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Final Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys

24-28 April 2017

Vigo, Spain

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CIEM Conseil International pour l'Exploration de la Mer

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Executive summary

During its 3-year cycle, the ICES Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS) met twice, on 20–24 April 2015 and 24–28 April 2017. During the survey year in 2016 there was no meeting but a report was published fine tuning of the 2016 survey plan and presenting results of the 2015 North Sea mackerel egg survey. WGMEGS was chaired by Cindy van Damme (Wageningen Marine Research, the Netherlands) and Finlay Burns (MSS, Aberdeen, Scotland). The meeting in 2015 dealt with the planning of the 2016 Northeast Atlantic mackerel and horse mackerel egg survey and the 2015 North Sea mackerel egg survey. In 2017 WGMEGS met to evaluate the results of the Mackerel and Horse Mackerel Egg Survey in 2016 and to plan the North Sea Mackerel Egg Survey in 2017. The main objective of the survey is to produce both an index and a direct estimate of the biomass of the Northeast Atlantic mackerel stock and an index for the western horse mackerel stock.

Netherlands was the sole participant of the North Sea survey in 2015 (and will be again in 2017). Peak spawning was well covered in 2016. Egg production was $119*10^{12}$, and SSB was $170*10^{3}$ tonnes. A slight increase compared to 2011.

In 2016, Portugal, Spain, Scotland, Ireland, the Netherlands, Germany, Iceland, and the Faroe Islands participated in the survey in the Northeast Atlantic. The application of an alternate transect survey design made it possible to survey the increasingly wide area that became necessary due to the continuing expansion of mackerel spawning area and season. Northern and northwestern spawning boundaries for mackerel during peak spawning periods 5 and 6 were not fully delineated. However, analyses showed that the mackerel core spawning area was covered and a reliable estimate of mackerel annual egg production was delivered. The estimate of total mackerel egg production was $1.77*10^{15}$ which is a decrease of 34% compared to that of 2013 (rev. $2.71*10^{15}$).

SSB for the NEA mackerel stock in 2016 was estimated at:

- 3.08 million tonnes for western component (2013: 3.9).
- 0.45 million tonnes for southern component (2013: 0.9).
- 3.52 million tonnes for western and southern components combined (2013: 4.83).

The analyses showed that the NEA mackerel stock has decreased by 27%.

Western horse mackerel was found to have spawned less in 2016; $3.31*10^{14}$. This is a decrease of almost 9% compared to 2013 and the lowest production in the time-series ever.

Peak spawning for mackerel in the western area in 2016 was observed during period 5 (May). This was significantly later than was observed in 2013 (February/March).. WGMEGS recognizes the need to investigate mackerel spawning in 2017 and 2018 to check if 2016 was an exceptional year. In order to inform WGMEGS during the planning process for the 2019 survey, participants are requested to pursue additional opportunities for plankton and fecundity sampling in 2017 and 2018, for both mackerel spawning components. For western horse mackerel the spawning peak was observed in period 6 (June).

1 Administrative details

Working Group name

Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS)

Year of Appointment within the current three-year cycle

2014

Reporting year concluding the current three-year cycle

3

Chair(s)

Cindy van Damme, The Netherlands

Finlay Burns, UK (Scotland)

Meeting venue(s) and dates

20–24 April 2015, Copenhagen, Denmark, (17 participants)

2016 by correspondence

24–28 April 2017, Vigo, Spain, (19 participants)

2 Terms of Reference a) – k)

a) Coordinate the timing and planning of the 2016 Mackerel/Horse Mackerel Egg Survey in the ICES Subareas 6 to 9.

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

f) Analyse and evaluate the results of the 2014 mackerel egg survey in the North Sea.

g) Analyse and evaluate the suitability of the spawning fraction and batch fecundity data collected during the 2013 enhanced DEPM sampling programme within periods 3 and 5 for both species.

h) Examine the results of the Hamburg and Bergen workshops (October and November 2015) on mackerel and horse mackerel egg staging and identification and fecundity and histology, and incorporate these into the WGMEGS manuals in time for the 2016 survey.

i) Fine-tune survey execution in 2016.

j) Analyse and evaluate the results of the 2016 mackerel and horse mackerel egg surveys in the western and southern areas.

k) Plan and coordinate the 2017 North Sea mackerel egg survey.

3 Summary of Work plan

Year 1	**Planning of the egg survey in 2016 and reporting on the North Sea egg survey of 2014.**
Year 2	**Survey year, the Atlantic survey is conducted in 2016, no meeting takes place in year 2. A report, by correspondence, with the updated planning and manuals is published.**
Year 3	**Reporting and finalizing of the results of the 2016 egg survey. Planning of the 2017 North Sea egg survey.**

4 Summary of Achievements of the WG during 3-year term

- Planning, execution and reporting on the 2016 Atlantic mackerel and horse mackerel egg survey.
- Total Annual Egg Production of western and southern mackerel and western horse mackerel and SSB estimate of western and southern mackerel for the assessment of these stocks to WGWIDE.
- Daily Egg Production and SSB estimate of southern horse mackerel.
- Report on the 2015 mackerel eggs survey in the North Sea.
- Total Annual Egg Production and SSB estimate of North Sea mackerel for the assessment of this stock to WGWIDE.
- Planning of the 2017 North Sea mackerel egg survey.
- Review results from egg staging and fecundity workshops as reported in the 2015 WKFATHOM Report (ICES, 2015a).
- Finalize historic Atlantic mackerel and horse mackerel egg dataset and uploading to the ICES Egg and Larvae database.
- Publish updated manuals for execution of the mackerel and horse mackerel egg surveys: 1) Sampling at sea (SISP 6) and 2) AEPM and DEPM fecundity estimation for mackerel and horse mackerel (SISP 5)
- Prepare input format for the ICES database for the mackerel and horse mackerel biological, fecundity and atresia data.
- New R-script for estimation of Total Annual Egg Production for mackerel and horse mackerel (*Teggprod*), and uploading to the ICES GitHub.
- CV estimates of Atlantic mackerel and horse mackerel egg productions.
- Development of Environmental Niche Model (ENM) to improve the egg survey. A distribution forecast system for the spawning of mackerel in the Northeast Atlantic.

5 Final report on ToRs, workplan, and Science Implementation Plan

5.1 Activities in 2015, 2016, and 2017

WGMEGS met in Copenhagen, Denmark, in April 2015 to plan the ICES Triennial Mackerel and Horse Mackerel Egg Survey in 2016 (ICES 2015a). Due to limited resources available, gaps in the survey planning schedule occurred which could not be solved during the meeting. Subsequently, additional survey effort was provided by Scotland and the Netherlands to cover these gaps in the survey plan. These additional surveys were completed using commercial fishing vessels and with the cooperation of industry representatives from those two countries. Despite the addition of these extra surveys it was clear at the end of 2015 that the 2016 survey could only be executed by utilizing the alternate transect sampling option. Two workshops in October and November 2015 on mackerel and horse mackerel egg staging and identification, and fecundity and atresia sampling and estimation were held in Hamburg, Germany, and Bergen, Norway, (ICES 2015b). The workshops standardized methods and analyses between survey participants and ensured training of new participants. During the workshops the manuals for sampling at sea (SISP 6) and fecundity and atresia analyses (SISP 5) were revised and updated.

The North Sea mackerel egg survey was conducted in May-June 2015. Details and results of the survey were published in the 2016 report (ICES, 2016). The survey was coordinated by Cindy van Damme. Total annual egg production (TAEP) and SSB estimation were presented to WGWIDE in 2016 for use in the assessment (Damme, 2015).

The final planning of the egg survey was published in the 2016 WGMEGS report (ICES 2016). The Triennial Mackerel and Horse Mackerel Egg Survey was carried out during February - July 2016. An extra cruise outwith the core survey period was added in August 2016 to check for continued horse mackerel spawning. Details on the survey are given in this report. The survey was coordinated by Brendan O'Hea. Preliminary results of the TAEP of western and southern mackerel and western horse mackerel and SSB of western and southern mackerel were delivered to WGWIDE in 2016 for use in the assessment in 2016 and benchmark in 2017 for both species. Southern horse mackerel biological data were submitted to WGHANSA in 2016 for use in the assessment of the stock.

Since 2004 and subsequent demands for up-to-date data for the assessment, WGMEGS aims to provide a 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. Calculation of the preliminary results for WGWIDE necessitated a comprehensive work up of the data from the egg survey as well as the mackerel fecundity and atresia samples. Due to the very short time frame between the survey completion and the submission of preliminary results only samples from period 2 and 3 were available to calculate the potential fecundity. The same time constraints meant that there was no current data available on the prevalence and intensity of atresia and the average of the historical atresia estimates between 2001 and 2013 was used to provide a preliminary estimate of realized fecundity. The subsequent comprehensive and full analysis of the fecundity samples from all periods has therefore resulted in a revised estimate and these finalized results are reported in this report. Working documents with the preliminary results of the survey were submitted to WGWIDE members prior to the 2016 meeting and prior to the benchmark in 2017, as requested (Burns *et al.*, 2016, Costas *et al.*, 2017).

Daily egg production adult parameter and SSB estimates were estimated for Northeast Atlantic mackerel, Western and Southern horse mackerel and North Sea mackerel. These estimations are still preliminary as methods are still under development. Results are presented in this report.

In 2017 the planning for the North Sea mackerel egg survey was conducted during the WGMEGS meeting. The survey is due to be executed in May and June 2017.

The development of an Environmental Niche Model (ENM) to improve the egg survey and a distribution forecast system for the spawning of mackerel in the Northeast Atlantic is set to continue in 2017.

5.2 Western and Southern egg surveys in 2016 (ToR a, b, i, j)

5.2.1 Countries and Ships Participating

In contrast to recent surveys, the 2016 mackerel and horse mackerel egg survey was designed to cover the whole spawning area of the two species within 7 sampling periods of differing geographical coverage (ICES 2015a). The deployment of research vessel effort in 2016 is given in Table 5.2.1. 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 2016, a total of 19 individual cruises were carried out totalling 367 survey days, with the contribution of Spain (IEO: 46 days at sea, AZTI: 41 days), Scotland (75 days), Ireland (55 days), Portugal (30 days), Germany (27 days), the Netherlands (56 days), the Faroe Islands (13 days) and Iceland (14 days). This marks an increase in survey effort compared to 341 survey days in 2013 and 334 days in 2010.

Table 5.2.1: Participating countries, vessels, areas assigned, dates and sampling periods of the 2016 surveys.

Country	Vessel	Area	Dates	Period
Portugal	Noruega	West Portugal	11 Mar–1 Apr	3
		Cadiz, southern Portugal	9 April–1 May	4
Ireland	Celtic Explorer	Celtic Sea, Biscay, Cantabrian Sea	2–22 February	2
	Corystes	West of Ireland, west of Scotland	2–22 June	6
	Atlantic Challenge	West of Ireland, west of Scotland	10–22 August	8
Scotland	Altaire	West of Scotland, west of Ireland	22–29 February	2
	Altaire	West of Scotland, west of Ireland	1–7 March	3
	Altaire	West of Scotland, west of Ireland	13–27 April	4
	Scotia	West of Scotland, west of Ireland	7–29 May	5
	Altaire	West of Scotland, west of Ireland, Celtic sea, Biscay	27 June–20 July	7
Spain (IEO)	Vizconde de Eza	Cantabrian Sea, Galicia	7 March–2 April	3

	Vizconde de Eza	Cantabrian Sea, Galicia	8–28 April	4
Spain (AZTI)	Ramon Margalef	Biscay	19 March–7 April	3
	Ramon Margalef and Emma Bardan	Biscay, Cantabrian Sea	30 April–20 May	5
Germany	Walther Herwig	Celtic sea, west of Ireland	25 March–8 April	3
	Walther Herwig	Celtic sea, west of Ireland	11–16 April	4
Netherlands	Tridens	Biscay, Celtic sea	12 April–4 May	4
	Atlantic Lady	Biscay, Celtic sea	11–24 May	5
	Tridens	Biscay, Celtic sea	1–21 June	6
Iceland	Bjarni Saemundsson	Faroes and Shetland	3–15 May	5
Faroes	Magnus Heinason	Faroes	26–30 May	5
	Magnus Heinason	Shetland	31 May–6 June	6

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

In addition to the seven sampling periods an eighth period was added, after the nominal end survey date of 31 July, at the request of the pelagic industry. The deployment of vessels to areas and periods is summarized in Table 5.2.1.

As a result of the reduction in survey participants after 2013, and due to the continued expansion of the mackerel spawning area since 2007, WGMEGS was required to source additional participation in the survey in 2016. The group approached national pelagic industry organizations to seek support. The pelagic associations of Scotland, Netherlands, Ireland and Denmark subsequently expressed a willingness for industry vessels to be used in the 2016 survey. This support is reflected in the increased number of survey days noted compared to both 2010 and 2013. The geographical area covered by the survey continues to expand in line with the increased spawning area and therefore it was not felt that the slight net increase in effort had enhanced in any way the surveys ability to satisfactorily survey the spawning activity during all periods.

Due to vessel issues Portugal was unable to carry out their DEPM survey in ICES Division 9a in Period 1. Instead the survey was split resulting in it being carried out during periods 3 and 4. Sampling in the western area commenced in period 2 with Ireland and Scotland surveying from the west of Scotland to the eastern Cantabrian Sea. Period 3 saw the survey extend westwards into the Cantabrian Sea, Galicia and 9a north. Sampling continued in this area in period 4, with Portuguese sampling moving from 9a north to 9a south. All sampling in Galicia, and Area 9, ceased after period 4. From period 6 onwards, only the western area north of the Cantabrian Sea was covered.

Due to the expansion of the spawning area which has been observed since 2007 the emphasis was even more focused on full area coverage and delineation of the spawning boundaries. 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 during the return leg.

The planned and realized survey coverage by period is described in detail below (Maps of numbers of completed samples/sampling rectangle for all periods can be found in Annex 6):

Period 1 –Portugal were programmed to carry out a DEPM survey in ICES Division 9a between Cadiz and Galicia, mainly targeting the southern horse mackerel stock. This survey is designed for this purpose but it provides mackerel egg samples as well. Due to issues with vessel availability the survey was delayed and took place instead during periods 3 and 4.

Period 2 - Period 2 traditionally marks the start of the surveys in the western area. Since 2010 the commencement date of this period has been moving forward in time. The results of the 2013 MEGS survey and the Winter 2014/Spring 2015 industry surveys indicated that early spawning in the western area was set to continue. As a result, the start of period 2 in 2016 was brought forward in time to commence at the start of February. The justification being to try and 'capture' spawning activity before its peak. Sampling was undertaken by Ireland (Celtic Sea, Biscay and the eastern Cantabrian Sea) and Scotland (Northwest Ireland and West of Scotland).

Survey coverage was good with 176 stations sampled, 9 interpolated and there were 17 replicate samples.

Period 3 – In period 3 the German vessel was operating to the West of Ireland, Celtic Sea and N Biscay. The Bay of Biscay, the Cantabrian Sea and Galicia were covered by Spain (IEO and AZTI). Portugal sampled in Division 9a from the Portuguese border south to Lisbon.

Denmark had hoped to participate during this period covering Northwest Ireland and the West of Scotland but were unable to do so. Scotland modified and extended their period 2 survey and completed the proposed Danish area on alternate transects during period 3. AZTI lost a number of days due to weather and vessel issues.

640 stations were sampled, 32 were interpolated and there were 208 replicate samples which were predominantly completed in the Cantabrian Sea and west of Portugal.

Period 4 – This period was due to be covered by five surveys. Scotland was operating to the west of Scotland on board a commercial vessel, Germany to the west of Ireland and northern Celtic Sea, Netherlands in the southern Celtic sea and Biscay. Spain (IEO) sampled southern Biscay, the Cantabrian Sea and Galicia. Portugal sampled the south of 9a, from Lisbon to Cadiz.

Due to operational difficulties, the German vessel was unable to collect plankton samples in this period. Instead they collected adult samples for fecundity analysis prior to heading home for repairs. Scotland and Netherlands extended their survey areas to provide a complete coverage west of Ireland. Scotland managed to sample every transect while Netherlands sampled alternate transects in the additional area. During this period Netherlands also lost three days in port due to engine failure.

550 stations were sampled and 44 were interpolated. There were 243 replicate samples taken from the Cantabrian Sea and southern Portugal.

Period 5 – In period 5, five surveys sampled the area from the Cantabrian Sea to the Faroes. AZTI carried out a targeted DEPM survey for anchovy in southern Biscay and Cantabrian Sea and although it also provides mackerel and horse mackerel egg samples, the design of this survey means that it is constrained in that purpose. Netherlands surveyed northern Biscay and the Celtic Sea using a commercial vessel. Scotland sampled west of Ireland and Scotland, while Iceland and the Faroe Islands sampled from the north of Scotland to Faroes.

Despite all the effort deployed in this period the western and northern boundaries remained unsecured. Stations sampled by Scotland on Hatton Bank contained large numbers of stage 1 eggs, while large numbers were also found to the south of the Faroes, on the northern boundary of the Faroese survey.

The Faroese survey had been due to survey only in period 6 but due to vessel availability their survey had to be split between periods 5 and 6.

435 stations were sampled and 132 were interpolated. Seventeen replicate samples were collected, mainly in the Cantabrian Sea.

Period 6 – In this period Netherlands surveyed Biscay, north of 46°N, and the Celtic Sea, Ireland sampled to the west of Ireland and Scotland, and Faroes continued their survey to the north of Scotland. Netherlands successfully delineated the southern boundary of spawning for this period.

Once again there were significant issues securing boundaries to the West and the North, however boundary egg counts were not as high as in Period 5.

319 stations were sampled, with 109 interpolated and there was only 1 replicate.

Period 7 – This period was covered entirely by Scotland sampling mainly on alternate transects in the area from 46°15N in the South to the most northern transect on 59°15N. The southern boundary of sampling was delineated at 50°N and only very low levels of spawning were observed during this period. Similar to the 2013 survey the northern spawning boundary was delineated at 58°N.

144 stations were sampled, 62 were interpolated and there were 2 replicates.

Period 8 – As a result of the 2013 WGMEGS survey the pelagic industry had expressed concern that by using 31 July as the nominal end of spawning the triennial MEGS survey was missing horse mackerel spawning to the west of Ireland. WGMEGS was asked to look into this during the 2016 survey. The result was an additional survey undertaken outwith the core survey window. It was completed by Ireland in the area from 51°15N in the South to 57°45N in the north, using a commercial vessel. Only very low levels of spawning were observed during this period.

88 stations were sampled with 7 interpolated. There were no replicate stations completed.

5.2.3 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 half degree longitude were conducted on alternating transects covering the complete spawning area. The 2016 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 2194 plankton samples were collected and sorted. Mackerel, horse mackerel and hake and ling eggs were identified and the egg development stages determined.

In addition, all samples were investigated for presence of blue whiting larvae. Depending on the vessel facilities and the experience of the participants this was done either during the cruise or back in the institute laboratories.

Double micropipette samples and sections from 1427 ovaries of mackerel and horse mackerel were also taken on board. After finishing the individual surveys these samples were sent to six different European research institutes for the analysis and estimation of realized fecundity (potential fecundity minus atresia). For the mackerel atresia analysis only fish with atretic oocytes or spawning markers can be used. These markers can only be reliably detected histologically and these procedures and the resultant estimates are described in detail in section 5.4. WGMEGS decided that from the 2013 survey onwards, and in the period of peak of spawning, extra sampling effort would be dedicated to collect additional adult samples for the estimation of adult parameters to apply the DEPM.

The analysis of the plankton samples as well as of the fecundity samples were carried out according to the sampling protocols as described in the WGMEGS Survey Manual v1.2 (SISP 5 and 6).

Horse mackerel is believed to be an indeterminate spawner and therefore since 2007 IPMA has adopted the DEPM methodology for southern horse mackerel (ICES Division 9a). The egg survey design in the western horse mackerel is directed at the AEP method for mackerel which produces an estimate of SSB. Fecundity samples for horse mackerel were taken during the expected peak spawning period in survey in order to develop a modified DEPM approach for estimating the biomass of the horse mackerel stocks.

5.2.4 Sampling Strategy for Horse Mackerel in the Southern Area

The Portuguese (IPMA) 2016 DEPM survey directed at southern horse mackerel (PT-DEPM16-HOM) was carried out on board RV Noruega between 11 March and 1 May (Period 3 and 4), later than scheduled due to logistic issues with the research vessel and with several interruptions due to adverse weather conditions and technical issues. It covered the area between the northern Spain-Portugal border and Cape Trafalgar. Unfortunately, the northernmost part of Division 9a (western Galician) could not be surveyed. The 2016 survey was conducted concurrently to the spring acoustic survey (PELAGO16) on board the same vessel, which required some sampling adaptations, namely that plankton sampling was mainly completed at night while during the day acoustic surveying and fish trawling for the two methods took place. Plankton surveying was conducted along-transects perpendicular to the coast and spaced 12 nautical miles apart.

The plankton samples were collected using a CalVET with CTD system (paired nets with 40 cm diameter mouth aperture and 150 µm mesh size); plankton hauls (and CTDF casts) were conducted down to 200 m depth maximum, following a predefined grid of stations (every 3 or 6 nautical miles) along the transects. The plankton samples from each net were stored in separate containers, one preserved in 4% buffered formaldehyde solution in distilled water (for laboratory eggs identification, staging and counting) and the other in 98% ethanol (for *Trachurus* spp. genetic analyses). CUFES samples (335 µm mesh size) were gathered continuously along the path between the vertical plankton tows, as an auxiliary sampler for adaptive area surveying, and surface temperature, salinity and fluorescence data were recorded. During the survey, a total of 393 CalVET with CTD samples were collected along 42 out of the 48 planned transects.

Fishing hauls were performed opportunistically during the survey using bottom trawl and pelagic gears. On the whole, 52 fishing hauls were obtained on board the research vessel, 16 hauls (31%) being positive for horse mackerel. These horse mackerel fish samples were augmented by 21 samples collected by the bottom-trawl and purse-seine fleets and landed at 6 Portuguese harbours (Matosinhos, Aveiro, Peniche, Sesimbra, Portimão/Olhão) and from the same period that the research vessel was surveying in each area. On the whole, biological data from 2451 fish were obtained from these 37 samples, 957 ovaries were preserved and stored in 4% buffered formaldehyde for histological processing, and 673 otoliths collected for age determination.

5.3 Hydrography

5.3.1 Southern Horse Mackerel DEPM Survey

In 2016, the joint DEPM and PELAGO survey started on the 11 March off river Minho and ended on 1 May in front of Lisbon after 31 effective days of work at sea. Due to technical problems and weather constraints the campaign suffered several interruptions which led to temporal and also spatial sampling discontinuities. The hydrography results are shown in Figure 5.3.1.

The sea surface temperature distribution patterns observed reflect the survey discontinuities, with lower values (12–14ºC) at the start, over the NW shelf, where usually the temperature is comparatively lower than in the more southern regions, but below average temperature for early spring were also observed on western Algarve shores. Overall, the water temperature was lower than during other corresponding periods in previous years, with only the inner Bay of Cadiz reaching close to 18ºC. During early spring, freshwater effects were still apparent mainly in the NW coast and due particularly to some rainy events which preceded the campaign. Higher fluorescence spots were mostly associated to the colder waters and/or to regions of river influence.

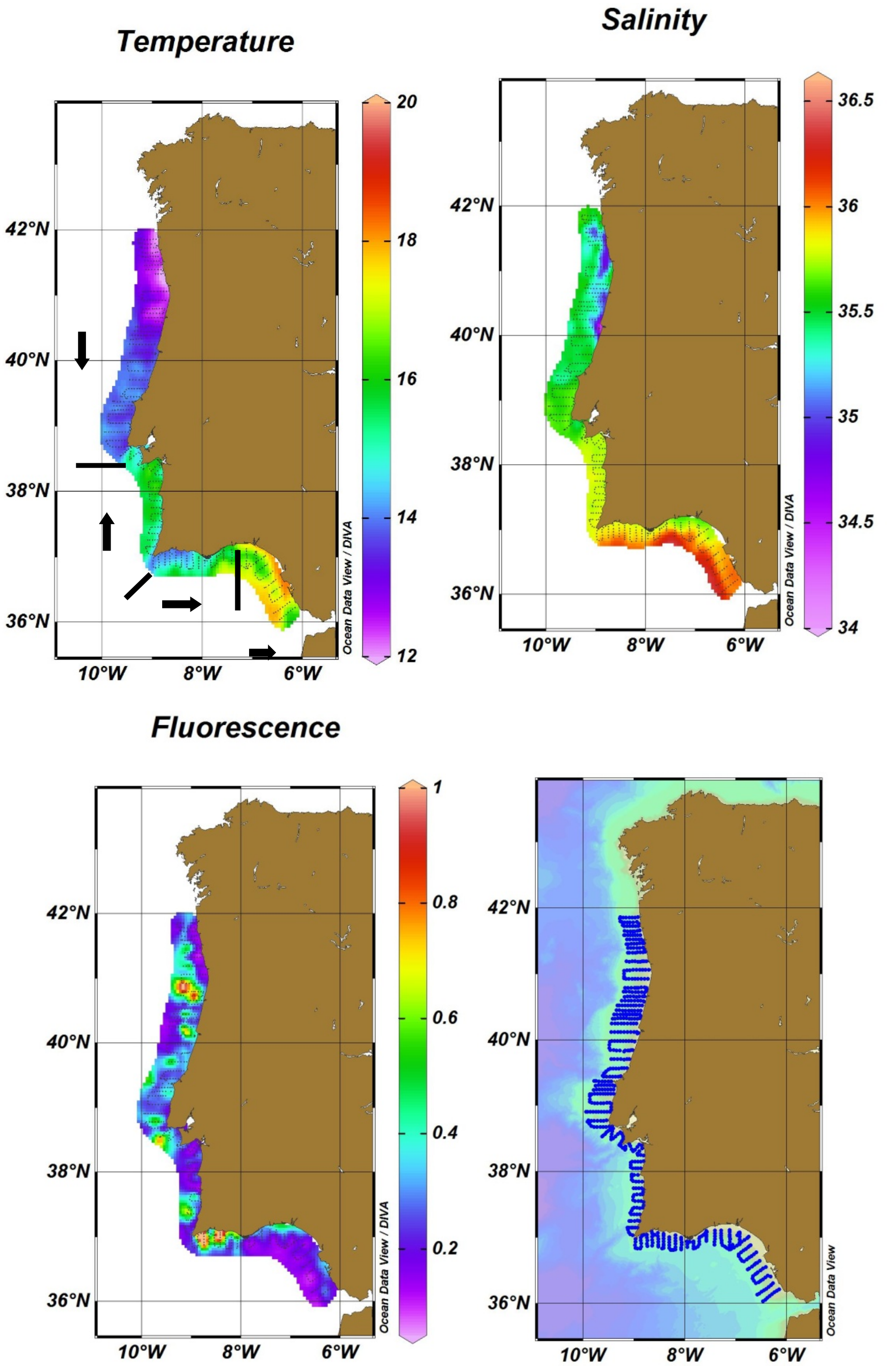


Figure 5.3.1. Temperature (°C) (top left panel), salinity (top right panel) and fluorescence (volt) (bottom left panel) distributions using the data obtained by the sensors associated to the CUFES-EDAS system and location of the CUFES samples (bottom right panel). In the top left panel, the black lines indicate the temporal discontinuities in surveying and the black arrows indicate the navigation direction.

5.3.2 Mackerel and Western Horse Mackerel Egg Surveys

Temperatures encountered by mackerel and horse mackerel during the spawning season are influenced by the seasonal warming of the surface layers (Figure 5.3.2). These temperatures are also used in the calculation of the daily egg production in both, mackerel and horse mackerel.

During period 2 temperatures at the sea surface varied between 8°C in the Northwest and >14°C in the southeastern corner of the Bay of Biscay. Temperatures increased gradually from North to South and no distinct fronts could be detected throughout the survey area.

While the survey area was extended to the southwest, covering the Cantabrian Sea and waters west of Galicia, the temperature ranges during period 3 was very similar to period 2, with values ranging between 8.0°C and 14.9°C. Warmest temperatures were again encountered in the southeastern corner of the Bay of Biscay. Thermal fronts appeared to have developed in the Bay of Biscay and west of Ireland.

During period 4, sea surface temperatures had increased over the complete survey area between the Galician coast and west of Scotland. Temperatures ranged between the 8.2°C northwest of Scotland and 17.8°C isotherm off Galicia. A strong temperature gradient straddled the Celtic Sea that separated the faster warming southern waters from an area where the seasonal temperature rise was less pronounced. Because of the stronger warming in the surface layers, the thermal front in the Bay of Biscay was no longer evident.

In period 5, the survey area extended further northwestwards covering the entire Rockall Bank and parts of Hatton Bank as well as waters east and west of the Faroese. In the South, the survey area shrunk and left the waters off Galicia unsampled. Consequently, the temperature range dropped to values between 7.5°C in the Northwest and 15.5°C in the eastern Bay of Biscay. However, overall and by region, temperatures had increased compared with period 4.

In periods 6 and 7 temperatures increased furthers to values between 8.5°C in the North (period 6) and 20.4°C in the South (period 7).

Because of the different time of particularly the sampling periods 2–5, a direct comparison between periods of the 2016 with previous survey years becomes difficult. However, it became apparent that during the earlier periods (2–4), water temperatures west of the British Isles were about 0.5°C lower than in 2013, where already a slight decrease in water temperatures were observed compared to surveys of the early 2000s. In all other areas, water temperatures were comparable to those or even higher than during previous surveys. These observations fit well with the cooling of the surface layers in the northern North Atlantic, chiefly west of the British Isles Islay and the Bay of Biscay, that were observed during the early 2010s (Larsen *et al*., 2016). That cooling reached its maximum in 2015 while in all other areas to the north and south temperature anomalies remained positive. That cooling may have acted as a barrier in blocking mackerel from migrating from their overwintering areas to their southern spawning areas.

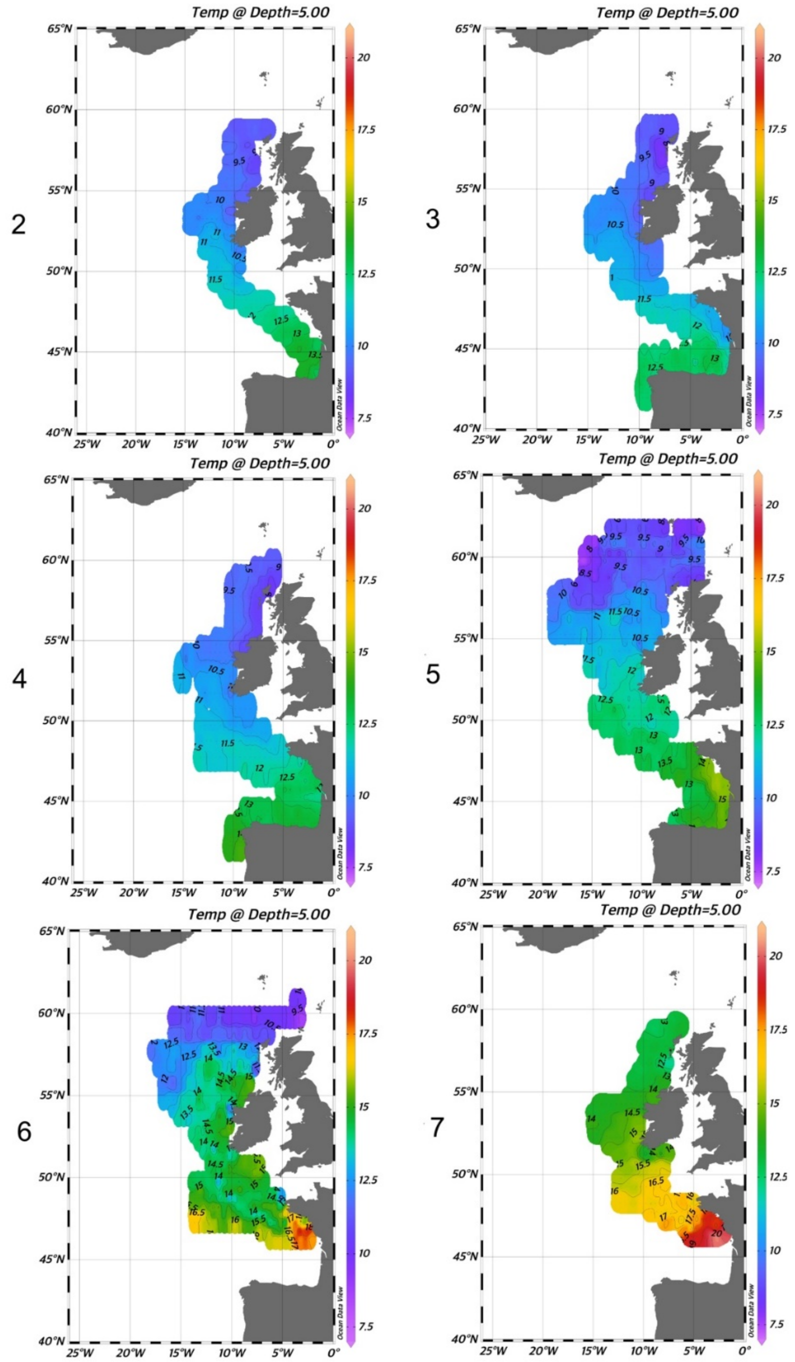


Figure 5.3.2: The distribution of the sea surface temperatures during MEGS periods 2 to 7.

5.4 Mackerel in the western and southern spawning areas: 2016 egg survey results (ToR j)

5.4.1 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. Distribution maps of mackerel spawning for both the southern and western areas are presented in Annex 7.

Period 1 – Due to difficulties in obtaining a vessel Portugal was unable to sample in division 9.a during this period. Instead this survey was split into two and took place during periods 2 and 3.

Period 2 –As a result of data obtained from the 2013 MEGS surveys and the winter 2014/2015 surveys period 2 was moved forward to start at the beginning of February. Unlike 2013 however no sign of spawning was found during this period in the Celtic Sea, Bay of Biscay or the Cantabrian Sea. Instead low levels of spawning were found north of 53.5°N by the Scottish survey with very small numbers of eggs found by Ireland on the two transects to the south of this. In 2016 the start of mackerel spawning in the western area was captured.

Period 3 – In period 3 the German vessel operated to the West of Ireland, Celtic Sea and N Biscay. Northwest Ireland and the West of Scotland was covered by Scotland on alternate transects. The Bay of Biscay, the Cantabrian Sea and Galicia were sampled by IEO and AZTI, and Portugal surveyed in the north of Subarea 9a. Low levels of mackerel spawning were found west of Ireland, Bay of Biscay and in the Cantabrian Sea. All boundaries were successfully delineated.

Period 4 – In period 4 sampling in the western area was carried out by IEO, Netherlands and Scotland, with the area covered running from Galicia in the south to Shetland in the north. Portugal completed their southern coverage in the south of Subarea 9a. Continuous low levels of mackerel spawning were observed throughout the survey area, with highest egg numbers concentrated along the 200 m contour. Egg numbers throughout Biscay were unusually low.

Period 5 – In period 5 five countries surveyed the area. AZTI conducted their DEPM survey in southern Biscay and the Cantabrian Sea targeting sardines and anchovies. Netherlands sampled the Celtic sea and northern Biscay, with Scotland surveying west of Ireland and west of Scotland. Faroes and Iceland surveyed north of this, up to 62°N. Low egg numbers were found in the Cantabrian Sea, with very few eggs in Biscay. Elsewhere within period 5 however spawning activity was very widely dispersed with Scotland, Iceland and Faroes encountering large numbers of eggs in northern waters. Northern and northwestern boundaries were not delineated during this period. Scotland encountered significant egg numbers on Hatton bank, west of Scotland at 19°W. Iceland encountered large numbers of eggs at the majority of their stations, and Faroes recorded eggs all along the northern boundary.

Period 6 – This period was covered by Ireland, Netherlands and Faroes. Netherlands delineated the spawning boundary in the south. Issues with eggs on the boundaries were still encountered in the north and northwest, albeit at much lower levels than in period 5.

Period 7 – Period 7 was surveyed entirely by Scotland, sampling on alternate transects, from 46°15N in the South to the most northern transect on 59°15N. The southern boundary was delineated at 50°N and only very low levels of spawning were observed during this period. Similar to the 2013 survey all boundaries were delineated.

5.4.2 Egg production in Northeast Atlantic mackerel

5.4.2.1 Stage I egg production in the western area

2010 provided an unusually large spawning event early in the spawning season, 2013 yielded an even larger spawning event indicating that spawning was probably taking place well before the nominal start date of 10 February (day 42) (Figure 5.4.1). In 2016 the first survey commenced on 5 February which is five days prior to the nominal start date. This year however, mackerel migration was later and slower than that recorded in the previous two surveys. Early peak spawning was not repeated and instead occurred during period 5 (May) (Figure 5.4.1). It is also important to note that during this period the majority of spawning was taking place not in the traditional spawning areas west of Ireland, the into the Bay of Biscay but in the northern offshore waters far west of Scotland and the Faroe Islands (Annex 7). During this period the northern and northwestern boundaries were not fully delineated and it is highly likely that a small amount of spawning was missed. Production estimates for the individual survey periods and the periods prior to the survey are presented in Table 5.4.1.

The nominal end of spawning date of the 31 July is the same as was used during previous survey years and the shape of the egg production curve for 2016 does not suggest that the chosen end date needs to be altered. The total annual egg production (TAEP) for the western area in 2016 was calculated as $1.55*10^{15}$. This is a 30% reduction on the revised 2013 TAEP estimate using the 2017 Teggprod script (section 5.11) which was $2.2*10^{15}$.

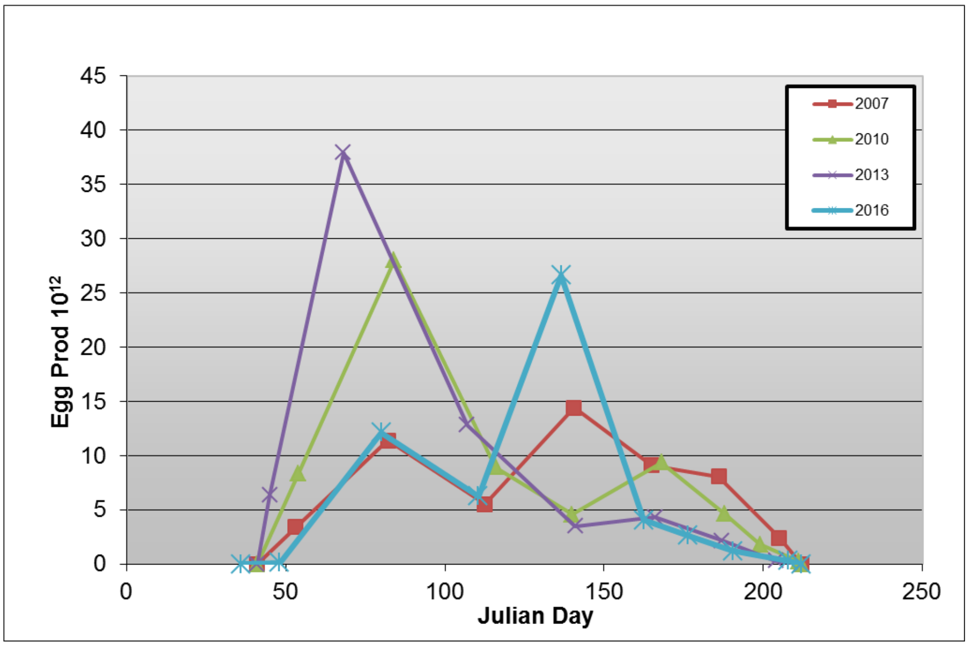


Figure 5.4.1. Annual egg production curve for mackerel in the western spawning component in 2016. The curves for 2007, 2010, and 2013 are included for comparison. (Curves for all years are recalculated using the Mendiola development equation and the 2017 *Teggprod* script).

Table 5.4.1: Western estimate of mackerel total stage I egg production by period using the histogram method for 2016.

Dates	Period	Days	Annual stage I egg production $*10^{15}$
	1	**No sampling**	
5–29 February	**2**	**25**	**0.003**
1 March–8 April	**3**	**39**	**0.47**
9–30 April	**4**	**22**	**0.14**
1–30 May	**5**	**30**	**0.80**
31 May–21 June	**6**	**22**	**0.09**
22–27 June	**6 – 7**	**6**	**0.02**
28 June–19 July	**7**	**22**	**0.02**
20–31 July	**Post 7**	**12**	**0.004**
Total			**1.55**
CV			**35.6%**
Variance			**3.04*e29**
Data CV			**2.197**

5.4.2.2 Stage 1 Egg production in the Southern spawning area

The start date for spawning in the southern area was on 15 February (Table 5.4.2) and this is 5 days later than the start date that was used in 2013. This is due to the delay to the start of the Portuguese survey in Subarea 9a. Sampling instead within Subarea 9a took place within periods 3 and 4. Conversely, surveying in the Cantabrian Sea where the majority of spawning occurs within the Southern area commenced 5 days earlier than in 2013 on the 8 March. The same end of spawning date of the 17 July was used again this year and the spawning curve suggests that there is no reason for this to change (Figure 5.4.2). As in 2013 the survey periods were not completely contiguous and this has been accounted for (Table 5.4.2). In contrast to previous years the mean daily egg production curve for 2016 does not display a distinct spawning peak. The total annual egg production (TAEP) estimate for the southern area in 2016 was calculated as $2.25*10^{14}$. This is a 55% reduction on the recalculated 2013 TAEP estimate using the 2017 Teggprod script (section 5.11) which was $5.06*10^{14}$.

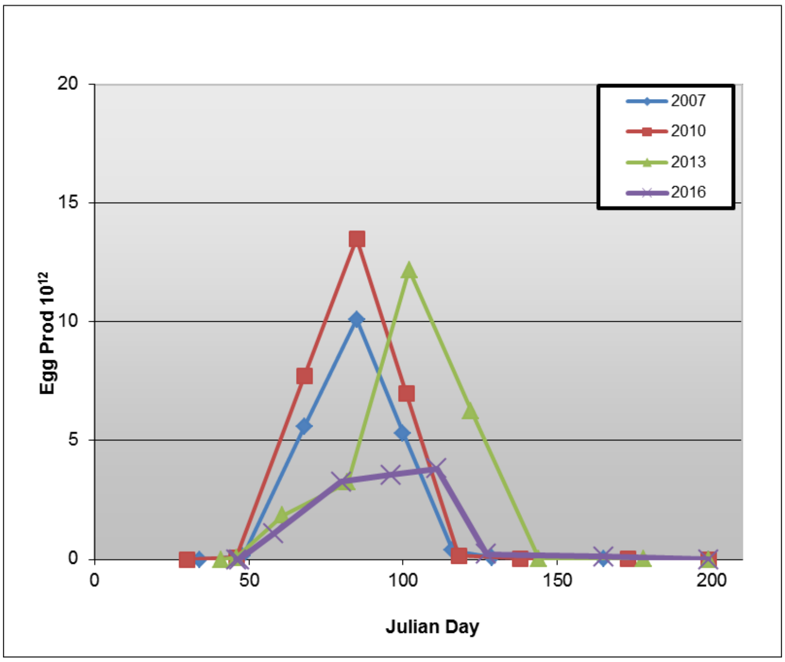


Figure 5.4.2. Annual egg production curve for mackerel in the southern spawning component in 2016. The curves for 2007, 2010, and 2013 are included for comparison. (Curves for all years are recalculated using the Mendiola development equation and the 2017 Teggprod script).

Table 5.4.2: Southern estimate of mackerel total stage I egg production by period using the histogram method for 2016.

Dates	Period	Days	Annual stage I egg production x 10^{14}
	1	No sampling	
15–16 Feb	2	2	0
17 Feb – 7 Mar	2-3	20	0.21
8 March – 1 April	3	25	0.82
2–8 April	3-4	7	0.25
9 April – 1 May	4	23	0.88
2–9 May	5	8	0.02
10 June – 17 July	Post 5	69	0.07
Total			2.25
CV			132.1%
Variance			8.85 *e28
Data CV			4.639

5.4.2.3 Total egg production

Total annual eggs production (TAEP) for both the western and southern components in 2016 is $1.77*10^{15}$. This equates to a net decrease in production of 34% compared to the recalculated 2013 TAEP estimate using the 2017 Teggprod script (section 5.11) which was $2.71*10^{15}$. Figure 5.4.3 below displays the historical TAEP of NEA Mackerel back as far as 2007.

