8 Northeast Atlantic Mackerel

8.1 ICES Advice and International Management Applicable to 2020

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 agreement from 2014 was extended for two further years until 2020. No agreement on the share of the stock has been reached after Brexit for 2021. Despite various agreements, the total declared quotas in each of the years 2015 to 2020 all exceeded the TAC advised by ICES. An overview of the declared quotas and transfers for 2021, as available to WGWIDE, is given in the text table below. Total removals of mackerel are expected to be approximately 1.2 million tonnes in 2021, exceeding the ICES advice for 2021 by about 347 000 t (41%).

Estimation of 2021 catch	Tonnes	Reference
EU quota	200 179	NEAFC HOD 21/22
UK quota	222 288	Department for Environment Food & Rural Affairs (UK). April 2021
Norwegian quota	298 299	NEAFC HOD 21/22
Inter-annual quota transfer 2020->2021 (NO)	-10 210	NEAFC HOD 21/22
Russian quota	120 423	NEAFC HOD 21/22
Discards	9 280	Previous years estimate
Icelandic expected catch	120 000	WGWIDE
Faroese quota	167 048	Faroese Fisheries Ministry regulations No. 85 and 115/2021
Inter-annual quota transfer 2020->2021 (FO)	33 796	Faroese Fisheries Ministry regulations No. 85 and 115/2021
Greenland expected catch	38 000	Ministry of Fisheries, Hunting and Agriculture in Greenland
Total expected catch (incl. discards) [1,2]	1 199 103	

[1] No estimates of banking from 2020 to 2021.

[2] Quotas refer to claims by each party for 2021 and include exchange to other parties

The quota figures and transfers in the text table above were based on various 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 Table 8.2.4.1 for an overview.

8.2 The Fishery

8.2.1 Fleet Composition in 2020

The total fleet can be considered to consist of the following components:

Freezer trawlers. These are commonly large vessels (up to 150 m) that usually operate a single mid-water pelagic trawl, although smaller vessels may also work as pair trawlers. These vessels are at sea for several weeks and sort and process the catch on board, storing the mackerel in frozen 20 kg blocks. The Dutch, German and the majority of the French and English fleets consist of these vessels which are owned and operated by a small number of Dutch companies. They fish in the North Sea, west of the UK and Ireland and also in the English Channel and further south along the western coast of France. Russian freezer trawlers fish for mackerel during the summer (June-September) in the Norwegian Sea in Division 2.a, mainly inside the NEAFC regulatory area. Part of the Icelandic fishery is in Division 5.a and in some years in 14.b.

Purse seiners. The majority of the Norwegian catch is taken by these vessels, targeting mackerel overwintering close to the Norwegian coastline. The largest vessels (> 20 m) used refrigerated seawater (RSW), storing the catch in tanks containing RSW. Smaller purse seiners use ice to chill their catch which they take on prior to departure. A purse seine fleet is also the most important component of the Spanish fleet. They are numerous and target mackerel early in the year close to the northern Spanish coast. These are dry hold vessels, chilling the catch with ice. Denmark also has a purse seine fleet operating in the northern North Sea.

Pelagic trawlers. These vessels vary in size from 20—100 m and operate both individually and as pairs. The largest of the pelagic trawlers use RSW tanks for storage. Iceland, Greenland, Faroes, Scotland and Ireland fish mackerel using pelagic trawlers. Scottish and Icelandic vessels mostly operate as single trawlers whereas Ireland and Faroese vessels tend to use pair trawls. Spain also has a significant trawler fleet which target mackerel with a demersal trawl in Subarea 8 and Division 9.a.N.

Lines and jigging. Norway and England have handline fleets operating inshore in the Skagerrak (Norway) and in Divisions 7.e/f (England) around the coast of Cornwall, where other fishing methods are not permitted. Spain also has a large artisanal handline fleet as do France and Portugal. A small proportion of the total catch reported by Scotland (Divisions 4.a and 4.b) and Iceland (Division 5.a) is taken by a handline fleet.

Gillnets. Gillnet fleets are operated by Norway and Spain.

8.2.2 Fleet Behaviour in 2020

The northern summer fishery in Subareas 2 and 5 continued in 2020. There was no fishery in Subarea 14. 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 the third quarter of 2020 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 2020, with catch also taken in 5.a in waters to the south, east and west of Iceland. In 2020 Greenland targeted mackerel in Division 2.a with no catch taken from 14.b. In 2019 Greenland fished in 14.b and in 2018 both Greenland and Iceland reported landings from this area. Catches from Greenland have decreased again in 2020 to 27 kt, down from 30 kt in 2019 and almost 63 kt in 2018. The Faroese fleet targeted mackerel during late summer and early autumn with nearly half of the catches taken in 2.a and 4.a. The remaining catch was taken in quarter 1 mainly in 4.a and some in 6.a.

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.

In 2020 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, although the 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 the northern summer fishery did not extend as far west as in previous years.

As a result of this expansion, Icelandic vessels have increased effort and catch dramatically in recent years from 4 kt in 2006 to an average 159 kt annually since 2011. This fishery operates over a wide area E, NE, SE, S and SW of Iceland. Since 2011, there has been less fishing activity to the north and north-east and an increase in catches taken south and west of Iceland. Greenland has reported catches from Division 14.b since 2011, and reached the biggest catch by this fleet to date in 2014, with a catch of 78 kt. In 2020 the catch reported from Greenland was mainly from Division 2.a.

8.2.4 Regulations and their Effects

An overview of the major existing technical measures, effort controls and management plans are given in Table 8.2.4.1. Note that there may be additional existing international and national regulations that are not listed here.

Between 2010 and 2020 no overarching Coastal States Agreement/NEAFC Agreement was in place and no overall international regulation on catch limitation was in force. In 2014, three of the Coastal States (The EU, Faroes and Norway) agreed on a Management Strategy for 2015 and the subsequent five years. In November 2018, the agreement from 2014 was extended for two more years until 2020. However, the total declared quotas taken by all parties since 2015 have greatly exceeded the TAC advised by ICES (see Section 8.1). Currently there is no agreement on a management strategy covering all parties fishing mackerel.

Management aimed at a fishing mortality in the range of 0.15—0.20 in the period 1998—2008. In 2008 the Coastal states agreed a long term management plan which aimed at a fishing mortality in the range 0.20—0.22. The fishing mortality realised during 1998—2008 was in the range of 0.27 to 0.46. Implementation of the management plan resulted in a reduced fishing mortality and increased biomass. The last agreed management plan was in 2017 (ICES, 2017a). During the Coastal States' negotiations in 2019 for 2020, it was recognised that the F and B were outdated after the recent MSE on mackerel (ICES, 2019). Therefore, the Coastal States used F_{MSY} as reference F in setting their TAC for 2020. At the same time, they requested ICES to evaluate a new management plan for mackerel, which was finally evaluated by ICES in 2020. However, the Coastal States have not considered the response from ICES yet. Since 2008 catches have greatly exceeded those given by the plan.

The measures advised by ICES to protect the North Sea spawning component aim at setting the conditions for making a recovery of this component possible. Before the late 1960s, the North Sea spawning biomass of mackerel was estimated at above 2.5 million tonnes. The collapse of mackerel in the North Sea in the late 1960s was most likely driven by very high catches and associated fishing mortality. However, the lack of recovery of mackerel in the North Sea was probably associated with unfavourable environmental conditions, particularly reduced temperatures (unfavourable for spawning), lower zooplankton availability in the North Sea and increased wind-stress induced turbulence (Jansen, 2014). These unfavourable environmental conditions probably led the mackerel to spawn in western waters instead of in the North Sea.

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. Management should ensure that fisheries do not decrease genetic and behavioural diversity, since this could reduce future production. Protection of mackerel that tend to spawn in the north-eastern parts of the spawning area is therefore still advisable to some extent.

In the southern area, a Spanish national regulation affecting mackerel catches of Spanish fisheries has been implemented since 2010. In 2015, fishing opportunities were distributed by region and gear and for the bottom trawl fleet, by individual vessel. This year, Spanish mackerel fishing opportunities in Divisions 8.c and 9.a were established at 39 674 t resulting from the quota established (Commission Regulation (EU) No 104/2015). This was reduced by 9 797 t due to the scheduling payback quota due to overfishing of the mackerel quota allocated to Spain in 2010 (Commission Regulation No 976/2012).

Within the area of the southwest Mackerel Box off Cornwall in southern England only handliners are permitted to target mackerel. This area was set up at a time of high fishing effort in the area in 1981 by Council Regulation to protect juvenile mackerel, as the area is a well-known nursery. The area of the box was extended to its present size in 1989.

Additionally, there are various other national measures in operation in some of the mackerel catching countries.

The first phase of a landing obligation came into force in 2015 for all EU vessels in pelagic and industrial fisheries. Since 2019, all species that are managed through TACs and quotas must be landed under the obligation unless there is a specific exemption such as *de minimis*. There are *de minimis* exemptions for mackerel caught in bottom-trawl fisheries in the North Western Waters (EC 2018/2034) and in the North Sea (EC 2018/2035).

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

Year	WG Total Catch (t)	% catch covered by sampling programme*	No. Samples	No. Measured	No. Aged
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
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

Overall sampling effort in 2020 was similar to previous years with 87 % of the catch sampled. It should be noted that this proportion is based on the total sampled catch. Nations with large, directed fisheries are capable of sampling 100 % of their catch which may conceal deficiencies in sampling elsewhere.

The 2020 sampling levels by country are shown below.

Country	Official catch	% WG catch covered by sampling programme	No. Samples	No. Measured	No. Aged
Belgium	124	0 %			
Denmark	38589	90 %	14	1515	967
Faroe Islands	69064	98 %	12	726	625
France	21936	0 %			
Germany	25030	65 %	88	15351	716
Greenland	26577	100 %	42	1998	88
Iceland	151534	99 %	112	4895	2755
Ireland	74232	99 %	47	8937	2061
Lithuania	815	0 %			
Netherlands	30321	62 %	35	2633	861
Norway	211672	96 %	65	2280	1776
Poland	5302	0 %			
Portugal	4799	12 %	101	2525	988
Russia	128817	100 %	201	64339	1349
Spain	34613	99 %	622	30510	2223
Sweden	3672	0 %			
UK (England & Wales)	30430	1 %	54	3165	227
UK (Northern Ireland)	14855	34 %	1	166	49
UK (Scotland)	167131	89 %	36	3951	1000

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. Sweden, Lithuania and Poland did not supply sampling information in 2020. Portugal sampled landings from 9.a only. England only samples landings from the handline fleet operating off the Cornish coast, representing only a small proportion of the national catch, the remainder reported from freezer trawlers. Cooperation between the Dutch and German sampling programmes (which sampled 65 % and 62 % respectively) 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	11	11	0	0	0
2.a	310223	310223	318	69611	3424
3.a	567	567	0	0	0
3.b	16	16	0	0	0
3.c	4	4	0	0	0
3.d	19	19	0	0	0
4.a	450720	450720	228	26072	5480
4.b	5024	5024	0	0	0
4.c	861	861	0	0	0
5.a	44867	44867	44	1979	1074
5.b	1879	1879	0	0	0
6.a	130903	130903	40	6206	1355
6.b	15	15	0	0	0
7.a	5	5	0	0	0
7.b	20281	20281	15	2261	622
7.c	191	191	1	51	25
7.d	5637	5637	0	0	0
7.e	8652	8652	55	3278	252
7.f	260	260	0	0	0
7.g	37	37	0	0	0
7.h	7	7	0	0	0
7.j	13629	13629	5	383	135
7.k	1	1	0	0	0
8.a	2688	2688	0	0	0
8.b	4727	4727	185	5150	389
8.c	24128	24128	47	428	639
8.c.E	11328	11328	316	24466	704

Division	Official Catch (t)	WG Catch (t)	No. Samples	No. Measured	No Aged
8.d	754	754	0	0	0
9.a	2070	2070	176	3106	1586
9.b	2	2	0	0	0
12.c	6	6	0	0	0

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

8.4 Catch Data

8.4.1 ICES Catch Estimates

In 2021 the catch data time series was revised due to additional catch data reported from Division 8.c and the removal of logbook discard data from the working group catch. The led to new working group catch figures as well as a revised catch numbers at age and mean weights at age time series from 2010-2019.

The additional catch in Division 8.c was unsampled. Division 8.c was well sampled by other countries and these samples were allocated to the unsampled catch. For most years and ages, the differences between the previous and the revised catch numbers at age is less than 1 %. For the years and ages when the difference is higher this is due to the proportions at age in the sampled catch.

The logbook discard data reported in 2018 and 2019 were submitted from countries that also submitted discard data from observer programmes. It is not known if logbook registered discards are consistently recorded because the reporting of this data is not mandatory and there is a possibility of double counting. It was therefore decided to remove the logbook registered discards and only use the estimates from observer programme. Again, the differences in the previous estimates and the revised estimates was very small. The highest difference was for ages 0 and 1 in 2018 and this was because of the proportions at age in the discard samples that were used in allocations.

The total ICES estimated catch for 2020 was 1 039 513 an increase of 199 786 t on the estimated catch in 2019. Catches increased substantially from 2006—2010 and have averaged 1 040 kt since 2011.

The combined 2020 TAC, arising from agreements and autonomous quotas, amounts to 1 090 879 t. The ICES catch estimate (1 039 513 t) represents an undershoot of this but is still above the ICES advice of 992 064 t. The combined fishable TAC for 2021, as best ascertained by the Working Group (see Section 8.1), amounts to 1 199 103 t.

Catches reported for 2020 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.

The text table below gives a brief overview of the basis for the ICES catch estimates.

Country	Official Log Book	Other Sources	Discard Information
Denmark	Y (landings)	Y (sale slips)	Y
Faroe[1]	Y (catches)	Y (coast guard)	NA
France	Y (landings)		Y
Germany	Y (landings)		Y
Greenland	Y (catches)	Y (sale slips)	Y
Iceland[1]	Y (landings)		NA
Ireland	Y (landings)		Y
Netherlands	Y (landings)	Y	Y
Norway[1]	Y (catches)		NA
Portugal		Y (sale slips)	Y
Russia[1]	Y (catches)		NA
Spain	Y	Y	Y
Sweden	Y (landings)		Y
UK	Y (landings)	Y	Y

[1]For these nations a discarding ban is in place such that official landings are considered to be equal to catches.

The Working Group considers that the estimates of catch are likely to be an underestimate for the following reasons:

- Estimates of discarding or slipping are either not available or incomplete for most countries. Anecdotal evidence suggests that discarding and slipping can occur for a number of reasons including high-grading (larger fish attract a premium price), lack of quota, storage or processing capacity and when mackerel is taken as by-catch.
- Confidential information suggests substantial under-reported landings for which numerical information is not available for most countries. A study carried out in 2010 indicated considerable uncertainty in true catch figures (Simmonds *et al.*, 2010) for the period studied.
- Estimates of the magnitude and precision of unaccounted mortality suggests that, on average for the period prior to 2007, total catch related removals were equivalent to 1.7 to 3.6 times the reported catch (Simmonds *et al.*, 2010).
- Reliance on logbook data from EU countries implies (even with 100 % compliance) a precision of recorded landings of 89 % from 2004 and 82 % previous to this (Council Regulation (EC) Nos. 2807/83 & 2287/2003). Given that over reporting of mackerel landings is unlikely for economic reasons; the WG considers that the reported landings may be an underestimate of up to 18 % (11 % from 2004), based on logbook figures. Where inspections were not carried out there is a possibility of a 56 % under reporting, without there being an obvious illegal record in the logsheets. Without information on the percentage of the landings inspected it is not possible for the Working Group to evaluate the underestimate in its figures due to this technicality.

- The accuracy of logbooks from countries outside the EU has not been evaluated by WGWIDE. Monitoring of logbook records is the responsibility of the national control and enforcement agencies.

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 2020, discard data for mackerel were provided by France, Ireland, Spain, Portugal, Denmark, England, Scotland and Sweden. Total discards amounted to 9 280 t which is an increase from 2019. Higher discards were reported by UK England and Wales mainly from one fleet. 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.

Age-disaggregated discard data was limited in 2020 due to reduced sampling opportunities as a result of COVID but data available indicates that, in Division 8.b the majority of discarded fish were aged 0 to 3. In Divisions 8.c and 9.a, the majority of the discarded fish were 0 group.

Discarding of small mackerel has historically been a major problem in the mackerel fishery and was largely responsible for the introduction of the south-west mackerel box. In the years prior to 1994, there was evidence of large-scale discarding and slipping of small mackerel in the fisheries in Division 2.a and Subarea 4, mainly because of the very high prices paid for larger mackerel (> 600 g) for the Japanese market. This factor was put forward as a possible reason for the very low abundance of the 1991 year-class in the 1993 catches. Anecdotal evidence from the fleet suggests that since 1994, discarding/slipping has been reduced in these areas.

In some of the horse mackerel directed fisheries, *e.g.,* those in Subareas 6 and 7, mackerel is taken as by-catch. Reports from these fisheries have suggested that discarding may be significant because of the low mackerel quota relative to the high horse mackerel quota, particularly in those fisheries carried out by freezer trawlers in the fourth quarter. The level of discards is greatly influenced by the market price and by quotas.

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. Of the total catch in 2020, Norway accounted for the greatest proportion (20 %) followed by Scotland (16 %), Iceland (15 %), Russia (12 %), Ireland (7 %) and Faroes (7 %). In the absence of an international agreement, Greenland, Iceland and Russia declared unilateral quotas in 2020. Russia and Iceland both had catches over 100 kt with Faroes catching 69 kt. Greenlandic catches decreased again from 30 kt to 27 kt. Scotland had catch in excess of 100 kt and Ireland caught 74 kt. Denmark had catches of around 35 kt. The Netherlands and Spain caught around 30 and 34 kt, respectively while UK England had increased catches in 2020 to 30 kt. German catch also increased to 25 kt. France had catches of the order of 22 kt.

In 2020, catches in the northern areas (Subareas 1, 2, 5, 14) amounted to 356 985 t (see Table 8.4.2.1), an increase of 11 966 t on the 2019 catch. Icelandic, Norwegian and Russian catches were all over 100 kt. Catches from Division 2.a accounted for 30 % of the total catch in 2020, similar to 2019. Almost all the Russian catch in 2020 was taken in Division 2.a. 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 2020 amounted to 457 211 t and represents a significant increase of 149 164 t from the 2019 catch figure (308 047 t). 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) increased in 2020 to 187 788 t. This is an increase of around 26 000 t from 2019. 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 of 37 529 t represents an increase of almost 13 000 t from 2019. 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
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

Year	Q1	Q2	Q3	Q4
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

The quarterly distribution of catch from 2010- 2019 is similar to recent years with the northern summer fishery in Q3 accounting for the greatest proportion of the total catch. In 2020 the proportion in quarter 3 is still the highest at 34 % but is similar to the quarter 1 and quarter 4 catches which both account for 31 % of the total.

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.

- First quarter 2020 (322 419 t – 31 %)

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 increased in 2020 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. An increase in catch from 4.a and 7.b Q1 was seen again in 2020. The Spanish fisheries also take significant catches along the north coast of Spain during the first quarter.

- Second quarter 2020 (43 011 t – 4 %)

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 2020. 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 2020 (356 006 t – 34 %)

Figure 8.4.2.3 shows the distribution of the quarter 3 catches. Large catches were taken throughout Divisions 2.a (Russian, Norwegian and Faroese vessels), 4.a (Norwegian, Scottish vessels), 5.a (Icelandic vessels).

- Fourth quarter 2020 (318 077 t – 31 %)

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 increased from 26 % in 2019 to 31 % in 2020. The summer fishery in northern waters has largely finished with very small catches reported from Division 2.a. The largest catches are taken by Norway and Scotland around the Shetland Isles.

ICES cannot split the reported mackerel catches into different stock components because there is no clear distinction between components upon which a split could be determined. Mackerel with a preference for spawning in the northeast area, including the North Sea, cannot presently be identified morphometrically or genetically (Jansen and Gislason, 2013). Separation based on time and area of the catch is not a precise way of splitting mackerel with different spawning preferences, because of the mixing and migration dynamics including inter-annual (and possibly seasonal) variation of the spawning location, combined with the post-spawning immigration of mackerel from the south-west where spawning ends earlier than in the North Sea.

8.4.3 Catch-at-Age

This catch in numbers relates to a total ICES estimated catch of 1 039 513 t. 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, Russia, Scotland, Northern Ireland and Spain. There remain gaps in the age sampling of catches, notably from France (length samples were provided), 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 80 % of the catch in numbers in 2020 consists of 3 to 10-year olds with all year classes between 2010 and 2014 contributing over 10 % to the total catch by number. The 2016 year-class was strong in the fishery in 2020 and accounts for 11 % of the catch numbers at age. The 2015 year-class does not look as strong as the other year and represents 5 % of the total. In 2020 there is an increase in the proportion of fish in the plus group. Fish at 12+ represent 7 % of the total which is an increase from 3 % in 2019.

There is a small presence of juvenile (age 0) fish within the 2020 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 2020 are 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 2020 for 0 group mackerel (177 mm – 266 mm) is similar to 2019 (172 mm-267 mm) and higher than those in 2018 (162 mm-254 mm) and 2017 (131 mm-212 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 2020 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 six 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 2019 egg survey for the southern and western components and the 2017 egg survey for the North Sea component). Mean weight-at-age in 2020 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, coming 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 2020 were calculated from samples of the commercial catches collected from Divisions 4.a and 4.b in the second quarter of 2020. Stock weights for the southern component, are based on samples from the Spanish catch taken in Divisions 8.c and 9.a in the 2nd quarter of the year. The mean weights in the three component and in the stock in 2020 are shown in the text table below.

As for the catch 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 7 years do not show any specific trend (except for weights of ages 2 to 5 which have been increasing, Figure 8.5.2.2).

Age	North Sea Component	Western Component	Southern Component	NEA Mackerel 2020 Weighted mean*
0				0.000
1	0.128			0.068
2	0.248	0.204	0.213	0.210
3	0.284	0.230	0.306	0.252
4	0.353	0.266	0.334	0.289
5	0.346	0.347	0.352	0.348
6	0.380	0.360	0.365	0.363
7	0.365	0.376	0.377	0.375
8	0.424	0.389	0.400	0.394
9	0.431	0.394	0.406	0.400

Age	North Sea Component	Western Component	Southern Component	NEA Mackerel 2020 Weighted mean*
10	0.454	0.416	0.433	0.423
11	0.468	0.454	0.412	0.445
12+	0.482	0.481		0.486
Component Weighting	8.5 %	67.9 %	23.6 %	
Number of fish sampled	206	856	1897	

*** 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 2020 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 2020 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	0.000
1	0	0.129	0.02	0.092
2	0.37	0.385	0.54	0.420
3	1	0.971	0.70	0.909
4	1	0.997	1	0.998
5	1	1	1	1.000
6	1	0.999	1	0.999
7	1	0.999	1	0.999
8	1	1	1	1.000
9	1	1	1	1.000
10	1	1	1	1.000
11	1	1	1	1.000

Age	North Sea Component	Western Component	Southern Component	NEA Mackerel
12+	1	1	1	1.000
Component Weighting	8.5 %	68.1 %	23.4 %	

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 in 2020 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

8.6.1.1 Survey Planning for the 2022 Northeast Atlantic survey

The last mackerel egg survey (MEGS, I4189) was carried out in the NEA mackerel spawning areas in 2019 and a presentation with the final results were given during the WGWIDE meeting by the survey coordinator in 2020 (ICES, 2020a).

The ICES Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS) met in an online meeting in April 2021 to plan the international mackerel and horse mackerel egg survey in 2022. The nations participating in the 2022 MEGS survey will be Portugal, Spain, Scotland, Ireland, The Netherlands, Germany, Norway and the Faroe Islands.

In 2022, the MEGS survey in the western and southern areas for mackerel will continue as an Annual Egg Production Method (AEPM) survey; however, as with the surveys in 2013, 2016 and 2019, the intention will be to also carry out intensive Daily Egg Production Method (DEPM) adults sampling during the expected peak spawning period, in an attempt to calculate a DEPM SSB estimate.

WGMEGS considered a proposal to move the timing of the North Sea survey to the same year as the western surveys. If approved this survey would now be conducted by Denmark and England in 2022. Their participation would not lead to any reduction of available effort for the western surveys in 2022. This North Sea survey will be conducted as a DEPM survey (ICES, 2021).

The provisional survey plan of the 2022 mackerel and horse mackerel egg survey in the western and southern areas, as agreed during last the WGMEGS meeting (ICES, 2021), is presented in Table 8.6.1.1.1.

In preparation for the 2022 survey a workshop on Mackerel, Horse Mackerel and Hake Egg Identification and Staging (WKMACHIS) will take place during October 2021 and a Workshop on Adult Egg Production Methods Parameters estimation in mackerel and horse mackerel (WKAEPM) will be held in November 2021.

8.6.1.2 Changing from the Annual to Daily Egg Production Method.

From the start in 1977, WGMEGS has used the AEPM for estimation of NEA mackerel SSB (Lockwood *et al*. 1981; Lockwood, 1988) under the assumption that mackerel has a determinate fecundity. These surveys are carried out triennially.

The key concept for egg production method is very simple; if we know how many eggs have been spawned over a period of time (e.g., daily or annually) in the spawning area (egg production), and we know how many eggs an average individual mature female can produce over the same period (fecundity), then we can estimate the size of the spawning population (Bernal *et al.*, 2012).

There are two primary egg production methods (Gunderson, 1993; Hunter and Lo, 1993), namely the AEPM and the DEPM. The first method is designed for species with a determinate fecundity, i.e., those in which all the eggs to be spawned during the year are present and identifiable in the ovary immediately prior to spawning. With the AEPM, estimated total egg production is integrated over the whole annual spawning season and how many eggs are produced on average by female in the year (Costas *et al.*, WD04 in Annex 05). Whereas the application of AEPM is suitable for determinate annual spawners, the DEPM can in principle be applied to indeterminate and determinate spawners.

The AEPM requires several ichthyoplankton surveys covering the whole spawning season and spawning area to estimate total annual egg production and sampling of pre-spawning adults to estimate annual potential fecundity. (Armstrong *et al.*, 2012). Species with determinate fecundity have as an assumption that the fecundity is fixed before the onset of spawning (Hunter *et al.*, 1992).

The DEPM can be used for species with an indeterminate fecundity, in which the potential fecundity is not fixed before the onset of spawning (Stratoudakis *et al.*, 2006) and oocytes are recruited over the spawning season. The DEPM requires a single ichthyoplankton survey covering the entire spawning area during a brief period at or near the annual peak of spawning to estimate the mean daily egg production and to have representative samples of spawning adults during this survey period to estimate the mean daily fecundity (Parker, 1980; Stratoudakis *et al.*, 2006). Accordingly, the DEPM provides a snapshot rather than an integrated view of the spawning season as the AEPM (Stratoudakis *et al.*, 2006).

The main difference of the DEPM in relation to the AEPM method resides on the appropriate measure of fecundity, (Stratoudakis *et al.*, 2006, Bernal *et al.*, 2012).

In 2012, WGMEGS coordinated the Workshop on Survey Design and Mackerel and Horse Mackerel Spawning Strategy (ICES, 2012) as there are some indications that mackerel would be rather an indeterminate spawner and the DEPM might be more appropriate (Armstrong and Witthames, 2012). This workshop recommended that extra adult samples should be collected on surveys to investigate the estimation of DEPM adult parameters, and to attempt a contrast between AEPM and DEPM results.

During its 2018 WGMEGS meeting, after assessing the quality of the 2017 North Sea survey results, it was decided to consider utilizing DEPM for this survey, starting in 2020 (Costas *et al.*, WD04 in Annex 05). Utilizing DEPM for the North Sea mackerel egg survey would have the advantage of requiring only one full coverage of the spawning area over a shorter time period (ICES, 2018b).

For the western and southern areas WGMEGS continues the use of the AEPM for mackerel.

8.6.1.3 2021 North Sea mackerel egg survey

The North Sea Mackerel Egg Survey (NSMEGS, I1582) is designed to estimate the spawning stock biomass (SSB) of mackerel of the North Sea spawning component of the Northeast-Atlantic stock on a triennial basis. Prior to 2017 this survey was done utilizing the AEPM. In the 2018 WGMEGS meeting, it was agreed to switch to the DEPM for the NSMEGS in 2020 (ICES, 2018b). However, due to the pandemic and the implementation of Covid-19 measures, the survey has to be postponed to 2021 (van Damme *et al.*, WD01).The NSMEGS was carried out from 25th May to 12th June by The Netherlands, Denmark and Scotland. During this period the spawning area between 53ºN and 62ºN in the North Sea was covered by a total of 294 plankton stations and 22 pelagic trawl hauls were performed for the collection of mackerel adult and ichthyoplankton samples (Figure 8.6.1.3.1).

The spatial egg production distribution is shown in Figure 8.6.1.3.2. The mean Daily egg production was calculated for the total investigated area (Table 8.6.1.3.1).

The Netherlands sampled 524 mackerel during the survey and collected ovary samples of 164 females. Denmark sampled 817 mackerel during the survey and collected ovary samples of 119 females. The adult parameters are still very preliminary and without adult parameters the SSB cannot be estimated. When final fecundity parameter estimates are available and agreed by WGMEGS, an estimate of SSB will be provided to WGWIDE.

8.6.1.4 Results of the 2021 Exploratory Egg Survey in the Norwegian Sea.

Since 2007 WGMEGS has been observing and reporting on the offshore westwards and northwards expansion of NEA mackerel spawning. Initially spawning densities within these expanded areas were low, however the results from the most recent MEGS surveys in 2016 and 2019 provided clear evidence of a significant and unprecedented shift north and also westwards with some of the highest spawning densities observed being very close to the northern and north-western survey boundaries. During the last NEA mackerel benchmark in 2017 (ICES, 2017b) WGMEGS committed to undertake exploratory ichthyoplankton surveys within these remote boundary regions in the North and Northwest.

In 2017 and 2018 exploratory surveys undertaken by Ireland and Scotland as well as additional samples collected using existing Nordic surveys successfully mapped and delineated a mackerel spawning boundary within the North and northwest areas of Hatton Bank/South Iceland Basin and the Scotland-Faroe-Iceland Ridge (ICES, 2018b). The results and knowledge gleaned, informed the survey planning process ahead of the 2019 MEGS triennial survey but left the Norwegian Sea as an area that still provided a level of uncertainty and with the 2019 MEGS survey results providing evidence that mackerel appeared to be taking the North-eastern route towards their summer feeding grounds (Figure 8.6.1.4.1). A third and final exploratory survey was completed between the 7th – 22nd June 2021, (Burns and O' Hea, WD 15 in Annex 05) using the charter vessel Altaire. This would conclude the exploratory objective by surveying mackerel spawning activity up and along the Norwegian Sea and during the month when the highest mackerel spawning densities were likely to be encountered within this region. Additionally, 3 survey transects were also undertaken within the Northern North Sea area extending the survey's geographical footprint up to nearly 62N.

78 plankton deployments were completed with the Gulf VII sampler during the survey, which due to the relatively calm conditions experienced throughout was able to survey as far North as Lofoten at 68.25N. 5123 mackerel eggs of all stages were recorded during the survey, of which 1671 were recently spawned stage 1 eggs. Mackerel eggs were recorded from every deployment with stage 1 eggs being recorded on all but 2 of the stations completed. The numbers of mackerel eggs extracted from the Gulf VII samples were standardised and the stage 1 data presented as numbers /m^2/day (Figure 8.6.1.4.2). Egg counts recorded during the survey area were generally low with the highest egg counts generally being reported within the southern half (south of 66N) of the survey area. Densities reduced gradually with increasing latitude until down to single figures on transects West of Lofoten as even surface temperatures approached the temperature threshold for spawning mackerel at between 8 – 9 degrees Celsius. 2 successful deployments were completed with the vessels own midwater trawl providing 123 adult mackerel which were sampled for biological parameters and in addition 60 ovaries were also collected to progress ongoing research for IMR, Bergen.

Additional complementary plankton samples were collected by the Faeroe Islands during the IESNS survey during May 2021 and within the region extending from the east side of Iceland across to the north of Faroe and Shetland. These samples were collected using a vertically deployed WP2 net that is lowered to a depth of 50m. These samples have yet to be analysed but the results will be available prior to WGMEGS in 2022 and incorporated into the WG report.

The exploratory survey was unable to find a hard spawning boundary at its Northern extent albeit the numbers being encountered were very low at those high latitudes. This survey contrasted markedly with the previous exploratory surveys undertaken during 2017 and 2018 where the results reaffirmed the existence of the cold water barrier stretching from the East coast of Iceland across to the Faroe/Shetland channel and above which virtually no mackerel spawning takes place in June. The situation up and along the Norwegian Sea is very different with the influence of the Norwegian Current keeping sea surface temperatures (even at those high latitudes) well within a range that is tolerable for spawning mackerel. Nevertheless, the spawning levels observed in the sampled stations North of 62 degrees are overall very low with an estimated contribution to the overall total annual egg production (TAEP) of around 2-3%. Looking ahead to the 2022 survey, WGMEGS therefore does not identify any immediate requirement to significantly extend the survey coverage in this region much beyond what was undertaken in 2019. All the information gathered from these exploratory egg surveys as well as the additional samples received from the various Nordic surveys since 2017 have proved to be invaluable and provide an opportunity not available during the triennial survey year to map the distribution of spawning mackerel within these remote northern boundary regions ahead of the triennial survey in 2022.

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

The data and the model

An index of survivors in the first autumn-winter (recruitment index) was 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 were compiled from several bottom trawl surveys conducted between October and March from 1998—2021 by research institutes in Denmark, England, France, Germany, Ireland, Netherlands, Norway, Scotland and Sweden. Surveys conducted on the European shelf in the first and fourth quarters are collectively known as the International Bottom Trawl Survey (IBTS), although several of the surveys use different names. All surveys sample the fish community on the continental shelf and upper shelf slope. IBTS Q4 covers the shelf from the Bay of Biscay to North of Scotland, excluding the North Sea, while IBTS Q1 covers the shelf waters from north of Ireland, around Scotland, the North Sea, Skagerrak and Kattegat.

