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

9 - 13 April 2018

Marine Institute, Dublin, Ireland

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International Council for the Exploration of the Sea
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Executive summary

The ICES Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS), chaired by Gersom Costas (IEO, Spain) and Matthias Kloppmann (TISF, Germany), met at the Marine Institute, Dublin from 9–13 April 2018, to plan the Mackerel and Horse Mackerel Egg Survey in 2019 and finalize results of the 2017 North Sea mackerel egg survey. The nations participating in the 2019 Northeast Atlantic (NEA) MEGS survey will be Portugal, Spain, Scotland, Ireland, The Netherlands, Norway, Denmark, Germany, Iceland and the Faroe Islands. The main aim of the survey is to relate the number of freshly spawned eggs found in the water to the number of females having produced these eggs. Knowing the fecundity of the females and sex ratio provides an estimate for the spawning-stock biomass.

The 2019 survey will be based on seven regular sampling periods (Section 5). Norway announced that it will re-join the survey in 2019. In addition, Denmark disclosed that they will participate in 2019 and probably also in the 2020 North Sea MEGS, provided the necessary ship time is granted by their administrative bodies. The 2010 and 2013 surveys pointed to progressive forward shifting of peak spawning, the 2016 NEA MEGS pointed to a return to the traditional spawning peak in May, but much further North than anticipated. In contrast, spawning in the southern areas remained comparatively low during the whole 2016 spawning season. Additional information, however, collated from spring surveys undertaken in 2017 (Section 5.10) point towards an increase of spawning activities in the South to levels observed before 2016 but also to a continuation of spawning at the northern boundaries of the enlarged survey area.

The return of Norway and possibly the return of Denmark would be extremely helpful to be able to plan a full coverage of the survey area in 2019. The survey plan will be further elaborated during the course of 2018 and an updated survey plan will be presented after WKFATHOM.

In 2019, the MEGS survey will continue as an AEPM survey; however, as with the surveys in 2013 and 2016, the intention will be to also carry out intensive DEPM sampling during expected peak spawning periods of both species in an attempt to calculate a DEPM SSB estimate. The periods highlighted as being the likely peak spawning periods are periods 3 and 4 for mackerel and period 6 and 7 for western horse mackerel. Fecundity analysis will be conducted by Norway (IMR), the Netherlands (Wageningen Marine Research), Scotland (MSS), Ireland (MI) and Spain (IEO and AZTI).

The WKFATHOM staging and fecundity workshops will take place during October in Bremerhaven (egg identification and staging) and in November in IJmuiden (fecundity and atresia). These workshops are essential to maintain the quality assurance of the mackerel and horse mackerel egg surveys and it is strongly advised that participating analysts attend these workshops. Final amendments to the egg survey /fecundity sampling planning schedules will be made during these workshops and distributed among all survey participants. The revised and finalized survey plan will be published in the second interim report of WGMEGS in September 2019.

With Norway withdrawing their participation from the Mackerel Egg Survey in the North Sea, the Netherlands were left as its sole participant. The coverage of the North Sea MEGS suffered substantially due to this withdrawal and it was not possible in the 2015 and 2017 surveys to achieve results consistent with the time-series. WGMEGS concluded that the best option for the North Sea survey would be to use the DEPM rather than AEPM method. The DEPM would only require one full coverage of the

spawning area over a shorter period. Still any help from other countries is strongly requested.

1 Administrative details

Working Group name

Working Group On mackerel and horse mackerel egg surveys (WGMEGS)

Year of Appointment within the current cycle

2018

Reporting year within the current cycle

1

Chair(s)

Gersom Costas, Spain

Matthias Kloppmann, Germany

Meeting venue

Dublin, Ireland,

Meeting dates

9–13 April 2018

2 Terms of Reference a) – d)

a) Coordinate the timing and planning of the 2019 Mackerel/Horse Mackerel Egg Survey in the ICES areas 5 to 9.

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

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

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

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

f) Analyse and evaluate the results of the 2017 mackerel egg survey in the North Sea.

3 Summary of Work plan

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

4 List of Outcomes and Achievements of the WG in this delivery period

- Planned the 2019 mackerel and horse mackerel egg survey in the western and southern area;
- Planned the 2019 sampling programme for mackerel and horse mackerel fecundity and atresia;
- Reviewed procedures for egg sample sorting, fish egg identification and staging;
- Reviewed procedures for fecundity and atresia estimation
- Updated survey manuals;
- Reviewed the results of the 2017 mackerel egg survey in the North Sea.

5 Progress report on ToRs and workplan

- ToR a) the planning process for the 2019 MEGS survey has been completed and is reported in Section 6. Fine-tuning of the adopted plan and any subsequent amendments will take place intersessional and will be reported in the WGMEGS correspondence report in April 2019. The final settled survey plan will be inserted into the WGMEGS Manual for the Mackerel and Horse Mackerel Egg Surveys (ICES SISP 6);
- ToR b) the planning for the adult mackerel/horse mackerel fecundity and atresia sampling has been completed and is reported in Section 7. The final adult sampling scheme will be inserted into the WGMEGS Manual for the AEPM and DEPM estimation of fecundity in mackerel and horse mackerel (ICES SISP 5, 2018). This will be subsequent to any amendments in the overall survey plan(Section 6) for the 2019 MEGS survey as any survey changes will invariably affect the adult sampling plan;
- ToR's c and e) The Manual for the Mackerel and Horse Mackerel Egg Surveys (ICES SISP 6, 2018) was reviewed and the findings reported in Section 9. A further review of the manual will be undertaken subsequent to the WKFATHOM staging workshop in October 2018;
- ToR d) The procedures for egg sampling sorting, species ID, staging, data submission and subsampling as detailed in the WGMEGS Manual for the AEPM and DEPM estimation of fecundity in mackerel and horse mackerel (ICES SISP 5, 2018) were reviewed and are reported in Section 10. A further review of the manual will be undertaken subsequent to the WKFATHOM fecundity workshop in November 2018;
- ToR f) the mackerel survey in the North Sea in 2017 has been analysed and evaluated. The results for this are fully explained in Section 12.

6 Planning of the 2019 mackerel and horse mackerel egg survey in the western and southern areas (ToR a)

6.1 Countries and Ships Participating

Germany, Ireland, Netherlands, Scotland, Portugal, Spain (IEO), Spain (AZTI), Iceland, Faroe Islands, Norway and Denmark will participate in the mackerel and horse mackerel egg surveys in the western and southern area in 2019. Provisional dates (where possible), as well as vessel details, for the forthcoming surveys can be found in table 6.1.1 (Annex 5). Two additional participants have been added for 2019 (compared to 2016) with the return of Norway and also the likely inclusion of Denmark. Their inclusion is indeed timely as the 2016 results provided evidence of further significant challenges facing the survey, with both a spatial as well as a temporal shift in peak spawning of mackerel with a move away from February/March to May, and from the Bay of Biscay to a large area to the west of Scotland. This resulted in an inability to fully delineate the spawning boundaries in the North and West, and of particular concern during 2016 was how close these were situated to the area of peak spawning. Subsequent interim monitoring work (See section 14) provides some evidence suggesting that 2016 might well have been anomalous, however the proposed survey plan for 2019 has been devised to try to manage either scenario with additional effort being devoted to the Northern areas whilst also retaining sufficient survey effort at the start of the spawning season. Survey coverage of the western and southern areas is given by area and period in table 6.1.2 (Annex 5). Detailed maps of survey coverage by period are given in figures 6.1.1 – 6.1.7 in Annex 6. Both vessel availability and area assignments are provisional and will be finalized by the survey coordinator at the appropriate times.

The survey coordinator for the 2019 survey will be Brendan O' Hea, Marine Institute, Galway, Ireland.

6.2 Survey Design

The AEPM survey design for mackerel and horse mackerel for 2019 will not change, however another attempt will be made to estimate DEPM adult parameters for both species. This will require additional sampling during the perceived peak spawning periods for both species, as identified from the 2010 surveys during WKMSPA (WKMSPA, 2012). For the 2019 survey this sampling will take place during periods 3 and 4 for mackerel, and periods 6 and 7 for horse mackerel.

In 2019 the survey will be split into seven sampling periods, and the design and survey deployment plan will be very similar to that employed in 2016. Once again the Faroe Islands and Iceland will participate in the survey during May, which will expand the geographic range of the survey in the North during that period. In 2019 Norway will once again participate in the survey, during period 6. Denmark will also join the survey for the first time, sampling in period 4.

Period 1 (mid to end of January) will involve a survey in ICES division 27.9.a only, with more extensive coverage starting in period 2. In 2019 the survey effort in division 27.9.a will mainly be targeted on a single extended DEPM survey, (see section 6.4). No sampling in division 27.9.a will take place after the end of period 4. Period 2 will commence at the end of January.

Sampling in the western area will commence in period 2. During period 2 the survey will concentrate on the Bay of Biscay, the Celtic Sea, West of Ireland and West of Scotland. Periods 3 and 4 will see sampling begin in the Cantabrian Sea and continue north to the northwest of Scotland. No sampling will take place in the Cantabrian Sea, or the southern Bay of Biscay, after period 5. Periods 5 and 6 will also see the survey area extend north into Faroese and Icelandic waters. In periods 6 and 7 the surveys are designed to identify a southern boundary of spawning and to survey all areas north of this. The deployment of vessels to areas and periods is summarized in Table 6.1.2 (Annex 5).

In 2013 the peak of mackerel spawning occurred in March, in the Bay of Biscay, however in 2016 it occurred in May, to the west of Scotland. Due to the expansion of the spawning area that has been taking place since 2010 the emphasis in 2019 will once again be focused on maximizing area coverage. Cruise leaders will be asked to cover their entire assigned area using alternate transects and then use any remaining time to fill in the missed transects. If time is short, this should be concentrated in those areas identified as having the highest densities of egg abundance. Particular points to note are:

Period 1

Only the southern area, division 27.9.a to the west of Portugal, will be surveyed in period 1. This will be the Portuguese DEPM survey, which will also extend into period 2, (Annex 6, figure 6.1.1).

Period 2

Portugal will continue their DEPM survey in division 27.9.a.

Period 2 marks the commencement of the western area surveys. As a result of the early spawning encountered in 2013 the timing of this period in 2016 was moved earlier in the year to commence at the beginning of February. It was hoped that this would help capture the start of mackerel spawning in the western area. As it turned out spawning in 2016 was later than in 2013 with peak spawning also taking place much further north. For 2019 it has been decided to retain the same start dates as for the 2016 survey. The Irish survey therefore will commence at the beginning of period 2 covering the Bay of Biscay, the Celtic Sea, and to the west of Ireland, initially sampling on alternate transects. Scotland will be undertaking their IBTS survey off the west coast of Scotland and has allocated some effort to MEGS sampling, (Annex 6, figure 6.1.2).

Period 3

Period 3 surveys will be carried out by Spain (IEO), Spain (AZTI), Germany, and Scotland. IEO will survey in the Cantabrian Sea and the southern Bay of Biscay. AZTI will survey the northern part of the Bay of Biscay not covered by IEO. Germany will cover the Celtic Sea and the west of Ireland. Scotland will survey the area west of Scotland, as well as northwest Ireland, (Annex 6, figure 6.1.3).

WGMEGS have undertaken to collect additional adult DEPM samples in periods 3 and 4 for mackerel, and instructions for collection of these samples can be found in section 5.3. It is also especially desirable that as far as is possible comprehensive survey coverage is achieved within this enhanced area and this should be the prime consideration when completing the second sweep of the survey area during this period.

Period 4

During period 4 sampling will be carried out by three vessels. IEO will carry out their second survey in the Cantabrian Sea and south of the Bay of Biscay. Germany will sample in the north of the Bay of Biscay, the Celtic Sea and west of Ireland. Denmark will sample to the west of Scotland and northwest of Ireland, (Annex 6, figure 6.1.4).

Mackerel DEPM sampling will continue within period 4.

Period 5

In period 5 AZTI will conduct a targeted DEPM survey for anchovy in the Cantabrian Sea and the southern Bay of Biscay; the design of the survey is therefore constrained by that purpose. This survey does however provide data on mackerel and horse mackerel egg numbers. Netherlands will sample in the northern part of the Bay of Biscay and the Celtic Sea to the southwest of Ireland. Scotland will survey to the west of Ireland and Scotland. In addition the Faroe Islands and Iceland will each provide a 2 week survey which will cover the area to the north of 58° 30′N. Iceland will survey the area west of 11° 30′W whilst the Faroese will survey eastwards of that line, (Annex 6, figure 6.1.5). These survey areas are provisional and definitive survey areas, as well as starting positions, will be provided by the survey coordinator and will largely be dependent on what is observed in period 4. Providing adequate survey coverage during this period will be challenging.

Period 6

In period 6 three vessels will survey the area between the Bay of Biscay and the Northern area.

Netherlands will survey in the Bay of Biscay and the Celtic Sea with Ireland surveying west of Ireland and west of Scotland. Norway will survey north of 58° 30′N, and will continue sampling through the Faroes / Shetland channel, and along the Norwegian coast. This will be an exploratory component of the survey and will test whether mackerel spawning extends up along the Norwegian coast. As in period 5 this will expand the survey range and attempt to secure a northern boundary within this period, (Annex 6, figure 6.1.6). The Dutch vessel will commence the survey along the southern boundary of the designated area although its exact latitude will depend on the results from period 5.

In 2019, as with the mackerel in periods 3 and 4, WGMEGS have undertaken to collect additional adult horse mackerel DEPM samples during periods 6 and 7, and information and instructions pertaining to the collection of these samples can be found in section 7.2. As with periods 3 and 4 however every effort should be made to achieve as comprehensive coverage as is possible within this enhanced area.

Period 7

In period 7, only one vessel will be available, and will have to cover the entire spawning area. This assignment will be undertaken by Scotland. As with period 6 the southern boundary (starting location) will be dictated by the results of the previous period. Irrespective of this an alternate transect design will be necessary, (Annex 6, figure 6.1.7).

Horse mackerel DEPM sampling will continue during this period.

6.3 Sampling Areas and Sampling Effort

As in 2016 it was decided that the spatial and temporal distribution of sampling would be designed to ensure maximum coverage of both mackerel and horse mackerel spawning and that estimates of stage 1 annual egg production would be made for both species.

Since the surveys were started in 1977 considerable changes have been made to the standard sampling area and these have been described in Section 8.4 (ICES, 1994). In 1995 changes were made to the western boundaries of the western area because of the unusual westerly distribution of mackerel eggs which occurred in period 3, 1992 (ICES, 1996). Examination of the 1995 egg distributions prior to the 1998 survey resulted in the addition of further rectangles to the standard sampling area. A total of eight rectangles were added at the northern edge and twenty-five on the western edge between latitude 45° 30′N and 51°N (ICES, 1997). Examination of the 1998 survey data showed that the distribution of mackerel and horse mackerel spawning in both the western and southern areas was adequately covered with the exception of mackerel spawning from mid-May to July at the northern edge of the western standard area. As a result, some additional rectangles were added to the standard area north of latitude 58° 30′N.

Based on this steady growth of the "standard area" every survey, the Working Group agreed at the Dublin meeting (ICES, 2002) to reconsider its use. It was agreed that the existing "standard area" should be retained only as a guide to the core survey area for cruise leaders, and that the extent of coverage should be decided based on finding the edges of the egg distribution only, i.e. boundaries should be set based on the adaptive sampling guidelines (Annex 6). The core areas for the western and southern surveys for both species are presented in figures 6.3.1 and 6.3.2 in Annex 6. A more detailed survey map of the Iberian areas as surveyed by IEO and IPMA can be found in figures 6.3.3 and 6.4.1 (Annex 6). Section 5.1.4 also provides a description of the Portuguese DEPM survey.

The sampling area in the south has been modified from the design used in 2001 and previously. The stations have been placed closer together in the onshore/offshore direction and further apart in the alongshore direction. As stated above the limits of the survey in both areas should be established on the basis of two consecutive zero samples, and not by the boundaries on this map.

6.4 DEPM survey for the southern stock horse-mackerel

Since 2007 IPMA have adopted the DEPM - Daily Egg Production Method, for horse-mackerel of the Southern stock (ICES division 27.9.a - Gibraltar-Finisterre) and have developed and implemented several aspects of the methodology since. Modifications introduced included the plankton sampling gear and design, and laboratory and data analyses developments for egg and adult samples (e.g. Cunha et al., 2008; Gonçalves et al., 2012; SISP 5, 2014; Angélico et al., 2015; Mouchlianitis et al., 2018).

The DEPM survey will take place during January-February 2019 (provisional dates: 17th Jan-20th Feb), onboard RV Noruega covering the area from Gibraltar to Finisterre (Annex 6, figure 6.4.1). A detailed description of the standardized methodology is included in the WGMEGS SISP survey manual (SISP 5). Surveying for adult horse mackerel will take place simultaneously to the ichthyoplankton sampling.

Data analyses will be undertaken using adapted versions of the R packages (geofun, eggsplore and shachar) available at ichthyoanalysis 5 (http://sourceforge.net/projects/ichthyoanalysis) and routines developed at IPMA.

7 Planning and sampling programme for the mackerel and horse mackerel AEPM and DEPM adult parameters (ToR b)

7.1 Sampling for mackerel fecundity and atresia in the Western and Southern areas

A preliminary version of the sampling scheme for the 2019 survey has been prepared, this will be finalized at the WKFATHOM Fecundity workshop in November 2018. For the mackerel DEPM samples the sampling periods have been changed from period 2-3 (February-March) to period 3-4 (March-April) based on the results of peak spawning from previous surveys, and results of the PELACUS (Riveiro et al., 2017) surveys in 2017 and 2018.

The samples that need to be collected are the same as before. Fecundity and atresia samples are currently fixated in 3.6% buffered formaldehyde. There are other fixatives, based on ethanol, available which would be better to use with regards to health issues. During the 2017 North Sea egg survey a first trial was carried out. Based on those initial results it was decided to further test the use of the ethanol based fixatives. Survey participants will be asked to collect some extra samples for this investigation. Details of the sampling will be finalized at the WKFATHOM and published in the updated survey and fecundity manuals.

The fecundity samples will still be taken with the pipettes.

7.2 Western horse mackerel DEPM adult parameter sampling

Western horse mackerel sampling will still be carried out in period 6-7 (June-July). The amount of samples to be collected is the same as in 2016 and no AEPM samples for horse mackerel will be taken.

7.3 DEPM sampling for mackerel

WGMEGS decided to continue with the collection of adult samples for the DEPM method as an alternative to samples for the AEPM for mackerel. For the AEPM method to be valid the fecundity type must be determinate. In the paper of Greer-Walker *et al.* (1994) it was concluded that for practical purposes the mackerel could be considered to have a determinate fecundity type. However, there is evidence to suggest mackerel is indeterminate (ICES, 2011; ICES, 2012).

