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

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Introduction

The North Sea Mackerel Egg Survey (NSMEGS) is designed to estimate the spawning stock biomass (SSB) of mackerel of the North Sea spawning component of the Northeast-Atlantic stock on a triennial basis. Up to and including 2017 this was undertaken utilizing the annual egg production method (AEPM). This method estimates and combines total annual egg production (TAEP), realized fecundity per gram female, and sex (male to female) ratio to calculate SSB.

Spatial and temporal coverage in the North Sea was reduced with the withdrawal of Norway from the NSMEGS in 2014, with the Netherlands left as the sole survey participant in 2015 and 2017. In 2020 Denmark was recruited as a new participant for the NSMEGS, but due to the Covid-19 pandemic and the implementation of associated measures it was not possible to complete the survey in 2020. After consultation with WGMEGS chairs and the mackerel assessor it was agreed to postpone the survey to 2021.

An issue for the NSMEGS is that since 1982 it has been impossible to collect and sample pre-spawning mackerel, which are necessary in order to estimate the potential fecundity. For SSB estimation using the AEPM, the realized fecundity value used was from the 1982 estimate (Iversen and Adoff, 1983). Also, the planned coverage for 2020 (which was postponed to 2021) of the mackerel spawning in the North Sea, both temporally and spatially, was far from ideal for the Annual Egg Production Method (AEPM; ICES 2018). Consequently, WGMEGS discussed utilizing the Daily Egg Production Method (DEPM) for the NSMEGS. The DEPM requires only one full sweep, in a short time period, of the entire mackerel spawning area, and preferably during peak spawning time, in order to estimate the Daily Egg Production (DEP). A disadvantage of the DEPM is that it requires many more mackerel ovary samples to be collected to estimate batch fecundity and spawning fraction. Considering the pros and cons of the AEPM and DEPM for the NSMEGS, at the 2018 meeting WGMEGS decided to switch to the DEPM for the NSMEGS in 2020 (which was then postponed to 2021; ICES 2018).

Survey

In 2021 Netherlands and Denmark conducted the NSMEGS. Whilst completing an exploratory egg survey along the Norwegian Sea, similar to those in 2017 and 2018 to the west of Faroes, Scotland was also able to contribute several additional survey transects within the Northern North Sea that were then incorporated into the 2021 NSMEGS dataset.

During 2021, Covid 19 measures continued to pose significant challenges that impeded the execution of the survey plan. The Dutch vessel was not permitted to enter foreign harbours during survey breaks, instead being required to undertake the long steam back to a Dutch harbour. As a consequence the Netherlands was unable to sample the most northerly transect. However, Scotland was able to complete this transect during their exploratory survey.

The samples were collected and analysed according to the WGMEGS manuals (ICES 2019a, 2019b). The Netherlands and Scotland sampled eggs with a Gulf VII plankton sampler while Denmark used a Nackthai

sampler. The Netherlands and Denmark utilised a 500 µm plankton net whereas Scotland used a 250 µm plankton net. At each station a double oblique haul was performed from the surface to 5 m above the bottom, a maximum depth of 200 m, or 20 m below the thermocline in case of stratification of the water column. Temperature and salinity were measured during the haul with a CTD mounted on top of the plankton sampler. Electronic flowmeters were mounted on the plankton sampler to monitor flow.

The NSMEGS was carried out from 25th May to 12th June (Table 1). During this period the spawning area between 53ºN and 62ºN was surveyed once, receiving a single coverage (Fig. 1). The survey is designed to cover the entire spawning area with samples collected every half ICES statistical rectangle (ICES, 2014). In total 294 plankton stations were sampled. In 26 of the half rectangles more than one plankton sample was collected (Fig. 1a). These rectangles were used to estimate the CV and variance of the DEP. On each transect at least one pelagic trawl haul was performed for the collection of mackerel adult samples (Fig. 1b).

