Living Resources Committee

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REPORT OF THE

WORKING GROUP ON MACKEREL AND HORSE MACKEREL EGG SURVEYS

Hamburg, Germany
13–17 April 1999

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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SUMMARY

The Working Group addressed the problem of estimating spawning stock sizes of mackerel and horse mackerel in the western spawning area (VI, VII, VIIIabde) and southern spawning area (VIIIc and IXa). The annual egg production method was implemented using international egg surveys completed in 1998 from 17 January to 5 July and associated estimates of fecundity and atresia. Sampling was completed as planned, but the WG concluded that the surveys began too late in the year to cover fully the mackerel spawning event in the western area, and ended too early to cover fully the horse mackerel spawning event in the western area. Spawning events for both species in the southern area were not comprehensively covered. Egg production estimates for both species in the western area are therefore considered minimum estimates.

Estimates of egg production and of spawning biomass for both species in both areas are provided. In the western area, egg production of mackerel is estimated to have decreased by 8 % but as total corrected fecundity is estimated to have decreased by 23 % this indicates an increase in spawning biomass of 19 % to 2.95 Million t in 1998. In the southern area, estimated mackerel egg production has increased by 122 % from 1995 to 1998 and fecundity has increased by 8 %, indicating an increase in spawning biomass of 106 %. Overall the ratio of southern:western component biomasses is revised from 15 % in 1995 to 26 % in 1998. Mackerel biomass for the southern and western components of the North East Atlantic mackerel is estimated at 3.73 Million t, but is subject to revision.

Estimation of horse mackerel fecundity in 1998 has not been possible. Horse mackerel egg production in the western area has fallen by 18 % from 1995 to 1998. An estimate of biomass of 1.4 Million t is provided on the assumption that fecundity in 1998 was as estimated for this stock in previous years. In the southern area, estimated horse mackerel egg production excluding a small number of very abundant egg samples is 18.6 10^{13} (s.e. 7.7 10^{13}). If these samples are included the estimate is 100.3 10^{13} (s.e. 80.7 10^{13}).

Comparison of egg staging among participating countries indicated good consistency of mackerel staging for stage I eggs but poor consistency of horse mackerel staging. GAM- based egg production estimates for mackerel were similar to estimates calculated using the WG’s usual method. A mackerel egg survey in the North Sea is planned for summer 1999 and is expected to report preliminary results by September 1999.

1 INTRODUCTION

1.1 Terms of Reference

At the ICES Annual Science Conference in October 1998 it was decided that (C.Res.1998/2:49) the Working Group on Mackerel and Horse Mackerel Egg Surveys [WGMEGS] (Chair: Mr J.H. Nichols, UK) will meet in Hamburg, Germany from 13–19 April 1999 to:

a) analyse and evaluate the results of the 1998 mackerel and horse mackerel egg surveys of the western and southern areas, including the comparisons of egg staging;

b) calculate the total seasonal stage 1 egg production estimates for mackerel and horse mackerel separately for the western and southern areas;

c) analyse and evaluate the results of the mackerel and horse mackerel fecundity and atresia sampling in the western and southern areas and provide estimates of fecundity, corrected for atresia, separately for each area;

d) investigate the possibilities of combining the mackerel fecundity estimates, corrected for atresia, from the western and southern areas;

e) analyse and evaluate the results of the sampling for mackerel and horse mackerel maturity in the western and southern areas and produce maturity ogives for 1998 for each area;

f) provide estimates of the spawning stock biomass of mackerel and horse mackerel, using stage 1 egg production estimates and the estimates of fecundity and atresia, separately for the western and southern areas;

g) provide an estimate of the spawning stock biomass of the North-East Atlantic mackerel by combining the estimates from the western and southern areas;

h) use the new estimates of the spawning stock biomass from the egg surveys to re-tune the VPA estimates of stock size for the North-East Atlantic mackerel, western horse mackerel and southern horse mackerel and produce a report for the ACFM meeting in May 1999 (relevant assessment biologists to carry out this task);

i) obtain a peer review of the Working Group report from the appropriate assessment working group prior to the 1999 Annual Science Conference;

j) comment on the draft objectives and activities in the Living Resources Committee component of the ICES Five-Year Strategic Plan, and specify how the purpose of the Working Group contributes to it.

WGMEGS will report to the Living Resources and Resource Management Committees at the 1999 Annual Science Conference and to WGMHSA.

Since the above resolution was tabled terms of reference h) and j) have been deleted by ICES. As a consequence the Chair agreed with the ICES General Secretary that the meeting time would be from 13–17 April 1999.

1.2 Participants

The Working Group met in Hamburg, Germany from 13–17 April 1999 with the following participants:

John Nichols (Chair)	UK (E&W)
Pablo Abaunza	Spain
Paula Alvarez	Spain
Guus Eltink	Netherlands
Concha Franco	Spain
Francois Gregoire	Canada
Cornelius Hammer	Germany
Svein Iversen	Norway
Steve Milligan	UK (E&W)
John Molloy	Ireland
Alberto Murta	Portugal
Kenneth Patterson	UK (Scotland)
Jose-Ramon Perez	Spain
Dave Reid	UK (Scotland)
Aileen Shanks	UK (Scotland)
Amor Sola	Spain

Bas Vingerhoed	Netherlands
Peter Witthames	UK (E&W)
Christopher Zimmermann	Germany

2 GENERAL ASPECTS

2.1 Comparison of Egg Staging

Two samples of 100 eggs (one of mackerel, one of horse mackerel), collected from the Celtic Sea area during May 1995 were passed to each institute in turn. The egg stages were identified and counted, and the results collated (Tables 2.1.1 and 2.1.3).

In both samples the total number of eggs decreased (due to loss and damage both in transit and 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 (Tables 2.1.2 and 2.1.4) (Figures 2.1.1 and 2.1.2).

2.1.1 Mackerel

Some participants experienced difficulty when separating stage I eggs into stages IA and IB and two participants did not split the stage I eggs (Tables 2.1.1 and 2.1.2). Comparison of the numbers of stage I eggs (IA and IB combined) shows a good consistency of staging between institutes with 30 % to 38 % of the eggs being allocated to this stage (Figure 2.1.1). This was very reassuring as the annual egg production is based upon the abundance of eggs in this stage. These results also compare favourably with a similar exercise conducted for the 1995 survey when the numbers of eggs allocated to stage I ranged between 32 % and 48 %.

The greatest differences between participants can be seen in the allocation of eggs to stage II. Both the Netherlands and England allocated a greater proportion of eggs to stage II with correspondingly fewer eggs allocated to stage III.

Norway found 11 eggs in the sample, which they would not have identified as mackerel eggs had they occurred in the survey samples.

2.1.2 Horse mackerel

For the first time, the 1995 egg survey report (ICES, 1996b) recommended that a sample of horse mackerel eggs should be passed around the participants for comparative egg staging. The analysis of the results (Tables 2.1.3 and 2.1.4) (Figure 2.1.2) show some cause for concern. There was a large variability in the allocation of eggs to stage I ranging from 29 % (England) to 55 % (Germany). If translated to the survey samples, these discrepancies would lead to large differences in the estimate of abundance of stage I eggs, with a direct and significant effect on the estimate of horse mackerel SSB.

Large differences also occur in the allocation of eggs to the other stages. England found the highest number of stage II eggs (38 %) with Germany allocating only 7 % to this stage. There not only appears to be some miss allocation of eggs between stages I and II but also between stages II and III, with Norway allocating 13 % to stage II but very large numbers of eggs (37 %) to stage III.

Germany found some eggs in stage 5, a stage not normally found in horse mackerel.

The difficulties experienced by all participants in allocating horse mackerel eggs to the various stages may be due to the age of the samples. Horse mackerel eggs have a dense, segmented yolk and the yolk would have darkened further, having been fixed for three years. A clearing technique described by Gurr, 1963, was suggested by the 1995 WG (ICES, 1996b) but was not applied by any of the participants.

It may be that the problems of staging horse mackerel eggs encountered during this comparison would have been greater than those experienced if analysts had been looking at recently fixed samples from the 1998 survey. However, such large discrepancies cannot be overlooked because they may have serious effects on the estimates of SSB. This workshop therefore recommends that the EU is approached to fund an egg identification and staging workshop prior to the 2001 survey to try and resolve some of the problems encountered. **Action: S.Milligan, G.Eltink.**

2.2 Between Country Variation

There was little sampling of the same rectangles, by different vessels, within the same time period. On the few occasions when this did occur the sampling dates were too far apart for any valid comparisons to be made.

2.3 Vertical Distribution of Mackerel and Horse Mackerel Eggs

No additional information on the vertical distribution of the eggs of either species was collected during these surveys.

2.4 Sampler calibration

During an EU funded Concerted Action (Anon., 1997) the performance of Gulf III samplers currently used in the mackerel and horse mackerel egg surveys was examined. As a result of calibrations carried out in a flume tank using a Laser/Doppler system it was concluded that these samplers are between 100 % and 105 % efficient. The performance of the flowmeters used in national variations of these samplers is also checked over a range of speeds on most surveys prior to sampling. Full account is therefore taken of the performance of individual flowmeters and, together with the results of the 1996 calibrations, allows accurate calculation of the volume of water filtered.

A 20 cm Bongo sampler was also calibrated in the flume during the EU Concerted Action and was found, somewhat surprisingly, to be only 85 % efficient. Three sizes of this type of sampler were used (Tables 4.3.1 and 4.3.2) on the mackerel and horse mackerel egg surveys and are regularly calibrated over a range of speeds at sea. Flowmeters mounted in the aperture of the Bongos provide an accurate measure of the water velocity and hence distance travelled by the samplers on each deployment. However, to date, no account has been taken of the EU Concerted Action results and an efficiency of 100 % has been assumed. The volume of water filtered on each deployment is calculated by multiplying the estimate of distance travelled (using the flowmeter) by the aperture area.

The efficiency, which is used in the calculation of volume filtered for Bongo type samplers, has a direct and identical effect on the calculation of egg densities. Therefore, if the efficiency of these samplers is 85 % (Anon., 1997), then the numbers of eggs m^{-2} from each survey tow can be increased by 15%. It is clear, therefore, that the 1998 survey results could be an under-estimate of the numbers of eggs produced where a Bongo sampler has been used.

2.5 Definition of the stocks

Mackerel

Traditionally and according to main spawning sites three mackerel stocks were previously considered by ICES, the southern, the western and the North Sea stock. However, data from egg surveys have demonstrated that it is impossible clearly to distinguish between a southern and a western spawning area. Tagging experiments have demonstrated that after spawning fish from these areas migrate into the Norwegian Sea and the North Sea during the second half of the year to feed where they mix with mackerel from the North Sea stock. Since it is impossible to allocate catches to stock, mackerel are at present, for practical reasons, considered as one stock: **the North East Atlantic Mackerel Stock.** However, to be able to keep track of the development of the spawning biomass in different spawning areas, the North East Atlantic mackerel stock is divided into three spawning components, i.e. the Western Spawning Component, the North Sea Spawning Component and the Southern Spawning Component. The Western Component, spawning in the western spawning area (ICES Divisions and Sub-Areas VI, VII, VIII a,b,d,e) comprises approximately 85 % of the entire North East Atlantic Stock. The Southern Component is spawning in the southern area (ICES Divisions VIIIc and IXa). Although the North Sea Component has been at an extremely low level since the early 1970s the WG regards the North Sea Component as still existing (Section 3). This component is spawning in the North Sea and Skagerrak (ICES Sub-Area IV and Division IIIa). The egg surveys indicate that minor spawning also occur outside the three main spawning areas.

The North East Atlantic mackerel stock is distributed and fished in the ICES Sub-Areas and Divisions: IIa, IIIa, IV, Vb, VI, VII, VIII, IXa.

The definitions of stock, components and spawning areas, as used by this Working Group and the MHSA Working Group, are summarised in the text table below.

North-East Atlantic Mackerel			
Distributed and fished in ICES Divisions IIa, IIIa, IV, Vb, VI, VII, VIII and IXa			
Spawning Component	**Western**	**Southern**	**North Sea**
Spawning Areas	VI, VII, VIIIa,b,d,e.	VIIIc, IXa.	IV, IIIa.

Horse Mackerel

There is some biological evidence (see ICES 1999/G:16) that horse mackerel form three different spawning populations. These populations are regarded as stocks, i.e., the Southern Stock, the North Sea Stock and the Western Stock. Extensive migration and mixing of the stocks is likely to occur. The catches are allocated to the different stocks on an arbitrary basis according to the temporal and spatial distribution of the fishery (ICES 1999/ACFM:6).

The definitions of stocks, spawning areas and fishing areas, as used by this Working Group and the MHSA Working Group, are summarise in the text table below.

Horse Mackerel			
Stock	**Western**	**Southern**	**North Sea**
Spawning Area	VI, VIIa-c, e-k, VIIIa,b,d,e.	VIIIc, IXa.	IVb, c and VIId
Fishing Area	IIa, IVa, VIa, VIIa-c, e-k, VIIIa,b,d,e, IIIa (western)	VIIIc, IXa	IIIa (eastern), IVb, c and VIId

Table 2.1.1	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	24	8	32	24	17	15	12	100
Ireland	22	13	35	13	18	19	14	99
Spain (AZTI)	16	14	30	16	21	18	14	99
Spain (IEO)	17	15	32	16	23	16	12	99
Portugal	16	22	38	13	17	12	19	99
Scotland (1)			28	15	23	12	13	91
Scotland (2)			30	16	23	8	16	93
Norway	25	5	30	7	18	12	14	81
Germany	9	27	36	10	26	10	14	96
Netherlands			35	24	18	10	11	98

Note: The total number of eggs staged by Norway excludes 11 eggs which were not identified as mackerel

Table 2.1.2	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	24.0	8.0	32.0	24.0	17.0	15.0	12.0	100
Ireland	22.2	13.1	35.4	13.1	18.2	19.2	14.1	100
Spain (AZTI)	16.2	14.1	30.3	16.2	21.2	18.2	14.1	100
Spain (IEO)	17.2	15.2	32.3	16.2	23.2	16.2	12.1	100
Portugal	16.2	22.2	38.4	13.1	17.2	12.1	19.2	100
Scotland (1)			30.8	16.5	25.3	13.2	14.3	100
Scotland (2)			32.3	17.2	24.7	8.6	17.2	100
Norway	30.9	6.2	37.0	8.6	22.2	14.8	17.3	100
Germany	9.4	28.1	37.5	10.4	27.1	10.4	14.6	100
Netherlands			35.7	24.5	18.4	10.2	11.2	100

Table 2.1.3	The number of horse mackerel eggs allocated							
Country	**Development Stage**							
	1A	**1B**	**Total 1**	**2**	**3**	**4**	**5**	**Total**
England	24	5	29	38	10	23	0	100
Ireland	31	8	39	25	11	25	0	100
Spain (AZTI)	21	10	31	24	24	21	0	100
Spain (IEO)	21	19	40	22	17	21	0	100
Portugal	30	15	45	20	8	26	0	99
Scotland (1)			35	16	20	24	0	95
Scotland (2)			44	14	12	19	0	89
Norway	33	1	34	12	35	14	0	95
Germany			52	7	15	16	4	94
Netherlands			38	31	19	10	0	98

Table 2.1.4	The percentage of horse mackerel eggs allocated to each develoopment stage by country.							
Country	**Development Stage**							
	1A	**1B**	**Total 1**	**2**	**3**	**4**	**5**	**Total**
England	24.0	5.0	29.0	38.0	10.0	23.0	0.0	100
Ireland	31.0	8.0	39.0	25.0	11.0	25.0	0.0	100
Spain (AZTI)	21.0	10.0	31.0	24.0	24.0	21.0	0.0	100
Spain (IEO)	21.0	19.0	40.0	22.0	17.0	21.0	0.0	100
Portugal	30.3	15.2	45.5	20.2	8.1	26.3	0.0	100
Scotland (1)			36.8	16.8	21.1	25.3	0.0	100
Scotland (2)			49.4	15.7	13.5	21.3	0.0	100
Norway	34.7	1.1	35.8	12.6	36.8	14.7	0.0	100
Germany			55.3	7.4	16.0	17.0	4.3	100
Netherlands			38.8	31.6	19.4	10.2	0.0	100

Figure 2.1.1 Comparison between institutes when allocating a sample of mackerel eggs to five development stages.

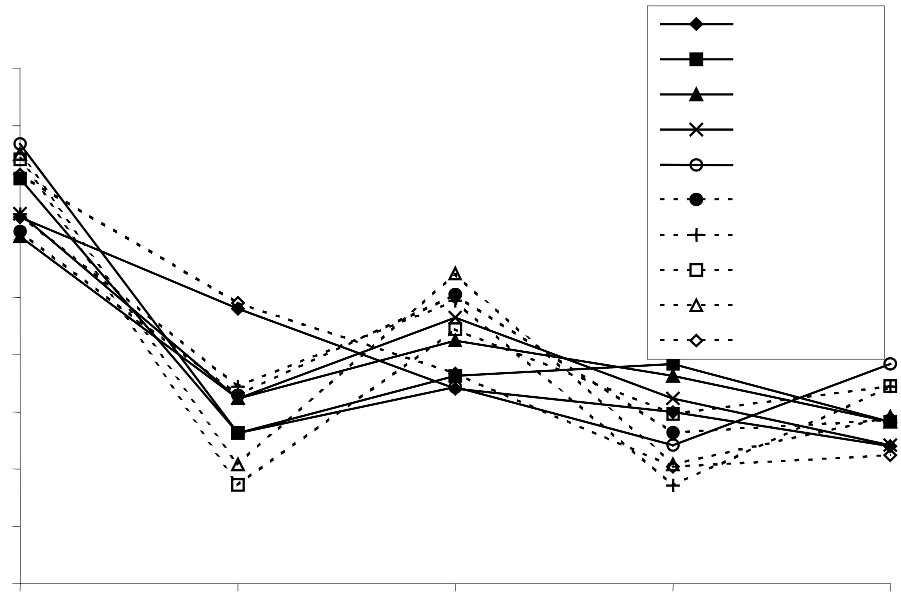
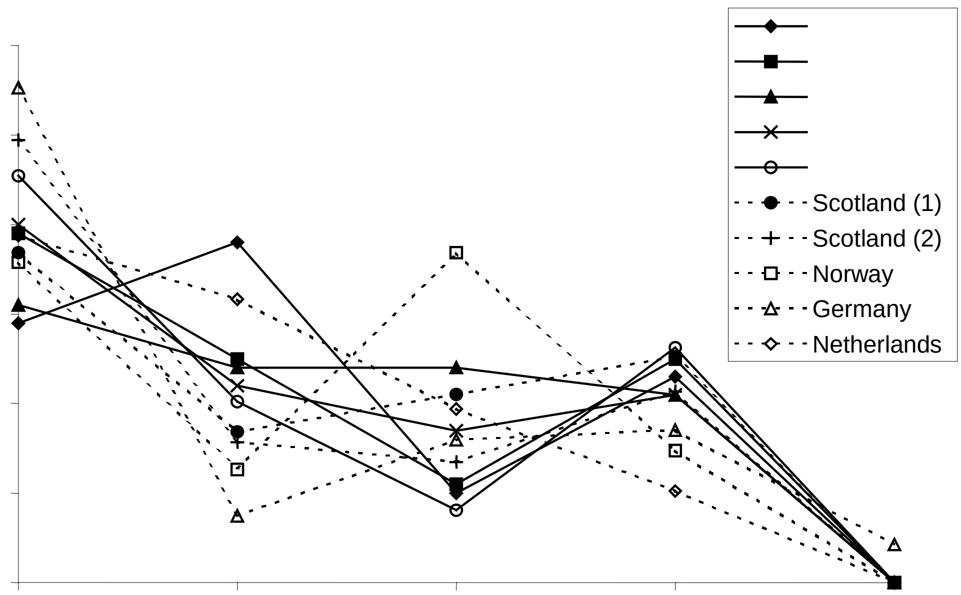


Figure 2.1.2 Comparison between institutes when allocating a sample of horse mackerel eggs to five development stages.



3 NORTH SEA EGG SURVEYS IN 1999

3.1 Countries and Ships Participating

The last AEPM surveys for mackerel eggs in the North Sea were carried out in 1990 (Iversen *et al*., 1991) and in 1996 (ICES, 1997/H:4). In 1990 the spawning stock was estimated at 78,000 t and in 1996 at 110,000 t. Rather large quantities of mackerel of the 1996-year class were observed in the North Sea in the autumn and winter of 1996/1997. This was for the first time in many years that large numbers of 0- and 1-group mackerel were observed in the North Sea. If this year class were of North Sea origin it would be fully recruited to the spawning stock in 1999. Therefore the egg WG recommended to carry out new AEPM surveys in the North Sea in 1999 (ICES, 1997/H:4).

The Netherlands and Norway will carry out mackerel egg surveys in the North Sea in 1999. They will work for about three weeks each and will cover the spawning area three times during 20 May–27 June. This will not cover the total spawning period, which usually starts in mid May and ends late July. However, the peak period is usually around mid June and may therefore be covered. One vessel will survey the spawning area in about two weeks. The surveys will be carried out by the Dutch and Norwegian research vessels “Tridens” and “G. O. Sars” respectively, and the coverages are planned as follows:

Vessel/Coverage	1	2	3
“Tridens”	25 May–4 June	5–11 June	
“G. O. Sars”		5–14 June	15–27 June

3.2 Sampling Area and Survey Design

Usually the main spawning area is located between 55–58^o north and 1–5^o east. However in 1996 the spawning took place in a wider area, 53^{o}30′–58^o north and 2^o west – 8^o east. Based on the findings in 1996 areas to be covered during the three coverages were suggested. The 1996 survey results were also used to identify high priotity areas.The plankton samples should be analysed on board and the sampling area should be adjusted according to the findings.

Traditionally sections along whole or ½ degrees latitude have been sampled. Ideally one sample should be taken in each of the rectangles. However, experience has shown that it is better to survey a larger area less intensively than a lesser area more intensively. As usual Norway will use a 20 cm Bongo sampler towed for 5 minutes in each of the depths 20 m, 15 m, 10 m, 5 m and in the surface. The towing speed will be about 2.5 knots. The Netherlands will use a Gulf III either stepwise as for the Bongo net or in double oblique hauls with a towing speed of 5 knots. As usual nets with mesh size of 500 microns are recommended, as nets with smaller mesh size will easily become clogged.

3.3 Sampling and Data Analysis

The samples will be placed in standard fixative of buffered 4 % formaldehyde. For the purpose of estimating the age of the eggs the temperature in the surface layer (5 m) is required. It is recommended to record a temperature depth profile for each sampling station.

For each station, data on the number of stage I mackerel eggs per sample, the filtered volume and temperature at 5m are required. If possible a preliminary estimate of the mackerel egg production in 1999 should be available for the MHMSA WG in September 1999.

At present no funds are available to investigate the ovaries histologically for fecundity and atresia. If the egg production is found to be at a similar level to that in 1996 there will be no need to carry out these investigations because then the stock is still on or close to its historical low level. However, if the egg production is found to have increased significantly it is more urgent to investigate these parameters so that the estimated SSB of the North Sea component can be compared with the two other spawning components. Therefore ovaries should be sampled to enable these parameters to be checked later if necessary.

<u>Total fecundity</u>: During the first survey 100 mackerel ovaries in pre-spawning stage 3 (Walsh *et al*.,1990) should be collected.

Atresia: During each of the coverages 50 mackerel ovaries from mature fish (maturity stages 3–6, Walsh *et al*., 1990) should be collected and dissected carefully out without damage to the wall of the ovary.

The ovaries sampled for both total fecundity and atresia should be fixed in a minimum of two volumes of 4% formaldehyde, 0.1M phosphate buffered to pH 7 for subsequent histological analysis.

4 WESTERN AND SOUTHERN EGG SURVEYS IN 1998

4.1 Countries and Ships Participating

The deployment of research vessel effort in the western mackerel/horse mackerel egg survey for 1998 is given in Table 4.1.1 and for the southern mackerel/horse mackerel egg survey for 1998, in Table 4.1.2.

4.2 Sampling Areas and Sampling Effort

4.2.1 Egg surveys in the Western Area

The standard sampling area used for the western mackerel/horse mackerel survey for 1998 is shown in Figure 4.2.1. The standard survey area for 1998 is described in Section 4.3.1. The expansion is along the western edge between 45° and 49°N. As with the 1995 survey, sampling was not constrained to be within the standard area. Where reasonably large samples were encountered at the edge of the area it was expected that the survey would be continued until zero samples were found.

The number of hauls taken by half ICES rectangle and by sampling period are presented in Figures 4.2.2c–f. The figures also include those rectangles where egg production was calculated by interpolation from neighbouring, sampled, rectangles.

Within the periods surveyed, the spatial and temporal coverage was very good. Sampling appeared to cover the entire spatial range of both mackerel and horse mackerel spawning, and reached zero samples along most of the edges of the distribution. Slight exceptions to this were seen in period 3, where there were small numbers of eggs on the most northern transect, and in periods 5 and 6 where the western edge in the northern part of the area was poorly defined (see Figures 5.1.1c–f and 6.1.1a–d). For the mackerel surveys there was strong evidence that the surveys were started late in relation to the actual spawning. The daily egg production in period 3 was 90 % of the peak production in period 4. For horse mackerel, it appears that the spawning continued well after the surveys. The egg production reached a maximum in period 6. Thus overall, the temporal coverage was inadequate to fully describe the spawning season for both mackerel and horse mackerel. In turn this effects the choice of start date for mackerel and end date for horse mackerel, the implications of this are discussed more fully in Sections 5.2.1.and 6.2.

4.2.2 Egg surveys in the Southern Area

As in previous years, the spatial and temporal coverage was designed to ensure an adequate coverage of both mackerel and horse mackerel.

The standard sampling area used for the western mackerel egg surveys in 1998 was defined as the Atlantic coast of Spain and Portugal, between 36°N and 45°N latitude and the western boundary at 11°W longitude (Figure 4.2.1). The same area was used in the previous surveys in 1995, since coverage appeared to be adequate and no additional sampling stations were necessary.

Temporal coverage in the southern area during 1998 was more extended than in 1995 allowing full coverage of the spawning season and it was split into 6 periods (from 17 January to 21 June). Surveys were carried out by Portuguese, English, Dutch and Spanish research vessels covering the standard spawning area defined according to the Report of Mackerel and Horse mackerel Egg Production Workshop (ICES, 1997b), Table 6.1.

The number of hauls made per half ICES rectangle per survey period and the rectangles in which egg production values have been interpolated are shown in Figures 4.2.2a–f.

One change was made in the survey schedule. The third Portuguese survey was carried out two weeks earlier than scheduled so it was included in period 2. As a result, the coverage during period 3 did not include the area from 37° to 43°N on the Portuguese coast. It should be noted that this means that there was no temporal overlap between surveys on the Portuguese coast and the north Spanish coast. Additionally, and as in the western area, spawning on the north Spanish coast was already well under way by the time of the first survey in that area.

4.3 Sampling and Data Analysis

The 1998 surveys were carried out in accordance with the modified sampling strategy described in detail for the 1995 survey (ICES 1996b) and by the planning group for the 1998 surveys (ICES 1997b).

4.3.1 Sampling strategy

Thirty-two rectangles were added to the standard area as a result of changes in the distribution of mackerel and horse mackerel eggs noted during the 1995 surveys. The flexible sampling strategy, adopted for the 1998 survey, to take account of observations during the survey resulted in some additional rectangles being sampled outside the standard area at the northern boundary. Poor weather and limited vessel time resulted in very few replicate rectangle samples being taken by any of the vessels. Similarly, very few rectangles were sampled by more than one vessel within the same time period (see Section 2.2).

4.3.2 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 Norway and Spain who used Bongo samplers (Table 4.3.1).

Each Gulf III type sampler was fitted with a conical nosecone with an aperture of either 19.5 cm (Netherlands) or 20 cm diameter. 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 ship speed of approximately five knots. Calibrated flowmeters, mounted both inside the nosecone and externally on the body of each sampler, were used to calculate the volume of water filtered on each deployment.

The presence or absence of a thermocline on each survey is shown in Table 4.3.1. A thermocline was recorded only on the English survey in period six. The sampling strategy was not changed, as fish larvae were required from the samples as part of an EU funded project (INDICES).

In the southern area Bongo samplers were used by Portugal (60 cm diameter) and Spain (40 cm diameter) (Table 4.3.2) while the Netherlands and England used Gulf III's. The Bongo samplers, used in the southern and western areas were also deployed on double oblique hauls to a maximum depth of 200 m or to within 3 m of the bottom in shallower water. They were towed at a ship speed of 2-3 knots and calibrated flowmeters mounted in the aperture were used to calculate the volume of water filtered.

In all the surveys a full temperature/depth profile was recorded. The temperature at 20 m on each deployment was used as a parameter in the calculation of the production of eggs per day in each rectangle.

4.3.3 Data analysis

All data analysis was carried out in accordance with the procedures described in detail for the 1995 survey (ICES 1996b) and at the planning group for the 1998 surveys (ICES 1997b). For all sampling in the western area, individual countries supplied data on an electronic database form to the data co-ordinator at the Marine Laboratory, Aberdeen. For sampling in the southern area data were supplied in Excel spreadsheet format to the data co-ordinator in Madrid.

The data consisted of, sample position, numbers of eggs (both mackerel and horse mackerel) in each development stage, sub sample size, volume of water filtered by the sampler, depth sampled and temperature and salinity profiles. Each country was responsible for validating their own basic data and there were also some checks built into the Aberdeen database.

Because of the absence of adequate replicate rectangle samples, in the southern area, the standard error in the western area, obtained in 1995, was used to estimate variance (1.27 for mackerel; 1.44 for horse mackerel). The variance of the total annual egg production was assumed to be the weighted sum of the variances of the total daily production in each sampling period (ICES 1996b). In the western area the standard errors were calculated for both mackerel (s.e.0.212) and horse mackerel (s.e.0.325).

