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Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS)

11–15 April 2011

San Sebastian, Spain

ICES International Council for the Exploration of the Sea

CIEM Conseil International pour l'Exploration de la Mer

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Executive summary

The Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS) met in San Sebastian, Spain from 11–15 April, chaired by Jens Ulleweit (vTI-SF, Germany), to evaluate the results of the Mackerel and Horse Mackerel Egg Survey in 2010 and to plan the North Sea Mackerel Egg Survey in 2011.The main subject of the surveys is to relate the number of freshly spawned eggs found in the water to the number of females having produced these eggs. Knowing the fecundity of the females provides an estimate for the spawning-stock biomass. The group evaluated the survey results and assessed the size of the mackerel population in the Northeast Atlantic and the egg production of horse mackerel in the Western stock.

In 2010 for the first time the Faroe Islands and Iceland participated in the triennial survey, contributing survey effort and vessel resources in addition to Portugal, Spain, Scotland, Ireland, the Netherlands, Norway and Germany. Overall, temporal and spatial coverage was good. The participation of Iceland and the Faroe Islands, and the application of an alternating transect survey design made it possible to survey a much wider area than in previous years which was necessary due to the expansion of the spawning area of mackerel. The sampling for fecundity and atresia was completed successfully. As with previous years, several replicates from each fish were collected then distributed equitably between relevant institutes for analysis according to codes assigned by the coordinators.

The estimate of total mackerel egg production was $2.12*10^{15}$ which is an increase of $0.42*10^{15}$ (+19%) with respect to 2007 (rev. $1.70*10^{15}$).

The analyses of potential fecundity gave a value of 1140 eggs per gram female for mackerel for the western and southern components combined. This represents an increase of 42 eggs /g female when compared to 2007. The overall prevalence of atresia as a percentage of the population was 33% and the potential fecundity lost in the spawning season was 70 eggs /g. This reduced the potential fecundity by 6% giving a realized fecundity of 1070 eggs /g female.

Spawning-stock biomass (SSB) for the **NEA mackerel stock** was estimated using the realized fecundity estimate of 1070 oocytes/g female, a sex ratio of 1:1 and a raising factor of 1.08 (ICES, 1987) to convert spawning fish to total fish. This gave an estimate of spawning-stock biomass in 2010 of:

- 3.431 million tonnes for the western component (preliminary: 3.226; rev. 2007: 2.945).
- 0.858 million tonnes for the southern component (preliminary: 0.907; rev. 2007: 0.701).
- 4.289 million tonnes for the combined western and southern components (preliminary: 4.133; rev. 2007: 3.646).

The analyses showed that the **NEA mackerel stock** has increased by 643,000 t (+15%).

The **western horse mackerel stock** was found to have produced less eggs in 2010 ($1.093*10^{15}$; se = $0.347*10^{15}$; preliminary $1.005*10^{15}$) than in 2007 (rev. $1.640*10^{15}$). The decrease in total egg production was 33%.

As a consequence of the northwestern expansion in the spawning area the methods to calculate the egg production were reviewed and adapted. These adaptations made it necessary to revise the 2007 survey results and the 2010 preliminary results. Recent investigations in the spawning dynamics of mackerel show that the centre of gravity

for spawning mackerel is moving north and that the shift might be related to sea surface temperature.

The survey design was reviewed in order to allow covering a wider area without increasing ship time. The review showed that spreading the investigation area by sampling only every other transects may have implications on the results when temporal variability of spawning is high during a given period.

The analysis for the southern horse mackerel DEPM survey was not finalized prior the WGMEGS meeting. The southern horse mackerel assessment was moved from WGWIDE to WGANSA. Results on the egg production will be completed before WGANSA in June but due to the necessary development of reliable methods for the determination of the spawning fraction results will be only finalized in summer.

The mackerel egg survey in the North Sea was planned for May/June 2011 and it is expected that preliminary results will be reported by end of August 2011.

Furthermore, the working group proposed a workshop prior to the next WGMEGS meeting in order to review actual research results on the spawning strategies of mackerel and horse mackerel and their possible implications on the future survey design.

1 Introduction

1.1 Terms of Reference

The Working Group on Mackerel and Horse Mackerel Egg Surveys met in San Sebastian (Spain) from 11–15 April 2011 to:

a) Analyse and evaluate the results of the 2010 mackerel and horse mackerel egg surveys of the western and southern areas;

- i) calculate the total seasonal stage 1 egg production estimates for mackerel separately for the western and southern areas;
- ii) calculate the total seasonal stage 1 egg production estimates for the western horse mackerel stock (AEPM) and for southern stock (DEPM);
- iii) consider whether stage 1A and 1B could be amalgamated into a single stage both for the survey samples and future workshops.
- iv) analyse and evaluate the results of the mackerel and horse mackerel fecundity and mackerel atresia sampling in the western and southern areas;
- v) analyse and evaluate the results of the horse mackerel batch fecundity and spawning fraction in the southern stock;
- vi) evaluate the results of studies on horse mackerel fecundity determination and proxies on the basis of data collected during the 2010 surveys and in other relevant work;
- vii) provide estimates of the spawning-stock biomass of mackerel, using stage 1 egg production estimates and the estimates of fecundity and atresia, separately for the western and southern areas;
- viii) provide estimates of the spawning-stock biomass of horse mackerel, using production estimates and the estimates of batch fecundity and spawning frequency for southern stock
- ix) evaluate the quality and reliability of the 2010 survey in the light of the previous surveys and to evaluate the reliability of the preliminary estimates calculated in 2010 against the final estimates.

b) Re-analyse the survey data under a survey design where the transects are spread out to allow covering a wider area but without increasing ship time. The analysis should aim to estimate the impact of such changes on bias and precision for both mackerel and horse mackerel estimates.

c) Plan and coordinate the 2011 North Sea mackerel egg survey.

1.2 Participants

A list of participants can be found in Annex 1 of this report.

1.3 Adoption of the Agenda

The adoption of the agenda is shown in Annex 2 of this report.

1.4 Terms of Reference for 2012

The terms of reference for the next meeting, for a proposed workshop in 2012 and for WKFATHOM are shown in Annex 3 of this report.

2 General Aspects

2.1 Summary of WGMEGS Activities in 2009 and 2010

WGMEGS met in Hamburg 2009 to plan the ICES Triennial Mackerel and Horse Mackerel Egg Survey in 2010. The report was published as ICES CM 2009/LRC:09 and presented to the Steering Group on Ecosystem Surveys Science and Technology at the ASC in Berlin in September 2009.

Two workshops in October and December 2009 on mackerel and horse mackerel egg staging and identification and histology were held in IJmuiden and San Sebastian (ICES CM 2009/LRC:13 and below in Section 2.2).

The ICES Triennial Mackerel and Horse Mackerel Egg Survey was carried out during January – July 2010. Details on the survey are given in this report. The survey was coordinated by Finlay Burns. The detailed planning of the report was published as ICES CM 2010/SSGESST:02.

Since 2004 and subsequent to demands for up-to-date data for the assessment WGMEGS aims to provide an preliminary estimate of NEA mackerel biomass and western horse mackerel egg production in time for the assessment meetings within the same calendar year as the survey.

Following a request of ICES in 2010 it was agreed, that results have to be presented at the latest on 23 August, to WGWIDE, 4 days before the actual meeting of WGWIDE, and no revisions to the preliminary results were allowed after 27 August.

This required a complete work up of the data from the egg survey itself as well as the histological data on mackerel fecundity and atresia. Survey data (egg abundances and ancillary data plus preliminary fecundity and atresia estimates) were collated at the beginning of August 2010. This was the third time that the preliminary survey estimate was available the same year as the survey. A report with the preliminary results of the survey was distributed to WGWIDE members on time (Ulleweit *et al.*, 2010). However, revisions had to be made on this report regarding the fecundity estimates (Thorsen, 2010).

2.2 Workshop on Mackerel and Horse Mackerel Egg Staging and Identification

2.2.1 Scientific justification

Identification of eggs to species and the staging of those eggs remain two of the key areas in the execution of the mackerel and horse mackerel egg surveys. As this process is carried out by a number of different analysts in many different countries, and then the data combined, it is vital that the process be standardized. WGWIDE and WGMEGS feel strongly that this is best done through the mechanizm of sample exchange programmes and regular workshops to compare results. In the context of the triennial egg surveys it would seem appropriate to hold a workshop prior to every survey to standardize approaches and methodologies in the run-up to the surveys. This will have the advantage of training new participants as well as harmonizing the approach of experienced analysts. An egg-staging workshop was held for the first time in 2000 and was very successful in achieving some of these aims. The scope of these workshops were extended in 2003 (prior to the 2004 survey) to address all aspects plankton analysis, including removal of eggs from the samples, identification as well as allocation to development stage. The 2003 workshop (ICES, 2004) was also tasked to produce a standard manual of procedures, descriptions and photographs to assist in the plankton sample handling and identification process. The latest work-

shops held in 2006 and 2009, (ICES, 2006, 2009) provided further enhanced descriptions and utilized some 'validated' eggs of known species.

2.2.2 Results and recommendations from WKMHMES 2009

Egg sorting:

The 'spray technique' was, once again, evaluated at WKMHMES in 2009. The results were consistent, showing that the technique was very effective at removing eggs from the rest of the plankton samples. The 'spray technique' is now used as the primary method for removing eggs from large plankton samples during the 2010 triennial surveys.

Egg identification and staging:

The majority of the time at the Workshop was spent identifying and staging mackerel, horse mackerel and similar eggs. The results promoted discussion and highlighted specific problem areas. These discussions led to the further development of standard protocols, and enhancements to the species and stage descriptions. The results were very re-assuring and similar to those obtained at the 2006 workshop. There was an overestimate of stage 1 mackerel eggs (stages 1a and 1b combined) during the first round of analysis (15%) but this reduced (5%) during the second round. The results for stage 1 horse mackerel eggs were similar to underestimates of –2% and overestimate of 6% respectively. This is particularly re-assuring as it is this stage on which the egg production estimates are based.

Fecundity and atresia:

The fecundity and atresia calibration proved beneficial to all participants. After discussion the manual has been improved and there was agreement on identification of vitellogenic and early alpha-atretic oocytes.

Recommendations and terms of reference:

The Workshop on Mackerel and Horse mackerel Egg staging and Identification [WKMHMES]) will be renamed Workshop on Egg staging, Fecundity and Atresia in Horse mackerel and Mackerel [WKFATHOM]. The egg identification and staging workshop will take place at IMARES - IJmuiden, Netherlands and the fecundity workshop will take place at Vigo, Spain. Both workshops will take place in autumn 2012, with the following terms of reference:

- carry out comparative plankton sorting trials on typical survey samples. This should follow the pattern of trial – analysis – retrial – identification of problem areas;
- carry out a comparative egg staging trial for mackerel and horse mackerel eggs following the pattern used in the 2009 egg staging workshop;
- update a set of standard pictures and descriptions for species identification and egg staging;
- provide a review of any available documentation on identifying eggs to species and define standard protocols;
- carry out inter-calibration work on fecundity determination and harmonize the analysis and interpretation of fecundity samples;

2.3 ICES Requests for WGMEGS Input to the Marine Strategy Framework Directive Steering Group (MSFDSG) and the Strategic Initiative on Area Based Science and Management (SIASM) as well as for WKCATDAT

In March 2011, ICES requested that all Expert Groups (EG's) should provide input to both MSFDSG and SIASM to meet the challenges of implementing an ecosystem approach. The MSFDSG requested that the following Terms of Reference (TOR) were added to all Expert Groups.

Identify elements of the EGs work that may help determine status for the 11 descriptors set out in the Commission Decision.

Provide views on what good environmental status (GES) might be for those descriptors, including methods that could be used to determine status.

In addition, the following TORs were received from SIASM.

Take note of and comment on the Report of the Workshop on the Science for area-based management Coastal and Marine Spatial Planning in Practice (WKCMSP).

Provide information that could be used in setting pressure indicators that would compliment biodiversity indicators currently being developed by the Strategic Initiative on Biodiversity Advice and Science (SIBAS). Particular consideration should be given to assessing the impacts of very large renewable energy plans with a view to identifying/predicting potentially catastrophic outcomes.

Identify spatially resolved data, for e.g. spawning grounds, fishery activity, habitats, etc.

In order to address some of these TORs, the Workshop on Cataloguing Data Requirements from Surveys for the EAFM (WKCATDAT, ICES CM 2010/SSGESST:09), drafted a table which was subsequently utilized by the International Bottom Trawl Surveys Working Group (IBTSWG).

WGMEGS have taken a similar approach, to give some consistency to the responses provided by the various Expert Groups. Table 2.3 identifies elements which could be incorporated into the work of WGMEGS, which might contribute to a broader 'ecosystem approach'. However, it must be noted that these additional tasks are likely to impact the existing surveys, unless sufficient additional resources (staff, ship time, equipment) become available. Even if these resources are available, it must be remembered that these plankton and trawl surveys already involve the vessels working 24 hours per day, and that the synoptic picture resulting from these surveys will be disrupted if other time demanding tasks are undertaken.

In view of these evaluation WGMEGS recommends to the Working Group for Integrating Surveys for the ecosystem approach (WGISUR) that they need to be aware of the following concerns:

Additional tasks undertaken to address the 'ecosystem approach' are likely to impact the existing surveys, unless sufficient additional resources (staff, ship time, equipment) become available. In fact it is unlikely that most additional tasks will be conducted by WGMEGS participants without these additional resources.

Any additional tasks that require the survey vessels to stop or slow down or divert course from the original survey plan will seriously impact the quasi-synoptic nature of these surveys.

It was not possible for the participants of WGMEGS to provide views on what good environmental status (GES) might be for the descriptors in the table. WGMEGS felt that they did not have the required level of expertise within the group to provide an opinion on such a wide range of descriptors and what GES might be for each.

WGMEGS anticipates that it is unlikely that large offshore renewable energy plans will significantly impact the vast oceanic spawning areas of either mackerel or horse mackerel. WGMEGS produces spatially (and temporally) resolved data for both mackerel and horse mackerel spawning and has done this every three years since 1977. Some environmental parameters such as sea surface temperature and salinity have often been obtained concurrently. In more recent years full CTD profiles are obtained at most sampling positions. On occasion various other parameters such as Chlorophyll 'a' fluorescence, turbidity, light attenuation and nutrient concentrations are also measured, which could help to describe the spawning habitat favoured by these species.

Table 2.3. WKCATDAT Data Catalogue.

	MSFD descriptor related to													Preparation	During survey				After survey				
Task	1	2	3	4	5	6	7	8	9	10	11	Fisheries survey for data collection	Additional equipment	Additional skills	Extra personnel	Extra shiptime	Facilities	Additional personnel	Facilities	Lab facilities	Sample storage	Data storage	Analytical instruments	Analysis software
Fish and shellfish (survey specific)																								
												Triennial mackerel and horse mackerel												
Organism collection (e.g. for contaminants, fatty acids analysis etc.)	x	x	x	x				x	x			egg survey utilising:	no	no	dependent on the amount of sampl	no	sample storage	not for collection	not for collection					
Stomach sampling	x		x	x								Plankton samplers & trawls	no	no	yes	dependent on the amount of	preparation and preservation facilities, sampl	yes if analysis not conduc	yes if analysis not conducte	x	x	x	dependent on analysis	
Additional biological data (e.g. isotopes, liver/gonad weight, otoliths, scales, fin-rays, length-weight	x	x	x	x				x				Limited acoustic facilities	no	dependent on sampling type addition	dependent on the amount of sampl	no	no	yes if analysis not conduc	yes if analysis not conducte	x	x	x	dependent on analysis	on analysis (e.g. otoliths)
Disease/parasite registration	x	x	x		x			x	x			Occassional use of hand-lines.	no	knowledge of fish diseases /parasites	dependent on the amount of sampl	dependent on the amount of	dependent on data request: preservation facil	yes if analysis not conduc	yes if analysis not conducte	x	x	x		
Genetic information	x		x									Use of station specific CTDs	Sampling equipment, ethanol	Training required to prevent cross-co	dependent on the amount of sampl	no	dependent on data request: preservation facil	yes	yes	x	x	x	x	x
Lipid content				x								"	Fat meter; Calibration series for the s	skills for operation of the device	dependent on the amount of sampl	no	dependent on data request: preservation facil	yes	yes if analysis not conducte	x	x	x	x	x
Sonar observations pelagic fish			x									"	scientific sonar	skills for operation of the device	dependent on variables being collec	no	data storage, synchronisation unit	yes if analysis not conduc	no			x		x
Tagging			x									"	Tags and fish handling	tagging skills	dependent on the amount of sampl	dependent on the amount of	fish handling facilities	no	no			x		
Bioactive materials in marine species (e.g. for medical purposes)												"	no	no	dependent on the amount of sampl	dependent on the amount of	preservation facilities, sample storage	yes if analysis not conduc	yes if analysis not conducte	x	x	x	x	
Echosounder observations pelagic fish	x	x	x									"	no	no	dependent on variables being collec	yes (equipment calibration)	data storage, synchronisation unit	yes if analysis not conduc	no			x		x
Other sampling of fish/shellfish not taken in main gear	x	x		x								"	Alternative appropriate gear	no	dependent on variables being collec	yes	preservation facilities, sample storage	yes if analysis not conduc	no			x		
Physical and chemical oceanography (e.g. CTD, chlorophyll, oxygen, nutrients, turbidity, etc.)																								
Continuous underway oceanographic measurements [from the ship]							x					"	dependent on variables being collec	skills for operation of the device	dependent on variables being collec	no	pumped clean seawater supply	yes	no			x		
Station oceanographic measurements							x					"	dependent on variables being collec	skills for operation of the device	dependent on variables being collec	yes (deploy/recover)	dependent on the device used	dependent on variables be	no			x		
Continuous underway oceanographic measurements [autonomous devices]							x					"	dependent on variables being collec	skills for operation of the device	no	yes (deploy/recover)	no	dependent on variables be	no			x		
Water movement							x					"	ADCP	skills for operation and analysis	no	no	no	yes if analysis not conduc	no			x		x
Station nutrient samples					x							"	Water sampler	skills for operation of the device	dependent on variables being collec	yes (deploy/recover)	no	yes	yes	x	x	x	x	x
												"												
Biological oceanography																								
Station microbiological samples	x	x	x	x				x				"	Water sampler	skills for operation of the device	yes	yes (deploy/recover)	lab facilities, preservation facilities	yes if analysis not conduc	yes	x	x	x	x	
Station phytoplankton samples	x	x	x	x	x			x				"	Water sampler	skills for operation of the device	dependent on variables being collec	yes (deploy/recover)	preservation & storage facilities	yes	yes	x	x	x	x	
Continuous phytoplankton samples	x	x	x	x	x			x				"	Fluorometer	skills for operation of the device	dependent on variables being collec	no	preservation & storage facilities	dependent on analysis re	yes if analysis not conducte	x	x	x	x	
Station zooplankton samples [towed]	x	x	x	x				x				"	Towed samplers	skills for operation of the device	dependent on variables being collec	depends on routine survey g	preservation & storage facilities	yes	yes	x	x	x	x	
Station zooplankton samples [dipped]	x	x	x	x				x				"	Dipped samplers	skills for operation of the device	dependent on variables being collec	depends on routine survey g	preservation & storage facilities	yes	yes	x	x	x	x	
Continuous zooplankton samples	x	x	x	x				x				"	CPR	skills for operation of the device	dependent on variables being collec	no	preservation & storage facilities	yes	yes	x	x	x	x	
Gelatinous zooplankton samples	x	x	x	x								"	Various plankton nets towed / haule	skills for operation of the device		depends on routine survey g	preservation & storage facilities	yes	yes if analysis not conducte	x	x	x	x	
Invertebrates																								
Infauna	x	x		x		x						"	Grab/corer, sieves	sorting and identification skills	yes	yes	preservation & storage facilities	yes	yes if analysis not conducte	x	x	x	x	
Epifauna [towed]	x	x		x		x						"	Beam trawl/dredge/sledge/bottom t	sorting and identification skills	yes	yes	preservation & storage facilities	yes	yes if analysis not conducte	x	x	x	x	
Epifauna [video]	x	x		x		x						"	Video	skills for operation of the device	yes	yes	no	yes	yes if analysis not conducted at sea			x		x
Pelagic	x	x		x								"	Trawls, seines and plankton nets	sorting and identification skills	dependent on the amount of sampl	depends on organisms being	preservation & storage facilities	yes	yes if analysis not conducte	x	x	x	x	
Megafauna																								
ESAS sampling (birds, sea mammals)	x	x		x								"	Binoculars	identification, knowledge of methods	yes (expert)	no	observation platform	no	no					
Towed hydrophones	x	x		x								"	Towed hydrophone	skills for operation of the device	yes (expert)	yes (deploy/recover)	data storage	yes if analysis not conduc	yes if analysis not conducted at sea			x		x
												"												
Habitat description																								
Camera [towed/dropped]	x	x				x						"	Towed/dropped camera	skills for operation of the device	yes	yes	data storage, synchronisation unit	yes	yes if analysis not conducted at sea			x		x
Side-scan sonar	x					x						"	Side-scan sonar	skills for operation of the device	yes (expert)	yes (deploy/recover)	data storage, synchronisation unit	yes if analysis not conduc	yes if analysis not conducted at sea			x		x
Multi beam echosounder	x					x						"	Multi beam echosounder	skills for operation of the device	yes (expert)	no	data storage, tide gauge (costs), synchronisati	yes if analysis not conduc	yes if analysis not conducted at sea			x		x
Ground truthing	x					x						"	Grab/corer, sieve	Dependant on the level of analysis re	yes (expert)	yes	Storage facilities depending on analysis requir	yes if analysis not conduc	yes if analysis not conducte	x	x	x	x	
												"												
Pollution																								
Floating litter										x		"	no	no	no if taken with main gear	depends on gear selected an	preservation & storage facilities	yes if analysis not conduc	yes if analysis not conducte	x	x	x	x	
Sinking litter										x		"	no	no	no	depends on gear selected an	preservation & storage facilities	yes if analysis not conduc	yes if analysis not conducte	x	x	x	x	
Pollution in the water column								x	x	x		"	dependent on variables being collec	skills for operation of the device	dependent on variables being collec	yes (deploy/recover)	dependent on variables being collected	yes if analysis not conduc	yes if analysis not conducte	x	x	x	x	x
Pollution in the sediment								x	x	x		"	Grab/corer	skills for operation of the device	dependent on variables being collec	yes (deploy/recover)	dependent on variables being collected	yes if analysis not conduc	yes if analysis not conducte	x	x	x	x	x
Pollution in organisms								x	x	x		"	Selected gear appropriate for sampli	skills for operation of the device	dependent on variables being collec	depends on organisms being	dependent on variables being collected	yes if analysis not conduc	yes if analysis not conducte	x	x	x	x	x
												"												
Environmental conditions																								
Weather conditions							x					"	no	no	no	no	no	no	no			x		
Sea state							x					"	no	no	no	no	no	no	no			x		

(can also be found as Excel table on the WKCATDAT SharePoint http://groupnet.ices.dk/wkcatdat2010/default.aspx)

3 Western and Southern Egg Surveys in 2010

3.1 Countries and Ships Participating

As for previous surveys, the 2010 mackerel and horse mackerel egg survey was designed to cover the whole spawning area of the two species within 6 sampling periods of differing geographical coverage (ICES, 2009). The deployment of research vessel effort in 2010 in the combined western and southern mackerel and horse mackerel sampling area is given in Table 3.1. As a consequence of the long spawning period and the large survey area involved, the mackerel and horse mackerel egg surveys have always relied on broad international participation. In 2010 a total of 16 individual cruises were carried out with a total of 331 survey days, with the contribution of Spain (IEO: 48 days at sea, AZTI: 41 days), Scotland (58 days), Ireland (44 days), Portugal (35 days), Germany (36 days), the Netherlands (36 days), and Norway (25 days) and for the first time with the contribution of the Faroe Islands (15 days) and Iceland (14 days).

Table 3.1. Participating countries, vessels, areas assigned, dates and sampling periods of the 2010 surveys.

Country	Vessel	Areas	Dates	Period
Portugal	Noruega	Cadiz, Portugal & W Galicia	25 Jan – 28 Feb	1
Spain (IEO)	Cornide de Saavedra	Galicia, Cantabrian Sea & Biscay	15 Mar – 05 Apr	2
			16 Apr – 9 May	3
Germany	Walther Herwig III	West Ireland & W Scotland	24 Mar – 12 Apr	2
		Celtic Sea & Biscay	13 – 30 Apr	3
Netherlands	Tridens	Celtic Sea & Biscay	3 – 20 May	4
		Celtic Sea & Biscay	1 – 19 June	5
Spain (AZTI)	Investigador	Biscay	23 Mar – 14 April	2
		Biscay & Cantabrian Sea	5 May – 26 May	4
Norway	Johan Hjort	West Ireland & West of Scotland	11 May – 5 June	4
		West of Scotland		5
Ireland	Celtic Explorer Celtic Voyager	Celtic Sea	5 – 29 March	2
		Celtic Sea, West Ireland & West of Scotland	8 – 28 July	6
Scotland	Scotia	West Ireland & West of Scotland	20 April – 11 May (22 Days)	3
	Corystes	NW Ireland & West of Scotland	19 May – 1 June	4
	Unity	West of Ireland & West of Scotland	14 June – 5 July	5
Faroe Islands	Magnus Heinason	Faroes & Shetland	19 May – 2 June	4
Iceland	Arni Fridriksson	Faroes & Shetland	9 – 22 June	5

3.2 Sampling Areas and Sampling Effort in the Western and Southern Areas

In keeping with 2007, the survey was split into six sampling periods. A significant change to 2007 was the inclusion of the Faroese and Icelandic survey in May and June which expanded the geographic range of the survey in the North and West during periods 4 and 5. In terms of survey days this represents an overall increase for 2010 compared to 2007, however the significant expansion of the geographical survey area to the northwest during periods 4 and 5 meant that there was no net increase in survey effort for the standard areas.

The first period (January and February) was covered by a single extended DEPM survey in ICES area IXa only, with fuller coverage starting in period 2 (March). Regarding period and design this was almost identical with the 2007 survey in this area. No sampling took place in area IXa thereafter. Sampling of the western area commenced in period 2 and included the Cantabrian Sea and waters off Galicia. Sampling off Galicia ceased after period 3 and from period 5 onwards, only the western area north of the Cantabrian Sea was covered. Although some spawning was expected in the Cantabrian Sea during period 5, (as it has been surveyed at this time in earlier years), as in 2007, no vessels were available to survey it. In periods 5 and 6 the surveys were designed to identify a southern boundary of spawning and to survey all areas north of this boundary.

Maximum deployment of effort in the western area was during the second, third and fourth sampling periods. These periods coincided with the expected peak spawning of both mackerel and horse mackerel in the area. Due to the expansion of the spawning area which was observed in 2007 the emphasis was even more focused on full area coverage and finding the edges of the egg distribution. Cruise leaders had been asked to cover their entire assigned area using alternate transects and then use any remaining time to fill in the missed transects.

The planned and realized survey coverage by period is described in detail below:

Period 1 – In this period only the southern area between Cadiz and West of Galicia was surveyed by a single survey done by Portugal. This DEPM survey is mainly targeting the southern horse mackerel stock and designed for this purpose but providing mackerel egg samples as well. Due to bad weather the survey lost 7 days at sea and 2 planned transects were not completed. Despite this a good spatial coverage was achieved with 414 stations being sampled. There were no interpolated samples. See Figure 3.2.1 for numbers of completed samples/ sampling rectangle.

Period 2 - Period 2 marks the commencement of the western area surveys. Sampling was undertaken by Ireland (Celtic Sea), Spain (IEO: Galicia and Cantabrian Sea and AZTI: Bay of Biscay) and Germany (Northwest Ireland and West of Scotland).

Significant disruption due to a combination of extremely bad weather coupled with access restrictions in the Northern Biscay area due to French naval exercises hampered survey progress during this period. This resulted in missed transects at 45°15N, 48°15N, 49°15N and 56°45N. Otherwise survey coverage was good with 367 stations sampled and 67 interpolations. There were 58 replicate samples which were predominantly completed in the Cantabrian Sea. See Figure 3.2.2 for numbers of completed samples/ sampling rectangle.

Period 3 – In period 3 the German vessel was operating in the Celtic Sea. Northwest Ireland and the West of Scotland were covered by Scotland, the Bay of Biscay, the Cantabrian Sea and Galicia by Spain (IEO).

To the west of Scotland mackerel spawning was observed as far as 20°W and still the boundary could not be defined. This extension of the spawning area west approximately doubled the survey area which resulted in only an alternate transect survey being completed. In addition the Scottish survey lost 2 days of survey time due to unforeseen circumstances requiring an exchange of crewman on Scotia. 447 stations were sampled and there were 122 interpolations. There were 62 replicate samples which once again were completed predominantly in the Cantabrian Sea. See Figure 3.2.3 for numbers of completed samples/ sampling rectangle.

Period 4 – This period was covered by four dedicated mackerel egg surveys. The Dutch vessel was operating in the Celtic Sea and Biscay. West of Scotland and Irish waters were covered by the Scottish and the Norwegian vessels with also the Faroese vessel extending the survey boundary north of this. In addition AZTI was carrying out a targeted DEPM survey for anchovy in the Biscay and Cantabrian Sea and although it provides mackerel and horse mackerel egg samples as well, the design of this survey is constrained in that purpose. AZTI extended the survey 1º westerly to secure the horse mackerel spawning boundary in the Cantabrian Sea. Despite this endeavour the objective was not completely successful.

The extension west of the mackerel spawning area seen in period 3 west of Scotland continued albeit at a lower level. Unfortunately the operational range of the Scottish vessel "Corystes" was restricted to 17°W preventing the delineation of the northwestern spawning boundary. This situation was ameliorated by the decision of the survey coordinator to divert the Norwegian vessel to the unsampled stations west of 17°W. 1.5 days of survey time were lost due to technical problems and weather conditions. Coverage was good although the expansion of the survey area in the northwest resulted once more in only an alternate transect survey being completed. 527 stations were sampled and there were 175 interpolations. Due to the aforementioned constraints as well as only restricted sampling in the Cantabrian Sea there were only 10 replicate samples collected. See Figure 3.2.4 for numbers of completed samples/ sampling rectangle.

Period 5 – In period 5, the Netherlands and Scotland had to cover the entire spawning area from the northern Biscay to the West of Scotland up to 58°45N. In consultation with the Scottish vessel the Norwegian vessel completed also one transect in period 5 along 59°15N. As in period 4 an additional survey was planned to cover the northern extension of the survey area. Iceland surveyed this northerly area between 60°15N, 19°15W and 62°45N, 2°15W.

In contrast to the two previous periods spawning activity in the West of Scotland was much more concentrated around the shelf edge. However extreme weather during the latter part of the period resulted in the loss of 3 survey days and negated any benefit gained from a reduction in the survey area. Overall, survey coverage was good however north of the Celtic Sea sampling was restricted largely to an alternate transect survey in order to ensure adequate geographical coverage. 415 stations were sampled and there were 171 interpolations. There was only one replicate sample. See Figure 3.2.5 for numbers of completed samples/ sampling rectangle.

Period 6 – This period was covered entirely by Ireland sampling on alternate transects in the area from 47°15 N in the South to the most northern transect on 56°45 N.

48 hours of survey time were lost due to heavy weather and unforeseen circumstances resulting in a change of crewman. 101 stations were sampled with 69 interpo-

lations. There were no replicate stations completed. See Figure 3.2.6 for numbers of completed samples/ sampling rectangle.

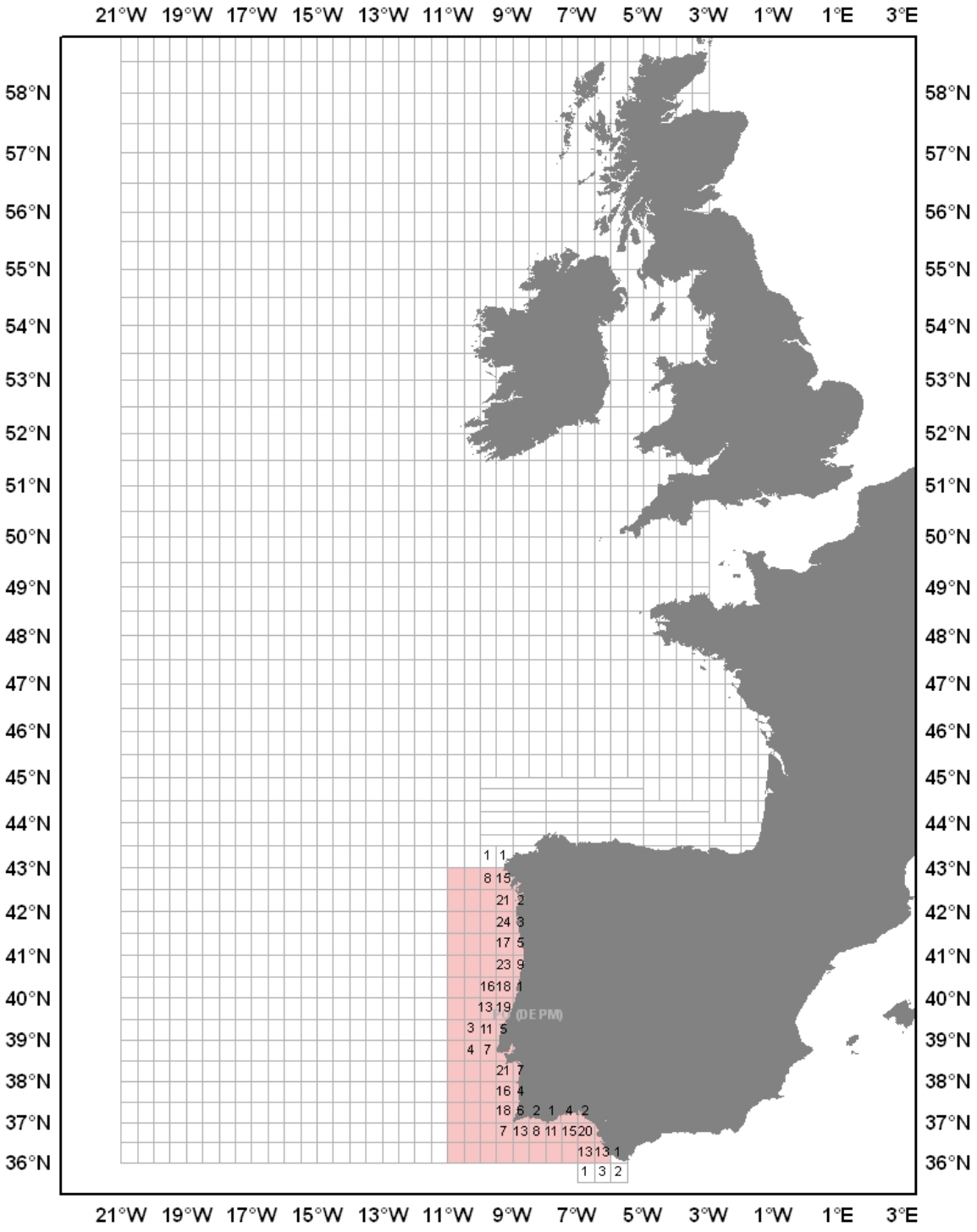


Figure 3.2.1. Number of observations per rectangle in period 1 (30 January – 7 March) and the country assigned areas (shaded).

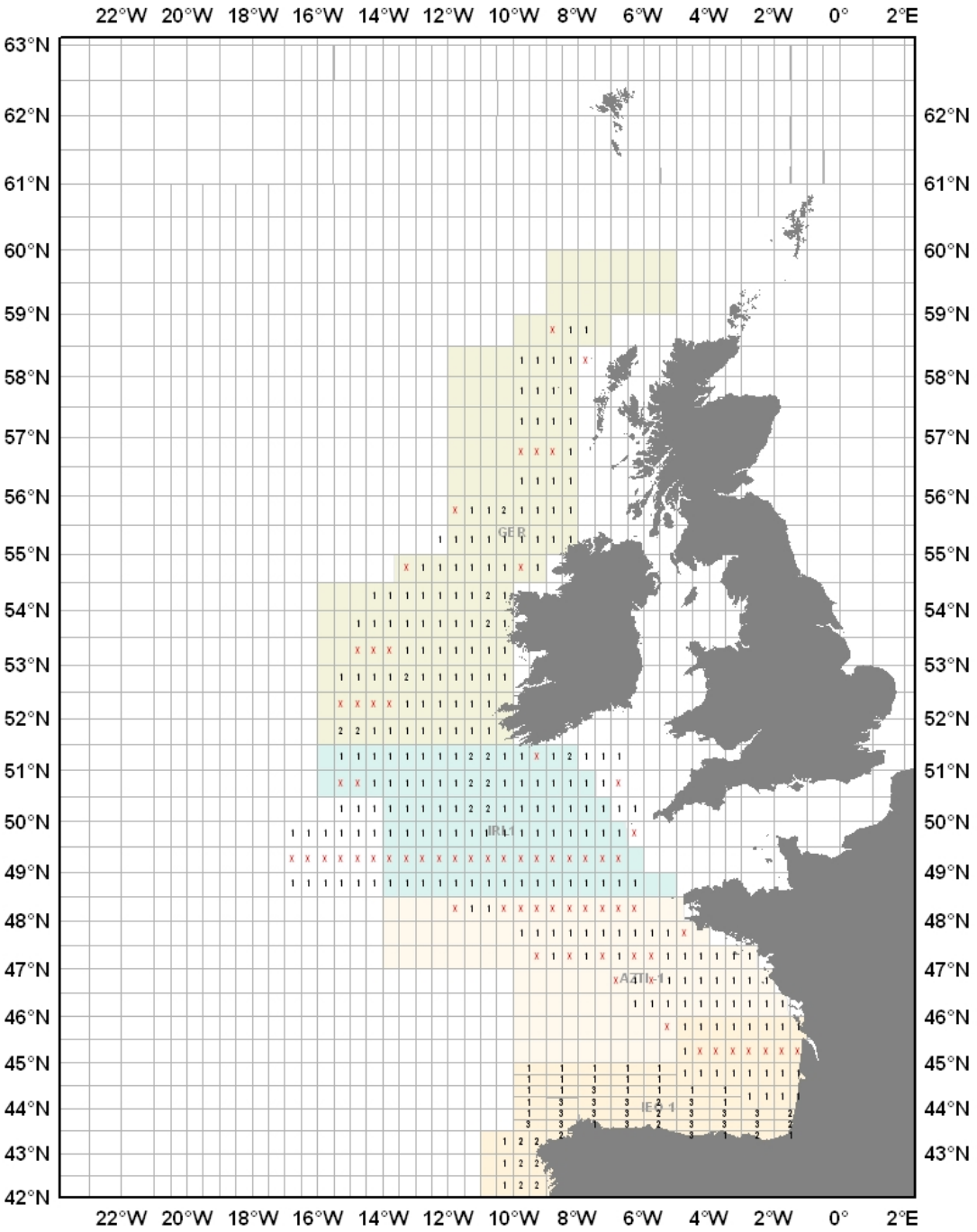


Figure 3.2.2. Number of observations per rectangle in period 2 (8 March – 11 April) and the country assigned areas (shaded) – X represents interpolated rectangles.

