8 Northeast Atlantic Mackerel

8.1 ICES Advice and International Management Applicable to 2021

From 2001 to 2007, the internationally agreed TACs covered most of the distribution area of the Northeast Atlantic mackerel. From 2008 to 2014, no agreement was reached among the Coastal States on the sharing of the mackerel quotas. In 2014, three of the Coastal States (European Union, Norway and the Faroe Islands) agreed on a Management Strategy for 2014 to 2018. In November 2018, the 2014 agreement was extended for a further two years until 2020. No agreement on the share of the stock has been reached for 2021 and 2022. Despite various agreements, the total declared quotas in each of the years 2015 to 2021 all exceeded the TAC advised by ICES. An overview of declared quotas and transfers for 2022, as available to WGWIDE, is given in the text table below. An estimate of the expected quota uptake in 2022 was carried out based on the fishery up to the end of August 2022 and knowledge of the fishery development from September to December 2021. Total removals of mackerel are expected to be approximately 1.1 million tonnes in 2022, exceeding the ICES advice for 2022 by approximately 336 500 tonnes (30%).

The quota figures and transfers in the text table below were based on national regulations, official press releases, and discard estimates.

Various international and national measures to protect mackerel are in operation throughout the mackerel catching countries. Refer to the stock annex for an overview.

Estimation of 2022 catch (t)	Unilateral quotas	Reference	Expected uptake	Justification
EU quota	183 359	Record of fisheries consultations between the United Kingdom and the European Union for 2022	183 359	Full uptake
UK quota	210 820	Footnote [1]	210 820	Full uptake
Norwegian quota	278 222	NEAFC HOD 04/2022	278 222	Full uptake
Inter-annual quota transfer to 2022	23 763	NEAFC HOD 04/2022	23 763	Full uptake
Russian expected catches 2022	-	Last year's quota	112 319	Russian expected catch [3]
Icelandic quota	120 210	Footnote [2]	120 210	Icelandic expected catch [4]
Inter-annual quota transfer to 2022 plus special quota	28 026	Footnote [2]	9 790	Icelandic expected catch [4]
Faroese quota	155 804	Faroese Fisheries Ministry regulations No. 182/2022	155 804	Faroese expected catch [4]
Inter-annual quota transfer to 2022	20 905	Faroese Fisheries Ministry regulations No. 182/2022	0	

Estimation of 2022 catch (t)	Unilateral quotas	Reference	Expected uptake	Justification
Greenland quota	51 670	Ministry of Fisheries, Hunting and Agriculture, Greenland	34 000	Greenland expected catch [4]
Discards	3 129	Previous years estimate	3 129	Previous years estimate
Total expected catch (incl. discards) [5, 6]			1 131 416	tonnes

[1]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1059641/Outcomes_of_annual_negotiations_for_UK_fishing_opportunities_in_2021_and_2022.pdf
[2]https://www.fiskistofa.is/veidar/aflaupplysingar/heildaraflamarksstada/?timabil=2122&fyrirsp=4&lang=is&landhelgi=U
[3] **The Russian estimated uptake in 2022 was set as the Russian quota in 2021 scaled by the reduction of the ICES advised TAC from 2021 to 2022 (-6.7%).**
[4] **The estimated catch of mackerel in 2022 was obtained by summing recorded catches as of August 25th 2022 and the catches from that date to end of the fishing season 2021, assuming a similar development in the fishery for the remainder of the 2022 season as in 2021.**
[5] **Quotas refer to claims by each party for 2022 and include exchange to other parties.**
[6] **No estimates of banking from 2022 to 2023 are available.**

8.2 The Fishery

8.2.1 Fleet Composition in 2021

The total fleet can be considered to consist of the following components: freezer trawlers, purse seiners, pelagic trawlers, lines and jigging, and gillnets (see stock annex for detailed description of each component).

8.2.2 Fleet Behaviour in 2021

The northern summer fishery in Subarea 2 continued and increased significantly in 2021 with Norway reporting 80% of their catches in Division 2.a quarter 3. There was no fishery in Subarea 14 and a reduced fishery in Subarea 5. The Russian freezer trawler fleet operates over a wide area in northern international waters. This fleet targets herring and blue whiting in addition to mackerel. In 2021 the Russian vessels took the vast majority of their catch in Division 2.a.

Total catches from Icelandic vessels were similar to those in recent years and were in excess of 100 kt. The majority of the catch was taken in Division 2.a in quarter 3 of 2021, with very small catch also taken in Divisions 5.a and 5.b. In 2021 Greenland targeted mackerel in Division 2.a with no catch taken from Division 14.b. In 2019 Greenland fished in Division 14.b and in 2018 both Greenland and Iceland reported landings from this area. Catches from Greenland have increased in 2021 to 33kt up from 27 kt in 2021 but lower than the peak of 63 kt in 2018. The Faroese fleet targeted mackerel during quarters 2,3 and 4 with 96% of the catches taken in Division 2.a. The remaining catch was taken in Division 5.b in quarter 2. No catch was reported from Divisions 4.a or 6.a as had been in previous years.

Fishing in the North Sea and west of the British Isles followed a traditional pattern, targeting mackerel on their spawning migration from the Norwegian deep in the northern North Sea, westwards around the north coast of Scotland and down the west coast of Scotland and Ireland. The majority of the Irish mackerel fishery took place in quarter 1 along the west coast of Scotland and Ireland, with the Scottish fleet operating in the same area at this time. The Scottish fishery in quarter 4 was more concentrated in the North Sea where 51% of the Scottish catch was taken.

In 2021 the Spanish fishery started at the beginning of March, as in previous years.

8.2.3 Recent Changes in Fishing Technology and Fishing Patterns

Northeast Atlantic mackerel, as a widely distributed species, is targeted by a number of different fishing métiers. Most of the fishing patterns of these métiers have remained unchanged during the most recent years (see stock annex), although the variation in timing of the spawning migration and geographical distribution can change from year to year and this affects the fishery in various areas. The most important changes in recent years are related to the geographical expansion of the northern summer fishery (Subareas 2, 5 and 14) and changes in southern waters due to stricter TAC compliance by Spanish authorities. In 2020 and 2021 the northern summer fishery did not extend as far west as in previous years. In 2021 the summer fishery in Division 2.a increased substantially. The annual fishing pattern by statistical rectangle from 2003-2021 is shown in Section 1.8.

8.2.4 Recent regulations and management

Currently there is no agreement on a management strategy covering all parties fishing mackerel.

An overview of the technical measures, effort controls and management plans are given in the stock annex. Note that there may be additional existing international and national regulations that are not listed.

8.3 Quality and Adequacy of sampling Data from Commercial Fishery

The sampling of the commercial catch of Northeast Atlantic mackerel is summarised below:

Year	WG Total Catch (t)	% catch covered by sampling programme*	No. Samples	No. Measured	No. Aged
1992	760000	85	920	77000	11800
1993	825000	83	890	80411	12922
1994	822000	80	807	72541	13360
1995	755000	85	1008	102383	14481
1996	563600	79	1492	171830	14130
1997	569600	83	1067	138845	16355
1998	666700	80	1252	130011	19371
1999	608928	86	1109	116978	17432
2000	667158	76	1182	122769	15923
2001	677708	83	1419	142517	19824
2002	717882	87	1450	184101	26146

Year	WG Total Catch (t)	% catch covered by sampling programme*	No. Samples	No. Measured	No. Aged
2003	617330	80	1212	148501	19779
2004	611461	79	1380	177812	24173
2005	543486	83	1229	164593	20217
2006	472652	85	1604	183767	23467
2007	579379	87	1267	139789	21791
2008	611063	88	1234	141425	24350
2009	734889	87	1231	139867	28722
2010	877272	91	1241	124695	29462
2011	948963	88	923	97818	22817
2012	899551	89	1216	135610	38365
2013	938299	89	1092	115870	25178
2014	1401788	90	1506	117250	43475
2015	1215827	88	2132	137871	24283
2016	1100135	89	2200	149216	21456
2017	1159641	87	2183	151548	24104
2018	1023144	83	1858	139590	20703
2019	839727	88	1835	141561	17646
2020	1039513	87	1430	142991	15685
2021	1081540	79	1783	76325	18736

Overall sampling effort in 2021 was lower than previous years with 79 % of the catch sampled. It should be noted that this proportion is based on the total sampled catch and in 2021 there was no sampling reported from Russia. Nations with large, directed fisheries are capable of sampling 100 % of their catch which may conceal deficiencies in sampling elsewhere.

The 2021 sampling levels by country are shown below.

Country	Official catch	% WG catch covered by sampling programme	No. Samples	No. Measured	No. Aged
Belgium	110	0%			
Denmark	32813	93%	5	111	111
Faroe Islands	105096	98%	20	1001	960

Country	Official catch	% WG catch covered by sampling programme	No. Samples	No. Measured	No. Aged
France	16686	0%			
Germany	11996	92%	34	6389	310
Greenland	33360	100%	23	1768	138
Iceland	132109	96%	108	2823	4810
Ireland	60795	96%	51	8971	1899
Lithuania	6655	0%			
Netherlands	24594	92%	34	2450	844
Norway	270653	96%	92	2423	2336
Poland	1779	0%			
Portugal	4723	20%	77	2287	897
Russia	136176	0%			
Spain	30085	99%	1134	32868	3207
Sweden	3514	0%			
UK (England & Wales)	22094	54%	154	9533	1747
UK (Northern Ireland)	16464	50%	1	164	50
UK (Scotland)	171840	92%	50	5537	1427

The majority of countries achieved a high level of sampling coverage. Belgian catches consist of by-catch in the demersal fisheries in the North Sea. France supplied a quantity of length-frequency data to the working group which can be utilised to characterise the selection of the fleet but requires an allocation of catch at age proportions from another sampled fleet in order to raise the data for use in the assessment. Russia, Sweden, Lithuania and Poland did not supply sampling information in 2021. Portugal sampled landings from 9.a only. England sampled landings from the handline fleet operating off the Cornish coast as well as from freezer trawlers. Cooperation between the Dutch and German sampling programmes is designed to provide complete coverage for the freezer trawlers operating under these national flags and also those of England and France. Catch sampling levels per ICES Division (for those with a WG catch of >100 t) are shown below.

Division	Official Catch (t)	WG Catch (t)	No. Samples	No. Measured	No Aged
1	0.03	0.03	0	0	0
2.a	657905	657905	238	7828	8095
3.a	439	439	0	0	0
3.b	19	19	0	0	0

Division	Official Catch (t)	WG Catch (t)	No. Samples	No. Measured	No Aged
3.c	24	24	0	0	0
3.d	59	59	0	0	0
4.a	216985	216985	96	12866	2244
4.b	2837	2837	0	0	0
4.c	1078	1078	1	92	25
5.a	933	933	1	34	25
5.b	4273	4273	2	102	75
6.a	146583	146583	75	10372	2250
6.b	52	52	0	0	0
7.a	11	11	0	0	0
7.b	2778	2778	3	366	102
7.c	124	124	1	46	25
7.d	6180	6180	1	59	25
7.e	808	808	71	3747	1466
7.f	258	258	75	5016	82
7.g	12	12	0	0	0
7.h	38	38	1	111	25
7.j	2740	2740	6	476	168
8.a	1096	1096	1	54	1
8.b	4338	4338	196	3950	66
8.c	29120	29120	569	22553	2504
8.d	40	40	0	0	0
8.e	0.0096	0.0096	0	0	0
9.a	2807	2807	446	8653	1558

In general, areas with insufficient sampling have relatively low levels of catch.

8.4 Catch Data

8.4.1 ICES Catch Estimates

Missing 2021 data

In 2022, WGWIDE did not receive a data submission from Russia with the 2021 catch and sampling information. Preliminary catch data were available for 2021 from Russia and were reported by ICES division by year. From 2018-2020 the Russian catch accounted for an average of 13% of the total working group catch. The preliminary figure for 2021 also represents 13% of the total working group catch. Historically, preliminary catches are comparable to ICES final estimated catch.

The majority of the Russian catch was from ICES division 2.a and a three year average (2018-2020) was used to distribute the data by quarter. This resulted in the data assigned 7% in quarter 2, 92% in quarter 3 and 1% in quarter 4. The remaining data was from Division 5.b and was all assumed to be taken in quarter 3 as has been the case in previous years by the Russian fleet.

Catch maps were produced by country to determine the fishing pattern particularly in Division 2.a quarter 3. The Russian fishery is concentrated mainly in Division 2.a with an average of 90% of the catch from Division 2.a.1 and a consistent distribution of the fishery in the last three years. Iceland and the Faroes also fish in a similar area to the Russian fleet and use similar gear. Comparisons of the age and length data from Division 2.a quarter 3 were presented and a decision made to use samples from Iceland and the Faroes to allocate to the Russian catches.

Total Catch 2021

The total ICES estimated catch for 2021 was 1 081 540 tonnes, an increase from 1 039 513 tonnes in 2020.

The combined 2021 TAC, arising from agreements and autonomous quotas, amounts to 1 199 103 tonnes. The ICES catch estimate (1 081 540 tonnes) represents an undershoot of this but is still above the ICES advice of 852 284 tonnes for 2021. The combined fishable TAC for 2022, as best ascertained by the Working Group (see Section 8.1), amounts to 1 131 416 tonnes.

Catches reported for 2021 and in previous Working Group reports are considered to be best estimates. In most cases, catch information comes from official logbook records. Other sources of information include catch processors. Some countries provide information on discards and slipped catch from observer programs and compliance reports. In several countries discarding is illegal. Spanish data is based on the official data supplied by the Fisheries General Secretary (SGP) but supplemented by scientific estimates which are recorded as unallocated catch in the ICES estimates. A detailed basis for the ICES catch estimates is presented in the stock annex.

The total catch as estimated by ICES is shown in Table 8.4.1.1. It is broken down by ICES area group and illustrates the development of the fishery since 1969.

Discard Estimates

With a few exceptions, estimates of discards have been provided to the Working Group for the ICES Subareas and Divisions 6, 7/8.a,b,d,e and 3/4 (see Table 8.4.1.1) since 1978. Historical discard estimates were revised during the data compilation exercise undertaken for the 2014 benchmark assessment (ICES, 2014). The Working Group considers that the estimates for these areas are incomplete. In 2021, discard data for mackerel were provided by France, Ireland, Spain, Denmark, England, Scotland and Sweden. Total discards amounted to 3 129 tonnes which is a decrease from 2020. The German, Dutch and Portuguese pelagic discard monitoring programmes did not record any instances of discarding of mackerel. Estimates from the other countries supplying data include results from the sampling of demersal fleets.

8.4.2 Distribution of Catches

A significant change in the fishery took place between 2007 and 2009 with a greatly expanded northern fishery becoming established. This fishery has continued to the present but with a clear tendency for an eastern retraction, especially from the Greenlandic area and also western parts of the Icelandic area in the most recent three years. In 2021 there was only a small amount of catch from southern Iceland with the fishery moving further east. Of the total catch in 2021, Norway accounted for the greatest proportion (25%) followed by Scotland (16%), Russia (13%), Iceland (12%), Faroes (10%) and Ireland (6%). In the absence of sharing arrangements, the fishing parties declared unilateral quotas for 2021.

In 2021, catches in the northern areas (Subareas 1, 2, 5, 14) increased significantly and amounted to 663 111 tonnes (see Table 8.4.2.1), an increase of 306 126 tonnes on the 2020 catch. Norwegian catches were over 270 kt and Icelandic, Russian, Scottish and Faroese catches were all over 100 kt. Catches from Division 2.a accounted for 61% of the total catch in 2021. The wide geographical distribution of the fishery noted in previous years has continued.

The time series of catches by country from the North Sea, Skagerrak and Kattegat (Subarea 4, Division 3.a) is given in Table 8.4.2.2. Catches in 2021 decreased to 221 340 tonnes from 457 211 tonnes in 2020. The majority of the catch is from Subarea 4 with small catches were also reported in Divisions 3.a-d.

Catches in the western area (Subareas 6, 7 and Divisions 8.a, b, d and e) decreased in 2021 to 165 060 tonnes. This is a decrease of around 22 000 t from 2020. The catches are detailed in Table 8.4.2.3.

Table 8.4.2.4 details the catches in the southern areas (Divisions 8.c and 9.a) which are taken almost exclusively by Spain and Portugal. The reported catch in 2021 of 31 928 tonnes represents a decrease of almost 5 600 tonnes from 2020. The catch is above the long-term average.

The distribution of catches by quarter (%) is described in the text table below:

Year	Q1	Q2	Q3	Q4
1990	28	6	26	40
1991	38	5	25	32
1992	34	5	24	37
1993	29	7	25	39
1994	32	6	28	34
1995	37	8	27	28
1996	37	8	32	23
1997	34	11	33	22
1998	38	12	24	27
1999	36	9	28	27

Year	Q1	Q2	Q3	Q4
2000	41	4	21	33
2001	40	6	23	30
2002	37	5	29	28
2003	36	5	22	37
2004	37	6	28	29
2005	46	6	25	23
2006	41	5	18	36
2007	34	5	21	40
2008	34	4	35	27
2009	38	11	31	20
2010	26	5	54	15
2011	22	7	54	17
2012	22	6	48	24
2013	19	5	52	24
2014	20	4	46	30
2015	20	5	44	31
2016	23	4	44	29
2017	24	3	45	28
2018	20	3	40	37
2019	28	5	42	26
2020	31	4	34	31
2021	19	5	56	20

The quarterly distribution of catch from 2010- 2020 is similar to recent years with the northern summer fishery in Q3 accounting for the greatest proportion of the total catch. The average proportion taken in quarter 3 from 2010-2020 is 46%. In 2021 this proportion increased to 56% and is higher than the quarter 1 and quarter 4 catches which when combined account for 39% of the total. The proportion of the catch taken in quarter 2 has remained stable.

Catches per ICES statistical rectangle are shown in Figures 8.4.2.1 to 8.4.2.4. It should be noted that these figures are a combination of official catches and ICES estimates and may not indicate the true location of the catches or represent the location of the entire stock. These data are based on catches reported by all the major catching nations and represents almost the entire ICES estimated catch except Russia.

- First quarter 2021 (208 190 tonnes – 19%)

The distribution of catches in the first quarter is shown in Figure 8.4.2.1. The proportion of the fishery taken in quarter 1 has decreased in 2021 with the Scottish and Irish pelagic fleets targeting mackerel in Divisions 6.a, 7.b and 7.j. Substantial catches are also taken by the Dutch owned freezer trawler fleet. The largest catches were taken in Division 6.a, as in recent years. The Spanish fisheries also take significant catches along the north coast of Spain during the first quarter.

- Second quarter 2021 (55 707 tonnes – 5%)

The distribution of catches in the second quarter is shown in Figure 8.4.2.2. The quarter 2 fishery is traditionally the smallest and this was also the case in 2021. The most significant catches where those in Division 8.c and at the start of the summer fishery in northern waters by Icelandic, Norwegian and Russian fleets in Division 2.a.

- Third quarter 2021 (599 548 tonnes – 56%)

Figure 8.4.2.3 shows the distribution of the quarter 3 catches. Large catches were taken throughout Division 2.a, with high concentrations in international waters. Fishing was carried out mainly by vessels from Russia, Norway, Iceland, the Faroes and Greenland. There were also catches from Division 4.a but very little from Division 5.a.

- Fourth quarter 2021 (218 186 tonnes – 20%)

The fourth quarter distribution of catches is shown in Figure 8.4.2.4. The proportion of the catch taken in the fourth quarter has decreased from 31 % in 2020 to 20% in 2021. The summer fishery in northern waters has largely finished with some catches reported from Division 2.a. The largest catches in quarter 4 are taken by Scotland around the Shetland Isles in Division 4.a.

8.4.3 Catch-at-Age

This catch in numbers relates to a total ICES estimated catch of 1 081 540 tonnes. These figures have been appended to the catch-at-age assessment table (see Table 8.7.1.2).

Age distributions of commercial catch were provided by Denmark, England, Germany, Faroes, Iceland, Ireland, the Netherlands, Norway, Portugal, Scotland, Northern Ireland and Spain. There remain gaps in the age sampling of catches, notably from France (length samples were provided), Russia, Sweden, Lithuania and Poland.

Catches for which there were no sampling data were converted into numbers-at-age using data from the most appropriate fleets. Accurate national fleet descriptions are required for the allocation of sample data to unsampled catches.

The catch numbers at age show a number of strong year classes in this fishery. Over 85 % of the catch in numbers in 2021 consists of 2 to 10-year olds with the 2016-year class being the strongest. The 2016 year-class was strong in the fishery in previous years and accounted for 14% of the catch numbers at age in 2021. The 2019-year class, which are now 2 years old accounts for 13% of the catch numbers at age and were not evident in the fishery before. The 2015 year-class does not look as strong as the other year classes and represents 7 % of the total. In 2021 there is a decrease in the proportion of fish in the plus group from 7% in 2020 to 5% in 2021. Year classes from 2009 and earlier are now in the plus group.

There is a small presence of juvenile (age 0) fish within the 2021 catch. As in previous years catches from Divisions 8.c and 9.a have contained a proportion of juveniles.

8.5 Biological Data

8.5.1 Length Composition of Catch

The mean length-at-age in the catch for 2021 is given in Table 8.5.1.1.

For the most common ages which are well sampled there is little difference to recent years. The length of juveniles is traditionally rather variable. The range of lengths recorded in 2021 for 0 group mackerel is 180mm-222 mm. The rapid growth of 0-group fish combined with variations in sampling between northern and southern areas will contribute to the observed variability in the observed size of 0-group fish. Growth is also affected by fish density as indicated by a recent study which demonstrated a link between growth of juveniles and adults (0—4 years) and the abundance of juveniles and adults (Jansen and Burns, 2015). A similar result was obtained for mature 3- to 8-year-old mackerel where a study over 1988—2014 showed declining growth rate since the mid-2000s to 2014, which was negatively related to both mackerel stock size and the stock size of Norwegian spring spawning herring (Ólafsdóttir *et al*., 2015).

8.5.2 Weights at Age in the Catch and Stock

The mean weight-at-age in the catch for 2021 are given in Table 8.7.1.3. There is a trend towards lighter weight-at-age for the most age classes (except 0 to 2 years old) starting around 2005, continuing until 2013 (Figure 8.5.2.1). This decrease in the catch mean weight-at-age seems to have stopped since 2013 and values for the last seven years do not show any particular trend for the older ages (age 6 and older) and are slightly increasing for younger ages (ages 1 to 5). These variations in weight-at-age are consistent with the changes noted in length in Section 8.5.1.

The Working Group used weight-at-age in the stock calculated as the average of the weight-at-age in the three spawning components, weighted by the relative size of each component (as estimated by the 2022 egg survey for the southern and western components and the 2017 egg survey for the North Sea component). Mean weight-at-age in 2021 for the western component are estimated from Dutch, Irish and German commercial catch data, the biological sampling data taken during the egg surveys and during the Norwegian tagging survey. Only samples corresponding to mature fish, from areas and periods corresponding to spawning, as defined at the 2014 benchmark assessment (ICES, 2014) and laid out in the Stock Annex, were used to compute the mean weight-at-age in the western spawning component. For the North Sea spawning component, mean weight-at-age in 2021 were calculated from samples of the commercial catches collected from Divisions 4.a and 4.b in the second quarter of 2021 and samples collected during the 2021 egg survey conducted in the North Sea. Stock weights for the southern component, are based on samples from the Spanish catches and surveys in Divisions 8.c and 9a in the 2nd quarter of the year. The mean weights in the three component and in the stock in 2021 are shown in the text table below.

As for the stock weights, the decreasing trend observed since 2005 for fish of age 3 and older seems to have stopped in 2013 and values in the last 8 years show an increasing trend (except for weights of ages 0 and 1 which have been stable, Figure 8.5.2.2).

Age	North Sea Component	Western Component	Southern Component	NEA Mackerel 2021 Weighted mean*
0				0.000
1	0.132		0.103	0.064
2	0.224	0.186	0.163	0.186
3	0.280	0.267	0.218	0.261
4	0.328	0.278	0.277	0.281
5	0.360	0.316	0.344	0.323
6	0.407	0.343	0.379	0.352
7	0.412	0.389	0.395	0.392
8	0.444	0.414	0.415	0.416
9	0.463	0.417	0.437	0.423
10	0.510	0.438	0.459	0.446
11	0.509	0.447	0.493	0.458
12+	0.535	0.487	0.523	0.496
Component Weighting	7.1%	78.6%	14.3%	
Number of fish sampled	800	646	1123	

*** Missing value of mean weight-at-age per component are replaced by component mean value in the calculation of the stock weights**

8.5.3 Natural Mortality and Maturity Ogive

Natural mortality is assumed to be 0.15 for all age groups and constant over time.

The maturity ogive for 2021 was calculated as the average of the ogives of the three spawning components weighted by the relative size of each component calculated as described above for the stock weights. The ogives for the North Sea and Southern components are fixed over time. For the Western component the ogive is updated every year, using maturity data from commercial catch samples from Germany, Ireland, the Netherlands and the UK collected during the first and second quarters (ICES, 2014 and Stock Annex). The 2021 maturity ogives for the three components and for the mackerel stock are shown in the text table below.

Age	North Sea Component	Western Component	Southern Component	NEA Mackerel
0	0	0	0	0
1	0	0.15	0.02	0.12
2	0.37	0.59	0.54	0.57
3	1	0.98	0.70	0.94
4	1	1	1	1
5	1	1	1	1
6	1	1	1	1
7	1	1	1	1
8	1	1	1	1
9	1	1	1	1
10	1	1	1	1
11	1	1	1	1
12+	1	1	1	1
Component Weighting	7.1%	78.6%	14.3%	

A trend towards earlier maturation (increasing proportion mature at age 2) has been observed from around 2008 to 2015. A change in the opposite direction has been observed since then and the proportion of fish mature at age since 2018 are now markedly lower than in the previous years and at levels comparable with the ones observed at the end of the 2000s (Figure 8.5.3.1).

8.6 Fishery Independent Data

8.6.1 International Mackerel Egg Survey

The ICES Triennial Mackerel and Horse Mackerel Egg Survey 2022 was carried out during January – July. The results have been used in the assessment for mackerel since 1977. Since 2004 and subsequent to demands for up-to-date data for the assessment, WGMEGS aims to provide a preliminary estimate of NEA mackerel biomass and western horse mackerel egg production in time for the assessment meetings within the same calendar year as the survey.

WGMEGS provided the preliminary results of the 2022 mackerel and horse mackerel egg survey for WGWIDE in August 2022. The final survey results will be available following the next WGMEGS meeting (April 2023). This is due to the extremely large numbers of plankton and fecundity samples to be analysed following the surveys as well as the tight deadline set by WGWIDE for delivering these estimates. A Working Document (WD07: O'Hea et al. 2022) with the preliminary results of the 2022 survey was presented to the WGWIDE 2022 meeting.

The 2022 survey was split into 6 separate sampling periods. Maximum deployment of effort in the Western area was during periods 3-6. Historically these periods would have coincided with the expected peak spawning of both mackerel and horse mackerel. Recent years have seen mackerel peak spawning taking place during periods 3 and 5. Due to the expansion of the spawning area which has been observed since 2007, survey effort allocation focuses on achieving full area coverage and delineation of the spawning boundaries.

Analyses of the plankton and fecundity samples were carried out according to the sampling protocols as described in the WGMEGS Survey Manual (ICES, 2019a) & Fecundity manual (ICES, 2019b).

8.6.1.1 Data analysis for mackerel annual egg production

Stage 1 egg counts were converted to daily egg production using the development equations given in the survey manual. Procedures to estimate the total annual egg production are described in the WGMEGS Survey Manual (ICES, 2019a). Plots of the distribution of egg production for the western area are presented in Figures 8.6.1.1.1-8.6.1.1.5. The area coverage is described in detail in WD07 (O'Hea et al. 2019).

Figure 8.6.1.1.6 presents the egg production curve for the western area for the 2022 survey, along with those for the previous surveys for comparison. 2010 provided an unusually large spawning event early in the spawning season, 2013 yielded an even larger spawning event indicating that spawning was probably taking place well before the nominal start date of 10th February (day 42). In 2016 the first survey commenced on February 5th which is five days prior to the nominal start date. 2019 followed that of 2016 with no early peak spawning being recorded. The 2022 egg production curve is very similar to that of 2016, with peak spawning again occurring during Period 5. The expansion observed in western and northwestern areas during Periods 5 and 6 in 2016 was once again reported during 2022. During these periods it was not possible to fully delineate the northern and north-western boundaries, however the production in Periods 5 and 6 in the current survey year was lower in these northwestern areas. (Figures 8.6.1.1.4-5)~~.~~

Due to the cancelation of the Irish survey in June the area from 53N to 61N, and 3.5W to 21W could not be covered in period 6. In order to estimate the egg production in this uncovered area WGMEGS estimated the spawning area that was missed and also estimated mean daily egg production for the period. Positive stations (spawning area) were selected where stage 1 eggs were found in a rectangle on at least two occasions over last three MEGS surveys. MEGS estimated this amounted to 127 missed stations during the period and also estimated mean daily egg production for period 6 in 2022 at 19.58 stage 1 eggs/m^2/day (WD07: O'Hea et al. 2022).

The inclusion of the estimated egg abundance for the missing stations in Period 6 accounts for 10% of the annual egg production estimate in the western area for the 2022 survey.

The nominal end of spawning date of the 31st July is the same as used during previous survey years and the shape of the egg production curve for 2022 does not suggest that the end date needs to be altered. The provisional total annual egg production (TAEP) for the western area in 2022 was as 1.795×10^{15}. This is a 47% increase on the 2019 TAEP estimate which was 1.22×10^{15}.

Figure 8.6.1.1.7 shows the egg production curve for the southern area for the 2022 survey, along with those from previous surveys for comparison. The start date for spawning in the southern area was the 23rd January. Portugal surveyed in Period 2 in division 9a. Sampling in the Cantabrian Sea where the majority of spawning occurs within the Southern area commenced on the 18th March. The same end of spawning date of the 17th July was used again this year and the spawning curve suggests that there is no reason for this to change. As in 2019 the survey periods were not completely contiguous and this has been accounted for. The provisional total annual egg production (TAEP) for the southern area in 2022 was calculated as 3.21 x 10^{14}. This is a 25% decrease on the 2019 TAEP estimate of 4.23 x 10^{14}. A comparison of the total annual egg production (TAEP) for the western and southern area since 1998 is given below:

Year	Western TAEP	Southern TAEP
2022	1.795 x 10^{15} #	3.21 x 10^{14} #
2019	1.22 x 10^{15}	4.19 x 10^{14}
2016	1.55 x 10^{15}	2.25 x 10^{14}
2013	2.20 x 10^{15}	5.06 x 10^{14}
2010	1.92 x 10^{15}	4.59 x 10^{14}
2007	1.42 x 10^{15}	3.48 x 10^{14}
2004	1.36 x 10^{15}	1.38 x 10^{14}
2001	1.35 x 10^{15}	3.18 x 10^{14}
1998	1.54 x 10^{15}	4.79 x 10^{14}

The total annual egg production (TAEP) in 2022 for the western and southern components combined is 2.116 x 10^{15}. This is an increase in production of 29% compared to the 2019 estimate of 1.64 x 10^{15} (Figure 8.6.1.1.8).

8.6.1.2 Mackerel fecundity and atresia estimation

Estimates of fecundity are given as preliminary realised fecundity which is the potential fecundity minus the atresia rate (for details see WD07: O'Hea et al. 2022). Atlantic mackerel samples were collected during survey periods 2-7 over an area bounded by 59.36˚N 14.20˚W – 36.54˚N 2.32˚W. The analysis of potential fecundity is carried out by nine participating institutes. Preliminary fecundity results are based on 169 samples from periods 2 and 3. The number of samples is higher than in 2019, when only 62 samples were available for the preliminary potential fecundity. The preliminary relative potential fecundity in 2022 is 1253 oocytes/gram female which is slightly higher than the preliminary estimate in 2019 of 1224 oocytes /gram female (Table 8.6.1.2.1). Due to time constraints no samples were analysed for atresia at the time of WGWIDE. For the preliminary estimation of the realised fecundity the mean atresia rate based on the previous seven surveys (6%) was used. This resulted in a preliminary realised fecundity estimate for 2022 of 1178 oocytes/gram female fish.

8.6.1.3 Quality and reliability of the 2022 egg survey

The surveys in 2010 and 2013 were dominated by the issue of an early peak of western mackerel spawning and its close proximity to the nominal start date. In 2016 peak spawning reverted to May/June, a time that would traditionally be considered normal. In 2019, peak spawning in the western area was found to have occurred slightly earlier in Period 4 (Fig. 8.6.1.1.6). For 2022 the spawning pattern is remarkably similar to that reported for 2016.

The bulk of the spawning activity reported during historical surveys resulted from several egg production hotspots on and around the continental shelf edge and usually around the Celtic Sea and Porcupine Bank region. During 2016, high levels of spawning were recorded over a large area of the Northeast Atlantic with a large number of the stations being reported over deep water and well away from the continental shelf. In 2019 numbers of stage 1 eggs recorded on these northerly and western boundary stations were much reduced, although still present (Figures 8.6.1.1.4-5). This expansion was repeated in 2022 during Periods 5 and 6, however spawning densities recorded in these areas were significantly lower than reported in 2016 and 2019. Available surveys deployed during these periods were unable to fully delineate all boundaries. However, WGMEGS is satisfied that significant additional egg production is not being missed in these northern and western areas. Despite the inability to secure a northern spawning boundary for western area mackerel during periods 5 and 6, results from the recent exploratory MEGS surveys undertaken within these regions and reported to WGWIDE in 2021 (ICES, 2021a) provide reassurance that the fraction of spawning missed is a minor one and that the survey has indeed been successful in capturing the majority of spawning activity. An approach to estimate and account for the egg production missed as a result of the Irish survey cancellation in period 6 was developed and is detailed in WD07 (O'Hea et al. 2022).

8.6.1.4 Mackerel biomass estimates.

Based on the procedures of the WGMEGS Survey Manual (ICES, 2019a) & Fecundity manual (ICES, 2019b) the preliminary spawning stock biomass (SSB) by components and components combined have been estimated as shown below using a preliminary fecundity estimate of 1178 oocytes/g female:

- 3.292Mt for western component (2019: 2.29Mt).
- 0.589Mt for southern component (2019: 0.80Mt).
- 3.881Mt for western and southern components combined (2019: 3.09Mt)

8.6.1.5 2022 North Sea mackerel egg survey

The North Sea Mackerel Egg Survey (NSMEGS) is designed to estimate the spawning stock biomass (SSB) of mackerel of the North Sea component of the Northeast Atlantic stock on a triennial basis. Prior to 2017 this survey was done utilizing the annual egg production method (AEPM). At the 2018 WGMEGS meeting, it was agreed to switch to the Daily Egg Production Method (DEPM) for the following survey NSMEGS (ICES, 2018b). The DEPM requires only one full sweep, in a short time period, over the entire mackerel spawning area, preferably during peak spawning time. A disadvantage of the DEPM is that it requires many more mackerel ovary samples to be collected in order to estimate batch fecundity and spawning fraction.

In 2022, the UK, Denmark and Norway conducted the North Sea survey between 5th–24th June. The spawning area (between 54˚N and 62˚N) in the North Sea was surveyed with a single sweep. A total of 259 plankton stations and 38 pelagic trawl hauls were performed for the collection of mackerel adult and ichthyoplankton samples (O'Hea et al, WD08). The total area sampled in 2022 was slightly smaller than the area sampled during the previous survey in 2021.

The spatial daily egg production distribution is shown in Fig. 8.6.1.5.1. Procedures to estimate the Daily egg production are described in the WGMEGS Survey Manual (ICES, 2019a).

The DEP was calculated for the total investigated area. Provisional mackerel daily egg production for 2022 for the North Sea was estimated as 0.67 x 10^{13} eggs. This is a 50% decrease on that reported for the 2021 survey.

Adult parameters

Denmark sampled 1180 mackerel and collected ovary samples from 364 females. England sampled 225 mackerel and collecting ovary samples of 74 females. Norway collected 239 female mackerel (O'Hea et al, WD08). These samples were collected in June 2022 and at the time of writing, no analysis has yet been carried out. Analysis will take place before the end of 2022, with the results to be delivered prior to the WGMEGS meeting in April 2023.

8.6.1.6 2021 North Sea mackerel egg survey

In 2021 a North Sea Mackerel Egg Survey (NSMEGS, I1582) was carried out to estimate the spawning stock biomass (SSB) of mackerel of the North Sea component of the Northeast-Atlantic stock using DEPM methodology. The survey was designed to cover the whole spawning area in the North Sea (53˚N to 62˚N).

The NSMEGS was carried out from 25th May to 12th June by The Netherlands, Denmark and Scotland (van Damme *et al*., WD03). The samples were collected and analysed according to the WGMEGS manuals (ICES 2019a, 2019b). A total of 294 plankton stations ,23 pelagic trawl hauls and 283 collected female samples were performed for the collection of mackerel adult and ichthyoplankton samples.

The spatial egg production distribution is shown in Fig. 8.6.1.6.1. The Daily egg production was calculated as 128 x 10^{13} mackerel eggs for the total investigated area (Table 8.6.1.6.1).

The DEPM adult parameters were estimated with the data provided by the Netherlands (van Damme et al., WD03). Batch fecundity was estimated 18735 eggs/g. Corrected mean female weight was estimated as 331g. Spawning fraction in the North Sea was calculated as 18% and sex ratio was 0.53. Adult parameters are presented in Table 8.6.1.6.2.

Using the DEP (stage Ia) for the entire sampled area and the estimated adult parameters for the North Sea component leads to an estimated SSB of 2380x10^3 t in 2021.

8.6.2 Demersal trawl surveys in October – March (IBTS Q4 and Q1)

An index of survivors in the first autumn-winter (recruitment index) is normally derived from a geostatistical model fitted to catch data from bottom trawl surveys conducted during autumn and winter. A complete description of the data and model can be found in Jansen *et al*. (2015) and the NEA mackerel Stock Annex.

The data collection in 2022 Q1 was incomplete as two Scottish surveys (IBTS-NS Q1 and SWC Q1) were cancelled due to technical issues with R/V Scotia.

The area covered by IBTS-NS Q1 and SWC Q1 have historically been an important nursery area. A major fraction of the total estimated recruits are in this area in Q1 (Figure 8.6.2.1). The fraction varies from year to year and it was considered too uncertain to interpolate or assume that the same fraction was in the area as in Q1 2021. As a result, the recruitment index (survivors in the first autumn-winter) has not been updated in 2022 to estimate the value for the 2021 year-class. The time series from ICES (ICES, 2021b) that is used for this years' assessment is shown in Figure 8.6.2.2.

8.6.3 International Ecosystem Summer Survey in Nordic Seas (IESSNS, A7806)

IESSNS is the only annual survey providing data used in the assessment and covers summer feeding distribution of mackerel age 3+ in Nordic Seas and was successfully conducted in 2022. Major survey results worth mentioning is that survey coverage expanded 32%, compared to 2021, as Greenlandic waters, north of 62°N, were surveyed again and mackerel distribution south of Iceland demanded southward expansion of survey to latitude 61°15′ in the Iceland basin and on the Reykjanes ridge. Value of the mackerel index was impacted by two extremely large catches, 103 and 70 tonnes km^{-2}, which contributed 33% of the biomass index value. Extreme catches also impacted index calculations in 2017, 2019 and 2020. Analytical work to develop index calculation method less sensitive to extreme catches will be undertaken at ICES Working Group on Improving use of Survey Data for Assessment and Advice (WGISDAA) annual meeting in October 2022. The western part of the northern Norwegian Sea (stratum 9) was oversampled as three surface trawl stations were added, at the dynamic stratum boundary, at only half the distance from next station, 35 nm instead of 70 nm. Mackerel was caught at two of these stations and the maximum catch per station was approximately one ton. All three stations were included in the index calculations and the dynamic stratum boundary extended 35 nm westward of these three stations. The zero-line for mackerel abundance was reached south and north of Iceland and in Greenlandic waters. It was not reached in the north-western and north-eastern part of the Norwegian Sea but given that the polar front with water too cold for mackerel is usually found close to the north-westernmost catches, we assume that the zero-line was practically reached there. Towards the Barents Sea the zero-line was not reached but this is considered of less quantitative importance based on low catch rates. The zero-line was not reached on the European shelf, where mackerel are present west of the British Isles and in the southern North Sea. The IESSNS cruise report is available as a working document to this report (WD01) and a detailed survey description is available in the mackerel Stock Annex.