Table 4.1.1 The deployment of research vessel effort in the 1998 western mackerel and horse mackerel egg survey

Period	Country	Vessel	Dates	Area Coverage
3	Spain Germany	Cornide de Saavedra Walther Herwig	15/3–2/4 22/3–25/4	44°30'–46°00'N 44°15'–53°15'N
4	Netherlands Scotland Spain	Tridens Scotia Cornide de Saavedra	16–30/4 29/4–14/5 20–22/4	45°15'–49°00'N 48°15'–58°45'N 44°15'–44°45'N
5	Netherlands Spain Norway England Ireland	Tridens Investigador GO Sars Corystes Celtic Voyager	12–22/5 19/5–7/6 26/5–13/6 4–13/6 1–6/6	42°00'–48°00'N 43°00'–47°00'N 48°15'–53°45'N 44°15'–48°45'N 54°15'–58°45'N
6	Ireland England Scotland	Celtic Voyager Corystes Scotia	17–26/6 14–26/6 17/6–5/7	50°15'–53°45'N 42°00'–49°00'N 48°15'–59°45'N

Table 4.1.2 The deployment of research vessel effort in the 1998 southern mackerel and horse mackerel egg survey

Period	Country	Vessel	Dates	Area Coverage
1	Portugal	Noruega	17–31/1	36°00'–42°45'N 06°00'–11°00'W
2	Portugal Portugal	Noruega Noruega	7–15/2 21/2–1/3	37°45'–42°45'N 08°30'–11°00'W 36°00'–42°45'N 07°00'–11°00'W
3	Spain (IEO)	Cornide de Saavedra	14/3–1/4	43°00'–45°00'N 01°00'–11°00'W
4	Spain (IEO)	Cornide de Saavedra	13–27/4	42°00'–44°30'N 01°00'–10°00'W
5	Netherlands Spain (AZTI)	Tridens Investigador	15–20/5 19–24/5	42°00'–45°00'N 05°00'–11°00'W 43°15'–44°30'N 01°00'–05°00'W
6	England	Corystes	15–21/6	42°00'–44°45'N 01°00'–11°00'W

Table 4.3.1 Sampling gears and procedures adopted during the 1998 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**	**Used for Prod.**	
Germany	3	Gulf III	20	200	2.5C/10m	200 m	Full profile	temp @ 20m	Thermocline not found
Spain (IEO)	3 + 4	Bongo	40	200	2.5C/10m	200 m	Full profile	temp @ 20m	Thermocline not found
Netherlands	4 + 5	Gulf III	19.5	200	2.5C/10m	200 m	Full profile	temp @ 20m	Thermocline not found
Scotland	4 + 6	Gulf III	20	200	2.5C/10m	200 m	Full profile	temp @ 20m	Thermocline not found
Spain (AZTI)	5	Bongo	40	200	2.5C/10m	200 m	Full profile	temp @ 20m	Thermocline not found
Norway	5	Bongo	20	200	2.5C/10m	200 m	Full profile	temp @ 20m	Thermocline not found
England	5 + 6	Gulf III	20	200	2.5C/10m	200 m	Full profile	temp @ 20m	Thermocline
Ireland	5 + 6	Gulf III	20	200	2.5C/10m	200 m	Full profile	temp @ 20m	Thermocline not found

Table 4.3.2 Sampling gears and procedures adopted during the 1998 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	Bongo	60	200	2.5C/10m	200 m	Full profile	temp @ 20m	Thermocline not found
Spain (IEO)	3 + 4	Bongo	40	200	2.5C/10m	200 m	Full profile	temp @ 20m	Thermocline not found
Spain (AZTI)	5	Bongo	40	200	2.5C/10m	200 m	Full profile	temp @ 20m	Thermocline not found
Netherlands	5	Gulf III	19.5	200	2.5C/10m	200 m	Full profile	temp @ 20m	Thermocline not found
England	6	Gulf III	20	200	2.5C/10m	200 m	Full profile	temp @ 20m	Thermocline not found

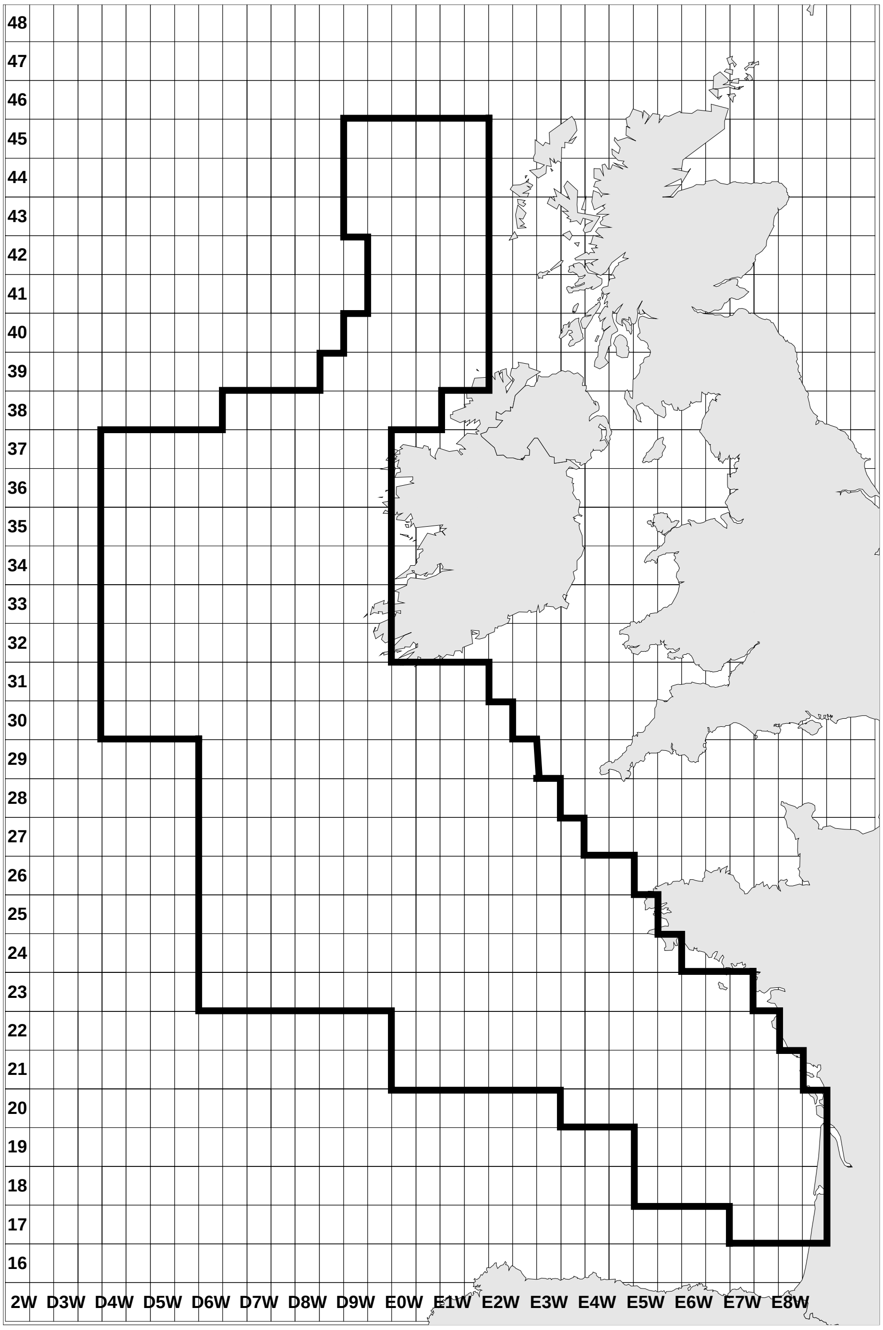


Figure 4.2.1 1998 standard survey area for the western area mackerel and horse mackerel surveys.

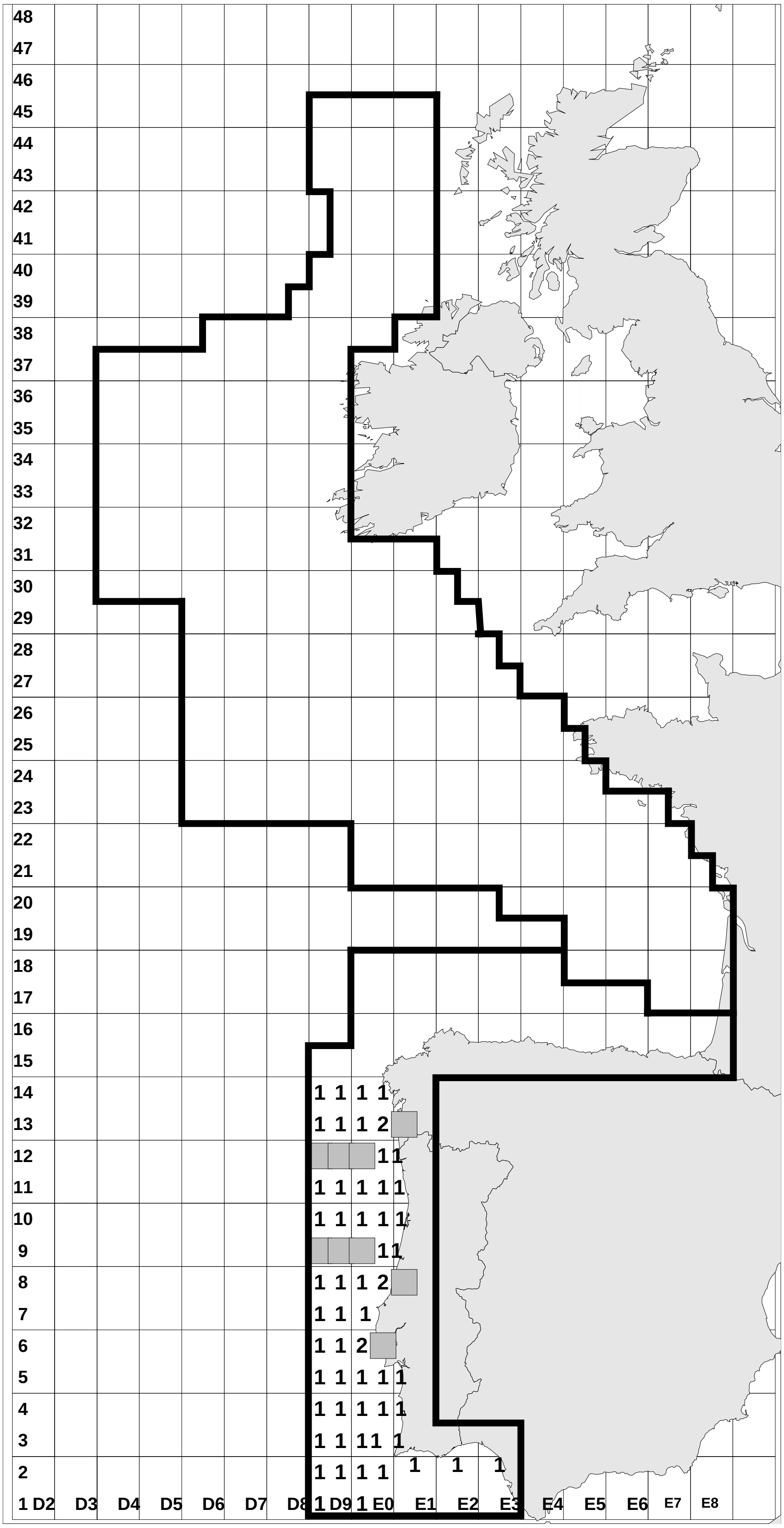


Figure 4.2.2a Number of observations per rectangle in period 1 (17 - 31 January). Grey squares represent those rectangles assigned interpolated values.

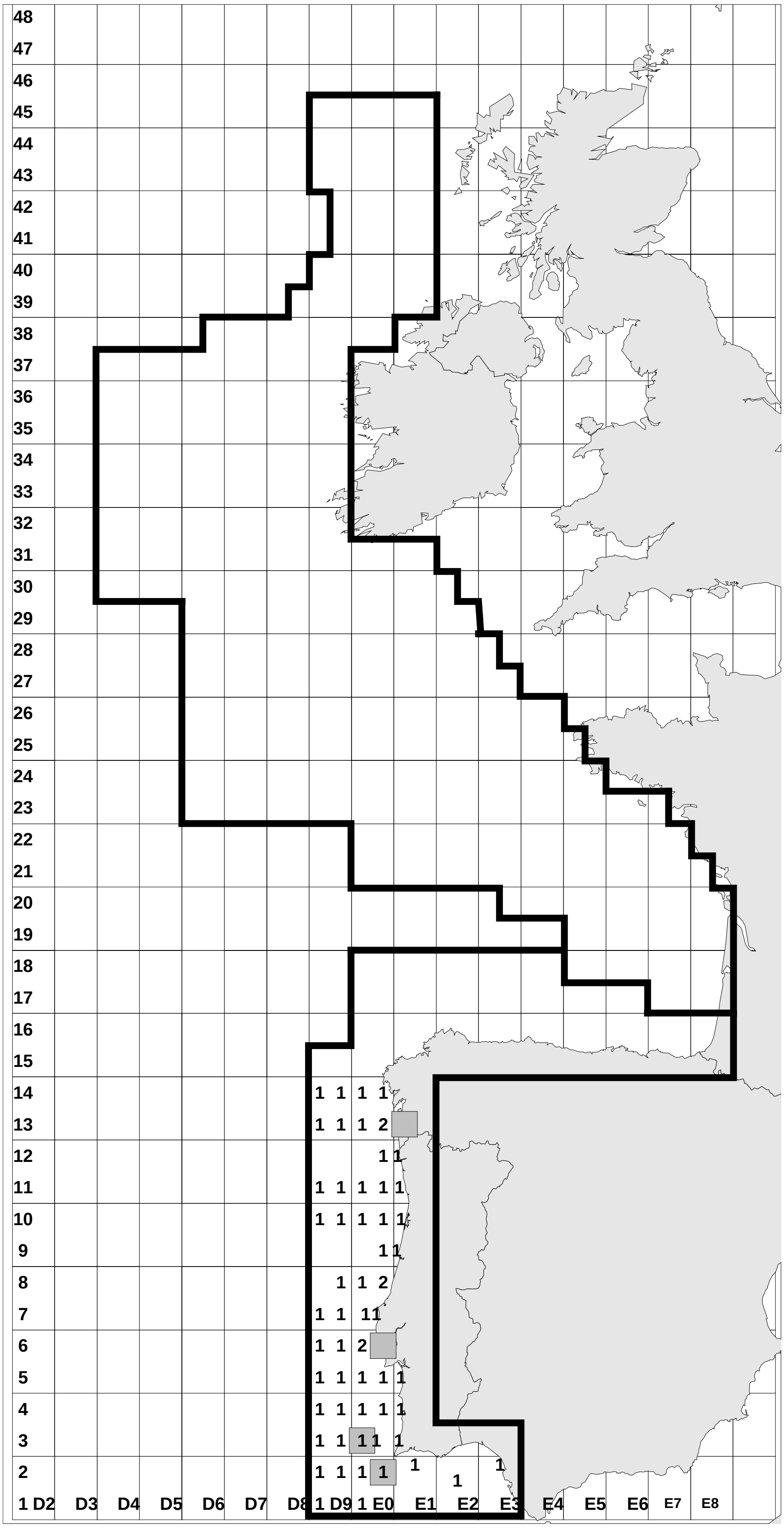


Figure 4.2.2b Number of observations per rectangle in period 2 (7 February - 1 March). Grey squares represent those rectangles assigned interpolated values.

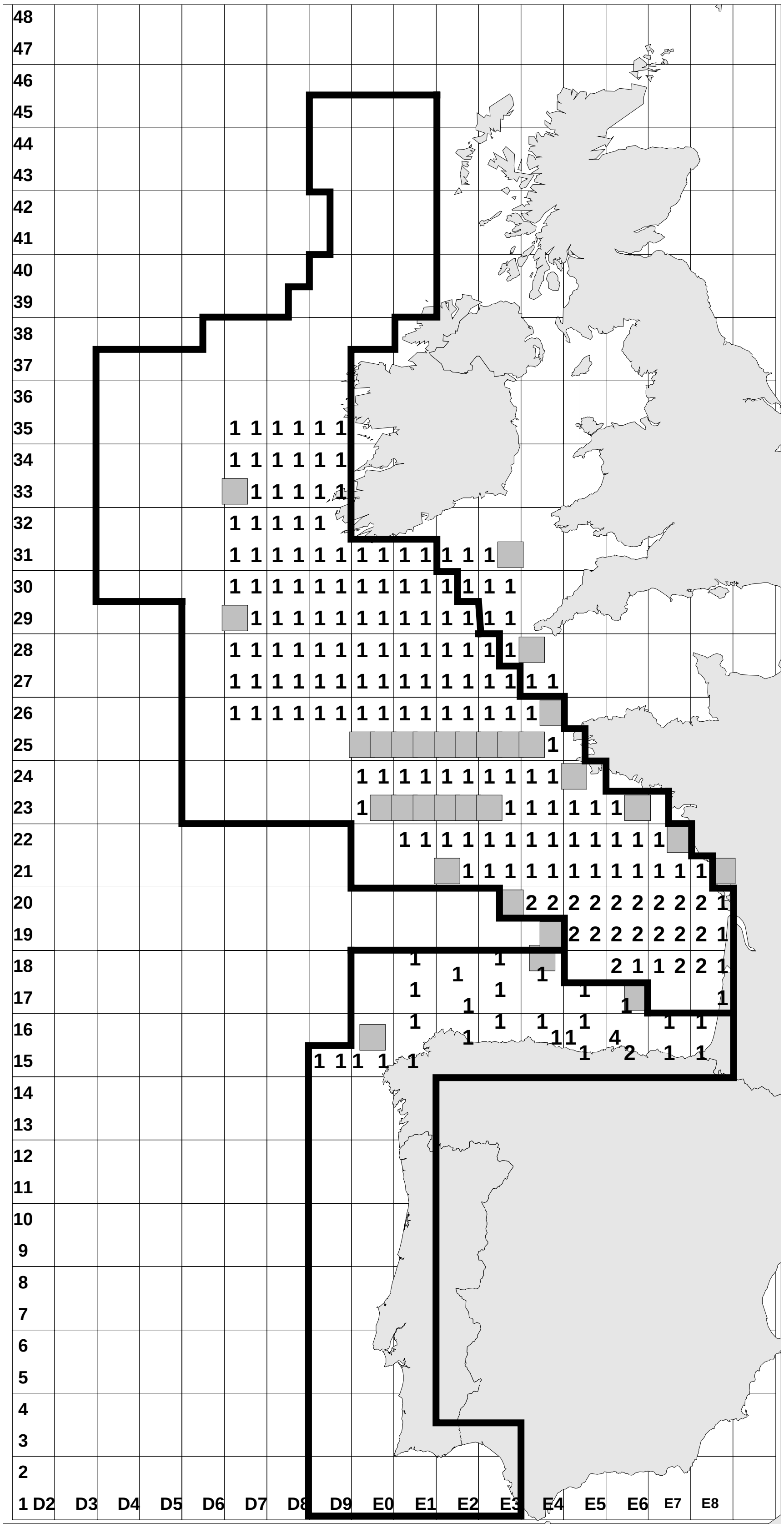


Figure 4.2.2c Number of observations per rectangle in period 3 (15 March - 6 April) - Grey squares represent those rectangles assigned interpolated values.

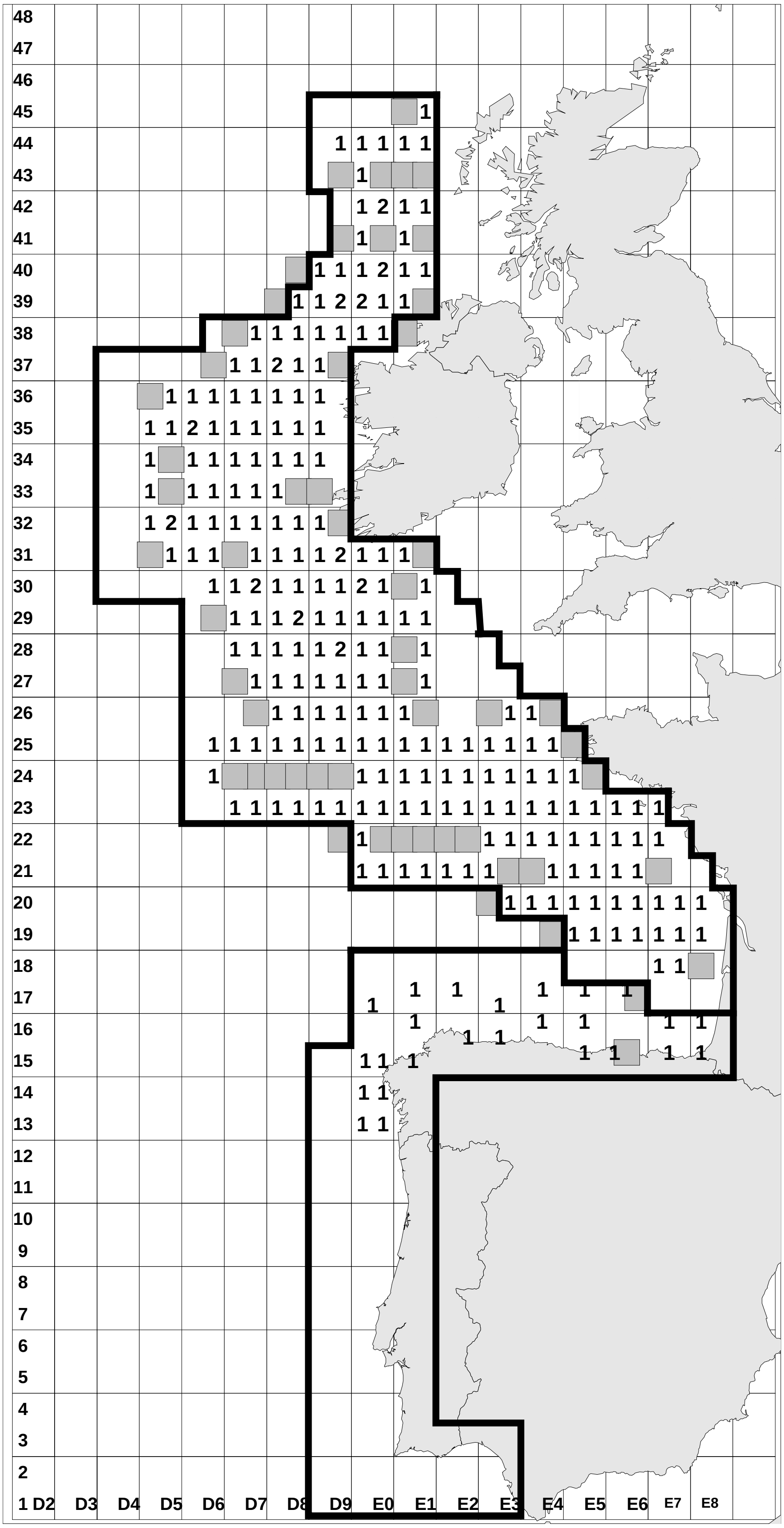


Figure 4.2.2d Number of observations per rectangle in period 4 (16 April – 15 May) - Grey squares represent those rectangles assigned interpolated values.

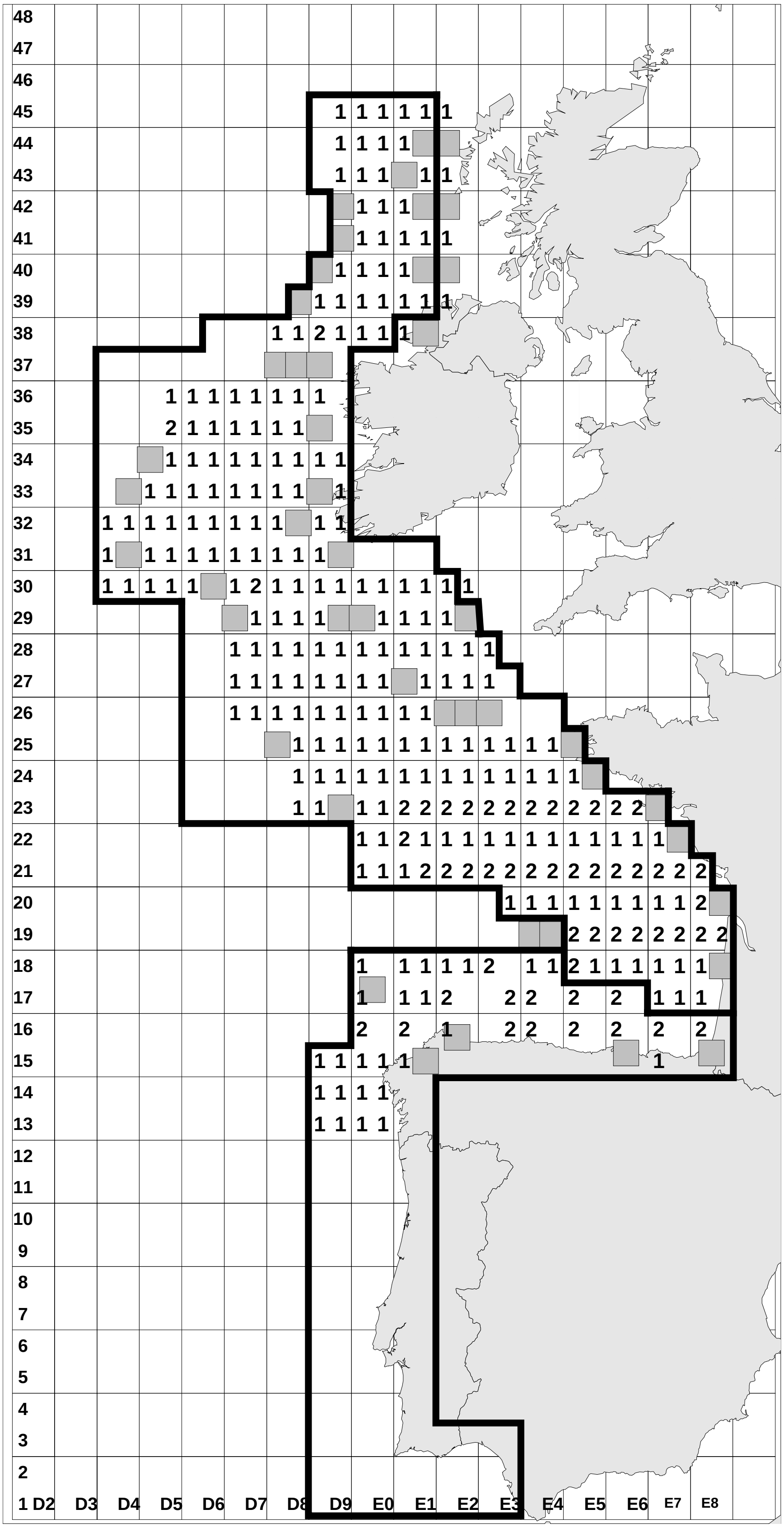


Figure 4.2.2e Number of observations per rectangle in period 5 (16 May -13 June) - Grey squares represent those rectangles assigned interpolated values.

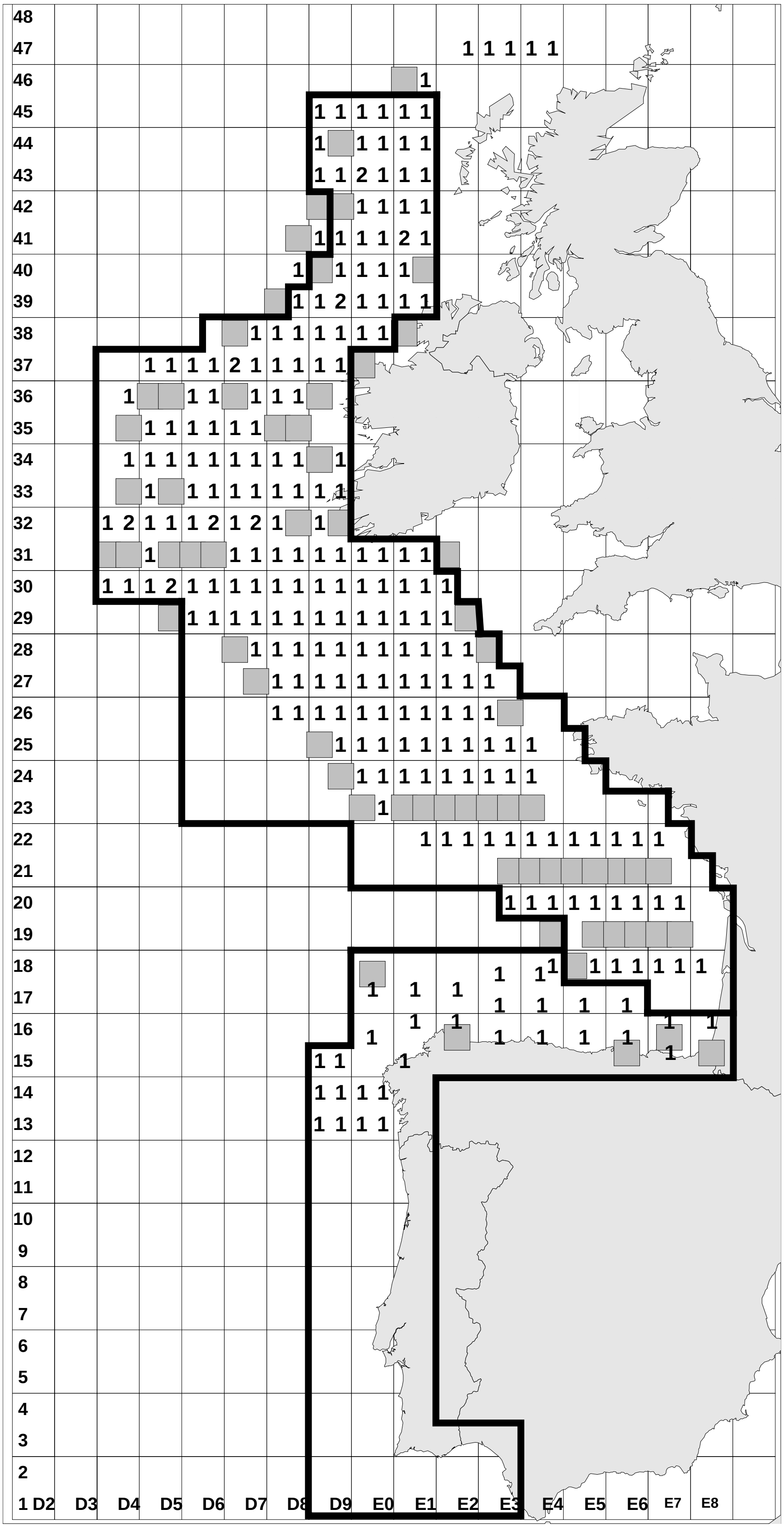


Figure 4.2.2f Number of observations per rectangle in the western spawning area in period 6 (14 June –5 July) Grey squares represent those rectangles assigned interpolated values.

5 MACKEREL IN THE WESTERN AND SOUTHERN SPAWNING AREAS: 1998 EGG SURVEY RESULTS.

5.1 Spatial distribution of stage 1 mackerel eggs

5.1.1 Western spawning area

The first survey in the western area was in Period 3 (Figure 5.1.1c). Coverage of the area was reasonably good, although as indicated in 4.2.1 the northern limit of the egg distribution was not reached. Egg abundance along this edge was, however, relatively low (below 50 eggs.$m^{-2}d^{-1}$). One other problem was the lack of sampling at 48°15′N (row 25) which was missed due to bad weather, and thus required interpolation. Due to the high densities at 48°45′N (row 26), these interpolated values were relatively high. As in previous surveys the egg production was well defined and concentrated along the 200 m contour from the southern end of Biscay to SW Ireland. The main concentrations were in the area of the southern Celtic Sea. The spawning during this period appeared to be well advanced and may indicate that the surveys were started later than required.

In period 4 (Figure 5.1.1d) the survey area was completely covered from north to south. Again the edges were generally well defined and little important interpolation was required. Production was well distributed along the whole shelf edge from Biscay to north of Ireland. Little evidence was seen of a westward extension of spawning in the area 46° to 48°N (rows 21–24) as was reported for the 1995 and 1992 surveys. This period represented the peak of spawning in 1998.

In period 5 (Figure 5.1.1e) the survey again covered the full area. The edges were mostly well defined except in the extreme north-west, off the Hebrides. There was little spawning south of 46°30′N (row 22), as in 1995. North of here spawning remained close to the 200 m contour with no evidence of the westward extension seen in previous years. Unlike previous years, the main concentrations of eggs in this period were in the area from the north of Ireland and northwards. In 1995 there were only low abundances north of 55°30′N (row 40), while in 1998 the highest densities were located north of this latitude. Additionally, high densities were located at the northern limit of the survey area and also along the western edge in this area. There is a clear need to take more care in following guidelines and continue sampling until zero or low egg densities are encountered.

In 1998 period 6 (Figure 5.1.1f) was the last survey period. Egg abundances were well reduced from period 5 although the area occupied was similar. Again coverage was good and the boundaries mostly well defined. South of 52° (row 32) there was evidence of spawning spreading further onto the Celtic Sea shelf, also further north there was evidence of spawning extending further inshore. This contrasts with 1995 where the spawning tended to spread offshore. Two main concentration areas could be discerned, one in the Celtic Sea and the other north and west of Ireland, continuing the trends seen in period 5. North of 56°N (row 41) the spawning displayed a sharp shift offshore in comparison with the areas further south. One result of this was that again the western edge in this area was poorly defined. Some samples were taken to the north of the standard area, and mostly contained some mackerel eggs, in one case in reasonable numbers (27 eggs. m^{-2} day^{-1}). As reported previously, this may indicate that the sampling should be extended further north in future years.

5.1.2 Southern spawning area

Distribution maps of daily stage I egg production.m^{-2} are given for the six survey periods in Figures 5.1.1a–f. The timing of the survey periods was synchronised for the western and southern area.

During period 1 only the southern part of the southern area was surveyed by the first Portuguese cruise (36º00′N–43º00′N) as scheduled. Very low abundance of mackerel eggs stage I were found in between 38º30 and 43º00′N and near the coast. There were no eggs south of 38°30′N.

In Period 2 again only the southern part of the southern area was sampled (36º00′N–43º00′N) as planned. In the original survey schedule, Portugal was to carry out one survey in this period and another one in period 3. This latter survey was made 2 weeks earlier and so was included within period 2, combining both cruises. To obtain the egg production for period 2, data from samples in the same rectangles were combined and the arithmetic mean calculated to obtain one production value for each rectangle. Mackerel eggs were absent during the first cruise in this period, and very sparse in the second cruise, with very low abundances appearing south of 39º00′N, and very close to the coast around 37°N.

During period 3 only the north of the Iberian Peninsula was sampled, and following the recommendation of the planning group, the survey was carried out earlier than in 1995. Thus, the sampling did not cover the whole spawning area as the western Iberian shelf was not covered.

The mackerel egg distribution during this period indicates the start of the peak of spawning in the southern area, and shows some similarities with 1995. The eggs were distributed between the coast and the 200 m contour. There was some extension to the north between 5 and 6°W. Highest abundances were from 6°00′W to the east (1°00′W) and the maximum value appeared in the inner part of the Bay of Biscay (3,107 eggs.m^{2}.day^{1}).

