WORKING GROUP ON MACKEREL AND HORSE MACKEREL EGG SURVEYS (WGMEGS; outputs from 2022 meeting)

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Contents

i Executive summary

The Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS) is responsible for the planning, data collection, and data analysis of the ICES triennial mackerel and horse mackerel egg surveys. This report focuses on the execution of the mackerel and horse mackerel egg survey (MEGS) in 2022.

The results of the two 2021 online Workshops on Mackerel, Horse Mackerel and Hake Eggs Identification and Staging (WKMACHIS) and on Adult Egg Production Methods Parameters estimation in Mackerel and Horse Mackerel (WKAEPM) were discussed, with the subsequent enhancements and recommendations proposed during these workshops outlined in the workshop reports (ICES, 2022 a,b) and also incorporated into both of the WGMEGS manuals **(ICES 2019a, b).**

Although the broad planning of the 2022 survey was undertaken during the 2021 planning meeting and detailed in the WGMEGS 2021 report, the provisionally agreed plan required additional intersessional refinements. The settled plan for the 2022 survey has been included as an annex in the latest version of the WGMEGS Manual for the Mackerel and Horse Mackerel Egg Surveys (ICES SISP 6, 2019a).

In 2022, the survey once again faced significant challenges with regards to its ability to provide adequate geographical and temporal coverage given the limited vessel resources at our disposal. In 2022, Portugal, Spain (IEO and AZTI), Ireland, UK/Scotland, the Netherlands, Germany, the Faroe Islands, and Norway participated in the egg survey in the western and southern areas. Denmark and UK/England, with some additional assistance from Norway surveyed the North Sea as a single-pass DEPM survey. This is the first time in many years that all surveys have been completed in the same year.

In 2022, the survey was split into six sampling periods. The final period ended in late July. Waters west and southwest of Portugal were surveyed in period 2 only. The Cantabrian Sea was sampled in periods 3–5 while Biscay was sampled in periods 3 to 6. The Celtic Sea and waters west of the British Isles were sampled in periods 3 to 7, and the waters north and northwest of Britain towards Iceland and into the Norwegian Sea were sampled in periods 5 and 6.

Mackerel daily egg production was highest in period 5, (May), for the western component, while for the southern component the maximum spawning intensity was observed in period 3. Total mackerel egg production (provisional, southern and western component combined) was $1.64 * 10^{15}$. Provisional fecundity estimate was 1178 egg per gram female, resulting in an SSB index of $3.88 * 10^{6}$ tonnes.

For the Western stock of horse mackerel, highest mean daily egg production was estimated during June, period 6. Spawning was very low throughout all survey periods, with an obvious peak occurring in period 6. Total annual egg production for western Horse mackerel was $5.15 * 10^{14}$, almost a 300% increase on 2019.

ii Expert group information

Expert group name	Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS)
Expert group cycle	Multiannual
Year cycle started	2021
Reporting year in cycle	2/3
Chair(s)	Brendan O'Hea, Ireland
	Gersom Costas, Spain
Meeting venue(s) and dates	26–29 April 2021, virtual meeting (29 participants)
	22 – 23 August 2022, Copenhagen, HQ (14 participants)

1 The timing and planning of the 2022 Mackerel/Horse Mackerel Egg Survey in the ICES sub-areas 5 to 9 – amendments to the original plan (ToR a)

1.1 Countries and Ships Participating

The 2022 survey plan, designed at the WGMEGS meeting in April 2021, was modified and updated during the WKMACHIS meeting in October 2021. Eleven Institutes from ten countries participated; Portugal, Spain (AZTI), Spain (IEO), Netherlands, Germany, Denmark, UK (Scotland), UK (England), Norway, Faroes and Ireland. Survey dates, as well as vessel details, for cruises can be found below in Table 1.1. In 2022 the North Sea survey was undertaken in the same year as the Atlantic surveys. This was facilitated by the participation of Denmark and UK (England).

The survey coordinator for the 2022 survey was Brendan O' Hea, Marine Institute, Galway, Ireland.

Table 1.1 Countries, vessels, areas assigned, dates and sampling periods for the 2022 surveys.

Country	Vessel	Area	Dates	Period
Portugal	Vizconde de Eza	Portugal	Jan 23rd – Feb 20th	2
Ireland	Celtic Explorer	West of Ireland, Celtic sea, Biscay,	March 2nd – 22nd	2
	Prince Madog	West of Ireland, west of Scotland	June 11th – 18th	6
Scotland	Altaire	West of Scotland	April 12th – 27th	4
	Scotia	West of Scotland, west of Ireland	May 13th – June 2nd	5
	Altaire	West of Scotland, west of Ireland, Celtic sea, Biscay	July 4th – 26th	7
Spain (IEO)	Miguel Oliver	Cantabrian sea, Galicia, southern Biscay	March 14th – April 3rd	3
	Miguel Oliver	Cantabrian sea, Galicia, Biscay	April 4th – April 30th	4
Spain (AZTI)	Ramon Margalef	Northern Biscay	March 10th – 30th	3
	Vizconde de Eza Emma Bardan	Biscay, Cantabrian sea	April 30th – May 19th	5
Germany	Walther Herwig	Celtic sea, west of Ireland	March 31st – April 8th	3
	Walther Herwig	Celtic sea, west of Ireland, west of Scotland	April 10th – 22nd	4
Netherlands	Tridens	Northern Biscay, Celtic sea	May 8th – 26th	5
	Tridens	Biscay, Celtic sea	June 5th – 24th	6
Norway	Brennholm	Faroes & Norway	June 7th – 20th	6
Faroes	Jakup Sverri	Faroes, Iceland	May 19th – June 1st	5

Denmark	Dana	North Sea	June 7th – 19th	6
England	Cefas Endeavour	North Sea	June 4th - 25th	6

1.2 Survey Design

The AEPM survey design for mackerel and horse mackerel (Western and Southern stocks) for 2022 was not changed, however another attempt was made to estimate DEPM adult parameters for both species. This required additional sampling during the perceived peak spawning periods for these stocks, as identified from the 2010 surveys during WKMSPA 2012 (ICES 2012a). For the 2022 survey, this sampling was planned to take place during periods 2 and 3 for mackerel, periods 6 and 7 for western horse mackerel, and during period 2 for southern horse mackerel.

The 2022 survey plan was split into 6 sampling periods (Table 1.2). In 2022 the survey effort in ICES Division 9a was again targeted at a single extended DEPM survey.

Sampling continued in the southern area and commenced in the western area during period 3. During period 3 the survey concentrated on the Cantabrian Sea, Bay of Biscay, the Celtic Sea, West of Ireland and West of Scotland. No sampling took place in the Cantabrian Sea, and southern Biscay, after period 5. In Periods 5 and 6 the survey area was extended into Faroese and Icelandic waters. In periods 6 and 7 the surveys were designed to identify a southern boundary of spawning and to survey all areas north of this. The deployment of vessels to all areas and periods is summarised in Table 1.2.

Maximum deployment of effort in the western area was during periods 3, 4, 5 and 6. Historically these periods would have coincided with the expected peak spawning of both mackerel and horse mackerel. Recent years have seen mackerel peak spawning taking place during periods 3, 4 and 5.

Due to the expansion of the spawning area which has been observed since 2007 the emphasis was even more focused on full area coverage and delineation of the spawning boundaries. Cruise leaders had been asked to cover their entire assigned area using alternate transects then use any remaining time to fill in the missed transects.

In 2013 the peak of mackerel spawning occurred in period 2 in the Bay of Biscay, in 2016 it occurred in May, to the west of Scotland and in 2019 occurred in April, close to the Shetland Islands. Therefore, and due to the expansion of the spawning area that has been taking place since 2007, the emphasis in 2022 was once again focused on maximising area coverage. Cruise leaders were asked to cover their **entire** assigned area using alternate transects then use any remaining time to fill in the missed transects. If time was short this should be concentrated in those areas identified as having the highest densities of egg abundance.

Table 1.2 Periods and area assignments for vessels by week for the 2022 survey.

		Area							
week	Starts	Portugal, Cadiz & Galicia	Cantabrian Sea	Biscay	Celtic Sea	North west Ireland	West of Scotland	Northern Area	Period
4	23-Jan-22	PO1 (DEPM)							2
5	30-Jan-22	PO1 (DEPM)							2
6	6-Feb-22	PO1 (DEPM)							2
7	13-Feb-22	PO1 (DEPM)							2
8	20-Feb-22	PO1 (DEPM)							2
9	27-Feb -22				IRL1	IRL1	IRL1		3
10	6-Mar-22				IRL1	IRL1	IRL1		3
11	13-Mar-22	IEO1	IEO1	AZTI1	IRL1	IRL1	IRL1		3
12	20-Mar-22		IEO1	IEO1 / AZTI1					3
13	27-Mar-22	IEO1	IEO1	IEO1 / AZTI1	GER1				3
14	3-Apr-22	IEO1	IEO2	IEO2	GER1				3
15	10-Apr-22		IEO2	IEO2	GER2	GER2	SCO1	SCO1	4
16	17-Apr-22		IEO2	IEO2	GER2	GER2	SCO1	SCO1	4
17	24-Apr-22	IEO2	IEO2		GER2	GER2	SCO1	SCO1	4
18	1-May -22		AZTI2 (DEPM)	AZTI2 (DEPM)					5
19	8-May-22		AZTI2 (DEPM)	AZTI2 (DEPM)	NED1	SCO2	SCO2		5
20	15-May-22		AZTI2 (DEPM)	AZTI2 (DEPM)	NED1	SCO2	SCO2	FAR	5
21	22-May-22				NED1	SCO2	SCO2	FAR	5
22	29-May-22					SCO2	SCO2	FAR	5
23	5-Jun-22			NED2	NED2		IRL2	NOR	6
24	12-Jun-22			NED2	NED2		IRL2	NOR	6
25	19-Jun-22			NED2	NED2			NOR	6
26	26-Jun-22								6

27	3-Jul-22			SCO3	SCO3	SCO3	SCO3		7
28	10-Jul-22			SCO3	SCO3	SCO3	SCO3		7
29	17–Jul-22			SCO3	SCO3	SCO3	SCO3		7
30	24-Jul-22			SCO3	SCO3	SCO3	SCO3		7

2 The timing and planning of the 2022 Mackerel/Horse Mackerel Adult Sampling Programme in the ICES sub-areas 5 to 9– amendments to the original plan (ToR b)

2.1 Sampling for mackerel AEPM/DEPM in the Western and Southern areas.

Samples for estimation of mackerel potential fecundity and atresia (AEPM), and batch fecundity and spawning fraction (DEPM) should be mostly taken on vessels participating in the egg survey or from commercial fishing vessels by observers. Recognising the constraints of the egg survey, which has to prioritise its sampling to the correct estimation of either annual or daily egg production, cruise leaders were asked to try to distribute trawl stations for the above-mentioned estimations across the survey area aiming at a widespread sampling regime for adults. Maturity of fish should be determined according to the Walsh Scale and the WKASMSF revised maturity scale (ICES, 2018a).

On each transect, trawl hauls were attempted close to stations with high stage 1 mackerel egg production. Trawling should be carried out preferably at dusk or during the night in the western area, and during the afternoon in the southern area.

Detailed survey procedures are laid out in the respective appendices of the WGMEGS survey and fecundity manuals (ICES 2019a, b).

2.2 Sampling for horse mackerel DEPM in the Western and Southern stocks.

Samples for horse mackerel DEPM adult parameters should be collected during periods 6 and 7 from trawl hauls on the Western horse mackerel stock and during period 2 from trawl hauls on the Southern horse mackerel stock. All procedures for sampling adult horse mackerel are laid out in detail in the WGMEGS survey and fecundity manuals (ICES 2019 a, b). Additional adult samples have been requested from the Irish WESPAS survey carried out in the Celtic Sea and west of Ireland in June / July, and also from the Netherlands pelagic fisherman's association, PFA.

3 Results of mackerel and horse mackerel egg staging and identification and fecundity and atresia workshops (WKMACHIS & WKAEPM) (ToRs c, d, e, g)

The Workshop on Mackerel, Horse Mackerel and Hake Egg Identification and Staging (WKMACHIS) is part of a series of workshops (WKMHMES, WKFATHOM) that aim to standardize the process of fish egg identification and staging. It was planned to take place 11-15 October 2021 in Bremerhaven, Germany, but had to be held online for the first time due to the continuing SARS-CoV2 pandemic. All egg identification and staging during the workshop were undertaken using images on the SmartDots WebApp, as opposed to the established method that utilises real samples under microscopes.

The majority of the time at the workshop was spent completing 2 rounds of identifying and staging mackerel, horse mackerel, hake and similar looking eggs.

After the first round of the egg staging and identifying exercise the main discussion was with the stages 1A and 1B. To clarify the characteristics that separate these from the other stages, several 1A and 1B images were viewed on the screen and discussed. However, correct discrimination between those two stages did not improve considerably during the second round. While for calculation of the annual egg production only eggs of stage 1 (i.e. 1A and 1B combined) are used, the apparent inability to correctly discriminate between those two stages will not negatively influence the results of the egg survey at the current design. This inability, however is present throughout all previous workshops (ICES 2003, 2006, 2019, 2012, 2015 and 2018) and therefore, any move towards utilizing and implementing a finer staging system, e.g. by using stage 1A eggs only for DEP calculation, should be considered with care and should certainly involve thorough training of all participants in correct egg staging.

Otherwise, the results were reassuring and improved from the first to the second round of the exercises. However, and particularly in horse mackerel, bias in correctly identifying stage 1 eggs was higher than in previous workshops for both, experts and non-experts. These results can almost exclusively be explained by the change in workshop methodology that saw a move from a live view of the fish eggs to images.

Exercises, practicing and evaluating the spray method for egg removal from plankton samples and as proposed in the WKMACHIS resolution, were not able to be carried out.

As the mackerel and horse mackerel egg surveys are carried out once every three years, the workshop functions as a refresher for expert survey participants and as an introduction for new participants in egg analyses. It should however be realized that one week of workshop for egg identification and staging, particularly if carried out online and based on images, is not sufficient to train new participants. Institutes should ensure newcomers receive a thorough training while also allowing more experienced participants to refresh their knowledge ahead of the survey.

Again, as all previous workshops, the meeting demonstrated the importance of conducting the workshop a few months ahead of the mackerel and horse mackerel egg survey. For several valuable fish stocks in the Northeast Atlantic, the survey delivers the only fishery-independent SSB indices based on correctly identified and staged fish eggs. Ongoing discussion and training for consistency is, therefore, imperative. While many participants had problems working with images only, the use of image-based systems for (egg) analysis will become a central part of future workshops.

The survey manual SISP 6 (ICES 2019a) was updated.

The Workshop on Adult Egg Production Methods Parameters estimation in Mackerel and Horse Mackerel (WKAEPM) looked at imprecision between institutes when processing survey samples. A number of protocol improvements were proposed, and these will be in place prior to the adult parameter analysis in 2022.

A calibration exercise was carried out prior to the workshop using standard mackerel and horse mackerel egg survey (MEGS) protocols. A second exercise was conducted during the workshop using a newly developed SmartDots module. Subgroups dealt with issues regarding annual egg production method (AEPM) and daily egg production method (DEPM) and added their recommendations to the manuals.

Descriptions for spent and massive atresia terms used during the screening process were redefined by adding further text and higher quality images into the ICES Survey Protocol Manual for the AEPM and DEPM estimation of fecundity in mackerel and horse mackerel (SISP- 5). Differences were noted in post ovulatory follicle (POF) and early alpha atresia identification, showing the difficulty associated with this work. In Fecundity samples, there was high variance when identifying small oocytes close to the 185µm size threshold. It was recommended to have all fecundity samples analysed by two readers, and new criteria for the measurement of small oocytes were agreed. In atresia analysis, high variance was observed in both point and profile counting. High-resolution images are essential to this work, thus in 2022 slide scanner pictures were taken for atresia analysis and sent around to all labs. There is still poor consensus on POF staging. Misclassifications between recent POFs and artefacts have now been clarified. Recent POF stages are used in spawning fraction estimation thus it is vital to be clear about them. A reference catalogue of images of early alpha atresia and POFs will be compiled and stored in SmartDots.

The desired number of gonad samples to be collected during the egg surveys, including North Sea samples, was defined. WGMEGS has requested that additional mackerel and horse mackerel female gonad samples would be collected by the Blue whiting survey, the Irish WESPAS survey and the Dutch Pelagic Fisherman's Association, PFA. An updated version of the ICES Fecundity and Atresia database will be ready for testing at the beginning of 2022 and the survey protocol manual will be updated in 2024.

4 2022 Mackerel AEPM/DEPM Survey execution and preliminary results (ToR h)

4.1 The 2022 survey execution

As already described in section 1.1, the 2022 MEGS was split into 6 survey periods, the start and end dates of which can be found in Table 1.1. For each of the 6 sampling periods, particular points to note are:

Period 2 – Portugal started the 2022 survey series on January 23rd. This is a DEPM survey mainly targeting the southern horse mackerel stock and is designed for this purpose, however it also delivers mackerel egg abundance data. The survey is usually undertaken between Cadiz and Galicia and is confined to ICES Division 9a.

Period 3 – Period 3 marks the commencement of the western area surveys as well as a continuation of sampling in the southern area. Sampling was undertaken by Ireland (West of Scotland, west of Ireland, Celtic Sea), Germany (Celtic Sea) and AZTI (northern Biscay). Further south the Bay of Biscay, Cantabrian Sea and Galicia were covered by Spain (IEO).

No eggs were found by Ireland in northern waters so after a number of days the vessel turned south and sampled in the Celtic sea. Due to issues with Covid cases among the crew, the German survey was delayed in starting, however it was successful in linking with the Irish vessel. Both IEO and AZTI experienced difficulties with their vessels, and lost a number of sampling days, however full coverage was achieved (Figure 4.1).

Egg numbers were relatively low to the west of Ireland. In contrast, further south large numbers of eggs were found close to the 200m contour line. In Biscay and the Cantabrian Sea AZTI and IEO recorded a number of stations with large numbers of mackerel eggs. 298 stations were sampled and there were only 13 interpolations. There were 52 replicate samples with the majority being completed in the Cantabrian Sea.

Period 4 – This period was covered by three surveys. Scotland sampled the area from the northwest of Ireland to the Shetland Islands. Germany surveyed west of Ireland, Celtic sea and northern Biscay while IEO completed the survey coverage in southern Biscay and the Cantabrian Sea (**Figure 4.2**).

Due to difficulties in acquiring diplomatic clearance, the Scottish survey was unable to sample in Irish waters. As a result, Germany extended their survey area northwards to ensure continuity of survey coverage.

Once again moderate levels of eggs were recorded throughout the area, with the highest concentrations still being found close to the 200m contour line. Large numbers of mackerel eggs were once again recorded to the west of Scotland, however, they were lower within this area and time period than those reported in 2019. 327 stations were sampled and there were 46 interpolations. 52 replicate samples were taken and once again most of these were collected from the Cantabrian Sea.

Period 5 – In Period 5, the entire spawning area from the Cantabrian Sea to the West of Scotland, and up to Faroese waters at around 61°N was surveyed by AZTI, the Netherlands, Scotland, and Faroes.

Spawning in the Cantabrian Sea was tailing off with only low egg numbers being found. Throughout Biscay and into the southern Celtic Sea numbers were generally low to moderate.

Figure 4.3). This pattern continued west of Ireland, to around 54°N, with spawning remaining on and around the shelf edge. North of this, however, and similar to that noted in 2016 and 2019, spawning activity fanned out both west- and northwards. Due to the large area Scotland had to survey, their vessel was forced to restrict exploration of the western boundary around the SW of Rockall Bank. Egg counts recorded from the boundary stations within this area were lower than reported in 2019 so while the western boundary wasn't fully delineated, MEGS is happy that the survey has captured the majority of egg production in this area. North of this, the Faroese survey completed stations North of Hatton Bank and up towards the Icelandic coast. Some egg production was found to the north of Rockall, however the largest number of eggs were encountered west of the Shetland Islands. In total 444 stations were sampled and there were 214 interpolations. One replicate sample was undertaken.

Period 6 – During period 6 northern Biscay, northwards from 46°N and also the Celtic Sea were covered by the Netherlands while Ireland was to cover west of Ireland and also west of Scotland. Norway surveyed the area north of 59°N from the south of Iceland to the Norwegian coast, as well as carrying out four transects in the northern North Sea to assist England and Denmark in providing full coverage for the DEPM survey.

Ireland had plannedto charter a research vessel from Northern Ireland to conduct the period 6 survey. One week prior to departure the vessel had to go to dry dock for emergency repairs. After much searching, a smaller Welsh RV was contracted as a replacement. Once at sea however it quickly became clear that the replacement vessel was wholly unsuitable and not up to the task. With only two stations successfully completed the decision was made to abandon the survey leaving the area from 53N to 61N unsampled. Norway and Netherlands both completed their survey sampling successfully.

Low levels of spawning were observed in Biscay and to the south to the West of Ireland and Porcupine bank (Figure 4.4). Similarly, in the northern area spawning was observed at low levels, with the exception once again of the area west of the Shetland Islands. Due to an unavoidable reduction in the number of survey days available, Norway was unable to secure either the northwestern or northern boundary within the northern area, while Netherlands secured the western boundary in their area. 184 stations were sampled with 36 interpolations. No replicate stations were completed.

Period 7 – This period was covered entirely by Scotland sampling on alternate transects in the area from 47°15N to north of the Hebrides and 59°N (Figure 4.5). Due to the lack of eggs encountered, the Scottish survey adhered very closely to the 200m contour and 144 stations were sampled with 24 interpolations. 2 replicate stations were completed. Only very low levels of spawning were observed and these were confined to the continental shelf and shelf edge with all spawning boundaries being delineated successfully.

