INTER-BENCHMARK PROTOCOL OF NORTH SEA WHITING (IBPNSWHITING)

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International Council for the Exploration of the Sea
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H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Editors

Timothy Earl

Authors

Alan Baudron • Timothy Earl • Raphäel Girardin • Tanja Miethe

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i Executive summary

The Inter-Benchmark Protocol of North Sea Whiting (IBPNSWhiting 2021) met to consider the use of updated Natural Mortality estimates from the North Sea multispecies assessment model developed by the Working Group on Multispecies Assessment Methods (WGSAM; ICES 2021a) for Whiting in Subarea 4 and Division 7.d (North Sea and eastern English Channel). In this report the estimates of Natural Mortality are compared to previous estimates (WGSAM, 2018a), the effects of this change on the assessment model are considered, and reference points recalculated. The estimates of Natural Mortality from the most recent multispecies assessment model were slightly higher than from the previous run, particularly at age 0. Incorporating these revised Natural Mortality estimates into the assessment resulted in only minor changes to the stock size, recruitment and exploitation estimates, and to the quality of the model fit. The updated model showed higher retrospective bias than previously, but was still judged to be acceptable. Following the revision of the assessment model, reference points were re-calculated following the ICES Technical guidance (ICES, 2021) using the same assumptions as for previous assessments (ICES, 2018b). This resulted in lower biomass reference point (e.g. MSY $B_{trigger}$ decreased from 167 000 t to 144 000 t) and a substantial increase in F_{MSY} (from 0.172 to 0.371).

ii Expert group information

Expert group name	Inter-benchmark Protocol of North Sea Whiting (IBPNSWhiting 2021)
Expert group cycle	Annual
Year cycle started	2021
Reporting year in cycle	1/1
Chair	Timothy Earl, United Kingdom
Meeting venue and dates	6 April 2021, Online, eight participants

1 Introduction

New natural mortality estimates were obtained from the 2020 WGSAM SMS key run. The 2020 SAM assessment was run with the new smoothed mortality estimates and the Q1 survey data truncated from 1983 onwards (years 1978 to 1982 were previously left in by mistake). Results from this new SAM assessment were compared to (i) the results from the 2020 SAM assessment, (ii) the results from the 2020 SAM assessment with the Q1 survey data truncated from 1983 onwards and (iii) the results from the SAM assessment model used in the last benchmark in 2018. Next, the EqSim was run on the new SAM assessment results to determine new reference points which were compared to the previous reference points obtained during the last benchmark in 2018. The EqSim was run with the average of the last ten years of biological data and the last three years of fishing selectivity data, the default values of sigmaF and sigmaSSB (0.2), and autocorrelation in recruitment, as was done in the last benchmark. The suggested new reference point F_{MSY} for North Sea whiting was 0.371, compared to 0.172 obtained in the last benchmark where F_{MSY} was capped at $F_{P.05}$. The main difference between the last benchmark and the new reference points obtained here is the new higher value of $F_{p.05}$ of 0.385.

The reviewer concluded that the updates to the assessment model and reference points was consistent with ICES guidance, and formed a suitable basis for advice as an ICES Category 1 assessment.

1.1 ToRs

The Inter-benchmark Protocol of North Sea Whiting, chaired by Timothy Earl, UK and reviewed by Bjarki Elvarsson, Iceland will be established and will meet by correspondence on April 6th 2021 to:

a) Test the inclusion of newest natural mortality estimates from ICES WGSAM in the assessment;

b) Determine whether reference points from the current management strategy are still applicable using EqSim. Update the reference points if necessary.

The IBP will report by 23rd April for the attention of the ACOM, WGNSSK and WGSAM.

2 New natural mortality estimates

New estimates of natural mortality-at-age for North Sea whiting were obtained from the latest North Sea SMS key run reviewed during the last WGSAM meeting (ICES, 2021a). The new raw natural mortality-at-age estimates (Table 1) were smoothed to reduce the effect of interannual variability while capturing the trend in natural mortality over time, as was done during the benchmark in 2018. The gam function (R package gam) was used to fit a generalized additive model to smooth natural mortality for each age class separately. Smoothing spline was applied assuming Gaussian error and df=5 (where degrees of freedom df=1 implies a linear fit) as follows:

gam(new_nm[,i] ~ s(c(1978:2019),5),family=gaussian)

Table 1. Whiting in area 4 and 7d. New raw values for natural mortality (quarterly sum of M1 and M2), output from WGSAM (ICES, 2021a).

Year/Age	0	1	2	3	4	5	6	7	8
1978	1.421	1.501	0.862	0.563	0.524	0.451	0.451	0.289	0.241
1979	0.947	1.153	0.772	0.524	0.505	0.461	0.437	0.267	0.243
1980	1.408	1.256	0.695	0.492	0.46	0.436	0.396	0.31	0.255
1981	1.864	1.754	0.927	0.553	0.526	0.455	0.439	0.37	0.252
1982	1.597	1.621	0.754	0.572	0.531	0.45	0.387	0.267	0.236
1983	1.297	1.327	0.791	0.49	0.463	0.431	0.424	0.33	0.258
1984	1.789	1.137	0.666	0.469	0.449	0.431	0.411	0.3	0.242
1985	1.246	1.196	0.725	0.455	0.453	0.416	0.409	0.274	0.274
1986	1.374	1.007	0.589	0.482	0.426	0.395	0.353	0.243	0.225
1987	1.586	1.232	0.686	0.434	0.429	0.393	0.387	0.241	0.233
1988	1.149	1.498	0.653	0.518	0.476	0.439	0.402	0.232	0.226
1989	1.604	1.325	0.6	0.482	0.465	0.436	0.415	0.365	0.365
1990	1.616	1.353	0.654	0.501	0.449	0.449	0.416	0.244	0.234
1991	1.486	1.147	0.603	0.494	0.468	0.438	0.438	0.415	0.328
1992	1.63	1.25	0.546	0.456	0.441	0.431	0.421	0.421	0.236
1993	1.601	1.336	0.632	0.444	0.428	0.422	0.414	0.403	0.359
1994	1.55	1.221	0.615	0.462	0.451	0.428	0.428	0.4	0.23
1995	1.852	1.252	0.602	0.438	0.422	0.407	0.4	0.356	0.271
1996	1.715	1.384	0.678	0.477	0.463	0.436	0.421	0.375	0.231
1997	1.991	1.148	0.581	0.461	0.437	0.416	0.402	0.396	0.278

Year/Age	0	1	2	3	4	5	6	7	8
1998	1.92	1.388	0.659	0.467	0.43	0.419	0.408	0.408	0.4
1999	2.099	1.593	0.601	0.492	0.474	0.438	0.427	0.419	0.419
2000	2.006	0.905	0.512	0.432	0.416	0.414	0.407	0.406	0.403
2001	1.985	1.336	0.569	0.427	0.411	0.393	0.389	0.389	0.38
2002	2.465	1.682	0.646	0.514	0.445	0.421	0.416	0.384	0.384
2003	2.589	1.877	0.664	0.49	0.463	0.437	0.406	0.403	0.403
2004	2.489	1.436	0.77	0.565	0.522	0.485	0.47	0.467	0.461
2005	2.586	1.297	0.637	0.519	0.483	0.473	0.471	0.471	0.431
2006	2.605	1.091	0.728	0.547	0.505	0.484	0.435	0.435	0.435
2007	2.468	1.479	0.694	0.508	0.475	0.435	0.457	0.435	0.432
2008	2.473	1.375	0.643	0.518	0.518	0.446	0.446	0.46	0.446
2009	2.006	1.233	0.665	0.522	0.457	0.451	0.451	0.451	0.451
2010	2.348	1.01	0.595	0.458	0.42	0.412	0.416	0.269	0.416
2011	2.806	1.111	0.638	0.482	0.437	0.431	0.431	0.431	0.431
2012	2.736	1.343	0.685	0.501	0.443	0.443	0.436	0.38	0.38
2013	2.289	1.202	0.611	0.516	0.475	0.432	0.289	0.285	0.382
2014	2.514	1.039	0.595	0.513	0.493	0.424	0.371	0.225	0.371
2015	2.729	0.948	0.585	0.482	0.461	0.461	0.361	0.277	0.369
2016	2.171	1.165	0.662	0.521	0.486	0.475	0.451	0.236	0.236
2017	2.584	1.354	0.621	0.491	0.455	0.423	0.333	0.333	0.24
2018	2.069	1.254	0.722	0.545	0.478	0.473	0.233	0.286	0.229
2019	1.447	1.067	0.655	0.498	0.464	0.432	0.412	0.325	0.325

Mortality estimates for 2020 were obtained by averaging the smoothed values at each age over the last three years (Table 2). The smoothed natural mortality-at-age estimates (Figure 1), hereafter referred to as new mortalities, were used as input for the SAM assessment model.

Table 2. Whiting in area 4 and 7d. New smoothed values for natural mortality-at-age (using the output from WGSAM 2020) for 1978–2019, with values for 2020 estimated by averaging over 2017–2019.

Year/Age	0	1	2	3	4	5	6	7	8
1978	1.351	1.420	0.833	0.546	0.514	0.454	0.434	0.296	0.243
1979	1.378	1.406	0.814	0.537	0.507	0.450	0.428	0.295	0.244
1980	1.406	1.392	0.795	0.529	0.499	0.446	0.422	0.295	0.245
1981	1.429	1.377	0.776	0.520	0.491	0.442	0.417	0.294	0.246
1982	1.446	1.357	0.756	0.512	0.484	0.437	0.412	0.292	0.247
1983	1.455	1.334	0.736	0.504	0.476	0.433	0.408	0.290	0.248
1984	1.459	1.311	0.715	0.496	0.469	0.430	0.405	0.289	0.249
1985	1.460	1.291	0.695	0.489	0.462	0.427	0.403	0.288	0.251
1986	1.463	1.278	0.676	0.484	0.457	0.425	0.402	0.291	0.254
1987	1.469	1.271	0.660	0.480	0.454	0.424	0.402	0.296	0.257
1988	1.480	1.268	0.645	0.477	0.451	0.424	0.404	0.304	0.261
1989	1.499	1.266	0.633	0.474	0.449	0.425	0.406	0.316	0.265
1990	1.524	1.266	0.623	0.472	0.447	0.426	0.408	0.329	0.269
1991	1.556	1.267	0.615	0.469	0.445	0.426	0.410	0.343	0.274
1992	1.595	1.270	0.610	0.466	0.444	0.425	0.412	0.356	0.279
1993	1.642	1.276	0.607	0.464	0.442	0.425	0.413	0.368	0.285
1994	1.696	1.285	0.606	0.462	0.441	0.424	0.413	0.377	0.292
1995	1.758	1.296	0.606	0.462	0.441	0.424	0.414	0.385	0.302
1996	1.827	1.311	0.608	0.463	0.441	0.424	0.414	0.393	0.314
1997	1.900	1.328	0.609	0.465	0.442	0.424	0.415	0.399	0.329
1998	1.978	1.347	0.612	0.468	0.444	0.425	0.416	0.405	0.346
1999	2.057	1.366	0.616	0.472	0.446	0.427	0.418	0.410	0.362
2000	2.137	1.384	0.622	0.477	0.449	0.429	0.420	0.415	0.378
2001	2.217	1.400	0.630	0.483	0.454	0.432	0.424	0.420	0.392
2002	2.293	1.411	0.639	0.490	0.459	0.436	0.428	0.424	0.405
2003	2.360	1.411	0.648	0.497	0.464	0.440	0.432	0.427	0.416
2004	2.415	1.399	0.656	0.503	0.469	0.444	0.436	0.429	0.425
2005	2.457	1.378	0.661	0.508	0.472	0.446	0.439	0.429	0.432

