INTER-BENCHMARK PROTOCOL FOR SOLE IN THE EASTERN ENGLISH CHANNEL (IBPSOL7D)

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Editor

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i Executive summary

The ICES Inter-Benchmark Protocol of sole in the Eastern English Channel stock (IBPsol7d) met to investigate the effect of the missing UK beam trawl commercial index (UK-CBT) in 2017 and 2018, that was related to the recent change in the database system in UK. The aim was to investigate the internal consistency of the new UK-CBT and to analyse its influence on the sole in 7d assessment. The model currently used to assess this stock is an extended survival analysis (XSA). No other model was tested. During the IBP, it was decided to revise the Belgium beam trawl commercial index (BE-CBT) to move from a Landing Per Unit of Effort (LPUE) index to a Catch Per Unit of Effort (CPUE). This decision was motivated by the increase of age 2 sole discards in recent years, and also to investigate the feasibility of adding a second index to tune age 2 sole in the assessment and put UK-BTS survey index into perspective.

The IBP investigated alternatives to calculate both new commercial indices. In the old UK-CBT a 10% threshold of sole in the landings was applied to select the vessels used in that index. The IBP decided to remove that threshold to produce the new UK-CBT, assuming that all beam trawlers using an appropriate mesh size have some sole in their bycatch. The new BE-CBT now includes both small and large fleet segments in addition to the discard information. A vessel effect is applied to standardize the new BE-CBT index. Both indices were calculated using mixed GLMs.

Several assessment settings were tested, replacing each new index one at a time. The IBP agreed to use the new UK-CBT and the new BE-CBT in the assessment of this stock. However, the age 2 sole in the new BE-CBT were removed, as the residual pattern of the model at age 2 was considered too high by the IBP (absolute value of 2 or above in a log-scale). The diagnostics of the assessment were considered good enough to use the assessment as the basis for advice in 2019, although some unresolved issues with input data remain. The final XSA assessment run included the revised UK-CBT and the revised BE-CBT, as well as the FRA-COTB as commercial tuning series, and the UK BTS, FRA-YFS and the UK-YFS as survey tuning series.

New reference points were estimated following ICES guidelines. F_{MSY} analyses were conducted with Eqsim.

Short-term forecast assumptions were investigated. Based on the retrospective pattern of the recruitment estimates, the IBP decided to replace the two last years of recruitment by a geometric mean.

Future research and the need for a full benchmark were identified, also by the external reviewer.

ii Expert group information

Expert group name	Inter-benchmark Protocol for sole in the Eastern English Channel (IBPsol7d)
Expert group cycle	NA
Year cycle started	2019
Reporting year in cycle	1/1
Chair	Raphaël Girardin, France
Meeting venue and dates	20-21 August 2019, Ostend, Belgium, 6 participants

1 Introduction

An **Inter-benchmark Protocol for sole in the Eastern English Channel** (IBPSol7d), chaired by Raphael Girardin, France, and attended by one invited external expert, Alexander Kempf, Germany, met in Ostend, Belgium, 20–21 August 2019 to:

a) Revise the UK commercial beam trawl tuning fleet (UK-CBT), in light of recent changes to the UK national fishery activity database. This revision should include the 2017 and 2018 data, and should ensure that the time series is self-consistent (e.g. the effort data is comparable throughout).

b) Revise the Belgium commercial beam trawl tuning fleet (BE-CBT) to investigate the possibility to convert it into CPUE and add more information at age 2 in the assessment model.

c) Revise the assessment to include the revised UK-CBT and BE-CBT time series developed in (a and b).

d) Re-examine and update (if necessary) MSY and PA reference points according to ICES guidelines (see Technical document on reference points);

Stocks	Stock leader
Sole (*Solea solea*) in Division 7.d (Eastern English Channel), sol.27.7d	Lies Vansteenbrugge

The inter-benchmark workshop will report by 14 October 2019 for the attention of ACOM.

2 Adoption of the Agenda

The following was added to the agenda:

- Revise the Belgium commercial beam trawl tuning fleet to investigate the possibility to convert it into CPUE and add more information at age 2 in the assessment model.

3 Description of the Benchmark Process

The ICES Inter-benchmark Protocol of sole in the Eastern English Channel stock included the followings steps:

1. ToR was validated on 7 June 2019 and a deadline was set for the mid-July 2019 to provide the revise UK-CBT and mid-August to provide a working document. The deadline to provide UK-CBT index was extend to 12 August 2019.
2. A phone call meeting was set on 13 August between the chair and the stock coordinator to discuss the analyses to perform in preparation of the workshop.
3. IBPsol7d workshop 20–21 August 2019.

4. The deadline for the working documents, external reviewer report, the workshop report, and the stock annex was set for 14 October. The stock annex deadline was extended to 18 October.
5. Discussion on the forecast and advice sheet occurred after the IBP, to decide which hypothesis to use and the different issues with the forecast. A Webex was set on 9 October by the chair of WGNSSK to discuss with WGNSSK members the forecast and finalize the advice sheet.

List of data and working documents for sole 7.d are detailed below:

Title	Description	Contributors
UK-CBT LPUE index	Revising the UK-CBT LPUE index using delta-mixed effect model on all beam trawler trip.	Michael A. Spence, Johnathan E. Ball, Lisa Readdy
BE-CBT CPUE index	Moving from LPUE index to CPUE index using a mixed-GLM model on all TBB_DEF_70-99 Belgium fleet	Klaas Sys, Lies Vansteenbrugge

The first day was dedicated to the presentation of the methods used to develop the UK-CBT LPUE (Annex 2) and the discussion of the outputs from sol.27.7d assessment model using the this new UK index. Discussions were held after each presentation, at the end of the morning it was decided to modify UK-CBT LPUE to account for all beam trawl trips in the calculation of the index. During the afternoon, the revision of BE-CBT into a CPUE index was decided to check the possibility of having a second indices to tune age 2 in the assessment model. The method to develop Belgium index was presented to the group (Annex 3), and indices were calculated.

The second day, it was decided to include the new BE-CBT CPUE index to the assessment using all Belgium beam trawl trips from TBB_DEF_70-99 fleet segment. To correct a small mistake in the UK-CBT calculation, the index was rerun. Final assessment runs were presented and validated by the group using BE-CBT CPUE and UK-CPUE LPUE new indices and the reference points were calculated. Finally, scenarios to be tested for the short term forecast were discussed as well as the time schedule to write the report and finalize the advice sheet.

Notes on the benchmark process

Not all the data and working document arrived by the first deadline, leaving not enough time to review the data leading to several rerun of the analysis during the workshop. The meeting was held in part remotely which complicated to all process. Despite this, all the working document were completed by the deadline.

4 Stock Sole (*Solea solea*) in Division 27.7.d (Eastern English Channel)

4.1 Stock ID and sub-stock structure

No results were presented on the stock ID during the Inter-benchmark Protocol.

4.2 Issue list

Issue	Problem/Aim	Work needed / possible solution	Comments
Data	French data were provided with a plusgroup to InterCatch and 2018 data where corrected but it is clear that 2016-2017 data contain also plusgroup that affect catch data and the French commercial otter trawl tuning fleet	Rerun will be submitted for WKFlatCSNS	
	This year, the French SMAC project will be finalised. The main aims of this project were to investigate connectivity within the stock (between the different nursery areas) and with the neighbouring sole stocks. The potential presence of subpopulations and migration from or to other stocks is an important issue to consider in the assessment.		
	During the previous benchmark (WKNSEA 2017), decreasing mean weight and mean length at age were observed. This should be further investigated and followed up.		
	Issues with the UK commercial beam trawl tuning fleet link to the change in database structure and data collection of effort information.	Revision of the UK-CBT and investigation of internal consistency of the new UK-CBT.	New UK-CBT was produced, description of the process can be found in Annex 2 and the new index was included to the assessment in section 4.6.
Assessment	Currently, XSA is used as the assessment model for this stock. This VPA-based model calculates the population abundance at age directly from catch-at-age (treated as known and without error in every time step) and natural mortality, starting from the latest year and oldest true age for each cohort (excluding the plus group) (ICES, 2012). One of its limitations compared to statistical catch-at-age models, such as SAM, is that highly structured fishing mortality calculations allow less flexibility in distributing the goodness of fit.	Other models could be further explored to have at least some idea of error.	
Short-term forecast	Recruitment estimates are driven by the UK BTS tuning fleet and the French YFS survey. Due to the large variation and uncertainty in the recruitment estimates, it should be investigated if this uncertainty can be taken better into account when running the short term forecast		

4.3 Scorecard on data quality

A scorecard was not used for this Inter-benchmark Protocol.

4.4 Multispecies and mixed fisheries issues

No new information was presented at the Inter-benchmark Protocol.

4.5 Ecosystem drivers

No new information was presented at the Inter-benchmark Protocol.

4.6 Stock Assessment

4.6.1 Landings, discards and TAC uptake

Total official landings are estimated at 2307 tonnes in 2018, of which Belgium landed approximately 28% (651 t), France 55% (1265 t) and UK (E&W) 17% (391 t). A very small amount is landed by the Netherlands and Scotland.

Since 2010, a full uptake of the sole 27.7.d TAC has not been realised. When comparing ICES catch estimates (InterCatch) with the TAC (catch), a total uptake of 88% was realized in 2016, 89% in 2017 and 77% in 2018.

Discards are included in the assessment since the previous benchmark in WKNSEA 2017. When discards were not available, these were raised in InterCatch. More information on how discard raising was performed is provided in the Stock Annex and the WKNSEA 2017 benchmark report and associated working document (ICES, 2017a).

4.6.2 Tuning series

During the benchmark, the tuning series used for the calibration of the assessment of sole in Division 27.7.d were modified. More specifically, the Belgian commercial beam trawl tuning series was shortened (starting in 2004, instead of 1986) and focused only on the large fleetsegment (horsepower of > 221 kW). A French commercial otter trawl series was added (from 2002 onwards) and the UK commercial beam trawl series (from 1986 onwards) remained in the assessment as prior to the benchmark. However, all commercial tuning series were trimmed to age 3–8. The three survey data series (FRA YFS from 1987 funded by EDF (Noursom), UK YFS from 1987–2006 and the UK BTS from 1989) remained in the assessment as prior to the benchmark.

The main goal of the IBP was to include a revised UK commercial beam trawl tuning series. For the 2019 ICES data call, it was not possible for the UK (E&W) to provide the effort, Kw.hours fished, data for the commercial beam trawl fleet (UK-CBT) for 2018 and the same data provided for 2017 was not complete, and therefore unreliable to use in the assessment. The UK national fishing activity database has been under redesign since June 2017 and the necessary derived variables to estimate the effort series have not been available in the database since then. The lack of these variables precluded the estimation of the UK-CBT for 2017 and 2018. On closer inspection of the effort time series it was noted that some of the variables are identified as optional fields in the logbooks, one such field is hours fished, this leads us to the conclusion that hours fished is not consistently filled and therefore makes this field inappropriate to use as a metric for effort.

Instead, we now advocate the use of activity days as a more reliable measure, since it is mandatory to record and report "activity days". The working document on the new UK-CBT gives a detailed description of the calculation of this new index (Annex 2).

During the IBP, also the Belgian commercial index was investigated to check whether it could be converted to a CPUE index. There were two reasons to do so: 1) there is a pattern of increased discarding in the most recent years, and 2) having a second tuning fleet to tune age 2 in the assessment could put the UK-BTS-Q3, with spatial coverage restricted to inshore waters, into perspective. The working document on the new BEL-CBT gives a detailed description of the calculation of this new index (Annex 3).

4.6.3 Weights, maturity and natural mortality

Analysing the available data on biological parameters revealed that the mean weights have dropped over time (Figure 1 and Figure 2).

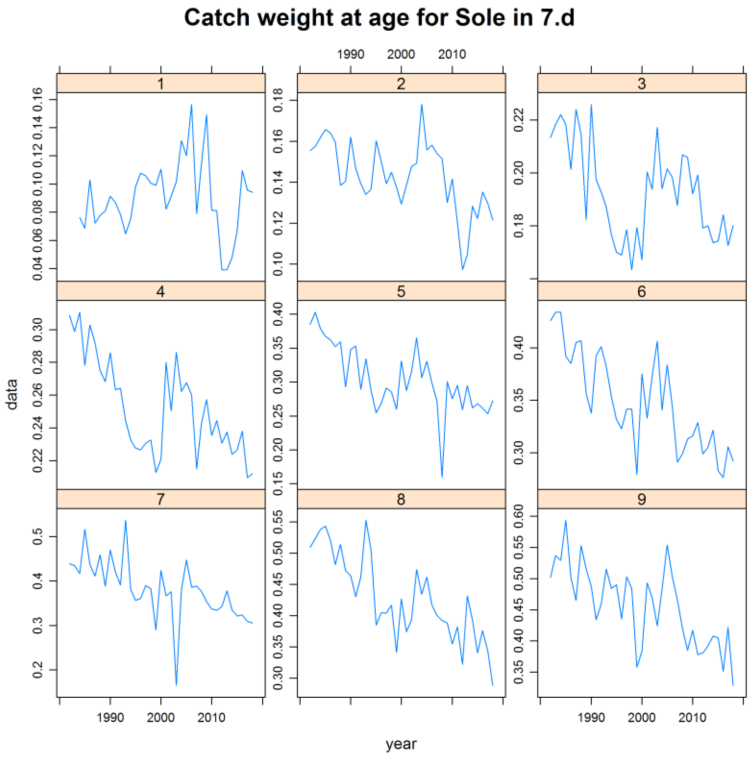

Figure 1: Catch weight-at-age.

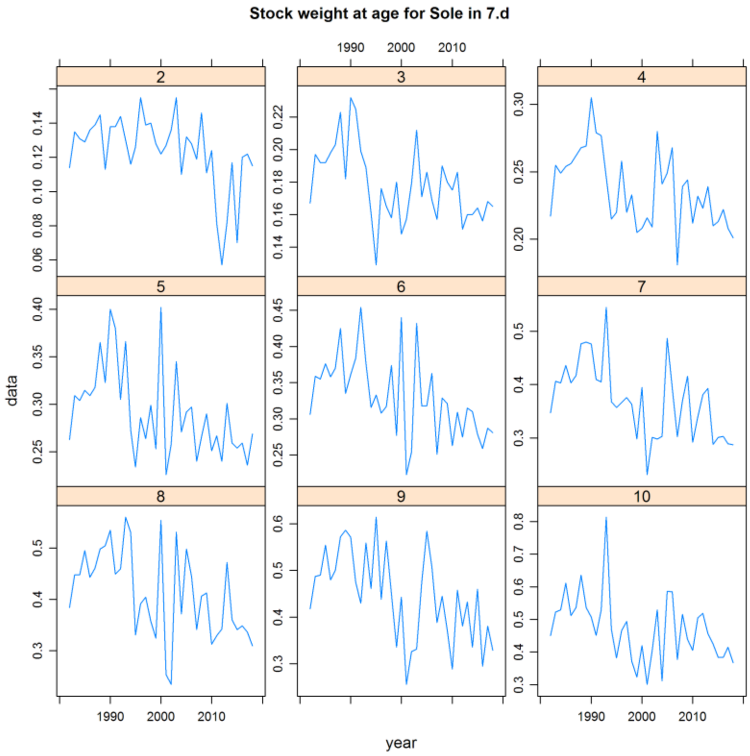

Figure 2: Stock weight-at-age.

During the benchmark WKNSEA in 2017, a thorough analysis of all available maturity data was done, resulting in a maturity ogive as shown in Table. Natural mortality is assumed to be a fixed value (0.1) for all ages across all years.

Table 1: Maturity ogive for sole in 27.7.d as calculated during the WKNSEA benchmark in 2017

Age	0	1	2	3	4	5	6	7	8	9	10	11(+)
Maturity	0.00	0.00	0.53	0.92	0.96	0.97	1.00	1.00	1.00	1.00	1.00	1.00

4.6.4 Assessment model

The model used to assess Eastern English Channel sole is an extended survival analysis (XSA). No new assessment models were tested during this IBP.

4.6.5 WGNSSK 2019 – base run

During the WGNSSK 2019, an XSA model was used to assess Eastern Channel sole. Three scientific surveys (UK(E&W)-BTS-Q3, UK-YFS and FRA-YFS) and three commercial tuning series (UK(E&W)-CBT, BE-CBT and FRA-COTB) were incorporated in the assessment. However, for the WGNSSK 2019, the 2018 value of the UK-CBT tuning fleet could not be provided due to database issues. Moreover, the 2017 value was not considered correct and problems were identified for the earlier years as well (see working document on new UK-CBT series, Annex 2). Consequently, only the UK-CBT series was included up to 2016, but no advice was produced with these settings (deviation from the stock annex and cause for the IBP).

The final settings used in the WGNSSK 2019 assessment are listed in Table.

Table 2: XSA diagnostics used during the WGNSSK 2019.

2019 ASSESSMENT			
Fleets	**Years**	**Ages**	**α-β**
BE_CBT_2004–2018 commercial	04–18	3–8	0–1
FR_COT commercial	02–18	3–8	0–1
UK(E&W)_CBT commercial	86–16	3–8	0–1
UK(E&W)_BTS survey	89–18	1–6	0.5–0.75
UK_YFS survey	87–06	1–1	0.5–0.75
FR_YFS survey	87–18	1–1	0.5–0.75

-First data year	1982	
-Last data year	2018	
-First age -Last age	1 11+	
Time series weights	None	
-Model		No Power model
-Q plateau set at age	7	
-Survivors estimates shrunk towards mean F		5 years / 5 ages
-s.e. of the means	2.0	
-Min s.e. for pop. Estimates	0.3	
-Prior weighting	None	

With the addition of the 2018 data (WGNSSK 2019), F was scaled down whereas SSB was scaled up for the most recent years (Figure 3). Recruitment showed to be highly uncertain in the most recent years.

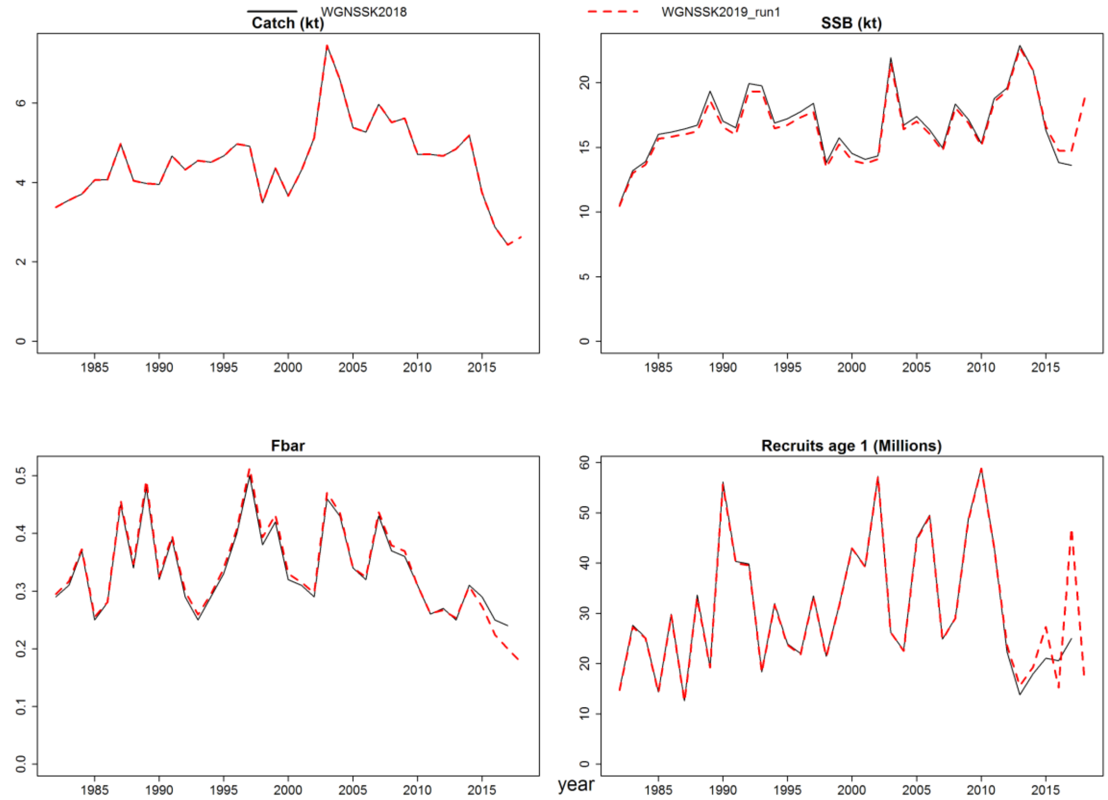

Figure 3: Comparison of the summary plots for catch, SSB, Fbar and recruits between the WGNSSK 2018 assessment and the WGNSSK 2019 assessment.

In the working document on the new UK and new Belgian commercial beam trawl series, both indices are investigated and modified (Annex 2 and 3). These commercial tuning series were tested in several exploratory assessment runs, which are described below. An overview of the settings are listed in the table below.

Run	Tuning fleet	Years	Ages
Baserun - WGNSSK 2019	BE-CBT	2004-2018	3-8
	FR-COT	2002-2018	3-8
	UK (E&W)-CBT	1986-2016	3-8
	UK (E&W)-BTS	1989-2018	1-6
	UK-YFS	1987-2006	1-1
	FR-YFS	1987-2018	1-1
Run 1	BE-CBT	2004-2018	3-8
	FR-COT	2002-2018	3-8
	new UK (E&W)-CBT	1986-2018	3-8
	UK (E&W)-BTS	1989-2018	1-6
	UK-YFS	1987-2006	1-1
	FR-YFS	1987-2018	1-1
Run 2	new BE-CBT	2004-2018	3-8

Run	Tuning fleet	Years	Ages
	FR-COT	2002-2018	3-8
	UK (E&W)-CBT	1986-2016	3-8
	UK (E&W)-BTS	1989-2018	1-6
	UK-YFS	1987-2006	1-1
	FR-YFS	1987-2018	1-1
Run 3	new BE-CBT	2004-2018	2-8
	FR-COT	2002-2018	3-8
	UK (E&W)-CBT	1986-2016	3-8
	UK (E&W)-BTS	1989-2018	1-6
	UK-YFS	1987-2006	1-1
	FR-YFS	1987-2018	1-1
Run 4	new BE-CBT	2004-2018	3-8
	FR-COT	2002-2018	3-8
	new UK (E&W)-CBT	1986-2018	3-8
	UK (E&W)-BTS	1989-2018	1-6
	UK-YFS	1987-2006	1-1
	FR-YFS	1987-2018	1-1

4.6.5.1 Run 1: including the new UK(E&W)-CBT

Data

Same catch data (total weight, mean weight- and number-at-age for landings and discards) as used in the WGNSSK 2019 assessment.

Biological parameters

Same biological parameters as used in the WGNSSK 2019 assessment.

Tuning series

The old BE-CBT, the French commercial otter trawlers (FRA-COTB) and the **new UK(E&W)-CBT** were included as commercial tuning fleets. The UK(E&W)-BTS-Q3 and the French and UK YFS were included as survey tuning series. The internal consistency plots of the tuning series and their similarity are shown in figures 4–8. The new UK-CBT series follows the trends of the other series and gives the most positive estimates compared to the other commercial tuning series. Figure 9 shows the catchability of the different tuning fleets.

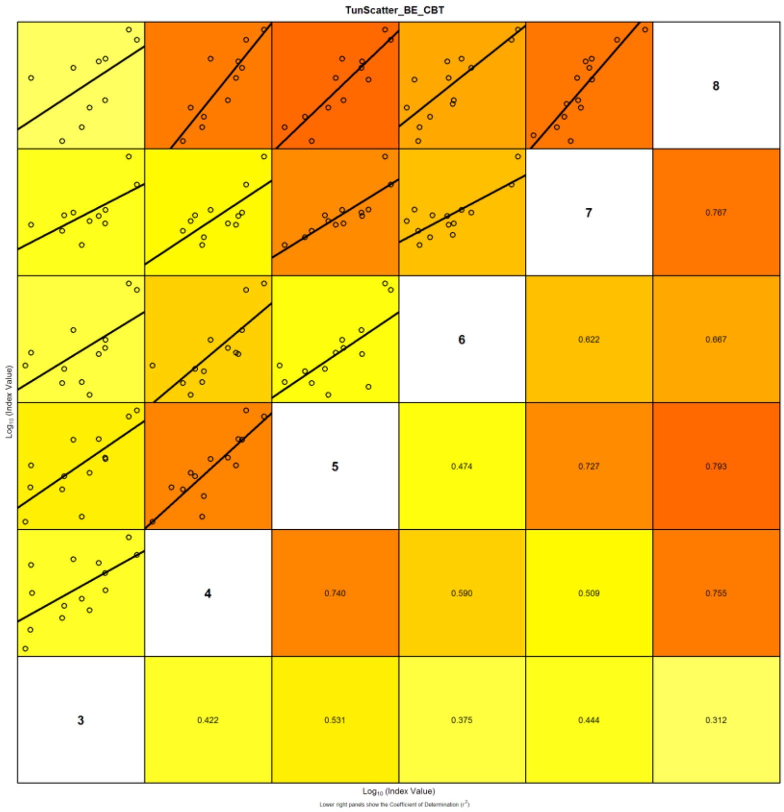

Figure 1: Internal consistency plot of the old BE_CBT (2004–2018) tuning series.

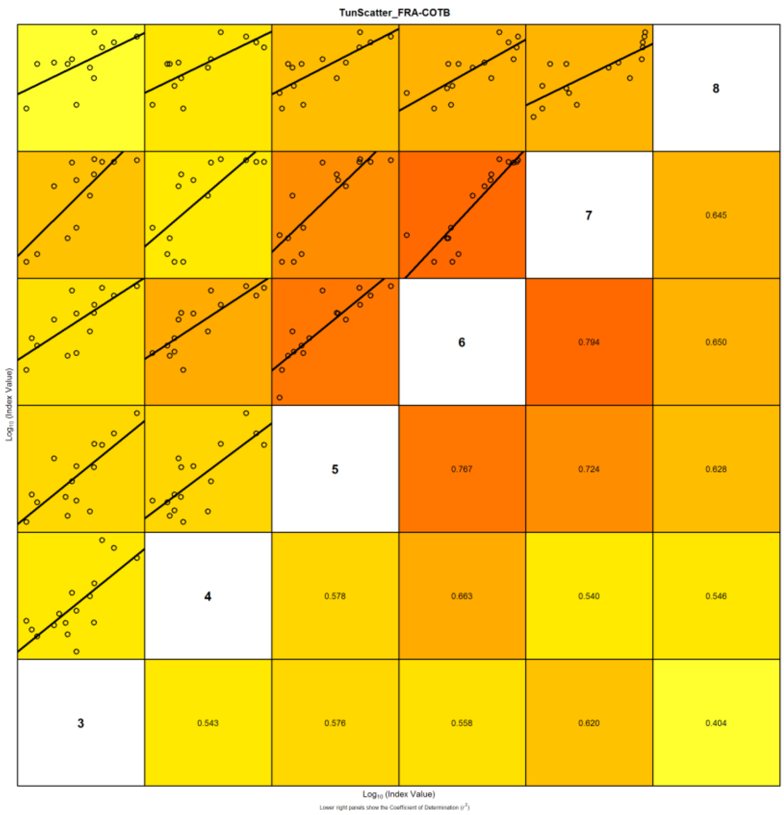

Figure 2: Internal consistency plot of the FRA COTB (2002–2018) tuning series.

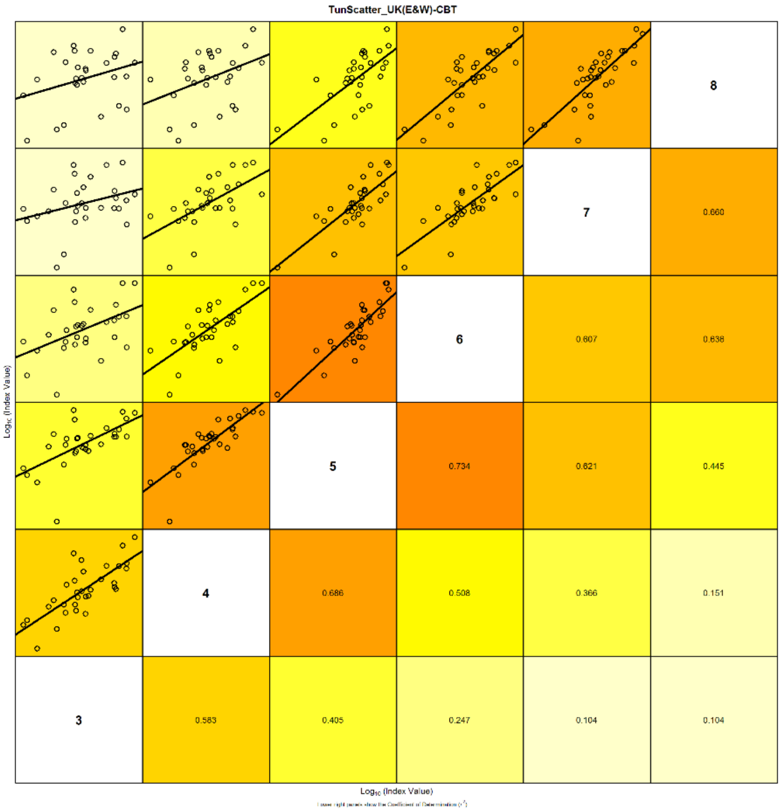

Figure 6: Internal consistency plot of the new UK CBT (1986–2018) tuning series.

