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REPORT OF THE

Working Group on Mackerel and Horse Mackerel Egg Surveys

Dublin, Ireland
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International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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SUMMARY

The Working Group addressed the problem of estimating the spawning stock sizes of mackerel and horse mackerel in the western spawning area (VI, VII, VIIIa,b,d,e) and the southern spawning area (VIIIc and IX a). As in the previous years the annual egg production method was implemented, using international egg surveys conducted in 2001 between January 11 and July 23 and associated estimates of fecundity and atresia. The sampling was completed as planned, and the Working Group concluded that in 2001 the temporal and spatial coverage for the plankton sampling was very good. Also, the sampling for fecundity and atresia was much better than in 1998. With a total of more than 380 ship days the entire survey effort was nearly 40% higher than in the previous one.

The ICES Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS) met in Dublin on April 16-20, under the chairmanship of Dr. Cornelius Hammer, to analyse the data from the 2001 Mackerel and Horse Mackerel Egg Survey. This survey takes place triennially under the participation of Portugal, Spain, England, Scotland, Ireland, The Netherlands, Norway and Germany. The basis of the survey is to relate the number of freshly spawned eggs found in the water with the number of females having produced these eggs. Knowing the fecundity of the females it renders an estimate for the spawning stock biomass. Now the large number of samples has been analysed and the group met to evaluate the results and to assess the size of the mackerel and horse mackerel stocks in the NE Atlantic.

The analyses show that the western component of the **NEA Mackerel** stock has been declining by 420 000 t to a total of 2.53 mill. t (-14%). For the NE-Atlantic mackerel a new model has been applied to estimate the fecundity. Amongst other variables the model includes the effect of decreasing fecundity with latitude as well as time of sampling.

During the past three years the **Western Horse Mackerel** seems to have undergone a process of change in fecundity. In 1998, 2000 and 2001 a drop of the fecundity by approximately 1/3 has been observed compared to earlier years. While in the last triennial survey in 1998 the higher historical value for the fecundity was used, the calculations have now been done adopting the lower fecundity value, since substantial biological information has accumulated by now, suggesting a lower fecundity rate for the past three years. The SSB of western horse mackerel was revised for 1998 from 1.4 million t to 2.0 million t, due to the new low fecundity of 1002 eggs/g. Based on a new low fecundity of 994 eggs/g the 2001 SSB was estimated at 1.38 million t. At the working group the matter of determinacy in spawning has been discussed again. It is still not confirmed that horse mackerel is an indeterminate spawner.

The SSB of the **Southern Horse Mackerel** Stock has declined from 301.000 t in 1998 to 228.000 t in 2001 (± 41%), even though the total egg production was found to be the same as in 1998. However, the fecundity of the female increased from 1245 egg/g in 98 to 1578 egg/g in 2001, which implies that less females have contributed to the total egg production.

The **Southern Mackerel Component** was found to have produced far less eggs in 2001 ($28 * 10^{13}$ eggs) than in 1998 ($43 * 10^{13}$ eggs). In conjunction with a drastic increase of the fecundity (1998: 1171 eggs/g to 2001: 1647 eggs/g) it implies a decrease of the stock from 800,000 t in 1998 (± 68%) to 371,000 t in 2001 (± 21%), corresponding to a drop of SSB by over 50%. However, it must be born in mind that the 1998 stock size estimate was very uncertain, the stock size fluctuates greatly due to extensive migration, and that acoustic surveys have recently supported the present stock estimate.

1 INTRODUCTION

1.1 Terms of Reference

At the ICES Annual Science Conference in September/October 2001 it was decided that (C. Res. 2001/2G07) the Working Group on Mackerel and Horse Mackerel Egg Surveys [WGMEGS] (Chair: Dr. C. Hammer, Germany) will meet in Dublin, Ireland, 16-20 April 2002 to:

a) analyse and evaluate the results of the 2001 mackerel and horse mackerel egg surveys of the western and southern areas;
b) calculate the total seasonal stage 1 egg production estimates for mackerel and horse mackerel separately for the western and southern areas;
c) analyse and evaluate the results of the mackerel and horse mackerel fecundity and atresia sampling in the western and southern areas;
d) investigate the possibilities of combining the mackerel fecundity estimates, corrected for atresia, from the western and southern areas;
e) analyse and evaluate the results of the sampling for mackerel and horse mackerel maturity in the western and southern areas and produce maturity ogives for 2001 for each area;
f) provide estimates of the spawning stock biomass of mackerel and horse mackerel, using stage 1 egg production estimates and the estimates of fecundity and atresia, separately for the western and southern areas;
g) evaluate the quality and reliability of the 2001 survey in the light of the previous surveys.

The above terms of reference are set up to provide ACFM with the information required to respond to requests for advice/information from the Commission indicated below.

WGMEGS will report to the Living Resources and Resource Management Committees at the 2002 Annual Science Conference and to the WGMHMSA.

1.2 Participants

The Working Group met in Dublin, Ireland from April 15-20 2002 with the following participants:

Cornelius Hammer (Chair)	Germany
Dough Beare	UK (SCO)
Ingeborg De Boois	Netherlands
Ana-Maria Costa	Portugal
Leonie Dransfeld	Ireland
Guus Eltink	Netherlands
Anabela Farinha	Portugal
Concha Franco	Spain
Claire Imrie	UK (E)(Imperial Collage)
Svein Iversen	Norway
Ciaran Kelly	Ireland
Ana Lago de Lanzos	Spain
Deirdry Lynch	Ireland
Steve Milligan	UK (E&W)
John Molloy	Ireland
Iago Mosqueira	UK (E&W) (Imperial Collage)
Jose-Ramon Perez	Spain
Joaquim Pissarra	Portugal
Carmela Porteiro	Spain
Dave Reid	UK (SCO)
Beatriz Roel	UK (E&W)
Maria Santos	Spain (BC)
Peter Witthames	UK (E&W)
Christopher Zimmermann	Germany

1.3 Glossary

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
Residual fecundity	Number of vitellogenic oocytes in spawning or recently spent females.
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)

2 GENERAL ASPECTS

2.1 Summary of WGMEGS activities in 2000 and 2001

In the period 2000 – 2001 the activities of WGMEGS concentrated on the preparation of the 2001 survey. This included detailed planning and coordination of the sampling and the individual cruises and also the analysis of the samples. Based on the experiences of a plankton sample exchange carried out in 1999/2000 (ICES, 1999) it appeared urgent to conduct a workshop to train analysts in the staging of mackerel and horse mackerel eggs. In addition, it was proposed to connect a workshop to this event, to teach the analysis of histological slides for the determination of the fecundity and atresia of mackerel and horse mackerel.

To finance this workshop an application for an Accompanied Measure was directed to the European Commission, which was fully granted (Q5AM 2000/0031), and coordinated by the Chair. Both workshops were held in Dec 2000 and reported to ICES (ICES 2001a).

During the staging workshop it was found that in the first reading the agreement for stages Ia and Ib was over 90% for mackerel and horse mackerel. This was indeed better than expected. In the second reading, and after discussion the agreement improved to 96% for mackerel and 94% for horse mackerel. The overall agreement for all stages was 71% for mackerel in the first reading, improving to 82% in the second. The overall agreement for all stages was 74% for horse mackerel in the first reading, improving to 85% in the second.

The initial average mis-estimation of stages Ia and Ib for mackerel was -2.5% and +1.5% for horse mackerel. This implies that in earlier years the numbers of mackerel eggs were slightly under-estimated and for horse slightly over-estimated. The *individual* mis-estimations were partly however great and varied from -16% to +15% for horse mackerel and from -16% to +10% for mackerel.

In addition the workshop provided the opportunity to discuss the future sampling (in 2001) especially for fecundity of mackerel and horse mackerel (ICES 2001b).

For the 2001 survey an application for a supporting study was directed to the Commission in 2001 and also fully granted. The study (“EGGSURVEYS” (00/038)) was coordinated by the chair and had a volume of over 2.5 mill. €. From this funding a great part of the ship time and the sample analyses was covered and allowed for far more extensive sampling than otherwise would have been possible.

The final reports and the consolidated cost statements of both projects have been accepted by the Commission.

2.2 Comparative Fecundity and atresia estimation 2001

Following the egg identification and fecundity workshop in Lowestoft November 2000 a reference collection of images was circulated to all the analysts representing the participating countries (Azti-Spain, Germany IEO Spain, Ireland, Netherlands, Norway and Scotland). Table 2.2-1 shows the results for the Institutes that that completed the analysis. Good agreement was found for the prevalence of early alpha atresia (range 0.5 to 0.6 with a mean of 5.7) in mackerel and also for vitellogenic oocytes in horse mackerel (range 28-34 with a mean of 30 excluding one outlier of 22 MLA-1). POF, and early alpha atresia intensity were quite variable. In summary this would indicate that fecundity analysis and the major parameter of atresia estimation (prevalence) should be fairly consistent but scoring to reject spawning fish and atresia intensity need further discussion to improve interpretation. Prior to the Dublin WGMEGS it was not possible to complete the analysis of slides to provide additional quality assurance for the 2001 triennial atresia assessment but this information will be available for the 2004 WGMEGS planning meeting.

Fecundity samples collected for the western mackerel spawning component were distributed alternately between the countries contributing to the analysis. The results are compared in Table 2.2-2 show that Scotland was more selective, rejecting higher numbers of fish and probably reducing the variance in their data. Overall, the estimates were significantly different with higher and lower values reported by England and Norway respectively. Part of the bias likely lies in the interpretation of the Gilson fixed samples because there has been no consistent order in the estimates from previous surveys. For example, in 1989 the fecundity estimate from Scotland, using the same method but with different analysts was higher than 29% than CEFAS. The Gilson free method based on formaldehyde preserved ovaries (see Section 2.4) should reduce these differences in interpretation because oocyte structure is better conserved.

2.3 Comparative sample sorting exercise 2001/2

The results of the mackerel and horse mackerel egg staging workshop (Section 2.1) showed excellent agreement between participants in the allocation of mackerel and horse mackerel eggs to the various development stages. To help maintain consistency of egg staging and also to address the potential problems of sorting and identification of fish eggs, a small sample exchange (organised by CEFAS) was conducted following the 2001 surveys.

Three plankton samples were selected from the CEFAS survey, Cirolana 4/01 (Apr.-May 2001), which contained large numbers of mackerel and horse mackerel eggs in all stages of development. The samples were to be passed around each institute in turn. Standard institute protocols were employed, to sort all fish eggs from the samples (or sub-samples). The total numbers of fish eggs were to be recorded and mackerel and horse mackerel eggs were to be identified and counted. A minimum of 100 eggs of each species were to be taken at random and allocated to development stages. When the WG convened, six of the nine participating institutes have analysed the samples and the results had been collated.

A brief presentation of the incomplete results was given at this meeting. These preliminary results show large discrepancies between institutes in total numbers of fish eggs present in each sample, egg identification and the number of eggs allocated to each of the development stages. The reasons for these discrepancies prompted much discussion and are of some concern. However, the group felt that a full interpretation of the results can only take place once all the participants have had the opportunity to examine the samples. The full results will be prepared as a working document and distributed to all participants for comment before the next meeting of WGMEGS in 2003.

It is recommended that such data quality checks, including plankton and histological analysis be conducted periodically for the mackerel and horse mackerel egg surveys. It is recommended that another egg workshop, this time to include sample sorting and egg identification, be conducted prior to the 2004 survey.

2.4 Proposed methodology to estimate mackerel SSB parameters: Gilson free preservation

Since the 1989 triennial survey mackerel fecundity estimates have regularly contained a component of potential bias dependent on the country where the analysis was carried out. Throughout this period the same methodology (Walsh *et al*., 1990) has been used but different analysts have carried out the work and this may introduce errors arising from subjective judgements on whether particles are damaged oocytes or debris (Figure 2.4-1). Hunter *et al*. (1989) described an alternative gravimetric technique based on sub-sampling formaldehyde preserved tissue and this offers several important advantages: Gilson (Simpson, 1951) fixative is highly toxic containing mercuric chloride and is also strongly acidic with a high environmental impact and associated risk to all workers at sea and in the laboratory. After an initial shrinkage (25%) oocytes continue to break down slowly throughout the digestion period prior to analysis (Witthames & Greer Walker, 1987).

Three months or more are required for the fixative to break down the tissue and separate the oocytes whilst formaldehyde fixed ovaries can be worked on 1 week following preservation. Formaldehyde fixed ovaries have well preserved morphology (Fig. 2.4-2), offering the possibility to carry out automated image (Thorsen & Kjesbu, 2001) and to classify ovaries for presence of POF and atretic oocytes without relying on histology.

To adopt a fecundity method using formaldehyde fixed tissue it is necessary to carry out an inter- calibration to make future fecundity estimates comparable with the past. Table 2.4-1 shows the results of preliminary work (Witthames and Greenwood WD WGMEGS 2001) comparing the Gilson fecundity with gravimetric estimates of the total oocyte numbers in the formaldehyde fixed ovary in each of 21 fish. This data indicates that the fecundity estimate based on Gilson fixed ovaries equates to using a threshold of 0.185 mm to estimate fecundity in formaldehyde fixed tissue. Further work is required involving Norway, Scotland and Spain to remove the country effect in the reference fecundity data and investigate the precision and variance in an independent set of samples.

2.5 Latitudinal effect on fecundity: is our estimate of mackerel spawning stock biomass biased by oversimplifying the effect of location on fecundity?

The relative potential fecundity (the number of oocytes >130µm per gram whole fish weight) has been estimated for the mackerel triennial surveys since 1977 (Lockwood *et al*., 1981) because it is used to relate egg production by the fish to spawning stock biomass (SSB). During the 2001 survey, fish were caught for fecundity analysis over a much larger spatial area and over a longer time period than has been usual in the past. This relatively intensive sampling has allowed mackerel fecundity to be examined in more detail. In order to cope with the extra work, the number of countries participating in the assessment of fecundity was expanded, with Germany and Norway joining England and Scotland.

Once the samples from the 2001 survey were collated, examination of the data showed that mackerel fecundity is indeed related to the particular location they were collected and to the time of year (Witthames & Greenwood, 2001). In general, female mackerel are more fecund in the south, having larger ovaries for a given body weight. As described above, estimation of spawning stock biomass (SSB) by egg survey requires an estimate of mackerel fecundity. SSB is calculated from the annual egg production according to methods outlined in Section 4.3.4 of the current document. In the past, average fecundity has been applied across an entire particular spawning area to get at the SSB estimate (see note above). However, the 2001 survey demonstrated clearly that mackerel fecundity depends on location. It is, therefore, possible that the application of average fecundity for the entire spawning area may lead to biased estimates of SSB.

The following model for latitudinally dependent fecundity was developed:

Fecundity per gramme=1902 + (Female weight x 0.597) + (-20.26 x Latitude)

To investigate the size of this potential bias a modelled spatio-temporal, stage I western mackerel egg production surface for the 1998 data was used to obtain an SSB per period applying either an average fecundity (1068 egg/g) or a latitudinally dependent fecundity according to the model above. This allowed assessing the effect of oversimplifying mackerel fecundity within the spawning area on estimated SSB. The results are displayed in Table 2.5-1. In every period the application of a latitudinally variable fecundity resulted in a lower SSB (Table 2.5-1) compared to the application of an average fecundity across the entire western area.

It should be noted that in order to investigate the effect of latitude in isolation other variables were kept constant. A female weight of 295g was assumed across the western area; and a fixed rate of atretic loss of 200 eggs/g was assumed. It is accepted that this may not be realistic since female weight can vary with location and time of year. This, however, is preliminary work with the single objective of quantifying the importance of one variable on the SSB estimation (the effect latitude on fecundity). Further computations will be performed to investigate some of the other potentially important factors such as spatially varying average female weight and temporally variable fecundity and/or atretic loss.

2.6 Horse mackerel SSB estimate for area B for 1998

The annual horse mackerel stage I egg production in 1998 was estimated at 17.85 x 1013 eggs with a CV of 42.2% (ICES, 2000a).

Portuguese and Spanish data on fecundity being corrected for atresia, the fecundity was estimated at 1245 eggs/g with a CV of 26.8% (Costa *et al*., WD). A lower fecundity was observed in larger adults (Figure 2.6-1). The small fish were collected mainly from the Portuguese coast while the larger ones were taken from the Cantabrian Sea.

Fecundity of the larger adults might have been underestimated due to possible spawning. Not all spawning females can be excluded from the fecundity sampling because of the long batch interval compared to the duration of the early POF stage.

The estimate of SSB from the AEPM in 1998 is 301,084 t, which is close to the VPA estimate of 279,463 t (7% overestimation).

The text able below presents an overview of the parameters for SSB estimation from the 1998 southern horse mackerel egg surveys.

	Total annual egg production	**Fecundity per gramme of fish weight**	Total spawning stock biomass
Value	**17.85 x 10^{13} eggs**	**1245 eggs/g**	**301,084 t**
CV	42.2%	26.8%	50.0%

Table 2.2-1 Results of comparative scoring by individuals at CEFAS, IEO, MIA and MLA (contractor) for mackerel and Horse mackerel. Each individual scored 6 markers used to quantify fecundity, spawning activity and atresia in 10 standard images taken from slides prepared from both mackerel and horse mackerel ovaries. The codes for the markers in the left hand column are vitellogenic oocytes (VO) early alpha atretic oocytes (EA) prevalence of EA (Prev EA) late alpha atresia (LA) post ovulatory follicles (POF) and Hydrated oocytes (HYD. The scores are presented as the mean of the total number of each marker in each image.

Mackerel

Marker	Institute - scorer						Overall mean
	CEFAS	IEO	IPIMAR	MIA-1	MIA-2	MLA-JW	
VO	13.0	6.0	12.5	13.8	12.4	5.4	10.6
EA	7.6	10.0	3.4	5.4	5.5	8.0	6.6
Prev EA	0.6	0.5	0.5	0.6	0.6	0.6	0.57
LA	4.4	7.0	2.0	4.4	3.7	4.1	4.3
POF	0.2	0.0	0.4	0.1	0.1	0.3	0.2
Hyd.	0.4	0.5	0.4	0.4	0.4	0.3	0.4
n images	10	8	8	10	10	10	56

Horse mackerel

Marker	Institute - scorer								Overall mean
	CEFAS	IEO	IPIMAR	RIVO-1	RIVO-2	MLA-1	MIA-2	MIA-3	
VO	32.7	28.9	33.7	30.9	29.0	21.8	31.8	34.6	30.4
EA	0.9	0.4	0.6	0.0	0.6	1.8	3.1	2.4	1.2
LA	0.5	0.7	0.2	0.1	0.0	0.5	1.1	1.2	0.5
POF	0.3	0.9	0.6	0.4	0.4	0.4	0.2	0.4	0.4
Hyd.	0.3	0.6	0.2	0.3	0.3	0.2	0.3	0.3	0.3
n images	10	7	9	10	10	10	9	10	75

Table 2.2 – 2 A comparison of fecundity analysis results by country for the Western mackerel spawning component.

Data	Country				Total
	England	Norway	Scotland	Average	
Relative fecundity (Mean and s.e.)	1176 285	804 214	1055 175	1069	
Percentage of sample selected for fecundity analysis.	57	50	28		
Length (Mean and s.e.)	357	354	358	356	
N samples	117	46	24		187

Table 2.4 –1 Details of the relationship between the size threshold used to exclude small oocytes from estimates of total oocyte numbers based on sub sampling the formaldehyde fixed ovaries and the Gilson based fecundity. The number of fish analysed was 21.

Threshold (mm)	Mean ratio (formaldehyde oocyte count / Gilson fecundity)	Standard error
0.170	1.12	0.072
0.175	1.09	0.070
0.180	1.03	0.063
0.185	1.00	0.058
0.190	0.94	0.053
0.195	0.91	0.051
0.200	0.87	0.048
0.205	0.85	0.047
0.210	0.81	0.045

Table 2.5 - 1 Comparison of the estimates of western mackerel SSB per period using a fixed fecundity of 1068eggs/g or a latitudinally dependent fecundity estimated from the model described above. In all cases, atretic loss was taken to be 200 eggs/g and female weight 295g.

	Period				
	3	**4**	**5**	**6**	**Total**
Current Approach	8.4e+04	6.9e+05	2.0e+05	5.4e+05	**1.52e+06**
Lat "Model "	7.9e+04	6.5e+05	1.9e+05	5.2e+05	**1.44e+06**
Bias	+7%	+6%	+6%	+4%	+5%

Figure 2.4.-1 View of a sub sample taken from an oocyte suspension following fixation in Gilson over several months. The oocytes show poor oocyte definition with a ragged outline and other debris also occurs making counting more subjective. The scale bar above the arrow is used to manually assess oocyte diameter and select which oocytes should be included in the count. GFA (Pilkington Image Analysis Systems).

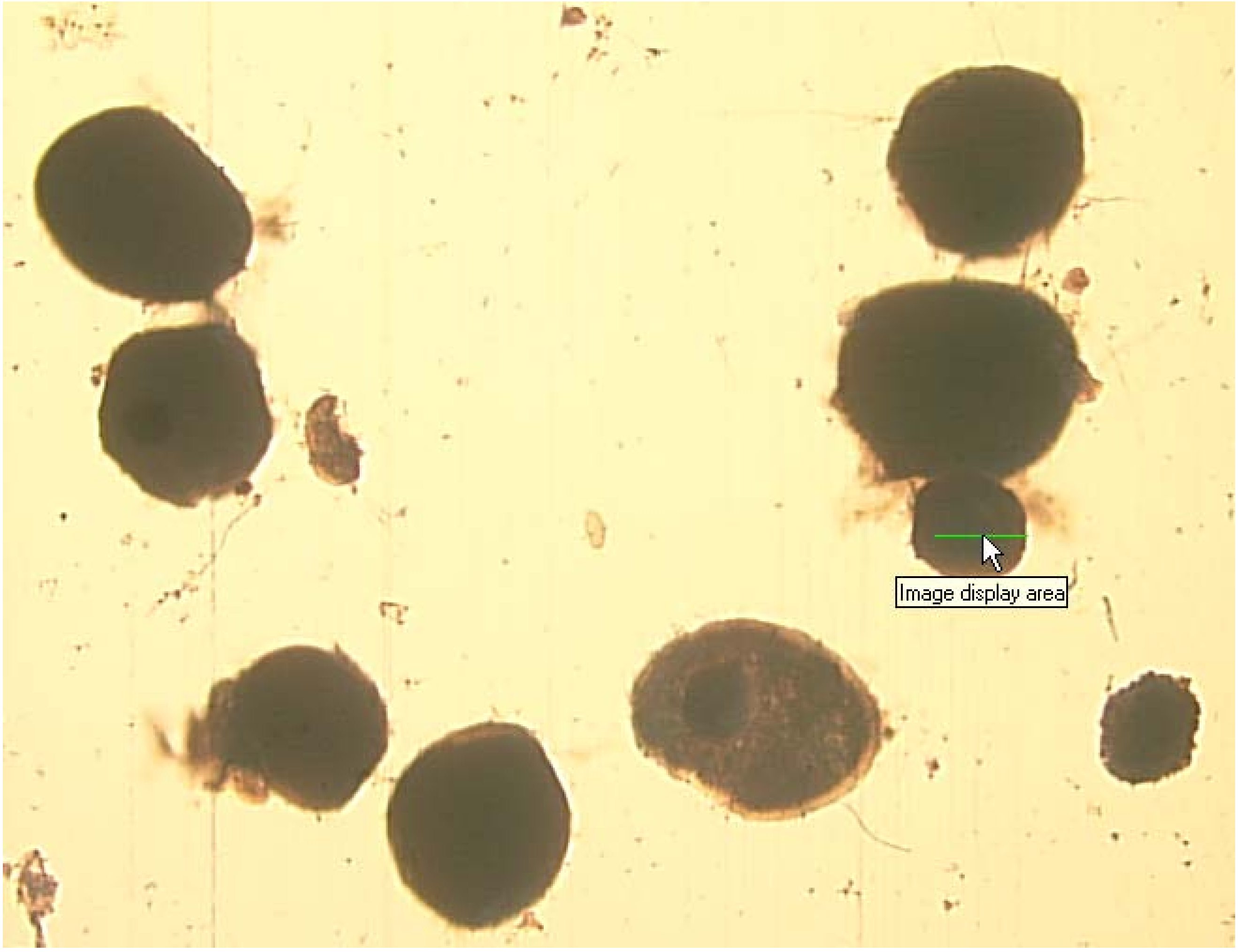


Figure 2.4.-2 Image of formaldehyde fixed oocytes showing the morphology of previtellognic oocytes (PVO) with clear contents and a visible nucleus, opaque regular shaped vitellogenic oocytes (N) and atretic (A) oocytes. The latter are characterised by an irregular shape and wrinkled outline.

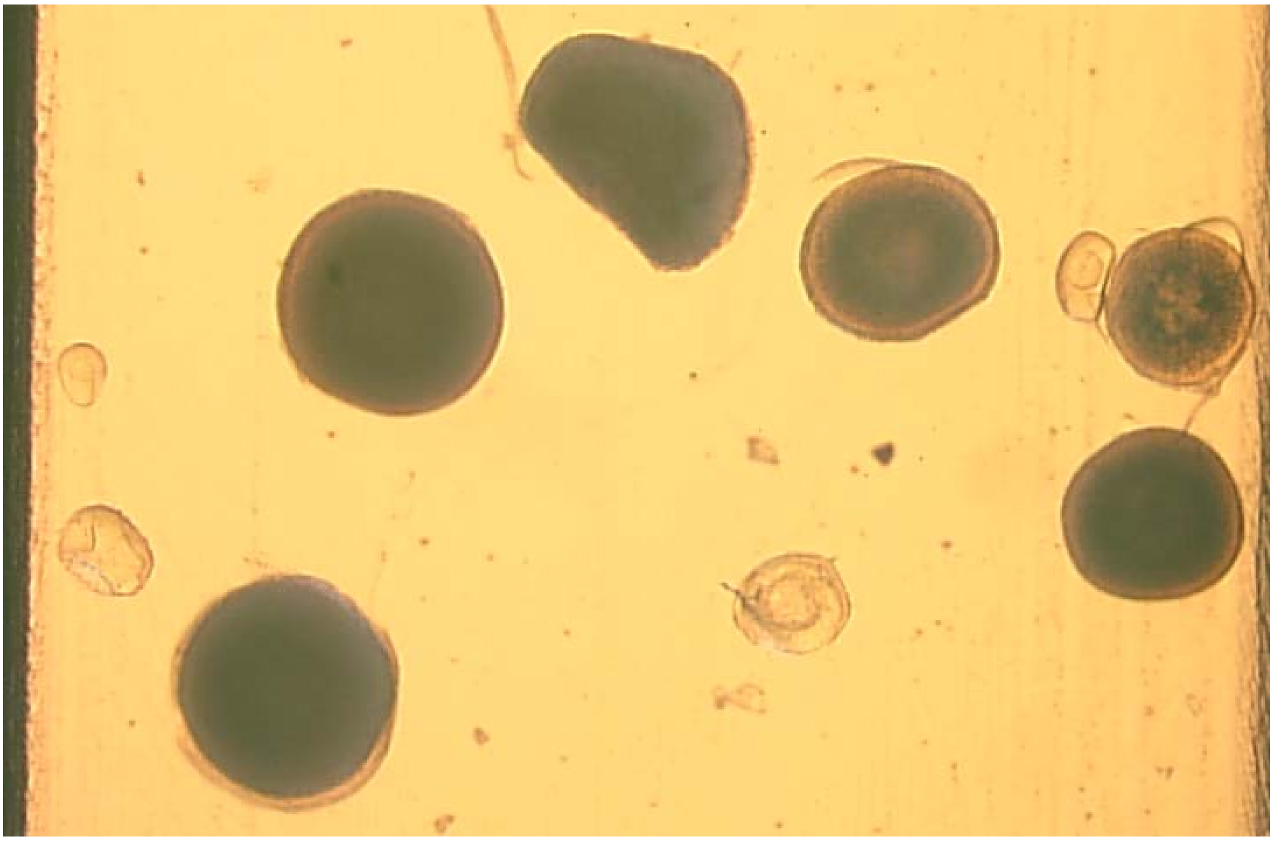
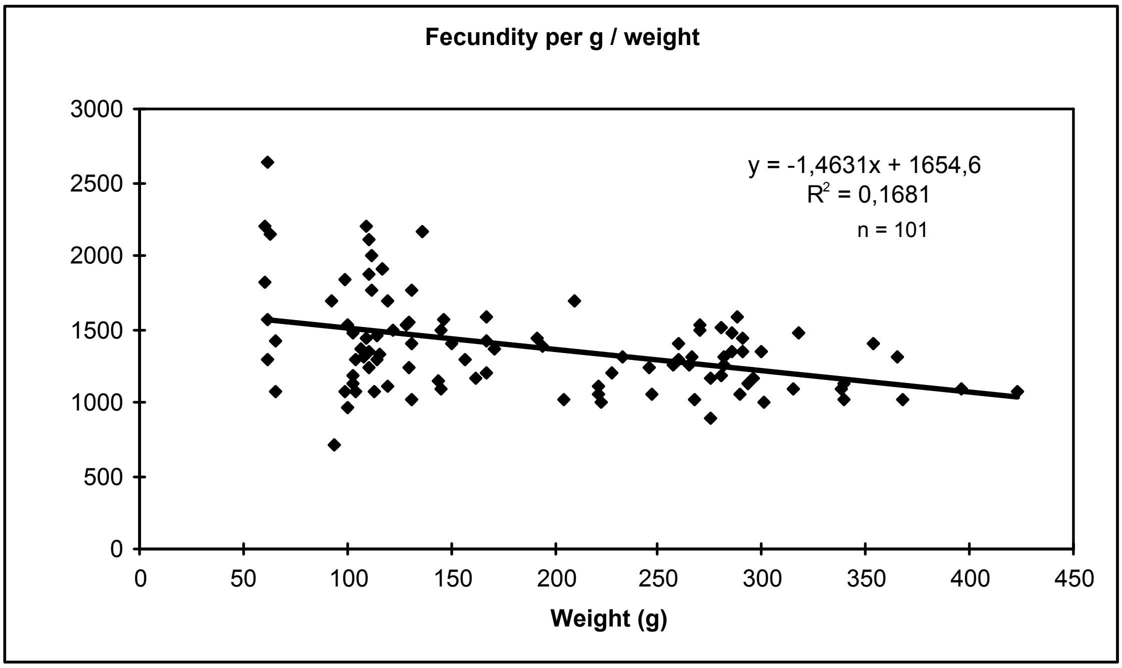


Figure 2.6-1 Fecundity – weight relationship for southern horse mackerel



3 NORTH SEA EGG SURVEY 2002

3.1 Countries and Ships participating

Until 1990 egg surveys in the North Sea were carried out usually every second year. Since then surveys were carried out in 1996 (ICES, 1997) and in 1999 (ICES, 2000a). Based on these surveys the SSB was estimated at 78 000 tonnes in 1990 (Iversen *et. al*., 1991), 110,00 and 68,000 tonnes in 1996 and 1999 respectively. The SSB of North Sea mackerel has for many years been on a historical low level.

As in 1999 the Netherlands and Norway will carry out a mackerel egg survey in the North Sea in 2002. The total survey period, 3-25 June, will not cover the total spawning period. However, the main spawning period has in all years investigated been observed about mid June, and will therefore probably also be covered during the survey period in 2002. Usually one vessel covers the North Sea spawning area in about two weeks, and two vessels will cover the area in one week. The spawning area is planned to be surveyed three times:

Vessel/Coverage	1	2	3
R/V “Tridens”	3-6 June	10-14 June	17-19 June
R/V “G. O. Sars”	3-9 June	10-16 June	17-25 June

The spawning area will be covered three times during 3-25 June. R/V “Tridens” will have to brake for the first weekend in IJmuiden (7-9 June) and both vessels will probably have a brake in Aberdeen or Esbjerg (15-16 June).

3.2 Sampling Area and Survey Design

Usually the main spawning area is located between 55-58° North and 1-5° East. However, the main spawning area was more south-westerly in 1996 and 1999 than in previous years. In 1999 the main spawning area was observed to be located between 54.30-56° North and 1° West (UK coast)- 2° East.

R/V “Tridens” will start in the south working northwards and R/V “G.O. Sars” will start in the north working southwards. The survey grid during the second and third coverages will be adjusted according the findings during the previous coverage. The samples will be analysed onboard the vessels during the survey. The two vessels will be in daily contact to exchange data.

As usual sections along whole or half degree latitude will be worked, and plankton samples will be collected along these lines in the middle between whole and half degree longitude. As in previous years Norway will use a 20 cm Bongo net towed for 5 minutes in each of the depths 20, 15, 10, 5m and just below the surface. The towing speed will be 2.5 knots. The Netherlands will use a Gulf or Bongo towed in double oblique hauls with a towing speed of respectively 5 or 2.5 knots. A net with a mesh size of 500 microns will be applied by both vessels, as nets with smaller mesh size will easily become clogged.

3.3 Sampling and Data Analysis

The plankton samples will be placed in buffered 4% formaldehyde. The sea temperature at 5 m will be noted from each of the plankton stations and used for ageing the eggs.

The fish eggs will be sorted from the plankton samples and the mackerel eggs will be classified and the number of stage I eggs will be counted. The volume of seawater filtered on each of the plankton stations should will also be recorded. Thereby the number of mackerel eggs produced per m^2 sea surface per day will be calculated. A preliminary estimate of the mackerel egg production in the North Sea will probably be available for the WGMHSA meeting in September 2002. The final results will be reported to the next WGMEGS meeting in 2003.

3.4 Fecundity and Atresia

If the egg production is observed to still be at historical low level there is no need to study fecundity and atresia. However if a significant increase in egg production is observed it is more urgent to investigate these parameters and produce a spawning stock estimate of North Sea mackerel of the same standard as for the western and southern spawning components. Therefore if possible, 50 ovaries in pre-spawning stage 3 (Walsh *et. al.,* 1990) should be collected during the first period for estimating potential fecundity. For investigating atresia 25 mature fish, stage 3-6 (Walsh *et. al*., 1990), should be collected from each of the coverages. Both research vessels will trawl to obtain these samples and samples for age-, weight- and length distribution of North Sea mackerel. North Sea mackerel is defined as mackerel spawning in the North Sea. Therefore fish with ovaries in development stages 3-6 (Walsh *et. al.*, 1990) will be classified as North Sea spawners. In addition to the fishing and sampling carried out by the two research vessels a Norwegian fishing vessel will be hired to fish in the area for 1-2 days during the later part of the survey to assist in sampling North Sea mackerel.

The ovaries sampled for atresia and fecundity studies should be fixed in 4% formaldehyde, buffered with 0.1 M phosphate to pH 7.

4 WESTERN AND SOUTHERN EGG SURVEYS IN 2001

4.1 Countries and ships participating

As for the previous survey the 2001 Mackerel and Horse Mackerel Egg Survey in 2001 was designed to cover the survey area completely within 7 sampling periods of differing geographical coverage (Table 4.1-1, ICES 2000a). The deployment of research vessel effort in the western mackerel/horse mackerel egg survey for 2001 is given in Table 4.1-2 and for the southern mackerel/horse mackerel egg survey for 2001, in Table 4.1-3. A total of 244 ship days were invested into the western and 138 into the southern area. The total for both areas is 382 ship days, which exceeds the total invested ship time of the previous survey (275 ship days) by 39% (Figure 4.1-1) and the invested effort of the surveys during the 1980s by 180%. The increase of the ship time, as compared to the previous survey, is the response to the shortcomings of the sampling in the previous survey, as stated in ICES (1999, 2000a,b).

4.2 Sampling areas and sampling effort

The area coverage of the individual cruises of the 2001 survey is given in the Tables 4.1-1 and 4.1-2. The sampling effort is given in Table 4.2-1. A total 1906 plankton samples were collected, of which 1316 came from the western area and 590 from the southern. In addition 106 trawl hauls were made to collect mackerel and horse mackerel ovaries. 72 hauls were taken in the western area and 34 in the southern.

4.2.1 Egg surveys in the western area

The suggested sampling area used for the triennial western mackerel and horse mackerel surveys has changed almost every year the survey has been conducted. It is therefore inappropriate to call this the ‘standard’ survey area. The area has been, and will remain, flexible in order to ensure adequate coverage of both mackerel and horse mackerel spawning. The area of suggested coverage, in both the western and southern areas, for the 2001 survey is shown in Figure 4.2.1-1.

The number of hauls taken by half ICES rectangle and by sampling period in the western area are presented in Figures 4.2.1-2c-f. The figures also include those rectangles where egg production was calculated by interpolation from neighbouring, sampled, rectangles.

Within the periods surveyed, the spatial and temporal coverage was very good. Sampling appeared to cover the entire spatial range of both mackerel and horse mackerel spawning, and reached zero samples along most of the edges of the distribution. Slight exceptions to this were seen in;

- Period 3 - Some interpolated mackerel samples of reasonable size along the western edge between 53 and 55°N and one unsampled line at 48° 15‘N.
- Period 4 - A small number of interpolated mackerel samples along the western edge between 48 and 57°N.
- Period 5 - A large amount of interpolation but generally well supported by adjacent observations. One anomalous interpolation at 51° 15‘N.
- Period 7 - Relatively high values for both species on the southernmost transect at 49° 15‘N.

For both species the egg production curves were well behaved. The mackerel egg production peaked in period 3 (May) and both the first and last periods showed relatively low production and fitted well with the predicted start and end dates. There was no sign of the early peak in egg production seen in 1998. The same was true of horse mackerel which also peaked in Period 5 and had low production in the first and last periods, The horse mackerel production curve was highly anomalous in 1998, but the situation was much better for 2001. It can be concluded that both the spatial and temporal coverage for both species was fully adequate to carry out the aims of the survey.

4.2.2 Egg surveys in the southern area

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

The sampling area used for the western mackerel egg surveys in 2001 was defined as the Atlantic coast of Spain and Portugal, between 36ºN and 45ºN latitude and the western boundary at 11º W longitude (Figures 4.2.1-2a-g). The same area was used in the previous surveys in 1998, since coverage appeared to be adequate and no additional sampling stations were necessary.

The temporal aspects of the sampling were improved from 1998. In 1998 the first two periods were sampled only on the Portuguese coast. The first sampling on the north Spanish coast was in period 3. In 2001, there was a survey in both areas in period 2. Furthermore, only very low egg production was observed in the north Spanish area in Period 2 confirming the lack of a need for a survey there in period 1.

4.3 Sampling and data analysis

As the previous survey, the 2001 survey was carried out in accordance with the modified sampling strategy described in detail for the 1995 survey (ICES 1996, 1997).

4.3.1 Sampling strategy (Southern area)

The plankton survey grid was designed according to the procedure described in AEPM manual (ICES, 1994). The basic sampling unit was 0.5º longitude * 0.5º latitude, half of an ICES rectangle. In the Cantabrian coast and in the south of Portugal and Spain, the standard half ICES rectangle was changed to a quarter degree latitude by one degree longitude because transects in those regions were done perpendicular to the 200 m depth contour line.