In period 4 only the north part of the area was sampled. The cruise had many difficulties due to the extremely bad weather conditions and it was not possible to cover all the area completely, so the last two rectangles of each row were not sampled. Mackerel egg production during period 4 suggests that this was the peak spawning of mackerel in Cantabrian Sea (the same period as in the western area). The pattern was very similar to that in period 3, with higher abundance between the coast and the shelf break, but the spawning was extended further to the west. Very few eggs were found over the deeper water. The highest abundance was found between 4°00 and 8°00′W, with two patches of high densities, one at 8°W, which has been a typical place for high egg abundance in previous years, and one between 5 and 6°W, with a maximum value (3,112 eggs.m^{-2}.day^{-1}).

In period 5 all the north part of the area was sampled by AZTI and the Netherlands survey, covering the area as scheduled. Mackerel egg distribution was the same as in all previous periods, close to the coast and confined to the shelf, but with much lower densities and a reduction of the spawning area.

In period 6 the northern part of the area was sampled by the English cruise as scheduled, but, because of time constraints, sampling did not reach the edge of the area, and the last rectangle of each row was not sampled. Mackerel egg distribution showed a continued reduction in abundance and the distribution pattern was very similar to that of period 5.

5.2 Egg production of the North East Atlantic Mackerel

This chapter includes information on egg production derived from surveys in the western and southern spawning areas. No information is included on the North Sea spawning component.

5.2.1 Stage I Egg production in western spawning area

The mean daily stage I egg production estimates for each survey period are plotted against the mid-period days in Figure 5.2.1 to provide an egg production curve as presented for previous surveys. The data values are presented in Table 5.2.1.

The start date was assumed to be the 10 February as used in 1995, when spawning also occurred earlier than in the previous survey year. This date was earlier than used for the surveys before 1995 (19 February). No histological or survey data were available in the western area or in the Cantabrian Sea prior to period 3 to suggest any alternative start date. The end date is the same as that used in 1995 - 31 July. Samples in the northern part of the survey area at the end of period 6 found no eggs which suggests that spawning had substantially ended by the second week in July. Production estimates for the individual survey periods, the periods before and after the surveys and for the unsampled period in April are presented in Table 5.2.2. There was no temporal overlap between periods for the 1998 survey. The standard errors are slightly greater than 1995, probably due to a reduced number of duplicated samples. These calculations are based on the complete survey results including observations beyond the edge of the 1998 standard survey area. No data from the southern area were included in the analysis. There was a negligible effect on the estimate of expanding the 1998 area, the two estimates are identical to two decimal places. A calculation of the estimate using the 1995 standard area gives a production of 1,350 10^{15} for 1998. This value is given for comparison purposes only, the extended 1998 area estimate has been used for all subsequent biomass estimates.

Also for comparison purposes, a calculation was made of the annual egg production using the start date used prior to 1995 (19 February). The annual egg production was reduced by approximately 3%, from $1.37.10^{15}$ to $1.33.10^{15}$.

5.2.2 Stage I Egg production in southern spawning area

The mean daily egg production estimated for each individual period is given in Table 5.2.3.

The start date of spawning for mackerel was 17 January, earlier than the start date assumed in previous years. It is based on the eggs found on the Portuguese coast during period 1 where a few mackerel eggs in stage II occurred on 19 January.

The end date of the spawning was assumed to be the 17 July (the same date that was used in 1995) based on the fact that some mackerel eggs stage I appeared in the monthly ichthyoplankton sampling carried out in July in front of Santander coast.

Total production values for the individual time periods and interpolated periods are given in Table 5.2.4 and the daily egg production estimates for each survey period were plotted against the mid cruise dates to give the production curve (Figure 5.2.2).

Total egg production for the standard sampling area was estimated by integrating the area under the curve between 17 January and 17 July.

Total egg production for mackerel during 1998 and comparison with egg production in 1995 are shown in the text table below.

Estimates of the total mackerel egg production in the southern spawning area in 1995 and 1998		
Year	**Annual stage I egg production $*10^{-13}$**	
	estimate	**se**
1995	20.72	1.25
1998	46.09	18.59

In 1998, the mackerel egg production estimate has increased considerably compared with 1995. This increase could be due to the improved temporal and spatial coverage of the spawning. In 1998 spawning in the Cantabrian Sea, started one month earlier than in 1995 and an additional sampling period (period 3) was included. As a consequence, the potential underestimation of egg production was less than in 1995.

In 1998, the spawning area along the Cantabrian coast was more confined to the coast than in 1995. It was also different to distributions obtained in previous survey years (1988, 1990 and 1992) when higher densities appeared beyond the 200 m depth contour.

Although some mackerel eggs appeared very early in January in the Western Iberian Peninsula, their abundance was very low in each of the sampling periods. This result is similar to that obtained in 1995.

The coefficient of variation (c.v.) of the total egg production (40.34 %) is very high, mainly due to the high standard error (s.e.) values obtained during periods 3 and 4. In these periods, the adaptive sampling strategy was applied. Therefore it is probable that the lapse of two weeks between consecutive transects could increase the variance estimate.

5.3 Potential fecundity of North East Atlantic mackerel

Term	**Definition**
Previtellogenic oocyte	A precursor oocyte stage that develops into a vitellogenic oocyte
Vitellogenic oocyte (VO)	Oocytes that comprise the annual potential fecundity
De novo vitellogenesis	The process of producing vitellogenic oocytes from previtellogenic oocytes; ysed especially in relation to determinate / indeterminate fecundity.
Determinate	A fish is described as ‘determinate’ when the annual potential fecundity is either the same as or more than the number of eggs shed during the spawning season. This is a basic assumption of the annual egg production based mackerel stock assessment
Annual potential fecundity	The number of vitellogenic oocytes in a female just before the start of spawning and often expressed as the relative potential fecundity (oocytes per g female)
Migratory nucleus stage oocyte	Oocytes in the final stage of maturation which are about to hydrate prior to ovulation and spawning.

Term	Definition
Hydrated oocyte	Fully mature oocytes ready for ovulation but still held in a follicle and part of the ovary tissue.
Ovulated oocyte	Loose oocytes ready for spawning, found in ‘running’ females.
Realised fecundity	Number of ovulated oocytes spawned in a year by a female.
Post ovulated follicle	A structure marking the site in the ovary where an oocyte grew to maturity. They quickly collapse and disappear after ovulation and are used as indicators of previous spawning activity
Atretic oocyte	Oocytes that used to be part of the potential fecundity which abort development and regress through stages classified by histological structure. Only the first stage (early alpha atresia) is estimated to discount from the potential fecundity to calculate realised fecundity.
Atresia stage duration	The early alpha atresia stage has been estimated to last 7.5 days in mackerel.
Prevalence of atresia	The proportion of fish with one or more early alpha atretic oocytes present in a section of the ovary.
Relative intensity of atresia	The number of early alpha stage atretic oocytes found in the ovary estimated by stereological analysis (expressed as the number per g. female).

Tereshchenko & Shamray (WD 1999) reported that SSB was 30% underestimated by ICES during the 1989 triennial survey. They attributed the difference to the potential relative fecundity (Figure 5.3.1) because this was 30% greater in the case of ICES 1989 than in their estimate, based on collections of fish sampled in 1986, 1988, 1992, 1993 and 1996 and the earlier estimate (Lockwood 1981). The inference was that fecundity had not changed since 1989. After considering the WD by Tereshchenko & Shamray and additional evidence (Mazhirina WD 1999) on mackerel ovary development the WG concluded the 30 % difference lay in the method to determine potential fecundity. The WG method includes all oocytes >165 (130 µm in Gilson fixative) following Walsh et al 1990 whilst the WD excluded all oocytes <250 µm in the fecundity count. It was also acknowledged by Walsh et al that a minimum size of 130 µm would accommodate possible recruitment of reserve oocytes during spawning (De Novo vitellogenesis). The fecundity estimate is very sensitive to the minimum size of oocytes counted because a large population of reserve oocytes remain below the cut off size (ICES 1987b). The authors of the working document did not appreciate that the 1981 estimate was also based on counting oocytes >130µm and gave no reason to restrict their fecundity counts to oocytes >250 µm. The WG felt the original ICES figure was still the most accurate estimate of fecundity.

5.3.1 Potential fecundity in the Western spawning component

Ovaries from over 148 mackerel at maturity stage 3 (Walsh *et al*., 1990) were collected by RV Cirolana on the Western Ground fish survey in ICES rectangles 27D8-9, 27E0, 28D8, 29D9, 30D9, and 33D8, during period 3 and treated as in ICES 1987b. The collection was divided equally between CEFAS and MLA to determine potential fecundity using the method developed previously (Walsh *et al*., 1990). One of the ovaries from each fish was examined, following histology, to reject spawning fish (presence of post ovulatory or hydrated oocytes) and fish that contained largely atretic oocytes (abortive maturation). Relative potential fecundity was estimated by raising the counts of oocytes >130 µm in gravimetric subsamples to the total weight of both ovaries. A comparison of the results (detailed in Table 5.3.1) in the text table below show a small but significant difference between the fecundity data from each Institute.

		Institute		Total samples	% difference (p)
Year	**Data**	**CEFAS**	**MLA**		
1998	Average of Samples	1176	1255		
	Std of Samples	165	172		
	Count of Samples	45	52	97	7 (0.013)

The data were combined (Figure 5.3.2) and showed relative fecundity was significantly dependent on fish weight but the effect was not very great. Assuming the mean weights of 339 g (fish in the fecundity samples) and 227 g (mature fish in the maturity samples) represented the extremes in our estimate of mean weight of mature females in the population the relative fecundity would change by 3.1 %. Compared with the triennial survey in 1995 potential relative fecundity (Figure 5.3.3) showed a significant reduction ($p<0.001$) of 16 % from 1437 (se 29.2) to 1206 (se 20.5) oocytes g^{-1} total weight and this value was accepted as representative of the Western area.

5.3.2 Potential fecundity in the Southern spawning component

Following the recommendation of the planning meeting (ICES., 1997) the IEO (Spain) collected ovaries in February from mackerel over the length range of 22 cm and above, with a purse seine in the position 43º37′N 3º37′W, ICES Division VIIIc, (Table 5.3.2). Potential relative fecundity was estimated by the same procedure as in Western area mackerel. A total of 69 fish were examined by histology of which 28 were rejected (presence of hydrated oocytes, migratory oocytes and post-ovulatory follicles) because they had started spawning. The results of fecundity for the remaining fish are shown in Figure 5.3.4. The mean of individual fish weight was 278 g and their mean relative fecundity was 1276 (s.e. 39.98) oocytes g^{-1} total weight. As in the Western area the relative fecundity showed a small dependence on fish weight but in the absence of any data on the mean fish weight in the population the mean value was taken as representative of the population.

5.4 Atresia and realised fecundity in the North East Atlantic mackerel

5.4.1 Atresia and realised fecundity in the Western spawning component

Ovaries from random samples of fish collected in periods 3 to 6 (Table 5.4.1) were prepared for sterometric analysis to quantify prevalence (number of fish with atresia present in the ovary) and relative intensity (number of atretic oocytes g^{-1} total weight). Methods of data analysis to discount the production of atretic oocytes over the predicted spawning duration (60 days) from the relative potential fecundity are as described in ICES 1996. At the time of the WG only results (Table 5.4.2) from the analysis of samples sent to CEFAS were available but a similar number are presently waiting analysis at MLA.

The extended analysis of atresia data collected in triennial surveys from 1989 to 1995 (ICES 1997) showed significant temporal differences within and between years. In 1998 this peak of atresia appeared earlier in the last week of April and extended to the last week in May compared to a peak in the last week in May in 1995. It is probable that this may have coincided with the drop in egg production (two peaked production curve) seen in the 1998 GAM analysis and in some previous triennial surveys (e.g. 1989). Overall atresia in the Western area was higher (see text table below) and this compounded the drop in relative potential fecundity to substantially reduce the realised fecundity in the Western spawning component.

Year	Relative fecundity (se)	Atresia loss (se)	Realised fecundity
1995	1437 (se 29.2)	171 (11.6)	1303 (36.5)
1998	1206 (20.5)	204 (36.5)	1002 (40.7)

The above results will profoundly raise SSB and it is appropriate to review the strengths and weakness of the data. The temporal coverage was well distributed between the four periods but about double the number of samples are still available for inclusion in the data set and this is very desirable. Efforts to standardise the interpretation of slides as recommended in the ICES 1997 have not been completed but pictures and or slides were sent from CEFAS to MLA and IEO as detailed in the text table below. The WG recommends this comparison and evaluation is carried out and the results presented to the Assessment Working Group.

Date	Slides to	Pictures to
December 1997		Aberdeen University
Early January 1998		Aberdeen University, IEO and MLA
Early March 1998	MLA &Aberdeen University	
May 1999 to implement on completion by MLA and Aberdeen University	IEO	

5.4.2 Atresia and realised fecundity in the Southern spawning component

To study atresia, a sample of 368 mackerel was collected in periods 3 to 5 (Table 5.4.3). Ovaries were prepared for stereometric analysis by IEO and atresia scored as in the Western area. All of these samples are ready for analysis but at the time of the Working Group only 97 ovaries from the third period were analysed of which 56 were in spawning condition (Table 5.4.4). The prevalence was 0.21 and the fecundity was 1,171 oocytes g^{-1}. The number of atretic oocytes was $105g^{-1}$ and the relative intensity of atresia 14.7 %, see Table 5.4.4.

5.4.3 Combining spawning component estimates of potential and realised fecundity

The mean relative fecundity estimates from the Western component (1176 CEFAS, and 1255 MLA) and the Southern component (1276) show considerable overlap. In this context it is important to note that three independent analyses of fish collected over a large spatial range provide very similar results. This assumption is especially valid if the Southern area population is close to, or a little below the mean size of fish in the Southern fecundty sample. At the WG it was not possible to combine estimates of realised fecundity because the Southern component atresia data was not complete.

5.5 Mackerel Biomass Estimate

5.5.1 Estimate of the western spawning component

Total stage I egg production using all data both inside and outside the 1998 standard sampling area, and interpolated rectangles both inside and outside the standard area is given in Table 5.2.2. Total spawning stock biomass (SSB) was estimated using the fecundity estimate of 1,002 oocytes/g female, corrected for atresia (see Sections 5.3 and 5.4), a sex ratio of 1:1 and a raising factor of 1.08 (ICES 1987b) to convert pre-spawning to spawning fish. This gave an estimate of spawning stock biomass for 1998 of 2.95 million tonnes. with a standard error of 0.6 million tonnes. The variance in this estimate attributable to the egg survey is 58 % and to the fecundity estimate is 42 %.

Comparative data from earlier years are shown in Table 5.5.1. These indicate a 19 % increase in biomass compared to the previous egg survey estimate in 1995. This increase in the estimate of biomass has resulted from an 8 % decrease in annual egg production, an 18 % reduction in potential fecundity and a 19 % increase in atresia over the values obtained in 1995.

5.5.2 Estimate of the southern spawning component

Production estimates for the individual and interpolated periods and a total stage I egg production estimate for 1998 are given in Table 5.2.4.

The fecundity estimate of 1,171 oocytes/gram female adjusted for atresia, was estimated using the samples collected by the IEO in Division VIIIc (Tables 5.4.3 and 5.4.4).

Total spawning stock biomass (SSB) was estimated using a sex ratio of 1:1 and a raising factor of 1.08 (ICES, 1987) to convert pre-spawning to spawning fish. This gave an estimate of spawning stock biomass for 1998 of 850,166 tonnes adjusted for atresia and with a standard error of 312,959 tonnes. In this estimate 70 % of the variance is attributable to the egg survey and 30 % to the fecundity estimate.

A comparison with the 1995 biomass estimate shows an increase of 124.64 %. This is mainly due to the increased egg production.

Year	Total egg production (x 10^{-13})	Total fecundity (egg/gr. female)	Spawning Stock Biomass (tonnes)
1995	20.73	1,183	378,450
1998	46.09	1,171	850,166

5.5.3 North East Atlantic Mackerel biomass estimate

The survey estimates of egg production for the southern and western spawning components have been combined to produce a single egg production curve (Figure 5.5.1).

As noted in Section 5.4.3 the fecundity estimates for the two spawning components were not significantly different and could therefore be combined. However there are potential problems because of differences in the length compositions of the two spawning components. As a consequence the Working Group decided that the best estimate of the spawning stock biomass of the western and southern components of the North East Atlantic mackerel was the sum of the estimated biomass of each component which gives a value of 3.80 million tonnes. This estimate may be revised once all the fecundity analyses have been completed. The estimate does not include any element of the North Sea spawning component for which the SSB was 110,000 tonnes when last estimated by egg survey in 1996 (ICES 1997b).

5.6 Mackerel Maturity

5.6.1 Maturity in the Western spawning component

Only 3 samples, each of 100 fish, were collected from the Western spawning component. The data was too limited for constructing a maturity ogive.

5.6.2 Maturity in the Southern spawning component

It was not possible to assess female maturity in the Southern component because the data were not available to the WG. Analysis of the histological slides already prepared will be completed and incorporated in a working document for the Mackerel, Horse Mackerel, Sardine and Anchovy Working group.

Table 5.2.1 Western mackerel mean daily stage I egg production.10^{-12}

Period	Dates	Estimate	s.e.
3	15/3 - 6/4	12.5	4.4
4	16/4 - 15/5	13.9	2.8
5	16/5 - 13/6	7.9	1.8
6	14/6 - 5/7	5.3	1.0

Table 5.2.2 Western mackerel total stage I egg production estimates by time period for 1998

Dates	Period	No. of days	Annual stage I egg production.10^{-15}
10/2 - 14/3		33	0.153
15/3 - 6/4	3	23	0.287
7/4 - 15/4		9	0.118
16/4 - 15/5	4	30	0.418
16/5 - 13/6	5	29	0.228
14/6 - 5/7	6	22	0.117
6/7 - 31/7		26	0.049
	total	172	1.370
	s.e.		0.212

Table 5.2.3 Southern spawning component of mackerel mean daily stage I egg production in 1998 (x 10 $^{-12}$)					
Period	**Dates**			**Production and standard errors**	
	From	**To**	**Midpoint**	**Mackerel**	
				Production	**Se**
1	17 January	31 January	24/01	0.16	0.10
2	7 February	1March	18/02	0.03	0.03
3	14 March	1 April	23/03	7.05	4.04
4	13 April	27 April	20/04	8.25	4.80
5	15 May	24 May	19-20/05	0.12	0.06
6	15 June	21 June	18/06	0.09	0.06

Table 5.2.4 Southern spawning component of mackerel total stage I egg production estimates by time period for 1998 (x 10 $^{-13}$)			
Dates	**Period**	**No of days**	**Annual stage I egg production x 10 $^{-13}$**
			Mackerel
January – 31 January	**1**	**15**	**0,24**
1 February – 6 February	*	6	0,06
7 February – 1March	**2**	**23**	**0,07**
2 March – 13 March	*	12	4,50
14 March – 1 April	**3**	**19**	**13,39**
2 April – 12 April	*	11	8,46
13 April – 27 April	**4**	**15**	**12,37**
28 April – 14 May	*	17	6,53
15 May –24 May	**5**	**10**	**0,12**
25 May – 14 June	*	21	0,21
15 June – 21 June	**6**	**7**	**0,06**
22 June - 17 July	*	26	0,08
	Total	**182**	**46,09**
	Se		**18,59**
	CV		**0,40**

Table 5.3.1 Details of length, total weight fecundity and relative fecundity for Western mackerel spawning component determined by CEFAS and MLA.

Institute	Length (mm)	Fish wt (g)	Fecundity	Eggs g^{-1}
MLA	367	373	455552	1221
MLA	317	224	287202	1282
MLA	295	184	235673	1281
MLA	271	154	178790	1161
MLA	306	202	243536	1206
MLA	315	237	298590	1260
MLA	338	280	405525	1448
MLA	373	381	474722	1246
MLA	346	293	373085	1273
MLA	388	393	604793	1539
MLA	382	441	541833	1229
MLA	380	397	548594	1382
MLA	397	555	724150	1305
MLA	413	569	685422	1205
MLA	345	282	397114	1408
MLA	329	246	308366	1254
MLA	327	246	289343	1176
MLA	353	334	397237	1189
MLA	377	367	356969	973
MLA	394	403	575988	1429
MLA	386	457	595179	1302
MLA	391	469	532654	1136
MLA	369	395	488815	1238
MLA	304	173	195845	1132
MLA	362	350	364168	1040
MLA	364	326	350494	1075
MLA	354	319	300261	941
MLA	362	330	352227	1067
MLA	333	271	334679	1235
MLA	361	318	264539	832
MLA	304	200	259098	1295
MLA	348	269	306609	1140
MLA	321	217	286316	1319
MLA	356	314	488706	1556
MLA	370	358	462244	1291

Table 5.3.1. continued

Institute	Length (mm)	Fish wt (g)	Fecundity	Eggs g^{-1}
MLA	352	304	353511	1163
MLA	358	334	383174	1147
MLA	294	158	166718	1055
MLA	318	208	275256	1323
MLA	410	557	784817	1409
MLA	400	480	696478	1451
MLA	410	488	704412	1443
MLA	417	545	834767	1532
MLA	430	585	515849	882
MLA	435	577	791679	1372
MLA	429	628	783921	1248
MLA	431	680	862030	1268
MLA	435	617	786577	1275
MLA	438	683	1122945	1644
MLA	395	509	782880	1538
MLA	289	157	213876	1362
MLA	303	186	199082	1070
CEFAS	332	269	271975	1011
CEFAS	324	234	234076	1000
CEFAS	327	267	344427	1290
CEFAS	321	247	273089	1106
CEFAS	322	219	225159	1028
CEFAS	371	421	419108	996
CEFAS	345	316	415764	1316
CEFAS	378	431	514225	1193
CEFAS	367	357	399788	1120
CEFAS	412	592	657643	1111
CEFAS	402	497	500478	1007
CEFAS	377	377	419108	1112
CEFAS	389	431	487102	1130
CEFAS	374	413	412420	999
CEFAS	401	487	646497	1328
CEFAS	408	534	724522	1357
CEFAS	357	332	352972	1063
CEFAS	362	371	470382	1268
CEFAS	336	261	343312	1315
CEFAS	362	335	480786	1435
CEFAS	417	567	537261	948
CEFAS	301	162	182803	1128
CEFAS	354	316	319904	1012
CEFAS	344	267	371178	1390
CEFAS	345	293	320276	1093
CEFAS	348	329	402389	1223
CEFAS	338	262	363376	1387
CEFAS	374	386	446975	1158
CEFAS	394	390	468153	1200
CEFAS	419	579	540605	934
CEFAS	416	539	698514	1296
CEFAS	400	504	668790	1327
CEFAS	421	582	851592	1463
CEFAS	421	541	802548	1483
CEFAS	431	609	733439	1204
CEFAS	422	681	872771	1282
CEFAS	440	696	937420	1347
CEFAS	295	159	195435	1229
CEFAS	336	279	316561	1135
CEFAS	335	251	331051	1319
CEFAS	381	410	441401	1077
CEFAS	311	211	168312	798
CEFAS	404	531	628662	1184
CEFAS	423	630	814809	1293
CEFAS	306	203	166083	818
Arith. Mean	**364**	**369**	**453992**	**1221**

Table 5.3.2 Length, weight and fecundity estimated by gravimetric method of the southern mackerel spawning component.

	Length (cm)	Weight (g)	Eggs 1ml	Total fecundity eggs / fish
	28	146.1	124	166169
	29	171.8	168	225132
	29	172.0	167	223792
	30	172.0	158	211284
	30	175.2	206	275608
	30	187.0	162	217538
	30	181.2	150	201457
	30	184.8	246	328987
	30	184.6	195	260867
	30	220.2	157	210391
	31	297.2	211	282755
	31	199.4	172	230939
	32	195.4	174	232725
	32	190.0	132	176889
	32	204.6	208	278734
	32	201.8	160	214411
	32	225.6	191	256400
	32	224.8	155	207264
	33	289.2	304	407828
	34	245.4	310	414975
	34	285.8	315	422122
	35	302.6	338	453390
	35	284.4	335	448923
	36	311.6	295	395320
	36	350.2	346	463217
	37	375.2	360	482425
	37	331.4	366	490912
	37	387.8	345	462324
	38	420.6	371	497166
	39	454.4	353	473491
	40	536.4	648	867918
	41	550.6	756	1012646
	41	516.4	457	612858
Arith. Mean	**33**	**278.1**	**273.8**	**366874**

Table 5.4.1 Details of the mackerel collection from the Western spawning component to estimate relative atresia in periods 3-6.

Period 3

Ship	Date	Lat N	Long W	Total Weight (g)	Ovary Weight (g)	Length (mm)	Age	alpha atresia
Walther Herwig	17-Mar-98	50°15'	10°37'	326	43	340	5	
Walther Herwig	17-Mar-98	50°15'	10°37'	383	37	350	4	
Walther Herwig	17-Mar-98	50°15'	10°37'	394	26	360	6	3212
Walther Herwig	17-Mar-98	50°15'	10°37'	588	33	420		4238
Walther Herwig	17-Mar-98	50°15'	10°37'	309	26	350		11385
Walther Herwig	17-Mar-98	50°15'	10°37'	269	28	330	3	
Walther Herwig	17-Mar-98	50°15'	10°37'	355	28	370	3	20502
Walther Herwig	17-Mar-98	50°15'	10°37'	355	20	370	3	8964
Walther Herwig	20-Mar-98	53°15'	11°22'	244	14	310	4	20449
Walther Herwig	24-Mar-98	49°48'	10°53'	315	21	340	5	
Walther Herwig	24-Mar-98	49°48'	10°53'	300	21	340	5	14964
Walther Herwig	24-Mar-98	49°48'	10°53'	398	18	370	5	26140
Walther Herwig	24-Mar-98	49°48'	10°53'	274	24	330	4	
Walther Herwig	24-Mar-98	49°48'	10°53'	233	22	310	4	
Walther Herwig	24-Mar-98	49°48'	10°53'	337	20	370	5	
Walther Herwig	31-Mar-98	45°56'	02°15'	181	6	290	3	6599
Walther Herwig	31-Mar-98	45°56'	02°15'	284	7	310	3	3721
Walther Herwig	31-Mar-98	45°56'	02°15'	321	9	360	5	21548
Walther Herwig	31-Mar-98	45°56'	02°15'	209	9	300	3	9491
Walther Herwig	1-Apr-98	46°15'	03°58'	304	19	340	4	
Walther Herwig	1-Apr-98	46°15'	03°58'	377	29	360		
Walther Herwig	1-Apr-98	46°15'	03°58'	274	19	330	4	
Walther Herwig	1-Apr-98	46°15'	03°58'	234	24	320	3	9398
Walther Herwig	1-Apr-98	46°15'	03°58'	381	26	370	4	
Walther Herwig	1-Apr-98	46°15'	03°58'	207	11	320	3	
Walther Herwig	1-Apr-98	46°15'	03°58'	291	10	340	3	4062
Walther Herwig	1-Apr-98	46°15'	03°58'	363	17	360	4	
Walther Herwig	1-Apr-98	46°15'	03°58'	192	14	300	3	
Walther Herwig	2-Apr-98	46°50'	05°04'	359	40	360		25785
Walther Herwig	2-Apr-98	46°50'	05°04'	456	33	390		25725
Walther Herwig	2-Apr-98	46°50'	05°04'	461	36	390	8	58582
Walther Herwig	2-Apr-98	46°50'	05°04'	403	48	370	6	30365
Walther Herwig	2-Apr-98	46°50'	05°04'	533	66	400		57341
Walther Herwig	2-Apr-98	46°50'	05°04'	389	40	360	5	
Walther Herwig	2-Apr-98	46°50'	05°04'	437	42	380		
Walther Herwig	2-Apr-98	46°50'	05°04'	443	32	370	5	
Walther Herwig	2-Apr-98	46°50'	05°04'	371	45	350	5	
			AM	339	26	349	4	
							Geomean	13490

Table 5.4.1 continued

Period 4

Ship	Date	Lat N	Long W	Total Weight (g)	Ovary Weight (g)	Length (mm)	Age	alpha atresia
Tridens	24-Apr-98	45°24'	2°45′	306	15	374	7	14339
Tridens	24-Apr-98	45°24'	2°45′	338	12	370	5	66800
Tridens	24-Apr-98	45°24'	2°45′	428	6	390	5	52638
Tridens	24-Apr-98	45°24'	2°45′	210	6	317	3	33081
Tridens	24-Apr-98	45°24'	2°45′	293	8	363	5	
Tridens	24-Apr-98	45°24'	2°45′	340	13	363	5	38442
Tridens	24-Apr-98	45°24'	2°45′	349	10	377	5	58937
Tridens	24-Apr-98	45°24'	2°45′	311	11	363	5	41308
Tridens	24-Apr-98	45°24'	2°45′	378	20	392	6	14054
Tridens	24-Apr-98	45°24'	2°45′	300	7	361	5	5270
Tridens	24-Apr-98	45°24'	2°45′	602	27	449	9	52540
Tridens	24-Apr-98	45°24'	2°45′	316	9	362	5	41326
Tridens	24-Apr-98	45°24'	2°45′	284	3	361	5	7133
Tridens	24-Apr-98	45°24'	2°45′	328	8	365	5	78069
Tridens	24-Apr-98	45°24'	2°45'	475	19	418	9	
Tridens	24-Apr-98	45°24'	2°45'	198	12	323	3	14899
Tridens	24-Apr-98	45°24'	2°45'	277	13	347	6	18490
Tridens	24-Apr-98	45°24'	2°45'	120	8	271	2	
Tridens	24-Apr-98	45°24'	2°45'	503	11	419	9	68976
Tridens	30-Apr-98	47°50'	6°00'	351	3	371	5	28298
Tridens	30-Apr-98	47°50'	6°00'	188	11	297	3	
Tridens	30-Apr-98	47°50'	6°00'	320	11	361	5	42832
Tridens	30-Apr-98	47°50'	6°00'	401	7	390	5	76005
Tridens	30-Apr-98	47°50'	6°00'	360	4	369	5	31036
Tridens	30-Apr-98	47°50'	6°00'	377	6	376	5	53040
			AM	334	10	366	5	
							Geomean	31989

Table 5.4.1 continued

Period 5

Ship	Date	Lat N	Long W	Total Weight (g)	Ovary Weight (g)	Length (mm)	Age	alpha atresia
Tridens	25-May-98	47°23′	05°54′	331	4	377	6	1217
Tridens	25-May-98	47°23′	05°54′	432	6	412	9	12060
Tridens	25-May-98	47°23′	05°54′	311	5	365	5	1416
Tridens	25-May-98	47°23′	05°54′	342	3	370	7	446
Tridens	25-May-98	47°23′	05°54′	478	8	424	9	11323
Tridens	25-May-98	47°23′	05°54′	443	8	402	8	43376
Tridens	25-May-98	47°23′	05°54′	528	8	430	6	29908
Tridens	25-May-98	47°23′	05°54′	537	6	437	8	5035
Tridens	25-May-98	47°23′	05°54′	458	6	409	7	
Tridens	25-May-98	47°23′	05°54′	506	12	421	11	123552
Tridens	25-May-98	47°23′	05°54′	422	7	394	5	54941
Tridens	25-May-98	47°23′	05°54′	450	8	406	7	28288
Corystes	6-Jun-98	48°11′	08°17′	416	17	394	6	1696
Corystes	6-Jun-98	48°11′	08°17′	407	14	397	10	26165
Corystes	6-Jun-98	48°11′	08°17′	357	13	383	7	
Corystes	6-Jun-98	48°11′	08°17′	388	17	376	7	
Corystes	6-Jun-98	48°11′	08°17′	383	13	381	6	
Corystes	6-Jun-98	48°11′	08°17′	416	21	396	7	
Corystes	6-Jun-98	48°11′	08°17′	512	13	402	8	
Corystes	6-Jun-98	48°11′	08°17′	366	24	388	5	
Corystes	6-Jun-98	48°11′	08°17′	316	23	353	4	
Corystes	6-Jun-98	48°11′	08°17′	480	21	402	8	8819
Corystes	6-Jun-98	48°11′	08°17′	393	17	392	8	35256
Corystes	6-Jun-98	48°11′	08°17′	427	20	393	7	11973
Corystes	6-Jun-98	48°11′	08°17′	451	15	419	9	3061
			AM	422	12	397	7	
							Geomean	9763

Table 5.4.1 continued

Period 6

Ship	Date	Lat N	Long W	Total Weight (g)	Ovary Weight (g)	Length (mm)	Age	alpha atresia
Corystes	22-Jun-98	45°44'	02°49'	628	82	402	5	
Corystes	22-Jun-98	45°44'	02°49'	161	19	279	2	
Corystes	22-Jun-98	45°44'	02°49'	132	6	268	2	
Corystes	22-Jun-98	45°44'	02°49'	246	29	318	5	
Corystes	22-Jun-98	45°44'	02°49'	183	22	295	2	
Corystes	22-Jun-98	45°44'	02°49'	320	8	379	6	26660
Corystes	22-Jun-98	45°44'	02°49'	165	12	283	2	698
Corystes	22-Jun-98	45°44'	02°49'	198	23	310	4	456
Corystes	22-Jun-98	45°44'	02°49'	214	22	319	6	
Corystes	22-Jun-98	45°44'	02°49'	174	9	308	4	44844
Corystes	22-Jun-98	45°44'	02°49'	366	27	376	7	
Corystes	22-Jun-98	45°44'	02°49'	343	29	371	8	
Corystes	27-Jun-98	48°35'	09°40'	353	16	356	7	
Corystes	27-Jun-98	48°35'	09°40'	444	16	389	10	39879
Corystes	27-Jun-98	48°35'	09°40'	260	29	327	4	
Corystes	27-Jun-98	48°35'	09°40'	352	51	351	5	
Corystes	27-Jun-98	48°35'	09°40'	170	28	272	2	
Corystes	27-Jun-98	48°35'	09°40'	186	13	299	4	
Corystes	27-Jun-98	48°35'	09°40'	280	36	330	4	
Corystes	27-Jun-98	48°35'	09°40'	277	17	334	4	
Corystes	27-Jun-98	48°35'	09°40'	443	15	384	8	33802
Corystes	27-Jun-98	48°35'	09°40'	271	38	315	5	
Corystes	27-Jun-98	48°35'	09°40'	357	89	336	5	
Corystes	27-Jun-98	48°35'	09°40'	441	56	382	6	
Corystes	27-Jun-98	48°35'	09°40'	271	17	331	3	
			AM	289	28	333	5	
							Geomean	8947

Table 5.4.2 Summary of mackerel atresia data from the Western spawning component by vessel and period and estimation of realised fecundity.