Following the WGMEGS manual temperature at 5m depth was used to estimate egg development (ICES 2019a). For the DEPM only the mackerel eggs in development stage 1A are used to estimate daily egg production.

Results

Mackerel daily egg production

During the survey the weather was fine. Denmark and Scotland managed to sample all their planned plankton stations. The Netherlands missed 4 plankton stations due to technical issues and limited sampling time.

The spatial egg distribution is shown in Fig. 2. The standard MEGS interpolation rules (ICES, 2019a) were applied where needed (see interpolated stations in Fig. 2). The interpolated egg production accounted for 7.3% of the DEP. The egg distribution is comparable to previous surveys in the same area and period, with the highest numbers of eggs found in the south western area. Previous surveys did not sample above 59ºN and no comparison with previous years is available for this area.

The DEP was calculated for the total investigated area (Table 2). For comparison with the previous survey, a DEP was also calculated for the area between 53.5 and 59ºN and 0.5ºW and 5.5ºE, which was the area sampled in 2017 in the same period of the year (extended period 2 of 2017; see Fig. 2 for sampled area in 2017). DEP of 2021 was 10% higher compared to 2017 (Table 3), however the sampled area in 2021 was also larger (9%) due to coastal stations not sampled or interpolated in 2017.

Adult parameters

Denmark sampled 817 mackerel and collected ovary samples of 119 females. Of these 34 were suitable for estimating batch fecundity, and 112 for POF analyses for spawning fraction estimation. The Netherlands sampled 524 mackerel during the survey and collected ovary samples of 164 females. Of these 164 ovaries 73 qualified for batch fecundity estimation, and 108 for POF analyses.

Denmark did not deliver the results of the batch fecundity and POF analyses. In agreement with the chairs of WGMEGS, the DEPM adult parameters were therefore estimated with the data provided by the Netherlands. Adult parameters are presented in Table 4.

Of the samples analysed for batch fecundity 54 could be used for batch fecundity estimation. In these samples the batch was clearly separated from the standing stock of vitellogenic oocytes. In the remaining 19 samples the new batch of oocytes was not separated from the standing stock. Batch fecundity was 18735 eggs (Table 4). This is higher compared to the estimate of 12391 in the Atlantic in 2019 (ICES, 2021). Corrected female weight was lower compared to the Atlantic in 2019, 331 and 346 grammes respectively. Spawning fraction in the North Sea was 18%, while this was 23% in the Atlantic in 2019. Sex ratio was 0.53 and this was similar compared to the Atlantic.

SSB

Using the stage 1A (stage duration of 1A is 1 day) egg data and the estimated adult parameters, the DEP for the entire sampled area in 2021 amounts to an SSB of 2380 * 10^3 tonnes (Table 4). This estimate is

an order of magnitude higher compared to the estimates of previous surveys in the North Sea using the AEPM. The SSB estimated in 2017 using the AEPM was 287 * 10^3 tonnes.

The total area sampled in 2021 was much larger compared to the area sampled in 2017 (Fig. 2). In 2017 sampling was only conducted south of 59ºN. In 2021 sampling was carried out as far as 62ºN with substantial numbers of eggs being found in this northern area (Fig. 2). In the area above 59ºN there maybe overlap with the western component.

For comparison between 2021 and 2017 a DEPM estimation of SSB was done using the egg production in the area between 53.5 and 59ºN. No adult parameters were available for 2017, so these were assumed to be same as in 2021. The SSB in the area between 53.5 and 59ºN is substantially lower compared to the entire sampled area in 2021 and would be 915 * 10^3 tonnes (Table 5). In 2017 the SSB would be 821 * 10^3 tonnes. For 2017 this is 3 times higher compared to the AEPM estimate of 287 * 10^3 tonnes. Kraus *et al*. (2012) and Köster *et al*. (2020) compared the AEPM and DEPM methods for a time-series of cod in the Baltic. They found the trend and SSB in most years were similar using both methods and similar to the ICES estimate of SSB. However, in years with high SSB the two methods diverged (Kraus *et al*. 2012, Köster *et al*. 2020).