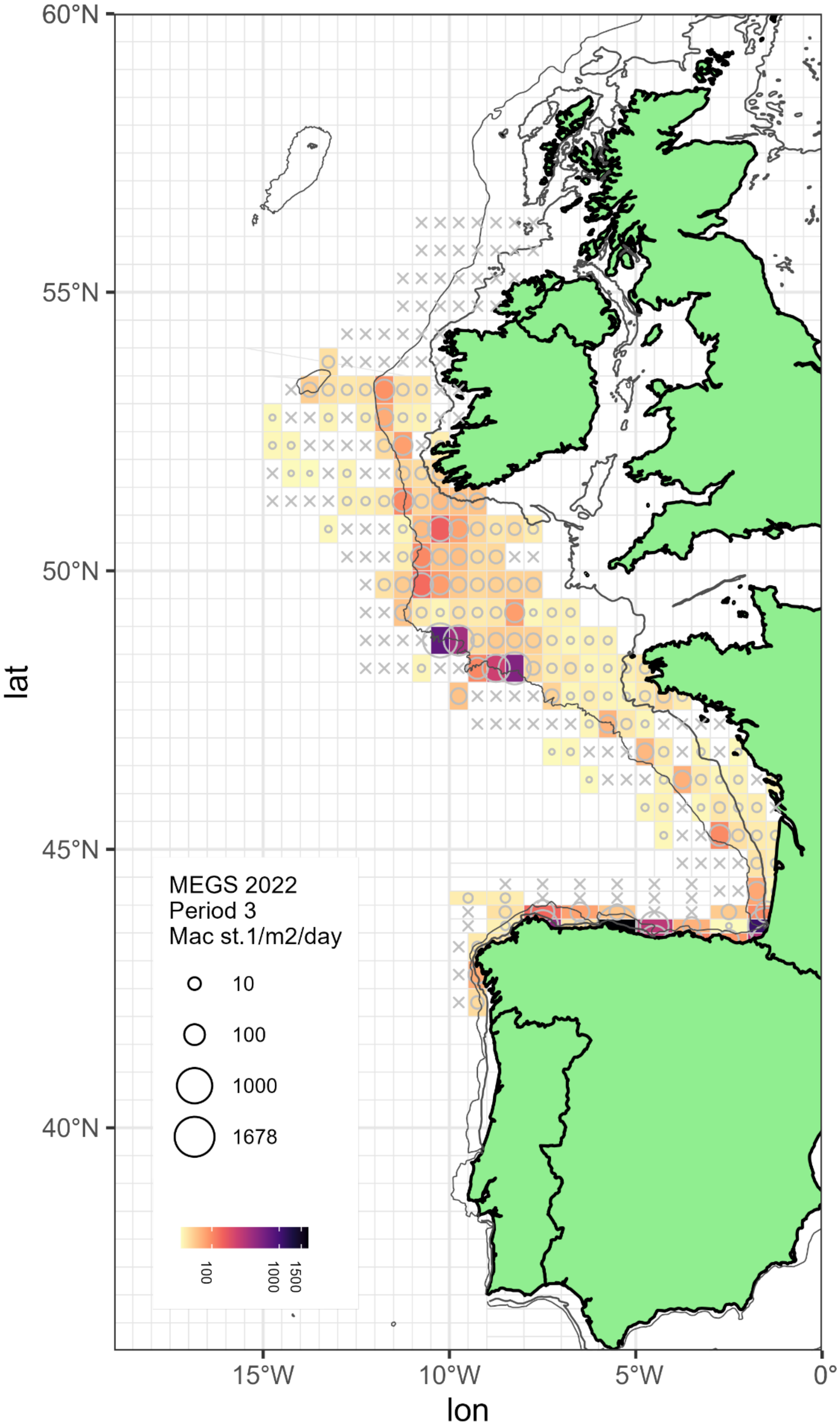

Figure 4.1 Mackerel egg production by half rectangle for period 3 (Mar 4th – Apr 8th). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

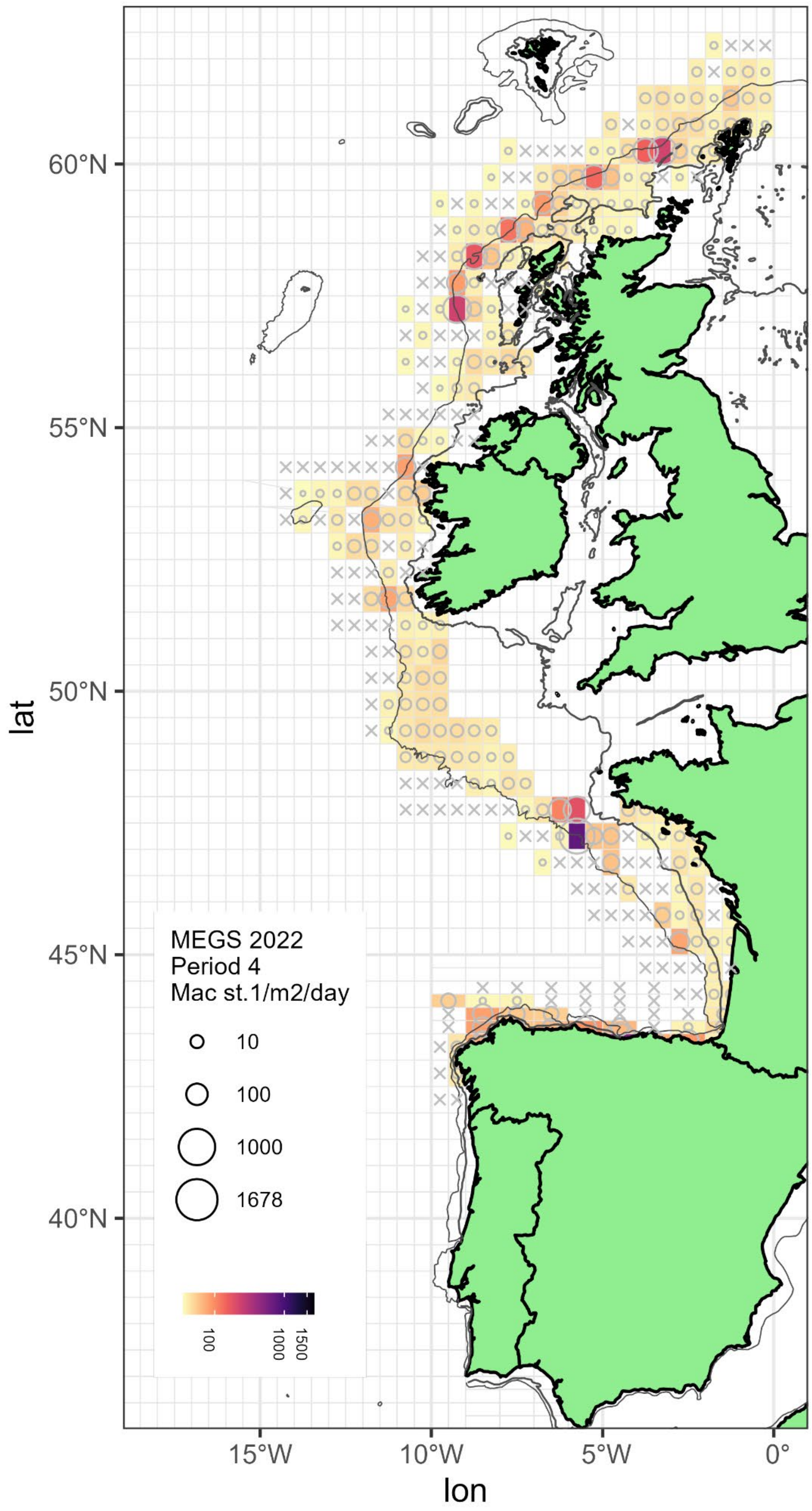

Figure 4.2 Mackerel egg production by half rectangle for period 4 (Apr 9th – 29th). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

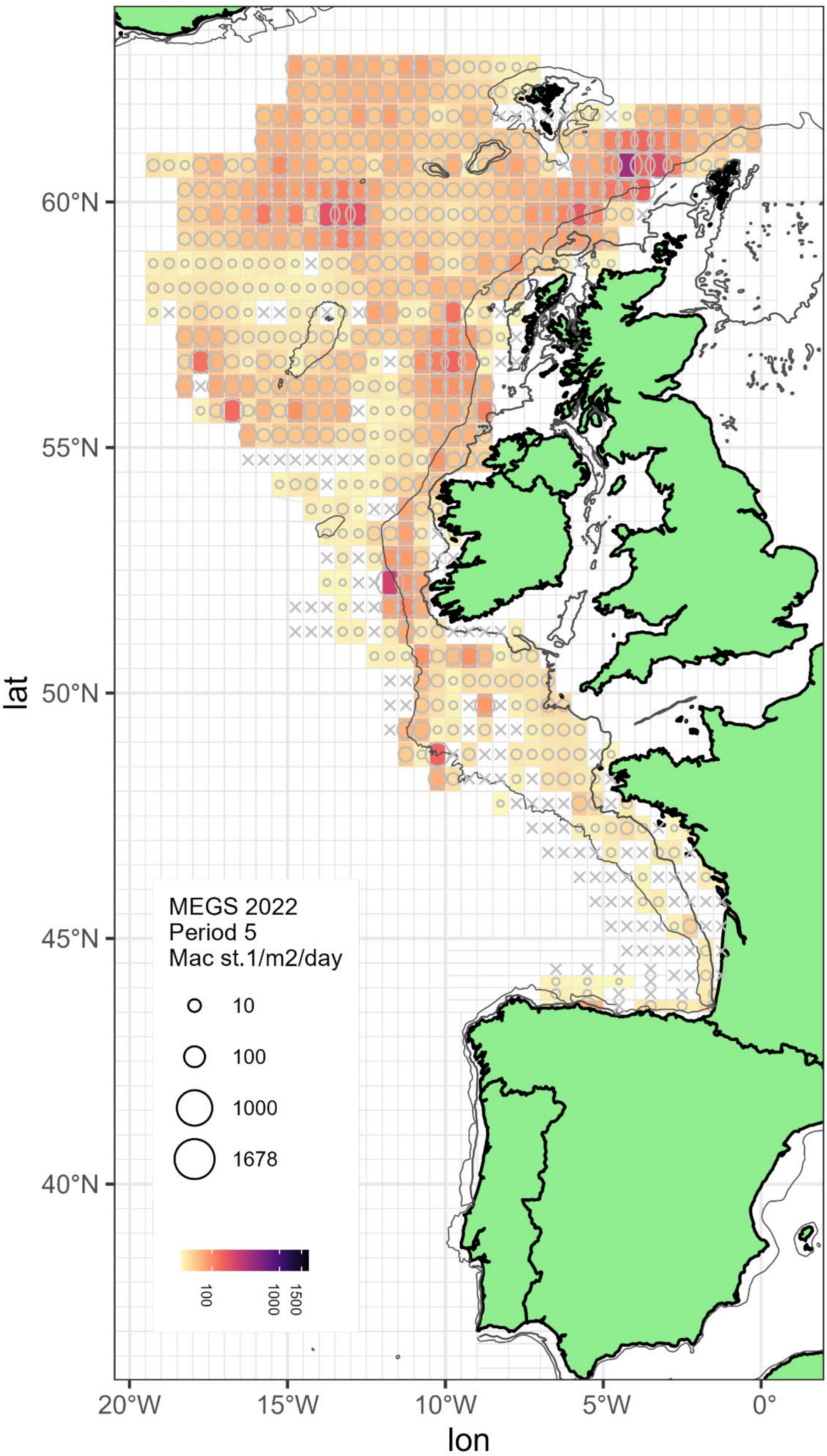

Figure 4.3 Mackerel egg production by half rectangle for period 5 (Apr 30th – May 31st). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

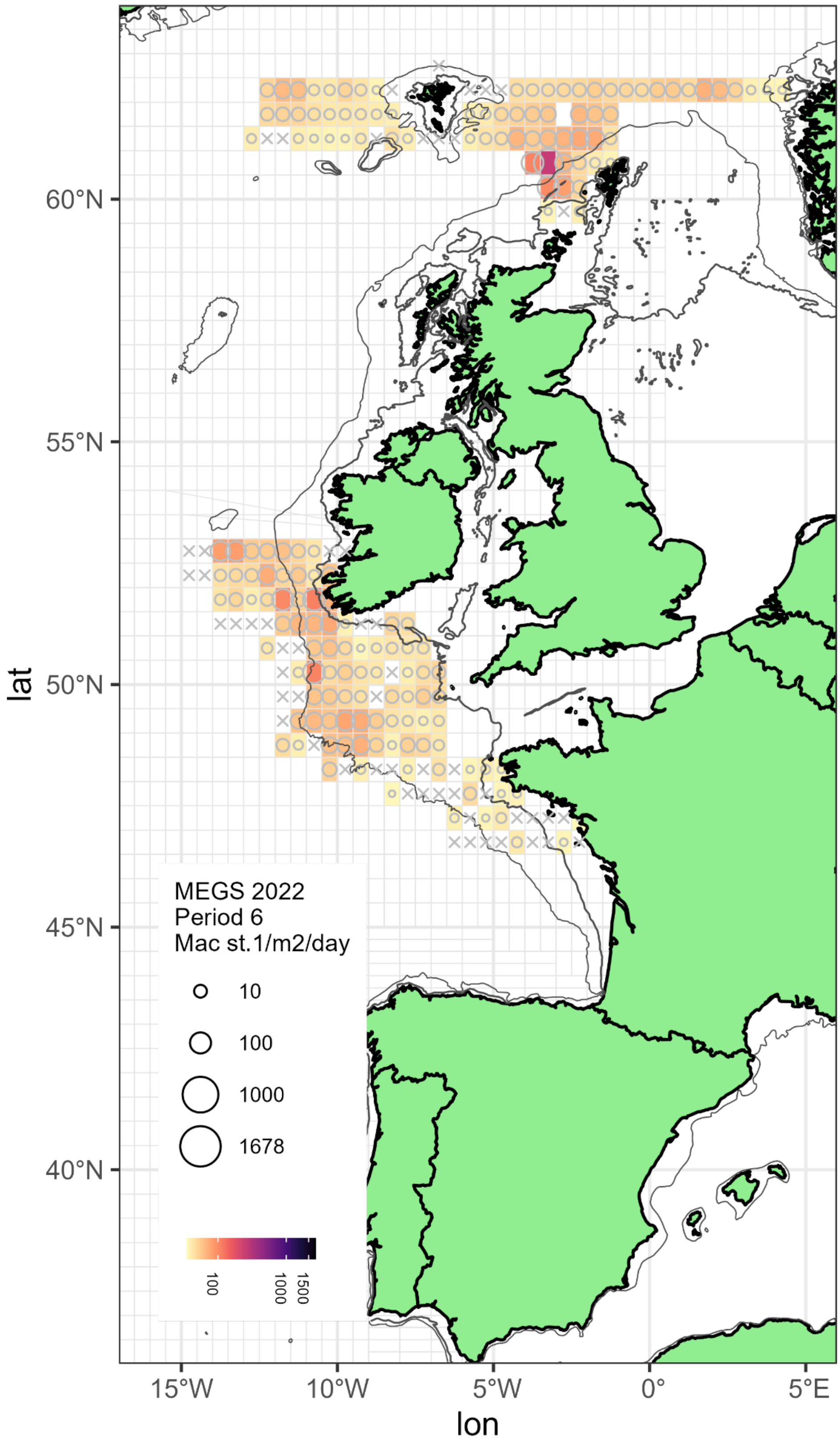

Figure 4.4 Mackerel egg production by half rectangle for period 6 (June 1st – 30th). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

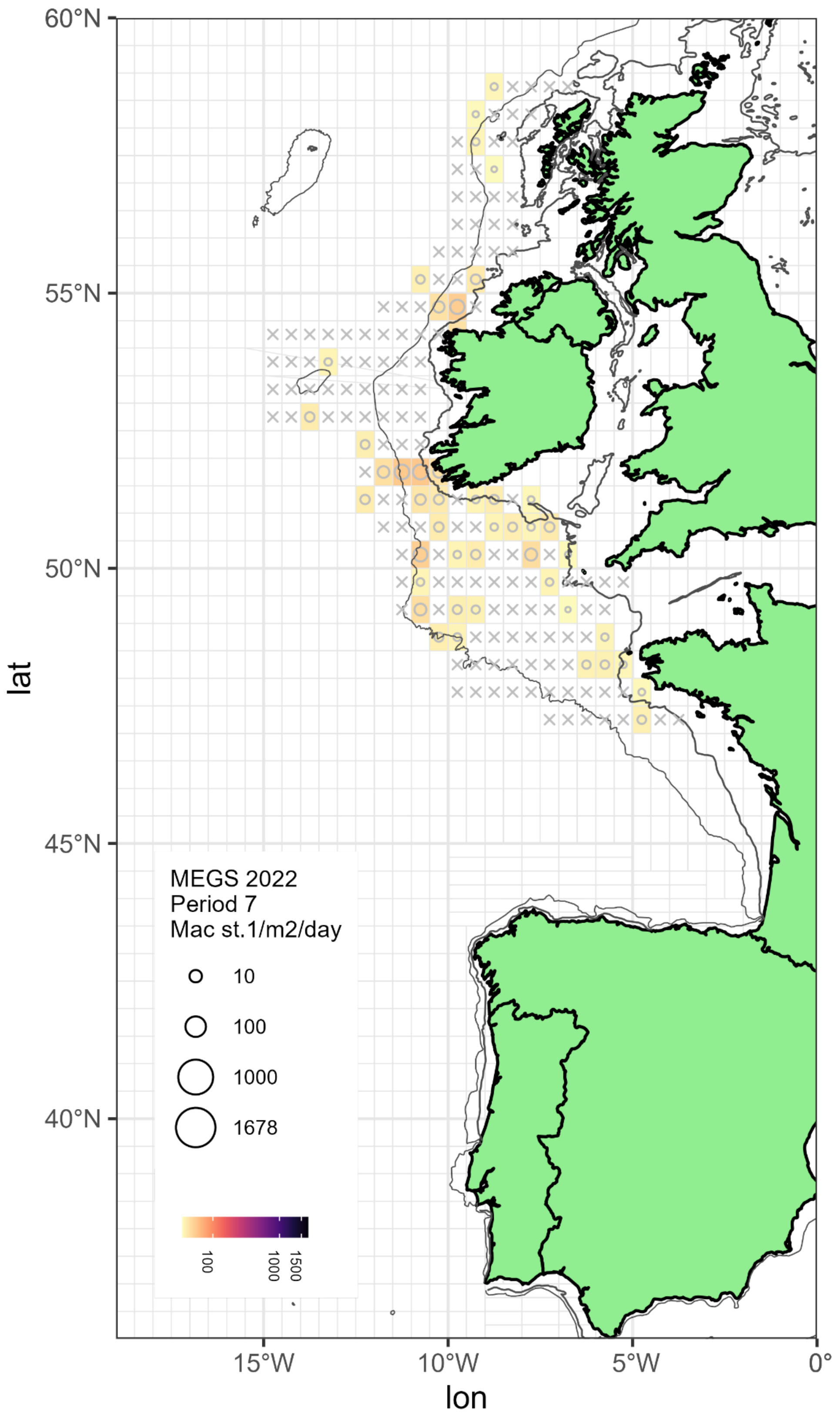

Figure 4.5 Mackerel egg production by half rectangle for period 7 (July 1st – 31st). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

4.2 Hydrography – Temperatures at 20 m (5 m) depth

For the Northeast Atlantic MEGS, the temperature values at 20m 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, except for period 2, are displayed in Figure 4.6. Overall, temperatures at 20 m depth ranged from values < 8.5 °C to >18 °C and were, though very similar in their distribution, about 0.5 – 1.0 °C warmer than those observed during the 2019 MEGS for almost all survey periods. Only during period 4, temperatures were very similar to those observed in 2019 followed by a steep incline towards period 5. Lowest temperatures were always observed in the North increasing towards the South and also with progression of the sampling periods. Temperatures everywhere were almost all the time higher than the supposed threshold minimum value of 8 °C, associated with an increased probability of mackerel egg occurrence.

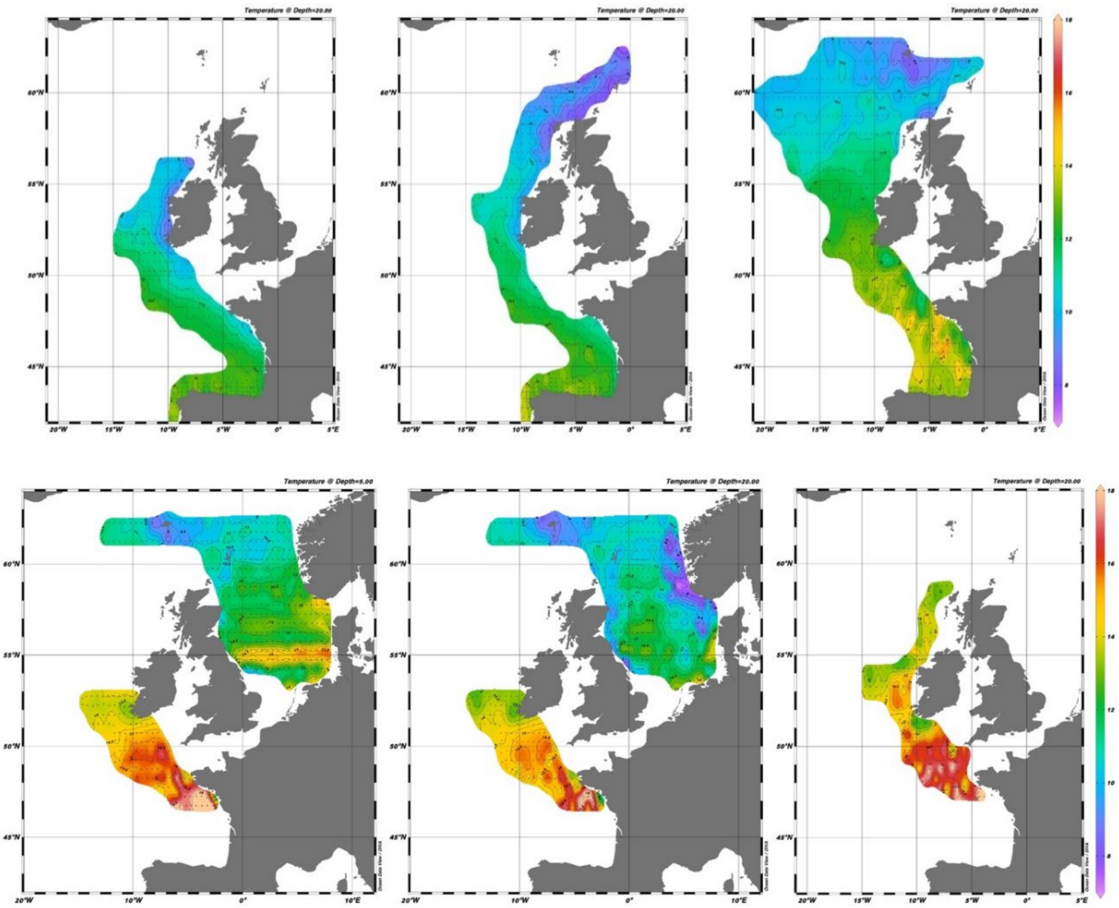

Figure 4.6 The 20 m depth temperature distribution for periods 3 – 5 (top row, left to right) and periods 6 including the North Sea, at depths 5 and 20 m, and 7 at 20 m (bottom row, left to right).

For North Sea mackerel egg production, temperatures 5 m depth are used. For period 6, therefore, also temperatures at this depth are displayed (Figure 4.6 lower left panel). Temperatures at that shallower depth were considerably warmer than at 20 m. Due to their stronger direct exposition to atmospheric forcing, (i.e. high daily and day to night variability of sun radiation), and in particular for the North Sea, the spatial distribution of temperatures reflects rather the progression of the survey than the seasonal dynamics of the hydrography.

