Feasibility study combining North Sea and Atlantic mackerel egg surveys

C.J.G. van Damme[1], A. Thorsen[2], T. Brunel[1] & R.D.M. Nash[2]

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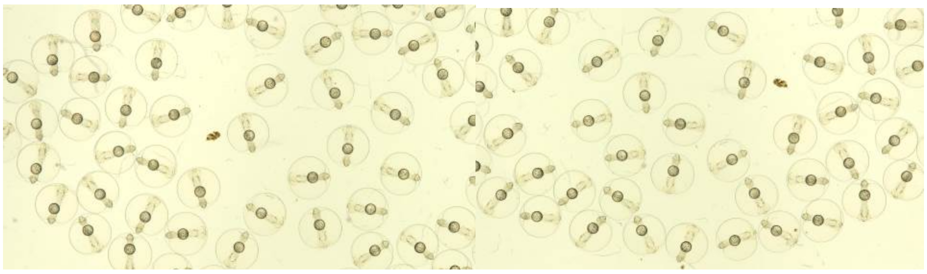

[1] IMARES
[2] IMR (Institute for Marine Research), Bergen, Norway

IMARES Wageningen UR

(IMARES - Institute for Marine Resources & Ecosystem Studies)

Client: H.R. Offringa
Ministerie EZ, Directie ELVV
Postbus 20401
2500 EK Den Haag

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P.O. Box 68	P.O. Box 77	P.O. Box 57	P.O. Box 167
1970 AB IJmuiden	4400 AB Yerseke	1780 AB Den Helder	1790 AD Den Burg Texel
Phone: +31 (0)317 48 09 00	Phone: +31 (0)317 48 09 00	Phone: +31 (0)317 48 09 00	Phone: +31 (0)317 48 09 00
Fax: +31 (0)317 48 73 26	Fax: +31 (0)317 48 73 59	Fax: +31 (0)223 63 06 87	Fax: +31 (0)317 48 73 62
E-Mail: imares@wur.nl	E-Mail: imares@wur.nl	E-Mail: imares@wur.nl	E-Mail: imares@wur.nl
www.imares.wur.nl	www.imares.wur.nl	www.imares.wur.nl	www.imares.wur.nl

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Summary

Mackerel *Scomber scombrus* is a widely distributed species with a high economic and ecological importance. The North East Atlantic mackerel comprises three different spawning components. The Spawning Stock Biomass (SSB) index from the mackerel egg surveys is used as a fisheries independent tuning index for the mackerel assessment. The North Sea mackerel triennial egg survey is carried out in the year after the egg survey of the Western and Southern spawning components. Due to this time lag currently the North Sea egg survey SSB index is not used directly in the mackerel assessment. However, the egg survey is the only available information on the mackerel spawning component in the North Sea. Can the North Sea mackerel egg survey index be incorporated in the mackerel assessment and what is the impact of the incorporation of this index? Could the North Sea and Atlantic egg surveys be carried out in the same sampling year?

The incorporation of the North Sea SSB index (even with a one year time lag) in the mackerel assessment has little effect on the assessment output. It is therefore recommended to continue performing the North Sea survey in the year after the Atlantic survey. No extra vessels and no extra trained staff will then be necessary. This way the surveys can be carried out with available experienced staff and vessels and the high quality of the data from the survey can be ensured.
It is important though that the North Sea survey is carried out with two vessels instead of one to increase the accuracy of the survey index and to decrease the vulnerability of the survey to technical problems.

North Sea mackerel should be continued to be monitored to ensure the diversity of the fish fauna in the North Sea ecosystem. Mackerel has the potential to cause major ecosystem restructuring through alterations of the food web and thus the functioning of the North Sea ecosystem.
Currently the incorporation of North Sea mackerel egg survey SSB index has little impact on the output of the mackerel assessment. But this is only the case if the North Sea component remains at its current low level. In the current assessment setup, the North Sea component cannot be distinguished from the other spawning components and only contributes to a minor extend to the total abundance estimate. This makes the egg survey the only key source of information on the North Sea component dynamics. Substantial increases or decreases may affect the survival and exploitation potential of the small pelagic species in the North Sea and the resilience of mackerel in itself.

Ideally, the current mackerel assessment model should be adjusted to incorporate the North Sea egg survey. The assessment model should simulate all spawning components separately, together adding up to the total North East Atlantic stock. This will allow estimation of the total mackerel stock, fit for fisheries management, but also allows tracking relative changes in spawning component and as such addresses the ecosystem relevance of mackerel. Such an extension is however a complex task.

The egg survey index is used as a relative index. When the temporal variations are unchanged in the index, this has no effect on the assessment output, only on the estimated catchability within the survey. Incorporating the North Sea index does not significantly affect the temporal variation of the SSB index; therefore, it has virtually no effect on the assessment output. As long as the North Sea component remains at a low level and its importance compared to the total stock does not vary, including the North Sea survey data in the SSB index does not have an effect on the output of the assessment.
Given the (current) small proportion of the stock represented by the North Sea index, combined to the fact that mackerel SSB does not vary abruptly from year to year, the loss in accuracy resulting of combining indices with one year of difference is extremely minor. Adding the historical North Sea index to the Western and Southern index with one year lag seems to be an acceptable way of constructing an index representative of the 3 components. This has however no implication for the mackerel assessment output.

The Atlantic egg survey is carried out from January till August; the North Sea egg survey is carried out in May – June with an extra short cruise needed in April-May for the collection of potential fecundity samples. Due to the overlap in timing the North Sea survey has always been carried out in the year after the Atlantic survey.
Due to the overlap in the timing extra vessels would need to be found to participate in the survey and extra trained staff is necessary to carry out both surveys in the same year. Also extra staff will need to be found to analyse the fecundity and atresia samples in the same year. This will lead to extra costs and reduction of the quality of the data from the survey since the extra staff will need to be trained to identify eggs and analyse fecundity samples.