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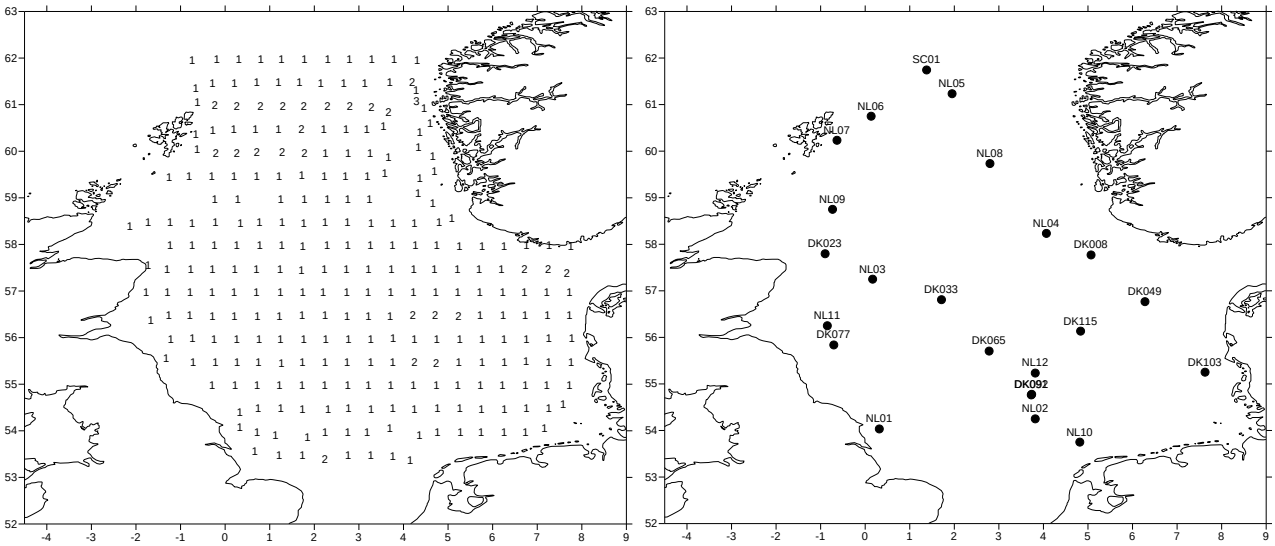

Figure 1. Number of samples for NSMEGS 2021; plankton samples per half ICES rectangle (left) and pelagic trawl hauls for mackerel adult samples (right; all hauls included).

