2022 Mackerel and Horse Mackerel Egg Survey

Preliminary Results

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Not to be cited without prior reference to the authors

1 Introduction

The mackerel and horse mackerel egg survey is an ICES-coordinated international study in the north east Atlantic conducted during the first half of 2022. This study is a combined plankton and fishery investigation formed by a series of individual surveys which have taken place triennially since the late 1970s and is coordinated by the ICES Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS). Historically a North sea mackerel egg survey is carried out in the year after the western and southern surveys. in 2022, due to the presence of new participants, the all surveys were carried out in the same year

The main objective of this series of individual cruises from January until July is to produce both an index and a direct estimate of the biomass of the north east Atlantic mackerel stock and an index for the southern and western horse mackerel stocks. The results have been used in the assessment for mackerel since 1977 and from 1992 for horse mackerel. The mackerel and horse mackerel egg survey is still a principal source of data providing fisheries independent information for these stocks.

The general method is to quantify the freshly spawned eggs in the water column on the spawning grounds. To be able to establish a relationship between eggs and biomass of the spawning stock, the fecundity of the females must also be determined. This is undertaken by sampling ovaries before and during spawning. In cases where the annual egg production method is applied the potential fecundity is counted from whole mount volumetric subsamples using a dissecting microscope while atresia is counted histologically from slides. Realised fecundity is estimated as potential fecundity minus atresia. The realised fecundity is used in combination with the calculated number of freshly spawned eggs in the water to estimate the spawning stock biomass.

To provide reliable estimates of spawned eggs and fecundity an extensive coverage of the spawning area is required both in time and space. The spawning of the southern horse mackerel stock and mackerel starts in late December off the Portuguese coast. Spawning proceeds further north along the continental shelf edge as water temperature increases during late winter and spring. In the past peak spawning of mackerel has normally occurred in April-May in the area of the Sole Banks with an extension to the Porcupine Bank. Whilst the distribution and timing of peak western horse mackerel spawning has remained fairly stable during recent surveys the same cannot be said for NEA mackerel. The 2010 and 2013 MEGS surveys saw peak mackerel spawning in February – March with 2013 also demonstrating a shift in the geographical centre of spawning further south within the southern Biscay region. Since then however mackerel spawning is now observed over a large region of the Northeast Atlantic both on and off the continental shelf, ranging as far west as Hatton Bank, as far north as Iceland and the Faroe Islands and in recent years around the Shetland Islands and the Norwegian coast in the Northeast.

This survey report presents the preliminary results of the 2022 mackerel and horse mackerel egg survey provided for WGWIDE in August 2022. The survey report and the analysis will be finalised during the next WGMEGS meeting in April 2023. Although every effort was made to ensure that WGWIDE were provided with the most recent and accurate data-set, WGMEGS cannot guarantee that there will not be changes prior to the analysis being finalised. This is due to the extremely large numbers of plankton and fecundity samples to be analysed following the surveys as well as the tight deadline set by WGWIDE for delivering these estimates. This has resulted in a very limited time within which to process the 2022 MEGS data.

Survey effort

As a consequence of the long spawning period and the large survey area involved, the mackerel and horse mackerel egg surveys have always relied on broad international participation. In 2022 a total of 18 individual cruises were carried out, 16 in the Atlantic and 2 in the North sea, for a total of 321 at-sea survey days. Individual contributions were; Spain (IEO: 42 days at sea, AZTI: 30 days), Scotland (53 days), the Netherlands (39 days), Ireland (28 days), Portugal (34 days), Germany (23 days), Norway (15 days), Faroe Islands (14 days), England (23 days) and Denmark (14 days). Denmark joined the group in 2020 and participated in the 2021 North Sea survey along with the Netherlands. England rejoined the group in 2021 and in 2022 conducted the North Sea survey in participation with Denmark.

Survey design

The aim of the triennial egg survey is to determine the annual egg production (AEP). This is calculated using the mean daily egg production rates per pre-defined sampling period for the complete spawning area of the Northeast Atlantic Mackerel and Horse Mackerel Stocks. To achieve this, one plankton haul per each half rectangle (separated by approximately 15-20 NM, depending on latitude) is conducted on alternating transects covering the complete spawning area. The 2022 egg survey was designed in order to maximise both the spatial and temporal coverage in each of the sampling periods. Given the very large area to be surveyed this design minimises the chances of under/overestimation of the egg production (ICES 2008).

The 2022 survey plan was split into 6 sampling periods (Table 1). Portugal were assigned to start the survey in the southern area during Period 2. No sampling was scheduled to take place in ICES division 9a after Period 2. Sampling of the western area commenced in Period 3, and included coverage of the west of Scotland, west of Ireland, Biscay and the Cantabrian Sea. Surveying in the Cantabrian Sea ended at the end of Period 5. In Periods 6 and 7 the surveys were designed to identify a southern boundary of spawning and to survey all areas north of this boundary.

Maximum deployment of effort in the western area was during Periods three, four, five and six. 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 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 and then use any remaining time to fill in the missed transects.

Table 1. Participating countries, vessels, areas covered, dates and sampling periods of the 2022 surveys.

Country	Vessel	Area	Dates	Period
Portugal	Vizconde de Eza	Portugal	Jan 23rd – Feb 26th	2
Ireland	Celtic Explorer	West of Ireland, Celtic sea, Biscay,	March 2nd – 22nd	2
	Corystes	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 12th – June 1st	5
	Altaire	West of Scotland, west of Ireland, Celtic sea, Biscay	July 4th – 27th	7
Spain (IEO)	Miguel Oliver	Cantabrian sea, Galicia, southern Biscay	March 14th – April 3rd	3
	Vizconde de Eza	Cantabrian sea, Galicia, Biscay	April 4th – April 30th	4
Spain (AZTI)	Ramon Margalef	Northern Biscay	March 10th – 30th	3
	Vizconde de Eza Ramon Margalef	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	Magnus Heinason	Faroes, Iceland	May 19th – June 1st	5
Denmark	Dana	North Sea	June 7th – 18th	
England	Cefas Endeavour	North Sea	June 4th - 25th	

Processing of samples

The analysis of the plankton and fecundity samples were carried out according to the sampling protocols as described in the WGMEGS Manuals for Survey (ICES, 2019a) and Fecundity (ICES, 2019b).

A total of 1780 plankton samples were collected and sorted. Mackerel and horse mackerel 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 national institutes.

Double micropipette samples and slices from ovaries of mackerel were taken during each survey. Additional samples were collected during periods 3 and 4 by participants in an effort to carry out DEPM analysis, along with AEPM analysis. Fecundity sampling for horse mackerel only took place during the expected peak spawning Periods, 6 and 7.

In order to increase the number of samples available for fecundity analysis additional mackerel gonads were collected from some Dutch pelagic vessels, and also on the Dutch and Irish Blue whiting surveys in Periods 2, 3 and 4.

After each survey the ovary screening and fecundity samples were shared between the participating research institutes for histological and whole mount analysis to determine the realised fecundity (potential fecundity minus atresia). Screening samples, and fecundity samples, have to be analysed in the laboratory upon return from sea. These procedures are not straightforward and require time. The last histology samples were collected in July and because of the narrow time frame only a selection of the fecundity samples have been analysed up to this date. Samples were therefore only analysed from sampling Periods 2 and 3 for the preliminary estimate.

Horse mackerel is considered to be an indeterminate spawner and therefore since 2007 IPMA has adopted the DEPM methodology for the southern horse mackerel stock (div. 9a). The egg survey design in the western area is directed at the AEP method for mackerel which produces an estimate of SSB. Fecundity samples for horse mackerel were taken during the survey in the western areas in order to develop a modified DEPM approach for estimating the biomass of the horse mackerel stocks. Additional samples were collected during the Irish WESPAS survey in the Celtic Sea and west of Ireland in Periods 6 and 7.

Even though the partial processing of the screening samples has identified ovaries to be analysed for DEPM, none of these samples have been analysed yet.

Survey coverage and mackerel egg production by period

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, but it provides mackerel egg samples as well. 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 starting, however it subsequently linked with the Irish vessel. Both IEO and AZTI suffered difficulties with their vessels, and lost a number of sampling days, however full coverage was achieved (Fig. 1.1).

Egg numbers were quite low to the west of Ireland, however further south large numbers of eggs were found close to the 200m contour line. In Biscay and the Cantabrian Sea IEO and AZTI recorded a number of stations with large egg numbers. 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 (Fig. 1.2).

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 to ensure continuity of sampling 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 egg numbers were recorded to the west of Scotland, however numbers were lower than those reported for 2019 within this area and time period. 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 (Fig. 1.3). 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 westwards 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 numbers in 2022 within this area were lower than reported in 2019 so while the western boundary wasn't delineated, MEGS is happy that major egg production isn't being missed. 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 Shetlands. In total 444 stations were sampled and there were 214 interpolations. No replicate samples were taken.

Period 6 – During period 6 northern Biscay, 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 provide full coverage for the DEPM survey.

Ireland was due to charter a research vessel from Northern Ireland to conduct the survey. One week before the survey was due to depart this vessel had to go to dry dock for emergency repairs. After much searching a smaller Welsh RV was contracted. Once at sea however it quickly became clear that the replacement vessel was not going to be suitable for the survey. Only two successful stations were carried out before a decision was eventually made to abandon the survey. 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 (Fig. 1.4). Similarly in the northern area spawning was persistent at low levels, apart again from the area west of the Shetland. Due to an unavoidable reduction in the number of survey days available Norway was unable to secure either the western or northern boundary in the northern area, however 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 in the south to north of the Hebrides and 59°N (Fig. 1.5). 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 station was 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.

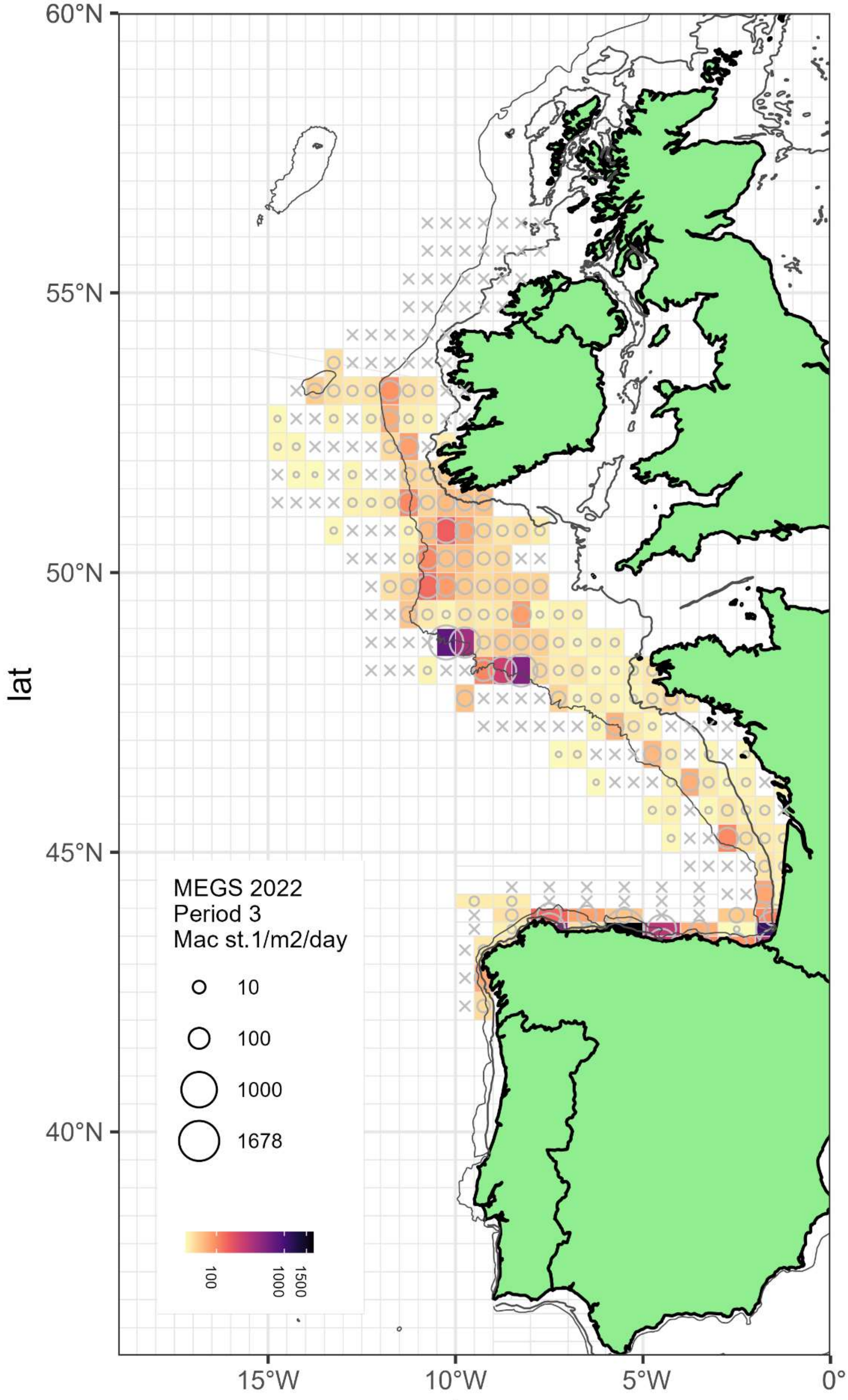

Figure 1.1: Mackerel egg production by half rectangle for period 3 (Mar 4th – Apr 8th). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