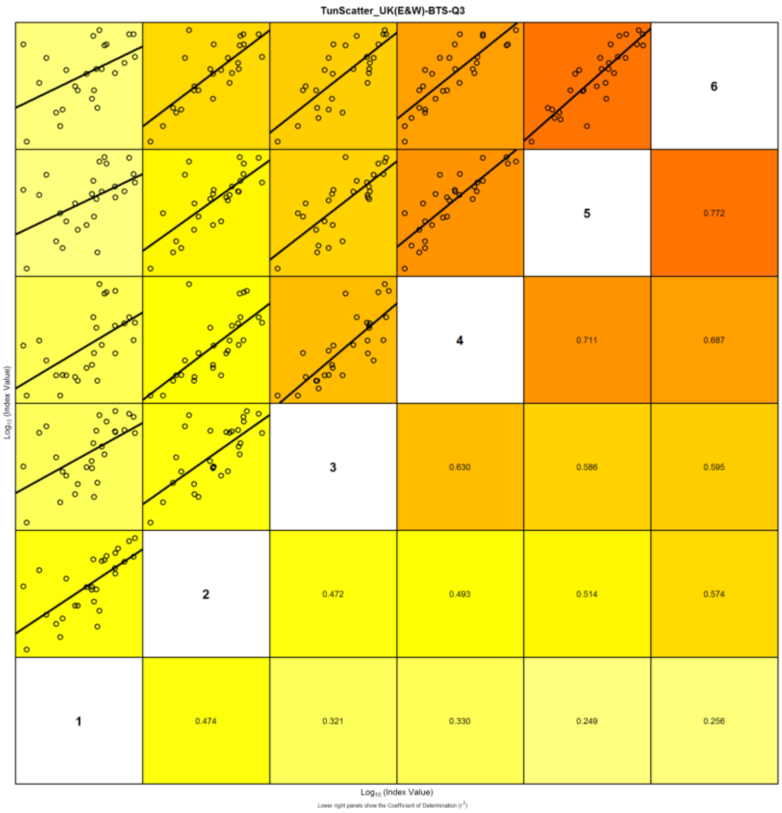

Figure 7: Internal consistency plot of the UK(E&W)-BTS (1989–2018).

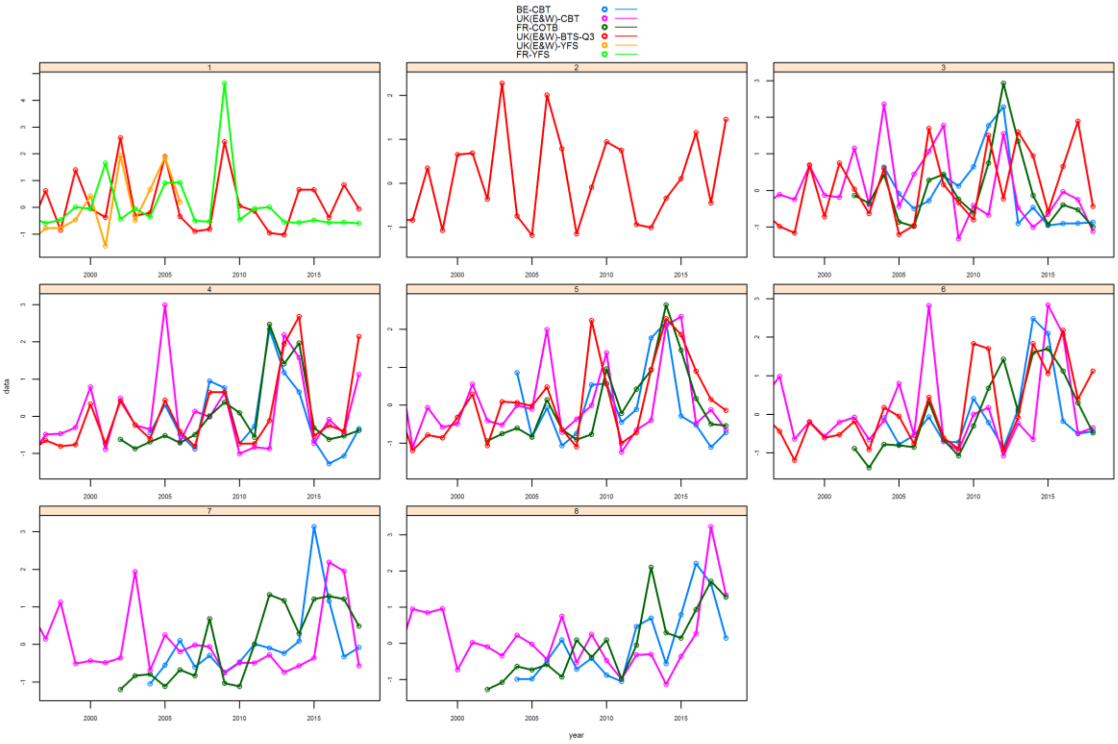

Figure 8: Standardised indices by age of the tuning series for run 1, including the old Belgian tuning series as created during the last benchmark in 2017 (blue), the new UK-CBT series (pink), the French COTB (dark green), the UK-BTS (red), the UK-YFS (up to 2006, orange) and the FRA-YFS (light green).

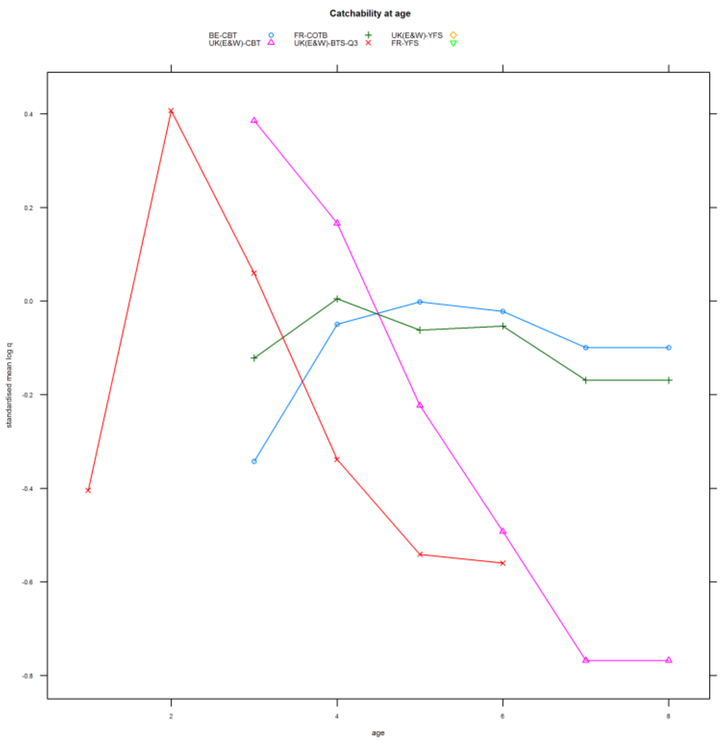

Figure 9: Standardised mean log Q by age of the tuning series for run 1 (including the new UK-CBT series in pink).

Model settings for run 1 are listed in Table 3.

Table 1: XSA diagnostics used for run 1 (including the new UK-CBT series).

2019 ASSESSMENT			
Fleets	**Years**	**Ages**	**α-β**
Old BE_CBT_2004–2018 commercial	04–18	3–8	0–1
FR_COT commercial	02–18	3–8	0–1
new UK(E&W)_CBT commercial	**86–18**	**3–8**	**0–1**
UK(E&W)_BTS survey	89–18	1–6	0.5–0.75
UK_YFS survey	87–06	1–1	0.5–0.75
FR_YFS survey	87–18	1–1	0.5–0.75
-First data year	1982		
-Last data year	2018		
-First age -Last age	1 11+		
Time series weights	None		
-Model		No Power model	
-Q plateau set at age	7		
-Survivors estimates shrunk towards mean F		5 years / 5 ages	
-s.e. of the means	2.0		
-Min s.e. for pop. Estimates	0.3		
-Prior weighting	None		

Figures 10–12 present the model output for this run. Figure 10 shows the residuals for each index and age. The new UK-CBT shows a moderate year effect around 2010, but this disappears in the most recent years. Figure 11 shows mean squared natural logarithm transformed residuals and reveals an MSE >0.3 for age 1 for the UK-BTS, which is higher than a target coefficient of variation (c.v.) of 20–30% (Doonan and Dunn, 2011). This large deviation for age 1 should be investigated e.g. during a full benchmark. The new UK-CBT shows an acceptable c.v. (<0.3). Figure 12 shows no clear retrospective pattern for Mean F and SSB. Recruitment estimates are uncertain.

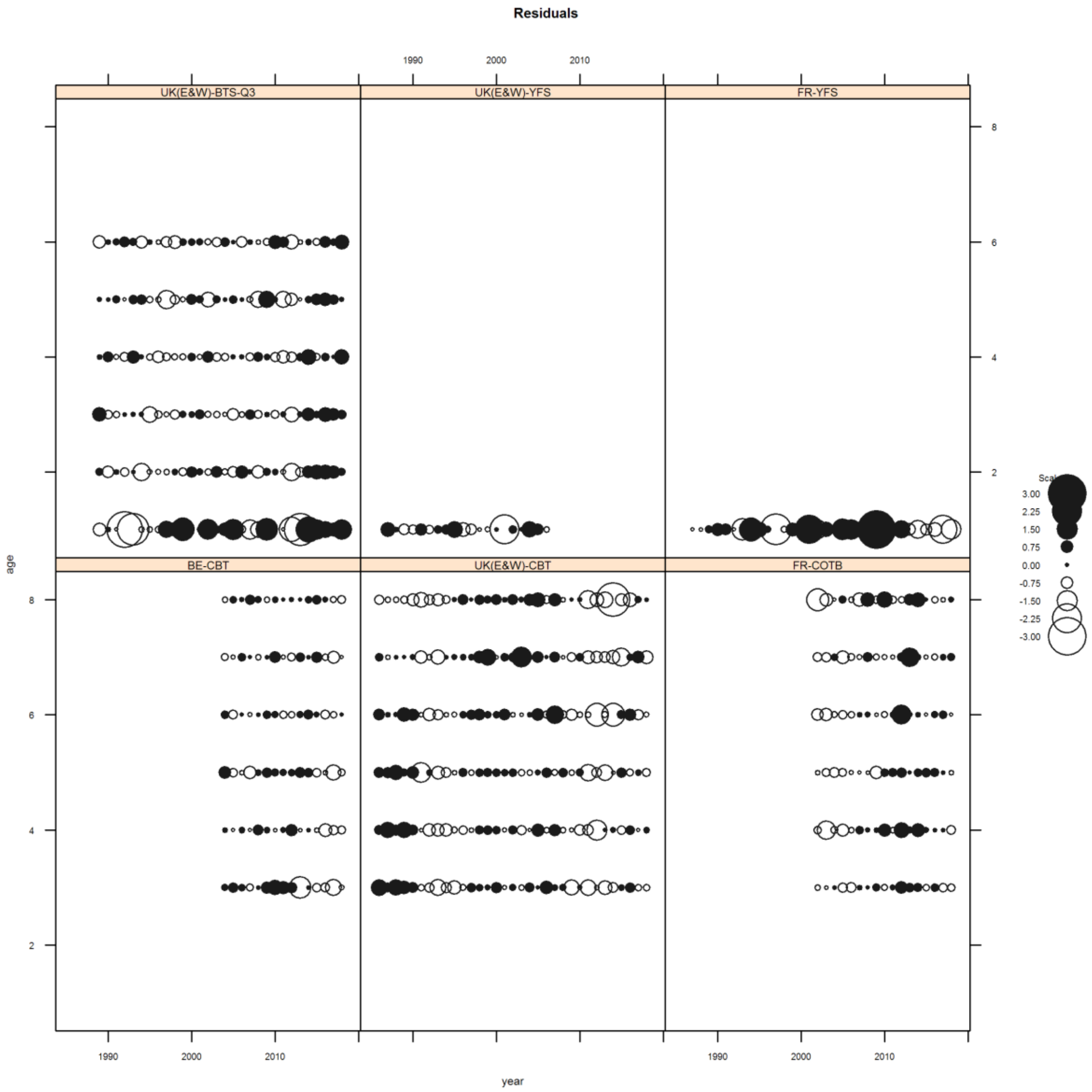

Figure 10: Residuals for the different tuning series for run 1 (including the new UK-CBT and the old Belgian CBT).

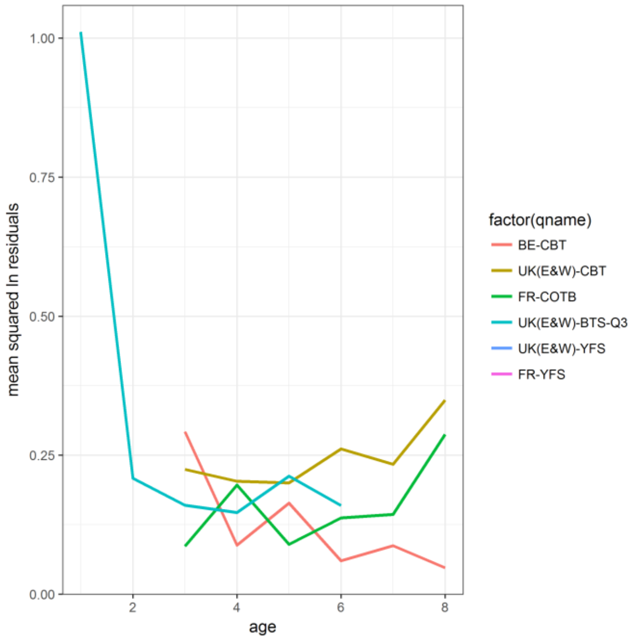

Figure 11: Mean squared natural log residuals for each index and age for run 1 (including the new UK-CBT).

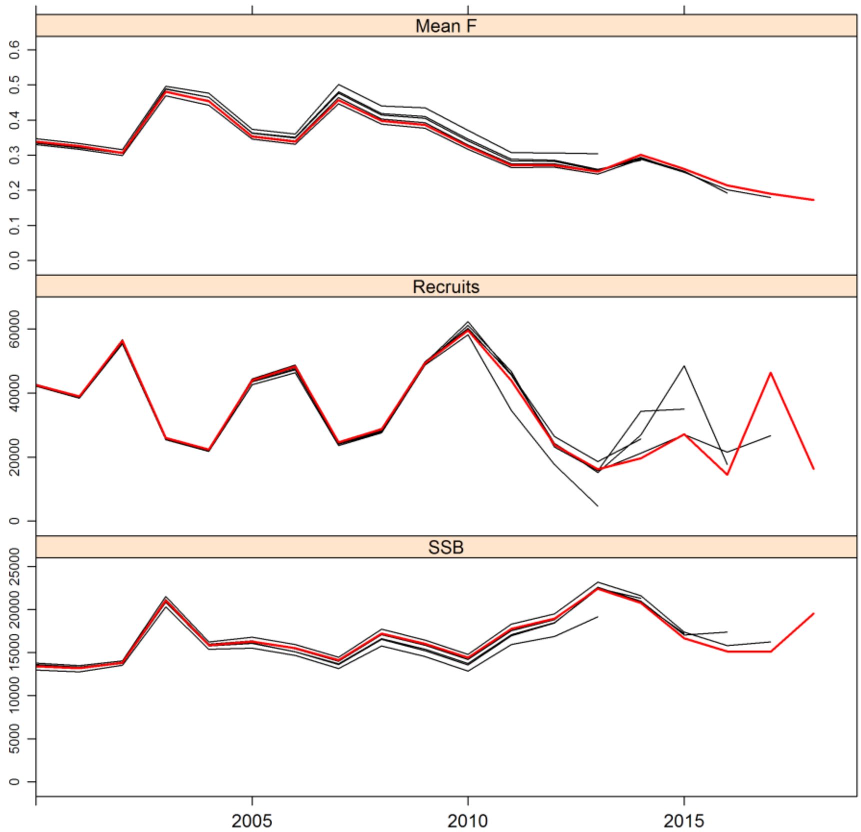

Figure 12: Retrospective XSA analysis for run 1 (including the new UK-CBT).

Differences between the WGNSSK 2019 assessment and run 1 (*i.e.* including the new UK-CBT) can be observed in Figure 13. The SSB of run 1 is estimated lower compared to the WGNSSK run for the period 1990–2002, while it is estimated slightly higher for the most recent year. The F_{bar} shows the opposite pattern with slightly higher values in the period 1990–2002 and the lowest value in the time series in the most recent year. The recruitment is similar for both runs.

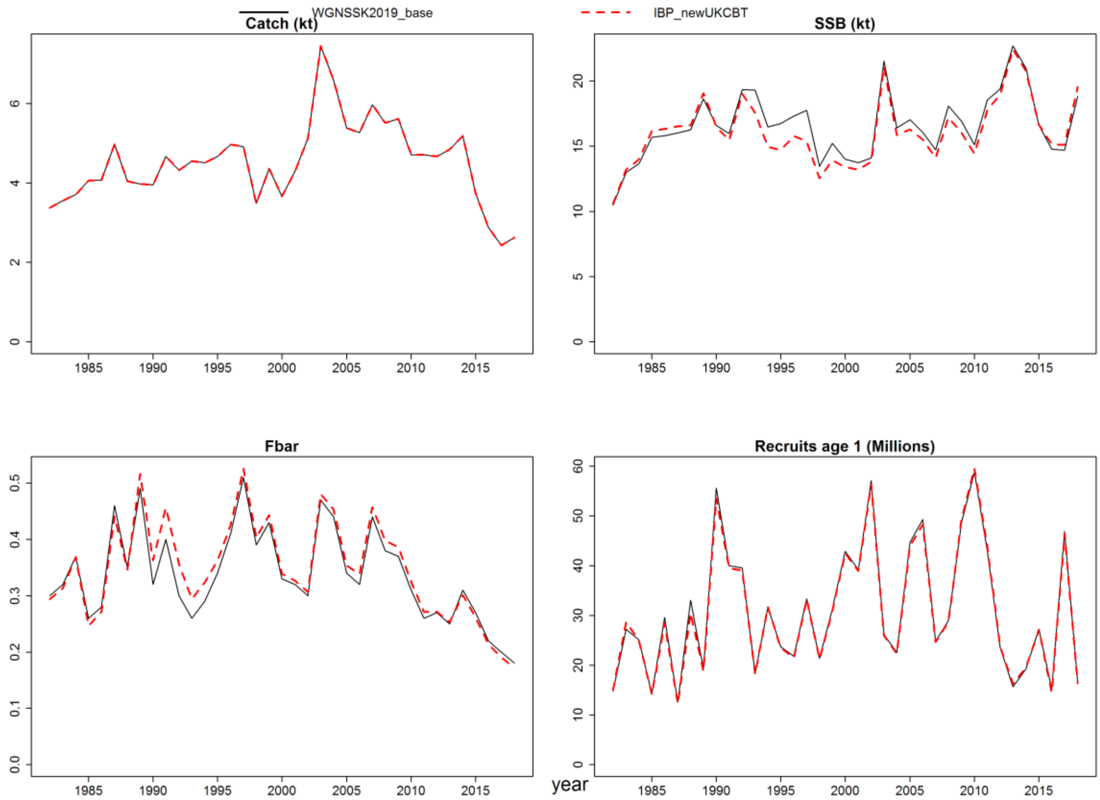

Figure 13: Comparison of the summary plots for catch, SSB, F_{bar} and recruits between the WGNSSK 2019 assessment and run 1 (including the new UK-CBT series).

4.6.5.2 Run 2: including the new Belgian CBT (age 3–8)

Data

Same catch data (total weight, mean weight- and number-at-age for landings and discards) as used in the WGNSSK 2019 assessment (base run).

Biological parameters

Same biological parameters as used in the WGNSSK 2019 assessment.

Tuning series

The French commercial otter trawlers (FRA-COTB), the old UK(E&W)-CBT and the **new BE-CBT** were included as commercial tuning fleets. The new Belgian index is a CPUE index and was used from age 3–8. The UK(E&W)-BTS-Q3 and the French and UK YFS were included as survey tuning series. The internal consistency plots of the new Belgian commercial beam trawl tuning series and the old UK CBT up to 2016 is shown in figures 14–15. The similarity plot including the new Belgian index is shown in Figure 16. The new Belgian index gives higher estimates than the old index (compare Figure 8 and Figure 16). Figure 17 shows the catchability of the different tuning fleets.

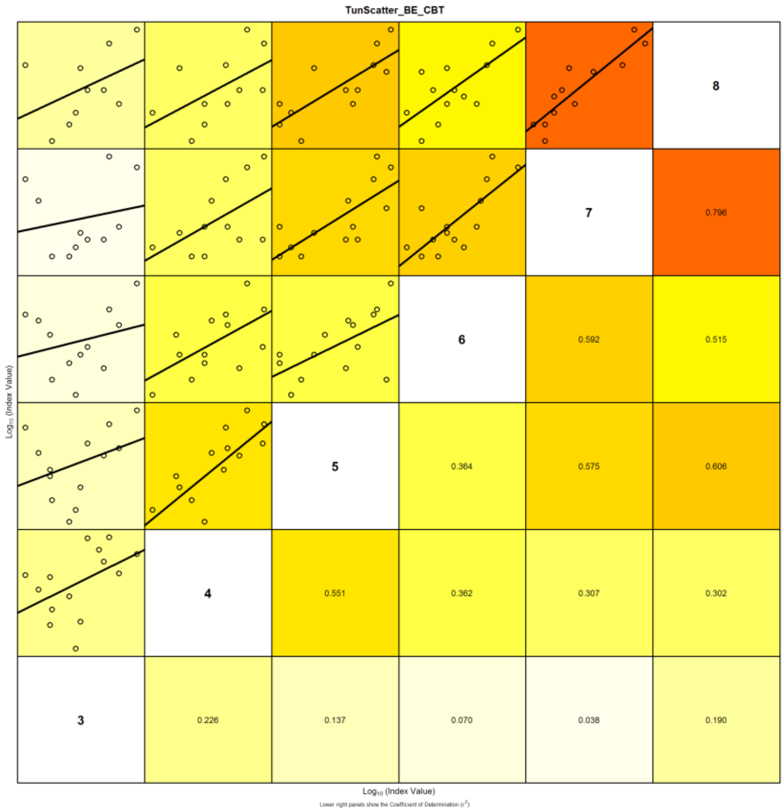

Figure 14: Internal consistency of the new BE-CBT (2004–2018) tuning series.

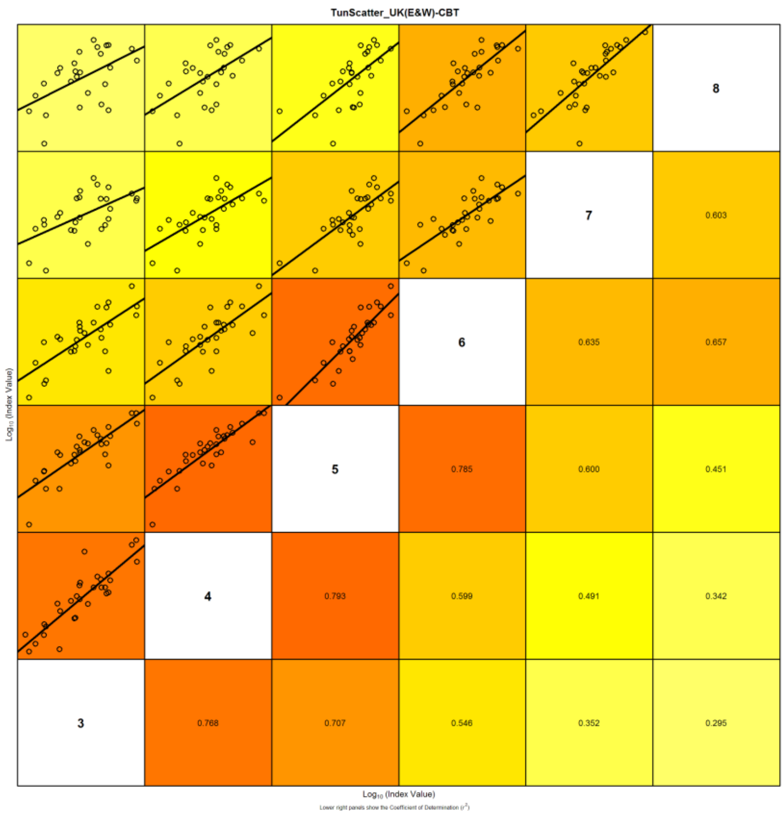

Figure 15: Internal consistency of the old UK-CBT (1986–2016) tuning series.

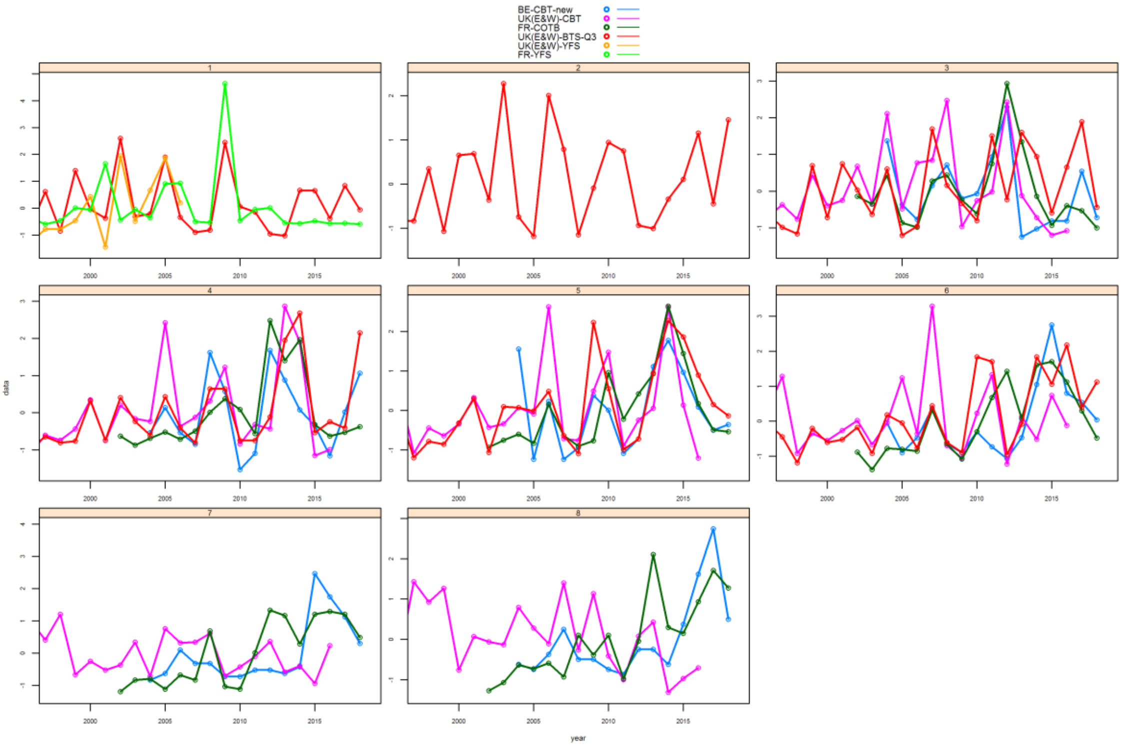

Figure 16: Standardised indices by age of the tuning series for run 2, including the new Belgian tuning series (blue), the old UK-CBT series up to 2016 (pink), the French COTB (dark green), the UK-BTS (red), the UK-YFS (up to 2006, orange) and the FRA-YFS (light green).

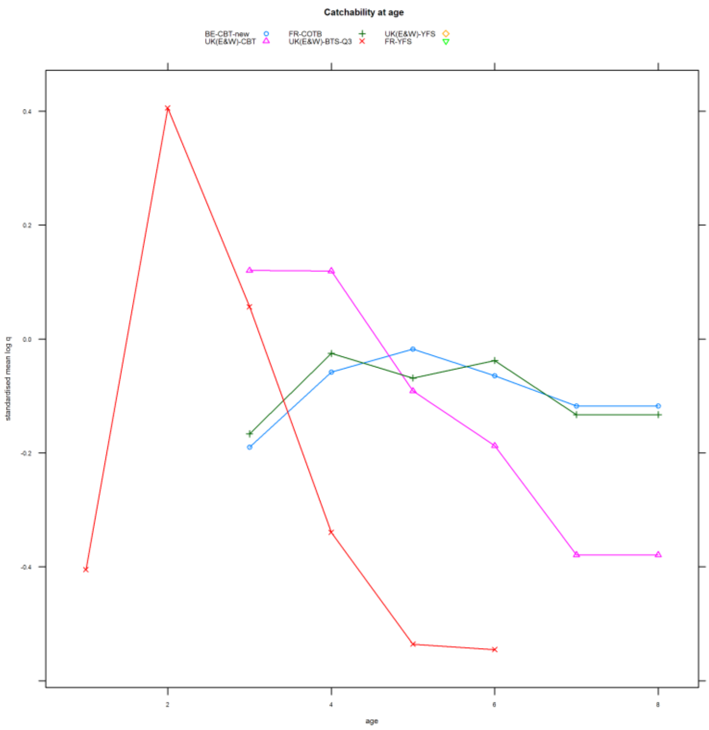

Figure 17: Standardised mean log Q by age of the tuning series for run 2 (including the new BEL-CBT series in blue).