Vessel/ Dates	Lat (N)	Long (W)	Nos Fish	Period	Atresia Prevalence	Atresia Intensity	Oocytes lost Per Day
Walther	50°15'	10°37'	7	3	0.51	40	2.749
Herwig	50°15'	10°37'	1				
17 March-	53°15'	11°22'	7				
2 April	45°56'	02°15'	4				
	46°15'	03°58'	9				
	46°50'	05°04'	9				
Tridens	45°24'	2°45'	19	4	0.84	95	10.650
24,30 April	47°50'	6°00'	6				
Tridens	47°23'	05°54'	12	5	0.92	95	5.326
25 May							
Corystes	48°11'	08°17'	13		0.46	21	
6 June							
Corystes				6	0.24	34	1.075
22,27 June	45°44'	02°49'	25				

Summary of all cruises combined

Total number of fish analysed	112
Geometric mean of relative atresia intensity	46.0
Prevalence of atresia	0.55
Duration of atresia stage (days)	7.5
Number of oocytes lost per day through atresia (46.0 x 0.55/7.5)	3.40
Potential fucundity	1206
Number of oocytes lost (atresia) over 60 days spawning	204
Realised fecundity	1002
Potential fecundity loss (%)	17

Table 5.4.3 Mackerel sample collected from the Southern spawning component to estimate atresia in 1998.

Period	Country	Collection dates	Vessel	Area coverage	
2	Portugal (IPIMAR)	17 Feb - 15 Mar	*Noruega*	42º09–38º38'N	9º15–9º29'W
3	Spain (IEO)	16 Mar - 1 April	*Cornide Saavedra*	43º00–45º00'N	1º00–11º00'W
3-4	Spain (IEO)	20 Mar - 26 Mar	*Cornide Saavedra*	42º00–44º30'N	1º00–10º00'W
3	Spain (IEO)	28 Mar - 8 April	*Thalassa*	42º39–46º53'N	4º41–9º26'W
5	Spain (IEO)	7 May	*Purse Seiner*	43º37'N	3º42'W

Table 5.4.4 The length, weight, residual fecundity and the number of atretic oocytes in the Southern spawning component of mackerel. Females identified in spawning conditions by the presence of migratory nuclei, hydrated oocytes or post ovulatory follicles.

Length (cm)	**Fish weight (g)**	**Residual fecundity (Vitell. oocytes)**	**SE fecundity**	**Number of atretic oocytes**	**SE atresia**	**Nº of atretic oocytes/g**
30	197	303545	9630			
30	193	288624	9705			
34	233	427653	39424			
35	268	284048	20694			
35	304	563347	14581			
35	299	420082	33499			
37	296	368993	20245			
38	338	486477	23313			
33	246	388273	25274			
32	210	112680	7805	8654	2785	41
33	227	336164	5536			
35	282	364330	17037			
33	225	110627	8158	62167	10728	276
43	505	542691	50472			
29	175	112345	4096			
31	180	315402	11399			
32	206	96301	7783	27745	2486	135
38	358	483506	11379			
32	207	138572	5504			
32	203	275597	13281			
30	213	326126	27402			
32	235	227026	9407			
36	350	422679	8278			
39	401	624082	23262			
35	252	137297	9653			
37	312	207018	11419	71872	8751	231
37	292	194077	7364	120135	11538	412
36	339	329560	11640			
37	338	448433	25269			
37	373	325933	33082	14096	7436	38
37	374	371032	7668			
38	363	378229	9197	53104	18997	146
38	390	451282	4098			
38	377	634930	31056			
38	386	692975	36568			
38	401	458001	8426			
39	415	627486	23166			
39	420	525681	37244	25266	10181	60
39	433	483838	21655			
33	283	430246	19423			
36	346	234208	15442			
36	335	370315	14845			
38	413	683322	13506			
40	501	504533	10674			
28	158	164646	3655	894	914	6
37	323	160445	40281	132638	3827	411
35	309	349146	19547			
36	340	600081	10592			
37	343	427653	39424	13641	5116	40
38	378	384020	26795			
38	417	733933	45087			
38	437	693845	35713			
39	438	685469	47469			
40	475	751316	36186			
40	458	622185	25726			
41	548	812593	49667	230444	21439	421
Arith.Mean	327	408802	Arith.Mean	63388	Geo.Mean	105

Table 5.5.1 Spawning stock biomass for the western spawning component of mackerel and western horse mackerel. Spawning stock biomass estimates are corrected for atresia. A sex ratio of 1:1 is assumed. The SSB was calculated from the total egg production based on arithmetic mean of unsampled rectangles if available.

Annual egg production method – western mackerel						
Year	**Total egg prod ($x10^{-15}$) (mean for unsampled rectangles)**		**Total fecundity (eggs/g female)**	**Total fecundity corrected for atresia**	**Pre-spawning stock biomass ($x10^{-6}$ tonnes)**	**Spawning stock biomass ($x10^{-6}$ tonnes)**
	Geometric	**Arithmetic**	**(atresia oocytes/gm female)**	**(eggs/g female)**		**(conversion factor 1.08)**
1977	1.98		1526 [211]	1315	3.01	3.25
1980	1.48 a		1526 [211]	1315	2.25	2.43
1980	1.84 b		1526 [211]	1315	2.80	3.02
1983	1.50	1.53	1526 [211]	1315	2.33	2.51
1986	1.15	1.24	1457 [211]	1246	1.99	2.15
1989	1.45	1.52	1608 [326]	1282	2.37	2.56
1992	1.83	1.94	1569 [138]	1431	2.71	2.93
1995	-	1.49	1473 [171]	1302	2.28	2.47
1998	-	1.37	1206 [203]	1002	2.73	2.95

Annual egg production method – western horse mackerel						
Year	**Total egg prod ($x10^{-15}$) (mean for unsampled rectangles)**		**Total fecundity (eggs/g female)**	**Total fecundity corrected for atresia**	**Pre-spawning stock biomass ($x10^{-6}$ tonnes)**	**Spawning stock biomass (conv f 1.05) ($x10^{-6}$ tonnes)**
	Geometric	**Arithmetic**		**(eggs/g female)**		
1977	0.533 c		1557	1504	0.71	0.74
1980	0.635 c		1557	1504	0.84	0.89
1983	0.381 c		1557	1504	0.51	0.53
1986	0.508 c		1557	1504	0.68	0.71
1989	1.54	1.63	1557	1504	2.17	2.28
1992	1.37	1.58	1557	1504	2.10	2.21
1995	-	1.226	1557	1504	1.63	1.71
1998		1.003	(1557) d	(1504) d	(1.33) d	(1.40) d

a Egg survey data for period 3 included. b Egg survey data for period 3 excluded.
c Eaton (1989). In 1977 incomplete coverage. d see Section 6.3 &6.4 of (ICES 1999)

Estimates by Generalised Additive Modelling (provisional)

Egg Production x 10^{15}						
Year	**Area**	**Mackerel**			**Horse Mackerel**	
		GAM (no bc)	**GAM (with bc)**		**GAM (no bc)**	**GAM (with bc)**
1995	Western	0.854 *0.02* [2.7]	1.623 *0.05* [2.9]		0.886 *0.09* [10.2]]	1.554 *0.24* [15.4]
	Southern	0.136	0.202		0.396	0.553
1992	Western	1.744 *0.05* [2.6]	2.366 *0.07* 2.9		1.44 *0.11* [7.5]	1.804 *0.21* 11.9
1989	Western	1.373 *0.09* [6.5]	3.027 *0.12* [3.8]		1.308 *0.09* [6.7]	1.635 *0.14* [9.2]
1998	Western					

bc = bias correction. Figures in italics are standard errors. Figures in brackets are % cv’s

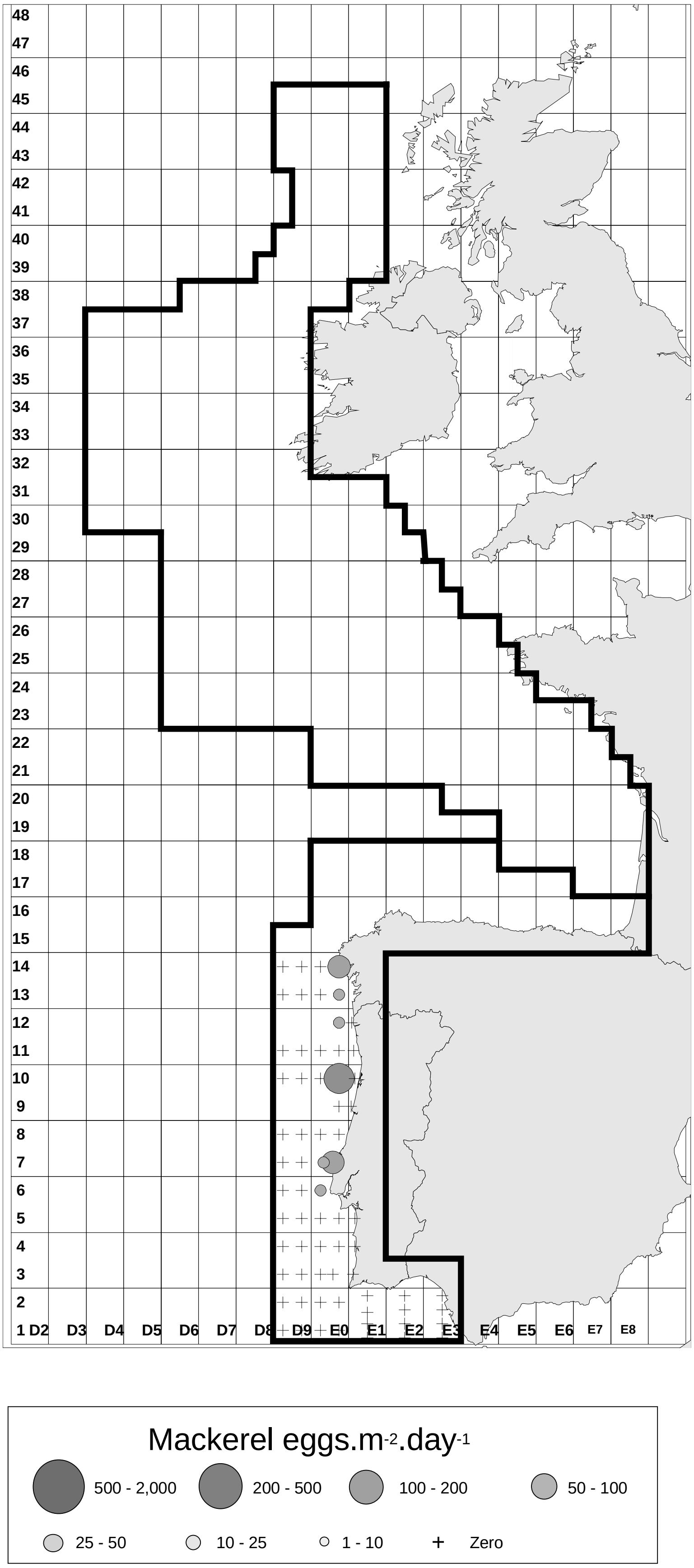


Figure 5.1.1a Mackerel egg production by rectangle for period 1 (17–31 January). Diamonds represent interpolated data, x represents interpolated zeroes.

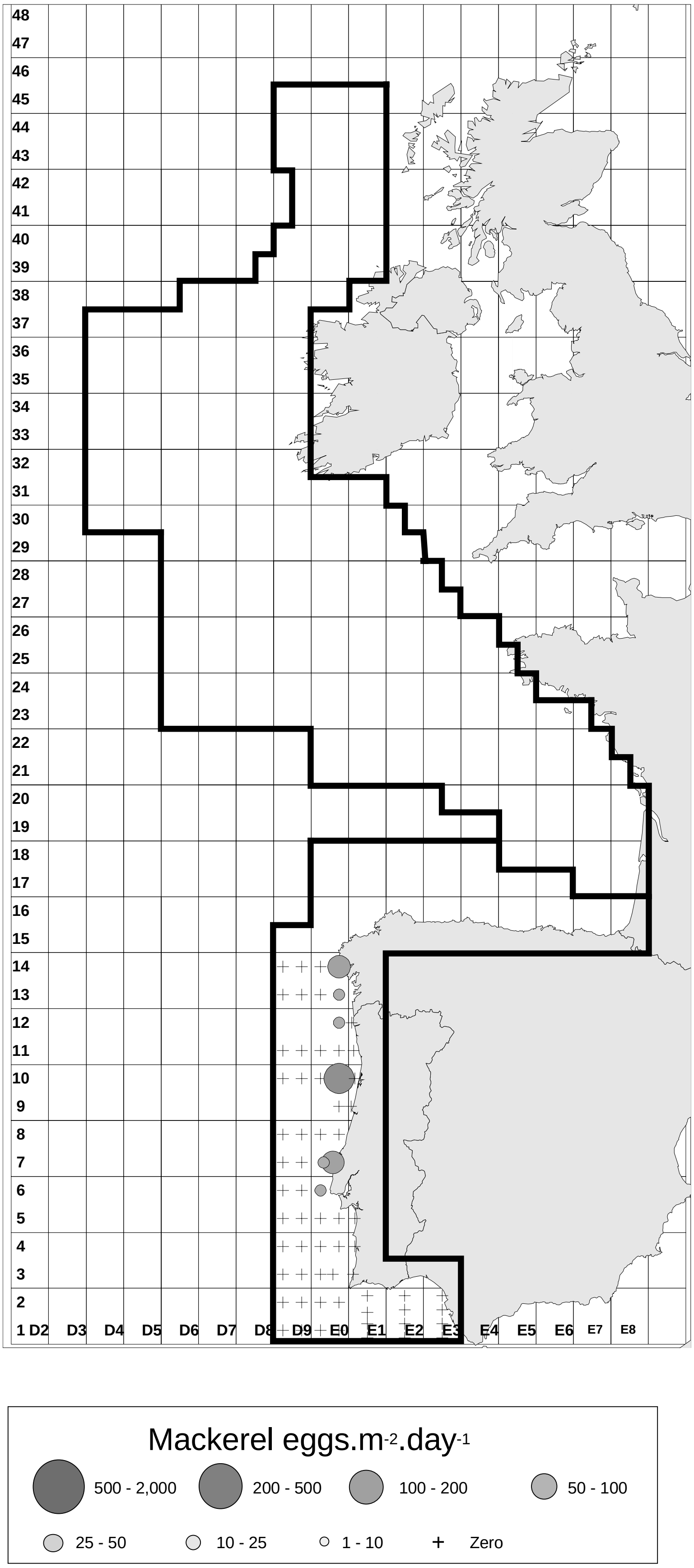


Figure 5.1.1b Mackerel egg production by rectangle for period 2 (7 February–1 March). Diamonds represent interpolated data, x represents interpolated zeroes.

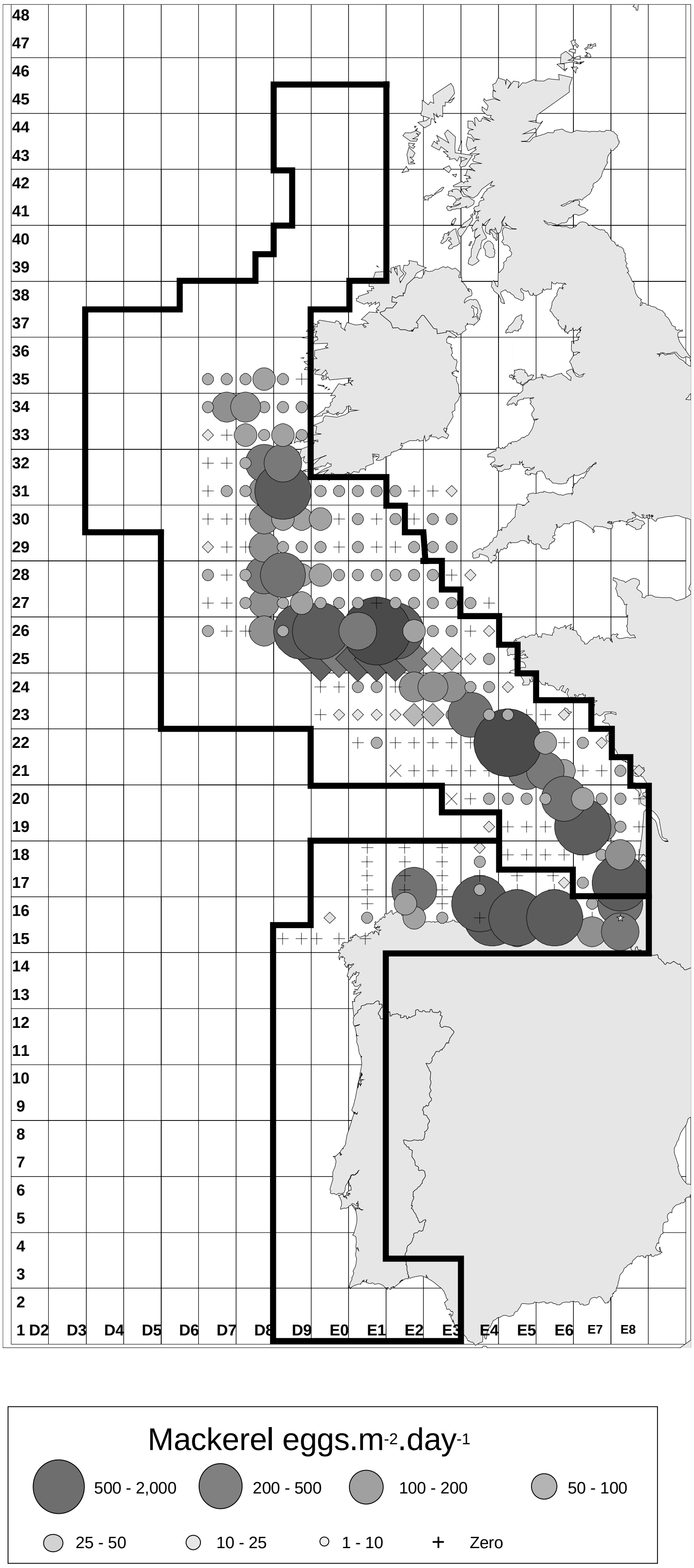


Figure 5.1.1c Mackerel egg production by rectangle for period 3 (15 March–6 April). Diamonds represent interpolated data, x represents interpolated zeroes.

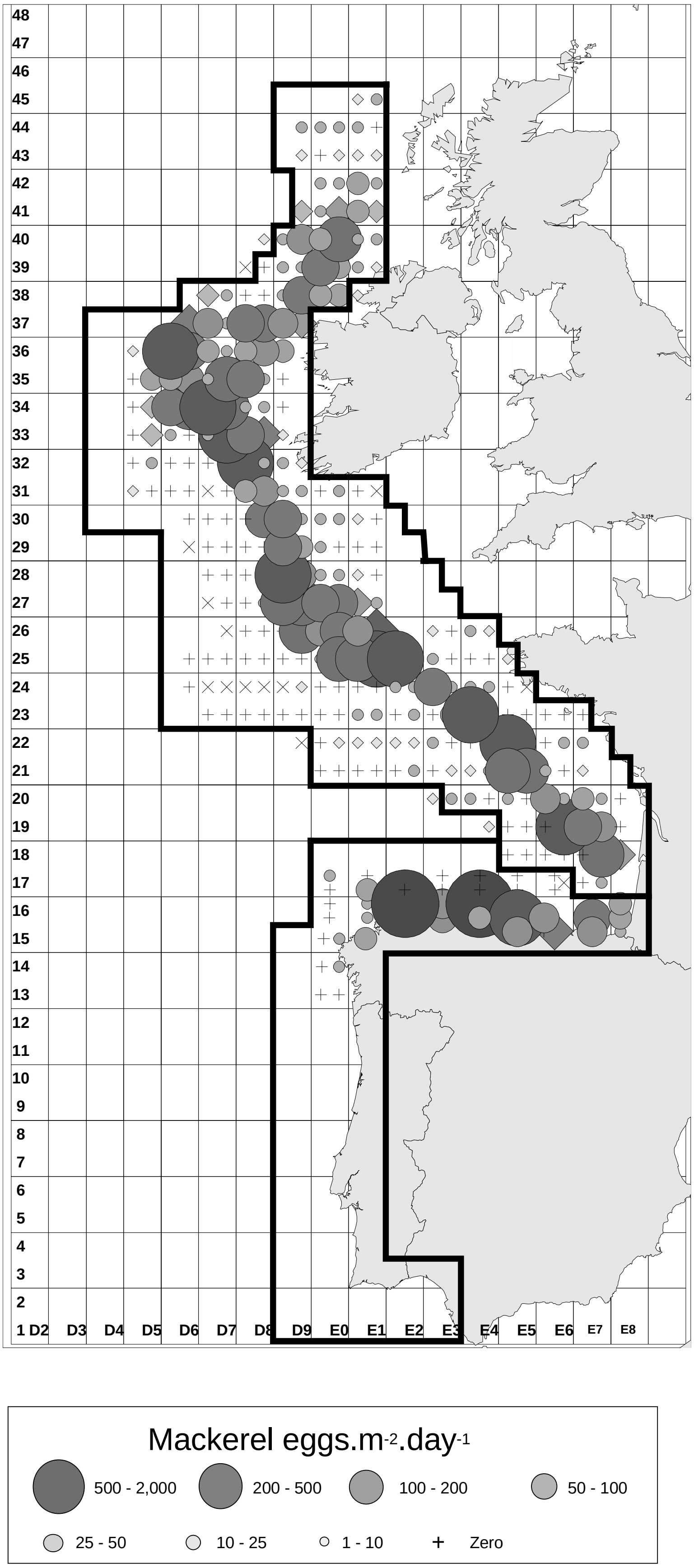
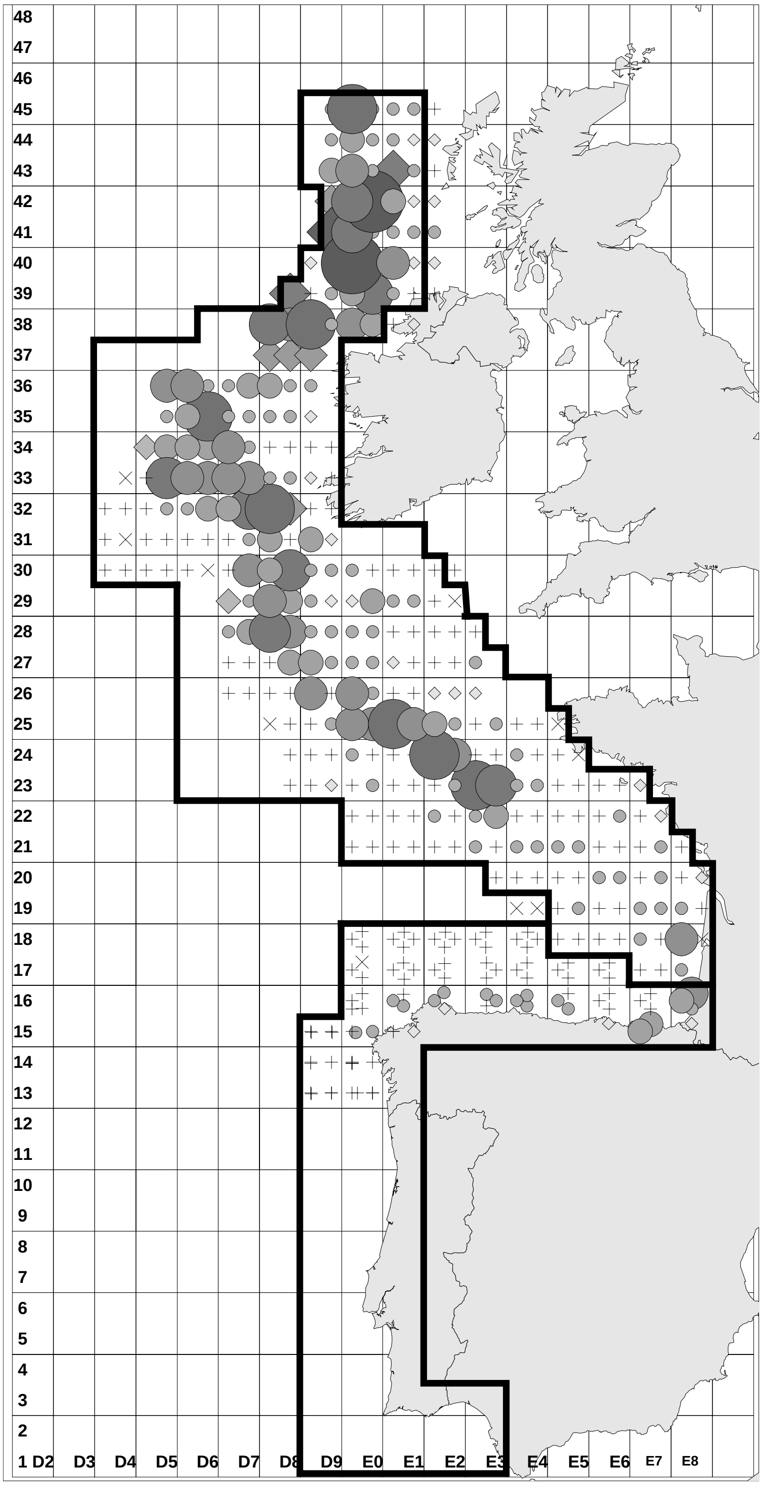


Figure 5.1.1d Mackerel egg production by rectangle for period 4 (16 April–15 May). Diamonds represent interpolated data, x represents interpolated zeroes.



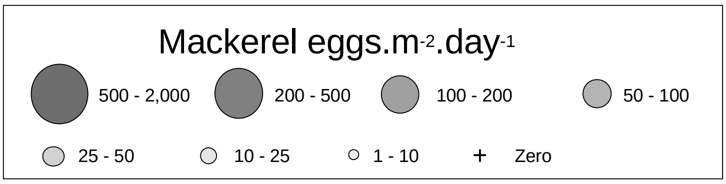


Figure 5.1.1e Mackerel egg production by rectangle for period 5 (16 May–13 June). Diamonds represent interpolated data, x represents interpolated zeroes.

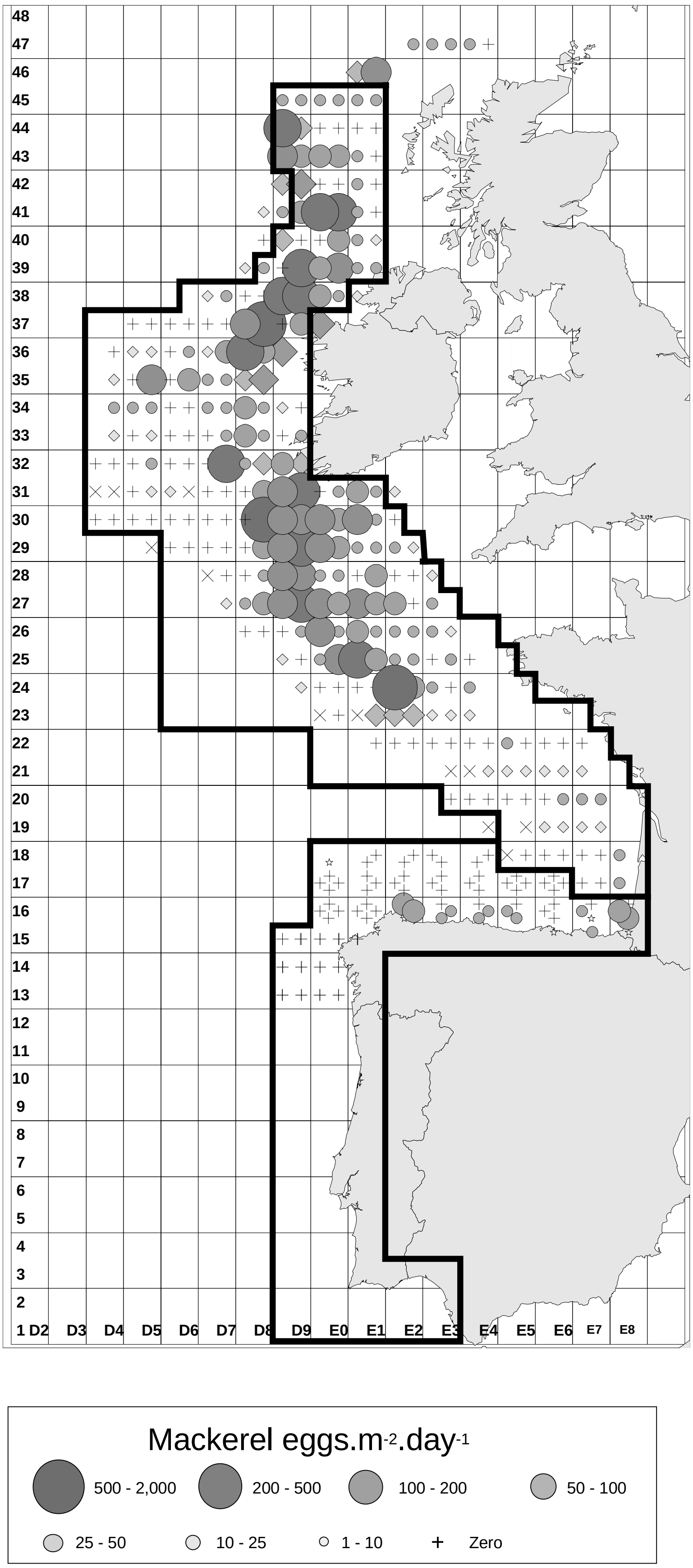


Figure 5.1.1f Mackerel egg production by rectangle for period 6 (14 June–5 July). Diamonds represent interpolated data, x represents interpolated zeroes.

