Living Resources Committee **ICES CM 2000/G:01**
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REPORT OF THE

WORKING GROUP ON MACKEREL AND HORSE MACKEREL EGG SURVEYS

Santander, Spain
18–21 January 2000

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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1 INTRODUCTION

1.1 Terms of Reference

At the ICES Annual Science Conference in Stockholm, Sweden, in September/October 1999 it was decided that (C.Res. 1999/2G01) the Working Group on Mackerel and Horse Mackerel Egg Surveys [WGMEGS] (Chair Dr. C. Hammer, Germany) would meet in Santander, Spain from 18-21 January 2000 to:

a) co-ordinate the timing and planning of the 2001 Mackerel/Horse Mackerel Egg Surveys in the ICES Sub-areas VI to IX for estimating the spawning stock size;

b) co-ordinate the planning of sampling for maturity of both mackerel and horse mackerel for analysis histologically;

c) co-ordinate the planning of sampling for fecundity and atresia taking into account the recommendations of the WGMHSA regarding the level of sampling;

d) review all the mackerel fecundity and atresia data collected in the western area as part of the 1998 survey and report back to the WGMHSA on whether or not any changes should be made to the 1998 data set;

e) review all information on maturity, fecundity and atresia for both mackerel and horse mackerel, analysed since the last meeting of WGMEGS. (All relevant working documents presented to the 1999 WGMHSA should be made available to this WG);

f) examine the reasons for the high variance on the estimate of mackerel egg production in the southern area in 1998 and decide on whether the sampling strategy needs to be revised in this area;

g) present horse mackerel fecundity and atresia estimates for the southern area from sampling in 1998. Review the egg production estimate and calculate a revised estimate of SSB for the southern horse mackerel in 1998;

h) review the results of the 1999 North Sea Egg Survey;

i) consider producing a manual detailing all methods used in the current egg surveys from sample collection through to the final estimate of SSB's.

1.2 Participants

The Working Group met in Santander (Spain) from 18-21 January 2000 with the following participation:

Abaunza, Pablo	Spain
Alvarez, Paula	Spain
Beare, Doug	Scotland (& Dave Reid, Scotland, in support)
Bernal, Miguel	Spain
Bez, Nicholas	France (part time)
Costa, Ana-Maria	Portugal
Eltink, Guus	Netherlands
Farinha, Anabel	Portugal
Franco, Concha	Spain
Hammer, Cornelius	Germany (Chair)
Iversen, Svein	Norway
Lago de Lanzos, Ana	Spain
Milligan, Steve	England
Molloy, John	Ireland
Nichols, John	England
Perez, Jose-Ramon	Spain
Pissarra, Joaquim	Portugal
Porteiro, Carmela	Spain
Santos, Maria	Spain
Villamor, Begona	Spain (part time)
Witthames, Peter	England

2 GENERAL ASPECTS

2.1 Planning of the Egg Identification and Staging Workshop in Lowestoft

WGMEGS (ICES, 1999) recommended that a study group should meet to resolve problems of egg identification and staging highlighted by the egg exchange experiment conducted during 1998. An application for an "accompanying measure" will be submitted by the chair to the EU, to provide funding for travel to CEFAS, Lowestoft (13-17 November 2000). It is hoped that each participating country will be able to send at least one plankton analyst to this workshop. The workshop shall be organised and conducted by S. Milligan (CEFAS). However, the analysis of the individual performance of the participants shall be handled in the same way as during the Lowestoft Horse Mackerel Otolith Workshop (Eltink, 1999). For this reason A. Eltink (RIVO-DLO) was asked by the working group to assist during the planned workshop in the statistical evaluation and documentation of the individual performances.

2.2 Planning of the Atresia and Fecundity Evaluation Workshop in Lowestoft

The quantification of realised fecundity in many fish species depends on the evaluation of atresia and fecundity in sectioned ovaries. The most recent mackerel and horse mackerel egg survey clearly underpinned the importance of regular and extensive determination of the fecundity and atresia. More extensive sampling was also requested by the WGMHSA in 1999 (ICES, 2000). To comply with this, more institutes are in future going to contribute in the slide preparation and interpretation.

Due to the fact that such evaluation is dependent on the skills of the individual readers, lengthy discussions at the working group showed the need for training and harmonisation. In order to guarantee the required accuracy, individual training is necessary. For this reason the working group decided to use the opportunity of the egg identification and staging workshop in Lowestoft (see sect. 2.1) to extend this meeting for those participants who are also involved in the interpretation of slides. Additionally those readers shall participate who are not involved in the analysis of plankton samples but analyse slides.

2.3 Plankton Exchange Programme

As a result of a recommendation of WGMEGS (ICES, 1999), three mixed plankton samples are currently being passed around each institute in turn. These samples contain both mackerel and horse mackerel eggs in all stages of development. Each participant is asked to sort, count, identify and stage the mackerel and horse mackerel eggs found in each sample. To date (Jan. 2000), only England and Germany have completed this analysis. However, there are some discrepancies between the two sets of results which highlight the need for the workshop described above (Section 2.1). The aim is to complete analysis of these samples by the end of July 2000.

2.4 Report from the EU-INDICES Project with Relevance to WGMEGS

INDICES is an EU project (97/017) designed to produce *'Ichthyoplankton-based indices of spring spawning commercial fish populations in Western European waters.* The project has three objectives:

- The assessment of the abundance of eggs and larvae of some commercial fish populations from the samples collected during the ICES 1998 international egg survey.

- Evaluation of the capabilities of CUFES (Continuous Underway Fish Egg Sampler) for sampling fish eggs.

- Estimation of the maturity ogive for western horse mackerel.

Seven commercially important species (including mackerel and horse mackerel larvae) were selected as being suitable for further data analysis. The target species (blue whiting, hake, megrim, sardine and anchovy) were all known to spawn in the same area and at a similar time to mackerel and horse mackerel.

All the plankton samples from the 1998 surveys were re-sorted. The eggs of the target species were identified, counted and staged. The larvae were identified, counted and measured. Maps showing distribution and abundance of eggs and larvae of the target species will be produced. A description of the methodology for abundance index estimation for these species, using geo-statistical techniques, was presented at the WGMEGS (Bez, 2000 WD).

Some problems were encountered whilst re-sorting the samples. In some samples many mackerel and horse mackerel eggs were found and it was unclear whether these eggs had previously been sub-sampled. There was also a problem with the identification of mackerel and horse mackerel eggs. Some samples contained labelled tubes of mackerel and horse mackerel eggs and when re-analysed were found to contain eggs of other species. It is hoped that these problems will be resolved at the egg identification and staging workshop to be held at the CEFAS laboratory, Lowestoft during November 2000.

The final report of INDICES will be produced by the end of July 2000.

2.5 Recommendations of the Plankton Sampler Study Group

At the last meeting of this working group (ICES, 1999) information was given on the plankton sampler calibrations that have taken place in recent years during an EU funded Concerted Action to investigate high speed plankton sampler design (see Section 2.4 of Anon., 1997). The following conclusions were drawn in the final report of this Concerted Action:

* Corrections to the ICES historic data bases should be considered for surveys where the Dutch, English or German versions of the Gulf III sampler have been used. Over estimations of abundance have been made in the order of 10% by England and 8% by Germany, and under estimations of 16.6% by the Netherlands.

* Any flow measuring device for use in high speed plankton samplers, whether intrusive or non intrusive, must be calibrated in situ in the sampler using either a towing tank or flume. This must be done over a range of relevant towing speeds and include simulated clogging conditions. Manufactures calibrations of any device should not be accepted and used because performance is affected by placing them inside a sampler.

* Pitot-static tubes should not be used for calibration of plankton samplers other than as primary devices to measure flume speed or towing tank carriage speed.

* Any device used for primary calibration of high speed plankton samplers, in a flume or towing tank, must be transected directly across the entry plane of the sampler. A non intrusive device such as a miniature head Laser-Doppler system is preferred. Where this is not available then a miniature flowmeter can be used provided that due caution is exercised regarding the edge effect.

* The standard Laser-Doppler system is too expensive for routine use in the field for measuring volume filtered by high speed plankton samplers. A cheaper system using fibre optics is too delicate and impractical for use at sea.

* The inherent efficiency of Gulf III samplers is dictated by the length of the nose cone, its aperture diameter and its diameter at the sampler body which control the nose cone angle. The efficiency of samplers in current use vary between 100% and 110%. This can be increased by the addition of a tube at the front of the nose cone and reduced by the addition of a tapered end section on the sampler.

* No preference could be expressed for either a Gulf III or Bongo sampler for use on ICES co-ordinated surveys. A recommendation for a standard design construction and sampling protocol the Bongo has been made. Similar recommendations for the Gulf III design should now be drawn up by the ICES Plankton Sampler Workshop as soon as possible.

However, recommendations of the Plankton Sampler Study Group are not available since this study group does not exist any more.

3 NORTH SEA EGG SURVEY IN 1999

3.1 Spatial and Temporal Coverage

During the period 25 May-25 June 1999 Netherlands and Norway carried out the egg survey in the North Sea to estimate the spawning stock biomass (SSB) of mackerel. During this period the spawning area was covered three times. The last time the North Sea was covered several times during the spawning season in order to estimate SSB was in 1996. During the period 1980-1984 the SSB was estimated based on several cruises carried out annually. From 1986 and until 1990 the SSB was based on a survey carried out every second year. No international surveys were carried out from 1991-1995. In 1990 the Netherlands, Denmark and Norway took part in these investigations (Iversen *et al.,* 1991) and the survey started in March because the investigation also covered the spawning of horse mackerel and some demersal species. Usually the mackerel spawn in the North Sea during the period from mid May towards the end of July. About 95 ship days were spent in 1990 while only 30 ship days were spent in 1996 and 1999.

3.2 Sampling and Data Analysis

In 1999 the data collecting and the handling of the samples were carried out according to ICES (1997b). R/V "Tridens" carried out the survey with a Gulf III working in double oblique hauls from the surface to 5m above the bottom. "G. O. Sars" towed a 20 cm Bongo for 5 minutes in each of the depths 20m, 15m, 10m, 5m and in the surface. The timing and the results of the cruises are given in Table 3.2.1.

The eggs were sorted from each of the sampled stations and their age were estimated according to development stage and to the observed temperature in 5 m. The development stages used in calculating the daily egg production are eggs without visible embryo (*i.e*. stage 1A+1B, Lockwood *et al.,* 1981). The average number of eggs produced per day per m^2 was calculated for each statistical rectangle of 0.5° lat. * 0.5° long (Figure 3.2.1). The spawning area was covered three times and the egg production was calculated for the total investigated area for each of the three periods (Table 3.2.1).

Table 3.2.1 Mackerel egg surveys in the North Sea in 1999

Coverage	1	2	3
"Tridens" **"G. O. Sars"**	25 May-1 June	7-10 June 6-11 June	 11-25 June
Midpoint of survey	29 May	9 June	18 June
Egg x 10^{-12}	0.41	0.30	1.38 (1.71)

3.3 Mackerel Egg Distribution

The distribution of daily egg production per m^2 surface is shown for each of the cruises in Figures 3.3.1-3. The sampled stations are also given in these figures. The egg density was relatively low particularly during the first and second cruises. The main densities of eggs were observed in the west part of the spawning area.

3.4 Mackerel Egg Production and Spawning Stock Size estimate

Based on the three production estimates the spawning curve was drawn (Figure 3.4.1). The parameters necessary for drawing the egg production curve and calculating the egg production and SSB are given in Table 3.4.1. In 1999 the highest egg production was observed during the last survey. This is considered to represent the peak of spawning. If the spawning in 1999 which took place after the peak period, had a similar development as in previous years (Fig. 3.4.1) it then seems fair to assume that the spawning after the last measured point would have followed a line from this point to zero production towards the end of July.

Table 3.4.1 Parameters and formulas used in the egg production and SSB estimates

Parameter	value/formula	Reference
Age of stage 1A+1B eggs	Age = Temp $^{-1.61}$ * e $^{7.76}$	Lockwood *et al*., 1981
Fecundity North Sea	Fec. = 560 * weight(g) $^{1.14}$ (*i.e.* 1401 eggs g^{-1} $female^{-1}$)	Iversen and Adoff, 1983
Fecundity Western area 1998	1206 eggs g^{-1} $female^{-1}$	ICES 1999
Atresia in Western area 1998	16.9 % (*i.e.* realised fec. = 1002 eggs g^{-1} $female^{-1}$)	ICES 1999
Sex ratio	1 : 1	as in previous years
Spawning period	17 May - 27 July	as in previous years, excl. 1990
Number of spawning days	72	as in previous years, excl. 1990

By integrating the egg production curve the total egg production was estimated at $40*10^{12}$ eggs. By applying the weight fecundity relationship 1401 eggs g^{-1} $female^{-1}$ (Iversen and Adoff, 1983) a SSB of 57,000 tons would be calculated.

There are no new fecundity data for the North Sea since 1982 (Iversen and Adoff, 1983). So far atresia in ovaries from North Sea spawners has not been studied. For mackerel spawning in the western area such data are available from the 1998 investigations (ICES, 1999). If the same weight fecundity relation and atresia as observed in the Western area in 1998 (*i.e.* 1002 eggs g^{-1} $female^{-1}$) are applied the SSB in the North Sea is estimated at 80,000 tons. The very low realized fecundity observed in the western area in 1998 was due to low relative fecundity and relatively high level of atresia. It is probably not wise to apply these low values observed in the western area in 1998 when calculating the SSB in the North Sea in 1999.

The 1999 egg survey did not cover the total spawning area and spawning period. The last cruise gave the highest egg production. This was expected according to results from previous investigations. However, if the third cruise was carried out previous to the peak of spawning in 1999, the egg production might be seriously underestimated. However, this is not likely since the peak has never been observed that late in previous years (Figure 3.4.1). During the last cruise there are uncovered rectangles which are likely to produce significant amounts of eggs. If these rectangles are assumed to have interpolated values as given in Figure 3.4.2, the egg production in the third coverage is estimated at $1.71*10^{12}$ eggs. This would increase the total estimate of the egg production by 20% corresponding to a SSB of 68,000 tons. This is considered as the best estimate of the SSB in 1999 and is 38% less than the SSB estimated in 1996.

Table 3.4.2 gives the estimated egg production in the North Sea for the years with multiple cruises of the spawning area per season (given in different ICES papers by Iversen and Iversen *et al.*). The corresponding SSB's based on a standard fecundity of 1401 eggs g^{-1} $female^{-1}$ (Iversen and Adoff, 1983) are also given in the same table.

Table 3.4.2 Egg production estimates from egg surveys in the North Sea and corresponding SSB based on a standard fecundity of 1401 eggs g^{-1} $female^{-1}$

Year	Egg prod $*10^{-12}$	SSB$*10^{-3}$ tons
1980	60	86
1981	40	57
1982	126	180
1983	160	228
1984	78	111
1986	30	43
1988	25	36
1990	53	76
1996	77	110

3.5 Maturity and Fecundity

No new information was obtained about the maturity ogive of North Sea mackerel in 1999.

During the survey ovaries were collected in order to study fecundity and atresia. However, due to the low egg production it is not planned to analyze these samples. This because even if the realized fecundity in the North Sea were found to be at the very low level, as observed in the western area in 1998, the estimated SSB would still be close to historical low level.

3.6 Review of the Results of the 1999 North Sea Egg Survey (referring to TOR "h")

Due to the limited input of effort in the 1999 survey the total spawning area and spawning period were not covered. Based on the observations (Figure 3.4.1) a better use of the limited survey time available would have been to start the investigations at the time of the second cruise. However, data obtained during an English crab larva survey during 9-19 July 1999 (Milligan pers. com.) indicate that the applied egg production curve is realistic. The estimate of the SSB depends on the realized fecundity in 1999 which was not investigated. However, even assuming the lowest level of realized fecundity as observed in the western area in 1998 the SSB in the North Sea would be 95,000 tons indicating that this stock is still close to historical low level.

To follow the development of the North Sea mackerel which at present is managed as part of the North East Atlantic mackerel stock the Working Group recommends that a new egg survey should be carried out in the North Sea in 2002 in order to estimate the SSB.

Daily egg production per square metre

	2 W		1w		0		1E		2		3		4		5		6		7		8		9		10
59																									
											1	17	3	0											
58											2	1	33	2	0	0	0								
						0	0	1	7	0.4	0.2	0.2	13	17	3	5	0		0.2	0.2	0	0.3			
57			0		0	19	10	1	2		2		27	25	5	9	1	1	8	0.2	5	1			
						0.2	4	1	0	0	1	1	14	17	4	8	6	1	0.6						
56			0	0	0	1	18	0.6	0.4	0	0	2	12	2	0	2	3	6							
			0	0	1	3	0.2	0	0	0.4	0.4	4	0.7	2	1	11	7	1							
55				72	6	9	44	49	1	0	0	0	0	1	0	0	0.3		0.4						
					0.1	57	183	2	0.4	0	0	0	0	0.2	1	0.1	1		0						
54						0.1													0.3						
							0	0	0	0	0.2	1	4	4	0	0	0	0							
53																									

Figure. 3.2.1 Daily production of mackerel eggs per m^2 per rectangle during the third coverage in 1999

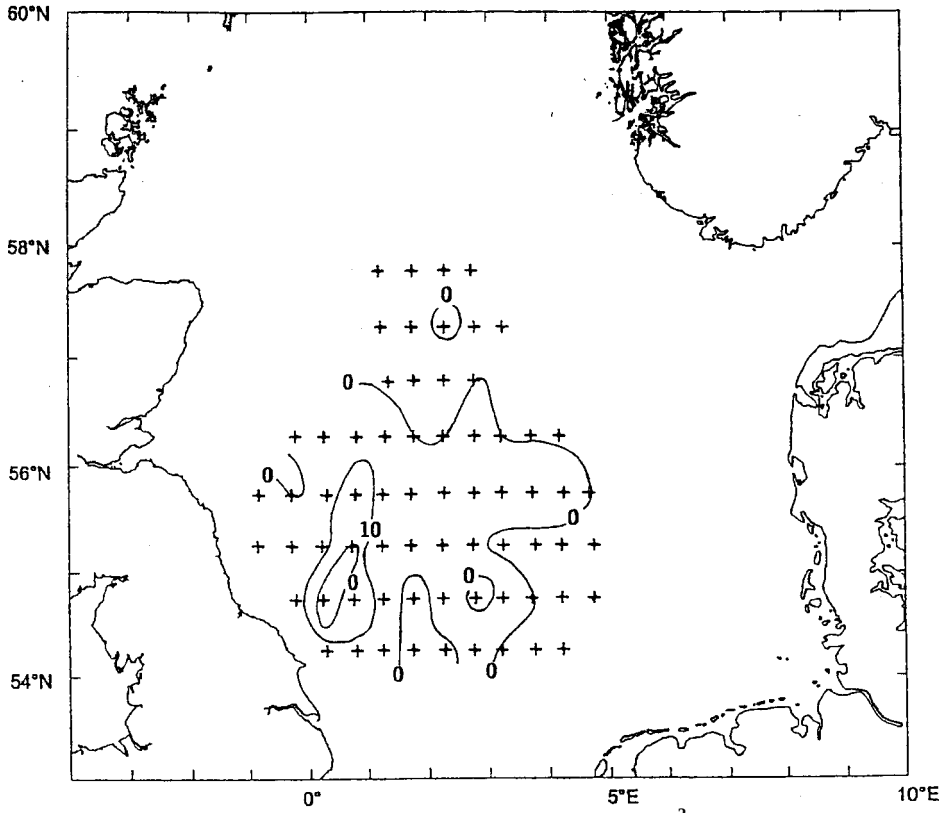


Figure 3.3.1 The distribution of daily production of mackerel eggs per m^2 during the first coverage, 25 May-1 June 1999, and the stations sampled by R/V "Tridens"