The plankton survey effort was increased in 2001 following the recommendations of the Working Group (ICES, 2000a) to decrease the variance of the mackerel egg production estimate. In periods 1, 2 and 3 Portugal made two hauls per ICES rectangle. In periods 3 and 4 additional sampling was carried out by Spain (IEO) and replicate rectangles were made in areas where high densities of mackerel and horse mackerel eggs were expected. In these periods (3 and 4) three vessels were operating in each period in the Cantabrian Sea and three and four hauls were made in some half rectangles.

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

4.3.2 Replicate sampling

Repetition experiments of two different kinds were carried out during the “Walther Herwig III” cruise. This cruise was divided into two legs, the first surveying the standard sampling area from north to south and back from south to north after a stopover. During both parts every second leg was sampled, according to the instruction (ICES, 2000a). To be able to sample the alternating transects on the way back the sampled transects from the first leg had to be crossed. Using the opportunity the rectangles, which had been sampled on the first leg were then sampled again, with a variable time lag between the two samplings (Tab. 4.3.2-1). Due to this survey design the more southerly rectangles were resampled sooner than the more northerly ones. A total of 15 rectangles were resampled this way. The numbers of sampled and resampled eggs were classified into either being in the same order of magnitude or not. If being in the same order of magnitude the samples were classified as not being different, and thus to match, and vice versa, not to match if the difference between the two samples was larger than an order of magnitude. Table 4.3.2-1 shows that out of the 15 resampled rectangles only 4 were of a different order of magnitude. The comparison with the horizontal distribution of the egg concentrations shows that the rectangles with a non-match of egg concentrations were all in regions where either the egg concentrations had been high during the first leg (hot spots) and had disappeared between first and second sampling, or where in an area where on the first leg the egg concentrations had been low, but had increased to become a new “hot spot” between the first and second sampling (Bez & Hammer, 2001).

These results indicate that the sampling precision is relatively good. The V-shaped hauls taken in the half-rectangles by means of the Gulf-sampler, or in this case its derivate “Nackthai”, apparently samples the eggs reasonably well. To investigate the influence of the time vector on the sampling, another eight hauls were made in the ICES-half rectangle 29D9-West. All these samples were taken during one night and were distributed along the 200 meter shelf contour. Table 4.3.2-2 shows that the egg concentrations were all in the same order of magnitude, and in fact fairly close together, with a mean of 423 eggs per haul and a standard deviation of ±179, and a coefficient of variation of 58%. With respect to the patchiness of eggs and the size of the sampling area, this is considered to be very close together, again indicating that the single hauls in the ICES-half rectangles are reasonably well representative.

4.3.3 Sampling gears and procedure

In the western area plankton sampling was carried out, using national versions of a Gulf III type sampler with the exception of Norway and Spain who used Bongo samplers (Table 4.3.3-1).

Each Gulf III type sampler was fitted with a conical nosecone with an aperture of either 19.5cm (Netherlands) or 20cm diameter. The Gulf III type samplers were deployed to within 3m of the bottom or to a maximum of 200m in deeper water. A double-oblique haul was carried out at each sampling position at a ship speed of approximately 5 knots. Calibrated flowmeters, mounted to both inside the nosecone and externally on the body of each sampler, were used to calculate the volume of water filtered on each deployment. The presence or absence of a thermocline on each survey is shown in Table 4.3.1-1 and 4.3.1-2. A thermocline was recorded only on the Irish survey in the period 7.

In the southern area Bongo samplers were used by Portugal (60 cm diameter) and Spain (40 cm diameter) while the Netherlands, Germany and England used Gulf III's (Table 4.3.3-2). Both nets were deployed on double oblique hauls to a maximum depth of 200 m or to within 3 m of the bottom in shallower water. They were towed at a ship speed of 2-3 knots and calibrated flowmeters mounted in the aperture were used to calculate the volume of water filtered.

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

4.3.4 Data analysis

All data analysis was carried out in accordance with the procedures described in detail for the 1995 survey (ICES, 1996) and the planning group for the 1998 surveys (ICES, 1997).

For all sampling in the western area, individual countries supplied data on an electronic database form to the data coordinator at the Marine Laboratory, Aberdeen. For sampling in the southern area data were supplied in Excel spreadsheet format to the data coordinator in Madrid.

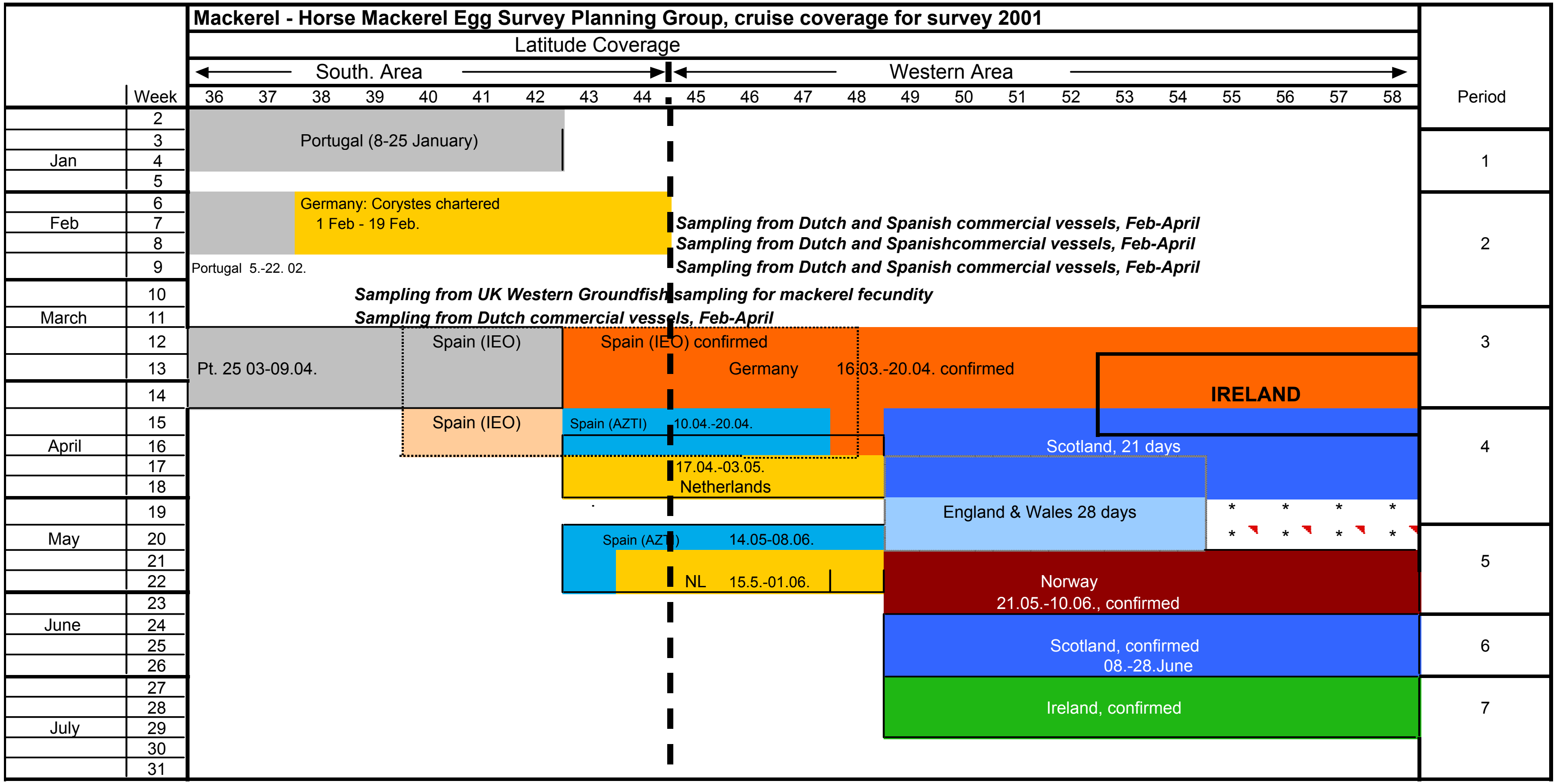
The data consisted of sample position, numbers of mackerel and horse mackerel eggs, counted in each deployment stage, sub sample size, volume of filtered seawater by the sampler, depth sampled, together with temperature and salinity profiles. Each country was responsible for validating their own basic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

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

Individual countries supplied plankton data from sampling in the southern area in Excel spreadsheet format to the data co-ordinator in Madrid. All data analyses were carried out in accordance with the procedures described in detail for the 1995 survey (1996) and at the planning group for the 2001 survey (ICES 2000a).

Replicate rectangle samples were taken mainly in periods 3 and 4, when three vessels in each period were operating. For both species, the coefficient of variation σ were estimated by the residual standard deviation from an analysis of variance of log (stage I eggs/m2/day) by rectangle (ICES 1996). The estimated σ values (0.81 for mackerel and 0.54 for horse mackerel) were used to estimate variance. As a result of the higher sampling intensity, the estimated σ values were significantly lower than the corresponding ones estimated in 1998 (1.27 for mackerel and 1.44 for horse mackerel).

Table 4.1-1. Scheduled cruise coverage according to ICES (2001a).



* Areas with asterics are considered to be important and need to be covered.
Coverage can not yet be confirmed

Table 4.1-2. Deployment of research vessel effort in the 2001 western mackerel and horse mackerel egg survey.

Period	Country	Vessel	Dates	Area Coverage (total)	Ship days
3 12.3.-8.4.	Spain (IEO) Germany Ireland	Cornide Walther Herwig III Emerald Dawn	16.03.-05.04 16.03.-03.04. 18.03.-11.04.	42°15'N-45°00'N 59°45'N-43°15'N 56°15'N-49°15'N	5 19 25
4 9.4.-30.4.	Spain (IEO) (Spain (IEO)) Spain (AZTI) Germany Scotland Netherlands England & Wales	Cornide Thalassa Investigador Walther Herwig III Scotia Tridens Cirolana	09.04.-29.04. 05.04.-21.04. 10.04.-18.04. 08.04.-20.04. 10.04.-01.05. 17.04.-26.05. 24.04.-30.04.	45°45'N-42'15'N 43°45'N-43°15'N 43°00'N-47°00'N 59°45'N-43°15'N 60°30'N-49°15'N 48°00'N-41°15'N 54°15'N-46°45'N	5 (7*)) 4 13 22 10 7
5 1.5.-31.5.	England & Wales Spain (AZTI) Netherlands Norway	Cirolana Investigador Tridens G.O.Sars	01.05.-20.05. 14.05.-08.06. 21.05.-31.05. 23.05.-31.05.	54°15'N-46°45'N 43°00'N-47°00'N 48°00'N-45°00'N 58°45'N-49°15'N	21 25 11 9
6 1.6.-30.6.	Scotland Norway	Scotia G.O.Sars	07.06.-29.06. 01.06.-14.06.	47°15'N-60°15'N 58°45'N-49°15'N	23 15
7 1.7.-31.7.	Ireland	Celtic Voyager	01.07.-23.07.	49°15'N-58°15'N	23
				Sum of realised ship days:	**244**

*) 19 trawl hauls within 14 days of another pelagic survey, registered as 0.5 realised ship days

Table 4.1-3. Deployment of research vessel effort in the 2001 southern mackerel and horse mackerel egg survey

Period	Country	Vessel	Dates	Area Coverage	Ship days
1 1.-31.1.	Portugal	Noruega	11.01.-02.02.	36°15'N-42°45'N	23
2 1.2.-11.3.	Germany/ England Portugal	Corystes Capricórnio	01.02.-19.02. 14.02.-01.03.	46°15'N-39°15'N 36°15'N-41°15'N	19 16
3 12.03.-8.4.	Portugal Spain (IEO) Germany	Capricórnio Cornide Walther Herwig III	13.03.-01.04. 16.03.-05.04. 04.04.-07.04.	36°15'N-42°45'N 46°45'N-42°15'N 59°45'N-43°15'N	20 15 4
4 9.4.-30.4.	Spain (IEO) Spain (AZTI) Netherlands	Cornide Investigador Tridens	09.04.-29.04. 10.04.-18.04. 26.04.-03.05.	45°45'N-42°15'N 43°00'N-47°00'N 45°00'N-41°15'N	15 5 8
5 1.5.-31.5.	Spain (AZTI) Netherlands	Investigador Tridens	14.05.-19.05. 15.05.-21.05.	43°00'N-47°00'N 45°00'N-41°15'N	6 7
				Sum of realised ship days:	**138**

Table 4.2-1 Sampling intensity during the 2001 Mackerel and Horse Mackerel Egg Survey.

		Plankton Hauls		Trawl Hauls	
		Western Area	**Southern Area**	**Western Area**	**Southern Area**
Noruega	11.01.-01.02.		103		6
Corystes	01.02.-19.02.	14	46	2	11
Capricornio	14.02.-01.03.		84		9
Capricornio	13.03.-01.04.		80		6
Cornide	16.03.-05.04.	26	69		
Walther Herwig III	16.03.-20.04.	212	18	14	2
Emerald Dawn	18.03.-15.04.	160			
Cornide	09.04.-29.04.	28	94		
Investigador	10.04.-18.04.	33	11		
Scotia	10.04.-01.05.	165		8	
Tridens	17.04.-03.05.	65	35	8	
Cirolana	24.04.-20.05.	150		11	
Tridens	14.05.-31.05.	77	39	8	
Investigador	15.05.-08.06.	34	11		
G.O.Sars	23.05.-14.06.	126		16	
Scotia	07.06.-29.06.	147		5	
Celtic Voyager	01.07.-23.07.	79			
	total	**1316**	**590**	**72**	**34**

Table 4.3.2-1. Replication of plankton hauls on cruise "Walther Herwig III" (cruise 227).

rep.#	haul no.	rectangle	DATE 1st sampling	DATE 2nd sampling	time diff. (days)	**#eggs 1st sampl.**	**#eggs 2nd sampl.**	difference (%)	match
1	126, 168	22E4 (E)	02.04.2001	10.04.2001	8	**0**	**0**	0.0	y
2	100, 174	24E2 (E)	01.04.2001	11.04.2001	10	**926**	**58**	-93.7	n
3	100, 181	26E0 (W)	30.03.2001	11.04.2001	12	**1473**	**237**	-83.9	n
4	64, 194	32D7 (E)	26.03.2001	13.04.2001	18	**1**	**0**	-100.0	y
5	65, 193	32D8 (W)	26.03.2001	13.04.2001	18	**62**	**100**	61.3	y
6	66, 192	32D8 (E)	26.03.2001	13.04.2001	18	**540**	**203**	-62.4	y
7	67, 199	32D9 (W)	26.03.2001	14.04.2001	21	**5**	**741**	14720.0	n
8	68, 201	31D9 (E)	26.03.2001	14.04.2001	21	**38**	**311**	718.4	n
9	69, 202	31E0 (E)	26.03.2001	14.04.2001	21	**6**	**16**	166.7	y
10	70, 203	31E0 (E)	27.03.2001	14.04.2001	20	**4**	**6**	50.0	y
11	77, 204	30E0 (W)	27.03.2001	14.04.2001	20	**191**	**278**	45.5	y
12	78, 205	30D9 (E)	27.03.2001	14.04.2001	20	**209**	**694**	232.1	y
13	79, 206	30D9 (W)	27.03.2001	14.04.2001	20	**496**	**671**	35.3	y
14	86, 218	28E0 (E)	28.03.2001	15.04.2001	20	**39**	**43**	10.3	y
15	92, 225	27E3 (E)	29.03.2001	16.03.2001	21	**17**	**15**	-11.8	y

Table 4.3.2-2. Eight replication plankton hauls of "Walther Herwig III" in ICES half-rectangle 29D9-West, along the shelf contour.

haul no.	date	**eggs**
207	14.04.2001	**318**
208	15.04.2001	**605**
209	15.04.2001	**632**
210	15.04.2001	**566**
211	15.04.2001	**322**
212	15.04.2001	**182**
213	15.04.2001	**230**
214	15.04.2001	**526**
	mean	**423**
	sd	179
	+/-	58%

Table 4.3.3-1. Sampling gears and procedures adopted during the 2001 western mackerel and horse mackerel egg surveys									
Country	Sampling Period	**Sampler**		**Max depth (m)**	Thermocline		**Temperature (ºC)**		**Comments**
		Type	**Aperture diam (cm)**		**Definition**	**Sampling strategy**	**Measured**	**Use for prod.**	
Germnay	2, 3, 4	Gulf III	20	200	2.5C/10m	200 m	Full Profile	Temp @ 20 m	Thermocline not found
Spain (IEO)	3, 4	Bongo	40	200	2.5C/10m	200 m	Full Profile	Temp @ 20 m	Thermocline not found
Netherlands	4, 5	Gulf III	19.5	200	2.5C/10m	200 m	Full Profile	Temp @ 20 m	Thermocline not found
Scotland	4, 5, 6	Gulf III	20	200	2.5C/10m	200 m	Full Profile	Temp @ 20 m	Thermocline not found
Spain (AZTI)	4, 5	Bongo	40	200	2.5C/10m	200 m	Full Profile	Temp @ 20 m	Thermocline not found
Norway	5	Gulf III	20	200	2.5C/10m	200 m	Full Profile	Temp @ 20 m	
England	4, 5	Gulf III	20	200	2.5C/10m	200 m	Full Profile	Temp @ 20 m	Thermocl. rule not applied
Ireland	3, 4, 7	Gulf III	20/25	200	2.5C/10m	200 m	Full Profile	Temp @ 20 m	Thermocline in July

Table 4.3.3-2. Sampling gears and procedures adopted during the 2001 southern mackerel and horse mackerel egg surveys

Country	Sampling Period	**Sampler**		**Max depth (m)**	**Thermocline**		**Temperature (ºC)**		**Comments**
		Type	**Aperture diam (cm)**		**Definition**	**Sampling strategy**	**Measured**	**Use for prod.**	
Portual	1+2+3	Bongo	60	200	2.5C/10m	200 m	Full Profile	Temp @ 20 m	Thermocline not found
England	2	Gulf III	20	200	2.5C/10m	200 m	Full Profile	Temp @ 20 m	Thermocline not found
Spain (IEO)	3+4	Bongo	40	200	2.5C/10m	200 m	Full Profile	Temp @ 20 m	Thermocline not found
Germany	3	Gulf III	20	200	2.5C/10m	200 m	Full Profile	Temp @ 20 m	Thermocline not found
Netherlands	4+5	Gulf III	19.5	200	2.5C/10m	200 m	Full Profile	Temp @ 20 m	Thermocline not found
Spain (AZTI)	4+5	Bongo	40	200	2.5C/10m	200 m	Full Profile	Temp @ 20 m	Thermocline not found

Figure 4.1-1 Deployment of ship time in the Mackerel and Horse Mackerel Egg Surveys 1977-2001.

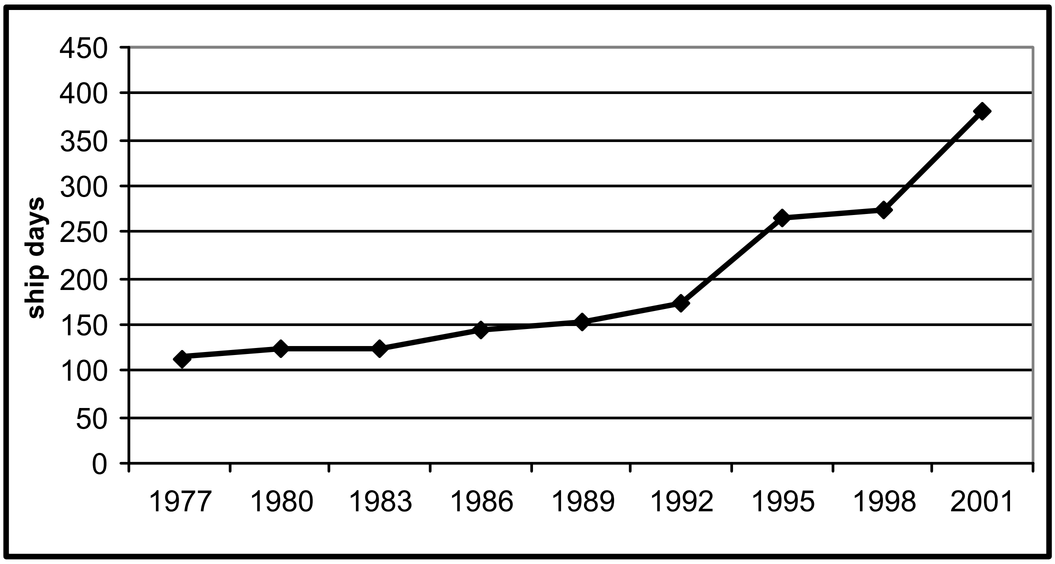


Figure 4.2.1.-1. Standard survey area.

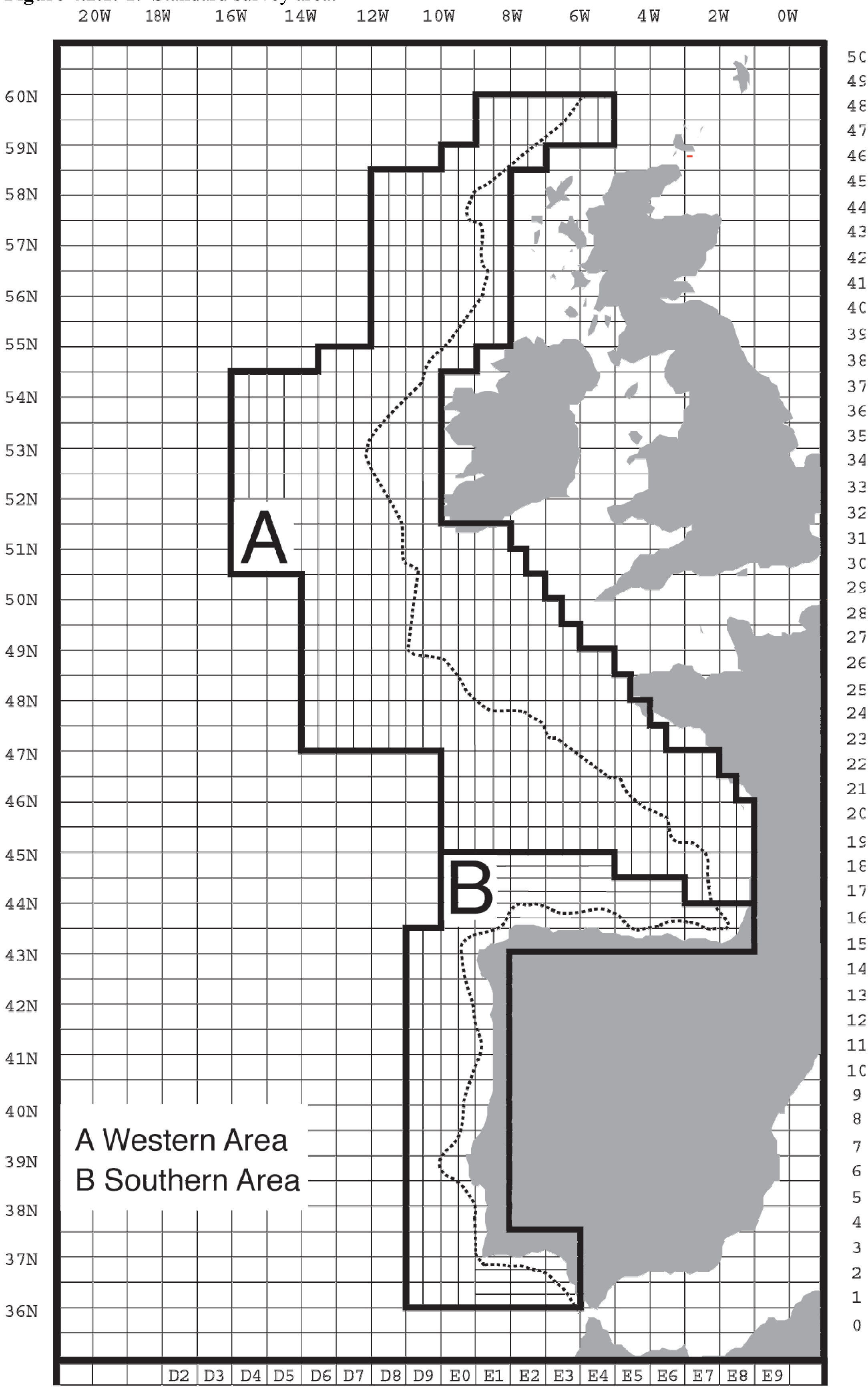
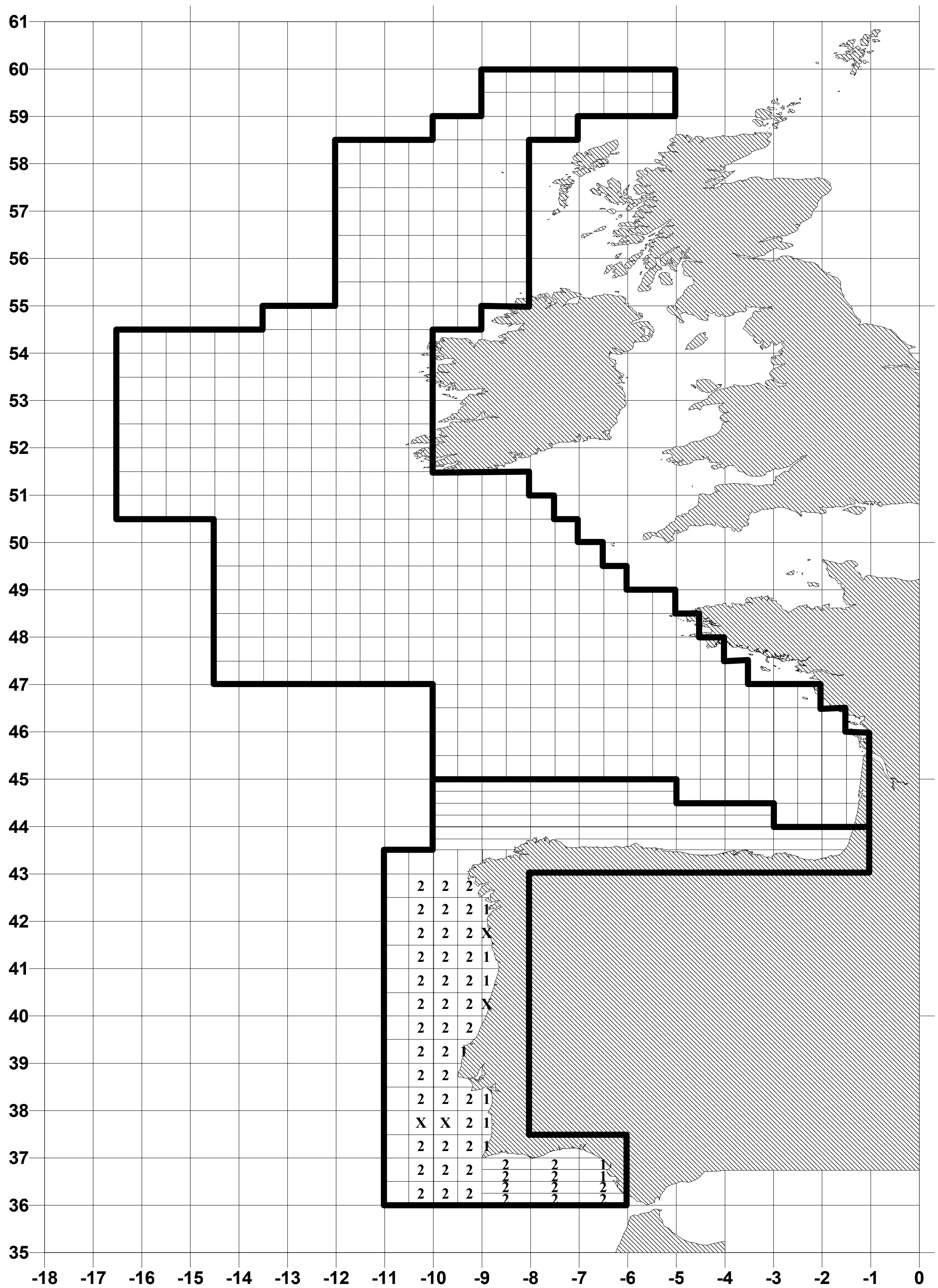


Figure 4.2.1-2a. Number of observations per rectangle in period 1 (21 January – 10 February) – X represents



interpolated rectangles.

Figure 4.2.1-2b. Number of observations per rectangle in period 2 (11 February – 17 March) – X represents interpolated rectangles

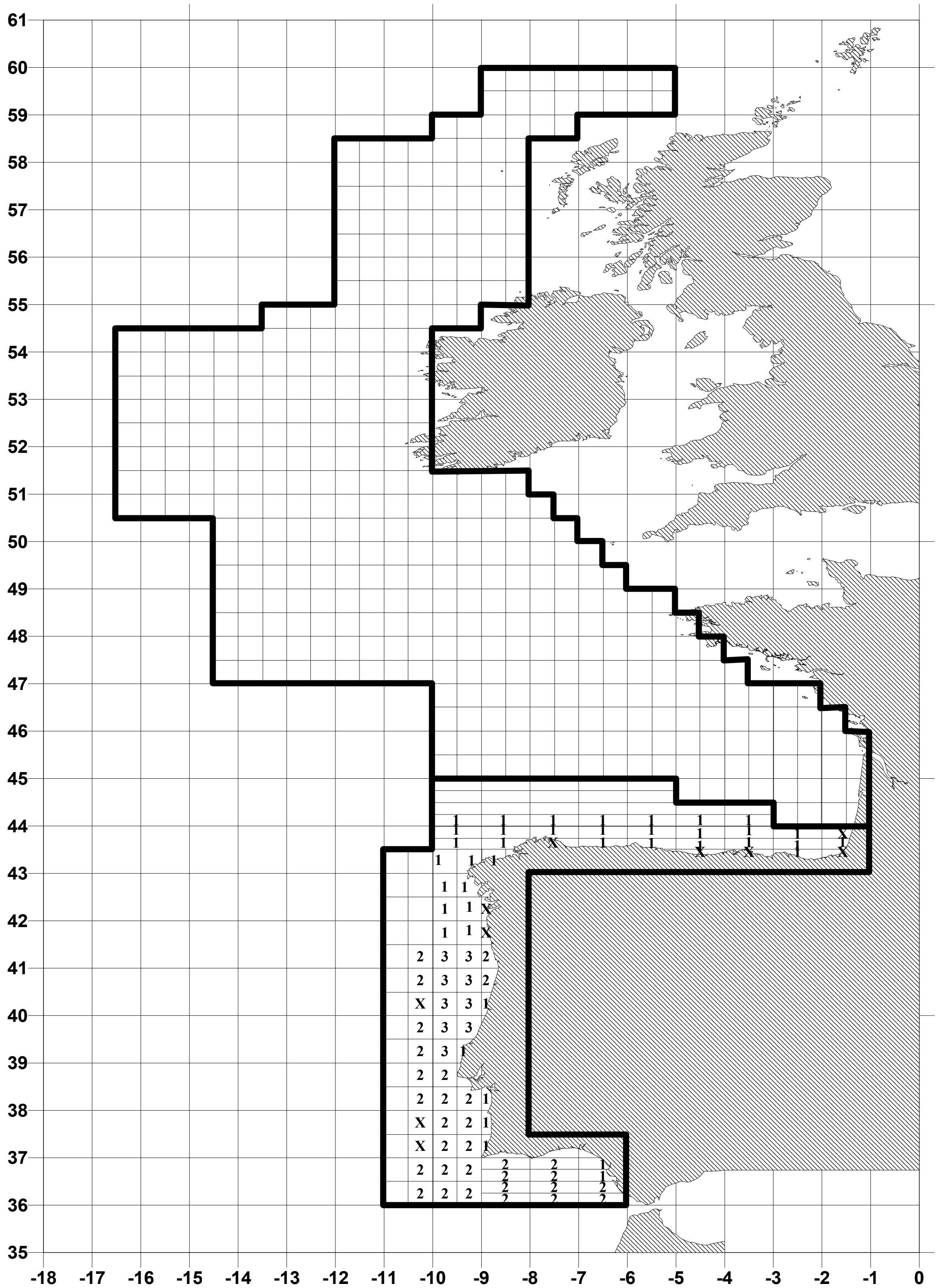


Figure 4.2.1-2c. Number of observations per rectangle in period 3 (18 March – 14 April) – X represents interpolated rectangles

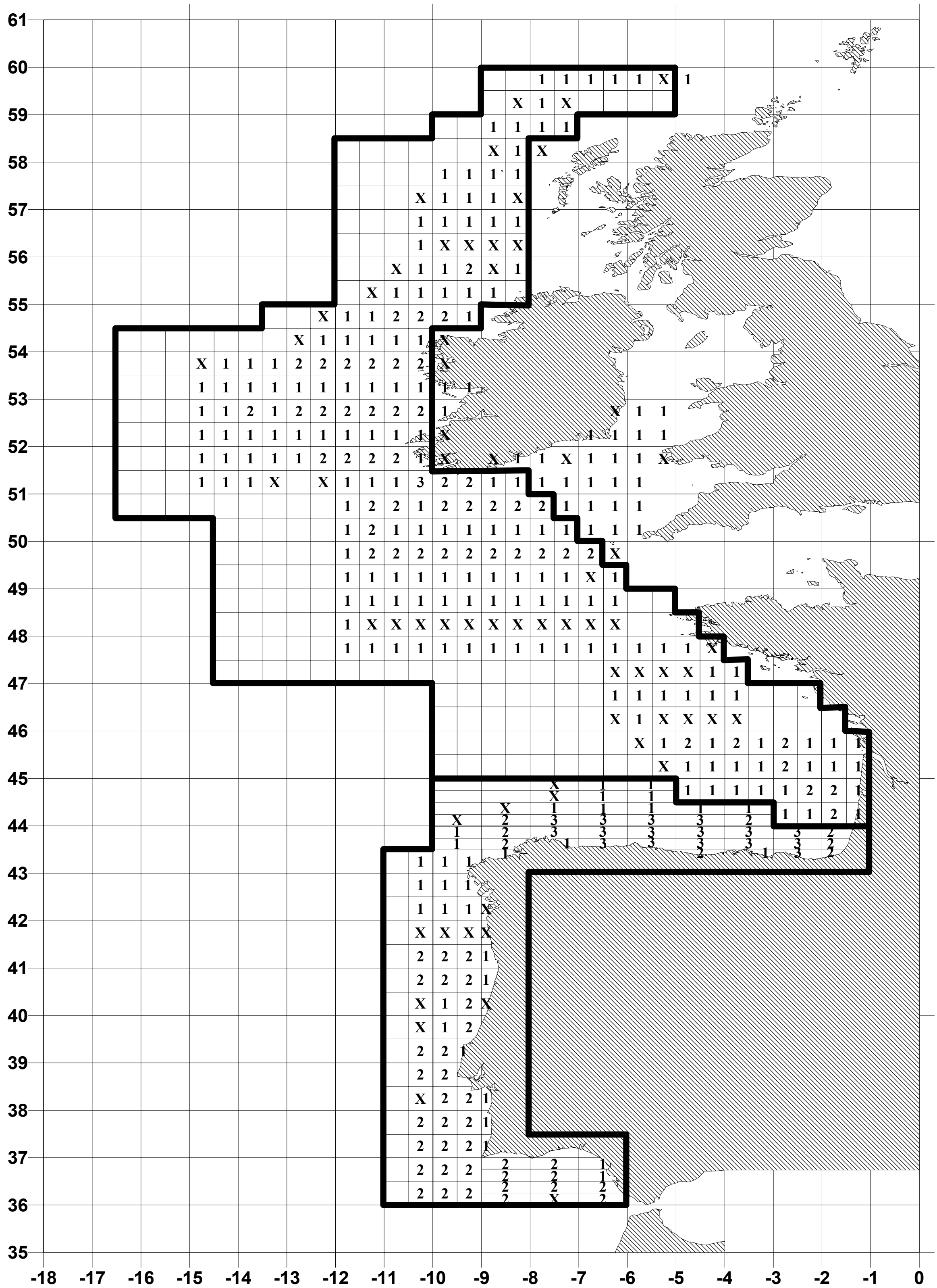


Figure 4.2.1-2d. Number of observations per rectangle in period 4 (15 April – 19 May) – X represents interpolated rectangles

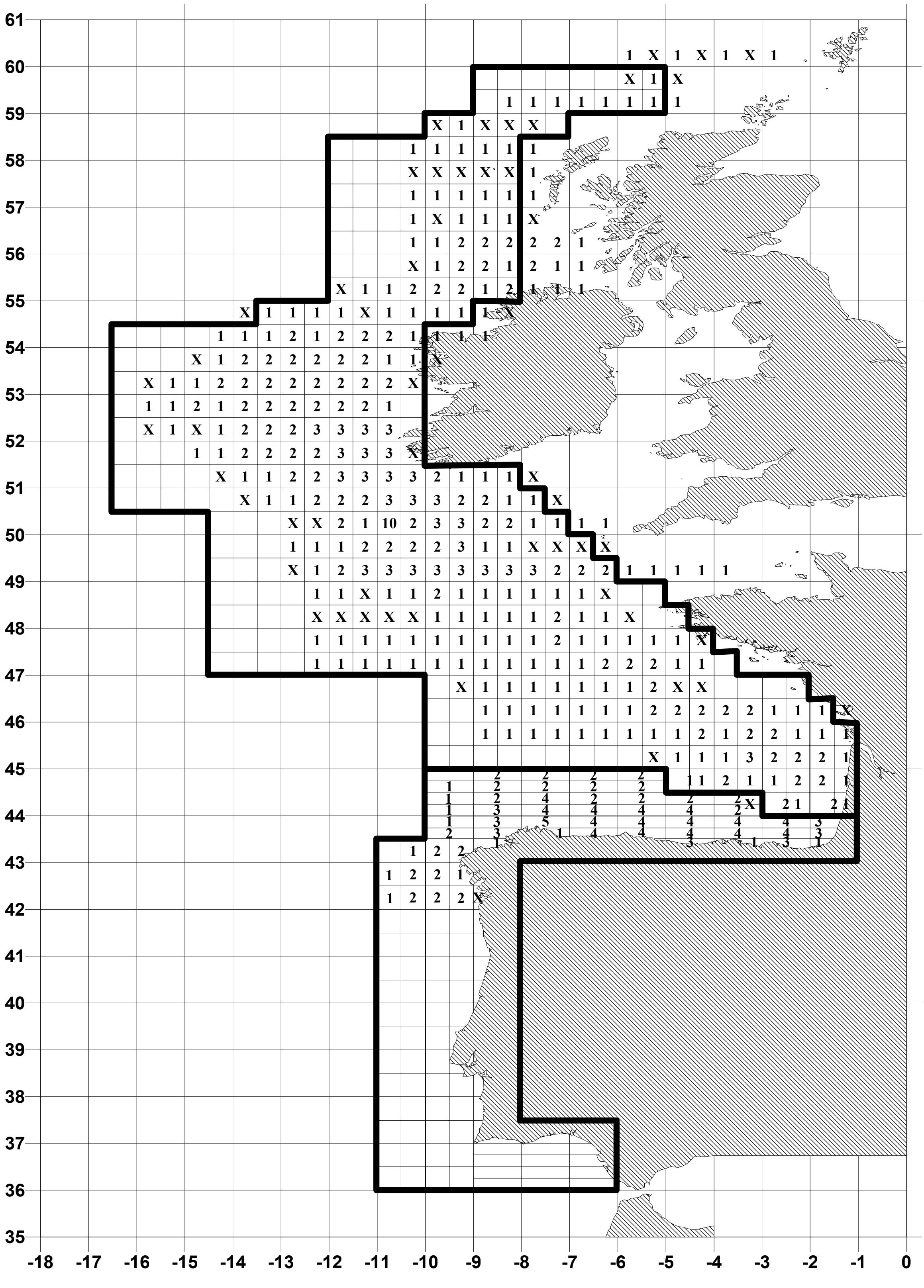


Figure 4.2.1-2e. Number of observations per rectangle in period 5 (20 May – 16 June) – X represents interpolated rectangles

