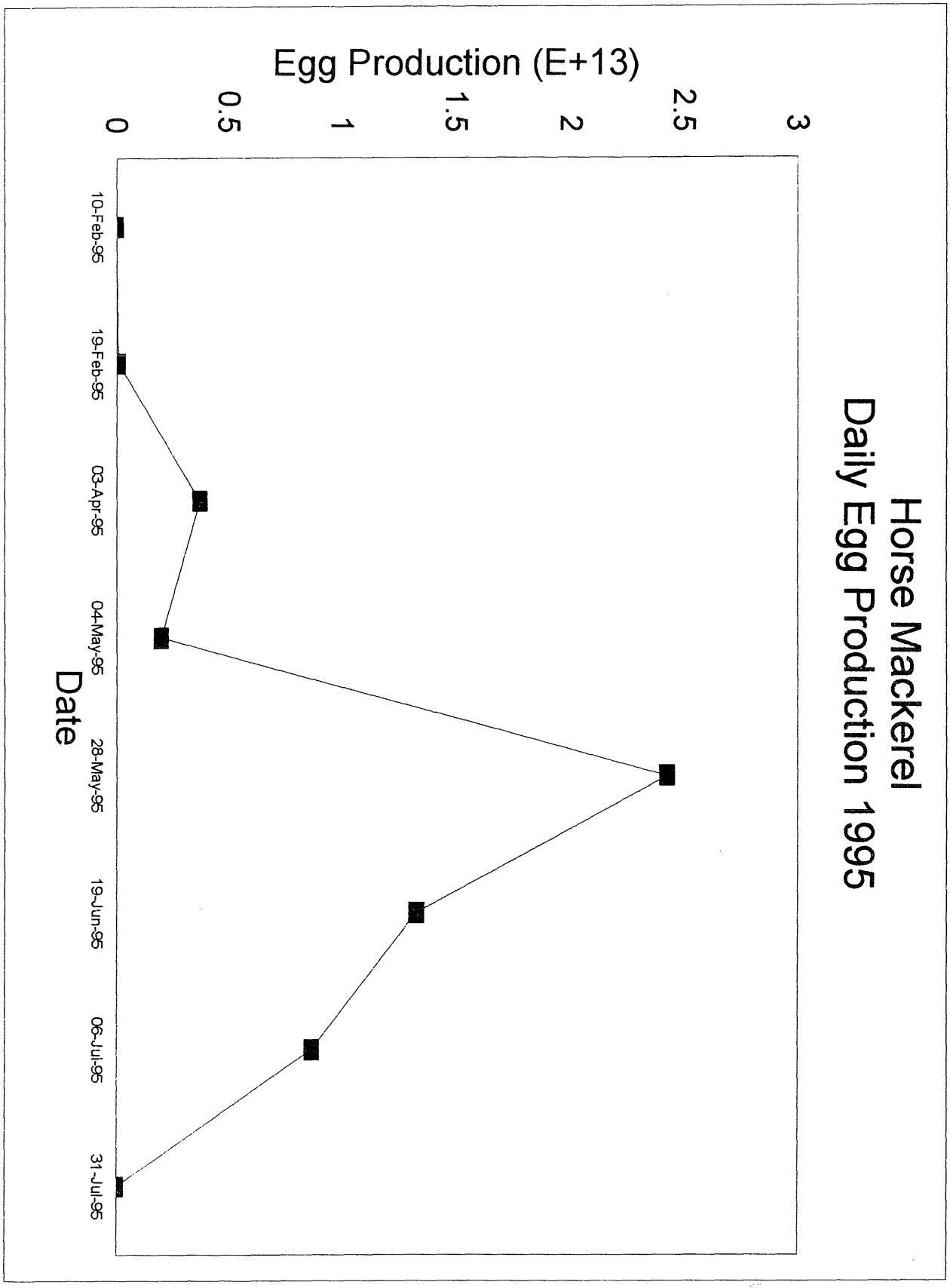
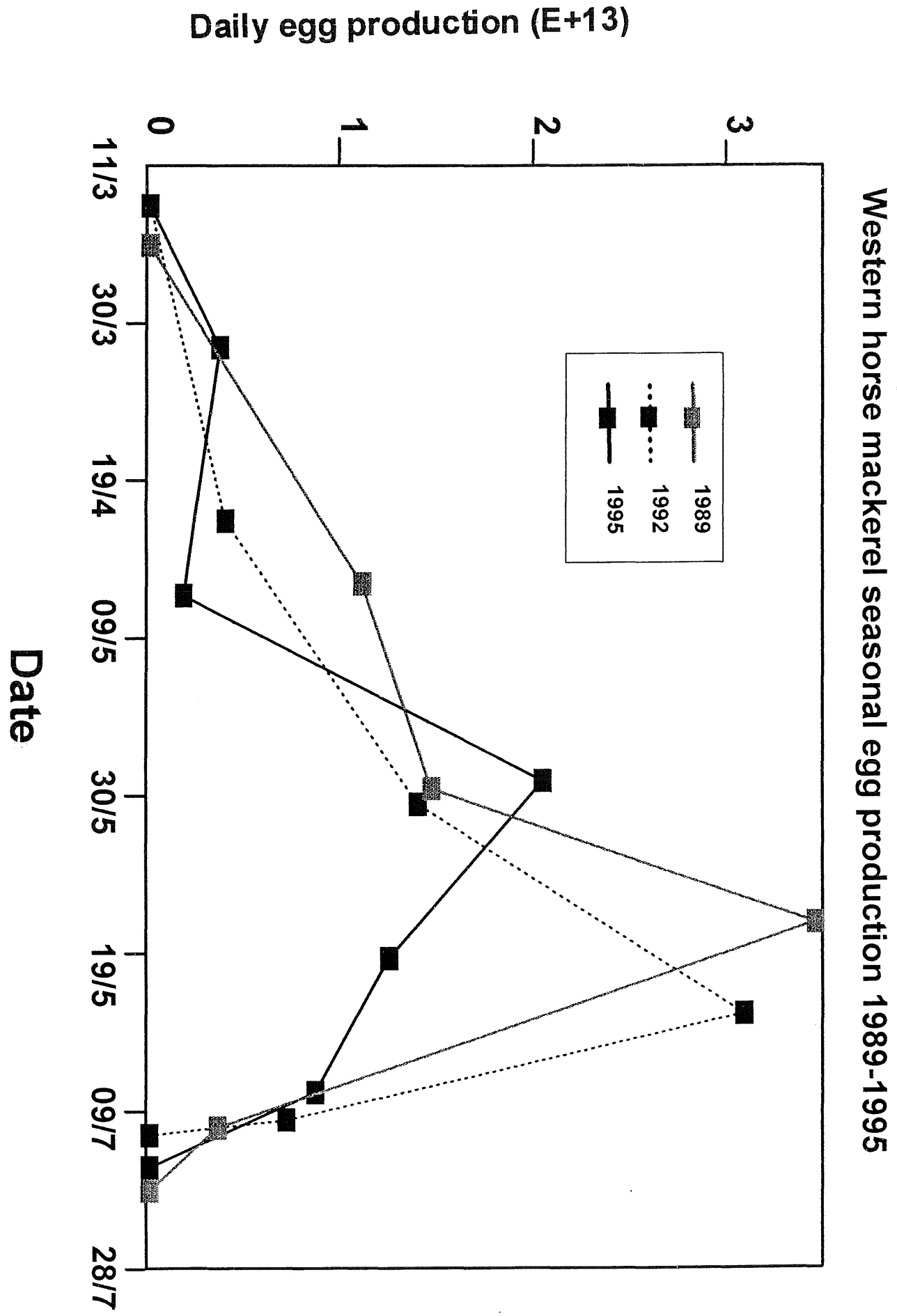


**Figure 5.7b**

Note: Production 'curve' for 1989 used geometric means for interpolated rectangles. For 1992 & 1995 arithmetic means were used. The 1995 'curve' uses values derived from data within the 1992 standard survey area and the same start and finish dates of spawning as for 1992.



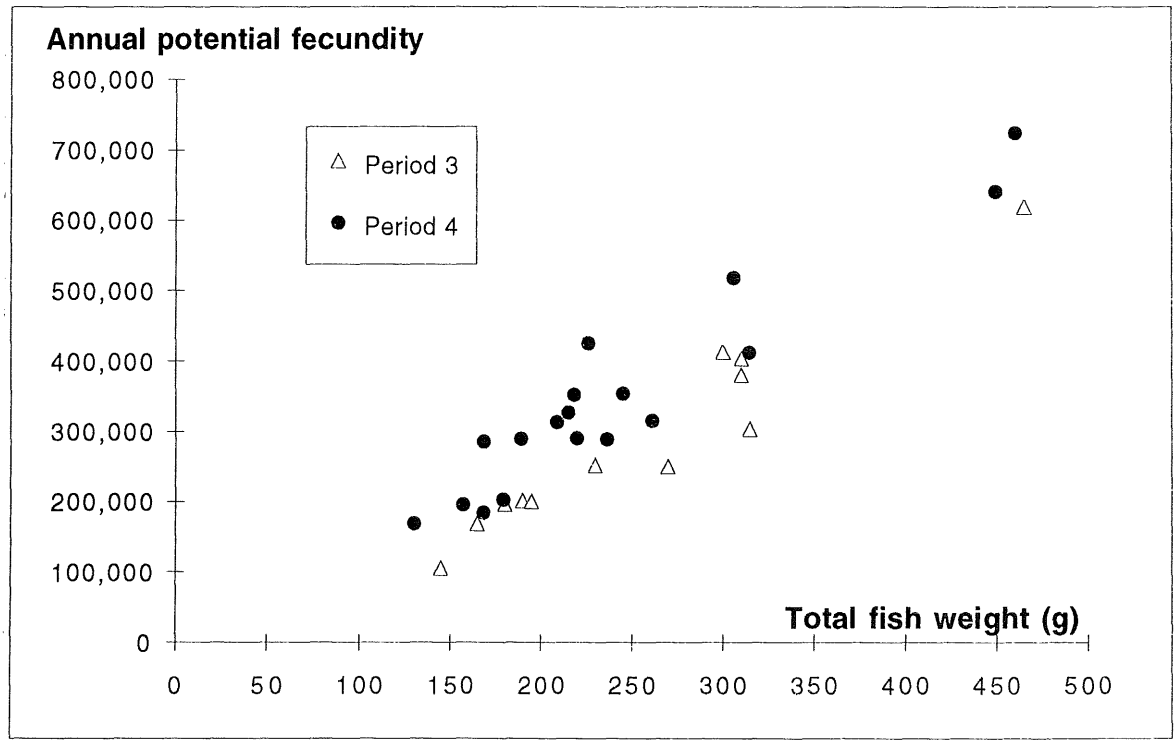



**Figure 5.8A** The relation between weight (g) and annual potential fecundity as estimated from western horse mackerel collected in 1995 during period 3 and 4 (resp. 12 and 18 fish).

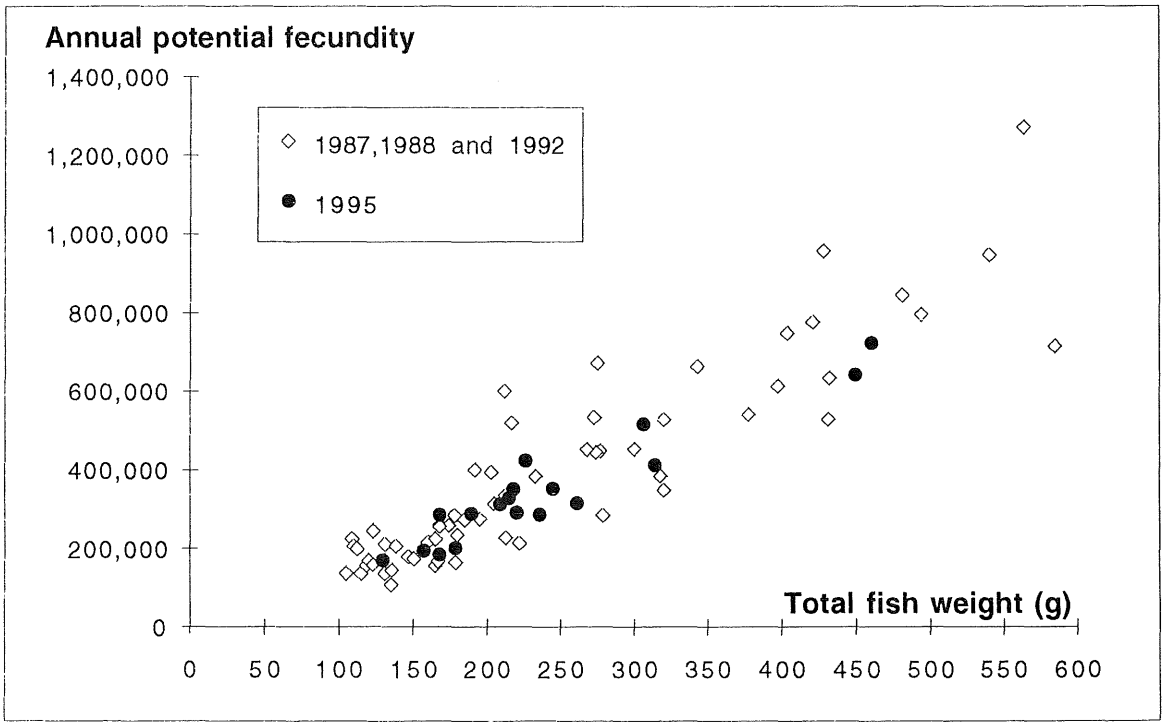



**Figure 5.8B** The relation between weight (g) and annual potential fecundity as estimated from western horse mackerel collected in 1987, 1988 and 1992 compared to the fish collected in 1995. The annual potential fecundity was estimated at 1557 eggs per gramme female based on all years.

# 6 SOUTHERN MACKEREL AND HORSE MACKEREL EGG SURVEY IN 1995 (DIVISION VIIIC AND IXA)

Estimation of biomass from the egg survey - annual egg production method (AEPM)

## 6.1 Countries and Ships Participating

The deployment of research vessel effort in the southern mackerel/horse mackerel 1995 egg survey is shown in Table 6.1.1. The egg surveys in the southern area were carried out from 16 February to 8 June and surveys were split into five periods covering the whole spawning season.

## 6.2 Sampling Areas and Sampling Effort

### 6.2.1 Egg surveys

The AEPM has not previously been applied in the southern area, and so the area to be covered was defined as being the coast of Spain and Portugal, between 36°N and 45°N respectively, and the western boundary at 11°W (Fig. 6.2a).

As recommended by the ICES Working Group (Anon, 1994), for the Cantabrian coast, the south of Spain (Gulf of Cádiz) and in the south of the Iberian peninsula, the standard half ICES rectangle was replaced by a rectangle of a quarter degree latitude by one degree longitude, as transects in those regions were done near perpendicular to the 200 m depth contour line. Samples were collected on north-south transects in the north and south of the Iberian Peninsula and east-west transects off the Portuguese coast. The number of hauls made per half ICES rectangle per survey period are shown in Figures 6.2b-f.

## 6.3 Sampling and Data Analysis

The 1995 survey was conducted according to the sampling strategy described in the Report of the Mackerel and Horse mackerel Egg Production Workshop (Anon, 1994).

