6 Sardine in divisions 8a, b, d

6.1 Population structure and stock identity

Sardine in Celtic Seas (7a, b, c, f, g, j, k), English Channel (7d, e, h) and in Bay of Biscay (8a, b, d) are considered to belong to the same stock from a genetic point of view.

Therefore, it has been previously considered that the sardine stock in divisions 8a, b, d and in Subarea 7 as a single-stock unit. The assessment of this stock as a single unit assumed that the trends derived from the observations made in the Bay of Biscay through the scientific surveys (PELGAS, BIOMAN) could be extended to the Subarea 7.

Information from the ICES WKSAR workshop (ICES, 2016) suggests higher growth rates for the populations of the English Channel and Celtic Seas than for the Bay of Biscay but it is unknown if this results from different oceanographic conditions or from population characteristics. Furthermore, there is no information on connectivity between the Bay of Biscay and English Channel/Celtic Sea. Bordering catches in Subarea 7 (statistical rectangles 25E4, 25E5) to the Bay of Biscay are generally considered to be taken from sardine populations in the Bay of Biscay. The recent PELTIC surveys (abundance of eggs, larvae, recruits and adults in the Channel) and results from the calorimetry/growth analysis suggest that Channel/Celtic Sea can be a self-sustained population. In fact, there are historical (Wallace and Pleasants, 1972) and recent evidence (Coombs *et al*., 2009) that a significant spawning takes place regularly in Subarea 7 and in a recent acoustic survey series in this area (PELTIC surveys) relevant concentrations of all life stages (eggs, juveniles and adults) have been found as well (van der Kooij *et al*. Presentation to WKSAR report ICES CM 2016/ACOM:41). Furthermore, the Cornish fisheries has been operating there for more than a century.

In terms of stock assessment, the availability of data strongly differs between the northern (Celtic Seas, English Channel) and the southern areas (Bay of Biscay). Additionally, each area presents different historical exploitation patterns. Therefore, analysis and management advice between the areas may differ.

The workshop concluded that in the absence of evidence of connectivity between the Bay of Biscay and Subarea 7 sardine populations, and taking into account the indications of shelf-sustained populations in each area (whereby all stages are found in substantial amounts in both regions) it would be preferable to deal with the Bay of Biscay and Subarea 7 separately.

6.2 Input data in 8a, b, d

6.2.1 Catch data in divisions 8a, b, d

Official landings per country are given in Table 6.2.1.1. Working group estimates are provided in Table 6.2.1.2. Differences are generally related to unallocated catches. Most of the landings correspond to France and Spain. As part of the interbenchmark process in 2019, French landings have been revised from 2013 to 2017 (ICES, 2019).

As in previous years, French sardine landings have been corrected for notorious misallocations between 7e,h and 8a. A substantial part of the French catches originates from divisions 7h and 7e, but these catches have been assigned to division 8a due to their very concentrated location at the boundary between 8a, 7h and 7e. French sardine landings declared in 25E5 and 25E4 have hence been reallocated to 8a. Those two rectangles use to typically account for 25% of the French sardine catches reported in the Bay of Biscay. In 2021, they account for 61%. This is the highest proportion of catches in 25E4-25E5 in the time-series.

The Spanish fishery takes place mainly during March and April and in the fourth quarter of the year. Spanish vessels are purse-seines from the Basque Country and other regions of the north of Spain, which operate mostly in division 8b (Spanish landings averaged around 4000 tonnes in the late 1990s early 2000s with peaks in 1998 and 1999 at almost 8 thousand tonnes. Catches have then decreased until 2010 to below 1 thousand tonnes. Since 2011, catches have raised again, reaching 16 237 tonnes in 2014. Landings in 2021 were 5 922 tonnes.

French catches consistently increased from 1983 to 2008, with values ranging from 4367 tonnes in 1983 to 21 104 tonnes in 2008. Since 2009, French landings displayed an increasing trend which stopped in 2013 with 20 066 tonnes landed, which is close to the time-series maximum. In 2018, landings reached a new maximum with 25 195 tonnes. In 2021, 20 239 tonnes were landed. About 86.7% of French catches are taken by purse-seiners while the remaining 13% is reported by pelagic trawlers (mainly pair-trawlers). Both purse-seiners and pelagic trawlers target sardine in French waters. Average vessel length is about 18 m. Purse-seiners and trawlers operate mainly in coastal areas (<10 nautical miles. Both pair-trawlers and purse-seiners operate close to their base harbour when targeting sardine. The highest catches are usually taken in summer, even if sometimes catches can be important during winter. Almost all the catches are taken in southwest Brittany.