4.3 Mackerel AEPM Preliminary Results

4.3.1 Stage 1 Egg production in the Western Areas

The cancelling of the Irish survey in period 6 was addressed by WGMEGS. The group estimated the spawning area that was missed and also estimated mean daily egg production for the period. The survey area from 53N to 61N, and 3.5W to 21W was looked at for the same time interval in the 2013 (period 5), 2016 (period 6) and 2019 (period 6) surveys. Positive stations were selected where stage 1 eggs were found in a rectangle on at least two occasions over these three surveys (Figure 4.7, blue rectangles). WGMEGS estimated this amounted to 127 missed stations during the period. WGMEGS then calculated mean daily egg production from all the completed survey stations for period 6 in 2022 to be 19.58 stage 1 eggs/m^2/day, and applied this figure to the 127 stations. Figure 4.8 shows the spawning curve for 2022, with and without the correction for the Irish survey.

2010 provided an unusually large spawning event early in the spawning season, 2013 yielded an even larger spawning event indicating that spawning was probably taking place well before the nominal start date of 10th February (Figure 4.9). 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 (Figure 4.9and Table 4.1).

In 2016 concern was expressed that a non-sufficient survey coverage may have underestimated the total egg production estimate. The expansion observed in western and northwestern areas during Periods 5 and 6 in 2016 was once again reported during 2022, however this year production in Periods 5 and 6 was lower in these northwestern areas.

In 2017 and 2018 WGMEGS organised exploratory egg surveys in this region. These surveys provided significant evidence that while some spawning has been missed the loss of egg abundance is not sufficiently large to significantly impact the SSB estimate.

The 2022 spawning curve is very similar to that of 2016, with peak spawning again occurring during Period 5. Annual egg production since 1992 is shown in Figure 4.10. Mackerel egg production by period since 2004 is shown in Figure 4.11.

Overall, the inclusion of the estimated egg abundance for the missing stations in Period 6 has an impact of 10% on the annual egg production 2022.

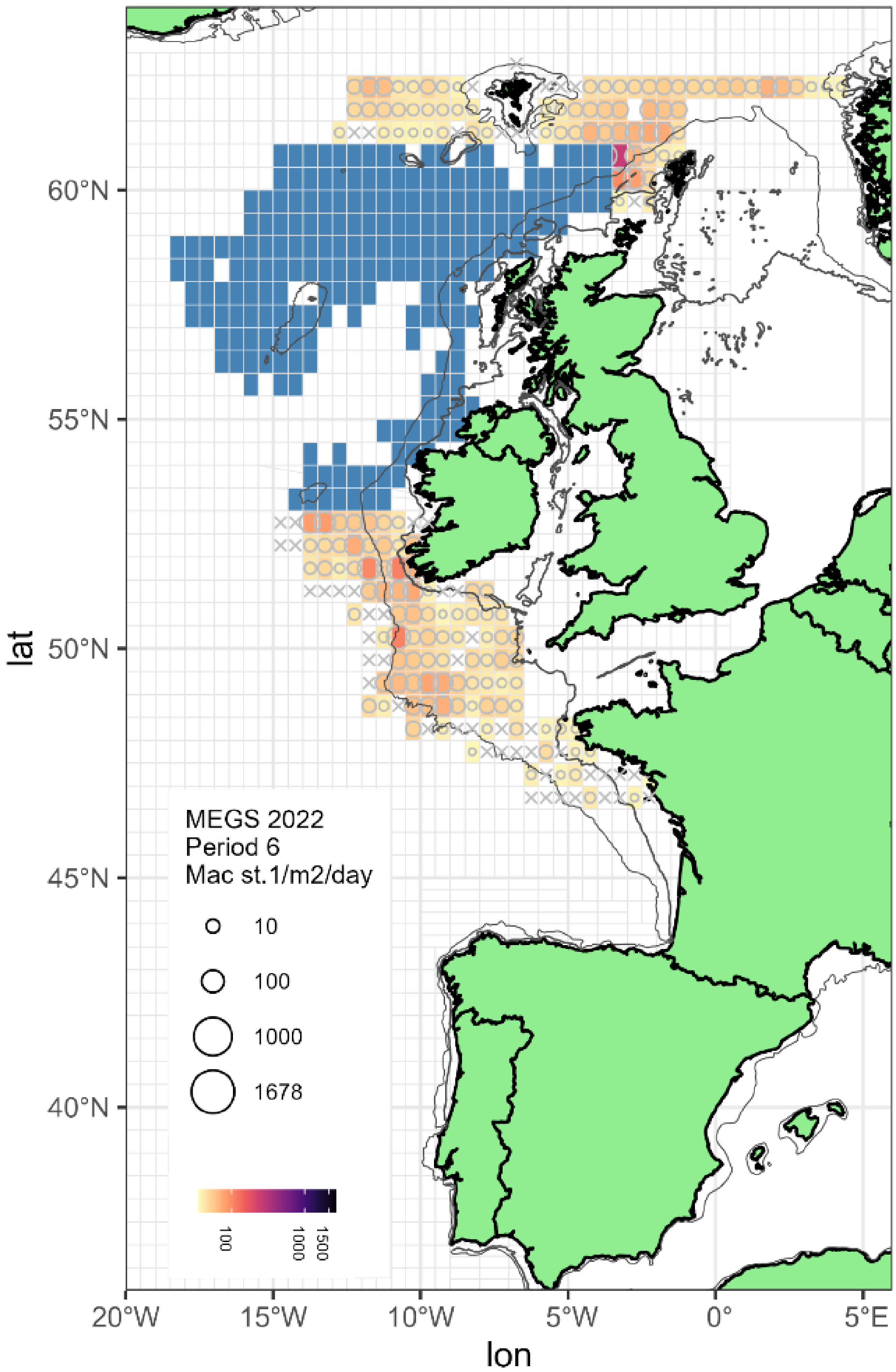

Figure 4.7 Area, blue colour, from period 6 where it is estimated eggs would have been found

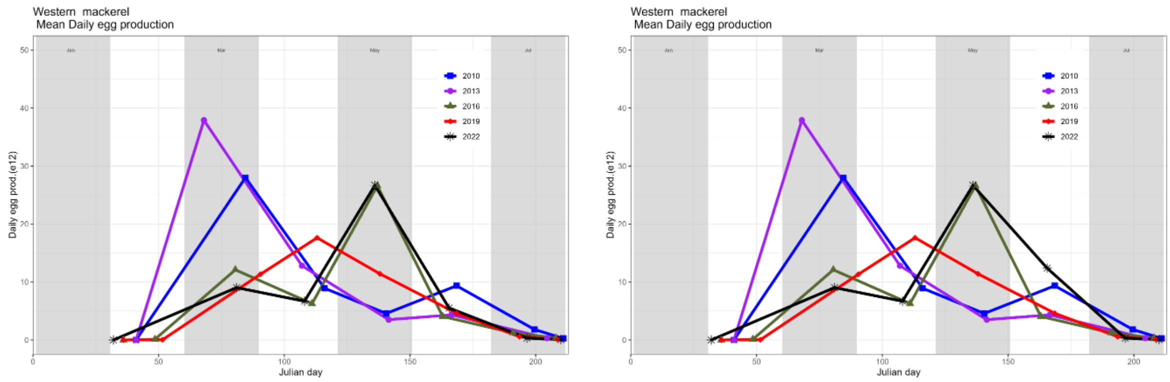

Figure 4.8 The daily mackerel egg production curves for 2010 – 2022 surveys with (right) and without (left) corrected estimates for period 6 of 2022 (black lines).

The nominal start and end dates of spawning are February 10th and July 31st respectively. These are the same dates that were used during previous survey years and the shape of the egg production curve for 2022 does not suggest that the chosen dates needs to be altered. The provisional total annual egg production (TAEP) for the western area in 2022 was calculated as **1.795 * 10^{15}** (Table 2). This is a 47% increase on the 2019 TAEP estimate which was 1.22 * 10^{15}.

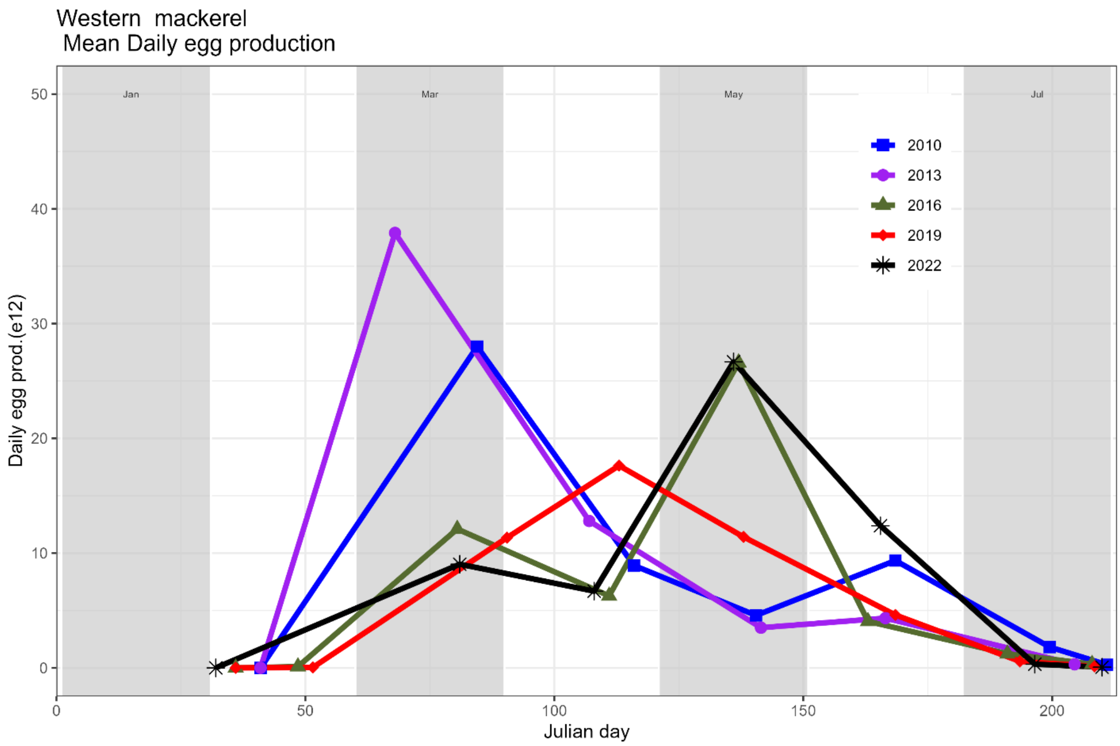

Figure 4.9 Provisional annual egg production curve for mackerel in the western spawning component in 2022, (black line). The curves for 2010, 2013, 2016 and 2019 are included for comparison.

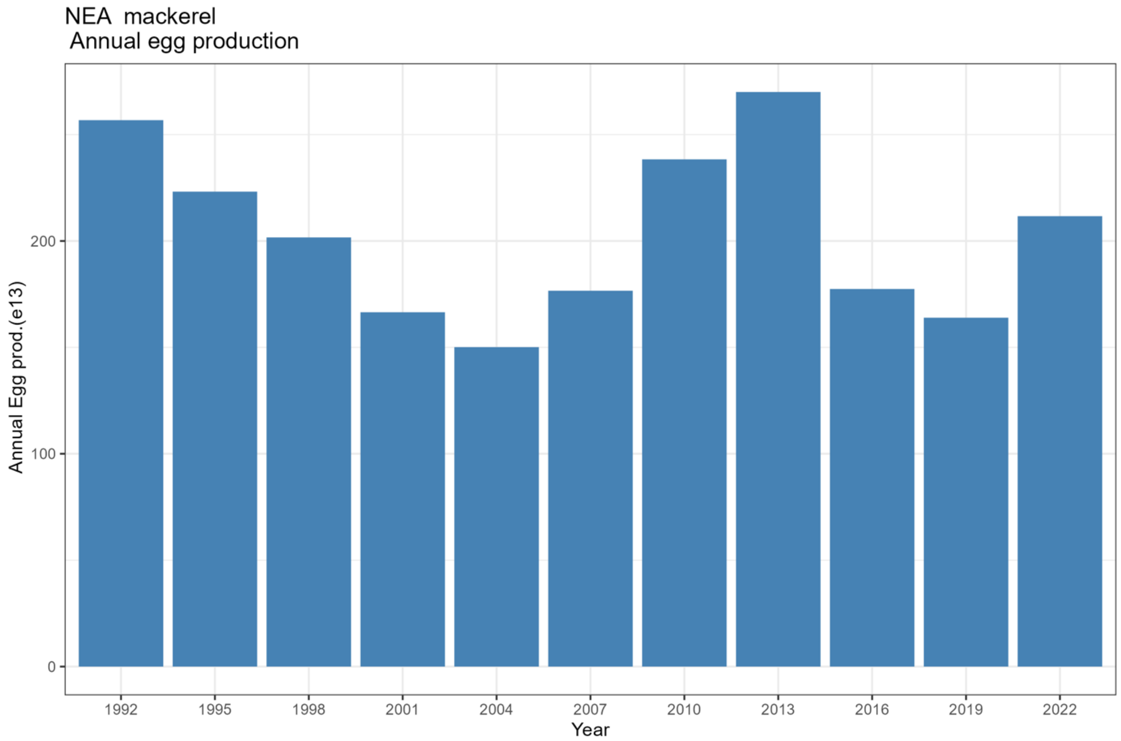

Figure 4.10 The total annual mackerel egg production for 1992 – 2022 (provisional for 2022) for the western spawning component.

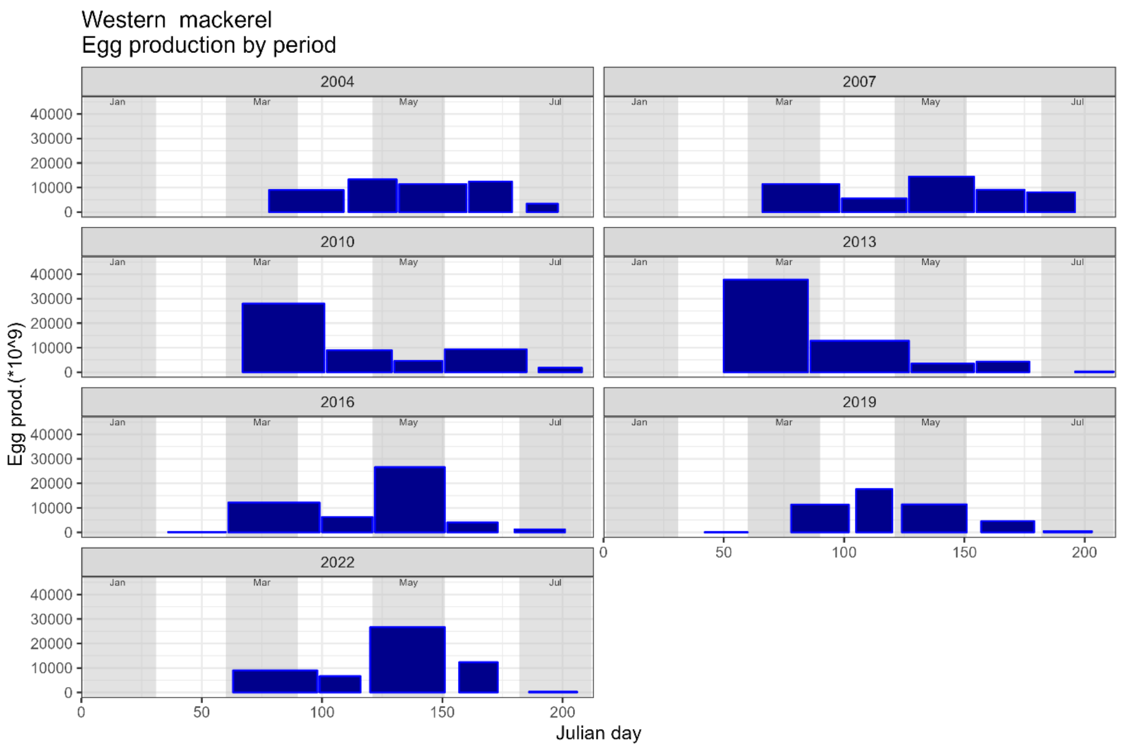

Figure 4.11 Egg production by period for the western spawning component since 2004

Table 4.1 Estimate of the 2022 total mackerel stage I egg production by period for the western component using the histogram method.

Dates	Period	Days	Annual stage I egg production * 10^{15}
Feb 5th – Mar 3rd	Pre 3	31	0.090
Mar 4th – Apr 8th	3	36	0.325
Apr 9th – Apr 26th	4	18	0.120
Apr 27th – Apr 29th	4 - 5	3	0.043
Apr 30th – May 31st	5	32	0.853
Jun 1st – 5th	5 - 6	5	0.067
Jun 6th – Jun 22nd	6	17	0.210
Jun 23rd – Jul 4th	6-7	12	0.081
Jul 5th – Jul 25th	7	21	0.007
Jul 26th – 31st	Post 7	6	0.0003
Total			1.795

4.3.2 Stage 1 Egg production in the Southern Areas

The start date for spawning in the southern area was the 23rd January (Table 4.2). Portugal surveyed in Period 2 in division 9a. Sampling in the Cantabrian Sea where the majority of spawning occurs within the Southern area commenced on the 18th March. The same end of spawning date of July 17th was used again this year and the spawning curve suggests that there is no reason for this to change Figure 4.12). As in 2019 the survey periods were not completely contiguous and this has been accounted for (Table 4.2).. The provisional total annual egg production (TAEP) for the southern area in 2022 was calculated as **3.21 * 10^{14}** (Table 4.2). This is a 25% decrease on the 2019 TAEP estimate which was 4.23 * 10^{14} (Figure 4.13). The mackerel egg production by period since 2004 is shown in Figure 4.14.

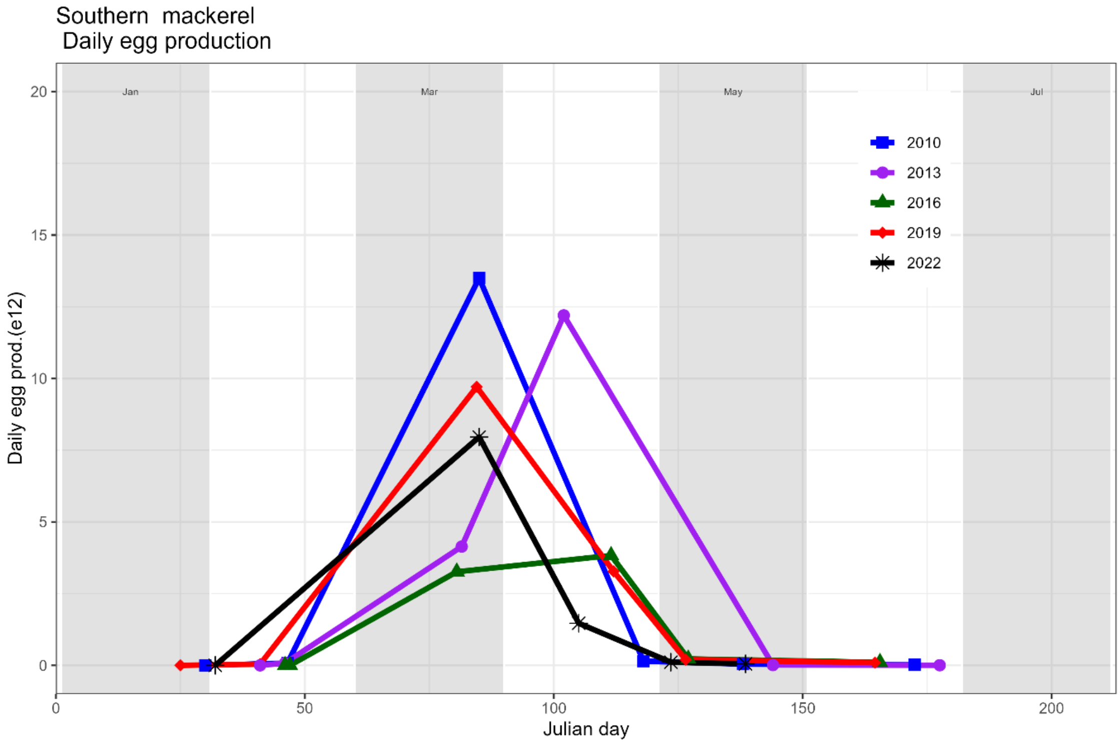

Figure 4.12 Provisional annual egg production curve for mackerel in the southern spawning component for 2022, black line). The curves for 2010, 2013, 2016 and 2019 are included for comparison.

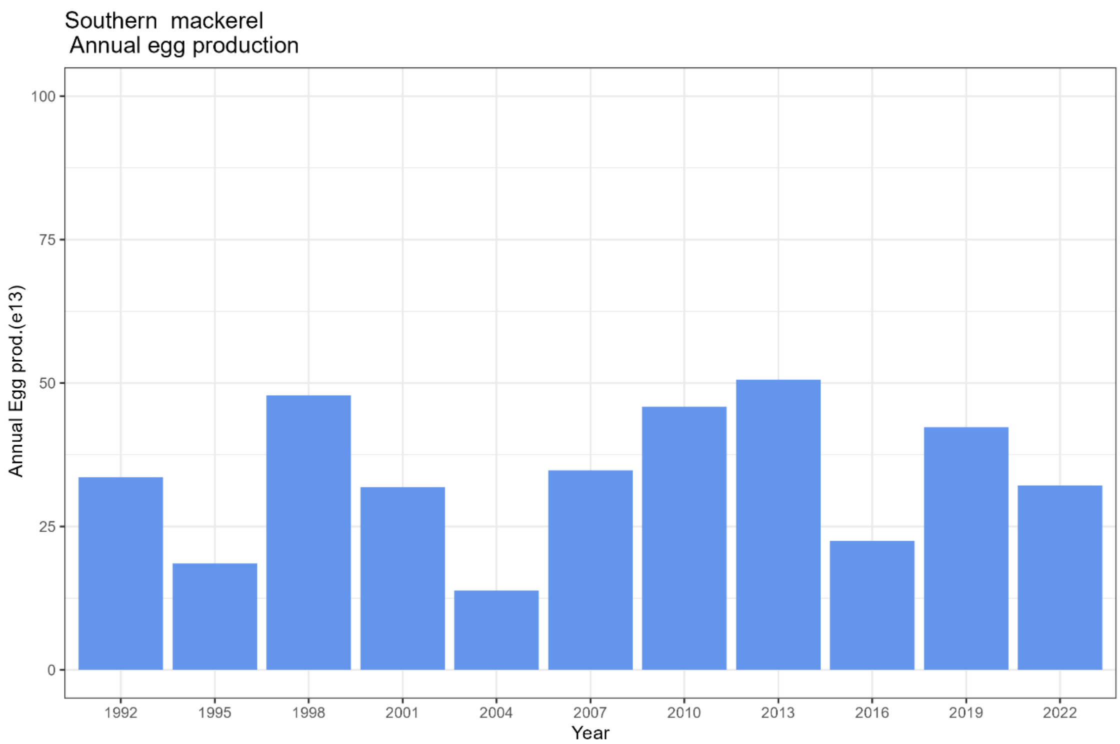

Figure 4.13 The total annual mackerel egg production for 1992 – 2022 (provisional for 2022) for the southern spawning component.