Trawl operations during the IBTS have largely been standardized through the relevant ICES working group (ICES, 2013). Furthermore, the effects of variation in wing-spread and trawl speed were included in the model (Jansen *et al*., 2015). Trawling speed was generally 3.5—4.0 knots, and trawl gear is also standardized and collectively known as the Grande Ouverture Verticale (GOV) trawl. Some countries use modified trawl gear to suit the particular conditions in the respective survey areas, although this was not expected to change catchability significantly. However, in other cases, the trawl design deviated more significantly from the standard GOV type, namely the Spanish BAKA trawl, the French GOV trawl, and the Irish mini-GOV trawl. The BAKA trawl had a vertical opening of only 2.1—2.2 m and was towed at only 3 knots. This was considered substantially less suitable for catching juvenile mackerel and, therefore, was excluded from the analysis. The French GOV trawl was rigged without a kite and typically had a reduced vertical opening, which may have reduced the catchability of pelagic species like mackerel. Catchability was assumed to equal the catchability of the standard GOV trawl because testing has shown that the recruitment index was not very sensitive to this assumption (Jansen *et al*., 2015). Finally, the Irish mini-GOV trawl, used during 1998—2002, was a GOV trawl in reduced dimensions which was accounted for by inclusion of the wing-spread parameter in the model.

All surveys in 2020 Q4 and 2021 Q1 were conducted according to standards. Figure 8.6.2.1 provides an overview of the distribution and number of samples.

A geostatistical log-Gaussian Cox process model (LGC) with spatiotemporal correlations was used to estimate the catch rates of mackerel recruits through space and time.

Results

The index of survivors in the first autumn-winter (recruitment index) was updated with data from surveys in 2020 Q4 and 2021 Q1. Parameter estimates and standard errors in the final model are listed in Table 8.6.2.1. An overview of the IBTS survey is given in Figure 8.6.2.1. The modelled average recruitment index (squared CPUE) surfaces were mapped in Figure 8.6.2.2a and b. The time series of spatially integrated recruitment index values is used in the assessment as a relative abundance index of mackerel at age 0 (recruits). All annual index values were estimated to be slightly higher than during the previous model fit (IBPNeaMAC: ICES, 2019), but with the same interannual pattern ($p < 0.001$, $r > 0.99$). This increase does not affect the stock assessment because it is used in the assessment as a relative abundance index. The estimated index value for the 2020 year-class is above average (Figure 8.6.2.3).

Discussion

The combined demersal surveys have incomplete spatial coverage in some areas that can be important for the estimation of age-0 mackerel abundance, namely: (i) Since 2011, the English survey (covering the Irish sea and the central-eastern part of the Celtic sea including the area around Cornwall) has been discontinued, (ii) the Scottish survey has not consistently covered the area around Donegal Bay, (iii) the IBTS has observed high catch rates in some years at the north-eastern edge of the survey area (towards the Norwegian trench) in winter. It is therefore possible that some recruits are also overwintering on the other side of the trench along the south western shelf edge of Norway. Consequently, the NS-IBTS in Q1 should be extended to include the south-western Norwegian shelf and shelf edge in proximity to the Norwegian trench.

Finally, WGWIDE encourages studies of vertical distribution and catchability of age-0 mackerel in the Q4 and Q1 surveys, to evaluate if it is comparable in all areas (see acoustic information in Jansen *et al*., 2015).

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. In 2021, survey coverage in the western area was reduced as Greenlandic waters, Iceland basin (south of latitude 62°45′) and the Reykjanes ridge (south of latitude 62°45′) were not surveyed. Coverage reduction did no impact quality of the survey as zero mackerel boundary was established north, west, and south of Iceland. The survey was successfully conducted in 2021. IESSNS cruise report is available as a working document to this report and a detailed survey description is available in the mackerel Stock Annex.

Abundance estimates by age are displayed in input data for the assessment (Table 8.7.1.9), survey estimates of total stock abundance and stock biomass with confidence intervals in Figures 8.6.3.1-2, internal consistency of mackerel abundance from 2012 to 2021 is displayed in Figure 8.6.3.3 and catch curves abundance at age from 2010 to 2021 in Figure 8.6.3.4. Estimated total stock abundance and total biomass declined 53 % and 58 % respectively compared to 2020. Abundance declined for all cohorts age 3+ but the decline was greater for age 5+. Internal consistency declined compared to 2020, particularly for ages 5 – 8 years. This is a sudden and unexpected decline in mackerel abundance compared to 2019-2020 but when compared to 2018 it is 28 % lower. Further analysis of the IESSNS time series is needed to evaluate if the survey index is an overestimate in 2019-2020 or an underestimate in 2018 and 2021. The sudden drop in abundance is reflected in declining internal consistency and drop in catch curves. Bootstrap estimation of abundance by age displayed in Figure 8.6.3.5. Swept area trawl catch and mean catch rate for 2021 is displayed in Figure 8.6.3.6 and mean mackerel catch rate per rectangle for years 2010 and from 2012 to 2021 in Figure 8.6.3.7.

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, WD06 in Annex 05). 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 automatic data processes with recaptures from scanned landings at factories in Norway, Scotland and Iceland now being updated real time in an IMR data base over internet.

The data format is the same for both tag types; a table showing 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 new 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, 2019) 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 (Slotte and Hølleland, WD06 in Annex 05). 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 based on the fact that 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 WGWIDE2021 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 WGWIDE2021 from release years 2013 onwards (Figure 8.6.4.5). Especially the marked decrease in SSB from 2017-2019 seem to follow the decline in the RFID biomass estimates, which may explain why leave out RFID runs from WGWIDE2021 tends to lift the SSB upwards. The signals of total mortality rate (Z) in fully mature fish aged 4-12 for year classes 2003-2014 tends to be higher in the RFID data than in the catch data tightly overlapping with Z signals in the final WGWIDE2021 assessment, whereas for the international trawl survey IESSNS the estimated Z is even lower (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 combined survey in May during the International Ecosystem survey in the Norwegian Sea (IESNS) targeting herring and blue whiting (Salthaug *et al*. 2019; 2020). The spatial distribution pattern of mackerel was quite similar in 2020 compared to 2019 Salthaug *et al*., 2019). Mackerel was caught within a more expended area and in more trawl stations of the Norwegian Sea in May 2020 compared to May 2019 (Salthaug *et al*., 2019; 2020). In 2020, the northernmost mackerel catch was at 69°N and the westernmost catch was around 4°W, which is further north and west than recorded in 2019 (Salthaug *et al*. 2019; 2020). Mackerel of age 4 dominated, followed by age 6 in 2020, whereas there was found more 1-year olds compared to last year, particularly in the north (Salthaug *et al*., 2020). Mackerel was present in the southern and eastern part of the Norwegian Sea (as far north as 68°N) in the beginning of May 2021.

The IESNS survey provides valuable, although limited, quantitative information on mackerel. This acoustic based survey is not designed to monitor mackerel, and does not provide proper mackerel sampling in the vertical dimension and involves too low trawl speed for representative sampling of all size groups of mackerel. The trawl hauls are mainly targeting acoustic registrations of herring and blue whiting during the survey in May (IESNS) (Salthaug *et al*., 2019, 2020, WD14 in Annex 05). Therefore, no further quantitative information can be drawn from these data as this survey is not designed to monitor mackerel.

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 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 2021

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 fitted to catch-at-age data for ages 0 to 12 (plus group) for the period 1980 to 2020 (with a strong down-weighting of the catches for the period 1980-1999) and three surveys: 1) the SSB estimates from the triennial Mackerel Egg survey (every three years in the period 1992-2019); 2) the recruitment index from the western Europe bottom trawl IBTS Q1 and Q4 surveys (1998-2020); and 3) the abundance estimates for ages 3 to 11 from the IESSNS survey (2010, 2012-2021). 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 2020 (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:

- Update of the recruitment index until 2020.
- Addition of the 2021 survey data in the IESSNS indices.
- Addition of the 2020 catch-at-age, weights-at-age in the catch and in the stock and maturity ogive, proportions of natural and fishing mortality occurring before spawning.
- Update of the catch-at-age and mean-weight-at-age in the catch for the period 2010-2019 (see Section 8.4.3).
- The inclusion of the tag recaptures from 2020.

Input parameters and configurations are summarized in Table 8.7.1.1. The input data are given in Tables 8.7.1.2 to 8.7.1.9. Given the size of the tagging 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 the catches. The IESSNS age 3 is very poorly fitted 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 1.22, larger than 1, which implies that the assessment considers the egg survey index to be an overestimate. The catchabilities at age for the IESSNS increase from 0.81 for age 3 to 1.95 for age 7 and 9. Since the IESSNS index is expressed as fish abundance, this also means that the assessment considers the IESSNS to provide over-estimated abundance values for the oldest ages. The post tagging mortality estimate is higher for the steel tags (around 40 %) than for the RFID tags (around 15 %).

The process error standard deviation (ages 1-11) is moderate as well as the standard deviation 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 have a slightly higher standard deviation, except for the catchability of the IESSNS at age 3 which has a much higher standard deviation. 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 on the assessment (Figure 8.7.2.2). Uncertainty on the overdispersion of the RFID 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=0.77), then 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 reflects 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.

Residuals

The "one step ahead" (uncorrelated) residuals for the catches did not show any temporal pattern (Figure 8.7.2.5) except for 2014 for which they were mainly positive for 2014 (modelled catches lower than the observed ones). This may result from the random walk that constraints the variations of the fishing mortality, which prevents the model from increasing the fishing mortality suddenly (which probably happened given the sharp increase in the catches in 2014). 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. Residuals for the 2020 catches-at-age show that the model was not able to fully reproduce the strong increase in the catches of fish of age 9 and older although the estimated fishing mortality on the older fish has increased substantially 2020 (see results in section below).

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 in 2016 and 2019. This pattern reflects the fact that the model, based on all the information available, does not follow the recent trend present in the egg survey (with an historical low estimate for 2019) and considers those two last years as large negative observation errors. The relatively high observation variance for this survey indicates a poor fit with the egg survey due mainly to these two observations which point towards a very different direction from the other observations. Residuals for the IESSNS indices are relatively well balanced for most of the years, except for the 2019 and 2020 index, where residuals tend to be mainly positive. Despite the strong drop in the abundances at age in 2021, the residuals for this year do not indicate any year effect (e.g., no large residuals of the same sign observed across ages) . Residuals to the recruitment index show no particular pattern, and appear to be relatively randomly distributed in the earlier years, but positive residuals are consistently observed over the last 5 years, indicating that the model has difficulties agreeing with this sustain period of high values in the index.

Finally, inspection of the residuals for the tag recaptures (Figure 8.7.2.6) 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 the respective impact of the different surveys on the estimated stock trajectories, the assessment was run leaving out successively each of the data sources (Figure 8.7.2.7).

All leave one out runs showed parallel trajectories in SSB and Fbar, except the one leaving out the RFID tag information, which shows a less steep decline in SSB since 2014, and continued decline in Fbar in the most recent years. For recruitment, all runs also resulted in similar trajectories, expect the run without the recruitment index, which recruitment decreased from high levels in the mid-2010s to historical low levels currently.

Removing the IESSNS resulted in lower SSB estimates and higher Fbar estimates for the period covered by the survey. Removing the recruitment index had a similar effect on SSB and Fbar. On the opposite, removing the egg survey results in a larger estimated stock, exploited with a lower fishing mortality. In both cases, the estimated stock trajectories are well within the confidence interval of the assessment using all data sources. As in previous years, the update assessment seems to make a trade-off between the information coming from the IESSNS which leads to a more optimistic perception of the stock, and the information from the egg survey which suggests a more pessimistic perception of the stock. The run leaving out the RFID also resulted in a higher SSB than in the assessment using all data, and a slightly higher fishing mortality between 2007 and 2014, but higher after 2016. The magnitude of the effect of removing the RFID data is similar to removing other surveys. This is a contrasting situation compared to the 2020 WGWIDE assessment, in which the RFID had a very small influence on the assessment (no effect on estimated stock trajectory, slightly reduced uncertainty when RFID data are included). This indicates that the influence of the RFID data compared to other data sources has increased this year. This point is further discussed below in a section presenting additional exploratory runs (Section 8.7.5.2.).

Additional sensitivity runs

A series of additional sensitivity runs were done to identify the cause of the change in stock trajectories in the 2021 WGWIDE assessment compared to previous years assessment (see Section 8.10 for a description of this revision).

First, the influence of revisions in the historical data (catch-at-age and mean weight-at-age in the catch for the years 2010-2019) was tested by running the assessment using last year's data for 2010-2019, but keeping the new 2020. This run was almost identical to the WGWIDE 2021 update assessment (not presented here).

Then, the influence of the data added in 2021 was tested by running the model removing separately each of the new data added in 2021 (2020 catch-at-age, 2020 recruitment index, 2020 RFID recaptures and 2021 IESSNS index). The two model runs excluding the 2020 recruitment index and the 2021 IESSNS are very similar to the current assessment and are not shown on Figure 8.7.2.8.

The exclusion of the 2020 RFID data leads to larger SSB and lower Fbar estimates over the most recent years (2019-2020). The information from the 2020 recaptures indicate that abundance has declined in 2019 for the third year in a raw. Adding this information to the assessment therefore leads to the reduction of stock abundances, and hence SSB.

The 2020 catch-at-age also seem to have a strong influence on the assessment. Excluding this information leads to stock trajectories very similar to those from the WGWIDE2020 assessment. The stock trajectories are revised over almost a decade (since about 2009), with lower SSB and higher Fbar estimated when the 2020 catches are not used. The data for 2020 are characterised by a sharp increase in the catches for the older fish (age 9 and older, including the plus group) compared to 2019. No particular changes in fishing patterns for the fleets have been reported and the reason for this increase is not fully understood. Given the low observation variance for the catch-at-age 2 and older, the SAM model follows tightly this increase in the catches of 9+ fish in 2020. The fit to these higher catches can be achieved partly by increasing the fishing mortality on the older age. However, the extend by which fishing mortality-at-age can increase in a year is limited by the amplitude of the random walk, and the variance of these processes is rather low for the mackerel assessment (Table 8.7.2.1). In addition, to be able to fit these higher catches, the model estimated relatively large abundances for old fish in 2020, which seems to have caused an upward revision of the abundance of these cohorts as far back in time as 2014 (based on the comparison of abundance-at-age from last year’s and this year’s assessment, no shown). This upward revision for abundance-at-age explains the downwards revision of fishing mortality at age. Last year’s assessment (WGWIDE 2020; ICES, 2020a) was also quite sensitive to addition of a latest year of catch data (analysis done this year and hence not presented in the previous report) but the sensitivity is larger this year, probably due to the unexpected catches of old fish.

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 5.55 million tonnes in 2014 and 2015 and subsequently declined to reach a level just above 3.87 million tonnes in 2019 and increase slightly in 2020 to 3.94 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 well below F_{MSY} (0.26) since 2015 and increased to just under F_{MSY} in 2020. The recruitment time series from the assessment is not considered a reliable indicator of year-class strength (see Section 8.7.5.1).

There is some indication of changes in the selectivity of the fishery over the last 30 years (Figure 8.7.3.2.). In the years 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 pattern became less steep (decreasing selection on the ages2-5). After 2008, the pattern changed again towards a steeper selection pattern.

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 2020 is estimated with a precision of +/- 24 % (Figure 8.7.3.1 and Table 8.7.3.1). There is generally also a corresponding large uncertainty on the fishing mortality, especially before 1995. The estimate of F_{bar4-8} in 2020 has a precision of +/- 25 %.

Model instability

The retrospective analysis was carried out for 7 retro years, (or peels) by fitting the assessment using the 2021 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 -3 to current year -7) with a systematic downwards revision. However, this pattern is not apparent in the most recent peels, and the Mohn's rho value of the last 5 years is of 0.16. There is no retrospective pattern in the SSB and the value of the Mohn's rho on SSB for the last 5 peels if low (-0.03). Recruitment appears to be quite consistently estimated for the 6 older retrospective peels, but over the last 2 peels, recruitment has been revised downwards. This is related to the increase in the observation variance for the recruitment index, and corresponding decrease in recruitment random walk variance. Recruitment estimates have progressively become less influenced by the recruitment index (which displays high value in the recent years and revised recent estimates upwards).

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 (Figure 8.7.4.3) shows indications of some pattern across time and ages. There is a predominance of positive deviations in the recent years for age-classes 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 temporarily.

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 globally estimates larger abundances-at-age than corresponding to the survival equation) have been alternating with periods with negative values (1991-1994 and 2004 and 2006). For the years between 2008 and 2017, the biomass cumulated process error remains positive, and large (reaching in 2013 almost the weight of the catches). The reason for this misbehaviour of the model 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 mode 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, there is a greater discrepancy between recruitment at age 0 and at older ages. While the age 0 abundances indicate very high recruitment for the year-classes 2012 to 2018, number 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 age 0 and 2 and 3, exploitation is not likely to explain these changes in 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, processes occurring at the juvenile stage are more likely to dampen the variations in cohorts' size (e.g., density dependent mechanisms) than increasing it. In addition, some cohorts increase in size as they become older (e.g., 2001 and 2002), 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, thanks 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 on year-class strength, and should not be used to make assumption on stock development in the near future. This has implications for the short term forecast done to compute the catch advice, in which last estimated recruitment value (R2020 this year) contributes to around 10 % of the catch and SSB 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 relevant to start the assessment at age 0 or 1. 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 leave the rest of the data and model configuration unchanged).

The estimated parameters had in general similar values in the 2 models (Table 8.7.5.1) with a largest difference of 6 % for the IESSNS catchability at age 3, except for the process variances where large differences are observed. Recruitment variability increases by 246 %, and this is associated to an 80 % decrease on the standard deviation (uncertainty) on this parameter. F random walk variance increase by 24 % (with a 24 % reduction on the standard deviation) and the process error variance is reduced by 16 % (but this a larger standard deviation). The model starting at age 2 therefore gives a similar weight to the different data sources as the current model (same observation variances) but estimates a much more variable recruitment, and slightly more variable fishing mortality.

Both assessments give a very similar perception of the SSB and Fbar trajectories (Figure 8.7.5.2). There is a small different in SSB in the years 2010 and 2011, and in the last year with catch information (2020). Fbar trajectories are very consistent, with slightly larger variations for the assessment starting at age 2. 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 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 broadly agree both in terms of fit to the data and in terms of stock trajectories, and the model starting at age 2 could be considered as potential alternative to the current model at the next benchmark for this stock. The two models however have very different implications regarding advice. While the current model assumes a high 2020 year-class, that will contribute to 10 % in the SSB and catch and advice year (age 2), the alternative model suggests a low 2018 year-class (age 4 in advice year) and average recruitments (geometric mean assumption) for the 2019 and 2020 year classes (age 3 and 2 in advice year).

8.7.5.2 Assessment using tag data as abundance indices

The last inter-benchmark (ICES, 2019) showed that the RFID tagging data had a very high influence on the previous assessment, simply due to the fact that it was a much larger dataset than other survey data (and growing much faster as well). The changes made during this IBP involved filtering out a large part of the RFID dataset (tags recovered after more than 2 years at liberty were excluded due to the suspicion of tag loss). At the time of the IBP, this decreased considerably the weight of the RFID data on the assessment (as measured then by the leave one out run). This year, with 2 additional years of data, the RFID dataset has grown by 28 data points, while the second largest index, the IESSNS, has grown by 18 data point. At the same time, the leave one out run (Figure 8.7.2.7) shows that the influence of the RFID dataset has increased markedly compared to last year. It is unclear whether this increasing influence is due to the RFID data being very informative, and therefore receiving a higher weight, or if it is due to the increase in the number of observations.

In order to investigate this, the SAM model was fitted using the RFID tag data expressed as abundance-at-age indices for the ages 5 to 11 (see Figure 8.6.4.5). In this configuration, the RFID data has a similar number of observations as for the IESSNS survey. The assessment using RFID as indices gives a perception of the stock very similar to the WGWIDE 2021 assessment (Figure 8.7.5.3). There is hardly any difference in the estimated SSB, and Fbar and recruitment are slightly higher. This strong similarity between the assessments using the RFID data as recaptures or as abundance indices indicates that the stronger influence of the RFID seen for the WGWIDE2021 is not likely to be due to the larger increase in number of data points compared to other data sources, but rather to the information contained in the dataset.

8.8 Short term forecast

The short-term forecast provides estimates of SSB and catch in 2022 and 2023, given assumption of the current year's (also called intermediate year) catch and a range of management options for the catch in 2022.

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 (2021) is based on declared quotas and interannual transfers as 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 (2020) 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 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.

The weighting calculated by RCT3 was 76 % (recruitment index) and 24 % (time tapered geometric mean), which leads to an expected recruitment of 5 743 million.

8.8.3 Short term forecast

A deterministic short-term forecast was calculated using FLR (www.flr-project.org). Table 8.8.3.1 lists the input data and Tables 8.8.3.2 and 8.8.3.3 provide projections for various fishing mortality multipliers and catch constraints in 2022.

Assuming catches for 2021 of 1 199 kt, F was estimated at 0.35 (above F_{MSY}) and SSB at 3.51 Mt (above B_{pa}) in spring 2021. If catches in 2022 equal the catch in 2021, F is expected to increase to 0.42 (above F_{pa}) in 2022 with a corresponding decrease in SSB to 3.21 Mt in spring 2022. Assuming an F of 0.42 again in 2023, the SSB will further decrease to 2.89 Mt in spring 2023.

Following the MSY approach, exploitation in 2022 shall be at F_{MSY} (0.26). This is equivalent to catches of 795 kt and a decrease in SSB to 3.31 Mt in spring 2022 (6 % decrease). During the subsequent year, SSB will remain at a similar level (3.27 Mt) in spring 2022.

8.9 Biological Reference Points

A management strategy evaluation Workshop on northeast Atlantic mackerel (MKMSEMAC) was conducted during 2020 (ICES, 2020b) 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 (2020b)
	F_{MSY}	0.26	Stochastic simulations	ICES (2020b)
Precautionary approach	B_{lim}	2.00 million tonnes	B_{loss} in 2003 from the 2019 WGWIDE assessment (ICES, 2019)	ICES (2020b)
	B_{pa}	2.58 million tonnes	B_{lim} x exp(1.645 × σ), with σ_{SSB} = 0.15	ICES (2020b)
	F_{lim}	0.46	F that, on average, leads to B_{lim}	ICES (2020b)
	F_{pa}	0.36	F_{p05} (the F that leads to SSB ≥ Blim with 95 % probability)	ICES (2020b)

8.10 Comparison with previous assessment and forecast

Stock assessment output

The last available assessment used for providing advice was carried out in 2020 during the WGWIDE. The new 2021 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). For the latest year, the differences in the 2019 TSB, SSB and Fbar estimates between the previous and the present assessments are small, of -0.7 %, 3.9 % and -3.6 %, respectively. The 2018 fishing mortality is unchanged (0.2 % difference).

	TSB 2019	SSB 2019	Fbar4-8 2019
Values			
2020 WGWIDE	4 966 328 tonnes	3 731 510 tonnes	0.223
2021 WGWIDE	4 933 409 tonnes	3 876 306 tonnes	0.215
% difference	-0.7 %	3.9 %	-3.6 %

The addition of a new year of data has slightly modified model parameters compared to last year (Figure 8.10.2). The observation standard deviation has decreased for the IESSNS survey, and increased for the egg survey (although changes are very minimal in both cases). The observation standard deviation for the recruitment index increased by a larger proportion. This increase comes with a substantial decrease of the random walk variance for recruitment, and a larger uncertainty on this parameter. The 2021 model fit follows less the recruitment index and, in absence of other source of information on age 0, produces a smoother recruitment time series.

Although the parameters corresponding to the weight of the different data sources on the assessment (observation standard deviations) have not changed, the analyses presented in Section 8.7 indicated that the influence of the RFID time series has increased. In addition, Section 8.7 also showed that the revision observed this year is mainly due to the influence of the inclusion of the 2020 catch at age, which effect propagated backward in time.

The uncertainty on the parameter estimates has decreased for some parameters (observation standard deviation on the IESSNS survey, standard deviations of the F random walk for age 0 and 1, figure 8.10.2), but increased markedly for recruitment variance. The uncertainty on SSB and $F_{bar4\text{-}8}$ in this year's assessment is higher for the earlier years (before 2015), but has reduced for the most recent estimates (Figure 8.10.3).

Short term forecast

The intermediate year catch assumption for 2020 used for the short-term forecast in the advice given last year (sum of 2020 TAC of 1 090 879 tonnes) was slightly lower than the actual 2020 catch reported for WGIWIDE 2021 and used in the present assessment (text table below). The new assessment produced an estimate of the SSB in 2020 which was 7 % higher than the 2020 WGWIDE forecast prediction. This discrepancy in the SSB is explained by the revision of the perception of the abundance at age 6 to 12+ (Figure 8.10.4) and possibly also by the actual 2020 catch being lower than the value assumed last year. The fishing mortality $F_{bar4\text{-}8}$ for 2020 estimated at the WGWIDE 2020 is 21.9 % lower than the value estimated by the short-term forecast in the previous assessment also due to the combination of the stock being actually larger than forecasted, and the stock being revised upwards in 2020 (Figure 8.10.1).

	Catch (2020)	SSB (2020)	$F_{bar4\text{-}8}$ (2020)
2020 WGWIDE forecast	1 090 879 t	3 681 413 t	0.32
2021 WGWIDE assessment	1 039 863 t	3 938 555t	0.25
% difference	-4.7 %	7.0 %	-21.9 %

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 for 2014 to 2018. In November 2018, the agreement from 2014 was extended for two more years until 2020. No agreement on the share of the stock has been reached after Brexit for 2021. Despite various agreements, the total declared quotas in each of the years 2015 to 2020 all exceed the TAC advised 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. The mackerel in the Northeast Atlantic appears on one hand to mix extensively whilst, on the other hand, exhibit some tendency for homing (Jansen *et al.*, 2013; Jansen and Gislason, 2013). Consequently, it cannot be considered either a panmictic population, nor a population that is composed of isolated components (Jansen and Gislason, 2013). 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.

Nevertheless, stock components are still being used to identify the different spawning areas where mackerel are known to spawn. The trends in the different components is derived from the triennial egg survey in the western and southern area and a dedicated egg survey in the North Sea the year following the western survey.

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 recommended closure of Division 4.a for fishing during the first half of the year is based on the perception that the western mackerel enter the North Sea in July/August, and remain there until December before migrating to their spawning areas. Updated observations from the late 1990s suggested that this return migration actually started in mid- to late February (Jansen *et al.*, 2012). The EU TAC regulations stated that within the limits of the quota for the western component (ICES Subareas and Divisions 6, 7, 8.a,b,d,e, 5.b (EU), 2.a (non-EU), 12, 14), a certain quantity of this stock may be caught in 4.a between 1 September and 15 February. Up to 2010, 30 % of the EU TAC of mackerel (MAC/2CX14-) could be taken in 4.a. From 2011 until 2014, this percentage increased to 40 % and from 2015 onwards this increased to 60 %.

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). The 30 cm later became the norm for the North Sea MLS while the MLS for mackerel in western waters was set at 20 cm. 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)

Mackerel recruitment to the fishery (~ age 3) was high from year-class 2001, but recently have appeared to be reverting towards a low level. The recruitment index indicates high recruitment at age 0 up to 2020, however, since 2012 the recruitment index 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 is a sampling bias or altered mortality of the juveniles between age 0 and 3.

The increasing stock size was suggested to have an effect through density driven expansion of the spawning area into new areas with Calanus in oceanic areas west of the North European continental shelf (Jansen, 2016). There are several indications of a shift in spawning and mackerel recruitment/larvae and juvenile areas towards northern and north-eastern areas preceding the 2016 mackerel spawning (ICES, 2016; Nøttestad *et al*., 2018; Bjørdal, 2019). This northerly shift in spawning and recruitment pattern of NEA mackerel seems to have continued also in 2017 (Nøttestad *et al*., 2018), but spawning in the Norwegian Sea was shown to be of little quantitative significance in 2021 (Burns and O’ Hea, WD 15 in Annex 05).

From about 2005 to 2015 mackerel length- and weight-at-age declined substantially for all ages (Jansen and Burns, 2015; Ólafsdóttir *et al*., 2015). Growth of 0–3 years old mackerel decreased from 1998 to 2012. Mean length at age 0 decreased by 3.6 cm, however the growth differed substantially among cohorts (Jansen and Burns, 2015). For the 3-8 years old mackerel, the average size was reduced by 3.7 cm and 175 g from 2002 to 2013 (Ólafsdóttir *et al*., 2015). The variations in growth of mackerel in all ages are correlated with mackerel density. Furthermore, the density dependent regulation of growth from younger juveniles to older adult mackerel, appears to reflect the spatial dynamics observed in the migration patterns during the feeding season (Jansen and Burns, 2015; Ólafsdóttir *et al*., 2015). Growth rates of the juveniles were tightly correlated with the density of juveniles in the nursery areas (Jansen and Burns, 2015). For adult mackerel (age 3-8) growth rates 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.

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, 2019; 2020).

Spatial mackerel distribution and timing

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).

After a mackerel stock expansion during the feeding season in summer from 1.3 million km^2 in 2007 to at least 2.9 million km^2 in 2014, mainly towards western and northern regions of the Nordic seas (Nøttestad *et al*., 2016), a slight decrease in distribution area of mackerel in the Nordic Seas was observed in 2017 and 2018 with 2.8 million square kilometres (Nøttestad *et al*., 2017; ICES, 2018a). The mackerel distribution slightly increased to 2.9 million km^2 in 2019 (Nøttestad *et al*., 2019). However, we witnessed a substantial shift in mackerel concentrations and distribution during summers of 2020 and 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), followed by a decrease in 2021 (Nøttestad et al., WD09 in Annex 05). The mackerel was less patchily distributed within the survey area in 2020 compared to 2019. Overall, we have witnessed that mackerel had a much more eastern distribution in 2018 to 2021 compared to 2014-2017 (ICES, 2018a; Nøttestad *et al*., 2019; 2020b).

Spatial mackerel distribution related to environmental conditions

Ólafsdóttir *et al*. (2018) analysed the IESSNS data from 2007 to 2016 with the following results: Mackerel was present in temperatures ranging from 5 °C to 15 °C, but preferred areas with temperatures between 9 °C and 13 °C according to univariate quotient analysis. Generalized additive models showed that both mackerel occurrence and density were positively related to location, ambient temperature, meso-zooplankton density and SSB, explaining 47 % and 32 % of deviance, respectively. This seem to have changed during 2019 and particularly 2020 where higher concentrations of mackerel were caught in lower temperatures (7-8 °C) (Nøttestad *et al*., 2019; 2020b; WD09 in Annex 05). Mackerel relative mean weight-at-length was positively related to location, day-of-year, temperature and SSB, but not with meso-zooplankton density, explaining 40 % of the deviance. 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. Marine climate with multidecadal variability probably impacted the observed distributional changes but were not evaluated. Our results were limited to the direct effects of temperature, meso-zooplankton abundance, and SSB on distribution range during the last two decades (1997-2016) and should be viewed as such (Olafsdottir *et al*., 2019). 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 than 2018, might partly explain such changes (ICES, 2018a; Nøttestad *et al*., 2019; 2020a).

Trophic interactions

There are strong indications for interspecific competition for food between NSS-herring, blue whiting and mackerel (Huse *et al*., 2012). According to Langøy *et al*. (2012), Debes *et al*. (2012), Óskarsson *et al*. (2015) and Bachiller *et al*. (2016), the herring may suffer from this competition, as mackerel had higher stomach fullness index than herring and the herring stomach composition is different from previous periods when mackerel stock size was smaller. Langøy *et al*. (2012) and Debes *et al*. (2012) also found that mackerel consumed a wider range of prey species than herring. Mackerel may thus be thriving better in periods with low zooplankton abundances. Feeding incidence increased with decreasing temperature as well as stomach filling degree, indicating that feeding activity is highest in areas associated with colder water masses (Bachiller *et al*., 2016). A bioenergetics model developed by Bachiller *et al*. (2018) estimated that the NEA mackerel, NSS herring and blue whiting can consume between 122 and 135 million tonnes of zooplankton per year (2005-2010) This is higher than that estimated in previous studies (e.g., Utne *et al*., 2012; Skjoldal *et al*., 2004). NEA mackerel feeding rate can consequently be as high as that of the NSS herring in some years. Geographical distribution overlap between mackerel and NSS herring during the summer feeding season is highest in the south-western part of the Norwegian Sea (Faroe and east Icelandic area) (Nøttestad *et al*., 2016; 2017; Ólafsdóttir *et al*., 2017). The spatiotemporal overlap between mackerel and herring was highest in the southern and south-western part of the Norwegian Sea in 2018 and 2019 (ICES, 2018a, Nøttestad *et al*., 2019). This is similar as seen in previous years (Nøttestad *et al*., 2016; 2017). A change was seen in the northern Norwegian Sea in 2019-2021 where we had some increasing overlap between mackerel and herring (mainly 2013- and 2016- year classes) (Nøttestad *et al*., 2019; 2020; WD09 in Annex 05). There was, on the other hand, practically no overlap between NEA mackerel and NSSH in the central and northern part of the Norwegian Sea in 2018 and previous years, mainly because of very limited amounts of herring in these areas (ICES, 2018a).