### 6.3.1 Sampling strategy

The survey grid was designed according to the procedure described by AEPM manual (Anon, 1994). One main transect was carried out in the centre of the half ICES rectangle, adding one or two more equidistant transects when high egg abundances were found. Sampling stations were placed every 15 miles at the centre of each standard half ICES rectangle. One haul was made in areas of low egg abundance, while more intensive sampling (three hauls evenly spaced in an east/west direction) was carried out in the rectangles nearest to the coast where high egg abundances were found.

In order to quantify the unsampled rectangles, a procedure of interpolation was used according to the AEPM protocol (Anon, 1994). Only rectangles with a minimum of two immediately adjacent sampled rectangles were interpolated. The interpolated value was calculated as the arithmetic mean of all surrounding rectangles. Interpolated values were not used to obtain values for other unsampled rectangles, and no extrapolated values were obtained outside the sampled area.

### 6.3.2 Sampling gears and procedure

Plankton sampling was carried out using a 20 cm Bongo net fitted with 200 µm mesh in the Spanish surveys, a 60 cm WP2 plankton net with 200 µm mesh in the Portuguese surveys and a calVET net for the Spanish AZTI survey (Table 6.3.1). The tows were double oblique for the Bongo gear, oblique for

the WP2 and vertical for the calVET net. The nets were hauled from a maximum depth of 200 m or 2 m above the bottom in shallower water at a ship's speed of 2-3 knots. A General Oceanic flowmeter (GO 2030) was used to determine the water volume sampled. Full profiles of temperature were recorded in each station, using a Minilog data recorder in the Spanish surveys, and using a CTD in the Portuguese surveys.

During period 4 in the survey by R/V *Explorador*, the first six hauls were only sampled to a depth of 130 m because the depth meter failed to work correctly, and the hauls made by AZTI were made using a calVET net in vertical hauls to a maximum of 100 m.

### 6.3.3 Data analysis

Samples were sorted for all fish eggs. Horse mackerel eggs were counted and staged into one of four morphological stages (Pipe and Walker, 1987), and mackerel eggs into one of five morphological stages (Lockwood *et al.*, 1981).

Numbers of eggs per square metre were calculated from the total number of eggs per tow following standard techniques (Smith and Richardson, 1977) to obtain total egg abundances.

Daily egg production was calculated using the data on stage I eggs per $m^2$. The development equations are given by Lockwood *et al.* (1981) for mackerel and by Pipe and Walker (1987) for horse mackerel. The temperature used to calculate the duration of stage I eggs for both species was taken at 20 m depth in the Spanish surveys, and 5 m depth in the Portuguese surveys.

If more than one observation per half ICES rectangle was available, the arithmetic mean of the observed values was used. When the sampling position fell on a dividing line between rectangles, the sample was allocated to the rectangle to the north of the line of latitude and to the west of the line of longitude.

The mean eggs/$m^2$/day was then raised to the area of the rectangle they represented, and the total daily egg production of each sampling period was estimated by adding up the production calculated for each rectangle (sampled and interpolated) in the survey grid.

The total mackerel and horse mackerel stage I production estimate for each period was plotted against the midpoint cruise date to provide a production curve. Then, the total egg production for the spawning season throughout the area was calculated by integration of the area under the curve.

## 6.4 Egg Production of Mackerel

The mean daily egg production estimated for each individual period is shown in Table 6.4.1.
The start date of spawning for mackerel was taken as 10 February (see Section 5.4).

The finish date of spawning was taken as 17 July, estimated from the monthly sampling carried out by IEO in the north coast of Spain (Santander) (Fig. 6.4a).

Production values for the individual time periods and interpolated periods are given in Table 6.4.2 and the daily egg production estimates for each survey period were plotted against the mid cruise dates to give the production histogram (Fig. 6.4b).

Total egg production for the standard sampling area was estimated by integrating the area under the histogram between 10/2 and 17/7. Total egg production for mackerel is given in the table below:

| | Mackerel * 10 E 12 | s.e. (*10 E 12) | CV |
|---|---|---|---|
| Standard production | 169.211 | 11.2 | 6.62% |
| Alternative production | 207.273 | 12.59 | 6.07% |

Regarding the production histogram for mackerel, it seems clear that there has been a significant underestimate of daily production during period 2, because only the Portuguese coast was sampled. In the North of Spain a large spawning occurred, as can be seen from the AZTI data and from the high production found in this area during period 3, when the whole standard area was well covered. From these data it is evident that the area was insufficiently sampled during period 2. In future, sampling should start earlier in the Cantabrian Sea.

In order to obtain a more realistic production histogram, the sampling data in period 2 were replaced with an interpolation between period 1 and period 3 (Fig 6.4c). This resulted in higher estimated production.

## 6.5 Total Fecundity and Atresia of Mackerel

Following the recommendation of the planing meeting (Anon, 1994) 10 ovaries per cm group of mackerel in late pre-spawning stage 3 were collected for fecundity and 45 randomly selected females were collected for atresia estimation in the area from 39°-45°N. To estimate the annual potential fecundity the gravimetric method was used for those ovaries without post-ovulatory follicles. The atresia was estimated by the histometric method.

During period 1, a total of 111 mackerel ovaries were collected from the ICES rectangles 16E7 and 16E6 to estimate the annual potential fecundity. A further 28 mackerel ovaries were collected in period 6 (Table 6.5.1). A sample for atresia of 28 fish with a length range of 28-45 cm (Table 6.5.2) and with an age range 2-15 years (Table 6.5.3) was collected.

The ovary weight was recorded prior to preservation. One ovary was preserved in Gilsons fixative and the other in 4% formaldehyde in order to reject the spawning fish, indicated by the presence of post-ovulatory follicles or hydrated oocytes. After the slides were scored, 104 ovaries without post-ovulatory follicles or hydrated oocytes were used for the gravimetric method (Walsh *et al.*, 1990).

Table (6.5.4) shows fish length, weight (g), age, number of oocytes >130 μm counted and total potential annual fecundity per fish. The regression of fecundity against fish weight, forced through the origin, and weighted by the inverse of the fish weight is shown (Fig. 6.5a). Mean fish weight was 583 g, which corresponds to a total annual potential fecundity of 783,796 oocytes and to an estimated fecundity of 1,344 eggs per gramme pre-spawning female with a correlation of 96%, a s.e.24.83 eggs and a coefficient of variation 1.85%.

In the atresia, sample of 28 fish, 10 were immature and the remainder were rejected because they were pre-spawning. Western area atresia data were used to correct the southern area potential fecundity.

## 6.6 Biomass Estimated of Mackerel

The total egg production for the standard area and the adjusted production (see Section 6.4) is given in Table 6.6.1. To convert these estimates to the biomass of pre-spawning females the fecundity of 1344 eggs per gramme (Section 6.5), sex ratio of 1:1 and a raising factor of 1.08 (Anon, 1987) were used. The values are given in Table 6.6.1.

## 6.7 Egg Production of Horse Mackerel

The mean daily egg production estimated for each individual period is shown in Table 6.4.1.

The start date of spawning for horse mackerel was 10 February. The finish date of spawning for horse mackerel was taken as 17 July, estimated from the monthly sampling carried out in the north coast of Spain (Santander) (Fig. 6.7a).

Production values for the individual time periods and interpolated periods are given in Table 6.4.2 and the daily egg production estimates for each survey period were plotted against the mid cruise dates to give the production histogram (Fig. 6.7b).

The main spawning peak of horse mackerel appeared during period 1 in the Portuguese area, suggesting that the spawning started earlier than the first coverage. However, the main spawning of horse mackerel in the Cantabrian Sea was in May-June, with lower values. In future sampling should start earlier in the Portuguese area.

Total seasonal egg production was calculated in the same way as for mackerel, assuming the same start and finish dates. In order to carry out the same procedure as that used for mackerel, an alternative production histogram constructed replacing sampled data from period 2 with an interpolation between period 1 and period 3 (Fig 6.7c and the table below).

| | Horse mackerel * 10 E 12 | s.e (*10 E 12) | CV |
|---|---|---|---|
| Standard production histogram | 175.383 * 10 E 12 | 9.47 | 5.39% |
| Alternative production histogram | 172.744 * 10 E 12 | 7.99 | 4.46% |

## 6.8 Total Fecundity and Atresia of Horse Mackerel

In 1995 a total of 130 horse mackerel ovaries were collected for fecundity estimation in Division VIIIc and IXa North. Following the recommendation of the planning meeting in 1994 (Anon, 1994), the histometric method described by Eltink and Vingerhoed (1989) and Emerson *et al.* (1990) was used. During period 3 a total of 19 ovaries were collected in ICES rectangle 13E0, and 120 ovaries in ICES rectangle 16E7 (Table 6.5.1). Fish ranged from 22-41 cm length (Table 6.8.1), and the age from 2-16 years (Table 6.8.2). The weight range was 87-593 grammes (Table 6.8.3).

Damaged ovaries, ovaries not in pre-spawning stage and two ovaries with post-ovulatory follicles were rejected. This resulted in a total of 68 ovaries used to determine the total potential annual fecundity by raising the counts of vitellogenic and atretic eggs to the total volume of the ovary calculated. In this sample 22 ovaries showed $\alpha$ and/or $\beta$ atresia without spawning activity.

Sampling details of horse mackerel collected for fecundity estimation in period 3 are given in Table 6.8.3. The regression of fecundity against fish weight, forced though the origin and weighted to the inverse of the fish weight, during period 3 is plotted in Figure 6.8a. Mean fish weight was 237 g, which corresponds to a total potential annual fecundity of 362,063 oocytes and to an estimated fecundity of 1,526 eggs per gramme pre-spawning female with a s.e.of 44 eggs and a coefficient of variation of 3.8%.

This value is lower but close to value obtained by Eltink and Vingerhoed (1993) (1,598 eggs per gramme, length range 24-42 cm). The differences in the estimate of fecundity between both studies seems to be related to the length range of the samples.

During period 1 a total of 111 horse mackerel ovaries were collected. During the second and third periods 60 and 32 ovaries were collected respectively (Table 6.5.1).

Only the ovaries from the first period (111) were histologically processed, using glycol-methacrylate. From each ovary two histological slides were made. The 222 histological slides were examined to determine which ones could be used to estimate the total potential fecundity ie those without post-ovulatory follicles or hydrated oocytes. A total of 31 ovaries were found in pre-spawning condition and so used for the total potential annual estimation. The fish length ranged from 18 cm to 27 cm (average 24 cm) and the total weight corresponded to 53 g-183 g (average 116 g).

To estimate atresia the ovaries have to be in spawning condition, so the presence of post ovulatory follicles, hydrated oocytes or the migratory oocyte stage must be present. Twenty-eight of the ovaries were from fish in spawning condition. The average length of the fish observed for atresia estimation was 22 cm, ranging from 18-27 cm, and the average total weight 86 g, ranging from 52 g-158 g.

The mean fecundity was estimated as 157,212 eggs which divided by the mean weight gives a potential annual fecundity of 1,358 eggs per gram female. This estimate from Division IXa (central and south) is similar to the estimates obtained for sub-areas VII and VIII.

The mean relative intensity of atresia was estimated as 10% and the prevalence of atresia 66%. The number of atretic oocytes per gram female was calculated as 160. The values of atresia are higher than those estimated for Division VIIIc and the western area. The fish analysed were young adults which may explain the high level of atresia.

The Working Group recommended that the histological slides from the southern area should be exchanged between experts from Netherlands, Spain and Portugal for comparison. Additional unprocessed samples from subdivisions IXa, central-north, central-south and south should be prepared for examination and circulated for futher comparison.

To estimate atresia by the histometric method IEO colleted randomly a sample of 321 horse mackerel ovaries. In the periods 3, 4 and 5 respectively 19, 180 and 122 ovaries were collected (Table 6.5.1). During the third period the fish were collected in ICES rectangle 16E1, during the fourth period in16E8 and during the fifth in the rectangles 16E4 and 16E5 (Table 6.5.1). Details of the sampling data are shown in Tables 6.8.4 and 6.8.5. The results of atresia and fecundity estimates are presented in table 6.8.6.

The histological slides from each period were scored to establish the prevalence of atresia. Values of 0.50, 0.42 and 0.40 were obtained in period 3, 4 and 5 respectively. The mean prevalence is 0.44 (Table 6.8.7). The average remaining fecundity, number of atretic oocytes and mean fish weight for each period is shown in Table 6.8.7. For each period, the fecundity was 678, 1,396 and 1,493 oocytes/gramme, 40, 58 and 77 atretic oocytes/gramme respectively. The residual fecundity compared to potential fecundity for periods 3, 4 and 5 was 0.44, 0.92 and 0.98 respectively (Table 6.8.7).

The mean number of atretic oocytes per gram female in the population is obtained by multiplying the prevalence by the number of atretic oocytes/gramme female with atresia. The daily production rates of atretic eggs were calculated (see data analysis Section 6.3.3) as 118 eggs per gramme female. This is

7.7% of the annual fecundity with a s.e.of 1.5. The annual potential fecundity corrected for atresia is 1,408 eggs per gramme female with a s.e.of 46.

## 6.9 Biomass Estimate of Horse Mackerel

The total egg production for the standard sampling area is given in Table 6.9.1. To convert this to the biomass of pre-spawning females the same procedure was followed as for mackerel. Total spawning stock biomass was estimated using the fecundity of 1,526 eggs per gramme pre-spawning female (Section 6.8), and a sex ratio of 1:1. Finally, a raising factor of 1.05 (Eltink and Vingerhoed, 1989) was used to convert biomass of pre-spawning to spawning fish.

Using these data the spawning stock biomass for 1995 was estimated at 242,000 tonnes (Table 6.9.1). If the annual potential fecundity is corrected for 7.7 % atresia (Section 6.8) the estimate of spawning stock biomass of horse mackerel in this area increases to 261,000 tonnes.

As explained in Section 6.7, an alternative value of egg production was estimated. Using this alternative value gave a spawning stock biomass estimate of 237,000 tonnes. When corrected for atresia this gave a biomass estimate of 257,000 tonnes.