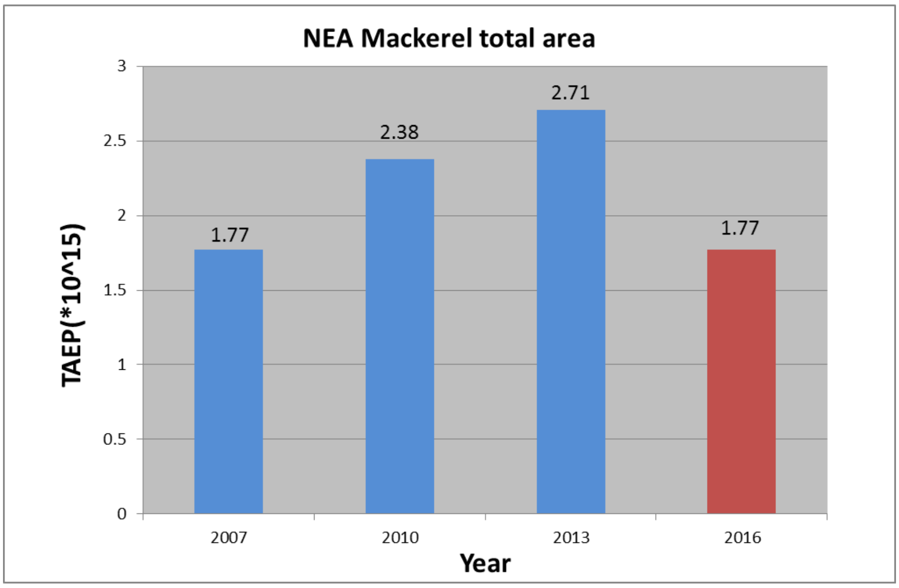


Figure 5.4.3. Combined Total Annual Egg Production estimates, 2007 – 2016.

5.4.3 Fecundity of Northeast Atlantic mackerel

5.4.3.1 Adult sampling

Following as much as possible the scheme initially proposed, during the 2016 survey a total of 1239 mackerel females were sampled., This is a smaller number than was originally planned to collect (Table 5.4.3). The most important deviation from the initial plan was observed in periods 2 and 3, due to the temporal change in the mackerel migration happening in 2016. While in 2010 and 2013 mackerels started their spawning migration at the beginning of February (period 2, became the peak of spawning for the species in 2013), in 2016 the first evidence of migration occurred in mid-March. A change of sampling scheme was rapidly adopted, increasing the sampling effort in period 4, as at this point this was the period perceived as most likely to contain the peak of spawning for mackerel. The extension of the spawning area during the actual peak of spawning in period 5 together with the limited number of days at sea reduced the opportunity of catching adults in periods 5,6, and 7.

Table 5.4.3. Summary of number of mackerel females planned and sampled during the 2016 surveys.

Period	2	3	4	5	6	7	Total
Planned	**1140**	**990**	**195**	**195**	**140**	**90**	**2750**
Sampled	**150**	**362**	**449**	**188**	**70**	**20**	**1239**

During the survey extra samples were collected both for DEPM parameters estimation and ring tests for AEPM quality control and improving standardization of sample analyses among the analysing institutes (Annex 8).

5.4.3.2 Historical estimate of reproductive parameters

Since the implementation of AEPM to estimate the SSB of mackerel, fecundity and atresia data were determined and reported. The inclusion in 1995 of Spain and Portugal to the survey extended the estimates of these reproductive parameters to the southern component (Table 5.4.4a).

The fecundity time-series is valuable as variations can reflect changes in the condition of the population. The potential fecundity in western mackerel varied significantly throughout the time-series (Table 5.4.4a).

Table 5.4.4a. Historical estimates of relative fecundity (n/g) and atretic loss (%) of NEA mackerel from Western and combined western and southern component. W = western component; S = southern component from 1977 to 2016.

Year	Component	Pot. Fec (n/g)	Atretic loss(%)	Realized fec (n/g)
1977	W	1475	8.8	1329
1980	W	1475	8.8	1329
1983	W	1475	8.8	1329
1986	W	1475	8.8	1329
1989	W	1608	8.8	1467
1992	W	1569	8.8	1431
1995	W	1473	11.6	1302
1998	W	1206	16.8	1003
2001	W	1097	5.8	1033
2004	W	1127	6.7	1052
2007	W/S	1098	8.1	1009
2010	W/S	1140	6	1070
2013	W/S	1257	4	1209
2016	W/S	1159	6	1087

Additionally, over the time-series, methods for estimating fecundity have changed and this might be reflected in the changes in fecundity over the periods. In the early surveys, fecundity was not estimated directly but was estimated using a length-fecundity relationship from literature. From 1992 onwards, fecundity was estimated from samples collected during the surveys, but with no atresia estimation being carried out. From 1998 onwards both fecundity and atresia was estimated during each survey. From 2004 on, the fecundity analysis changed from a volumetric to a gravimetric method. The changes in methods of fecundity estimation correspond to the periods where large changes in fecundity were observed. Calibrations were undertaken between the two methods, before changing to the gravimetric method. It cannot be proven that changes in the method are the underlying reason for the fecundity estimate changes, but one should be careful when interpreting these fecundity changes over time.

The percentage of oocyte loss during the spawning season, i.e. atresia, varied from high values in the period 1992–1998 to low values in the period 2010–2016 (Table 5.4.4a). For the period (1977–1992), atresia was considered constant.

For the southern component, atresia displayed the highest value in 1995, decreasing progressively until 2004 (Table 5.4.4b).

The differences observed in reproductive parameters through the time-series should be treated with caution due to the mentioned methodological aspects.

Table 5.4.4b. Historical estimates of reproductive parameters of southern NEA mackerel.

Year	Component	Pot.fec (n/g)	Atretic loss (%)	Realized fec (n/g)
1995	**S**	**1344**	**12.0**	**1083**
1998	**S**	**1276**	**8.2**	**1171**
2001	**S**	**1647**	**4.7**	**1647**
2004	**S**	**1016**	**5.1**	**964**

5.4.3.3 Histological Screening

A total of 1245 female samples from the surveys were screened by histology of which 16% were assigned to stage 3 (vitellogenic oocytes), 34% stage 4 (migratory nucleus stage), 22% stage 5 (hydrating oocytes), and 12% stage 1 (previtellogenic oocytes). 72% of the samples were taken from spawning or close to spawning females (Figure 5.4.4).

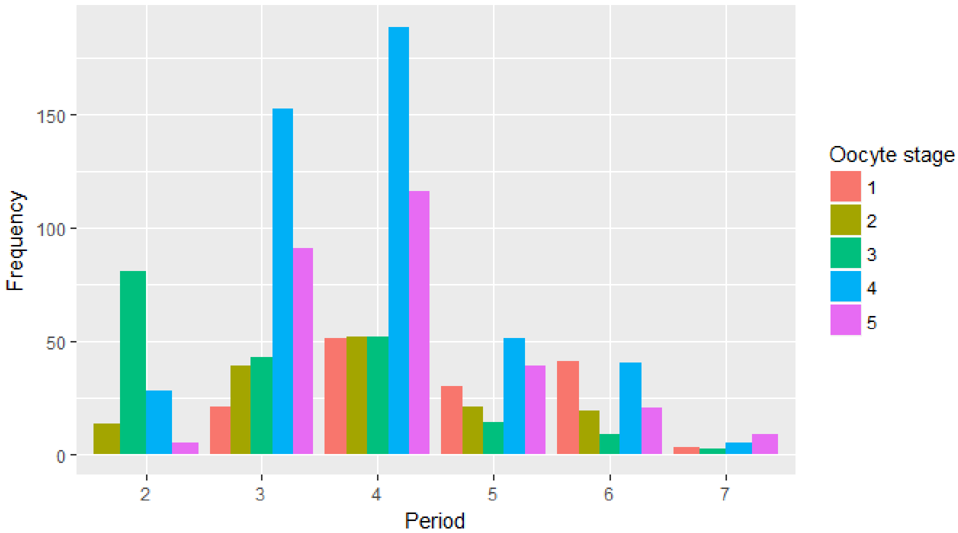


Figure 5.4.4. Frequency of the most advanced oocyte stage by survey periods 1 = pre-vitellogenic oocytes; 2 = early vitellogenic oocytes <400 µm; 3 = vitellogenic oocytes; 4 = migratory stage oocytes; 5 = hydrated oocytes).

Migratory nucleus stage (4) was the most frequent stage in periods 3 to 6, reaching its highest values in periods 3 and 4 (Figure 5.4.4). Among the samples that were analysed from period 2 the vitellogenic oocytes (3) was the most frequent. The hydrated stage (5) was presented in all periods but was most frequent in periods 3 and 4. POF´s were found in 63% of the samples and the frequency peaked in period 4. Samples from all periods contained POFs although in period 3 the frequency was low (Figure 5.4.5).

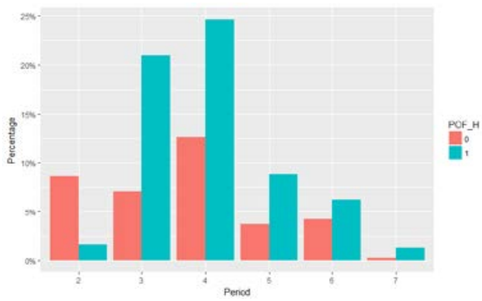


Figure 5.4.5. Frequency of POF's presence throughout the periods (0 = no POF's; 1 = POF's present).

From the histological screening 112 samples were identified for fecundity analysis, which was 9% of the total samples obtained during the survey. After the whole mount evaluation, this number decreased to 97. Most of the samples discarded at this stage were due to the presence of spawning markers, which were not detected in the histological screening.

Using histological screening 713 spawning fish were detected and among these 214 samples showed early alpha atresia, which gives a prevalence of 30%. Of the 214 samples showing early alpha atresia, every third sample (71) was randomly selected for analysis of intensity of atresia. Statistical analyses of the samples from the 2010 survey showed that 50–60 samples analysed for intensity of atresia would be enough, giving a considerable decrease of time and resources spent on atresia analysis.

Samples containing oocyte stages 4-5 were selected for analysis of batch fecundity, comprising 790 samples. Among the stage 4 samples, only samples that by judgement of oocyte size frequency histogram showed a defined batch were included in the final analysis.

5.4.3.4 Potential Fecundity in the Western and Southern combined components

Samples to determine mackerel potential fecundity were collected from trawl hauls made between 43°N and 56.30°N (Figure 5.4.6) during periods 2–7. These samples were distributed between Norway, Scotland, Ireland, the Netherlands and Spain and analysed according to methods described in the fecundity manual (SISP 5).

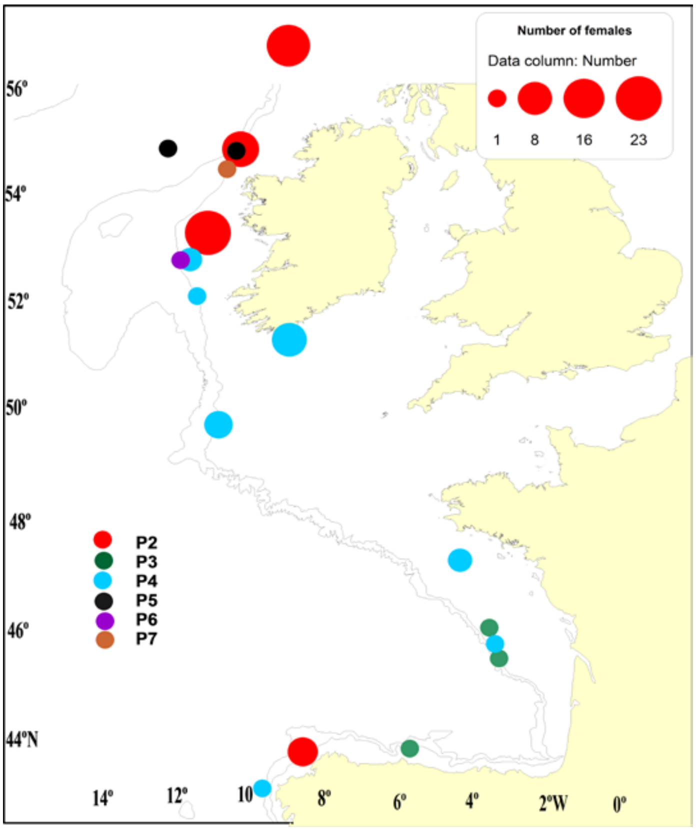


Figure 5.4.6. Map of distribution of samples analysed for fecundity from the different periods. The size of dots is proportional to number fish.

As an initial quality check on the data, frequency histograms of fish length, weight, Fulton´s condition factor (100 * weight/length^3), GSI (Gonad-somatic index; 100 * Ovary weight/Fish weight) for all mackerel sampled and for fecundity samples and relative fecundity were compiled (Figures 5.4.7–5.4.9).

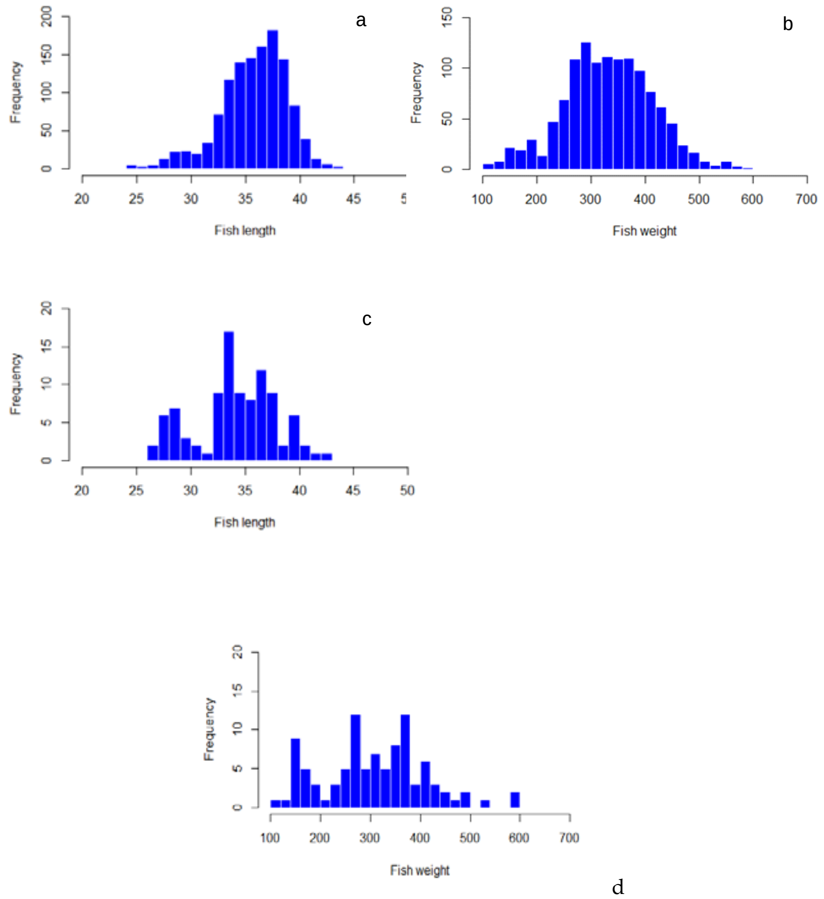


Figure 5.4.7. Frequency histograms of a) Fish lengths and b) Fish weights from mackerel sampled in 2016 and c) Fish lengths and d) Fish weights for mackerel assigned for fecundity analysis.

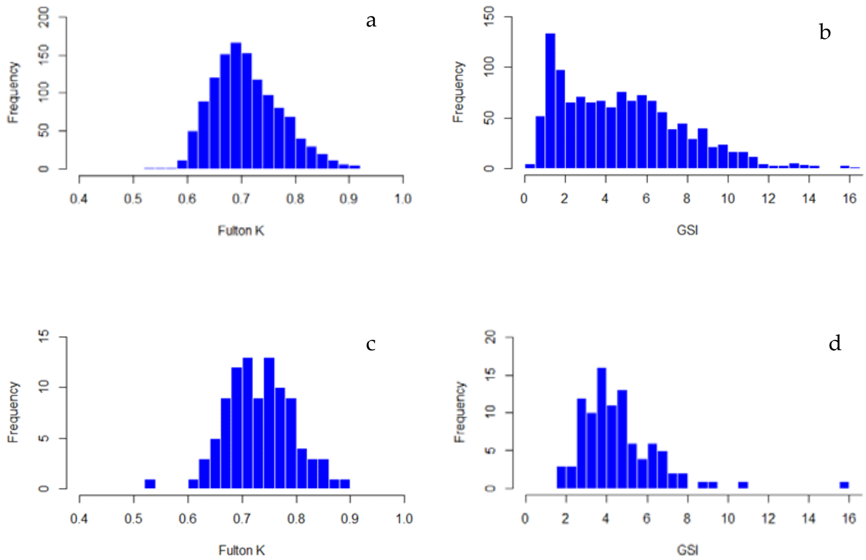


Figure 5.4.8. Frequency histograms of a) Fulton K and b) GSI from mackerel sampled in 2016; c) Fulton K and d) GSI for mackerel assigned for fecundity analysis.

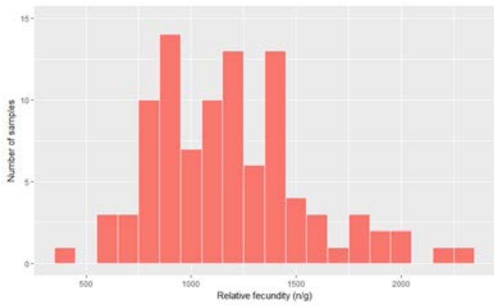


Figure 5.4.9. Relative fecundity values of 2016 samples.

Histograms of biological parameters for all mackerel sampled showed normal distributions, except for one fish with a low condition factor (approx. 0.52).

Similar to the previous year survey we only included fish with condition factors between 0.5 and 1.2 in our fecundity and atresia estimates. In 2016, no females needed to be excluded from the analysis based on the biological parameters.

Relative fecundity in 2016 ranged from 444 to 2260 n/g (Figure 5.4.9). In previous years, values below 300 and above 2100 were excluded, although finally in 2013 it was decided not to delete them. From the analysis done in 2014 (ICES 2014d) it was decided that for assessment the relative fecundity estimate should be based on the median instead of the mean, as the median was less influenced by extremes. In 2016 two values were outside this upper limit (Figure 5.4.9) but no data were eliminated for the analysis.

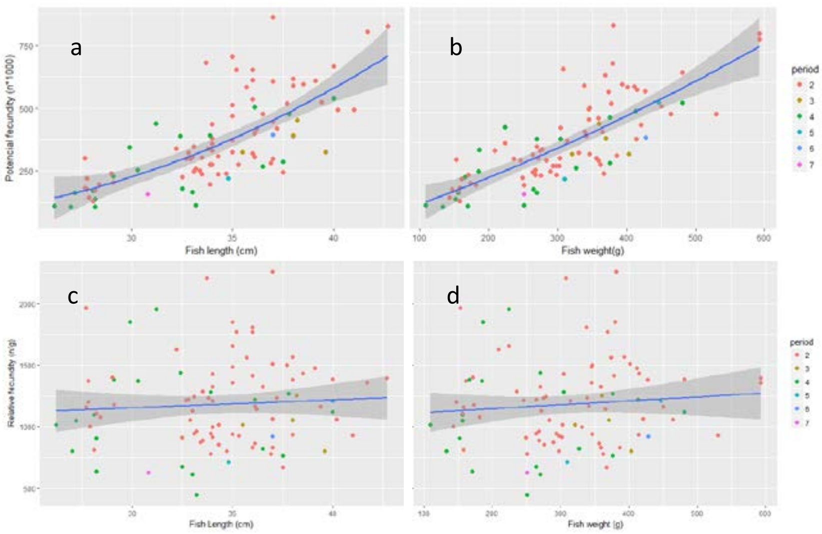


Figure 5.4.10. Relationship of Potential and Relative fecundity with fish length (a and c) and fish weight (b and d).

Plots of potential fecundity against fish length (Figure 5.4.10a) and weight (Figure 5.4.10b) by periods showed a positive trend that was similar to those found in previous years. Relative fecundity vs. length or weight (Figures 5.4.10c and d) only showed weak positive trends.

Relative fecundity vs. latitude showed similar range of values throughout the sampling area, and no clear trend was detected (Figure 5.4.11).

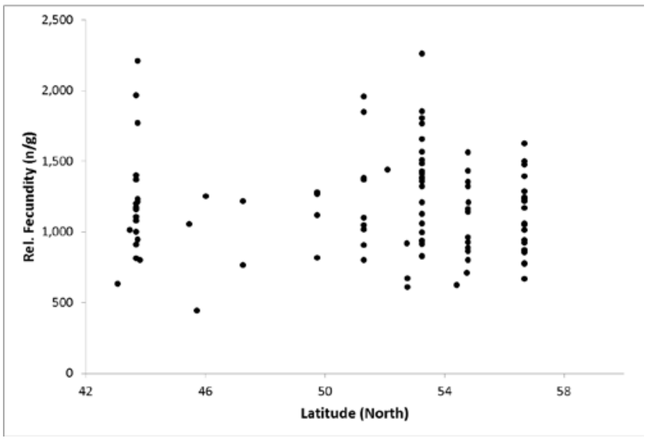


Figure 5.4.11. Relative potential fecundity (RFp) of Mackerel vs. Latitude (N) for the assessment year 2016.

From the oocyte size distributions the leading cohort (95 % percentile; the largest oocytes) could be estimated. Leading cohort may be interpreted as a proxy for maturity stage. A plot (Figure 5.4.12) with relative fecundity vs. leading cohort showed no particular trend, as was also the case in 2013. This indicates that samples with leading cohorts above 400 µm have fully recruited the maturing pool of oocytes and are therefore valid samples.

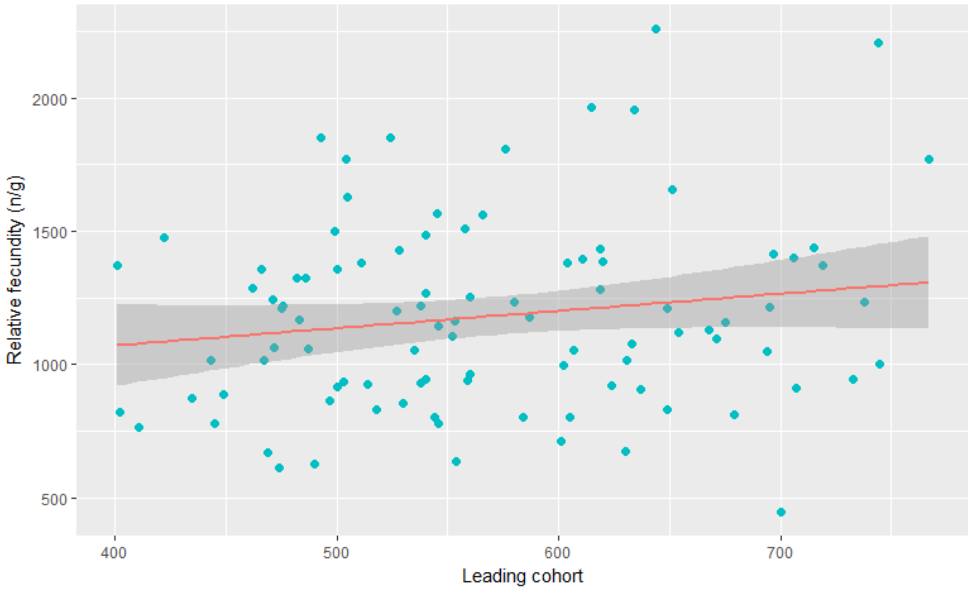


Figure 5.4.12. Relative potential fecundity (n/g) vs. oocyte diameter (µm) leading cohort (95 % percentile).

5.4.3.5 Atresia and realized fecundity

The samples used for analysis of atresia were collected from the entire survey area and during all periods (Table 5.4.5).

Table 5.4.5. Distribution of atresia samples during 2016 survey.

Period	No.	lat lower	lat upper
2	2	43.44ºN	56.40ºN
3	36	43.24ºN	46.09ºN
4	25	43.20ºN	52.45ºN
5	2	43.36ºN	54.45ºN
6	2	47.09ºN	52.45ºN
7	1	54.24ºN	

Prevalence atresia (Table 5.4.6) was found to be 30%, which is slightly less than the average (33%) for the previous surveys (Table 5.4.6). The relative intensity of atresia (Table 5.4.6) was estimated to be 30 (n/g) which is also slightly less than the average (34%) of what has been found in previous assessment years.

The overall relative atretic loss calculated from the prevalence and intensity of atresia was 72 (n/g) resulting in a realized fecundity estimate of 1087 (n/g) (Table 5.4.6). This value is close to the average (1078 n/g) for previous surveys.

Table 5.4.6. Fecundity and atresia for the assessment years 1998–2016.

Parameter	1998	2001	2004	2007	2010	2013	2016 pre	2016
N samples used for fecundity estimation	96	187	205	176	74	88	64	97
N samples anaysed for atresia	112	290	348	416	511	735	-	68
Relative potential fecundity (n/g)	1206	1097	1127	1098	1140	1257	1246	1159
Prevalence atresia	0.55	0.2	0.28	0.38	0.33	0.22	0.31	0.30
Geometric mean relative intensity of atresia	46	40	33	30	26	27	-	30
Potential fecundity lost per day (n/g)	3.37	1.07	1.25	1.48	1.16	0.8	-	1.2
Potential fecundity lost per spawning season (n/g)	202	64	75	89	70	48	-	72
Relative realised fecundity (n/g)	1002	1033	1052	1009	1161	1209	1159	1087
Percentage of relative potential fecundity lost	17	6	7	9	6	4	-	6

5.4.4 Biomass estimation of Northeast Atlantic mackerel

Total spawning-stock biomass (SSB) was estimated using the fecundity estimate of 1087 oocytes/g female, a sex ratio of 1:1 and a raising factor of 1.08 (ICES 1987) to convert prespawning to spawning fish. This gave an estimate of spawning-stock biomass of:

- 3,077 million tonnes for western component (2013:3,93*).
- 0,447 million tonnes for southern component (2013:0,9*).
- 3,52 million tonnes for western and southern components combined (2013:4,83*).

** SSB values recalculated using the using the 2017 Teggprod script (section 5.11)*

5.5 Horse mackerel in the western spawning area (ToR j)

5.5.1 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. Distribution maps of horse mackerel spawning for the western areas are presented in Annex 9.

Period 2 - Period 2 marks the commencement of the western area surveys. Sampling in period 2 commenced on 4 February which was two weeks earlier than in 2013. Sampling was undertaken by Ireland (Celtic Sea, Biscay and east Cantabrian sea) and Scotland (West of Ireland and West of Scotland). No horse mackerel spawning was observed during this period.

Period 3 – In period 3 the German vessel was operating in the West of Ireland, Celtic Sea and N Biscay. Northwest Ireland and the West of Scotland were covered by Scotland, the Bay of Biscay, the Cantabrian Sea and Galicia by Spain (IEO and AZTI). Increased levels of spawning were reported along the Cantabrian coast compared to period 2 however north of this again only isolated eggs were recorded as far north as the Porcupine Bank. All boundaries were well delineated and there were only 5 interpolated stations.

Period 4 - Sampling during this period was conducted from the Cantabrian Sea up to Shetland at 60°N. Once again low levels of spawning were found in the Cantabrian sea, with small levels of spawning also taking place in the southern Celtic sea. The boundaries during this period were generally well defined. There were 8 interpolated samples and 1 interpolated transects within the area.

Period 5 – Sampling during this period ran from the Cantabrian Sea to the Faroes. Very low levels of eggs were found in the Cantabrian Sea and Bay of Biscay, otherwise no horse mackerel eggs were encountered. There were 3 interpolated stations.

Period 6 - Sampling during this period ran from northern Biscay to Shetland, 46°N to 60°N, and was covered by Netherlands, Ireland and Faroes. The southern boundary of sampling was well delineated at 47°25N. Four stations with large egg counts were found in the south of the survey area but no eggs collected north of 53°N. There were 15 interpolated stations during this period.

Period 7- This period was sampled entirely by Scotland from 46°15N in the South to the most northerly transect at 59°15N. Peak spawning occurred during this period with several large egg counts found at stations in the Celtic sea and to the west of Ireland. Very few eggs were collected north of 55°N and all boundaries were successfully delineated. There were 62 interpolated stations during this period.

Period 8 - As a result of the 2013 WGMEGS survey the pelagic industry had expressed concern that by continuing with July 31st as the nominal end of spawning the survey hadn't completely delineated horse mackerel spawning to the west of Ireland. WGMEGS was asked to look into this during the 2016 survey. As a result, this period was covered from 10 to 23 August by Ireland, in the area from 51°15N in the South to 57°45N in the north, using a commercial vessel. Only very low levels of spawning were observed during this period. 7 stations were replicated. WGMEGS is satisfied to continue using 31 July as the end date for horse mackerel spawning in the western area.

5.5.2 Egg Production in Western Horse Mackerel

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 (Table 5.5.1). The shape of the egg production curve does not suggest that those dates should be altered for 2016 (Figure 5.5.1). Results from the additional period 8 survey in August 2016 further reinforced this position. The total annual egg production was estimated at $3.31*10^{14}$. This is a decrease of almost 9% on the 2013 TAEP estimate that has been recalculated also using the 2017 Teggprod script, (section 5.11) and was $3.66*0^{14}$. The 2016 value is the lowest estimate of annual egg production ever recorded for this species (Figure 5.5.2).

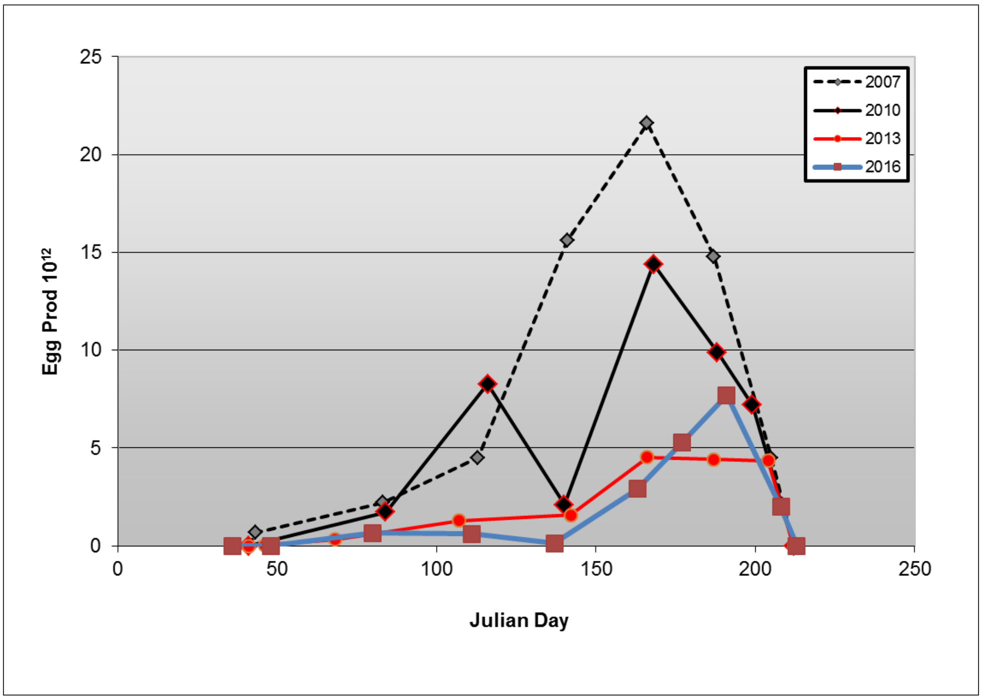


Figure 5.5.1. Annual egg production curve for western horse mackerel 2016. The curves for 2007 - 2013 are included for comparison (Curves for all years are recalculated using the 2017 Teggprod script).

Table 5.5.1. Western estimate of horse mackerel total stage I egg production by period using the histogram method for 2016.

Dates	Period	Days	Annual stage I egg production x 10^{15}
	1	No sampling	
5–29 February	2	25	0.000
1 March–8 April	3	39	0.025
9–30 April	4	22	0.013
1–30 May	5	30	0.004
31 May21 June	6	22	0.064
22–27 June	6-7	6	0.032
28 June–19 July	7	22	0.169
20–31 July	Post 7	12	0.024
Total			0.331
CV			146%
Variance			2.90 * e25
Data CV			0.02

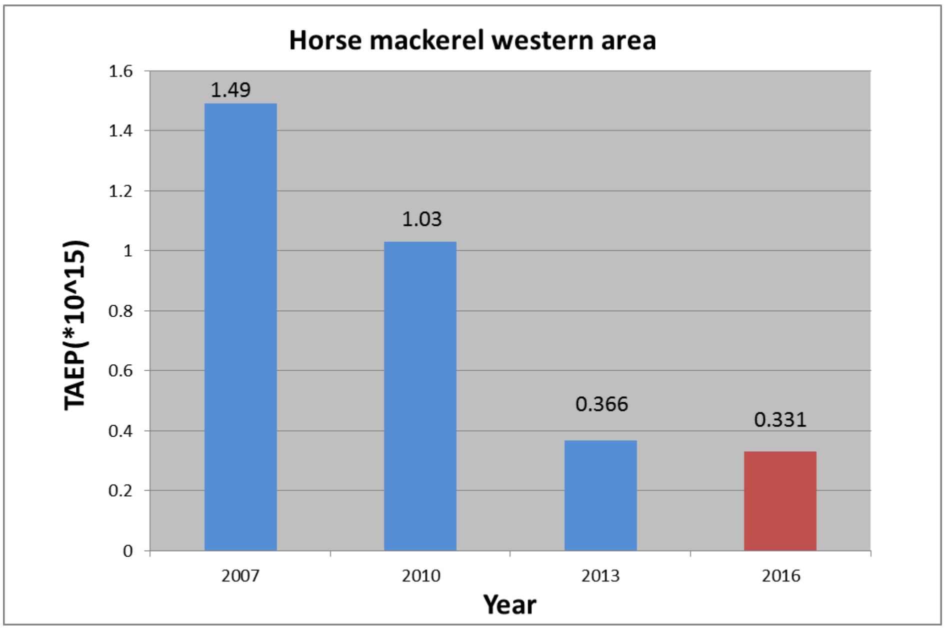


Figure 5.5.2 AEP estimates for western horse mackerel, 2007 – 2016.

5.6 Horse mackerel in the southern spawning area (ToR j)

5.6.1 Spawning area and egg production

In the laboratory, all plankton samples were sorted for fish eggs and larvae, and all horse mackerel eggs were identified and staged according to an eleven stages scale (IPMA). All calculations for area delimitation, egg ageing and model fitting for egg production (P_0) estimation were obtained using modified routines and the functions available in the ichthyoanalysis package (http://sourceforge.net/projects/ichthyoanalysis). Peak spawning time was considered to be at 19h (+/- 2*3h) (WGALES, 2016). Details on the eggs laboratory processing and analyses are described in detail in the MEGS Manual (SISP 6).

The egg distribution was very patchy and abundances were low when compared to previous surveys. There were also some regions, western Cadiz Bay, southwestern coast and the area between Nazaré Canyon and Aveiro where no eggs were collected (Annex 10). A total of 393 CalVET with CTDF samples were collected along 42 out of 48 planned transects. From the 393 CalVET hauls, 108 were positive for horse-mackerel eggs (27%); 747 eggs were gathered in the 52 099 km^2 surveyed.

The estimated spawning area in 2016 (19 442 km^2) was similar to the one calculated for the 2013 survey, when western Galicia was surveyed but no sampling occurred in the Spanish waters of Cadiz Bay. The higher egg densities in 2016 were observed off western Algarve, south of Nazaré Canyon and between Cape Mondego and river Minho. Total Egg Production estimation for the 2016 survey was 5.1 x 10^{11} Eggs (CV: 25%), slightly lower than the result obtained for the 2013 survey (Table 5.6.1).

Table 5.6.1: Egg Production results 2016 DEPM survey (PT-DEPM16-HOM).

Survey PT_DEPM16-HOM	Spawning area (Surveyed area) (km^2)	Mortality ($hour^1$) (CV%)	P0 ($eggs/m^2/day$) (CV%)	P0 tot (eggs/day)($x10^{11}$) (CV%)
11 Mar–1 May 2016	**19442 (52099)**	**- 0.03 (20)**	**26.1 (25)**	**5.1 (25)**

5.6.2 Adults data and parameters

The estimation of the sex ratio (R), the mean female weight (W) and the mean female expected batch fecundity (F) were based on the biological data recorded from the fish samples. The gonads preserved were used to measure the individual batch fecundity (F_{obs}), to assess the mature/immature condition of females, and to estimate the daily spawning fraction (S).

The estimation of the observed individual batch fecundity (F_{obs}) was based on the gravimetric method applied to the hydrated ovaries containing no POFs (in 2016, n = 15 ovaries). Spawning fraction estimation was based on the POFs used as spawning markers: histological slides were analysed for the presence of POFs, microscopic images of POFs were taken for POFs cross sectional area measurements, and then POFs were assigned to daily classes (aged) based on their histomorphological features (ICES, 2016a), their size, and the time of capture in relation to the peak spawning time (cf. section 5.6.1). The spawning fraction per haul was estimated based on the average number of females with Day-1 or Day-2 POFs, divided by the total number of mature females in the sample.

Adult parameters (W, R, F, and S) were estimated independently for each fishing haul, using only the mature fish (macroscopic maturity stage ≥2), whereas for the whole surveyed area means and CVs were calculated using the number of mature fish/females in the sample as weighing factor. Details on the biological sampling, laboratory work and parameters calculation are described in the MEGS Manual for AEPM and DEPM fecundity (SISP 5).

The horse mackerel sampled ranged in size from 4 to 42 cm, a larger range towards smaller fish compared to 2013 (20–38 cm) which is partly due to the fact that only commercial samples were obtained in 2013 (with a minimum landing size of 20 cm) whereas both survey and commercial samples were collected in 2016. Smaller fish were mostly sampled off South coast (with a length unique mode at 22–23 cm), whereas fish with a multimodal length distribution were observed off the West coast (Figure 5.6.1). About a quarter of the fish sampled were immature while ca. 5% of mature horse mackerel were reproductively inactive.

Adult parameters estimates presented during the WG meeting, and summarized in Table 5.6.2, are preliminary, daily fecundity final estimations being completed prior to WGHANSA. Mean female weight obtained for the 2016 survey was 121.71 g (11% CV), considerably lower than the value estimated for 2013 (203.59 g). Sex ratio mean value was similar compared to the previous survey (0.550 and 0.540, respectively). From all the ovaries collected, 15 hydrated (with no POFs) were effectively used for individual observed batch fecundity estimation, the resulting mean batch fecundity calculated for the 2016 survey was 15 991 eggs/female (18% CV), which is considerably lower than the value obtained in 2013 (41 064 eggs/female). Relative fecundity in 2016 was estimated to 131 eggs/g female, which is also lower than the value obtained in 2013 (202 eggs/g female). Daily spawning fraction estimate for the 2016 survey was

0.049 (25% CV), also noticeably much lesser than the one obtained in 2013 (0.134). The histological analysis of the ovaries sampled showed a reduced spawning activity during the 2016 survey comparatively to 2013, with a significant number of hauls with ovaries containing not one single POF. The observed spatial distribution of the spawning activity resulting from this analysis of this histological information (Figure 5.5.2.2) showed only partial equivalence to the eggs distribution/abundance obtained from the CalVET sampling: the area of eggs higher density (between Cape Mondego and Minho River) corresponded to almost no spawning activity, though this area was poorly sampled for adults, and thus the observation in this area is possibly biased. On the whole, several indices (lower fecundity and spawning fraction, larger proportion of inactive fish, a higher atresia intensity observed in some ovaries) might suggest that part of the horse mackerel population was closer to the end of spawning season.

Table 5.6.2. Adult parameters preliminary estimates for the 2016 Southern horse mackerel DEPM survey.

	W (g) (%CV)	R (%CV)	F (nb. eggs) (%CV)	S (%CV)
2016	121.71 (11)	0.550 (3)	15991 (18)	0.049 (25)

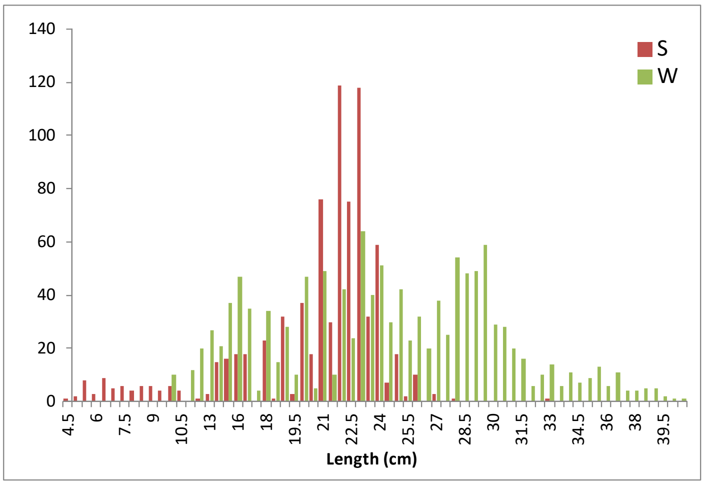


Figure 5.6.1. Length frequency distribution of the horse mackerel sampled in 2016 (both survey and commercial hauls) for the two geographical strata (S: South coast, including Cadiz Spanish waters, W: West coast).

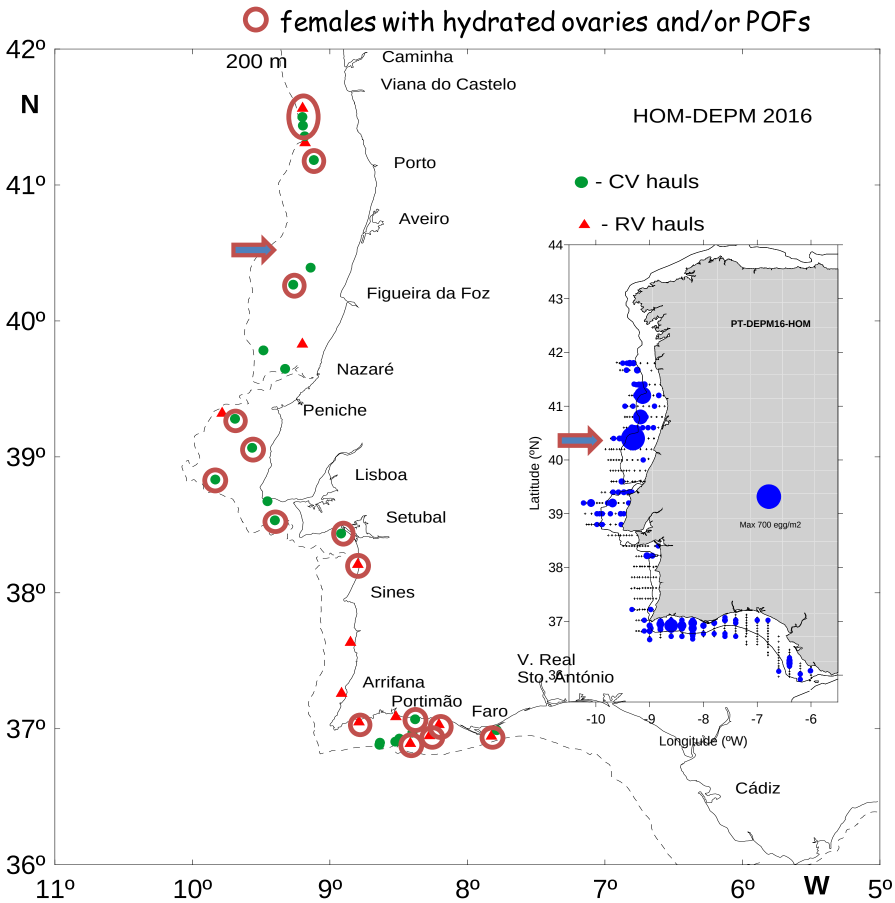


Figure 5.6.2. Distribution of the fishing hauls obtained in 2016 (CV: commercial vessels, RV: research vessel). Hauls highlighted by a red circle correspond to samples with females showing recent (presence of POFs in the ovary) and/or imminent (ovary containing hydrated oocytes) spawning activity. The arrow indicates the area with higher egg density (cf. Annex 10) but with no equivalent adults' spawning activity.