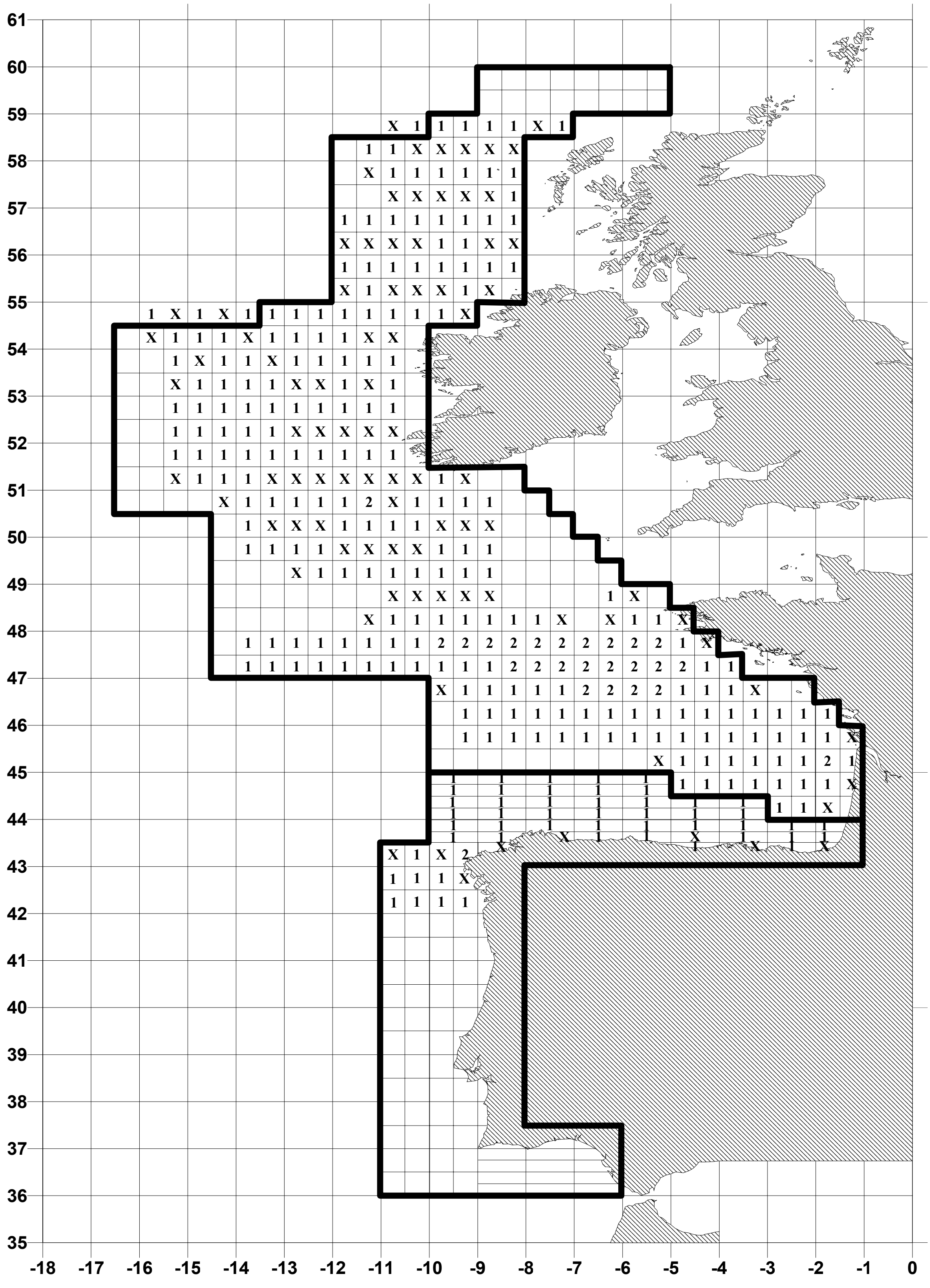


Figure 4.2.1-2f. Number of observations per rectangle in period 6 (17 June – 7 July) – X represents interpolated rectangles

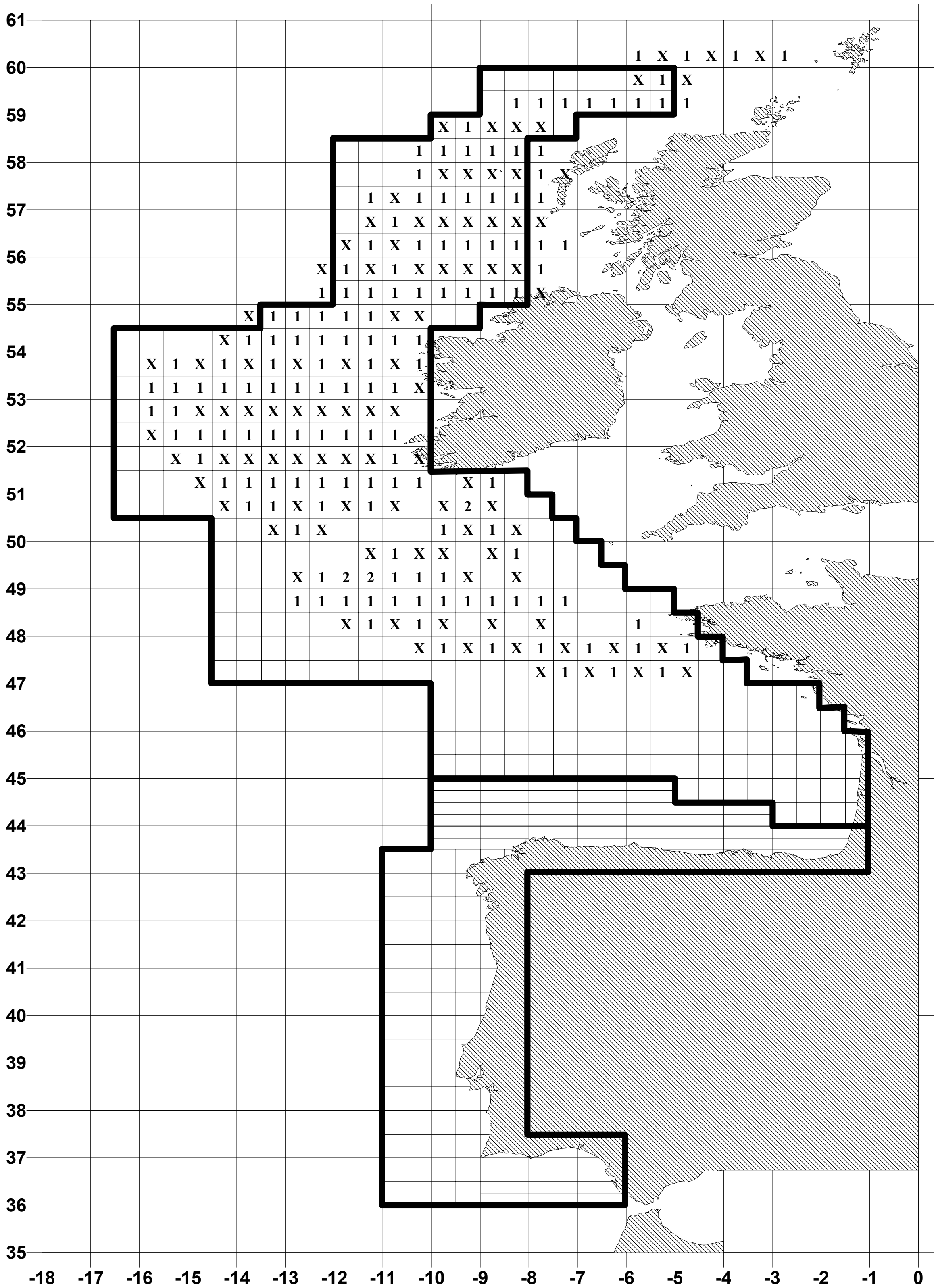
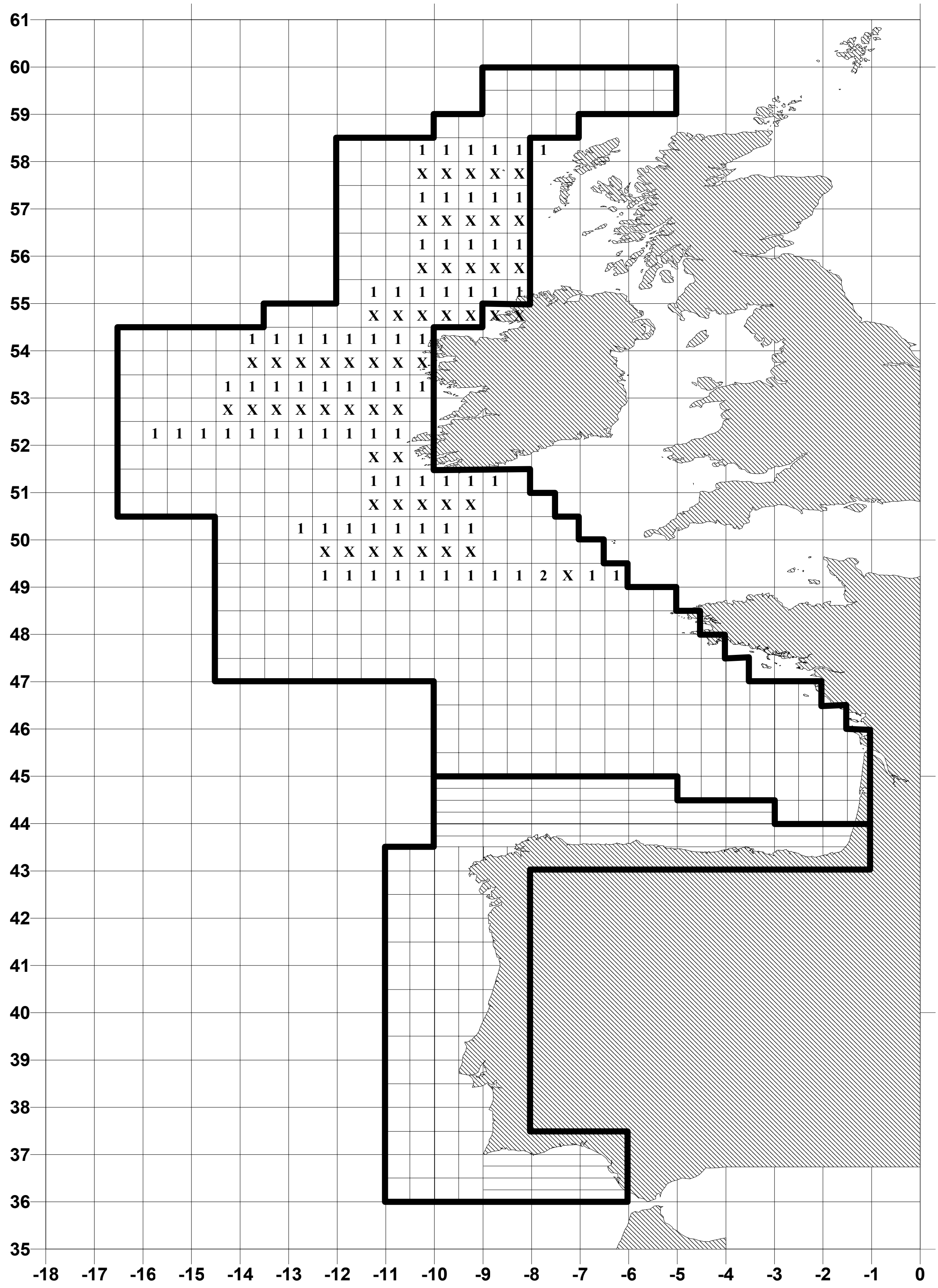


Figure 4.2.1-2g. Number of observations per rectangle in period 7 (8 July – 28 July) – X represents interpolated rectangles



5 MACKEREL IN THE WESTERN AND SOUTHERN SPAWNING AREAS: 2001 EGG SURVEY RESULTS

5.1 Spatial distribution of stage 1 mackerel eggs

5.1.1 Western Spawning area

The first survey in the western area was in Period 3 (18 March to 14 April) (Figure 5.1.1-1c). Coverage was very good over the entire area, from the Gulf of Cadiz to the North of Scotland. This is the first time that this has been achieved. Egg production was patchy between the inner corner of Biscay to the Northwest of Ireland, with concentrations around Grand Sole Bank, south west of Ireland, and on the Porcupine Bank. One transect was interpolated (48°15‘N) and there were a number of edge interpolations between 53 and 55°N on the western edge.

Coverage in Period 4 was also very good (Figure 5.1.1-1d). The main concentration of spawning was in the area of Porcupine Bank and south west of Ireland. There was some evidence of spawning at the 200m contour through Biscay and into the Celtic Sea, as well as to the Northwest of Ireland. It is interesting that there was still strong egg production in the Cantabrian Sea, which was not reflected in Biscay. There were no obvious problems with interpolation at the edges of the distribution.

Coverage in Period 5 was slightly less perfect than in the previous periods. A number of rectangles required interpolation, however, in most cases these were well supported. The only major anomaly from the interpolation was one rectangle at 51° 15‘N. The main spawning was in a continuous broad band from Porcupine Bank to the Hebrides west of the 200m contour. Another strong area was seen in the area west of Brittany. Spawning was substantially reduced in the Cantabrian Sea.

Coverage in Period 6 was again very good, although there were was a general pattern of every second transect being sampled, and the intervening transects being interpolated. The resultant distribution appears reasonable and there were no major interpolation anomalies. Distribution is similar to Period 5 with a broad band of spawning west of Ireland. The patch in the Celtic Sea was further north than in Period 5. There was also some evidence of spawning in the area north of Scotland as far north as 60° 15‘N. This area should be investigated in more detail in future surveys.

Only one vessel was available for Period 7 so the coverage was necessarily less complete than in previous periods. In general coverage was good, although as in Period 6 sampling was conducted on alternate transects, with the intervening transects interpolated. This did not constitute a problem as egg production was generally low in this period. The main problem in this period was the relatively high egg production at the southern edge of the surveyed area. This was surprising at this time of year, and may suggest that there were more eggs further south.

5.1.2 Southern spawning area

Distribution maps of daily stage I egg production m-2 are given for the five survey periods in Figures 5.1.1-1a-e. The timing of the survey periods was synchronised for the western and southern area.

As scheduled, the first Portuguese cruise surveyed the southern part of the southern area (36º00N - 43º00 N) in period 1. Mackerel eggs stage I were very sparse with very low abundance between 37º30 and 43º00 N and near the coast. The egg production was generally much lower than in 1998.

In Period 2, the southern area was sampled from 36º00’N to 44º15’N by the second Portuguese cruise and the English cruise. As in the previous period, the western half rectangles were not sampled as well as the last three northern half rectangles in the Cantabrian Sea. Very low abundances of mackerel eggs stage 1 were found in all the sampled area. There were no eggs south of 39º00’N. The egg production was slightly higher than in 1998 due to the fact that in 2001 the Cantabrian Sea was surveyed in this period.

During period 3, the total southern area was surveyed by Portugal, Spain (IEO) and Germany. Mackerel eggs were found in low abundance near the Portuguese coast. The highest densities were located along the Cantabrian Sea between the coast and the 1000 m contour. Mackerel egg distribution in the north part of the area during this period indicated the start of the peak of spawning in the southern area. In 1998 the abundance was much higher and to the east.

In period 4 only the north part of the southern area was sampled by Spain (IEO & AZTI) and the Netherlands, as scheduled. Mackerel egg production during period 4 suggests that this was the peak spawning of mackerel in

Cantabrian Sea as occurred in 1998. The pattern was very similar to that in period 3, with the higher abundance between the coast and the shelf break, but the spawning was extended to the east, the opposite to what happened in 1998. Very few eggs were found in deeper waters.

In period 5 all the north part of the area was sampled by AZTI and the Netherlands who covered the area as scheduled. There was little spawning in this period. Mackerel egg distribution was more spread offshore than in previous periods. The egg production in period 5 was low but higher than in 1998, this area should have been surveyed in period 6.

5.2 Egg production of the Northeast Atlantic Mackerel

5.2.1 Stage I egg production in western spawning area

The mean daily stage I egg production estimates for each survey period are plotted against the mid-period days in Figure 5.2.1-1 to provide an egg production curve as presented for previous surveys. The data values are presented in Table 5.2.1-1.

The start date was assumed to be the 10 February as used in 1995 and 1998, when spawning also occurred earlier than in the previous survey years. This date was earlier than used for the surveys before 1995 (19 February). No histological or survey data were available in the western area or in the Cantabrian Sea prior to period 3 to suggest any alternative start date. The end date is the same as that used in 1995 - 31 July. Samples in the northern part of the survey area at the end of period 7 found no eggs which suggests that spawning had substantially ended by the final week in July. Production estimates for the individual survey periods and the period before the surveys are presented in Table 5.2.1-2.

There was no temporal overlap between periods for the 2001 survey. The variance pattern is similar to 1998. The calculations are based on the complete survey results including all observations irrespective of the proposed survey area. This approach was used as the survey is based on surveying the entire stock, regardless of where it was, and also on the need after all previous surveys to update the „standard area" for each new survey (see 4.2.1). No data from the southern area were included in this analysis. In previous years, there was a negligible effect on the estimate of expanding the 1998 area as most of the additional observations were very low.

5.2.2 Stage I Egg production in southern spawning area

The mean daily stage I egg production estimated for each individual period is given in Table 5.2.2-1 Total egg production values for the individual time periods and interpolated periods are given in Table 5.2.2-2 and the daily egg production estimates for each survey period were plotted against the mid cruise dates to give the egg production curve (Figure 5.2.2-1).

The start of spawning for mackerel was assumed on the 17 January, the same as in 1998. It is based on the stage III eggs found off the Portuguese coast during period 1, on the 21 January. So, even though the first survey carried out by Portugal in period 1 started on January 11 it has been assumed, as in 1998, that the starting date of the first period is January 17. Similar to 1998, the end of the spawning was assumed to be the 17 July, instead of taking the last day that stage I was found in the last period surveyed.

Total egg production for mackerel in 2001 and comparison with egg production in 1998 are shown in the text table below.

Estimates of the total mackerel egg production in the southern spawning area in 1998 and 2001		
Year	Annual stage I egg production*10^{-13}	
	estimate	se
1998	43.37	18.84
2001	28.31	4.67

In 2001, the mackerel egg production decreased considerably (34.7%) compared with 1998. The coefficient of variation (CV) of the total egg production (16.5%) decreased a lot compared with 1998 (43.4%) due to replicate sampling in some rectangles during the 2001 surveys.

5.3 Potential fecundity of Northeast Atlantic mackerel

5.3.1 Potential fecundity in the western spawning component

A more detailed description of this assessment presented by Witthames and Greenwood (WD WGMHMES 2001) is summarised below. Ovaries from over 379 mackerel at maturity stage 3 (Walsh *et al*., 1990) were collected in periods 3 and 4 by several research vessels fishing over a wide part of the spawning area. These samples were distributed alternately between England, Germany (contracted to England) Norway and Scotland to estimate potential annual fecundity using methodology described in ICES 2000a. A substantial proportion of the ovaries were not suitable for the determination of potential fecundity because they were either too immature, very atretic or contained evidence of past spawning activity (presence of hydrated oocytes or POFS). The numbers of samples rejected 43, 45 and 72% varied between countries (England, Norway and Scotland). This left 187 ovaries collected over a range of latitude and time detailed in Table 5.3.1-1. Plots of annual potential fecundity (oocytes larger than 0.130mm) and relative potential annual fecundity in relation to fish weight are shown in Figures 5.3.1-1 and 5.3.1-2 respectively. Relative fecundity was weakly related to fish length. Further analysis of the variance in the data in relation to country, latitude of collection and time (week) was carried out and the results are shown in Table 5.3.1-1. In addition to the effect of country, previously discussed in section 2.3, latitude was also significant and indicated that fish in the south of the spawning area were more fecund. At this stage the effect of country is not likely to be resolved and effort should be directed to improving the proposed new method using formaldehyde fixed tissue. The effect of latitude and fish weight on relative fecundity in relation to the assessment of population fecundity is presented in section 2.5. At this stage this approach needs further consideration in relation to the historical time-series of fecundity, which may have inadequate coverage for this to be implemented. The overall mean of 1097 se 23.6 oocytes / gram female is significantly lower than that reported in 1998 (1206 se 17.5).

5.3.2 Fecundity versus condition factor

To monitor and investigate variability in fecundity from year to year the Working Group suggests that ovaries are collected every year to study potential and realised fecundity. In addition, the development of the condition factor prior to spawning (4. and 1. quarter) and during spawning (2. quarter) should also be monitored. Preliminary investigations of condition factors based on some Norwegian data (Slotte pers. comm.) indicated that the condition factor to some degree reflected the observed variation in fecundity from the high level in 1995 to the lower levels in 1998 and 2001. This should be investigated further to see if the condition factor prior to and during the spawning season might indicate the level of realised fecundity. Such information would be most helpful in years when egg surveys are carried out.

5.3.3 Potential fecundity in the Southern spawning component

The sampling of the adult to estimate potential fecundity of mackerel took place in 2001 following the procedures agreed upon by the WMHGSS planning group. The research vessels Walther Herwig III (Germany) and Corystes (UK) collected 82 ovaries of adults (Table 5.3.3-1) which were analysed by IEO. 42 ovaries with hydrated oocytes were rejected and 40 ovaries non hydrated and without POFs were accepted to estimate fecundity. The final sample consisted of fish between 70 and 452 g, the mean weight and the mean length being 267 g and 335 mm respectively. The relationship between weight and annual potential fecundity is shown in Fig. 5.3.3-1. The mean estimated relative fecundity was 1,689 (s.e. 31.77) oocytes/g (Table 5.3.3-2). This value is 24% higher than the corresponding one obtained in 1998.

5.4 Atresia and realised fecundity in the Northeast Atlantic Mackerel

5.4.1 Atresia and realised fecundity of the western spawning component

Ovaries from samples of fish collected according to the sampling protocol (ICES 2000a) in periods 3 to 6 (Table 5.4.1-1) were prepared for stereometric analysis to quantify prevalence (number of fish with atresia present in the ovary) and relative intensity (number of early alpha atretic oocytes g^{-1} total weight). Methods of data analysis to discount the production of atretic oocytes over the predicted spawning duration (60 days) from the relative potential fecundity are as described in ICES (1996). At the time of the WG only results from England and Norway were available for the assessment. Further data based on samples sent to Scotland require more information on:

- The histological embedding medium used to prepare slides for analysis.
- Details of the prevalence and intensity of atresia prepared according to the standard data format (ICES 2000a) from the Aberdeen University contract report.

The data on intensity and prevalence of atresia is plotted in Figure 5.4.1-1 in relation to fish weight. This data implies that atresia reduced potential fecundity more in the smallest and largest fish comprising the spawning population but the mean value (0.2) probably does not introduce an overall bias. In the case of intensity there is some tendency for larger females to loose more of their potential fecundity though this is not very marked. Overall the estimate in 2001 includes nearly three times the number of fish (290 compared to 112 Table 5.4.1-2) and the temporal coverage is also better. As in previous surveys the final period 6 has the most sparse coverage. During 2001 prevalence of atresia was less than half the value compared to 1998 whilst the Geometric mean intensity was similar 46 compared to 40.2 se 13.6 respectively. Overall realised fecundity after discounting fewer atretic oocytes (202 compared to 64 in 2001) was almost identical 1002 se 40.7 in 1998 compared to 1033 se 27.2 in 2001 (Table 5.4.1-3). The time-series of potential and realised fecundity estimated since 1989 (the first year of atresia adjustment of potential fecundity) is shown in Fig. 5.4.1-2. In 2001 potential fecundity was the closest ever to realised fecundity, because of the much lower value for atresia prevalence, and also followed the downward trend since 1989.

5.4.2 Atresia and realised fecundity in the southern spawning component

The IEO processed histologically 365 ovaries from random samples collected in periods 2, 3, 4 and 5 (Table 5.3.3-1) to estimate atresia in the Southern Area. A number of 212 ovaries in spawning conditions corresponding to the periods 2, 3, 4 and 5 were selected. The method to discount the atretic oocytes is described in ICES (1996).

The mean length and the mean weight of the accepted females were 460 mm and 393 g respectively. Atresia was found in 17 females, prevalence being 8% and intensity of atresia 68 oocytes/g. The fecundity adjusted for atresia was 1,647 oocytes /g with a coefficient of variation 12.6%. This value of fecundity is higher than the ones estimated in 1995 and 1998 but atresia was now estimated from a wider period. While in 2001 atresia was estimated from data in periods 2, 3, 4 and 5, in 1998 only data from period 3 was available. Estimated fecundity corrected for atresia would be 1,597 oocytes /g if only data from period 3 was used (prevalence 18%). However, the value of 1,647 oocytes /g is believed to be more accurate.

5.5 Mackerel biomass estimate

5.5.1 Estimate of the western spawning component

Total stage I egg production using all data both inside and outside the 1998 standard sampling area, and interpolated rectangles both inside and outside the standard area is given in Table 5.2.1-2. Total spawning stock biomass (SSB) was estimated using the fecundity estimate of 1,033 oocytes/g female, corrected for atresia (see Sections 5.3 and 5.4), a sex ratio of 1:1 and a raising factor of 1.08 (ICES 1987b) to convert pre-spawning to spawning fish. This gave an estimate of spawning stock biomass for 1998 of 2.53 million tonnes, with a variance of approximately 410,000 tonnes. The variance in the estimate due to the egg survey was 86% and 14% to the fecundity estimate.

Comparative data from earlier years are shown in Table 5.5.1-1. These indicate a 14% decrease in biomass compared to the previous egg survey estimate in 1998. This decrease in the estimate of biomass has resulted mainly from a decrease in annual egg production, realised fecundity was almost identical to that found in 1998 (1002 and 1033 oocytes/g female in 1998 and 2001 respectively).

5.5.2 Estimate of the southern spawning component

The annual mackerel egg production estimate was 28.31 x 10^{13} eggs with a CV of 16.53%. Spawning season coverage in the southern area during 2001 was less extended than in 1998. In 2001 the coverage was split in 5 periods (from 11 January to 21 May), one period less than in 1998 (from 17 January to 21 June), not allowing full coverage of the spawning season.

The realised fecundity of 1647 eggs/g, with a coefficient of variation of 12.6% was estimated using the samples processed by the IEO in division VIIIc. This realised fecundity is 41% higher than in 1998. This is related to a difference in the potential fecundity (24%) and in the percentage prevalence of atresia in 2001, which was 8%, compared to 15% in 1998 (Section 5.4.2).

Southern Mackerel		Total annual egg production ($*10^{13}$)	Fecundity per gram of fish weight (oocytes/g)	Total spawning stock biomass (tonnes)
1995	Standard Alternative	16.92 (CV = 6.62%) 20.72 (CV = 6.07%)	1183 (CV = 22.2%) 1183 (CV = 22.2%)	308 957 (CV = 23.2%) 378 450 (CV = 21.6%)
1998		43.37 (CV = 43.45%)	1171 (CV = 28.8%)	800 000 (CV = 68%)
2001		28.31 (CV = 16.53%)	1647 (CV = 12.6%)	371 279 (CV = 20.7%)

The SSB estimated in 2001 was 371 279 t with a CV of 20.7%. This estimation is 53% lower than the SSB estimated in 1998. With the increase of the realised fecundity, the total annual egg production in 2001 (34% lower than in 1998) resulted in a sharp reduction in SSB. However, the SSB estimated in 2001 is similar to the one in 1995.

Since 1999 an acoustic survey was carried out in spring to estimate the stock abundance of small pelagics (sardine, mackerel, horse mackerel and anchovy) off the Galician and Cantabrian Sea. In 2001, the SSB estimated for mackerel was 399,000 tonnes (ICES 2002, Carrera, WD 2001), very similar to the value estimated by means of the egg production method.

Southern Mackerel	SSB Acoustic (ton)	SSB Egg Surveys (ton)
1998		800,000
1999	320,000	
2000	706,000	
2001	399,000	**371,279**

Table 5.2.1-1. Western mackerel mean daily stage 1 egg production 10^{-12}			
Period	Dates	Estimate	Standard Deviation
3	12/3 – 8/4	4.19	0.95
4	9/4 – 13/5	8.35	1.32
5	14/5 – 10/6	20.00	4.66
6	11/6 – 1/7	7.47	1.59
7	2/7 –1/8	1.31	0.49

Table 5.2.1-2. Western mackerel total stage 1 egg production estimates by time period for 2001			
Dates	Period	Number of days	Annual stage 1 egg production.10^{-15}
11/2 – 11/3		30	0.043
12/3 – 8/4	3	28	0.117
9/4 – 13/5	4	35	0.292
14/5 – 10/6	5	28	0.560
11/6 – 1/7	6	21	0.157
2/7 – 1/8	7	30	0.039
	Total	172	1.209
	Standard deviation		0.188
	C.V.		16%

Table 5.2.2-1. Southern mackerel mean daily stage I egg production in 2001 (x 10^{-12})					
Period	**Dates**			**Production and standard errors**	
	From	**To**	**Midpoint**	**Mackerel**	
				Production	**Se**
1	17 January	1 February	24-25 / 01	**0.02**	0.02
2	5 February	26 February	15-16 / 02	**0.10**	0.06
3	14 March	7 April	26 / 03	**3.96**	1.18
4	9 April	3 May	21 / 04	**4.53**	0.79
5	14 May	21 May	17-18 /05	**0.47**	0.16

Table 5.2.2-2. Southern spawning component of mackerel total stage I egg production estimates by time period for 2001 (x 10^{13})

Dates	Period	Nº of days	Annual stage I egg production x 10^{13}
17 January – 1 February	**1**	**16**	**0.04**
2 February – 4 February	*	3	0.02
5 February – 26 February	**2**	**22**	**0.22**
27 February – 13 March	*	15	2.93
14 March – 7 April	**3**	**25**	**9.90**
8 April	*	1	0.42
9 April – 3 May	**4**	**25**	**11.32**
4 May – 13 May	*	10	1.85
14 May –21 May	**5**	**8**	**0.37**
30 May – 17 July	*	57	1.25
	Total	**174**	**28.31**
	Se		**4.67**
	CV		**0.16**

Table 5.3.1–1. Details of the number of fish analysed to estimate potential fecundity of the Western Mackerel Spawning Component

	Latitude degrees															
Week	44	45	46	47	48	49	50	51	52	53	54	55	57	58	59	Grand Total
7	10															10
9					9							6	9			24
10				3		4	26									33
11								11	6							17
12					3	1		10		7		18	15			54
13				2	4	1										7
14		1	4													5
15				4	7									15	4	30
16									2		5					7
Grand Total	10	1	4	9	23	6	26	21	8	7	5	24	24	15	4	187

Table 5.3.1–2 Results of the analysis to investigate variability in fecundity in relation to fish weight, country, latitude and time of collection using the model:

log10(Fg) = Intercept + 0.0015*wf -0.0045*L-0.0034*W+(C).

Where Fg = relative fecundity, wf = female weight, L = latitude, w = week and C = country coefficient.

	df	SS	MS	F	Pr(F)
Weight	1	6.97	6.97	681.48	0.00
Country	2	1.14	0.57	55.82	0.00
Latitude	1	0.08	0.08	7.96	0.01
Week	1	0.01	0.01	0.85	0.36
Residuals	179	1.83	0.01		

Table 5.3.3.-1 Fecundity and atresia samples analysed in 2001 for the Southern Mackerel.

		Slides ovaries		Period				
Mackerel	*RV*	controled	acepted	1	2	3	4	5
	Corystes	62	39		39			
Fecundity	*W. Herwig*	20	1		1			
	Total	82	**40**					
Atresia	*Corystes*	17	4		4			
	Cornide Saavedra	88	52			52		
	Thalassa	172	83			28	51	4
	Commercical ship	88	73				73	
	Total	365	**212**					

Table.-5.3.3-2 Potencial Fecundityfor the southern mackerel in 2001 in period 2.

Samples collected by RV Corystes and Walter Herwig and analized by the IEO (Spain).

Contry: Spain IEO Date	Position Lat.	Long.	Weight Class	Fish Length (mm)	Fish weight (g)	Ovary Weight g (Corystes)	Age Years	Mean Oocyte volumen mm^3	POF (Y/N)	Fecundity vit. Ooc.
14/02/01	43 45.7	5 13	<250	304	170	12.0		0.038	N	299,318
13/02/01	43 56.1	8 22		290	183	13.0		0.065	N	358,351
14/02/01	43 45.7	5 13		305	198	14.0		0.043	N	368,118
13/02/01	43 56.1	8 22		316	216	26.0		0.127	N	374,022
13/02/01	43 56.1	8 22		320	216	23.0		0.050	N	358143
14/02/01	43 45.7	5 13		321	216	20.0		0.038	N	399,891
08/02/01	43 51.1	7 18		314	218	24.0		0.058	N	427,661
14/02/01	43 45.7	5 13		320	222	24.0		0.106	N	455610
13/02/01	43 56.1	8 22		330	224	18.0		0.030	N	347,800
11/02/01	39 10.9	9 46		310	226	24.0		0.041	N	377,627
14/02/01	43 45.7	5 13		322	232	20.0		0.053	N	417,330
14/02/01	43 45.7	5 13		322	232	19.0		0.053	N	294,017
13/02/01	43 56.1	8 22		326	240	20.0		0.025	N	425,953
11/02/01	39 10.9	9 46		322	240	16.0		0.025	N	448153
14/02/01	43 45.7	5 13		330	242	24.0		0.088	N	401,429
06/02/01	43 32.9	3 20		320	248	21.0		0.058	N	352,639
15/02/01	43 37.6	3 47		344	250	26.0		0.091	N	500,656
13/02/01	43 56.1	8 22	251-400	328	256	30.0		0.065	N	435,365
14/02/01	43 45.7	5 13		336	256	28.0		0.077	N	442,527
14/02/01	43 45.7	5 13		334	260	34.0		0.082	N	490,563
13/02/01	43 56.1	8 22		337	260	20.0		0.027	N	392,276
14/02/01	43 45.7	5 13		337	262	26.0		0.083	N	491,972
13/02/01	43 56.1	8 22		340	262	20.0		0.066	N	420,038
14/02/01	43 45.7	5 13		344	266	18.0		0.042	N	452,048
13/02/01	43 56.1	8 22		331	270	34.0		0.086	N	443,354
15/02/01	43 31.0	2 56		341	272	18.0		0.038	N	394,468
14/02/01	43 45.7	5 13		332	276	34.0		0.049	N	541,465
13/02/01	43 56.1	8 22		336	282	38.0		0.051	N	510,316
14/02/01	43 45.7	5 13		336	284	24.0		0.051	N	428,035
13/02/01	43 56.1	8 22		341	289	19.0		0.035	N	438,475
13/02/01	43 56.1	8 22		348	298	24.0		0.112	N	500,956
06/02/01	43 32.9	3 20		342	300	30.0		0.028	N	435,556
11/02/01	39 10.9	9 46		340	302	30.0		0.046	N	443,601
14/02/01	43 45.7	5 13		347	304	28.0		0.070	N	595,574
13/02/01	43 56.1	8 22		354	306	29.0		0.043	N	528,679
14/02/01	43 45.7	5 13		364	318	38.0		0.089	N	434,394
13/02/01	43 56.1	8 22		366	319	25.0		0.048	N	466,514
13/02/01	43 56.1	8 22		371	363	14.6		0.055	N	657,626
15/02/01	43 31.0	2 56	401-550	385	449	39.0		0.053	N	715,536
15/02/01	43 31.0	2 56		388	452	58.0		0.098	N	601,569
				AM	267			Fecundity	1,689	eggs / g
									cv	11.9%

Table 5.4.1-1 Details of the number of fish collected by various ships to estimate atresia in the Western mackerel spawning component during the 2001 Triennial survey.

	Latitude of shooting position																
Week	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	Totals
7	34																34
8																	0
9					12								6	6			24
10				8		4	33										45
11								14	7								21
12					16	19		20		20		20		15			110
13				8	20	4											32
14		20	20														40
15				20	20	10		20							17	3	90
16									15		15						30
17				17	17		6					18					58
18	1								26	23							70
19					14		22	36									72
20	14			25													39
21														6	2		8
22										2	2		2				6
23						7		7	9					8			31
24																	0
25																	0
26											17						17
																	727

KEY
Corystes 1/01
Cirolana 3/01
Cirolana 4/01
Tridens
1 G.O. Sars
1 Scotia
1 Walther Hervig

Note table does not include 45 mackerel sent to Norway by FRS as only details of analysed fish were known
Dashed line denotes differences in preservation.
Above the line = Gilson and formaldehyde for fecundity or atresia
Below the line = Formaldehyde for atresia

Table 5.4.1-2 Details of the numbers of females in spawning condition collected by period and vessel to estimate prevalence, intensity and daily production of early alpha atretic oocytes by period in 1998 and 2001.

		1998					2001					
Period	Vessels	Latitude range	N fish	P	Intensity	oocytes lost per day	Vessels	Latitude range	N fish	P	Intensity	oocytes lost per day
3	Walther Herwig	46-50	37	0.51	40	2.749	Cirolana Walther Herwig	47 - 53	57	0.19	67.60	1.71
4	Tridens	45-48	25	0.84	95	10.65	Cirolana Scotia Walther Herwig Tridens	45 - 58	140	0.19	33.52	0.86
5	Tridens Corystes	47 48	25	0.69	58	5.326	Cirolana GOSARS	47 - 57	65	0.18	39.80	0.98
6	Corystes	45	25	0.24	34	1.075	GOSARS Scotia	52 - 57	28	0.29	36.95	1.41
Totals			112						290			

Table 5.4.1-3 A summary of data used to calculate realised fecundity in 1998 and 2001 Triennial surveys.