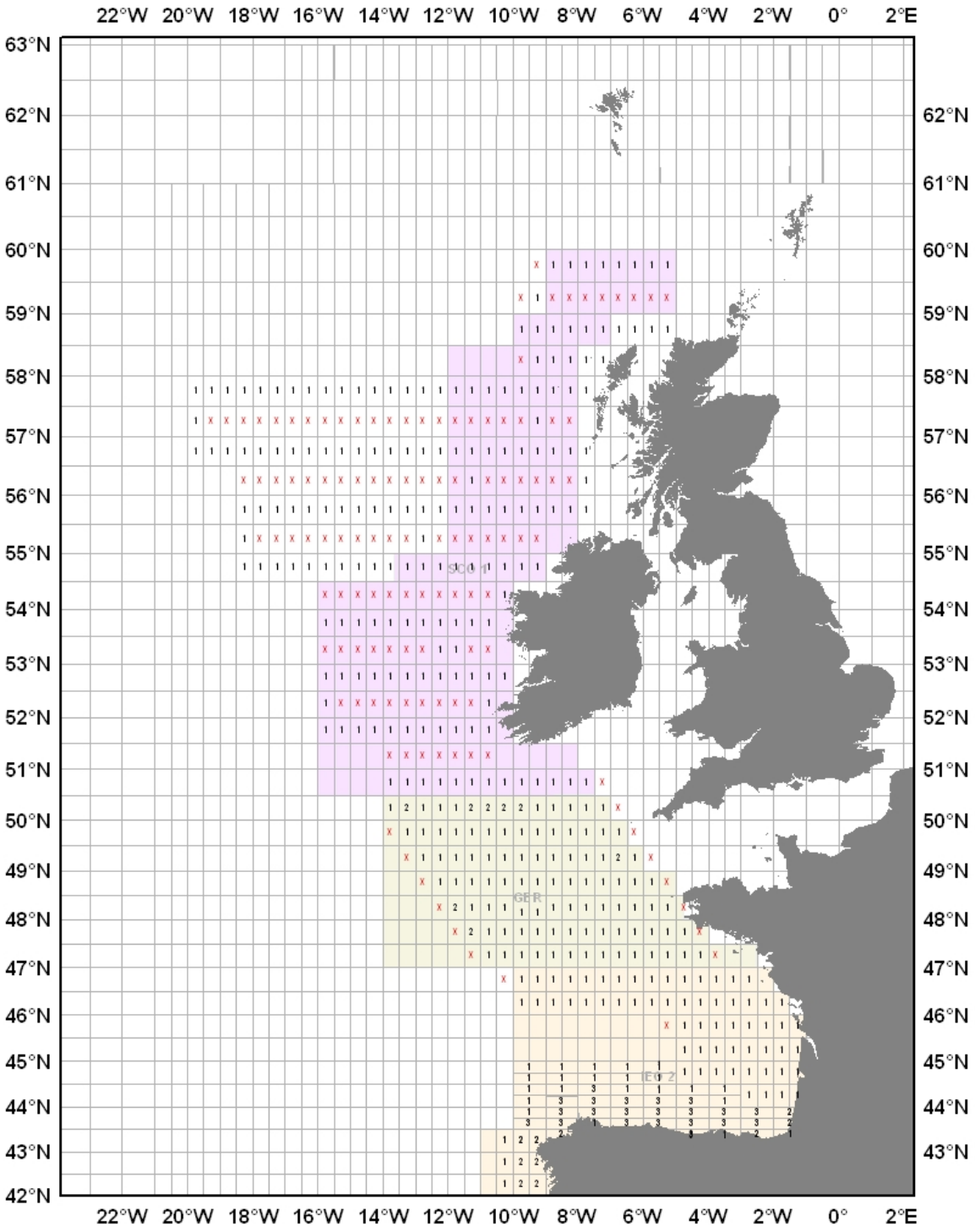


Figure 3.2.3. Number of observations per rectangle in period 3 (12 April – 9 May) and the country assigned areas (shaded) – X represents interpolated rectangles.

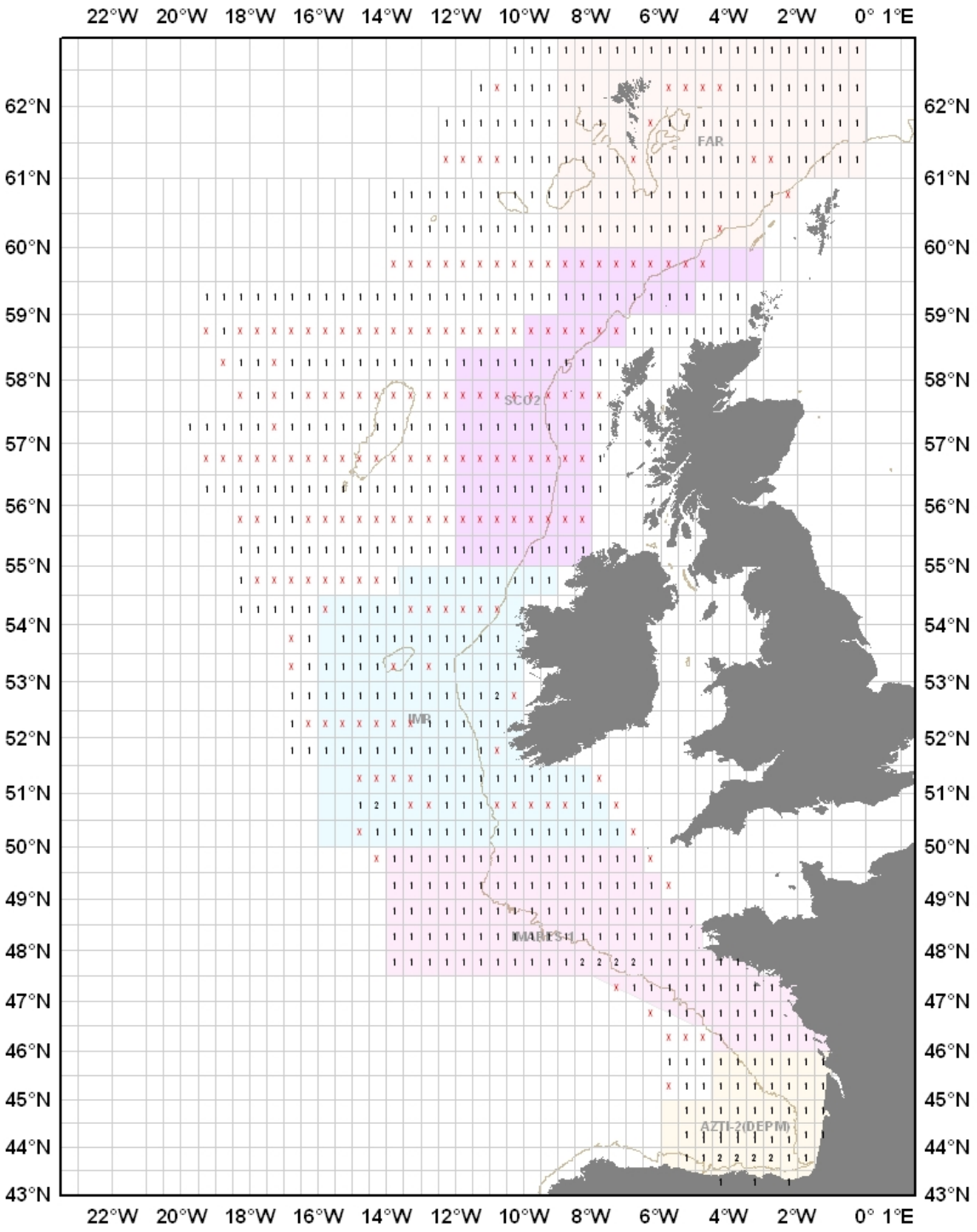


Figure3.2.4. Number of observations per rectangle in period 4 (10h May – 30 May) and the country assigned areas (shaded) – X represents interpolated rectangles.

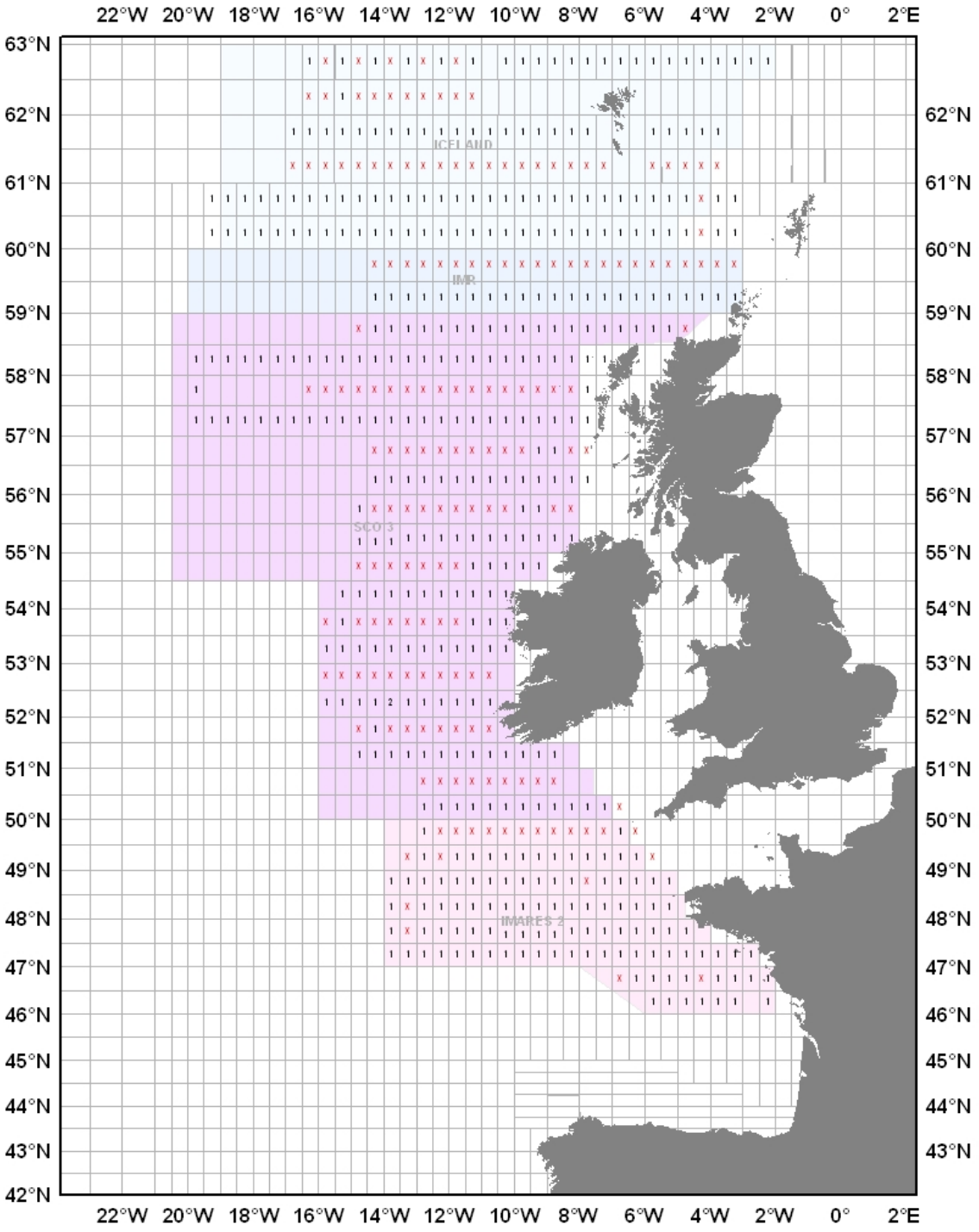


Figure 3.2.5. Number of observations per rectangle in period 5 (31 May – 4 July) and the country assigned areas (shaded) – X represents interpolated rectangles.

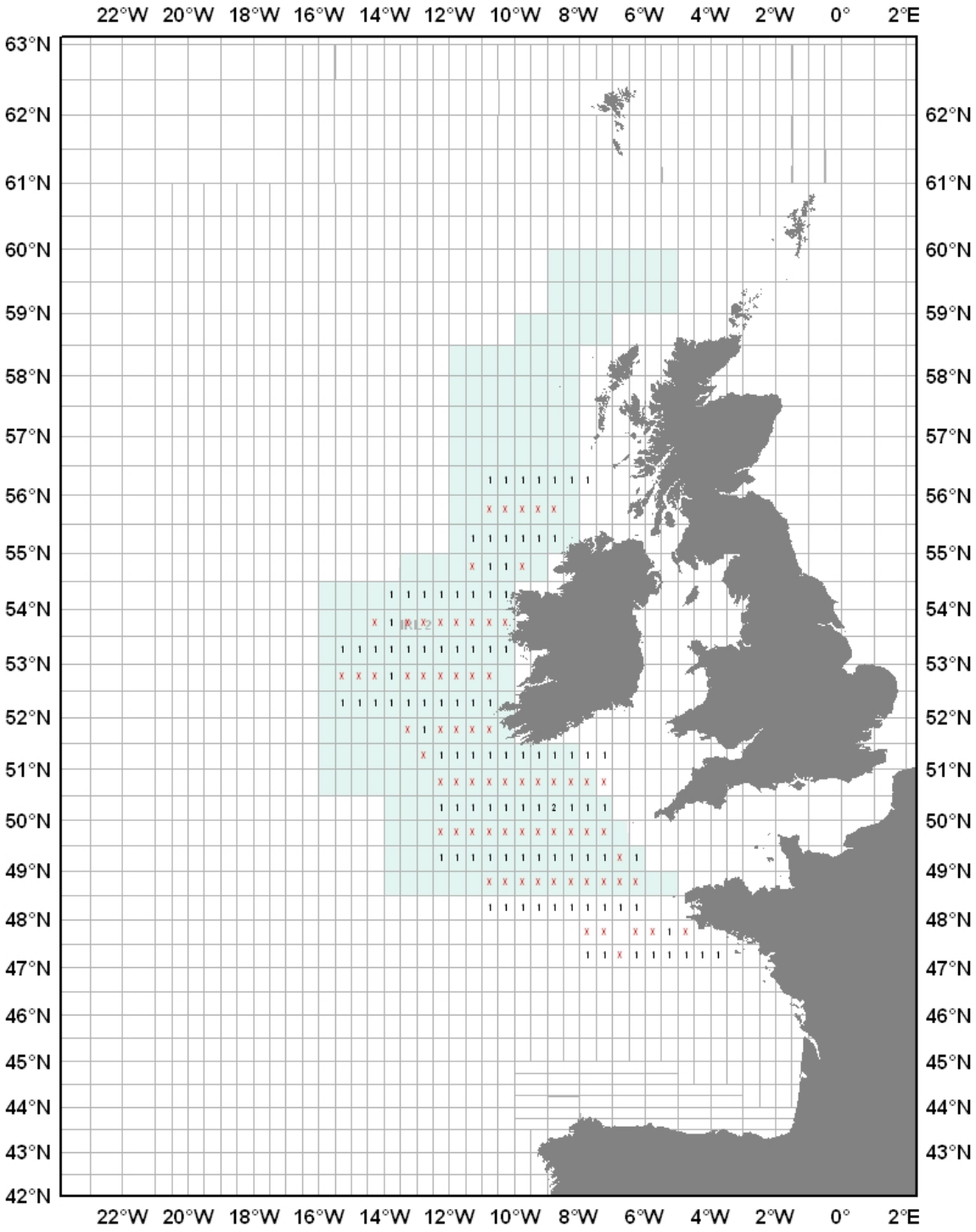


Figure 3.2.6. Number of observations per rectangle in period 6 (5July – 31 July) and the country assigned areas (shaded) – X represents interpolated rectangles

3.3 Sampling and Data Analysis

The triennial mackerel egg survey aims to determine annual egg production using the mean daily egg production rates per predefined sampling periods for the complete spawning area of the Northeast Atlantic mackerel and horse mackerel. To achieve this, plankton hauls per each half degree were conducted on alternating transects covering the complete spawning area. The 2010 egg survey was designed to reach a broad spatial and temporal coverage in each of the sampling periods. Given the high variability of egg production by station this design ensures the smallest chances of under- and overestimation of the egg production (comp. ICES, 2008).

A total of 2271 plankton samples were taken and sorted. Mackerel and horse mackerel eggs were identified and the development stages of these eggs determined. Depending on the vessel facilities and the experience of the participants this was done either during the cruise or back ashore in the laboratories.

Triplet micropipette samples and sections from 1273 ovaries of mackerel and horse mackerel were also collected onboard. After completion of the individual surveys these samples were sent to six different European research institutes for histological analysis of realized fecundity (potential fecundity minus atresia).

Analysis of the plankton samples as well as the fecundity samples were carried out according to the sampling protocols established by WGMEGS (ICES, 2009a, 2010 and older) and WKMHMES (ICES, 2009b).

Horse mackerel is believed to be an indeterminate spawner and therefore since 2007 IPIMAR has adopted the DEPM methodology for horse mackerel in the southern area. The egg survey design in the western area is directed at the AEP method for mackerel which produces an estimate of SSB. Fecundity samples for horse mackerel were taken during the survey in the western areas in order to develop a modified DEPM approach for estimating the biomass of the horse mackerel stocks.

3.3.1 Sampling Strategy for Horse Mackerel in the Southern Area

The Portuguese 2010 DEPM survey directed at horse-mackerel was carried out, onboard RV “Noruega”, between 28 January and 3 March covering the area from the eastern limit of the Gulf of Cadiz up to Cape Finisterre. Surveying was conducted along-transects (12 n.miles apart) perpendicular to the coast as shown in the map (Figure 6.1.1). During February 2010 the weather conditions were quite adverse and that led to a few interruptions and modifications in the course of the survey. Surveying was carried out from east to west in the south coast and then from south to north, in the west coast, until Lisbon; the northern area was covered from north to south with point changes. A total of 414 CalVET+CTDF samples were collected along 46 out of 48 transects.

Adult fish samples were obtained during the survey using bottom-trawling onboard RV “Noruega” and complemented by samples from the commercial fleet landed in several ports (Matosinhos, Aveiro, Figueira da Foz, Nazaré, Peniche and Portimão). Samples from the fishing fleet were acquired within four weeks of the surveying by RV "Noruega" in each area. In total, 57 fishing hauls were obtained; 33 bottom-trawls were carried out with RV ”Noruega” and 24 were obtained from the commercial fleet. In total, 3004 fish were biologically sampled and 1213 female gonads were collected and preserved, among which 27 were from hydrated females. The gonads were used for spawning fraction and fecundity (only the hydrated) estimation.

3.3.2 Sampling Gears and Procedure

In the western spawning area plankton sampling was carried out using national versions of Gulf VII type samplers with the exception of Spain which used a Bongo sampler. Gulf VII type samplers are fitted with a conical nose cone with an aperture of 20 cm diameter. The samplers were deployed to within 3 m of the bottom or to a maximum of 200 m in deeper water. A double-oblique haul was carried out at each sampling position at a ship speed of approximately 4 knots. Calibrated flowmeters mounted both inside the nose cone and externally on the body of each sampler, were used to calculate the volume of water filtered on each deployment. When a thermocline was identified, the samplers were deployed to 10m below the thermocline. In the southern area Bongo samplers with 40 cm openings were used by Spain whereas Portugal used a double CalVET as the main sampler and the CUFES system as auxiliary, Bongo samples were collected for comparison purposes. The bongo sampler was 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. CalVET sampler used by Portugal were deployed on vertical hauls to a maximum depth of 200 m or to within 3 m of the bottom in shallower water. An overview on all used sampling gears is given in the MEGS Survey Manual.

3.3.3 Data Analysis

All data analysis was carried out in accordance with the procedures described in detail for the 1995 survey and 1998 surveys (ICES, 1996, 1999). The detailed steps of the data analysis were updated for the 2003 WGMEGS report (ICES, 2003), then subsequently for the WKMHMES report (ICES, 2006b) and for the MEGS survey manual (Annex 2 of ICES, 2010). Individual countries supplied data in an electronic Excel template form to the data coordinator at the Marine Laboratory, Aberdeen. The data for each station consisted of:

sample time, date and position,

numbers of mackerel, horse mackerel and other eggs by stage.

sub sample size,

volume of sea water filtered (or flowmeter counts and calibration data)

water depth, depth sampled, 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.

The procedures for estimating the total annual egg production (TAEP) and its variance are those described in detail by Fryer (ICES WGMEGS, 1996). Total egg production is a weighted sum of the mean daily production in each period, *p*. The weights in the TAEP sum, λ_p arise from what is termed the histogram method for raising daily egg production, however, these weights could also come from the under-the-curve method. Both methods provide estimates of TAEP with associated variances, but the histogram method has several advantages over the under the curve method that will be discussed in a later Section 7.3. The histogram method is used to provide the revised estimates for 2007 and the final estimates for 2010.

Mean daily production is estimated by raising the observed mean production per m², $\bar{y}_{ps}$, for each sampled cell, *s*, in period *p*, to the total area of that cell plus any additional area due to the filling in of unsampled adjacent cells given by

$$\tilde{\mathrm{A}}_{ps} = \mathrm{A}_s + \sum_{u \in U_s} \frac{A_u}{n_{pu}}$$

Where A_s is area of cell *s*, U_s is the set of all unsampled cells adjacent to s, and n_{pu} the number of sampled cells in period *p* adjacent to *u*. Fill in rules are described in detail in ICES (1996). The equation for TAEP is

$$\sum_p \left[\lambda_p \sum_s \left(\tilde{\mathrm{A}}_{ps} \bar{y}_{ps} \right) \right]$$

The variance of the TAEP estimate is based on assuming that the raw production data are distributed with a constant Coefficient of Variation (CV) for all locations in all periods, resulting in the estimate of the variance being

$$\sum_p \left[\lambda_p \sum_s \left(\tilde{A}_{ps}^2 \frac{\bar{y}_{ps}^2}{h_{ps}} \right) \right] CV^2$$

where CV is the CV of the raw data and h_{ps} is the number of observations (hauls) in cell s in period p. The CV of the data can be estimated by assuming a lognormal distribution for the positive egg production observations and estimating the residual variance about the expected values of log egg production. The CV of the lognormal distribution is related to its variance on the log scale, σ^2 by

$$\mathrm{CV} = \sqrt{e^{\sigma^2} - 1}$$

In the current approach, σ is estimated by taking cells in each period that have at least two hauls of non-zero observations and using the standard deviation of the residuals about the cell means on the log scale. Effectively taking the residual standard deviation from the normal linear model

$$\log(\text{production}) \sim \text{square:period}$$

However, as the survey is spreading out in space there are fewer and fewer cells with multiple observations. An alternative method investigated at the working group estimates the expected value in each cell from a generalized additive model using a 3 dimensional thin plate regression spline to model a smoothly changing sea surface egg production through time, with each sampling square modelled as an uncorrelated random effect.

FIXED: $\log(\text{production}) \sim s(\text{period}, \text{latitude}, \text{longitude})$

RANDOM: $\sim \text{square}$

This allows more data to be used in the estimate of σ, for example for western-mackerel in 2010, the alternative method uses 1024 data points as opposed to 30 when duplicates are required, this has obvious implications on the precision of the CV es-

timate. This is a potentially useful approach but there was not enough time to fully develop and evaluate it so the resulting data CVs are presented here for interest and as a suggestion for future research, along with the residual degrees of freedom from each model.

		Current	alternative	df current	df alternative
Southern mackerel	2007	3.63	4.03	51	123
	2010	2.16	2.98	62	114
Western mackerel	2007	1.65	1.84	61	868
	2010	1.22	2.03	15	958
Combined mackerel	2007	2.42	2.10	112	868
	2010	1.96	2.17	77	958
Western horse mackerel	2007	3.17	2.83	74	585
	2010	1.84	2.95	47	402

Spawning-stock biomass is estimated from TAEP, relative potential fecundity (RF_P) and atretic loss (A_r). First relative realized fecundity (F_r) is estimated using $RF_P - A_r$ (measured in eggs per gram), then SSB (in grams) is estimated using

$$TAEP / F_r \times 2 \times 1.08$$

where 2 is used to raise from the mass of females to the stock (assuming equal weight for males and a sex ratio of 1:1) and 1.08 is a correction factor to adjust prespawning to average spawning fish weight. A simple way to estimate the variance of the SSB estimate is to assume that TAEP and F_r are distributed with constant CV, then the CV of the SSB estimate is

$$CV_{SSB} = CV_{TAEP} + CV_{Fr}$$

This comes from the application of the delta method (itself based on a Taylor expansion of $TAEP/F_r$). The CV is estimated from an estimate and its associated variance by

$$CV = \frac{\sqrt{Var}}{estimate} = \frac{SE}{estimate}$$

Finally the variance of Fr is estimated by assuming that RFp and A_r are independent and so the variance of RF_P - A_r is the sum of their variances, $Var(RF_P) + Var(A_r)$.

3.3.4 Data Analysis for Southern Horse Mackerel

For the southern horse-mackerel a DEPM approach is implemented. The spawning biomass (SSB) is estimated according to the following expression:

$$SSB = \frac{APW}{RSF}$$

A: spawning area

P: daily egg production density

W: female weight

R: sex-ratio

S: daily spawning fraction

F: batch fecundity

Spawning area: is calculated as the sum of the area represented by each station in the positive stratum, the area is delimited by the outer zero egg stations. It may sometimes contain a few inner zero egg stations embedded in it.

Daily egg production: The eggs staged in the laboratory (according to an 11 stages scales described in Cunha *et al.*, 2008) are transformed into daily cohort abundances. Daily egg production (P0) and mortality (z) rate is estimated by fitting an exponential mortality model to the egg abundance by cohorts and corresponding mean age:

$$E[P] = P_0 \, e^{-Z \, age}$$

The estimation of the sex ratio, the mean female weight and the mean female expected batch fecundity is based on the biological data collected from both survey and commercial samples.

The gonads preserved are used to measure the individual batch fecundity, to assess the mature/immature condition of females and to estimate the daily spawning fraction. Before the estimation of the mean *female weight* per haul (W), the individual total weight of the hydrated females is corrected by a linear regression between the total weight of non-hydrated females and their corresponding gonad-free weight.

Sex ratio: The *sex ratio* (R) in weight per haul is obtained as the quotient between the total weight of the females on the total weight of males and females. The expected individual *batch fecundity* (F) for all mature females (hydrated and non-hydrated) is estimated by the hydrated egg method (Hunter *et al*., 1985), i.e. by modelling the individual batch fecundity observed in the sample of hydrated females and their gonad-free weight by a GLM and applying this subsequently to all mature females.

3.4 Hydrography in the Spawning Area

Sea surface temperature and salinity distributions during the Portuguese survey in period 1 showed typical winter patterns for this region although the weather was quite severe in the 2010 winter period (Figure 3.4.1). In the northern region temperature values ranged from 12ºC to14ºC and in the Gulf of Cadiz from 14ºC to 17ºC, roughly. During the survey and also in the preceding weeks the whole Iberian Peninsula was under heavy rain and strong winds. These conditions led to strong river run-off with pronounced plumes appearing adjacent to the major estuaries, Guadalquivir and Guadiana in the south coast and Tejo and Douro-Minho-Rias Galegas in the northern shores. The patch of water with lower salinity and temperature was particularly evident over the northern platform. Gale force winds from S and SW gave rise to advection to the north of the freshwaters discharged by the River Tejo.

Temperatures encountered by mackerel during the spawning season are influenced by the seasonal warming of the surface layers and are best described by temperatures at 20 m depth that are also used for calculation of daily egg production (Figure 3.4.2).

During period 2 temperatures at 20 m depths varied between 7.7°C in the Northeast and 13.5°C off the Galician coast. A front that separated cool coastal waters from warmer Atlantic waters was evident along most of the shelf edge northwards of 45° N. That front was particularly pronounced west of Ireland and Scotland. Atlantic waters west of the front were warmer than 10°C throughout the survey area, which may also explain the spawning peak observed in this period.

Temperature range was only slightly increased during period 3 to values between 7.7 and 14.3°C. However, temperatures at 20 m depths had increased almost throughout the survey area, particularly in the southern Bay of Biscay and off the Cantabrian Coast. The front was still visible along the shelf edge, but not as pronounced as in period 2. The 10°C isotherm ran from slightly north of 56° Latitude in the West to about 58 °N at the shelf edge west of the Hebrides.

In the fourth period the 10 °C isotherm had moved further North by more than 3 – 4 degrees in the western part of the survey area and by 2 degrees in the East. Temperatures at 20 m depth ranged between 6.9°C around the Faroese Islands and 15.9°C in the southern Bay of Biscay.

Period 5 was characterized by rapid warming of the surface layers. Therefore, depiction of the temperature was split into areas north and south of 51°N.The southern area was surveyed earlier in the period and temperatures at 20 m depth were about 1°C cooler than west of Ireland that was surveyed later. North of 51°N temperatures at 20 m depth ranged between 8.1°C northeast of the Faroese Islands and 16.6°C in southwest of Ireland. Waters with temperatures > 10°C was spread out further to the Northeast and to the Northwest than in period 4.

The major deviations from the long-term monthly mean temperatures occurred in waters west of the British Isles, while in the Celtic Sea and in the Bay of Biscay waters were only slightly warmer or similar to the long-term monthly means (DHI 1967). Also observations by Holliday *et al.* (2009) indicate that in the Bay of Biscay temperature anomalies are less pronounced than west of the British Isles.

The hydrography west of the British Isles is mainly influenced by three major components: the Subpolar Gyre that may carry cool Subarctic water into the area, the North Atlantic Current (NAC) and by the advection Eastern North Atlantic Water (ENAW) that both may carry warmer and saline waters. Ultimately, the Subpolar Gyre dominates the influence of the two latter in the area. When the gyre is large, more cold Subarctic water is advected to the area in the Rockall Bank vicinity while the NAC and the ENAW is shifted eastwards towards the shelf edge. Under weak Subpolar Gyre situations the major northward branch of the NAC runs west of Rockall Bank while more warm and saline ENAW is advected to the area between the British Isles and Rockall Bank (Hatun *et al*., 2009). This situation might have been responsible for the relatively warm waters encountered west of the British Isles during the 2010 MEGS. The long-term trends for the area also indicate that temperatures were steadily rising in the area after the exceptionally cold period the ended in the mid 90s (Holliday *et al.*, 2009) indicating at a stronger influence of warm ENAW since then in the area.

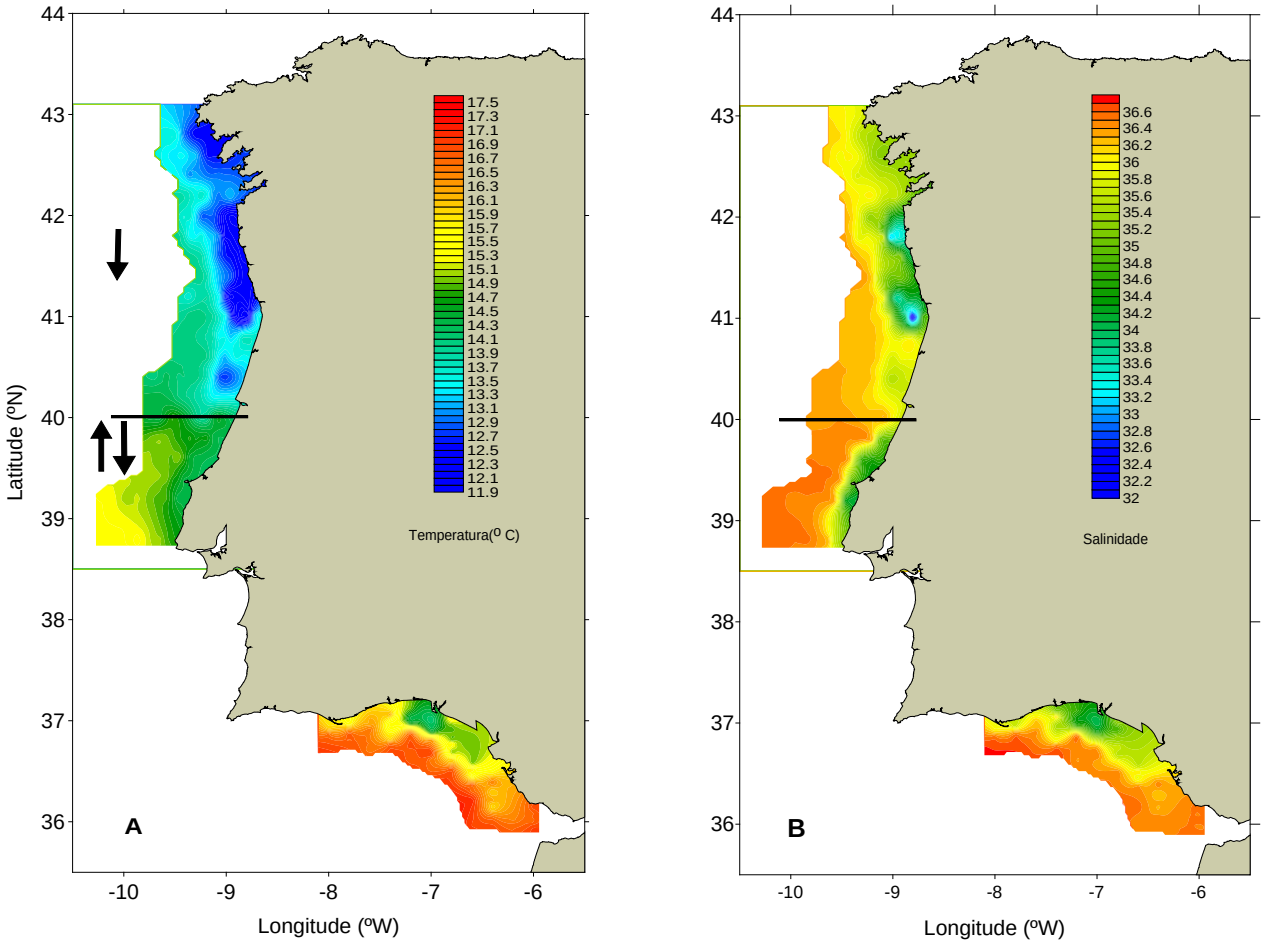


Figure 3.4.1. Sea surface temperature (A) and salinity (B) registered by the probes associated with the system CUFES+EDAS. Data were not available for the SW area. The black line indicates survey break due to adverse weather conditions; the arrows show the direction of surveying.

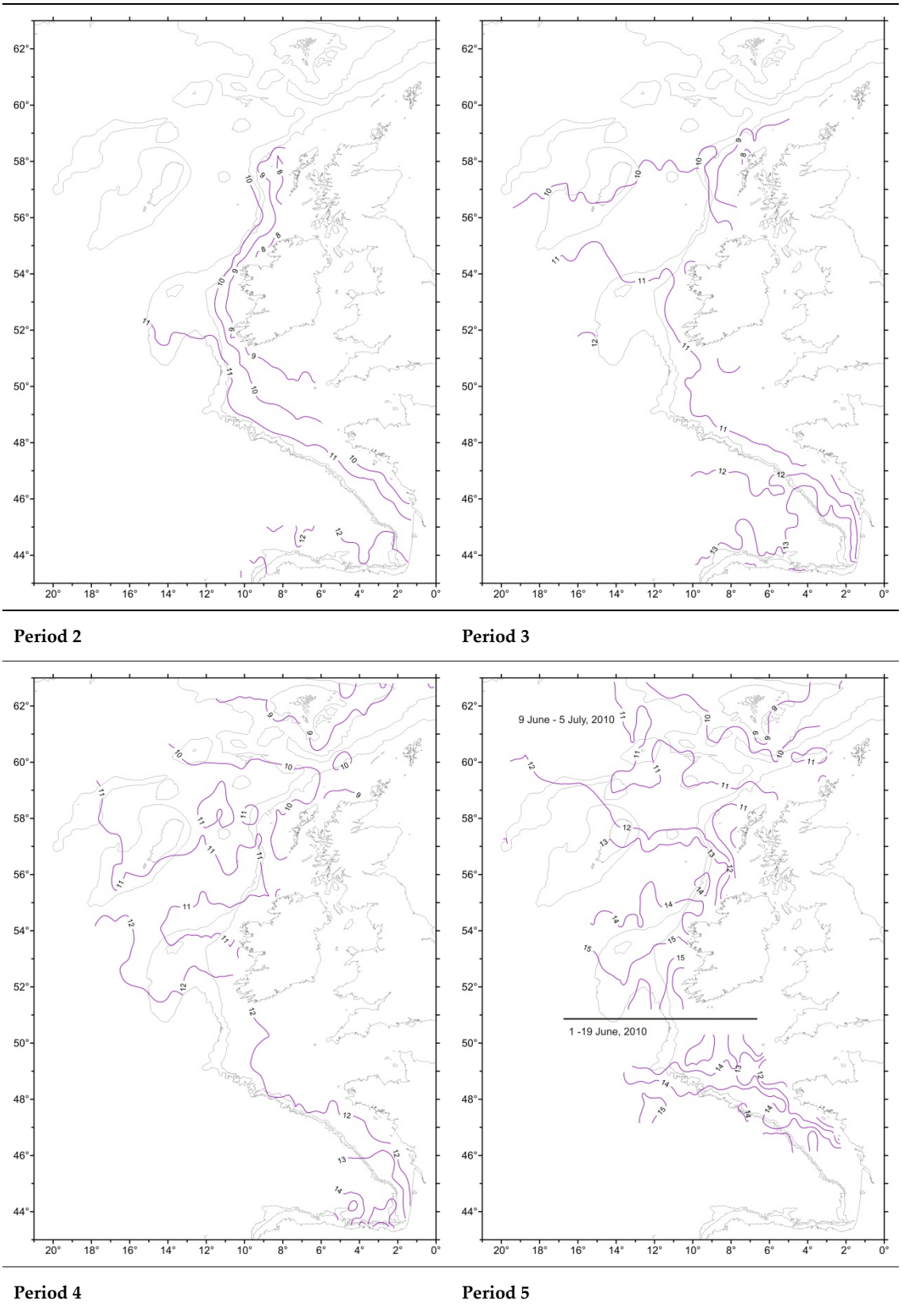


Figure 3.4.2. The temperatures at 20 m depth during the 2010 MEGS, periods 2 (top left) – 5 (bottom right).