The main results are that estimated total stock abundance and total biomass increased 43% compared to 2021. When the two extreme catches are excluded from index calculations in 2022, biomass and abundance is similar to 2021 values. Internal consistency increased compared to 2021, particularly for ages 5-8 years which had lower consistency than other ages in 2021. Abundance estimates by age are displayed in input data for the assessment (Table 8.7.1.9). Figures 8.6.3.1-2 display estimates of total stock abundance and stock biomass with confidence intervals, with and without two extreme catches in 2022, for the time series. Figures 8.6.3.3-4 show the internal consistency and catch curves for abundance at age from 2010 to 2022. Figures 8.6.3.6-7 display swept area trawl catch rate and mean mackerel density per rectangle for 2022, and mean mackerel density per rectangle for years 2010 and from 2012 to 2022.

8.6.4 Tag Recapture data

The following is a summary of the most important information on tag recapture data, more detailed info can be found in a working document attached to this report (Slotte and Hølleland, WD09). Information from steel tagging experiments conducted by Institute of Marine Research in Bergen (IMR) on mackerel at spawning grounds west of Ireland and British Isles in May-June and the respective recaptures at Norwegian factories with metal detectors (Tenningen et al. 2011) was introduced to the mackerel assessment during ICES WKPELA 2014 (ICES, 2014). Data from release years 1980-2004, and recapture years 1986-2006 have been used in the update assessments following this benchmark. From 2011 onwards IMR changed tagging methodology to radio-frequency identification (RFID), more specifically passive integrated transponder tags (PIT-tags). This allowed for more automated data processing with recaptures from scanned landings at factories in Norway, Scotland and Iceland now being updated in real time to an IMR database over internet.

The data format is the same for both tag types; a table containing the numbers of tagged fish per year class in each release year, and the corresponding numbers scanned and recaptured of the same year classes in all years after release. The RFID data were considered to be a separate time series with a different scaling factor (survival) than the steel tags, and it has been used in update assessments following the ICES WKWIDE2017 benchmark (ICES, 2017). For steel tags data from ages 2-11 and all recapture years are used in the assessment. During the 2017 benchmark it was decided to use the same filtering for the RFID data from release year 2011 onwards. However, following decisions made during ICES IBPNEAMac 2019 (ICES 2019c) update assessments are now only using RFID data from release years 2013 onwards, ages 5-11 and recapture year 1 and 2 after release.

An overview of all RFID tagging data in terms of numbers tagged, biomass scanned, and numbers recaptured per year, and geographical distributions of data are shown in Figures 8.6.4.1-3. The exclusion of recapture years 3 and longer after release is due to potential tag loss over time, which seem evident in the RFID data (WD09). The exclusion of release years 2011-2012 is mainly based in lack of distributional coverage of scanned fishery, which changed significantly when more countries joined the program from 2014 onwards (Figure 8.6.4.2). The exclusion of ages 1-4, was mainly because early in the time series these age groups were relatively few compared with the scanned fish year 1 and 2 after release, leading to some noise in the data. However, the age structure of tagged and scanned fish year 1-2 after release has developed over time series to be more overlapping, and high proportions of tagged mackerel are now at ages 2-4 (Figure 8.6.4.4).

Trends in year class abundance indices from RFID data based on recaptures year 1 and 2 after release now seem consistent and informative for assessment from ages 2-12 (Figure 8.6.4.5). Note that an alternative assessment at WGWIDE 2021 using these indices for the selected ages 5-11 instead of the regular data table resulted in negligible differences in SSB trend and same leave out RFID data effects; i.e. higher SSB in most recent years when excluding RFID data. Translating these abundance indices into different age-aggregated biomass indices also show comparable time trend with SSB from WGWIDE 2022 from release years 2013 onwards (Figure 8.6.4.5). Especially the marked decrease in SSB from 2017-2020 seem to follow the decline in the RFID biomass estimates, which may explain why leave out RFID runs from WGWIDE 2022 tends to lift the SSB upwards.

The signals of total mortality rate (Z) in fully mature fish ages 4-12 for year classes 2003-2014 tend to be higher in the RFID data than in the catch data with the data from final WGWIDE2022 assessment in between, whereas estimated Z from the international trawl survey (IESSNS) is sticking out as the lowest of all sources (Figure 8.6.4.6).

The overall conclusion is that the RFID time series is slowly developing, but still is a very short time series. Nevertheless, the data seem quite informative for stock assessment, although showing higher total mortality rate signals than the other input data. Such conflicting trends suggest that year to year variations in assessment and leave out effects may frequently occur in coming years when time series are short. Finally, the new development of the time series suggests that the current filtering of RFID data for use in stock assessment should be revised in near future.

This especially counts for the inclusion of younger ages 2-4 that may be informative for incoming year classes to the stock.

8.6.5 Other surveys

8.6.5.1 International Ecosystem survey in the Norwegian Sea (IESNS, A3675)

After the mid-2000s an increasing amount of NEA mackerel has been observed in catches in the Norwegian Sea during the International Ecosystem survey in the Norwegian Sea in May (IESNS) targeting herring and blue whiting (Salthaug *et al*. 2019; 2020).

The spatial distribution pattern of mackerel in 2022 was quite similar to previous years, with mackerel present in the south-eastern Norwegian Sea. However, there were small catches of mackerel as far north as 68°N in 2021, but this year the catches only extended north to about 64°N. This is the lowest northward extent of mackerel catches during IESNS after 2007 (first year with data from all participating vessels).

The IESNS survey provides valuable, although limited, quantitative information on mackerel. It is an acoustic survey and the trawl hauls are mainly targeting acoustic registrations of herring and blue whiting. Thus, the survey does not provide proper mackerel sampling in the vertical dimension and has too low trawl speed for representative sampling of all size groups of mackerel. Therefore, no further quantitative information can be drawn from these data.

8.6.5.2 Acoustic estimates of mackerel in the Iberian Peninsula and Bay of Biscay (PELACUS, A2548)

PELACUS survey data have not been processed on time for WGWIDE 2022 and therefore, no new information from the Bay of Biscay on mackerel distribution and abundance during spawning time is available.

8.7 Stock Assessment

8.7.1 Update assessment in 2022

The update assessment was carried out by fitting the state-space assessment model SAM (Nielsen and Berg, 2014) using the R library *stockassessment* (downloadable at install_github("fishfollower/SAM/stockassessment")) and adopting the configuration described in the Stock Annex.

The assessment model is fit to catch-at-age data for ages 0 to 12 (plus group) for the period 1980 to 2021 (with a strong down-weighting of the catches for the period 1980-1999) and three surveys:

1) SSB estimates from the triennial Mackerel Egg survey (every three years in the period 1992-2022),
2) a recruitment index from the western Europe bottom trawl IBTS Q1 and Q4 surveys (1998-2020, could not be updated for 2021) and
3) the abundance estimates for ages 3 to 11 from the IESSNS survey (2010, 2012-2022).

The model also incorporates tagging-recapture data from the Norwegian tagging program (for fish recaptured between 1980 and 2005 for the steel tags time series, and fish recaptured between 2014 and 2021 (age 5 and older at release) for the radio frequency tags time series).

Fishing mortality-at-age and recruitment are modelled as random walks, and there is a process error term on abundances at ages 1-11.

The differences in the new data used in this assessment compared to the last year's assessment were:

- Addition of the 2021 catch-at-age (0-12+), weights-at-age in the catch and in the stock and maturity ogive, proportions of natural and fishing mortality occurring before spawning.
- Addition of the 2022 abundance-at-age (3-11) index from IESSNS.
- Addition of the 2022 SSB index (preliminary value) from the 2022 mackerel egg survey
- The inclusion of the tag recaptures from 2021

Input parameters and configurations are summarized in Table 8.7.1.1. The input data are given in tables 8.7.1.2-9. Given the size of the data base, only the data from the last year of recaptures is given in this report (table 8.7.1.10).

8.7.2 Model diagnostics

Parameter estimates

The estimated parameters and their uncertainty estimates are shown in table 8.7.2.1 and figure 8.7.2.1. The model estimates different observation standard deviations for young fish and for older fish. Reflecting the suspected high uncertainty in the catches of age 0 fish (mainly discards), the model gives a very poor fit to this data (large observation standard deviation). The standard deviation of the observation errors on catches of age 1 is lower, though still high, indicating a better fit. For the age 2 and older, the fit to the catch data is very good, with a very low observation standard deviation.

The observation standard deviations for the egg survey and the IESSNS surveys ages 4 to 11 are higher, indicating that the assessment gives a lower weight to the information coming from these surveys compared to that from the catches. The IESSNS age 3 is very poorly fit in the assessment (high observation standard deviation). Overdispersion of the tag recaptures has the same meaning as the observation standard deviations, but is not directly comparable.

The catchability of the egg survey is estimated to be 1.17, greater than 1, which implies that the assessment considers the egg survey index to be an overestimate of SSB. The catchabilities at age for the IESSNS increase from 0.79 for age 3 to 1.96 for age 9. Since the IESSNS index is expressed as fish abundance, this also means that the assessment considers the IESSNS to provide overestimated abundance values for ages 4 to 11. The post tagging mortality estimate is higher for the steel tags (~40%) than for the RFID tags (~16%).

The process error standard deviation (ages 1-11) is moderate as are the standard deviations of the F and recruitment random walks.

The catchability parameters for the egg survey, recruitment index and post tagging survival appear to be estimated more precisely than other parameters (table 8.7.2.1). The catchability for the IESSNS has a slightly higher standard deviation, except for age 3 which is significantly higher. Uncertainty on the observation standard deviations is larger for the egg survey, the IESSNS age 3, for the recruitment index and for the catches at age 1 than for the other observations. The uncertainty on the observation variance estimates is not particularly high, especially for the data sources with the lowest observation variances, which are the most influential in the assessment (figure 8.7.2.2). Uncertainty on the overdispersion of the tag data is high. The standard deviation on the estimate of process error is low, and the standard deviations for the estimates of F random walk variances of age 0 and 1 are both very high. The uncertainty on the random walk variance for recruitment is very large, indicating that the parameter was poorly estimated.

The estimated AR1 error correlation structure for the observations from the IESSNS survey age 3 to 11 has a high correlation between the errors of adjacent ages (r=0.82), decreasing exponentially with age difference (figure 8.7.2.3.). This high error correlation implies that the weight of this survey in the assessment is lower than for a model without correlation structure, which is also reflected in the high observation standard deviation for this survey.

There are some correlations between parameter estimates (figure 8.7.2.4):

- catchabilities are positively correlated (especially for the IESSNS age 4 to 11), and negatively correlated to the survival rate for the RFID tags. This simply represents the fact that all scaling parameters are linked, which is to be expected.
- the observation variance for the recruitment index is inversely correlated to the variance of the random walk of the recruitment. This implies that when the model relies less on the recruitment index, the estimated recruitment time series becomes smoother.
- the parameter related to the magnitude of the correlation in the AR1 matrix for the IESSNS is correlated to the observation variance for this survey, which reflects the fact that a strong correlation for the errors is linked to lower weight of the surveys.

Residuals

The "one step ahead" (uncorrelated) residuals for the catches show some weak patterns in the residuals, with a prevalence of positive residuals for ages 3 to 10 between 2008 and 2014 and again in the last 2 years (figure 8.7.2.5). Empirical correlation plot in the residuals shows positive correlations between ages 3 to 12 (figure 8.7.2.6) which suggest that incorporating a correlation structure in the observation error for the catches might be appropriate. Residuals are of a similar size for all ages, indicating that the model configuration with respect to the decoupling of the observation variances for the catches is appropriate.

The residuals for the egg survey show a strong temporal pattern with large positive residuals for the period 2007-2010-2013, followed by large negative residuals for 2016, 2019 and 2022. This pattern reflects the fact that the model, based on all the information available, does not follow the trend present in the egg survey, with a steep decline between 2013 and 2016 (when the stock was at its highest) and the very low 2019 value. The relatively high observation variance for this survey indicates a poor fit with the egg survey due mainly to these observations which indicate a different trend to the other available observations.

Residuals for the IESSNS indices are relatively well balanced for most years. Despite the strong drop in the abundances at age in 2018 and 2021, the residuals for these years do not indicate any year effect (*e.g.* no large residuals of the same sign observed across ages). Correlations between age in the observation errors for this survey are explicitly modelled in the assessment, and as a result, empirical correlations in the one step ahead residuals between ages are low (figure 8.7.2.7).

Residuals for the recruitment index show no particular pattern, and appear to be relatively randomly distributed in the earlier years although positive residuals are consistently observed over the most recent 5 years, indicating that the model has difficulties agreeing with the sustained period of high values in the index.

Finally, inspection of the residuals for the tag recaptures (figure 8.7.2.8) did not show any specific pattern for the RFID data. For the steel tags, there is a tendency to have more positive residuals at the end of the period which could indicate that using a constant survival rate for this dataset may not be appropriate.

Leave one out runs

In order to visualise impact of individual surveys on the estimated stock trajectories, the assessment was run leaving out successively each of the survey data sources (figure 8.7.2.9).

All leave one out runs showed parallel trajectories in SSB and Fbar, except for the run that excluded the RFID tag information, which shows a less steep decline in SSB since 2014. For recruitment, all runs also resulted in similar trajectories, except for the run without the recruitment index, in which recruitment decreased from high levels in the mid-2010s to historically low levels in the terminal assessment year.

Excluding the IESSNS survey resulted in estimates very close to the base case run, with slightly lower SSB and higher Fbar for the period covered by this survey. Removing the recruitment index had a similar effect on the estimated stock trajectories, but with a larger discrepancy in SSB for the most recent years. Without the recruitment index, the estimates of age 0 abundance are only informed by the catch data, which are considered uninformative by the model. As a result, the estimated recruitment for this specific run has a very different trajectory, which – despite the adjustments of year-class strength through the process error as fish become older – has an effect on SSB estimates. The exclusion of SSB estimates from the egg survey resulted in a larger estimated stock, exploited with a lower fishing mortality. The run leaving out the RFID also resulted in a higher SSB than in the assessment using all data for the years after 2017, and a slightly higher fishing mortality between 2011 and 2015, but lower after 2019. The magnitude of the effect of removing the RFID data is similar to that of removing other surveys.

As in previous years, the update assessment appears to trade-off the information coming from the IESSNS which leads to a more optimistic perception of the stock, and the information from the egg survey and the tags which suggests a more pessimistic perception of the stock.

Additional sensitivity runs

A series of additional sensitivity runs were carried out to explore the potential influence of the additional uncertainty in some of the new data included in the 2022 update assessment namely the 2022 SSB index from the mackerel egg survey and the possible higher uncertainty in the 2021 catch-at-age data as a consequence of the missing Russian data.

- Sensitivity to assumption made for missing coverage in the 2022 egg survey index

The egg production assumed for the missing coverage in period 6 accounted for 9.4% of the 2022 SSB index from the mackerel egg survey. An alternative SAM assessment was run with a 2022 SSB index decreased by 9.4% (3.51Mt) compared to the value used in the update assessment (3.88Mt). The stock estimates for this run are almost identical to the update assessment (figure 8.7.2.10) which indicates that the current assessment is fairly robust to a 9.4% difference in the 2022 egg survey index of SSB

- Effect of increased uncertainty for 2021 catch-at-age

The current SAM assessment uses the same observation variance for all years, thereby considering that level of uncertainty in the catches does not vary over time. However, given the lack of sampling data from the Russian catch for 2021, and the uncertainty on the total catch value provided, the 2021 catches-at-age for the stock are potentially more uncertain than in normal years. In order to test the effect this potential larger uncertainty has on the assessment, the observation variance for the catch-at-age data for 2021 was increased by 50% compared to other years. This had no noticeable effect on the assessment (figure 8.7.2.11)

8.7.3 State of the Stock

The stock summary is presented in figure 8.7.3.1 and table 8.7.3.1. The stock numbers-at-age and fishing mortality-at-age are presented in tables 8.7.3.2-3. The spawning stock biomass is estimated to have increased almost continuously from just above 2 million tonnes in the late 1990s and early 2000s to 5.9 million tonnes in 2014 and 2015 and subsequently declined to reach a level just above 3.6 million tonnes in 2020 and increased slightly in 2021 to 3.9 million tonnes. The fishing mortality has declined from levels between F_{pa} (0.36) and F_{lim} (0.46) in the mid-2000s to levels at or below F_{MSY} (0.26) between 2010 to 2019 and increased sharply in the last two years to 0.31 in 2021. The recruitment time series from the assessment is not considered a reliable indicator of year-class strength (see section 8.7.5.1).

There are clear indications of changes in the selectivity of the fishery over the last 30 years (figure 8.7.3.2.). In the 1990s, the fishery seems to have had a steeper selection pattern (more rapid increase in fishing mortality with age). Between the end of the 1990s and the end of the 2000s, the selection on the ages 1 to 5 decreased, and selection of older fish (7 and older) increased. After 2008, the pattern started reversing towards a steeper selection pattern, until 2017. Since then, selection on age 2 to 5 decreased sharply, as the fishery targeted more the older part of the population (age 6 and older).

8.7.4 Quality of the assessment

Parametric uncertainty

Large confidence intervals are associated with the SSB in the years before 1992 (figure 8.7.4.1 and figure 8.7.2.7). This results from the absence of information from the egg survey index, the down-weighting of the information from the catches and the assessment being only driven by the tagging data and natural mortality in the early period. The confidence intervals become narrower from the early 1990s to the mid-2000s, corresponding to the period where information is available from the egg survey index, the tagging data and (partially) catches. The uncertainty increases slightly in the most recent years and the SSB estimate for 2021 is estimated with a precision of +/- 24.8% (figure 8.7.4.1). There is generally also a corresponding large uncertainty on the fishing mortality, especially before 1995. The estimate of $F_{bar4\text{-}8}$ in 2021 has a precision of +/- 27.4%.

Model instability

The retrospective analysis was carried out for 8 retro years, (or peels) by fitting the assessment using the 2022 data, removing successively 1 year of data (figure 8.7.4.2.). There was a systematic retrospective pattern found in Fbar for the older retrospective peels (current year -4 to current year -8) with a systematic downwards revision. The was also a pattern in the opposite direction for the SSB. However, this pattern is not apparent in the most recent peels (current -1 to -3), and the Mohn's rho value calculated over the last 5 years is of 0.18 for Fbar and -0.11 for SSB. Recruitment appears to be quite consistently estimated for the older peels (current -3 to -8), but the perception changed for the last 2 peels. This change is associated with an increase in the observation variance for the recruitment index, meaning that the recruitment estimates were more influenced by the recruitment index in the older peels, which was less the case in the last 2 peels.

Model behaviour

The realisation of the process error in the model was also inspected. The process error expressed as annual deviations in abundances-at-age is shown in figure 8.7.4.3 which shows indications of some pattern across time and ages. There is a predominance of positive deviations in the recent years for ages 5 to 8. While process error is assumed to be independent and identically distributed, there is clear evidence of correlations in the realisation of the process error in the mackerel assessment, which appears to be correlated both across age-classes and years.

The temporal autocorrelation can also be visualised if the process error is expressed in term of biomass (process error expressed as deviations in abundances-at-age multiplied by weight at age and summed over all age classes, figure 8.7.4.4). Periods with positive values (when the model estimates larger global abundances-at-age than corresponding to the survival equation) have been alternating with periods with negative values (1991-1994, 2004-2005, and 2017-2019). For the years between 2007 and 2016, the biomass cumulated process error remains positive, and large (e.g. in 2013 - almost equivalent to the total catch weight). The reason for this aspect of model behaviour could not be identified.

8.7.5 Exploratory runs

8.7.5.1 Assessment starting at age 2

The age 0 estimates in the current assessment mainly rely on the recruitment index; the catch-at-age 0 information is considered by the model as uninformative (large observation variance). Catch-at-age information becomes influential at age 2 (very low observation variance). The recruitment signal provided by abundances estimated at age 2 or 3 (when the fish enters the fishery), is different from the signal in the age 0 abundance (figure 8.7.5.1). Age 0 abundances are less variable than abundances at age 2 and 3. For the period before 2012, there is a broad agreement in the perception of year class strength, although some year classes that do not appear particularly large at age 0 are perceived as very large at age 2 and 3 (e.g. 2002 year-class). For the more recent period (since the 2013 year-class), there is a greater discrepancy between recruitment at age 0 and that derived at older ages. While the age 0 abundances indicate very high recruitment for the year-classes 2012 to 2019, some of those year-classes appear as particularly poor based on age 2 and 3 abundances (2015, 2017 and 2018). As very little fishing occurs between ages 0 and 2 and 3, exploitation is not likely to explain these changes in the perception of cohort strength. Such variations could be possibly due to variations in natural mortality (*e.g.* the strength of a cohort may not be fully determined at age 0 and processes occurring during the first years of life may still be determining year-class strength). However, some cohorts increase in size as they become older (*e.g.* 2002 and 2011), which clearly indicates that this is more likely a model artefact. The cohort strength at age 0, based on the recruitment index, is progressively revised, due to the process error occurring on annual survival, so that cohort strength at age 2 corresponds to the information coming from the catches.

This discrepancy between the recruitment estimates at age 0 and the actual size of the cohort when entering the fishery implies that the age 0 recruitment does not give an accurate indication of year-class strength, and should not be used to make assumptions on stock development in the near future. The implications of starting the assessment at age 0 for the short term forecast done to compute the catch advice, however, are relatively limited, with the last estimated recruitment value (R2021 this year) contributing to around 6% of the catch in the advice year.

As very little fishing occurs on 0 and 1 year olds, and catch-at-age data is considered very noisy, and since there appears to be a disagreement between the recruitment index at age 0 and at older ages in the recent years, it does not seem appropriate to use age 0 or 1 as the youngest age in the assessment. An exploratory run was conducted starting the assessment at age 2 (and hence removing catch-at-age information for age 0 and 1 and the recruitment index, while retaining the remainder of the data and an unchanged model configuration).

Both the update and exploratory assessments give a very similar perception of the SSB and Fbar trajectories (figure 8.7.5.2), with only small differences in the last 2 years for both SSB and Fbar. The recruitment at age 2 (in blue on figure 8.7.5.2, note that the curve should be shifted backwards by 2 years to compare year-class strength with the recruitment at age 0, red curve) shows a much more variable year-class strength signal, with the same perception of year class strength as the age 0 recruitment for some years (broadly between year-classes 2000 and 2012), but a much lower estimated year-class strength since 2012.

In conclusion, both models are in broad agreement in terms of fit to the available data and stock trajectories such that the model starting at age 2 could be considered as potential alternative to the current model at the next benchmark workshop for this stock.

8.8 Short term forecast

The short-term forecast provides estimates of SSB and catch in 2023 and 2024 (given an assumed catch for the current (intermediate) year) and a range of management options for the catch in 2023.

All procedures used this year follow those used in the benchmark of 2014 as described in the stock annex.

8.8.1 Intermediate year catch estimation

Estimation of catch in the intermediate year (2022) is based on declared quotas, interannual transfers and information from the fisheries shown in the text table in Section 8.1.

8.8.2 Initial abundances at age

The recruitment estimate at age 0 from the assessment in the terminal assessment year (2021) was considered too uncertain to be used directly, because this year class has not yet fully recruited into the fishery. The last recruitment estimate is therefore normally replaced by predictions from the RCT3 software (Shepherd, 1997). The RCT3 software evaluates the historical performance of the IBTS recruitment index, by performing a linear regression between the index and the SAM estimates over the period 1998 to the year before the terminal year. The recruitment is then calculated as a weighted mean of the prediction from this linear regression based on the IBTS index value, and a time tapered geometric mean of the SAM estimates from 1990 to the year before the terminal year. The time tapered geometric mean gives the latest years more weight than a geometric mean. This is done because the recent productivity of the stock appears different than in the 1990's.

However, no IBTS index data point is available for 2021 and therefore the time tapered geometric mean was used without adjustments. This is as close to the standard procedure as practicable and leads to an expected recruitment of 5 844 million.

8.8.3 Short term forecast

A deterministic short-term forecast was conducted using FLR (www.flr-project.org). Table 8.8.3.1 lists the input data to the forecast and tables 8.8.3.2 and 8.8.3.3 provide projections for various fishing mortality multipliers and catch constraints in 2023.

Assuming catches for 2022 of 1 131 kt, F was estimated at 0.36 (above F_{MSY}) and SSB at 3.77 Mt (above B_{pa}) in spring 2022. If catches in 2023 equal the assumed catch for 2022, F is expected to increase to 0.40 (above F_{pa}) in 2023 with a corresponding decrease in SSB to 3.60 Mt in spring 2023. Assuming an F of 0.40 again in 2024, the SSB will further decrease to 3.33 Mt in spring 2024.

Following the MSY approach, exploitation in 2023 shall be at F_{MSY} (0.26). This is equivalent to catches of 782 kt and a decrease in SSB to 3.68 Mt in spring 2023 (2% decrease). During the subsequent year, SSB will remain at a similar level (3.65 Mt) in spring 2024.

8.9 Biological Reference Points

A management strategy evaluation Workshop on northeast Atlantic mackerel (MKMSEMAC) was conducted during 2020 (ICES, 2020) which resulted in the adoption of new reference points for NEA mackerel stock by ICES.

The table below summarises the currently used reference points.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	2.58 million tonnes	B_{pa}	ICES (2020)
	F_{MSY}	0.26	Stochastic simulations	ICES (2020)
Precautionary approach	B_{lim}	2.00 million tonnes	B_{loss} in 2003 from the 2019 WGWIDE assessment (ICES, 2019c)	ICES (2020)
	B_{pa}	2.58 million tonnes	B_{lim} x exp(1.645 × σ), with σ_{SSB} = 0.15	ICES (2020)
	F_{lim}	0.46	F that, on average, leads to B_{lim}	ICES (2020)
	F_{pa}	0.36	F_{p05} (the F that leads to SSB ≥ Blim with 95 % probability)	ICES (2020)

8.10 Comparison with previous assessment and forecast

Stock assessment output

The last available assessment used for providing advice was carried out in 2021 during the WGWIDE. The 2022 WGWIDE assessment gives a slightly different perception of the development of the stock, with a higher SSB estimated for the period 2014-2017 and a lower Fbar estimated over the period 2009-2018 (figure 8.10.1). The differences in the 2020 TSB, SSB and Fbar estimates between the 2021 and 2022 assessments are -7.0%, -9.35% and 15.4% respectively.

	TSB 2020	SSB 2020	Fbar4-8 2020
Assessment			
2021 WGWIDE Update	5 131 499 tonnes	3 938 555 tonnes	0.249
2022 WGWIDE Update	4 772 765 tonnes	3 570 188 tonnes	0.287
Revision	-7.0%	-9.35%	15.4%

The addition of a new year of data modified only marginally the model parameters compared to last year (figure 8.10.2). The observation standard deviation has increased slightly for the IESSNS survey while it remained unchanged for the other data. Process variances all increased slightly, except the process error on abundances at age 1-11 which remained unchanged. There was also a minor change in the catchabilities for the age 4 to 6 in the IESSNS survey.

The uncertainty on the estimates of the process variances have decreased slightly (especially for the recruitment random walk) but the uncertainty on other parameters is very similar to last year. The uncertainty on SSB and $F_{bar4\text{-}8}$ in this year's assessment is lower for the recent period (for the estimates since 2010), but has increased slightly for the terminal year estimates (figure 8.7.4.1).

Short term forecast

The estimation for the intermediate year (2021) catch used for the short-term forecast in the advice given last year was 10.87% higher than the actual catches as reported to WGWIDE 2022 (table below). The intermediate year assumption is made by summing the unilateral TAC declared, taking interannual transfers into account, and adding anticipated discards. During the WGWIDE, participants may provide information from their national administration and industry on the expected rate of use of the TAC (most often 100%), which can lead to a modification of the expected national catches. In 2021, several countries were not able to catch their national TAC, due to restrictions on access to UK waters, and this could not be anticipated at the time of the working group. The undershoot of some of the national TACs lead to an assumed intermediate year catch that was too large. As the situation with regard to access to UK waters is still ongoing, an assumption regarding TAC undershoot is made in this year calculation of the intermediate year catch (see section 8.1).

Since the intermediate year catch was overestimated, the 2021 short-term forecast produced an underestimate of the 2021 SSB (by 9.78%) and 13.6% overestimation of Fbar 2021.

	Catch (2021)	SSB (2021)	$F_{bar4\text{-}8}$ (2021)
2021 WGWIDE forecast	1 199 103 t	3 510 849 t	0.35
2022 WGWIDE assessment	1 081 541 t	3 891 546 t	0.31
% difference	10.87%	-9.78%	13.60%

8.11 Management Considerations

Details and discussion on quality issues in this year's assessment is given in Section 8.7 above.

From 2001 to 2007, the internationally agreed TACs covered most of the distribution area of the Northeast Atlantic mackerel. From 2008 to 2014, no agreement was reached among the Coastal States on the sharing of the mackerel quotas. In 2014, three of the Coastal States (EU, NO and FO) agreed on a Management Strategy and sharing arrangement for 2014 to 2018. In November 2018, the agreement from 2014 was extended for two more years until 2020. There has been no new agreement on a new Management Strategy or share of the stock since then. Despite agreeing to abide by the ICES advice, the total declared quotas in each of the years 2015 to 2021 all exceed the advised catch by ICES (figure 8.11.1).

The mackerel in the Northeast Atlantic is traditionally characterised as three distinct 'spawning components': the southern component, the western component and the North Sea component. The basis for the components is derived from tagging experiments (ICES, 1974). However, the methods normally used to identify stocks or components (*e.g.*, ectoparasite infections, blood phenotypes, otolith shapes and genetics) have not been able to demonstrate significant differences between animals from different components. A review of the mackerel in the North Sea, carried out during WKWIDE 2017 (ICES, 2017) concluded that Northeast Atlantic mackerel should be considered as a single population (stock) with individuals that show stronger or weaker affinity for spawning in certain parts of the spawning area.

Since the mid-1970s, ICES has continuously recommended conservation measures for the North Sea component of the Northeast Atlantic mackerel stock (*e.g.,* ICES, 1974; ICES, 1981). The measures advised by ICES to protect the North Sea spawning component (*i.e.,* closed areas and minimum landing size) aimed to promote the conditions that make a recovery of this component possible.

The minimum landing size (MLS) for mackerel is currently set at 30 cm for the North Sea and 20 cm in the western area. The MLS of 30 cm in the North Sea was originally introduced by Norway in 1971 and was intended to protect the very strong 1969 year-class from exploitation in the industrial fishery (Pastoors, 2015). In the early 1990s, ICES recommended that, because of mixing of juvenile and adult mackerel on western waters fishing grounds, the adoption of a 30 cm minimum landing size for mackerel was not desirable as it could lead to increased discarding (ICES, 1990; 1991). A substantial part of the catch of (western) NEA mackerel is taken in ICES Division 4.a during the period October until mid-February to which the 30 cm MLS applies even though there is limited understanding on the effectiveness of minimum landing sizes in achieving certain conservation benefits (STECF, 2015).

8.12 Ecosystem considerations

An overview of the main ecosystem drivers possibly affecting the different life-stages of Northeast Atlantic mackerel and relevant observations are given in the Stock Annex. The discussion here is limited to recent features of relevance.

Production (recruitment and growth)

Since 2012 the recruitment index (age 0) has been estimating substantially larger year-classes than what is later estimated at age 3 when they enter the fishery and the other surveys. It is not known if this mismatch is a sampling bias or altered mortality of the juveniles between age 0 and 3.

The rapid increase in stock size up until around 2015 was suggested to drive the recent expansion of the spawning northward into new areas (Jansen, 2016). There are several indications of a northward shift and/or expansion in spawning and nursery area towards northern and northeastern areas since 2016 (ICES, 2016; Nøttestad *et al*., 2018; Bjørdal, 2019; Bjørdal et al. in press). This northerly shift seems to have continued (Nøttestad *et al*., 2018). However, spawning in the Norwegian Sea was shown to be of little quantitative significance in 2021 (Burns and O'Hea, WD 15 to WGWIDE 2021 (ICES, 2021b)).

Growth (*i.e.* length- and weight-at-age) have declined substantially in recent times for all ages (*e.g.* 0-3 year-old in 1998-2012, Jansen and Burns, 2015; all ages in 2005-2015, Jansen and Burns, 2015; Ólafsdóttir *et al*., 2015). The variations in growth of mackerel in all ages are correlated with mackerel density, *e.g.* mean weight-at-length have been shown to be positively related to location, day-of-year, temperature and SSB. Furthermore, the density dependent regulation of growth from juvenile to adult mackerel, appears to reflect the spatial dynamics observed in the migration patterns during the feeding season. As such, growth rates of the juveniles were tightly correlated with the density of juveniles in the nursery areas (Jansen and Burns, 2015) and growth for adults (age 3-8) were correlated with the combined effects of mackerel and herring stock sizes (Ólafsdóttir *et al*., 2015). Conspecific density-dependence was most likely mediated via intensified competition associated with greater mackerel density, possibly also coinciding with decreased prey availability. Nevertheless, weight-at-age of mackerel both from the catches and the surveys have increased during the last few years, particularly for the younger year classes from 1 to 6 years of age (ICES, 2019c; 2020; 2021b), coinciding with reduced abundance of mackerel in recent years.

Drivers of the spatial distribution of mackerel

In the mid-2000s, the summer feeding distribution of Northeast Atlantic mackerel (*Scomber scombrus*) in Nordic Seas began expanding into new areas (Nøttestad *et al*., 2016). During the period 2007 - 2016 the mackerel distribution range increased three-fold and the centre-of-gravity shifted westward by 1650 km and northward by 400 km. Distribution range peaked in 2014 and was positively correlated to Spawning Stock Biomass (SSB) (ICES 2020). During this period mackerel stock expansion during the feeding season in summer increased from 1.3 mill km^2 in 2007 to at least 2.9 mill km^2 in 2014, mainly towards western and northern regions of the Nordic seas (Nøttestad *et al*., 2016). The distribution area was stable around 2.8-2.9 mill km^2 during 2017-2019 (Nøttestad *et al*., 2017; 2019; ICES, 2018a). However, we witnessed a substantial shift in mackerel concentrations and distribution during summers of 2020-2021, when no mackerel were registered in Greenland waters, and a substantial decline was documented in Icelandic waters, whereas increased biomasses of mackerel were distributed in the central and northern part of the Norwegian Sea (Nøttestad *et al*., 2020b; WD09 in ICES 2021b). Overall, we have witnessed that mackerel had a much more eastern distribution in 2018-2022 compared to 2014-2017 (ICES, 2018a; Nøttestad *et al*., 2019; 2020b; 2021). Most of the surveyed mackerel still appears to be in the Norwegian Sea, but were more westerly distributed in 2022 than in the last 2 years. The survey coverage area was 2.9 million km^2 in 2022, which is 32% larger coverage compared to 2021. Survey coverage was increased in the western areas (Iceland and Greenland waters) compared to in 2021. Furthermore, 0.28 million km^2 was surveyed in the North Sea in July 2022.

Ólafsdóttir *et al*. (2018) modelled (GAM) IESSNS data (2007-2016) and found that mackerel was present in temperatures ranging from 5 °C to 15 °C, but preferred areas between 9 °C and 13 °C. The model showed that both mackerel occurrence and density were positively related to location, temperature, meso-zooplankton density and SSB. Thus, geographical expansion of mackerel during the summer feeding season in Nordic Seas was driven by increasing mackerel stock size and constrained by availability of preferred temperature and abundance of meso-zooplankton. However, these results are limited by time-series length (1997-2016; Olafsdottir *et al*., 2019). Notably, this seems to have changed during the most recent period from 2019 and onwards (e.g. high mackerel concentrations in 2020 at lower temperatures of 7-8 °C; Nøttestad *et al*., 2019; 2020b; WD09 in ICES 2021b). It is not clear what causes this distributional shift, but the SST were 1-2°C lower in the western and south-western areas as compared to a 20-years mean (1999-2009), and substantially lower zooplankton concentrations in Icelandic and Greenland waters in 2019 and 2020 might partly explain such changes (ICES, 2018a; Nøttestad *et al*., 2019; 2020a). Marine climate with multi-decadal variability might also have affected the observed distributional changes but were not evaluated.

Trophic interactions

There are strong indications for interspecific competition for food between mackerel, NSS-herring and blue whiting (Huse *et al*., 2012), where the competition between mackerel and herring being the best studied relationship. Both higher stomach fullness and prey shift for mackerel compared to herring during low stock size periods indicates that herring may suffer from this competition. Thus, an opportunistic (i.e. rapid shift in diet) and more generalist diet (i.e. wider range of prey) may be advantageous for mackerel in periods with low zooplankton abundances (Langøy *et al*. 2012; Debes *et al*. 2012; Óskarsson *et al*. 2015; Bachiller *et al*. 2016). Feeding activity seem to be highest in areas associated with colder water masses (Bachiller *et al*., 2016), and bioenergetics indicate that mackerel consumption may be as high as both herring and blue whiting in some years (122-135 mill t year^{-1}, Bachiller *et al*. 2018). Distribution overlap between mackerel and NSS herring during the summer feeding season is generally highest in the south-western part of the Norwegian Sea (Faroe and east Icelandic area) (Nøttestad *et al*., 2016; 2017; Ólafsdóttir *et al*., 2017). This spatiotemporal overlap between mackerel and herring have been present from 2016-2019 (ICES, 2018a, Nøttestad *et al*., 2016; 2017; 2019). In addition, increasing distribution overlaps in the north-western parts of the Norwegian Sea have also been observed since 2019 and onwards, which is in contrast to previous years (Nøttestad *et al*., 2019; 2020; WD09 in ICES 2021b). Overlapping distributions of mackerel and Norwegian spring-spawning herring (NSSH) were particularly present in the western and north-western part of the Norwegian Sea in 2022.

Recently, a number of predators have been highlighted as potential sources of mortality for mackerel. Although limited spatial overlap between marine mammals and mackerel during summers in the Nordic Seas (Nøttestad *et al*., 2019; Løviknes, 2019), orcas have been observed to actively search and hunt for mackerel schools (Nøttestad *et al*., 2014; Nøttestad *et al*., 2020a; 2021). Furthermore, the increases of 0- and 1-groups mackerel found along major coastlines of Norway (2016-2018, Nøttestad *et al*., 2018; Bjørdal, 2019) have coincided with predation by increasing numbers of adult Atlantic bluefin tuna (*Thynnus thunnus*, Boge, 2019; Nøttestad *et al*., 2020b). Additionally, stomach samples from several species document that smaller sized mackerel is now eaten by different predators in northern waters (e.g. cod, saithe, marine mammals and seabirds; Bjørdal, 2019). Although, fewer 1-groups have been observed in coastal Norway waters in recent years (2019-2022, IESSNS; Nøttestad *et al*., 2019; 2020b; 2021; 2022) predation by the Atlantic bluefin tuna is still evident. The predation pressure and associated mortality from various predators on NEA mackerel (both juveniles and adults) are still unknown, but could have ecological impact in both time (i.e. population) and space (i.e. local and regional) (ICCAT, 2019; Nøttestad *et al*., 2020b).

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Table 8.4.1.1. NE Atlantic Mackerel. ICES estimated catches by area (t). Discards not estimated prior to 1978 (data submitted by Working Group members).