Year/Age	0	1	2	3	4	5	6	7	8
2006	2.486	1.351	0.663	0.510	0.474	0.447	0.439	0.425	0.435
2007	2.505	1.321	0.662	0.511	0.474	0.447	0.438	0.418	0.436
2008	2.516	1.290	0.659	0.510	0.472	0.446	0.434	0.408	0.433
2009	2.522	1.258	0.654	0.508	0.470	0.445	0.429	0.394	0.427
2010	2.526	1.229	0.649	0.507	0.468	0.443	0.421	0.378	0.418
2011	2.523	1.204	0.645	0.505	0.466	0.442	0.412	0.362	0.405
2012	2.508	1.184	0.641	0.505	0.466	0.442	0.401	0.345	0.390
2013	2.478	1.169	0.638	0.505	0.466	0.442	0.391	0.328	0.372
2014	2.433	1.158	0.637	0.505	0.467	0.443	0.381	0.314	0.353
2015	2.370	1.152	0.638	0.506	0.467	0.444	0.371	0.302	0.332
2016	2.289	1.150	0.642	0.507	0.468	0.445	0.362	0.294	0.312
2017	2.192	1.151	0.647	0.508	0.468	0.446	0.353	0.288	0.292
2018	2.083	1.151	0.652	0.510	0.469	0.447	0.344	0.283	0.273
2019	1.967	1.151	0.658	0.511	0.469	0.448	0.336	0.278	0.255
2020	2.081	1.151	0.652	0.510	0.469	0.447	0.344	0.283	0.273

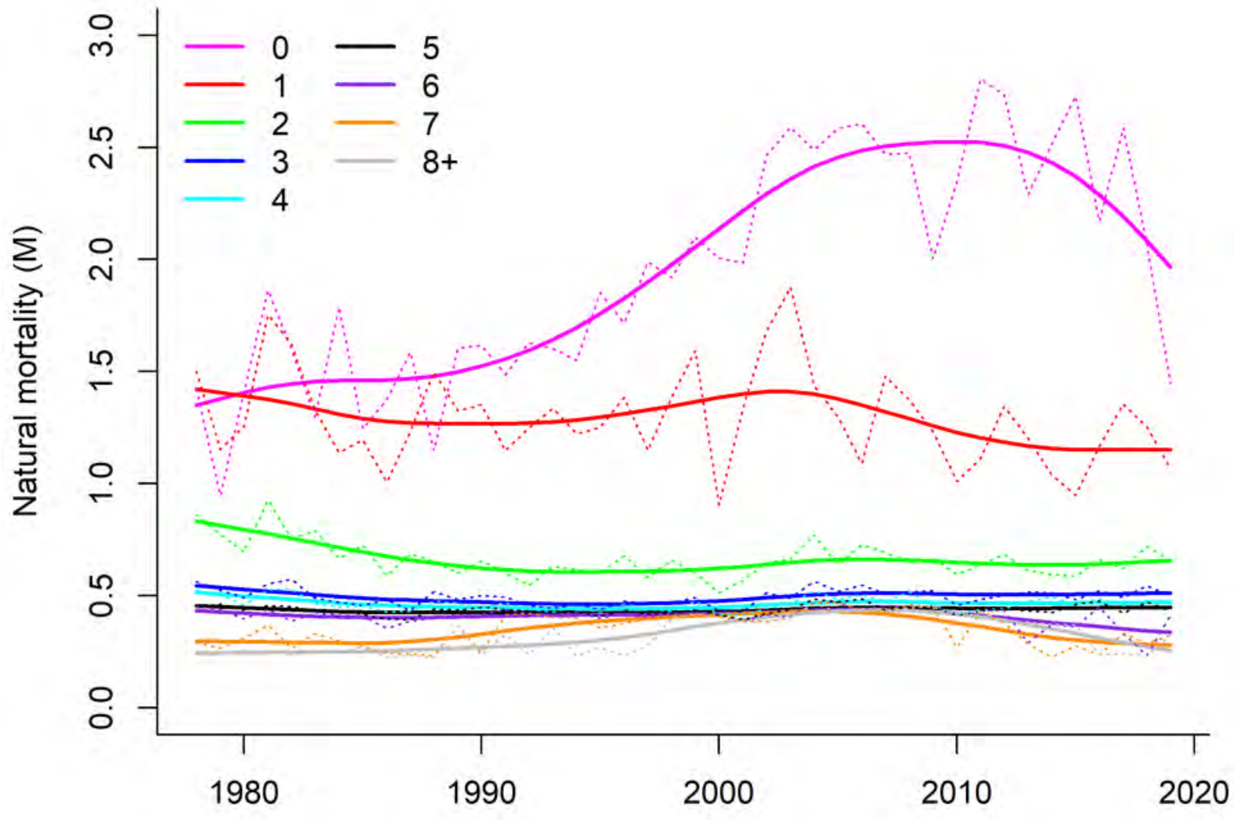


Figure 1. Raw (dashed lines) and smoothed (solid lines) natural mortality-at-age estimates from the 2020 North Sea SMS key run.

Compared to the smoothed natural mortality estimates from the previous key run from WGSAM (ICES, 2018a), the new mortalities show higher mortality estimates for age 0 (Figure 2). For age 1 and 2, the new mortalities are higher up to the early 2010s and late 2000s respectively, but are lower thereafter. The differences between new and old mortalities are very small for age 3 onwards.

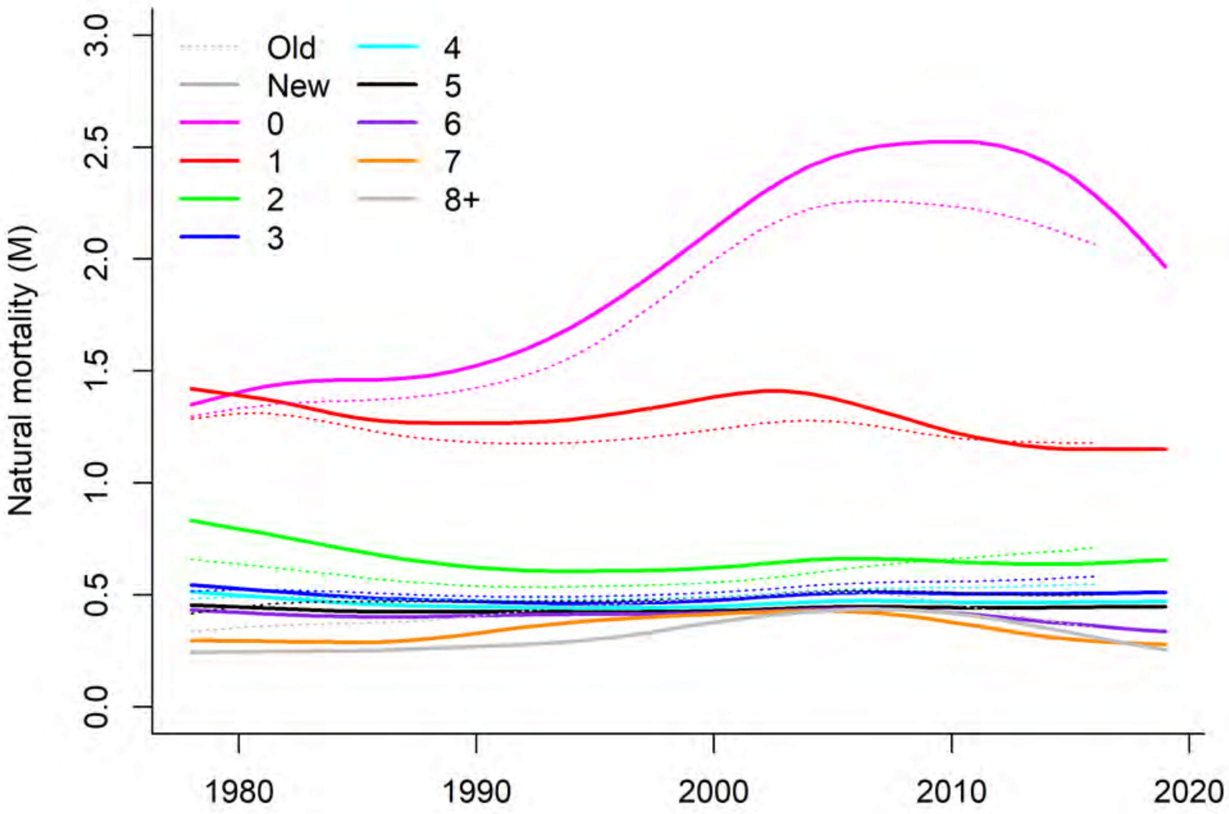


Figure 2. Comparison of new (solid line) smoothed natural mortality estimates with the old (dashed lines) smoothed natural mortality estimates from the previous North Sea SMS key run.

3 Impact of new natural mortality estimates on SAM assessment results

Results from different SAM assessment models were compared in order to assess the impact of the new mortalities. In addition, the SAM model used for the 2020 assessment included Q1 survey data from 1978 onwards, when in fact it was decided during the last benchmark that Q1 survey data from 1978 to 1982 should be removed. The model used to derive new reference points should include Q1 survey data from 1983 only, and comparisons were made to assess the impact of truncating the Q1 survey data from 1983 onwards. A comparison was also made with the SAM assessment model used in the last benchmark (ICES, 2018b), as this is relevant when comparing the new reference points to the previous ones. Hence the following four models were compared:

- The 2020 SAM model with the new mortalities and Q1 survey data starting in 1983;
- The 2017 SAM model with the old mortalities and Q1 survey data starting in 1983 (model used in the last benchmark; see ICES, 2018b);
- The 2020 SAM model with the old mortalities and Q1 survey data starting in 1978 (model used in the 2020 WGNSSK assessment; see ICES, 2020b);
- The 2020 SAM model with the old mortalities and Q1 survey data starting in 1983.

It should be noted that the survey indices used in the SAM model have been updated since the last benchmark. As such, the survey indices used in the three 2020 SAM models are slightly different from the ones used in the 2017 SAM model. However, the differences are small and the use of the new indices has been shown to only result in minor changes in the assessment results (see Working Document in ICES, 2020b).

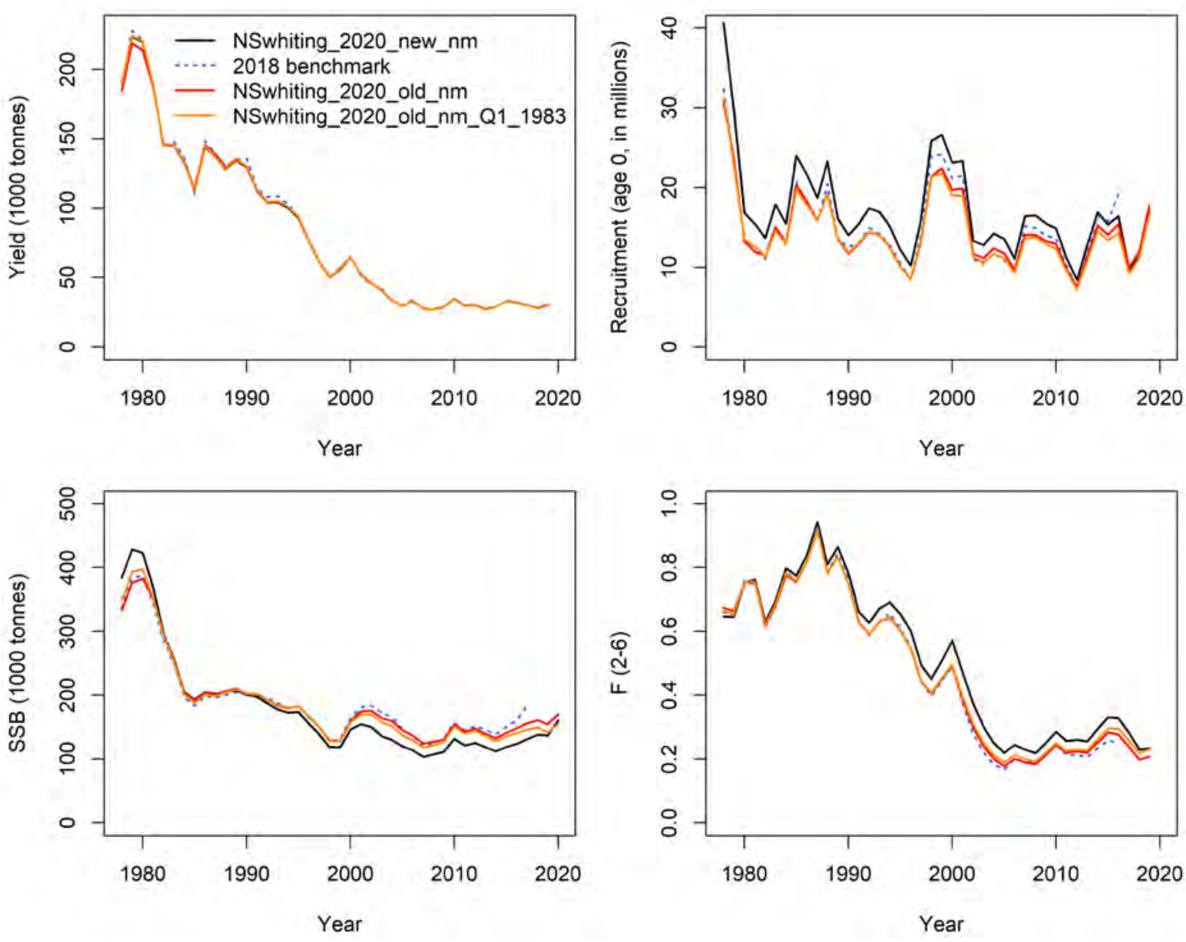


Figure 3. Comparison of the SAM assessment outputs between the four models.