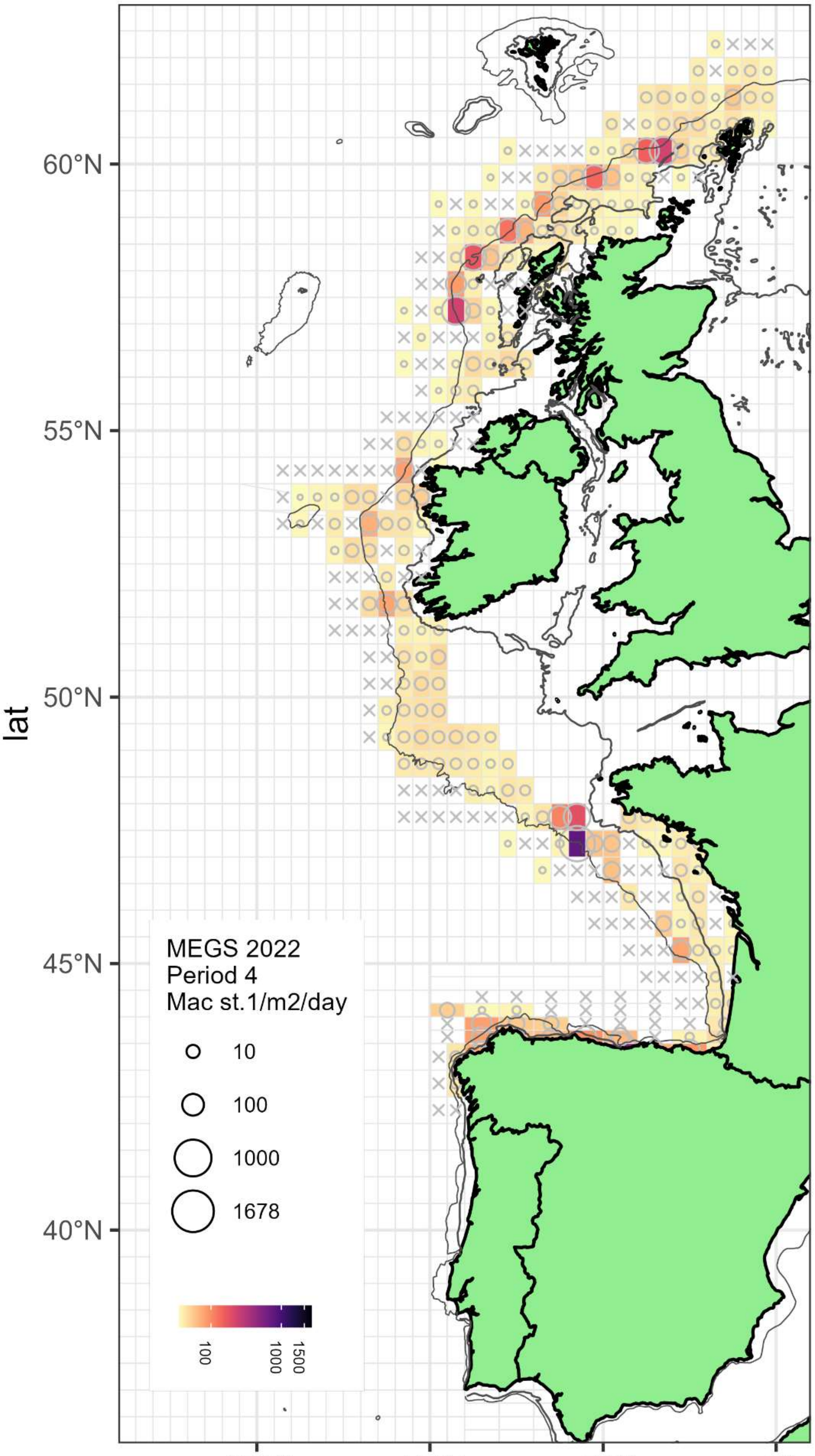

Figure 1.2: Mackerel egg production by half rectangle for period 4 (Apr 9th – 29th). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

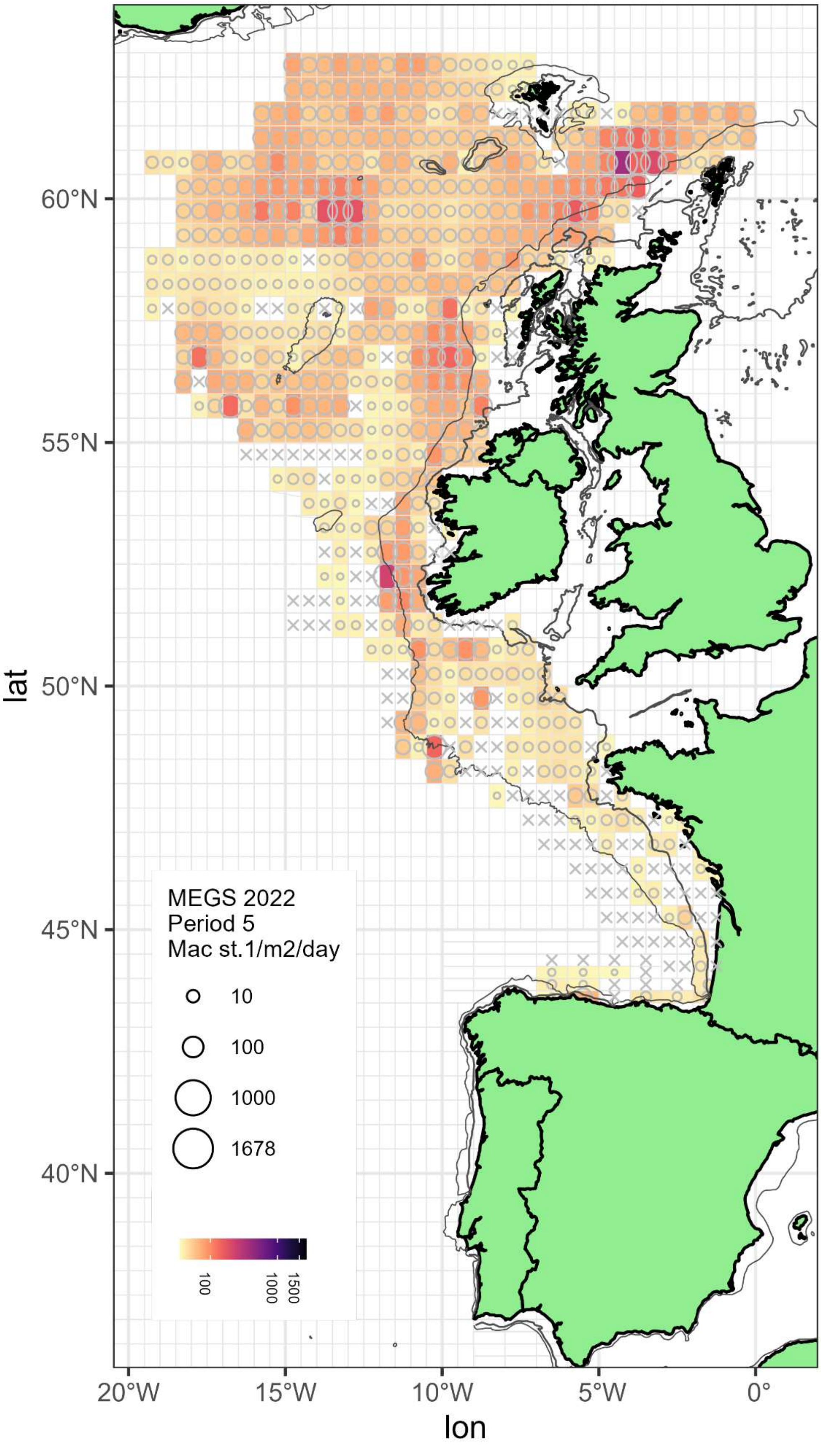

Figure 1.3: Mackerel egg production by half rectangle for period 5 (Apr 30th – May 31st). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

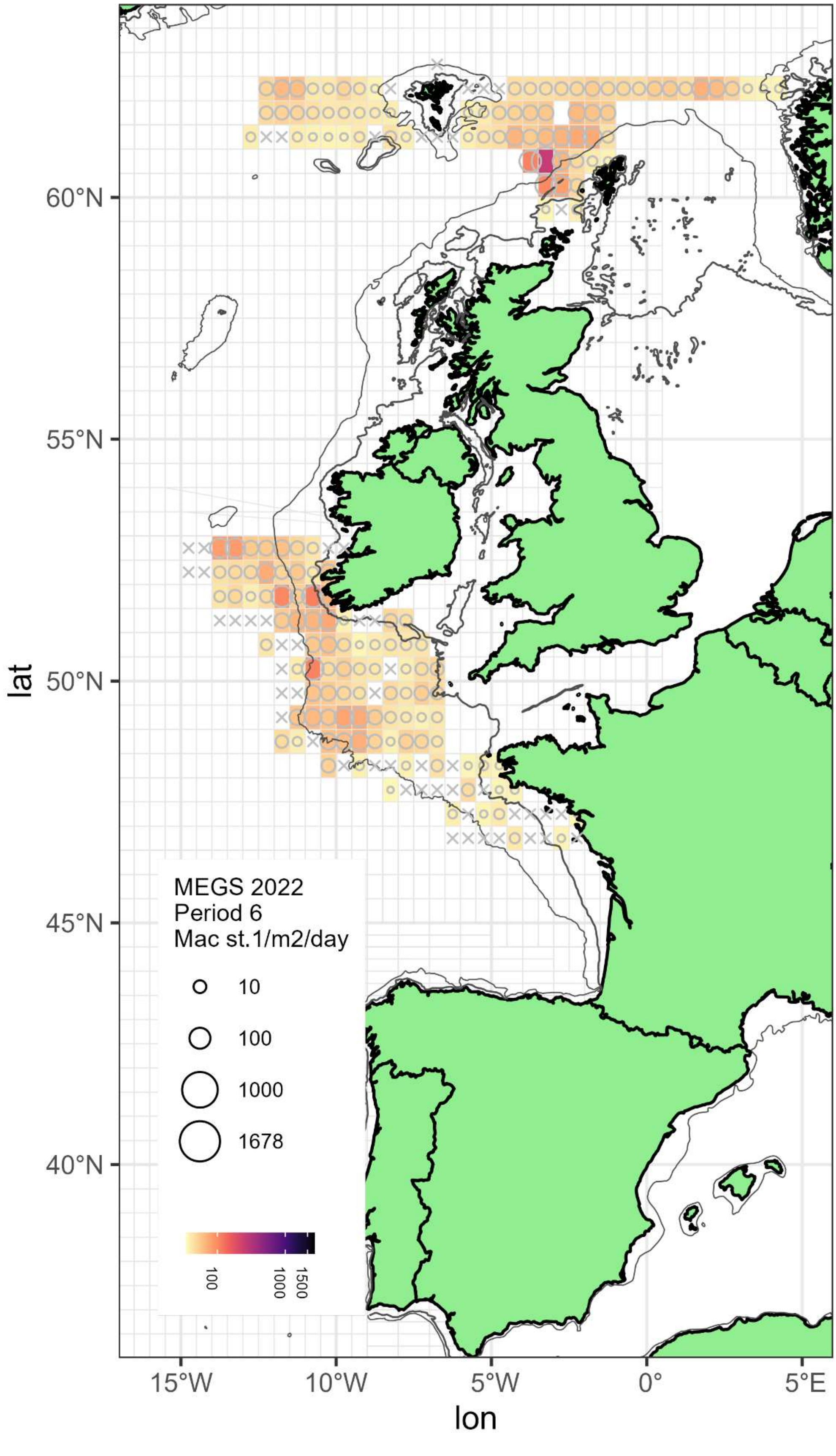

Figure 1.4: Mackerel egg production by half rectangle for period 6 (June 1st – 30th). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