Year	Subarea 6			Subarea 7 and Divisions 8.abde			Subareas 3 and 4			Subareas 1 2 5 and 14			Divisions 8.c and 9.a			Total		
	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch
1969	4800		4800	47404		47404	739175		739175	7		7	42526		42526	833912		833912
1970	3900		3900	72822		72822	322451		322451	163		163	70172		70172	469508		469508
1971	10200		10200	89745		89745	243673		243673	358		358	32942		32942	376918		376918
1972	13000		13000	130280		130280	188599		188599	88		88	29262		29262	361229		361229
1973	52200		52200	144807		144807	326519		326519	21600		21600	25967		25967	571093		571093
1974	64100		64100	207665		207665	298391		298391	6800		6800	30630		30630	607586		607586
1975	64800		64800	395995		395995	263062		263062	34700		34700	25457		25457	784014		784014
1976	67800		67800	420920		420920	305709		305709	10500		10500	23306		23306	828235		828235
1977	74800		74800	259100		259100	259531		259531	1400		1400	25416		25416	620247		620247
1978	151700	15100	166800	355500	35500	391000	148817		148817	4200		4200	25909		25909	686126	50600	736726
1979	203300	20300	223600	398000	39800	437800	152323	500	152823	7000		7000	21932		21932	782555	60600	843155
1980	218700	6000	224700	386100	15600	401700	87931		87931	8300		8300	12280		12280	713311	21600	734911
1981	335100	2500	337600	274300	39800	314100	64172	3216	67388	18700		18700	16688		16688	708960	45516	754476
1982	340400	4100	344500	257800	20800	278600	35033	450	35483	37600		37600	21076		21076	691909	25350	717259
1983	320500	2300	322800	235000	9000	244000	40889	96	40985	49000		49000	14853		14853	660242	11396	671638
1984	306100	1600	307700	161400	10500	171900	43696	202	43898	98222		98222	20208		20208	629626	12302	641928

Year	Subarea 6			Subarea 7 and Divisions 8.abde			Subareas 3 and 4			Subareas 1 2 5 and 14			Divisions 8.c and 9.a			Total		
	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch
1985	388140	2735	390875	75043	1800	76843	46790	3656	50446	78000		78000	18111		18111	606084	8191	614275
1986	104100		104100	128499		128499	236309	7431	243740	101000		101000	24789		24789	594697	7431	602128
1987	183700		183700	100300		100300	290829	10789	301618	47000		47000	22187		22187	644016	10789	654805
1988	115600	3100	118700	75600	2700	78300	308550	29766	338316	120404		120404	24772		24772	644926	35566	680492
1989	121300	2600	123900	72900	2300	75200	279410	2190	281600	90488		90488	18321		18321	582419	7090	589509
1990	114800	5800	120600	56300	5500	61800	300800	4300	305100	118700		118700	21311		21311	611911	15600	627511
1991	109500	10700	120200	50500	12800	63300	358700	7200	365900	97800		97800	20683		20683	637183	30700	667883
1992	141906	9620	151526	72153	12400	84553	364184	2980	367164	139062		139062	18046		18046	735351	25000	760351
1993	133497	2670	136167	99828	12790	112618	387838	2720	390558	165973		165973	19720		19720	806856	18180	825036
1994	134338	1390	135728	113088	2830	115918	471247	1150	472397	72309		72309	25043		25043	816025	5370	821395
1995	145626	74	145700	117883	6917	124800	321474	730	322204	135496		135496	27600		27600	748079	7721	755800
1996	129895	255	130150	73351	9773	83124	211451	1387	212838	103376		103376	34123		34123	552196	11415	563611
1997	65044	2240	67284	114719	13817	128536	226680	2807	229487	103598		103598	40708		40708	550749	18864	569613
1998	110141	71	110212	105181	3206	108387	264947	4735	269682	134219		134219	44164		44164	658652	8012	666664
1999	116362		116362	94290		94290	313014		313014	72848		72848	43796		43796	640311		640311
2000	187595	1	187595	115566	1918	117484	285567	165	304898	92557		92557	36074		36074	736524	2084	738608
2001	143142	83	143142	142890	1081	143971	327200	24	339971	67097		67097	43198		43198	736274	1188	737462

Year	Subarea 6			Subarea 7 and Divisions 8.abde			Subareas 3 and 4			Subareas 1 2 5 and 14			Divisions 8.c and 9.a			Total		
	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch	Ldg	Disc	Catch
2002	136847	12931	149778	102484	2260	104744	375708	8583	394878	73929		73929	49576		49576	749131	23774	772905
2003	135690	1399	137089	90356	5712	96068	354109	11785	365894	53883		53883	25823	531	26354	659831	19427	679288
2004	134033	1705	134738	103703	5991	109694	306040	11329	317369	62913	9	62922	34840	928	35769	640529	19962	660491
2005	79960	8201	88162	90278	12158	102436	249741	4633	254374	54129		54129	49618	796	50414	523726	25788	549514
2006	88077	6081	94158	66209	8642	74851	200929	8263	209192	46716		46716	52751	3607	56358	454587	26594	481181
2007	110788	2450	113238	71235	7727	78962	253013	4195	257208	72891		72891	62834	1072	63906	570762	15444	586206
2008	76358	21889	98247	73954	5462	79416	227252	8862	236113	148669	112	148781	59859	750	60609	586090	37075	623165
2009	135468	3927	139395	88287	2921	91208	226928	8120	235049	163604		163604	107747	966	108713	722035	15934	737969
2010	106732	2904	109636	104128	4614	108741	246818	883	247700	355725	5	355729	50826	4640	55466	864229	13045	877272
2011	160756	1836	162592	51098	5317	56415	301746	1906	303652	398132	28	398160	26337	1807	28144	938070	10894	948963
2012	121115	952	122067	65728	9701	75429	218400	1089	219489	449325	1	449326	29809	3431	33240	884377	15174	899551
2013	132062	273	132335	49871	1652	51523	260921	337	261258	465846	15	465861	24867	2455	27322	933567	4732	938299
2014	180068	340	180408	93709	1402	95111	383887	334	384221	684082	91	684173	53591	4284	57875	1395337	6451	1401788
2015	134728	30	134757	98563	3155	101718	295877	34	295911	632493	78	632571	43735	7133	50869	1205396	10431	1215827
2016	206326	200	206526	37300	1927	39227	248041	570	248611	563440	54	563494	39056	3220	42276	1094163	5971	1100135
2017	225959	151	226110	21128	1992	23119	269404	400	269804	603806	62	603869	36512	227	36739	1156809	2832	1159641
2018	157239	90	157329	32037	1611	33649	341527	620	342147	455689	51	455740	33761	518	34279	1020254	2890	1023144
2019	122995	144	123139	32840	5902	38742	307235	812	308047	345019	18	345037	23832	931	24763	831920	7807	839727
2020	130577	341	130918	48806	8065	56871	456479	732	457211	356985		356985	37386	143	37529	1030233	9280	1039513
2021	146519	117	146635	15901	2524	18425	221019	423	221442	663111		663111	31862	65	31928	1078411	3129	1081540

Table 8.4.2.1. NE Atlantic Mackerel. ICES estimated catch (t) in Subareas 1, 2, 5 and 14, 2000–2021 (Data submitted by Working Group members).

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Denmark	1375	7	1								4845
Estonia	2673	219									
Faroe Islands	5546	3272	4730		650	30		278	123	2992	66312
France					2	1					
Germany								7			
Greenland											
Iceland			53	122		363	4222	36706	112286	116160	121008
Ireland				495	471						
Latvia											
Lithuania	2085										
Netherlands			569	44	34	2393		10	72		90
Norway	31778	21971	22670	125481	10295	13244	8914	493	3474	3038	104858
Poland											
Sweden		8									
United Kingdom		54	665	692	2493				4		
Russia	49101	41566	45811	40026	49489	40491	33580	35408	32728	414141	58613
Misreported			-570		-553						
Unallocated				-44	32	-2393		-10	-18		

Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Discards					9				112		5
Total	92557	67097	73929	53883	62922	54129	46716	72891	148781	163604	355729
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Denmark	269		391	2345	4321	1	2	289			0.691
Estonia			13671								
Faroe Islands	121499	107198	142976	103896	76889	61901	66194	52061	37418	33291	105096
France	2		197	8	36			733		8	0.2
Germany		107	74		2963	3499	4064	577	190	206	9
Greenland	621	74021	541481	875811	30351	36142	46388	62973	30241	26555	33360
Iceland	159263	149282	151103	172960	169333	170374	167366	168330	128008	151534	132109
Ireland	90			1725	6	2					
Latvia											
Lithuania				1082		1931				2	
Netherlands	178	5	1	5887	6996	8599	7671	2697	13	0.73	
Norway	43168	110741	33817	192322	204574	153228	167739	46853	22605	15937	256124
Poland								2		0.044	8.2
Sweden		4	825	3310	740	730	1720	910		220	228
United Kingdom			2	5534	7851	5240	4601	2009		426	

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Russia	73601	74587	80812	116433	128433	121614	138061	118255	126543	128805	136176
Misreported											
Unallocated											
Discards	28	1	151	911	78	54	62	51	18	0.05	
Total	398160	449326	465729	684173	632571	563315	603869	455740	345036	356985	663111

Table 8.4.2.2. NE Atlantic Mackerel. ICES estimated catch (t) in the North Sea, Skagerrak and Kattegat (Subarea 4 and Division 3.a), 2000-2021 (Data submitted by Working Group members).

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Belgium	146	97	22	2	4	1	3	1	2	3	27
Denmark	27720	21680	343751	275081	25665	232121	242191	252171	26716	23491	36552
Faroe Islands	10614	18751	12548	11754	11705	9739	12008	11818	7627	6648	4639
France	1588	1981	2152	1467	1538	1004	285	7549	490	1493	686
Germany Fed. Rep.	78	4514	3902	4859	4515	4442	2389	5383	4668	5158	25621
Iceland											
Ireland	9956	10284	20715	17145	18901	15605	4125	13337	11628	12901	14639
Lithuania											
Netherlands	2262	2441	11044	6784	6366	3915	4093	5973	1980	2039	1300
Norway	142320	158401	161621	150858	147068	106434	113079	131191	114102	118070	129064
Poland						109					

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Sweden	49941	5090	52321	4450	4437	3204	3209	38581	36641	73031	34291
United Kingdom	58282	52988	61781	67083	62932	37118	28628	46264	37055	47863	52563
Russia	1672	1				4					696
Misreported (Area 6.a)	8591	39024	49918	62928	23692	37911	8719		17280	1959	
Unallocated	34761	24873	22985	-730	-783	7043	171	2421	2039	-629	660
Discards	1912	24	8583	11785	11329	4633	8263	4195	8862	8120	883
Total	304896	339970	394878	365894	317369	254374	209192	257208	236111	235049	247700
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Belgium	21	39	62	56	38	99	107	110	13	75	77
Denmark	32800	36492	31924	21340	35809	21696	27457	22207	25374	34375	28295
Faroe Islands	543	432	25	42919	25672	18193	12915	15475	17460	32860	
France	1416	5736	1788	4912	7827	3448	5942	6714	5455	8959	5041
Germany Fed. Rep.	52911	4560	5755	4979	6056	10172	11185	12091	7778	15946	9939
Iceland											
Ireland	15810	20422	13523	45167	34167	24437	35957	24567	1678	15395	11021
Lithuania				8340		596				813	6655
Netherlands	9881	6018	4863	24536	17547	11434	17401	13844	8957	18425	15983
Norway	162878	64181	130056	85409	36344	55089	51960	135715	135083	195515	14518

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Poland					24		0.721	4041	1394	16	559
Sweden	32481	4560	2081	1112	3190	2933	1981	3056	2152	3451	3277
United Kingdom	69858	75959	70840	145119	129203	99945	104499	103707	101890	130650	125553
Russia			4						0.12		
Misreported (Area 6.a)											
Unallocated											
Discards	1906	1089	337	334	34	559	400	620	812	732	423
Total	303652	219489	261258	384221	295911	248611	269804	342147	308047	457211	221340

Table 8.4.2.3. NE Atlantic Mackerel. ICES estimated catch (t) in the Western area (Subareas 6 and 7 and Divisions 8.a,b,d,e), 2000−2021 (Data submitted by Working Group members).

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Belgium					1					1	2
Denmark	82	835		113				6	10		48
Estonia											
Faroe Islands	4863	2161	2490	2260	674		59	1333	3539	4421	36
France	17857	18975	19726	21213	18549	15182	14625	12434	14944	16464	10301
Germany	22901	20793	22630	19200	18730	14598	14219	12831	10834	17545	16493
Guernsey							10				
Ireland	61277	60168	51457	49715	41730	30082	36539	35923	33132	48155	43355

Isle of Man											14
Jersey						9	8	6	7	8	6
Lithuania							95	7			
Netherlands	30123	33654	21831	23640	21132	18819	20064	18261	17920	20900	21699
Norway								7	3948	121	30
Poland						461	1368	978			
Russia											1
Spain	4500	4063	3483			4795	4048	2772	7327	8462	6532
United Kingdom	126620	139589	131599	167246	149346	115586	67187	87424	768821	109147	107840
Misreported (Area 4.a)	-3775	-39024	-43339	-62928	-23139	-37911	-8719		-17280	-1959	
Unallocated	31564	37952	27558	5587	9714	13412	4783	10042	-952	490	4503
Discards	1920	1164	15191	7111	7696	20359	14723	10177	27351	6848	7518
Total	297932	280553	252620	233157	244432	190597	169009	192201	177662	230603	218377
Country	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Belgium					14	44	21	58	53	49	34
Denmark	2889	8	903	18538	6741	19443	12569	8194	5189	4110	4463
Estonia											

Faroe Islands	8			3421	5851	13173	20559	13543	7787	2913	
France	11304	14448	12438	16627	17820	16634	16925	13974	12371	12816	11308
Germany	18792	14277	15102	23478	19238	9740	9608	7214	8936	8878	2049
Greenland										22	
Guernsey	10	5	9	9	4			12	9		
Iceland									69		
Ireland	45696	42627	42988	56286	54571	52087	48957	42181	51635	58720	49731
Isle of Man	11	11	8	3		8	2	3	3	2	
Jersey	7	8	8	7	3	3	0.003	3	2	5	
Lithuania	23			176	554	13					
Netherlands	18336	19794	16295	16242	15264	17896	18694	13851	13727	11895	8611
Norway	2019	1101	734		1313	1035	2657	4639	1420	221	11
Poland								14	2312	5286	1155
Portugal									46	35	32
Russia						30			1	10	
Spain	1257	773	635	1796	951	1253	786	4471	1220	1784	704
Sweden									805		
United Kingdom	111103	93775	92957	137195	110932	112268	116308	84309	50253	72637	84323

Unallocated	399	16	-144		34			13			
Discards	7153	10654	2105	1742	3185	2126	2142	1701	6046	8405	2640
Total	219007	197496	183857	275519	236475	245754	249229	194180	161883	187788	165060

Table 8.4.2.4. NE Atlantic Mackerel. ICES estimated catch (t) in Divisions 8.c and 9.a, 2000–2021 (Data submitted by Working Group members). 9.b is included in 2020.

Country	Div	2004	2005	2006	2007	2008	2009	2010	2011	2012
France	8.c	177	151	43	55	168	383	392	44	283
Portugal	8.c							1758	2302	4867.9437
Portugal	9.a	2289	1509	2620	2605	2381	1753	2363	962	824
Spain	8.c			43063	53401	50455	91043	38858	14709	17768
Spain	9.a			7025	6773	6855	14569	7347	2759	845
Discards	8.c	928	391	3606	156	73	725	4408	563	2187
Discards	9.a		405	1	916	677	241	232	1245	1244
Unallocated	8.c	28429	42851						4691	4144
Unallocated	9.a	3946	5107					108	871	1076
Total	9.a	6234	7021	9646	10293	9913	16562	10049	5836	3989
Total		35768	50414	56358	63906	60609	108713	55466	28146	33239

Country	Div	2013	2014	2015	2016	2017	2018	2019	2020	2021
France	8.c	220	171	21	106	83	50	43	96	93
Portugal	8.c	5134	7334	6836	6069	3697	3709	3188	4189	3738
Portugal	9.a	254	618	1456	619	634	855	706	575	953
Spain	8.c	14617	33783	29726	26553	30893	27190	19148	31143	25272
Spain	9.a	1162	2227	3853	2229	1206	1656	747	1379	1807

Russia									2	
Discards	8.c	1428	2821	4724	2469	84	324	760	28	18
Discards	9.a	1027	1463	2409	751	143	194	172	115	47
Unallocated	8.c	-573	8795	11	1357		300			
Unallocated	9.a	4053	662	1831	2123					
Total	9.a	6497	4308	9550	5722	1983	2736	1625	2070	2807
Total		27322	57874	50867	42276	36740	34279	24764	37529	31928

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2021 (Q1-Q4).

Age	1	2.a	3.a	3.b	3.c	3.d	4.a	4.b	4.c
0									
1	292	279	293	292	292	289	289	278	286
2	322	312	322	319	316	318	317	323	317
3	338	335	340	343	336	326	341	333	333
4	348	345	350	350	347	352	350	351	354
5	356	355	358	359	355	360	359	358	363
6	364	366	372	372	372	361	373	368	368
7	370	372	378	376	377	359	376	372	377
8	376	377	381	381	380	378	380	380	383
9	381	381	385	383	384	387	382	384	390
10	386	383	389	388	388	389	385	387	383
11	390	388	391	386	389	377	387	389	384
12	394	393	399	400	398	386	399	398	392
13	398	395	400	399	396	398	397	397	397
14	402	396	406	406	399	404	392	396	389
15	399	398	412				402	407	398

Age	5.a	5.b	6.a	6.b	7.a	7.b	7.c	7.h	
0									
1		289	209	207	231			103	
2	302		290	287	168			304	
3	341	342	324	327	97	352	354	314	
4	348	360	342	346	128	350	342	302	
5	354	353	353	358	172	356	359	341	
6	370	372	366	371	143	364	384	347	
7	376	378	372	373	132	379	396	373	
8	381	379	380	381	162	390	391	383	
9	381	377	382	383	256	385	400	387	

10	380	389	385	386	367	389	399	390
11	386	386	391	391	274	390	409	400
12	390	364	394	393	409	405	399	393
13	388		398	399	358	401	395	395
14	392		399	404	404	410	410	405
15	396		399	418	404	435	435	415

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2021 (Q1-Q4) continued.

Age	7.j	8.a	8.b	8.c	8.d	9.a	9.a.N	All
0		181	180	217		206	222	178
1	178	247	216	225	278	258	256	195
2	295	295	294	315	326	317	279	306
3	338	316	323	341	324	329	310	328
4	349	347	347	354	346	340	338	343
5	356	363	360	364	366	368	357	354
6	367	376	372	373	375	385	379	368
7	374	382	379	377	379	390	383	373
8	382	391	389	383	385	395	389	379
9	379	389	387	386	388	413	394	382
10	387	393	392	391	393	411	395	384
11	388	396	393	399	400	470	401	388
12	392	415	416	403	406	410	414	395
13	400	406	406	408	406	440	409	396
14	395	405	415	422	405		423	396
15	415							399

Table 8.6.1.2.1. Fecundity and atresia for the assessment years, from 1998 to 2022 (Preliminary values). n is the number of samples used, n/g refers to the number of oocytes or atretic oocytes by gram of fish (*) means median not mean relative for potential fecundity.

	Survey year							
	2001	2004	2007	2010	2013	2016	2019	2022 Prel.
Fecundity samples (n)	187	205	176	74	132	97	62	169
Prevalence of atresia (n)	290	348	416	511	732	713	895	559
Intensity of atresia (n)	290	348	416	511	56	66	64	
Relative potential fecundity (n/g)	1097	1127	1098	1140	1257*	1159*	1191*	1253*
Prevalence of atresia	0.2	0.28	0.38	0.33	0.22	0.3	0.28	0.28
Geometric mean intensity of atresia (n/g)	40	33	30	26	27	30	20	
Potential fecundity lost per day (n/g)	1.07	1.25	1.48	1.16	0.8	1.2	0.73	
Potential fecundity lost (n/g)	64	75	89	70	48	72	44	75
Relative potential fecundity lost (%)	6	7	9	6	4	6	4	6
Realised fecundity (n/g)*	1033	1052	1009	1070	1209	1087	1147	1178

Table 8.6.1.6.1. Daily egg production estimate (stage Ia) for mackerel in the North Sea using the DEPM in 2021.

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

Table 8.6.1.6.2. Estimated adult parameters and SSB for mackerel in the North Sea using the DEPM in 2021

Year	2021
Batch fecundity	18735
Relative batch fecundity (N/g)	42.7
CV Batch fecundity	0.87
Spawning fraction	0.18
Sex ratio	0.53
Female weight (g)	331.4
SSB (* 103 tonnes)	2380

Table 8.7.1.1. NE Atlantic mackerel. Input data and parameters and the model configurations for the assessment.

Input data types and characteristics:			
Name	Year range	Age range	Variable from year to year
Catch in tonnes	1980 -2021		Yes
Catch-at-age in numbers	1980 -2021	0-12+	Yes

Weight-at-age in the commercial catch	1980 –2021	0-12+	Yes
Weight-at-age of the spawning stock at spawning time.	1980 –2021	0-12+	Yes
Proportion of natural mortality before spawning	1980 -2021	0-12+	Yes
Proportion of fishing mortality before spawning	1980 -2021	0-12+	Yes
Proportion mature-at-age	1980 -2021	0-12+	Yes
Natural mortality	1980 -2021	0-12+	No, fixed at 0.15
Tuning data:			
Type	Name	Year range	Age range
Survey (SSB)	ICES Triennial Mackerel and Horse Mackerel Egg Survey	1992, 1995, 1998, 2001, 2004, 2007, 2010, 2013,2016,2019,2022.	Not applicable (gives SSB)
Survey (abundance index)	IBTS Recruitment index (log transformed)	1998-2020	Age 0
Survey (abundance index)	International Ecosystem Summer Survey in the Nordic Seas (IESSNS)	2010, 2012-2022	Ages 3-11
Tagging/recapture	Norwegian tagging program	Steel tags : 1980 (release year)-2006 (recapture years) RFID tags : 2013 (release year) 2021 (recapture year)	Ages 5 and older (age at release)

SAM parameter configuration :		
Setting	Value	Description
Coupling of fishing mortality states	1/2/3/4/5/6/7/8/8/8/8/8/8	Different F states for ages 0 to 6, one same F state for ages 7 and older
Correlated random walks for the fishing mortalities	0	F random walk of different ages are independent
Coupling of catchability parameters	0/0/0/0/0/0/0/0/0/0/0/0/0 1/0/0/0/0/0/0/0/0/0/0/0/0 2/0/0/0/0/0/0/0/0/0/0/0/0 0/0/0/3/4/5/6/7/8/9/10/10/0	No catchability parameter for the catches One catchability parameter estimated for the egg One catchability parameter estimated for the recruitment index One catchability parameter for each age group estimated for the IESSNS (age 3 to11)
Power law model	0	No power law model used for any of the surveys

Coupling of fishing mortality random walk variances	1/2/3/3/3/3/3/3/3/3/3/3/3	Separate F random walk variances for age 0, age 1 and a same variance for older ages
Coupling of log abundance random walk variances	1/2/2/2/2/2/2/2/2/2/2/2/2	Same variance used for the log abundance random walk of all ages except for the recruits (age 0)
Coupling of the observation variances	1/2/3/3/3/3/3/3/3/3/3/3/3 0/0/0/0/0/0/0/0/0/0/0/0/0 4/0/0/0/0/0/0/0/0/0/0/0/0 0/0/0/5/6/6/6/6/6/6/6/6/0	Separate observation variances for age 0 and 1 than for the older ages in the catches One observation variance for the egg survey One observation variance for the recruitment index 2 observation variances for the IESSNS (age 3 and ages 4 and older)
Stock recruitment model	0	No stock-recruiment model
Correlation structure	"ID", "ID", "ID", "AR"	Auto-regressive correlation structure for the IESSNS index, independent observations assumed for the other data sources

Table 8.7.1.2. NE Atlantic Mackerel. CATCH IN NUMBER

Units : thousands

age \ year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
0	33101	56682	11180	7333	287287	81799	49983	7403	57644	65400
1	411327	276229	213936	47914	31901	268960	58126	40126	152656	64263
2	393025	502365	432867	668909	86064	20893	424563	156670	137635	312739
3	64549	231814	472457	433744	682491	58346	38387	663378	190403	207689
4	328206	32814	184581	373262	387582	445357	76545	56680	538394	167588
5	254172	184867	26544	126533	251503	252217	364119	89003	72914	362469
6	142978	173349	138970	20175	98063	165219	208021	244570	87323	48696
7	145385	116328	112476	90151	22086	62363	126174	150588	201021	58116
8	54778	125548	89672	72031	61813	19562	42569	85863	122496	111251
9	130771	41186	88726	48668	47925	47560	13533	34795	55913	68240
10	39920	146186	27552	49252	37482	37607	32786	19658	20710	32228
11	56210	31639	91743	19745	30105	26965	22971	25747	13178	13904
12	104927	199615	156121	132040	69183	97652	81153	63146	57494	35814

age \ year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
0	24246	10007	43447	19354	25368	14759	37956	36012	61127	67003
1	140534	58459	83583	128144	147315	81529	119852	144390	99352	73597
2	209848	212521	156292	210319	221489	340898	168882	186481	229767	132994
3	410751	206421	356209	266677	306979	340215	333365	238426	264566	223639
4	208146	375451	266591	398240	267420	275031	279182	378881	323186	261778
5	156742	188623	306143	244285	301346	186855	177667	246781	361945	281041
6	254015	129145	156070	255472	184925	197856	96303	135059	207619	244212
7	42549	197888	113899	149932	189847	142342	119831	84378	118388	159019
8	49698	51077	138458	97746	106108	113413	55812	66504	72745	86739
9	85447	43415	51208	121400	80054	69191	59801	39450	47353	50613
10	33041	70839	36612	38794	57622	42441	25803	26735	24386	30363
11	16587	29743	40956	29067	20407	37960	18353	13950	16551	17048
12	27905	52986	68205	68217	57551	39753	30648	24974	22932	32446

age \ year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
0	36345	26034	70409	14744	11553	12426	75651	19302	25886	17615
1	102407	40315	222577	187997	31421	46840	149425	88439	59899	36514
2	142898	158943	70041	275661	453133	135648	173646	190857	167748	113574
3	275376	234186	367902	91075	529753	668588	159455	220575	399086	455113
4	390858	297206	350163	295777	147973	293579	470063	215655	284660	616963
5	295516	309937	262716	235052	258177	120538	195594	455131	260314	319465
6	241550	231804	237066	183036	145899	121477	97061	203492	255675	224848

7	175608	195250	151320	133595	89856	63612	73510	77859	124382	194326
8	106291	120241	118870	94168	65669	38763	33399	59652	57297	73171
9	52394	72205	79945	75701	40443	23947	18961	30494	32343	29738
10	31280	42529	43789	45951	35654	18612	13987	16039	19482	14989
11	18918	20546	21611	25797	16430	7955	8334	11416	6798	7470
12	34202	40706	40280	30890	19509	10669	10186	12801	9581	5003

age \ year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
0	23453	30429	23877	11325	62142	6732	716	28306	6995	6236
1	78636	62748	66370	47077	44558	104282	57466	43763	40332	41921
2	137351	115701	204121	235494	138880	127940	205840	89101	236207	126073
3	304647	323847	216711	400036	672022	250575	258176	461621	136779	350611
4	740816	471564	417953	371713	832975	583694	427212	353230	376312	114606
5	613418	656507	458718	445515	568835	651786	593046	398273	257069	295731
6	285438	490219	514489	433533	554367	453084	534943	505073	294539	226640
7	143537	244725	325982	340686	506804	416897	341408	432242	424715	229725
8	102446	113277	143643	190660	341618	356936	270586	262799	316779	267491
9	45963	53512	69962	113220	142398	206045	170574	189449	197761	204818
10	21268	25081	30761	46269	63871	107830	94849	138347	140403	102991
11	6272	12322	11657	19025	21501	26978	33910	59278	82812	66976
12	8529	10792	11720	17890	14123	22741	24427	51139	60485	74918

age	2020	2021
0	6443	2332
1	52637	29202
2	107302	326976
3	182163	217298
4	266760	281925
5	166627	366644
6	270154	182783
7	246268	300014
8	274182	208961
9	311215	228236
10	241775	198134
11	128294	128957
12	179703	118150

Table 8.7.1.3. NE Atlantic Mackerel. WEIGHTS AT AGE IN THE CATCH

Units : Kg

age \ year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
0	0.057	0.060	0.053	0.050	0.031	0.055	0.039	0.076	0.055	0.049	0.085	0.068
1	0.131	0.132	0.131	0.168	0.102	0.144	0.146	0.179	0.133	0.136	0.156	0.156
2	0.249	0.248	0.249	0.219	0.184	0.262	0.245	0.223	0.259	0.237	0.233	0.253
3	0.285	0.287	0.285	0.276	0.295	0.357	0.335	0.318	0.323	0.320	0.336	0.327
4	0.345	0.344	0.345	0.310	0.326	0.418	0.423	0.399	0.388	0.377	0.379	0.394
5	0.378	0.377	0.378	0.386	0.344	0.417	0.471	0.474	0.456	0.433	0.423	0.423
6	0.454	0.454	0.454	0.425	0.431	0.436	0.444	0.512	0.524	0.456	0.467	0.469
7	0.498	0.499	0.496	0.435	0.542	0.521	0.457	0.493	0.555	0.543	0.528	0.506
8	0.520	0.513	0.513	0.498	0.480	0.555	0.543	0.498	0.555	0.592	0.552	0.554
9	0.542	0.543	0.541	0.545	0.569	0.564	0.591	0.580	0.562	0.578	0.606	0.609
10	0.574	0.573	0.574	0.606	0.628	0.629	0.552	0.634	0.613	0.581	0.606	0.630
11	0.590	0.576	0.574	0.608	0.636	0.679	0.694	0.635	0.624	0.648	0.591	0.649
12	0.580	0.584	0.582	0.614	0.663	0.710	0.688	0.718	0.697	0.739	0.713	0.708

age \ year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
0	0.051	0.061	0.046	0.072	0.058	0.076	0.065	0.062	0.063	0.069	0.052	0.081
1	0.167	0.134	0.136	0.143	0.143	0.143	0.157	0.176	0.135	0.172	0.160	0.170
2	0.239	0.240	0.255	0.234	0.226	0.230	0.227	0.235	0.227	0.224	0.256	0.267
3	0.333	0.317	0.339	0.333	0.313	0.295	0.310	0.306	0.306	0.305	0.307	0.336
4	0.397	0.376	0.390	0.390	0.377	0.359	0.354	0.361	0.363	0.376	0.368	0.385
5	0.460	0.436	0.448	0.452	0.425	0.415	0.408	0.404	0.427	0.424	0.424	0.438
6	0.495	0.483	0.512	0.501	0.484	0.453	0.452	0.452	0.463	0.474	0.461	0.477
7	0.532	0.527	0.543	0.539	0.518	0.481	0.462	0.500	0.501	0.496	0.512	0.522
8	0.555	0.548	0.590	0.577	0.551	0.524	0.518	0.536	0.534	0.540	0.536	0.572
9	0.597	0.583	0.583	0.594	0.576	0.553	0.550	0.569	0.567	0.577	0.580	0.612
10	0.651	0.595	0.627	0.606	0.596	0.577	0.573	0.586	0.586	0.603	0.600	0.631
11	0.663	0.647	0.678	0.631	0.603	0.591	0.591	0.607	0.594	0.611	0.629	0.648
12	0.669	0.679	0.713	0.672	0.670	0.636	0.631	0.687	0.644	0.666	0.665	0.715

age \ year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
0	0.067	0.048	0.038	0.089	0.051	0.104	0.048	0.029	0.089	0.091	0.043	0.051
1	0.156	0.151	0.071	0.120	0.105	0.153	0.118	0.113	0.123	0.173	0.126	0.154
2	0.263	0.268	0.197	0.215	0.222	0.213	0.221	0.231	0.186	0.234	0.231	0.242
3	0.323	0.306	0.307	0.292	0.292	0.283	0.291	0.282	0.284	0.277	0.282	0.294
4	0.400	0.366	0.357	0.372	0.370	0.331	0.331	0.334	0.340	0.336	0.324	0.320
5	0.419	0.434	0.428	0.408	0.418	0.389	0.365	0.368	0.374	0.360	0.362	0.351
6	0.485	0.440	0.479	0.456	0.444	0.424	0.418	0.411	0.401	0.386	0.394	0.392
7	0.519	0.496	0.494	0.512	0.497	0.450	0.470	0.451	0.431	0.405	0.422	0.420
8	0.554	0.539	0.543	0.534	0.551	0.497	0.487	0.494	0.469	0.431	0.443	0.443
9	0.573	0.556	0.584	0.573	0.571	0.538	0.515	0.540	0.503	0.454	0.467	0.465
10	0.595	0.583	0.625	0.571	0.620	0.586	0.573	0.580	0.537	0.472	0.482	0.489
11	0.630	0.632	0.636	0.585	0.595	0.599	0.603	0.611	0.537	0.493	0.523	0.522
12	0.684	0.655	0.689	0.666	0.662	0.630	0.630	0.664	0.585	0.554	0.589	0.561

age \ year	2016	2017	2018	2019	2020	2021
0	0.035	0.018	0.066	0.057	0.057	0.049
1	0.154	0.178	0.147	0.112	0.174	0.163
2	0.240	0.266	0.247	0.260	0.285	0.277
3	0.297	0.311	0.320	0.297	0.322	0.338
4	0.329	0.356	0.355	0.360	0.360	0.374
5	0.356	0.377	0.397	0.388	0.389	0.406
6	0.383	0.397	0.410	0.429	0.417	0.441
7	0.411	0.415	0.426	0.441	0.444	0.457
8	0.438	0.444	0.446	0.453	0.459	0.477
9	0.453	0.465	0.469	0.472	0.471	0.486
10	0.479	0.484	0.492	0.497	0.495	0.501
11	0.499	0.497	0.507	0.514	0.519	0.514
12	0.520	0.531	0.537	0.537	0.554	0.548

Table 8.7.1.4. NE Atlantic Mackerel. WEIGHTS AT AGE IN THE STOCK

Units : Kg

age \ year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
0	0.063	0.063	0.063	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.114	0.112	0.112	0.111	0.108	0.111	0.104	0.075	0.099	0.058	0.096	0.174
2	0.205	0.179	0.159	0.179	0.204	0.244	0.184	0.157	0.181	0.162	0.166	0.184
3	0.287	0.258	0.217	0.233	0.251	0.281	0.269	0.234	0.238	0.230	0.247	0.243
4	0.322	0.312	0.300	0.282	0.293	0.308	0.301	0.318	0.298	0.272	0.290	0.303
5	0.356	0.335	0.368	0.341	0.326	0.336	0.350	0.368	0.348	0.338	0.332	0.347
6	0.377	0.376	0.362	0.416	0.395	0.356	0.350	0.414	0.392	0.392	0.383	0.392
7	0.402	0.415	0.411	0.404	0.430	0.407	0.374	0.415	0.445	0.388	0.435	0.423
8	0.434	0.431	0.456	0.438	0.455	0.455	0.434	0.431	0.442	0.449	0.447	0.492
9	0.438	0.454	0.455	0.475	0.489	0.447	0.428	0.483	0.466	0.432	0.494	0.500
10	0.484	0.450	0.473	0.467	0.507	0.519	0.467	0.487	0.506	0.429	0.473	0.546
11	0.520	0.524	0.536	0.544	0.513	0.538	0.506	0.492	0.567	0.482	0.495	0.526
12	0.532	0.530	0.542	0.528	0.566	0.590	0.541	0.581	0.594	0.556	0.536	0.619

age \ year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.130	0.145	0.114	0.116	0.097	0.084	0.083	0.087	0.093	0.113	0.109	0.112
2	0.201	0.190	0.163	0.200	0.185	0.196	0.170	0.210	0.194	0.190	0.206	0.181
3	0.260	0.266	0.240	0.278	0.250	0.257	0.251	0.260	0.253	0.246	0.245	0.251
4	0.308	0.323	0.306	0.327	0.322	0.310	0.300	0.317	0.301	0.303	0.288	0.277
5	0.360	0.359	0.368	0.385	0.372	0.356	0.348	0.356	0.357	0.342	0.333	0.341
6	0.397	0.410	0.418	0.432	0.425	0.401	0.384	0.392	0.394	0.398	0.360	0.401
7	0.419	0.432	0.459	0.458	0.446	0.460	0.409	0.424	0.415	0.417	0.418	0.407
8	0.458	0.459	0.480	0.491	0.471	0.473	0.455	0.456	0.438	0.451	0.429	0.489
9	0.487	0.480	0.496	0.511	0.513	0.505	0.475	0.489	0.464	0.484	0.458	0.490
10	0.513	0.515	0.550	0.517	0.508	0.511	0.530	0.508	0.489	0.521	0.511	0.488
11	0.543	0.547	0.592	0.560	0.538	0.546	0.500	0.545	0.514	0.535	0.523	0.521
12	0.572	0.580	0.608	0.603	0.573	0.583	0.549	0.575	0.551	0.572	0.558	0.540

age \ year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.112	0.114	0.114	0.095	0.133	0.112	0.096	0.080	0.089	0.076	0.107	0.078
2	0.157	0.140	0.164	0.148	0.160	0.162	0.159	0.175	0.155	0.144	0.165	0.207
3	0.258	0.221	0.236	0.206	0.207	0.214	0.199	0.223	0.216	0.179	0.199	0.247
4	0.319	0.328	0.291	0.285	0.260	0.268	0.246	0.274	0.255	0.249	0.238	0.254
5	0.356	0.378	0.333	0.329	0.346	0.295	0.296	0.332	0.288	0.280	0.291	0.288
6	0.406	0.403	0.400	0.363	0.354	0.351	0.345	0.369	0.312	0.319	0.321	0.336
7	0.449	0.464	0.413	0.448	0.393	0.386	0.389	0.389	0.360	0.341	0.341	0.350
8	0.482	0.481	0.437	0.452	0.448	0.437	0.407	0.430	0.390	0.375	0.387	0.381
9	0.506	0.547	0.455	0.514	0.452	0.461	0.439	0.452	0.453	0.416	0.416	0.412
10	0.519	0.538	0.469	0.538	0.478	0.517	0.489	0.495	0.498	0.441	0.466	0.447
11	0.579	0.509	0.531	0.542	0.487	0.548	0.532	0.518	0.503	0.496	0.472	0.485
12	0.588	0.603	0.566	0.585	0.510	0.557	0.572	0.525	0.558	0.522	0.517	0.551

age \ year	2016	2017	2018	2019	2020	2021
0	0.000	0.000	0.000	0.000	0.000	0.000
1	0.059	0.058	0.064	0.070	0.069	0.064
2	0.182	0.204	0.190	0.191	0.209	0.186
3	0.238	0.237	0.266	0.250	0.252	0.261
4	0.282	0.278	0.283	0.293	0.289	0.281
5	0.298	0.308	0.314	0.311	0.348	0.323
6	0.340	0.308	0.327	0.346	0.363	0.352
7	0.368	0.338	0.346	0.365	0.376	0.392
8	0.385	0.377	0.364	0.371	0.394	0.416
9	0.404	0.394	0.389	0.397	0.400	0.423
10	0.424	0.426	0.419	0.428	0.423	0.446
11	0.440	0.430	0.437	0.431	0.445	0.458
12	0.473	0.499	0.491	0.481	0.488	0.496

Table 8.7.1.5. NE Atlantic Mackerel. NATURAL MORTALITY

Units : NA

age \ year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
0	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
2	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
3	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
4	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
5	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
6	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
7	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
8	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
9	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
11	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
12	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15

age \ year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
0	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
2	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
3	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
4	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
5	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
6	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
7	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
8	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
9	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
11	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
12	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15

age \ year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
0	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
2	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
3	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
4	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
5	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
6	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
7	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
8	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
9	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
11	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
12	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15