Model settings for run 2 are listed in Table.

Table 4: XSA diagnostics used for run 2 (including the new BEL-CBT series).

2019 ASSESSMENT			
Fleets	**Years**	**Ages**	**α-β**
new BE_CBT_2004–2018 commercial	**04–18**	**3–8**	**0–1**
FR_COT commercial	02–18	3–8	0–1
Old UK(E&W)_CBT commercial	86–16	3–8	0–1
UK(E&W)_BTS survey	89–18	1–6	0.5–0.75
UK_YFS survey	87–06	1–1	0.5–0.75
FR_YFS survey	87–18	1–1	0.5–0.75
-First data year	1982		
-Last data year	2018		
-First age -Last age	1 11+		
Time series weights	None		
-Model		No Power model	
-Q plateau set at age	7		
-Survivors estimates shrunk towards mean F		5 years / 5 ages	
-s.e. of the means	2.0		
-Min s.e. for pop. Estimates	0.3		
-Prior weighting	None		

Figures 18–20 present the model output for this run. Figure 18 presents the residuals for each index and age, showing small values for the new Belgian index. Figure 19 shows mean squared natural logarithm transformed residuals and reveals an MSE <0.3 for the new Belgian CBT index, which is lower than a target coefficient of variation (c.v.) of 20–30% (Doonan and Dunn, 2011). Figure 20 shows a small retrospective pattern for Mean F and SSB. Recruitment estimates are uncertain.

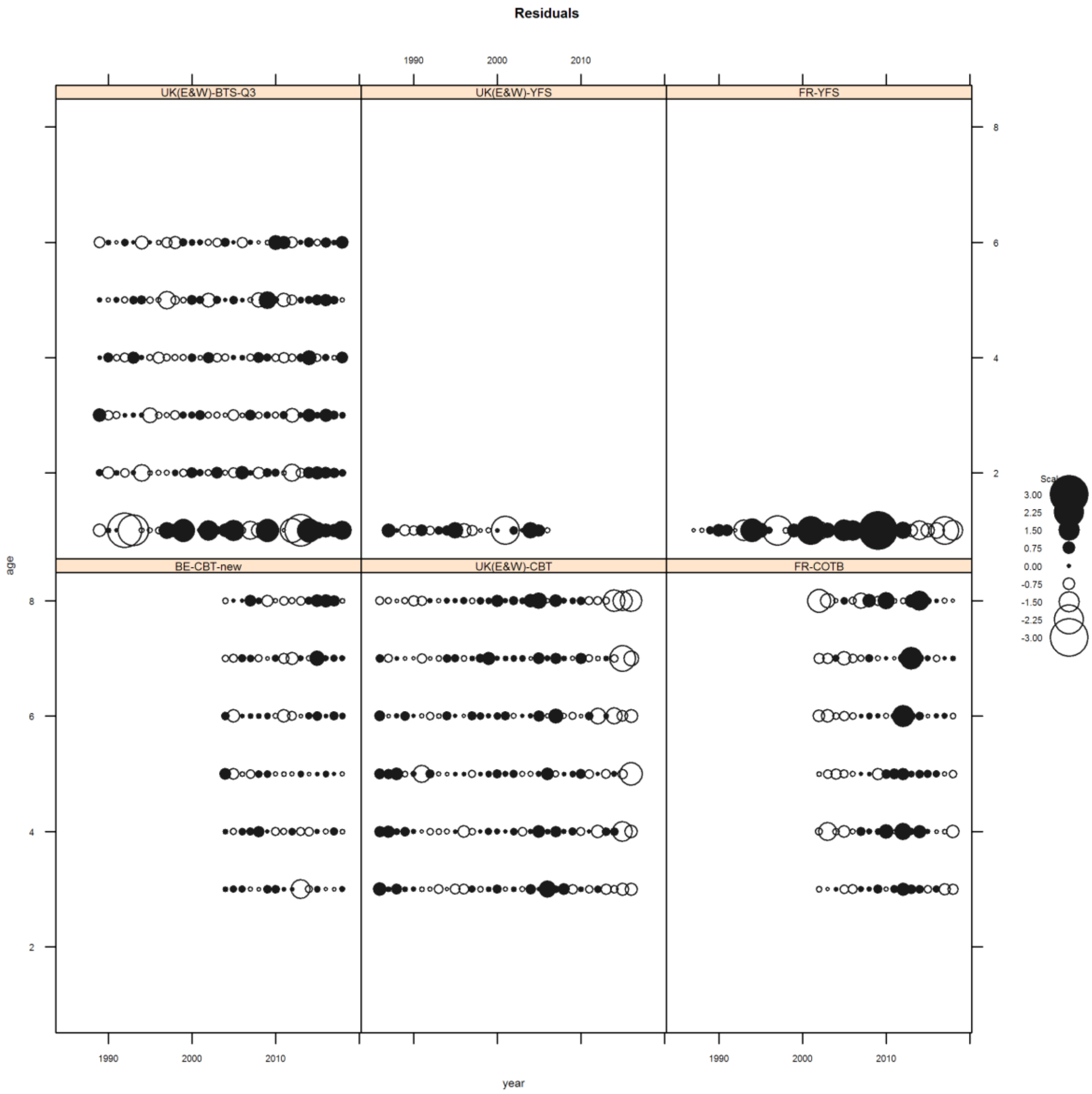

Figure 18: Residuals for the different tuning series for run 2 (including the new BE-CBT and the old UK-CBT up to 2016).

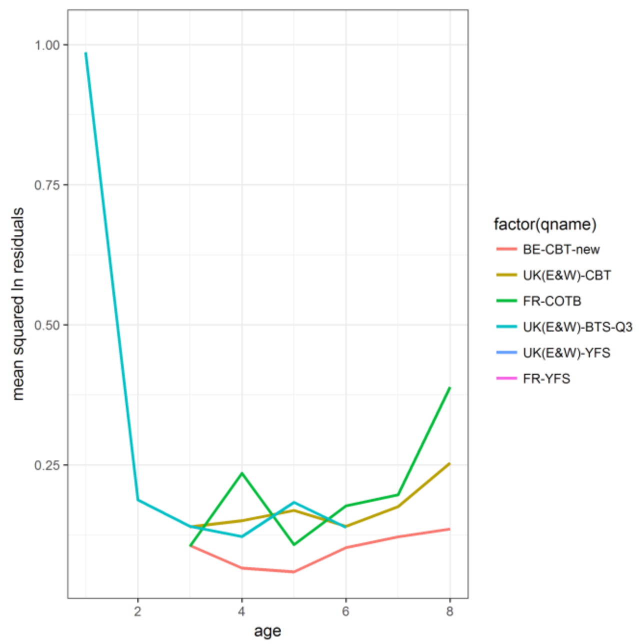

Figure 19: Mean squared natural log residual for each index and age for run 2 (including the new BE-CBT and the old UK-CBT up to 2016).

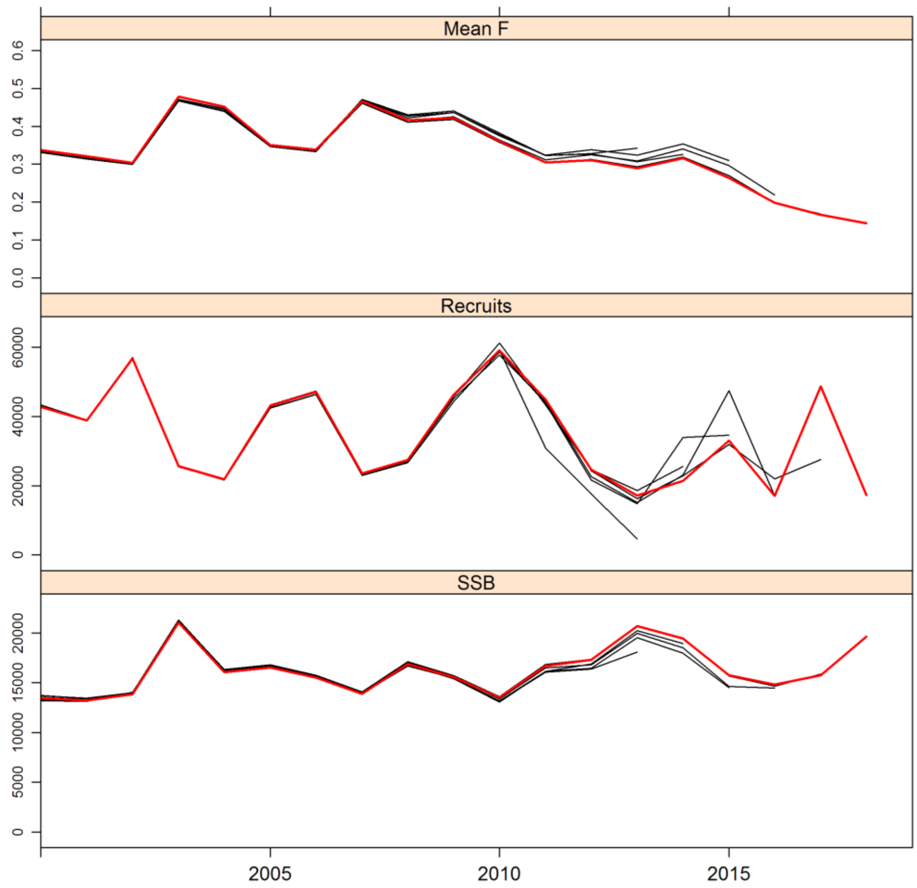

Figure 20: Retrospective XSA analysis for run 2 (including the new BE-CBT).

Differences between the WGNSSK 2019 assessment (base run), run 1 (including the new UK-CBT) and run 2 (including the new BE-CBT) can be observed in Figure 21. The SSB of run 2 is estimated lower compared to the WGNSSK run. In the most recent years, all three scenarios are giving a similar estimate for SSB. The F_{bar} shows the opposite pattern with higher values of run 2 in the period 2007–2015. In the most recent years, run 2 gives the lowest estimate for F_{bar} compared to the other runs. Recruitment is slightly higher for run 2 in 2015 than for the other runs.

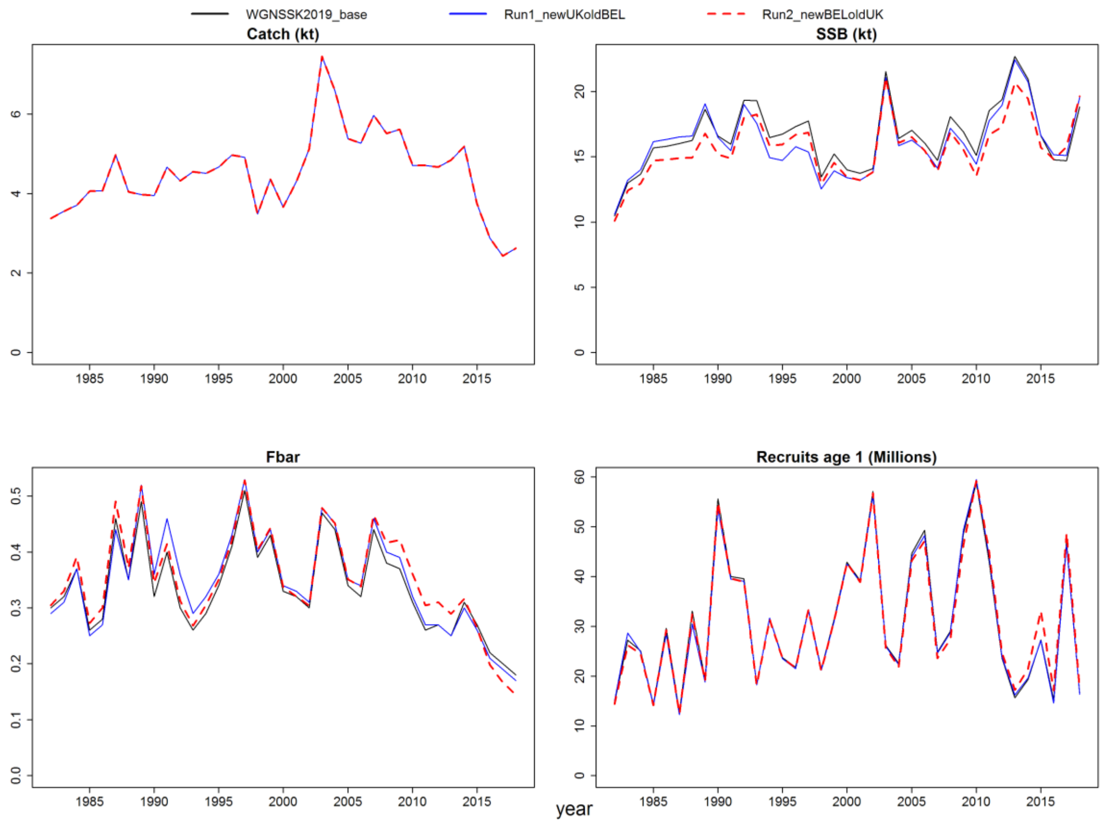

Figure 21: Comparison of the summary plots for catch, SSB, F_{bar} and recruits between the WGNSSK 2019 assessment, run 1 (including the new UK-CBT series) and run 2 (including the new BE-CBT series).

4.6.5.3 Run 3: including the new Belgian CBT from age 2 onwards

Data

Same catch data (total weight, mean weight- and number-at-age for landings and discards) as used in the WGNSSK 2019 assessment (base run).

Biological parameters

Same biological parameters as used in the WGNSSK 2019 assessment.

Tuning series

The French commercial otter trawlers (FRA-COTB), the old UK(E&W)-CBT and the new BE-CBT were included as commercial tuning fleets. The new BE-CBT is a CPUE index and was included from age 2–8 for the purpose of this run. The UK(E&W)-BTS-Q3 and the French and UK YFS were included as survey tuning series. The internal consistency plot of the Belgian CBT including age 2 is shown in Figure 22. A moderate correlation of 0.333 was found between age 2 and 3. The similarity plot is shown in Figure 23. The BE-CBT follows the same trends of the UK-BTS for age

2, but gives lower estimates for the most recent years. Figure 24 shows the catchability of the different tuning fleets with the new BE-CBT having a low catchability for age 2.

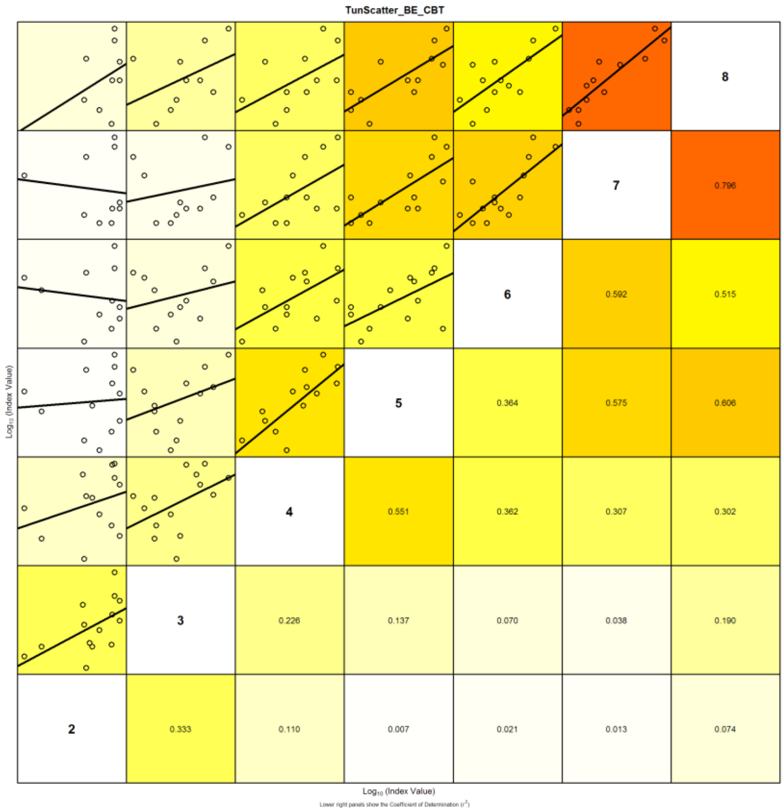

Figure 22: Internal consistency of the new BE-CBT (2004–2018) CPUE tuning series from age 2-8.

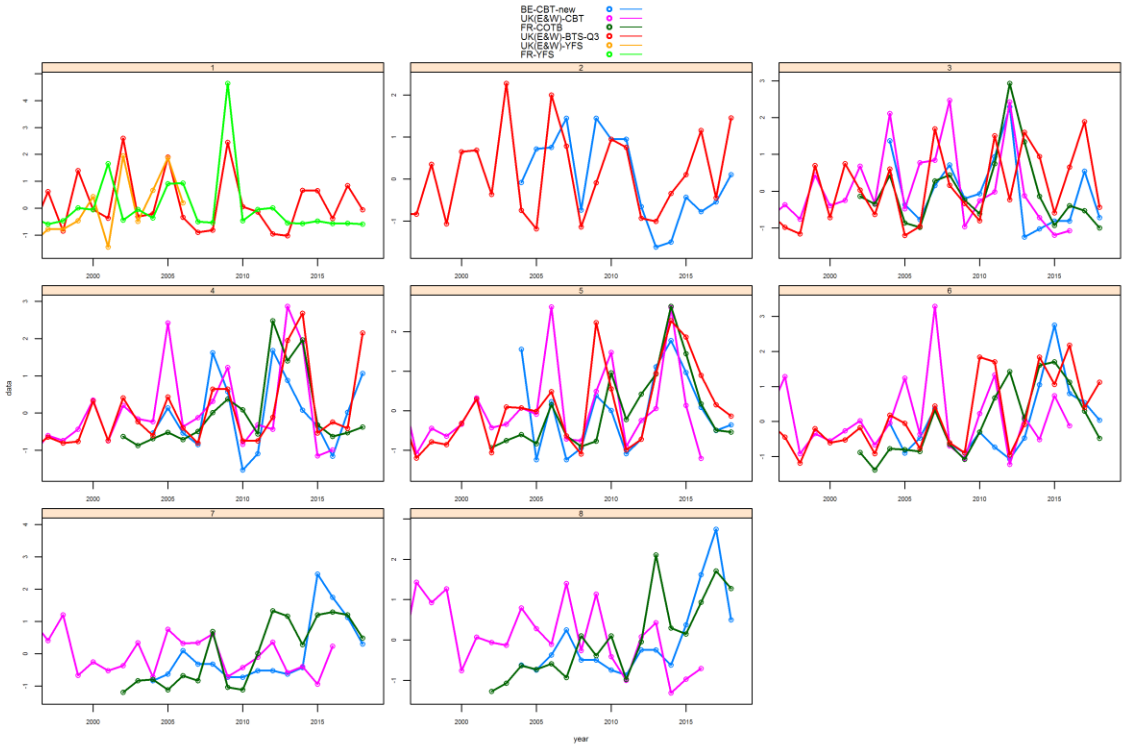

Figure 23: Standardised indices by age of the tuning series for run 3, including the new Belgian tuning series from age 2 onwards (blue), the old UK-CBT series up to 2016 (pink), the French COTB (dark green), the UK-BTS (red), the UK-YFS (up to 2006, orange) and the FRA-YFS (light green).

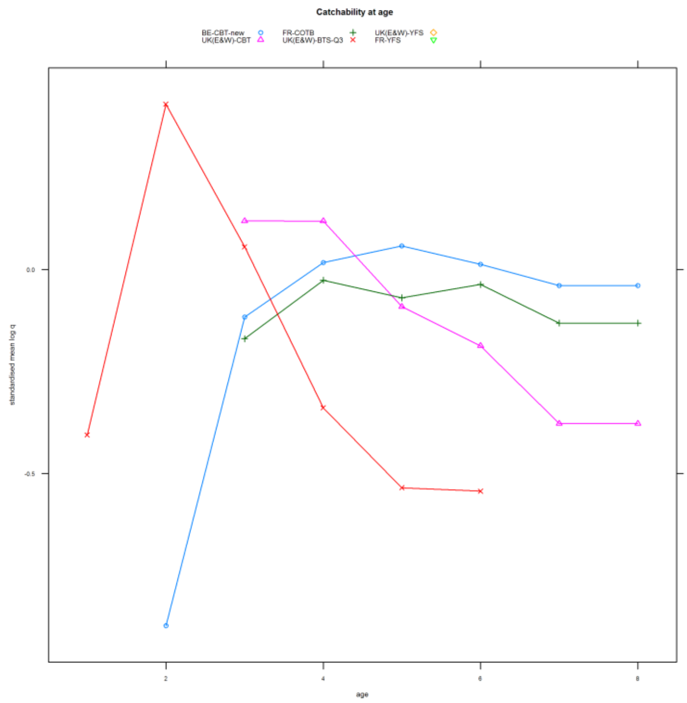

Figure 24: Standardised mean log Q by age of the tuning series for run 3 (including the new BE-CBT from age 2 onwards (blue)).

Model settings for this third run are listed in Table 5.

Table 5: XSA diagnostics used for run 3 including the new BE-CBT from age 2 onwards.

2019 ASSESSMENT			
Fleets	**Years**	**Ages**	**α-β**
new BE_CBT_2004–2018 commercial	04–18	2–8	0–1
FR_COT commercial	02–18	3–8	0–1
Old UK(E&W)_CBT commercial	86–16	3–8	0–1
UK(E&W)_BTS survey	89–18	1–6	0.5–0.75
UK_YFS survey	87–06	1–1	0.5–0.75
FR_YFS survey	87–18	1–1	0.5–0.75
-First data year	1982		
-Last data year	2018		
-First age -Last age	1 11+		
Time series weights	None		
-Model		No Power model	
-Q plateau set at age	7		
-Survivors estimates shrunk towards mean F		5 years / 5 ages	
-s.e. of the means	2.0		
-Min s.e. for pop. Estimates	0.3		
-Prior weighting	None		

Figures 25–27 present the model output for this second run. Figure 25 shows the residuals for each index and age. Age 2 of the new BE-CBT has higher residuals than for the other ages. Figure 26 shows mean squared natural logarithm transformed residuals and reveals an MSE >0.3 for age 2 of the new BE-CBT, which is higher than a target coefficient of variation (c.v.) of 20–30% (Doonan and Dunn, 2011). Figure 27 shows a small retrospective pattern for Mean F and SSB. Recruits are uncertain.

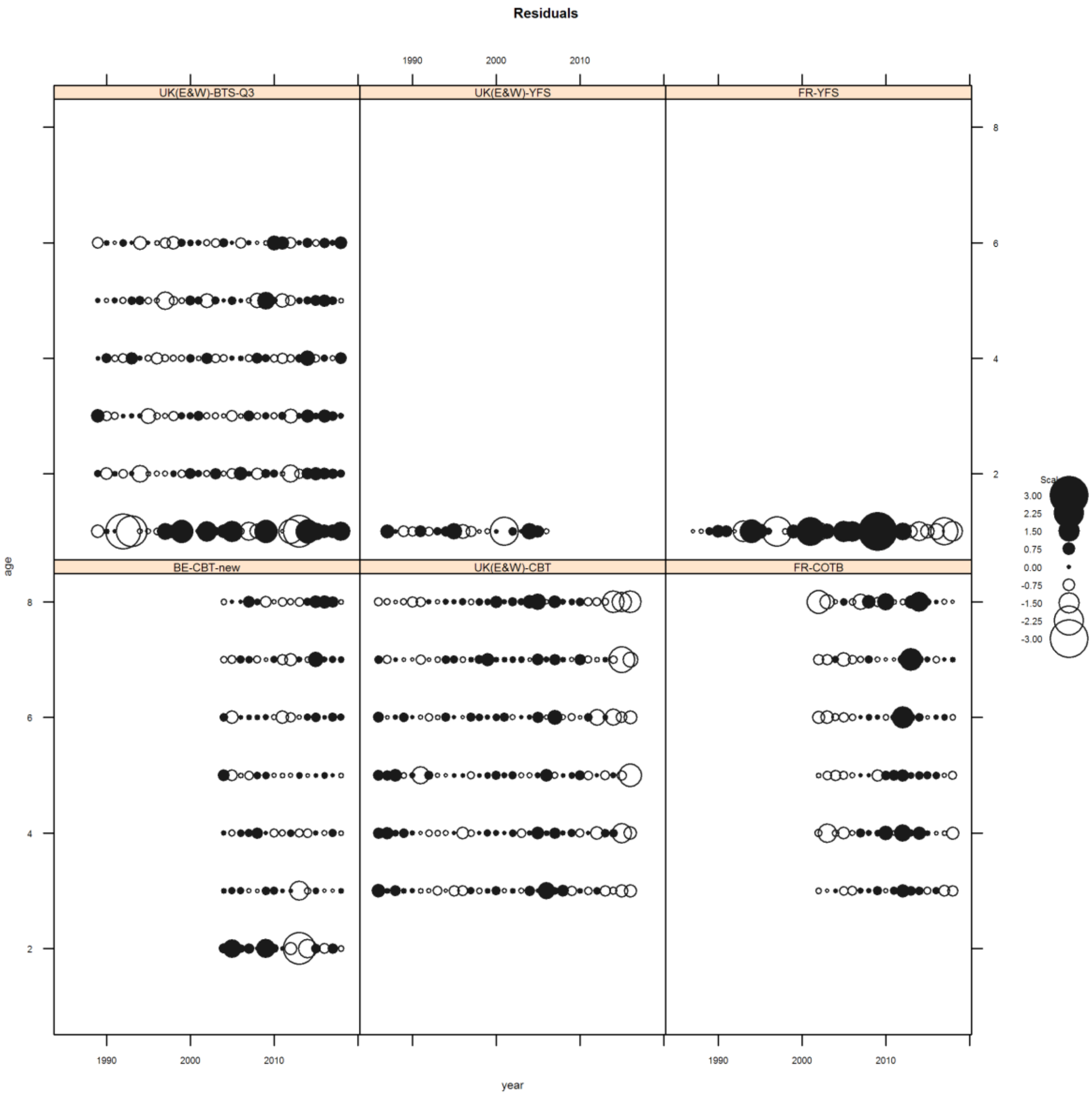

Figure 25: Residuals for the different tuning series for run 3 (including the new BE-CBT from age 2–8 and the old UK-CBT).

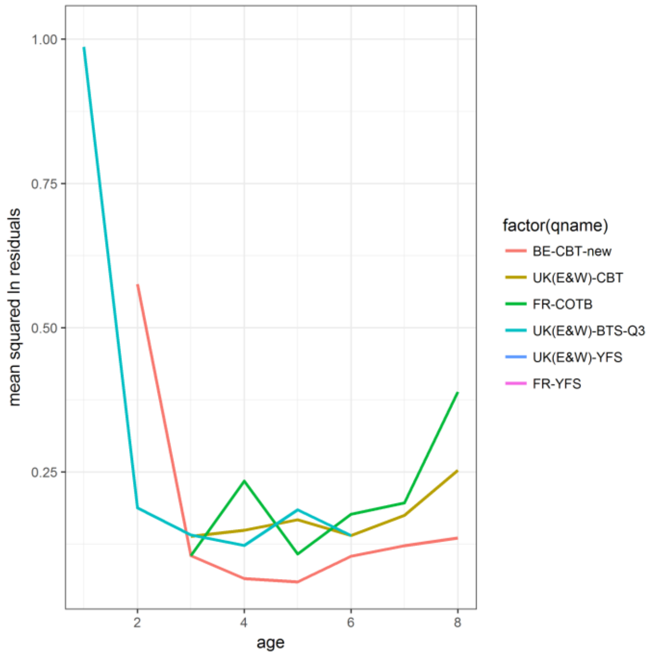

Figure 26: Mean squared natural log residual for each index and age for run 3 (including the new BE-CBT from age 2–8 and the old UK-CBT up to 2016).