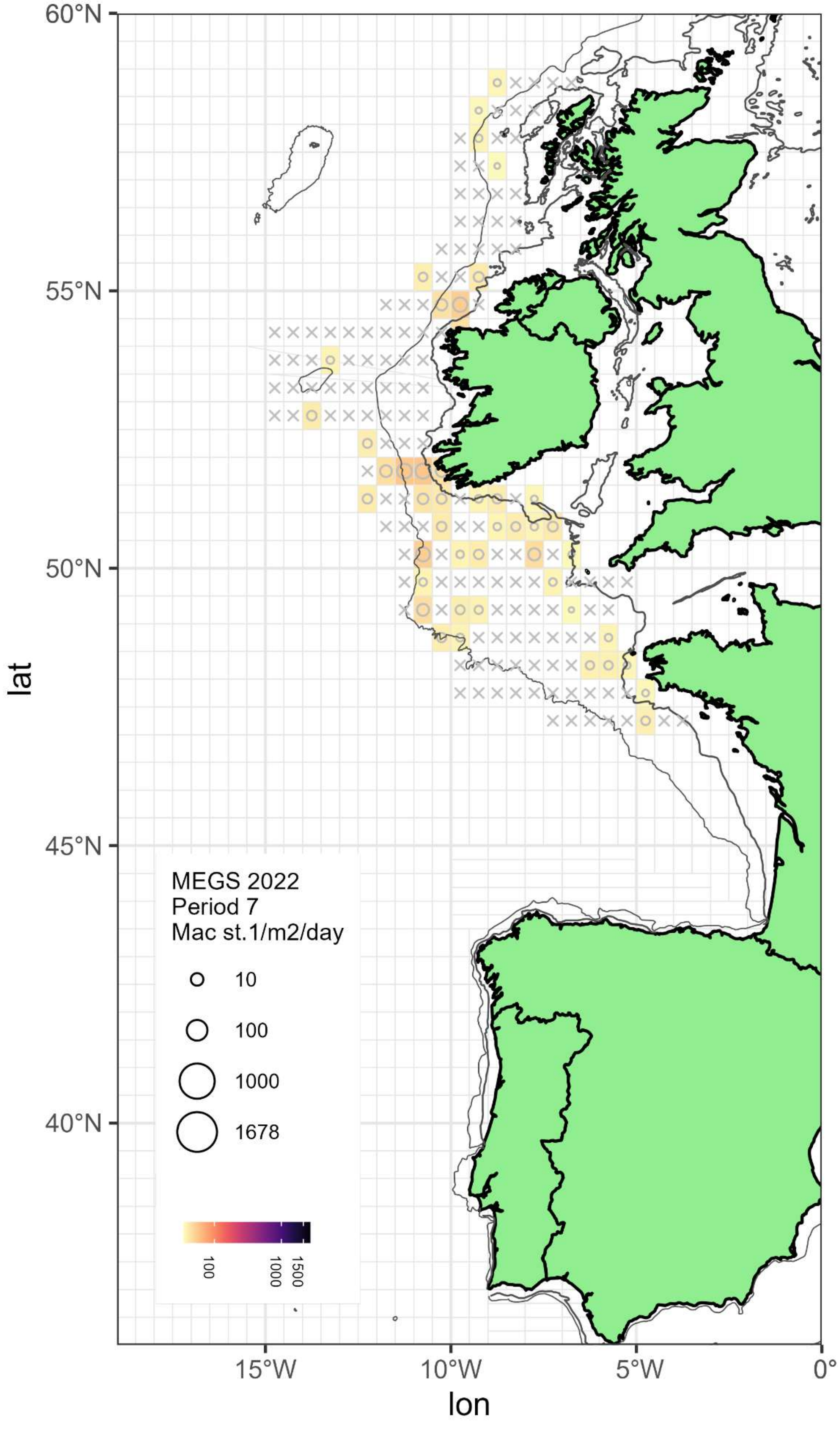

Figure 1.5: Mackerel egg production by half rectangle for period 7 (July 1st – 31st). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

2 Results - MACKEREL

Stage 1 Egg production in the Western Areas

The cancelling of the Irish survey in period 6 was addressed by MEGS. 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 2013, 2016 and 2019 surveys. Positive stations were selected where stage 1 eggs were found in a rectangle on at least two occasions over these three surveys (Fig. 2.1, blue rectangles). MEGS estimated this amounted to 127 missed stations during the period and also estimated mean daily egg production for period 6 in 2022 at 19.58 stage 1 eggs/m^2/day. Figure 2.2 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 (Fig. 2.3). 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 (Fig. 2.3 & Table 2).

In 2016 concern was expressed that 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. 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 2.4. Mackerel egg production by period since 2004 is shown in Figure 2.5.

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

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

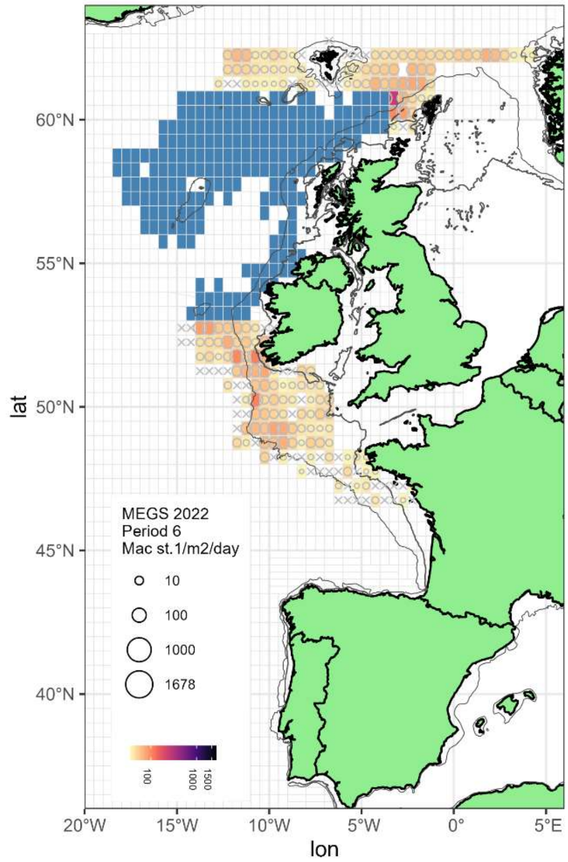

Figure 2.1: Area, blue colour, from period 6 where it is estimated eggs would have been found

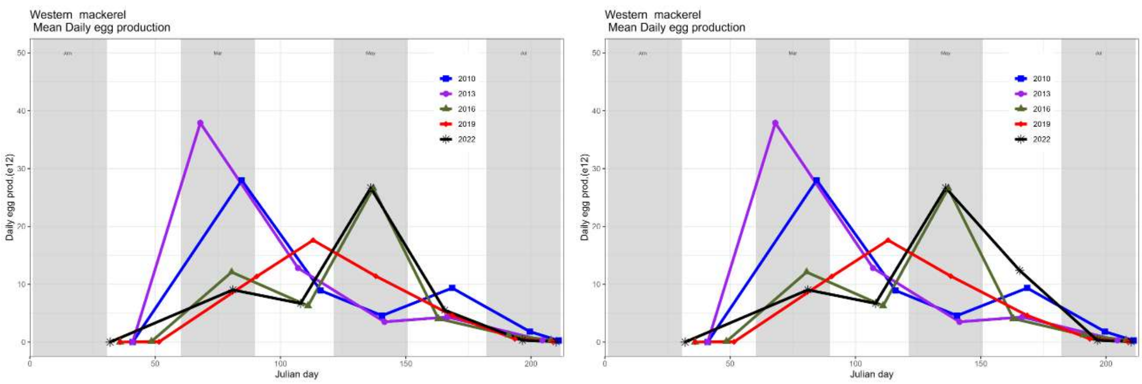

Figure 2.2: 2022 spawning curve showing uncorrected (left) and corrected (right) egg estimates for Period 6 (black line). The left hand plot shows the data from the Netherlands and Norwegian surveys. The right hand plot includes the addition of the estimated egg abundance calculated for the missing Irish Period 6 survey.

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 2022 does not suggest that the chosen end date 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}.

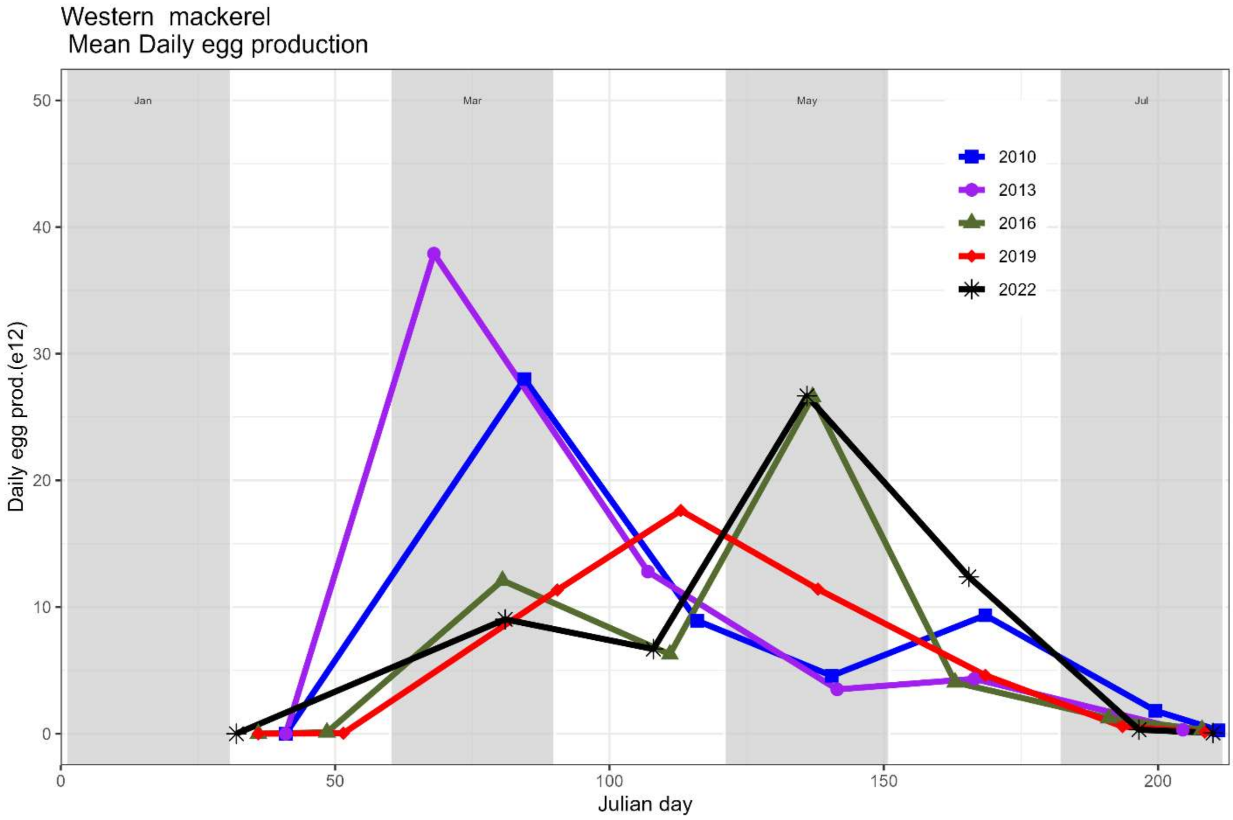

Figure 2.3: Provisional annual egg production curve for mackerel in the western spawning component in 2022, (black line). The curves for 2010, 2013, 2016 and 2019 are included for comparison.

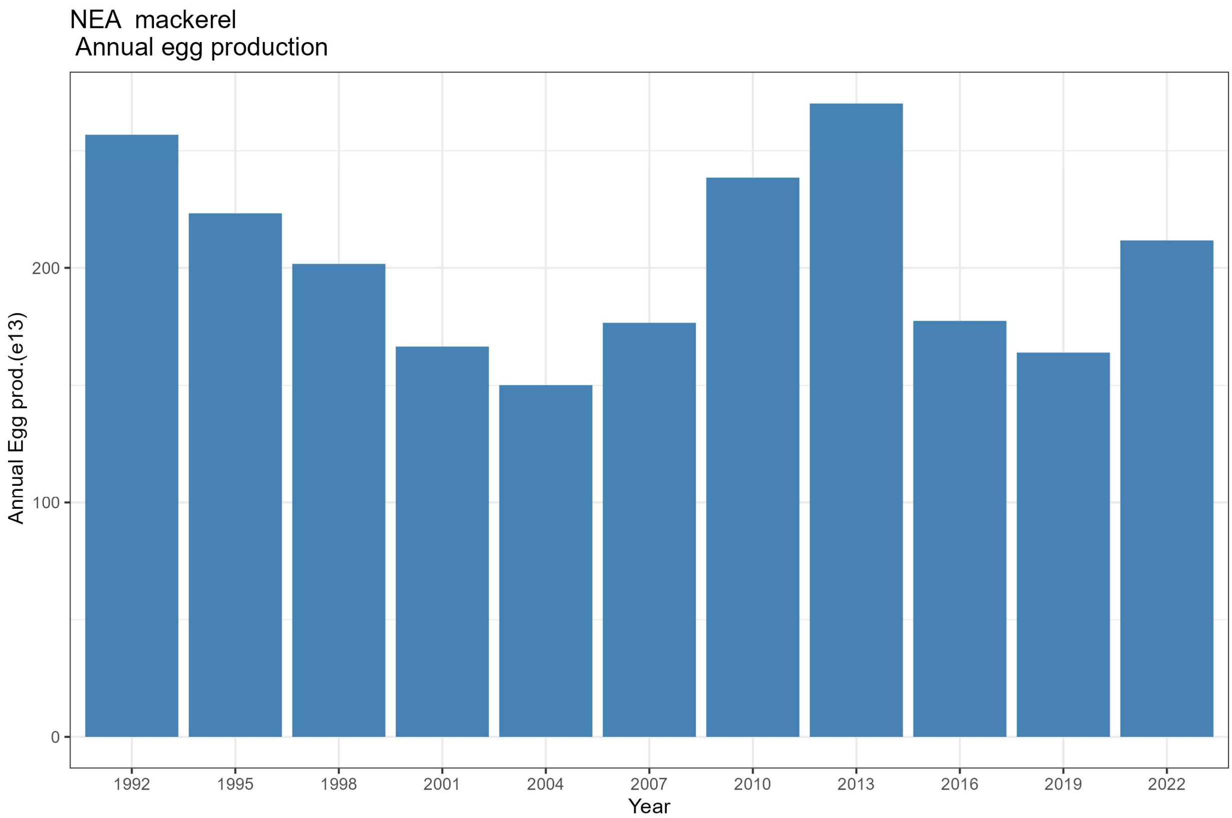

Figure 2.4: Provisional annual egg production for 2022 for the western spawning component.