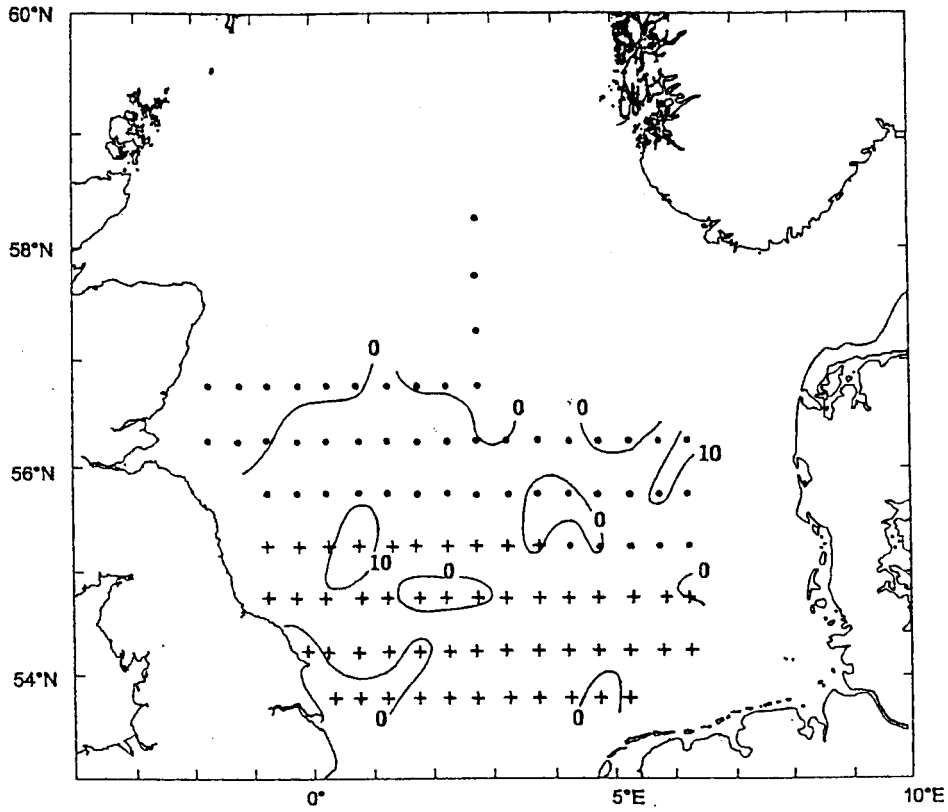


Figure 3.3.2 The distribution of daily production of mackerel eggs per m^2 during the second coverage, 6-11 June 1999, and the stations sampled by R/V "Tridens" and by R/V "G. O. Sars"

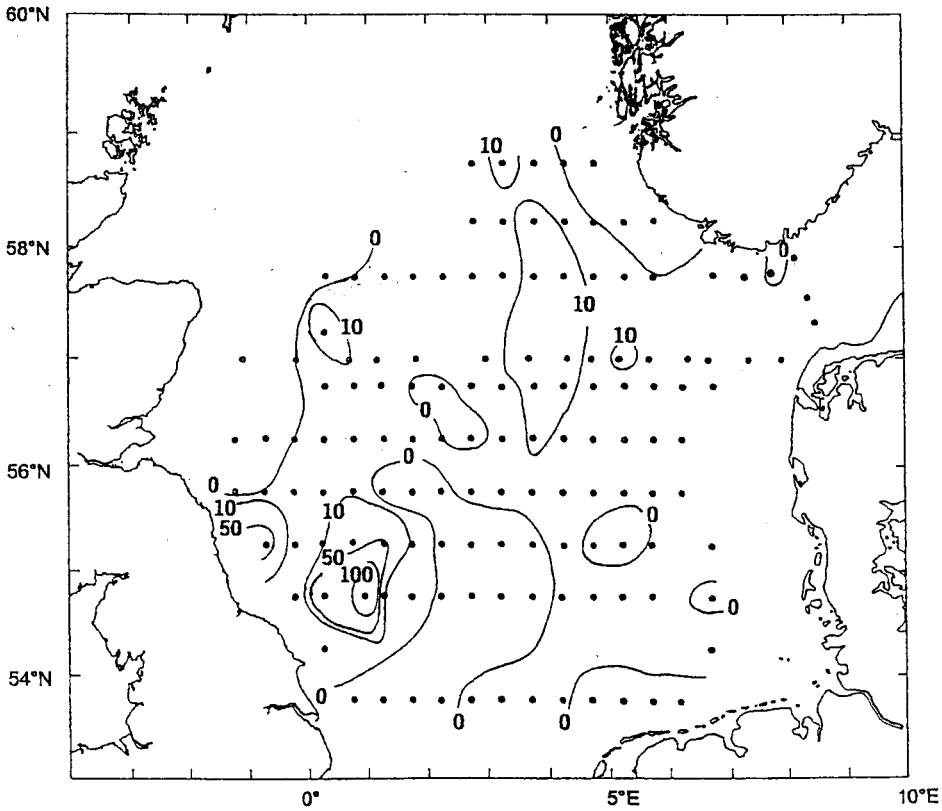


Figure 3.3.3 The distribution of daily production of mackerel eggs per m^2 during the third coverage, 11-25 June 1999, and the stations sampled by R/V "G. O. Sars"

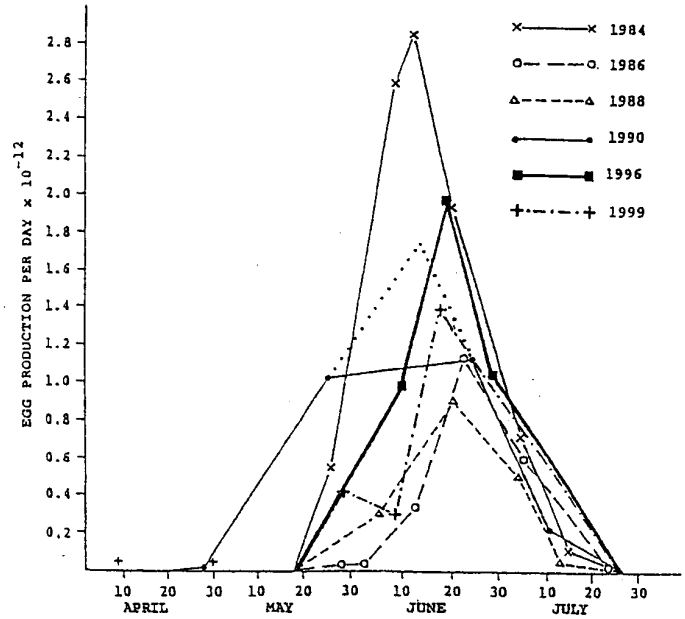


Figure 3.4.1 Mackerel egg production curves for the period 1984-1999. The + indicates that few eggs were observed during two coverages in April 1988. Dotted line indicates suggested alternative pattern for the peak spawning period in 1990

Daily egg production per square metre

	2W		1W		0		1E		2		3		4		5		6		7		8		9		10
59																									
											1	17	3	0											
58											2	1	33	2	0	0	0								
						0	0	1	7	0.4	0.2	0.2	13	17	3	5	0	0	0.2	0.2	0	0.3			
57			0	**0**	0	19	10	1	2	**2**	2	**14**	27	25	5	9	1	1	**8**	0.2	5	1			
						0.2	4	1	0	0	1	1	14	17	4	8	6	1	0.6						
56			0	0	1	18	0.6	0.4	0	0	2	12	2	0	0	2	3	6							
			0	0	1	3	0.2	0	0	0.4	0.4	4	0.7	2	1	11	7	1							
55			**36**	72	6	9	44	49	1	0	0	0	0	1	0	0	0.3	**0**	0.4						
				36	0.1	57	183	2	0.4	0	0	0	0	0.2	1	0.1	1	**1**	0						
54					**0**	0.1	**90**	**1**	**0**	**0**	**0**	**1**	**2**	**2**	**1**	**0**	**0**	**0**	0.3						
							0	0	0	0	0.2	1	4	4	0	0	0	0							
53																									

Figure 3.4.2 Observed and interpolated values (in bold) for daily production of mackerel eggs per m^2 per rectangle during the third coverage in 1999

4 EVALUATION OF GENERALISED ADDITIVE MODELLING AND GEOSTATISTICS

4.1 Review of the Results of the 1989, 1992, 1995 & 1998 Survey Analysis

4.1.1 Models Adopted

Explanatory variables

The explanatory variables used were:

date (in days from the 1st of January)
latitude (in degrees)
longitude (in degrees)
distance perpendicular to the 200m contour (in metres)
distance along the 200m contour N-S (in nautical miles)
logarithm of bottom depth (in metres)

Mackerel

For mackerel a single stage GAM was adopted. A log link was used and a negative binomial error distribution was assumed.

Horse Mackerel

For horse mackerel data a two step GAM methodology was adopted. The first stage models the probability of recording a stage I egg at a given time and location using a logit link and a binomial error distribution. In the second stage the abundance of eggs where present are modelled using gamma error and a log link. It was also noted here that the negative binomial distribution also appears to be adequate for horse mackerel, although no comparison of the relative merits of each procedure have been investigated.

In all cases model selection was done using smoothing splines with 4 degrees of freedom (df). Interactions between the covariates were allowed to enter the models as products of each covariate (also spline smoothing with 4df). Selecting smoothing parameters is difficult and the numbers of degrees of freedom were chosen based on visual inspections of the shapes of the various dependencies within the data.

Variances of each estimate were calculated by bootstrapping.

In the context of variance the working group also discussed the possible benefits of making replicate experiments when extra ship time becomes available, *i.e.* to take several samples instead of one at any particular point. The aim of such an exercise would be to provide information on the local variability of egg density, which is thought to have a large impact on the precision of abundance estimation.

Analyses based on geostatistical and non-linear regression techniques on western area data suggest that most of the variability in the stage I eggs is due to their location (spatial effects), time of year they were sampled (temporal effects) and measurement errors and can therefore be explained. Nicolas Bez showed to the Working Group that egg abundance within a sampling period can be estimated with good confidence (coefficient of variation can be as low as 10%). GAMs have also been found which explain much of the variability in the stage 1 egg data using simple covariates of location, date and depth.

It is widely appreciated that marine biota tend to be clumped in space and time. Statistically this leads to higher variances than would be expected and the mean: variance ratio is actually, therefore, a real measure of the aggregation of data in space and time. The fact that data are highly clumped, therefore, does not preclude them from being modelled. Incorporation of negative binomial error, for example, in which the mean is equal to the square of the variance, allows us to model these relationships and discriminate between the explanatory power of any particular predictor variable (*e.g*. latitude, depth).

It was also stressed to the WG that the question of variance should be addressed in the context of the specific question needing to be answered. For the western stage 1 egg surveys, where change occurs fairly gradually, it is more important

to have information covering the entire spatio-temporal range of the spawning area than to know in detail, for example, what happens on the Porcupine Bank. In the southern area, however, local changes may be much more pronounced and sudden, in the spatial dimension particularly, (viz. the much steeper depth gradients) and that area, therefore, may require more highly resolved information for adequate assessment of the annual egg production.

4.1.2 Problems Encountered

The main problems encountered in the development and application of the models were as follows:

a) Partial coverage of the area by the surveys.

b) Confounding of variation in space & time.

c) Choice of the size of the survey area over which to extrapolate from the models. This was finally based on the 1995 standard survey area (ICES, 1994), and hence was larger than that used by the traditional method in 1989 and 1992.

d) Choice of start and end dates. These were standardised at 10/2 to 31/7 for the western area and 10/2 to 17/7 for the southern area. Different start dates were tested for sensitivity. The chosen dates were adopted as wider dates had no effect on the integrated volume. Narrower dates did have an effect and this has a bearing on the comparison with traditional methods in 1989 and 1992.

e) Presence of bias. GAMs are inherently biased, although this can be corrected. In this study bias was always negative. This is likely to be due to the high variance associated with high data amplitude, allowing the model to fit less tightly in these areas. A number of remedial approaches were examined.

   i) **Increase in the df**. An optimal value of 12 df was chosen. This tends to reduce negative residuals in areas of high amplitude, but reduces precision in the fit generally and introduces negative bias in areas of low abundance.

   ii) **Bias correction by bootstrap**. This appeared to be promising but was computationally intensive, particularly for the variance calculations and was not adopted.

   iii) **Bias correction by regression**. This technique used a regression of the negative residuals against the fitted values to give a correction factor for the fitted surface. This appeared to work well, inasmuch as there was a closer correspondence with the traditional egg production curves.

4.1.3 Results

Mackerel

1995 Western Area

The model appeared to capture well; the south to north movement of spawning peak; the peak abundance and the westward shift of spawning in May. The production estimate was close to the traditional method.

1995 Southern Area

The model appeared to capture; the lack of eggs on the Portuguese coast and the high density of eggs in the Cantabrian Sea in April. There were considerable problems due to sparser data than the western area and the confounding of sampling in space and time. It was concluded that the data were inadequate for a spatio-temporal GAM.

1992

The model appeared to capture well the south to north movement of spawning peak in May/June and the westward shift of spawning in May. There was a suggestion of two peaks in spawning, and the GAM indicated that the start and end dates used for the traditional method may have been too narrow. The production estimate was less close to the traditional method, than in 1992. This may have been due to the atypical westward distribution which was poorly

sampled. The GAMs are better able to extrapolate this trend and would be expected to give a higher abundance. Other possibilities for the discrepancy are the smaller area and narrower dates used in the traditional analysis.

1989

This survey posed considerable problems (for both methods) due to the bias in the German sampling in Biscay early in the season. To cope with this, the GAM was run without temporal parameters, allowing spatial data from later in the season to be applied to the German data. However this then caused a tendency to OVER estimate later in the season. It was pointed out that no amount of statistics can account for a complete lack of data/information. GAMs can easily extrapolate/smooth effortlessly through unsampled areas and/or time-periods. It is tempting and straightforward to do but can reach such extremes that the results ought to be treated cautiously.

Horse Mackerel

1995 western area

The model appeared to capture the later peak compared to mackerel; the more southerly distribution and the presence of two spawning peaks (end of March and start of June). Some discrepancy between approaches can be seen but this is not explained.

1995 southern area

The model appeared to capture the initial high densities on the Portuguese coast in February/March. However, as in mackerel, the analysis was compromised by sparse data and the space/time confusion.

1992

The model appeared to capture one peak in late June. Again the dates used in the traditional method appeared to be too narrow and there was a problem with an absence of data in the south late in the survey period. The estimates were reasonably close to the traditional. Differences are possibly due to area and date effects.

1989

The model appeared to capture; the highest densities in May in the southern and central areas, the shift north and spreading east and west in June and the peak spawning in early June. There was a very good agreement between the two approaches.

4.2 Application of the Method to the 1998 Survey

The mackerel assessment WG (ICES, 1996b) identified a number of areas of concern. Namely:

selection of df
selection of the error distribution model
outer boundaries - spatial and temporal
choice of explanatory variables
existence of bias

The rationale for the choices for the first two points is covered in the final report to the EU on the study contract. Sensitivity to date choice has been discussed and appears to be robust. No clear examination of sensitivity to spatial boundaries has been carried out. The explanatory variables were chosen after examination of a range of possible parameters including temperature and vessel effects, however these were found to be unusable. The variables chosen seem sensible and apparently adequate.

The WG also highlighted that no formal test of the suitability of the GAM's chosen had been carried out and that no usable software and protocols have been produced.

The WG required (sect. 1.5.3. in respective report) that thorough testing be carried out using Monte Carlo simulation techniques. Tests of sensitivity of model specification were also required, particularly with reference to smoothing, choice of explanatory variables and error structures, and bias correction. The following section has been prepared in the

light of these comments and on the basis of a proposed short study contract to bring the techniques to a state where it can be applied to the 1998 surveys.

4.2.1 Study Proposal

This proposal is subject to a successful EU funding application. For this WG the project is vital for the application of the GAM analysis method to the egg surveys.

Proposal Summary

1. Develop models of real world egg distributions incorporating a variety of possible scenarios. Simulate sampling from these to reflect survey strategy as operated. Back check these sampling runs against real egg survey data and to integrate the GAM simulations with the simulations.

2. Evaluate model performance against simulated distributions for bias in point, variance and interval estimates. Correct the GAMs as appropriate to these evaluations. Test the robustness of the final models to a range of simulated real world scenarios.

3. Review the outcome of these studies against the traditional approach and for general use.

4. Produce usable, documented software.

Members of WGMEGS were asked to comment on the proposal and to participate in this study, particularly to define and tune the potential variety of real world situations the surveys may encounter. This would be operated mainly through two workshops during the study. The main aim of this study would be to assess the usability of the GAM technique with particular reference to the 1998 surveys.

Response from the WG

The initial project proposal has been considered by the WG and the following alterations suggested to the modellers.

1. It is felt that the appraisal should include the traditional method in the simulation studies so that the relative performance of the two techniques can be assessed, and an informed choice be made.

2. The suitability of a two-stage model for mackerel should be considered.

3. If possible the simulations should include some consideration of sampling design changes.

4. Some consideration of the sensitivity to placement of structural zeroes (area boundaries) should be included.

5. Software for general use should be implemented in S-plus for ease of use.

6. The most important real world scenarios for the simulation in order of priority should be:

    - One or two peaks in egg production
    - Westerly variation in the egg distribution
    - South to north changes in peak abundance
    - Variability in timing of peak spawning
    - Different start and end dates for egg production
    - Inclusion of large areas of low egg production outside the standard area

The WG also felt that some consideration of the use of the refined models to improving choices in effort allocation in time and space would be very useful. Particularly with reference to:

- Effectively reduce the sampling intensity in time and space, e.g. in relation to modifications of survey strategy as a result of vessel breakdown etc.
- What sampling design would work best with a GAM analysis
- The effect of large gaps in survey coverage for various reasons

4.3 EC Project No: 97/0097: Evaluation and Development of Spatio-Temporal Models and Survey Designs for Efficient Assessment of Mackerel and Horse Mackerel Stock Sizes

This project is currently in progress at the Research Unit for Wildlife Population Assessment at St. Andrews University and a successful Workshop was held between 16-17 July 1998. An Interim Report (Beare, Bernal, Borchers, Burt, Clark & Pout) outlining progress and preliminary results is appended to the current document. A brief summary of the results described in the report is given below.

Summary of Interim Report

The objectives of this project are:

a) to establish whether the current GAM-based point, variance and interval estimators developed for the AEPM under EC study project 94/107 are unbiased;

b) to develop survey designs to improve the cost efficiency and reliability of the stock biomass estimates used in management;

c) to produce usable, documented software for routine assessment of the stocks using a GAM-based AEPM. Software developed to do the simulation testing will also be documented and made available.

Progress: The GAM-based AEPM method has been programmed in S+ and has been made available to some partners on the project. Further work on its documentation is required. At the first meeting of project participants, the design of the “true” spatio-temporal egg distributions to be simulated was considered and their characteristics are summarised in Table 4.3.1.

Table 4.3.1 Summary of main characteristics of the six "true" scenarios used in the simulations derived by fitting GAM's with multi-dimensional smoothers to the egg-density data from the 1989, 1992 and 1995 surveys of the western stocks

"True" scenario	Westerly distribution	Strongly bimodal?	Early/Late peak	Total AEP
1989 mackerel	Concentrated along 200m contour	Yes	Early	$2.77\omega10^{15}$
1992 mackerel	Concentrate along 200m contour but higher abundances to the west	No	Neither	$1.93\omega10^{15}$
1995 mackerel	Concentrated along 200m contour	Yes	Late	$1.42\omega10^{15}$
1989 horse-mackerel	Dispersed around 200m contour	No	Late	$1.06\omega10^{15}$
1992 horse-mackerel	Dispersed around 200m contour	No	Late	$1.24\omega10^{15}$
1995 horse-mackerel	Dispersed around 200m contour	No	Late	$0.73\omega10^{15}$

Monte Carlo variation is introduced into the simulated data sets by generating the egg counts from the appropriate stochastic distribution given the "true" model and the location of the sample points.

The software allows new survey designs to be tested by simulation. Following meetings with relevant partners, a number of alternate, potentially more cost-effective survey designs have been developed and implemented in the simulation-estimation software developed thus far. The parameters of the simulated sampling methods include the number of vessels involved in the survey, their start dates, speeds and specific areas. In addition to the geographic location of a vessel at any particular time, weather and relevant physical and biotic characteristics in the survey area are simulated. These affect the survey in a way designed to mimic the way they would affect a real survey. The proposed designs include ones in which frequency and location of future samples is determined adaptively in response to the number of eggs sampled in the current trawl.