WGWIDE (WKMSPA, 2012) has asked for a time-series of 5 points before changing the AEPM method to DEPM for western and southern mackerel. For the 2013 and 2016 egg surveys, the DEPM adult parameter data are available. Mackerel SSB will be estimated, including variance, using the DEPM method for the two surveys, being the first two points of the DEPM time-series to compare with AEPM SSB. The results will be presented during the 2020 WGMEGS meeting.

The future DEPM estimations for the 2019, 2022 and 2025 egg surveys, will be improved, based on the experience from the earlier surveys.

- DEPM adult samples in 2013 and 2016 were taken under the AEPM sampling schedule, adapting this scheme in number and frequency during the peak spawning. Due to this, the actual number of ovary samples obtained has been lower than requested. A revision on the amount of samples needed for a correct spatial and temporal coverage of the spawning area for DEPM estimations is highly recommended.

- For histological screening currently an ovary spoon sample is used to prepare the slides. An evaluation of the quality of these slides compared to slides made from full sections of the ovary will be carried out before the WKFATHOM. A more detailed data template for the histological screening recording relevant data for DEPM has been developed.

The issues described in this section will be addressed at WKFATHOM in November 2018. Intensive training, ring tests, comparison between different methods and other appropriate issues need to be addressed. An action plan is drawn up for the upcoming period until the WKFATHOM 2018.

8 Year of the mackerel project

Background

The initiative of Martin Pastoors (PFA, Pelagic Freezer-trawler Association) 'Year of the Mackerel' was discussed during the WGMEGS meeting. Two things are of interest to WGMEGS:

1. The sector has been collecting data on the length and condition of mackerel.
2. Throughout the year PFA vessels catch mackerel either as target species or as bycatch.

Point 1

During the Skype meeting Martin Pastoors agreed to investigate which mackerel data are collected by the industry and could be made available for WGMEGS.

Point 2

The year-round availability of mackerel in the catches of the commercial fleet provides an excellent opportunity to obtain more information on oocyte development, especially outside of the spawning season. As well as this there is an opportunity to look deeper into gonad development of the males. The fish being caught on the trawlers are for human consumption, which creates restrictions for the collection of samples, i.e. the usage of formalin or other fixatives on board is not allowed. However, it is possible for some of the crews to collect and freeze fish and the gonads separately.

Wageningen Marine Research tested the use of frozen mackerel ovary samples for oocyte analyses from the 2017 North Sea mackerel egg survey. The results looked promising, although not as good as with immediate fixation of gonads in formaldehyde, but good enough for the aim of the 'Year of the Mackerel' project to follow oocyte development throughout the year.

PFA and Wageningen Marine Research will carry out a pilot project in 2018 for the collection and proper storage of samples on board the vessels. A more detailed plan will also be developed and the aim is to carry out the 'Year of the Mackerel' project in 2019. It is not foreseen that data from this project will feed directly into WGMEGS. But this project will provide a better insight into mackerel reproductive biology and help with the question as to whether mackerel is a determinate or indeterminate spawner. It is expected that Wageningen Marine Research will need help from other institutes for the analyses of the samples.

9 Review procedures for egg sample sorting, species ID, staging, data submission and subsampling (ToR c, e) including update of manual

The procedures for egg sample sorting, species ID, staging, data submission and subsampling were reviewed and published in 2014 as SISP 6 (Series of ICES Survey Protocols) Manual for the Mackerel and Horse Mackerel Egg Surveys (MEGS): sampling at sea.

During the 2018 WGMEGS meeting the manual was again reviewed and revised where necessary. The main changes are:

- It was decided by the group that the manual needs to be streamlined and generalized without references to the actual planning of the next survey. Therefore, the chapter on "Planning of the 2016 mackerel and horse mackerel egg survey in the Western and Southern areas" was taken out. Also, the chapter on the standardization of the adult parameter was revised in this view;
- The tables on the sampler specifications used in the Western and Southern areas were updated and amended;
- A chapter on clogging was amended;
- References on egg identification literature were added;
- Information and references on Scomber colias were updated and appended;
- New findings on the spraying method regarding hake were added.

The manual will be finally updated after the egg identification and staging workshop in autumn 2018 in order to add possible amendments identified during WKFATHOM.

10 Review procedures for fecundity, batch fecundity, spawning fraction and atresia estimation (ToR d)

The WGMEGS Manual for the AEPM and DEPM estimation of fecundity in mackerel and horse mackerel (SISP 5) was reviewed in during the meeting and will be finalized at the WKFATHOM workshop.

Most of the changes considered are minor, and concern in particular:

- Description of fecundity and batch fecundity throughout the report/manual for clarification;
- Update screening sheet template;
- Update the templates including "period" column;
- Include a protocol for uploading data to FTP-server;
- The FTP-site needs a better folder structure and a short protocol how it should be used and where which data should be stored;
- To prevent problems at the customs, during the interchange of samples, it is strongly advised to explicitly indicate 3.6% formaldehyde (not the 40%!) on the pro forma invoice. The samples should be sent as a parcel and to a home address, not a postbox;
- Collect extra samples for the Norwegian CLIMRATES project.
  During the 2019 mackerel and horse mackerel egg survey, extra samples of mackerel ovaries will be collected for the CLIMRATES project (Climate vital rates of marine stocks). The aim of the project is to estimate the oocyte packing density (OPD). It is therefore not possible to utilize the standard samples collected for the MEGS fecundity and atresia analyses. Thus, extra mackerel are requested to be sampled during the 2019 egg survey. Approximately 100 ovaries per period throughout the sampling/spawning area will need to be collected. Ovary samples can be collected in one or more trawl hauls. The sampling protocol will be similar to the one applied for the specific MEGS fecundity and atresia samples, but only the part regarding to screening and atresia analysis (Annex 6, figure 10.1), i.e. one lobe should be preserved in 3.6% buffered formaldehyde and a 2-3 g sample of the other lobe preserved in a small vial (with 3.6% buffered formaldehyde) for histology. Biological measurements to be taken are the same as for the standard MEGS samples. The standard sheet for the biological measurements can be used. Labels and samples codes will be provided before the survey. After the survey, the samples should be sent to the Institute of Marine Research (Bergen – No) care of Thassya dos Santos Schmidt;
- Use of slide scanner for atresia analysis;
- IMR has a slide scanner and all analysing institutes will send the atresia slides to IMR to take the images from the slides in a coherent way. This will save analyses time and more importantly all will be using the same magnification and field of view. The slide scanner could also be useful for the screening samples;
- Introduce detailed description of all analysis and statistics and sharing R-scripts;
- Comparison of parallel batch fecundity samples to test variance within ovaries. For some fish both batch fecundity samples will be analysed to check for the variance and whether the sample is big enough for batch fecundity;
- POF staging and other issues ring tests before WKFATHOM;

- Evaluate the potential use of the fecundity trimmed mean instead of the median by reanalysing comparatively series data. This will help to obtain confidence intervals for the realized fecundity estimations.

The fecundity and atresia manual will be finalized at WKFATHOM.

11 Analysis of fecundity estimation using MEGS fecundity database

A database template was compiled of all biological data collected from 1987 to 2016. One should be aware that North Sea component is also presented in this database.

Additionally, fecundity and atresia data, 2001, 2007 to 2016, were combined in one single database following the format recommended in the last WGMEGS report (Tables 5.14.2 – Table 5.14.7 in ICES 2017). A review of the data in this database is recommended.

At the time of the meeting the format for the ICES fecundity and atresia database was not ready yet. However, the ICES Data Centre has taken note of the WGMEGS 2017 recommendation with regards to this database. The ICES Data Centre has confirmed that the preparation of the fecundity and atresia database is on the workplan for 2018. The aim is to have a first version of this database format ready to be discussed at the next meetings of WGALES and WKFATHOM.

11.1 Analysis of Fecundity and Atresia mackerel database. Relative potential fecundity

A review of reported mackerel fecundity parameters from 2001 onwards was carried out in order to see if there was any trend or pattern in mackerel fecundity over the time-series.

Until 2004 realized fecundity for NEA mackerel was estimated for both Western and Southern spawning components and significant differences in fecundity were found between both components. But from 2007 onwards realized fecundity in the combined spawning components have been estimated (Annex 6, figure 11.1.1).

It was additionally agreed by WGMEGS in 2013 to estimate relative potential fecundity using the median instead the arithmetic mean (traditional methodology) in order to have a robust estimate of relative potential fecundity and to avoid any bias from extreme data (outliers).

In this work a recalculation of relative potential fecundity using the MEGS fecundity database was performed. Currently the MEGS fecundity database has only fecundity data from 2001 onwards. Unfortunately fecundity data for 2004 are not available.

The spatial and temporal distribution of relative potential fecundity samples seems to be appropriate (Annex 6, figure 11.1.2). Relative potential fecundity using both arithmetic mean and median was calculated.

A comparative plot showing recalculated values of mean and median and reported value of relative potential fecundity was performed. Significant mismatches were found in the 2001 data between reported relative potential fecundity and arithmetic mean and median estimates. This mismatch may be due to the fact that in the current MEGS fecundity database there are no samples from Southern component in 2001. (Annex 6, figure 11.1.3 and Annex 5, Table 11.1.1).

The median for relative potential fecundity is close to the arithmetic mean in most years. The largest difference is in 2013 but the median is inside the confidence interval of the potential fecundity arithmetic mean. (Annex 6 figure 11.1.4 and Annex 5, Table 11.1.2).

12 Analysis and evaluation of the results of the 2017 mackerel egg survey in the North Sea (ToR f)

12.1 Results of the 2017 mackerel egg survey in the North Sea

In 2017 Netherlands was again the sole survey participant. In order to get an adequate coverage of the spawning season in time and space, the Dutch government decided to again fund one extra survey week. From 22th May – 16th June 2017 Netherlands carried out an egg survey in the North Sea to estimate the mackerel total annual egg production (TAEP) and spawning-stock biomass (SSB). During this period the spawning area was covered four times (Annex 5, Table 12.1.1). The survey is designed to cover the entire spawning area with half ICES rectangle samples (ICES, 2014). However with one vessel the entire spawning area can only be covered using the alternative transect method (Annex 6, figures 12.1.1-12.1.4).

The previous mackerel egg survey in the North Sea was in 2015. The samples were collected and analysed according to the WGMEGS manual (SISP 5). Wageningen Marine Research on board R.V. Tridens carried out the survey with a Gulf VII plankton sampler with a 500 μm plankton net performing double oblique hauls from the surface to 5 m above the bottom or 20 m below the thermocline. Temperature and salinity where measured during the haul with a Seabird CTD mounted on top of the Gulf VII plankton sampler. Two Valeport electronic flowmeters and an altitude sensor were mounted on the plankton sampler to monitor flow, clogging and sampling depth.

During period 3 (Annex 6, figure 12.1.3) a summer storm, and technical problems caused by the storm, hampered the sampling severely and only 35 plankton stations could be sampled during that period. In other periods the weather was excellent and coverage could be maximized as far as the speed of the vessel allowed.

The temporal and spatial egg distribution is shown in Figures 12.1.1-12.1.4 in Annex 6 for each of the four individual cruises. The standard interpolation rules (SISP 5) were applied (see interpolated rectangles in Figures 12.1.1-12.1.4 in Annex 6) for the within period interpolation. Because very few stations were sampled in period 3 it is not possible to do a reliable period production estimation. This has not occurred before and the WGMEGS manual has no protocol for this situation. In the western area survey periods have been expanded when the coverage of the area was not complete. For this North Sea survey it was decided to add the period 3 samples to period 2 and extend the time period of period 2 (Annex 6, figure 12.1.5). Thus this year's North Sea survey has 3 periods.

The interpolated egg production values accounted for 45%, 25% and 38% for the three periods respectively. The spawning distribution is comparable to previous surveys and the main spawning still occurs in the southwestern area. The egg production curve shows that the peak of spawning was in period 2 (Annex 6, figure 12.1.6). However, with the small number of stations sampled in period 3 and some higher egg numbers in the southwest area in period 3 it is uncertain if the peak in 2017 was in period 2 or 3. This year the first period sampled already showed a high egg production (Annex 6, figure. 12.1.6). It is likely that spawning has been missed at the start of the spawning season. Also it is questionable if the start of the spawning period in the North Sea is still day 139, because of the steep rise in the egg production curve (Annex 6, figure. 12.1.6).

The egg production was calculated for the total investigated area for each of the periods (Annex 5, Table 12.1.1 and Annex 6, figure 12.1.6). Egg production decreased from period 2 to 4. The survey probably covered the peak of spawning, but some spawning may have been missed after period 4. Based on the four coverages the spawning curve was drawn (Annex 6, figure 12.1.6). Usually the egg production is underestimated due to the fact that neither the spawning area nor the spawning period can be fully covered during the available ship time.

Five trawl hauls were carried out by R.V. Tridens to collect adult mackerel fecundity and atresia samples. One haul was empty, but the other four contained mackerel. In total 100 mackerel females were sampled during the survey. To collect prespawning females for potential fecundity sampling, another 200 females were collected from commercial sampling. Samples from the industry were collected in early May, as early as 5th May. The commercial and survey samples were screened for the oocyte development. Unfortunately, all sampled females, except for 2, contained spawning markers (migratory nucleus or hydrated oocytes). It was therefore not possible to estimated potential fecundity, as prespawning females are necessary for that. A new realized fecundity estimate was again not possible. Therefore the total fecundity estimate, 1401 eggs/g female, from previous surveys has been used for the calculation of SSB (Iversen and Adoff, 1983).

By integrating the egg production curve over the "standard spawning time", 17th May-27th July, the total egg production was estimated at 201*1012 eggs. This was higher compared to the estimation of 2015. The SSB was estimated at 287,293 tonnes. SSB was higher compared to 2015 (Annex 5, Table 12.1.2).

Both the steep start of the egg production curve in 2017 and the early ovary samples showing spawning markers, suggest that start of the spawning season should be earlier than day 139. The earliest ovary samples, collected at day 125, showed spawning markers. Moving the start day to 125 has an impact on the annual egg production and SSB estimates (Annex 5, Table 12.1.3; figure 12.1.7 in Annex 6).

The assessment of total egg production and SSB for North Sea mackerel was moved to the Netherlands, when they were the only survey participant. There is no good description available of the estimation, nor the actual results of the different steps in the calculation process. The current egg production and SSB estimated are as described in the MEGS manual (SISP 5), but it needs to be checked if using this method for the survey data prior to 2015 would yield different results. It has not been possible to carry out this comparison.

The WG recommends that the survey effort should be increased to secure a proper coverage of spawning area and time and to carry out a sampling program for fecundity. The second half of the spawning period no sampling is available. The assumption that spawning ceases linearly is questionable, as can be seen at the spawning curves from past surveys.

12.2 North Sea MEGS in 2020

Because of the limited participation in the North Sea mackerel egg survey, it will again not be possible to cover the entire spawning area both in time and space. The results of the 2017 survey indicated that spawning commences even earlier compared to before thus the coverage problem is increasing. Denmark is considering participating in the 2020 North Sea egg survey. However, this is uncertain at the moment and even including the Danish participation, this will still not be enough to cover the full spawning season.

WGMEGS has been investigating using the DEPM in all stock components since 2012. Mackerel is an indeterminate spawner and the DEPM might be more appropriate. In the North Sea, switching to a DEPM for survey is less complicated compared to the western area, because the spawning area is more confined both spatially and temporally.

As a result WGMEGS concluded that the best option for the North Sea survey would be to use the DEPM rather than AEPM method. The DEPM would only require one full coverage of the spawning area over a shorter time period. However, this method also requires a large number of adult samples to be collected and analysed.

The final decision and the planning of the survey will be conducted during the 2020 meeting of WGMEGS.

13 Analysis of MEGS egg survey time-series

An analysis utilizing time-series of MEGS egg surveys was carried out in order to have a historical perspective of whole time-series for MEGS egg surveys (1992-2016). Graphs of this analysis are presented in Annex 6.

An expansion of the spawning time and area of NEA mackerel stock has been noticed in the recent years. This expansion resulted in an increase of survey effort for participants in MEGS surveys in order to monitor the complete spawning area and throughout the entire spawning season.

As a result of this, there has been an increase of about 15 % of the surveyed area in the last 3 surveys compared to surveys prior to 2010. The western spawning component area is about 90% of the entire surveyed area (Annex 6, figure 13.1).

Such an increase in area is even higher in the last 3 surveys (27%) if the total geographical scope of these surveys is considered, i.e. including sampled and interpolated rectangles. During the latest MEGS (2016), the survey's geographical scope was 3.84 million square kilometers, although the sampled survey area was only 2.92 million square kilometers. (Annex 6, figure 13.2).

This meant a significant increase in the utilization of spatial interpolation (interpolated area) of daily egg production for the unsampled area in recent surveys due to the increase of the spawning time and area that was not matched by an appropriate increase in available ship time (Annex 6 figure 13.2).

There has been an increase of 20 % in surveys days (ship days) in the recent surveys (Annex 6, figure 13.3). But considering only the effective surveys days (actual sampling days) excluding steaming days, days lost due to poor weather conditions, operational vessel days, it becomes apparent that actual sampling days have remained broadly stable since 2001 (Annex 6, figure 13.4).

For the Annual Egg Production Method, the spatial and temporal distribution of sampling is designed to ensure a representative coverage of whole spawning season. However, if the sampling design is not able to completely cover the whole spawning period and area at the desired resolution, spatial and temporal interpolation techniques have to be applied in the estimation of daily and annual egg production.

Mackerel: Western and Southern components

Over the MEGS egg survey time-series, positive (area with presence of mackerel eggs) was mostly between 50% and 60% of the complete surveyed area (Annex 6, figure 13.5). That positive area remained fairly stable over the entire time-series.

In last surveys, there has been a significant increase in the use of spatial interpolation in order to estimate daily egg production into unsampled areas. In recent surveys, more than 34% of the positive area was estimated using spatial interpolation for the Western component and about 11% for the Southern component (Annex 6, figure 13.6).

Regarding mackerel daily egg production, in last 3 surveys about 16% of annual egg production has been estimated using spatial interpolation for the Western component and about 1% for Southern component (Annex 6, figure 13.7).

Further it has to be noted that a temporal interpolation in order to estimate the mackerel annual egg production is used. Temporal interpolation involves the use of egg production in each sampling time period to calculate egg production of the unsampled time periods (inter-period). In recent surveys less that 5% of annual egg production has been estimated using temporal interpolation for the Western spawning component and about 30 % for the Southern spawning component (Annex 6, figure 13.8).

Western horse mackerel

A significant decrease of positive area was observed for horse mackerel eggs over the time-series. There were horse mackerel eggs in 17% of total surveyed area in the last survey (2016) (Annex 6, figure 13.9).

The use of spatial interpolation in estimate of horse mackerel annual egg production is relativity high (about 25%) in the last 2 surveys (Annex 6, figure 13.10). And use of temporal interpolation was about 18% of total egg production in the last 2 surveys (Annex 6, figure 13.11).