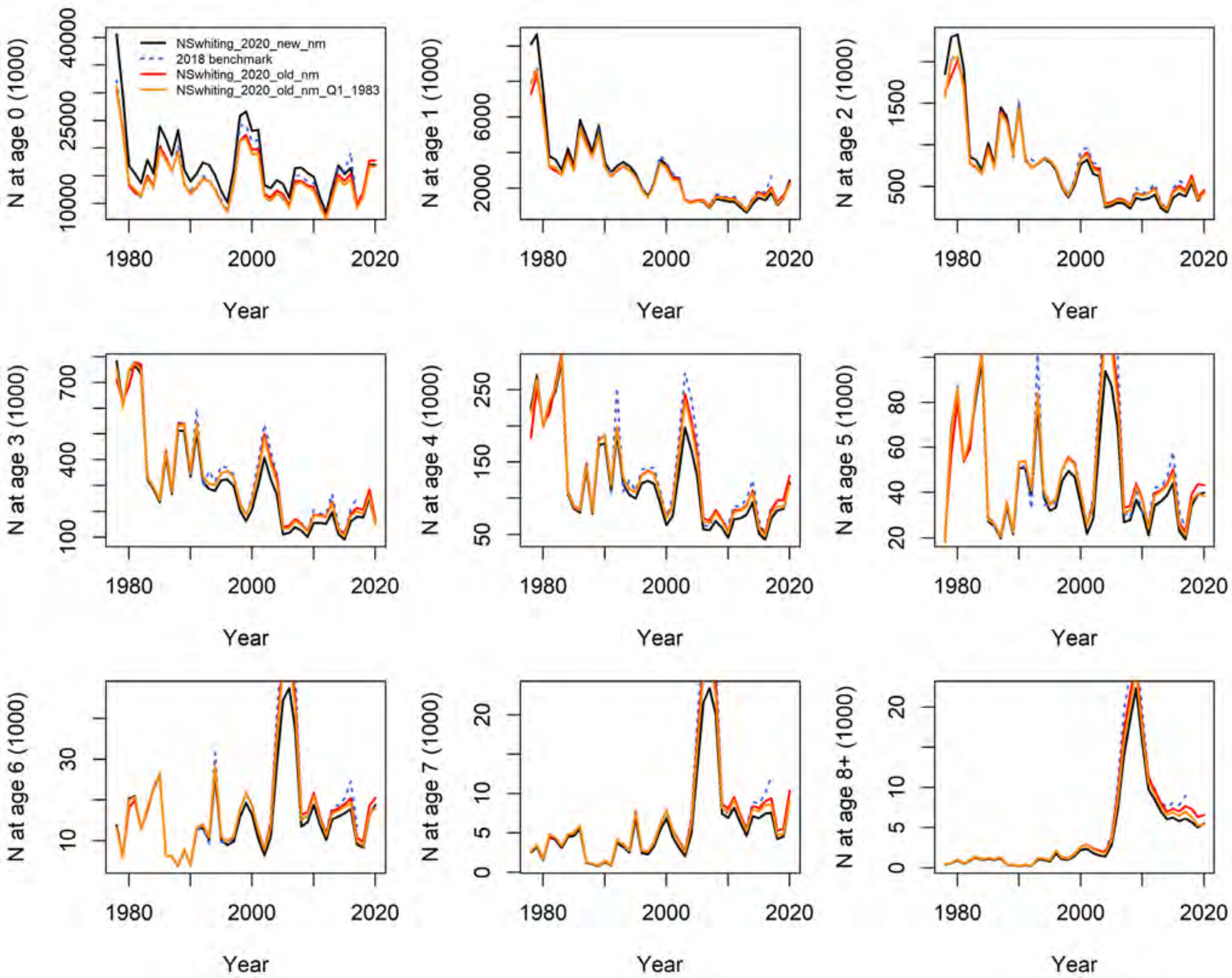


Figure 4. Comparison of the SAM assessment N-at-age outputs between the four models.

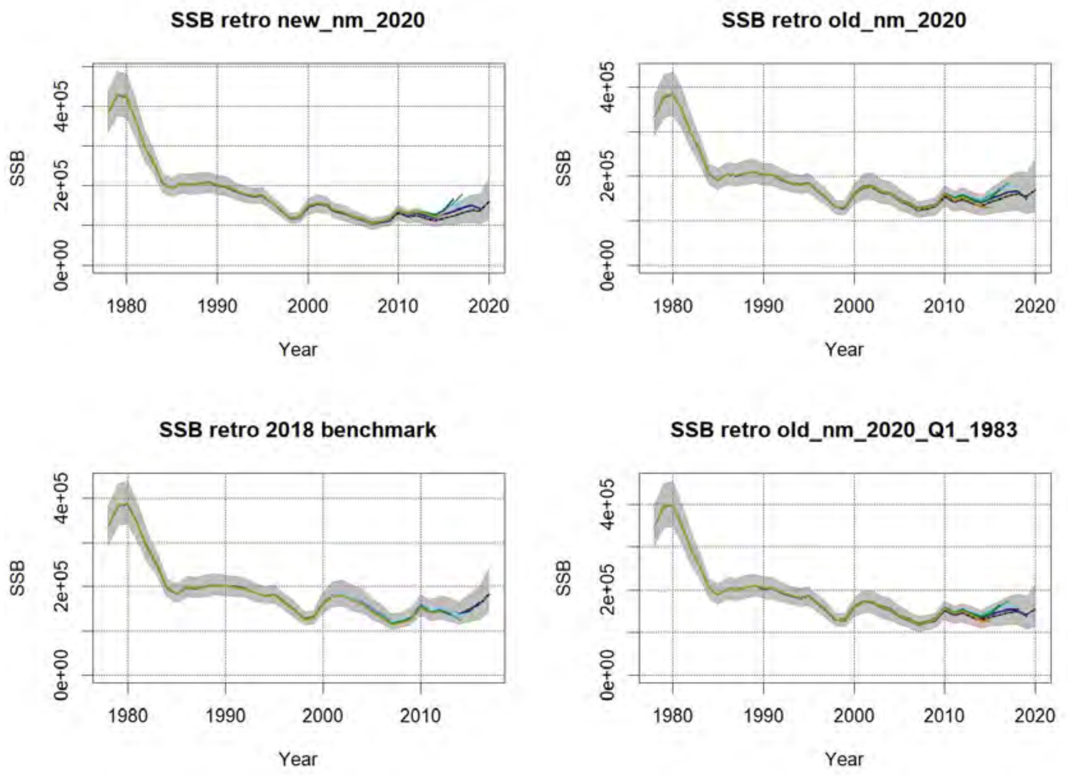


Figure 5. Comparison of the SSB retrospectives between the four SAM models.

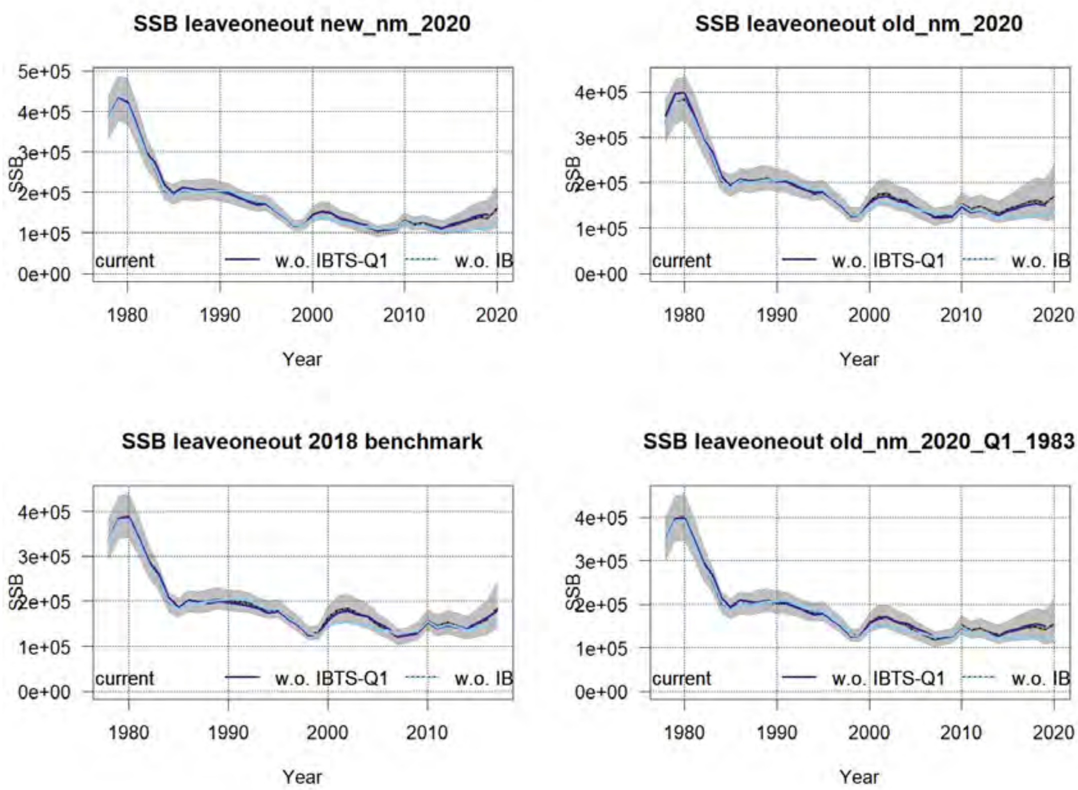


Figure 6. Comparison of the 'leave one out' runs between the four models.

Figure 7. Standardized one observation ahead residuals for the new 2020 SAM assessment model with new mortalities and Q1 survey starting in 1983.

Figure 8. Standardized one observation ahead residuals for the 2017 SAM assessment model with old mortalities and Q1 survey starting in 1983.

