ICES WORKING GROUP ON MACKEREL AND HORSE MACKEREL EGG SURVEYS (WGMEGS; outputs from 2020 meeting)

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Contents

i Executive summary

The ICES Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS) coordinates the mackerel and horse mackerel egg survey in the Northeast Atlantic (NEA) and the mackerel egg survey in the North Sea. The working group plans and reports on these surveys, with recent attention focused on the execution of the surveys given the increasing demands related to covering the expanding survey area as well as balanced fecundity sampling. WGMEGS also addresses data quality assurance in mackerel fecundity and total annual egg production estimation.

Currently, there are 3 surveys in place which are carried out triennially and deliver standing stock biomass (SSB) indices: (1) the survey for the western and southern stock components of the NEA mackerel stock, as well as for the western horse mackerel stock, (2) the survey for the NEA mackerel North Sea stock component, and (3) the survey for the southern horse mackerel stock.

For the North Sea component, the egg survey in 2017 revealed an estimated egg production of $201*10^{12}$, resulting in an SSB of $287*10^3$ tons. This is a strong increase of more than $100*10^3$ tons compared to 2015 (SSB = $170*10^3$ tons). While peak spawning in the North Sea was covered, the coverage of the complete spawning season and area was insufficient to produce a reliable estimate of survey indices.

In 2019, the application of an alternate transect survey design made it possible to survey the persistently expanding mackerel spawning area and season. Northern and northwestern spawning boundaries for mackerel during survey periods 5 (weeks 19 – 22) and 6 (weeks 23 – 26) were not fully delineated. Peak spawning was observed in period 4 (weeks 16 – 18). Subsequent analyses of survey results in conjunction with results from exploratory surveys in the inter-survey-years 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 $1.64*10^{15}$, which is a decrease of 7.6% compared to that of 2016 (rev. $1.77*10^{15}$).

Realized fecundity was estimated at 1147 per g female, revealing the SSB for the NEA mackerel stock in 2019 at 3.09 million tons indicating at 12 % decrease since the 2016 survey (SSB = 3.52 million tons). At only $1.78*10^{14}$, total annual egg production (TAEP) in western horse mackerel was found to be lowest production reported in the time series since 1992. The spawning maximum was detected in the last period 7 (weeks 27 – 29). It can, thus, not be concluded that peak spawning and the entire temporal extent of horse mackerel spawning had been sufficiently covered.

To further improve the quality of the index time series, WGMEGS will continue to dedicate much of its work to survey design and quality assurance in mackerel egg production and fecundity estimation.

ii Expert group information

Expert group name	Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS)
Expert group cycle	Annual
Year cycle started	2018
Reporting year in cycle	3/3
Chair(s)	Matthias Kloppmann, Germany
	Gersom Costas, Spain
Meeting venue(s) and dates	9 – 13 April 2018, Dublin, Republic of Ireland, (18 participants)
	26 – 27 August 2019, Sta Cruz de Tenerife, Spain, (8 participants)
	28 – 29 April 2020 by video conference (22 participants)
	4 – 6 November 2020 by video conference (24 participants)

1 Summary of Work plan

Year	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.

2 Summary of Achievements of the Work Group during 3-year term

- Planning, execution and reporting on the 2019 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 Daily Fecundity estimates of southern horse mackerel.
- First Daily Egg Production and SSB estimates of NEA mackerel (southern and western components) for 2019
- Planning of the 2021 (postponed from 2020) North Sea mackerel egg survey.
- Report on the 2017 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.
- Review results from egg staging and fecundity workshops as reported in the 2018 WKFATHOM Report (ICES, 2018b).
- Finalise 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 (ICES, 2019c; SISP 6) and 2) AEPM and DEPM fecundity estimation for mackerel and horse mackerel (ICES, 2019b; SISP 5)
- Publish two papers on mackerel fecundity and spawning dynamics

    1. K. Ganias, D. Marmara, A. Solla, D. Garabana, R. Dominguez-Petit. 2018. Atlantic mackerel daily spawning dynamics and implications for batch fecundity estimations. ICES Journal of Marine Science (Q1), 75(5): 1647-1654. doi: https://doi.org/10.1093/icesjms/fsy033.
    2. Charitonidou, K., Kjesbu, O.S., Dominguez-Petit, R., Garabana, D., Korta, M.A., Santos, M., Damme, C.J.G. van, Thorsen, A., Gania, K. 2020: Contrasting post-ovulatory follicle production in fishes with different spawning dynamics. Fisheries Research 231, https://www.sciencedirect.com/science/article/pii/S0165783620302277?via%3Dihub

3 Final report on ToRs, workplan and Science Implementation Plan

3.1 Activities in 2018, 2019 and 2020

WGMEGS met in Dublin, Ireland, in April 2018 to plan the ICES Triennial Mackerel and Horse Mackerel Egg Survey in 2019 (ICES 2018a). During the meeting during which Denmark indicated that they would participate and with Norway rejoining in the 2019 survey it looked like the survey area could be covered without additional resources. Later in 2019, Denmark and Iceland had to withdraw their participations. Also, Germany had to charter Danish RV Dana in order to replace their defunct vessel Walther Herwig III, which also truncated their available days at sea. Other participants had to fill in the resulting gaps in survey area coverage, and it became clear at the end of 2018 that the 2019 survey could not be executed with the preferred transect sampling, but would have to widely utilise the alternate transect sampling option.

Two workshops in October and November 2018 on mackerel and horse mackerel egg staging and identification, and fecundity and atresia sampling and estimation were held in Bremerhaven, Germany, and IJmuiden, The Netherlands, (ICES 2018b). The workshops standardised methods and analyses between survey participants and ensured training of new participants. During the workshops the manuals for sampling at sea (ICES, 2019c; SISP 6) and fecundity and atresia analyses (ICES, 2019b; SISP 5) were revised and updated.

Details and results of the North Sea mackerel egg survey in 2017 were published in the 2018 report (ICES, 2018a). The survey was coordinated by Cindy van Damme. Total annual egg production (TAEP) and SSB estimation were prepared for the attention of WGWIDE for information on the contribution of the North Sea stock component to total Northeast Atlantic mackerel.

In June 2017 and 2018 exploratory mackerel egg surveys were carried out in Nordic waters in order to collect information on the northern and north-western extension of mackerel spawning. A working document was presented to WGMEGS in 2019 (ICES, 2019a) and was published in the 2018 WGWIDE report (ICES, 2018c) reporting on the results of both these surveys.

The final planning of the egg survey was published in the 2019 WGMEGS report (ICES 2019a). The Triennial Mackerel and Horse Mackerel Egg Survey was carried out during February - July 2019. Details on the survey were provided in the 2019 report. Updates with finalized results on mackerel fecundity are also delivered 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 2019.

Since 2004 due to requests 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 timeframe 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 – 2016 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 finalised results are reported within this report.

Methods for daily egg production adult parameters and SSB estimates were further developed during this term for Northeast Atlantic mackerel and horse mackerel and North Sea mackerel. Development of the methods was finalised through successful cooperation of members of this WG with the Working Group on Atlantic Fish Larvae and Egg Surveys (WGALES). The cooperation resulted in a publication on POF assessment (Charitonidou et al. 2020), which provides evidence that mackerel can have up to four different batches of POFs in the ovary, showing that the traditional way of POF ageing and spawning fraction estimation in mackerel is not appropriate. WGMEGS will investigate the new method of spawning fraction estimation and assess the difference between the traditional (utilised for the DEPM results in this report and showing huge variability) and new way of spawning fraction estimation for mackerel.

The increasing discrepancies between WGMEGS survey based estimation of mackerel SSB to results from the assessment but also other survey based mackerel stock indices lead the group to dedicate extensive work to challenge and investigate major assumptions and methods on which the estimation of the SSB index for mackerel are based. The work includes investigation on representativeness of spatial and temporal coverage of spawning activity, methods of daily and total egg production estimation, and on methods and assumptions for potential fecundity and atresia estimation. Part of this work is done in cooperation with the ICES Working Group on Improving the use of Survey Data for Assessment and Advice (WGISDAA, see their corresponding reports e.g. ICES 2018, ICES 2020). This work is still in progress and will carry on during the next WGMEGS term 2021-23.

In 2020 the planning for the North Sea mackerel egg survey was conducted prior to and discussed and finalized during the WGMEGS meeting. The survey was due to be executed in May and June 2020 with the participation of Denmark and The Netherlands. Cindy van Damme was appointed to coordinate the survey. However, due to the COVID19 pandemic, the survey had to be cancelled and has been postponed until 2021.

3.2 Western and Southern egg survey in 2019

3.2.1 Countries and Ship Participating

The 2019 mackerel and horse mackerel egg survey was designed to cover the whole spawning area of the two species, within six sampling periods of differing geographical coverage (ICES 2019b, SISP 6). Nine institutes from eight countries, Germany, Ireland, Netherlands, Scotland, Portugal, Spain (IEO), Spain (AZTI), Faroes, and Norway participated. The return of Norway was welcomed and provided additional coverage in the northern area compared to 2016. Survey dates, as well as vessel details, can be found below in table 3.2.1.1.

In 2019 a total of eighteen individual surveys took place, totaling 343 days. Individual contributions were Portugal (37 days), IEO (51 days), AZTI (33 days), Germany (29 days), Netherlands (37 days), Ireland (40 days), Scotland (82 days), Faroes (14 days) and Norway (20 days). This is a decrease in the number of survey days compared to 2016. The number of survey days are comparable to 2013 (341 days) and 2010 (334 days).

Table 3.2.1.1: Participating countries, vessels, areas covered, dates and sampling periods of the 2019 surveys

Country	Vessel	Area	Dates	Period
Portugal	Noruega	Portugal	Jan 23rd – Feb 28th	2
Ireland	Celtic Explorer	West of Ireland, Celtic sea, Biscay,	February 8th – 28th	2
	Corystes	West of Ireland, west of Scotland	June 9th – 29th	6
Scotland	Scotia	West of Scotland	February 24th – Mar 1st	2
	Altaire	West of Scotland, west of Ireland	March 19th – Apr 1st	3
	Altaire	West of Scotland	April 16th – 29th	4
	Scotia	West of Scotland, west of Ireland	May 8th – 30th	5
	Altaire	West of Scotland, west of Ireland, Celtic sea, Biscay	July 1st – 23rd	7
Spain (IEO)	Vizconde de Eza	Cantabrian sea, Galicia, southern Biscay	March 14th – April 5th	3
	Vizconde de Eza	Cantabrian sea, Galicia, Biscay	April 9th – May 4th	4
Spain (AZTI)	Ramon Margalef	Northern Biscay	March 19th – 30th	3
	Ramon Margalef	Biscay, Cantabrian sea	May 3rd - 25th	5
Germany	Dana	Celtic sea, west of Ireland	March 29th – April 12th	3
	Dana	Celtic sea, west of Ireland, west of Scotland	April 15th – 30th	4
Netherlands	Tridens	Northern Biscay, Celtic sea	May 4th – 24th	5
	Tridens	Biscay, Celtic sea	June 5th – 23rd	6
Norway	Brennholm	Faroes & Norway	June 9th – 29th	6
Faroes	Magnus Heinason	Faroes, Iceland	May 23rd – June 5th	5

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

The survey was split into six sampling periods. The deployment of vessels to areas and periods is summarized in Table 3.2.1.1.

Sampling in both the southern and western areas commenced in period 2 with Portugal sampling in ICES division 9a, and Ireland and Scotland surveying from the west of Scotland to mid-Biscay. Surveying in division 9a was only carried out in period 2. Period 3 saw the survey continue in the western area with surveying extended westwards into the Cantabrian Sea and Galicia, and continuing further north in Biscay, west of Ireland and west of Scotland. Sampling continued in all areas in period 4. In period 5 sampling was discontinued in Galicia, but continued from the eastern Cantabrian Sea northwards. 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 survey emphasis has been focused on full area coverage and delineation of the spawning boundaries. Cruise leaders have 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 (Figure 3.2.2.1):

Period 2 – In period 2 Portugal carried out a DEPM survey in ICES Division 9a from Cadiz to Galicia, mainly targeting the southern horse mackerel stock. This survey is designed for this purpose but it provides mackerel egg and adult samples as well. 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 2010 and 2013 MEGS survey and the Winter 2014/Spring 2015 industry surveys indicated that early spawning in the western area was set to continue. In 2016 however peak spawning took place in May / June. It was decided for 2019 that, despite the result from 2016, sampling in the western area should once again commence in early February. Sampling in this area was undertaken by Ireland (west of Scotland, west of Ireland, Celtic Sea and Biscay) and Scotland (northwest Ireland and west of Scotland).

Poor weather was encountered in the western area at the start of the period however survey coverage was good. In the southern area Portugal sampled 531 stations with no interpolations. In the western area 115 stations were sampled, 20 were interpolated and there were 14 replicate samples.

Period 3 – During period 3 Biscay, the Cantabrian Sea and Galicia were surveyed by Spain (IEO and AZTI). The German survey was delayed due to problems with their preferred vessel and the requirement to charter a replacement. The survey was conducted in the Celtic sea and west of Ireland. Scotland surveyed west of Scotland and northwest of Ireland.

372 stations were sampled, 16 were interpolated and there were 39 replicate samples, the majority of which were completed in the Cantabrian Sea.

Period 4 – This period was covered by three surveys. Scotland was operating to the west of Scotland and northwest of Ireland on board a commercial vessel, Germany to the west of Ireland, Celtic Sea and northern Biscay. Spain (IEO) sampled southern Biscay, the Cantabrian Sea and Galicia.

The most surprising fact from this period were the large numbers of eggs encountered by Scotland to the north of the Hebrides. Scotland were successful in securing the northern boundary however.

319 stations were sampled and 55 were interpolated. There were 53 replicate samples taken primarily from the Cantabrian Sea.

Period 5 – Period 5 was covered by four surveys sampling 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. Scotland sampled west of Ireland and Scotland as well as Rockall and Hatton Bank, while Faroes sampled from the north of Scotland to Faroes.

Iceland had planned to participate in the 2019 survey and would have sampled during this period. Due to financial difficulties however they had to withdraw. Faroes agreed to modify its survey area and cover the entire northern section, sampling alternate transects. Faroes were also asked to extend their survey east of Faroes to monitor the stations where Scotland recorded large egg numbers in period 4. Egg numbers in that area were quite low in period 5. Due to poor weather at the end of their survey the Faroese were unable to close the northern boundary however egg numbers in this area were low.

Similar to 2016, and despite all the effort deployed in this period, the western and northern boundaries remained unsecured. This year however the numbers of eggs recorded on the boundary stations were much lower than in 2016.

407 stations were sampled and 184 were interpolated. Sixteen replicate samples were collected.

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 Norway sampled to the north of Scotland. Netherlands successfully delineated the southern boundary of spawning for this period.

Once again there were issues securing boundaries to the West and the North, however boundary egg counts were not as high as in Period 5, or as high as those encountered in 2016.

418 stations were sampled, with 210 interpolated and there were 6 replicate stations.

Period 7 – This period was covered entirely by Scotland sampling mainly on alternate transects in the area from 47°45N in the South to the most northern transect on 63°15N. The southern boundary of sampling was delineated at 49°N and only very low levels of spawning were observed during this period. Due to the low numbers of eggs encountered it was possible to conduct short transects with few stations straddling either side of the 200m contour line. Consequently Scotland was able to sample a number of stations to the north of Shetland to ensure spawning had concluded in this area.

145 stations were sampled, 60 were interpolated and there was 1 replicate.

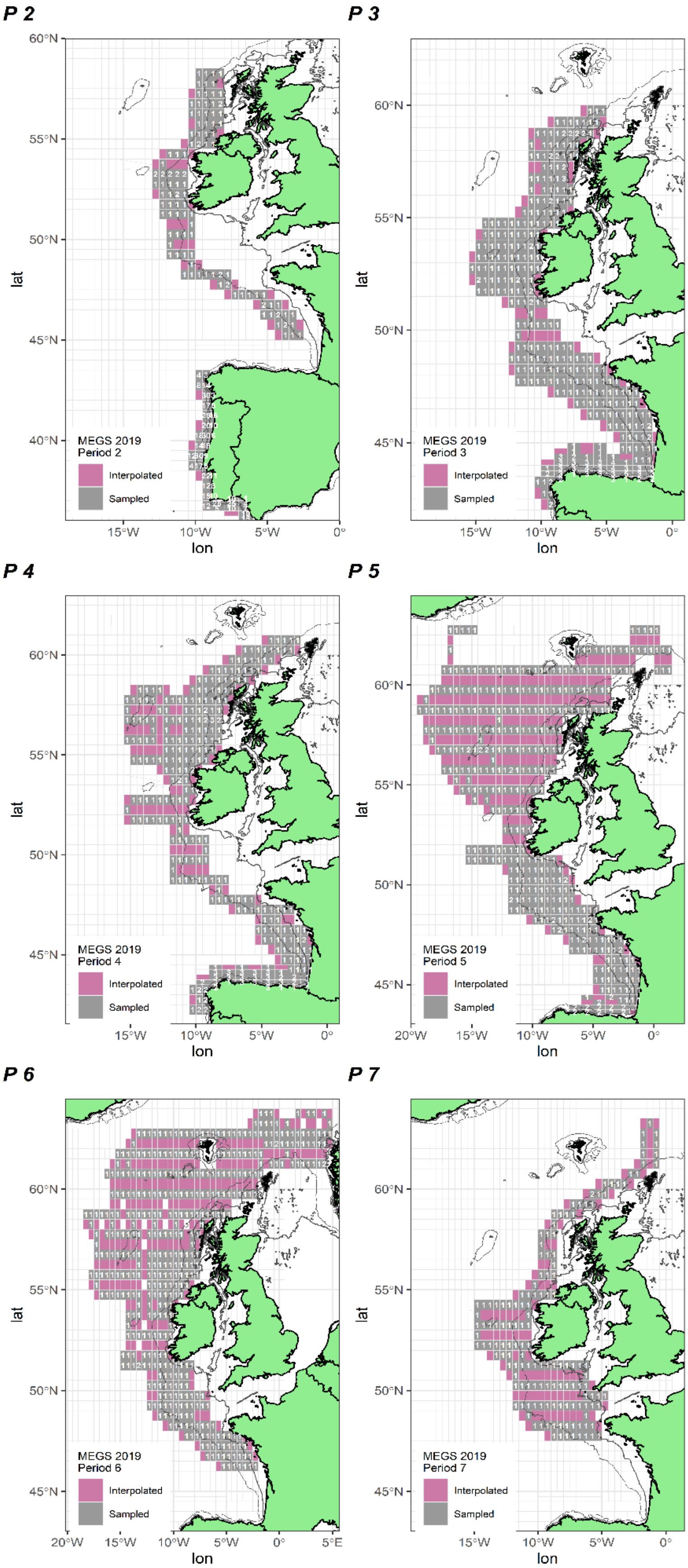


Figure 3.2.2.1: Survey coverage by period. Grey stations were sampled while purple is interpolated.

3.2.3 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. The 2019 egg survey was designed to reach a broad spatial and temporal coverage in each of the sampling periods. To achieve this, plankton hauls per half degree longitude were conducted on mostly alternating transects covering the complete spawning area. In core spawning areas, sampling was intensified and all transects were covered (Figure 3.2.2.1). 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 2310 plankton samples were collected and sorted. Mackerel, horse mackerel, hake and ling eggs were identified and the egg development stages determined. 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 1416 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 3.4.3. 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 SISP 5 and SISP 6 (ICES, 2019b; ICES 2019c).

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, however due to the low number of adult horse mackerel caught it was decided not to pursue this work.

3.2.4 Sampling Strategy for Southern Horse Mackerel in ICES division 9a

The Portuguese (IPMA) 2019 DEPM survey directed at southern horse mackerel (PT-DEPM19-HOM) was carried out on board RV Noruega between the 23rd January and the 28th February (Period 2), as scheduled. It covered the area between Cape Trafalgar and Cape Finisterre (ICES division 9a), the survey plan having been totally achieved.

Plankton surveying for obtaining egg density estimation and spawning area delimitation was conducted along transects perpendicular to the coast and spaced 12 nautical miles apart. The sampler used was a modified CalVET structure with a CTDF probe (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 pre-defined 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 96% ethanol (for Trachurus spp. and

Scomber spp. genetic analyses). Concurrently, CUFES samples (335 µm mesh size) were collected (every 3 nmiles) along the path between the vertical plankton tows, as an auxiliary sampler for adaptive area surveying. Also surface temperature, salinity and fluorescence data were recorded continuously using a probes associated to the water pumped by the CUFES sampler. During the survey, a total of 531 CalVET and 723 CUFES samples were collected.

Surveying for horse mackerel took place simultaneously with the ichthyoplankton sampling, 1-2 fishing hauls were performed opportunistically during the survey using bottom trawl gear. On the whole, 56 fishing hauls were obtained on board the research vessel, 20 hauls (37.5%) having been positive for horse mackerel. Sampling was complemented with fish from the bottom trawl and purse seine fleets at several harbours along the coast from the same period when the research vessel was surveying each area: a total of 15 samples were obtained at the harbours of Matosinhos, Aveiro, Figueira da Foz, Peniche, Sesimbra, and Portimão/Olhão. For each trawl, complete biological sampling of a random sample of 60 fish was undertaken: individual biological information was recorded, a minimum of 30 ovaries per trawl were preserved in 4% buffered formaldehyde for histology and fecundity estimation, and otoliths were collected for ageing. Extra effort was taken to obtain females with hydrated ovaries for the fecundity estimation (F), as well as to also collect fish of smaller sizes to obtain a maturity ogive.

Mackerel sampling was also carried out whenever possible to support the estimations undertaken by WGMEGS, the biological data and sub-samples of the preserved ovaries having been sent to all partner institutes for the screening analysis and the fecundity calculations (Angelico et al. 2019).

Details on the biological sampling, laboratory work and parameters calculation are described in the MEGS Manual for AEPM and DEPM fecundity (ICES 2019b).

3.3 Hydrography 2019 report

3.3.1 Southern Horse Mackerel DEPM Survey

The hydrography and plankton surveying during IPMA's days at sea took place between the 25th January and the 25th February. Accordingly, the weather and hydrographic conditions encountered were the typical for the winter time which can be shortly described by the maps in figure 3.3.1.1. Sea surface temperature varied from 12.5°C, in the northern shelf, to 17°C, in the eastern region of the southern coast. Water temperature in the whole western shelf was below 14°C and in the more northern region a large patch of colder water (~12.5-13°C) was very evident occupying the whole platform from the Galician rias to Aveiro. This plume was also noticeable in the surface coastal salinity distribution reflecting the winter freshwater runoff contribution. In the same region associated to these nutrient rich waters, some spots of higher fluorescence were apparent, indicating local phytoplankton blooming. In the southern coast, the region over the continental shelf was occupied mainly by water with temperature between 14.5°C and 15.5°C; river runoff and peaks of chlorophyll were not evident. The CTD profiles (not shown) indicated a characteristic winter mixed water column, with only occasional saline stratification in the regions of high influence of water from continental origin.

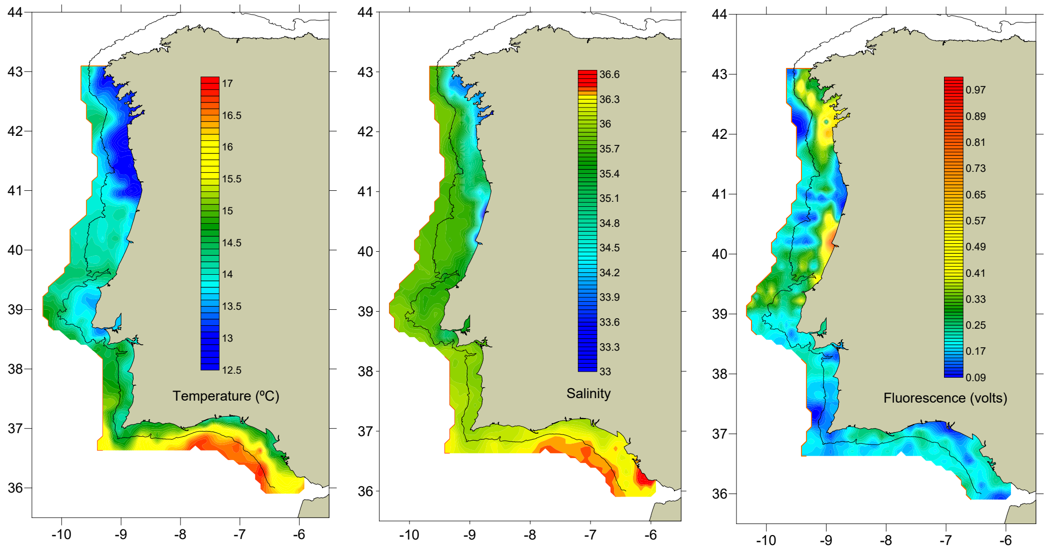
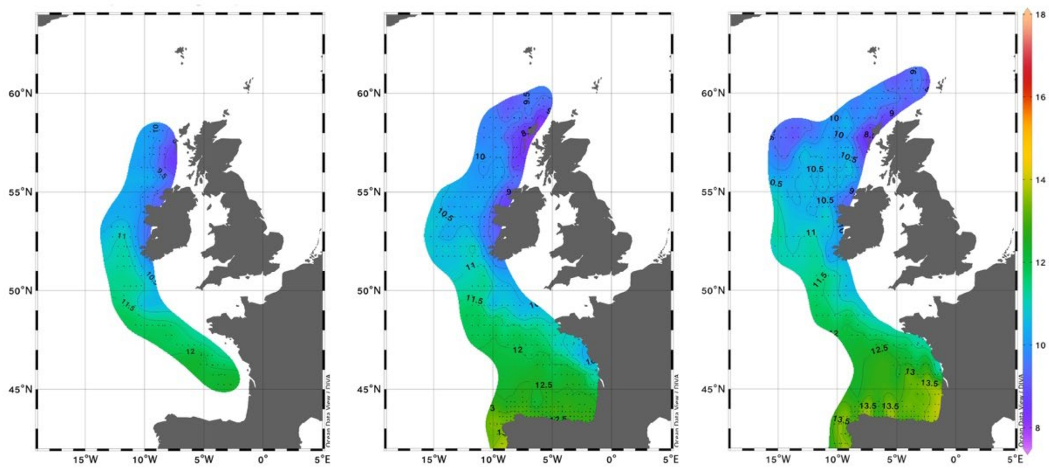


Figure 3.3.1.1: Temperature (°C) (left panel), salinity (middle panel) and fluorescence (volt) (right panel) distributions using the data obtained by the sensors associated to the CUFES-EDAS system.

3.3.2 Mackerel and Western Horse Mackerel Egg Survey

The temperature values at 20 m depth are used in the calculation of the daily egg production for mackerel and horse mackerel. Horizontal distribution of those temperatures during all sampling periods are displayed in figure 3.3.2.1. Overall, temperatures at 20 m depth ranged from values < 8 °C to >17.5 °C and were very similar in their distribution to those observed during the 2016 MEGS. Lowest temperatures were always observed in the North increasing towards the South and also with progression of the sampling periods. Temperatures were almost everywhere and all the time higher than the supposed threshold minimum value of 8 °C associated to an increased probability of mackerel egg occurrence.



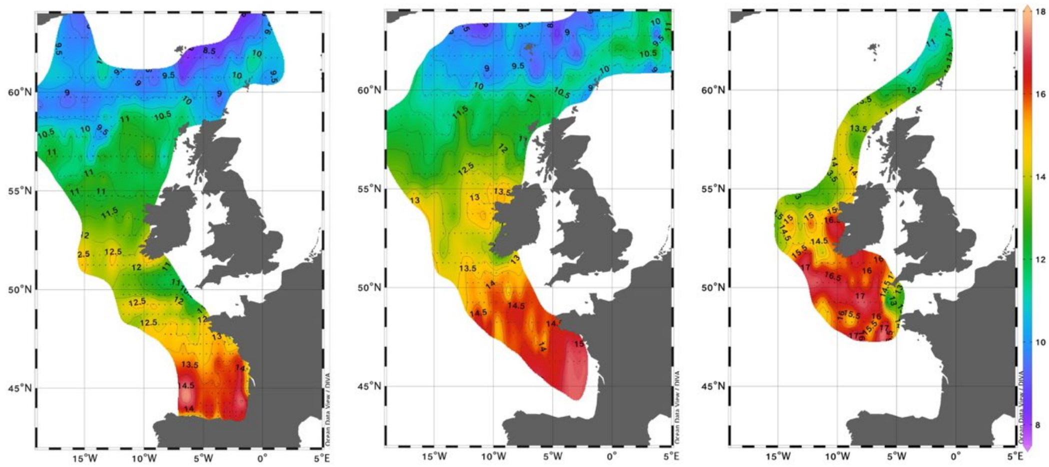


Figure 3.3.2.1: The 20 m depth temperature distribution for periods 2 – 4 (top row, left to right) and periods 5 – 7 (bottom row, left to right).

3.4 Mackerel in the western and southern spawning areas: 2019 egg survey results

3.4.1 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. An overview of mackerel spawning distribution of all periods for both the southern and western areas is presented in Figure 3.4.1.1.

Period 2 – Portugal started the 2019 survey series on January 23rd. This DEPM survey is mainly targeting the southern horse mackerel stock and is designed for this purpose, but it provides mackerel egg samples as well. The survey is usually undertaken between Cadiz and the Galicia (ICES division 9.a) and few mackerel eggs were found. Period 2 also marks the commencement of the western area surveys. In the west MEGS once again started sampling earlier in February than would have been the case prior to the 2010 and 2013 surveys. Sampling was undertaken by Ireland (West of Scotland, west of Ireland, Celtic Sea, Biscay), and Scotland (West of Ireland and West of Scotland) (Fig. 3.4.1.2). Similar to 2016 however, and in marked contrast to 2010 and 2013, no sign of spawning was found during this period in the Celtic Sea or Bay of Biscay. Instead very low levels of spawning were found north of 54.5°N by both the Scottish and Irish surveys. In 2019 the start of mackerel spawning in the western area was captured. The eggs that were collected were close to the 200m contour line.

Period 3 – In period 3 the German vessel operated to the West of Ireland and Celtic Sea. Northwest Ireland and the West of Scotland was covered by Scotland. The Bay of Biscay, Cantabrian Sea and Galicia were covered by Spain (IEO and AZTI). In contrast to 2016 large numbers of eggs were found in the Cantabrian Sea. High egg numbers were found close to the 200m contour in Biscay and to the west of Ireland. Low numbers were recorded northwest of Ireland and west of Scotland. All boundaries were successfully delineated (Fig. 3.4.1.3).

Period 4 – In period 4 sampling in the western area was carried out by IEO, Germany and Scotland, with the area covered running from Galicia in the south to Shetland in the north (Fig. 3.4.1.4). Egg numbers in the Cantabrian Sea were still quite high, again much higher than in 2016. Egg numbers were moderate to high in Biscay and the Celtic sea, with low numbers recorded west of Ireland. Again all spawning occurred close to the 200m contour. Egg numbers around Rockall were very low, but large numbers of eggs were found following the 200m contour from the Hebrides north to Shetland. The Scottish survey was able to close this northern boundary however. Once again all boundaries were successfully delineated.