4 Mackerel in the Western and Southern Spawning Areas: 2010 Egg Survey Results

4.1 Spatial Distribution of Stage 1 Mackerel Eggs

The description of the spatial distribution of stage 1 mackerel eggs is presented for both the southern and western areas together. The subsequent calculation of the egg production curve and biomass are considered separately for the two areas.

- **Period 1** - During the first Portuguese cruise surveyed the southern part of the southern area (36º00 N – 42º00 N; Figure 4.1.1). In Portuguese waters and the Gulf of Cadiz stage 1 mackerel eggs were very sparse and very low in abundance. Subsequently egg production in this period was very low. Coverage was good and there were no interpolations required.

- **Period 2** – During this period the area surveyed ran from the northwest coast of Spain to the north coast of Scotland, (42º00 N – 59º00 N; Figure 4.1.2). The area was sampled by four institutes. Unusually period 2 was peak spawning and significant concentrations of stage 1 eggs were encountered throughout almost the whole of the survey area with the exception of Biscay where only low levels of spawning were recorded. The highest concentrations of stage 1 eggs were found along just off the 200m contour between 48º30 N - 54º00 N and also on the stations right along the Cantabrian Sea. Area coverage was good and spawning boundaries were generally well defined although bad weather resulted in 3 transects being missed and were therefore interpolated. Total interpolations for this period numbered 67.

- **Period 3** - In Period 3 sampling again ran from the northwest coast of Spain to the north coast of Scotland, (Figure 4.1.3). Sampling was undertaken by three countries and whilst coverage was complete up to 50º30N, the remaining survey area north of this up to the boundary at 60ºN was completed using alternate transects. This was entirely due to an expansion of the spawning area which continued as far as 20Wº and in all likelihood spawning continued beyond this limit though west of this was outside the operational limits of the vessel involved. This resulted in limited delineation of the spawning boundary in this area especially the northwestern boundary at 57º45N. Egg production was continuous though significantly lower than in period 2 right along the survey area and below 51ºN was contained almost exclusively within the continental shelf break around the 200m contour. North of this and especially in the area north of the Porcupine Bank higher egg production was recorded and this was expanded much further west to at least Hatton Bank with spawning activity being evenly dispersed throughout this. Consequently, significant interpolation was necessary in this area and there were 122 interpolated stations.

- **Period 4** – Sampling during this period was conducted between the eastern Cantabrian Sea and Faroese waters up as far as 63°N (Figure 4.1.4). 5 vessels were surveying during this period and a similar pattern to period 3 was recorded with the expansion of the area in the northwest continuing once again out to Hatton Bank. Egg production in this area was continuous at a low level and evenly distributed over most of the survey area north of the Porcupine Bank. As in period 3 the expansion of the survey area in the northwest re-

sulted in a large number of interpolated transects and as such there were 175 interpolations stations.

- **Period 5** – The area was surveyed by 4 countries and survey coverage was from Biscay north to 63°N (Figure 4.1.5). Sampling in the Cantabrian Sea was discontinued. Egg production was encountered throughout the survey area however in contrast to periods 3 and 4 this was concentrated much more around the continental shelf and along the 200m contour line. Evidence of spawning was recorded in the northwest as far west as 16°W however this was at a much lower level than in the previous 2 periods. Boundaries were generally well defined although bad weather during the second half of this period curtailed sampling significantly, with the net result that the area north of 49°N was surveyed using only alternate transects. There were 171 interpolated stations.

- **Period 6** - Only one vessel was available for sampling in this period so consequently coverage was less comprehensive than in previous periods (Figure 4.1.6). Due to the size of the sampling area only alternate transects were sampled from 47°N to 56°30N. Despite this the boundaries were generally well defined especially in the south and west of the area where egg production was concentrated on and around the 200m contour. Generally egg production was low for this period although there were several higher density areas. The largest of these were present east of the shelf break in the Celtic Sea and around the Fastnet Rock to the south of Ireland. Insufficient time meant that the northern boundary was not as well defined although the indications are that there was not much egg production north of the survey boundary.

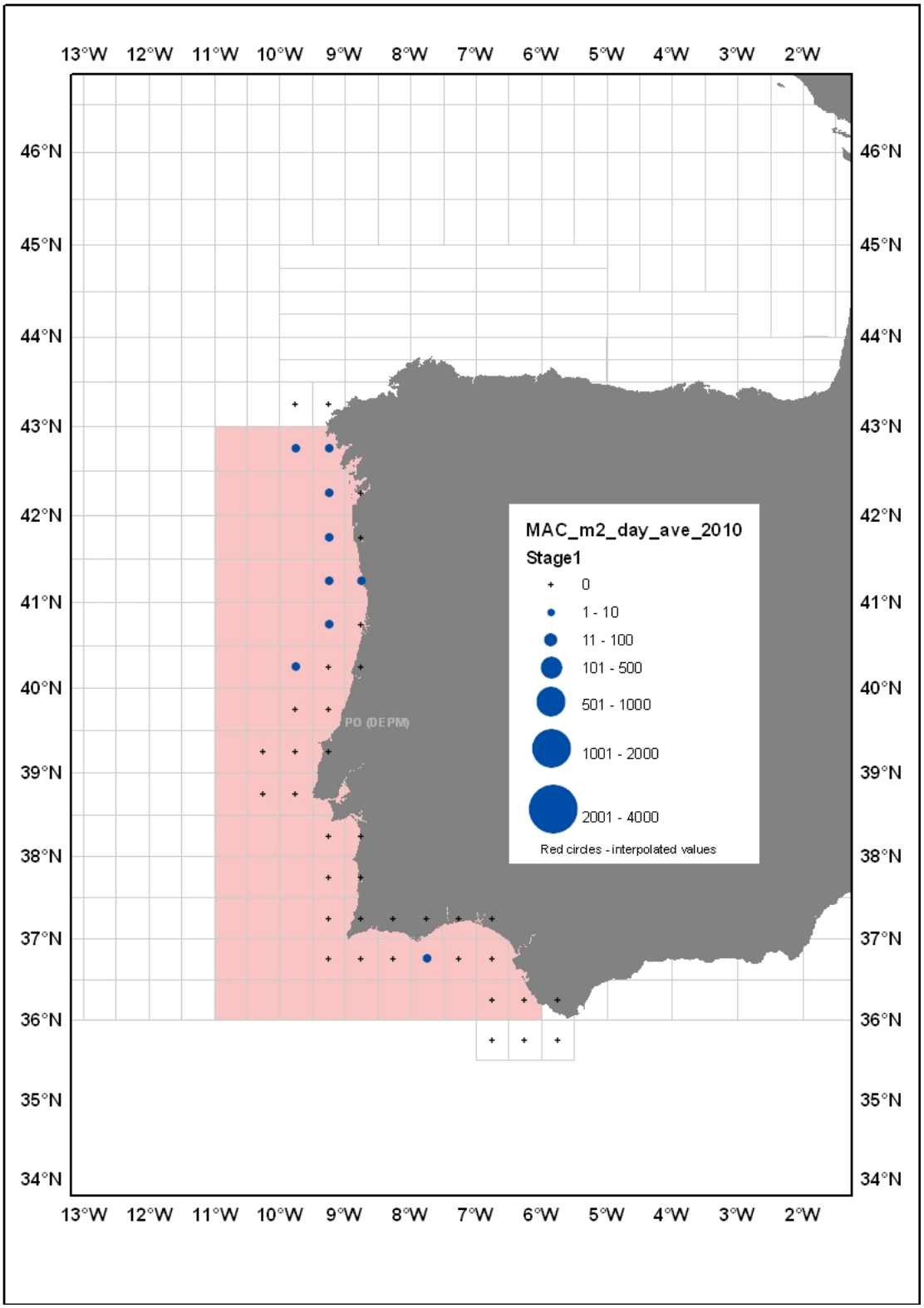


Figure 4.1.1. Mackerel spp. egg production by half rectangle for period 1 (30 January – 7 March). Filled blue circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

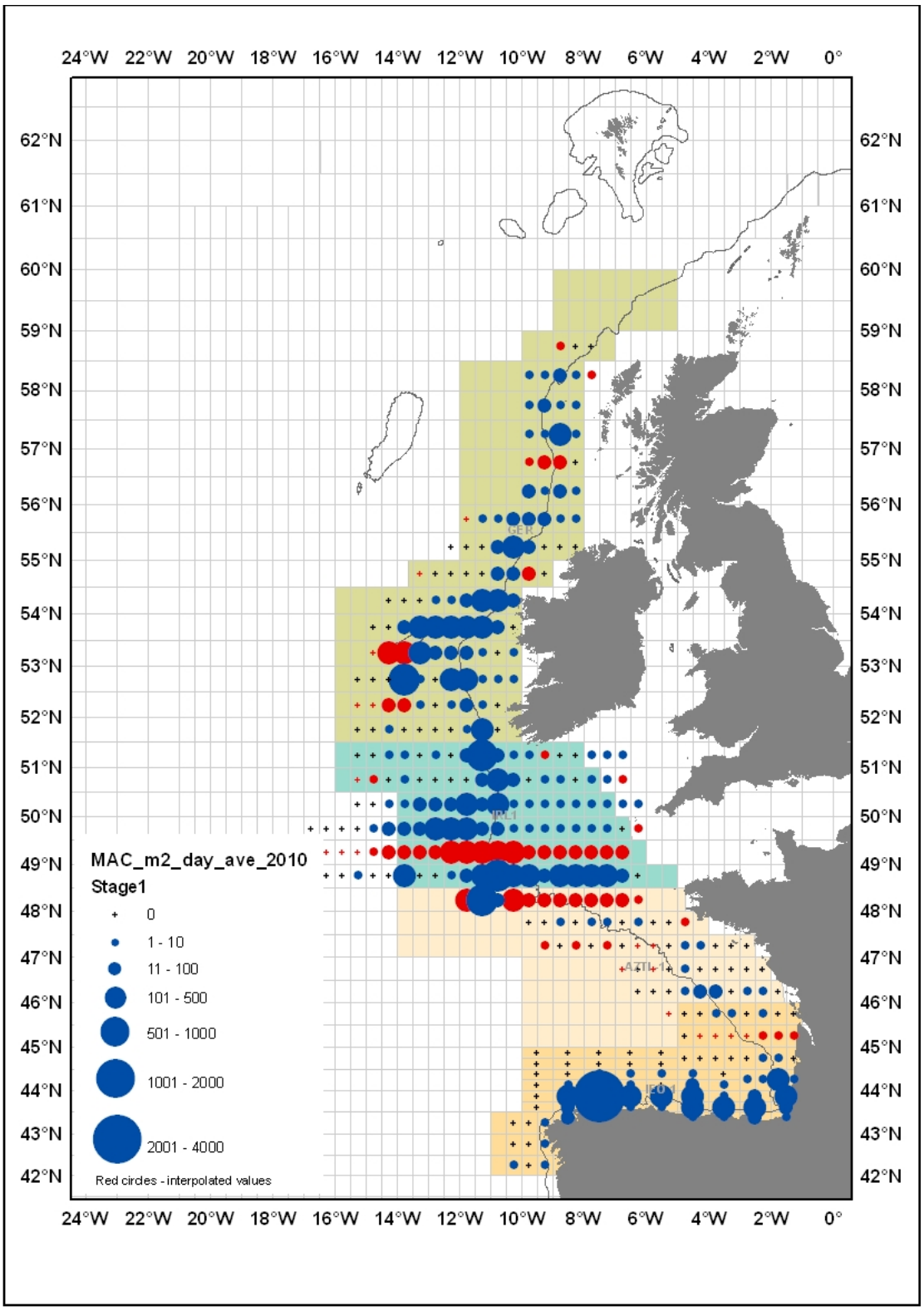


Figure 4.1.2. Mackerel egg production by half rectangle for period 2 (8 March – 11 April). Filled blue circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

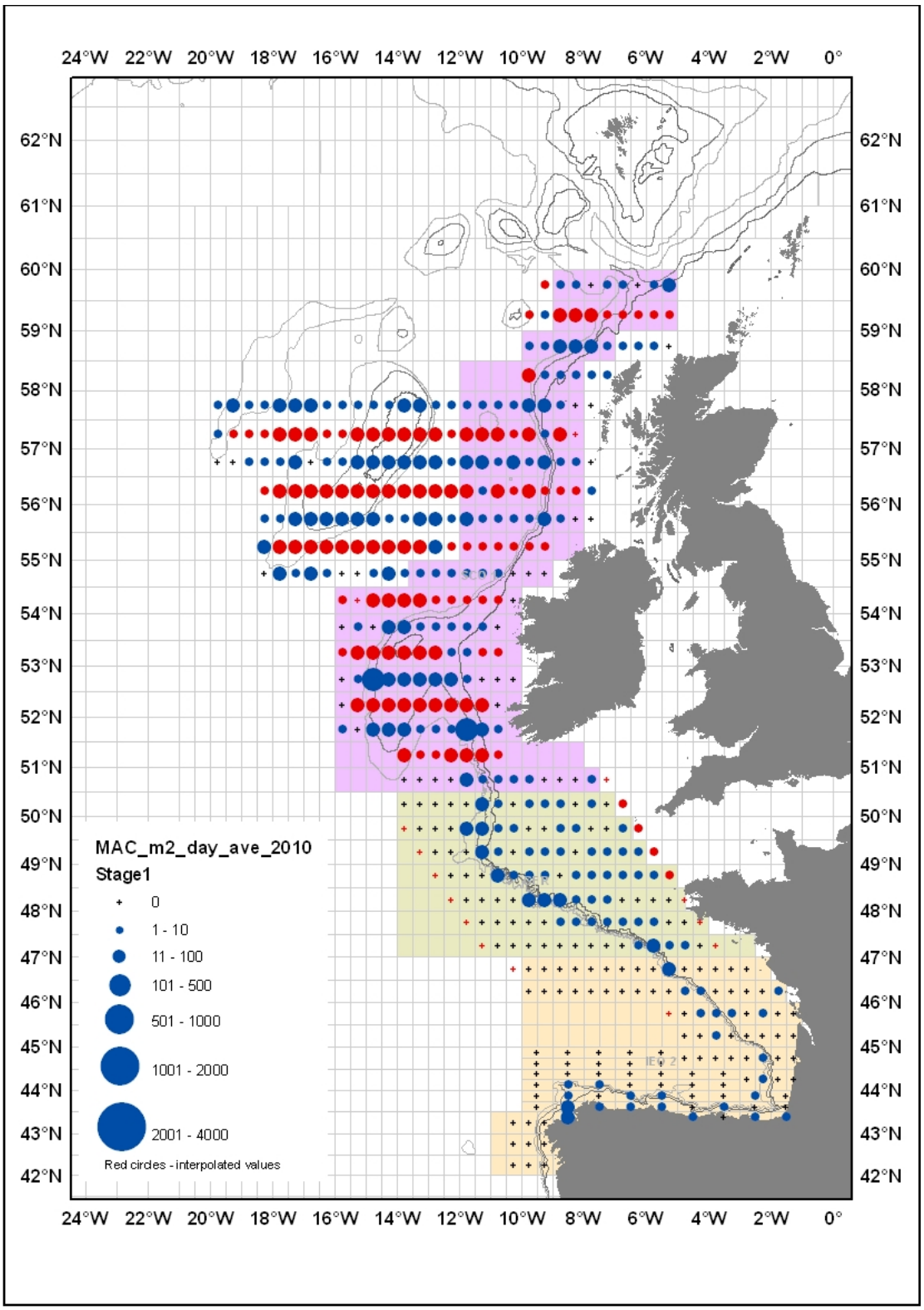


Figure 4.1.3. Mackerel egg production by half rectangle for period 3 (12 April – 9 May). Filled blue circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

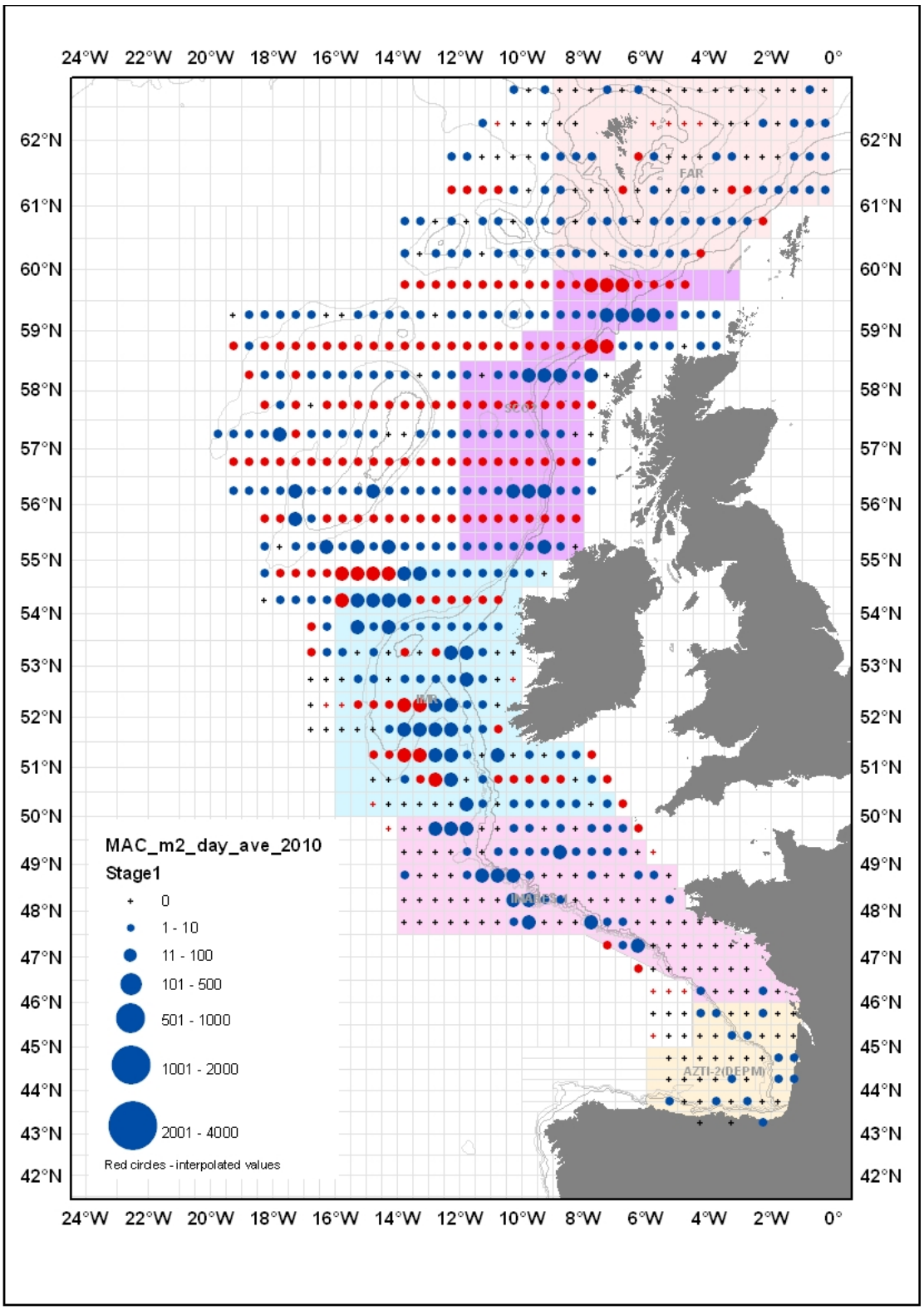


Figure 4.1.4. Mackerel egg production by half rectangle for period 4 (10 May – 30 May). Filled blue circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

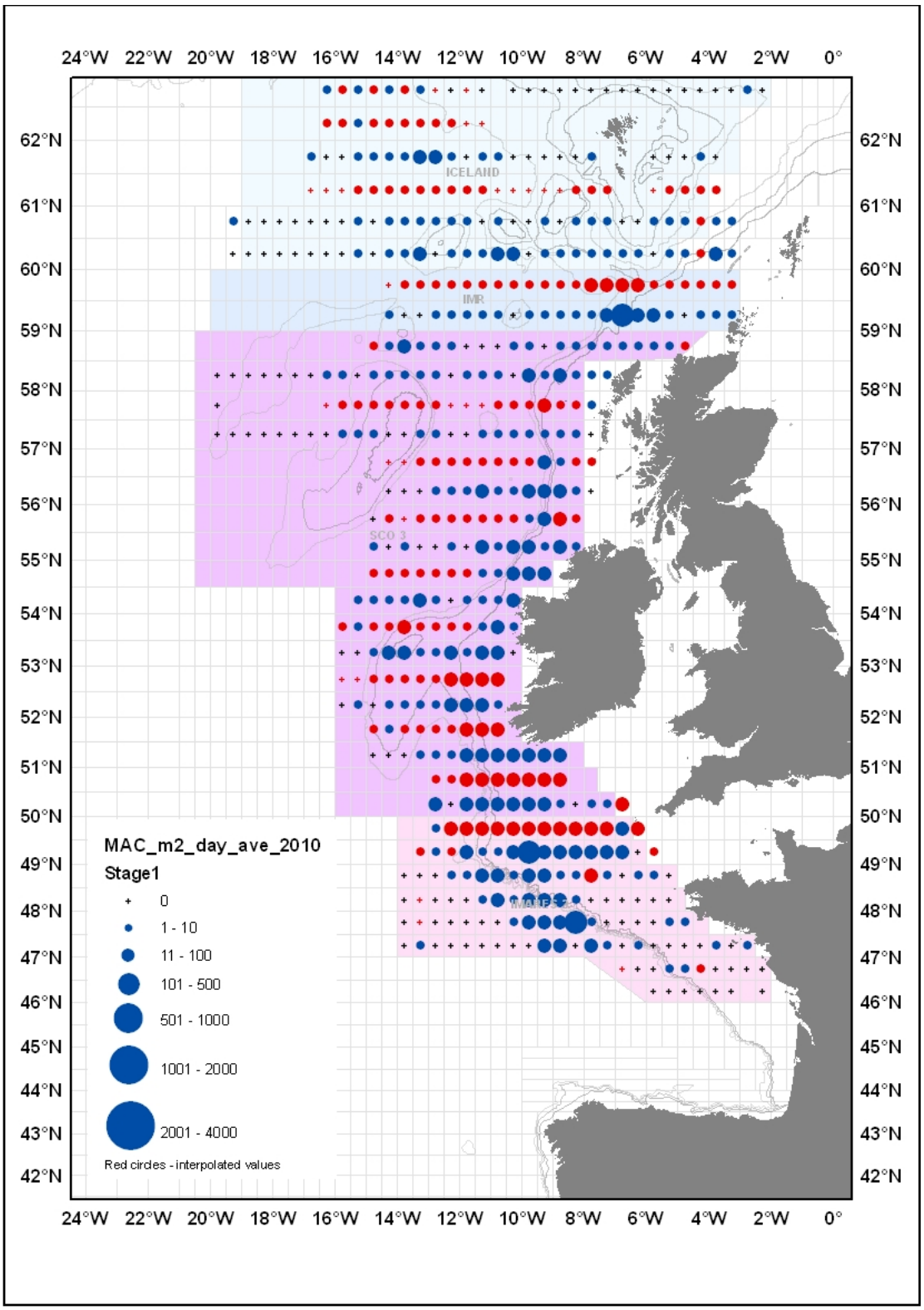


Figure 4.1.5. Mackerel egg production by half rectangle for period 5 (31 May – 4 July). Filled blue circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

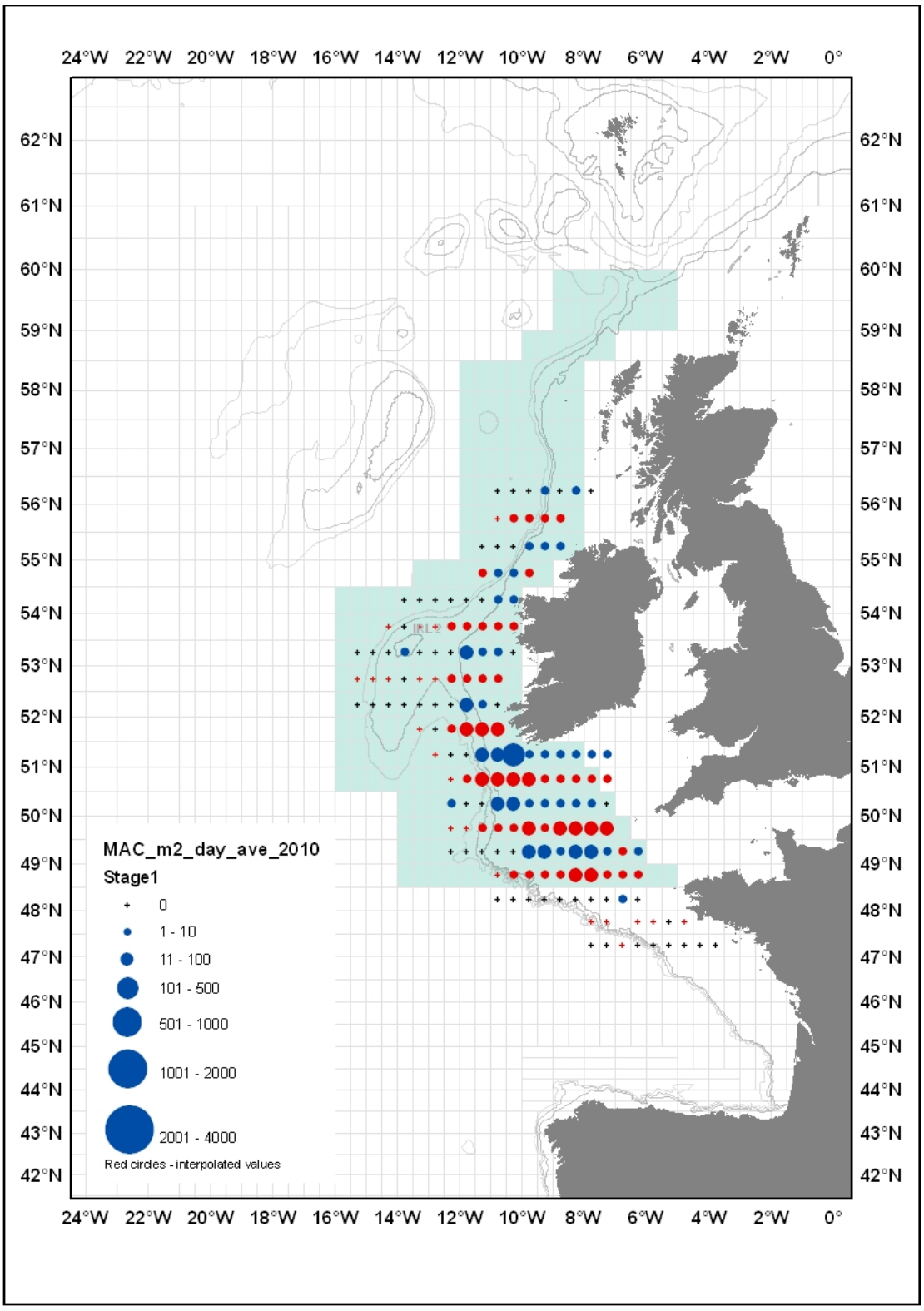


Figure 4.1.6. Mackerel egg production by half rectangle for period 6 (5 July – 31 July). Filled blue circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

4.2 Egg Production in NEA Mackerel

4.2.1 Stage I egg production in Northeast Atlantic Mackerel

Figure 4.2.1 represents the egg production curve for the western area for the 2010 survey, along with those for the surveys in 1998, 2001, 2004 and 2007 for comparison. The nominal start date(used since 1995) of the 10 February was used although for the 2010 estimate - as corroborated by the extremely large period 2 production value - the potential exists that this may not be the case. The nominal end of spawning date of 31 July is also the same as that used in previous years and the shape of the production curve during this period does not suggest that the chosen end date should be altered. Production estimates for the individual survey periods and the period before the surveys are presented in Table 4.2.1. Like 2004, the survey periods were not completely contiguous and this has been accounted for in table 2. The total annual egg production (TAEP) for the western area in 2010 was calculated as 1.70 × 1015. This is a 23.5% increase on the revised 2007 TAEP which was 1.38 × 1015. The spawning curve differs markedly from that seen in 2007 or in fact from any other curve from at least 1998 onwards. 66% of all the egg production in the western area took place between 10 February and 26 April which translates to periods 2 and 3. This is in marked contrast to previous years where peak spawning has tended to occur around May or June.

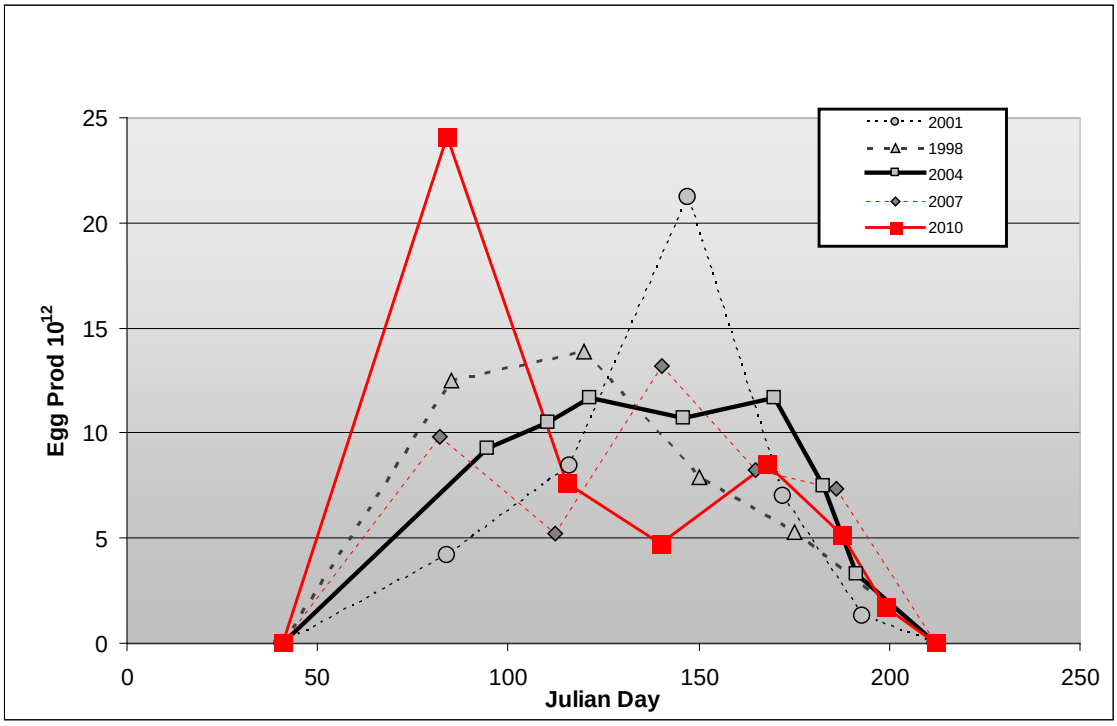


Figure 4.2.1. Annual egg production curve for mackerel in the western spawning component. The curve for 1998, 2001, 2004 and 2007 are included for comparison.

Table 4.2.1. Western estimate of mackerel total stage I egg production by period for 2010.

Dates	Period	Days	Annual stage I egg production x 10 15
< 8 March	Pre2	26	0.188
8 March – 11 April	2	35	0.847
12 April – 9 May	3	28	0.213
10 May – 30 May	4	21	0.099
31 May – 4 July	5	35	0.301
5 July – 8 July	*	4	0.017
9 July – 27 July	6	19	0.033
28 July – 31 July	*	4	0.001
Total			1.700
s.e.			0.240
CV			14.15%
Data CV			122%

4.2.2 Stage 1 Egg production in the Southern spawning area

Figure 4.2.2 presents the egg production curve for the southern area of the 2010 survey, along with the 2007 curve for comparison. Total egg production values by survey period are displayed in table 4. The start date for spawning in the southern area was the 30th January. This was almost one week earlier than in 2007 and is based on the occurrence of stage I eggs found off the Portuguese coast during the period 1 survey. As in 2007, the end date of spawning was again chosen on 17 July which was corroborated by the run of the spawning curve. Production estimates for the individual survey periods and for the period preceding the surveys are presented in Table 3. As in 2007, the survey periods were not completely contiguous and this has been accounted for in Table 4.2.2. The total annual egg production (TAEP) for the southern area in 2010 was calculated as $\mathbf{4.25 \times 10^{14}}$. This is a 29.8% increase compared to the revised 2007 TAEP which was 3.27×10^{14}. In keeping with the 2007 results the bulk of egg production (99%) took place between 15 February and 26 April.

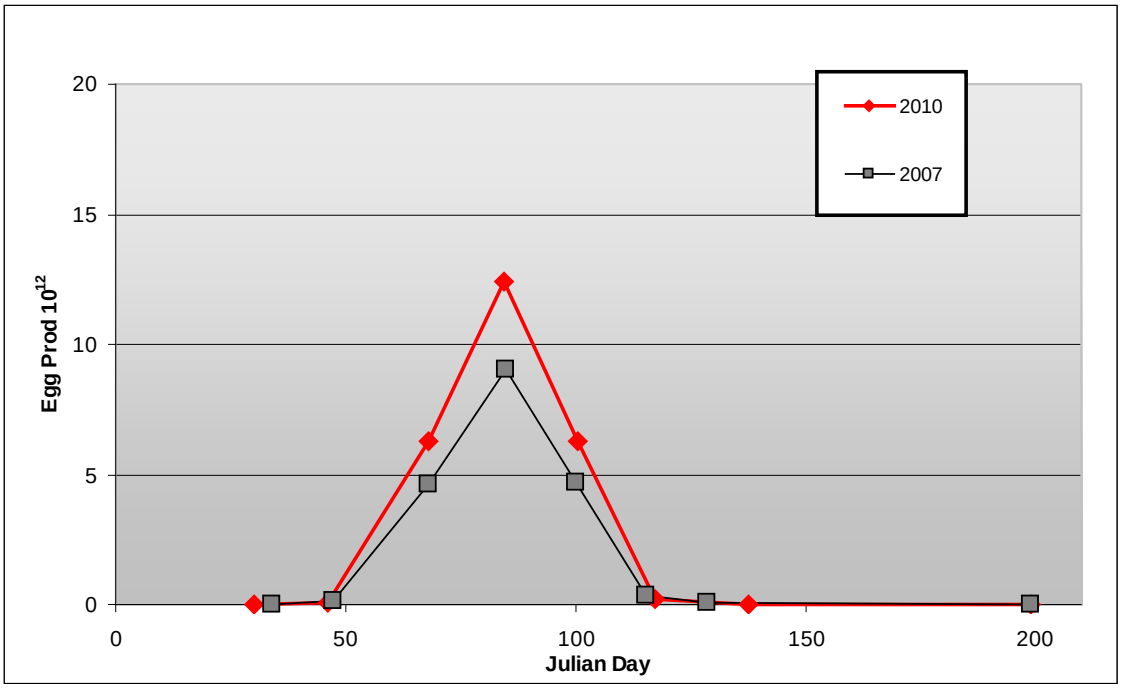


Figure 4.2.2. Annual egg production curve for mackerel in the southern spawning component for 2010. The curve for 2007 is included for comparison.

Table 4.2.2. Southern estimate of mackerel total stage I egg production by period for 2010.

Dates	Period	Days	Annual stage I egg production x 10 14
30 Jan – 3 March	1	33	0.002
4 March – 14 March	*	11	0.785
15 March – 5 April	2	22	2.74
6 April – 15 April	*	10	0.650
16 April – 9 May	3	24	0.005
10 May – 25 May	4	16	0.0005
26 May – 17 July	*	53	0.0007
Total		4.250	
s.e.		3.382	
CV		79.57%	
Data CV		216%	

4.2.3 *Total egg production*

Total annual eggs production (TAEP) for both the western and southern components in 2010 is **2.12 x 10^{15}** (se of 0.41 x 10^{15}; CV of 19.5%). This equates to a net increase in production of **24.7%** compared to the revised estimate of 1.70 x 10^{15} in 2007. Figure 4.2.3 below displays the historical TAEP of NEA Mackerel back as far as 1998.

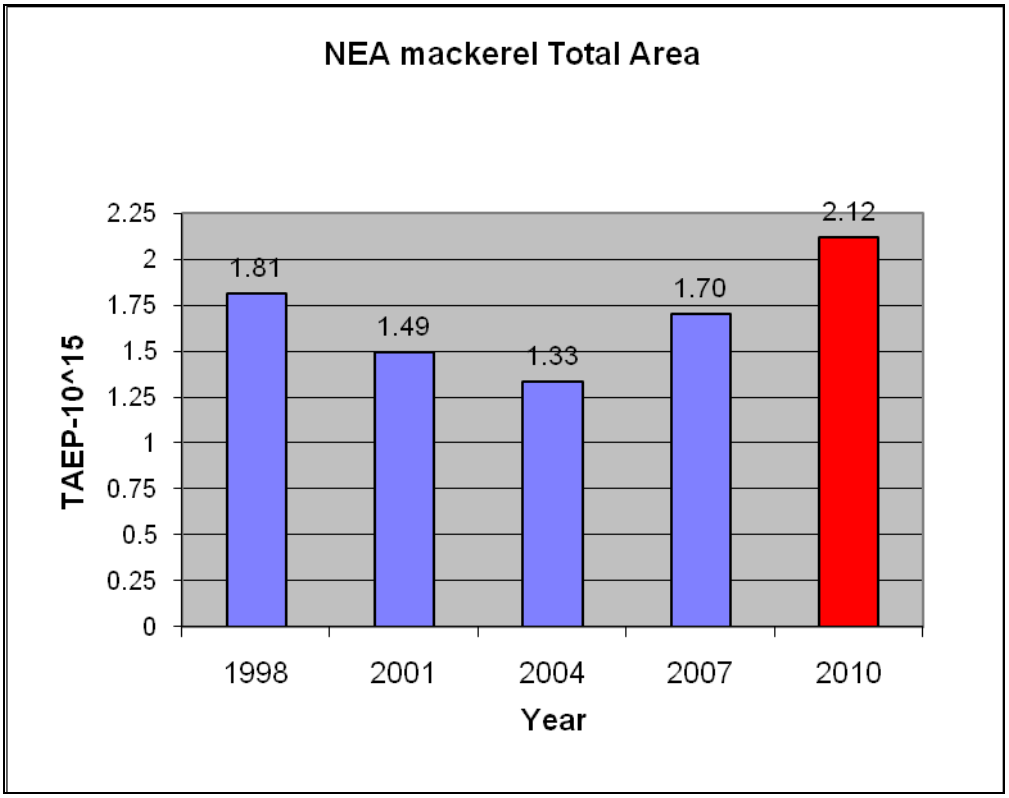


Figure 4.2.3. TAEP estimates, 1998 – 2010.