Table 8.7.1.6. NE Atlantic Mackerel. PROPORTION MATURE

age \ ear	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.093	0.097	0.097	0.098	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
2	0.521	0.497	0.498	0.485	0.467	0.516	0.522	0.352	0.360	0.372	0.392	0.435
3	0.872	0.837	0.857	0.863	0.853	0.885	0.926	0.922	0.901	0.915	0.909	0.912
4	0.949	0.934	0.930	0.940	0.938	0.940	0.983	0.994	0.989	0.994	0.996	0.991
5	0.972	0.976	0.969	0.972	0.966	0.966	0.965	0.997	0.994	0.996	0.998	0.996
6	0.984	0.984	0.987	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.996
7	0.990	0.987	0.985	0.984	0.975	0.976	1.000	1.000	1.000	1.000	1.000	1.000
8	1.000	0.999	0.999	0.999	0.999	0.999	0.991	0.992	0.991	0.993	0.995	1.000
9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
12	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

age \ year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.102	0.102	0.102	0.102	0.102	0.097	0.097	0.097	0.104	0.104	0.104	0.106
2	0.520	0.534	0.621	0.599	0.586	0.621	0.688	0.669	0.692	0.675	0.710	0.690
3	0.928	0.934	0.938	0.931	0.936	0.880	0.886	0.876	0.909	0.909	0.937	0.940
4	0.996	0.996	0.994	0.993	1.000	0.993	0.994	0.989	0.989	0.987	0.992	0.988
5	0.997	0.997	0.997	0.994	1.000	0.998	0.999	0.999	0.998	0.998	1.000	1.000
6	0.994	0.994	0.993	0.987	0.994	0.999	0.999	0.999	0.999	0.999	1.000	1.000
7	1.000	1.000	0.999	0.999	0.999	1.000	1.000	1.000	1.000	0.999	1.000	0.999
8	1.000	1.000	1.000	1.000	1.000	0.994	0.995	0.996	0.997	0.997	1.000	1.000
9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
12	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

age \ year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.106	0.106	0.095	0.095	0.095	0.096	0.096	0.096	0.094	0.092	0.092	0.104
2	0.761	0.616	0.589	0.546	0.524	0.541	0.667	0.655	0.604	0.683	0.675	0.763
3	0.962	0.959	0.928	0.921	0.917	0.919	0.930	0.927	0.926	0.921	0.916	0.944

4	0.993	0.993	0.994	0.994	0.999	0.999	0.999	0.999	0.999	0.998	0.999	0.998
5	0.999	0.999	1.000	1.000	0.999	1.000	1.000	1.000	0.999	1.000	1.000	0.999
6	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.999	0.999	0.999	1.000
7	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.999
8	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
12	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

	year					
age	2016	2017	2018	2019	2020	2021
0	0.000	0.000	0.000	0.000	0.000	0.000
1	0.127	0.125	0.105	0.105	0.105	0.119
2	0.633	0.606	0.464	0.534	0.519	0.569
3	0.937	0.945	0.902	0.910	0.915	0.943
4	0.997	0.998	0.998	0.999	0.998	0.999
5	0.999	1.000	1.000	1.000	1.000	1.000
6	1.000	1.000	1.000	1.000	1.000	0.999
7	0.999	0.999	0.999	1.000	1.000	0.999
8	1.000	1.000	1.000	1.000	1.000	1.000
9	1.000	1.000	1.000	1.000	1.000	1.000
10	1.000	1.000	1.000	1.000	1.000	1.000
11	1.000	1.000	1.000	1.000	1.000	1.000
12	1.000	1.000	1.000	1.000	1.000	1.000

Table 8.7.1.7. NE Atlantic Mackerel. FRACTION OF HARVEST BEFORE SPAWNING

	year											
age	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.139	0.111
2	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.240	0.272
3	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.240	0.272
4	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.209	0.240	0.272
5	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.393	0.406
6	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.393	0.406
7	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.393	0.406
8	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.393	0.406
9	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.393	0.406
10	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.393	0.406
11	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.393	0.406
12	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.393	0.406

	year											
age	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.084	0.165	0.249	0.331	0.269	0.206	0.144	0.125	0.106	0.088	0.142	0.197
2	0.304	0.301	0.298	0.296	0.295	0.295	0.295	0.320	0.347	0.373	0.360	0.347
3	0.304	0.301	0.298	0.296	0.295	0.295	0.295	0.320	0.347	0.373	0.360	0.347
4	0.304	0.301	0.298	0.296	0.295	0.295	0.295	0.320	0.347	0.373	0.360	0.347
5	0.419	0.444	0.469	0.494	0.494	0.494	0.495	0.461	0.426	0.392	0.408	0.425
6	0.419	0.444	0.469	0.494	0.494	0.494	0.495	0.461	0.426	0.392	0.408	0.425
7	0.419	0.444	0.469	0.494	0.494	0.494	0.495	0.461	0.426	0.392	0.408	0.425
8	0.419	0.444	0.469	0.494	0.494	0.494	0.495	0.461	0.426	0.392	0.408	0.425
9	0.419	0.444	0.469	0.494	0.494	0.494	0.495	0.461	0.426	0.392	0.408	0.425
10	0.419	0.444	0.469	0.494	0.494	0.494	0.495	0.461	0.426	0.392	0.408	0.425
11	0.419	0.444	0.469	0.494	0.494	0.494	0.495	0.461	0.426	0.392	0.408	0.425
12	0.419	0.444	0.469	0.494	0.494	0.494	0.495	0.461	0.426	0.392	0.408	0.425

	year											
age	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.251	0.262	0.274	0.285	0.206	0.125	0.047	0.092	0.138	0.183	0.170	0.156
2	0.334	0.317	0.300	0.284	0.266	0.249	0.232	0.176	0.119	0.064	0.117	0.171
3	0.334	0.317	0.300	0.284	0.266	0.249	0.232	0.176	0.119	0.064	0.117	0.171
4	0.334	0.317	0.300	0.284	0.266	0.249	0.232	0.176	0.119	0.064	0.117	0.171
5	0.441	0.409	0.376	0.344	0.310	0.275	0.242	0.233	0.225	0.216	0.203	0.189
6	0.441	0.409	0.376	0.344	0.310	0.275	0.242	0.233	0.225	0.216	0.203	0.189
7	0.441	0.409	0.376	0.344	0.310	0.275	0.242	0.233	0.225	0.216	0.203	0.189
8	0.441	0.409	0.376	0.344	0.310	0.275	0.242	0.233	0.225	0.216	0.203	0.189
9	0.441	0.409	0.376	0.344	0.310	0.275	0.242	0.233	0.225	0.216	0.203	0.189
10	0.441	0.409	0.376	0.344	0.310	0.275	0.242	0.233	0.225	0.216	0.203	0.189
11	0.441	0.409	0.376	0.344	0.310	0.275	0.242	0.233	0.225	0.216	0.203	0.189
12	0.441	0.409	0.376	0.344	0.310	0.275	0.242	0.233	0.225	0.216	0.203	0.189

	year					
age	2016	2017	2018	2019	2020	2021
0	0.000	0.000	0.000	0.000	0.000	0.000
1	0.143	0.232	0.393	0.581	0.533	0.187
2	0.224	0.153	0.179	0.183	0.184	0.090
3	0.224	0.153	0.179	0.183	0.184	0.090
4	0.224	0.153	0.179	0.183	0.184	0.090
5	0.178	0.295	0.196	0.301	0.317	0.233
6	0.178	0.295	0.196	0.301	0.317	0.233
7	0.178	0.295	0.196	0.301	0.317	0.233
8	0.178	0.295	0.196	0.301	0.317	0.233
9	0.178	0.295	0.196	0.301	0.317	0.233
10	0.178	0.295	0.196	0.301	0.317	0.233
11	0.178	0.295	0.196	0.301	0.317	0.233
12	0.178	0.295	0.196	0.301	0.317	0.233

Table 8.7.1.8. NE Atlantic Mackerel. FRACTION OF NATURAL MORTALITY BEFORE SPAWNING

	year											
age	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
0	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
1	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
2	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
3	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
4	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
5	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
6	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
7	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
8	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
9	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
10	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
11	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345
12	0.397	0.396	0.394	0.392	0.394	0.396	0.397	0.388	0.378	0.369	0.357	0.345

	year											
age	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
0	0.333	0.341	0.349	0.357	0.339	0.322	0.304	0.325	0.346	0.366	0.361	0.355
1	0.333	0.341	0.349	0.357	0.339	0.322	0.304	0.325	0.346	0.366	0.361	0.355
2	0.333	0.341	0.349	0.357	0.339	0.322	0.304	0.325	0.346	0.366	0.361	0.355
3	0.333	0.341	0.349	0.357	0.339	0.322	0.304	0.325	0.346	0.366	0.361	0.355
4	0.333	0.341	0.349	0.357	0.339	0.322	0.304	0.325	0.346	0.366	0.361	0.355
5	0.333	0.341	0.349	0.357	0.339	0.322	0.304	0.325	0.346	0.366	0.361	0.355
6	0.333	0.341	0.349	0.357	0.339	0.322	0.304	0.325	0.346	0.366	0.361	0.355
7	0.333	0.341	0.349	0.357	0.339	0.322	0.304	0.325	0.346	0.366	0.361	0.355
8	0.333	0.341	0.349	0.357	0.339	0.322	0.304	0.325	0.346	0.366	0.361	0.355
9	0.333	0.341	0.349	0.357	0.339	0.322	0.304	0.325	0.346	0.366	0.361	0.355
10	0.333	0.341	0.349	0.357	0.339	0.322	0.304	0.325	0.346	0.366	0.361	0.355
11	0.333	0.341	0.349	0.357	0.339	0.322	0.304	0.325	0.346	0.366	0.361	0.355
12	0.333	0.341	0.349	0.357	0.339	0.322	0.304	0.325	0.346	0.366	0.361	0.355

	year											
age	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
0	0.350	0.346	0.342	0.339	0.311	0.283	0.255	0.252	0.249	0.246	0.278	0.311
1	0.350	0.346	0.342	0.339	0.311	0.283	0.255	0.252	0.249	0.246	0.278	0.311
2	0.350	0.346	0.342	0.339	0.311	0.283	0.255	0.252	0.249	0.246	0.278	0.311
3	0.350	0.346	0.342	0.339	0.311	0.283	0.255	0.252	0.249	0.246	0.278	0.311
4	0.350	0.346	0.342	0.339	0.311	0.283	0.255	0.252	0.249	0.246	0.278	0.311
5	0.350	0.346	0.342	0.339	0.311	0.283	0.255	0.252	0.249	0.246	0.278	0.311
6	0.350	0.346	0.342	0.339	0.311	0.283	0.255	0.252	0.249	0.246	0.278	0.311
7	0.350	0.346	0.342	0.339	0.311	0.283	0.255	0.252	0.249	0.246	0.278	0.311
8	0.350	0.346	0.342	0.339	0.311	0.283	0.255	0.252	0.249	0.246	0.278	0.311
9	0.350	0.346	0.342	0.339	0.311	0.283	0.255	0.252	0.249	0.246	0.278	0.311
10	0.350	0.346	0.342	0.339	0.311	0.283	0.255	0.252	0.249	0.246	0.278	0.311
11	0.350	0.346	0.342	0.339	0.311	0.283	0.255	0.252	0.249	0.246	0.278	0.311
12	0.350	0.346	0.342	0.339	0.311	0.283	0.255	0.252	0.249	0.246	0.278	0.311

	year					
age	2016	2017	2018	2019	2020	2021
0	0.343	0.327	0.312	0.296	0.312	0.329
1	0.343	0.327	0.312	0.296	0.312	0.329
2	0.343	0.327	0.312	0.296	0.312	0.329
3	0.343	0.327	0.312	0.296	0.312	0.329
4	0.343	0.327	0.312	0.296	0.312	0.329
5	0.343	0.327	0.312	0.296	0.312	0.329
6	0.343	0.327	0.312	0.296	0.312	0.329
7	0.343	0.327	0.312	0.296	0.312	0.329
8	0.343	0.327	0.312	0.296	0.312	0.329
9	0.343	0.327	0.312	0.296	0.312	0.329
10	0.343	0.327	0.312	0.296	0.312	0.329
11	0.343	0.327	0.312	0.296	0.312	0.329
12	0.343	0.327	0.312	0.296	0.312	0.329

Table 8.7.1.9. NE Atlantic Mackerel. SURVEY INDICES

Some random text

103

SSB-egg-based-survey

1992 2022

1 1 0 0

-1 -1

1	3874476.93
1	-1
1	-1
1	3766378.516
1	-1
1	-1
1	4198626.531
1	-1
1	-1
1	3233833.244

```
1              -1
1              -1
1              3106808.703
1              -1
1              -1
1              3782966.707
1              -1
1              -1
1              4810751.571
1              -1
1              -1
1              4831948.353
1              -1
1              -1
1              3524054.85
1              -1
1              -1
1              3087517.078
1              -1
1              3880895.853
R-idx

1998           2021

1              1              0              0

0              0

1              0.012476066
1              0.01862673
1              0.013289745
1              0.020583855
1              0.026244937
1              0.012684229
1              0.029582367
1              0.038157763
1              0.034722557
1              0.022670008
1              0.02064922
1              0.014607073
1              0.02237237
1              0.037563703
1              0.02733911
1              0.029964112
1              0.022348323
1              0.024720467
1              0.0432534
1              0.043849281
1              0.039094593
1              0.04381569
1              0.036397234
1              -1
Swept-idx

2010           2022

1              1              0.58           0.75

3              11

1              1617005        4035646        3059146        1591100        691936         413253
               198106         65803          24747
1              -1             -1             -1             -1             -1             -1
               -1             -1             -1
1              1283247        2383260        2164365        2850847        1783942        740361
               299490         149282         84344
1              9201746        2456618        3073772        3218990        2540444        1087937
               377406         144695         146826
1              7034162        4896456        2659443        2630617        2768227        1910160
               849010         379745         95304
1              2539963        6409324        4802298        1795564        1628872        1254859
               727691         270562         72410
1              1374705        2635033        5243607        4368491        1893026        1658839
               1107866        754993         450100
1              3562908        1953609        3318099        4680603        4653944        1754954
               1944991        626406         507546
1              496595         2384310        1200541        1408582        2330520        1787503
               1049868        499295         557573
1              3814661        1211770        2920591        2856932        1948653        3906891
               3824410        1499778        1248160
1              1430995        3361778        2134411        2528651        2525460        2032783
               2904239        3835479        1495649
1              709444         1220543        1527964        367017         1291607        811226
               1051955        969868         927410
1              2355905        944385         1307793        1043409        598182         956129
               995936         1862024        1605735
```

Table 8.7.1.10. NE Atlantic Mackerel. RFID recapture data for the year 2021

Release Yr	Recapture Yr	Year-class	age at release	Numbers scanned in recapture Yr	Numbers Released in Release Year	Numbers recaptured
2019	2021	2008	11	28671260	2556	19
2019	2021	2009	10	32424008	2871	22
2019	2021	2010	9	73535492	4728	37
2019	2021	2011	8	91009636	9483	79
2019	2021	2012	7	54099631	6785	57
2019	2021	2013	6	43820959	8040	70
2019	2021	2014	5	82980291	5824	51
2020	2021	2009	11	32424008	2191	28
2020	2021	2010	10	73535492	5001	67
2020	2021	2011	9	91009636	5081	70
2020	2021	2012	8	54099631	5474	76
2020	2021	2013	7	43820959	2665	36
2020	2021	2014	6	82980291	4339	68
2020	2021	2015	5	35012724	1509	28

Table 8.7.2.1. NE Atlantic Mackerel. SAM parameter estimates for the 2022 update.

	estimate	std.dev	confidence interval lower bound	confidence interval upper bound
observation standard deviations				
Catches age 0	0.89	0.18	0.63	1.28
Catches age 1	0.35	0.25	0.21	0.58
Catches age 2-12	0.11	0.15	0.08	0.15
Egg survey	0.32	0.25	0.20	0.53
Recruitment index	0.26	0.31	0.14	0.48
IESSNS age 3	0.66	0.23	0.41	1.04
IESSNS ages 4-11	0.45	0.14	0.34	0.60
Recapture overdispersion tags	1.25	0.24	1.40	1.15

random walk standard deviation				
F age 0	0.28	0.43	0.12	0.68
F age 1	0.18	0.46	0.07	0.45
F age 2+	0.15	0.14	0.11	0.20
N@age0	0.19	0.58	0.06	0.62
process error standard deviation				
N@age1-12+	0.21	0.08	0.18	0.24
catchabilities				
egg survey	1.17	0.11	0.94	1.47
recruitment index	4.99E-09	0.11	3.97E-09	6.28E-09
IESSNS age 3	0.79	0.22	0.51	1.22
IESSNS age 4	1.19	0.17	0.85	1.66
IESSNS age 5	1.64	0.17	1.18	2.29
IESSNS age 6	1.75	0.17	1.25	2.45
IESSNS age 7	1.94	0.17	1.37	2.73
IESSNS age 8	1.83	0.17	1.30	2.58
IESSNS age 9	1.96	0.17	1.39	2.77
IESSNS ages 10-11	1.88	0.17	1.34	2.63
post tagging survival steal tags	0.40	0.11	0.35	0.45
post tagging survival RFID tags	0.16	0.11	0.13	0.19

Table 8.7.3.1. NE Atlantic Mackerel. STOCK SUMMARY.

Year	Recruitment (age 2)			SSB at spawning time			Total catch	F (ages 4–8)		
	Low	Value	High	Low	Value	High		Low	Value	High
1980	741662	2256379	6864651	1931692	4095763	8684237	734950	0.13	0.21	0.33
1981	1483866	3954164	10536946	1908690	3610917	6831242	754045	0.13	0.21	0.33
1982	2251174	4258180	8054508	2034611	3475244	5935937	716987	0.13	0.21	0.32
1983	2476430	4189394	7087228	2412006	3685894	5632577	672283	0.14	0.21	0.31
1984	1048672	1945021	3607518	2800858	3989717	5683201	641928	0.14	0.21	0.31
1985	911867	1761799	3403932	2949017	4015844	5468602	614371	0.15	0.21	0.31
1986	2414771	4075432	6878145	2709488	3608231	4805089	602201	0.15	0.22	0.31
1987	1645418	2713304	4474253	2689623	3575982	4754438	654992	0.16	0.22	0.31
1988	1704717	2668074	4175837	2719049	3526114	4572730	680491	0.17	0.23	0.32
1989	2626296	3859714	5672396	2586241	3297725	4204941	585920	0.18	0.24	0.33
1990	1615372	2352987	3427412	2703312	3381620	4230127	626107	0.19	0.26	0.34
1991	1806495	2640685	3860081	2648612	3278987	4059393	675665	0.21	0.27	0.36
1992	1255408	1959426	3058250	2453803	3005914	3682253	760690	0.22	0.29	0.38
1993	1667703	2400478	3455227	2192074	2665757	3241797	824568	0.24	0.31	0.39
1994	1937535	2792997	4026163	1924591	2323071	2804054	819087	0.25	0.32	0.40
1995	1447844	2068160	2954245	1914732	2290278	2739483	756277	0.25	0.31	0.39
1996	1465444	2062647	2903224	1825764	2174598	2590081	563472	0.25	0.30	0.37

Year	Recruitment (age 2)			SSB at spawning time			Total catch	F (ages 4–8)		
	Low	Value	High	Low	Value	High		Low	Value	High
1997	1220370	1738105	2475486	1824264	2144607	2521204	573029	0.24	0.30	0.36
1998	1445736	2299083	3656118	1799608	2120261	2498049	666316	0.25	0.30	0.37
1999	1262250	1918742	2916672	1958221	2301530	2705027	640309	0.27	0.32	0.38
2000	1646261	2242303	3054147	1970480	2266622	2607272	738606	0.29	0.34	0.39
2001	1930231	2565296	3409305	1874159	2147511	2460732	737463	0.32	0.37	0.43
2002	863381	1152032	1537189	1778419	2054100	2372516	771422	0.33	0.39	0.46
2003	3687488	4794496	6233834	1718635	1993516	2312361	679287	0.34	0.41	0.48
2004	5011045	6668900	8875242	2204914	2608232	3085323	660491	0.32	0.38	0.45
2005	1745850	2356809	3181573	2013569	2404435	2871174	549514	0.26	0.31	0.36
2006	2532416	3427824	4639829	1888395	2242585	2663208	481181	0.24	0.28	0.33
2007	3624149	4994825	6883900	2021689	2380749	2803579	586206	0.27	0.31	0.37
2008	3651784	5064453	7023604	2354473	2800351	3330667	623165	0.25	0.30	0.36
2009	2640841	3641939	5022536	2915680	3480016	4153581	737969	0.23	0.27	0.33
2010	2971798	4083427	5610870	3290915	3901258	4624797	877272	0.22	0.26	0.32
2011	2520467	3464819	4762994	3791504	4504765	5352206	948963	0.22	0.26	0.31
2012	4214540	5786958	7946034	3548472	4225513	5031731	899551	0.20	0.24	0.29
2013	4871399	6709016	9239829	3935828	4705814	5626437	938299	0.19	0.24	0.29

Year	Recruitment (age 2)			SSB at spawning time			Total catch	F (ages 4–8)		
	Low	Value	High	Low	Value	High		Low	Value	High
2014	2729554	3753792	5162367	4924869	5898500	7064615	1401788	0.20	0.24	0.29
2015	2437757	3352679	4610983	4928398	5928946	7132621	1215827	0.18	0.22	0.27
2016	3652137	5035066	6941658	4638104	5598144	6756902	1100135	0.16	0.20	0.25
2017	1541675	2141687	2975221	4469022	5404599	6536037	1159641	0.17	0.21	0.25
2018	3434902	4853899	6859101	3859967	4667166	5643167	1023144	0.17	0.21	0.26
2019	2020927	2923019	4227783	3233573	3945436	4814014	839727	0.18	0.22	0.27
2020	1816780	2698510	4008168	2888782	3570188	4412324	1039513	0.23	0.29	0.36
2021	4313470	6801162	10723570	3044947	3891546	4973528	1081540	0.23	0.31	0.40
2022	2148239	4317473	8677141		3769326†					

† Estimated value from the forecast.

Table 8.7.3.2. NE Atlantic Mackerel. ESTIMATED POPULATION ABUNDANCE

Units:Thousands

age \ year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
0	4977824	4592946	3796286	3630479	4120760	4018388	3996884	4085430	3714031	3542109
1	4770227	4667307	4444600	2747095	2554680	4153858	3337149	3297715	4020185	2989130
2	2256379	3954164	4258180	4189394	1945021	1761799	4075432	2713304	2668074	3859714
3	912180	1820022	3310754	4041761	4235132	1338773	1230503	4005081	2150334	2331117
4	1566134	705301	1375181	2796871	3678706	3995572	998216	837570	3714427	1671198
5	3406968	1168826	510471	949136	2140450	3017436	3135126	783356	528198	2969366
6	2631794	2415970	846616	379243	656491	1605024	2219979	2159711	600448	343216
7	822419	1788183	1638596	578072	268789	459973	1078736	1503046	1411112	463388
8	309077	572320	1245878	1138797	397837	195390	311847	770217	1046138	1067708
9	848340	215083	397825	867613	789693	278639	139301	210575	547400	732107
10	233382	590713	149594	276223	603333	546635	196960	96371	141292	376120
11	341202	162433	410639	104016	191710	418065	376311	135405	66188	92257
12	690723	718841	612445	708530	561998	521034	644266	694742	562107	422472

age \ year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
0	3297094	3318561	3327308	3098419	2964293	2859040	2952257	2923500	2987978	3289960
1	3097593	2570564	2856940	3087202	2565454	2505469	2258676	2639679	2400853	2618309
2	2352987	2640685	1959426	2400478	2792997	2068160	2062647	1738105	2299083	1918742
3	3890784	2115127	2534665	1621187	1967779	2382272	2153403	1924846	1227717	2350070
4	1827221	3033337	1514054	2017745	1086566	1416848	1800381	1772730	1630353	1239955
5	1073211	1243666	1917567	979620	1372311	673445	964445	1200871	1508741	1265166
6	1973779	775220	945978	1153956	583882	966540	489028	724376	855047	899888
7	214236	1223334	473593	569829	648711	343790	572199	320013	479077	614420
8	351975	137286	732262	309748	336390	280329	212476	344773	262374	310595
9	731514	249257	88556	410862	181936	175936	135539	150472	211003	180762
10	478615	497774	159923	52759	214721	108449	92183	85476	101841	131487
11	252493	302692	312443	97205	29473	129461	62308	49031	52952	63338
12	342343	388796	440913	466489	339941	219549	209528	169160	140089	124666

age \ year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
0	3144960	4433789	5064730	4013211	4940011	6087928	6119559	5148658	4756583	4639324
1	3035680	1857761	5101748	6175998	2832192	3897654	5945414	5618783	4333207	4134463
2	2242303	2565296	1152032	4794496	6668900	2356809	3427824	4994825	5064453	3641939
3	1790222	1727766	2474397	798852	3936615	5336987	1738772	2564331	4591346	5210179
4	1819767	1279107	1516076	1553732	750904	1902452	3240215	1511773	2043494	4067468
5	1010369	1237307	970982	902493	996705	540476	1055644	2123609	1264672	1661329
6	859823	660339	800265	568797	472792	482143	376210	757409	1140265	931368
7	619464	600842	404644	376524	265228	233351	284819	255528	426786	710562
8	375412	410741	343916	238702	183557	135455	133426	184948	179036	270518
9	191120	238796	226933	192419	115881	87835	74299	95034	102742	111945
10	113685	126738	126615	116014	91545	62816	53326	47505	59034	53904
11	70379	68495	62601	65601	46922	31568	32450	34341	22259	29446
12	122286	126402	111017	80331	56491	40612	39033	39894	31628	21099

age \ year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
0	5520852	6360676	5704912	5490274	5587694	5154715	5999571	6307925	6367101	7176591
1	4273885	5587697	6415242	4551906	4222134	5704906	3528918	5217025	4291009	4229297
2	4083427	3464819	5786958	6709016	3753792	3352679	5035066	2141687	4853899	2923019
3	3515562	3836598	2860930	5634314	7160193	3007330	2663718	4323592	1345459	3459984
4	4900988	3206377	3179936	2539120	5288131	4883570	2789692	2085552	2773684	904800
5	3065295	3582228	2550450	2653768	2532000	3851455	3615558	2164113	1356115	1440392
6	1322833	2226928	2584252	2393429	2527420	2092277	3059819	3088656	1481157	972355
7	584975	951404	1432488	1727766	2164657	1975678	1678923	2744688	2330127	1046798
8	391333	429065	634372	925526	1446550	1628395	1450473	1350611	1926895	1629024
9	175392	215371	282202	434894	648104	1042218	973051	1143531	1041363	1332009
10	76179	98128	130947	176676	286800	493250	571416	704991	709220	605128
11	26303	47692	55031	86098	98402	148441	246010	388856	490368	436225
12	32975	40716	51979	72920	71228	109057	146957	280765	354142	451171

age \ year	2020	2021	2022
0	6610775	6333542	6333542
1	6919855	5097986	5442078
2	2698510	6801162	4317473
3	2019484	2072539	5459511
4	2203869	1865960	1413880
5	733129	1694067	1344203
6	1008745	533527	989652
7	831732	991559	350945
8	850646	675470	542972
9	1081500	769063	399065
10	923342	698265	557747
11	437216	503532	472776
12	620191	465215	581817

Table 8.7.3.3. NE Atlantic Mackerel. ESTIMATED FISHING MORTALITY

age	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
0	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.008	0.008	0.008
1	0.033	0.033	0.033	0.033	0.033	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
2	0.058	0.058	0.057	0.057	0.058	0.057	0.057	0.057	0.057	0.058	0.058	0.059	0.059
3	0.106	0.106	0.105	0.106	0.107	0.109	0.111	0.113	0.116	0.119	0.122	0.126	0.129
4	0.174	0.174	0.175	0.175	0.176	0.180	0.184	0.191	0.197	0.205	0.211	0.218	0.222
5	0.193	0.194	0.194	0.196	0.198	0.201	0.206	0.210	0.217	0.222	0.227	0.234	0.244
6	0.238	0.238	0.240	0.241	0.245	0.249	0.255	0.261	0.268	0.281	0.293	0.304	0.314
7	0.213	0.213	0.213	0.213	0.214	0.218	0.223	0.230	0.239	0.253	0.275	0.304	0.335
8	0.213	0.213	0.213	0.213	0.214	0.218	0.223	0.230	0.239	0.253	0.275	0.304	0.335
9	0.213	0.213	0.213	0.213	0.214	0.218	0.223	0.230	0.239	0.253	0.275	0.304	0.335
10	0.213	0.213	0.213	0.213	0.214	0.218	0.223	0.230	0.239	0.253	0.275	0.304	0.335
11	0.213	0.213	0.213	0.213	0.214	0.218	0.223	0.230	0.239	0.253	0.275	0.304	0.335
12	0.213	0.213	0.213	0.213	0.214	0.218	0.223	0.230	0.239	0.253	0.275	0.304	0.335

year

age	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
0	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.007	0.006	0.005	0.005
1	0.032	0.032	0.032	0.032	0.032	0.031	0.031	0.031	0.029	0.029	0.025	0.020	0.018
2	0.060	0.061	0.062	0.063	0.065	0.066	0.067	0.069	0.069	0.068	0.066	0.069	0.062
3	0.133	0.136	0.138	0.141	0.144	0.149	0.158	0.168	0.161	0.161	0.143	0.148	0.135
4	0.225	0.228	0.228	0.228	0.228	0.233	0.243	0.258	0.270	0.267	0.238	0.223	0.192
5	0.251	0.254	0.259	0.268	0.281	0.300	0.317	0.341	0.327	0.334	0.328	0.314	0.275
6	0.322	0.326	0.326	0.324	0.325	0.330	0.344	0.366	0.413	0.406	0.412	0.388	0.340
7	0.367	0.385	0.376	0.349	0.328	0.329	0.343	0.355	0.411	0.475	0.529	0.480	0.360
8	0.367	0.385	0.376	0.349	0.328	0.329	0.343	0.355	0.411	0.475	0.529	0.480	0.360
9	0.367	0.385	0.376	0.349	0.328	0.329	0.343	0.355	0.411	0.475	0.529	0.480	0.360
10	0.367	0.385	0.376	0.349	0.328	0.329	0.343	0.355	0.411	0.475	0.529	0.480	0.360
11	0.367	0.385	0.376	0.349	0.328	0.329	0.343	0.355	0.411	0.475	0.529	0.480	0.360
12	0.367	0.385	0.376	0.349	0.328	0.329	0.343	0.355	0.411	0.475	0.529	0.480	0.360

year

age	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
0	0.005	0.005	0.005	0.004	0.004	0.004	0.003	0.003	0.003	0.002	0.001	0.001	0.001
1	0.019	0.017	0.015	0.014	0.014	0.013	0.013	0.013	0.013	0.014	0.013	0.011	0.010
2	0.054	0.044	0.038	0.036	0.037	0.037	0.038	0.039	0.041	0.042	0.045	0.047	0.050
3	0.111	0.101	0.099	0.098	0.096	0.093	0.087	0.086	0.098	0.099	0.109	0.117	0.116
4	0.176	0.169	0.167	0.173	0.173	0.169	0.160	0.167	0.171	0.156	0.173	0.182	0.163
5	0.246	0.254	0.246	0.235	0.234	0.222	0.215	0.212	0.234	0.210	0.203	0.217	0.230
6	0.327	0.323	0.293	0.288	0.268	0.261	0.243	0.231	0.249	0.244	0.217	0.213	0.241
7	0.334	0.413	0.401	0.338	0.324	0.320	0.285	0.283	0.270	0.250	0.207	0.208	0.214
8	0.334	0.413	0.401	0.338	0.324	0.320	0.285	0.283	0.270	0.250	0.207	0.208	0.214
9	0.334	0.413	0.401	0.338	0.324	0.320	0.285	0.283	0.270	0.250	0.207	0.208	0.214
10	0.334	0.413	0.401	0.338	0.324	0.320	0.285	0.283	0.270	0.250	0.207	0.208	0.214
11	0.334	0.413	0.401	0.338	0.324	0.320	0.285	0.283	0.270	0.250	0.207	0.208	0.214
12	0.334	0.413	0.401	0.338	0.324	0.320	0.285	0.283	0.270	0.250	0.207	0.208	0.214

year

age	2019	2020	2021	2022
0	0.001	0.001	0.001	0.001
1	0.010	0.009	0.008	0.008
2	0.048	0.047	0.051	0.051
3	0.114	0.109	0.116	0.116
4	0.152	0.150	0.166	0.167
5	0.247	0.262	0.264	0.264
6	0.277	0.329	0.400	0.407
7	0.213	0.348	0.355	0.342
8	0.213	0.348	0.355	0.342
9	0.213	0.348	0.355	0.342
10	0.213	0.348	0.355	0.342
11	0.213	0.348	0.355	0.342
12	0.213	0.348	0.355	0.342

Table 8.8.3.1. NE Atlantic Mackerel. Short-term prediction: INPUT DATA

	Stock Numbers	M	Maturity ogive	Prop of F before spw.	Prop of M before spw.	Weights in the stock	Exploitation pattern	Weights in the catch
2022								
0	4497060	0.15	0.000	0.000	0.312	0.000	0.001	0.054
1	5025194	0.15	0.110	0.433	0.312	0.068	0.009	0.150
2	4317473	0.15	0.541	0.152	0.312	0.195	0.049	0.274
3	5459511	0.15	0.922	0.152	0.312	0.254	0.115	0.319
4	1413880	0.15	0.999	0.152	0.312	0.288	0.159	0.365
5	1344203	0.15	1.000	0.284	0.312	0.328	0.262	0.394
6	989652	0.15	1.000	0.284	0.312	0.354	0.335	0.429
7	350945	0.15	1.000	0.284	0.312	0.378	0.302	0.447
8	542972	0.15	1.000	0.284	0.312	0.394	0.302	0.463
9	399065	0.15	1.000	0.284	0.312	0.406	0.302	0.476
10	557747	0.15	1.000	0.284	0.312	0.432	0.302	0.498
11	472776	0.15	1.000	0.284	0.312	0.445	0.302	0.516
12+	581817	0.15	1.000	0.284	0.312	0.488	0.302	0.546
2023								
0	4497060	0.15	0.000	0.000	0.312	0.000	0.001	0.054
1	-	0.15	0.110	0.433	0.312	0.068	0.009	0.150
2	-	0.15	0.541	0.152	0.312	0.195	0.049	0.274
3	-	0.15	0.922	0.152	0.312	0.254	0.115	0.319
4	-	0.15	0.999	0.152	0.312	0.288	0.159	0.365
5	-	0.15	1.000	0.284	0.312	0.328	0.262	0.394
6	-	0.15	1.000	0.284	0.312	0.354	0.335	0.429
7	-	0.15	1.000	0.284	0.312	0.378	0.302	0.447
8	-	0.15	1.000	0.284	0.312	0.394	0.302	0.463
9	-	0.15	1.000	0.284	0.312	0.406	0.302	0.476
10	-	0.15	1.000	0.284	0.312	0.432	0.302	0.498
11	-	0.15	1.000	0.284	0.312	0.445	0.302	0.516
12+	-	0.15	1.000	0.284	0.312	0.488	0.302	0.546
2024								
0	4497060	0.15	0.000	0.000	0.312	0.000	0.001	0.054
1	-	0.15	0.110	0.433	0.312	0.068	0.009	0.150
2	-	0.15	0.541	0.152	0.312	0.195	0.049	0.274
3	-	0.15	0.922	0.152	0.312	0.254	0.115	0.319
4	-	0.15	0.999	0.152	0.312	0.288	0.159	0.365
5	-	0.15	1.000	0.284	0.312	0.328	0.262	0.394
6	-	0.15	1.000	0.284	0.312	0.354	0.335	0.429

	Stock Numbers	M	Maturity ogive	Prop of F before spw.	Prop of M before spw.	Weights in the stock	Exploitation pattern	Weights in the catch
7	-	0.15	1.000	0.284	0.312	0.378	0.302	0.447
8	-	0.15	1.000	0.284	0.312	0.394	0.302	0.463
9	-	0.15	1.000	0.284	0.312	0.406	0.302	0.476
10	-	0.15	1.000	0.284	0.312	0.432	0.302	0.498
11	-	0.15	1.000	0.284	0.312	0.445	0.302	0.516
12+	-	0.15	1.000	0.284	0.312	0.488	0.302	0.546

Table 8.8.3.2. NE Atlantic Mackerel. Short-term prediction: Multi-option table for 1 131 416 t catch in 2022 and a range of F-values in 2023.