Period 5 –In period 5 four 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 as well as Rockall and Hatton Banks. Faroes and Iceland had been scheduled to survey north of this, however unfortunately Iceland had to withdraw from the survey. Faroes agreed to cover the whole area and also surveyed the area east of Faroes where large egg numbers were found by Scotland in period 4 (Fig. 3.4.1.5). Low egg numbers were found in the Cantabrian Sea and Biscay. Elsewhere within period 5 spawning activity was very widely dispersed with Scotland and Faroes encountering mackerel eggs spread over a large area in northern waters. Northern and north-western boundaries were not delineated during this period, however egg numbers encountered at the boundary stations were much lower than those found in 2016.

Period 6 –This period was covered by Ireland, Netherlands and Norway (Fig. 3.4.1.6). Netherlands delineated the spawning boundary in the south at 48°N. Issues continued with eggs on the boundaries in the northwest but egg numbers in this area were very low, again much lower than in 2016. Norway successfully delineated the northern boundary to the north of Faroes. Norway also found low numbers of eggs to the north of Shetland, as far as 64°N.

Period 7 –Period 7 was surveyed entirely by Scotland, sampling on alternate transects, from 47°45N in the South to the most northerly station at 63°15N (Fig. 3.4.1.7). The southern boundary was delineated at 49°N and only very low levels of spawning were observed during this period, mainly to the west of Ireland with very little reported for the Celtic Sea. Due to the low numbers of eggs encountered the Scottish survey was able to travel northwards quite quickly and as a result were able to sample some stations north of Shetland, where very few eggs were found. Similar to the 2016 survey all boundaries were delineated.

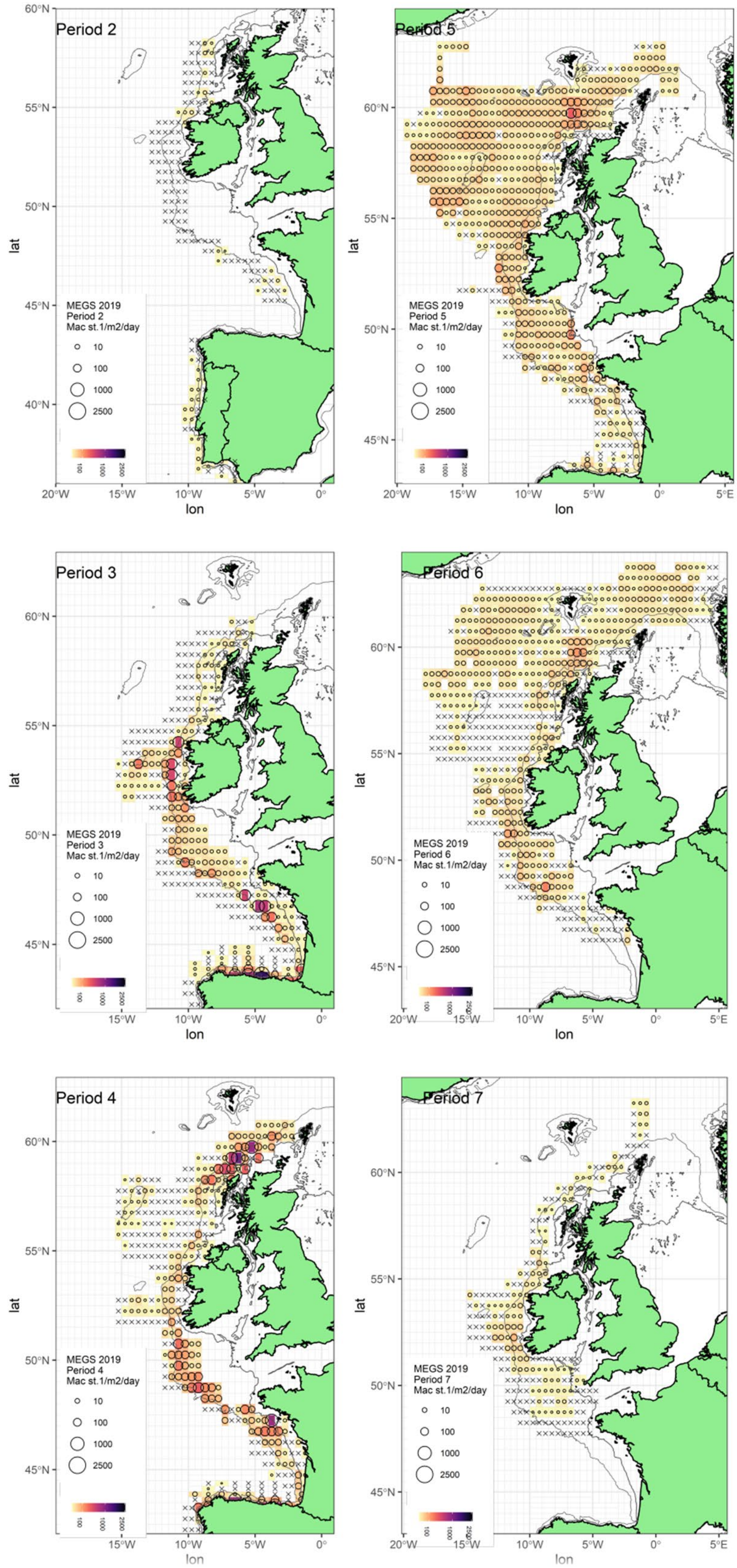


Figure 3.4.1.1: Mackerel egg production by half rectangle for all periods. Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

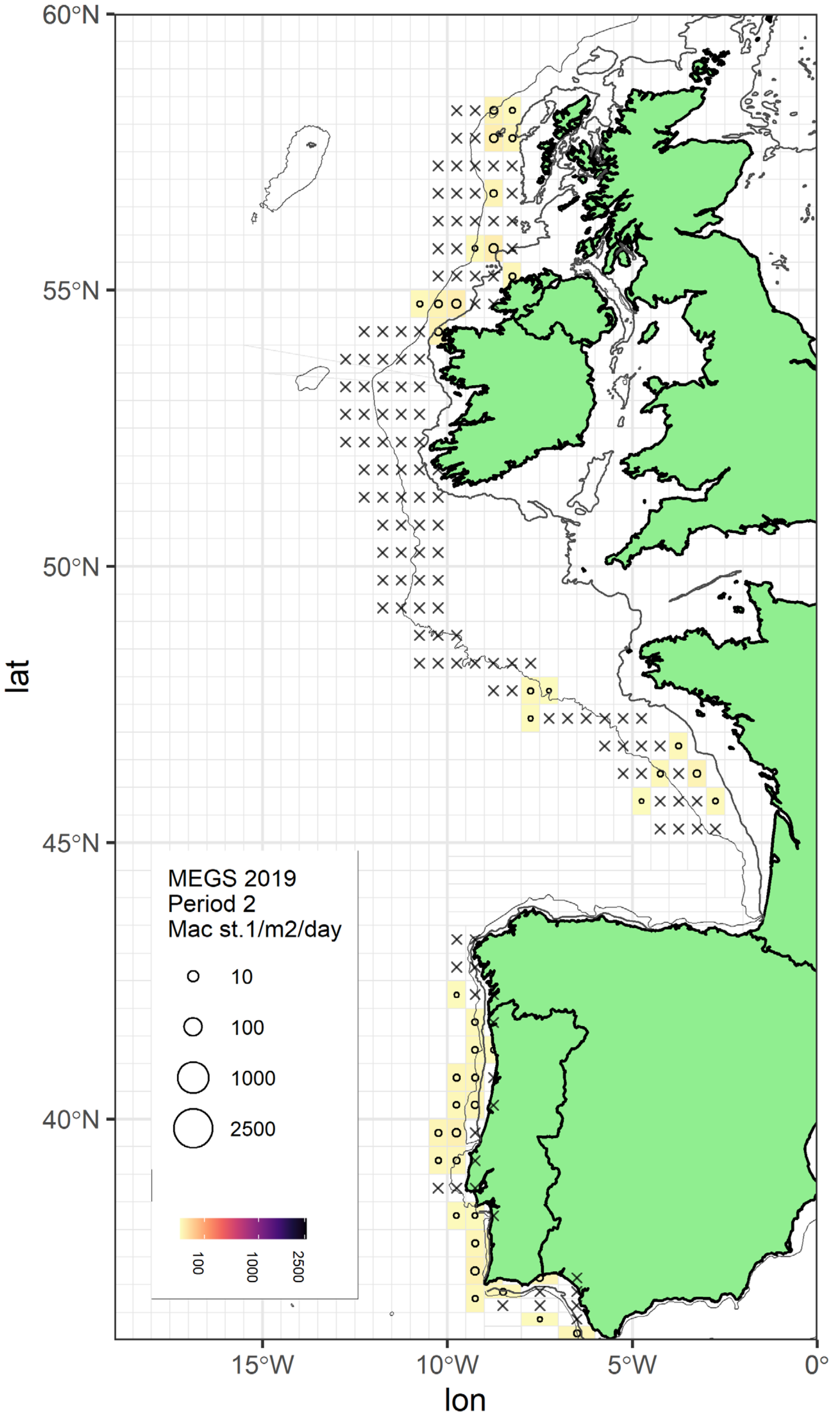


Figure 3.4.1.2: Mackerel egg production by half rectangle for period 2 (Feb 5th – Mar 3rd). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

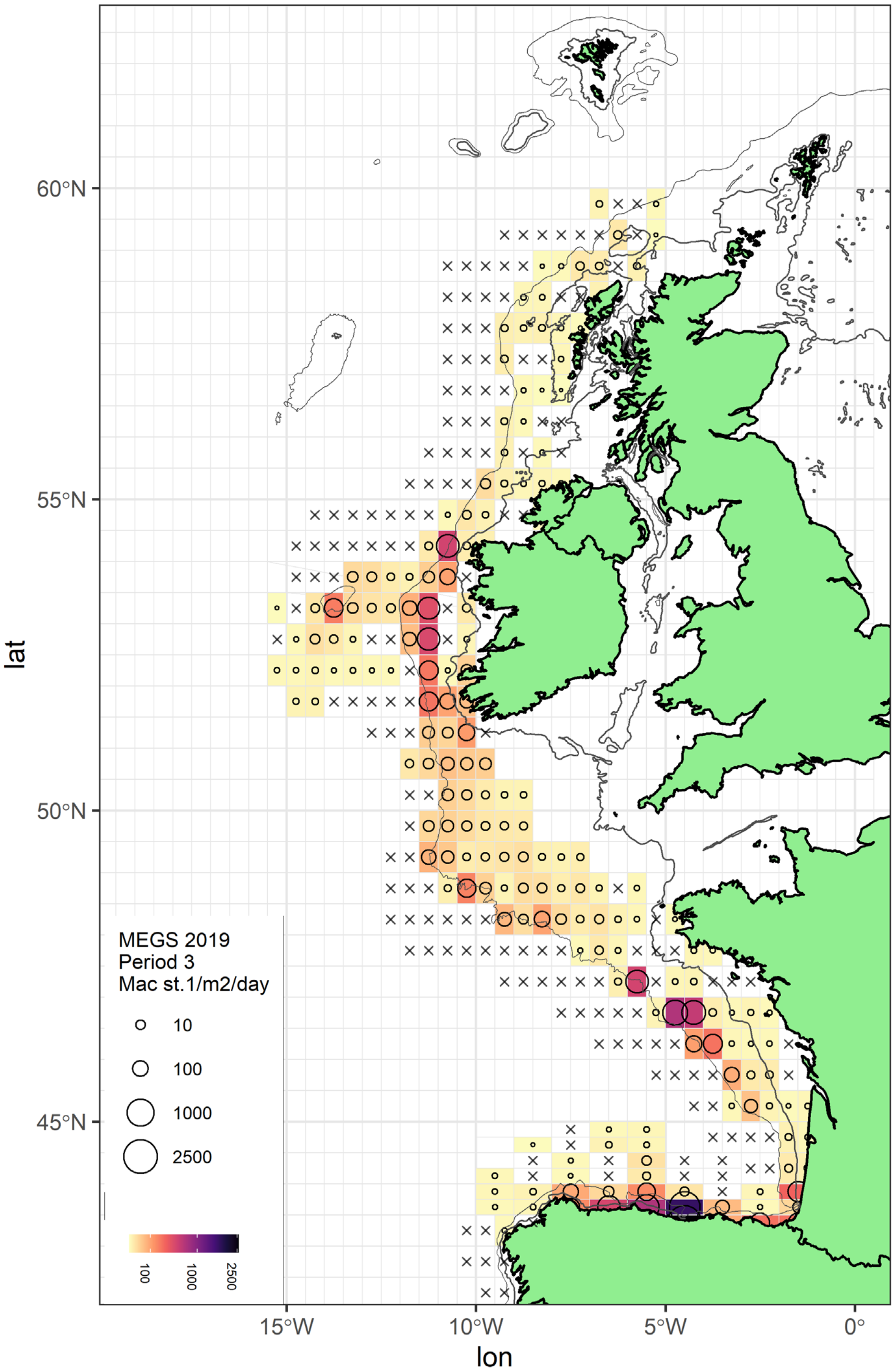


Figure 3.4.1.3: Mackerel egg production by half rectangle for period 3 (Mar 4th – Apr 12th). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

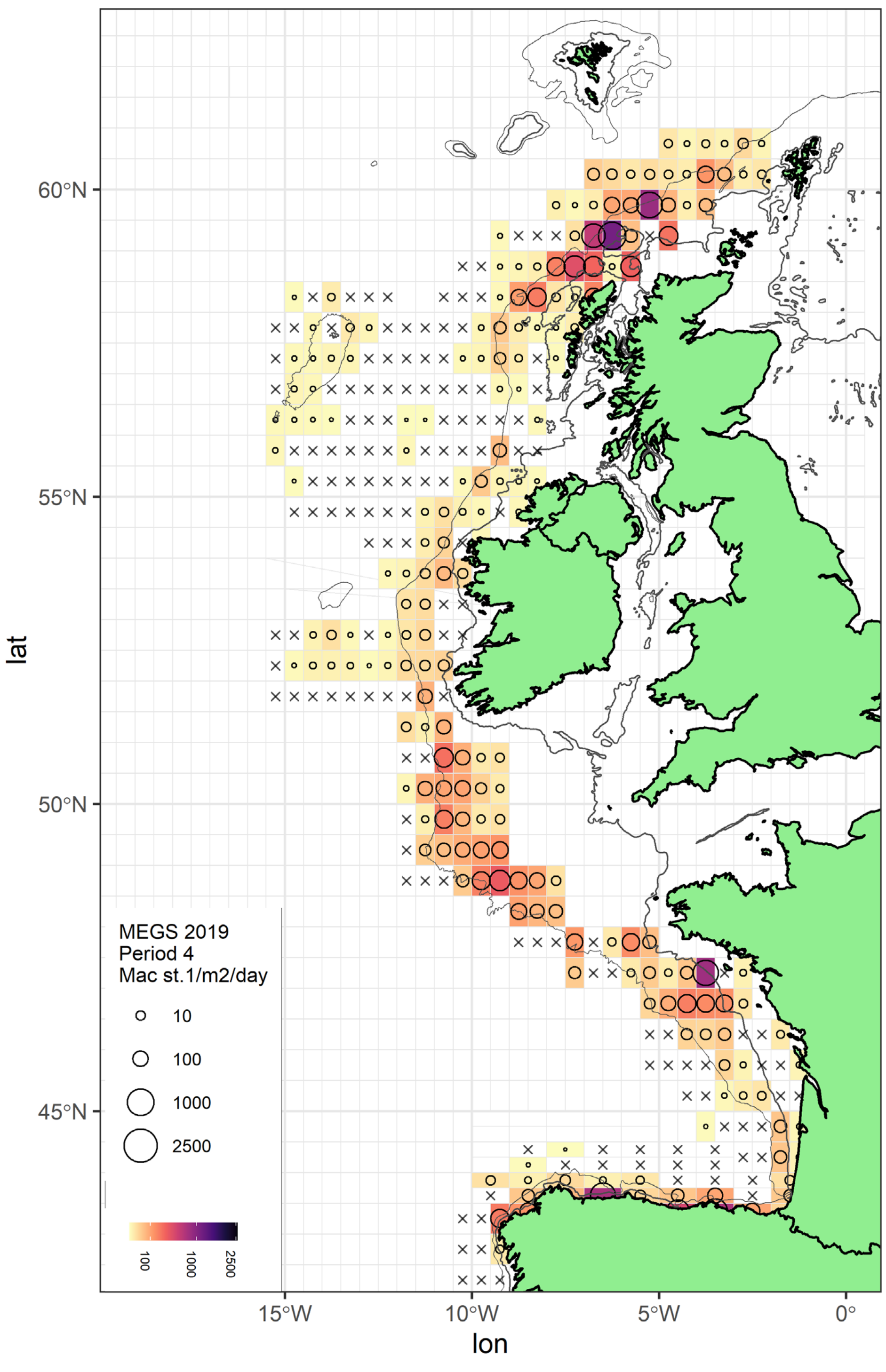


Figure 3.4.1.4: Mackerel egg production by half rectangle for period 4 (Apr 13th – May 3rd). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

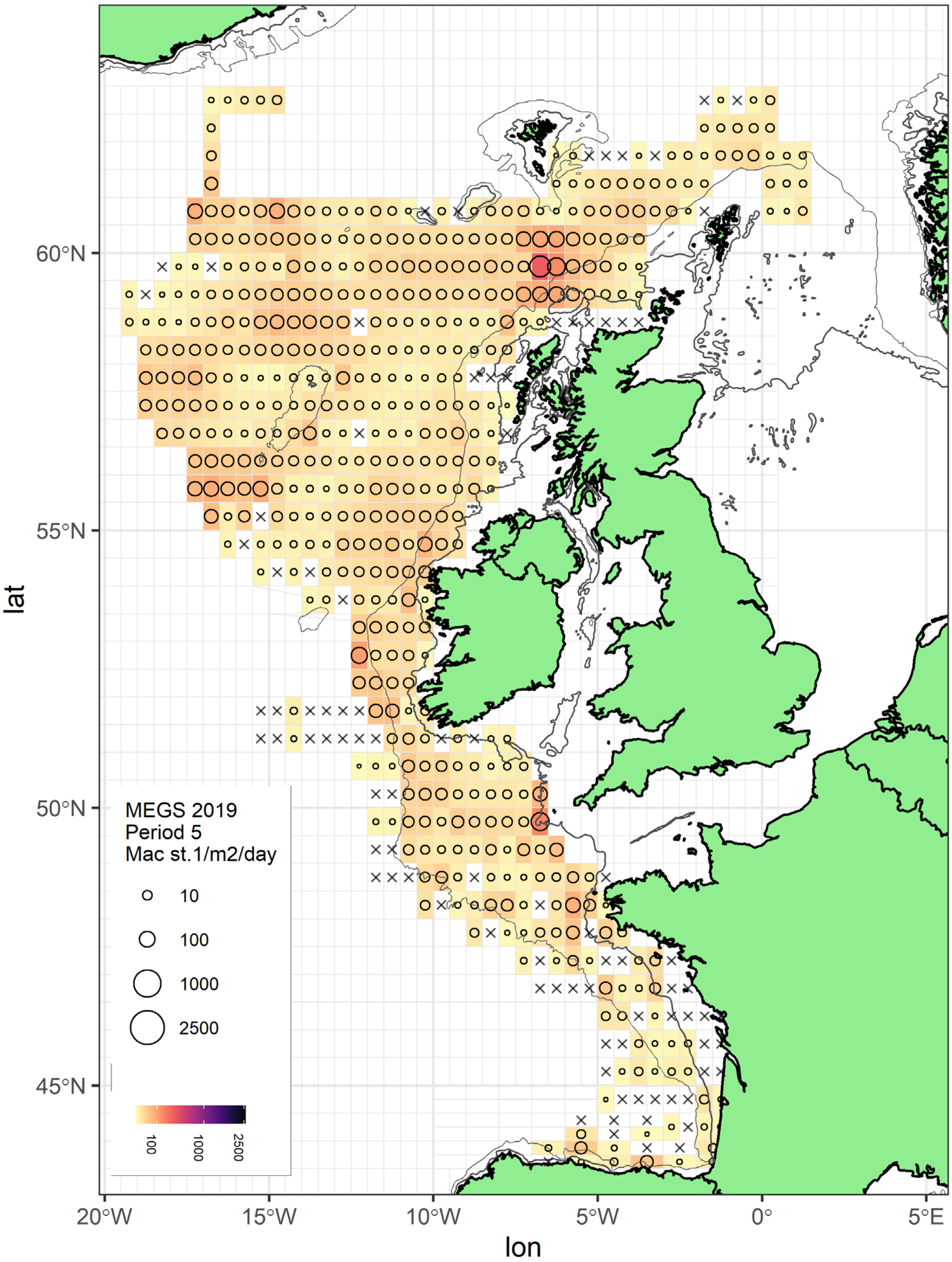


Figure 3.4.1.5: Mackerel egg production by half rectangle for period 5 (May 4th – June 5th). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

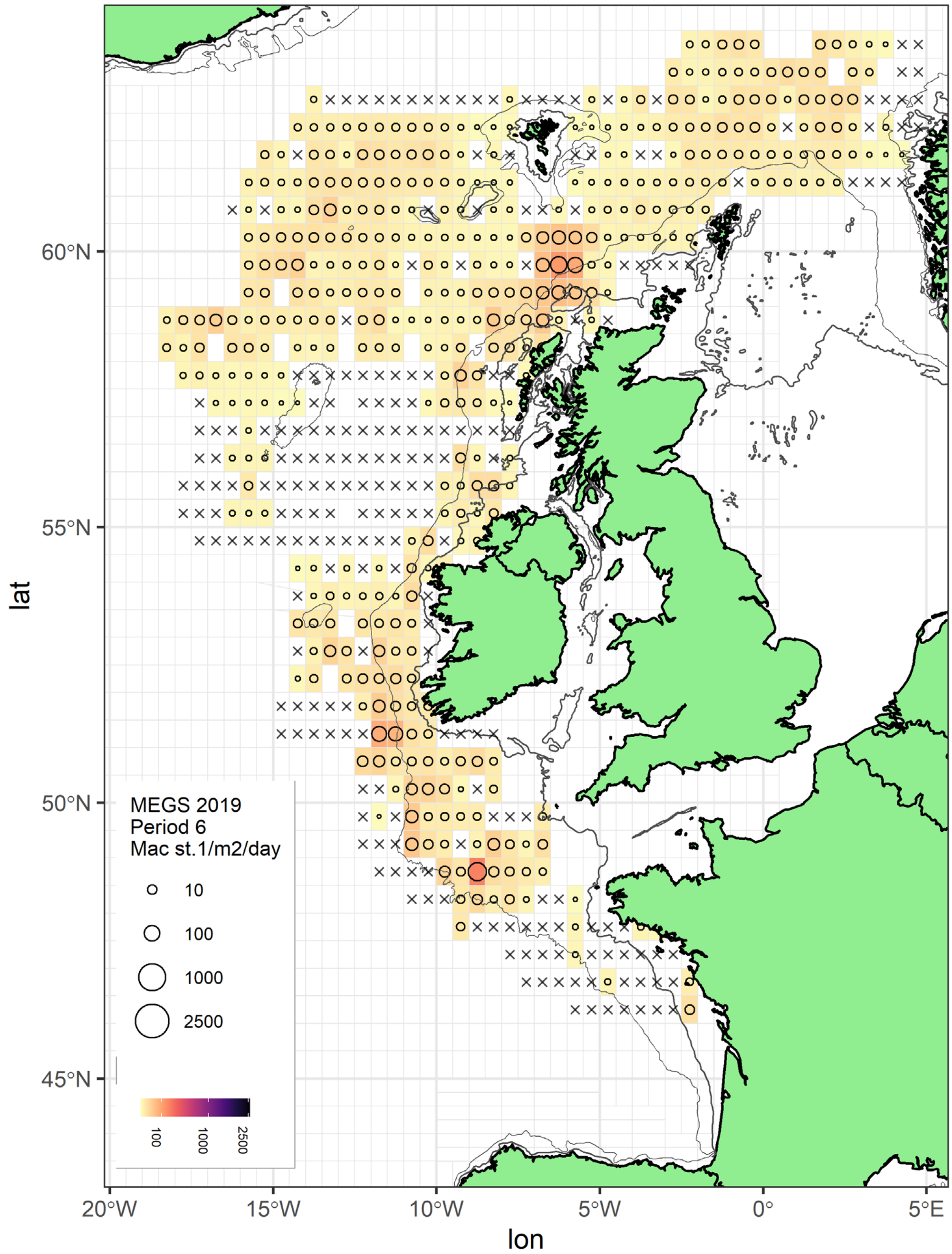


Figure 3.4.1.6: Mackerel egg production by half rectangle for period 6 (June 6th – 30th). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

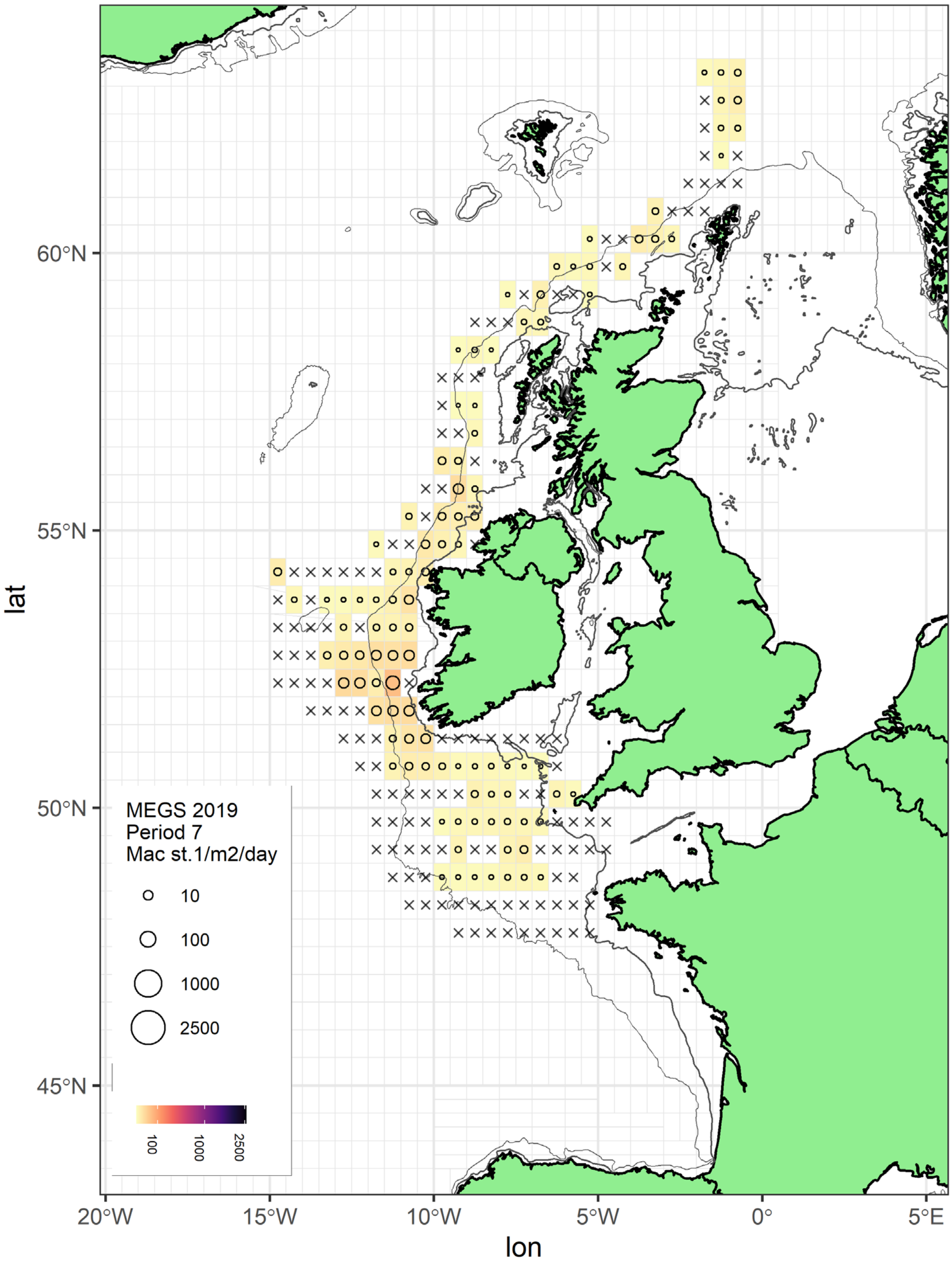


Figure 3.4.1.7: Mackerel egg production by half rectangle for period 7 (July 1st – 31st). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

3.4.2 Egg production in Northeast Atlantic mackerel

3.4.2.1 Stage I egg production in the western area

2010 provided an unusually large spawning event early in the spawning season, while 2013 yielded an even larger spawning event indicating that spawning was probably taking place well before the nominal start date of 10th February (day 42). In 2016 the first survey commenced on February 5th which is five days prior to the nominal start date. That year, however, mackerel migration was later and slower than that recorded in the previous two surveys. The pattern in 2019 followed that of 2016 with no early peak spawning being recorded (Fig. 3.4.2.1.1 & Table 3.4.2.1.1). In 2019, however, peak spawning was found to have occurred in period 4, rather than period 5 as was the case in 2016 (Figure 3.4.2.1.2). Unlike 2016 when concern was expressed that survey coverage may have underestimated the total egg production estimate, area coverage in 2019 was much better. The expansion observed in western and north-western areas during periods 5 and 6 in 2016 was once again observed during 2019, however egg numbers were not as large as in 2016. During period 5, the northern and north-western boundaries were once again not delineated, however the exploratory egg surveys carried out in this region during both 2017 and 2018 provide robust evidence that while some spawning has been missed the loss of egg abundance is not sufficiently large to significantly impact the SSB estimate (ICES, 2019a)

The nominal end of spawning date of the 31st July is the same as was used during previous survey years and the shape of the egg production curve for 2019 does not suggest that the chosen end date needs to be altered. The total annual egg production (TAEP) for the western area in 2019 was calculated as $1.22 * 10^{15}$ (Table 3.4.2.1.1). This is a 20% reduction on the 2016 TAEP estimate which was $1.55 * 10^{15}$.