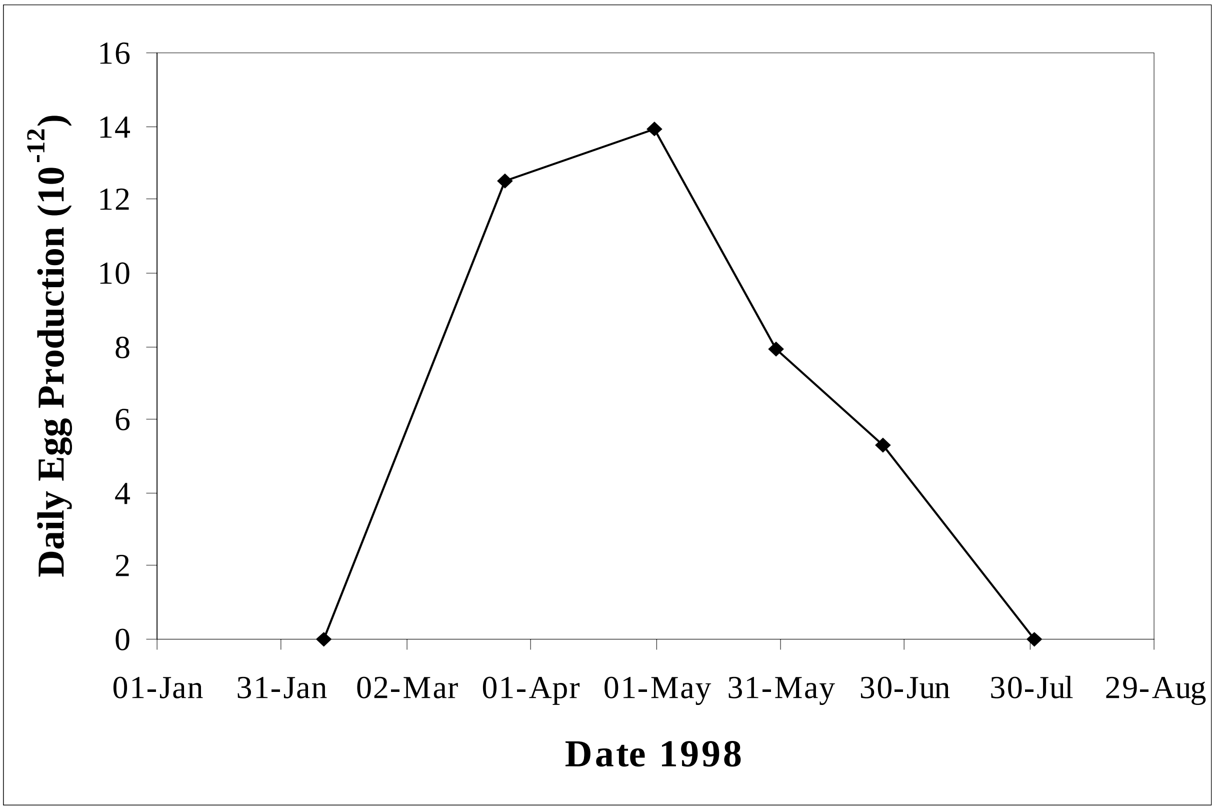


Figure 5.2.1 Mackerel daily egg production curve for the surveys in the western spawning area in 1998

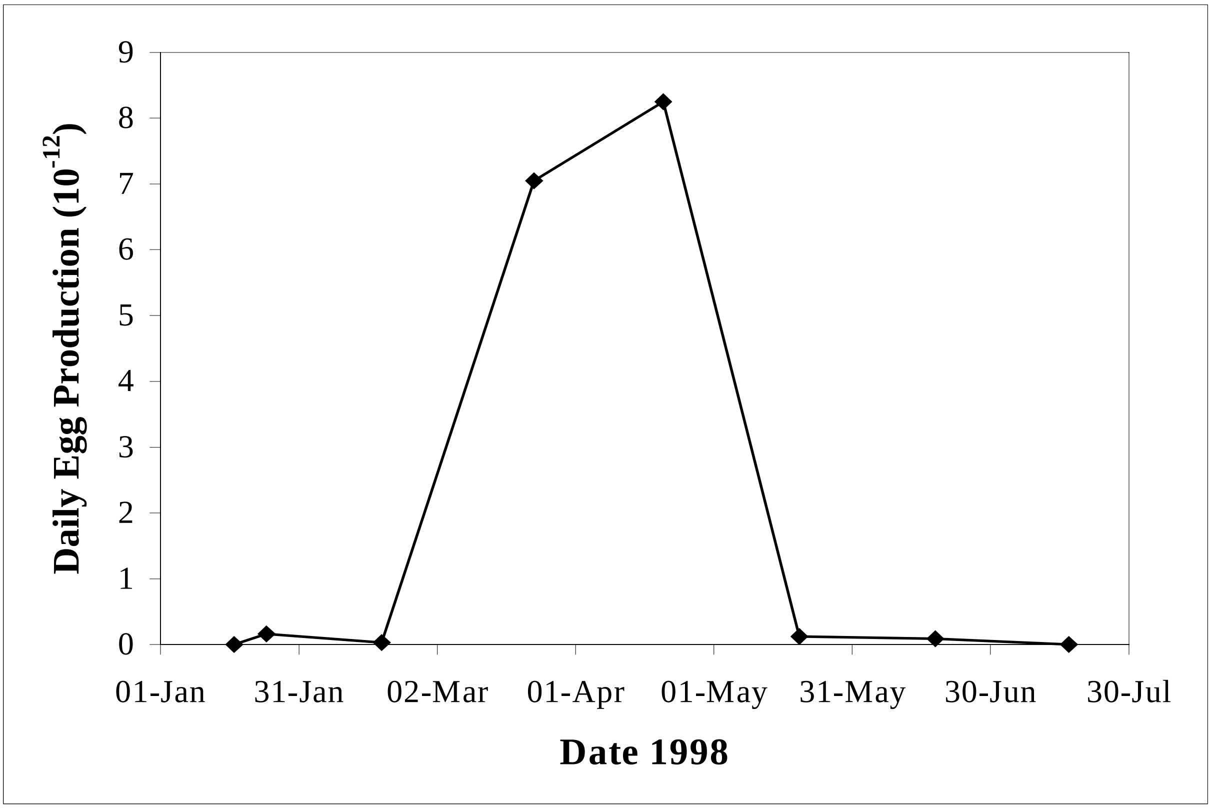


Figure 5.2.2 Mackerel daily egg production curve for the surveys in the southern spawning area in 1998. The curve was produced assuming start and finish dates of 17 January and 17 July respectively.

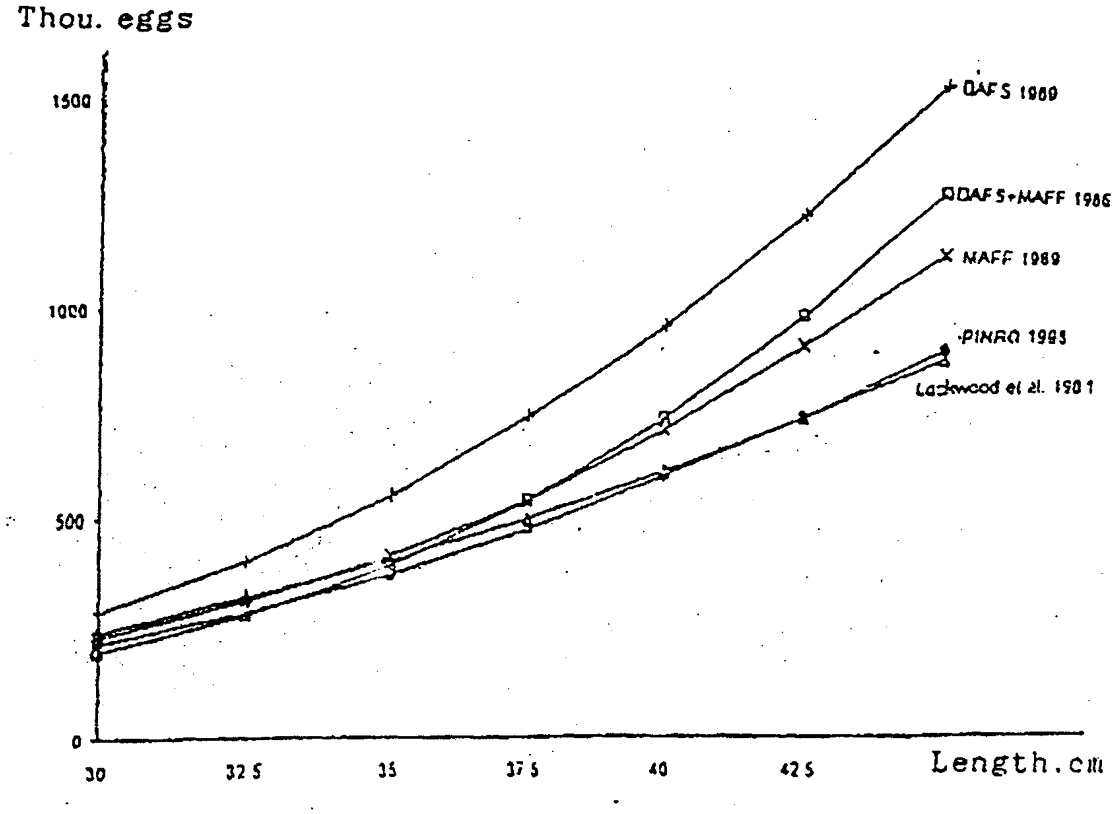


Figure 5.3.1 Change of individual fecundity of mackerel in dependence of fish weight due to Russian and foreign data (WD Tereshchenko & Shamray)

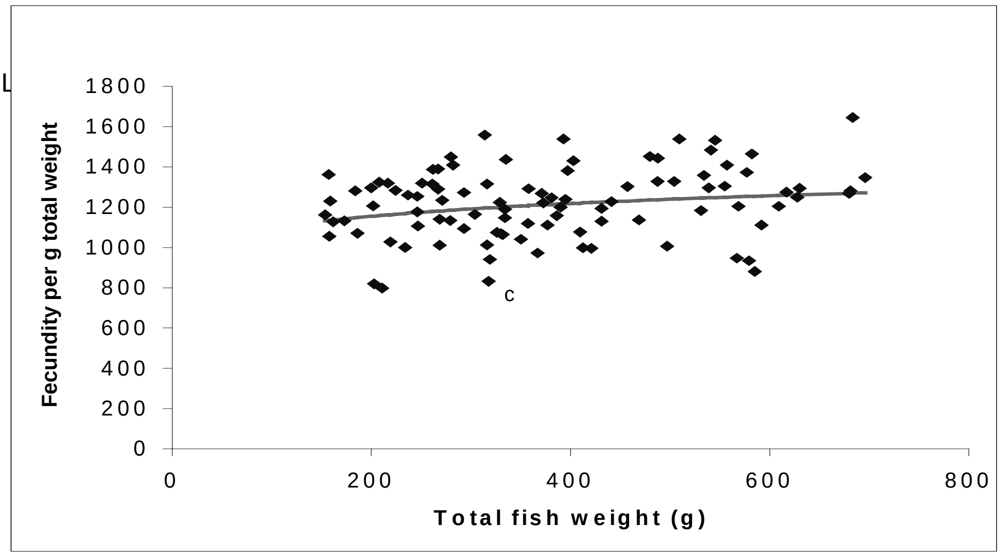


Figure 5.3.2 The relationship between relative fecundity and total body weight in the Western mackerel spawning component.
Ln Relative fecundity = Ln Total weight x 0.077220593 +6.642189 P>0.05 n = 97

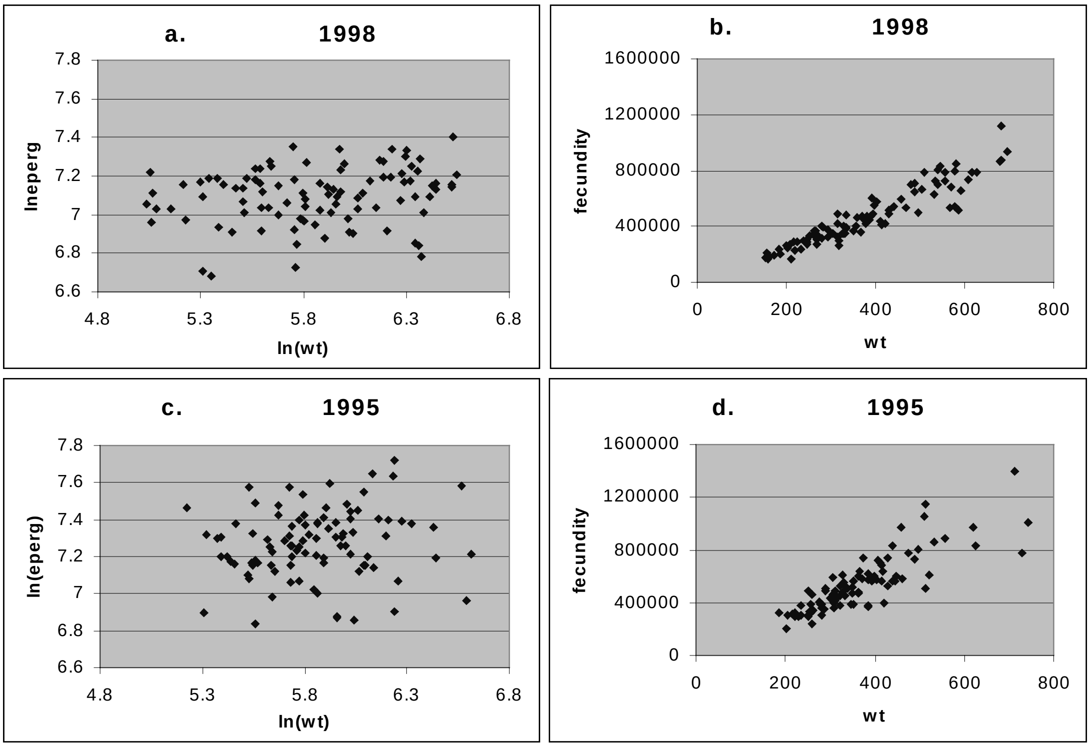


Figure 5.3.3 Comparison of fecundity observations in 1998 (a and b) and in 1995 (c and d) in the Western spawning component. Left panels (a and c) are plots of the logarithms of weight-specific egg production plotted on logarithms of body weight. Right panels (b and d) show observations of fecundity and body weight on untransformed scales.

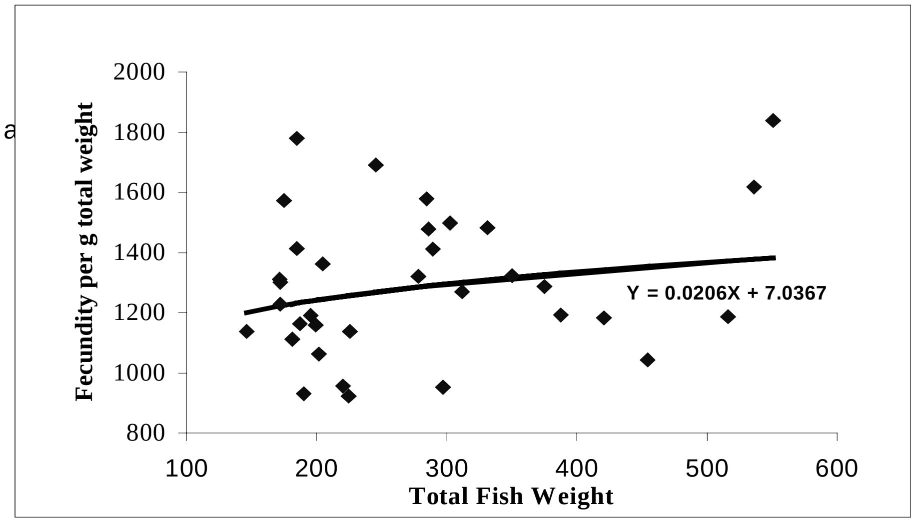


Figure 5.3.4 Summary of relative potential fecundity for mackerel in Southern spawning component.

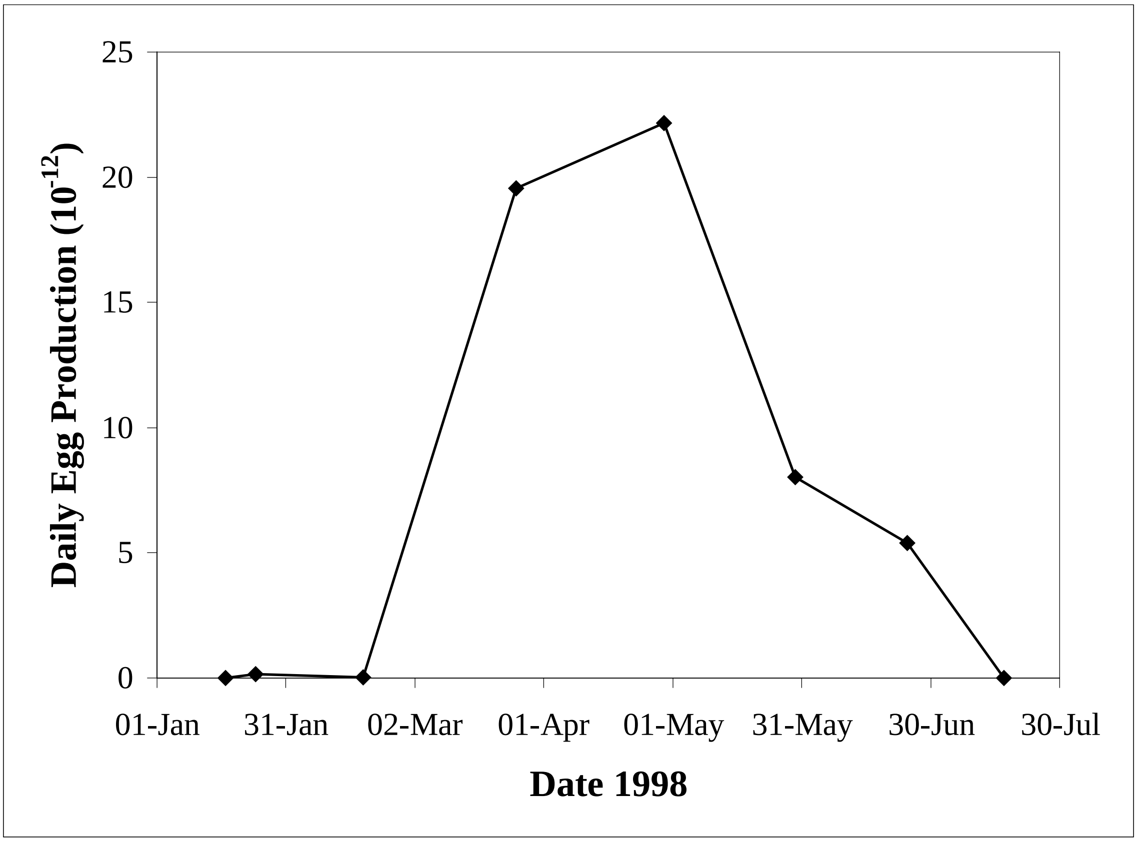


Figure 5.5.1 Mackerel daily egg production curve for the surveys in the southern and western spawning areas combined.

6 WESTERN HORSE MACKEREL: 1998 EGG SURVEY RESULTS

6.1 Spatial distribution of Stage 1 Horse mackerel eggs.

Distribution maps of daily egg production per m^2 surface are given for the four time periods 3 to 6 in Figures 6.1a–d. No surveys were carried out in the western area during periods 1 or 2.

During period 3 the overall egg production was low. Small numbers of eggs were distributed over a large area south of 53°30′ (row 35) with the highest concentrations being found along the shelf edge west of the Bay of Biscay. Although some eggs were found outside the standard survey area in the Celtic Sea and in the English Channel the standard area seemed to cover the egg distribution adequately. The overall distribution was similar to that found in 1995.

The egg production increased considerably during period 4. The main spawning appeared to take place in a narrow restricted area along the continental shelf that extended from south west of Ireland (52°30′) (row 33) to the centre of the Bay of Biscay (rows 21 and 22). Some small concentrations of eggs were found scattered over a large area west of Ireland and west of Scotland as far north as 58°30′ (row 45). During the same period in 1995 eggs were distributed over a much wider area than in 1998. Again the standard survey area in 1998 appeared to adequately contain the egg production.

During period 5, when peak spawning would be expected, the overall egg production decreased considerably. No explanation is presently available for apparent bimodality in the spawning period. There are no obvious differences in length or age between fish sampled during period 4 and period 5. Eggs were located over a much wider area than in period 4. Although high numbers of eggs were located further to the west than in the previous period the main spawning again appeared to take place along the continental shelf edge. Compared to the 1995 distribution during the corresponding period more spawning appeared to have taken place in the northern parts of the survey area. High numbers of eggs were located along the Cantabrian coast during the western survey. However the values present along the north Spanish coast in periods 5 and 6 are derived from western egg surveys which also sampled the southern area. These values have not been included in the egg production calculations for the southern area.

The egg distribution during period 6 in 1998 appeared to be very unusual both in distribution and in concentration. The daily egg production indicates that peak spawning occurred during this period and this is considered to be much later than that indicated by any of the previous surveys. The highest concentrations of eggs were found over a very wide area with the densest concentrations being located between 47°–48°30′ (rows 24 and 25) i.e. west of Brittany and also to the south west of Ireland. High concentrations were also located west of Ireland between 53°–54° (rows 30–37). In the area north-west of Ireland and west of Scotland the egg distributions indicate that spawning took place to the west of the standard area. Spawning also took place in this area in 1995 and as a result the western edge of the standard area was extended. However the extended area did not adequately cover the entire egg production.

6.2 Stage I Egg production of Western Horse Mackerel

The mean daily stage I egg production estimates for each survey period are plotted against the mid-period dates (Figure 6.2.1) to provide an egg production curve as presented for previous surveys. The data values are presented in Table 6.2.1.

The start date was assumed to be the 10 February as used in 1995. This date was earlier than used for the previous surveys (19 February). No survey data was available in the western area or in the Cantabrian Sea prior to period 3 to assist in setting a start date. All survey data and histological data suggest that this date could be considered as the latest appropriate start date. Given the low egg production in period 3 this date seems reasonable. The end date is the same as that used in 1995 - 31 July. No survey or histological data were available to question this date. Production estimates for the individual survey periods, the periods before and after the surveys and for the unsampled period in April are presented in Table 6.2.2.

There was no temporal overlap between periods for the 1998 survey. The standard errors are slightly greater than 1995, probably due to a reduced number of duplicate samples. These calculations are based on the complete survey results including observations beyond the edge of the 1998 standard survey area. No data from the southern area were included in the analysis. There was a negligible effect on the estimate of expanding the 1998 area, the two estimates are identical to two decimal places. A calculation of the estimate using the 1995 standard area gives a production of $1.01\ 10^{15}$ for 1998. This value is given for comparison purposes only, the extended 1998 area estimate has been used for all subsequent biomass estimates.

6.3 Potential Fecundity and Atresia of Western Horse Mackerel

The Netherlands was responsible for the estimation of fecundity, atresia and maturity of western horse mackerel. However, not all of the atresia ovaries and none of the maturity ovaries were analysed at the time of this meeting, because of a long-lasting sickness of the Dutch expert on horse mackerel histology. Unfortunately, nobody else with that expertise was available replace him. Therefore, only preliminary results could be presented at this meeting, but a working document will be presented to the assessment Working Group meeting in September 1999 with the final results.

Potential Fecundity

Following the recommendation of the planning meeting in 1997 (ICES, 1997b) 10 ovaries per cm group of horse mackerel in late pre-spawning stage 3 were collected for fecundity estimation in April. RV Tridens collected 98 horse mackerel ovaries for fecundity estimation in April 1998 (period 4) between 45ºN and 48º30'N. However, most of these fish showed already signs of spawning based on histological analysis and only 17 ovaries were selected for fecundity 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 total fecundity by raising the counts of vitellogenic and atretic oocytes to the total volume of the ovary.

The 90 randomly selected adult females collected for atresia estimation in March 1998 (period 3) by Germany were also taken into account for fecundity estimation in order to have more ovaries available for the fecundity estimation. However, again most of these fish showed signs of spawning based on histological analysis and only 28 fish could be selected for fecundity estimation. For period 3 and 4 a total of 45 ovaries were available for fecundity estimation.

Information on the percentages of fish by maturity stage and month for both 1995 and 1998 (Dutch market-sampling program for horse mackerel) confirmed that the ovaries of the fish collected in 1998 were more developed compared to those collected in 1995. The histometric method to estimate the total fecundity is described in Eltink and Vingerhoed (1989) and Emerson *et al*. (1990).

Figure 6.3.1 shows the plot of the fecundity against the fish weight from fish collected in period 3 and 4. This corresponds to an estimated fecundity of 605 eggs per gram pre-spawning female (SE 38 eggs/g) as given in Table 6.3.1. The fecundity estimate of 516 eggs/g (SE 22) for period 3 differs considerably from 776 eggs/g (SE 58) for period 4. These fecundity estimates differ even more from the fecundity of 1557 eggs/g (SE 43), which was used for the conversion of total egg productions to biomass for all egg surveys up to 1995 (Table 5.5.1). Figure 6.3.2 shows a comparison of the 1998 fecundity estimates with the fecundity estimates as obtained from ovaries collected in 1987, 1988, 1992 and 1995. The fecundity estimates of 1998 clearly do not fit into the data series of the historic fecundity estimates. In earlier years the fecundity estimates of each year fitted quite well within the earlier estimated fecundity data. It is not clear what could have caused this apparent low fecundity in 1998. Food conditions before the spawning season of 1998 might have been worse compared to 1995 and might have caused this lower fecundity. However, a comparison of condition factors over the period January to May both in 1995 and 1998 showed that the condition factor in 1998 was only 5 % lower than in 1995. The Working Group did not expect that this would have caused a much lower fecundity.

It was observed that the vitellogenic oocytes in ovaries collected in period 3 and 4 in 1998 had a rather large diameter. Comparison of frequencies of the diameter distributions from ovaries collected in 1995 and 1998 showed that the modes differed considerably. In 1998 the mode was at 0.5 mm compared to a mode of 0.2 mm in 1995 (Figure 6.3.3). This much larger diameter of the vitellogenic oocytes in 1998 could be related to this lower fecundity, since there would be less space in the same volume of ovary for these larger oocytes (ovary volumes in 1995 and 1998 were approximately the same). The mode of the oocyte diameter of the vitellogenic oocytes in ovaries collected during the later survey periods of 1998 was different to that observed in 1995. The observed larger mode in oocyte diameter is often observed in ovaries of fish, which are in a very advanced stage of spawning (spawning of their last batches).

The histological sections were examined to ensure that spawning had not yet commenced before they were used for fecundity estimation. Spawning is indicated by the presence of post-ovulatory follicles. However, spawning fish cannot be identified as spawning if the duration of the batch interval is longer than the duration of the resorption of the post-ovulatory follicles. In this case fish, which had spawned, might have been used for fecundity estimation, although they showed no signs of spawning by post-ovulatory follicles. Potential fecundity estimates are not valid if fish have spawned already in the current spawning season. It is therefore recommended that the fish samples for fecundity estimation are collected as early as possible in 2001, when the next egg survey will be carried out.

In principle the residual fecundity by survey period should decrease during the course of the spawning season, because it represents the number of vitellogenic oocytes remaining in the ovary due to spawning. This gradual decrease of residual fecundity was observed during 1995 egg survey (ICES, 1997). However, Figure 6.3.4 shows that in 1998 the residual fecundity, over time, increases up to survey period 5 and then decreases in period 6. Also the potential fecundity, as estimated from ovaries that did not show signs of spawning, increased up to survey period 5 and remained at the same level in survey period 6. A possible explanation for the increase in residual and potential fecundity is the decrease of the mode in the frequency distribution of the oocyte diameters. It should be noted that individual fish are expected to spawn approximately over two months while the entire spawning season lasts about six months. This implies that fish that are spawning in the end of the spawning season replace the fish that are spawning at the beginning of the spawning season. The potential fecundity does not necessarily have to be the same at the beginning and the end of the spawning season. Furthermore the residual fecundity can remain rather high, when the nearly spent fish leave the spawning area. The very high residual fecundity of survey period 6 indicates that a large proportion of the western horse mackerel would continue to spawn after period 6. The assumed end date of the spawning season of 31 July was probably too early. Furthermore it indicates that a survey in July is really necessary for the estimation of the egg production curve during the egg survey in 2001.

The fecundity estimates of earlier years (1987,1988, 1992 and 1995) were mainly based on fish of the extremely strong 1982 year class, which showed a retarded growth and which matured much later than observed before. During the 1998 survey, many small mature fish were caught. These fish were already mature at a length of 20 cm onwards. It was remarkable that many of these young fish had already spawned in April. The mean length at age, which was estimated from the randomly collected adult females during periods 3–6, was respectively 25.3, 26.1, 26.8 and 29.6 cm. This is in contrast with what is observed in mackerel, where the older and larger fish spawn first more to the edge of the continental shelf and the younger and smaller fish spawn later on the continental shelf.

De novo vitellogenesis is the development of resting oocytes into vitellogenic oocytes during the course of the spawning season. This might also explain the increase in fecundity during the course of the spawning season. The increase in fecundity might therefore be explained, if the rate of production of vitellogenic oocytes is higher than the rate of spawning vitellogenic oocytes. If this is the case, then horse mackerel would be an indeterminate spawner and the annual egg production method can not be applied to estimate the spawning stock biomass. **The Working Group, therefore, recommends that tank experiments with horse mackerel be carried out to investigate whether horse mackerel is an indeterminate or a determinate spawner.**

Based on the observations described above it is impossible to present a fecundity estimate for 1998. However, the Working Group regarded the biomass estimates, as obtained from the egg surveys up to 1995, reliable enough to be used as absolute biomass indices for stock assessment purposes by the Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy. This was based on the following arguments:

All estimates of fecundity from fish collected in 1987, 1988, 1992 and 1995 agreed quite well and did not show these large discrepancies as observed in 1998 (ICES, 1996b).

The spawning stock biomass estimates from the Annual Egg Production Method (AEPM) and the Daily Egg Production Method (DEPM) based on the 1992 egg surveys were quite well in agreement. There was no indication that the AEPM overestimated spawning stock biomass because of a underestimation of the fecundity, which would be the case if horse mackerel were an indeterminate spawner (ICES, 1993b).

In 1995 a gradual decrease of residual fecundity was observed during the spawning season (ICES, 1996b).

<u>Atresia</u>

Preliminary results on the number of atretic oocytes per gram female by survey period are presented in Table 6.3.2. The first impression is that atresia levels in 1998 do not differ very much from those estimated during the 1995 egg survey (ICES, 1996b). Information on atresia based on all atresia samples will become available in September 1999 to the Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy.

6.4 Biomass Estimate of Western Horse Mackerel

The total stage I egg production for western horse mackerel is $1.003*10^{15}$ as given in Table 6.2.2. It is based on an assumed end date of the spawning season of 31 July. The total egg production would be much higher, if the end date had been taken much later (as is indicated by the residual fecundity in survey period 6 (see Section 6.3)). A fecundity estimate could not be provided due to the problems outlined in Section 6.3. Therefore, a biomass estimate of the western horse mackerel can not be calculated for 1998 using the 1998 fecundity estimate. However, applying the historical fecundity of 1504 eggs/g female (corrected for atresia) would result in a biomass estimate of 1.40 million tonnes (see Table 5.5.1). This can be regarded as the most conservative estimate of biomass, since fecundity is likely to have been lower and egg production is likely to have been higher. Both of these factors would have increased the biomass estimate.

6.5 Western Horse Mackerel Maturity

The Netherlands was responsible for the estimation of the maturity ogive for western horse mackerel. However, at the time of this meeting none of the histological slides of the maturity ovaries were analysed because of reasons outlined in the beginning of Section 6.3 and because a first priority was given to the analysis of the fecundity and atresia samples. A working document will be presented to the assessment Working Group meeting in September 1999 with the final results on western horse mackerel maturity.

Table 6.2.1 Western horse mackerel mean daily stage I egg production.10^{-12}

Period	Dates	Estimate	s.e.
3	15/3 - 6/4	1.0	0.4
4	16/4 - 15/5	11.7	5.1
5	16/5 - 13/6	3.9	1.2
6	14/6 - 5/7	14.4	8.4

Table 6.2.2 Western horse mackerel total stage I egg production estimates by time period for 1998

Dates	Period	No. of days	Annual stage I egg production.10^{-15}
10/2 - 14/3		33	0.013
15/3 - 6/4	3	23	0.024
7/4 - 15/4		9	0.053
16/4 - 15/5	4	30	0.351
16/5 - 13/6	5	29	0.113
14/6 - 5/7	6	22	0.317
6/7 - 31/7		26	0.132
	total	172	1.003
	s.e.		0.325

Table 6.3.1 The length, weight, annual potential fecundity and its standard error (s.e), and the number of atretic oocytes and its s.e from 24 western horse mackerel collected by 'RV Walther Herwig' in March and 17 fish collected by 'RV Tridens' in April 1998. The annual potential fecundities do not include the number of atretic oocytes.
AM = arithmetic mean: GM = geometric mean.