14 2017/2018 Interrim Survey Results

14.1 2017 mackerel egg exploratory survey

At the 2017 WGMEGS meeting in Vigo members were asked to provide any additional information on spawning in 2017 and 2018 which could assist in the planning of the 2019 surveys. Ireland organized a 14 day survey on a 45m vessel, Girl Stephanie, to survey west of Hatton bank, south of Iceland and in the Faroe / Shetland channel. Stations were sampled to a depth of 100m using a GULF 7 sampler. Sixty stations were carried out over 2800 miles. Eggs were identified and staged according to MEGS protocols. Results were presented as stage 1 mackerel eggs/m2/day. Stage 1 eggs were found at 80% of the stations sampled but generally numbers were very low.

14.2 2017 Nordic sampling

To expand the sampled area additional plankton samples were also collected by both the Faroe Islands and Iceland during their IESNS surveys in May, in the areas between Iceland and Shetland, using a WP2 net. GULF VII samples were also collected by Iceland during their spring capelin survey, also in May, and a further 11 samples using the WP2 net on the IESSNS survey in mid-July. The IESNS samples contained no mackerel eggs, whilst the majority of the stations from the Icelandic spring capelin survey recorded either zero or very small numbers of eggs, in single figures. Three stations however, two on the south coast and one on the southwest coast of Iceland, recorded stage 1 mackerel numbers per m2 per day of between 12 and 25. Only one station on the IESSNS survey in July contained any mackerel eggs.

14.3 IEO Surveys – Cantabrian Sea

IEO-Spain carried out two pelagic spring surveys in the Cantabrian Sea: the PELACUS acoustic survey which is an annual survey and the SAREVA DEPM-sardine survey which is undertaken on a triennial basis, both in March-April. In contrast to the conditions observed in 2016, when weather and oceanographic conditions were cooler and relatively unsettled, the 2017 spring surveys sea surface temperature was higher and this has had an important effect on mackerel and horse mackerel and subsequently also mackerel eggs (collected with CUFES and CalVET). The result being that in 2017 both were much more abundant and also more widely distributed than in 2016. Preliminary mackerel egg results for the 2018 PELACUS mackerel also show a good agreement in egg abundance and distribution when compared with 2017.

14.4 Conclusions and future work in 2018

The Northern exploratory survey was not a comparative survey and because the dates spanned a temporal period that straddled both periods 5 and 6 from the 2016 survey, any direct comparisons are difficult. In addition the areas sampled during the 2017 survey were not generally the same as those covered during the 2016 triennial survey. The main premise behind the exploratory 2017 survey was to survey in those areas around the margins of and beyond what was achieved by the triennial survey in 2016. However, it should be noted that where there was an overlap in survey stations between the two surveys, the 2017 estimates are generally lower. Spanish results from the Cantabrian Sea in March 2017 also indicate that mackerel spawning in 2017 returned to a pattern consistent with that reported during the 2010 and 2013 MEGS surveys, with significant spawning taking place early in the year and in southern waters, rather than that reported in 2016, when the temperature was exceptionally low. It is tempting to speculate that 2016 was something approaching an anomalous event, however recent surveys provide evidence that such fluctuations in behaviour may well become the norm.

The Northern exploratory survey was successful in answering several survey related questions. First, the expected drop in temperature as the surveys proceeded northwards provided a natural barrier to mackerel spawning, with no stage 1 mackerel eggs being recorded in any of the sampled stations where the temperature at 20m was less than 8 degrees Celsius. A small amount of caution should be applied when interpreting results from the WP2 stations, for although the observations are indeed valid and valuable, the volume filtered by these vertical samplers is much less than for a Gulf 7 which samples obliquely. Nevertheless it would appear sensible to assume that in the region stretching from the East coast of Iceland across to the Faroe/Shetland channel that the Northern boundary used by MEGS should be relatively secure with very little mackerel spawning taking place at that time of year at latitudes North of the Faroe Islands. To the south of Iceland the situation is a little less clear and requires further investigation. This will be the focus of another similar survey to be undertaken in May/June 2018 by Scotland (see figure 14.4.1 in Annex 6 for proposed survey track). This survey will concentrate on the area to the west of Hatton Bank and the Iceland Basin and hopefully provide evidence as to whether during the months of May and June the mackerel are choosing to avoid the relatively oligotrophic waters of the Iceland Basin in favour of the narrow corridor along the south coast of Iceland (Pacariz et al., 2016). As previously mentioned the knowledge gleaned from this, as well as from the 2017 surveys will be extremely useful during the planning process for the 2019 triennial survey.

15 Recommendations

15.1 Replies to WGALES recommendations

1 → WGALES recommends that all ichthyoplankton survey groups should check their survey manuals as to whether clogging and other data quality issues are dealt with and sufficient protocols are in place. Survey manuals should be revised accordingly.

Reply of WGMEGS: Clogging has been observed several times at various intensities and frequencies during previous egg surveys. Measures to deal with clogging, in particular with respect to adjustment of fish egg abundance estimates, are currently not in place. WGMEGS acknowledges that clogging can have a biasing effect on the sampling results because the desired, even sampling of the water column can be severely affected. However, the group concluded that the potential error is difficult to quantify without a thorough analysis of sampling results in conjunction with accessory sampling data, which are currently not being collected. The necessary data will be collected during the 2019 survey and will be analysed. Results will be presented at the 2020 meeting.

2 → WGALES recommends exploration and testing of new methods for estimating spawning fraction alternative to the postovulatory follicle (POF) method. These methods should be more cost-effective and less labour-intensive and applicable to any kind of spawners.

Reply of WGMEGS: Spawning fraction estimation was a new analysis for the 2013 and 2016 DEPM exercise. Staging of post ovulatory follicles turned out to be a difficult task to perform in a uniform way. For the 2019 survey the focus will be on how to improve this sample analyses. A subgroup of WGALES, including WGMEGS members, is investigating alternative methods to estimate spawning fraction. This subgroup will present results during the 2018 WGALES meeting. Results from this project will be discussed during the WKFATHOM 2018 in November and incorporated in the protocols for the 2019 egg survey.

15.2 WGMEGS Recommendations

The list of the 2018 WGMEGS recommendations is given in Annex 2.

16 Next meetings

The meeting for year 2 as well as the preparation of the respective interim report will be done chiefly by correspondence. However, a WGMEGS subgroup will meet shortly before the 2019 WGWIDE meeting to collate the preliminary survey results and prepare the final version of the interim report.

The meeting for the final year of this term will be held in Madrid. The proposed dates are 27th April – 1st May, 2020. The dates are, however, subject to further negotiation because of the public holiday on 1st May.

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Annex 2: Agenda

Monday 9 April

09:00 Start; General announcements; Introduction;

09:30 Request from EOSG chair to fill in FutureSurveyRiskForm

10:00 Coffee Break

10:15 Presentations:

3. Results of CEFAS study on MEGS ichthyoplankton (Hayden)
4. Adding Value to Triennial surveys: Spawning grounds of Northern European hake stock in 2016. Is the hake EP a good proxy of SSB (Paula)
5. Results from the stand-alone survey on a chartered vessel (Fin, Brendan)
6. Results from WP-2 sampling in Faroese and Icelandic waters in May – June/July during IESNS and IESSNS (Björn)
7. Results from IEO surveys including PELACUS, SAREVA and RADIALES (NN)
8. Analysis of MEGS effort across years (Gersom)
9. WGISDAA Suggestions and Recommendations (Matthias)
10. A review of fecundity estimation based on fecundity basic data (Gersom)

12:30 Lunch break

13:15 Continuation of morning presentations (see list above)

Discussion of morning presentations: The implication of the presented results for the planning of the 2018 between survey years and the 2019 survey

15:00 Coffee break

15:15 Presentation: Atlantic mackerel daily spawning dynamics and implications for batch fecundity (Lola)

15:30 Presentation: Mackerel fecundity time-series and related issues (Thassya)

16:00 Plenary discussion on quality of adult parameter data in mackerel and horse mackerel. The "year of the mackerel" industry proposal – video conference necessary.

17:15 Collation of prospective survey times by country/institute (have them ready, everyone!!!!)

17:30 End of the day

Tuesday 10 April

09:00 Planning and coordination of the 2019 egg survey, ToR a

10:00 Coffee break

10:30 Planning and coordination of the 2019 egg survey, ToR a

12:30 Lunch

13:15 Continue planning and coordination of the 2019 egg survey, ToR a

15:00 Coffee break

15:15	Continue planning and coordination of the 2019 egg survey, ToR a
17:30	End of the day

Wednesday 11 April

09:00 Split into subgroups:

a) Ichthyoplankton methodology

b) Fecundity and atresia methodology

and work on the following ToRs

Group a:

1. Review and report on procedures for egg sample sorting, species identification and staging (ToR c)
2. Review and update the survey manual, considering in particular recommendation "WGALES 1" and make recommendations for the standardization of all sampling tools, survey gears and procedures (ToR e)

Group b:

1. Coordinate the planning of the sampling programme for mackerel/horse mackerel fecundity and atresia (ToR b)
2. Review and report on procedures for fecundity and atresia estimation (ToR d)
3. Review and update survey manual fecundity-sampling chapters and the fecundity and atresia manual, considering in particular recommendation "WGALES 2". Make recommendations for the standardization of all sampling tools, survey gears and procedures (ToR e)

10:00	Coffee break, continue group work afterwards
12:30	Lunch
13:15	Presentation: Results of the 2015 and 2017 mackerel egg surveys in the North Sea (ToR f, Cindy)
13:30	Plenary discussion on the future of the North Sea mackerel egg survey
15:00	Coffee break
16:00	Video conference with Martin Pastoors on industry commitment and year of the mackerel.
17:30	End of day

Thursday 12 April

09:00	Presentation: DEPM results from 2013 and 2016 MEGS: SSB estimates in comparison to AEPM results (Cindy)
09:30	Discussion: Continuation of DEPM exercise during the 2019 MEGS?
12:30	Lunch
13:15	Future or WGMEGS: Keeping and/or improving the quality of the support for advice on mackerel and horse mackerel stocks.

- Work with WGISDAA on our own recommendation on improving the interpolation methods.
- Survey design, independent of varying changes in spawning behavior of both target species at limited resources
- Databases
- Cooperation with other surveys

15:00	Coffee break
15:15	Report writing
17:30	End of day

Friday 13 April

09:00	Multi-annual ToR's update and Recommendations, WKFATHOM
09:30	Report writing (based on ToR's and presentations)
10:00	Coffee break
10:15	Report writing
12:30	End of meeting

Annex 3: Recommendations

Recommendation	Addressed to
1. WGMEGS recommends that the egg stages in the ICES fish egg and larvae database are referenced to the MEGS manual, published as SISP 6 by ICES 2014, instead of using the current TR1 and TR2 codes which do not reflect the MEGS stages correctly.	ICES data centre DIG
2. The group reiterates the need to continue with the egg identification/staging and fecundity workshops prior to the egg surveys. WKFATHOM are crucial refreshers for scientists and technicians who participate in the triennial egg surveys. Therefore, WGMEGS recommends that all survey participants and/or sample analysts should participate in the workshops.	MEGS participants WGBIOP
3. WGMEGS recommends that the following work is conducted during the next survey in 2019: Participants are if possible urged to continue the mackerel egg development experiments as undertaken by both Lockwood and Mendiola with the results being presented to WGMEGS 2020. Participants should attempt to compile photos and obtain egg samples from fertilization experiments and produce comparative egg descriptions for presentation at the next WKFATHOM meetings and use in the egg survey manuals. Participants should look into the feasibility of conducting genetic analyses on egg samples from the whole survey area to assess degree of misidentification between species with very similar eggs.	WGMEGS Survey participants
4. WGMEGS recommends that the niche modelling work that was initiated prior to the 2016 MEGS survey and predicts mackerel spawning in space and time is resumed and further progressed. The group expects that the model predicts the spatial and temporal distribution of mackerel egg abundance across the entire mackerel egg survey area at a spatial resolution of the survey grid, i.e. half ICES rectangle. The development of the model should help to improve survey planning and execution. Model output results should be made available for coming surveys prior to the planning meetings. Also, during surveys, refined model results based on recently collected egg data shall be made available to assist survey execution.	WGS2D

Annex 4: Working documents presented to WGMEGS

Fish egg larval assemblages in the Western approaches to the Celtic Sea of the United Kingdom

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Abstract

The ichthyoplankton of the Celtic Sea has been poorly studied. The International Council for the Exploration of the Sea (ICES) Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS) coordinates a triennial mackerel and horse mackerel egg survey covering the outer Celtic Sea Shelf and surrounding waters. The surveys began in 1977 and sample analysis for selected species has resulted in a long-term assessment of the distribution, abundance and spawning stock of mackerel and horse mackerel. The survey series provides extensive coverage and added value can be gained from the re-analysis of these samples for all ichthyoplankton species and not only just for the eggs of mackerel and horse mackerel. These surveys have been running for over 40 years, so they may also offer insights into how environmental changes affect both distribution and abundance of fish eggs and larvae. Re-analysis of the ichthyoplankton samples collected in 2016 provides updated details of the distribution and spawning intensity of species with planktonic stages in the Western Approaches to the Celtic Sea. The last full analysis of all ichthyoplankton was carried out on samples collected in 1998.

A total of 551 samples collected in 2016 were analysed and 59,160 eggs and 78,067 larvae were found. In total 49 species were recorded with a further 27 taxa identified to genus or family due to damage to identifying features, a paucity of information in available literature and time constraints. Mackerel, horse mackerel and pearlside were the most abundant species of eggs; and blue whiting, mackerel and pearlside the most abundant larval species. Spatial distribution of the ichthyoplankton has changed little since the late 1990s with the eggs and larvae of deep sea and oceanic species concentrated beyond the shelf edge where the water depth exceeds 1000 m. In contrast, the eggs and larvae of shallower living species were concentrated along the shelf edge. High concentrations of larvae were recorded in areas of upwellings along the shelf edge and over the Porcupine Bank. Here oceanographic conditions cause the entrapment of plankton along with elevated nutrient concentrations which support the diverse larval assemblages.

The project has provided important distributional and abundance data for the early life history stages of several commercially important species. However, this study has not been completed since the late 1990s and represents a snapshot of one year. Noticeable differences can be seen, most likely due to interannual variability; e.g. WGMEGS identified a shift in the spawning timing and location of the peak 2016 spawning mackerel from March to May and spatially from the west coast of Ireland to the Bay of Biscay to west of Scotland. Despite this, the analysis provides new information for those fish species spawning on offshore grounds in the Western Approaches to the Celtic Sea. Such evidence will be used to support and better substantiate the descriptions of important spawning and nursery grounds and the analysis will update egg and larval distributions of seven fish species in Northeast Atlantic waters was based on analyses of biological samples collected as part of the triennial mackerel egg survey series. In the case of stocks of hake and megrim, for example, these analyses have not

subsequently been repeated and it is timely to re-consider the utility of the latest mackerel egg survey samples to provide species information on other stocks in the Celtic Seas to supplement, and enhance, existing knowledge in the region and so further guide the work of ICES WGMSFDemo and to update evidence with respect to egg and larval distributions. Further studies that could be considered are: modelling of the potential drift of eggs and larvae to locate nursery grounds, ichthyoplankton surveys to plug long-standing gaps in data due to WGMEGS limited coverage from the shelf edge to coastal waters of France, the UK and southeast of Ireland.

Spawning grounds of Northern European hake stock in 2016. Is hake egg production a good proxy of SSB?

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Abstract

Within ICES WGMEGS is in charge of planning and executing the Triennial Mackerel and Horse mackerel egg surveys. The aim of this program is to estimate the biomass of mackerel and horse mackerel populations using the ichthyoplankton method. In 2015, due to the noticeable presence of hake eggs in plankton samples from the 2013 survey, the WG agreed to request participants to identify hake eggs within their routine plankton analysis process. This Working Document presents the results of the spatial distribution of hake eggs (i.e. stage 1 and total abundances) observed throughout the surveys from February to July in the northern hake stock area. Stage I eggs abundance was transformed into egg production - and the results obtained for the whole area in 2016 were compared with those observed in 1995 and 1998 surveys.

The coincidence between the historical biomass trend described in the assessment-working group for this species and the egg indices estimated here, suggests that the ichthyoplankton method can be considered a good tool to detect hake biomass variability, which may be use together with the current method (Stock Synthesis 3 assessment model (SS3)).

2017 mackerel egg exploratory survey and additional sampling

Brendan O' Hea[1], Finlay Burns[2], Bjorn Gunnarsson[3]

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Abstract

At the 2017 WGMEGS meeting in Vigo members were asked to provide any additional information on spawning in 2017 and 2018 which could assist in the planning of the 2019 surveys. Ireland organised a 14 day survey on a 45m vessel, Girl Stephanie, to survey west of Hatton bank, south of Iceland and in the Faroe / Shetland channel. Stations were sampled to a depth of 100m using a GULF 7 sampler.

Sixty stations were carried out over 2800 miles. Eggs were identified and staged according to MEGS protocols. Results were presented as stage 1 mackerel eggs/m2/day.

Stage 1 eggs were found at 80% of the stations sampled but numbers were generally low. The maximum egg count was 57 MAC1/m2/day to the west of Hatton bank, however at 67% of the stations where stage 1 eggs were found counts were in single figures. Additional information was also provided by Iceland and the Faroe Islands and provided a similar picture to those reported on the exploratory survey. A follow up survey tasked with completing the picture to the south and west of Ireland is due to be completed in May / June 2018.

Results of IEO 2017 spring pelagic surveys

Isabel Riveiro[1], Gersom Costas[1], Pablo Carrera[1], Dolores Garabana[2], Jose Ramón Pérez[1], Rosario Domínguez[1], Paz Diaz[1].

[1] Instituto Español de Oceanografía. C. O. de Vigo. Vigo, Spain.
[2] Instituto Español de Oceanografía. C. O. de A Coruña. A Coruña. Spain.

Abstract

In 2017, IEO carried out two pelagic spring surveys in the MEGS area: the PELACUS acoustic survey and the DEPM-sardine survey, both in March-April, covering the north Spanish waters (Atlantic and the Bay of Biscay, ICES Divisions 27.9.a and 27.8.c), together with the southern part of the French continental shelf (27.8.b until 45ºN).

The Spanish acoustic-trawl survey PELACUS 0317 was carried out on board RV Miguel Oliver from 13th March to 16th April. Acoustic, fishing stations, fish egg counting (from CUFES sampler), microplastic, and apical predator observations were done during daytime whilst the oceanographic characterization was done during night-time.

DEPM sardine survey, SAREVA0317 was performed onboard RV Vizconde de Eza from 22th March to 15th April with the main objective of sardine egg sampling for the estimation of the SSB using the Daily Egg Production Method (DEPM). In addition, eggs from other commercial species, i.e. horse mackerel, mackerel, anchovy, etc. were also collected with CalVET (up to 100m depth) and CUFES (5m depth).