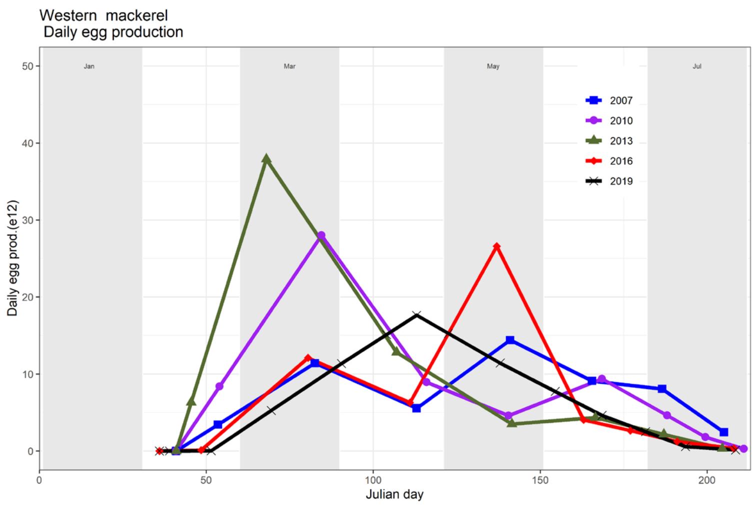


Figure 3.4.2.1.1: Annual egg production curve for mackerel in the western spawning component. The curves for 2007, 2010 2013 and 2016 are included for comparison. Months of January, March, May and July are highlighted in grey background

Table 3.4.2.1.1: Western estimate of mackerel total stage I egg production by period using the histogram method for 2019

Dates	Period	Days	Annual stage I egg production * 10 15
	Pre 2		**0**
Feb 11th – Mar 1st	2	25	0.0007
Mar 2nd – 18th	2-3	17	0.09
Mar 19st – April 12th	3	25	0.28
Apr 13th – 14th	3-4	2	0.03
Apr 15th – April 30th	4	16	0.28
May 1st – 3rd	4-5	3	0.05
May 4th – May 31st	5	28	0.32
Jun 1st – 5th	5-6	5	0.04
Jun 6th – June 28th	6	23	0.11
June 29th – July 1st	6 – 7	3	0.008
July 2nd – July 22nd	7	21	0.01
July 20th – July 31st	Post 7	12	0.004
Total	1.22		
CV	20%		
Variance	6.09*e28		
Data CV	2.22		

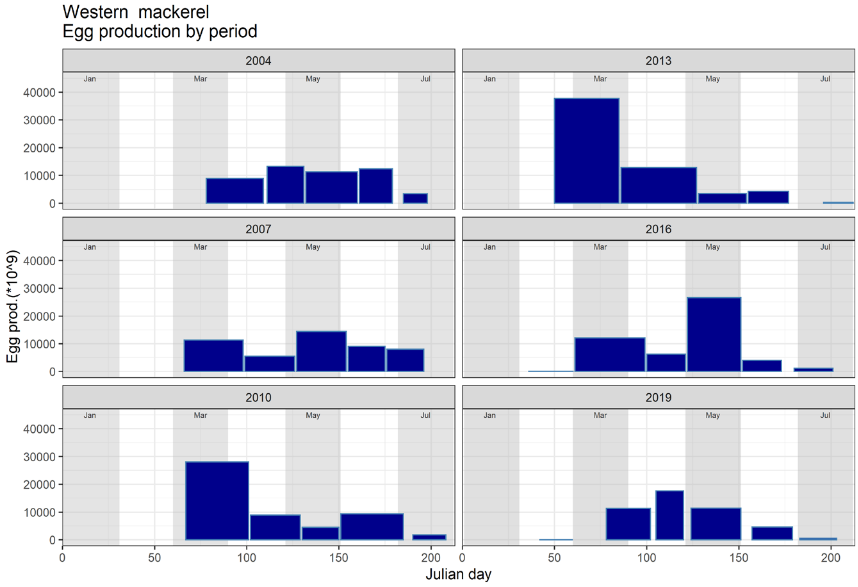


Figure 3.4.2.1.2: Egg production by period for mackerel in the western spawning component. Months of January, March, May and July are highlighted in grey background

3.4.2.2 Stage I egg production in the southern area

The start date for spawning in the southern area was the 23rd January (Table 3.4.2.2.1). The start date of the Portuguese period 1 survey in division 9.a was delayed by around 1 week. As a result, the survey dates aligned more closely to period 2. It was subsequently reclassified within period 2 and survey period 1 was removed. Sampling in the Cantabrian Sea where most of the spawning occurs within the Southern area commenced 6 days later than in 2016 on the 14th March. The same end of spawning date of the 17th July was used again this year and the spawning curve suggests that there is no reason for this to change (Fig. 3.4.2.2.1). As in 2013 the survey periods were not completely contiguous, and this has been accounted for (Figure 3.4.2.2.2 &Table 3.4.2.2.1). The provisional total annual egg production (TAEP) for the southern area in 2019 was calculated as **4.23 * 10^{14}**(Table 4.3.2.1). This is an 88% increase on the 2016 TAEP estimate which was only 2.25 * 10^{14}.

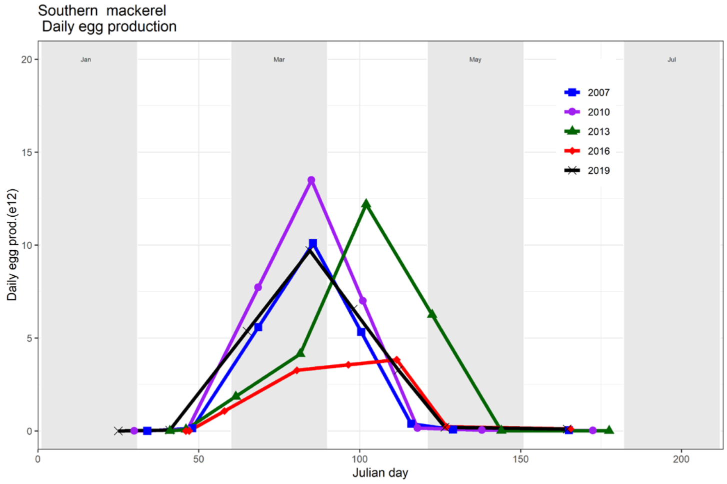


Figure 3.4.2.2.1: Annual egg production curve for mackerel in the southern spawning component. The curves for 2007, 2010, 2013 and 2016 are included for comparison. Months of January, March, May and July are highlighted in grey background.

Table 3.4.2.2.1: Southern estimate of mackerel total stage I egg production by period using the histogram method for 2019.

Dates	Period	Days	Annual stage I egg production x 10^{14}
	1	No sampling	
Jan 23rd – Feb 26th	2	35	0
Feb 27th –Mar 13th	2-3	15	0.86
March 14th – April 5th	3	23	2.23
April 6th – April 9th	3-4	4	0.26
April 10th – May 3rd	4	24	0.79
May 4th – May 8th	5	5	0.01
May 9th –July 17th	Post 5	71	0.07
Total	4.23		
CV	99%		
Variance	1.72*e29		
Data CV	1.97		

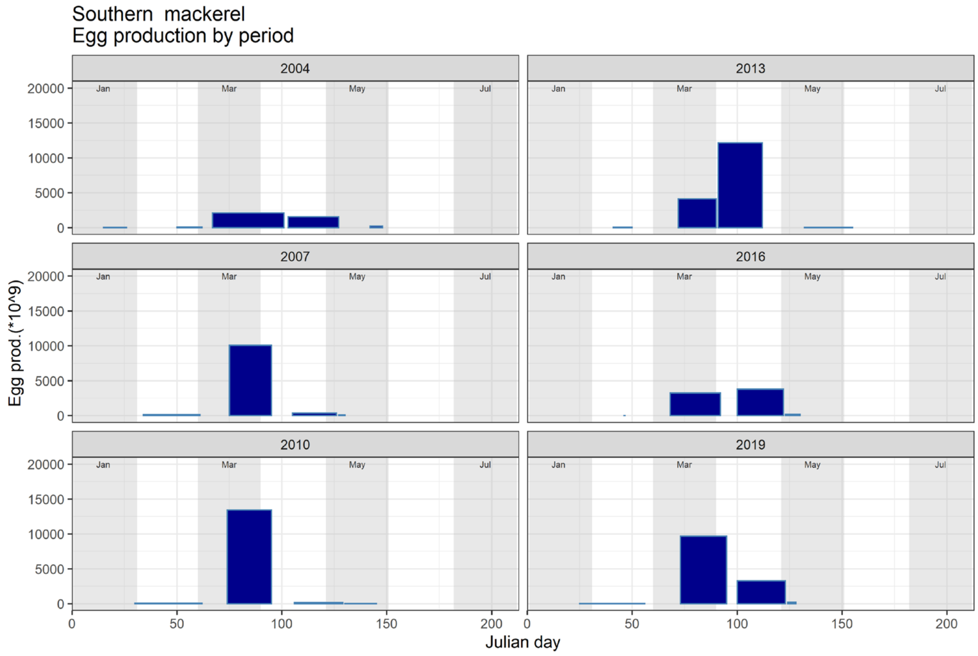


Figure 3.4.2.2.2: Egg production by period for mackerel in the southern spawning component. Months of January, March, May and July are highlighted in grey background

3.4.2.3 Total Egg production

While NEA mackerel total annual eggs production (TAEP) in the western component was recorded at the historically lowest level in the time series since 1992, the southern component's TAEP value was the fourth highest within the same time frame (Figure 3.4.2.3.1). TAEP for both the western and southern components combined in 2019 is **1.64 * 10^{15}**. This is a decrease in egg production by **7.6%** compared to the 2016 TAEP and is the second lowest value in the time series since 1992 (Figure 3.4.2.3.2 and Table 3.4.4.1).

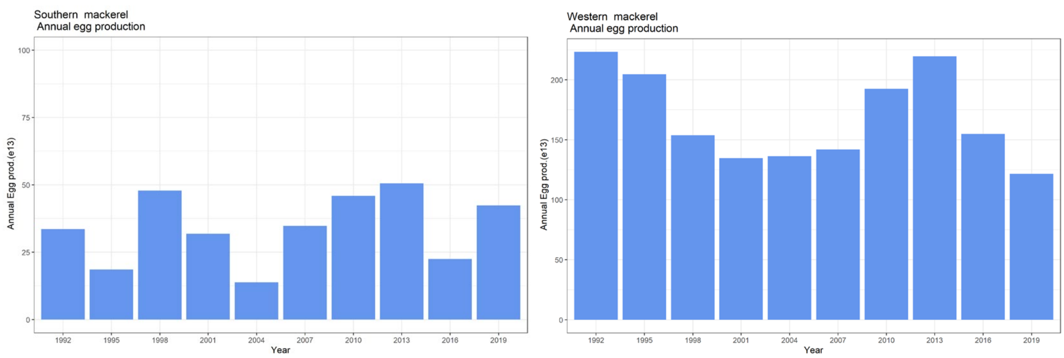


Figure 3.4.2.3.1: Annual Egg Production estimates for both southern (left) and western (right) components. 1992-2019

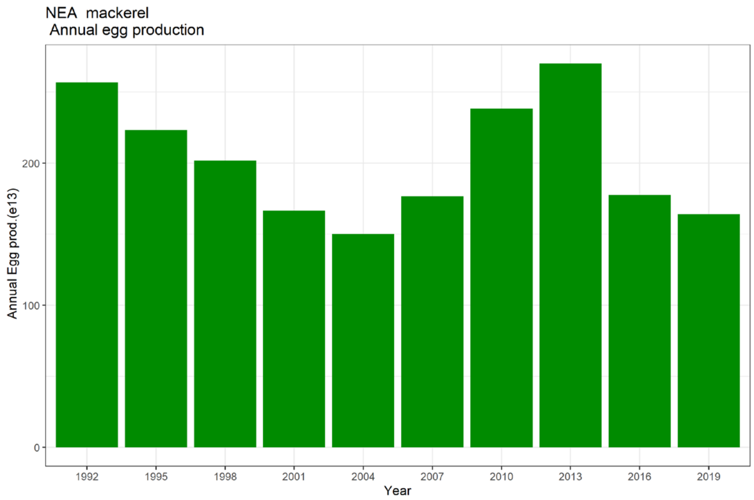


Figure 3.4.2.3.2: Combined mackerel Total Annual Egg Production estimates. 1992-2019

3.4.3 Fecundity of Northeast Atlantic mackerel

3.4.3.1 Adult sampling

During the 2019 survey 4604 adult mackerel were collected from 72 trawl hauls between 36.91°N and 62.77°N during periods 2–7. The results presented in this section refer to only females. All together 1391 ovary samples (Figure 3.4.3.1.1-A) were used for AEPM (annual egg production method) and DEPM (daily egg production method). Only 63% of the samples planned were collected (Table 3.4.3.1.1). Deviation from the initial plan was observed in all periods; the inter-annual variability in the mackerel migration as well as the probability of successful fishing effort makes it difficult to fit to the original sampling scheme.

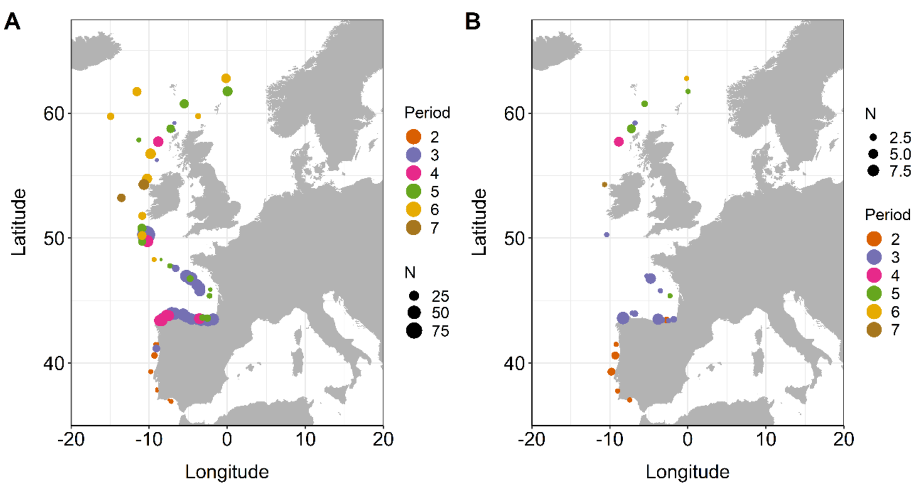


Figure 3.4.3.1.1: A: Mackerel ovary samples collected in 2019 for AEPM and DEPM by period. B: Mackerel ovary samples that were used for fecundity counting by period.

Table 3.4.3.1.1: Summary of fishing effort and number of mackerel samples collected for AEPM and DEPM during the 2019 survey. Positive and negative hauls show the number of hauls where mackerel was present or absent, respectively. Number of collected and planned ovary samples are shown both in numbers and as percentage (number of collected samples compared to planned).

Period	2	3	4	5	6	7	Total
Positive hauls	**12**	**26**	**8**	**14**	**10**	**2**	**72**
Negative hauls	44	12	3	3	4	4	70
Ovary samples	57	703	233	156	154	47	1391
Planned	200	990	1260	225	175	100	2950
Percentage (%)	28.5	71.0	18.5	69.3	88.0	47.0	47.2

3.4.3.2 Histological screening

From the 1391 ovary samples, a total of 1364 samples were screened by histology and classified as described in the manual (ICES, 2019b; for DEPM samples see DEPM section). 1353 were valid for further analysing. The remaining samples were not analysed because of various technical issues. From the 1353 samples analysed (Figure 3.4.3.1.2), 8 % were assigned to stage 2 (early vitellogenic oocytes), 9 % to stage 3 (vitellogenic oocytes), 43% to stage 4 (migratory nucleus stage), 32% to stage 5 (hydrated oocytes), 7% to stage 1 (previtellogenic oocytes). In total only 6% of the females (Figure 3.4.3.1.1-B) were classified as pre-spawning or close to spawning (i.e. samples could be used for potential fecundity analyses), and 66 % of the females were classified as spawning. Spawning females were only used for analyses of atresia.

Migratory nucleus (4) and hydrated stages (5) were the most abundant stages in periods 3 to 6, reaching the highest values in periods 3 and 4. Stage 1 increased significantly in period 6 (Figure 3.4.3.2.1).

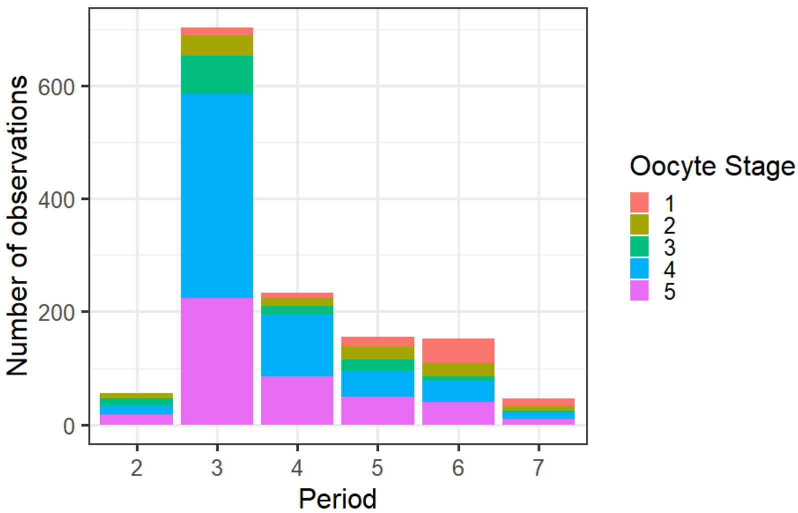


Figure 3.4.3.2.1: Number of observations of the most advanced oocyte stage by survey periods. Stage 1 = pre-vitellogenic oocytes; 2 = early vitellogenic oocytes (<400 µm); 3 = vitellogenic oocytes; 4 = migratory stage oocytes; 5 = hydrated oocytes.

From the histological screening, a total of 78 samples qualified for potential fecundity analysis, which represent ~6% of the total samples screened by histology (N = 1353). After the whole mount screening, this number decreased to 65 samples. Samples were discarded by whole mount screening because of detection of immature ovaries, presence of hydrated oocytes, or spent condition. The number of samples used to estimate fecundity decreased again to 62, since 3 samples had an oocyte leading cohort diameter smaller than 400 µm. According to the manual (ICES 2019b, SISP 5), ovaries with a leading cohort smaller than 400 µm are considered as not fully recruited yet; not all oocytes that are going to be spawned may have reached the 185 µm threshold that is used to classify oocytes as maturing.

POF´s (Post Ovulatory Follicles) are important spawning markers and were found in 72% of the samples (Figure 3.4.3.1.2). For all periods except period 2, when the frequency of samples with POF´s was slightly lower than without, females with POF´s were more than twice as frequent as females without.

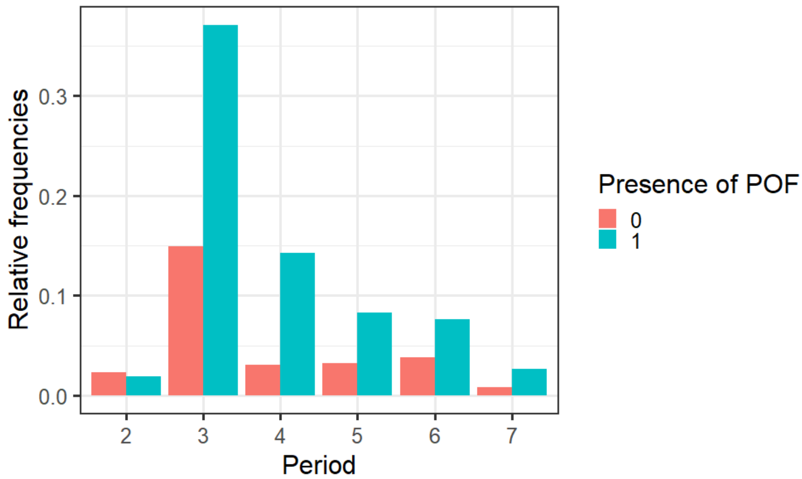


Figure 3.4.3.1.2: Frequency of POF's presence throughout the survey periods (0 = no POF's; 1 = POF's present).

3.4.3.3 Potential Fecundity in the Western and Southern combined components

For all mackerel females collected we did an initial check (Figure 3.4.3.3.1 a-b and Figure 3.4.3.3.2 a-b) on the distribution of fish length, weight, Fulton's condition factor (100 × weight/length^3), and gonad-somatic index (GSI; 100 × Ovary weight/Fish weight). Similarly, we analysed separately the samples qualified for potential fecundity estimation (Figure 3.4.3.3.1 c-d and Figure 3.4.3.3.2 c-d).

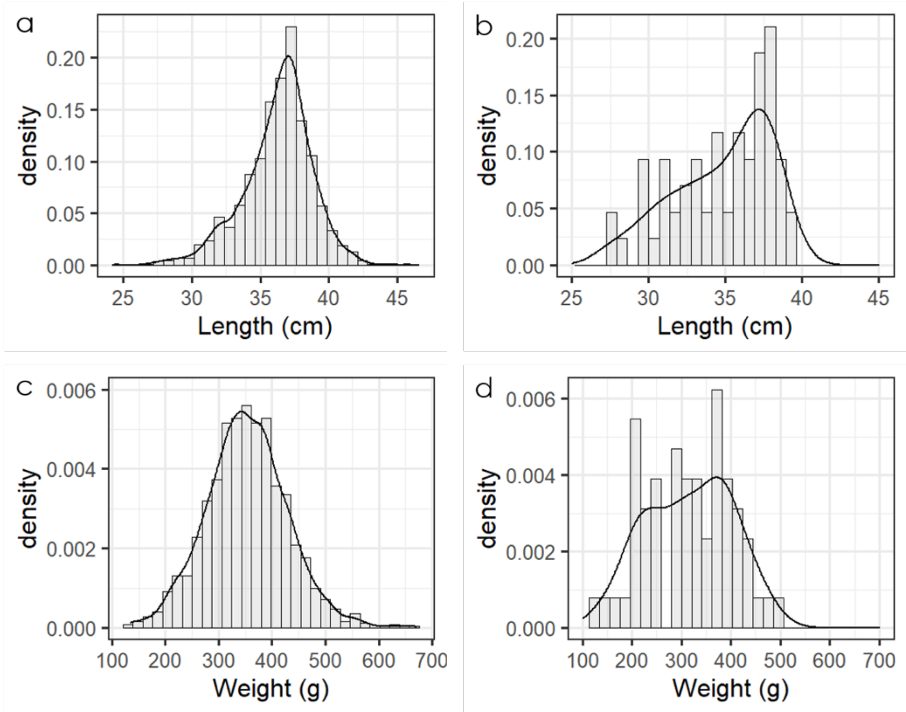


Figure 3.4.3.3.1: Frequency histograms of a) Fish length and c) Fish weight from all mackerel females sampled in 2019 and b) Fish length and d) Fish weight for mackerel assigned for potential fecundity analysis. Curves demonstrate the interpreted data distribution.

Similar to the previous surveys only fish with condition factor between 0.5 and 1.2, and GSI between 1 and 25 were included (ICES 2014) in the fecundity and atresia estimates (Figure 3.4.3.3.2). In 2019, no females needed to be excluded from the analysis based on these biological parameters.

Relative potential fecundity in 2019 ranged from 324 to 2098 oocytes/g fish, with a median value of 1191 oocytes/g fish (Figure 3.4.3.3.3). In the years before 2013, values below 300 and above 2100 were excluded. Since the 2013 survey (ICES 2014) it was agreed not to delete them, but instead replace the use of arithmetic mean by median. The median is considered to be more robust. In 2019, this issue was discussed again and we agreed to test a trimmed mean as an alternative to the median. We analysed the time-series (Figure 3.4.3.3.4) and found that the median estimates were close to the mean and trimmed mean estimates. For consistency with previous years we continue using the median. To assure that we in the future are consistent in the way we statistically treat the AEPM data and calculate realised fecundity, the working group in 2020 made a detailed calculation manual complete with corresponding STATA and R-code. Both STATA and R are being used for the calculations. This manual is planned to be appended to the current manual for the fecundity work after being reviewed during the next fecundity workshop.

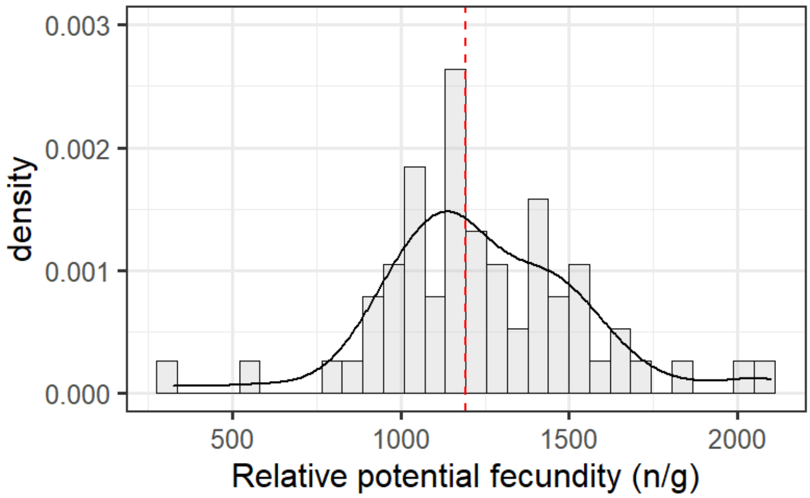


Figure 3.4.3.3.3: Relative fecundity values of 2019 mackerel samples. The red dotted line is the median value of relative potential fecundity (1191 n oocytes/g fish). Curve shows the interpreted data distribution.

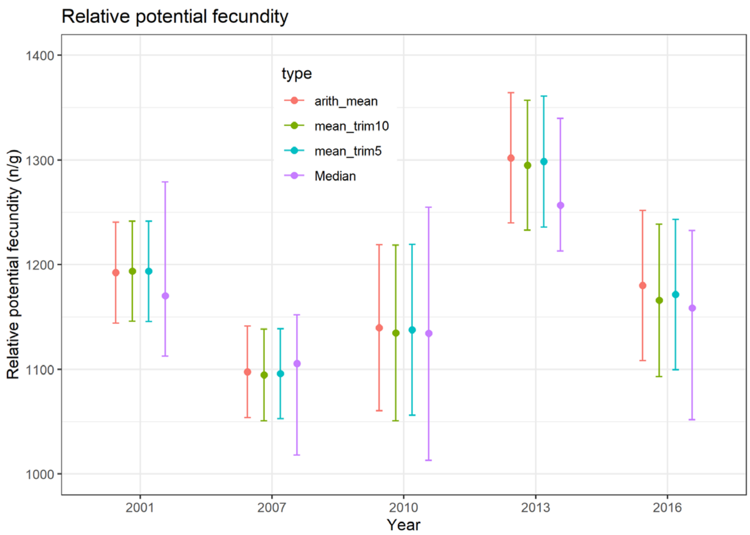


Figure 3.4.3.3.4: Relative potential fecundity by year as given by various measures of central tendency (Arithmetic mean, median, trimmed mean 5 %, trimmed mean 10 %).

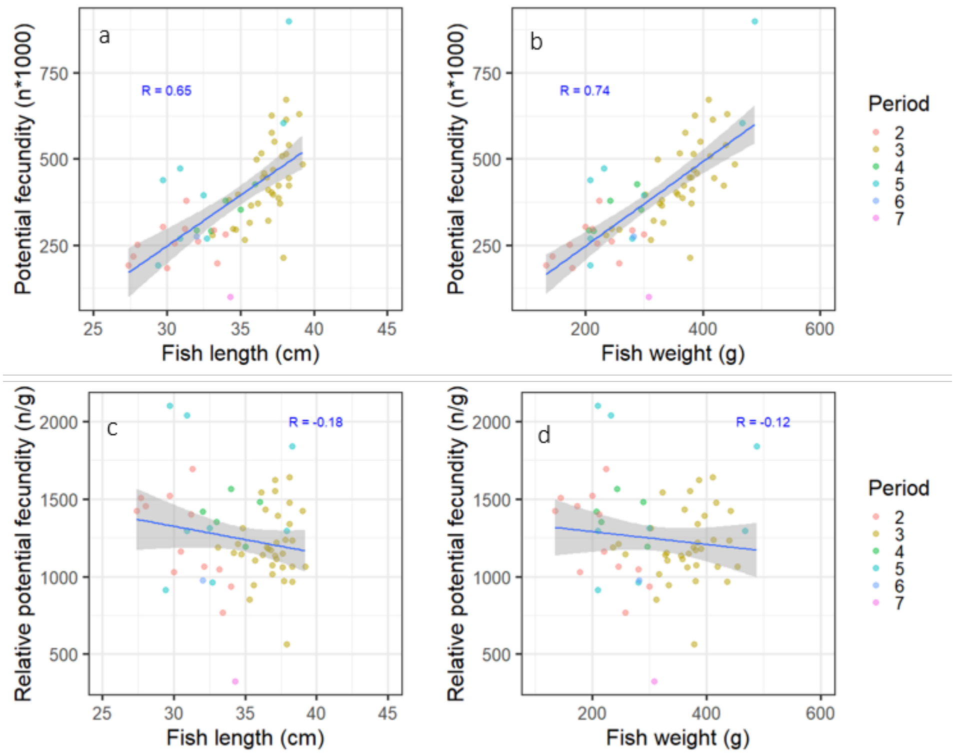


Figure 3.4.3.3.5: Relationship of potential and relative fecundity with fish length (a and c) and fish weight (b and d). Linear regressions displayed with 95 % CI.

Potential fecundity against fish length (Figure 3.4.3.3.5a) and weight (Figure 3.4.3.3.5b) showed a positive trend that was similar to those found in previous years (ICES 2014 and ICES 2017). Relative potential fecundity vs. length or weight (Figure 3.4.3.3.5c and 3.4.3.3.5d) showed no clear trends. Relative potential fecundity vs. latitude showed similar range of values throughout the sampling area, and no trend was detected (Figure 3.4.3.3.6).

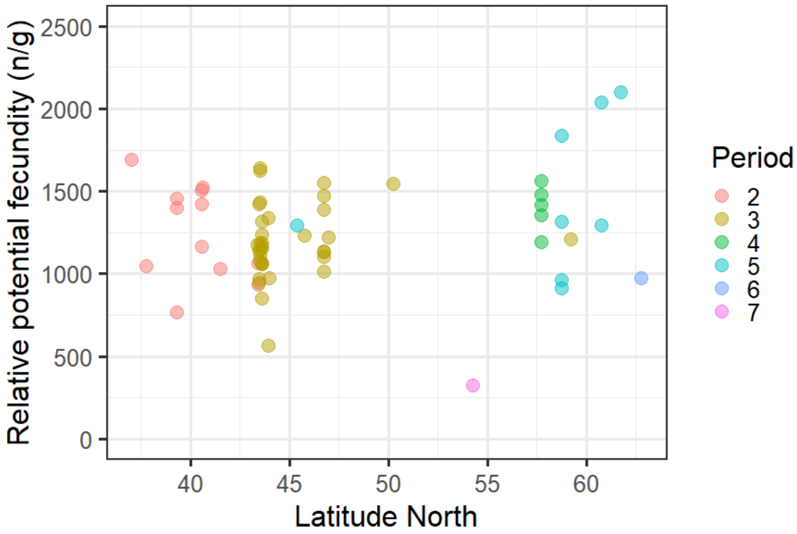


Figure 3.4.3.3.6: Relative potential fecundity of mackerel vs. latitude (N) in 2019.