2022			
TSB	**SSB**	**F_{bar}**	**Catch**
5 011 502	3 769 326	0.361	1 131 416

2023				**2024**		
TSB	**SSB**	**Fbar**	**Catch**	**TSB**	**SSB**	**Implied change in the catch**
4703613	3834187	0	0	5260647	4442903	-100%
-	3827916	0.01	33188	5232934	4408097	-97%
-	3821661	0.02	66109	5205449	4373667	-94%
-	3815422	0.03	98764	5178190	4339610	-91%
-	3809199	0.04	131156	5151155	4305920	-88%
-	3802991	0.05	163288	5124341	4272593	-86%
-	3796799	0.06	195161	5097748	4239624	-83%
-	3790623	0.07	226780	5071371	4207009	-80%
-	3784463	0.08	258145	5045210	4174744	-77%
-	3778318	0.09	289260	5019263	4142824	-74%
-	3772188	0.1	320127	4993527	4111245	-72%
-	3766074	0.11	350747	4968000	4080003	-69%
-	3759975	0.12	381124	4942680	4049094	-66%
-	3753892	0.13	411260	4917566	4018513	-64%
-	3747824	0.14	441156	4892655	3988258	-61%
-	3741771	0.15	470816	4867945	3958323	-58%

-	3735734	0.16	500241	4843435	3928704	-56%
-	3729712	0.17	529434	4819123	3899399	-53%
-	3723704	0.18	558397	4795006	3870403	-51%
-	3717712	0.19	587132	4771083	3841712	-48%
-	3711735	0.2	615640	4747353	3813322	-46%
-	3705773	0.21	643925	4723812	3785231	-43%
-	3699826	0.22	671989	4700460	3757434	-41%
-	3693894	0.23	699832	4677295	3729928	-38%
-	3687977	0.24	727458	4654314	3702709	-36%
-	3682074	0.25	754869	4631517	3675774	-33%
-	3676187	0.26	782066	4608901	3649119	-31%
-	3670314	0.27	809052	4586464	3622741	-28%
-	3664456	0.28	835827	4564206	3596637	-26%
-	3658612	0.29	862396	4542124	3570803	-24%
-	3652783	0.3	888758	4520217	3545237	-21%
-	3646969	0.31	914917	4498482	3519934	-19%
-	3641169	0.32	940874	4476920	3494891	-17%
-	3635384	0.33	966631	4455527	3470106	-15%
-	3629613	0.34	992190	4434302	3445576	-12%
-	3623856	0.35	1017552	4413244	3421297	-10%
-	3618114	0.36	1042720	4392350	3397266	-8%
-	3612386	0.37	1067695	4371621	3373481	-6%
-	3606673	0.38	1092479	4351053	3349939	-3%
-	3600973	0.39	1117074	4330646	3326635	-1%
-	3595288	0.4	1141482	4310398	3303569	1%
-	3589617	0.41	1165704	4290308	3280736	3%
-	3583960	0.42	1189741	4270373	3258135	5%
-	3578317	0.43	1213597	4250594	3235762	7%
-	3572688	0.44	1237271	4230967	3213615	9%
-	3567073	0.45	1260767	4211492	3191690	11%

-	3561472	0.46	1284085	4192167	3169986	13%
-	3555885	0.47	1307228	4172992	3148499	16%
-	3550312	0.48	1330196	4153964	3127228	18%
-	3544752	0.49	1352992	4135082	3106169	20%
-	3539207	0.5	1375617	4116345	3085321	22%
-	3533675	0.51	1398072	4097752	3064680	24%
-	3528157	0.52	1420360	4079300	3044244	26%
-	3522652	0.53	1442481	4060990	3024010	27%
-	3517161	0.54	1464437	4042819	3003978	29%
-	3511684	0.55	1486230	4024787	2984143	31%
-	3506220	0.56	1507861	4006892	2964504	33%
-	3500769	0.57	1529332	3989132	2945058	35%
-	3495332	0.58	1550643	3971507	2925803	37%
-	3489909	0.59	1571797	3954015	2906737	39%
-	3484499	0.6	1592795	3936656	2887858	41%
-	3479102	0.61	1613639	3919427	2869163	43%
-	3473718	0.62	1634329	3902328	2850651	44%
-	3468348	0.63	1654867	3885357	2832319	46%
-	3462991	0.64	1675254	3868514	2814165	48%
-	3457647	0.65	1695492	3851797	2796187	50%
-	3452316	0.66	1715583	3835205	2778383	52%
-	3446998	0.67	1735527	3818737	2760751	53%
-	3441693	0.68	1755325	3802392	2743289	55%
-	3436402	0.69	1774980	3786168	2725995	57%
-	3431123	0.7	1794492	3770065	2708867	59%
-	3425857	0.71	1813863	3754081	2691903	60%
-	3420605	0.72	1833093	3738216	2675101	62%
-	3415365	0.73	1852185	3722468	2658460	64%
-	3410137	0.74	1871139	3706836	2641977	65%
-	3404923	0.75	1889957	3691320	2625652	67%

-	3399721	0.76	1908639	3675917	2609481	69%
-	3394533	0.77	1927188	3660628	2593463	70%
-	3389356	0.78	1945604	3645451	2577596	72%
-	3384193	0.79	1963888	3630385	2561880	74%
-	3379042	0.8	1982041	3615429	2546311	75%
-	3373903	0.81	2000065	3600582	2530888	77%
-	3368778	0.82	2017962	3585844	2515611	78%
-	3363664	0.83	2035731	3571212	2500476	80%
-	3358563	0.84	2053374	3556687	2485482	81%
-	3353475	0.85	2070892	3542267	2470628	83%
-	3348399	0.86	2088287	3527952	2455912	85%
-	3343335	0.87	2105559	3513740	2441333	86%
-	3338283	0.88	2122709	3499630	2426889	88%
-	3333244	0.89	2139739	3485622	2412578	89%
-	3328217	0.9	2156649	3471714	2398399	91%
-	3323202	0.91	2173442	3457907	2384351	92%
-	3318200	0.92	2190116	3444198	2370432	94%
-	3313209	0.93	2206675	3430587	2356641	95%
-	3308231	0.94	2223118	3417074	2342975	96%
-	3303264	0.95	2239446	3403657	2329434	98%
-	3298310	0.96	2255662	3390335	2316017	99%
-	3293368	0.97	2271765	3377108	2302722	101%
-	3288437	0.98	2287757	3363974	2289547	102%
-	3283519	0.99	2303638	3350934	2276491	104%
-	3278612	1	2319410	3337986	2263554	105%
-	3273718	1.01	2335073	3325129	2250733	106%
-	3268835	1.02	2350629	3312362	2238027	108%
-	3263964	1.03	2366078	3299685	2225435	109%
-	3259104	1.04	2381422	3287098	2212956	110%
-	3254257	1.05	2396660	3274598	2200589	112%

-	3249421	1.06	2411795	3262186	2188331	113%	
-	3244596	1.07	2426827	3249860	2176183	114%	
-	3239783	1.08	2441756	3237621	2164143	116%	
-	3234982	1.09	2456585	3225466	2152209	117%	

Table 8.8.3.3. NE Atlantic Mackerel. Short-term prediction: Management option table for 1 131 416 t catch in 2022 and a range of catch options in 2023.

Rationale	Catch (2023)	F_{bar} (2023)	SSB (2023)	SSB (2024)	% SSB change *	% catch change **	% advice change ***
Catch(2023) = Zero	0	0.000	3834187	4442903	2%	-100%	-100%
Catch(2023) = 2022 catch -20%	905133	0.306	3649147	3494839	-3%	-20%	14%
Catch(2023) = 2022 catch	1131416	0.396	3597636	3333051	-5%	0%	42%
Catch(2023) = 2022 catch +25%	1414270	0.517	3529667	3131128	-6%	25%	78%
Fbar(2023) = 0.26 (Fmsy)	782066	0.260	3676187	3649119	-2%	-31%	-2%
Fbar(2023) = 0.36 (Fpa)	1042720	0.360	3618114	3397266	-4%	-8%	31%
Fbar(2023) = 0.46 (Flim)	1284085	0.460	3561472	3169986	-6%	13%	62%

*** SSB 2023 relative to SSB 2022.**

**** Catch in 2023 relative to assumed catches in 2022 (1 131 416 t). There is no internationally agreed TAC for 2022.**

***** Catch in 2023 relative to the advice value for 2022 (794 920 t).**

8.14 Figures

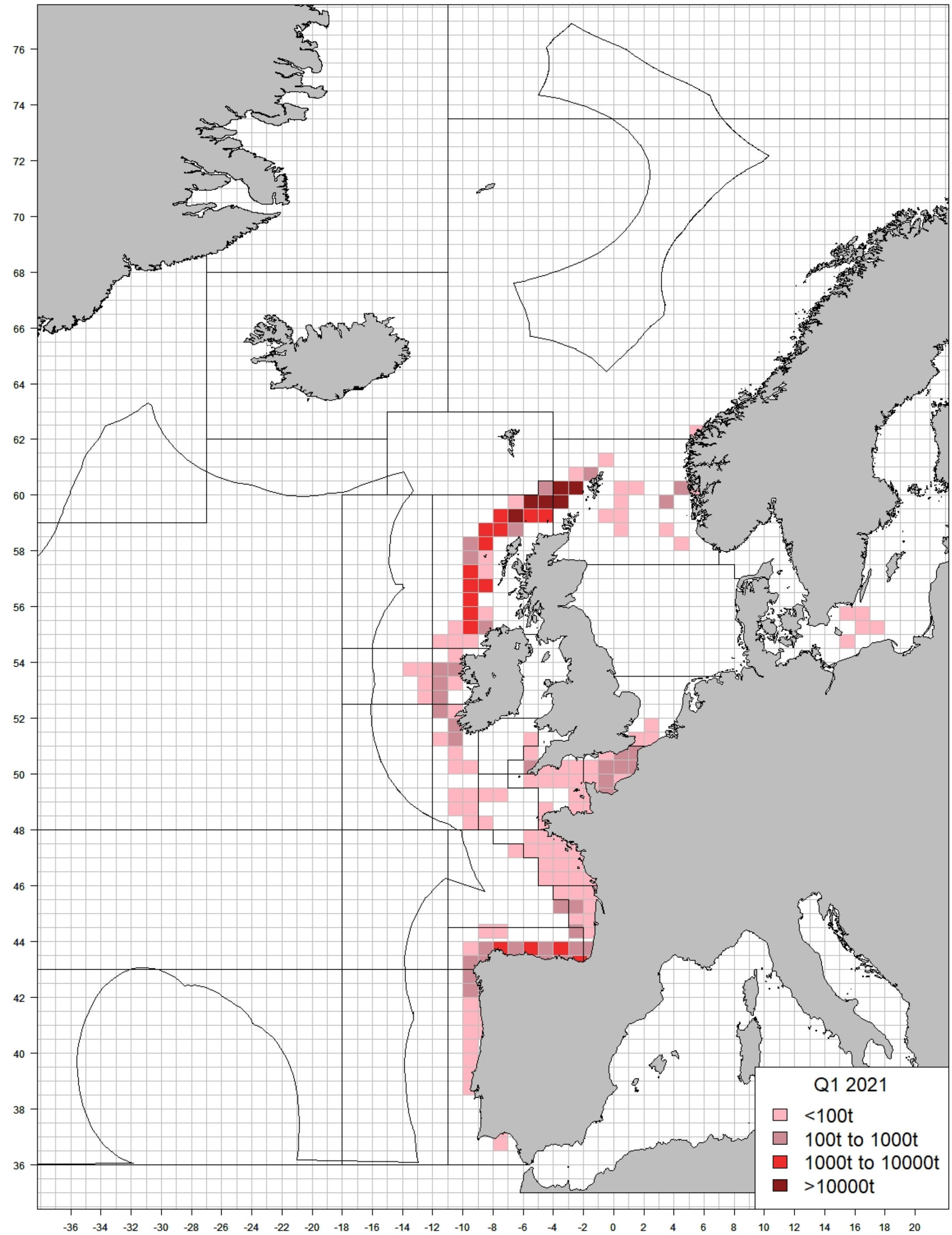


Figure 8.4.2.1. NE Atlantic Mackerel. Commercial catches in 2021, quarter 1.

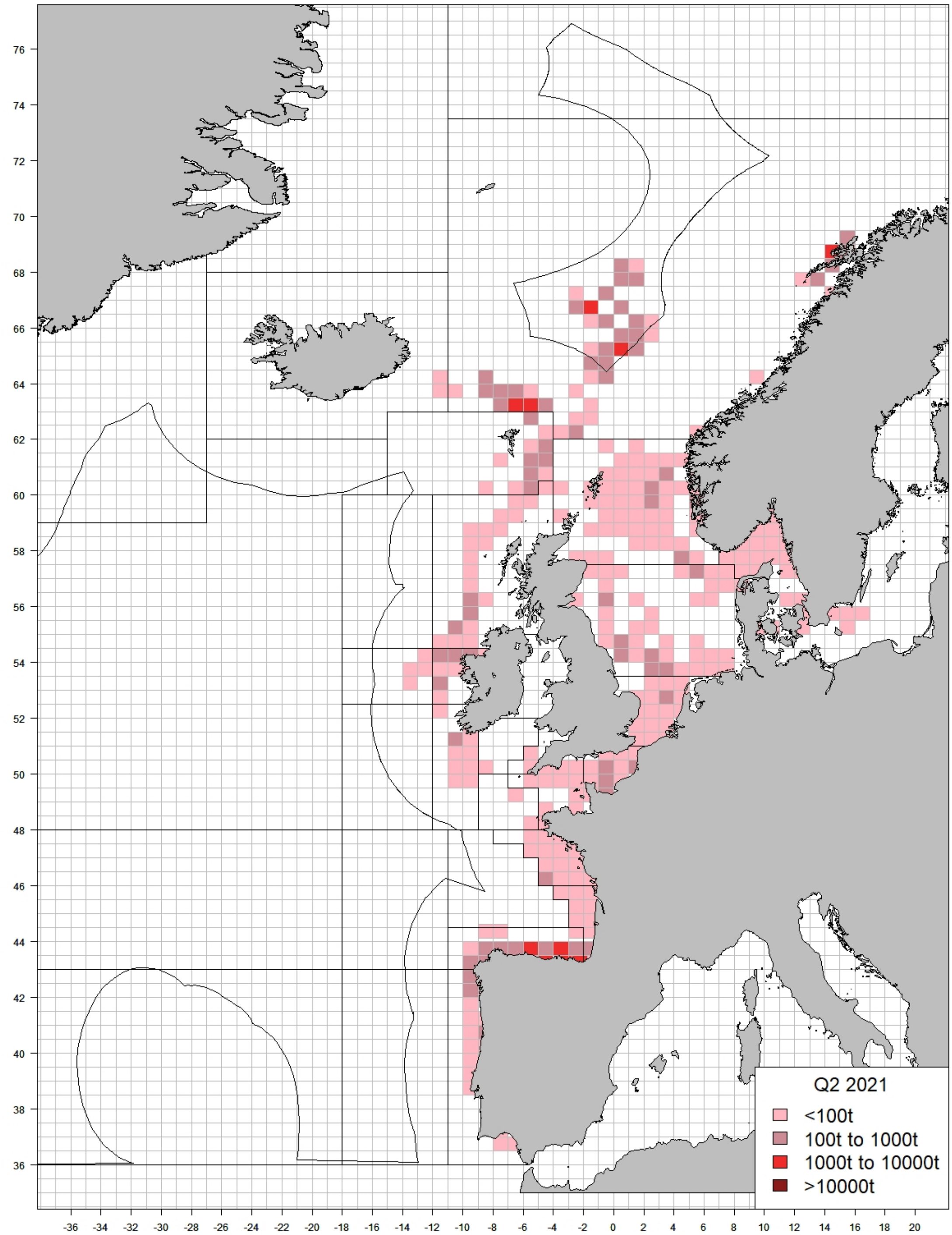


Figure 8.4.2.2. NE Atlantic Mackerel. Commercial catches in 2021, quarter 2.

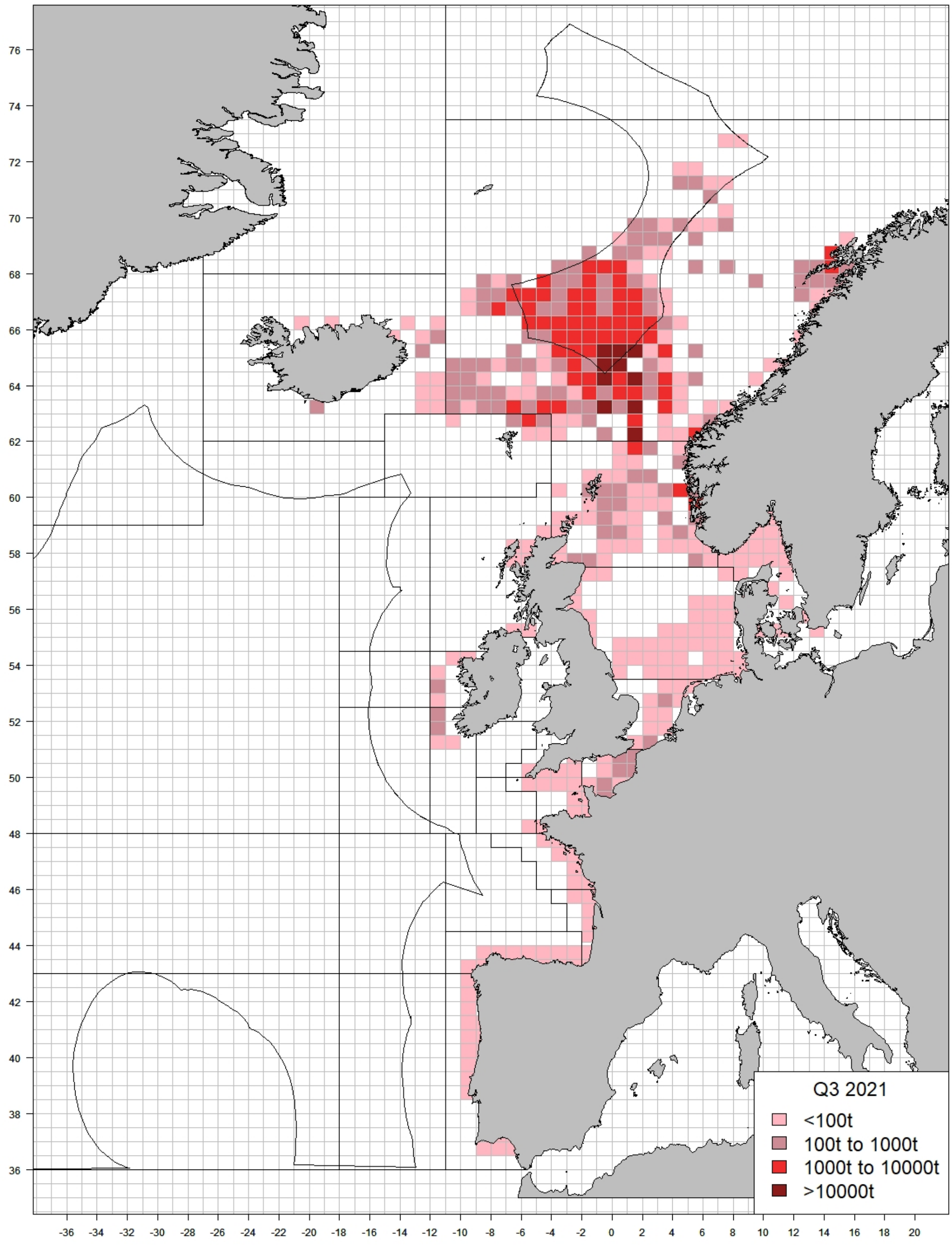


Figure 8.4.2.3. NE Atlantic Mackerel. Commercial catches in 2021, quarter 3.

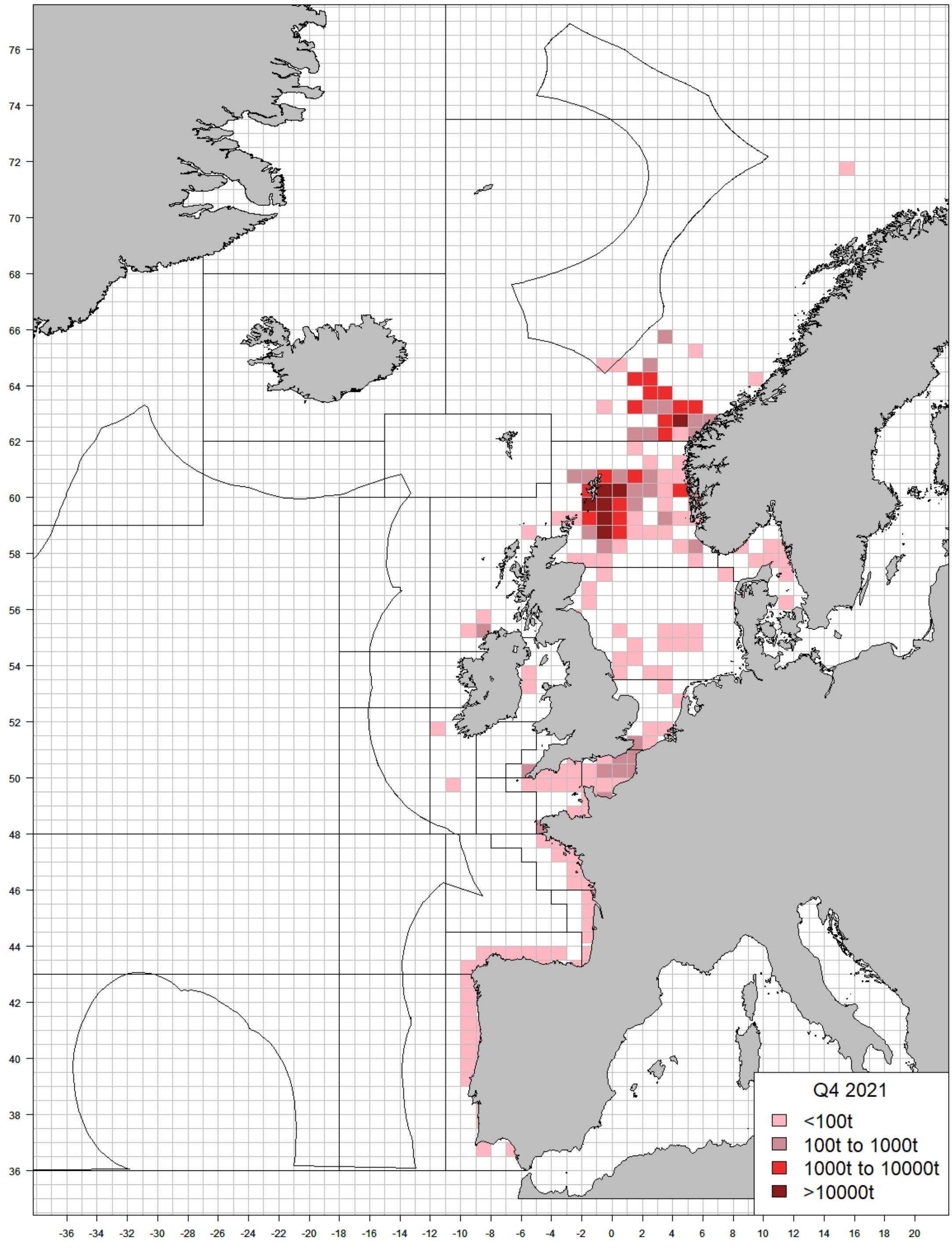


Figure 8.4.2.4. NE Atlantic Mackerel. Commercial catches in 2021, quarter 4.

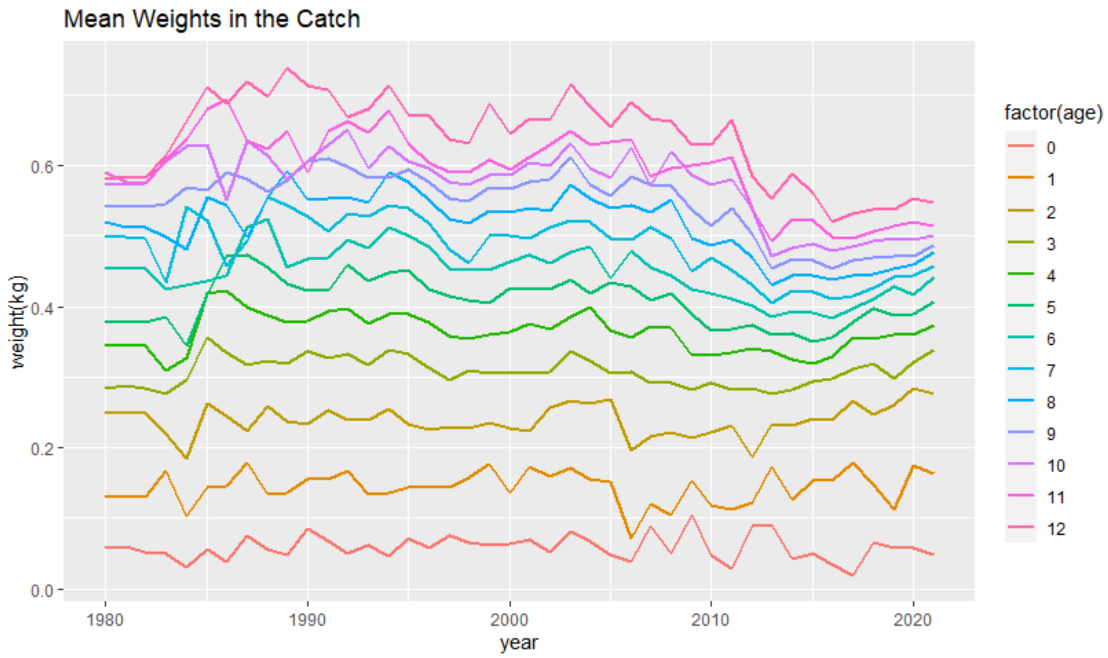


Figure 8.5.2.1. NE Atlantic mackerel. Weights-at-age in the catch.

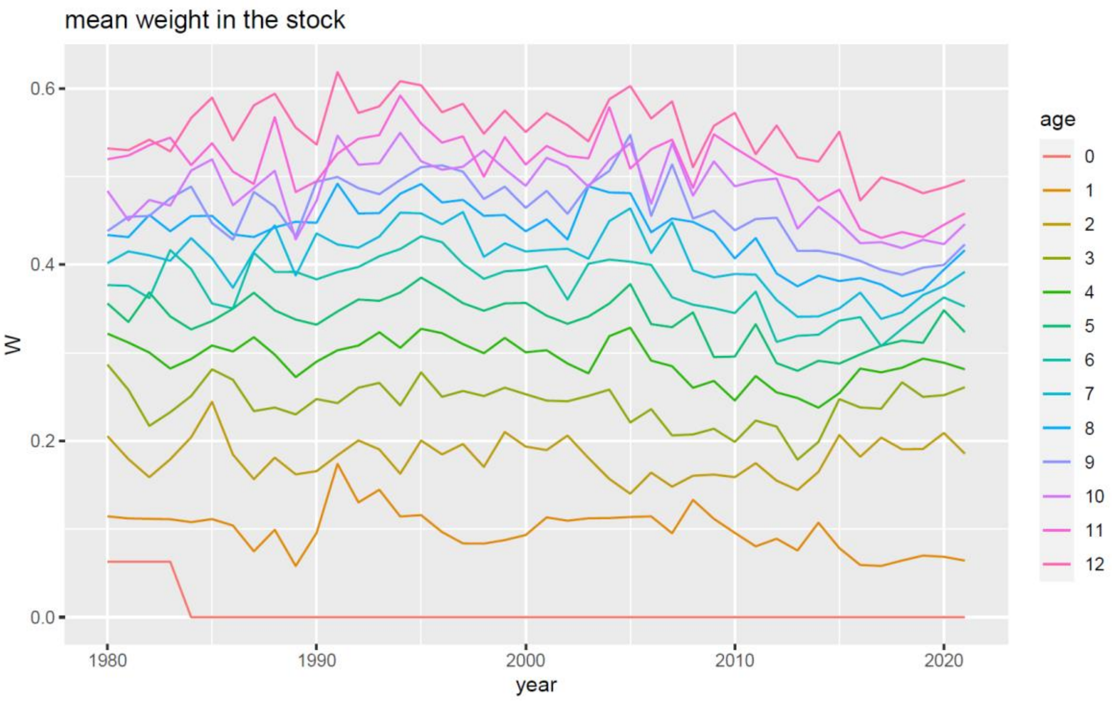


Figure 8.5.2.2. NE Atlantic mackerel. Weights-at-age in the stock.

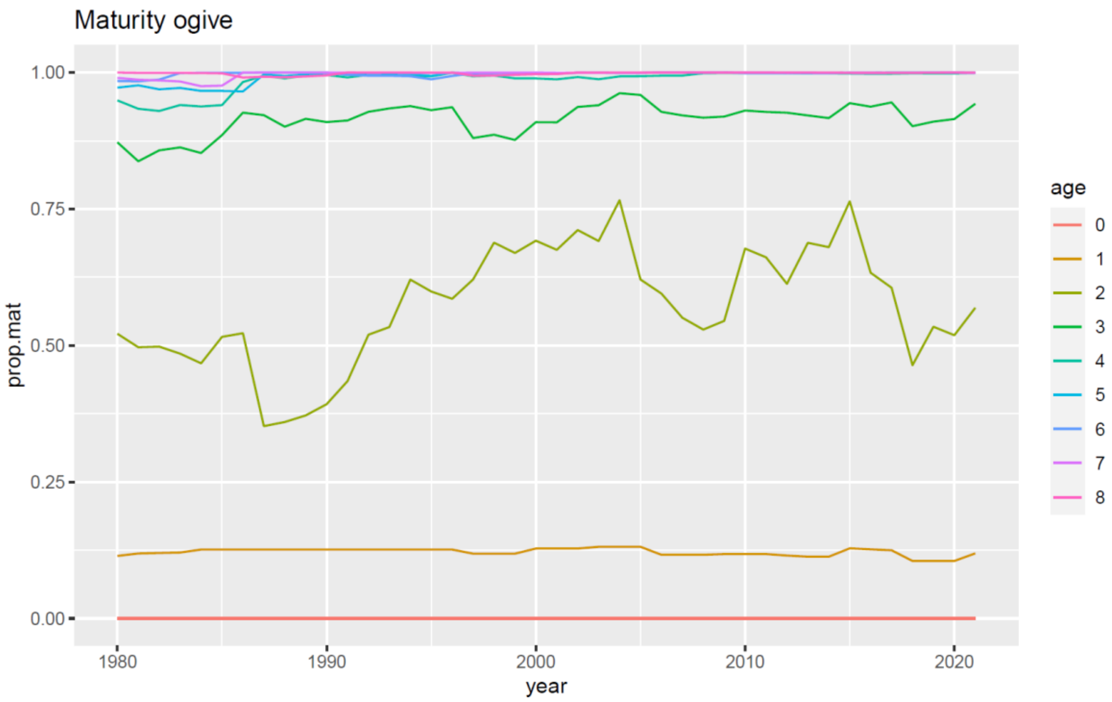


Figure 8.5.3.1. NE Atlantic mackerel. Proportion of mature fish at age.

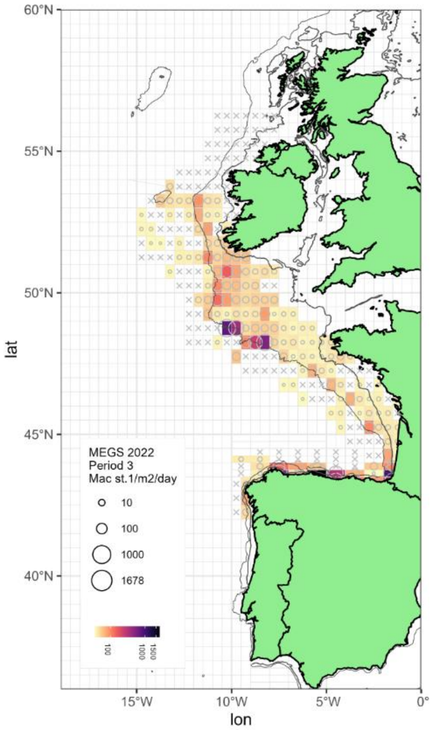


Figure 8.6.1.1.1. Mackerel egg production by half rectangle for period 3 (Mar 4th–Apr 8th). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

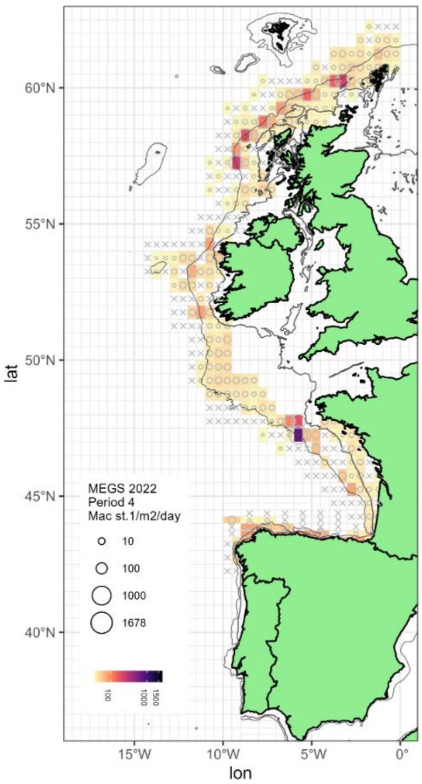


Figure 8.6.1.1.2. Mackerel egg production by half rectangle for period 4 (Apr 9th –29th). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

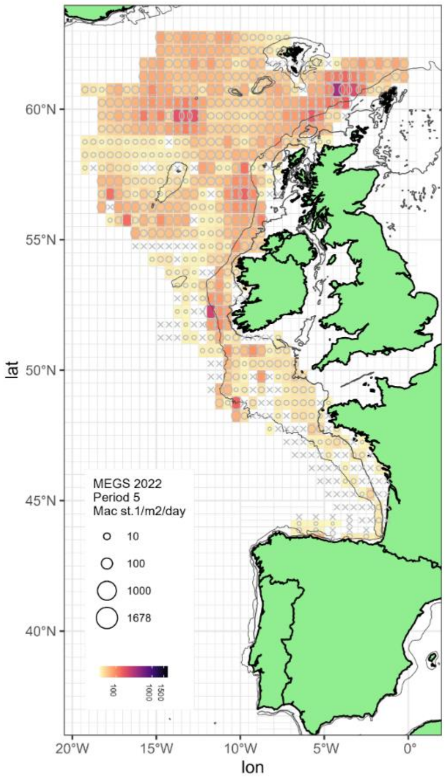


Figure 8.6.1.1.3. Mackerel egg production by half rectangle for period 5 (Apr 30th–May 31st). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

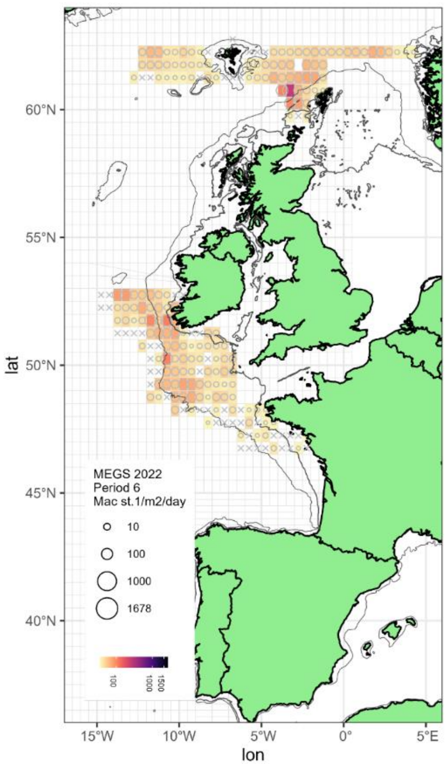


Figure 8.6.1.1.4. Mackerel egg production by half rectangle for period 6 (June 1st–30th). Circle areas and colour scale represent mackerel stage I eggs/m^2/day by half rectangle. Crosses represent zero values.

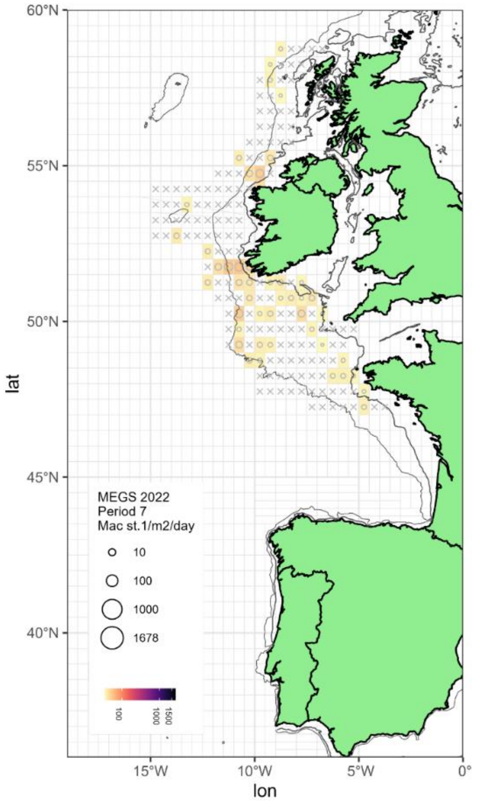


Figure 8.6.1.5. Mackerel egg production by half rectangle for period 7 (July 1st – 31st). Circle areas and colour scale represent mackerel stage I eggs/m2/day by half rectangle. Crosses represent zero values.

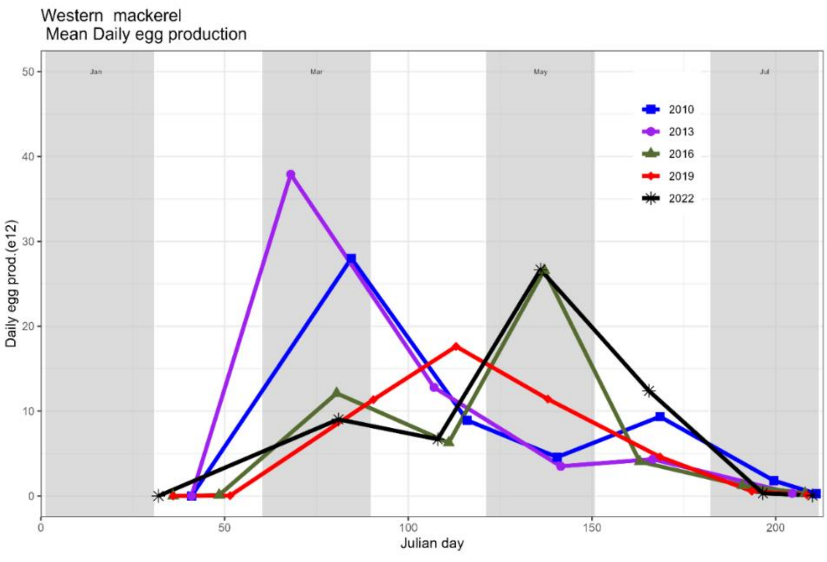


Figure 8.6.1.1.6. Provisional annual egg production curve for mackerel in the western component in 2022, (black line). The curves for 2007, 2010 2013 2016 and 2019 are included for comparison.

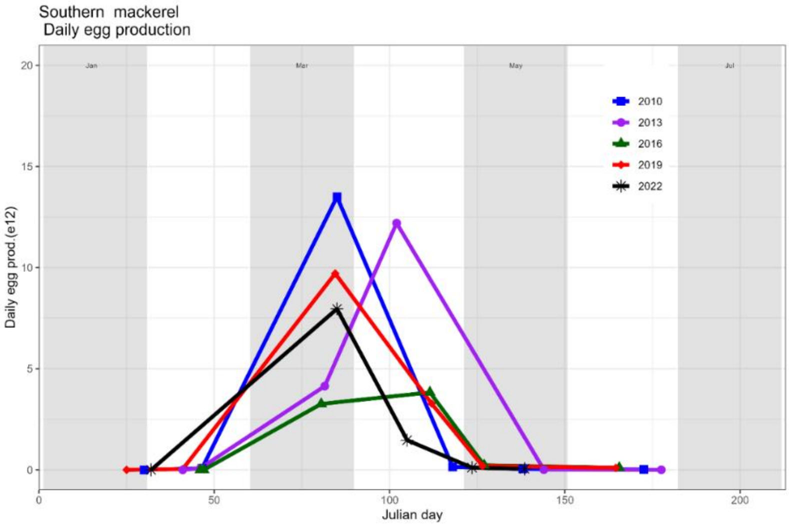


Figure 8.6.1.1.7. Provisional annual egg production curve for mackerel in the southern component in 2022, (black line). The curves for 2007, 2010 2013 2016 and 2019 are included for comparison.

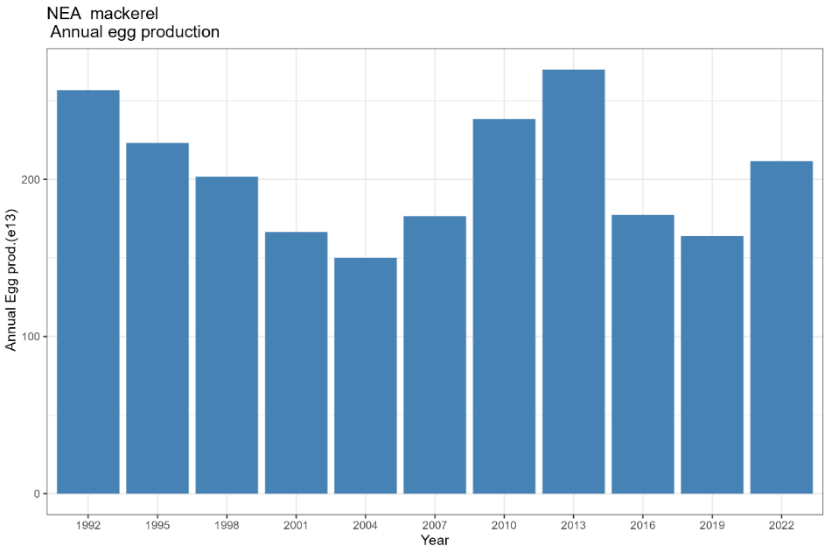


Figure 8.6.1.1.8. Combined mackerel TAEP estimates (*10[13]) - 1992 – 2022.