There seem to be rather limited spatial overlap between marine mammals and mackerel during summers in the Nordic Seas (Nøttestad *et al*., 2019; Løviknes, 2019). There is spatial overlap between killer whales and mackerel in the Norwegian Sea, and killer whales are actively hunting for mackerel schools close to the surface during summer (Nøttestad *et al*., 2014; Nøttestad *et al*., 2020a). The increase of 0- and 1-groups of NEA mackerel found along major coastlines of Norway both in 2016 and 2017 (Nøttestad *et al*., 2018) and 2018 (Bjørdal, 2019), has created some interesting new trophic interactions. Increasingly numbers of adult Atlantic bluefin tuna (*Thynnus thunnus*), with an average size of approximately 200 kg, have been documented to feed on 0-group mackerel from the 2016, 2017-year classes during the commercial bluefin tuna fishery in Norway (Boge, 2019; Nøttestad *et al*., 2020b). Additionally, the new situation of numerous 0- and 1-group mackerel in Norwegian coastal waters in 2018 (Bjørdal, 2019), have created favourable feeding possibilities for larger cod, saithe, marine mammals and seabirds in these waters. Repeated stomach samples from several species document that smaller sized mackerel is now eaten by different predators in northern waters (60-70°N) (Bjørdal, 2019). Although much fewer 1-groups of NEA mackerel were found along the coast in Norway during the IESSNS 2019 (Nøttestad *et al*., 2019) and to some extent in 2020 (Nøttestad *et al*., 2020b) and 2021 (*Nøttestad et al*., 2021), the Atlantic bluefin tuna is still indeed targeting schools of 1-group mackerel during their intense feeding migration in Norwegian waters (Nøttestad *et al*., 2020a). The predation pressure and mortality from and increasing Atlantic bluefin tuna stock on NEA mackerel (both juveniles and adults) are unknown, but could have ecological impact on both regional and population level (ICCAT, 2019; Nøttestad *et al*., 2020b).

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8.14 Tables

Table 8.2.4.1. Overview of major existing regulations on mackerel catches.

Technical measure	National/International level	Specification	Note
Catch limitation	Coastal States/NEAFC	2010-2020	Not agreed
Management strategy (EU, NO, FO agreement London 12. Oct. 2014)	European (EU, NO, FO)	If SSB >= 3.000.000t, F = 0.24 If SSB is less than 3.000.000t, F = 0.24 * SSB/3.000.000 TAC should not be changed more than 20% A party may transfer up to 10% of unutilised quota to the next year	Not agreed by all parties
Management strategy with updated reference points 2019 (EU, NO, FO agreement London 17. Oct. 2019)	European (EU, NO, FO)	If SSB >= 2.500.000t, F = 0.23 If SSB is less than 2.500.000t, F = 0.23 * SSB/2.500.000 TAC should not be changed more than +25% or -20% A party may transfer up to 10% of unutilised quota to the next year A party may fish up to 10% beyond the allocated quota, that have to be deduced from next year's quota.	Not agreed by all parties
Minimum size (North Sea)	European (EU, NO)	30 cm in the North Sea	
Minimum size (all areas except North Sea)	European (EU, NO)	20 cm in all areas except North Sea	10% undersized allowed
Minimum size	National (NO)	30 cm in all areas	
Catch limitation	European (EU, NO)	Within the limits of the quota for the western component (6, 7, 8.a-b,d,e, 5.b (EC), 2.a (nonEC), 12, 14), a certain quantity may be taken from 4.a but only during the periods 1 January to 15 February and 1 October to 31 December.	
Area closure	National (UK)	South-West Mackerel Box off Cornwall	Except where the weight of the mackerel does not exceed 15 % by liveweight of the total quantities of mackerel and other marine organisms onboard which have been caught in this area
Area limitations	National (IS)	Pelagic trawl fishery only allowed outside of 200 m depth contours around Iceland and/or 12 nm from the coast.	

Technical measure	National/International level	Specification	Note
National catch limitations by gear, semester and area	National (ES)	28.74 % of the Spanish national quota is assigned for the trawl fishery, 34.29 % for purse seiners and 36.97% for the artisanal fishery	Since 2015, the trawl fishery has the individual quotas assigned by vessel.
Discard prohibition	National (NO, IS, FO)	All discarding is prohibited for Norwegian, Icelandic and Faroese vessels	
Landing Obligation	European	From 2015 onwards a landing obligation for European Union fisheries is in place for small pelagics including mackerel, horse mackerel, blue whiting and herring. In 2016 it was extended to certain demersal fisheries and since 2019 it applies to all TAC species.	There are *de minimis* exemptions for mackerel caught in bottom-trawl fisheries in the North Western Waters (EC 2018/2034) and in the North Sea (EC 2018/2035).

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	1030232	9280	1039513

Table 8.4.2.1. NE Atlantic Mackerel. ICES estimated catch (t) in Subareas 1, 2, 5 and 14, 2000 – 2020 (Data submitted by Working Group members).

Year	Denmark	Estonia	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Lithuania	Netherlands	Norway	Poland	Sweden	United Kingdom	Russia	Mis-reported	Unallocated	Discards	Total
2000	1375	2673	5546						2085		31778				491001				92557
2001	7	219	3272								21971		8	54	41566				67097
2002	1		4730				53			569	22670			665	45811	-570			73929
2003							122	495		44	125481			692	40026		-44		53883
2004			650	2				471		34	10295			2493	49489	-553	32	9	62922
2005			30	1			363			2393	13244				40491		-2393		54129
2006							4222				8914				33580				46716
2007			278		7		36706			10	493				35408		-10		72891
2008			123				112286			72	3474			4	32728		-18	112	148781
2009			2992				116160				3038				414141				163604
2010	4845		66312				121008			90	104858				58613			5	355729
2011	269		121499	2		621	159263	90		178	43168				73601			28	398160
2012			107198		107	74021	149282			5	110741		4		74587			1	449326
2013	391	13671	142976	197	74	541481	151103			1	33817		825	2	80812			151	465729
2014	2345		103896	8		875811	172960	1725	1082	5887	192322		3310	5534	116433			911	684173
2015	4321		76889	36	2963	30351	169333	6		6996	204574		740	7851	128433			78	632571
2016	1		61901		3499	36142	170374	2	1931	8599	153228		730	5240	121614			54	563315

Year	Denmark	Estonia	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Lithuania	Netherlands	Norway	Poland	Sweden	United Kingdom	Russia	Misreported	Unallocated	Discards	Total
2017	2		66194		4064	46388	167366			7671	167739		1720	4601	138061			62	603869
2018	289		52061	733	577	62973	168330			2697	46853	2	910	2009	118255			51	455740
2019			37418		190	30241	128008			13	22605				126543			18	345036
2020			33291	8	206	26555	151534		2	0.73	15937	0.044	220	426	128805			0.05	356985

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), 2000-2020 (Data submitted by Working Group members).

Year	Belgium	Denmark	Faroe Islands	France	Germany.	Ireland	Lithuania	Netherlands	Norway	Poland	Sweden	United Kingdom	Russia	Misreported (Area 6.a)	Unallocated	Discards	Total
2000	146	27720	10614	1588	78	9956		2262	142320		49941	58282	1672	8591	34761	1912	304896
2001	97	21680	18751	1981	4514	10284		2441	158401		5090	52988	1	39024	24873	24	339970
2002	22	343751	12548	2152	3902	20715		11044	161621		52321	61781		49918	22985	8583	394878
2003	2	275081	11754	1467	4859	17145		6784	150858		4450	67083		62928	-730	11785	365894
2004	4	25665	11705	1538	4515	18901		6366	147068		4437	62932		23692	-783	11329	317369
2005	1	232121	9739	1004	4442	15605		3915	106434	109	3204	37118	4	37911	7043	4633	254374
2006	3	242191	12008	285	2389	4125		4093	113079		3209	28628		8719	171	8263	209192
2007	1	252171	11818	7549	5383	13337		5973	131191		38581	46264			2421	4195	257208
2008	2	26716	7627	490	4668	11628		1980	114102		36641	37055		17280	2039	8862	236111
2009	3	23491	6648	1493	5158	12901		2039	118070		73031	47863		1959	-629	8120	235049

Year	Belgium	Denmark	Faroe Islands	France	Germany.	Ireland	Lithuania	Netherlands	Norway	Poland	Sweden	United Kingdom	Russia	Misreported (Area 6.a)	Unallocated	Discards	Total
2010	27	36552	4639	686	25621	14639		1300	129064		34291	52563	696		660	883	247700
2011	21	32800	543	1416	52911	15810		9881	162878		32481	69858				1906	303652
2012	39	36492	432	5736	4560	20422		6018	64181		4560	75959				1089	219489
2013	62	31924	25	1788	5755	13523		4863	130056		2081	70840	4			337	261258
2014	56	21340	42919	4912	4979	45167	8340	24536	85409		1112	145119				334	384221
2015	38	35809	25672	7827	6056	34167		17547	36344	24	3190	129203				34	295911
2016	99	21696	18193	3448	10172	24437	596	11434	55089		2933	99945				559	248611
2017	107	27457	12915	5942	11185	35957		17401	51960	0.721	1981	104499				400	269804
2018	110	22207	15475	6714	12091	24567		13844	135715	4041	3056	103707				620	342147
2019	13	25374	17460	5455	7778	1678		8957	135083	1394	2152	101890	0.12			812	308047
2020	75	34375	32860	8959	15946	15395	813	18425	195515	16	3451	130650				732	457211

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 – 2020 (Data submitted by Working Group members).

Year	Belgium	Denmark	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Lithuania	Netherlands	Norway	Poland	Portugal	Russia	Spain	Sweden	United Kingdom	Misreported	Unallocated	Discards	Total
2000		82	4863	17857	22901			61277		30123					4500		126620	-3775	31564	1920	297932
2001		835	2161	18975	20793			60168		33654					4063		139589	-39024	37952	1164	280553

Year	Belgium	Denmark	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Lithuania	Netherlands	Norway	Poland	Portugal	Russia	Spain	Sweden	United Kingdom	Misreported	Unallocated	Discards	Total
2002			2490	19726	22630			51457		21831					3483		131599	-43339	27558	15191	252620
2003		113	2260	21213	19200			49715		23640							167246	-62928	5587	7111	233157
2004	1		674	18549	18730			41730		21132							149346	-23139	9714	7696	244432
2005				15182	14598			30082		18819		461			4795		115595	-37911	13412	20359	190597
2006			59	14625	14219			36539	95	20064		1368			4048		67205	-8719	4783	14723	169009
2007		6	1333	12434	12831			35923	7	18261	7	978			2772		87430		10042	10177	192201
2008		10	3539	14944	10834			33132		17920	3948				7327		768828	-17280	-952	27351	177662
2009	1		4421	16464	17545			48155		20900	121				8462		109155	-1959	490	6848	230603
2010	2	48	36	10301	16493			43355		21699	30			1	6532		107860		4503	7518	218377
2011		2889	8	11304	18792	10	45696	11	18336	2019					1257		111133		399	7153	219007
2012		8		14448	14277	5	42627	11	19794	1101					773		93783		16	10654	197496
2013		903		12438	15102	9	42988	8	16295	734					635		92965		-144	2105	183857
2014		18538	3421	16627	23478	9	56286	3	16242						1796		137378			1742	275519
2015	14	6741	5851	17820	19238	4	54571		15264	1313					951		111489		34	3185	236475
2016	44	19443	13173	16634	9740		52087	8	17896	1035				30	1253		112284			2126	245754

Year	Belgium	Denmark	Faroe Islands	France	Germany	Greenland	Iceland	Ireland	Lithuania	Netherlands	Norway	Poland	Portugal	Russia	Spain	Sweden	United Kingdom	Misreported	Unallocated	Discards	Total
2017	21	12569	20559	16925	9608		48957	2	18694	2657					786		116308			2142	249229
2018	58	8194	13543	13974	7214			42181		13851	4639	14			1269		84327		13	1701	190978
2019	53	5189	7787	12371	8936		69	51635		13727	1420	2312	46	1	1217	805	50267			6046	161879
2020	49	4110	2913	12816	8878	22		58720		11895	221	5286	35	10	1784		72645			8405	187788

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

Country	France 8.c	Portugal 9.a	Portugal 8.c	Russia 9.b	Spain 8.c	Spain 9.a	Discards 8.c	Discards 9.a	Unallocated 8.c	Unallocated 9.a	Total 9.a	Total 8c and 9a
2000		2253			30061	3760		6013			12026	42087
2001		3119			38205	1874					4993	43198
2002		2934			38703	7938					10873	49575
2003	226	2749			17384	5464	531				8213	26354
2004	177		2289				928		28429	3946	6234	35768
2005	151		1509				391	405	42851	5107	7021	50414
2006	43		2620		43063	7025	3606	1			9646	56358
2007	55		2605		53401	6773	156	916			10293	63906
2008	168		2381		50455	6855	73	677			9913	60609
2009	383		1753		91043	14569	725	241			16562	108713
2010	392	1758	2363		38858	7347	4408	232		108	10049	55466
2011	44	2302	962		14709	2759	563	1245	4691	871	5836	28146
2012	283	4868	824		17768	845	2187	1244	4144	1076	3989	33239
2013	220	5134	254		14617	1162	1428	1027	-573	4053	6497	27322
2014	171	7334	618		33783	2227	2821	1463	8795	662	4308	57874
2015	21	6836	1456		29726	3853	4724	2409	11	1831	9550	50867
2016	106	6069	619		26553	2229	2469	751	1357	2123	5722	42276
2017	83	3697	634		30893	1206	84	143			1983	36740

Country	France 8.c	Portugal 9.a	Portugal 8.c	Russia 9.b	Spain 8.c	Spain 9.a	Discards 8.c	Discards 9.a	Unallocated 8.c	Unallocated 9.a	Total 9.a	Total 8c and 9a
2018	50	3709	855		27190	1656	324	194	300		2736	34279
2019	43	3188	706		19148	747	760	172			1625	24764
2020	96	4189	575	3	31143	1379	28	115			2069	37529

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2020 (Q1-Q4).

Age	1	2.a	2.a1	2.a2	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a
0					249				244	217	197	
1		280	263	263	292	289	292	292	296	295	295	
2	335	327	329	329	321	324	317	323	320	321	322	
3	348	331	331	331	330	336	327	320	332	323	326	353
4	358	341	343	343	343	348	340	329	344	338	341	351
5	353	345	357	357	354	360	355	348	356	350	354	367
6	371	360	368	368	363	368	363	366	364	351	357	369
7	373	364	365	366	372	375	372	381	371	365	370	373
8	379	369	371	371	376	378	376	384	375	366	376	376
9	385	374	377	377	378	380	379	389	378	372	374	377
10	390	373	374	374	384	389	386	386	383	382	383	379
11		377	376	376	384	391	389	397	388	383	384	384
12		382	389	389	391	396	399	390	391	389	380	390
13		385	380	381	395	399	399	403	393	390	391	392
14		390	392	392	396	402	415	393	397	390	392	394
15+		398	395	395	403	406	406	402	397	396	402	390

Age	5.b	5.b.1	6.a	6.b	7.a	7.b	7.c	7.d	7.g	7.h	7.j	7.k
0								173				
1			174	248		295		283				
2			296	314		304	306	318				
3	353	353	328	325		328	325	330	113	174	335	345
4	352	351	342	344	131	341	339	343	268	287	336	358
5	359	364	359	357	306	361	347	359	361	361	365	365
6	367	368	365	365	353	367	365	371	313	306	369	369
7	369	371	372	372	362	373	376	372	352	361	370	380
8	371	374	376	375	350	375	397	383	362	369	380	381
9	372	375	377	378	381	376	382	379	379	379	379	379

Age	5.b	5.b.1	6.a	6.b	7.a	7.b	7.c	7.d	7.g	7.h	7.j	7.k
10	374	377	383	385	388	382	393	385	387	385	384	398
11	374	380	391	393	402	387	403	424	409	433	423	399
12	385	388	394	396	373	387	387	405	399	403	402	395
13	389	391	397	399		389	392	393	395	395		
14	391	393	404	413		388	388	396	425	425	425	425
15+	380	388	409	412		401	401	416				

Table 8.5.1.1. NE Atlantic Mackerel. Mean length (mm) -at-age by area for 2020 (Q1-Q4) continued.

Age	8.a	8.b	8.c	8.c.E	8.c.W	8.d	8.e	9.a	9.a.N	12.c	All
0	177	177	202	186	0			266	194		192
1	287	246	252	297	322	322	307	288	251		125
2	305	295	290	308	323	322	295	294	280		291
3	331	335	321	338	335	337	316	325	306	335	320
4	357	353	343	353	353	339	351	354	350	333	342
5	361	351	354	364	370	357	369	371	357	365	351
6	362	361	368	366	380	363	378	377	361	368	363
7	358	362	374	374	384	366	381	385	373	369	369
8	379	377	377	378	384	379	382	377	377	380	374
9	374	379	382	379	385	375	385	395	379	378	377
10	374	375	391	387	390	376	389	405	389	382	380
11	372	374	394	392	415	386	415	405	399	455	384
12	384	390	403	397	411	391	415		401	405	388
13	382	382	400	425		382		420			390
14	396	396	410	435		396					393
15+	405	405	432	432		405			420		398

Table 8.6.1.1.1. International mackerel and horse mackerel egg survey in the western and southern areas: Periods and area assignments for countries/institutes by week for the 2022 survey. Area assignments and dates are provisional.

Week	Starts	Area 9a	Cantabrian Sea	Biscay	Celtic sea	West of Ireland	West of Scotland	Northern area	Period
3	09-Jan-22								1
4	16-Jan-22	PO1							2
5	23-Jan-22	PO1							2
6	30-Jan-22	PO1							2
7	06-Feb-22	PO1							2
8	13-Feb-22	PO1							2
9	20-Feb -22	PO1				SCO (IBTS)	SCO (IBTS)		2
10	27-Feb-22					SCO (IBTS)	SCO (IBTS)		2
11	06-Mar-22			IEO1	IRL 1	IRL 1	IRL 1		3
12	13-Mar-22			IEO1	IRL 1	IRL 1	IRL 1		3
13	20-Mar-22		IEO1	AZTI1	GER1	IRL 1	IRL 1		3
14	27-Mar -22		IEO1	AZTI1	GER1	GER1			3
15	03-Apr-22			AZTI1	GER1	GER1			3
16	10-Apr-22		IEO2	IEO2	GER2	GER 2 /SCO1	SCO1		4
17	17-Apr-22		IEO2	IEO2	GER2	GER 2 /SCO1	SCO1		4
18	24-Apr -22		IEO2	IEO2	GER2	GER 2 /SCO1	SCO1		4
19	1-May-22		IEO2/AZTI2 (DEPM)	IEO2					4
20	8-May-22		AZTI2 (DEPM)	AZTI2 (DEPM)/ NED1	NED1	NED1 / SCO2	SCO2	NOR	5
21	15-May-22			AZTI2 (DEPM)/ NED1	NED1	NED1 / SCO2	SCO2	NOR	5
22	22-May -22			AZTI2 (DEPM)/ NED1	NED1	NED1 / SCO2	SCO2	NOR	5
23	29-May-22							FAR	6
24	5-Jun-22			NED2	NED2	IRL2	IRL2	FAR	6
25	12-Jun-22			NED2	NED2	IRL2	IRL2	FAR	6
26	19-Jun -22			NED2	NED2	IRL2	IRL2		6
27	26-Jun -22								6
28	3-Jul-22				SCO3	SCO3	SCO3		7

Week	Starts	Area 9a	Cantabrian Sea	Biscay	Celtic sea	West of Ireland	West of Scotland	Northern area	Period
29	10 –Jul-22				SCO3	SCO3	SCO3		7
30	17-Jul-22				SCO3	SCO3	SCO3		7
31	24-Jul-22				SCO3	SCO3	SCO3		6

Table 8.6.1.3.1. Daily egg production estimate (stage 1A) for mackerel in the North Sea using the DEPM.

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

Table 8.6.2.1. Model parameter estimates and standard errors.

Symbol	Description	Unit	Estimate	Std.Error
T	Decorrelation time	year	1,9	0.3
H	Spatial decorrelation distance	km	455	82
WS	Log Wing spread	nmi	-1.0	0.6
σ_N^2	Variance of the nugget effect	1	3.7	
σ_{xy}^2	Spatial variance parameter (year specific surfaces)	1	5.3	
σ_x^2	Spatial variance parameter (intercept surface)	1	5.4	

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 -2020		Yes
Catch-at-age in numbers	1980 -2020	0-12+	Yes
Weight-at-age in the commercial catch	1980 –2020	0-12+	Yes
Weight-at-age of the spawning stock at spawning time.	1980 –2020	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.	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, 2012-2021	Ages 3-11
Tagging/recapture	Norwegian tagging program	Steal tags : 1980 (release year)-2006 (recapture years) RFID tags : 2013 (release year) 2020 (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

year

age	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

year

age	2020
0	6443
1	52637
2	107302
3	182163
4	266760
5	166627
6	270154
7	246268
8	274182
9	311215
10	241775
11	128294
12	179703

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

Units : Kg

year

age	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

year

age	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

	year											
age	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

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

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

Units : Kg

age	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	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	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	2016	2017	2018	2019	2020
0	0.000	0.000	0.000	0.000	0.000
1	0.059	0.058	0.064	0.070	0.068
2	0.182	0.204	0.190	0.191	0.210
3	0.238	0.237	0.266	0.250	0.252

4	0.282	0.278	0.283	0.293	0.289
5	0.298	0.308	0.314	0.311	0.348
6	0.340	0.308	0.327	0.346	0.363
7	0.368	0.338	0.346	0.365	0.375
8	0.385	0.377	0.364	0.371	0.394
9	0.404	0.394	0.389	0.397	0.400
10	0.424	0.426	0.419	0.428	0.423
11	0.440	0.430	0.437	0.431	0.445
12	0.473	0.499	0.491	0.481	0.486

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
0	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
2	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
4	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
6	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

8	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
10	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
12	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

ear

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	0.093	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

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	0.102	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

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	0.106	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

age	2016	2017	2018	2019	2020
0	0.000	0.000	0.000	0.000	0.000
1	0.111	0.109	0.092	0.092	0.092
2	0.632	0.604	0.469	0.440	0.420
3	0.937	0.945	0.902	0.902	0.909
4	0.997	0.998	0.999	0.998	0.998
5	0.999	1.000	1.000	1.000	1.000
6	1.000	1.000	1.000	1.000	0.999
7	0.999	0.999	0.999	1.000	0.999
8	1.000	1.000	1.000	1.000	1.000
9	1.000	1.000	1.000	1.000	1.000
10	1.000	1.000	1.000	1.000	1.000
11	1.000	1.000	1.000	1.000	1.000
12	1.000	1.000	1.000	1.000	1.000

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

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

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

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

age												
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
0	0.000	0.000	0.000	0.000	0.000
1	0.143	0.232	0.393	0.581	0.532
2	0.224	0.153	0.180	0.183	0.184
3	0.224	0.153	0.180	0.183	0.184
4	0.224	0.153	0.180	0.183	0.184
5	0.176	0.291	0.193	0.299	0.321
6	0.176	0.291	0.193	0.299	0.321
7	0.176	0.291	0.193	0.299	0.321
8	0.176	0.291	0.193	0.299	0.321
9	0.176	0.291	0.193	0.299	0.321
10	0.176	0.291	0.193	0.299	0.321
11	0.176	0.291	0.193	0.299	0.321
12	0.176	0.291	0.193	0.299	0.321

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
  0  0.343 0.327 0.312 0.296 0.296
  1  0.343 0.327 0.312 0.296 0.296
  2  0.343 0.327 0.312 0.296 0.296
  3  0.343 0.327 0.312 0.296 0.296
  4  0.343 0.327 0.312 0.296 0.296
  5  0.343 0.327 0.312 0.296 0.296
  6  0.343 0.327 0.312 0.296 0.296
  7  0.343 0.327 0.312 0.296 0.296
  8  0.343 0.327 0.312 0.296 0.296
  9  0.343 0.327 0.312 0.296 0.296
  10 0.343 0.327 0.312 0.296 0.296
  11 0.343 0.327 0.312 0.296 0.296
  12 0.343 0.327 0.312 0.296 0.296
```

Table 8.7.1.9. NE Atlantic Mackerel. SURVEY INDICES

```
Some random text
103
SSB-egg-based-survey
1992          2020
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		
R-idx			
1998	2020		
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		
Swept-idx			
2010	2021		
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

Table 8.7.1.10. NE Atlantic Mackerel. RFID recapture data for the year 2020.

Release Yr	Recapture Yr	Year-class	age at re-lease	Numbers scanned in recapture Yr	Numbers Released in Release Year	Numbers re-captured
2018	2020	2007	19391477	1670.4499	7	2
2018	2020	2008	29244736	4092.9627	20	2
2018	2020	2009	39505301	3273.9251	17	2
2018	2020	2010	99081840	6506.48	40	2
2018	2020	2011	110470858	7923.5647	50	2
2018	2020	2012	61620787	2290.2767	15	2
2018	2020	2013	53083627	3049.499	20	2
2019	2020	2008	29244736	2556.359	28	2
2019	2020	2009	39505301	2871.3265	30	2
2019	2020	2010	99081840	4727.5524	49	2
2019	2020	2011	110470858	9482.5831	101	2
2019	2020	2012	61620787	6784.5181	72	2
2019	2020	2013	53083627	8039.9448	82	2
2019	2020	2014	73636345	5824.132	59	2

Table 8.7.2.1. NE Atlantic Mackerel. SAM parameter estimates for the 2021 update.

	esti-mate	std.dev	confidence interval lower bound	confidence interval upper bound
observation standard deviations				
Catches age 0	0.91	0.18	0.63	1.29
Catches age 1	0.36	0.23	0.23	0.58
Catches age 2-12	0.11	0.16	0.08	0.15
Egg survey	0.31	0.26	0.19	0.53
Recruitment index	0.28	0.30	0.15	0.50
IESSNS age 3	0.65	0.24	0.40	1.05
IESSNS ages 4-11	0.39	0.14	0.29	0.51
Recapture overdispersion tags	1.23	0.25	1.38	1.14

	esti-mate	std.dev	confidence interval lower bound	confidence interval upper bound
random walk standard deviation				
F age 0	0.25	0.49	0.09	0.66
F age 1	0.15	0.49	0.06	0.40
F age 2+	0.13	0.19	0.09	0.18
N@age0	0.16	0.74	0.04	0.70
process error standard deviation				
N@age1-12+	0.21	0.09	0.18	0.26
catchabilities				
egg survey	1.22	0.11	0.98	1.53
recruitment index	5.13E-09	1.25E-01	3.99E-09	6.59E-09
IESSNS age 3	0.82	0.23	0.52	1.30
IESSNS age 4	1.25	0.16	0.91	1.74
IESSNS age 5	1.71	0.16	1.24	2.37
IESSNS age 6	1.83	0.16	1.32	2.53
IESSNS age 7	1.95	0.16	1.41	2.70
IESSNS age 8	1.85	0.16	1.34	2.56
IESSNS age 9	1.95	0.16	1.41	2.69
IESSNS ages 10-11	1.76	0.16	1.28	2.42
post tagging survival steal tags	0.40	0.11	0.35	0.46
post tagging survival RFID tags	0.15	0.11	0.12	0.18

Table 8.7.3.1. NE Atlantic Mackerel. STOCK SUMMARY.

Year	Recruitment			SSB			Total	F		
	Age 0	97.5%	2.5%		97.5%	2.5%	Catch	Ages 4-8	97.5%	2.5%
	thousands			tonnes			tonnes			
1980	4811944	9103354	2543547	4119074	8671627	1956585	734950	0.22	0.34	0.142
1981	4534674	7611843	2701483	3605227	6741744	1927937	754045	0.22	0.33	0.145
1982	3958511	6325237	2477347	3447225	5801256	2048412	716987	0.22	0.33	0.148
1983	3818369	6144951	2372671	3653848	5503280	2425937	672283	0.22	0.32	0.152
1984	4135091	6275612	2724671	3961825	5566850	2819557	641928	0.22	0.32	0.156
1985	4044346	6012357	2720520	3991611	5369066	2967548	614371	0.23	0.32	0.161
1986	4002878	5882364	2723910	3583027	4725155	2716966	602201	0.23	0.32	0.167
1987	4028611	5995185	2707124	3546607	4679351	2688070	654992	0.24	0.32	0.174
1988	3736555	5367336	2601261	3495772	4501128	2714969	680491	0.24	0.32	0.182
1989	3575256	5131339	2491056	3278812	4158628	2585134	585920	0.25	0.33	0.192
1990	3369803	4917469	2309231	3365579	4194884	2700222	626107	0.26	0.34	0.20
1991	3351837	4800953	2340121	3266335	4031197	2646595	675665	0.28	0.35	0.22
1992	3326467	4738555	2335182	3003550	3672340	2456556	760690	0.29	0.37	0.23
1993	3138516	4505113	2186467	2673128	3248102	2199935	824568	0.30	0.38	0.24
1994	3023339	4400830	2077012	2337129	2819585	1937226	819087	0.31	0.39	0.25
1995	2938787	4375909	1973640	2304484	2756672	1926471	756277	0.31	0.38	0.25
1996	3002031	4359860	2067082	2190841	2612949	1836922	563472	0.30	0.37	0.25

Year	Recruitment			SSB			Total	F		
1997	2993152	4357776	2055857	2158199	2542155	1832234	573029	0.30	0.36	0.25
1998	3048761	4319517	2151848	2130817	2517107	1803809	666316	0.31	0.37	0.26
1999	3293974	4450358	2438065	2320394	2739168	1965643	640309	0.32	0.38	0.27
2000	3271449	4951287	2161535	2295030	2650345	1987350	738606	0.33	0.38	0.29
2001	4292777	6126570	3007872	2179261	2512207	1890440	737463	0.36	0.42	0.31
2002	4815423	7417020	3126363	2090999	2438985	1792662	771422	0.38	0.45	0.32
2003	4130904	6090027	2802018	2008630	2340992	1723455	679287	0.39	0.48	0.33
2004	4802786	6583472	3503736	2633091	3115008	2225730	660491	0.37	0.44	0.31
2005	5625640	9180956	3447116	2382116	2826649	2007492	549514	0.31	0.36	0.26
2006	5667557	8983000	3575776	2166834	2566138	1829664	481181	0.29	0.34	0.25
2007	4995749	6845907	3645610	2288905	2690795	1947040	586206	0.32	0.37	0.27
2008	4707792	6651030	3332312	2662883	3174335	2233837	623165	0.31	0.36	0.26
2009	4664141	6892403	3156260	3312494	3959391	2771290	737969	0.28	0.34	0.24
2010	5334499	7424733	3832715	3704409	4398473	3119866	877272	0.28	0.33	0.23
2011	5942633	9273284	3808240	4259835	5076085	3574841	948963	0.27	0.32	0.23
2012	5531582	7705525	3970969	3946707	4738821	3286997	899551	0.25	0.31	0.21
2013	5385707	7419743	3909279	4381909	5289301	3630182	938299	0.25	0.31	0.21
2014	5476329	7597921	3947156	5554870	6686129	4615013	1401788	0.26	0.31	0.21
2015	5171170	7228917	3699172	5554841	6735571	4581090	1215827	0.24	0.30	0.194
2016	5760094	8655929	3833059	5278481	6432921	4331214	1100135	0.22	0.27	0.174

Year	Recruitment			SSB			Total	F		
2017	5990287	9301147	3857969	5161638	6292364	4234102	1159641	0.22	0.27	0.175
2018	6041636	9229645	3954797	4521691	5529480	3697579	1023144	0.22	0.27	0.175
2019	6511865	10937279	3877051	3876306	4840328	3104283	839727	0.22	0.27	0.170
2020	5743130*			3938555	5014229	3093639	1039513	0.25	0.32	0.193
2021	4367513**			3510849†						
Average	4437228	6589293	2961178	3336758	4296605	2630110	770070	0.28	0.35	0.22

*** RCT3 estimate.**

**** Geometric mean 1990–2019.**

† Estimated value from the forecast.