Contrary to the conditions found in 2016, when weather and oceanographic conditions were those of winter time, during 2017 spring surveys higher sea surface temperature was register and had an important effect in fish availability.

During PELACUS, mackerel was the most abundant fish species in biomass occurred at the fishing stations. It was widely distributed all around the surveyed area, with juveniles being located in 9a and also in French waters (8b) and the bulk of the spawning-stock biomass occurring in the Cantabrian Sea, which is in agreement with the mackerel egg records obtained with CUFES. This situation clearly differs from that observed in 2016 when mackerel showed a lower abundance and highly patchy distribution.

Horse mackerel abundance in 8c subdivision showed an important decrease from to 2016 mainly due to a diminution of younger individuals. On overall, 83% of the young fish (age groups 1 and 2) were located on the French shelf (8b) while the 85% of older fish (age group 3+) occurred in 8c.

Results from SAREVA0317 survey showed a good correspondence between CUFES and CalVET for mackerel and horse mackerel eggs presence.

Horse mackerel eggs were much more abundant in Cantabrian waters, while eggs were scarce in the French shelf, where PELACUS detected a greater presence of juvenile (no

mature) individuals. In average horse mackerel egg densities were similar between SAREVA0317 and JUREVA0416, and lower in CAREVA0316.

Mackerel was the more and widely distributed species with an average density in CalVET of 519 eggs/m2, what supposes a presence and concentration much greater of the registered in 2016 (104 and 387 eggs/m2 in CAREVA0316 (March) and JUREVA0416 (April) respectively).

With the purpose of obtaining an abundance index of mackerel from SAREVA, mackerel eggs from CALVET were staging and egg production was calculated.

Comparing with 2016 MEGS result, considering 22 days (SAREVA duration) in the same period (same dates), same surveyed area (SAREVA area) and no-interpolation, results showed a good coincidence.

Preliminary results of 2018 spring acoustic survey PELACUS mackerel abundance in CUFES were also presented, showing a good agreement in egg abundance and distribution with 2017.

Looking back: Raw analysis of MEGS surveys

Gersom Costas[1], Matthias Kloppmann[2], Brendan O´Hea[3]

[1] Instituto Español de Oceanografía. C. O. de Vigo. Spain.

[2]Thünen Institute of Sea Fisheries. Hamburg, Germany

[3] Marine Institute, Rinville west, Oranmore, Co. Galway, Ireland.

Abstract

An analysis utilizing time-series of MEGS surveys was carried out in order to have a historical perspective of whole temporal series for MEGS surveys (1992-2016).

These egg surveys covering the eastern Atlantic from Gibraltar to the south coast of Iceland, of which 90% is the Western component area. Due to expansion of the spawning time and area of mackerel in recent years, there has been an increase of about 15 % surveyed area in last 3 surveys compared to backward 2010 surveys. A total of 8 institutions (7 countries) participated in last MEGS survey (2016). This increase in spawning area has prompted an increase in survey days lately (20%). But if we consider effective sampling days, survey days not including days lost by poor conditions weather, steaming days, operational vessel days, …, we can see that effective sampling days have remained broadly stable lately.

In addition there has been an increase of sampling period throughout temporal series in Western spawning component area.

As a result of this increase in time and area of spawning season for mackerel and not fairly increase in effective survey days has been needed use of interpolation methods in order to have a proper coverage in spawning period. Resulting in recent surveys there has been a 34% of positive area (area with presence of mackerel eggs) that comes from interpolation for Western component area and 11% for Southern component. In addition, we need use time interpolation for egg production in unsampled time periods (inter-periods).

As a consequence of use of temporal and spatial interpolation, about 16% of total egg production for mackerel Western component comes from spatial interpolation and less than 5% come from temporal interpolation. And total egg production for mackerel

Southern component about 1% comes from spatial interpolation and 30% come from temporal interpolation.

Western horse mackerel

We found that positive area (presence of horse mackerel eggs) has had a substantial decreasing over temporal series. In last survey (2016) there were only horse mackerel eggs in 17% of total surveyed area in 2016 survey.

Consequence of spatial and temporal interpolation for horse mackerel egg production: at about 25% of horse mackerel egg production comes from spatial interpolation and about 18% egg production comes from temporal interpolation in the last 2 surveys

Atlantic mackerel daily spawning dynamics and implications for batch fecundity estimations.

Kostas Ganias[1], D. Marmara, Antonio Solla[2], Dolores Garabana[3], Rosario Dominguez-Petit[2].

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[2] Instituto Español de Oceanografía. C. O. de Vigo. Vigo. Spain.

[3] Instituto Español de Oceanografía. C. O. de A Coruña. A Coruña, Spain

Abstract

The present study contributes to a better understanding of the daily spawning dynamics of southern NEA mackerel (*Scomber scombrus*) with implications for the estimation of batch fecundity. It shows that there is a time window during the day, mainly in the afternoon, during which the advanced oocyte mode in imminent spawners separates from the remaining, smaller oocytes. This synchronicity in the separation of the spawning batch among imminent spawners corroborates evidence for the existence of daily spawning synchronicity in the population. This is particularly important for applications of the daily egg production method (DEPM) because such pattern facilitates both the ageing of eggs for the estimation of the daily egg production at sea and the ageing of postovulatory follicles for the estimation of spawning frequency. For NEA mackerel, batch fecundity could only be measured when a clear hiatus was established between the spawning batch and the smaller oocytes. Hydrated females that do not show such hiatus would not be valid for batch fecundity measurements suggesting that the 'hydrated oocytes method' is not fully applicable for this stock. Knowing the time of day at which the batch is separated, will facilitate the sampling of valid females for the estimation of batch fecundity.

On-going and planned postdoc work on various aspects of the life history of Atlantic mackerel

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Institute of Marine Research N-5817, Bergen – NO

Abstract

The project CLIMRATES (Climate and vital rates of marine stocks) has three years duration (2018 – 2020) and it is supported by the Norwegian Fisheries Industry. The main hypothesis addressed to this project is "Is mackerel spawning activity extending northwards?" However, other questions will be addressed, such as: 1. How is the northward feeding migration affecting life history-traits, mainly fecundity, of mackerel? 2. How is

the density-dependent effect influencing life-history traits, mainly fecundity, of mackerel? 3. Is there any latitudinal gradient in the age structure of mackerel? 4. Are larger individuals migrating all the way back to the main spawning grounds? To achieve these objectives different datasets will be used. i) WGMEGS database - all biological data, but also data from fecundity and atresia; ii) Institute of Marine Research (IMR) database - data from research and commercial vessels collected in the Norwegian Sea, northern North Sea, and west of Ireland; iii) Mackerel biomass landing data from 2005 – 2016; and iv) New fecundity data collected from May 2018 to June 2019. The first step was to merge and to standardize all the WGMEGS data. Over the last 10 years, mackerel has extended north- and westwards the feeding migration area. A similar pattern has been recorded for egg density. Although egg density has increased north- and westwards, the density is still low in these areas. Another indication that suggests some spawning activity in northern areas is the presence of mackerel from the 2016 year-class, from found from Bergen to Lofoten during the 2017 mackerel survey. Besides this historical data, new samples will be collected to cover the next maturation cycle (2018-2019) aiming to investigate possible spawning events in northern areas. At the same time, new fecundity estimates will be applied, including the oocyte packing density theory. In addition, changes in energy allocation will be investigated. Over the last 20 years (1984 – 2013) a decline in growth and condition was recorded for mackerel. This decline was associated with density-dependent effect and negative effect of herring stock size. Therefore, the following step of the project will be investigating in depth variations in life-history traits of mackerel, as for example annual variation in Fulton's condition. One of the last points to be evaluated refers to the difference in age structure found in the mackerel landings. Preliminary results showed that there are indications of a northward increase in the age structure over the years, together with an increase of landings in the Norwegian Sea and Icelandic Sea.

MEGS Fecundity and Atresia Database. Raw analysis for Mackerel Relative potential fecundity

Gersom Costas[1], Matthias Kloppmann[2], Anders Thorsen[3]

[1] Instituto Español de Oceanografía. C. O. de Vigo. Spain.

[2]Thünen Institute of Sea Fisheries. Hamburg, Germany.

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Abstract

An analysis utilizing time-series of MEGS eggs surveys was carried out in order to have a historical perspective of whole temporal series for MEGS surveys (1992-2016).

These egg surveys covering the eastern Atlantic from Gibraltar to the south coast of Iceland, of which 90% is the Western component area. Due to expansion of the spawning time and area of mackerel in recent years, there has been an increase of about 15 % surveyed area in last 3 surveys compared to backward 2010 surveys. A total of 8 institutions (7 countries) participated in last MEGS survey (2016). This increase in spawning area has prompted an increase in survey days lately (20%). But if we consider effective sampling days, survey days not including days lost by poor conditions weather, steaming days, operational vessel days, …, we can see that effective sampling days have remained broadly stable lately.

In addition there has been an increase of sampling period throughout temporal series in Western spawning component area.

As a result of this increase in time and area of spawning season for mackerel and not fairly increase in effective survey days has been needed use of interpolation methods in order to have a proper coverage in spawning period. Resulting in recent surveys there has been a 34% of positive area (area with presence of mackerel eggs) that comes from interpolation methodology into Western component area and 11% into Southern component area. In addition, we need the use time interpolation in order to estimate the egg production in unsampled time periods (inter-periods).

As a consequence of use of temporal and spatial interpolation, about 16% of total egg production for mackerel Western component comes from spatial interpolation and about 5% come from temporal interpolation in last surveys. However the total egg production for mackerel Southern component about 1% comes from the spatial interpolation and 30% come from the temporal interpolation.

Western horse mackerel

We found that positive area (presence of horse mackerel eggs) has had a substantial decreasing over temporal series. In last survey (2016) there were only horse mackerel eggs in 17% of total surveyed area in 2016 survey.

Consequence of spatial and temporal interpolation for horse mackerel egg production: at about 25% of horse mackerel egg production comes from spatial interpolation and about 18% egg production comes from temporal interpolation in the last 2 surveys

The use of the CUFES in acoustic surveys to estimate the egg abundance of mackerel (*Scomber scombrus*) and horse mackerel (*Trachurus trachurus*).

Paz Diaz[1], Isabel González[2], Pablo Carrera[1], Gersom Costas[1], Isabel Riveiro[1], Dolores Garabana[2].

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Abstract

Results of mackerel and horse mackerel egg abundances using CUFES sampler (Continuous Underway Fish Egg Sampler) during Spanish acoustic survey in 2018.

Planning for the Portuguese DEPM survey for horse-mackerel in 2019. PT-DEPM19-HOM

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Abstract

IPMA adopted the DEPM - Daily Egg Production Method, for the horse-mackerel of the southern stock (ICES 9a - Gibraltar-Finisterre) since 2007 and have developed and implemented several aspects of the methodology, since. Modifications introduced included the plankton sampling gear and design, and laboratorial and data analyses developments for egg and adult samples. This document summarizes the planning for plankton and adult surveying for the 2019 horse-mackerel DEPM survey (PT-DEPM19-HOM, PNAB/DCF-EU).

Annex 5: Tables

Table 6.1.1 Countries, vessels, areas assigned, dates and sampling periods for the 2019 surveys.

Country	Vessel	Areas	Dates	Period
Portugal	Noruega	Cadiz, Portugal & Galicia	17th Jan – 20th Feb	1,2
Spain (IEO)	Vizconde de Eza	Cantabrian Sea & Bay of Biscay	10th Mar – 4th Apr	3
		Biscay & Cantabrian Sea	7th Apr – 2nd May	4
Germany	W. Herwig III	West Ireland & Celtic Sea	21st Mar – 26th Apr	3,4
Netherlands	Tridens	Bay of Biscay & Celtic Sea	6th May – 24th May	5
		Celtic Sea & Bay of Biscay	3rd June – 21st June	6
Spain (AZTI)	Ramon Margalef	Bay of Biscay	19th Mar – 9th Apr	3
		Bay of Biscay & Cantabrian Sea	6th May – 28th May	5
Ireland	Celtic Explorer	Celtic Sea & Bay of Biscay	3rd Feb – 24th Feb	2
	Charter	West of Ireland & west of Scotland	9th June – 30th June	6
Scotland	Scotia	West of Ireland & west of Scotland	IBTS	2
	Charter	West of Ireland & west of Scotland	17th Mar – 27th Mar	3
	Scotia	West of Ireland & west of Scotland	5th May – 25th May	5
	Charter	Celtic sea, West of Ireland & West of Scotland	7th July – 27th July	7
Faroe Islands	Magnus Henderson	Faroes & Shetland	22nd May – 5th June	5
Iceland	Bjarni Saemundsson	Iceland	5th May – 18th May	5
Denmark	Dana	West of Scotland	14th Apr – 27th Apr	4
Norway	Johann Hjort	Faroes, west of Norway	9th June – 29th June	6

Table 6.1.2 Periods and area assignments for vessels by week for the 2019 survey. Area assignments and dates are provisional.

		Area							
week	Starts	Portugal, Cadiz & Galicia	Cantabrian Sea	Bay of Biscay	Celtic Sea	North-west Ireland	West of Scotland	Northern Area	Period
3	13-Jan-19	PO1 (DEPM)							1
4	20-Jan-19	PO1 (DEPM)							1
5	27-Jan-19	PO1 (DEPM)		IRL1	IRL1				2
6	3-Feb-19	PO1 (DEPM)		IRL1	IRL1				2
7	10-Feb-19	PO1 (DEPM)		IRL1	IRL1				2
8	17-Feb-19	PO1 (DEPM)				SCO (IBTS)	SCO (IBTS)		2
9	24-Feb -19					SCO (IBTS)	SCO (IBTS)		2
10	3-Mar-19								3
11	10-Mar-19		IEO1			SCO2	SCO2		3
12	17-Mar-19		IEO1	AZTI1	GER1	SCO2	SCO2		3
13	24-Mar-19		IEO1	AZTI1	GER1	GER1			3
14	31-Mar -19		IEO1	AZTI1	GER1	GER1			3
15	07-Apr-19		IEO2	IEO2 AZTI1	GER2	GER2			4
16	14-Apr-19		IEO2	IEO2	GER2	GER2	DEN	DEN	4
17	21-Apr-19		IEO2	IEO2	GER2	DEN	DEN	DEN	4
18	28-Apr -19		IEO2	IEO2					4
19	5-May-19		AZTI2 (DEPM)	AZTI2 (DEPM)	NED1	SCO3	SCO3	ICE	5
20	12-May-19		AZTI2 (DEPM)	AZTI2 (DEPM)	NED1	SCO3	SCO3	ICE	5
21	19-May-19		AZTI2 (DEPM)	AZTI2 (DEPM)	NED1	SCO3	SCO3	FAR	5

22	26-May -19		AZTI2 (DEPM)	AZTI2 (DEPM)				FAR	5
23	2-Jun-19			NED2	NED2			FAR	5
24	9-Jun-19			NED2	NED2	IRL2	IRL2	NOR	6
25	16-Jun-19			NED2	NED2	IRL2	IRL2	NOR	6
26	23-Jun -19					IRL2	IRL2	NOR	6
27	30-Jun -19								6
28	7-Jul-19				SCO3	SCO4	SCO4		7
29	14 –Jul-19				SCO3	SCO4	SCO4		7
30	21-Jul-19				SCO3	SCO4	SCO4		7
31	28-Jul-19								7

Table 11.1.1. NEA Mackerel. Historical estimates of Relative potential fecundity (n/g) , realized fecundity (n/g) and atretic loss (%) of NEA mackerel from Western, Southern and combined components from 1992 to 2016.

Year	Spawning component	Realized fecundity	Relative potential fecundity	Atretic loss
1992	Combined	1431	1569	8.8
1995	Southern	1083		
1995	Western	1302	1473	11.6
1998	Southern	1171		
1998	Western	1002	1206	16.8
2001	Southern	1647		
2001	Western	1033	1097	5.8
2004	Southern	964		
2004	Western	1052	1127	6.7
2007	Combined	1009	1098	8.1
2010	Combined	1070	1140	6
2013	Combined	1209	1257	4
2016	Combined	1087	1159	6

Table 11.1.2. NEA Mackerel. Comparison of Arithmetic mean and Median values of relative potential fecundity (n/g) based in MEGS fecundity database.

Year	Arithmetic mean	standard error	Median
2001	1192	24	1170
2004			
2007	1098	22	1106
2010	1140	40	1135
2013	1302	31	1257
2016	1180	36	1159

Table 12.1.1. NEA Mackerel. Mackerel egg surveys cruise in the North Sea in 2017.

Period	1	2 extended	4
Dates	22.05-27.05	29.05-10.06	12.06-16.06
Midpoint of survey (Julian day)	144	154	165
Total daily egg production $\times 10^{12}$	2.15	4.43	2.60
Interpolated daily egg production $\times 10^{12}$	0.97	1.12	1.00

Table 12.1.2. North Sea Mackerel. Egg production estimates from egg surveys in the North Sea and corresponding SSB based on a standard fecundity of 1401 eggs/g/female.

Year	Egg prod $*10^{12}$	SSB $*10^3$ tons	Observed peak of spawning (midpoint of the coverage giving the highest production)
1980	60	86	25 June
1981	40	57	17 June
1982	126	180	23 June
1983	160	228	13 June
1984	78	111	12 June
1986	30	43	23 June
1988	25	36	20 June
1990[2]	53	76	24 June
1996	77	110	19 June
1999	48	68	Peak might occur later than last coverage
2002	147	210	Peak might occur later than last coverage
2005	155	223	22 June
2008	108	154	18 June
2011	116	165	Peak might occur before first coverage
2015	119	170	4 June
2017	201	287	3 June

Table 12.1.3. North Sea Mackerel. Egg production and SSB estimates from the 2017 egg surveys with early start of spawning on 5th May.