Bars from 1992 are included for comparison.

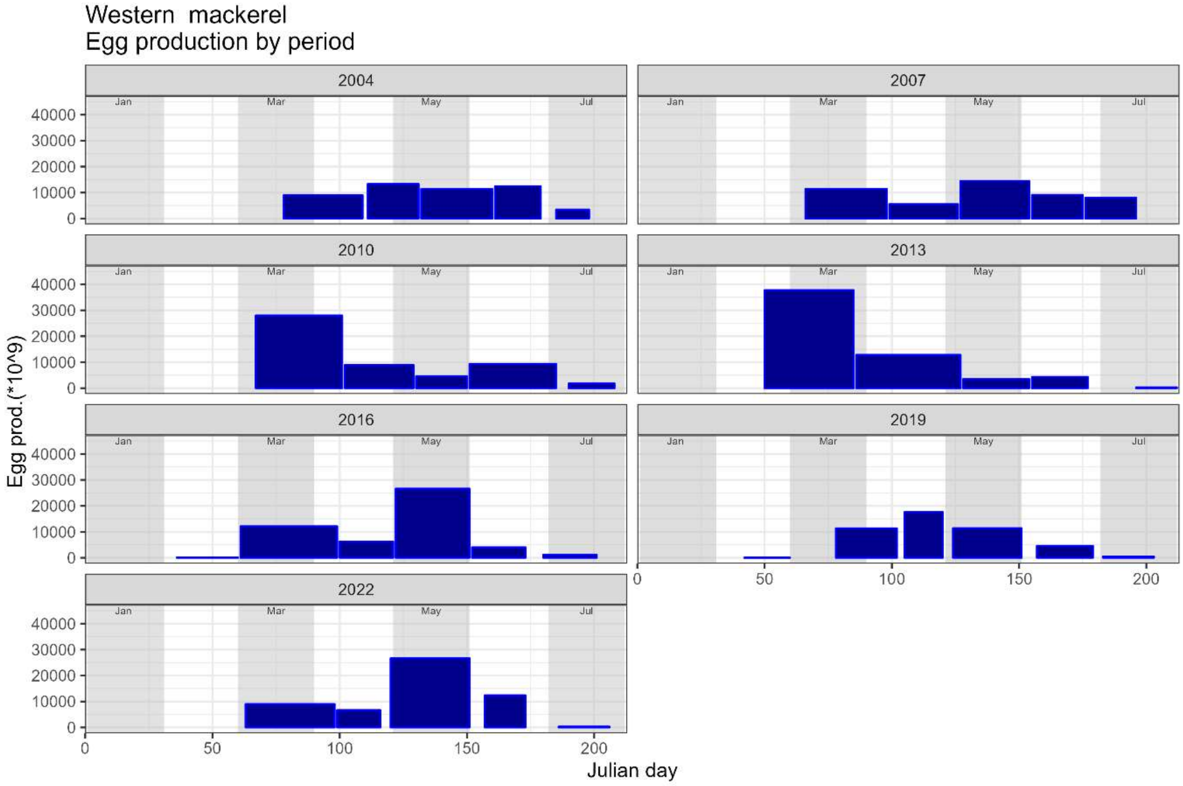

Figure 2.5: Egg production by period for the western spawning component since 2004

Table 2. Western estimate of 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 5th – Mar 3rd	Pre 3	31	0.09
Mar 4th – April 8th	3	36	0.325
Apr 9th – April 26th	4	18	0.120
April 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 – June 22nd	6	17	0.21
June 23rd – July 4th	6 – 7	12	0.081
July 5th – July 25th	7	21	0.007
July 26th – 31st	Post 7	6	0.0003
Total			1.795

Stage 1 Egg production in the Southern Areas

The start date for spawning in the southern area was the 23rd January (Table 3). 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 the 17th July was used again this year and the spawning curve suggests that there is no reason for this to change (Fig. 2.4). As in 2019 the survey periods were not completely contiguous and this has been accounted for (Table 3). The mackerel egg production by period since 2004 is shown in Figure 2.6. The provisional total annual egg production (TAEP) for the southern area in 2022 was calculated as **$3.21 * 10^{14}$** (Table 3). This is a 25% decrease on the 2019 TAEP estimate which was $4.23 * 10^{14}$ (Fig. 2.5).

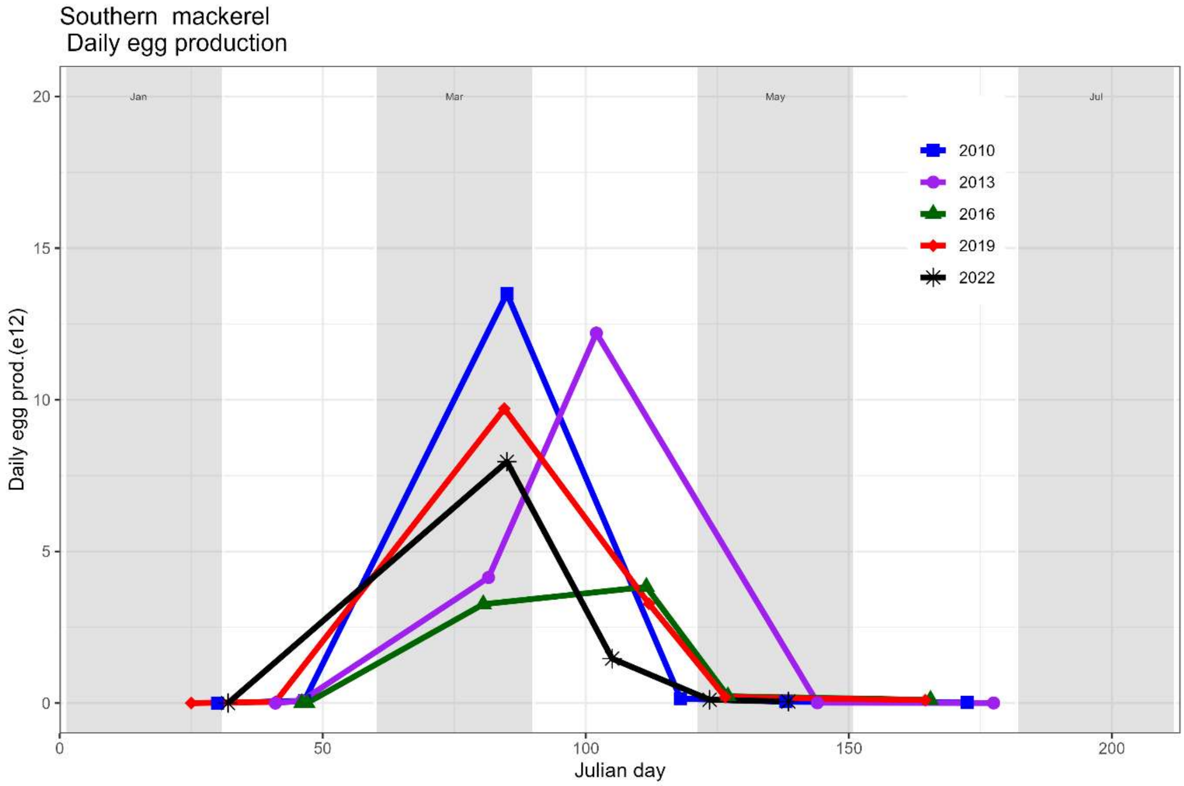

Figure 2.4: Provisional annual egg production curve for mackerel in the southern spawning component for 2022, black line). The curves for 2010, 2013, 2016 and 2019 are included for comparison.

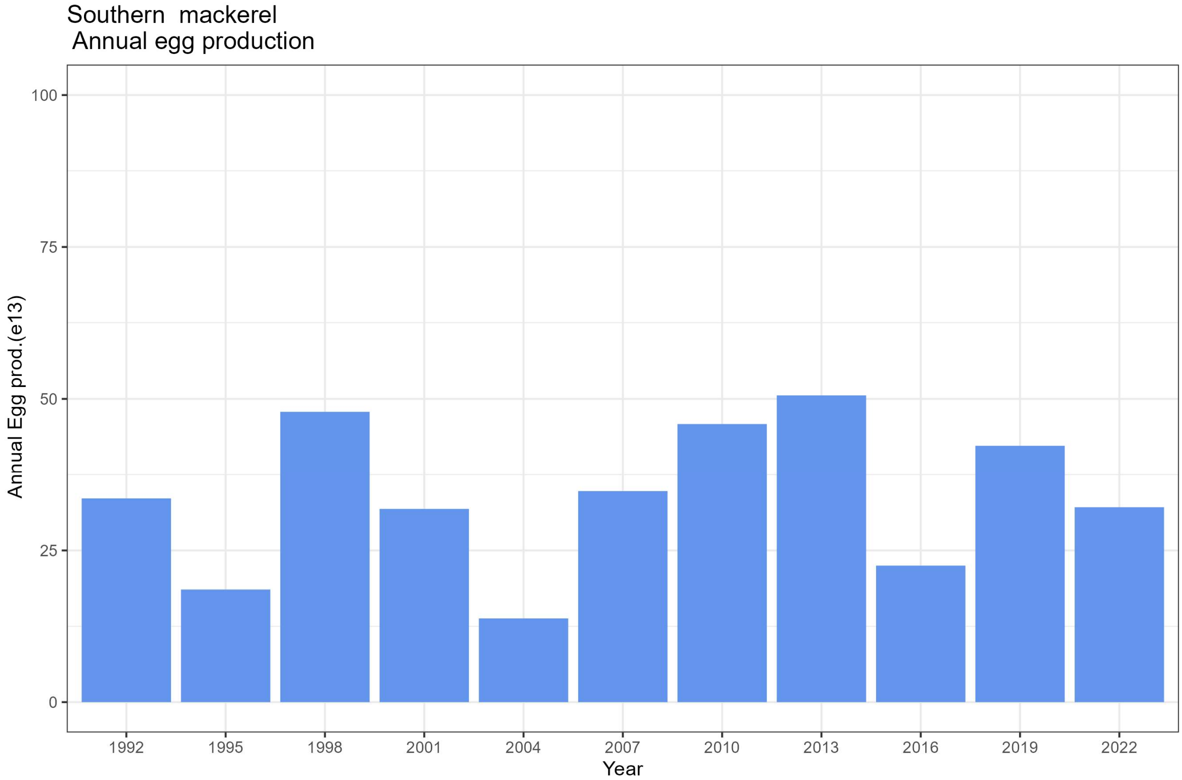

Figure 2.5: Provisional annual egg production for the southern spawning component for 2022. Bars from 1992 are included for comparison.

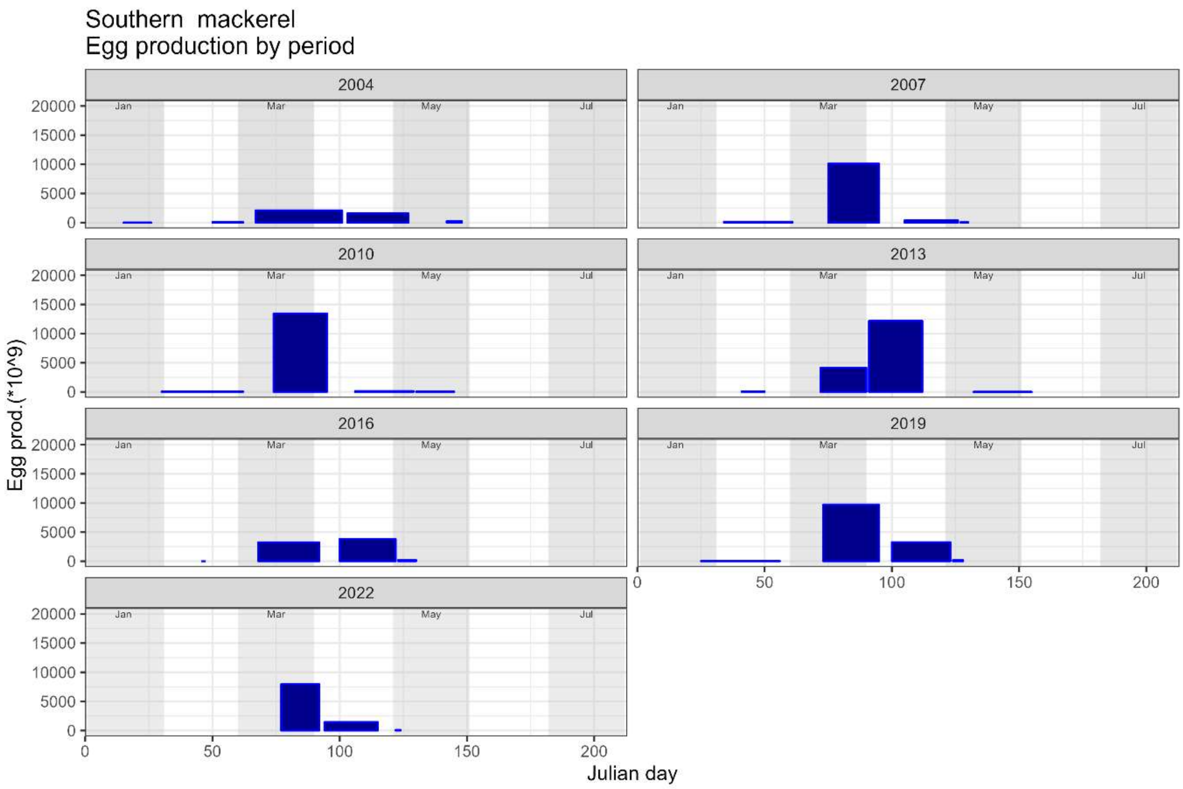

Figure 2.6: Egg production by period for the southern spawning component since 2004

Table 3. Southern estimate of mackerel total stage I egg production by period using the histogram method for 2022.