**Table 6.1.1 Detail of research vessel effort in the southern mackerel/horse mackerel 1995 egg survey**

| Period | Country | Vessel | Cruise data | Area covered |
|---|---|---|---|---|
| 1 | Portugal | *Noruega* | 16 February - 6 March | 36°00'N-41°30'N |
| 2 | Portugal | *Noruega* | 14-24 March | 36°00'N-43°00'N |
| 3 | Portugal | *Noruega* | 28 March - 10 April | 36°00'N-43°00'N |
| | Spain (IEO) | *Cornide de Saavedra* | 25 March - 13 April | 39°00'N-45°00'N |
| 4 | Spain (IEO) | *Explorador* | 9-12 May | 43°30'N-45°00'N |
| | Spain (AZTI) | *Explorador* | 11-18 May | 43°30'N-44°00'N |
| 5 | Spain (IEO) | *Cornide de Saavedra* | 30 May - 8 June | 43°30'N-45°00'N |

**Table 6.3.1 Sampling gears and procedures adopted during the 1995 southern mackerel and horse mackerel egg surveys**

| Country | Sampling period | Sampler | | Max depth (m) | Thermocline | | Temperature (°C) | | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | Type | Aperture diam (cm) | | Definition | Sampling strategy | Measured | Used for prod | |
| Portugal | 1,2+3 | WP2 | 60 | 200 | 2.5°C/10 m | 200 m | Full CTD profile<br>Reversing thermometers | Temp at 5 m<br>Temp at 5 m | |
| Spain (AZTI) | 4 | Pairovet | 25 (0.05 $m^2$) | 100 | 2.5°C/10 m | 200 m | full profile | Temp at 20 m | Double calvet net hauled vertically |
| Spain (IEO) | 3,4+5 | Bongo | 20 | 200 | 2.0°C/10 m | 200 m | Full profile | Temp at 20 m | |

**Table 6.4.1 Mean daily egg production estimate for each period sampled**

| Period | Cruise data | Area covered | Days | Midpoint | Estimated mean daily egg production * 10-E12 | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Mackerel | s.e. | Horse mackerel | s.e. |
| 1 | 16 February - 6 March | 36°00'N-41°30'N | 19 | 25 Feb | 0.012 | 0.006 | 3.91 | 1.230 |
| 2 | 14-24 March | 36°00'N-43°00'N | 11 | 19 March | 0.023 | 0.051 | 2.20 | 1.540 |
| 3 | 25 March - 13 April | 36°00'N-45°00'N | 20 | 3-4 April | 4.32 | 1.930 | 0.69 | 0.263 |
| 4 | 9-18 May | 43°30'N-45°00'N | 10 | 13-14 May | 1.03 | 0.393 | 0.149 | 0.026 |
| 5 | 30 May - 8 June | 43°30'N-45°00'N | 10 | 3-4 June | 0.137 | 0.090 | 0.799 | 0.412 |

| Table 6.4.2 | Southern mackerel and horse mackerel total stage I egg production estimates by time periods for 1995 | | | | |
|---|---|---|---|---|---|
| Start/ Finish date | Midpoint date | Survey date | No of days | Total stage I egg production *10 E12 | |
| | | | | Mackerel | Horse mackerel |
| 10-15 February | 12-13 February | * | 6 | 0.012 | 4.536 |
| 16 Feb - 6 March | 25 March | 1 | 19 | 0.228 | 74.29 |
| 7-13 March | 10 March | * | 7* | 0.112 | 20.3 |
| 14-24 March | 19 March | 2 | 11 | 0.253 | 24.2 |
| 25 March - 13 April | 3-4 April | 3 | 20 | 86.4 | 13.92 |
| 14 April - 8 May | 26 April | * | 25* | 61.75 | 9.7 |
| 9-18 May | 13-14 May | 4 | 10 | 10.3 | 1.49 |
| 19-29 May | 24 May | * | 11* | 6.43 | 5.258 |
| 30 May - 8 June | 3-4 June | 5 | 10 | 1.37 | 7.99 |
| 9 June - 17 July | 27 June | * | 39* | 2.34 | 13.806 |
| Total | | | 158 | 169.211 | 175.383 |

*Interpolated periods

| Table 6.5.1 Details of ships, sample dates and areas used to collect Mackerel and Horse Mackerel in Divisions VIIIc and IXa for fecundity and atresia | | | | | |
|---|---|---|---|---|---|
| **Fecundity** | **Period** | **Vessel** | **Date** | **ICES Division/ rectangle** | **Number of fish collected and processed** |
| Mackerel | 1 | Purse seiner (IEO) | 14-22 February | VIIIc/16E6-16E7 | 111 |
| Horse mackerel | 1 | *Noruega* (IPIMAR) | 16 February - 6 March | IXa Central - South, South | 111 |
| | 3 | *Cornide Saavedra* (IEO) | 6 March | VIIIc/13EO | 19 |
| | 3 | Purse seine (IEO) | 20-26 March | VIIIc/16E7 | 120 |
| Mackerel | 4 | *Noruega* (IPIMAR/ IEO) | 1-6 June | VIIIc/16E4, 16E5 | 28 |
| Horse mackerel | 1 | *Noruega* (IPIMAR) | 16 February - 6 March | IXa/Central - South, South | 111 |
| | 3 | Purse seine (IEO) | 25-29 April | VIIIc/16E1 | 19 |
| | 4 | *Noruega* (IPIMAR/ IEO) | 5-9 May | VIIIc/16E8 | 180 |
| | 5 | *Cornide Saavedra* (IEO) | 106 June | VIIIc/16E4, 16E5 | 122 |

**Table 6.5.2. Length of mackerel length sampled for fecundity estimation in coverage 1 (14-22 February)**

| Haul | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Rectangle | 16E7 43°25'N 02°08'W | 16E6 43°26'N 03°05'W | 16E7 43°26'N 02°41'W | 16E7 43°25'N 02°31'W | 16E7 43°25'N 02°33'W | 16E7 43°26'N 02°31'W | 16E7 43°21'N 02°24'W | Total |
| Length cm | | | | | | | | |
| 28 | | | | | 1 | | | 1 |
| 29 | | | | | | | | |
| 30 | | | | | 1 | | | 1 |
| 31 | | | | | | 1 | | 1 |
| 32 | | | | | 2 | 3 | 1 | 6 |
| 33 | | | | | | | 1 | 1 |
| 34 | | | | | | 1 | 1 | 2 |
| 35 | | | | | | | | 0 |
| 36 | 1 | | | | | | | 1 |
| 37 | 1 | | | | | | 7 | 8 |
| 38 | 7 | 1 | 2 | 1 | | | 1 | 12 |
| 39 | 12 | | 1 | 1 | | | | 14 |
| 40 | 9 | | | 2 | | | | 11 |
| 41 | 11 | | | 1 | | | | 12 |
| 42 | 6 | | | 2 | | | 5 | 13 |
| 43 | 3 | | | | | | 4 | 7 |
| 44 | 1 | | | 1 | | | 8 | 10 |
| 45 | | | | | | 1 | 3 | 4 |
| 46 | | | | | | | | |
| **Total** | 51 | 1 | 3 | 8 | 4 | 6 | 31 | 104 |

| Table 6.5.3. Age of mackerel length sampled for fecundity estimation in coverage 1 (14-22 February) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Haul** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **Total** |
| **Rectangle** | **16E7 43°25'N 02°08'W** | **16E6 43°26'N 03°05'W** | **16E7 43°26'N 02°41'W** | **16E7 43°25'N 02°31'W** | **16E7 43°25'N 02°33'W** | **16E7 43°26'N 02°31'W** | **16E7 43°21'N 02°24'W** | |
| Age | | | | | | | | |
| 2 | | | | 1 | 1 | 1 | | 3 |
| 3 | | | | | | 1 | | 1 |
| 4 | | | | | 1 | | 3 | 4 |
| 5 | 1 | | 2 | | | 1 | 2 | 6 |
| 6 | 5 | | 1 | 1 | | | 4 | 11 |
| 7 | 5 | | | 2 | | | | 7 |
| 8 | 7 | | | | | | 1 | 8 |
| 9 | 1 | | | | | | 2 | 3 |
| 10 | 1 | | | 1 | | | 1 | 3 |
| 11 | 2 | | | | | | 2 | 4 |
| 12 | | | | | | | 2 | 2 |
| 13 | 1 | | | | | | 1 | 2 |
| 14 | 1 | | | | | 1 | 1 | 3 |
| 15 | | | | | | | 2 | 2 |
| Total aged | 24 | 0 | 3 | 5 | 2 | 4 | 21 | 59 |
| No age | 27 | 1 | | 3 | 2 | 2 | 10 | 45 |
| **Total** | 51 | 1 | 3 | 8 | 4 | 6 | 31 | 104 |

| Table 6.5.4 Length weight fecundity calculated by gravimetric method period 1 of the Mackerel Egg Survey in the ICES Division VIIIc | | | | |
|---|---|---|---|---|
| Eggs per ml calculated from 2.5 ml sub-sample | | | | |
| Length (cm) | Weight (g) | Age | Eggs 1 ml | Total fecundity eggs/fish |
| 28 | 146,8 | 2 | 167 | 230470 |
| 30 | 199,0 | * | 358 | 492920 |
| 31 | 218,2 | 2 | 248 | 341295 |
| 32 | 223,8 | 3 | 305 | 420691 |
| 32 | 303,6 | 4 | 322 | 443297 |
| 32 | 262,0 | * | 252 | 347911 |
| 32 | 283,0 | * | 296 | 408561 |
| 32 | 229,6 | * | 248 | 342397 |
| 32 | 320,4 | * | 426 | 587203 |
| 33 | 351,8 | 4 | 422 | 582241 |
| 34 | 338,0 | * | 419 | 577830 |
| 34 | 332,0 | 5 | 302 | 415729 |
| 36 | 355,4 | 6 | 380 | 523245 |
| 37 | 713,0 | 4 | 680 | 937320 |
| 37 | 369,4 | 6 | 412 | 568457 |
| 37 | 456,2 | 5 | 461 | 635723 |
| 37 | 447,4 | * | 464 | 640134 |
| 37 | 415,2 | 4 | 528 | 728353 |
| 37 | 463,8 | * | 514 | 709055 |
| 37 | 404,6 | 6 | 423 | 583344 |
| 38 | 473,2 | 10 | 379 | 522142 |
| 38 | 416,4 | 5 | 520 | 716223 |
| 38 | 536,4 | * | 428 | 589960 |
| 38 | 502,2 | * | 392 | 540889 |
| 38 | 495,2 | * | 461 | 635172 |
| 38 | 484,5 | 5 | 464 | 640134 |
| 38 | 491,2 | * | 489 | 674319 |
| 38 | 521,2 | 8 | 452 | 623593 |
| 38 | 415,2 | * | 410 | 565700 |
| 38 | 440,6 | * | 520 | 716223 |
| 38 | 510,8 | 2 | 483 | 666048 |
| 38 | 514,2 | 5 | 323 | 445503 |
| 39 | 559,2 | * | 516 | 710709 |
| 39 | 594,2 | * | 517 | 712914 |
| 39 | 560,4 | * | 674 | 929049 |
| 39 | 495,6 | * | 406 | 560186 |
| 39 | 620,5 | * | 568 | 782386 |
| 39 | 528,4 | 5 | 444 | 612015 |
| 39 | 553,0 | 6 | 471 | 649507 |
| 39 | 574,2 | 6 | 535 | 737726 |
| 39 | 608,0 | 8 | 606 | 835317 |
| 39 | 532,2 | * | 495 | 682038 |
| 39 | 557,2 | * | 595 | 820430 |
| 39 | 500,2 | 7 | 525 | 723390 |
| 39 | 353,4 | 7 | 470 | 648405 |
| 39 | 513,6 | * | 482 | 664946 |
| 40 | 635,5 | 11 | 478 | 659432 |
| 40 | 588,2 | 6 | 494 | 681487 |
| 40 | 638,5 | 7 | 632 | 870605 |
| 40 | 540,2 | 7 | 562 | 775219 |
| 40 | 514,0 | 6 | 611 | 842485 |
| 40 | 555,2 | * | 653 | 900378 |
| 40 | 586,4 | 11 | 540 | 744893 |
| 40 | 657,0 | 8 | 492 | 677627 |
| 40 | 623,5 | * | 558 | 769154 |
| 40 | 654,5 | 8 | 556 | 766397 |
| 40 | 570,2 | * | 580 | 799479 |

**Continued**

| Table 6.5.4 Length weight fecundity calculated by gravimetric method period 1 of the Mackerel Egg Survey in the ICES Division VIIIc | | | | |
|---|---|---|---|---|
| Eggs per ml calculated from 2.5 ml sub-sample | | | | |
| Length (cm) | Weight (g) | Age | Eggs 1 ml | Total fecundity eggs/fish |
| 41 | 663,5 | 7 | 630 | 868950 |
| 41 | 706,5 | 6 | 800 | 1102729 |
| 41 | 796,5 | 8 | 681 | 938422 |
| 41 | 613,0 | * | 492 | 678178 |
| 41 | 649,0 | * | 524 | 722839 |
| 41 | 622,0 | * | 594 | 818776 |
| 41 | 687,5 | 8 | 491 | 676524 |
| 41 | 661,5 | 7 | 844 | 1163931 |
| 41 | 705,5 | 8 | 489 | 673767 |
| 41 | 675,0 | * | 594 | 818776 |
| 41 | 583,8 | 7 | 612 | 844139 |
| 41 | 646,0 | * | 668 | 921330 |
| 42 | 645,0 | 11 | 749 | 1032706 |
| 42 | 670,0 | 9 | 586 | 807198 |
| 42 | 685,0 | * | 762 | 1050349 |
| 42 | 697,0 | 9 | 693 | 955515 |
| 42 | 709,0 | 9 | 616 | 848550 |
| 42 | 705,5 | 13 | 495 | 682038 |
| 42 | 747,5 | 6 | 671 | 1049247 |
| 42 | 716,0 | 10 | 874 | 1205283 |
| 42 | 726,0 | 14 | 855 | 1178817 |
| 42 | 672,5 | * | 573 | 790105 |
| 42 | 693,5 | * | 621 | 855718 |
| 43 | 675,0 | 11 | 914 | 1260419 |
| 43 | 710,0 | * | 669 | 922433 |
| 43 | 768,5 | * | 916 | 1263176 |
| 43 | 781,5 | * | 606 | 834766 |
| 43 | 782,5 | 12 | 903 | 1244430 |
| 43 | 748,5 | * | 705 | 972056 |
| 43 | 741,5 | 10 | 687 | 947244 |
| 43 | 736,0 | * | 653 | 899827 |
| 43 | 740,5 | * | 706 | 973710 |
| 44 | 750,5 | 15 | 833 | 1148492 |
| 44 | 710,0 | 8 | 712 | 981429 |
| 44 | 760,0 | 15 | 511 | 704644 |
| 44 | 744,0 | * | 926 | 1275858 |
| 44 | 796,5 | 13 | 672 | 926292 |
| 44 | 782,5 | * | 692 | 953861 |
| 44 | 791,5 | * | 352 | 484649 |
| 44 | 834,5 | * | 840 | 1157866 |
| 44 | 824,0 | 12 | 634 | 873361 |
| 44 | 856,5 | * | 1182 | 1628731 |
| 45 | 77,5 | * | 732 | 1008446 |
| 45 | 723,5 | 14 | 812 | 1118719 |
| 45 | 922,0 | * | 877 | 1209142 |
| 45 | 819,5 | 14 | 635 | 875016 |
| Average | 582 | | 569 | 783796 |

(*) age no available

Fecundity 1344 eggs/g female

Table 6.6.1 Annual Eggs Production Method 1995. Biomass estimated to souther mackerel.