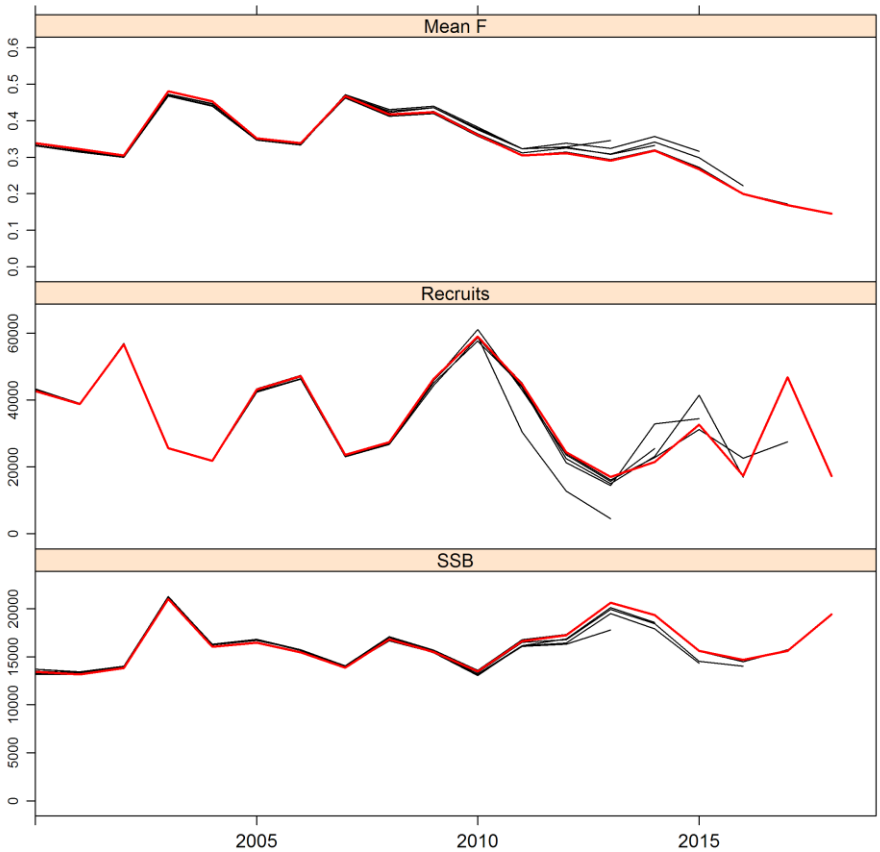

Figure 27: Retrospective XSA analysis for run 3 (including the new BE-CBT from age 2–8 and the old UK-CBT up to 2016).

Differences between the WGNSSK 2019 assessment, run 2 including the new BE-CBT from age 3 onwards and run 3 including the new BE-CBT from age 2 onwards can be observed in Figure 28. Differences between run 2 and 3 are very small. Considering the higher residuals for age 2 in the new BE-CBT (figures 25–26), the IBP decided to proceed with the new BE-CBT from age 3 onwards.

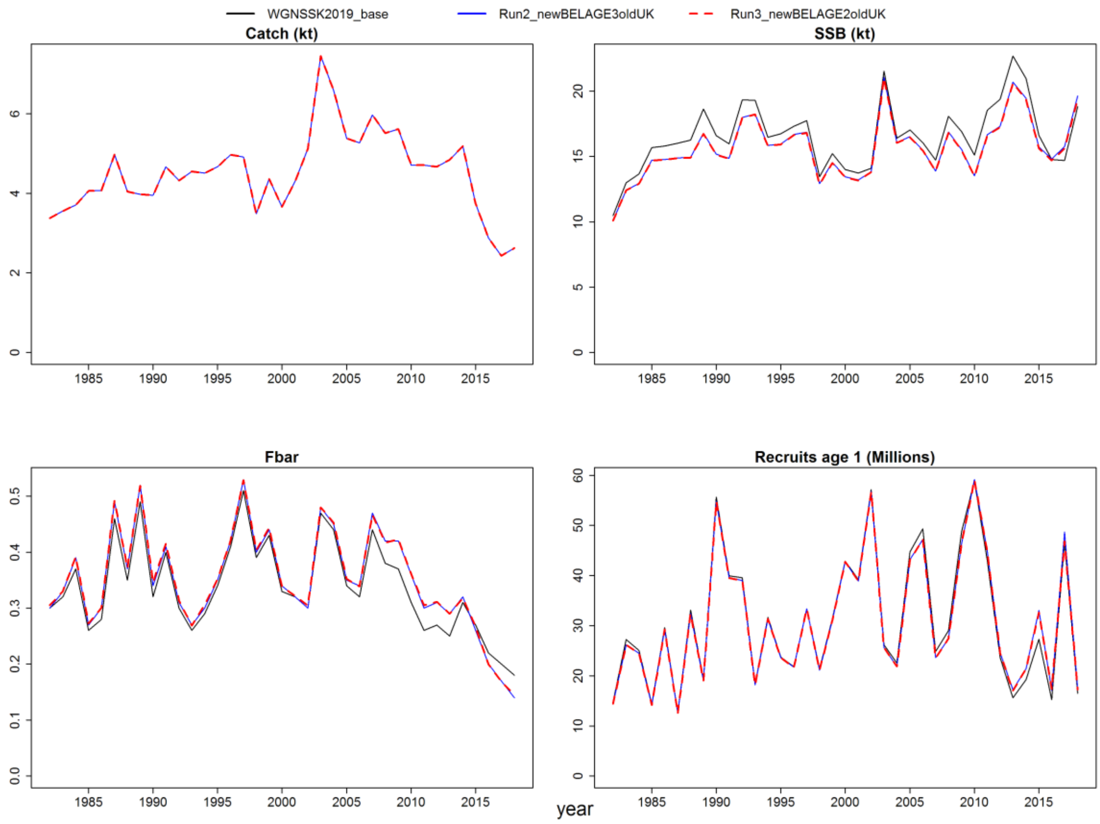

Figure 28: Comparison of the summary plots for catch, SSB, F_{bar} and recruits between the WGNSSK 2019 base run, run 2 including the new BE-CBT from age 3–8 and run 3 including the new BE-CBT from age 2–8.

4.6.5.4 Run 4: Final run: including both the new Belgian (age 3–8) and new UK CBT

Data

Same catch data (total weight, mean weight- and number-at-age for landings and discards) as used in the WGNSSK 2019 assessment (base run).

Biological parameters

Same biological parameters as used in the WGNSSK 2019 assessment.

Tuning series

The French commercial otter trawlers (FRA-COTB), the new UK(E&W)-CBT and the new BEL-CBT (from age 3 onwards) were included as commercial tuning fleets. The UK(E&W)-BTS-Q3 and the French and UK YFS were included as survey tuning series. The similarity plot is shown in Figure 29. Figure 30 shows the catchability of the different tuning fleets.

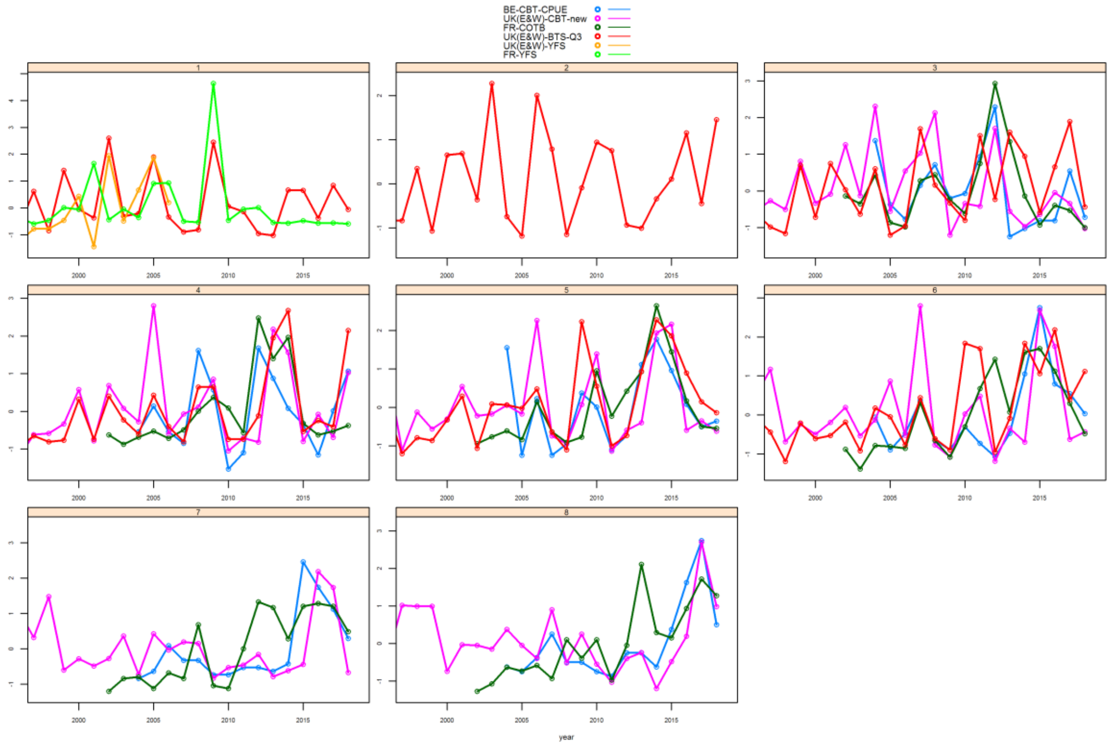

Figure 29: Standardised indices by age of the tuning series for this final run, including the new Belgian tuning series (from age 3, blue), the new UK-CBT series (pink), the French COTB (dark green), the UK-BTS (red), the UK-YFS (up to 2006, orange) and the FRA-YFS (light green).

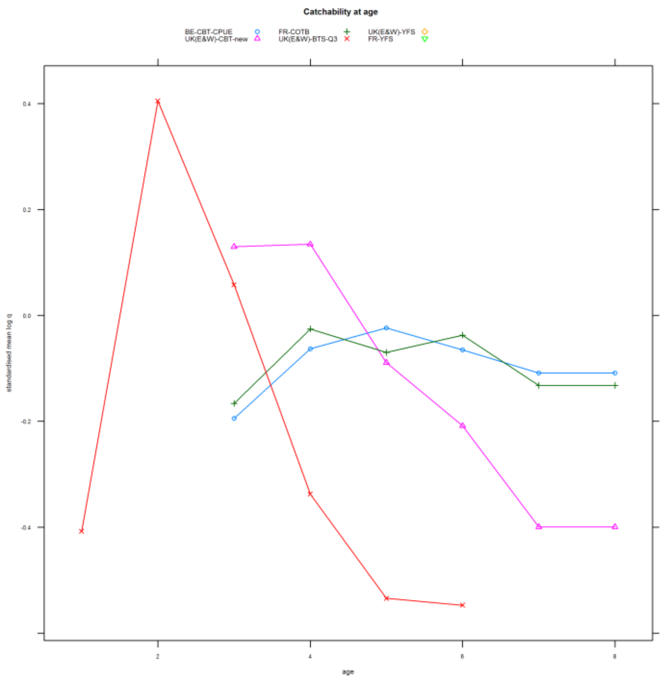

Figure 30: Standardised mean log Q by age of the tuning series for the final run (including both the new BE-CBT (blue) and UK-CBT series (pink)).

Model settings for this final run are listed in Table 6.

Table 6: XSA diagnostics used for the final run (including both the new UK-CBT and new BE-CBT).

2019 ASSESSMENT			
Fleets	**Years**	**Ages**	**α-β**
new BE_CBT_2004–2018 commercial	**04–18**	**3–8**	**0–1**
FR_COT commercial	02–18	3–8	0–1
new UK(E&W)_CBT commercial	**86–18**	**3–8**	**0–1**
UK(E&W)_BTS survey	89–18	1–6	0.5–0.75
UK_YFS survey	87–06	1–1	0.5–0.75
FR_YFS survey	87–18	1–1	0.5–0.75
-First data year	1982		
-Last data year	2018		
-First age -Last age	1 11+		
Time series weights	None		
-Model		No Power model	
-Q plateau set at age	7		
-Survivors estimates shrunk towards mean F		5 years / 5 ages	
-s.e. of the means	2.0		
-Min s.e. for pop. Estimates	0.3		
-Prior weighting	None		

Figures 31–33 present the model output for this second run. Figure 31 shows the residuals for each index and age. Figure 32 shows mean squared natural logarithm transformed residuals and reveals an MSE >0.3 for age 1 of the UK-BTS and age 8 of the FRA-COTB, which is higher than a target coefficient of variation (c.v.) of 20–30% (Doonan and Dunn, 2011). Figure 33 shows no clear retrospective pattern for Mean F and SSB. Recruits are uncertain.

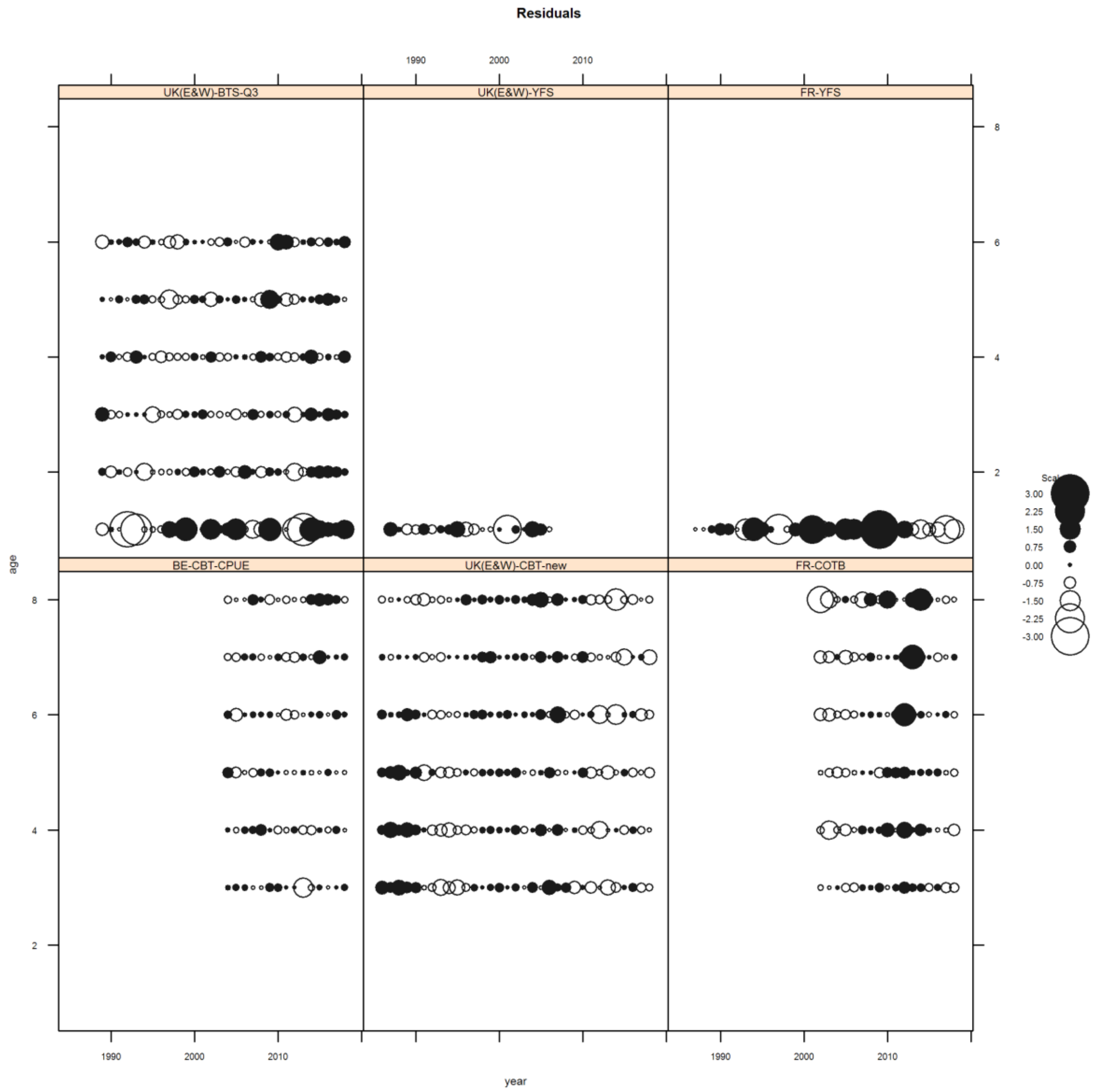

Figure 31: Residuals for the different tuning series for the final run (including the new BE-CBT and new UK-CBT).

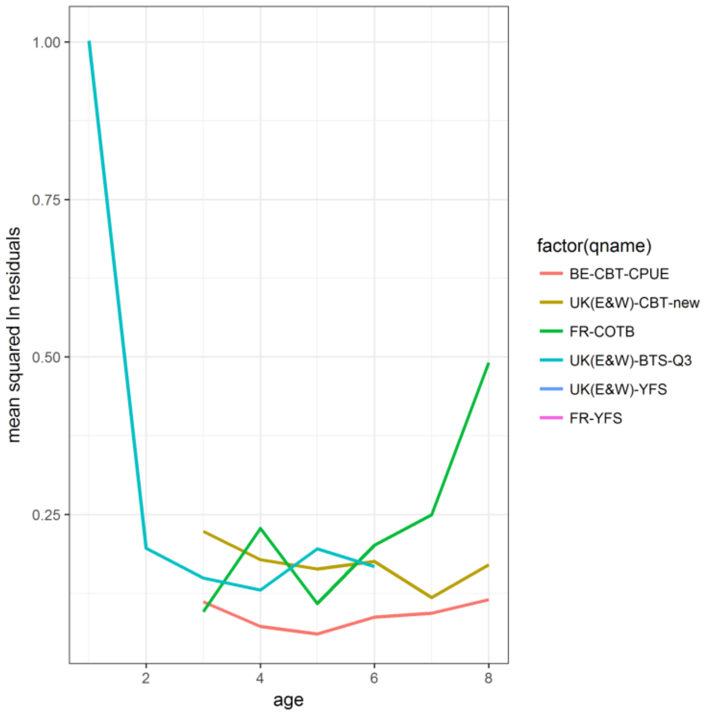

Figure 32: Mean squared natural log residuals for each index and age for the final run (including the new UK-CBT and new BE-CBT).

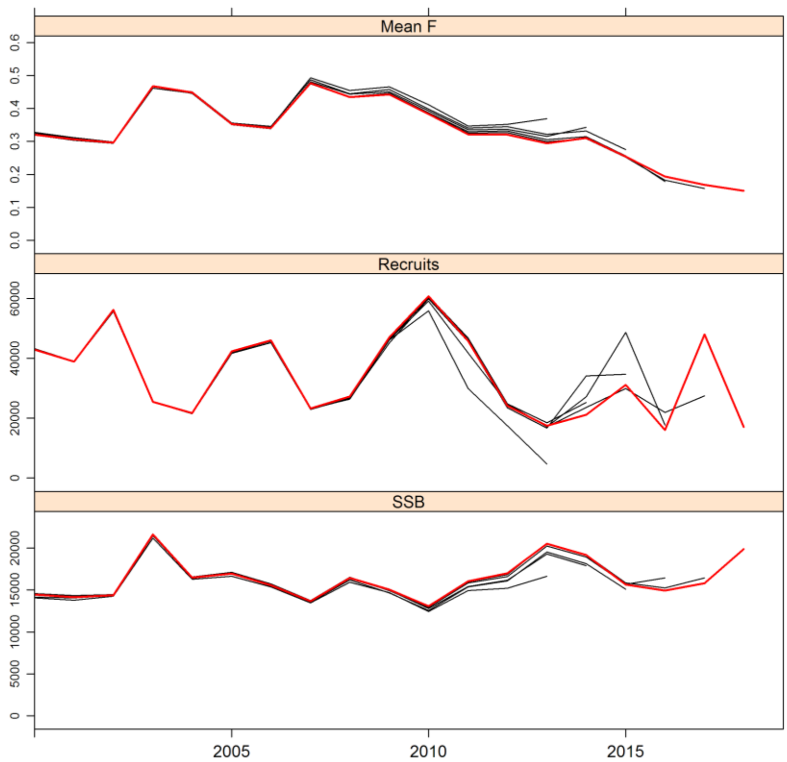

Figure 33: Retrospective XSA analysis for the final run (including the new UK-CBT and new BE-CBT).

Differences between the WGNSSK 2019 assessment and the final run (including both new tuning fleets) can be observed in Figure 34. From 2005–2015, the SSB is estimated lower by the final run and the F is estimated higher. However, for the most recent years, the SSB is estimated higher compared to the WGNSSK run, while the F is estimated lower (lowest of the time series). The recruitment is quite similar between both runs. However, there is a slight difference in 2015 where the assessment including the new indices gives a higher estimate.

Figure 34: Comparison of the summary plots for catch, SSB, F_{bar} and recruits between the WGNSSK 2019 base run assessment and the final IBP run (including the new UK-CBT and new BE-CBT).

4.6.5.5 Summary text

Figure 35 shows the comparison of the summary plots of the WGNSSK 2019 assessment (base run) and 3 of the 4 runs performed during the IBP (run 3 with the new BE-CBT from age 2 onwards was excluded). The differences between the 3 runs and the base run were small. All 3 runs seemed to give a slightly higher estimate of SSB and a lower estimate of F in the most recent years. Recruitment only differed from 2016 onwards, which corresponds to tuning from age 3 onwards by the revised commercial indices. The effect of using this final run including 2 new revised commercial tuning series on stock advice is described in Section 4.7: Short term projections.

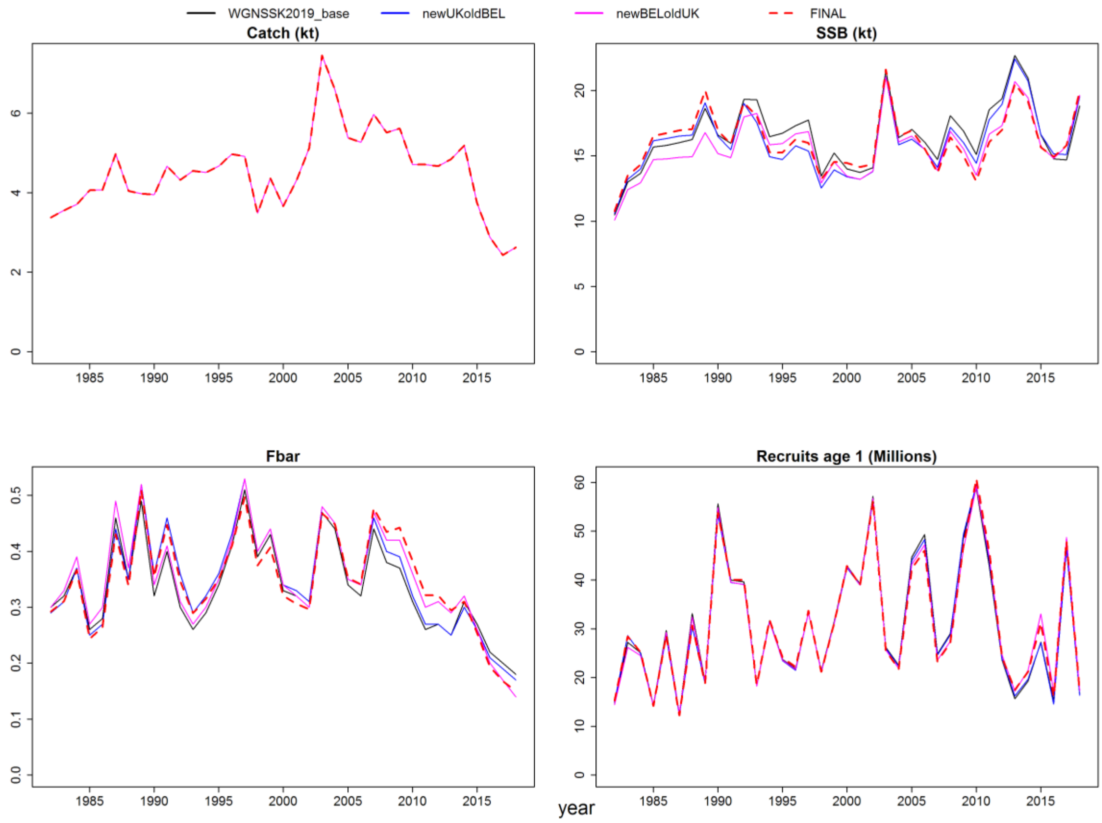

Figure 35: Comparison of the summary plots for catch, SSB, F_{bar} and recruits between the WGNSSK 2019 base run assessment, run 1 including the new UK CBT, run 2 including the new BE-CBT (from age 3 onwards) and the final run including both revised tuning series.

4.7 Short term projections

From the retrospective analysis it is clear that recruitment is highly variable in the most recent years. Age 1 is tuned by the French YFS and UK-BTS. Age 2 is only tuned by the UK-BTS. From age 3 onwards, the commercial tuning series give information. From one year to the next, recruitment can be revised markedly, creating instability in the forecast from one year to the next.

The IBP decided to change the settings of the forecast and more specifically the estimation of age 1, 2 and 3 in 2019. Up until now, only age 1 was altered and estimated by an RCT3 estimate or the geometric mean minus the last 3 data years. By altering age 1, 2 and 3, we affect approximately 20% of the estimation of the catch in 2020. The IBP decided to use a *short* geometric mean for age 1, 2 and 3. The short geometric mean was calculated using the final data year -5 to the final data year -2 (in this case 2013–2016).

- For age 1, the geometric mean from 2013–2016 corresponded to 20 753 thousand individuals (**GM 2013–2016@age1**).
- To obtain the stock numbers for age 2, this value was multiplied by the mortality (fishing mortality and natural mortality = Z) of age 1 in 2018 as follows: **GM 2013–2016@age1** * (e^{-Z} @age1 in 2018), giving 18 077 thousand individuals.
- To obtain the stock numbers for age 3, the GM 2013-2016@age1 was multiplied by the mortality (Z) of age 1 in 2017 and by the mortality (Z) of age 2 in 2018 as follows: **GM 2013-2016@age1** * (e^{-Z} @age1 in 2017)* (e^{-Z} @age2 in 2018), giving 15 707 thousand individuals.

The estimates of year-class strength used for prediction can be summarised as follows (in thousands individuals):

Year class	@ age in 2019	GM	Settings
2016	3	15707	GM 2013–2016
2017	2	18077	GM 2013–2016
2018	1	20753	GM 2013–2016
2019 and 2020	recruits	20753	GM 2013–2016

Weights-at-age in the catch and in the stock are averages for the years 2016–2018.

4.8 Appropriate Reference Points (MSY)

4.8.1 Reference points prior to inter-benchmark

Reference points prior to the inter-benchmark are listed in the table below. The management plan (MAP) referred to is the EU multiannual plan (MAP) for the Western Waters (EU, 2019).

Framework	Reference point	Value	Technical basis
MSY approach	MSY $B_{trigger}$	19251 t	B_{pa}
	F_{MSY}	0.256	EQsim analysis based on the recruitment period 1983–2012
Precautionary approach	B_{lim}	13751 t	Break-point of hockey stick stock-recruit relationship, based on the recruitment period 1983–2012
	B_{pa}	19251 t	$B_{lim} \times \exp(1.645 \times 0.2) \approx 1.4 \times B_{lim}$
	F_{lim}	0.359	EQsim analysis, based on the recruitment period 1983–2012
	F_{pa}	0.256	$F_{lim} \times \exp(-1.645 \times 0.2) \approx F_{lim} / 1.4$
Management plan	MAP MSY $B_{trigger}$	19251 t	MSY $B_{trigger}$
	MAP B_{lim}	13751 t	B_{lim}
	MAP F_{MSY}	0.256	F_{MSY}
	MAP range F_{lower}	0.195–0.256	Consistent with ranges provided by ICES (2017a), resulting in no more than 5% reduction in long-term yield compared with MSY
	MAP range F_{upper}	0.256–0.322	Consistent with ranges provided by ICES (2017a), resulting in no more than 5% reduction in long-term yield compared with MSY

4.8.2 Source of data

Data used in the MSY analyses were taken from the FLStock object created in the assessment of sole in Division 27.7d during the 2019 interbenchmark including a new tuning series for the UK commercial beam trawl fleet and a new Belgian commercial beam trawl tuning fleet.

4.8.3 Methods and settings

All analyses were conducted with Eqsim and following the ICES technical guidelines as described in ICES (2017b). The R code is included in Annex 4. Model and data selection settings are listed in Table 7.

Table 7: Model and data selection settings.

Data and parameters	Settings	Comments
SSB-recruitment data	Truncated time series by removing the last 2 years (2017 and 2018)	The last 2 years were removed, because they are most uncertain.
Exclusion of extreme values (option extreme.trim)	No	
Mean weights and proportion mature; natural mortality	2014–2018	Mean weight at age has decreased over the past ten years. Therefore, instead of taking the default 10-year-period, only the last 5 years were selected.
Exploitation pattern	2014–2018	There is a slight pattern in the exploitation of this stock with less of the younger ages and more of the older ages in the catch. Therefore, instead of taking the default 10-year-period, only the last 5 years were selected (see Figure 36).
Assessment error in the advisory year. CV of F	0.212	Default value for stocks where these uncertainties cannot be estimated
Autocorrelation in assessment error in the advisory year	0.423	Default value for stocks where these uncertainties cannot be estimated.