Dates	Period	Days	Annual stage I egg production x 10^{14}
Feb 1st – Mar 17th	2 - 3	45	1.52
March 18th – April 2nd	3	16	1.27
April 3rd	3 - 4	1	0.052
April 4th – 25th	4	22	0.323
Apr 26th – May 1st	4 - 5	6	0.026
May 2nd – 4th	5	3	0.003
May 5th –July 17th	Post 5	71	0.014
Total	3.212		

Total egg production

Total annual eggs production (TAEP) for both the western and southern components combined in 2022 is **2.116*10^{15}**. (Fig. 2.3). This is an increase in production of **29%** compared to 2019, 1.64*10^{15} (Fig. 2.3).

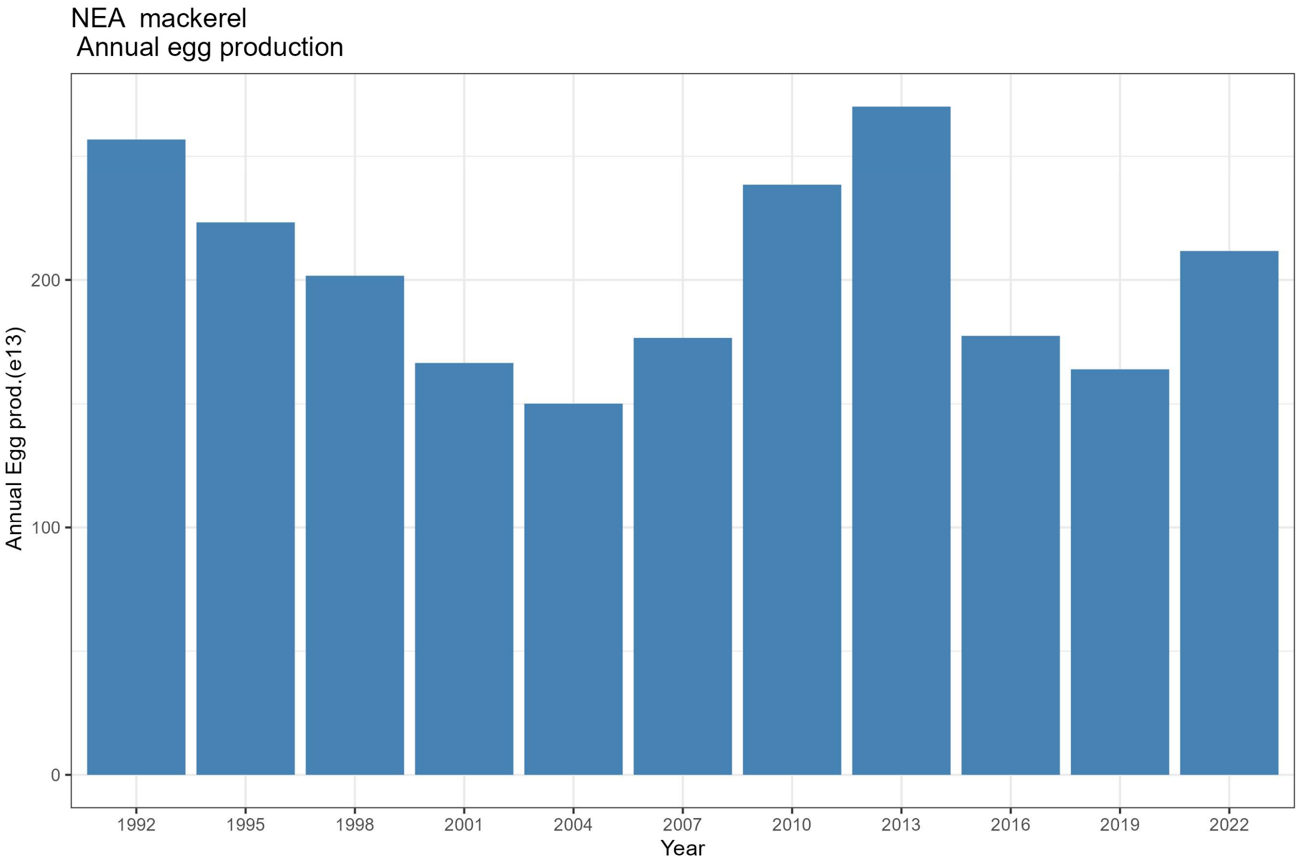

Figure 2.3: Combined mackerel TAEP estimates (*10^{13}) - 1992 – 2022.

Fecundity – Preliminary estimates

Adult Parameters

Fecundity Sample distribution

Atlantic mackerel samples were collected during periods 2-7 spread over an area with a bounding box of 59.36N 14.20W – 36.54N 2.32W. Nine institutes participated. The histological screening of samples was performed by five institutes while fecundity was analysed by six of them.

As usual for the preliminary report, only samples from Periods 2 and 3 were selected. This is because there is not enough time to analyse samples from the other periods. For the final report samples from the other periods will be included also. Experience from earlier surveys is that the preliminary estimate and the final estimate is close.

Screening

Potential fecundity counts were based on whole mount samples taken from maturing females which had not started spawning. To select these samples, a histological screening procedure was used followed by a screening procedure on the selected whole mount samples.

A total of 918 samples were screened, of which 793 were from periods 2 and 3 (
Table). Of those, 482 samples showed spawning markers, i.e. migratory nucleus stage (MIG), hydrated oocytes, eggs, and post ovulatory follicles (POFs). 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. WKFATHOM2 (2018) 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).

Table 4. POF scoring using histology by periods 2-3.

Period	Screened	Spawning Markers	POFs	Fecundity Histology	Fecundity Whole mount	Atresia Presence
2	32	24	21	2	2	3
3	675	541	494	38	33	156

Results from previous surveys showed that POF scoring could vary considerably between periods. At WKFATHOM2 (ICES 2018) this issue was discussed and more detailed criteria for POF staging were elaborated. 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 5).

Table 5. POF scoring using histology (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

A total of 159 samples from periods 2-3 showed presence of atresia without considering those that were classified as "spent" or having "massive atresia" (Table).

Looking at the oocyte stage most of the samples in periods 2-3 were at MIG or hydrated oocyte stage (n = 545) and that less than half (n = 217) were in vitellogenic oocyte stage.

Potential fecundity

For the 2022 preliminary estimate of potential fecundity, 169 samples were available, which represents 21% of all samples screened for periods 2 and 3. This number is much higher than in 2019, when 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 previous surveys (in recent time) where the most advanced oocyte stage included was stage 3 (advanced vitellogenesis). However, the MIG oocyte stage is not a true spawning marker, but a marker that shows that spawning likely will take place within a few days. For previous surveys samples with MIG´s were excluded for precautious reasons.

Since the 2013 MEGS survey, the median has been used for relative fecundity estimation rather than the mean which was used previously. The reason for the change is related to the fact that that unlike the mean, the median is not influenced by extreme values. A posterior analysis showed that the median for relative potential fecundity was close to the arithmetic mean in most years. The largest difference was in 2013, but even then, the median was within the confidence interval of the potential fecundity arithmetic mean. WGMEGS 2018 (ICES 2018) discussed whether to use the trimmed mean instead of the median for the potential fecundity estimate. A trimmed mean is preferred for calculation of confidence intervals. However, until the time-series data is reanalyzed in the near future, it was decided that the relative fecundity estimate should still be based on the median rather than the mean.

The distribution of relative potential fecundity values (Figure 2.4) was close to a normal distribution and ranged from 623 to 1972 (n/g). The distribution was almost similar both for samples with the MIG oocyte stage (stage 4) and stage 3 (Figure 2.4). 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 have not significantly changed the median or mean value, and that our previous cautious procedure excluding MIG´s is probably unnecessary.

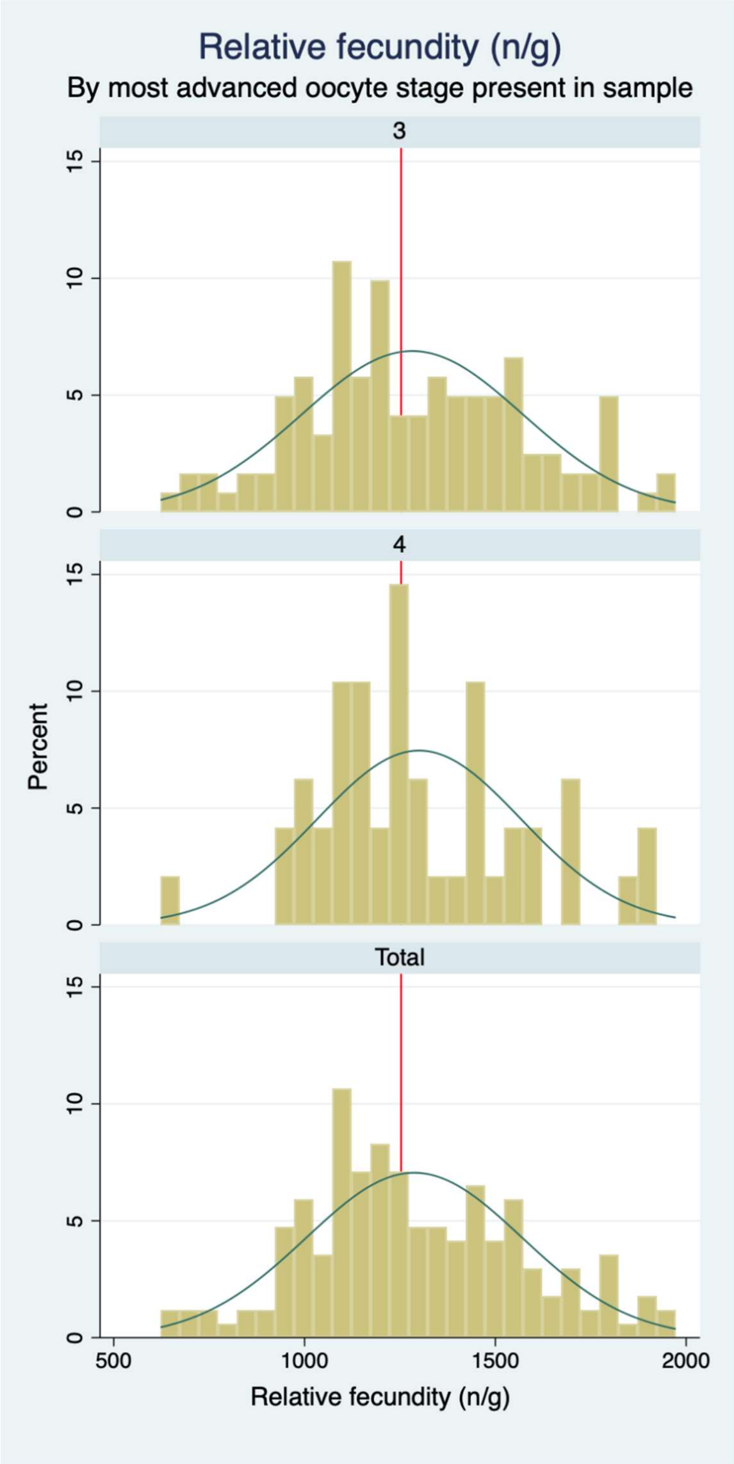

Figure 2.4. Relative fecundity preliminary estimation in 2022. The panels show the distribution (in %) of relative fecundity using samples in which the most advanced oocyte stage present was 3 (advanced vitellogenesis, top panel), samples where the most advanced oocyte stage was MIG (stage 4, middle 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 6 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 samples to fecundity

The distribution of fish length, weight, Fulton's condition factor (100 × weight/length^3), and gonad-somatic index (GSI; 100 × Ovary weight/Fish weight) is shown in Figure 2.5.

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. For this preliminary estimation, no females needed to be excluded from the analysis based on these biological parameters.