| | | | | | Corrected 12% atresia | |
|---|---|---|---|---|---|---|
| Total egg production (x $10^{12}$) | Total fecundity eggs/g female | Spawning stock biomass (conv f 1.08) (x $10^6$ tonnes) | Variance of biomass | Total fecundity eggs/g female | Spawning stock biomass (conv. f. 1.08) (x$10^6$tonnes) | Variance of biomass |
| 169.211 | 1,344 | 0.271946 | 3,490 | 1,183 | 0.308957 | 5.120 |
| 207.273 | 1,344 | 0.333117 | 4,470 | 1,183 | 0.378450 | 6.690 |

| Table 6.8.1 Length of horse mackerel sampled for fecundity estimation in coverage 3 ( 6-23 March) | | | | | | |
|---|---|---|---|---|---|---|
| **Date** | **6-March** | | **20-26 March** | | | **Total** |
| **Haul** | **1** | **2** | **2** | **3** | **4** | |
| **Rectangle** | **13EO** | **13EO** | **16E7** | **16E7** | **16E7** | |
| Length cm | | | | | | |
| 22 | | | 1 | | | 1 |
| 23 | | | 1 | | 2 | 3 |
| 24 | | | 6 | | | 6 |
| 25 | | | 5 | | | 5 |
| 26 | | | 5 | 1 | | 6 |
| 27 | | | 1 | | 3 | 4 |
| 28 | | | 1 | | 3 | 4 |
| 29 | | | 1 | | 5 | 6 |
| 30 | | | 2 | 1 | 2 | 5 |
| 31 | | | 1 | | | 1 |
| 32 | | | | 1 | | 1 |
| 33 | 7 | | | | 1 | 8 |
| 34 | 1 | | | | 2 | 3 |
| 35 | | 1 | | | 3 | 4 |
| 36 | | 1 | 1 | | | 2 |
| 37 | | | | | | 0 |
| 38 | 1 | 1 | | | 3 | 5 |
| 39 | | | | | 1 | 1 |
| 40 | | | | | 2 | 2 |
| 41 | | | | | 1 | 1 |
| 42 | | | | | | 0 |
| **Total** | 9 | 3 | 25 | 3 | 28 | 68 |

| Table 6.8.2 Age of horse mackerel length sampled for fecundity estimation in coverage 3 ( 6-23 March) | | | | | | |
|---|---|---|---|---|---|---|
| **Date** | **6-March** | | **20-26 March** | | | **Total** |
| **Haul** | **1** | **2** | **2** | **3** | **4** | |
| **Rectangle** | **13E0** | **13E0** | **16E7** | **16E7** | **16E7** | |
| Age | | | | | | |
| 2 | | 1 | | | | 1 |
| 3 | | 1 | | | 1 | 2 |
| 4 | | 1 | 9 | 1 | 2 | 13 |
| 5 | | | 6 | | 1 | 7 |
| 6 | 1 | | 3 | | 2 | 6 |
| 7 | | | 3 | 1 | 1 | 5 |
| 8 | 2 | | 3 | 1 | 4 | 10 |
| 9 | 1 | | | | 2 | 3 |
| 10 | | | | | 1 | 1 |
| 11 | 1 | | | | | 1 |
| 12 | 1 | | 1 | | 4 | 6 |
| 13 | 2 | | | | 7 | 9 |
| 14 | 1 | | | | 1 | 2 |
| 15 | | | | | 1 | 1 |
| 16 | | | | | 1 | 1 |
| **Total** | 9 | 3 | 25 | 3 | 28 | 68 |

| Table 6.8.3 Horse mackerel fecundity estimates from the coverage 3 | | | | | | |
|---|---|---|---|---|---|---|
| Length (cm) | Weight (g) | Age | Total fecundity (Vitell. oocytes) | SE fecundity | Number of atretic oocytes | SE atresia |
| 22 | 87 | 4 | 154700 | 4390 | | |
| 23 | 94 | 4 | 101996 | 8179 | 4249 | 1300 |
| 23 | 94 | 3 | 74190 | 11206 | | |
| 23 | 88 | 4 | 76033 | 1774 | | |
| 24 | 104 | 4 | 86423 | 18026 | 5621 | 1119 |
| 24 | 92 | 5 | 217789 | 9052 | 5928 | 1086 |
| 24 | 107 | 4 | 179768 | 13291 | | |
| 24 | 109 | 5 | 131098 | 8003 | 12107 | 1836 |
| 24 | 112 | 4 | 139927 | 1573 | | |
| 24 | 123 | 4 | 224360 | 6773 | | |
| 25 | 128 | 5 | 241583 | 7579 | | |
| 25 | 122 | 6 | 143010 | 2666 | 13696 | 2774 |
| 25 | 120 | 4 | 212187 | 11365 | | |
| 25 | 118 | 4 | 137071 | 21438 | | |
| 25 | 120 | 4 | 170800 | 5473 | 3115 | 410 |
| 26 | 127 | 7 | 192648 | 4771 | | |
| 26 | 129 | 5 | 239663 | 7889 | 16183 | 2292 |
| 26 | 143 | 7 | 260064 | 16564 | | |
| 26 | 137 | 5 | 185623 | 4963 | | |
| 26 | 135 | 5 | 109261 | 29450 | | |
| 26 | 154 | 6 | 333226 | 17240 | | |
| 27 | 150 | 7 | 273230 | 4989 | | |
| 27 | 144 | 6 | 215127 | 5336 | | |
| 27 | 152 | 5 | 143785 | 29589 | | |
| 27 | 145 | 8 | 193822 | 3454 | | |
| 28 | 158 | 8 | 261261 | 9888 | | |
| 28 | 171 | 9 | 252277 | 6086 | 22081 | 3484 |
| 28 | 182 | 7 | 260436 | 6851 | | |
| 28 | 163 | 4 | 181429 | 14131 | 21446 | 2827 |
| 29 | 166 | 8 | 336178 | 9228 | | |
| 29 | 191 | 9 | 254015 | 8910 | | |
| 29 | 205 | 8 | 254890 | 14268 | | |
| 29 | 179 | 8 | 236466 | 4746 | | |
| 29 | 185 | 6 | 215210 | 12646 | 37565 | 5428 |
| 29 | 218 | 12 | 424852 | 42423 | 10086 | 1324 |
| 30 | 194 | 8 | 328274 | 16691 | | |
| 30 | 200 | 7 | 314133 | 3391 | | |
| 30 | 224 | 8 | 315565 | 6199 | | |
| 30 | 202 | 8 | 247693 | 6015 | | |

| Table 6.8.3 Horse mackerel fecundity estimates from the coverage 3 | | | | | | |
|---|---|---|---|---|---|---|
| Length (cm) | Weight (g) | Age | Total fecundity (Vitell. oocytes) | SE fecundity | Number of atretic oocytes | SE atresia |
| 30 | 238 | 10 | 359392 | 13825 | | |
| 31 | 244 | 5 | 221029 | 5605 | | |
| 32 | 228 | 4 | 341580 | 7174 | 1459 | 1313 |
| 33 | 278 | 12 | 505044 | 10600 | 42197 | 6030 |
| 33 | 316 | 6 | 508815 | 35454 | | |
| 33 | 307 | 9 | 509712 | 13622 | | |
| 33 | 309 | 12 | 731694 | 34218 | 9671 | 2591 |
| 33 | 316 | 11 | 411770 | 13806 | | |
| 33 | 296 | 8 | 430443 | 5447 | | |
| 33 | 281 | 13 | 446020 | 7508 | | |
| 33 | 287 | 8 | 574191 | 3004 | | |
| 34 | 286 | 13 | 274189 | 9880 | 20894 | 2494 |
| 34 | 312 | 14 | 376955 | 11677 | | |
| 34 | 315 | 12 | 557071 | 28929 | 5340 | 4806 |
| 35 | 342 | 13 | 849570 | 21018 | 15227 | 3846 |
| 35 | 329 | 13 | 624381 | 12160 | | |
| 35 | 368 | 3 | 553677 | 17506 | 37509 | 4181 |
| 35 | 357 | 13 | 683535 | 48761 | | |
| 36 | 393 | 4 | 702641 | 21729 | | |
| 36 | 354 | 12 | 337792 | 34230 | | |
| 38 | 434 | 13 | 610939 | 12543 | | |
| 38 | 469 | 2 | 856315 | 18146 | | |
| 38 | 413 | 12 | 819186 | 15922 | 13974 | 2669 |
| 38 | 445 | 15 | 600060 | 19303 | 40934 | 6919 |
| 38 | 444 | 13 | 591150 | 4040 | | |
| 39 | 448 | 16 | 583077 | 8135 | | |
| 40 | 555 | 13 | 788525 | 29527 | 22437 | 7251 |
| 40 | 509 | 14 | 694348 | 17412 | | |
| 41 | 593 | 13 | 757151 | 28307 | 20361 | 4256 |
| Average | 237 | | 362063 | | 13618 | |
| | | | Total fecundity | 1526 | | |

| Table 6.8.4 Length of horse mackerel sampled for atresia estimation in coverage 3.4 and 5 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **25-26April** | | **9-14 May** | | **3-8 June** | | | | **Total** |
| **Haul** | **1** | **3** | **1** | **6** | **2** | **3** | **4** | **5** | |
| **Rectangle** | **16E1** | **16E1** | **16E8** | **16E8** | **16E4** | **16E4** | **16E4** | **16E5** | |
| Length cm | | | | | | | | | |
| 22 | | | | | | | | | 0 |
| 23 | | | 1 | | | | 1 | | 2 |
| 24 | | | | | | | 2 | | 2 |
| 25 | | | 3 | 6 | | | | | 9 |
| 26 | 1 | | 1 | 10 | | | | | 12 |
| 27 | 1 | | 6 | 4 | | 1 | | | 12 |
| 28 | 1 | | 3 | 3 | 2 | | | | 9 |
| 29 | 2 | 1 | 4 | 1 | | 3 | 2 | 1 | 14 |
| 30 | | | | 3 | | | | 1 | 4 |
| 31 | 1 | | | 1 | | 1 | | | 3 |
| 32 | | | | | | | | 2 | 2 |
| 33 | | | | | | 1 | | | 1 |
| 34 | | | | | | | | | 0 |
| 35 | | | | | | 1 | | | 1 |
| 36 | | | | | | | | | 0 |
| 37 | | | | | | | | | 0 |
| 38 | | | | | | 1 | | | 1 |
| 39 | | | | | | | | | 0 |
| 40 | | | | | | | | | 0 |
| 41 | | | | | | | | | 0 |
| 42 | | | | | | | | | 0 |
| **Total** | 6 | 1 | 18 | 28 | 2 | 8 | 5 | 4 | 72 |

| Table 6.8.5 Age of horse mackerel sampled for atresia estimation in coverage 3.4 and 5 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **25-26April** | | **9-14 May** | | **3-8 June** | | | | |
| **Haul** | **16E1** | **16E1** | **16E8** | **16E8** | **16E8** | **16E7** | **16E8** | **16E8** | |
| **Rect** | **16E1** | **16E1** | **16E8** | **16E8** | **16E4** | **16E4** | **16E4** | **16E5** | |
| Age | | | | | | | | | |
| 2 | | | | | | | | | 0 |
| 3 | | | 1 | 1 | | | 1 | | 3 |
| 4 | | | 3 | 4 | | | 2 | | 9 |
| 5 | | | 1 | 5 | | | | | 6 |
| 6 | 1 | | 1 | 2 | | 1 | | | 5 |
| 7 | | | 1 | 2 | | | | | 3 |
| 8 | 2 | | 6 | 7 | | | | 2 | 17 |
| 9 | | | | 1 | | | | | 1 |
| 10 | 2 | 1 | 5 | 2 | 1 | 1 | | | 12 |
| 11 | | | | 1 | | 1 | | | 2 |
| 12 | | | | 2 | 1 | 1 | 1 | | 5 |
| 13 | 1 | | | 1 | | 4 | 1 | 2 | 9 |
| 14 | | | | | | | | | 0 |
| 15 | | | | | | | | | 0 |
| 16 | | | | | | | | | 0 |
| **Total** | 6 | 1 | 18 | 28 | 2 | 8 | 5 | 4 | 72 |

## Table 6.8.6

Horse mackerel atresia estimates from period 3.

The length, weight, remaining fecundity, number of atretic oocytes and its standard error.

| Length (cm) | Fish weight (g) | Age | Remaing fedundity Vitell.oocy. | SE fecundity | Number of atretic oocytes | atre. oocytes / weight | SE atresia |
|---|---|---|---|---|---|---|---|
| 29 | 188 | 8 | 101688 | 5197 | 5137 | 27 | 561 |
| 29 | 188 | 13 | 101688 | 5197 | 5137 | 27 | 561 |
| 27 | 149 | 6 | 80539 | 1516 | 12712 | 85 | 1609 |
| 28 | 168 | 10 | 78895 | 8998 | 8540 | 51 | 1388 |
| 28 | 183 | 8 | 94506 | 6031 | 2802 | 15 | 490 |
| 32 | 259 | 13 | 276315 | 12565 | 19734 | 76 | 2493 |
| 30 | 249 | 10 | 206291 | 15449 | 9922 | 40 | 3145 |
| Aritmetic | 198 | | 134275 | | 9141 | | |
| Geometric mean | | | | | | 40 | |

Horse mackerel atresia estimates from period 4.

| Length (cm) | Fish weight (g) | Age | Remaing fedundity Vitell.oocy. | SE fecundity | Number of atretic oocytes | atre. oocytes / weight | SE atresia |
|---|---|---|---|---|---|---|---|
| 28 | 175 | 8 | 340278 | 5357 | 4125 | 24 | 1350 |
| 28 | 153 | 8 | 261280 | 10666 | 41828 | 273 | 2928 |
| 28 | 167 | 8 | 361107 | 12829 | 15761 | 94 | 4098 |
| 27 | 161 | 7 | 506655 | 16271 | 11947 | 74 | 3631 |
| 26 | 144 | 4 | 235001 | 15798 | 8949 | 62 | 2221 |
| 29 | 200 | 8 | 188071 | 7330 | 2089 | 10 | 1073 |
| 29 | 203 | 6 | 424246 | 13862 | 24783 | 122 | 5829 |
| 28 | 143 | 5 | 215662 | 5297 | 19672 | 138 | 4026 |
| 24 | 111 | 3 | 121693 | 2830 | 9503 | 86 | 908 |
| 27 | 166 | 10 | 274150 | 12501 | 23982 | 144 | 2938 |
| 25 | 137 | 4 | 155119 | 5468 | 3487 | 25 | 1166 |
| 29 | 205 | 8 | 498077 | 14752 | 7836 | 38 | 1896 |
| 28 | 169 | 10 | 277426 | 7346 | 4805 | 28 | 1338 |
| 29 | 186 | 12 | 443895 | 8244 | 73265 | 394 | 9183 |
| 28 | 169 | 8 | 502580 | 14728 | 10319 | 61 | 1752 |
| 25 | 142 | 4 | 355489 | 6070 | 10622 | 75 | 2852 |
| 29 | 179 | 10 | 248486 | 11551 | 23381 | 131 | 3655 |
| 29 | 179 | 10 | 248486 | 11551 | 23381 | 131 | 3655 |
| 31 | 221 | 12 | 239261 | 3228 | 7521 | 34 | 1272 |
| 26 | 148 | 5 | 275949 | 17679 | 17167 | 116 | 3525 |
| 28 | 157 | 10 | 183066 | 12783 | 21463 | 137 | 1785 |
| 29 | 186 | 11 | 296289 | 11657 | 10607 | 57 | 1572 |
| 29 | 198 | 10 | 275032 | 7355 | 40605 | 205 | 4340 |
| 30 | 207 | 12 | 297003 | 7687 | 28076 | 136 | 4253 |
| 30 | 196 | 7 | 143799 | 9873 | 30781 | 157 | 2174 |
| 26 | 152 | 8 | 33188 | 2764 | 2106 | 14 | 486 |
| 26 | 141 | 8 | 158105 | 3781 | 3728 | 26 | 997 |
| 25 | 133 | 4 | 45191 | 3923 | 3544 | 27 | 320 |

## Table 6.8.6 (continued)

Horse mackerel atresia estimates from period4 continued.
The length, weight, remaining fecundity, number of atretic oocytes and its standard error.