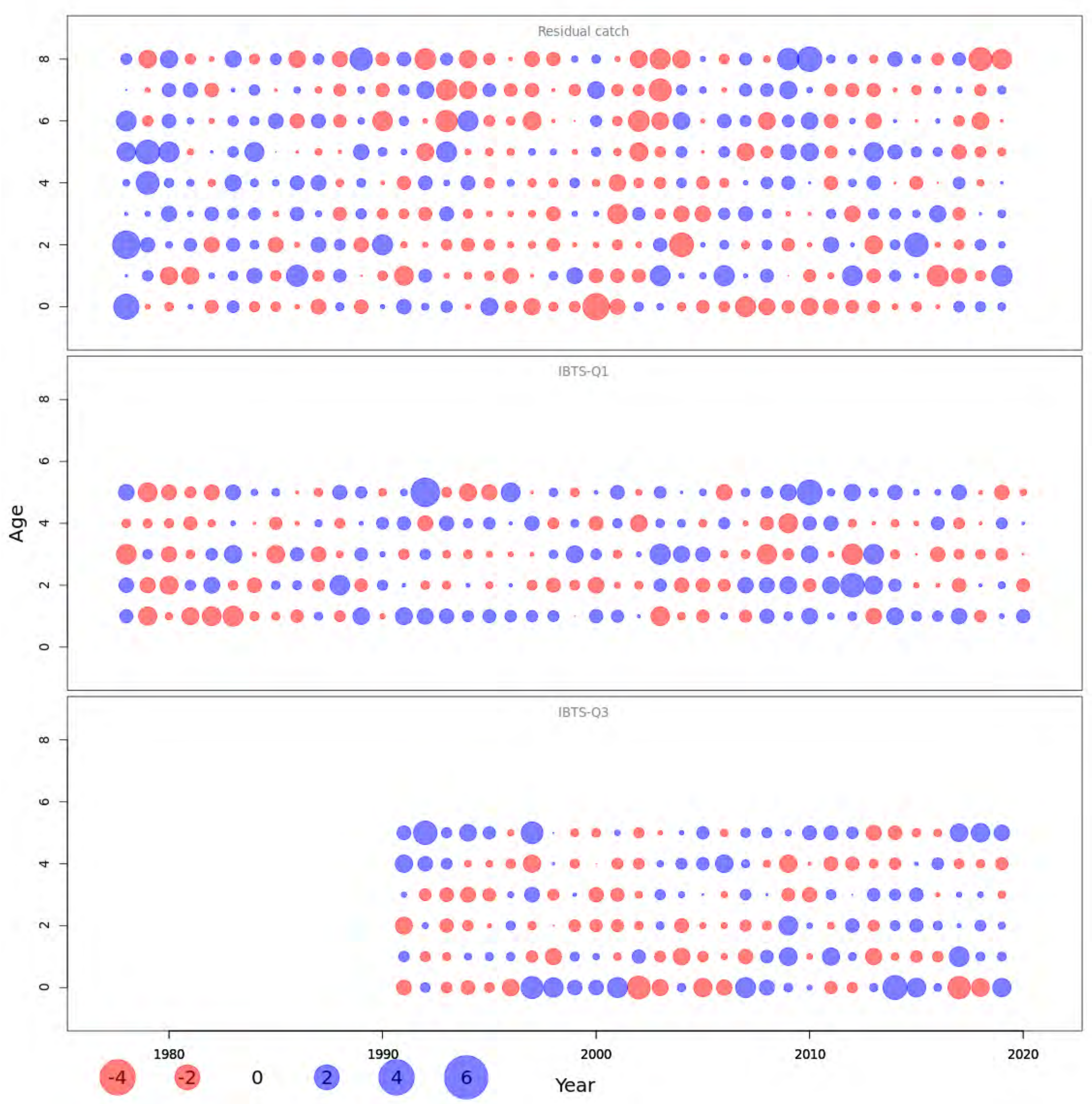


Figure 9. Standardized one observation ahead residuals for the old 2020 SAM assessment with old mortalities and Q1 survey starting in 1978.

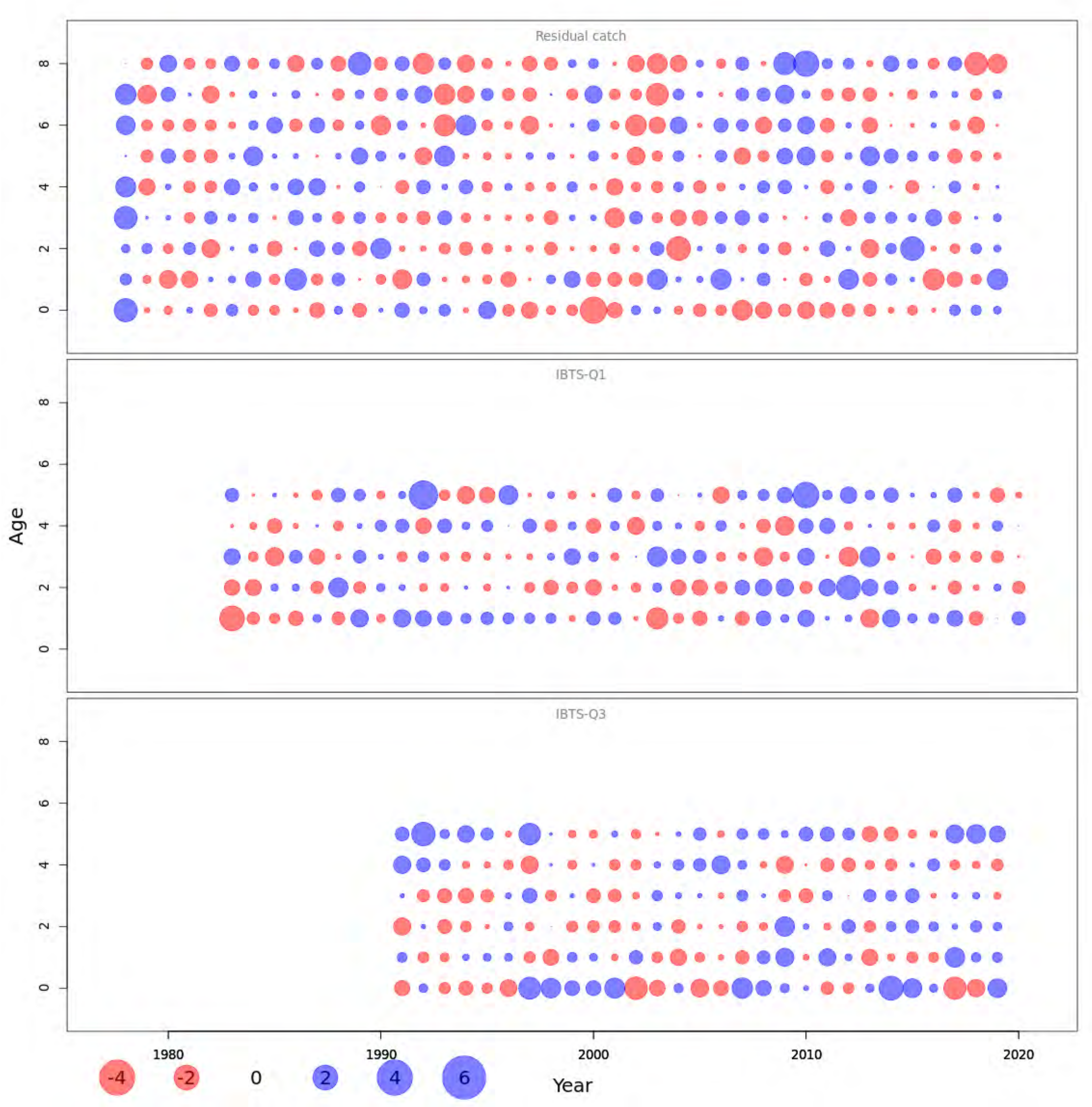


Figure 10. Standardized one observation ahead residuals for the old 2020 SAM assessment with old mortalities and Q1 survey starting in 1983.

Table 3. Mohn's rho for SSB (lag 0) and recruitment and F_{bar} (lag 1) comparison between the four models.

Mohn's rho			
SAM model	SSB	R(age 0)	F_{bar}(2–6)
new_nm_2020	0.2006	0.2445	-0.179
benchmark_2018	-0.0516	-0.122	0.0024
old_nm_2020	0.0641	0.0763	-0.1092
old_nm_2020_Q1_1983	0.0653	0.0859	-0.1071

The assessment outputs did not show drastic differences across the four models (Figure 3). However, the new mortalities resulted in higher recruitment and fishing mortality, but lower SSB. They also resulted in higher N-at-age 0, probably owing to the larger recruitment estimated (Figure 4). Most importantly the new mortalities affected the SSB retrospective, with two peels ending up outside the confidence interval (Figure 5), and the Mohn's rho value being at 0.2 (Table 3), which is right on the acceptable threshold for long-lived stocks as recommended by WKFORBIAS (ICES, 2020a). As for the leave-one-out runs, very little difference could be seen across the four models (Figure 6). Likewise, for the standardised one observation ahead residuals, very little difference could be seen between the four models (Figure 7–10). The removal of the years 1978 to 1982 of the Quarter 1 survey had very little impact overall (Figure 3–6), with the Mohn's rho values being really close to the model with the 1978–1982 values included (Table 3).

4 Estimation of new reference points

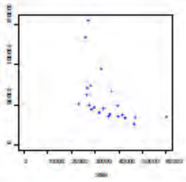
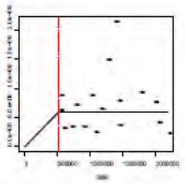
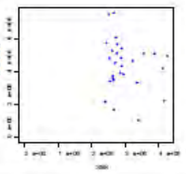
New reference points were estimated for the new SAM assessment model with the new mortalities and the Q1 survey starting in 1983. This was done in a stepwise process, using the EqSim analysis (standardized ICES code) and ICES technical guidelines (ICES, 2014; ICES, 2016b; ICES, 2017), detailed in the sections below. These new reference points were then compared to the ones obtained during the last benchmark (ICES, 2018b).

4.1 Methods

4.1.1 Estimating B_{lim} and PA reference points

B_{lim} is an important reference point from which other precautionary reference points are derived. To determine B_{lim}, the full assessment dataseries should be used to determine stock type in terms of the SSB–recruitment relationship (Table 4).

Table 4. Categorization of stock types as presented in ICES Technical Guidelines (ICES, 2017).

Type 4	Stocks with a wide dynamic range of SSB, and evidence that recruitment increases as SSB decreases.			No B_{lim} from this data, only the PA reference point. (B_{loss} would be a candidate for B_{pa}.)
Type 5	Stocks showing no evidence of impaired recruitment or with no clear relation between stock and recruitment (no apparent S–R signal).		$B_{lim} = B_{loss}$	
Type 6	Stocks with a narrow dynamic range of SSB and showing no evidence of past or present impaired recruitment.			No B_{lim} from this data, only the PA reference point. (B_{loss} could be a candidate for B_{pa}, but this is dependent on considerations involving historical fishing mortality.)

B_{pa} was estimated based on B_{lim} as follows, where the default value of 0.2 was used for sigmaSSB, as decided during the last benchmark (ICES, 2018b):

$$B_{pa}=B_{lim}*\exp(1.645*\text{sigmaSSB})$$

To estimate F_{lim}, EqSim was run without assessment/advice error and without advice rule (without $B_{trigger}$), using a segmented regression with a breakpoint fixed at B_{lim} to model the spawning stock–recruitment relationship, in order to get the F (F_{50}) that ensures a 50% probability for SSB to remain above B_{lim}.

According to the latest ICES Technical Guidelines (ICES, 2021b), F_{pa} is no longer estimated from F_{lim} ($F_{pa}=F_{lim}*\exp(-1.645*\text{sigmaF})$ but instead should be at F_{p05}.

4.1.2 Estimating F_{msy}, MSY $B_{trigger}$

F_{MSY} was initially calculated based on an EqSim with assessment/advice error, which should give maximum yield, and without advice rule (without MSY $B_{trigger}$). For the spawning stock–recruitment relationship a segmented regression was used with a freely estimated breakpoint.

To include assessment and advice error, the values $(F_{cv}, F_{phi}) = (0.212, 0.423)$, the default values suggested by WKMSYREF4 (ICES, 2016b).

To ensure consistency between the precautionary and the MSY frameworks, F_{MSY} is not allowed to be above F_{pa}; therefore, if the initial F_{MSY} value is above F_{pa}, F_{MSY} is reduced to F_{pa}.

MSY $B_{trigger}$ is a lower bound of the SSB distribution when the stock is fished at F_{MSY} (ICES, 2017). To set MSY $B_{trigger}$ the flowchart in Figure 11 is followed together with recent fishing mortality estimates.

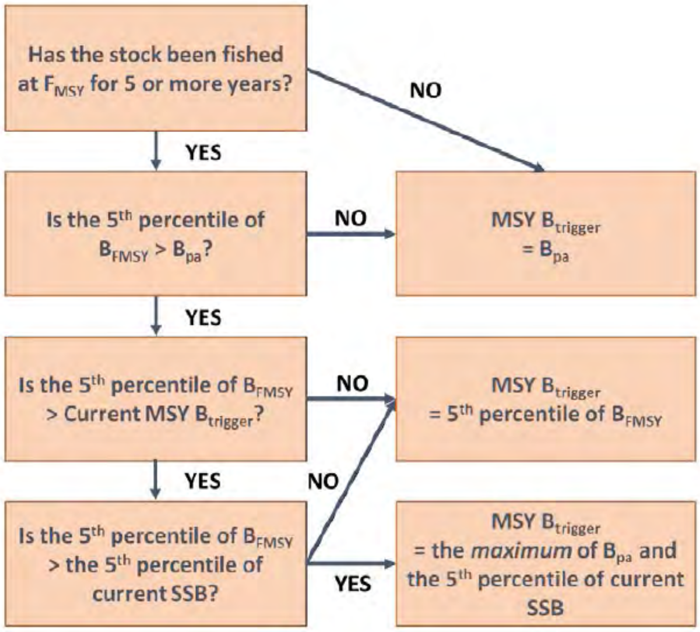


Figure 11. Flow chart to set MSY $B_{trigger}$ as given by ICES Advice Technical guidelines (ICES, 2017).