4.3 Comparative Fecundity and Atresia Estimation 2010

4.3.1 Fecundity and Atresia Ring Test Report

Standardization of fecundity estimation

Images were prepared at IMR from unstained whole mount samples of mackerel ovary tissue. Each analyst attending the workshop meeting in San Sebastian 2009 counted the number of maturing oocytes (oocytes above 185 µm) in these images using the same open source ImageJ (http://rsb.info.nih.gov/ij/) software setup. Only the images which were scored as prespawning were counted. We accepted the automatic diameter measurements as the source for our diameter estimates although the automatic procedure did not measure oocytes below 250 µm. However, the purpose of our diameter measurements was mainly to estimate leading cohort diameter, which is the 10% largest oocytes present in the ovary.

The results of (Table 4.3.1.1) the automatic counts and diameter measurements were almost identical for all labs except for MSS and one sample for MI. The manual counting of the remaining oocytes differed in one case considerable, causing the total count (automatic counts plus manual counts) in one case to vary unacceptably. Some of the participants counted pictures that most of the group scored as spawning. Several of the persons attending the test were doing this work for the first time and some differences were therefore expected at this point. The results and pictures were discussed in plenum so that similar differences could be avoided in future.

Following the workshop a new set of scaled mackerel oocyte pictures were distributed to all the participating labs. This test (Table 4.3.1.2) showed rather similar results between the labs, except for diameter measurements of one sample done by IMARES. This was probably caused by a calibration error.

Standardization of mackerel atresia estimation

Serial sections stained with toluidine blue were produced from one single ovary and scored by AZTI, IEO, Cefas, IMARES, MI, MSS and IMR for early alpha atresia in the 3 follicle classes (Table 4.3.1.3).

There were large differences in negative grid counting and we found that this was due to a misunderstanding of which area should be included. The misunderstanding was clarified after reading in the manual. There were also large differences in counting hits (hit: When a gridline hits an early alpha atretic cell) and profs (an early alpha atretic cell inside the forbidden lines). These differences were probably due to the fact that the persons in the test were inexperienced in this kind of work. The pictures were looked at in plenum and difficulties were discussed. It was decided to do another ring test after the workshop but before the survey.

Following the workshop a new set of pictures where prepared from slides from two different fish, 7 pictures for each fish. The pictures were scored for early alpha atresia in the 3 follicle classes by AZTI, IEO, IMARES, MI and IMR (Table 4.3.1.4).

For sample C25 the differences was in general less than that found during the former ringtest, but MI and AZTI 2 scored a much larger number than the others. For sample G73, MI still scored too high and IEO had a low score. MI did not participate in the atresia analysis of the survey samples.

Because the labs involved had different equipment and histological standard procedures it was decided that AZTI would use haematoxylin and eosin staining, IEO Pass-schiff, whilst IMARES and IMR used toluidine blue. From discussions on images taken from slides with different staining the participants considered staining method to be of little importance for the atresia scoring.

4.3.2 Comparison of Mackerel Fecundity Data from the 2010 Triennial Survey

The fecundity samples of the 2010 triennial survey were evenly distributed between the labs. A comparison of the fecundity estimates (Table 4.3.2.1) between Scotland (MSS), Norway (IMR), Ireland (MI) and Spain (AZTI, IEO) showed that all institutes except MI had similar results. AZTI, IEO, IMR and MSS were not significantly different from the overall mean whilst MI was significantly lower (P = 0.9996). The reason for the small numbers from MI was probably due to unsatisfactory image quality; the pictures from MI had low contrast, hence the small transparent oocytes became more or less invisible. This also made it difficult to see the POF`s. Because of that MI also scored many more samples as prespawning compared to the other labs.

Based on these things WGMEGS decided to exclude the data from MI from the final fecundity estimates.

In 2010 two fecundity samples for each fish were distributed for comparison between the labs. In the discussion of this comparison we will leave out MI since the data they delivered was significantly different from the other labs (see above). For 57samples both labs agreed that the ovary sample should be analysed for fecundity. If we also accepted samples where only one of the labs scored it for fecundity, the number of samples rose to 82. If we in addition to this also included samples that by histology had been scored to be fit for fecundity analysis the number of samples further rose to 86. Tests showed that the overall mean fecundity estimate only changed very little between the three choices; 57, 82, or 86 samples. Therefore, we decided to accept all these 86 samples. However, some of these samples were later excluded because of other biological criteria (condition factor, leading cohort and relative fecundity).

All taken together this clearly shows that for future work we should put even more effort into ring tests (distribute parallel samples among the labs) in the preparation for the next survey. It is also important that the equipment used for these analyses is of appropriate quality and is calibrated correctly in all the participating labs.

4.3.3 Comparison of Mackerel Atresia Data from the 2010 Triennial Survey

The geometric mean of early alpha atresia showed good similarity between the labs (Table 4.3.3.1). For prevalence there were larger differences. In particular IMARES and MSS differed from the others with IMARES having a very low value while MSS had a very high one. However, this is probably caused by IMARES preparing all the images for both labs then by coincidence sending images with high atresia levels to MSS. The combined prevalence for IMARES and MSS was 0.3, which is close to the other institutes.

In total it seems like the ring tests on atresia had a good effect and that the final survey analysis were reasonably similar between the labs.

Table 4.3.1.1. Fecundity counts comparing participants working with 8 images.

Total counts	**Image number**							
Participant	A09	A109	A113	A125	A81	A85	A97	C49
MSS 1		318	228	290			340	
IEO 1	197	302	222					
AZTI	199	296	235	293	380	278	336	
IMR 1		313	224	288			330	
Cefas		290		206			320	
IMARES 1		308	227	290			331	
MSS 2		297	219	286			293	
IMARES 2		275	210	277		296	302	
IEO 2		305	223	287				
IMR 2		313		298			340	
MII		295		283			318	
Average	**198**	**301**	**224**	**280**	**380**	**287**	**323**	
Median	**198**	**302**	**224**	**288**	**380**	**287**	**330**	
Min	**197**	**275**	**210**	**206**	**380**	**278**	**293**	
Max	**199**	**318**	**235**	**298**	**380**	**296**	**340**	
SD	**1.4**	**12.3**	**7.3**	**26.5**		**12.7**	**16.7**	

Manual counts	**Image number**							
Participant	A09	A109	A113	A125	A81	A85	A97	C49
MSS 1		92	78	69			138	
IEO 1	73	72	72					
AZTI	75	66	85	72	142	100	134	
IMR 1		86	74	68			128	
Cefas		61		68			118	
IMARES 1		78	77	69			129	
MSS 2		69	69	65			91	

Total counts	Image number							
IMARES 2		45	60	56		118	100	
IEO 2		75	73	66				
IMR 2		85		78			138	
MII		66		62			116	
Average	**74**	**72**	**74**	**67**	**142**	**109**	**121**	
Median	**74**	**72**	**74**	**68**	**142**	**109**	**128**	
Min	**73**	**45**	**60**	**56**	**142**	**100**	**91**	
Max	**75**	**92**	**85**	**78**	**142**	**118**	**138**	
SD	**1.4**	**13.2**	**7.3**	**5.8**		**12.7**	**16.7**	

Automatic counts	Image number							
Participant	A09	A109	A113	A125	A81	A85	A97	C49
MSS 1		226	150	221			202	
IEO 1	124	230	150					
AZTI	124	230	150	221	238	178	202	
IMR 1		227	150	220			202	
Cefas		229		138			202	
IMARES 1		230	150	221			202	
MSS 2		228	150	221			202	
IMARES 2		230	150	221		178	202	
IEO 2		230	150	221				
IMR 2		228		220			202	
MII		229		221			202	
Average	**124**	**229**	**150**	**213**	**238**	**178**	**202**	
Median	**124**	**229**	**150**	**221**	**238**	**178**	**202**	
Min	**124**	**226**	**150**	**138**	**238**	**178**	**202**	
Max	**124**	**230**	**150**	**221**	**238**	**178**	**202**	
SD	**0.0**	**1.4**	**0.0**	**26.2**		**0.0**	**0.0**	

Mean Diameter	Image number							
Participant	A09	A109	A113	A125	A81	A85	A97	C49
MSS 1		412	423	425			388	
IEO 1	584	507	546					
AZTI	584	507	546	500	283	525	526	
IMR 1		507	546	501			526	
Cefas		507		501			527	
IMARES 1		507	546	500			526	
MSS 2		507	546	500			526	
IMARES 2		507	547	500		525	526	
IEO 2		507	546	500				
IMR 2		507		501			526	
MII		507		500			924	
Average	**584**	**498**	**531**	**493**	**283**	**525**	**555**	

Total counts	**Image number**							
Median	**584**	**507**	**546**	**500**	**283**	**525**	**526**	
Min	**584**	**412**	**423**	**425**	**283**	**525**	**388**	
Max	**584**	**507**	**547**	**501**	**283**	**525**	**924**	
SD	**0.0**	**28.6**	**43.5**	**23.8**		**0.0**	**145.7**	

Maximum diameter	**Image number**							
Participant	A09	A109	A113	A125	A81	A85	A97	C49
MSS 1		787	775	771			810	
IEO 1	918	787	775					
AZTI	918	787	775	771	733	944	810	
IMR 1		787	775	771			810	
Cefas		787		771			810	
IMARES 1		787	775	771			810	
MSS 2		787	775	771			810	
IMARES 2		787	775	771		944	810	
IEO 2		787	775	770				
IMR 2		787		771			810	
MII		787		771			1025	
Average	**918**	**787**	**775**	**771**	**733**	**944**	**834**	
Median	**918**	**787**	**775**	**771**	**733**	**944**	**810**	
Min	**918**	**787**	**775**	**770**	**733**	**944**	**810**	
Max	**918**	**787**	**775**	**771**	**733**	**944**	**1025**	
SD	**0.0**	**0.0**	**0.0**	**0.3**		**0.0**	**71.7**	

Minimum diameter	**Image number**							
Participant	A09	A109	A113	A125	A81	A85	A97	C49
MSS 1		258	252	251			264	
IEO 1	262	258	252					
AZTI	262	258	252	251	250	274	264	
IMR 1		258	252	251			264	
Cefas		258		251			264	
IMARES 1		258	252	251			264	
MSS 2		258	252	251			264	
IMARES 2		257	251	251		274	264	
IEO 2		257	251	251				
IMR 2		258		251			264	
MII		229		251			824	
Average	**262**	**255**	**252**	**251**	**250**	**274**	**326**	
Median	**262**	**258**	**252**	**251**	**250**	**274**	**264**	
Min	**262**	**229**	**251**	**251**	**250**	**274**	**264**	
Max	**262**	**258**	**252**	**251**	**250**	**274**	**824**	
SD	**0.0**	**8.7**	**0.5**	**0.0**		**0.0**	**186.7**	

Table 4.3.1.2. Post workshop ring test on whole mount fecundity counting.

Counts							
	hm03	hm05	hm07	hm09	hm11	hm15	il60
AZTI_1	320	280	768	778	347	299	749
AZTI_2	323	268	805	790	366	318	
AZTI_3	332	276	806	831	365	329	844
IEO_1	341	280	807	831	372	330	807
IEO_2	327	273	786	800	362	321	797
IMA_1	316	271	572	795	355	335	804
IMR_2	325	274	796	806	355	331	784
IMR_1	329	274	804	802	350	337	806
MII	320	267		784	342		772
Average	**326**	**274**	**768**	**802**	**357**	**325**	**795**
Median	**325**	**274**	**800**	**800**	**355**	**330**	**801**
Min	**316**	**267**	**572**	**778**	**342**	**299**	**749**
Max	**341**	**280**	**807**	**831**	**372**	**337**	**844**
SD	**7.5**	**4.6**	**80.3**	**18.7**	**9.9**	**12.3**	**28.1**

Mean diameter							
	hm03	hm05	hm07	hm09	hm11	hm15	il60
AZTI_1	491	523	360	399	427	458	356
AZTI_2	406	523	360	400	427	459	
AZTI_3	491	524	360	400	426	459	357
IEO_1	491	524	360	400	426	459	357
IEO_2	491	524	360	400	426	459	357
IMA_1	234	523	359	399	426	458	356
IMR_2	491	523	360	400	426	459	357
IMR_1	491	524	360	400	426	459	357
MII	491	523		399	427		356
Average	**453**	**523**	**360**	**400**	**426**	**459**	**357**
Median	**491**	**523**	**360**	**400**	**426**	**459**	**357**
Min	**234**	**523**	**359**	**399**	**426**	**458**	**356**
Max	**491**	**524**	**360**	**400**	**427**	**459**	**357**
SD	**86.8**	**0.5**	**0.4**	**0.5**	**0.5**	**0.5**	**0.5**
Leading cohort (p95)							
	hm03	hm05	hm07	hm09	hm11	hm15	il60
AZTI_1	611	684	423	516	683	750	519
AZTI_2	606	684	423	516	683	750	
AZTI_3	611	685	423	517	683	750	524
IEO_1	611	685	423	517	683	750	524
IEO_2	611	685	423	517	683	750	524
IMA_1	584	684	423	516	683	750	524
IMR_2	611	684	423	516	683	750	524
IMR_1	611	685	423	517	683	750	524
MII	611	684		515	683		524

Average	**607**	**684**	**423**	**516**	**683**	**750**	**523**
Median	**611**	**684**	**423**	**516**	**683**	**750**	**524**
Min	**584**	**684**	**423**	**515**	**683**	**750**	**519**
Max	**611**	**685**	**423**	**517**	**683**	**750**	**524**
SD	**8.9**	**0.5**	**0.0**	**0.7**	**0.0**	**0.0**	**1.8**

Table 4.3.1.3. Atresia ring test scores for 10 participating persons from seven institutes. Persons scored alpha atresia in three follicle classes, from six pictures stained with Toluidine blue.

YV	YV-YG	YG	NegGrid	YV-P	YV-YG-P	YG-P	Fish_id	Institute	Person	Hits	Profs
0	0	67	6	0	0	6	C57	IEO	1	67	6
0	0	92	5	0	0	8	C57	AZTI	1	92	8
0	0	96	5	0	0	6	C57	IMR	1	96	6
0	19	114	96	0	2	6	C57	Cefas	1	133	8
0	0	108	5	0	0	7	C57	IMARES	1	108	7
0	15	94	96	0	2	8	C57	IMARES	2	109	10
0	0	55	0	0	0	6	C57	IEO	2	55	6
0	0	135	124	0	0	8	C57	MSS	1	135	8
0	0	98	5	0	0	6	C57	IMR	2	98	6
0	20	98	5	0	17	6	C57	MI	1	118	23
									Average	**101.1**	**8.8**
									Median	**103**	**7.5**
									Min	**55**	**6**
									Max	**135**	**23**
									SD	**25.8**	**5.2**

Table 4.3.1.4. Atresia ring test scores for 7 participating persons from 5 institutes. Persons scored alpha atresia in three follicle classes, from 2 different fish, six pictures each, stained with Toluidine blue.

YV	YV-YG	YG	NegGrid	YV-P	YV-YG-P	YG-P	Fish_id	Institute	Person	Hits	Profs
60	0	0	7	21	0	0	C25	IMR	1	60	21
0	61	0	8	0	23	0	C25	IMR	2	61	23
0	119	13	9	0	36	5	C25	MI	1	132	41
67	0	0	0	24	0	0	C25	AZTI	1	67	24
102	0	0	0	34	0	0	C25	AZTI	2	102	34
50	3	0	0	18	2	0	C25	IEO	1	53	20
61	0	0	9	21	0	0	C25	IMARES	1	61	21
									Average	**77**	**26**
									Median	**61**	**23**
									Min	**53**	**20**
									Max	**132**	**41**
									SD	**29.2**	**8.0**

YV	YV-YG	YG	NegGrid	YV-P	YV-YG-P	YG-P	Fish_id	Institute	Person	Hits	Profs
33	210	629	0	14	47	37	G73	IMR	1	872	98
0	346	562	2	0	63	36	G73	IMR	2	908	99
5	614	332	2	3	95	23	G73	MI	1	951	121
0	217	416	0	0	50	48	G73	AZTI	1	633	98
0	289	406	0	0	58	46	G73	AZTI	2	695	104
23	74	499	0	6	17	28	G73	IEO	1	596	51
0	435	352	2	0	65	19	G73	IMARES	1	787	84
									Average	**777**	**94**
									Median	**787**	**98**
									Min	**596**	**51**
									Max	**951**	**121**
									SD	**139.5**	**21.7**

Table 4.3.2.1. Relative potential fecundity estimates based on fecundity counts from the 5 participating labs. Estimates were taken from the 2010 triennial dataset.

Lab	Mean	N	SD	Lower 95% CI	Upper 95% CI
AZTI	1155	28	361	1014	1294
IEO	1260	19	353	1090	1430
IMR	1099	24	403	929	1269
MI	895	29	285	800	990
MSS	1129	13	269	966	1291
All	1129	91	32	995	1123
All minus MI	1140	74	342	1039	1196

Table 4.3.3.1. Relative atresia estimates based on counts from the 5 participating labs. Estimates were taken from the 2010 triennial dataset.

Variable	Obs	GeometricMean	Lower 95% CI	Upper 95% CI	Total N	Prevalence
AZTI	33	29.0	21.7	38.8	86	0.38
IEO	35	29.6	21.6	40.5	110	0.32
IMARES	19	28.0	17.8	44.1	104	0.18
MSS	22	25.9	15.8	42.6	33	0.67
IMR	82	23.8	18.8	30.2	179	0.46

4.4 Fecundity Estimation of Northeast Atlantic Mackerel

4.4.1 Potential Fecundity in the Western and Southern Combined Spawning Component

Samples to determine mackerel potential fecundity were collected from trawl hauls made between 40 to 62 degrees north from 15 different vessels (Table 4.4.1.1, Figure 4.4.1.1) in period 1–6. These samples were distributed between Norway, Scotland, Ireland and Spain and analysed according to methods described in the ICES, 2009

fecundity manual. Spawning fish were excluded from the estimate of fecundity on the presence of hydrated oocytes, postovulatory follicles and leading cohort below 400 μm or above 800 μm in the dispersed ovary samples (see Section 4.3.2 for more details).

As a quality check on the data we initially did frequency histograms of fish length, weight, Fulton´s condition factor (100 • weight/length^3), and relative fecundity (Figures 4.4.1.2–5). Histograms of fish length and weight apparently showed only normal values. The histograms of Fulton´s K and relative potential fecundity however, showed outlier values that most likely were caused by some sort of measuring error. For further fecundity and atresia estimates we therefore decided to only include samples that came from fish with condition factors between 0.5 and 1.2. Also we decided to consider relative fecundities outside the interval 300–2100 (n/g) as errors.

Plots of annual potential fecundity against fish length (Figure 4.4.1.6) and weight (Figure 4.4.1.7) showed a strong positive trend that was rather similar to those that were found in 2004 and 2007. As was also seen in previous years relative fecundity vs. length or weight (Figures 4.4.1.8 and 4.4.1.9) only showed weak positive trends.

In 2001, 2004 and 2007 the overall estimate of relative potential fecundity seemed to be slightly influenced by latitude but this pattern was absent in 2010 (Figure 4.4.1.10)

From the oocyte size distributions we could estimate what is commonly called the leading cohort. For the assessment year of 2010 leading cohort is defined as the 95 percentile which should correspond well with the definition of leading cohort in 2007 (mean of the largest 10% in the oocyte size distribution). Leading cohort may be interpreted as a proxy for stage of maturity. When plotting (Figure 4.4.1.11) relative fecundity for all periods against leading cohort we got a domed shape curve in 2007. The initial rise in relative fecundity in 2007 showed that ovaries in early maturation are still recruiting new oocytes from the pre-vitellogenic pool. The observed decrease seemed to occur when the leading cohort was larger than 800 μm. This was probably caused by atresia, or because some of these fish had started spawning. With the criteria used to select fecundity samples in 2010 (see above) we no longer found any trend in relative fecundity by leading cohort (Figure 4.4.1.12). This may especially be due to the stricter criteria to discriminate spawning fish, but also the limitations set on leading cohort (400–800 μm).

The stricter criteria used in 2010 to discriminate spawning fish was probably the cause of the much smaller number of fecundity samples obtained (74 samples, Table 4.4.1.2) compared to the years from 1998–2007 (96–205 samples). It would be desirable to have a larger sample number than that obtained for 2010. However, preference is given to a smaller number of samples - such as was obtained in 2010 - using stricter criteria for detection of spawning, compared to the larger number of samples obtained in previous years where the estimates most likely included data from spawning fish. The likely consequence of including data from spawning fish in the fecundity estimate is a skewing of the fecundity estimate downwards.

In earlier years the final potential fecundity estimate used for the SSB estimate was based on samples collected early in the spawning season (period 1 and 2) only. The reasoning for this choice was that samples from later in the spawning season were more likely to come from spawning fish.

Looking into the fecundity estimates by periods (Table 4.4.1.3) we can see that for 2007 the potential fecundity estimates were reduced from period 1–2 (1066–1119 n/g) to a lower level for the later periods (819–925 n/g). For 2010 the changes between

periods were different, starting high at 1289 (n/g) in period 1 then being reduced to 927 (n/g) by period 3 then increased again to 1364 (n/g) in period 5. In period 6 there were no samples passing the prespawning criteria.

With the much stricter criteria to discriminate spawning fish used for the 2010 season we see no biological reason to continue using only period 1 and 2 for the final fecundity estimate. Including all periods will most probably reflect the total fecundity more correctly. However, since our fecundity estimates add to a time-series it is also important to evaluate how such changes will influence our final fecundity estimate (Table 4.4.1.4). For our 2010 estimate relative potential fecundity changed from 1167 (n/g) to 1140 going from a period 1–2 estimate to a 1–6 estimate. We consider this change as minor and not a serious change in the time-series. For 2007 however (Table 4.4.1.3), the reduction was larger, from 1098 to 995. The larger reduction for the 2007 estimate might be caused by a higher fraction of samples from spawning fish in the later periods.

4.4.2 Atresia and Realized Fecundity of the Western and Southern Combined Spawning Component

The samples used for analysis of atresia were collected from the entire survey area and during all periods. The samples were processed into histological sections and analysed by AZTI, IEO, IMARES, MSS and IMR (Table 4.4.2.1). The sections were used to determine the prevalence (proportion of fish with early alpha atresia) and relative intensity of atresia (number of atretic eggs per g female). These numbers were used to determine the amount of potential fecundity that did not contribute to the annual egg production of the stock. The loss of potential fecundity through atresia was calculated from the following equation (Horwood, 1990):

$A_r = A_g \times P \times D \times S$

Where Ar = loss of potential fecundity through atresia

A_g = geometric mean of relative atresia.

P = prevalence of atresia

D = duration of alpha atresia (7.5 days)

S = duration of mackerel spawning (60 days)

The atretic loss was highest in period 2–3 and period 6 (Table 4.4.2.1). This was mainly caused by higher incidence values (fraction of samples that have atresia) in these periods. The overall relative atretic loss (period 1–6) was estimated in 2010 to be 70 (n/g). This value is rather similar to what was estimated for the years from 2001 to 2007 (64–89 n/g), while earlier atresia estimates (Figure 4.4.2.1) in general were higher (320–180 n/g). We do not know whether this change has been caused by changes in methodology or represent real biological changes.

The level of atretic loss that have been estimated since 2001 (Figure 4.4.2.1) are small compared to the potential fecundity estimates that were found in the same period. Thus for the final realized fecundity estimate atresia has only been a small adjustment to the potential fecundity value.

By subtracting the estimated atretic loss (Table 4.4.2.1) estimated for 2010 (period 1–6) from the relative potential fecundity estimate (Table 4.4.1.4) from the same periods

we ended up with a final relative realized fecundity estimate for 2010 of 1070 (n/g). This was 6% higher than the value that was estimated for 2007 (1009). Looking at the time-series (Figure 4.4.2.1) it is clear that all the realized fecundity estimates from 1998 until today are rather close (1002–1070). However, earlier realized fecundity estimates were higher (1250–1430). It would be interesting to investigate whether this shift could be caused by methodological changes or a change in biology. Possibly the change may have been caused by a shift in fish condition, however this needs to be investigated further.

The standard error of the potential relative fecundity and relative atretic loss estimates were 39.75 and 4.10, respectively, resulting in a standard error of 39.97 and a CV of 3.7% for the realized relative fecundity estimate. Furthermore the 95% CI for the realized relative fecundity estimate was calculated to span from 992 – 1149 (Table 4.4.2.2).

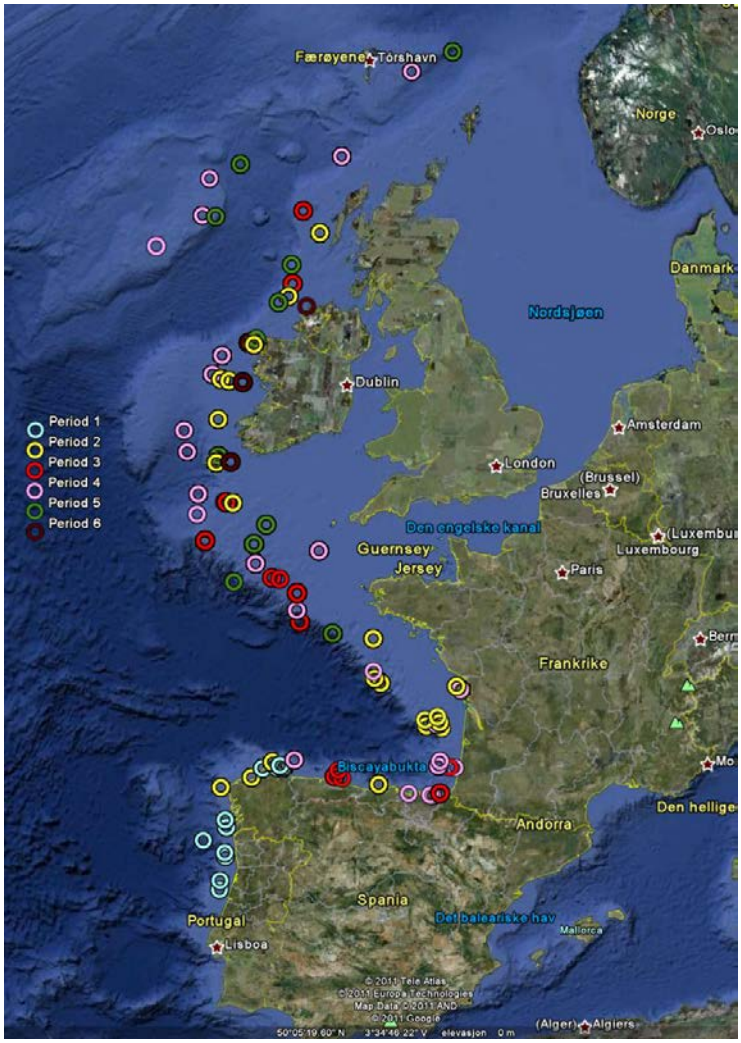


Figure 4.4.1.1. Distribution of ovary samples over the survey area for the assessment year 2010.

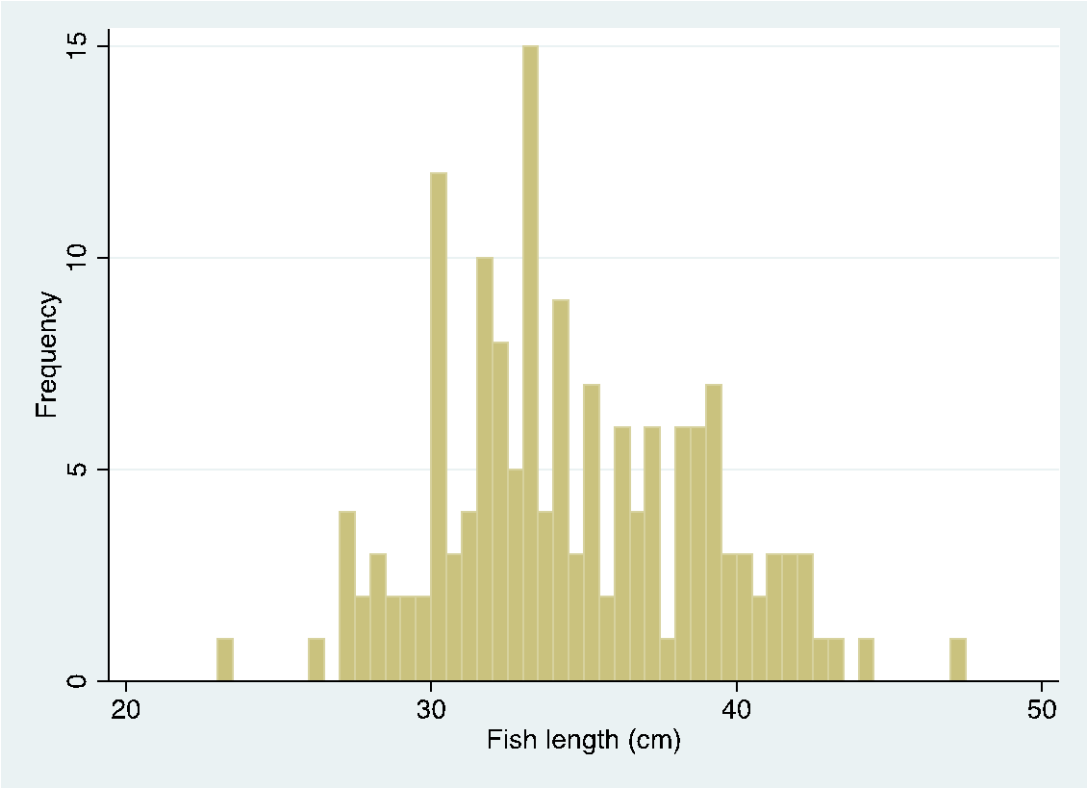


Figure 4.4.1.2. Fish lengths from Mackerel sampled during the 2010 surveys.

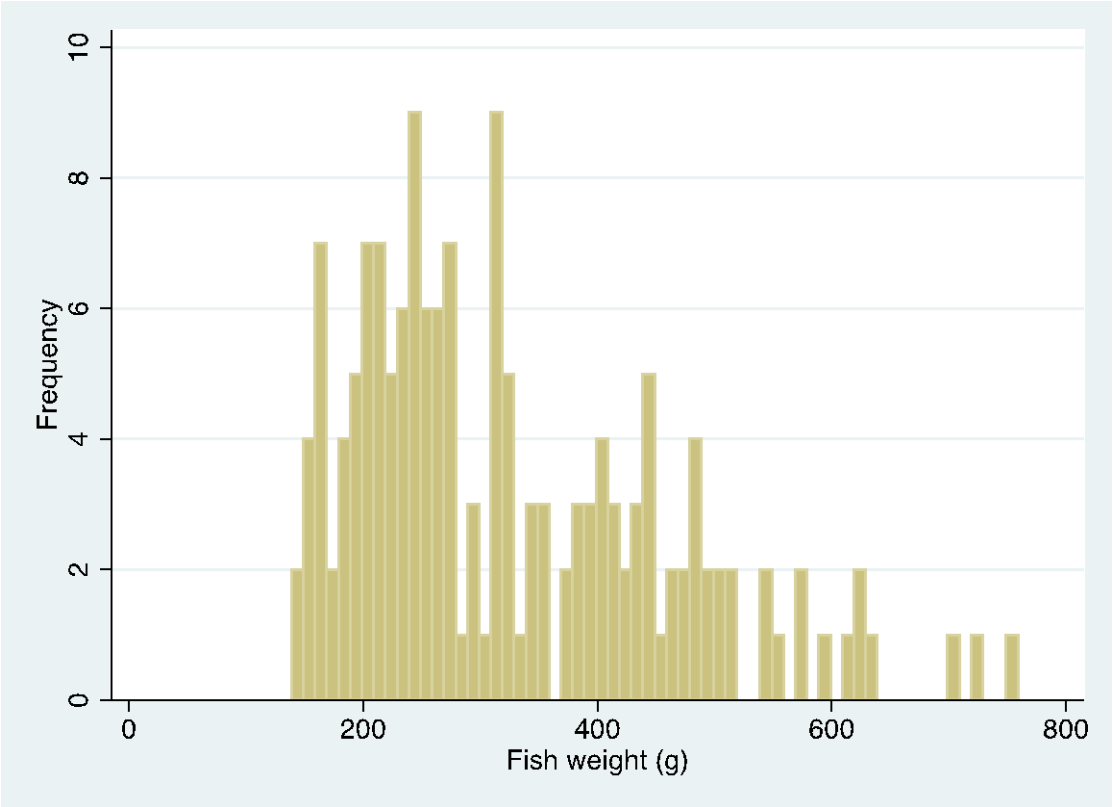


Figure 4.4.1.3. Fish weights from Mackerel sampled during the 2010 surveys.

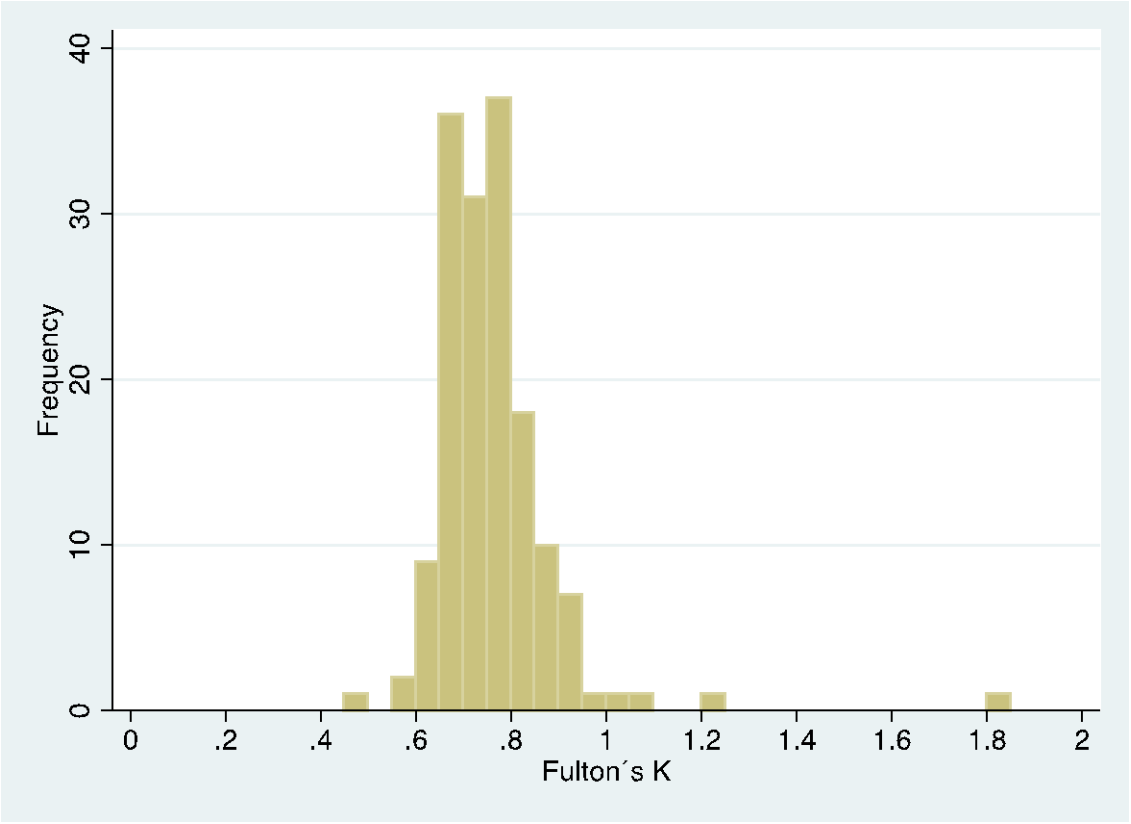


Figure 4.4.1.4. Fulton´s condition factor (100 • weight/length^3) from Mackerel sampled during the 2010 surveys.

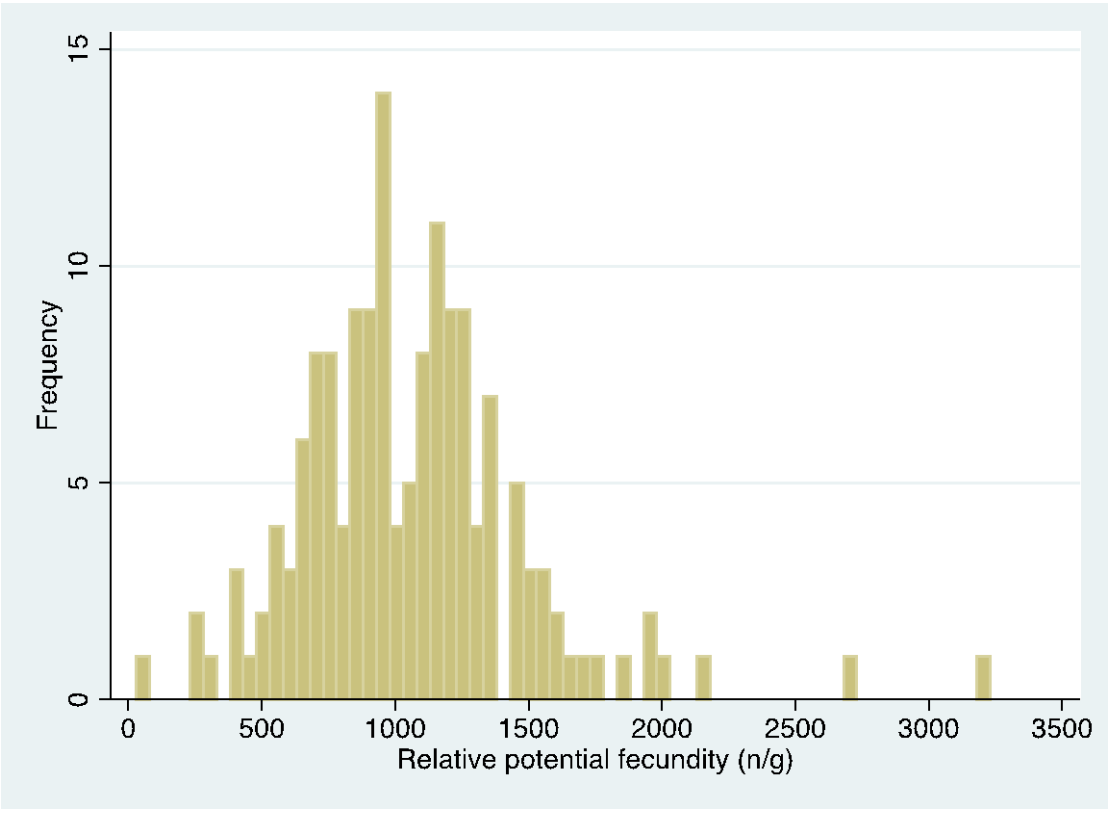


Figure 4.4.1.5. Relative potential fecundity (n/g) from Mackerel sampled during the 2010 surveys.