Table 6.2.1.1. Sardine in 8abd. Official landings (in tons) reported to ICES (1989–2021).

	8 a,b,d									
year	France	Spain	Netherlands	Ireland	UK	Denmark	Germany	Lithuania	Belgium	Total
1989	8811	0	0	0	0	0	0	0	0	8811
1990	8543	0	0	0	0	0	0	0	0	8543
1991	12482	35	0	0	0	0	0	0	0	12517
1992	8847	43	0	0	0	0	0	0	0	8890
1993	8805	45	0	0	0	308	0	0	0	9158
1994	8604	0	0	0	0	0	0	0	0	8604
1995	9877	0	24	0	0	0	0	0	0	9901
1996	8604	0	0	0	0	0	0	0	0	8604
1997	10706	0	26	0	0	0	0	0	0	10732
1998	9778	873	0	0	0	0	68	0	0	10719
1999	0	2384	0	0	0	124	11	0	0	2519
2000	10615	3158	34	0	0	0	38	0	0	12505
2001	10004	3720	333	0	0	0	135	0	0	10589
2002	11977	4428	23	19	276	0	4	0	0	15519
2003	9809	1113	68	1750	68	0	0	0	0	14925
2004	11155	342	6	1401	0	0	0	0	0	13231
2005	10975	898	1	974	0	0	54	0	0	17694
2006	10884	825	2	49	0	12	78	5	0	16986

	8 a,b,d									
year	France	Spain	Netherlands	Ireland	UK	Denmark	Germany	Lithuania	Belgium	Total
2007	13231	1263	0	0	0	48	0	0	0	16814
2008	18071	717	0	0	1	39	0	0	0	23133
2009	15847	228	0	0	0	0	0	0	0	21229
2010	12877	642	0	0	0	0	0	0	0	22432
2011	12469	5283	5	0	0	0	0	0	0	25155
2012	10854	14948	0	0	0	0	0	0	0	33100
2013	13614	12423	445	0	252	0	0	0	0	37291
2014	14730	16237	0	0	0	0	0	0	0	39829
2015	13132	13055	0	25	7	0	1	0	0	31574
2016	14320	6824	65	0	0	0	0	0	0	30122
2017	17265	6380	0	0	0	0	0	0	0	30249
2018	18161	7094	0	0	0	0	0	0	0	32289
2019	21099	3250	0	0	0	0	0	0	0	24349
2020	24596	6746	0	0	0	0	0	0	0	31342
2021	20239	5922	0	0	0	0	0	0	0	26161

Table 6.2.1.2. Sardine in 8abd. Sardine landings (in tons) by France (1983–2020) and Spain (1996–2020) in ICES divisions 8a,b,d as estimated by the WG.

Year	France	Spain	Total
1983	4367	n/a	
1984	4844	n/a	
1985	6059	n/a	
1986	7411	n/a	
1987	5972	n/a	
1988	6994	n/a	
1989	6219	n/a	
1990	9764	n/a	
1991	13965	n/a	
1992	10231	n/a	
1993	9837	n/a	
1994	9724	n/a	
1995	11258	n/a	
1996	9554	2053	11607
1997	12088	1608	13696
1998	10772	7749	18521
1999	14361	7864	22225
2000	11939	3158	15097
2001	11285	372	11657
2002	13849	4428	18277
2003	15494	1113	16607
2004	13855	342	14197
2005	15462	898	16360
2006	15916	825	16741
2007	16060	1263	17323
2008	21104	717	21821
2009	20627	228	20855
2010	19485	642	20127
2011	17925	5283	23208
2012	15952	14948	30900
2013	20515	12423	32938
2014	19467	16237	35704
2015	15701	13055	28756
2016	22930	6824	29754
2017	24055	6380	30435
2018	25195	7104	32299
2019	21300	3279	24579