Summary of all cruises combined for Western mackerel spawning component			
Assessment year		1998	2001
Total number of fish analysed	Fecundity	96	187
	Atresia	112	290
Potential fecundity		1206	1097
Prevalence of early alpha atresia		0.55	0.20
Geometric mean of relative early alpha atresia		46	40.21
Duration of atresia stage		7.5	7.5
Number of oocytes lost per day		3.37	1.07
Number of oocytes lost over 60 days spawning cycle		202	64
Realised		1002	1033
Percentage of potential fecundity lost		17	6

Table 5 4 2 1 Details of the mackerel southern component collection to estimate relative atresia during the 2001 trienial surveys

Period	Weight class	Date		Position Lat	long	Total weight	Ovary weight	Length mm	Age	i/W	atretic oocy e-alfa-A / female i
2	<250	15	02	43º28'79N	02º53'4W	174	8.7195	350		62	10,804
2	251-400	15	02	43º28'79N	02º53'4W	324	14.972	362		101	32,799
2	251-400	15	02	43º28'79N	02º53'4W	316	31.386	356		257	81,197
2	251-400	15	02	43º28'79N	02º53'4W	254	33.801	330			
3	<250	19	03	43º53'42N	08º11'99W	216	13	310	2	164	35,514
3	<250	19	03	43º53'42N	08º11'99W	204	6.8	305	2		
3	<250	20	03	43º48'74N	06º29'34W	190	9.2	302	2	87	16,492
3	<250	21	03	43º39'74N	04º47'12W	241	10.8	333	4	88	21,155
3	<250	21	03	43º39'74N	04º47'12W	235	7	329	4	141	33,108
3	<250	21	03	43º39'74N	04º47'12W	195	7.8	305	3	44	8,574
3	<250	21	03	43º39'74N	04º47'12W	184	6.6	295	2	81	14,896
3	<250	21	03	43º39'74N	04º47'12W	215	10	310	3	52	11,124
3	<250	08	04	43º42'41N	08º20'82W	134	27.4	393	8		
3	<250	19	03	43º53'42N	08º11'99W	224	8.8	319	3		
3	<250	19	03	43º53'42N	08º11'99W	228	14	309	2		
3	<250	19	03	43º53'42N	08º11'99W	240	9.4	321	5		
3	251-400	22	03	43º30'00N	02º15'08W	267	13	341	4		
3	251-400	21	03	43º39'74N	04º47'12W	255	10.2	330	4	193	49,105
3	251-400	21	03	43º39'74N	04º47'12W	286	19.4	349	4	152	43,575
3	251-400	22	03	43º30'00N	02º15'08W	283	19.4	339	4		
3	251-400	06	04	43º38'44N	08º54'71W	389	22.4	380	6		
3	251-400	21	03	43º39'74N	04º47'12W	317	22.6	361	4		
3	251-400	08	04	43º42'41N	08º20'82W	381	27.4	377	5		
3	251-400	08	04	43º42'41N	08º20'82W	392	17	390	6		
3	251-400	20	03	43º48'74N	06º29'34W	314	16.2	355	4		
3	251-400	20	03	43º48'74N	06º29'34W	372	39	370	6		
3	251-400	20	03	43º48'74N	06º29'34W	386	26.2	380	6		
3	251-400	20	03	43º48'74N	06º29'34W	395	30.2	365	8		
3	251-400	19	03	43º53'42N	08º11'99W	279	33.4	330	3		
3	251-400	19	03	43º53'42N	08º11'99W	289	11.8	339	4		
3	251-400	19	03	43º53'42N	08º11'99W	300	9.6	319	4		
3	251-400	19	03	43º53'42N	08º11'99W	391	23	384	6		
3	401-550	22	03	43º30'00N	02º15'08W	538	45.8	410	9		
3	401-550	22	03	43º30'00N	02º15'08W	521	36.6	415	7		
3	401-550	20	03	43º48'74N	06º29'34W	448	27.4	404	6		
3	401-550	06	04	43º38'44N	08º54'71W	407	29.6	388	8		
3	401-550	06	04	43º38'44N	08º54'71W	408	58.8	405	8		
3	401-550	06	04	43º38'44N	08º54'71W	409	36.4	390	5		
3	401-550	06	04	43º38'44N	08º54'71W	410	32.2	402	6		
3	401-550	06	04	43º38'44N	08º54'71W	415	29	393	5		
3	401-550	06	04	43º38'44N	08º54'71W	430	34	401	7		
3	401-550	06	04	43º38'44N	08º54'71W	455	31	401	8		
3	401-550	06	04	43º38'44N	08º54'71W	458	32.4	401	8		
3	401-550	06	04	43º38'44N	08º54'71W	463	25	403	7		
3	401-550	06	04	43º38'44N	08º54'71W	470	37.6	398	5		

Table 5 4 2 1 continued

Period	Weight class	Date		Lat	Position long	Total weight	Ovary weight	Length mm	Age	i/W	atretic oocy e-alfa-A / female i
3	401-550	06	04	43º38'44N	08º54'71W	481	41	409	6		
3	401-550	06	04	43º38'44N	08º54'71W	484	24.8	403	4		
3	401-550	06	04	43º38'44N	08º54'71W	496	42.8	410			
3	401-550	06	04	43º38'44N	08º54'71W	508	55	403	8		
3	401-550	06	04	43º38'44N	08º54'71W	528	59.8	410	6		
3	401-550	06	04	43º38'44N	08º54'71W	547	41.2	419	8		
3	401-550	08	04	43º42'41N	08º20'82W	456	19.4	403	8		
3	401-550	08	04	43º42'41N	08º20'82W	471	23	399	7		
3	401-550	08	04	43º42'41N	08º20'82W	482	20.2	415			
3	401-550	08	04	43º42'41N	08º20'82W	484	34.4	405	4		
3	401-550	08	04	43º42'41N	08º20'82W	504	30	416	8		
3	401-550	08	04	43º42'41N	08º20'82W	532	18.2	416	8		
3	401-550	20	03	43º48'74N	06º29'34W	416	25.8	389	6		
3	401-550	20	03	43º48'74N	06º29'34W	426	64.8	370	6		
3	401-550	20	03	43º48'74N	06º29'34W	451	44.8	386	8		
3	401-550	20	03	43º48'74N	06º29'34W	473	49.4	396	8		
3	401-550	19	03	43º53'42N	08º11'99W	416	33.4	379	6		
3	401-550	19	03	43º53'42N	08º11'99W	417	31.2	384	6		
3	401-550	19	03	43º53'42N	08º11'99W	440	45.6	381	8		
3	401-550	19	03	43º53'42N	08º11'99W	502	51.8	405	7		
3	401-550	19	03	43º53'42N	08º11'99W	533	54.6	396	7		
3	>551	22	03	43º30'00N	02º15'08W	582	47.4	431	9		
3	>551	22	03	43º30'00N	02º15'08W	563	61.8	409	7		
3	>551	22	03	43º30'00N	02º15'08W	671	80.8	440	10		
3	>551	22	03	43º30'00N	02º15'08W	663	85.6	419	9		
3	>551	22	03	43º30'00N	02º15'08W	579	90.8	409	8		
3	>551	22	03	43º30'00N	02º15'08W	589	73.2	415			
3	>551	20	03	43º48'74N	06º29'34W	591	75.2	409	7		
3	>551	22	03	43º30'00N	02º15'08W	556	71.6	403	8		
3	>551	22	03	43º30'00N	02º15'08W	571	77.2	399	6		
3	>551	22	03	43º30'00N	02º15'08W	600	107.2	392	7		
3	>551	22	03	43º30'00N	02º15'08W	628	71.8	421	9		
3	>551	06	04	43º38'44N	08º54'71W	566	40.8	426	10		
3	>551	06	04	43º38'44N	08º54'71W	611	104.2	415	7		
3	>551	19	03	43º53'42N	08º11'99W	553	48.6	414	8		
3	>551	19	03	43º53'42N	08º11'99W	557	46.2	395			
3	>551	19	03	43º53'42N	08º11'99W	598	59.6	410	8		
3	>551	19	03	43º53'42N	08º11'99W	605	67.4	413	11		
3	>551	19	03	43º53'42N	08º11'99W	621	88.6	427			
4	<250	09	05	43º35'05N	03º56'00W	187	6.34	297	2		
4	<250	20	04	43º32'89N	03º02'00W	203	12.4	310	3		
4	<250	20	04	43º32'89N	03º02'00W	226	23	311	2		

Table 5 4 2 1 continued

Period	Weight class	Date		Position Lat	long	Total weight	Ovary weight	Length mm	Age	i/W	atretic oocy e-alfa-A / female i
4	<250	19	04	43°28'92N	02°40'04W	227	9.8	310	3		
4	<250	19	04	43°28'92N	02°40'04W	239	12.2	319	3		
4	<250	10	05	43°34'00N	03°54'00W	177	12.6	283			
4	<250	10	05	43°34'00N	03°54'00W	179	12.6	290	2		
4	<250	10	05	43°34'00N	03°54'00W	203	11.6	299			
4	<250	10	05	43°34'00N	03°54'00W	206	21.4	296	2		
4	<250	10	05	43°34'00N	03°54'00W	207	19	301	3		
4	<250	10	05	43°34'00N	03°54'00W	210	18.4	300	2		
4	<250	10	05	43°34'00N	03°54'00W	217	11.9	308	3		
4	<250	10	05	43°34'00N	03°54'00W	223	23.9	303	2		
4	<250	10	05	43°34'00N	03°54'00W	226	10.5	315	3		
4	<250	10	05	43°34'00N	03°54'00W	232	18.17	311	2		
4	<250	09	05	43°35'05N	03°56'00W	183	14.0	291	2		
4	<250	09	05	43°35'05N	03°56'00W	192	15.1	296	3		
4	<250	09	05	43°35'05N	03°56'00W	198	12.2	303	4		
4	<250	09	05	43°35'05N	03°56'00W	202	21.1	301	3		
4	<250	09	05	43°35'05N	03°56'00W	208	19.8	294	2		
4	<250	09	05	43°35'05N	03°56'00W	208	9.3	308	2		
4	<250	09	05	43°35'05N	03°56'00W	216	15.4	304	3		
4	<250	09	05	43°35'05N	03°56'00W	223	17.1	309	3		
4	<250	09	05	43°35'05N	03°56'00W	229	26.4	312	2		
4	<250	09	05	43°35'05N	03°56'00W	230	17.4	315	3		
4	<250	09	05	43°35'05N	03°56'00W	231	14.8	315	3		
4	<250	09	05	43°35'05N	03°56'00W	231	22.2	321	5		
4	<250	09	05	43°35'05N	03°56'00W	232	4.4	314	3		
4	<250	09	05	43°35'05N	03°56'00W	232	25.0	301	2		
4	<250	09	05	43°35'05N	03°56'00W	232	21.2	316	3		
4	<250	09	05	43°35'05N	03°56'00W	232	19.2	312	5		
4	<250	09	05	43°35'05N	03°56'00W	233	11.6	301	3		
4	<250	09	05	43°35'05N	03°56'00W	234	12.6	323	3		
4	<250	09	05	43°35'05N	03°56'00W	235	14.8	321	3		
4	<250	09	05	43°35'05N	03°56'00W	239	18.7	319	3		
4	<250	09	05	43°35'05N	03°56'00W	248	22.3	319	3		
4	<250	13	04	43°57'41N	06°52'48W	131	20.8	395	5		
4	251-400	10	05	43°34'00N	03°54'00W	386	7.9	374	6	13	4,918
4	251-400	10	05	43°34'00N	03°54'00W	401	18.4	376	5		
4	251-400	20	04	43°32'89N	03°02'00W	255	12.4	333	4		
4	251-400	20	04	43°32'89N	03°02'00W	393	10.6	387		20	7,928
4	251-400	20	04	43°32'89N	03°02'00W	346	19.0	365	5		
4	251-400	19	04	43°28'92N	02°40'04W	321	34.6	346	5		
4	251-400	19	04	43°28'92N	02°40'04W	253	17.2	329	3		
4	251-400	19	04	43°28'92N	02°40'04W	341	33.6	378	3		
4	251-400	19	04	43°28'92N	02°40'04W	393	26.2	381	4		
4	251-400	20	04	43°30'55N	03°24'03W	347	21.8	361	6		
4	251-400	20	04	43°32'89N	03°02'00W	288	21.8	345	4		

Table 5 4 2 1 continued

Period	Weight class	Date		Position Lat	long	Total weight	Ovary weight	Length mm	Age	i/W	atretic oocy e-alfa-A / female i
4	251-400	10	05	43º34'00N	03º54'00W	277	29.0	309	3		
4	251-400	10	05	43º34'00N	03º54'00W	283	20.8	335	4		
4	251-400	10	05	43º34'00N	03º54'00W	319	37.6	333	3		
4	251-400	10	05	43º34'00N	03º54'00W	357	16.7	366	5		
4	251-400	10	05	43º34'00N	03º54'00W	367	16.9	376	8		
4	251-400	10	05	43º34'00N	03º54'00W	381	12.8	361	3		
4	251-400	10	05	43º34'00N	03º54'00W	386	20.2	361	4		
4	251-400	10	05	43º34'00N	03º54'00W	387	3.2	381	3		
4	251-400	10	05	43º34'00N	03º54'00W	399	2.8	377	4		
4	251-400	09	05	43º35'05N	03º56'00W	256	25.5	323	3		
4	251-400	09	05	43º35'05N	03º56'00W	306	10.6	357	5		
4	251-400	09	05	43º35'05N	03º56'00W	380	23.8	367	5		
4	251-400	16	04	43º40'70N	05º13'97W	343	25.6	358	4		
4	251-400	12	04	43º47'75N	07º26'07W	358	14.8	362	5		
4	251-400	12	04	43º47'75N	07º26'07W	365	29.4	373	4		
4	251-400	12	04	43º47'75N	07º26'07W	385	15.6	374	4		
4	251-400	13	04	43º57'41N	06º52'48W	285	5.2	346	4		
4	251-400	13	04	43º57'41N	06º52'48W	342	22.8	367	6		
4	251-400	13	04	43º57'41N	06º52'48W	360	17.8	358	4		
4	251-400	13	04	43º57'41N	06º52'48W	379	25.6	364	4		
4	251-400	13	04	43º57'41N	06º52'48W	391	12.0	390	6		
4	401-550	10	05	43º34'00N	03º54'00W	519	17.9	414	7		
4	401-550	10	05	43º36'00N	03º55'00W	507	23.5	411	6	5	2,735
4	401-550	10	05	43º34'00N	03º54'00W	492	5.6	402			
4	401-550	20	04	43º32'89N	03º02'00W	462	17.2	391	8	68	31,534
4	401-550	13	04	43º57'41N	06º52'48W	453	16.8	396	9	87	39,495
4	401-550	19	04	43º28'92N	02º40'04W	419	5.0	455	13		
4	401-550	20	04	43º30'55N	03º24'03W	404	10.0	386	6		
4	401-550	20	04	43º32'89N	03º02'00W	495	38.0	411	8		
4	401-550	10	05	43º34'00N	03º54'00W	402	8.7	384	5		
4	401-550	10	05	43º34'00N	03º54'00W	414	4.2	387	5		
4	401-550	10	05	43º34'00N	03º54'00W	436	40.8	386	5		
4	401-550	10	05	43º34'00N	03º54'00W	447	5.3	390	8		
4	401-550	10	05	43º34'00N	03º54'00W	450	27.0	386	4		
4	401-550	10	05	43º34'00N	03º54'00W	455	24.6	391	8		
4	401-550	10	05	43º34'00N	03º54'00W	459	13.9	398	8		
4	401-550	10	05	43º34'00N	03º54'00W	467	32.1	401	7		
4	401-550	10	05	43º34'00N	03º54'00W	513	24.4	401	9		
4	401-550	10	05	43º34'00N	03º54'00W	517	46.8	406	6		
4	401-550	10	05	43º34'00N	03º54'00W	531	20.0	414	10		
4	401-550	10	05	43º34'00N	03º54'00W	536	42.8	406	9		
4	401-550	10	05	43º34'00N	03º54'00W	542	36.3	408	7		
4	401-550	09	05	43º35'05N	03º56'00W	403	21.3	384	5		
4	401-550	09	05	43º35'05N	03º56'00W	466	9.0	393	8		
4	401-550	09	05	43º35'05N	03º56'00W	475	21.9	391	7		

Table 5 4 2 1 continued

Period	Weight class	Date		Position Lat	long	Total weight	Ovary weight	Length mm	Age	i/W	atretic oocy e-alfa-A / female i
4	401-550	09	05	43º35'05N	03º56'00W	526	50.3	407	5		
4	401-550	10	05	43º36'00N	03º55'00W	531	59.5	409	6		
4	401-550	10	05	43º36'00N	03º55'00W	545	40.8	412			
4	401-550	12	04	43º47'75N	07º26'07W	436	24.6	394	8		
4	401-550	12	04	43º47'75N	07º26'07W	458	41.6	393	5		
4	401-550	12	04	43º47'75N	07º26'07W	502	33.6	404	6		
4	401-550	12	04	43º47'75N	07º26'07W	527	53.4	411	7		
4	401-550	13	04	43º57'41N	06º52'48W	408	22.4	374	7		
4	401-550	13	04	43º57'41N	06º52'48W	459	27.2	394	9		
4	401-550	13	04	43º57'41N	06º52'48W	465	32.4	377	5		
4	401-550	13	04	43º57'41N	06º52'48W	470	27.0	400	6		
4	401-550	13	04	43º57'41N	06º52'48W	484	31.6	397	9		
4	401-550	13	04	43º57'41N	06º52'48W	539	38.2	412	8		
4	401-550	11	04	44º00'72N	07º48'00W	427	31.8	371	6		
4	401-550	11	04	44º00'72N	07º48'00W	433	23.6	397	7		
4	401-550	11	04	44º00'72N	07º48'00W	433	28.4	400	6		
4	401-550	11	04	44º00'72N	07º48'00W	446	20.4	398	5		
4	401-550	11	04	44º00'72N	07º48'00W	450	20.8	396	5		
4	401-550	11	04	44º00'72N	07º48'00W	455	21.6	420	8		
4	401-550	11	04	44º00'72N	07º48'00W	460	18.2	394	8		
4	401-550	11	04	44º00'72N	07º48'00W	489	33.6	411	8		
4	401-550	11	04	44º00'72N	07º48'00W	491	31.2	394	5		
4	401-550	11	04	44º00'72N	07º48'00W	529	41.0	419	9		
4	>551	10	05	43º34'00N	03º54'00W	554	66.2	406	6		
4	>551	10	05	43º34'00N	03º54'00W	645	31.0	434	8		
4	>551	10	05	43º34'00N	03º54'00W	656	30.6	452	15		
4	>551	10	05	43º36'00N	03º55'00W	565	26.7	413	7		
4	>551	10	05	43º36'00N	03º55'00W	601	28.0	426	9		
4	>551	12	04	43º47'75N	07º26'07W	581	49.0	421	10		
4	>551	12	04	43º47'75N	07º26'07W	618	54.2	422	13		
4	>551	13	04	43º57'41N	06º52'48W	890	20.2	381	5		
5	<250	20	04	43º24'20N	03º09'13W	250	9.0	328	3		
5	251-400	20	04	43º24'20N	03º09'13W	347	26.8	364	5		
5	251-400	20	04	43º24'20N	03º09'13W	351	31.4	364	4		
5	401-550	20	04	43º24'20N	03º09'13W	535	45.8	416	6		

Females with atresia e-alfa 17 AM weight 393 atresia intensity i / W GM 68 ooc / g
Spawning conditions female 212
Prevalence p 8.-% A=GM(i/W)*p*(s/d) A= 4,333 oocytes

Table 5.5.1-1 Spawning stock biomass for the western component of the NEA mackerel and for western horse mackerel. Spawning stock biomass estimates are calculated after correction for atresia except for horse mackerel from 1998 onwards. A sex ratio of 1:1 is assumed for both species. The SSB was calculated from total annual egg production including arithmetic means calculated for unsampled rectangles where possible.

Annual egg production method – western mackerel							
Year	**Total egg prod ($x10^{-15}$) (mean for unsampled rectangles)**		**Total potential Fecundity and [atresia] (eggs/g female)**	**Total fecundity corrected for atresia (eggs/g female)**	**Pre-spawning stock biomass ($x10^{-6}$ t)**	**Conver-sion factor**	**Spawning stock biomass ($x10^{-6}$ t)**
	Geo-metric	**Arith-metic**					
1977	1.98		1526 [211]	1315	3.01	1.08	3.25
1980	1.48 a		1526 [211]	1315	2.25	1.08	2.43
1980	1.84 b		1526 [211]	1315	2.80	1.08	3.02
1983	1.50	1.53	1526 [211]	1315	2.33	1.08	2.51
1986	1.15	1.24	1457 [211]	1246	1.99	1.08	2.15
1989	1.45	1.52	1608 [326]	1282	2.37	1.08	2.56
1992	1.83	1.94	1569 [138]	1431	2.71	1.08	2.93
1995	-	1.49	1473 [171]	1302	2.28	1.08	2.47
1998	-	1.37	1206 [203]	1002	2.73	1.08	2.95
2001	-	1.21	1097 [64]	1033	2.34	1.08	2.53

Annual egg production method – western horse mackerel							
Year	**Total egg prod ($x10^{-15}$) (mean for unsampled rectangles)**		**Total Fecundity (eggs/g female)**	**Total fecundity corrected for atresia (eggs/g female)**	**Pre-spawning stock biomass ($x10^{-6}$ t)**	**Conver-sion factor**	**Spawning stock biomass ($x10^{-6}$ t)**
	Geometric	**Arithmetic**					
1977	0.533 c		1557	1504	0.71	1.05	0.74
1980	0.635 c		1557	1504	0.84	1.05	0.89
1983	0.381 c		1557	1504	0.51	1.05	0.53
1986	0.508 c		1557	1504	0.68	1.05	0.71
1989	1.54	1.63	1557	1504	2.17	1.05	2.28
1992	1.37	1.58	1557	1504	2.10	1.05	2.21
1995	1.83	1.226	1557	1504	1.63	1.05	1.71
1998	-	1.003	1002	1002 (d)	2.00	1.00 (e)	2.00
2001	-	0.684	994	994 (d)	1.38	1.00 (e)	1.38

a. Egg survey data for period 3 included
b. Egg survey data for period 3 exuded
c. Eaton (1989). In 1977 incomplete coverage
d. From 1998 onwards fecundity was not corrected for atresia as this was negligible (section 6.4)
e. A conversion factor of 1.00 was used , because fecundity samples were taken during the spawning season

Figure 5.1.1-1a. Mackerel egg production by rectangle for period 1 (21 January – 10 February). Filled circles represent observed values, filled squares represent interpolated values, crosses represent observed zeroes. Interpolated zeroes are not included. Circles and squares are square root scaled to a maximum of 800 eggs $m^{-2}.day^{-1}$.

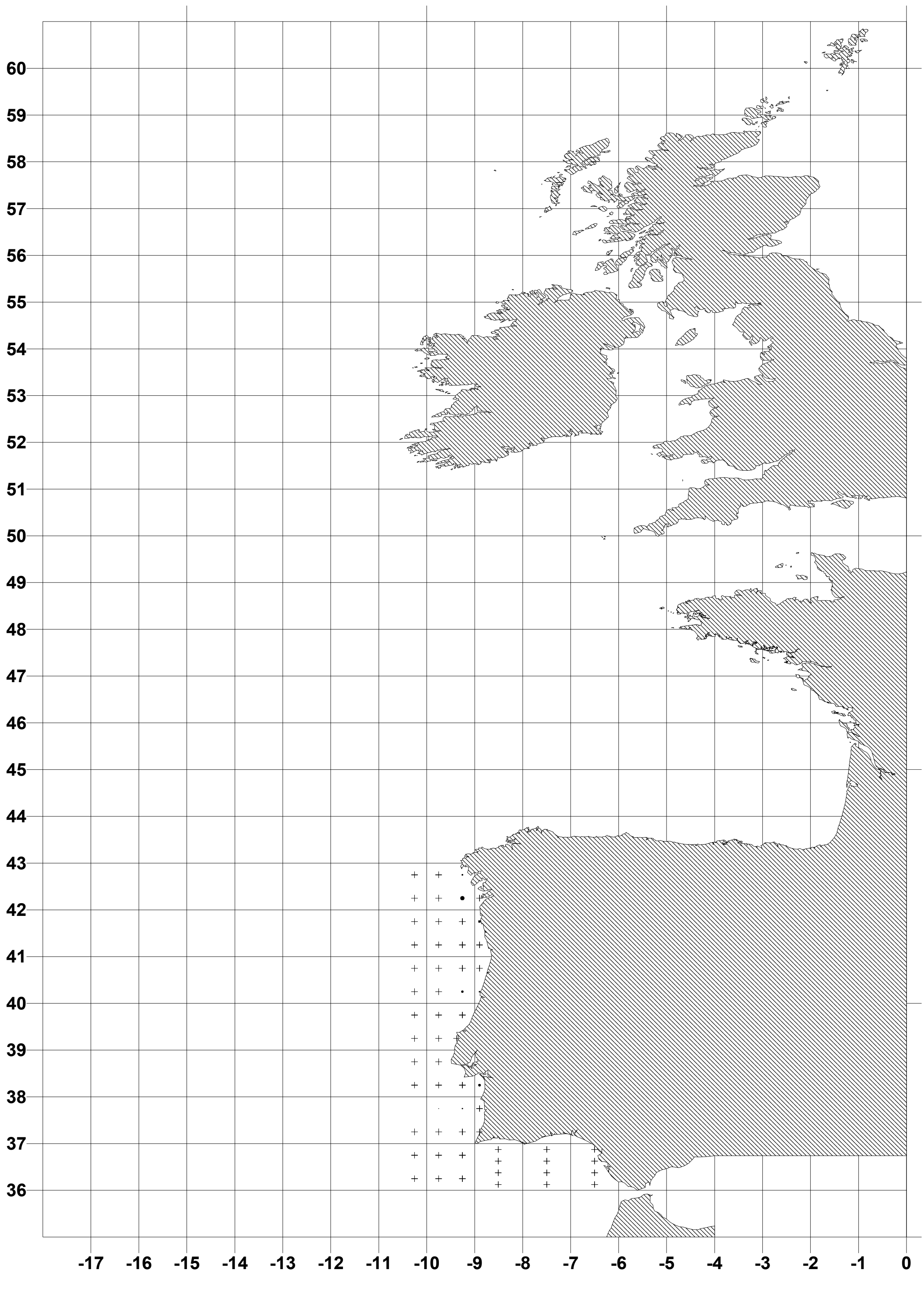


Figure 5.1.1-1b. Mackerel egg production by rectangle for period 2 (11 February – 11 March). Filled circles represent observed values, filled squares represent interpolated values, crosses represent observed zeroes. Interpolated zeroes are not included. Circles and squares are square root scaled to a maximum of 800 eggs $m^{-2}.day^{-1}$.

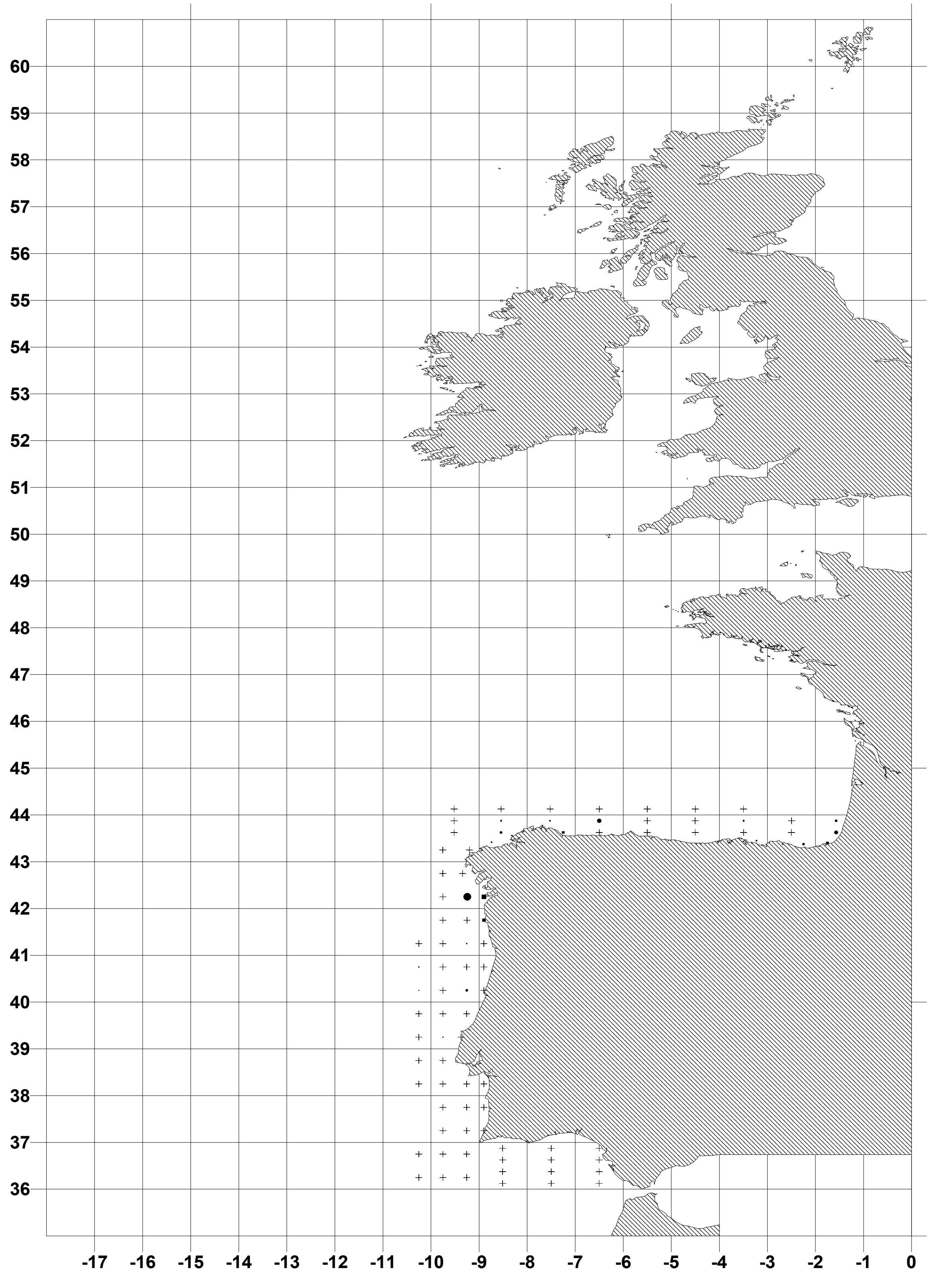


Figure 5.1.1-1c. Mackerel egg production by rectangle for period 3 (12 March – 8 April). Filled circles represent observed values, filled squares represent interpolated values, crosses represent observed zeroes. Interpolated zeroes are not included. Circles and squares are square root scaled to a maximum of 800 eggs $m^{-2}.day^{-1}$.

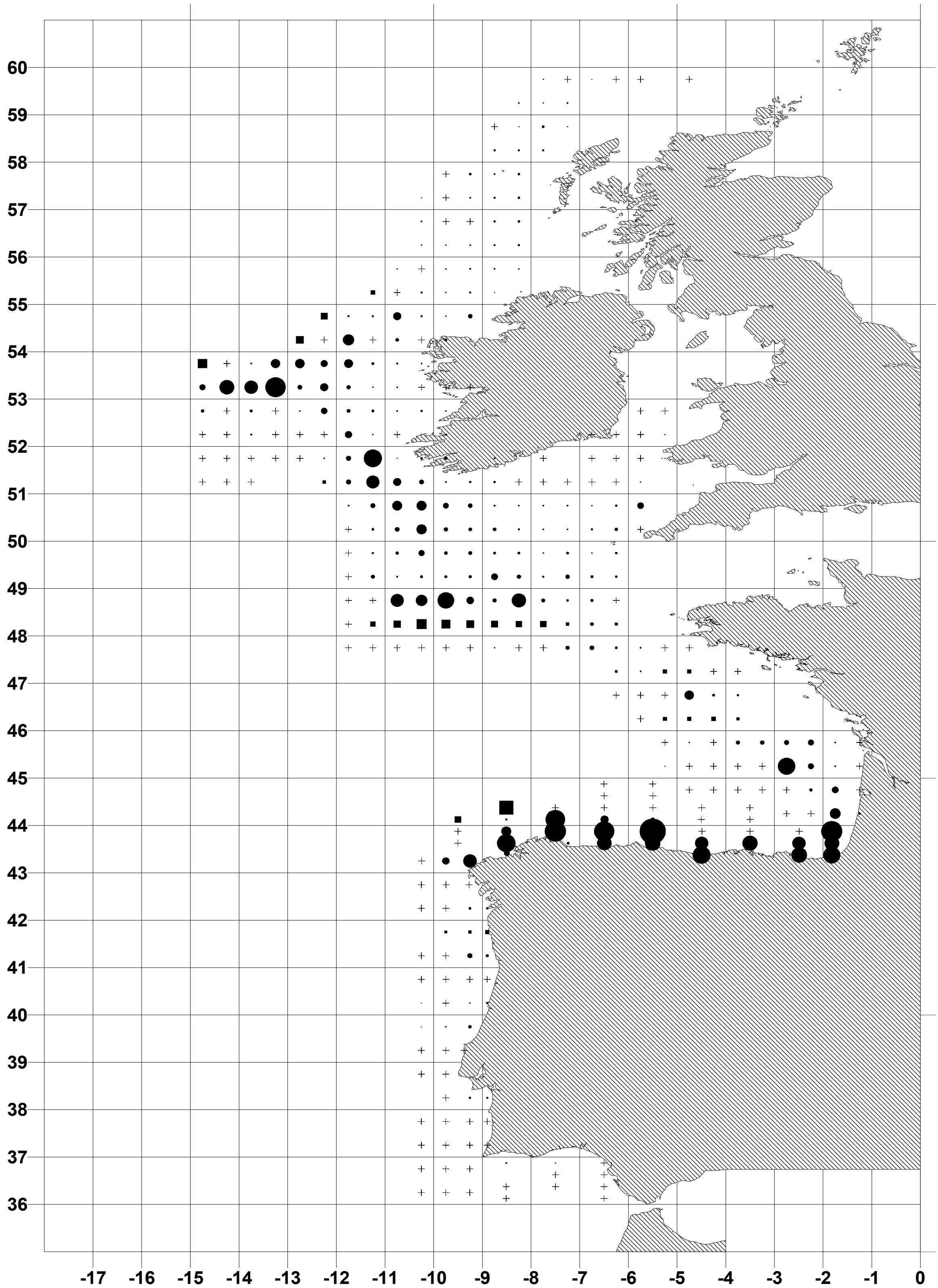


Figure 5.1.1-1d. Mackerel egg production by rectangle for period 4 (9 April – 13 May). Filled circles represent observed values, filled squares represent interpolated values, crosses represent observed zeroes. Interpolated zeroes are not included. Circles and squares are square root scaled to a maximum of 800 eggs m^{-2}.day^{-1}.

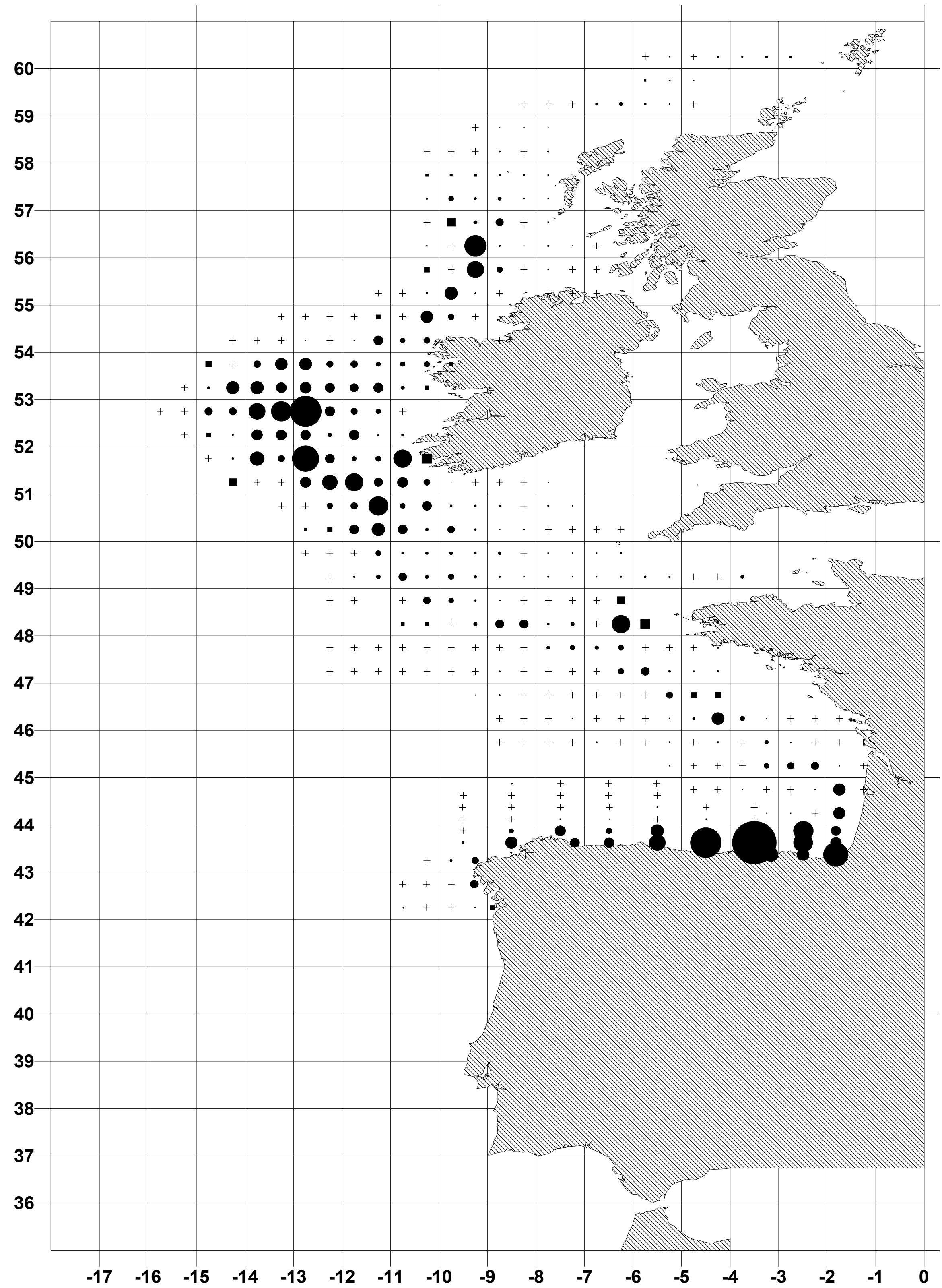


Figure 5.1.1-1e. Mackerel egg production by rectangle for period 5 (14 May – 10 June). Filled circles represent observed values, filled squares represent interpolated values, crosses represent observed zeroes. Interpolated zeroes are not included. Circles and squares are square root scaled to a maximum of 800 eggs $m^{-2}.day^{-1}$.