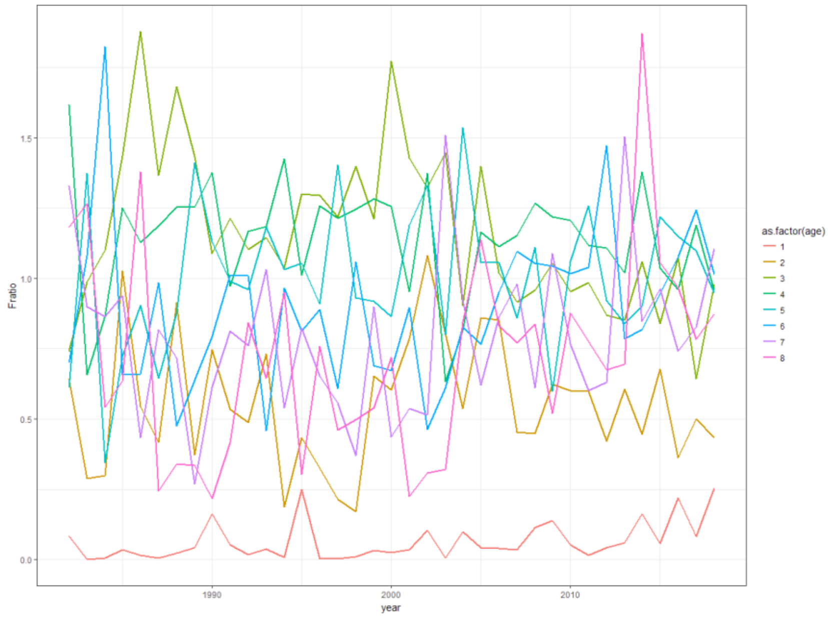

Figure 36: Plot showing the exploitation at age by dividing the fishing mortality at age as estimated by the assessment by the F_{bar} (age 3–7) per year.

4.8.4 Results

4.8.4.1 Stock recruitment relation and new B_{lim} and B_{pa} reference points

To fit stock recruitment models, the available time-series was truncated by removing the last 2 data years (2017 and 2018) to avoid evaluating the most recent and uncertain recruitment values. First, all three stock recruit models were used (Ricker, Beverton-Holt, and segmented regression), weighted by the default 'Buckland' method (Figure 37).

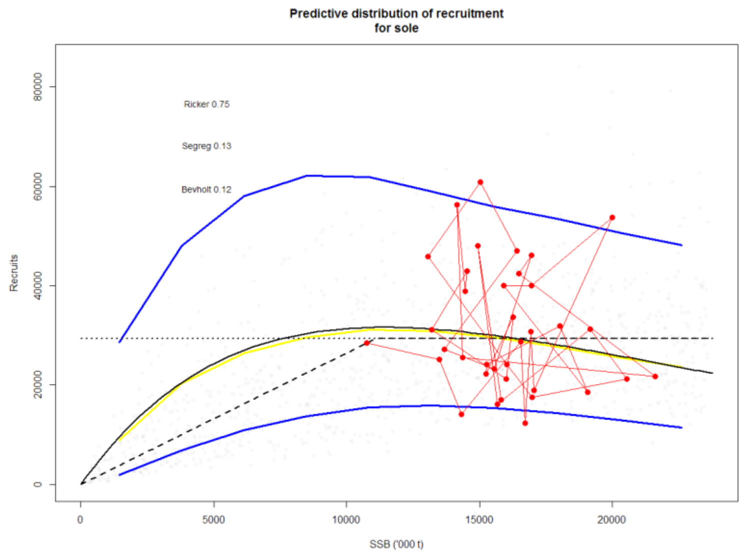

Figure 37: Stock recruitment relations for sole in area 27.7.d showing the estimation of the three regression models over the truncated time period (excluding 2017–2018) (Ricker: full black line; Beverton-Holt: dotted line; segmented regression: dashed line; yellow line represents the best fit over the three models).

The stock-recruitment relation was evaluated as **type 5**, showing a stock with no evidence of impaired recruitment or with no clear relation between stock and recruitment (no apparent S-R signal). Therefore, B_{lim} should be set to B_{loss}, being 10 766 tonnes. The breakpoint of the hockey stock SRR was very close to B_{loss}. B_{pa} was then derived using the standard multiplier of 1.4, resulting in 15 072 tonnes.

4.8.4.2 Determine F_{lim} and F_{pa}

The preferred method to derive F_{lim} is simulating a stock with a segmented regression S-R relation (Figure 38) with the point of inflection fixed at B_{lim}, thus determining the fishing mortality (F) that, at equilibrium, gives a 50% probability of the SSB being larger than B_{lim}. This simulation was conducted based on a fixed F (*i.e.* without inclusion of a $B_{trigger}$) and without inclusion of assessment/advice errors (*i.e.* F_{cv} and F_{phi} set to zero).

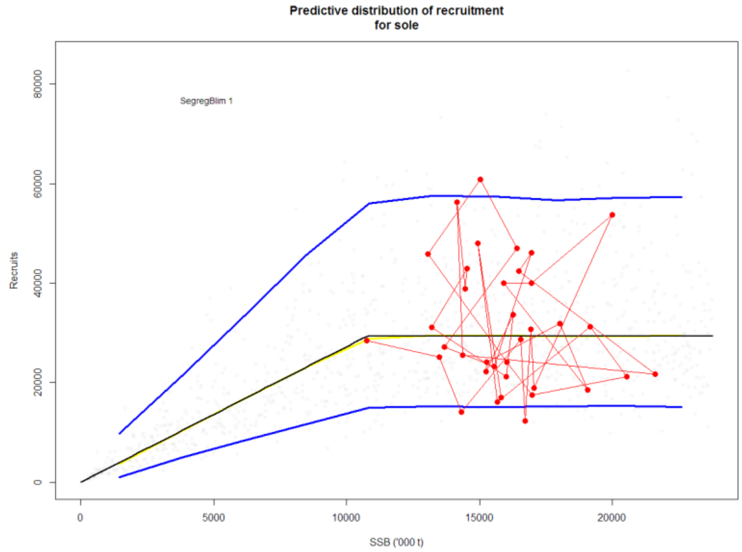

Figure 38: Stock recruitment relationship for sole in area 27.7.d based on segmented regression over the truncated time period (excluding 2017 and 2018), where the inflection point was set to B_{lim}.

F_{lim} was estimated at 0.421 (0.4205795) (see table below). F_{pa} was estimated at 0.300 (0.3004139) from the equation $F_{pa} = F_{lim}/1.4$.

	F05	F10	F50	medianMSY	meanMSY	Medlower	Meanlower	Medupper	Meanupper
catF	0.343	0.361	**0.421**	NA	0.240	NA	NA	NA	NA
lanF	NA	NA	NA	0.196	0.180	0.123	0.110	0.335	0.329
catch	4542.872	4507.470	4087.475	NA	4624.873	NA	NA	NA	NA
landings	NA	NA	NA	4180.731	4162.659	3969.576	4066.964	3967.451	4057.628
catB	14286.675	13555.629	10752.712	NA	19923.650	NA	NA	NA	NA
lanB	NA	NA	NA	23698.800	25512.165	33930.185	NA	14663.696	NA

4.8.4.3 Determine initial F_{MSY} and its ranges

The initial F_{MSY} was calculated using the fit by the segmented regression model (Beverton-Holt did not contribute much to the S-R relation and Ricker showed lower recruitment when biomass was high, which is unexpected and not fully supported by the raw data, see Figure 37) using the whole time-series with the exclusion of 2017 and 2018 (Figure 39).

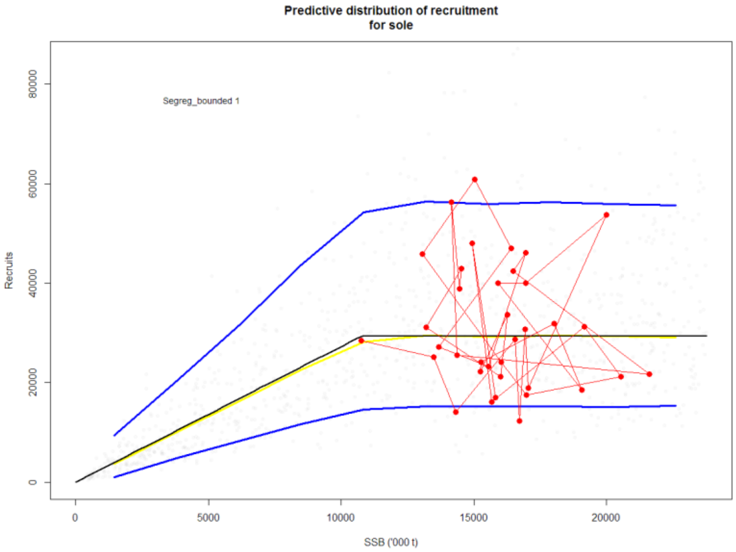

Figure 39: Stock recruitment relation for sole in area 27.7.d, based on segmented regression over the truncated time period (excluding 2017 and 2018).

For this simulation run, the assessment/advice errors were set to the default values (Table 7) and $B_{trigger}$ was set to zero. This resulted in a median F_{MSY} of 0.192 (0.1921922) (< F_{pa}). The median of the SSB estimates at F_{MSY} was 23 851 tonnes. The upper bound of the F_{MSY} range, giving at least 95% of the maximum yield, was estimated at 0.319 and the lower bound at 0.116. The results of the Eqsim simulations are shown in the table below and Figure 40–42.

	F05	F10	F50	medianMSY	meanMSY	Medlower	Meanlower	Medupper	Meanupper
catF	0.309	0.330	0.399	NA	0.240	NA	NA	NA	NA
lanF	NA	NA	NA	**0.192**	0.180	**0.116**	0.106	**0.319**	0.308
catch	4503.126	4454.834	3834.313	NA	4552.151	NA	NA	NA	NA
landings	NA	NA	NA	4117.554	4106.455	3906.643	4074.255	3907.252	4067.819
catB	15634.457	14609.234	10751.422	NA	19731.535	NA	NA	NA	NA
lanB	NA	NA	NA	**23850.531**	25238.616	35253.697	NA	15119.471	NA

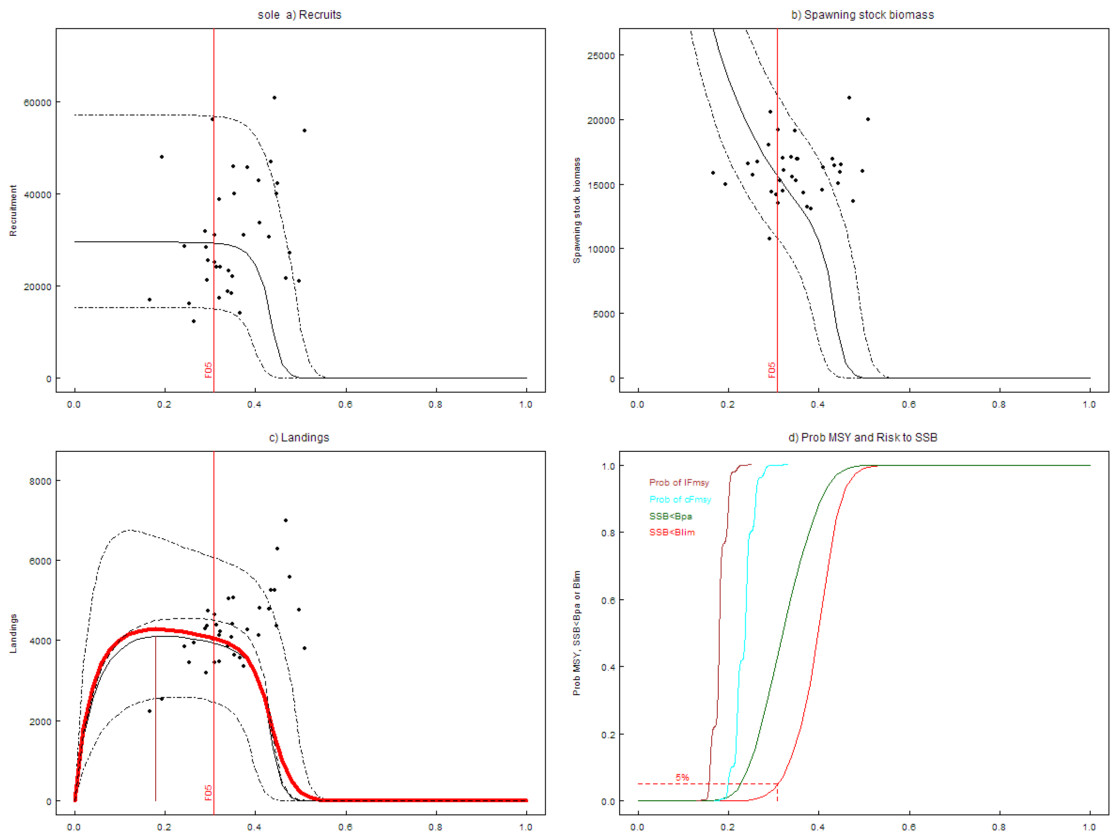

Figure 40: Eqsim summary plot for sole in area 27.7.d (without $B_{trigger}$). Panels a-c: historic values (dots) median (solid black line) and 90% intervals (dotted black lines) for recruitment, SSB and landings for exploitation at fixed values of F (on x-axis). Panel c also shows mean landings (red solid line). Panel d shows the probability of SSB < B_{lim}(red), SSB < B_{pa} (green), and the cumulative distribution of F_{MSY} based on yield as landings (brown) and catch (cyan).

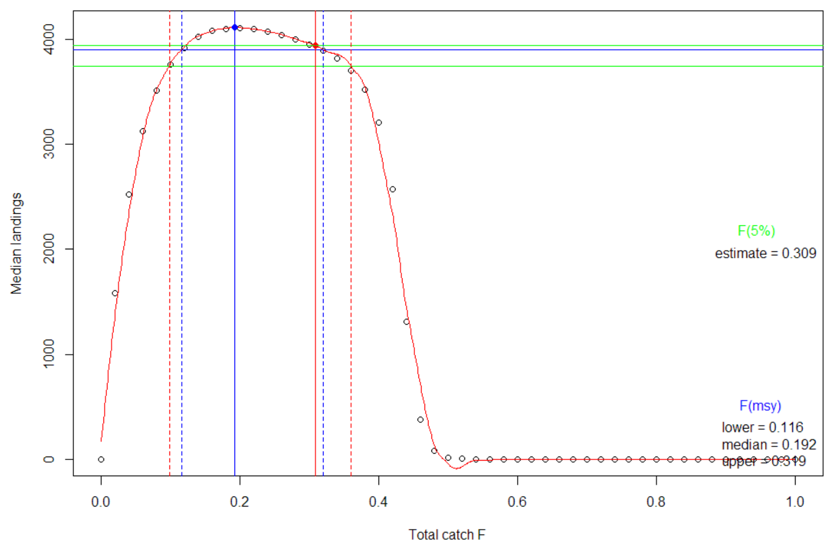

Figure 41: Median landings yield curve for sole in area 27.7.d, with estimated reference points (without $B_{trigger}$) and with a fixed F exploitation from F = 0 to 1.0. Blue lines: F_{MSY} estimate (solid line) and range at 95% of maximum yield (dotted lines). Green lines: Fp0.5 estimate (solid line) and range at 95% of yield implied by Fp0.5 (dotted lines).

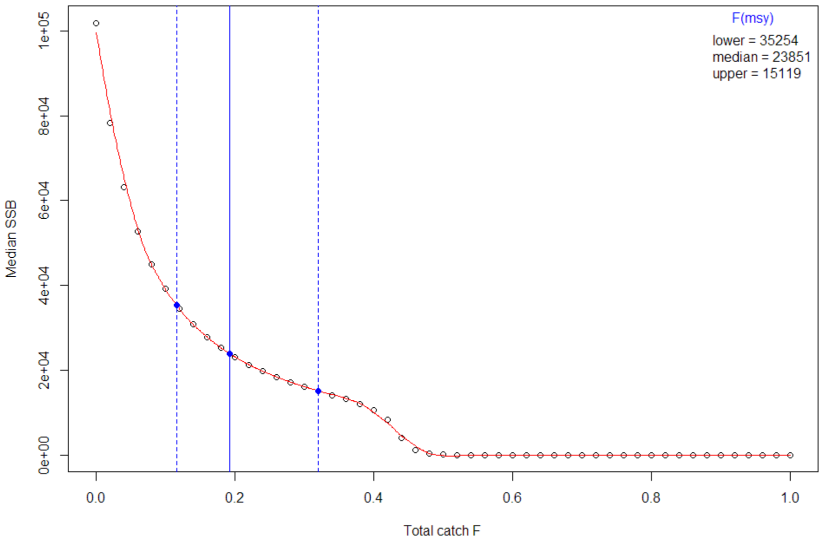

Figure 42: Median SSB curve over a range of target F values (without $B_{trigger}$) for sole in area 27.7.d. Blue lines: F_{MSY} estimate (solid line) and range at 95% of maximum yield (dotted line).

4.8.4.4 Determine MSY $B_{trigger}$ and evaluate ICES MSY Advice rule

Since the stock has not been fished at F_{MSY} for 5 or more years, MSY $B_{trigger}$ should be set at B_{pa}: 15 072 tonnes.

To evaluate the reference points when enforcing the $B_{trigger}$, a final Eqsim run was performed. When applying the ICES MSY advice rule with a $B_{trigger}$ of 15 072 tonnes, the Fp.05 value is estimated at 0.387. This value is larger than the F_{MSY} upper (0.319). Therefore, F_{MSY} stays at the value initially calculated and the F_{MSY} range should not be truncated.

The results of the Eqsim simulations are shown in the table below and in figures 43–45.

	F05	F10	F50	medianMSY	meanMSY	Medlower	Meanlower	Medupper	Meanupper
catF	**0.387**	0.424	0.578	NA	0.240	NA	NA	NA	NA
lanF	NA	NA	NA	0.191	0.180	0.116	0.108	0.346	0.335
catch	4453.655	4393.763	4023.856	NA	4556.397	NA	NA	NA	NA
landings	NA	NA	NA	4116.578	4108.136	3911.846	4008.656	3907.315	4004.927
catB	13769.394	13065.258	10764.940	NA	19717.533	NA	NA	NA	NA
lanB	NA	NA	NA	23905.031	25195.415	35124.204	NA	14738.668	NA

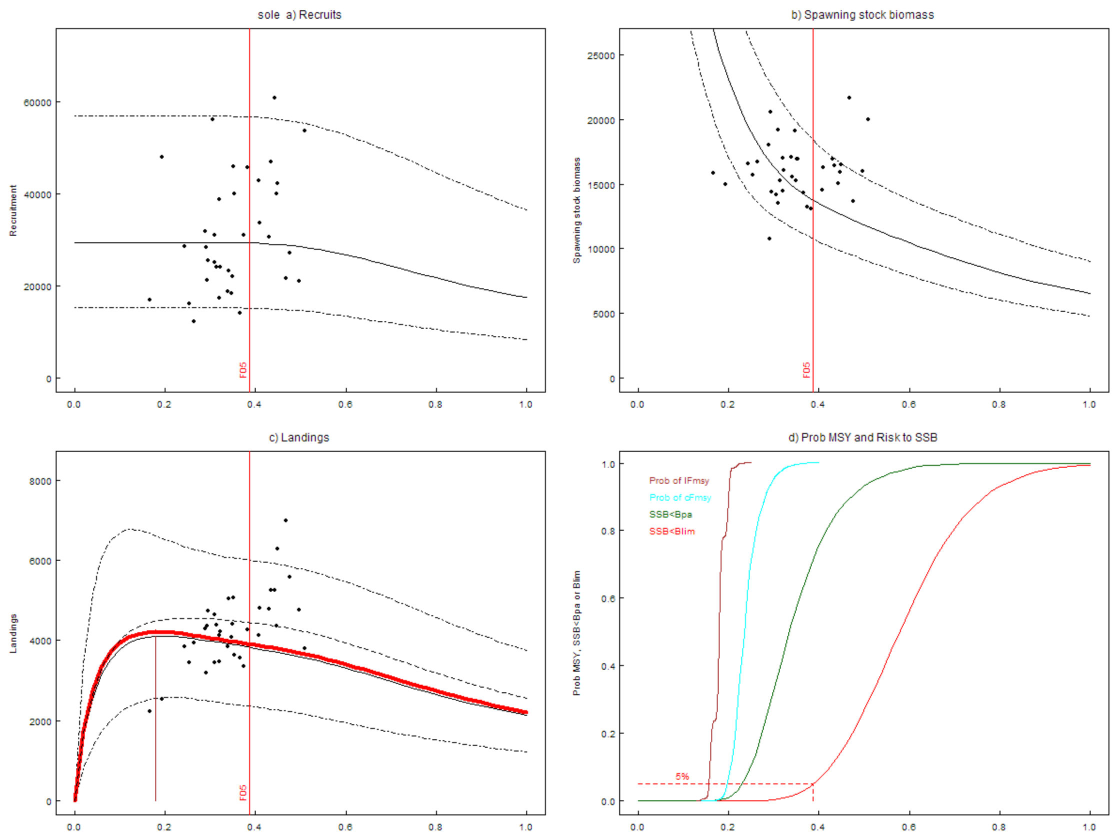

Figure 43: Eqsim summary plot for sole in area 27.7.d (with $B_{trigger}$). Panels a-c: historic values (dots) median (solid black line) and 90% intervals (dotted black lines) for recruitment, SSB and landings for exploitation at fixed values of F (on x-axis). Panel c also shows mean landings (red solid line). Panel d shows the probability of SSB < Blim(red), SSB < B_{pa} (green), and the cumulative distribution of F_{MSY} based on yield as landings (brown) and catch (cyan).

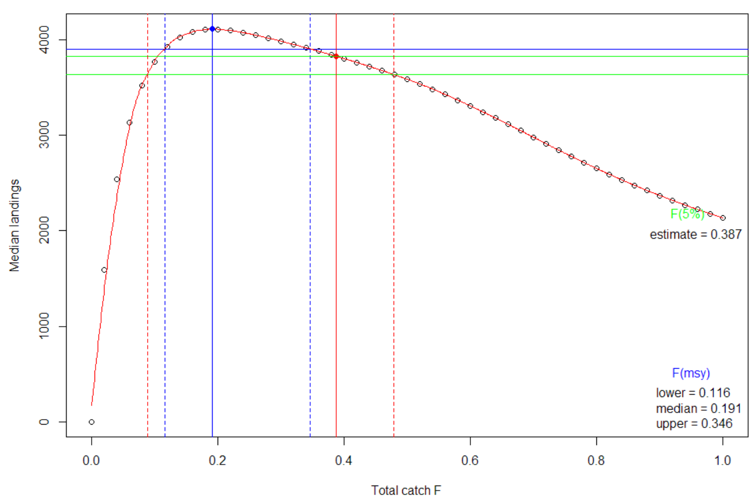

Figure 44: Median landings yield curve for sole in area 27.7.d, with estimated reference points ($B_{trigger}$ = 15 072 tonnes) and with a fixed F exploitation from F = 0 to 1.0. Blue lines: F_{MSY} estimate (solid line) and range at 95% of maximum yield (dotted lines). Green lines: Fp0.5 estimate (solid line) and range at 95% of yield implied by Fp0.5 (dotted lines).

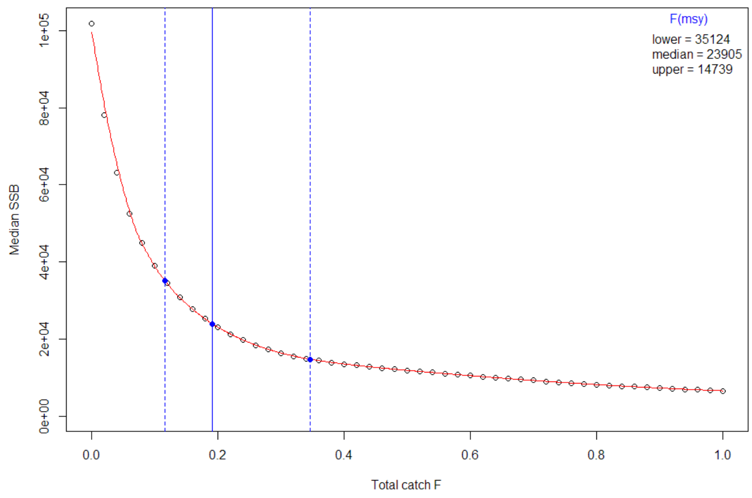

Figure 45: Median SSB curve over a range of target F values ($B_{trigger}$ = 15 072 tonnes) for sole in area 27.7.d. Blue lines: F_{MSY} estimate (solid line) and range at 95% of maximum yield (dotted line).

4.8.5 New reference points

Framework	Reference point	Value	Technical basis
MSY approach	MSY $B_{trigger}$	15072 t	B_{pa}
	F_{MSY}	0.192	EQsim analysis based on the recruitment period 1982–2016
Precautionary approach	B_{lim}	10766 t	B_{loss}
	B_{pa}	15072 t	$B_{lim} \times \exp(1.645 \times 0.2) \approx 1.4 \times B_{lim}$
	F_{lim}	0.421	EQsim analysis, based on the recruitment period 1982–2016
	F_{pa}	0.300	$F_{lim} \times \exp(-1.645 \times 0.2) \approx F_{lim} / 1.4$
Management plan	MAP MSY $B_{trigger}$	15072 t	MSY $B_{trigger}$
	MAP B_{lim}	10766 t	B_{lim}
	MAP F_{MSY}	0.192	F_{MSY}
	MAP range F_{lower}	0.116–0.192	Consistent with ranges provided in this IBP report, resulting in no more than 5% reduction in long-term yield compared with MSY
	MAP range F_{upper}	0.192–0.319	Consistent with ranges provided in this IBP report, resulting in no more than 5% reduction in long-term yield compared with MSY

4.8.6 Sensitivity runs

A sensitivity analysis was conducted which involved running Eqsim with a moving window of 10 years of selectivity data starting with 1991–2000 and ending with 2009–2018 (bio data year range 2014–2018 remained constant). The effect on the estimate of median F_{MSY} is shown in Figure 46. The estimate varies between 0.191 and 0.194 depending on the year range chosen and is thus very stable over the entire time period.

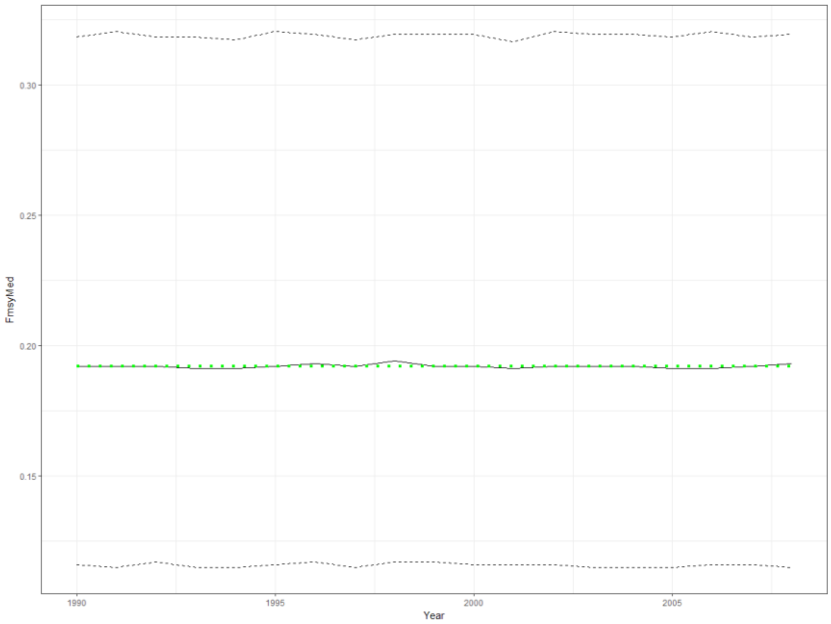

Figure 46: Sensitivity of F_{MSY} estimate (solid black line) to year range of selectivity data for sole in area 27.7.d (Year label is 1st year of a 10 year range). Dotted lines represent the 5th and 95th percentiles of F_{MSY}. Green striped line represents the F_{MSY} value as estimated by the Eqsim analysis described above (= 0.192).

5 Future Research and data requirements

During this IBP, several issues with data, tuning fleets and the assessment model became clear. A benchmark in the near future will therefore be inevitable.

- Annex 3 describes the revision of the Belgian commercial tuning fleet. When comparing data from trips which only covered the 7.d area, with data from trips which covered several ICES divisions, some misreporting of landings was suspected. This should be investigated further. To estimate the quantity of misreported sole landings, logbook data can be used to model the landings per unit effort of fishing trips where fishing activity was limited to the eastern English Channel. Whereas VMS data can be used to estimate the true fishing activity in the eastern English Channel from fishing trips where fishing activity occurred in multiple ICES divisions. Finally, the regression model and the estimated fishing effort can be used to predict the sole landings in the eastern English Channel. As such, the difference between the sum of the predicted landings and the reported landings provides an estimate of misreporting.

- The Belgian commercial index covers the largest area of the 7.d compared to the other indices. A combination of the different commercial indices should be investigated, to end up with an index covering the whole area of the stock.

- Abundance/biomass trends in different areas should be analysed combining survey, commercial and observer data to rule out that 1) important trends are missed by the UK-BTS (stations are located along the French and UK coast only) or 2) give a biased picture because of shifts in distribution of the sole stock (*e.g.* shift from offshore to coastal areas).

The numbers at age of the time series from the assessment show a jump for age 11 (*i.e.* plus group) from 535 thousand to 7019 thousand. Most likely, this has been driving the jumps in advice between last and this year. XSA is known to have a problem with plus group calculations. Moreover, for these ages we do not have tuning data (only up to age 8). Other assessment models such as SAM and AAP should therefore be explored.