Calculations for MSY $B_{trigger}$ were based on EqSim runs without assessment/advice error and without advice rule, using segmented regression with a freely estimated breakpoint.

When applying the advice rule (AR), F was reduced when SSB falls below this threshold. Using the advice rule, it should be checked that when fishing at F_{MSY} the probability of falling below B_{lim} remains smaller than 5%. Therefore, it should be ensured that the initially calculated F_{MSY} was at or below $F_{.05}$.

4.1.3 EqSim settings

The sigmaF and sigmaSSB for the new SAM model with new mortalities were 0.1869284 and 0.1584248 respectively. Since both values were below 0.2, the default values of 0.2 were used instead for both sigmaF and sigmaSSB, as decided during the last benchmark (ICES, 2018b). For fisheries selectivity, an average of the most recent three years was found to be representative and was used throughout (Figure 12). It should be noted that the highest selectivities seen on Figure 12 were all observed in the early part of the time-series (prior 1985). For weights-at-age, an average of the most recent ten years was found to be representative and was used throughout (Figure 13). As in the last benchmark, the time-series since 1983 are included for estimation of stock–recruitment relationship, excluding years 1978–1982.

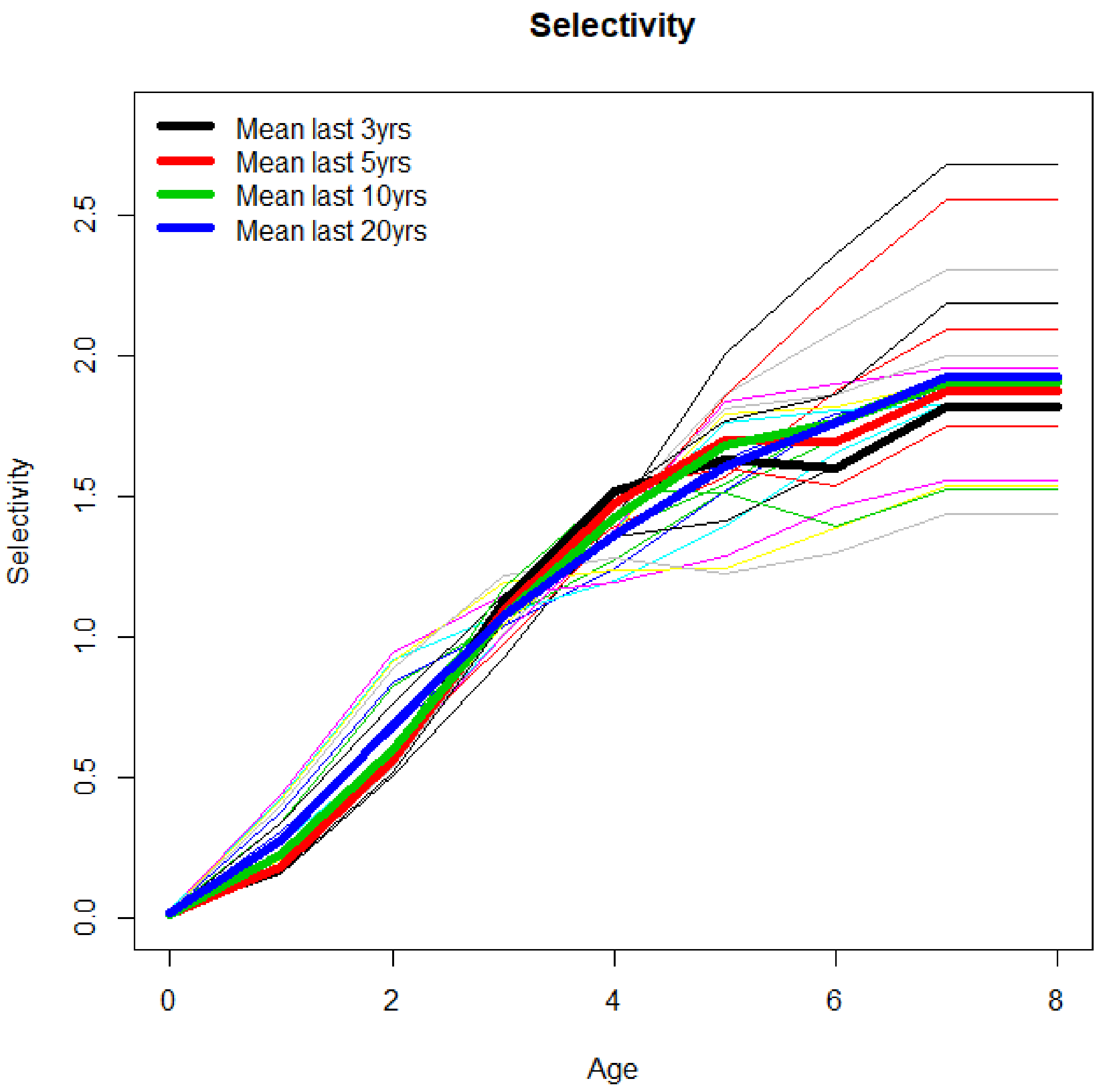


Figure 12. Fisheries selectivity-at-age by year and averages for recent three, five, ten, 20 years.

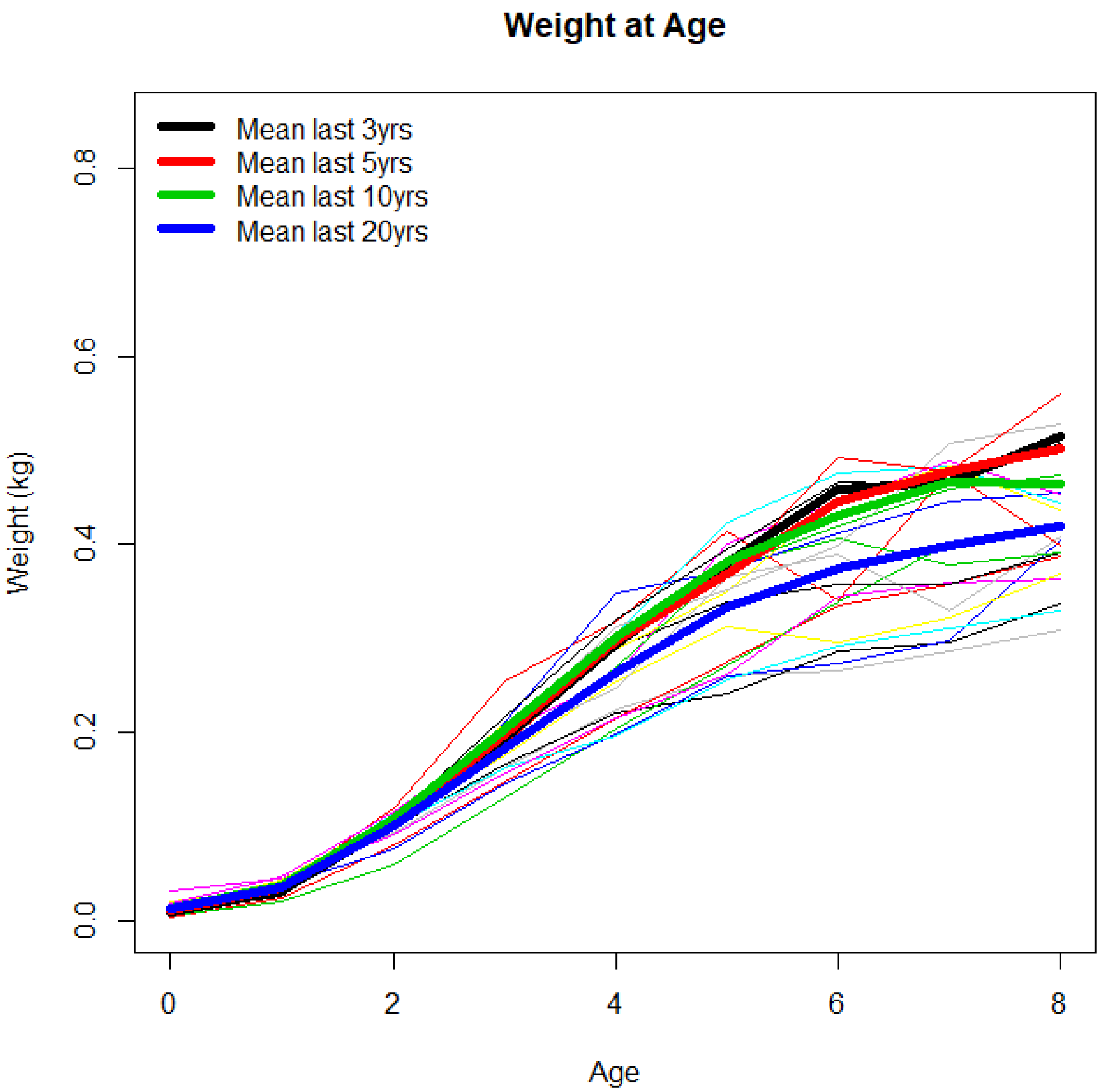


Figure 13. Weights-at-age by year and averages for the recent three, five, ten, 20 years.

Autocorrelation in recruitment was significant at lag 1 and was included (Figure 14).

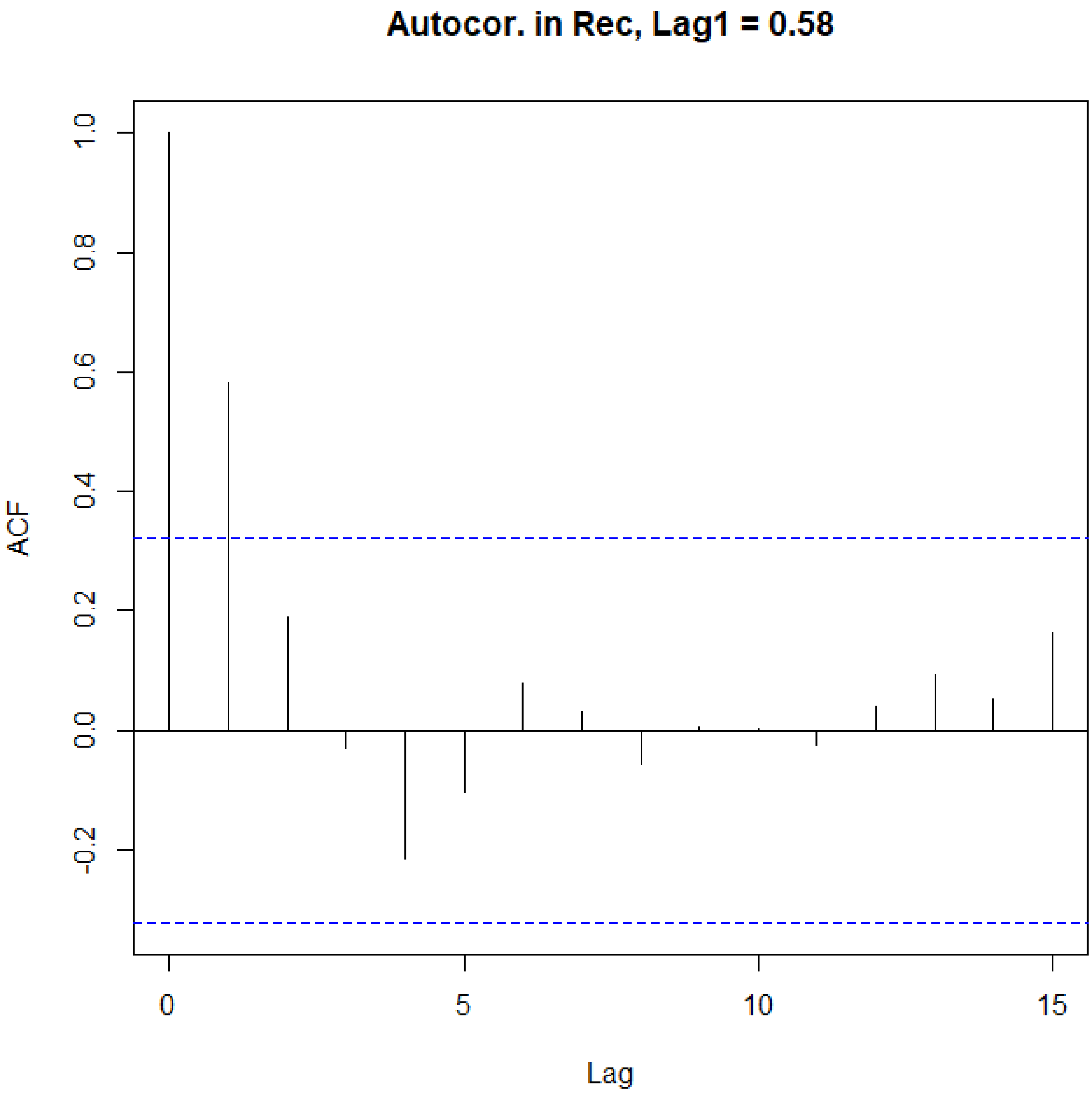


Figure 14. Autocorrelation in recruitment.