5.7 Daily Egg Production Method analyses in the western and North Sea spawning areas (ToR g, j)

5.7.1 Western Mackerel

At the Workshop on Survey Design and Mackerel and Horse Mackerel Spawning Strategy WKMSPA (ICES, 2012a) it was decided that during those surveys in the period of peak spawning, sampling effort will be directed at collecting mackerel samples to estimate DEPM adult parameters. In 2016, samples for AEPM fecundity analysis were taken from 1263 mature mackerel females during all periods, and during periods 3 and 4) the sampling effort was strengthened for DEPM sampling (Annex 11).

Histological sections from the 1263 mature females were screened for the most advanced oocyte stage and for spawning markers in order to flag samples that were valid for AEPM or DEPM analyses. A total of 513 both random and directed sampled individuals were valid for batch fecundity estimations and 617 samples were considered valid for POFs ageing.

The diameters of migratory nucleus (MN) and hydrated (H) oocytes were measured in the available 513 samples using ImageJ in whole mount images. Usually batch fecundity is based on hydrated oocytes, but ovaries in migratory nucleus maturity stage were also included to test if they were suitable to batch fecundity estimation. The size frequency distribution of the oocytes was studied grouping them in 50 microns clusters. The number of oocytes in the batch was recorded in those samples (n = 190) that presented a clear gap (minimum 50 μm) separating the standing stock of oocytes from MN or H oocytes.

Spawning fraction was estimated in a total of 617 histological sections. Following morphological criteria, POFs present in the slides were assigned to 7 stages depending on their age.

Staging POFs present important bias because is difficult to describe objective criteria to separate stages. To test discrepancies between readers, a ring test was performed using ovary histological sections of 5 mackerel females. From each ovary, sequential ovary sections were taken and distributed between the eight involved readers. The ring test showed very low agreement between readers in POF stage assignment (Annex 11). This could be due to the inexperience of the readers in mackerel POFs and/or due to the fact that sequential sections could not show exactly the same.

The number of samples with aged POFs was 616 (Table 5.7.1). Laboratory with more experience in POFs aging (AZTI and IEO) read a substantial larger number of samples.

Results on spawning fraction should be taken with caution, because of the discrepancies observed during ring test for mackerel POFs aging.

The R script used for sardine DEPM in the WGACEGG was adapted to estimate DEPM mackerel adult parameters. Data from biological sampling of males and females were used in the estimations.

Biological data of the 4345 male and female mackerel from all hauls were used for the adult parameters estimations. In general, sampling spatial and temporal coverage was good, although the southern area (41° to 45°N) concentrate a large number of samples. (Annex 11, Table 5.7.2).

From the total mature females (1820), 616 were valid for spawning fraction and 128 were valid for batch fecundity estimations. Most samples were taken during periods 3 and 4 (Table 5.7.3). Box 1 in Annex 11 shows a relation of the script sections. The script analysis starts checking data, and after this, the bias produced by hydrated females in expected weight is corrected (boxes 2 and 3, annex 11). The script calculates first the parameters by haul and later is extrapolated to population level, giving the same weight to all hauls.

Following, the mean weight for mature females by haul is calculated, and subsequently the sex-ratio in weight is estimated.

For batch fecundity calculations, a total of 190 batch counting were introduced in the analysis. After batch fecundity estimation, outliers were checked and removed, resulting in a total of 128 valid samples (Table 5.7.4)

Outliers were batches with the higher and smaller number of oocytes. The highest values were those associated to ovaries with MN oocytes, i.e. likely include more oocytes than the real batch (H oocytes), and the lowest values (less than 5 oocytes per batch) were probably due to sampling failure or the presence of residual hydrated oocytes, because of this, they were removed from the analysis. Annex 11 shows batch fecundity Fh data fitness to a negative binomial model.

Total batch fecundity for each female was calculated according to the gravimetric method as the mean oocyte density in the ovary (n/g of ovary) multiplied by the total weight of the ovary.

The spawning fraction (SF) was estimated as the proportion of active females from the total of mature ones in each haul. The number of active females was estimated from the addition of females presenting day 1 and day 2 POFs (recent spawning) divided by 2. Finally, the total SF was the average of the SF by haul.

Table 5.7.5 shows the estimated values of the DEPM adult parameters for mackerel and its associated coefficients of variation. Average female weight is 326.7 g and sex ratio is 0.515, and batch fecundity is 8820 eggs and spawning frequency is 6.13 days.

Table 5.7.1. Number of samples with POFs aged by period and latitude.

	Periods						
Latitude	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
42-45	16	108	129				253
45-48		74	33	7	9	1	124
48-51			34	17	11		62
51-54	9		48	1	15	1	74
54-57	14			26	14	7	61
57-60				28	4		32
60-63					10		10
Total	39	182	244	79	63	9	616

Table 5.7.2. Total sampled fish (male and females) for fecundity analysis by period and latitude.

	Periods						
Latitude(N)	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
56-60	100		6	175	274		555
51-55	200	2	243	143	199	74	861
46-50		234	302	300	149	4	989
41-45	297	767	719	157			1940
Total	597	1003	1270	775	622	78	4345

Table 5.7.3. Distribution by period of the total sampled fish, the mature females and the batch fecundity and spawning fraction samples.

Period	**Hauls**	**Fish**	**Mature Females**	**Spawning fraction valid samples**	**Batch Fecundity valid samples**
2	6	597	316	39	5
3	11	1003	432	182	46
4	16	1270	562	229	51
5	14	775	299	94	14
6	8	622	188	63	12
7	4	78	23	9	0
Total	59	4345	1820	616	128

Table 5.7.4. Valid samples for batch fecundity mackerel analysis by period and latitude.

	Periods					
Latitude	**2**	**3**	**4**	**5**	**6**	**Total**
42-45	5	35	40			80
45-48		11		2		13
48-51			5	1	2	8
51-54			8		5	13
54-57				2		2
57-60				7	1	8
60-63					4	4
Total	5	46	53	12	12	128

Table 5.7.5. DEPM mackerel adult parameters estimated values and correspondent coefficients of variation (cv).

Parameters	**estimate**	**cv**
Average Female Weight (g)	326.77	0.0305
Sex ratio (nº of females/total)	0.515	0.0052
Batch Fecundity (nº eggs/batch per mature female)	8820	0.0413
Spawning fraction (number of spawning females per mature female)	0.163	0.1238

5.7.2 North Sea Mackerel

In 2015 the North Sea mackerel egg survey was conducted with the aim of utilizing the same annual egg production methodology (AEPM) methodology as is used for the western and southern mackerel surveys. Ovary samples were collected during the survey, but as spawning had already commenced it was not possible to estimate the potential and realized fecundity from these samples. Instead, the samples were used for the estimation of the Daily Egg Production Method (DEPM) adult parameters, i.e. batch fecundity, spawning fraction and sex ratio.

The survey covered 4 periods and peak of spawning occurred in period 2. Adult mackerel were only caught in two pelagic trawl hauls, one in period 2 and the other in period 3. In both hauls 100 mackerel were sampled (Table 5.7.6). In period 2 47 ovaries were sampled and in period 3, 53 ovaries (Table 5.7.6).

Table 5.7.6. Fish and ovary samples collected during the 2015 North Sea mackerel egg survey.

Period	1	2	3	4
Dates	26.05-31.05	01.06-06.06	08.06-13.06	13.06-17.06
N fish	0	100	100	0
Female/Male		51/49	53/47	
N ovary samples		47	53	
Screening **N batch fecundity**		25	38	
Oocyte stage 4/5		5/20	2/36	

For batch fecundity estimation 25 samples were available from period 2 and 38 from period 3 (Table 5.7.6). Mean oocyte diameter was 569 µm and maximum oocyte diameter varied from 744 to 1091 µm over all the samples. Only very few samples were available in oocyte stage 4 (migratory nucleus stage; Figure 5.7.1 and Table 5.7.6), but batch fecundity did not vary between oocyte stage 4 and stage 5 samples (Figure 5.7.1). Batch fecundity did not vary significantly between period 4 and 5 (Figure 5.7.1).

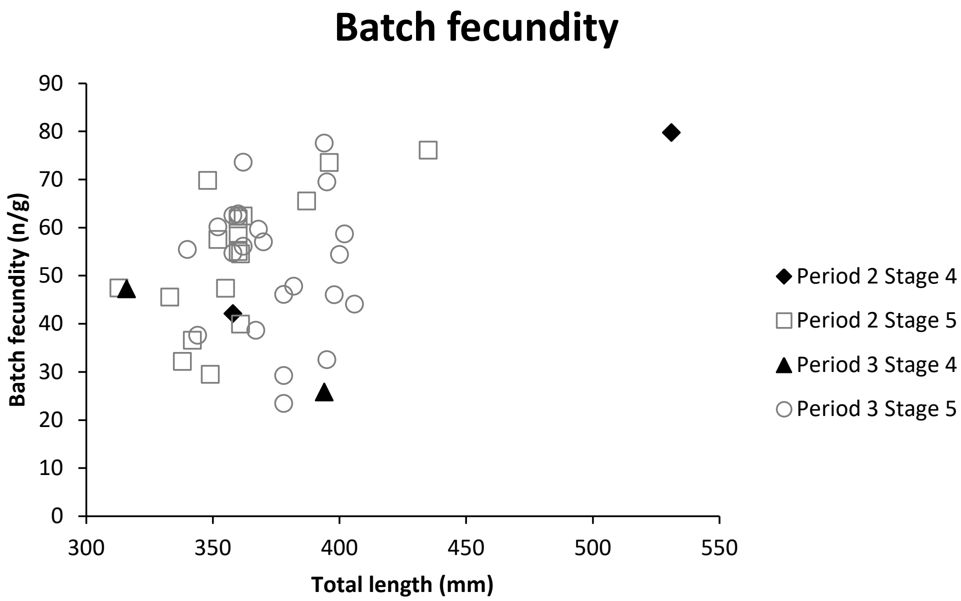


Figure 5.7.1. Mackerel batch fecundity for period 2 and 3 and for oocyte development stage 4 (filled) and 5 (open symbols).

Spawning fraction estimation was based on the POF method as described in the manual (SISP 5). Spawning fraction was higher in period 2 at the time of peak spawning compared to period 3 (Table 5.7.7). Spawning fraction was also higher compared to the Western stock.

Table 5.7.7. Mackerel spawning fraction for the North Sea (2015) and western (2013) stocks (SF = Spawning fraction).

Period	SF (2015)	SF (2013)
2	0.37	0.25
3	0.32	0.24

SSB was estimated for both period 2 and 3 (Table 5.7.8). During the peak spawning period SSB based on the DEPM was twice as high as the DEPM estimate for period 2 and the SSB estimate using the AEPM (Table 5.7.8). The AEPM is underestimating the total egg production as not the whole spawning period and spawning borders are delineated during the survey.

Table 5.7.8. North Sea mackerel SSB estimations using the DEPM and AEPM methods (R = sex ratio, F_b = batch fecundity).

Period	Egg production ($*10^{12}$)	SF	R	Avg F_b (n/g)	SSB DEPM ($*10^3$ tonnes)	SSB AEPM ($*10^3$ tonnes)
2	3.69	0.37	0.51	54.4	357	170
3	1.53	0.32	0.53	51.3	176	

5.7.3 Western Horse mackerel

Sample used

In order to apply the Daily Egg Production Method (DEPM) for further spawning-stock biomass (SSB) estimation, 336 females and 351 males of horse mackerel were taken during the survey in periods 6 and 7 (Table 5.7.9).

180 females were used for the estimation of required reproduction parameters to apply the above method. The histological screening results showed that only 37 of them were destined to batch fecundity estimation (Table 5.7.9) while 143 were not. These samples consisted of ovaries in migratory nucleus and hydrated (without POFs) stages, i.e. oocyte stages 4 and 5 in the oocyte development stages. Besides, 75 of the total samples had postovulatory follicles (Table 5.7.9) in any of the POFs stages.

Table 5.7.9 Data for DEPM parameters estimation.

Parameters	No	Yes
Batch fecundity	143	37
Spawning fraction (POFs)	105	75
Sex ratio	Female	Male
	336	351

Batch fecundity

Only 5 samples were identified as being hydrated ovaries without POFs. 4 of them were available for batch fecundity estimation using the hydrated oocytes method. Batch fecundity ranged from 708 to 103 360 oocytes. Due to these poor data, ovaries in migratory nucleus stage (stage 4, with or without POF) were also analysed, i.e. oocyte size frequency distribution method. The later method consists on finding a hiatus in the oocyte size frequency distribution that may separate the batch and allow to count the number of oocytes in it (Figure 5.7.2). Oocytes with a diameter bigger than 400 microns were counted in 19 ovaries. There was not a gap in the distribution between migratory nucleus and the previous oocyte stage. The average mode of the distributions was at 564 microns.

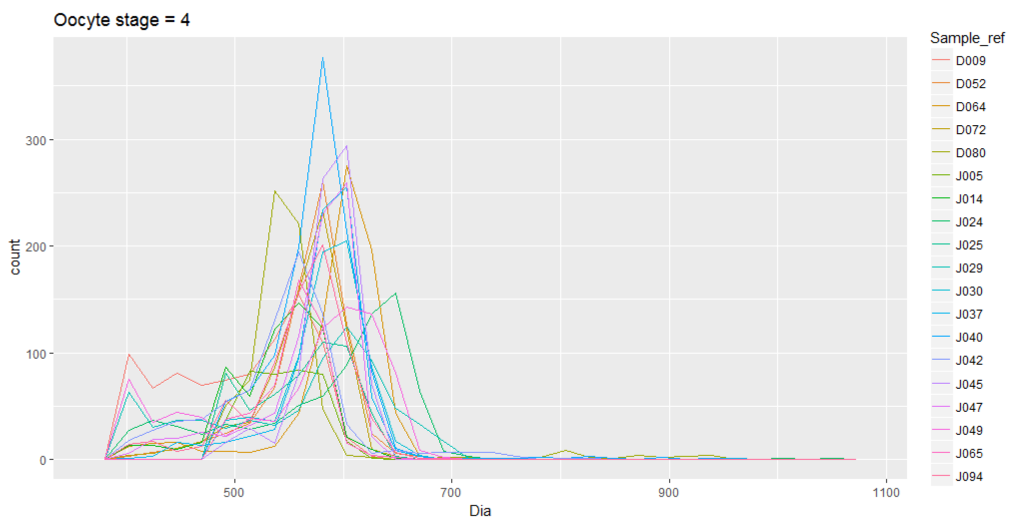


Figure 5.7.2. Oocyte size frequency distribution in samples with migratory nucleus stage.

No concluding result was obtained for batch fecundity by any of the methods mentioned above. Only half of the samples analysed gave results in the range of what it is expected for horse mackerel (157 and 331 oocytes/g). Relative batch fecundity estimation was 72.02 oocytes/g in 2013 which was lower than the values obtained from the literature (Table 5.7.10), i.e. the range is from 124 to 205 oocytes/g (Karlou-Riga and Economidis, 1997; Abaunza, 2003; Goncalves *et al.*, 2009). It was also lower than the values obtained for the southern component within the triennial surveys 2013 and 2016, i.e. the relative batch fecundity were 131 oocytes/g (n = 15) and 202 oocytes/g (n = 23) respectively (per. comm., C. Nunes).

Table 5.7.10. Literature review on horse mackerel relative batch fecundity estimation.

Species	BF rel (n/g)	Source
T. trachurus	172–209	Abaunza, 2003
T. trachurus	124–175	Goncalves *et al.*, 2009
T. trachurus	205	Karlou-Riga and Economidis, 1997

Spawning fraction

The spawning stages of the horse mackerel ovary were classified histologically according to POFs stages and used to estimate the proportion of spawning females. The spawning stages used to establish the spawning fraction (SF) were characterized by POF stages 1-2-3, which correspond to Day 0 spawning. Thus, the SF was estimated from the average prevalence of Day 0 POF stage ovaries. The inverse of SF gives the average spawning frequency of the mature females. Mean and variance of SF were calculated according to the equations developed by Picquelle and Stauffer (1985), which weight each haul according to sample size.

The SF was 10% in June while it increased to 33% in July (Figure 5.7.3). These results gave an average spawning frequency ranging from 10 to 3 days.

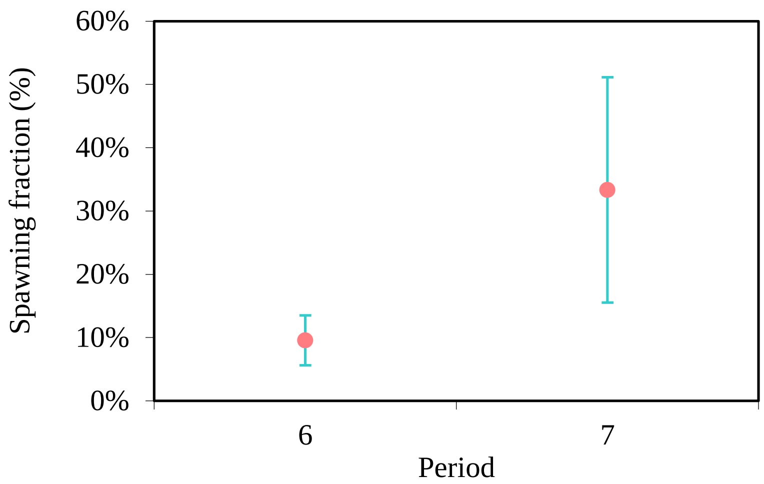


Figure 5.7.3 Spawning fraction on horse mackerel in periods 6 and 7.

The SF results for June are similar to the previous triennial survey (2013) where SF was 11% (pers. comm. C. van Damme) and is also within the range reported by Goncalves *et al.* (2009) (Table 5.7.11).

Table 5.7.11 Literature review on horse mackerel spawning fraction estimation.

Species	SF (%)	1/SF (days)	Source	Comments
T. trachurus	8.5	11.76	Eltink, 1991	Based on migratoriy nucleus
T. trachurus	9.1-33.9	12.3-2.95	Goncalves *et al.*, 2009	Based on migratoriy nucleus
T. trachurus	7.6-33.3	13.15-3.00	Goncalves *et al.*, 2009	Baed on Hydrated oocytes
T. trachurus	14.7-30.9	6.8-3.23	Goncalves *et al.*, 2009	Based on POFs assuming 2d-duration
T. trachurus	9.8-20.6	10.2-4.85	Goncalves *et al.*, 2009	Based on POFs assuming 3d-duration

Sex ratio

The sex ratio in weight per haul is estimated as the ratio between the average female weight and the sum of the average female and male weights of the horse mackerel in each of the samples. 8 hauls were used to estimate the sex ratio for period 6 and 7. In total, 596 individuals gave a sex ratio of 0.503 (Table 5.7.12).

Table 5.7.12. Sex ratio by haul and period and weighted by the number in each haul.

Period	Day	R	N	R*N
6	4	0.46	100	46.03
6	5	0.50	100	50.30
6	6	0.80	15	12.02
6	13	0.50	100	49.84
6	15	0.43	7	3.04
6	30	0.52	87	45.10
7	4	0.50	86	42.98
7	16	0.50	101	50.36

Average female weight

The mean weight was 283.03 g taking into account both periods together. The mean weight for mature females was 281.22 g and 287.38 g for period 6 and 7 respectively (Figure 5.7.4). There was no significant difference in average weight between periods (Kruskal–Wallis Chi-squaredd = 13.561, d.f. = 13, p-value = 0.4055).

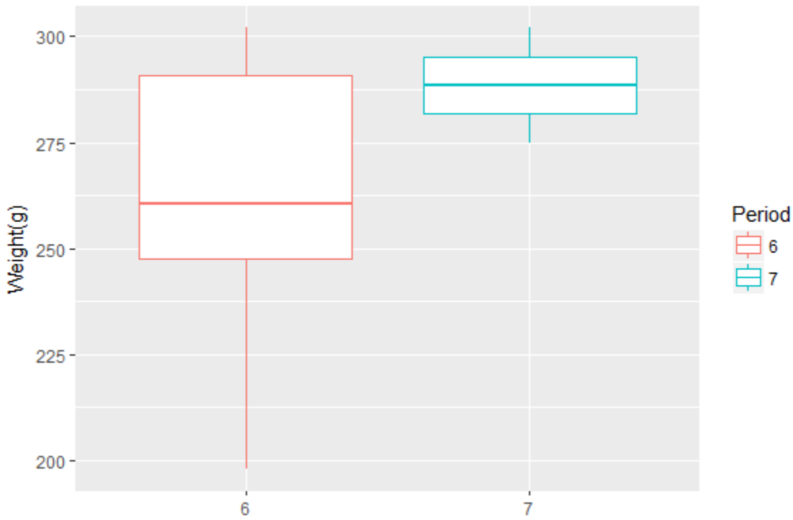


Figure 5.7.4 Box plot of female weights by period.

Spawning-stock biomass

The Spawning-stock biomass (SSB) was estimated as the ratio between the total egg production during this period (Ptot) and daily fecundity (DF).

$$DF = \frac{\mathrm{R} * \mathrm{F} * \mathrm{S}}{\mathrm{W}f}$$

where R is the sex ratio in weight, F is the batch fecundity (eggs per batch per female weight), S is the spawning fraction (percentage of females spawning per day) and W is the female mean weight.

Thus, SSB is:

$$SSB = \frac{\mathrm{Ptot}}{\mathrm{DF}}$$

The spawning-stock biomass for horse mackerel applying the DEPM was estimated for 2 periods (June and July) and for different alternatives of adults parameters (Table 5.7.13). For June, considering the SF estimated for that period (0.1) and B_{fec} of 157 eggs/g female, the SSB was 368 153 tonnes of horse-mackerel.

For July, using SF of 0.33 and similar Bfec the SSB estimated was 295,696 tons.

Table 5.7.13. DEPM parameters estimated for Western stock of horse mackerel in 2016.Different alternatives are presented varying the adult's parameters. Additionally, the SSB is estimated for two periods, June (upper panel) and July (bottom panel).

PARAMETERS	Period 6			Period 7		
Total Daily Egg Production (P_{tot})	2.89E+12	2.89E+12	2.89E+12	7.66E+12	7.66E+12	7.66E+12
Sex ratio (nº of females/total) (R)	0.5	0.5	0.5	0.5	0.5	0.5
Spawning fraction (number of spawning females per mature female) (SF)	0.33	0.1	0.33	0.33	0.1	0.33
1/SF (in days)	3	10	3	3	10	3
Batch Fecundity (nº eggs/per gr)[1] (B_{fec})	331	157	157	331	157	157
Daily Fecundity (DF)	54.615	7.85	25.905	54.615	7.85	25.905
SSB (tonnes)	52 916	368 153	111 561	140 255	975 796	295 696

[1] In order to estimate SSB those values of Bfec more similar to those referenced in the bibliography were used.

These estimations should be accepted with caution because of the small number of adults collected for the analysis, which precludes obtaining robust estimates of these parameters.

5.8 Quality aspects of the 2016 survey (ToR c, d, e, h)

The estimation of total annual egg production in mackerel and horse mackerel stocks necessitates a thorough and coordinated execution of the survey. During most of the recent surveys the major sources for data quality issues were identified as being

- Spatial and temporal coverage of the spawning area, in particular the progressive forward shifting of mackerel peak spawning and the northwestward extension of the spawning area
- The correct identification of mackerel and horse mackerel eggs, particularly to discriminate those from hake eggs, and to efficiently sort the eggs from the plankton samples
- The calculation of daily egg production utilizing the appropriate egg development model

These aspects are dealt with in the following paragraphs.

5.8.1 Spatial and temporal coverage during the 2016 egg survey

Geographical coverage during the 2016 MEGS survey did not match that undertaken during either the 2010 or 2013 survey. The reasons for this are several and highlight new but also longstanding issues that WGMEGS has been attempting to address for some time.

Additional early sampling period

Subsequent to the very early peak spawning that was observed during the 2010 and 2013 MEG surveys, additional effort was diverted to cover a perceived early spawning peak. This assumption was reinforced subsequent to the results of the winter surveys that were completed during the December 2014 – March 2015. The results of which were reported to WGWIDE in 2015 (ICES, 2015c). These provided a compelling case that suggested a continuation of early spawning in the Biscay region. Consequently, additional and valuable survey effort was diverted to survey an early spawning event that unfortunately never materialized in 2016.

Concentration of survey effort into 'core high abundance areas'

In 2014 WGMEGS sought the advice of WGISDAA specifically regarding the expansion of mackerel spawning in the western area and the ability of the MEGS survey to adequately cope with this. Specifically, the practice of utilizing the alternate transect methodology whereby to maximize geographical survey coverage only 'every other' transect is sampled with the in between transect being interpolated. The response from WGISDAA to WGMEGS recommended (ICES, 2015a) that in addition to a detailed analysis of the survey method that the survey focus on the core high abundance areas where variability was high and the likelihood of bias associated with interpolated transects would similarly be high. In contrast, the areas in the northwest were considered stable, of low density and with comparatively low contribution to the TAEP. If prioritization was required, then restricting the survey geographically in these fringe areas was considered to present a lower risk to the overall TAEP index than reducing the sampling intensity in the higher abundance areas further south. This advice was welcomed and was incorporated into the 2016 survey plan for the western area together with an additional earlier sampling period (see above). Unfortunately, during 2016 the spawning behaviour of the NEA mackerel in the western area changed dramatically with peak spawning being observed later and also to a large extent well away from the core high abundance areas and very much closer to these fringe areas in the North and west. In light of this shift, WGMEGS is likely to revert back to the previous policy of attempting to provide maximum geographical survey coverage during future WGMEGS surveys, although this issue will be discussed further and reported on during the WGMEGS planning meeting in April 2018.

Loss of survey effort / restricted resources

While MEGS in 2016 had approximately 30 additional survey days (363) when compared to 2013 (334), these additional survey days were utilized to cover an additional early survey period in early February as well as an additional period 8 survey in August undertaken by Ireland (outwith the official survey window). The hole left by the loss of the Norwegian survey in 2014 was partially mitigated by additional surveys undertaken by Scotland and the Netherlands during 2016, however the subsequent cancellation of the proposed Danish survey as well as the significant vessel issues experienced by the German survey in period 4 meant that in real terms there was no overall increase in survey effort compared to 2013. Fundamentally, despite the best efforts of the MEGS participants the resources at the surveys disposal were not sufficient to adequately delineate all the spawning boundaries during all the survey periods. While WGMEGS is confident that the present survey and its current design continue to adequately capture the spawning activity of NEA mackerel in the western area this is nevertheless becoming increasingly difficult to achieve.

5.8.2 Egg diameter measurements

During recent surveys, the increasing occurrence of hake eggs in the plankton samples raised concerns about the correct discrimination of these from mackerel and horse mackerel eggs. The size range of hake eggs overlaps with that of horse mackerel eggs at its lower and with that of mackerel eggs at its upper margins. Consequently, egg identification exercises at the recent WKFATHOM staging workshop demonstrated that these eggs are easily confused with each other. Therefore, in 2015 WKFATHOM proposed that participants of the 2016 mackerel egg surveys should collect size measurements of egg and oil globule diameters from 100 mackerel, 100 horse mackerel and 100 hake for each survey on which they participated. Varying amounts of data were delivered by all nations.

The results of the egg and oil globule diameter measurements are shown in Figure 5.8.1. The data pointed to a mean egg diameter size for mackerel of just under 1.2 mm, hake, just under 1.1 mm and horse mackerel just under 1.0 mm. Horse mackerel therefore have the smallest eggs and oil globules, mackerel the largest and hake egg and oil globule diameters are in between both species. However, there was a lot of overlap particularly between mackerel and hake eggs in both egg and oil globule diameter, indicating that besides the measurements other diagnostics should be considered for reliable identification. In particular, the spray method could be used as a tool to reliably sort hake eggs from other eggs (see below, chapter 5.8.3). The exercise also pointed to a reduction in egg diameters in later survey periods. Updated diagnostic criteria will be added to the sampling at sea manual (SISP 6) subsequent to the next staging workshop (WKFATHOM) in 2018.

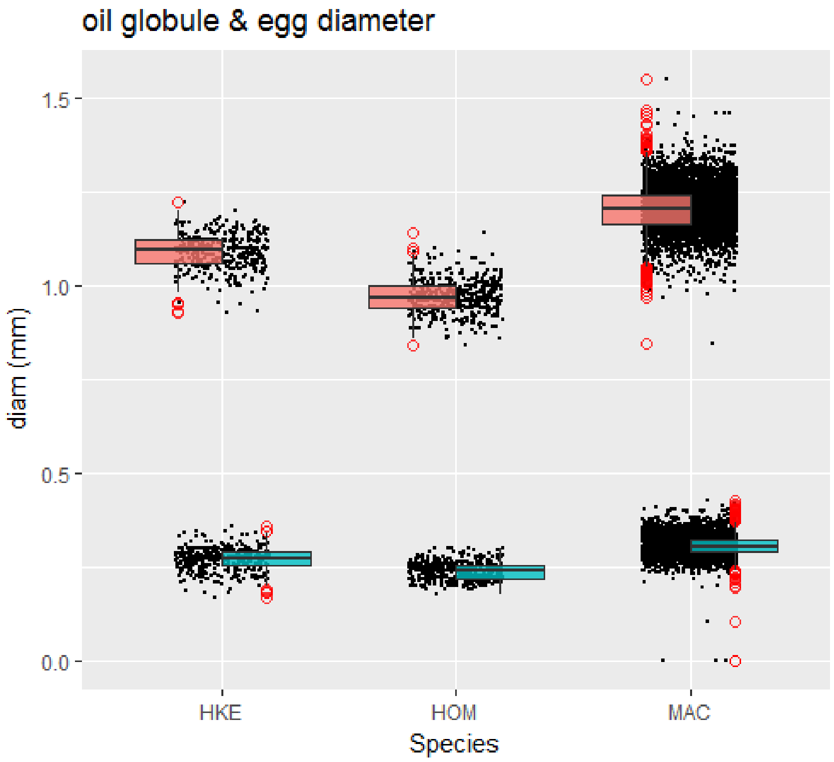


Figure 5.8.1. Box plots of all egg and oil globule diameter measurements carried out by the participants of the 2016 egg survey.

5.8.3 Spray method

The survey manual of the mackerel and horse mackerel egg surveys recommends that all survey participants are using the spray method as a standard to quickly remove the majority of eggs from the samples during their surveys. By application of the spray method aerated seawater is sprayed into a concentrated zooplankton sample with the spray of a jet water pump. The air bubbles from the spray will be entangled in most of the zooplankton particles, e.g. in the various appendices of the zooplankters which will then float to the surface whereas the smooth fish eggs will sink to the bottom. By using a separating funnel, it is easy to separate the eggs by draining them into a beaker.

However, spraying experiments with determined numbers of mackerel, horse mackerel, hake and *Maurolicus* eggs as well as other zooplankton components undertaken by the Thünen-Institute demonstrate that not all eggs behave in the same way during the spraying procedure (Figure 5.8.2 and 5.8.3). While 93% of all mackerel eggs and 97% of all horse mackerel eggs were removed with the first spraying, 95% of all *Maurolicus* eggs and 99% of all hake eggs remained in the samples even after five spraying procedures. Therefore, while mackerel and horse mackerel can be easily separated and drained by the recommended method, eggs with an adhesive and hydrofuge chorion like hake eggs (Porebski, 1975; Zaitsev, 1971) or eggs with corrugated surfaces like those of *Maurolicus* spp. remain floating on the surface.

Following these findings WGMEGS recommends that all survey participants use the spray method. Eggs found in the surface layer should not be mixed with the eggs which are sinking to the bottom but should be looked at separately. In this way it would be possible to easily separate mackerel and horse mackerel eggs from the majority of hake eggs.

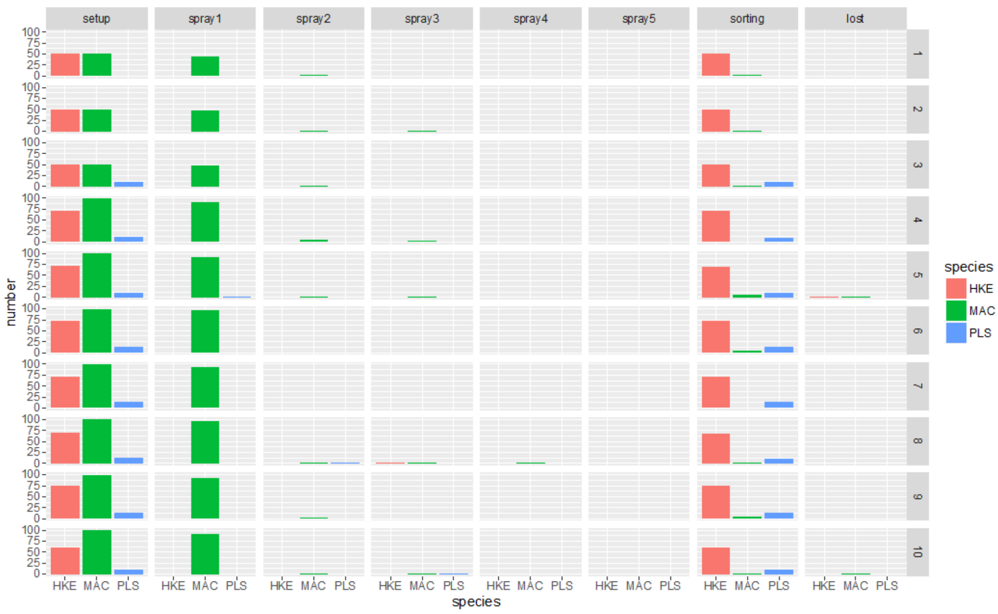


Figure 5.8.2. Results of the spraying experiment I. The setup column is showing the sample composition before the spraying procedures. The columns spray1 to spray5 are showing the number of eggs found after each spraying procedure. The sorting column shows the eggs found in the remaining sample. HKE = hake eggs, MAC = mackerel eggs, PLS = *Maurolicus* eggs. Samples 1 and 2 didn't contain any PLS eggs. Plankton content in the samples was 7 g.

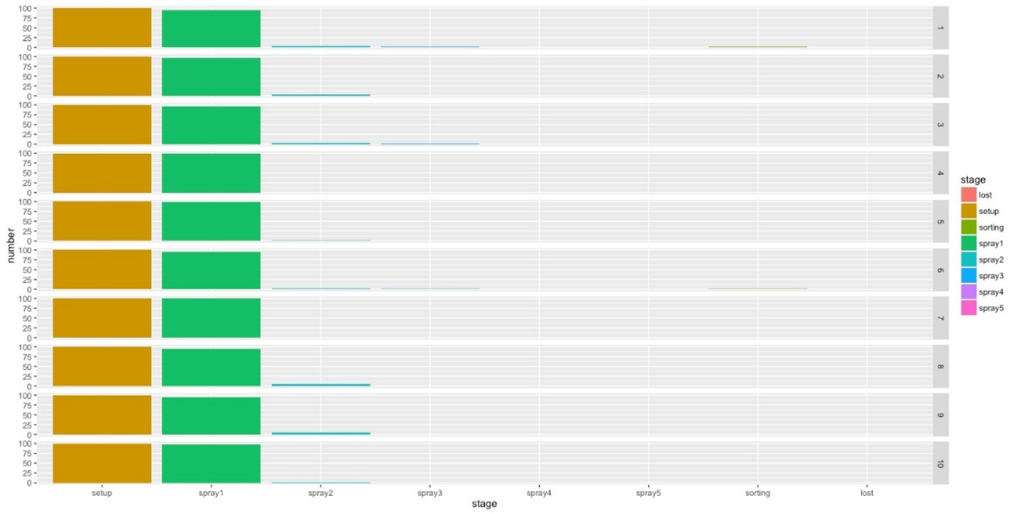


Figure 5.8.3. Results of the spraying experiment II (horse mackerel eggs only). The setup column is showing the sample composition before the spraying procedures. The columns spray1 to spray5 are showing the number of found eggs after each spraying procedure. The sorting column shows the found eggs in the remaining sample. Plankton content in the samples: 12 g and 20 g.

5.8.4 Mackerel egg development

Development of fish eggs depends on the temperature of the seawater the eggs are spawned in. The equation describing the relationship between egg development and temperature is a vital parameter for the estimation of SSB, as it is used to calculate the daily egg production. Two studies have been carried out in the past to establish the relationship between Northeast Atlantic mackerel egg development and temperature (Lockwood *et al*., 1977, 1981, Mendiola *et al*., 2006). The study of Mendiola *et al*. (2006) suggests a more rapid development at low temperatures compared to Lockwood *et al*. (1977, 1981).

The Lockwood equation has been the basis for calculating daily egg production of stage I eggs on all the surveys from 1977 until 2010. With the completion of the 2013 MEGS it was decided to utilize the more recent Mendiola (Mendiola *et al*., 2006) egg development parameters instead of those derived by Lockwood *et al*. (1981) for the calculation of the daily and total annual egg production in mackerel. While the application of the Mendiola parameters on the mackerel egg survey data time-series delivered an up to 15% higher SSB estimate, its validity for TAEP estimation was questioned because of concerns about the methods with which the new parameters were derived by Mendiola *et al*. (2006). In particular, the lag period between fertilization and commencement of the experiments during which time the eggs were kept at 5°C. This period of transit could have affected the estimation of the stage 1 duration time of the eggs in the lower temperature range, and WGALES (ICES, 2014a) recommended to revisit and redo the mackerel egg development experiments.

During the 2016 mackerel and horse mackerel egg surveys Wageningen Marine Research carried out two experiments to establish the relationship between mackerel egg development and temperature. To establish if there might be an adaptation of mackerel to warmer sea temperatures, one experiment was carried out during the April survey and the second one during the June survey. The adult fish were caught just north of the Bay of Biscay in the Celtic Sea. Sampling positions of Lockwood *et al*. (1977, 1981) and Mendiola *et al*. (2006) were also in this area, though they both sampled in March. Seawater temperature was 10°C in April and 12°C in June at 20 m depth. There was stratification of the water column and at the bottom temperature was 11°C in both months. Lockwood *et al*. (1977, 1981) and Mendiola *et al*. (2006) both report seawater temperature of 12°C at the surface. However, Lockwood *et al*. (1977, 1981) notes that there is no stratification of the water column, while Mendiola *et al*. (2006) does not give information on this.

In the 2016 experiments running males and females were selected from the catch, eggs stripped off and artificially fertilized. Eggs were put in separate beakers and the experiment started with all eggs at the ambient seawater temperature. Eggs were slowly acclimatized to the experimental temperatures of 8, 10, 12, 14, and 16°C, respectively. In April, the experiment could be run fully until eggs hatched at all temperatures. In June, algal blooms occurred and the experiment could only be run until egg development stage 2 for all temperatures.

When comparing the results from the two experiments, egg development was quicker in June, except for the highest temperature (Figure 5.8.4). When comparing the results with the previous investigations, the results of this study were similar to Lockwood *et al*. (1977, 1981). The slopes of the temperature to stage duration relationships of the 2016 experiments and the Lockwood *et al*. (1977, 1981) are similar (Figure 5.8.5). In contrast, the temperature to stage duration relationship of stage 1A in Mendiola *et al*. (2006) has a less steep slope, with higher development rates at the lower temperatures compared to all other studies (Figure 5.8.5).

However, because of the high variability of egg development rates and in particular at the lower temperatures, the results were considered inconclusive with regards to which egg development model to be utilized for daily egg production estimates. WGMEGS therefore recommends that these experiments are repeated not only for the North Sea mackerel, since no information is available for that spawning component, but also to repeat the experiments for mackerel during the 2019 survey. Also, such experiments should be carried out for horse mackerel since up to this point, only one study is available for this species (Pipe and Walker, 1987).

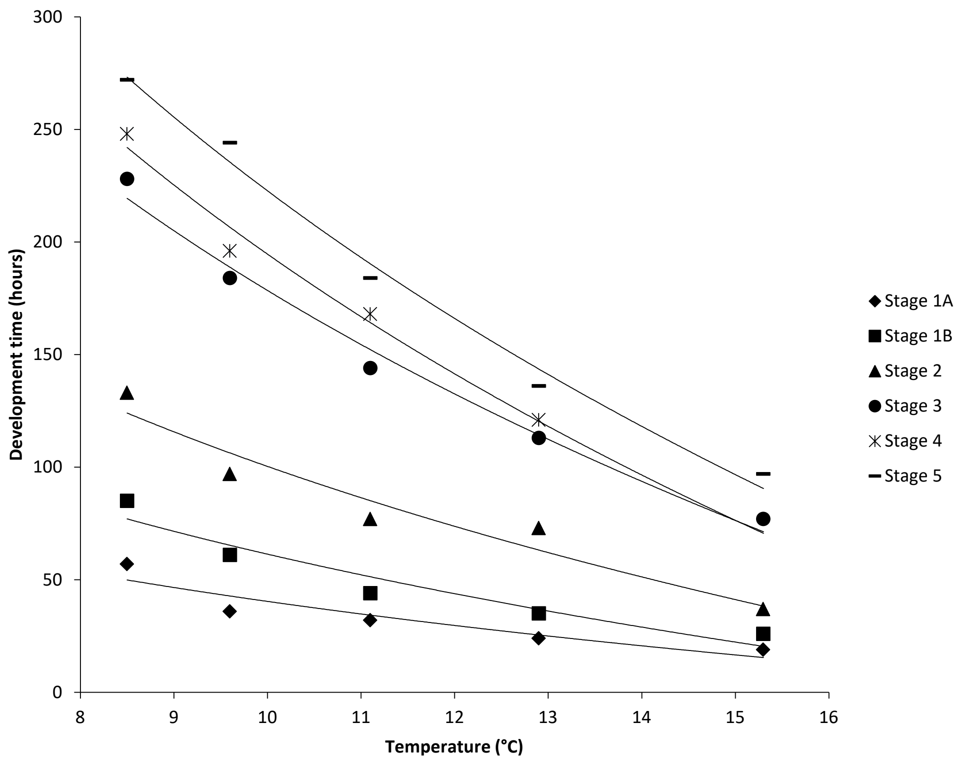


Figure 5.8.4a. Mackerel egg development time for all the egg development stages in April 2016.