The leading cohort (95% percentile) was estimated from the oocyte size distribution. It may be interpreted as a proxy for maturity stage. Relative fecundity vs. leading cohort showed no particular trend (Figure 3.4.3.3.7), as was also the case in 2013 and 2016 (ICES 2014 and 2017).

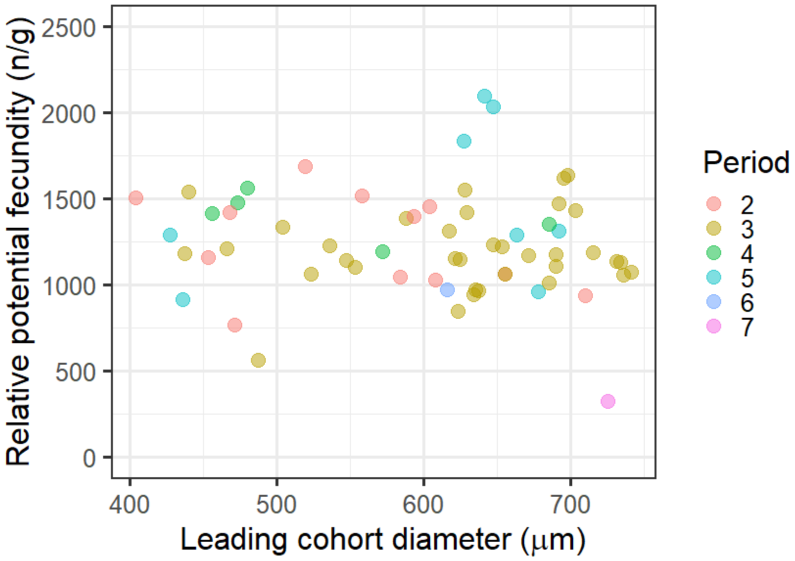


Figure 3.4.3.3.7: Relative potential fecundity (n oocytes/g fish) vs. oocyte diameter (µm) leading cohort (95 % percentile).

3.4.3.4 Atresia and realized fecundity

The samples used for analysis of atresia were collected from the entire survey area and during all periods (Table 3.4.3.4.1). Of the 895 fish which were classified as spawning, 252 showed signs of early alpha atresia, which resulted in a prevalence of 28%. This value was very close to the value obtained in 2016 (Table 3.4.3.4.1).

For the 2019 surveys, 64 samples were analysed for intensity of atresia (among the 252 spawning fish with atresia every fourth sample was randomly selected) resulting in a geometric mean of 19.5 atretic oocytes/g fish (Table 3.4.3.4.1). This value is lower than recorded for previous surveys (average 33.1). The overall relative atretic loss calculated from prevalence and intensity of atresia was 44 (atretic oocytes /g fish) resulting in a final relative realized fecundity estimate of 1147 (oocytes /g fish). This value is within the range of values of the previous surveys (Table 3.4.3.4.1).

In the period from 1998 - 2019 (Table 3.4.3.4.1) the final realised fecundity estimates were in the rather narrow range from 1002-1209 (grand mean = 1087, SD = 70). The 2019 estimate (1147 oocytes/g fish) is within this range. In spite of the low number of fecundity samples in 2019 and the quality issues reported in section 3.8.2, we therefore think that the fecundity estimate reflects well enough the stock fecundity of 2019 and we recommend this number to be used to calculate the 2019 SSB.

Table 3.4.3.4.1: Fecundity and atresia from 1998 to 2019. N is the number of samples used, n/g refers to the number of oocytes or atretic oocytes by gram of fish.

	Assessment year							
Parameter	1998	2001	2004	2007	2010	2013	2016	2019
Fecundity samples (N)	96	187	205	176	74	132	97	62
Prevalence of atresia (N)	112	290	348	416	511	735	713	895
Intensity of atresia (N)	112	290	348	416	511	56	66	64
Relative Potential fecundity (n/g)	1206	1210	1127	1098	1140	1257*	1159*	1191*
Prevalence of atresia	0.55	0.20	0.28	0.38	0.37	0.22	0.30	0.28
Geometric mean intensity of atresia (n/g)	46	40	33	30	26	27	30	19.52
Potential fecundity lost per day (n/g)	3.37	1.07	1.25	1.48	1.16	0.8	1.2	0.73
Potential fecundity lost (n/g)	202	64	75	89	70	48	72	44
Relative potential fecundity lost (%)	17	6	7	9	6	4	6	4
Realised fecundity (n/g)*	1002	1033	1052	1009	1070	1209	1087	1147

*median

3.4.4 Biomass estimation of Northeast Atlantic mackerel

Total spawning stock biomass (SSB) was estimated using the realised fecundity estimate of 1147 oocytes/g female, a sex ratio of 1:1 and a raising factor of 1.08 (ICES 1987) to convert pre-spawning to spawning fish. This gave an estimate of spawning stock biomass of:

- 2.29 million tonnes for western component (2016: 3.07).
- 0.80 million tonnes for southern component (2016: 0.45).
- 3.09 million tonnes for western and southern components combined (2016: 3.52).

This is a decrease in SSB estimate of 12% compared to 2016 SSB estimate (Figure 3.4.4.1 & Table 3.4.4.1) and is the lowest value in the time series since 1992.

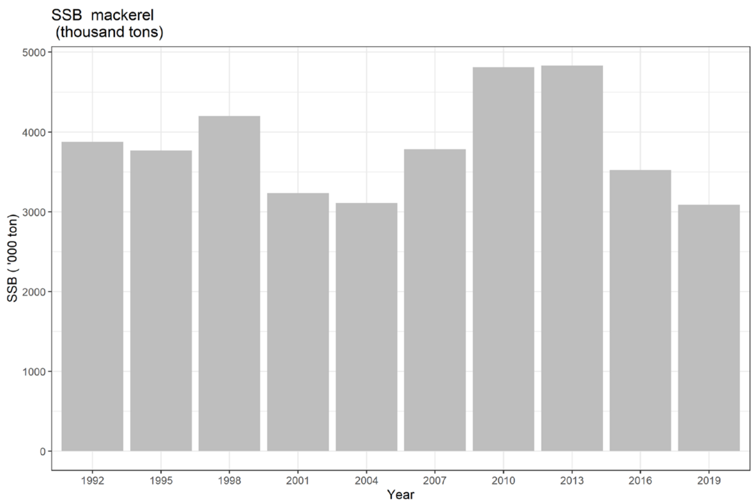


Figure 3.4.4.1: SSB estimates for NEA mackerel. 1992-2019

Table 3.4.4.1: NE Atlantic Mackerel SSB (kt) and Total Annual egg production (TAEP) derived from the mackerel egg surveys for the Southern, Western and combined survey area.

Year	Component	TAEP	SSB (kt)
1992	Combined	2.57*e15	3874.5
1995	Combined	$2.23*e^{15}$	3766.4
1998	Combined	$2.02*e^{15}$	4198.6
2001	Combined	$1.67*e^{15}$	3233.8
2004	Combined	$1.50*e^{15}$	3106.8
2007	Combined	$1.77*e^{15}$	3783.0
2010	Combined	$2.38*e^{15}$	4810.8
2013	Combined	$2.70*e^{15}$	4831.9
2016	Combined	$1.77*e^{15}$	3524.1
2019	Combined	$1.64*e^{15}$	3087.5
1992	Southern	$3.36*e^{14}$	507.2
1995	Southern	$1.86*e^{14}$	370.4
1998	Southern	$4.79*e^{14}$	882.9
2001	Southern	$3.18*e^{14}$	417.5
2004	Southern	$1.38*e^{14}$	309.2
2007	Southern	$3.48*e^{14}$	744.7
2010	Southern	$4.59*e^{14}$	926.3
2013	Southern	$5.06*e^{14}$	904.0
2016	Southern	$2.25*e^{14}$	447.3
2019	Southern	$4.23*e^{14}$	796.7
1992	Western	$2.23*e^{15}$	3367.2
1995	Western	$2.05*e^{15}$	3396.0
1998	Western	$1.54*e^{15}$	3315.8
2001	Western	$1.35*e^{15}$	2816.4
2004	Western	$1.36*e^{15}$	2797.6
2007	Western	$1.42*e^{15}$	3038.3
2010	Western	$1.92*e^{15}$	3884.4
2013	Western	$2.20*e^{15}$	3927.9
2016	Western	$1.55*e^{15}$	3076.8
2019	Western	$1.22*e^{15}$	2290.8

3.5 Horse mackerel in the western spawning area

3.5.1 Spatial Distribution of Stage I Horse Mackerel Eggs

An overview of horse mackerel spawning distribution of all periods for western stock is presented in Figure 3.5.1.1.

Period 2 – No horse mackerel eggs were found in this period (to see the extent of the sampling area, see Fig. 3.5.1.1).

Period 3 – In period 3 horse mackerel spawning starts in the Cantabrian Sea, but numbers of eggs were found to be low. Very low numbers of eggs were found in the Celtic sea and southwest of Ireland (Fig. 3.5.1.2).

Period 4 – Horse mackerel spawning continued in the Cantabrian Sea, extending into southern Biscay. Small numbers of eggs were found in the Celtic Sea (Fig. 3.5.1.3).

Period 5 – Horse mackerel spawning continued in the Cantabrian Sea, Celtic Sea and northern Bay of Biscay, but in low numbers around the 200m depth contour. Some eggs were also found south and west of Ireland (Fig. 3.5.1.4).

Period 6 – Spawning was confined to the Celtic sea with very few eggs being found outside this area, apart from some stations close to the French coast (Fig. 3.5.1.5). 10 fishing trawls, four of which contained horse mackerel, caught 404 individuals from an area between the Celtic Sea and north of Ireland/West coast of Scotland. (Fig. 3.5.1.5)

Period 7 – Eggs were found from the Celtic Sea to west of Scotland. In general egg numbers were low but occasional stations with high counts were found, notably off the southwest coast of England. Spawning intensity was highest during this period (Fig. 3.5.1.6). While sampling during a later period 8 (August) in 2016 didn't reveal any significant horse mackerel spawning, it remains uncertain that period 7 of 2019 represented peak spawning.

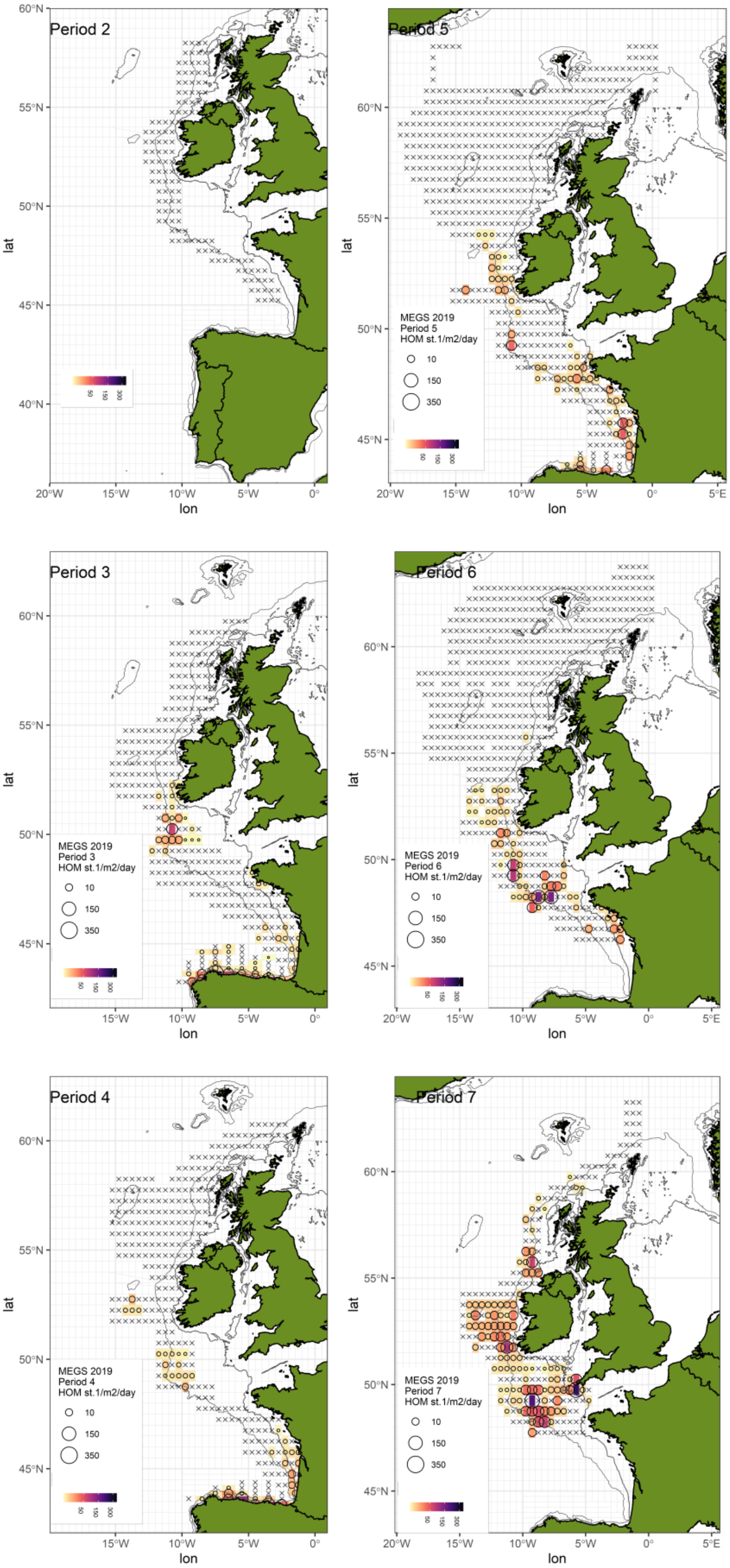


Figure 3.5.1.1: Horse mackerel egg production by half rectangle for all periods. Circle areas and colour scale represent horse mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

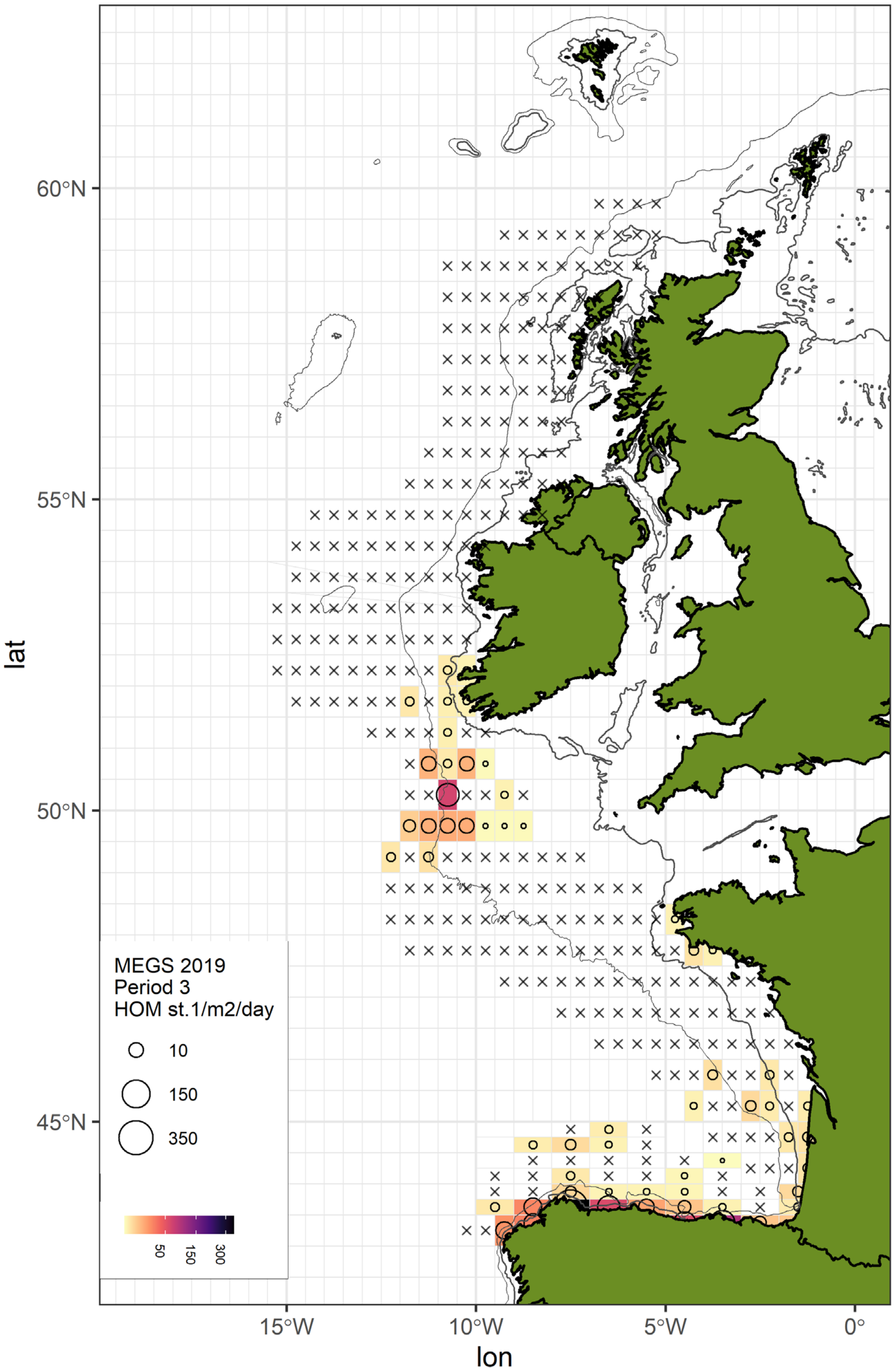


Figure 3.5.1.2: Horse mackerel egg production by half rectangle for period 3 (March 4th – April 14th). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

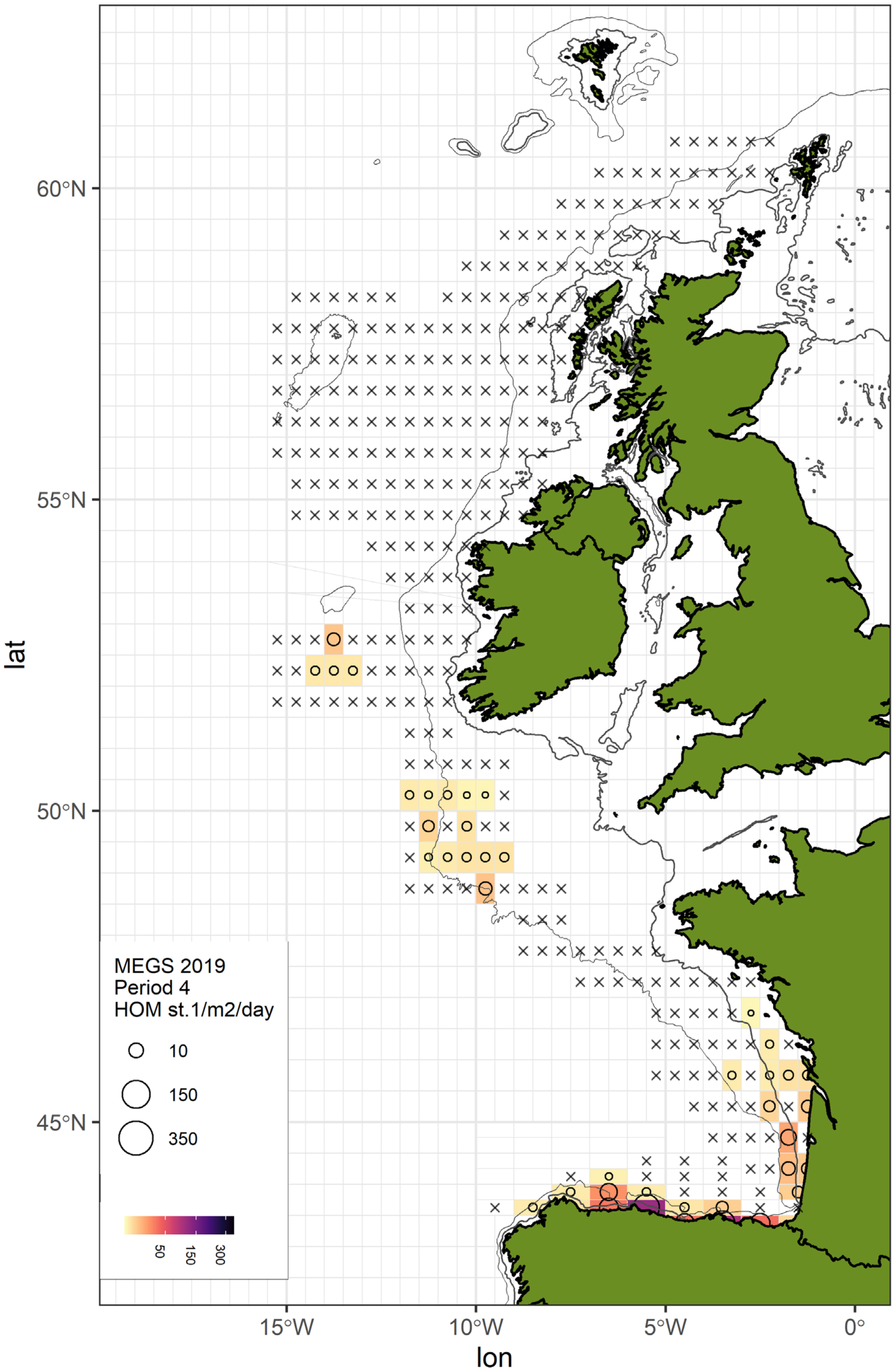


Figure 3.5.1.3: Horse mackerel egg production by half rectangle for period 4 (April 13th – May 3rd). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

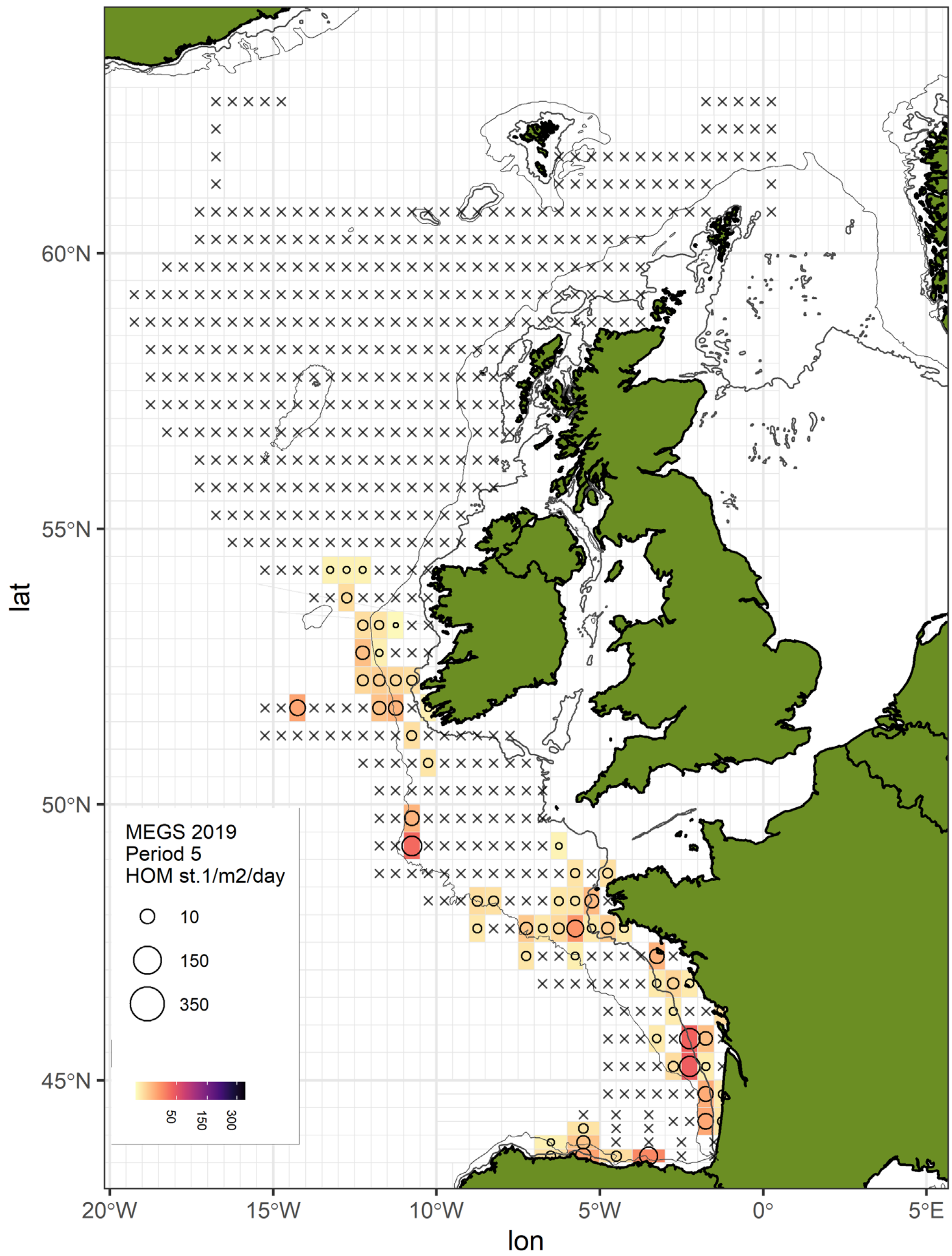


Figure 3.5.1.4: Horse mackerel egg production by half rectangle for period 5 (May 4th – June 5th). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

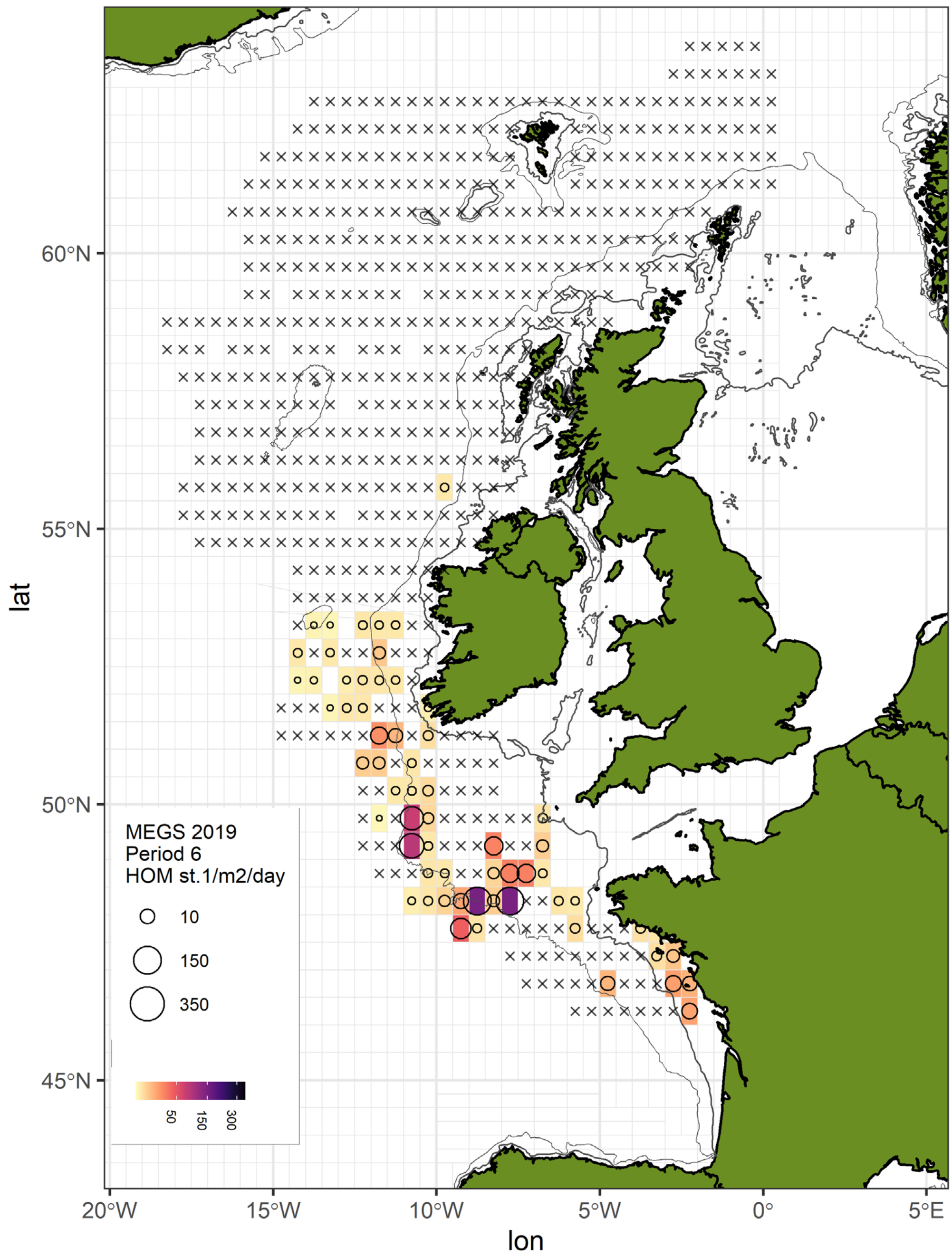


Figure 3.5.1.5: Horse mackerel egg production by half rectangle for period 6 (June 6th – 30th). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

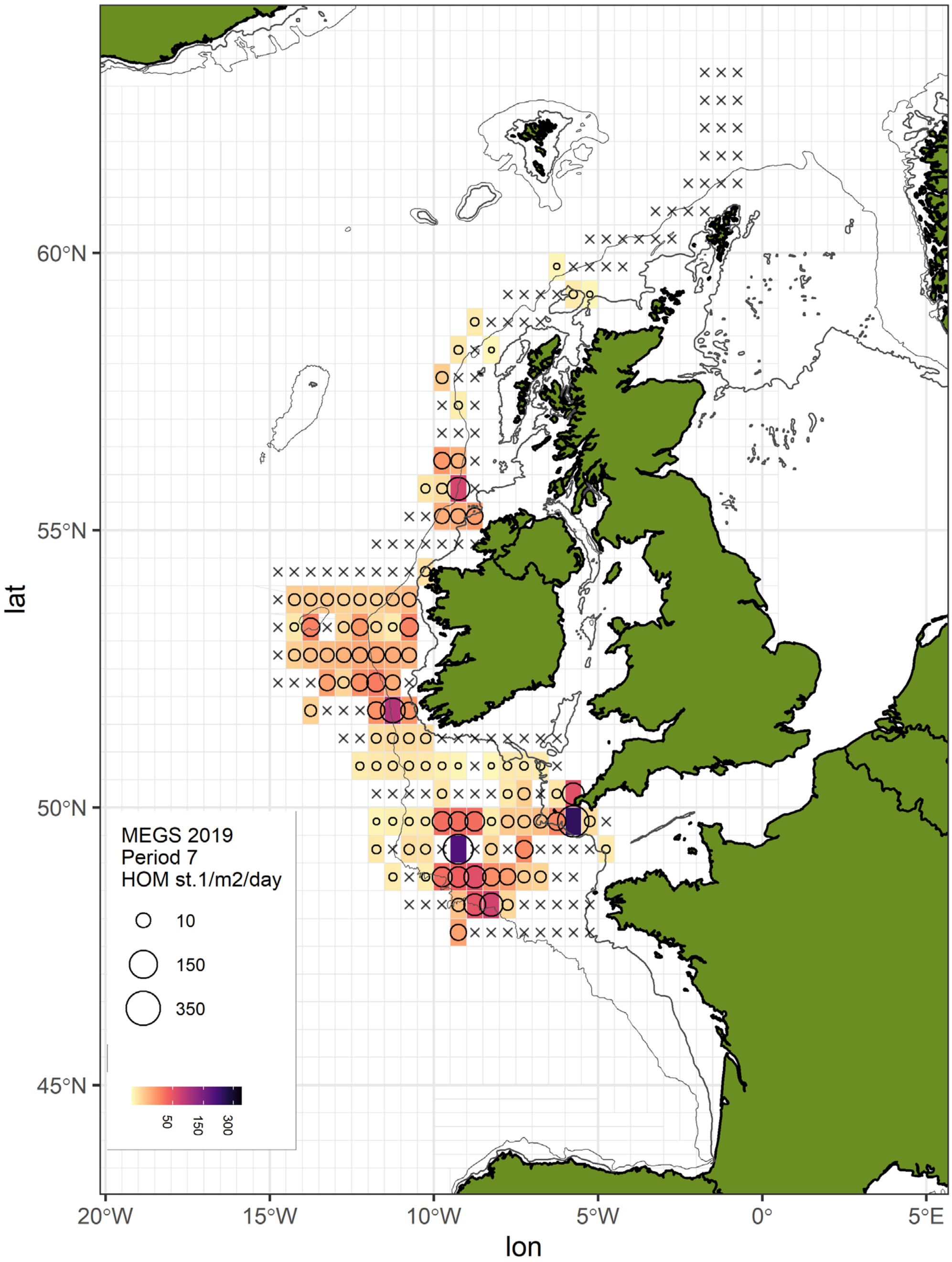


Figure 3.5.1.6: Horse mackerel egg production by half rectangle for period 7 (July 1st – July 31st). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

3.5.2 Egg Production in Western Horse Mackerel

Total Egg production

Period number and duration are the same as those used to estimate the western component mackerel stock, as are the dates defining the start and end of spawning (Table 3.5.2.1). The mean daily stage I egg production estimates (DEP) for each survey period are plotted in figures 3.5.2.1 and 3.5.2.2. The total annual egg production was estimated at 1.78 x 10^{14}. This is a decrease of almost 53% on 2016 which was 3.33 × 10^{14} and is the lowest estimate of annual egg production ever recorded for this species (Figure 3.5.2.3 & Table 3.5.2.2).