Table 8.7.3.2. NE Atlantic Mackerel. ESTIMATED POPULATION ABUNDANCE

Units:Thousands

year

age	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
0	4811944	4534674	3958511	3818369	4135091	4044346	4002878	4028611	3736555	3575256
1	4906985	4565117	4423099	2843973	2671751	4185674	3365317	3309721	3999914	3008842
2	2352319	4073393	4218329	4206696	2001915	1834723	4127487	2744499	2686413	3878239
3	946215	1895555	3410854	4050384	4288850	1366283	1274935	4071426	2175748	2352879
4	1634417	727096	1423284	2873361	3706346	4055632	1011884	860882	3774327	1688475
5	3502369	1211575	522286	974609	2188505	3047018	3179966	793384	539031	3020884
6	2698169	2450353	867262	383786	666298	1626455	2228626	2173505	604829	346712
7	802869	1805822	1637759	584461	268795	462096	1081089	1497106	1410459	465834
8	298539	550334	1240000	1121849	396720	192990	309071	762959	1032937	1062503
9	825062	204624	376826	851091	766625	274128	135828	205838	536597	717372
10	222856	565887	140182	257707	583219	522820	191155	92645	136364	364659
11	326164	152766	387492	95996	176141	398065	354576	129493	62794	87873
12	674935	686985	574941	656675	512830	469173	586231	631401	508358	379329

year

age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
0	3369803	3351837	3326467	3138516	3023339	2938787	3002031	2993152	3048761	3293974
1	3122075	2615669	2885102	3098425	2585116	2539144	2302095	2669526	2455580	2667233
2	2372219	2660273	1987271	2427002	2816896	2075235	2080200	1758428	2314624	1963068
3	3940417	2140088	2559852	1644365	1987870	2401889	2173801	1941637	1231726	2379204
4	1842341	3069095	1526566	2037733	1095936	1426580	1816052	1786099	1641456	1259088
5	1079949	1252621	1937084	988781	1386293	677896	971840	1209516	1522591	1270361
6	1990828	775860	949151	1158070	584868	973641	492322	730339	861227	903114
7	214963	1227778	471291	569476	649669	343127	574871	321440	481979	618348
8	352590	137127	733390	310132	339398	281855	214493	347588	264687	311353
9	722972	249253	88658	412282	183807	178892	136670	152721	212067	181519
10	464602	490373	160056	53134	216892	111103	94119	86468	103085	131703

11	242415	291894	307588	97913	30040	133054	64441	49787	53266	63649
12	307504	356962	413037	448912	334155	220092	214507	173790	142603	125449

age \ year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
0	3271449	4292777	4815423	4130904	4802786	5625640	5667557	4995749	4707792	4664141
1	3069524	1905634	5055227	6085740	2853647	3788048	5562698	5232261	4119724	3991675
2	2282784	2595111	1160261	4805824	6767442	2348077	3340129	4693422	4700668	3396575
3	1842612	1751779	2524613	792439	3971769	5359865	1678094	2442601	4353419	4927061
4	1844107	1308343	1555153	1568371	753796	1863630	3158145	1454237	1944926	3896436
5	1037294	1251170	994749	921241	1008506	536915	1021782	2077797	1227021	1588070
6	862156	678869	813023	582841	479413	477746	372778	748714	1106484	907378
7	619208	607205	414817	383143	268963	231907	280874	254789	421706	693813
8	375071	412556	349520	245409	186923	135367	131299	185038	178773	265207
9	190676	240199	230717	197698	118090	87514	73349	95048	102537	109904
10	113401	128306	128642	119191	93961	62992	52736	47701	59082	53007
11	69909	68730	63614	67505	47920	31275	31986	34478	22178	28775
12	122154	127574	113255	82479	57594	40348	38469	39885	31447	20450

age \ year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
0	5334499	5942633	5531582	5385707	5476329	5171170	5760094	5990287	6041636	6511865
1	4157195	5347146	6063029	4400260	4140907	5638931	3535950	5147012	4157675	4085909
2	3868325	3287650	5496980	6407927	3633802	3302939	5043805	2171821	5012797	2968396
3	3337197	3625580	2687931	5237881	6886128	2894679	2655306	4399675	1391233	3595444
4	4653138	3033068	2956488	2402430	5041550	4608605	2702920	2090078	2795349	944287
5	2934771	3375706	2376216	2458937	2391391	3592391	3380966	2094232	1343719	1457244
6	1266128	2128897	2415490	2204974	2341222	1947569	2822270	2867086	1439873	1044754
7	567224	916877	1361364	1608738	2009982	1829486	1558096	2537033	2178762	1045851
8	379544	415737	602998	861848	1342799	1506580	1335250	1254062	1787575	1533512
9	170567	207787	269303	409522	600520	959816	891519	1058229	978854	1263562
10	74593	94860	125480	167550	268317	457779	524716	655479	664292	585991
11	25440	46199	52475	81814	91627	135696	224733	358678	461162	405285
12	32038	39467	49456	69104	65793	100889	133922	260203	331065	441157

age \ year	2020
0	6597436
1	5442333
2	2773562
3	2031825
4	2325558
5	815955
6	1175515
7	987483
8	1021186
9	1197961
10	1075322
11	509948
12	715077

Table 8.7.3.3. NE Atlantic Mackerel. ESTIMATED FISHING MORTALITY

1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993		
0	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
1	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031
2	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.060	0.061	0.061
3	0.112	0.112	0.112	0.112	0.113	0.115	0.117	0.119	0.121	0.124	0.127	0.130	0.132	0.136
4	0.182	0.183	0.183	0.184	0.185	0.187	0.191	0.197	0.201	0.208	0.213	0.218	0.222	0.225
5	0.207	0.207	0.208	0.210	0.211	0.214	0.218	0.222	0.227	0.232	0.237	0.242	0.251	0.257
6	0.253	0.254	0.255	0.256	0.259	0.263	0.267	0.273	0.278	0.289	0.299	0.308	0.316	0.324
7	0.228	0.228	0.228	0.229	0.230	0.233	0.238	0.244	0.252	0.264	0.281	0.304	0.329	0.352
8	0.228	0.228	0.228	0.229	0.230	0.233	0.238	0.244	0.252	0.264	0.281	0.304	0.329	0.352
9	0.228	0.228	0.228	0.229	0.230	0.233	0.238	0.244	0.252	0.264	0.281	0.304	0.329	0.352
10	0.228	0.228	0.228	0.229	0.230	0.233	0.238	0.244	0.252	0.264	0.281	0.304	0.329	0.352
11	0.228	0.228	0.228	0.229	0.230	0.233	0.238	0.244	0.252	0.264	0.281	0.304	0.329	0.352
12	0.228	0.228	0.228	0.229	0.230	0.233	0.238	0.244	0.252	0.264	0.281	0.304	0.329	0.352

	year													
age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
0	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.007	0.007	0.006	0.005	0.005	0.005	0.005
1	0.030	0.030	0.030	0.030	0.030	0.030	0.029	0.028	0.027	0.024	0.021	0.019	0.019	0.018
2	0.062	0.063	0.063	0.065	0.066	0.067	0.068	0.068	0.067	0.066	0.068	0.063	0.055	0.046
3	0.138	0.140	0.143	0.146	0.149	0.156	0.164	0.158	0.158	0.144	0.146	0.135	0.115	0.107
4	0.228	0.229	0.230	0.230	0.235	0.242	0.254	0.263	0.259	0.235	0.222	0.196	0.182	0.176
5	0.261	0.266	0.273	0.285	0.300	0.314	0.331	0.321	0.325	0.320	0.309	0.278	0.254	0.261
6	0.327	0.329	0.329	0.331	0.336	0.348	0.366	0.401	0.396	0.399	0.381	0.343	0.331	0.327
7	0.367	0.363	0.346	0.333	0.335	0.347	0.357	0.406	0.464	0.510	0.467	0.363	0.341	0.411
8	0.367	0.363	0.346	0.333	0.335	0.347	0.357	0.406	0.464	0.510	0.467	0.363	0.341	0.411
9	0.367	0.363	0.346	0.333	0.335	0.347	0.357	0.406	0.464	0.510	0.467	0.363	0.341	0.411
10	0.367	0.363	0.346	0.333	0.335	0.347	0.357	0.406	0.464	0.510	0.467	0.363	0.341	0.411
11	0.367	0.363	0.346	0.333	0.335	0.347	0.357	0.406	0.464	0.510	0.467	0.363	0.341	0.411
12	0.367	0.363	0.346	0.333	0.335	0.347	0.357	0.406	0.464	0.510	0.467	0.363	0.341	0.411

	year												
age	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
0	0.005	0.004	0.004	0.004	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002
1	0.016	0.015	0.015	0.014	0.014	0.013	0.013	0.014	0.013	0.012	0.012	0.012	0.011
2	0.041	0.039	0.039	0.039	0.040	0.041	0.042	0.043	0.045	0.046	0.049	0.047	0.044
3	0.104	0.103	0.102	0.099	0.094	0.093	0.102	0.102	0.109	0.114	0.112	0.110	0.105
4	0.176	0.182	0.183	0.179	0.173	0.178	0.180	0.165	0.177	0.180	0.160	0.145	0.138
5	0.254	0.247	0.246	0.237	0.232	0.230	0.248	0.226	0.218	0.225	0.231	0.239	0.244
6	0.303	0.298	0.282	0.276	0.262	0.253	0.269	0.263	0.236	0.228	0.243	0.254	0.270
7	0.403	0.347	0.335	0.333	0.302	0.303	0.292	0.272	0.229	0.226	0.229	0.219	0.296
8	0.403	0.347	0.335	0.333	0.302	0.303	0.292	0.272	0.229	0.226	0.229	0.219	0.296
9	0.403	0.347	0.335	0.333	0.302	0.303	0.292	0.272	0.229	0.226	0.229	0.219	0.296
10	0.403	0.347	0.335	0.333	0.302	0.303	0.292	0.272	0.229	0.226	0.229	0.219	0.296
11	0.403	0.347	0.335	0.333	0.302	0.303	0.292	0.272	0.229	0.226	0.229	0.219	0.296
12	0.403	0.347	0.335	0.333	0.302	0.303	0.292	0.272	0.229	0.226	0.229	0.219	0.296

Table 8.7.5.1. NE Atlantic Mackerel. Comparison of estimated SAM parameters (and uncertainty) between the 2021 WGIWDE assessment and an assessment starting at age 2.

	parameters values			parameter standard deviation		
	current	Age 2	% difference	current	Age 2	% difference
observation standard deviations						
Catches age 0	0.91	X		0.18	X	
Catches age 1	0.36	X		0.23	X	
Catches age 2-12	0.11	0.11	3%	0.16	0.15	-9%
Egg survey	0.31	0.32	1%	0.26	0.26	0%
Recruitment index	0.28	X		0.30	X	
IESSNS age 3	0.65	0.61	-5%	0.24	0.24	-1%
IESSNS ages 4-11	0.39	0.39	2%	0.14	0.14	3%
Recapture overdispersion tags	4.33	4.25	-2%	0.25	0.24	-2%
process variances						
F age 0	0.25	X		0.49	X	
F age 1	0.15	X		0.49	X	
F age 2+	0.13	0.16	24%	0.19	0.14	-24%
Rec Var	0.16	0.55	246%	0.74	0.15	-80%
Proc Err Var	0.21	0.18	-16%	0.09	0.10	14%
catchabilities						
egg survey	1.22	1.23	1%	0.11	0.11	-1%
recruitment index	0.00	X		0.13	X	
IESSNS age 3	0.82	0.87	6%	0.23	0.22	-5%
IESSNS age 4	1.25	1.26	1%	0.16	0.16	-2%
IESSNS age 5	1.71	1.68	-2%	0.16	0.16	-1%
IESSNS age 6	1.83	1.79	-2%	0.16	0.16	-1%
IESSNS age 7	1.95	1.96	0%	0.16	0.16	0%
IESSNS age 8	1.85	1.86	1%	0.16	0.16	0%
IESSNS age 9	1.95	1.96	1%	0.16	0.16	0%
IESSNS ages 10-11	1.76	1.77	0%	0.16	0.16	0%

	parameters values			parameter standard deviation		
	current	Age 2	% difference	current	Age 2	% difference
logitReleaseSurvival_0	0.67	0.64	-4%	0.11	0.10	-10%
logitReleaseSurvival_1	0.17	0.17	2%	0.11	0.11	-4%

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	Exploita-tion pat-tern	Weights in the catch
2021								
0	4367513	0.15	0.000	0.000	0.301	0.000	0.002	0.060
1	4935722	0.15	0.092	0.502	0.301	0.067	0.012	0.144
2	4631377	0.15	0.443	0.182	0.301	0.197	0.047	0.264
3	2123273	0.15	0.905	0.182	0.301	0.256	0.110	0.313
4	1673559	0.15	0.998	0.182	0.301	0.289	0.149	0.358
5	1724965	0.15	1.000	0.271	0.301	0.324	0.239	0.391
6	418933	0.15	1.000	0.271	0.301	0.345	0.256	0.419
7	948935	0.15	1.000	0.271	0.301	0.362	0.247	0.437
8	612978	0.15	1.000	0.271	0.301	0.377	0.247	0.453
9	700155	0.15	1.000	0.271	0.301	0.395	0.247	0.471
10	741590	0.15	1.000	0.271	0.301	0.423	0.247	0.495
11	696832	0.15	1.000	0.271	0.301	0.438	0.247	0.513
12+	784248	0.15	1.000	0.271	0.301	0.486	0.247	0.543
2022								
0	4367513	0.15	0.000	0.000	0.301	0.000	0.002	0.060
1	-	0.15	0.092	0.502	0.301	0.067	0.012	0.144
2	-	0.15	0.443	0.182	0.301	0.197	0.047	0.264
3	-	0.15	0.905	0.182	0.301	0.256	0.110	0.313
4	-	0.15	0.998	0.182	0.301	0.289	0.149	0.358
5	-	0.15	1.000	0.271	0.301	0.324	0.239	0.391
6	-	0.15	1.000	0.271	0.301	0.345	0.256	0.419

	Stock Numbers	M	Maturity ogive	Prop of F before spw.	Prop of M before spw.	Weights in the stock	Exploita-tion pat-tern	Weights in the catch
7	-	0.15	1.000	0.271	0.301	0.362	0.247	0.437
8	-	0.15	1.000	0.271	0.301	0.377	0.247	0.453
9	-	0.15	1.000	0.271	0.301	0.395	0.247	0.471
10	-	0.15	1.000	0.271	0.301	0.423	0.247	0.495
11	-	0.15	1.000	0.271	0.301	0.438	0.247	0.513
12+	-	0.15	1.000	0.271	0.301	0.486	0.247	0.543
2023								
0	4367513	0.15	0.000	0.000	0.301	0.000	0.002	0.060
1	-	0.15	0.092	0.502	0.301	0.067	0.012	0.144
2	-	0.15	0.443	0.182	0.301	0.197	0.047	0.264
3	-	0.15	0.905	0.182	0.301	0.256	0.110	0.313
4	-	0.15	0.998	0.182	0.301	0.289	0.149	0.358
5	-	0.15	1.000	0.271	0.301	0.324	0.239	0.391
6	-	0.15	1.000	0.271	0.301	0.345	0.256	0.419
7	-	0.15	1.000	0.271	0.301	0.362	0.247	0.437
8	-	0.15	1.000	0.271	0.301	0.377	0.247	0.453
9	-	0.15	1.000	0.271	0.301	0.395	0.247	0.471
10	-	0.15	1.000	0.271	0.301	0.423	0.247	0.495
11	-	0.15	1.000	0.271	0.301	0.438	0.247	0.513
12+	-	0.15	1.000	0.271	0.301	0.486	0.247	0.543

Table 8.8.3.2. NE Atlantic Mackerel. Short-term prediction: Multi-option table for 1 199 103 t catch in 2021 and a range of F-values in 2022.

2021			
TSB	SSB	F_{bar}	Catch
4 828 401	3 510 849	0.354	1 199 103

2022				2023		
TSB	SSB	Fbar	Catch	TSB	SSB	Implied change in the catch
4419995	3479949	0.00	0	4918697	4056937	-100.0%
-	3473113	0.01	33966	4890260	4022211	-97.2%
-	3466295	0.02	67639	4862072	3987876	-94.4%
-	3459494	0.03	101023	4834131	3953927	-91.6%
-	3452710	0.04	134118	4806433	3920358	-88.8%
-	3445943	0.05	166930	4778976	3887167	-86.1%
-	3439194	0.06	199460	4751758	3854347	-83.4%
-	3432461	0.07	231710	4724778	3821894	-80.7%
-	3425746	0.08	263685	4698031	3789803	-78.0%
-	3419048	0.09	295386	4671516	3758070	-75.4%
-	3412366	0.10	326816	4645232	3726691	-72.7%
-	3405702	0.11	357978	4619174	3695661	-70.1%
-	3399055	0.12	388874	4593342	3664975	-67.6%
-	3392424	0.13	419507	4567733	3634630	-65.0%
-	3385810	0.14	449879	4542345	3604621	-62.5%
-	3379213	0.15	479994	4517176	3574945	-60.0%
-	3372633	0.16	509853	4492223	3545596	-57.5%
-	3366070	0.17	539459	4467485	3516571	-55.0%
-	3359522	0.18	568814	4442959	3487866	-52.6%
-	3352992	0.19	597921	4418643	3459476	-50.1%
-	3346478	0.20	626783	4394536	3431399	-47.7%
-	3339981	0.21	655400	4370635	3403630	-45.3%
-	3333500	0.22	683777	4346938	3376165	-43.0%

2022				2023		
TSB	**SSB**	**Fbar**	**Catch**	**TSB**	**SSB**	**Implied change in the catch**
-	3327035	0.23	711915	4323443	3349000	-40.6%
-	3320587	0.24	739817	4300148	3322132	-38.3%
-	3314155	0.25	767485	4277052	3295558	-36.0%
-	3307739	0.26	794920	4254153	3269273	-33.7%
-	3301339	0.27	822126	4231447	3243274	-31.4%
-	3294956	0.28	849105	4208935	3217558	-29.2%
-	3288588	0.29	875858	4186613	3192120	-27.0%
-	3282237	0.30	902388	4164480	3166958	-24.7%
-	3275902	0.31	928697	4142534	3142068	-22.6%
-	3269583	0.32	954787	4120773	3117447	-20.4%
-	3263279	0.33	980661	4099195	3093092	-18.2%
-	3256992	0.34	1006320	4077800	3068999	-16.1%
-	3250720	0.35	1031766	4056584	3045165	-14.0%
-	3244464	0.36	1057002	4035546	3021586	-11.9%
-	3238224	0.37	1082029	4014685	2998261	-9.8%
-	3232000	0.38	1106849	3993998	2975185	-7.7%
-	3225791	0.39	1131465	3973485	2952356	-5.6%
-	3219598	0.40	1155878	3953143	2929770	-3.6%
-	3213421	0.41	1180091	3932971	2907425	-1.6%
-	3207259	0.42	1204104	3912966	2885318	0.4%
-	3201112	0.43	1227921	3893129	2863446	2.4%
-	3194981	0.44	1251543	3873456	2841805	4.4%
-	3188866	0.45	1274971	3853946	2820394	6.3%
-	3182766	0.46	1298209	3834598	2799209	8.3%
-	3176681	0.47	1321256	3815410	2778247	10.2%
-	3170611	0.48	1344116	3796381	2757507	12.1%
-	3164557	0.49	1366790	3777509	2736984	14.0%
-	3158517	0.50	1389280	3758793	2716677	15.9%

2022				2023		
TSB	SSB	Fbar	Catch	TSB	SSB	Implied change in the catch
-	3152493	0.51	1411587	3740231	2696584	17.7%
-	3146484	0.52	1433714	3721821	2676700	19.6%
-	3140491	0.53	1455662	3703563	2657024	21.4%
-	3134512	0.54	1477432	3685454	2637554	23.2%
-	3128548	0.55	1499027	3667494	2618287	25.0%
-	3122599	0.56	1520448	3649680	2599219	26.8%
-	3116665	0.57	1541696	3632012	2580350	28.6%
-	3110746	0.58	1562774	3614488	2561677	30.3%
-	3104841	0.59	1583682	3597107	2543196	32.1%
-	3098952	0.60	1604424	3579867	2524907	33.8%
-	3093077	0.61	1624999	3562767	2506806	35.5%
-	3087217	0.62	1645410	3545806	2488892	37.2%
-	3081371	0.63	1665658	3528982	2471162	38.9%
-	3075540	0.64	1685745	3512294	2453613	40.6%
-	3069724	0.65	1705672	3495741	2436245	42.2%
-	3063922	0.66	1725441	3479322	2419054	43.9%
-	3058135	0.67	1745053	3463035	2402038	45.5%
-	3052362	0.68	1764509	3446878	2385196	47.2%
-	3046603	0.69	1783812	3430852	2368525	48.8%
-	3040859	0.70	1802963	3414954	2352024	50.4%
-	3035130	0.71	1821962	3399183	2335689	51.9%
-	3029414	0.72	1840812	3383538	2319520	53.5%
-	3023713	0.73	1859513	3368018	2303514	55.1%
-	3018026	0.74	1878068	3352622	2287670	56.6%
-	3012353	0.75	1896478	3337349	2271985	58.2%
-	3006694	0.76	1914743	3322196	2256458	59.7%
-	3001050	0.77	1932866	3307164	2241086	61.2%
-	2995419	0.78	1950847	3292252	2225868	62.7%

2022				2023		
TSB	**SSB**	**Fbar**	**Catch**	**TSB**	**SSB**	**Implied change in the catch**
-	2989803	0.79	1968688	3277457	2210802	64.2%
-	2984200	0.80	1986391	3262779	2195887	65.7%
-	2978611	0.81	2003955	3248217	2181120	67.1%
-	2973037	0.82	2021384	3233769	2166499	68.6%
-	2967476	0.83	2038678	3219436	2152024	70.0%
-	2961929	0.84	2055838	3205214	2137692	71.4%
-	2956395	0.85	2072865	3191105	2123501	72.9%
-	2950876	0.86	2089761	3177105	2109450	74.3%
-	2945370	0.87	2106528	3163215	2095538	75.7%
-	2939878	0.88	2123165	3149434	2081762	77.1%
-	2934399	0.89	2139675	3135760	2068122	78.4%
-	2928934	0.90	2156058	3122192	2054615	79.8%
-	2923483	0.91	2172316	3108730	2041239	81.2%
-	2918045	0.92	2188450	3095372	2027994	82.5%
-	2912621	0.93	2204460	3082118	2014878	83.8%
-	2907210	0.94	2220349	3068966	2001890	85.2%
-	2901812	0.95	2236118	3055916	1989027	86.5%
-	2896428	0.96	2251766	3042966	1976289	87.8%
-	2891057	0.97	2267296	3030116	1963673	89.1%
-	2885700	0.98	2282709	3017364	1951180	90.4%
-	2880355	0.99	2298005	3004711	1938806	91.6%
-	2875024	1.00	2313186	2992154	1926551	92.9%
-	2869706	1.01	2328252	2979694	1914413	94.2%
-	2864402	1.02	2343205	2967328	1902392	95.4%
-	2859110	1.03	2358047	2955057	1890485	96.7%
-	2853831	1.04	2372777	2942879	1878691	97.9%
-	2848566	1.05	2387396	2930793	1867010	99.1%
-	2843313	1.06	2401907	2918800	1855439	100.3%

2022				2023		
TSB	SSB	Fbar	Catch	TSB	SSB	Implied change in the catch
-	2838074	1.07	2416310	2906897	1843978	101.5%
-	2832847	1.08	2430605	2895084	1832624	102.7%
-	2827634	1.09	2444794	2883360	1821378	103.9%

Table 8.8.3.3. NE Atlantic Mackerel. Short-term prediction: Management option table for 1 199 103 t catch in 2021 and a range of catch options in 2022.

Rationale	Catch (2022)	F_{bar} (2022)	SSB (2022)	SSB (2023)	% SSB change	% catch change	% advice change
MSY approach: F = FMSY	794920	0.26	3307739	3269273	-1.2	-33.7	-6.7
Catch (2022) = Zero	0	0	3479949	4056937	16.6	-100.0	-100.0
Catch (2022) = 2021 catch −20%	959282	0.32	3268490	3113212	-4.8	-20.0	12.6
Catch (2022) = 2021 catch	1199103	0.42	3208545	2889918	-9.9	0.0	40.7
Catch (2022) = 2021 catch +25%	1498879	0.55	3128589	2618418	-16.3	25.0	75.9
Fbar (2022) = Fbar (2021)	1041030	0.35	3248428	3036502	-6.5	-13.2	22.1
Fbar (2022) = 0.36 (Fpa)	1057002	0.36	3244464	3021586	-6.9	-11.9	24.0
Fbar (2022) = 0.46 (Flim)	1298209	0.46	3182766	2799209	-12.1	8.3	52.3
SSB (2023) = Blim	2220349	0.94	2907210	2001890	-31.2	85.4	160.8
SSB (2023) = Bpa	1541696	0.57	3116665	2580350	-17.3	28.8	81.2

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

**** Catch in 2022 relative to estimated catches in 2021 (1 199 103 t). There is no internationally agreed TAC for 2021.**

***** Advice value for 2022 relative to the advice value for 2021 (852 284 t).**

8.15 Figures

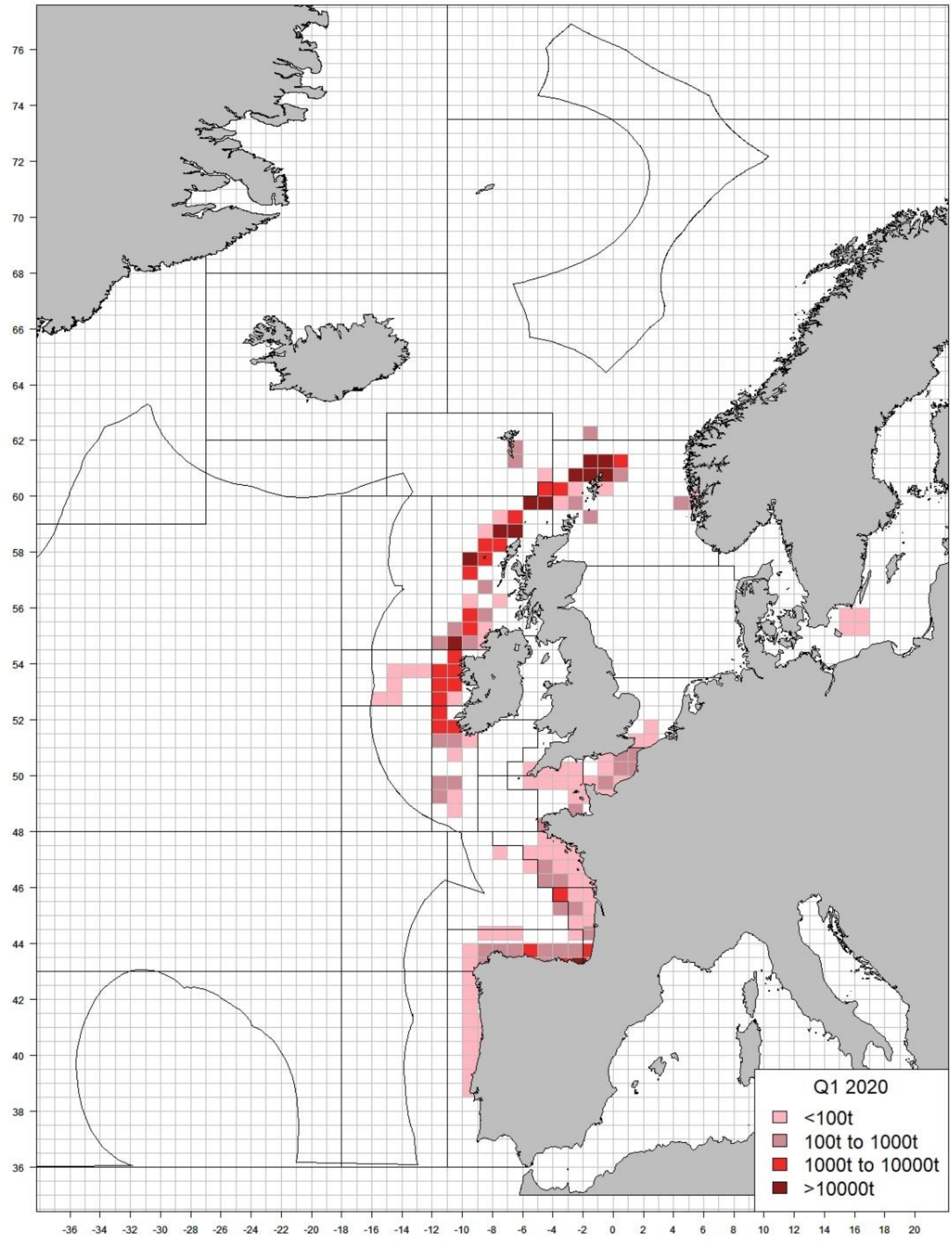


Figure 8.4.2.1. NE Atlantic Mackerel. Commercial catches in 2020, quarter 1.

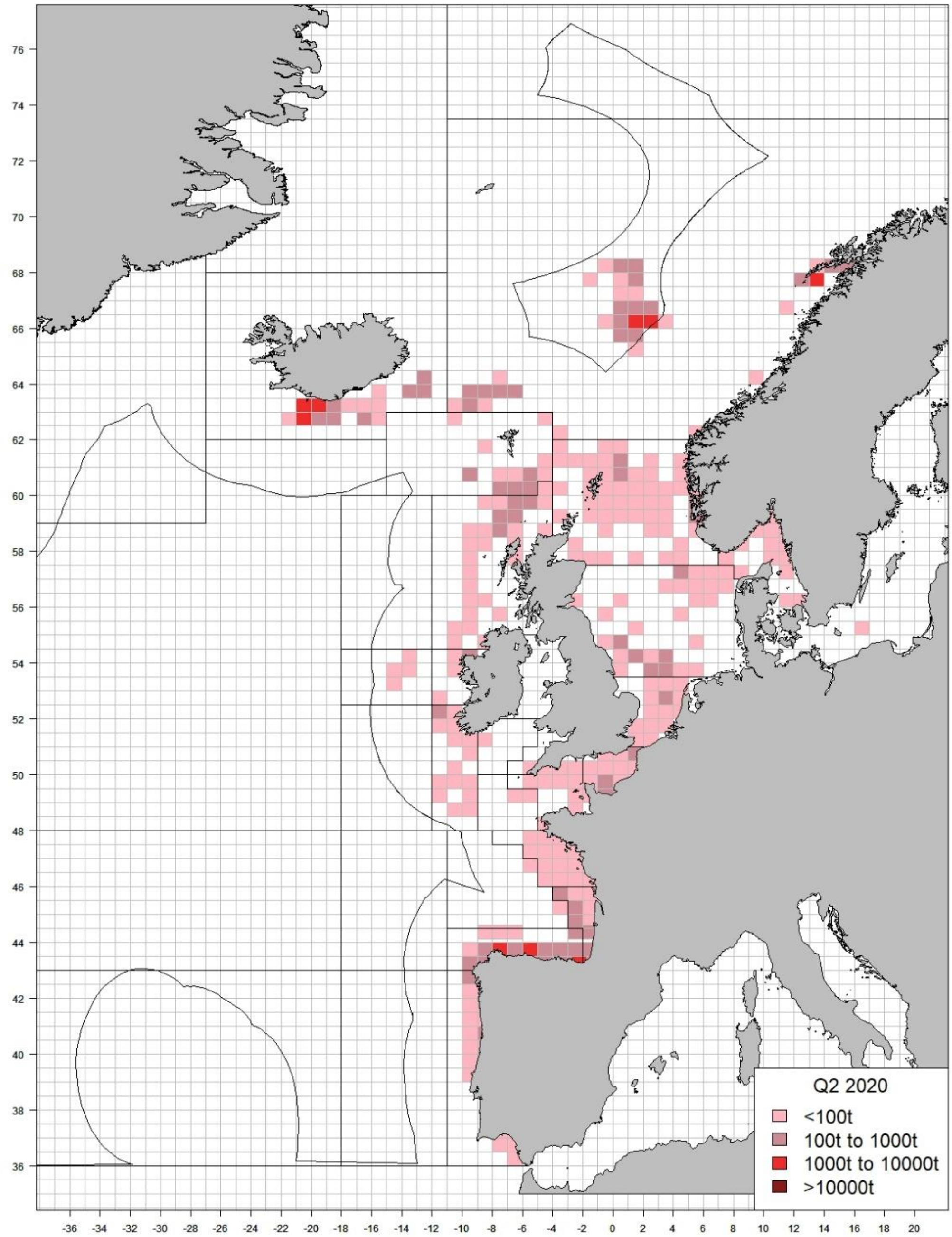


Figure 8.4.2.2. NE Atlantic Mackerel. Commercial catches in 2020, quarter 2.

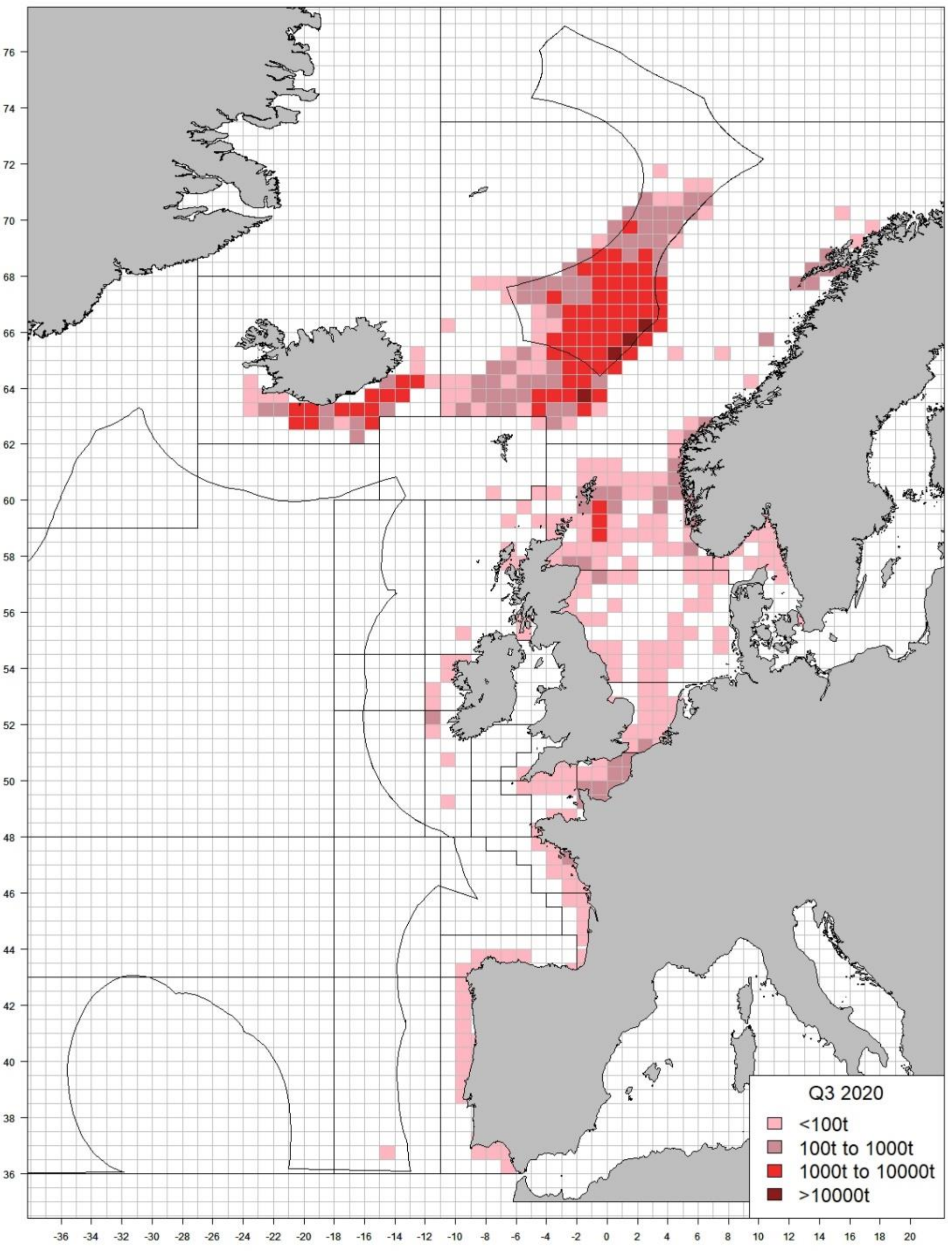


Figure 8.4.2.3. NE Atlantic Mackerel. Commercial catches in 2020, quarter 3.