4.2 Results

4.2.1 B_{lim}, F_{lim}, and B_{pa}

No clear relation between SSB and recruitment could be seen, with no identifiable SSB level at which recruitment was impaired (Figure 15). Following ICES technical guidelines, we are therefore in a Type 5 stock situation, and B_{lim} should be equal to B_{loss} which is the lowest SSB observed historically. Based on the results from the new SAM model with the new mortalities, the lowest SSB was observed in 2007 and was 103 560 tonnes. Therefore, here B_{lim} = 103 560 tonnes. A segmented regression was used (Table 4).

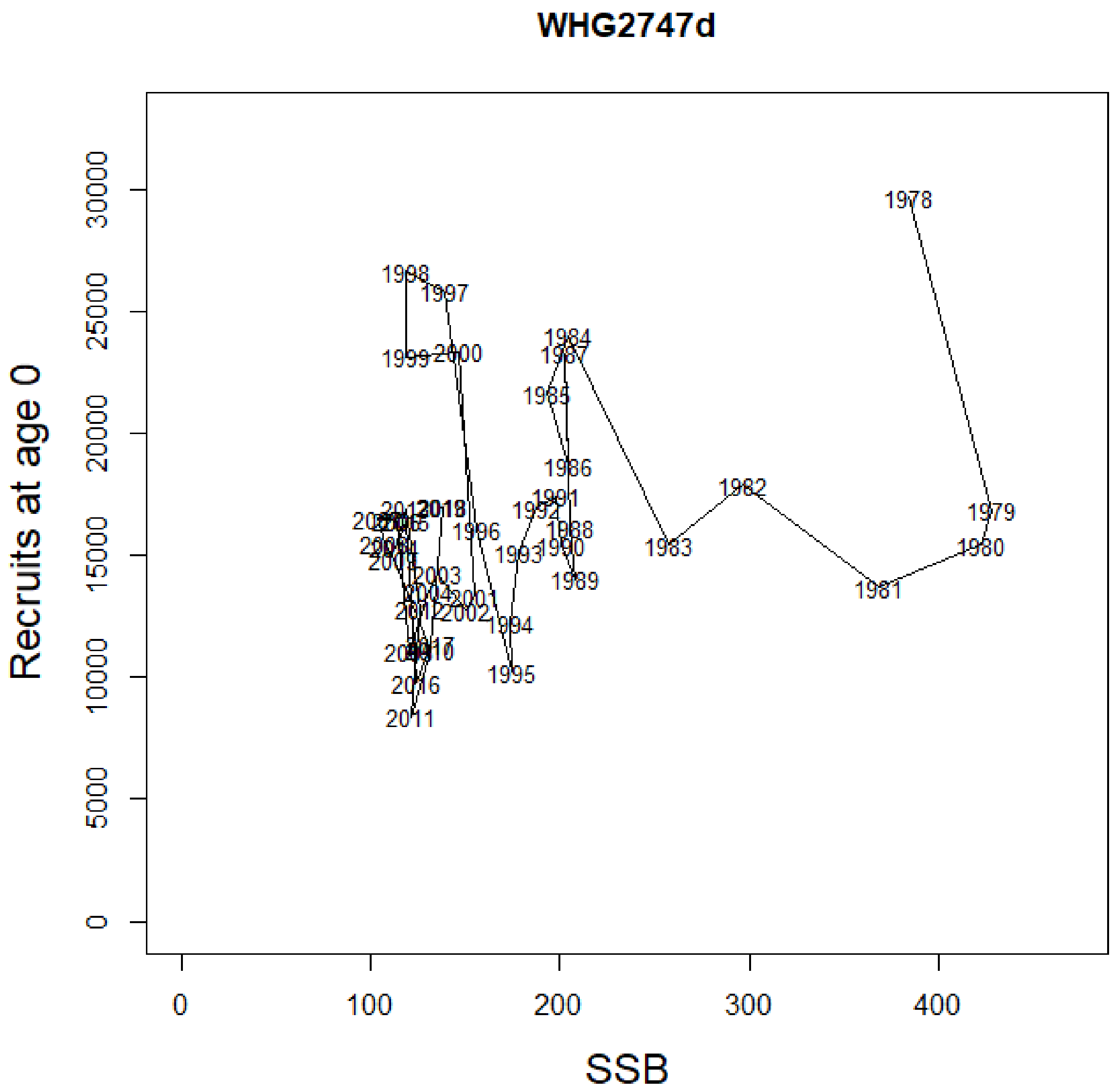


Figure 15. North Sea whiting: plot of age 0 recruits against SSB.

To estimate Flim, EqSim was run without assessment/advice error, without the advice rule. In the absence of a clear relation between SSB and recruitment (Figure 12), a segmented regression with the breakpoint fixed at B_{lim} for the spawning stock–recruitment relationship was used here to model recruitment in EqSim. The resulting F_{lim} (F_{50}) obtained was 0.718 (Table 5).

Table 5. EqSim run without advice/assessment error and without advice rule, to determine F_{lim} (segmented regression using B_{lim} as breakpoint).

	catF	lanF	catch	landings	catB	lanB
F_{05}	0.419946	NA	50189.82	NA	144881.4	NA
F_{10}	0.482387	NA	52943.77	NA	136387.5	NA
F_{50}	0.717769	NA	55239.73	NA	103549.4	NA
medianMSY	NA	0.64965	NA	56742.71	NA	115103.2
meanMSY	0.61	0.61	56456.28	56456.28	120415.4	120415.4
Medlower	NA	0.508509	NA	53920.76	NA	133047.3
Meanlower	NA	0.473784	NA	53409.39	NA	NA
Medupper	NA	0.738739	NA	53895.83	NA	98806.61
Meanupper	NA	0.704685	NA	53407.1	NA	NA

The B_{pa} value obtained based on B_{lim} was B_{pa} = 143 904.7 tonnes.

4.2.2 Unconstrained F_{MSY}

To estimate the unconstrained F_{MSY}, the EqSim was run without the advice rule (i.e. no MSY $B_{trigger}$), with assessment and advice error using the default values $(F_{cv}, F_{phi}) = (0.212, 0.423)$ as suggested by WKMSYREF4 (ICES, 2016b), and with a segmented relationship with a freely estimated breakpoint (Figure 16). The resulting unconstrained F_{MSY} obtained (median MSY for lanF) was F_{MSY} = 0.371 (Table 6). The corresponding equilibrium plots are shown in Figure 17.

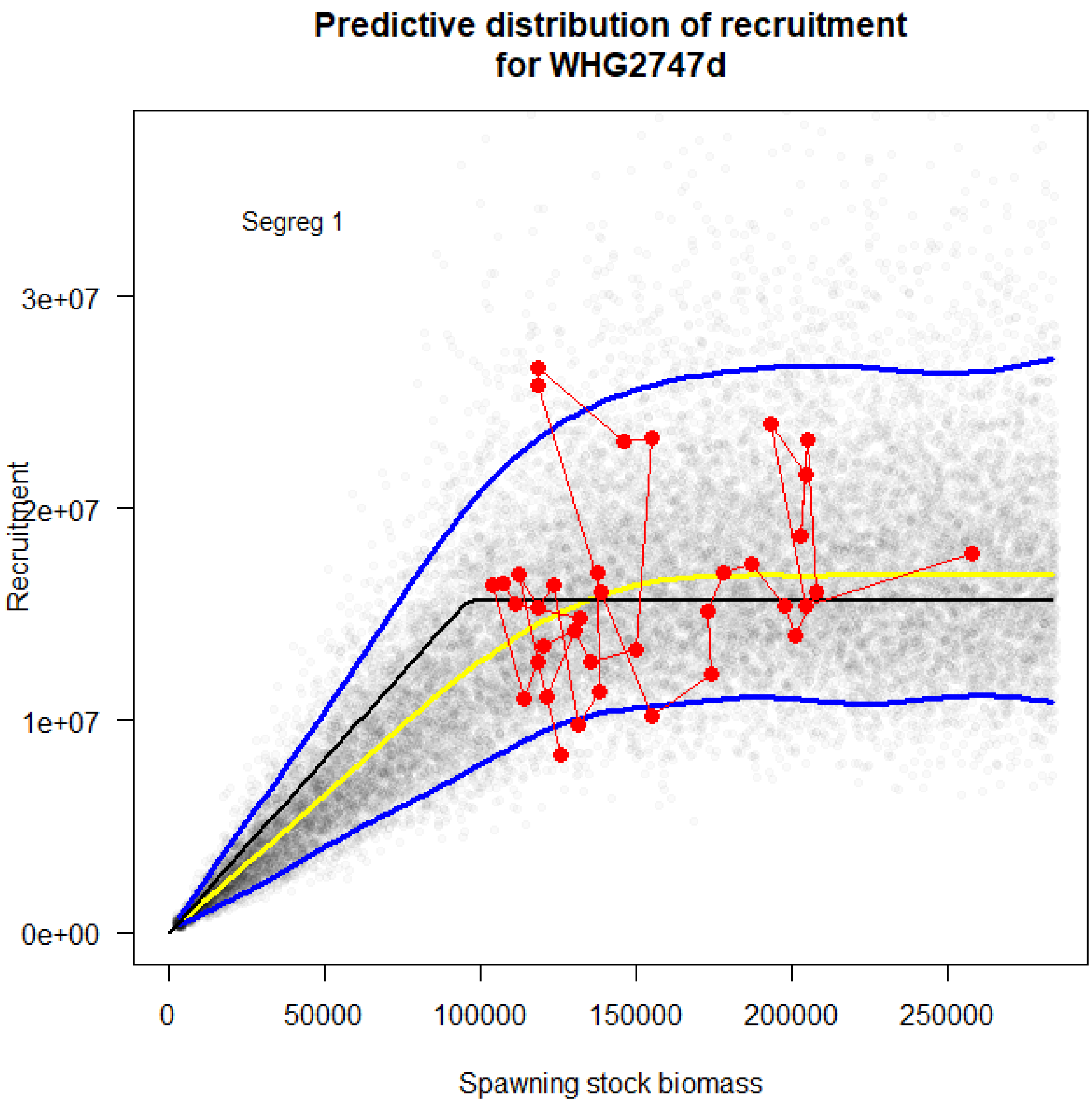


Figure 16. Segmented regression using a freely estimated breakpoint to fit the spawning stock–recruitment relationship.