| Length (cm) | Fish weight (g) | Age | Remaing fedundity Vitell.oocy. | SE fecundity | Number of atretic oocytes | atre. oocytes / weight | SE atresia |
|---|---|---|---|---|---|---|---|
| 26 | 153 | 5 | 136874 | 10513 | 7041 | 46 | 758 |
| 29 | 188 | 13 | 345616 | 9032 | 9473 | 50 | 2394 |
| 26 | 146 | 4 | 106341 | 4793 | 6376 | 44 | 1014 |
| 25 | 132 | 4 | 136567 | 6089 | 4404 | 33 | 849 |
| 26 | 133 | 5 | 170818 | 8411 | 9465 | 71 | 2158 |
| 26 | 149 | 3 | 141228 | 5361 | 4812 | 32 | 1739 |
| 27 | 175 | 8 | 204641 | 11145 | 14371 | 82 | 3595 |
| 27 | 167 | 5 | 242067 | 5321 | 16148 | 97 | 2785 |
| Average | 166 | | 163181 | | 13760 | | |
| Geometric mean | | | | | | 58 | |

Horse mackerel atresia estimates from period 5
The length, weight, remaining fecundity, number of atretic oocytes and its standard error.

| Length (cm) | Fish weight (g) | Age | Remaing fedundity Vitell.oocy. | SE fecundity | Number of atretic oocytes | atre. oocytes / weight | SE atresia |
|---|---|---|---|---|---|---|---|
| 29 | 167 | 12 | 217011 | 7654 | 11800 | 71 | 2952 |
| 29 | 174 | 10 | 428291 | 11684 | 31880 | 183 | 2155 |
| 28 | 166 | 13 | 264167 | 4913 | 16650 | 100 | 1944 |
| 33 | 275 | 12 | 547476 | 36812 | 18492 | 67 | 3618 |
| 38 | 412 | 13 | 825478 | 30367 | 37786 | 92 | 5732 |
| 31 | 226 | 10 | 254589 | 6095 | 16492 | 73 | 3344 |
| 29 | 194 | 13 | 219684 | 12548 | 1898 | 10 | 1708 |
| 30 | 207 | 6 | 207513 | 9471 | 54349 | 263 | 3121 |
| 29 | 195 | 11 | 327053 | 5699 | 29959 | 154 | 8106 |
| 35 | 380 | 13 | 720401 | 10879 | 22083 | 58 | 7109 |
| 24 | 107 | 4 | 66797 | 4407 | 4912 | 46 | 1248 |
| 24 | 118 | 4 | 238525 | 1435 | 6811 | 58 | 1384 |
| 30 | 221 | 13 | 390218 | 7934 | 43796 | 198 | 3327 |
| 25 | 130 | 3 | 64400 | 2912 | 6051 | 47 | 816 |
| 29 | 190 | 12 | 375963 | 6364 | 9441 | 50 | 1330 |
| 31 | 232 | 13 | 135106 | 3313 | 54523 | 235 | 5651 |
| 30 | 206 | 8 | 149780 | 1428 | 16153 | 78 | 1971 |
| 32 | 263 | 13 | 213867 | 8560 | 9612 | 37 | 1951 |
| 32 | 261 | 8 | 511326 | 14245 | 16199 | 62 | 3193 |
| Average | 217 | | 324087 | | 21520 | | |
| Geometric mean | | | | | | 77 | |

**Table 6.8.7** **The number of atretic oocytes per gramme female horse mackerel in the population during the coverage 3,4 and 5 as obtained from the fraction of femles with atresia and the number of atretic oocytes per gramme female with atresia .The propotion of residual fecundity compared to annual potential fecundity**

| Survey coverage | Prevalence of atresia | No of fish for scoring prevalence | No of atretic oocytes/g female with atresia | No of fish for counting atresia | No of atretic oocytes/g female in the population | Standard error | Relative intensity of atresia % | Proportion of remaining fecundity compared to annual potential fecundity |
|---|---|---|---|---|---|---|---|---|
| 3 | 0.50 | 14 | 39.5 | 7 | 19.8 | 6.8 | 1.3 | 0.44 |
| 4 | 0.42 | 110 | 58.0 | 46 | 24.2 | 4 | 1.6 | 0.91 |
| 5 | 0.40 | 48 | 76.9 | 19 | 30.4 | 7.5 | 2.0 | 0.98 |
| 4-5 | 0.44 | 172 | | 72 | 25 | 46 | | 0.78 |

| Coverage | Average weight | Remaining fecundity | No atretic oocytes | No females sampled | Females witht atresia | No of females used count atre oocytes | Fecundity oocytes/g female | annual potential fecundity eggs / gramme female |
|---|---|---|---|---|---|---|---|---|
| **3** | 198 | 134275 | 9141 | 14 | 7 | 7 | 678 | 1526 |
| **4** | 166 | 231735 | 13760 | 110 | 46 | 46 | 1396 | 1526 |
| **5** | 217 | 324087 | 21520 | 48 | 19 | 19 | 1493 | 1526 |
| average | 194 | 230032 | 14807 | | | | | 1189 |

| Table 6.9.1 Annual eggs production method 1995. Biomass estimated to southern horse mackerel. | | | | | | |
|---|---|---|---|---|---|---|
| Corrected for 7.7% atresia | | | | | | |
| **Total egg production ($x10^{12}$)** | **Total fecundity eggs/g female** | **Spawning stock biomass (conv f 1.05) ($x10^6$ tonnes)** | **Variance of biomass** | **Total fecundity eggs/g female** | **Spawning stock biomass (conv f 1.05) ($x10^6$ tonnes)** | **Variance of biomass** |
| 175.383 | 1526 | 0.241353 | 2180 | 1408 | 0.261580 | 2,710 |
| 172.744 | 1526 | 0.237721 | 1670 | 1408 | 0.257644 | 2,120 |

CV F=2.88% without atresia.
CV F=3.26% with atresia.