Year	France	Spain	Total
2020	24593	6747	31368
2021	20370	5828	26198

6.2.2 Surveys in divisions 8abd

6.2.2.1 DEPM surveys in Divisions 8abd

The DEPM survey BIOMAN takes place annually in spring in the Bay of Biscay with the main objective of estimate the total biomass and distribution of anchovy as well as the numbers-at-age, percentage at age length-at-age weight at age and anchovy biomass at age in the Bay of Biscay (8abcd) and the egg abundance of sardine in 8abd. The triennial DEPM is as well available as an index since 2011. Since 2020 the SSB for sardine will be estimate annually as well as the numbers-at-age, percentage at age, weight at age and length-at-age to be available as inputs for the assessment. This year the daily egg production (P_0; eggs /m²), daily mortality rates (z) and total daily egg production (P_{tot})(eggs) estimates were as well estimate trying to obtain it for all the historical series (**Table 6.2.2.1.1**). The following years those parameters will be estimate for the previous years to complete the series and to have a historical series of a more precise egg index as a proxy of the biomass for the past in 8abd. For the time been, this estimates P_0, z and P_{tot} are available for years 2002 and 2005 to 2022 . This year apart from the frequentist method that was applied during all the years up to now to estimate P_0, z and P_{tot}, a Bayesian method was study (see Santos Mocoroa *et al* 2022 in annex 3 WGACEGG) with the aim to avoid incurring in incorrect sign for z. Currently, the input used for the assessment is the total egg abundance in the 8abd without the Northwest part to be consistent with the historical series and the triennial DEPM since 2011 .

The survey took place from the 5th of April to the 27th of May. All the methodology concerning the survey and the estimates performance, are described in detail in the annex A.5_stock annex - Bay of Biscay Anchovy (Subarea 8). A detailed report of the survey and results 2022 is attached as a working document in ICES WGACEGG 2022 in **annex** 3 (**Santos Mocoroa. M *et al.* BIOMAN 2022).**

This year the sardine eggs were found in the Cantabrian Sea all along the area almost until 200m depth isoline, more abundant at the west of the area surveyed. In the French platform, from South to North all along the East of the 100m depth isoline area. (**Figure 6.2.2.1.2**)

In the sampling with the PairoVET net (vertical sampling) from 757 stations a total of 256 (34%) had sardine eggs with an average of 150 eggs/m² per station in the positive stations, a maximum of 2550 egg m² in a station and a total number of 39390 eggs/m². In the sampling with CUFES (horizontal sampling) a total of 542 stations (32%) had sardine from 1700 stations. (**Figure 6.2.2.1.2**)

Total egg abundance for sardine was estimated as the sum of the numbers of eggs in each station multiplied by the area each station represents. This year sardine egg abundance estimate was 5.78E+12 eggs, considered the whole area surveyed. Considering the 8abd the estimate was 5.17+12 and removing part of the Northwest for assessment propose, to be consistent with the historical series, was 3.29E+12 eggs, below the time-series average (5.68E+12) (**Figure 6.2.2.1.1, Table 6.2.2.1.2**).

To estimate the reproductive parameters for sardine in the Bay of Biscay from BIOMAN survey, 16 adult hauls were available. Mean weight and mean length are showed in **Figure 6.2.2.1.3**. Age composition and mature fish expressed in times one within each haul are showed in **Figure 6.2.2.1.4**. All the adult samples were processed, and the histology analysis and oocytes count were conducted but the estimates of the batch fecundity, spawning frequency and spawning stock biomass are still in process.

Table 6.2.2.1.1. Sardine in 8abd. Daily egg production (P_0) (eggs /m2), daily mortality rates (z) and total daily egg production (P_{tot})(eggs) estimates and their corresponding standard error (S.e.) and coefficient of variation (CV) for all the area surveyed area, 8abd and 8abd without NW from BIOMAN 2022.