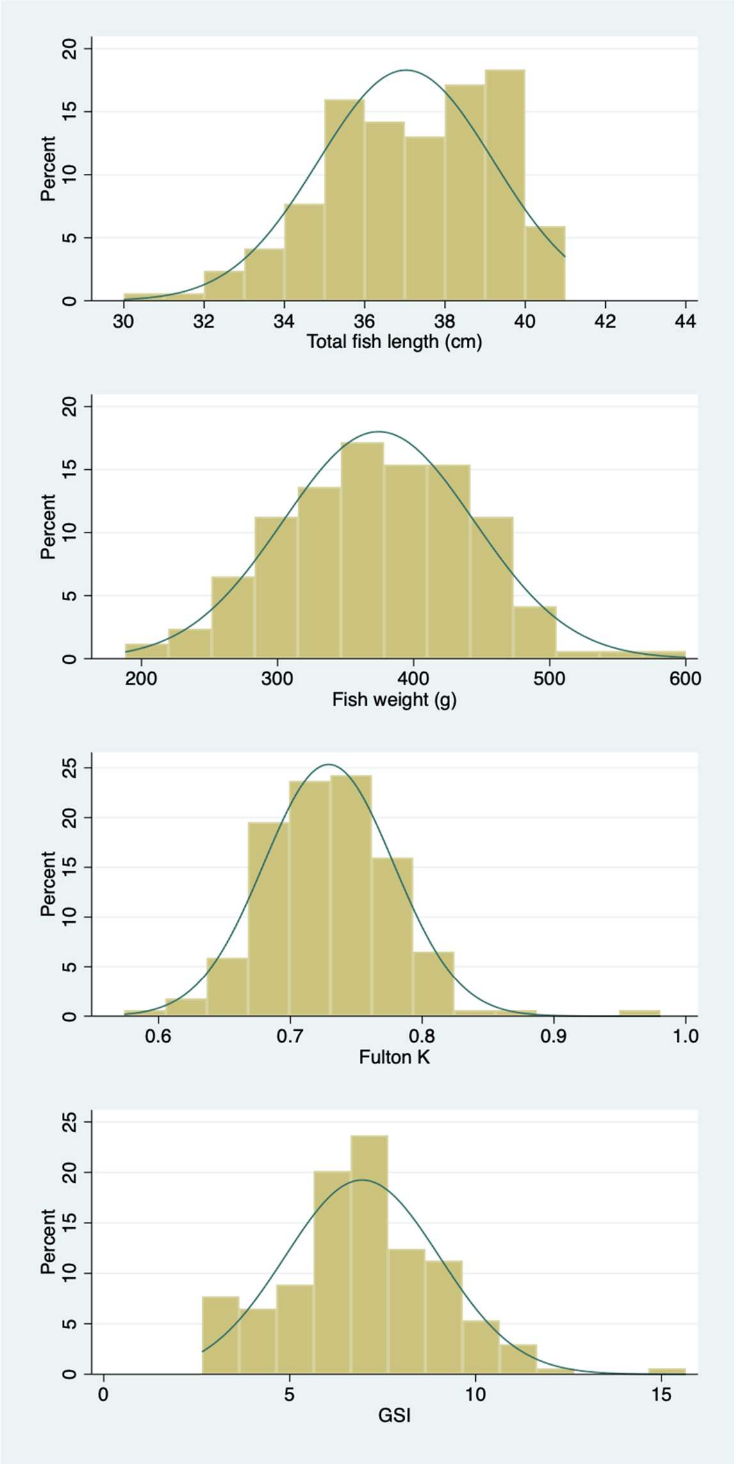

Figure 2.5. Fish length and weight, Fulton's Condition index and GSI of individuals analysed for fecundity.

Atresia

Atresia is the loss of oocytes by reabsorption before spawning and must be subtracted from the potential fecundity (whole mount fecundity counting) to estimate the realised fecundity. In this preliminary report, intensity of atresia can not be presented due to the time consumed for the histology screening.

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 estimated was 0.28, (fish from period 2-3, excluding spent fish and fish with massive atresia).

Realised fecundity

Realised fecundity is defined as the potential fecundity minus the loss by atresia. The loss by atresia is a function of both intensity of atresia and prevalence of atresia. The intensity of atresia for 2022 is still unavailable, therefore the loss was calculated from the average loss from the surveys since 2001 (Table). 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 female. The estimate is well within the observed range of realized fecundity (1009-1209, average 1087 egg per gram female) from all previous surveys back to 2001 (Table 7). For the three most recent surveys, realized fecundity varied between 1087 and 1209 eggs per gram female (average 1148).

Table 7. Summary table of mackerel fecundity and atresia by survey year.

	Survey year							
	2001	2004	2007	2010	2013	2016	2019	2022 Prel.
Fecundity samples (n)	187	205	176	74	132	97	62	169
Prevalence of atresia (n)	290	348	416	511	732	713	895	559
Intensity of atresia (n)	290	348	416	511	56	66	64	
Relative potential fecundity (n/g)	1097	1127	1098	1140	1257*	1159*	1191*	1253*
Prevalence of atresia	0.2	0.28	0.38	0.33	0.22	0.3	0.28	0.28
Geometric mean intensity of atresia (n/g)	40	33	30	26	27	30	20	
Potential fecundity lost per day (n/g)	1.07	1.25	1.48	1.16	0.8	1.2	0.73	
Potential fecundity lost (n/g)	64	75	89	70	48	72	44	75
Relative potential fecundity lost (%)	6	7	9	6	4	6	4	6
Realised fecundity (n/g)*	1033	1052	1009	1070	1209	1087	1147	1178

*Median not mean relative potential fecundity.

Biomass estimation

Total spawning stock biomass (SSB) was estimated using a preliminary fecundity estimate of 1178 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:

- 3.292 million tonnes for western component (2019: 2.29).
- 0.589 million tonnes for southern component (2019: 0.80).
- 3.881 million tonnes for western and southern components combined (2019: 3.09)

3 Results – HORSE MACKEREL

Horse mackerel egg production by period

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 (Fig. 3.1).

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 (Fig. 3.2).

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 (Fig. 3.3).

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 in this period (Fig. 3.4).

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 (Fig. 3.5).

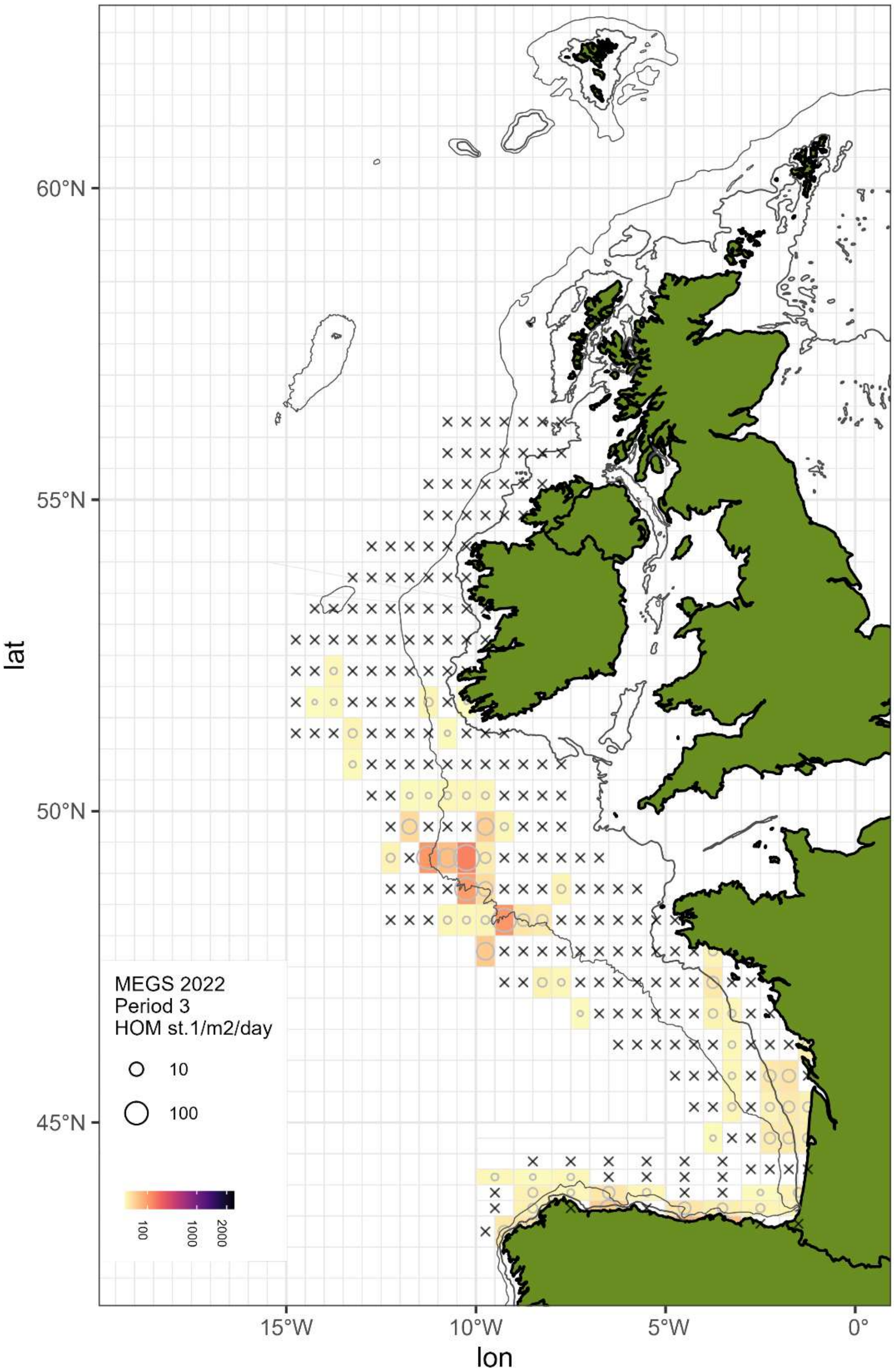

Figure 3.1: Horse mackerel egg production by half rectangle for period 3 (March 4th – April 8th). Circle areas and colour scale represent horse mackerel stage I eggs/m^2/day by half rectangle. Crosses represent zero values.

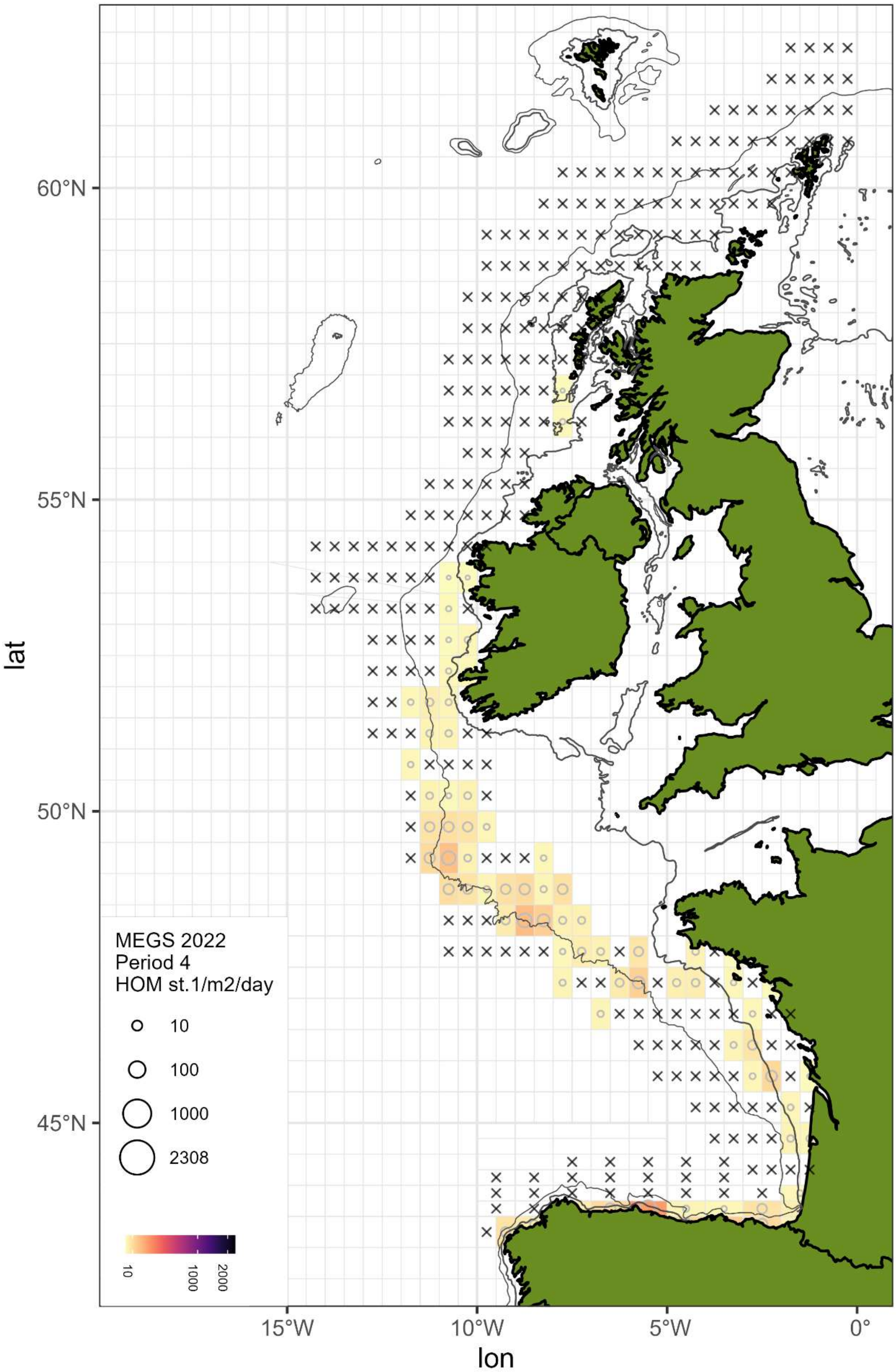

Figure 3.2: Horse mackerel egg production by half rectangle for period 4 (April 9th – 29th). Circle areas and colour scale represent horse mackerel stage I eggs/m^2/day by half rectangle. Crosses represent zero values.