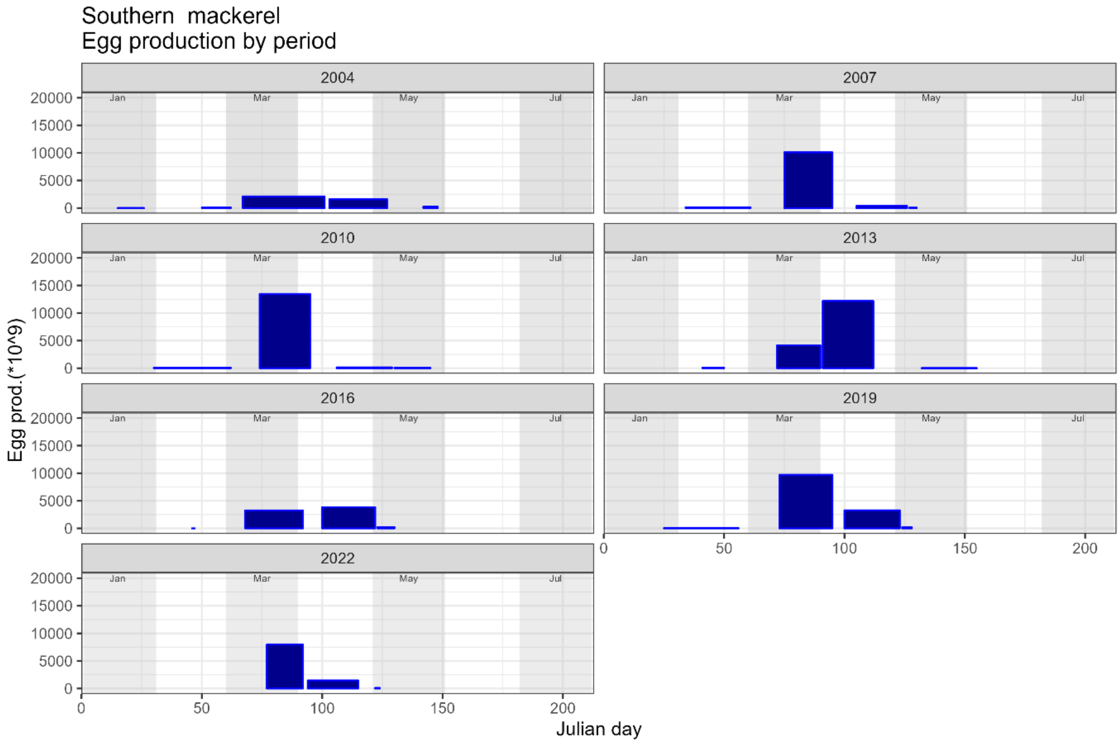

Figure 4.14 Egg production by period for the southern spawning component since 2004

Table 4.2 Estimate of the 2022 total mackerel stage I egg production by period for the southern component using the histogram method.

Dates	**Period**	**Days**	**Annual stage I egg production x 10 ^{14}**
Feb 1st – Mar 17th	2 - 3	45	1.520
Mar 18th – Apr 2nd	3	16	1.270
Apr 3rd	3 - 4	1	0.052
Apr 4th – 25th	4	22	0.323
Apr 26th – May 1st	4 - 5	6	0.026
May 2nd – 4th	5	3	0.003
May 5th –Jul 17th	Post 5	71	0.014
Total	3.212		

4.3.3 Total Egg production

The total annual egg production (TAEP) for both the western and southern components combined in 2022 is **2.116x10^{15}** (Figure 4.15). This is an increase in production of **29%** compared to 2019, 1.64*10^{15} Figure 4.15).

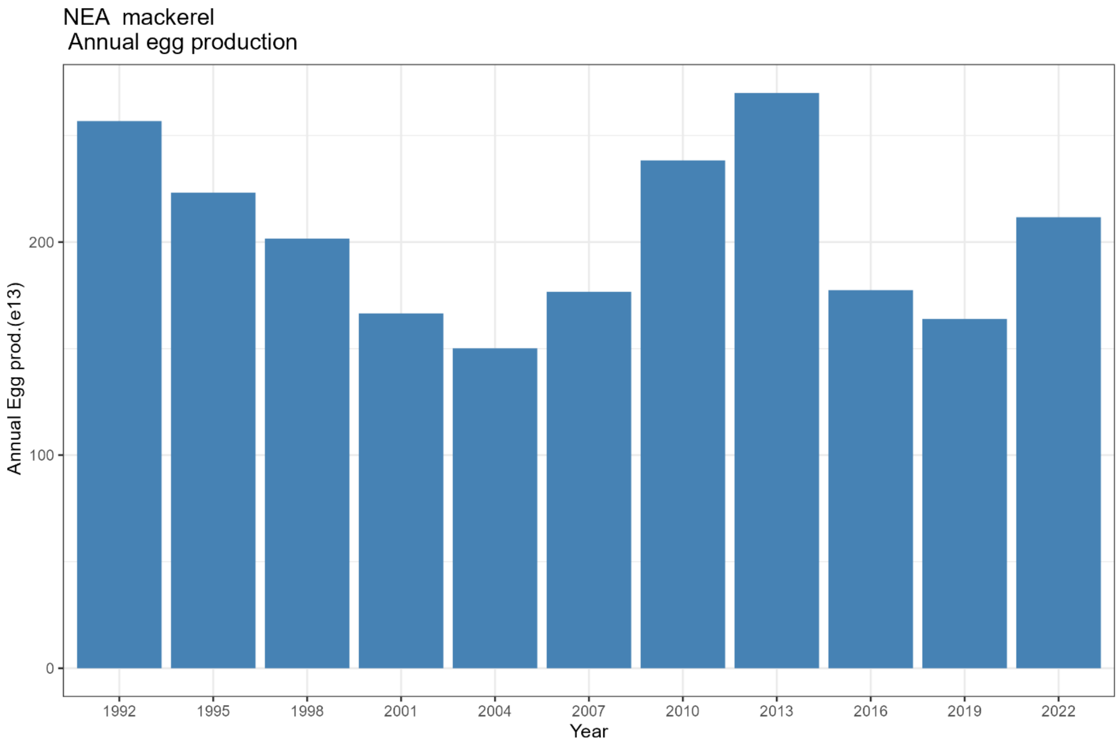

Figure 4.15 Combined mackerel TAEP estimates (*10^{13}) - 1992 – 2022.

4.3.4 Adult sampling

Samples distribution

Atlantic mackerel samples were collected during periods 2-6 spread over an area with a bounding box of 59.36N 14.20W – 36.54N 2.32W. Eleven institutes participated in sample collection during their surveys, in addition samples were collected from the Netherlands pelagic fleet. The histological screening of samples was performed by five institutes while fecundity was analysed by six of them.

Because of time constraints, and as usual for the preliminary report, only samples from periods 2 and 3 were selected. For the final report samples from the other periods will be included as well. Experience from earlier surveys is that the preliminary estimate and the final estimate are close.

Screening

In total 918 samples were screened, of which 793 came from periods 2-3. 482 out of the 793 samples showed spawning markers, i.e. migratory nucleus stage (MIG), hydrating oocytes, eggs, and post ovulatory follicles (POF). A total of 175 samples from periods 2-3 showed presence of atresia without considering those that were classified as “spent” or having “massive atresia”.

From previous survey reports we know that POF scoring has varied considerably between periods. WKAPEM (2021) discussed this issue and came up with more detailed criteria for POF staging. Looking at screening results from 2022, POFs were identified less frequently than in 2019 for periods 2 and 3, i.e. 58 % vs 74% (Table 4.3).

Table 4.3 POF scoring using histology samples from periods 2-3.

Period	No POF	POF	%POF	%POF 2019
2	66	55	52	66
3	260	404	60	74
2-3	326	459	58	74

Considering the oocyte stage, most of the samples in periods 2-3 were at MIG (oocyte stage 4) or hydration (stage 5) oocyte stage (n = 545) and less than half (n = 217) were in advanced vitellogenic oocyte stage (oocyte stage 3). The number of oocyte stage 3 samples was however considerably higher than in 2019 (n = 66) due to the fact that in 2022 extra samples were collected in collaboration with the Netherlands pelagic fishing industry.

4.3.5 Potential Fecundity

For the 2022 preliminary estimate of potential fecundity 169 samples were available, which represents 21% of all the samples screened for periods 2 and 3. This number was much higher than in 2019, where only 34 samples were available for the preliminary report.

The potential fecundity estimate is based on samples from pre-spawning fish. The pre-spawning status is confirmed using a detailed histology screening procedure that detects the most advanced oocyte stage (stage 1-5) as well as spawning markers (POF´s, post ovulatory follicles and eggs). This year the fecundity estimate is based on samples that may also include the MIG oocyte stage. This is different from recent surveys where the most advanced oocyte stage included was stage 3 (advanced vitellogenesis). However, the MIG oocyte stage is not a true spawning marker, only indicating that spawning will likely take place within a few days. In previous surveys samples with MIG´s were excluded for precautionary reasons. The distribution of samples with the migratory nucleus oocyte stage (stage 4) and vitellogenic oocyte stage (stage 3) was very similar (Figure 4.16). The median value for stage 3 samples was 1247 (mean 1282, SD 290) while for the MIG stage the median was 1256 (mean 1300, SD 267). This shows that including samples with MIG´s in the fecundity estimate did not significantly change the median or mean value, and that our previous precautionary procedure of excluding MIG´s is probably unnecessary. The distribution of relative potential fecundity values (Figure 4.16) was close to a normal distribution and ranged from 623 to 1972 (n/g).

Since 2013 WGMEGS has used the median relative potential fecundity value instead of the mean that was used previously. The reason for this is that the median is more robust to outliers than the mean. When WGMEGS made this transition, the time series was analysed and it was found that the median was close to the arithmetic mean in most years.

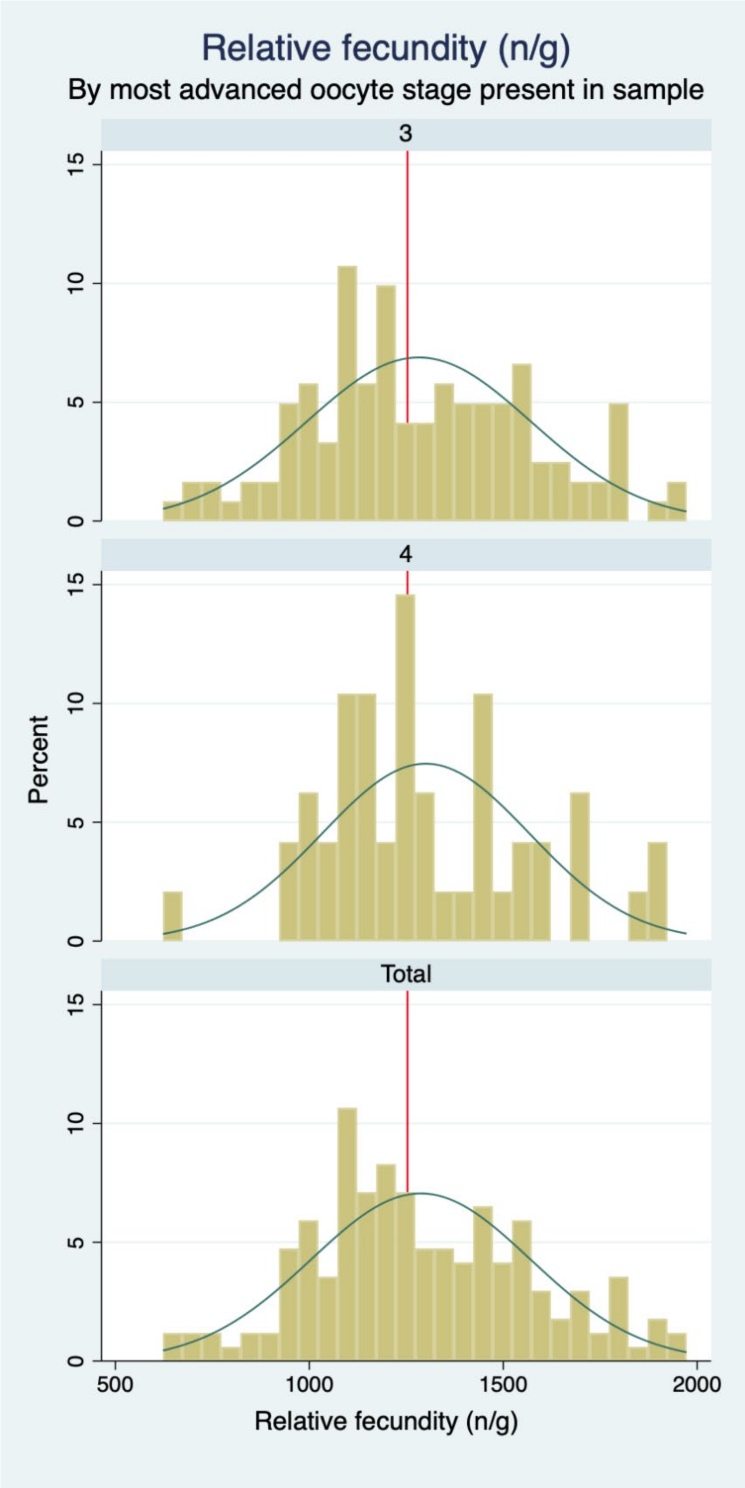

Figure 4.16. Preliminary estimate of relative fecundity in 2022. The panels show the distribution (in %) of relative fecundity using samples in which the most advanced oocyte stage present was 3 (advanced vitellogenesis, top panel), samples where the most advanced oocyte stage was MIG (stage 4, middle panel) and the combined histogram (bottom panel).

The preliminary relative potential fecundity in 2022 was slightly higher than in 2019 (1253 and 1191, respectively).

Table 4.4 Estimate of relative fecundity (n/g fish) and statistics.

Year	N	Median	Mean	sd	Max	Min	95%CI
2022	169	1253	1288	283	1972	623	1252-1324
2019	34	1215	1263	285	2029	564	1163-1362

Biological data of fish used for the potential fecundity estimate.

The distribution of fish length, weight, Fulton's condition factor (100 × weight/length3), and gonad-somatic index (GSI; 100 × Ovary weight/Fish weight) is shown in Figure 4.17.

Similar to previous surveys only fish with condition factor between 0.5 and 1.2, and GSI between 1 and 25 were included in the fecundity and atresia estimates, (ICES 2021). For this preliminary estimation, no females needed to be excluded from the analysis based on these biological parameters.

Atresia

Atresia is the loss of oocytes by reabsorption before spawning and must be subtracted from the potential fecundity (whole mount fecundity counting) to get the realised fecundity. Intensity of atresia has not been analysed for this preliminary report due to lack of time.

The prevalence of atresia estimated by histological screening may however be a good indicator of the level of atresia. Prevalence of atresia is defined as the percentage of spawning fish which have early stage atresia (early alpha-atresia). Among the 559 samples considered the prevalence of atresia was 0.28 (fish from period 2-3, excluding pre-spawning fish, spent fish, and fish with massive atresia).

4.3.6 Realised Fecundity

The loss by atresia is a function of both intensity of atresia and prevalence of atresia. As mentioned above the intensity of atresia for 2022 is still unavailable, therefore the loss was calculated from the average loss from the surveys since 2001 (Table 4.5**Error! Reference source not found.**). The relative loss by atresia from this period (2001-2019) ranged from 6-9% (average 6%).

Based on this the preliminary realised fecundity estimate for 2022 was 1178 oocytes/gram fish.

This estimate is well within the range of estimates (1002-1209, average 1076) for all the previous surveys back to 1998 (Table 4.5). For the last three surveys the variation was from 1087 to 1209 (average 1148).

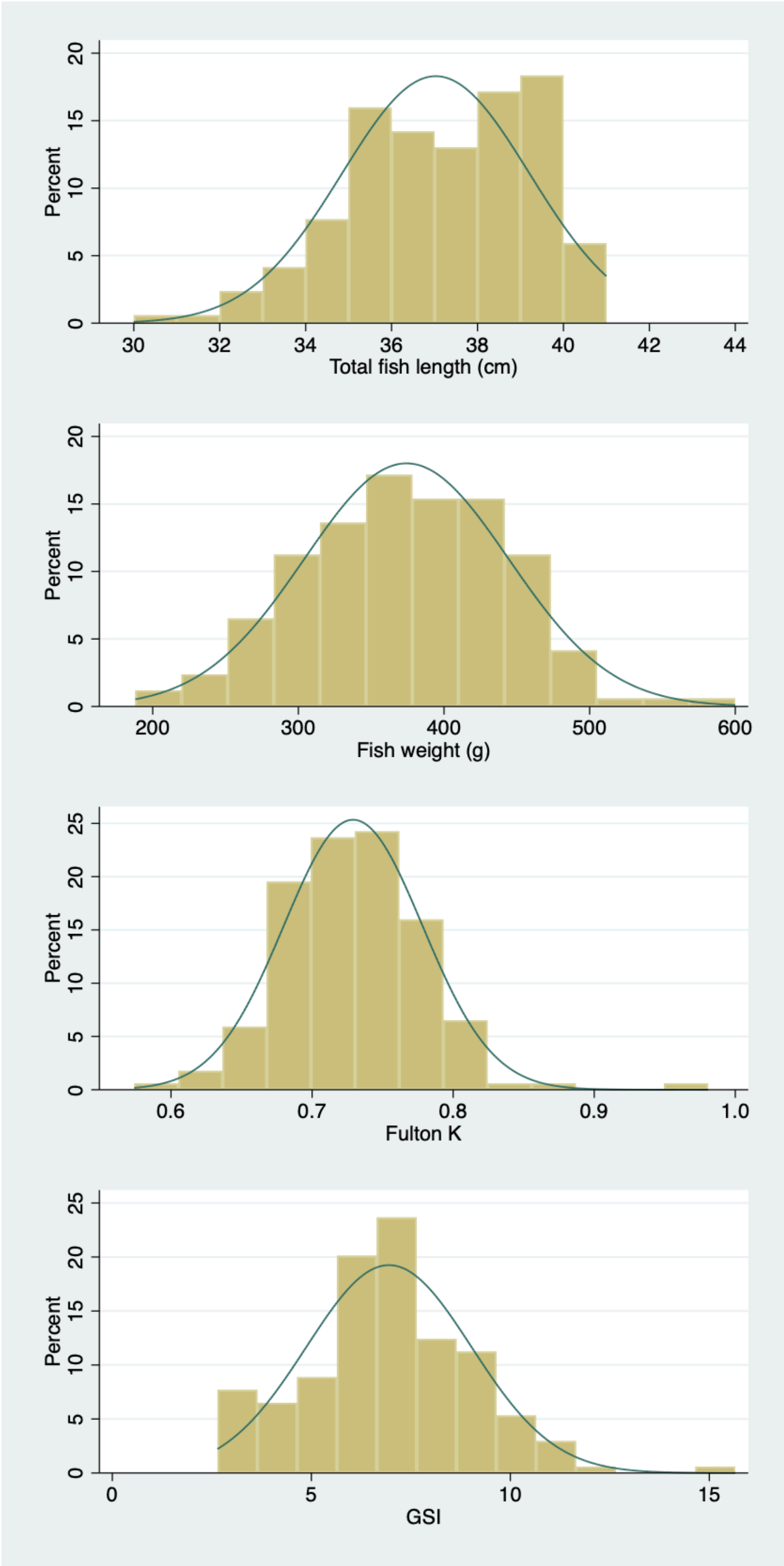

Figure 4.17 Fish length and weight, Fulton index and GSI of individuals analysed for fecundity.

Table 4.5 Summary table of mackerel fecundity and atresia by survey year.

	Assessment year								
Parameter	1998	2001	2004	2007	2010	2013	2016	2019	**2022 prelim**
Fecundity samples (n)	96	187	205	176	74	132	97	62	**169**
Prevalence of atresia (n)	112	290	348	416	511	735	713	895	**559**
Intensity of atresia (n)	112	290	348	416	511	56	66	64	
Prevalence of atresia	0.55	0.20	0.28	0.38	0.37	0.22	0.30	0.28	**0.28**
Relative Potential fecundity (n/g)	1206	1210	1127	1098	1140	1257*	1159*	1191*	**1253***
Geometric mean intensity of atresia (n/g)	46	40	33	30	26	27	30	20	
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	**75**
Relative potential fecundity lost (%)	17	6	7	9	6	4	6	4	**6**
Realised fecundity (n/g)*	1002	1033	1052	1009	1070	1209	1087	1147	**1178**

*Median not mean

4.3.7 Biomass estimation

Based on the total annual egg production (TAEP) for the western and southern component, a preliminary realized fecundity estimate of 1178 oocytes/gr female, a sex ratio of 1:1 and a raising factor of 1.08 (ICES, 1987), the preliminary total spawning stock biomass (SSB) was estimated as shown below:

$$SSB = \frac{TAEP}{F'} * s * cf$$

Where

F' = realized fecundity,

s = 2 for a given sex ratio of 1:1,

cf = 1.08 (fixed raising factor to convert pre-spawning to spawning fish)

Giving

3.292 million tonnes for western component (2019: 2.301).

0.589 million tonnes for southern component (2019: 0.792).

3.881 million tonnes for western and southern components combined (2019: 3.093)

4.4 Mackerel DEPM Preliminary Results

4.4.1 Egg Production

Egg production data are provided by periods 3, 4 and 5 surveys (see Table 4.6). Detailed analysis and corresponding results for daily egg production will be presented in the final WGMEGS report in 2023.

4.4.2 Adult sampling

The number of adults collected was 4581, corresponding to individuals in the peak of spawning (see Table 4.6, previous section). 1322 ovaries were stored for fecundity analysis. Thus, the DEPM sampling objective was achieved in a 29% of samples.

Screening

By the time of reporting preliminary results, 881 out of 1322 individuals were screened (Table 4.6) for batch fecundity and POFs. 78 samples were candidate for batch fecundity estimation according to screening results available so far. Further samples still have to be screened, some of which may potentially also be used for batch fecundity estimation. Regarding POFs, during the screening process only POFs presence/absence is recorded; POFs staging, which is used for spawning fraction estimation, will be carried out at a later stage. POF staging requires analysts with good morpho-physiological experience and is a time consuming process. In addition, results from previous surveys showed that POF scoring can vary considerably between periods. At WKAEPM (ICES 2022b) POF scoring was discussed once again and more detailed criteria were elaborated for use in 2022.

Table 4.6. Number of samples identified by histological screening for POF staging and batch fecundity analysis.