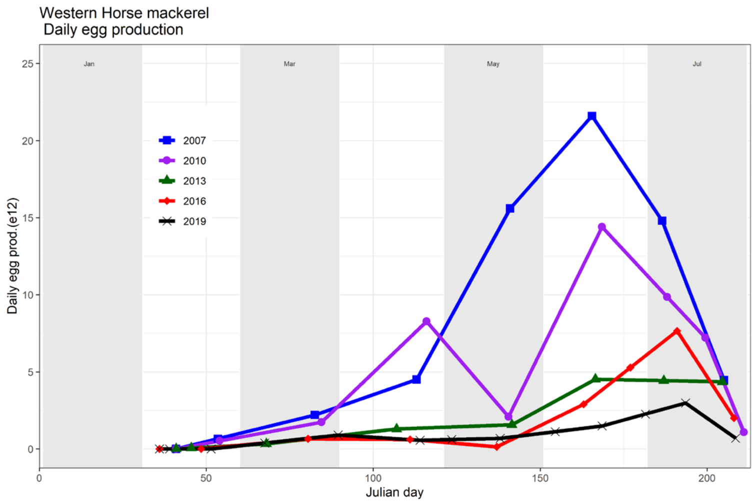


Figure 3.5.2.1: Annual egg production curve for western horse mackerel stock. The mean daily stage I egg production estimates for each survey period plotted against the mid-period days. The curves for 2007, 2010, 2013 and 2016 are included for comparison. Months of January, March, May and July are highlighted in grey background.

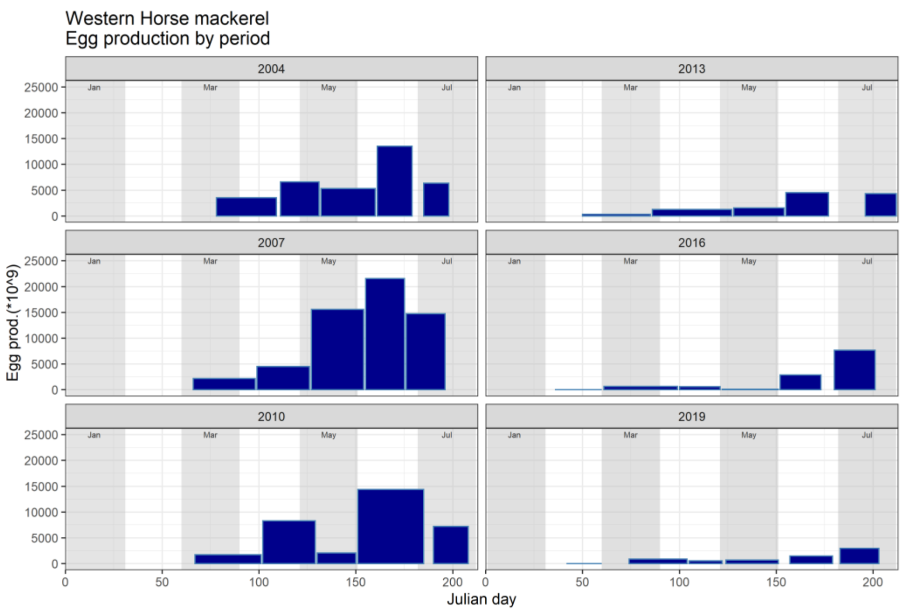


Figure 3.5.2.2: Egg production by period for horse mackerel in the western stock. Months of January, March, May and July are highlighted in grey background

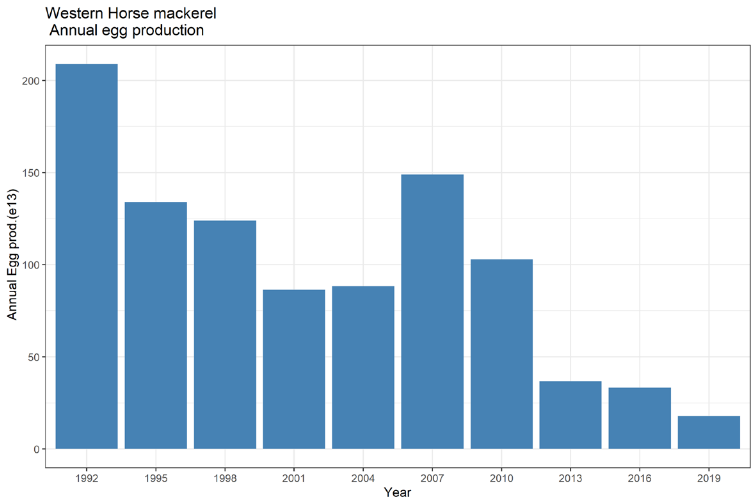


Figure 3.5.2.3: Total Annual Egg Production estimates for western horse mackerel stock. 1992-2019.

Table 3.5.2.1: Western estimate of horse mackerel total stage I egg production by period using the histogram method for 2019.

Dates	Period	Days	Annual stage I egg production * 10^{15}
	Pre 2		**0**
Feb 11th – Mar 1st	2	25	0
Mar 2nd – 14th	2 - 3	13	0.005
Mar 15th – April 14th	3	31	0.03
Apr 15th – May 2nd	4	18	0.01
May 3rd	4 - 5	1	0.0006
May 4th – May 31st	5	28	0.02
Jun 1st – 5th	5 - 6	5	0.006
Jun 6th – June 28th	6	23	0.034
June 29th – July 1st	6 – 7	3	0.007
July 2nd – July 22nd	7	21	0.06
July 23rd – 31st	Post 7	9	0.007
Total	0.178		
CV	57%		
CV data	3.29		

Table 3.5.2.2. Western horse mackerel. The time series of Total Annual Egg Production (TAEP) estimates (10^{12} eggs).

Year	TAEP ($*e^{12}$)
1992	2094
1995	1344
1998	1242
2001	864
2004	884
2007	1486
2010	1033
2013	366
2016	331
2019	178

3.5.3 Horse mackerel fecundity sampling

WGMEGS had planned to collect samples of 1300 female horse mackerel in period 6 and 7 of the 2019 egg survey, for batch fecundity and POF analyses. In total 625 horse mackerel were caught in these periods together. Of these 350 were females, of which 183 where in the Walsh maturity stages 3 to 5 (Table 3.5.3.1). All 183 ovaries were screened histologically to define the oocyte development stage. Only females with oocytes in hydration stage 2 and no eggs or signs of being spent can be used to correctly estimate batch fecundity. Of all 183 females only 2 were in this oocyte development stage (Table 3.5.3.1). It was checked if the number of females could be increased by including other hydration stages and migratory nucleus stage. These stages are close to spawning, but it can sometimes be difficult to identify the separate batch from the other developing vitellogenic oocytes. However, including those stages only increased the number of female to 44 (Table 3.5.3.1). In period 7, when highest horse mackerel egg production was found (chapter 3.5.1), only 18 females with hydrated and migratory nucleus stage were found.

Table 3.5.3.1: Number of female horse mackerel planned, caught and in different development stages.

N planned	N caught	N fecundity	N Hydration stage 2	N Hydration stage	N Hydration and Migratory nucleus stage
1300	350	183	2	10	44

With respect to the planned target of 1300 samples, WGMEGS considered the number of females sampled, which showed the necessary oocyte development for batch fecundity estimation, as too low for a reliable estimate. Because the assessment of western horse mackerel currently only uses the egg production data, WGMEGS decided not to analyse the batch fecundity samples beyond the screening for the oocyte development stage.

3.6 Horse mackerel in the southern spawning area

3.6.1. Egg distribution, spawning area and egg production

The horse-mackerel egg distribution during the 2019 survey is shown in figure 3.6.1.1. The spatial pattern observed was, as usual, very patchy, but high egg densities were present in the core, usual, spots: outer shelf and vicinity of canyons, in the west of the southern coast and in the south and central western shores. The higher abundances in the south coast were observed in the region between Quarteira and Portimão whereas in the west coast there were more locations with higher egg densities, namely, south of Setúbal, just to the north of Lisbon, north of Cape Carvoeiro and over the mid-outer shelf between Cape Mondego and the Portugal-Galicia border. Horse-mackerel eggs were found in 18% of the total 531 CalVET samples collected, representing 7% of all the fish eggs sorted.

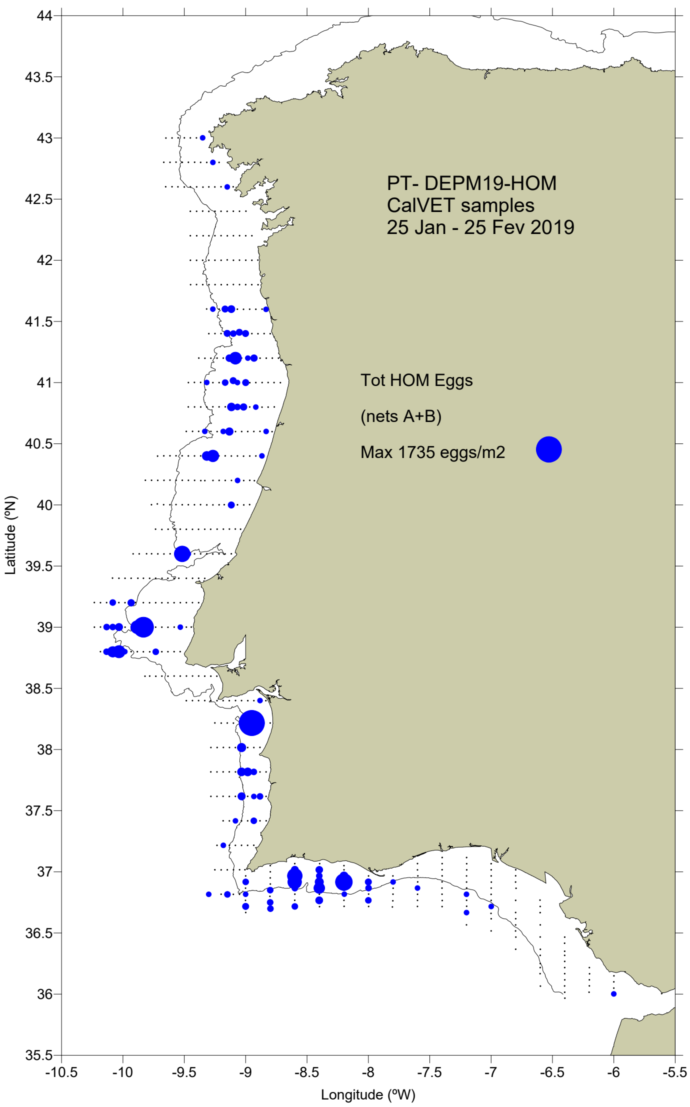


Figure 3.6.1.1: Horse-mackerel egg density distribution (eggs/m2) derived from the CalVET samples collected in the period 25 January – 25 February 2019.

Following the laboratorial work for identification and staging of all horse-mackerel eggs (using an 11 stages scale), all the calculations for area delimitation, egg ageing and model fitting for egg production (P0) 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 (ICES, 2019c).

The spawning area estimated for the 2019 survey was 21360km2 representing an increase of around 10% compared to the 2016 value. Nonetheless, in the west coast in particular, the egg distribution was irregular and a few samples with no eggs were imbedded in the zone estimated as the spawning area.

The Total Egg Production estimated for the 2019 survey was 8.25 x 1011 Eggs/day (CV: 36%), 38% higher than the estimation for the previous survey in 2016 (Table 3.6.1.1).

Table 3.6.1.1: Egg Production results 2019 DEPM survey (PT-DEPM19-HOM).

Survey	Spawning area (Surveyed area) (km^2)	Mortality ($hour^{-1}$) (CV%)	P0 ($eggs/m^2/day$) (CV%)	P0 tot (eggs/day)($x10^{11}$) (CV%)
PT_DEPM16-HOM 25 Jan – 25 Feb 2019	21360 (58805)	-0.04 (19.0)	38.6 (36.6)	8.25 (36.6)

3.6.2. Daily fecundity

Overall during the survey, 20 samples of horse mackerel fish were obtained, complemented by the 15 additional ones from the commercial fleet (see section 3.2.4). Despite a large effort in fishing in the Cadiz Spanish waters (9 trawls), no horse mackerel were caught in this area (result corroborated also by the absence of eggs of the species as depicted in the map of figure 3.6.1.1). Biological data from a total of 2215 fish were obtained from these 35 samples, 1051 ovaries were preserved and stored in 4% buffered formaldehyde for histological processing (among which 102 hydrated ovaries for batch fecundity estimation), and 1483 otoliths collected for age determination. Three of these samples, one for each of the 3 areas (South, Southwest, Northwest Portugal) were collected for the specific purpose of estimating a maturity ogive, as most of the fish caught were of smaller size (lengths from 13 to 22 cm).

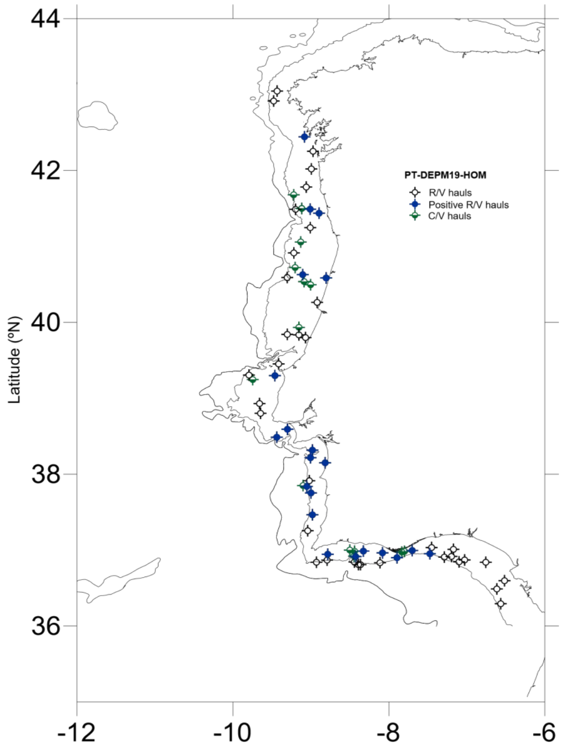


Figure 3.6.2.1: Position of the fishing hauls carried out during the survey onboard the research vessel or from the commercial fleet (R/V hauls: by Noruega), C/V hauls: by the commercial vessels) and identification of those from which horse mackerel samples were obtained for the estimation of the DEPM parameters (Positive R/V e C/V hauls).

The horse mackerel sampled ranged in size from 13 to 42 cm, a similar range compared to 2016 (except a few even smaller fish caught in the South in 2016). Smaller fish were caught significantly in the South (where the size frequency distribution appears clearly bimodal) but also in the West coast (Figure 3.6.2.2). Apart from the three samples referred above for the maturity ogive, the large majority of the female fish sampled were mature (~10% of macroscopically scored fish as immature); less than 1% of the females were in a post-spawning phase whereas ~1/4 were in a developing one.

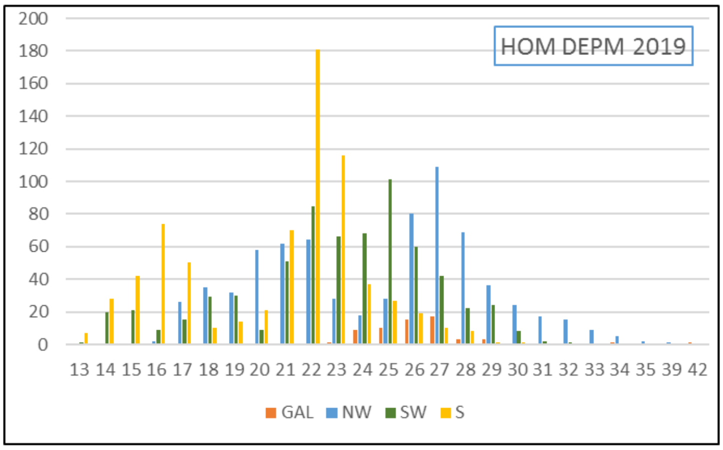


Figure 3.6.2.2: Length frequency distribution of the horse mackerel sampled in 2019 (both R/V and C/V samples) by area (GAL: Galicia; NW: Northwest Portugal; SW: Southwest Portugal; S: South Portugal).

In laboratory, the preserved ovaries were weighed, processed histologically, and the histological slides analysed according to the criteria described in the ICES SISP 5.

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 and histological slides were used to measure the individual batch fecundity (Fobs), to assess the mature/immature condition of females, and to estimate the daily spawning fraction (S). 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.

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 2019, n = 37 ovaries were effectively used). Spawning fraction estimation was based on the POFs used as spawning markers: histological slides were analyzed 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, their size, and the time of capture in relation to the peak spawning time (cf. section 3.6.1). 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 estimates presented during the WG meeting are summarized in Table 3.6.2.1.

Table 3.6.2.1: Adult parameters estimates for the 2019 Southern horse mackerel DEPM survey

	W (g) (%CV)	R (%CV)	F (nb. eggs) (%CV)	S (%CV)	F_{rel} (nb. eggs)	DF (nb. eggs/day.g female)
2019	118.1 (8)	0.519 (5)	17762 (10)	0.057 (28)	150	4.45
2016	121.71 (11)	0.550 (3)	15991 (18)	0.049 (25)	131	3.54

Globally, the estimates obtained in 2019 and in 2016 were very comparable. Mean female weight (W) was very similar to the one estimated in 2016 (118.1 g), confirming the similar size range of the horse mackerel sampled in both surveys. Compared to 2016, slightly higher estimates of batch fecundity (F) and relative fecundity (F_{rel}) were obtained (17762 eggs, 150 eggs/g female, respectively), daily fecundity (DF) having increased 20% in relation to the previous survey (4.45 eggs/day.g female). Daily spawning fraction (S) in 2019 (0.057) was also very similar to the estimate obtained for 2016, both remaining at considerably lower values when compared to the S calculated in 2013 (0.134). In 2016, a noticeable reduction of the horse-mackerel spawning activity was observed during the survey, several indices suggesting that part of the population would have been closer to the end of spawning season. In 2019, the survey took place earlier in the season, about 2/3 of the fish sampled were actively reproducing, whereas ~1/4 of the fish were at a developing stage, as referred above (most of them of smaller size: 80% of these sizing ≤ 24 cm), one hypothesis being that these fish would be starting reproducing for the first time.

The comparison of the spatial distribution between egg density and fish spawning activity (figure 3.6.2.3) show only partial correspondence between these life cycle stages: in particular, the area between Cape da Roca and Nazare Canyon showed high egg densities in the outer shelf but scarce spawning activity; this is also an area poorly sampled for adults, despite the fish trawling effort (only 1 out of 5 hauls caught horse-mackerel), and thus the observation in this area could be biased, with consequences for the S estimation.

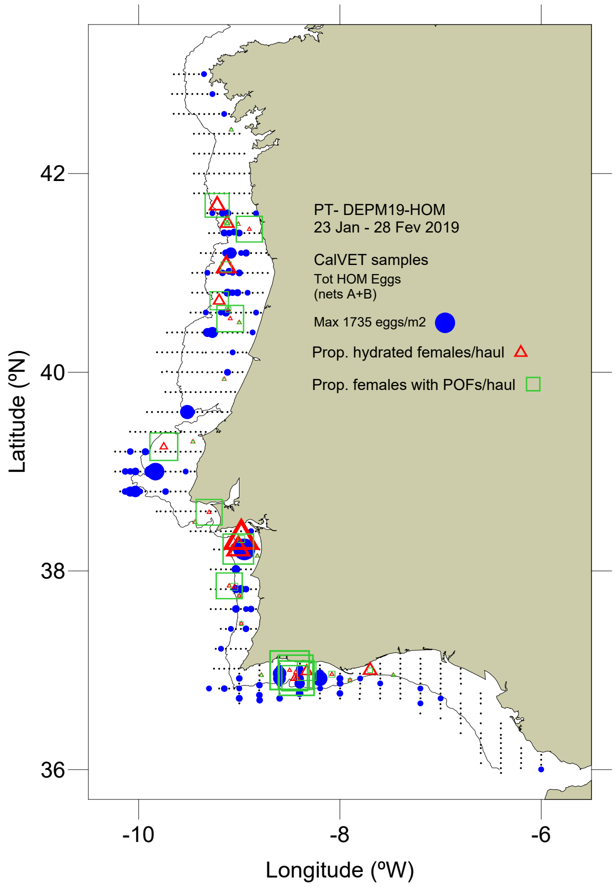


Figure 3.6.2.3: Overlapping of the spatial distribution of the eggs density (CalVET; eggs/m²) and of the spawning activity of the horse-mackerel sampled (based on the histological analysis); blue circles diameter proportional to eggs density; red triangles correspond to the proportion of females showing imminent spawning (ovary containing hydrated oocytes); green squares correspond to the proportion of females presenting recent spawning activity (presence of POFs in the ovary).

3.7 Daily Egg Production Method analyses in the western and North Sea spawning areas and Southern? spawning areas

3.7.1 Western Mackerel

Mackerel Daily Egg Production Method parameters

Following the recommendation of WKMSPA (ICES, 2012) to compare the Annual Egg Production Method (AEPM) and the Daily Egg Production Method (DEPM), during the 2019 Egg Survey the DEPM method was implemented again next to the AEPM, as has been done in 2013 and 2016.

Adult sampling for 2019 mackerel DEPM

The DEPM requires an intensive sampling for adult parameters. However, as the survey prioritizes TAEP sampling in a large area, leaving only little time for additional trawling, to achieve the planned number of samples, proved to be difficult. The number of required adults has, therefore, been supplemented, where possible, with samples collected from other scientific surveys or from the fish market, coinciding in time and area with the egg sampling. Next to the difficulty of collecting the samples, ovary samples taken for batch fecundity and spawning fraction estimation are chosen based on macroscopic maturity criteria and have to be screened later in the lab to test their suitability for each analysis. The number of samples collected for batch fecundity is, thus, subsequently reduced after histological screening.

DEPM sampling was directed to the two months where peak spawning was expected to occur, i.e. period 3 and 4 (ICES, 2019b), but batch fecundity samples were collected throughout the survey to check for differences between periods. Mackerel was caught in 71 hauls. The optimum number of fish for batch fecundity, spawning fraction (S) and sex ratio (R) estimation per haul is 100 individuals. These fish should be randomly selected and total size, weight, sex, maturity and female gonad weight taken. In many of the 71 hauls 100 mackerel were sampled. Sample coverage was highest in Cantabrian Sea, Bay of Biscay and Celtic Sea areas with less coverage further north (Figure 3.7.1.2 A). Sampling was more intensive during the expected peak spawning (periods 3 and 4) as can be seen in Figure 3.7.1.2 B. A total of 4324 mackerel were sampled, 58.2 % of these were captured during the periods 3 and 4 between 41° and 50 °N (Table 3.7.1.1), covering the largest part of the spawning area in those periods (see daily egg production maps in section 3.4.1).

Table 3.7.1.1: The number of mackerel (male and females) sampled by period and latitude. The proportion of the total of 4324 sampled fish is also shown in parentheses.

	Period 2		Period 3		Period 4		Period 5		Period 6		Period 7		
Latitude °N	**n**	**(%)**	**n**	**(%)**	**n**	**(%)**	**n**	**(%)**	**n**	**(%)**	**n**	**(%)**	**Total**
36-40	81	(1.9)											81
41-45	109	(2.5)	1176	(27.2)	505	(11.7)	66	(1.5)					1856
46-50			733	(17.0)	100	(2.3)	418	(9.7)	49	(1.1)			1300
51-55			13	(0.3)	18	(0.4)			200	(4.6)	137	(3.2)	368
56-60			63	(1.5)	100	(2.3)	155	(3.6)	203	(4.7)			458
61-65							48	(1.1)	150	(3.5)			198
Total n	**190**		**1922**		**723**		**687**		**602**		**137**		**4324**

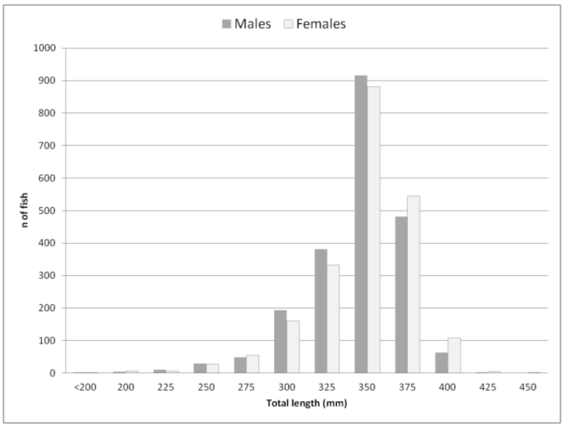


Figure 3.7.1.1: Male and female length frequency distribution for 25 mm size classes sampled for DEPM parameters

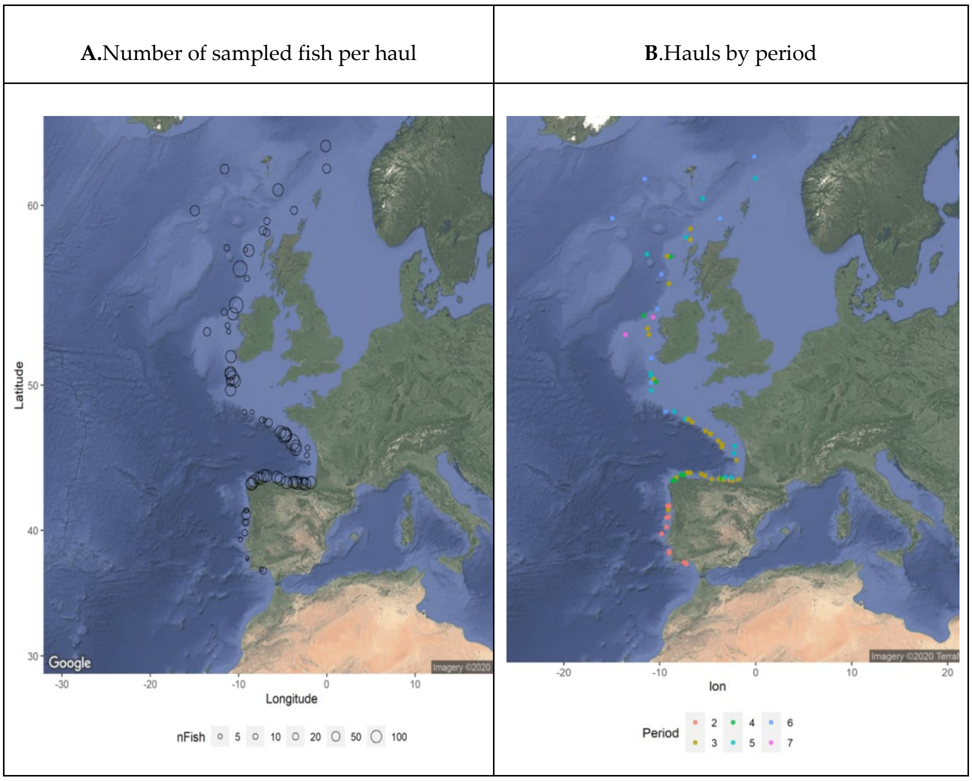


Figure 3.7.1.2: a) Number of sampled fish per haul (optimum sample size is 100 indivuals per haul) b) Distribution of hauls by survey period.

Mackerel total length ranged from 190 to 459 mm, modal size class 350 mm (Figure 3.7.1.1). Slightly higher numbers of females were sampled at the larger sizes (Figure 3.7.1.1). Apart from the lower latitudes between 36 to 40°N where only small individuals were caught, mackerel sizes did not vary with latitude (Figure 3.7.1.3).