Year	Start day	Egg prod $*10^{12}$	SSB $*10^{3}$ tons
2017	139	201	287
2017	125	231	330

Annex 6: Figures

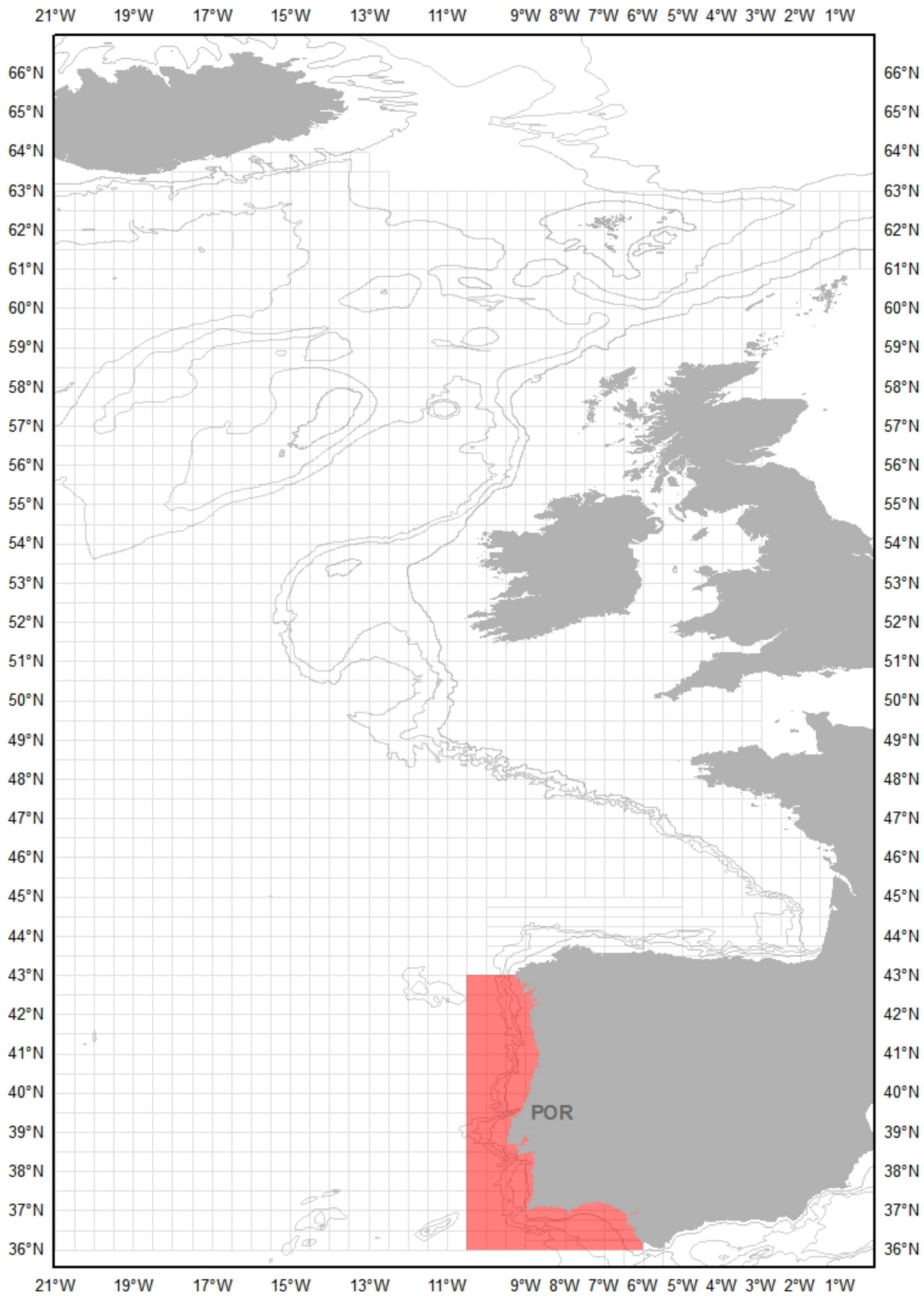


Figure 6.1.1 Survey plan for Period 1

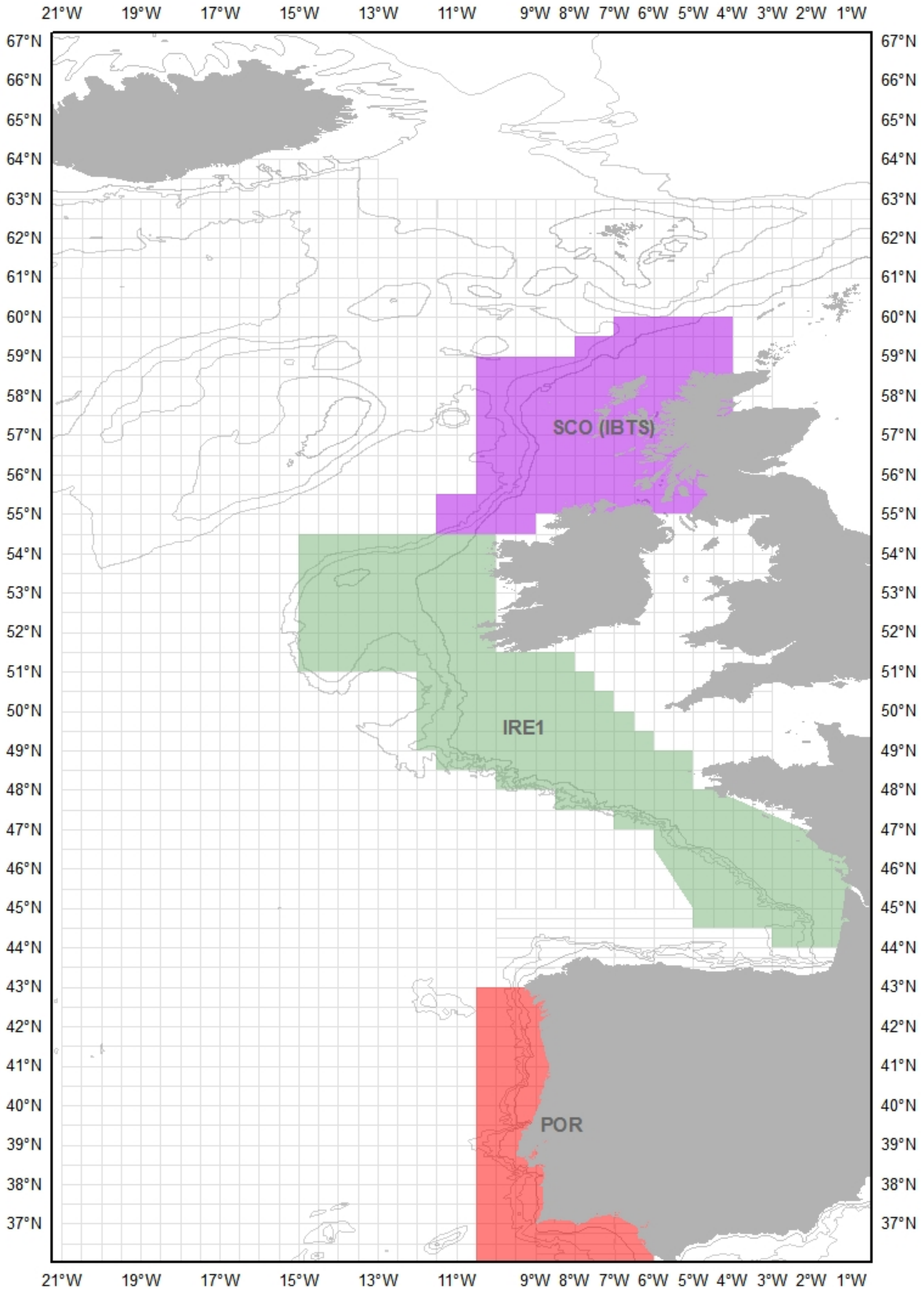


Figure 6.1.2 Survey plan for Period 2

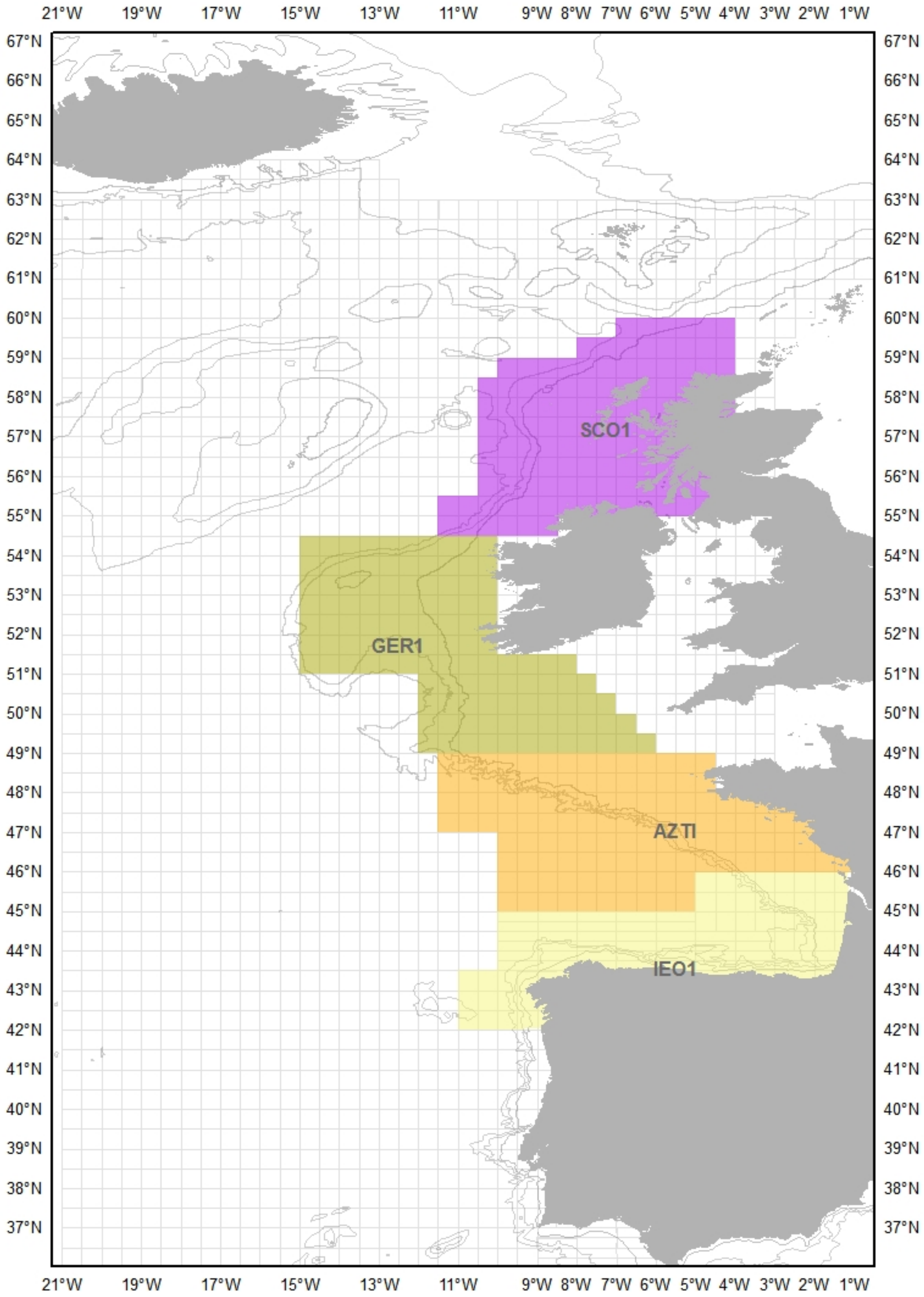


Figure 6.1.3 Survey plan for Period 3.

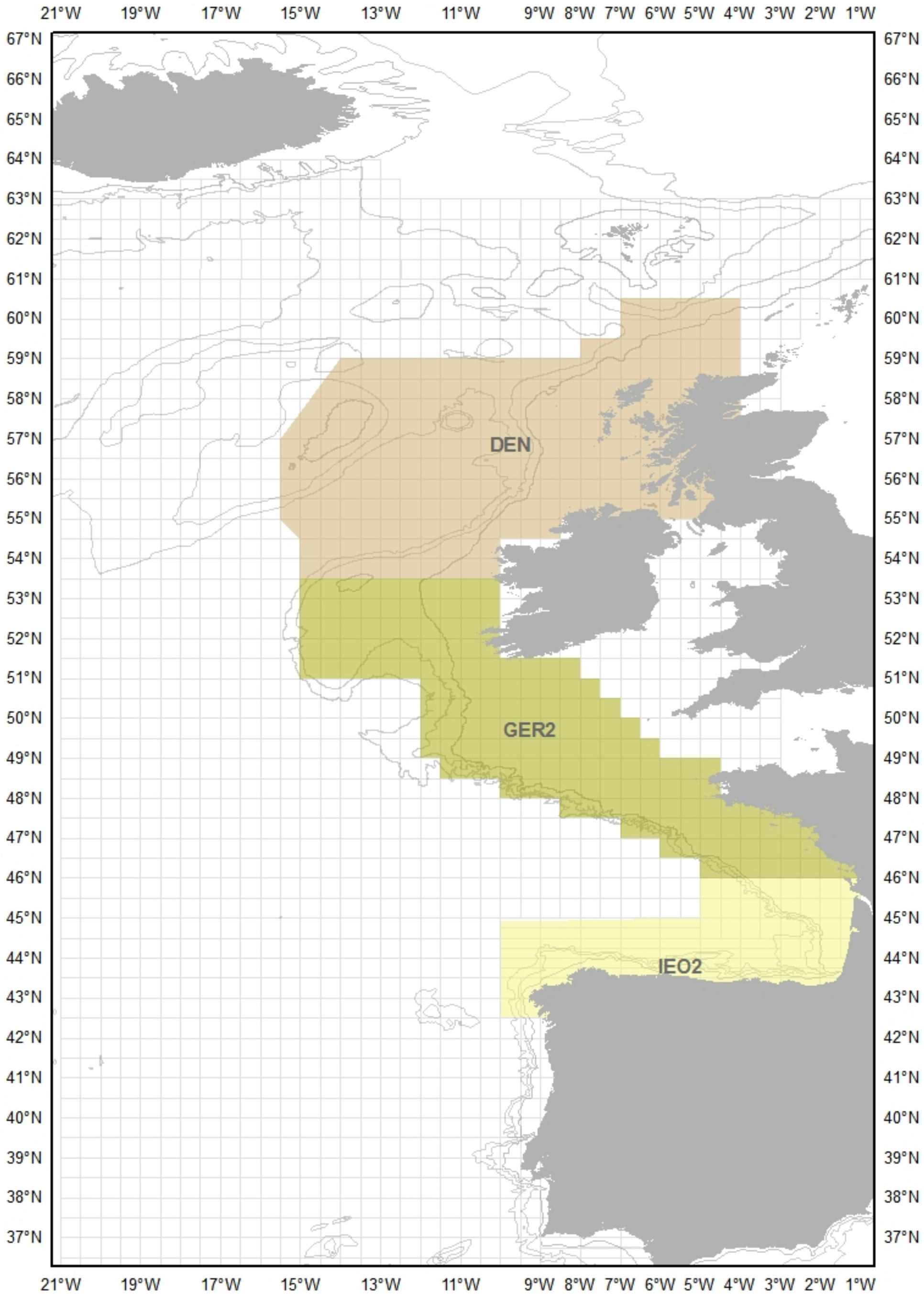


Figure 6.1.4 Survey plan for Period 4

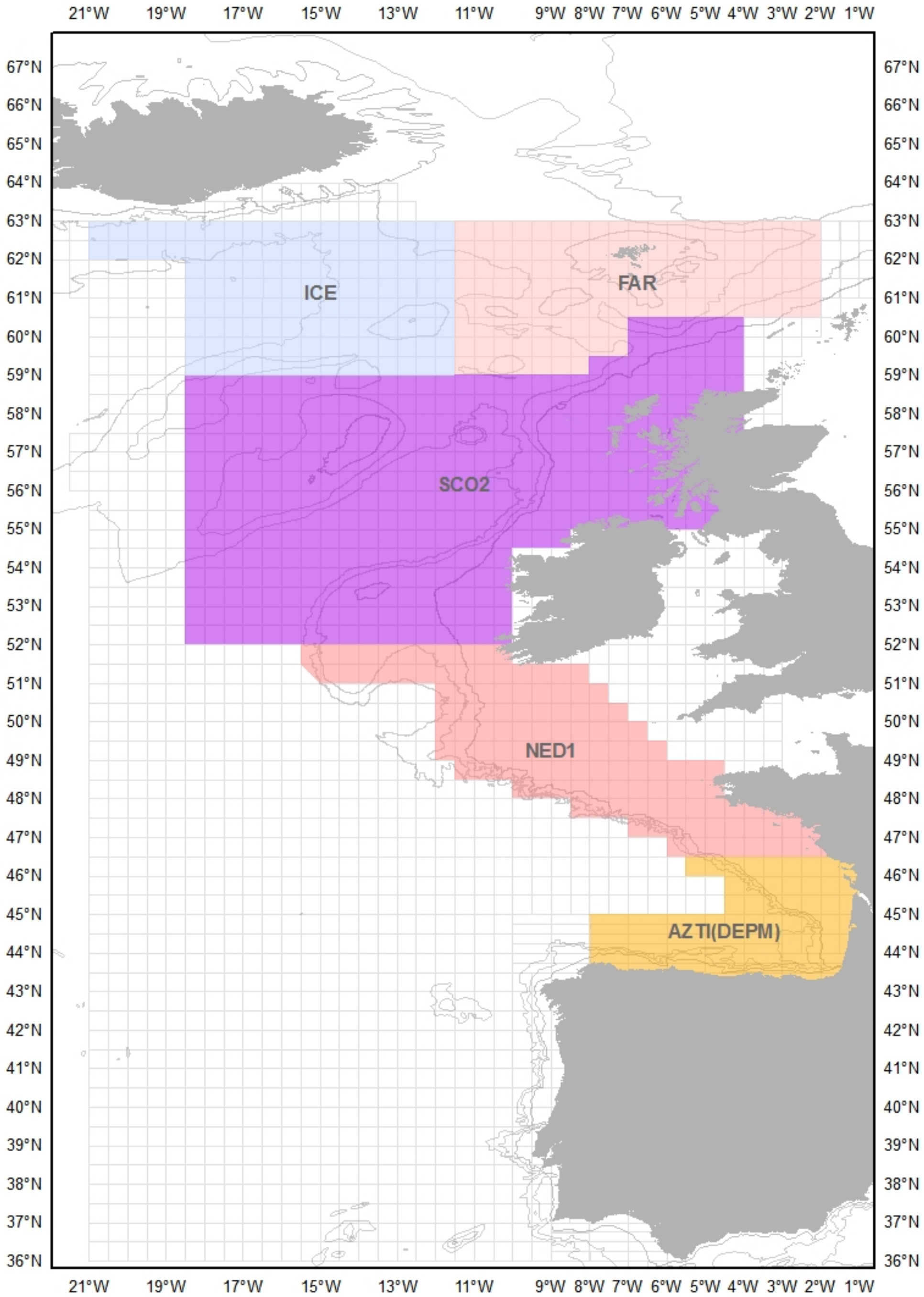


Figure 6.1.5 Survey plan for Period 5.