Table 6. EqSim run with advice/assessment error and without advice rule, to determine unconstrained F_{MSY} (segmented regression with freely estimated breakpoint).

	catF	lanF	catch	landings	catB	lanB
F_{05}	0.309877	NA	45519.57	NA	171150.1	NA
F_{10}	0.345515	NA	46679.85	NA	160791.5	NA
F_{50}	0.492288	NA	39157.04	NA	103485.6	NA
medianMSY	NA	**0.371371**	NA	47002.28	NA	152844.9
meanMSY	0.35	0.35	46771.22	46771.22	159447.8	159447.8
Medlower	NA	0.293293	NA	44685.97	NA	175900.5
Meanlower	NA	0.27955	NA	45690.34	NA	NA
Medupper	NA	0.438438	NA	44732.2	NA	128587.1
Meanupper	NA	0.413333	NA	45733.68	NA	NA

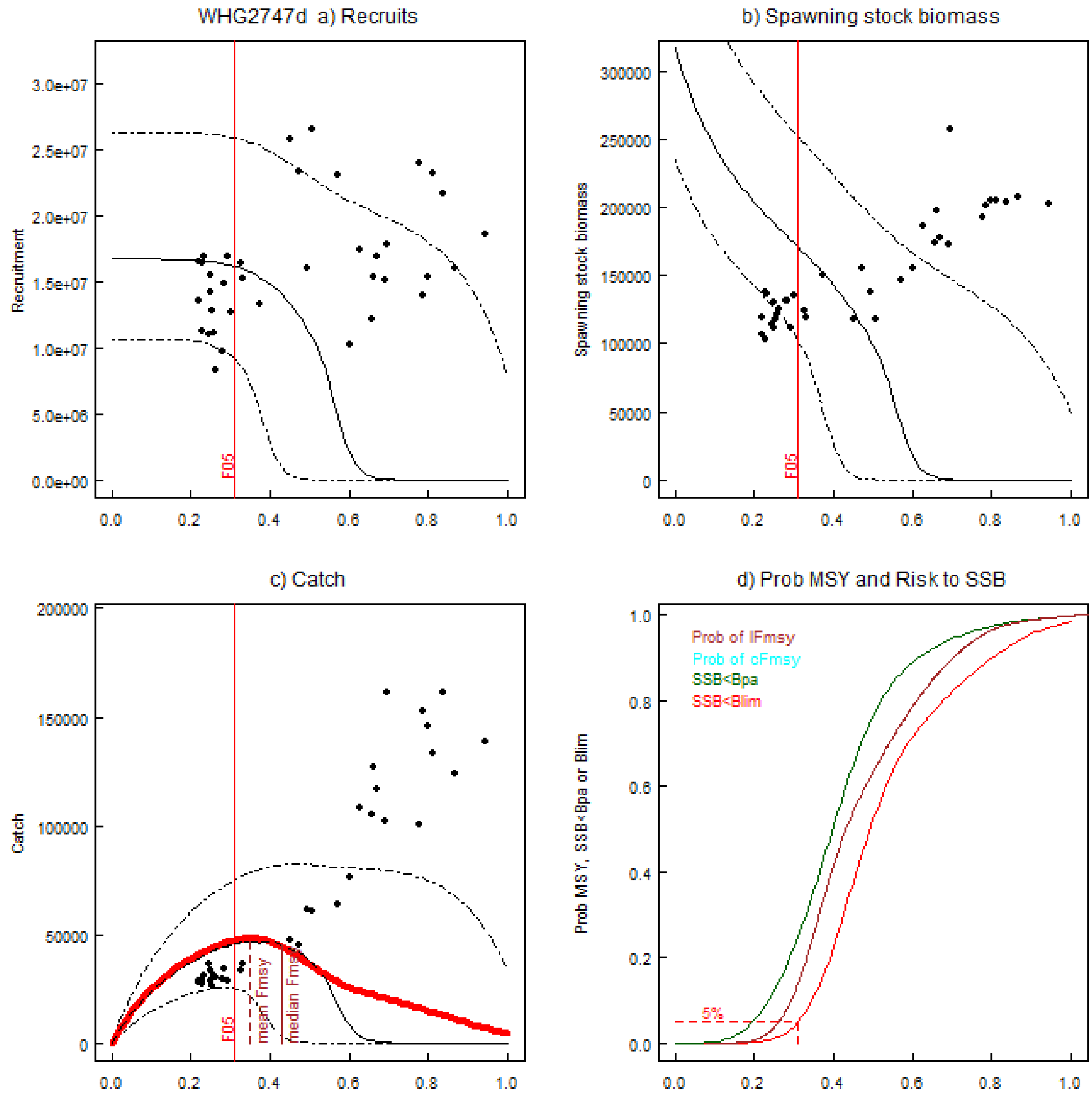


Figure 17. Equilibrium plots for the estimation of the initial (unconstrained) F_{MSY} (EqSim with assessment/advice error, and without advice rule, and with a segmented regression with freely estimated breaking point).

4.2.3 MSY $B_{trigger}$

For most stocks that lack data on fishing at F_{MSY}, MSY $B_{trigger}$ is set at B_{pa}. However, as a stock starts to be fished consistently with F_{MSY}, a value for MSY $B_{trigger}$ could be set to reflect the 5th percentile definition of MSY $B_{trigger}$. Here, the stock has been fished below F_{MSY} (0.371) for the last five years (Table 7). The 5th percentile of BF_{MSY} was calculated running an EqSim without assessment/advice error and without advice rule, using a segmented regression with freely estimated breakpoint (Figure 18). The 5th percentile of BF_{MSY} is estimated to be 74 787.67 tonnes which is less than B_{pa} (143 904.7 tonnes). Therefore, according to Figure 8 our MSY $B_{trigger}$ is B_{pa}, and MSY $B_{trigger}$ = 143 904.7 tonnes.

Table 7. Summary table (last five years only) of the new SAM assessment model results with the new mortalities and Q1 survey data starting in 1983.

	R(age 0)	Low	High	SSB	Low	High	Fbar(2-6)	Low	High
2015	15325623	11164841	21036996	118643	99997	140767	0.331	0.261	0.42
2016	16395911	11781584	22817467	123726	101755	150441	0.328	0.248	0.434
2017	9769782	6874175	13885105	131380	105324	163881	0.282	0.203	0.391
2018	11319642	7692210	16657670	138176	108070	176667	0.23	0.161	0.328
2019	16987139	10071546	28651300	137286	104506	180348	0.234	0.161	0.34
2020				160397	116840	220192			

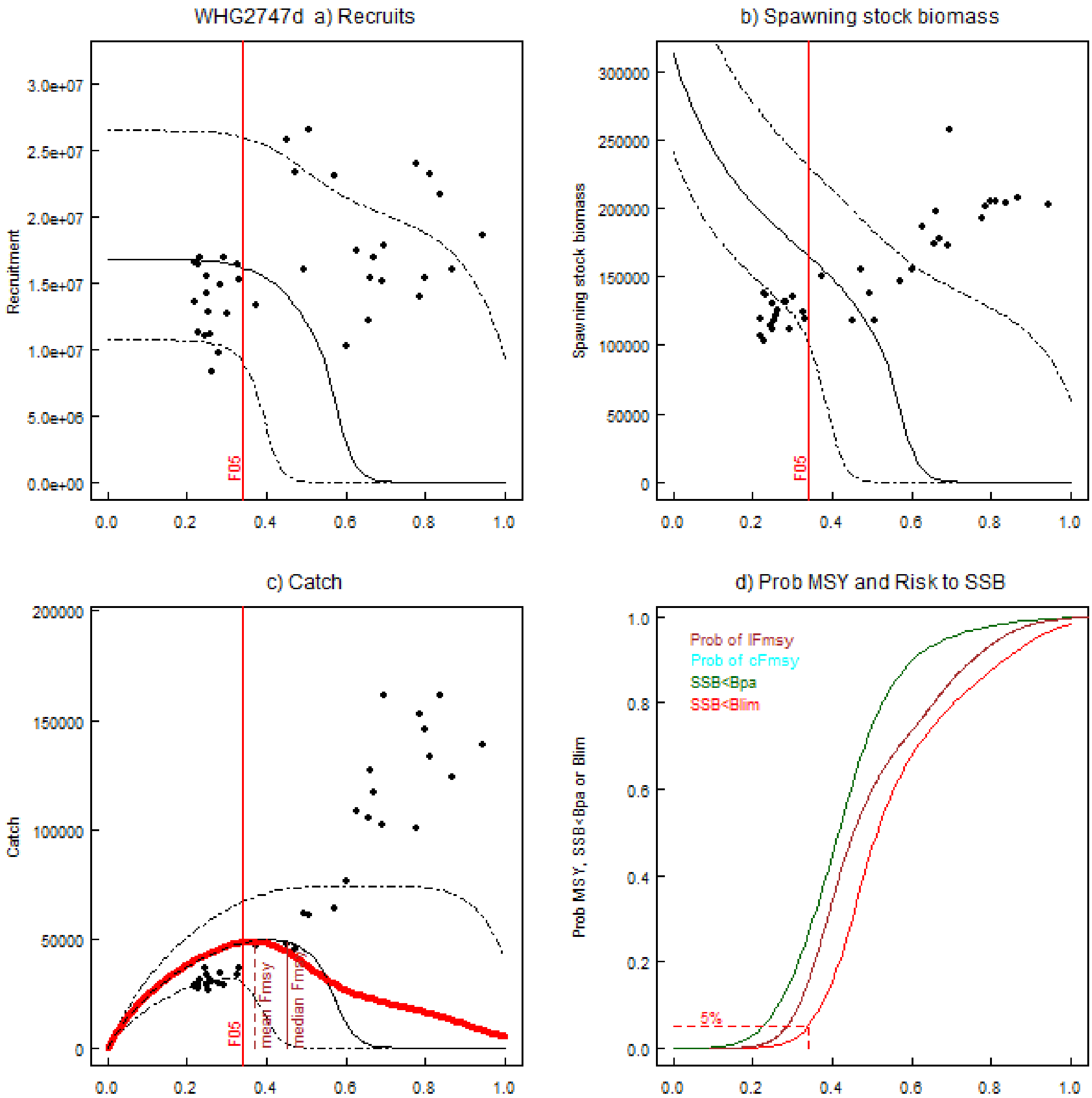


Figure 18. EqSim without assessment/advice error and without $B_{trigger}$, with a freely estimated breaking point of segreg to estimate the 5th percentile of BF_{MSY}.

4.2.4 $F_{p.05}$ and F_{pa}

$F_{p.05}$ was calculated by running EqSim with assessment/advice error and with advice rule to ensure that the long-term risk of SSB<B_{lim} of any F used does not exceed 5% when applying the advice rule (Figure 19).

$F_{p.05}$ was estimated to be 0.385 (Table 8). Therefore, as explained in section 1.3 above, F_{pa} = 0.385.

Since F_{MSY} (0.371) is smaller than F_{pa} (0.385), out F_{MSY} remains uncapped at 0.371.

Table 8. EqSim run with assessment/advice error, with advice rule to test whether F_{MSY} was at or below $F_{.05}$ (segmented regression with freely estimated breakpoint).

	catF	lanF	catch	landings	catB	lanB
F_{05}	**0.385274**	NA	49255.55	NA	156907	NA
F_{10}	0.450167	NA	50445.89	NA	144427.1	NA
F_{50}	0.763738	NA	44229.06	NA	103549.5	NA
Median MSY	NA	0.473473	NA	50527.3	NA	140376.9
Mean MSY	0.49	0.49	50490.82	50490.82	137642.6	137642.6
Median lower	NA	0.35035	NA	48024.89	NA	164343.3
Mean lower	NA	0.34991	NA	49657.96	NA	NA
Median upper	NA	0.62963	NA	48020.87	NA	118209.6
Mean upper	NA	0.697748	NA	49646.64	NA	NA