Frequentist	all area			8abd			8abdwithoutNW		
Parameter	Value	S.e.	CV	Value	S.e.	CV	Value	S.e.	CV
P0	120.7	19.8	0.1638	134.8	23.8	0.1766	161.6	32.7	0.2027
z	0.69	0.12	0.1795	0.75	0.13	0.1804	0.88	0.15	0.1741
Ptot	4.4.E+12	7.3.E+11	0.1638	4.2.E+12	7.3.E+11	0.1766	3.7.E+12	7.4.E+11	0.2027

Table 6.2.2.1.2. Sardine in 8abd. Time-series for sardine, total egg abundances (Σ(egg_St*area_st)) in numbers of eggs, without the Northwest, the one adopted as an input for the assessment of sardine in 8abd.

year	Tot.ab.8abdwithout NW
1999	1.06E+12
2000	5.03E+12
2001	2.20E+12
2002	7.82E+12
2003	3.26E+12
2004	7.83E+12
2005	1.09E+13
2006	3.84E+12
2007	2.33E+12
2008	9.37E+12
2009	6.05E+12
2010	1.03E+13
2011	4.29E+12
2012	5.60E+12
2013	5.47E+12
2014	8.21E+12
2015	5.52E+12
2016	8.56E+12
2017	5.99E+12
2018	4.67E+12
2019	4.49E+12
2020	3.75E+12
2021	4.02E+12
2022	3.29E+12
mean	5.58E+12
Std.Dev	2.61E+12
CV	0.4686

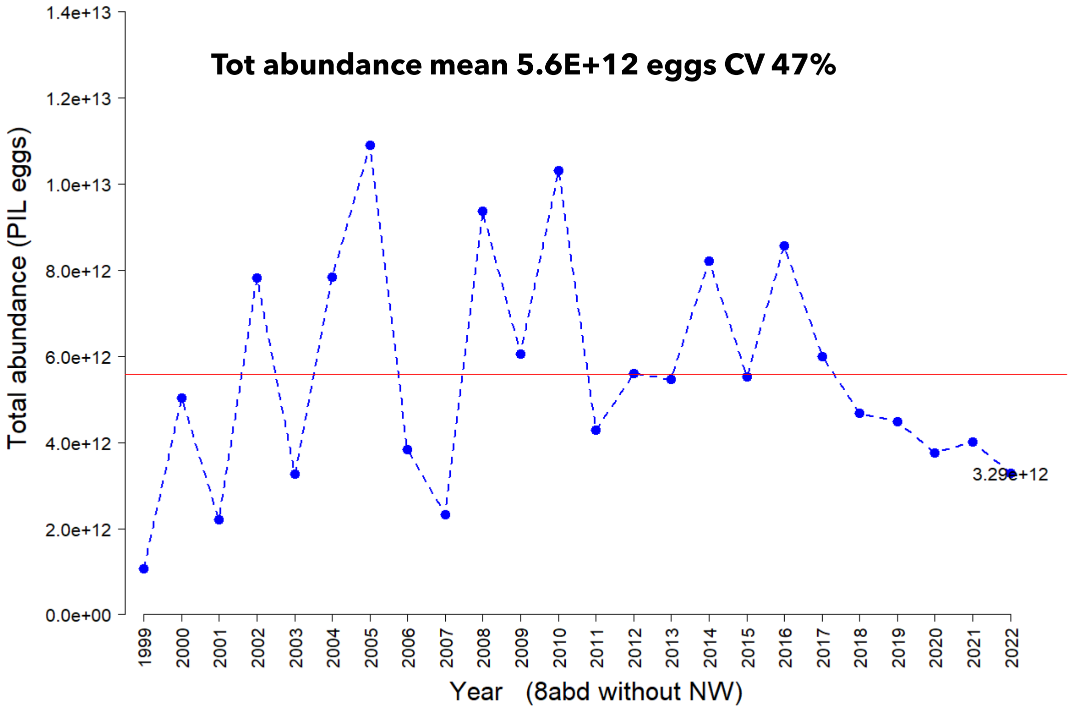


Figure 6.2.2.1.1. Sardine in 8abd. historical series for sardine egg abundances in 8abd without Northwest stations including 2022 value. The red line is the historical mean.