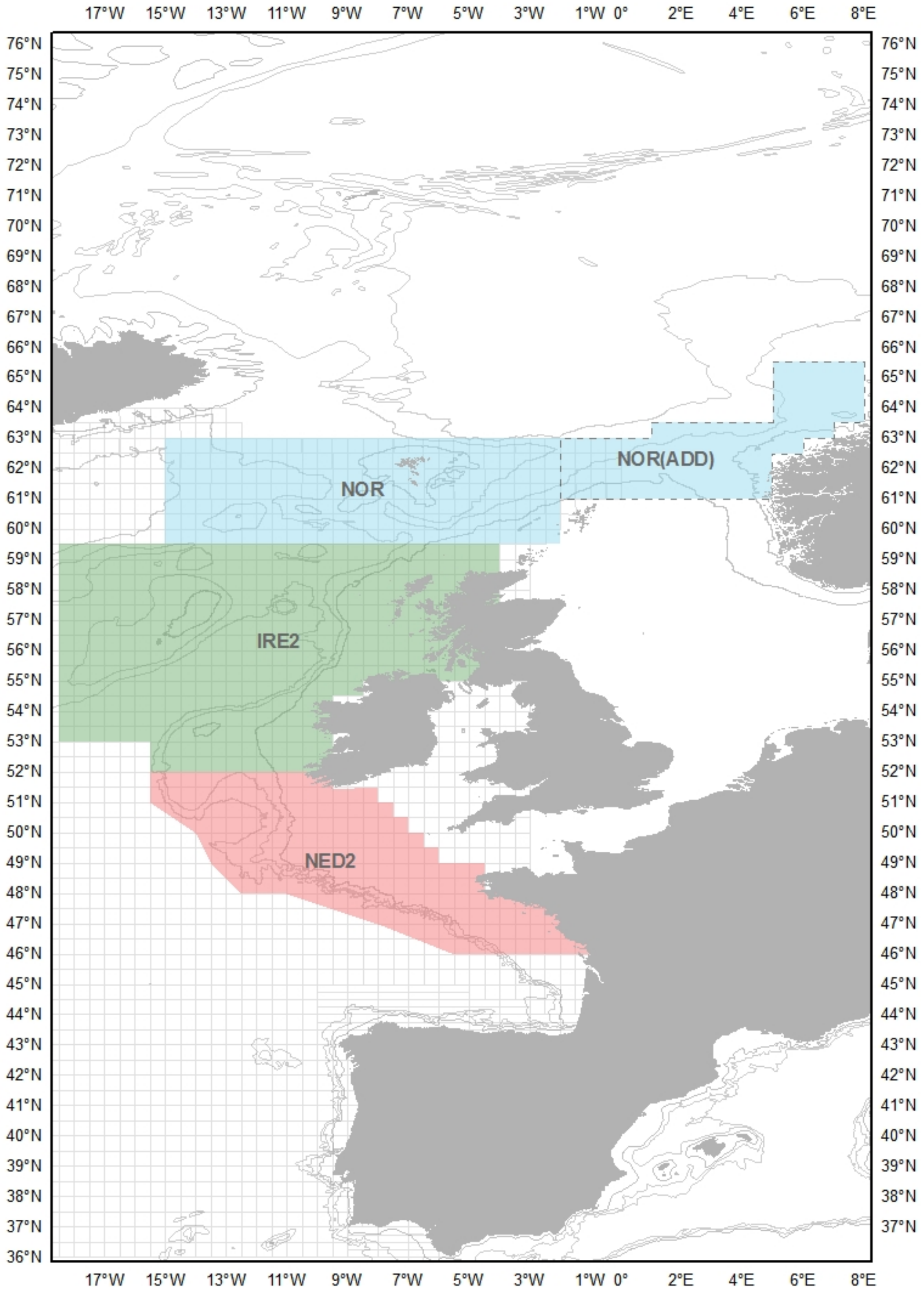


Figure 6.1.6 Survey plan for Period 6

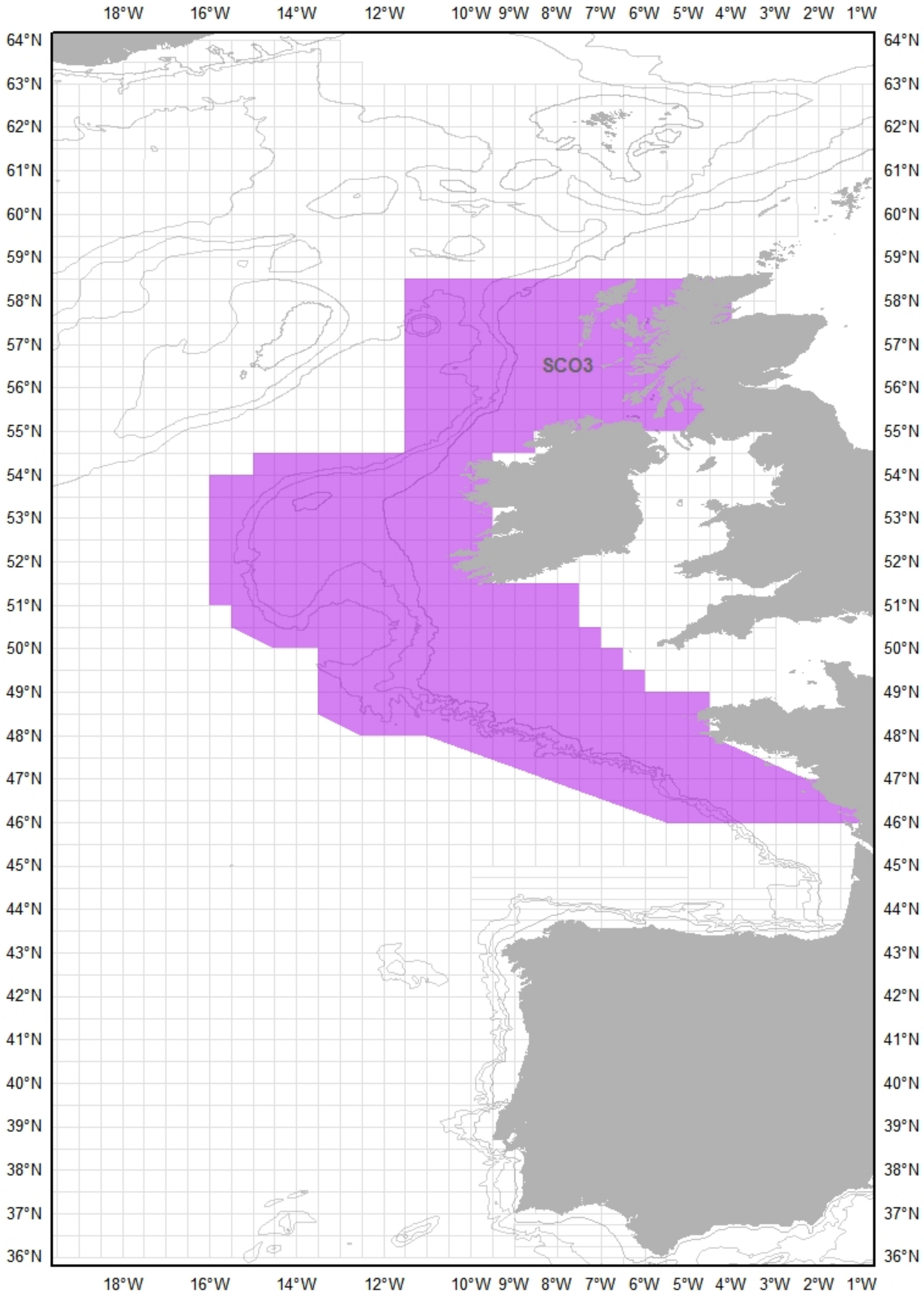


Figure 6.1.7 Survey plan for Period 7

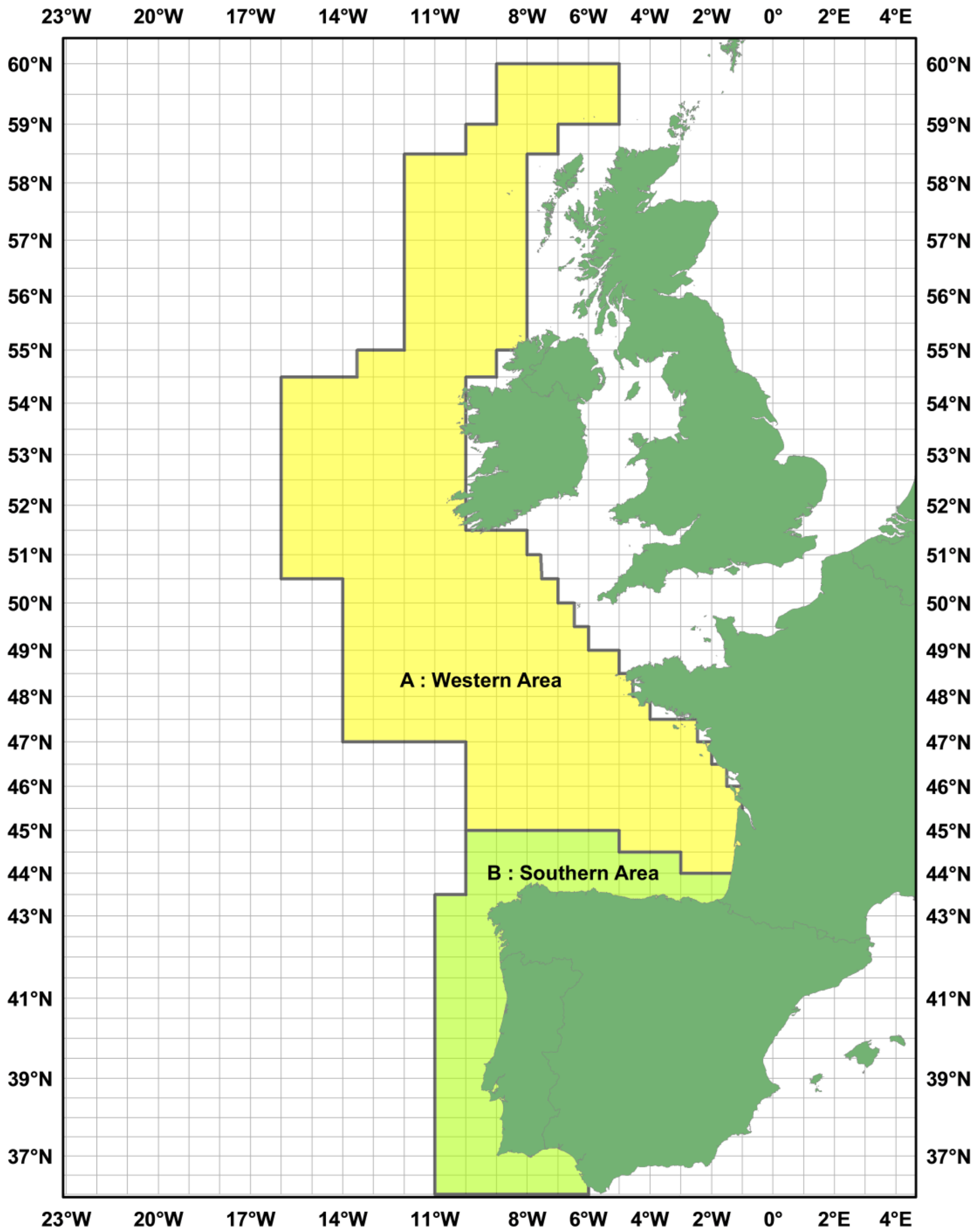


Figure 6.3.1: Core sampling areas for mackerel eggs in the western and southern areas for 2019. Sampling will be continued outside these limits on surveys based on the adaptive sampling guidelines

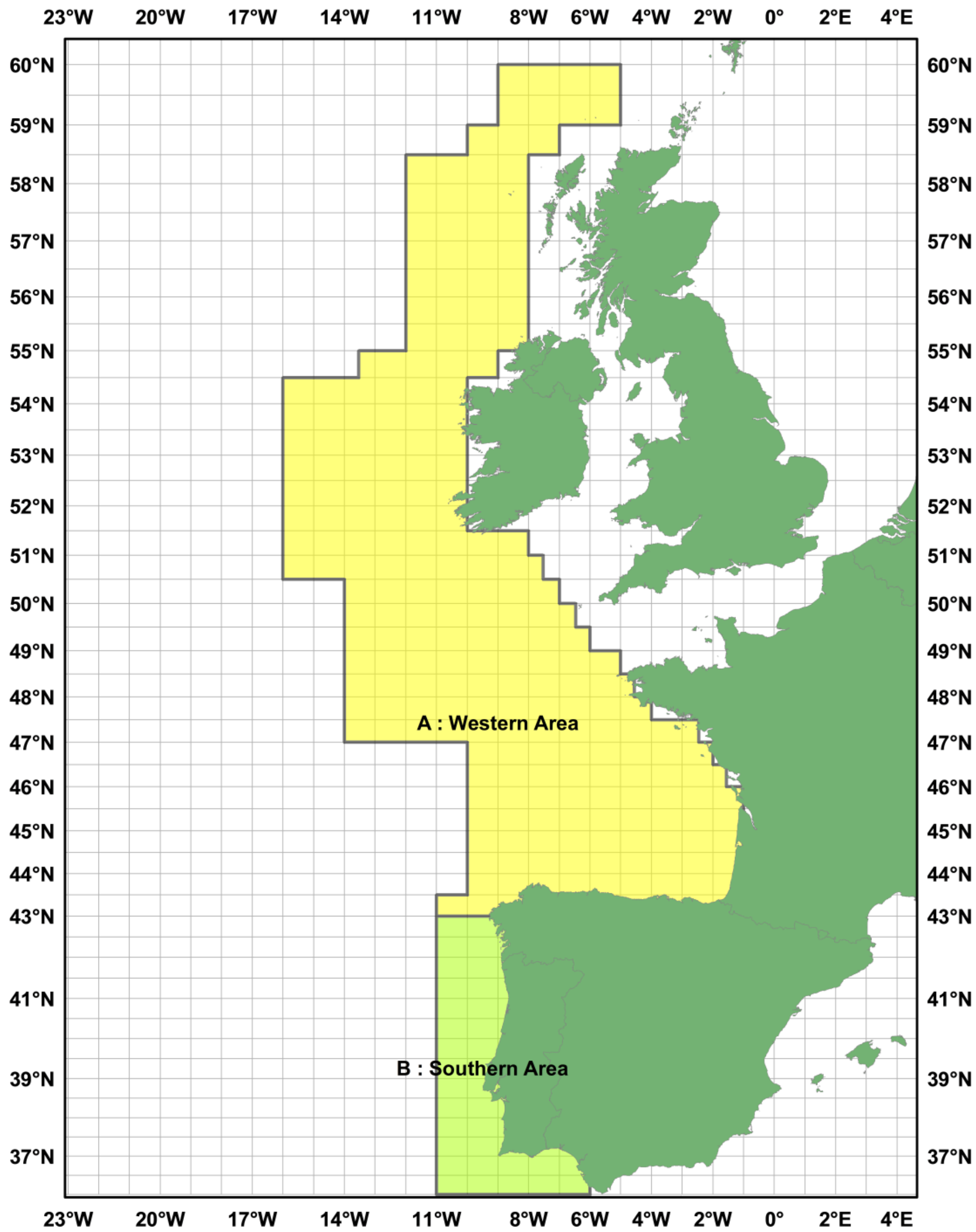


Figure 6.3.2: Core sampling areas for horse mackerel eggs in the western areas for 2019. Sampling will be continued outside these limits on surveys based on the adaptive sampling guidelines

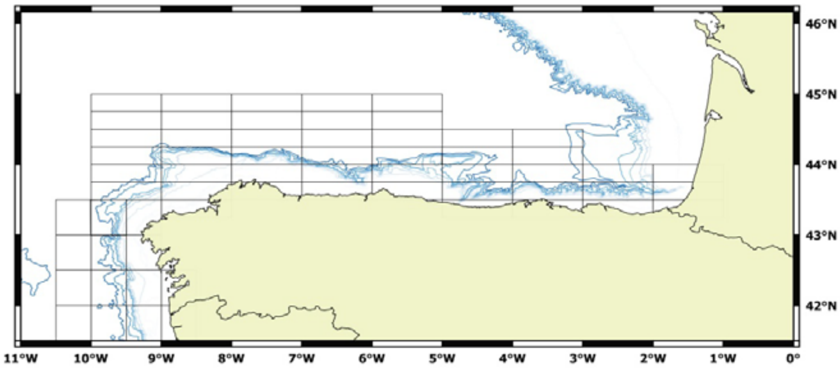


Figure 6.3.3: Southern Component NEA Mackerel. Survey grid for Galicia and the Cantabrian Sea.

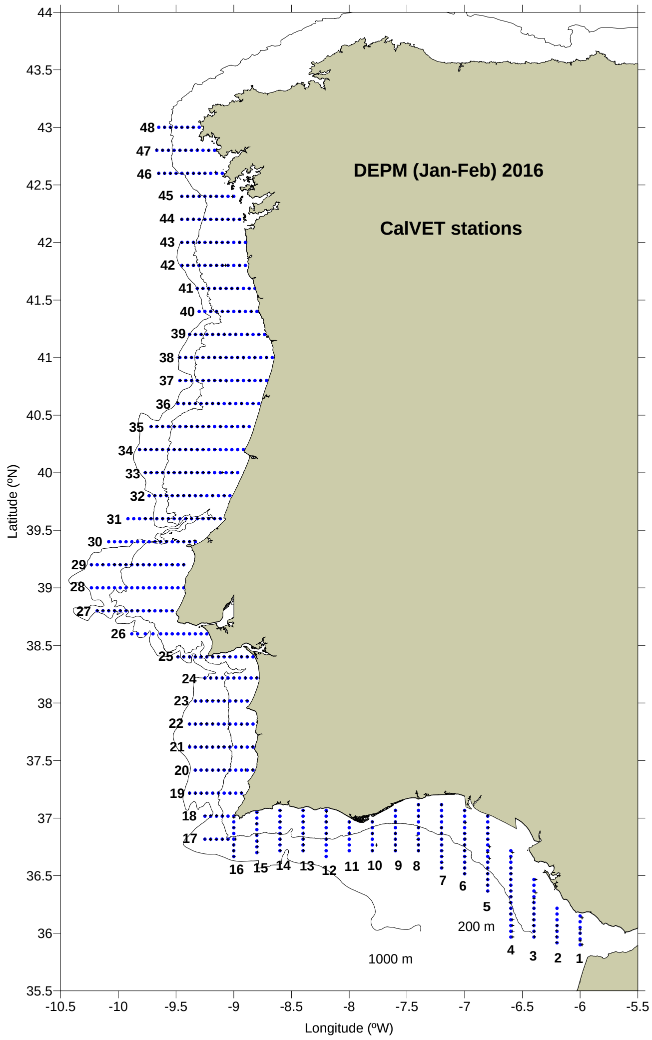


Figure 6.4.1. Southern Horse Mackerel. Sampling grid for CalVET stations.