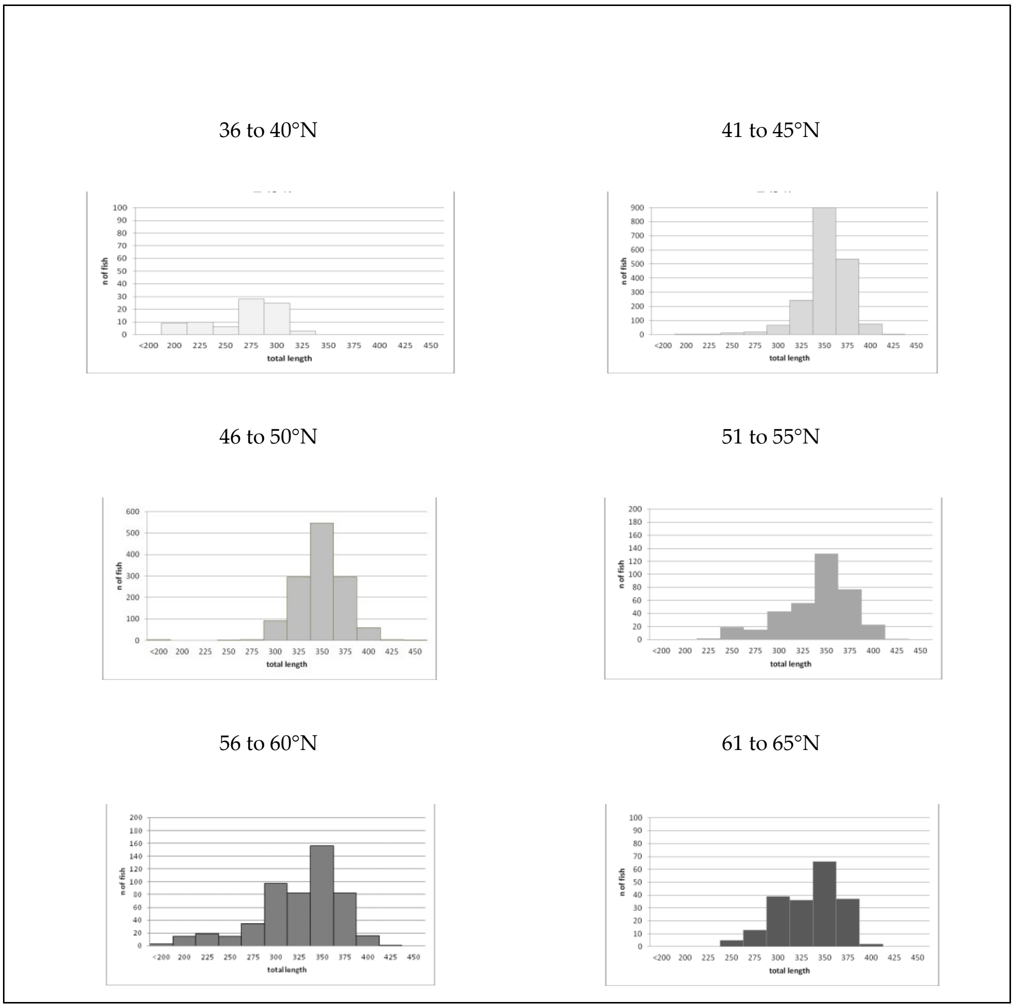


Figure 3.7.1.3: Mackerel length frequency distribution (50 mm classes) by latitude.

Table 3.7.1.2 shows the DEPM adult parameters sampling in 2016 and 2019. Number of sampled individuals was similar, but in 2019 more hauls were carried out compared to 2016 (Table 3.7.1.2). The number of mature females caught in 2019 was 13% higher than in 2016, and because of this the number samples for batch fecundity was 22% higher in 2019. Also the number samples for the estimation of spawning fraction was 11% higher in 2019.

Length distribution was similar between 2016 and 2019 (Figure 3.7.1.4), except for the 325 and 350 mm size classes.

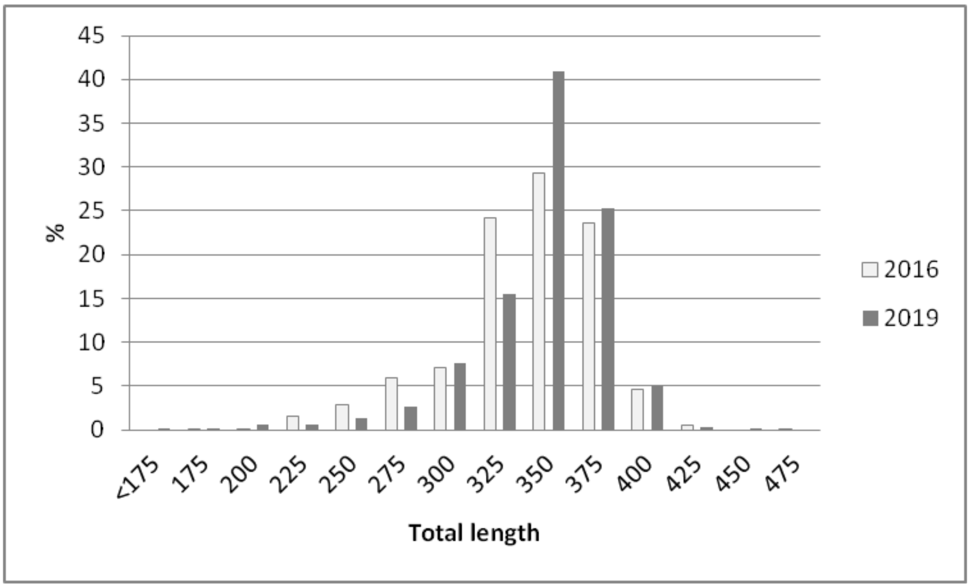


Figure 3.7.1.4: Percentage of females by size class in 2016 and 2019.

Table 3.7.1.2: Summary table of DEPM sampling for 2019 and 2016 surveys by period.

Period	Hauls	Total Fish	Mature Females	Spawning fraction valid samples	Batch Fecundity valid samples
2019					
2	11	190	106	14	1
3	27	1985	958	497	91
4	8	723	314	189	40
5	14	687	332	41	4
6	9	602	336	39	4
7	2	137	51	12	2
Total	**71**	**4324**	**2097**	**792**	**142**
2016					
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**

Sampling of ovaries for batch fecundity and spawning fraction estimations.

From each haul, according to the manual of mackerel and horse mackerel fecundity estimation (ICES 2019b) ovary samples were collected from 30 females of the 100 sampled fish. Most of the samples were taken in the periods 3 and at 40 to 50°N (Table 3.7.1.3). All 1383 ovary samples were histologically examined under the microscope. Based on the screening results, 198 samples qualified for batch fecundity and 792 for spawning fraction determination (Table 3.7.1.4). Batch fecundity samples were collected throughout the spawning area (Figure 3.7.1.5) though highest numbers were collected in the Cantabrian Sea, Bay of Biscay and Celtic Sea.

Table 3.7.1.3: Number of screened ovary samples.

	Period						
Latitude	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
61-65				25	44		**69**
56-60			30	42	51		**123**
51-55			2		43	47	**92**
46-50		302	40	60	23		**425**
41-45	36	408	166	40			**650**
36-40	24						**24**
Total	**60**	**710**	**238**	**167**	**161**	**47**	**1383**

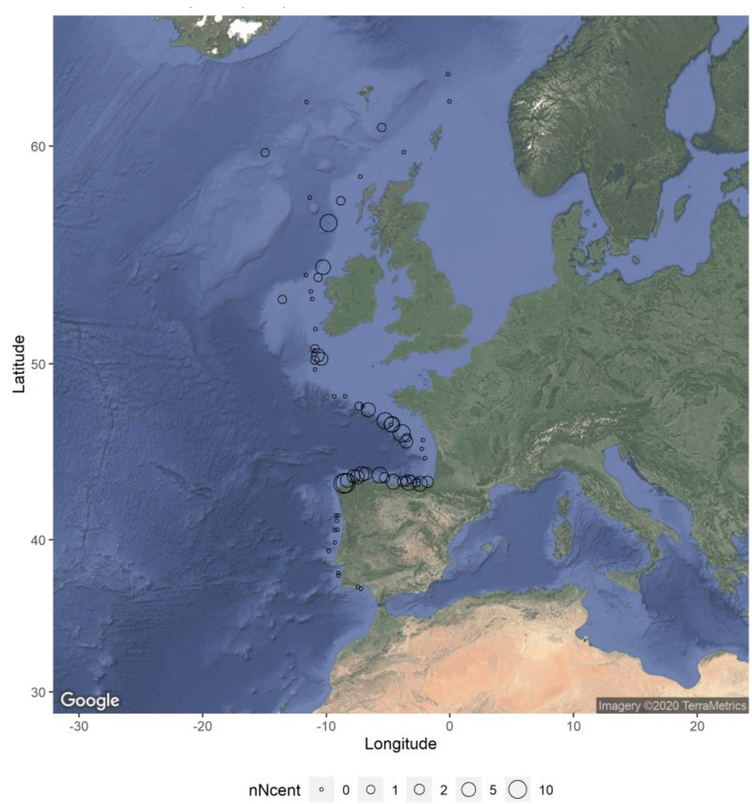


Figure 3.7.1.5: Distribution of the batch fecundity samples.

Table 3.7.1.4: Temporal and spatial distribution of ovary samples analyzed for POF aging.

POF age			**Period**				
Latitude	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
61-65				6	11		17
56-60			15	10	12		37
51-55			2		10	12	24
46-50		208	25	15	6		254
41-45	9	289	147	10			455
36-40	5						5
Total	**14**	**497**	**189**	**41**	**39**	**12**	**792**

Mackerel DEPM Adult parameters

The average weight per mature female is 8% higher compared to 2016 (Table **3.7.1.5**). The sex ratio was very close to 50% in both years. Batch fecundity by haul, ranged from 9342 to 14410 hydrated oocytes. Median batch fecundity for the entire population was 12257, 28% higher compared to 2016 (Table 3.7.1.5).

Batch fecundity variability is high from year to year as well as within each year. This variability can be attributed to different feeding conditions but also size of the females. In 2019 the average female weight was higher compared to 2016. Numbers of larger fish were also higher in 2019 (Figure 3.7.1.4) probably explaining the higher female mean weight found. There was a poor fit batch fecundity and gonad-free female weight in 2019 (Figure 3.7.1.6), indicating that in general fish with larger gonads (larger fish) do not spawn bigger batches. It might be possible that fish condition in 2019 was higher compared to 2016, explaining the higher batch fecundity. However, fish condition was not directly estimated in either year.

Spawning fraction in 2019 was 0.198 (i.e. 19.8 females of each 100 mature females were spawning). This also higher compared to 2016, when spawning fraction was 0.163 (Table 3.7.1.5).

Table 3.7.1.5: Northeast Atlantic mackerel adult parameters estimated for the 2019 and 2016 surveys, and coefficients of variation (cv).

	2019		2016	
Adult patameters	**Estimate**	**CV**	**Estimate**	**CV**
Average Female Weight (g)	355.66	0.0218	326.77	0.0305
Sex ratio (nº of females/total)	0.520	0.0100	0.515	0.0052
Batch Fecundity (n° eggs/batch)	12257	0.0106	8820	0.0413
Spawning fraction (n° of spawning females)	0.198	0.0904	0.163	0.1238

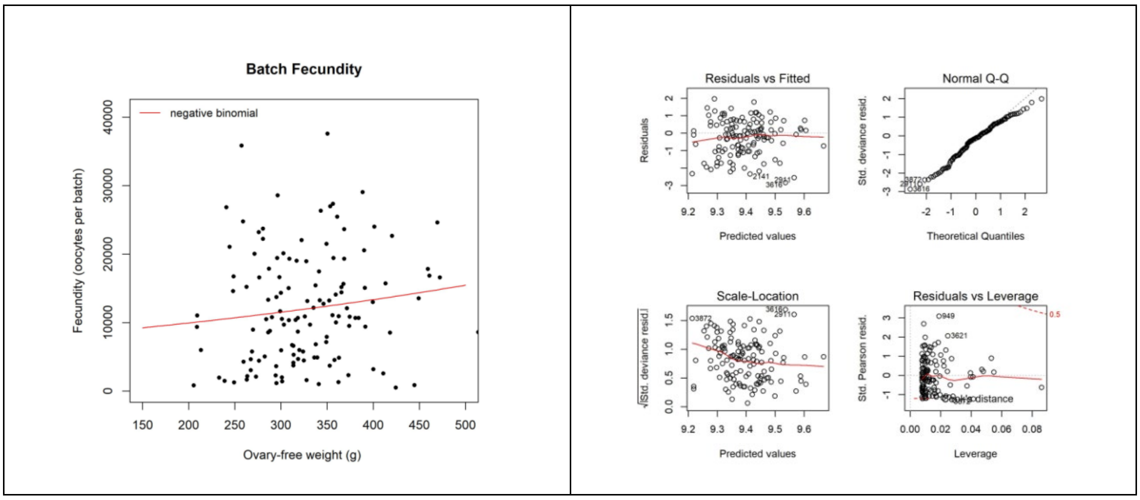


Figure 3.7.1.6: Batch fecundity by weight of the female (and model fitness).

Mackerel DEPM adult parameters by latitude

Seasonal and spatial differences in adult parameters have often been reported in Scombrids, requiring spatial approaches to obtain unbiased estimates (ICES, 2012). During their reproductive migration, Northeast Atlantic mackerel move northwards from the south of Portugal to Iceland over a 6 month spawning period. In this broad range of space and time the environmental conditions change (see section 3.3.2) and it is likely that also the adult parameters, such as batch fecundity and spawning fraction vary throughout the spawning period.

In order to study the latitudinal heterogeneity, adult parameters have been calculated separately for areas south and north of the 44.5° N (Table 3.7.1.6).

Table 3.7.1.6: Northeast Atlantic mackerel adult parameters estimated for the 2019 and 2016 surveys south and north of 44.5 N, and coefficients of variation (cv).

	2016		2019	
North of 44.5 N	**Estimate**	**CV**	**Esti-mate**	**CV**
Average Female Weight (g)	328.53	0.0339	361.55	0.032
Sex ratio (nº of females/total)	0.517	0.0075	0.527	0.0157
Batch Fecundity (nº eggs/batch)	8833	0.1054	12528	0.0697
Spawning fraction (number of spawning females)	0.151	0.1688	0.17	0.1623
South of 44.5 N	**Estimate**	**CV**	**Esti-mate**	**CV**
Average Female Weight (g)	323.39	0.0628	347.22	0.0264
Sex ratio (nº of females/total)	0.512	0.0061	0.509	0.0064
Batch Fecundity (nº eggs/batch)	8544	0.121	12014	0.0691

Spawning fraction (number of spawning females)	0.186	0.1812	0.23	0.0859

Average female weight and batch fecundity were higher in the northern area (Table 3.7.1.6). On the other hand, spawning fraction in the south was higher. These differences are shown in both 2019 and 2016. A sensitivity analysis conducted by Kraus et al. (2017) indicated that variability in fecundity measures and spawning fraction was less influential on the estimation of the SSB than e.g. the proportion of mature females in the stock. While those findings were for Baltic cod, they could have validity in Atlantic mackerel as well. However, this needs to be investigated utilizing a similar approach as demonstrated by Kraus et al (2017). Thus it should be studied whether differences in adult parameters north and south of 44.5 N result in significantly different biomass values.

Biomass estimation of Northeast Atlantic mackerel using DEPM methodology

The Spawning-stock biomass (SSB) was estimated as the ratio of the total daily egg production during peak spawning period (P_{tot}) to the daily stock fecundity (DF). DF is calculated as

$$DF = \frac{R * F * S}{W_f}$$

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_f is the female mean weight.

Thus, SSB is:

$$SSB = \frac{P_{tot}}{DF}$$

Total daily egg production (P_{tot}) is estimated multiplying egg production per unit of area per day (eggs/m2/day) by spawning area in peak of spawning. As a proxy of Total egg production was used the arithmetic mean of Daily egg production in period 3 and 4 of stage Ia mackerel eggs calculated for the Annual Egg Production Method. Taking in account that the positive area in period 3 and period 4 is nearly the same and temperature in positive stations (mackerel egg presence) were mostly between 10-12 ºC (stage Ia duration near to 24 h in Mendiola eq.; Mendiola et al., 2006).

From the total mature females (1265) collected in periods 3 and 4, 685 were valid for spawning fraction and 130 were valid for batch fecundity estimations (Table 3.7.1.2). Adult parameters are calculated by haul and later are extrapolated to population level, giving the same weight to all hauls.

Table 3.7.1.7 shows the estimated values of the DEPM adult parameters for mackerel and its associated coefficients of variation. Average female weight is 346 g and sex ratio is 0.52, and batch fecundity is 12391 eggs and spawning fraction is 0.23.

Table 3.7.1.7: DEPM mackerel adult parameters estimated values and correspondent coefficients of variation (cv) in periods 3 and 4.

Parameters	Estimate	CV
Average Female Weight (g)	345.8	0.0217
Sex ratio (nº of females/total)	0.52	0.01
Batch Fecundity (nº eggs/batch per mature female)	12391	0.0153
Spawning fraction (number of spawning females per mature female)	0.23	0.0941

Total daily egg production (P_{tot}) at peak spawning for both western and southern spawning components was estimated as the average daily stage Ia mackerel egg production of period 3 and 4 from the Annual Egg Production Method sampling (Table 3.7.1.8).

Table 3.7.1.8: Estimated Daily egg production of stage Ia mackerel eggs during peak of spawning for both, southern and western components.

Component	Total Daily Egg production (stage Ia)
Southern	$6.19*e^{12}$
Western	$1.56*e^{13}$

Table 3.7.1.9 shows SSB estimates for both southern and western components. Mackerel SSB in 2019 based on the DEPM was 5087 kt. This value is about a 65% higher than SSB estimated using AEPM (Table 3.4.4.1).

Table 3.7.1.9 mackerel SSB estimations using the DEPM method for western and southern mackerel components.

Component	SSB (kt)
Southern	1445.2
Western	3642.2
Total	5087.4

3.7.2 Western Horse mackerel

In 2019 horse mackerel egg production was the lowest in the time series since 1992 (Table 3.5.2.2 & Figure 3.5.2.2). The peak spawning was in July, the last sampling period of the egg survey (Figures 3.5.2.1 & 3.5.2.2). In 2013 and 2016 highest production of horse mackerel eggs was also found in July. Before 2013 peak production was in June. In 2016 an extra sampling period was added to the egg survey in August (ICES, 2017). The egg production in August 2016 was very low, confirming the peak of egg production in early July, and no substantial horse mackerel egg production was missed in 2016.

In 2019 the egg production peak in the first half of July was much lower compared to 2013 and 2016 (add ref to figure showing egg production curves). In July, 33% of the horse mackerel males and females caught were in Walsh maturity scale 2 or 3. Still in early gonad development, Screening of the ovary samples resulted in 55% of the females in early oocyte development stage with no signs of recent spawning. Only 3% of the females caught in July showed signs of recent spawning.

The low horse mackerel peak egg production and the high number of adult horse mackerel in early gonad development stage indicates that in 2019 it is likely that horse mackerel egg production has been missed during the egg survey, and that horse mackerel spawning had shifted to even later in the year. WGMEGS encourages to investigate if horse mackerel spawning has been shifted.

3.8 Quality aspects of the 2019 survey (ToR c, d, e, h)

3.8.1 Spatial and temporal coverage during the 2019 egg survey

Historically, peak mackerel spawning took place in May / June to the west of Ireland. The WGMEGS surveys of 2010 and 2013 appeared to indicate that this peak spawning was moving earlier in the year and taking place in the Celtic sea / Biscay. As a result in 2016 WGMEGS redistributed survey effort to ensure this early spawning was adequately sampled.

In 2016 early spawning never happened. Peak spawning occurred again in May / June, but this time in the northwest. Due to the reallocation of survey effort to earlier in the year, and also the withdrawal of one of the participants, it was thought that significant egg production was missed in northwestern areas during periods 5 and 6, May – June. However, subsequent analysis of the contribution of the single ICES half-rectangles to mackerel total annual egg production showed that 90 % of TAEP was well contained in the survey area (ICES 2017, Annex 14).

In 2017 WGMEGS asked participants to acquire any extra information on egg distributions prior to the planning of the 2019 survey (ICES 2017). Ireland, in 2017, and Scotland, in 2018, carried out exploratory surveys on commercial vessels, to the west of Rockall and Hatton banks, as far north as the Icelandic coast. These surveys gave an indication of egg production in these areas that would not normally be sampled during a survey year. They indicated that while some egg production was taking place its contribution to TAEP was negligible.

For the 2019 survey WGMEGS decided to cover as much of the area in each survey period as possible. Despite the unfortunate withdrawal of Iceland, the return of Norway to the survey meant that 2019 survey coverage was much improved. While some survey effort was once again directed to cover an early start to spawning, coverage for later in the year was deemed adequate.

Adult migration into the Celtic sea and Biscay took place as normal, unlike 2016 when there was a major delay. In 2019 peak spawning took place during period 4 and was generally well delineated. The expansion in egg distribution in the west, north and northwest, during periods 5 and 6 took place once again. For 2019 survey coverage in these areas was sufficient, and while not all boundaries were delineated WGMEGS are satisfied that the number of eggs missed in these areas would not add much to the calculated SSB.

Whilst the 2017 and 2018 exploratory surveys provided many of the answers relating to the western and northwestern spawning expansion issues referenced in the previous paragraphthere remains some uncertainty regarding missed egg production up and along the Norwegian shelf. As referenced within this report, Scotland encountered large concentrations of eggs on the shelf edge west of Orkney and Shetland during period 4. The boundary was successfully delineated, however spawning of this magnitude so far north and early in the season raises serious concerns regarding the mackerel spawning dynamics within this region. To help alleviate some of these concerns Scotland plan to survey the waters north of Shetland, and along the Norwegian coast during June 2021. The most southerly transects of this survey will overlap with stations to be carried out by Netherlands as part of the 2021 North Sea survey. The survey will then carry on up along the Norwegian shelf towards Lofoten. During this survey, in addition to standard plankton sampling, trawling will also be carried out, to collect adult fish for fecundity analysis as well as to ascertain more generally the maturity of mackerel present within the region and period.

3.8.2 Fecundity and atresia sampling

Origin of ovary samples

For 2019 the ovary samples collected for AEPM and DEPM were collected over a large area stretching from around 35° to 65° North (Figure 3.8.2.1). Previous surveys collected samples within the same area, but the boundaries did not stretch as far north and south. Based on microscopy screening pre-spawning fish were selected from this material and used for potential fecundity counting. The number of potential fecundity samples in the period ranged from 205 (year 2004) to 62 (year 2019) samples (Table 3.4.3.4.1) and was distributed as shown in figure 3.8.2.2. The number of batch fecundity samples was 97 and 131 for 2016 and 2019, respectively. These samples were distributed through period 3 and 4 as shown in the figure 3.8.2.3.

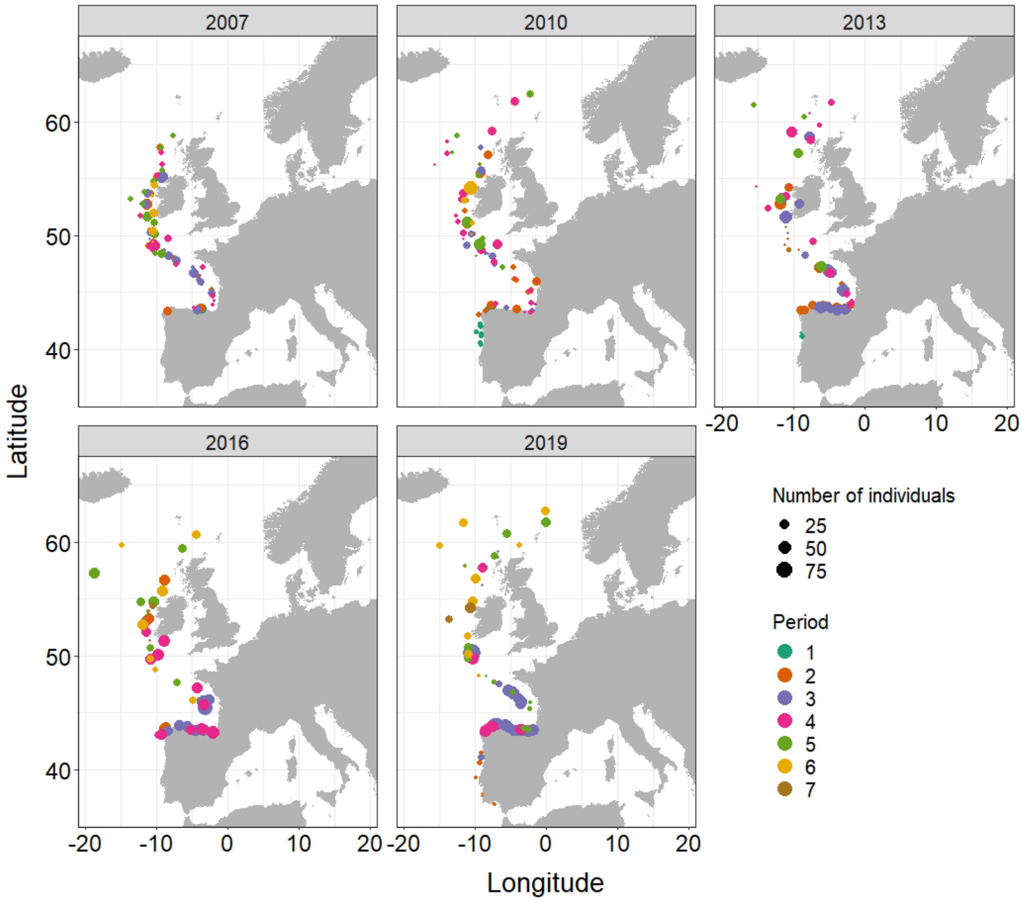


Figure 3.8.2.1: Map showing location and number of samples collected for fecundity and atresia per period during the triennial mackerel survey from 2007 to 2019.

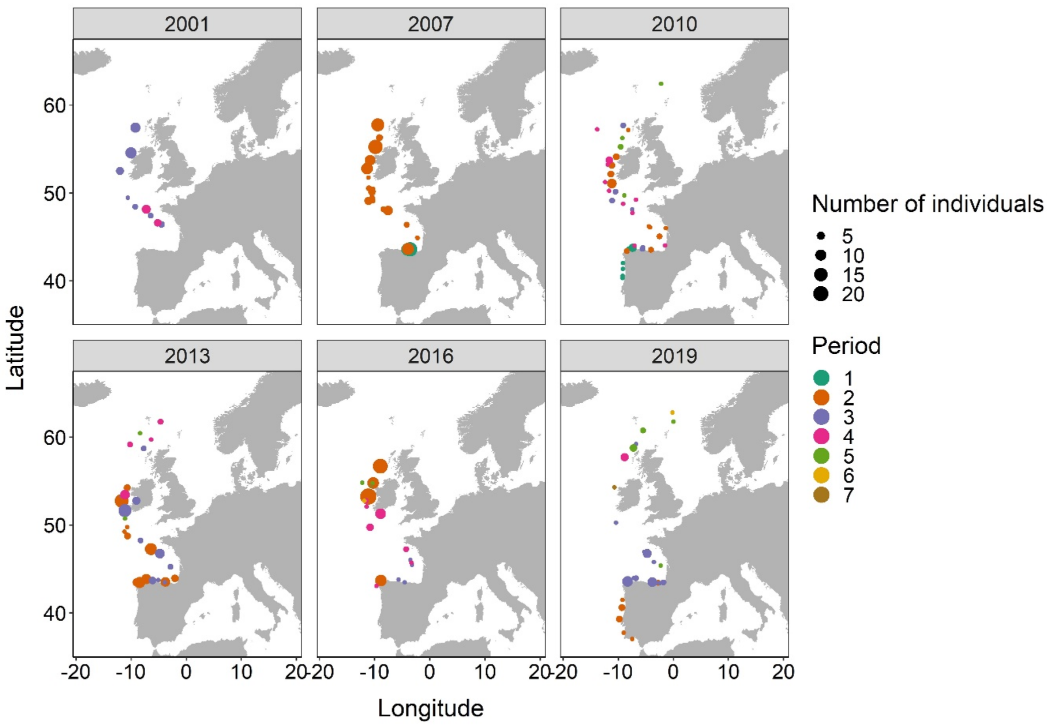


Figure 3.8.2.2: Map showing location and number of validated samples used for potential fecundity estimates per period, from 2001 to 2019.

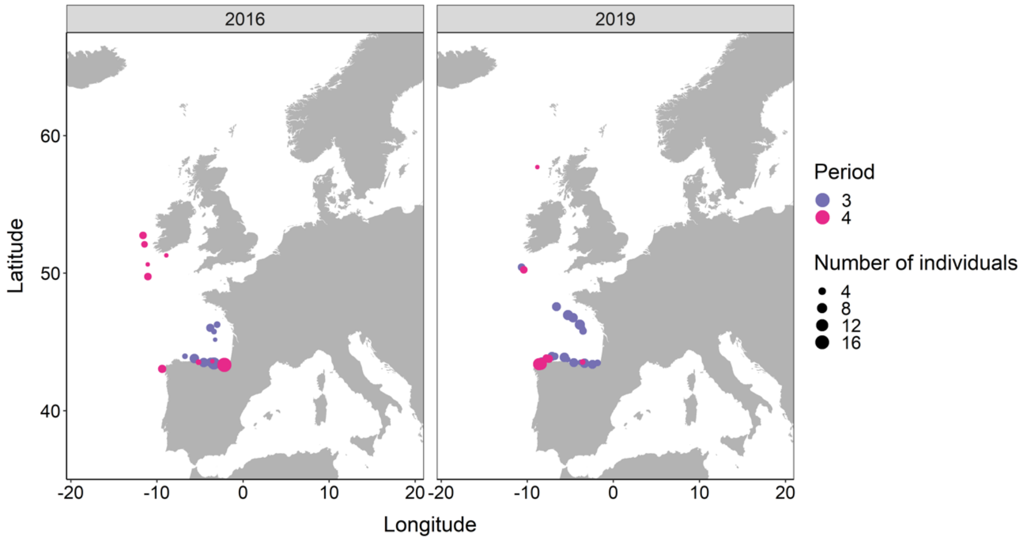


Figure 3.8.2.3: Mackerel ovary samples used for batch fecundity analysis in 2016 and 2019.

Quality aspects of sample analysis

In January and February 2019 all WGMEGS-labs, which perform the histological analyses for screening, took part in a ringtests to test quality and consistency between the survey participants. Since all screening analyses are performed using images, these ringtests could be organized by distributing anonymized images from previous surveys. The results of the ringtest are presented in this section.

Histological screening - ringtest

The histology screening ringtest was performed using 11 anonymized samples from previous surveys. The image material was distributed as digital slides from a Hamatsu NanoZoomer S60 slidescanner with a resolution comparable to using the 40X objective lens in a compound microscope. In most cases, the results (Table 3.8.2.1.1) were quite consistent between participantes, and only in a few instances, particularly for Post Ovulatory Follicles (POF) and early alpha atresia identification, some differences could be detected in a limited set of samples (1 sample for POFs and 2 for early alpha atresia).

Table 3.8.2.1: Histology screening ringtest results.