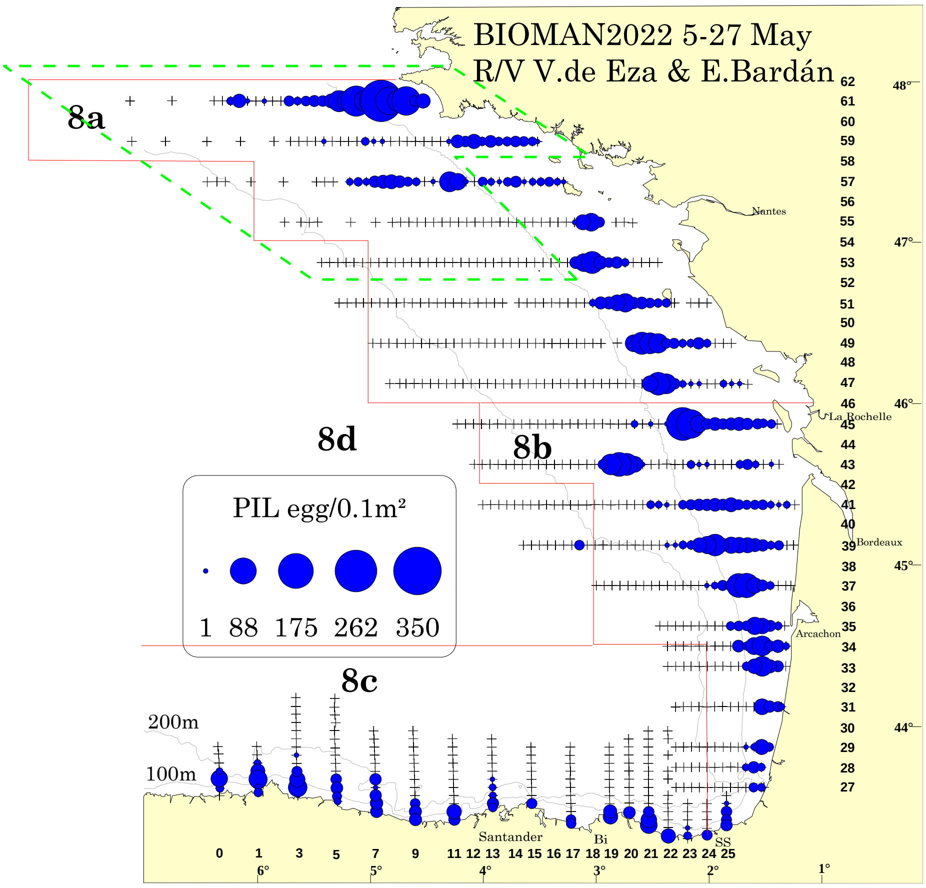
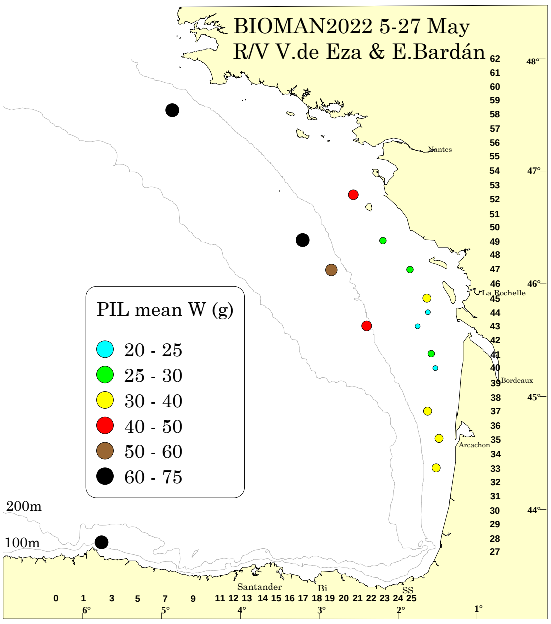


Figure 6.2.2.1.2. Sardine in 8abd. Spatial distribution and abundance of sardine eggs per 0.1m² from the DEPM survey BIOMAN2022 obtained with PairoVET (vertical sampling). The dash green line represents the stations removed for assessment propose in 8abd to be consistent with the historical series. Red lines represent the limits of 8abcd.