In addition to the simulated sample data, the software records the distance travelled and elapsed time for each survey vessel. This allows the cost-effectiveness as well as the estimation efficiency of survey designs to be evaluated.

Selected Results

Mackerel

A summary of the estimated bias of each estimator for each scenario is given in Table 4.3.2. Differences between the mean traditional annual egg production method estimates within any one year in Table 4.3.2 is purely Monte-Carlo variation. Similarly the estimates of bias presented in Table 1 contain Monte-Carlo error.

Table 4.3.2 Simulated "true" and estimated mean egg production (E_a 10^{15}) for western mackerel from the GAM and Traditional methods with and without use of structural zeros. In all cases the 1995 survey design is used to generate simulated data. Figures in brackets are the approximate estimated bias of the estimator

		No Structural Zeros		**Structural Zeros**	
Year	**"True"**	**GAM**	**Trad.**	**GAM**	**Trad.**
1989	2.71	2.80 (3%)	2.49 (-9%)	2.36 (-13%)	2.55 (-6%)
1992	1.99	1.93 (-3%)	1.68 (-16%)	1.70 (-15%)	1.67 (-16%)
1995	1.35	1.38 (2%)	1.31 (-3%)	1.22 (-10%)	1.32 (-2%)

When no structural zeros are used, the GAM estimator performs substantially better than the traditional method, in terms of bias. Use of structural zeros appears to introduce negative bias in the GAM estimator, making it more negatively biased than the traditional method estimator. The reasons for this are not at this stage clear, but a working hypothesis is that use of structural zeros introduces negative bias when the survey design is adequate without structural zeros. This problem is currently being investigated.

Horse mackerel

The results relating to estimator bias are less clear in the case of horse mackerel than mackerel (Table 4.3.3). With the exception of 1992, the GAM method estimator performance is almost identical to that of the Traditional method estimator.

Table 4.3.3 Simulated "true" and estimated mean egg production (E_a 10^{15}) for western horse-mackerel from the GAM and Traditional methods with and without use of structural zeros. In all cases the 1995 survey design is used to generate simulated data. Figures in brackets are the approximate estimated bias of the estimator

		No Structural Zeros		Structural Zeros	
Year	**"True"**	**GAM**	**Trad.**	**GAM**	**Trad.**
1989	1.03	0.96 (-7%)	0.96 (-7%)	0.95 (-8%)	0.96 (-7%)
1992	1.43	1.65 (15%)	1.43 (0%)	1.28 (-10%)	1.47 (3%)
1995	0.73	0.75 (3%)	0.69 (-5%)	0.68 (-7%)	0.69 (-5%)

4.4 Geostatistical Applications

Nicolas Bez gave a presentation on the potential of transitive geostatistics when applied to fish egg distributions. The objectives of his presentation were:

1. to explain why spatial statistics should be used,

2. to present the centre of gravity and the inertia which are two simplistic, powerful and spatial statistics for describing sets of maps,

3. to described the spatial structure in more details using the covariogram,

4. to model this spatial structure,

5. to use the spatial structure to compute a global estimation variance, compare spatial aggregations and create interpolated maps.

Shortcuts on the method

Centre of gravity and inertia of the egg density have a clear physical meaning, describing the mean location of the eggs and their dispersion around this mean location. They have the advantage to be unaffected by the number of zeroes used in the computation and to be affected by the locations of the values in space (spatial statistics).

Autocorrelation between, say, N sample values means that redundancy exists between them and that the N values provide in fact less information than N uncorrelated samples. Autocorrelation appears when the sampling grid is regular and / or when the target variable is regionalised. If this is so, geostatistic provides tools such as the covariogram that allow to take the autocorrelation into account when estimating global quantities. The covariogram describes and quantifies the importance of each distance class in the overall inertia. Anisotropies can be revealed and the behaviour of the covariogram near the origin, and in particular its discontinuity also called nugget effect, is associated to the more or less spatial heterogeneity of the egg density. By construction the covariogram is also unaffected by the amount of zeroes involved in the computation.

The global estimation variance is directly computed from the covariogram model. Two assumptions rely in this approach:

1. The origin of the sampling grid is supposed to be located at random.

2. Unobserved areas are assumed to be null.

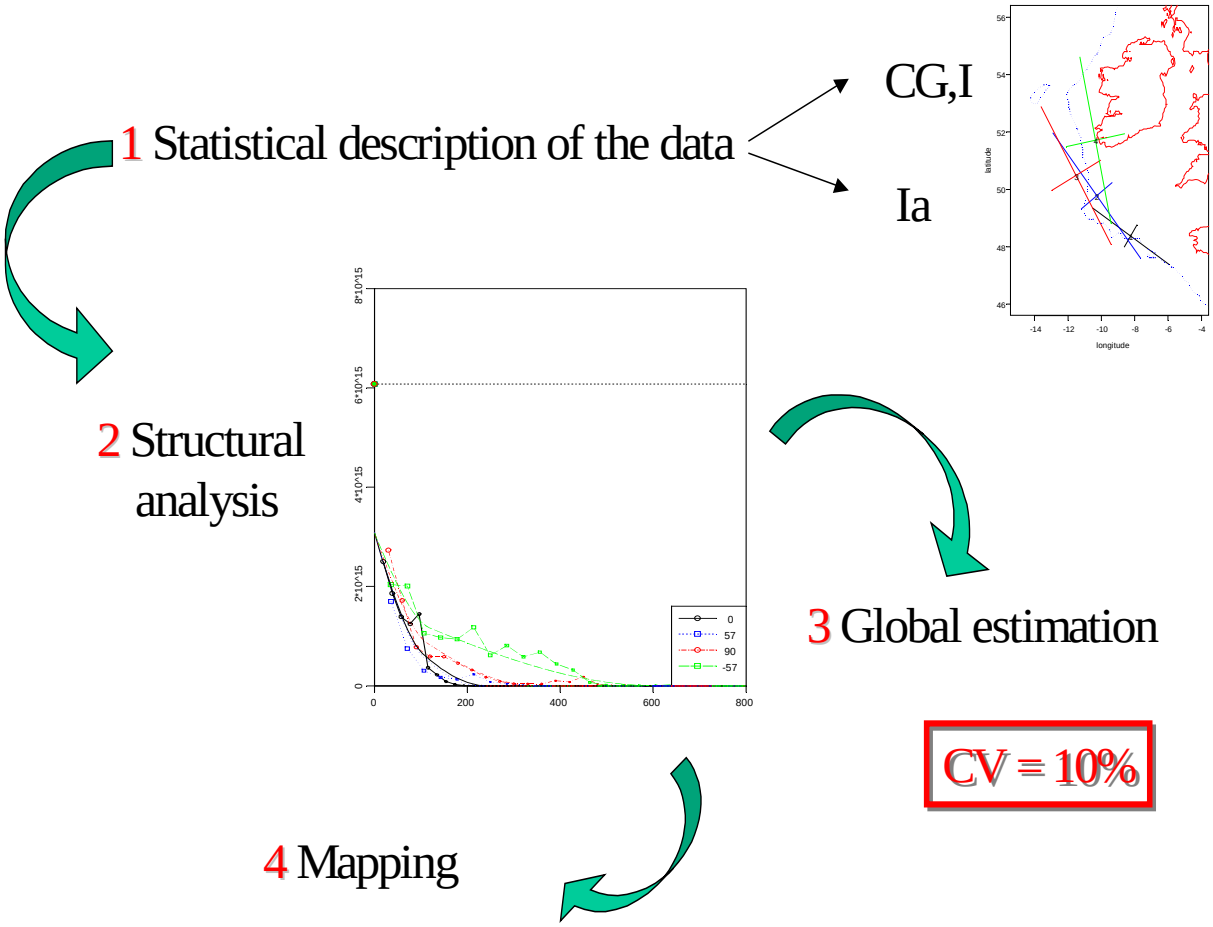
Shortcuts on the results

In the example presented in Santander (stage I mackerel egg, 2d sampling period of 1989), the covariogram indicates that more than half of the dispersion of eggs is due to spatial structures with scales smaller than the sampling grid mesh or to random measurement errors (the latter have to be distinguished from systematic measurement errors). Nevertheless, the coefficient of variation of the global estimation for a given sampling period is 10%. This CV includes the error due to the fact that we do not have an exhaustive information but rather a discrete one and the error due to unsystematic measurement errors.

A kriging map was also presented (Figure 4.4.1).

Recommendations

The low CV means that the spatial coverage is fine enough to insure confidence in the order of magnitude of the estimate (at least in the studied example) provided that no systematic measurement errors exist. However, very large uncertainties still exist on the precision of the field observations and on the egg determination and count which, in fact, leads at the end to a much less precise estimate of the production of eggs. In this regard, effort is needed to reduce this part of uncertainties in the overall SSB estimation process.



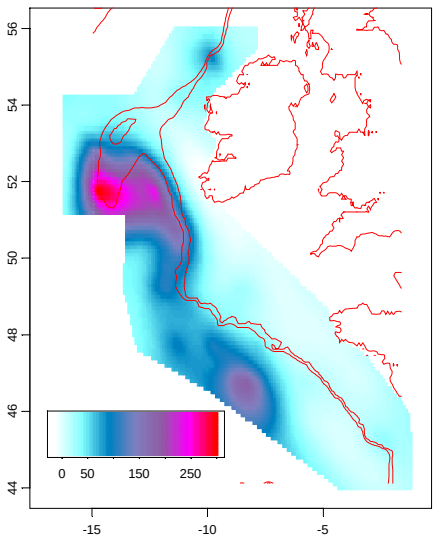


Figure 4.4.1 Process of analysis and results of kriging

5 PLANNING OF THE 2001 MACKEREL AND HORSE MACKEREL EGG SURVEY IN THE WESTERN AND SOUTHERN AREAS (REFERRING TO TOR "A")

5.1 Countries and Ships Participating

England, Germany, Ireland, Netherlands, Scotland, Portugal, Spain, Spain/Basque Country and Norway will participate in the mackerel/horse mackerel egg surveys in the western and southern area in 2001. The survey coverage of the western and southern area (Figure 5.1) is attempted to be even better than in the previous survey (Table 5.1).

Table 5.1 Tentative data for the 2001 mackerel and horse mackerel egg survey

Sampling Period	Country	Area	Ship	#	Period	Survey mid-point	Latitude covered
1	Portugal	South	?		Appr.15.01-02.02.	Appr.25.01	36-42
2							
3							
3	Germany	West/South	W.Herwig III	WH 228	15.02-31.03	8 03.	42-58
3	Portugal	South			Appr. 19.03-07.04.	Appr. 28.03	36-42
4	Scotland	West	Scotia?		Appr. 01.04-early May	mid April	
3/4	Spain	South/IEO	Cornide de Saavedra		12.03-20.04	30.03.	41-46
4	Scotland	West	Scotia		14.04-1405	30.04	52-60
4/5	Spain	South/AZTI	?		mid April-20.05	05.05.	43-47
4/5	England/Wales	West	Corystes?		mid April – mid May	Appr. 01.05	47-51
4/5	Netherlands	South/West	Tridens		17.04-04.05.	Appr.25.04.	43-48
5	Netherlands	South/West	Tridens		Appr. 11.05.-01.06.	Appr. 22.05.	43-48
5	Norway	West	G.O.Sars?		Appr. 16.05-09.06.	Appr. 27.05	49-60
6	Scotland	West	Scotia		Appr. 10-30.06	Appr. 20.06	47-60
7	Ireland	West	?		Appr. 01.-21.07	Appr.10.07	49-60

As for the previous survey, it will be split into seven sampling periods, allowing full coverage of the expected spawning area (periods 1-6) and six of the western area (periods 2-7) (see Table 5.1). The widest area cover is provided during the third sampling period when the distribution of mackerel and horse mackerel spawning is at this most widespread in the southern and western area. For this period an overlap of the sampling areas is planned for the Spanish and German surveys, in order to ensure a complete coverage of the southern area at the time of peak spawning. For this purpose a flexible spatial coverage, into the southern area and at the north-western edge of the survey area, is allocated to the German survey. The details of the coverage of the Cantabrian Sea will be coordinated by direct communication between RV "Cornide de Saavedra" and RV "Walther Herwig III" when operating in the area. The German vessel is expected to cover the Cantabrian Sea at the beginning of the survey period in February and subsequently move northwards. In order to be able to cover the entire sampling area, the German survey is expected to omit every second transect when coming north into Irish waters.

In the western area maximum deployment of effort is during the fourth, fifth and sixth sampling periods, the latter two coincided with expected peak spawning of mackerel and horse mackerel in the area. In order to achieve maximum coverage of the western area in each sampling period the Scottish survey in the fourth sampling period will attempt to cover the entire area from north to south omitting every second transect. In the sixth sampling period the transects previously omitted will be sampled from the south to the north. The same sampling strategy will apply to the Norwegian survey in the fifth period.

Three vessels will be operating in the Cantabrian Sea and the southern part of the Bay of Biscay in the periods forth and fifth period. Again, the details of coverage will be discussed ad hoc between the Spanish, English and Dutch vessels. **Countries should report changes to the ship's deployment schedule as soon as possible to Cornelius Hammer (Fed. Res. Centre for Fisheries, Hamburg). This will allow any resultant problems to be addressed in good time and potential solutions explored**.

The high variance of data from the 1998 annual egg production estimates from the southern stocks of mackerel and horse mackerel between Cadiz and Finisterre is probably related to the poor sampling density and low number of stations (see section 6.2). For this reason it deems necessary to achieve a better use of available ship time and to

improve the quality of the daily egg production data sets. Portugal intends to perform two cruises between Cadiz and Finisterre as part of the 2001 survey programme.

The first cruise will take place in January/February (30 days) to coincide with the DEPM survey for sardine SSB evaluation. The objectives will be

1. To obtain egg distribution data from the standard grid stations for mackerel and horse mackerel,
2. To compare data from bongo and CALVET sampling nets on common stations,
3. To improve the quality of data (lower variance) using the high density CALVET station grid.

The second cruise will take place in March/April (21 days) as part of the hydroacoustic survey for sardine, using available ship time during the night.

It is intended to use the CUFES (Continuous Under Water Fish Eggs Sampler) to enhance the sampling density.

5.2 Sampling Areas and Sampling Effort

As in previous years it was decided that the spatial and temporal distribution of sampling would be designed to ensure an adequate coverage of both mackerel and horse mackerel spawning and that estimates of stage 1 egg production would be made for both species.

Since the surveys were started in 1977 considerable changes have been made to the standard sampling area and these are described in Section 8.4 (ICES, 1994). In 1995 changes were made to the western boundaries of the western area because of the unusual westerly distribution of mackerel eggs which occurred in period 3, 1992. Examination of the 1995 egg distributions prior to the 1998 survey resulted in the addition of further rectangles to the standard sampling area. A total of eight rectangles were added at the northern edge and twenty five on the western edge between latitude 45°30'N and 51°N (ICES, 1997b).

The distributions of the stage 1 eggs of mackerel and horse mackerel in the 1998 surveys were examined in order to determine whether any changes were needed to the standard sampling area for 2001. Those distributions are described in detail (ICES, 1999) for mackerel in section 5.1 and for horse mackerel in Section 6.1 (western) and 7.1 (southern).

Examination of the 1998 survey data showed that the distribution of mackerel and horse mackerel spawning in both the western and southern areas was adequately covered with the exception of mackerel spawning from mid May to July at the northern edge of the western standard area. As a result some additional rectangles have been added to the standard area north of latitude 58°30'N (Figure 5.2).

5.3 Sampling Strategy, Gear and Procedures

A manual for the conduct of egg surveys, targeted at the AEPM, is given in Section 8 of the Report of the Mackerel/Horse Mackerel Egg Production Workshop (ICES, 1994). The instructions given there are repeated in the following Sections 5.3.1 to 5.3.8. Any alterations from the 1994-Report, changes, additions or clarifications, have been underlined in this report.

5.3.1 Sampling Gear

The standard samplers acceptable for use on the 2001 surveys are national variants of the Gulf III or towed Bongo samplers. The Gulf III sampler is deployed on a double oblique tow, at 5 knots, from the surface to sampling depth and return, and the Bongo sampler at 2-3 knots. The aim is for an even, not stepped, dive profile filtering the same volume of water from each depth band. The towing speed is 4.5-5 knots for the Gulf sampler and 2-3 knots for the Bongo.

Although a mesh size of 500 micron aperture is adequate for sampling mackerel and horse mackerel eggs, a nylon mesh with an aperture between 250 and 280 microns is the recommended size for these surveys. This allows the plankton samples to be more widely used for investigations on other species and taxa. If serious clogging occurs then a change to a 500 micron aperture mesh can be made (this change has only rarely been made on any of the surveys).

<u>The aperture on the Gulf III type sampler should be 20 cm in diameter in order to ensure that an adequate volume of water is filtered to quantitatively sample the eggs of other species, in particular hake, which may be present at lower densities than the target species. The aperture of the Bongo samplers should be either 40 cm or 60 cm diameter.</u>

5.3.2 Target Species

The sampling programme for 2001 will be targeted at mackerel and horse mackerel. An egg production estimate will be calculated for both species in both areas. In addition, an egg production estimate for mackerel will be calculated for the combined North East Atlantic area.

5.3.3 Standard Sampling Area

Changes to the standard sampling area for 2001 are defined and described in section 5.2 of this report. Additional rectangles have been added to the standard area as a result of the changes in the distribution of mackerel and horse mackerel eggs noted in the 1998 survey (Fig. 5.2).

5.3.4 Sampling Strategy

The sampling strategy in the western and southern areas in 1998 will be targeted at the AEPM only. From analyses of 1992 egg survey data presented to the 1994 Egg Production Workshop (ICES, 1994) and from knowledge of previous years distributions, it is clear that egg distributions in all survey periods conform to a characteristic spatial pattern which can be modelled. These analyses indicate that changes in the distribution of sampling effort, coupled with the use of a model based approach, could lead to significant improvements in estimates of egg production in future. From the point of view of sampling effort the analysis indicated that two important factors needed to be considered when planning the survey strategy.

Firstly, a set of rules must be established in order to decide when to stop sampling along a given transect, in order to ensure that the whole area of egg distribution is sampled with no effort wasted outside the spawning area.

Secondly, some guide-lines need to be provided to cruise leaders on the number and spacing of transects which may be omitted in order to best match available effort to the size of the area to be surveyed. This approach was adopted for the 1995 and 1998 surveys and it is proposed that the same flexible approach be adopted for the 2001 surveys. This will permit an alternative analysis of the data set using a GAM as discussed in Chapter 4.

As a first guide to planning the distribution of sampling effort in the western and southern areas in 2001, historic egg distributions are provided in Figures 5.1.1a-f for mackerel and 6.1.1a-d for horse mackerel in ICES (1999). The core distributional areas, identified for each of the different sampling periods, should always be sampled to the north/south and east/west limits although individual transects may be omitted. When sampling along transects, shipboard enumeration of results should be undertaken several rectangles before the limit of the core area is reached. Sampling should be completed either after one zero (or near zero) value or two consecutive low values, *i.e.* less than about 20 stage I eggs of either species are present in the sample. In practice eggs do not become visible until an hour or so after fixation – roughly the steaming time between stations – so that one extra station after a zero or 2 low values will always be necessary before steaming to the next transect. In some cases it will be necessary to sample beyond the core area limits and even beyond the standard survey area limits.

With regard to the spacing and omission of sampling transects this will depend on the size of the area to be covered and the amount of ship time available. During periods when several ships are available it should be possible to sample all transects while at other times it may be necessary to omit several, at least during the first pass over the designated sampling area. No more than three consecutive transects should ever be omitted. Given that the area to be covered is more or less known, as is ship time, cruise leader should be able to estimate fairly accurately the number of the full transects they will be able to make. **It is strongly recommended that, where practical, and even where total coverage is expected, a first pass over the area be made on alternate transects. The intervening transect should be sampled on the return leg**. In this way weather problems, equipment failure and vessel breakdown need not seriously prejudice results. Such a strategy, furthermore, enables better evaluation of distributional change with time which is likely to be important in modelling the results. An example of an appropriate sampling strategy where one in three transects is fully sampled is given in Figure 6.16 in ICES (1994).