**Figure 6.2a**
Standard sampling rectangles for the southern area mackerel and horse mackerel egg survey in 1995.

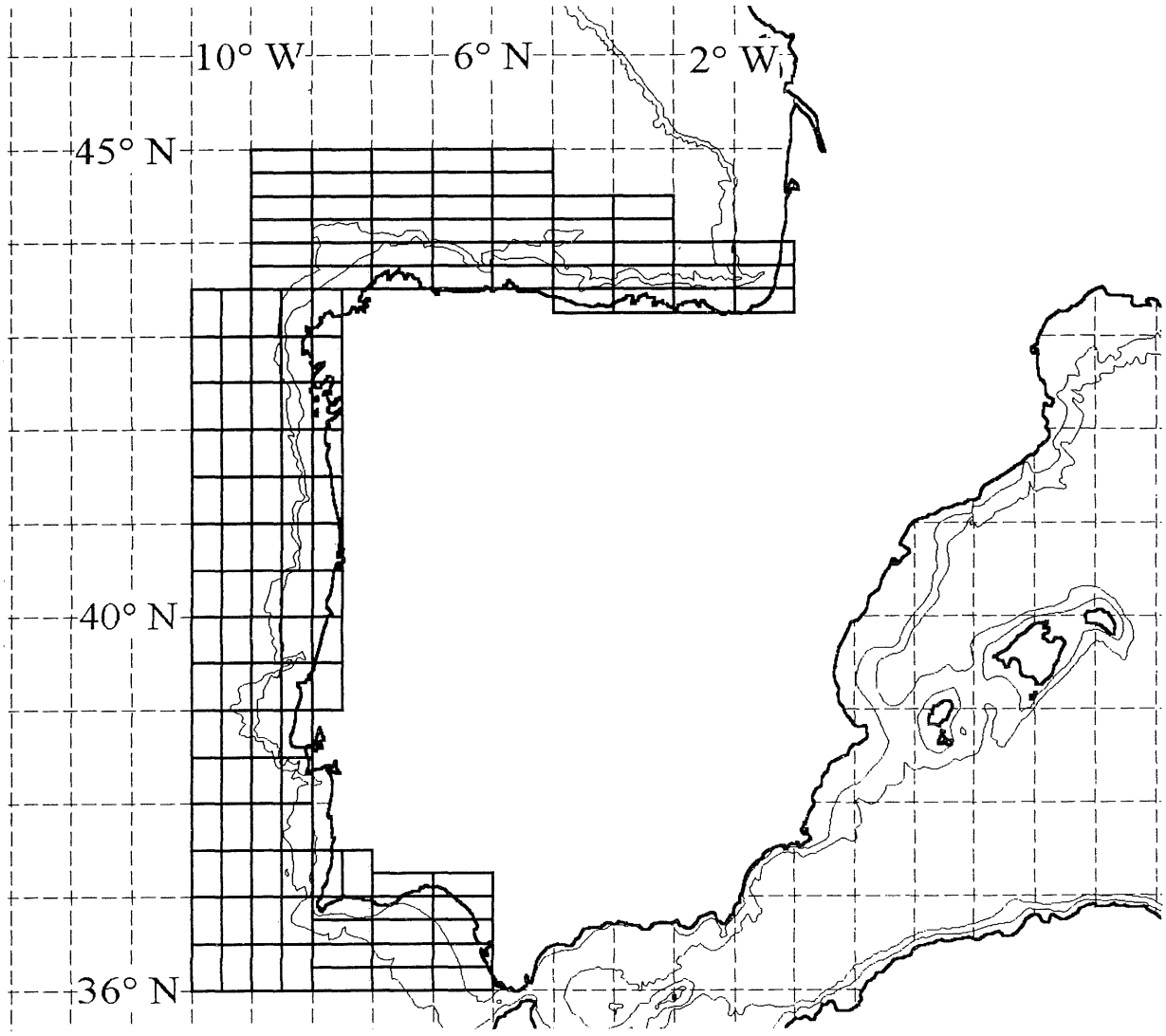


**Figure 6.2b**
Southern area, period 1 - number of observations per rectangle.

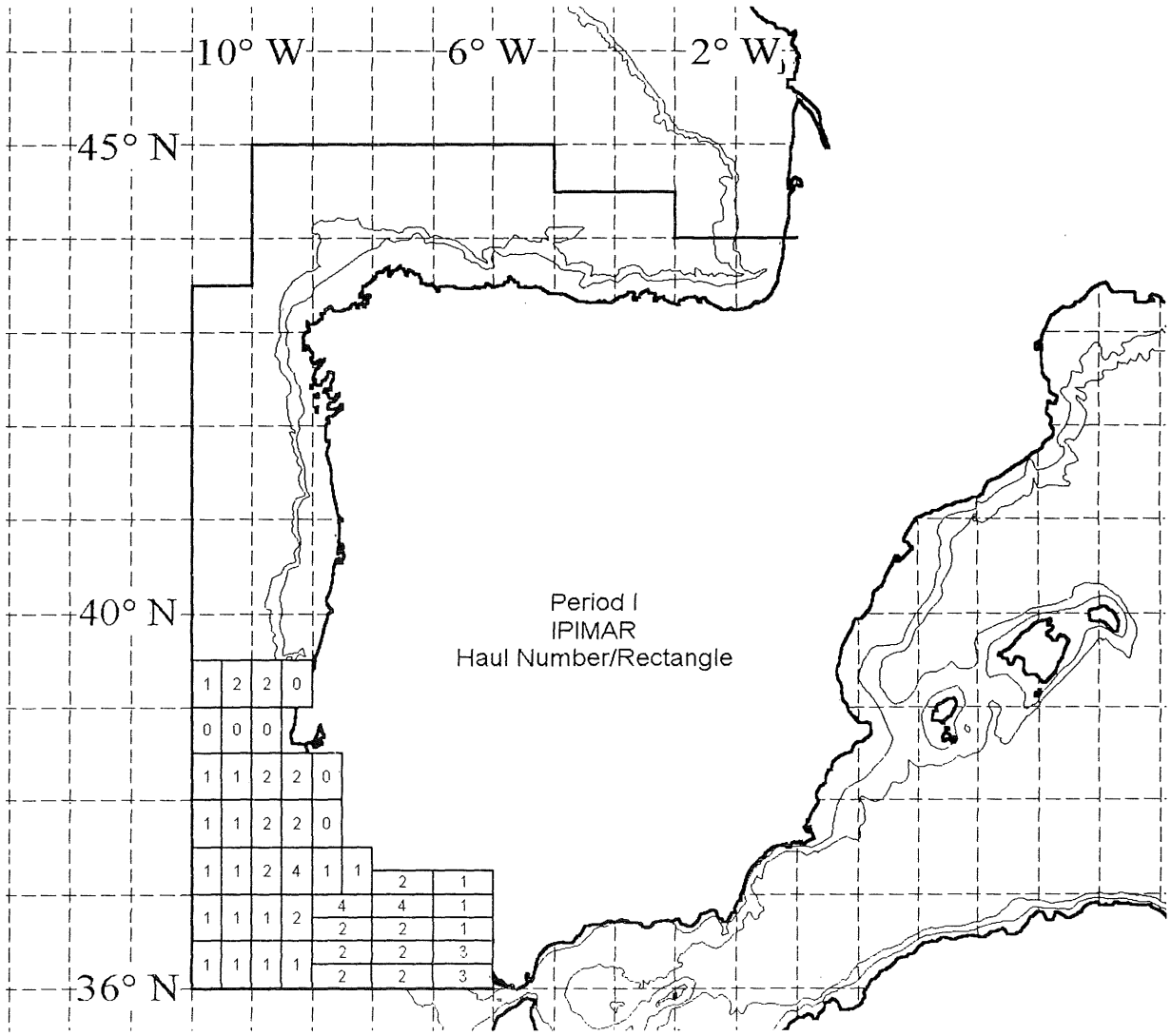


**Figure 6.2c**
Southern area, period 2 - number of observations per rectangle.

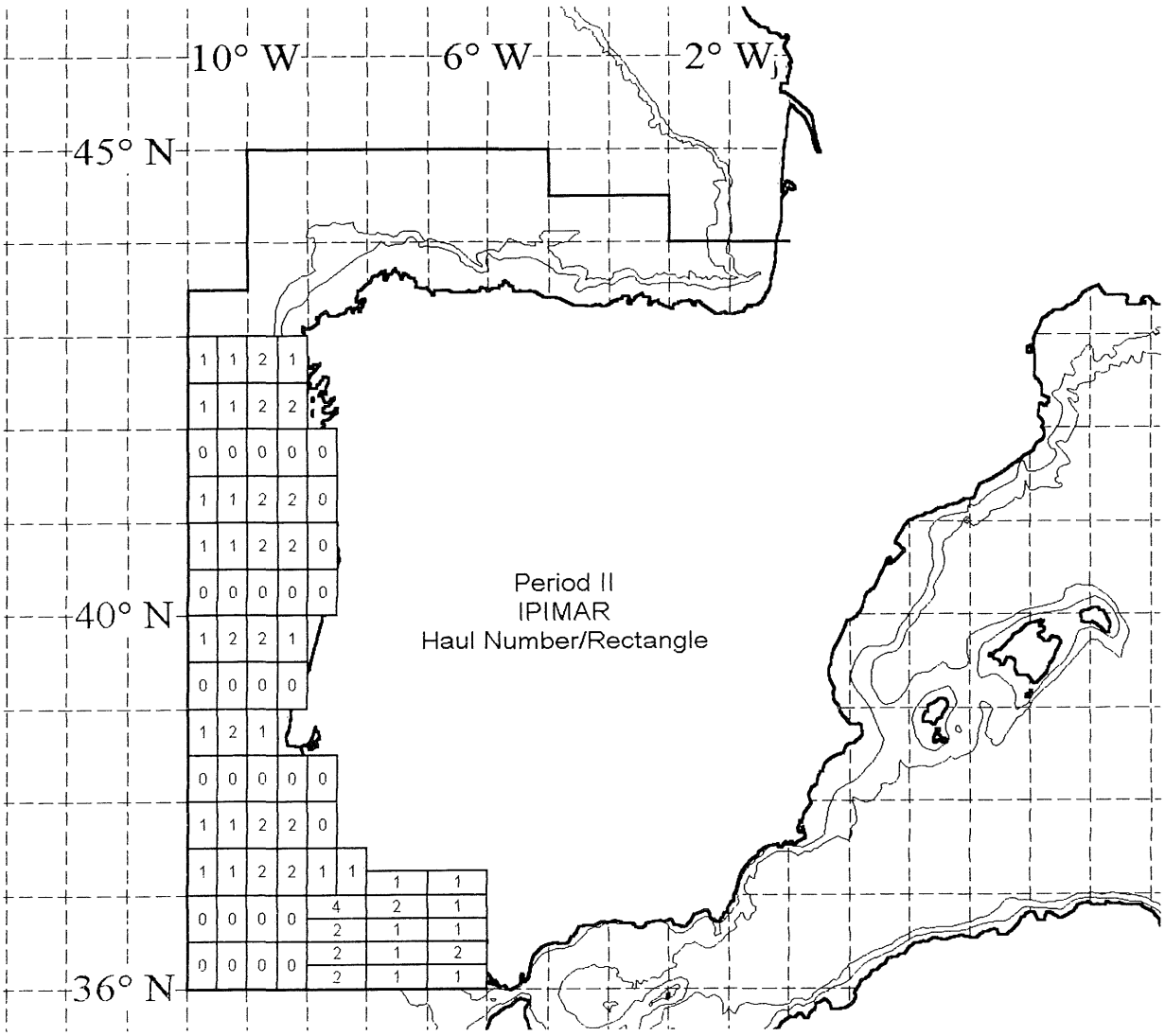


**Figure 6.2d**
Southern area, period 3 - number of observations per rectangle.

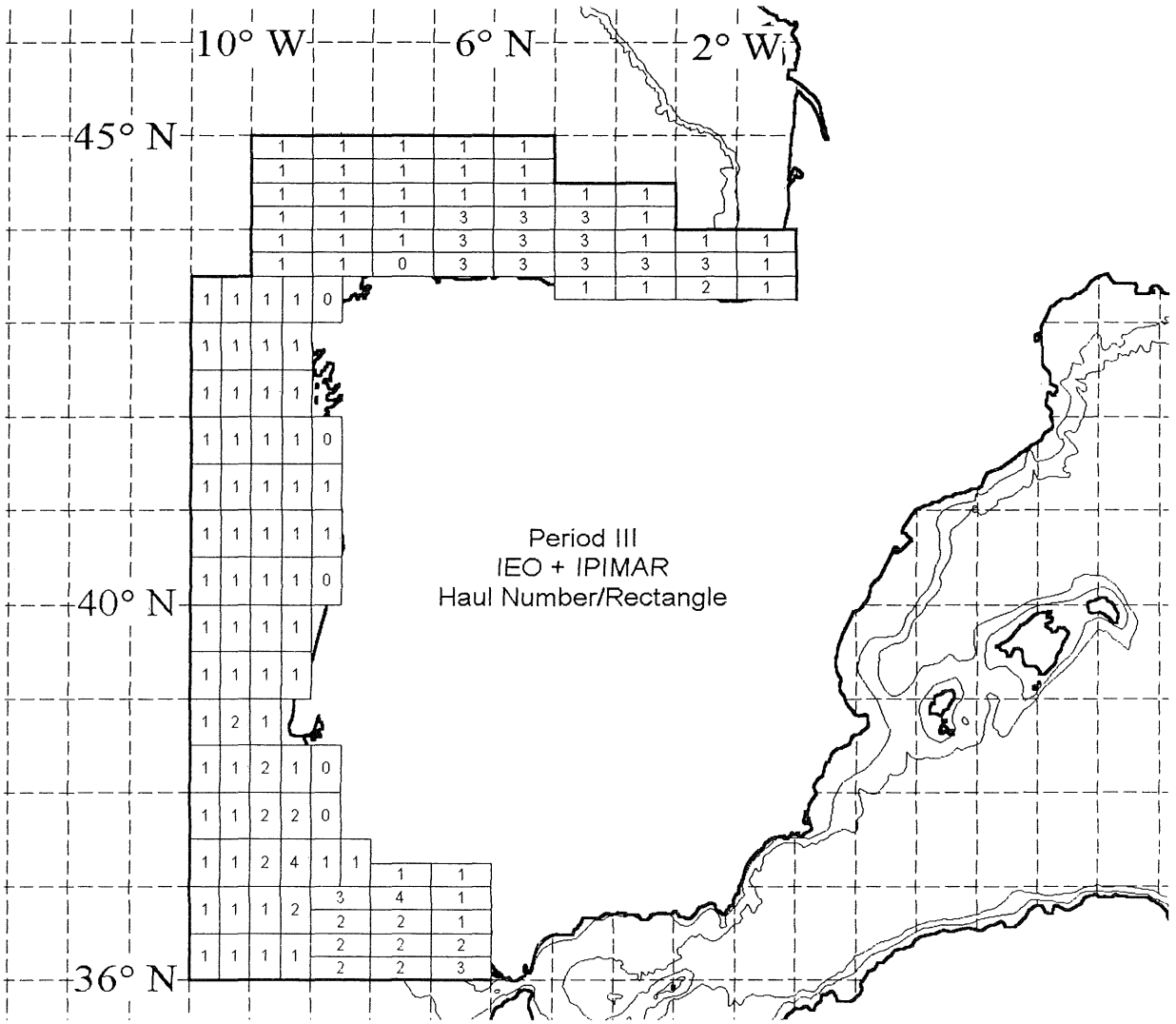


**Figure 6.2e**
Southern area, period 4 - number of observations per rectangle.

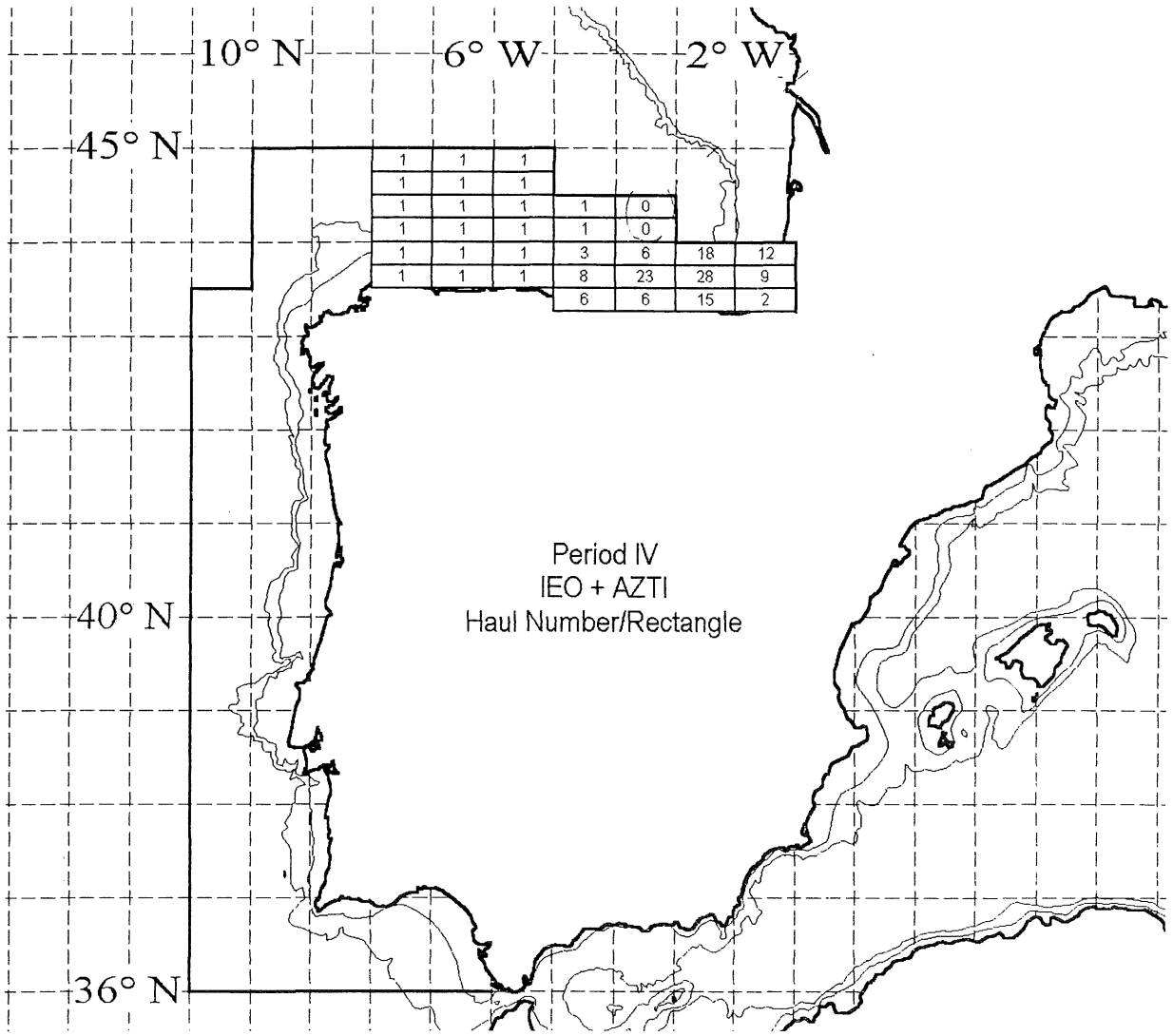
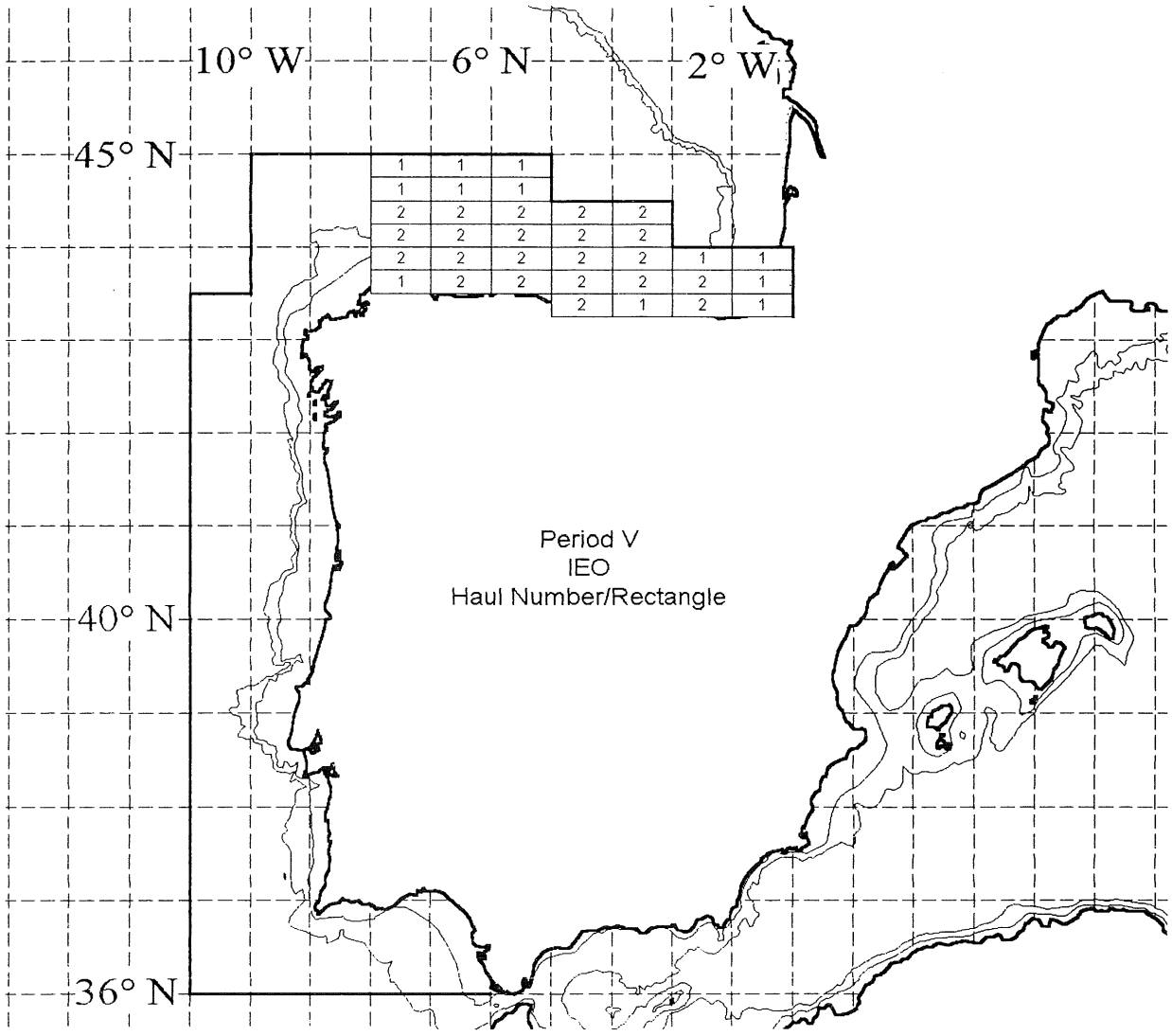