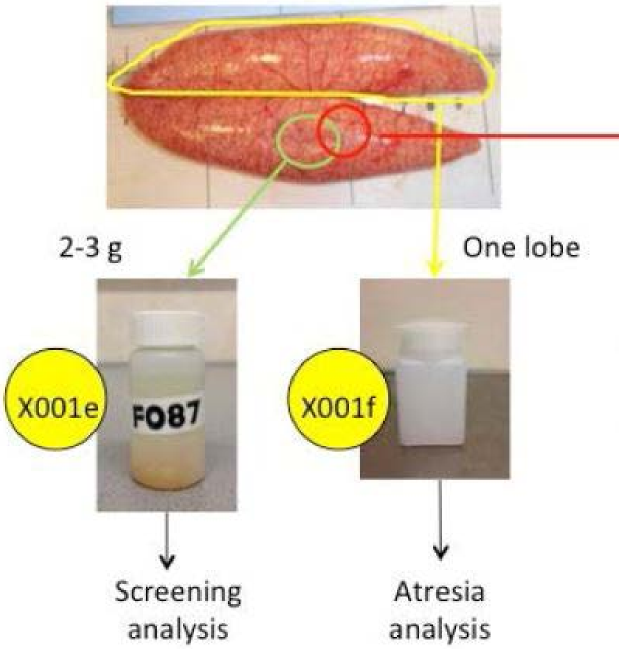


Figure 10.1. Sampling protocol for the extra mackerel ovary samples

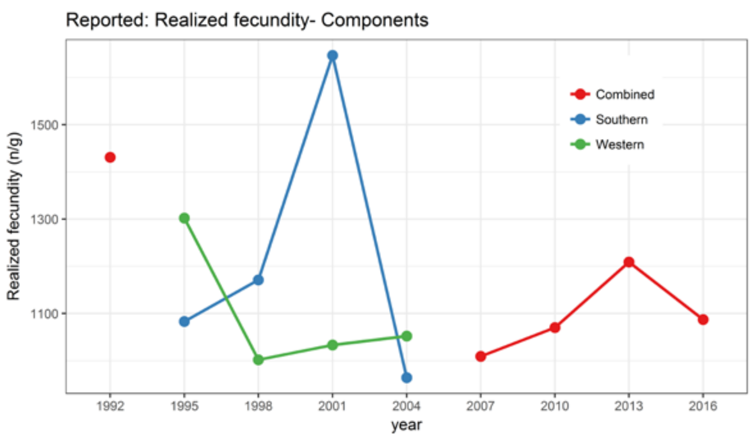


Figure 11.1.1. NEA Mackerel. Reported realized fecundity for mackerel in WGMEGS reports

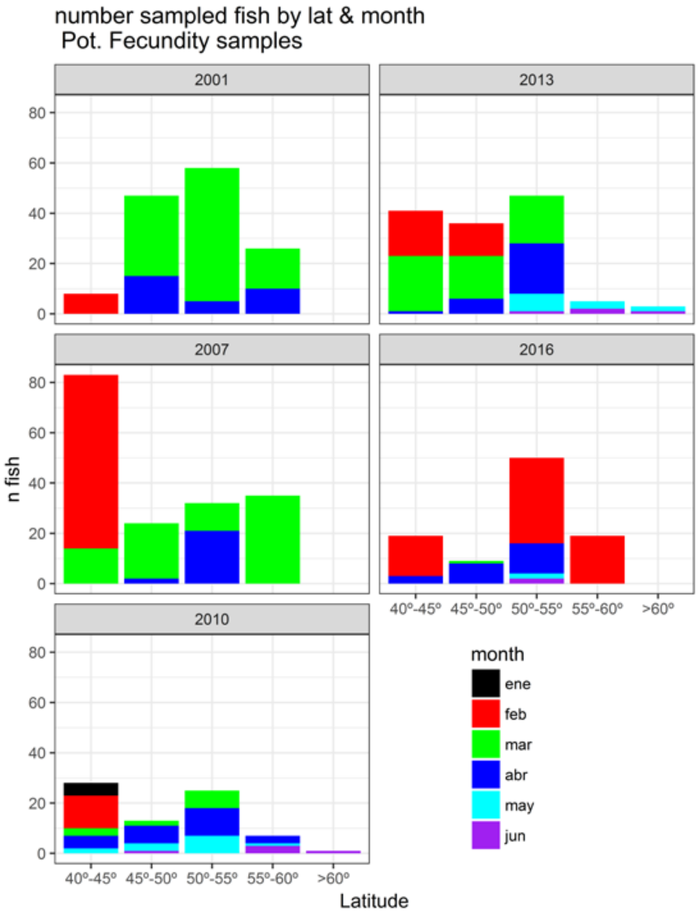


Figure 11.1.2. NEA Mackerel. Number of samples of potential fecundity for mackerel by month and latitude 5º range

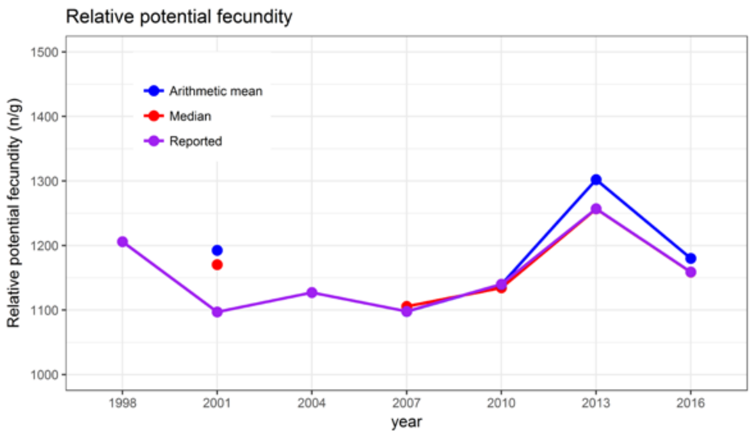


Figure 11.1.3. NEA Mackerel. Relative potential fecundity in reports (purple), arithmetic mean esti-mate (blue) and median estimate (red) since 1998

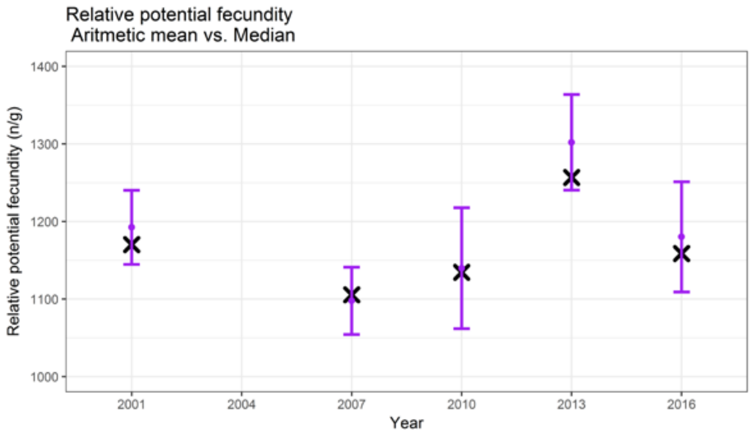


Figure 11.1.4. NEA Mackerel. Arithmetic mean of relative potential fecundity (purple circle) and 95% confidence interval (purple vertical bars) from 2001 to 2016. Black crosses mean median of rel. po-tential fecundity.

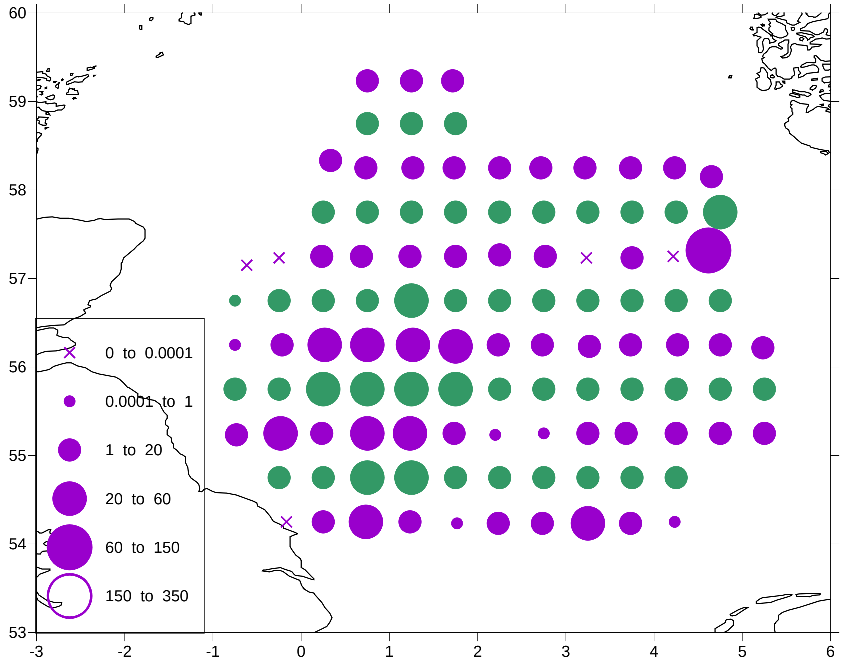


Figure 12.1.1. North Sea Mackerel. Mackerel egg production (eggs/m²/day) by half rectangle for period 1. Purple circles represent observed values, green circles represent interpolated values, and crosses represent observed zeroes.

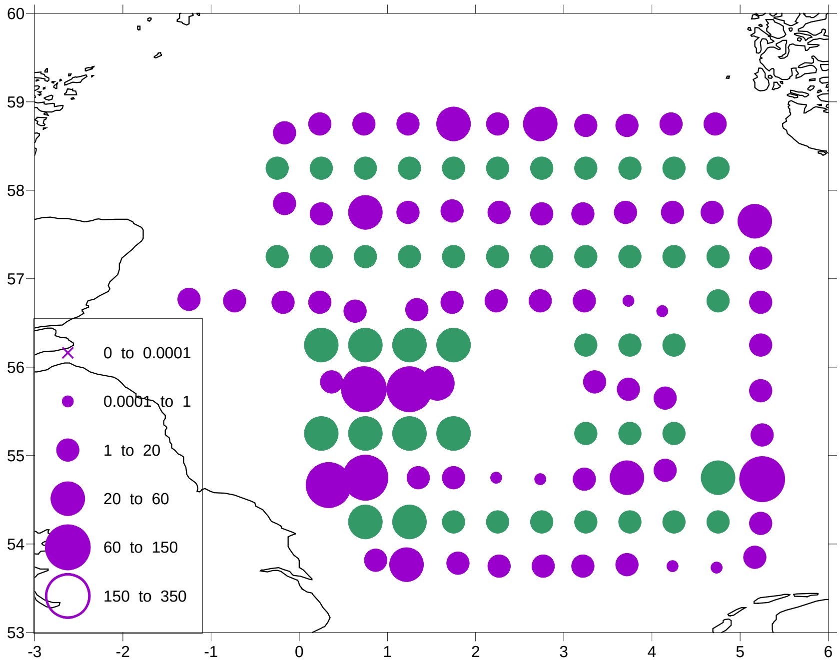


Figure 12.1.2. North Sea Mackerel. Mackerel egg production (eggs/m²/day) by half rectangle for period 2. Purple circles represent observed values, Green circles represent interpolated values, and crosses represent observed zeroes.

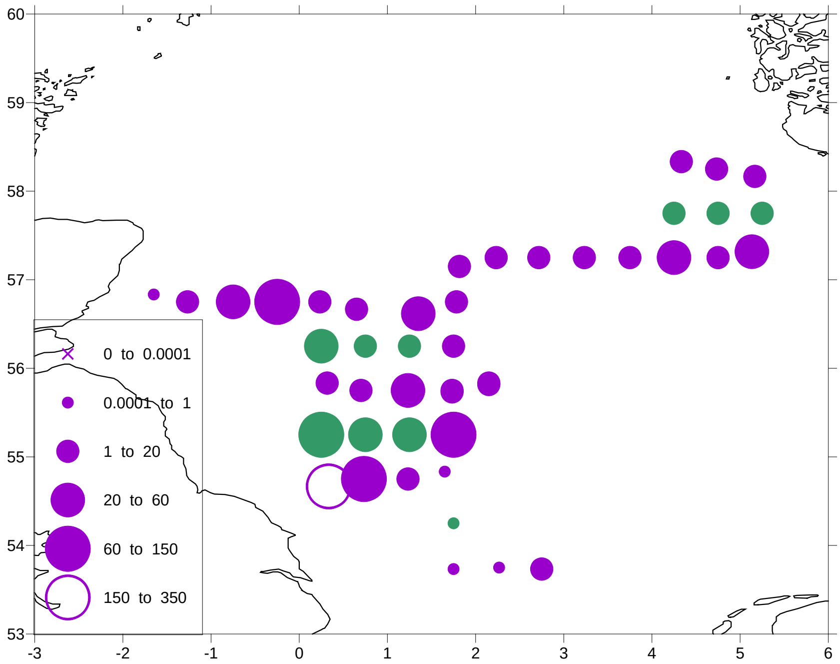


Figure 12.1.3. North Sea Mackerel. Mackerel egg production (eggs/m²/day) by half rectangle for period 3. Purple circles represent observed values, green circles represent interpolated values, and crosses represent observed zeroes.

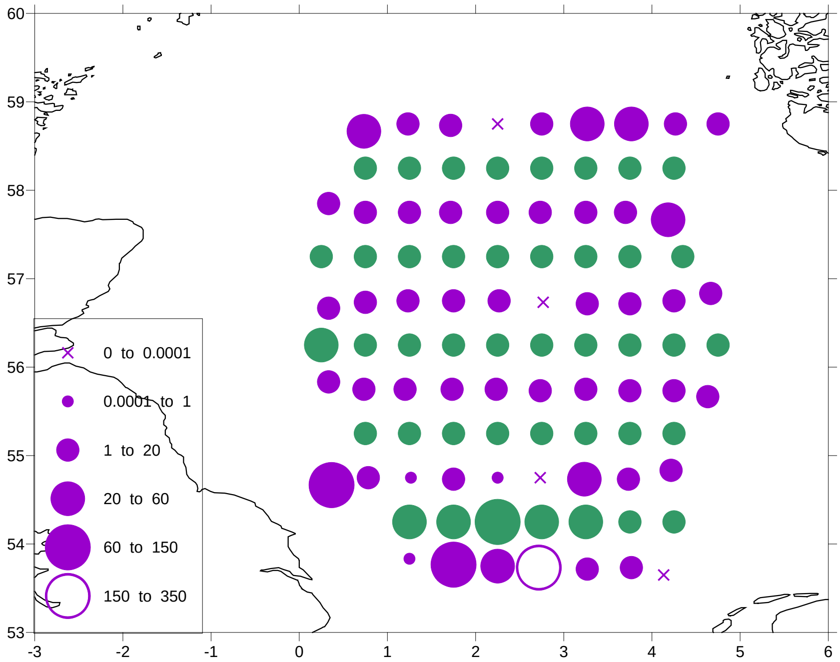


Figure 12.1.4. North Sea Mackerel. Mackerel egg production (eggs/m²/day) by half rectangle for period 4. Filled purple circles represent observed values, filled green circles represent interpolated values, and crosses represent observed zeroes.

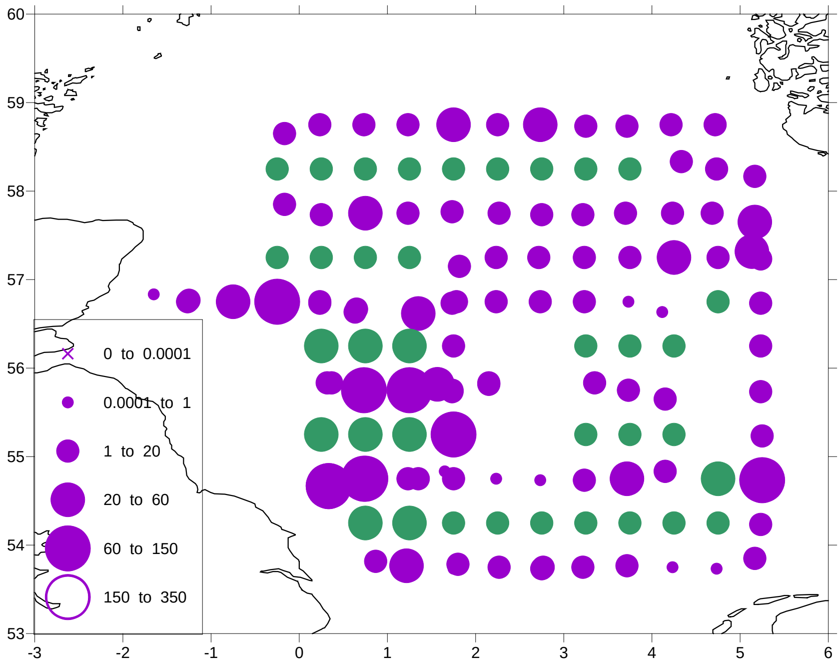


Figure 12.1.5. North Sea Mackerel. Mackerel egg production (eggs/m²/day) by half rectangle for extended period 2. Filled purple circles represent observed values, filled green circles represent interpolated values, and crosses represent observed zeroes.

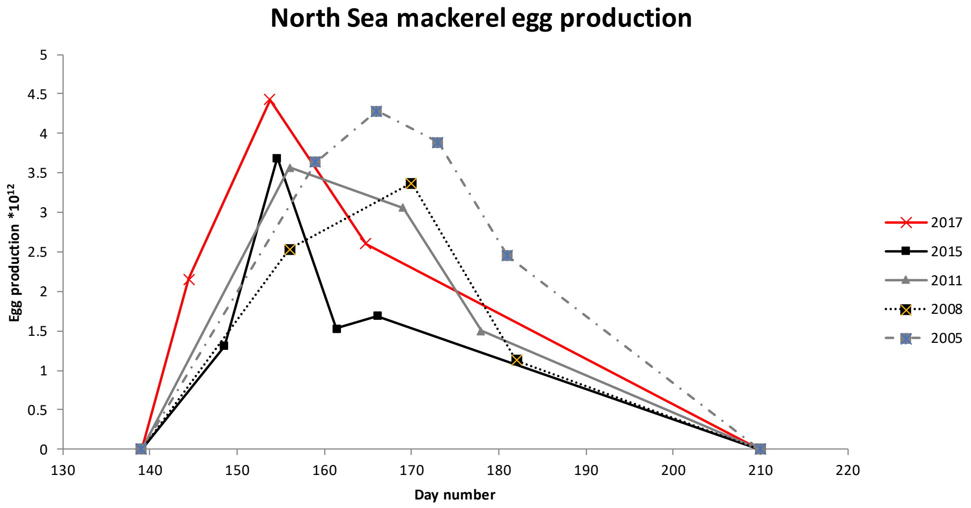


Figure 12.1.6. North Sea Mackerel. Annual egg production curves for North Sea mackerel (prior to 2015 the Lockwood egg development equation was used, since 2015 the Mendiola equation was used).