Annual potential fecundity estimates (period 3) German samples						
Length (cm)	**Fish weight (g)**	**Annual potential fecundity (vitell. oocytes)**	**Eggs/gram (vitell. Oocytes)**	**SE fecundity**	**Number of atretic oocytes**	**SE atresia**
21	105	49,487	471	2,696		
22	81	78,679	971	10,133		
22	86	44,507	518	2,491		
22	87	52,567	604	2,801	327	384
22	92	33,989	369	1,771	399	327
23	100	37,565	376	1,417	2,111	722
23	103	59,767	580	2,879	639	337
23	107	55,384	518	2,522	2,542	480
23	109	58,655	538	5,857	396	387
23	116	53,091	458	2,448	4,022	914
23	127	77,325	609	2,271		
24	96	56,849	592	2,552		
24	99	52,903	534	2,142	869	427
24	113	52,535	465	2,174	560	548
24	124	60,224	486	4,683	1,099	595
25	116	55,043	475	1,601	4,427	886
25	117	64,486	551	2,808	174	188
25	121	73,756	610	2,755	3,140	1,210
26	142	67,813	478	5,721	977	427
26	147	63,187	430	3,952	5,474	2,488
27	142	51,939	366	2,334	1,086	709
27	150	76,308	509	5,878		
28	151	99,745	661	8,464	437	427
33	295	142,469	483	6,396	21,293	1,212
	122 AM	**63,261 AM**	**516 GM**		**2,776 AM**	

Annual potential fecundity estimates (period 4) Dutch samples						
Length (cm)	**Fish weight (g)**	**Annual potential fecundity (vitell. oocytes)**	**Eggs/gram (vitell. Oocytes)**	**SE fecundity**	**Number of atretic oocytes**	**SE atresia**
25	148	108,493	733	6,544	792	772
26	154	106,639	692	7,880	5,321	1,458
28	176	105,931	602	12,370		
28	172	226,766	1,318	10,833		
29	211	211,380	1,002	15,500	8,210	3,497
29	187	151,072	808	19,330		
29	206	78,773	382	2,410		
30	207	161,460	780	9,336	715	801
30	216	236,008	1,093	18,374	12,811	6,154
30	266	152,351	573	10,382		
30	200	217,641	1,088	16,294		
30	223	247,261	1,109	7,093		
31	238	173,177	728	12,252	4,790	1,844
31	238	155,908	655	10,062		
34	314	164,320	523	6,617	3,456	2,334
34	336	257,916	768	16,579	19,200	4,950
39	393	260,443	663	15,860		
	229 AM	**177,385 AM**	**760 GM**		**6,912 AM**	

Period 3	**Fecundity in eggs/g female = 516**	**SE 22**
Period 4	**Fecundity in eggs/g female = 760**	**SE 58**
Period 3+4	**Fecundity in eggs/g female = 605**	**SE 38**

Table 6.3.2 The residual fecundity and the potential fecundity from ovaries with no signs of spawning, and the number of atretic oocytes per gramme female. The prevalence of atresia is the percentage of fish showing atresia.

Period	Mean weight	Mean fecundity	Residual fecundity eggs/g	No signs of spawning Fecundity eggs/g	Number of atretic oocytes	Number of atretic oocytes/g	Prevalence of atresia
3	125	60,491	484		3,562	12	77 %
4	232	208,179	897	872	5,421	19	34 %
5	145	150,364	1038	1,078	9,349	44	17 %
6	220	190,787	866	1,071	11,311	17	29 %

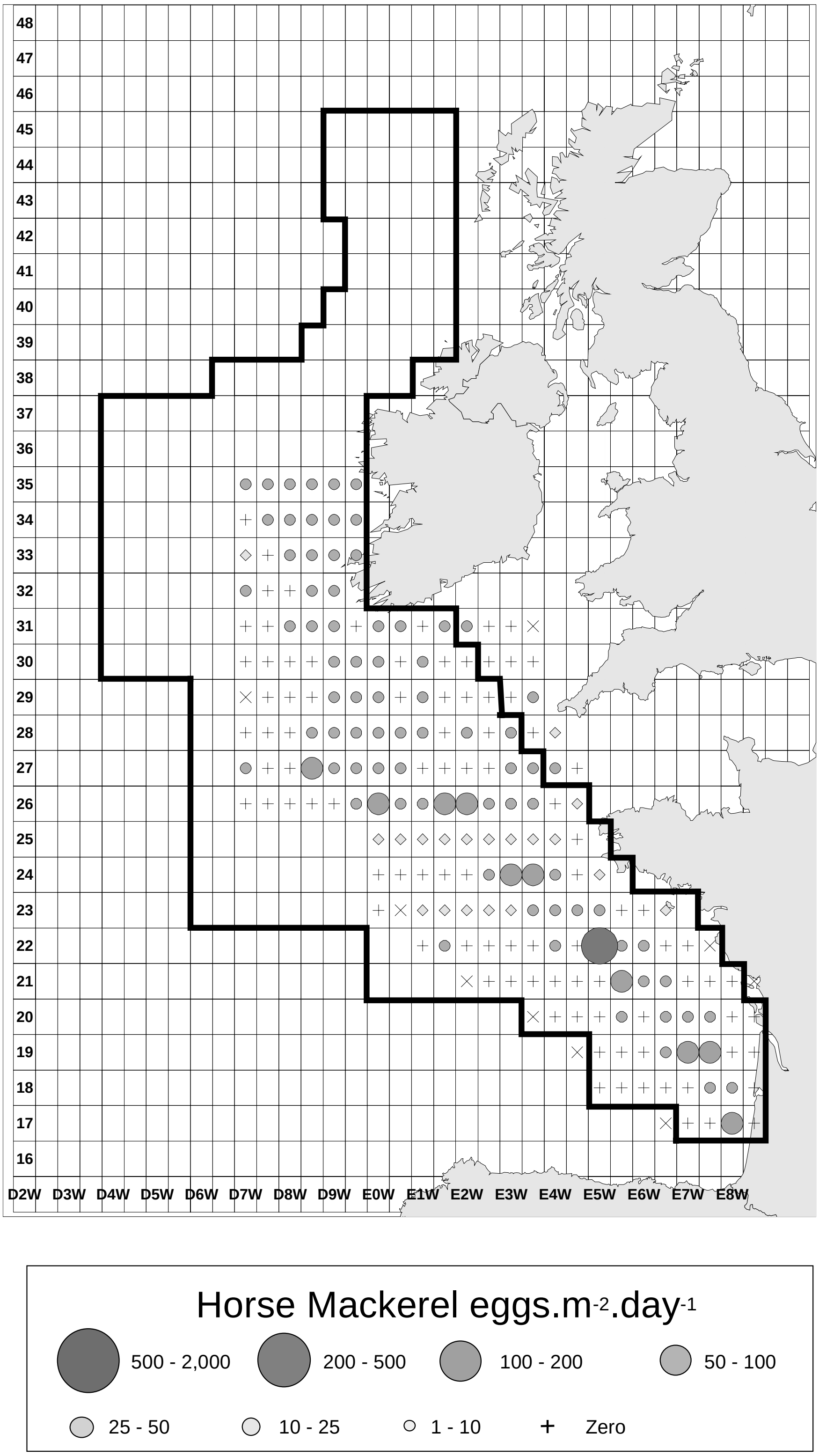


Figure 6.1.1a Horse mackerel egg production by rectangle for period 3 (15th March to the 6th April). Diamonds represent interpolated data, x represents interpolated zeroes.

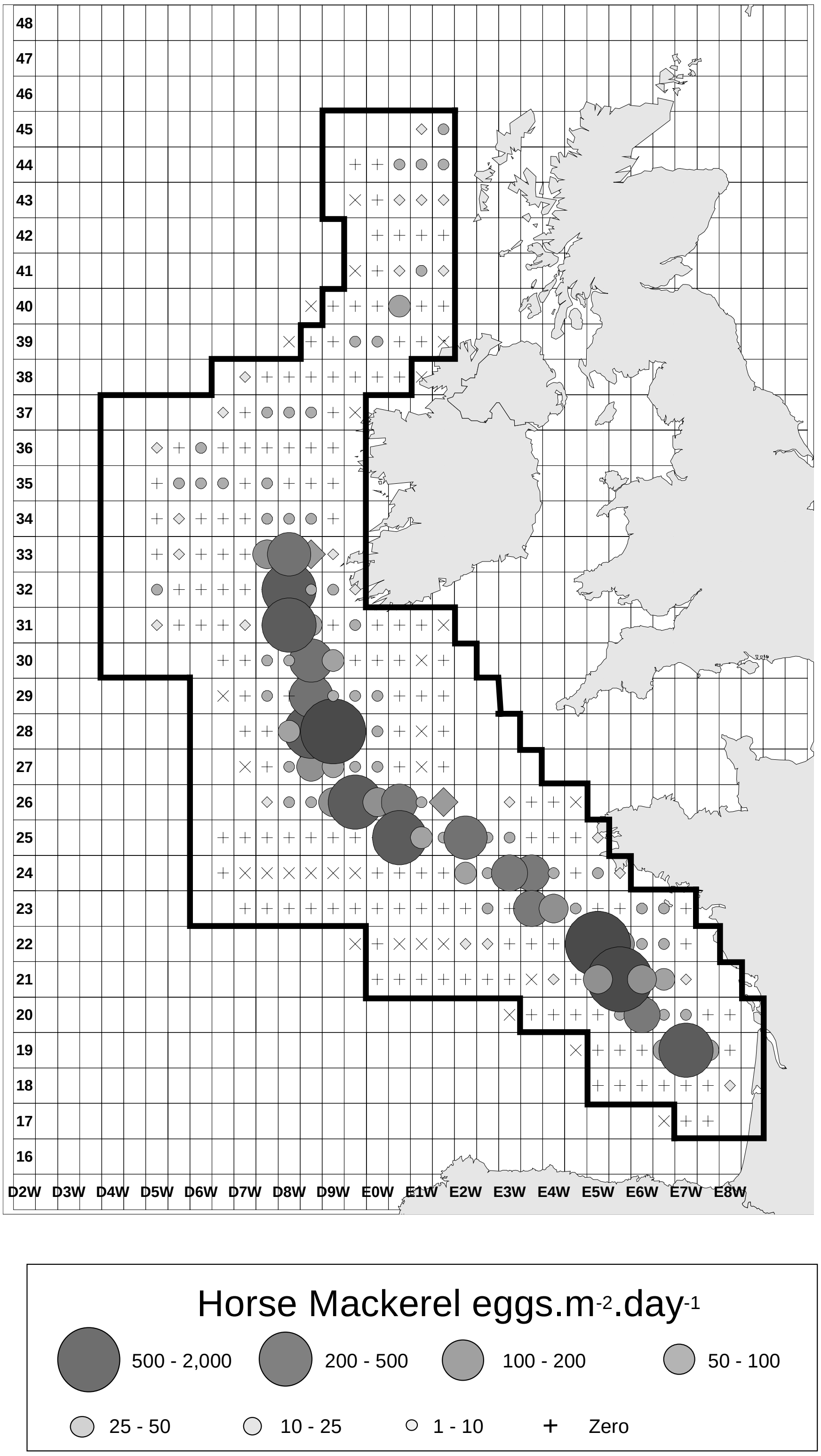


Figure 6.1.1b Horse mackerel egg production by rectangle for period 4 (16th April to the 15th May). Diamonds represent interpolated data, x represents interpolated zeroes.

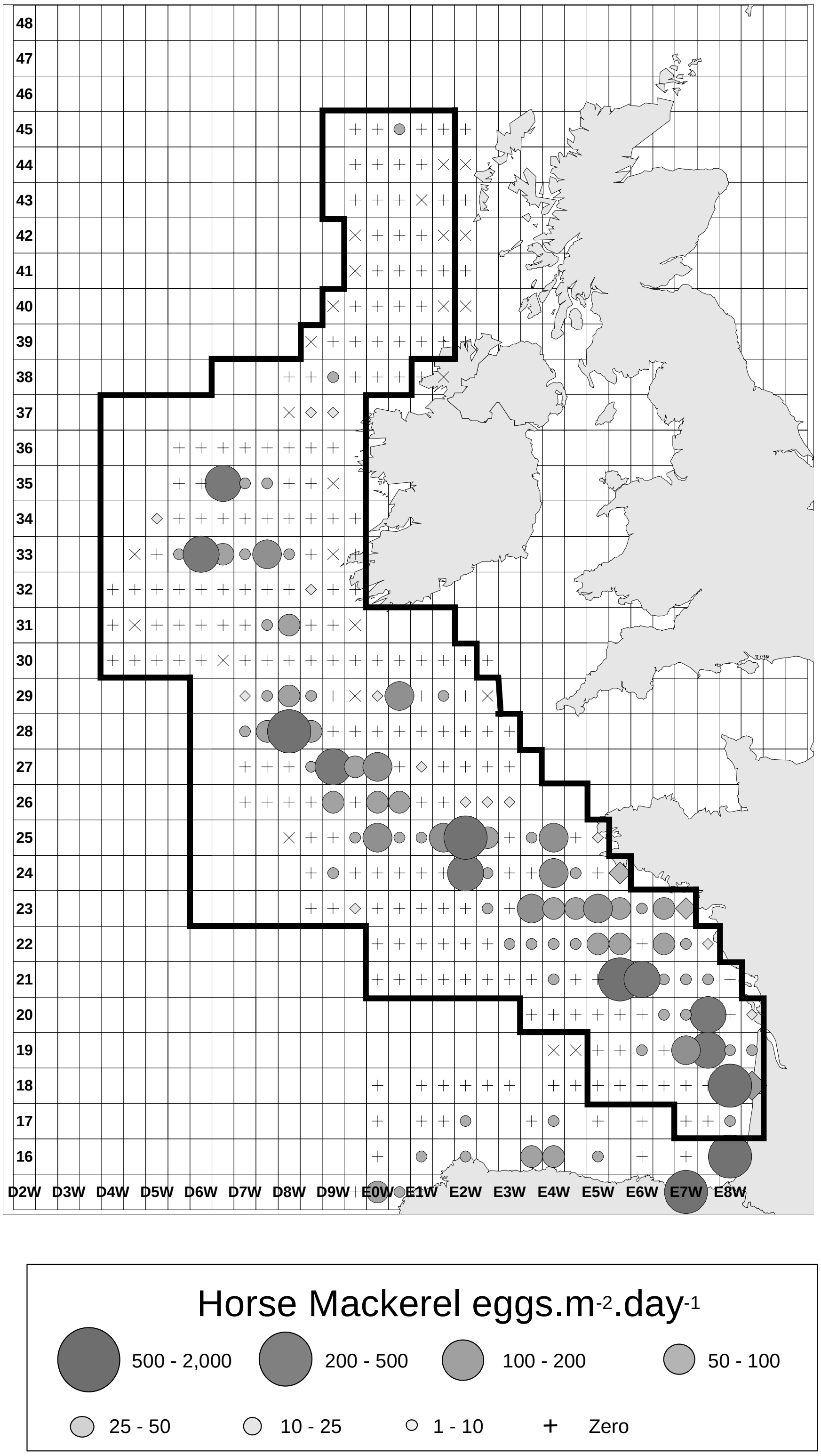


Figure 6.1.1c Horse mackerel egg production by rectangle for period 5 (16th May to the 13th June). Diamonds represent interpolated data, x represents interpolated zeroes.

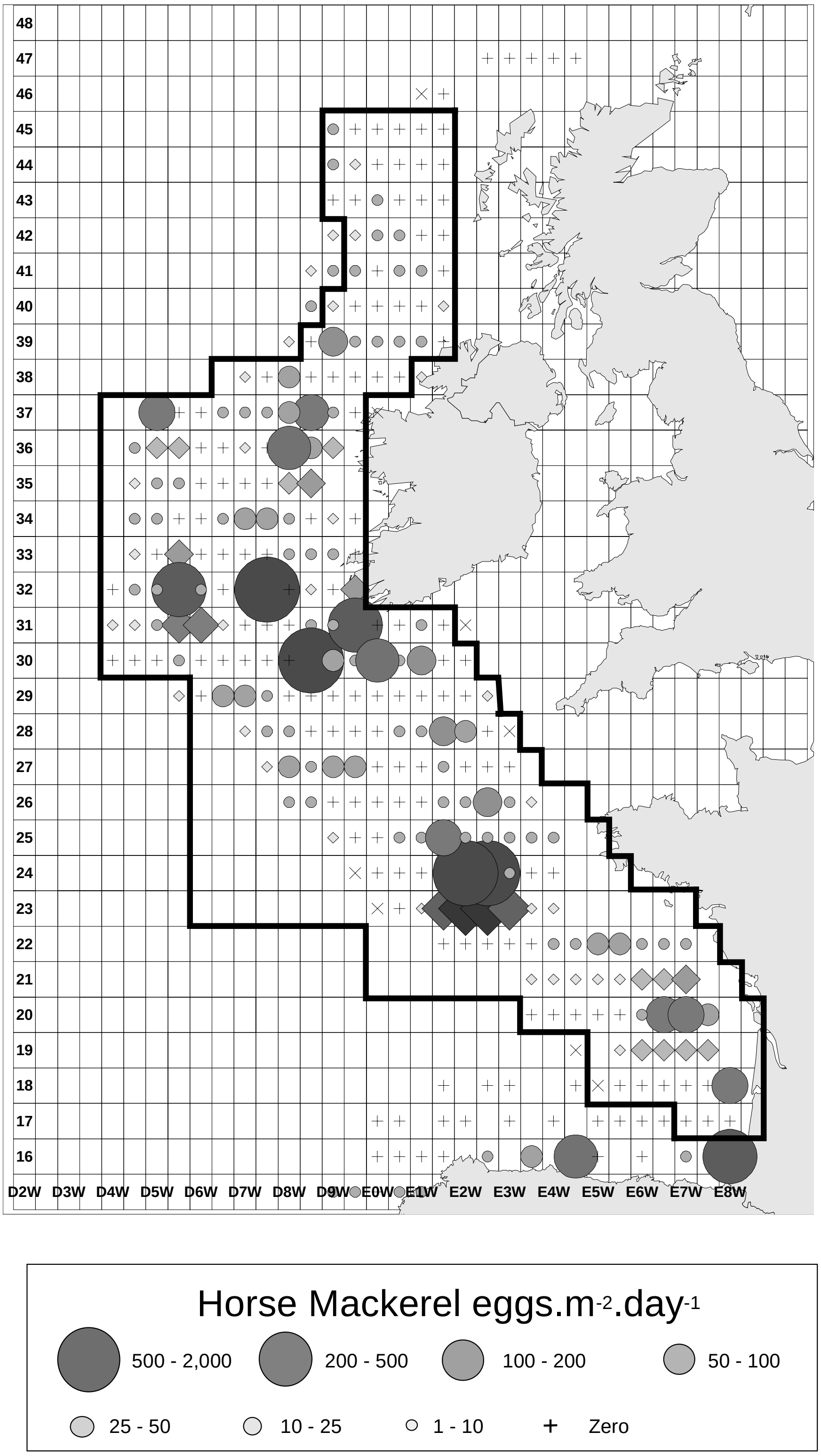


Figure 6.1.1d Horse mackerel egg production by rectangle for period 6(14th June to the 5th July). Diamonds represent interpolated data, x represents interpolated zeroes.

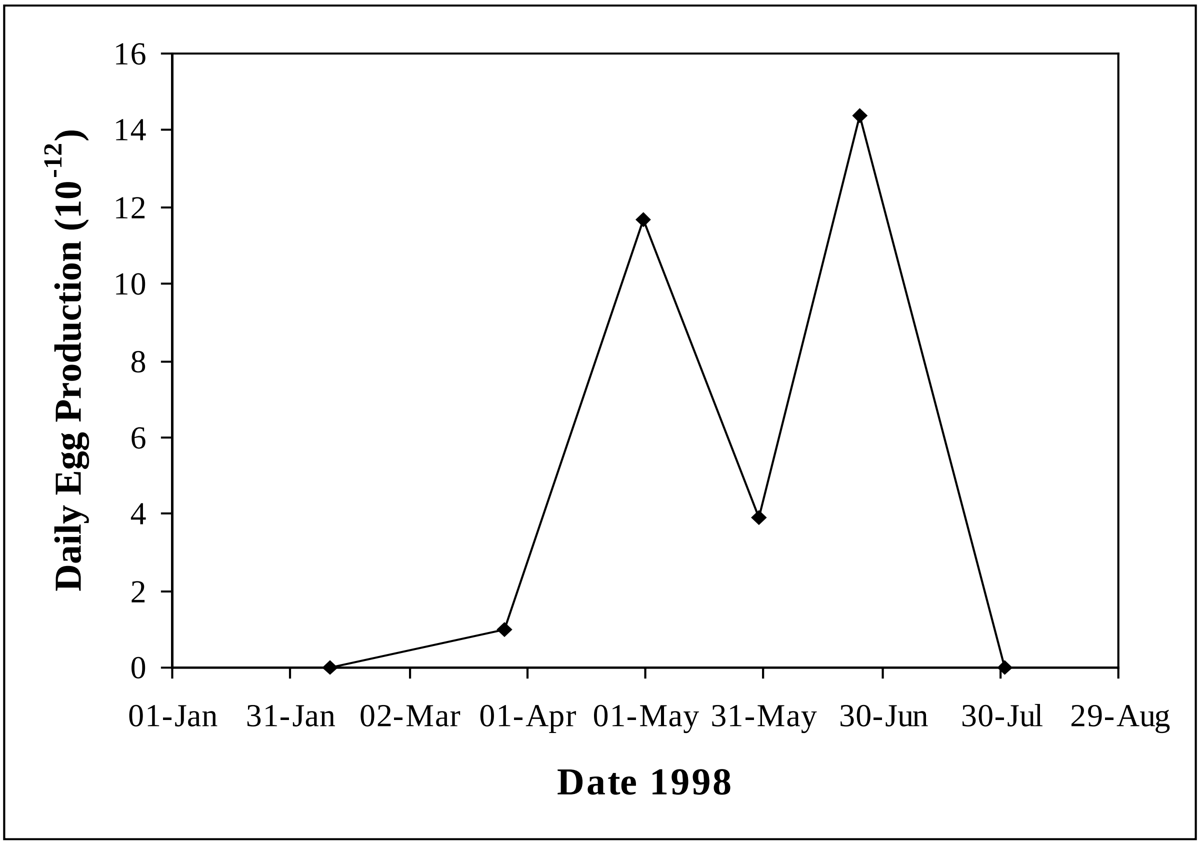


Figure 6.2.1 Horse mackerel daily egg production curve for the surveys in the western spawning area in 1998

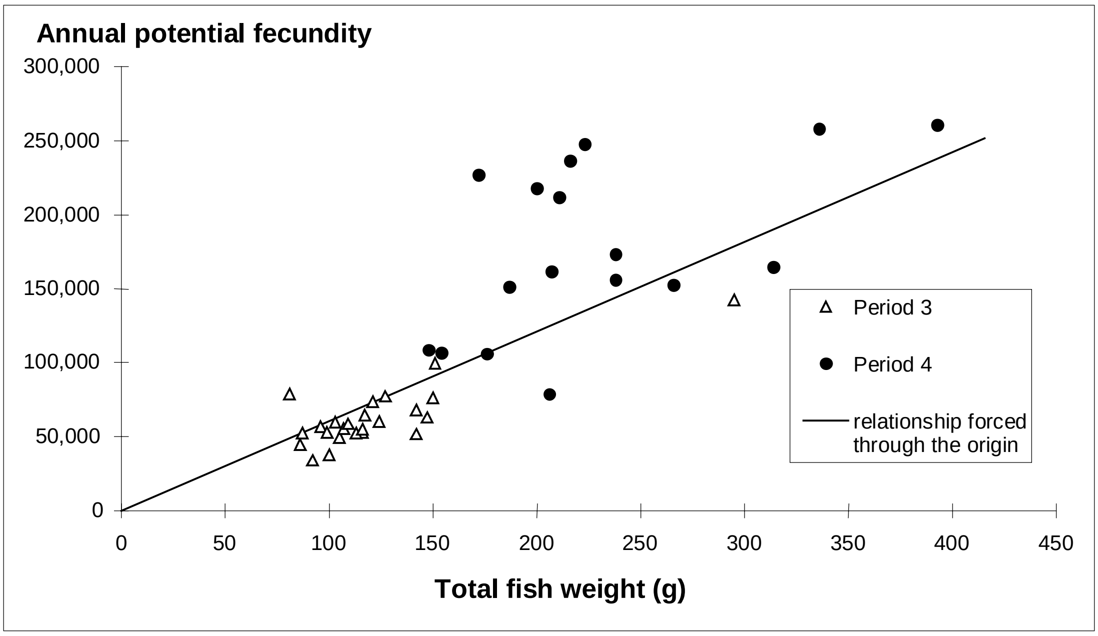


Figure 6.3.1 The relationship between fish weight (g) and annual potential fecundity as estimated from Western horse mackerel collected in survey periods 3 (28 fish) and 4 (17 fish) in 1998.

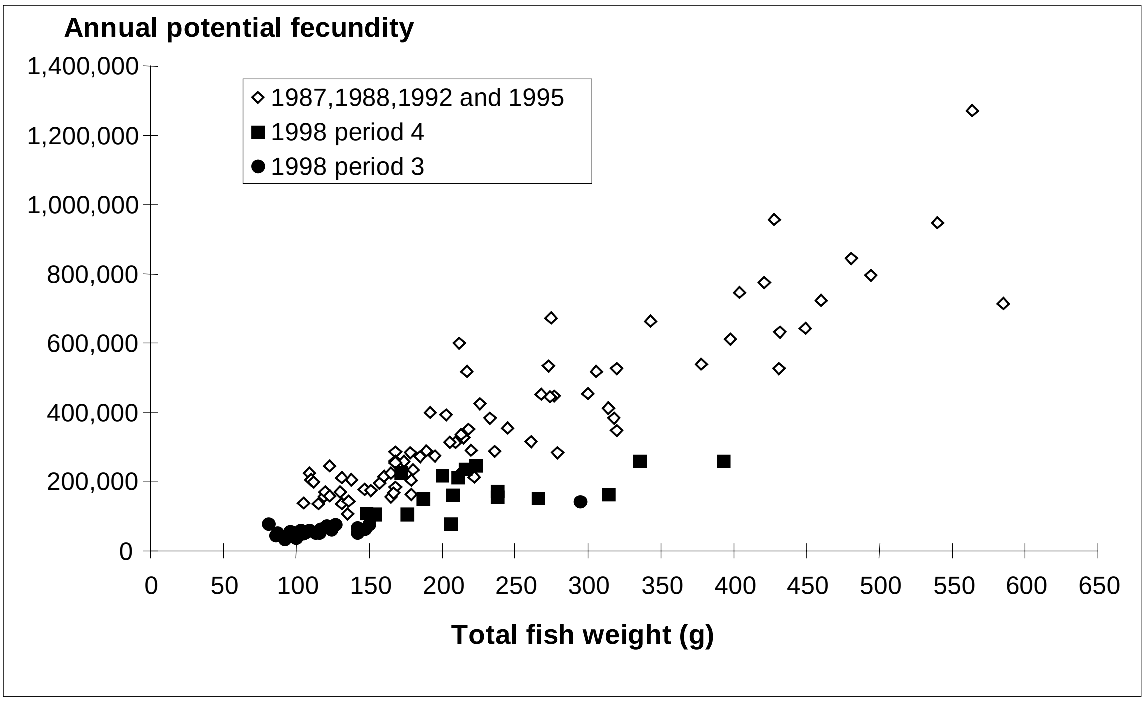


Figure 6.3.2 The relationship between weight (g) and annual potential fecundity as estimated from Western horse mackerel collected in 1987, 1988, 1992 and 1995 compared to fish collected in period 3 and 4 1998.

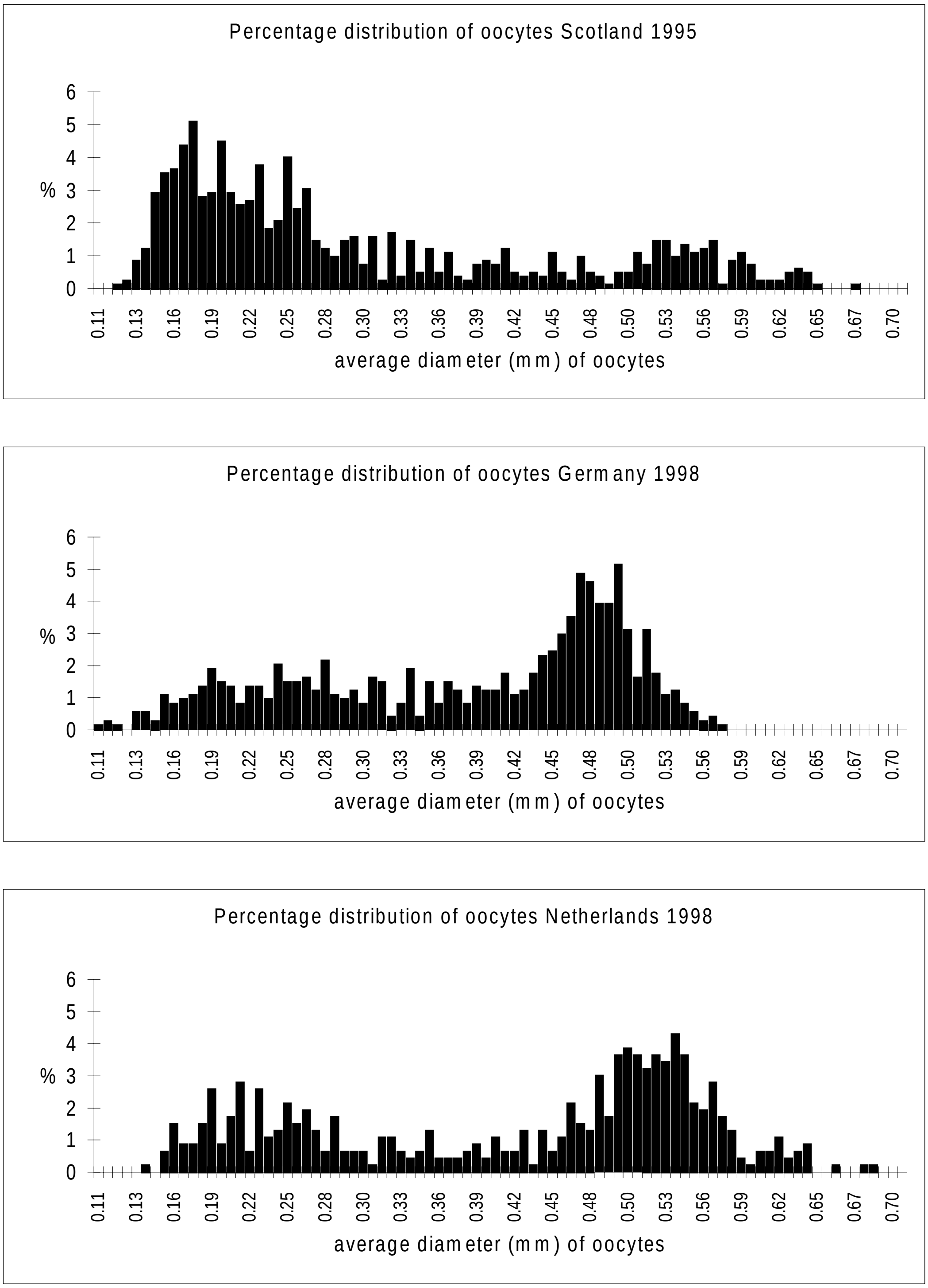


Figure 6.3.3 Comparison of frequencies of the diameter distributions from ovaries collected in 1995 and 1998.

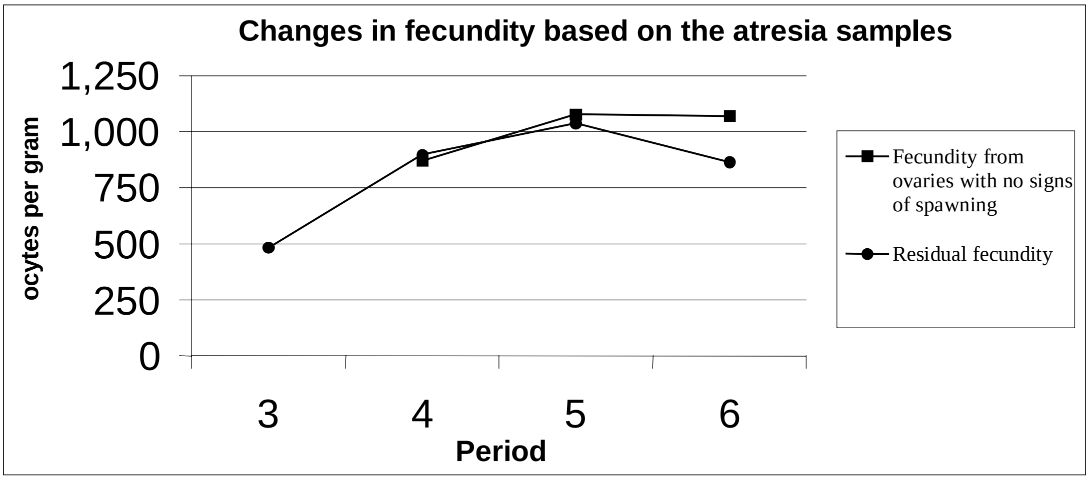


Figure 6.3.4 Changes in residual and potential fecundity as estimated from the atresia samples.