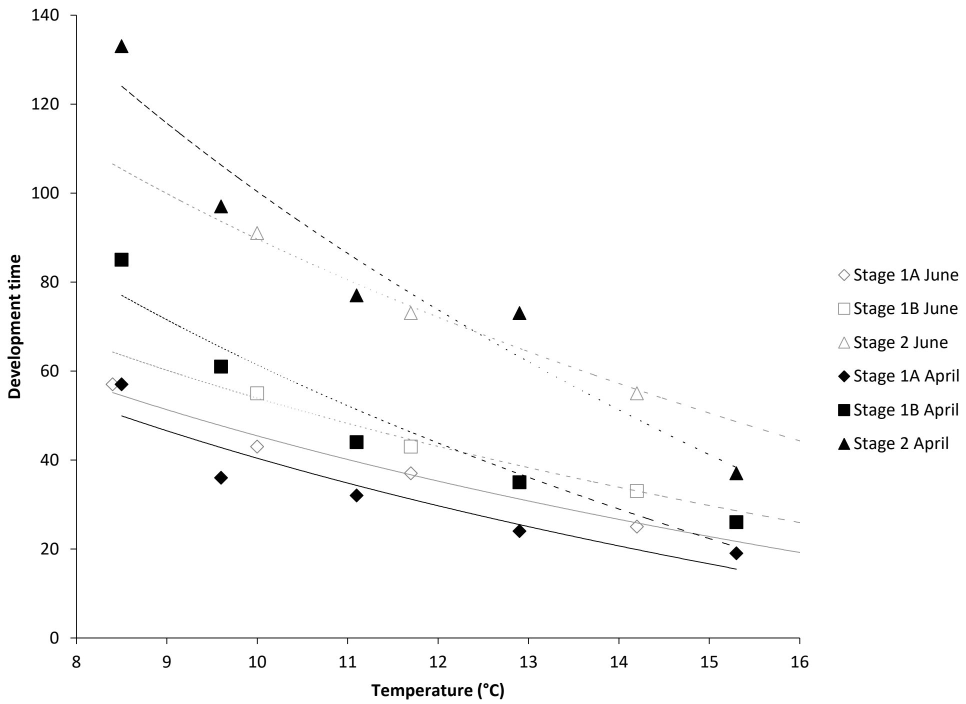


Figure 5.8.4b. Mackerel egg development time for the early egg development stages in April and June 2016. (April: black and filled; June: grey and open markers)

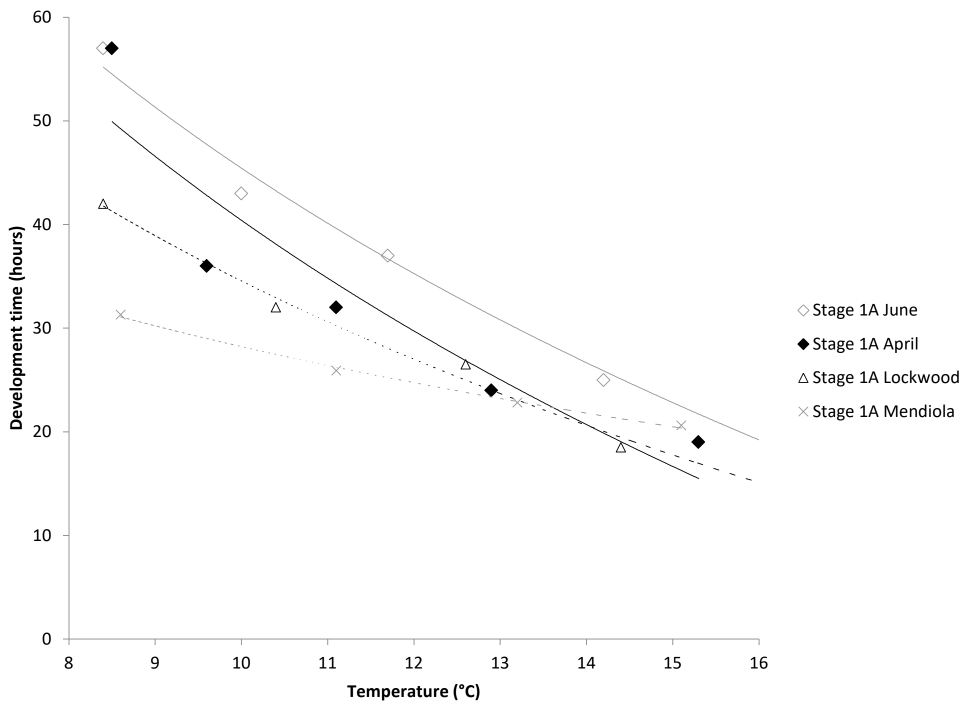


Figure 5.8.5. Mackerel egg development time for the development stage 1A in April and June 2016, Lockwood *et al.* (1977, 1981) and Mendiola *et al.* (2006). (April: black and filled; June: grey and open; Lockwood black and open; Mendiola: grey crosses)

5.8.5 Eggs and larvae of non-target species

Cefas have recently won government funding to help identify and potentially address data gaps in our knowledge of fish (spawning) distributions and to provide added value from the icthyoplankton samples collected as part of the 2016 western mackerel egg surveys. The primary area of interest is to the west and southwest of Ireland from 48°N to 54.5°N and out to 18°W. (ICES Areas 7b, c, g, h, j and k).

A request was sent to participants of the 2016 WGMEGS plankton surveys for access to these samples, with a view that Cefas would sort, identify (to species if possible) and count the fish eggs and larvae present. The resultant data will be shared with the parent institute in the first instance and eventually released to all participants of the 2016 WGMEGS surveys. Ultimately it is hoped that these data can be made widely available via the ICES Egg and Larvae database.

There are three main benefits from this request.

1) The recently published Fish Atlas of the Celtic Sea, North Sea and Baltic Sea edited by Henk Heessen, Niels Daan and Jim Ellis provides an in-depth reference work on marine fish based on data for all western European fish species caught in the period 1977 to 2013. However, coverage of the Celtic Seas is limited and omits the most recent four years.
2) In April 2016, ICES published the latest report from the Working Group to Demonstrate a Celtic Seas wide approach to the application of fisheries related science to the implementation of the MSFD (WGMSFDemo); a science group co-chaired by the UK (Cefas – Carl O'Brien), France (Ifremer – Jean-Paul Lecomte) and Ireland (Marine Institute – Eugene Nixon). Case study work is being progressed by the three nations on the implementation of an integrated ecosystem survey in the Celtic Sea. This will build upon the DCF-funded surveys, the science developed in the Defra-funded TIME project and will address wider ecosystem issues than just fisheries.
3) As part of an EU funded project (INDICES) in the early 2000s, plankton samples from the 1998 triennial mackerel egg survey were re-analysed to describe the egg and larval distributions of seven fish species in Northeast Atlantic waters (Ibaibarriaga *et al.*, 2007). This included the larvae of mackerel and horse mackerel and the eggs and larvae of hake, megrim, blue whiting, sardine, and anchovy. In the case of hake and megrim, for example, these analyses have not subsequently been repeated and it is timely to re-consider the utility of the latest mackerel egg survey samples to provide species information on other stocks in the Celtic Seas to supplement, and enhance, existing knowledge in the region and so further guide the work of ICES WGMSFDemo.

For the 2016 mackerel and horse mackerel egg survey there was a request from WGWIDE to collect also data on presence or absence of blue whiting larvae in the plankton samples. That request was fulfilled by all survey participants and the resulting data submitted to Mark Payne (DTU-Aqua).

5.8.6 Fecundity and atresia sampling

The main aspects of the sampling affecting quality of fecundity and atresia estimation are:

1) Problems to obtain, during surveys, samples of hydrated ovaries for batch fecundity estimation, especially in the case of horse mackerel. Even when some samples (macroscopically staged as hydrated) are collected, many of them are histologically classified as non-valid because of the presence of POFs. Some attempts have been made to overcome this handicap, for example, by using migratory-nucleus oocytes stage to define the batch.

However, at this stage there is no clear gap among the leading cohort and the standing stock of oocytes, thus to obtain a consistent estimate of batch fecundity based on migratory nucleus oocytes has not been possible.

The reasons behind this limitation could be the sampling method. Samples for histological screening are collected in fresh ovaries by using a spoon. This could produce tissue tearing and generate “false POFs”, reducing the number of valid samples for batch fecundity estimation. In order to address this, IEO is testing differences between the spoon and gonad whole section cut methods.

Potential discrepancies in classification between micropipette and histology samples have been detected suggesting that there may be bias associated with samples collected using the micropipette. This could be as a result of the oocytes not being uniformly distributed along the full length of the ovary during certain maturity stages. It is therefore recommended that the calibration between micropipette and gravimetric method for the different species be updated during the next fecundity workshop in 2018 (WKFATHOM).

2) Difficult to obtain precise ovary weight on board because of vessel instability. In 2016, Wageningen Marine Research reported in the dataset sent to the coordinator that fresh ovary weights were not recorded on board for some of the horse mackerel samples. Therefore weights could only be taken after fixation at laboratory. Fresh-fixed weight correction factor should be estimated in both mackerel and horse mackerel to homogenize data in case fresh weights where not available. In any case, sampling incidences must be reported in the database as comments. Correction factor equation should be included in the manual.

Additionally, some laboratory processes have been identified as potentially affecting fecundity and atresia estimations:

1) Small well defined batches have been detected when oocyte size frequency is analysed. It could be due to sampling limitations (see above) or presence of residual hydrated oocytes; nevertheless there is no threshold to define when a group of hydrated oocytes can be considered a batch and this could lead to an underestimation of batch fecundity. A potential solution would be counting mature oocytes smaller than 500 microns to estimate the batch size in relation to the oocytes standing stock in order to define that threshold.

2) Some histological images for atresia analysis had higher magnification than others, but the number of pictures taken was not corrected for that, i.e. the analysed area was lower. The protocols relating to image capture and area to be analysed for atresia analyses need to be reviewed to ensure standardization across all institutes. Necessary changes would then be updated in the fecundity manual (SISP 5).

5.9 North Sea mackerel egg survey in 2017 (ToR f, k)

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 in the year after the Atlantic survey. From 1999 till 2011 these surveys were carried by the Netherlands and Norway. In 2014 no survey was carried out due to technical problems with the vessel. Instead the survey was carried out in 2015, with the Netherlands being the sole participant.

Within the Northeast Atlantic mackerel stock, three spawning components are identified, the western and southern spawning component in the Atlantic and the North Sea spawning component. The North Sea component is only properly separated from the other two components during the spawning season. The size of the North Sea spawning component is estimated to be about 4% of the total Northeast Atlantic stock. The egg survey data are the sole source of data of the North Sea mackerel proper. The data are used to monitor the SSB development of North Sea mackerel over time and to estimate the relative contribution of the North Sea mackerel to the total Northeast Atlantic stock. As such it is vital to the understanding of the stock structure and status.

5.9.1 Survey participation, Sampling area and Survey design

The Netherlands, as sole survey participant, will carry out a mackerel egg survey in the North Sea in 2017. The survey period, 22 May-16 June, will not cover the total spawning period (mid-May-end July). The peak of spawning has usually been observed during mid-June, but in 2011 and 2015 peak spawning was observed beginning of June (4 June in 2015). The timing of the survey has been brought forward by 1 week compared to 2015 to cover the peak of spawning. The timing of the coverage will therefore probably be adequate to define the main part of the egg production curve. One vessel can cover the North Sea spawning area in one week using the alternate transect method. The spawning area is planned to be surveyed four times in 2017 as shown in Table 5.9.1.

Table 5.9.1. Timing for the North Sea mackerel egg survey in 2017.

Period	1	2	3	4
RV Tridens	22–27 May	29 May–3 June	5–10 June	12–16 June

The suggested sampling area for each of the three periods based on recent surveys will be covered the whole spawning area over 4 weeks (Annex 12). Only every other transect can be sampled and the intermittent transects will need to be interpolated.

5.9.2 Plankton sampling and egg production estimation

Plankton sampling and egg identification will be carried out according to the WGMEGS manual (SISP 6). The plankton samples will be fixed in 4% buffered formaldehyde solution. The sea temperature at 5 m and 20 m will be recorded for each of the plankton stations and used for ageing the eggs.

All fish eggs will be sorted from the plankton samples and identified. The mackerel eggs will be staged and counted, using image analysis procedure for detection and diameter measurements combined with visual identification and staging of eggs. Flowmeter revolutions will be recorded during each plankton haul and volume filtered will be calculated. The number of mackerel eggs produced per m^2 sea surface per day will be calculated. A preliminary estimate of the mackerel egg production in the North Sea will probably be available for the WGWIDE meeting in August 2017. The final results will be reported to the next WGMEGS meeting in 2018.

5.9.3 Fecundity and atresia sampling

Next to the egg production, it is also vital to collect fecundity and atresia samples to convert egg production to SSB. They survey will most likely after spawning has commenced, hence collection of potential fecundity samples during the survey will not be possible (as it has not been possible in the past surveys). Norway, Denmark, Germany, and the Netherlands have been asked to collect mackerel from ongoing surveys, commercial samplings or from their fishing industry. The mackerel collected this way will be frozen. This is less ideal for the estimation of fecundity. However, since the last North Sea estimate is from 1983 (Iversen and Adoff, 1983) there is an imperative to provide an updated estimate of fecundity.

During the egg survey, adult samples will also be collected for estimation of atresia. Each period at least one fishing haul is planned to be carried out. The fishing haul will be at different positions each period. Depending on the egg distributions the actual fishing haul positions will be determined. The aim is to collect 100 mackerel each haul. In total, 100 female mackerel will be sampled for atresia estimation. From the same females, also samples will be collected for the DEPM estimation.

The intention is to investigate at least 50 ovaries for potential fecundity and 50 ovaries for atresia. The samples will be collected and analysed as described in WGMEGS fecundity and atresia manual (SISP 5). Ovaries for fecundity and atresia analyses will be collected from mature, late prespawning or spawning or spent females.

5.10 Planning for the 2019 survey (ToR a)

The significant and unpredictable changes in spawning behaviour that have being observed in NEA mackerel signify that the MEGS survey is in an era of uncertainty with regards to its future spawning behaviour. WGMEGS will attempt to obtain additional information from these boundary regions during the interim years ahead of the next MEGS survey in 2019 and specifically around the months of March/April and also May/June. This equates to the temporal periods when 1) mackerel spawning begins and also 2) the period when in 2016 it reached its peak and within the northern regions. It is hoped that these additional data can be used to inform the MEGS group and will aid in the planning process ahead of the 2019 MEGS survey.

The additional data inputs/work during 2017 include:

1) Collection and analysis of additional WP2 samples from the Faroese and Icelandic area components of the ASH and IESNS in May 2017. These will be analysed and the results presented/reported in time for the WGMEGS planning meeting in 2018.
2) Stand-alone mackerel egg survey charter to be completed in May/June 2017 by Ireland within the Northern region and where peak spawning was observed during the 2016 survey. The intention is to sample along 3 transects (Hatton Bank, SE Iceland and West of Shetland) and to sample beyond the current maximum survey extent in this region. This survey will utilize the Gulf VII plankton sampler and the results, together with those from the ASH and IESNS survey will be reported to WGMEGS in 2018.
3) Presentation of egg data from existing IEO surveys/projects that are currently collecting/reporting abundance of mackerel and horse mackerel eggs. These include the annual PELACUS survey, the triennial SAREVA survey completed in March/April and also the indices from the monthly sampled transects (RADIALES). Egg abundance plots from these sources will be presented to WGMEGS in 2018.
4) Mark Payne from DTU-Aqua will aim to resume and further progress the niche modelling work that was initiated prior to the 2016 MEGS survey. A

presentation describing the objectives of this work was delivered to WGWIDE, 2015 (ICES, 2015c).

5.11 Index calculation of Mackerel and Horse mackerel egg production (ToR j)

Prior to 2010 a code written in FORTRAN was used to estimate the total annual egg production (TAEP) for NEA mackerel stock as well as for western horse mackerel. During 2010 the decision was taken by MSS in Aberdeen to rewrite the original FORTRAN code and to replace it with a newly developed code. The R code (*eggprod* R package) was more dynamic in its ability to cope with an expanding spawning area whereas the original code was restrictive in that it only accepted data within a fixed geographical area. The code developed using R, was used to estimate TAEP for mackerel and the western horse mackerel stocks and was reported at WGMEGS in 2011 (Figure 5.11.1; ICES, 2011).

At WGMEGS in 2012 a major change in the TAEP estimation methodology was agreed and subsequently adopted by the MEGS survey group. A new egg development equation developed by Mendiola was adopted for mackerel (Mendiola *et al.*, 2006) that would replace the existing egg development equation developed by Lockwood (Lockwood *et al.*, 1977) and had been used up to and including the 2010 MEGS survey Compared with the estimates calculated using the Lockwood equation, those using Mendiola provided a slightly higher egg production due to a shorter period of observed egg development. (ICES, 2012b)

Subsequent to a recommendation from the benchmark workshop WKPELA 2014 (ICES, 2014b), the working group of mackerel and horse mackerel egg surveys (WGMEGS) proceeded to undertake a comprehensive revision of the MEGS survey database for years 1992 to 2013. Consequently, a new time-series of egg-production based SSB utilizing the Mendiola development equation were presented to WGMEGS and WGWIDE in 2014, with the 1992, 1995 and 2013 data points being revised substantially (Figure 5.11.1 and 5.11.2; Table 5.11.1). The originally reported 1992 estimate did not include egg production from the southern area of the survey and so the revised estimate corrected this and those data were subsequently included. The originally reported 1995 estimate used only data from a standard geographical area that corresponded to that covered during the 1992 MEGS survey. Once again the newly revised estimate corrected this including all the survey data. The 2013 SSB estimate was revised significantly due to the reallocation of out of period stations to their correct survey period (ICES 2014c).

Improvements since WKPELA 2014

During the MEGS survey data review, TAEP estimates of the whole time-series were calculated using the new updated code in R that has been developed in recent years. A new version of the code in R (*Teggprod* R package) was updated and developed further in 2015 and 2016 to include checking routines that consequently detected some bugs in the existing script and which have now been corrected.

The most significant mistakes detected were:

1) Discovery of an error in the interpolation algorithm. The interpolated rectangle value is estimated as the arithmetic mean of the daily egg production values of all those surrounding sampled rectangles. The error consisted of estimating the interpolated value as the sum of surrounding sampled rectangle values divided by number of all surrounding rectangles (sampled and **unsampled** rectangles) (Figure 5.11.3). This resulted in an under-

estimation of the egg production for interpolated rectangles. Consequently, the TAEP and SSB estimates time-series presented to WGWIDE in 2014 were underestimated (Figure 5.11.3; Tables 5.11.1 and 5.11.2). The revised time-series of TAEP and SSB estimates were presented to WGWIDE 2015 (ICES, 2015c) showed an increase for the TAEP and SSB compared to previously reported estimates in 2014 (Figure 5.11.4).

2) There was an error in the algorithm to raise egg production by period survey to the total annual egg production (histogram method). The histogram method consists of estimating the unsampled gaps between sampled periods as an interpolation from adjoining periods. This bug overestimated the egg production for unsampled gaps (interpolated periods) in the decreasing part of histogram (Figure 5.11.5). Consequently, the time-series of TAEP and SSB estimates were presented to WGWIDE in 2015 and 2016 were overestimated (Figure 5.11.6).

3) An error in the extrapolation method. A misunderstanding concerning interpretation of the qualifying criteria required for interpolation of unsampled rectangles as described in manual for the mackerel and horse mackerel egg surveys (SISP 6; Figure 5.11.7). Consequently, there was an overestimation of egg production due to an increase in the number of extrapolated rectangles out of surveyed area in the time-series presented to WGWIDE in 2015 and 2016 (Figure 5.11.6).

Although these errors were detected in period 2015–2016 only, the error in the interpolation algorithm was implemented in the time-series reported to WGWIDE 2015 and WGGWIDE 2016 (ICES, 2015c, 2016b). The reason was to avoid reporting several corrected versions of this time-series that could create confusion in the reliability of this index. It was therefore decided to present the entire updated index of TAEP/SSB time-series from 1992 to 2013 for NEA mackerel in time for WKWIDE 2017. Hence the complete corrected historic TAEP and SSB time-series for NEA mackerel and the historic index of TAEP for western horse mackerel are presented in section 5.12.

A TAEP estimate was calculated manually using the 2016 survey egg production data of NEA mackerel for both the western and the southern area components according to the methods described in the Manual for the Mackerel and Horse Mackerel Egg Surveys (SISP 6). The manually calculated daily egg production (DEP) values for each half rectangle by sampling period were compared with those generated by the estimation script. These included the DEP values from both observed as well as the interpolated values from eligible unsampled rectangles. In addition, the daily egg production estimates from interpolated periods were also compared prior to the overall comparison of total annual egg production (TAEP) estimates. Agreement between methods for both the western and southern areas was almost perfect with the disparity in TAEP being 0.04% and 0.02%, respectively. A more detailed breakdown of the results of the comparison by period and method for both areas can be found in Annex 13. WGMEGS is confident that this current version of the estimation script is now correct with all errors detected and corrected however it will continue to enhance and refine the quality control checks as well as the outputs associated with this script.

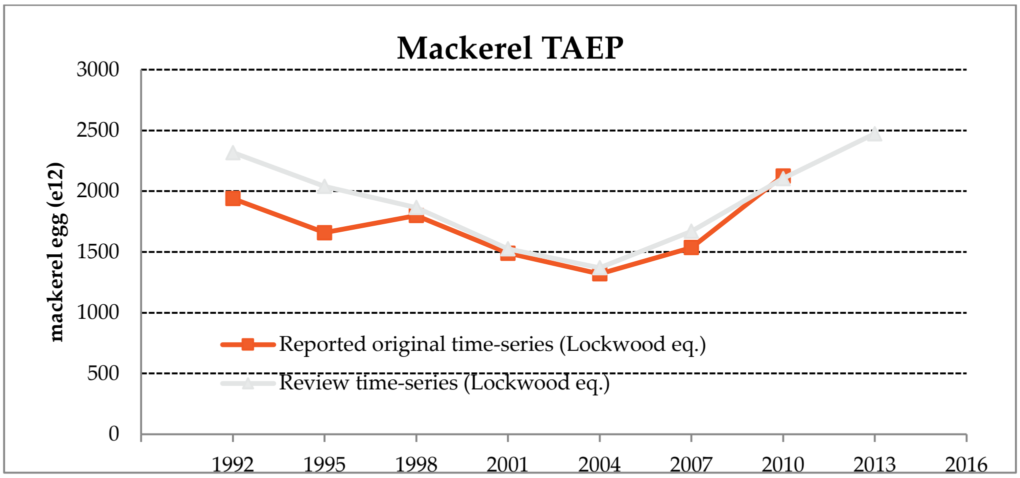


Figure 5.11.1. NE Atlantic Mackerel review TAEP estimates calculated using R script (blue line) and reported TAEP by WGMEGGS using FORTRAN code (red line).

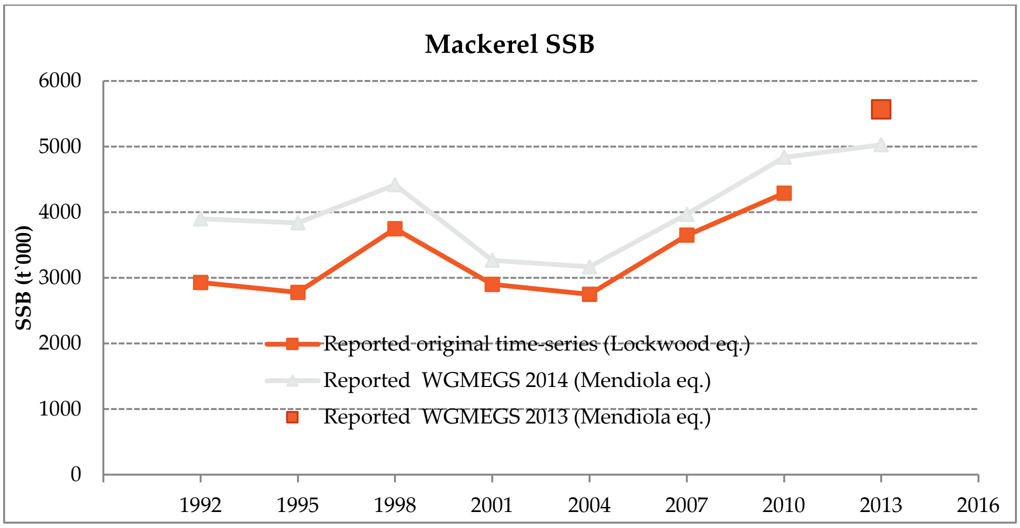


Figure 5.11.2a. NE Atlantic Mackerel SSB estimates derived from the mackerel egg surveys for the combined survey area. The blue line represents the input data for the mackerel assessment using the Lockwood traditional egg development equation. The blue square is the estimate given to WGMEGS 2013 using the new egg development equation developed by Mendiola. The red line represents the agreed input data using Mendiola eq. and presented to WGWIDE 2014.

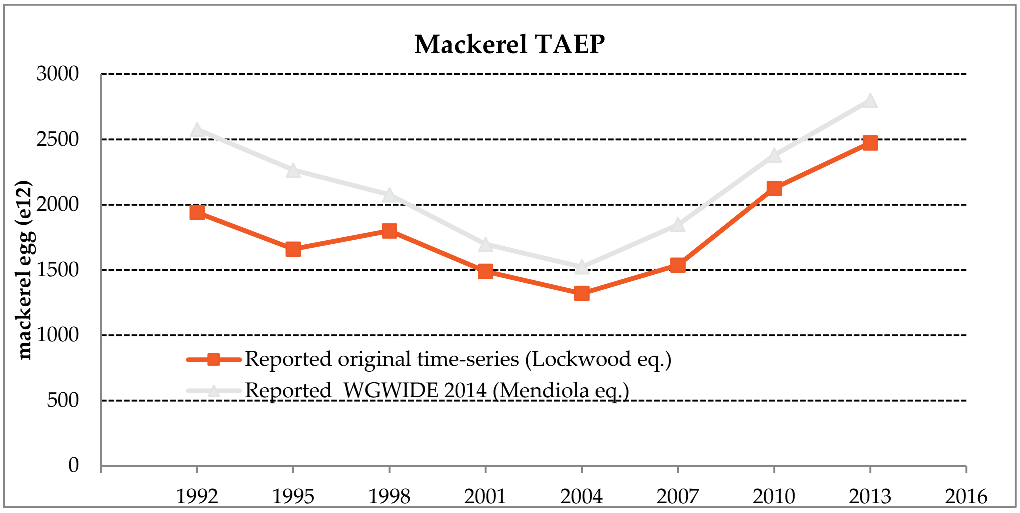
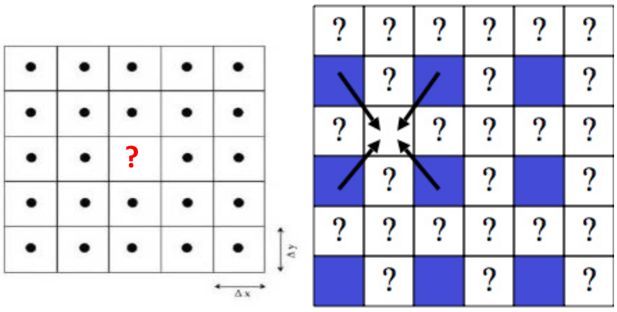
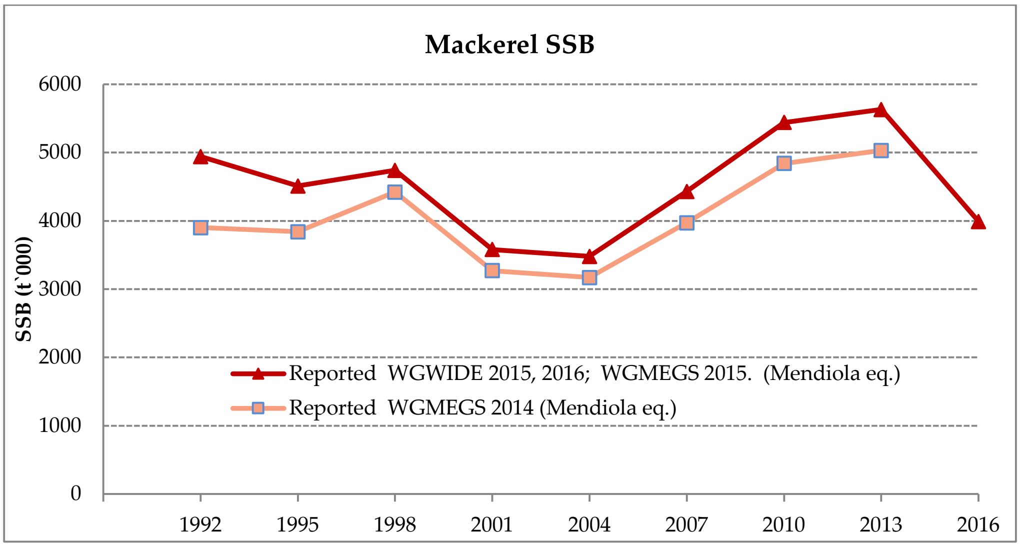


Figure 5.11.2b. NE Atlantic Mackerel TAEP estimates derived from the mackerel egg surveys for the combined survey area. The blue line represents the input data for the mackerel assessment using the Lockwood traditional egg development equation. The red line represents the agreed input data using Mendiola eq. and presented to WGWIDE 2014.



Figures 5.11.3. Synoptic view of bug in the interpolation algorithm. The interpolated rectangle value is estimated as the arithmetic mean of the daily egg production values of all those surrounding sampled.



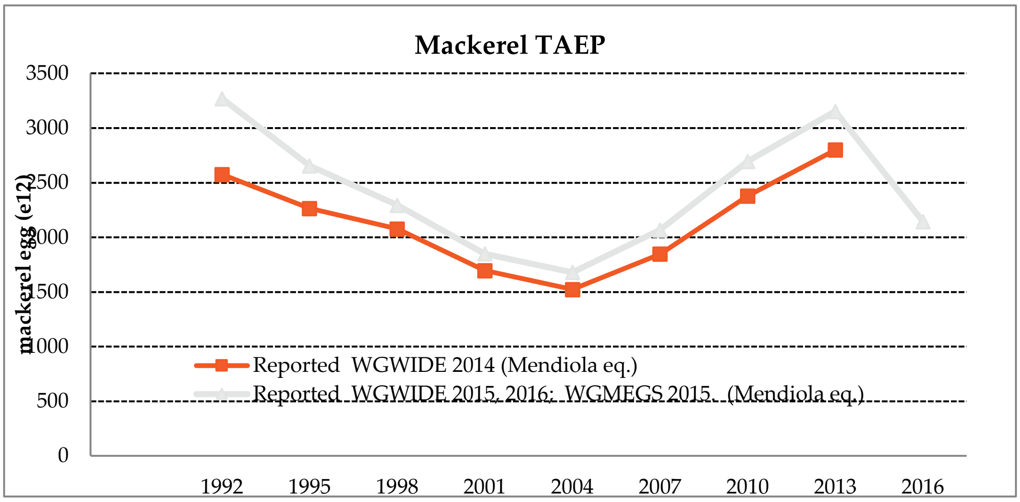
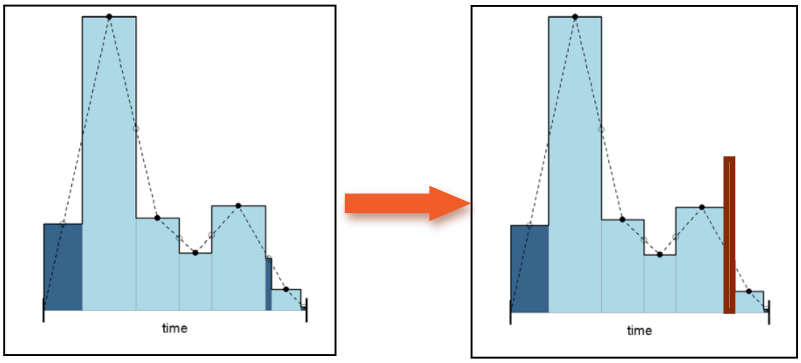
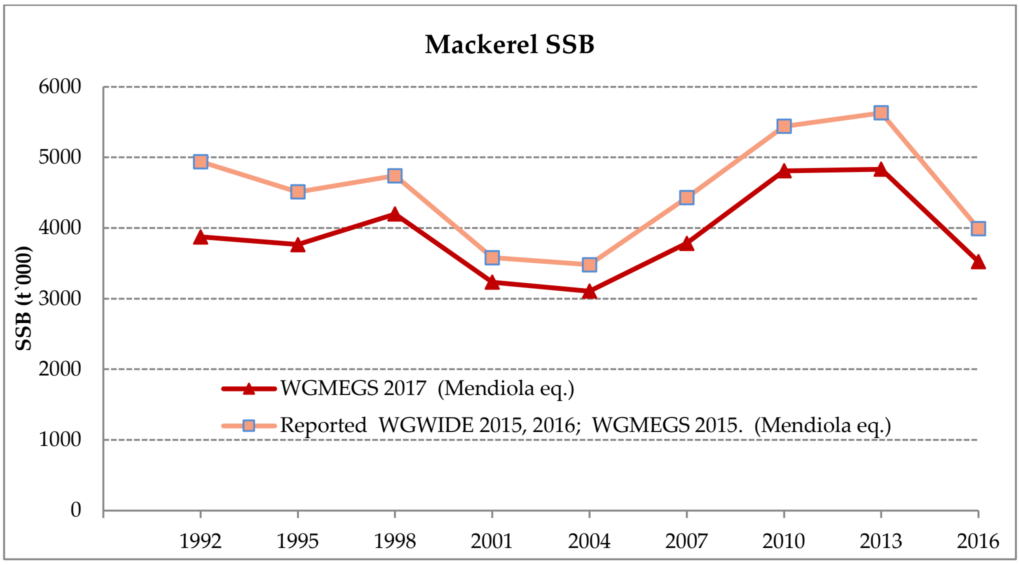


Figure 5.11.4. Comparison between reported to WGWIDE 2014 and revised estimation of the SSB and TAEP reported to WGWIDE 2015 for NEA mackerel. The revised estimate calculated using the script with the bug and finally the newly revised estimation of the Total Annual Egg Production for mackerel calculated using the corrected scripts (both components combined).



Figures 5.11.5. Synoptic view of bug in estimate the unsampled gaps between survey periods. Unsampled gaps (dark blue) are estimated as an interpolation from adjoining survey periods (light blue).



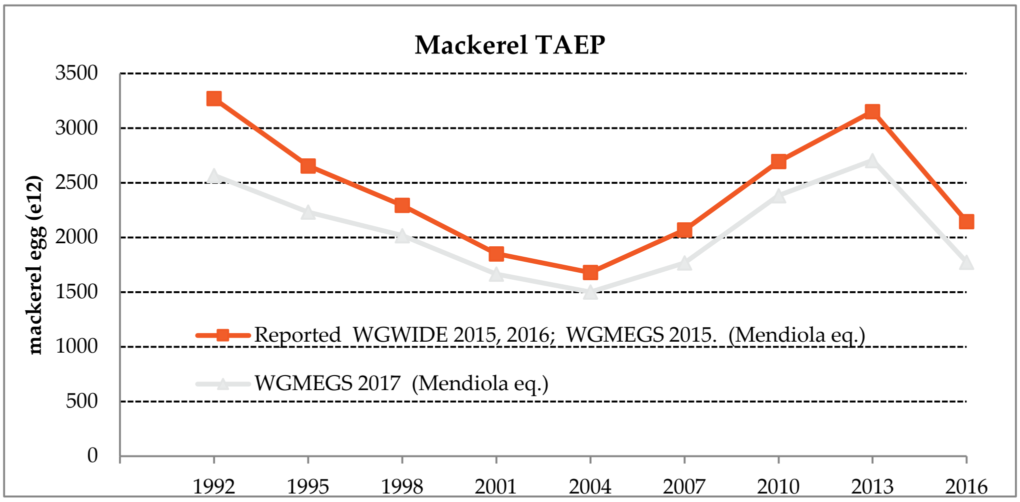


Figure 5.11.6. Comparison between SSB and TAEP reported to WGWIDE 2015,2016 and WGWIDE 2016 and revised estimation presented to WGMEGS 2017 for NEA mackerel. The revised estimate was calculated using the corrected script.

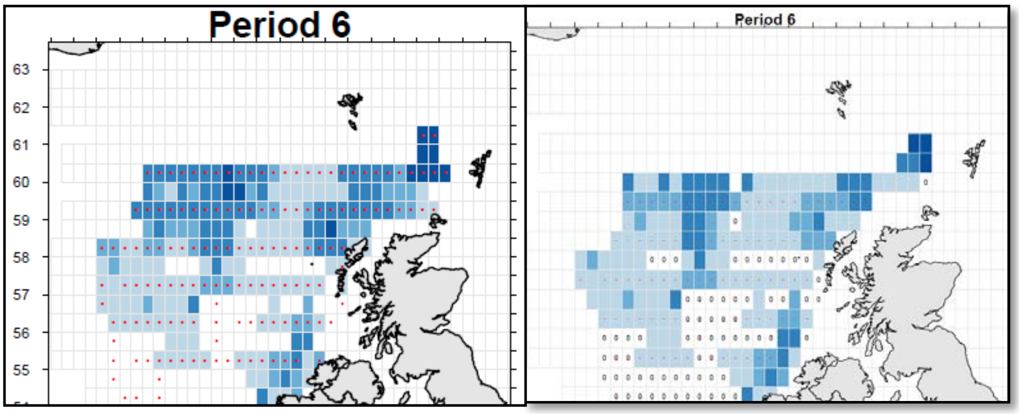


Figure 5.11.7. Synoptic view of bug in extrapolation method. Left map with extrapolated bug and right map corrected bug. Blue range in rectangles represents mackerel egg production. Red dots denote interpolated rectangles. Rectangles with 0 correspond to no mackerel egg production.

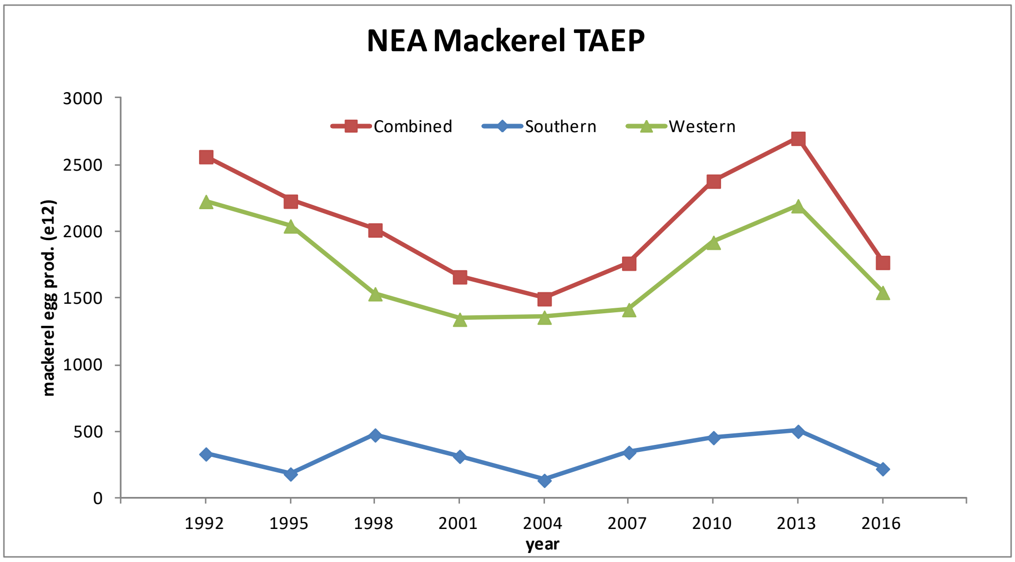
5.12 Historic mackerel and horse mackerel TAEP and SSB estimations

5.12.1 NEA Mackerel

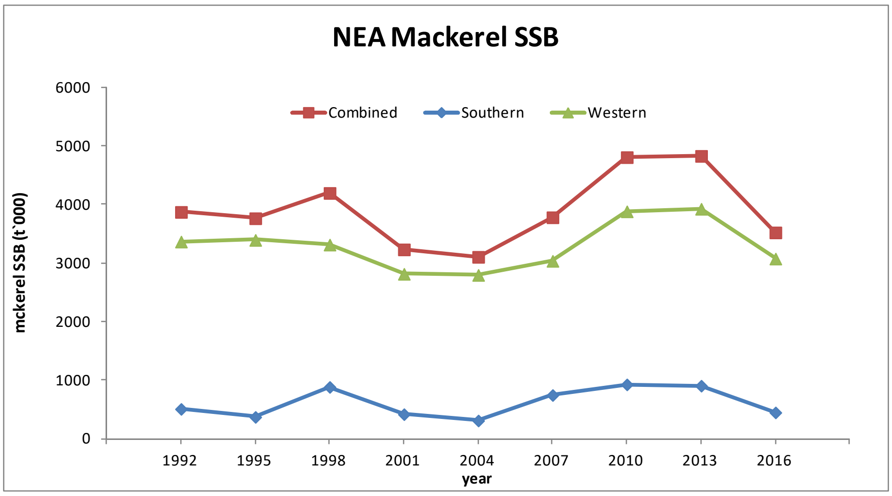
As result of the review of the historical MEGS survey database (MEGS, 2015), use the Mendiola mackerel egg development equation (Mendiola *et al.*, 2006) instead of the Lockwood equation (Lockwood *et al.*, 1977) (MEGS,2012), and use of a new reliable updated software (*Teggprod* R package)(ICES, 2017a) to estimate the total annual egg production for mackerel an updated index of Total Annual Egg Production (TAEP) and SSB for NEA mackerel was calculated. Results of these updated SSB and TAEP for mackerel by spawning component and combined components are shown in Table 5.12.1 and Figures 5.12.1 and 5.12.2.

Table 5.12.1 Updated Total Annual egg production (TAEP) for NEA mackerel derived from the MEGS surveys. Comparison between the updated estimates and reported estimates of Western horse mackerel TAEP. Standard deviation (sd) was calculated using the traditional methodology.

Year	Component	TAEP	sd TAEP	SSB (kt)
1992	Western	2.23*e15	1.48*e14	3367
1992	Southern	3.36*e14	1.36*e13	507
1992	Combined	2.57*e15	1.62*e14	3874
1995	Western	2.05*e15	4.84*e14	3396
1995	Southern	1.86*e14	1.83*e14	370
1995	Combined	2.23*e15	6.66*e14	3766
1998	Western	1.54*e15	2.54*e14	3316
1998	Southern	4.79*e14	1.61*e15	883
1998	Combined	2.02*e15	1.86*e15	4199
2001	Western	1.35*e15	3.16*e14	2816
2001	Southern	3.18*e14	2.08*e14	417
2001	Combined	1.67*e15	5.24*e14	3234
2004	Western	1.36*e15	4.53*e14	2798
2004	Southern	1.38*e14	5.63*e13	309
2004	Combined	1.50*e15	5.09*e14	3107
2007	Western	1.42*e15	2.36*e14	3038
2007	Southern	3.48*e14	3.42*e14	745
2007	Combined	1.77*e15	5.79*e14	3783
2010	Western	1.92*e15	2.94*e14	3884
2010	Southern	4.59*e14	3.67*e14	926
2010	Combined	2.38*e15	6.61*e14	4811
2013	Western	2.20*e15	1.68*e15	3928
2013	Southern	5.06*e14	1.04*e15	904
2013	Combined	2.70*e15	2.72*e15	4832
2016	Western	1.55*e15	5.51*e14	3077
2016	Southern	2.25*e14	2.97*e14	447
2016	Combined	1.77*e15	8.48*e14	3524



Figures 5.12.1. Total Annual egg production estimates (TAEP) for NEA Atlantic Mackerel derived from the mackerel egg surveys for the Southern, Western and combined survey area. The green line is Western component, blue line is Southern component and red line is combined components. TAEP estimates using Mendiola egg development equation.



Figures 5.12.2. NE Atlantic Mackerel SSB (t) estimates derived from the mackerel egg surveys for the Southern, Western and combined survey area. The green line is Western component, blue line is Southern component and red line is combined components. SSB estimates using Mendiola egg development equation.

5.12.2 Western horse mackerel

While undertaking the process of overhauling the mackerel and horse mackerel historical egg survey database carried out by WGMEGS in 2014 (ICES. 2014b), the decsion was made to exclude the egg survey data prior to 1992. This was due in the most part because these early surveys did not survey the entire spawning area for Western horse mackerel and NEA mackerel. No sampling was undertaken in divisions 8.c. and 9.a.

As a result, the revised egg production index for western horse mackerel was estimated using the surveys from 1992 onwards. In the originally reported TAEP estimate for western horse mackerel in 1992 the southern part of Western horse mackerel stock (division 8.c) was not been included in the estimation, however in the reviewed estimate this component has been included (Figure 5.12.3). The updated time-series was calculated using a *Teggprod* R code (Table 5.12.2)

Table 5.12.2. Updated Total Annual egg production (TAEP) for Western horse mackerel derived from the MEGS surveys. Comparison between the updated estimates and reported estimates of Western horse mackerel TAEP. Standard deviation (sd) was calculated using the traditional methodology.