6 External Reviewer Comments

Dr. Alexander Kempf (Thünen-Institut of Sea Fisheries, Germany) was the external reviewer of this IBP. His comments are listed below.

The IBP sole 2019 benchmark meeting was held in Ostende, although attended by correspondence. The reason for the IBP was missing UK commercial index (UK CBT) data for 2017 and 2018 and a general need to update and standardize the UK CBT time series based on a new database system in the UK.

Finally, the IBP investigated not only the UK CBT time series, but also the Belgian commercial index and alternatives to calculate it. The final IBP assessment included a new Belgian index based on CPUE instead of LPUE to take increasing discard rates in recent years into account. Also the index now includes information from small vessels standardized with a vessel effect. A continuous time series for the UK CBT could be derived from the old and new UK databases. An original 10% threshold to select vessels for the index has been withdrawn under the assumption that all beam trawlers applying a suitable mesh size have sole at least as valuable bycatch. Based on the new final benchmark assessment reference points were estimated following ICES guidelines.

The external reviewer agrees to the decisions made during the IBP and the final IBP assessment can be regarded as being suitable to provide category 1 advice based on XSA diagnostics. However, concerns still exist about a potential bias in the Belgian CPUE index caused by potential misreporting and the absence of a scientific survey covering the whole area 7.d and not only the coastal regions. A full benchmark is recommended in the near future to test also alternative assessment modelling approaches.

In detail, the following topics were discussed during the benchmark:

6.1 UK commercial index

A new database with partly different parameters made it necessary to combine information from the old and new database to derive a continuous time series of LPUE indices. During the IBP it was questioned whether the original 10% threshold is necessary and too arbitrary. Only vessels that had at least in one trip with >10% sole landings were selected in the original index although it can be expected that vessels using beam trawls and a suitable mesh size have sole at least as valuable bycatch. Therefore, finally an index based on all trips with beam trawls and a suitable mesh size was created.

Next to this, also seasonal and area effects were tested. Especially in recent years the spatial distribution of sole catches from the UK beam trawl fleet concentrates in just three rectangles while in earlier time periods more rectangles were fished. This is also due to changes in the structure of the UK fleet (no vessels >15 m left in recent years). However, neither the seasonal nor the area effect was significant and only had very minor impact on the index trend over time. Therefore, the final LPUE model included a year and a vessel effect (showed by far the best log likelihood compared to models only taking into account engine power and vessel length).

Given increasing discard rates in recent years, a CPUE index would have been preferable over a LPUE index. However, discard information from the UK commercial tuning fleet was not available.

6.2 Belgian commercial index

An analysis revealed serious significant differences in LPUE and CPUE between trips that exclusively fish in 7.d ("pure") and trips with fishing operations also in other areas (e.g., 4 and 7.e,f,g; "mixed"). The LPUE and CPUE was consistently higher in mixed trips compared to pure trips. In a preliminary analysis no larger differences in the composition with smaller and larger vessels were found between both types of trips. After discussions, it was decided to use all trips for this IBP (as also decided in the last full benchmark) and not only pure trips because otherwise nearly 2/3 of the trips would have been excluded from the index calculation. However, if the difference in CPUE or LPUE comes from misreporting sole from other areas, this would mean a serious bias to the assessment. Test runs with an index based on pure trips only gave a lower SSB in recent years because the "pure" LPUE/CPUE showed a stronger decrease compared to the index taking all trips into account. Time was not sufficient to look deeper into the issue during this IBP, however, it is strongly recommended to further analyse these differences and to try to find out which processes lead to this difference.

Because discards at age 2 to 4 are increasing to a larger extent in recent years, it was decided to calculate the Belgian index based on CPUE instead of LPUE. Next to this, in the last benchmark the index has been based on larger vessels only while now also information from smaller vessels is included and standardized via vessel effects. It was also tried to use the Belgian CBT CPUE index from age 2 instead of age 3 onwards to have more information on age 2 abundance. However, this did not improve the assessment and age 2 estimates were still dominated by the influence of the scientific UK BTS survey and only to a minor extent by the Belgian CBT.

6.3 Assessment

The assessment is tuned via 3 scientific surveys (2 recruitment indices and UK BTS for ages 1 to 6) and 3 commercial indices from Belgian, UK and French fleets (Ages 3–8). None of the surveys and commercial indices covers the whole of area 7.d. The Belgian commercial index covers the largest area compared to the other indices. Effort should be made in the near future to combine *i.e.* the commercial indices into one index covering the whole area of the stock.

XSA estimates for young year classes (*i.e.* age 1 and 2) are mainly impacted by the UK BTS while its influence becomes lower with age and the commercial indices become more important. The recruitment estimates are uncertain and in general the scientific survey is more optimistic about the stock development than the CPUE/LPUE indices (see leave one out runs).

The residual plots and retrospective patterns of the final assessment look acceptable. However, recruitment estimates turn out to be uncertain and get revised over the years as visible in the retrospective analysis. Mean squared residuals also indicate that especially the UK BTS age 1 index is not reliable. The final assessment is slightly more positive than the WGNSSK 2019 assessment. This is mainly caused by the use of CPUE instead of LPUE for the Belgian commercial index. However, the usage of CPUE can be justified by the observed trends in discards in recent years.

Overall, the diagnostics of the assessment are good enough to use the assessment as basis for advice although some issues with input data remain.

6.4 Reference points

The external reviewer agrees to the reference point calculations made during the IBP following ICES guidelines.

An investigation of stock recruitment pairs gave no indication of impaired recruitment. The break point of a Hockey stick SRR was very close to B_{loss}. Therefore, B_{lim} was set at B_{loss}. When fitting Ricker, Hockey stick and Beverton and Holt recruitment models via Eqsim, the Ricker got the highest weight. However, this is driven by very few data points at higher SSBs and it could not be distinguished whether this is really a density dependent effect or caused by normal recruitment variability and other environmental factors. Therefore, a Hockey Stick was chosen as recruitment model for the reference point determination. There are some trends in mean weight at age and the exploitation pattern. Therefore, the last 5 years were seen as more representative than the last 10 years.

6.5 Forecasts

The influence of different scenarios to derive starting values for the short-term forecast (RCT3, XSA, geometric mean also for the last or the last two recruitment estimates from the assessment) were evaluated. According to the retrospective pattern, the recruitment estimates and the strength of a cohort can be revised considerably until the commercial indices start to have an impact from age 3 onwards. Therefore, a replacement of up to the two most recent recruitment estimates from the assessment with a geometric mean could be justified by the time needed until enough information is available to estimate the strength of a cohort with more certainty.

6.6 Recommendations

For the next full benchmark, the reasons have to be investigated further why the CPUE for “pure” (only in 7.d) and “mixed trips” (also fishing in other areas during the trip) of the Belgium fleet are so different. This is a major issue and influences the assessment to a larger extent. If the higher CPUE for mixed trips is mainly caused by misreporting from other areas, the assessment may be biased. A similar analysis may be carried out also for the other CPUE indices.

The assessment is tuned with 3 commercial indices, each of them being representative mainly for another area inside 7.d. Effort should be made to combine the commercial indices into one index that is representative for the whole area of the stock.

Abundance/biomass trends in different areas should be analysed with survey, commercial and observer data in combination to rule out that important trends are either missed by the UK BTS because hauls are taken along the French and UK coast only or give a biased picture because of shifts in distribution of the sole stock (*i.e.* shift from offshore to coastal areas).

Alternative modelling approaches like SAM or AAP could be tested in a future benchmark.

7 Conclusions

The focus of this inter-benchmark was to revise the UK commercial beam trawl tuning fleet and include it in the assessment of sole in division 7.d. During the IBP, the Belgian commercial tuning series was also revised. Instead of an LPUE, a CPUE index was made to account for increased discarding in the most recent years and also data from the small fleet segment were included in the calculation of the index. This revised index provides information for the period 2004–2018, ages 3–8 and covers almost the entire 7.d area.

The final XSA assessment run included the revised UK-CBT and the revised BE-CBT and the FRA-COTB as commercial tuning series and the UK BTS, the FRA-YFS and the UK-YFS as survey tuning series. This resulted in a minor increase of the SSB and a decrease of F in recent years.

New reference points were calculated using the Eqsim functions.

8 Stock annex

The stock annex for sole in 7.d was updated after the IBP 2019.

Stock annexes for stocks which ICES assesses are available on the ICES website Library under the Publication Type "Stock Annexes". Use the search facility to find a particular Stock Annex, refining your search in the left-hand column to include the *year*, *ecoregion*, *species*, and *acronym* of the relevant ICES expert group.

9 References

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Annex 2: Working document: Revision of the UK-CBT LPUE time-series.

The following working document on sole UK commercial tuning series was presented at IBPsol7d 2019.

Revision of the UK-CBT LPUE time-series

WD for IBPSol7d, Oostende, Belgium, 20–21 August 2019

Michael A. Spence, Johnathan E. Ball, Lisa Readdy

Cefas

Abstract

Due to ongoing upgrades in the UK database, Cefas was unable to provide the same index as previously. This relates to the structural changes and the loss of derived variables between the old and new databases. Given these changes and the loss of derived fields, a full analysis was carried out to review the suitability and completeness of all fields needed to derive a Landings Per Unit of Effort (LPUE) time series. Having completed the analysis a modelled Landings Per Unit of Effort (LPUE) index was developed from a Sole fishing fleet time series from 1986 to 2018. A modelled LPUE was generated using a random effects model which was then disaggregated to LPUE at age using sampled length-weight-age data.

Introduction

In the 2019 ICES data call, it was not possible for the UK (E&W) to provide the effort, Kw.hours fished, data for the commercial beam trawl fleet (UK-CBT) for 2018 and the same data provided for 2017 was not complete, and therefore unreliable to use in the assessment. The UK national fishing activity database has been under redesign since June 2017 and the necessary derived variables to estimate the effort series have not been available in the database since then. The lack of these variables precluded the estimation of the UK-CBT for 2017 and 2018.

On closer inspection of the effort time series it was noted that some of the variables are identified as optional fields in the logbooks, one such field is hours fished, this leads us to the conclusion that hours fished is not consistently filled and therefore makes this field inappropriate to use as a metric for effort. Instead, we now advocate the use of activity days as a more reliable measure, since it is mandatory to record and report “activity days”.

Revision of the UK-CBT LPUE time series for Sole in 27.7d

Previously, the data used in the index provided to ICES has been compiled using SQL queries and consisted of an unmodelled effort series from a beam trawl fleet between specific overall lengths and engine power. The migration of this data to a new database has necessitated a change in this process as the structure and availability of data fields has changed. The base data is still retrieved using SQL; however, it is now processed in R to increasing transparency and traceability of any changes or alterations made to the data during the preparation of the index.

MMO landings for 27.7.d were retrieved from the old and new databases using the RODBC (Ripley and Lapsley, 2017) package in R (R Core Team, 2019). The old and new databases overlap between 2000 and 2016. The overlapping years were used to test if the data retrieved could form a continuous time series linking the old database (FAD) to the new database (IFish2). After adjusting for the differences in the two databases', data was retrieved from the FAD from 1986 to 2016 and from IFish2 for 2017 to present. All voyages in 27.7D not landing sole were treated as zero catch for sole. Two ICES rectangles were also excluded from the time series as the fleet had been historically misreporting its landings from the neighbouring 27.7.e into 27.7.d via rectangles 29E8 and 28E8. This emerged in 2005 with the implementation of the buyers and seller's legislation in the UK and increased scrutiny of the fishing fleet (The Registration of Fish Buyers and Sellers and Designation of Fish Auction Sites Regulations, 2005). The UK fleet targeting sole in 7.d has decreased significantly since the beginning of the time series (Figure 1). A marked decrease in larger vessels can be seen with no over 15 m vessel present in the last few years of the time series. This corresponds to an overall decrease in landings and a concentration of the remaining effort to the coastal areas (figures 2 and 3).

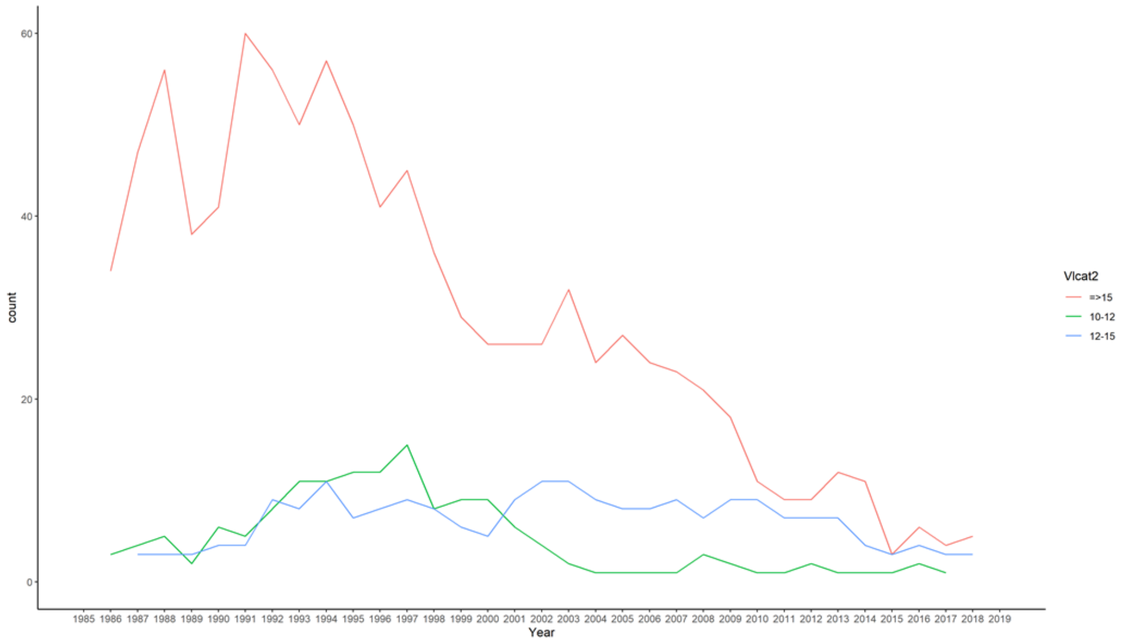

Figure 1.Number of vessels in area 27.7.d from 1985 to 2018.

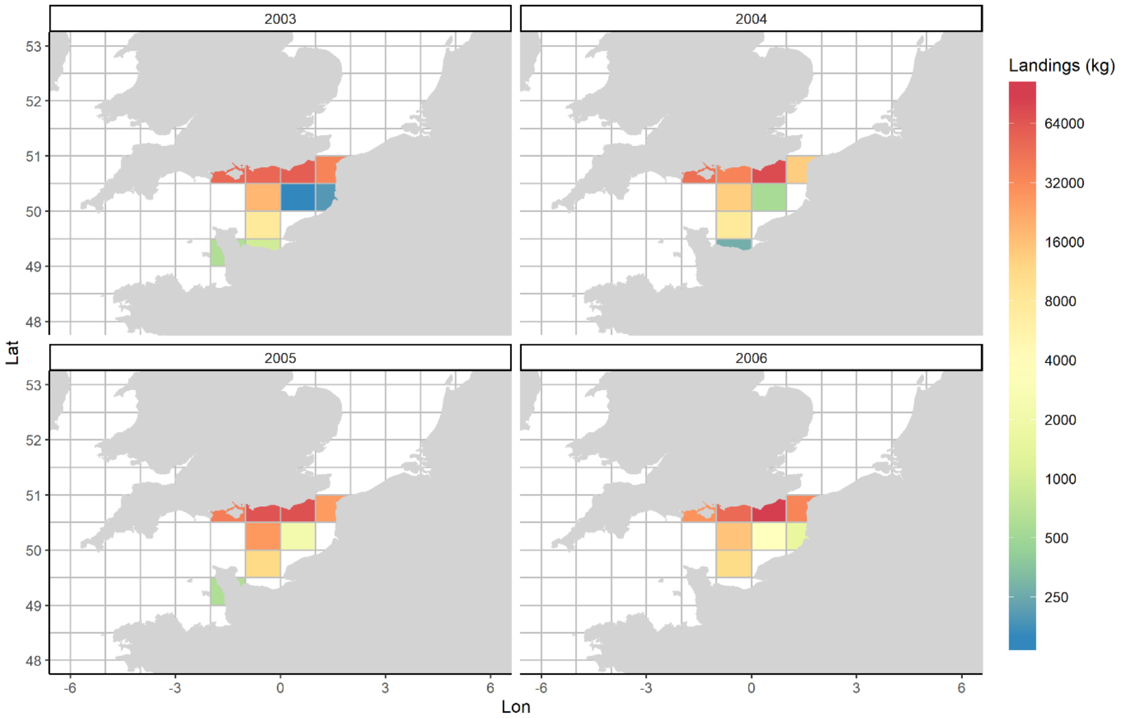

Figure 2. ***Solea solea*** **landings for ICES Division 27.7.d between 2003 and 2006.**

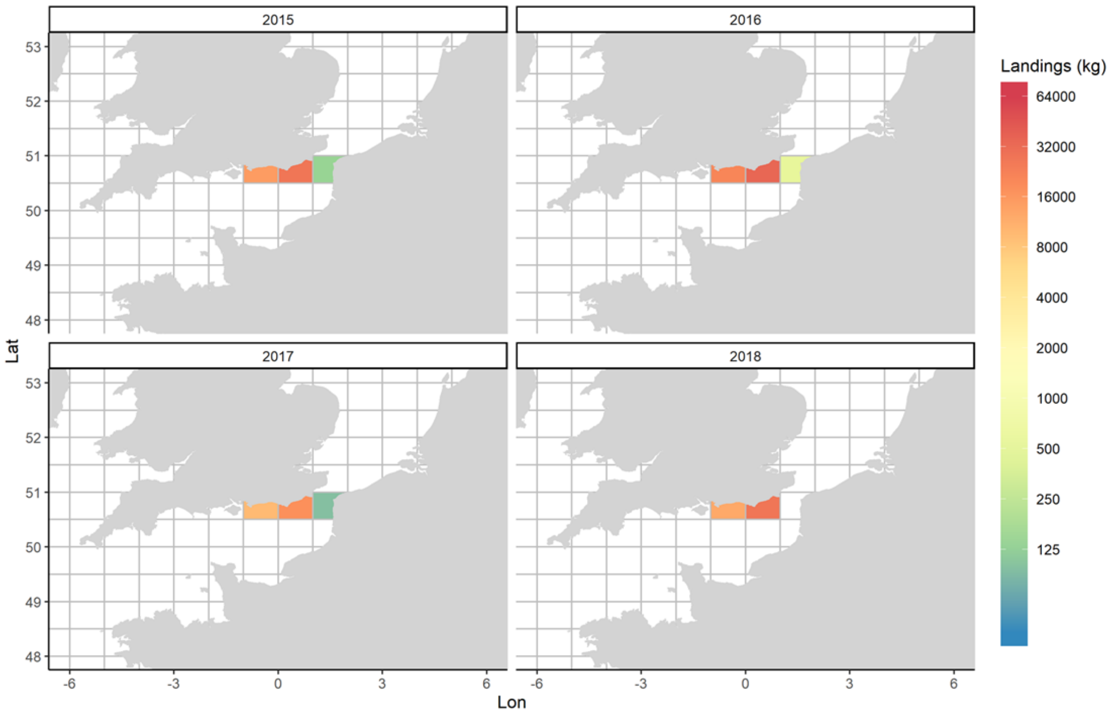

Figure 3. ***Solea solea*** **landings for ICES Division 27.7.d between 2015 and 2018.**

Model

Due to differences in the fleet make up (Figure 1), we modelled the landings per day. A delta-mixed effects model was developed to describe the catch per activity day of the fishery for each voyage.

Method

The catch, $c_{i,j,t}$, per activity day, $a_{i,j,t}$, for the ith vessel on the jth voyage in the tth year was

$$\log c_{i,j,t} - \log a_{i,j,t} \sim \begin{cases} N\left(\eta_{i,j,t}, \dfrac{\sigma^2}{a_{i,j,t}}\right) & wp\ \left(1-(1-p_{i,j,t})^{a_{i,j,t}}\right), \\ 0 & otherwise, \end{cases}$$

with

$$p_{i,j,t} = logit^{-1}\left(\eta_{i,j,t} + \theta\right),$$

where $\eta_{i,j,t}$ was the expected log catch per activity day,

$$\eta_{i,j,t} = \omega_t + f_i,$$

with ω_t following a random walk,

$$\omega_t \sim N(\omega_{t-1}, \sigma_\omega^2),$$

and f_i is the vessel effect. We fitted three models for f_i: a linear model, cubic splines and a random effects model. For the linear model and the cubic splines we used vessel i's engine power, u_i, and the length, l_i, as covariates. The linear model was then:

$$f_i = \beta_1 \log u_i + \beta_2 \log l_i.$$

The cubic spline model was

$$f_i = s_u(\log u_i) + s_l(\log l_i),$$

with

$$s_k(x) = \sum_{h=1}^{H_k} 1_{x \geq \lambda_{h,k}} \beta_{h,k} \left(x - \lambda_{h,k}\right)^3.$$

In the above equation, when $k = u$, then the number of knots was $H_u = 7$ with locations $\lambda_{u,1} = 2.25$, $\lambda_{u,2} = 2.5$, $\lambda_{u,3} = 2.75$, $\lambda_{u,4} = 3$, $\lambda_{u,5} = 3.25$, $\lambda_{u,6} = 3.5$ and $\lambda_{u,7} = 3.75$; for $k = l$, then the number of knots was $H_l = 5$ with locations $\lambda_{l,1} = 4$, $\lambda_{l,2} = 5$, $\lambda_{l,3} = 6$, $\lambda_{u,4} = 7$ and $\lambda_{u,5} = 8$. The third model was a random effect for each vessel with

$$f_i \sim N\left(0, \sigma_f^2\right).$$

In addition, we examined a mixed effect model,

$$\eta_{i,j,t} = \omega_t + f_i, + \lambda_{r_{i,j,t}},$$

where $r_{i,j,t}$ is the rectangle of the ith vessel on the jth trip in the tth year, with

$$\lambda_k \sim N(0, \sigma_\lambda^2),$$

for $k = 1,2, \dots, 13$, the number of rectangles in the data.

Results

The models were fitted using TMB (Kristensen *et al.*, 2016) and the maximum likelihood value compared. We found that the cubic spline model had a log-likelihood that was 199.7 larger than that of the linear model and the random effects model was 1959.9 larger still. Despite the cubic spline having more parameters than the linear model, such a large difference in log-likelihood means that we think that it was preferred. Furthermore, the random effects model was much better than that of the cubic splines, even if we were to consider the large increase in the number of parameters.

We compared the two mixed effects models using the Watanabe–Akaike information criterion (WAIC, Watanabe, 2010). We found that the model without spatial random effects had a lower WAIC value than the that did. We therefore explore the rest of the analysis for only the random effects model. Figure shows the diagnostics for the random effects model. The residuals, of the non-zero data, for the random effects model appear to be independent with and follow a Gaussian distribution.

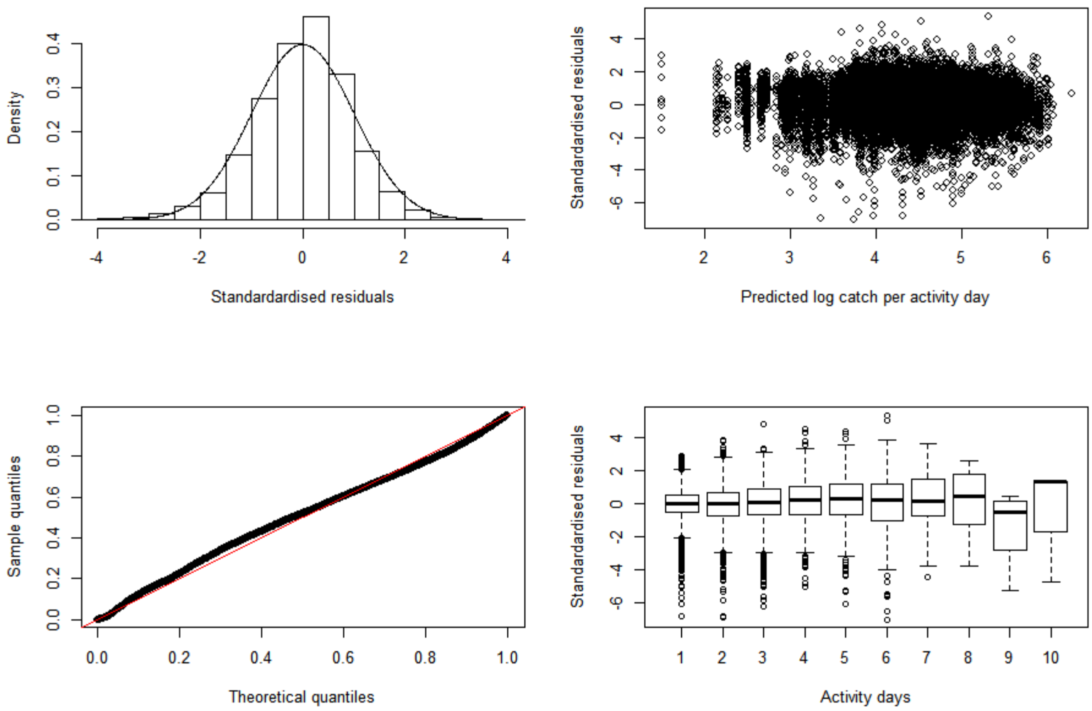

Figure 4. Diagnostic plots for the random effects model.

To assess the uncertainty in the model parameters we fitted the model in a Bayesian framework using the No-U-Turn Sampler for Hamiltonian Monte Carlo (NUTS-HMC) (Hoffman and Gelman, 2014) algorithm using the software Stan (Stan Development Team, 2018). We included uninformative priors:

$$\omega_1 \sim N(0,100)$$
$$\sigma^2 \sim \text{Inv-Gamma}(0.01,0.01)$$
$$\sigma_\omega^2 \sim \text{Inv-Gamma}(0.01,0.01)$$
$$\sigma_f^2 \sim \text{Inv-Gamma}(0.01,0.01)$$
$$\theta \sim N(0,100).$$

Figure 5 shows the posterior expected catch per activity day for each year, ω_t. With the values being shown in Table 1.

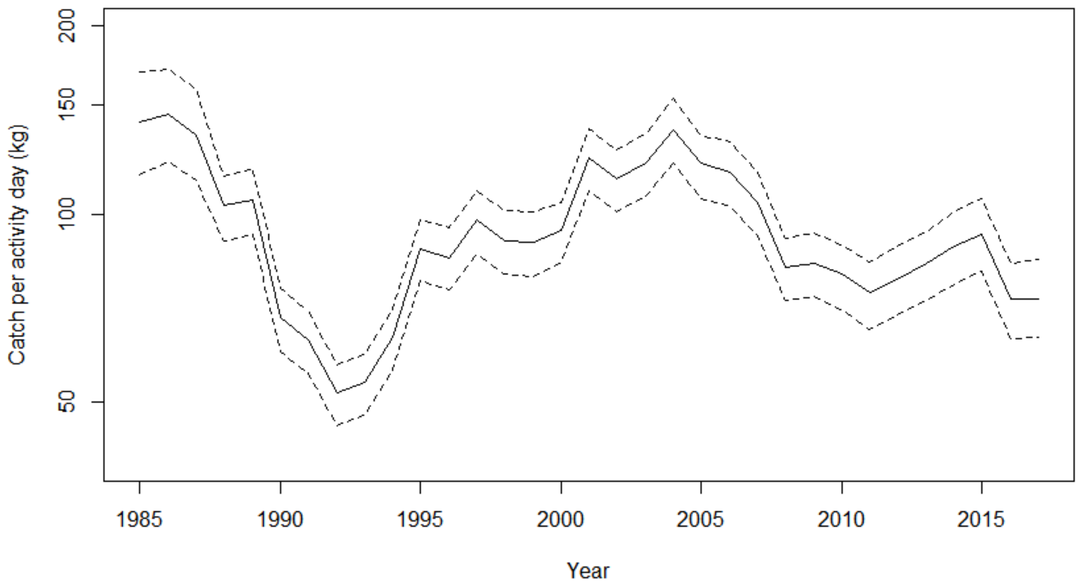

Figure 5. The posterior distribution of the expected catch per activity day. The solid line is the median and the dashed lines are the 95% confidence intervals.

Table 1. The median and 95% confidence intervals of the posterior distribution.