A flexible approach will again be adopted to replicate sampling within a rectangle. Additional sampling should be carried out in areas where high densities of either mackerel or horse mackerel eggs can be expected. As guidance to the areas where high densities are likely to occur, cruise leaders should refer to the charts showing the maximum contribution to egg production of either species in each time period in the previous reports of this WG. In order to improve spatial resolution, replicate samples within a rectangle should not be taken in the centre of those rectangles but should be evenly spaced in an east-west direction.

5.3.5 Sampling Depth

Maximum sampling depth is to **200m** or to within **2m of the bottom** where the bottom is less than 200m. In the presence of a thermocline greater than **2.5°C in 10m depth**, sampling can be confined to a maximum depth of **20m below the base of the thermocline**.

Some research about the relation between the sampling depth and other covariates like bottom depth and filtered volume has been carried out within the EC project 97/097 "Evaluation and development of spatio-temporal models and survey designs for efficient assessment of mackerel and horse mackerel". As a result, some possible problems related to the depth measurements have been found for the 1992. These problems are shown by a large range of filtered volumes for depths of approximately 200m, and also by a large number of samples taken with exactly 200 meters maximum depth. Similar features, although less marked, can be observed in the 1995 survey. The high frequency of samples taken at exactly the recommended maximum depth can only be achieved by vessels with automatic devices controlling the sampling depth of the gear (like the German vessel) or by vessels with real-time bathymeters. Otherwise, these features can indicate some bias in the depth measures. As a results, and because depth is an important parameter to calculate egg densities, the working group recommends the depth measurements to be taken more carefully, and also to carry exploratory analysis of the data related to the net deployment in order to detect possible problems.

5.3.6 Sample Fixation

The standard fixative for use on these surveys is a 4% solution of buffered formaldehyde in either distilled or freshwater. This solution is approximately iso-osmotic with sea water and should be used in preference to a 4% formaldehyde solution in sea water in order to minimise the problem of distortion. The sample should be directly fixed with the addition of the 4% formaldehyde solution and should not come into contact with formaldehyde strength in excess of 4%.

The 4% solution should be made up as follows; 40 % formaldehyde as purchased, 1 part; distilled or freshwater, 9 parts, plus an appropriate buffer to pH 7-8.

The volume of plankton in the sample jar must never exceed 50% of the volume of the jar. Excess sample should be fixed separately in additional jars. Details of an alternative fixative, giving better definition of egg development stage, for a more precise estimate of elapsed time since spawning, were given in ICES (1988). That fixative is ethanol (95%), 9.5 parts; formalin (10%), 1 part; glacial acetic acid, 0.5 parts.

5.3.7 Sample Sorting, Egg Identification, Staging and Ageing

Whenever practicable the whole sample should be sorted in order to remove all the eggs of non target species such as hake and sardine, which may be present in lower densities than the target species. All sorted eggs should be kept in tubes, in fixative, inside the sample container for future reference and use. Only the eggs of mackerel and horse mackerel need be identified to species. A minimum of 100 eggs of each of the target species must be staged from the sorted sample or sub-sample.

To be able to reconstruct the sub-sampling of the individual samples of all cruises, it is recommended to use a standard data sheet. This data sheet will be provided by CEFAS and will be circulated to all participants before the survey starts.

The eggs of mackerel should be classified into one of five morphological stages (I, II, III, IV and V) (Lockwood *et al*., 1981) following the development criteria described for plaice (Simpson, 1959). For horse mackerel the description of stages is the same with the exception of stage V which does not exist. Horse mackerel larvae hatch at the end of egg stage IV (Pipe and Walker, 1987).

For the estimation of the daily egg production for both species only the counts of stage I eggs are used. This is recognised as a conservative estimate of the total spawned because some mortality probably occurs during development. However, until there is consistency between all countries in the identification of the other stages (see Section 2.1), the other stages cannot be used for the estimation of total eggs spawned.

To convert abundance of eggs into daily egg production, data on the rate of development is required. For mackerel the relationship between egg development rate and temperature was described by Lockwood *et al*. (1977, 1981). This has been used as the basis for calculating daily egg production of stage I eggs on all the surveys from 1977. For horse

mackerel similar egg development data are given by Pipe and Walker (1987) and have also been used for the calculation of stage I egg production since 1977.

The formula for calculating the age of **stage I mackerel eggs** from the sea temperature (T°C) is

$$\text{Log}_e \text{ time (hours)} = -1.61 \log_e (T°C) + 7.76$$

For calculating the age of **stage I horse mackerel eggs** the formula is:

$$\text{Log}_e \text{ time (hours)} = -1.608 \log_e (T°C) + 7.713$$

When available the temperature at 20 m depth should be used for the calculation of egg stage duration. If that is not available then the sub-surface temperature (ca. 3m) should be used.

5.3.8 Rectangle Sampling

The protocol is a s follows. In order to qualify for an interpolated value an unsampled rectangle must have a minimum of two sampled rectangles immediately adjacent to it. Once qualified the sample values of all surrounding rectangles, both immediately adjacent and diagonally adjacent, are used to calculate the interpolated value. The interpolated value is the arithmetic mean of all those surrounding rectangles.

Once calculated, interpolated values are not used in order to calculate values for other unsampled rectangles, or to qualify those rectangles for interpolation. No values are to be extrapolated outside the sampled area.

On some occasions, and in particular where multiple observations are made within a rectangle, for example the CALVET net sampling by Spain, sampling positions may fall on a dividing line between rectangles. When this occurs the sample is allocated to the rectangle to the north of the line of latitude and to the west line on longitude.

5.4 Biological Sampling for Fecundity, Atresia and Maturity (referring to TOR "b,c)")

5.4.1 Definition of Terms

Table 5.4.1.1 Definition of terms

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; used 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
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)

5.4.2 Sampling for Fecundity

The 1999 WGMHSA recommended (TOR d) that fecundity sampling for both species should be based on weight rather than length sampling targets (Darby WD in ICES 2000) and collected over a wide part of the spawning area. They also expressed the view that sampling should be greater in numerical terms. In response to this the sampling strategy below has been designed for each species, mackerel and horse mackerel. Consequential to this it will be necessary to persuade more countries to participate in the analysis of the additional samples collected. To facilitate their participation a training course will be organised in Lowestoft following the mackerel and horse mackerel egg identification course in November 2000. Also some rationalisation of the sampling is proposed by reducing the sampling for horse mackerel atresia because the potential fecundity correction was less than 1%. It was also agreed that an estimate of residual fecundity was not required in each sample collected for atresia.

The temporal trend in fecundity estimated in the Western horse mackerel was not consistent with a determinate spawning strategy because the potential fecundity was lower (nearly two fold) than residual fecundity determined in fish collected for atresia analysis (ICES, 1999). The oocyte frequency distribution in the fish collected for estimation of potential fecundity was also more like a fish that had commenced the batch production process. Part of the explanation may lie in the screening method used to reject spawning fish because the batch interval is long (possibly 8 days) compared to the combined duration of both POF, migratory nucleus and hyaline stages. Under these circumstances these structures would not always indicate recent batch production and the start of spawning. It is therefore necessary to investigate the temporal changes in potential fecundity from January to March in order to optimise when to take samples for fecundity. The aim should be to identify the period when recruitment of previtellogenic oocytes has finished but before the start of spawning (Greer Walker *et al.* (1994) studies on mackerel). The Netherlands and Ireland will collect horse mackerel fecundity samples over a period from January to April 2000 to study this process and may recommend modification to the sampling strategy in this report. Germany will try to provide a driver to move fecundity and atresia samples from the 2001 survey between Germany, Netherlands, England, Scotland and Norway. CEFAS will arrange carriage of horse mackerel samples to Ireland.

The WGMEGS proposes to investigate a new method for estimation of fecundity in both species. The special advantages are:

- Discontinuing the use of a highly toxic fixative containing mercuric chloride (mackerel fecundity analysis only) to lessen the environmental impact of this work.
- A saving of at least 50% analysis time.
- The possibility of automating the analysis of fecundity determination by the use of image analysis.

The method is based on measurements of ovary weight and mean oocyte volume to calculate fecundity. Evaluation will be presented by England (for mackerel) and the Netherlands (for horse mackerel) at the 2002 WGMEGS meeting.

5.4.3 Sampling for Potential Fecundity

Mackerel

Western area

Ovary samples for estimation of potential fecundity will be collected by England on the CEFAS western Channel Groundfish Survey (from 47° to 52°N in March) and by Germany (from 52° to 60°N weeks 12-13 in March). FRS, CEFAS and hopefully Norway will each screen a minimum of 133 samples from these collections although it is expected that at least one third will be rejected from the gravimetric analysis.

Southern area

Spain and Germany will collect samples during their survey in weeks 12 to 16 and Spain will undertake the analysis to estimate potential fecundity.

Western and Southern areas

A total of 200 females should be collected by both England and Germany (Western) and Spain and Germany (Southern) from a minimum of 10 stations spread along the 200 m depth contour. This equates to 20 fish per station and they

should also be divided equally amongst 4 weight categories as below. CEFAS will investigate the possibility to circulate 10 gravimetric samples amongst participants before the general analysis starts.

Weight category [g]	<250	251 – 400	401-550	>551	Total
Number of fish	5	5	5	5	20

Sample jars of 250 ml capacity should be pre-filled at the laboratory, close to half full, to a standard weight with either 0.1M phosphate buffered pH 7.0 4% formaldehyde and another one with GILSON fixative (Simpson, 1951). A wide neck (>50mm) plastic jar should be used that has proven leak proof capabilities such as one supplied by SURGIPATH EUROPE. Only fish in late pre-spawning stage 3 should be collected (Walsh *et al.*, 1990). Ovaries should be weighed (if shipboard weighing facilities have a resolution of +/- 0.1g) and carefully dissected out of the fish. One ovary should be placed intact in buffered formaldehyde and the other split along its longest axis and placed in GILSON'S fluid (minimum 2x ovary volume). Lids should always be tightly screwed up to reduce evaporative loss and eliminate the possibility of spilling the poisonous fixatives during transport.

The ovary fixed in formaldehyde should be weighed and embedded in TECHNOVIT resin (7100) to produce resin sections on slides stained (PAS / Mallory). These slides will be examined to exclude spawning fish from the sample and estimate mean oocyte volume. The other ovary (fixed in GILSON) will be used for gravimetric fecundity analysis (Walsh *et al.*, 1990). Length and weight of each fish should be recorded and otoliths collected for age determination. Results will be presented at the 2002 WGMEGS meeting as in Table 5.4.4.1. Length, weight and maturity should also be collected from random samples of the catch close to 100 mature females on all stations used for collection of samples for fecundity and tabulated as in Table 5.4.4.2.

Horse Mackerel

Western area

Ireland, Germany and the Netherlands should collect a series of samples comprising 80 fish for total fecundity estimation from a minimum of 4 stations at intervals of two weeks from January to April 2001. Ireland and the Netherlands will take an equal share of these samples for the estimation of fecundity.

Southern area

Portugal should collect 160 fish for total fecundity studies during December 2000 and March 2001. Spain will collect 100 fish in January and Germany will collect a further 100 fish in March 2001 from a minimum of 5 stations. Portugal should analyse the samples they collect and Spain should analyse the remainder and also both should consider the issue of temporal changes in fecundity as shown in the Western area during the 1998 triennial survey.

Southern and Western areas

The samples should be collected along the 200 m depth contour and be divided equally amongst 4 weight categories as below. In the extreme south it may not be possible to fill the larger weight class and the 20 fish should be spread over the three smaller groups.

Weight category [g]	<150	151 – 250	251-350	>350	Total
Number of fish	5	5	5	5	20

Only fish in late pre-spawning stage 3 should be collected (Walsh *et al*., 1990). Ovaries should be carefully dissected out of the fish avoiding damage when separating them from the central spine in the body cavity. If the ovary is split during this process the fish and its associated data should not be included in the sample. A fish that appears to be a suitable female (judged by experience) should be carefully dissected, opening the body staring at a dorso-cranial position behind the gill cavity. Moving further backwards the cut should not even destroy the peritoneum. In wide bow in dorso-caudal direction, then eventually turning ventrally, the anus is approached, but should not directly be reached. Then the body cavity can be inspected and the development of the gonads evaluated by lifting the belly flap carefully off the body cavity. If the female appears to be in the appropriate state of maturity, work is continued otherwise the specimen is discarded. In the next step the belly flap is put back into place and the fish turned around to it’s other site where the same cut is applied. In a next step a circular cut is made around the anal spine and the spine being cut off at the inner side. In a next step the peritoneum is carefully opened. Finally both gonads can be lifted and carefully taken

out of the body cavity, both parts being still connected to each other by the tissue around the fragments of the anal spine. As a last step remaining fat tissue and as much tissue around the anal spine should be removed before weighing and preserving.

Both ovaries should be weighed (if shipboard weighing facilities have a resolution of ± 0.1g) and placed in 0.1M phosphate buffered pH7.0 4% formaldehyde (minimum 2x ovary volume). Length and weight of each fish and ovary weight should be recorded and the otoliths removed for age determination. These ovaries will be used to prepare resin (TECHNOVIT 7100) slides stained with heamotoxylin and eosin for histological analysis. Results should be presented at the next WGMHSA meeting as in Table 5.4.4.1.

5.4.4 Sampling for Atresia

Mackerel western and southern area

For the estimation of prevalence and relative intensity of atresia 600 and 300 females respectively in maturity stages 3-6 (Walsh *et al.*, 1990) should be collected along the 200 m contour in the western and southern areas. As in the fecundity analysis the samples should be spread across the weight categories as shown above with a limit of 20 fish per station. The coordinator will circulate positions of these stations allocated to the participating ships when details of each ship's coverage has been resolved. England, Scotland and hopefully Norway will all share the work in the analysis of these samples. It is recommended that a midwater trawl, fished close to the surface in the dark or fished close to the bottom during day light, is used to sample the population along the north-south axis of the egg survey area, close to the 200 metre contour along the shelf edge. Ovaries should be dissected out without damage to the outer wall of the ovary and fixed in a minimum of two volumes of 4% formaldehyde, 0.1M phosphate buffered to pH 7, for subsequent histological analysis. These will be used for the preparation of resin (TECHNOVIT 7100) slides for histological analysis. It is only necessary to estimate the prevalence and intensity of atresia and not residual fecundity for all fish collected for the analysis of atresia. Only fish in spawning condition (histological markers include presence of migratory nuclei, hydrated oocytes and post ovulatory follicles) should be included in this selection. Length, weight and maturity should be collected from random samples of the catch at each station for approximately 100 mature females on all stations used for collection of samples for atresia and tabulated as in Table 5.4.4.2. The atresia results should be presented in the format given in Table 5.4.4.3 and presented at the next meeting of WGMEGS. **It is recommended that ten slides are circulated by CEFAS at the beginning of 2001 to check the interpretation and estimation criteria before the general work commences.**

Horse mackerel western and southern area

In view of the low atresia, as a proportion of the potential fecundity and the small reduction in realised fecundity, it was agreed that atresia sampling would not be undertaken in 2001. The effort would be better diverted to increasing the coverage of fecundity sampling. However length, weight and maturity should be collected from random samples of the catch at each station for close to 100 mature females on all stations used for collection of samples for atresia and tabulated as in Table 5.4.4.3. The coordinator will circulate positions of these stations allocated to the participating ships when details of each ship's coverage have been resolved.

Table 5.4.4.1 Details required for samples collected to estimate potential fecundity

Country	Position		Weight Class	Fish Length (mm)	Fish Weight (g)	Ovary[1] Weight (g)	Age Years	Mean [2] Oocyte volume (mm^3)	POF (Y/N)	Fecundity
	Lat	Long								

[1]Total ovary weight is determined directly if ship board weighing has a resolution of ± 0.1g or calculated by doubling the weight of the ovary fixed in formaldehyde. The method should be indicated in a table footnote.

Table 5.4.4.2 Population weight frequency distribution from random samples of mature female mackerel collected during the 2001 triennial surveys to be tabulated by area

Sample position		Date	Period	Population Weight / frequency distribution								
				<250g		251 – 400		401-550		>551		
				Mean weight	Freq-uency	Mean weight	Freq-uency	Mean weight	Freq-uency	Mean weight	Freq-uency	Total number

Table 5.4.4.3 Population weight frequency distribution from random samples of mature female horse mackerel collected during the 2001 triennial surveys to be tabulated by area

Sample position		Date	Period	Population Weight / frequency distribution								
				<150g		151 – 250		251-350		>350		
				Mean weight	Freq-uency	Mean weight	Freq-uency	Mean weight	Freq-uency	Mean weight	Freq-uency	Total number

Table 5.4.4.4 Details of the mackerel collection to estimate relative atresia collected during the 2001 triennial surveys to be tabulated by period and area

Ship	Weight class	Date	Position		Total weight (g)	Ovary weight (g)[1]	Length (mm)	Age	Alpha atresia[2]
			Lat	Long					

[1]*Indicate in a table foot note the method of determining ovary weight*

[2] *Calculate the prevalence and geometric mean relative intensity of alpha atresia at the bottom of the column by weight class. Count the number of fish included.*

5.4.5 Sampling for Maturity at Age

All information on the maturity at age for both mackerel and horse mackerel became only available after the meeting of this Working Group in April 1999. At that meeting it was recommended that the results should be presented as working documents at the September 1999 meeting of the Working Group on the Assessment of Mackerel, Horse Mackerel, Horse Mackerel, Sardine and Anchovy (ICES, 2000). These results are now also reported in section 6.2 in this report as in agreement with terms of reference 'e'.

The maturity data have extensively been discussed at the 1999 Working Group on the Assessment of Mackerel, Horse Mackerel, Horse Mackerel, Sardine and Anchovy (ICES, 2000). For western horse mackerel in section 6.4.3, for horse mackerel from Division VIIIc in section 7.3.3 and for North East Atlantic mackerel in section 2.4.4 of the ICES (2000) report.

The difficulties in estimating maturity at age have extensively been described in this report (see section 6.2) and ICES (2000). This Working Group regarded it as an impossible task to estimate maturity at age accurately during the egg surveys, when the main priority should be given to the plankton sampling and biological sampling for fecundity and atresia. Therefore no planning is carried out for the maturity sampling during the 2001 egg surveys.

5.5 Data analysis

To convert the number of eggs in each sample or subsample to the number of eggs per m^2, the following calculations are made. Firstly the volume of sea water filtered by the sampler during the haul is calculated.

$$\text{Volume filtered } (m^3) = \frac{\text{Flowm-revs x Aperture}}{\text{Flowm-calib}} \times \text{Efficiency Factor}$$

The number of egg m^{-2} is calculated from the formula:

$$\text{Eggs}/m^2 = \frac{\text{Eggs counted x Factor}}{\text{Volume Filtered } (m^2)} \times \text{Depth Sampled}$$

Where:

Flowm-revs.	=	Number of revolutions of the flow meter during tow
Aperture	=	The area of the mouth opening of the sampler in m^2
Flowm-calib.	=	The number of flow meter revolutions per metre towed, obtained from the flume or sea calibration in free flow
Eggs counted	=	Number of eggs in sub-sample

Factor	=	Raising factor from the sub-sample to the whole sample
Depth Sampled	=	The maximum depth of the sampler during the tow in metres
Efficiency Factor	=	The sampler efficiency from flume or towing tank calibration

Numbers of eggs per m^2 are raised to number per m^2 per day using development equation for both species in the following way:

For stage I **mackerel** eggs:

$$\text{Eggs/m}^2\text{/day} = 24 \times \text{Eggs/m}^2 \ / \ \exp[-1.61 \log_e (T°C) + 7.76]$$

For stage I **horse mackerel** eggs:

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

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

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

The next stages in the estimation of annual egg production are:

- Estimating the daily egg production for each survey period in turn
- Integrating the daily egg production histogram, to give annual egg production
- Calculating the variance of the estimate of annual egg production

The method was modified for use in the analysis of the 1995 survey data. It is fully described in section 5.3.3 of the report of those surveys (ICES, 1996b). The same methods used for these analyses will be used for the analysis of the 2001 survey data.