	Reported TAEP	Review TAEP	Review sd
1983	5.13*e14		
1989	1.762*e15		
1992	1.712*e15	2.0941*e15	3.0129*e14
1995	1.265*e15	1.3438*e15	1.0214*e15
1998	1.136*e15	1.2422*e15	5.7044*e14
2001	8.21*e14	8.6428*e14	2.749*e14
2004	8.89*e14	8.8428*e14	2.849*e14
2007	1.64*e15	1.4863*e15	9.1634*e14
2010	1.093*e15	1.0334*e15	3.8605*e14
2013	3.97*e14	3.6636*e14	1.2478*e14
2016		3.3054*e14	1.1895*e14

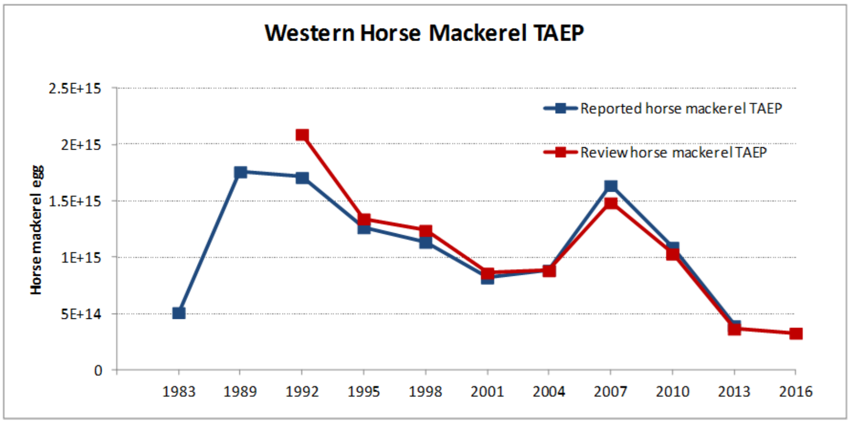


Figure 5.12.3 Western horse mackerel Total Annual Egg Production (TAEP). Comparison of updated and reported TAEP for Western horse mackerel (1983–2013).

5.12.3 Error in MEGS Survey Datefile For Period 6, 2007

While reviewing the original date input file for the historic egg surveys an error in the date of period 6 for 2007 egg survey was detected. The mistake refers to the final date for period 6 (last period in 2007). Instead of the final sampling date being used to define the end of survey period 6 (15 July), the nominal end spawning date for the spawning season was used (31 July). When corrected the period 6 duration was now 21 days instead of 37 days. The impact of this error was an overestimation of around 5% in Total egg production and SSB for mackerel and 10% in TAEP for Western horse mackerel in 2007. This error has been amended in this current AEP and SSB time-series presented for both mackerel and horse mackerel.

5.13 Historic Mackerel spawning overview and boundaries

NEA mackerel spawning distribution maps were presented covering the pre, and present expansion period within the western area from 2001 to 2016. Together with the maximum geographical extent for the western area they provide the survey rectangles by survey year that captured 90% and 50% of daily egg production for each of those survey years. They highlight those rectangles that when ranked in descending order of abundance captured that respective proportion of the overall spawning within that survey year (Annex 14).

The 90% egg production plots provide information on the north and westwards expansion as well as the overall increase in spawning density within this region while the 50% egg production plots provide additional information in that they identify those locations where the highest concentrations of spawning were observed in each of the survey years. While it is clear that mackerel spawning activity has expanded into the North and West since 2007, the situation with regards to the areas recording the highest spawning densities is more complex. For years 2001–2010 (Annex 14 Figure 7–10), the situation appears fairly stable with the majority of spawning activity being centred on the traditional centre of gravity of spawning for the western areas i.e the continental shelf edge areas around the Porcupine Bank and Celtic Sea. 2013 witnessed the largest single spawning peak in the surveys history which was unusual not only in terms of its magnitude and intensity (70% of all spawning within period 2) but also because it came very early in the spawning season on day 68. Mackerel spawning in the western area in 2013 (Annex 14 Figure 5) was reported over the largest geographical extent in the surveys history, however the 50% plot for 2013 (Annex 14 Figure 11) reveals that the majority of the reported spawning activity was contained in just a few stations within the Biscay and Cantabrian Sea regions. The Porcupine region being represented by just a solitary rectangle. The situation in 2016 appears to have changed once again although one would expect that had the survey coverage headed as far North as in 2013 then the geographical extent of spawning would have been broadly similar to that observed in both 2010 and 2013. That is however where the similarities end as in 2016, the picture is once again a very different one with more than half of the rectangles contributing to 50% of the reported spawning being located North of 57 degrees (Annex 14 Figure 12). While there were localized areas within the Cantabrian Sea, Biscay and Porcupine Bank that recorded high concentrations of stage 1 eggs it is clear from the survey data and the egg production curves (Annex 14 Figure 6) that the majority of spawning recorded during the 2016 survey took place in these northerly latitudes and in the main well away from the continental shelf edge.

5.13.1 Mackerel spawning in the Nordic Seas

During the last decade, the Northeast Atlantic mackerel has extended its spawning and feeding migration farther to the west and north. In Icelandic waters mackerel has, until recent years, only been observed sporadically and its presence during certain periods (Astthorsson *et al*., 2012). Since 2007, this led to an extensive fishery within Iceland's, Faroese's and now for the last four years, in Greenland's Exclusive Economic Zone (EEZ). Furthermore, juvenile mackerel have been observed sporadically during annual groundfish surveys on the Icelandic shelf since 2004, and in recent years over a wide area to the southeast, south, southwest, and west of Iceland. Estimation of the juvenile hatching date distributions by means of otolith microstructure analysis indicate that the juveniles may originate in spawning in the northwestern part of the spawning area in the NE-Atlantic (Gunnarsson *et al*., 2013). This may be an indication that the nursery area of the NE-Atlantic area may be extending. Furthermore, based on data from the triennial egg survey, Hughes *et al.* (2014) showed the underlying patterns on the location and density changes of the western spawning component of adult NE-Atlantic mackerel 1977–2010. The results demonstrated northwards shift in center of gravity of egg production.

The participation of the Faroese Islands and Iceland in the egg survey since 2010 and the application of an alternating transect survey design, made it possible to survey a much larger area thereby expanding and redrawing the northern and northwestern boundaries of mackerel spawning. The results from the egg surveys in 2010 and 2013, together with indications of almost absent spawning activity in the northwestern corner of the western spawning component of NE-Atlantic mackerel in July and August 2013, provided compelling evidence that the tail end of the spawning season in the northwest is well covered both in time and space.

During 2016 survey on the other hand high levels of spawning were recorded over a far larger area of the Northeast Atlantic with a large number of the stations being reported over deep water and well away from the continental shelf. Available surveys deployed during these periods were unable to adequately cover this area and so moderate to large numbers of stage 1 eggs were recorded on several northerly and western boundary stations. Spawning within this area has been observed since 2007 however only at low concentrations. It was accepted that north and northwesterly unaccounted for spawning was a reality but contributed only a tiny proportion of the TAEP in the western area. In 2016 and with the large decrease in the southern mackerel component it seems certain that a large proportion of the fish remained in northerly latitudes for most of the season.

The international coordinated ecosystem survey in the Norwegian Sea and adjacent areas (IESSNS) was performed during 1 July to 31 July 2016 by five vessels from Norway (2), Iceland (1), Faroese (1) and Greenland (1). A standardized pelagic trawl swept-area method has been developed and used to estimate a swept-area abundance estimate of NEA mackerel in the Nordic Seas in recent years. The method is analogous to the various bottom-trawl surveys run for many demersal stocks. Zooplankton was sampled with a WP2-net on all vessels. Mesh size was 200 µm. The net was hauled vertically from a depth of 50 m (or bottom depth at shallower stations) to the surface at a speed of 0.5 m/s. All samples were preserved in formaldehyde for species identification and enumeration. Approximately 30 samples collected on board the Icelandic vessel off the south and east coast of Iceland from 13 to 19 July 2016, were checked for mackerel eggs. Spawning activity was recorded at only one station off the southeast coast of Iceland where 3 mackerel eggs was found at a station sampled on the 24th of July. Furthermore, maturity stage of 1000 females were recorded and of them only four were running or had hydrated eggs. The results indicate that the triennial egg survey in 2016 successfully covered the end of the spawning season, at least in time.

The change in NEAM spawning distribution has implications for the triennial international mackerel survey design. Increased effort is required to maintain the adaptive design of the survey (to capture spawning extent) should be taken into account in the planning of future surveys, with the more northerly latitude countries taking on an important role. It is important to acquire extra information on egg distributions prior to the planning of the 2019 surveys. It may be necessary to carry out some additional surveys in northern areas in the next couple of years, similar to the ones done in Biscay in 2014/2015, to observe if spawning is still taking place up there. WGMEGS is planning to secure the collection of additional mackerel egg samples from other ICES coordinated surveys within this region as well as an additional survey prior to the next MEGS survey in 2019 (See section 5.10).

5.14 Database

5.14.1 Egg data

For the mackerel and horse mackerel egg surveys the station data are categorized by survey period. The survey periods change with each survey, as it is largely dependent on the availability of survey vessels in any given survey year. There is no standard code to deduce the survey period from the day, month and year combination. WGMEGS recommends adding the field 'Survey Period' to the ICES Eggs and Larvae database (Table 5.14.1).

Table 5.14.1. New suggested field for the Eggs and Larvae data input format: Haul data.

Field	Mandatory	Units/references
Survey Period		Division of the survey in a certain year into different periods, numbered from 1 to 99 Temporal sampling period of which the exact duration is determined by the realized start and finish of sampling within the predetermined dates. The egg production methods require that the whole spawning area is sampled within one Survey Period.

5.14.2 Fecundity and Atresia database

Next to the fecundity and atresia sampling of adult females during the egg surveys, biological parameters are collected from a greater sample of the mackerel and horse mackerel catches that have previously not been stored in a central database. These data include length, weight and maturity of males as well as age data for both sexes. These data proved to be of value for the mackerel and horse mackerel assessment and benchmark groups. Therefore, it was recommended that a database template was set up to ensure the standardized transmission of the data, next to the fecundity and atresia database. Both the fish and fecundity and atresia data can be stored in one database.

The egg data are collected separately from the fish data, but for the estimation of the spawning stock both datasets are needed. It is therefore recommended that both the Egg and Larvae database and the Fecundity and Atresia database should be accessed via one data portal called 'Fish Reproduction'.

WGMEGS advises that all biological data should be sent as soon as the samples are processed after the individual surveys to the biological sampling coordinator with the following entries (Table 5.14.2 and 5.14.3).

For the next survey period it is planned that a Fecundity and Atresia database will be installed. Tables 5.14.2–5.14.7 show the suggested format for the Fecundity and Atresia database.

Table 5.14.2. Fecundity and atresia data input format: Haul data (In yellow are mandatory fields; Fields with * have a lookup table attached.)

Field	Mandatory	Units/references
Survey *	y	RECO DatasetVer
Country *	y	RECO ISO_3166
Institute*		EDMO codes Please register the missing institutes at EDMO (http://seadatanet.maris2.nl/v_edmo/welcome.asp). Contact Peter Thijsse at MARIS (peter@maris.nl) and he will help you proceed with entering any missing institutes and obtaining EDMO codes.
Campaign		The national campaign name/ Survey name (e.g. BOCADEVA)
Ship *	y	RECO SHIPC
Gear *	y	RECO SMTYP
Station Number	y	The number of the station
HaulID	y	ID of that haul
SampleID		
Day	y	Start date of the haul in UTC
Month	y	Start date of the haul in UTC
Year	y	Start date of the haul in UTC
Hour	y	Start time of the haul in UTC
Minute	y	Start time of the haul in UTC
Survey Period		Division of the survey in a certain year into different periods, numbered from 1 to 99 Temporal sampling period of which the exact duration is determined by the realized start and finish of sampling within the predetermined dates. The egg production methods require that the whole spawning area is sampled within one Survey Period.
ShootLat	y	Latitude at shooting in decimal degrees and using + and – for North/South
ShootLong	y	Longitude at shooting in decimal degrees and using + and – for East/West
Haul Duration minutes		minutes
Haul Duration seconds		seconds
Distance		Distance towed in metre
Notes		Free text

Table 5.14.3. Fecundity and atresia data input format: Fish measurement data (In yellow are mandatory fields; Fields with * have a lookup table attached. Orange: denote fields for which WGMEGS provided an (updated) lookup table.)

Field	Mandatory	Units/references
HaulID	y	
indiv_seq_no		Number of the individual fish measured
Species *	y	Latin name as in WoRMS
Total Length	y	Total length of the fish in 0.1 cm
Total Weight	y	Total weight of the fish in 1 g
Sex*	y	RECO AC_Sex
Maturity*	y	Walsh scale
Age	y	
Age Identification_serial_number		
Ovary Weight	y	Total weight of the the ovary in 0.1 g
Fecundity Sample Number	y	Unique code assigned to the ovary samples
Notes		Free text

Table 5.14.4. Fecundity and atresia data input format: Whole mount screening data (In yellow are mandatory fields; Fields with * have a lookup table attached. Orange: denote fields for which WGMEGS provided an (updated) lookup table.)

Field	Mandatory	Units/references
Fecundity Sample Number	y	Unique code assigned to the ovary samples
HaulID	y	
Analysing Institute*	y	EDMO codes Please register the missing institutes at EDMO (http://seadatanet.maris2.nl/v_edmo/welcome.asp). Contact Peter Thijsse at MARIS (peter@maris.nl) and he will help you proceed with entering any missing institutes and obtaining EDMO codes.
Oocyte Stage*	y	The most advanced oocyte development stage present. 1 = previtellogenic oocytes, 2 = early vitellogenic oocytes<400 µm, 3 = vitellogenic oocytes, 4 = migratory nucleus, 5= hydrated oocytes (note: we do not consider stage 4 (migratory stage on whole mount)
Egg Stage*	y	Egg stages present; 0 = No eggs present, 1 = New eggs present, 2 = Residual eggs present, 3 = New and residual eggs present
Spent	y	Yes or no
Discard	y	Yes or no. Discard sample for further analyses, other than for the reasons in columns Oocyte Stage, Egg Stage or Spent. If Yes, the Notes column will need to be filled.
Fecundity	y	Yes or no. Can the sample be used based on the results of columns Oocyte Stage, Egg Stage, Spent and Discard for fecundity estimation.
Spawning Marker	y	Yes or no. Are there spawning markers present in the sample, based on the columns Oocyte Stage and Egg Stage.
Atresia	y	Yes or no. Can the sample be used based on the results of columns Oocyte Stage, Egg Stage, Spent and Discard for atresia analyses.
Batch Fecundity	y	Yes or no. Can the sample be used based on the results of columns Oocyte Stage, Egg Stage, Spent and Discard for batch fecundity estimation.
Notes		Free text

Table 5.14.5. Fecundity and atresia data input format: Histology screening data (In yellow are mandatory fields; Fields with * have a lookup table attached. Orange: denote fields for which WGMEGS provided an (updated) lookup table.)

Field	Mandatory	Units/references
Fecundity Sample Number	y	Unique code assigned to the ovary samples
HaulID	y	
Analysing Institute*	y	EDMO codes Please register the missing institutes at EDMO (http://seadatanet.maris2.nl/v_edmo/welcome.asp). Contact Peter Thijsse at MARIS (peter@maris.nl) and he will help you proceed with entering any missing institutes and obtaining EDMO codes.
Oocyte Stage*	y	The most advanced oocyte development stage present. 1 = previtellogenic oocytes, 2 = early vitellogenic oocytes <400 µm, 3 = vitellogenic oocytes, 4 = migratory nucleus, 5 = hydrated oocytes (note: we do not consider stage 4 (migratory stage on whole mount)
Egg Stage*	y	Egg stages present; 0 = No eggs present, 1 = New eggs present, 2 = Residual eggs present, 3 = New and residual eggs present
POF	y	Yes or no
Spent	y	Yes or no
Massive Atresia	y	Yes or no
Early Alpha Atresia	y	Yes or no
Discard	y	Yes or no. Discard sample for further analyses, other than for the reasons in columns POF, Spent, and Massive Atresia. If Yes, the Notes column will need to be filled.
Fecundity	y	Yes or no. Can the sample be used based on the results of columns POF, Spent, Massive Atresia, Early Alpha Atresia and Discard for fecundity estimation.
Spawning Marker	y	Yes or no. Are there spawning markers present in the sample, based on the columns POF and Spent.
Atresia	y	Yes or no. Can the sample be used based on the results of columns POF, Spent, Massive Atresia, Early Alpha Atresia and Discard for Atresia estimation.
Embedding	y	Yes or no. Should the sample be embedded based on the results of columns POF, Spent, Massive Atresia, Early Alpha Atresia and Discard for Atresia analyses.
Batch Fecundity	y	Yes or no. Can the sample be used based on the results of columns POF, Spent, Massive Atresia, Early Alpha Atresia and Discard for batch fecundity estimation.
Notes		Free text

Table 5.14.6. Fecundity and atresia data input format: Fecundity and batch fecundity data (In yellow are mandatory fields; Fields with * have a lookup table attached.)

Field	Mandatory	Units/references
Fecundity Sample Number	y	Unique code assigned to the ovary samples
HaulID	y	
Analysing Institute*	y	EDMO codes Please register the missing institutes at EDMO (http://seadatanet.maris2.nl/v_edmo/welcome.asp). Contact Peter Thijsse at MARIS (peter@maris.nl) and he will help you proceed with entering any missing institutes and obtaining EDMO codes.
Fecundity Sample Weight	y	Weight of the ovary sample in 1 mg
Number Oocytes	y	Number of vitellogenic oocytes in the Fecundity Sample
Notes		Free text

Table 5.14.7. Fecundity and atresia data input format: Atresia data (In yellow are mandatory fields; Fields with * have a lookup table attached. Orange: denote fields for which WGMEGS provided an (updated) lookup table.)

Field	Mandatory	Units/references
Fecundity Sample Number	y	Unique code assigned to the ovary samples
HaulID	y	
Analysing Institute*	y	EDMO codes Please register the missing institutes at EDMO (http://seadatanet.maris2.nl/v_edmo/welcome.asp). Contact Peter Thijsse at MARIS (peter@maris.nl) and he will help you proceed with entering any missing institutes and obtaining EDMO codes.
Ovary Stage*	y	Development stage of the ovary based on the histology sample.
Grid Points	y	Number of grid points in the Weibel Grid used for the analyses.
Field Area	y	Area of the field that has been analysed for a single picture.
Pictures	y	Number of pictures analysed.
Negative Grid	y	Number of points for negative grid count, i.e. grid points outside the ovary for the entire sample.
Yolk Vesical	y	Number of Yolk Vesical Grid Points in the entire sample.
Yolk Vesical Points	y	Number of Yolk Vesical cells (point counts).
Yolk Vesical_Yolk Granule	y	Number of Yolk Vesical-Yolk Granule Grid Points in the entire sample.
Yolk Vesical_Yolk Granule Points	y	Number of Yolk Vesical-Yolk Granule cells (point counts).
Yolk Granule	y	Number of Yolk Granule Grid Points in the entire sample.

Yolk Granule Points	y	Number of Yolk Granule cells (point counts).
Notes		Free text

Historic biological datasets were also supplied to the biological sampling coordinator. Regarding mackerel the Faroese Islands (2010, 2013 data), Germany (1987–2013), Iceland (2010, 2013), Ireland (2004–2013), the Netherlands (1998–2013), Norway (1995–2010), Portugal (2004–2013), Spain (IEO and AZTI: 2007–2013) and UK-Scotland (2004 – 2013) delivered datasets. Horse mackerel data were delivered by Germany (2004–2010), Ireland (2004–2010), Norway (1995–2010), Spain (2004–2015) and UK-Scotland (2004–2013). These datasets comprise different excel files which are stored on the 2017 WGMEGS SharePoint

5.15 Deficiencies and recommendations

5.15.1 Deficiencies

The spatial and temporal coverage of the expanded Mackerel spawning area and time observed since 2010 remains to be a challenge for WGMEGS and resulted in an increase of survey effort in 2016. However, some participating countries had difficulties to secure a research vessel for their scheduled sampling period. Therefore, no sampling was carried out in period 1 and sampling effort in period 3 and 6 needed to be re-scheduled and taken over by other countries (see chapter 5.2 for a detailed description). This and additional technical problems on other vessels in other sampling periods resulted in the alternate transect design being utilized even more than was initially intended..

Available effort for the North Sea mackerel egg survey remains to be limited since the the withdrawal of Norway in 2013. With only the Netherlands carrying out the survey will result in smaller temporal and spatial coverage for the 2017 North Sea survey than is desirable.

5.15.2 Replies to WKIELD and WKFATHOM recommendations

1) WKIELD recommends creating an overview of the egg and larval development scales (with descriptions of the different stages) which are used in the ichthyoplankton surveys.

Reply of WGMEGS: An overview of the egg development scales is given in the manual of the mackerel and horse mackerel egg surveys (SISP 6). These egg stages are already incorporated in the ICES egg and larval database.

2) WKIELD recommends creating a table of flowmeter types used and position of the flowmeter in the inlet in the various ichthyoplankton surveys.

Reply of WGMEGS: A table with the specification of the used flowmeters is given in the survey manual of the mackerel and horse mackerel egg surveys. The table was updated during the current WGMEGS meeting and is shown in Annex 15. Flowmeter types used by WGMEGS are already in the table for the ICES egg and larval database.

3) WKIELD All ichthyoplankton survey groups should provide WGALES with a list of possible outputs needed for the WGs.

Reply of WGMEGS: Possible outputs are egg abundance plots by species, stage and period, daily egg production plots and annual egg production curves etc. To be discussed further with the ICES data centre.

4) WKIELD The appropriate grid for the distribution maps as output of the ICES Eggs and Larvae database needs to be defined by WGALES, based on recommendations from the ichthyoplankton groups.

Reply of WGMEGS: Half ICES statistical rectangles are the appropriate grid for the distribution maps with regards to the mackerel and horse mackerel egg surveys.

5) WKFATHOM It is recommended that all WGMEGS participants carry out artificial fertilizations of any species, which have eggs similar to those of mackerel and horse mackerel. It would be useful if egg and oil globule diameters are measured and that photographs are taken of as many stages as possible. It would also be beneficial if the eggs were preserved at various stages of development and any morphological changes noted following fixation. These eggs should be made available for analysis during the next workshop (scheduled for 2018).

Reply of WGMEGS: This recommendation was taken into account by survey participants. However, only a very limited number of fertilizations were carried out due to the lack of suitable fish.

6) WKFATHOM It is recommended that all microscopes at the next workshops are fitted with eyepiece graticules. These graticules should be calibrated to the same standard i.e. that one eyepiece unit (epu) should be equivalent to the same number of millimetres, regardless of microscope used. All workshop participants should bring a calibration micrometre to the workshop in 2018.

Reply of WGMEGS: This recommendation will be taken into account in preparation of the next workshop in 2018.

7) WKFATHOM All survey participants are reminded that the procedures described in the WGMEGS survey manual (SISP 6) should be followed during the 2016 surveys. Participants are particularly reminded that 4% formaldehyde, buffered with sodium acetate tri-hydrate, is the standard survey fixative and that plankton samples should never come into contact with formaldehyde of a concentration greater than 4%. All participants are encouraged to check the pH of their fixative on a regular basis.

Reply of WGMEGS: This recommendation was taken into account by survey participants during the 2016 survey.

8) WKFATHOM Based on the experiences at the workshop a recommended binocular microscope should have the following features:

- Options for a black or white stage plate for use with incident (top) light.
- A transparent stage plate for transmitted (bottom) light.
- Dark field illumination for contrast.
- Adjustable brightness.
- Magnification with click stops.
- Magnification should be at least 1.6x.
- A choice of 10x and 20x eyepieces.
- Adjustable binocular head and ergonomic design to allow flexibility of movement.
- Adjustable focus on all eyepieces.
- Calibrated eyepiece graticules.
- Double (fibre optic) cold light source, with adjust-able focus, to avoid shadows.

- Mechanical stages to position samples easily in the field of view and to hold the samples firmly.

Reply of WGMEGS: This recommendation will be taken into account in preparation of the next workshop in 2018.

9) WKFATHOM All survey participants are requested to measure formaldehyde preserved egg diameters and oil droplet diameters of 100 hake, 100 mackerel and 100 horse mackerel eggs during each individual cruise, to identify changes in egg diameter over spawning time and area. Also the development stage should be reported.

Reply of WGMEGS: This recommendation was taken into account by survey participants during the 2016 survey (see chapter 5.8.2 of this report).

10) WKFATHOM All survey participants are requested to investigate genetic analyses of fish eggs to aid species identification.

Reply of WGMEGS: Due to budget restrictions genetic analysis could not be carried out.

11) WKFATHOM recommends that institutes provide continuity of staff to carry out the plankton identification and staging to ensure high quality standard of the survey. It is the institutes' responsibility to provide appropriate training for new staff in advance of the survey. This should be done through institute workshops, as one week of WKFATHOM is not enough to turn trainees into experts.

Reply of WGMEGS: This recommendation was taken into account by survey participants during the 2016 survey.

12) WKFATHOM encourages exchanges of staff between participating institutes, to allow exchange of knowledge and increase expertise among survey participants.

Reply of WGMEGS: This recommendation will be taken into account for the next survey in 2019. However, due to the different timing of the individual surveys the exchange of staff might be difficult.

13) WKFATHOM All survey participants should take pictures of mackerel, horse mackerel and also species with similarly sized eggs in the different development stages of formaldehyde fixed eggs.

Reply of WGMEGS: This recommendation was taken into account by survey participants during the 2016 survey.

5.15.3 Recommendations

See Annex 2 for a list of recommendations

5.16 Working documents presented to WGMEGS

Working Document to DCWKWIDE, ICES, Copenhagen, 15/11 – 18/11, 2016

Finlay Burns[1], Brendan O' Hea[2], Gersom Costas[3]

[1] Marine Scotland Science, Marine Laboratory, Victoria Rd., Aberdeen

[2] Marine Institute, Rinville, Oranmore Co. Galway, Ireland

[3] IEO, Vigo, Spain

A presentation was delivered to DCWKWIDE in November 2016 which provided an updated revised estimate of the 2016 TAEP/SSB estimate. An error was detected within the Faroese data that had the net effect of overestimating (by around 50%) mackerel egg abundance for 86 plankton stations. This affected all samples found along the Northern boundary during survey periods 5 and 6 and once corrected, reduced the majority of egg counts on these boundary stations to single figures thus providing a harder survey boundary. A series of maps presenting mackerel spawning distribution over the last 7 MEGS surveys was presented at the workshop. The distribution of survey rectangles representing 90% of the total spawning demonstrated the large changes which have taken place in spawning behaviour over the period 2001–2016. The rectangles accounting for 50% of the total spawning were also presented and both highlight the change in the location of the spawning areas where the highest spawning concentrations have been observed over the same period. The data appear to show spawning activity moving northwards and increasingly away from the shelf edge and over deeper water. Also covered were the challenges the MEGS survey faced in 2016 and specifically its reduced geographical coverage, due to extending the coverage at the start of the spawning season as well as a reduced number of participating institutes, when compared to 2010 and 2013. Proposals for future work ahead of the next MEGS survey in 2019 including a potential additional egg survey were also presented.

New calculation of egg production and SSB estimation

Gersom Costas

A re-viewing the work undertaken on the survey dataset together with the progress made in developing the new egg abundance estimation script since the benchmark meeting in 2014 (WKPELA 2014). A detailed explanation of the bugs detected within the previous versions of the Teggprod R script and the results of comparative checks that were undertaken to quality check the final version of the script.

In addition, a manual TAEP estimate was calculated using the 2016 survey egg production data for both the western and the southern area components in order to perform an additional quality check. Agreement between methods for both the western and southern areas was almost perfect with the disparity in TAEP being 0.04% and 0.02% respectively.

Results of August 2016 horse mackerel egg survey

Brendan O' Hea

As a consequence of the 2013 MEGS survey results, national pelagic industry associations expressed concerns with regard to the end of spawning date used in the calculation of the horse mackerel egg abundance. The 2013 data appeared to indicate that horse mackerel spawning might be extending into August, past the nominal end of spawning date of 31 July, used by MEGS. WGMEGS was asked to investigate this matter during the 2016 survey. As a result, a 2-week survey was carried out by Ireland to the west of Ireland and west of Scotland during August. Only very low levels of horse mackerel eggs were found which confirmed the MEGS assertion that 31 July was the correct date to use as the end of spawning.

Not all eggs sink: Revision of the spray method

Jens Ulleweit, Matthias Kloppmann and Sakis Kroupis

During the Mackerel and Horse Mackerel Egg Survey (MEGS), the spray method is a widely accepted method to quickly remove almost all fish eggs from plankton samples. During the 2016 MEGS, the German participants also applied this method at their survey. After completion of the survey, all samples were re-examined to remove all remaining eggs by hand. It turned out that on some stations, a large number of eggs were apparently not removed by the spray method. While disturbing at a first glance, identification and staging of the eggs showed that the major part of those were neither mackerel nor horse mackerel rather than belonging to other, non-target species. One of those species was *Maurolicus muelleri*, which eggs have a sculptured chorion and offer high friction allowing air bubbles to lift them upwards with the other plankton. But also eggs of other species appeared to remain consistently with the plankton. The findings from the re-examination were experimentally validated with mackerel and other fish species eggs.

Mackerel egg development

C.J.G. van Damme[1], E. Blom[1], L. Fulbrook[1], S. Audier[1], A. Zagorska[1], I. Pennock[1] and R. D.M. Nash[2]

[1] Wageningen Marine Research, IJmuiden, The Netherlands

[2] Institute for Marine Research, Bergen, Norway

For the egg production methods it is vital to have the correct relationship between egg development and temperate to estimate daily egg production. Two studies have been carried out in studying mackerel egg development, Lockwood *et al*., 1977, and Mendiola *et al*., 2006. WMEGS has used the Lockwood equation up to 2013, and then changed to the Mendiola equation. However, when recalculating the Total Annual Egg Production time-series with the Mendiola equation there was a constant difference of 15% over time. This raised questions and it was advised to redo the mackerel egg development experiment. The study from Lockwood was carried out on board the vessel during the survey, but egg numbers were high and oxygen levels might have been a problem during the experiment (Lockwood *et al.*, 1977). Mendiola could not carry out the experiment on the vessel and eggs were fertilized and kept at 5°C before the experiment started.

Wageningen Marine Research carried out an experiment during the April and June egg survey in the Bay of Biscay and Celtic Sea in 2016. Running males and females were selected from the catch, eggs collected and artificially fertilized. Eggs were put in beakers and the experiment started with all eggs at the seawater temperature, 10°C in April and 12°C in June. Eggs were slowly acclimatized to the experiment temperatures and the experiment was run at 8, 10, 12, 14, and 16°C. In April the experiment could be run fully until eggs hatched at all temperatures. In June algal blooms occurred and the experiment could only be run until egg development stage 2. When comparing the results from the two experiments, egg development was quicker in June, except for the highest temperature. When comparing the results with the previous investigations, the results of this study were similar to Lockwood.

Egg and oil droplet diameter measurements.

Brendan O' Hea

In 2015 WKFATHOM made a recommendation that participants on the 2016 WGMEGS surveys should measure the egg diameter and oil globule diameter of 100 mackerel, 100 horse mackerel and 100 hake eggs, on each survey on which they participated. The data pointed to a mean egg diameter size for mackerel of just below 1.2 mm, for hake of just below 1.1 mm and just below 1.0 mm for horse mackerel, however there was a lot of overlap in the outliers. The exercise also pointed to a reduction in egg diameters in later survey periods.

Southern horse-mackerel 2016 DEPM survey (PT-DEPM16-HOM)

Angélico M.M., E. Henriques, A.M. Costa, C. Silva, and C. Nunes

IPMA – Portuguese Institute for the Ocean and Atmosphere

Surveying directed at spawning-stock biomass estimation for the southern horse-mackerel using the DEPM approach is conducted by IPMA in a triennial basis, with national and EU-DCF funding, the survey taking place during peak spawning period and covering the southern and western Atlantic-Iberian waters (ICES Area 9a). In 2016, the survey was carried out later than scheduled (11 March to 1 May), and it was not possible to survey the northern most area, western Galician. The survey was conducted concurrently to the spring acoustics onboard the same vessel, which implied that plankton sampling was mainly completed at night while during the day acoustic surveying and fishing for the two methods took place. Egg production and provisional adult parameters estimates were presented to the 2017 WGMEGS meeting. The egg distribution observed in 2016 was very patchy and abundances were low when compared to previous surveys. The estimated spawning area in 2016 was similar to the one calculated for the 2013 survey, but corresponding surveyed areas were not equivalent. Total Egg Production estimation for the 2016 survey was slightly lower than for the 2013 survey. Resulting female mean weight and relative fecundity were lower compared to the 2013 survey, and batch fecundity and spawning fraction estimates showed considerably lower values in relation to the previous survey. DEPM parameters and spawning-stock biomass final estimations will be completed prior to WGHANSA 2017.

North Sea Mackerel Daily Egg Production Method

C.J.G. van Damme, I. Pennock, E. Blom, R. Hoek, J. Wiegerinck and C. Bakker

Wageningen Marine Research, IJmuiden, The Netherlands

In 2015 Wageningen Marine Research carried out the North Sea mackerel egg survey using the Annual Egg Production Method (AEPM). Ovary samples were also collected to estimate the Daily Egg Production Method (DEPM) adult parameters. Only two trawls hauls could be carried out. 47 and 53 ovary samples were collected in period 2 and 3 respectively. After screening of these samples, 25 and 38 samples were available for batch fecundity analyses in the two periods. Most of these samples the oocytes were in stage 5 (hydrated oocytes).

Relative batch fecundity was similar in the two periods, 54 and 51 n/g female in period 2 and 3 respectively. Spawning fraction was 0.37 in period 2 and 0.32 in period 3. Ratio between females and males was 0.51 in period 2 and 0.53 in period 3. These number led to an SSB estimation of $357*10^3$ tonnes and $176*10^3$ tonnes in period 2 and 3 respectively. The SSB estimation using the AEPM was $170*10^3$ tonnes.

Weight at length relationships of mackerel and horse mackerel from 2007 to 2010 during their spawning season.

Paula Alvarez (AZTI)

Comparative study was conducted to analyse the weight at length relationships from samples of mackerel and horse mackerel collecting in 2007, 2010, 2013, and 2016 during Triennial surveys. The length-weight equations were estimated yearly for male and females, separately, and in all of them the co-efficient of determination values (r^2 > 85%) explained the good fit of the model for growth. T-test analysis was used to compare the regression coefficients, and most of them were found to be significantly different between years. For a standard size, the weight predicted was lower in 2016 than in 2007, for both mackerel males and females. The % of change was size´s dependent, varying between 2–8% for size of 30 to 45 cm. Similar trend was observed in horse mackerel males and females for period 2010–2016. For a standard length, the predicted weight of horse mackerel in 2016 was an 8% lower than in 2007 for a fish of 40 cm length. Ovary weight –Total weight relationships were also estimated for both species. Linear model (for mackerel) and power model (for horse mackerel) were selected to fix these variables. Depending on year and species, between 30% and 74% of ovary variability was explained by the total weight. T-test denoted yearly statistically differences among model´s coefficients. For a standard total weight of 450 gr, the predicted ovary weight of mackerel female was 28% lower in 2016 than 2010. For horse mackerel the small numbers of samples analysed make the interpretation difficult.

Teggprod R package: New tool to estimate TAEP for mackerel and the western horse mackerel stocks

Gersom Costas

Prior to 2010 a code written in FORTRAN was used to estimate the total annual egg production (TAEP) for NEA mackerel stock as well as for western horse mackerel. During 2010 the decision was taken by MSS in Aberdeen to rewrite the original FORTRAN code and to replace it with a newly developed code. The R code (*eggprod* R package) was used to estimate TAEP for mackerel and the western horse mackerel stocks and was reported at WGMEGS in 2011.

After that, as a consequence of review of historical MEGS survey database (1992–2013), a new version of the code in R (*Teggprod* R package) to estimate TAEP for mackerel and the western horse mackerel was developed in 2015.

The main characteristics of *Teggprod* R package are.

- Use an open source code system (R code) that gives users easy access to the calculations.
- More dynamic and flexible than previous software
- Estimations have improved the quality and consistency of the NEA mackerel and Western Horse mackerel TAEP estimates.
- Use egg survey data as Spatial data. Use of spatial analysis packages could be developed in the near future.

Eggs and larvae of non-target species

Steve Milligan, Cefas

Cefas has recently identified the potential to address data gaps in our knowledge of fish (spawning) distributions and to provide 'added value' from the samples collected as part of the 2016 western mackerel egg surveys.

A request has been submitted to selected participants of the 2016 WGMEGS plankton surveys for access to these samples, with a view that Cefas will sort, identify (to species if possible) and count the fish eggs and larvae present. The resultant data will be shared with all participants of the 2016 WGMEGS surveys. There are three main benefits to be derived from this request.

1) To update the recently published Fish Atlas of the Celtic Sea, North Sea, and Baltic Sea (2015).
2) To progress the implementation of an integrated ecosystem survey in the Celtic Sea following discussions at WGMSFDemo.
3) To repeat and enhance the work conducted under an EU funded project (INDICES) in the early 2000's. To provide species information on other fish stocks in the Celtic Seas and to further guide the work of ICES WGMSF-Demo.

2016 Horse mackerel Biological parameters Lat 43º April – 53ºN June

G. Costas, R. Domínguez, JR. Pérez.

IEO Instituto Español de Oceanografía C. Oceanográfico de Vigo

Adults horse mackerel sampling survey was carried out in the northern area of the Western stock at June- July of 2016 in order to apply the DEPM planned by WGMEGS. The IEO has a historical series of adults parameters from surveys delivered in March-April in the Spanish coast since 1992 and still maintain the sampling program although at low level. Despite IEO's sampling takes place out of the peak of spawning, obtained data are useful to continue tracking of horse mackerel spawning activity.

The aim of this presentation was the graphical comparison of the variability of females biometric parameters (Total and gutted weight, ovary weight and GSI) along maturity cycle in both, northern (46–54ºN 4.6–11.2ºE) and southern (46ºN 2.2–7.5ºE) areas within the Western stock in 2016. Maturity classification was based on Walsh scale.

Results show that all studied parameters are smaller in the southern area than in the northern one, but in general they follow the same trends in relation to maturity cycle.

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6 Cooperation

6.1 Cooperation with other WG's

WGMEGS has a close cooperation with the ICES groups WGWIDE, WGHANSA, WGALES, WKFATHOM and WGBIOP.

WGWIDE

WGMEGS delivers a SSB estimate of western, southern and North Sea mackerel and a total annual egg production estimate for western and southern horse mackerel. These data are used in the assessment of these stocks carried out by WGWIDE. Members of WGMEGS participate in the meetings of WGWIDE to present results of WGMEGS and update WGWIDE on ongoing research with regards to these species. At special request of WGWIDE, WGMEGS also delivers data on egg production of hake and the presence of blue whiting larvae. These data are for information to aid the assessment of these species but are currently not incorporated in the assessment.

WGHANSA

WGMEGS delivers adult biological data to WGHANSA for use in the assessment of southern horse mackerel. Results of the DEPM survey for southern horse mackerel are also presented to WGHANSA. Unfortunately, the time-series of DEPM surveys for southern horse mackerel are still too short for the DEPM estimate to be actually incorporated into the assessment.

WGALES

WGMEGS has a close cooperation with WGALES on ichthyoplankton and adult sampling and data analyses issues. WGALES gives the possibility to discuss ichthyoplankton survey related issues with a wider audience and improve and further develop the egg production methods carried out by WGMEGS. A large portion of the WGMEGS members participate in WGALES.

WKFATHOM

WKFATHOM workshops have been established by WGMEGS. This workshop is essential to WGMEGS as it standardizes sampling and sample analyses among the various institutes taking part in the MEGS surveys.

WGBIOP

As WGBIOP is the group dealing with standardization and quality control of biological parameters, there is a close linkage with WGMEGS through the WKFATHOM workshops.

6.2 Cooperation with Advisory structures

There is a good cooperation with SSGIEOM. Inter-working group issues can be addressed through SSGIEOM.

6.3 Cooperation with other IGO's

Cooperation with other IGO's is not applicable for WGMEGS.

7 Summary of Working Group self-evaluation and conclusions

A list of the WGMEGS achievements during this cycle are listed in section 4 of this report. In addition to the planning, execution and reporting of the NEA MEGS survey in 2016 and the North Sea surveys in 2015 and 2017, it was also involved in the benchmark (ICES, 2017a) for NEA mackerel and horse mackerel in 2017, providing historical time-series indices of TAEP for both species and SSB for NEA mackerel. The continued expansion of the NEA mackerel spawning area remains a challenge for WGMEGS to cope with and in addition to this, vessel issues and dropped surveys ensured that during much of the survey in 2016 the alternate transect methodology was utilized. In the North Sea, the Netherlands are the sole surveying nation which will result in restricted temporal and spatial coverage once again.

The group will continue a new cycle in 2018 with new chairs and will commence the formal planning process for the 2019 NEA survey as well as reporting on the 2017 North Sea MEGS survey. WGMEGS would benefit greatly from gaining access to person with (geo) statistical expertise as this would benefit the group in its ability to progress several ongoing survey related issues such as developing a new interpolation method. The TAEP and SSB estimates from the southern horse mackerel DEPM survey are not currently used in the assessment process but it is anticipated that in the near future and as the time-series extends that they will be reported to WGHANSA and be incorporated into the assessment process.

The full Working Group self-evaluation can be found in annex 5. of the report.

Annex 1: List of participants

Name	Institute	E-mail
Paula Alvarez	AZTI Foundation Herrera kaia-Portu aldea, z/g 20110 Pasaia (Gipuzkoa) Spain	palvarez@azti.es
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WGMEGS 2017 participants, from left to right: Gersom Costas, Cristina Nunes, Maria Korta, Jose Ramon Perez, Björn Gunnarsson, Rosario Dominguez, Paula Alvarez, Cindy van Damme, Merete Fonn, Jens Ulleweit, Steve Milligan, Dolores Garabana, Anders Thorsen, Finlay Burns, Paul Bouch, Matthias Kloppmann and Brendan O'Hea.