7 SOUTHERN HORSE MACKEREL: 1998 EGG SURVEY RESULTS

7.1 Spatial Distribution of Stage I Eggs of Southern Horse Mackerel

Distribution maps of daily stage I egg production per m^2 surface are given for six survey periods in Figures 7.1a–f. The surveys were co-ordinated over both western and southern areas.

During period 1 only the western Iberian Peninsula was surveyed. Horse mackerel eggs appear along the sampled area in low and patchy abundance. Most of the eggs were found over the continental shelf or over the edge and very few eggs appear beyond the 200 m depth contour line. Higher densities were located to the south of latitude 37º00′N.

In period 2 only the western Iberian Peninsula was sampled (36º00′N–43º00′N) and the data presented in this period are the combination of two Portuguese cruises. To obtain the egg production for period 2, samples from the same rectangles were combined and the arithmetic mean was made to obtain only one production value for each rectangle.

Horse mackerel egg abundance during period 2 marks the peak spawning in the Portuguese area. The egg distribution appeared throughout the area, with a very localised patch of very high egg abundance concentrated around 41º00′N. The abundance obtained in those two rectangles had values over 6,000 egg/m^2/day and they are surrounded to the west and east by rectangles with 0 values. These values represent the maximum abundance of horse mackerel eggs found over all the spawning season in the southern area.

During period 3 only the area to the north of the Iberian Peninsula was sampled and following the recommendation of the planning group the survey was carried out earlier than in 1995. Therefore the sampling did not cover all the main spawning area, because the western Iberian shelf was missed. There was a very high production of eggs in this area in the previous period.

Horse mackerel egg distribution is similar to that of mackerel and eggs were found all along the continental shelf and confined to the coast but with much lower abundance. The low abundance in this area agrees with the spawning behaviour, which is longer but peak spawning is smoother and continues later than mackerel.

In period 4 only the area to the north of the Iberian Peninsula was sampled. Horse mackerel egg abundance suggests the peak of spawning in the Cantabrian Sea occurs in this period. The egg abundance was lower than that found for mackerel, but the egg distribution was very similar for both species. The eggs appeared very close to the coast with a patch of high density eggs located in the Western part of the Cantabrian Sea. No eggs were found in the offshore stations.

During period 5 the area to the north of the Iberian Peninsula was sampled. Although a similar pattern of distribution to period 4 was observed, there was a significant reduction in horse mackerel egg abundance.

In period 6 the coverage area was the same as the previous period. Horse mackerel eggs were still evident in the area, and even a little increase in abundance was observed, mainly in the inner corner of the Bay of Biscay.

7.2 Stage I Egg Production of Southern Horse Mackerel

The mean daily egg production estimated for each individual period is given in Table 7.2.1.

The start date of spawning for horse mackerel was taken as 17 January, earlier than the start date assumed in previous years. It is based on the eggs found in the Portuguese coast during period 1 where a few horse mackerel in stage II occurred on 17 of January.

The end date of the spawning was assumed to be the 17 July (in 1995 the same date was used), based on the fact that some horse mackerel eggs in stage I appeared in the monthly ichthyoplankton sampling carried out in July along the coast off Santander.

Total egg production values for the individual time periods and interpolated periods are given in Table 7.2.2. The daily egg production estimates for each survey period were plotted against the mid cruise dates to give the production curve (Figure 7.2.1).

Total egg production for the standard sampling area was estimated by integrating the area under the curve between 17 January and 17 July.

Total egg production for horse mackerel during 1998 and comparison with the egg production in 1995 years are shown in the text table below.

Estimates of the total egg production of southern horse mackerel in 1995 and 1998		
Year	**Annual stage I egg production $*10^{-13}$**	
	estimate	**SE**
1995	17.27	0.79
1998	100.3	80.70
1998 *(excluding the two rectangles with very high egg abundance)*	18.59	7.70

Horse mackerel egg production has increased greatly compared with 1995. This is due to the very high production obtained to the west of the Iberian Peninsula during period 2 (26.59 E^{12} total egg production). This high production off the Portuguese coast shows a big difference with the production values and temporal distribution of horse mackerel found in the Cantabrian Sea, where peak spawning occurs later and with lower densities, although spawning takes place over a longer period.

An alternative estimate of egg production was carried out to estimate the impact of the two rectangles with the very high egg abundance in period 2 on the total egg production estimate. The egg abundance of these two rectangles was replaced by an average of the adjacent rectangles. This resulted in a total egg production estimate of 18,59 $*10^{13}$ (CV 41 %), which is a reduction of 82 % compared to the original calculated egg production.

As for mackerel, horse mackerel eggs show a more coastal distribution pattern in the Cantabrian Sea during 1998 than in previous years.

The coefficient of variation (c.v.) of the total egg production (80,4 %) is very high, mainly due to the high standard error (s.e.) in period 2 when the peak of spawning occurred on the Western Iberian shelf. However, the variance in period 3 and 4 did not change so much in spite of the adaptive sampling strategy. This could be due to the fact that the spawning season of horse mackerel is longer in time and the peak is smoother with lower densities. Therefore the lapse of two weeks between consecutive transects will produce less influence in the temporal variance.

7.3 Potential fecundity and atresia of Southern Horse Mackerel

To estimate potential fecundity in 1998, a total of 123 horse mackerel ovaries were collected by IEO in Divisions VIIIc and IXa North, and 361 were collected by IPIMAR in Divisions IXa Centre-South and IXa South (Tables 7.3.1a and b) all in late pre-spawning condition. The samples were taken according to the recommendation of the Working Group on Mackerel and Horse mackerel Egg Surveys (ICES, 1997). The analysis performed by IEO followed the histometric method described in Eltink and Vingerhoed (1989) and Emerson *et al*. (1990), while in IPIMAR the method described by Laird and Priede (1986) was used.

Weight of individual fish and ovary was recorded with a precision of 0.1g prior to preservation, and the volume of the ovaries were determined by water displacement for the IPIMAR samples. Otoliths were also removed for ageing. After rejecting the damaged ovaries, 103 slides were prepared by IEO and 361 by IPIMAR. From these, only 53 ovaries from IEO and 29 from IPIMAR were found histologically in real late pre-spawning stage, with length ranges 25–38 cm (IEO) and 20–28 cm (IPIMAR). Tables 7.3.2a,b show the total numbers of oocytes counted. These ovaries showed no signs of spawning activity and were used to determine the potential annual fecundity by raising the counts of vitellogenic oocytes to the total volume of the ovary. In the samples from IEO there were 11 ovaries with atresia, 4 ovaries had alpha and beta atresia, 1 beta gamma and 6 the gamma atresia or later.

The regression of fecundity against the weight for the IEO data was forced through the origin and weighted to the inverse of the weight of the fish (Fig. 7.3.1). The correlation coefficient was 0.97 and the total fecundity was estimated using the mean weight: 265 g, which corresponds to a total potential fecundity of 330,620 vitellogenic oocytes. The fecundity was 1247 eggs/g, with a standard error of 26 and a coefficient of variation of 2.1 %. This fecundity is lower than the one estimated in 1995 (1572 eggs) (ICES, 1996a). More research is needed to find an explanation for this decrease, although some of the possible causes could be the same as those discussed in Section 6.3. An estimate of the potential fecundity with IPIMAR data was not obtained, given that the analysis of the slides was made with a method different from the one used by the other WG members. **It is recommended that an exchange of samples for assessing the coherence of results is carried out. This sample exchange was recommended previously (ICES CM 1996/H:2) but has never been carried out.**

Atresia and realised fecundity of Southern horse mackerel

For the calculation of prevalence and relative intensity of atresia fish must be in spawning condition, thus at least one of these following stages has to be present in the ovaries: post-ovulatory follicules, hydrated oocytes or migratory oocyte stage.

To estimate the atresia by the histometric method a random sample of 210 horse mackerel ovaries were collected by IEO during the third and fourth periods. The ovaries were processed using glycol-methacrylate and two cuts were made in each ovary. 38 of the slides observed were selected for estimation. Only 11 ovaries belonging to the third period were in spawning condition. The mean weight was 152 g. The residual number of vitellogenic oocytes, in a total of 161269 residual fecundity, are in Table 7.3.3a. The number of atretic oocytes per female was 28 oocytes/g in the sample and 13 atretic oocytes/g in the population. The prevalence was 0.45 and the residual fecundity 1061 eggs/g., that represented the 85 % of the potential fecundity in period 3 (Table 7.3.4). In the fifth period 90 ovaries were collected by the Netherlands, but have not been analysed.

The number of atretic eggs per gram female produced during the spawning season was estimated by IPIMAR as described in ICES (1996b). The mean number of atretic oocytes was estimated in 16161 for period 1 (determined from the observation of 18 ovaries from fish between 20 and 30 cm length), 4478 for period 2 (2 females with 20 cm length) and 17403 eggs for period 3 (18 fish from length groups 23 to 29 cm). Prevalence of atresia, number of atretic oocytes per gramme female in the population, relative intensity and the proportion of residual fecundity compared to total fecundity are shown in Table 7.3.3b. Atresia per gramme female was estimated as 68.88 eggs/gramme and the fecundity corrected for atresia was estimated as 247 eggs per gram female.

Because of the differences in the potential fecundity estimates from the IEO and IPIMAR a final fecundity estimate is not provided. The Working Group recommends that an exchange of slides and a comparison of results between methods should be made in time to provide fecundity estimates to the Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy.

7.4 Biomass Estimate of Southern Horse Mackerel

The spawning biomass of the southern horse mackerel was not calculated due to problems in the fecundity estimation as explained above (Section 7.3). Furthermore uncertainties exist concerning the extremely high egg production estimate during the period 2 (see Section 7.2). This unusual egg production estimate originates from the high abundance of eggs observed in only two rectangles located between the 40ºN and 42ºN. If the values of these rectangles are changed by a mean value obtained from the adjacent rectangles, then the egg production estimate would be 18.59 x 10^{-13}, which would reduce the biomass estimation by 81.5 %.

7.5 Southern Horse Mackerel Maturity

Samples for maturity estimation were collected, but have not been processed. **This Working Group recommends that a maturity at age estimation should be available in September 1999 for the Working Group on the assessment of Mackerel, Horse Mackerel, Sardine and Anchovy.**

Table 7.2.1 Southern spawning component of horse mackerel mean daily stage I egg production in 1998 (x 10^{12})

Period	**Dates**			**Production and standard errors**	
	From	**To**	**Midpoint**	**Horse mackerel**	
				Production	**SE**
1	17 January	31 January	24/01	0.92	0.43
2	7 February	1March	18/02	26.59	25.11
3	14 March	1 April	23/03	0.89	0.14
4	13 April	27 April	20/04	2.42	1.84
5	15 May	24 May	19-20/05	0.59	0.42
6	15 June	21 June	18/06	1.50	1.19

Table 7.2.2 Southern spawning component of horse mackerel total stage I egg production estimates by time period for 1998 (x 10^{-13})

Dates	**Period**	**No of days**	**Annual stage I egg production x 10^{-13}**
			Horse mackerel
17 January – 31 January	1	15	1,38
1 February – 6 February	*	6	7,01
7 February – 1 March	2	23	61,11
1 March – 13 March	*	12	15,54
14 March – 1 April	3	19	1,69
2 April – 12 April	*	11	1,88
13 April – 27 April	4	15	3,63
28 April – 14 May	*	17	2,49
15 May –24 May	5	10	0,59
25 May – 14 June	*	21	2,22
15 June – 21 June	6	7	1,05
22 June - 17 July	*	26	1,71
	Total	182	100,3
	SE		80,70
	CV		0,80

Table 7.3.1a Horse mackerel collected to estimate the total annual fecundity and atresia in 1998.

Period	Country	Vessel	Cruise data	Area coverage	
3	Spain (IEO)	*Thalassa*	17/03–30/03	42°38–43°54′N	9°20–3°45′W
3 3–4	Spain (IEO) Spain (IEO)	*Cornide Saavedra* *Cornide Saavedra*	07/02–15/02 21/02–01/03	43°00–45°00′N 42°00–44°30′N	1°00–11°00′W 1°00–10°00′W
5	Netherlands (RIVO)	*Tridens*	11/05–29/05	43°50′N	5°30′W

Table 7.3.1b Horse mackerel ovaries collected for the estimation of total fecundity and atresia in the Southern area.

Period	Cruise dates	Sampling day	ICES Division/ rectangle	Position		Number of females collected	Number of females processed
				Lat. N	Long. W		
1	16 Jan. – 1 Feb.	18 jan.(1) 18 jan.(2) 20 jan.(3)	IXa/2E2 IXa/2E1 IXa/4E0	36° 55′ 36° 50′ 37° 51′	07° 24′ 08° 13′ 09° 04′	50 131 20	19 131 12
2	9–16 Feb.	10 Feb.(4)	IXa/5E0	38° 37′	09° 29′	58	53
3	21 Feb. – 3 Mar.	25 Feb.(5)	IXa/2E0	36° 52′	08° 43′	101	93
Total						360	308

Table 7.3.2a The total annual potential fecundity of horse mackerel collected in ICES Division VIIIc and IXa North in Period 3.

	Length (cm)	Fish weight (g)	Annual potencial fecundity vitell. Oocytes	SE fecundity	Number of Atretic oocytes	SE atresia
	25	131	230937	10973		
	26	145	159225	2056		
	27	157	201344	4731		
	28	167	264014	12611	14510	9275
	27	167	201344	4731		
	27	167	235696	8959		
	28	171	232910	8912		
	29	191	275696	10623		
	29	194	268775	6647	12384	861
	30	204	208431	8065		
	30	210	354657	16132		
	30	221	232476	25226	13566	5710
	31	221	246119	20646		
	29	223	224785	15422		
	31	227	271681	9530		
	32	233	304807	32957		
	31	245	301094	13730		
	32	247	261726	5916		
	32	257	321282	11073	17580	5828
	32	260	363611	16626	22713	8761
	32	260	333905	19510		
	34	266	347397	12314		
	32	267	274201	18712		
	32	270	412562	26119		
	32	270	401429	13370		
	32	275	242525	15782		
	33	275	322490	8459		
	33	280	423733	20053		
	34	280	332628	6247		
	34	281	368909	23326	11453	2891
	33	281	351468	4086		
	33	286	387028	15143		
	33	286	418695	44191		
	33	288	455114	29451		
	34	289	304936	7811	40899	6387
	34	291	393834	21768		
	34	291	415881	17708	13544	6637
	34	293	329441	68241		
	34	317	467737	61176		
	35	296	344295	39686		
	35	299	400880	20483		
	35	301	300411	15741		
	35	315	341889	17438		
	36	338	370745	18293	36645	14010
	36	339	381835	21335	19316	4751
	35	340	348151	4260		
	35	354	493084	11148	57119	12425
	35	365	480850	16544		
	36	368	372690	11240		
	36	396	431358	24927	23813	11543
	38	423	450894	7896		
AM	32	265	330620		23628	

Table 7.3.2b Fecundity estimates from Portuguese sampling (Jan. / Feb.1998).

Fish number	Length (cm)	Weight (g)	Total fecund. (vitell. ooc)
1	20.2	61	8511
2	20.3	63	15868
3	20.4	61	14537
4	20.5	62	24468
5	20.6	65	12956
6	20.9	62	11797
7	20.9	65	18898
8	21.4	62	15638
9	22.2	85	31269
10	22.9	92	39640
11	23.1	110	86145
12	23.3	100	35623
13	23.8	99	46259
14	23.9	107	32006
15	24.2	94	21057
16	24.3	103	27565
17	24.5	110	52138
18	24.7	116	37591
19	25.2	108	38288
20	25.4	114	20528
21	26.3	128	41860
22	26.3	146	62264
23	26.6	136	24387
24	26.9	131	43821
25	27.0	117	15587
26	27.3	130	47917
27	27.7	162	67654
28	27.9	145	27096
29	28.1	150	19077
Average	24.0	102.9	32429.1

Corrected fecundity = F_{TW} – A
Corrected fecundity = 316.77 – 68.88
Corrected fecundity = 247 $_{\text{OVOS}}$/g

Table 7.3.3.a Horse mackerel: The length, weight, residual fecundity and the number of atretic oocytes from period 3 in ICES Division VIIIc and IXa North.

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
24	104	130767	5206	2197	917	21
24	93	145947	4100			
24	104	150739	8911	11166	4150	108
25	125	46468	6505			
26	129	125842	3266			
26	155	266780	18364			
27	99	108800	1969	1391	625	14
28	156	88597	11144	2764	1513	18
30	157	391598	6034			
32	275	115256	2185	8506	6805	31
32	271	203170	8566			
27	152	161269	GM	3809		28

Table 7.3.3b Atresia estimates from Portuguese sampling (Jan./ Feb. 1998)

Fish number	Length (cm)	Weight (g)	Number of atret. ooc.	i / w
1	20.5	67	8475	126.49254
2	20.8	66	5450	82.575758
3	20.9	62	3506	56.548387
4	23.6	85	23353	274.74118
5	23.7	107	13864	129.57009
6	24.0	110	9780	88.909091
7	24.2	98	8287	84.561224
8	24.3	99	8072	81.535354
9	24.3	117	15337	131.08547
10	24.2	103	16372	158.95146
11	24.5	97	5564	57.360825
12	24.5	104	6704	64.461538
13	24.5	104	11866	114.09615
14	24.5	108	12646	117.09259
15	24.7	116	23482	202.43103
16	25.0	123	34286	278.74797
17	25.1	112	13522	120.73214
18	25.4	107	10714	100.13084
19	25.4	109	7389	67.788991
20	25.4	114	25287	221.81579
21	25.5	120	20462	170.51667
22	25.6	111	21324	192.10811
23	25.6	114	22785	199.86842
24	25.6	120	33628	280.23333
25	25.7	131	17742	135.43511
26	26.0	120	21241	177.00833
27	26.0	122	13776	112.91803
28	26.1	119	9224	77.512605
29	26.4	123	26921	218.86992
30	26.5	137	14762	107.75182
31	26.7	130	39053	300.40769
32	27.8	131	25926	197.9084
33	28.0	155	13473	86.922581
34	28.3	146	10741	73.568493
35	28.9	194	16703	86.097938
36	29.2	155	7261	46.845161
37	29.9	174	23894	137.32184
38	30.5	219	10236	46.739726
Average	25.5	119.2	16134.4	137.0
Geomean			11247.9	120.55419

Atresia/g = GM (i/w) p (s/d)   Atresia/g = 68.88

GM = geometric mean
i = intensity (nr. of atretic oocytes in each female)
w = total fish weight in grams
p = prevalence of atresia (% of females with atresia)
s = spawning duration (70 days)
d = duration of the atresia stage (15 days)

Table 7.3.4 The number of atretic oocytes per gramme female horse mackerel (NM Fop's Hydrated oocytes) in the population during Period 3 in ICES Division VIIIc and IXa North (Spain). The proportion of remaining fecundity compared to total 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	Relative intensity of atresia %	Proportion of remaining fecundity compared to total fecundity
3	0.45	11	28	11	13	2.0	0.85

Survey period	Average weight	Remaining fecundity	nº atretic oocytes	Females with atresia	nº of females used to count atretic. oocytes	nº females sampled	Fecundity oocytes / g female	Total fecundity eggs / gramme female
3	152	161269	3809	5	11	11	1061	1247

Predicted fecundity	189544
Remaining fecundity	161269

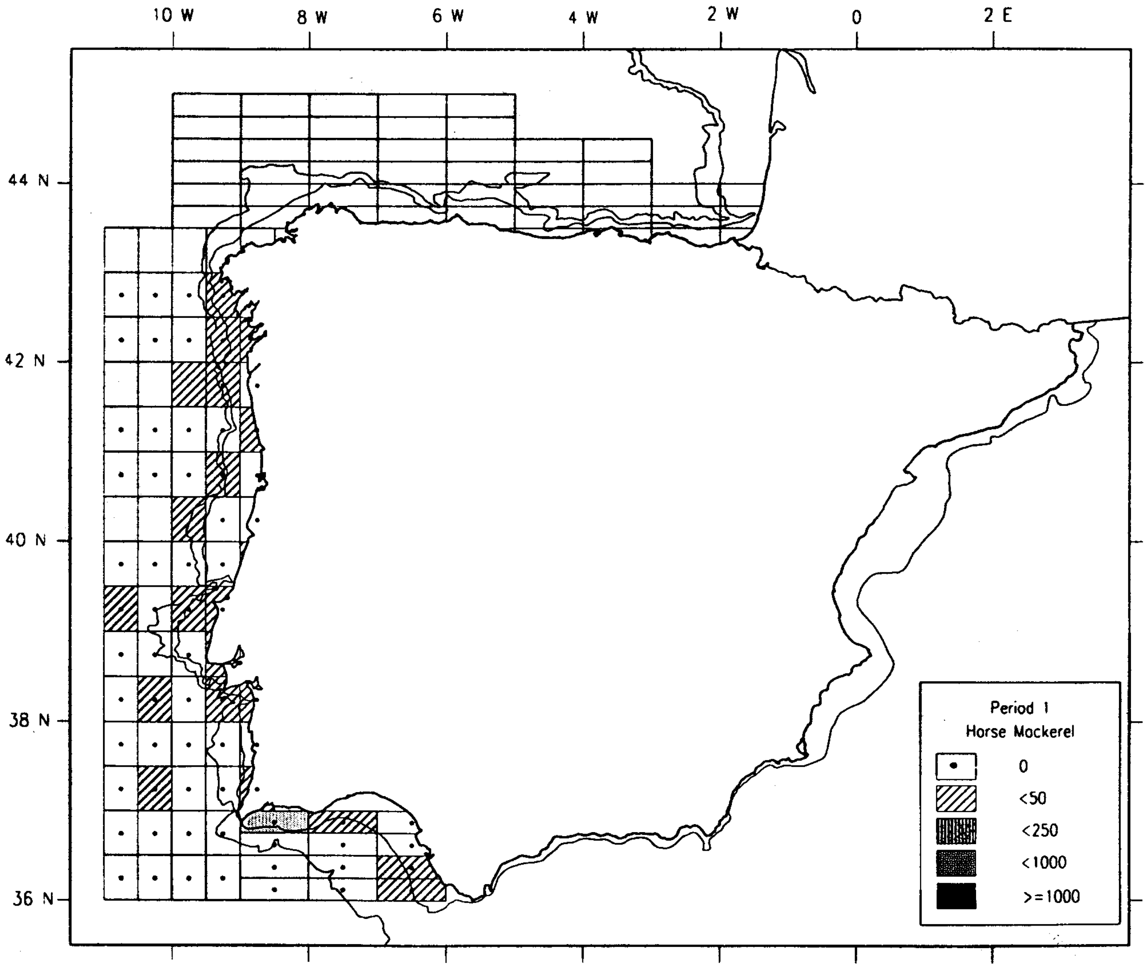


Figure 7.1a. Horse mackerel egg production by rectangle for period 1 (17 to 31 January).

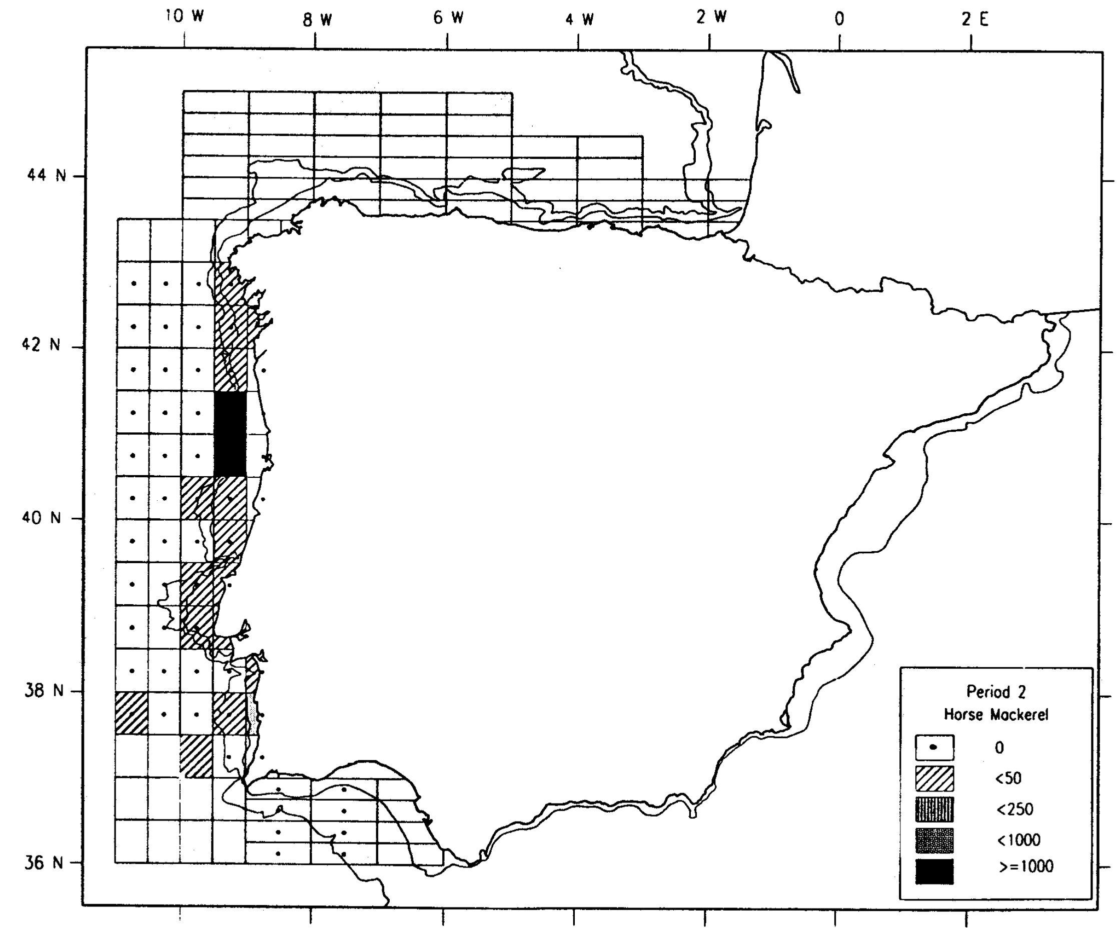


Figure 7.1b. Horse mackerel egg production by rectangle for period 2 (7 February to 1 March).

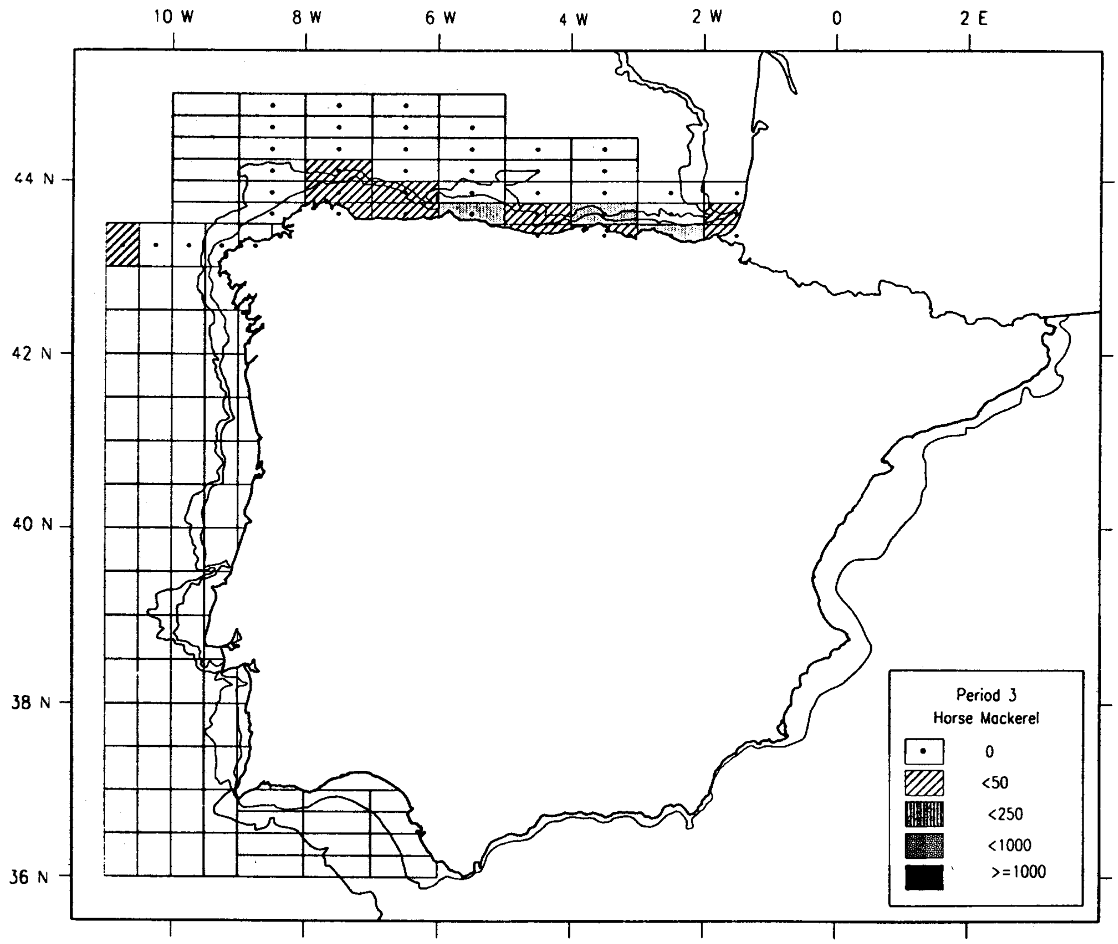


Figure 7.1c. Horse mackerel egg production by rectangle for period 3 (14 March to 1 April).

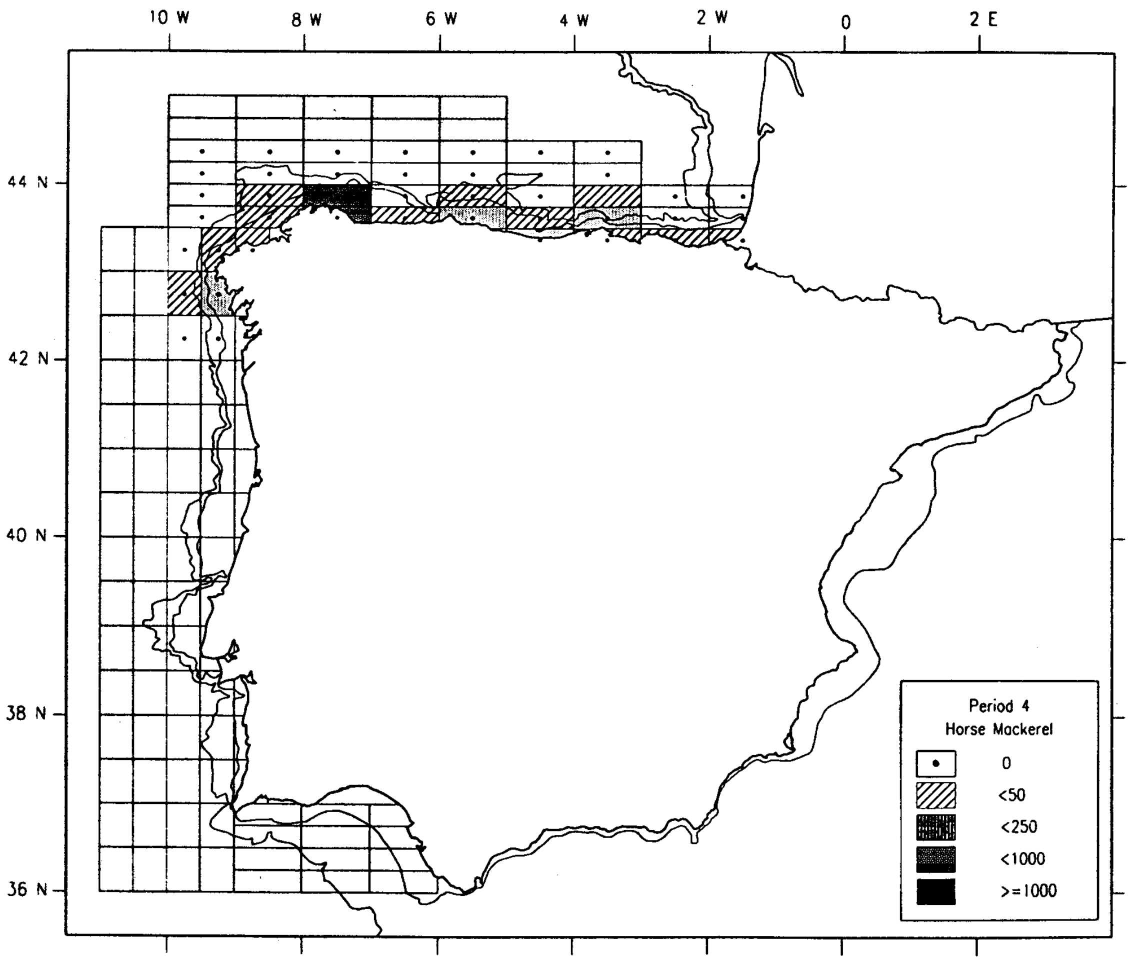


Figure 7.1d. Horse mackerel egg production by rectangle for period 4 (13 to 27 April).