1. Introduction

Mackerel *Scomber scombrus* is one of the most widely distributed fish stocks. In North East Atlantic mackerel three different spawning components are recognised: Western, Southern and North Sea. These spawning components have distinct spawning areas, but come together on the summer feeding and overwintering grounds. Mackerel from the Western and Southern components overspill into the North Sea as well.
In the North Sea, mackerel from the different spawning components are caught together but these mixed catches cannot be allocated to the different spawning stocks (ICES, 2014c). Therefore, mackerel is assessed in practice as a single stock, and the catch data is representative of the three spawning components, including the North Sea (ICES, 2014c).
However, the Spawning Stock Biomass (SSB) index derived from the mackerel egg surveys, used as a tuning series (among others) for the assessment, is representative only of the Southern and Western components. Due to the one year time lag between the egg surveys of the Western and Southern components and the survey of the North Sea component, the North Sea egg survey data are not incorporated into the SSB index and are currently not (directly) used in the assessment.

Mackerel has a large economic value and it is also an important part in the North Sea ecosystem, though its ecological importance is currently still poorly understood (Jansen, 2013). Mackerel is a predatory fish that feeds on zooplankton, as well as larval and juvenile fish. Changes in the mackerel stock will also influence the predatory pressure of this fish. Monitoring of changes in the mackerel stock is not only important for the management of the stock but also for the ecosystem management of the North Sea.

1.1 Problem definition

The North Sea mackerel egg survey is the only available spawning component specific data on the North Sea mackerel stock (as catches contain a mixture of Western, Southern and North Sea mackerel) and is currently used to monitor the state of the North Sea mackerel spawning component. Since the overexploitation and recruitment failure of 1969 the North Sea mackerel component is low.
Due to the one year time lag between the mackerel egg surveys in the Atlantic and in the North Sea, the North sea egg survey results are currently not directly used in the mackerel stock assessment. In addition there is uncertainty as to how reliable these data are with respect to matching the abundance fluctuations of the components of the stock.
The following questions arise:

- Can the North Sea egg survey data be incorporated in the current mackerel assessment?
- Is it feasible to carry out the North Sea and Atlantic egg surveys in the same year?

1.2 Setup of the report

In this report first the sensitivity of the mackerel assessment is discussed followed by the effect of incorporating the North Sea egg survey data into the current mackerel assessment (Chapter 3). In order to evaluate if it is feasible to carry the North Sea an Atlantic egg survey in the same year it is necessary to understand the survey requirements. Therefore, background information on sampling at sea and sample analyses is also provided (Chapter 4). Finally results of the effect on the mackerel assessment and practical implications of the actual egg surveys are combined to an assessment on the feasibility of carrying out the North Sea and Atlantic mackerel egg surveys in the same year (Chapter 5).

2. Assignment

The aims of this project are:

- To evaluate the possibility of incorporating the North Sea mackerel egg survey data into the mackerel assessment, test the sensitivity of the current assessment to the incorporation of the North Sea historic time series and to evaluate the accuracy of the mackerel SSB index incorporating the North Sea data.
- To evaluate the feasibility of actually carrying out the Western and Southern and North Sea mackerel egg surveys in the same season and year and estimate the logistics and costs necessary to undertake this.

This research is performed within the EZ-program Beleidsondersteunend Onderzoek (BO) theme Verduurzaming Visserij.

3. Mackerel assessment

The current mackerel assessment (ICES, 2014a) is based (among other surveys) on the SSB index from the triennial mackerel egg surveys in the Western and Southern areas. This index covers the period from 1992 to 2013 and has a prominent influence on the assessment. Within this period, the North Sea spawning component has been estimated to represent a marginal proportion of the entire North East Atlantic mackerel stock (between 2 and 4%, Fig. 3.1 and ICES, 2014a). The North Sea component is currently not incorporated in the SSB index. The main reason is that the North Sea egg survey is carried out one year after the egg survey of the Western and Southern components.
Given the relative small size of the North Sea component, it is considered that not incorporating the North Sea survey in the index is not likely to have a great impact on the assessment. The weight of this assumption will be quantified in this report. It is not within the scope of this report to carry out a separate assessment for the North Sea mackerel spawning component.

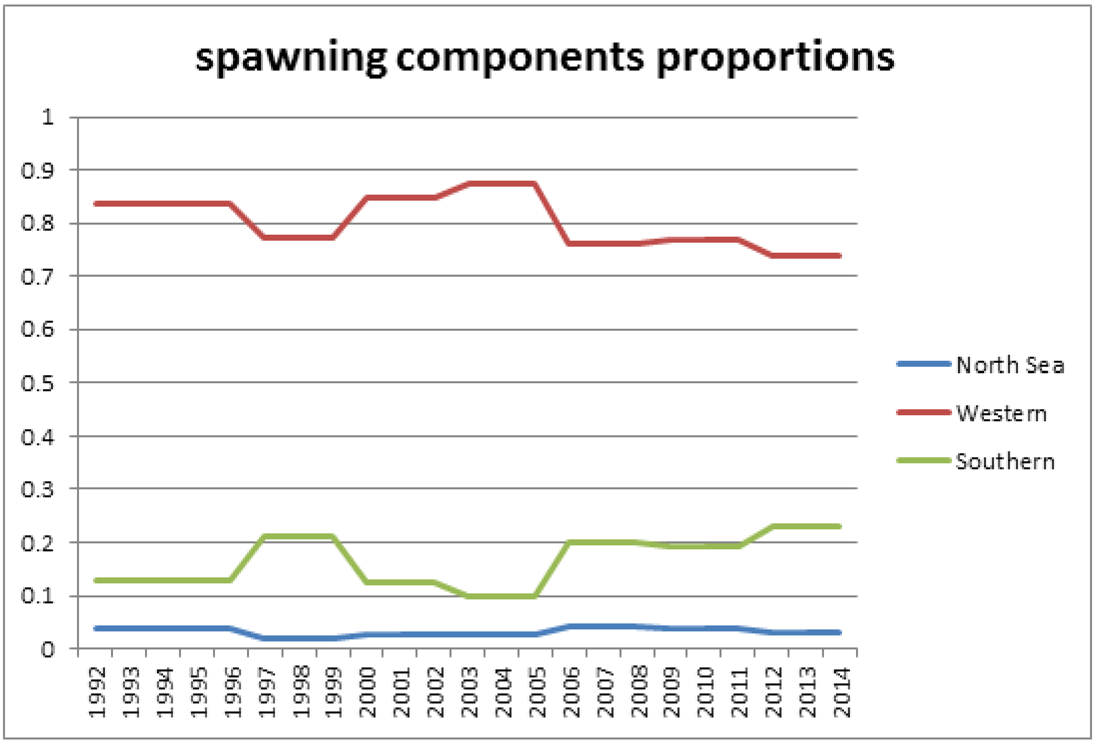

Figure 3.1. Spawning components proportions over the time series.