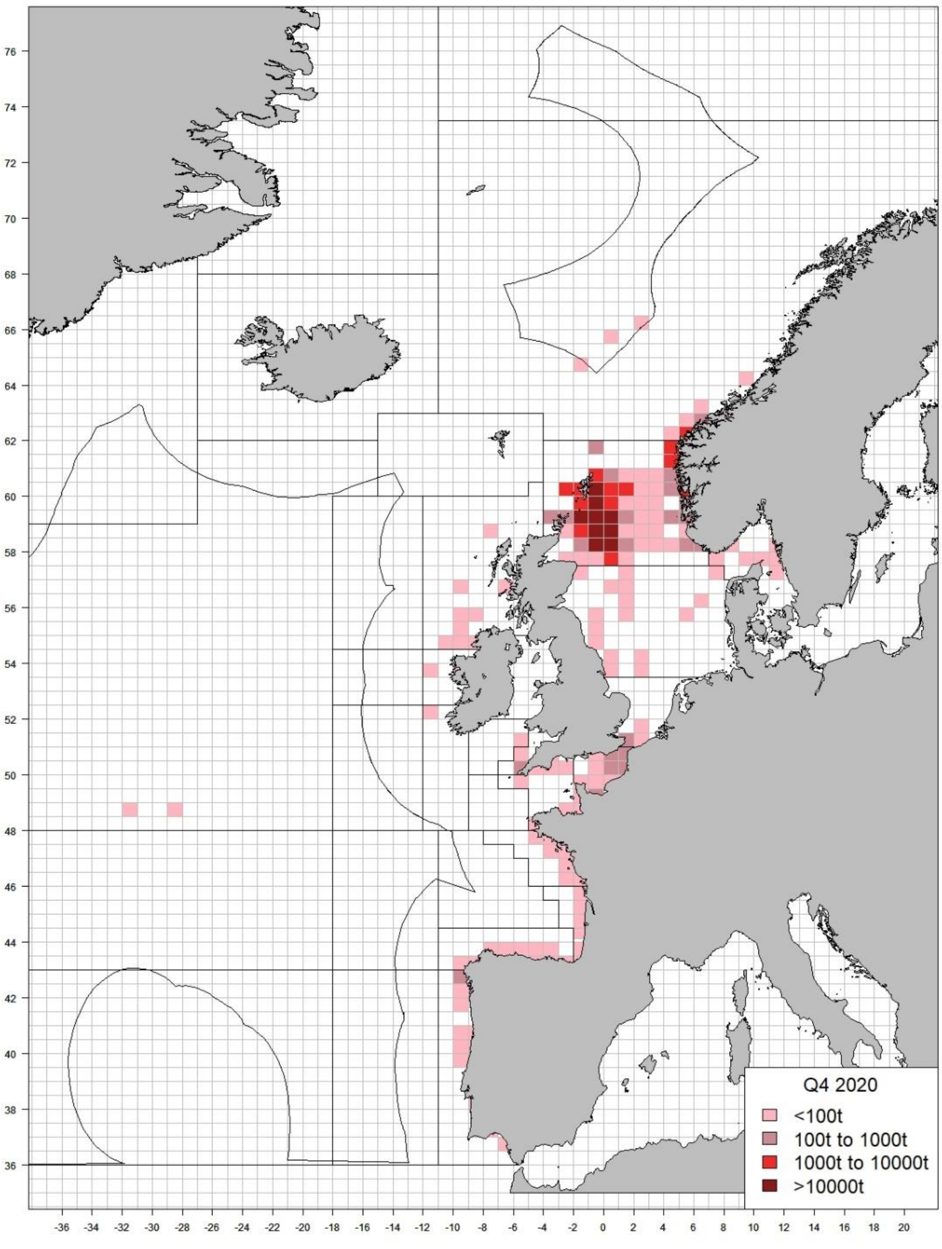


Figure 8.4.2.4. NE Atlantic Mackerel. Commercial catches in 2020, quarter 4.

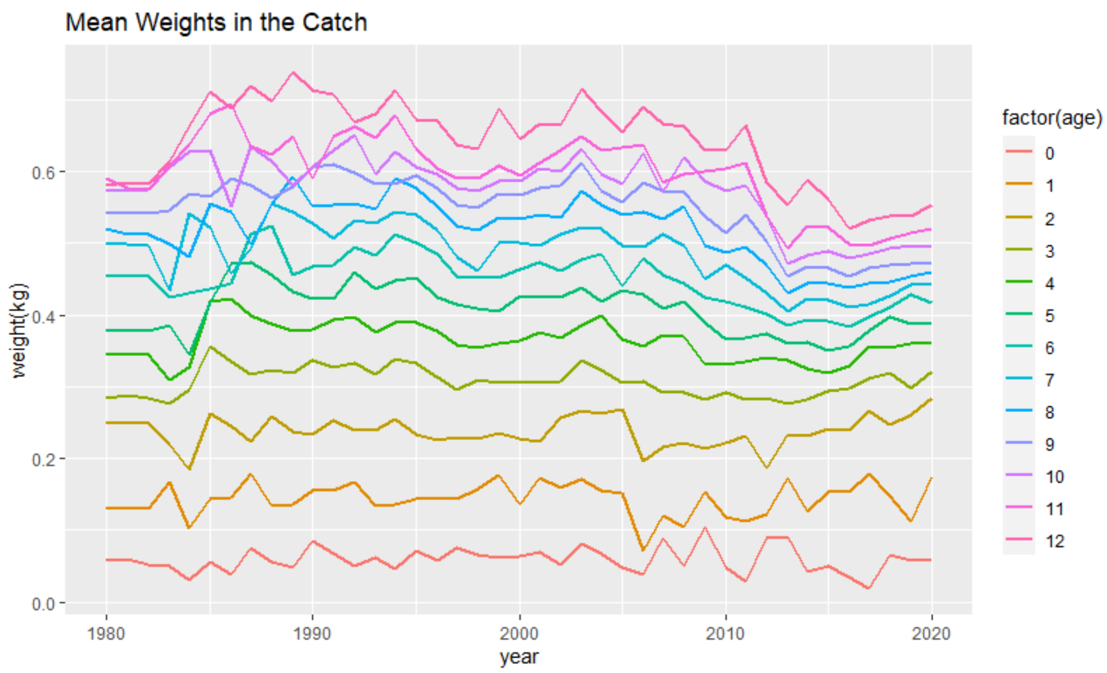


Figure 8.5.2.1. NE Atlantic mackerel. Weights-at-age in the catch.

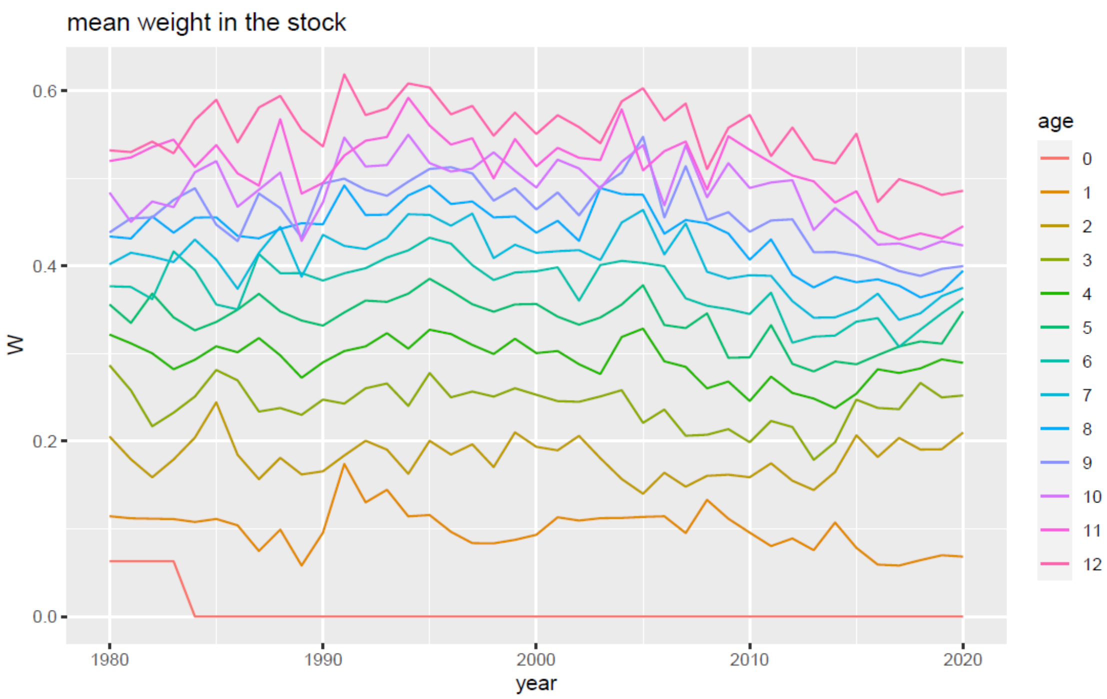


Figure 8.5.2.2. NE Atlantic mackerel. Weights-at-age in the stock.

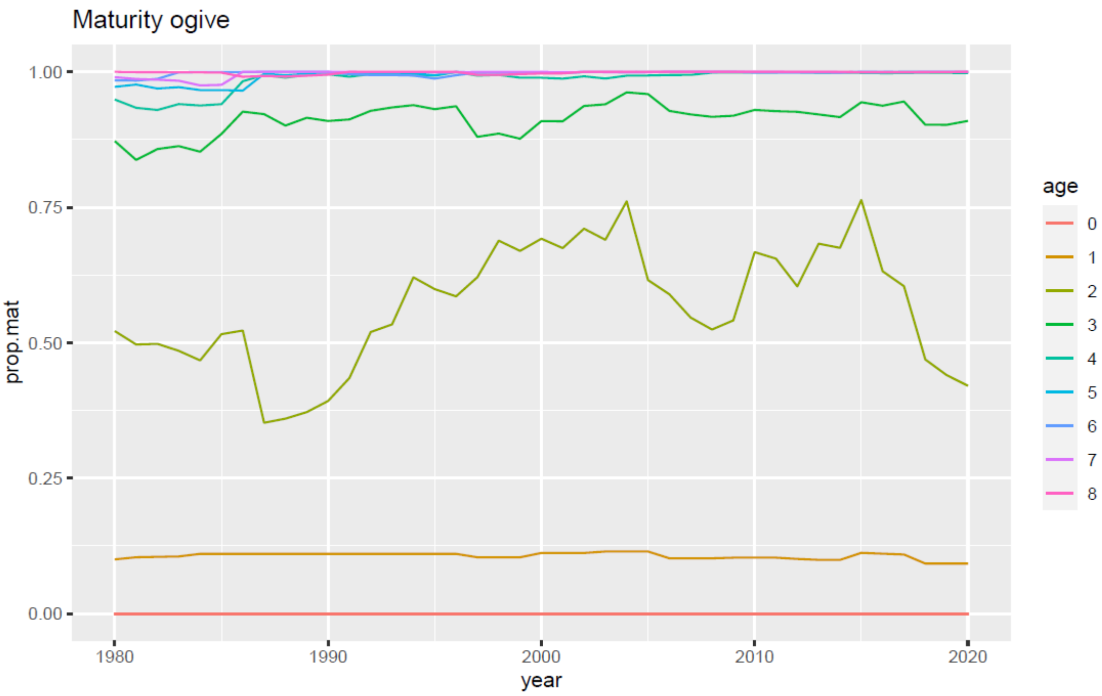


Figure 8.5.3.1. NE Atlantic mackerel. Proportion of mature fish at age.

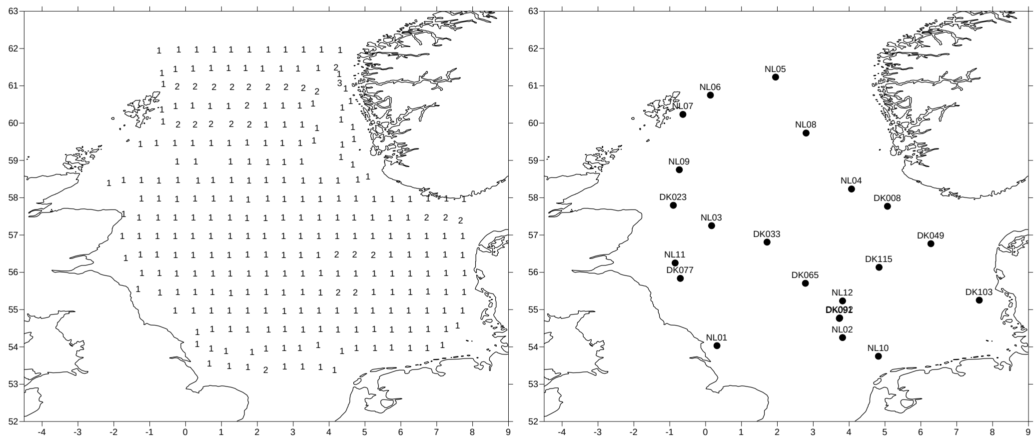


Figure 8.6.1.3.1. Number of samples for NSMEGS 2021; plankton samples per half ICES rectangle (left) and pelagic trawl hauls for mackerel adult samples (right).

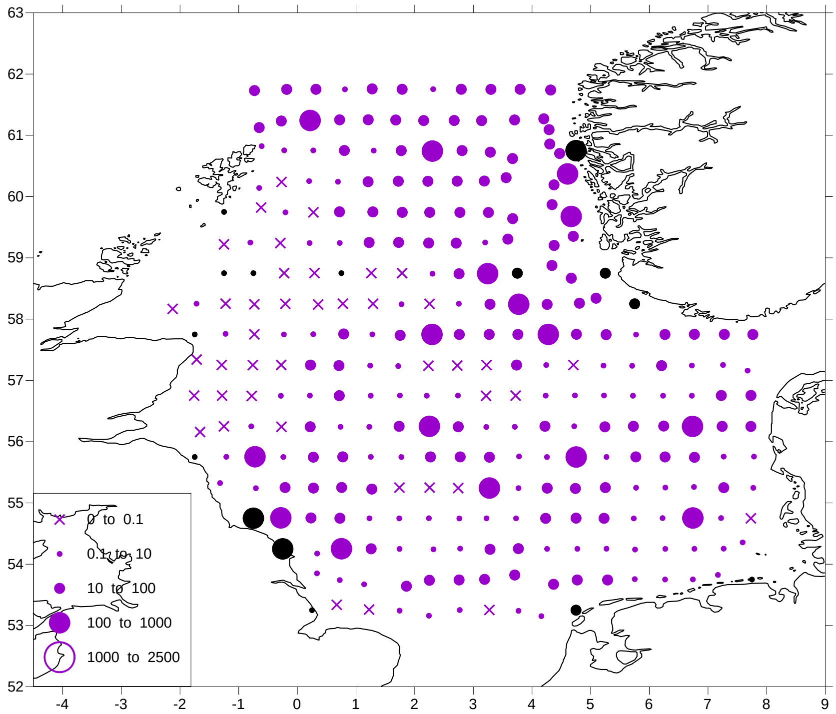


Figure 8.6.1.3.2. Stage 1A mackerel egg production (eggs/m²/day) by half rectangle for NSMEGS 2021. Purple circles represent observed values, black circles represent interpolated values, and crosses represent observed zeros.

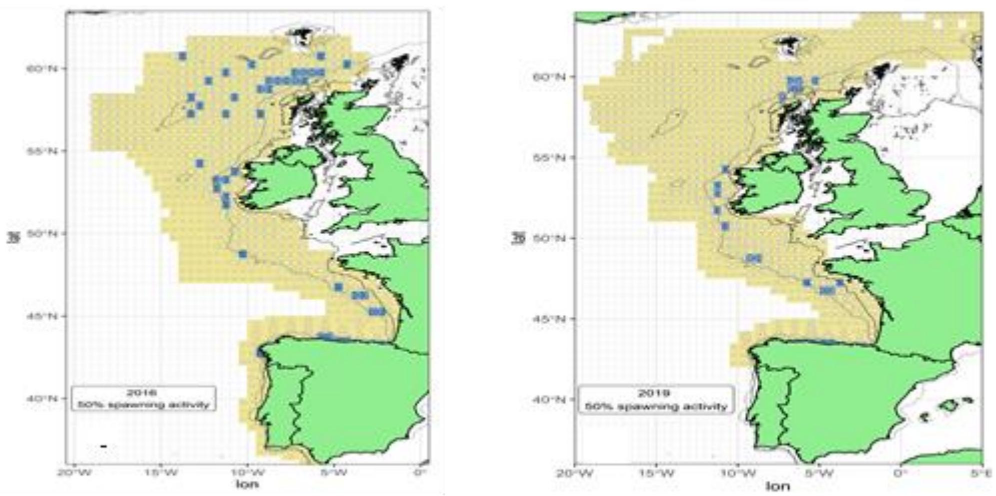


Figure 8.6.1.4.1.: Aggregated daily egg production values (stage 1 eggs/m2 /day) by half ICES rectangle for all MEGS stations sampled in 2016 and 2019 for all periods. Egg production values are square root transformed. Crosses denote locations where sampling was undertaken but where no spawning was recorded. Area in yellow denotes the maximum geographical survey extent for the western and southern survey area. Stations ranked in descending order and half ICES rectangles capturing 50% of total spawning activity overlaid in blue.

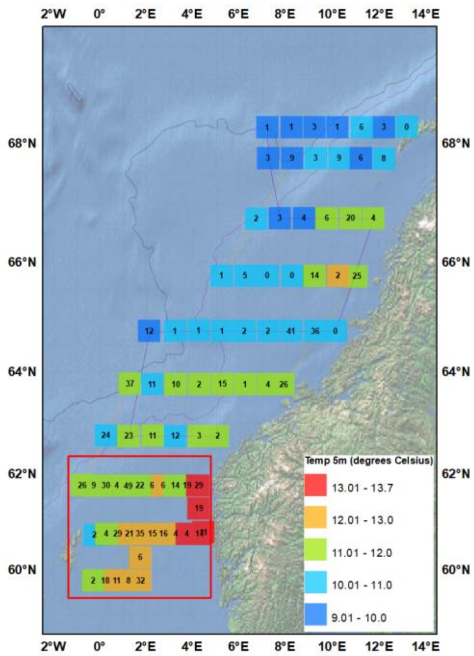


Figure 8.6.1.4.2.: Mackerel stage 1 egg counts/m^2/day survey 0321H, for all stations sampled. The coloured squares represent the surface temperature in degrees Celsius at 5m depth during the ichthyoplankton deployments. Red outlined area denotes stations completed as part of North Sea MEGS.

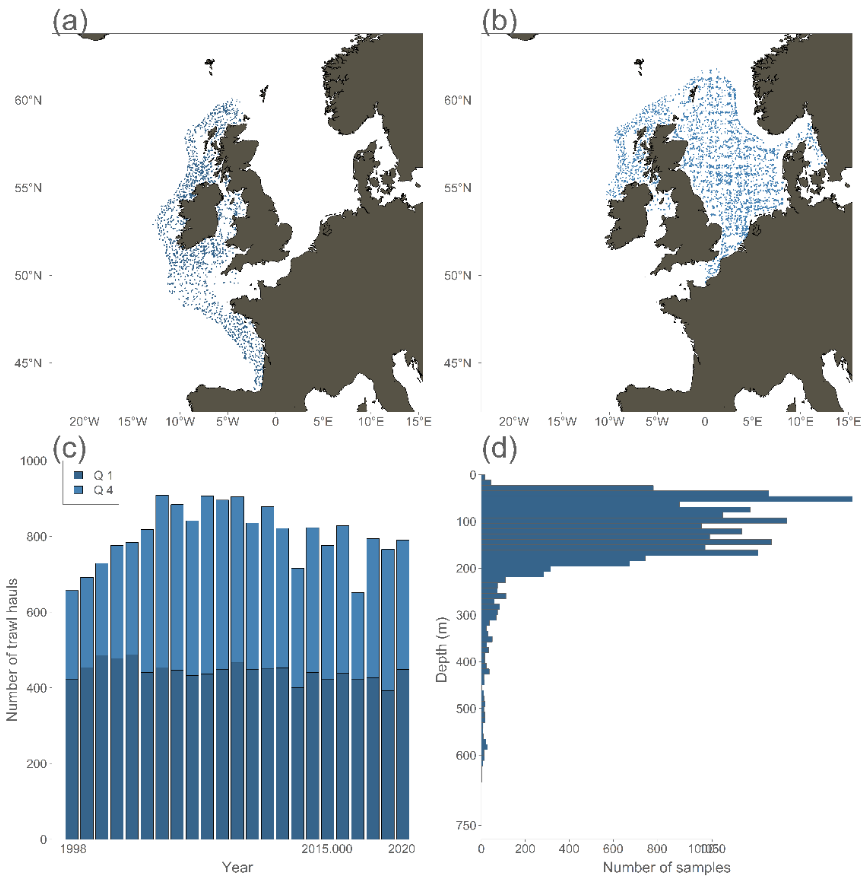


Figure 8.6.2.1. Demersal trawl survey data used to derive the abundance index of age-0 mackerel. (a) Trawl sample locations in the fourth quarter (Q4, October - November, blue dots); (b) trawl sample locations in the first quarter (Q1, January - March, light blue dots); (c) number of samples by year and quarter; and (d) depth.

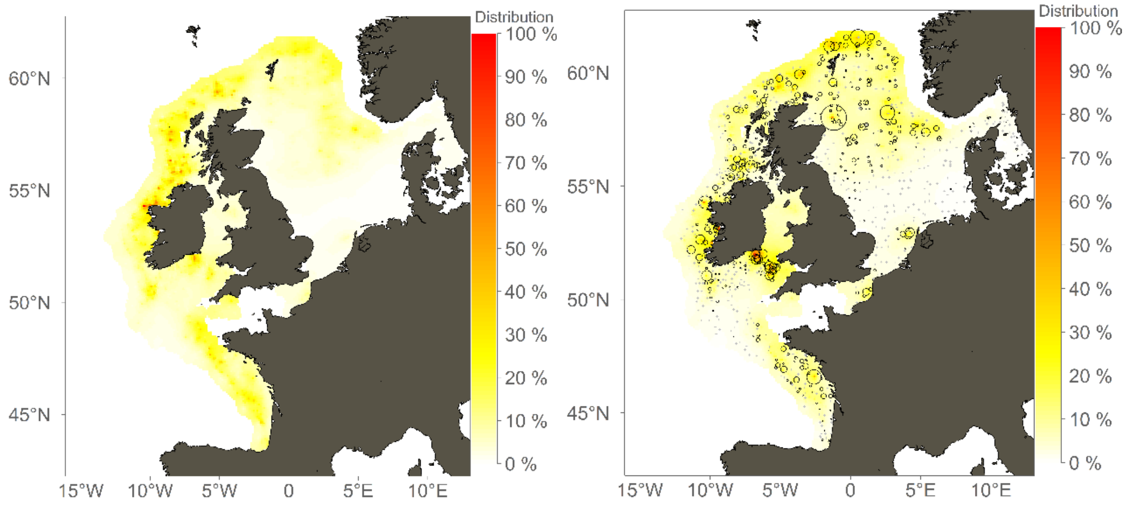


Figure 8.6.2.2. Spatial distribution of mackerel juveniles at age 0 in October to March. On the left, average for cohorts from 1998-2020; and on the right, 2020 cohort. Mackerel squared catch rates by trawl haul (circle areas represent catch rates in kg/km2) overlaid on modelled squared catch rates per 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.

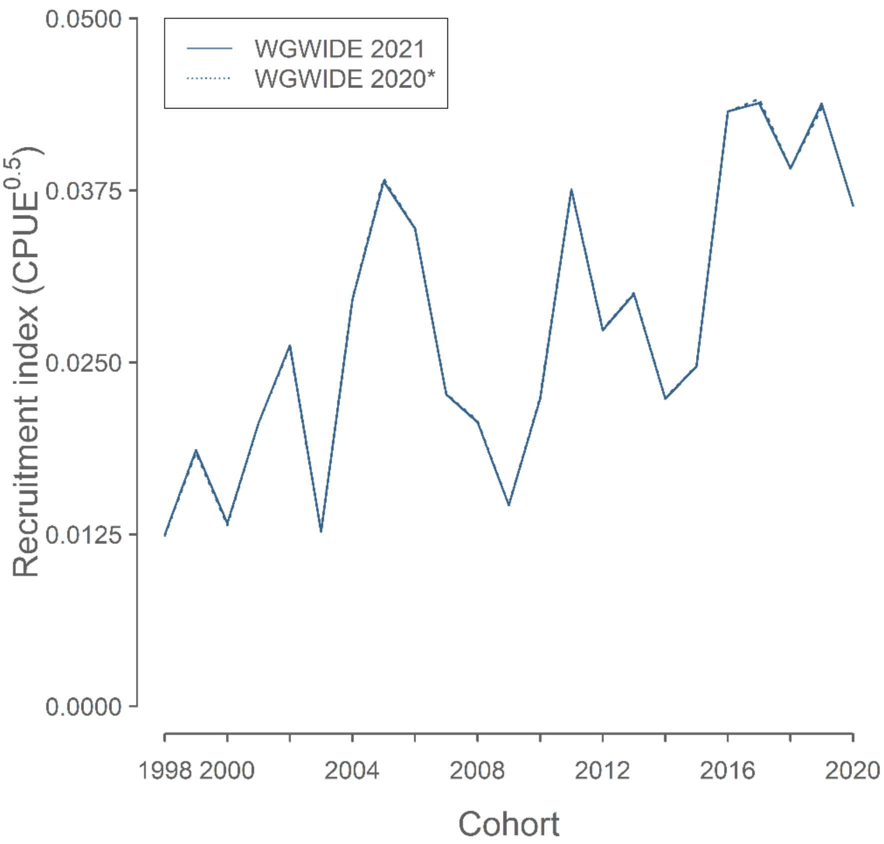


Figure 8.6.2.3. Index of mackerel juveniles at age 0 in October to March proxied by annual integration of square root of expected catch in demersal trawl surveys (Blue lines). See Jansen *et al.* (2015) for details. * Rescaled

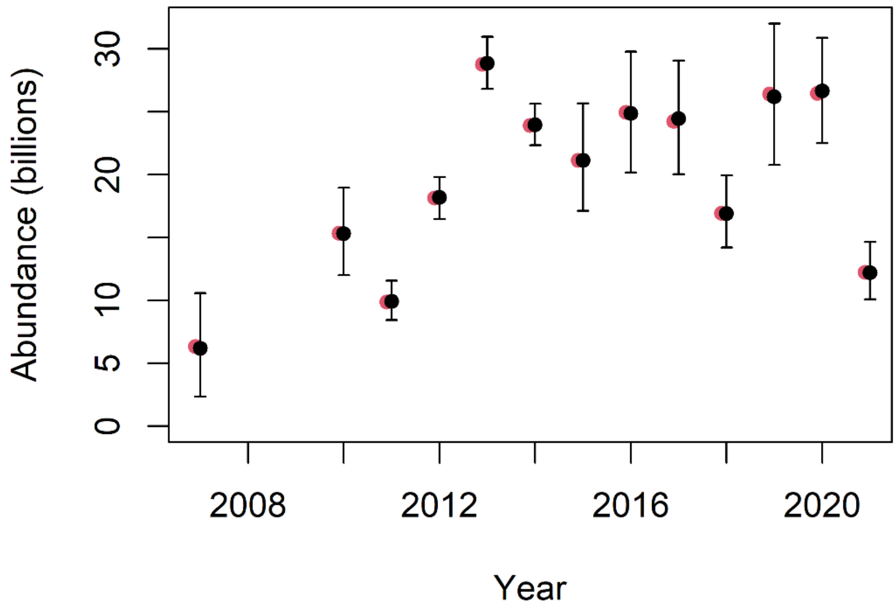


Figure 8.6.3.1. Estimated total stock numbers (TSN) of mackerel from IESSNS calculated using StoX for the years 2007 and from 2010 to 2021. Displayed is StoX baseline estimate (red dot) and a bootstrap estimate (black dot), calculated using 1000 replicates, with 90% confidence intervals (vertical line) based on the bootstrap. Analysis excludes the North Sea and survey coverage was incomplete in 2007 and 2011.

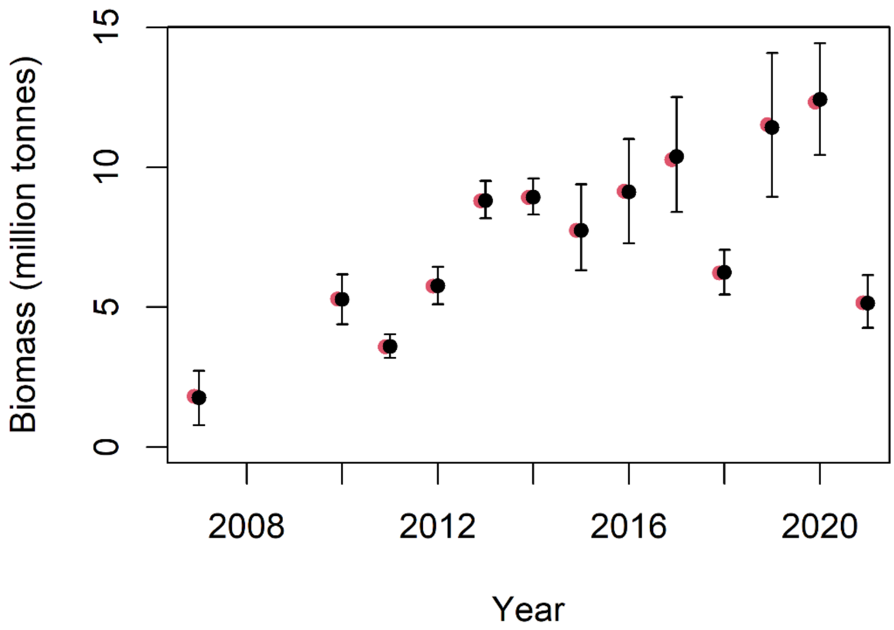


Figure 8.6.3.2. Estimated total stock biomass of mackerel from IESSNS calculated using StoX for the years 2007 and from 2010 to 2021. Displayed is StoX baseline estimate (red dot) and a bootstrap estimate (black dot), calculated using 1000 replicates, with 90% confidence intervals (vertical line) based on the bootstrap. Analysis excludes the North Sea and survey coverage was incomplete in 2007 and 2011.

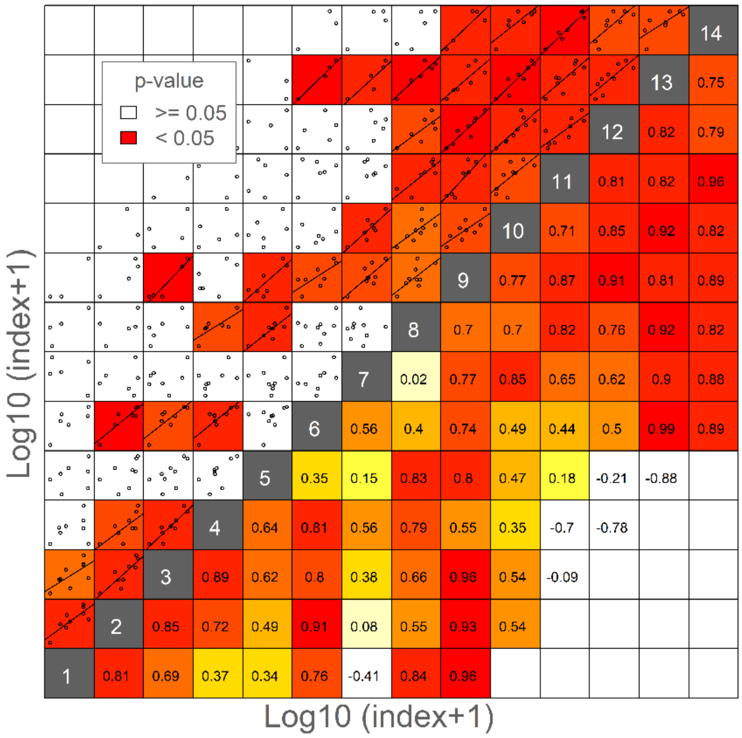


Figure 8.6.3.3. Internal consistency of the mackerel abundance index from the IESSNS surveys including data from 2012 to 2021, excluding North Sea. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (*p<0.05*) are indicated by regression lines and 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 2021, excluding the North Sea. Each cohort is marked by a uniquely coloured line that connects the estimates indicated by the respective ages.