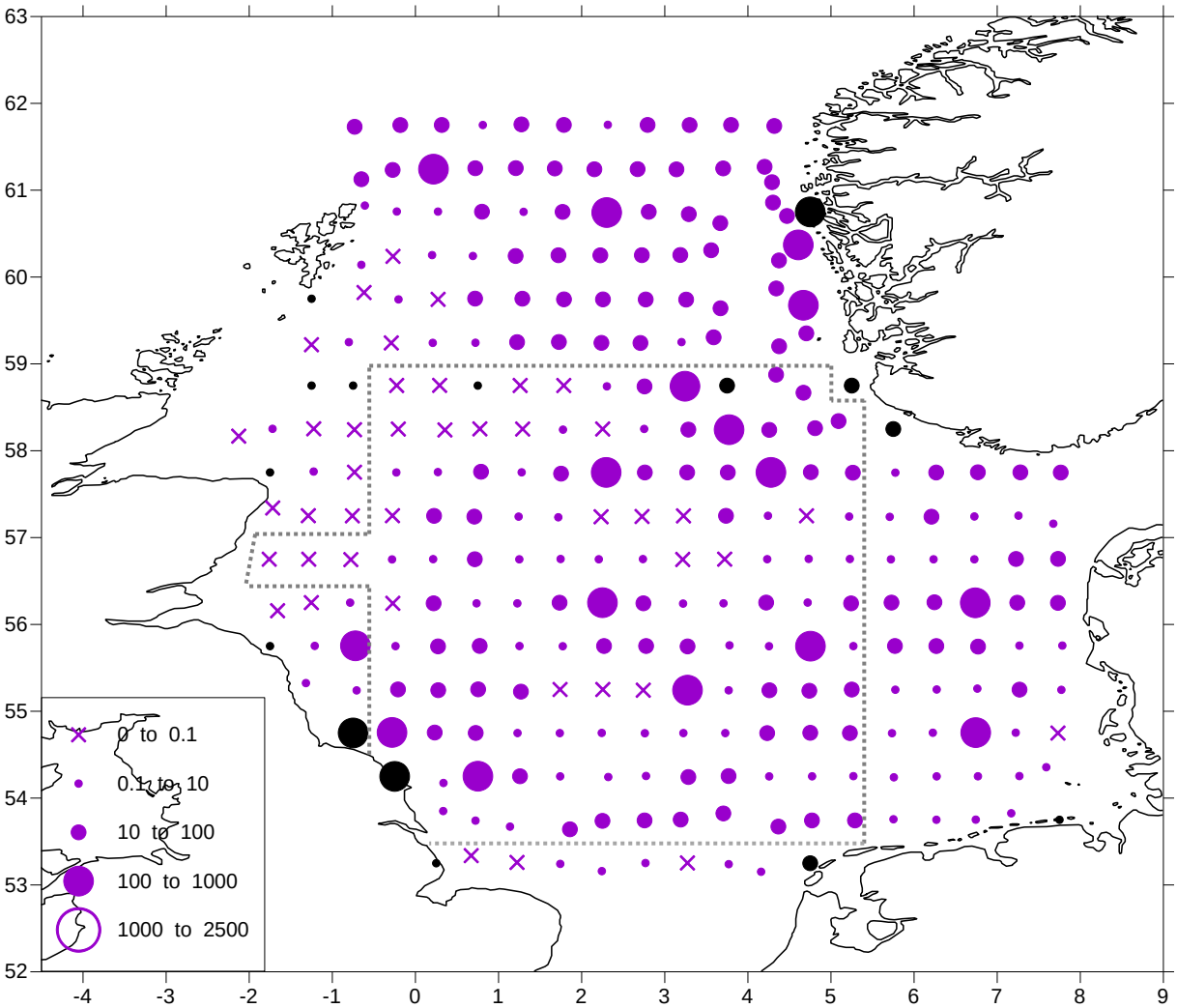

Figure 2. Stage 1A mackerel egg production (eggs/m^2/day) by half rectangle for NSMEGS 2021. Purple circles represent observed values, black circles represent interpolated values, and crosses represent

observed zeros. Dashed line shows sampled area in extended period 2 in 2017 which was used for comparison calculation between the years.

Table 1. NSMEGS surveys cruise dates in 2021 (For Scotland only stations used in the NSMEGS DEP calculation are shown.)

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

Table 2. Daily egg production estimate (stage 1A) in the North Sea.

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

Table 3. Comparison of Daily Egg production (stage 1) between 2021 and 2017, in the area between 53.5 and 59ºN.

Year	**2021**	**2017 Extended period 2**
DEP $*10^{12}$	4.94	4.43
Area sampled ($* 10^{11}$ m^2)	2.25	2.01

Table 4. Adult parameters and SSB.

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

Table 5. Comparisons EPM calculation of stage 1 eggs between 2021 and 2017 (extended period 2). (For 2017 the same batch fecundity, S and R are used as for 2021, as these data were not available for 2017.)

Year	DEP *10^{12}	SSB (*$10^{3)}$ tonnes		
		AEPM	DEPM (below 59^{0}N)	DEPM (total area)
2021	4.94	-	915	2380
2017 Extended period 2	4.43	287	821	-