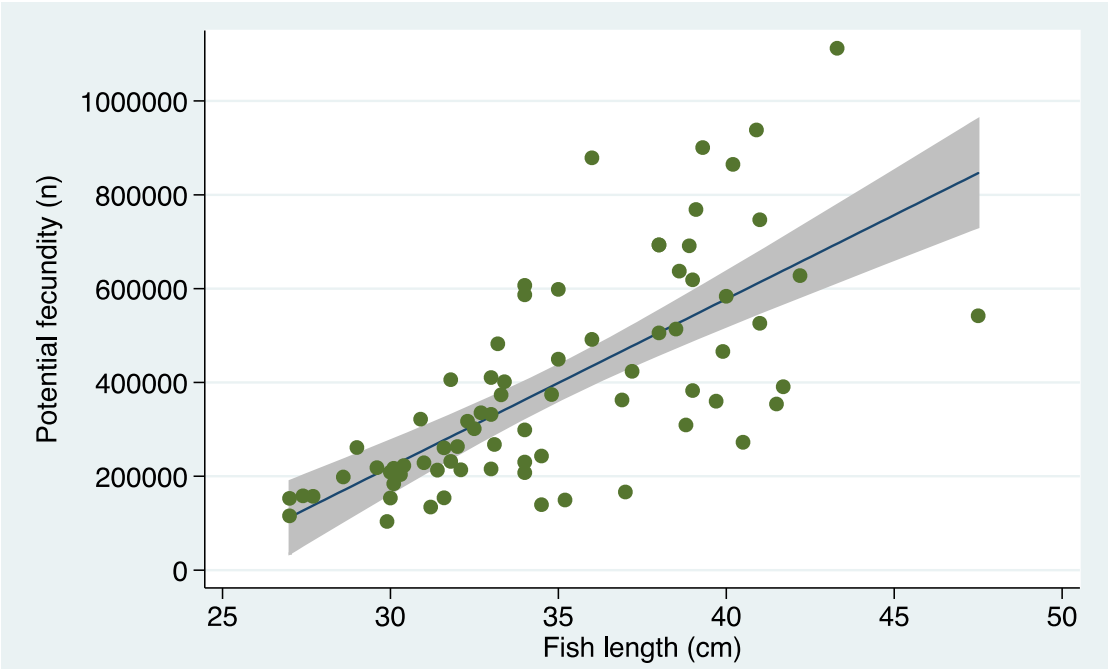


Figure 4.4.1.6. Potential fecundity (Fp) of Mackerel vs. length (L) for the assessment year 2010. Regression line: Fp = -853420 + 35781• L (R^2 = 0.49). Shaded area around regression line corresponds to 95% CI.

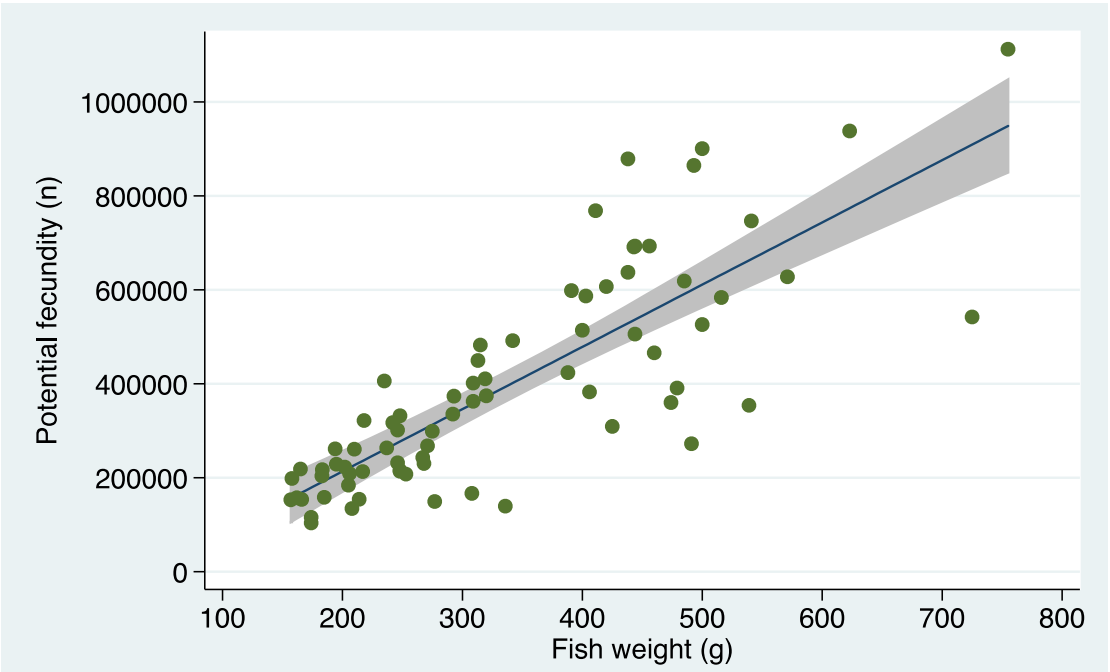


Figure 4.4.1.7. Potential fecundity (Fp) of Mackerel vs. weight (W) for the assessment year 2010. Regression line: Fp = -51669 + 1325 • W (R^2 = 0.66). Shaded area around regression line corresponds to 95% CI.

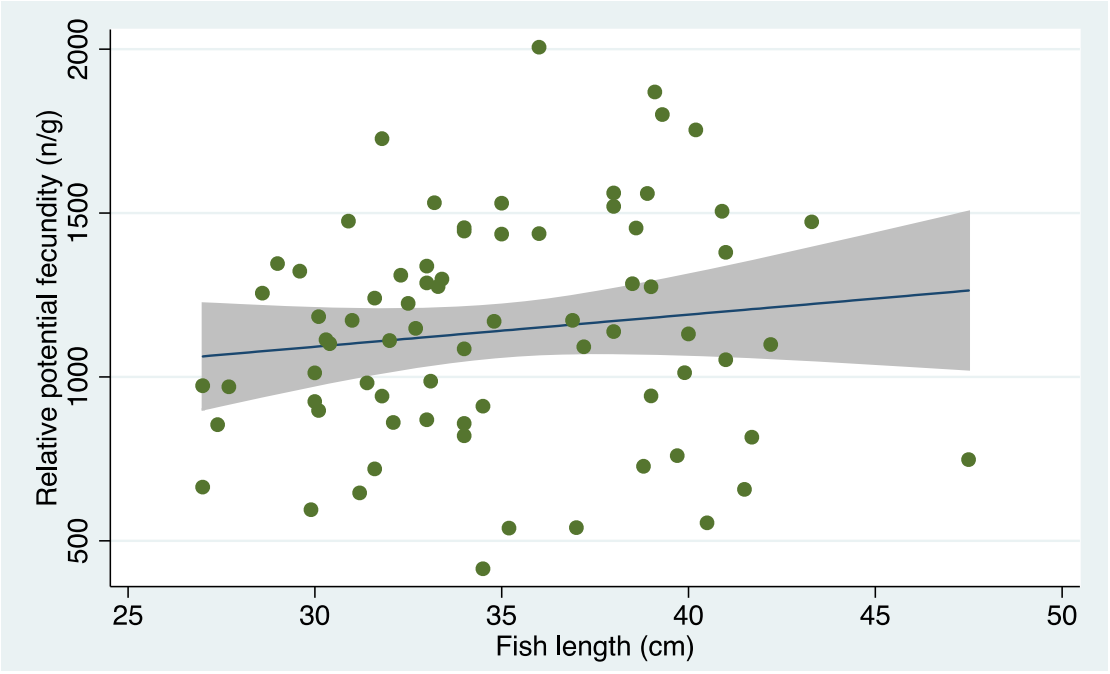


Figure 4.4.1.8. Relative potential fecundity (RFp) of Mackerel vs. length (L) for the assessment year 2010. Regression line: RFp = 798 + 9.80 • L (R^2 = 0.016). Shaded area around regression line corresponds to 95% CI.

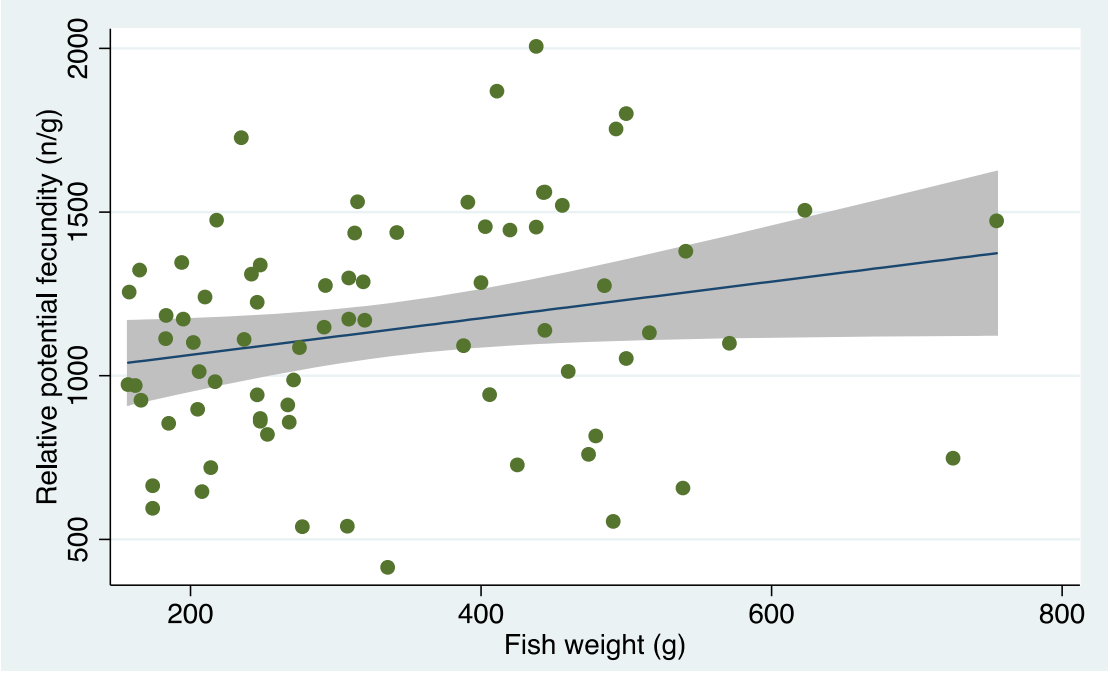


Figure 4.4.1.9. Relative potential fecundity (RFp) of Mackerel vs. weight (W) for the assessment year 2010. Regression line: RFp = 952 + 0.560 • W (R^2 = 0.052). Shaded area around regression line corresponds to 95% CI.

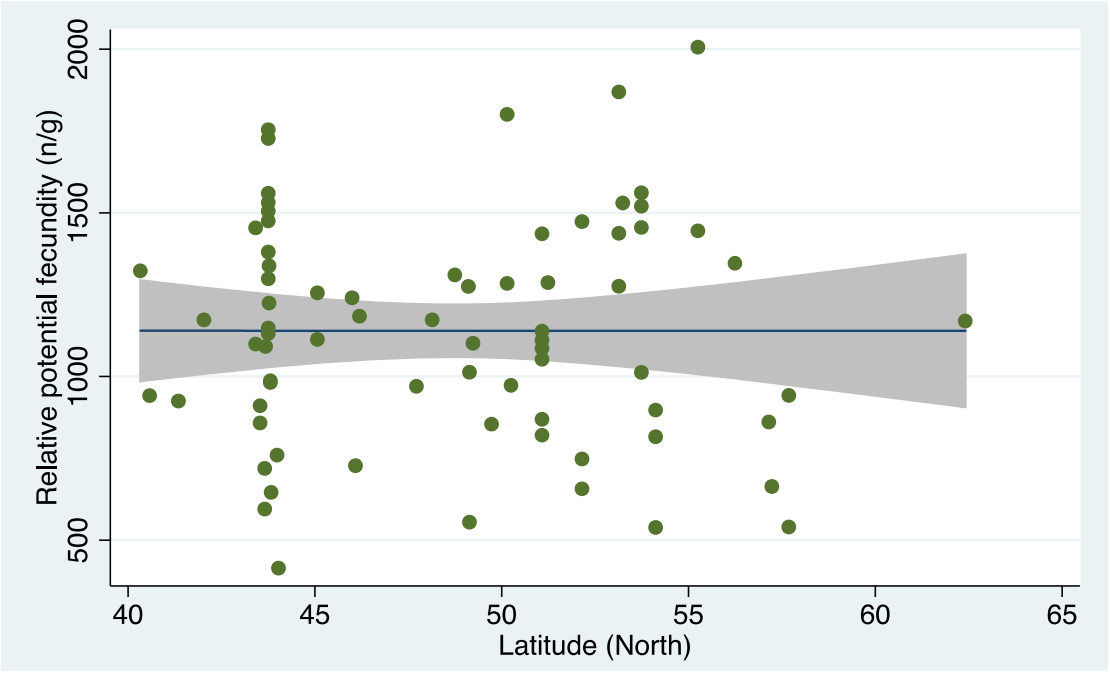


Figure 4.4.1.10. Relative potential fecundity (RFp) of Mackerel vs. latitude (N) for the assessment year 2010. Shaded area around regression line corresponds to 95% CI.

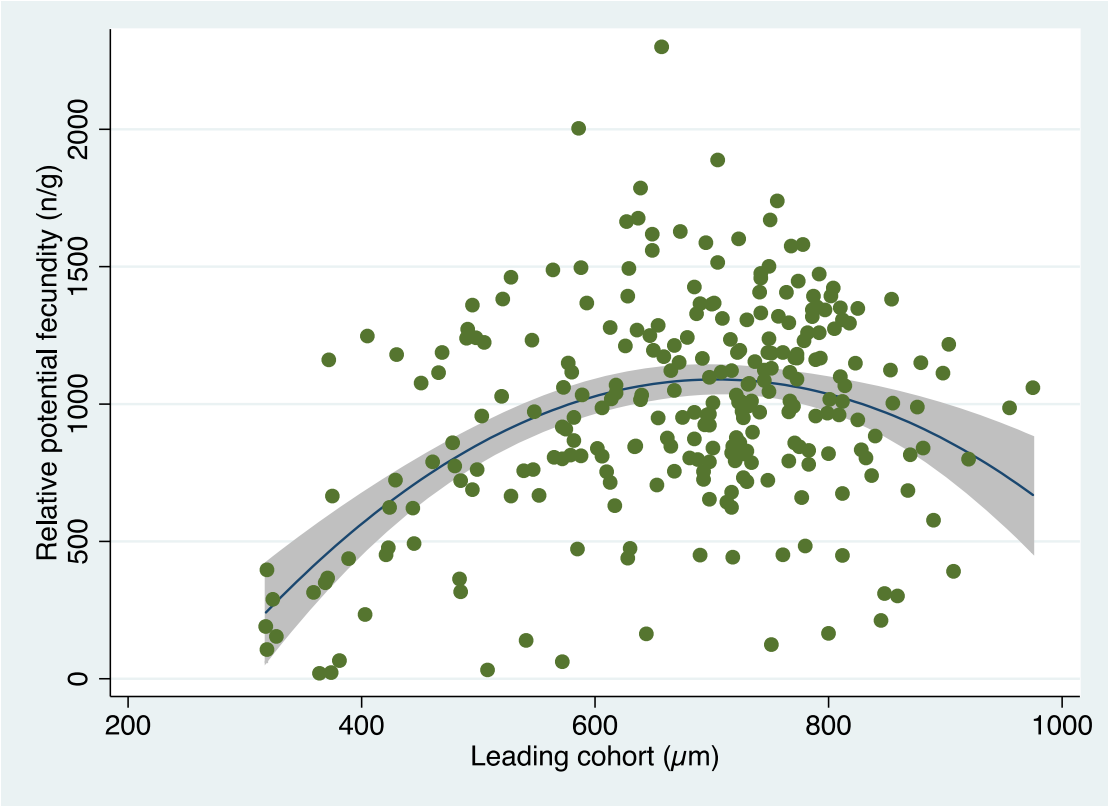


Figure 4.4.1.11. Relative potential fecundity of Mackerel vs. oocyte leading cohort for the assessment year 2007. Leading cohort was defined as the mean of the upper 10% of the maturing oocyte size distribution. Shaded area around regression line corresponds to 95% CI.

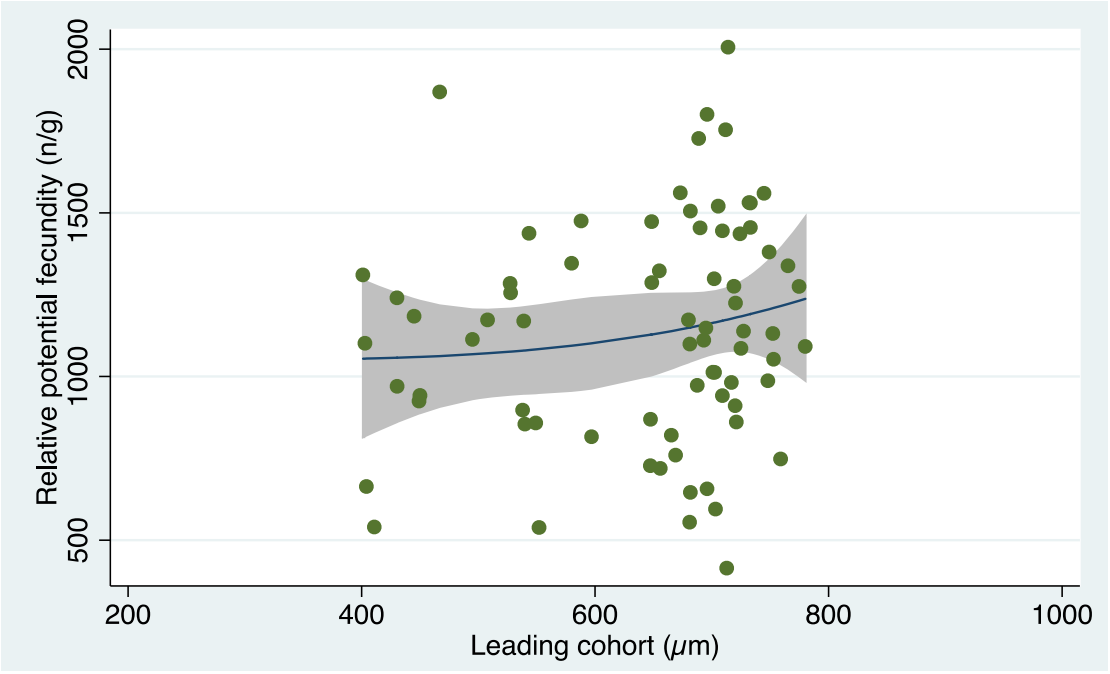


Figure 4.4.1.12. Relative potential fecundity of Mackerel vs. oocyte leading cohort for the assessment year 2010. Leading cohort was defined as the 95 percentile. Shaded area around regression line corresponds to 95% CI.

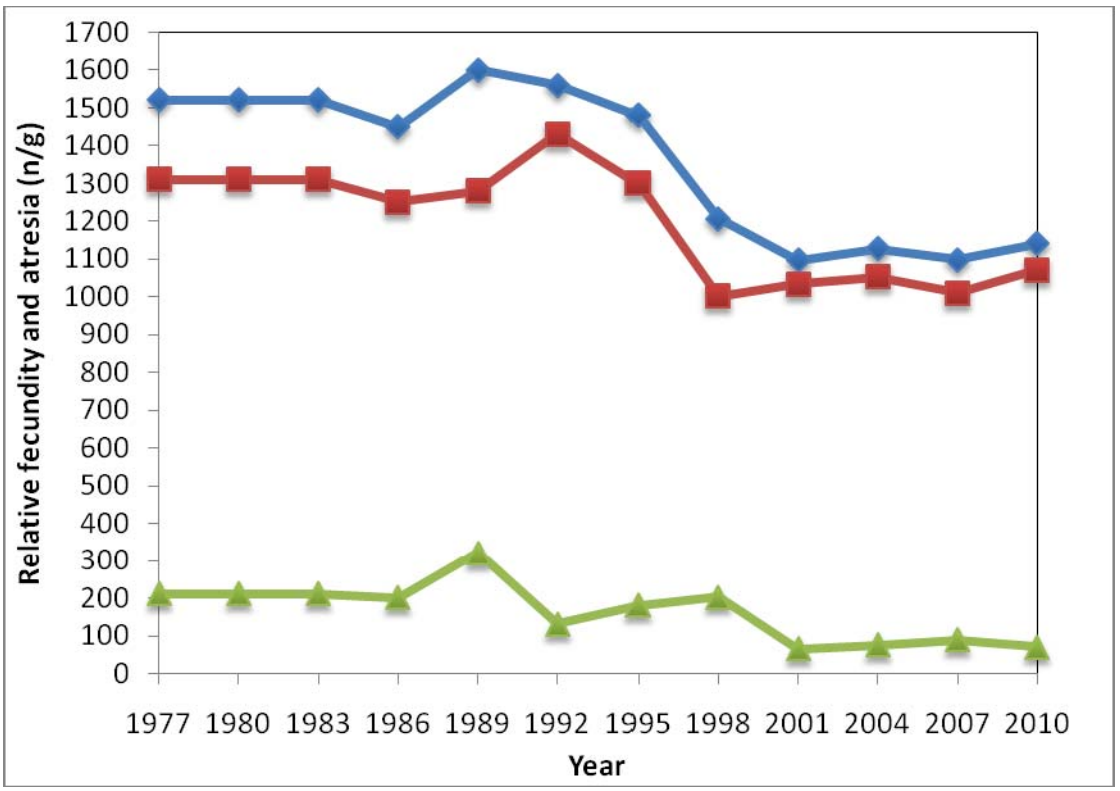


Figure 4.4.2.1. Relative potential fecundity (blue upper line), relative realized fecundity (red middle line) and relative atresia (green lower line) by assessment year.

Table 4.4.1.1. Number of fecundity and atresia samples collected by each vessel.

Ship	No. Samples
Celtic Explorer	130
Commercial samples.	60
Cornide de Saave	32
Thalassa	40
CV_SinNombre	20
Emma Bardan	101
Johan Hjort	60
Noruega	40
Tridens	120
Walther Herwig III	159
Corystes	36
Scotia	31
Unity	55
Magnus Heinason	20
Árni Friðriksson	15
Total	919

Table 4.4.1.2. Results of fecundity and atresia analysis in the assessment years from 1998 to 2010.

	Assessment year				
Parameter	1998	2001	2004	2007	2010
Number of samples analysed for fecundity (n)	96	187	205	176	74
Number of samples analysed for atresia (n)	112	290	348	416	511
Relative potential fecundity (n/g)	1206	1097	1127	1098	1140
Prevalence of atresia	0.55	0.2	0.28	0.38	0.33
Geometric mean relative intensity of atresia (n/g)	46	40	33	30	26
Potential fecundity lost per day (n/g)	3.37	1.07	1.25	1.48	1.16
Potential fecundity lost per spawning season (n/g)	202	64	75	89	70
Relative realized fecundity (n/g)	1002	1033	1052	1009	1070
Percentage of relative potential fecundity lost	17	6	7	9	6

Table 4.4.1.3. Relative potential fecundity (n/g) by period for the assessment year 2007.

2007				
Period	Average	Count	Lower 95% CI	Upper 95% CI
1	1066	71		
2	1119	105		
3	819	48		
4	840	29		
5	869	36		
6	925	9		
1–2	**1098**	**176**	**1054**	**1141**
1–6	**995**	**298**		

Table 4.4.1.4. Relative potential fecundity (n/g) by period for the assessment year 2010.

2010					
Period	Average	St. dev	Count	Lower 95% CI	Upper 95% CI
1	1289	255	19	1172	1406
2	1081	301	27	966	1197
3	927	405	10	671	1182
4	1120	364	13	919	1321
5	1364	423	5	987	1741
6					
1–2	**1167**	**299**	**46**	**1078**	**1256**
1–6	**1140**	**342**	**74**	**1060**	**1219**

Table 4.4.2.1. Relative atresia (n/g) by period for the assessment year 2010.

Period	Geom. mean	Lower 95% CI	Upper 95% CI	Total Count	Preval-ence	Mean loss
1	28.3	18.0	44.4	70	0.19	42.0
2	26.5	21.8	32.1	163	0.50	106.7
3	35.4	26.3	47.8	53	0.53	149.6
4	24.3	12.0	49.0	113	0.11	20.6
5	14.0	3.3	59.3	74	0.07	7.6
6	21.0	13.5	32.8	38	0.76	128.2
1–2						
1–6	**26.3**	**22.8**	**30.3**	**511**	**0.33**	**69.6**

Table 4.4.2.2. Realized relative fecundity (n/g) by periods for the assessment year 2007 and 2010.

	2007	2010		
Period	Average	Average	Lower 95% CI	Upper 95% CI
1 - 2	1009	1097		
1 - 6	906	1070	992	1149

Biomass Estimation

Spawning-stock biomass (SSB) was estimated using the realized fecundity estimate of 1070 oocytes/g female, a sex ratio of 1:1 and a raising factor of 1.08 (ICES, 1987) to convert spawning fish to total fish. Standard errors and CVs were estimated using the methods in Section 3.3.3. This gave an estimate of spawning-stock biomass in 2010 of:

- 3,431 (SE of 613; CV of 17.9%) million tonnes for western component (2007: 2,945).
- 858 (SE of 715; CV of 83.3%) million tonnes for southern component (2007: 701).
- 4,289 (SE of 997; CV of 23.2%) million tonnes for western and southern components combined (2007: 3,646).

5 Horse Mackerel in the Western Areas: 2010 Egg Survey Results

5.1 Spatial Distribution of Stage I Horse Mackerel Eggs

The description of the spatial distribution of stage 1 horse mackerel eggs is presented for western area that since the WGMEGS 2005 also includes the Cantabrian Sea.

- **Period 2** – This period marked the start of surveying in the western area. There was comprehensive coverage throughout almost the entire western survey area for almost the entire area from Galicia north to northwest Scotland at 59°N (Figure 5.1.1). As a result of bad weather there were 3 interpolated transects at 45°15N, 48°15N and 49°15N. Significant egg production was reported along the Cantabrian Coast but other than that there were only low levels of egg production reported for this period and no spawning reported north of 52°N. Delineation of spawning boundaries was good and egg production tended to be concentrated around the 200m contour. Edges of spawning were well defined for almost the entire area. There were 32 interpolated stations.
- **Period 3** – In Period 3 sampling again ran from the north coast of Galicia to the north coast of Scotland, (Figure 5.1.2). Sampling was undertaken by three countries and whilst coverage was complete up to 50º30N, the remaining survey area north of this up to the boundary at 60ºN was completed using alternate transects. Significant spawning was recorded from the Cantabrian Sea north up to the northern boundary of the Porcupine Bank. The spawning boundaries were generally well delineated throughout the area with zero observations. There were 51 interpolated stations.
- **Period 4** – Sampling during this period was conducted between the eastern Cantabrian Sea and Faeroese waters up as far as 63°N (Figure 5.1.3). 5 vessels were surveying during this period and only very low levels of spawning activity were recorded during period 4. Any egg production was restricted to the Cantabrian Sea and the areas south of 52ºN along the 200m contour. Once again the boundaries were generally well defined although the likelihood is that some spawning activity was missed in the western Cantabrian Sea area. There were 10 interpolated samples.
- **Period 5** – Sampling was confined to an area north of 46° N, therefore a firm southern spawning boundary could not be established for horse mackerel in this period. However, given the absence of any significant egg production in the neighbouring observed stations it seems unlikely that any significant egg production has been missed in this area during period 4. Elsewhere the spawning boundary was generally well defined. This was the peak spawning period for the western horse mackerel with the highest densities being found between 47°N and 54° N. Egg production was typically concentrated around the 200m contour or contained within the continental shelf. There were 66 interpolated samples.
- **Period 6 –** Only one vessel was available for sampling in this period so consequently coverage was less comprehensive than in previous periods (Figure 4.1.5). Due to the size of the sampling area only alternate transects were sampled from 47°N to 56°30N. Despite this the boundaries were generally well defined especially in the south of the area where a firm spawning boundary was established. Less so the southwest corner of the Porcupine bank where some stations were missed due to lack of time

available as was the case with the northern boundary. It again seems unlikely that much spawning has been missed in the area north of 56°30N. Egg production was lower than in period 5 although there were a couple of spawning hot spots notably in the Celtic Sea and the Porcupine Bank. Again spawning tended to be concentrated around the 200m contour or contained within the continental shelf. There were 67 interpolated stations for period.

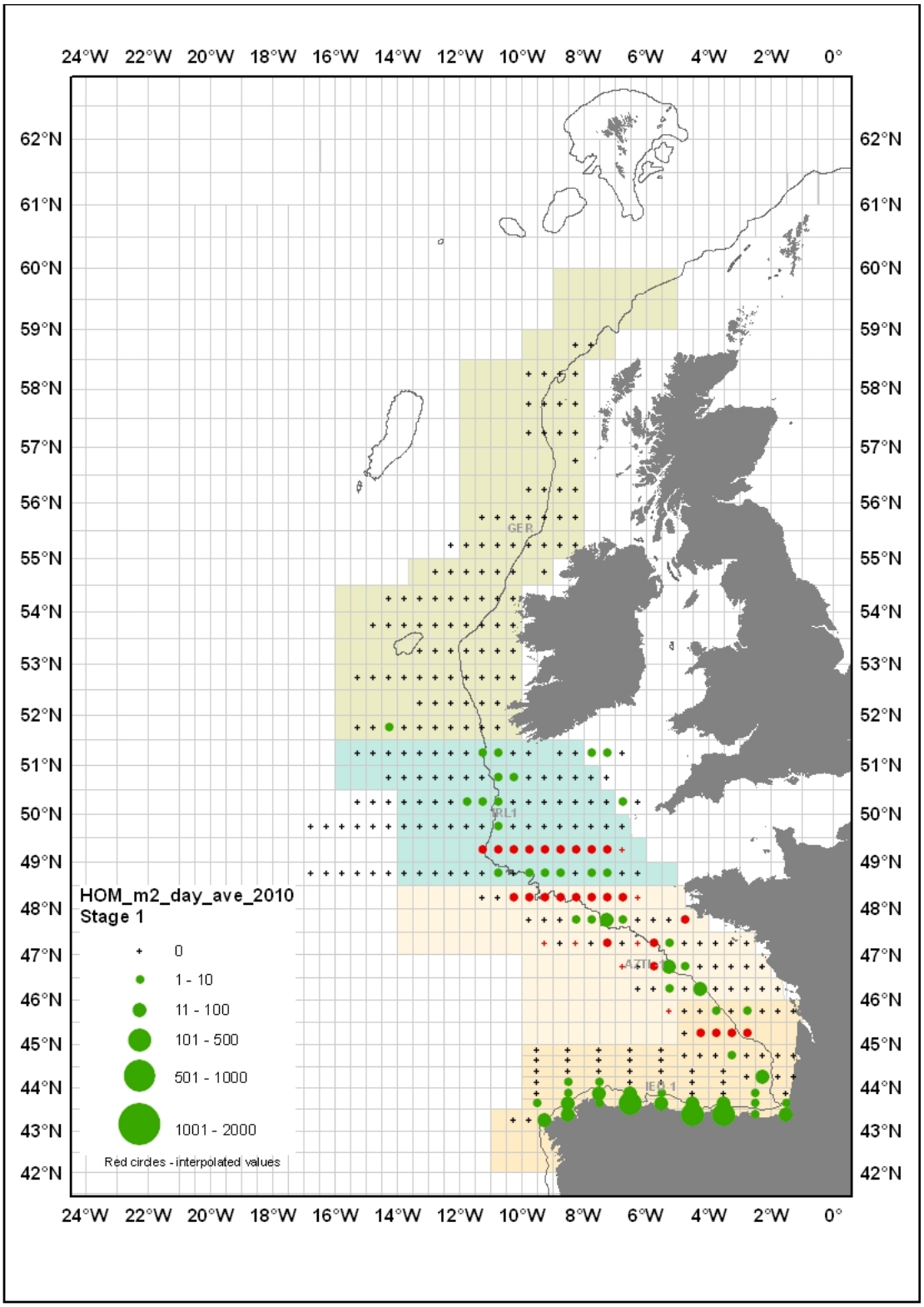


Figure 5.1.1. Horse mackerel egg production by half rectangle for period 2 (8 March – 11 April). Filled green circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

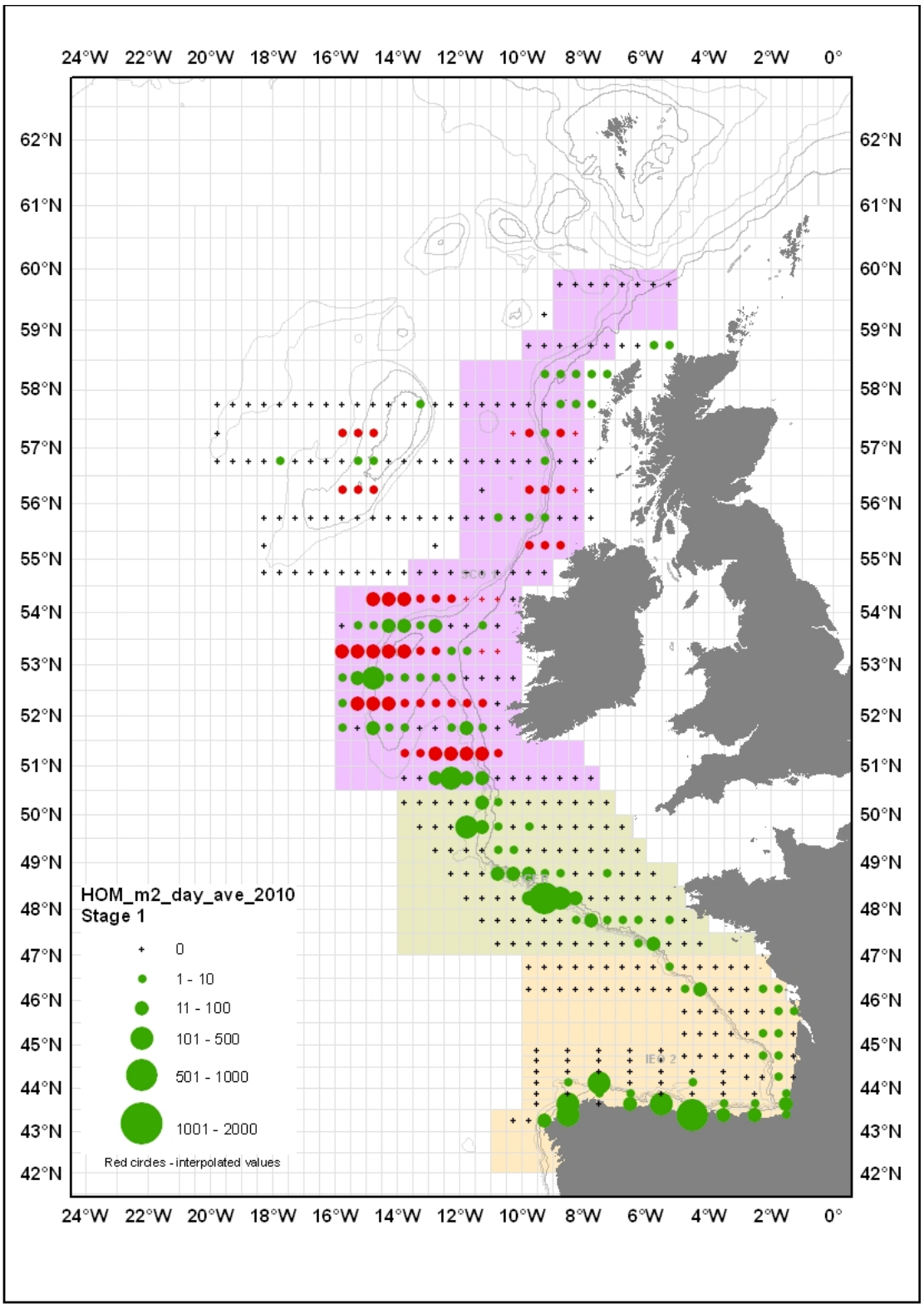


Figure 5.1.2. Horse mackerel egg production by half rectangle for period 3 (12 April – 9 May). Filled green circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

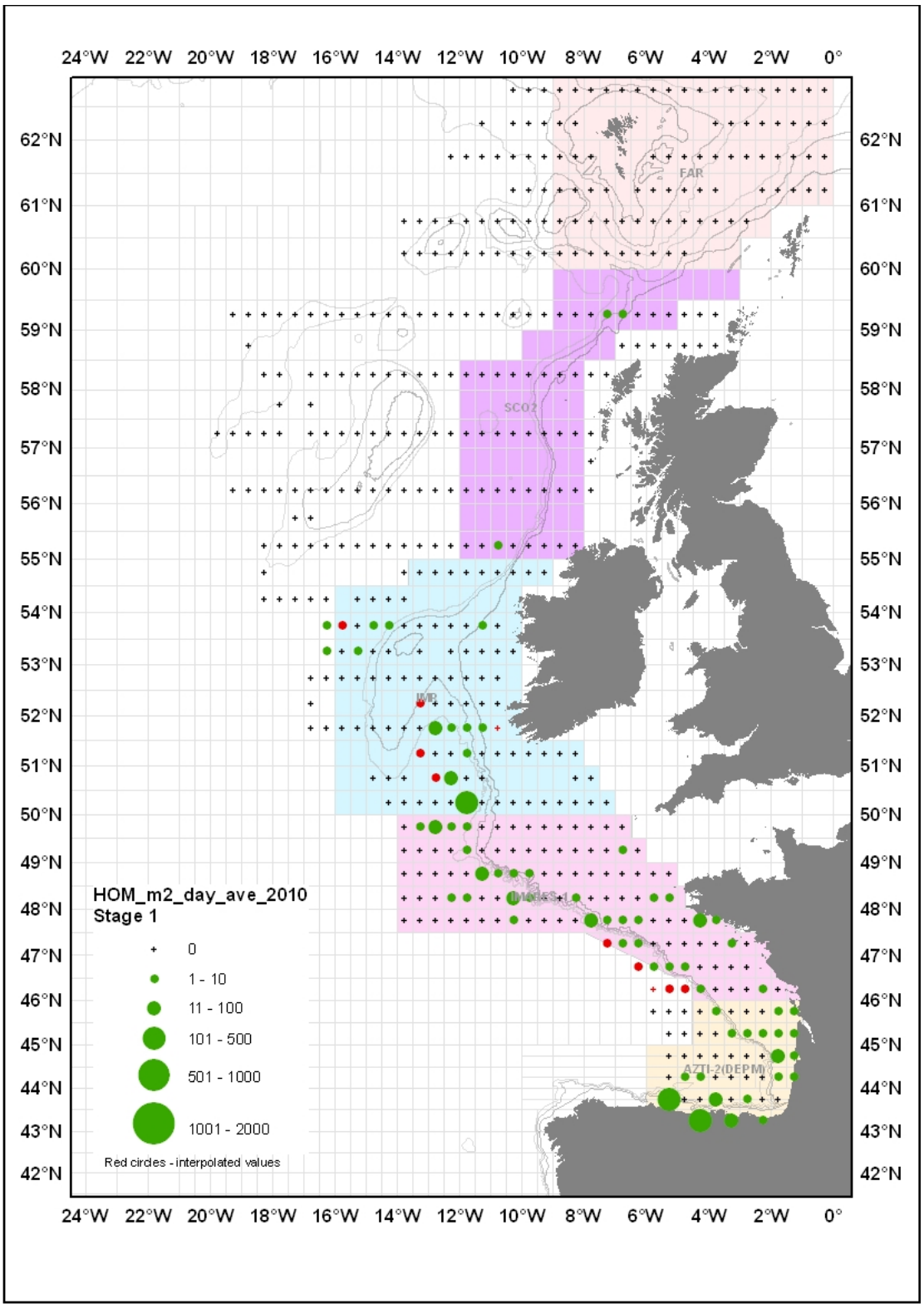


Figure 5.1.3. Horse mackerel egg production by half rectangle for period 4 (10 May – 30 May). Filled green circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