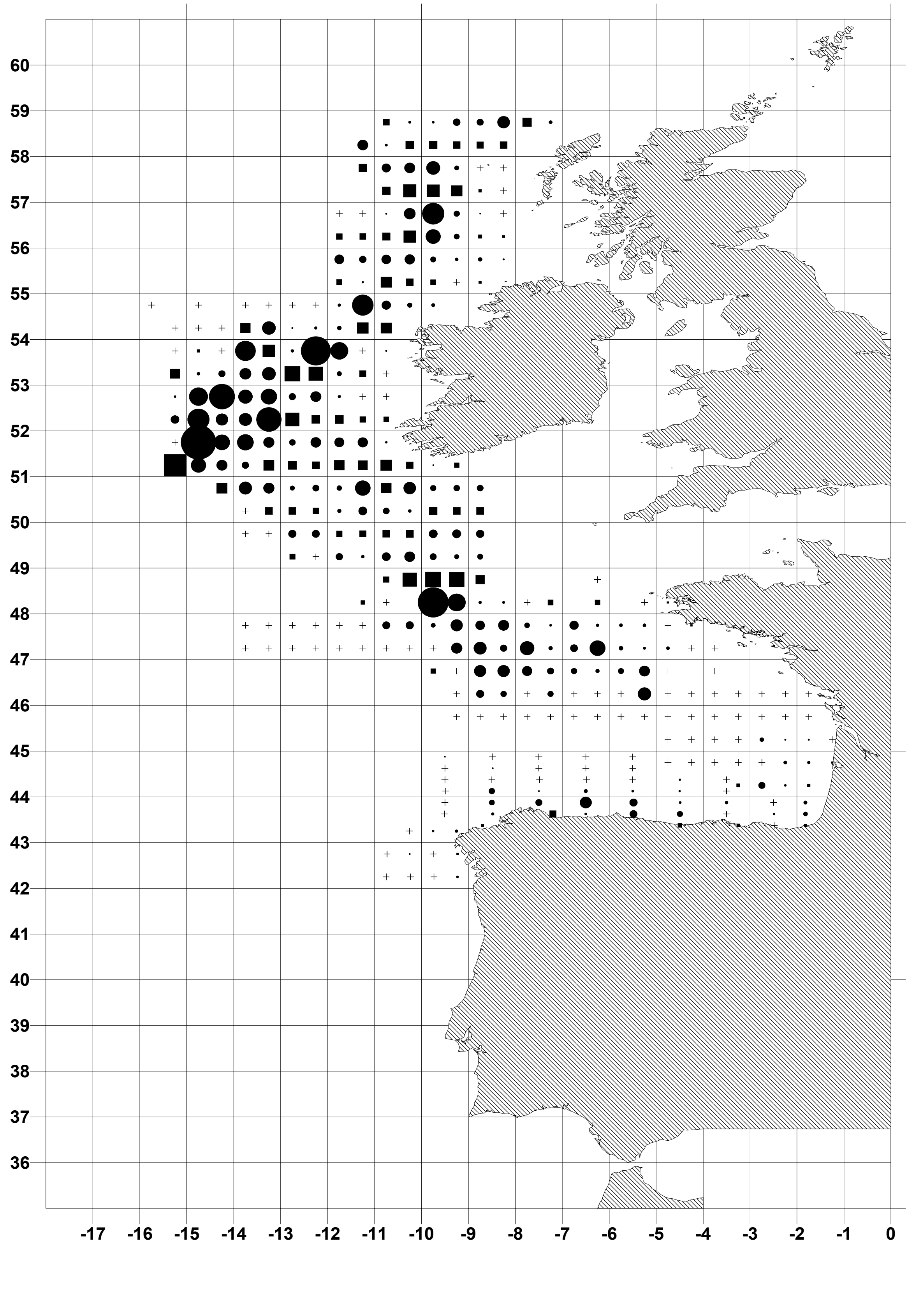


Figure 5.1.1-1f. Mackerel egg production by rectangle for period 6 (11 June – 1 July). Filled circles represent observed values, filled squares represent interpolated values, crosses represent observed zeroes. Interpolated zeroes are not included. Circles and squares are square root scaled to a maximum of 800 eggs $m^{-2}.day^{-1}$.

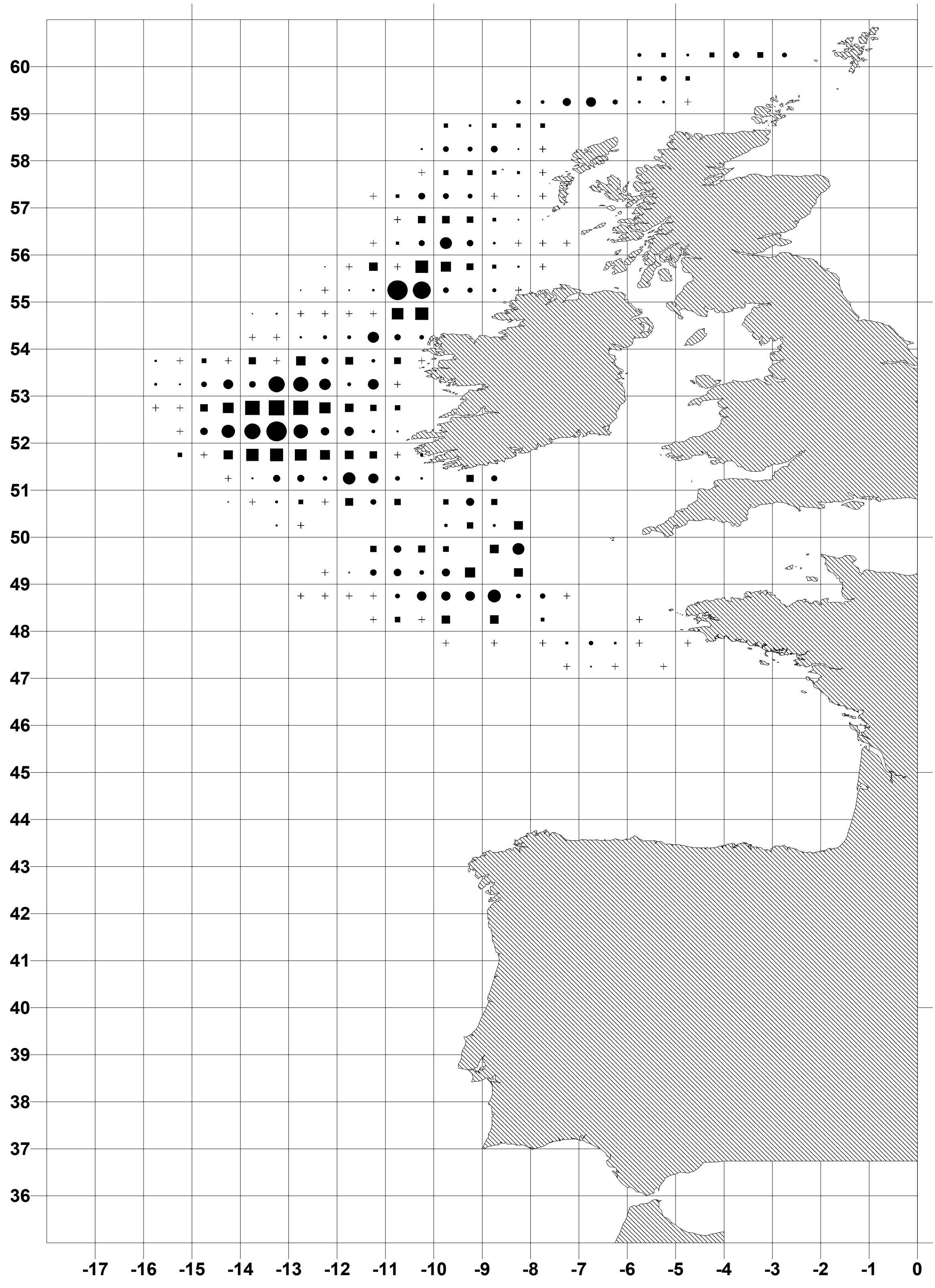


Figure 5.1.1-1g. Mackerel egg production by rectangle for period 7 (2 July – 1 August). Filled circles represent observed values, filled squares represent interpolated values, crosses represent observed zeroes. Interpolated zeroes are not included. Circles and squares are square root scaled to a maximum of 800 eggs $m^{-2}.day^{-1}$.

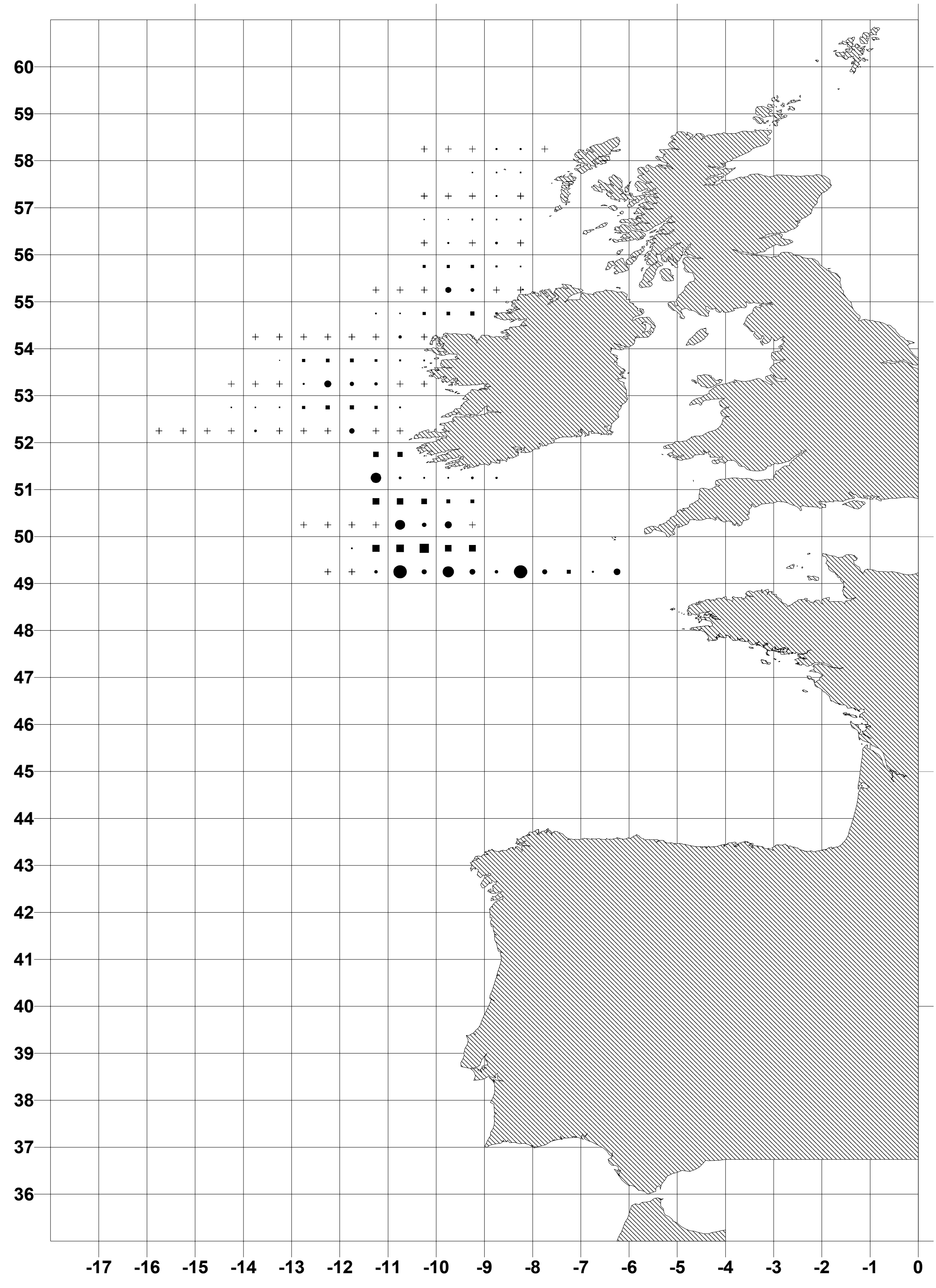


Figure 5.2.1-1. Mackerel daily egg production curve for the surveys in the western spawning area in 2001. The 1998 curve is included for comparison.

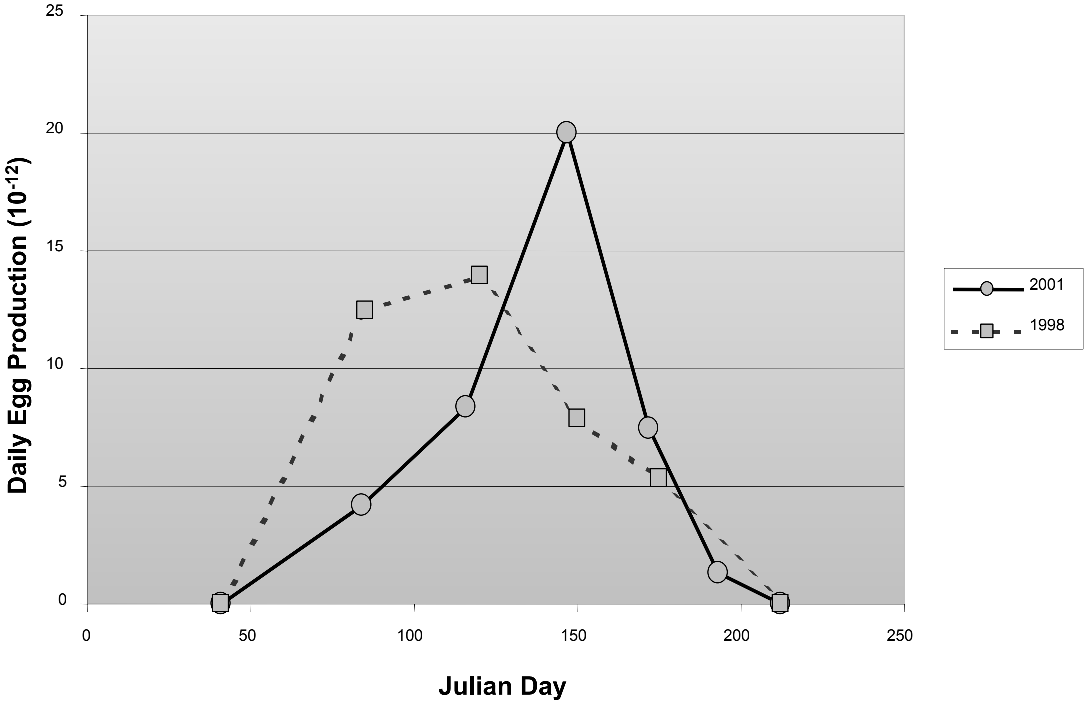


Figure 5.2.2-1. Mackerel daily egg survey production curve for the surveys in the southern area in 2001

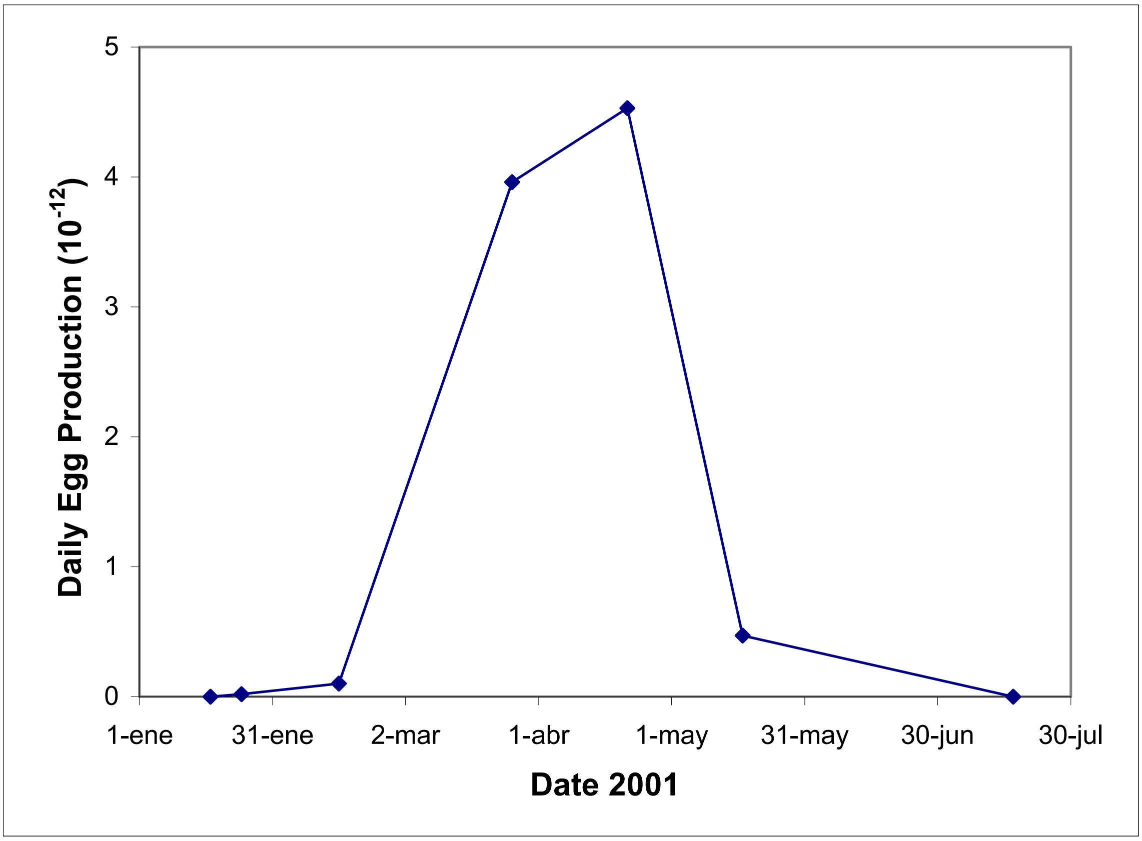


Figure 5.3.1-1 Potential annual fecundity and total weight for the Western Mackerel Spawning Component in 2001 classified according to the origin of the data by country

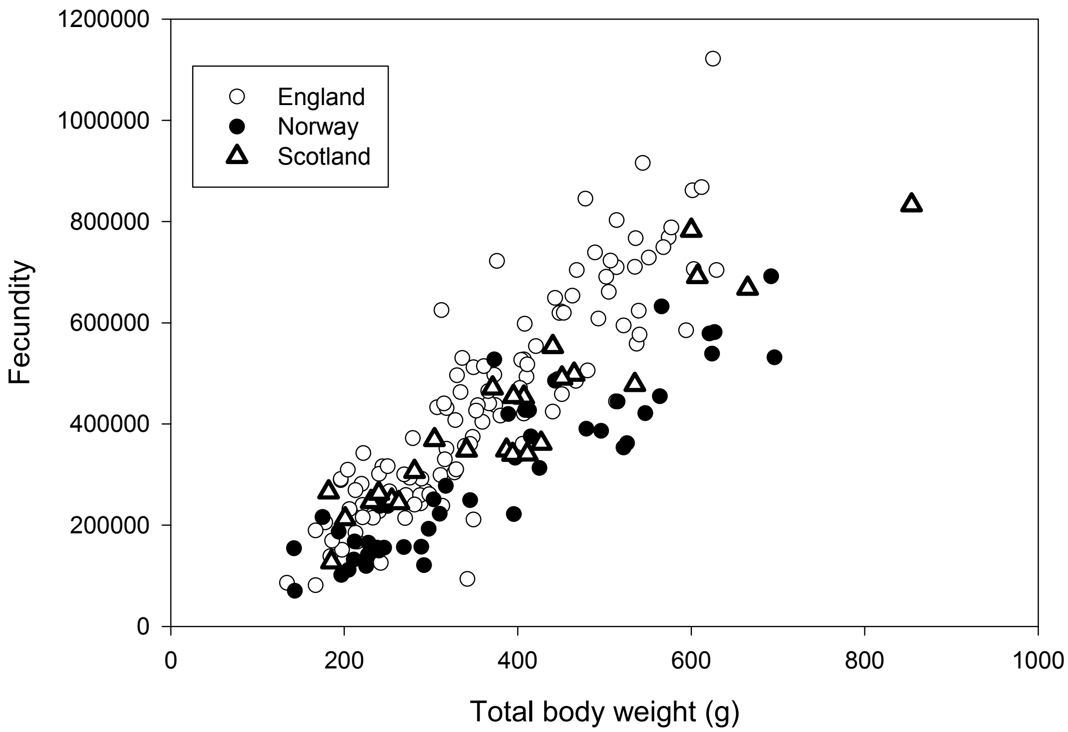


Figure 5.3.1 - 2 The relationship between relative fecundity and body weight .

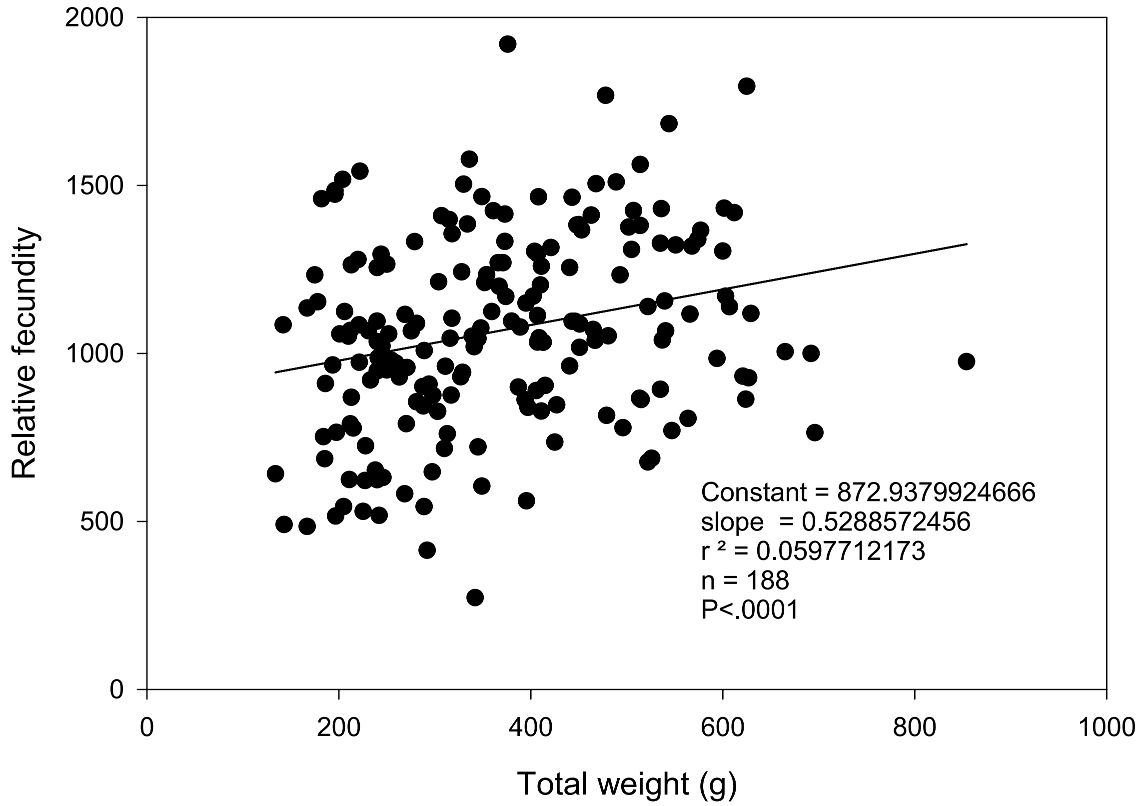


Figure 5.3.3-1 Potencial Fecundity of Southern mackerel in period 2 (2001)

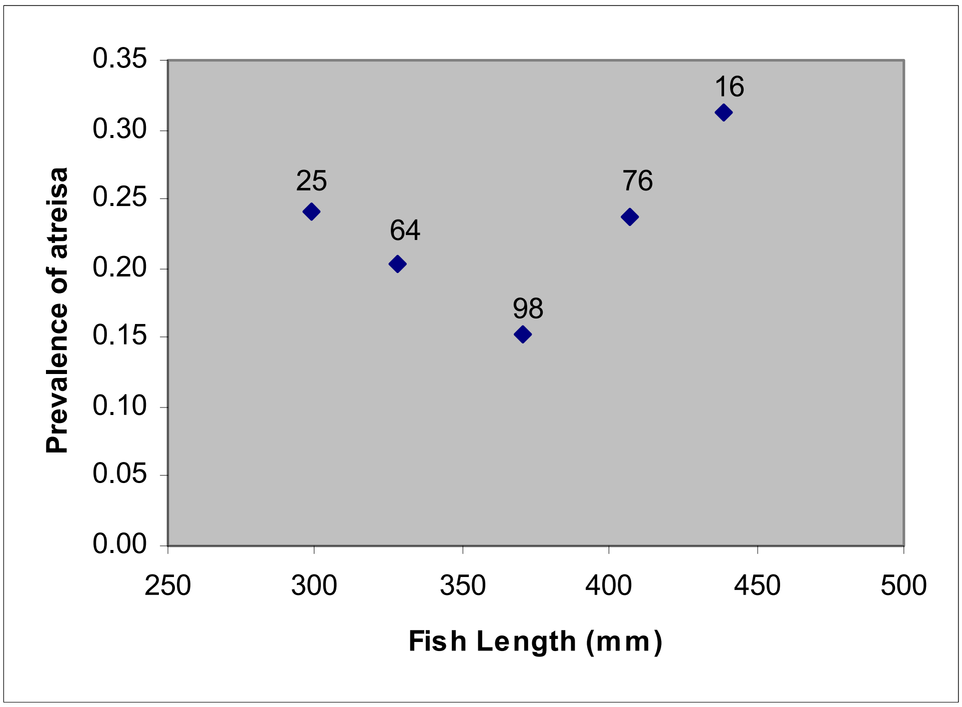


Figure 5.4.1-1a Prevalence of early alpha atresia in relation to fish length in spawning mackerel collected in the table 5.4.1-1. Numbers above each point refer to the numbers of fish in each length class.

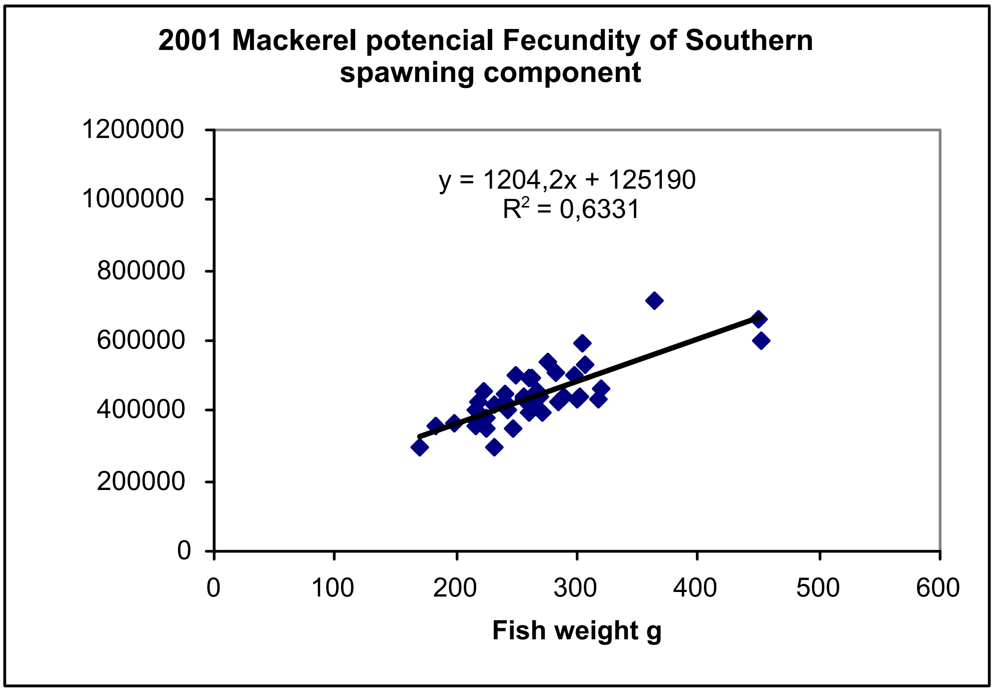


Figure 5.4.1-1b Intensity of atresia in spawning mackerel in relation to length collected as detailed in Table 5.4.1-1

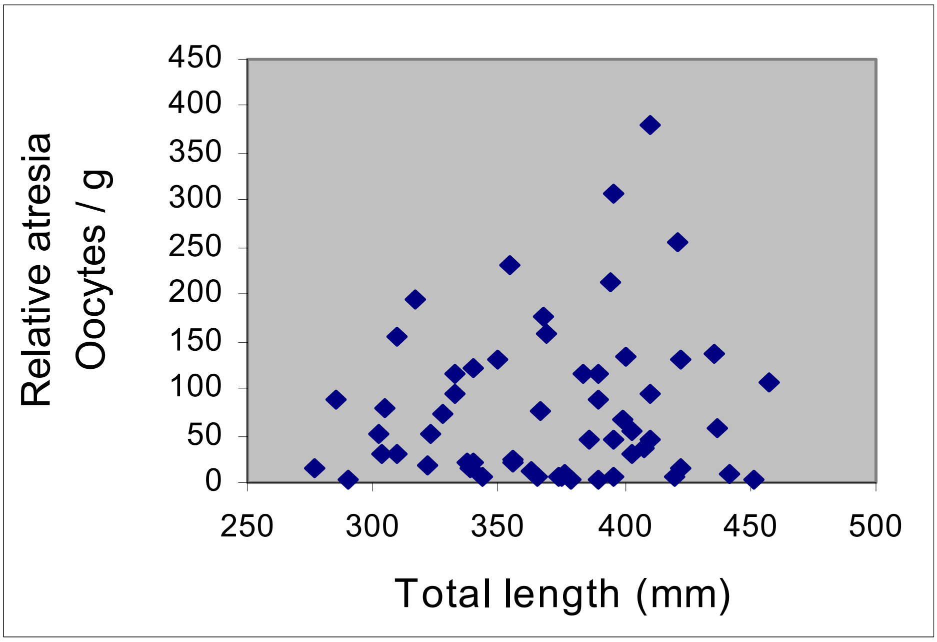
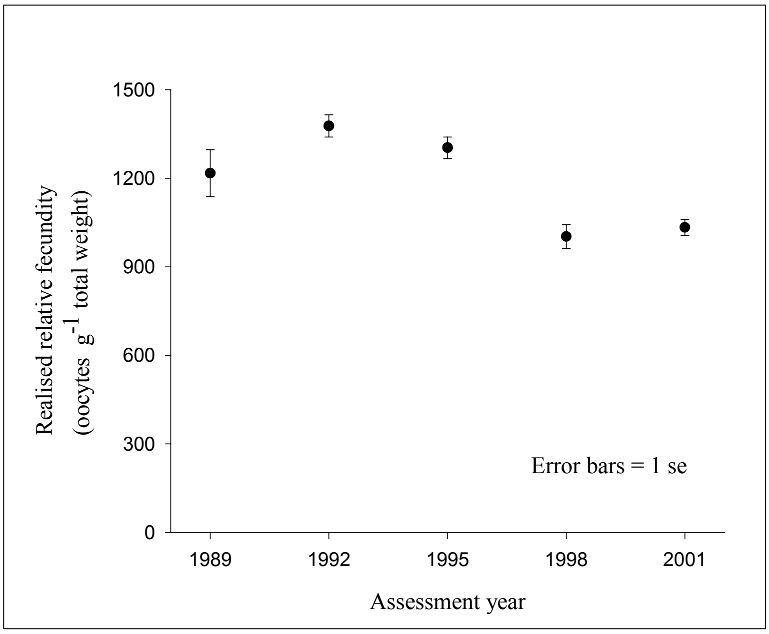


Figure 5.4.1-2 Historical time series of potential and realised fecundity plotted from the first year (1989) when atresia was deducted from the potential fecundity.



6 WESTERN HORSE MACKEREL: 2001 EGG SURVEY RESULTS

6.1 Spatial distribution of stage I horse mackerel eggs

The first survey in the western area was in Period 3 (18 March to 14 April) (Figure 6.1-1a). As for mackerel, coverage was very good over the area. Very little horse mackerel egg production was seen, except in the inner corner of Biscay. Interpolations were minimal and added very little to the estimate.

Coverage in Period 4 was also very good (Fig. 6.1-1b). Egg production was still fairly low, with patches distributed along the shelf break from 46 to 53°N. The only major interpolated values were at 46°45‘N, the easternmost of these is probably higher than might be expected. There were no other obvious problems with interpolation at the edges of the distribution.

Coverage in Period 5 was slightly less perfect than in the previous periods. A fairly large number of rectangles required interpolation, however, in most cases these were well supported. The only major anomaly from the interpolation was one rectangle at 51° 15‘N (the same as for mackerel). The tow interpolated values in the inner corner of Biscay were also slightly suspect. The main spawning was in a continuous broad band from the inner corner of Biscay to the Porcupine Bank along and around the 200m contour. A small patch of eggs were seen north of the main area around 54°N.

Coverage in Period 6 was again very good, although there were was a general pattern of every second transect being sampled, and the intervening transects being interpolated. The resultant distribution appears reasonable and there were no major interpolation anomalies with the possible exception of some values at 48°15‘N. The distribution was fairly concentrated, with the main areas being around Grand Sole Bank (49°N) and at Porcupine Bank. Spawning was seen on both sides of the 200m contour

Only one vessel was available for Period 7 so the coverage was necessarily less complete than in previous periods. In general coverage was good, although as in Period 6 sampling was conducted on alternate transects, with the intervening transects interpolated. The two main patches were in similar locations to Period 6 but displaced north by around one degree. There was also a patch of spawning off north west Ireland, however, the bulk of the rectangles in this area were interpolated. Only one real sample was observed with particularly high values. As with the mackerel there was relatively high egg production at the southern edge of the surveyed area, which may suggest that there were more eggs further south.

6.2 Stage I egg production of western horse mackerel

The mean daily stage I egg production estimates for each survey period are plotted against the mid-period days in Fig. 6.2-1 to provide an egg production curve as presented for previous surveys. The data values are presented in Table 6.2-1.

The start date was assumed to be the 10 February as used in 1995 and 1998, when spawning also occurred earlier than in the previous survey years. No histological or survey data were available in the western area or in the Cantabrian Sea prior to period 3 to suggest any alternative start date. The end date is the same as that used in 1995 - 31 July. Samples in the northern part of the survey area at the end of period 7 found no eggs which suggests that spawning had substantially ended by the final week in July. Production estimates for the individual survey periods and the period before the surveys are presented in Table 6.2-2.

There was no temporal overlap between periods for the 1998 survey. The variance pattern is similar to 1998. The calculations are based on the complete survey results including all observations irrespective of the proposed survey area. This approach was used as the survey is based on surveying the entire stock, regardless of where it was, and also on the need after all previous surveys to update the „standard area“ for each new survey (see 4.2.1). No data from the southern area were included in the analysis. There was a negligible effect on the estimate of expanding the 1998 area as most of the additional observations were very low.

6.3 Atresia of western horse mackerel

The atresia results of the 1998 egg surveys were not prepared in time for the WGMEGS meeting in Hamburg in 1999 (ICES, 1999/G:5). Therefore a working document on the atresia analysis had been presented to the ICES Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy in September 1999. Although the 1998 atresia result have been presented at the WG MHSA meeting in September 1999, they are summarised in this report as well.

Table 6.3-1 shows for survey year 1998 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, 1996/H:2). 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/G:5). 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.

Because of the relatively low impact of atresia on the realised fecundity estimate, the WGMEGS decided not to sample horse mackerel for atresia during the 2001 egg surveys.

6.4 Total fecundity of western horse mackerel

As has been indicated previously (ICES, 1999), there is a range of problems associated with the determination of the appropriate level of horse mackerel fecundity and of how to apply that to the estimation of biomass.

Fish collections were made for horse mackerel fecundity estimation during the 1998 and 2001 triennial surveys and additionally in 2000 (Table 6.4-1, Figs. 6.4.-1a-e). Fig. 6.4-2 shows a comparison between this data and earlier years (1987/88, 1992, 1995), when the population was dominated by the very abundant 1982 year class, and the effect of period and source of data on the fecundity estimate. There are two options to use this data based on acceptance or rejection of the view that horse mackerel fecundity is determinate (see discussion below).

The first option is that WGMEGS accepts that horse mackerel has a determine fecundity and data collected since 1998 should be used in the 1998 and 2001 WGMEGS assessments. Selecting fish without post-ovulatory follicle provides data indicating that relative fecundity has little dependence on fish weight. However there has been a reduction in relative fecundity between 1995 and 1998, which is consistent with the trend in mackerel realised relative fecundity (Figure 5.4.1-2). The values of relative fecundity for the 1998 and 2001 assessments are 1002 and 994 respectively and are also similar to that estimated in 2000. The second option, regarded by WGMEGS as less acceptable, is based on the assumption that horse mackerel has an indeterminate fecundity. In this case there is no guidance on the best available evidence for estimating SSB.

Is fecundity in horse mackerel determinate or indeterminate? One of the basic assumptions in the annual egg production method (AEP) for the estimation of the spawning stock biomass is that fecundity in horse mackerel is determinate, which means that the number of eggs to be produced by an individual female fish in the current spawning season is determined before the beginning of the spawning season. In the AEP method it is assumed that no previtellogenic oocytes mature to ripe eggs during the spawning season following de novo vitellogenesis. If this process was very active it could lead to a significant underestimate of realised fecundity.

According Hunter *et al.* (1985) many fishes in temperate and tropical areas have a fecundity that is seasonally indeterminate. These fishes are frequently called multiple, partial, serial, or heterochronal spawners. The standing stock of yolked eggs, regardless of maturity stage, give no indication of realised annual fecundity. In the cases of species like *Scomber*, *Trachurus* and *Merluccius* detailed examination of the bio-energetics, dynamics of egg development and spawning processes should be provided before the annual egg production method can be applied without serious bias. The plasticity of fish reproductive strategy may mean that the difference between potential and realised fecundity may evolve in response to changes in climate and food availability over a period of time.

There are indications that horse mackerel might be an indeterminate spawner based on the following observations. The fecundity estimates in 1998 and 2001 show that fecundity within the population seems to increase after the onset of spawning (Fig. 6.2-1). However, this does not necessarily mean that the fecundity for an individual female increases after the onset of spawning, because some fish within the population might be spawning early and some might be late.