5.6 Co-ordination, Communication, Deadline, Reporting

The co-ordinator of the 2001 western egg survey will be Cornelius Hammer, Fed. Res. Centre for Fisheries, Palmaille 9, 22767 Hamburg, Germany.

The co-ordinator of the 1998 southern egg survey will be Alberto Murta, IPIMAR, Avenida Brasila, 1400 Lisboa, Portugal.

Participants who will be surveying during the same time period, should contact each other prior to their cruises to co-ordinate strategies and areas of overlap if any. Co-ordinators will obtain and provide details of vessels communication systems for use in maintaining regular contact during surveys. Contact with cruise leaders from the previous survey is also recommended to give prior indication of any distributional abnormalities.

Data input forms for the survey results and charts showing the proposed trawling positions for sampling maturity will be despatched to all participants by the area-coordinators after the meeting of WGMHSA in September 2000.

The co-ordinator of the western egg survey data base will be Dave Reid, Marine Laboratory, P.O. Box 101, Victoria Rd., Aberdeen AB9 8DB, Scotland, UK.

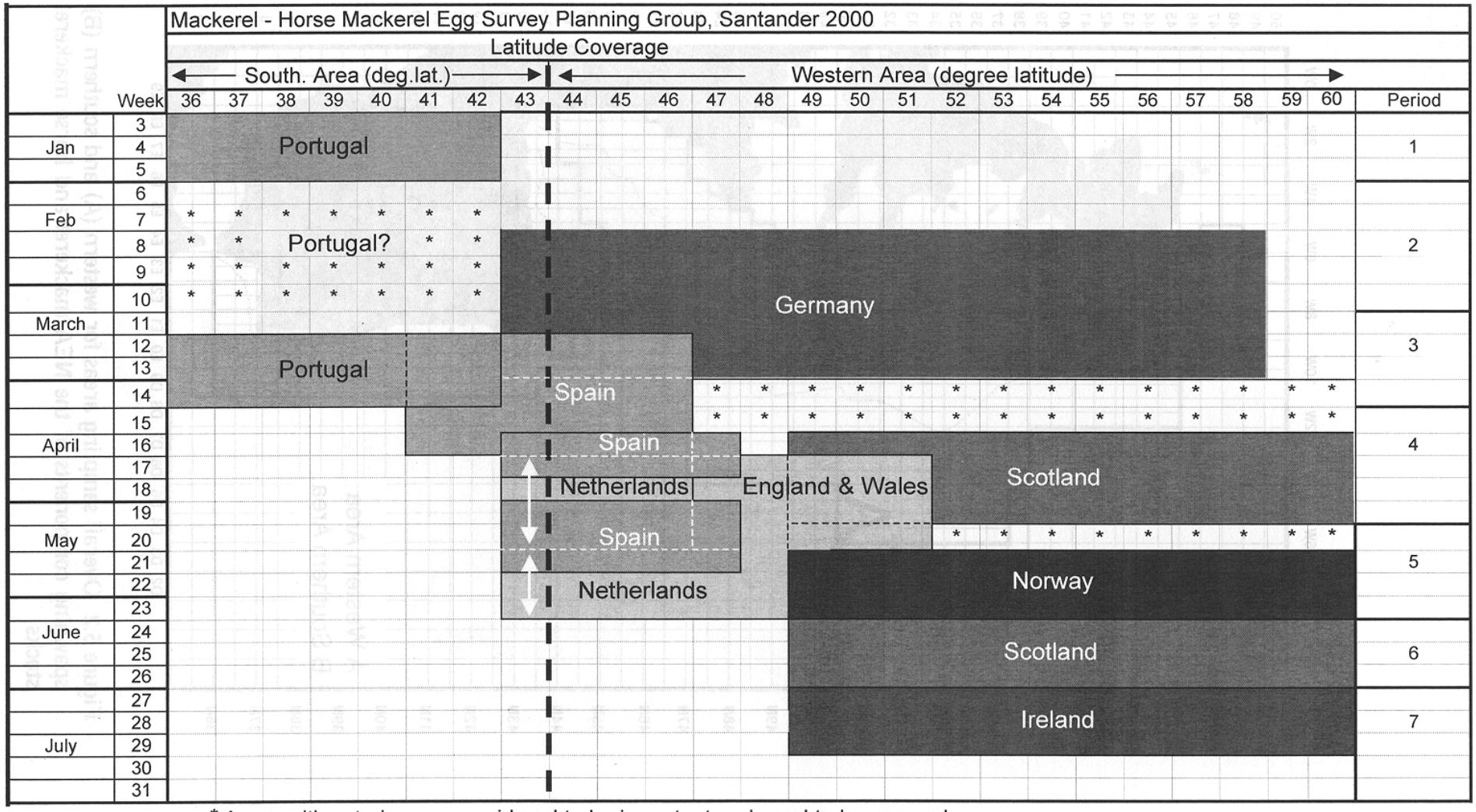
The co-ordinator of the southern egg survey data base will be Concha Franco, IEO, Avda. Del Brasil, 1449-006 Lisbon, Portugal.

The two co-ordinators of the egg survey data bases (D. Reid and C. Franco) will be responsible for loading data onto the database, checking their validity and estimating stage I densities. The data base will be available to all participants in the survey.

01 September 2001 is the requested date for sending egg survey results of both mackerel and horse mackerel to the egg survey data base co-ordinators.

The deadline for the analysis of all the samples and data relating to the adult parameters, collected during the 2001 surveys, is 15 March 2002.

The next meeting of the ICES Working Group on Mackerel and Horse Mackerel Egg Surveys is proposed to be held from 16 – 20 April 2002, in Dublin.



* Areas with asterics are considered to be important and need to be covered

Fig. 5.1 Mackerel Horse Mackerel Egg Survey 2001, Survey Schedule

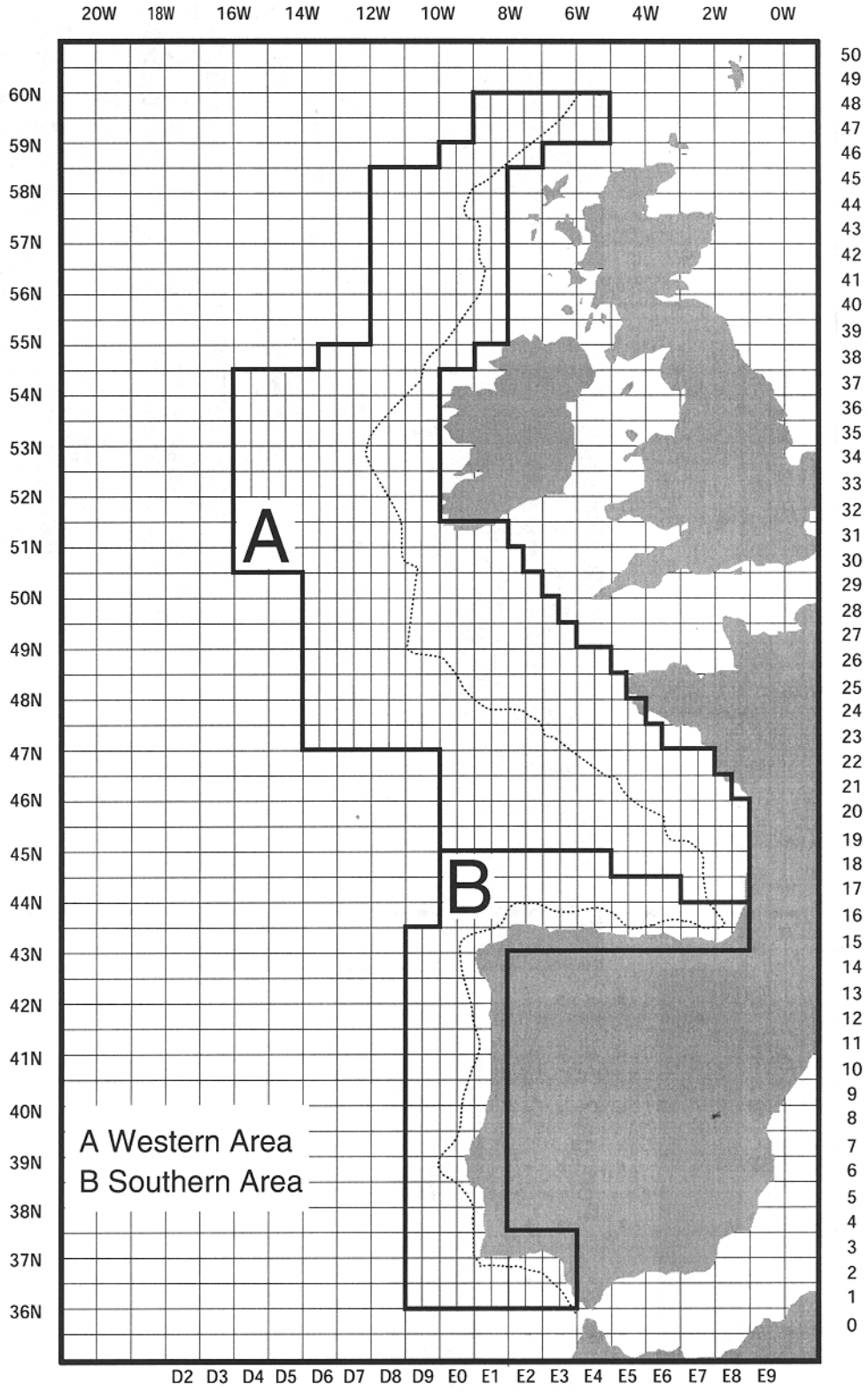


Figure 5.2 Overall sampling areas for western (A) and southern (B) spawning components of the NEA mackerel and horse mackerel stocks

6 REVIEWS AND RE-EXAMINATION OF DATA FROM THE 1998-SURVEY

6.1 Review of Mackerel Atresia and Fecundity Data from the Western Area in 1998 (referring to TOR "d")

The 1999 WGMHSA recommended a review of all the 1998 mackerel maturity, fecundity and atresia data from samples collected in the western area. In all these analyses the sampling collection was not adequate with regard to temporal and spatial coverage but for the most part all these samples were analysed. However the analysis of some atresia samples collected in the North of the western area by Scotland are still outstanding with respect to the intensity of atresia. If this analysis was completed it would almost double the range of temporal and spatial coverage. The WGMEGS recommends this work is completed for the 2000 WGMHSA meeting.

6.2 Review of Information on Maturity, Fecundity and Atresia for Mackerel and Horse Mackerel Analysed Since WGMEGS Meeting in April 1999 (referring to TOR "e")

This section deals with the "Review all information on maturity, fecundity and atresia for both mackerel and horse mackerel, analysed since the last meeting of WGMEGS" in April 1999. This information will be reviewed for mackerel is Section 6.2.1 and for horse mackerel in Section 6.2.2.

6.2.1 Mackerel: Review of Information on Maturity, Fecundity and Atresia

Mackerel Western Area

No new information became available since the last meeting of this Working Group (April 1999), as insufficient maturity samples were collected during the 1998 egg survey.

Mackerel Southern Area

No new information became available on fecundity and atresia, but the following information became available on maturity.

Following the recommendations of Mackerel, Horse Mackerel, Sardine and Anchovy 1996 Working Group (ICES, 1997a) an estimation of the maturity ogive in 1998 was estimated for the Northeast Atlantic mackerel females from the Southern area. These estimations were based on histological and macroscopical analyses (Perez, Villamor and Abaunza, 1999).

IEO (Spain) took maturity samples in the juvenile and adult areas of Division VIIIc and IXa North, around peak spawning time in March 1998 from trawl catches during the acoustic survey by R/V Thalassa. This was done in accordance with the sampling strategy established at the WGMEGS (ICES, 1997b).

Figure 6.2.1 shows the percentage mature, resorbing and immature mackerel at age for the whole area. The explanation of these stages is given in the text table below:

Fish were classified as **mature** if ovaries contained:

Large viable vitellogenic oocytes >425µm
Hydrated oocytes
Post Ovulatory Follicles (POF's)

Fish were classified as **resorbing** if ovaries contained:

No oocytes > 425 µm
100% atresia in oocytes <425µm

Fish were classified as **immature** if ovaries contained:

Only previtellogenic oocytes (<165µm) in sections
Ovaries weigh <2g mackerel and 1g horse mackerel

High numbers of immature fish are observed in age groups 1 and 2 (Figure 6.2.1). The proportion of fish with ovaries in which the vitellogenic oocytes are resorbed is high for ages 2 and 3, and remains high at age 10.

Figure 6.2.2 compares the proportions of maturity at age obtained macroscopically, microscopically and that used in the ICES Working Group without applying the logistic model. An overestimation is seen in maturity of the macroscopic ogive and that used in the ICES WG for ages 1 to 3 with respect to the maturity obtained microscopically.

The logistic model fits to the maturity data perfectly, obtaining R^2 equal to 100% in the ogives estimated using macroscopic and microscopic criteria. When comparing both ogives with that used in the Working Group (Figure 6.2.3), a good agreement is observed with the macroscopic ogive, and an overestimation of maturity results from the microscopic ogive for the age range below 5 years.

In a view of these results, the 1999 Working Group on asssessment on mackerel, horse mackerel, sardine and anchovy (ICES, 2000) changed the southern maturity ogive used in the assessment by the maturity ogive based on histological analysis. This Working Group set the proportion mature for ages 4-6 to 1.00, because spent fish with only atretic oocytes have been classed to resorbing stage in the histological analysis.

6.2.2 Horse Mackerel: Review of Information on Atresia and Maturity

Fecundity

No new information is available on fecundity.

Atresia

The histological slides of the 1998 atresia samples were prepared, but the scoring, staging and measuring of the histological slides of horse mackerel ovaries were not carried out in time before the meeting of the Mackerel / Horse Mackerel Egg Survey Working Group, which met in April 1999 in Hamburg (ICES, 1999). Therefore this information on the atresia analysis is presented at this meeting.

The planning of the sampling for atresia is described in the report of the ICES Working Group on Mackerel and Horse Mackerel Egg Surveys (ICES, 1997b). During each period 90 ovaries of randomly selected adult females should be collected.

Table 6.2.2.1 shows which countries collected the ovaries for the atresia analysis in periods 3–6. The total number of ovaries by period used in the analysis is listed in this table as the number of fish for scoring atresia. The prevalence of atresia indicates what percentage of fish actually showed signs of atresia. The number of fish, which actually have atresia in their ovaries, are indicated as the number of fish with atresia. By period the geometric mean is calculated of the number of atretic oocytes per gram female fish, which have atresia in their ovaries.

Table 6.2.2.2 shows the prevalence by period, the number of fish for scoring prevalence, the number of atretic oocytes per gram female and the number of fish for counting atresia. The number of atretic oocytes per gram female in the population is calculated by taking into account the prevalence of atresia. A mean number of 4 atretic oocytes per gram female in the population was calculated for the periods 3–6 in 1998. This is much lower than the 12 atretic oocytes per gram female in the population for the 1995 egg survey (ICES, 1996a). The relative intensity of atresia, expressed in percentage, is the number of atretic oocytes per gram female in the population divided by to the total fecundity of 1557 eggs per gram female, which total fecundity was used in the earlier egg surveys (ICES, 1999). A relative intensity of atresia of 0.3% indicates that the potential fecundity is hardly reduced by atresia and that the realised fecundity is very close to the potential fecundity as estimated at the start of the spawning season.

Maturity

The histological slides of the 1998 maturity samples were prepared, but the scoring, staging and measuring of the histological slides of horse mackerel ovaries was not carried out in time before the meeting of the Mackerel / Horse Mackerel Egg Survey Working Group, which met in April 1999 in Hamburg. Therefore the results of the maturity analysis is presented at this meeting.

The planning of the sampling for maturity is described in report of the ICES Working Group on Mackerel and Horse Mackerel Egg Surveys (ICES, 1997b). This report shows the proposed trawl sampling areas for collecting horse mackerel for the estimation of the proportion mature at age. A total of 14 trawl hauls should be carried out around peak spawning time and 100 ovaries should be collected randomly from both juvenile and adult females. The ovaries were preserved in 4% buffered formalin and sent to RIVO-DLO in the Netherlands for the preparation of histological slides.

Table 6.2.2.1 Sampling for maturity in 1998 for western horse mackerel

	Country	Sample number	Collection date	ICES rectangle	Ovaries collected
1	Netherlands	540	21/05/98	22E6	100
2	Netherlands	541	21/05/98	21E6	100
3	Netherlands	542	25/05/98	23E5	100
4	Netherlands	543	25/05/98	23E4	100
5	Scotland	307	29/06/98	28D9	100
6	Scotland	308	30/06/98	30D9	100
7	Scotland	311	30/07/98	36D6	100
8	England	001	06/06/98	25E1	100
9	England	002	07/06/98	25E4	100
10	England	003	25/06/98	25E3	100
11	England	004	26/06/98	26E0	100
12	England	005	27/06/98	28E5	100
13	AZTI-Thalassa	228	29/05/98	20E7	93 *
14	AZTI-Thalassa	245	01/06/98	20E6	100 *

** could not be used due to insufficient preservation*

- Fish were classified as mature if ovaries contained:

  Large viable vitellogenic oocytes >425µm
  Hydrated oocytes
  Post Ovulatory Follicles (POF's)

- Fish were classified as **resorbing** if ovaries contained:

  No oocytes >425µm
  100% atresia in oocytes <425µm.

- Fish were classified as **immature** if ovaries contained:

  Only previtellogenic oocytes (<165µm) in sections
  Ovaries weigh < 2g mackerel and 1g horse mackerel.

The total egg production is converted into spawning stock biomass. Therefore the maturity ogive should be based on only female fish, which really produce eggs. The stage resorbing is introduced to exclude young female fish from being mature, if these fish resorb all vitellogenic oocytes and do not produce any eggs. There is no macroscopic classification to identify resorbing fish that outwardly appear mature but are atretic and aborting maturation.

Figure **6.2.2.4** shows the number / percentage of mature, resorbing and immature horse mackerel by ICES rectangle. The western Channel (rectangle 28E5) is a very evident juvenile area and to a lesser extent the area west of Brittany (25E4 and 25E3) and an even much lesser extent the area south-west of Brittany (23E5 and 23E4).

Figure **6.2.2.5** shows the number / percentage of mature, resorbing and immature horse mackerel by age group. Age 3 (year class 1995) is the most abundant age group followed by respectively age 4 (year class 1994) and age 2 (year class 1996). High numbers of immature fish are observed in age groups 2 and 3. The proportion of fish, having ovaries in which the vitellogenic oocytes are resorbed, is high for ages 2 and 3, but still high for ages 7 to 12. The high percentage resorbing for these older fish is due to the fact that spent ovaries with no oocytes larger than 425µm and 100% atresia in the smaller oocytes are scored as resorbing, while spent fish in principle should have been scored as mature! It is assumed that 6-year and older fish are spent fish, if they are classified as resorbing.

Table 6.2.2.2 Proportion of mature fish at age for all samples combined, for the juvenile (28E5) and the adult area (36D6, 30D9, 28D9, 26E0, 25E1, 23E4 and 21E6)

AGE	**Mean** value of proportion mature (%) as obtained from all samples	**Minimum** value of proportion mature (%) as obtained from juvenile area (28 E5)	**Maximum** value of proportion mature (%) as obtained from rectangles along the continental shelf	**Guessed** value of proportion mature (%) taking into account the relative distribution by age group
1	-	-	-	0%
2	53% (n=139)	3% (n=36)	90% (n=31)	30%
3	67% (n=354)	2% (n=60)	85% (n=136)	60%
4	90% (n=174)	-	93% (n=116)	90%
5	97% (n=103)	-	99% (n=83)	97%
6	88% (n=58)	-	89% (n=44)	100%
7	83% (n=53)	-	85% (n=39)	100%
8	84% (n=44)	-	79% (n=28)	100%
9	94% (n=50)	-	95% (n=37)	100%
10	88% (n=34)	-	85% (n=26)	100%
11	90% (n=30)	-	91% (n=23)	100%
12	92% (n=25)	-	95% (n=21)	100%
13	98% (n=43)	-	98% (n=41)	100%
14	100% (n=26)	-	100% (n=25)	100%
15+	100% (n=39)	-	100% (n=32)	100%

The mean proportion mature at age as shown in Figure 6.2.5 and the text table above is not representing the actual maturity ogive of the western horse mackerel, because these do not include a weighting according to the abundance at age in the juvenile and adult areas. The abundance of 2-year olds is relatively much higher in the juvenile area than in the adult area compared to 3-year olds. The minimum value of proportion mature at age is obtained from samples from the juvenile area (western Channel rectangle 28E5), while the maximum value of proportion mature at age is obtained from samples along the edge of the continental shelf. The actual proportion mature at age of the western horse mackerel is somewhere in between. Only 3% of the 2-year olds are mature in the juvenile area, while 90% are mature in the adult area along the edge of the continental shelf. The actual proportion mature of these 2-year olds is closer to 3% than 90%. If two samples were taken in the juvenile area, the mean proportion mature of 2-year olds would have been much lower.