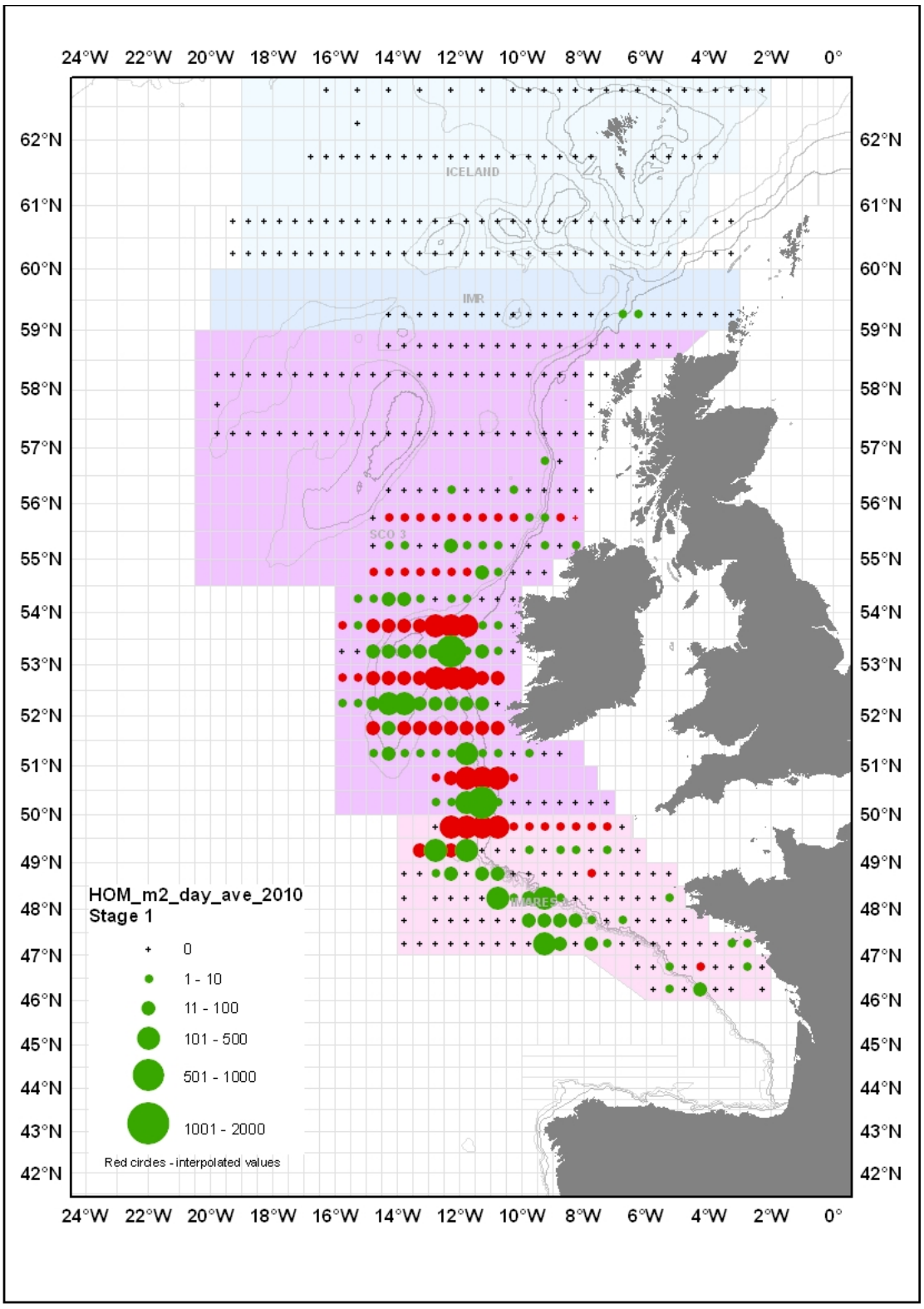


Figure 5.1.4. Horse mackerel egg production by half rectangle for period 5 (31 May – 4 July). Filled green circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

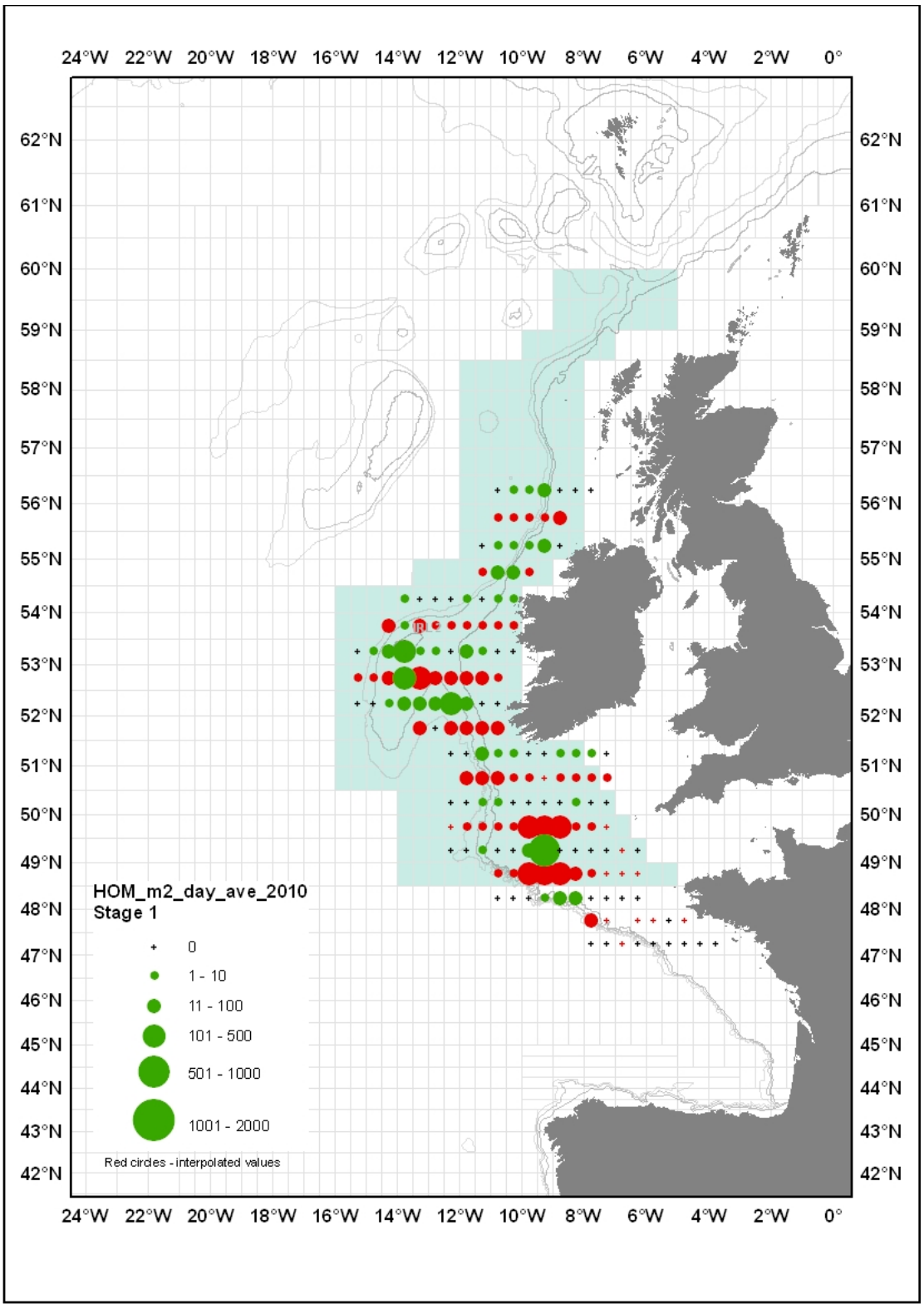


Figure 5.1.5. Horse mackerel egg production by half rectangle for period 6 (5 July – 31 July). Filled green circles represent observed values, filled red circles represent interpolated values, black crosses represent observed zeroes, red crosses interpolated zeroes.

5.2 Egg Production in Western Horse Mackerel

Figure 5.2.1 displays the mean daily stage I egg production estimates (DEP) for each survey period plotted against the mid-period days. The results of 1998, 2001, 2004 and 2007 are also included in the figure for comparison. Period production estimates are presented in Table 5. Period number and duration are the same as those used to estimate the western mackerel stock, as are the dates defining the start and end of spawning. The shape of the egg production curve does nothing to suggest that those dates should be altered for 2010 although it seems likely that some spawning will continue after the end of July. Production estimates for the individual survey periods and the period before the surveys are presented in Table 5.2.1. Like 2004, the survey periods were not completely contiguous and this has been accounted for in table 5. Annual egg production estimate for western horse mackerel in 2010 was **1.09 x 10^{15}** . This is a decrease of **33%** on the revised 2007 estimate which was 1.64 × 10^{15}. Figure 5.2.2 below displays the historical AEP estimate for western horse mackerel back as far as 2001. In contrast to 2007 the 2010 egg production curve displays a bimodal distribution which is almost identical both in shape and scale to that seen in 1998 with peak spawning occurring in periods 3 and 5 and a significant decline in production being observed during period 4.

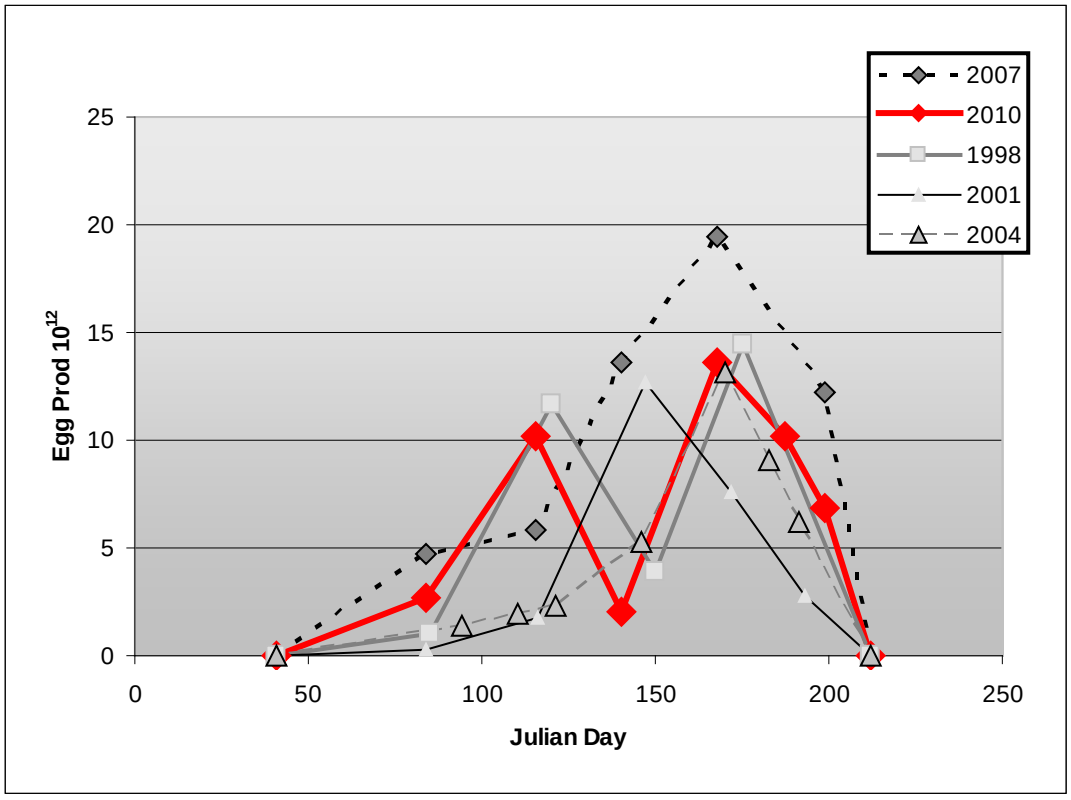


Figure 5.2.1. Annual egg production curve for western horse mackerel. The curves for 1998, 2001, 2004 and 2007 are included for comparison.

Table 5.2.1. Western estimate of horse mackerel total stage I egg production by period for 2010.

Dates	Period	Days	Annual stage I egg production x 10 15
< 8 March	Pre2	26	0.021
8 March – 11 April	2	35	0.095
12 April – 9 May	3	28	0.286
10 May – 30 May	4	21	0.043
31 May – 4 July	5	35	0.477
5 July – 8 July	*	4	0.037
9 July – 27 July	6	19	0.130
28 July – 31 July	*	4	0.004
Total		1.093	
s.e.		0.347	
CV		31.72%	
Data CV		184%	

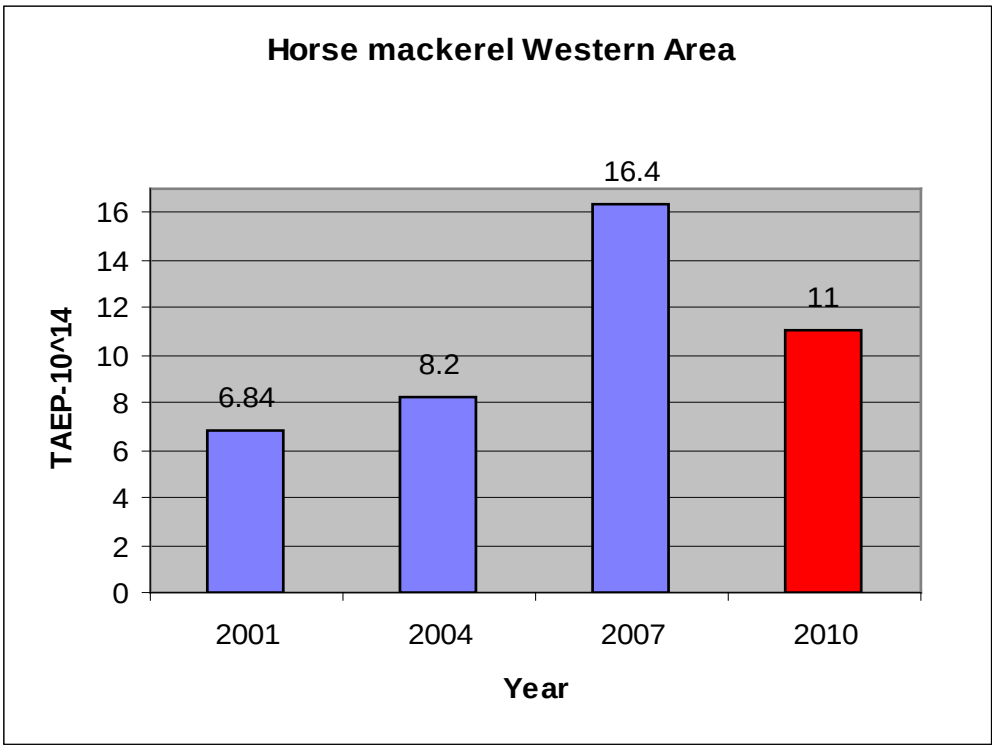


Figure 5.2.2. AEP estimates for western horse mackerel, 1998 – 2010.

5.3 Fecundity of Western Horse Mackerel

Problems associated with the fecundity of horse mackerel including the debate whether horse mackerel is a determinate or indeterminate spawner have been highlighted in previous meetings (ICES, 2003) and sample protocols have been prepared to address these problems.

A total of 420 female horse mackerel were sampled during the 2010 western egg surveys from February until July with a good spatial coverage from 43ºN to 55ºN. *Sample details included fisheries parameter and are given in the ICES planning meeting* (ICES,

2009). Triplicate ovary samples were taken with a pipette from each fish. The mean weight of the pipette samples is 0.026 gram. Two samples from each fish were analysed by two different institutes. Samples were analysed by Ireland (MI), Netherlands (IMARES), Norway (IMR) and Spain (AZTI and IEO). Samples were analysed for oocyte diameter and total standing stock of vitellogenic oocytes derived by the gravimetric whole mount method. Samples containing spawning markers were not included in the fecundity analyses. Threshold oocyte diameter to be included in the counts was 185 μm. Samples with leading cohort oocyte size over 800 μm were considered as spawning and not included in the fecundity estimation.

Based on the results for the 2006 maturity workshop (ICES, 2006) it was decided that for the whole mount analysis the samples would not be stained. A ring-test was carried out before the survey for calibration of the whole mount analysis between the institutes. The same procedure was used for horse mackerel whole mount analysis as was done for mackerel, therefore only one ring-test was carried out for the whole mount analysis. Results are shown in Section 4.3.

All samples were evaluated before analysis if they contained spawning markers or if the leading cohort of oocytes was below 400 μm or above 800 μm. The sample evaluation showed only 154 fish samples could be used for fecundity analysis (Table 5.3.1).

Table 5.3.1. Number of fecundity samples analysed.

Institute	N samples
Number of fish sampled:	420
Total number of fecundity samples:	154
AZTI	35
IEO	39
IMARES	71
IMR	48
MI	63

Because of the reporting of the mackerel results to WGWIDE the analysis of the mackerel whole mount samples was carried out first. This showed a problem with the set up for the whole mount analysis in the Irish institute. These problems were solved when the horse mackerel samples were analysed. The mean number of oocytes recorded from samples analysed by MI was not significantly lower compared to that of other (Figure 5.3.1) institutes and therefore the mean of all samples excluding MI was not significantly lower to the overall mean. The overall mean of the standing stock of vitellogenic oocytes per gram fish is 1058.28 ± 440.79.

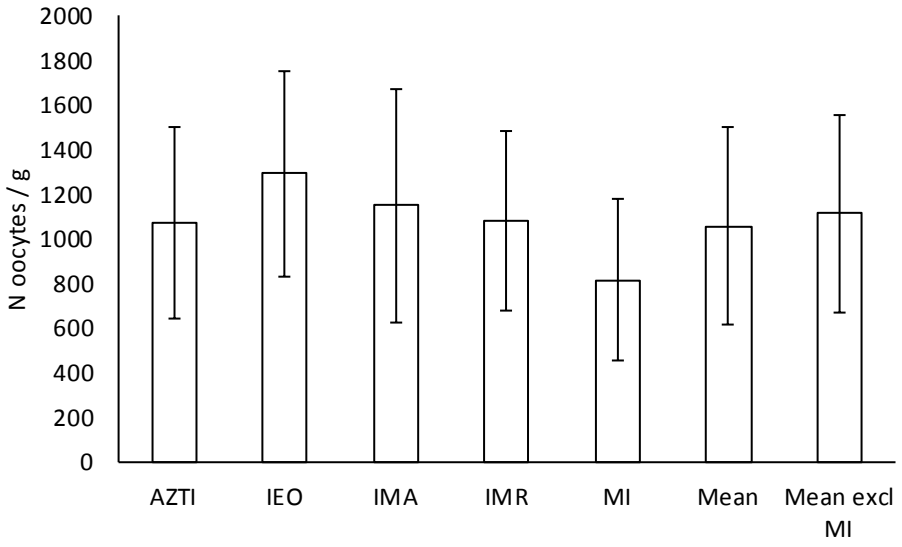


Figure 5.3.1. Mean standing stock of vitellogenic oocytes estimated by the individual institutes.

The leading cohort (10% biggest oocytes) oocytes diameters varied between 399 μm (2 samples) and 750 μm (Figure 5.3.2).

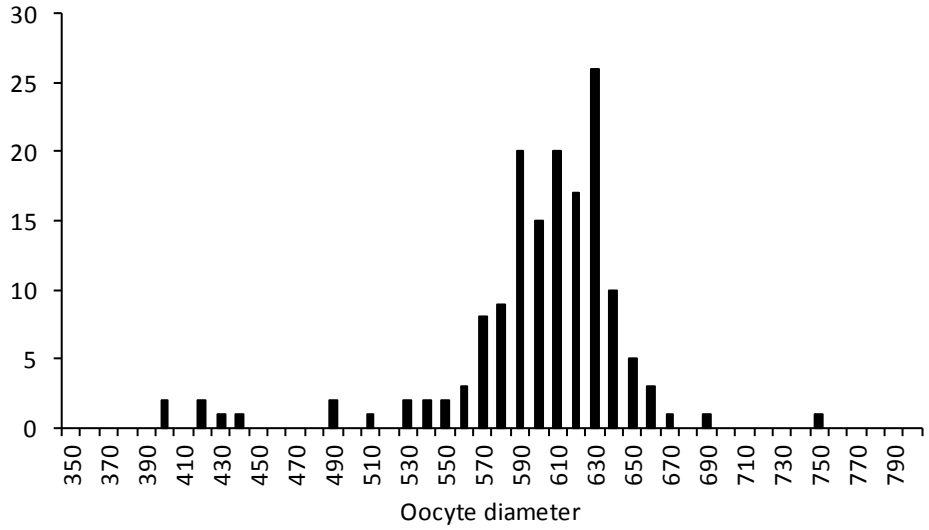


Figure 5.3.2. Leading cohort of oocyte diameter in the horse mackerel fecundity samples.

Standing stock of vitellogenic oocytes increases from period 2 to period 5 and declines again in period 6 (Figure 5.3.3). Results of the previous surveys showed (ICES, 2005, 2008), total and relative fecundity within the western population is increasing after the onset of spawning up to period 4 in the 2004 and 2007 survey whilst in this survey there was an increase up to period 5 (Figure 5.3.3). This does not necessarily mean that the fecundity for individual female increases after the onset of spawning, because some fish within the population might be spawning early and some might be late. However, this may also be an indication of horse mackerel being an indeterminate spawner.

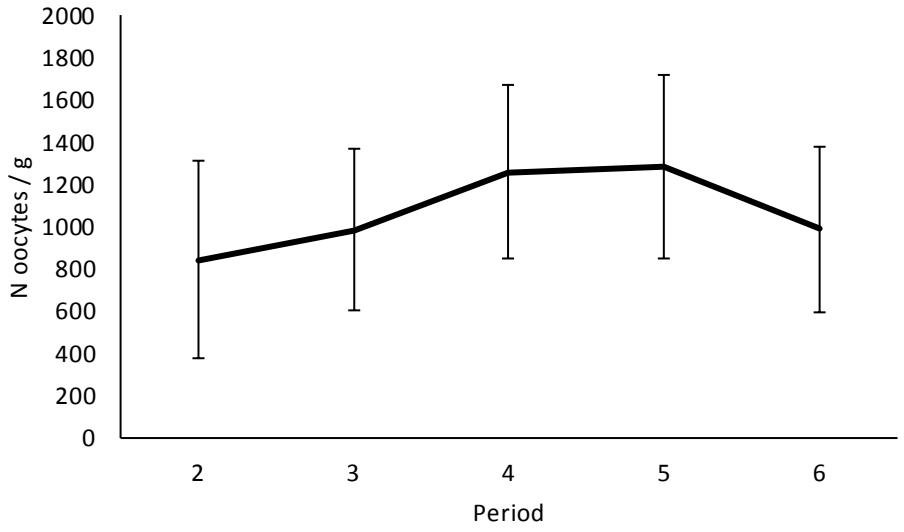


Figure 5.3.3. Standing stock of vitellogenic oocytes per gram fish of western horse mackerel.

The spread in horse mackerel fish length was low and there was no significant change over the different sampling periods (Table 5.3.2). There is no relationship between fish length and relative standing stock of vitellogenic oocytes (Figure 5.3.4). Given the variation in fecundity over time and the probable indeterminacy the WG decided again not to use fecundity data in an AEPM biomass estimate for the western area.

Table 5.3.2. Horse mackerel fish length samples during the 2010 survey.

Period	Fish length (mm)	StdDev
2	332.64	27.38
3	299.91	30.01
4	308.80	30.70
5	286.17	25.30
6	335.00	21.21
Mean	308.76	31.84

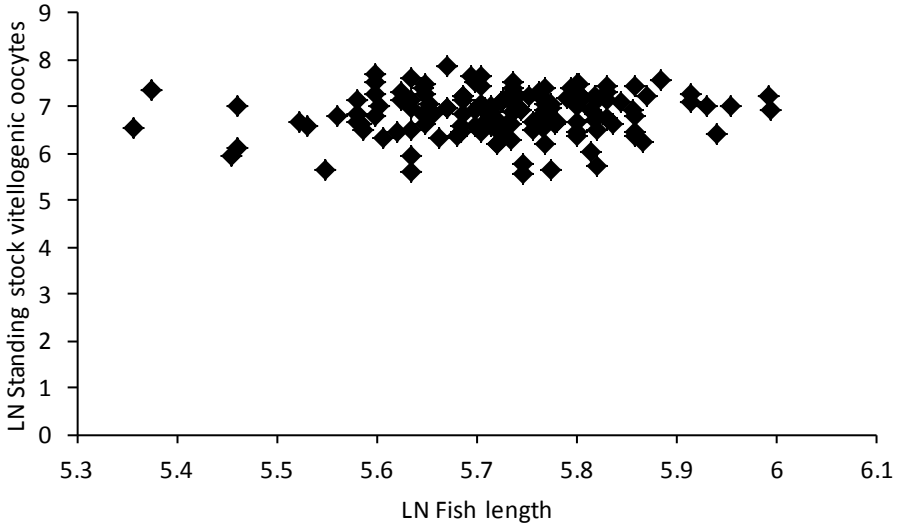


Figure 5.3.4. Relation between fish length and standing stock of vitellogenic oocytes.

5.4 Modified DEPM Approach for Estimating Horse Mackerel SSB

Horse mackerel is believed to be an indeterminate spawner and therefore, since 2007, IPIMAR has adopted the DEP methodology (DEPM=Daily Egg Production Method) for the species in the area of the southern stock (ICES IXa).

In the western area the egg survey is directed at the AEP method which produces an index of mackerel SSB while for horse mackerel the egg data are collected to provide a relative indicator of its spawning-stock biomass. The procedures used (and resources available) for the AEP method do not allow for a DEP estimation of horse mackerel in the western area. It is necessary to have a good spatial coverage of both egg and adult sampling in a short period for the DEP method to be effective. In the western area, the requirement is to cover as much of the egg production as possible, both temporally and spatially, and resources are not available for intensive adult sampling.

During 2010 it was investigated if the data from the samples collected in the western area might be used for a modified DEPM for horse mackerel (see also ICES, 2009). The 'traditional' DEPM estimates batch fecundity from the composition of migratory nucleus oocytes or hydrated oocytes and post-ovulatory follicles (POF's) for the estimation of the spawning fraction. Horse mackerel spawn at night and the duration of these stages is short and with the current limited sampling effort in the western area, mostly conducted during the daytime; it is not possible to use these stages for determining batch fecundity. It is possible to determine the batch fecundity at an earlier stage, where the batches of larger vitellogenic oocytes start to separate from the standing oocyte stock (ICES, 2009). Results of the 2007 survey gave a batch fecundity of 132 oocytes per gram female. This is similar to the batch fecundity found in 2007 in the southern area (ICES, 2008; 2009) and similar to a study on horse mackerel in Greek waters (Karlou-Riga and Economidis, 1997). However, the estimation of the spawning fraction is not possible from these data. Estimating spawning fraction from the earlier batches results in high spawning fractions of 75%, while in the southern stock and other studies found 25% (Karlou-Riga and Economidis, 1997).

Results of the modified DEPM method were presented at the ICES/FRESH EPM workshop held in Athens, March 2010. The results were discussed with DEPM ex-

perts participating in the workshop and it was concluded that the estimation for batch fecundity is possible but the estimation of spawning fraction is not. Therefore WGMEGS decided not to develop this method further.

6 Southern Horse Mackerel Stock: 2010 Egg Survey Results

A working document with results for the Southern horse mackerel stock was presented to WGMEGS (Angélico *et al.*, 2011). The analysis for Southern horse mackerel was not finalized prior the WGMEGS meeting. The Southern horse mackerel assessment was moved from WGWIDE to WGANSA. Results on the egg production will be completed before WGANSA in June but due to the necessary development of reliable methods for the determination of the spawning fraction results will be only finalized in summer.

6.1 Egg Distribution

A total of 414 CalVET+CTDF samples were collected along 46 out of 48 transects (Figure 6.1.1). The number of Bongo samples initially planned (3 per transect) had to be altered due to lack of time; 39 samples were obtained during the whole survey (data not shown here). From the 414 CalVET hauls 110 were positive for horse-mackerel eggs (27%); 1123 eggs were gathered. The highest egg abundance per haul was 148 (average 3). The distribution of eggs per stage included 3% of stage I and 25% of stage II (Figure 6.1.2).

The survey covered the continental platform and slope in an extension of 57899.71 km^2, from the entrance of the Strait of Gibraltar to Cape Finisterre; for the first time during an egg production method, the whole area of the horse-mackerel southern stock was fully surveyed. The horse-mackerel spawning area was estimated to be around 23446.15 km^2, about 40% of the total area. Egg abundance was higher in the western Algarve and SW coast; around Cape Carvoeiro and north of Cape Mondego in particular in northern Galicia. Horse-mackerel eggs were collected in places with depth ranging from 20 to 1500 m but the higher densities were observed over the outer shelf. The egg abundance data in 2010 was similar to the observations carried out during the previous DEPM survey in 2007 (404 CalVET samples, 32% with eggs, 865 eggs in total, maximum abundance 118). Moreover, the higher egg densities were found in roughly the same spots.

The egg production estimation will be achieved using the routines presented by Murta and Vendrell (2009) and the functions included in the ichthyoanalysis package (http://sourceforge.net/projects/ichthyoanalysis). These results will be available for the WGANSA in June.

6.2 Adult Parameters

In total 57 fishing hauls were obtained; 33 bottom-trawls were carried out with RV "Noruega" and 24 were obtained from the commercial fleet: 5 from Matosinhos (MAT); 4 from Figueira da Foz (FIG); 5 from Aveiro (AVE); 1 from Nazaré (NAZ); 5 from Peniche (PEN) and 4 from Portimão (POR). Horse-mackerel was present in 19 out of the 33 trawls conducted by RV "Noruega". In total, 3004 fish were biologically sampled and 1213 female gonads were collected and preserved, among which 27 were from hydrated females. Figures 6.2.1 and 6.2.2 are showing the sampling locations and the horse mackerel length distributions of the adult sampling, resp.

To obtain the length compositions of horse mackerel the Portuguese coast was divided into three geographic zones – northwest coast, southwest coast and south coast – and the fishing stations were grouped according to these three zones (Table 6.2.1).

Table 6.2.1. Number of fishing hauls by geographic zone.

Geographic zones	Nr. of RV Noruega trawls	Commercial samples
NW coast	17	20 (MAT, AV, FIG, NAZ, PEN)
SW coast	6	
S coast	13	4 (POR)

Fish lengths ranged from 16 cm to 41 cm. The range of lengths from fish caught in the northwest coast was wider than those from the south, with two modes around 22–26 cm and 31–33 cm. In the south the length distribution showed only one mode around 22 cm to 26 cm. Juveniles were merely caught in the north, mainly by the commercial fleet, with the dominance of length classes of 18–19 cm.

The analysis of the data collected during the survey and from the commercial samples shows that the sex-ratio ranged between 0.45 and 0.50 in most of the stations (Table 6.2.2). However, in three stations from RV "Noruega", it was not been possible to determine the sex-ratio. In those samples, two of them had only females and immature males (NOR-05 and NOR-06) and in the case of sample NOR- 19 no mature females were captured (Table 6.2.2). The total number of fish collected in those three samples was also reduced.

The mean weight of females varied between 100 and 300 g, the highest values were observed in the samples from the commercial fleet.

A linear regression model (LM) was adjusted to the observed batch fecundity estimates (number of hydrated oocytes) from the 27 females with hydrated oocytes (Figure 6.2.3 and Figure 6.2.4).

```
LM
lm(formula = Fobs ~ Wnov, data = adults.dat, na.action = "na.omit")


Residuals:
    Min      1Q  Median      3Q     Max
-16497.8 -4853.4   179.1  3344.0 26628.0


Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)   938.81    5023.54   0.187    0.853
```

According to Figures 6.2.3 and 6.2.4, observations 22 and 304, could be considered outliers, however the analyses done with or without these values did not change much. For this reason and because the number of hydrated females was limited we decided to keep all observations for the regression analysis. Using the LM the batch

fecundity was estimated for the whole population (observations) as a function of female weight. The mean potential fecundity obtained was 36115.00, *i.e*. number of eggs produced per female per batch.

The estimates of the adult parameters achieved for the 2010 DEPM survey (data combined from survey and commercial samples) are summarized in Table 6.2.3.

Table 6.2.3. Values of the means (and their coefficients of variance) for each of the adult spawning parameters: mean female weight (W) in grams; sex ratio (R); mean potential fecundity (F): number of eggs per batch and per female.

Parameter	Estimate	CV
W	155.300	0.0666
R	0.482	0.0076
F	36115.000	0.0853

The fraction of females spawning per day is going to be determined, for each haul, as the average number of females with Day-1 or Day-2 POF, divided by the total number of mature females. Following the slide analyses for POF presence (already completed) the next step will be the POF area determination based on image analyses applying the ImageJ software. Subsequently the area of each POF has to be linked to POF age (daily cohorts) in order to estimate S. This approach is going to be developed for horse-mackerel in a similar way to what was done for sardine (Ganias *et al.*, 2007). However, sardine exhibits a clear daily spawning rhythm, which helps with POF ageing, but that pattern is not fully investigated for horse-mackerel.

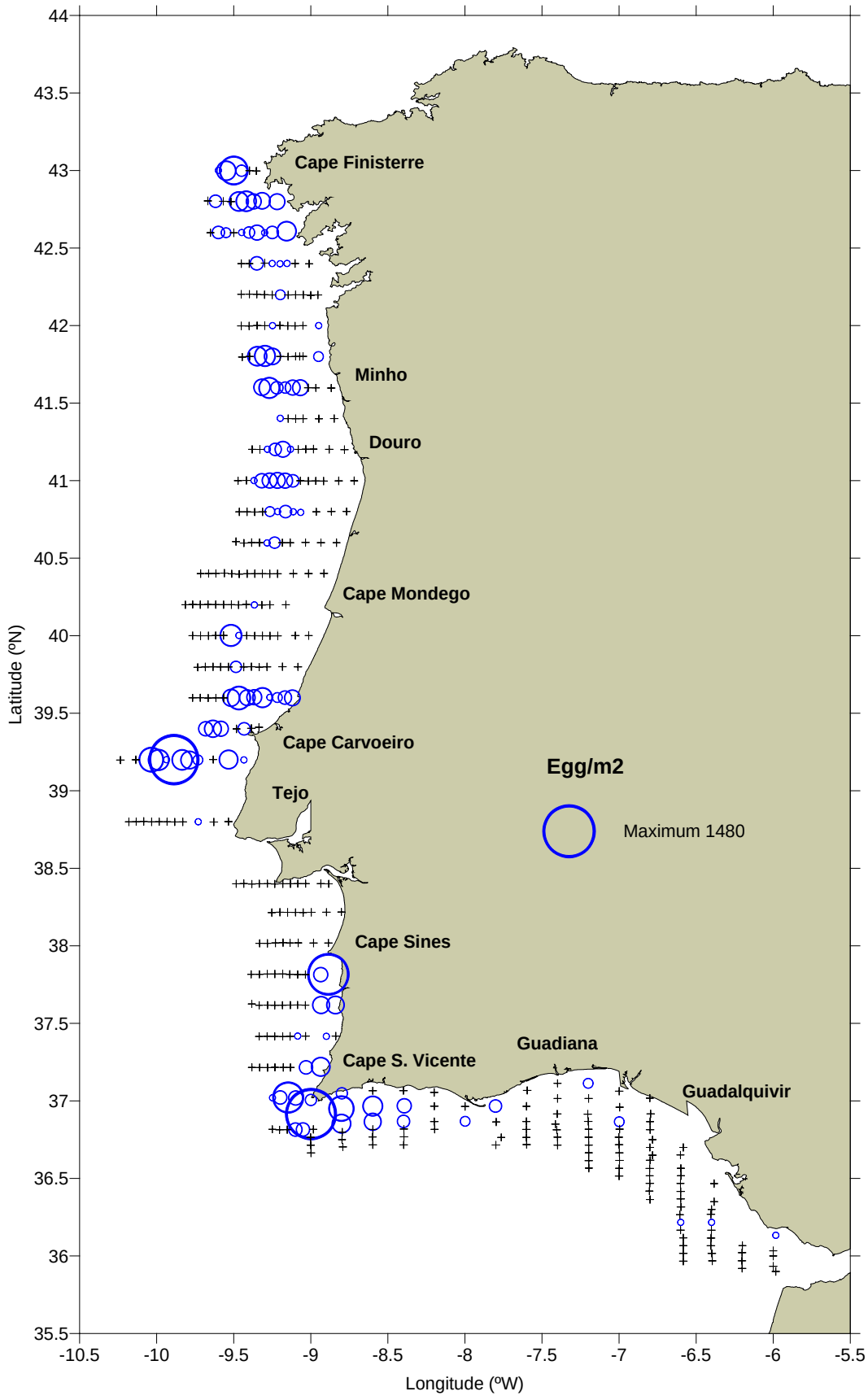


Figure 6.1.1. Egg distribution (egg/m2) from CalVET samples.