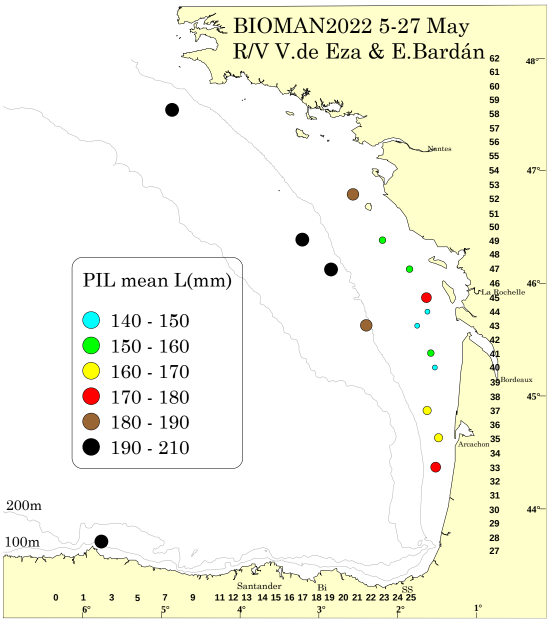


Figure 6.2.2.1.3. Sardine in 8abd. Sardine spatial distribution of mean weight (left) and mean length (right) in the Bay of Biscay from BIOMAN 2022 survey.

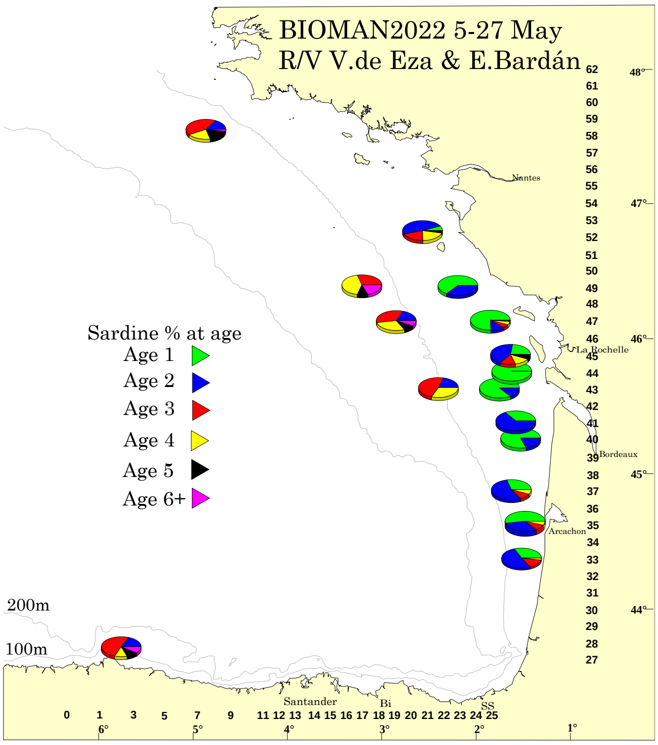


Figure 6.2.2.1.4. Sardine in 8abd. Sardine spatial distribution of percentage at age by haul in the Bay of Biscay from BIOMAN 2022 survey. The different colours are the different ages.

6.2.2.2 Acoustic spring survey (PELGAS): 8ab

The biomass estimate of sardine observed during PELGAS22 is **218 700** tons, which is a decrease compared with the previous surveys, the biomass reaching a medium level of the PELGAS series (below the average). It must be noticed that the sardine abundance index is very variable, and it could be explained that this survey doesn't cover the total area of potential presence of sardine, and it is possible that some years, this specie could be present up to the North, in the Celtic sea, SW of Cornouailles or Western Channel where some fishery occurs. It is also possible that sometimes, a part of the population could be present in very coastal waters, when the RV Thalassa is unable to operate in those waters. The estimate is representative of the sardine present in the survey area at the time of the survey and can be therefore considered as an estimate of the Bay of Biscay sardine population.