3.1 Sensitivity of the assessment to the North Sea mackerel egg survey

In order to assess the consequence of not incorporating the North Sea survey in the SSB index, the 2014 mackerel assessment (ICES, 2014c) was run using a modified SSB index including the North Sea component. Given the one year time lag between the surveys, the incorporation of the North Sea component was done by simply adding the SSB index from the North Sea survey to the original index from the Western and Southern component (W+S index) from the previous year (thus assuming the surveys were carried out in the same year). The modified index differs by 2 to 7% from the original one (Table 3.1).

Table 3.1. Calculation of the mackerel SSB index incorporating the North Sea survey data and difference between the original index (W+S) and the combined index.

Survey year	**1992**	**1993**	**1995**	**1996**	**1998**	**1999**	**2001**	**2002**	**2004**	**2005**	**2007**	**2008**	**2010**	**2011**	**2013**	**2014**
North Sea		0.15		0.10		0.07		0.21		0.22		0.15		0.17		0.16*
W+S	3.90		3.84		4.42		3.27		3.17		3.97		4.84		5.03	
Combined	4.05		3.94		4.49		3.48		3.39		4.12		5.00		5.18	
Difference	4%		3%		2%		6%		7%		4%		3%		3%	

Data sources: North Sea (ICES, 2012), W+S (ICES, 2014c)

** No egg survey was carried out in 2014. This value was calculated, using the estimated proportion of the North Sea component in the recent years (ICES, 2014a).*

The output of the assessment with the combined index differs only marginally from the original WGWIDE assessment, run with only the Western and Southern component index. The maximum difference observed is of 1.4% for the fishing mortality in 2013 and of -1.1% for the SSB in 2014. The magnitude of this difference is negligible compared to the width of the confidence bounds of the assessment output (± 45% for the recruitment, ±18% for the SSB and ± 24% for the fishing mortality).

If fishing pressure is equally distributed over all areas (which is what you assume in the assessment), a stable contribution of stock components is desirable. If either the fisheries distribution or the spawning component productivity changes, problems occur. For the relative small North Sea spawning component a change might lead to a wipe-out of the North Sea mackerel.

3.2 Evaluating the accuracy of the historic egg survey time series incorporating the North Sea egg data

The construction of a single index for the three spawning components based on the historical data requires summing SSB indices with one year lag (as done in the previous section). In this section, the accuracy of such an index is compared with an index calculated by summing North Sea, Western and Southern survey data of the same year. This last index is generated by artificially creating a time series of annual values for the SSB index, by multiplying the SSB with the survey catchability both estimated by the assessment (ICES, 2014c). This yearly SSB index was assumed to be representative for the three components. Using the relative contributions of the three components to the total stock (ICES, 2014a), an artificial annual time series of SSB indices corresponding to both the North Sea component and the joint Western and Southern components were computed.

Based on these annual time series, three different triennial indices were created: 1) combined North Sea and Western and Southern indices with one year lag, 2) combined North Sea and Western and Southern indices from the same survey year, and 3) Western and Southern index only.

The indices obtained are very similar (Fig. 3.2).

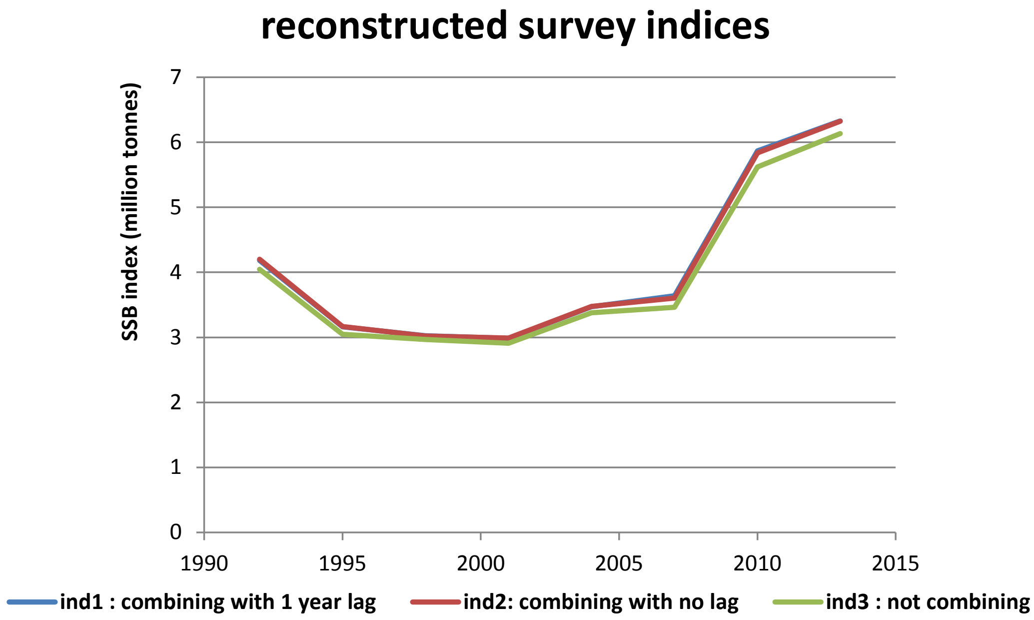

Figure 3.2. Reconstructed triennial survey indices combining the North Sea index with the Western and Southern index with (ind 1) and without one year lag (ind 2), and not incorporating the North Sea data in the index (ind 3).

Notably, using the North Sea survey with one year lag makes virtually no difference compared to when surveys would be carried out on the same year. Not incorporating the North Sea component results in an index around 3% lower (Fig. 3.2).
When running the mackerel assessment using these three indices separately, the output shows, again, barely any difference.