Oocyte stage

Sample	Person									
code	1	2	3	4	5	6	7	8	9	1
RTS1	3	3	3	3	3	3	3	3	3	
RTS10	5	5	5	5	5	5	5	5	5	
RTS11	5	5	5	5	5	5	5	5	5	
RTS2	3	3	3	3	3	3	3	3	3	
RTS3	2	2	2	2	2	2	3	3	3	
RTS4	5	5	5	5	5	5	5	5	5	
RTS5	5	5	5	5	5	5	5	5	5	
RTS6	2	2	1	1	4	1	1	1	1	
RTS7	5	5	4	5	4	4	4	4	4	
RTS8	5	5	5	5	4	4	4	5	5	
RTS9	1	1	1	1	1	1	1	1	1	

Oocyte hydration state

Sample	Person									
code	1	2	3	4	5	6	7	8	9	1
RTS1	0	0	0	0	0	0	0	0	0	
RTS10	2	2	2	2	2	2	2	2	2	
RTS11	3	3	3	3	3	3	3	2	2	
RTS2	0	0	0	0	0	0	0	0	0	
RTS3	0	0	0	0	0	0	0	0	0	
RTS4	1	1	1	1	1	1	1	1	1	
RTS5	3	3	3	3	3	3	3	3	3	
RTS6	0	0	0	0	0	0	0	0	0	
RTS7	1	1	0	1	0	0	0	0	0	
RTS8	1	1	1	1	0	0	0	1	0	
RTS9	0	0	0	0	0	0	0	0	0	

Presence of eggs

Sample	Person									
code	1	2	3	4	5	6	7	8	9	1
RTS1	0	0	0	0	0	0	0	0	0	
RTS10	0	0	0	0	0	0	0	0	0	
RTS11	0	0	0	0	0	0	0	0	0	
RTS2	0	0	0	0	0	0	0	0	0	
RTS3	0	0	0	0	0	0	0	0	0	
RTS4	0	0	0	0	0	0	0	0	0	
RTS5	1	1	0	1	1	0	0	0	0	
RTS6	0	0	0	0	0	0	0	0	0	
RTS7	0	0	0	0	0	0	0	0	0	
RTS8	0	0	0	0	0	0	0	0	0	
RTS9	0	0	0	0	0	0	0	0	0	

POF

Sample	Person									
code	1	2	3	4	5	6	7	8	9	1
RTS1	0	0	0	0	0	0	0	0	0	
RTS10	1	1	1	1	1	1	1	1	1	
RTS11	1	1	1	1	1	1	1	1	1	
RTS2	1	0	0	0	0	0	0	0	0	
RTS3	1	1	0	1	1	1	0	0	0	
RTS4	1	1	1	1	1	1	1	1	1	
RTS5	1	1	1	1	1	1	0	1	0	
RTS6	0	0	0	0	1	0	0	0	0	
RTS7	1	1	1	1	1	1	0	1	1	
RTS8	1	1	1	1	1	1	1	0	0	
RTS9	0	0	0	0	1	0	0	0	0	

Spent

Sample	Person									
code	1	2	3	4	5	6	7	8	9	1
RTS1	0	0	0	0	0	0	0	0	0	
RTS10	0	0	0	0	0	0	0	0	0	
RTS11	0	0	0	0	0	0	0	0	0	
RTS2	0	0	0	0	0	0	0	0	0	
RTS3	0	1	0	1	0	0	0	0	0	
RTS4	0	0	0	0	0	0	0	0	0	
RTS5	0	0	0	0	0	0	0	0	0	
RTS6	1	1	1	1	1	1	1	1	1	
RTS7	0	0	0	0	0	1	0	0	0	
RTS8	0	0	0	0	0	0	0	0	0	
RTS9	1	0	1	0	0	0	0	0	0	

Massive atresia

Sample	Person									
code	1	2	3	4	5	6	7	8	9	1
RTS1	0	0	0	0	0	0	0	0	0	
RTS10	0	0	0	0	0	0	0	0	0	
RTS11	0	0	0	0	0	0	0	0	0	
RTS2	0	0	0	0	0	0	0	0	0	
RTS3	0	0	0	0	0	0	0	0	0	
RTS4	0	0	0	0	1	0	0	0	0	
RTS5	0	0	0	0	0	0	0	0	0	
RTS6	1	1	1	1	1	1	0	0	0	
RTS7	0	0	0	0	1	0	0	0	0	
RTS8	0	0	0	0	0	0	0	0	0	
RTS9	0	0	0	0	0	0	0	0	0	

Early alpha atresia										
Sample	Person									
code	1	2	3	4	5	6	7	8	9	1
RTS1	0	0	0	0	0	0	0	0	0	
RTS10	0	0	0	0	0	0	0	0	0	
RTS11	0	0	0	0	0	0	0	0	0	
RTS2	1	0	1	1	0	0	0	0	0	
RTS3	0	0	0	0	0	0	0	0	0	
RTS4	1	1	1	1	1	1	1	1	1	
RTS5	0	0	0	1	0	0	0	0	0	
RTS6	0	0	0	1	1	1	0	0	0	
RTS7	1	1	1	1	1	1	1	1	1	
RTS8	0	0	0	0	1	1	0	0	0	
RTS9	1	0	0	0	0	0	0	0	0	

Discard										
Sample	Person									
code	1	2	3	4	5	6	7	8	9	1
RTS1	0	0	0	0	0	0	0	0	0	
RTS10	0	0	0	0	0	0	0	0	0	
RTS11	0	0	0	0	0	0	0	0	0	
RTS2	0	0	0	0	0	0	0	0	0	
RTS3	0	0	0	0	0	0	0	0	0	
RTS4	0	0	0	0	0	0	0	0	0	
RTS5	0	0	0	0	0	0	0	0	0	
RTS6	0	0	0	0	0	0	0	0	0	
RTS7	0	0	0	0	0	0	0	0	0	
RTS8	0	0	0	0	0	0	0	0	0	
RTS9	0	0	0	0	0	0	0	0	0	

Potential fecundity

Seven picture-based fecundity samples were made available to the 10 readers of the different analysing labs (Table 3.8.2.2). In most of the samples, counting results were quite consistent among participants, showing low SD. Two of the samples, F3 and F6 however, stand out as there were large differences between the highest and lowest counts, 78 and 75 % respectively. However, even in those samples, at least 50 % of the readers came to results close to the overall mean, suggesting that the very high or low results may average each other out. The results also show that there is no systematic over- or undercounting by readers, as minimum and maximum values never came consistently from the same analysts. Inspection of the image markings of some readers with high and low counts indicate that it is the small oocytes, close to the size threshold of 185 µm, that cause most of these differences. Some readers may overlook some of the small oocytes while others may mark too many of them, not paying close attention to particularly one of the size threshold rules: that oocytes should fully fill the 185 µm marker ring in order to qualify for counting.

Table 3.8.2.2: Potential fecundity ringtest. Reader numbers may not correspond to reader numbers used in other tables.

Reader counts											Statistics				
												Relative			(max/min)
Sample	1	2	3	4	5	6	7	8	9	10	Average	SD %	min	max	*100
F1	501	521	526	496	478	486	549	496	507	500	506	4.1	478	549	115
F2	870	874	914	828	764	793	1021	990	876	883	881	9.0	764	1021	134
F3	645	662	678	601	555	558	884	719	784	498	658	17.6	498	884	178
F4	828	842	865	769	688	750	955	846	816	889	825	9.1	688	955	139
F5	514	528	528	469	480	504	556	540	538	553	521	5.6	469	556	119
F6	1107	1232	1130	999	795	913	1394	1144	1260	980	1095	16.2	795	1394	175
F7	316	327	327	300	311	315	351	365	323	301	324	6.4	300	365	122

Intensity of atresia

The ringtest on the intensity of atresia was run based on seven samples (Table 3.8.2.3). The differences between persons (readers) were considerably. In the most extreme case (C117) the estimate ranged from 11 to 139 oocytes/gram, but also for the other samples the differences were conspicuous. However, variability by individual sample can be much higher than the variability of mean intensity of atresia across all readers.

Table 3.8.2.3: Intensity of atresia ringtest. Results given as oocytes/gram fish. Reader numbers may not correspond to reader numbers used in other tables.

Reader								Statistics				
Sample code	1	2	3	4	5	6	7	Average	Relative SD %	Min	Max	(Max/Min)* 100
C117	138.6	40.8	13.6	13.7	46.9	11.3	73.7	48.4	**94.9**	11.3	138.6	**1228**
I044	69.2	54.4	30.6	31.2	72.0	42.0	45.7	49.3	**34.0**	30.6	72.0	**235**
K053	3.7	2.0	4.0	4.0	1.3	7.1	1.9	3.4	**57.4**	1.3	7.1	**552**
K132	3.6	6.7	14.0	14.0	26.0	12.8	3.6	11.5	**68.4**	3.6	26.0	**727**
K220	52.5	62.2	46.7	46.8	63.3	58.0	77.4	58.1	**18.6**	46.7	77.4	**166**
M162	24.4	18.6	16.1	17.3	66.9	16.8	7.4	23.9	**81.9**	7.4	66.9	**899**
M367	36.7	27.1	39.4	35.2	49.5	29.0	14.8	33.1	**33.0**	14.8	49.5	**334**
Average	**46.9**	**30.2**	**23.5**	**23.2**	**46.6**	**25.3**	**32.1**	32.5	**31.6**	23.2	46.9	**203**

Staging of postovulatory follicles

The ringtest on POF stages evidenced the discrepancy of the POF staging among readers; the coefficient of unalikeability ranged from 0.43 to 0.93 (Table 3.8.2.4). This shows that the differences between persons in many cases were considerable. This coefficient decreased when aggregating POF stages by daily cohort reaching 0 values in a few samples. That means readers reached 100 % agreement in these samples. However, in general the POF stages per sample still differed quite often. Charitonidou et al. (2020) have shown that mackerel can have up to four batches of POFs in the ovary at the same time. This complicates the staging of POFs and might be the causing the large differences amongst readers.

Table 3.8.2.4: POF staging ringtest. Analysis of staging variability by POF stages and POF daily cohorts. Person (reader) numbers may not correspond to person numbers used in other tables.

POF stage										
	Person								Statistics	
Sample code	1	2	3	4	5	6	7	8	Coefficient of Unalikeability (CU) - stages	Coefficient of Unalikeability (CU) - grouped by day
C009e_POF1	1	6	2	1	2	6	4	4	0.86	0.71
C021e_POF2	1	2	1	1	3	3	3	3	0.68	0.00
C025e_POF3	1	3	3	3	3	4	4	4	0.68	0.54
K001e_POF4	3	4	5	3	1	3	4	4	0.79	0.57
K005e_POF5	1	4	3	2	3	4	4	4	0.75	0.57
K017e_POF6	1	3	3	3	3	3	4	4	0.61	0.43
K021e_POF7	1	4	3	2	1	3	4	4	0.82	0.54
M033e_POF8	1	6	1	1	1	4	1	1	0.46	0.46
M045e_POF9	1	5	5	3	1	4	4	4	0.82	0.54
M053e_POF10	1	2	1	3	3	2	4	4	0.86	0.43
M057e_POF11	4	5	1	4	2	5	1	1	0.82	0.57
M065e_POF12	0	0	1	0	5	0	6	6	0.75	0.75
M073e_POF13	2	3	3	3	3	3	1	1	0.61	0.00
M081e_POF14	2	4	4	4	3	4	4	4	0.46	0.43
M085e_POF15	7	0	4	6	1	0	2	1	0.93	0.86
M097e_POF16	5	5	4	4	4	4	4	4	0.43	0.00
M101e_POF17	5	5	4	4	4	5	1	1	0.75	0.43
M105e_POF18	4	5	3	4	4	4	1	1	0.75	0.54
M113e_POF19	6	6	0	5	5	5	1	1	0.82	0.82
M117e_POF20	5	5	3	5	4	4	4	3	0.75	0.43
M125e_POF21	4	4	3	4	4	4	1	1	0.61	0.54
M129e_POF22	6	6	4	3	4	5	1	1	0.89	0.75
M137e_POF23	2	3	2	3	3	3	4	4	0.71	0.43
M141e_POF24	4	4	5	4	4	4	1	1	0.61	0.43
M145e_POF25	1	3	1	3	3	3	2	2	0.71	0.00

Conclusions

For the calculation of the realised fecundity there is large differences between the inputs in how much they influence the final estimate (Presentation abstract: "Sensitivity of mackerel fecundity (AEPM)", Annex 3).

In a few instances, the ringtest on potential fecundity showed considerable variability by individual readers, which was particularly related to the inclusion or non-inclusion of the smallest oocytes. Errors in the potential fecundity estimate may have a significant impact on the realised fecundity estimate. While the majority of the readers had counting results similar to the overall mean, a small number of analysts either over- or underestimated their counts, with the likely net result being that these counting errors neutralised each other. The impact of errors in the atresia related parameters is relatively low, since the atretic loss is small compared to the potential fecundity, the value that atretic loss is to be subtracted from (Table 3.4.3.4.1).

For the 2019 egg survey WGMEGS cannot know for sure how much impact the above errors had, however the final realised fecundity estimate was entirely consistent with the estimates reported from previous surveys (Table 3.4.3.4.1). With all the issues considered there is no reason to think that the 2019 estimate is anything other than a valid estimate of mackerel fecundity during 2019.

In the 2021 fecundity workshop, it is important that the quality issues that have been revealed in this section are closely investigated. Since all the work has taken place on digital images, both the ringtest material and the 2019 survey samples can be reassessed during the upcoming workshop.

3.8.3 Egg diameter measurements

Over recent surveys the presence of other fish eggs with similar characteristics to mackerel and horse mackerel, particularly hake and ling, has raised concerns about the correct identification of all species. The size range of hake eggs overlaps with that of horse mackerel eggs at the lower end of its range, and with that of mackerel at its upper. In 2015 WKFATHOM proposed that participants on the 2016 MEGS 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 (ICES 2015). The results of this exercise are reported in the 2017 WGMEGS report (ICES 2017).

As the results were somewhat inconclusive, participants were asked to repeat the exercise during the 2019 survey. Results were received from Portugal, Spain IEO, Spain AZTI, Netherlands, Germany, Ireland, Scotland, Faroes and Norway. Not all countries reported for the three species while some countries reported measurements for Ling, which are encountered in northern latitudes in moderate numbers.

Results from all laboratories were in close agreement with the same size ranges being reported for each species. There is some overlap in the sizes reported at the top of the range for Hake with the bottom of the range for Mackerel. A similar overlap occurs between Hake and Ling. Mackerel and Horse mackerel eggs are well separated with no overlap.

WGMEGS reiterates the need to use the spray technique to extract eggs from the plankton samples and subsequently to conduct the Surface Adhesion Test, SAT, to ensure that Hake eggs are adequately separated in the samples. Further work will be carried out at WKMACHIS, the Workshop on Mackerel, Horse Mackerel and Hake Eggs Identification and Staging to be held in Bremerhaven in 2021.

Horse-mackerel egg sizes distribution along the southern and western Atlantic Iberian shores

For each species the spectrum of egg sizes found in the plankton samples may differ according to parental effects, such as size/age of the progenitors or their condition and environmental factors like water density which in turn depends on the local salinity and temperature. Investigation on possible geographical and seasonal variability in the egg sizes together with information on the eggs quality and on the adult fish population size structure may help in understanding early life stages survival and recruitment spatial patterns. Chorion and oil droplet sizes were measured for horse-mackerel eggs from the last four DEPM surveys conducted by IPMA in the southern and western Atlantic Iberian shores. In total, 3000 eggs collected by CalVET nets in 2010, 2013, 2016 and 2019 were analysed. The preliminary results highlighted clear inter-annual variability and also spatial differences in the chorion diameter of the eggs collected in the three areas analysed (NW, SW and S coasts) but not for every year analysed. The relationships encountered between chorion sizes and sea surface temperature and salinity were weak. Although statistically significant for area and year, the differences in chorion diameter found may reflect the parents size distribution and other parental effects which need to be considered in further analyses.

3.8.4 Mackerel egg development experiments

Experimentally derived temperature-dependent development rates for mackerel eggs are required for transforming the mackerel egg abundance into production. In 2013, WGMEGS replaced the equation provided by Lockwood *et al.* (1977) with the one estimated by Mendiola *et al.* (2006). Although the Mendiola equation was considered an improvement, some doubts arose regarding the effects that the area the adults were collected from and different methodologies used for the experiments might have had on the results.

The development of Northeast Atlantic mackerel eggs, obtained from artificial fertilisation was examined in several years, periods, and areas. Wageningen Marine Research (WMR) carried out experiments in May and June 2016 in the Bay of Biscay and Celtic Sea, in June 2017 in the North Sea, and in May 2019 in the Bay of Biscay. AZTI and IEO conducted experiments in March 2019 in the Bay of Biscay and the Cantabrian Sea respectively.

Six potential models were fit for each of the experiments. The new models gave faster development rates for stage 1 than that reported by Mendiola *et al.* 2006, and the ANOVA comparing AZTI+IEO curves with Mendiola *et al.* (2006) indicated that development rates differed significantly ($P<0.01$). All new models would reduce the mackerel egg production between 10 to 26% depending on temperature and model. Further analysis will be conducted to investigate how the area and season might affect these relationships.

3.8.5 Gonad development of female mackerel

From February 2019 till February 2020 mackerel were sampled to study year-round gonad development of males and females. This project was a cooperation between the pelagic industry and research institutes. Results showed that female gonads contained vitellogenic oocytes throughout the year. These oocytes were in true vitellogenesis, they were beyond the cortical alveoli stage. This shows that contrary to believe, mackerel females do not have a 'true' resting period after the spawning season, but are continuously developing oocytes. Late vitellogenic stages were found just prior to and during the spawning season.

This probably shows the flexibility mackerel females have for spawning eggs. Once the environmental circumstances are correct, the vitellogenic oocytes can be further developed quickly to spawning. It might also explain why the start of the spawning season varies considerably from year to year. Results of this project will be published in a peer-reviewed paper.

3.9 North Sea mackerel egg survey in 2020 (ToR f, j)

WGMEGS planned to conduct a mackerel egg survey in the North Sea in 2020 to estimate egg production and SSB for North Sea mackerel. The Netherlands and Denmark would participate in the survey in May and June (Table 3.9.1).

Table 3.9.1: Planned sampling periods for North Sea mackerel egg survey in 2020.

Country	Netherlands	Denmark
Sampling period	**25 May – 12 June**	**29 May – 7 June**

In 2018 WGMEGS had decided to move to a DEPM survey for the North Sea for various reasons, such as the difficulty in getting potential fecundity samples, the survey participation did not allow for full coverage of the spawning area in multiple periods and the mackerel spawning in the North Sea is contained in a certain area (unlike the shifts seen in the Northeast Atlantic) (ICES, 2018). The planning was to do one full coverage of the whole North Sea during the egg survey (Fig. 3.9.1).

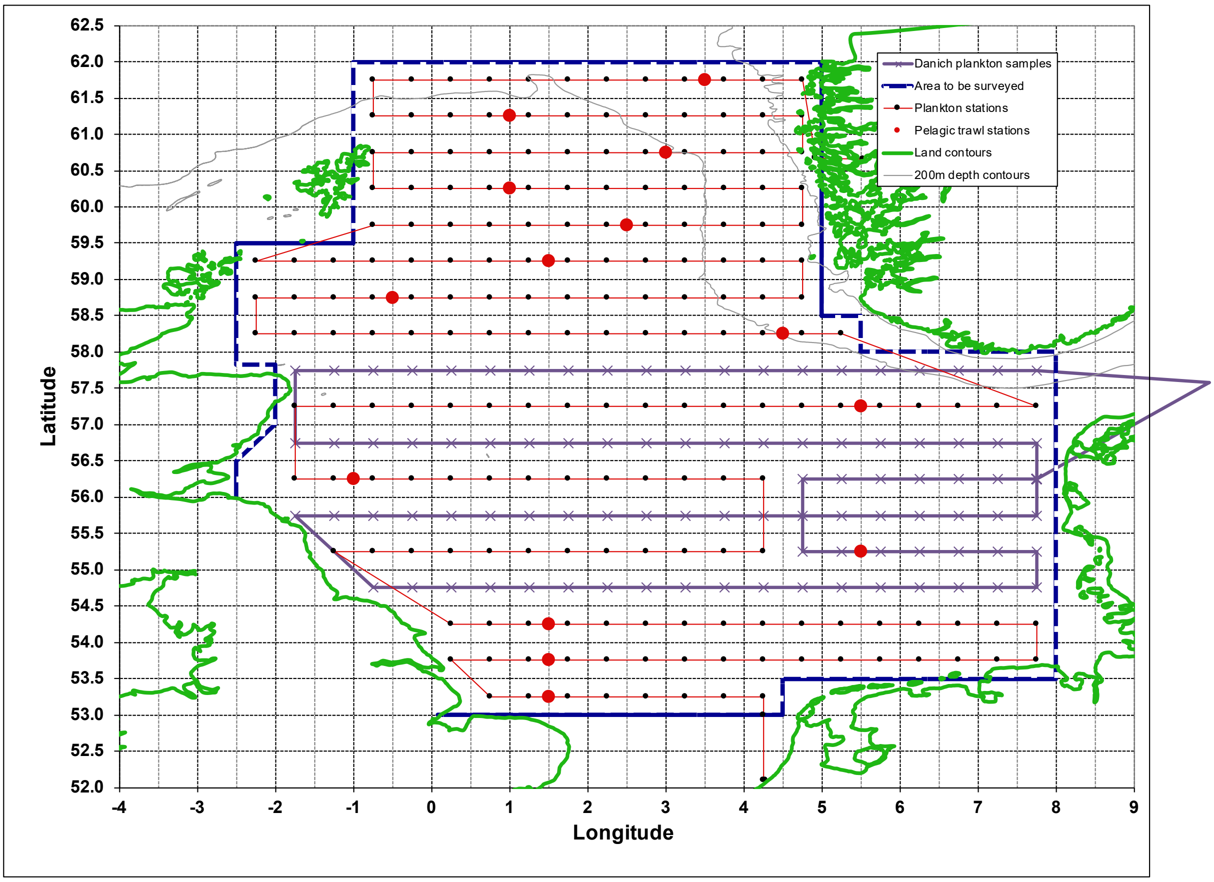


Figure 3.9.1. Planned plankton sampling for the Netherlands (red line with black squares) and Denmark (blue line with crosses) during the North Sea mackerel egg survey.

Due to the COVID19 restrictions in 2020 it would be difficult to carry out the North Sea mackerel egg survey in 2020. The effect, of postponing the North Sea egg survey to 2021, on the mackerel assessment was discussed with the mackerel stock assessor and WGMEGS chairs. It was concluded that the effect would be small. The Netherlands and Denmark have both decided to postpone their surveys to 2021. The sampling timing and planning will be as similar as possible in 2021 as to the planning described above.

3.10 Planning for the 2022 survey (ToR a)

Planning for the 2022 egg survey is in its early stages. This work will be completed at the WGMEGS meeting due to take place in April 2021.

As well as planning for the standard western and southern survey for 2022, WGMEGS has been requested to consider carrying out the North Sea egg survey in the same year, instead of the following year as is current practice (ICES 2019d). A review was carried out of recent survey effort and requirements in both areas. This led to a number of questions being asked of MEGS participants. It was decided to draft a questionnaire to be sent to all participants requesting information on a number of these topics, with replies to be received by the survey coordinator early in 2021. These responses will inform the 2021 WGMEGS survey planning meeting, at which a decision will be made on whether a change will take place in 2022.

3.11 Database (ToR k)

Egg data

In 2012 WGMEGS began discussions with ICES about including current and historic survey data in the ICES egg and larval database, to make it publically available. This data would include station data as well as egg identification and staging data. After careful consideration WGMEGS decided that historical data from the Western survey as far back as 1992 was of sufficient quality to be included in the database. This was initiated subsequent to a change in the development equation (from Lockwood – Mendiola) used to estimate mackerel egg abundance and subsequently required a recalculation of the entire historic egg abundance time-series back as far as 1992. During 2013 and 2014 Finlay Burns and Gersom Costas cleaned and reformatted the individual survey data files into a coherent and standardised format that would enable easy transfer into the ICES input format. The first version of the historic eggdata was uploaded in December 2014 but during subsequent years amendments were made to the database format resulting in a further submission being required and so in early 2019 all the eggdata from 1992 to 2018 in the southern and western areas was uploaded to ICES. As well as the triennial survey data this also included the additional exploratory surveys undertaken in the interim years such as those in 2017 and 2018. Work is currently ongoing to incorporate data from the North Sea surveys into the required format.

The 2019 survey data was uploaded to ICES subsequent to the 2020 WGMEGS meeting.

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 data base 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.

Following discussions at WGMEGS meetings and Skype meetings between WGMEGS members and the ICES data centre, a format has been suggested based on existing ICES databases and datasheets used by WGMEGS for reporting of fecundity and atresia data. The working title of the ICES database is: Fish Reproduction portal, Fecundity and atresia database.

The proposed format will allow for all haul, fish, fecundity and atresia parameter data which are collected, to be stored in a relational database. It is planned that the historic biological data and fecundity and atresia (from 1986 to 2016) will be included in the ICES database.

The ICES data centre is planning to have the database implemented in 2020.

For the next survey 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 (jens.ulleweit@thuenen.de) with the agreed data entries (ICES, 2017).

4 References

Charitonidou, K., Kjesbu, O.S., Dominguez-Petit, R., Garabana, D., Korta, M.A., Santos, M., Damme, C.J.G. van, Thorsen, A., Gania, K. 2020: Contrasting post-ovulatory follicle production in fishes with different spawning dynamics. Fisheries Research 231, https://www.sciencedirect.com/science/article/pii/S0165783620302277

ICES. 1987. Report of the Mackerel Working Group. ICES CM 1987/Assess:11, 72pp.

ICES. 2008. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS). ICES CM 2008/LRC:09. 111pp

ICES, 2012. Report of the Workshop on Survey Design and Mackerel and Horse Mackerel Spawning Strategy (WKMSPA), 16-17 April, Galway, Ireland. ICES CM 2012/SSGESST: 05,32 pp

ICES 2014. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS), 7-11 April 2014, Reykjavik, Iceland. ICES CM 2014/SSGESST:14. 110 pp.

ICES. 2015. Report of the Workshop on Egg staging, Fecundity and Atresia in Horse mackerel and Mackerel (WKFATHOM). ICES CM 2015/SSGIEOM:01, 72 pp.

ICES. 2017. Final Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys. WGMEGS Report 2017 24-28 April 2017. Vigo, Spain. ICES CM 2017/SSGIEOM:18. 134 pp.

ICES. 2018. Report of the Working group on improving use of Survey Data for Assessment and Advice (WGISDAA). 3-5 July 2018. Copenhagen, Denmark. ICES CM 2018/EOSG: 15. 30 pp.

ICES. 2018a. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS). ICESCM 2018/EOSG: 17.

ICES. 2018b. Report of the Workshop on egg staging, fecundity, and atresia in horse mackerel and mackerel (WKFATHOM2). 8-12 October and 19-23 November. Bremerhaven, Germany and IJmuiden, Netherlands. ICES CM 2018/EOSG:22. 74pp

ICES. 2018c. Report of the Working Group on Widely Distributed Stocks (WGWIDE), 28 August- 3 September 2018, Torshavn, Faroe Islands. ICES CM 2018/ACOM: 23. 488 pp.

ICES. 2019a. Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS). ICES Scientific Reports. 1:66. 233 pp. http://doi.org/10.17895/ices.pub.5605

ICES. 2019b. Manual for the AEPM and DEPM estimation of fecundity in mackerel and horse mackerel. Series of ICES Survey Protocols SISP 5. 89 pp. http://doi.org/10.17895/ices.pub.5139

ICES. 2019c. Manual for mackerel and horse mackerel egg surveys, sampling at sea. Series of ICES Survey Protocols SISP 6. 82 pp. http://doi.org/10.17895/ices.pub.5140

ICES. 2019d. Workshop on a Research Roadmap for Mackerel (WKRRMAC). ICES Scientific Reports. 1:48. 23 pp. http://doi.org/10.17895/ices.pub.5541

ICES. 2020. Final report of the Working group on improving use of Survey Data for Assessment and Advice (WGISDAA). In preparation

Lockwood, S. J., Nichols, J. H., and Coombs, S. H. 1977. The development rates of mackerel (Scomber scombrus L.) eggs over a range of temperature. ICES CM 1977/J:13, 8 pp.

Mendiola, D., Alvarez, P., Cotano, U., Etxebeste, E., and Martinez de Murguia, A. 2006. Effects of temperature on development and mortality of Atlantic mackerel fish eggs. Fisheries Re-search, 80: 158–168.

Annex 1: List of participants

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Annex 2: Agendas of the 2020 meetings

A2.1 Agenda of the first video meeting, 28 and 29 April 2020

Agenda WGMEGS April 2020, by WebEx

ToRs

ToRi: Analyse and evaluate the results of the 2019 mackerel and horse mackerel egg surveys in the western and southern areas;

1. calculate the total seasonal stage 1 egg production estimates for mackerel separately for the western and southern areas;
2. calculate the total seasonal stage 1 egg production estimates for the western horse mackerel stock (AEPM);
3. analyse and evaluate the results of the mackerel and horse mackerel fecundity and mackerel atresia sampling in the western and southern areas;
4. 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;
5. 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.

ToR j: Plan and coordinate the 2020 North Sea mackerel egg survey.

WebEx agenda

Meeting times

Tuesday, 28 April 2020,	10:00 – 12:00 and 13:00 – 15:00
Wednesday, 29 April 2020,	10:00 – 12:00 and 13:00 – 15:00 (if necessary)

Tuesday, 28 April

10:00 – 12:00	Introduction (chairs), delegation of tasks for report (draft only) writing **ToR i:** 2019 survey – updates, presentation of results with new scaling (Gersom), AEP for mackerel and horse mackerel. **Discussion** of the survey results w.r.t. spatial and temporal coverage.
13:00 – 15:00	**ToR i:** 2019 survey – fecundity. Presentation of the results (Anders or Maria) for mackerel and horse mackerel Mackerel DEPM results, Horse Mackerel DEPM results Portuguese DEPM survey results Horse Mackerel (Cristina)

Wednesday, 29 April

10:00 – 12:00	**ToR j:** North Sea MEGS, planning for 2020, postponement to 2021 or 2022 (then together with NEA MEGS???) (Cindy, Brendan, Richard, chairs)
	Year of the mackerel – updates (Cindy). Discussion on possible utilization of the data
	2019/2020 Workplan for WGMEGS – who is doing what, status of the work done so far
13:00 – 15:00	WGMEGS ToRs for 2021 – 2023, new chair
	2021 workshops (successors of WKFATHOM): ToRs and chairs (either confirm current ones or chose new ones)

A2.2 Agenda of the second video meeting, 4 – 6 November 2020

Draft agenda WGMEGS November 2020, by WebEx
Relevant ToRs (year 3)

ToR i: Analyse and evaluate the results of the 2019 mackerel and horse mackerel egg surveys in the western and southern areas;

1. calculate the total seasonal stage 1 egg production estimates for mackerel separately for the western and southern areas;
2. calculate the total seasonal stage 1 egg production estimates for the western horse mackerel stock (AEPM);
3. analyse and evaluate the results of the mackerel and horse mackerel fecundity and mackerel atresia sampling in the western and southern areas;
4. 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;
5. 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.

ToR j: Plan and coordinate the 2020 North Sea mackerel egg survey.