Period	Collected	Screened	POFs	Batch Fecundity Histology
3	889	642	411	62
4	348	162	117	10
5	85	77	66	6

4.4.3 Batch fecundity

As mentioned previously, there is no data available yet due to time limitations.

Spawning fraction-POFs will be staged during the current autumn-winter along with a POF ring test that will be carried out among survey participants in order to calibrate the readings, the results will be provided during the WGMEGS 2023 meeting.

5 2022 Horse Mackerel AEPM/DEPM Survey execution and preliminary results (ToR h)

5.1 Western Horse Mackerel AEPM Survey execution

Period 3 – In period 3 horse mackerel spawning started in the Cantabrian Sea and southern Biscay, but numbers of eggs found were very low. Higher spawning took place in the Celtic Sea but numbers were still low (Figure 5.1).

Period 4 – Horse mackerel spawning continued in the Cantabrian Sea, extending into southern Biscay. Eggs were again found in the Celtic Sea but numbers were lower than in period 3 (Figure 5.2).

Period 5 – Horse mackerel spawning continues in the Cantabrian Sea, Celtic Sea and northern Bay of Biscay, but still in low numbers. Some eggs were also found south and west of Ireland (Figure 5.3).

Period 6 –Spawning continued in northern Biscay, the Celtic Sea and to the southwest of Ireland. For the first time in a number of years large numbers of eggs were reported in a number of stations close to the 200m contour. Peak spawning took place during this period (Figure 5.4).

Period 7 – Eggs were found from northern Biscay to west of Scotland, being concentrated off the southwest of Ireland. In general egg numbers were low but occasional stations with moderate to high counts were observed (Figure 5.5).

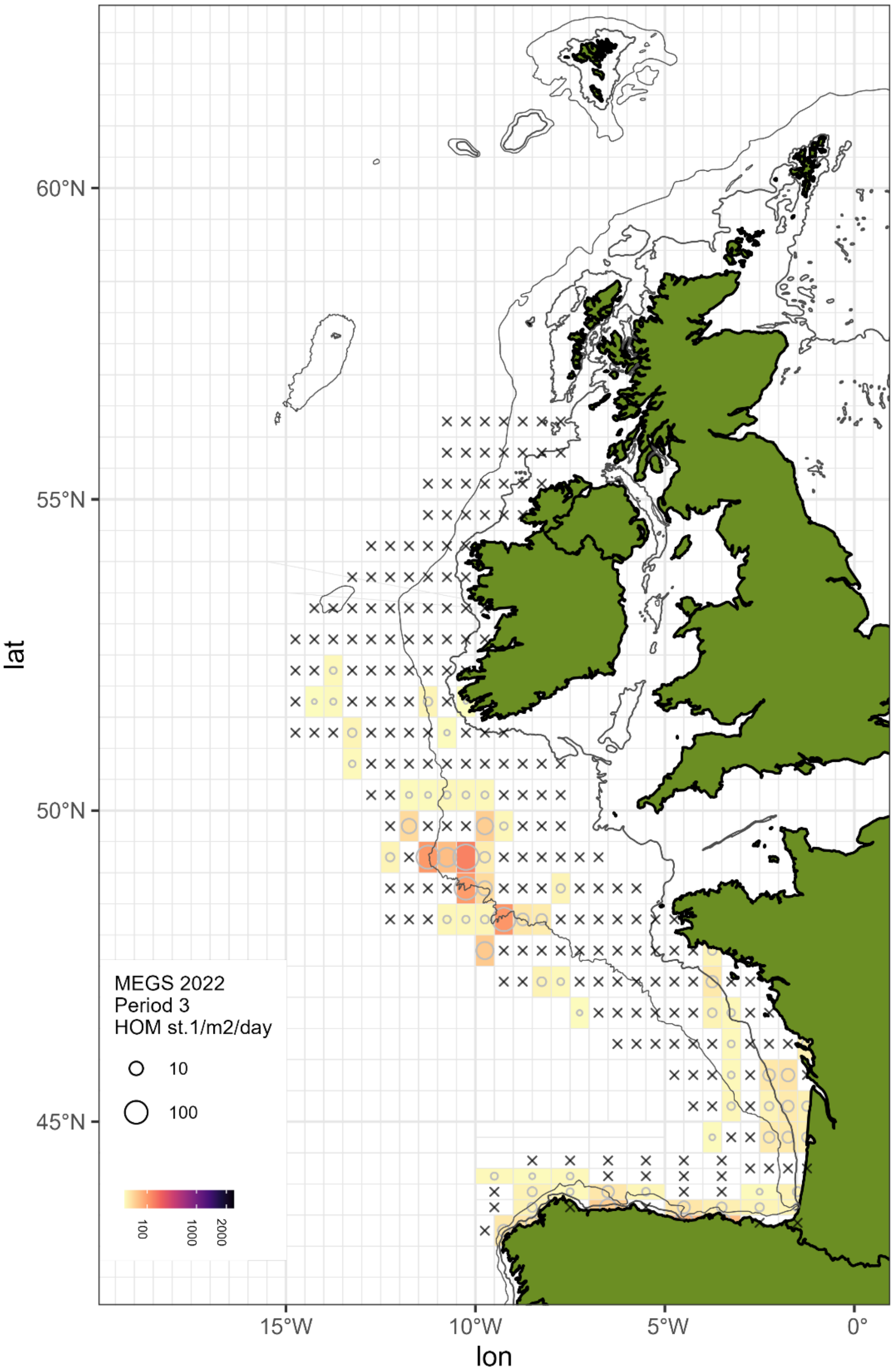

Figure 5.1. Horse mackerel egg production by half rectangle for period 3 (March 4th – April 8th). Circle areas and colour scale represent horse mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

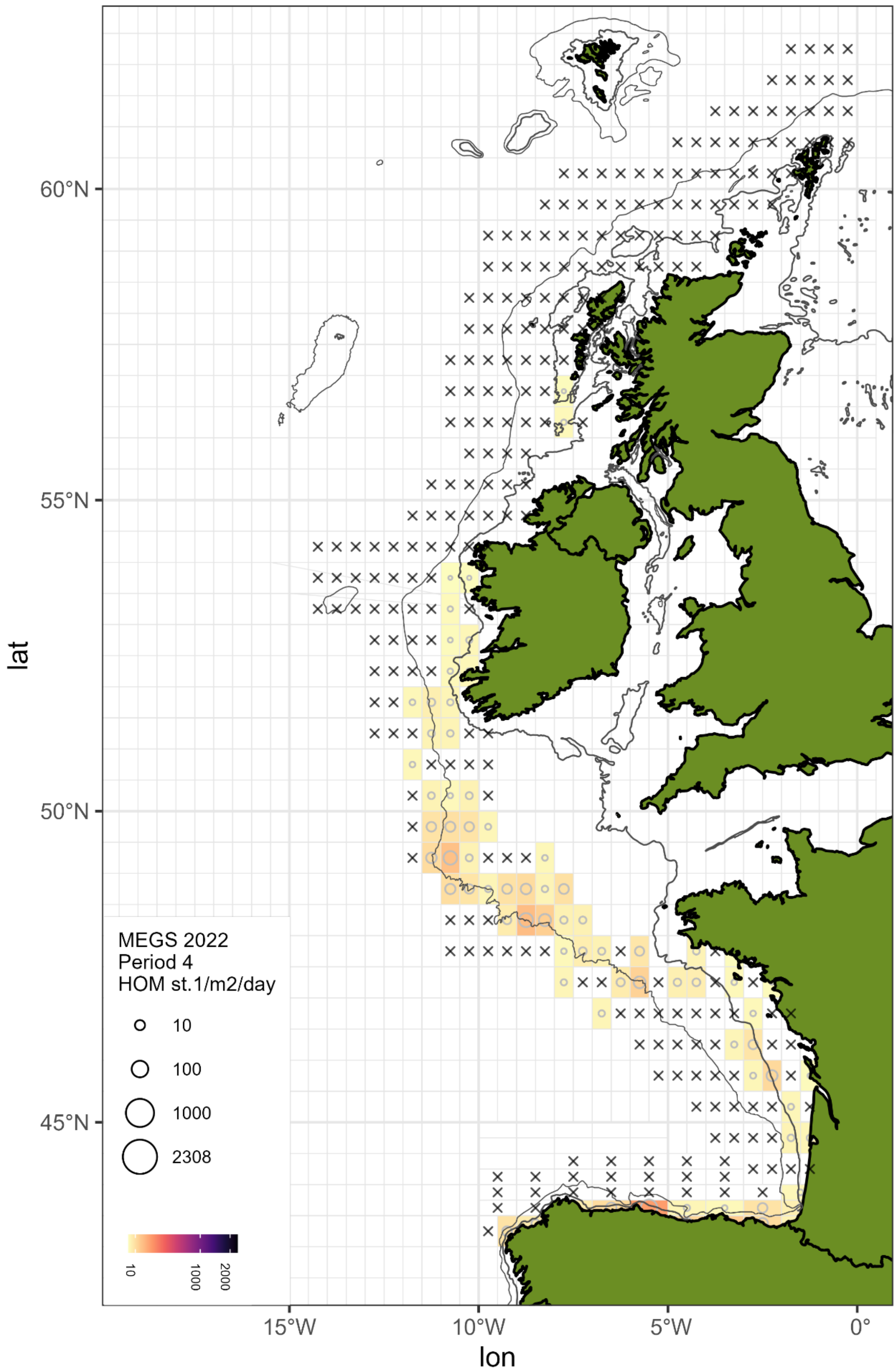

Figure 5.2 Horse mackerel egg production by half rectangle for period 4 (April 9th – 29th). Circle areas and colour scale represent horse mackerel stage I eggs/m²/day by half rectangle. Crosses represent zero values.

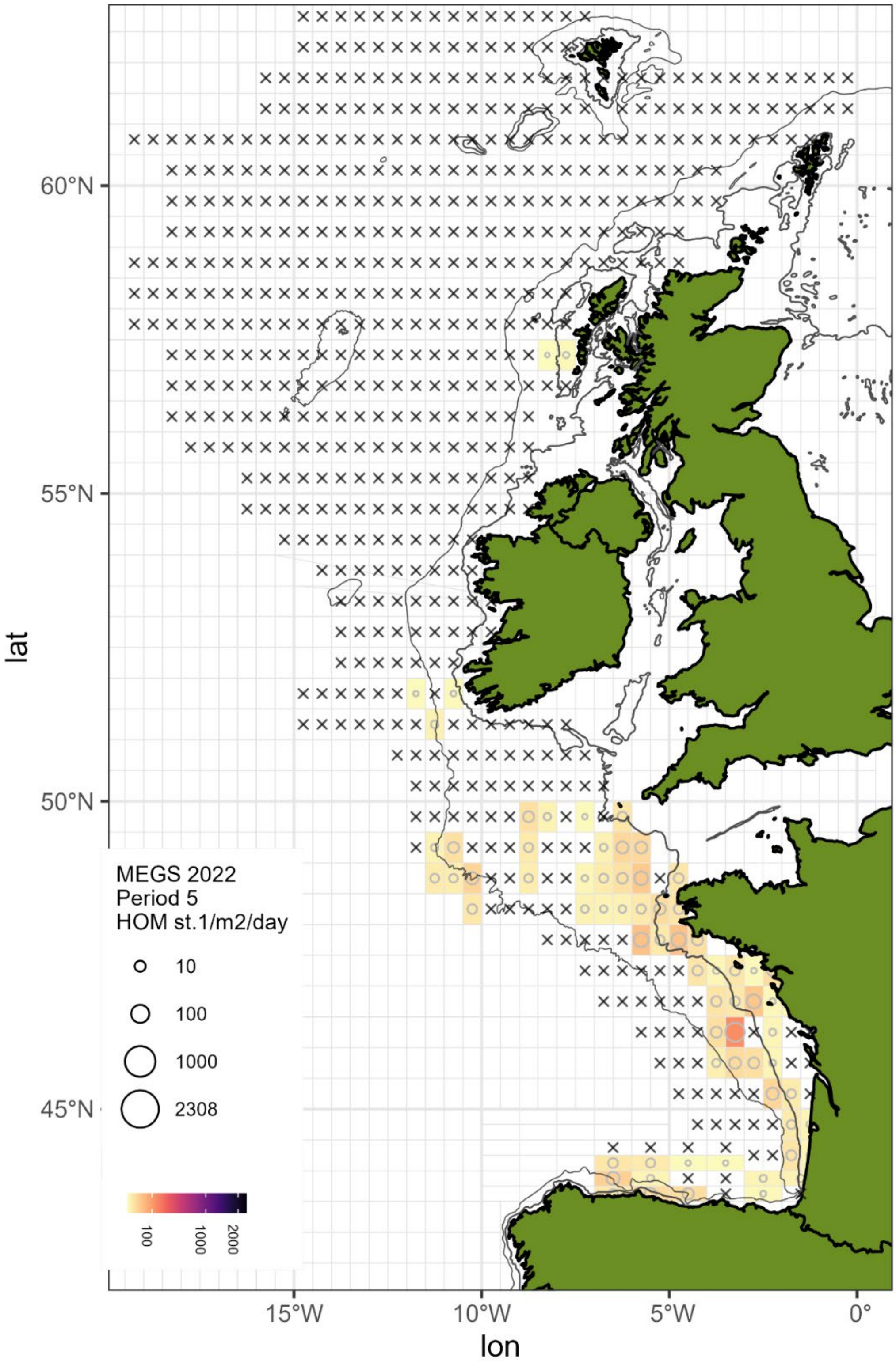

Figure 5.3 Horse mackerel egg production by half rectangle for period 5 (Apr 30th – May 31st). Circle areas and colour scale represent horse mackerel stage I eggs/m²/day by half rectangle. Crosses represent zero values.

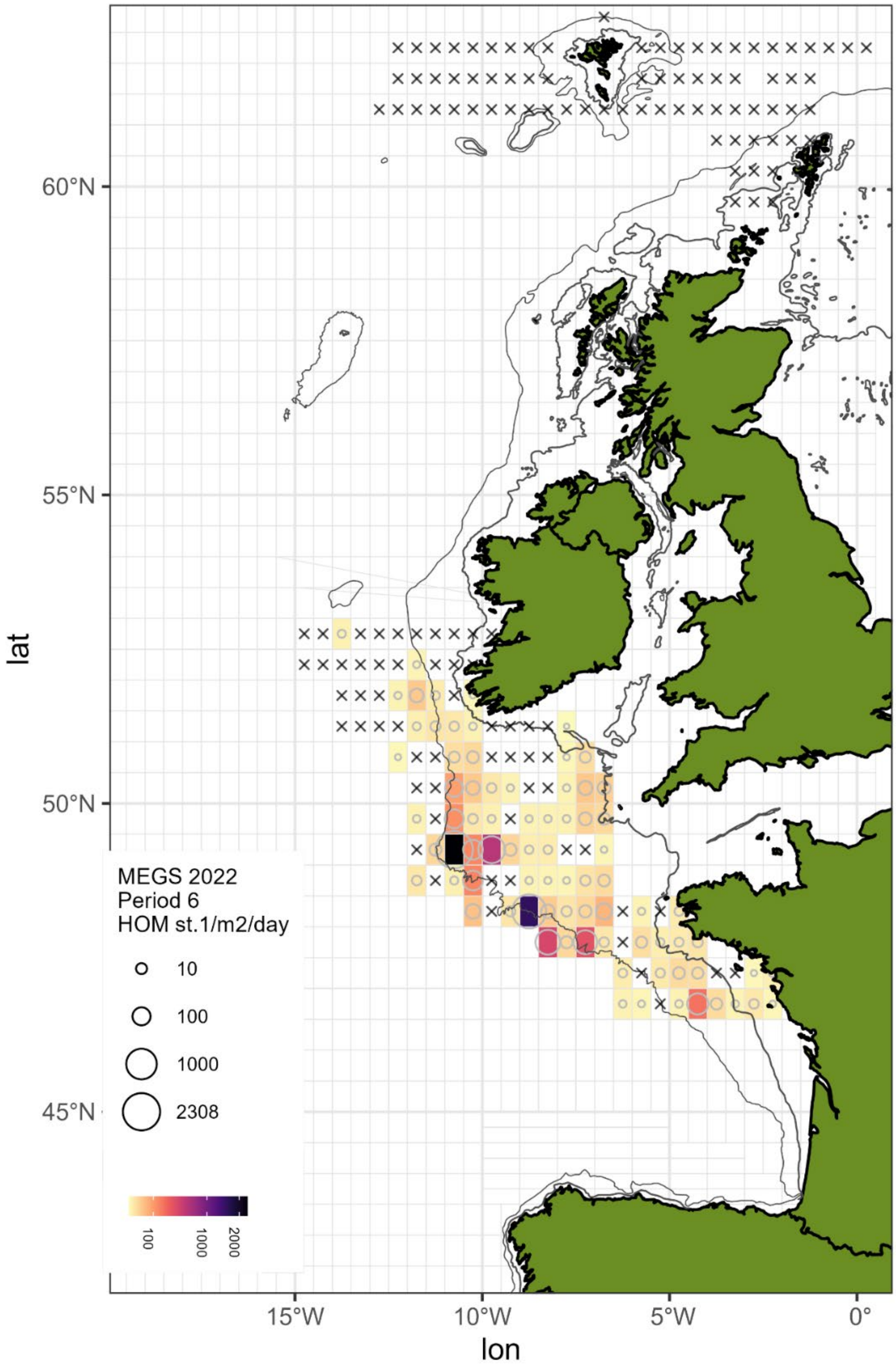

Figure 5.4 Horse mackerel egg production by half rectangle for period 6 (June 1st – 30th). Circle areas and colour scale represent horse mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

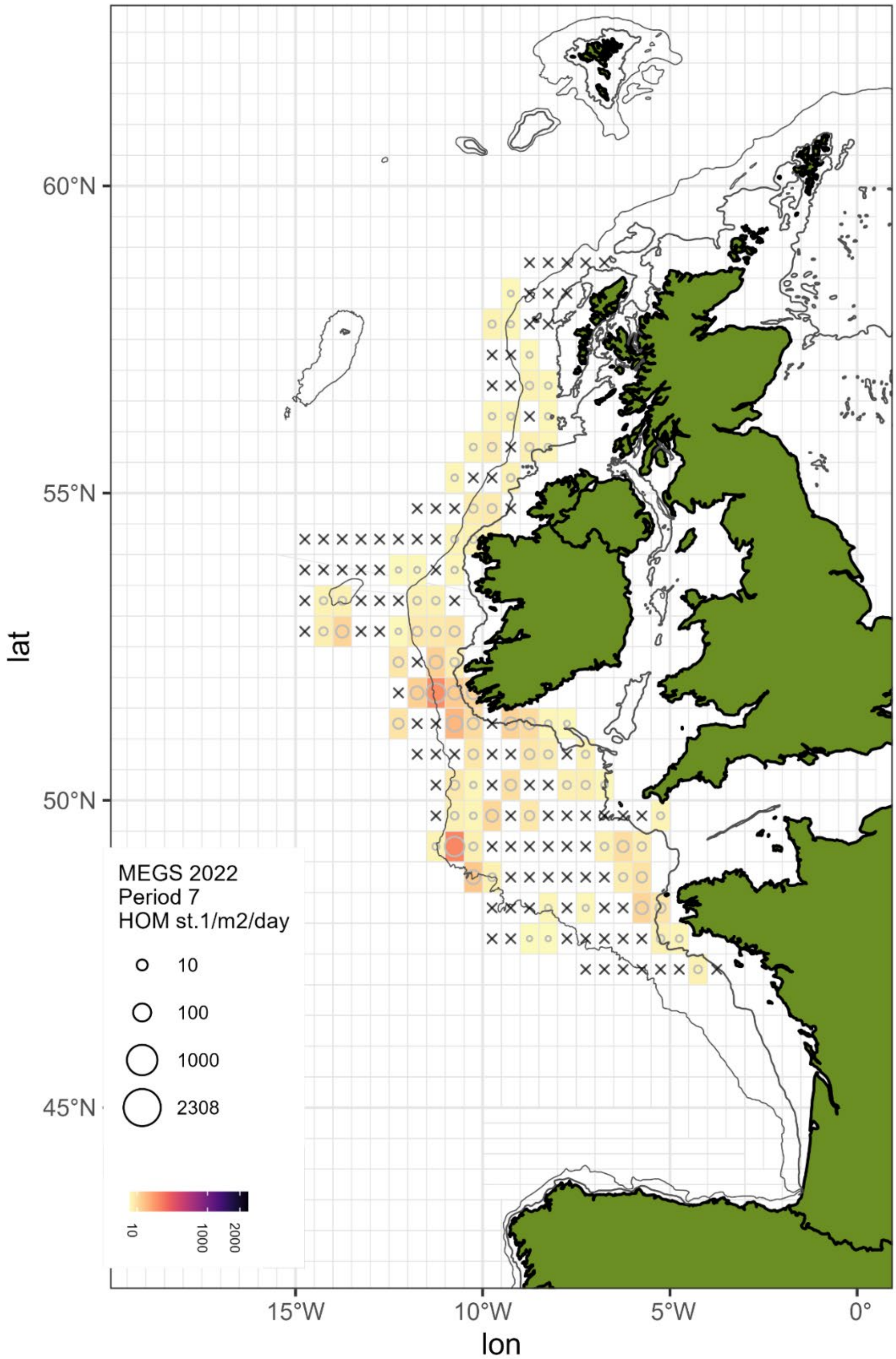

Figure 5.5 Horse mackerel egg production by half rectangle for period 7 (July 1st – July 31st). Circle areas and colour scale represent horse mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

5.2 Western Horse Mackerel AEPM Preliminary Results.

5.2.1 Total annual egg production results

Period number and duration are the same as those used to estimate the western mackerel stock, as are the dates defining the start and end of spawning (Table 5.1). The shape of the egg production curve does not suggest that those dates should be altered for 2022 (Figure 5.6). An exercise, similar to the one carried out for mackerel in period 6, was not carried out for horse mackerel as MEGS feel that the Netherlands period 6 survey adequately delineated the northern boundary of horse mackerel spawning during this period. The total annual egg production was estimated at **5.15 x 10^{14}**. This is almost a threefold increase on 2019 which was 1.78 × 10^{14} which was the lowest estimate of annual egg production ever recorded for this species (Figure 5.7). Horse mackerel egg production by period since 2007 is shown in Figure 5.8.