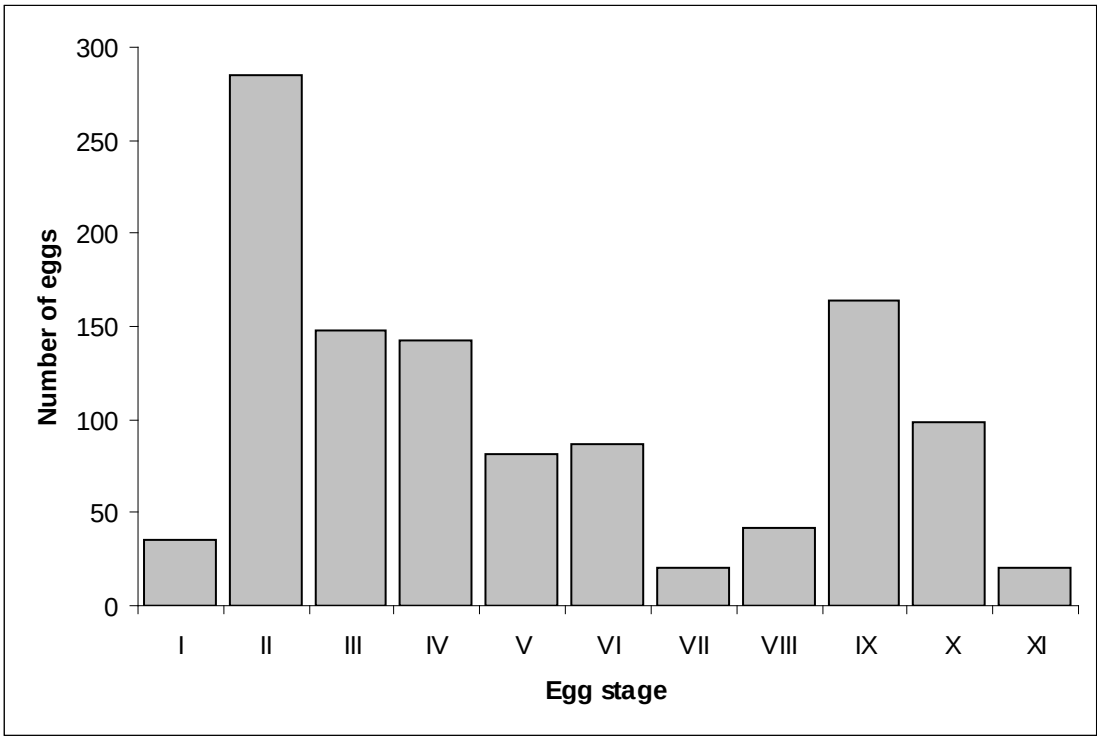


Figure 6.1.2. Egg per stage of development from CalVET surveying (total eggs).

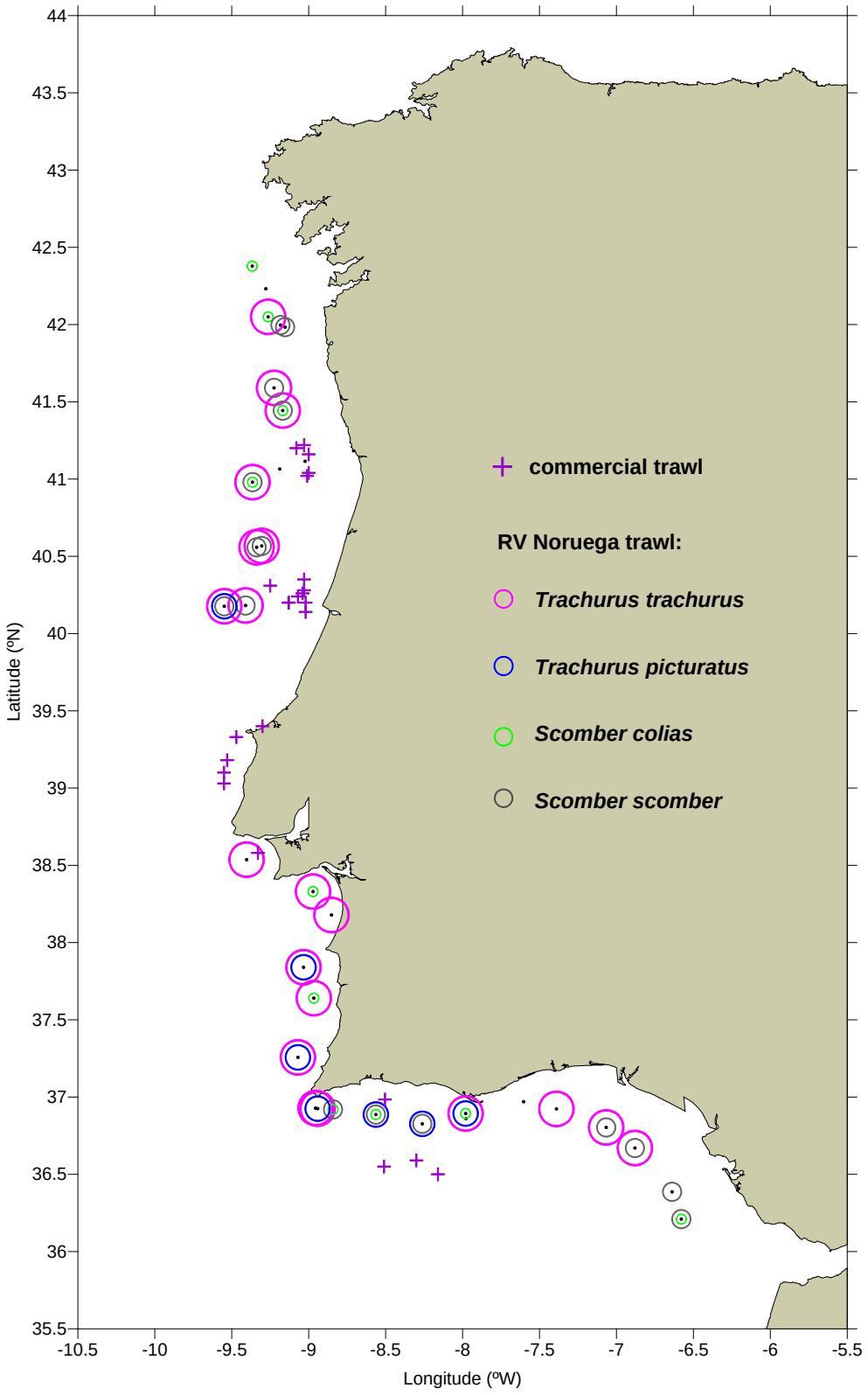


Figure 6.2.1. Location of fishing samples collected by bottom-trawling during the survey (circle) and from commercial vessels (crosses).

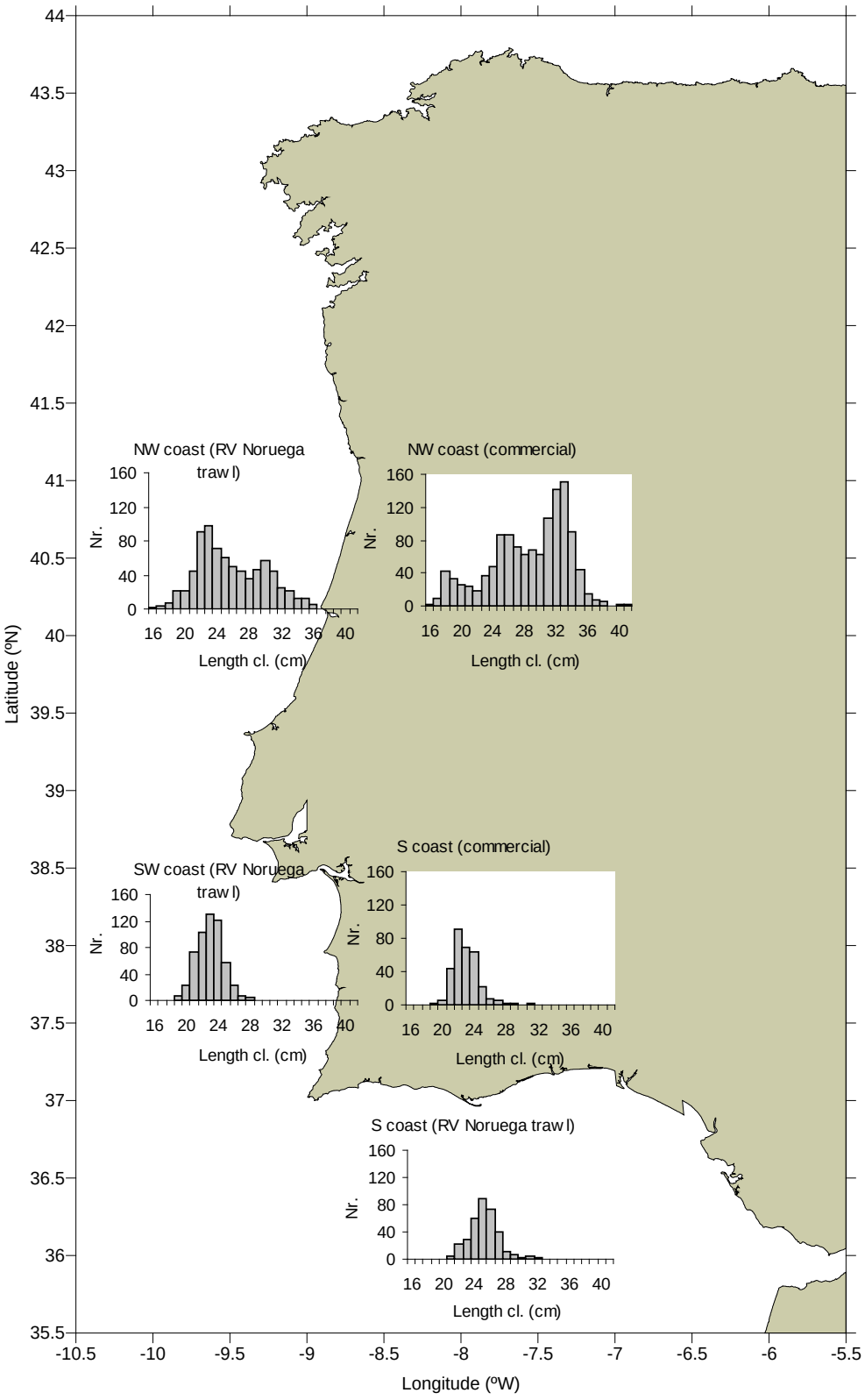


Figure 6.2.2. Horse-mackerel length distribution from RV "Noruega" sampling and from commercial catches, per area (S, SW and NW).

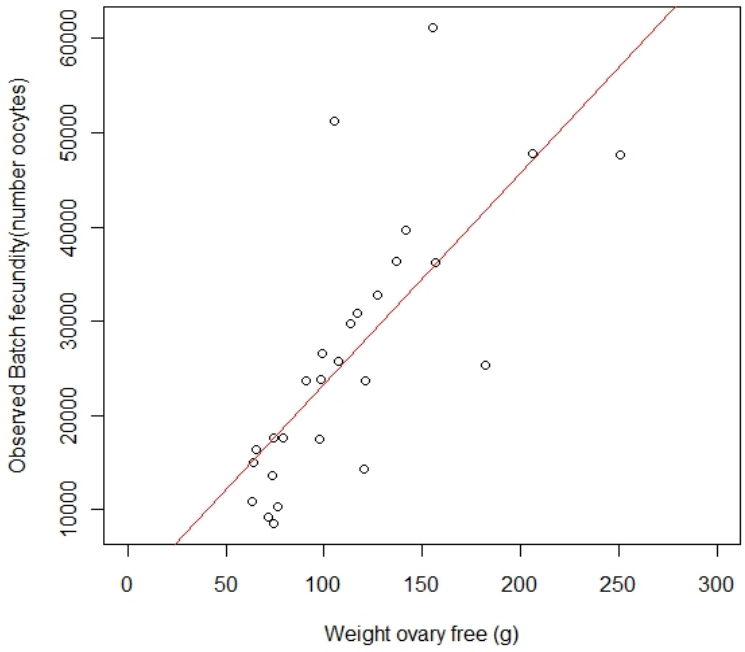


Figure 6.2.3. LM for the relationship between the observed individual batch fecundity and the ovary-free weight (n=27).

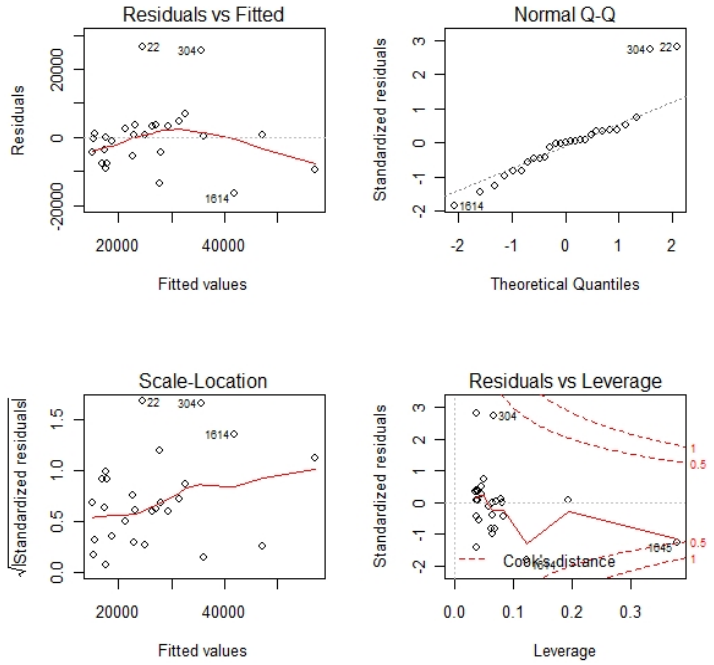


Figure 6.2.4. Residual plots for the LM fitted to the individual batch fecundity data in function of the female gonad-free weight.

Table 6.2.2. Mean weight of males (Mean W♂), number of males (n♂), mean weight of females (Mean W♀), number of females (n♀), sex-ratio, batch fecundity (F) and number of ovaries samples used for histological processing from survey (RV "Noruega") and from commercial catches.

Station code	Type	Mean W♂	n ♂	Mean W♀	n ♀	sex-ratio	F	Histology samples (n)
NOR-01		128.35	71	130.94	26	0.505	30275.90	36
NOR-05		139.90	41	143.08	46	0.506	32995.44	49
NOR-06		NA	NA	167.61	9	NA	38490.98	9
NOR-07		NA	NA	206.00	1	NA	47092.68	1
NOR-10		160.59	41	132.34	27	0.452	30590.14	27
NOR-13		123.04	46	113.08	9	0.479	26274.40	9
NOR-14		111.18	68	99.89	24	0.473	23371.12	37
NOR-15		106.13	62	93.36	31	0.468	21855.20	32
NOR-16		124.54	46	111.61	28	0.473	25945.68	28
NOR-17		90.88	34	92.30	32	0.504	21617.66	39
NOR-18		90.76	55	82.40	29	0.476	19401.13	32
NOR-19		95.64	11	103.25	18	0.519	24072.75	18
NOR-20		123.14	7	NA	NA	NA	NA	NA
NOR-25		145.40	53	145.91	26	0.501	33628.61	30
NOR-26		89.12	43	92.86	14	0.510	21742.94	30
NOR-27		214.69	32	205.68	30	0.489	47020.31	30
NOR-30		112.62	74	98.65	30	0.467	23040.39	40
NOR-31		106.31	77	98.07	28	0.480	22910.39	29
NOR-32		239.84	74	204.99	29	0.461	46866.54	31
NOR-33		184.88	40	163.73	30	0.470	37622.25	30
AVE-01		276.16	27	245.56	33	0.471	58167.85	33
AVE-02		328.14	25	306.17	14	0.483	69537.53	14
AVE-03		276.59	42	269.39	27	0.493	60870.42	27
AVE-04		242.70	47	239.54	13	0.497	53312.85	29
AVE-05		302.40	44	274.26	29	0.476	64979.22	29
FIG-02		312.80	51	284.90	9	0.477	67224.58	14
FIG-03		49.51	25	53.39	13	0.519	12318.21	31
FIG-04		293.74	21	264.59	39	0.474	61853.89	39
MAT-01		187.09	24	211.99	32	0.531	45621.36	36
MAT-02		56.47	21	56.45	10	0.500	13565.86	30
MAT-03		283.04	23	186.84	36	0.398	49932.69	37
MAT-04		121.98	25	117.94	28	0.492	27530.17	35
MAT-05		129.93	28	121.35	24	0.483	29001.67	32
PEN-01		215.31	23	168.08	37	0.438	38596.54	37
PEN-02		160.56	15	144.43	30	0.474	33299.02	30
PEN-03		223.23	33	205.87	30	0.480	47063.78	30
PEN-04		108.24	26	115.50	30	0.516	26815.37	30
PEN-05		192.01	30	188.60	30	0.496	43195.29	30
POR-01		100.72	25	96.01	34	0.488	22449.39	35
POR-02		115.84	25	103.77	36	0.473	24189.26	42
POR-03		99.77	35	95.07	36	0.488	22100.65	26

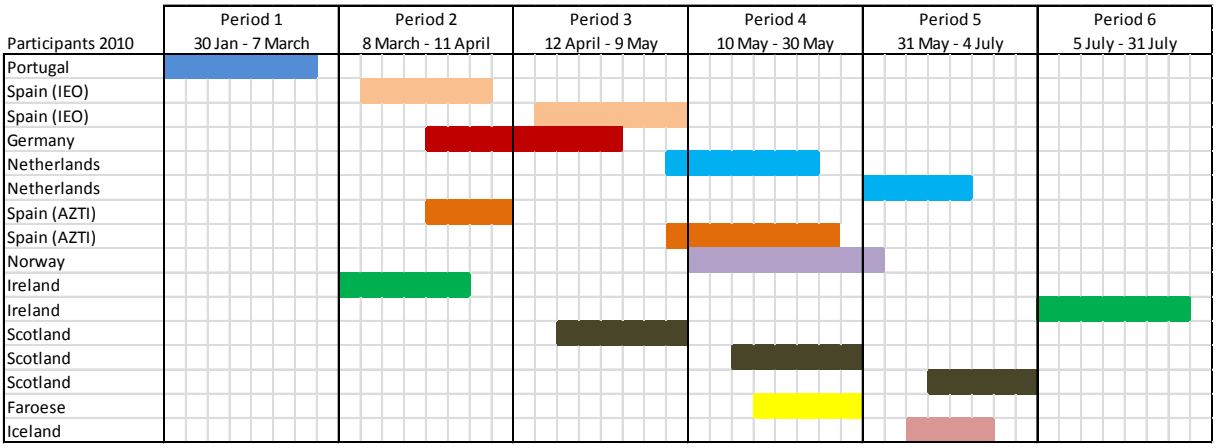
7 Quality Aspects of the Survey

7.1 Coverage of the 2010 Egg Survey in the Light of Spatial and Temporal Changes in the Spawning Behaviour of Mackerel

7.1.1 Review of Temporal and Spatial Coverage

Overall, temporal and spatial coverage was good. The participation of Iceland and the Faroese Islands, and the application of an alternating transect survey design made it possible to survey a much wider area than in previous years. Table 7.7.1 shows temporal coverage by participating nation and by geographical area. That table shows that survey effort is particularly centered on the traditional seasonal development of mackerel spawning with best coverage of the complete area (except Portugal) in periods 3 and 4. The Portuguese area was only covered once in Period 1 while no other areas were surveyed during that period. In period 2, good temporal coverage was only given for the Cantabrian and Celtic Seas while Bay of Biscay, West of Ireland and Porcupine and West of Scotland were only sampled during the second half of the period. Due to cessation of mackerel and horse mackerel spawning in the southern areas (Cantabrian Sea and Biscay) temporal and spatial coverage in periods 5 and 6 was again sufficient.

Table 7.7.1. Temporal coverage MEGS sampling periods by participating nation and by geographical area



The observed early peak as well as the northwestern expansion of mackerel spawning revealed a few possible shortcomings of the overall survey design. In particular, the true onset of spawning, and the establishment of northern and northwestern boundaries of mackerel spawning in the western component of the stock were not sufficiently covered.

Results from a non-WGMEGS coordinated survey carried out by IEO prior to period 2 showed that mackerel spawning had commenced already in February in the Can-

tabrian Sea. Furthermore, the encountered high spawning activity in period 2 over almost the complete area suggests that spawning started much earlier in 2010 than in previous years. In order to cover the entire mackerel spawning season earlier commencements of cruises are highly recommended for future surveys. In particular, a period 1 survey should be carried out in the Cantabrian Sea and possibly as well in the Celtic Sea. Germany and Spain (AZTI) should consider starting their period 2 survey earlier than previously. Both participants started their survey in the second half of period 2 leaving the first half unsampled in their survey area. Alternatively, Ireland and Germany could consider covering a wider survey area between west of the Hebrides and Bay of Biscay on alternating transects during period 2.

In order to cover the northwestern spawning boundaries, Iceland and the Faroese should be encouraged to carry on their participation during future surveys. It should be recommended to all participating countries to keep their survey design flexible in order to assist other participants when a widening of the survey area becomes necessary.

7.1.2 Spawning Dynamics of Mackerel

A working document presented to WGMEGS (Hughes 2011) showed the underlying patterns in the location and density changes of the western spawning component of adult Northeast Atlantic mackerel (*Scomber scombrus*) 1977 – 2010. Spatial statistics including the centre of gravity (most likely place an egg picked at random from the entire population is likely to be), inertia (variance around the centre of gravity) and anisotropy (spatial direction of the inertia) were employed with the raw and GAM modelled stage 1 egg data. There was a statistically significant northward shift in the annual centre of gravity when correlated against year, in the raw and modelled data; and western shift in the modelled data. Survey effort is significantly correlated with the northern shift in annual centre of gravity but cannot alone explain the significant northward shift in the GAM smoothed data. Sea surface temperature of the Northeast Atlantic as a whole is increasing but is not significantly correlated with the sea surface temperature of the spawning areas. There is a significant correlation between the mean annual centre of gravity of northings and mean sea surface temperature of the Northeast Atlantic. Multiple regression analysis shows for every 1 degree of warming, the annual centre of gravity is moving just over 58km north, independent of survey effort. The results demonstrate Atlantic mackerel are moving north in their spawning location and that the shift might be related to sea surface temperature. Work continues to improve the GAM fit in terms of the nature of the data, and relate the centre of gravity work to other environmental variables.

Spatial distribution of commercial catches, the 2010 egg distribution and results from summer trawl and acoustic surveys in the Norwegian Sea indicate as well that the NEA mackerel stock has expanded north-westwards during their spawning and summer feeding migration. These recent changes might be a consequence of observed increase in sea surface temperature, or changes in food availability. As a consequence of this, a new fishery for mackerel has recently developed in Icelandic waters. In the last two years it appears that at least parts of the NEA mackerel stock have left their feeding areas in the Norwegian Sea earlier than has previously been observed and are rapidly migrating southwards bypassing their usual feeding/wintering area (August-February) in the northern part of the North Sea. This was reflected in a lower availability of mackerel for the fishing fleet in the northeastern part of the North Sea in 2009 and 2010.

The main spawning period was observed earlier (period 2, March) in 2010 than during previous egg surveys. This change in migration patterns may have shortened the period of oocyte development resulting in earlier spawning. However, it was not possible to confirm this from examination of the fecundity samples collected and analysed during the 2010 survey. The second peak in spawning observed in 2010 (Figure 4.2.1) might be the result of the remaining mackerel in the Norwegian Sea continuing to feed as normal during autumn and winter before migrating to their spawning area. This would have probably resulted in delayed gonad development and spawning period such has been corroborated during previous MEGS.

7.1.3 Changes to the Timing of Mackerel Ovary Development

IEO collects monthly data on the maturity stages of mackerel throughout the year. These data have been collected since 2000 and since then it can be seen that mackerel ovaries are developing earlier in the year. This was noticed several years ago (Punzón *et al.*, 2004, Punzón and Villamor, 2009) and resulted in mackerel samples being collected from the commercial fleet prior to the triennial surveys in 2007 and 2010. In 2007, 100 samples were taken in period 1, and in 2010 60 samples were collected from the commercial fleet.

During the 2010 survey, 919 mackerel ovary samples were taken for fecundity determination. However, only 74 were suitable for fecundity analysis because the majority of the samples collected showed signs of spawning following histological examination.

In preparation for the 2013 survey, IEO will carefully observe mackerel maturity stage development during January-February 2012, in an attempt to predict the most appropriate date for fecundity sampling to begin prior to the 2013 survey. With this knowledge and sampling 100 individuals, it is hoped that the number of suitable ovaries for fecundity analysis can be increased.

7.2 Re-analysis of the Survey Data under a Survey Design where Transects are spread out to allow covering a Wider Area but without Increasing Ship Time

During the 2007 MEGS a large expansion to the mackerel spawning area in the Northwest was observed for the first time. This raised concerns regarding the ability of the existing survey design to provide comprehensive coverage during future surveys with the limited ship time available. As an alternative survey strategy, sampling on every other standard transect was proposed in order to release ship time thereby enabling a much larger area to be surveyed in the Northwest. However, any such modifications to the survey strategy must not impact on the reliability of the survey results.

In order to test possible effects of sampling every other transect, the 2007 annual egg production was recalculated based on even or odd numbered transects only. Therefore, results from either even or odd transects were deleted and subsequently interpolated from neighbouring stations as described in the MEGS manual. The recalculation was completed for the western component of the mackerel stock and for periods 2 – 5 only, since period 6 was already completed using alternate transects.

In addition to recalculation of the 2007 survey results, the same procedure was applied to results from the 2010 MEGS, but this time only for period 2. The remaining periods to a large extent having been surveyed utilizing an alternate transect strategy

that enabled the expansion of the spawning area in the northwest to be surveyed more comprehensively.

Recalculation of the 2007 survey results showed that using an alternate transect approach would have resulted in either a 16.7% under or a 14.7%overestimation of the total annual stage I egg production depending on whether interpolation was done on even or odd numbered transects. Total annual egg production was either $1.11 * 10^{15}$ when interpolated on even transects or $1.53 * 10^{15}$ when interpolated on odd transects while the originally calculated egg production was $1.34 * 10^{15}$ (Table 7.2.1, Figures 7.2.1 and 7.2.2).

Table 7.2.1. Western estimate of mackerel total stage I egg production by period after integration of area under the egg production histogram for 2007. Grey: values not recalculated.

period	days	Total (even interpolated) production x 1015	Total(odd interpolated) production x 1015
pre 2	41	0.07	0.17
2	30.5	0.19	0.46
3	28	0.14	0.16
4	24.5	0.34	0.37
5	21	0.16	0.17
6	21	0.15	0.15
post 6	15	0.05	0.05
total		**1.11**	**1.53**

While in periods 3 – 5 differences between odd and even transect interpolation were only marginal, major differences were observed for period 2 and, hence, pre 2 (Table 7.3.1, Figures 7.3.1 and 7.3.2). These differences were attributable to a major mackerel spawning event within period 2 commencing only after the first leg of the period 2 survey west of Ireland had finished and, thus, more eggs were found on the return leg while filling in the remaining transects. During all other periods, spawning appeared to be more uniformly distributed, with only marginal differences being observed between survey transects.

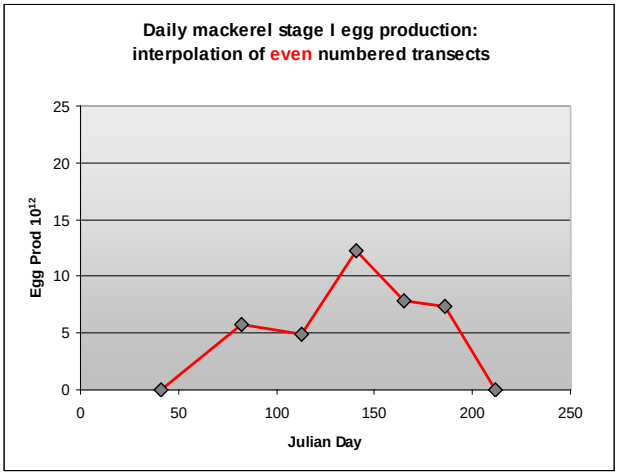


Figure 7.2.1. Daily mackerel stage I egg production in 2007 calculated after interpolating the even numbered transects.

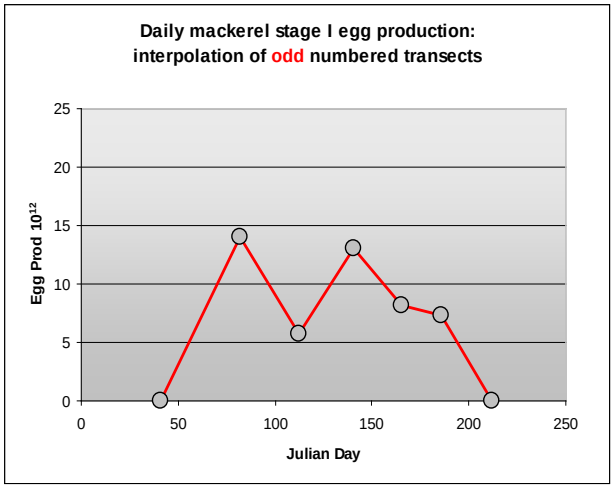


Figure 7.2.2. Daily mackerel stage I egg production in 2007 calculated after interpolating the odd numbered transects.

In contrast to the 2007 recalculation the reanalysed 2010 period 2 data did not reveal the same level of disparity using the same methods. Daily egg production estimate was 2.18 * 10^{13} and 2.34 * 10^{13} for interpolation on even and odd transects, respectively. Both values were slightly lower than the original complete estimate which was 2.41 * 10^{13} (Figure 7.2.3).

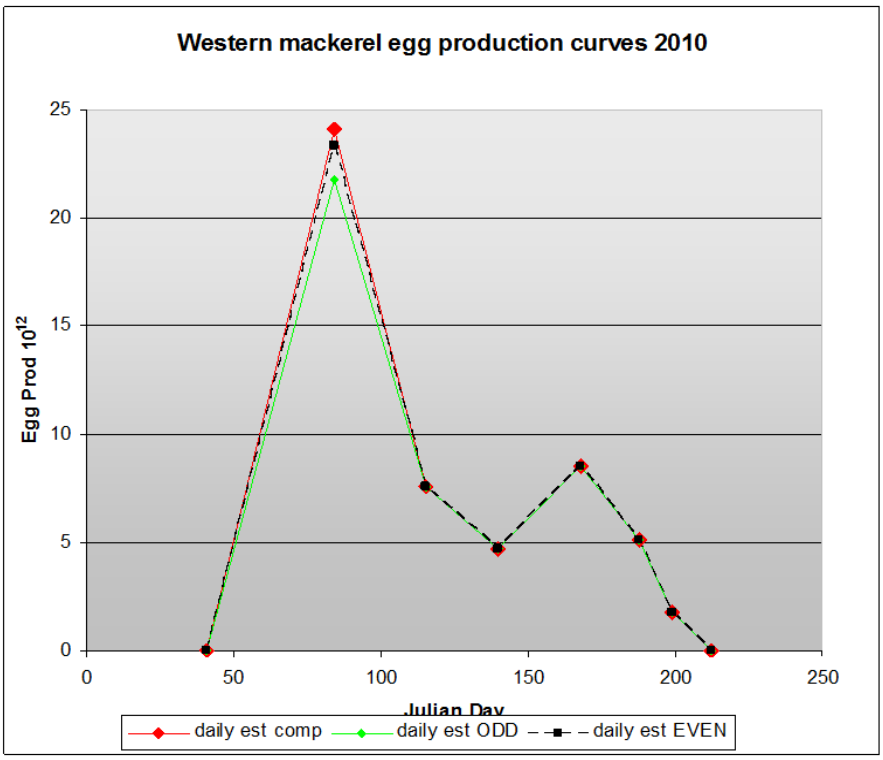


Figure 7.2.3. Daily mackerel stage I egg production in 2010 calculated after interpolation of odd and even numbered transects in period 2.

The impact on the total annual egg production was less than in 2007 with underestimations of 5.96% and 1.97%, respectively. The results for the 2010 recalculation suggest that already in period 2 an alternate transect survey design would have been appropriate without revealing spurious results. However, the results also suggest that spawning was already going on at the same intensity over the complete survey area and that, possibly, the true starting point of mackerel spawning west of the British Isles was not covered by the 2010 survey.

7.3 Review on the Calculation of Egg Production

7.3.1 TAEP estimation Methodologies

There have been two approaches used in the past to raise mean daily egg production from each period to the total annual egg production: the under-the-curve method and the histogram method. The under-the-curve method was the first to be used, followed later in 1996 by the histogram method. The under-the-curve method takes the estimate of TAEP to be the area under the egg production curve such as that shown in Figure 4.2.1. The histogram method takes total period egg production to be the mean daily production in that period multiplied by the number of days in that period. Between period production is estimated from a combination of the mean daily production in neighbouring periods. The two approaches are compared graphically in Figure 7.3.1.

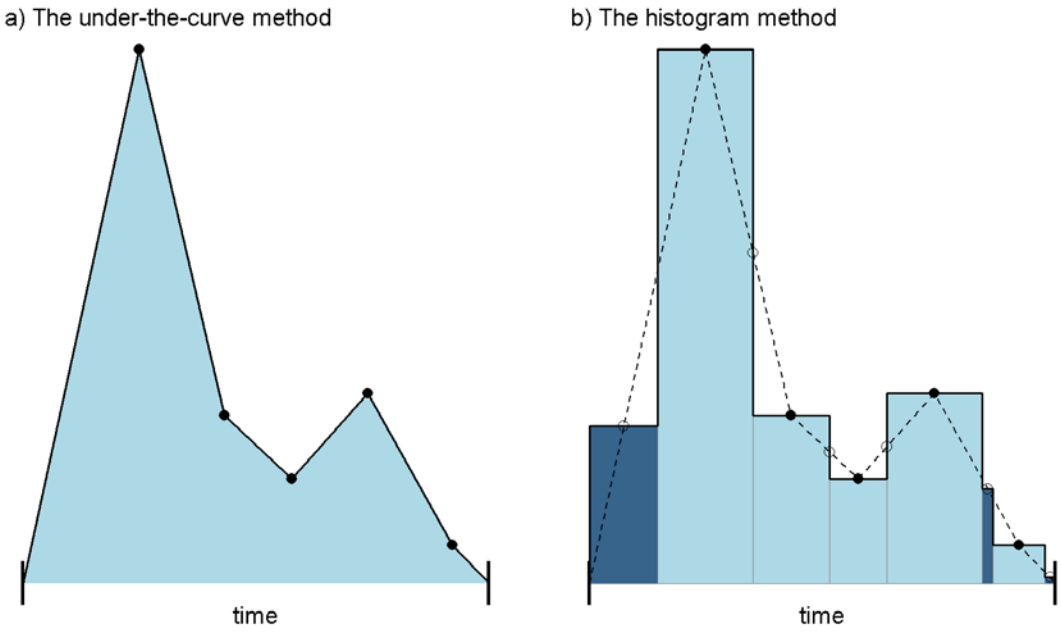


Figure 7.3.1. A comparison of the under-the-curve method with the histogram method of estimating total annual egg production (TAEP) based on the 2010 data. The filled dots show the midpoints of the sampled periods, the open dots show the midpoints of the unsampled periods; the shaded area under the black line is the estimate of TAEP, in figure b) the darker shading represents the estimates for unsampled periods, the under-the-curve method only depends on the midpoints of the sampled period so implicitly doesn't recognize unsampled periods.

Referring to the equation for TAEP given in Section 3.3.3, the mean daily egg production values are combined in a weighted sum, with the weights being referred to as λ_p. In the histogram method the unsampled gaps between periods are interpolated from adjoining periods. This is equivalent to increasing the number of days in each period

in order to fill in gaps between sampled periods and these values are the weights λ_p The calculation for these weights for the histogram method is given in ICES (1996). The under-the-curve method also has associated weights, but these do not depend on the length of the sampled periods, only the mid points of the sampled periods and the start and end times of spawning There are two consequences of this: the first is that if the entire spawning period is sampled as one period, the under the curve method will always underestimate TAEP, however, it is also possible to overestimate TAEP in other circumstances using this method – Figure 7.3.1.

1 is an example of such a situation; the other consequence is that the variance of the under-the-curve TAEP estimate does not depend on the amount of between period fill in, only on the midpoints of the periods.

7.3.2 Revision of TAEP estimates for 2007 NEA mackerel and western horse mackerel and subsequent revision of biomass estimate for NEA mackerel.

The original FORTRAN code that was used prior to the 2007 survey to estimate TAEP for mackerel and horse mackerel using the histogram method (ICES, 1996) was not able to cope with the expanding spawning area as the code only works within the 'standard survey area'. Therefore, the total annual egg production (TAEP) estimates for 2007 were calculated utilizing the under-the-curve method described above in Section 7.3.1. In September 2010 the methods to calculate the egg production were reviewed and adapted by MSS Aberdeen. A new updated code in R was developed that delivers a combined TAEP estimate for NEA mackerel stock as well as the western horse mackerel stock. The new code utilizes the original histogram method as described in detail by Fryer (ICES, 1996). However it is more dynamic in its ability to deal with the survey data, it receives rather than adhering to a standard geographical area template which was the principal shortcoming of the previous program. To test the competency of the new code the 2010 TAEP estimates as derived from the new code were compared with results calculated manually using the histogram method. The results were identical to and within 2 decimal places for all of the estimates which provided sufficient agreement for WGMEGS to accept the new routine as a suitable replacement for the FORTRAN code. The next logical step was to recalculate the TAEP estimate for the 2007 data which had previously been estimated using the under-the-curve method. The revised TAEP estimates for the 2007 survey together with the corresponding S.E and CV values can be found in Tables 7.3.2.1 – 7.3.2.3. An explanation of the methodology used to calculate the SE and CV estimates can also be found in Section 3.3.3.

Table 7.3.2.1. Revised Western estimate -using the histogram method and R code- of mackerel total stage I egg production by period for 2007, using pooled data CV (210%) and western only data CV (165%)

Dates	Period	Days	Annual stage I egg production x 10 15
< 7 March	Pre2	25	0.075
7 March – 8 April	2	33	0.330
9 April – 6 May	3	28	0.149
7 May – 3 June	4	28	0.372
4 June – 24 June	5	21	0.178
25 June – 31 July	6	37	0.271
Total	1.376		**1.376**
s.e.	0.322		0.220
CV	23.43%		16.02%
Data CV	210%		165%

Table 7.3.2.2. Southern estimate of mackerel total stage I egg production by period for 2007 using histogram method and newly configured R script.

Dates	Period	Days	Annual stage I egg production x 10 14
3 Feb – 2 March	1	33	0.047
4 March – 15 March	*	13	0.660
16 March – 5 April	2	21	1.92
6 April – 14 April	*	9	0.440
15 April – 6 May	3	22	0.105
7 May – 10 May	4	4	0.011
11 May – 17 July	*	68	0.090
Total			**3.274**
s.e.			2.216
CV			67.68%
Data CV			242%

Table 7.3.2.3. Estimate of western horse mackerel total stage I egg production by period for 2007 using the histogram method and newly configured R script.