**Figure 6.2f**
Southern area, period 5 - number of observations per rectangle.



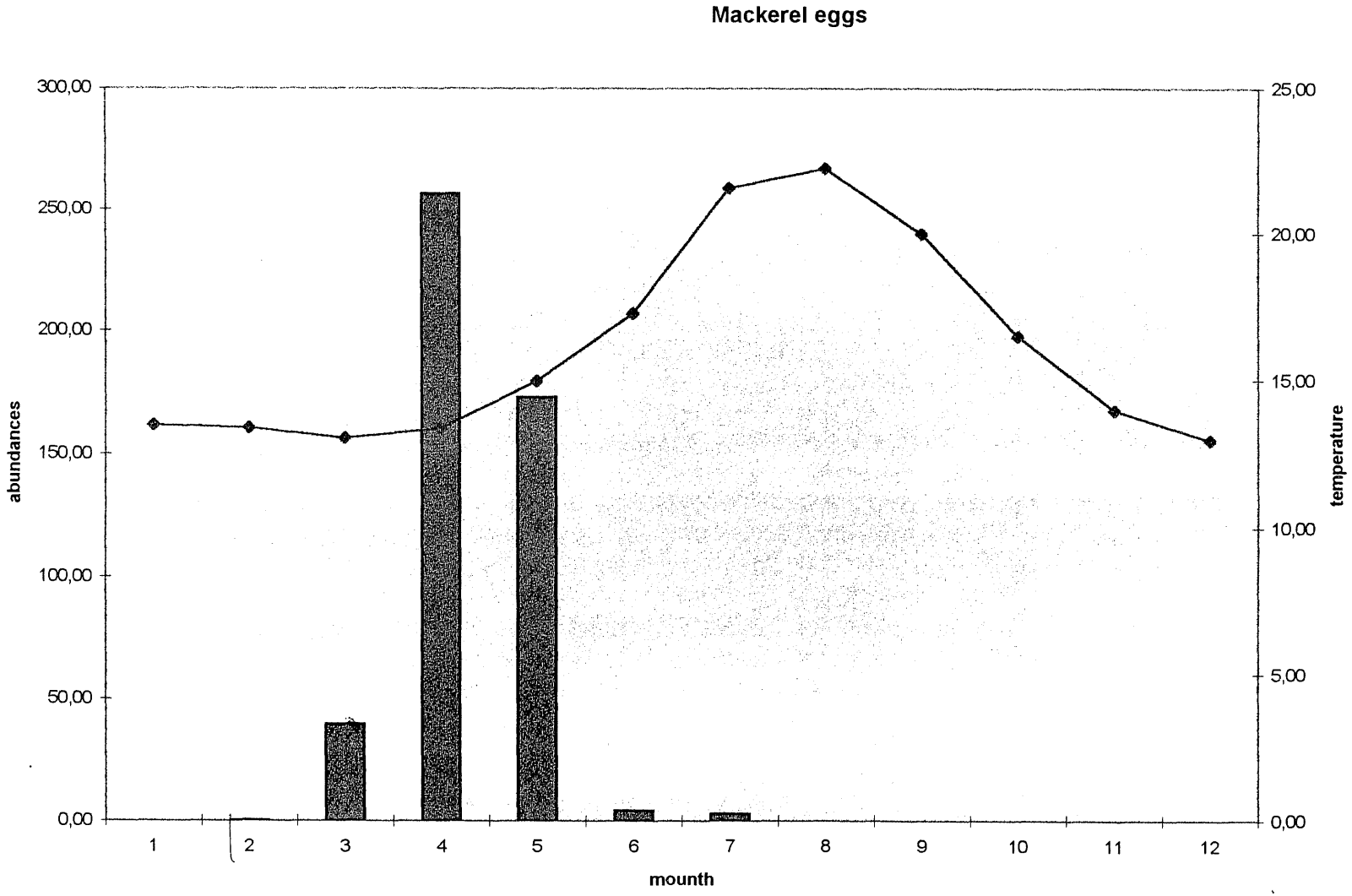



**Figure 6.4a**
Mackerel egg abundance from monthly sampling off Santander (Northern Spain). Sea surface temperature $^{o}C$ at the sampling station is also shown.

**Figure 6.4b**
Daily mackerel egg production 'curve' and histogram for sampled and interpolated periods.

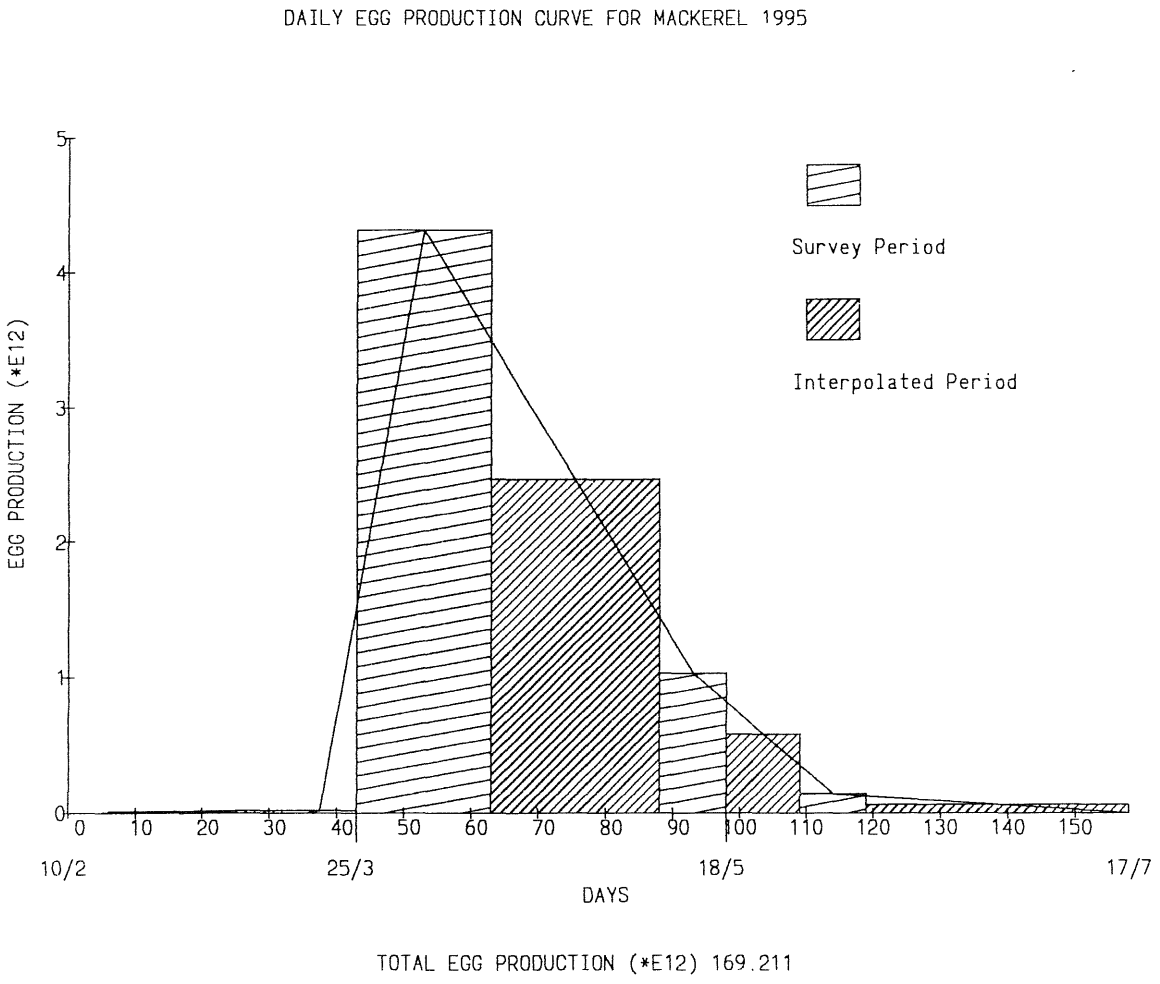


**Figure 6.4c**
An alternative daily mackerel egg production 'curve' and histogram (see Section 6.4).

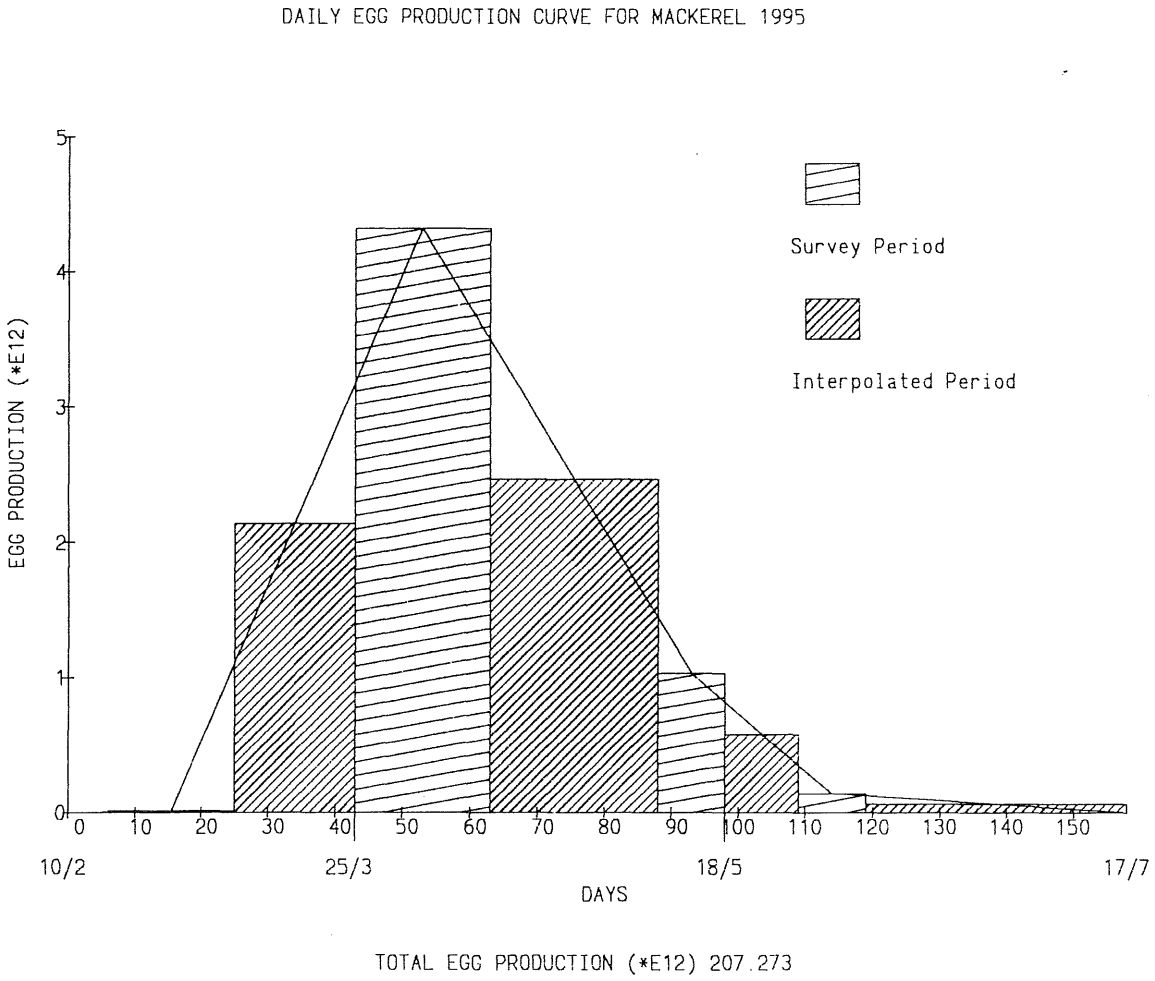
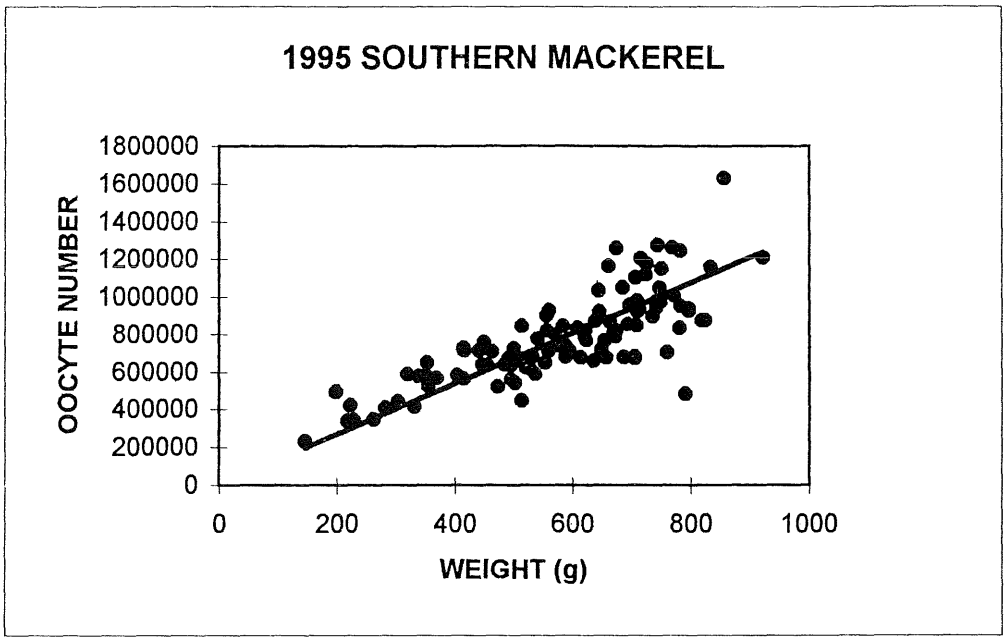


**Figure 6.5a**
Southern area mackerel - the relationship between weight (grams) and total annual potential fecundity, forced through the origin and weighted to the inverse of the corresponding fish weight (104 fish)



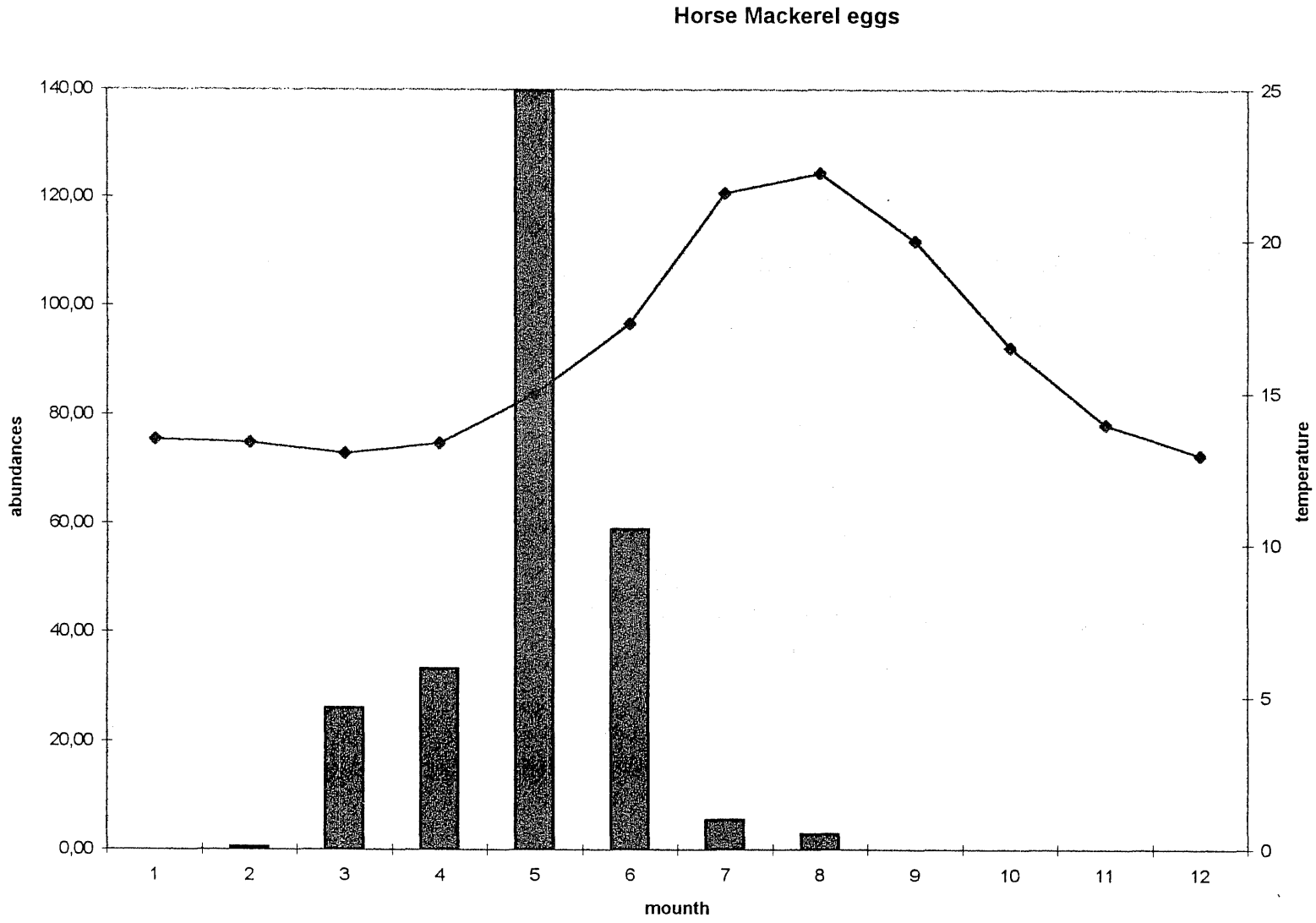



**Figure 6.7a**
Horse mackerel egg abundance from monthly sampling off Santander (Northern Spain). Sea surface temperature $^{o}C$ at the sampling station is also shown.