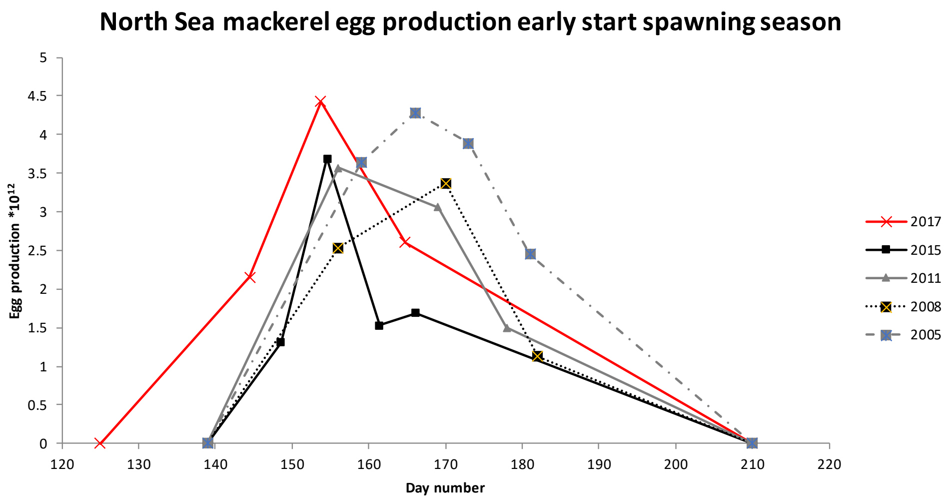


Figure 12.1.7. North Sea Mackerel. Annual egg production curves for North Sea mackerel with early start of spawning period according to the ovary samples (prior to 2015 the Lockwood egg development equation was used, since 2015 the Mendiola equation was used).

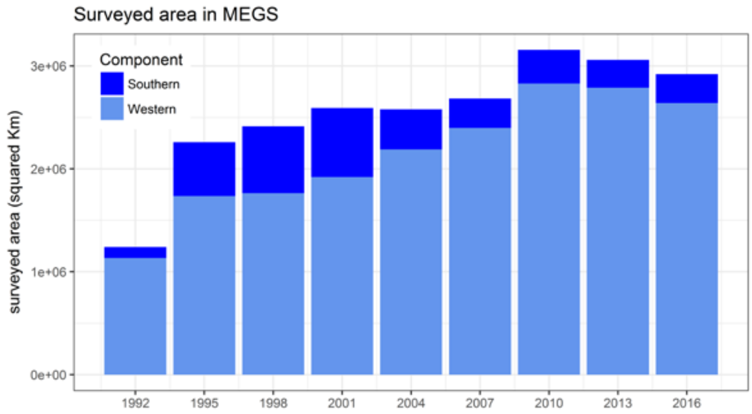


Figure 13.1. Prospected area (sq km) by survey year over MEGS time-series. Light blue represents Western component area and dark blue represents Southern component area.

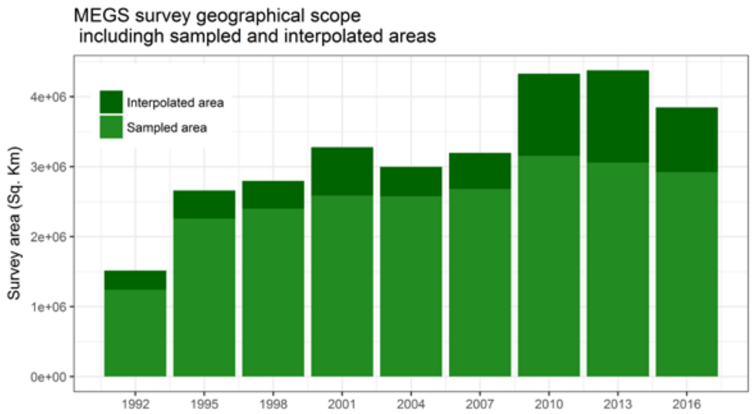


Figure 13.2. Survey geographical scope (sq km) by survey year from MEGS time-series: Including prospected area and interpolated area. Light green represents prospected area and dark green represents interpolated area.

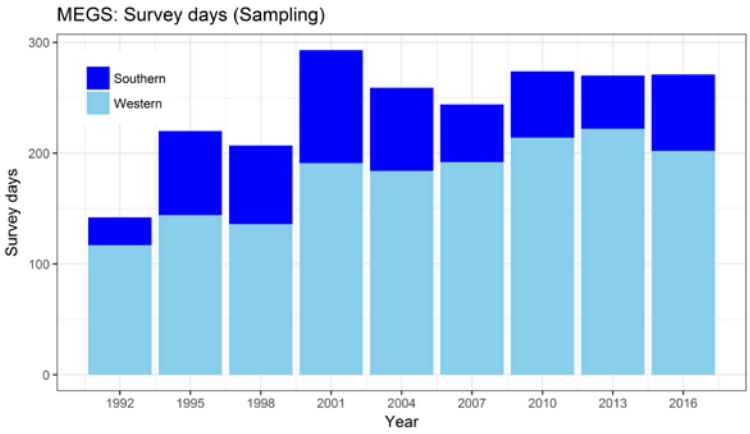


Figure 13.3. Effective survey days by survey year over MEGS time-series: Sampling survey days without considering lost days due to e.g. steaming time, poor weather conditions. Light blue represents survey days in Western component area and dark blue represents survey days in Southern component area.

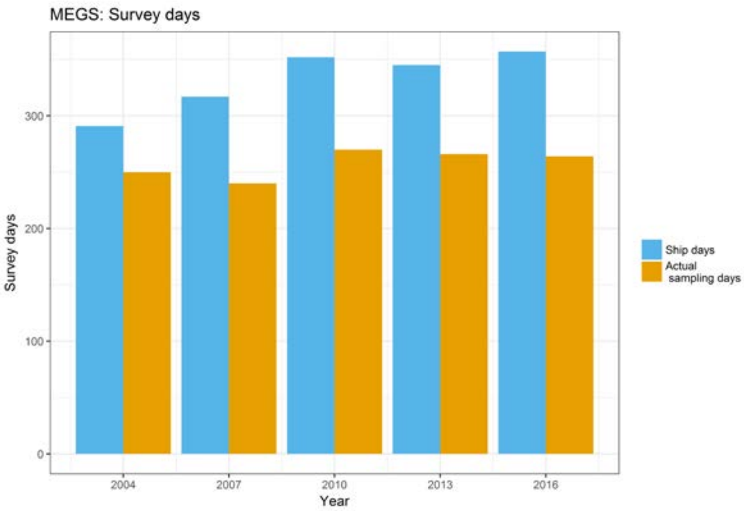


Figure 13.4. Comparison between effective survey days (Actual sampling days - orange color) and total survey days (ship days - blue color) since 2004.

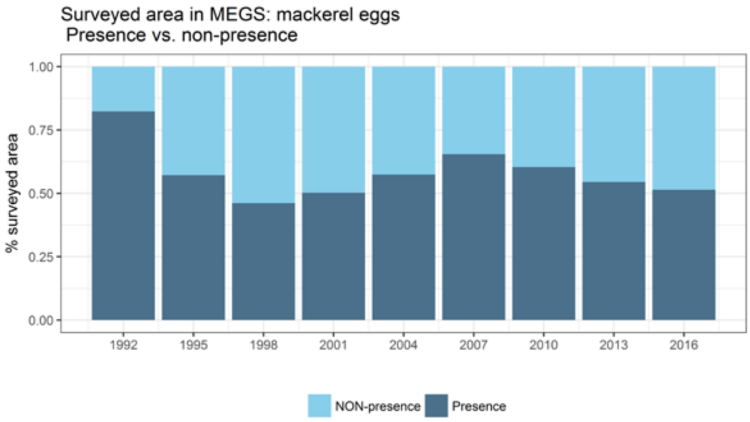


Figure 13.5. NEA Mackerel. Surveyed area with presence of mackerel eggs (positive area) or non-presence of mackerel eggs, each by survey year. Represented is the space occupied by mackerel eggs densities strictly above zero. Dark blue means presence of mackerel eggs in survey area and light blue means non presence of mackerel eggs.

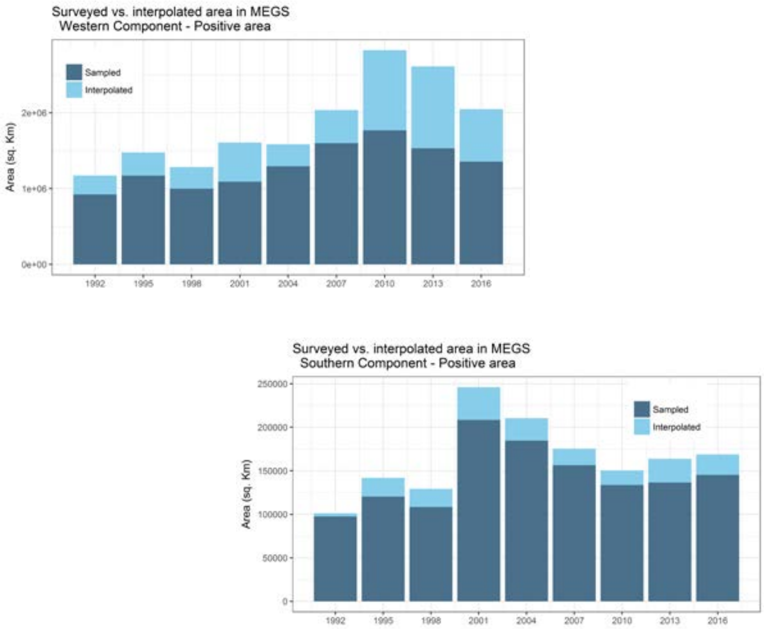
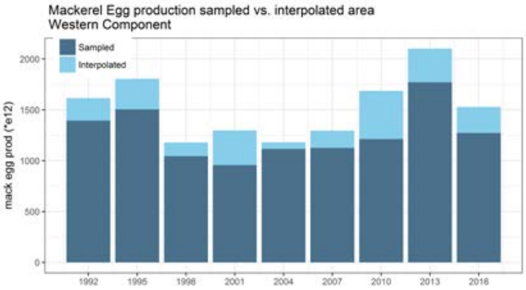


Figure 13.6. NEA Mackerel. Prospected and interpolated area rate inside positive area for Western (left) and Southern (right) components from MEGS time-series, each by survey year. Dark blue means sampled area and light blue means interpolated area during survey.



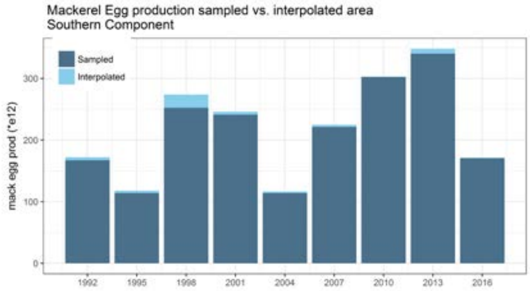


Figure 13.7. NEA Mackerel. Effect of spatial interpolation on mackerel daily egg production for Western (left) and Southern (right) components from MEGS time-series, each by survey year. Dark blue means egg production in sampled area and light blue means egg production in interpolated area.

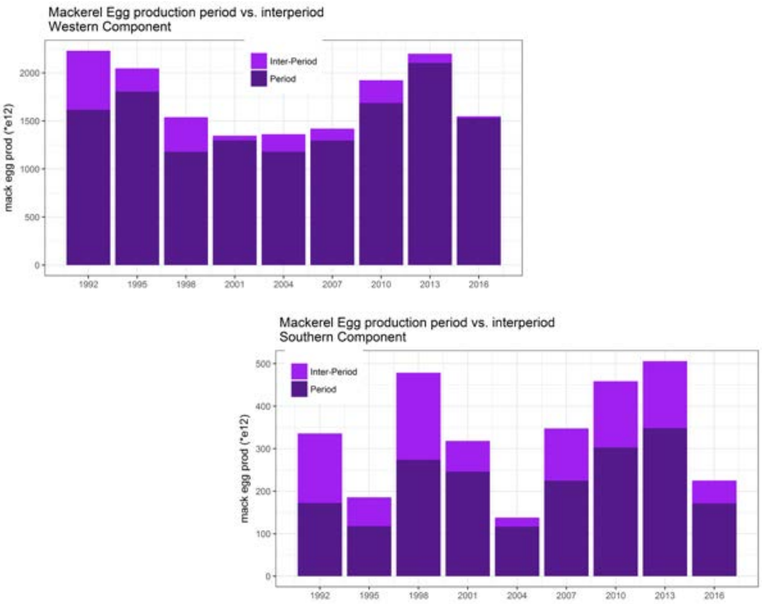


Figure 13.8. NEA Mackerel. Effect of temporal interpolation on annual egg production of mackerel for Western (left) and Southern (right) components for each survey year from MEGS series. Dark purple means egg production in sampling period and light purple means egg production in interpolated period (interperiods).

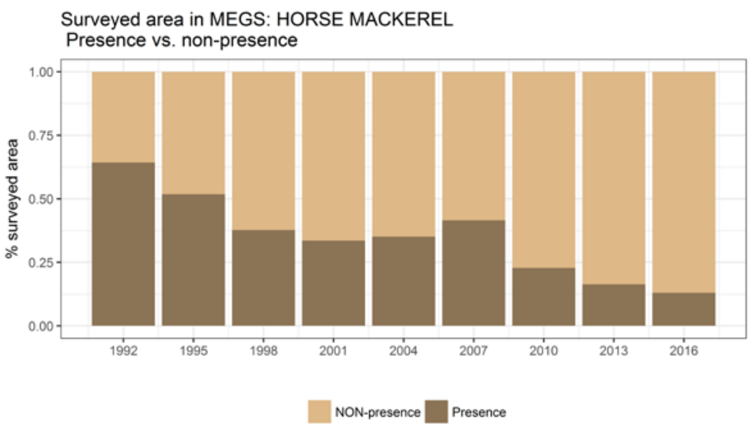


Figure 13.9. Western Horse mackerel. Surveyed area with presence of horse mackerel eggs (positive area) or non-presence of horse mackerel eggs by survey year. Represented the space occupied by horse mackerel eggs densities strictly above zero. Dark brown means presence of eggs in survey area and light brown means non presence of eggs.

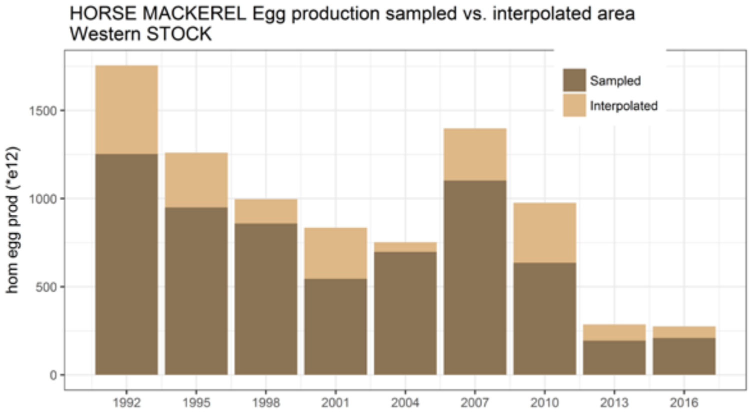


Figure 13.10. Western Horse Mackerel. Effect of spatial interpolation on horse mackerel daily egg production by survey year for Western stock from MEGS time-series. Dark brown reflects measured egg production in the sampled area and light brown reflects calculated egg production in the interpolated area.

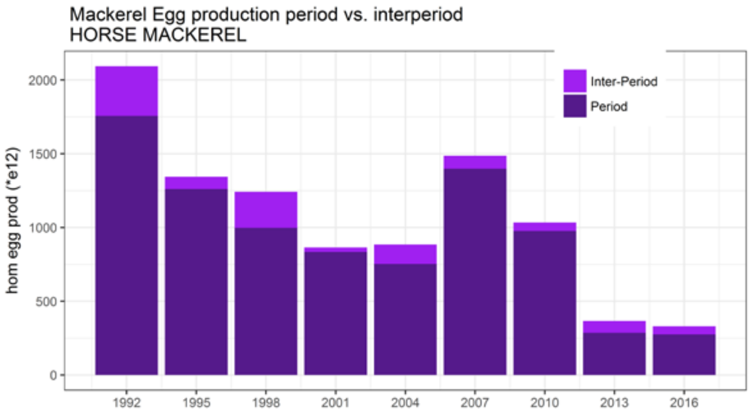


Figure 13.11. Western Horse Mackerel. Effect of temporal interpolation on annual egg production of horse mackerel by survey year for Western stock from MEGS time-series. Dark purple area reflects measured egg production in a sampling period while the light purple area reflects interpolated egg production in an inter-period.

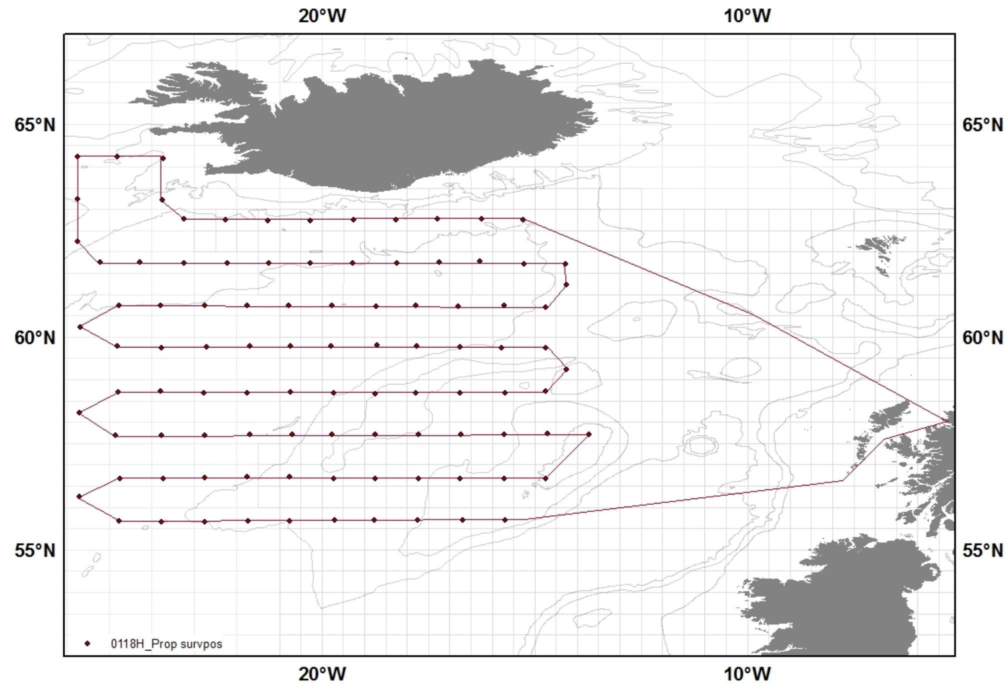


Figure 14.4.1: Proposed track of the 2019 interim mackerel egg survey in the northeast Atlantic