	2.5%	50%	97.5%
1986	115.84897	140.3841531	169.1233059
1987	121.2108044	144.5004837	170.9481539
1988	113.240584	134.0918091	158.4513622
1989	90.91579703	103.4392466	115.3981855
1990	93.15922203	105.729543	118.5817061
1991	60.40963077	68.52945319	76.29565446
1992	55.9017443	63.04439281	70.05250035
1993	45.90729209	51.91785747	57.44296804
1994	47.82270653	53.85957215	59.6578665
1995	56.24953051	63.68993649	70.28885931
1996	78.39781082	88.17163106	98.07110876
1997	75.752506	85.27561434	95.16423629
1998	86.509935	97.83838174	108.9132003
1999	80.32767214	90.82328419	101.6451106
2000	79.59123369	90.12233839	100.7547788
2001	83.97959284	94.38842882	104.2680932
2002	109.2228171	123.3637805	137.3348724
2003	101.0510124	114.05349	126.9674122
2004	106.9807398	120.9017462	134.6421561
2005	120.6609127	136.3652675	153.0941692
2006	105.8078668	121.0016374	133.6930328
2007	102.8798502	116.9444035	130.420619
2008	92.64336173	104.4202685	116.5906161
2009	72.92929702	82.37961409	91.59632864
2010	73.98497445	83.6890925	93.52571218
2011	70.47600124	80.13896456	89.49028284
2012	65.34376015	75.10438558	83.8661468
2013	69.07246466	78.93644202	88.94078069
2014	72.89606145	83.60653295	93.86455696
2015	77.2526192	88.78939829	101.1796427
2016	81.30436564	92.87617093	105.9087804
2017	63.38391367	73.12266048	83.65200821
2018	63.5802388	73.24319624	84.70059916

LPUE to age composition

Due to a lack of sample data for beam trawls the age composition used is from 7.d samples from all gears combined, then raised to all trawl landings. The raised age composition data was then used to disaggregate the modelled LPUE to provide the beam trawl LPUE at age for Sole in 7.d for ages 1–15.

The numbers sampled, $N_{g,t}$ at age g and time t, was multiplied by the mean weight at age from the assessment, $\overline{w}_{g,t}$, to get the weight caught at age, $w_{g,t}$. Using this we set the catch at age by $\omega_t \hat{q}_{g,t}$ where

$$\hat{q}_{g,t} = \frac{w_{k,t}}{\sum_{k=1}^{15} w_{k,t}}.$$

Using the mean weight at age from the assessment, $\overline{w}_{g,t}$, we calculated the numbers at age by $\omega_t \hat{q}_{g,t} / \overline{w}_{g,t}$. The median LPUE age compositions is shown in Table 2.

Table 2: The median LPUE numbers in thousands at age. The columns represent age and the rows years.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1986	0.000	35.486	171.222	118.868	33.173	34.075	46.656	1.410	2.821	6.149	2.990	3.272	1.805	2.031	6.262
1987	0.000	195.271	82.189	111.325	76.966	14.446	11.323	29.186	1.123	0.342	2.587	0.830	1.171	2.538	1.855
1988	0.000	93.297	233.772	46.825	52.257	32.893	7.444	9.556	13.479	1.660	0.201	3.822	4.074	0.000	0.151
1989	0.000	126.939	61.085	112.803	14.251	24.825	18.101	3.965	3.275	12.757	0.747	0.460	1.724	2.126	10.114
1990	0.000	66.198	192.542	28.041	38.879	8.309	8.896	8.896	2.438	4.335	13.050	1.129	0.226	1.987	4.470
1991	0.000	139.168	55.522	77.841	3.342	12.248	2.023	2.947	4.332	1.077	0.748	3.342	0.110	0.000	2.001
1992	0.331	62.601	134.675	21.185	43.657	2.904	5.282	1.676	3.801	1.286	0.565	0.390	0.858	0.039	0.643
1993	0.032	51.592	65.630	64.567	10.202	15.537	1.547	3.159	1.322	0.886	0.983	0.338	0.387	0.629	0.838
1994	0.051	10.709	83.132	45.902	36.102	8.756	14.481	1.414	3.351	1.027	1.297	1.179	0.775	0.505	2.964
1995	1.666	57.048	33.680	69.428	33.891	29.800	5.779	11.810	1.708	2.974	0.633	1.350	1.371	0.274	2.425
1996	1.046	102.966	87.480	27.655	58.805	29.441	23.445	6.097	11.557	1.429	3.061	1.454	1.888	1.250	4.158
1997	2.368	85.674	105.661	50.583	13.534	39.949	16.217	15.540	3.698	7.347	0.846	2.272	0.363	1.208	2.417
1998	2.967	134.969	90.499	52.074	34.827	11.832	27.632	15.392	11.943	3.078	6.676	1.076	2.856	0.779	4.785
1999	7.647	99.540	175.680	61.843	25.519	18.620	7.190	15.378	7.564	4.281	1.995	2.203	0.416	1.455	2.411
2000	4.629	86.345	101.488	97.329	31.070	14.672	10.317	3.923	12.279	5.492	3.256	1.334	2.393	0.314	4.472
2001	4.534	124.607	117.472	44.256	49.063	19.286	8.313	8.585	2.539	6.439	5.290	2.177	0.605	1.330	2.056
2002	0.615	143.849	205.286	101.575	32.790	25.119	10.455	8.481	2.751	1.424	2.363	1.068	1.101	0.194	1.327
2003	5.318	201.110	115.031	77.873	33.777	14.159	16.695	7.819	2.923	3.029	0.458	2.184	1.479	1.021	2.677
2004	2.111	69.529	273.558	64.104	38.660	20.263	5.968	11.291	2.688	1.995	1.795	0.336	2.059	0.748	2.624
2005	2.054	83.329	87.001	183.719	33.874	35.261	17.257	8.496	7.602	5.476	2.080	3.851	1.307	1.561	5.338
2006	6.332	179.081	158.840	51.418	85.634	14.371	12.742	6.141	4.092	2.458	1.249	0.367	0.677	0.119	1.325
2007	2.253	105.240	190.480	72.045	21.715	64.455	15.050	14.773	5.887	0.834	2.595	1.736	0.581	1.146	3.730
2008	4.275	65.223	262.119	79.001	17.389	10.546	14.629	5.374	1.887	2.718	1.945	0.541	0.973	0.048	1.523
2009	7.616	114.602	44.863	107.885	39.069	6.059	4.927	10.494	3.037	5.454	1.062	0.107	0.736	0.753	0.351

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2010	5.917	101.742	100.944	33.811	67.158	22.557	7.911	5.188	9.332	3.254	2.250	2.462	0.417	0.377	1.852
2011	0.000	179.727	96.125	47.189	13.094	29.438	8.550	1.983	1.989	2.036	0.672	1.683	0.447	0.056	0.640
2012	0.000	32.280	233.871	43.067	24.805	4.248	11.549	6.169	1.020	1.028	2.656	0.492	0.199	0.638	1.125
2013	0.000	12.383	87.165	159.577	29.022	16.981	5.356	7.189	2.132	0.668	0.341	1.729	0.399	0.236	0.847
2014	1.371	62.226	60.027	135.701	78.676	11.742	7.045	0.848	4.900	1.854	0.971	0.196	0.544	0.000	0.426
2015	0.626	87.058	81.673	43.546	83.641	62.807	8.753	5.624	1.477	2.308	1.569	0.471	0.376	0.584	0.861
2016	0.000	62.686	120.214	71.722	24.842	48.736	34.572	10.100	6.080	0.715	1.994	1.169	0.375	0.240	0.613
2017	2.365	27.530	100.926	47.774	30.008	12.756	30.135	26.708	7.204	3.339	1.199	2.315	0.664	0.118	1.155
2018	0.623	65.177	56.727	114.668	24.332	15.748	6.503	15.349	13.155	2.631	1.795	0.770	0.662	0.406	0.396

Conclusion

The Modelled LPUE provides a continuous time series from 1986 to the present day, accounting for changes in the make-up of the fleet. In combination with the ALK data from the UK commercial sampling programme it also provides the age composition of the catch.

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Appendix

Seasonal coefficient

Figure S 1 shows the observed LPUE for all years by each month. We do not see a trend so we did not include any seasonal effects in any of our proposed models.

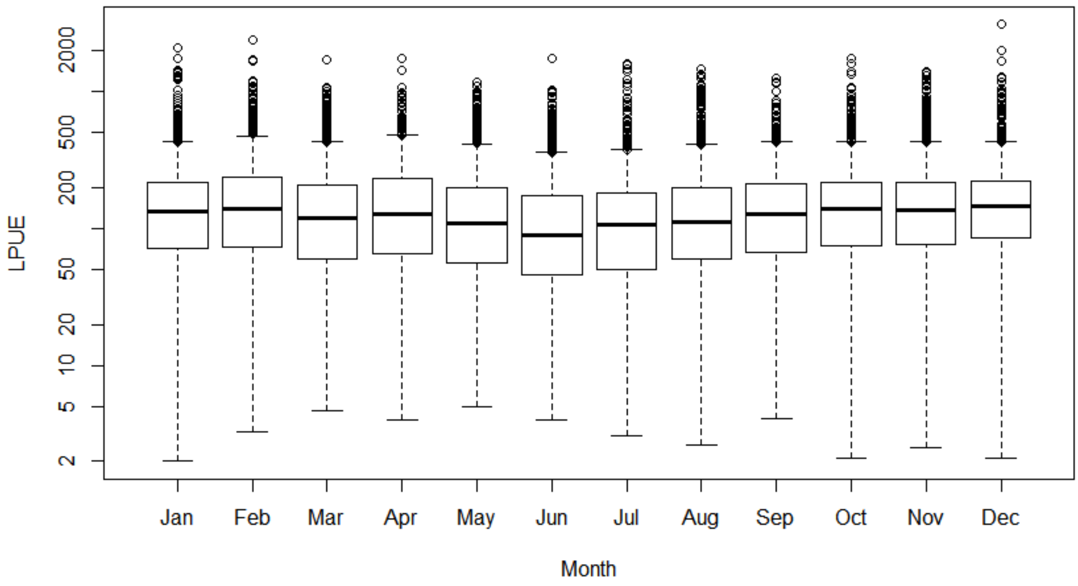

Figure S 1: The observed LPUE for each month for all years.

Comparisons using different ratios of sole to total landings

To investigate the effect of only including vessels that target sole, the combined dataset was filtered to remove vessels with a consistent landing of sole greater than 10% and 20% of the total landed weight in any given year. Vessels with landing above 10% (or 20%) on a voyage in a year were retained in the data set with all associated landings for that vessel in that year. **Error! Reference source not found.** shows the maximum likelihood for the year effect, ω_t, for different threshold ratios. The absolute value of the year effect was sensitive to the threshold value, but the overall trend did not change much.

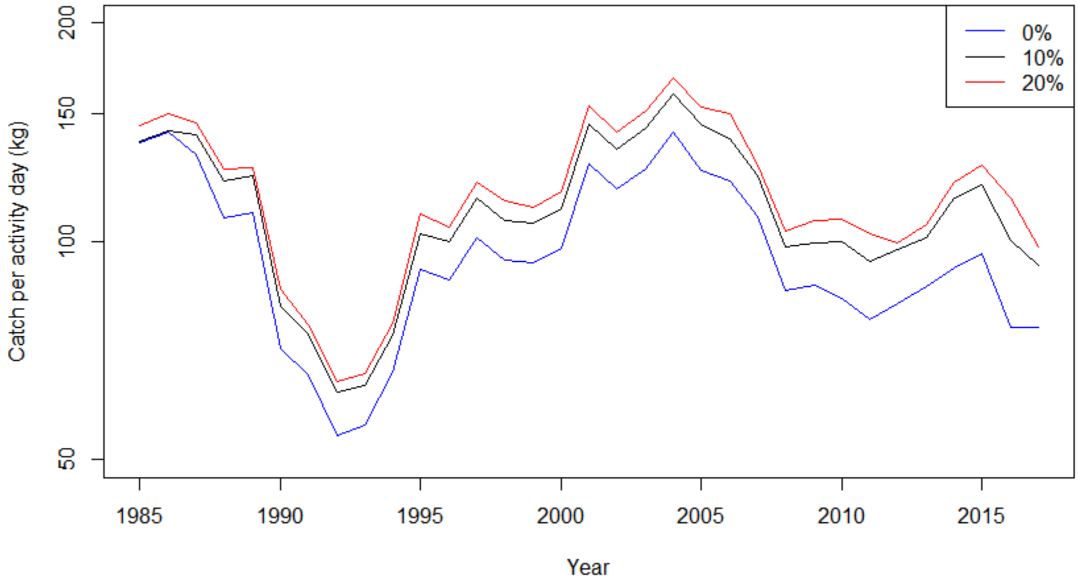

Figure S 2: Comparison plot of different threshold ratios for the sole fleet.

3 rectangles

We fitted the model using only the rectangles 30E9, 30F0 and 30F1. The results of the model are shown in Figure S 3. Only fitting to these 3 rectangles does not greatly change the model results.

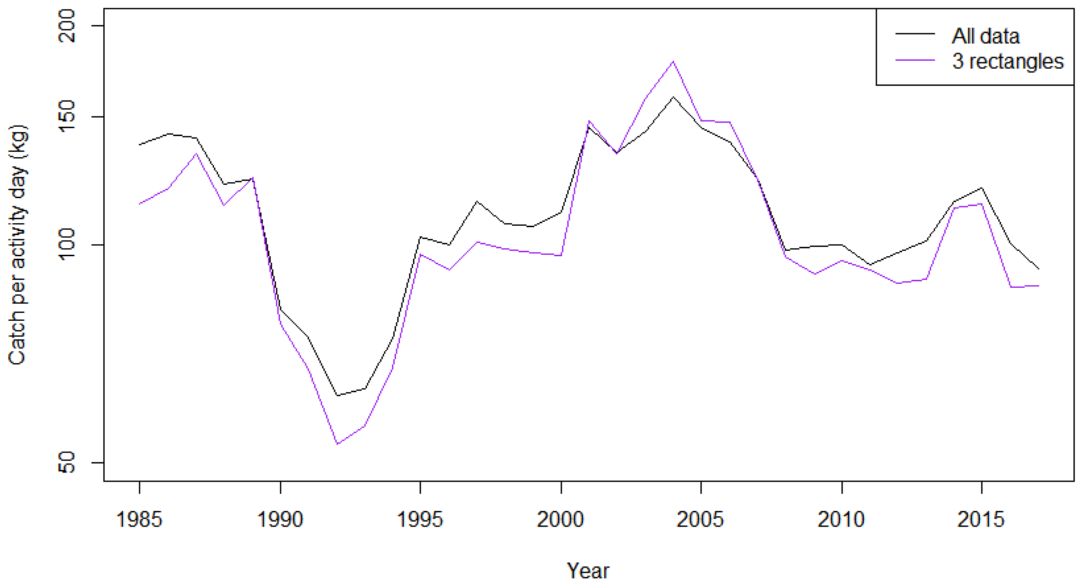

Figure S 3: The model fitted to all of the data and data from 30E9, 30F0 and 30F1.

Uncertainty in LPUE by age

Table S 1 and Table S 2 show the 0.025 and the 0.975 quantiles for the LPUE at age.

Table S 1: The 0.025 quantile for the LPUE by age.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1986	0.000	29.284	141.297	98.093	27.375	28.120	38.502	1.164	2.328	5.075	2.467	2.700	1.490	1.676	5.168
1987	0.000	163.798	68.942	93.383	64.561	12.118	9.498	24.482	0.942	0.287	2.170	0.696	0.983	2.129	1.556
1988	0.000	78.790	197.420	39.544	44.131	27.778	6.286	8.070	11.383	1.402	0.170	3.228	3.440	0.000	0.127
1989	0.000	111.571	53.689	99.146	12.526	21.819	15.910	3.485	2.879	11.213	0.657	0.404	1.515	1.869	8.889
1990	0.000	58.327	169.650	24.708	34.256	7.321	7.838	7.838	2.148	3.820	11.498	0.995	0.199	1.751	3.939
1991	0.000	122.678	48.943	68.618	2.946	10.797	1.783	2.597	3.819	0.950	0.659	2.946	0.097	0.000	1.764
1992	0.294	55.509	119.417	18.785	38.711	2.575	4.683	1.486	3.370	1.141	0.501	0.346	0.760	0.035	0.570
1993	0.029	45.619	58.032	57.092	9.021	13.738	1.368	2.793	1.169	0.784	0.869	0.299	0.342	0.556	0.741
1994	0.045	9.509	73.814	40.757	32.055	7.775	12.858	1.256	2.975	0.912	1.151	1.047	0.688	0.449	2.631
1995	1.471	50.383	29.746	61.317	29.932	26.319	5.104	10.431	1.509	2.626	0.559	1.192	1.211	0.242	2.142
1996	0.930	91.552	77.783	24.589	52.286	26.177	20.846	5.421	10.276	1.270	2.722	1.293	1.679	1.112	3.697
1997	2.104	76.107	93.861	44.934	12.023	35.488	14.406	13.804	3.285	6.527	0.751	2.018	0.322	1.073	2.147
1998	2.624	119.342	80.020	46.044	30.795	10.462	24.432	13.610	10.560	2.722	5.903	0.951	2.525	0.689	4.231
1999	6.764	88.037	155.378	54.697	22.570	16.468	6.359	13.601	6.690	3.786	1.764	1.948	0.368	1.287	2.132
2000	4.088	76.255	89.628	85.956	27.439	12.957	9.112	3.465	10.844	4.850	2.876	1.178	2.113	0.277	3.950
2001	4.034	110.865	104.518	39.376	43.652	17.160	7.396	7.638	2.259	5.729	4.707	1.937	0.538	1.183	1.829
2002	0.545	127.360	181.754	89.931	29.031	22.239	9.257	7.509	2.436	1.261	2.092	0.946	0.974	0.172	1.175
2003	4.712	178.183	101.917	68.995	29.926	12.545	14.791	6.928	2.590	2.684	0.406	1.935	1.311	0.905	2.372
2004	1.868	61.523	242.060	56.723	34.208	17.930	5.281	9.991	2.379	1.766	1.589	0.297	1.822	0.662	2.322
2005	1.817	73.733	76.982	162.561	29.973	31.200	15.270	7.517	6.727	4.845	1.840	3.408	1.156	1.381	4.723

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2006	5.537	156.595	138.895	44.962	74.881	12.566	11.142	5.370	3.578	2.149	1.092	0.321	0.592	0.104	1.158
2007	1.982	92.583	167.571	63.381	19.103	56.704	13.240	12.997	5.179	0.734	2.283	1.527	0.511	1.009	3.281
2008	3.793	57.867	232.556	70.091	15.428	9.356	12.979	4.768	1.674	2.412	1.726	0.480	0.863	0.042	1.352
2009	6.742	101.455	39.716	95.509	34.587	5.364	4.362	9.290	2.689	4.828	0.941	0.095	0.652	0.666	0.311
2010	5.231	89.945	89.239	29.891	59.371	19.942	6.994	4.586	8.250	2.877	1.989	2.176	0.368	0.333	1.637
2011	0.000	158.056	84.535	41.499	11.515	25.888	7.519	1.744	1.749	1.790	0.591	1.480	0.393	0.049	0.562
2012	0.000	28.085	203.477	37.470	21.582	3.696	10.048	5.368	0.887	0.894	2.311	0.428	0.174	0.555	0.979
2013	0.000	10.836	76.273	139.636	25.395	14.859	4.686	6.291	1.866	0.584	0.299	1.513	0.349	0.206	0.741
2014	1.195	54.255	52.337	118.317	68.597	10.238	6.142	0.739	4.273	1.616	0.847	0.171	0.474	0.000	0.371
2015	0.545	75.746	71.061	37.888	72.773	54.646	7.616	4.893	1.285	2.008	1.365	0.410	0.327	0.508	0.749
2016	0.000	54.875	105.236	62.786	21.747	42.663	30.265	8.842	5.323	0.626	1.746	1.024	0.328	0.210	0.536
2017	2.050	23.863	87.484	41.411	26.011	11.057	26.121	23.151	6.244	2.894	1.039	2.006	0.575	0.103	1.001
2018	0.541	56.578	49.243	99.540	21.122	13.670	5.645	13.324	11.419	2.284	1.559	0.668	0.574	0.352	0.344

Table S 2: The 0.975 quantile for the LPUE by age.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1986	0.000	42.750	206.274	143.203	39.964	41.051	56.207	1.699	3.398	7.408	3.602	3.942	2.175	2.447	7.544
1987	0.000	231.011	97.231	131.701	91.053	17.091	13.395	34.528	1.328	0.404	3.060	0.982	1.386	3.002	2.194
1988	0.000	110.246	276.239	55.331	61.750	38.868	8.796	11.292	15.928	1.961	0.238	4.517	4.814	0.000	0.178
1989	0.000	141.615	68.147	125.845	15.899	27.695	20.194	4.423	3.654	14.232	0.833	0.513	1.923	2.372	11.283
1990	0.000	74.244	215.947	31.450	43.605	9.319	9.977	9.977	2.735	4.862	14.636	1.266	0.253	2.228	5.014
1991	0.000	154.939	61.814	86.662	3.721	13.636	2.252	3.280	4.823	1.200	0.832	3.721	0.122	0.000	2.228
1992	0.368	69.560	149.646	23.540	48.510	3.227	5.869	1.862	4.223	1.429	0.628	0.433	0.953	0.043	0.715
1993	0.036	57.082	72.615	71.438	11.288	17.191	1.712	3.495	1.462	0.981	1.088	0.374	0.428	0.695	0.927
1994	0.056	11.862	92.081	50.843	39.988	9.699	16.040	1.567	3.712	1.138	1.436	1.306	0.858	0.560	3.283

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1995	1.839	62.959	37.170	76.621	37.403	32.887	6.377	13.034	1.885	3.282	0.698	1.490	1.513	0.303	2.677
1996	1.163	114.526	97.302	30.760	65.407	32.746	26.078	6.782	12.854	1.589	3.405	1.617	2.100	1.390	4.625
1997	2.643	95.609	117.914	56.449	15.103	44.582	18.097	17.342	4.126	8.199	0.944	2.535	0.405	1.349	2.697
1998	3.303	150.247	100.743	57.968	38.770	13.171	30.760	17.135	13.295	3.427	7.432	1.197	3.179	0.867	5.326
1999	8.558	111.400	196.613	69.212	28.559	20.838	8.047	17.210	8.465	4.791	2.233	2.465	0.465	1.628	2.698
2000	5.175	96.532	113.461	108.812	34.736	16.403	11.535	4.386	13.728	6.140	3.640	1.491	2.675	0.351	5.000
2001	5.009	137.649	129.768	48.888	54.198	21.305	9.183	9.484	2.805	7.113	5.844	2.404	0.668	1.469	2.271
2002	0.685	160.140	228.535	113.078	36.504	27.963	11.639	9.441	3.063	1.586	2.631	1.189	1.225	0.216	1.477
2003	5.921	223.881	128.055	86.690	37.601	15.762	18.585	8.704	3.254	3.372	0.510	2.431	1.647	1.137	2.980
2004	2.351	77.431	304.648	71.389	43.053	22.565	6.647	12.574	2.994	2.222	1.999	0.374	2.293	0.833	2.922
2005	2.305	93.552	97.674	206.257	38.030	39.587	19.374	9.538	8.535	6.148	2.335	4.324	1.467	1.752	5.993
2006	6.996	197.865	175.500	56.811	94.616	15.878	14.078	6.785	4.521	2.715	1.380	0.405	0.748	0.132	1.464
2007	2.513	117.367	212.430	80.347	24.217	71.883	16.784	16.476	6.566	0.930	2.894	1.936	0.648	1.279	4.160
2008	4.773	72.825	292.669	88.209	19.416	11.775	16.334	6.000	2.107	3.035	2.172	0.604	1.086	0.053	1.701
2009	8.468	127.424	49.882	119.955	43.440	6.737	5.478	11.668	3.377	6.064	1.181	0.119	0.819	0.837	0.390
2010	6.612	113.701	112.808	37.786	75.052	25.209	8.841	5.797	10.429	3.636	2.515	2.751	0.465	0.421	2.069
2011	0.000	200.700	107.342	52.696	14.621	32.873	9.548	2.214	2.221	2.273	0.750	1.879	0.500	0.062	0.714
2012	0.000	36.046	261.155	48.091	27.699	4.744	12.896	6.889	1.139	1.148	2.966	0.550	0.223	0.712	1.256
2013	0.000	13.953	98.212	179.801	32.700	19.133	6.034	8.100	2.403	0.752	0.384	1.948	0.449	0.266	0.954
2014	1.539	69.861	67.392	152.351	88.329	13.183	7.909	0.952	5.501	2.081	1.091	0.220	0.611	0.000	0.478
2015	0.713	99.207	93.070	49.623	95.313	71.572	9.974	6.409	1.683	2.630	1.788	0.537	0.429	0.665	0.981
2016	0.000	71.482	137.083	81.786	28.328	55.574	39.423	11.517	6.934	0.815	2.274	1.333	0.427	0.273	0.699
2017	2.706	31.494	115.459	54.653	34.329	14.593	34.474	30.554	8.241	3.820	1.372	2.648	0.759	0.135	1.321
2018	0.721	75.372	65.601	132.605	28.138	18.211	7.520	17.750	15.213	3.043	2.076	0.891	0.765	0.469	0.458

Annex 3: Working document: Revision of the Belgian commercial beam trawl tuning

The work realised during IBPsol7d 2019 on sole - Belgium commercial tuning series is summarized in the following working document below:

Working document: Revision of the Belgian commercial beam trawl tuning fleet for Sole in the Eastern English Channel (27.7.d).

Klaas Sys and Lies Vansteenbrugge (ILVO, Belgium)

Objective

The assessment of sole in the Eastern English Channel is tuned with three survey (UK(E&W)-BTS-Q3, UK-YFS and FRA-YFS) and three commercial tuning series (FRA-COTB, UK(E&W)-CBT and BE-CBT). The BE-CBT (Belgian commercial beam trawl) tuning series was revised during the benchmark in 2017 (WKNSEA), using data from the large fleet segment (>221 kW engine power) (ICES, 2017).

For the purpose of the inter-benchmark, the Belgian commercial index was investigated to check whether it could be converted to a CPUE index. There were two reasons to do so: 1) there is a pattern of increased discarding in the most recent years, and 2) having a second tuning fleet to tune age 2 in the assessment could put the UK-BTS-Q3, with spatial coverage restricted to inshore waters, into perspective.

This document describes how commercial data of the Belgian beam trawl fleet was used to obtain an index of abundance based on the catch and specifies the pre-processing of the data, the model, and the upscaling and coupling with observer data.

Data sources

Every period of 24 hours during a fishing trip, except while steaming, the skipper has to report his fishing activity in the electronic logbook. The logbooks contain the estimated live weight (kg) for all commercial species landed, grouped by ICES statistical rectangle (if fishing activity occurred in more than one ICES statistical rectangle, the ICES statistical rectangle with the highest proportion of fishing effort must be reported) and by day. They also provide information on the hours spent fishing per day. The landed weights were divided by those **fishing hours** to calculate the landings per unit effort (LPUE; in kg/h). As the retained landings from the logbooks are estimated weights (with an upper and lower tolerance of 10%), the **landed weights** are derived from the quantities recorded in the sales notes. The sales notes contain information on the quantities auctioned by market category for all species landed, but no area information. Therefore, the percentage share of a species in an ICES statistical rectangle from the logbooks, is the basis for the distribution of the quantities auctioned on the ICES statistical rectangles.

Available data

1.1 Introduction

The landings of sole and effort data from beam trawlers (métier: TBB_DEF_70-99) active in ICES Division 27.7.d were combined from 2004 onwards.

Information on ICES statistical rectangle, year, month, fleet segment, engine power (kW) and vessel reference number is available for the analyses.

1.2 Large and small fleet segment

During the WKNSEA benchmark in 2017, only the large fleet segment was selected to construct the Belgian commercial index (ICES, 2017). The main reason for this was suspected misreporting of horse power by the small fleet segment (≤221 kW).

During this inter-benchmark, we included both the large and small fleet segment (TBB_DEF_70-99) and corrected for potential misreporting of horse power by including a vessel effect in the final model. By including both fleet segments, this index covers the major part of the Eastern English Channel, which was currently missing in the assessment. The small fleet segment vessels are allowed to fish within the 12 miles zone, and thus fish closer to the coast in the most northern rectangles, while the large fleet segment vessels cover all rectangles.

1.3 Including zero landings

The index as calculated during the WKNSEA benchmark in 2017 did not account for zero observations in the landings. The effort data was merged to the landings data, however, effort records without matching landings data were excluded.

For the inter-benchmark, landings records were matched with effort data, so that records without landings data were retained and considered as zero landings.

1.4 From LPUE to CPUE

To better account for the observed changes (increase) in discard rates of the fleet in the most recent years, a CPUE index was investigated. The raw landings data were raised to catch data using an annual discard proportion that was estimated from the observer trips in the Eastern English Channel. The discard rates per year are listed in Table 1.

Table 1: The annual discard proportion estimated from observer trips in the Eastern English Channel.

2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
0.040	0.056	0.044	0.037	0.047	0.083	0.098	0.059	0.093	0.111	0.085	0.088	0.060	0.077	0.121

Data analysis

1.5 Data exploration

Visual data exploration was performed to detect potential anomalies. Inspection of the boxplots did not indicate problems in terms of outliers (Figure 1).