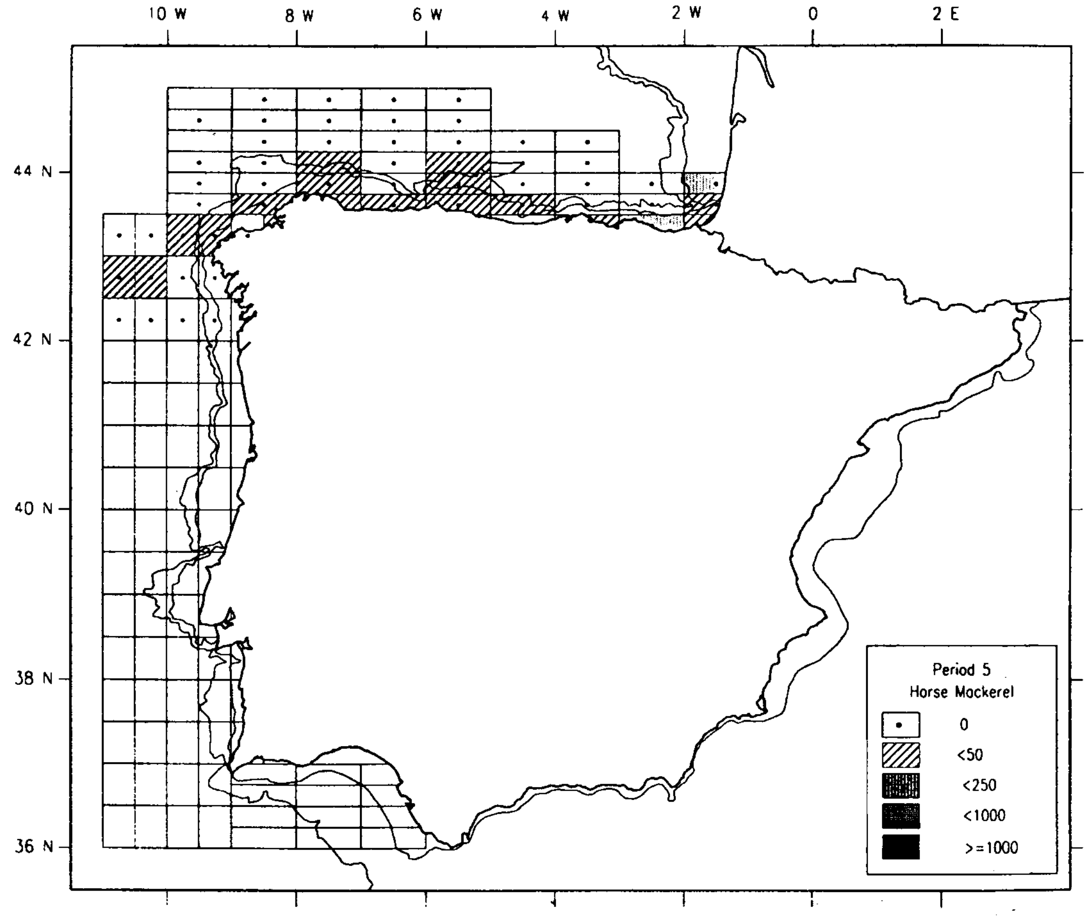


Figure 7.1e. Horse mackerel egg production by rectangle for period 5 (15 to 24 May).

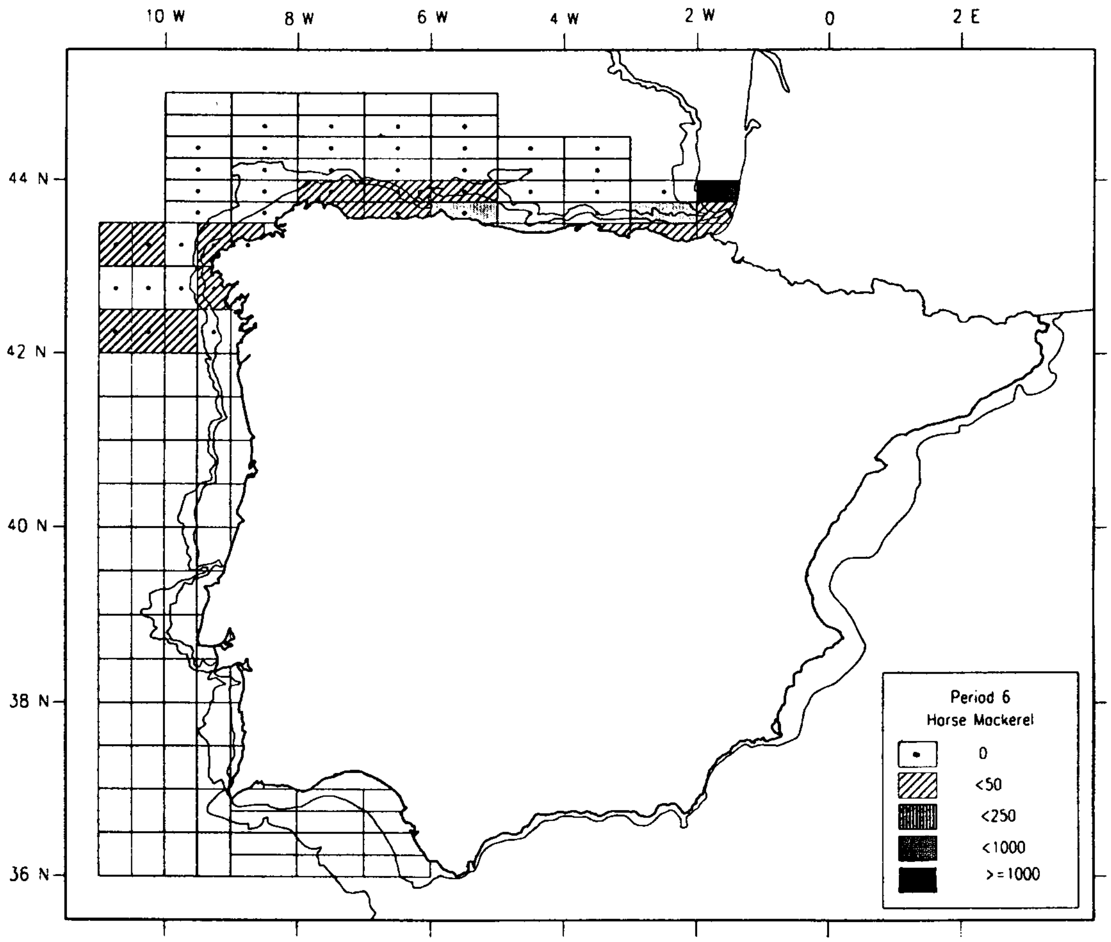


Figure 7.1f. Horse mackerel egg production by rectangle for period 6 (15 to 21 June).

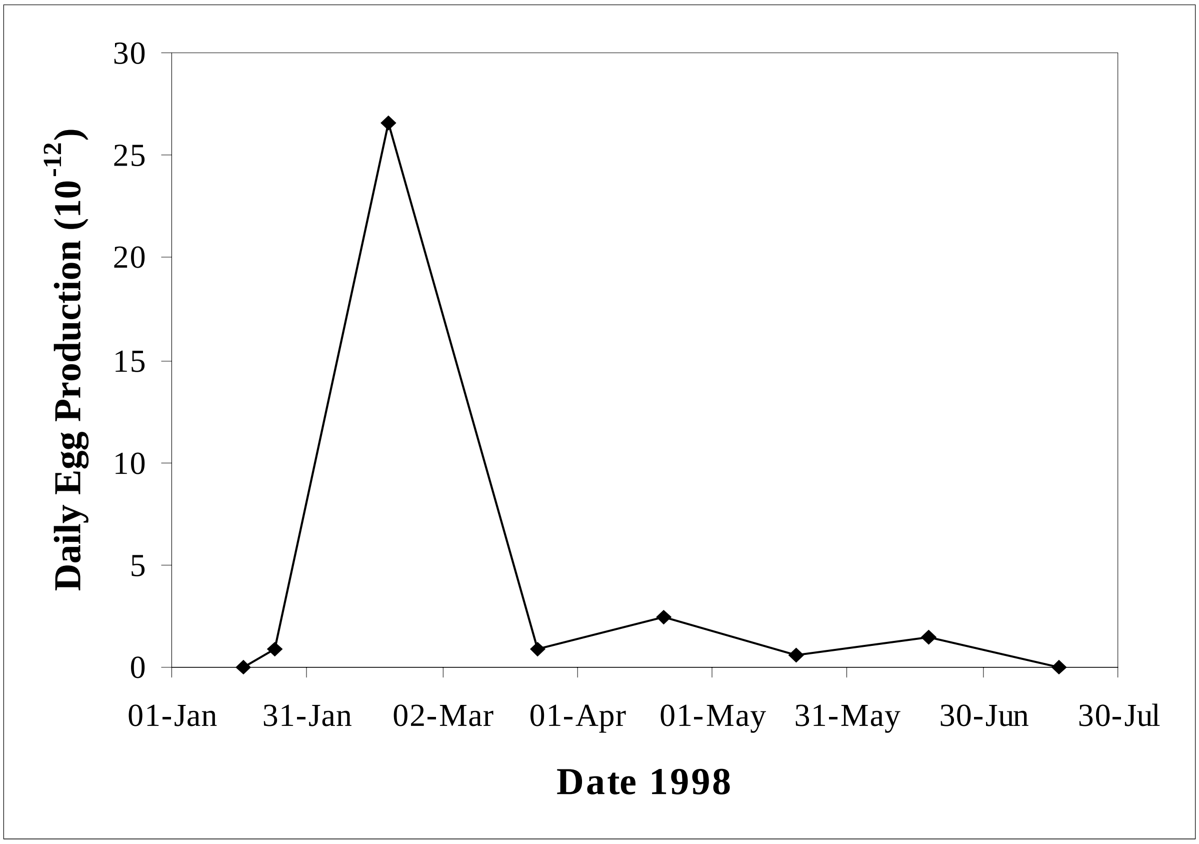


Figure 7.2.1 Horse mackerel daily egg production curve for the surveys in the southern spawning area in 1998. The curve was produced assuming start and finish dates of 17 January and 17 July respectively.

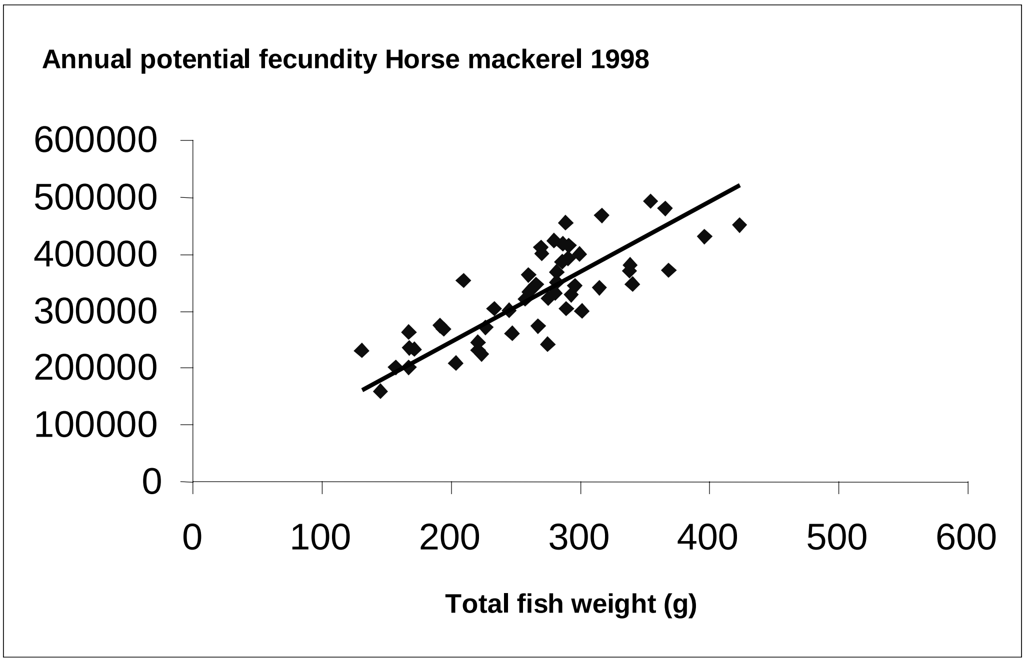


Figure 7.3.1 The relationship between weight and potential annual fecundity in southern horse mackerel.

8 GENERALIZED ADDITIVE MODELLING OF EGG PRODUCTION

8.1 Results for Mackerel of the Western Spawning Component

Generalized additive models (GAMs) were described in detail previously (ICES, 1996b).

The 1998 survey data were restricted to observations made from latitudes 44°N northwards (1019 observations). The same constraints in space and time were used to analyse the 1998 survey data as were used before; see Figure 3.6.1a, ICES, 1996b for constraints in space and the start and end dates of spawning were assumed to be 10 February and 31 July, respectively. The explanatory variables used in the GAMs were as follows:

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

The model initially run was that found by Augustin *et al*, 1998. Stage 1 egg density was the response variable and was fitted using a negative binomial distribution and log link function. The egg production curve from this model (Figure 8.1.1) was bi-modal having two peaks at approximately mid-April and end of May.

8.1.1 Comparison with traditional method

The egg production curve from the traditional method showed a single peak at approximately the end of April. This difference is likely to be due to the fact that high egg densities were found during the first survey in March 1998 (see Figure 5.1.1c), leading to some uncertainty about the start date of spawning. The GAM–based total stage 1 egg production estimate is 1.16×10^{15} while that for the traditional method is 1.37×10^{15} (se = 0.21). Considerable effort is still required to investigate distributions other than the negative binomial, the effect of degree of smoothing and the effect of the "structural zeros" on final model selection and ultimately on the estimate of stage 1 egg production and its standard error.

8.2 Results for Western Horse Mackerel

The same constraints in space were applied to the 1998 survey data as were applied previously (see Figure 3.6.1b, ICES, 1996b). The start and end dates were those used for the mackerel. The initial model fitted was the same as for the mackerel. The resulting egg production curve gives a peak at the end of the assumed spawning period which is a consequence of high horse mackerel stage 1 egg densities being found in the final survey in July.

8.2.1 Comparison with traditional method

The stage 1 egg production estimate from the traditional method was 1.00×10^{15} while the GAM-based estimate was much higher. As with the mackerel considerable further modelling is required but it may be that the failure of the surveys to cover the entire horse mackerel spawning period, results in over-estimates of production.

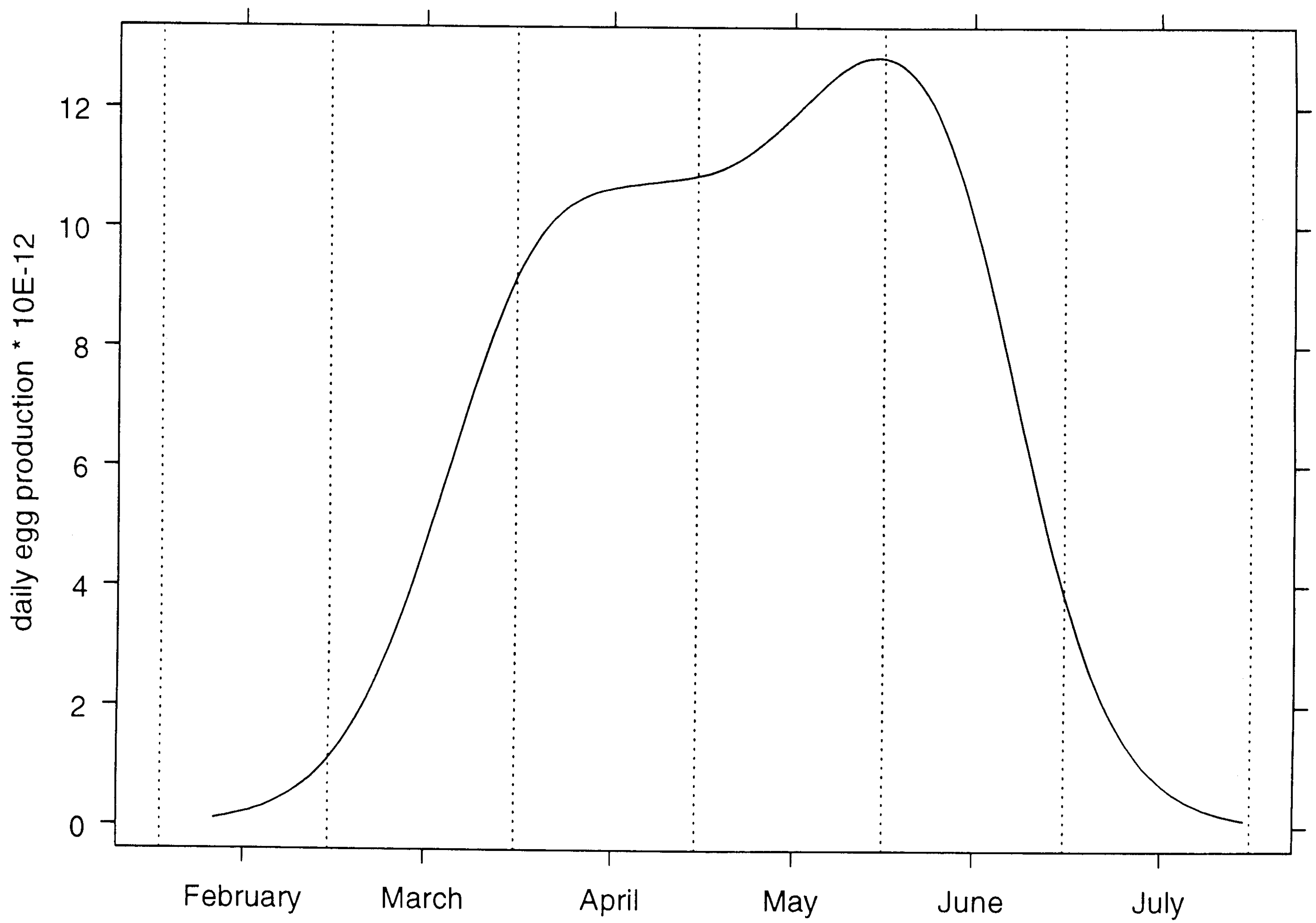


Figure 8.1.1. Production curve for the western spawning component of mackerel, based on GAMs.

9 SEAMAR PROJECT

Joachim Bartsch gave a presentation on the SEAMAR (Shelf-Edge Advection, Mortality and Recruitment programme) at the ICES Mackerel Egg Working Group meeting in Hamburg. In addition to this, he gave an example of a modelling study conducted within the SEFOS project (Shelf Edge Fisheries and Oceanographic Study).

SEAMAR is 3-year research programme (1999-2001) on bio-physical transport modelling of larvae and post-larvae of mackerel (*Scomber scombrus*) in the eastern North Atlantic (Figure 9.1). The strategic design of the work programme, a combination of field studies and use of historical data within a modelling framework, incorporates many elements of the GLOBEC philosophy. Funding is provided, in part, by the Directorate-General XIV (Fisheries) of the European Commission (EU).

The overall objective of SEAMAR is to develop a model to predict year-to-year survival of mackerel during the planktonic stages in the first 2–3 months of life. A transport model, utilising circulation from the HAMburg Shelf Ocean Model (HAMSOM), will be used to predict the dispersal of the eggs, larvae and post-larvae in response to real wind fields and density forcing. At the same time, differential survival rates will be implemented via individual-based growth and mortality modules as functions of the local physical and biological environment (Figure 9.2).

There is already a considerable wealth of information on the early life history of the mackerel, which spawn along the shelf-edge in the western North Atlantic. Routine egg surveys for stock estimation have been carried out in this area every three years since 1977 with additional studies in many of the intervening years. SEAMAR will build on this existing knowledge and add to it with mesoscale process-orientated cruises (e.g. eddies in Biscay) and targeted sampling for the later post-larval stages.

Parameterisation of growth and survival will be based both on literature-derived functions and on the basis of the cruise studies, including the proximate linkage with food abundance and temperature. Satellite imagery will provide regional coverage of sea-surface temperature as a primary forcing function and to derive regional production indices using SeaWiFS data. Output from the model will be validated against recruit survey results and annual recruitment indices.

Participant laboratories and university departments include those at Santander (IEO), Hamburg (IHF), Bremerhaven (BAH-AWI), San Sebastian (AZTI), Aberdeen (MLA-FRS), Galway (NUI-MRI) and Lisbon (IPIMAR), with project co-ordination from Plymouth (CCMS-PML).

One of the target species in the SEFOS programme was Blue Whiting. A numerical circulation and transport model system was used to simulate the dispersion of blue whiting larvae under climatological and meteorological forcing, and using actual ECMWF (European Centre for Medium-Range Weather Forecasting) data for 1994 and 1995. These different wind regimes caused variations in the dispersal patterns especially with respect to on shelf drift and the distribution in the Rockall Gyre, with possible effects on year class strength. Details may be found in Bartsch and Coombs (1997).

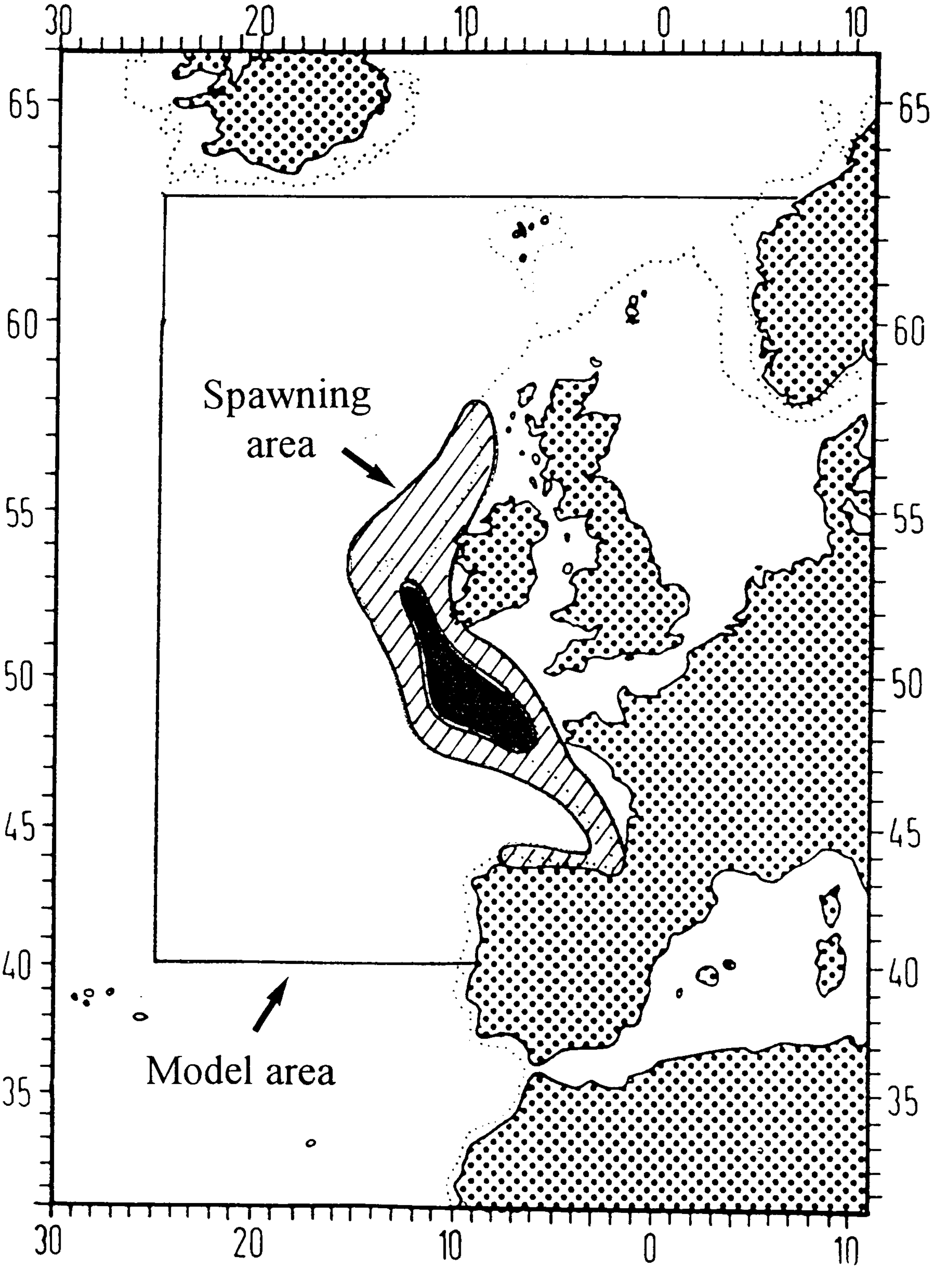


Figure 9.1. SEAMAR study area for bio-physical transport model for mackerel larvae.

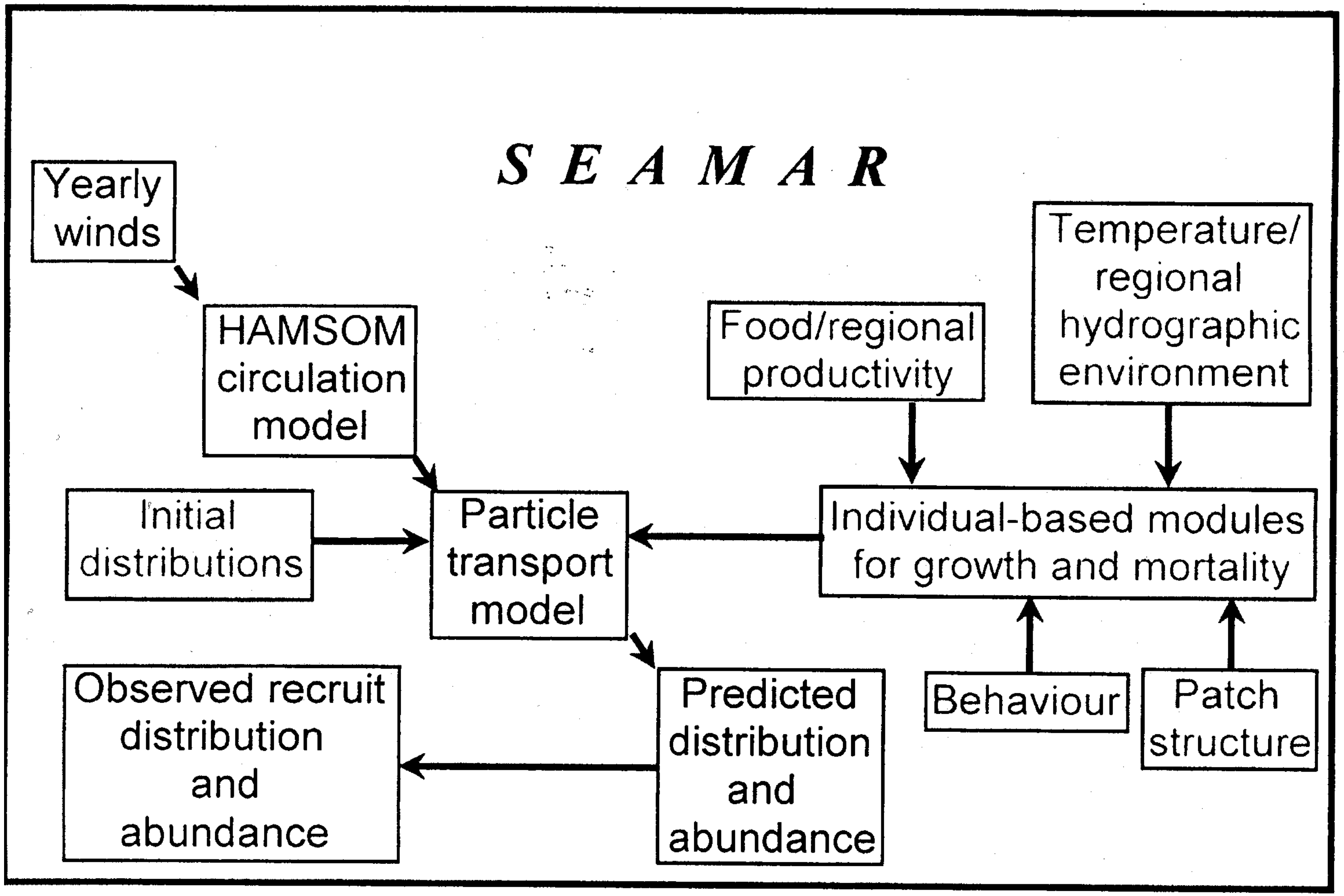


Figure 9.2. Flow diagram for proposed SEAMAR bio-physical model.

10 PLANNING MEETING FOR 2001 SURVEYS

The Working Group decided to request that its next meeting, for planning the proposed 2001 Mackerel and Horse Mackerel Egg Surveys, should be held from 18–21 February 2000 in Santander (Spain). The Working Group decided to nominate Cornelius Hammer, Germany, as its new Chair. The above request and nomination will be sent to the ICES Living Resources Committee for consideration at the Annual Science Conference in October 1999. The terms of reference for the Planning Meeting will be provided by the Working Group for the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy.

The following nations intend to participate in the 2001 survey: Ireland, Scotland, Spain (2–3 weeks ship time but depending on the availability of a new research vessel), Netherlands (6 weeks), Germany (4 weeks, possibly up to 6 weeks) and Norway (3 weeks). England might face some problems with the provision of research vessel time. No information on potential participation was available for Portugal.

11 DEFICIENCIES AND RECOMMENDATIONS

Deficiencies

The timing of the surveys did not adequately cover the whole spawning period of mackerel and horse mackerel in the western area. Deployment of effort should be addressed by the Planning Group for the proposed 2001 surveys, in order to achieve an earlier start and a later end to the surveys.

Recommendations

1) The Chair should seek EU funding for a proposed Study Group to meet in Lowestoft (UK) before the proposed 2001 surveys, in order to resolve problems of staging horse mackerel eggs and in particular to obtain consistently accurate counts of stage 1 eggs.
2) Mixed plankton samples, containing the eggs of mackerel, horse mackerel and those of species with similar eggs, should be circulated amongst potential participants in the 2001 surveys. The exchange will be organised by Ruth Harrop (UK) and the results of sorting analysed to compare the accuracy of sorting and identifying mackerel and horse mackerel eggs.
3) The Working Group recognises that the SEAMAR project will provide valuable information on recruitment processes in mackerel and therefore supports it and encourages all members to make survey data available.
4) The Working Group recommends that tank experiments with horse mackerel be carried out to investigate whether horse mackerel are determinate or indeterminate spawners.
5) The Working Group recommends that an exchange of histological slides or photographs of mackerel and horse mackerel ovaries be carried out in order to identify the problems in recognising atresia and in determining the different atretic oocytes stages. Bas Vingerhoed (Netherlands) will be co-ordinator for horse mackerel, and Peter Witthames (UK) will be co-ordinator for mackerel.
6) The Working Group recommends that a maturity at age estimation for the southern mackerel spawning component and the southern and western horse mackerel stocks should be made available by September 1999 for the MHSA Working Group.
7) The Working Group recommends that an exchange of slides and a comparison of results, between methods, should be made in order to resolve differences in fecundity estimates of southern horse mackerel across the whole southern area. The results should be presented to the MHSA Working Group in September 1999.
8) The Working Group recommends that the samples, collected for fecundity, atresia and maturity, that were not available at the Working Group, should be analysed. The results should be used to revise and complete the estimates of realised fecundity and maturity at age. The results should be presented as a working document to the next assessment working group

12 WORKING DOCUMENTS

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Tereshchenko, E.S. and Shamray, E.A. Materials on Fecundity of West Ireland Mackerel.

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ICES 1996 b /H:2. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys. ICES CM 1996/H:2, 146 pp.

ICES 1997 a /Assess:3. Report of the Working group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy. ICES CM 1997/Assess:3.

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