**Figure 6.7b**
Daily horse mackerel egg production 'curve' and histogram for sampled and interpolated periods.

**Figure 6.7c**
An alternative daily horse mackerel egg production 'curve' and histogram (see Section 6.7).

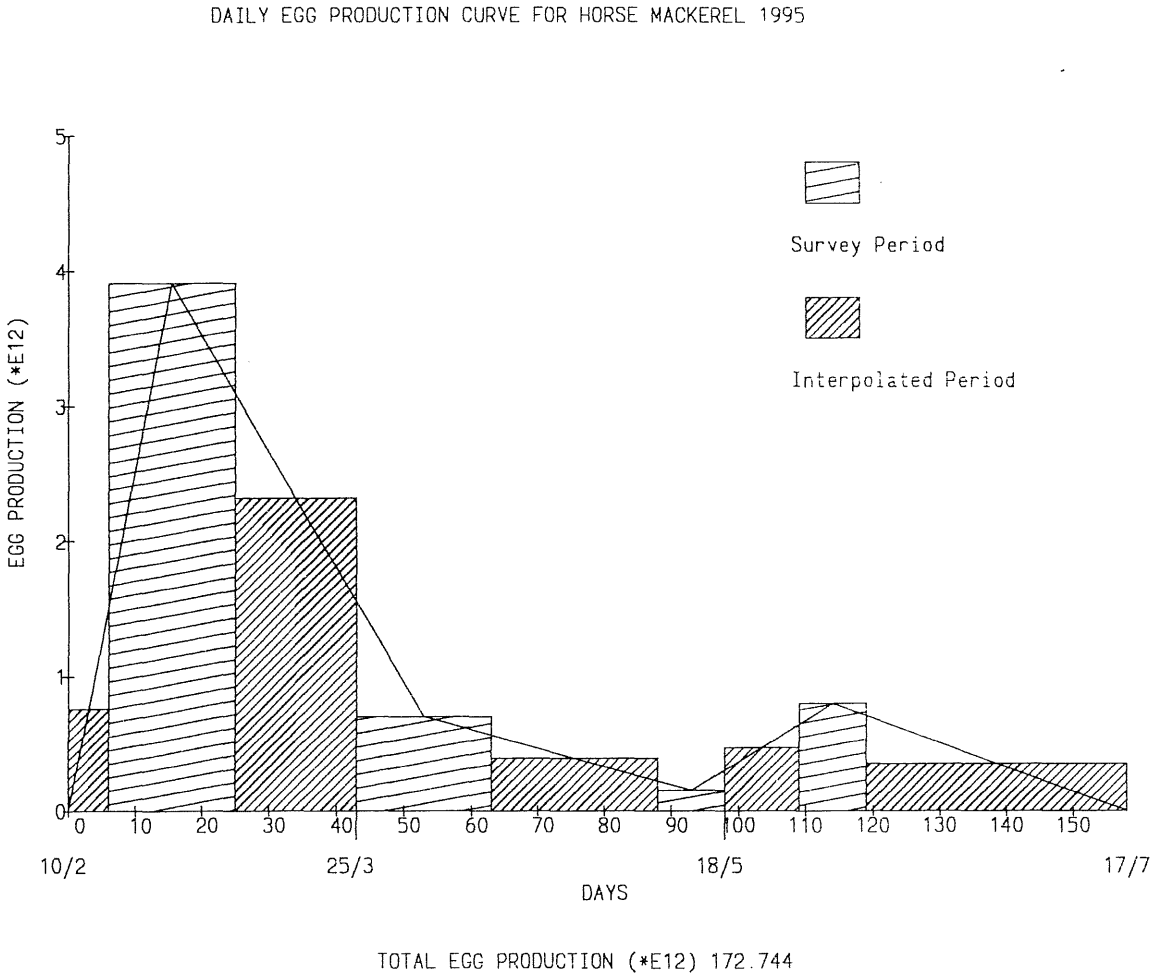
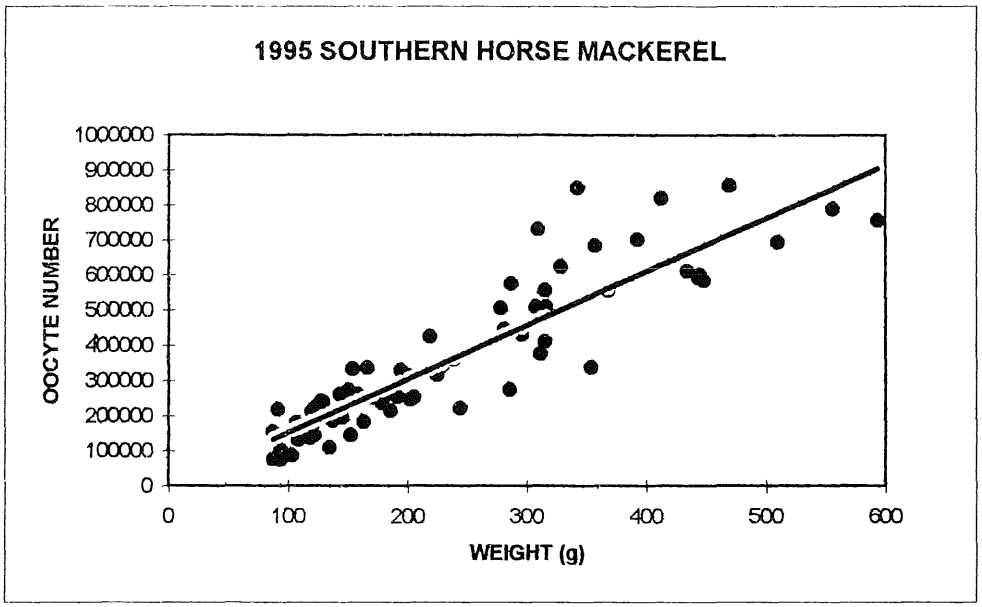


**Figure 6.8a**
Southern area horse mackerel - the relationship between weight (grams) and total annual potential fecundity, forced through the origin and weighted to the inverse of the corresponding fish weight (68 fish)



## 7 PLANNING MEETING FOR 1998 SURVEYS

The next series of triennial mackerel and horse mackerel egg surveys of the western and southern areas is scheduled for 1998. The Working Group proposed that a meeting to plan these surveys should be held in either Lisbon or Hamburg from 3 to 7 February 1997.

## 8 DEFICIENCIES AND RECOMMENDATIONS

This Working Group would welcome advice from the ICES Plankton Sampler Study Group on whether or not any correction should be made to the mackerel and horse mackerel egg data base following the investigations carried out under the EU Concerted Action.

This Working Group needs advice from the ICES Plankton Sampler Study Group on:

i) the type of samplers to be used in future surveys and their efficiency; and
ii) the recommended method for the measurement and subsequent calculation of volume filtered by the samplers.

This advice should be available before the meeting, scheduled for February 1997, to plan the proposed egg surveys of the western and southern areas in 1998.

This Working Group recommends that a maturity ogive for the western mackerel be constructed based on the biological samples taken during the trawl surveys carried out for the Daily Egg Production Method in 1992.

In the 1995 egg exchange only mackerel egg stagings were compared. The Working Group recommends that at a next exchange a mixture of both mackerel and horse mackerel eggs be used.

The Working Group recommends that the fish collected for atresia estimation be taken from as many hauls as possible.

The Working Group recommends that the historic biomass estimates of western horse mackerel be adjusted by 3.4% instead of 10% used previously.

The Working Group recommends that the available histological slides from the southern area be exchanged between experts of the Netherlands, Spain and Portugal for comparison. The additional unprocessed samples from Sub-divisions IXa central-north, central-south and south should be prepared and circulated for comparison.

The Working Group recommends that in future egg sampling in both Divisions VIIIb,c (southern Biscay and Cantabrian Sea) and Division IXa (Iberian peninsula) be started earlier than in 1995.

The Working Group recommends that the bias, precision and accuracy of the GAM and the traditional method should be evaluated with respect to the use of the two methods in the stock assessment and management procedures.

The Working Group recommends that a meeting should be held either in Lisbon or Hamburg from 3-7 February 1997 to plan the next series of triennial egg surveys scheduled for 1998.

## 9 Working Documents

Augustin, N.H., Borchers, D.L., Clarke, E.D. and Buckland, S.T. Spatio-temporal model development to improve annual egg production method of western mackerel/horse mackerel.

Costa, A.M. and Borges, M.F. annual potential fecundity and atresia of horse mackerel (*Trachurus trachurus* L.) in Division IXa.

Solá, A., Lago de Lanzós, A., Franco, C., Sanchez, P., Valdés, L. and Farinha, A. Mackerel and horse mackerel egg production in ICES Divisions VIIIb, c and IXa in 1995.

Walsh, M. An evaluation of possible sources of error in 1995 western area egg production estimates derived by the traditional method of calculations.

## 10 References


Anon. 1985. Report of the Mackerel Egg Production Workshop. ICES CM 1985/H:7, 22pp.

Anon. 1993. Report of the Mackerel/Horse Mackerel Egg Production Workshop. ICES CM 1993/H:4, 142pp (mimeo).

Anon. 1994. Report of the Mackerel/Horse Mackerel Egg Production Workshop. ICES CM 1994/H:4, 58pp (mimeo).

Anon. 1996. Report of the Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy. ICES CM 1996/Assess:7 340pp (mimeo).

Anon. 1987. Report of the Mackerel Egg Production Workshop. ICES CM 1987/H:2, 58pp.

Anon. 1990. Report of the Mackerel/Horse Mackerel Egg Production Workshop. ICES CM 1990/H:2, 89pp.

Borchers, D.L., Buckland, S.T. and Ahmadi, S. 1994. Biomass estimates for western horse mackerel using generalized additive models. *(unpublished).*

Borchers, D.L., Buckland S.T. and Ahmadi, S. 1995. Improving the daily egg production method using generalized additive models: western mackerel and horse mackerel. *Submitted to Can. J. Fish. and Aquat. Sci.*

Bravington, M. 1993. Unpublished PhD thesis, Imperial College, London.

Coello, S., Dawson, W.A. and Grimm, A.S. 1989. Incidence of abortive maturation in the western mackerel stock of the north-east Atlantic mackerel (*Scomber scombrus* L.) during the 1987 spawning season. ICES CM 1989/H:49.

Coombs, S.H., Morgans, D. and Halliday, N.C. In press (a). The vertical distribution of eggs and larvae of mackerel (*Scomber scombrus*).

Coombs, S.H., Conway, D.V.P. and Halliday, N.C. In press (b). the vertical distribution of eggs and larvae of horse mackerel (*Trachurus trachurus*).

Efron, B. and Tibshirani, R.J. 1993. *An introduction to the bootstrap*. Chapman and Hall, London.

Eltink, A. and Vingerhoed, B. 1989. The annual potential fecundity of western horse mackerel (*Trachurus trachurus* L.). ICES CM 1989/H:44.

Eltink, A. and Vingerhoed, B. 1993. The total fecunidyt of western horse mackerel (*Trachurus trachurus* L.) in 1992. ICES CM 1993/H: 17, 7pp.

Emelson, L.S., Greer Walker, M. and Witthames, P.R. 1990. A stereological method for estimating fish fecundity. *J. Fish. Biol.*, **36**, 721-730.

Greer Walker, M., Witthames, P.R. and Bautista De Los Santos, I. 1994. Is fecundity of Atlantic mackerel (*Scomber scombrus*: Scombridae) determinate? *Sarsia*, **79**, 13-26.

Greer Walker, M., Witthames, P.R., Emerson, L. and Walsh, M. 1987. Estimation of fecundity in the western mackerel stock, 1986. ICES CM 1987/H:41.

Gurr, G.T. 1963. Biological staining methods. G.T. Gurr Ltd. HMSO, London.

Hastie, T. and Tibshirani, R. 1990. *Generalized Additive Models*. Chapman and Hall, London.

Iversen, S.A., Eltink, A., Kirkegaard, E. and Skagen, D.W. 1991. The egg production and spawning stock size of the North Sea mackerel stock in 1990. ICES CM 1991/H:11, 16pp (mimeo).

Kjesbu, O.S. 1994. Time of spawning in Atlantic cod (*Gadus morhua*) in relation to vitellogenic oocyte diameter, temperature, fish length and condition. *J. Fish. Biol.*, **45**, 719-735.

Lockwood, S.J. 1978. The fecundity of mackerel *Scomber scombrus* L. ICES CM 1978/H:9, 5pp.

Lockwood, S.J., Nichols, J.H. and Dawson, W.A. 1981. The estimation of a mackerel (*Scomber scombrus* L.) spawning stock size by plankton survey. *J. Plankt. Res.*, **3**(2), 217-233.

Macer, C.T. 1976. Observations on maturity and fecundity of mackerel (*Scomber scombrus* L.). ICES CM 1976/H:6.

Maridueña, L.S. 1984. The sexual maturation *Scomber scombrus* L. M.Phil Thesis, Univ of East Anglia, UK.

McCullagh, P. and Nelder, J.A. 1989. *Generalized Linear Models*. London: Chapman and Hall. 511 pp.

Pipe, R.K. and Walker, P. 1987. The effect of temperature on the development and hatching of scad (*Trachurus trachurus* L.) eggs. *J. Fish Biol.*, **31**, 675-682.

Ramsay, K. and Witthames, P.R. In press. *Netherlands Journal of Sea Research*.

Smith, P. and Richardson, S.L. 1977. Standard techniques for pelagic fish eggs and larvae surveys. *FAO Fisheries Technical Paper*, No 175, 100pp.

Swartzman, G., Huang, C. and Kaluzny, S. 1992. Spatial analysis of Bering sea groundfish survey data using generalized additive models. *Can. J. of Fish. Aquat. Sci.*, **49**, 1366-1378.

Walsh, M., Hopkins, P., Witthames, P.R., Greer Walker, M. and Watson, J. 1990. Estimation of the total potential fecundity and artesia in the western mackerel stock, 1989. ICES CM 1990/H:31, 22pp.

West, G. 1990. Methods of assessing ovarian development in fishes: a review. *Australian Journal of Marine and Fresh Water Research*, **41**, 199-222.

Wood, S.N. and Horwood, J.W. 1995. Spatial distribution functions and abundances inferred from sparse noisy plankton data: an application of constrained thin-plate splines. *Journal of Plankton Research*, **17**, 1189-1208.