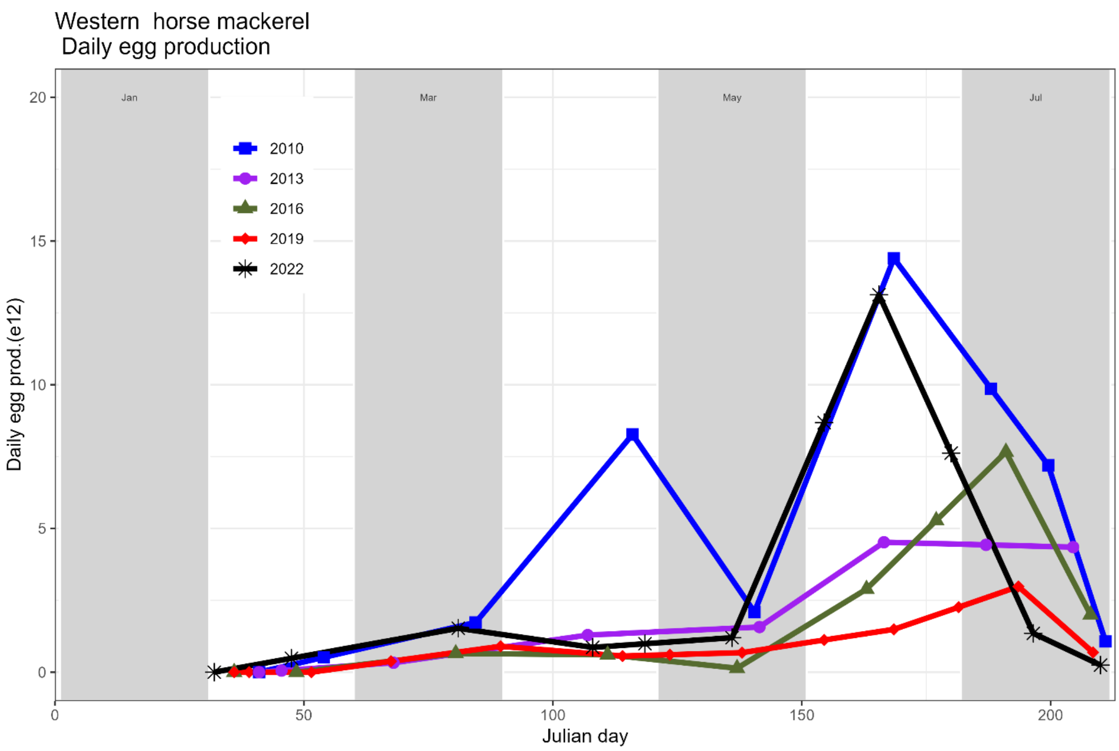

Figure 5.6 Provisional annual egg production curve for western horse mackerel for 2022, (black line). The curves for 2010, 2013, 2016 and 2019 are included for comparison.

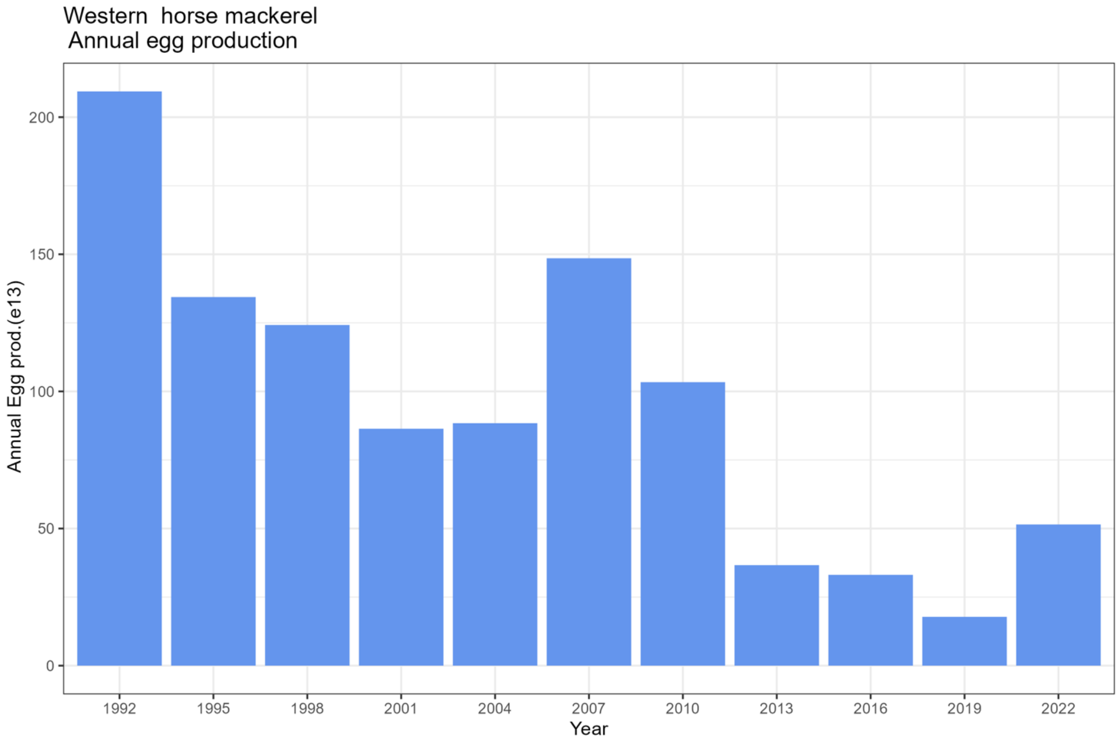

Figure 5.7 The total annual horse mackerel egg production for 1992 – 2022 (provisional for 2022) for the Western stock.

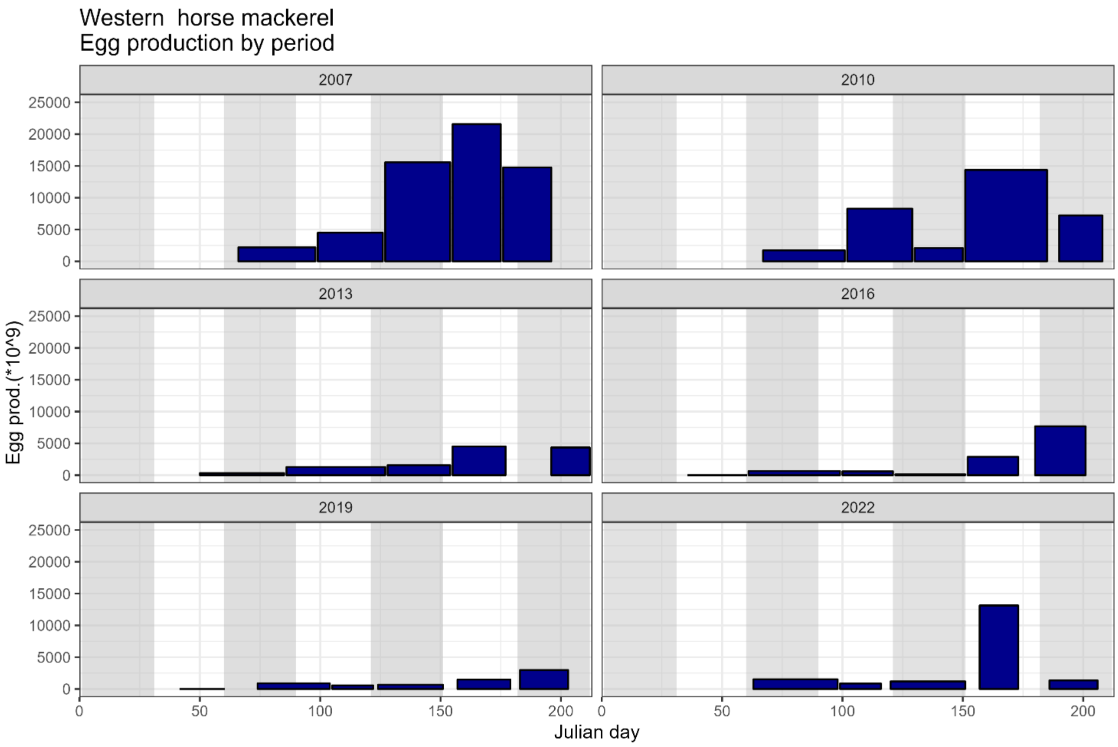

Figure 5.8 Egg production by period for the western horse mackerel spawning component since 2007.

Table 5.1 Estimate of western horse mackerel total stage I egg production by period using the histogram method for 2022.

Dates	Period	Days	Annual stage I egg production * 10^{15}
Feb 1st – Mar 3rd	Pre 3	31	0.016
Mar 4th – Apr 8th	3	36	0.055
Apr 9th – 26th	4	18	0.016
Apr 27th – 29th	4 - 5	3	0.003
Apr 30th – May 31st	5	32	0.038
Jun 1st – 5th	5 - 6	5	0.043
Jun 6th – 22nd	6	17	0.223
Jun 23rd – Jul 4th	6 – 7	12	0.091
Jul 5th – 25th	7	21	0.028
Jul 26th – 31st	Post 7	6	0.001
Total			0.514

5.3 Western Horse Mackerel DEPM Preliminary Results

5.3.1 Egg production in the peak spawning period.

Expected peak spawning for western horse mackerel is during June to July. This year, peak spawning for western horse mackerel was found to have taken place in period 6 (June). Daily egg production using Stage I horse mackerel was estimated at 1.31 *10^{13} eggs/day during peak spawning (period 6). Stage I horse mackerel Annual egg production was calculated at 5.14 * 10^{14} eggs, a 290% increase on 2019. (Table 5.1).

5.3.2 Adult sampling

This year for horse mackerel only DEPM ovary samples were collected during Periods 6 and 7, during peak of spawning. In addition to those samples collected during the MEGS surveys additional samples were collected from the Irish WESPAS surveys in periods 6 and 7. Since horse mackerel fecundity is at this moment not used for estimating the spawning stock biomass the focus of the fecundity analysis has been on mackerel. Therefore, at this time no horse mackerel fecundity results are ready to be presented. All samples will be analysed and results presented at the 2023 WGMEGS meeting.

5.4 Southern Horse Mackerel DEPM. Survey execution and preliminary results

5.4.1 Survey execution

The Portuguese survey takes place in, and covers, the southern and western Atlantic-Iberian waters (ICES Division 9a). The DEPM methodology involves surveying during the peak spawning time in the spawning area of the target species for the estimation of the daily total egg production and positive spawning area. Concurrently, adult samples are obtained for adult parameters estimation (female mean weight, sex-ratio, batch fecundity and spawning fraction).

In 2022 the DEPM for southern horse mackerel survey was carried out by Portugal (IPMA) in the period 23 January - 20 February in division 9a. A total of 530 stations were sampled along 46 of the 48-transects regular grid, the two closest transects to the Gibraltar Strait were unable to be covered due to significant adverse sea conditions. Except for these two transects, the survey plan was achieved as expected.

The provisional information from the 2022 survey is summarized in Table 5.2. Laboratory processing and analyses of samples is still underway, the final eggs data (from both horse-mackerel and mackerel) should be available by the end of 2022, with the final horse mackerel data (from eggs and adults) expected to be available in April 2023 for WGMEGS meeting.

Mackerel ovary samples and fish biological data were sent to MEGS participating laboratories for analyses.

Table 5.2. Summary of the Portuguese 2022 DEPM survey (PT-DEPM22-HOM)

	South	West	Total area
RV	Vizconde de Eza	Vizconde de Eza	
Sampling period	25-31/01/2022	31/01 - 19/02/2022	
Transects for plankton sampling	16	30	46
Plankton samples CalVET system	134 (x2 nets)	396 (x2 nets)	530 (x2 nets)
Plankton samples CUFES system	217	514	731
CTD profiles	134	396	530
Fishing hauls (positive for HOM) + commercial hau	12/11 + 2	21/9 + 8	
Fishing hauls (positive for MAC)	12/3	21/5	
HOM sampled (from commercial hauls)	119	622	741
HOM gonads preserved (from commercial hauls)	68	256	324
HOM otoliths collected (from commercial hauls)	43	306	349
HOM sampled (from research vessel)	909	369	1278
HOM gonads preserved (from research vessel)	315	152	467
HOM otoliths collected (from research vessel)	476	244	720
MAC sampled	91	91	182
MAC gonads preserved	22	29	51
MAC otoliths collected	55	91	146

5.4.2 Hydrography

In 2022, and according to schedule, surveying during the PT-DEPM22-HOM started at its southern limit, off Cape Trafalgar, in the Bay of Cadiz, on the 23rd of January and ended at its northern border, close to Cape Finisterre, on the 20th of February. The vessel took a one day break in Lisbon on the 6th February for vessel and scientific material replenishment, transportation to IPMA of the eggs and fish samples from the 1st leg, and team replacements.

The oceanographic conditions encountered during the period of late January – end of February are shown in Figure 5.9, and will be described with further detail in the 2023 report.

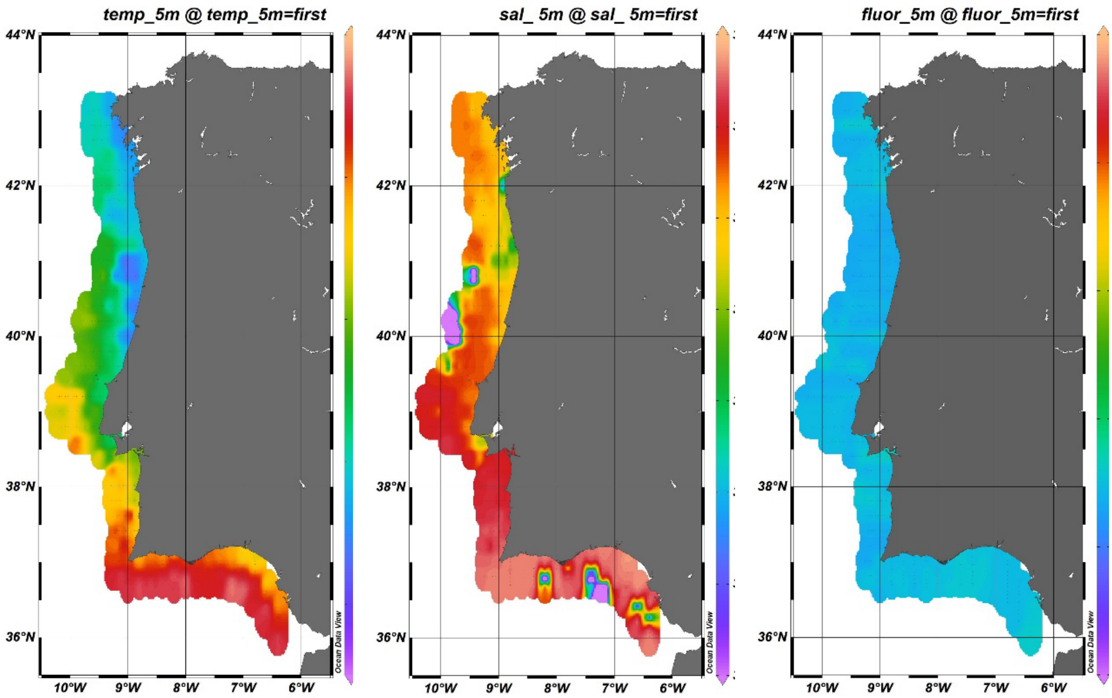

Figure 5.9 Sea surface distributions of temperature (left panel), salinity (middle panel) and fluorescence (right panel). The data were obtained by the sensors associated to the CUFES system.

5.4.3 Egg sampling

Currently the analysis of the samples is in progress. So far, identification and stageing for horse-mackerel and mackerel (*Scomber spp.*) is complete for one of the CalVET nets (the one preserved in formalin). For the entire survey, 530 CalVET samples were collected (with the pair of nets, it accounts for a total of 1060 plankton samples). These CalVET samples were associated to the same number of CTDF profiles. On transit between the CalVET stations, the CUFES underway system collected 731 samples.

In the plankton samples analysed so far, 53% of the stations contained fish eggs. Horse-mackerel eggs represented 3.3% of the total eggs collected (19% of the stations being positive for the species), while *Scomber spp*. accounted for 0.4% of the total eggs (only 1% of the stations being positive for mackerel). The dominating fish species present in the ichthyoplankton samples this year was sardine (which added up 78.7% of the total fish eggs, in 30% of the CalVET stations).

Figure 5.10 show the eggs total abundance distributions for both horse-mackerel and mackerel (*Scomber spp.*). Similar to 2019, very few horse mackerel eggs were observed in the Gulf of Cadiz waters, as well as in Galicia. The higher densities were obtained in the SW Portuguese waters, over most of the continental shelf, the highest horse mackerel egg density having been found between Aveiro and Porto, at the shelf edge. As for mackerel, the higher egg densities were observed in the northern 9a division, from Aveiro to Cape Finisterre, but also over the transects closest to Cape S. Vincent in the south.

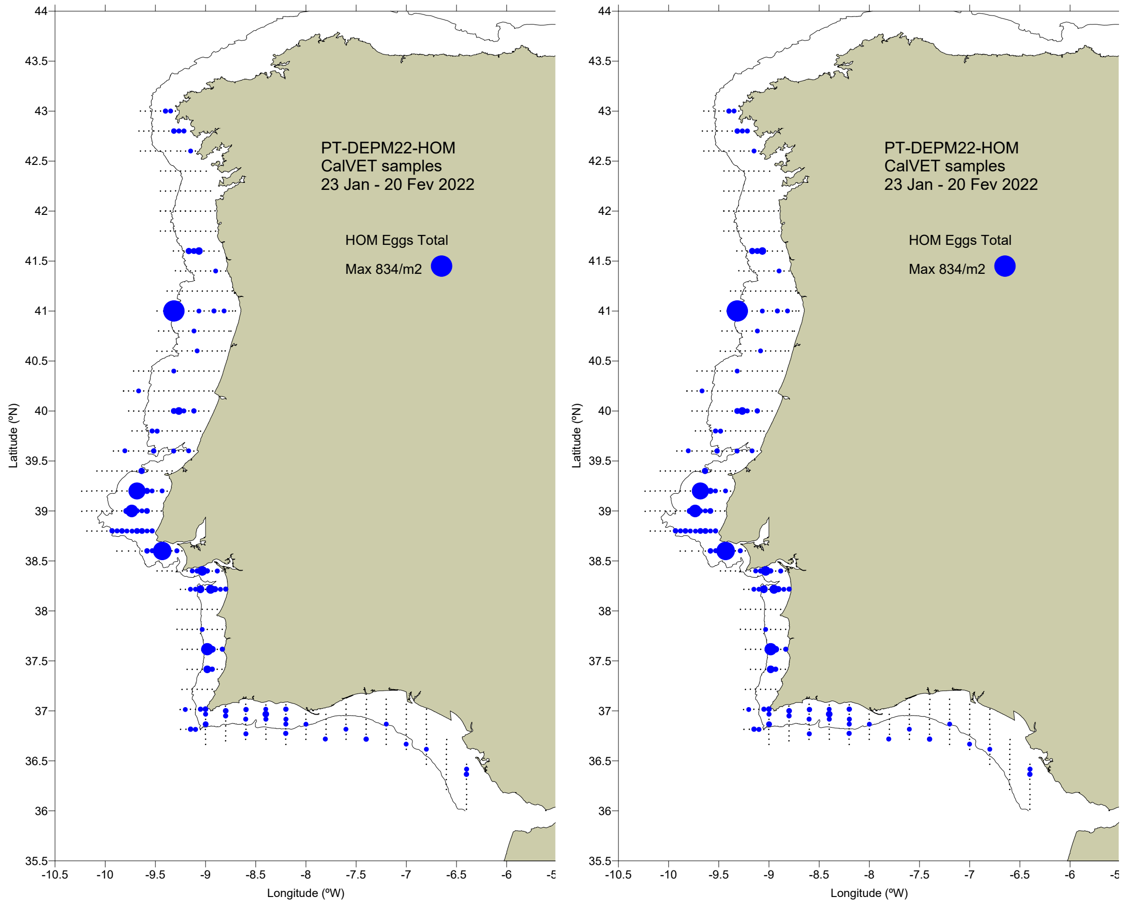

Figure 5.10 Survey coverage, sampling stations occupied,and fish egg abundance distributions. Left panel, horse-mackerel (HOM) (in blue) and right panel, mackerel (MAC) (Scomber spp.) (in purple) total egg abundance distributions. The analyses for HOM and MAC eggs correspond so far to the data obtained with one of the two CalVET nets (formalin preserved).

5.4.4 Adult sampling

For the collection of adult samples for DEPM calculations, fish were sampled from 43 fishing hauls. Thirty three of these hauls were carried out on board the research vessel, with a further 10 being undertaken by vessels from the pelagic fleet. From the research vessel fishing hauls, 20 (61%) contained horse mackerel. Most of the hauls which contained horse mackerel were undertaken off the south coast, while more than half of the tows carried out off the west coast did not capture any horse mackerel (Table 5.2). In Galician waters, horse mackerel were absent from nearly all the hauls. As for mackerel, 8 out of the 33 hauls (24%) captured the species, mainly off the west coast.

Biological data from 2019 horse mackerel and from 182 mackerel were collected. The horse mackerel fish sampled ranged in size from 7 to 39 cm. From these, around 13% were assigned macroscopically as immature females, while less than 1% of the females were in a post-spawning phase, and about 16% in a developing one. The horse mackerel samples also provided 791 ovaries which were preserved for histology analysis. Among these 84 ovaries were scored macroscopically as actively spawning, hydrated, which could potentially be used for batch fecundity estimation upon microscopic analysis. 1069 otoliths were collected for age determination.

The mackerel ranged from 23 to 33 cm in total length. Roughly 80% of the females were reproductively active, and no immature fish were sampled. The ovaries (whole gonad lobes and micropipete subsamples) from 51 mackerel females (22 from the south and 29 from the west coasts) were also preserved and shipped to various WGMEGS laboratories to be processed histologically for the AEPM parameters estimation.

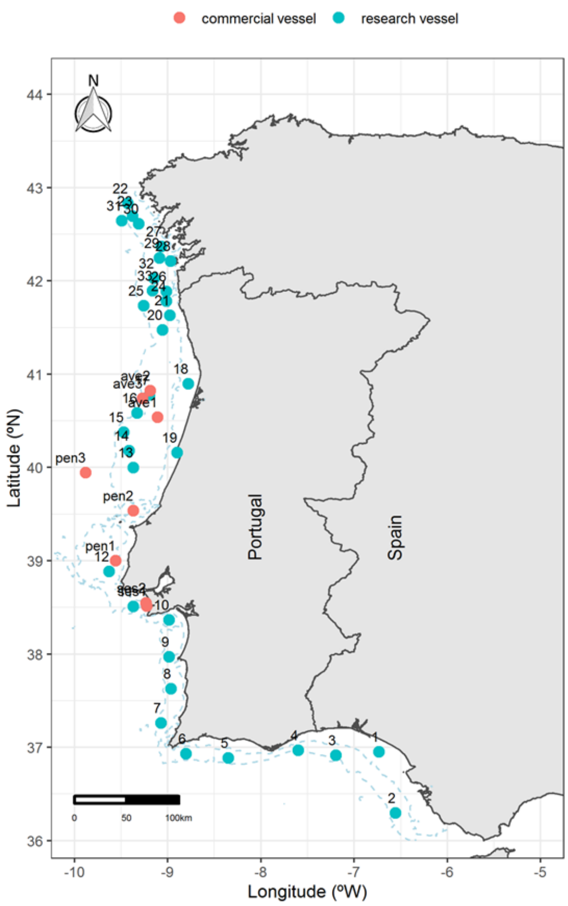

Figure 5.11 Position of the fishing hauls carried out during the survey onboard the research vessel or from the commercial fleet, fromwhich horse mackerel samples were obtained for the estimation of the DEPM parameters, and mackerel samples for the application of the AEPM.