ToR k: Review and reformat the historic time-series of North Sea mackerel egg surveys and upload data to the ICES egg and larvae database

WebEx agenda – Times in CET (UTC +1)

Meeting times

Wednesday, 4 November 2020,	10:00 – 12:00 and 13:00 – 15:00
Thursday, 5 November 2020,	10:00 – 12:00 and 13:00 – 15:00
Friday, 6 November 2020,	10:00 – 12:00 and 13:00 – 15:00 (if necessary)

Wednesday, 4 November

10:00	Introduction (chairs), delegation of tasks for report writing
10:15	**Final estimates DEPM southern HOM 2019 – Cristina, Maria**
	ToR i, fecundity: 2019 survey updates on mackerel results, mackerel fecundity and SSB estimation time series
10:30	Mackerel fecundity data in 2019 - Anders

10:45	Fecundity sensitivity in SSB estimate – Gersom
11:00	Mackerel oocyte recruitment dynamics and fecundity pattern – Thassya
11:15	Year of the mackerel results – Cindy
11:30	Skipped spawning in mackerel? – Maria Korta
11:45	Unforeseen, lagged linkages between bioenergetic and reproductive dynamics in North East Atlantic mackerel (Scomber scombrus) may explain inconsistencies among diverse stock assessment results – Teunis
12:00 – 13:00	Lunch break
13:00	Discussion on morning presentations
13:30	Interannual variations in timing of maturation and spawning activities of NEA mackerel in Nordic waters – Thassya
13:45	Long term changes in length distribution and age structure of mackerel sampled during the triennial mackerel egg surveys – Thassya
14:00	Research collaboration Mackerel year class spatiotemporal dynamics – the WGMEGS time series on biological data
14:15	Discussion, report writing

Thursday, 5 November 2020

10:00	MEGS estimates for mackerel and horse mackerel assessment (WGWIDE) – Gersom
10:15	New calculation of annual egg production from the ICES Mackerel Egg Survey – Ismael
10:45	DEPM for SSB estimation in mackerel – Gersom
11:00	HOM and MAC egg sizes distribution along the southern and western Atlantic Iberian shores – Cristina, Maria
11:15	Mackerel and horse mackerel egg size variation in 2019 IEO surveys. – Isabel
11:30	Egg diameter measurements in mackerel and horse mackerel during the 2019 survey - Brendan
11:45	Effect of temperature on the development of Atlantic mackerel eggs from the experiments of incubation carried out during Triennial campaigns in 2019 by AZTI, IEO and WUR – Paula
12:00 – 13:00	Lunch break
13:00	Exploratory Survey in the Nordic Seas – Fin
13:15	North Sea Egg Survey 2021 (updates) – Cindy
13:30	Triennial Survey including all "stock components" of mackerel – Brendan
14:00	Review of the fishing effort during the recent 3 MEGS – Paula
14:15	Report writing

Friday, 6 November 2020

10:00	Egg and Larvae Database, Biological Database, Report, Recommendations
12:00	End of meeting (or resume at 13:00 and continue until 15:00)

Annex 3: Abstracts of presentations given during the second WebEx meeting in November 2020

Effects of temperature on the development rates of mackerel eggs: Experiments conducted during MEGS surveys by AZTI, IEO and WMR.

Alvarez, Paula; Riveiro, Isabel and van Damme, Cindy.

Experimentally derived temperature-dependent development rates for mackerel (Scomber scombrus) eggs are required for transforming the mackerel egg abundance into production. In 2013, WGMEGS agreed to replace the equation provided by Lockwood et al. (1977) with the one estimated by Mendiola et al. (2006). This equation produces higher egg production and biomass values because the eggs develop faster. Although the Mendiola equation was considered an improvement, some doubts arose regarding the effects that the area the adults were collected from and different methodologies used for the experiments might have had on the results. Therefore, WGMEGS recommended checking the development equations through new experiments.

The development of Northeast Atlantic mackerel eggs, obtained from artificial fertilisation was examined in several years, periods, and areas, by Wageningen Marine Research (WMR), AZTI and IEO during the MEGS surveys. WMR carried out experiments in May and June 2016 in the Bay of Biscay and Celtic Sea, in June 2017 in the North Sea, and in May 2019 in the Bay of Biscay. AZTI and IEO conducted experiments in March 2019 in the Bay of Biscay and the Cantabrian Sea respectively.

Running females and males were selected from the hauls and the gametes were artificially fertilised. Once the fertilization occurred the material was immediately transferred to the incubators. This is the same as Lockwood et al. (1977) did, but different from Mendiola et al. (2006), who fertilised the eggs and kept them at 5℃ until reaching the laboratory to start the experiment. In the new experiments development rates were determined at temperatures ranging from 8 to 17ºC. The temperature and oxygen levels (WMR) were recorded automatically using sensors (AZTI and IEO) or manually during the egg sampling. On a daily basis (AZTI+WMR) or twice a day (IEO) part of the sea water was replaced to avoid the depletion of oxygen. The end of a stage was defined as the time at which 50% of the sampled eggs have passed into the next stage. The effect of temperature on the process was studied using the power function, fitted using ordinary least-squares for the log-transformed data.

Six potential models from stage 1A, 1B, 2, 3 and 5 were fit for each of the experiments. Since the number of temperatures essayed by the IEO was not enough to fix an independent model, IEO and AZTI results were modelled together. All the studies showed a curvilinear relationship between age at stage and temperature. The new models gave faster development rates for stage 1 than that reported by Mendiola et al. 2006, and the ANOVA comparing AZTI+IEO curves with Mendiola et al. (2006) indicated that development rates differed significantly ($P<0.01$). All new models would reduce the mackerel egg production between 10 to 26% depending on temperature and model. Further analysis will be conducted to investigate how the area and season might affect these relationships.

Retrospective of adult hauls during the last three surveys (2013 to 2019).

Alvarez, Paula and Korta, María.

Biomass estimation of Atlantic mackerel and horse mackerel depends, to a great extent, on reproductive parameters, as we need to relate the number of eggs collected with the fish fecundity. For mackerel, since 2013, daily and annual production methods, i.e., DEPM and AEPM respectively, have being applied together, resulting in an increase of the number of females needed to achieve both goals. In the case of horse mackerel, only the DEPM is applied, which constraints the sampling to the peak of spawning. During the last surveys, the analysis of fecundity parameters faced serious issued due to the paucity of suitable samples. The situation was so extreme for horse mackerel that in 2019 it was decided not to carry out the estimation of these parameters.

For this reason, it was considered convenient to explore how our hauls have been conducted to propose future actions to improve the adult collecting efficiency.

A common excel file was distributed between the partners to compile the information on hauls in terms of date, position and both the number of fish collected, and the number of fish retained for reproduction studies. The hauls and catches in Portugal waters were not included in the analysis as they are deemed independently.

Variable considered in the present study were the number of hauls and the number of fish by period and area. For mackerel, the analysis revealed that 70% of hauls were positives, but this feature decreased from 111 hauls in 2013 to 86 and 87 in 2016 and 2019, respectively. The hauls were well-spatially distributed, however temporally the numbers were significantly highest in Period 3 and Period 4 in 2019 and 2016, respectively. In 2013 the distribution of number of hauls was quite homogenous. The analysis illustrated that there was little coincidence not only in the number of planned and retained fish but also in the distribution by periods. In 2013 the differences in respect to the number of fish scheduled were lower. Regarding the area, it was split into three sub-areas, Bay of Biscay, Celtic Sea-south Ireland, and north of 53ºN. The analysis revealed that the Bay of Biscay (43ºN-48ºN) was the best represented in terms of the number of fish retained, while the Celtic Sea (48º-53ºN), a well-known spawning ground, might be considered as under-sampled. This trend was common for the three years analysed. The situation for horse mackerel was still more worrying. The maximum number of hauls per year hardly varied, i.e. it ranged from 23 to 25 total hauls, but not more than 17 of them were positives for horse mackerel. Most of the hauls were carried out in Period 5 onwards, as the peak of spawning seems to take place between spring-summer. The hauls were mainly located in the Celtic sea, being its distribution wider in 2016 than in 2013 and 2019. Considering the number of horse mackerel retained in relation to areas and periods, the results showed that both met the schedule proposed. On the one hand, the Celtic Sea was the area best represented and on the other hand, Period 5 onward the best sampled. However, the problem here arises with the number of specimens obtained; in general, it was achieved less than a third of what was planned. In terms of number, the situation can be summarized as follows: for mackerel less than 50% (±1250 fish) of numbers planned were obtained. Besides, to estimate AEPM parameters the samples reduced to 62 fish for fecundity and 64 for intensity of atresia in 2019, for instance. For DEPM the situation was similar: in the case of horse mackerel the number of fish retained barely achieved 20% (±150 fish) which led to extremely low figures i.e., between 27 to 37 fish in 2013 and 2016 respectively, as to conduct any valid statistical analysis.

HOM egg sizes distribution along the southern and western Atlantic Iberian shores

Angélico, Maria Manuel; Nunes, Cristina and Henriques, Elisabete

For each species the spectrum of egg sizes found in the plankton samples may differ according to parental effects, such as size/age of the progenitors or their condition and environmental factors like water density which in turn depends on the local salinity and temperature. Investigation on possible geographical and seasonal variability in the egg sizes together with information on the eggs quality and on the adult fish population size structure may help in understanding early life stages survival and recruitment spatial patterns. Chorion and oil droplet sizes were measured for horse-mackerel eggs from the last four DEPM surveys conducted by IPMA in the southern and western Atlantic Iberian shores. In total, 3000 eggs collected by CalVET nets in 2010, 2013, 2016 and 2019 were analysed. The preliminary results highlighted clear inter-annual variability and also spatial differences in the chorion diameter of the eggs collected in the three areas analysed (NW, SW and S coasts) but not for every year analysed. The relationships encountered between chorion sizes and sea surface temperature and salinity were weak. Although statistically significant for area and year, the differences in chorion diameter found may reflect the parents size distribution and other parental effects which need to be considered in further analyses.

Southern horse-mackerel 2019 DEPM survey - PT-DEPM19-HOM

Angélico, Maria Manuel; Henriques, Elisabete and Nunes, Cristina.

The DEPM survey directed at providing spawning-stock biomass estimation (SSB) for the southern horse-mackerel stock is carried out by IPMA since 2007 every three years, within the framework of the EU-DCF/PNAB, and coordinated under the auspices of the ICES-WGMEGS. Additionally, the Portuguese survey provides the samples and the data required for the application of the AEPM to estimating mackerel biomass in European waters. The Portuguese survey takes place close to the horse-mackerel peak spawning period and aims at surveying/sampling over the southern and western Atlantic-Iberian waters, from Cape Trafalgar to Cape Finisterre (ICES area 9a), simultaneously collecting plankton and fish samples. In 2019, the survey was carried out, as scheduled, in the period 23 January - 28 February onboard the RV Noruega, the survey plan having been totally achieved. Typical oceanographic conditions for a winter situation were observed. Horse mackerel eggs were collected over the entire surveyed area (in 18% of the plankton hauls), nevertheless more densely in the usual "core spots" (the outer shelf and the vicinity of canyons), and presenting a considerable patchy distribution, with some negative stations within the positive spawning stratum. The resulting 2019 estimate for the Spawning Area was slightly higher than in 2016 (21360 km2). Both Daily Egg Production and Total Egg Production increased significantly, compared to the previous survey (38.6 eggs/m2/day, 8.25 eggs/day x1011, respectively). Fish sampling objectives were also achieved, despite the fact that only 37.5% of the fishing hauls resulted positive for horse-mackerel. In particular, and despite a large effort, no horse-mackerel were sampled in the Cadiz Spanish waters, corroborating the absence of eggs of the species in the area. Overall, the adult parameters estimated in 2019 and in 2016 were very comparable. Mean Female Weight was very similar (118.1 g), confirming the similar size range of the horse mackerel sampled in both surveys. Slightly higher estimates of Batch Fecundity, Relative Fecundity, and Daily Fecundity were obtained (17762 eggs, 150 eggs/g female, 4.45 eggs/day.g female, respectively). Spawning Fraction in 2019 was also very similar, compared to 2016, remaining at low values (0.057), possible hypotheses having been discussed within the group.

Exploratory egg surveys, realised and proposed 2017 - 2021

Burns, Finlay

During the last NEA mackerel benchmark in 2017 and as part of the WGMEGS survey review process a commitment was made to undertake exploratory ichthyoplankton surveys within the mackerel spawning boundary regions in the North and Northwest and where the MEGS surveys have hitherto struggled to delineate a hard spawning boundary. Mackerel spawning within these offshore regions was first reported back in 2007 but only at relatively low levels. The 2016 MEGS survey delivered a significant change to this situation with peak spawning taking place over a broad swathe of open ocean to the West and Northwest of Scotland, far away from the traditional spawning hotspots and uncomfortably close to the Northern and northwestern survey boundary. During 2017 and 2018 exploratory surveys undertaken by Ireland and Scotland and utilising Gulf 7 samplers successfully mapped and delineated a mackerel spawning boundary within the offshore areas of Hatton Bank/South Iceland Basin and the Scotland-Faroe-Iceland Ridge. The results from these surveys played a useful role in informing the survey planning process ahead of the 2019 MEGS triennial survey. During June 2021 Scotland plans to conclude this exploratory objective by undertaking a further survey up and along the Norwegian Shelf and during the month when the highest mackerel spawning densities are likely to be encountered within this region and the results from the 2019 MEGS survey also confirm this. In addition to the exploratory objective, the proposed survey will also contribute 3 overlapping Gulf 7 transects to the North Sea MEGS survey schedule and the intention will be to also collect adult samples using the pelagic trawl. The full survey results will be provided to WGMEGS in time to feed into the planning process of the triennial MEGS survey in 2022.

Mackerel and horse mackerel egg size in IEO 2019 surveys.

Cortegoso, Patricia and Riveiro, Isabel

During the 2019 IEO MEGS surveys, the evolution of the egg size for both mackerel and horse mackerel was analyzed in relation to the area and the timing of the spawning. Likewise, the effect of environmental variables on the egg size and oil drop size was studied.

The results obtained showed very different patterns for both species. In the case of mackerel, egg size was related to temperature, with larger sizes as the temperature increases. In the case of horse mackerel, a relationship between oil droplet size and salinity was observed, which could be related to maintenance of buoyancy.

Sensitivity of mackerel fecundity (AEPM).

Costas, Gersom.

A sensitivity analysis was performed in order to know the impact of some fecundity parameters in SSB estimation. It has been used the One-At-a-Time (OAT=) technique which analyze the effect of one parameter on output, keeping the other parameters (inputs) fixed. A sensitivity analysis was performed applying an increase or decrease percentage change of mean realised fecundity (Fr) estimated during period 2001-2019. Effect in SSB calculated according to the equation of Annual Egg Production Method. Egg production values (AEPM) when is applied a percentage change in mean realised fecundity (from 50% to 150%). An asymmetric impact has been noted depending on whether change in Fr is increased or is decreased. Then decrease in Fr has a greater impact in SSB estimates that increase in Fr such as an increase of 20% in Fr produces a decrease of 17% of SSB but a decrease of 20% produces an increase of 25% of SSB. same analysis has been performed in atretic assumptions of duration of early alpha atresia and spawning duration (7.5

days and 60 days) of the fish in both assumptions a low impact were observed and an asymmetric impact was only observed in variation of duration of early alpha atresia.

DEPM for estimating mackerel SSB in 2019.

Costas, Gersom and Garabana, Dolores

In 2018 during WGMEGS meeting was agreed that periods highlighted as being the likely peak spawning periods were periods 3 and 4 for mackerel. Due to this the intensive DEPM sampling was mostly carried out during periods 3 and 4.

Consequently the Daily Egg Production Method (DEPM) for mackerel SSB estimate was applied in periods 3 and 4.

The SSB was estimated as the ratio between the total egg production and daily fecundity during peak of spawning. As a proxy of total egg production (eggs/m2/day) was used the arithmetic mean of Daily egg production in period 3 and 4 of stage Ia mackerel eggs calculated by the Annual Egg Production Method. Taking in account that the positive area in period 3 and period 4 is almost the same area and temperature in positive stations were mostly between 10-12 ºC (stage Ia duration is close to 24 h in Mendiola equation).

Fecundity parameters were estimated using DEPM samples collected in periods 3 and 4. As a result, batch fecundity was estimated 12391 eggs per batch, average female weight was 345.8 g, sex ratio was 0.52 and spawning fraction was 0.23.

SSB was estimated for both southern and western components. As result combined SSB was estimated 5087 kt. This value represents a 65% higher than SSB estimate using AEPM.

Unforeseen, complex linkages between bioenergetics and reproductive dynamics in NEA mackerel may explain inconsistencies among diverse stock assessment results.

Jansen, Teunis; Slotte, Aril; dos Santos Schmidt, Thassya C. ; Sparrevohn, Claus; Jacobsen, Jan Arge and Kjesbu, Olav Sigurd

The energetic annual cycle was documented, showing that the available energy for fecundity has varied substantially over the years. This is in contrast to the steady F from the egg surveys. Also, we found the batch fecundity to be largely constant, and we show that this species feeds intensively during the spawning season. Together, this is in line with an indeterminate spawning type where the number of batches are the main dynamic reproductive parameter.

2019 western mackerel DEPM adult parameters.

Garabana, Dolores; Sampedro Paz; Solla Antonio.

This presentation describes the methodology used in 2019 for the calculation of the adult parameters, that is, the average female weight, the sex ratio, the batch fecundity, and the spawning fraction from the raw data calculated in the different institutes. The large number of samples that have to be worked on in histology to obtain valid samples for each of the parameters studied, especially batch fecundity, is noteworthy.

The results of the adult parameters and their relation to those obtained in 2016 are shown. The average weight per female is 355.7 grams, 8% higher than in 2016 which was 326.8grams. The sex ratio was very close to 50% both years. Batch fecundity by haul (Fh), ranged from 9342 to 14410 hydrated oocytes, with a media for all the population of 12257 hydrated oocytes. This value is a 28% higher than in 2016, when population batch fecundity was 8820 hydrated oocytes. In 2019 spawning fraction was 19.8 against 16,3% in 2016.

Spatial differences in adult parameters have been studied north and south of 44.5 N. Average female weight and batch fecundity were higher in the north than in the south. On the other hand, there were more females spawning in the south (spawning fraction 19%) than in the north (spawning fraction 15%). The impact that these differences may have on the calculation of spawning biomass should be studied.

Do some Atlantic mackerel skip spawning?

Korta, Maria; Thorsen, Anders and dos Santos Schmidt, Thassya.

This is an exploratory exercise to evaluate possible skip spawning, i.e., individuals capable to spawn each year but do not spawn, in Atlantic Mackerel. The aim is to identify the features that can bring us closer to having a position on this issue. The importance of this consideration relays in the fact that most fisheries models assume that fish above specified age/size all spawn annually and then overestimate the true number of spawners. According to the literature, the phenomenon of skip spawning is widespread being reported not only in fresh and marine species but also in traveller species between the two habitats. It presents advantages in additional energy demanding reproductive behaviour like migration and seems not only limited to determinate fecundity marine species but may be present in indeterminate fecundity species as well. Indeed, all these characteristics that do not exclude Atlantic mackerel of skip spawning. Screening data from 2013, 2016 and, 2019 surveys (3759 individuals) were used to classify non-reproductive as those individuals identified as being both resting, .i.e., no ovary development in that year, and reabsorbing, .i.e., ovary showing massive atresia. Results show that resting individuals and reabsorbing individuals are 3% and 12%, respectively of the samples on average spread through the whole range of length and all periods. Resting individuals have smaller ovaries but higher condition than the rest of individuals (u-test (resting, others), $p < 0.05$), which may indicate a higher investment in survival than in reproduction. Reabsorbing individuals are spread through the whole range of length and all periods as well but having similar ovary sizes they have lower condition than resting (pairwise wilcoxon test (resting, others, massive), $p < 0.05$), due to certain degree of reproductive investment have taken place before. Remarkably, massive atresia individuals are more common in larger size fish as spawning season progress, showing a length-based post spawning wave common to indeterminate fecundity species rather than scaled down skip spawning. A more in deep study will conclude whether resting individuals are the skipper ones while the ones presenting massive atresia are not and its potential impact on the biomass estimation.

Mackerel oocyte recruitment dynamics and fecundity pattern.

dos Santos Schmidt, Thassya C.; Slotte, Aril; Thorsen, Anders and Kjesbu, Olav S.

Mackerel ovary samples were collected from May 2018 to June 2019 to track the oocyte development and estimate fecundity by using the oocyte packing density (OPD) theory. This method estimates the number of oocytes per stage per gram of ovary and can be applicable for both species with determinate and indeterminate spawning. Additionally, the oocyte ratio (OR) was applied to determinate the female spawning status, based on the ratio between previtellogenic and advanced oocytes stages. Each female was, then classified as: pre or early-spawning fish, mid-spawning fish, late-spawning fish, and very late- or post-spawning fish based on the OR value. A total of 13 oocytes stages were identified, including six previtellogenic stages (PVO1 a PVO4a-c). The OPD showed that these PVO stages are constantly present in the females' ovary in high number (millions g-1 for PVO2-3, and 100 thousands g-1 for PVO4a-c), and all these PVO stages peaked in October then declined, indicating that onset of maturation in mackerel takes place in October (after autumn equinox). The appearance of cortical alveoli stage occurs in October and vitellogenic stage (VTO1) are present in January. Relative fecundity by oocyte stage was compared according to the female spawning status (OR) and shows that oocytes in PVO4c stage are continuously recruited during the spawning which can indicate that mackerel is an indeterminate spawner species. At the same time the relative fecundity of vitellogenic oocytes showed an increase in number in the mid-spawning fish, showing that some oocytes were recruited after the spawning has already started.

Interannual variations in timing of maturation and spawning activities of Northeast Atlantic mackerel in Nordic waters

dos Santos Schmidt, Thassya C. ; Slotte, Aril; Nøttestad, Leif; Ólafsdóttir, Anna; Jansen, Teunis; Jacobsen, Jan Arge; Homrum, Eydna í; Eliasen, Sólva; Smith, Leon; Lusseau, Susan M.; Bjarnason, Sigurvin; Thorsen, Anders; Kjesbu, Olav S.

Mackerel has a long spawning period (from January to July) and spawning takes place from Cadiz, Portugal to southern of Nordic Waters. Over the last years, mackerel egg density distribution has extended north- and westwards. Therefore, the main objective of this study was to verify whether mackerel is extending its spawning activity into Nordic Seas. Maturity stage from time series data (2004-2020) of Northeast Atlantic mackerel collected during the International Ecosystem Survey in Nordic Seas in May (IESNS) and International Ecosystem Summer Survey in Nordic Seas in July (IESNSS) was used. Data were provided by five countries (Denmark, Faroe Islands, Iceland, Greenland, and Norway) and each country has their own maturity scale. Therefore, a standardize maturity scale was defined so the data could be directly compared. Additionally, one-year (2018) case study was investigated using histology to an accurate overview of spawning in the area. Our results indicated that the frequency of mackerel in maturation, mature and spawning has increased in May (from 6.6% to 87.1%), and as expected, in lower percentage in July (from 0.77% to 8.1%). Histology confirmed that most fish classified macroscopically as in spawning condition in May were in fact spawning capable. On the other hand, samples collected in July were both in spawning condition or were spent fish showing massive atresia. Temperature in the area seems to be suitable for mackerel distribution and spawning. It seems that mackerel has indeed extending the spawning into Nordic Seas, however we advise to confirm this statement with more samples being analyzed by histology. Data from June will be also included to provide a better overview of spawning activity in Nordic waters.

Long term changes in length distribution and age structure of mackerel sampled during the triennial mackerel egg surveys

dos Santos Schmidt, Thassya C. and Costas, Gersom.

An overview of the time series of mackerel biological samples which were collected during the triennial egg survey (southern and western components) and North Sea mackerel egg survey was presented during the WGMEGS meeting. The idea was to show long term changes in length distribution and age structure of adults' mackerel sampled over the years and months. In fact, it was observed a slightly increased of fish mean length over the years, and difference in mean length can be found among months within a year. For the age structure, the percentage of younger age classes has decreased, and older fish has increased over the years, especially from April to June. Changes in length distribution and age structure were not very clean for mackerel samples collected in the North Sea. It was also pointed the lack of some data, as for example sampling position and age sampling in same years. This data will be used for a research collaboration to investigate year class effect of spatiotemporal distribution of mackerel, leading by Anna Ólafsdóttir and Aril Slotte.

2022 North Sea survey

O'Hea, Brendan.

WGMEGS has been requested to consider carrying out the North Sea egg survey in the same year as the Western and Southern surveys. A review was carried out of recent survey effort and requirements in both areas. This led to a number of questions being asked of MEGS participants. It was decided to draft a questionnaire to be sent to all participants requesting information on a number of these topics, with replies to be received by the survey coordinator early in 2021. These responses will inform the 2021 WGMEGS survey planning meeting, at which a decision will be made on whether a change will take place in 2022.

Egg diameter measurements

O'Hea, Brendan.

National laboratories were asked to measure the egg and oil globule diameters of one hundred Mackerel and Horse mackerel eggs. Laboratories were also asked to measure Hake and Ling eggs if these were available. Results were received from Spain IEO, Spain AZTI, Netherlands, Germany, Ireland, Scotland, Faroes and Norway.

Results from all laboratories were in close agreement with the same size ranges being reported for each species. There is some overlap in the sizes reported at the top of the range for Hake with the bottom of the range for Mackerel. A similar overlap occurs between Hake and Ling. Mackerel and Horse mackerel eggs are well separated with no overlap.

WGMEGS reiterates the need to use the spray technique to extract eggs from the plankton samples and subsequently to conduct the Surface Adhesion Test, SAT, to ensure that Hake eggs are adequately separated in the samples.

Year of the Mackerel: Year round gonad development of mackerel

van Damme ,Cindy; Blom, Ewout; Thorsen, Anders; Thorsheim, Grethe; Korta, Maria; Alvarez, Paula; Tomkiewicz, Jonna: Nielsen ,Julie Josias and Pastoors, Martin

From February 2019 to February 2020 mackerel were collected to study the development of male and female gonads throughout the year. This was a cooperation between the pelagic fishing industry (Pelagic Freezer Trawler Association (PFA)) and scientific institutes. Seven trawlers of the PFA collected samples on a monthly basis. The fish were opened on board and the gonad dissected. The gonad was shock-frozen separately from the fish. The shock-freezing is important in order to avoid too much damage to the gonad. In the laboratory the still frozen gonads were weighed and put in 3.6% buffered formaldehyde for defrosting. Of the gonads histological sections were prepared. Wageningen Marine Research (WMR), IMR and AZTI analysed the female samples and DTU Aqua analysed all the male samples.

Results show that mackerel spawn from February till July west of Ireland and the UK, and also until July in the North Sea. For the North Sea this is later than presumed in the calculation of the SSB in the Annual Egg Production Method. After spawning females still develop oocytes. In all months oocytes in early vitellogenesis were found. This shows that females does not have a true 'resting' period in which no oocytes are developing. Rather the females are always developing oocytes and are flexible in starting spawning, when the environmental circumstances are right they can react quickly to finalise the development of oocytes to be ready for spawning. This is probably the reason why the start of the spawning season of mackerel is so variable in time.

Also early developing oocytes are present during the whole spawning season, thus showing de-novo development of oocytes and underpinning the indeterminacy of mackerel.

Only few developing mackerel males were found in the samples in December and January. This indicates that males have a short period for developing the sperm cells ready for spawning. At the start of the spawning season males were in spawning condition. From halfway the spawning season spent males were found. From August to November all collected males were in spent condition.

Strikingly, 8% of males in the North Sea and 13% of males in the western area had encapsulated eggs in the testis. In other species this has been proven as a result of pollution in the water. It is unknown if in the mackerel is a reaction to pollution as well.

New calculation of annual egg production from the ICES Mackerel Egg Survey

Núñez-Riboni, Ismael; Kloppmann, Matthias; Ulleweit, Jens and Diekmann, Rabea

The mackerel egg survey has taken place every three years in the northeast Atlantic since the 1980s. Its goal is to obtain an estimate of total annual egg production (TAEP) to deliver a spawning stock biomass estimate, supporting the sustained management of the mackerel stock. The traditional calculation of the TAEP uses individual observations of daily egg production (DEP), independently if they are extreme, seldom observed values. In the few sampling cells with replicas, the DEP is estimated as the arithmetic average of all replicas. Estimates of DEP for cells which (due to e.g. weather conditions) could not been sampled, are obtained from the arithmetic average of neighboring cells (i.e. meaning a spatial interpolation data). Since 2007, the mackerel spawning area has been expanding towards the north and northwest. To cope with this expansion but keeping the survey effort and costs unchanged, fewer replicas have been taken and more cells have remained unsampled, increasing the amount of interpolated DEP estimates. Motivated by obtaining more accurate DEP estimates, in this study we propose an alternative method to calculate the TAEP (only for the western component, so far). We apply a generalized additive model (GAM) with logarithmic link and Tweedie distribution to individual DEP values, using longitude and latitude as input variables. Once the model has been fitted, DEP is predicted on the nodes of the sampling grid. Only nodes inside a convex hull defined by all observations with a Delaunay triangulation are used. This avoids extrapolating DEP beyond the survey limits and reduces GAM "edge effects". The DEP is then integrated in space and time following the standard method. Error bars of TAEP were estimated with a bootstrapping of DEP observations in cells of 2°×2°.. Our results show multi-year trends similar to those in the traditional method, but with a TAEP roughly 4×1014 eggs lower. This difference seems explained with the superior ability of the GAM to deal with highly skewed data in comparison to using individual observations or arithmetic averages: Histograms of DEP in the 2º×2º cells show that the GAM estimates are closer to the most commonly observed values than the arithmetic means. Furthermore, even if rarely occurring, extreme values dominate the integral of DEP and yield a TAEP up to one order of magnitude larger than in the absence of outliers. As conclusion, the traditional method could systematically overestimate the real TAEP.

MEGS estimates for mackerel and horse mackerel assessment (WGWIDE)

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The Working Group on Widely Distributed Stocks (**WGWIDE**) compiles and analyses data on large stocks of pelagic species as NEA mackerel, blue whiting, Western horse mackerel, and herring. The analysis will consist of a stock assessment which will then lead to a forecast of catch options for the year ahead.

The NEA Mackerel stock assessment uses many different datasets such as catches, catch at age, weight at age, mature at age, length composition data, natural mortality, survey indices and tagging data to inform on stock trends and rate of exploitation. The current assessment model for NEA mackerel (SAM) incorporates as tuning data the steel and RFID tagging–recapture data, and three survey indices: the IBTS recruitment index, the mackerel egg survey SSB index (MEGS survey)and abundances indices from the International Ecosystem Summer Survey in Nordic Seas (IESSNS).In addition MEGGS surveys provide data for proportions of individuals mature at age and weight at age in stock.

The Western Horse mackerel stock assessment uses many different datasets such as catches, catch at age, mature at age, length composition data and survey indices to inform on stock trends and rate of exploitation. The current assessment model for Western horse mackerel (Stock Synthesis) incorporates as tuning data the PELACUS Acoustic survey, the IBTS recruitment index and the egg production survey index for horse mackerel (MEGS surveys).