Only a rough guess can be made about the proportion mature at age of western horse mackerel, because of the absence of a weighting factor by area (the actual distribution at age by rectangle is unknown). Therefore, only a rough guess is presented in the text table above.

Southern Horse Mackerel

Fecundity

As recommended at the Working Group on Mackerel and Horse Mackerel Egg Surveys meeting in April 1999, (ICES, 1999) the Portuguese horse mackerel ovary samples were re-analysed using the "Weibel" method, instead of the method developed by Aberdeen University. A comparison between both methods was made, which clearly showed that much higher and more variable fecundities were obtained with the latter method. The fecundity estimates by the "Weibel" method are also used by other participants of the egg survey, which has be verified with the gravimetric method (Eltink and Vingerhoed, 1989; Emmerson *et al*., 1990). These samples from the southern horse mackerel stock have been re-analysed in order to calculate potential fecundity and its respective variance. Until now, about 30% of the samples were re-analysed of which the results are shown in Table 6.2.3 for both fecundity and atresia. With these fecundity data a preliminary spawning stock biomass for the southern horse mackerel was estimated. Figure 6.2.6 shows fecundity/weight regression lines obtained with both methods, being the histometric correlation coeficient higher than the stereological one.

Table 6.2.3 Portuguese horse mackerel fecundity and atresia

Histometric method

Date	Fish no.	Length (cm)	Weight (g)	Fecundity (Total)	Atresia (Total)	Fecundity (eggs/g)	Atresia/g
Jan. - # 1	5	26.5	137				
Jan. - # 1	11	26.6	136				
Jan. - # 1	28	27.7	162	189558	1173	1170.11	3.67
Jan. - # 1	50	28.9	194				
Jan. - # 1	89	30.5	219				
Jan. - # 2	3	20.5	67				
Jan. - # 2	5	22.9	92	154885		1683.53	
Jan. - # 2	9	22.2	85				
Jan. - # 2	10	23.9	107				
Jan. - # 2	11	23.0	103	120983		1174.60	
Jan. - # 2	13	23.3	100				
Jan. - # 2	14	23.1	110				
Jan. - # 2	23	23.7	107	145458	2132	1359.42	19.92
Jan. - # 2	37	23.5	104	133544		1284.07	
Jan. - # 2	46	23.8	99	106738		1078.16	
Jan. - # 2	51	24.5	104				
Jan. - # 2	54	24.7	116				
Jan. - # 2	66	24.0	110				
Jan. - # 2	71	24.2	113				
Jan. - # 2	72	24.3	103				
Jan. - # 2	73	24.0	100	96799		967.99	
Jan. - # 2	81	24.5	110				
Jan. - # 2	83	24.6	112	198112		1768.86	
Jan. - # 2	89	24.3	117				
Jan. - # 2	97	24.7	116	153935		1327.03	
Jan. - # 2	100	25.7	130	160076		1231.36	
Jan. - # 2	101	25.6	120				
Jan. - # 2	104	25.7	131	183945	3431	1404.16	26.19
Jan. - # 2	107	25.0	110	135016		1227.42	
Jan. - # 2	112	25.5	120				
Jan. - # 2	122	25.0	123				
Jan. - # 2	123	25.1	112				
Jan. - # 2	126	26.3	146	228480		1564.93	
Jan. - # 2	131	28.0	155				
Jan. - # 3	6	24.2	98				
Jan. - # 3	11	25.2	108	141308		1308.41	
Jan. - # 3	17	26.0	122				
Fev. (1)	11	20.3	63				
Fev. (1)	12	20.4	61	111431		1826.73	
Fev. (1)	22	20.9	62				
Fev. (1)	22	20.9	62	80342	122	1295.83	1.96
Fev. (1)	26	20.2	61				

Fev. (1)	30	20.9	65				
Fev. (1)	38	20.6	65				
Fev. (1)	40	20.5	62				
Fev. (1)	46	20.8	66				
Fev. (1)	57	21.4	62	96870	401	1562.42	6.46
Fev. (1)	58	24.2	94	67436		717.40	
Fev. (2)	7	23.6	85				
Fev. (2)	11	24.5	108				
Fev. (2)	16	24.5	104				
Fev. (2)	26	24.5	97				
Fev. (2)	27	24.3	99				
Fev. (2)	31	25.4	109				
Fev. (2)	43	25.4	114	146760		1287.37	
Fev. (2)	43	25.4	114				
Fev. (2)	53	25.6	114				
Fev. (2)	56	25.6	111				
Fev. (2)	63	25.4	107				
Fev. (2)	76	26.1	119				
Fev. (2)	80	26.7	130				
Fev. (2)	82	26.9	131				
Fev. (2)	83	26.4	123				
Fev. (2)	84	26.3	128				
Fev. (2)	87	26.0	120				
Fev. (2)	93	27.9	145				
Fev. (2)	103	27.8	131				
Fev. (2)	104	27.0	117				
Fev. (2)	107	27.3	130				
Fev. (2)	130	28.1	150				
Fev. (2)	135	28.3	146				
Fev. (2)	139	29.2	155				
Fev. (2)	140	29.9	174				
Média		**24.8**	**112**	**139561.9**	**1451.8**	**1328.411**	**11.64**

Atresia

To estimate atresia by the histometric method a random sample of 70 ovaries in spawning condition were collected from the Portuguese coast of which 38 ovaries showed signs of atresia. The mean weight of fish with atresia was 112g. The 12 atretic oocytes per gramme female was estimated in the atretic samples and only 3 atretic oocytes per gramme female in the population (atresia prevalence was 0.26). These results show a very low effect of atresia, when the potential fecundity is corrected for atresia (atresia correction is less than 1% compared to total fecundity).

Maturity

Observations on maturation stages of horse mackerel females in ICES Sub-divisions VIIIc East, VIIIc West and IXa North were analysed to examine relationships between fish size or age and maturity. Histological sections of ovaries and macroscopical criteria were used to describe gonadal development. Age at first maturity was derived by fitting the logistic model to the observed maturity proportions. Analyses were restricted to the samples collected during the Spanish acoustic survey in March 1998.

Table 6.2.4 shows the number of ovaries analysed micro and macroscopically by ICES Sub-Division (Sub-Division IXa North, VIIIc West and VIIIc East) and total area, as well as the length range, mean length, age range and mean age.

Table 6.2.4 number of ovaries analysed macroscopically and microscopically

	ICES sub-Divisions	Ovaries analysed	Length range [cm]	Mean length [cm]	Age range [years]	Mean age [years]
Histological	IXa North	34	29-38	30	5-14	7.6
	VIIIc West	65	27-35	31	4-15	9.7
	VIIIc East	201	19-33	26	2-14	5.6
	Total	300	19-38	29	2-14	7.6
Macroscopic	IXa North	40	29-38	33	5-14	7.9
	VIIIc West	75	27-35	32	4-15	9.4
	VIIIc East	262	18-37	27	1-14	5.9
	Total	377	18-37	28.8	1-15	6.85

The results of the microscopic analysis by age are presented in Figure 6.2.7. It shows the percentage of mature individuals, resorbing and immature horse mackerel at age for the whole area. The higher percentages of immature fish are found at ages 1 to 4, although there is a residual presence up to age 14. The percentage of resorbing is very low, found only in ages 3 and 7.

Figure 6.2.8 compares the proportions of maturity at age obtained macroscopically, microscopically and that used in the ICES Assessment Working Group without applying the logistic model. An overestimation is seen in maturity, particularly in the macroscopic data in comparison with that used in the WG. From ages 1 to 3, good agreement is seen between maturity used in the WG and that obtained microscopically.

The logistic model fits to the maturity data well, obtaining R^2 higher than 95 % in the ogives estimated using macroscopic and microscopic criteria.

The ogive resulting from the application of the macroscopic criteria presents a more abrupt vertical cut/section than the ogive obtained by applying the microscopic criteria, pass from an immature stage to one of maturity in a shorter age interval (Figure 6.2.9). Nevertheless, the mean age at first maturity of both ogives is the same, calculated at 3.5 years. On comparing both ogives with that used in the Assessment Working Group, an underestimation of the maturity proportions is observed in the latter, above all with respect to age ranges over 6 years. The ogive applied in the Assessment Working Group in age ranges below 5 years presents a better agreement with the microscopic ogive.

The possible underestimation of the spawning stock gives rise to a more cautious management of the stock and thus to a reduced risk of overexploitation than in the case of overestimation. On the other hand the ogive applied in the Assessment Working Group may also have reflected a better fit with the reality than now. During recent years the 1982 cohort has had an important presence in catches. This highly abundant cohort, due to denso-dependent phenomena, presents a lower growth and possibly later maturity than would be reflected by the smoother shape of the ogive.

However, the maturity data are not yet fully summarised for the Portuguese area. This Working Group recommends that the combined maturity information (Div. VIIIc and IXa) should become available at the next meeting of the Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy in September 2000.

6.3 Analysis of the Reasons on High Variance of the Estimate of Mackerel Egg Production in the Southern Area in 1998, and it's Implications on the Sampling Strategy (referring to TOR "f")

To estimate 1998´s production of mackerel stage I eggs in the southern area the IEO carried out 2 surveys, one of them in period 3 and the other in period 4. Despite the ICES recommendations to increase the sampling intensity in the southern areas by obtaining multiple samples within each ICES rectangle, only one sample per ICES rectangle was

obtained, due to bad weather conditions. Moreover, in period 4 it was necessary to reduce the sampling area, again due the bad weather, so that the last two rectangles of each row were not sampled.

In both period 3 and 4, a couple of the sampled rectangles showed a high density of mackerel stage I eggs, and due to the reasons explained above, it was not possible to obtain more samples within those rectangles. Those high density values were thus extrapolated to the whole rectangle area, and so they ended up having a large impact in the total egg production estimate for that year, rising it to more than double the one in 1995. Moreover, the existence of these large values rose the estimated standard error of the egg production in periods 3 and 4. This yields an overall increase of the estimated coefficient of variation of the total egg production in the south component.

One of the possible solutions to decrease the variance of the egg production estimate would be to follow the recommendations of the Working group and increase the survey effort in the southern areas, especially in areas were high density of eggs are expected. Nevertheless when the weather conditions are not the appropriate ones, increasing the number of samples while covering the whole sampling area at the same time can be impossible.

6.4 Mackerel Fecundity and Atresia Estimates for the Southern Area from Sampling in 1998 (referring to TOR "g")

The data corresponding to the fecundity and atresia from the mackerel in the southern area (Division VIIIc and Sub-Division IXa North) has been revised. There are no changes from those presented at the 1999 Working Group on Mackerel and Horse Mackerel Egg Surveys (ICES 1999).

Atresia and realised fecundity in the Southern component

To study atresia, a sample of 368 mackerel was collected in periods 3 to 5 (Table 6.4.1). 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 6.4.2). The prevalence was 0.21, the fecundity was 1.171 oocytes g^{-1}. The number of atretic oocytes was $105g^{-1}$ (Table 6.4.2) and the relative intensity of atresia 14.7%.

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 are close to, or a little below the mean size of fish in the Southern fecundity sample. At the WG meeting it was not possible to combine estimates of realised fecundity because the Southern component atresia data was not complete.

Table 6.4.1 Mackerel sample collected from the Southern spawning component to estimate atresia in 1998

Period	Country	Collection dates	Vessel	Area coverage	
2	Portugal	17 Feb - 15 Mar	Noruega	42º09-38º38N	9º15-9º29W
3	Spain	16 Mar - 1 April	*Cornide Saavedra*	43º00-45º00N	1º00-11º00W
3-4	Spain	20 Mar - 26 Mar	*Cornide Saavedra*	42º00-44º30N	1º00-10º00W
3	Spain	28 Mar - 8 April	*Thalassa*	42º39-46º53N	4º41-9º26W
5	Spain	7 May	*Purse Seine*	43º37N	3º42W

Table 6.4.2 The length, weight, residual fecundity and the number of atretic oocytes in Southern mackerel spawning component identified in spawning condition by presence of females in spawning conditions (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
AM	327	408802	AM	63388	GM	105

6.5 Review of the Mackerel Egg Production Estimate for the Southern Area for 1998 (referring to TOR "g")

At the meeting of the WGMHSA in September 1999 (ICES, 2000) the high variance of the mackerel egg production estimate in the southern area was commented on. As a consequence, and in response to TOR (f), the egg production data have been thoroughly reviewed. As a result of that review an error was found in the flow meter data on one station during sampling period 4. The estimate of egg abundance for that period has been corrected resulting in a reduction in the estimate of stage I egg production for period 4 from $8.25*10^{12}$ (s.e 4.8) to $7.30*10^{12}$ (s.e. 4.56) (Table 6.5.1).

Table 6.5.1 Southern 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**	4.40
4	13 April	27 April	20 / 04	**7.30**	4.56
5	15 May	24 May	19-20 /05	**0.12**	0.06
6	15 June	21 June	18 /06	**0.09**	0.06

The total production values for the individual time periods and the interpolated periods after this correction are shown in Table 6.5.2. The revised value for period 4 has resulted in a reduction of 6% in the estimate of total stage I egg production in the southern area from $46.09*10^{13}$ to $43.37*10^{13}$ with a CV of 43.45%. The resultant proportion of stage I egg production in the southern area is reduced by only 1% from the original estimate of 25%.

Table 6.5.2 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
17 January – 31 January	**1**	**15**	**0.24**
1 February – 6 February	*	6	0.06
7 February – 1 March	**2**	**23**	**0.07**
2 March – 13 March	*	12	4.50
14 March – 1 April	**3**	**19**	**13.39**
2 April – 12 April	*	11	7.9
13 April – 27 April	**4**	**15**	**10.95**
28 April – 14 May	*	17	5.79
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**	**43.37**
	Se		**18.84**
	CV		**0.43**

The revised estimate of total spawning stock biomass for the southern area is reduced from 850,200 tonnes to 800,000 tonnes with a CV of 68%. This reduces the estimate of SSB for the North East Atlantic mackerel from 3.80 to 3.75 million tonnes. The proportion of the stock spawning in the southern area is reduced from 22% to 21%. A comparison of this data with the 1995 biomass estimate (378,450 tonnes) shows an increase of 111%.

The daily egg production estimates for each survey period have been plotted against the mid cruise dates to give the production curve (Figure 6.5.1).

6.6 Revised Estimate of the SSB for the Southern Horse Mackerel for 1998 (referring to TOR "g")

The egg prodution estimate was revised using mean values instead the unusual high egg density values for two rectangles in the North Portuguese coast, in period 2, and the distribution map of daily stage I production per m^2 surface are given in Figure 6.6.1.

Revised mean daily stage I egg production and its variance for the six periods are in Table 6.6.1. The correspondent revised daily egg production curve is in Figure 6.6.2. The curve was produced assuming start and finish dates of 17 January and 17 July respectively.

The annual stage I egg production estimates was $17.85*10^{13}$ eggs with a CV of 42.2% (Table 6.6.2).

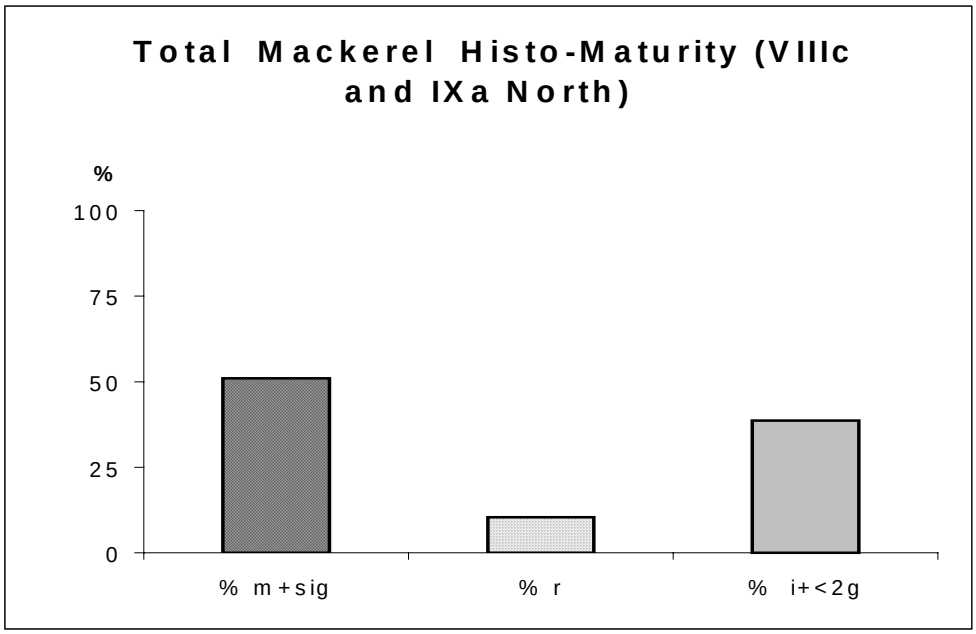
Table 6.6.1 Southern horse mackerel mean daily stage I egg production in 1998 (x 10^{12})

Period	Dates			Production and standard errors	
				Horse Mackerel	
	From	To	Midpoint	Production	Se
1	17 January	31 January	24 / 01	**0.92**	0.43
2	7 February	1March	18 /02	**0.21**	0.56
3	14 March	1 April	23 /03	**0.89**	0.14
4	13 April	27 April	20 / 04	**2.33**	1.83
5	15 May	24 May	19-20 /05	**0.59**	0.42
6	15 June	21 June	18 /06	**1.50**	1.19

As only about 30% of the fecundity data are available from the area between Cadiz and Finisterra (IXa ICES division) it was not possible to have an estimation of the SSB for the Southern horse mackerel.