6 North Sea 2021

6.1

The North Sea mackerel egg survey (NSMEGS) is designed to estimate the spawning stock biomass (SSB) of mackerel in the North Sea on a triennial basis. Up to, and including, 2017 this was undertaken using the annual egg production method (AEPM).

Spatial and temporal coverage in the North Sea was reduced with the withdrawal of Norway from the NSMEGS in 2014. The Netherlands was left as the sole survey participant in 2015 and 2017. In 2020 Denmark agreed to participate in the 2020 survey, however due to the Covid-19 pandemic the survey had to be postponed to 2021.

An issue for NSMEGS is that since 1982 it has been impossible to collect and sample pre-spawning mackerel. For SSB estimating the AEPM the realised fecundity value from 1982 is used, (Iversen and Adoff, 1983). Secondly the planned survey coverage for 2020, both spatially and temporally, was far from ideal for the AEPM. Consequently at the 2018 meeting WGMEGS discussed conducting a DEPM survey for NSMEGS, (ICES, 2018c). This would involve one full sweep of the entire survey area, preferably during peak spawning time, collecting standard plankton samples plus an increased number of mackerel ovaries to estimate batch fecundity and spawning fraction.

In 2021 Netherlands and Denmark undertook the survey. Scotland, who were conducting an exploratory survey in the Norwegian Sea at the same time, also assisted by sampling a number of stations in the northern North Sea. The samples were collected every half ICES statistical rectangle and analysed according to WGMEGS protocols (ICES 2019a, 2019b). The Netherlands and Scotland sampled plankton using a GULF VII sampler, while Denmark used a Nackthai. The Netherlands and Denmark used a 500µm mesh net while Scotland used 250µm.

The survey was carried out between May 25th and June 12th (Table 6.1). The plankton stations between 53°N and 62°N were sampled once. In total 294 stations were sampled, (Figure 6.1). In 26 of the half rectangles more than one plankton sample was collected. These rectangles were used to calculate the CV and variance of the daily egg production. On each transect at least one trawl haul was carried out, (Figure 6.2). Following the WGMEGS manual temperature at 5m depth was used to estimate egg development (ICES 2019a). For the DEPM only mackerel eggs in development stage 1a are used to estimate daily egg production.

6.2 Results

6.2.1 Mackerel daily egg production

Denmark and Scotland managed to sample all of their planned plankton stations. Due to technical issues the Netherlands missed four of theirs. The spatial distribution is shown in Figure 6.1. The standard MEGS interpolation rules (ICES 2019a) were followed where necessary (Figure 6.1). The egg distribution is comparible to previous surveys in the same area and period, with the highest number of eggs found in the south western area. Previous surveys did not sample above 59°N so no comparison is available for this area. Interpolated egg production accounted for 7.3% of the daily egg production.

The daily egg production was calculated for the entire survey area using stage 1a egg data (Table 6.2). For comparison the daily egg production was also calculated for the area from 53.5°N to 59°N, and 0.5°W to 5.5°E, the area sampled in 2017. The daily egg production of 2021 was 10% higher than 2017, but the sampled area in 2021 was 9% larger due to some coastal stations not being sampled or interpolated in 2017.

6.2.2 Adult parameters

Denmark sampled 817 mackerel and collected ovary samples from 119 females. Of these 34 were suitable for estimating batch fecundity, and 112 for POF analyses for spawning fraction estimation. The Netherlands sampled 524 mackerel and collected ovary samples from 164 females. Of these 73 were suitable for batch fecundity, and 108 for POF analysis. Adult parameters are presented in Table 6.3.

6.2.3 SSB

Using the stage 1A egg data and the estimated adults parameters, the DEP for the entire sampled area amounts to an SSB of 2380 * 10^3 tonnes. This estimate is an order of magnitude higher compared to the estimates of previous surveys in the North Sea using the AEPM (Table 6.3).

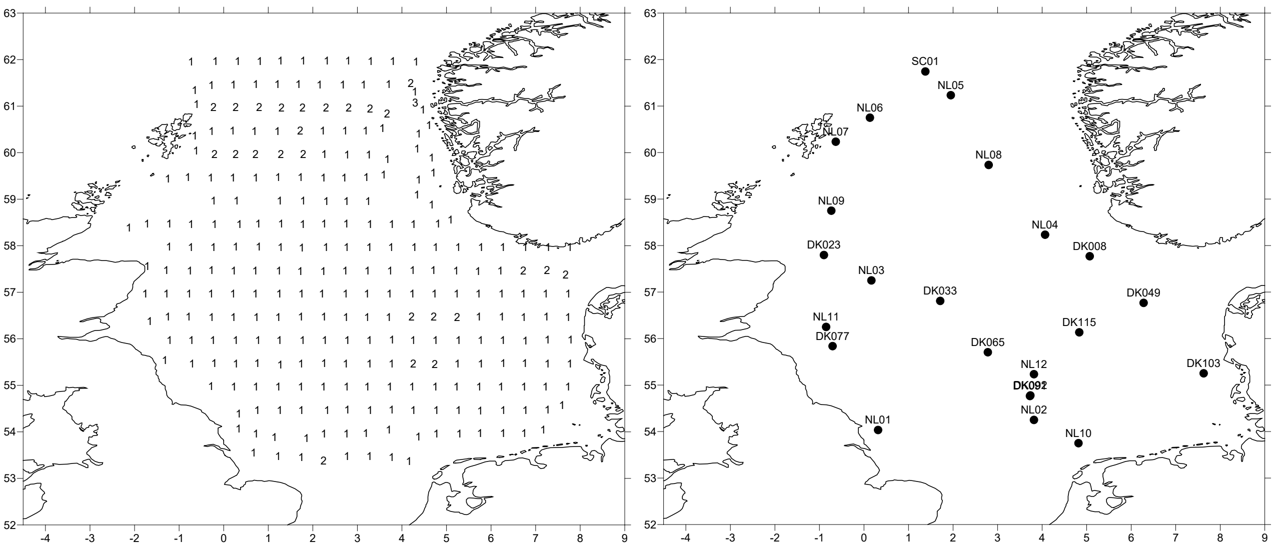

Figure 6.1. Number of samples for NSMEGS 2021; plankton samples per half ICES rectangle (left) and pelagic trawl hauls for mackerel adult samples (right; all hauls included).

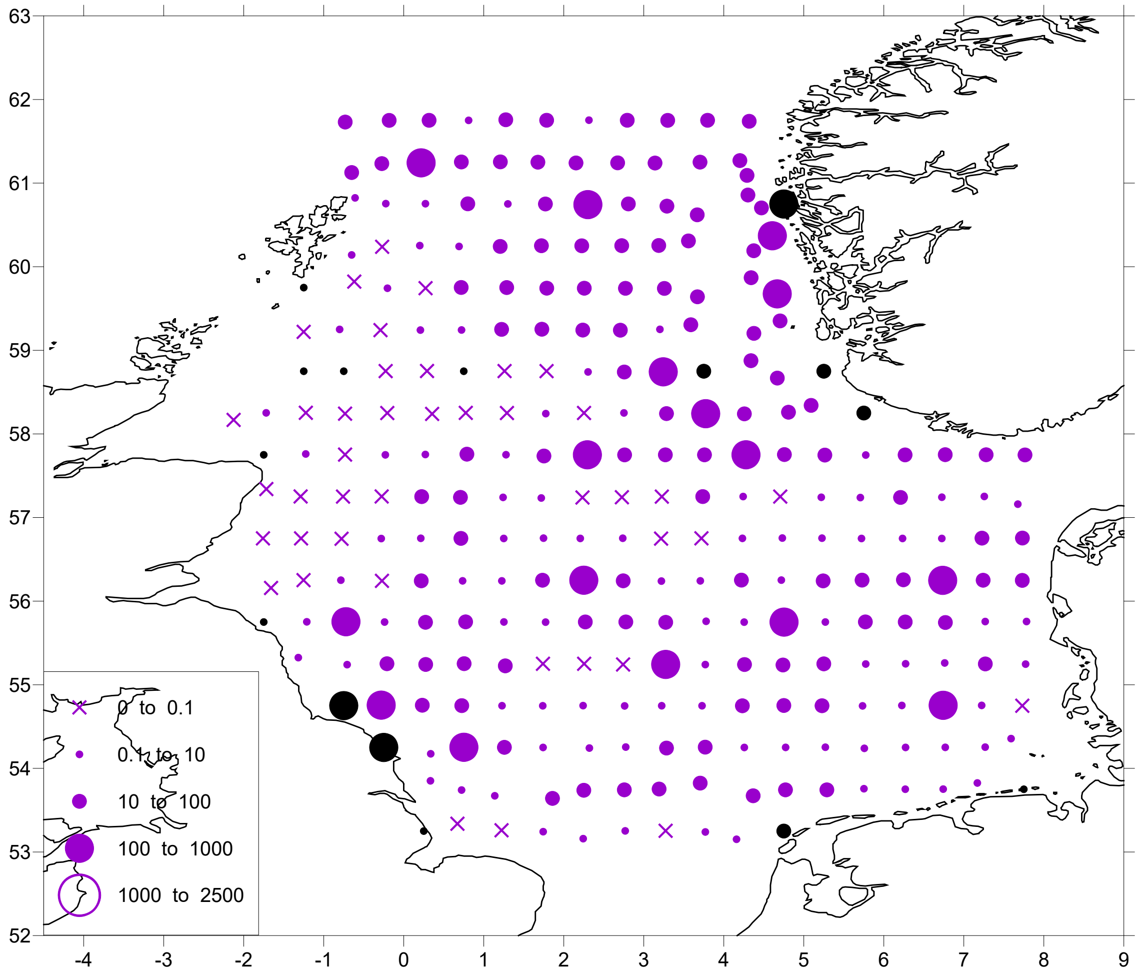

Figure 6.2. Stage 1A mackerel egg production (eggs/m²/day) by half rectangle for NSMEGS 2021. Purple circles represent observed values, black circles represent interpolated values, and crosses represent observed zeros.

Table 6.1. NSMEGS surveys cruise dates in 2021 (For Scotland only stations used in the NSMEGS DEP calculation are shown.)

Country	NL	DK	SCO
Period	1	1	1
Dates	25.05-12.06	31.05-9.06	8.06-11.06
Plankton stations sampled	174	91	29
Pelagic trawl hauls	12	10	1

Table 6.2. Daily egg production estimate (stage 1A) in the North Sea.

Year	DEP $*10^{13}$	CV DEP
2021	1.28	16%

Table 6.3. Adult parameters and SSB.

Year	2021
Batch fecundity	18735
Relative batch fecundity (N/g)	42.7
CV Batch fecundity	0.87
Spawning fraction	0.18
Sex ratio	0.53
Female weight (g)	331.4
SSB (* 10^3 tonnes)	2380

7 North Sea 2022

7.1 Results of the 2022 mackerel egg survey in the North Sea

In 2022 a coordinated survey was undertaken by the UK (England), Denmark and Norway between the 5th and 24th June 2022. The egg survey in the North Sea was set up to estimate the total annual egg production (TAEP) and spawning stock biomass (SSB) for mackerel using a single pass Daily Egg Production Method (DEPM) (Table 7.1) as was undertaken in 2021 (see section 6). The survey was designed to cover the entire spawning area using half ICES rectangle samples (ICES, 2014) as the standard sampling unit (Figure 7.1). There was a concern that as the North Sea is such a large area England and Denmark would not have sufficient survey days available to survey it all. As a result Norway agreed to survey the four northernmost transects, before they began their survey in the western area.

Due to technical reasons, allied to the sampling, the majority of the stations along the transects between 53 and 54°N do not have valid quantitative data, however qualitative data describing the mackerel stage 1A and 1B egg abundance are available to interpret the overall egg distribution in this area. For DEPM estimations only stage 1a egg numbers are used, unlike AEPM where all stage 1 eggs are counted, therefore during this survey it was necessary to carefully differentiate between stage 1a and 1b eggs.

The samples were collected and analysed according to the WGMEGS manuals (ICES 2019a, 2019b). UK and Norway sampled eggs with a Gulf VII plankton sampler, while Denmark used a Nackthai sampler. The UK and Denmark utilised a 500 µm plankton net which is standard protocol for the North Sea due to issues with clogging, while Norway used a 250µm mesh. At each station a double oblique haul was performed from the surface to 5 m above the bottom, with a maximum depth of 200 m, or 20 m below the base of the thermocline, where these were detected. Temperature and salinity were measured during the haul with a CTD mounted on top of the plankton sampler. Either electronic or mechanical flowmeters were mounted on the plankton sampler to monitor flow (internal and external). The flow rates gave the volume of water filtered (sampled) and the degree of clogging during the haul. In total 259 plankton stations were sampled, with 19 stations interpolated.

The spatial egg distribution is shown in Figure 7.2. The standard interpolation rules (ICES 2019a) were applied where necessary. Egg distributions are comparable to 2021, however egg numbers seem to be more evenly distributed throughout the survey area this year. The egg production was calculated for the North Sea between 53°N and 62°N and bounded by the relevant coastlines to the east and west.

On each of the Danish transects at least one pelagic trawl haul was performed for the collection of mackerel adult samples. Denmark conducted 33 hauls, from which they sampled 1180 mackerel and collected ovary samples from 364 females. Due to problems with their fishing gear Cefas (UK) carried out 20 rod and line fishing events of which 9 were positive, biologically sampling 225 mackerel and collecting ovary samples of 74 females. Norway collected 239 female mackerel samples from 5 fishing hauls (Table 7.1). As these samples were collected in June no analysis has been carried out on them.

The total area sampled in 2022 was slightly smaller than the area sampled in 2021, the first full transect was started at 54° 15'N compared to 53° 15'N in 2021. The two southern transects were sampled but there were issues with many of the stations re the accuracy of the flow data. This resulted in three valid stations south of 54°N with a further three being interpolated. The invalid stations do give an indication of the presence and absence (qualitative data) of mackerel stage 1A and above over this area.

The DEP was calculated for the total investigated area (Table 7.2). Total production for 2022 was $0.6699*10^{13}$ eggs. This is a 50% decrease in egg numbers reported in 2021 (Table 7.3).

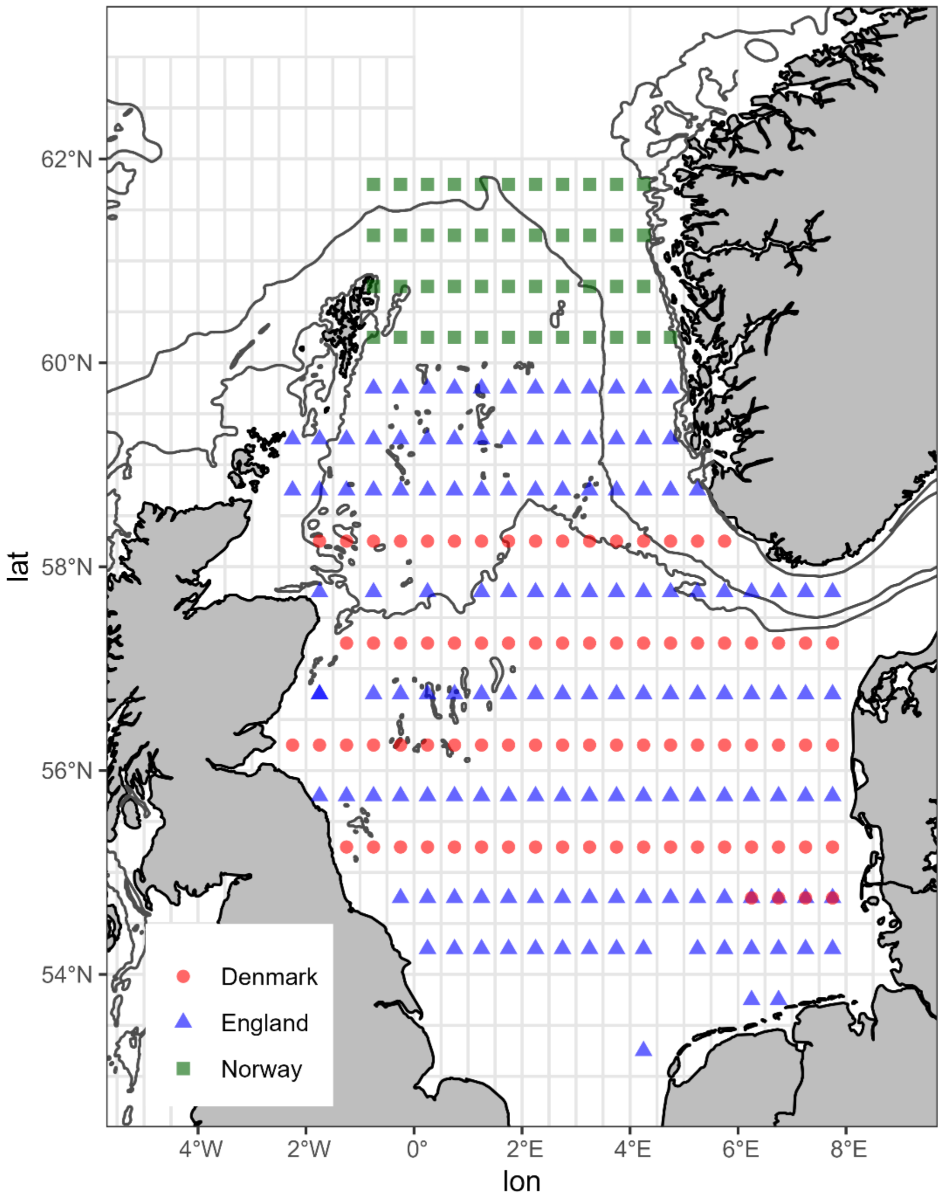

Figure 7.1 Ichthyoplankton stations for the North Sea, 2022.

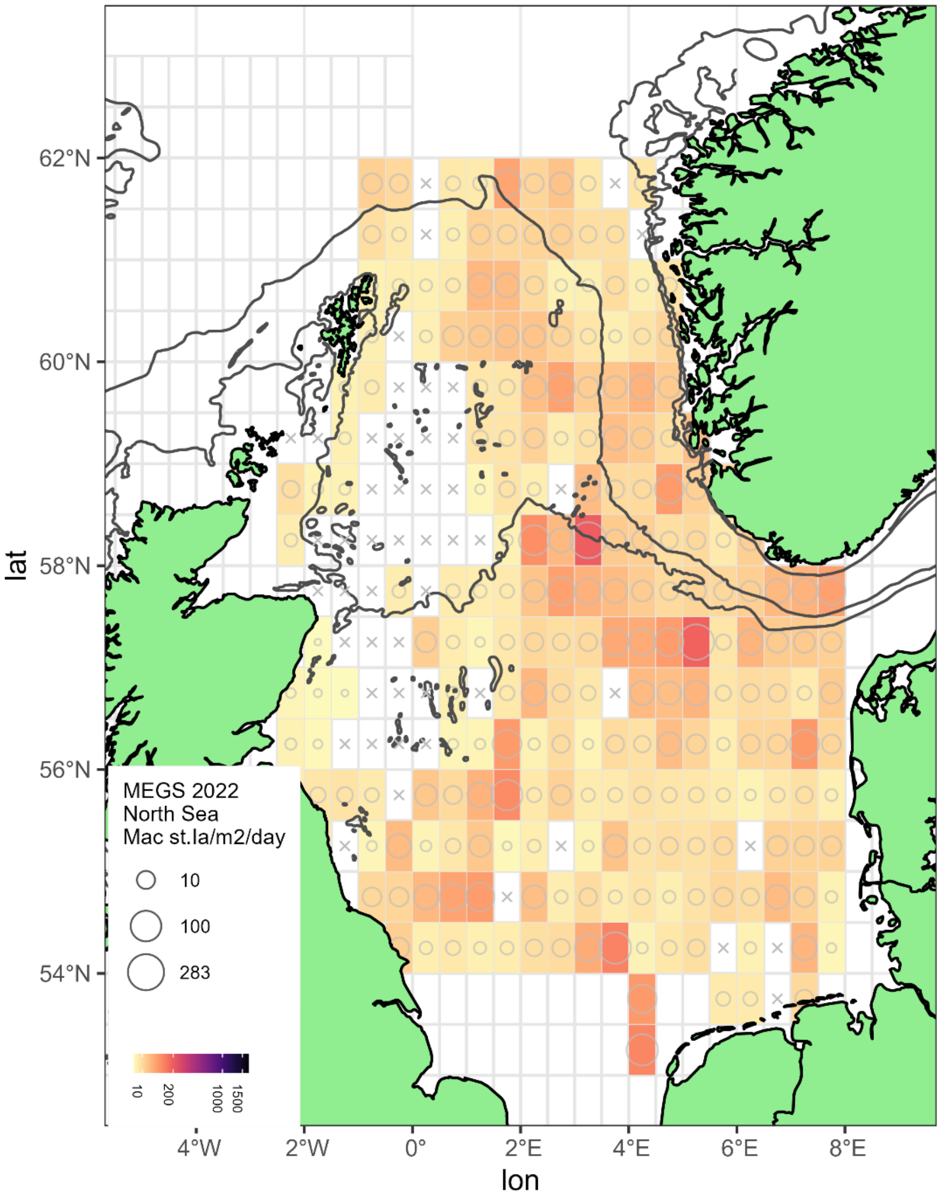

Figure 7.2 Heat map of Stage 1A mackerel egg production (eggs. m-2. Day-1) by half rectangle for the North Sea, 2022. Grey circles represent observed values, crosses represent observed zeros.

Table 7.1 NSMEGS surveys cruise dates in 2022 (For Norway only stations used in the NSMEGS DEP calculation are shown). UK = UK England, DK = Denmark, NO = Norway.

Country	UK	DK	NO
Period	6	6	6
Dates (2022)	5.06-24.06	08.06-19.06	7.06-19.06
Plankton stations sampled	135	85	45
Pelagic trawl hauls		33	5
Positive rod and line events	9		

Table 7.2 Daily egg production estimate (stage 1A) in the North Sea.

Year	DEP $*10^{13}$	CV DEP
2022	0.67	

Table 7.3 Comparison of Daily Egg production (stage 1a) between 2022 and 2021.

Year	2022	2021
DEP $*10^{13}$	0.67	1.28

8 Coastal States

At the Coastal States meeting (19-21st and 27th October 2021) the delegations (the European Union, the Faroe Islands, Greenland, Iceland, Norway, the United Kingdom, the Fishing Party, and the Russian Federation) agreed to establish a Working Group. It's Terms of Reference was to collect and collate information on the geographical distribution of the mackerel stock in the North-East Atlantic, based on internationally recognised data collection methods and on the distribution of catches from this stock.