Individual fish spawning probably lasts for only 2 months within a 5-6 month spawning season, so fish which have not spawned may be found throughout most of the spawning period. At the very onset of the spawning season one would expect for a determinate spawner that the first spawning fish have the highest fecundity, while the fish with developing ovaries, and therefore with a later onset of spawning, might have a lower fecundity.

However, at the onset of spawning in 2001 the fecundity of fish with signs of spawning (POF's) have a fecundity of approximately 684 eggs/g (based on 20 fish with POF's on Julian days 100 and 110 in 2001), while the fecundity of fish without these signs of spawning have a fecundity of approximately 813 eggs/g (based on 28 fish without POF's on Julian days 100 and 110). Assuming that horse mackerel is a determinate spawner this phenomenon can only be explained by the fact that already advanced spawning fish e.g. from further south have mixed with the not-yet spawning fish. Assuming that horse mackerel is an indeterminate spawner this can be explained by the fact that the spawning females have just released their first batch of eggs of approximately 200 eggs/g female (Priede, 1994) and both the spawning and not yet spawning fish continue to develop de novo vitellogenetic oocytes.

Given the assumption that the AEPM is valid, a suitable fecundity value needs to be determined. As mentioned above, in 1998 the WG rejected the observed data (approximately 1000 eggs per gram female) and adopted the historical fecundity of 1504. One possibility was to continue to use this value. However, the observed fecundity data collected in 1998 AND 2001 were consistent with each other, and also substantially different from the historical time series, back from 1995. A further aspect was that in and prior to 1995, the stock was dominated by the large 1982 year class. From 1998 onwards, this year class had substantially disappeared from the population, and the age structure was more uniform. Using the historical value assumes that there has been a constant fecundity over the complete time series, and hence that the best index of stock abundance would effectively be the egg production. Using the observed 2001 data assumes that fecundity varies from year to year and that the combination of egg production with fecundity would be the best index of stock abundance. Essentially, this can be reduced to a question of whether the inclusion of fecundity increases or decreases the variance in the egg production based abundance estimate. However, if the observed fecundity is an underestimate, including it will introduce a bias into the estimate of SSB.

Bearing all these problems in mind, the WG concluded that the 2001 egg production should be converted to biomass using the realised fecundity data collected in 2001 rather than using the historic mean. This was based on:

1. The substantially lower realised fecundity in most samples collected in 2001 than in all samples in and prior to 1995.

2. The similarity between the data collected in 1998 (and 2000) and that collected in 2001.

3. The larger sample size in 2001, and greater spatio-temporal sampling spread

4. The substantial change in the population structure after 1995, with the loss of the 1982 year class.

5. That there were similar changes in the potential fecundity of mackerel in the 1998 and 2001 surveys – it should be noted that realised fecundity (after atresia) was different in these two years.

It should be noted that the observed horse mackerel fecundity in the southern area in 2001was close to the long term mean value at around 1500.

Additionally, the WG decided that the best estimate of fecundity for use in converting egg production into SSB would be obtained using data collected in the spawning area from Julian day 100 (just after the onset of spawning) up to the peak of spawning, rather than a mean of all samples. This was in recognition of the low observed fecundity in fish sampled early in the spawning season. The fecundity samples used were collected during the spawning season. This means that the PRE-SSB to SSB conversion factor is no longer required. This conversion factor of 1.05 was based on samples being collected early in the spawning season, and was required to compensate for growth between then and the time of peak spawning.

Given the uncertainty about the fecundity the WG VERY strongly recommends that the stock abundance estimate derived from the egg surveys is used as a relative index in the assessment and not as an absolute measure of biomass.

The 1998 Survey

As a corollary to this, the WG also felt that the fecundity estimate used in 1998 should also be changed to reflect sampling in that year. This will have a consequent effect on the estimated biomass.

The future

There are a number of questions, which **MUST** be answered prior to the next egg survey.

6. Most importantly, is horse mackerel a determinate or an indeterminate spawner? If this cannot be answered prior to the survey, the collection of data to answer this question should be incorporated in the design of the 2004 survey.

7. If it is determinate, what level of adult sampling would be required to adequately define potential fecundity?

8. If it is indeterminate, what use can be made of the egg production data from the survey? Should the total egg production be used as an index alone? Should the survey at peak spawning be used to provide a Daily Egg Production Method (DEPM) SSB estimate?

In 1999 the WG recommended that tank experiments be used to investigate determinacy in horse mackerel. The WG again recommends that these be carried out as a matter of urgency. Whether the egg survey is used in AEPM or DEPM mode it is clear that there will also have to be a substantial increase in the scale of adult sampling. It is unlikely that this can be carried out by the research vessels already involved in the survey, and would ideally involve the chartering of a commercial vessel dedicated to the collection of adult samples. A side benefit of this approach would be that the vessel could also be used to collect more mackerel samples. The WG recognized that these proposals have significant resource implications. The funding of this work would be appropriate for the EC and/or commercial fishing organizations.

6.5 Biomass Estimate of Western horse mackerel

<u>SSB estimate for 2001</u>

Total stage I egg production using all data both inside and outside the standard sampling area, and interpolated rectangles both inside and outside the standard area is given in Table 6.2-2. The final annual egg production estimate was $0.684*10^{15}$ eggs. Total spawning stock biomass (SSB) was estimated using the fecundity estimate of 994 oocytes/g female, not corrected for atresia (see Sections 6.4), a sex ratio of 1:1 and a raising factor of 1.00 (see section 6.4) to convert pre-spawning to spawning fish. This gave an estimate of spawning stock biomass for 2001 of 1.38 million tonnes with a variance of approximately 560,000 tonnes. The variance in the estimate due to the egg survey was 35% and 65% to the fecundity estimate.

<u>Revision of SSB estimate for 1998</u>

Total spawning stock biomass (SSB) in 1998 was revised using a new low fecundity estimate of 1002 oocytes/g female, not corrected for atresia (see Sections 6.3), a sex ratio of 1:1 and a raising factor of 1.00 (see section 6.4) to convert pre-spawning to spawning fish. This gave an estimate of spawning stock biomass for 1998 of 2.00 million tonnes

Comparative data from earlier years are shown in Table 6.5.1. These indicate a 31% decrease in biomass in 2001 compared to the previous egg survey estimate in 1998. This resulted mainly from a decrease in annual egg production, because the fecundities for 1998 and 2001 were almost identical. It now appears that SSB has increased by 17% from 1995 to 1998, because of the revision in the 1998 fecundity.

Table 6.2-1 Western horse mackerel mean daily stage 1 egg production 10^{-12}			
Period	Dates	Estimate	Standard Deviation
3	12/3 – 8/4	0.29	0.14
4	9/4 – 13/5	1.71	0.49
5	14/5 – 10/6	11.9	2.87
6	11/6 – 1/7	9.31	3.08
7	2/7 –1/8	2.76	1.14

Table 6.2-2 Western horse mackerel total stage 1 egg production estimates by time period for 2001			
Dates	Period	Number of days	Annual stage 1 egg production.10^{-15}
11/2 – 11/3		30	0.003
12/3 – 8/4	3	28	0.008
9/4 – 13/5	4	35	0.060
14/5 – 10/6	5	28	0.334
11/6 – 1/7	6	21	0.196
2/7 – 1/8	7	30	0.083
	Total	172	0.684
	Standard Deviation		0.14
	C.V.		20%

Table 6.4-1 The number of atretic oocytes per gramme female horse mackerel in the population during the third to sixth survey coverage in 1998 as obtained from the fraction of females with atresia and the number of atretic oocytes per gramme female with atresia. The proportion of residual fecundity compared to annual potential fecundity and relative intensity are also shown.

1998 Survey period	Preva-lence of atresia # (%)	No of fish for scoring preva-lence	No of atretic oocytes/g female with atresia	Standard error atretic egg/g (SE)	No of fish for counting atresia	No of atretic oocytes/g female **in the population**	Relative intensity of atresia * (%)	Residual fecundity compared to total fecundity (%)
3	34%	86	14	3	29	5	0,3%	30%
4	18%	93	16	5	17	3	0,2%	56%
5	14%	44	25	19	6	4	0,2%	67%
6	30%	37	17	8	11	5	0,3%	56%
3-6	24%	260	**18**		63	**4**	0,3%	

= fraction of fish with atresia (in %)
* = number of atretic oocyte /g in the population divided by total fecundity of 1557 eggs/g (in %)

Table 6.5-1 A summary of mean (arithmetic) horse mackerel weight, fecundity relative fecundity atresia (geometric) and number of fish sampled by year, latitude and period.

Year	Period	Fish weight	Fecundity	Fec/g	Atresia	n	Latitude
1998	4	232	208179	872	5421	4	
1998	5	145	150364	1078	9349	5	
1998	6	220	190787	1071	11311	2	
	Mean fecundity for Julian day >=100			**1002**			
2000[2]	1	323	75812	118	2223	6	48, 50
2000[2]	2	289	156061	442	2643	72	49, 50
2000[2]	3	316	299573	785	16730	10	49, 50
2000[2]	4	299	296983	893	1919	30	49, 51
2001	1	159	45698	256	3183	9	50
2001	2	182	59277	183	2424	45	47, 48
2001	3	171	91921	532	1997	71	46-50
2001	4	131	109934	819	10081	36	46-50
2001	5	108	81115	721	1119	21	46
2001	6	178	251719	1361	1473	43	46, 49, 51
	Mean fecundity for Julian day >=100			**994**	**se 80**		**46-51**

[1] mean weighted by number of ovaries (n)
[2] periods as used in 2001.

Figure 6.1-1a. Horse mackerel egg production by rectangle for period 3 (12 March – 8 April). Filled circles represent observed values, filled squares represent interpolated values, crosses represent observed zeroes. Interpolated zeroes are not included. Circles and squares are square root scaled to a maximum of 500 eggs $m^{-2}.day^{-1}$.

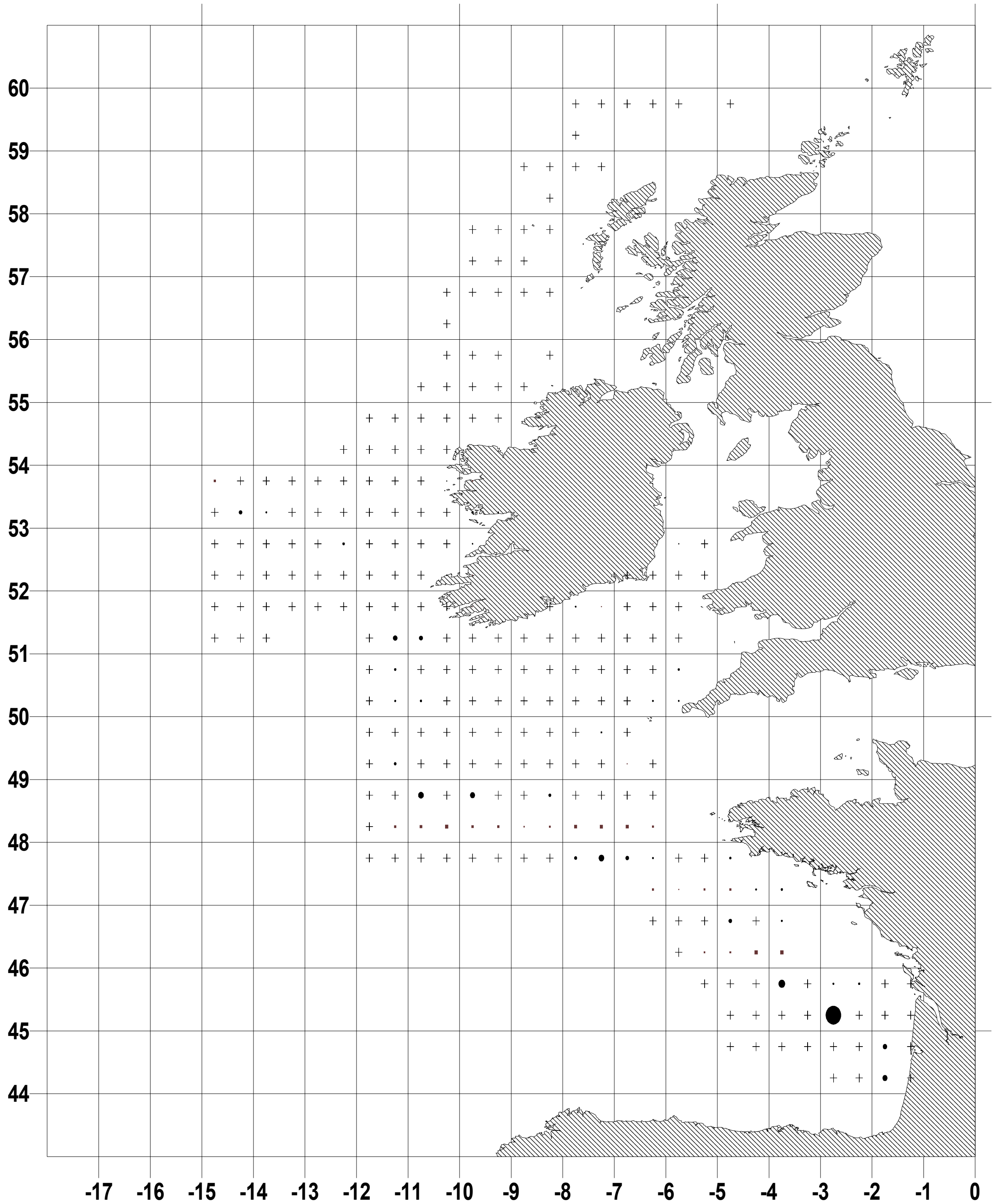


Figure 6.1-1b. Horse mackerel egg production by rectangle for period 4 (9 April – 13 May). Filled circles represent observed values, filled squares represent interpolated values, crosses represent observed zeroes. Interpolated zeroes are not included. Circles and squares are square root scaled to a maximum of 500 eggs $m^{-2}.day^{-1}$.

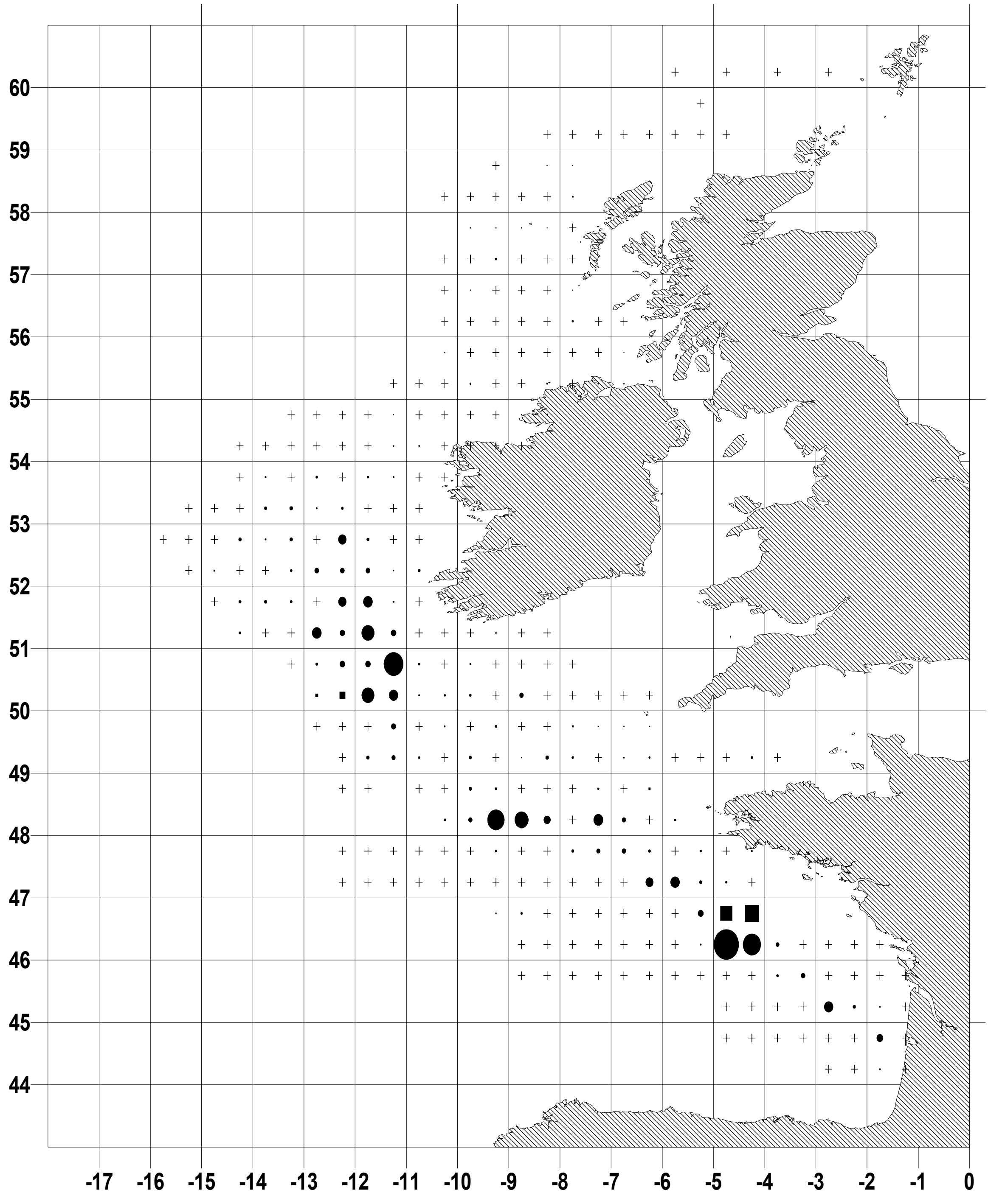


Figure 6.1-1c. Horse mackerel egg production by rectangle for period 5 (14 May – 10 June). Filled circles represent observed values, filled squares represent interpolated values, crosses represent observed zeroes. Interpolated zeroes are not included. Circles and squares are square root scaled to a maximum of 500 eggs $m^{-2}.day^{-1}$.

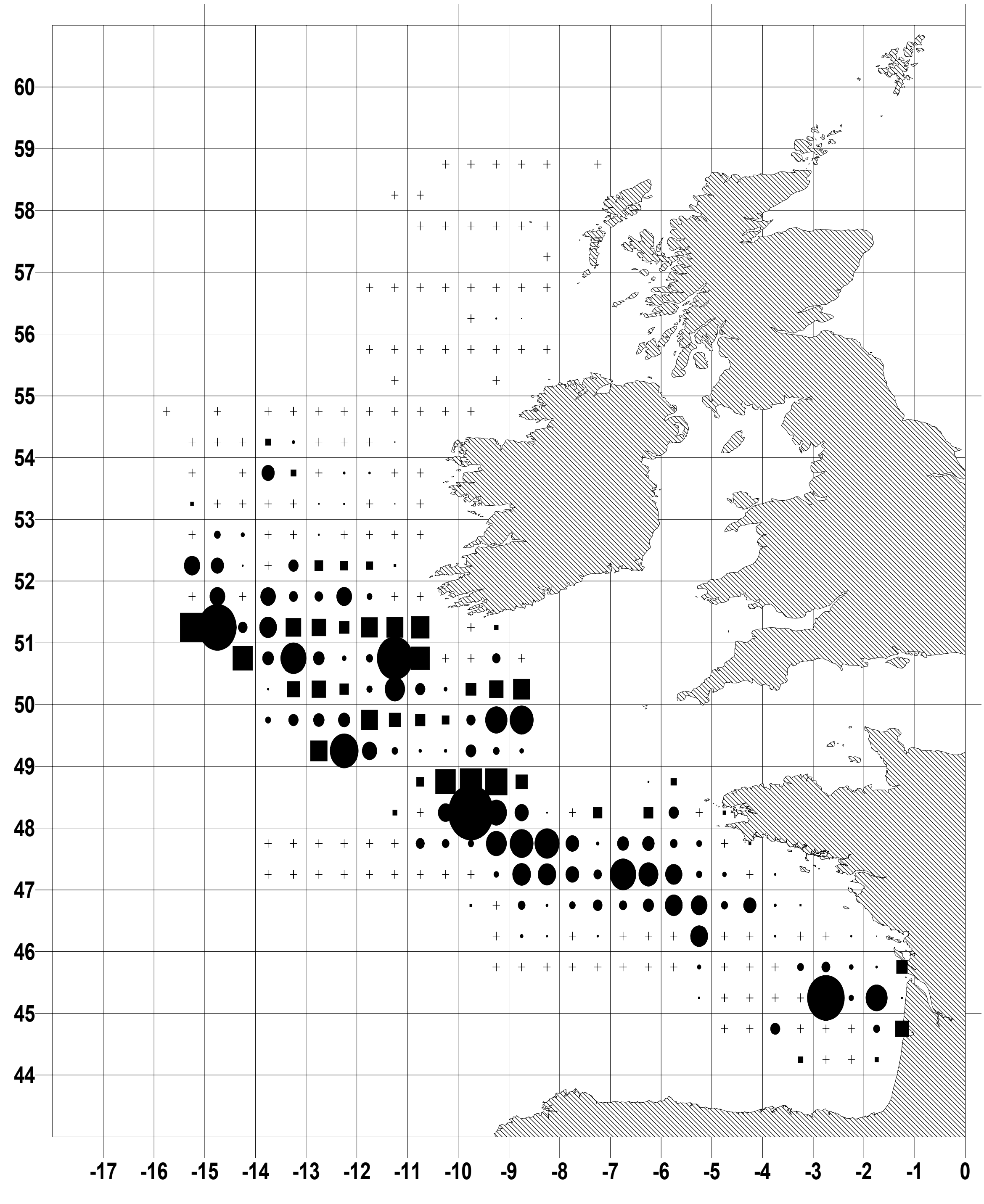


Figure 6.1-1d. Horse mackerel egg production by rectangle for period 6 (11 June – 1 July). Filled circles represent observed values, filled squares represent interpolated values, crosses represent observed zeroes. Interpolated zeroes are not included. Circles and squares are square root scaled to a maximum of 500 eggs $m^{-2}.day^{-1}$.

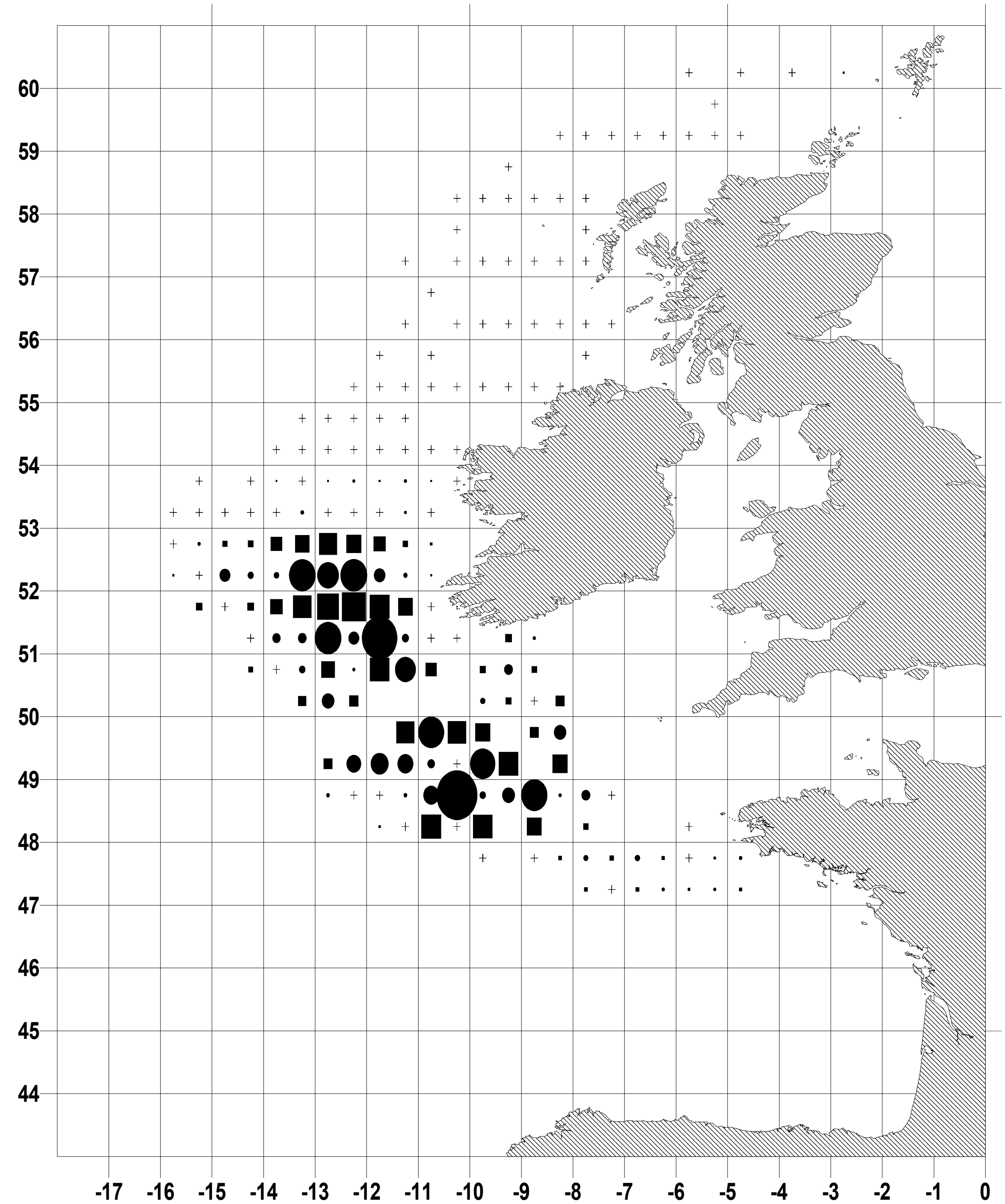


Figure 6.1-1e. Horse mackerel egg production by rectangle for period 7 (2 July – 1 August). Filled circles represent observed values, filled squares represent interpolated values, crosses represent observed zeroes. Interpolated zeroes are not included. Circles and squares are square root scaled to a maximum of 500 eggs $m^{-2}.day^{-1}$.