Annex 2: Recommendations

Recommendation	Adressed to
1. WGMEGS is extremely concerned about the limited resources that are available to complete the 2019 egg survey. In 2016 resources from the fishing industry were put in for the survey coverage, even then the alternate transect method had to be used and the spawning boundaries could not be delineated in the north. In order to ensure a better coverage in future, WGMEGS recommends that ACOM requests through the EC for the RCGs NS&EA and NA to consider if it is possible to involve more EU countries in the egg survey especially if their quota share of mackerel and /or horse mackerel is above the threshold of 3%.	ACOM
2. WGMEGS recommends to continue the mackerel egg development experiments and redo the horse mackerel egg development experiment during the 2017 and 2019 surveys.	WGALES
3. For the planning of the 2019 survey WGMEGS recommends to continue pursuing extra data collections in 2017 and 2018 in order to keep track of changes in mackerel spawning behaviour.	WGALES
4. WGMEGS recommends to investigate and review the interpolation methods utilized on the egg survey data. A (geo)statistical expert is needed for this work. WGMEGS recommends participating institutes to look for an available expert in their institutes	WGALES

Annex 3: WGMEGS terms of reference 2018-2020 (Draft resolution for approval)

The **Working Group on Mackerel and Horse mackerel Egg Surveys (WGMEGS)**, chaired by Matthias Kloppmann, Germany, and Gersom Costas, Spain, will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2018	9–13 April 2018	Dublin/Edinburgh/ Madrid(TBC)	Interim report by 1 June 2018 to SSGIEOM, SCICOM, WGISUR, ACOM and WGWIDE	
Year 2019	via correspondence		Interim report by 15 September 2019 to SSGIEOM, SCICOM, WGISUR, ACOM and WGWIDE	second meeting of group via correspondence as it falls within the year of the triennial MEGS Survey. The date for report delivery is set after the WGWIDE meeting to be able to include the preliminary results of the 2019 survey.
Year 2020	April 2020	To be decided	Final report by 1 June 2020 to SSGIEOM, SCICOM, WGISUR, ACOM and WGWIDE	

ToR descriptors

ToR	Description	Background	Science Plan topics addressed	Duration	Expected Deliverables
a	Coordinate the timing and planning of the 2019 Mackerel/Horse Mackerel Egg Survey in the ICES areas 5 to 9.	The egg survey provides important fishery-independent stock estimates for Northeast Atlantic mackerel and for both the western and the southern horse mackerel stocks. The survey is part of a		year 1	Planning description and updated manuals for the survey in 2019 for WGMEGS

		time-series that commenced in 1977. For calculating SSB from egg surveys it is important to cover the entire spawning season and area. In order to be able to cover the entire spawning season for both species a comprehensive survey plan is required that covers the area from Portugal to Iceland.		
b	Coordinate the planning of the sampling programme for mackerel/horse mackerel fecundity and atresia.	In order to recalculate the egg production estimate into a SSB estimate a reliable estimate of realized fecundity is needed. It is therefore important to provide a suitable plan for sampling of potential fecundity and atresia.	Year 1	Planning description and updated manuals for the survey in 2019 for WGMEGS through WKFATHOM
c	Review and report on procedures for egg sample sorting, species identification and staging.	To provide accurate estimates of the egg production of mackerel and horse mackerel it is vital to have good descriptions for the sampling, sorting and identification and staging of the eggs observed. Since the survey is undertaken only every 3 years, it is important for the participants that these skills are refreshed prior to the	Year 1	Updated manual for the survey in 2019 for WGMEGS through WKFATHOM

		survey.		
d	Review and report on procedures for fecundity and atresia estimation.	Techniques for fecundity and atresia estimation are developing quickly. Since the survey is carried out once every 3 years it is important to update the protocols on the estimation of fecundity and atresia.	Year 1	Updated manual for the survey in 2019 for WGMEGS through WKFATHOM
e	Update the survey manual and make recommendations for the standardization of all sampling tools, survey gears and procedures.	Standardization of sampling and sampling gear is important in surveys to produce a reliable estimate of SSB for stocks. As MEGS is a triennial survey it is important to update manuals in order to provide as much standardization as possible.	Year 1	Updated manual for the survey in 2019 for WGMEGS through WKFATHOM
f	Analyse and evaluate the results of the 2017 mackerel egg survey in the North Sea.	The North Sea mackerel egg survey is the only available information on the state of the North Sea mackerel. Currently the North Sea survey is carried out in the year after the Atlantic survey. Results of the survey should be evaluated and finalized during the WGMEGS meeting.	Year 1	Final estimate of North Sea mackerel SSB for WGWIDE 2018.
g	Examine the results of the Bremerhaven, Germany and IJmuiden, The Netherlands workshops (8 – 12 October and 19 – 23	For quality assurance in the year before the Atlantic survey a workshop (WKFATHOM) is organized in	Year 2	Updated manual for the survey in 2019 for WGMEGS

	November 2018) on mackerel and horse mackerel egg staging and identification and fecundity and histology, and incorporate these into the Survey Manual for the 2019 survey;	which survey participants are obliged to participate in order to standardize egg identification and staging and fecundity estimation. The WGMEGS manual is required to be updated with the results from the WKFATHOM workshop.		
h	Fine-tune survey execution in 2019.	Not all institutes have the vessel planning ready one year before the Atlantic survey. Hence it is necessary to fine-tune and finalize the planning of the survey in the actual survey year.	Year 2	Finalized planning for the survey in 2019 for WGMEGS
i	Analyse and evaluate the results of the 2019 mackerel and horse mackerel egg surveys in the western and southern areas; calculate the total seasonal stage 1 egg production estimates for mackerel separately for the western and southern areas; calculate the total seasonal stage 1 egg production estimates for the western horse mackerel stock (AEPM); analyse and evaluate the results of the mackerel and horse mackerel fecundity and mackerel atresia sampling in the western and southern areas;	Provisional estimates of mackerel SSB, and egg production of horse mackerel are delivered in the year of the survey. The estimates however are finalized during the WGMEGS meeting in the year after the Atlantic survey.	Year 3	Finalized results of the mackerel SSB index, western horse mackerel egg production for WGWIDE.

	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; evaluate the quality and reliability of the 2019 survey in the light of the previous surveys and to evaluate the reliability of the preliminary estimates calculated in 2019 against the final estimates. evaluate			
j	Plan and coordinate the 2020 North Sea mackerel egg survey.	Currently the North Sea mackerel egg survey is carried out in the year after the Atlantic survey. Careful planning is necessary in order to get a reliable North Sea mackerel SSB estimate with the limited resources available.	Year 3	Planning of the North Sea mackerel egg survey for WGMEGS.
k	Review and reformat the historic time-series of North Sea mackerel egg surveys and upload data to the ICES egg and larvae database	The egg data of the North Sea mackerel egg survey were stored at the Norwegian institute in the past and since 2014 were handed to the Netherlands. The data needs to be checked and revised and put in the correct format to be uploaded to the ICES egg and larvae database	Year 3	Historic dataset of the North Sea mackerel egg surveys in the ICES egg and larvae database.

Summary of the Work Plan

Year 1	Planning of the egg survey in 2019 and reporting on the North Sea egg survey of 2017.
Year 2	Survey year, the Atlantic survey is conducted in 2019, no meeting takes place in year 2. A report, by correspondence, with the updated planning and manuals and the preliminary results of the 2019 survey, is published.
Year 3	Reporting and finalizing of the results of the 2019 egg survey. Planning of the 2020 North Sea egg survey.

Supporting information

Priority	Essential. The egg survey provides important fishery-independent stock data used in the assessment for Northeast Atlantic mackerel and for the western horse mackerel stocks.
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. 15–20 participants from ICE, Far, N, NL, P, ESP, UK (E), UK (Scot), DE, IRL.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	The survey data are prime inputs to the assessments carried out by WGWIDE 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	WGWIDE, WKFATHOM, WGALES, WGBIOP.
Linkages to other organizations	There have been a number of associated EU funded projects in the past.

Annex 4: WKFATHOM terms of reference (Draft resolution for approval)

The Workshop on Egg staging, Fecundity and Atresia in Horse mackerel and Mackerel (WKFATHOM) chaired by Maria Korta, Spain, and Matthias Kloppmann, Germany, will meet in Bremerhaven, Germany, 8-12 October 2018 (egg staging) and in IJmuiden, The Netherlands, 19-23 November 2018 (fecundity) 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) Review available documentation on identifying eggs to species and define standard protocols;

e) Carry out inter-calibration work on fecundity and atresia determination and POFs staging;

f) Update a set of standard pictures for both oocytes and POFs stages;

g) Harmonize the analysis and interpretation of fecundity and atresia samples;

h) Review the methodology in use and available documentation on fecundity determination in order to redefine the standard protocols.

WKFATHOM will report by 11 January 2019 (via SSGIEOM) for the attention of SCICOM, WGMEGS and WGWIDE.

Supporting Information

Priority	Information quality, used to provide fisheries advice through WGWIDE, 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, and then the data combined, it is vital that the process be standardized. WGMEGS strongly feels that this is best done through the mechanism of regular workshops to compare results between survey participants. In the context of the triennial egg surveys, it proved 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 since 2000, and were very successful in achieving these aims. It is recommended that experiences gatherd during these be used for setting up the procedures for the proposed workshop in 2018. 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, and 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 and embedded into the agreed MEGS standard survey manual at previous workshops. In the context of these surveys, and equivalent to egg staging, fecundity estimation is fundamental for conversion of egg production to spawning stock biomass in western and southern mackerel stock components. Both fecundity and atresia estimation are carried out using histological and image analysis methods, and the analysis and interpretation of these material also requires standardization across participating institutes. The standardization in this aspect is carried out in workshops since 2001 which have been extremelly helpull for agreed practices among institutes As in the case of egg staging workshop, it is recommended that experiences gatherd during these workshops be extended during the consecutive workshop in 2018. It is expected that the workshop will refine the developed methodogies for fecundity estimation to overcome problems identified during surveys by means of several inter-institutes exercirses that may test the new techniques. In this sense, the workshop will also update the manual assisting the fecundity estimation from sampling to analysis procedures. As in the case of egg staging, the material will improve the agreed MEGS standard survey manual.
Resource requirements	None
Participants	Mainly scientists and technicians (approximately 20) involved in the surveys .
Secretariat facilities	None.
Financial	No financial implications.
Linkages to advisory committees	SCICOM, ACOM
Linkages to other committees or groups	WGMEGS and WGWIDE
Linkages to other organizations	None.

Annex 5: Working Group self-evaluation

1) **Working Group name:** Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS)

2) **Year of appointment:** 2014

3) **Current Chairs:** Cindy van Damme, The Netherlands and Finlay Burns, UK (Scotland)

4) **Venues, dates and number of participants per meeting:**
20–24 April 2015, Copenhagen, Denmark, (17 participants)

2016 by correspondence

24–28 April 2017, Vigo, Spain, (19 participants)

WG Evaluation

5) **If applicable, please indicate the research priorities (and sub priorities) of the Science Plan to which the WG make a significant contribution.**

Not applicable.

6) **In bullet form, highlight the main outcomes and achievements of the WG since their last evaluation. Outcomes including publications, advisory products, modelling outputs, methodological developments, etc.**

- Planning, execution and reporting on the 2016 Atlantic mackerel and horse mackerel egg survey.
- Total Annual Egg Production of western and southern mackerel and western and horse mackerel and SSB estimate of western and southern mackerel for the assessment of these stocks to WGWIDE.
- Daily Egg Production and SSB estimate of southern horse mackerel.
- Report on the 2015 mackerel eggs survey in the North Sea.
- Total Annual Egg Production and SSB estimate of North Sea mackerel for the assessment of this stock to WGWIDE.
- Planning of the 2017 North Sea mackerel egg survey.
- Review results from egg staging and fecundity workshops as reported in the 2015 WKFATHOM Report (ICES, 2015a).
- Finalize historic Atlantic mackerel and horse mackerel egg dataset and uploading to the ICES Egg and Larvae database.
- Publish updated manuals for execution of the mackerel and horse mackerel egg surveys: 1) Sampling at sea (SISP 6) and 2) AEPM and DEPM fecundity estimation for mackerel and horse mackerel (SISP 5)
- Prepare input format for the ICES database for the mackerel and horse mackerel fecundity and atresia data
- New R-script for estimation of Total Annual Egg Production for mackerel and horse mackerel, and uploading to the ICES GitHub.
- CV estimates of Atlantic mackerel and horse mackerel egg productions.
- Development of Environmental Niche Model (ENM) to improve the egg survey. A distribution forecast system for the spawning of mackerel in the Northeast Atlantic.

7) **Has the WG contributed to Advisory needs?**

Benchmark for mackerel and horse mackerel in 2017 (WKWIDE). WGMEGS provided advice in the form of providing historical time-series of TAEP for both species and SSB for NEA mackerel.

8) **Please list any specific outreach activities of the WG outside the ICES network (unless listed in question 6).**

Not applicable

9) **Please indicate what difficulties, if any, have been encountered in achieving the workplan.**

The spatial and temporal coverage of the expanded Mackerel spawning area and time observed since 2010 remains to be a challenge for WGMEGS and resulted in an increase of survey effort in 2016. However, some participating countries had difficulties securing a suitable vessel for their scheduled sampling period. Therefore, no sampling was carried out in period 1 and sampling effort in period 3 and 6 needed to be re-scheduled and taken over by other countries. This and additional technical problems on other vessels in other sampling periods resulted in an even heavier utilization of the alternate transect design than already planned. The effort available for the North Sea mackerel egg survey remains very limited since the withdrawal of Norway 2014. Only the Netherlands are carrying out the survey leading to a smaller temporal and spatial coverage for the 2017 North Sea survey than desirable.

Future plans

10) **Does the group think that a continuation of the WG beyond its current term is required?**

WGMEGS does require a continuation beyond the current term as the results and the outputs from the MEGS survey are and will continue to be used in the current assessment models for both NEA mackerel and western horse mackerel.

11) **If you are not requesting an extension, does the group consider that a new WG is required to further develop the science previously addressed by the existing WG.**

Not applicable

12) **What additional expertise would improve the ability of the new (or in case of renewal, existing) WG to fulfil its ToR?**

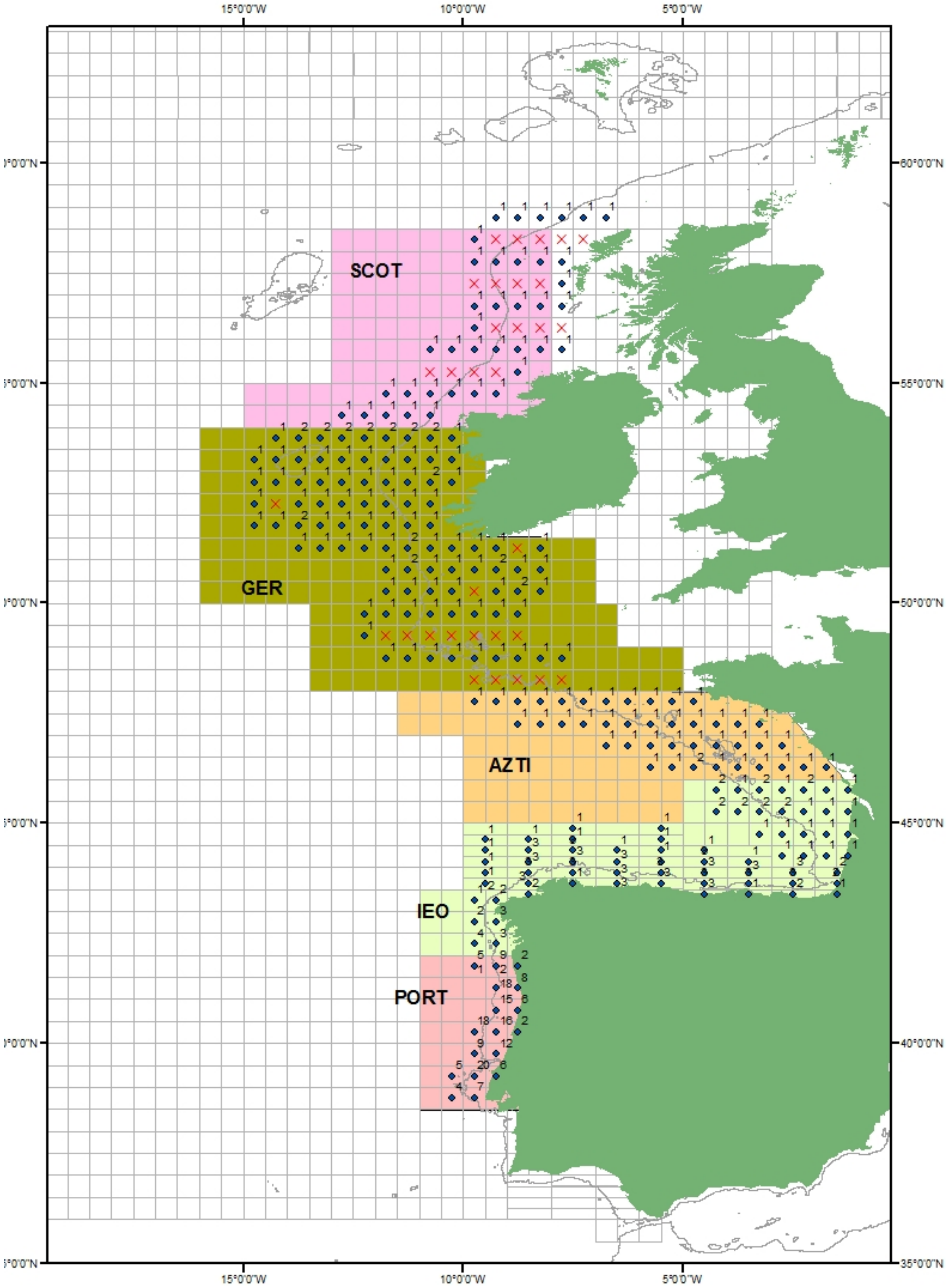
(Geo)Statistical expertise. This would greatly benefit our ability to progress several survey related issues such as the development of a new interpolation method.

13) **Which conclusions/or knowledge acquired of the WG do you think should be used in the Advisory process, if not already used? (please be specific)**

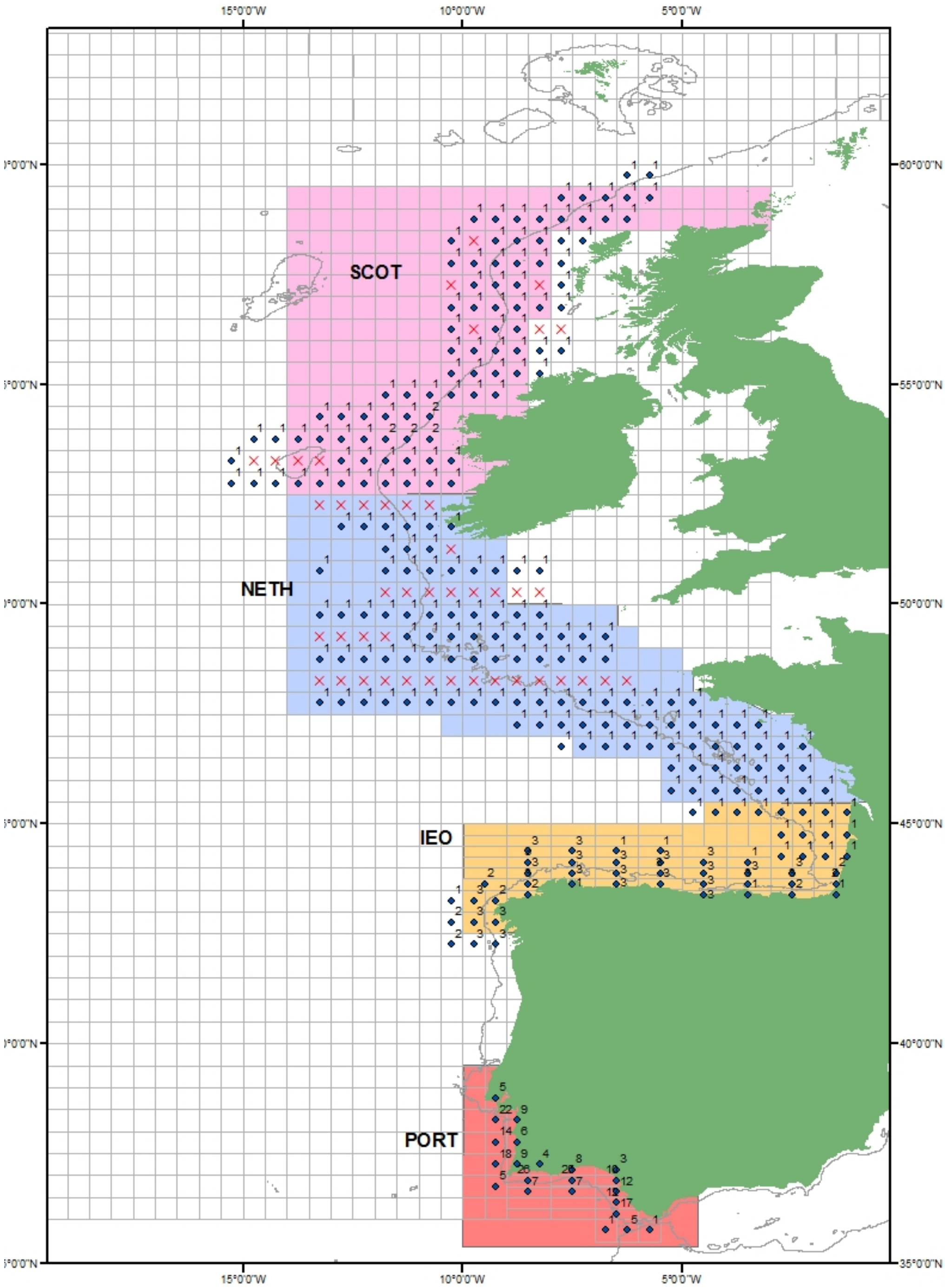
The TAEP and SSB estimates from the southern horse mackerel DEPM survey are not currently used in the assessment process but it is anticipated that with the extension of the time-series that they will be reported to WGHANSA and incorporated into the assessment process.

Annex 6: Numbers of samples per rectangle per period in 2016

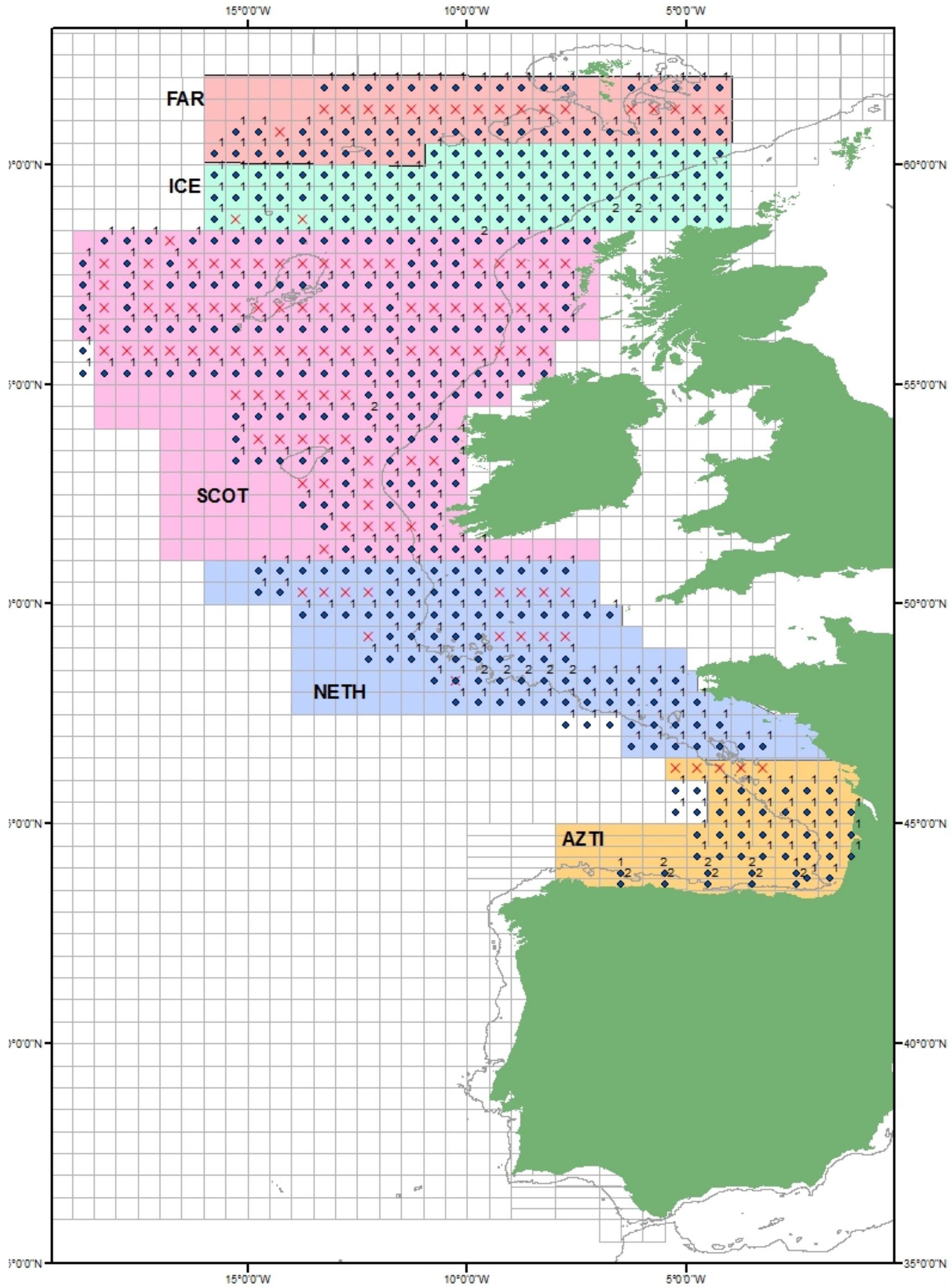
Period 3 (1 March – 8 April) and the country assigned areas (shaded) - X represents interpolated rectangles.



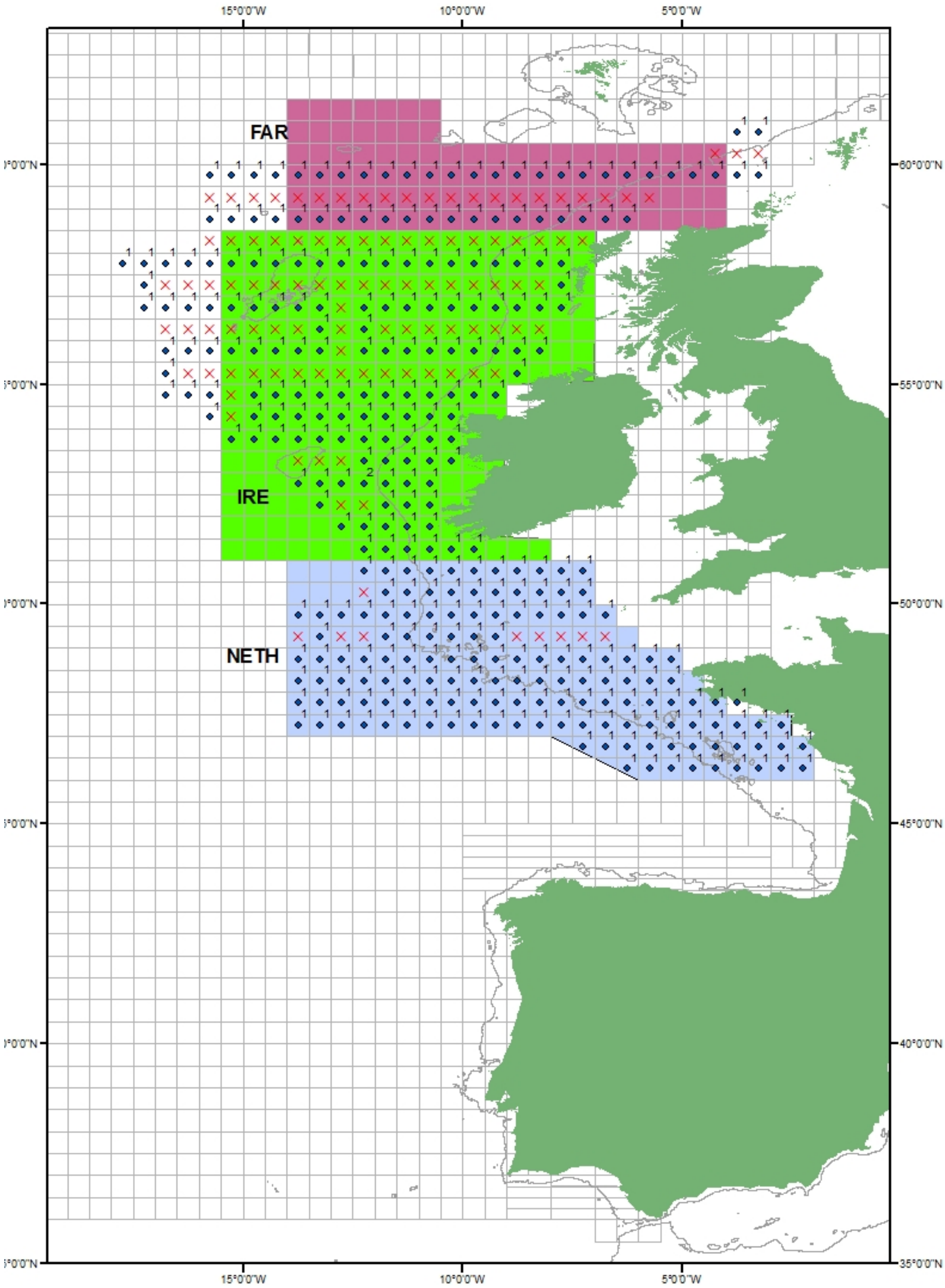
Period 4 (9–30 April) and the country assigned areas (shaded) – X represents interpolated rectangles.



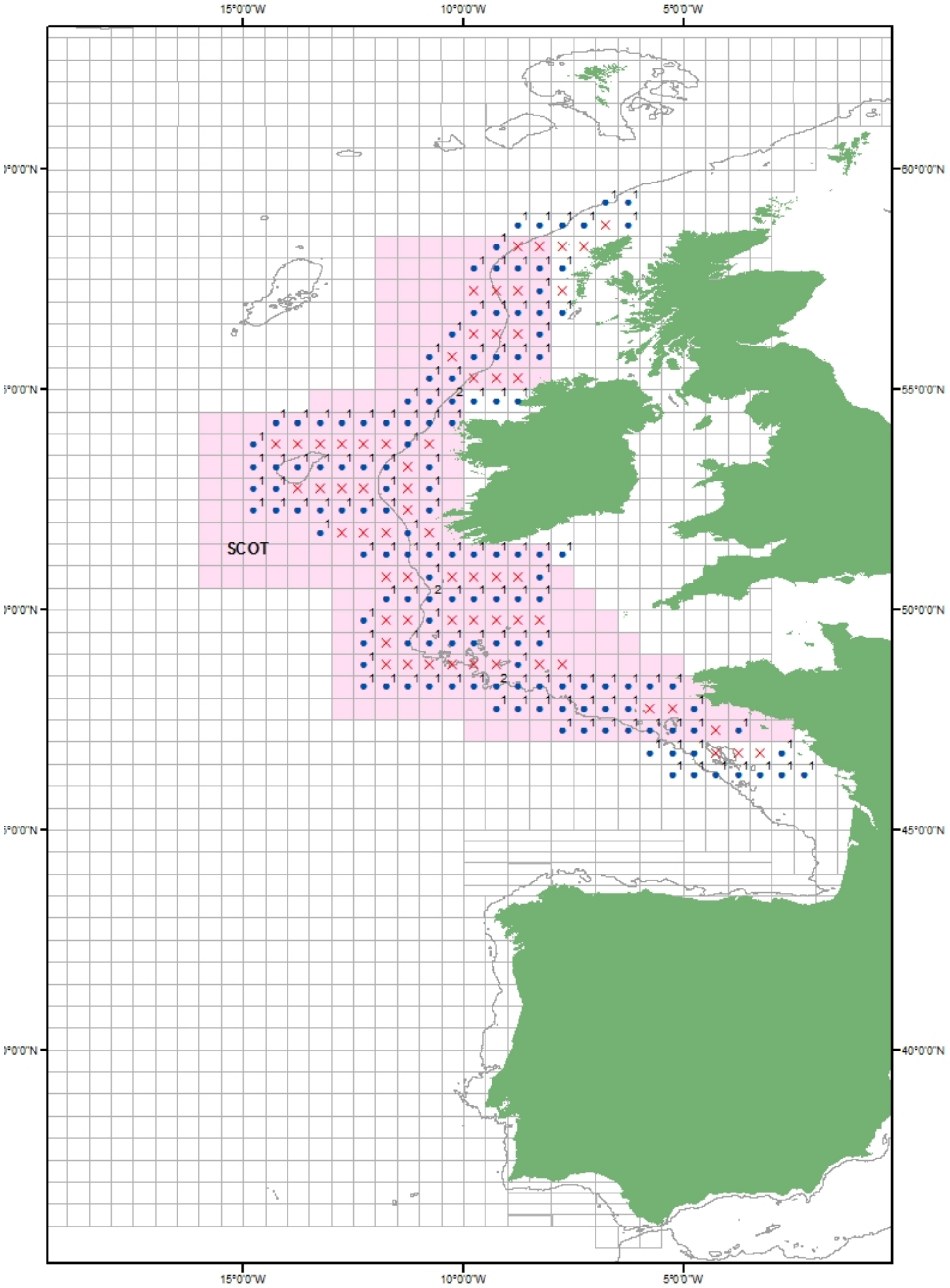
Period 5 (1–30 May) and the country assigned areas (shaded) – X represents interpolated rectangles.



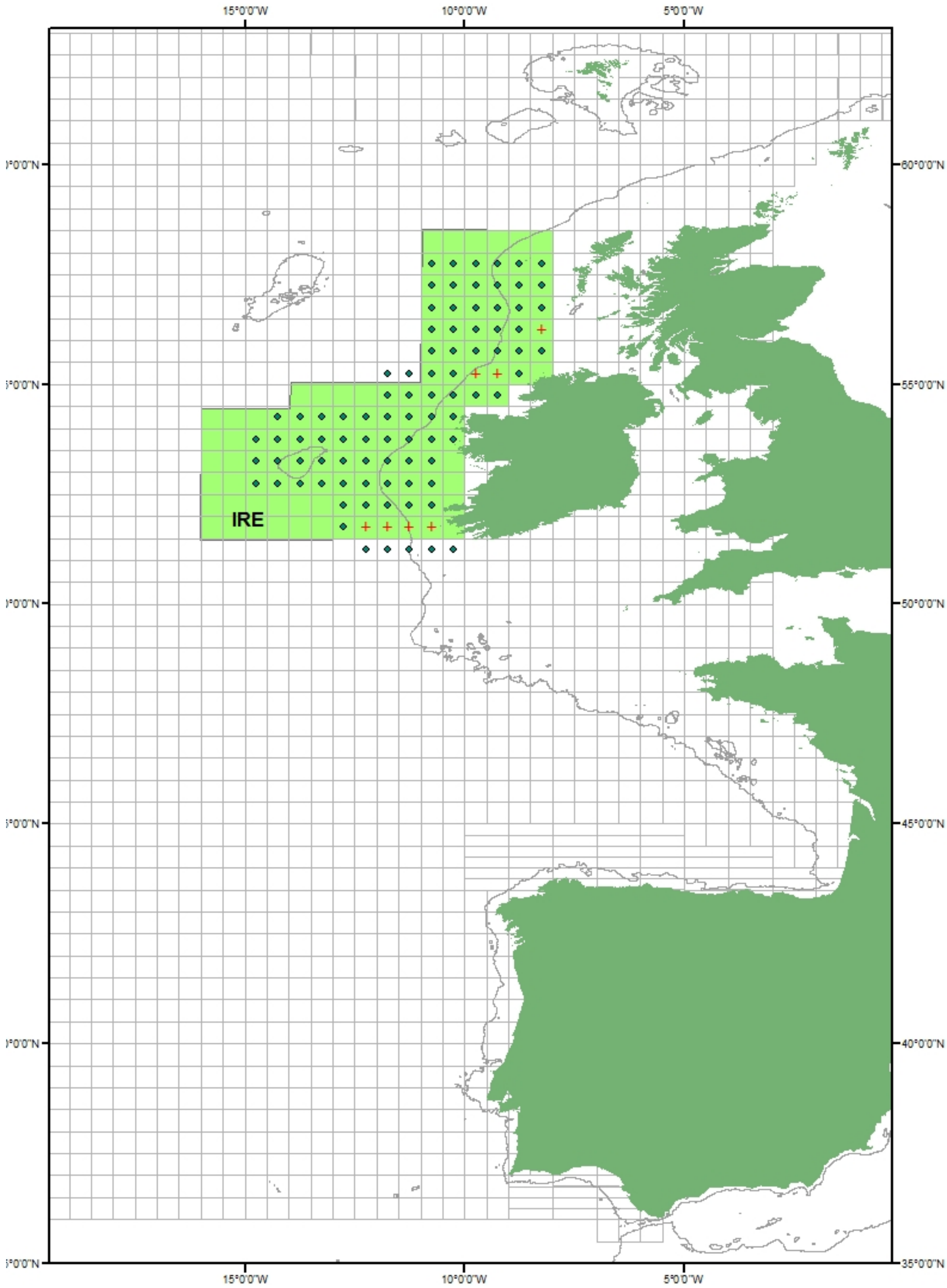
Period 6 (31 May – 27 June) and the country assigned areas (shaded) – X represents interpolated rectangles.



Period 7 (28 June – 31 July) and the country assigned areas (shaded) – X represents interpolated rectangles

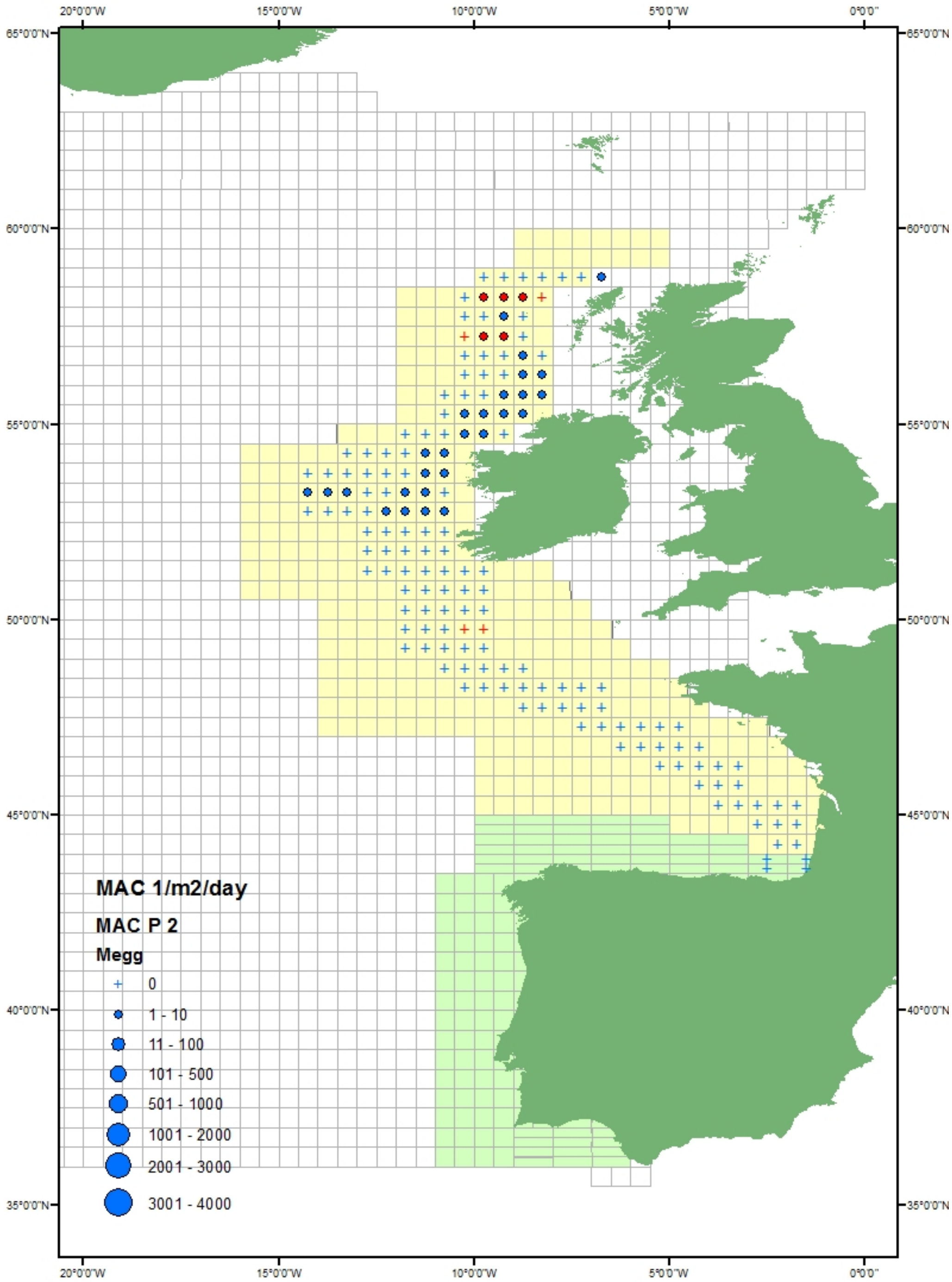


Period 8 (10–22 August) and the country assigned areas (shaded) – X represents interpolated rectangles

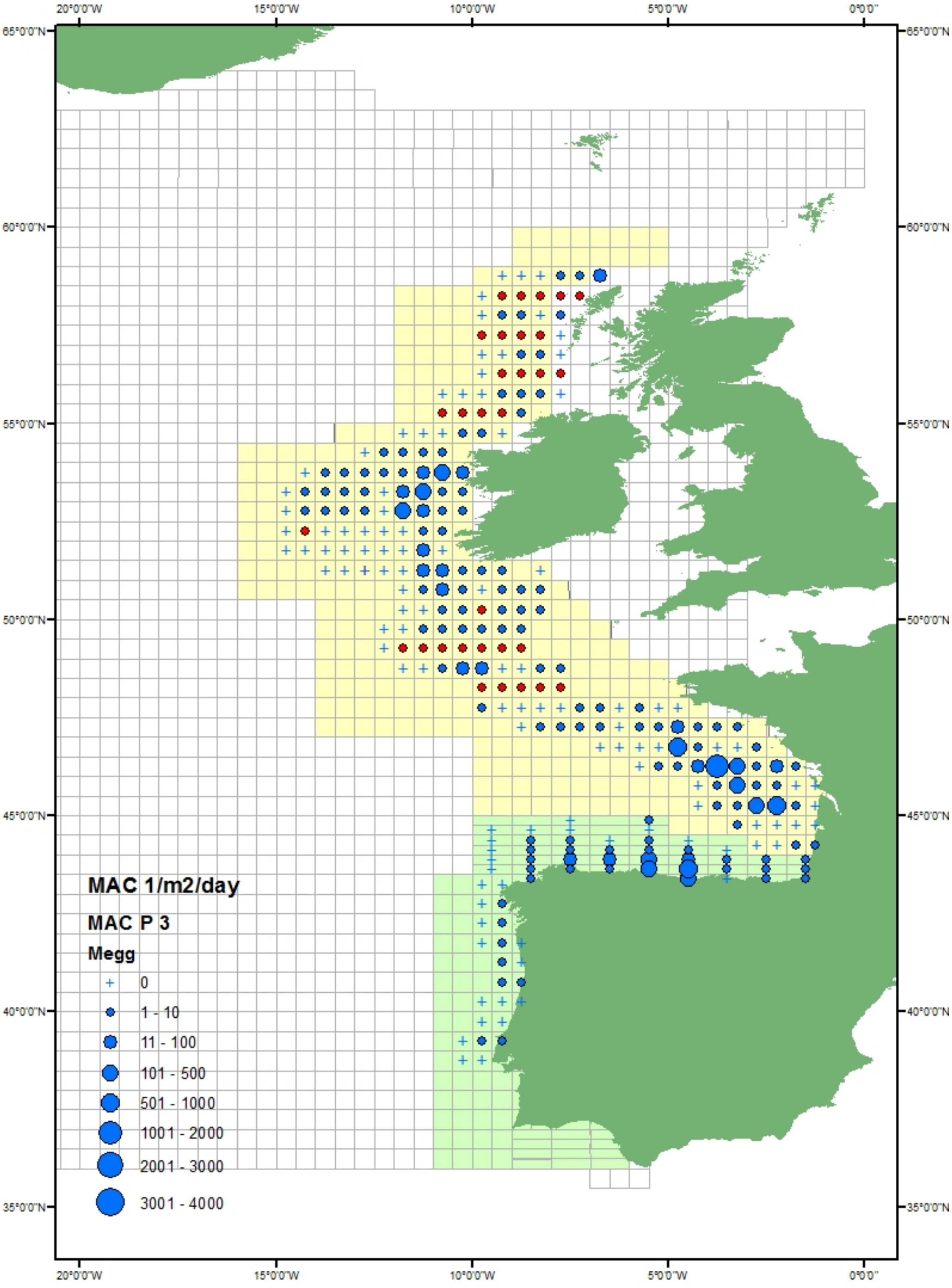


Annex 7: Distribution maps of mackerel spawning

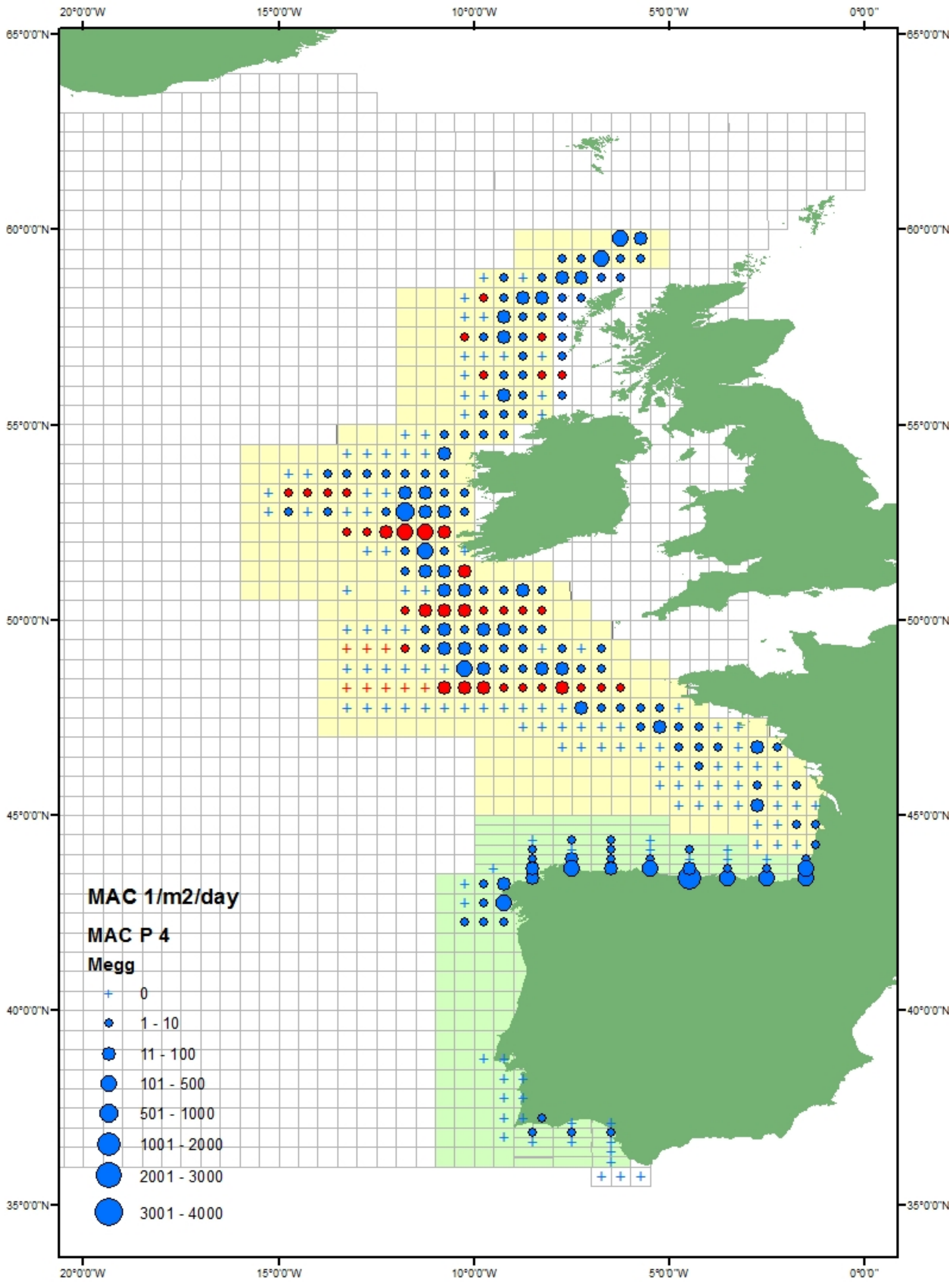
Mackerel egg production in period 2 (4–29 February). Filled blue circles represent observed values, filled red circles represent interpolated values, blue crosses represent observed zeroes.