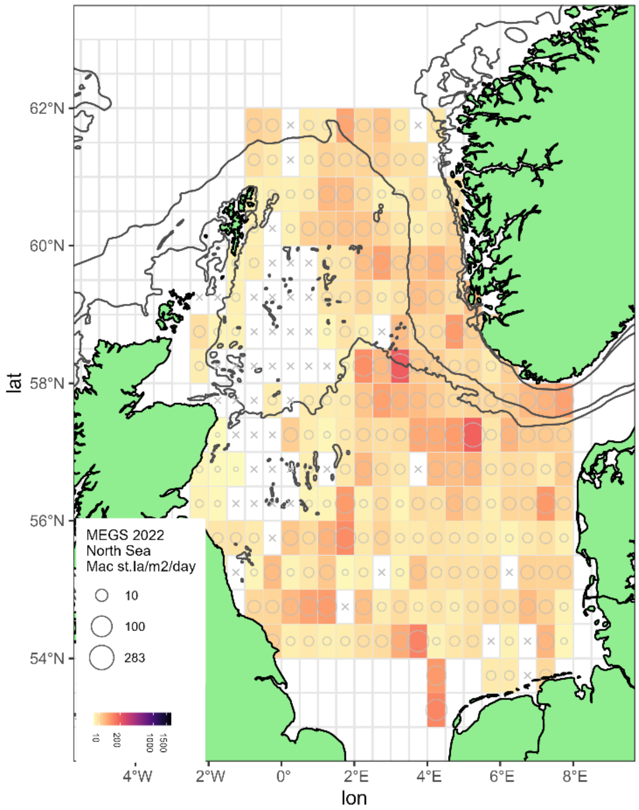


Fig. 8.6.1.5.1. Stage 1a mackerel egg production (eggs/m2/day) by half rectangle for NSMEGS 2022. Circle areas and colour scale represent mackerel stage 1 eggs/m2/day by half rectangle. Crosses represent zero values.

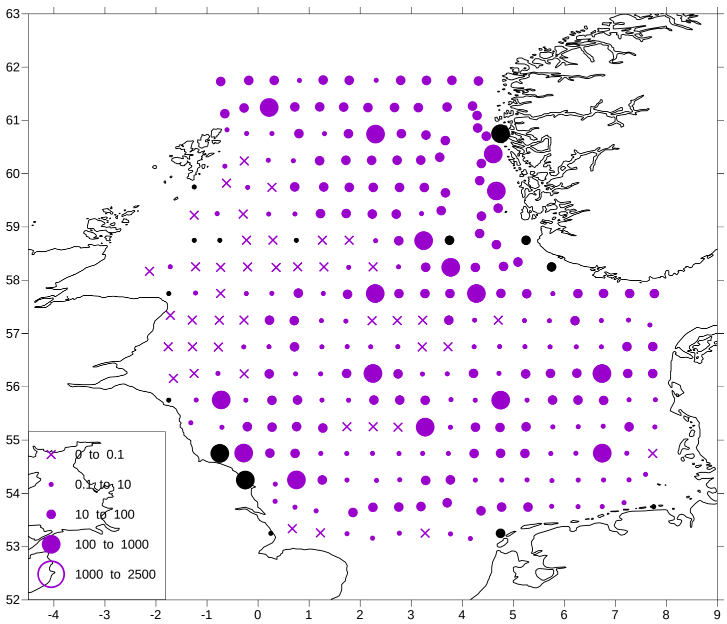


Figure 8.6.1.6.1. Stage Ia mackerel egg production (eggs/m²/day) by half rectangle for NSMEGS 2021. Purple circles represent observed values, black circles represent interpolated values, and crosses represent observed zeros.

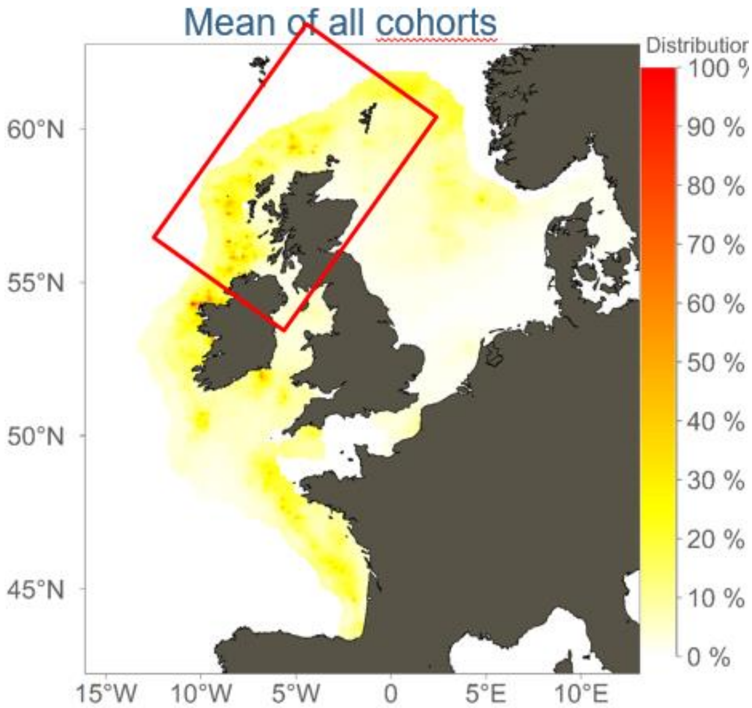


Figure 8.6.2.1. Spatial distribution of mackerel juveniles at age 0 in October to March. Average for cohorts from 1998-2020. Mackerel squared catch rates by trawl haul (circle areas represent catch rates in kg/km2) overlaid on modelled squared catch rates per 10 x 10 km rectangle. Each rectangle is coloured according to the expected squared catch rate in percent of the highest value for that year. See Jansen *et al.* (2015) for details. Red box indicates the approximate typical coverage of the IBTS-NS Q1 and SWC Q1 surveys.

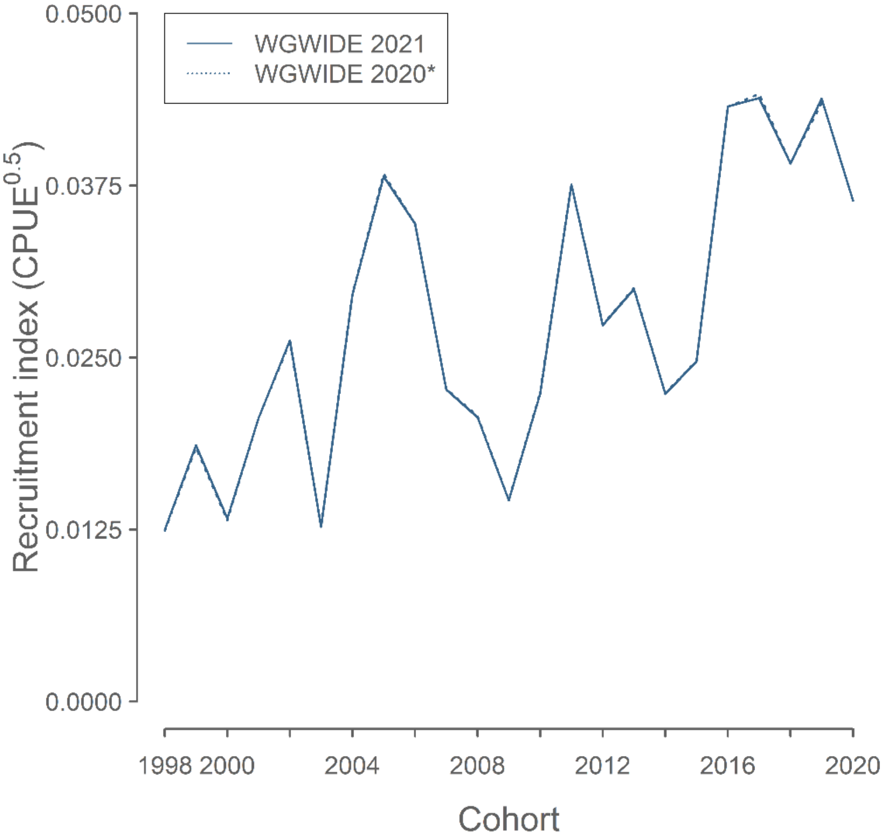


Figure 8.6.2.2. Index of mackerel juveniles at age 0 in October to March proxied by annual integration of square root of expected catch in demersal trawl surveys (Blue lines). See Jansen *et al.* (2015) for details. * Rescaled

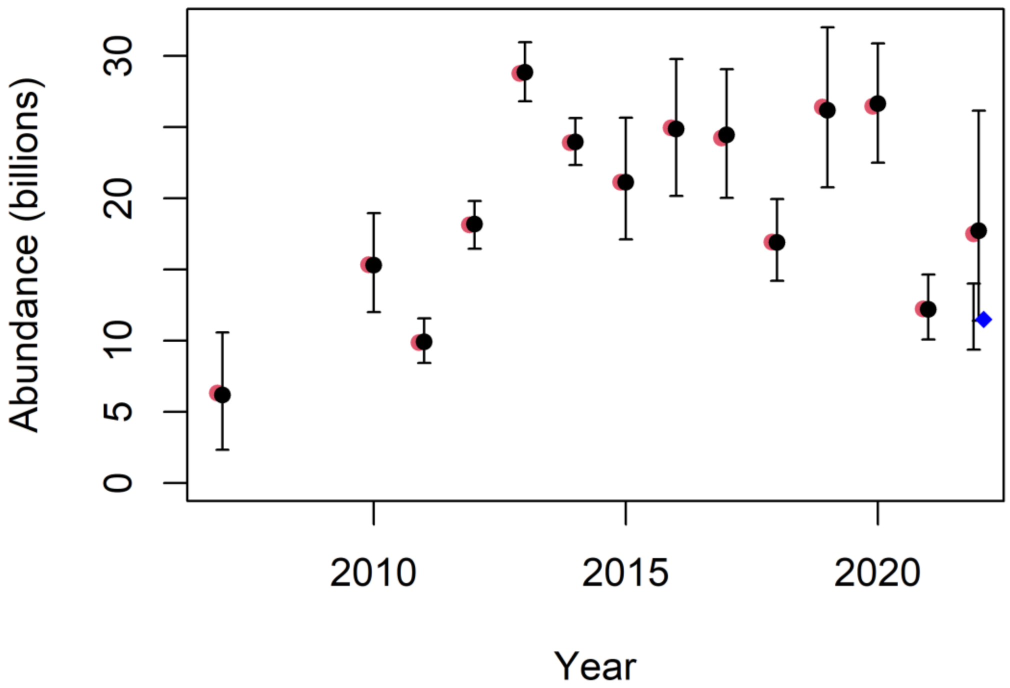


Figure 8.6.3.1. Estimated total stock numbers (TSN) of mackerel from IESSNS calculated using StoX for the years 2007 and from 2010 to 2022. Displayed is StoX baseline estimate (red dot) and a bootstrap estimate (black dot), calculated using 1000 replicates, with 90% confidence intervals (vertical line) based on the bootstrap. Analysis excludes the North Sea and survey coverage was incomplete in 2007 and 2011. For 2022, index value is also calculated excluding the two extreme catches (filled blue diamond) including 90% confidence interval.

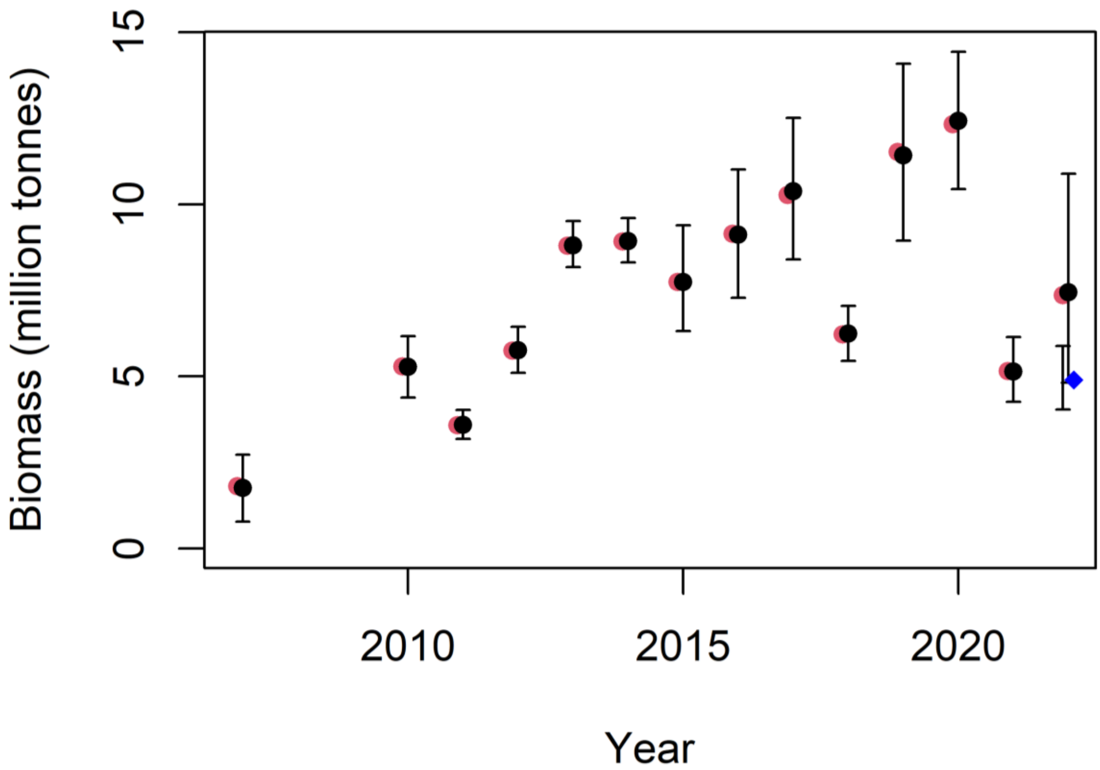


Figure 8.6.3.2. Estimated total stock biomass of mackerel from IESSNS calculated using StoX for the years 2007 and from 2010 to 2022. Displayed is StoX baseline estimate (red dot) and a bootstrap estimate (black dot), calculated using 1000 replicates, with 90% confidence intervals (vertical line) based on the bootstrap. Analysis excludes the North Sea and

survey coverage was incomplete in 2007 and 2011. For 2022, index value is also calculated excluding the two extreme catches (filled blue diamond) including 90% confidence interval.

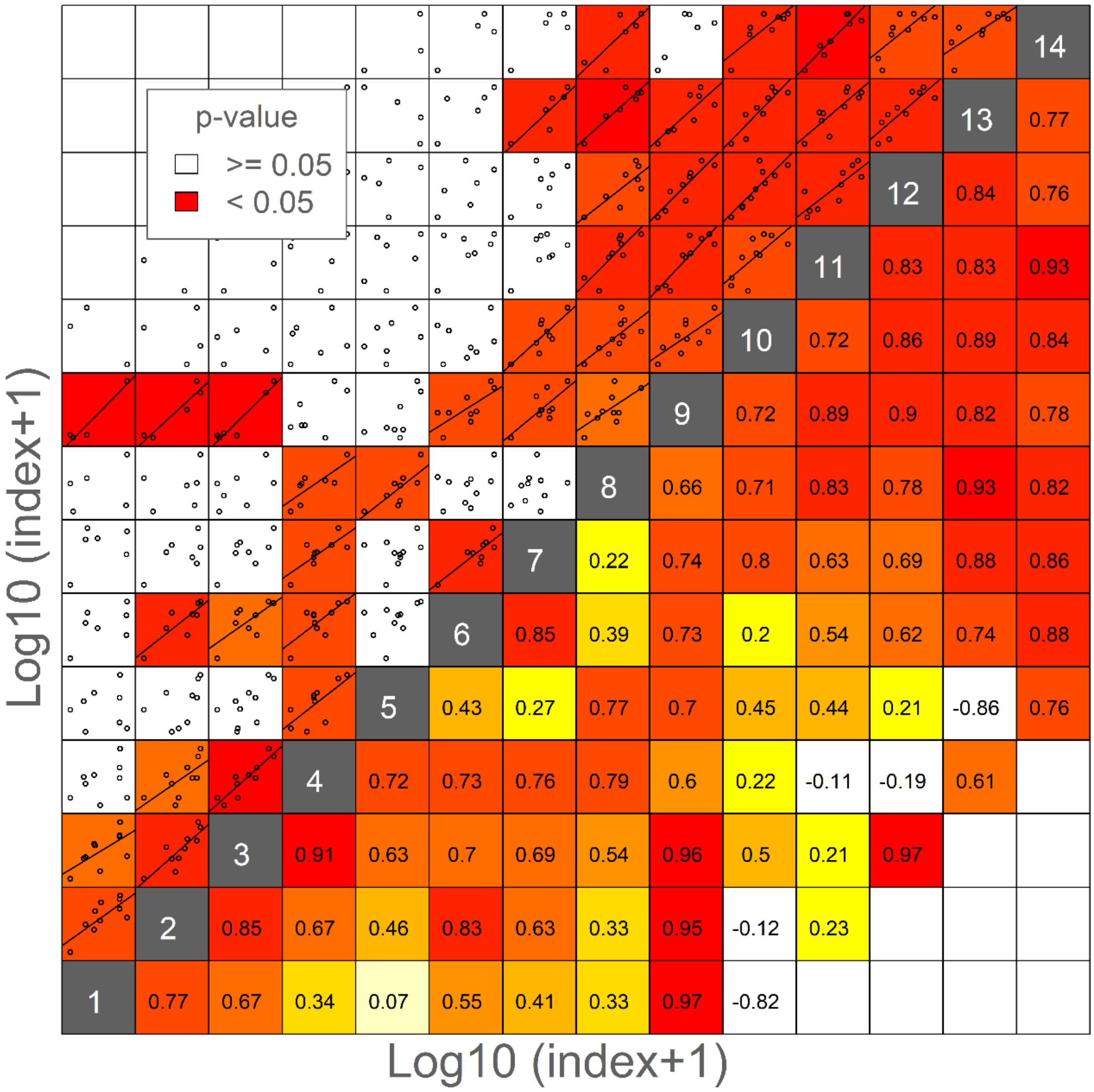


Figure 8.6.3.3. Internal consistency of the mackerel abundance index from the IESSNS survey including data from 2012 to 2022, excluding North Sea. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (*p<0.05*) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given in the lower right half.

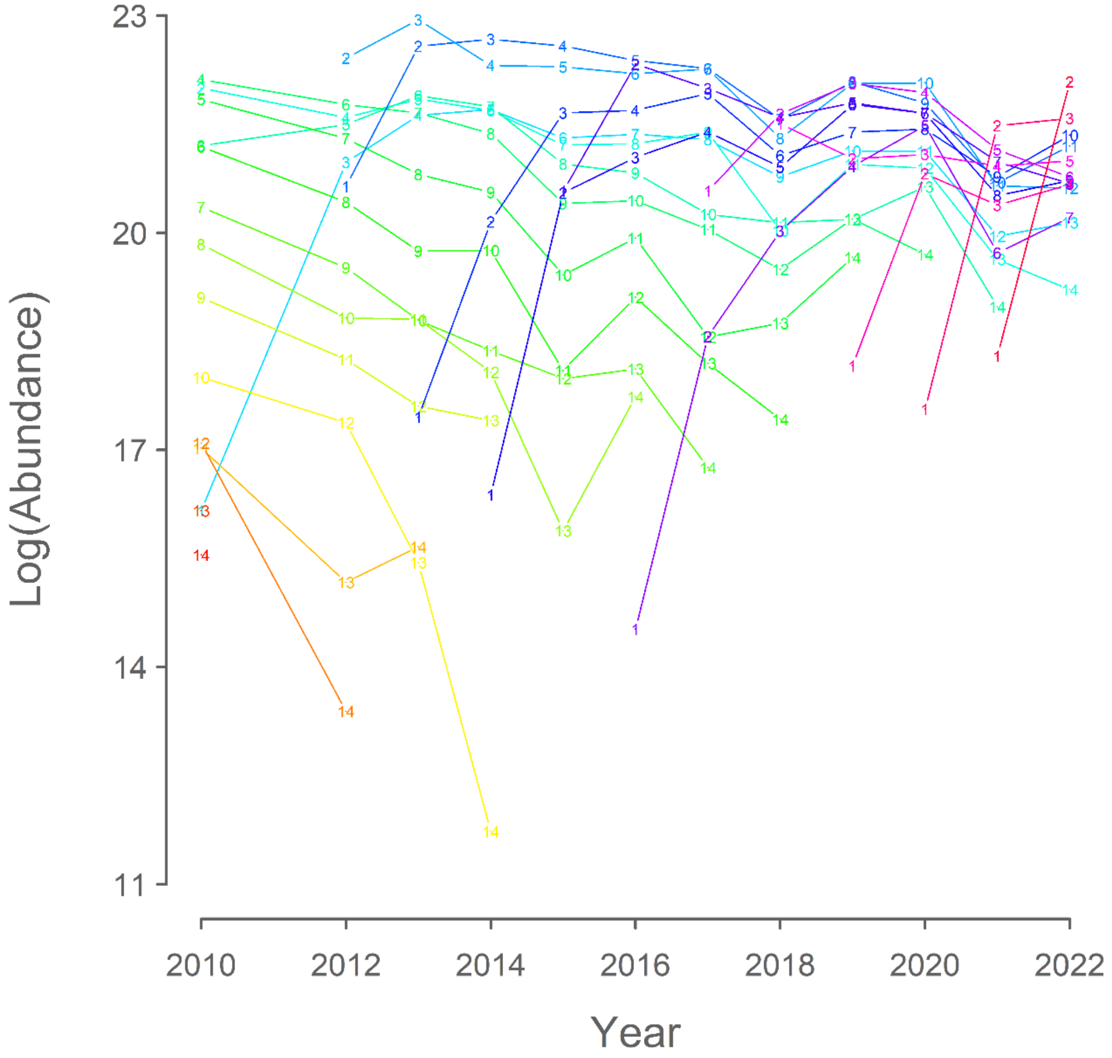


Figure 8.6.3.4. Mackerel catch curves from the estimate stock size at age from the IESSNS in 2010 and from 2012 to 2022, excluding the North Sea. Each cohort is marked by a uniquely coloured line that connects the estimates indicated by the respective ages.

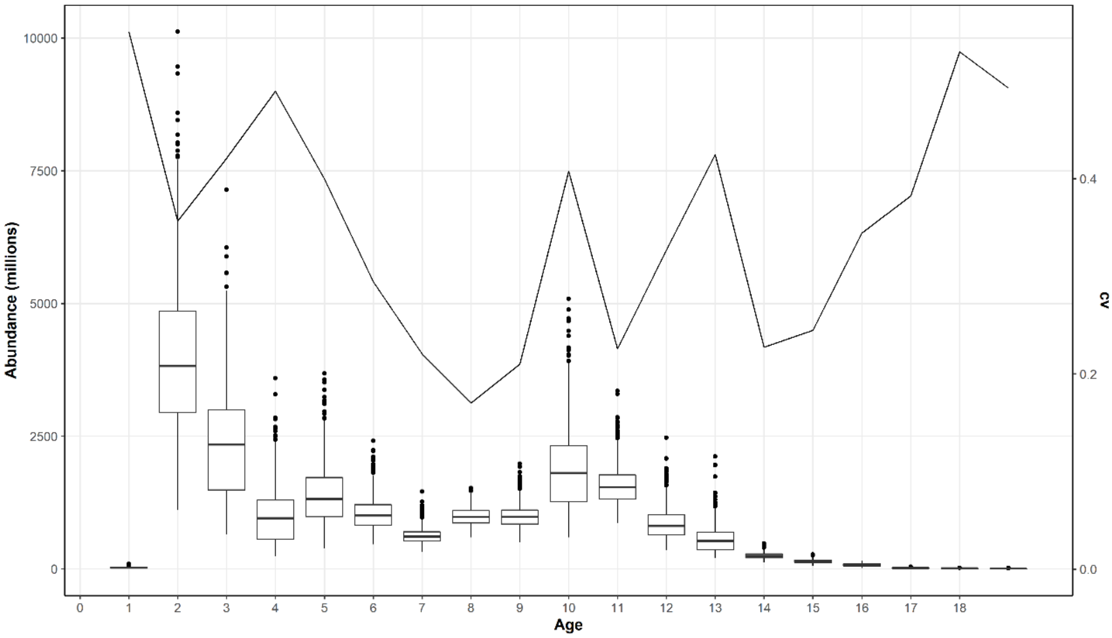


Figure 8.6.3.5. Mackerel numbers by age from the IESSNS survey in 2022, excluding North Sea. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using StoX version 3.5.0.

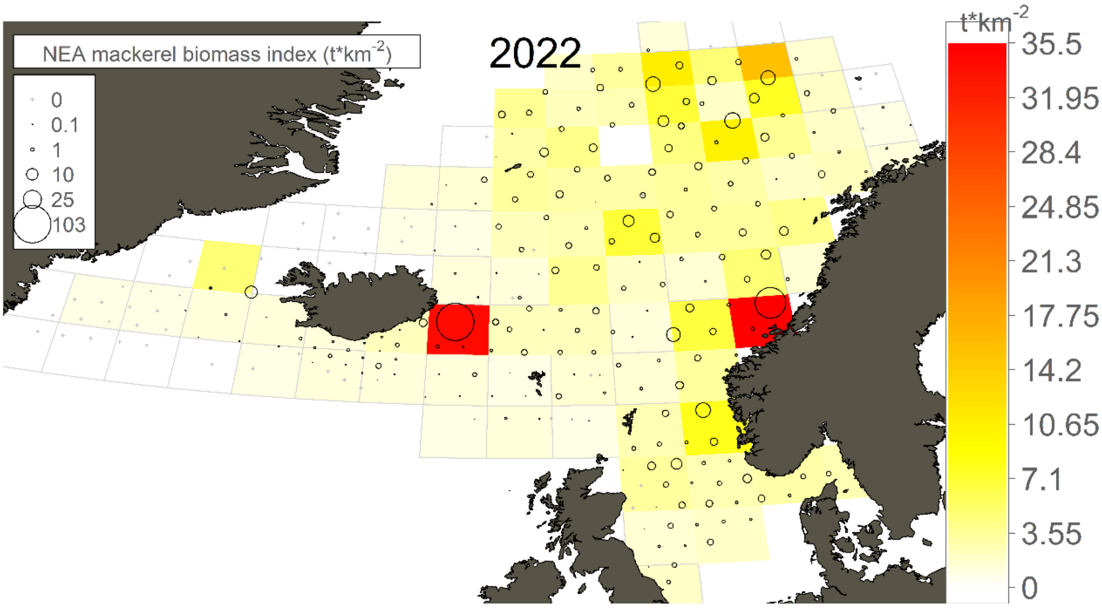


Figure 8.6.3.6. Mackerel catch rates from predetermined surface trawl stations (circle size represents catch rate in kg/km2) overlaid on mean catch rate per standardized rectangle (2° lat. x 4° lon.) from the 2022 IESSNS, including North Sea. Zero mackerel catches are displayed as grey crosses.

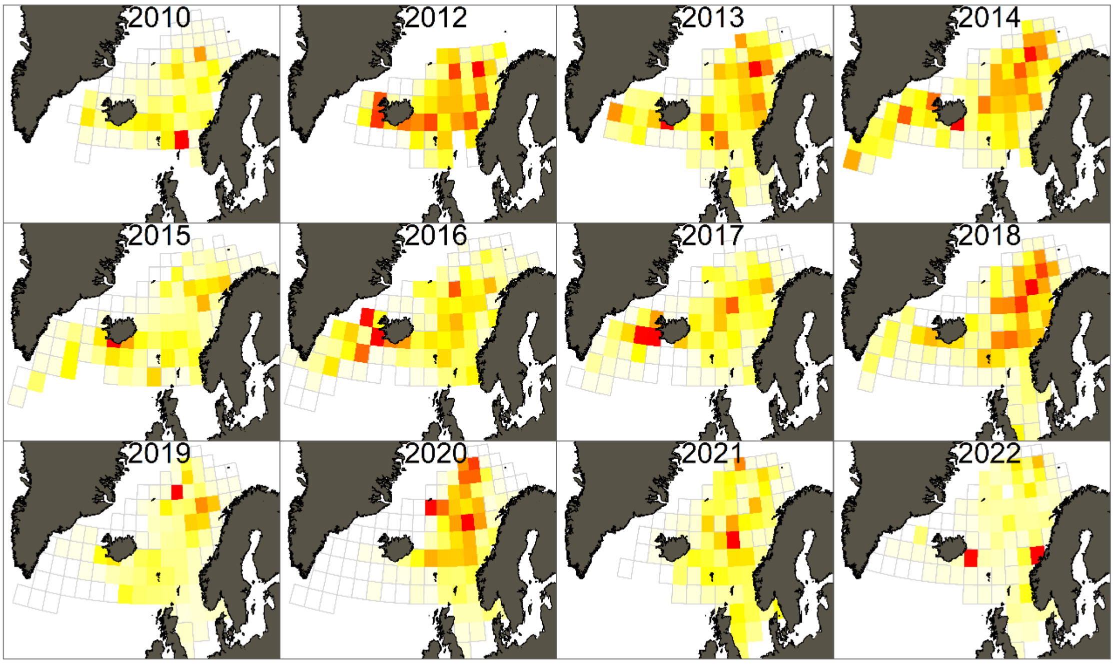


Figure 8.6.3.7. Mackerel annual distribution proxied by the absolute distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from predetermined surface trawl stations from IESSNS in 2010 to 2022, including North Sea. Colour scale goes from white (= 0) to red (= maximum value for the given year).

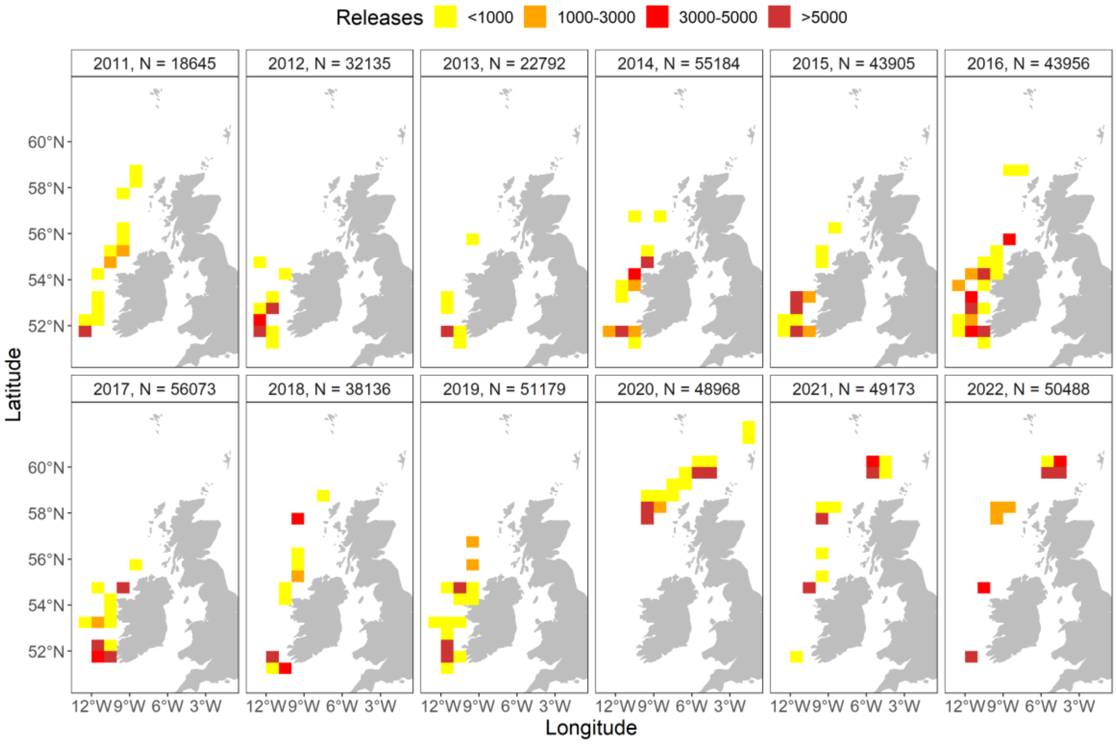


Figure 8.6.4.1. Number and distribution of RFID tagged mackerel from experiments west of Ireland and British Isles during 2011-2022. Note that data from releases 2011-2012 are not used in the stock assessment, based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019c), and data from experiments in 2021-2022 are not included as there are no full years with recaptures yet.

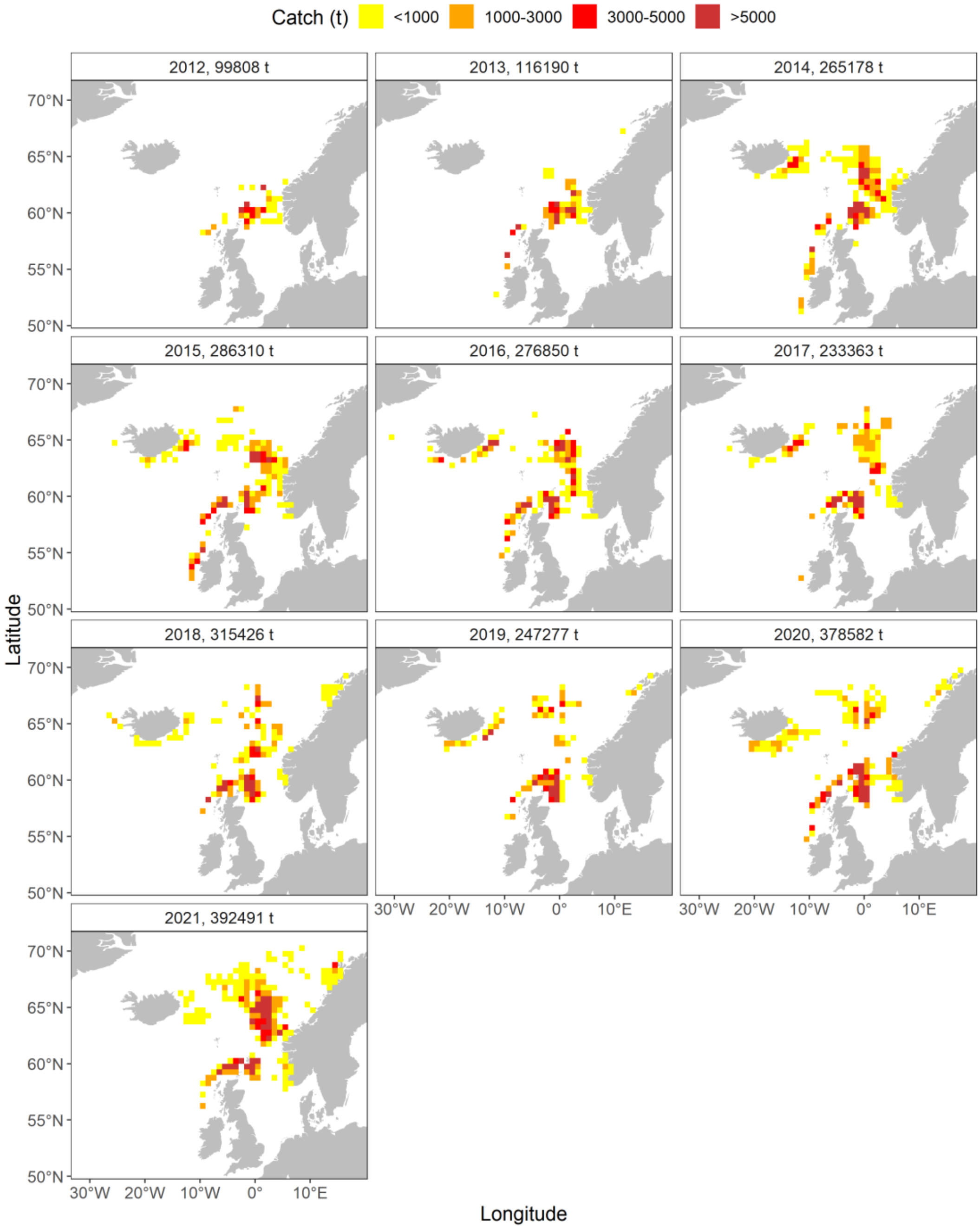


Figure 8.6.4.2. Biomass and distribution of catches scanned for RFID tagged mackerel during 2012-2021. Note that data from scanned catches in 2012-2013 are not used in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019c).

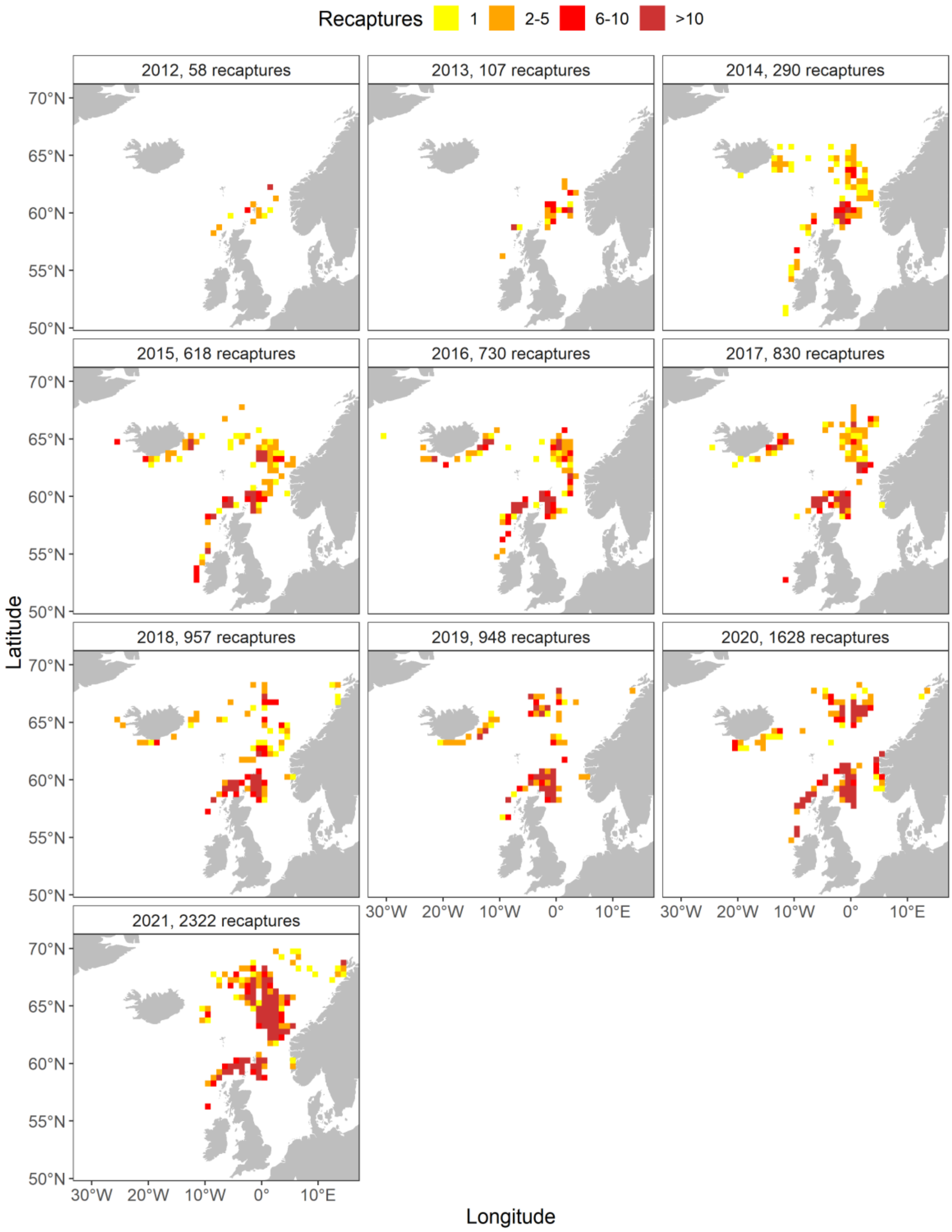
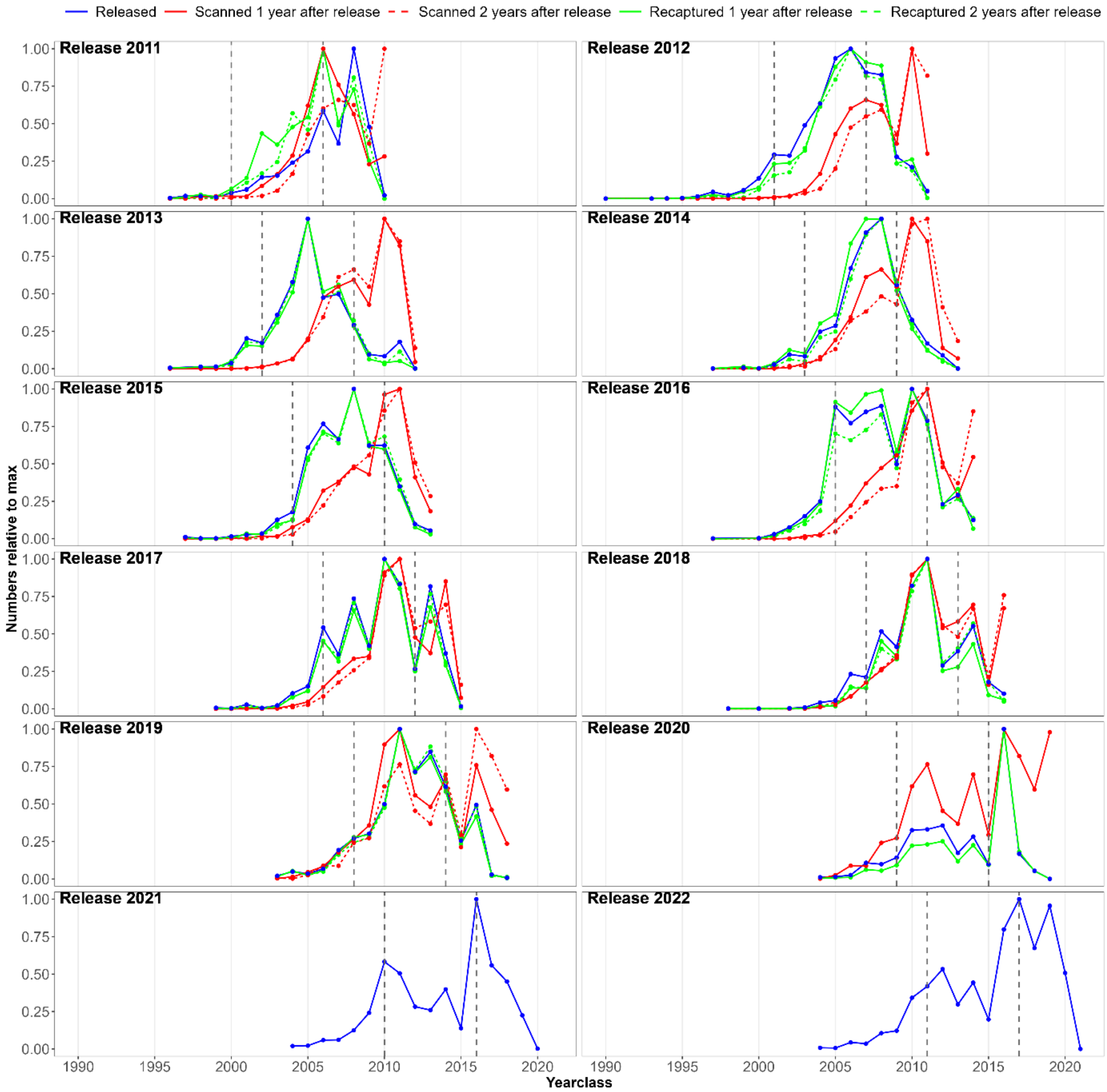


Figure 8.6.4.3. Distribution of recaptures of RFID tagged mackerel during 2012-2021. Note that data on recaptures in 2012-2013 are not used in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019c).