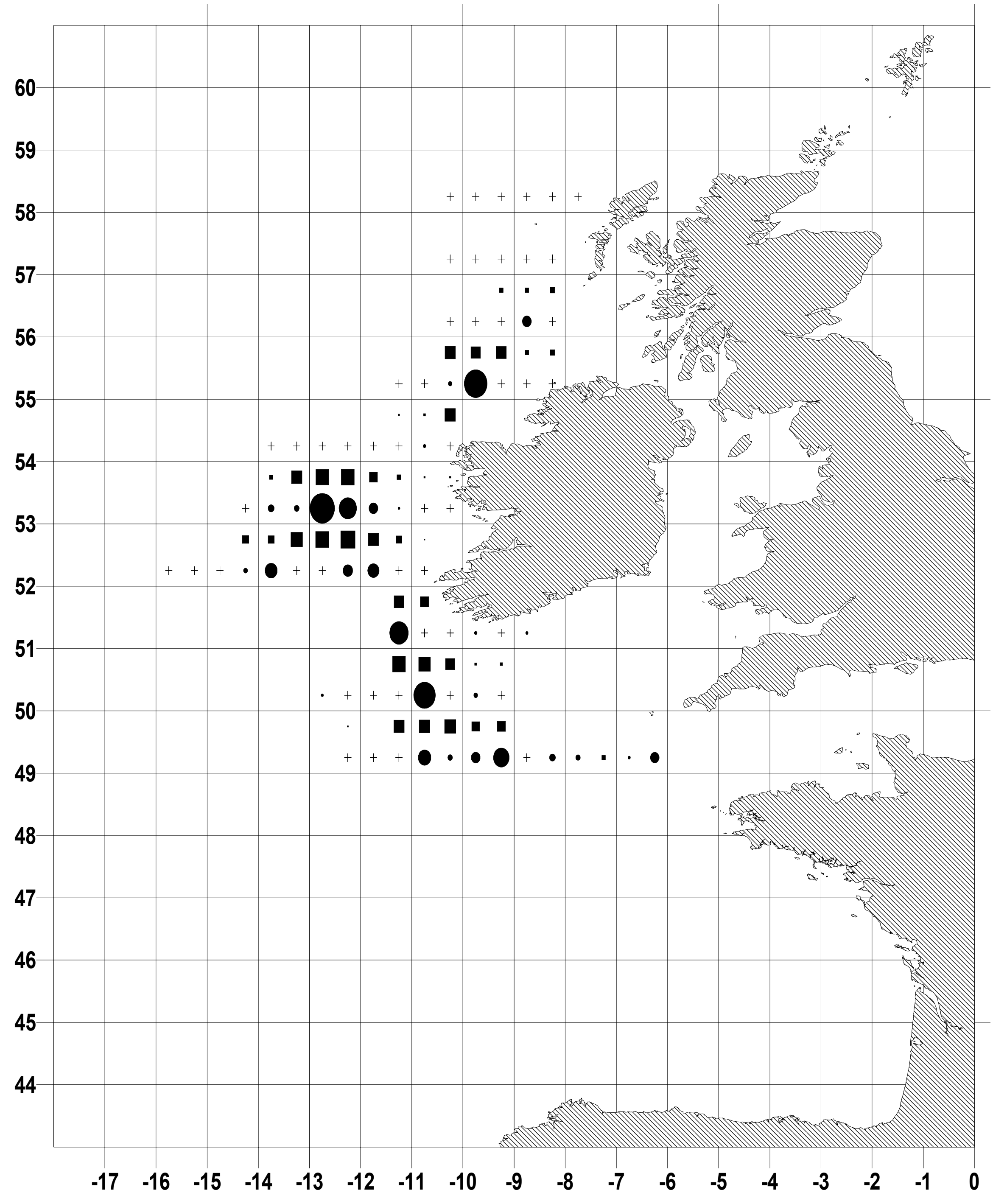


Figure 6.2 – 1a Horse Mackerel egg distribution during period 3

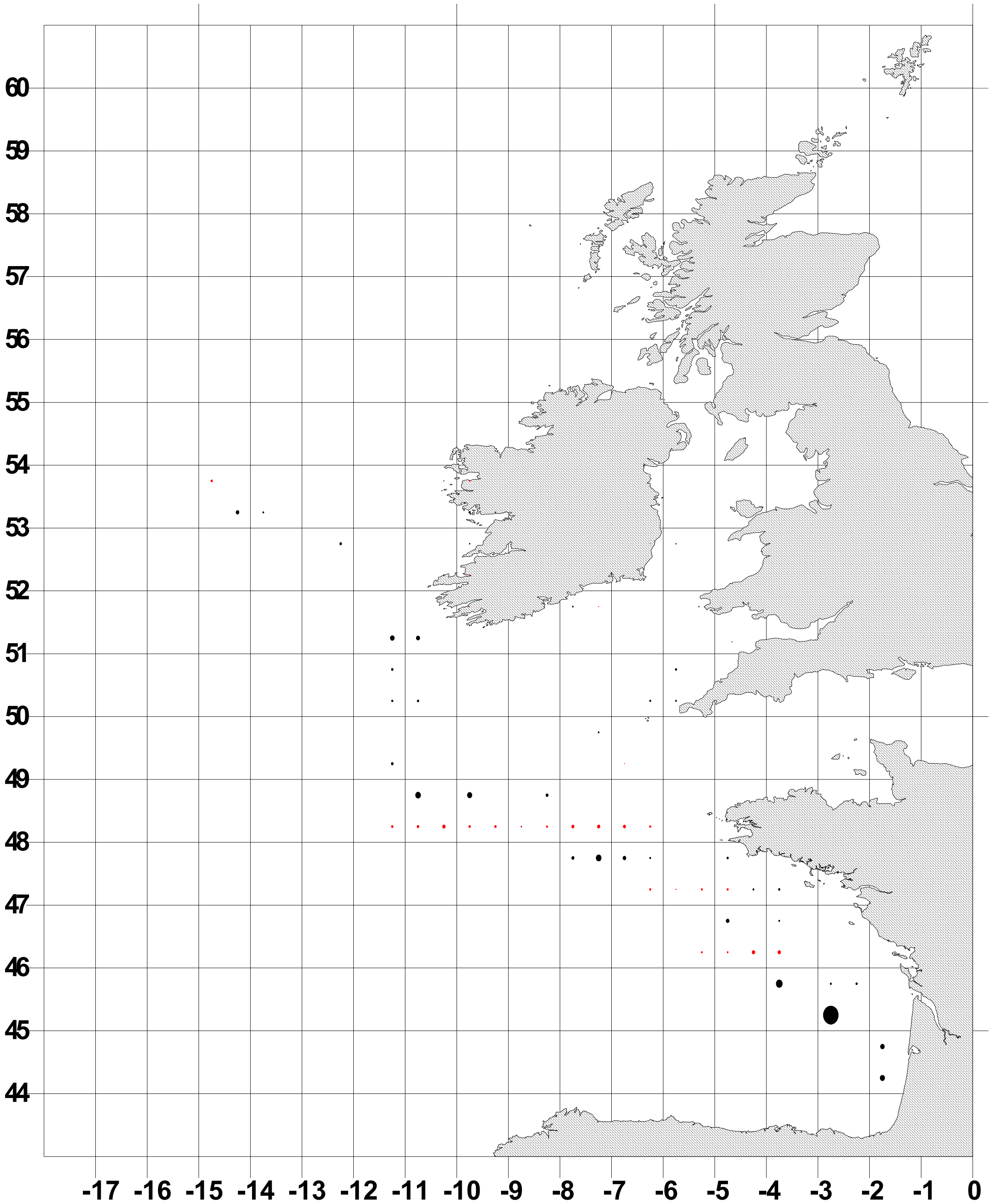


Figure 6.2 – 1b Horse Mackerel egg distribution during period 4

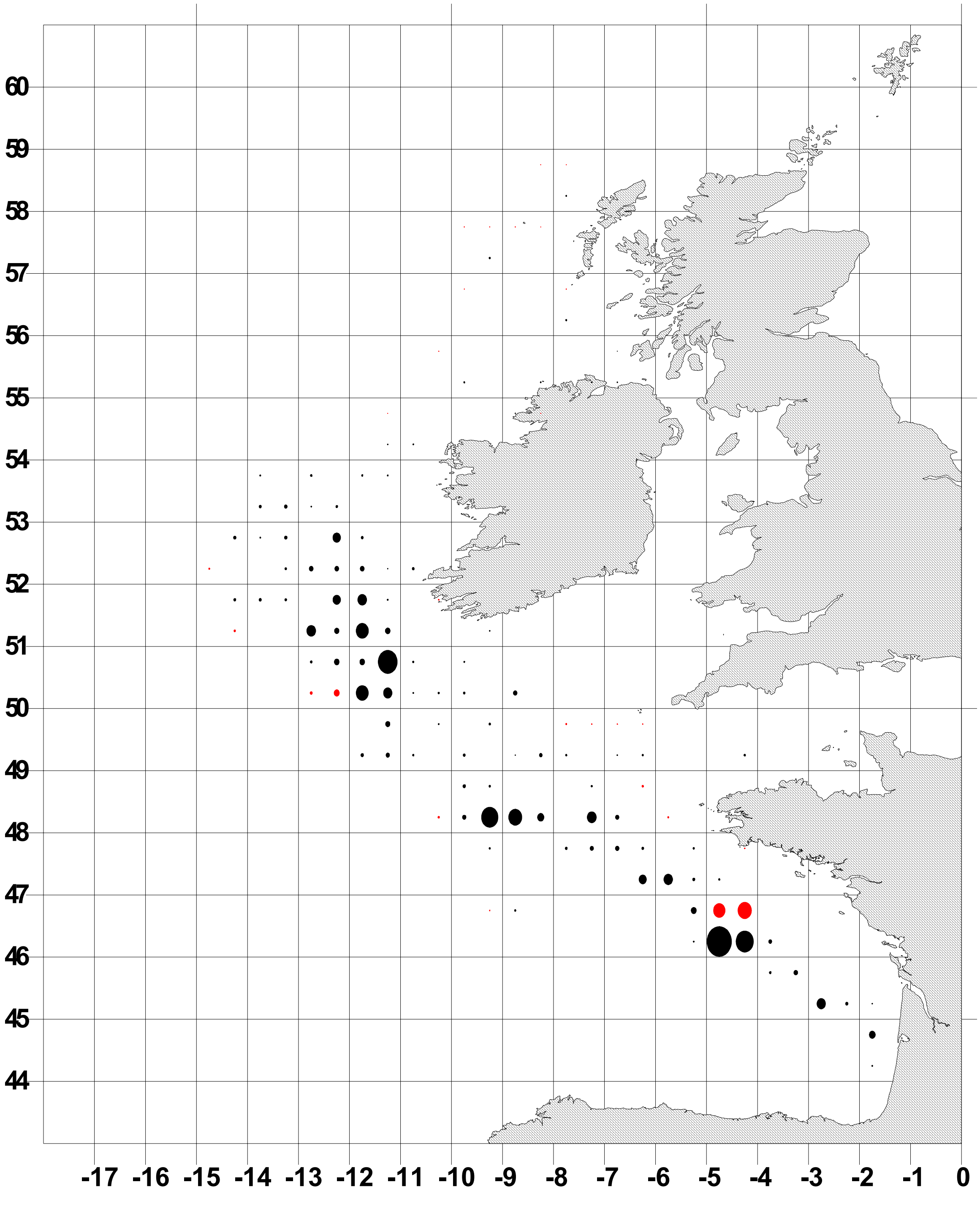


Figure 6.2 – 1c Horse Mackerel egg distribution during period 5

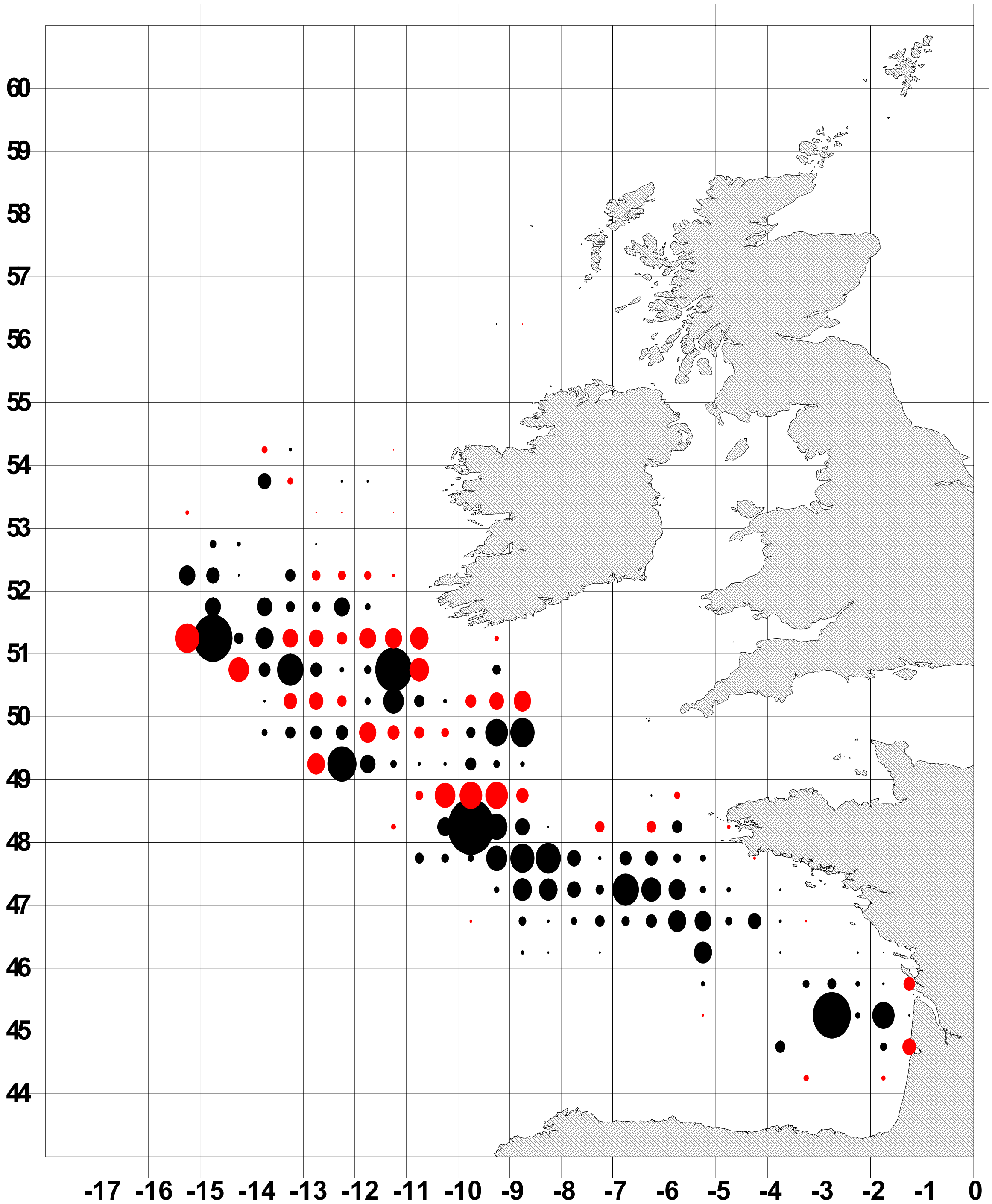


Figure 6.1 – 1d Horse Mackerel egg distribution during period 6

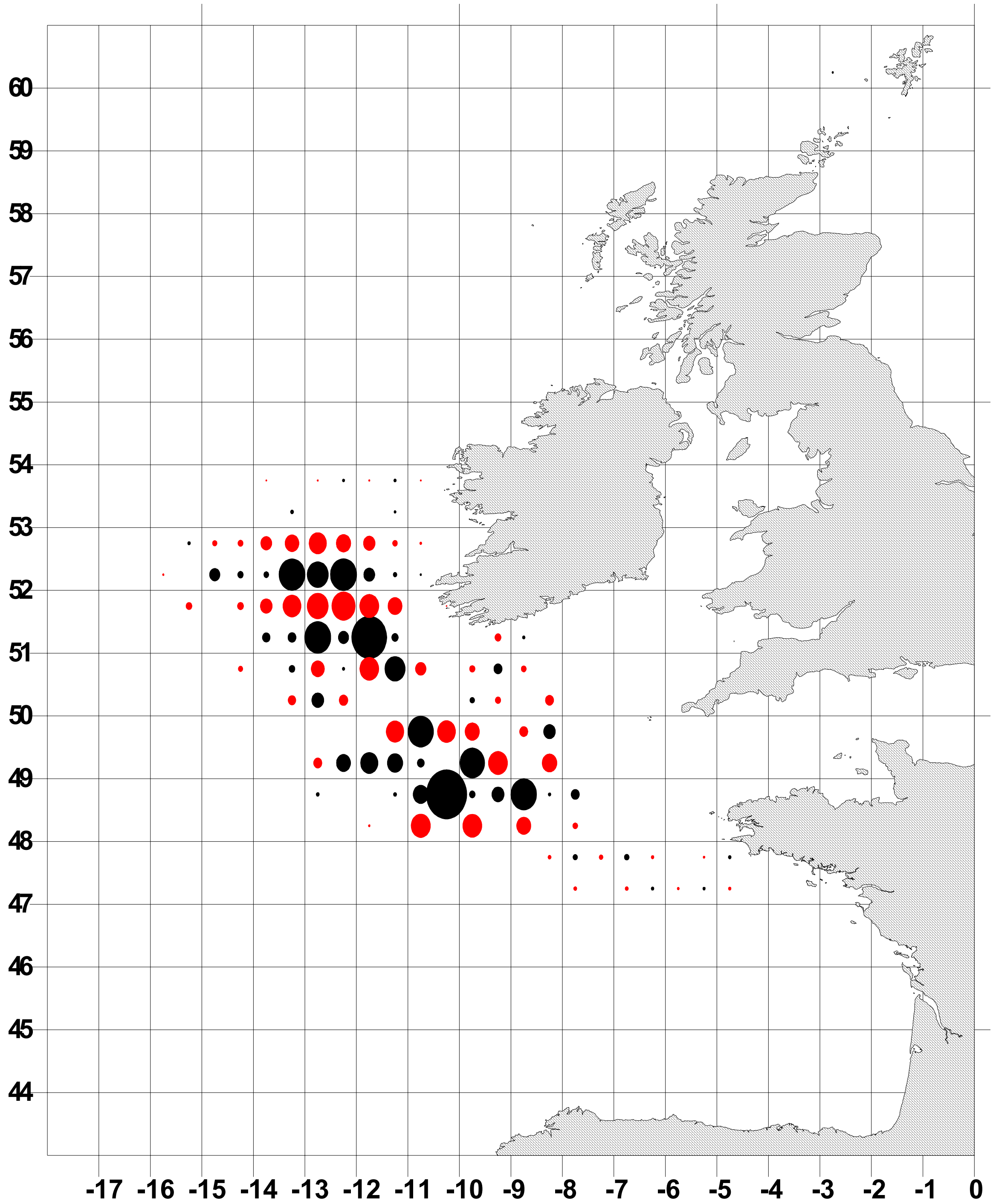


Figure 6.1 – 1e Horse Mackerel egg distribution during period 7

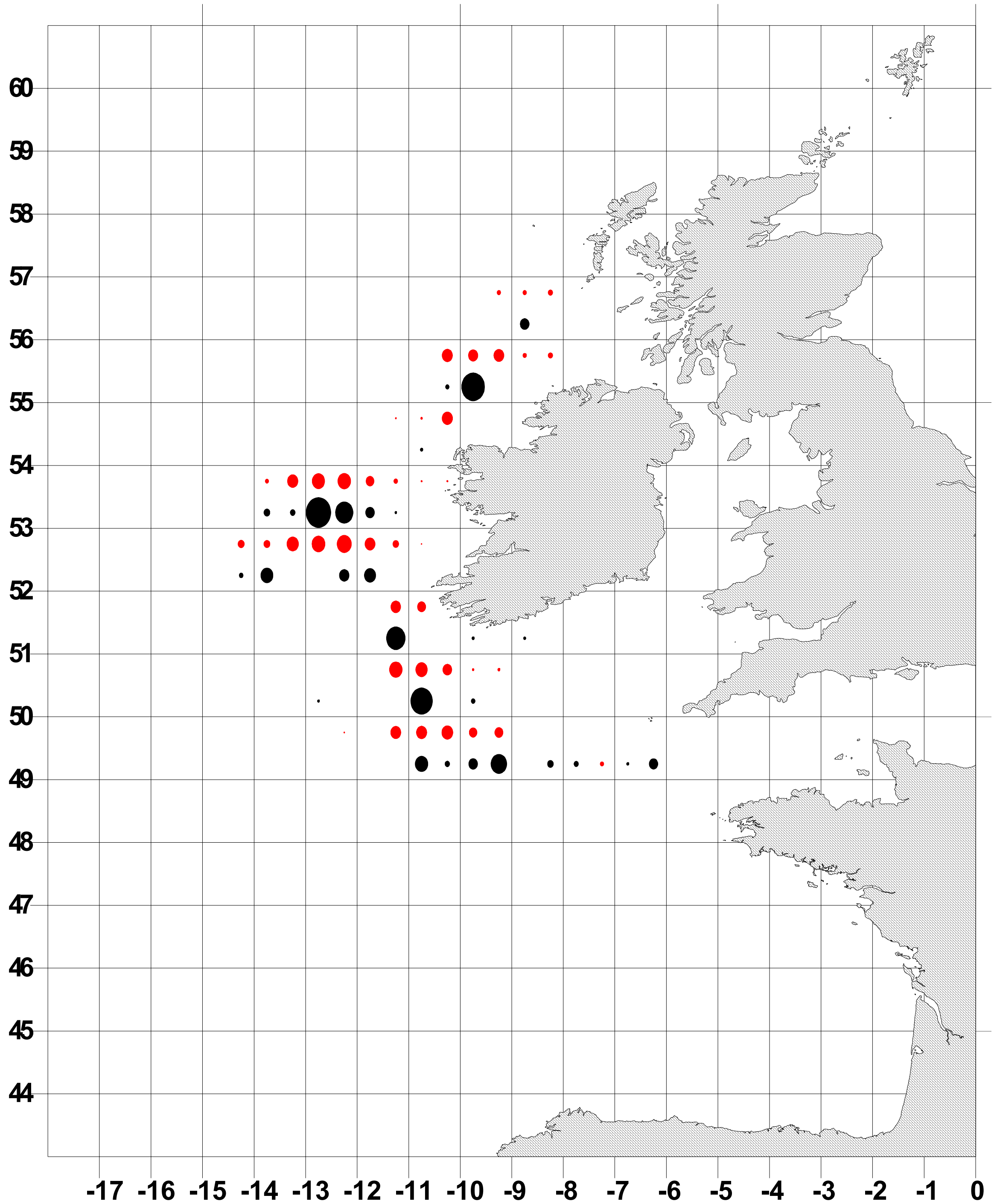


Figure 6.2-1. Horse mackerel daily egg production curve for the surveys in the western spawning area in 2001. The 1998 curve is included for comparison.

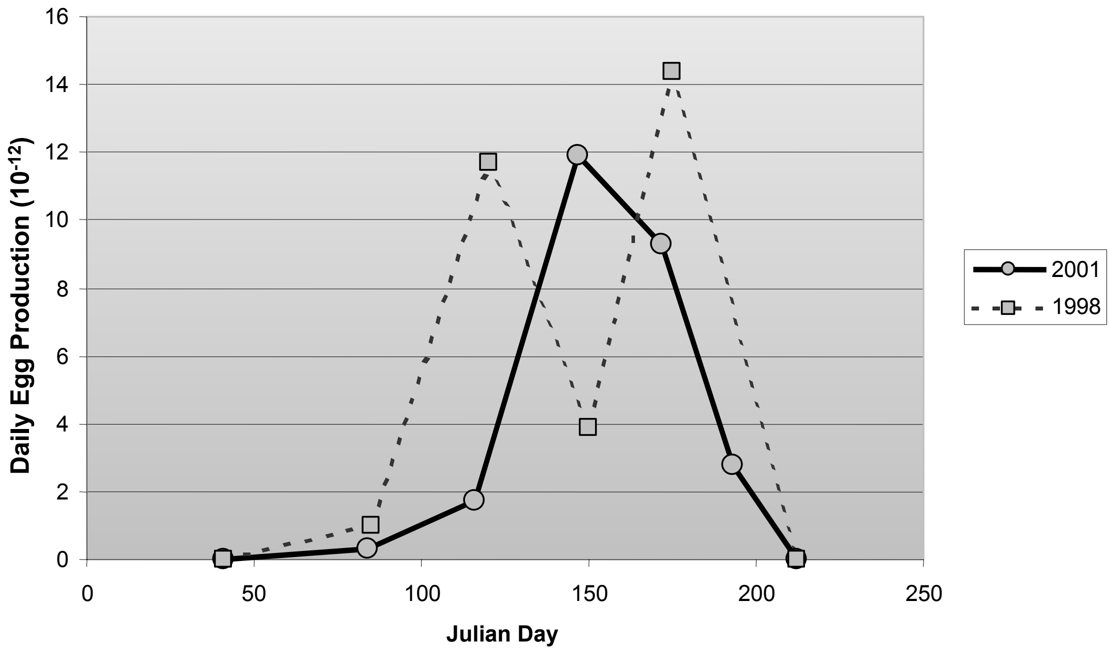


Figure 6.4..-1a-e Fecundity and relative fecundity of horse mackerel showing the data for historical (pre 1998) and from 1998 onwards as indicated in the figure legends. In the 2001 plots details of the source of the data are also indicated in the legend. The lowest panel shows the change in relative fecundity by period.

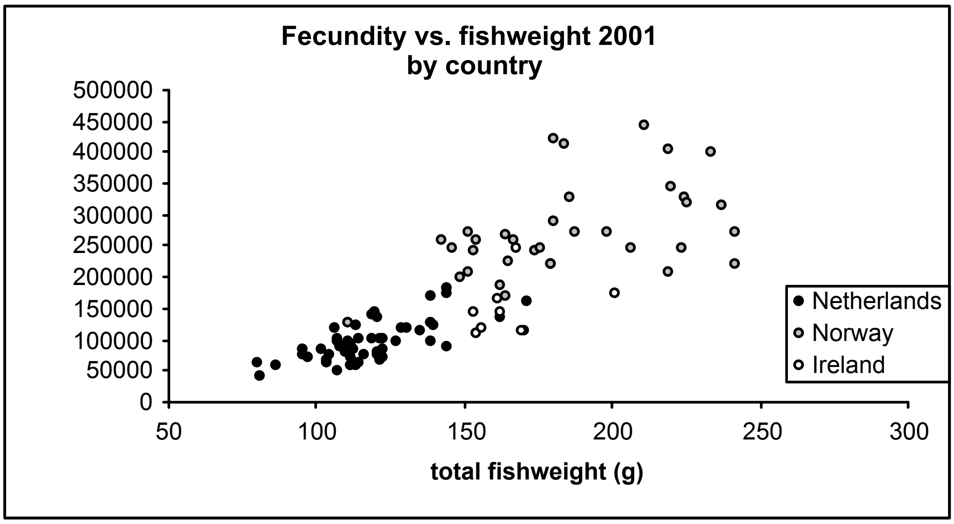


Figure 6.4.-1a

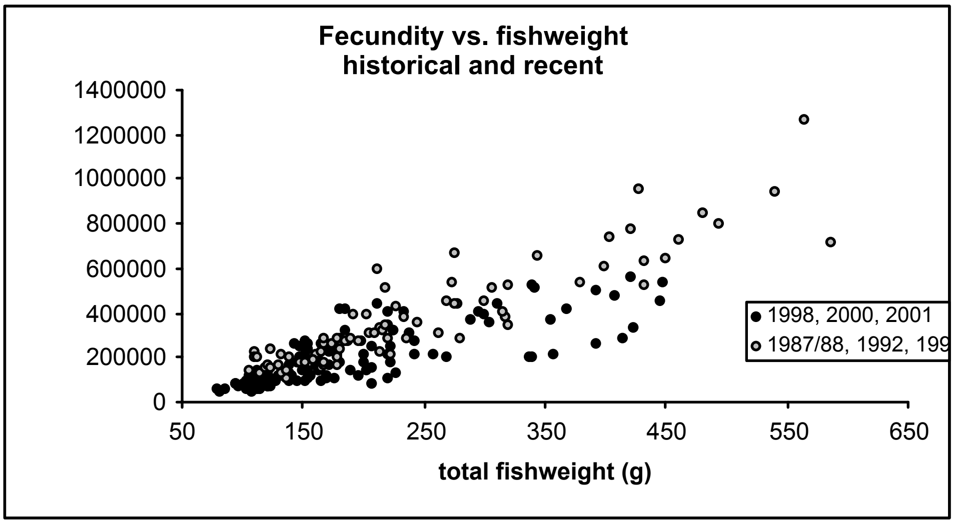


Figure 6.4.-1b

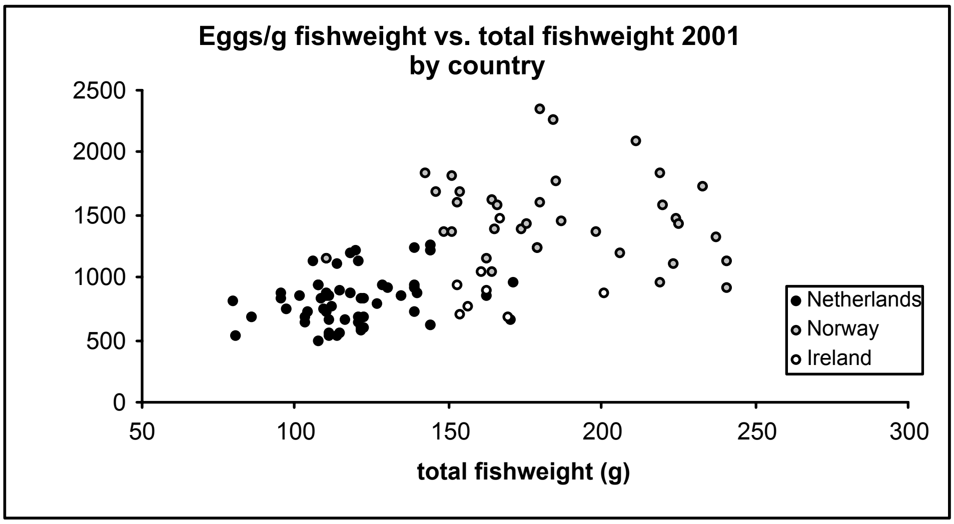


Figure 6.4.-1c

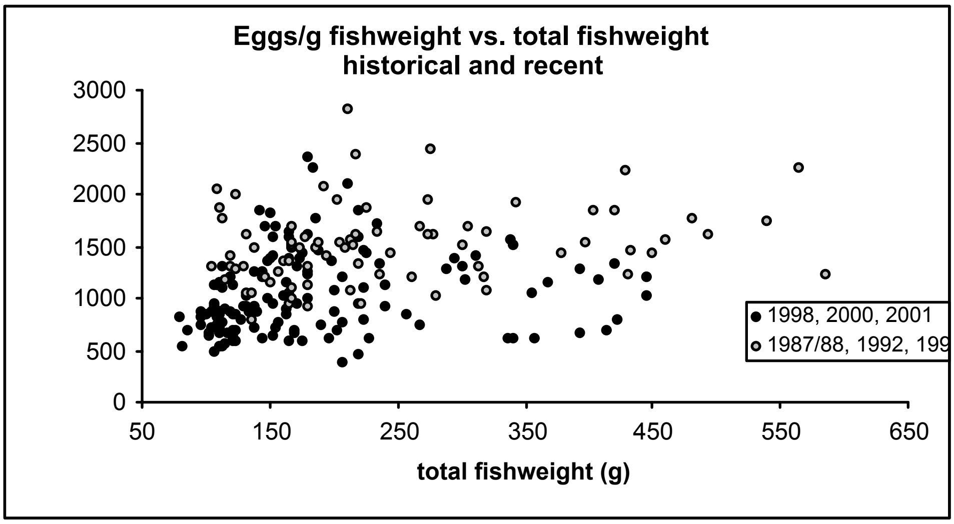


Figure 6.4.-1d

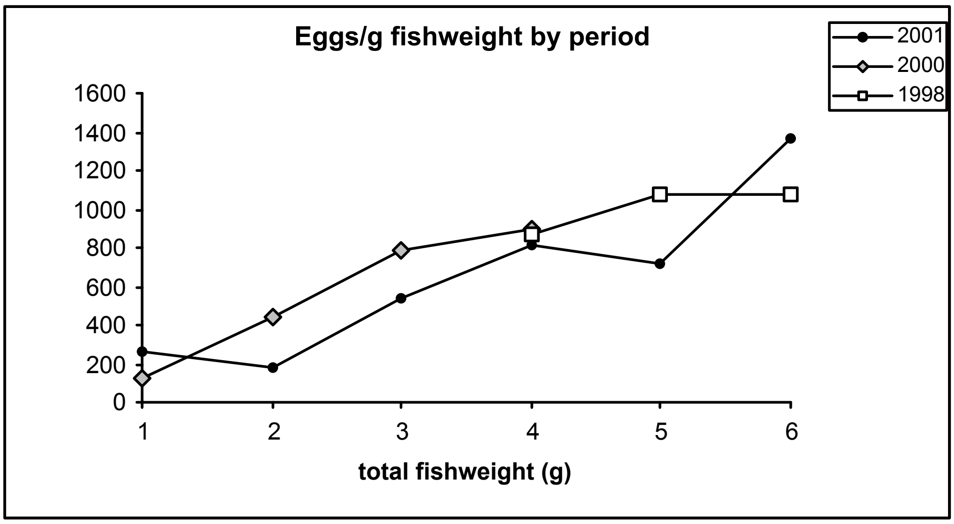


Figure 6.4.-1e

7 SOUTHERN HORSE MACKEREL: 2001 EGG SURVEY RESULTS

7.1 Spatial Distribution of Stage I Horse Mackerel eggs

Distribution maps of daily stage I egg production per m^2 surface are given for the five survey periods in Figures 7.1-1a-e.

During period 1 only the south and western Atlantic Iberian Peninsula was surveyed. Very small numbers of horse mackerel eggs appeared in stations between 37º30'N and 40º30'N near the coast. The egg production was much lower than in 1998.

In Period 2, the southern area was sampled from 36º00'N to 44º15'N. As in previous periods the western half of the rectangles were not sampled and neither were the last three northern half rectangles of the Cantabrian Sea. Horse mackerel egg abundance during period 2 increased a little. A nucleus with the maximum abundance was located to the north of the Portuguese coast. In the Cantabrian Sea horse mackerel eggs were very sparse. There were no eggs south of 39º00'N.

During period 3 the survey again covered the southern area by Portugal, Spain (IEO) and Germany. The highest densities were found to the north of 43º00'N along the continental shelf. Egg production in period 3 is substantially higher than in the previous period suggesting the start of the peak of spawning in the southern area.

The north part of the southern area was sampled in period 4. Horse mackerel eggs appear distributed along the continental shelf and restricted to the coast but in slightly lower abundance than in period 3. In 1998 the peak of spawning took place in period 4 while in 2001 the peak occurred in period 5.

In period 5 all the northern part of the southern area was sampled by AZTI and Netherlands survey, as scheduled. This period showed a higher abundance of horse mackerel eggs. The eggs were distributed mainly to the east of the sampled area and very close to the coast. This area should also have been surveyed in period 6 as the peak of horse mackerel egg production was found in period 5.

7.2 Stage I Egg Production of Southern Horse Mackerel

The mean daily stage I egg production estimated for each individual period is given in Table 7.2-1. Total production values for the individual time periods and interpolated periods are given in Table 7.2-2 and the daily egg production estimates for each survey period were plotted against the mid cruise dates to give the egg production curve (Fig. 7.2-1).

The annual horse mackerel egg production estimate was 17.13 x 1013 eggs with a CV of 36%. Spawning season coverage in the southern area during 2001 was less extended than in 1998. In 2001 the coverage was split in 5 periods (from 11 January to 21 May), one period less than in 1998 (from 17 January to 21 June), not allowing full coverage of the spawning season. The main spawning occurred from March to May, being the highest egg production in May (Period 5). To adequately describe the spawning season it will be advisable in the future to survey the period 6 (June). Some stage I mackerel and horse mackerel eggs were found in a sample collected on the 9 of July close to the coast of Gijon (central Cantabrian Sea). Consequently, the end of the spawning was assumed to be the 17 July, the same than in 1998.

Total egg production for horse mackerel in 2001 and comparison with egg production in 1998 are shown in the table below.

Estimates of the total horse mackerel egg production in the southern spawning area in 1998 and 2001		
Year	Annual stage I egg production*10^{-13}	
	estimate	se
1998	17.85	7.77
2001	17.13	6.16

In 2001, the horse mackerel egg production decreased slightly (4%) compared to 1998. The coefficient of variation (CV) of the total egg production (36%) also decreased compared to 1998 (42.2%).

7.3 Total fecundity and atresia of southern horse mackerel in 2001

In the 2000 WGMEGS meeting it was agreed that atresia sampling for horse mackerel would not be undertaken in 2001, because of the low level of atresia as a proportion of the potential fecundity and its small reduction in realised fecundity.

The fecundity was estimated by both Spain and Portugal based on 85 pre-spawning microscopic stage 3 ovary samples accepted from 269 macroscopic stage 3 ovaries collected by Portugal, England, Spain, Germany and the Netherlands (Figure 7.3-1). A fecundity of 1578 eggs/g was estimated with a CV of 19.4%. This fecundity is 27% higher than the value obtained in 1998 (Costa *et al.*, WD 2002). Also the mean fish weight was significantly lower and the fish weight range was narrower than in 1998.

A comparison between 1998 and 2001 fecundity and sampled fish weight composition is shown in the text table below.

	Fecundity (eggs/g)	Mean fish weight	Fish weight range
1998	1245 (CV 26.8%)	187 (CV 49.7%)	61 to 423
2001	1578 (CV19.4%)	170 (CV 19.6)	110-245

7.4 Biomass estimate of southern horse mackerel

The annual horse mackerel egg production estimate was 17.13 x 1013 eggs (CV 36.0%). The survey coverage over time was less extensive in 2001 than in 1998. In 2001 the coverage was split in 5 periods (from 11 January to 21 May), one period less than in 1998 (from 17 January to 21 June), not allowing full coverage of the spawning season. The main spawning occurred from March to May, being the highest egg production in May (period 5). To adequately describe the spawning season it will be advisable in the future to survey the period 6 (June).

In order to avoid an underestimation of total egg production and taking into account the fact that some mackerel and horse mackerel eggs stage I appeared in the 9 of July ichthyoplankton sampling in front of Gijon coast (central of Cantabrian Sea), the end of the spawning was assumed to be the 17 July, the same than in 1998 and 1995.

Using combined Portuguese, English, Spanish, German and Dutch data it was estimated a fecundity of 1578 eggs/g, with a coefficient of variation of 19.4%. This fecundity is 27% higher than the value obtained in 1998. Also the mean fish weight was significantly lower and the fish weight range was narrower than in 1998.

The SSB estimated was 227,966 t with a CV of 40.9% (Table 7.4 – 1). This estimation was very close to the 2001 VPA estimation of 221,482 t, with an overestimation of only 3% (ICES, 2001c).

Figure 7.4 - 1 shows the comparison between AEPM and VPA SSB estimations from 1995 to 2001.

7.5 Southern horse mackerel maturity

No planning was carried out for the maturity sampling during the 2001 egg surveys (ICES, 2001a). As for mackerel there was not enough ship time available to undertake investigation on the maturity of horse mackerel since this would have required investigations in the areas of the different year classes of the juveniles.

Table 7.2-1. Southern horse mackerel mean daily stage I egg production in 2001 (x 10^{-12})					
Period	**Dates**			**Production and standard errors**	
	From	**To**	**Midpoint**	**Mackerel**	
				Production	**Se**
1	17 January	1 February	24-25 / 01	**0.02**	0.01
2	5 February	26 February	15-16 / 02	**0.70**	0.28
3	14 March	7 April	26 / 03	**1.37**	0.38
4	9 April	3 May	21 / 04	**1.22**	0.25
5	14 May	21 May	17-18 /05	**1.79**	1.35

Table 7.2-2 Southern spawning component of horse mackerel total stage I egg production estimates by time period for 2001 (x 10^{13})			
Dates	**Period**	**Nº of days**	**Annual stage I egg production x 10^{13}**
17 Jan.uary – 1 February	**1**	**16**	**0.03**
2 February – 4 February	*	3	0.10
5 February – 26 February	**2**	**22**	**1.54**
27 February – 13 March	*	15	1.53
14 March – 7 April	**3**	**25**	**3.43**
8 April	*	1	0.13
9 April – 3 May	**4**	**25**	**3.05**
4 May – 13 May	*	10	1.13
14 May –21 May	**5**	**8**	**1.43**
30 May – 17 July	*	57	4.76
	Total	**174**	**17.13**
	Se		**6.16**
	CV		**0.36**

Table 7.4.-1 compares egg production evaluation from triennial surveys of 1998 and 2001.

	Total annual egg production	Fecundity per gramme of fish weight	**Total spawning stock biomass**
1998	17.85 x 10^{13} eggs CV = 42.2%	1245 eggs / g CV = 26.8%	**301 084 tones** **CV = 50.0%**
2001	17.13 x 10^{13} eggs CV = 36.0%	1578 eggs / g CV = 19.4%	**227 966 tones** **CV = 40.9%**

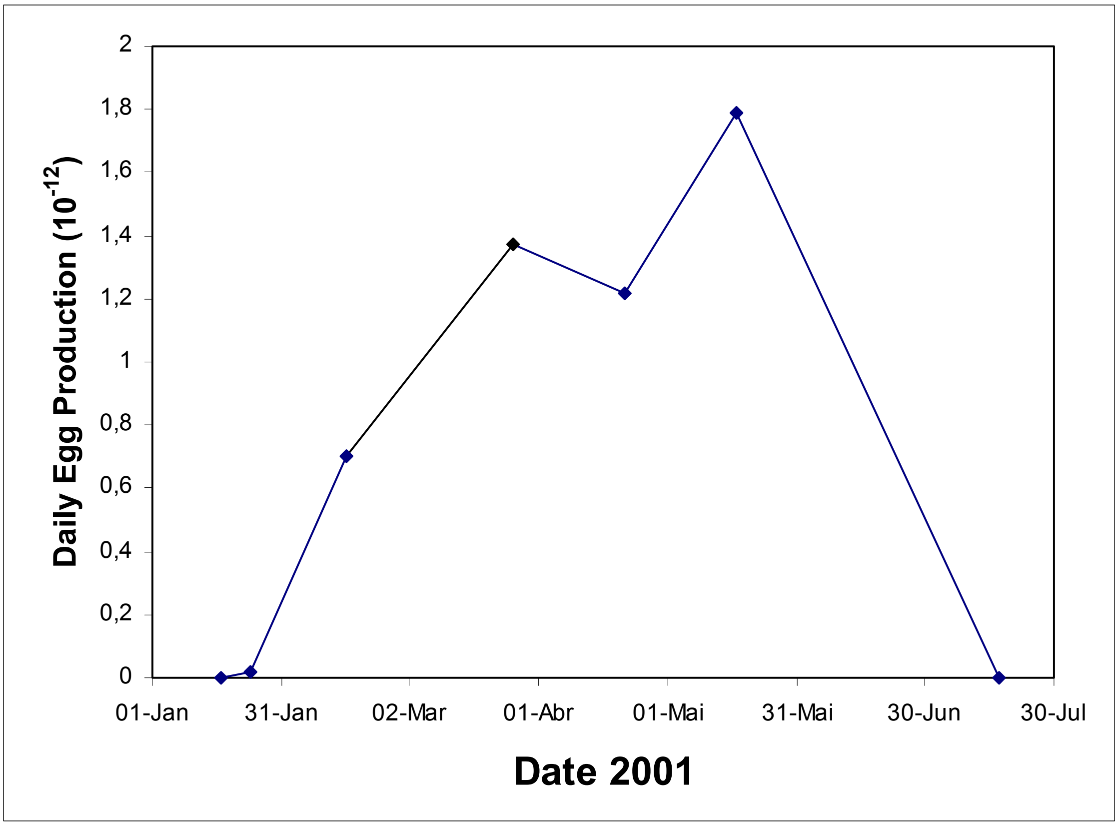


Figure 7.2 - 1. Horse mackerel daily egg survey production curve for the surveys in the southern area in 2001

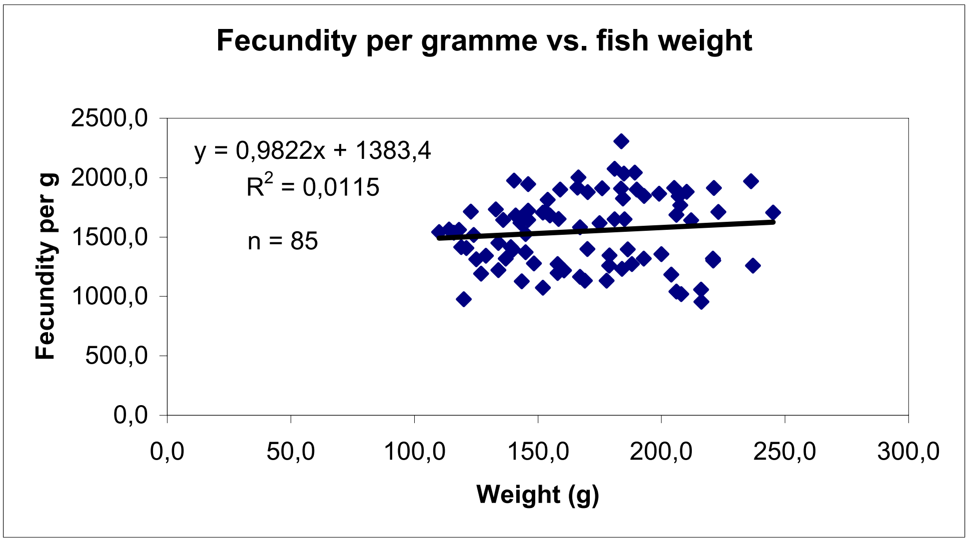


Figure 7.3-1 Eggs/g against horse mackerel weight in 2001. The fish collected in 2001 have a much lower weight compared to 1998.

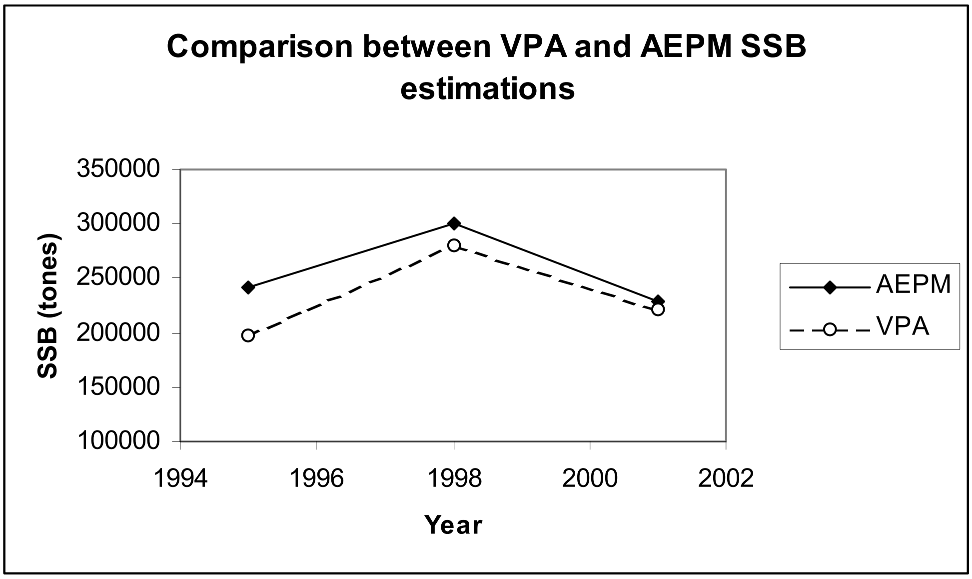


Figure 7.4 - 1 Comparison between AEPM and VPA SSB estimations from 1995 to 2001.

8 NEW APPROACHES TOWARDS TAEP AND UNCERTAINTY ESTIMATION

8.1 Introduction

As part of an EC-funded project, GBMAF (number QLRT-PL1999-01253), work is currently being undertaken on applying new methods for the estimation of TAEP and its associated uncertainty. One of the objectives of the project is to use these new methods, which involve combining geostatistics and Bayesian statistics, to test various sampling strategies with a view to optimising the egg density sampling campaigns. The project is co-ordinated by the Department of Environmental Science and Engineering, Imperial College, who are also responsible for the geostatistical and Bayesian research.

The first part of the work involved developing a geostatistical estimator. Its performance has been tested against the traditional method and the GAM method, which was present in the 1999 report, using a simulated dataset. The continuing development work on the GAM modelling and data simulator is being done by FRS.

This chapter presents a brief description of the data simulator, the three estimators and a comparison of the three estimators' performance. A brief description of the Bayesian methodology, and how it can be used to improve the estimation of bias and uncertainty, is also presented.

8.2 The data simulator

Proper testing of egg abundance estimators' performance needs to be based on a realistic simulator of egg abundance and distribution. This provides a framework whereby different estimators can be compared under different circumstances. The basis for the simulator to be used in this project is one based on a Generalized Additive Model [GAM (Hastie & Tibshirani, 1990)] developed by researchers at the University of St. Andrews (Augustin *et al*., 1998) as part of an EC-funded project (Study No. 97/0097). This involved fitting a GAM surface to mackerel data obtained in one of the ICES pelagic egg surveys using locally-weighted regression smoothers within the GAM regression framework (Beare & Reid, 2002).

One potential addition to the existing simulator being considered is the incorporation of certain biases. It is known that some of the parameters and assumptions in the traditional estimator, and thus in the sampling strategy, are significantly biased. Net bias is a function of depth, latitude and potentially other covariates such as time (Coombs *et al*., 1996). Combining the error structure present in the GAM simulator with a model of bias according to depth, latitude, and potentially date, may allow for more realistic scenarios in which estimators can be subsequently tested.

Simulated data were generated using the 1995 data and the "true" TAEP was calculated to be 1.715 x 1015 (Figure 8.2-1). The 2001 survey locations were then used to sample from the simulated spatio-temporal dataset and 1000 simulated datasets were created. Noise was added using the negative binomial distribution. A plot of the simulated datasets against week and Julian day revealed that there were spatio-temporal gaps in the sampling campaign that may have resulted in the occurrence of large egg abundances being unsampled. A geostatistical analysis confirmed that there was no spatio-temporal auto-correlation of the residuals, as required.

The simulated data were then used to construct estimates of TAEP using the Traditional, GAM and Geostatistical Estimators. The principal advantage of this approach is that the "true" TAEP is known, so the biases of the respective estimators can easily be ascertained. It should be noted that the main purpose of the current phase is to harmonise the respective software and identify the number of simulations and scenarios that can be realistically done given current time constraints and computing power. Once this has been done a large range of different "true" datasets and sampling designs can be simulated in order to investigate the performance of the four estimators.

8.3 The TAEP Estimators

The Traditional Estimator uses a highly stratified design in which ICES squares define spatial data. In the spatial dimension interpolation is done by using the average of adjacent squares, while in the time dimension, a piece-wise linear trend between sampling points is assumed. The main advantage of this type of method is that the properties of the estimator do not depend on the unknown true egg distribution, and it is the assumed randomness of the sampled points within squares which is the basis for drawing inferences about un-sampled parts of the survey. In the current context its main disadvantage is that it involves estimating many parameters, and the more parameters that are estimated, the higher the variance of the resulting egg production estimate.