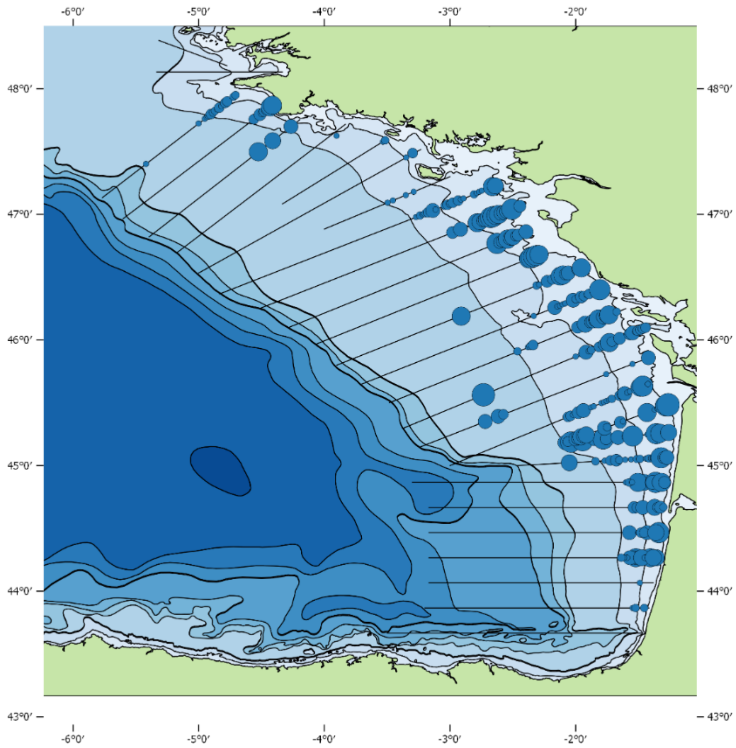


Figure 6.2.2.2.1. Sardine in 8abd. Distribution of sardine observed by acoustics during PELGAS22.

Sardine was distributed all along the French coast of the Bay of Biscay, from the South to the Loire river. The small sardine was present this year, rarely pure, regularly mixed with sprat or mackerel along the coast while the larger individuals were a bit offshore. It must be noticed that one more year, no sardine at all were detected along the shelf break.

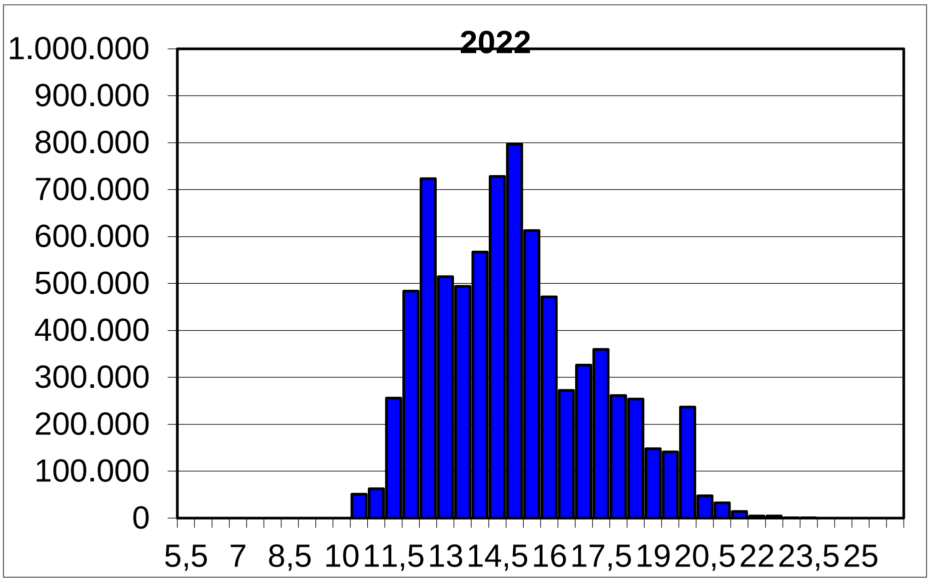


Figure 6.2.2.2.2. Sardine in 8abd. Length distribution of sardine as observed during PELGAS22.

Length distributions in the trawl hauls were estimated from random samples. The population length distributions have been estimated by a weighted average of the length distribution in the hauls. Weights used are the acoustic biomass estimated in the post-stratification regions comprising each trawl haul. The global length distribution of sardine is shown in Figure 6.2.2.2.2.