Table 6.6.2 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	0.37
7 February – 1 March	**2**	**23**	**0.48**
2 March – 13 March	*	12	0.68
14 March – 1 April	**3**	**19**	**1.69**
2 April – 12 April	*	11	1.83
13 April – 27 April	**4**	**15**	**3.49**
28 April – 14 May	*	17	2.36
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**	**17.85**
	Se		**7.77**
	CV		**42.18%**



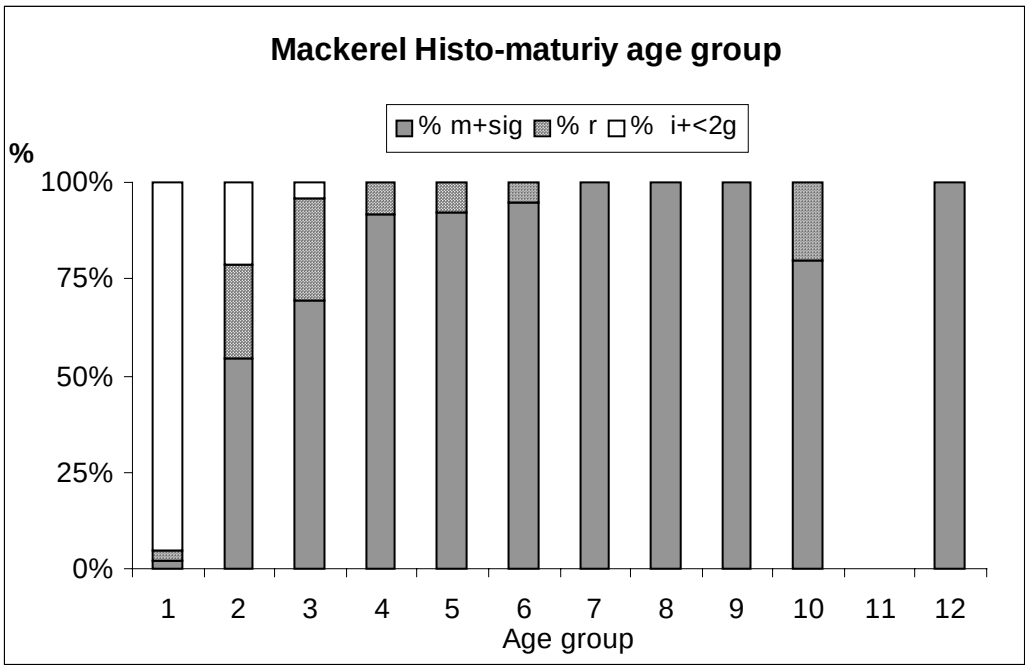
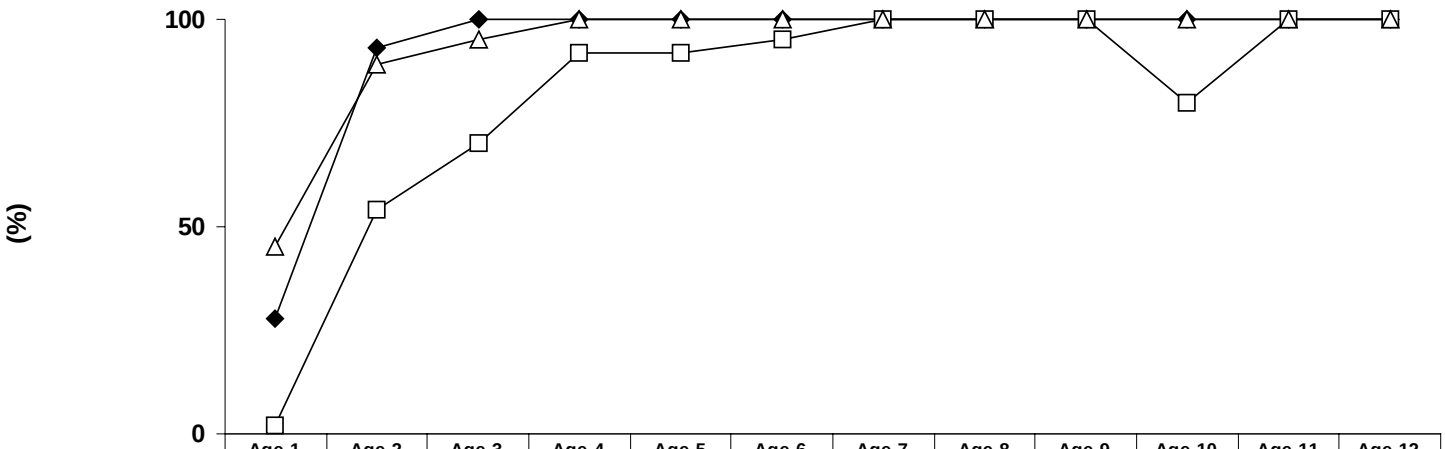
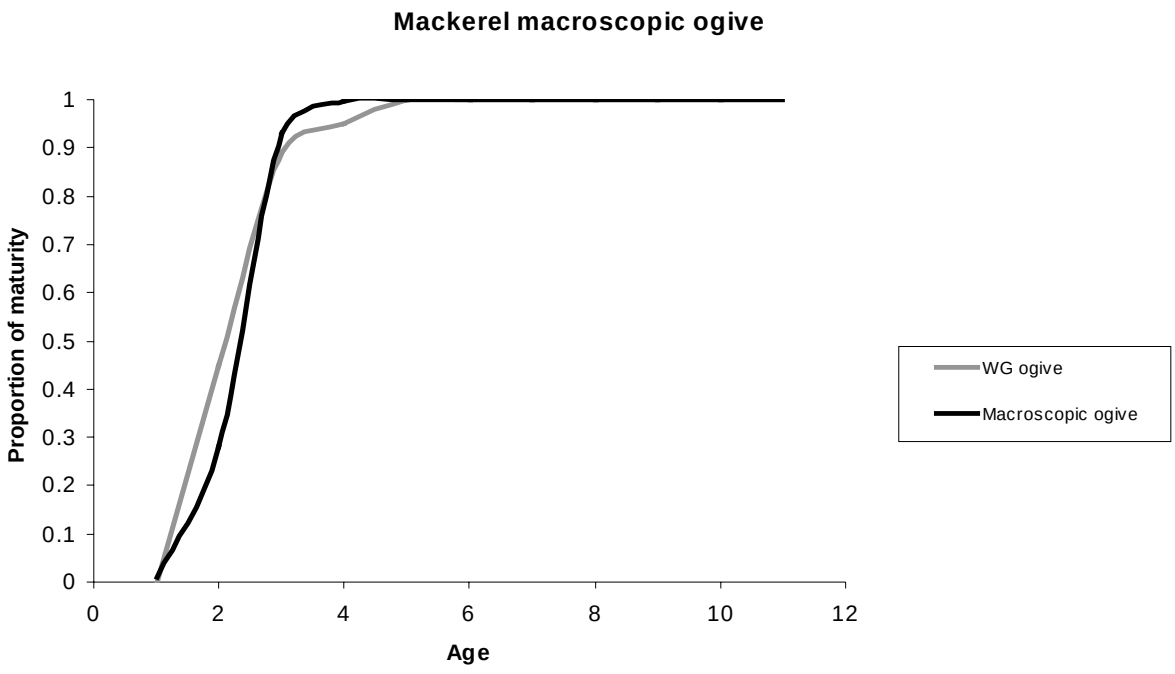


Figure 6.2.1 Mackerel microscopic maturity and percentage at age, including the ovaries with spawning signs in ICES Divisions VIIIc and IXa North (1998), (mature (m), resorbing (r), immature (i))



	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12
Macroscopic	28	93	100	100	100	100	100	100	100	100	100	100
Microscopic	2	54	70	92	92	95	100	100	100	80	100	100
ICES WG	45	89	95	100	100	100	100	100	100	100	100	100

Figure 6.2.2. Mackerel maturity ogives without applying logistic model



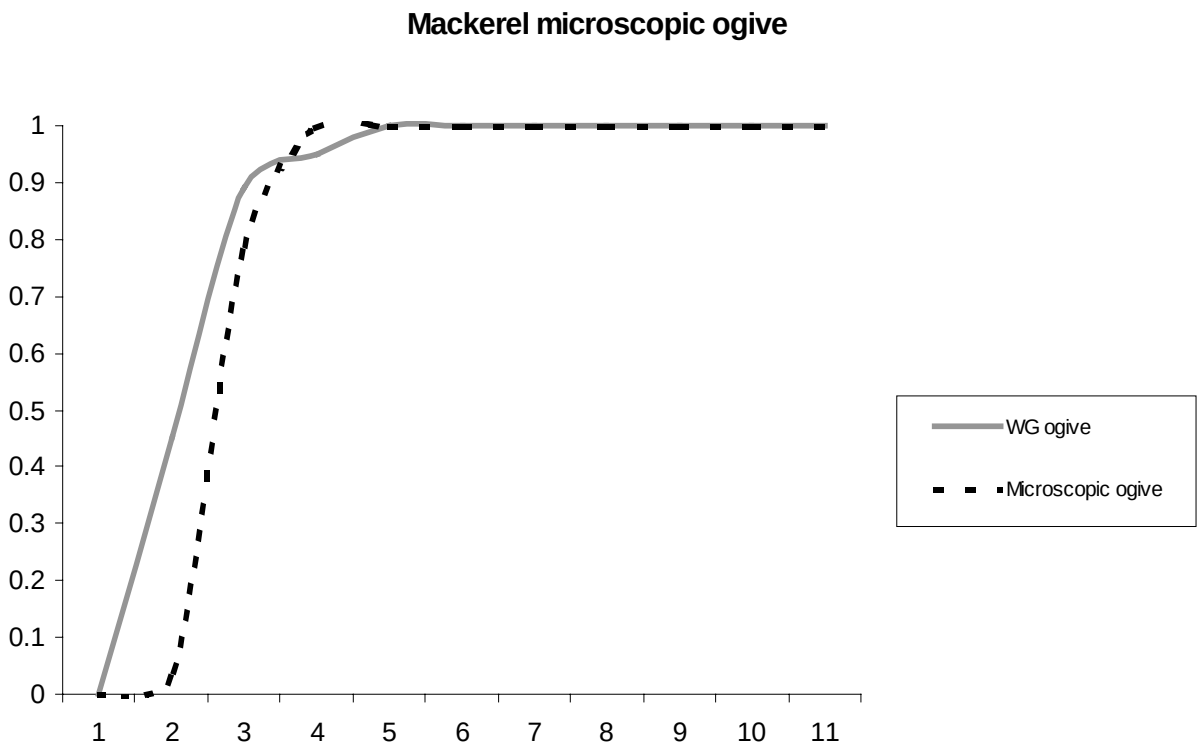
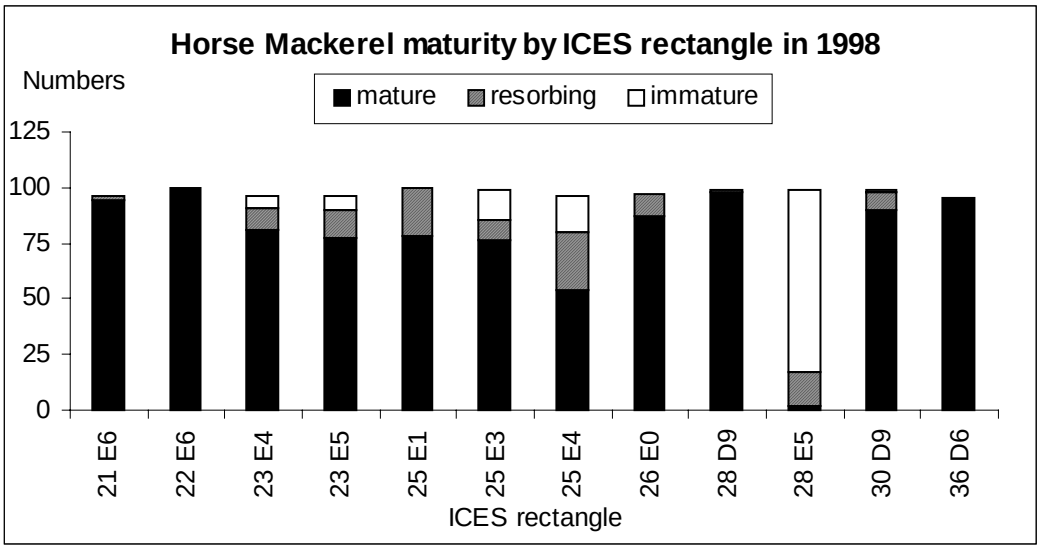


Figure 6.2.3 Mackerel maturity ogives after applying the logistic model and comparison with maturity ogive used in the ICES Working Group



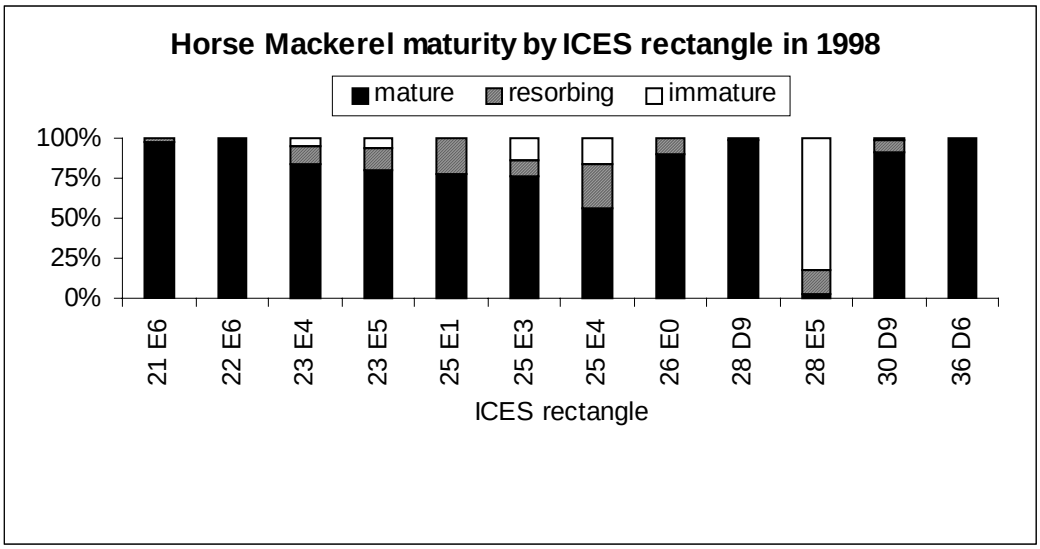
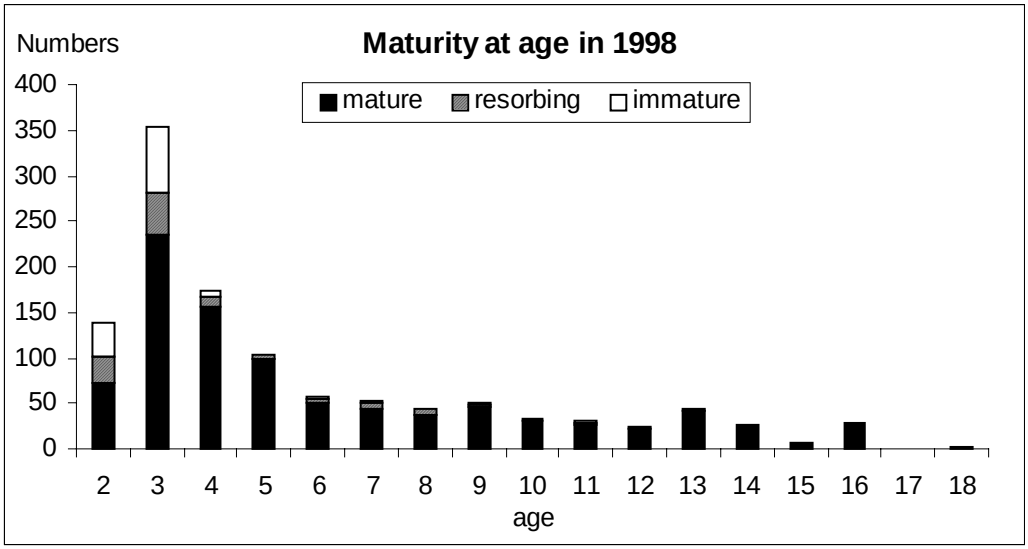


Figure 6.2.4 Number or rectangle of mature, resorbing and immature horse mackerel by ICES rectangle, collected in May-June 1998



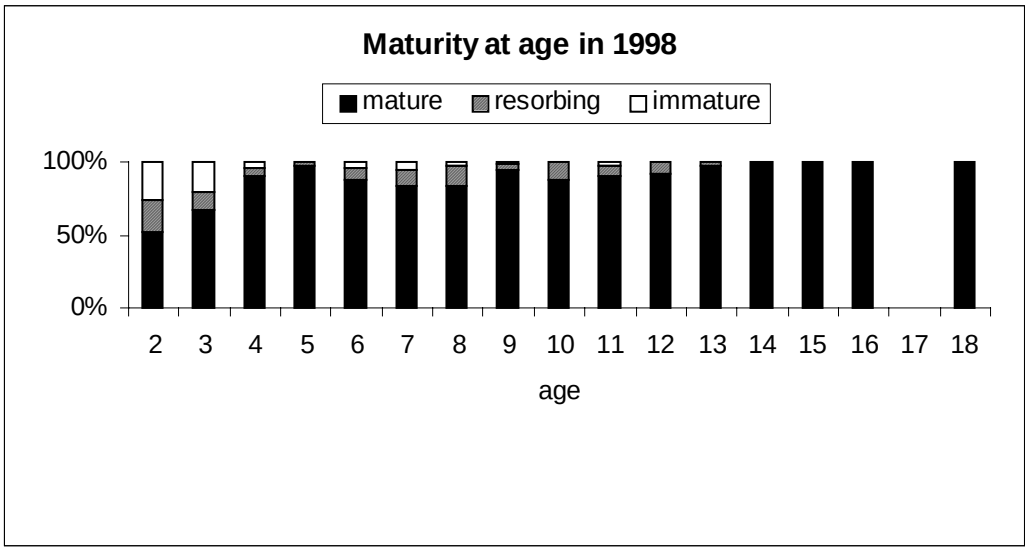


Figure 6.2.5 Number or percentage of mature, resorbing and immature horse mackerel by age group in May-July 1998