Inferences from the GAM-based TAEP Estimator are model based. Raw egg density measurements are modelled as smooth functions of space and time and TAEP is then estimated by integrating under the fitted curve (Borchers *et al.*, 1997). GAMs provide a flexible framework for accommodating a wide range of trends and random fluctuation in egg distributions, although accurate estimation of egg production depends on models fitting well, which is difficult to judge when data are so sparse. Most aspects of the GAM selection process can be automated although there are subjective elements to the process. The critical steps involved in obtaining an adequate GAM for egg production are:

- deciding on the form (*i.e*. loess, spline), dimension (*i.e.* 1-D, multi-D), and degree (span, degrees of freedom) of smoothing in the GAM;
- deciding which covariates are to be used in the GAM;
- deciding on an appropriate error distribution.

The Geostatistical Estimator is based on an advanced interpolation procedure whereby weights are given to adjacent data points according to the spatial correlation structure in the data (*e.g*. Bez *et al*., 1996). Kriging (estimation) can be done over fixed-size 3-D blocks representing the spatial and temporal domains to give weekly estimates of egg production. A number of covariates can also be included to improve the accuracy of the estimates and reduce error. Kriging variance, or estimation error, is computed from the covariance structure along with each estimate and depends on the overall covariance of the data, the proximity of the data points to the block being estimated, and the number of data points used to make the estimation. For the modelling of mackerel egg density, a measure of the distance from the mean depth at which eggs are found (*e.g.* 200 m) was found to be a useful covariate.

8.4 Initial Results

Traditional TAEP Estimator

In the past the Traditional Estimator used an estimate of variance based on a rather ad hoc procedure that only uses the positive part of the data. This was considered inadequate for the current project and variances have instead been estimated using bootstrap re-sampling. The Traditional Estimator runs quickly in FORTRAN and 1000 simulations with 1000 bootstrap estimates of variance can be done in about 5 hours. Clearly there is considerable scope for exploring a wide range of scenarios using this estimator.

Figure 8.4-1 shows the TAEPs calculated by FRS for the first 100 simulations. The average for the first 100 Traditional TAEP estimates was 1.661 x 1015, giving a small negative bias of –3.13%.

Variances for the estimations were calculated as follows. Firstly, 1000 bootstrapped point estimates are obtained for each of the 100 simulation models. The standard deviation σ and mean m of these point estimates are then calculated. The coefficient of variation (CV) is then obtained in the form of a percentage as follows:

$$\mathrm{CV} = \sqrt{\frac{m^2}{\sigma^2}} \times 100 \tag{1}$$

To obtain the confidence limits the point estimates are ranked in ascending order and the 2.5% and 97.5% quantiles extracted. As expected, the Traditional Estimator has very high variances and average coefficients of variation for 1000 simulations were 22.1%. The 95% confidence intervals are wide enough to encompass the 'true' TAEP for 99 of the 100 simulations.

GAM TAEP Estimator

The GAM estimation software is written in S-plus, which is very slow, and it currently takes over a week to do 1000 GAM simulations with relevant 1000 bootstrapped variance estimates. The average for the first 100 TAEP estimates by GAM was 1.548 x 1015, indicating a significant bias of –9.72 %. The TAEPS calculated for the first 100 simulations are plotted in Figure 8.4-2.

The variances and confidence intervals for the GAM estimates are calculated in the same manner as for the Traditional Estimator described above. The GAM estimator had much less variance than that of the Traditional Estimator, with an average coefficient of variation of 9.4%. However, the 95% confidence intervals enclose the ‘true’ TAEP for only 41% of the first 100 simulations. When the bias is removed, this figure increases to 72%.

It should be noted that the GAM Estimator has calculated its estimates after the addition of structural zeroes. However, as pointed out by one of us (DJB), the simulated dataset has been created in such a way that the edges of the simulated data behave better at the edges than raw data. This means that the values tend to come down at the edges in space and time, which is not necessarily true for real data. Therefore, structural zeroes are not in fact necessary for the simulated data, and have caused a significant bias in the GAM estimates. In fact, when the structural zeroes are omitted from the dataset, the mean TAEP is around 1.8 x 1015, signifying a slight positive bias.

Geostatistical Estimator

Due to the degree of manual input involved in the geostatistical estimation procedure, it has only been possible to obtain estimates for the first 100 of the simulated datasets so far. It is hoped that it will be possible to automate at least part of the procedure and hence obtain a greater number of estimates for future simulation exercises.

Unfortunately, the lack of a clear spatio-temporal covariance structure observed in the variograms suggested that the simulated data does not fully capture the spatial and temporal autocorrelation of the egg densities found in nature.

The geostatistics are performed on log-transformed data, so that the kriged estimation must be back-transformed prior to the calculation of TAEP. However, the back-transformed estimates do not always fulfil the non-bias condition and so the arithmetic mean of the estimated values can differ noticeably from the expected mean (Journel and Huijbregts, 1978). It is thus necessary to apply a correction factor to the back-transformed estimates. This can be determined using a cross-validation procedure. For the first 100 datasets, the mean TAEP estimated using the geostatistical method was 1.808 x 1015, which represents a positive bias of 5.40%. The TAEPs are plotted in Fig. 8.4-3.

There is a large spread of TAEP estimates around the ‘true’ figure. The CV of the estimates is 9.13%. The 95% confidence intervals enclose the ‘true’ TAEP in 90 of the first 100 simulated cases. However, if the bias is removed from the estimates, this figure increases to 95. The mean value for the per-estimate CV is 8.91%.

8.5 Summary and Discussion

Table 8.5-1 displays basic statistics calculated for each of the three estimators prepared so far over the first 100 simulations.

The TAEP estimates obtained with the Traditional Estimator tend to be less biased than those of the GAM and Geostatistical methods. However, the estimates of the Geostatistical estimator are the least spread around the mean value (CV = 9.13%). It is also noted that the inclusion of structural zeroes in the GAM Estimator resulted in the significant negative bias of –9.72%. It is interesting to see that the Geostatistical Estimator, which also included structural zeroes, is positively biased. This is because, while the GAM Estimator uses all of the data points (of which around 25% are structural zeroes) for its estimations, the Geostatistical Estimator bases its estimates on only those values that lie within local neighbourhoods.

The values of CV calculated for the TAEP estimations vary between each Estimator. The CVs associated with the Traditional Estimator are large, so that the error bars cover a very wide range of values. These error bars ensured that the 95% confidence interval associated with each TAEP estimate encompassed the true value 99% of the time. The CVs calculated for the Geostatistical Estimator are similar to those calculated for the GAM Estimator, although the GAM Estimator was less successful at encompassing the ‘true’ TAEP with its error bars, even when the bias was removed. Although the bias-free Geostatistical confidence intervals enclosed the target value in 95 of the cases as required, it should be remembered that the proper treatment of kriging variance is still under investigation.

It is also interesting to consider the correlation between the TAEP estimates of the different Estimators. Table 8.5-2 shows the correlation matrix calculated between the TAEP estimations from each estimator, and the mean and maximum values of the first 100 simulated datasets. The geostatistical estimator was most highly correlated with the Traditional Estimator, with a correlation coefficient of 0.82. The GAM Estimator is similarly correlated with both the Traditional (0.62) and Geostatistical (0.67) methods. While the Geostatistical Estimator seems to have the highest dependence on the mean value of the dataset, the Traditional Estimator is most highly correlated with the maximum value. This could suggest that Geostatistical and GAM methods may be more robust with respect to extreme values in the dataset than the Traditional Method.

The preliminary results provided above suggest that in terms of the TAEP estimations, the Traditional Estimator is the most accurate. However, the geostatistical estimates were less variable, and so potentially more robust. Furthermore, the current simulated dataset, was found to be less suited towards the GAM and Geostatistical methods than the actual survey data for the following reasons:

There was no need for structural zeroes, although these were included in the GAM estimation procedure for the sake of comparison;

The spatio-temporal correlation structure found in nature was not well recreated in the simulated dataset, rendering it less suitable for geostatistical modelling.

This first set of simulated data were particularly well-behaved, with no large values at the edges. It will be interesting to find out if the Traditional method performs as well when such troublesome features are introduced. Over the following months work will be undertaken into the generation of further datasets with which to analyse different surveying scenarios as well as the performance of the individual Estimators. It should be noted that even if the Traditional Estimator continues to perform comparatively well, the GAM and geostatistical estimators remain particularly useful for studying the spatio-temporal distribution of the egg density.

8.6 Estimation of Triennial Mackerel TAEP

The Geostatistical Estimator has also been used to make estimates of TAEP for mackerel from the triennial egg survey data. Fig. 8.6-1 shows these estimates along with their 95% confidence intervals, and the estimates made by the Traditional and GAM methods have also been plotted for comparison. It should be noted that the treatment of variance is not yet finalised and so the error bars should be treated as relative, rather than absolute, measures of confidence. What is most encouraging about Fig. 8.6-1 is that the size of the confidence intervals has reduced considerably between the early and recent surveys, signifying the benefits of the increased survey effort.

8.7 Bayesian analysis

As described above, the Geostatistical Estimator generates measures of confidence based on the number and locations of the data used to make the estimates. The confidence intervals therefore do not take account of external sources of error. The GBMAF project aims to improve the calculation of confidence and reduce estimation bias by integrating Bayesian techniques with the geostatistical modelling procedure.

There are many potential sources of bias and uncertainty in the calculation of TAEP. These include measurement errors, model assumptions and model parameters. The aim will be to identify the major sources of error and assess their potential impact on TAEP and SSB estimation.

An initial analysis has been undertaken on the Bayesian implementation of the annual egg production method for western mackerel. This involved a review of all the parameters in the model, with a more detailed analysis undertaken when the bias or error was estimated to be larger than 5%. For example, one of the parameters analysed was the volume of water sampled by the Gulf III or Bongo nets. Rejected parameters included the influence of development inside the net during sampling and the variation in speed as the net traverses different depth sections.

Another source of error is the female fecundity, which has been traditionally incorporated in the estimate of SSB as a point estimate. Fecundity values for each year tend to follow a normal curve, so a probability distribution combining data from multiple years could be used as a prior distribution in the Bayesian estimator. Data from 1992, 1995 and 1998 can be summarised by a distribution of the form $\overline{} \sim N(0,0.17^2)$.

By using the results of the latest egg exchange and staging exercises, prior probability distributions can be constructed to account for error in the identification and staging of mackerel and horse mackerel eggs.

A detailed analysis has been done on the assumption that egg production is negligible in waters deeper than 200 m. According to the only dataset available on the depth distribution of mackerel eggs (Coombs *et al.*, 2001), significant numbers of eggs might be present at unsampled depths, particularly in the early months of the spawning season. The dataset was compiled between 1974 and 1991, and consists of 84 profiles with egg densities measured at 5 m depth intervals. The samples were collected mainly along the 200 m isobath between the southern and northern limits of the western component, although they are mostly concentrated between 49° and 51°.

It was found that egg abundance estimates in deep waters appear to be significantly biased due to the 200 m sampling limit (RMSRE = 38.3%). In a small number of profiles, up to 80% of the production was concentrated below 200 m. However, error was found to be negligible after the 1st of May.

A further analysis was carried out on the use of t_{20} (the temperature at 20 m depth) in the formula for converting egg density into daily egg production. Conditions along the water column, especially in the first half of the spawning season and in deep waters, might differ significantly. This could result in a significant bias. The analysis was undertaken using the afore-mentioned depth profile dataset and additional contemporaneous temperature data extracted from the Global Ocean Database. Monte Carlo simulations were carried out, whereby each egg profile was matched with a randomly-selected temperature profile from the same month and latitude (±5º). Egg production was calculated at discrete depth sections, using the corresponding temperatures, and combined to give an estimate of the daily egg production. The procedure was repeated 1000 times to generate a distribution of error values. The bias introduced by the use of t_{20} was found to be significant (RMSRE = 14.9%).

A model of bias according to Julian day and bottom depth was created, incorporating the two significant error sources discussed above. The mode consists of the following steps:

1. The traditional DEP estimate is calculated from survey data for each sample;

2. Samples are selected depending on bottom depth, and the error due to using t_{20} is calculated;

3. DEP estimates, corrected for t_{20} bias, are calculated;

4. Samples in waters deeper than 200 m and collected early than Julian day 120 are selected for correction of bias due to the 200 m sampling limit;

5. Bias values are randomly sampled from a uniform U(-0.8,0) distribution;

6. Affected samples are corrected again, using the t_{20}-corrected DEP estimates;

7. The ratio between the original (step 1) and corrected (step 6) estimates is calculated;

The process is repeated 1000 times to generate a distribution of values for the corrected daily egg production.

The bias model was applied to the 1998 ICES mackerel survey data to test its influence on the individual DEP estimates and final AEP estimate. The ratio of values calculated for the corrected and uncorrected 1998 AEP estimates suggested a bias of –6.1%. The DEP estimates are on average biased by +3%, although the distribution of values ranges between –25% and +450%. Despite this relatively low average value, bias in AEP could be more important if samples with a large number of eggs were to fall on the extremes of the distribution. For example, in 1998 the 2% of samples with higher egg production amounted to over 50% of the DEP. Large bias in a reduced number of samples would therefore greatly influence the final SSB estimate and increase the uncertainty in its accuracy. Furthermore, in years where there appears to be an early spawning peak, such as 1992, a greater proportion of the egg production occurs in deeper waters.

A Bayesian implementation of the AEPM can be achieved by calculating a constant of proportionality (q), a probability distribution whose mean and variance will modify the standard SSB estimate according to the bias and error encountered. For ICES mackerel, three sources of error are incorporated into q: the bias model described above; error due to the uncertainty in the fecundity estimate; and error due to discrepancies in the egg counting and staging process. Random numbers were generated from the three distributions and summed to provide a probability distribution for q. The expected value and variance of q were found to be 1.064 and 0.175^2 respectively.

A future objective of GBMAF is to use Bayesian methods to assess the sensitivity of the calculation of TAEP by the Geostatistical Estimator to the model parameters, such as range, sill and shape. The resulting Bayesian-Geostatistical estimator will then be incorporated into a stock management model.

Planning Meeting 2003 For The 2004 Survey

The Working Group decided to request that its next meeting, for the planning of the proposed 2003 Mackerel and Horse Mackerel Egg Survey, should be held from 01.- 05. April 2003 in Lisbon, Portugal. The Working Group decided to nominate Dr. David Reid (Aberdeen, UK) as its new Chair. The above request and nomination will be sent to the ICES

Living Resources Committee for consideration at the Annual Science Conference in Oct. 2002. The Terms of Reference for the Planning Meeting of WGMEGS in 2003 will be provided by the WG for the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy.

The following nations intend to participate in the 2004 survey: Ireland, Scotland, Netherlands, Germany England, Norway, Spain (Azti), Spain (IEO), Portugal.

Table 8.5-1 Summary statistics relating to the performance of the three estimators over the first 100 simulations.

	Trad. Estimator	GAM Estimator	Geo. Estimator
Mean TAEP	1.661×10^{15}	1.548×10^{15}	1.808×10^{15}
Max TAEP	2.077×10^{15}	2.031×10^{15}	2.185×10^{15}
Min TAEP	1.281×10^{15}	1.202×10^{15}	1.453×10^{15}
TAEP CV (spread of estimates)	9.84%	10.92%	9.13%
Bias	-3.13%	-9.72%	+5.40%
Mean Estimate CV	22.10%	9.42%	8.91%
% Enclosed by Error Bars	99%	41%	90%
% “” when bias removed	100%	72%	95%

Table 8.5-2 Correlation matrix between the three TAEP Estimators and the mean and maximum values of the first 100 simulated datasets.

	Trad	GAM	Geostat	Mean	Max
Trad	1	0.62	0.82	0.42	0.41
GAM	0.62	1	0.67	0.45	0.15
Geostat	0.82	0.67	1	0.55	0.17
Mean	0.42	0.45	0.55	1	0.00
Max	0.41	0.15	0.17	0.00	1

Figure 8.2-1 Simulated spatio-temporal egg production surface based on data collected during the 1995 survey.

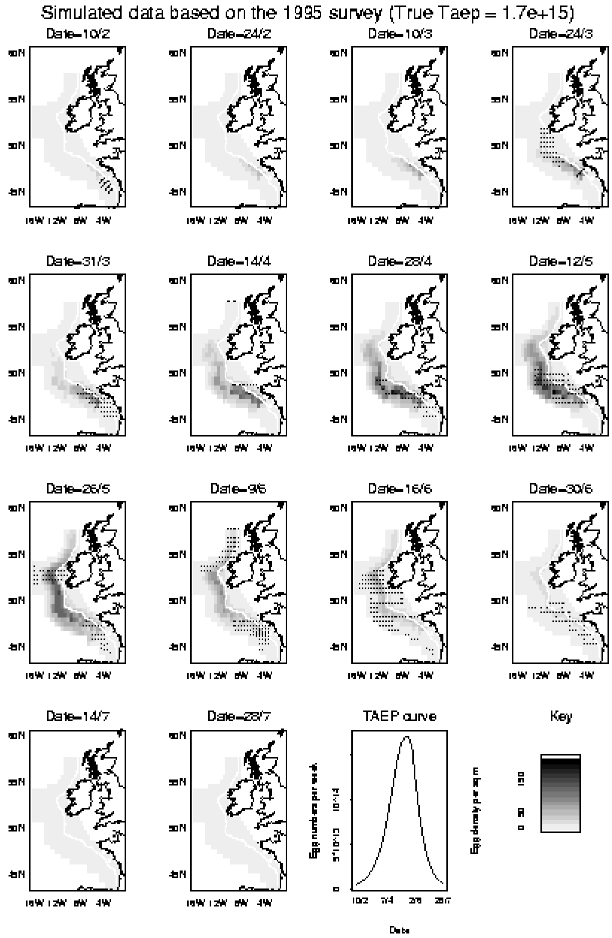


Figure 8.4-1 TAEPS calculated by the Traditional Estimator for the first 100 simulations.

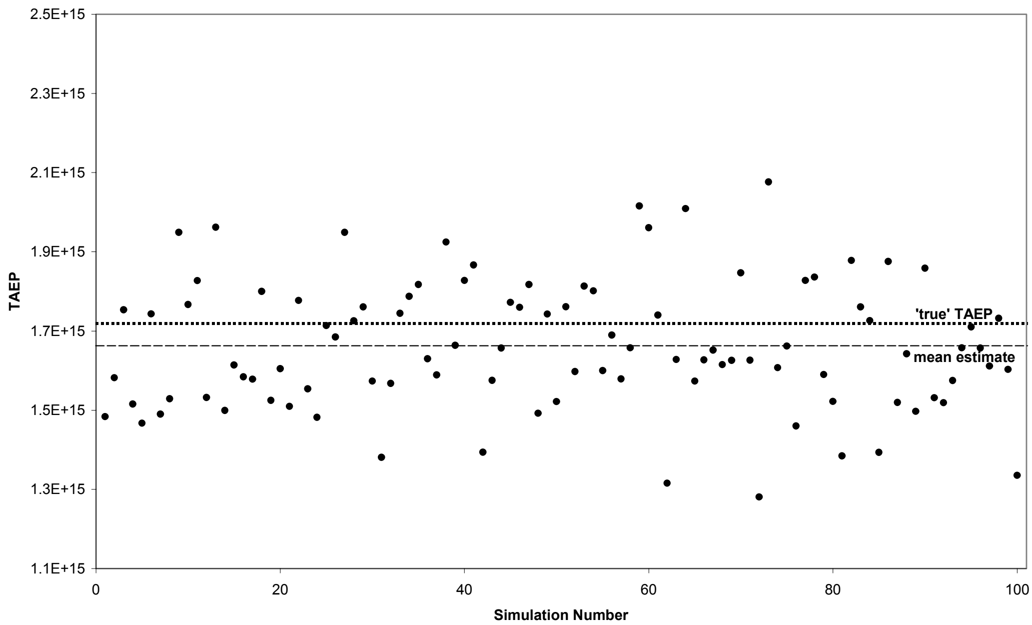


Figure 8.4-2 TAEPS calculated by the GAM Estimator for the first 100 simulations.

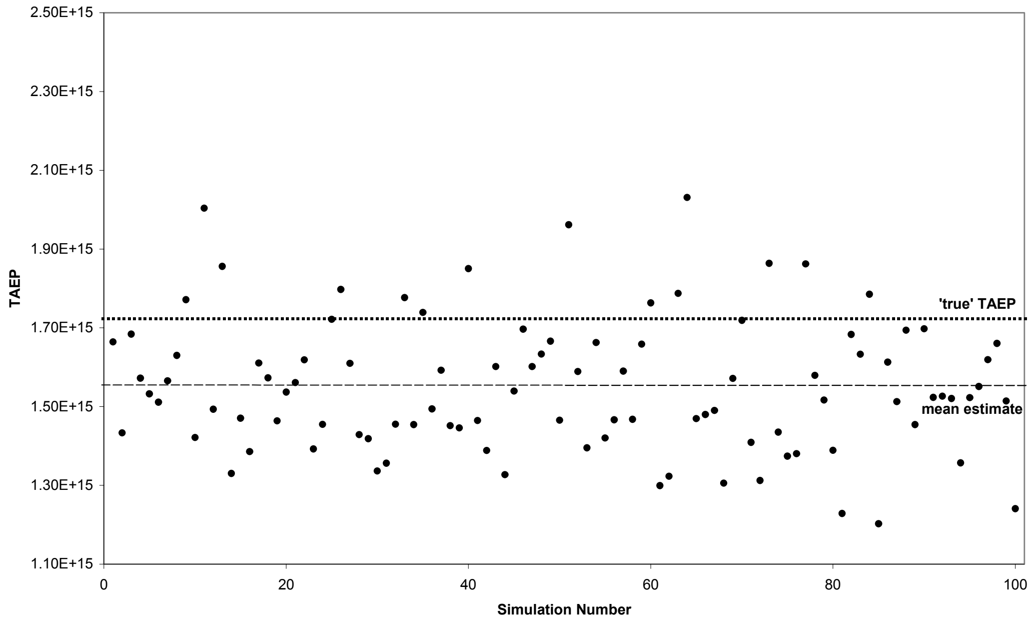


Figure 8.4-3 Plot of the first 100 Geostatistical estimates of TAEP from simulated dataset.

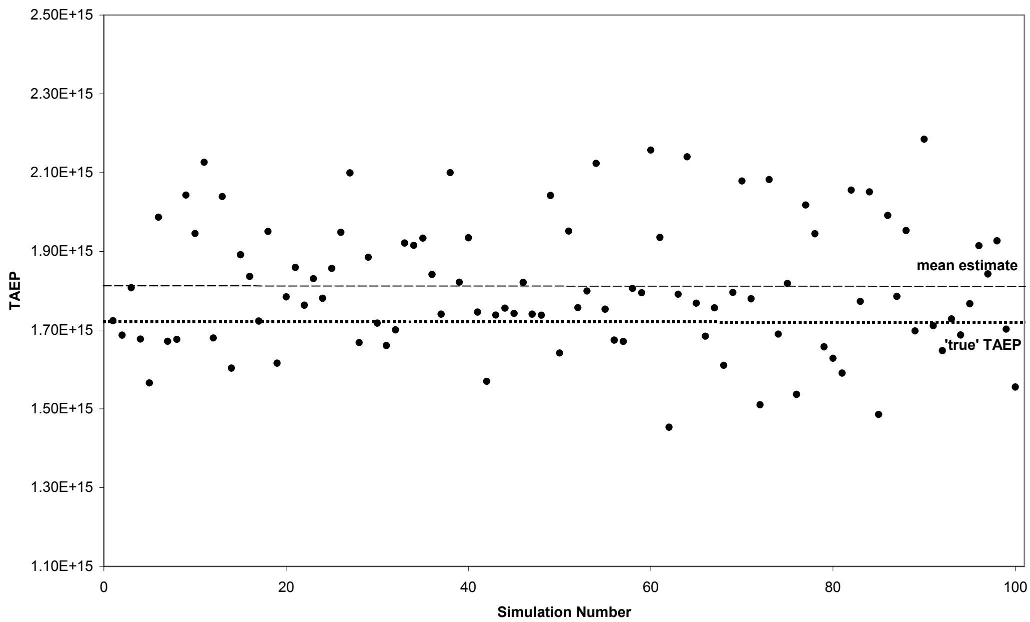
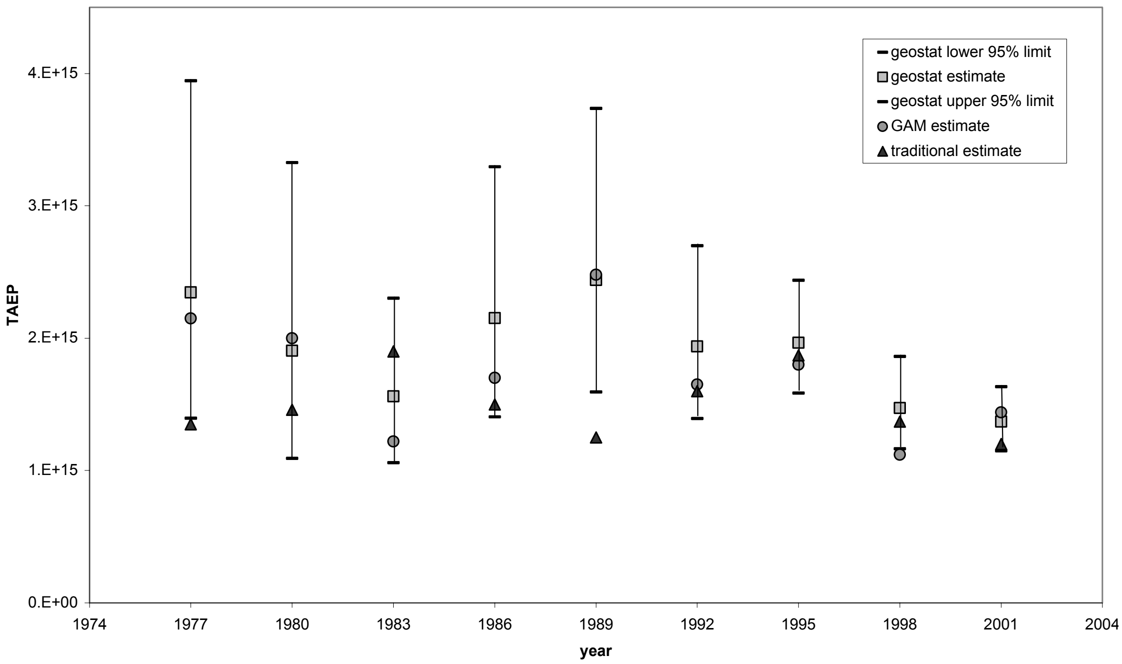


Figure 8.6-1 Geostatistical TAEP estimates and 95% confidence intervals, compared with Traditional and GAM estimates.



9 PLANNING MEETING 2003 FOR THE 2004 SURVEY

The Working Group decided to request that its next meeting, for the planning of the proposed 2003 Mackerel and Horse Mackerel Egg Survey, should be held from 01.- 05. April 2003 in Lisbon, Portugal. The Working Group decided to nominate Dr. David Reid (Aberdeen, UK) as its new Chairman. The above request and nomination will be sent to the ICES Living Resources Committee for consideration at the Annual Science Conference in Oct. 2002. The Terms of Reference for the Planning Meeting of WGMEGS in 2003 will be provided by the WG for the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy.

The following nations intend to participate in the 2004 survey: Ireland, Scotland, Netherlands, Germany England, Norway, Spain (Azti), Spain (IEO), Portugal.

10 DEFICIENCIES AND RECOMMENDATIONS

10.1 Deficiencies

The WG strongly felt that in the future it will be unable to produce a valid estimate from the 2004 survey if the questions about horse mackerel fecundity, as outline in Chapter 6.3, are not resolved. Resolving these questions implies however, considerable input into research on the reproductive biology of horse mackerel. The WG points out that this request is all but new. Substantial research on the reproductive biology of horse mackerel has been requested for many years.

The working group could not address TOR (e). The cruises of the 2001 survey were coordinated to maximise sampling of eggs of mackerel and horse mackerel and the ovaries of both species to determine the potential and realised fecundity. In order to sample for the determination of the maturity-at-age the cruises would have had to deviate from the designed sampling scheme to sample in the areas of the juveniles, which for both species are not in the same area as the sampling for plankton and fecundity took place. For this reason the WG did not have sufficient information available to present a maturity ogive and to comment on it.

10.2 Recommendations

- In the light of the considerable difference in the sorting, identification and staging of mackerel and horse mackerel eggs the WG strongly recommends that workshops be conducted on a regular basis between the triennial surveys. The workshops should in principle be organized as the workshop in Lowestoft in Dec. 2000. However, they should also include the sorting of the plankton sampling, the identification of the eggs and the staging.

- The WG recommends that the WGMEGS in 2003 reconsiders the appropriateness of the use of the “standard sampling area” in the course of the design of the survey strategy for 2004. The reason for this is the continuous changes and expansion of the standard sampling area.

- The group recommends further expansion of the investigation on the longitudinal effects on the fecundity for other scenarios and egg production surfaces.

- It is recommended that WGMEGS in 2003 investigates the use of the condition factor of mackerel as a proxy for atresia. If sufficient data are not available WGMEGS should plan accordingly for the 2004 survey for the collection of adequate data.

- The WG recommends that the expertise for the production and interpretation of histological slides be increased amongst the participants. This includes the development of a regular scheme for exchange of slides and CD images.

- The WG recommends to assess the bias introduced into the annual egg production method for horse mackerel spawning stock biomass by the assumption that this species is a determinate spawner.

- It was questioned by the WG whether the conversion factor of 1.05 between spawning and prespawning stock biomass for mackerel in the western area is still valid and appropriate. It is recommended by the WG to intersessionally investigate on the conversion factor and to suggest a new factor.

- Data on atresia prepared by Aberdeen University should be sent to the Western Mackerel co-ordinator if the analysis was carried out on slides prepared from ovary slices embedded in Technovit resin as per specified in ICES 2000.

- In future Triennial surveys, all fecundity samples should be divided equally amongst analysts in order to remove sources of variation attributable to country.

- Research is required to identify indices of individual reproductive output based on body condition (liver and somatic condition) to tune total egg production to produce estimates of SSB. Such research should focus on studies on the dynamics of egg production, size frequency of vitellogenic oocytes comprising the residual fecundity in relation to the seasonal changes in condition described above. The 2004 Triennial survey would provide the first opportunity to collect more information but a preliminary examination of existing condition data held by England, Netherlands and Norway should be presented to the next WGMHMES planning meeting.

- The precision of mackerel fecundity estimation based on gravimetric sampling of formaldehyde fixed ovaries should be assessed and involve analysis of samples held by England, Scotland, Norway and Spain.

- A random small subset of samples containing high numbers of eggs should be identified by 'The data co-ordinator for western mackerel and horse mackerel'. Each sample should be forwarded from the country undertaking the initial analysis for quality assurance (both initial sorting and species identification) to third party analysts working in other countries.

11 WORKING DOCUMENTS PRESENTED TO THE WORKING GROUP

Beare, D.J., Imrie, C., Mosqueira, I., Korre, A., McCallister, M., and Reid, D.G. - Comparing the performance of Traditional, Generalized Additive Model and Geostatistical Estimators of Mackerel Annual Egg Production along the Western Continental Shelf.

Costa, A.M., Pissarra, J.L., and Pérez, J.R., Southern horse mackerel spawning stock biomass estimate – 1998.

Costa, A.M., Pérez, J.R., Pissarra, J.L., Eltink, A., Hammer, C., & Milligan, S. - Southern Horse Mackerel Fecundity Estimate 2001. Working document for the WGMEGS – Working Group on Mackerel and Horse Mackerel Egg Surveys.

Franco, C., Lago de Lanzos, A., Farinha, A., Santos, M., Eltink, A., Hammer, C. & Milligan, S. – Mackerel and horse mackerel egg production in ICES Division VIIIc and IXa N in 2000.

Hammer, C. and Bez, N. - Results of the repetitive plankton sampling on “Walther Herwig III” during the 2001 Mackerel and Horse Mackerel Egg Survey.

Lago de Lanzos, A., Franco, C., Patrocinio, T. & Porteiro, C. – Mackerel and horse mackerel egg distribution in ICES Division VIIIb,c, and IXa N in 2001.

Mosqueira, I. – Bayesian implementation of the annual egg production method for Atlantic mackerel.

Pissarra, J., Farinha, A. & Costa, A.M. - Portuguese participation in the international "Mackerel and horse mackerel egg studies - 2001" project. WGMEGS meeting, Dublin 15-19 April 2002.

Witthames, P. & Greenwood, L. – Estimation of potential annual fecundity in the Mackerel Western Spawning component: 2001 Triennial Survey.

Witthames, P. & Greenwood, L. – Estimation of atresia and realised annual fecundity in the Mackerel Western Spawning component: 2001 Triennial Survey.

Witthames, P. & Greenwood, L. – Determination of potential annual fecundity: a better more environmentally friendly method using formaldehyde fixed tissue.

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APPENDIX

Data analysis

Annual egg production

The first step in the calculation is to estimate daily egg production per unit of surface area for each sampling square from the number of sampled eggs. Daily egg production, D_{psh}, for haul h, in sampling square s, during period p is estimated as

$$D_{psh} = \frac{N_{psh}}{V_{psh}} \cdot \frac{24}{H_{psh}} \cdot d_{psh}$$

where N_{psh} is the number of stage I eggs found in haul h of period p in rectangle s, d_{psh} is the sampling depth (m) reached in this haul, V_{psh} is the volume (l) of water filtered during this haul, and G_{phs} is the length in hours of stage I of egg development at the water temperature encountered in this haul. This is in turn calculated according to the equations developed by Lockwood (1977) for mackerel,

$$G = \exp(-1.61 \log(t_{20}) + 7.76)$$

and by Pipe & Walker (1987) for horse mackerel

$$G = \exp(-1.608 \log(t_{20}) + 7.713)$$

where t_{20} is the sea water temperature at 20m depth. An estimate of daily egg production in rectangle s in period p, D_{ps}, is calculated as the mean of all H_{ps} hauls in the rectangle, multiplied by its area, A_s (m^2)

$$D_{ps} = \frac{1}{H_{ps}} \sum\nolimits_{h=1}^{H_{ps}} D_{psh} \cdot A_s$$

Extrapolation based on arithmetic means is used in unsampled rectangles immediately adjacent to at least two sampled rectangles. Let u index unsampled rectangles, and let $\delta_{nsu}=1$ if sampled rectangle s in period p is adjacent (either immediately or diagonally) to rectangle u, and be 0 otherwise. Daily egg density in rectangle u is then estimated by

$$D_{pu} = A_u \left(\sum\nolimits_{s=1}^{S_p} \delta_{psu} \right)^{-1} \sum\nolimits_{s=1}^{S_p} \delta_{psu} D_{ps}$$

where S_p is the number of rectangles sampled in period p.

Daily egg production in each period is then estimated as a sum of the sampled and interpolated rectangles

$$D_p = \sum\nolimits_{s=1}^{S_p} A_s D_{ps} + \sum\nolimits_{u=1}^{U_p} A_u D_{pu}$$

where U_p is the number of unsampled rectangles adjacent to at least two sampled ones.

Finally, annual egg production, P is estimated by integration of the daily egg production histogram, from sum of the daily egg production estimates in each period p, multiplied by its length in days, λ, and the sum of the DEP estimates in each interpolated period i.

$$E = \frac{D_1}{2}(d_{1,1} - d_0) + \sum\nolimits_{p=1}^{P} \left[D_p(d_{p,2} - d_{p,1}) + \frac{D_p + D_{p+1}}{2}(d_{p+1,1} - d_{p,2}) \right]$$

where $d_{p,1}$ and $d_{p,2}$ are the start and end dates (in Julian days) of period p, and d_0 is the start date of the spawning season. For the last sampling period, when p=P, D_{p+1} will equal 0, and $d_{p+1,1}$=d_P, the end date of the spawning season.

The variance of the annual egg production estimate is the sum of all period variances,

$$Var(E) = \sum_{p=1}^{P} \lambda_p{}^2 Var(D_p)$$

which are in turn estimated as,

$$Var(D_p) = CV_p^2 \sum_s \left(A_s + \sum_u \frac{\delta_{us}}{\delta_u} A_u \right)^2 \frac{\bar{D}_s^2}{N_s}$$

where CV_p is an estimate of the global coefficient of variation for each period. It is calculated as

$$CV_p^2 = \left(\sum_{p=1}^{P} \sum_{s=1}^{S} H_{sp} - H_s \right)^{-1} \sum_{p=1}^{P} \sum_{s=1}^{S} \sum_{h=1}^{H} \left(\ln(D_{sh}) - \ln(\bar{D}_s) \right)^2$$

This is based on an estimate of the variance in egg densities for each sampling square (s) with two or more hauls (h) of non-zero values. In most periods the number of squares for which variance can be estimated is very low, so the estimates for all periods are pooled into a single CV.

Square area

The area of a sampling square, defined on a ½ degree by ½ degree grid, varies with latitude. Given the latitude ø of the center point of square s, area (in m^2) can easily be calculated as

$$A_s = \cos\left(\frac{\phi_s}{180} \cdot \pi \right) \cdot 32^2 \cdot 1853.2^2$$

Volume

The volume sampled during each net haul is measured by two flowmeters inside and outside of the net mouth. The inner flowmeter measures the volume of water flowing through the net, while the outside one is used to provide an indication of net clogging or flowmeter malfunction. To convert the number of revolutions recorded by the flowmeter into a volume measurement, net and flowmeters must be calibrated. This is achieved by recording the revolutions counted when towed over a known distance. Volume, V, in haul h can then be calculated as

$$V_h = \frac{r_h \omega}{c} e$$

where r_h is the number of revolutions recorded by the flowmeter, ω is the aperture of the net (m^2), c is the calibration value of the sampler ($revs/m$), and e is the efficiency factor.

Fecundity

Realised fecundity, F_r is estimated as

$$\bar{F}_r = \bar{F}_p - \left(\frac{\bar{\alpha}\psi}{l_a} l_s\right)$$

where F_p is the mean potential fecundity, α is the mean relative atresia, ψ is the prevalence of atresia (the percentage of females sampled with atretic eggs found), l_a is the length in days of the atresia stage, and l_s is the duration in days of a spawning event.

SSB

Finally, the spawning stock biomass *SSB* is estimated as

$$\mathrm{SSB} = \frac{P}{F_r S} \cdot C$$

where *P* is the annual egg production as estimated above, F_r is the realised fecundity per gram of female body weight, *S* is the sex ratio, expressed as the proportion of females in the population, and *C* is the correction factor that accounts for the difference in weight between the pre-spawning and the spawning stock.

The variance of the *SSB* estimate is based on both variance estimates, fecundity σ_{Fr} and annual egg production σ_P, escaled by all the remaining factors.

$$\sigma^2_{\mathrm{SSB}} = \left(\frac{P}{F_r}\right)^2 \left[\frac{\sigma^2_P}{P^2} + \frac{\sigma^2_{F_r}}{F^2_r}\right] C^2$$