4. Mackerel egg survey

4.1 Requirements and costs for the surveys

Although the egg production method is simple, it requires both an accurate estimate of the total numbers of eggs spawned over the entire spawning area and season, as well as an accurate fecundity (total number of eggs produced by a single female in one spawning period) of a female (Appendix A). For egg sampling the spawning area needs to be covered in transects east-west on the coast (or north-south in the area along the coast of northern Spain). Fecundity is different for the Atlantic and North Sea components and have to be estimated separately. Potential fecundity needs to be estimated just prior to spawning commences. Fecundity and atresia estimation cannot be done during the survey. This needs to be done in a specialised laboratory upon return from sea.

The identification and staging of fish eggs and analyses of the fecundity and atresia samples are highly specialised skills which need to be carried out by trained scientists. The surveys are carried out triennially and to ensure high quality data from the surveys there should be a continuation of the vessels and scientists involved in the survey, i.e. the survey should be carried out by the same scientists as much as possible.

Below are the requirements for carrying out a full North Sea and Atlantic mackerel egg survey (Table 4.1). The associated costs for a full North Sea survey are shown in Table 4.2. Costs for the Atlantic survey are shown for a single cruise (Table 4.3), since this survey is carried out by multiple countries and costs will differ by country.
It is important to note that there is an overlap in the timing of the Atlantic and North Sea surveys and the Netherlands is the only country currently participating in the North Sea survey. For 2016 the Netherlands will sample two cruises in the Atlantic in April and June on board RV Tridens. Hence two other available vessels would need to be found and scientists trained, to also be able to sample in the North Sea at the same time. Furthermore the Netherlands (and in the past Norway) analyses Atlantic and North Sea fecundity and atresia samples. Additional personnel should be trained to be able to analyse both sample sets in the same year. Therefore extra costs will have to be made to setup new vessels for mackerel egg sampling and the training of the extra scientists to collect and analyse the samples.

While finding extra costs and extra vessels is a practical matter that can probably be solved, finding staff will be a more difficult problem. The survey is only carried out once every three years so most likely for every survey extra new scientist will have to be employed for the survey only. Training new scientists every three years will lead to a reduction in the quality of the data of the surveys and this will reduce the quality of the mackerel assessment.

Table 4.1. Overview of requirements for the mackerel egg surveys in the different areas.

Area	Timing	No. cruises* (No. vessels)	No. scientists per cruise	Extra Potential fecundity sampling (days)	Potential fecundity / Atresia samples	No. institutes for analyses of potential fecundity samples	No. institutes for analyses of atresia samples
North Sea	May - June	8 (2)	4-5	3 (in April)	50/50	2	2
Atlantic	Jan - Aug	20 (20)	4-5	0	150/700	9	7

**Length of a North Sea cruise is 5.5 days; an Atlantic cruise is 19 days*

Table 4.2. Cost calculation for the total North Sea mackerel egg survey (for the purpose of this report assuming IMARES would be carrying out the complete survey).

	Ship time (days)	**IMARES crew (hours)**	**Lab time (hours)**	**Data analyses & reporting (hours)**
Preparation		184	84	
Potential fecundity cruise	3	72 (2*36)		
Period 1	11 (5.5+5.5)	740 (2*(5*74))		
Period 2	11 (5.5+5.5)	740 (2*(5*74))		
Period 3	11 (5.5+5.5)	740 (2*(5*74))		
Period 4	11 (5.5+5.5)	740 (2*(5*74))		
After survey			400	80
Total days/hours	**47**	**3216** Cat II 1906 Cat III 1310	**484** Cat II 476 Cat III 8	**80** Cat II 0 Cat III 80
Total costs	**€ 701.123***	**€ 280.264****	**€ 38.396****	**€ 7.920****
Total costs survey: €1.027.703				

**Based on cost indication by the Rijksrederij*

***Based on IMARES personnel EZ tariffs for 2015*

Table 4.3. Cost calculation for one cruise of the Atlantic mackerel egg survey (for the purpose of this report assuming the cruise of 3 weeks without breaks and carried out by IMARES, the laboratory analyses are divided equally over the cruises). IMARES carries out 2 cruises during the Atlantic survey.

	Ship time (days)	**IMARES crew (hours)**	**Lab time (hours)*** **	**Data analyses & reporting (hours)**
Preparation		164	34	
Potential fecundity cruise	0			
Egg survey cruise	19	1140 (5*(19*12))		
After survey			475	64
Total days/hours	**19**	**1304** Cat II 766 Cat III 538	**509** Cat II 501 Cat III 8	**64** Cat II 0 Cat III 64
Total costs	**€ 283.433***	**€ 113.776****	**€ 40.371****	**€ 6.336****
Total costs one cruise: € 443.916				

**Based on cost indication by the Rijksrederij*

***Based on IMARES personnel EZ tariffs for 2015*

****Lab time for the Atlantic includes the analysis for both mackerel and horse mackerel*

4.2 Requirements of the vessels

For the sampling at sea the participating vessels should have the ability to deploy plankton sampling gear (Gulf VII high speed plankton sampler, Nackthai or Bongo net) with a depth monitor and a CTD attached for temperature and salinity measurements. The vessels must also have the ability to trawl for mackerel (and horse mackerel for the Atlantic survey) using a pelagic trawl. It is essential to have on-board basic laboratory facilities for handling of samples.
The vessel also needs to have an area where the trawl catches can be sorted and individual mackerel measured and sampled for fecundity. This preferably should be an inside area since it can take up to 12 hours to work up one trawl haul.
The vessel needs to be able to accommodate at least 4-5 scientists. Sampling is carried out 24 hours, and the scientific crew need to work in shifts of at least 2 people.

Ideally plankton sampling and trawling should be carried out on the same vessel (as this reduces vessel time and personnel costs). However, there is the opportunity to use one vessel for the plankton sampling and have an extra vessel (for fewer days) with at least 2 scientists for the collection of the pelagic trawl samples for fecundity estimation.