Dates	Period	Days	Annual stage I egg production x 10 15
< 7 March	Pre2	25	0.036
7 March – 8 April	2	33	0.158
9 April – 6 May	3	28	0.159
7 May – 3 June	4	28	0.383
4 June – 24 June	5	21	0.453
25 June – 31 July	6	37	0.450
Total			**1.640**
s.e.			0.634
CV			38.66%
Data CV			317%

The revised 2007 TAEP estimate for mackerel in the western area is a 12% increase on the original 2007 estimate of 1.21 x 10^{15} that was calculated using the under-the-curve method. The revised estimate for mackerel in the southern area for 2007 resulted in a

5% increase compared to the original TAEP estimate of 3.12 x 10^{14}. This was despite the original estimate having been calculated independently using the histogram method by the southern coordinator. The revised TAEP estimate for the western horse mackerel was a 13% increase on the original 2007 estimate of 14.27 x 10^{14} that was calculated using the under-the-curve method.

Revised Total egg production NEA mackerel 2007and SSB estimate
Total annual egg production (TAEP) combined for both the western and southern components in 2007 was **1.703×10^{15}** . Consequently, a revision of the SSB estimate was performed using the realized fecundity estimate of 1009 oocytes/g female, a sex ratio of 1:1 and a raising factor of 1.08 (ICES, 1987) to convert spawning fish to total fish. This gave a revised estimate of spawning-stock biomass in 2007 of:

- 2.945 million tonnes for western component.
- 0.701 million tonnes for southern component.
- **3.646** million tonnes for western and southern components combined.

This equates to an 11% increase on the original combined SSB estimate for 2007 of 3.254 million tonnes.

In an effort to avoid confusion all references made to the 2007 TAEP results and presented within the 2010 WGMEGS report refer to the updated revised estimates that are published here.

7.3.3 Revision of provisional TAEP estimates for 2010 NEA mackerel and western horse mackerel and subsequent revision of biomass estimate for NEA mackerel.

The provisional TAEP estimates for 2010 as supplied to WGWIDE in August 2010 (Ulleweit *et al.*, 2010) were also calculated using the under-the-curve method. It was understood that the final TAEP estimates for both NEA mackerel and western horse mackerel would be calculated using the histogram method (WGMEGS, 1996) and using the newly configured R script that had been developed to allow data from the expanded survey area in the north and west to be incorporated into the estimate. The final TAEP estimate for mackerel in the western area for 2010 as reported in Section 4.2.1 was **1.70×10^{15}** . That is an increase of 9% from the provisional estimate of 1.54 × 10^{15} as reported to WGWIDE. The final TAEP estimate for mackerel in the southern area as reported in Section 4.2.2 was **4.25×10^{14}** . That is a decrease of just under 2% compared to the provisional estimate of 4.33 × 10^{14} that was submitted in August 2010 to WGWIDE. Therefore the revised combined TAEP for both components of NEA mackerel in 2010 is **2.12×10^{15}** . The consequent impact of this revision on the final 2010 SSB estimate for mackerel was further mitigated due to a revision upwards of the mackerel realized fecundity estimate from 1031 to 1070 oocytes/g female. This resulted in a final combined NEA mackerel SSB estimate of **4.289 million** tonnes. This is an increase of 3.79% on the provisional estimate of 4.133 million tonnes as reported to WGWIDE in 2010. The final TAEP estimate for western horse mackerel as reported in Section 5.2.1 was **1.09×10^{15}** . That is an increase of 8% from the provisional estimate of **1.005×10^{15}** as was reported to WGWIDE in 2010.

7.4 New Findings on the Mackerel Fecundity Type

During the meeting a working document was presented on fecundity type regulation in marine fish (Damme *et al.*, in prep). The study describes the regulation mechanizms behind fecundity type regulation and concludes that food availability is most important parameter determining fecundity type in marine fish. If fish have no food

available during the spawning season they have a determinate fecundity type. If females do have food available during the spawning season, theoretically they have an indeterminate fecundity type. Also fecundity type is flexible and a reaction to the environment, especially the food availability and feeding.

We do not have evidence of mackerel and horse mackerel from spawning experiments that mackerel and horse mackerel are indeterminate spawners. The spawning experiments showed that both mackerel and horse mackerel develop oocytes in experimental tanks but do not spawn. What is known from the surveys is that both species continue to feed throughout the spawning season. This implies therefore that they will be indeterminate spawners. In addition PCA analysis during the study placed mackerel and horse mackerel on the indeterminate side of the graph suggesting they have an indeterminate fecundity type.

Indeterminate spawners keep recruiting oocytes from the previtellogenic stock during the spawning season. It is therefore not possible to estimate potential fecundity prior to the survey. There is evidence from investigations of horse mackerel ovaries that horse mackerel might be an indeterminate spawner. However, thus far it has not been possible to prove whether mackerel or horse mackerel are indeterminate spawner. Total Annual Egg Production (TAEP) methods, such as the present mackerel and horse mackerel egg survey design, require reliable estimates of potential fecundity to estimate SSB from the total annual egg production. Hence they can only be used to estimate SSB for determinate spawners. Daily Egg Production Methods (DEPM) can be used to determine SSB from egg productions estimates for indeterminate as well as determinate spawners, since it uses batch fecundity and spawning fraction; however the DEPM method requires intensive sampling of both the eggs and adults during the peak of spawning.

If WGMEGS decides to change the survey from a TAEP to a DEPM, this will require a change of the survey design and sampling effort both for the egg and adult sampling. The change in survey design will also have implications for the time-series which is currently used for tuning the assessment of mackerel. WGMEGS therefore recommends to have a workshop prior to the planning meeting of the next egg survey (to be held in 2012) inviting international DEPM and other experts to inform and advise WGMEGS on how to proceed with a possible change towards a DEPM survey design. This group also has to review information about mackerel spawning, as well as batch fecundity, batch frequency, spawning fraction and POF ageing. Based on their findings the WGMEGS planning meeting in 2012 will decide how best to proceed with the survey design.

8 North Sea Egg Survey 2011

8.1 Countries and Ships participating

Mackerel egg surveys have been carried out in the North Sea more or less regularly since 1967. Since 1996 these surveys have been carried out triennially.

As since 1999 the Netherlands and Norway will carry out a mackerel egg survey in the North Sea in 2011. The survey period, 30 May-4 July, will not cover the total spawning period (mid-May-end July). The peak of spawning has usually been observed during mid-June. The timing of three different coverages will therefore probably be adequate to define the main part of the egg production curve. Usually one vessel can cover 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 in 2011 as shown in Table 8.1.1.

Table 8.1.1. Timing and areas for North Sea mackerel egg survey in 2011.

Vessel/Coverage	1	2	3
RV Tridens	30 May-10 June	13–17 June	
RV Håkon Mosby		15–20 June	21 June -3 July

8.2 Sampling Area and Survey Design

The suggested sampling area for each of the three periods based on recent surveys is shown in Figure 8.2.1. During the second coverage both *"Tridens"* and *"Håkom Mosby"* will start north in their respective areas working southwards and in the third coverage Norway will work from south to north. *"Tridens"* will start and end in Scheveningen, break for the two weekends in Aberdeen and Stavanger respectively and RV "Håkon Mosby" will start and end in Bergen.

All the logistical details concerning the vessels were not available during WGMEGS so the two institutes will be in close contact to ensure optimal use of the available ship time. The survey grid during the second and third coverage will be adjusted according the findings during the previous coverage. The samples will be analysed on board the vessels during the survey. The two vessels will be in daily contact to exchange data.

As usual, sections along whole or half degree latitudes will be worked, and plankton samples will be collected along these lines in the middle between whole and half degree longitudes. Both vessels will use a Gulf VII (mesh size 500 microns) towed in double oblique hauls with a towing speed of 5 knots.

8.3 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. During the survey an automatic image analysis procedure for detection and diameter measurements combined with visual identification and staging of mackerel eggs will be tried on board both "Tridens" and "Håkon Mosby". The volume of seawater filtered on each of the plankton stations should also be recorded. Thereby the number of mackerel eggs

produced per m² 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 WGWIDE meeting in August 2011. The final results will be reported to the next WGMEGS meeting in 2012.

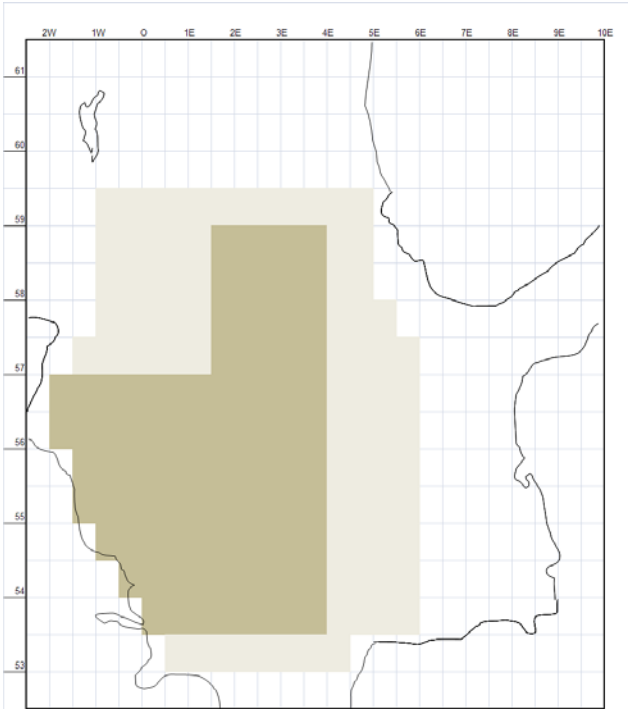


Figure 8.2.1. Suggested sampling area based on results from later surveys. Dark grey indicate the most intense production area.

8.4 Fecundity and Atresia

Mackerel will be sampled by "Tridens" during the survey for fecundity and atresia purposes. In 2008 "*Håkon Mosby"* was not able to collect representative samples of mackerel gonads. Therfore, "*Håkon Mosby"* will not carry out trawling this year. Norway will try to collect some fecundity samples during a sandeel survey with "*Johan Hjort"* in April.

The intention is to investigate 100 ovaries for potential fecundity and 50 ovaries for atresia. The samples will be taken, handled and analysed as described in ICES (2006 LRC:09). Ovaries for fecundity and atresia studies will be taken from mature, late pre-spawning, spawning or spent females from the for size groups: <250g/-400g/-550g/>550g. The ovaries have to be removed, weighed, and two parallel samples taken from one ovary (25µl) by a pipette. These samples should be put in Eppendorf tubes (4% formalin). The other ovary should be preserved in formalin jars. The liver, gut and carcass should also be weighed. The samples will be collected from trawl catches from different parts of the spawning area.

If there are surveys in the North Sea in May this year the WG recommends that they should try to provide samples for potential fecundity studies of North Sea mackerel.

9 Deficiencies and Recommendations

9.1 Deficiencies

Difficulties were encountered by the laboratory in Ireland with the fecundity analysis for mackerel. The contrast of the images taken was of a low quality and many of the smaller, more transparent oocytes were not counted. As a result the Irish data were excluded from the analysis. Measures will be put in place to ensure more consistency in analysis in future survey years.

The expansion of the survey area during many of the sampling periods in 2010 meant many national surveys were conducted using the alternate transect design. As a result there was a large reduction in the number of replicate samples taken, which had an impact on the variance calculation.

There were a number of shortcomings noted with the 2010 survey programme, particularly in covering the true onset of spawning, and also the establishment of the northern and northwestern boundaries of mackerel spawning in the western component of the stock.

9.2 Recommendations

See Annex 4 for the list of the Recommendations.

10 Working Documents Presented to the Working Group

1. Comparing the condition of mackerel females in 2007 and 2010.

Paula Alvarez: AZTI-Tecnalia, Herrera Kaiaportualdea z/g. 20110 Pasaia, Gipuzkoa. E-mail: palvarez@azti.es

Abstract

Different condition indices were estimated comparing female Mackerels data from 2007 and 2010 Triennial surveys. Total length, total weight, gonad, liver and gut weights relationships were established. Fulton index, gonad, liver and gut somatic indices were analysed in relation to maturity stages (2 to 6 using Walsh's key). Gut index was minimum for individuals in stage 3 and 4 (prespawning and spawning) and maximum for those in stage 6 (resting). Liver showed certainly dependent of maturity stage. When 2007 and 2010 are comparing the following aspects are observed: i) nutritional status of mackerel in 2010 seems to be better than in 2007 when the gut weight is considered. That could indicate the mackerel in 2010 feed more intensively than in 2007; ii) Liver (considered like lipid reserve organ) reserves can be used for ovarian recrudescence in female mackerel. In 2010 mackerel females for a given weigh presented heavier livers than in 2007. Assuming than the number of eggs female mackerel releases during the reproductive period is related to female condition the light increases in potential fecundity of mackerel in 2010 could be explained by their better condition.

2. Horse-mackerel DEPM 2010 – stock south, ICES IXa

Maria Manuel Angélico, Patrícia Gonçalves and Ana Maria Costa
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Abstract

Research undertaken in recent years revealed that horse-mackerel (Trachurus trachurus) is an indeterminate spawner (Gonçalves *et al.,* 2009; Karlou-Riga and Economidis, 1997; Eltinket *et al.*, 2000; Abaunza *et al.*, 2003; de Oliveira *et al.*, 2006; Gordo *et al.*, 2008) and subsequently the annual egg production method was substituted by the daily egg production method (DEPM). This change involved modifications in the sampling and laboratorial methodology, the inclusion of new parameters and also a revision in the way other are estimated. The shift to a full DEPM approach is not entirely achieved since some aspects of the reproductive strategy of the species are not well studied. An eventual daily period for spawning is an issue being addressed because it has an effect in the manner the eggs are aged and also in the way the daily fecundity is estimated.

Work is also undergoing in order to correctly assess the potential misidentification of the species eggs given that they are similar to other found along in the plankton samples.

3. Reproductive strategies and fecundity type regulation through food availability in marine fish

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Abstract

Marine fish show a wide range of reproductive strategies. On the one hand, capital spawners use energy reserves built-up prior to the spawning period, whereas income spawners utilize food resources during the spawning season. We hypothesis that the energy allocation pattern is adapted to the seasonal pattern in food availability and the spawning time, and determines the mechanizm of fecundity regulation, e.g. determinate and indeterminate spawning.

The hypothesis is tested by conceptually oriented comparing reproductive strategies of different fish species and populations with a range of fecundity types in relation to their pattern of energy intake and allocation of energy over somatic growth and reproduction, using empirical information.

We show that food availability is the most important factor regulating fecundity type. Also food availability for the larvae put constraints on the fecundity regulation of the adults. Other important factors for the determinate fecundity type are body condition, egg dry weight and latitude. For the indeterminate fecundity type the additional significant factors are relative fecundity, spawning period and environmental temperature.

If food is available during the spawning season a determinate spawner could in theory show a more indeterminate fecundity type, but will not become a definite indeterminate spawner. Thus, fecundity type of marine fish females is not fixed at the species level but represents a plastic response to the environment through food availability and energy allocation.

4. Spatial patterns of spawning locations in the ICES mackerel egg survey 1977 - 2010

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Abstract

The aim of this investigation was to determine underlying patterns in the location and density changes of spawning adult Northeast Atlantic mackerel (*Scomber scombrus*). Mackerel are one of the largest fisheries in Europe and spawn along the European continental shelf edge February to July. Under the current changing environment many species, particularly migratory marine species have been shown to undergo changes in range boundaries with a general poleward shift. Data for this investigation are from the "ICES Triennial Mackerel Egg Survey". Spatial statistics including the centre of gravity, inertia and anisotropy were employed with the raw and GAM modelled stage 1 egg data. Sea surface temperature was obtained from the Hadley dataset. Results from this investigation conclude the mackerel do spawn along, and follow the contours of the shelf edge. There was a statistically significant northward shift in the annual centre of gravity when correlated against year, in the raw and modelled data; and western shift in the modelled data. Survey effort cannot alone explain the significant northward shift in the GAM smoothed data. Sea surface

temperature of the Northeast Atlantic as a whole is increasing but is not significantly correlated with the sea surface temperature of the spawning areas. There is a significant correlation between the mean annual centre of gravity of northings and mean sea surface temperature of the Northeast Atlantic. Multiple regression analysis shows for every 1 degree of warming in the survey area, the annual centre of gravity is moving just over 58km north, independent of survey effort. The results demonstrate Atlantic mackerel are moving north in their spawning location and that the shift might be related to sea surface temperature. We show the influence of survey effort, and the importance of taking this into account when examining spatial statistics of this dataset.

5. Recalculation of the 2007 MEGS and of the 2010 period 2 MEGS results by interpolating between results of every other transect

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Abstract

Total annual egg production of mackerel was recalculated by using only daily egg production results of every other transect and interpolating egg production on missing transects from adjacent stations. This was done in order to test the feasibility of carrying out surveys on alternating transects while saving ship time for covering a wider survey area. Recalculation of the 2007 survey results showed that using alternating transect approach would have resulted in either 16.7% under- or 14.7% overestimation of the total annual stage I egg production depending on whether interpolation was done on even or odd transects. Total annual egg production was either $1.11 * 10^{15}$ when interpolated on the even transects or $1.53 * 10^{15}$ when interpolated on the odd transects while the originally calculated egg production was $1.34 * 10^{15}$. While in periods 3 – 5 differences between odd and even transect interpolation were only marginal, major differences occurred for period 2 and, hence, pre 2. These differences can be explained by the fact that in period 2 major mackerel spawning activity started only after completion of the first alternate leg of the survey and more eggs were found on the return leg while filling in the remaining transects. Contrasting to the 2007 recalculation results, recalculation of the 2010 period 2 results did not result in such a significant disparity between the two interpolation scenarios. Daily egg production estimate was $2.18 * 10^{13}$ and $2.34 * 10^{13}$ for interpolation on odd and even transects, respectively. Both values were slightly lower than the originally estimate without interpolation which was $2.41 * 10^{13}$. The impact on the total annual egg production was less than in 2007 with underestimations of 5.96% and 1.97%, respectively. Total annual egg production was either $1.66 * 10^{15}$ when interpolated on the even transects or $1.59 * 10^{15}$ when interpolated on the odd transects while the originally calculated egg production was $1.69 * 10^{15}$.

6. Mackerel and Horse mackerel egg production in 2010 in southern and western component and Western stock respectively

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Abstract

Egg production for mackerel and western horse mackerel stock was estimated in 2010. Stage I egg abundance data were provided by the different institutes which completed surveys between January and July adhering to a survey plan devised at the 2009 planning meeting in Hamburg in 2009. In an almost identical survey plan to the 2007 survey, data were split into 6 periods. Overall survey coverage was good although an expansion to the spawning area in the northwest part of the western area from period 3 onwards resulted in a large proportion of the western area being completed using an alternate transect sampling strategy. The egg production curve for the western mackerel area for 2010 showed that peak spawning occurred in period 2 and this was responsible for around 70% of the total egg production in the western area. This intensity of spawning so early in the season is totally unprecedented within the history of the MEGS survey. The total eggs production estimated for western area was $1.69*10^{15}$. This is a 21% increase on the revised estimate for 2007($1.34*10^{15}$). For the southern area the egg production curve showed a similar pattern to that observed in 2007 with a single peak of spawning in period 2. There was an overall increase in the annual egg production estimate of 27% to $4.26*10^{14}$ compared with the revised 2007 estimate of $3.12*10^{14}$. In contrast to 2007 the egg production curve for western horse mackerel showed a biomodality with the peaks of spawning in periods 3 and 5. Estimate of annual egg production for western area was 1. $09*10^{15}$. That is a decrease of 33% on the 2007 revised estimate of $1.64*10^{15}$.

7. Presence of mackerel egg off the North Spanish coast in 2011

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Abstract

From January to December several cross–shelf transects are sampled in a monthly basis following standard protocols in the Cantabrian Sea and Galician waters by the Instituto Español Oceanografia (IEO). Each transect consists of at least three sampling stations.

In this work we analyse monthly mean Mackerel abundances during the first quarter in 2010 from two transects (Coruña and Santander) off the North Spanish coast, in order to study occurrence and abundance for mackerel eggs in plankton samples.

Transect in the West Cantabrian Sea (Coruña) showed a slight mackerel egg abundance in January but low levels of mackerel egg in February and March by other hand in the East Cantabrian Sea (Santander) there was not presence of mackerel eggs in January samples however there were significant mackerel egg abundances in February and March samples.

These results suggest an earlier spawning time for mackerel the Cantabrian Sea in 2010. This earlier spawning time could have an effect on estimation of mackerel egg production.

11 References

Angélico, M. M., Gonçalves, P., Costa, A. M. 2011. Horse-mackerel DEPM 2010 – stock south, ICES IXa. Working Document to WGMEGS 2011.

Abaunza, P., Gordo, L., Karlou-Riga, C., Murta, A., Eltink, A. T. G.W., Garcia Santamaria, M. T., and Hammer, C. 2003. Growth and reproduction of horse mackerel, *Trachurus trachurus* (Carangidae). Reviews in Fish Biology and Fisheries, 13: 27–61.

Damme, C. J. G. van, Rijnsdorp, A. D., Dickey-Collas, M., and Kjesbu, O. S. (in prep) Reproductive strategies and fecundity type regulation through food availability in marine fish.

DHI. 1967. Monatskarten für den Nordatlantischen Ozean. Deutsches Hydrographisches Institut. Nr 2420. Hamburg. Atlas.

Eltink, G., Boois, I., and Wiegerink, H. 2000. Preliminary estimates of horse mackerel fecundity in 2000 and the planning of the fecundity sampling in 2001. RIVO—The Netherlands Institute for Fisheries Research, CO 046, November 2000. 7 pp.

Gonçalves, P., Costa, A. M., and Murta, A. G. 2009. Estimates of batch fecundity, and spawning fraction for the southern stock of horse mackerel, *Trachurus trachurus*, ICES Division IXa. ICES Journal of Marine Science, 66 (4): 617–622.

Gordo, L. S., Costa, A., Abaunza, P., Lucio, P., Eltink, A. T. G. W., and Figueiredo, I. 2008.Determinate versus indeterminate fecundity in horse mackerel. Fisheries Research, 89: 181–185.

Hátún, H., Payne, M. R., Beaugrand, G., Reid, P. C., Sandø, A. B., Drange, H., Hansen, B., Jacobsen, J. A., and Bloch, D. 2009. Large bio-geographical shifts in the north-eastern Atlantic Ocean: From the Subpolar Gyre, via plankton, to blue whiting and pilot whales. Progress in Oceanography, 80 (2009): 149–162.

Holliday, N. P., Hughes, S. L., and Beszczynska-Möller, A. (Eds). 2009. ICES Report on Ocean Climate 2008. ICES Cooperative Research Report No. 298. 66 pp.

Horwood, J. W. The Bristol Channel sole (*Solea solea* (L.)): A fisheries case study. Adv. Mar. Biol., 29: 215–368, 1993.

Hughes, K., Johnson, M., Dransfeld, L. 2010. Report on Spawning dynamics of mackerel from the ICES mackerel egg survey. Working Document to WGMEGS 2011.

ICES. 1996. Report of the working group on mackerel and horse mackerel egg surveys. ICES CM 1996/H:2, 146 pp.

ICES. 1999. Report of the working group on mackerel and horse mackerel egg surveys. ICES CM 1999/G:5.

ICES. 2003. Report of the working group on mackerel and horse mackerel egg surveys. ICES CM 2003/G:07.

ICES. 2004. Workshop on mackerel and horse mackerel egg staging and identification. ICES CM 2004/G:13.

ICES. 2005. Report of the working group on mackerel and horse mackerel egg surveys. ICES CM 2005/G:09.

ICES. 2006. Workshop on mackerel and horse mackerel egg staging and identification. ICES CM 2006/LRC:17.

ICES. 2008. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WEMEGS), 7–11 April 209, IJmuiden, Netherlands. ICES CM 2008/LRC:09

ICES. 2009. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS), 20–24 April 2009, Hamburg, Germany. ICES CM 2009/LRC:09. 107 pp.

ICES. 2009. Report of the Workshop on Mackerel and Horse Mackerel Egg Staging and Identification (WKMHMES), 5–9 October 2009 and 1–4 December 2009, IJmuiden, The Netherlands and San Sebastian, Spain. ICES CM 2009/LRC:13. 90 pp.

ICES. 2010. Report of the Working Group on Cataloguing Data Requirements from Survey for the EAFM (WKCATDAT), 26–28 January 2011, Dublin, Ireland, ICES CM 2010/SSGESST:09.

ICES. 2010. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS), By Correspondence. ICES CM 2010/SSGESST:02. 59 pp.

Karlou-Riga, C., and Economidis, P. S. 1997. Spawning frequency and batch fecundity of horse mackerel, *Trachurus trachurus* (L.), in the Saronikos Gulf (Greece). Journal of Applied Ichthyology, 13: 97–104.

Murta, A. G., and Vendrell, C. 2009. Using the EM algorithm to age fish eggs. ICES Journal of Marine Science, 66: 607–616.

Oliveira, J. A. A. de, Roel, B. A., and Dickey-Collas, M. 2006. Investigating the use of proxies for fecundity to improve management advice for western horse mackerel *Trachurus trachurus*. ICES Journal of Marine Science, 63: 25–35.

Punzón, A., Villamor, B., and Preciado, I. 2004. Analysis of the handline fishery targeting mackerel (*Scomber scombrus*, L.) in the North of Spain (ICES Division VIIIbc), Fisheries Research, 69: 189–204.

Punzón, A., Villamor, B. 2009. Does the timing of the spawning migration change for the southern component of the Northeast Atlantic Mackerel (*Scomber scombrus*, L. 1758)? An approximation using fishery analyses. Continental Shelf Research, Volume 29, Issue 8, 30 April 2009, Pages 1195–1204.

Thorsen, A. 2010. Appendum regarding the fecundity estimate of the 2010 International Mackerel and Horse Mackerel Egg Survey – Preliminary Results, Survey Report to WGWIDE 2010.

Ulleweit, J., Burns, F., van Damme, C., Fonn, M., Kloppmann, M., Milligan, S., Thorsen, A. 2010. The 2010 International Mackerel and Horse Mackerel Egg Survey – Preliminary Results, Survey Report to WGWIDE 2010.

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Annex 2: Agenda

All days:

Working hours: 09:00 - ca. 17:30
(Start on Monday at 09:30)

Morning/afternoon breaks: 15mins

Lunch break: 1 hour (ca. 13:00–14:00)

Monday, 11/04

09:30 – 11:00	Welcome – Opening of the meeting, housekeeping, adoption of the agenda, discussion on TORs, appointment of rapporteurs
11:00 – 17:30	Presentations / working documents:
	Mackerel condition in 2007 and 2010
	Mackerel and Horse Mackerel Egg Production in 2010
	Recalculation of the 2007 MEGS results by interpolation between results of every other transect
	A geostatistical analysis on the changes of the mackerel spawning area

Tuesday, 12/04

09:00 – 10:45	Report layout, presentations / Working documents
	New finding on mackerel spawning strategy
	Egg abundance estimation routines and variance estimates
11:00 - 17:30	report drafting, plenary/discussion if needed

Wednesday, 13/04

09:00 – 17:30	report drafting, plenary/discussion if needed
	Presentation of fecundity results

Thursday, 14/04

09:00 – 17:30	report drafting, plenary/discussion if needed
	Presentation: Presence of mackerel eggs off the North Spanish coast in 2011

Friday, 15/04

09:00 – 16:00	report drafting, plenary/discussion if needed

End of the meeting

Annex 3.1: Terms of Reference for 2012

The **Working Group on Mackerel and Horse Mackerel Egg Surveys** (WGMEGS) chaired by: Cindy van Damme*, the Netherlands and Finlay Burns*, UK-Scotland, will meet in Galway/Dublin, Ireland, 16–21 April 2012 to:

a) Coordinate the timing and planning of the 2013 Mackerel/Horse Mackerel Egg Survey in the ICES Sub-areas VI to IX;

b) Coordinate the planning of the sampling programme for mackerel/horse mackerel fecundity and atresia;

c) Review and report on procedures for egg sample sorting, species identification and staging;

d) Review and report on procedures for fecundity and atresia estimation;

e) Analyse and evaluate the results of the 2011 mackerel egg survey in the North Sea;

f) Update the survey manual and make recommendations for the standardization of all sampling tools, survey gears and procedures;

g) Consider the results of the workshop (held prior to the WGMEGS meeting) and plan for a possible DEPM and AEPM survey for mackerel in parallel in 2013.

WGMEGS will report by 1 June 2012 for the attention of the SSGESST, WGISUR, ACOM and WGWIDE.

Supporting information:

Priority	Essential. The egg survey provides the only fishery-independent stock data used in the assessment for Northeast Atlantic mackerel and for both the western and the southern horse mackerel stocks. As part of the multiannual management plan the index for horse mackerel is directly used for the calculation of the TAC.
Scientific justification	The egg survey provides the only fishery-independent stock estimates for Northeast Atlantic mackerel and for both the western and the southern horse mackerel stocks. The survey is based on a time-series since 1977.
Resource requirements	None. The surveys are all part of the national programs. The surveys and associated meetings are also partially funded under the EU fisheries data directive.
Participants	Usually ca. 20 participants from ICE, Far, N, NL, P, ESP, UK (E), UK (Scot), D, IRL.
Secretariat facilities	None
Financial implications	No financial implications
Linkages to advisory committees	The survey data are prime inputs to the assessments which provide ACOM with information required for responding to requests for advice/information from NEAFC and EC DG MARE.
Linkages to other committees or groups	WKFATHOM, WGNAPES, SGSIPS.

Linkages to other organizations	There have been a number of associated EU funded projects in the past.

Annex 3.2: Terms of Reference for a 2012 Workshop on Survey Design and Mackerel and Horse Mackerel Spawning Strategy

A **workshop on Survey Design and Mackerel and Horse Mackerel Spawning Strategy** (WKMSPA) chaired by Cindy van Damme*, The Netherlands and Finlay Burns*, UK-Scotland will meet in Galway/Dublin, Ireland 16–18 April 2012to:

a) Review the actual research results on the spawning strategies on mackerel and horse mackerel with their possible implications on the survey design and the historical time-series;

b) Obtain expert information on the sampling program for eggs as well as adult parameters (batch fecundity, batch frequency, duration of spawning, duration of POFs, spawning fraction) for a possible DEPM survey for both species;

c) Investigate the estimation procedure for historical data and future data based on the DEPM method for the SSB;

d) Give recommendations on the future format of the Triennial mackerel and horse mackerel egg survey.

WGMEGS members and experts on performing DEPM surveys and statistical analysis of DEPM surveys as well as assessment scientists will be invited.

Results of the workshop will be directly considered by WGMEGS.

Supporting information:

Priority	Essential. The egg survey provides the only fishery-independent stock data used in the assessment for Northeast Atlantic mackerel and for both the western and the southern horse mackerel stocks. As part of the multiannual management plan the index for horse mackerel is directly used for the calculation of the TAC.
Scientific justification	The egg survey provides the only fishery-independent stock estimates for Northeast Atlantic mackerel and for both the western and the southern horse mackerel stocks. The survey is based on a time-series since 1977. A working document was presented at the 2011 meeting indicating mackerel might have be an indeterminate spawner. The AEPM method, used for the triennial survey, is not possible for indeterminate spawners since it is not possible to estimate potential fecundity in these spawners. This workshop will review the available information on mackerel spawning, batch fecundity, spawning fraction, time between batches in order to assess the possibility of a DEPM survey. DEPM experts will help with the setup of a DEPM survey design and implications for the historical time-series.

Resource requirements	None. The surveys are all part of the national programs. The surveys and associated meetings are also partially funded under the EU fisheries data directive.
Participants	Members of WGMEGS, DEPM experts, assessment scientists.
Secretariatfacilities	None
Financial implications	No financial implications
Linkages to advisory committees	The survey data are prime inputs to the assessments which provide ACOM with information required for responding to requests for advice/information from NEAFC and EC DG MARE.
Linkages to other committees or groups	WKFATHOM, WGNAPES, SGSIPS.
Linkages to other organizations	-

Annex 3.3: Terms of Reference for the Workshop on Egg staging, Fecundity and Atresia in Horse mackerel and Mackerel [WKFATHOM]

2010/2/SSGESST18 The **Workshop on Mackerel and Horse mackerel Egg staging and Identification** (WKMHMES), chaired by Cindy van Damme*, the Netherlands, will be renamed the **Workshop on Egg staging, Fecundity and Atresia in Horse mackerel and Mackerel** (WKFATHOM) and will meet twice in autumn 2012 to:

a) Carry out comparative plankton sorting trials on typical survey samples. This should follow the pattern of trial – analysis – retrial – identification of problem areas;

b) Carry out a comparative egg staging trial for mackerel and horse mackerel eggs following the pattern used in the 2009 egg staging workshop;

c) Update a set of standard pictures and descriptions for species identification and egg staging;

d) Provide a review of any available documentation on identifying eggs to species and define standard protocols;

e) Carry out inter-calibration work on fecundity determination and harmonize the analysis and interpretation of fecundity samples;

WKFATHOM will report by January 2013 (via SSGEST) for the attention of SCICOM, WGISUR, WGMEGS and WGWIDE.

Supporting Information

Priority	Information quality, used to provide fishery advice through WGMHSA, will be impaired if this workshop is not conducted.
Scientific justification	Sorting eggs from plankton samples, Identification of eggs to species and the staging of those eggs remains one of the key areas in the execution of the mackerel and horse mackerel egg surveys. As this process is carried out by a number of different operators in many different countries, then the data combined, it is vital that the process be standardized. WGMHSA and WGMEGS strongly feel that this is best done through the mechanizm of sample exchange programmes and regular workshops to compare results. In the context of the triennial egg surveys it would seem appropriate to hold a workshop prior to every survey to standardize approaches and methodologies in the run-up to the surveys. This will have the advantage of training new operators as well as harmonizing the approach of experienced operators. Egg staging workshops were held in 2000, 2003and 2006 and were very successful in achieving these aims. It is proposed that these be used as a model for the proposed workshop in 2009. It is expected that the workshop will use the proven method of carrying out a set of sorting trials, analysing the results and identifying problems, then repeating the trials on the basis of the new understanding. The workshop will also be tasked to update a standard manual of descriptions and photographs to assist in the plankton sample handling procedure. This material was assembled into an agreed standard manual at previous workshops. In the context of these surveys, fecundity estimation is very important for conversion of egg production to biomass. Fecundity estimation is carried out using histological methods and the analysis and interpretation of this material also requires standardization across participating institutes. Standardization of this aspect of the work will be included in the workshop. Goal 1. Understand the physical, chemical, and biological functioning of

	marine ecosystems Modernise technologies and sampling designs for collecting, measuring, and enumerating marine organisms, and improve the precision and accuracy of resource surveys. Goal 4. Advise on the sustainable use of living marine resources and protection of the marine environment Develop quality assurance protocols to enhance confidence in scientific advice.
Resource requirements	None
Participants	Mainly scientists (approximately 20) involved in the surveys.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to advisory committees	ACOM
Linkages to other committees or groups	WGMEGS and WGWIDE.
Linkages to other organizations	None.

Annex 4: Recommendations

Recommendation	For follow up by:
1. WGMEGS recommends the continuation of the workshops, WKFATHOM, in the year prior to the survey. These workshops harmonize egg identification, (species and development stage), and determination of fecundity in mackerel, and spawning rates in horse mackerel. The next WKFATHOM workshops are scheduled for late 2012. WGMEGS recommends that the participation on these workshops should be co-financended by the EU as the workshops are essential to the quality assurance of the mackerel and horse mackerel egg survey.	ICES SCICOM, SSGESST, PGCCDBS
2. WGMEGS recommends that an exchange and analysis of fecundity samples takes place before the WKFATHOM fecundity workshop in 2012. This will highlight any potential problems with the analysis prior to the surveys starting. Any difficulties encountered can be discussed and resolved at the workshop.	WGMEGS and WKFATHOM participants
3. WGMEGS recommends that fecundity samples for mackerel and horse mackerel be collected from commercial vessels during 2013, the next survey year. This would necessitate sending samplers on a number of trips early in the year. In addition there may be an opportunity for collection of prespawning fecundity samples to be taken on IBTS surveys during Quarter 4 2012.	WGMEGS participants, IBTSWG, national institutes of mackerel catching countries
4. WGMEGS recommends to the Working Group for Integrating Surveys for the ecosystem approach (WGISUR) that they need to be aware of the following concerns: Additional tasks undertaken to address the 'ecosystem approach' are likely to impact the existing surveys, unless sufficient additional resources (staff, ship time, equipment) become available. In fact it is unlikely that most additional tasks will be conducted by WGMEGS participants without these additional resources. Any additional tasks that require the survey vessels to stop or slow down or divert course from the original survey plan will seriously impact the quasi-synoptic nature of these surveys.	WGISUR
5. WGMEGS recommends that a workshop should be conducted prior to the 2012 meeting. WGMEGS members and experts on performing DEPM surveys and statistical analysis of DEPM surveys as well as assessment scientists will be invited to: Review actual research results on the spawning strategies on mackerel and horse mackerel with their possible implications on the survey design and the historical time-series, Obtain expert information on the sampling program for eggs as well as adult parameters (batch fecundity, batch frequency, duration of spawning, duration of POFs, spawning fraction) for a possible DEPM survey for both species, Investigate the estimation procedure for historical data and future data based on the DEPM method for the SSB, Give recommendations on the future format of the Triennial mackerel and horse mackerel egg survey.	ICES SCICOM, SSGESST, WGMEGS, national institutes
6. WGMEGS recommends that in order to cover the entire mackerel spawning season allocation of survey area to	Participating countries, German national institute (vTI-SF), Irish

participating nations should be considered carefully accounting for deficiencies encountered during the 2010 survey. Also in some areas, surveys should start earlier in the year. In particular, a period 1 survey should be carried out in the Cantabrian Sea and possibly as well in the Celtic Sea. Germany and Spain (AZTI) should consider starting their period 2 surveys earlier than in previous years	national institute (MI), Spanish national institutes (IEO, AZTI)
7. WGMEGS recommends that in order to cover the northwestern spawning boundaries, Iceland and the Faroese should be encouraged to carry on their participation during future surveys. It should be recommended to all participating countries to keep their survey design flexible in order to assist other participants if a widening of the survey area becomes necessary.	Participating countries, Faroese national institute (FAMRI), Icelandic national institute (MRI)
8. WGMEGS recommends that the IBTSWG and WGNAPES are looking for possibilities to take ichthyoplankton samples for mackerel and horse mackerel during their surveys. Samples can be collected opportunistically within the first quarter of 2012 by IBTS and the Blue whiting survey in order to define the beginning of the spawning time and providing additional information on the Western spawning boundary of mackerel and horse mackerel.	ICES IBTSWG and WGNAPES