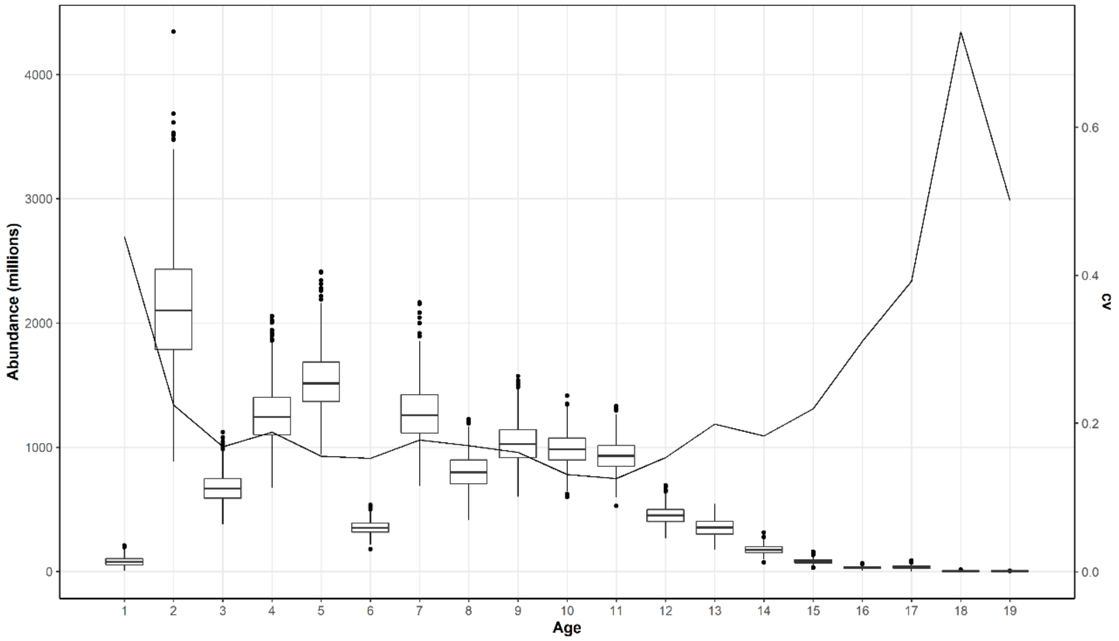


Figure 8.6.3.5. Mackerel numbers by age from the IESSNS survey in 2021, excluding North Sea. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using StoX version 3.10.

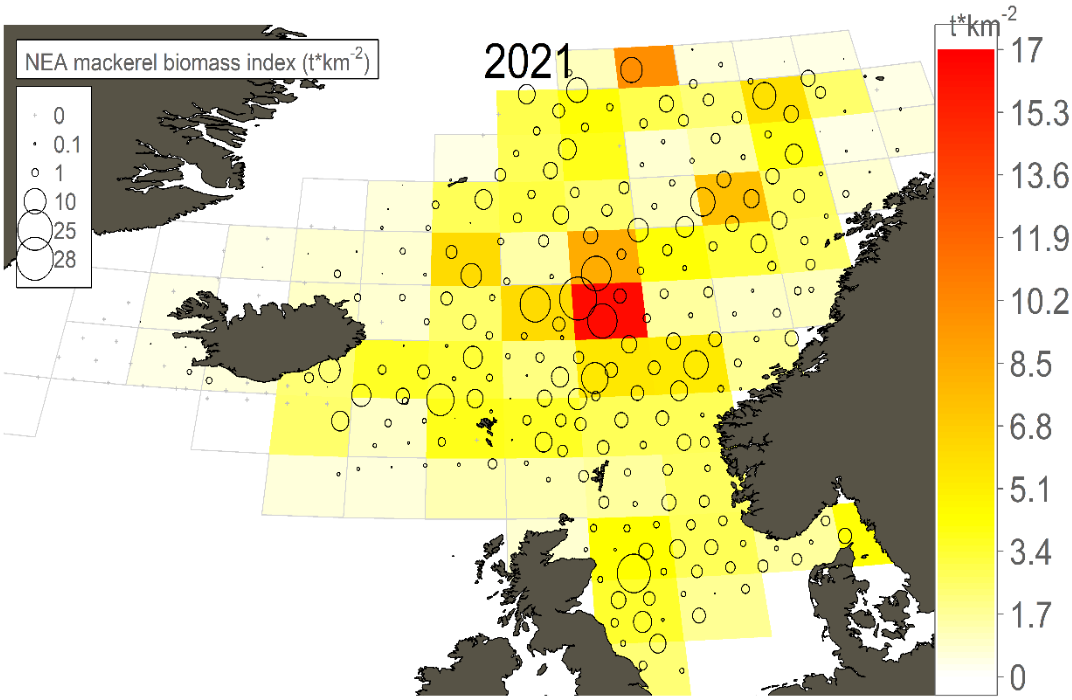


Figure 8.6.3.6. Mackerel catch rates from predetermined surface trawl stations (circle size represents catch rate in kg/km2) overlaid on mean catch rate per standardized rectangle (2° lat. x 4° lon.) from the 2021 IESSNS, including North Sea. Zero mackerel catches are displayed as grey crosses.

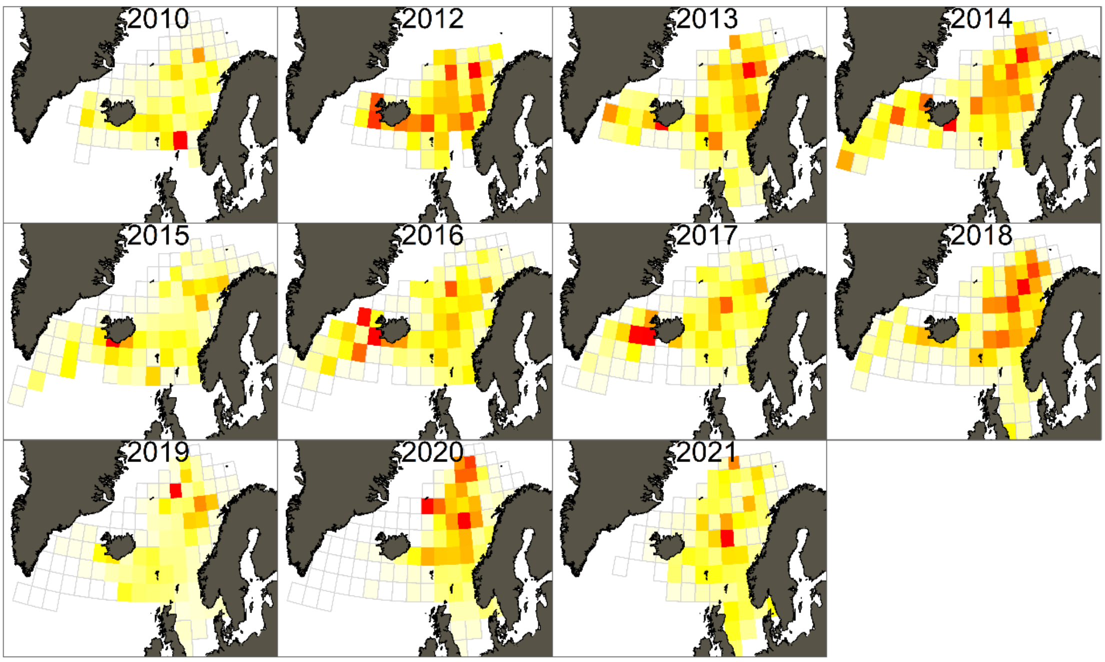


Figure 8.6.3.7. Mackerel annual distribution proxied by the absolute distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from predetermined surface trawl stations from IESSNS in 2010 to 2021, including North Sea. Colour scale goes from white (= 0) to red (= maximum value for the given year).

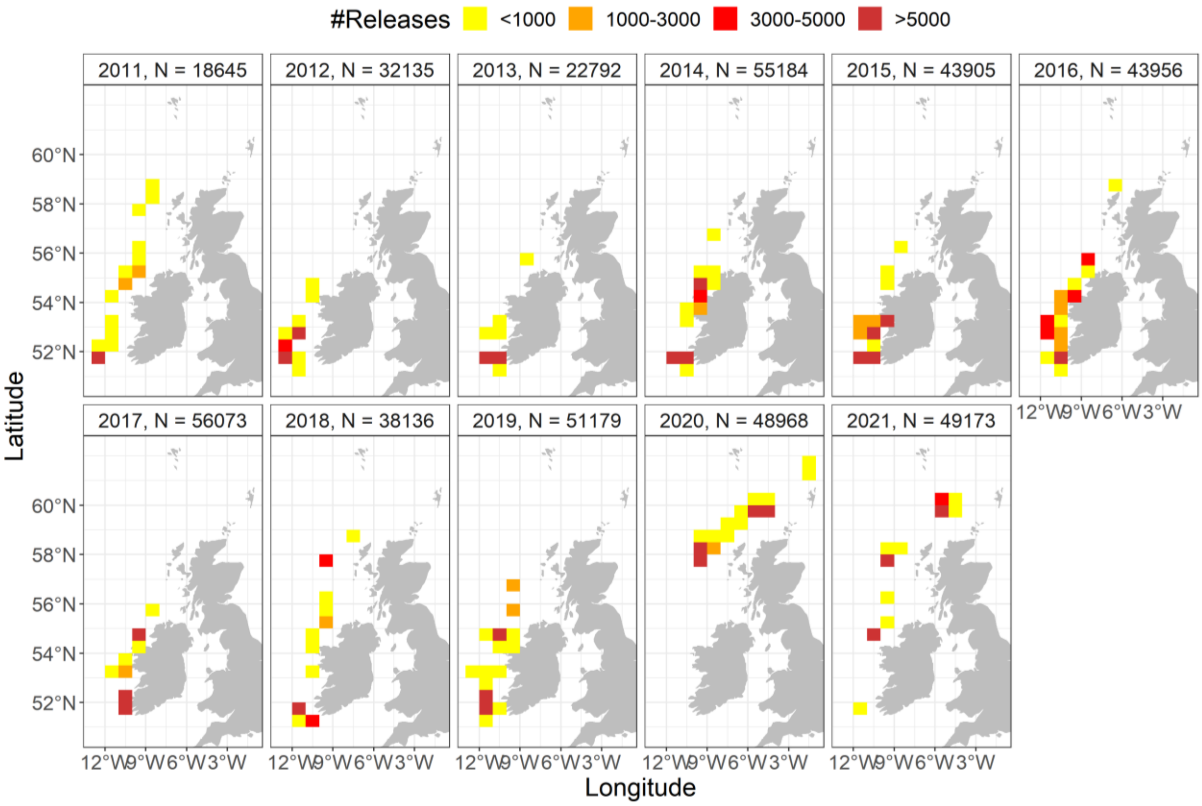


Figure 8.6.4.1. Number and distribution of RFID tagged mackerel from experiments west of Ireland and British Isles during 2011-2021. Note that data from releases 2011-2012 are not used in the stock assessment, based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019), and data from experiments in 2020-2021 are not included as there are no full years with recaptures yet.

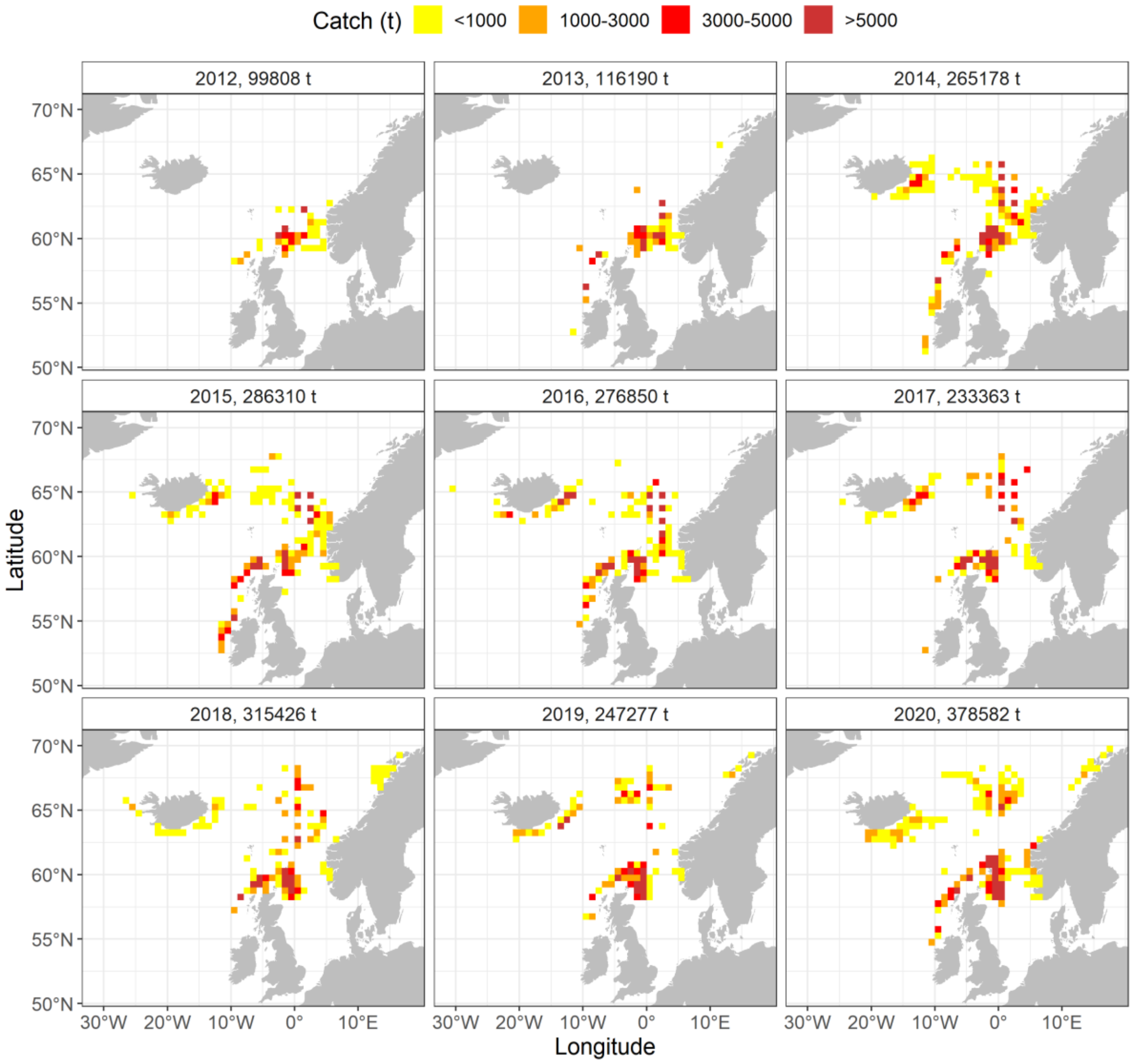


Figure 8.6.4.2. Biomass and distribution of catches scanned for RFID tagged mackerel during 2012-2020. Note that data from scanned catches in 2012-2013 are not used in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019).

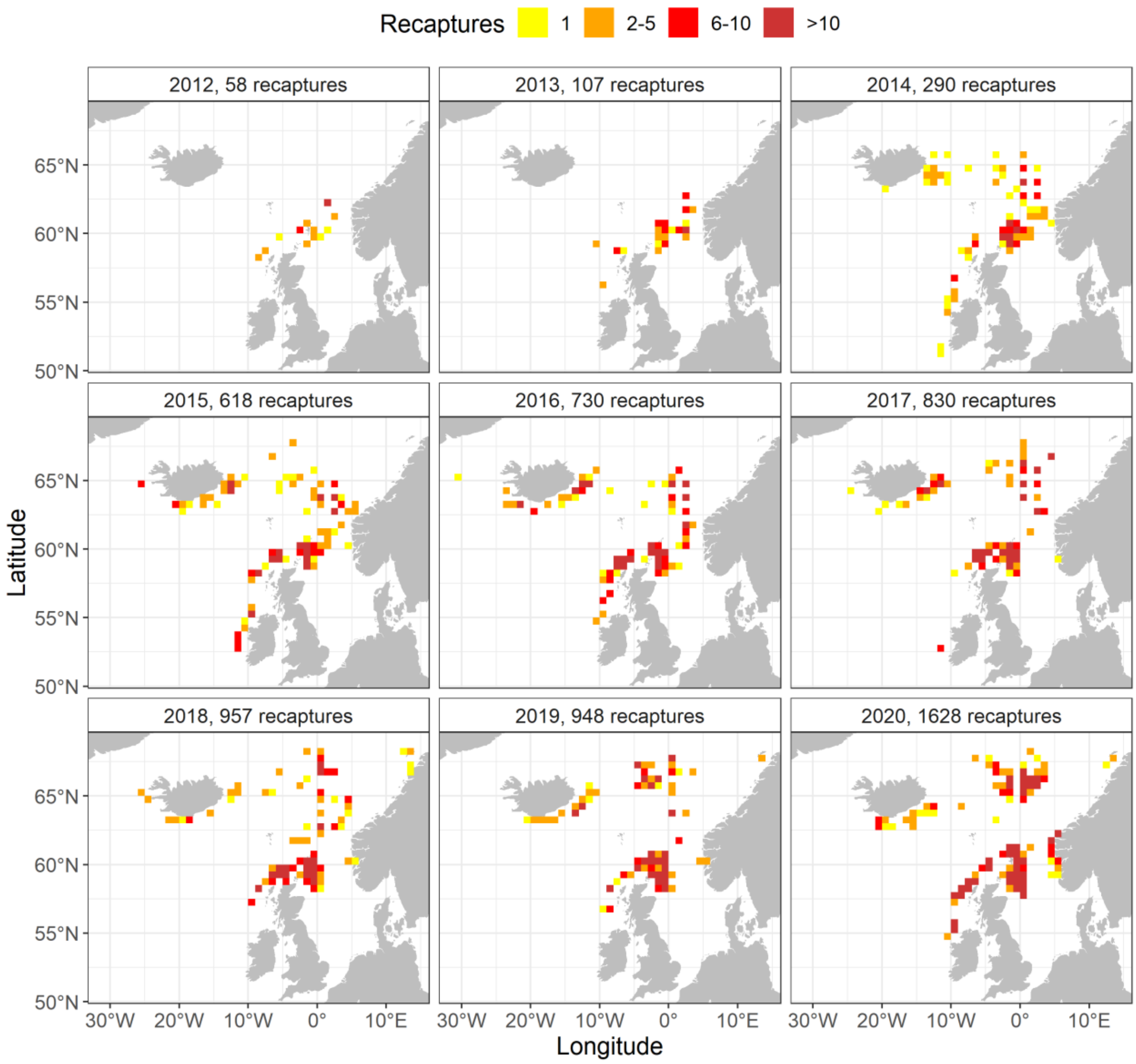
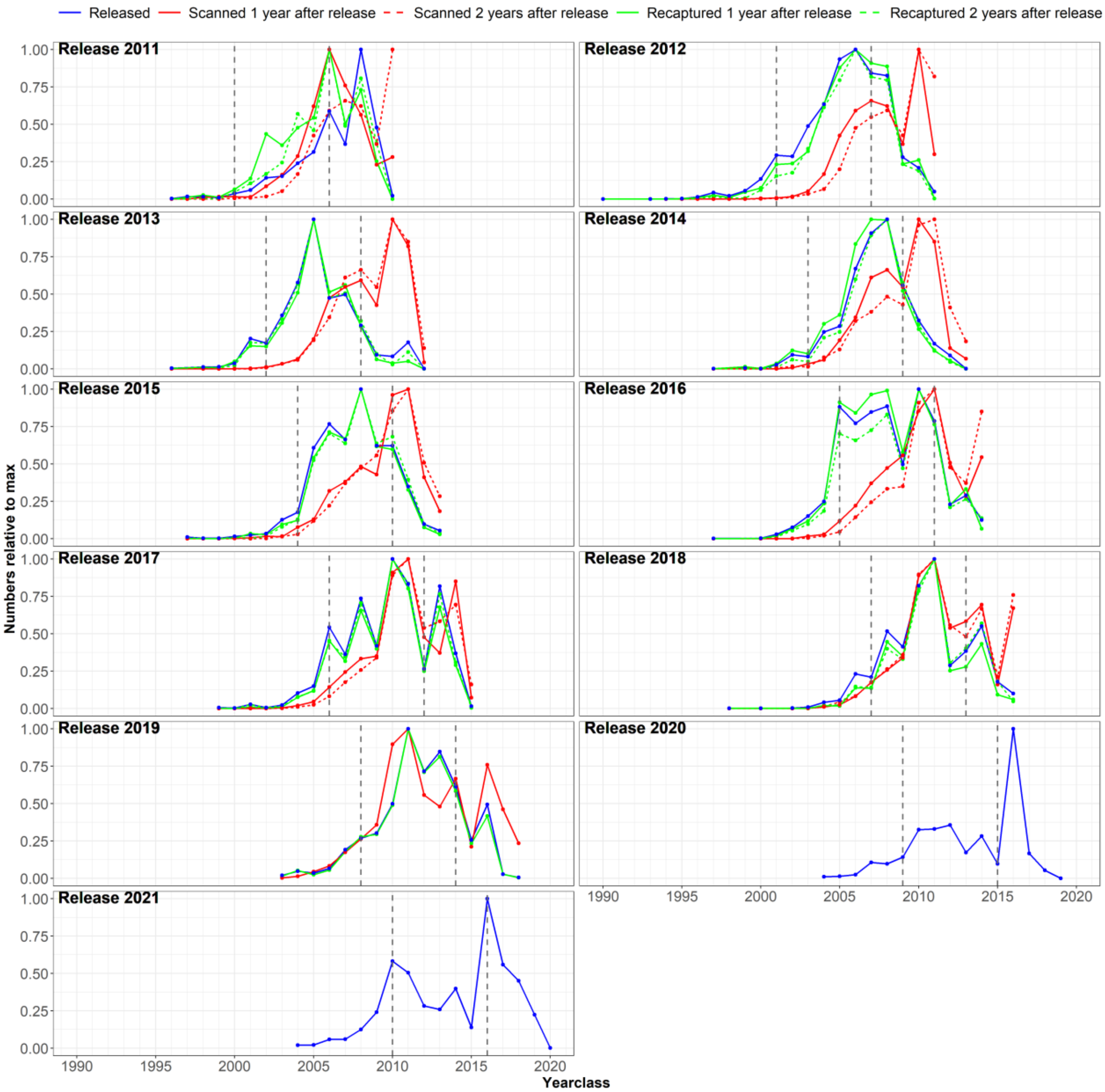


Figure 8.6.4.3. Distribution of recaptures of RFID tagged mackerel during 2012-2020. Note that data on recaptures in 2012-2013 are not used in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019).



8.6.4.4. Overview of the relative year class distribution among RFID tagged mackerel per release year from experiments west of Ireland and British Isles in May-June, compared with the number scanned and recaptured 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 2019). 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.

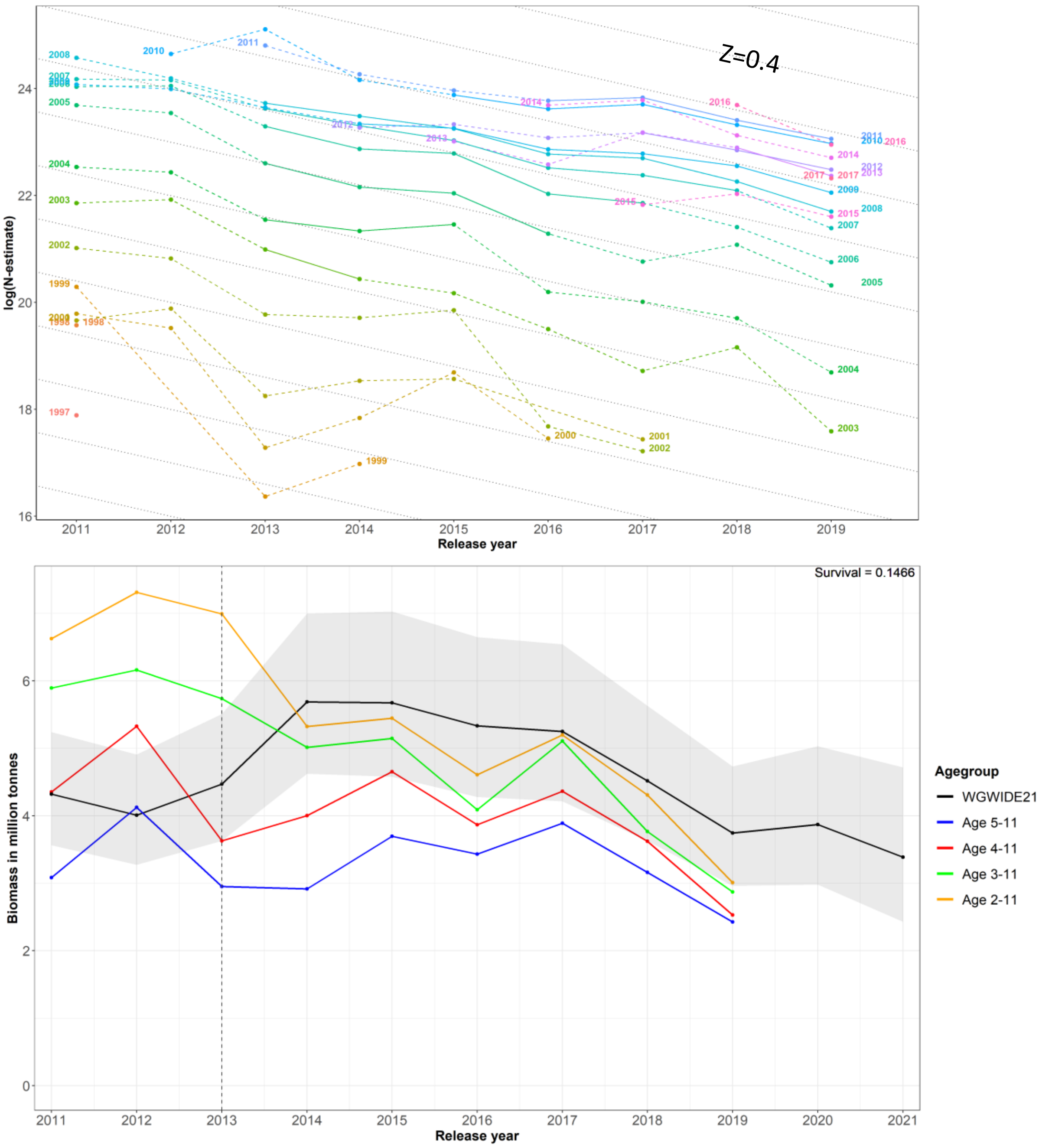


Figure 8.6.4.5. Upper panel: Trends in year class abundance (N=numbers released/numbers recaptured*numbers scanned) from RFID tag-recapture data based on aggregated data on recaptures and scanned numbers in year 1 and 2 after each release year. Data excluded in the stock assessment based on decisions in the ICES IBPNEAMac 2019 meeting (ICES 2019), release years 2011-2012 and ages 2-4 and 12+, are marked with dotted lines in year class trends. Bottom panel: Trends in various age aggregated biomass indices from RFID tag-recapture data compared with the SSB (±95 confidence intervals) from the WGWIDE2021 stock assessment. Data are based on a combination of estimated numbers by year class showed in upper panel scaled by survival parameter (0.1466) and weight at age in stock from WGWIDE2021. 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 2019 is only based on recapture year 2020 and will likely change when adding recapture year 2021 in WGWIDE2022.

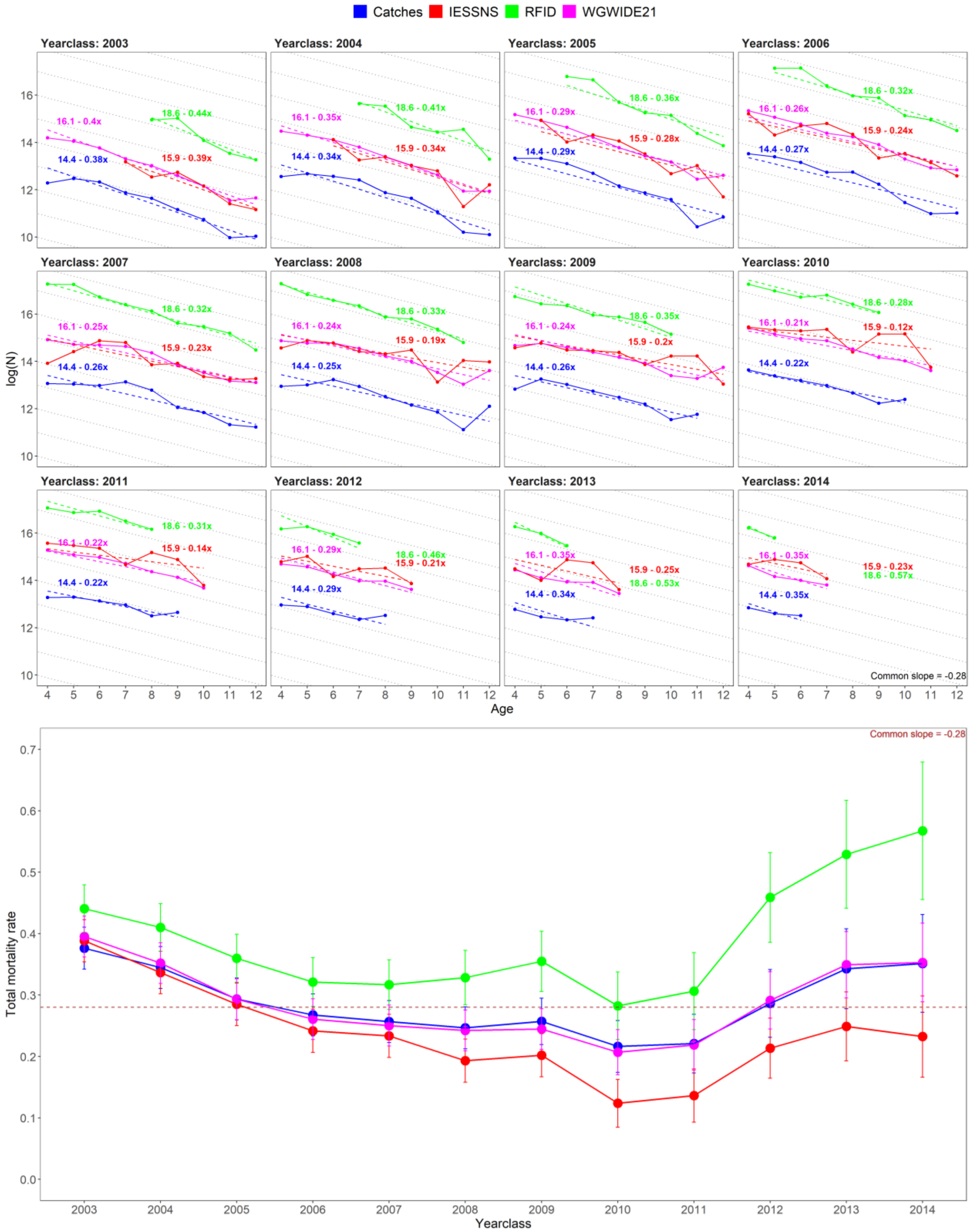


Figure 8.6.4.6. Signals of total mortality rate (Z). Upper panels show the trends in abundance of year classes 2003-2014 from unscaled input data (RFID, IESSNS and catches) and the WGWIDE2021 stock assessment. The estimated slope of decrease from the age 4 when it is fully recruited to the spawning stock until age 12 is interpreted as signal Z, grey dotted lines is Z=0.4. Bottom panels summarize the year class differences in estimated total mortality rate (with 95% confidence intervals), and differences between the various data sources.

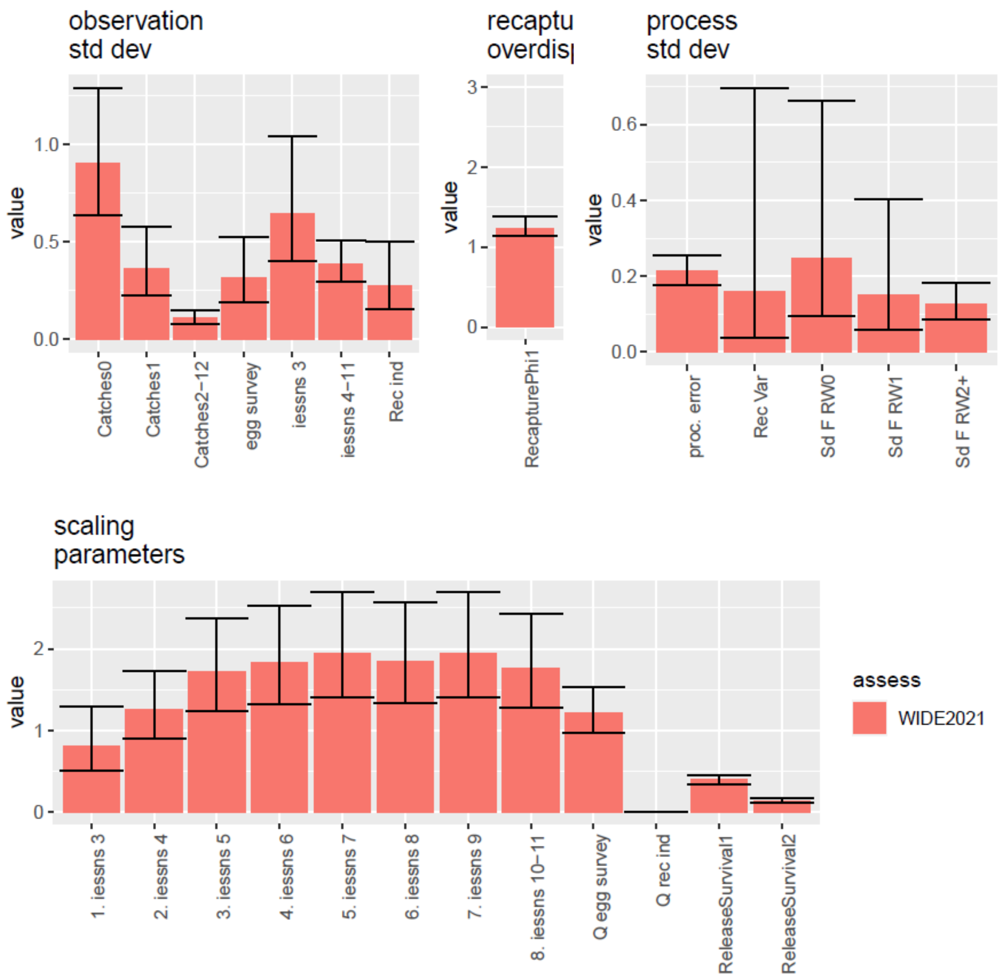


Figure 8.7.2.1. NE Atlantic mackerel. Parameter estimates from the SAM model (and associated confidence intervals) for the WGWIDE 2021 update assessment. top left : estimated standard deviation for the observation errors, top centre : estimated overdispersion for the errors on the tag recaptures, top right : standard deviation for the processes, bottom : survey catchabilities and post-release survival of tagged fish.