The plankton samples need to be gently washed with sea water from the net and fixed in 4% formaldehyde fixative. After 24 hours of fixation the formaldehyde samples needs to be analyzed for the abundance of mackerel eggs. Sorting and egg identification needs to be carried out under a microscope (or using image analyses if available). Thus the laboratory needs a wet space for fixation of the samples and a dry seating area for sorting and identification of the samples.

4.3 Egg surveys

The actual egg surveys consist of two elements, 1) the actual sampling at sea for the collection and estimation of number of eggs spawned and the collection of ovary samples from fresh fish for the estimation of fecundity and 2) the estimation of potential fecundity and atresia in the laboratory after returning from sea.

Mackerel spawns from south Portugal up to the Faroese Islands in the north, covering a period from February till July (ICES, 2014b). The Annual Egg Production Method (AEPM) requires an accurate sampling of this area in over the entire spawning period. In the central North Sea mackerel spawn in May – June (Appendix A).

The 2013 Atlantic survey results showed; 1) an ongoing shift in mackerel peak spawning from April – June to February – March, 2) a significant expansion in the western mackerel spawning area from April to June, and 3) no decline in horse mackerel egg production towards the end of the survey period (July 2013) (ICES, 2014b).
The planning (Table 6.1 in ICES, 2015) shows that 20 individual cruises are necessary to cover the entire spawning area and season in the Atlantic in 2016. In order to be able to cover the entire mackerel spawning season in the North Sea at least 4 survey periods are necessary (Appendix A).

4.4 Mackerel fecundity estimates

An accurate realised fecundity estimate is necessary to convert the numbers of eggs spawned to female SSB. The planning for possible future North Sea fecundity and atresia samplings should be based on the experience from former North Sea surveys as well as from the Atlantic surveys.
It is not possible to collect potential fecundity samples during the egg survey, but atresia samples can be collected.

North Sea realised fecundity estimate should be based on a minimum of 50 potential fecundity samples and a minimum of 50 atresia samples (Appendix B). Since the potential fecundity estimate is the most important number for the precession of the realised fecundity estimate, the most cost effective strategy will be to collect 80-100 potential fecundity samples and 50-70 atresia samples. After screening in the laboratory it can then be decided which samples to analyse for potential fecundity and which for atresia estimation.

Potential fecundity samples have to be collected from pre-spawning fish while atresia samples need to be collected from spawning fish. Previous North Sea egg surveys (including 2015) have shown that all the mature mackerel have started spawning when the egg surveys in the North Sea commence (end of May). This means that the atresia samples can be collected during the egg survey, but the fecundity samples have to be collected earlier, probably April-May. Extra fecundity sampling during this period requires an extra short (3 days) survey to be set up with at least 2 scientists on board. Alternatively, mackerel potential fecundity sampling may be included in another survey taking place during this period. Earlier experience has shown that the Norwegian North Sea Sand Eel survey in April-May may be combined successfully with mackerel fecundity sampling. To do this only small extra resources are needed; some time must be prioritized for mackerel trawling and an extra scientists needs to be on board to carry out the fecundity sampling. Previous experience shows it is necessary to have an extra scientist on board for the mackerel sampling.
Another survey in the North Sea area in April-May is the AtlantoScandian herring acoustic survey. However, we tried in 2014 to collect mackerel fecundity samples, but this survey only covers the North Sea mackerel juvenile area so it won’t be fit for purpose.

5. Conclusions

The aims of this project are to evaluate the possibility of incorporating the North Sea mackerel egg survey data into the mackerel assessment and to evaluate the feasibility of actually carrying out the Western and Southern and North Sea mackerel egg surveys in the same season.

Due to the overlap in the timing of the Atlantic and North Sea surveys extra vessels need be found to participate in the survey and extra trained staff is necessary to carry out both surveys in the same year. Also extra staff will need to be found to analyse the fecundity and atresia samples in the same year. Egg identification and staging and fecundity estimation are highly specialised skills which need to be carried out by trained staff. These skills are not easily gained and training new scientists every three years will lead to a reduction in the quality of the data from the surveys.

Since the incorporation of the North Sea SSB index in the mackerel assessment has little effect on the assessment output, and the North Sea index can be incorporated with the one year time lag, it is advised to stick to the current situation, i.e. the North Sea survey is conducted in the year after the Atlantic survey. This way no extra vessels and no extra trained staff will be necessary and the quality of the survey remains at a high level.

It is important that the North Sea survey is carried out with two vessels to decrease the vulnerability of the survey to bad weather or technical problems.

Currently the incorporation of North Sea mackerel SSB has little impact in the output of the mackerel assessment. But this is only the case if the North Sea component remains at its current low level. If changes occur in the relative importance of the North Sea spawning component this might lead to overfishing. It therefore is important to continue to monitor the North Sea mackerel egg survey SSB in the future to mark any (relative) changes in spawning component size and changes in importance of mackerel in the North Sea ecosystem.

Mackerel feeds on zooplankton, but also on larvae and juveniles of other (commercial) fish species, such as sandeels, herring, sprat and gadoids. After gadoids, mackerel is the most important fish predator in the North Sea (Mackinson and Daskalov, 2007; Trenkel *et al*., 2014). To ensure the diversity of the fish fauna in the North Sea, mackerel should be continued to be monitored in the North Sea ecosystem. This species has the potential to cause major ecosystem restructuring through alterations of the food web and thus the functioning of the North Sea ecosystem which in turn could have major consequences for the currently prosecuted fisheries.

In the current assessment setup, the North Sea component cannot be distinguished from the Western and Southern components and only contributes to a minor extend to the total abundance estimate. This makes the egg survey the only key source of information on the North Sea spawning component dynamics. Substantial increases or decreases may affect the survival and exploitation potential of the small pelagic species in the North Sea and the resilience of mackerel in itself.

Ideally, the current assessment model in place for mackerel should be adjusted to incorporate the egg survey in the North Sea. The assessment model should be modified to simulate the spawning components separately, together adding up to the total mackerel stock. This not only allows estimating the total stock, as is currently used for management purposes, but also allows to track relative changes in spawning component sizes throughout time. Simultaneously, this addresses the ecosystem relevance of mackerel as described above. Such an extension is however a complex task.