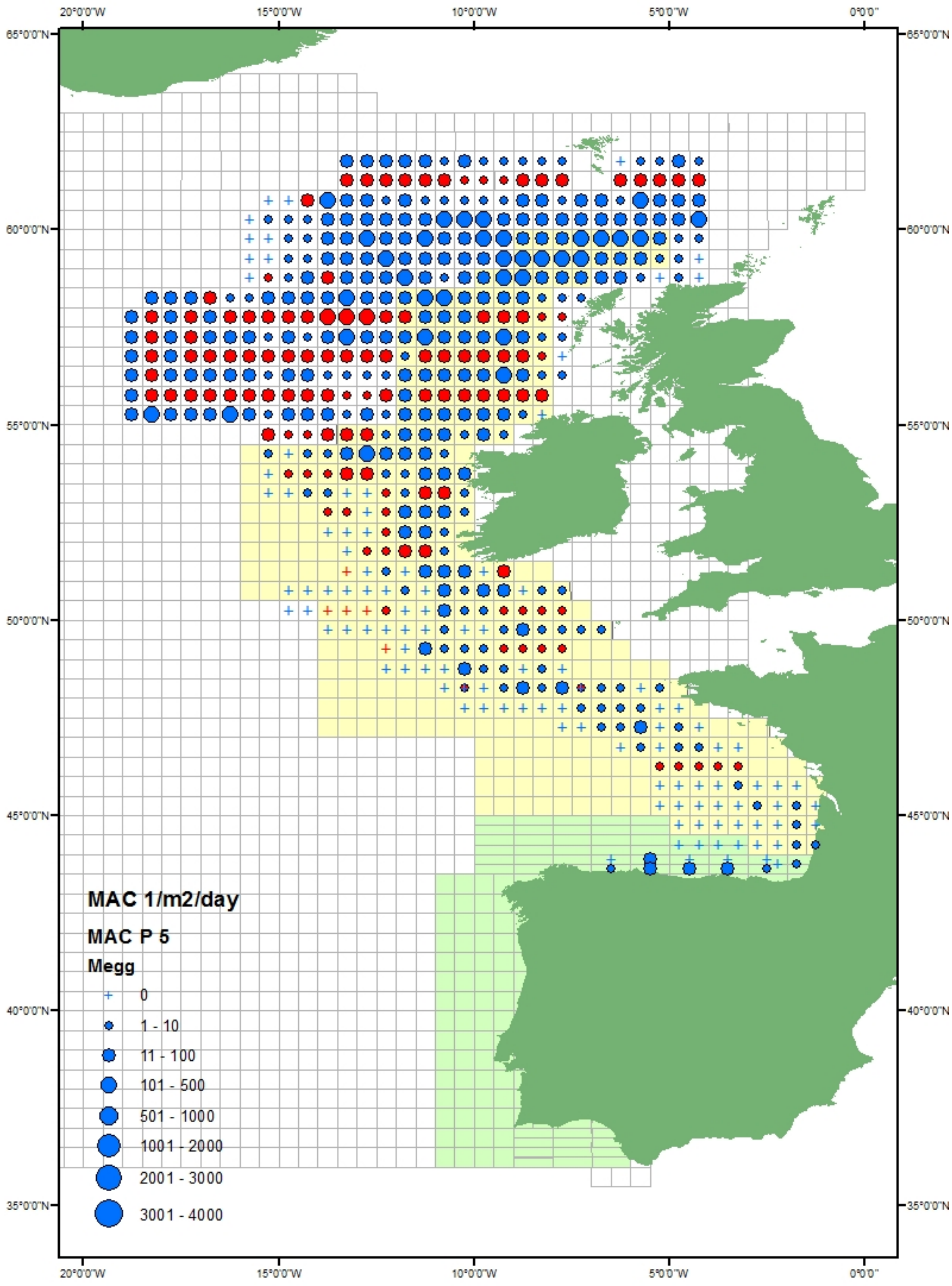
Mackerel egg production in period 3 (1 March – 8 April). Filled blue circles represent observed values, filled red circles represent interpolated values, blue crosses represent observed zeroes.



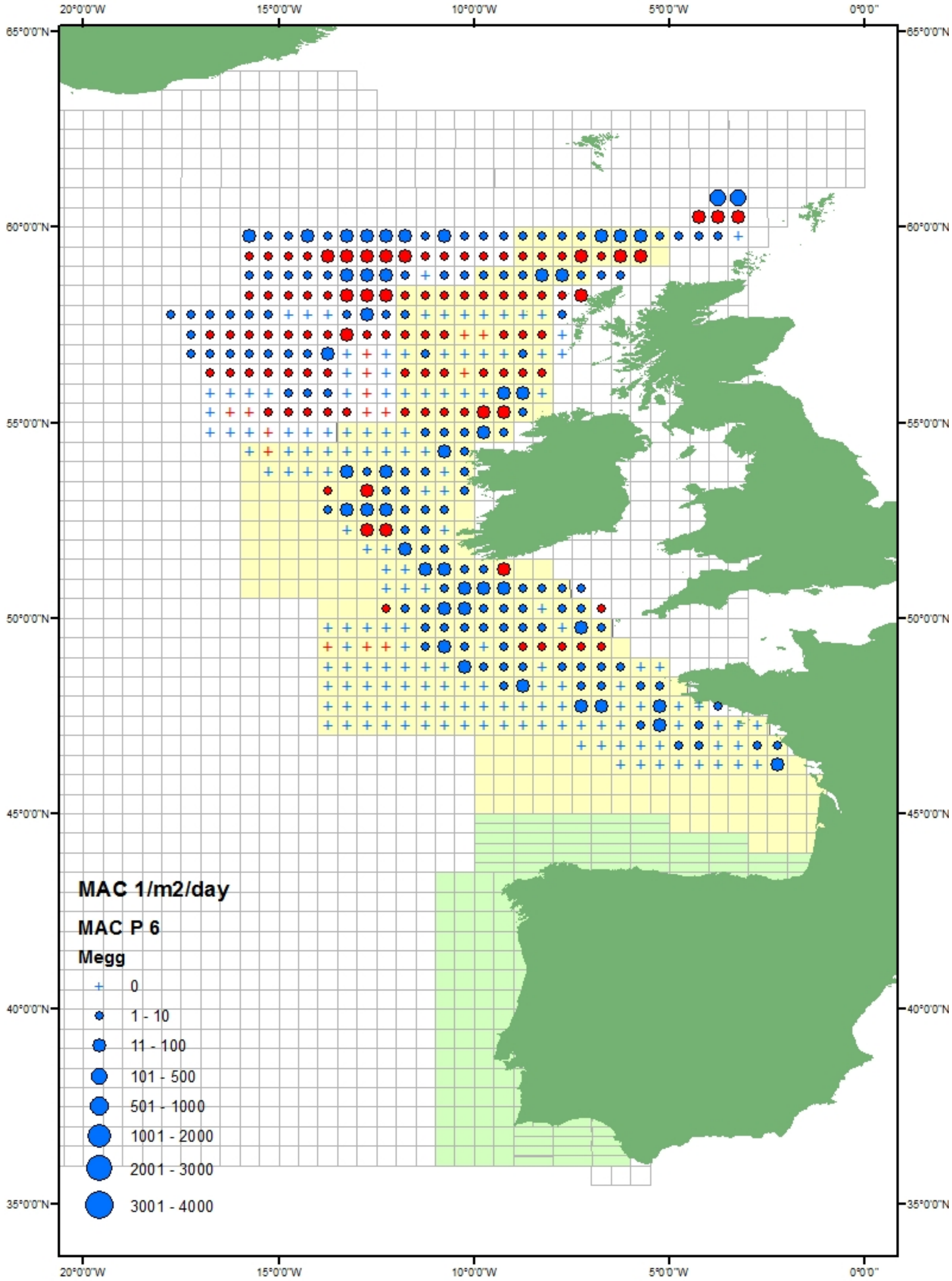
Mackerel egg production in period 4 (9–30 April). Filled blue circles represent observed values, filled red circles represent interpolated values, blue crosses represent observed zeroes.



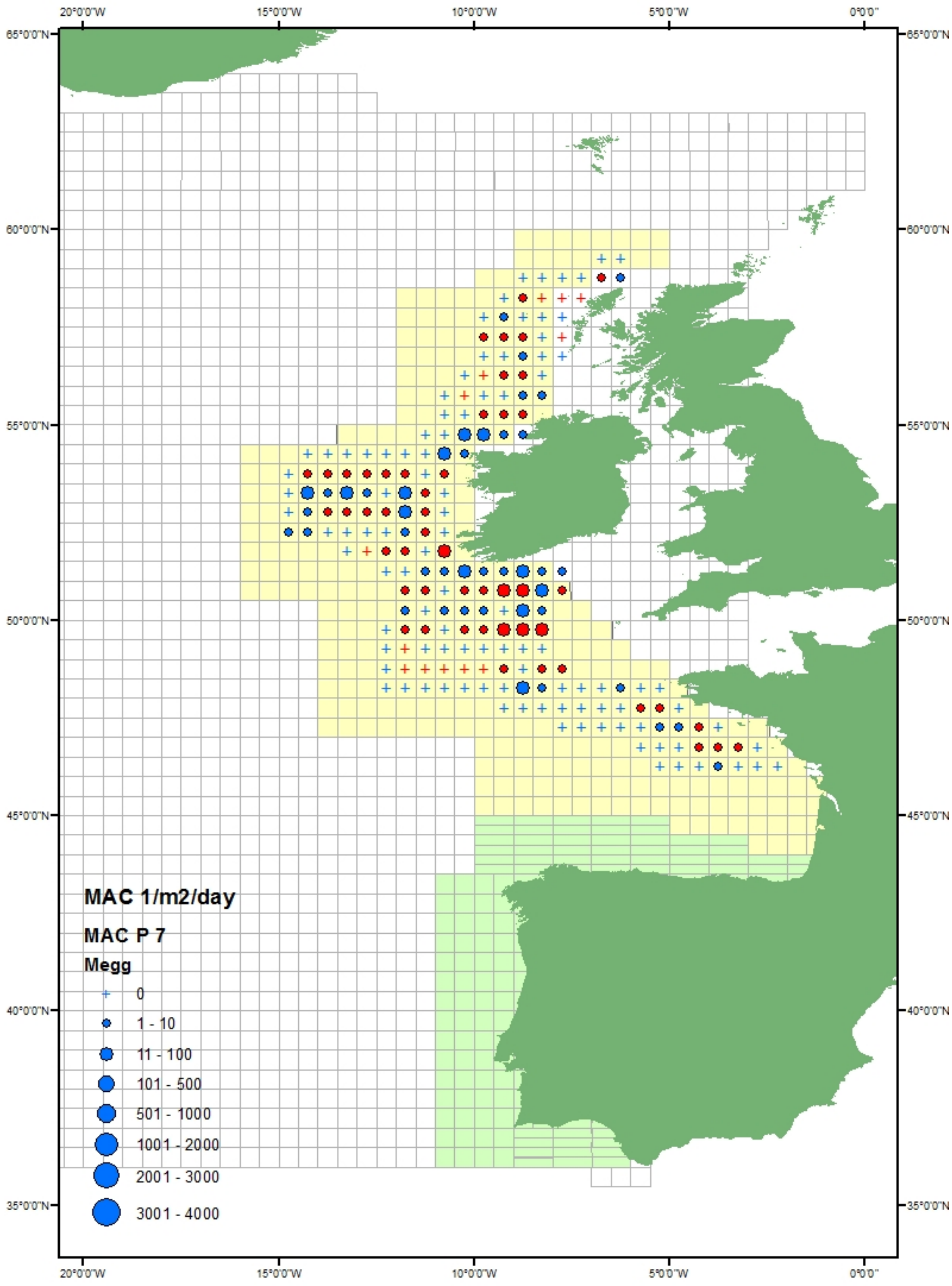
Mackerel egg production in period 5 (1–30 May). Filled blue circles represent observed values, filled red circles represent interpolated values, blue crosses represent observed zeroes.



Mackerel egg production in period 6 (31 May – 27 June). Filled blue circles represent observed values, filled red circles represent interpolated values, blue crosses represent observed zeroes.



Mackerel egg production in period 7 (28 June – 31 July). Filled blue circles represent observed values, filled red circles represent interpolated values, blue crosses represent observed zeroes.



Annex 8: Comparative fecundity and atresia analyses

Institute comparisons

As with previous assessment years, the ovary samples were randomly distributed among the institute laboratories for analysis. If all laboratories conducted their analysis similarly, all laboratories should in theory come up with similar values. However, institutes analyse different ovary samples so some differences should be expected also due to natural fish variability.

Histological screening

Using histology each participating institute screened between 301 and 317 samples (Table 1, first column).

These screening results decided whether a sample would be used for analysis of fecundity, atresia, batch fecundity, spawning fraction, or a combination.

Table 1. Summary of number of samples scored as for fecundity or POF's studies by institute. In brackets the percentage of samples assigned at each category. ***(IMARES is currently named Wageningen Marine Research.)***

		Fecundity		POFs	
Institute	**N**	**No**	**Yes (%)**	**No**	**Yes (%)**
AZTI	**301**	293	8 (3%)	51	250 (83%)
IEO	**311**	276	35 (11%)	136	175 (56%)
IMARES	**316**	275	41 (13%)	107	209 (66%)
IMR	**317**	289	28 (9%)	161	156 (49%)
Total	**1245**				

When identifying samples for fecundity analysis it is important to exclude all spawning fish (fish with POF´s, hydrated oocytes and hyaline eggs) and fish that have not yet finished recruitment of immature oocytes into the pool of vitellogenic oocytes (fish with a leading cohort diameter of less than 400 µm).

When scoring if samples were suitable for fecundity analysis or not (Table 1) all institutes were in close agreement (9–13%) except for AZTI who identified a only 3% of the samples as valid for fecundity.

POF´s (post ovulatory follicles) are spawning markers and the detection of these is important for correct screening. Histological POF scoring split by institute proved to be not as uniform as in 2013; AZTI detected POFs much more often than the other laboratories. This may at least partly explain the small number of fecundity samples found by AZTI.

Prevalence of atresia

Prevalence of early alpha atresia was very similar among institutes (CV = 17.8%) (Table 2). When prevalence of massive atresia is considered the differences was larger (Table 2). Similar results were observed in 2013. There were however also large differences among institutes in the detection of spent fish. Both spent fish and fish with mass atresia will be excluded from further analysis. Often at the end of spawning there will be mass atresia and it seems that some persons will score this as mass atresia and some as spent. If we look at these two categories together (Table 3), we see that the institutes have similar results, except for IMARES *(currently Wageningen Marine Research)* that had a lower value.

Table 2. Prevalence of atresia in split by institute and prevalence of massive atresia split by institute. N = number of samples with atresia or massive atresia from the total samples analysed. *(IMARES is currently named Wageningen Marine Research.)*

	Prevalence of Atresia		Prevalence of Mass atresia	
Institute	N	Prevalence (%)	N	Prevalence (%)
AZTI	51	27.7	62	20.6
IEO	52	34.0	67	21.5
IMARES	64	30.6	7	2.2
IMR	47	28.1	19	6.0
Total	214	30.0	155	12.5

Table 3. Prevalence of fish that were spent or had massive atresia. *(IMARES is currently named Wageningen Marine Research.)*

Institute	N	Prevalence (%)
AZTI	85	28.2
IEO	101	32.5
IMARES	30	9.5
IMR	87	27.4
Total	303	24.4

Intensity of atresia

Each institute estimated intensity of atresia (Table 4) using histological grid and profile counting. When split by institute the values ranged from 22 to 41 (n/g). Although these differences are large this is to be expected and acceptable considering the small number of samples analysed by each institute.

Table 4. Intensity of atresia (n/g) split by institute. *(IMARES is currently named Wageningen Marine Research.)*

Institute	N	Geom.Mean	Lower 95% CI	Upper 95% CI
AZTI	7	29.9	17.5	51.0
IEO	9	22.0	9.6	50.5
IMARES	14	40.7	22.6	73.0
IMR	17	28.0	16.0	49.1
MSS	10	29.5	13.1	66.7
Total	57	30.1	23.0	39.4

Fecundity ring test

During the 2016 survey some ovaries had several replicates sampled. These replicates were divided on the analysing institutes and the samples analysed for comparison. The source of variance in such a ringtest may be caused both by differences in the pipette samples as well as differences in laboratory procedures and in personal interpretation. For some of the samples the differences very large (Table 5) and the source of this variation needs to be looked upon during the coming fecundity workshop.

Table 5. Fecundity ring test, comparing different laboratories working with samples taken during 2016 survey. ***(IMARES is currently named Wageningen Marine Research.)***

Participant	A093	C1000	C999	Iceland_1	AZTI_1
AZTI_1	351	337	562		923
IEO_1	384	395	528	167	845
IMARES_1	573	422	494		808
IMARES_2	472	328	447		738
IMR_1	359	404	537	150	772
IMR_2	317	321	339	138	601
MI_1	280	361	348	149	493
MSS_1	366	399	433	172	771
Average	**388**	**371**	**461**	**155**	**744**
Median	**363**	**378**	**471**	**150**	**772**
Min	**280**	**321**	**339**	**138**	**493**
Max	**573**	**422**	**562**	**172**	**923**
SD	**93**	**39**	**85**	**14**	**137**
SD%	**24**	**11**	**18**	**9**	**18**

Relative fecundity

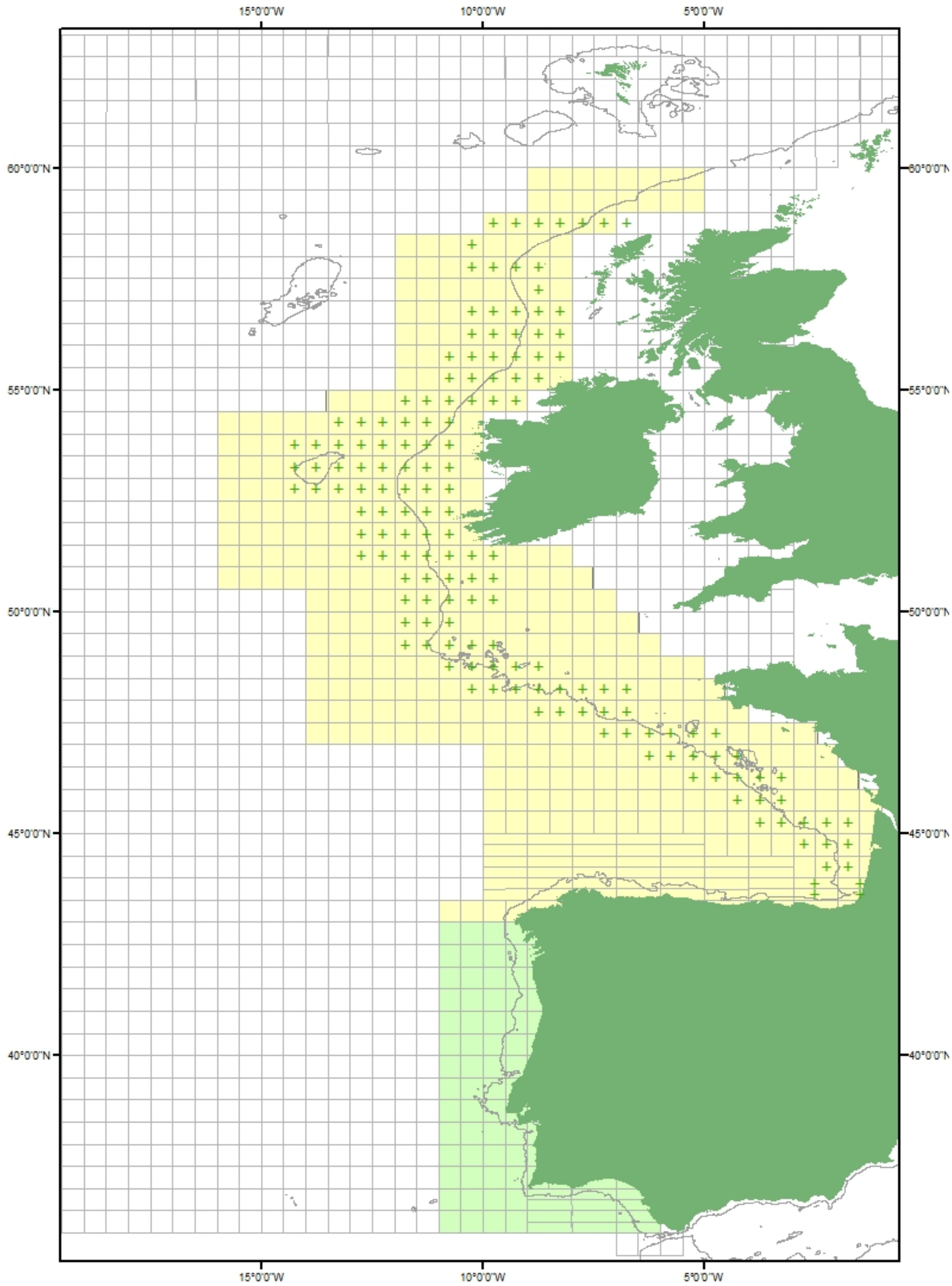
For fecundity, each institute analysed between 7 and 20 samples (Table 6). The median values ranged from 1024 to 1479. Such as it occurred in 2013, the highest counting was given by IEO and the lowest by IMARES *(currently Wageningen Marine Research)*. The number of samples for each lab was low therefor a considerable part of the differences might be caused by natural variability of fecundity.

Table 6. Relative fecundity (n/g) split by institute. ***(IMARES is currently named Wageningen Marine Research.)***

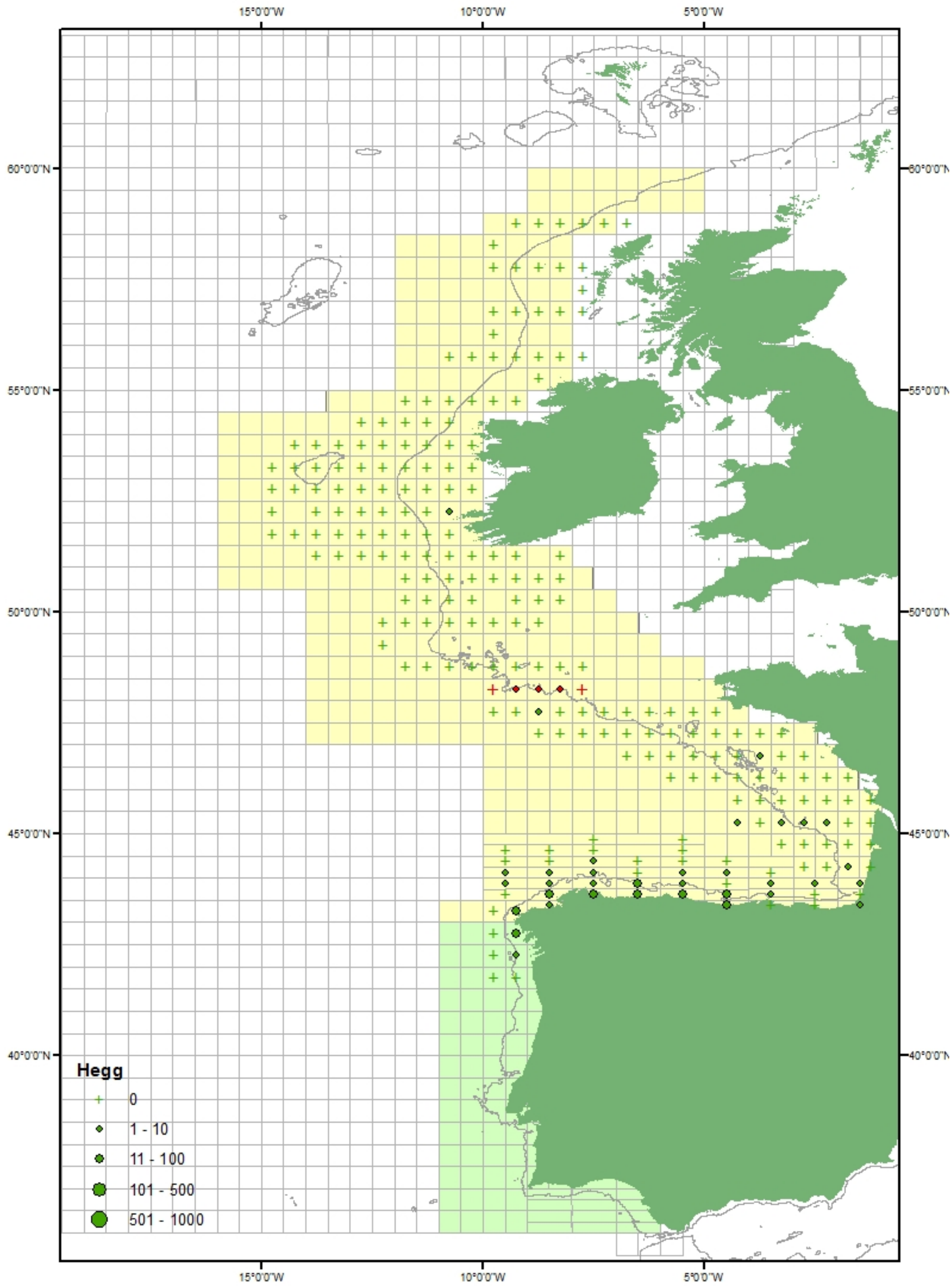
Institute	Median	Mean	N	sd	min	max	Lower 95% CI	Upper 95% CI
AZTI	1253	1230	7	268	670	1484	1027	1432
IEO	1479	1449	15	419	712	2261	1233	1666
IMARES	1024	1106	18	307	777	1958	961	1251
IMR	1136	1107	20	296	611	1657	975	1240
MII	1054	1077	20	311	803	2209	938	1216
MSS	1214	1207	17	410	445	1966	1009	1406
Total	1159	1180	97	357	445	2261	1108	1252

Annex 9: Distribution maps of horse mackerel spawning

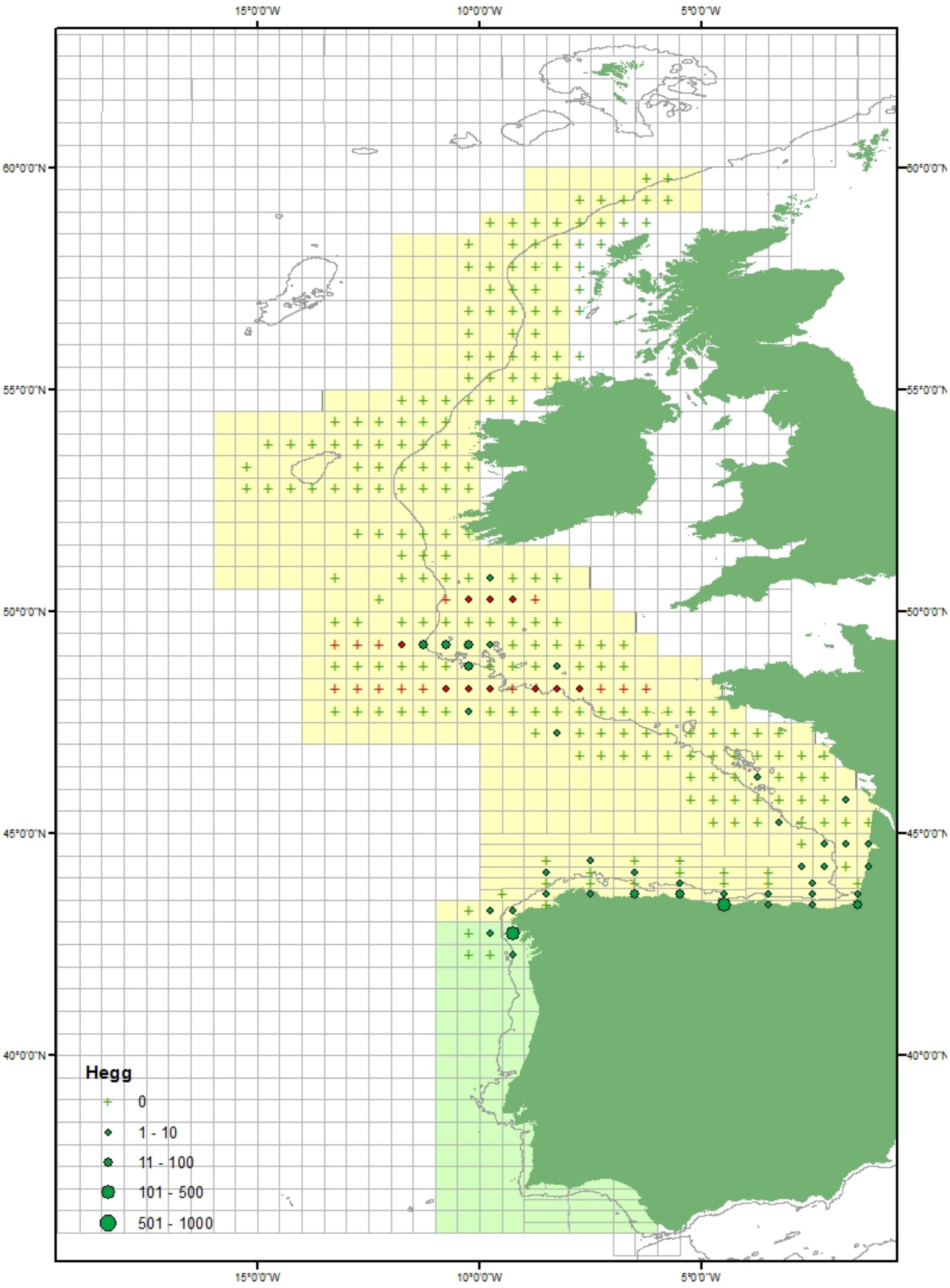
Horse mackerel egg production in period 2 (4–29 February). Filled green circles represent observed values, filled red circles represent interpolated values, green crosses represent observed zeroes.



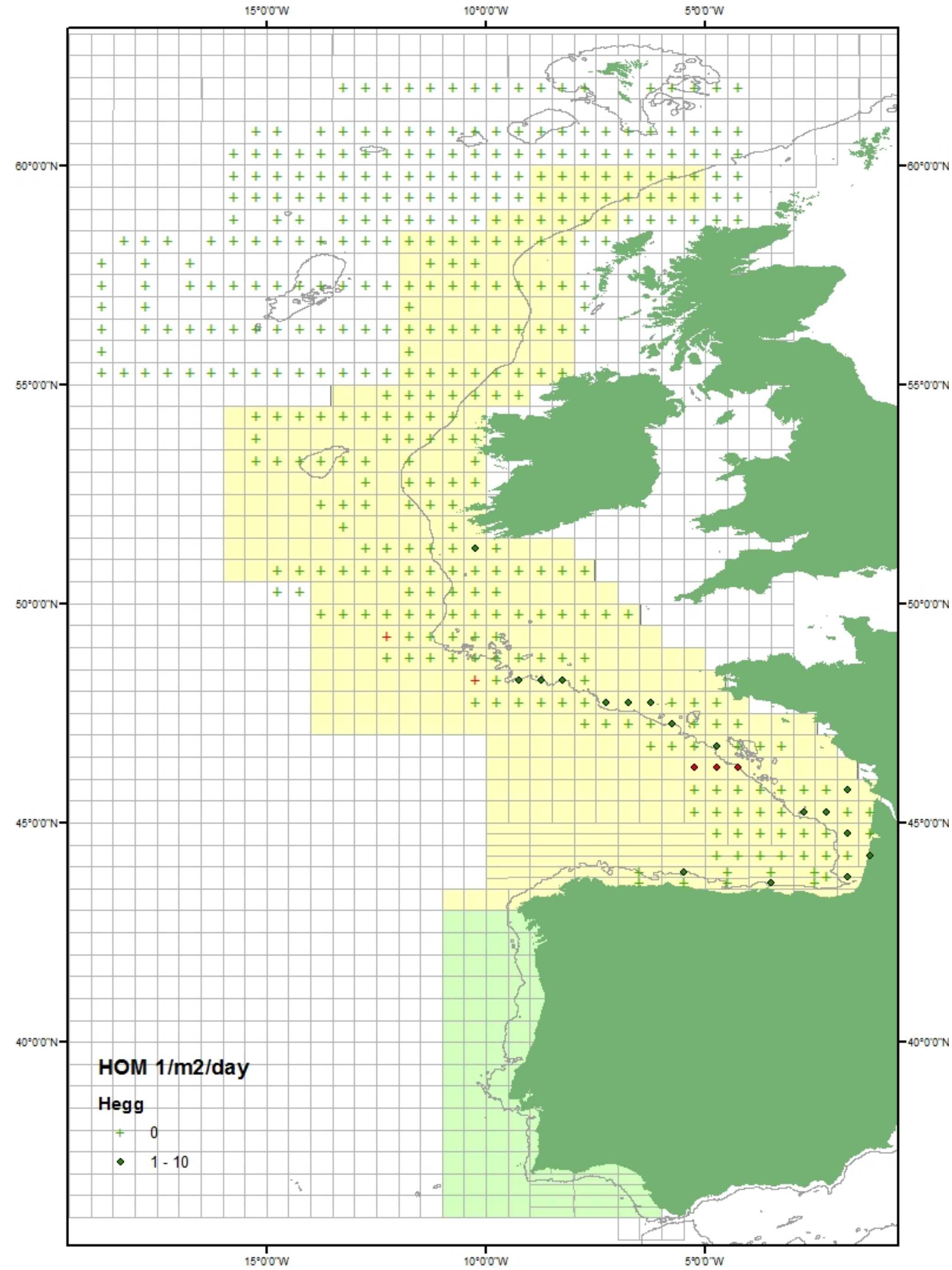
Horse mackerel egg production in period 3 (1 March – 8 April). Filled green circles represent observed values, filled red circles represent interpolated values, green crosses represent observed zeroes.



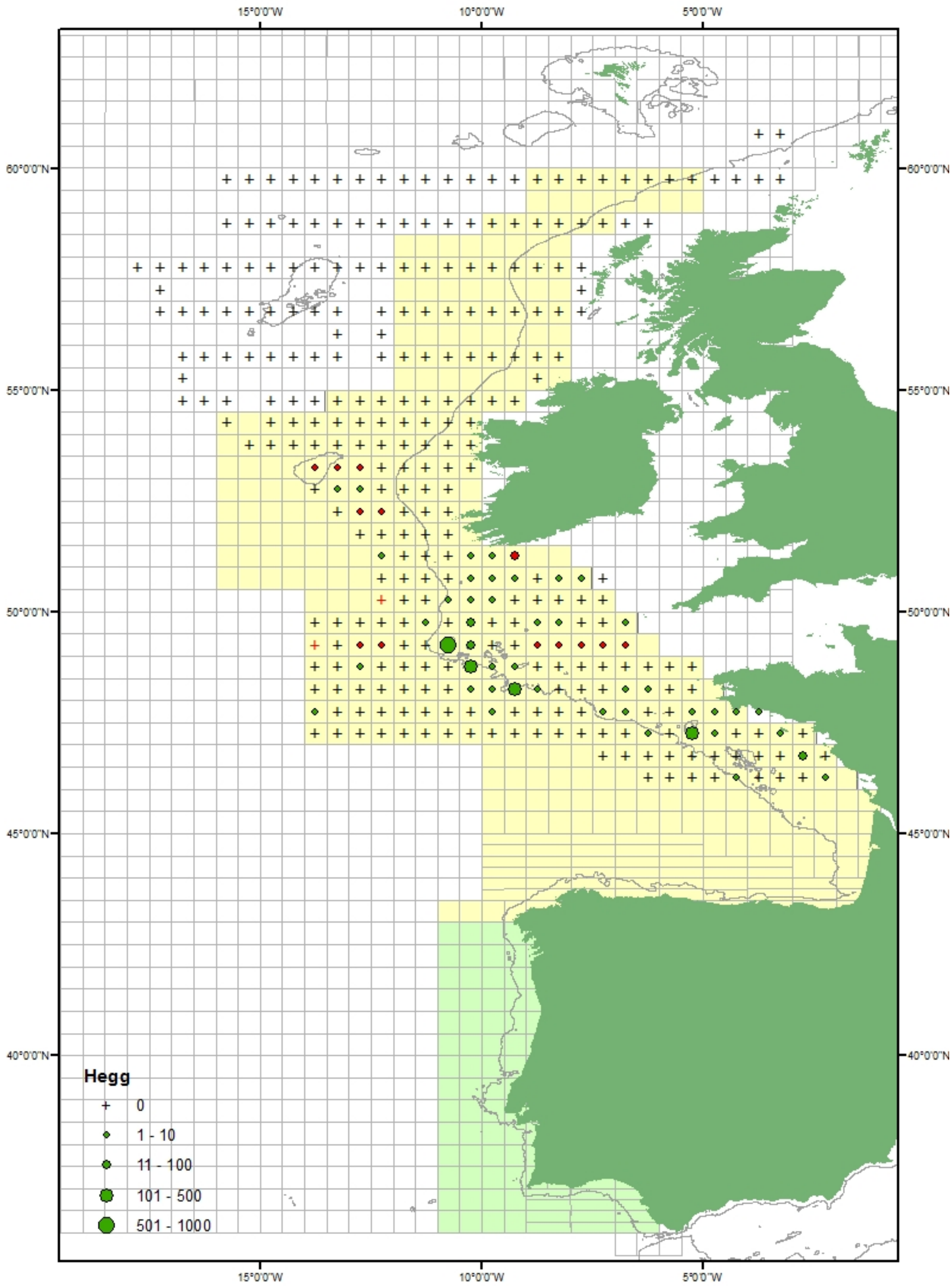
Horse mackerel egg production in period 4 (9–30 April). Filled green circles represent observed values, filled red circles represent interpolated values, green crosses represent observed zeroes.



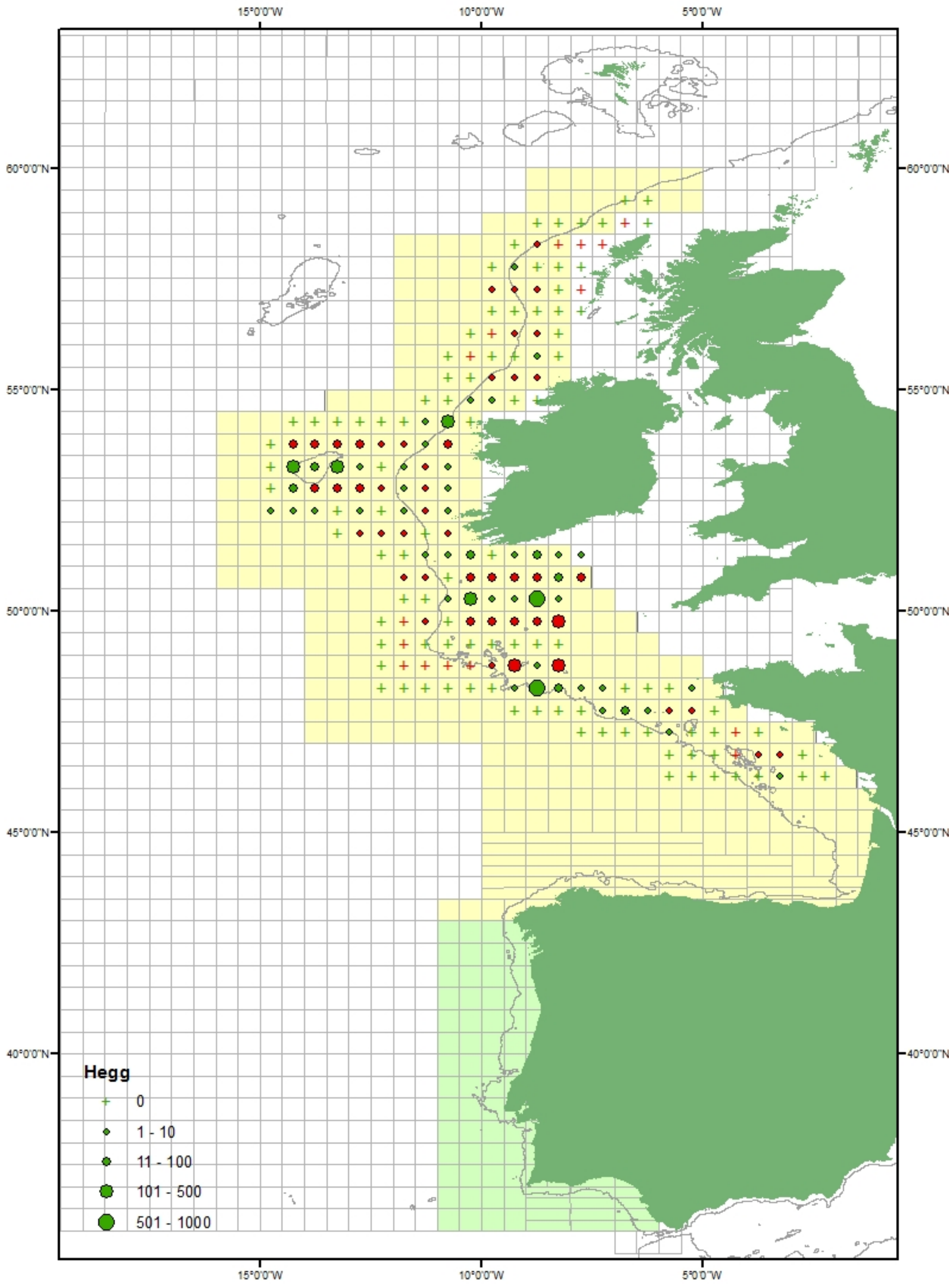
Horse mackerel egg production in period 5 (1–30 May). Filled green circles represent observed values, filled red circles represent interpolated values, green crosses represent observed zeroes.