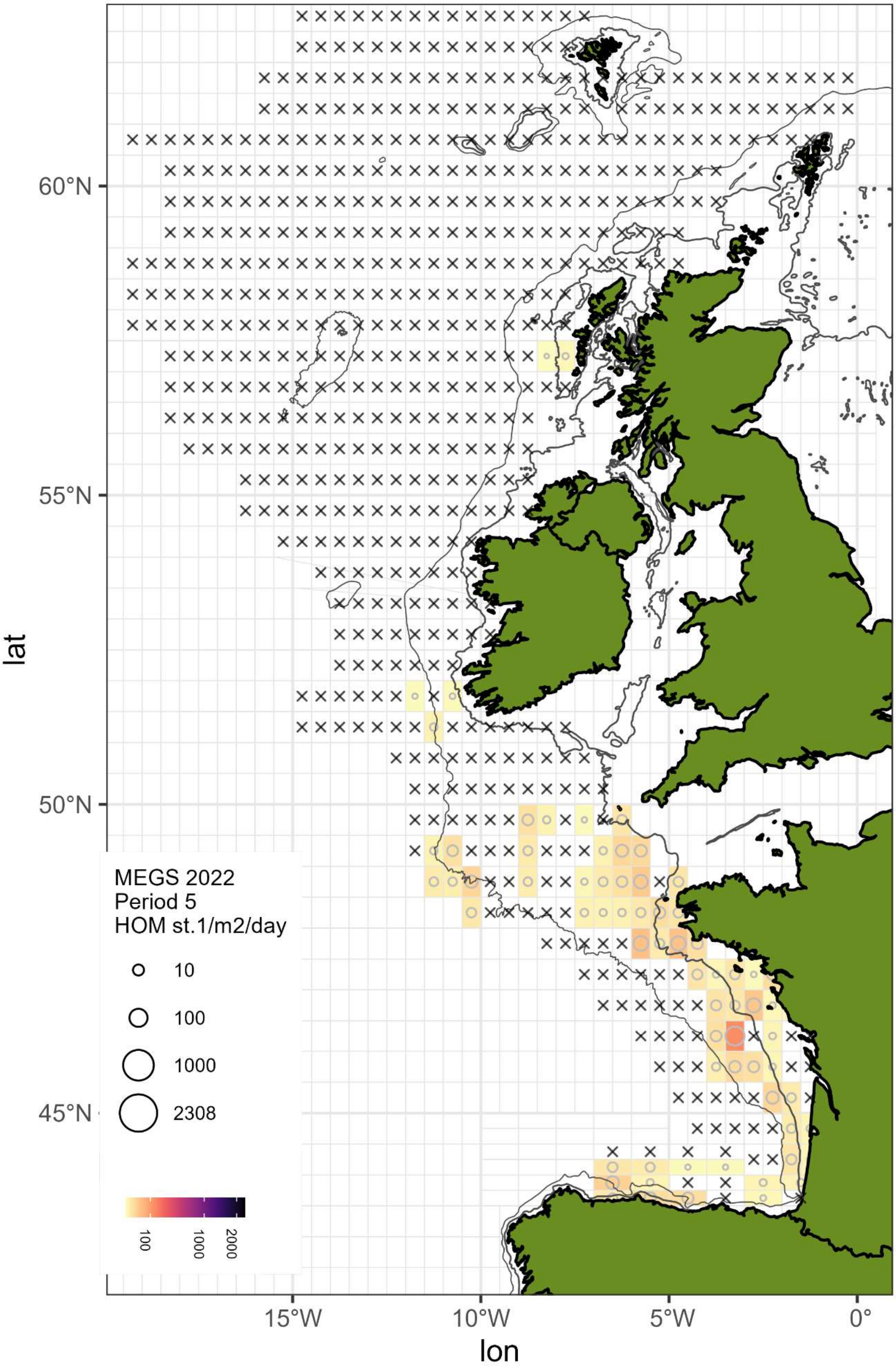

Figure 3.3: Horse mackerel egg production by half rectangle for period 5 (Apr 30th – May 31st). Circle areas and colour scale represent horse mackerel stage I eggs/m^2/day by half rectangle. Crosses represent zero values.

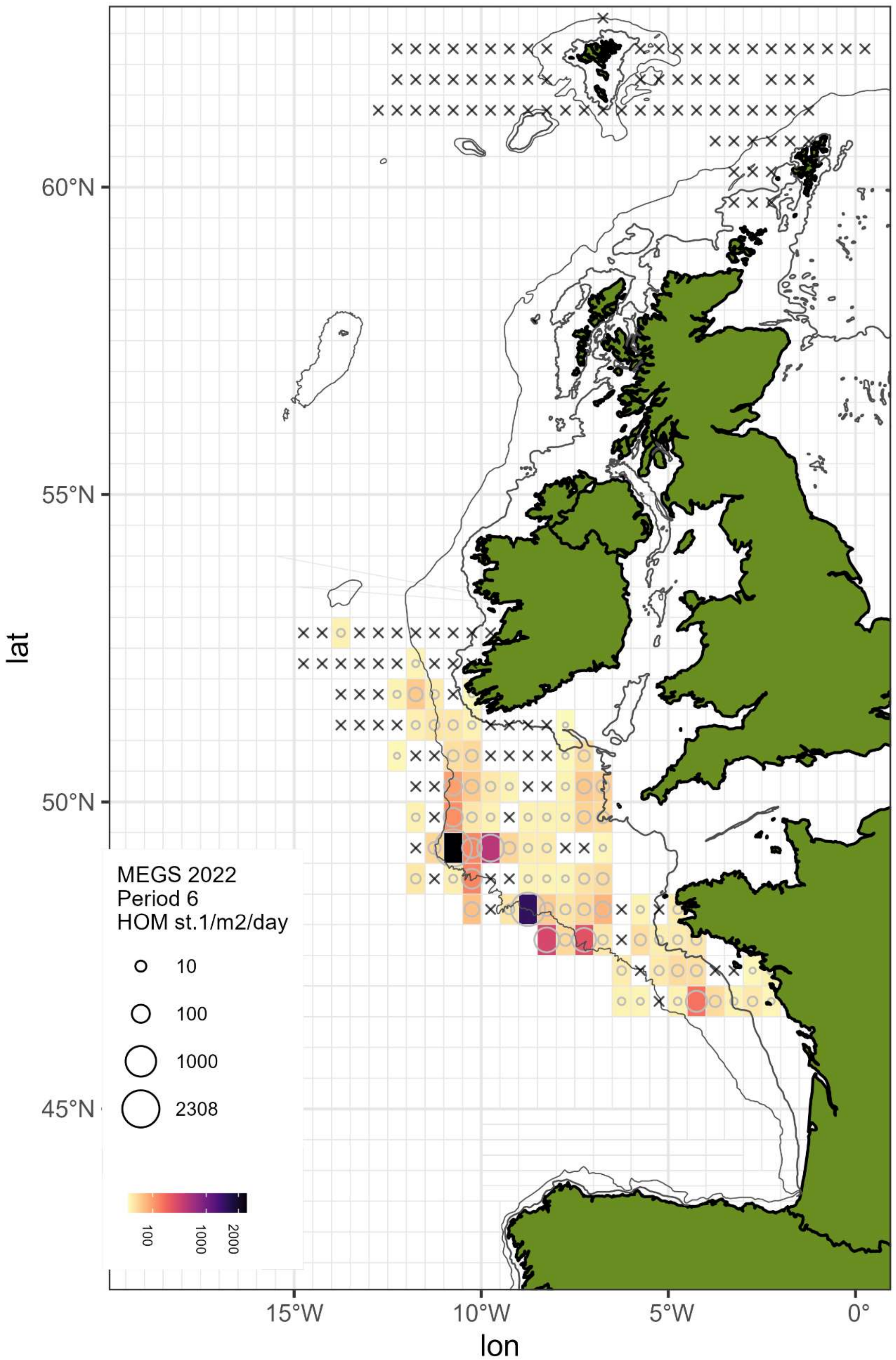

Figure 3.4: Horse mackerel egg production by half rectangle for period 6 (June 1st – 30th). Circle areas and colour scale represent horse mackerel stage I eggs/m²/day by half rectangle. Crosses represent zero values.

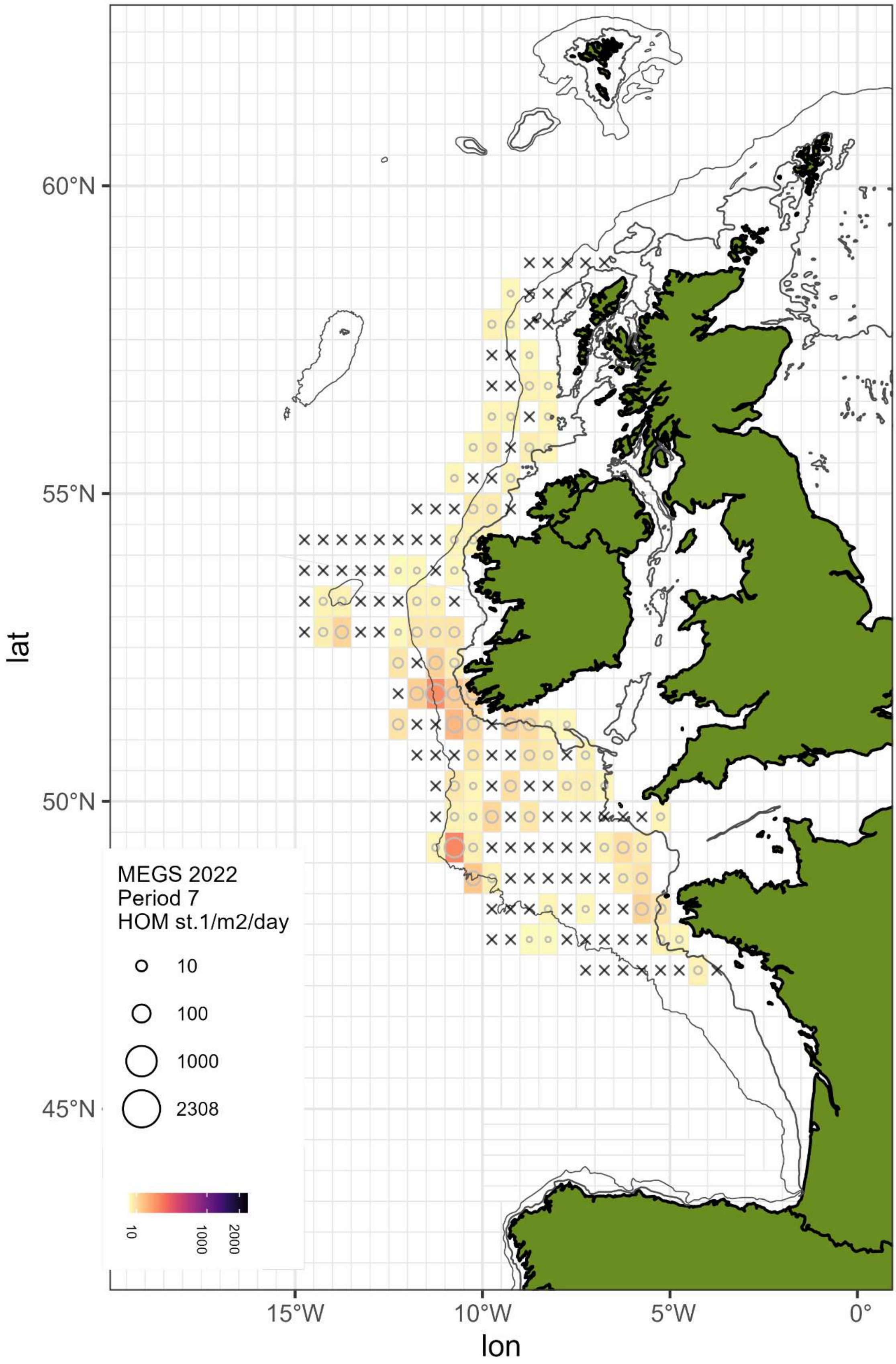

Figure 3.5: Horse mackerel egg production by half rectangle for period 7 (July 1st – July 31st). Circle areas and colour scale represent horse mackerel stage I eggs/m^2/day by half rectangle. Crosses represent zero values.

TAEP results – Western Horse Mackerel

Period number and duration are the same as those used to estimate the western mackerel stock, as are the dates defining the start and end of spawning (Table 6). The shape of the egg production curve does not suggest that those dates should be altered for 2022 (Fig. 3.6). 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 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 (Fig. 3.7). Horse mackerel egg production by period since 2007 is shown in Figure 3.8.