Incorporating the North Sea index does not significantly affect the temporal variation of the SSB index; therefore, it has virtually no effect on the assessment output. One can conclude that, as long as the North Sea component remains low, and its importance compared to the total stock does not vary, including or not the North Sea survey data in the SSB index does not have a marked effect on the output of the assessment. The egg survey index is not used as an absolute index in the assessment, but as a relative index. This means that, as long as the temporal variations are unchanged in the index, this has no effect on the assessment output, only on the estimated catchability (i.e. scaling factor) of the survey.

Given the small proportion of the stock represented by the North Sea index, combined with the fact that mackerel SSB does not vary abruptly from one year to the next, the loss in accuracy resulting of combining indices with one year of difference is minor. As long as the current situation remains, there is little precision to be gained by conducting the North Sea survey in the same year as the survey in the western waters. In addition, adding the historical North Sea index to the Western and Southern index with one year lag seems to be an acceptable way of constructing an index representative of the 3 components. This has however no implication for the assessment output.

The North Sea realised fecundity estimate should be based on 50-70 atresia samples and 80-100 potential fecundity samples. The potential fecundity samples have to be collected in April and May before the start of spawning. This may be arranged as a separate survey or be added to an existing survey, such as the Norwegian North Sea Sand Eel survey. The atresia samples can be collected during the North Sea mackerel egg survey.

6. Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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Justification

Rapport C124/15
Project Number: 4316810025

The scientific quality of this report has been peer reviewed by the two colleague scientists and the head of the department of IMARES.

Approved: N.T. Hintzen
Scientist

Signature:

Date: 1 September 2015

Approved: I.J. de Boois
Project leader WOT Surveys

Signature:

Date: 1 September 2015

Approved: J.H.M. Schobben
Head of department Fish

Signature:

Date: 1 September 2015

Appendix A. Annual Egg Production Method

The method used to estimate mackerel spawning stock biomass is the so-called Annual Egg Production Method (AEPM) (Lockwood *et al*., 1981). The method is a rather simple one (Bernal *et al*., 2012). The total annual egg production (TAEP), the total number of eggs produced during the entire spawning season, is estimated. Dividing the total egg production by the numbers of eggs produced by a single female gives an estimate of the female SSB. The ratio between female and male mackerel gives an estimate of the total SSB.

Although this method is simple, it requires both an accurate estimate of the total numbers of eggs spawned over the entire spawning area and season, as well as an accurate fecundity (total number of eggs produced by a single female in one spawning period) of a female. For the estimation of total egg production the spawning season is divided in multiple periods whereby the entire spawning area should be sampled within one period (ICES, 2014a). The period egg productions form the spawning curve over the spawning season and give the total annual egg production.

For egg sampling the spawning area needs to be covered in transects east-west on the coast (or north-south in the area along the coast of northern Spain). The transects are spaced half a degree apart (or one transect each half ICES rectangle). The setup of the survey is to cover each alternating transect at the beginning of the cruise in the assigned sampling area and filling in between the sampled transects on the way back, thus ensuring that all mackerel (and horse mackerel) spawning is covered.

For realised fecundity, an estimate of potential fecundity needs to be corrected for the loss of oocytes through resorption (the process called atresia) (ICES, 2014e). Potential fecundity needs to be estimated just prior to spawning commences. In practice the sampling for potential fecundity should be done before the actual egg surveys start, since at that time mackerel have already started spawning. Loss of oocytes due to atresia should be estimated during the actual spawning, thus samples can be collected during the egg surveys.

Mackerel egg surveys

The mackerel egg surveys are carried out triennially and the next so-called Atlantic survey for Western and Southern stocks is planned for 2016 (ICES, 2015). Germany, Ireland, Netherlands, Scotland, Portugal, Spain, Spain/Basque Country, Iceland and the Faroe Islands will participate.
Each cruise within the survey is assigned an area which can be covered in 2 to 3 weeks sampling (depending on the vessel speed) and is required to collect both plankton and pelagic trawl samples.
At the moment only 16 of the 20 cruises are covered by the participating countries, thus leaving four surveys which do not have confirmed participants (ICES, 2015). Efforts are continuing in attempting to attract additional nations to participate in the 2016 survey.

In order to be able to cover the entire mackerel spawning season in the North Sea at least 4 survey periods are necessary (Fig. 1). Sampling only the alternate transect, egg production in between transects needed to be interpolated for the 2015 North Sea survey. This lead to a huge increase of the interpolation compared to earlier surveys. The interpolated egg production values accounted for 45%, 40%, 44% and 43% for the four periods respectively. In 2011 interpolation accounted for 6%, 22% and 35% of the period egg productions. No CV calculations are available of the historic time series of North Sea mackerel egg productions. It was not possible to carry out that comparison within the scope of this project.
It is advised to carry out the survey by at least 2 vessels to bring down the number of interpolated values and increase the accuracy of the egg productions. In theory, the survey could be done by one vessel with 4-5 scientists. However, this makes the survey very vulnerable to technical problems, as shown in 2014.