A first meeting of the scientific working group was held on a Teams platform in November 2021. During that meeting an approach to deal with the terms of reference was agreed. A number of 'in-person' and virtual meetings were held, three virtual meetings specifically involving a subgroup of scientists involved with the mackerel egg surveys, with the last virtual meeting on the 28th February 2022.

The terms of Reference for the Working Group on mackerel distribution which were of relevance to MEGS were as follows:

The Working Group shall:

1. Present available fishery independent data on the geographical distribution on an annual, quarterly and/or monthly/survey basis for all life stages of Northeast Atlantic mackerel (biomass and abundance or their appropriate proxies) by the respective zones of fishery jurisdiction and in international waters since 1977. Assess the utility of available data for the purposes of assessing the distribution of the stock in time and space.

The Working Group should present a report by 28 February 2022.

Spawning distribution:

Objective: To determine the distribution of mackerel during the spawning period using the Mackerel Egg Survey data.

There were a number of challenges identified at the outset of the data compilation:

a. Availability and variability in the time period(s) of the survey and how to deal with the shifts in spawning distributions
b. Could egg abundance be a proxy for abundance of spawners
c. Which data should be presented – abundance and/or production
d. What were the data quality and time span of available survey data
e. Were there caveats to the data and any potential outputs
f. What was the realistic and realised survey coverage (including incorporating the North Sea into the overall spawning distribution given that the surveys were not in the same year)

These challenges were addressed and a series of maps and tables documenting the distributions compiled.

Annual egg distributions

Data are presented as distribution maps and tabulated as percentage of the total egg production which occurs in each of the Coastal States during each of the survey years. The acronyms for the 'Zones' (only those used in this report are current European Union (EU27), Faroes (FO), Faroes-Iceland disputed area (FO_IC), International waters/NEAFC Regulatory Area (INT), Iceland (IC), Norway (NO), United Kingdom (UK) and joint United Kingdom-Faroes (UK_FO). For the western and southern spawning area this constitutes: EU27, FO, FO_IC, INT, IC, NO, UK and UK_FO. For the North Sea three EEZs are recognised, namely: EU27, NO and UK.

Western and southern areas

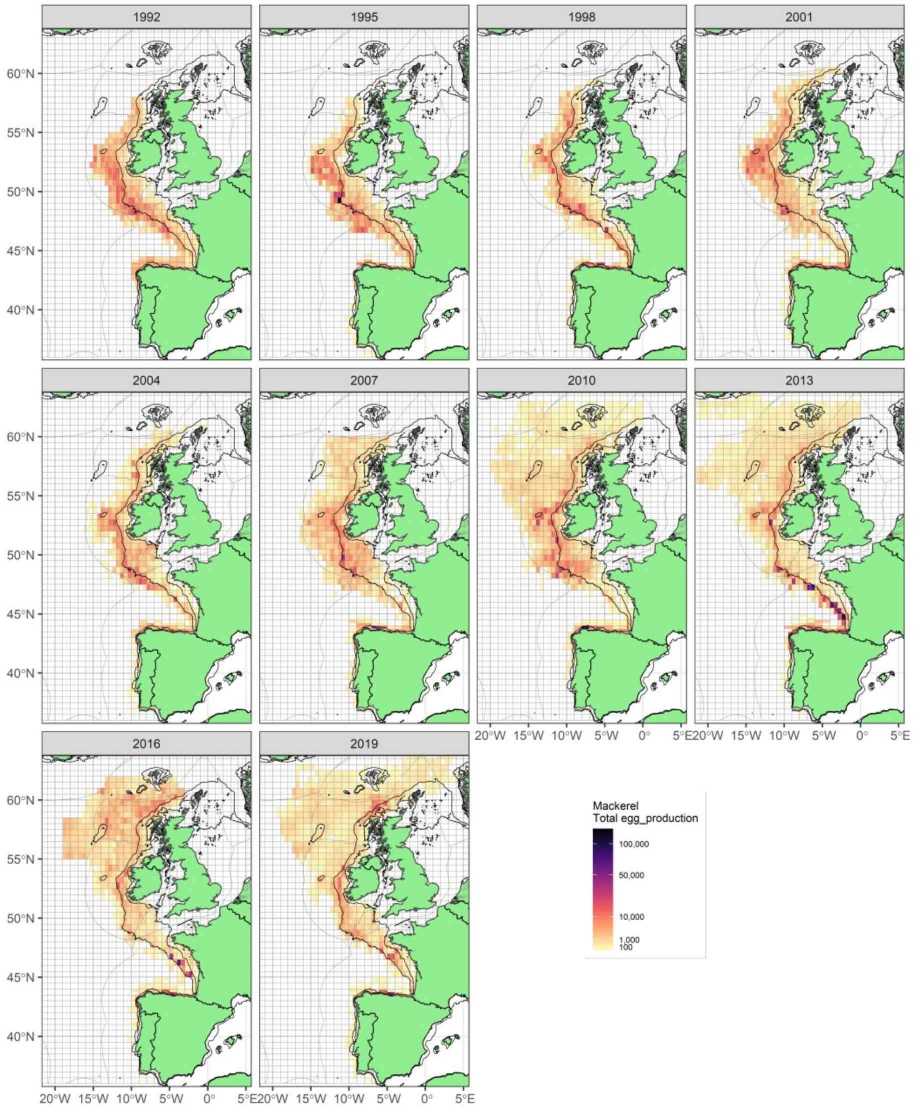

Figure 8.1. Annual distribution of total mackerel egg production between 1992 and 2019 from the Triennial Mackerel Egg Survey.

North Sea

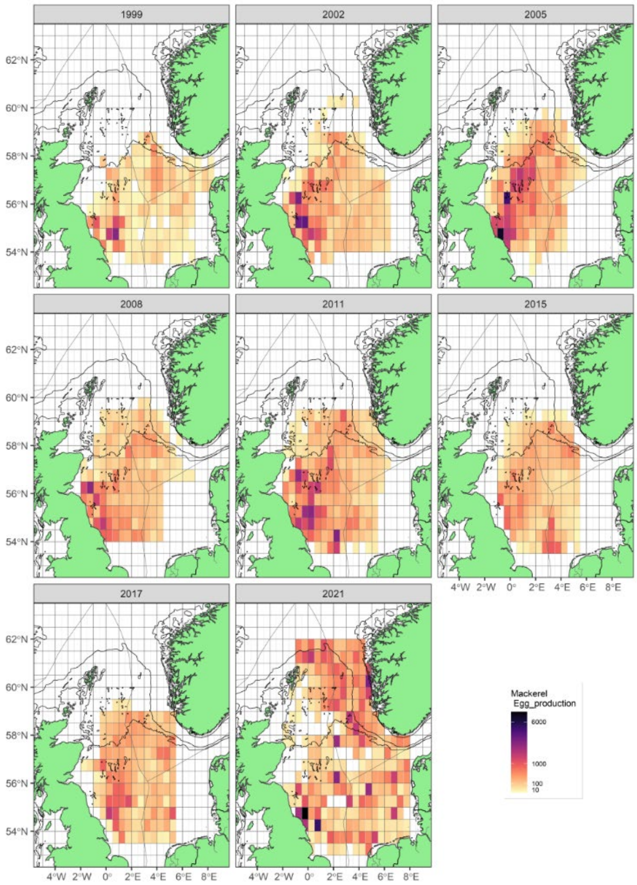

Figure 8.2. The total annual mackerel egg production in the North Sea between 1999 and 2021. Note that the 2021 data emanate from a single coverage Daily Egg Production Methodology rather than the previously used multiple coverage Annual Egg Production Methodology.

Report

A full report (Anon. Report of the Coastal States Working Group on the distribution of Northeast Atlantic Mackerel. 28th February 2022. With Errata: 31st March 2022. 105pp) which details all the available and potentially available data (fishery independent and dependent) can be obtained from the requestor's Head of Delegation for Coastal States Meetings on Mackerel.

9 Results of the 2021 Exploratory Mackerel Egg Survey in the Norwegian Sea

WGMEGS, the ICES Working Group tasked with coordinating the triennial Mackerel and Horse mackerel egg surveys (MEGS) has since 2007 been observing and reporting on the offshore westwards and northwards expansion of NEA mackerel spawning. Spawning densities within these expanded areas were initially low, however the results from the most recent MEGS surveys in 2016 and 2019 provided clear evidence of a significant and unprecedented shift north and also westwards with some of the highest spawning densities observed being very close to the northern and north-western survey boundaries. During the last NEA mackerel benchmark in 2017 (ICES, 2017) WGMEGS committed to undertake exploratory icthyoplankton surveys within these remote boundary regions in the North and Northwest.

In 2017 and 2018 exploratory surveys undertaken by Ireland and Scotland successfully mapped and delineated a mackerel spawning boundary within the North and northwest areas of Hatton Bank/South Iceland Basin and the Scotland-Faroe-Iceland Ridge (ICES,2018b), with the results from these surveys playing a useful role in informing the survey planning process ahead of the 2019 MEGS triennial survey. This, however, left the Norwegian Sea as an area that still provided a level of uncertainty, with the 2019 MEGS survey results providing evidence that mackerel appear to be taking the North-eastern route towards their summer feeding grounds (Figure 9.1) . A third and final exploratory survey was completed between the 7th – 22nd June 2021 onboard the charter vessel MFV Altaire. This would conclude the current exploratory objective by surveying mackerel spawning activity up and along the Norwegian Sea and during the month when the highest mackerel spawning densities were likely to be encountered within this region. Additionally, 3 survey transects were also undertaken within the Northern North Sea area that would augment and enhance survey coverage within the North Sea area south of 62 degrees North, during the 2021 North Sea survey. The results from this charter survey were presented to WGWIDE in August 2021 (ICES, 2021).

78 plankton deployments were completed with the Gulf VII sampler during the survey, which due to the relatively calm conditions experienced throughout was able to survey as far North as Lofoten at 68.25N. These stations yielded 5123 mackerel eggs of all stages, of which 1671 were recently spawned stage 1 eggs. Mackerel eggs were recorded from every deployment, with newly spawned stage 1 eggs being recorded on all but 2 of the stations completed. The numbers of mackerel eggs extracted from the Gulf VII samples were standardised, and the stage 1 data presented as numbers /m^2/day (figure 9.2). Egg counts encountered during the surveyed area were low to moderate with the highest egg counts generally being encountered within the southern half (south of 66°N) of the survey area, and reducing gradually as the survey proceeded Northwards until counts were down to single figures on transects West of Lofoten. In this area the surface temperatures cooled to levels approaching the lower temperature threshold for spawning mackerel at between 8 – 9 degrees Celcius. Two successful deployments were also made with the vessels own midwater trawl providing 123 adult mackerel which were sampled for biological parameters, and in addition 60 ovaries were collected to progress ongoing research for IMR, Bergen.

Additional plankton samples were collected by the Faroe Islands during their IESNS survey in 2021, within the region extending from the east side of Iceland across to the north of Shetland. This survey took place between April 29th and 8th May. These samples were collected using a vertically deployed WP2 net that is deployed to a depth of 50m. Twenty two WP2 samples were collected and their contents analysed to check for presence of mackerel eggs. WGMEGS can report that there were no mackerel eggs present in any of the samples collected during the aforementioned survey in 2021.

The Scottish exploratory survey in Norwegian waters was unable to find a hard spawning boundary at its Northern extent, albeit the numbers being encountered were very low at those high latitudes. This survey contrasted markedly with the previous exploratory surveys undertaken during 2017 and 2018 where the results reaffirmed the existence of the cold water barrier stretching from the East coast of Iceland across to the Faroe/Shetland Channel, north of which virtually no mackerel spawning takes place in June. The situation along the Norwegian Sea is very different with the influence of the Norwegian Current keeping sea surface temperatures within a range that is tolerable for spawning mackerel. Nevertheless, the spawning levels observed in the sampled stations North of 62 degrees are generally very low, with an estimated contribution to the overall total annual egg production (TAEP) of around 2-3%. When looking ahead to the triennial survey in 2022, there was no immediate requirement for WGMEGS to significantly extend the survey coverage within this region much beyond what was undertaken in 2019. All the information gathered from these exploratory egg surveys as well as the additional samples received from the various Nordic surveys since 2017 are invaluable, and provide an opportunity not available during the triennial survey year to map the distribution of spawning mackerel within these remote northern boundary regions.

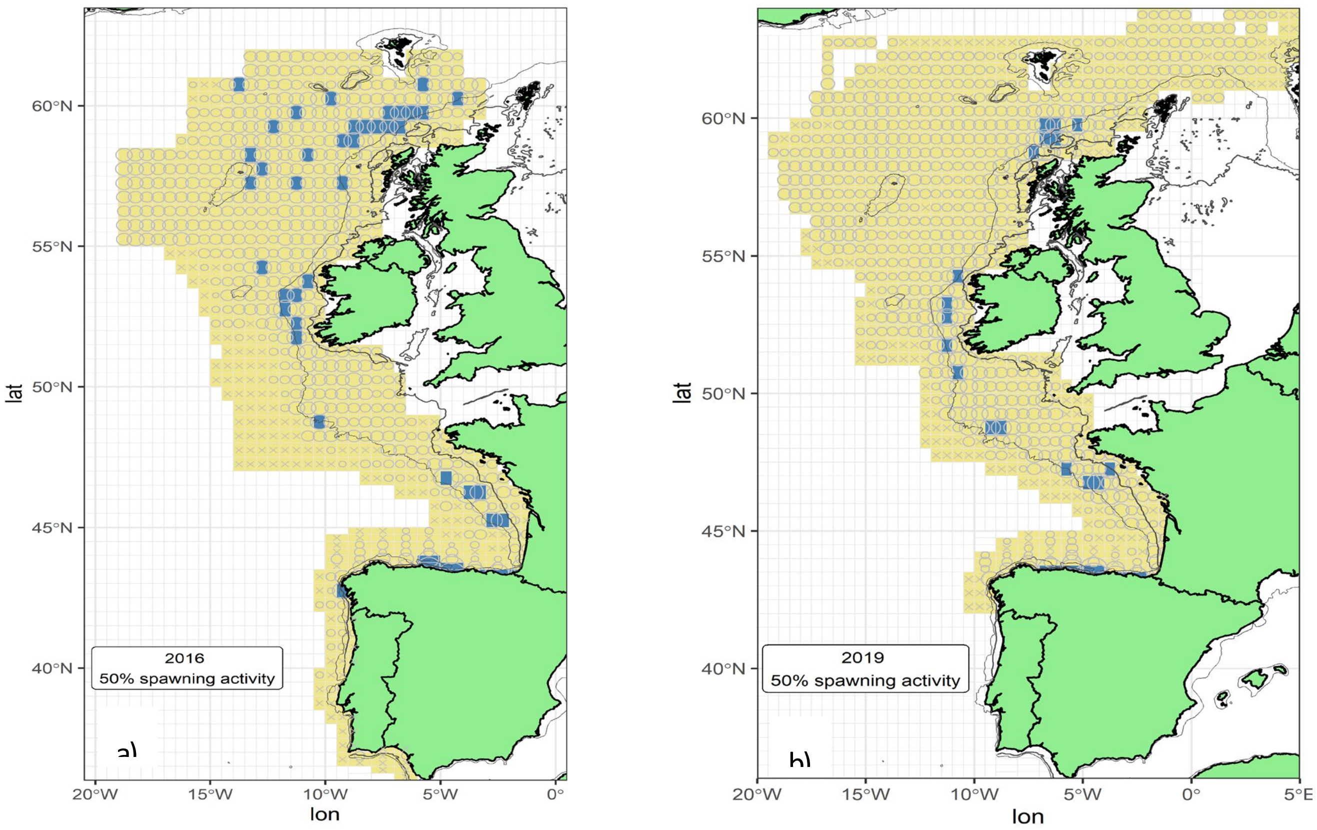

Figure 9.1. Aggregated daily egg production values (stage 1 eggs/m2 /day) by half ICES rectangle for all MEGS stations sampled in a) 2016 and b) 2019 and for all periods. Egg production values are square root transformed. Crosses denote locations where sampling was undertaken but where no spawning was recorded. Area in yellow denotes the maximum

geographical survey extent for the western and southern survey area. Stations were ranked in descending order and area/stations capturing 50% of total spawning activity within that year are overlaid in blue.

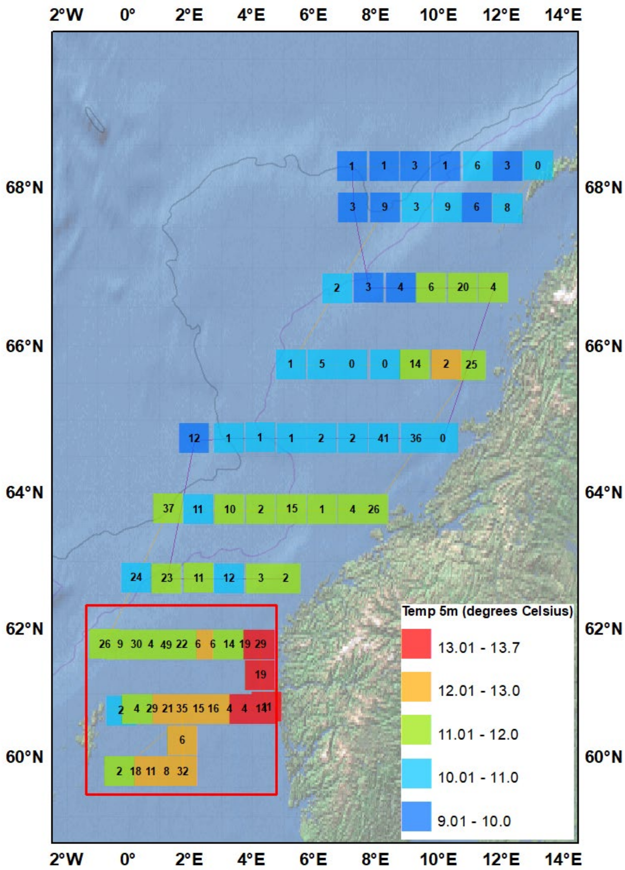

Figure 9.2. Mackerel stage 1 egg counts/m²/day from survey 0321H, for all stations sampled. The coloured squares represent the temperature in degrees Celsius at 5m depth during the icthyoplankton deployments.

10 Clogging

Several surveys during the 2022 MEGS programme reported significantly higher numbers of stations being affected by clogging, than from the same areas and periods in 2019. These were typically from the later survey periods (periods 5, 6 and 7) and from across several areas. Clogging is typically observed both on and off the continental shelf. Deeper stations off the Continental slope are susceptible to clogging from larger gelatinous zooplankton. Clogging reported from shallower continental shelf stations tends to occur due to other sources such as phytoplankton. The 2022 Netherlands surveys in period 5 and 6 reported that almost 50% of all the plankton deployments recorded reduced flowmeter counts. The Scottish surveys in period 5 and 6 recorded a 100% increase (on results from 2019) in the number of stations displaying flowmeter counts that were lower than expected, and which equated to almost 30% of the total stations from these surveys.

Clogging causes the meshes of the sampler to become coated thereby reducing the flow of water through the sampler. This then has an obvious impact on the volume of water that can be filtered by the sampler, and of course by implication also its ability to satisfactorily sample eggs in the water column. WGMEGS intends to conduct intersessional work prior to the next survey in 2025 that will attempt, through an additional experimental survey(s), to collect information on the vertical distribution/adundance of plankton in the water column and within some of the areas affected. The intention would be to devise an experiment deploying a multi-net-plankton sampler that will enable samples to be collected from a range of different depths. The main aims would be to determine vertical distribution patterns, if any, of plankton in the water column and also to try and investigate whether a relationship exists between mackerel egg abundance and density of plankton in the water column. All participants are encouraged to try and progress this work and to report their findings to WGMEGS before the next triennial survey in 2025.

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Annex 2: Resolutions

Request to WGALES - the description of clogging in the ICES vocabulary is vague and open to interpretation. Can WGALES provide a more defined description of amounts of clogging and if necessary update the scoring? It should also probably be a requirement to note the reason for the clogging, eg Phytoplankton, jellies, etc.

Request to ICES - to organise a workshop, WKMADE, Workshop on Mackerel Daily Egg production, in Q3-Q4, 2023, to identify the methodology and data inputs necessary to calculate a DEPM estimate for western / southern NEA mackerel components. These calculations should then be compared to recent AEPM estimates for the stock.

Annex 3: Agenda

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

22-23 August 2022, Copenhagen – post survey meeting

Relevant ToR’s (years 2 & 3)

Analyse and evaluate the results of the 2022 mackerel and horse mackerel egg surveys in the western and southern areas, and the North Sea;

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. calculate SSB for the North sea for 2021.
6. calculate seasonal egg production for the North sea for 2022

Provisional estimates of mackerel SSB, and egg production of horse mackerel are delivered in the year of the survey. The estimates however are finalized during the WGMEGS meeting in the year after the Atlantic survey.

Monday 22 August

9:00	Start; General announcements; Introduction; etc
09:30	Presentation of survey reports by country
11:00	Coffee Break
11:30	Continuation of survey report presentations
12:30	Lunch break
13:15	Continuation of morning presentations (if necessary)
	Discussion of morning presentations
14:00	Presentation of survey results (egg production) by the survey coordinator
14:30	Presentation of the survey results (fecundity)
15:00	Discussion of the results with respect to coverage, timing, gaps, and their consequences for the estimation of the TAEP/SSB

15:30	Coffee break
16:00	Start preparing and writing the interim WGMEGS report for presentation to WGWIDE
17:30	End of the day

Tuesday 23rd August

09:00	Presentation on clogging (Cindy)
09:15	Presentation on oocyte measurement (Anders)
09:30	Discussion of those results and their implications for future work of WGMEGS
10:30	Presentation coastal states work (Richard)
11:00	Coffee break
11:30	Plans for the final year of this term, delegation of tasks.
12:30	Lunch
13:15	Report writing, recommendations, action plan
17:30	End of meeting

Annex 4: Working Documents presented to WGMEGS

North Sea mackerel daily egg production and spawning stock biomass estimation in 2021

By C.J.G. van Damme, E. Blom, B. Huwer, F. Burns & G. Costas

North Sea mackerel daily egg production estimation in 2022.

By B. O' Hea, G. Costas, B. Huwer, R. Nash , L. Mann, A Thorsen

2022 Mackerel and Horse Mackerel Egg Survey. Adults Parameters. Preliminary Results AEPM

By A Thorsen, M Korta,….

2022 Mackerel and Horse Mackerel Egg Survey. Preliminary Results

By: Brendan O' Hea, Finlay Burns, Gersom Costas, Paula Alvarez, Maria Korta, Anders Thorsen