8.6.4.4. Overview of the relative year class distributions among RFID tagged mackerel per release year from experiments west of Ireland and British Isles in May-June compared with scanned and recaptured fish in year 1 and 2 after release of the same year classes. Note that data from releases in 2011-2012 are not used in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019c). Note also that it was decided to only use ages 5-11 in updated assessments, and limits for this age span is marked (vertical grey dotted lines) for each release year.

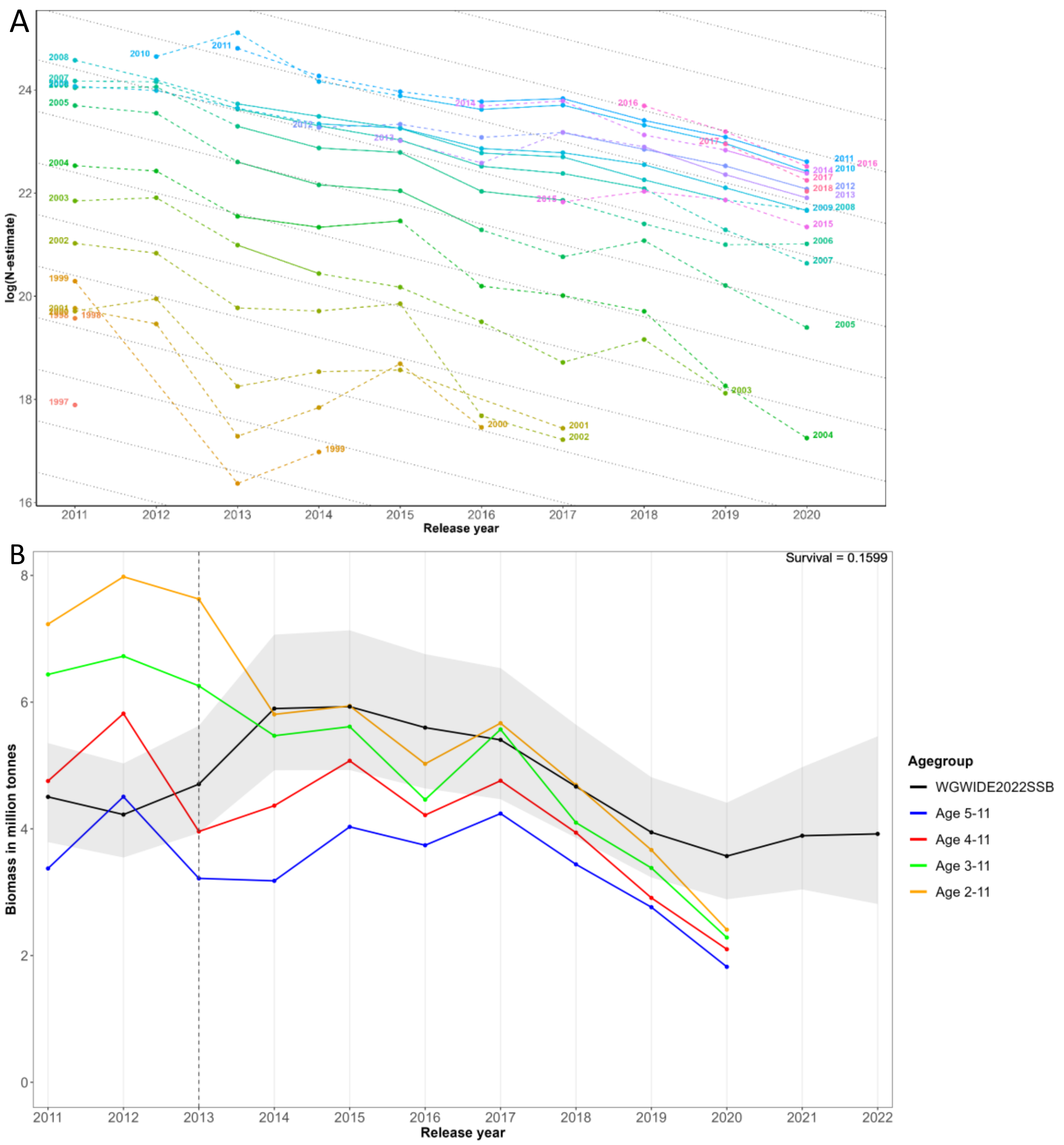


Figure 8.6.4.5. (A) Trends in year class abundance (N=numbers released/numbers recaptured*numbers scanned) from RFID tag-recapture data based on aggregated data on recaptures and scanned numbers in year 1 and 2 after each release year. Data excluded in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019c), release years 2011-2012 and ages 2-4 and 12+, are marked with dotted lines in year class trends. (B) Trends in various age aggregated biomass indices from RFID tag-recapture data compared with the SSB (±95 confidence intervals) from the WGWIDE 2022 stock assessment. Data are based on a combination of estimated numbers by year class (A) scaled by survival parameter (0.1599) and weight at age in stock from WGWIDE 2022. Vertical dotted line marks the starting year where RFID tagging experiments are used in the stock assessment. Note that final year with RFID biomass estimates in 2020 is only based on recapture year 2021 and will likely change when adding recapture year 2022 in WGWIDE 2023.

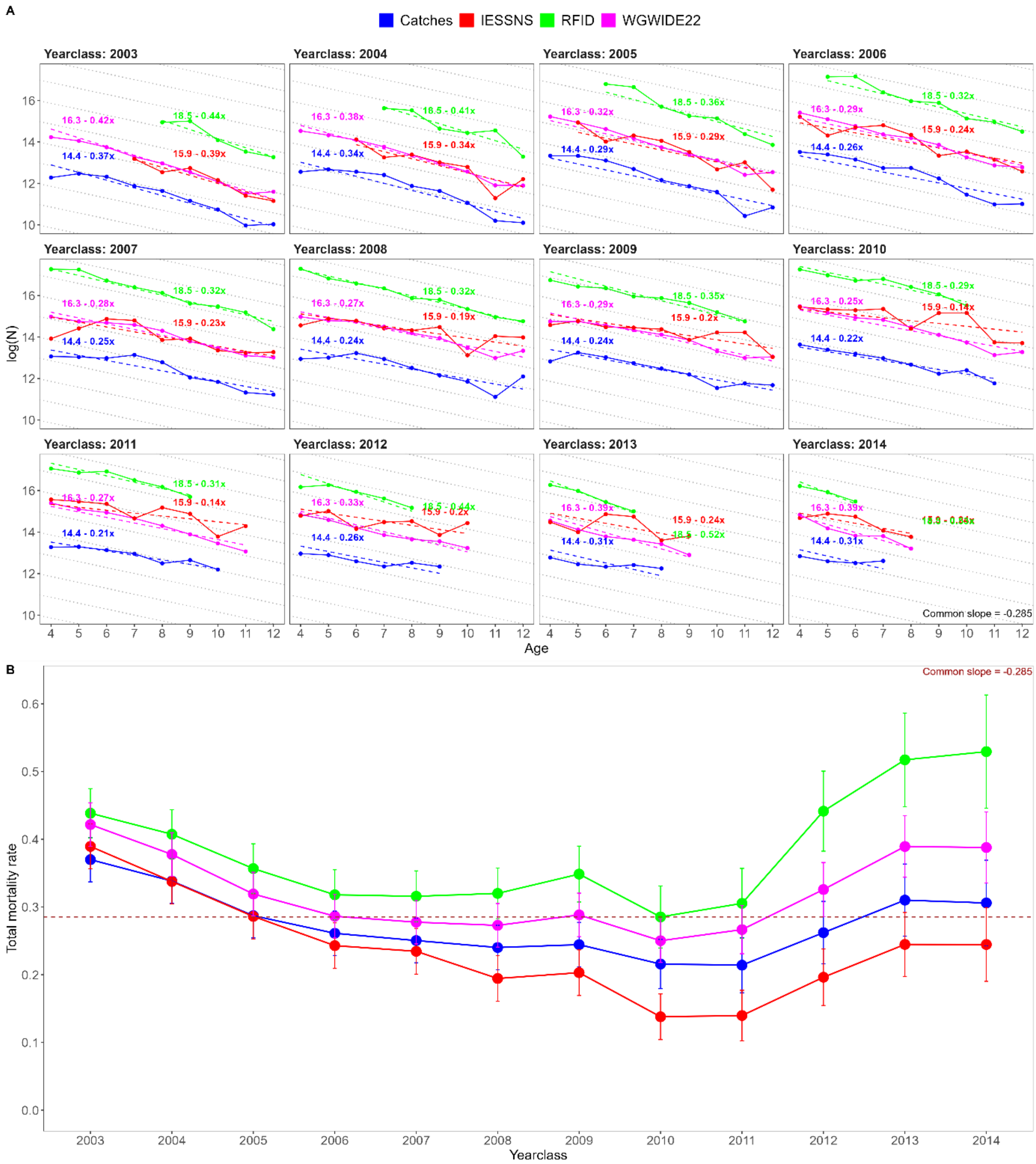


Figure 8.6.4.6. Signals of total mortality rate (Z). (A) Trends in abundance of year classes 2003-2014 from unscaled input data (RFID, IESSNS and catches) and the WGWIDE2022 stock assessment. The estimated slope of decrease from the age 4 when it is fully recruited to the spawning stock until age 12 is interpreted as signal Z, grey dotted lines is Z=0.4. (B) The estimated year class differences in Z (with 95% confidence intervals), and corresponding differences between the various data sources.

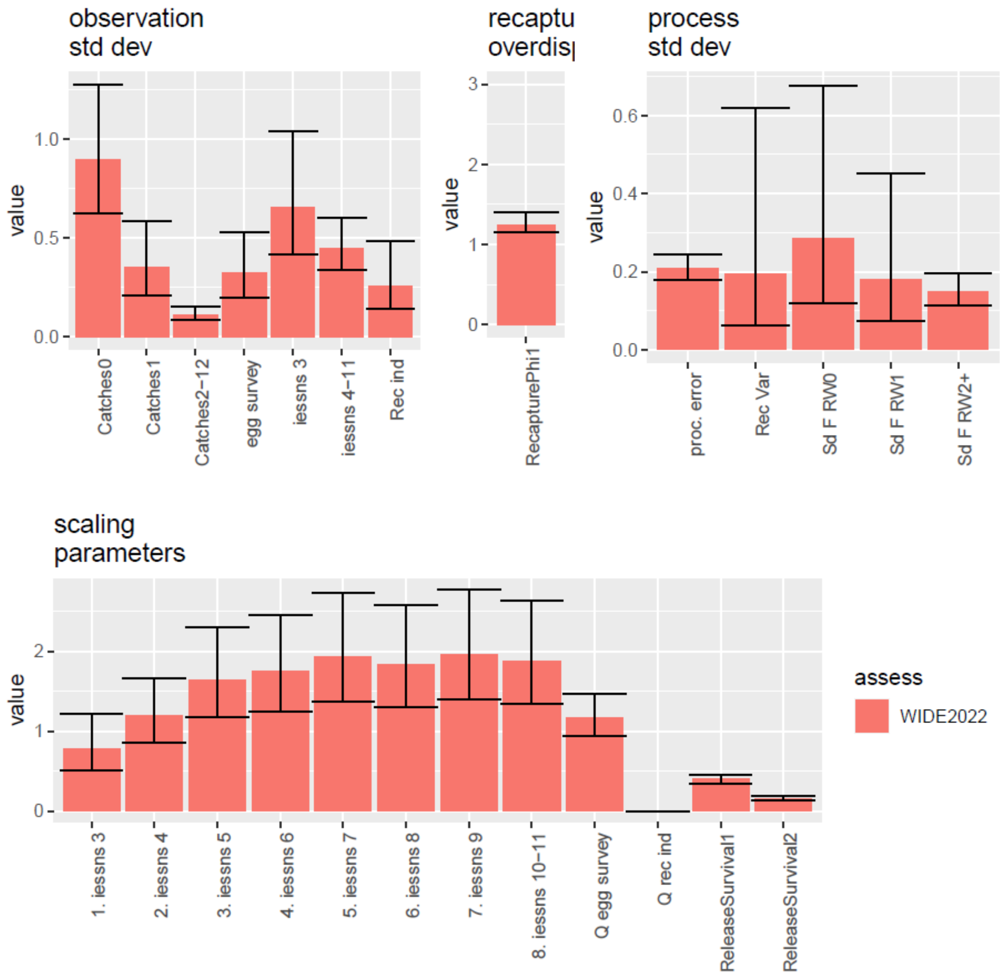


Figure 8.7.2.1. NE Atlantic mackerel. Parameter estimates from the SAM model (and associated confidence intervals) for the WGWIDE 2022 update assessment. top left : estimated standard deviation for the observation errors, top centre : estimated overdispersion for the errors on the tag recaptures, top right : standard deviation for the processes, bottom : survey catchabilities and post-release survival of tagged fish.

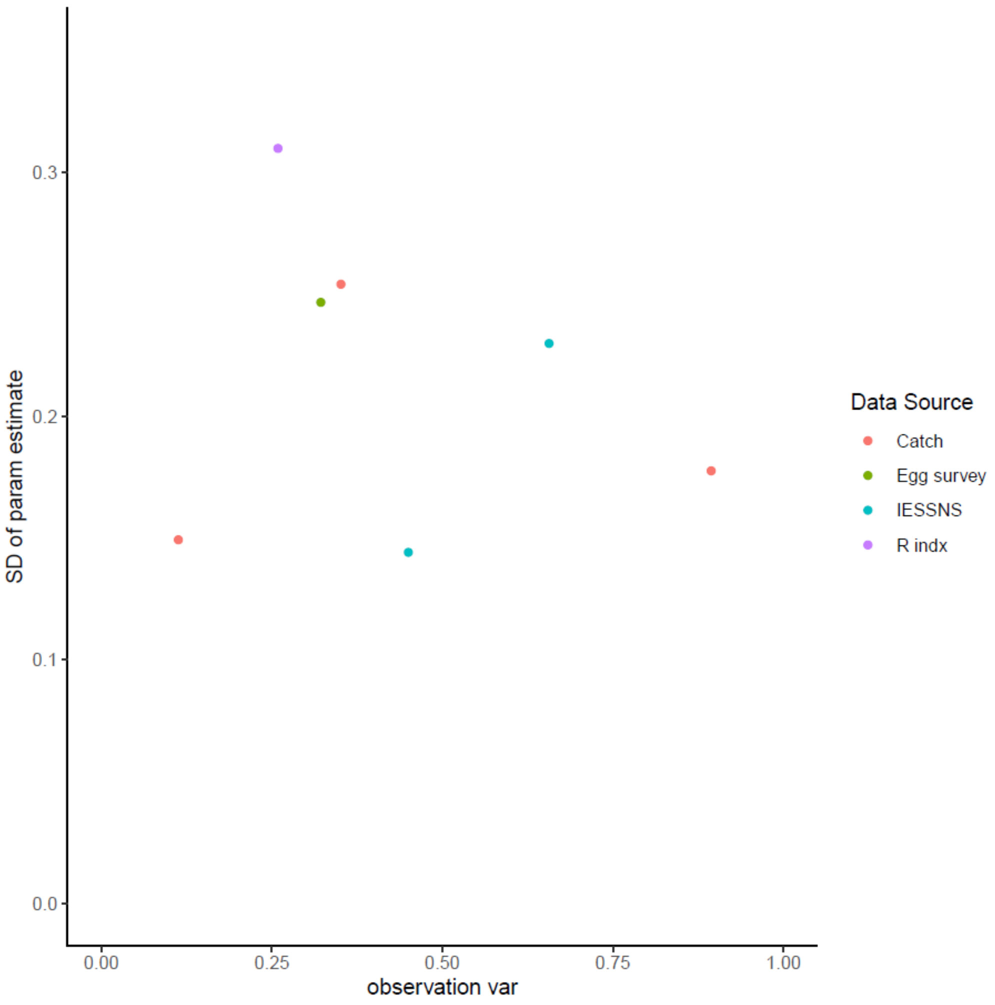


Figure 8.7.2.2. NE Atlantic mackerel. Parameter uncertainty (standard deviation of estimate) versus parameter value for the observation variances.

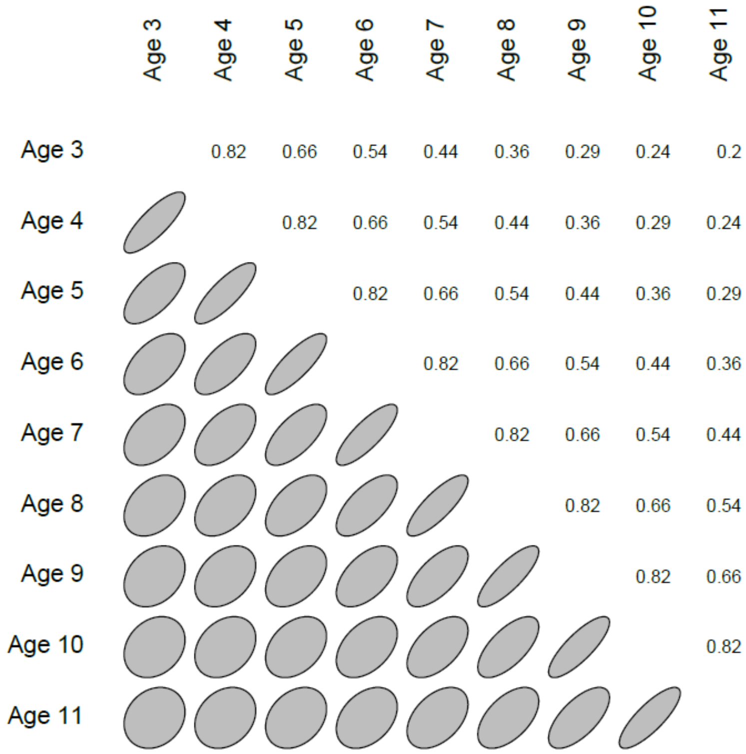


Figure 8.7.2.3. NE Atlantic mackerel. Estimated AR1 error correlation structure for the observations from the IESSNS survey age 3 to 11.

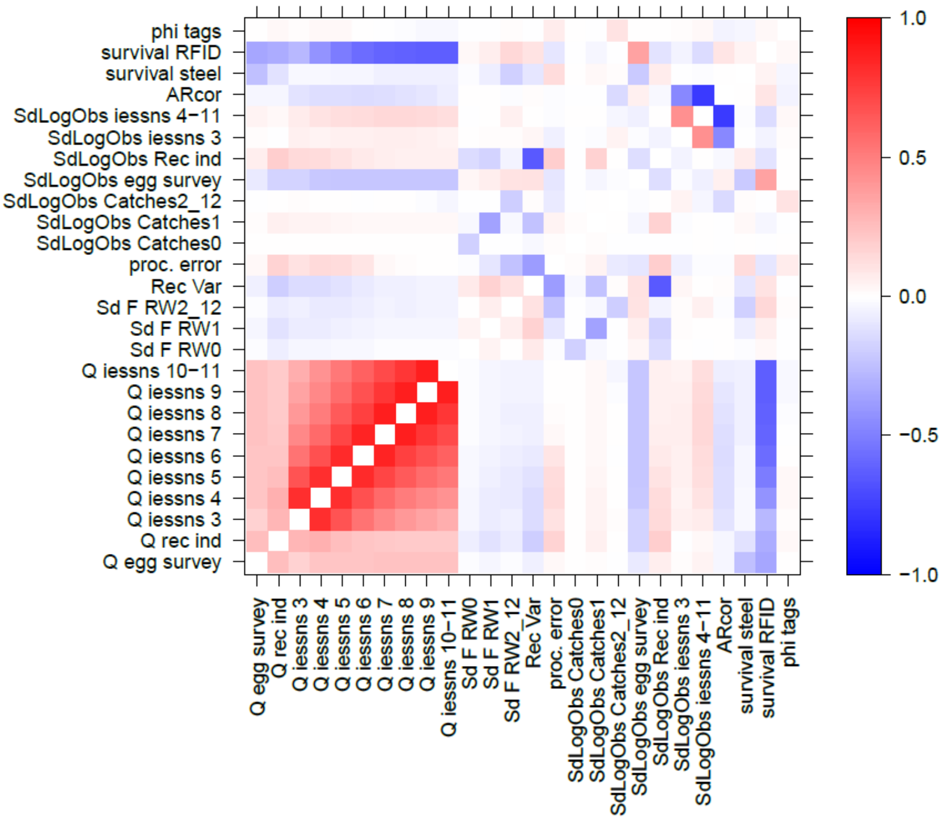


Figure 8.7.2.4. NE Atlantic mackerel. Correlation between parameter estimates from the SAM model for the WGWIDE 2022 update assessment

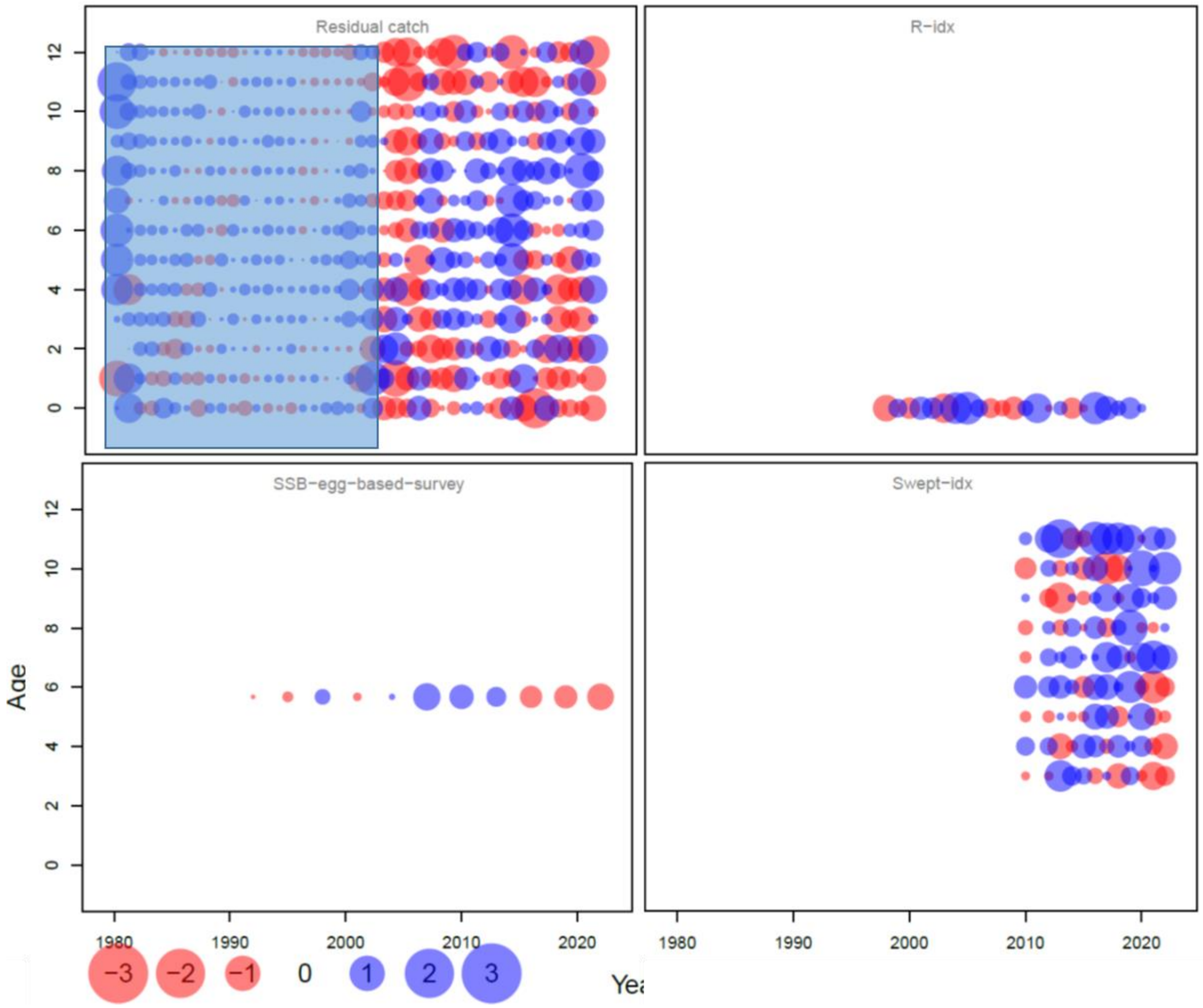


Figure 8.7.2.5. NE Atlantic mackerel. One Step Ahead Normalized residuals for the fit to the catch data (catch data prior to 2000 in blue rectangle were not used to fit the model). Blue circles indicate positive residuals (observation larger than predicted) and filled red circles indicate negative residuals.

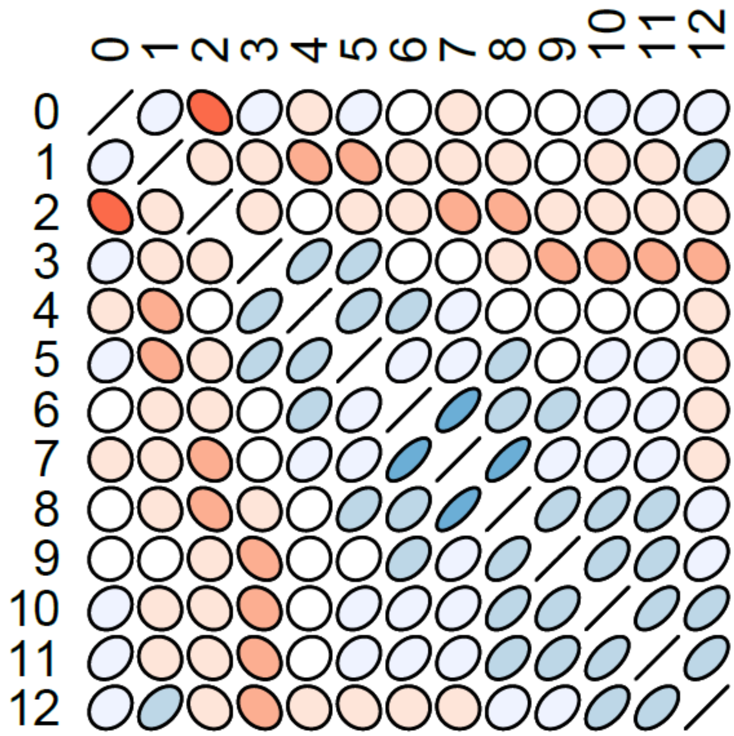


Figure 8.7.2.6. NE Atlantic mackerel. Empirical correlations between ages in the One Step Ahead residuals for the catch-at-age data.

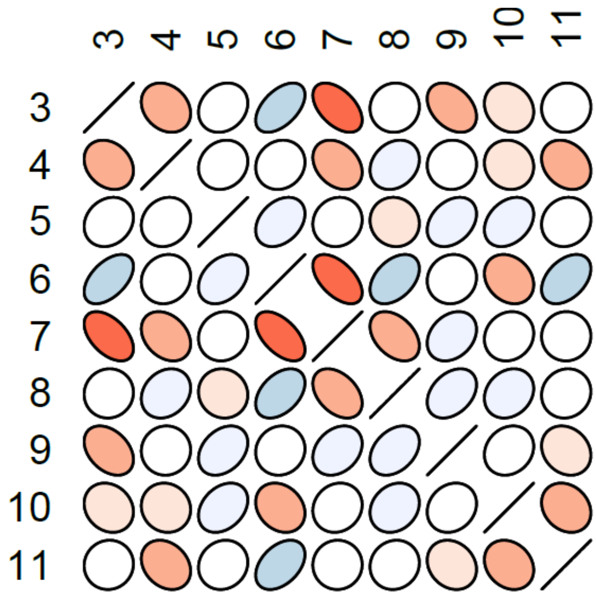


Figure 8.7.2.7. NE Atlantic mackerel. Empirical correlations between ages in the One Step Ahead residuals for the IESSNS abundances-at-age.

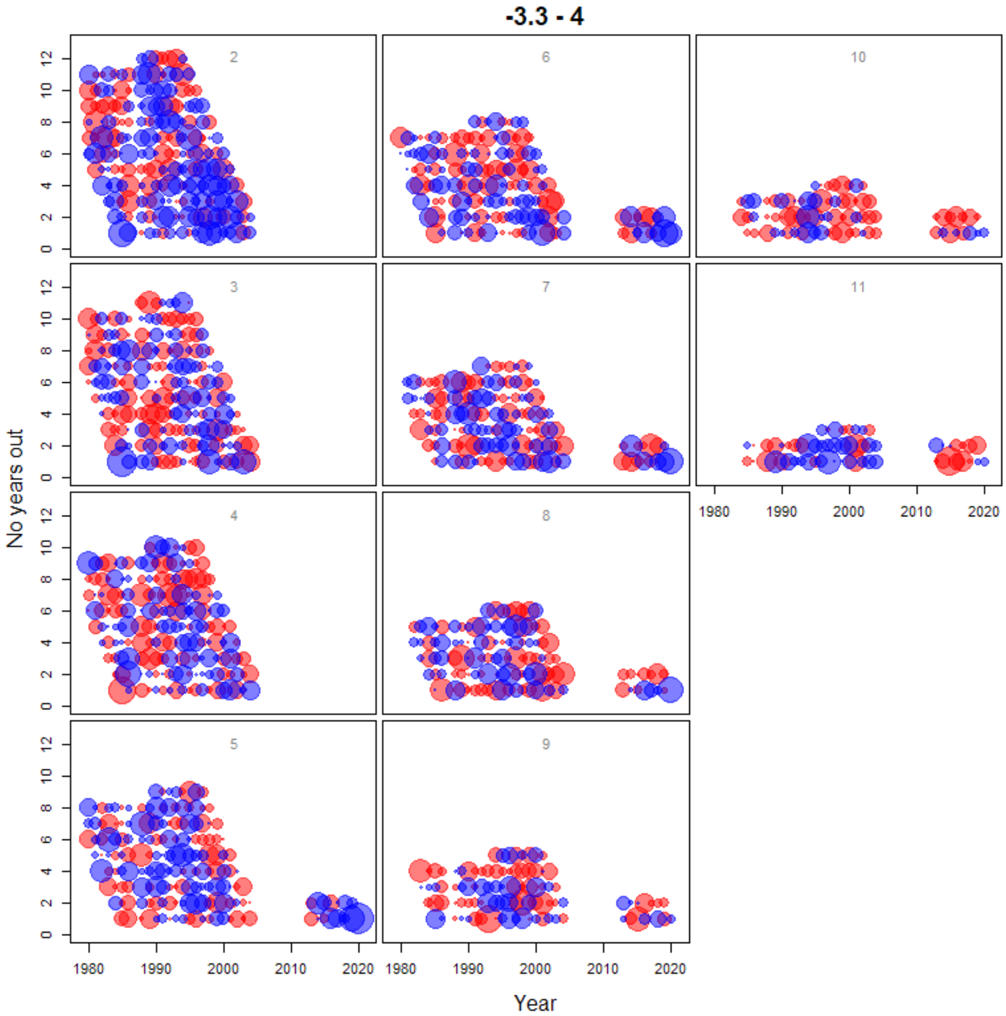


Figure 8.7.2.8. NE Atlantic mackerel. One step ahead residuals for the fit to the recaptures of tags in the final assessment. The x-axis represents the release year, and the y-axis is the number of years between tagging and recapture. Each panel correspond to a given age at release. Blue circles indicate positive residuals (observation larger than predicted) and filled red circles indicate negative residuals.

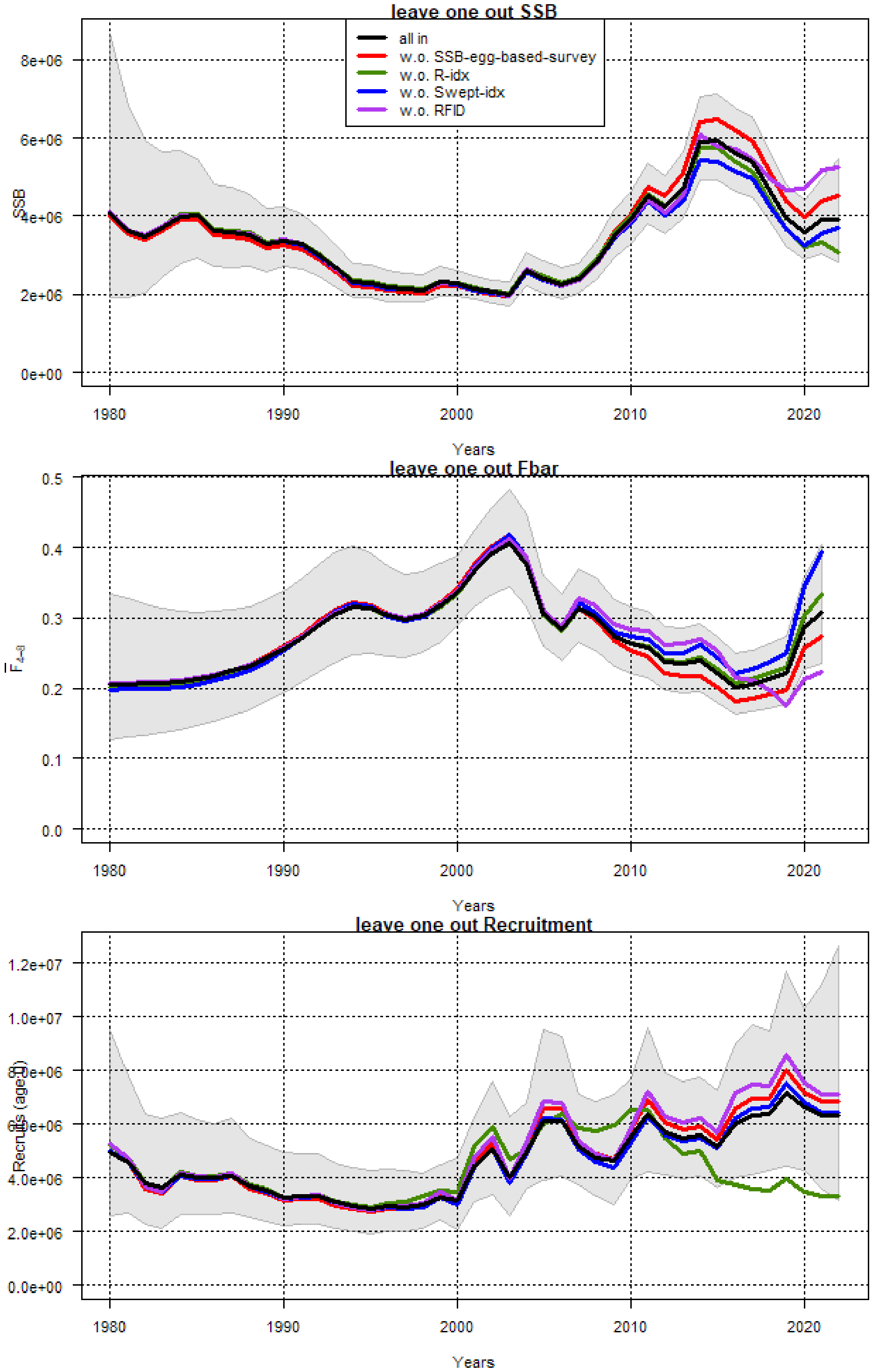


Figure 8.7.2.9. NE Atlantic mackerel. Leave one out assessment runs. SAM estimates of SSB , Fbar and recruitment, for assessments runs leaving out one of the observation data sets.