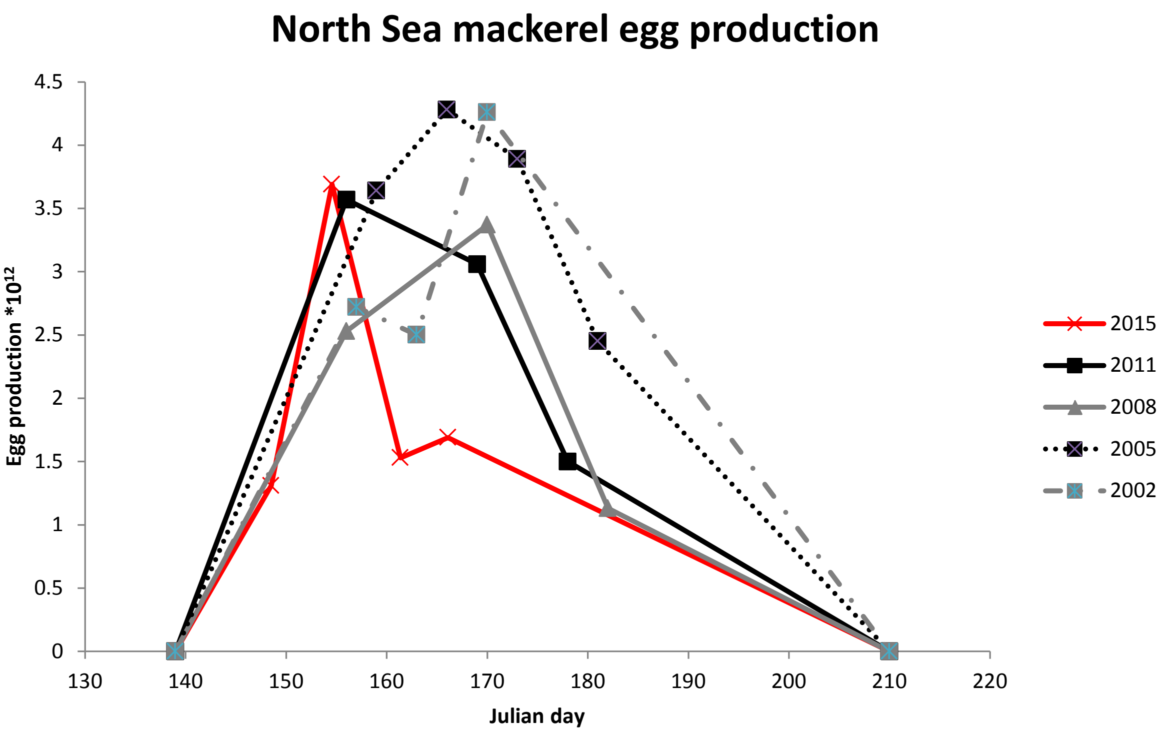

Figure 1. Annual egg production curves for North Sea mackerel.

Appendix B. Realised fecundity estimation

Using results from the 2013 Atlantic egg surveys, the precision of the potential fecundity estimate based on the number of samples analysed is investigated. In 2013, 132 fecundity samples were qualified to contribute to the potential fecundity estimate. By randomly taking an increasing number of fecundity samples from the total number of 132 it is possible to investigate the variation of the mean potential fecundity value and the corresponding 95% confidence intervals (CI) with number of samples (Fig. 2). The results indicate that the 95% CI is drastically reduced when the number of samples is increased from 10 to 50 samples. From 50 to 132 samples the change is much smaller and the mean fecundity estimate becomes much more stable (Fig. 2). Going from 50 to 100 samples reduced the 95% CI from 15% to 11% of the mean, while going from 100 to 132 samples only reduced the 95% CI from 11% to 10%. Assuming the individual fecundity of North Sea mackerel have a similar variance we may conclude that 50 fecundity samples could be regarded as a minimum number for a reliable potential fecundity estimate while extra samples above 50 have little extra benefit.

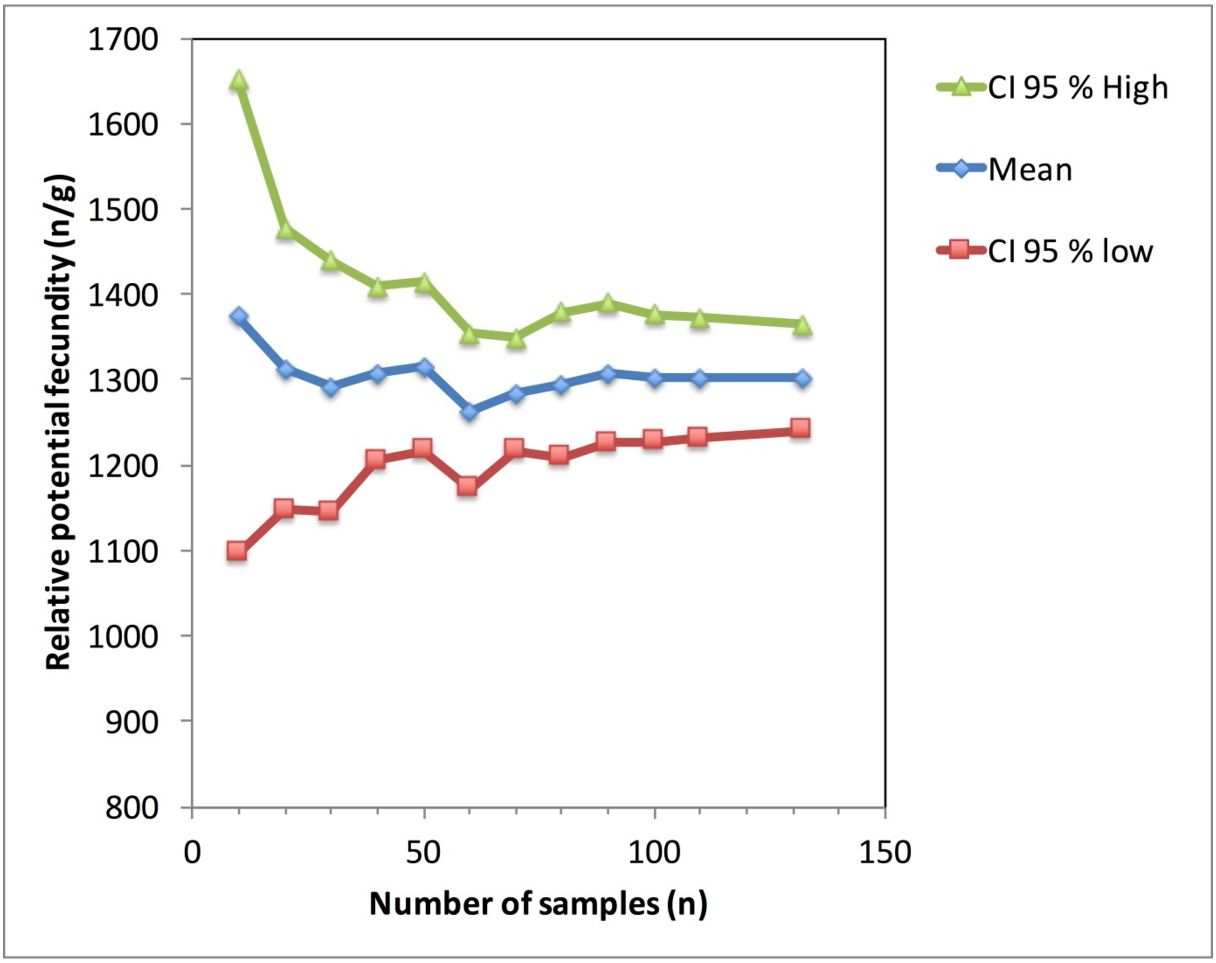

Figure 2. Mean relative potential fecundity and 95% Confidential Interval (CI) versus sample size. Data taken from 2013 Atlantic egg survey.