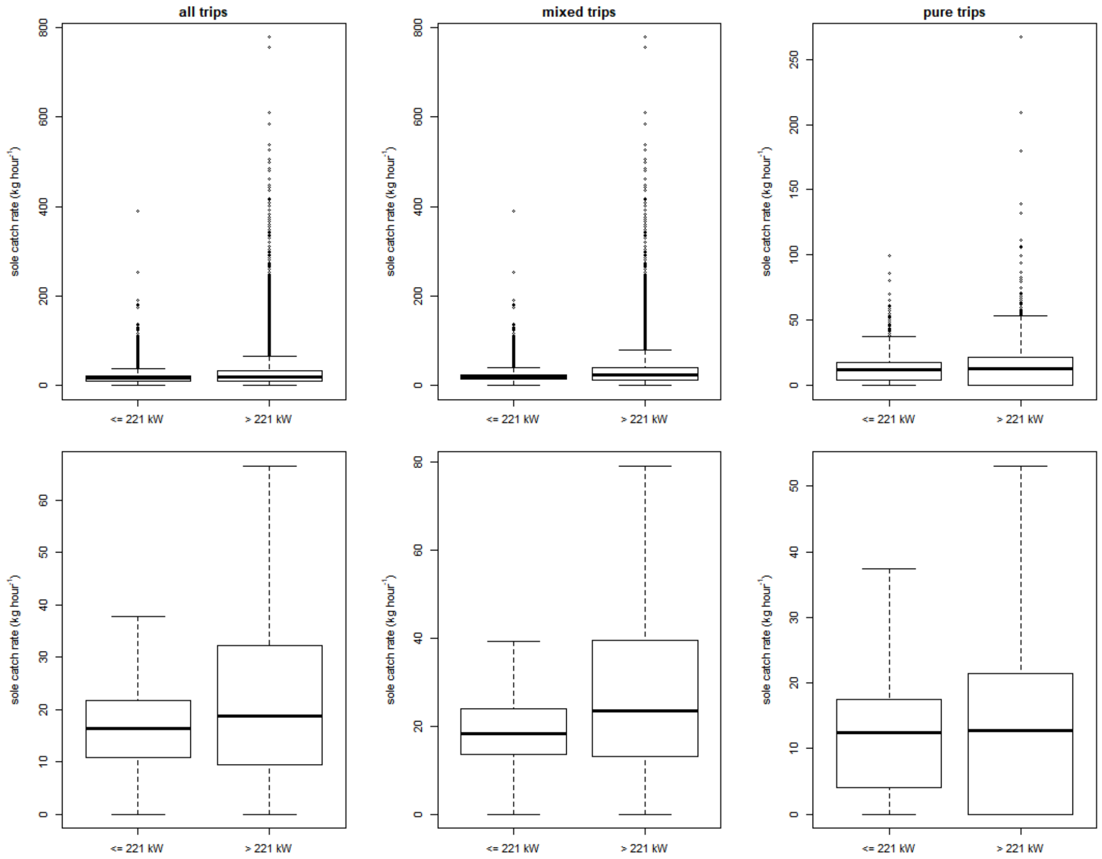

Figure 1: Boxplot of the observed CPUE's (kg/h) per fleet segment for each trip type. The upper panels include all the data, while the lower panels include the data outside a range of 1.5 time the interquartile range.

However, when splitting the observations into two groups based on trip characteristics (see below) to detect potential misreporting of landings from one ICES division to another, diverging patterns were found in the data (Table 2):

- observations from fishing trips during which a vessel registered fishing effort exclusively in the Eastern English Channel (*pure trips*)
- observations from fishing trips during which a vessel registered fishing effort in multiple ICES division (*mixed trips*)

Table 2: Number of observations recorded per trip type.

	Total # observations	# observations pure trips	# observations mixed trips
≤ 221 kW	10092	3965	6127
> 221 kW	11372	4267	710

The Belgian beam trawl fleet has fishing opportunities spread over different ICES divisions. To allow an efficient exploitation of the stocks over all these areas, vessels are allowed to fish in different ICES divisions within one trip (e.g. while steaming from a Belgian harbour to a foreign harbour). Nevertheless, an important drawback is that this flexibility creates an opportunity for noncompliance. It is generally known that fishers occasionally 'transfer' landings from one stock to another as a consequence of quota limitations (e.g. day limits). Obviously, such misreporting undermines the veracity of the data.

In the absence of misreporting through the transfer of landings between ICES subdivisions, it can be expected that both datasets are a random subsample from the total population, and consequently have similar characteristics. Hence, the distribution of landing rates in both datasets should be similar. To compare both datasets, a bootstrap analysis was performed. More specifically, both the *pure* and *mixed* observations were resampled 100 000 times based on similar characteristics of month, year, ICES statistical rectangle, and vessel.

Next, summary statistics (mean, variance and median) were calculated for each simulated data sample to construct a distribution which was then compared with the summary statistics of the observed data. This shows that observations from *mixed trips* have a higher mean, median and variance compared to observations from *pure trips* (Figure 2).

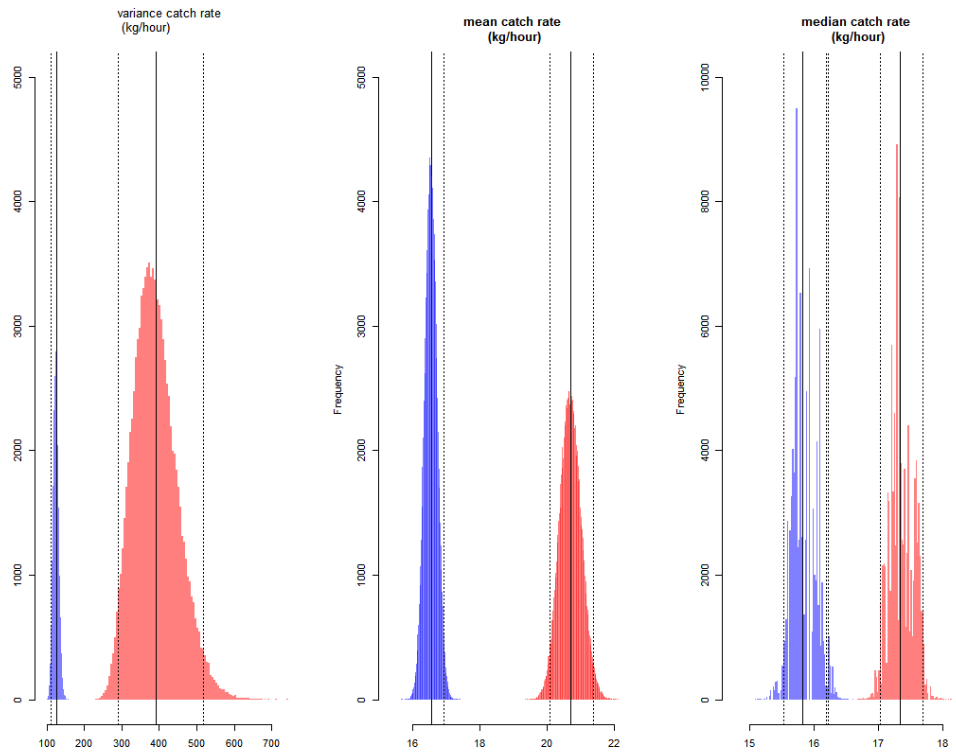

Figure 2: Distribution of the variance, mean, and median statistics based on a bootstrap simulation of the data of mixed (red) and pure (blue) trips. The dotted lines represent the 0.025 and 0.975 quantile of the distribution while the solid line represents the statistic of the true observations.

Plotting the effort against landings, shows that the difference between observations of *mixed* and *pure* trips is mainly found at low effort levels with higher landings in observations related to *mixed* trips (Figure 3). This supports the hypothesis that fishers may misreport landings in *mixed* trips from one ICES division to another by fishing for a very short time in a particular ICES division. Note that also more zero catches (24%) occurred in the *pure* trips compared to the *mixed* trips (5%).

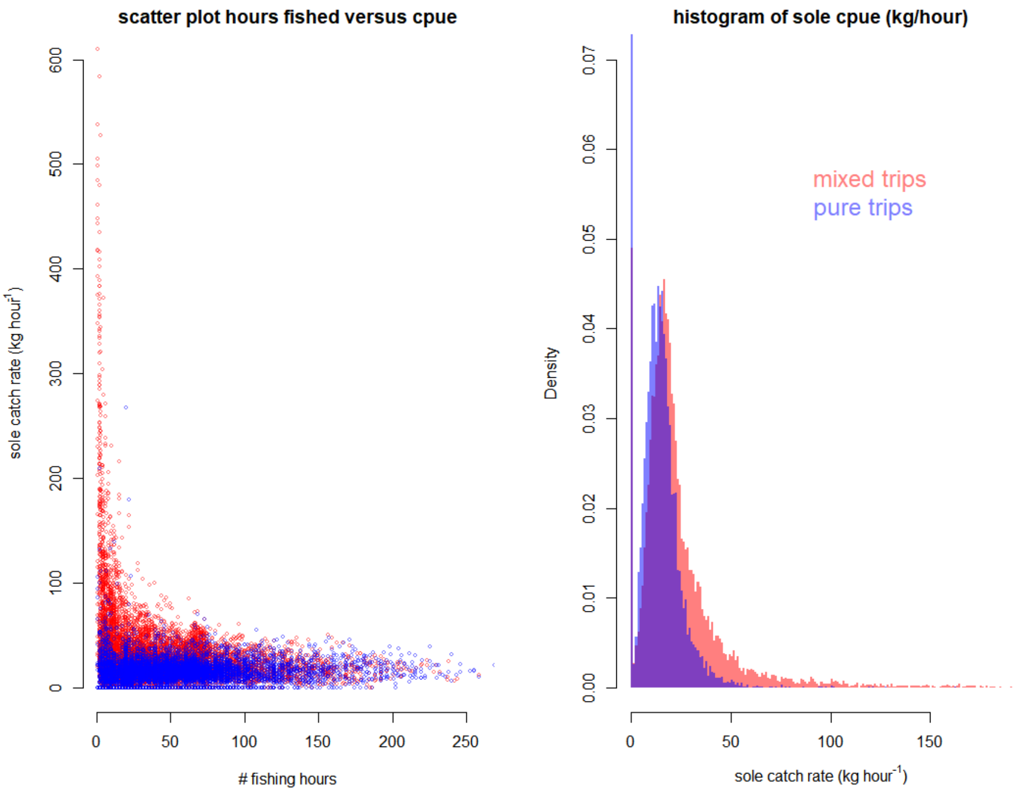

Figure 3: Scatter plot of fishing hours versus CPUE per trip type and overlaid histogram of CPUE per trip type.

To assess this effect in terms of a CPUE trend, an index was calculated based on the 3 data types, one dataset taking every observation (*pure* and *mixed* trips) into account, a dataset containing only observations from *pure* trips, and a dataset containing the observations associated with *mixed* trips.

1.6 Model

To analyse CPUE, the following regression model was fitted to the data with the indices y, m, r, v indicating the year, month, ICES statistical rectangle, and vessel reference number of the observation.

$$kg_{y,m,r,v} \sim NB\left(\mu_{y,m,r,v},\ \theta_{obs}\right)$$

$$E\left(kg_{y,m,r,v}\right) = \mu_{y,m,r,v}$$

$$var\left(kg_{y,m,r,v}\right) = \mu_{y,m,r,v} + {\mu_{y,m,r,v}}^2 / \theta_{obs}$$

$$\log\left(\mu_{y,m,r,v}\right) = intercept + \alpha_r + \beta_m + \gamma_v + \delta_y$$

$$\alpha_r \sim N(0, \theta_r)$$

$$\sum_{m=1}^{12} \beta_m \sim N(0, \theta_r)$$

$$\gamma_v \sim N(0, \theta_v)$$

$$\Delta\delta_y = \delta_y - \delta_{y-1} \sim N(0, \theta_y)$$

By using a random effects model for the ICES statistical rectangle, we could include spatial information without having to discard the years in which this information was not available (*i.e.* 2004, 2005). For the month effect, a seasonal random effects model was specified with periodicity 12 months so that the sum of the random effect vector ($\beta_{jan} + \cdots + \beta_{dec}$) follows a Gaussian distribution. Furthermore, a random vessel effect was included to account for skipper behaviour, or technical vessel aspects that were not recorded in the data (including horse power misreporting). This random vessel effect allowed to remove the engine power covariate from the final model. To account for temporal correlation between years, a first order random walk model was specified over the years. Finally, the observation error was assumed to follow a negative binomial distribution with logarithmic link function. To account for different levels of fishing effort, the logarithm of the hours fished was included as an offset variable in the model.

1.7 Model estimation

A Bayesian framework, as implemented by the INLA software, was used to estimate the model parameters. The default INLA settings were used so that prior distributions on the parameters are uninformative, while the hyperparameters were estimated through Laplace approximation. The posterior distributions of the fixed effect parameters and hyperparameters are shown in Figure 4. Model validation was performed by inspecting the Pearson residuals against all covariates.

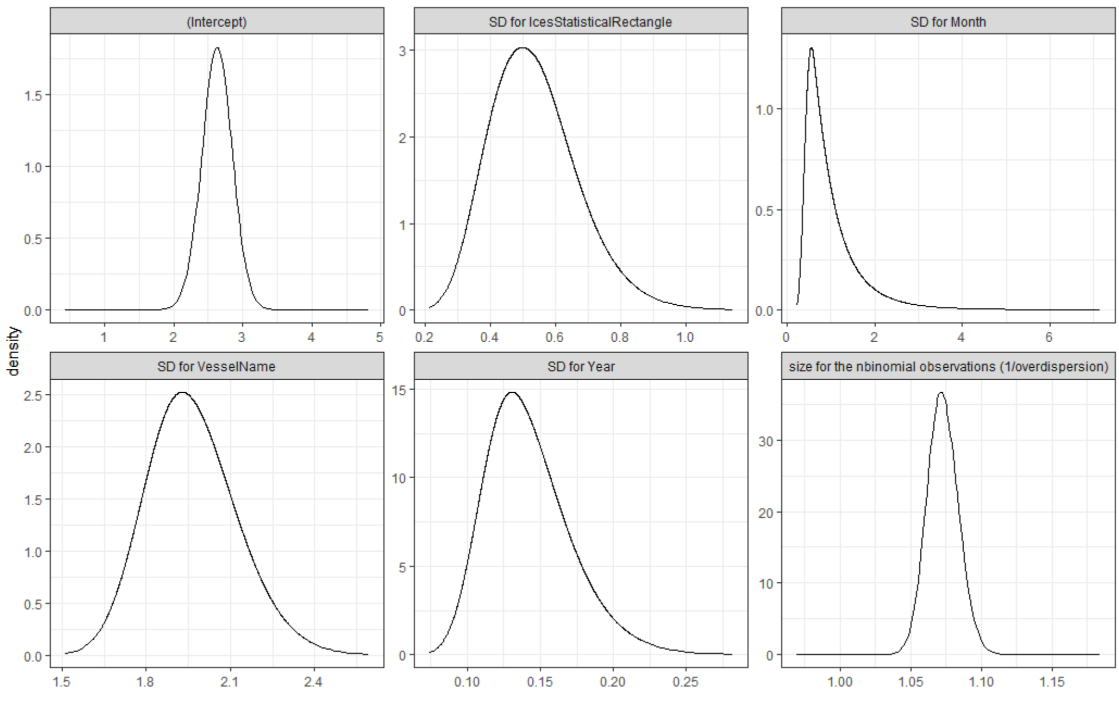

Figure 4: Posterior distributions of the model fixed effects (intercept) and hyperparameters governing the processes and observation model.

To estimate the annual CPUE trend and its 95% credible interval, the expected values and 0.025 and 0.975 quantiles were extracted from the marginal posterior distributions of the intercept and the annual yearly random effects (Table 3, Figure 5).

Table 4: Expected value and 0.025 and 0.975 quantile of the marginal posterior distribution (after exponential transformation) of each random year effect.

	expected	0.025	0.975
2004	1.301	1.077	1.568
2005	1.119	0.933	1.337
2006	1.105	1.051	1.161
2007	1.121	1.064	1.181
2008	1.057	1.001	1.115
2009	1.226	1.162	1.293
2010	1.137	1.077	1.200
2011	0.994	0.941	1.049
2012	0.988	0.930	1.048
2013	0.858	0.807	0.911
2014	0.969	0.916	1.026
2015	0.814	0.768	0.862
2016	0.779	0.734	0.827
2017	0.981	0.922	1.044
2018	0.749	0.704	0.795

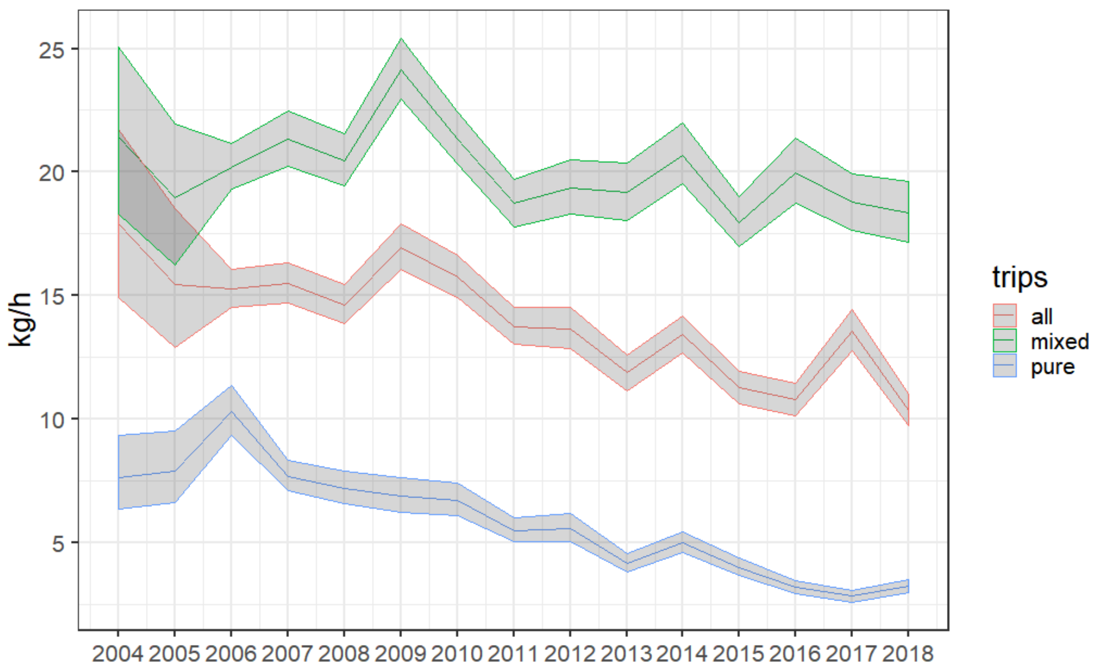

Figure 5: Estimated CPUE per year for each trip type.

Figure Figure5 shows that the index based on observations from *mixed* trips is more optimistic towards the end of the time series compared to the *pure* and *all* trips. Due to the high percentage of observations in mixed trips (~66%). It was decided to use the index based on all observations. However, the remarkable difference between both indices is a topic that requires in depth investigation.

2. Age-structured CPUE index

These numbers at age were obtained from observer trips and raised per year for landings and discards separately to the total weight of the fleet (landings and discards respectively). The numbers at age for the landings were summed with those of the discards.

To transform the CPUE (kg/h) index into an age structured index (N@A/h), the annual CPUE estimates were divided by the annual catches so that an annual standardized effort coefficient was derived (weight per year/standardized annual CPUE estimate). These standardized effort values were divided by the numbers at age of the catch. This resulted in an age based index expressed as numbers per unit of effort (Table 4).

Table 4: New Belgian commercial beam trawl tuning series from 2004-2018.

BE-CBT-new															
2004	2018														
1	1	0	1												
1	15														
1	0.01	0.44	0.89	0.34	0.50	0.18	0.04	0.04	0.03	0.03	0.01	0.02	0.00	0.01	0.01
1	0.07	0.65	0.49	0.45	0.12	0.08	0.06	0.03	0.02	0.01	0.02	0.00	0.00	0.00	0.00
1	0.04	0.66	0.40	0.34	0.32	0.13	0.13	0.06	0.03	0.02	0.02	0.01	0.01	0.00	0.00
1	0.01	0.84	0.61	0.29	0.12	0.23	0.09	0.11	0.04	0.01	0.02	0.01	0.00	0.00	0.02
1	0.15	0.27	0.74	0.69	0.16	0.11	0.09	0.05	0.01	0.03	0.01	0.00	0.00	0.00	0.01
1	0.26	0.84	0.53	0.52	0.34	0.08	0.05	0.05	0.02	0.01	0.02	0.01	0.01	0.00	0.01
1	0.10	0.71	0.56	0.18	0.29	0.15	0.05	0.03	0.04	0.01	0.03	0.01	0.00	0.00	0.02
1	0.02	0.71	0.79	0.25	0.14	0.10	0.07	0.02	0.03	0.02	0.00	0.01	0.00	0.00	0.00
1	0.00	0.29	1.10	0.70	0.19	0.06	0.07	0.07	0.01	0.00	0.01	0.00	0.01	0.01	0.01
1	0.00	0.04	0.29	0.57	0.44	0.13	0.06	0.07	0.05	0.02	0.01	0.00	0.00	0.01	0.01
1	0.02	0.07	0.34	0.44	0.53	0.31	0.08	0.04	0.04	0.02	0.00	0.01	0.00	0.01	0.00
1	0.07	0.35	0.39	0.37	0.42	0.51	0.36	0.12	0.02	0.06	0.03	0.01	0.00	0.01	0.01
1	0.03	0.26	0.39	0.24	0.30	0.28	0.29	0.22	0.04	0.06	0.04	0.04	0.01	0.00	0.02
1	0.09	0.32	0.70	0.43	0.22	0.25	0.23	0.31	0.18	0.06	0.02	0.03	0.02	0.01	0.03
1	0.04	0.49	0.41	0.60	0.24	0.19	0.15	0.13	0.15	0.10	0.03	0.01	0.02	0.03	0.03

3. Conclusion

The sales notes and logbooks of the Belgian beam trawl fleet were used to calculate the sole landing rates in the Eastern English Channel. Landings and discards data from the small and large fleet segment were selected and zero landings were allowed for. A regression model was fitted to the catch data including a random effect with ICES statistical rectangle, month and vessel reference number. The annual CPUE estimates from the model were divided by the annual catches so that an annual standardized effort coefficient was derived. These standardized effort values were divided by the numbers at age of the catch. This resulted in an age based catch index expressed as numbers per unit of effort.

4. Reference

ICES. 2017. Report of the Benchmark Workshop on North Sea Stocks (WKNSEA), 6–10 February 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:34. 673 pp.

Annex 4: Eqsim R code

```
########################################
# Calculating Reference points for SOL 7d
# IBP 2019 (aug 2019)
# script via Jan Jaap Poos and Helen Dobby
########################################
rm(list=ls())
# open R versie 3.3.1
# install.packages("msy")
library(msy);
getwd()
setwd("~/Development/RStudio/D1VISBIO/NDGP")
path<-getwd()
setwd(paste0(path,"/ICES/ASSESSMENTS/SOL_7D/IBPsol7d2019/XSAfinal/XSA/"))
load(file='xsastock.Rdata') #dit is het stock object zijnde een combinatie van assessment output en stock weights
setwd(paste0(path,"/ICES/ASSESSMENTS/SOL_7D/IBPsol7d2019/Refpoints/FinalAssRun/"))
source("eqsim functions.R")
#####################
name(xsa.stock) <- "sole"
# when removing last data year, this is not visible in red dots, but model values change:
FIT1 <- eqsr_fit(xsa.stock,
        nsamp = 1e3,
        models = c("Ricker", "Segreg", "Bevholt"),  remove.years=ac(c(2017,2018)))
eqsr_plot(FIT1,n=1e3)
# we choose type 5
# determine Blim = Bloss
Bloss <- min(ssb(xsa.stock))
Bloss
Blim <- Bloss
Blim
# determine Bpa
print(Bpa <-  Blim *1.4)
#################### Estimate Flim (=F50)
# -> based on stock with segmented regression SR relationship with inflection point at Blim
# Fix function to do segmented regression:
```

```
B<-Blim

SegregBlim <- function (ab, ssb) {

  log(ifelse (ssb>=B, ab$a*B, ab$a*ssb))

}

FIT2 <- eqsr_fit(xsa.stock, nsamp = 1e3, models = "SegregBlim", remove.years=ac(c(2017,2018)))

FIT2$sr.det # gives b = 1

#print(Blim <-  FIT2b[["sr.det"]][,"b"])

eqsr_plot(FIT2,n=1e3)

#simulation

SIM101 <- eqsim_run(FIT2,  bio.years = c(2014, 2018), bio.const = FALSE,

                 sel.years = c(2014, 2018), sel.const = FALSE,

                 Fcv=0, Fphi=0,

                 Btrigger = 0,Blim=Blim,Bpa=NA,

                 Fscan = seq(0,1.2,len=61),verbose=FALSE) #in 61 steps from F=0 to F=1.2

eqsim_plot(SIM101,catch="FALSE")

Coby.fit(SIM101,outfile='sole no Btrigger Blim set to find Flim Fcv=0 and Fphi=0')

# from this table get F50, catF

print(Flim <- SIM101$Refs2[1,3])

print(Fpa <- Flim/1.4)

##################### Calculate Fmsy

Segreg_bounded <- function(ab, ssb) {

  ab$b <- ab$b + Bloss

  Segreg (ab, ssb)

}

#fit

FIT3 <- eqsr_fit(xsa.stock,

               nsamp = 1e3,

               models = "Segreg_bounded", remove.years=ac(c(2017,2018))) #hier kan je ev ook andere modellen meenemen via c()

eqsr_plot(FIT3,n=1e3)

SIM1a <- eqsim_run(FIT3,  bio.years = c(2014,2018), bio.const = FALSE,

                sel.years = c(2014,2018), sel.const = FALSE,

                Fcv=0.212, Fphi=0.423,  # these are defaults, taken from WKMSYREF4, as used in Saithe assessments

                Btrigger = 0,Blim=Blim, Bpa=Bpa,Fscan = seq(0,1.0,len=51),verbose=FALSE)#in 51 stappen van F=0 naar F=1.0

eqsim_plot(SIM1a,catch="FALSE")

Coby.fit(SIM1a,outfile='sol sim1')

#get median MSY from lanF
```

```
print(Fmsy <- SIM1a$Refs2[2,4])

#also get F05 from catF

print(F05 <- SIM1a$Refs2[1,1])

#EVALUATE

# Gezien stock nog niet 5 of meer jaar op Fmsy wordt gevist, wordt MSYBtrigger op Bpa gezet.

# Om Advice rule nu te evalueren dienen we run te doen met bekomen Btrigger waarde ingevuld:

SIM2 <- eqsim_run(FIT3,  bio.years = c(2014,2018), bio.const = FALSE,

              sel.years = c(2014,2018), sel.const = FALSE,

              Fcv=0.212, Fphi=0.423,  # these are defauts, taken from WKMSYREF4, as used in Saithe assessments

              Btrigger = Bpa,Blim=Blim,Bpa=Bpa,Fscan = seq(0,1.0,len=51),verbose=FALSE, extreme.trim=c(0.05,0.95))

eqsim_plot(SIM2,catch="FALSE")

Coby.fit(SIM2,outfile='sol sim2')

print(F05 <- SIM2$Refs2[1,1])

#SIM1$rbp

##########

#  Sensitivity to year range in selectivity

out <-NULL

# 2008-2017 was the default year range for the Fmsy calculation

# the eqsim resamples fishery selectivity from these years (default is usually last 10 years)

# You use the same year range for the bio data - which includes mean weights, M, etc

sel.years <-c(2014,2018)

for(y in 1990:2008){

  cat(y,'\n')

# What I am doing here is choosing different blocks of years (each 10 years long) from which to resample the fishery selectivity.

# The first block (which is labelled '1990' in the output data) has a selectivity data year range from 1990 to 1999, the

# next 1991 to 2000 and so on, until the last on is 2008 to 2017 (which is the same as your base run)

  sel.years[1] <- y

  sel.years[2] <-y+9

  #  setup$sel.years <- c(y-4,y)

  sim <- eqsim_run(FIT3, bio.years = c(2014,2018), bio.const = FALSE,

               sel.years = c(2014,2018), sel.const = FALSE, Fscan = seq(0,1,0.02),

                    Fcv = 0.212, Fphi = 0.423, Blim = Blim, Bpa = Bpa,

                    Btrigger = 0, verbose = FALSE, extreme.trim = c(0.05,0.95))

# For each iteration (i.e different block of selectivity data) we save the estimate of Fmsy and lower and upper bounds

# So if selectivity has change significantly over time you might expect to see a significant change in your Fmsy

# estimate (FmsyMed)
```

```
  out0 <- data.frame(y,
          Fmsy05 = sim$Refs2[2,6],
          Fmsy95 = sim$Refs2[2,8],
          FmsyMed = sim$Refs2[2,4]
 )
 out <- rbind(out,out0)
}
################################
getwd()
save(out,file="out.rdata")
# save(out0,file="out0.rdata")
write.csv(out,file="out.csv")
# write.csv(out0,file="out0.csv")
out$Year <- out$y
out$FMSY <- 0.1921922
library(ggplot2)
ggplot(out, aes(Year, FmsyMed))+geom_line()+theme_bw()+
 geom_line(aes(Year, Fmsy05), linetype=2)+
 geom_line(aes(Year, Fmsy95), linetype=2)+
 geom_line(aes(Year, FMSY), linetype=3, color="green", size=1.5)
```