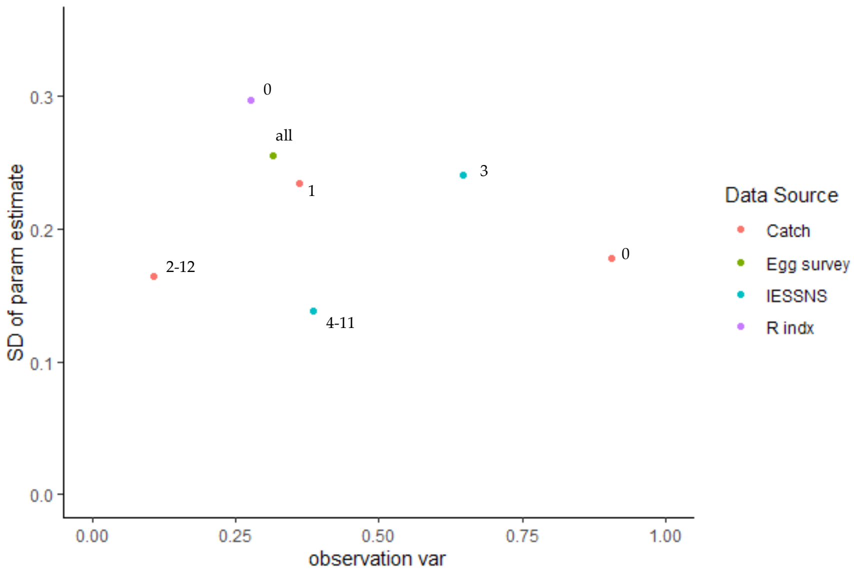


Figure 8.7.2.2. NE Atlantic mackerel. Parameter uncertainty (standard deviation of estimate) versus parameter value for the observation variances. The colours correspond to the different data sources and the number next to the dots indicate the age range to which each parameter apply.

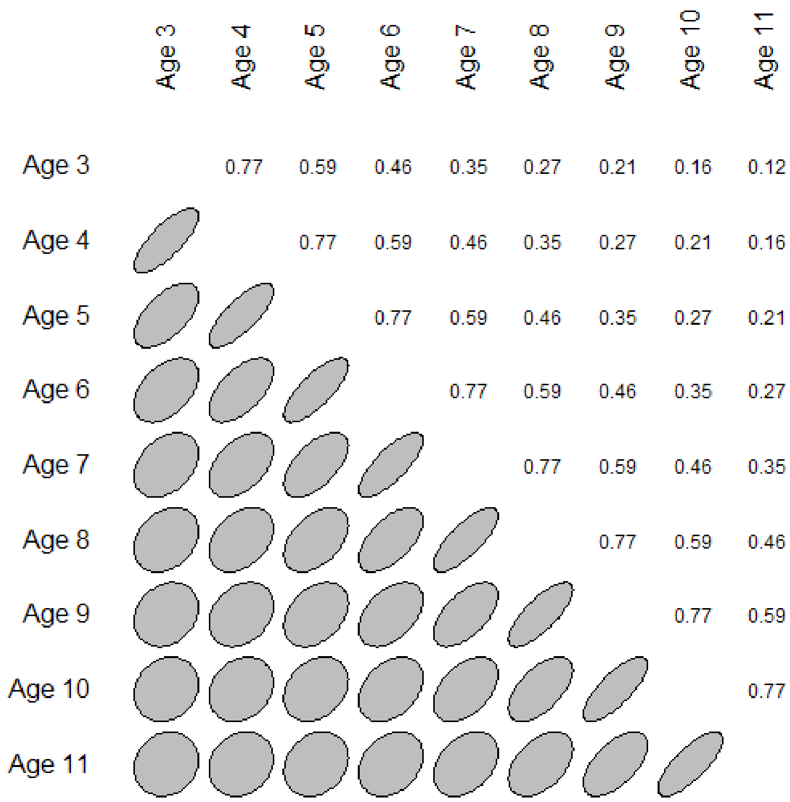


Figure 8.7.2.3. NE Atlantic mackerel. Estimated AR1 error correlation structure for the observations from the IESSNS survey age 3 to 11.

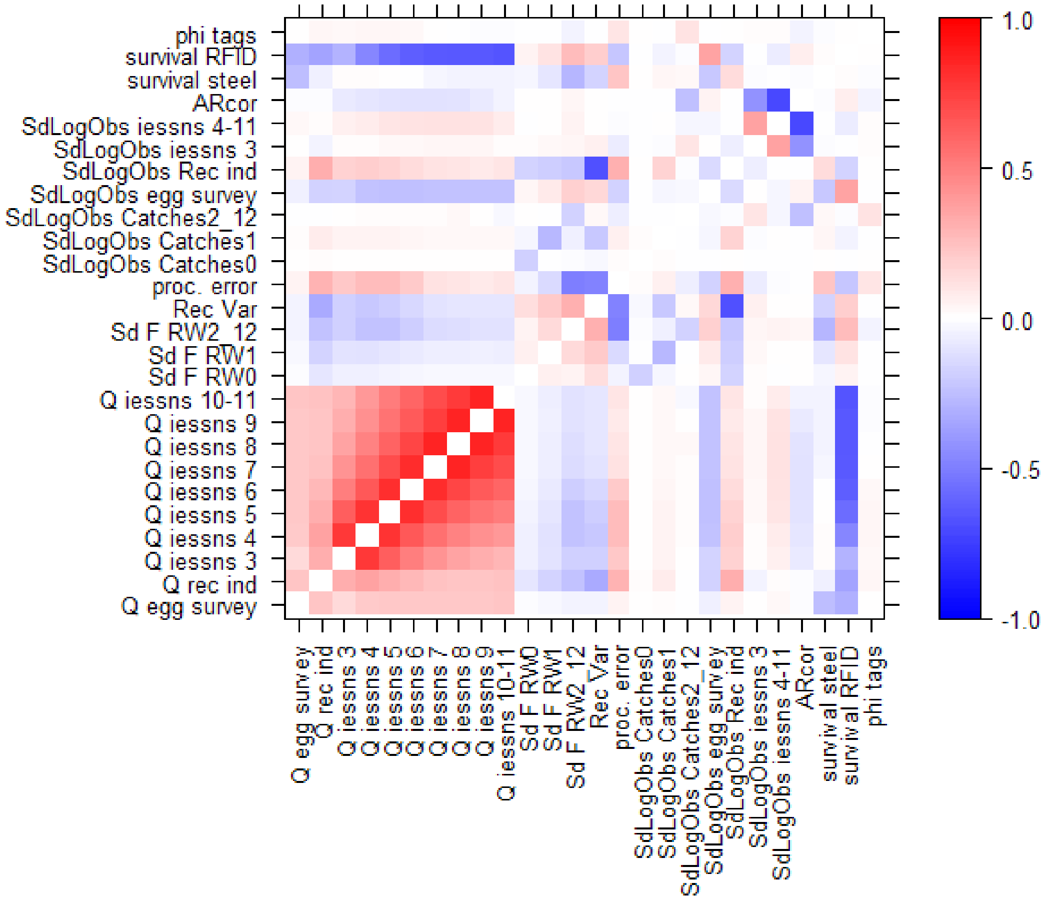


Figure 8.7.2.4. NE Atlantic mackerel. Correlation between parameter estimates from the SAM model for the WGWIDE 2021 update assessment

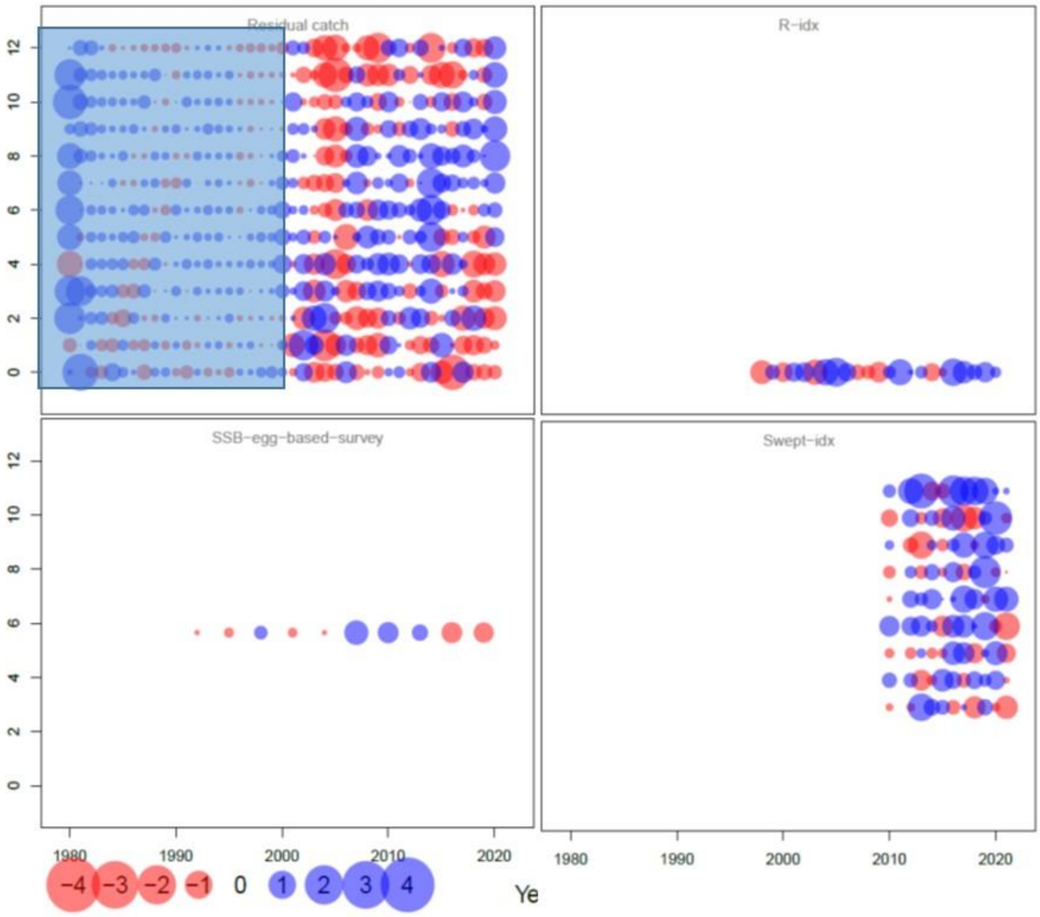


Figure 8.7.2.5. NE Atlantic mackerel. One Step Ahead Normalized residuals for the fit to the catch data (catch data prior to 2000 in blue rectangle were not used to fit the model). Blue circles indicate positive residuals (observation larger than predicted) and filled red circles indicate negative residuals.

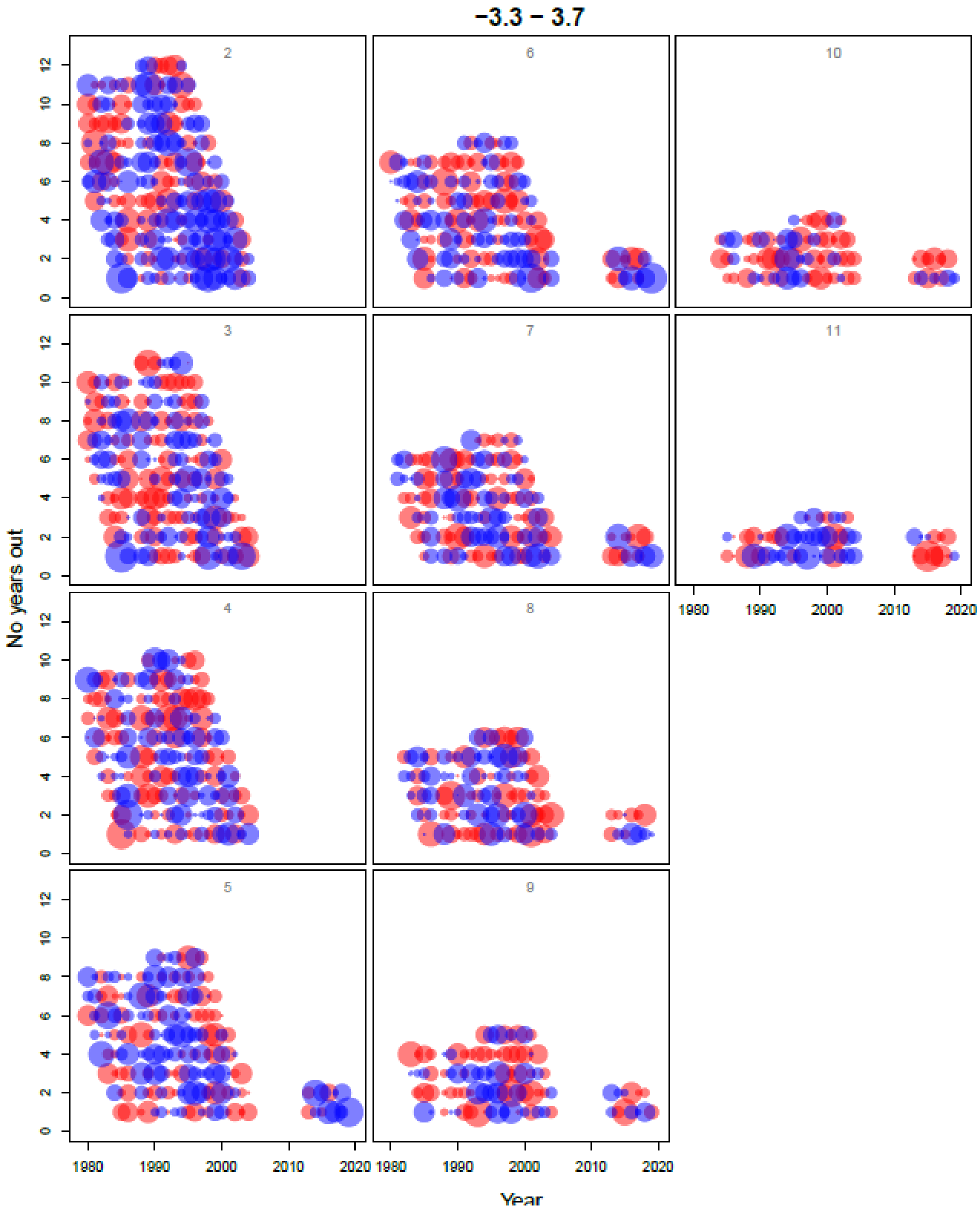


Figure 8.7.2.6. NE Atlantic mackerel. One step ahead residuals for the fit to the recaptures of tags in the final assessment. The x-axis represents the release year, and the y-axis is the number of years between tagging and recapture. Each panel correspond to a given age at release. Blue circles indicate positive residuals (observation larger than predicted) and filled red circles indicate negative residuals.

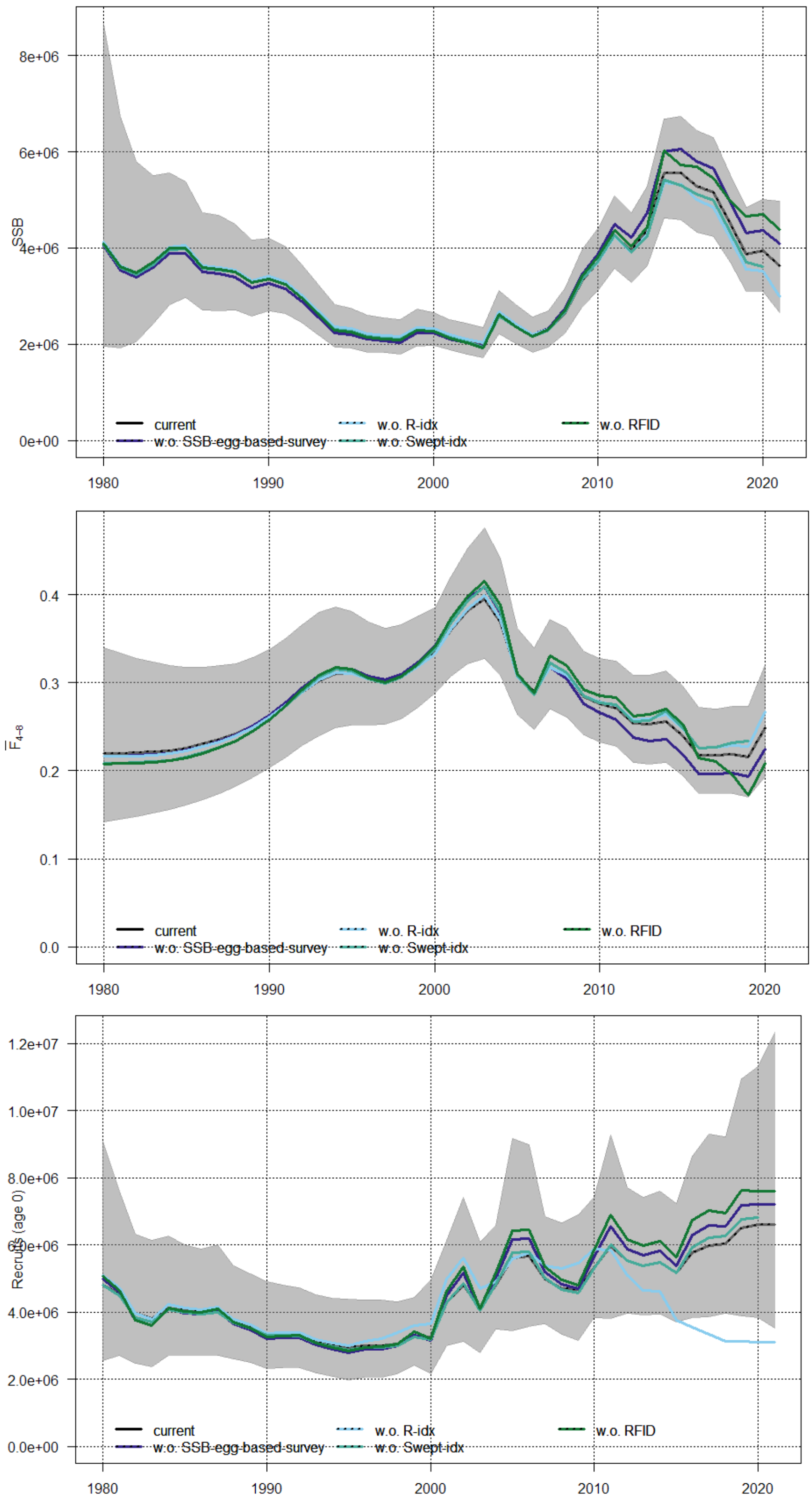


Figure 8.7.2.7. NE Atlantic mackerel. Leave one out assessment runs. SAM estimates of SSB, Fbar and recruitment, for assessments runs leaving out one of the observation data sets.

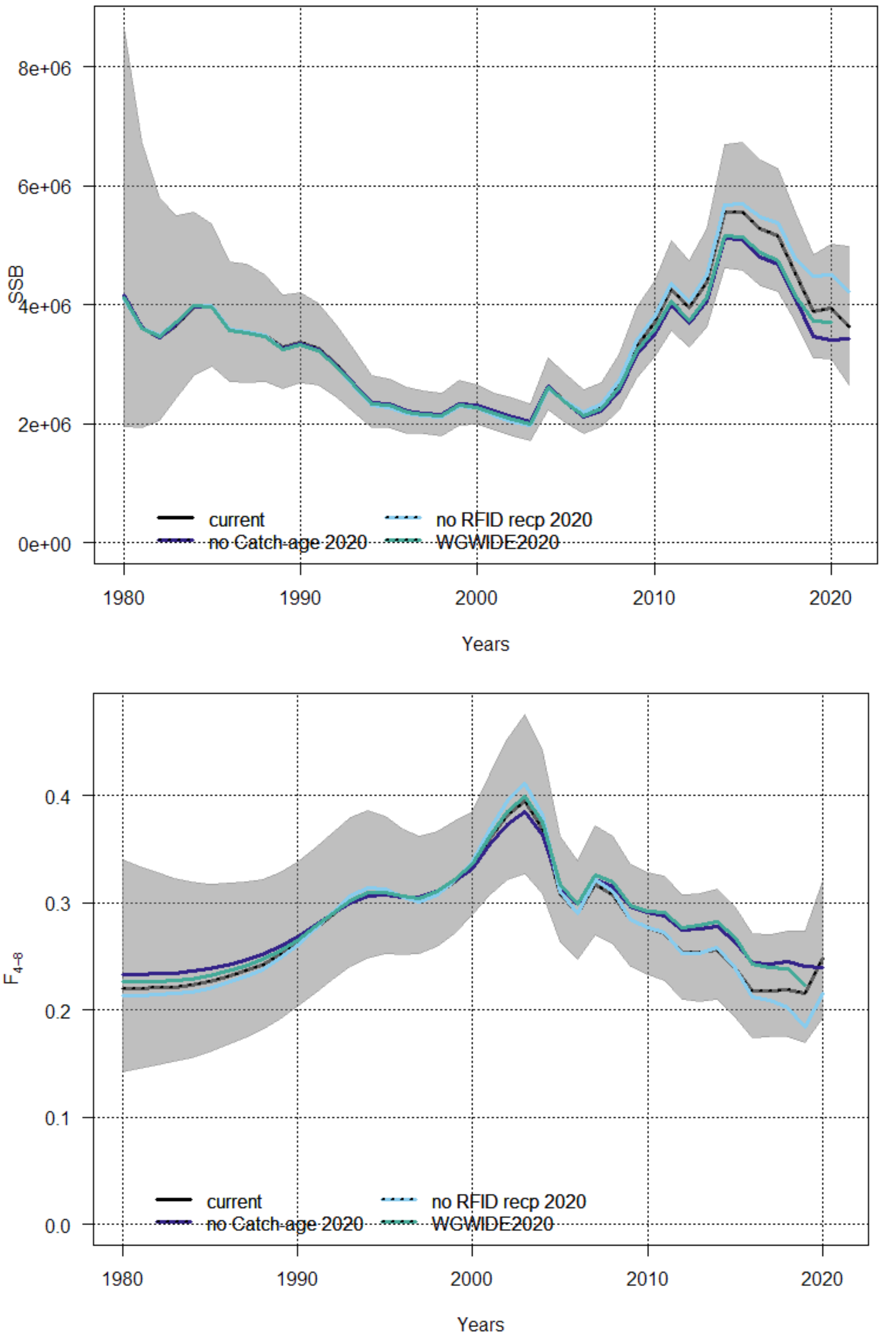


Figure 8.7.2.8. NE Atlantic mackerel. Estimated. Sensitivity of the estimated stock trajectories to the latest year of catch-at-age data and RFID data, and comparison with WGWIDE 2020 assessment.

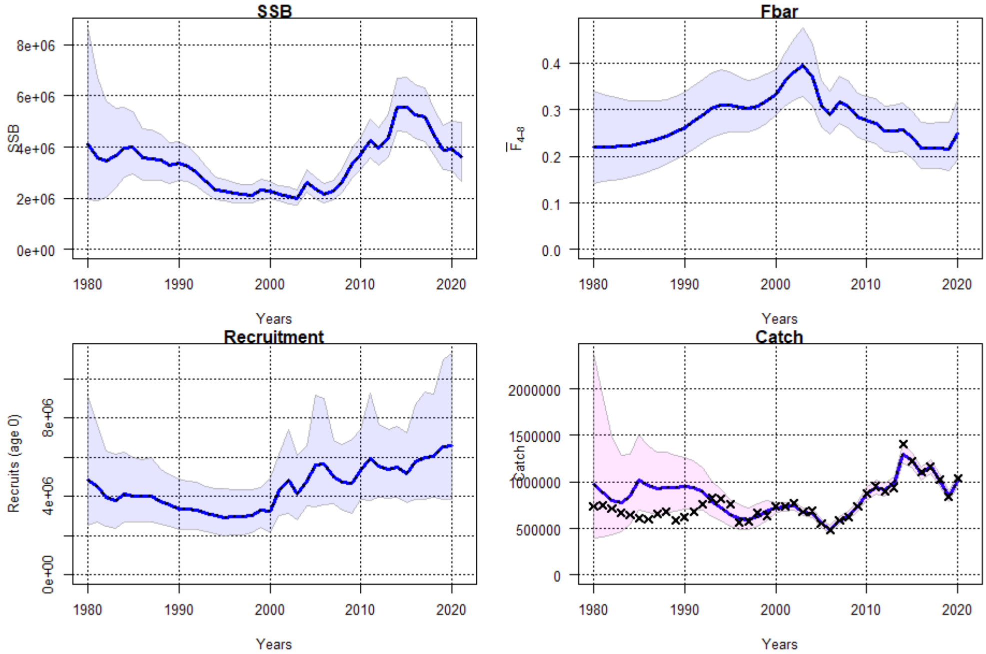


Figure 8.7.3.1. NE Atlantic mackerel. Perception of the NEA mackerel stock, showing the SSB, F_{bar}4-8 and recruitment (with 95% confidence intervals) from the SAM assessment.

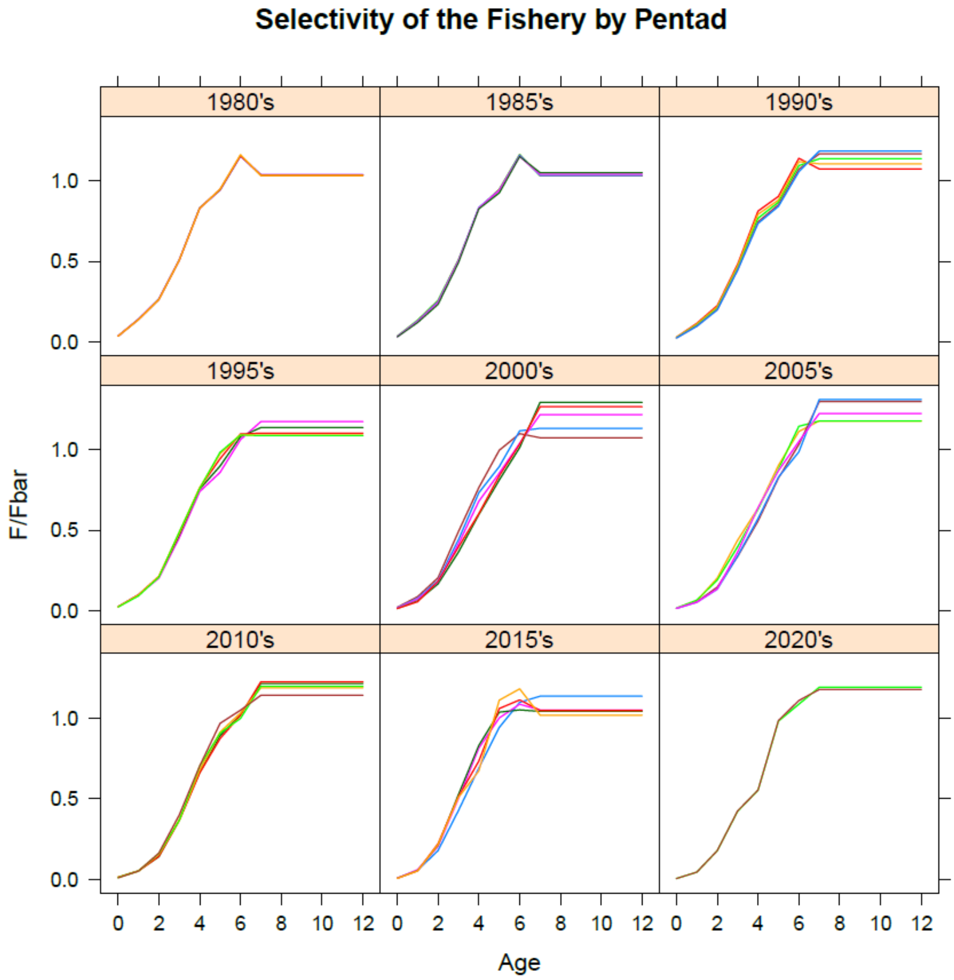


Figure 8.7.3.2. NE Atlantic mackerel. Estimated selectivity for the period 1990 to 2021, calculated as the ratio of the estimated fishing mortality-at-age and the Fbar4-8 value in the corresponding year.

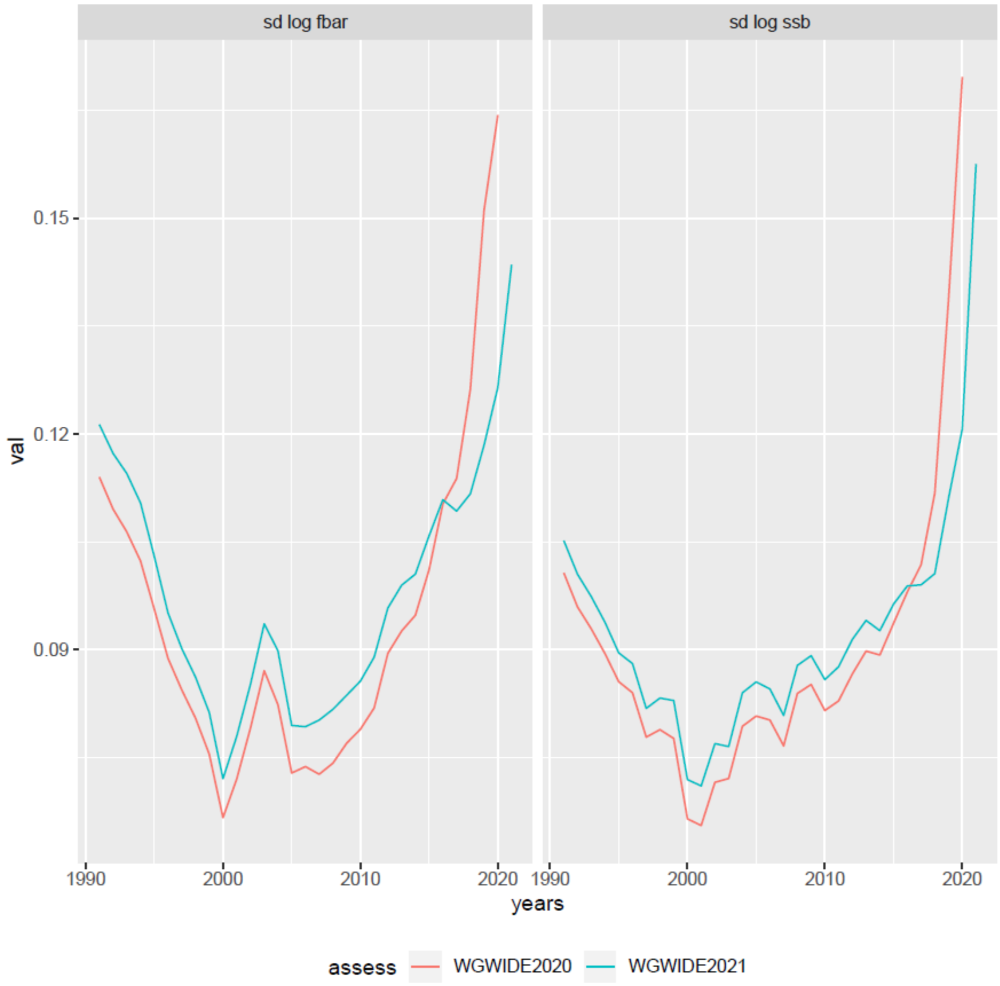


Figure 8.7.4.1. NE Atlantic mackerel. Uncertainty (standard deviation of the log values) of the estimates of SSB and Fbar from the SAM for the 2020 and 2021 WGWIDE assessments.

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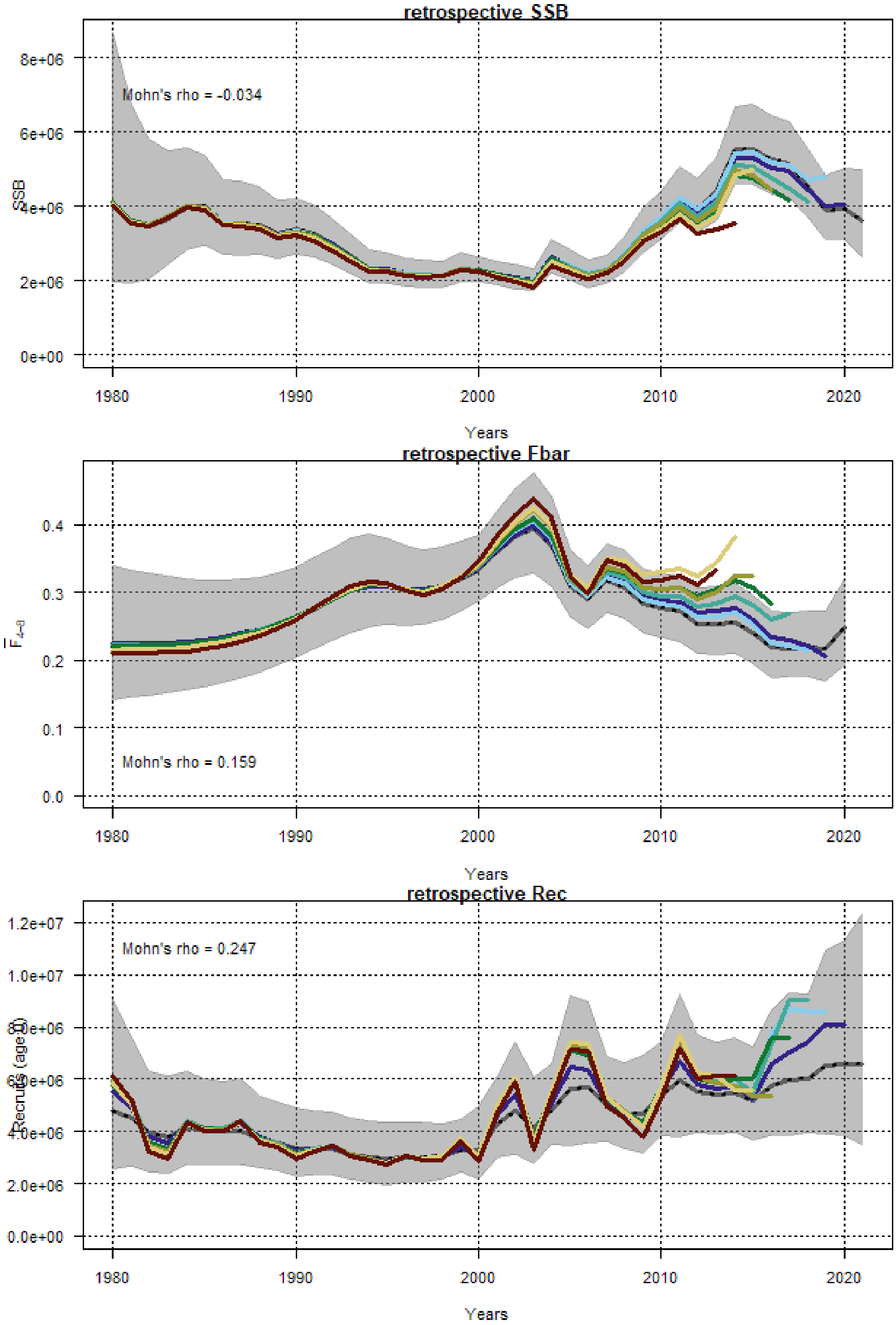

Figure 8.7.4.2. NE Atlantic mackerel. Analytical retrospective patterns (7 years back) of SSB, F_{bar}4-8 and recruitment from the WGWIDE 2021 update assessment. the Mohn's rho values are calculated based on 5 retro years .