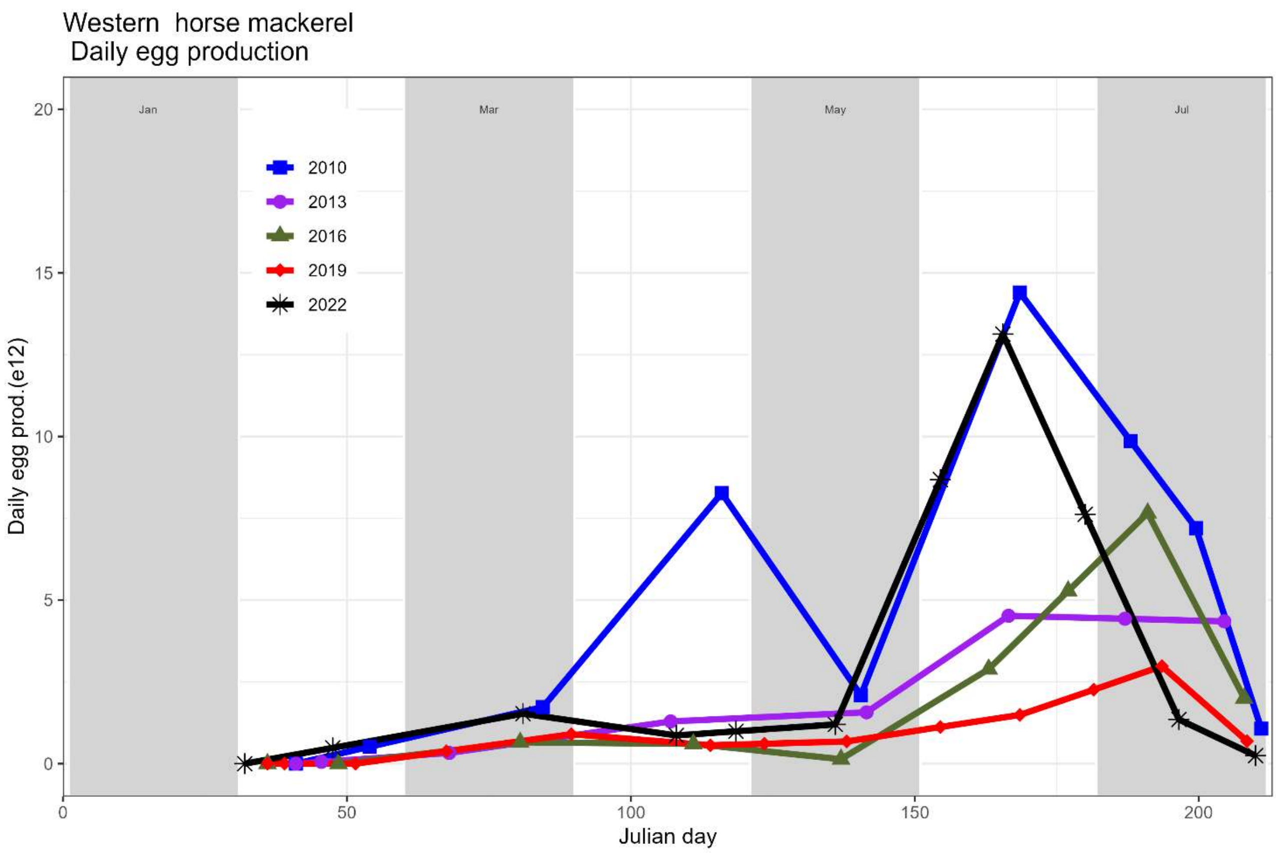

Figure 3.6: Provisional annual egg production curve for western horse mackerel for 2022, (black line). The curves for 2010, 2013, 2016 and 2019 are included for comparison.

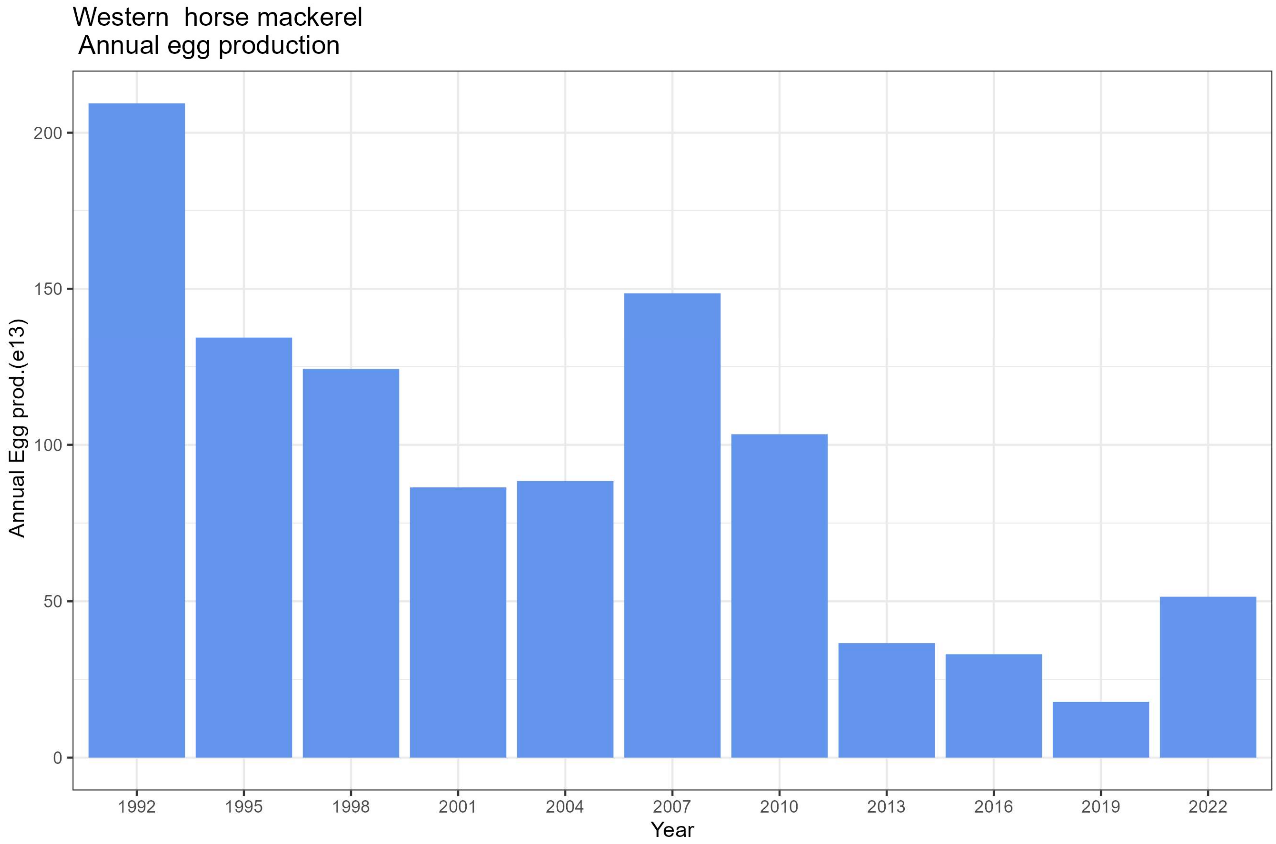

Figure 3.7: Provisional total annual egg production for western horse mackerel. Production figures back to 1992 are included for comparison.

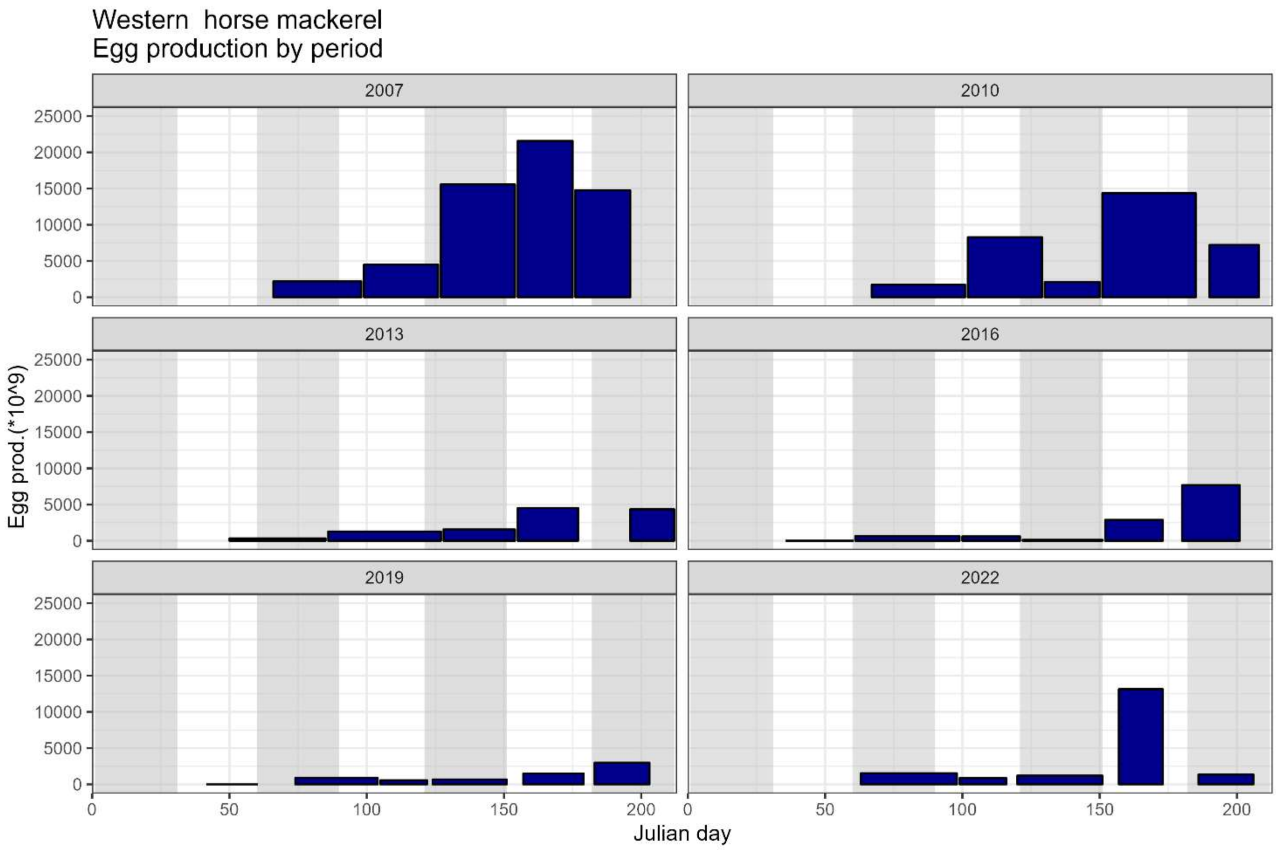

Figure 3.8: Egg production by period for the western horse mackerel spawning component since 2007

Table 6: Western estimate of 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 – April 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
June 5 – July 4th	6 – 7	12	0.091
July 5th – 25th	7	21	0.028
July 26th – 31st	Post 7	6	0.001
Total	0.514		

Fecundity investigations

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.

DEPM results –Western Horse Mackerel

The horse-mackerel egg data of the DEPM survey are still under revision. Samples will be analyzed before and results will be presented to the 2023 WGMEGS meeting.

4 Discussion

Since 2004 and subsequent to demands for up-to-date data for the assessment, WGMEGS has endeavored to provide an estimate of NEA mackerel biomass and western horse mackerel egg production within the same calendar year as the survey and in time for the assessment meetings taking place. This report represents the preliminary results of the 2022 egg survey. WGMEGS cannot guarantee that there will be no changes prior to the presentation of the final survey results at WGMEGS in April 2023. However, despite the tight deadline nearly all plankton samples were analyzed for mackerel (southern and western area) and horse mackerel (western area only) stage 1 eggs. Portugal still has to supply data for their Period 2 survey in division 9a. Historically not many mackerel are caught during this survey therefore only negligible changes in the total egg production values are to be expected

As with 2019 no fecundity samples from Period 1 were available, instead samples from Periods 2 and 3 were included in the potential fecundity estimate. For the final fecundity estimate the later periods will also be included, as was done for previous surveys. No estimate of loss by atresia is yet available for 2022. The realised fecundity estimate is therefore based on the average atretic loss found in the period from 2001-2019. Since the atretic loss has always been a small number compared to the potential fecundity, using this average value will likely not give a large error. The prevalence of atresia for 2022 (28%) is comparable to previous survey estimates, it is thus highly likely that the atretic loss will also be at the same level. Atretic loss will however be analysed and included in the final fecundity estimate at the WGMEGS meeting in 2023.

Previous surveys in 2010 and 2013 were dominated by the issue of the early peak of western mackerel spawning and its close proximity to the nominal start date. In 2016 peak spawning reverted to May / June, a time that would traditionally be considered normal. In 2019, peak spawning in the western area was found to have occurred slightly earlier in Period 4. For 2022 the spawning pattern is remarkably similar to that reported for 2016.

During 2016, high levels of spawning were recorded over a large area of the Northeast Atlantic with a large number of the stations being reported over deepwater and well away from the continental shelf. In 2019 numbers of stage 1 eggs recorded on these northerly and western boundary stations were much reduced, although still present. The expansion was repeated in 2022 during Periods 5 and 6, however spawning densities recorded in these areas were significantly lower than reported in 2016 and 2019. Available surveys deployed during these periods were unable to fully delineate all boundaries however WGMEGS are satisfied that significant additional egg production is not being missed in these northern and western areas.

For the first time in a number of surveys western horse mackerel has shown an increase in egg production.

The MEGS group is confident that this survey accurately reflects the spawning patterns as exhibited by both species and as is presented in this working document. Despite the inability to secure a northern spawning boundary for western mackerel during periods 5 and 6, results from the recent exploratory MEGS surveys undertaken within these regions and reported to WGWIDE in 2021 (ICES,

2021) provide reassurance that the fraction of spawning missed is a minor one and that the survey has indeed been successful in capturing the majority of spawning activity. The potential issue arising from the missing Irish survey has also been satisfactorily addressed.

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