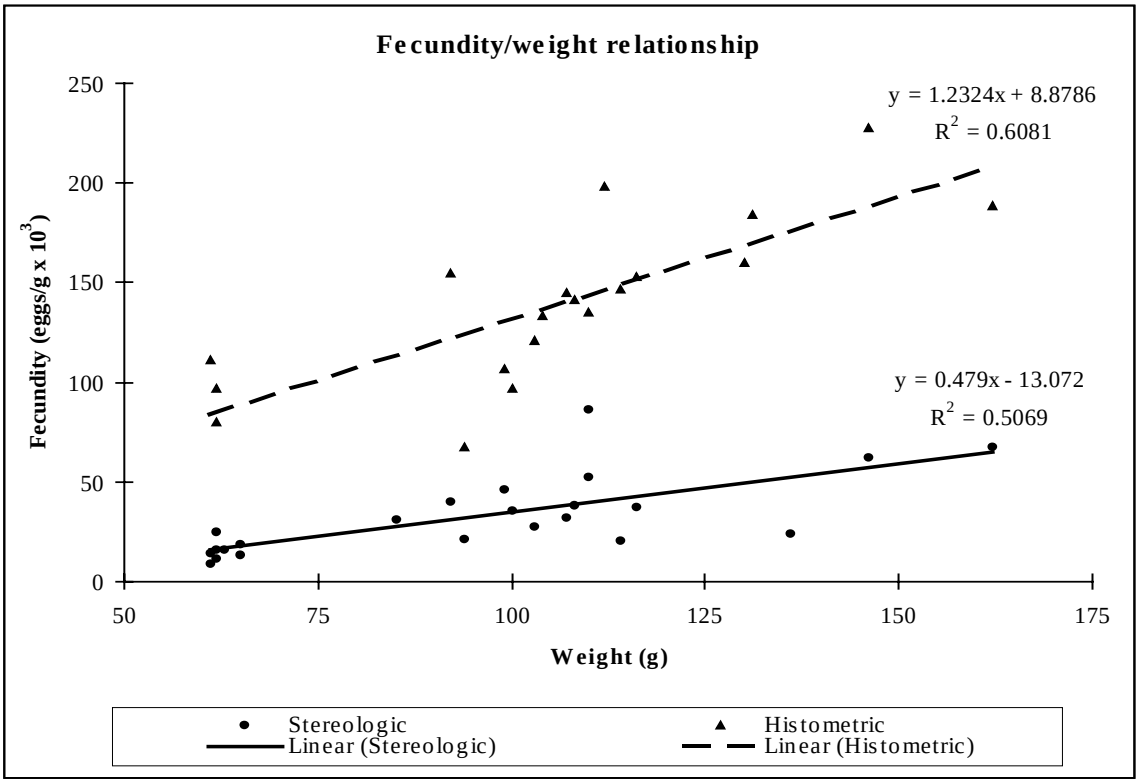


Figure 6.2.6 Fecundity / weight relationships of 1998 Portuguese horse mackerel

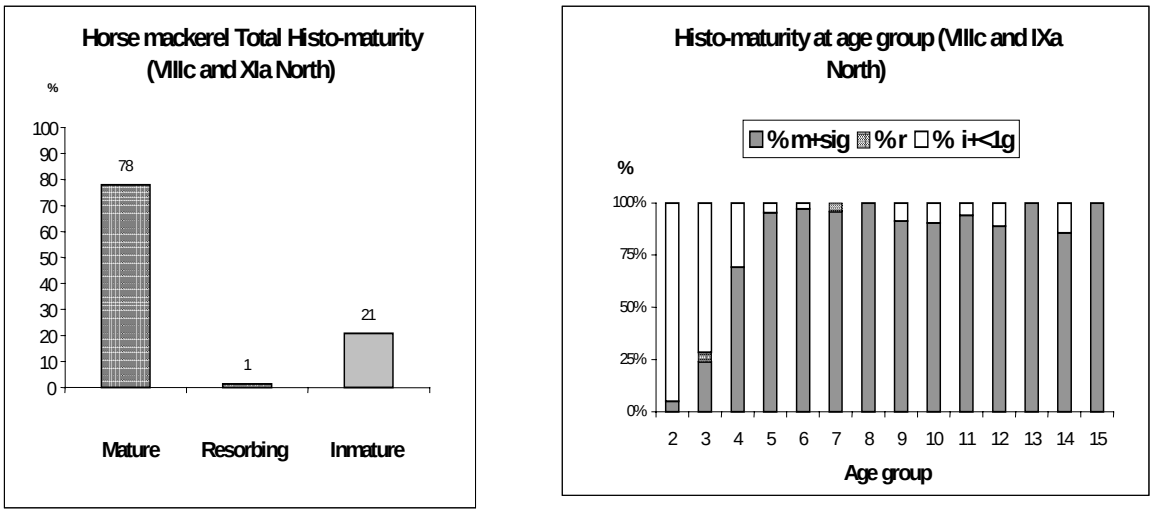
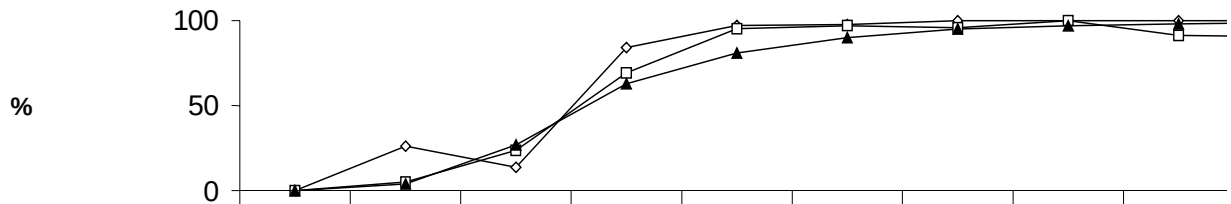
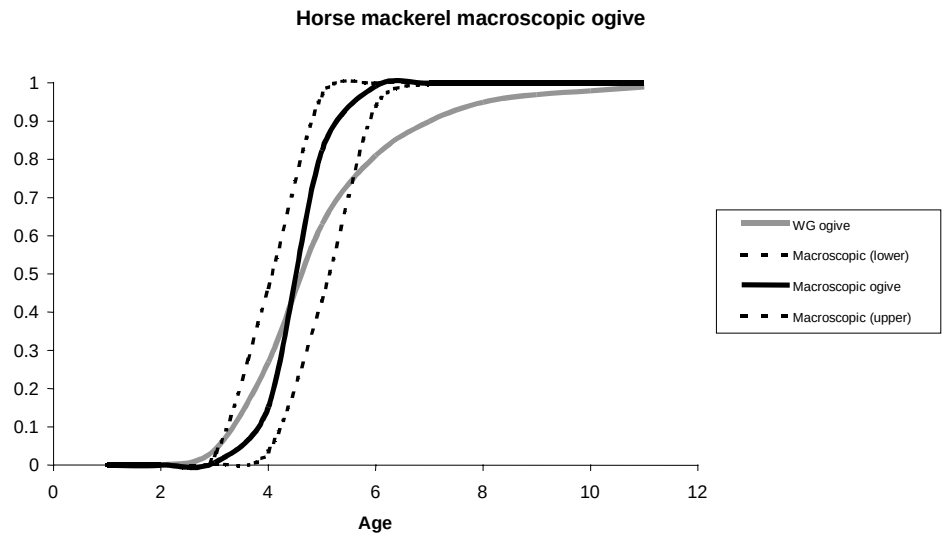


Figure 6.2.7 Horse mackerel microscopic maturity and percentage at age, including the ovaries with spawning signs in ICES Divisions VIIIc and IXa North (mature (m), resorbing (r), immature (i).



	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9
Macroscopic	0	26	14	84	97	98	100	100	100
Microscopic	0	5	24	69	95	97	96	100	91
ICES WG	0	4	27	63	81	90	95	97	98

Figure 6.2.8 Horse mackerel maturity ogives without applying a logistic model



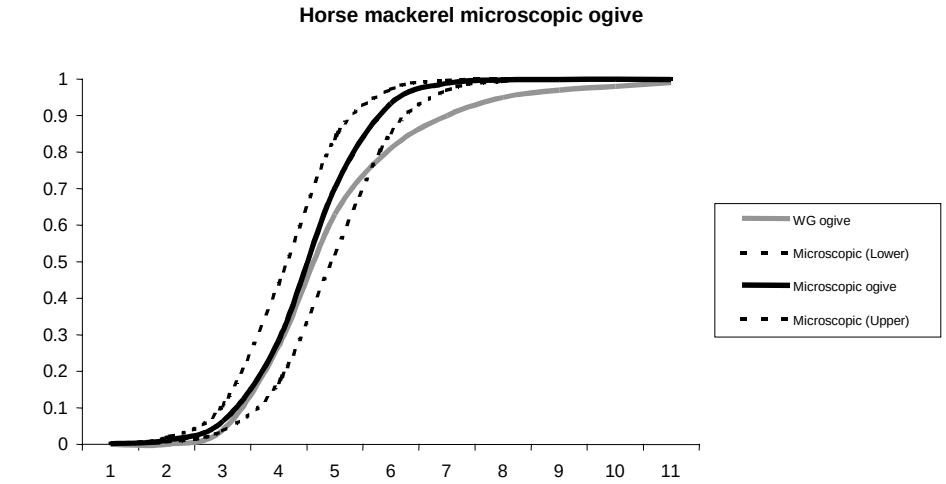


Figure 6.2.9 Horse mackerel maturity ogives after applying the logistic model and comparison with the maturity ogive used in the ICES Working Group

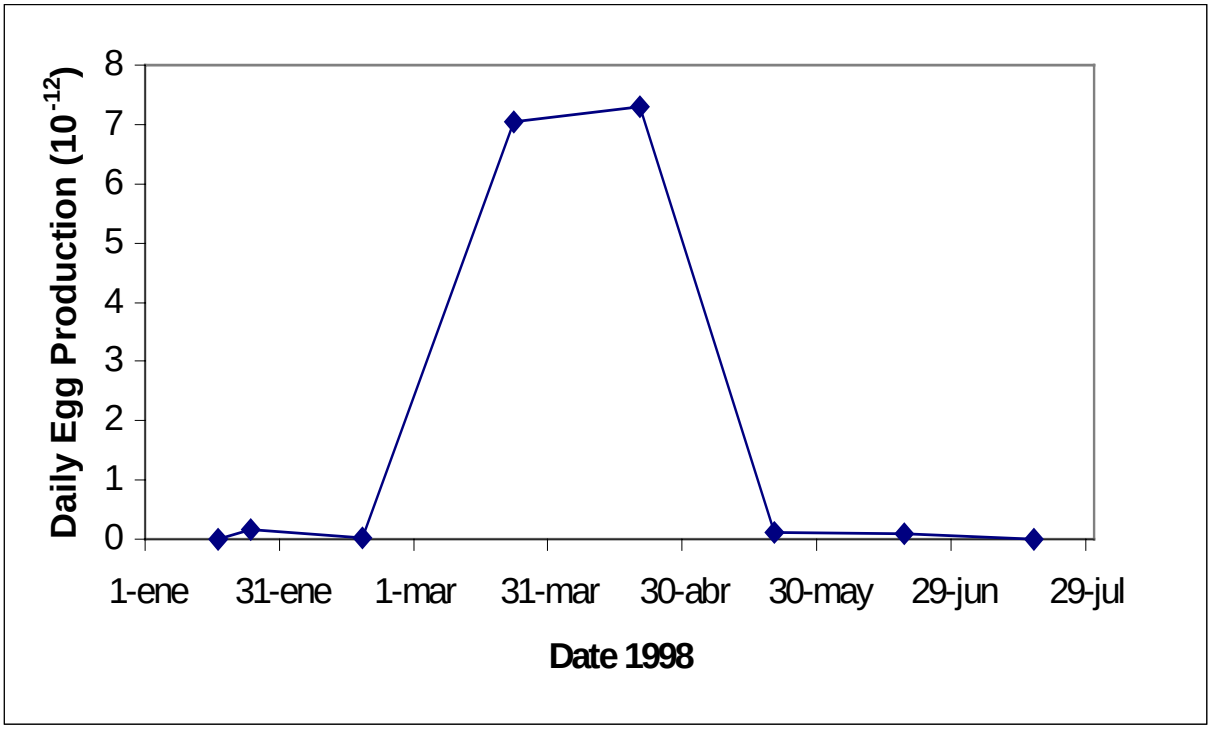


Figure 6.5.1 Mackerel daily egg production curve for the surveys in the southern spawning area in 1998. The curve was produced assuming start and finish date of 17 January and 17 July respectively

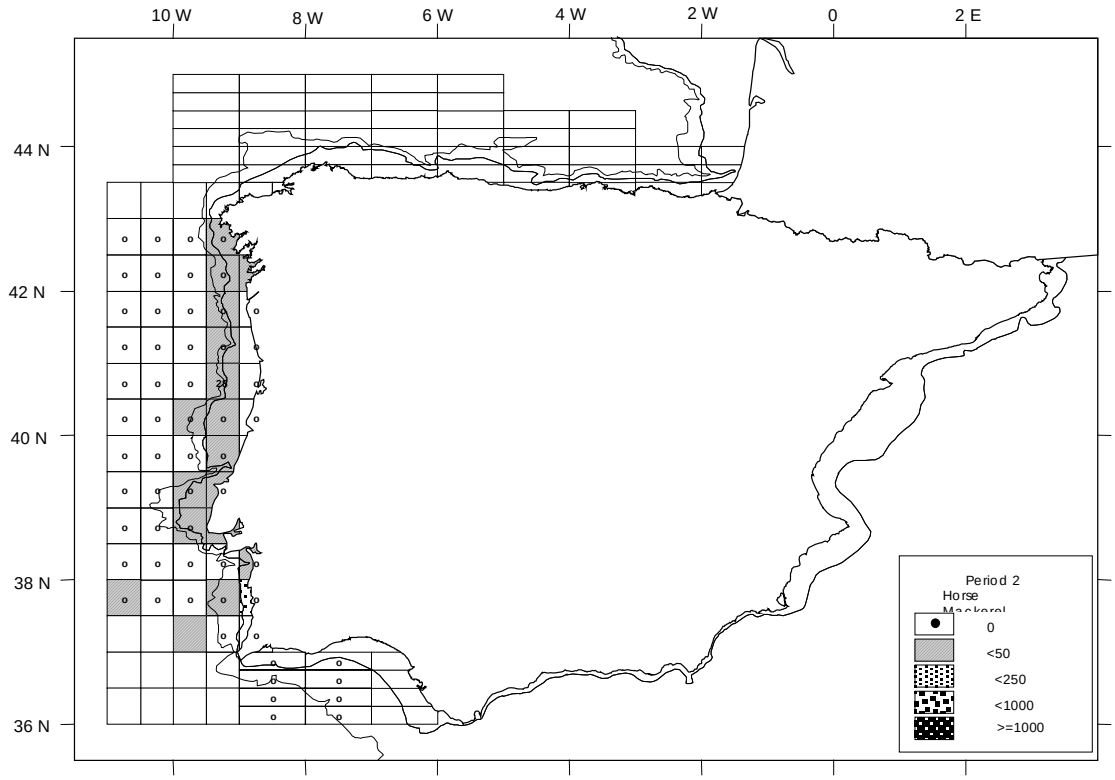


Figure 6.6.1 Horse mackerel egg production for period 2 (7 February to 10 March)

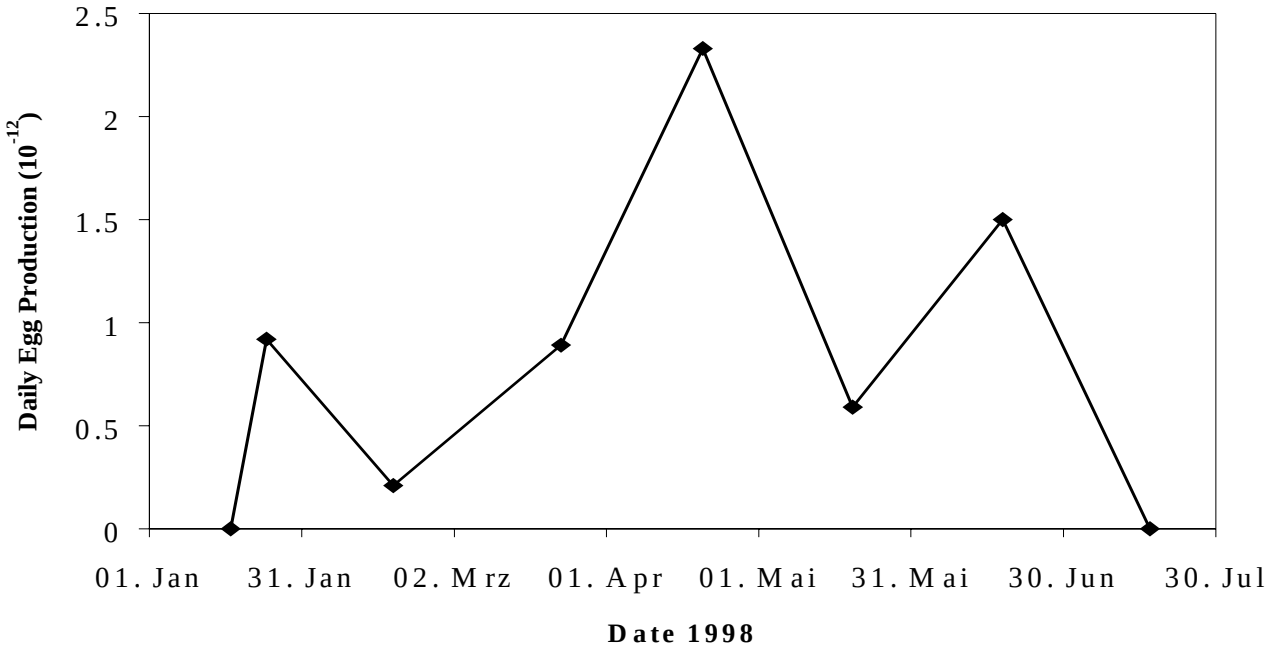


Figure 6.6.2 Horse mackerel daily egg production curve for the surveys in the southern spawning area in 1998

7 DEFICIENCIES AND RECOMMENDATIONS

General aspects on Egg Surveys

The results of the triennial egg surveys are used by the ICES Mackerel, Horse Mackerel, Sardine and Anchovy Assessment Working Group as tuning data series in the assessment of mackerel and horse mackerel stocks. The assessments provide estimates of stock size and catch options from which the ACFM provides advice on the management of these stocks. The advice is subsequently used by the management authorities to set annual TAC's and national quotas. The quality of the data used for the assessments is therefore extremely important as a basis for the provision of accurate and thus reliable advice.

The estimates of SSB from the egg surveys have provided a robust tuning index used in the assessment and updated on a triennial basis. Over the long history of the egg surveys, dating back to 1977, a considerable volume of research work has been generated as a result of close scrutiny of all the parameters used in the calculation of SSB. This research has highlighted a number of problem areas and areas of uncertainty of which the Working Group is aware. These problems potentially affect the precision of the estimate of total egg production and SSB.

The problem areas highlighted by the research include uncertainty in the calculation of some adult parameters such as fecundity estimation, determinate spawning, atresia, and maturity. There is also the potential for problems in the estimation of egg production generated by difficulties in egg identification and staging, measurement of volume of water filtered by samplers and spawning area coverage.

The problems are the subject of continuous investigation at a number of institutes involving valuable research and co-operation over many years. Much has already been accomplished in this respect but it is important that the research in all these areas continues to be encouraged and enhanced in order to further improve the quality of the advice on the management of these stocks.

1. The WG strongly recommends a mackerel egg survey on a triennial basis in the North Sea. This egg survey should be carried out in the year after the regular surveys on the western stock components. In the most recent years only Norway and The Netherlands have carried out the survey, covering the spawning area three times throughout the spawning season. However it is deemed necessary to cover the area at least four times to sufficiently cover the onset and end of the spawning. For this reason it appears necessary that at least one other nation joins the survey.

2. The WG was of the opinion that a specific recommendation for a sampling scheme is needed from the WGMHSA with regard to mackerel and horse mackerel. However, due constraints of ship time no sampling can be realised which would consume extra effort.

3. The WG recommends that the next meeting of the group should take place in Dublin from 16 to 20 April 2002. In arranging the meeting it is important that the meeting does not coincide with meeting of the Herring assessment Working Group.

4. The WG recommends that an exchange of histological atresia slides should take place between the institutes (CEFAS, Aberdeen University, IEO, IPIMAR for mackerel, and RIVO-DLO, IEO, IPIMAR and FRC for horse mackerel). The exchange should be coordinated by Mr. P. Witthames (CEFAS) for mackerel and Mr. A. Eltink (RIVO) for horse mackerel.

5. The WG recommends to connect a training course for identification of atresia and fecundity from prepared slides to the egg identification and staging workshop in Lowestoft in November 2001. The chair of WGMEGS is requested to apply for appropriate funds at the EU, together with the application for support for the egg-workshop. Due to the fact most of the persons expected to attend the atresia / fecundity – workshop will also be attending the egg staging workshop, the additionally arising costs and travel effort are expected to be reasonably low.

6. Sampling depth: The WG recommends to carry exploratory analysis of the data related to the net deployment, specially with the maximum sampling depth, in order to detect possible problems.

7. The WG recommends to extend the sampling area as much as necessary in order to delimitate the spawning area whenever possible, even when this results in reduced total number of stations.

8. The spawning stock biomass estimates obtained from egg surveys are used for tuning in assessment programmes. However, this requires furthermore reliable information on proportion mature at age. No accurate maturity ogives could be estimated from the biological samples collected during the 1998 egg surveys.

9. This WG recommends that the maturity ogive for the combined Divisions VIIIc and IXa should become available at the next meeting of the Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy in September 2000.

8 WORKING DOCUMENTS AND PRESENTATIONS

- Costa, A.M.: review of information on maturity, fecundity and atresia for mackerel and horse mackerel since WGMEGS in April 1999.
- Farinha, A. & J Pissarra: The 1998 egg production of horse mackerel in the southern area. WD addressing TOR "g".
- Iversen, S.: Results of the North Sea Egg Survey 1999. WD for WGMHSA, ICES 14-23.9.99.
- Milligan, S.: Results of the Ongoing Plankton Sample Exchange.
- Milligan, S.: Identification of fish eggs from two samples collected during the second Portuguese survey.
- Milligan, S.: Plankton Sampling Manual (Draft)
- Milligan, S.: Estimation of the beginning of spawning of the western component of mackerel (*Scomber scombrus* L.) in 1998. WD presented to the WGMHSA in 1999, brought to attention only.
- Santos, P.: Presentation on the Results from the INDICES Project.
- Nichols, J., Presentation of last Assessment: particular issues which are of concern to WGMEGS.
- Pérez, J.R., Abaunza, P., Villamore, B., Maturity ogive if the southern Atlantic mackerel (*Scomber scombrus* L.) using histological and macroscopic methods. WD presented also tp WGMHSA, 9.99.
- Pérez, J.R., Villamore, B., Abaunza, P., Maturity ogive of the Atlantic horse mackerel *(Trachurus trachurus* L.) from the southern area using histological and macroscopic methods. WD presented also to WGMHSA, 9.99.
- Reid, D. & Beare, D.: Evaluation of GAM in relation to WGMEGS.
- Reid, D. and Eltink, A. (WD from WGMHSA, 1999): Recent changes in the timing and pattern of the migration of western mackerel from the North Sea from surveys and commercial data and its impact on management measures.

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ICES, 1996 (a). Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys. ICES CM 1996/H:2.

ICES, 1996 (b). Report of the Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy. ICES C.M. 1996/Assess:7.

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

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