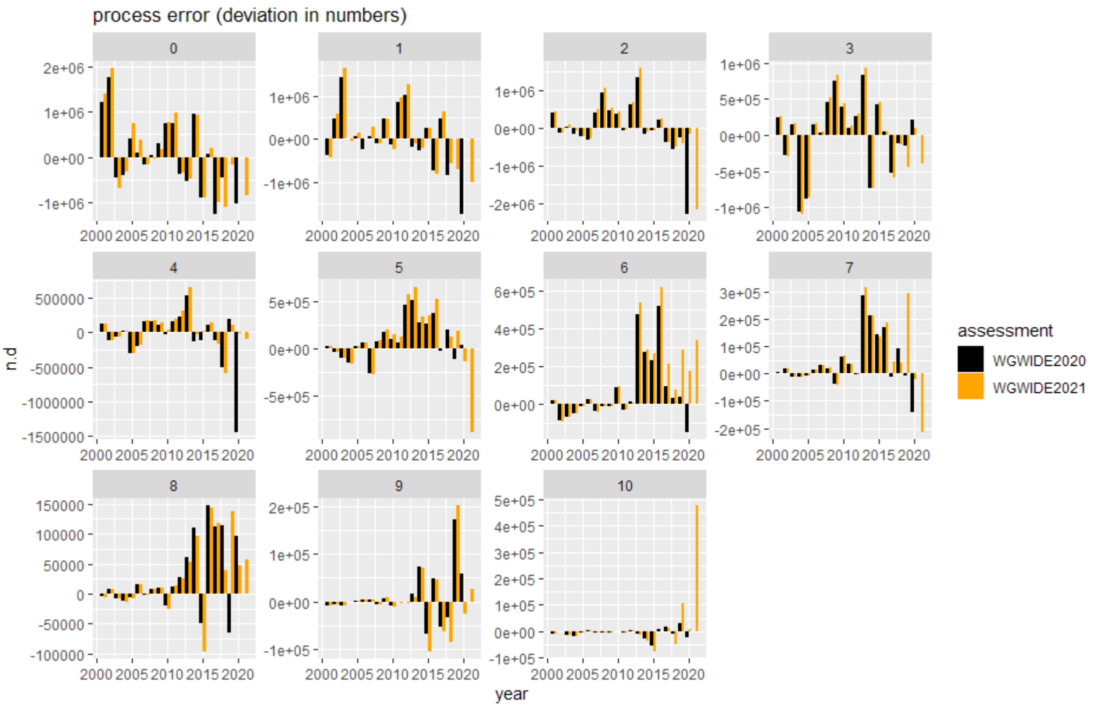

Figure 8.7.4.3. NE Atlantic mackerel. Process error expressed as annual deviations of abundances at age, for the 2021 WGWIDE assessment and from the 2020 WGWIDE assessment.

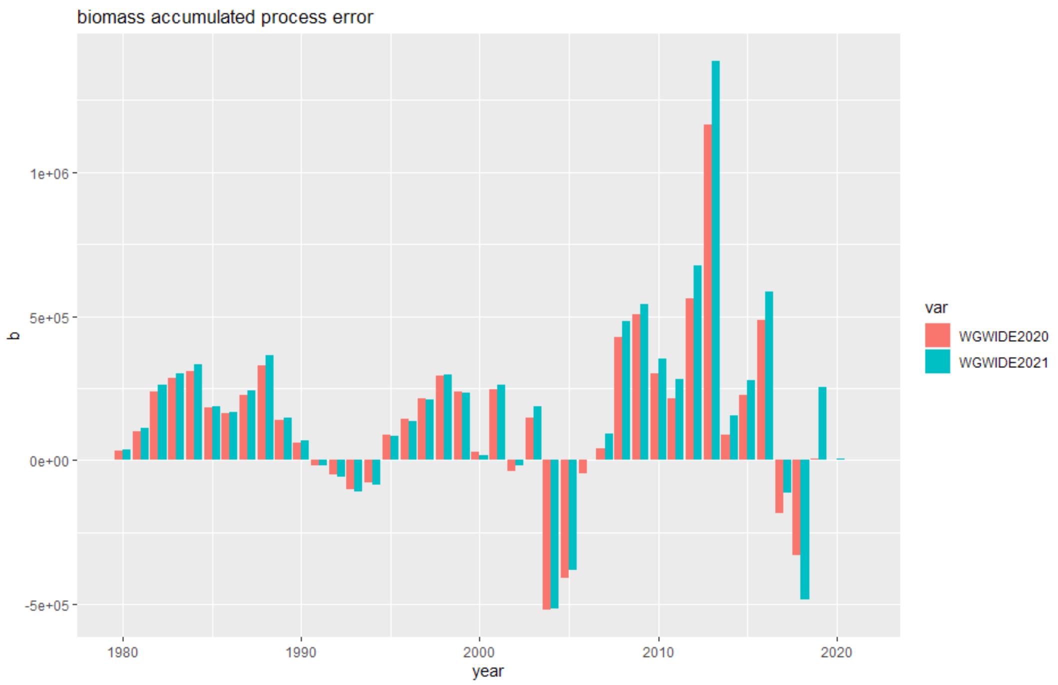

Figure 8.7.4.4. NE Atlantic mackerel. Model process error expressed in biomass cumulated across age-group for the 2021 WGWIDE assessment and for the 2020 WGWIDE assessment.

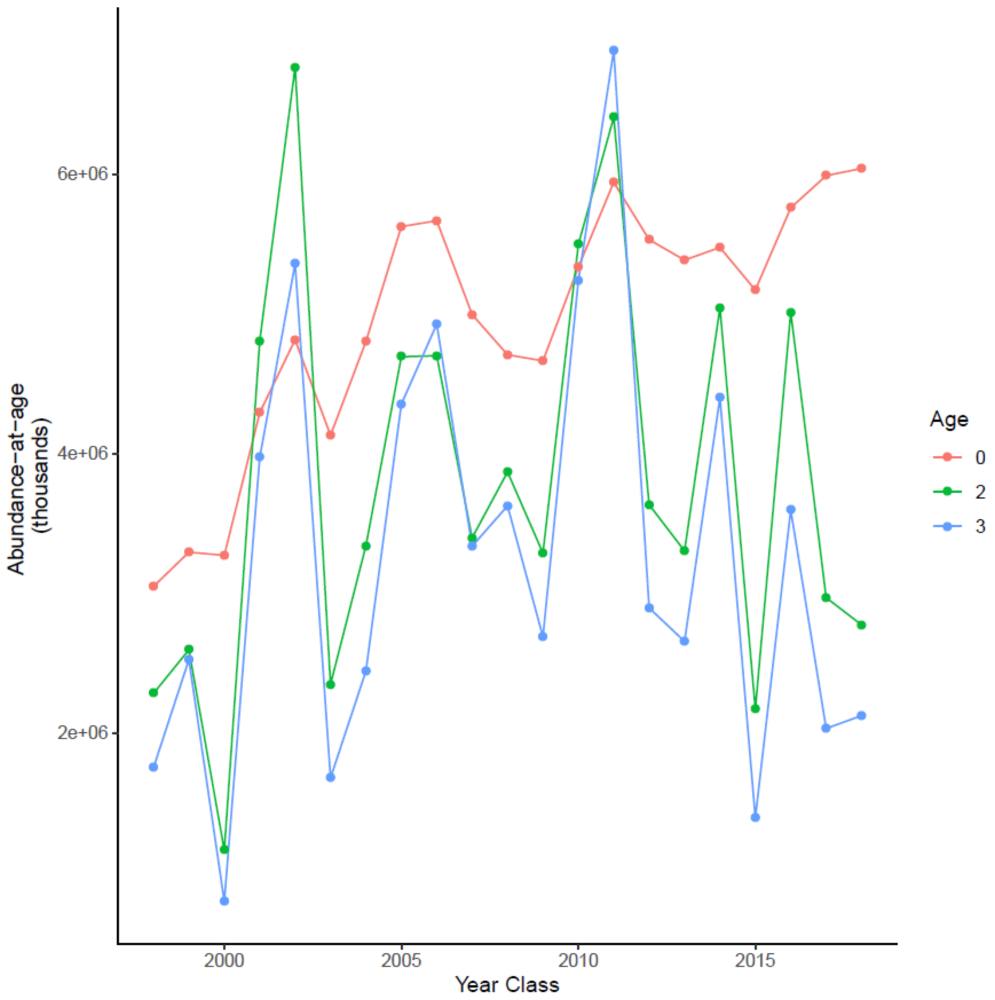

Figure 8.7.5.1. NE Atlantic mackerel. Model. comparison of the cohort signal based on SAM estimates at age 0, 2 and 3.

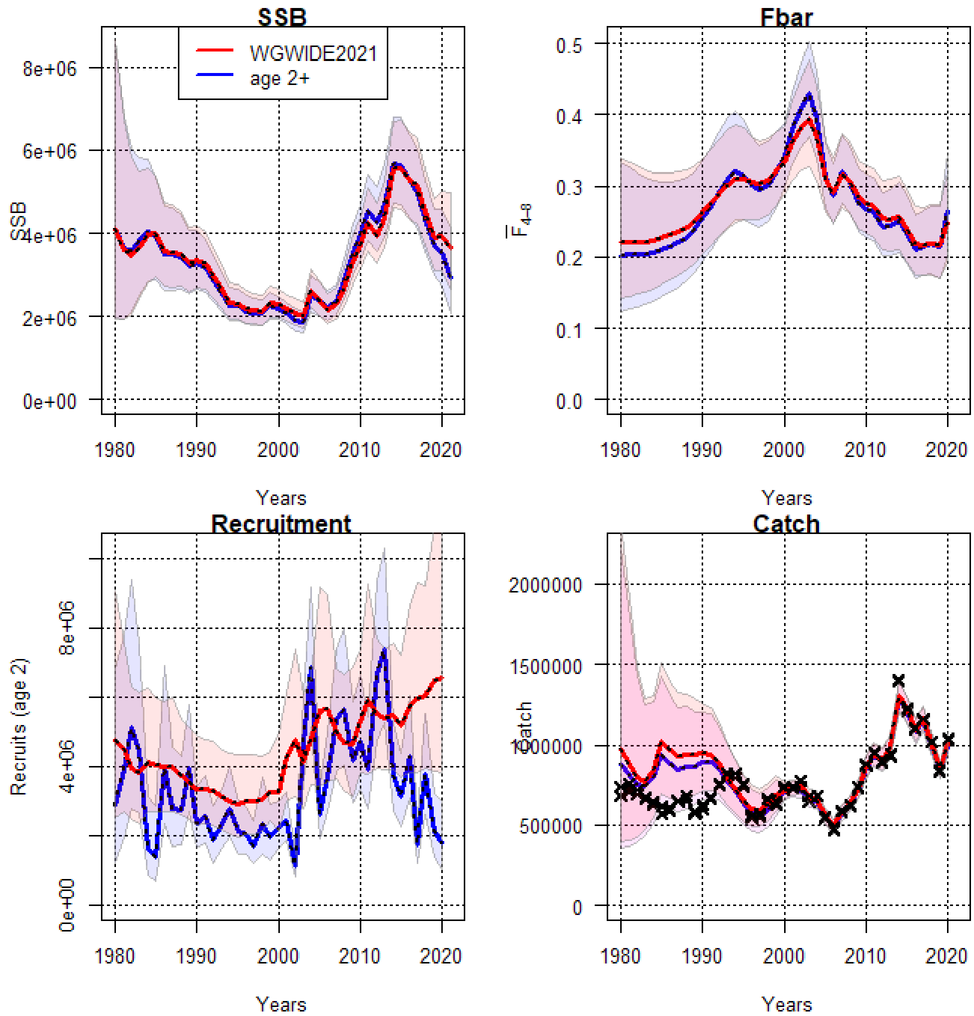

Figure 8.7.5.2. NE Atlantic mackerel. Model. comparison of the perception of the stocks from the WGWIDE 2021 assessment, and the assessment starting at age2.

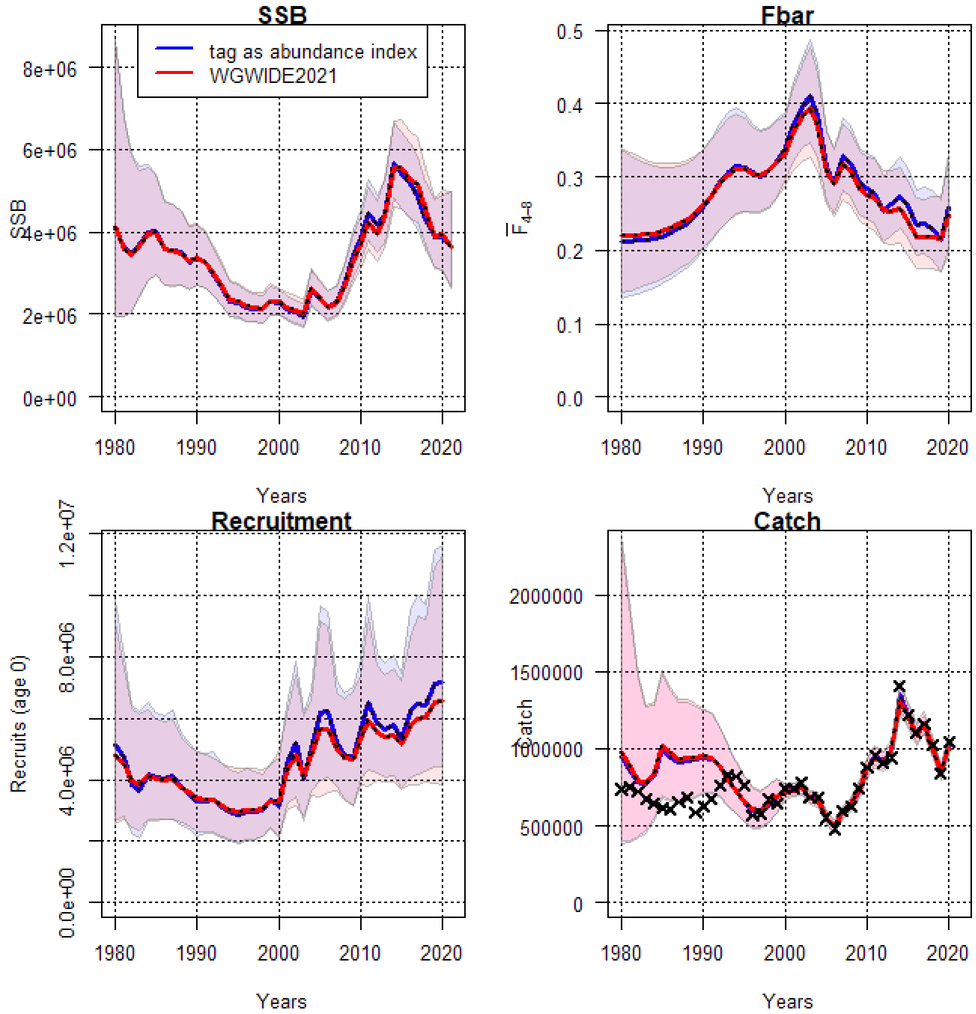

Figure 8.7.5.3 NE Atlantic mackerel. Model. comparison of the perception of the stocks from the WGWIDE 2021 assessment, and the assessment using the RFID data in the form of abundance index for ages 5 to 11.

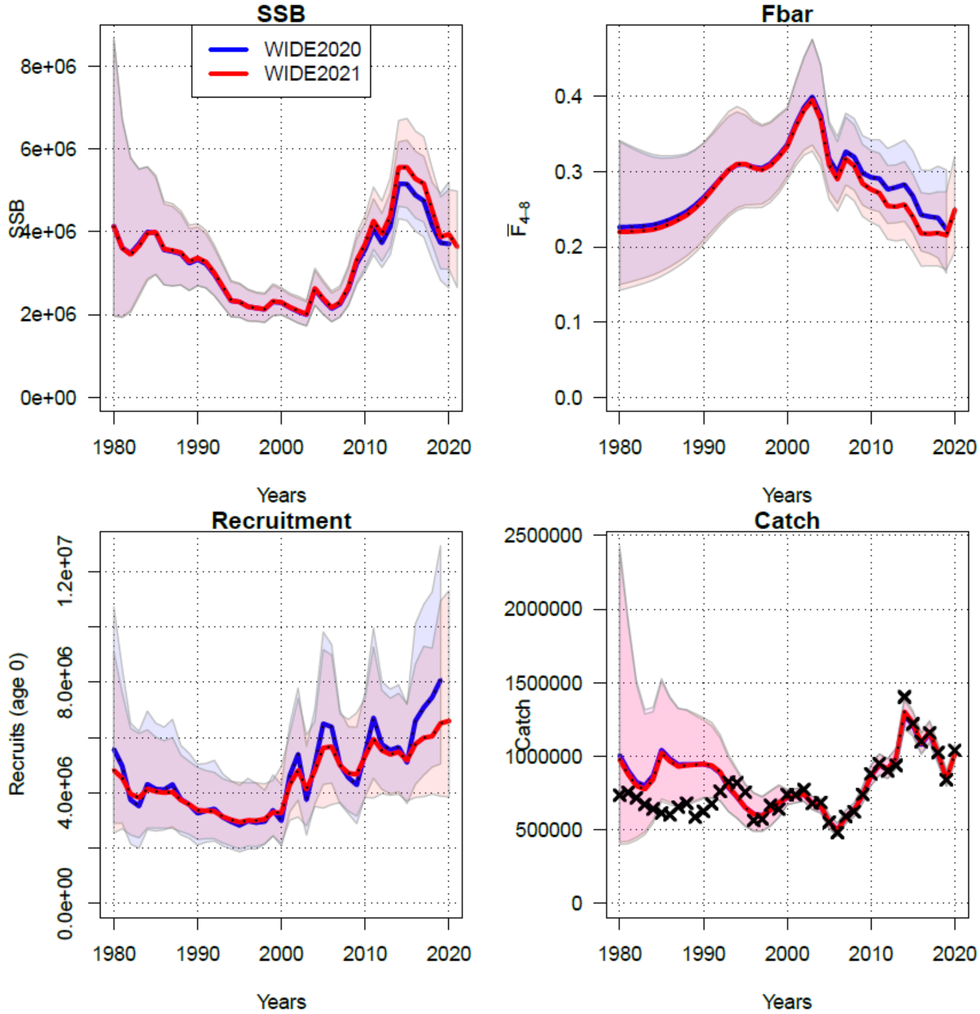

Figure 8.10.1. NE Atlantic mackerel. Comparison of the stock trajectories between the 2021 WGWIDE assessment and the 2020 WGWIDE assessment.

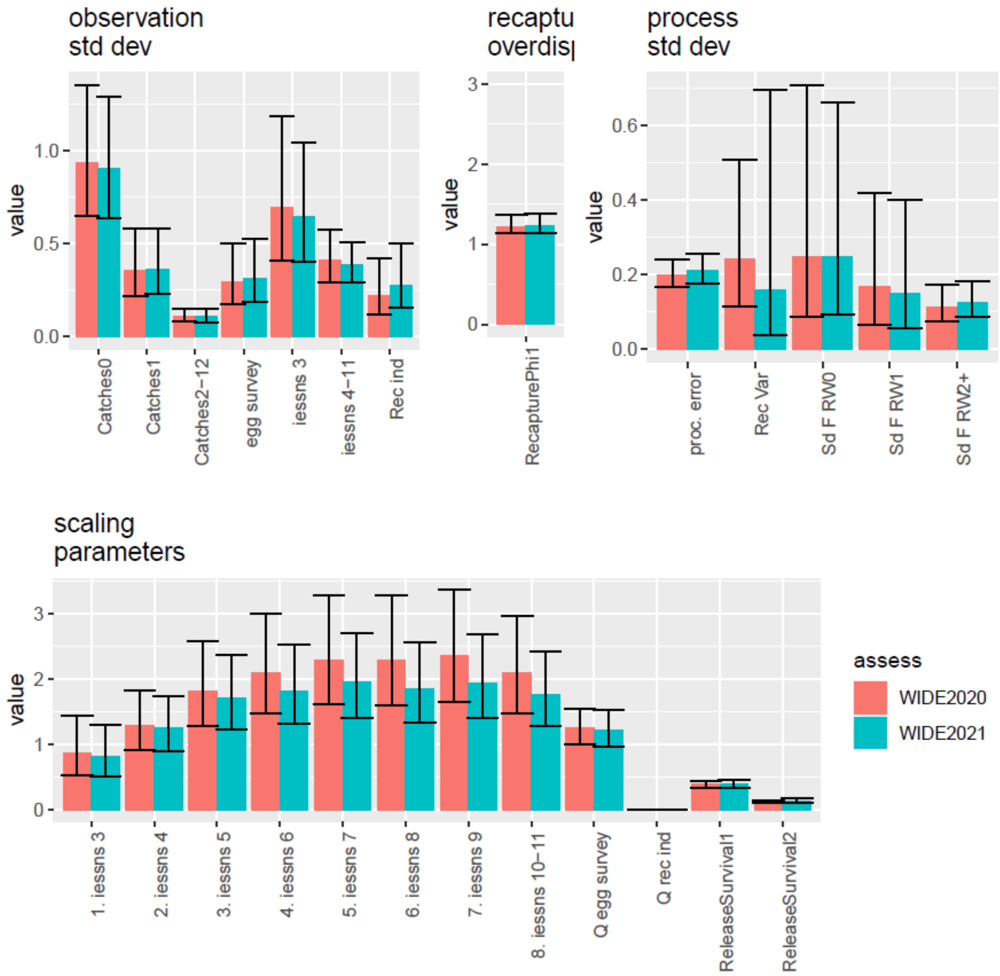

Figure 8.10.2. NE Atlantic mackerel. Comparison of model parameters and their uncertainty for the 2021 WGWIDE and the 2020 WGWIDE assessment

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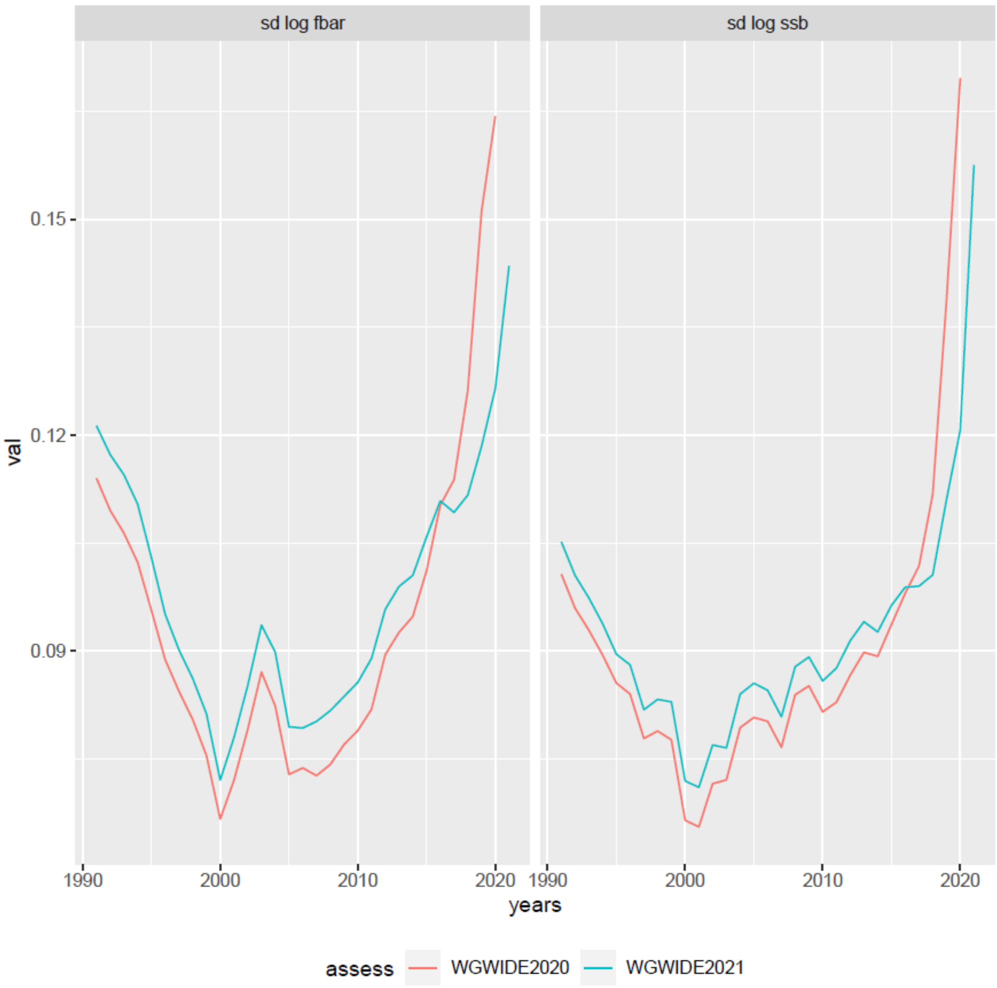

Figure 8.10.3. NE Atlantic mackerel. Comparison of the uncertainty on estimates of SSB and Fbar for the WGWIDE 2021 update assessment and the 2020 WGWIDE.

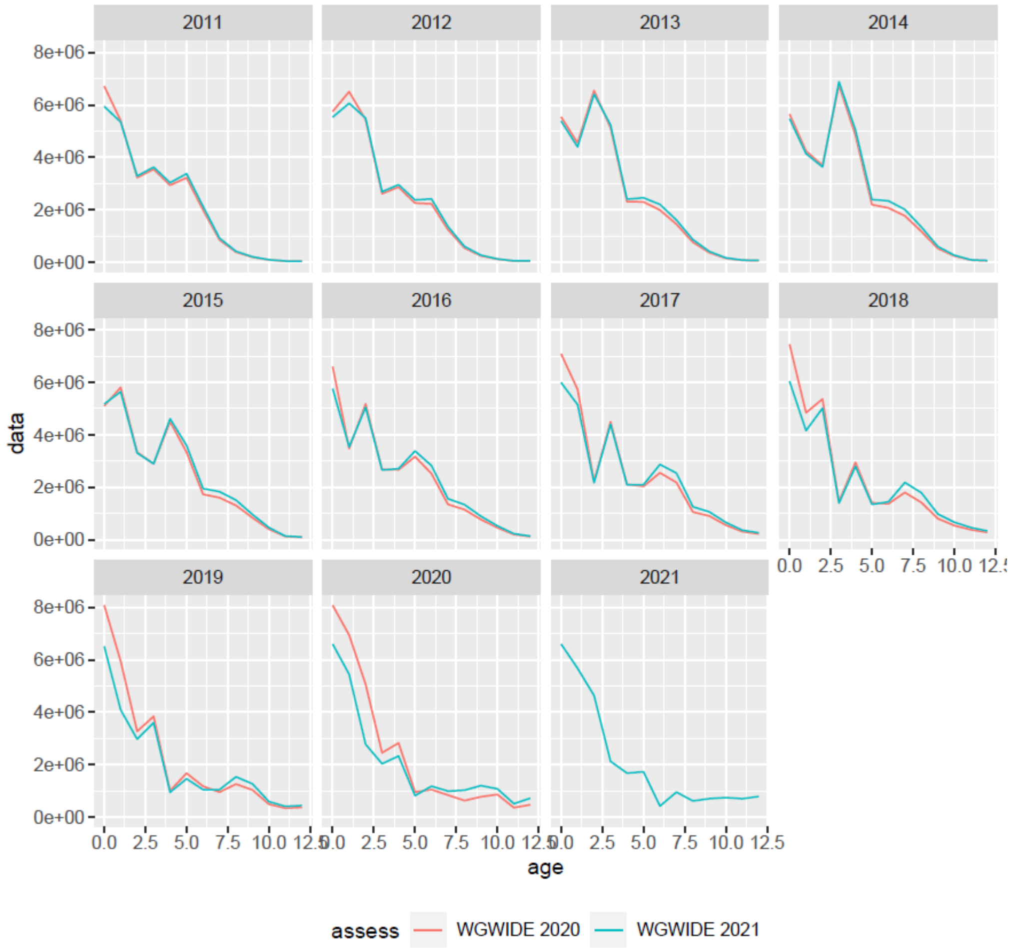

Figure 8.10.4. NE Atlantic mackerel. Comparison of the abundances at age from 2011 to 2021 estimated from the 2020 and 2021 assessments.

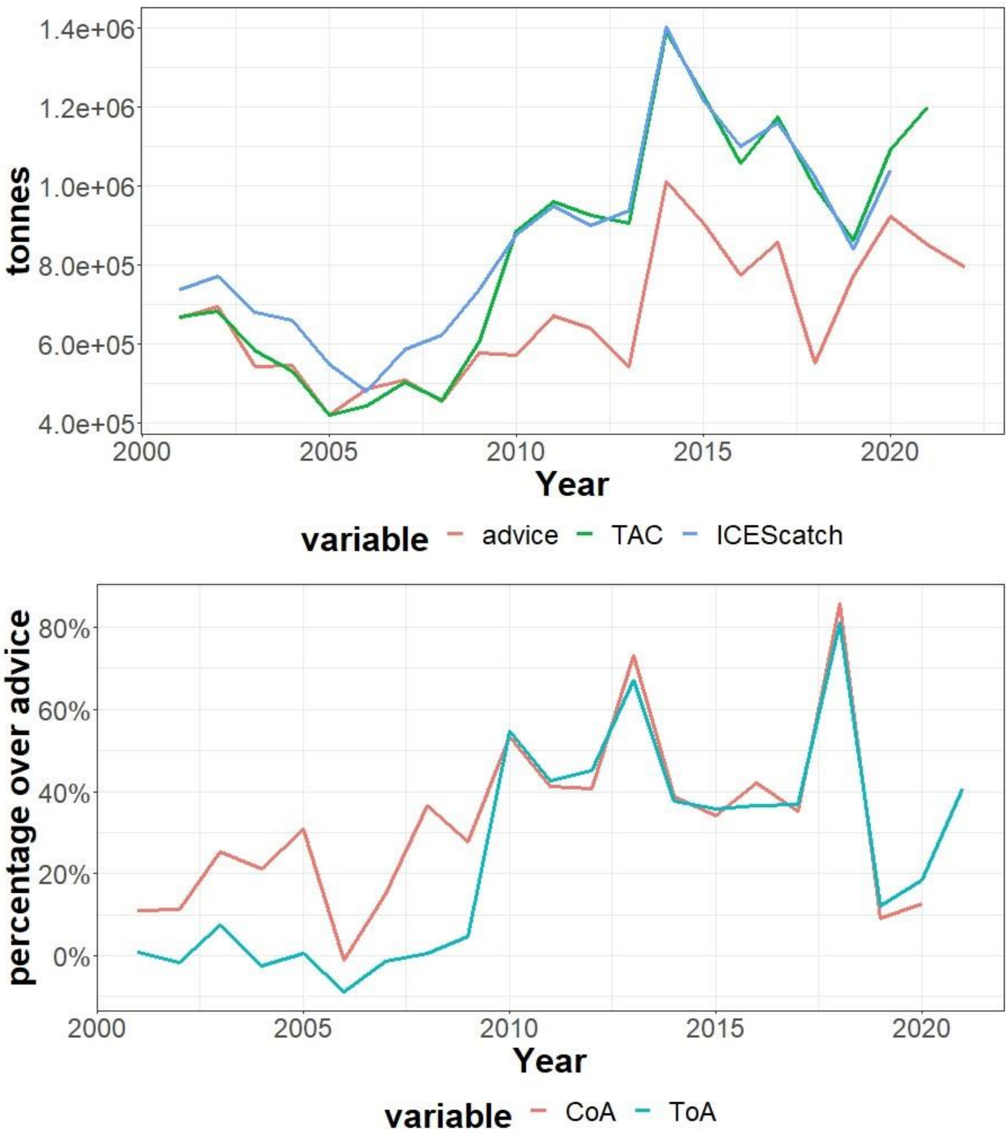

Figure 8.11.1. NE Atlantic mackerel. Top: comparison of the ICES advice, the agreed TAC (or the sum of the unilateral quota) and total catch. Bottom: calculated percentage of Catch over Advice (CoA) and TAC over Advice (ToA).