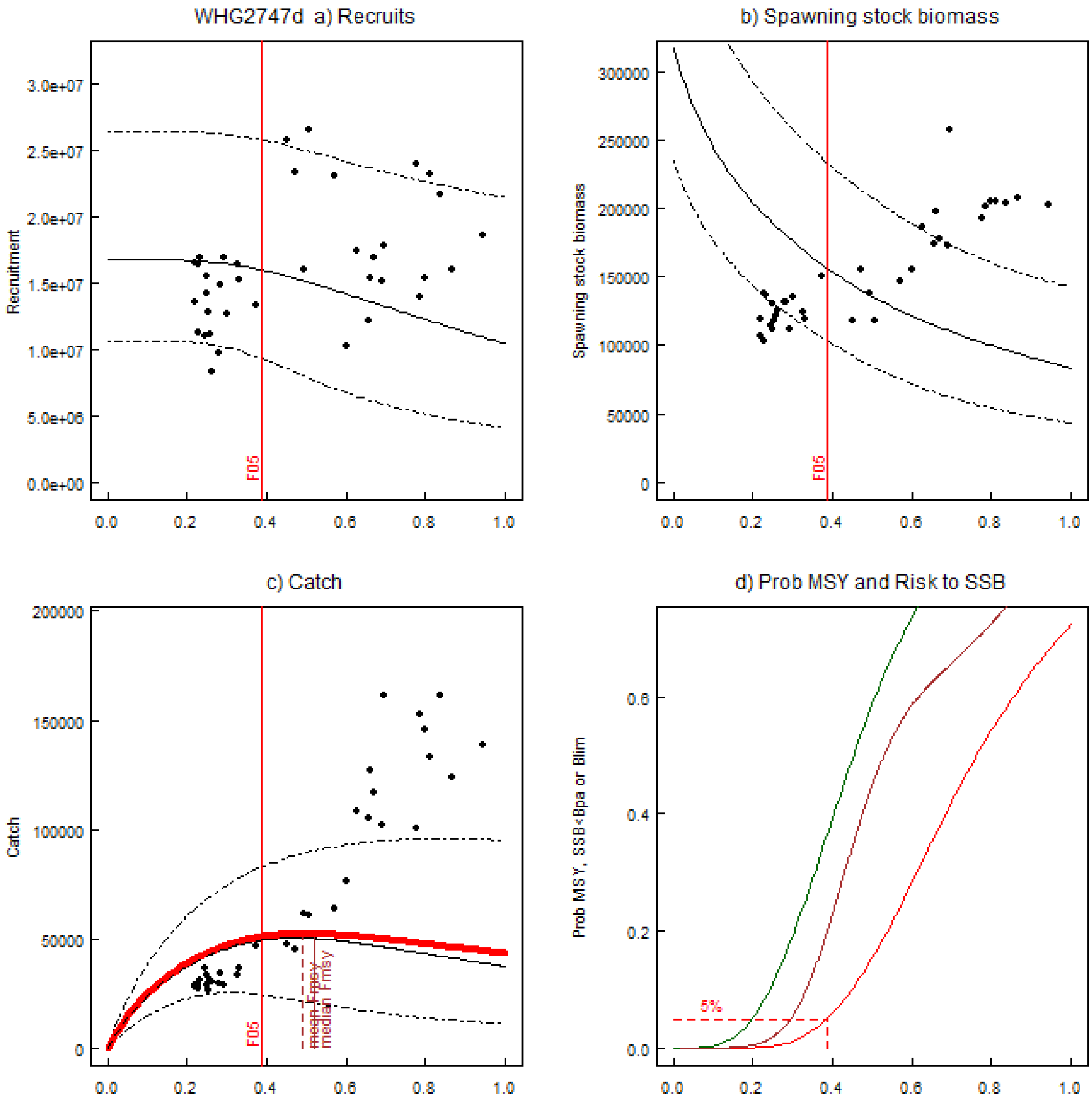


Figure 19. EqSim with assessment/advice error and $B_{trigger}$, and a freely estimated breakpoint for segreg to estimate F_{p05}.

4.3 Reference points summary table

Table 9. Reference points from final EqSim settings.

	$B_{trigger}$	B_{pa}	B_{lim}	F_{pa}	F_{lim}	F_{p05}	$F_{MSY\_unconstr}$	F_{msy}
Value	143905	143905	103560	0.385	0.718	0.385	0.371371	0.371

4.3.1 MSY ranges

The initially estimated F_{MSY} (0.371) was lower than $F_{p.05}$ (0.385). F_{MSY} is therefore uncapped at 0.371. However, the $F_{MSYupper}$ (0.438) obtained by estimating MSY and F_{MSY} without an MSY $B_{trigger}$ but including advice error in the evaluation was greater than $F_{p.05}$ (Figure 20). Following the guidelines, if the estimated $F_{MSYupper}$ exceeds the estimated $F_{p.05}$, $F_{MSYupper}$ is capped and specified as $F_{p.05}$, which was estimated with error and advice rule (ICES, 2016b). As a result, F_{MSY} ranges are as follows:

Table 10. MSY ranges.

Reference point	Value	Technical basis
$F_{MSYlower}$	0.293	$F_{MSYlower}$ (EqSim)
F_{MSY}	0.371	F_{MSY} (EqSim)
$F_{MSYupper}$	0.385	$F_{p.05}$

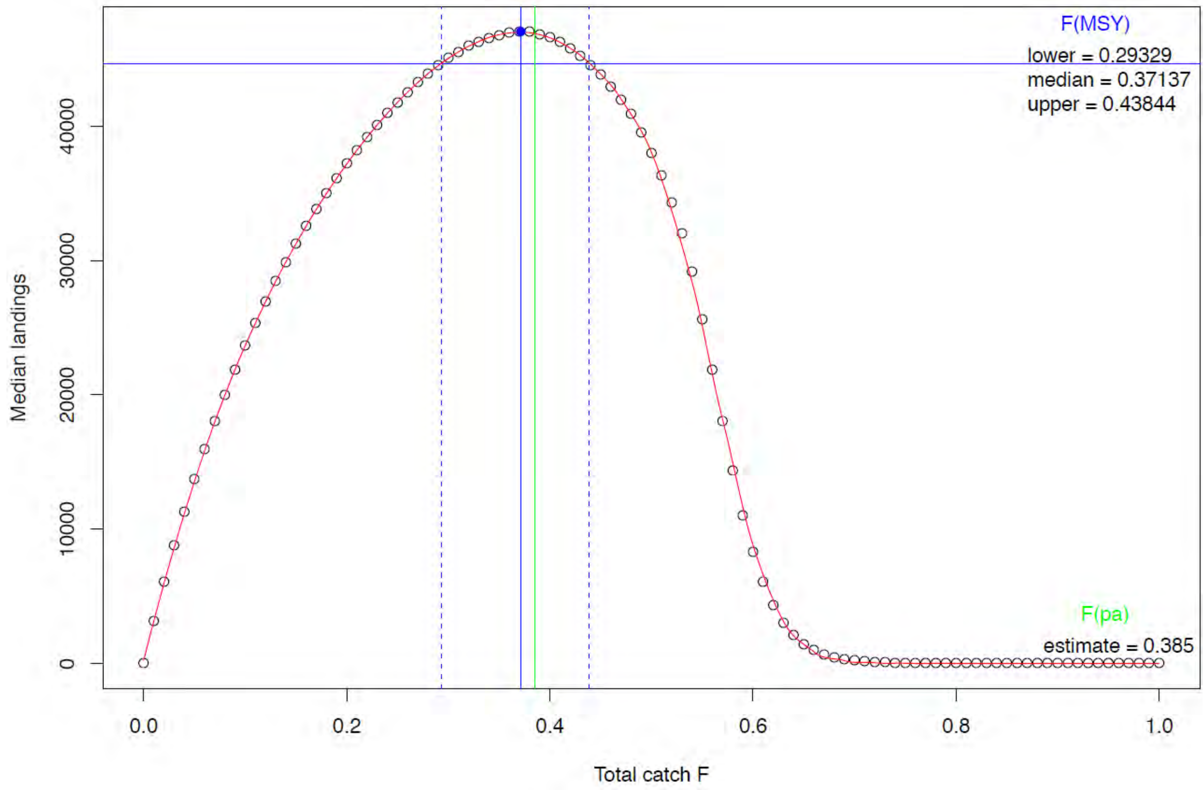


Figure 20. Median yield curve and upper and lower ranges (vertical dashed lines) for F_{msy}=0.371, as well as F_{pa} =$F_{p.05}$ (calculated with AR and errors) (green).

4.4 Comparison with previous reference points

In the last benchmark, the F_{MSY} and $F_{MSYupper}$ were estimated to be above $F_{p.05}$. Therefore, both F_{MSY} and $F_{MSYupper}$ were capped at F_{p05} (0.172). $F_{MSYlower}$ was in turn redefined as the lower fishing mortality providing 95% of the yield at $F_{p.05}$ ($F_{p.05lower}$) to obtain MSY ranges (Table 11). Here, the F_{MSY} estimated was found to be below $F_{p.05}$. Therefore, F_{MSY} is uncapped, however $F_{MSYupper}$ is capped at $F_{p.05}$. In summary, both the F_{MSY} and MSY ranges obtained here are larger than the ones previously estimated in the last benchmark (Table 11). B_{pa} and B_{lim} decreased compared to the last benchmark following the reduction in SSB level with the new natural mortalities.

Table 11. New reference points obtained with the new mortalities compared to the previous ones.

Reference point	New values	Values from 2018 benchmark
$F_{MSYlower}$	0.293	0.158
F_{MSY}	0.371	0.172
$F_{MSYupper}$	0.385	0.172
$B_{trigger}$	143905	166708
B_{pa}	143905	166708
B_{lim}	103560	119970
F_{pa}	0.385	0.325
F_{lim}	0.718	0.452
F_{p05}	0.385	0.172
$F_{msy\_unconstr}$	0.371	0.373

5 Reviewer's comments

I would like to thank the stock assessors for making a clear and concise presentation of the updated assessment, which was extremely helpful as the meeting was scheduled on short notice. The benchmark was conducted virtually which, given the issues that were to be addressed, worked well. The terms of reference for this inter-benchmark, i.e. update the assessment with the most recent estimate for natural mortality from WGSAM and review and update precautionary and MSY reference points, were met in full. In general, the updates to the assessment methodology and reference points appear to be in line with ICES guidelines and suitable as the basis of advice as ICES category 1 assessment.

Tor A

The stock assessment of NS whiting was performed using SAM with the same settings as in the benchmark. To test the effect of the new natural mortality estimates (M) to the assessment four model variants were presented:

1. Old M estimates and full survey time-series (WGNSSK 2020 assessment);
2. Old M estimates and survey time-series starting 1983;
3. The benchmark assessment in 2017;
4. New M estimates and survey time-series starting 1983.

where the reason for the inclusion of the full survey time-series was that it had been erroneously included into the assessment of NS Whiting since the benchmark. The results of this comparison indicated that including the full time-series did not affect the perception of the stock. The new M values did however result in an upwards revision of recruitment and fishing morality values and downwards revision of SSB in recent years, which is expected as the most recent SMS key-run estimated higher Ms on the youngest age groups. This change in M was attributed to a recent update in the method of determining stock weights at the 2017 benchmark, which was first included in the SMS key-run in 2020.

With respect to fit to data all four model variants appeared to fit equally to the survey and catch-at-age. An analytical retrospective analysis revealed a downwards revision of SSB estimates for all years resulting in a Mohn's rho slightly above 0.2. While this is the threshold determined by WKFORBIAS for biased assessments this is considered to be acceptable as long as the bias does not increase.

Tor B

The Precautionary Approach and MSY reference points were calculated in line with ICES guidelines. As in the benchmark B_{lim} was set as B_{loss}, which was based on a classification of the SSB–recruitment relationship as Type 5 ("Stocks showing no evidence of impaired recruitment or with no clear relation between stock and recruitment (no apparent S–R signal)"). As the estimate of B_{loss} was revised the reference points needed to be updated. The derivation of other reference points followed the same procedure as in the WKNSEA (2018).

The derivation of F_{pa} was the subject of considerable discussion during the meeting as the estimate of F_{pa} had changed dramatically since WKNSEA (2018), from 0.17 to 0.38. Although the changes to the assessment appear to be minor and does not warrant such as steep increase in the assessment, it is very likely that this change is the result of a combination of factors. The estimate of B_{lim} and B_{pa} is now lower, and while M on the youngest age groups is higher it has decreased substantially in recent years and is now estimated to be lower than the previous estimate for 2016 from WGSAM. This appears to have the effect that the estimated productivity of the stock has now increased in the projections resulting in a higher estimate of F_{pa}.

It is however worth noting that the results from the forward projections suggest that when fishing at F_{MSY} the median SSB will be at SSB $B_{trigger}$, suggesting that the realised fishing mortality will be less than F_{MSY}.

6 References

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Annex 1: List of participants

Name	Institute	Country (of institute)	Email
Alan Baudron	MSS	United Kingdom	Alan.Baudron@gov.scot
Bjarki Þór Elvarsson (Reviewer)	Marine and Freshwater Institute	Iceland	bjarki.elvarsson@hafogvatn.is
Colm Lordan	ICES	Denmark	Colm.lordan@ices.dk
Ghislain Chouinard	ICES	Denmark	ghislain@ices.dk
Raphael Girardin	IFREMER	France	Raphael.Girardin@ifremer.fr
Sarah Louise Millar	ICES	Denmark	sarah-louise.millar@ices.dk
Tanja Miethe	MSS	United Kingdom	t.miethe@marlab.ac.uk
Timothy Earl (Chair)	Cefas	United Kingdom	Timothy.earl@cefas.co.uk