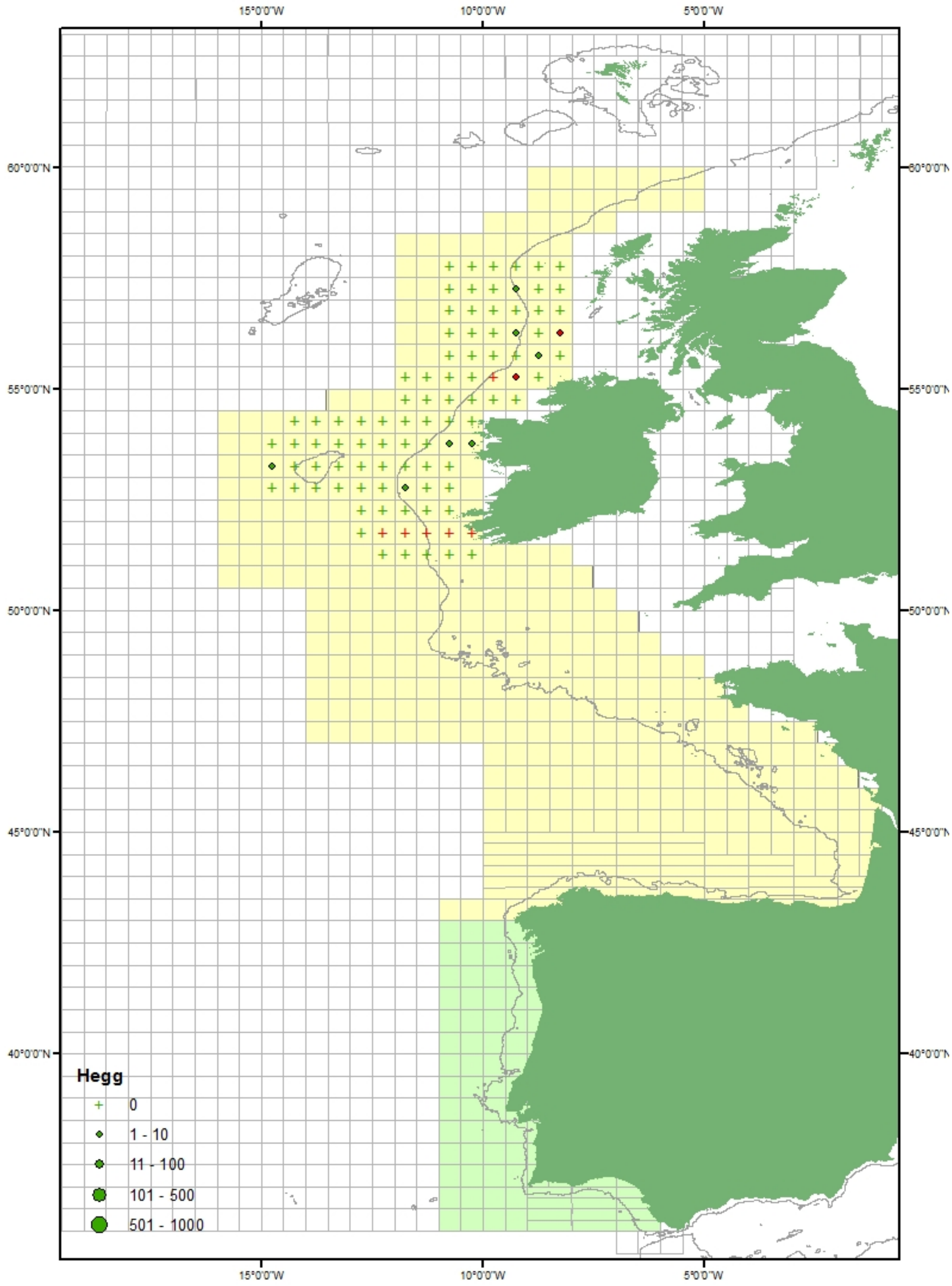
Horse mackerel egg production in period 6 (31 May – 27 June). Filled green circles represent observed values, filled red circles represent interpolated values, green crosses represent observed zeroes.



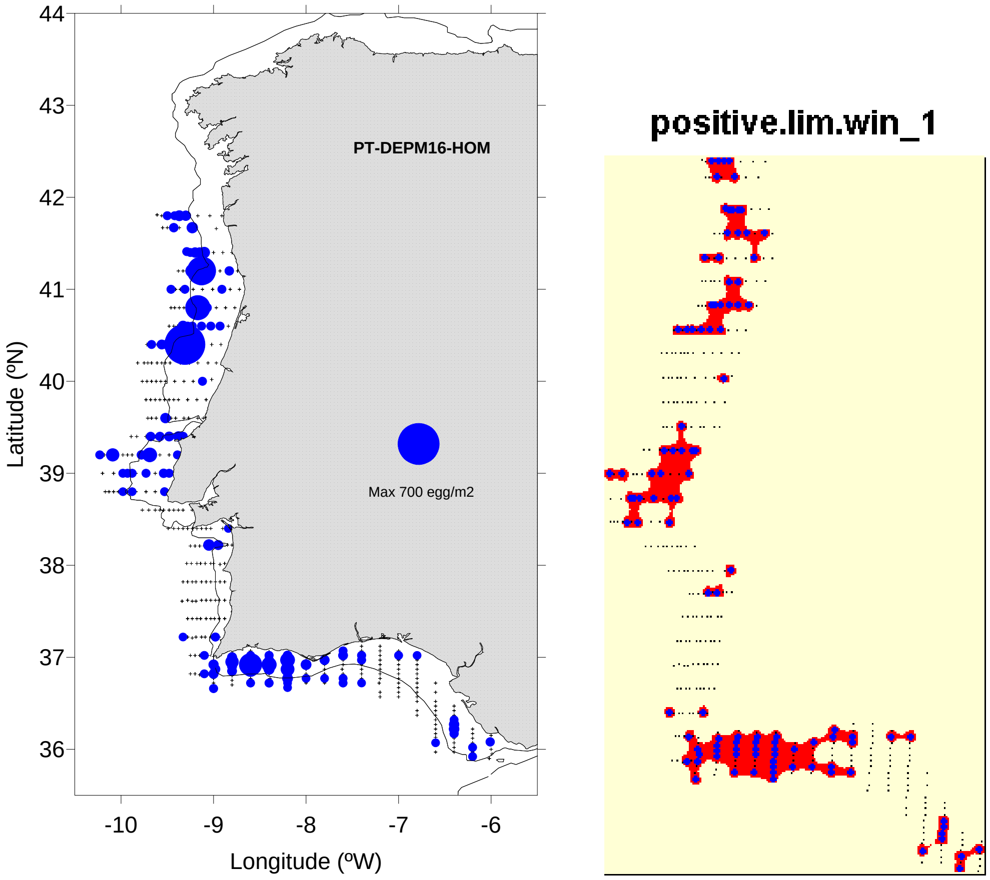
Horse mackerel egg production in period 7 (28 June – 31 July). Filled green circles represent observed values, filled red circles represent interpolated values, green crosses represent observed zeroes.



Horse mackerel egg production in period 8 (10–23 August). Filled green circles represent observed values, filled red circles represent interpolated values, green crosses represent observed zeroes.



Annex 10: Southern Horse mackerel sampling and egg distribution



Location of the CalVET stations and egg density distribution (left panel) and spawning area delimitation (right panel).

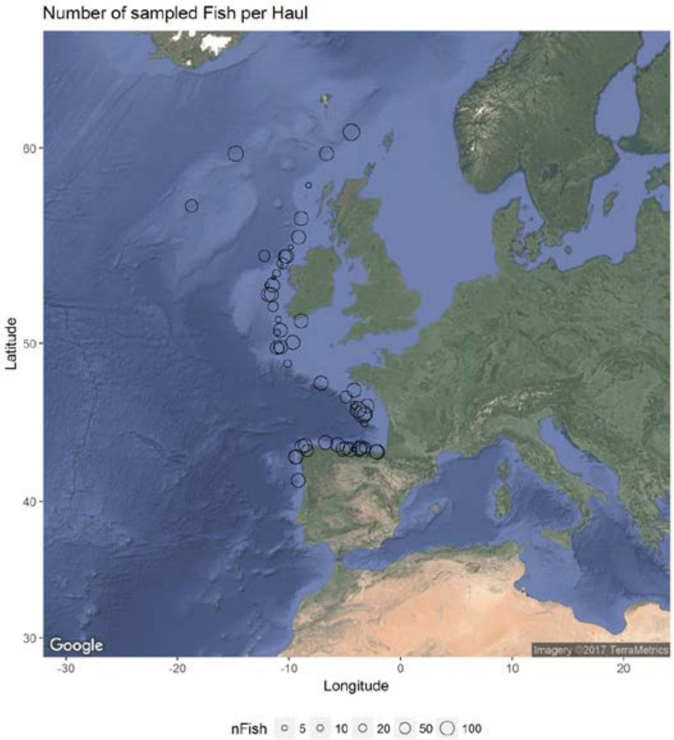
Annex 11: Western Mackerel DEPM

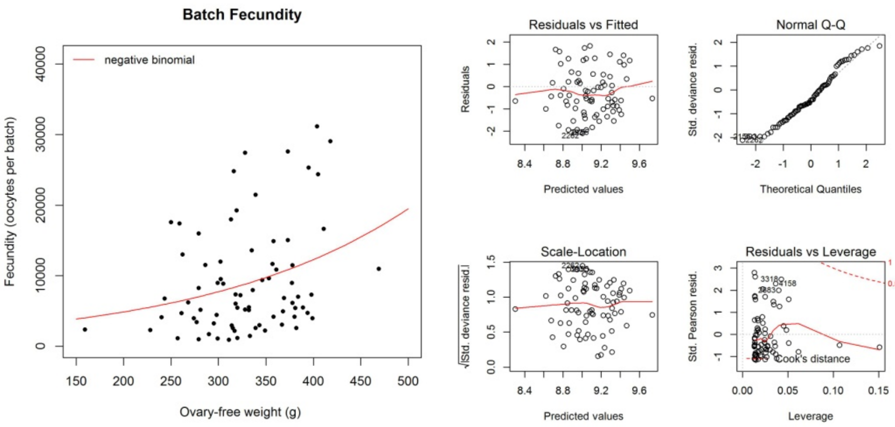
Total sampled mature females for fecundity analysis by period and latitude. AEPM samples were taken from all females, and during peak spawning (periods 3 and 4) the number or samples was higher for DEPM analysis.

	Periods						
Lattitude	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
43-45	52	267	266				585
46-48		80	30	15	24	1	150
49-51			126	30	15	2	173
52-54	45	1	61	54	30	17	208
55-57	30			36	30		96
58-60				20	31		51
Total	127	348	483	155	130	20	1263

Results of the ring test on POFs staging. The table shows the percent of agreement between the eight readers on the presence of the POFs stages in each sample.

	POFs STAGES						
Histological slides from	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Fish 1	12.5	62.5	62.5	62.5	62.5	37.5	37.5
Fish 2	12.5	0	0	25	25	50	100
Fish 3	12.5	0	25	25	62.5	87.5	25
Fish 4	0	25	75	50	87.5	37.5	50
Fish 5	87.5	62.5	62.5	25	50	25	50





Description of the negative binomial model fitness in batch fecundity data.

BOX 1. Summary of the script

Sections:

- # 0- Load and check data, define values for some parameters and summarize raw data
- # 1- Correct bias produced by hydrated females in expected weight

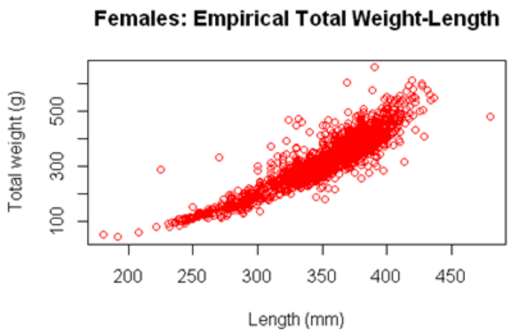
Estimations by haul:

- # 2- Mean weight for mature females (W)
- # 3- Sex-ratio in weight (R)
- # 4- Batch fecundity (F) (data from random and directed sampling)
- # 5- Spawning fraction (S)
- # 6- Plot of parameters by haul

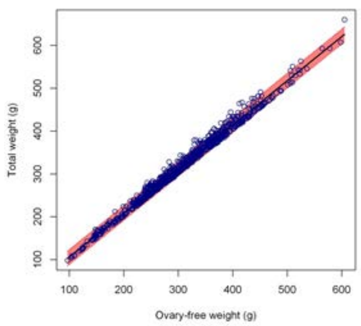
Population level:

- # 7- Mean parameter estimations and their coefficients of variation
- # 8- Poststratification: Mean parameter estimations and their coefficients of variation

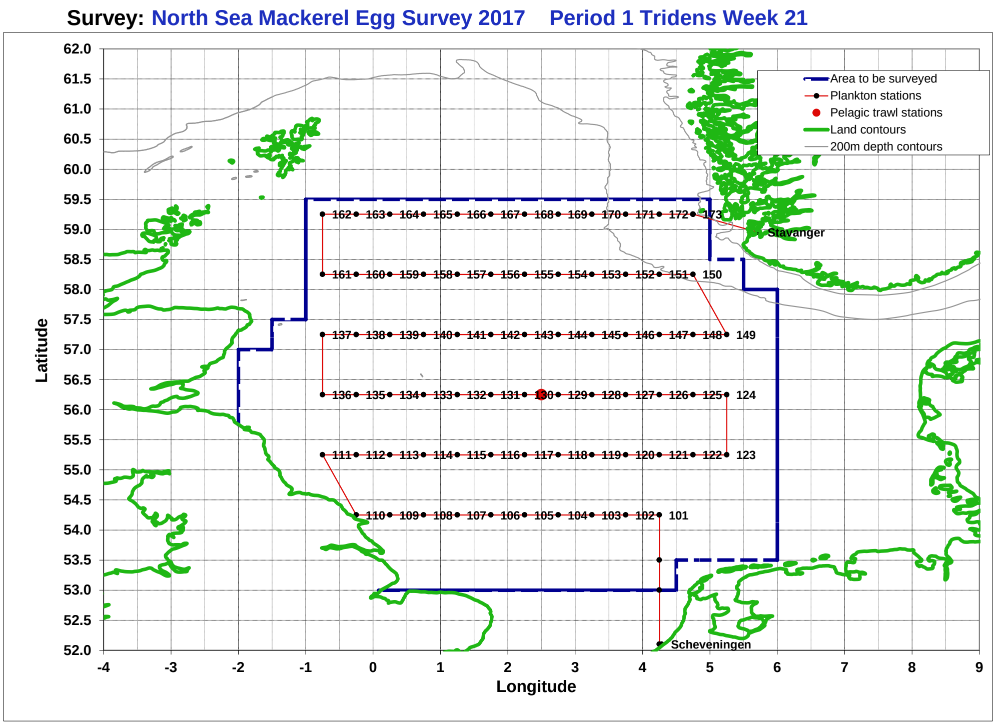
Box 2. Fit linear regression to total weight (Wt) female and weight without the ovary (Wnov)



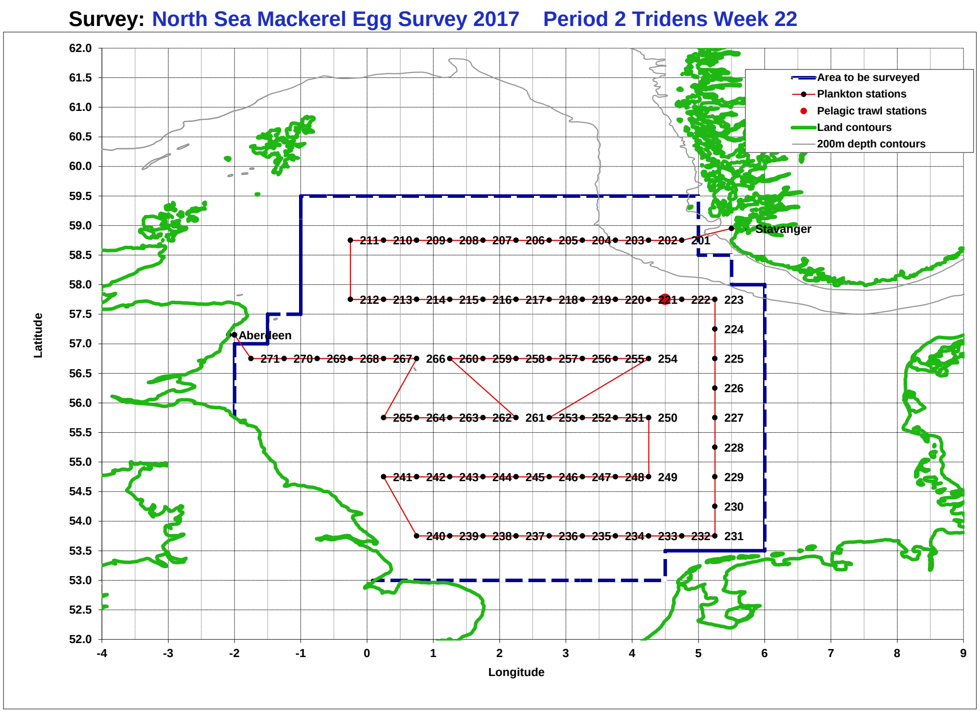
Box 3. Relationship between gonad-free female weight and total weight. Red shaded area = 95% CI



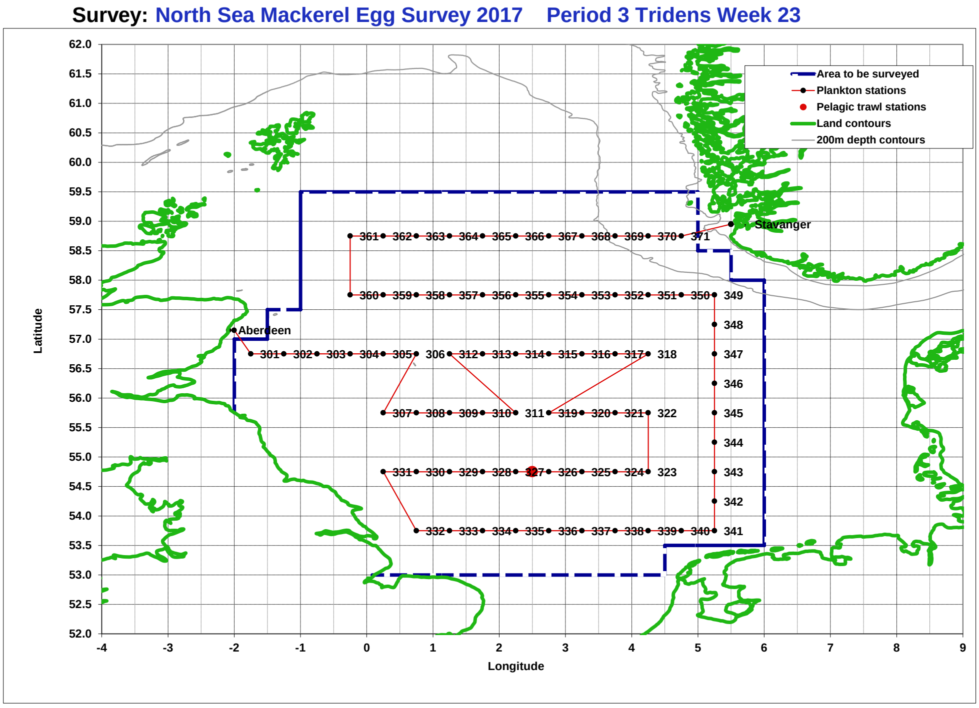
Annex 12: Planned sampling for the 2017 North Sea mackerel egg survey



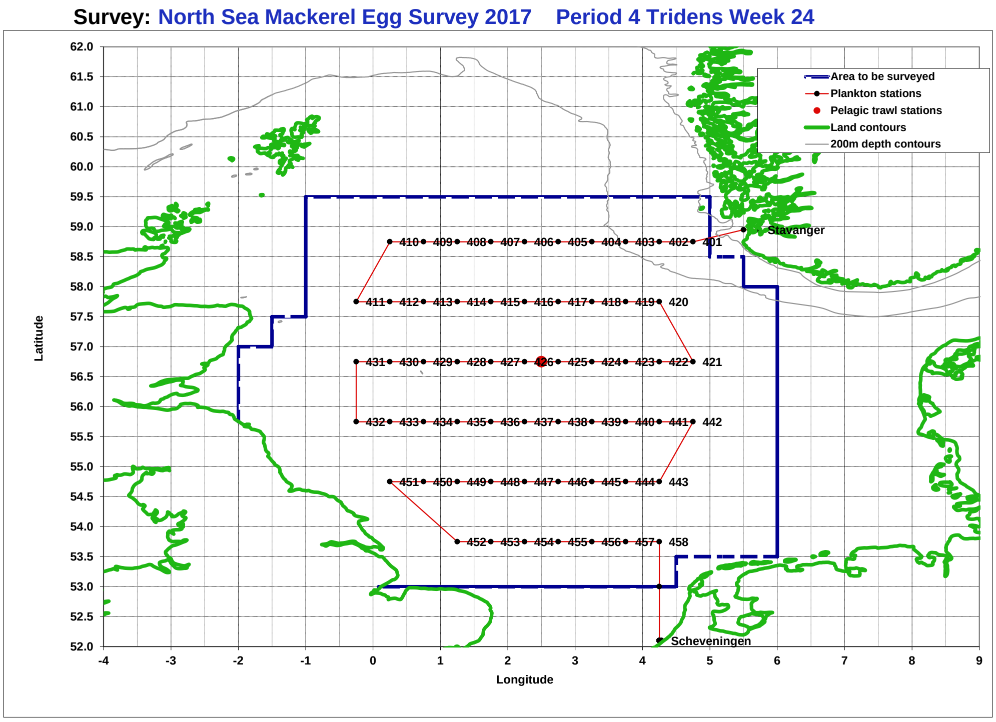
Planned sampling during the 2017 North Sea mackerel egg survey in period 1.



Planned sampling during the 2017 North Sea mackerel egg survey in period 2.



Planned sampling during the 2017 North Sea mackerel egg survey in period 3.



Planned sampling during the 2017 North Sea mackerel egg survey in period 4.

Annex 13: Comparative Mackerel TAEP analysis

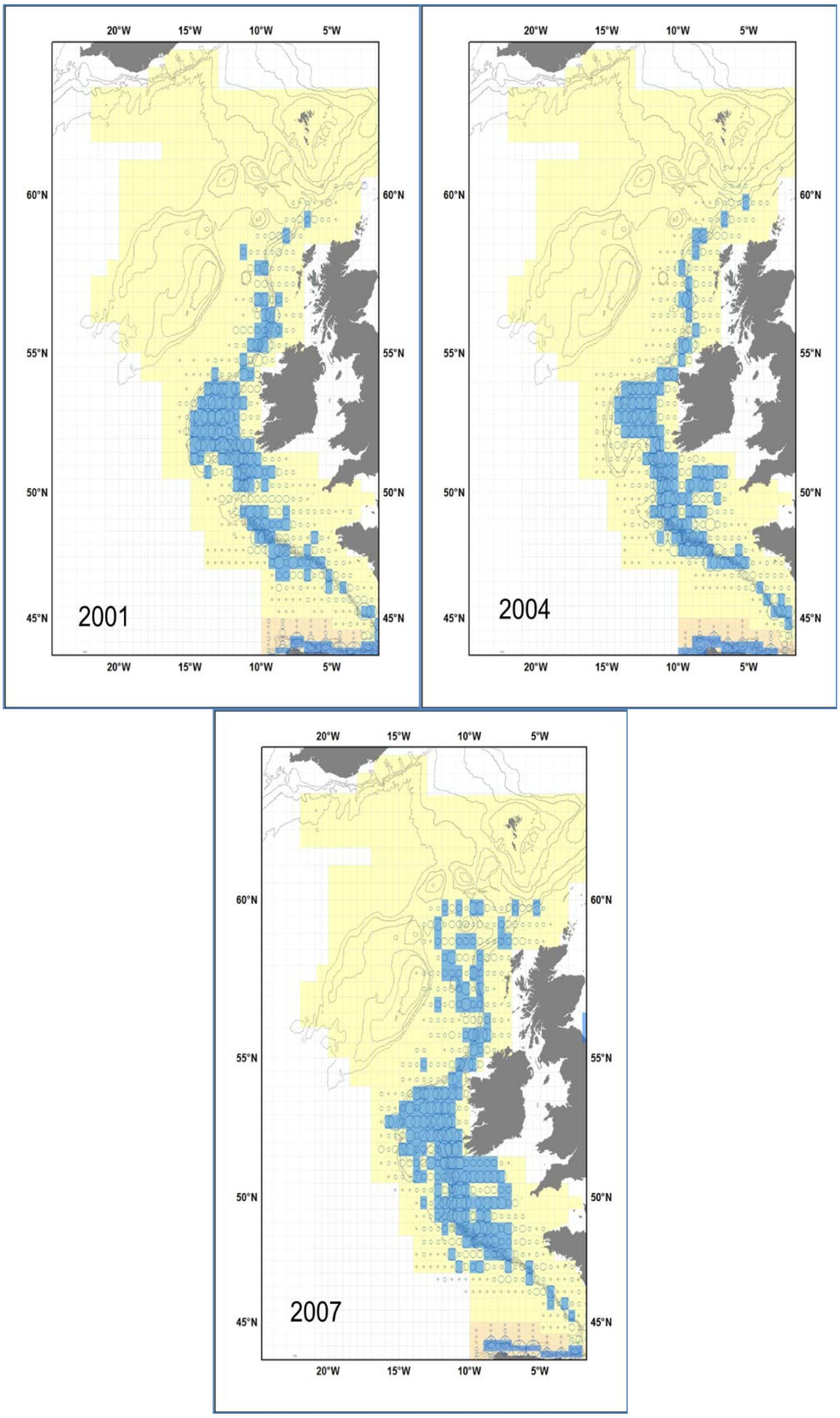
Year	Period	Component	Method	DEP - Obs	DEP - Int	DEP - Total	DEP - Agreement	Days	AEP	
2016	2	Western	R Script	9.6504E+10	1.1154E+10	1.07657E+11	100.0%	25	2.691E+12	
2016	2	Western	Manual Est	9.6504E+10	1.1152E+10	1.07656E+11		25	2.691E+12	TAEP Manual
2016	3	Western	R Script	1.1867E+13	2.7599E+11	1.21431E+13	99.9%	39	4.736E+14	1.54896E+15
2016	3	Western	Manual Est	1.1876E+13	2.7829E+11	1.21544E+13		39	4.74E+14	
2016	4	Western	R Script	4.7741E+12	1.491E+12	6.26508E+12	99.9%	22	1.378E+14	
2016	4	Western	Manual Est	4.7773E+12	1.4925E+12	6.26984E+12		22	1.379E+14	
2016	5	Western	R Script	2.072E+13	5.8979E+12	2.66178E+13	100.0%	30	7.985E+14	TAEP Script
2016	5	Western	Manual Est	2.0721E+13	5.8942E+12	2.66147E+13		30	7.984E+14	1.54833E+15
2016	6	Western	R Script	2.9322E+12	1.1168E+12	4.04902E+12	99.9%	22	8.908E+13	
2016	6	Western	Manual Est	2.9322E+12	1.1219E+12	4.05404E+12		22	8.919E+13	
2016	6-7	Western	R Script			2.63761E+12	99.8%	6	1.583E+13	
2016	6-7	Western	Manual Est			2.64199E+12		6	1.585E+13	Agreement
2016	7	Western	R Script	7.5904E+11	4.6601E+11	1.22505E+12	99.9%	22	2.695E+13	100.04%
2016	7	Western	Manual Est	7.5904E+11	4.6758E+11	1.22662E+12		22	2.699E+13	
2016	>7	Western	R Script			3.19577E+11	99.9%	12	3.835E+12	
2016	>8	Western	Manual Est			3.19988E+11		12	3.84E+12	

Results of 2016 comparative TAEP analysis, NEA mackerel - western area.

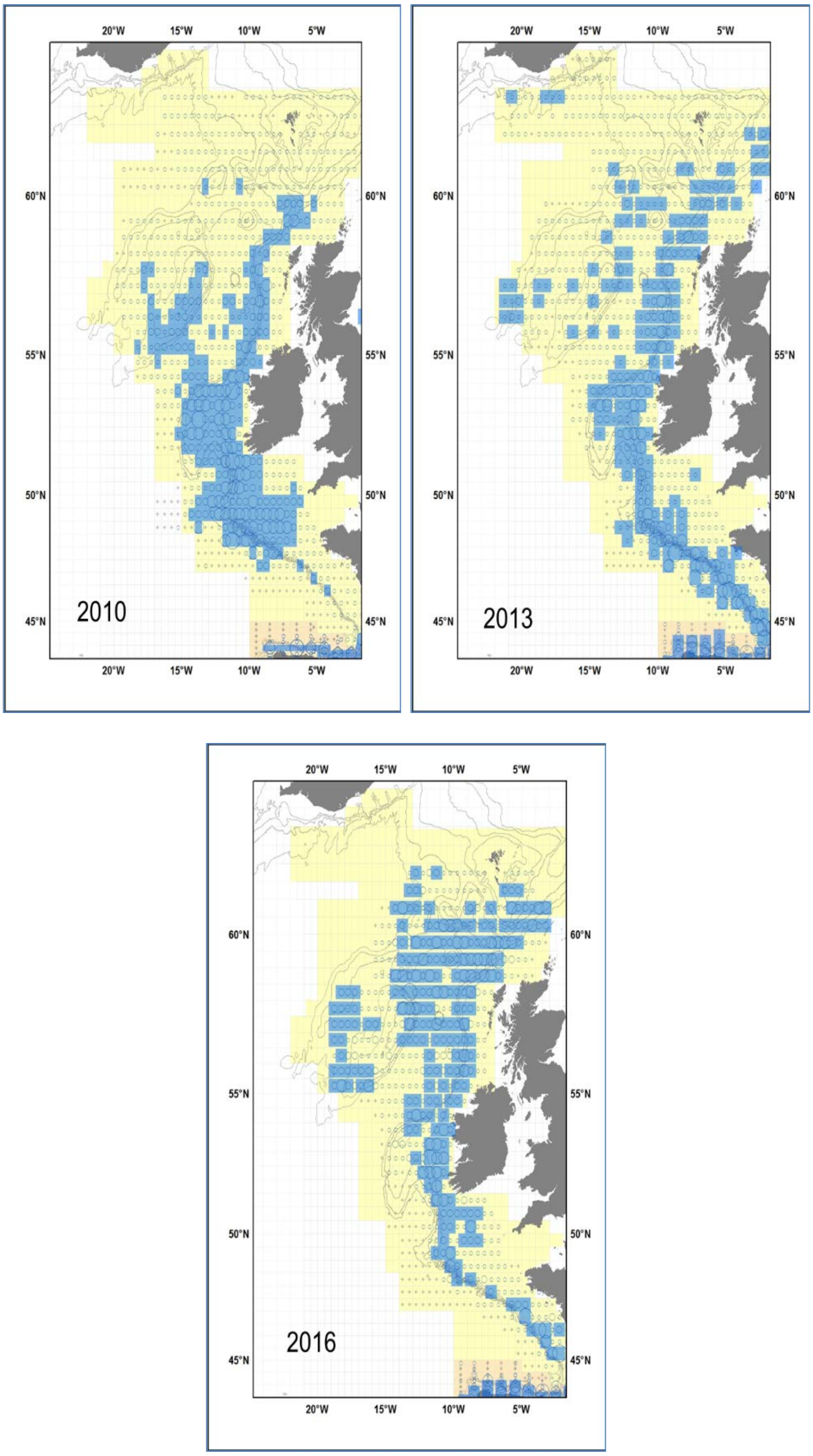
Year	Period	Component	Method	DEP - Obs	DEP - Int	DEP - Total	DEP - Agreement	Days	AEP	
2016	2	Southern	R Script	0	0	0	100.0%	2	0	
2016	2	Southern	Manual Est	0	0	0		2	0	TAEP Manual
2016	2-3	Southern	R Script			1.07E+12	99.9%	20	2.14E+13	2.25095E+14
2016	2-3	Southern	Manual Est			1.07E+12		20	2.14E+13	
2016	3	Southern	R Script	3.2499E+12	1.21E+10	3.26E+12	99.9%	25	8.15E+13	
2016	3	Southern	Manual Est	3.2513E+12	1.25E+10	3.26E+12		25	8.16E+13	
2016	3-4	Southern	R Script			3.56E+12	100.0%	7	2.49E+13	TAEP Script
2016	3-4	Southern	Manual Est			3.56E+12		7	2.49E+13	2.25149E+14
2016	4	Southern	R Script	3.8118E+12	2.07E+10	3.83E+12	100.0%	23	8.81E+13	
2016	4	Southern	Manual Est	3.8114E+12	2.07E+10	3.83E+12		23	8.81E+13	
2016	5	Southern	R Script	2.0626E+11	1.74E+10	2.24E+11	100.0%	8	1.79E+12	
2016	5	Southern	Manual Est	2.0665E+11	1.7E+10	2.24E+11		8	1.79E+12	Agreement
2016	>5	Southern	R Script			1.06E+11	100.0%	69	7.29E+12	99.98%
2016	>5	Southern	Manual Est			1.06E+11		69	7.29E+12	

Results of 2016 comparative TAEP analysis, NEA mackerel - southern area.

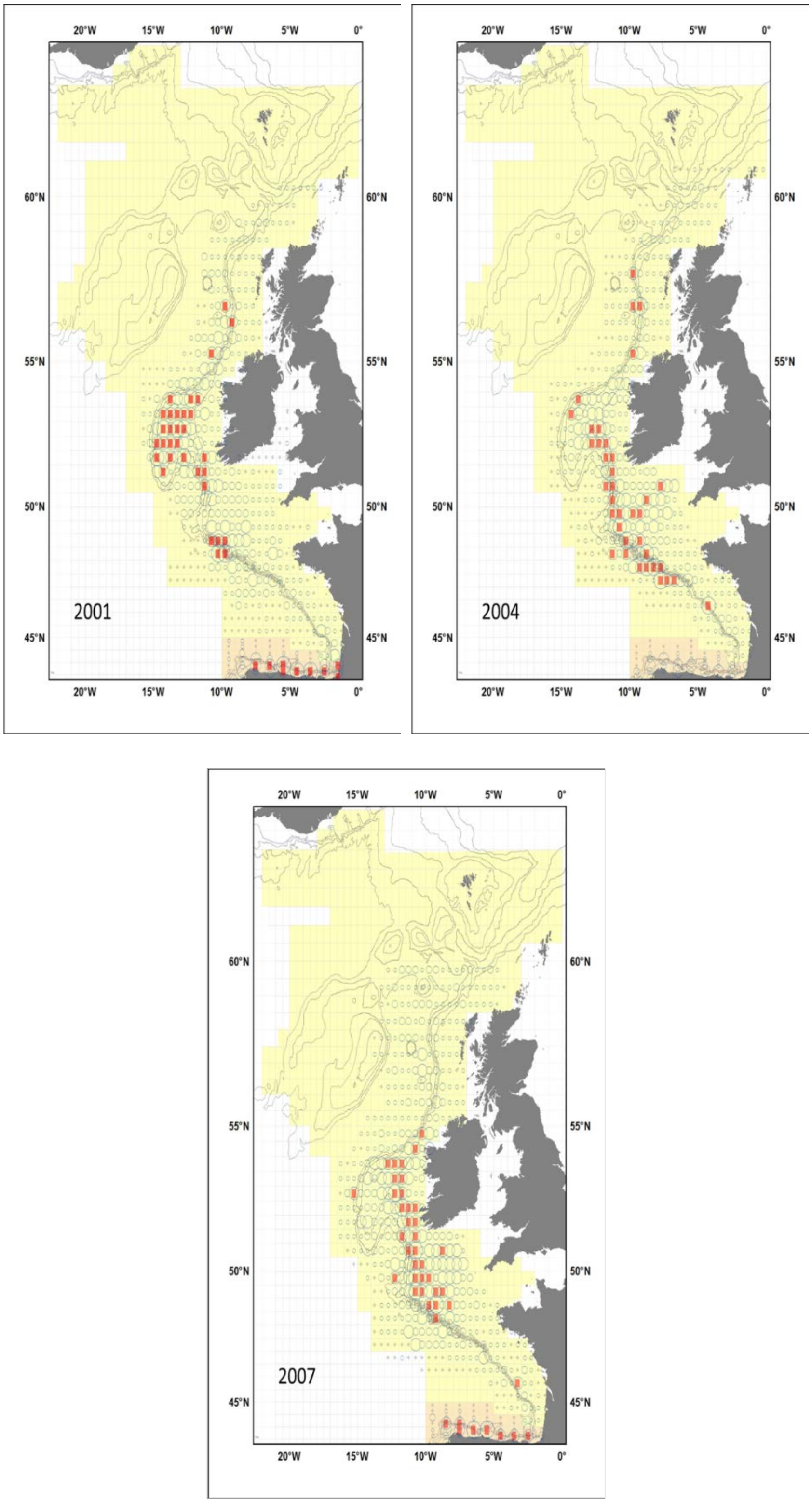
Annex 14: Time-series of mackerel core spawning area



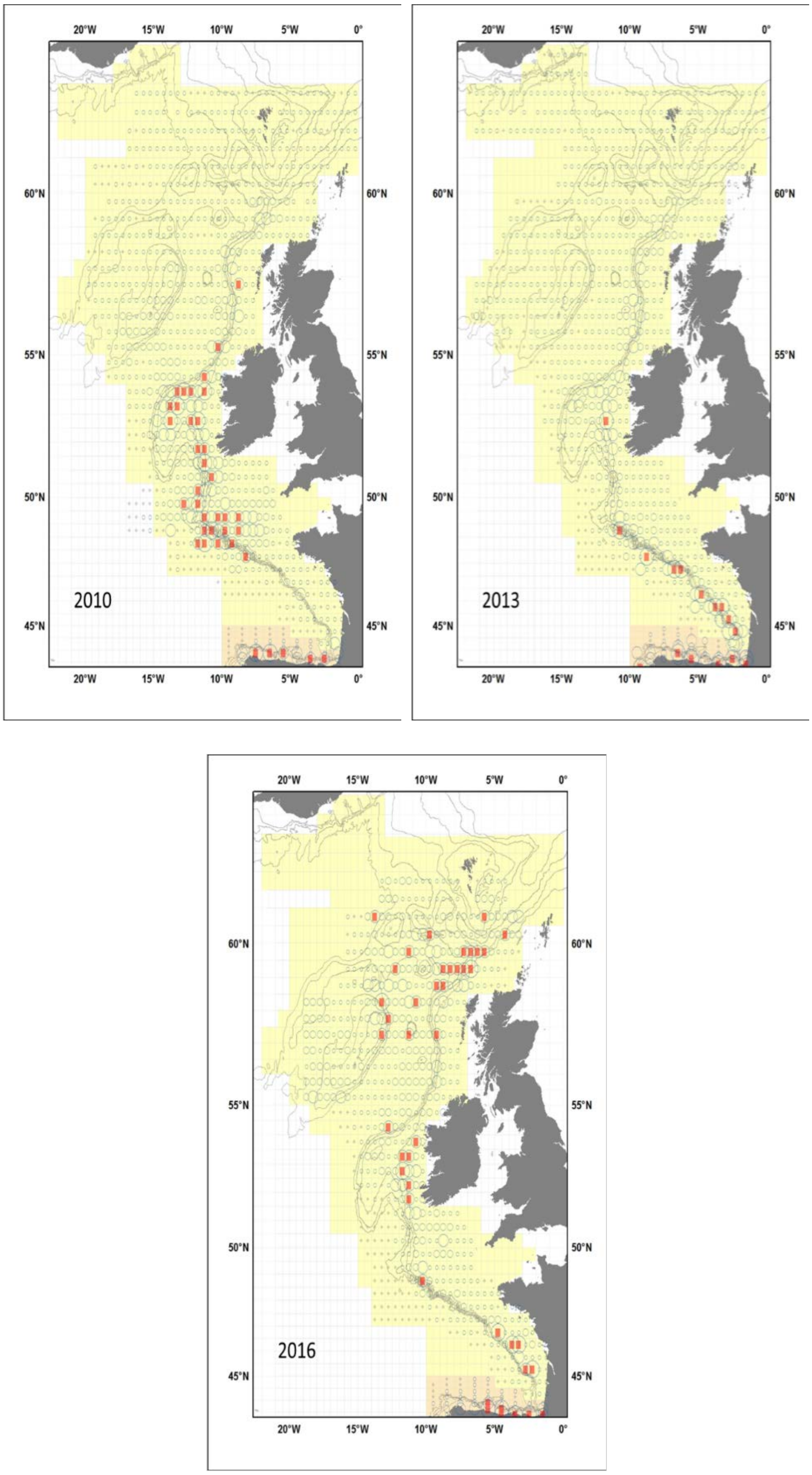
Figures 1. 3. Mean egg production (stage 1 eggs/m²/day) by half ICES rectangle for all MEGS stations sampled in years 2001–2007. Egg production values are square root transformed. (Crosses denote locations where sampling was undertaken but where no spawning was recorded). Area in yellow denotes the maximum geographical survey extent for the western survey area. Area/stations capturing 90% of spawning activity within that year are overlaid.



Figures 4. 6. Mean egg production (stage 1 eggs/m²/day) by half ICES rectangle for all MEGS stations sampled in years 2010–2016. Egg production values are square root transformed. (Crosses denote locations where sampling was undertaken but where no spawning was recorded). Area in yellow denotes the maximum geographical survey extent for the western survey area. Area/stations capturing 90% of spawning activity within that year are overlaid.



Figures 7. 9. Mean egg production (stage 1 eggs/m²/day) by half ICES rectangle for all MEGS stations sampled in years 2001 - 2007. Egg production values are square root transformed. (Crosses denote locations where sampling was undertaken but where no spawning was recorded). Area in yellow denotes the maximum geographical survey extent for the western survey area. Area/stations capturing 50% of spawning activity within that year are overlaid.



Figures 10 – 12. Mean egg production (stage 1 eggs/m²/day) by half ICES rectangle for all MEGS stations sampled in years 2010 - 2016. Egg production values are square root transformed. (Crosses denote locations where sampling was undertaken but where no spawning was recorded). Area in yellow denotes the maximum geographical survey extent for the western survey area. Area/stations capturing 50% of spawning activity within that year are overlaid.

Annex 15: Survey gears used during WGMEGS surveys

Institute	IMARES	IMARES	TI-SF	MI	CEFAS	MSS	MSS	IMR	HAFRO	FAMRI
Country	Netherlands	Netherlands	Germany	Ireland	England	Scotland	Scotland	Norway	Iceland	Faroes
Torpedo type	Gulf III	Gulf VII	Nackthai*	Gulf VII	Gulf VII	Gulf III	Gulf VII	Gulf VII	Gulf VII	Bongo
Years in use	before 2004	since 2004	since 2004	since 2004	1995 - 2001	before 2007	since 2007	2007 - 2013	2016	since 2010
Frame	Encased	Open	Open	Open	Open	Encased	Open	Open	Open	Open
Total length (cm)	224	275	275	272	278	230	273	273	273	250
Length frame (without nosecone) (cm)	199	215	221	214	215	199	213	213	213	250
Length nosecone (cm)	35	60	54	59	63	31	60	60	60	NA
Length of streched planktonnet (cm)	165	180	173	177	193	177	177	180	180	214
Diameter frame (cm)	50	50	43	53	53	50	53	50	50	60
Diameter planktonnet (cm)	41	40	38	50	45	46	46	38	46	58.5
Diameter codend (mm)	80	70	92	95	80	75	75	80	75	10
Diameter nosecone (cm)	19	20	20	20	20	19	20	20	20	60
Flowmeter position	internal	internal and external	internal and external	internal and external	internal and external	internal and external	internal and external	internal	internal and external	internal
Flowmeter brand/type		Valeport	Hydro-Bioss	Hydro-Bioss	Valeport	In-house design	Valeport-replica	Valeport	Valeport	Hydro-Bioss
Flowmeter blade diameter (cm)			7.5		12.5			5		
Mechanical/electronic	Mechanical	Electronic	Electronic	Electronic	Electronic	Mechanical	Electronic	Electronic	Electronic	Mechanical

* Modified Gulf VII; a similar type but shorter was used the years before.

Gears used in the western area

Country	Net	Diameter (cm)	Shape	Mesh size (µm)	Total length (cm)	years in use
Spain (IEO)	Bongo	40	Cylinder-cone	250	250	
Spain AZTI	Bongo	40	Cylinder-cone	250	250	from 2007 on
Portugal (IPMA)	CalVET	40	Cylinder-cone	150	200	

Gears in the southern area