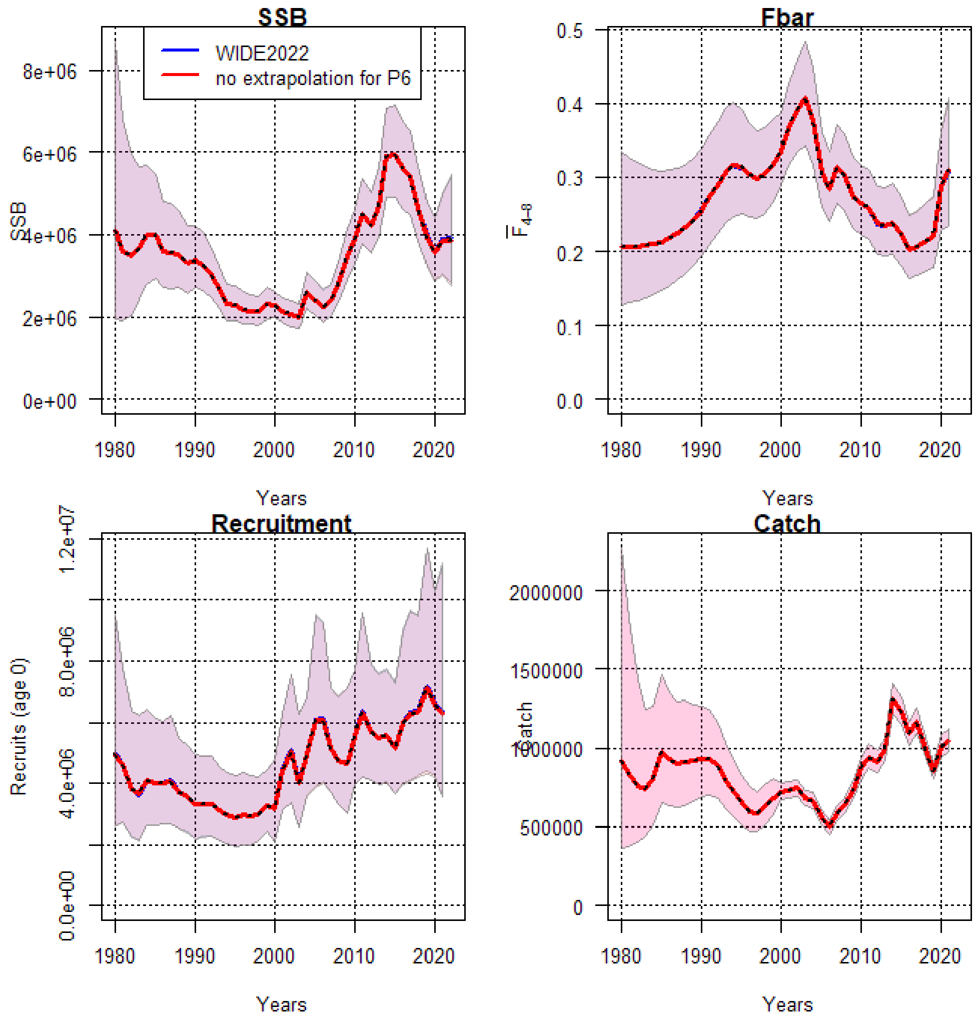


Figure 8.7.2.10. NE Atlantic mackerel. Sensitivity of the estimated stock trajectories to a 9.4% reduction of the 2022 SSB index from the egg survey (proportion of the total annual egg production corresponding to the interpolation done for the missing coverage in period 6 of the survey).

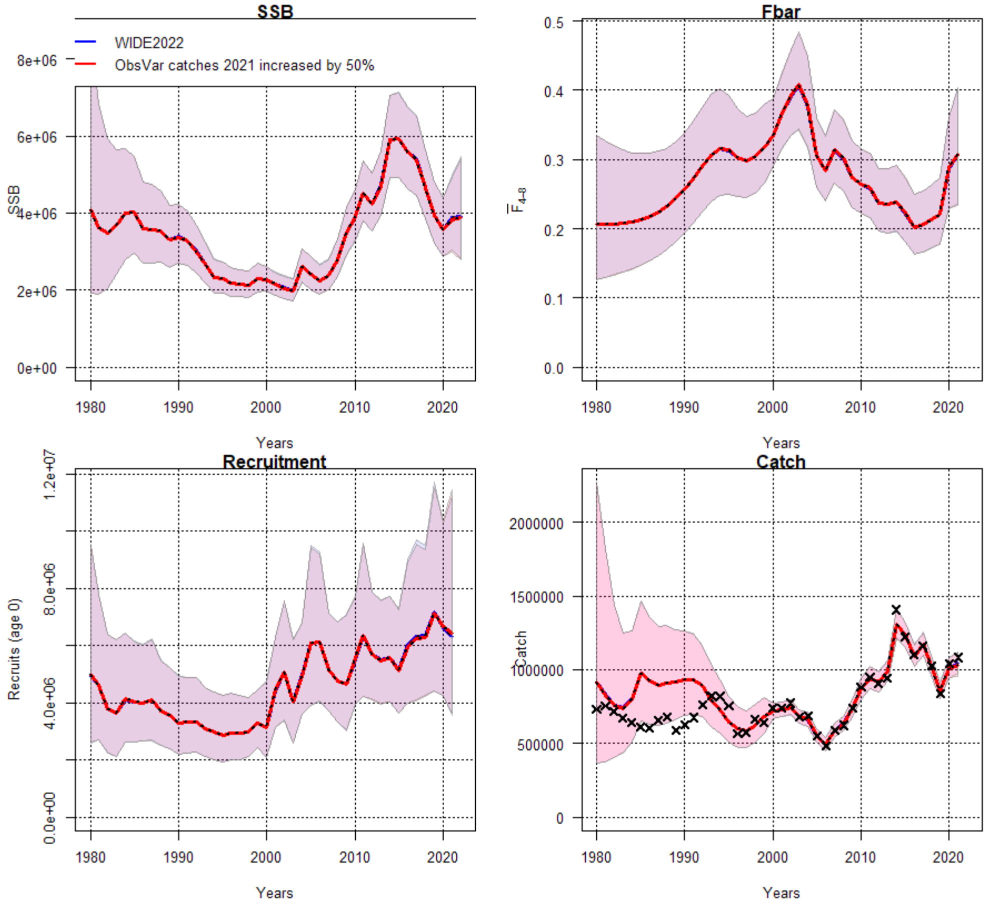


Figure 8.7.2.11. NE Atlantic mackerel. Sensitivity of the estimated stock trajectories to a 50% increase in the observation error variance for the catches-at-age for the year 2021 (to account for a potential higher uncertainty due to the lack of data from Russia).

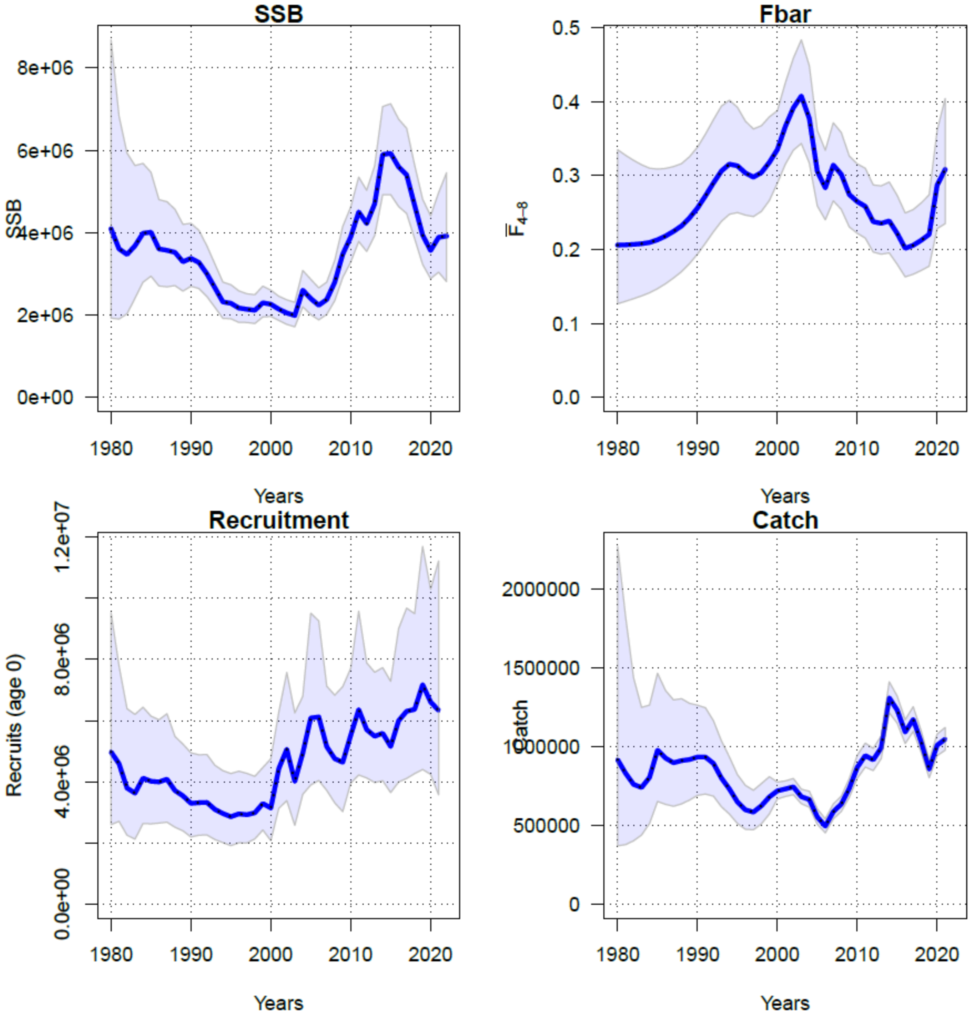


Figure 8.7.3.1. NE Atlantic mackerel. Perception of the NEA mackerel stock, showing the SSB, F_{bar}4-8 and recruitment (with 95% confidence intervals) from the SAM assessment.

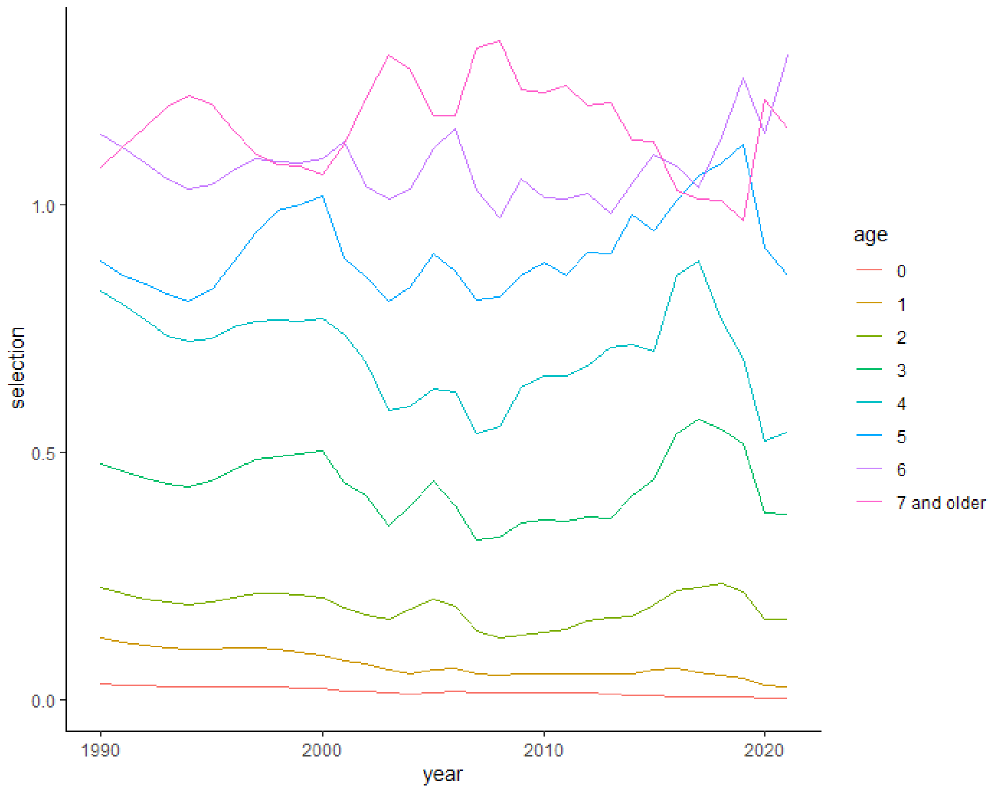


Figure 8.7.3.2. NE Atlantic mackerel. Estimated selectivity for the period 1990 to 2021, calculated as the ratio of the estimated fishing mortality-at-age and the Fbar4-8 value in the corresponding year.

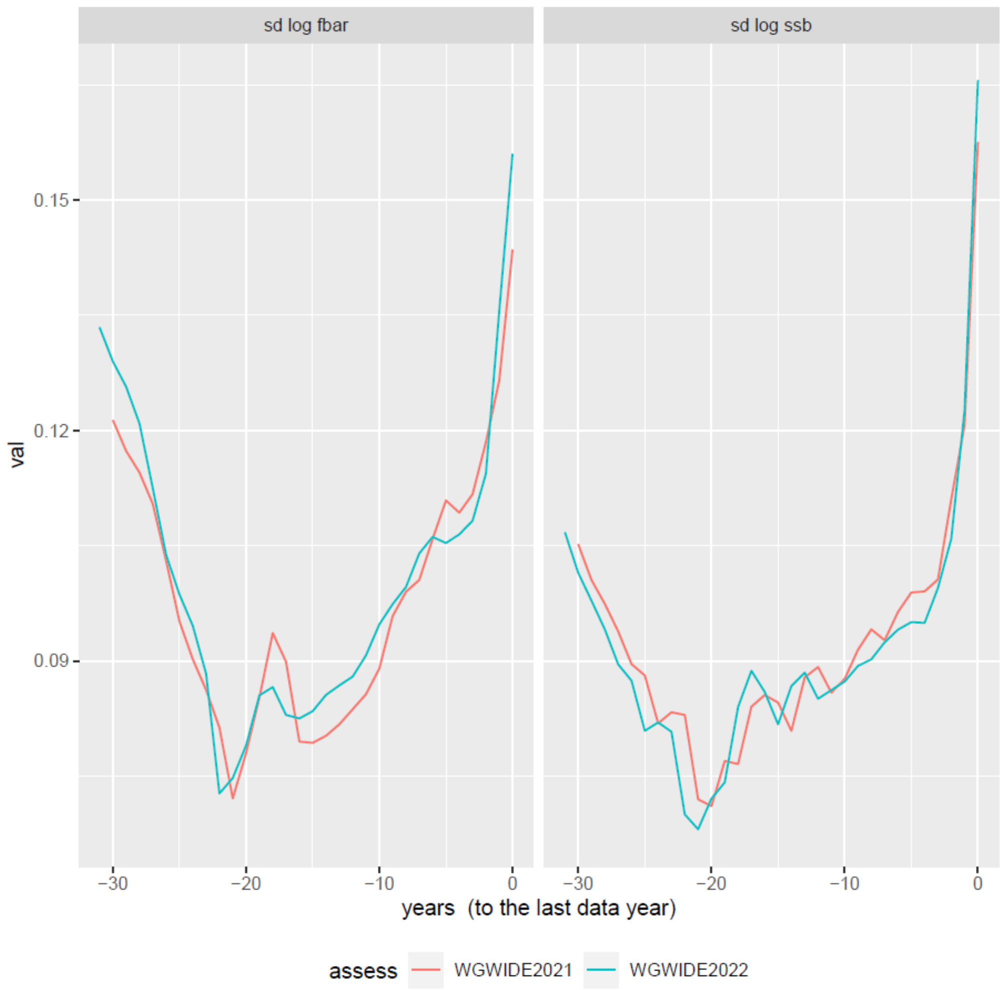


Figure 8.7.4.1. NE Atlantic mackerel. Uncertainty (standard deviation of the log values) of the estimates of SSB and Fbar from the SAM for the 2021 and 2022 WGWIDE assessments.

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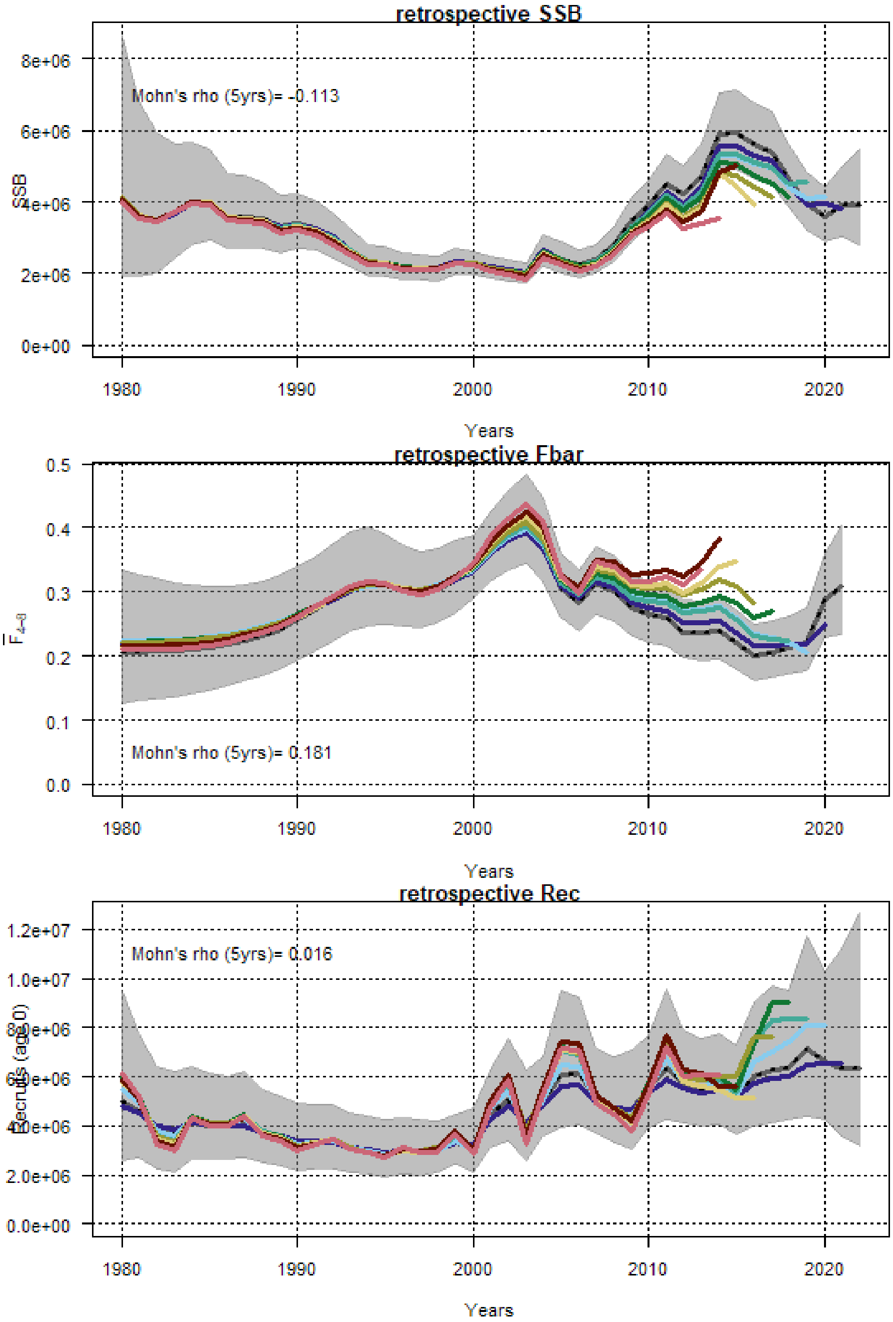


Figure 8.7.4.2. NE Atlantic mackerel. Analytical retrospective patterns (8 years back) of SSB, F_{bar}4-8 and recruitment from the WGWIDE 2022 update assessment. the Mohn's rho values are calculated based on 5 retro years.

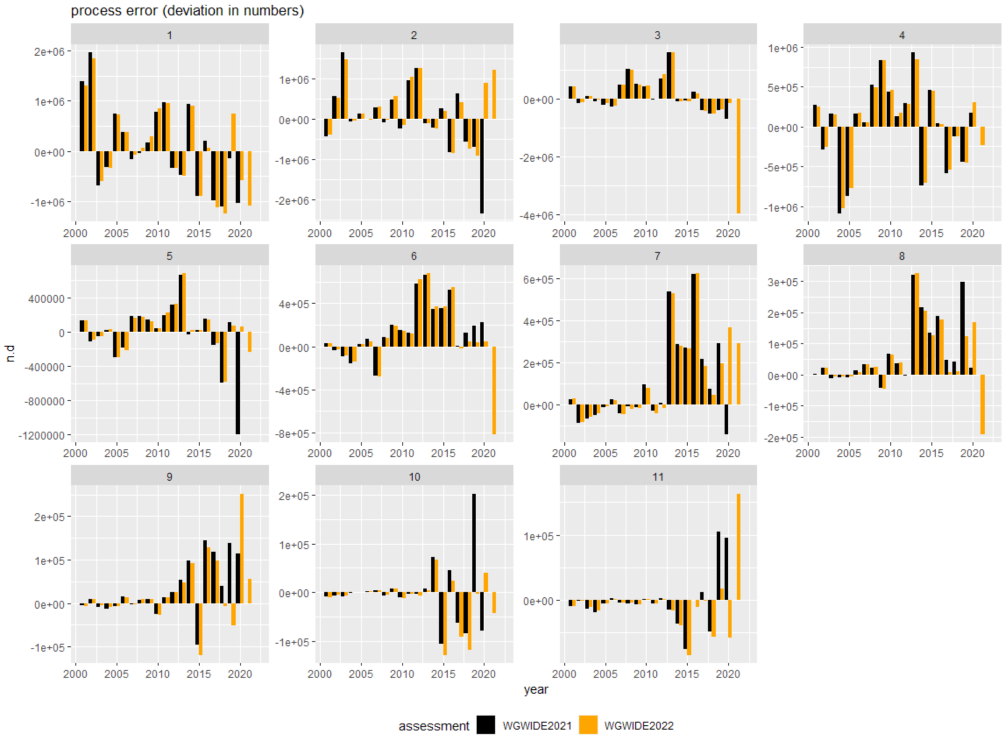


Figure 8.7.4.3. NE Atlantic mackerel. Process error expressed as annual deviations of abundances at age, for the 2022 WGWIDE assessment and from the 2021 WGWIDE assessment.

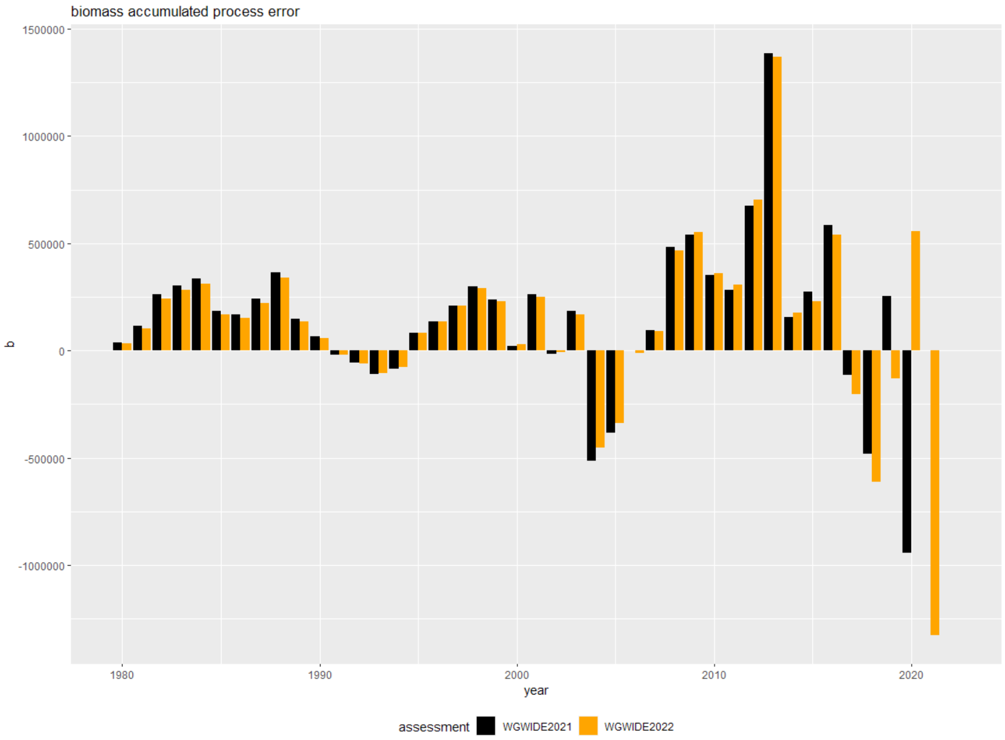


Figure 8.7.4.4. NE Atlantic mackerel. Model process error expressed in biomass cumulated across age-group for the 2022 WGWIDE assessment and for the 2021 WGWIDE assessment.

Figure 8.7.5.1. NE Atlantic mackerel. Model comparison of the cohort signal based on SAM estimates at age 0, 2 and 3.

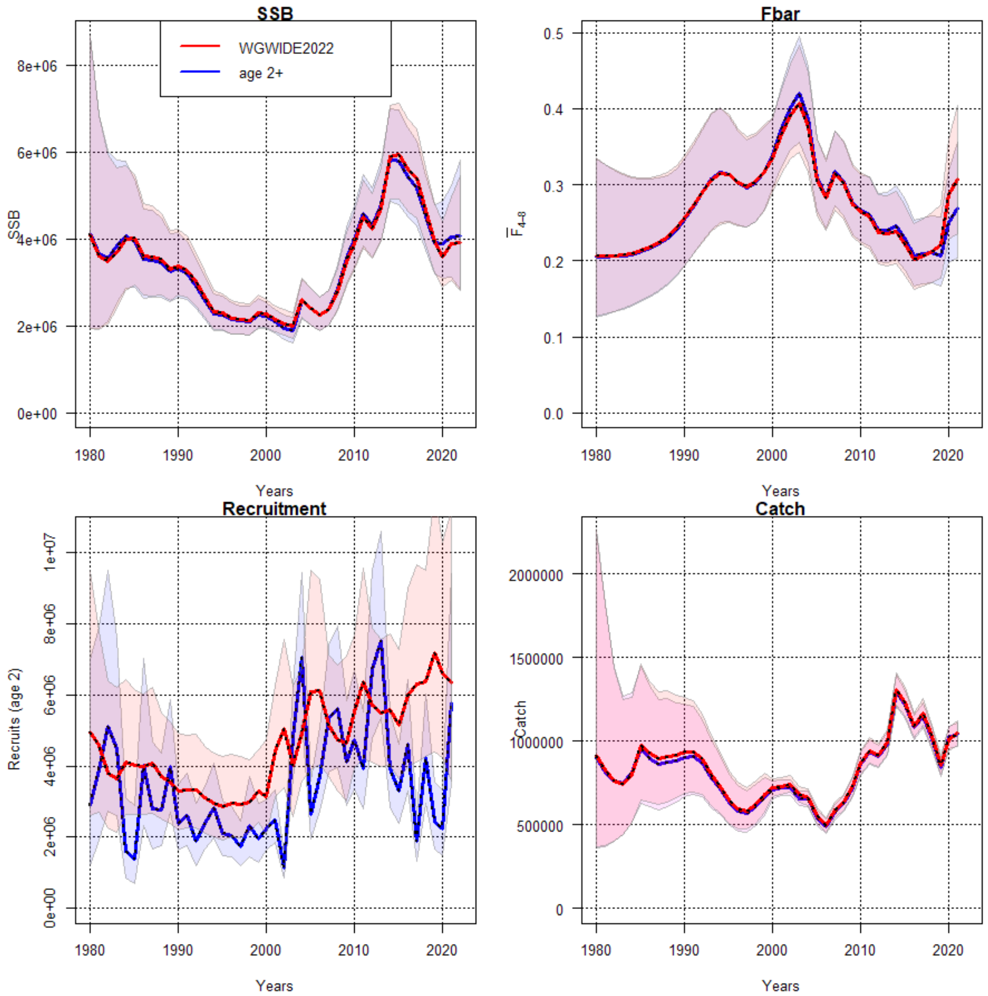


Figure 8.7.5.2. NE Atlantic mackerel. Model. comparison of the perception of the stocks from the WGWIDE 2022 assessment, and the assessment starting at age2.

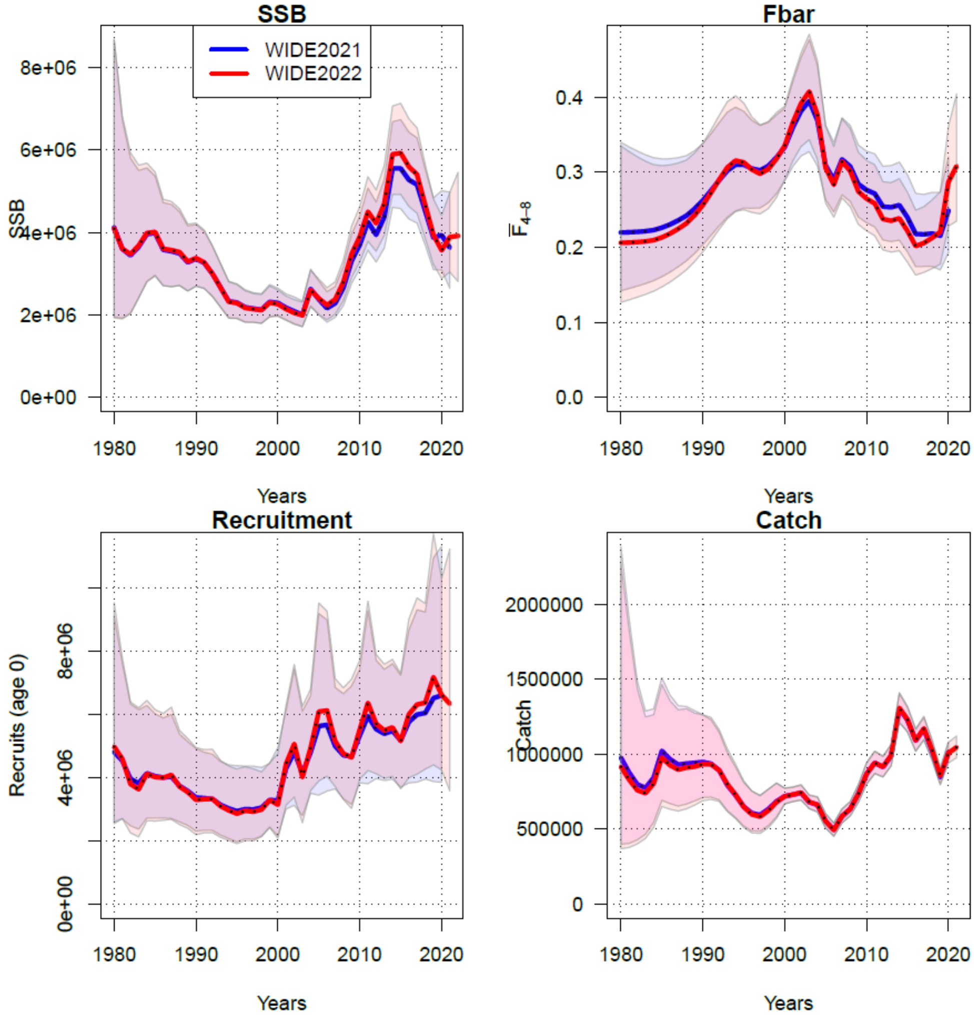


Figure 8.10.1. NE Atlantic mackerel. Comparison of the stock trajectories from the WGWIDE 2021 (blue) and 2022 (red) update assessments.

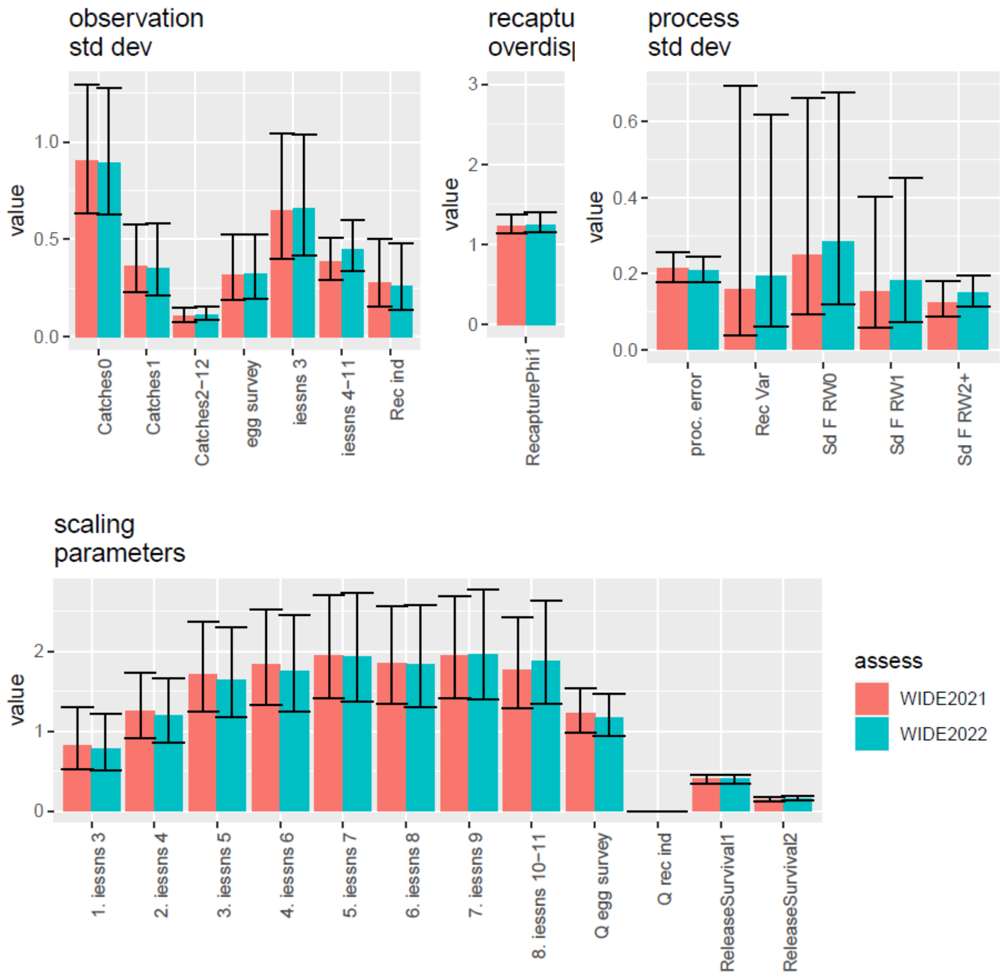
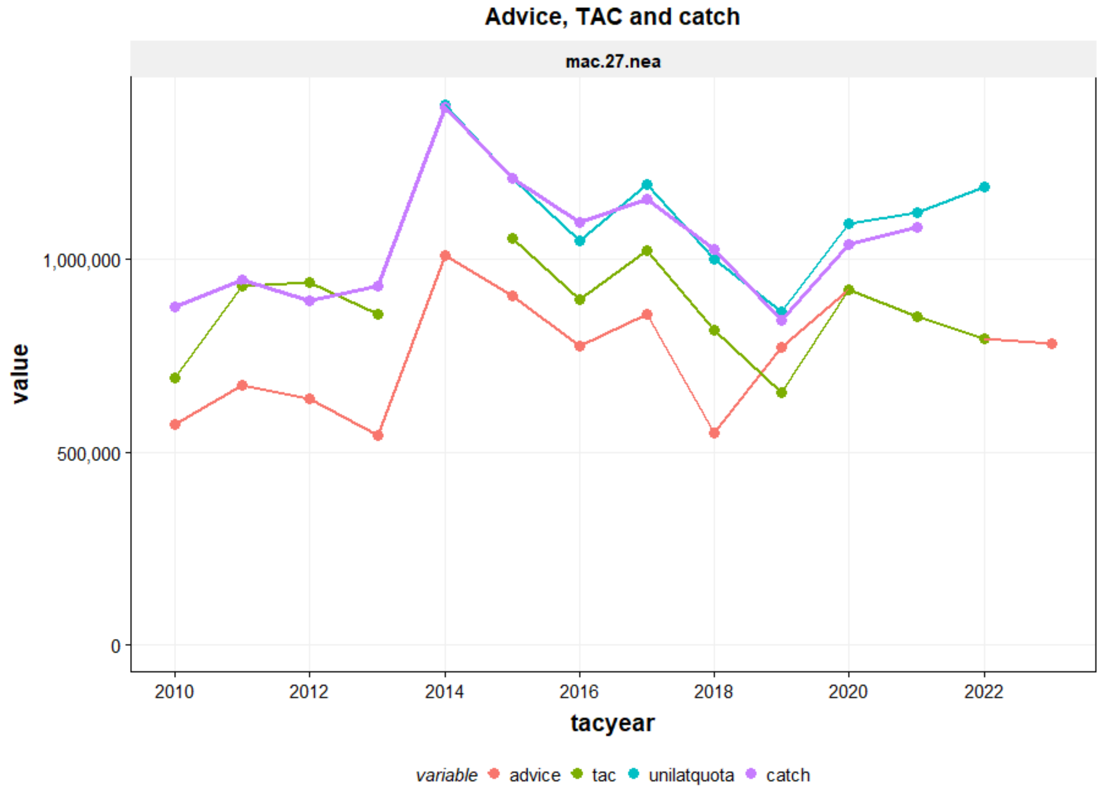


Figure 8.10.2. NE Atlantic mackerel. Comparison of model parameters and their uncertainty for the 2022 WGWIDE and the 2021 WGWIDE assessment



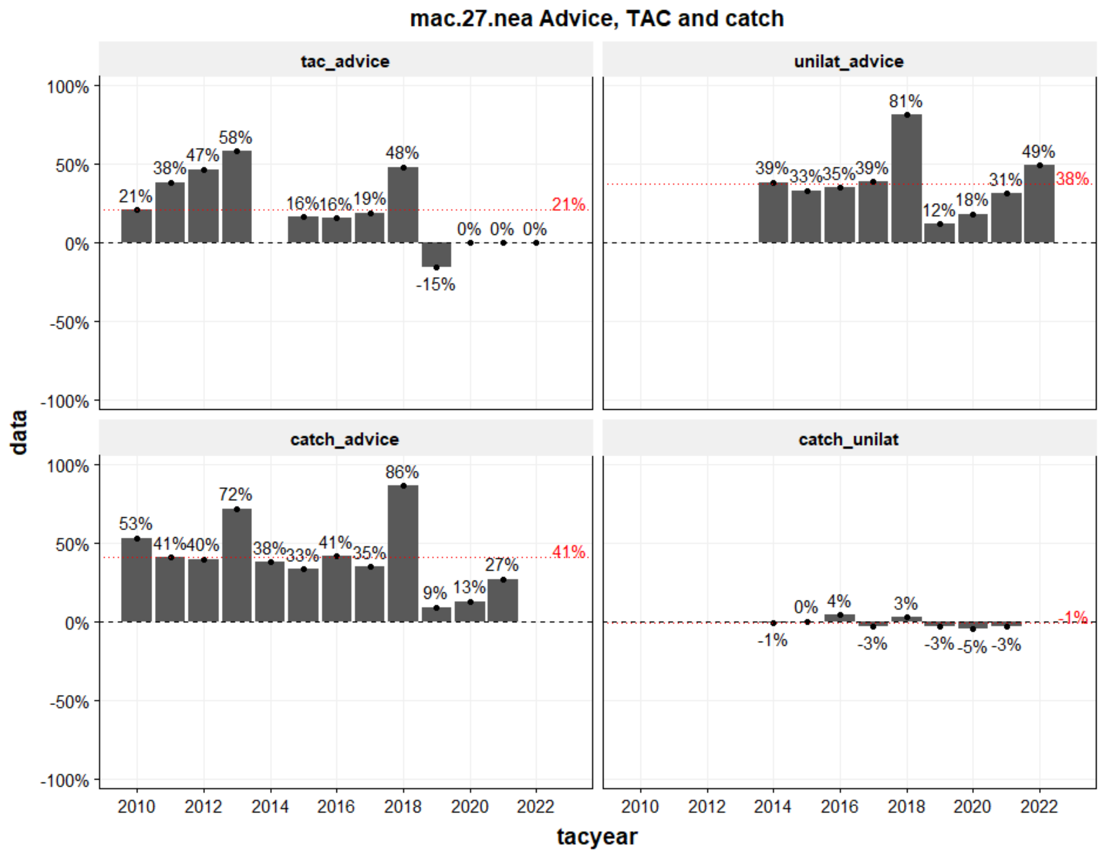


Figure 8.11.1. NE Atlantic mackerel. Top: comparison of the ICES advice, the agreed TAC, the sum of the unilateral quota and total catch. Bottom: calculated percentage of TAC over Advice, Sum of unilateral quota over Advice, Catch over Advice and Catch over Sum of unilateral quota.