A similar exercise was performed for estimation of the geometric mean intensity of atresia (Fig. 3). In this case the dataset of the 2010 Atlantic survey was used, which was considerable larger (191 atresia samples) compared to the one from 2013 (56 samples). For atresia the size of the 95% CI expressed as the percentage of the geometric mean was a larger value than found for fecundity at the same sample size (Fig. 3). With a sample size of 50 the 95% CI was 57% of the geometric mean, while at 100 samples it was 40%. However, since the atresia number is a much smaller number than the potential fecundity number (which it is subtracted from) variance in the atresia estimate has less influence on the final realised fecundity estimate. Therefore a lower precision in atresia estimate is acceptable compared to the potential fecundity estimate.

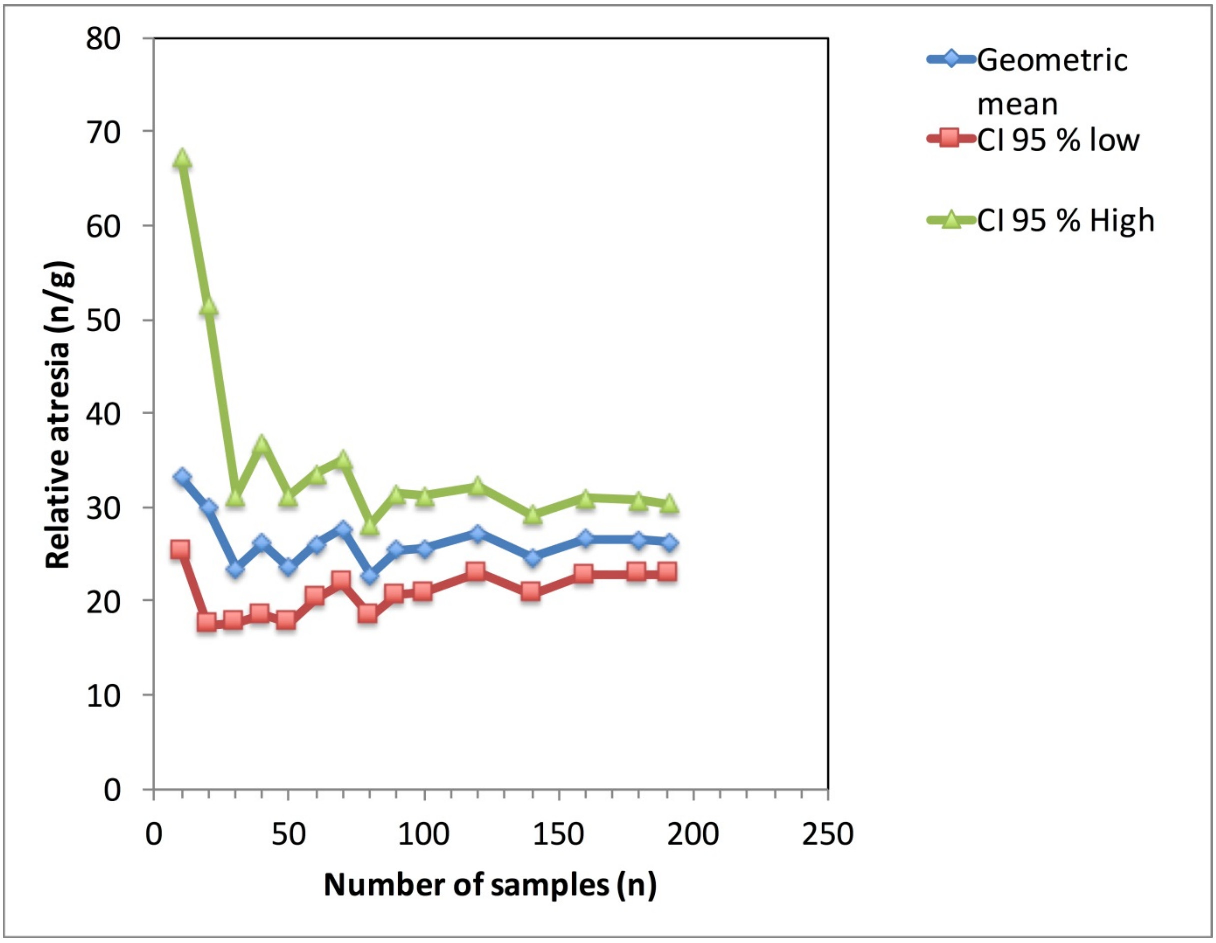

Figure 3. Geometric mean relative atresia and 95% Confidential Interval (CI) versus sample size. Data taken from the 2010 Atlantic egg survey.

For the Atlantic survey 100-150 potential fecundity samples and 700 atresia samples are analysed (ICES, 2015; ICES, 2014b).

The planning for collection and analyses of the fecundity and atresia samples of the Atlantic egg survey in 2016 shows no problems. Even if the 4 cruises that are currently not covered would not take place, the required potential fecundity and atresia samples can be taken and analysed, since all analysing institutes (Fecundity: Ireland, Netherlands, Scotland, Portugal, Spain, Spain/Basque Country and Norway; Atresia: Netherlands, Portugal, Spain, Spain/Basque Country and Norway) have agreed to participation. For the North Sea survey both Norway and the Netherlands have analysed the fecundity and atresia samples together in the past. If Norway would withdraw from the sample analyses another institute or extra resources for the Netherlands to analyse the samples would need to be found.