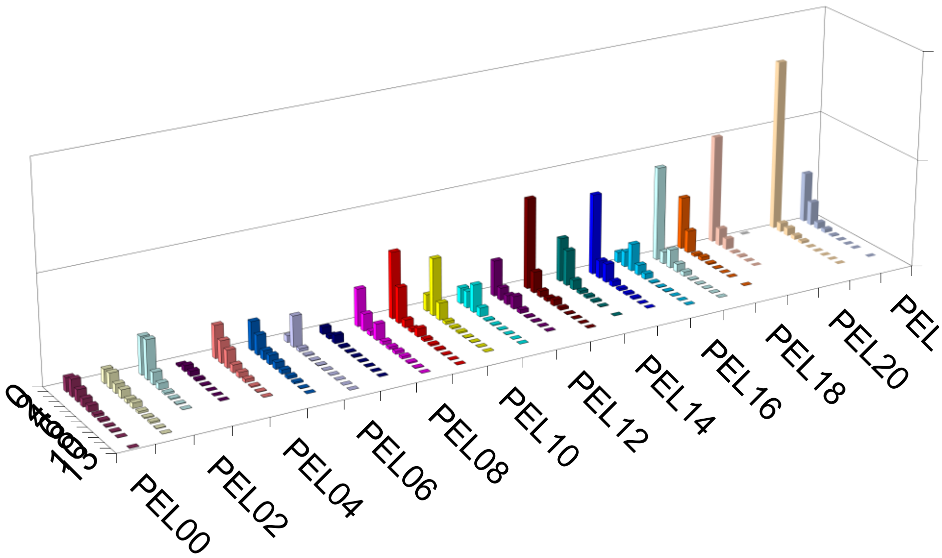


Figure 6.2.2.2.3. Sardine in 8abd. Age composition of sardine as estimated by acoustics since 2000.

PELGAS series of sardine abundances at age (2000-2021) is shown in Figure 6.2.2.2.3. Cohorts can be visually tracked on the graph particularly in the past: the respectively very low and very high 2005 and 2008 cohorts denote atypical years in terms of environmental conditions, and therefore fish (and particularly sardine) distributions. This is no more true in recent years, with the good recruitment in 2013 which doesn't profit to incoming years, or the 2017 year-class which seems to be one of the best recruitment ever and who seems to contribute not that much to the total abundance of sardine in 2018 (and 2019) in the bay of Biscay. 2021 seemed to be the best recruitment ever and the population appeared more and more young (88% of the fish were 1 year old). 2022 shows that this very strong cohort doesn't profit in 2022 to the population with an abundance at age 2 which is around the level of the serie. The population of sardine is still very young, with an age distribution largely dominated by age 1 and 2 groups (sum about 86% in numbers).

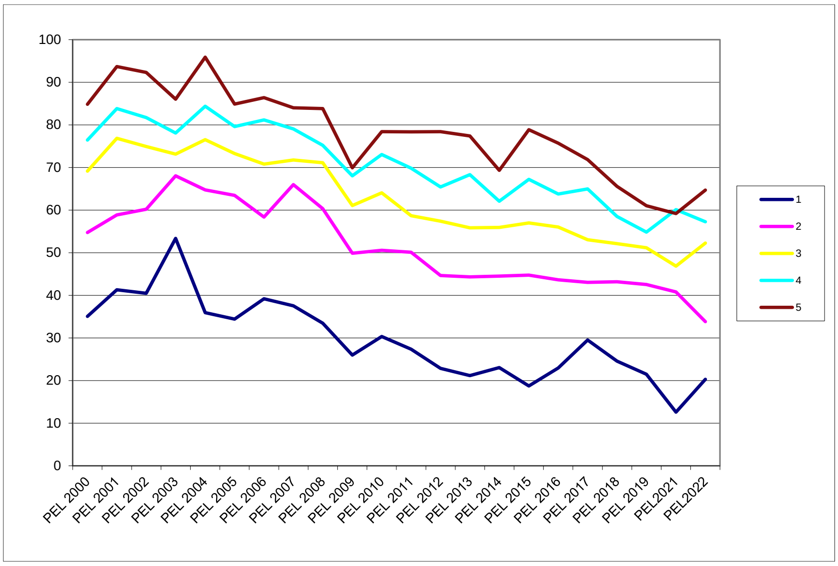


Figure 6.2.2.2.4. Sardine in 8abd. Evolution of mean weight at age (g) of sardine along PELGAS series.

The PELGAS sardine mean weights at age series (Figure 6.2.2.2.4) shows a clear decreasing trend, whose biological determinant is still poorly understood. Further studies are conducted, particularly on the nutritive quality of plankton. One year old sardines were about 40 grammes at the beginning of the serie, and reach only 20 grammes this year, with a strong minimum value in 2021 with 12.5 grammes.

Further work must be conducted to explore the causes of the fluctuation of mean weights at ages.

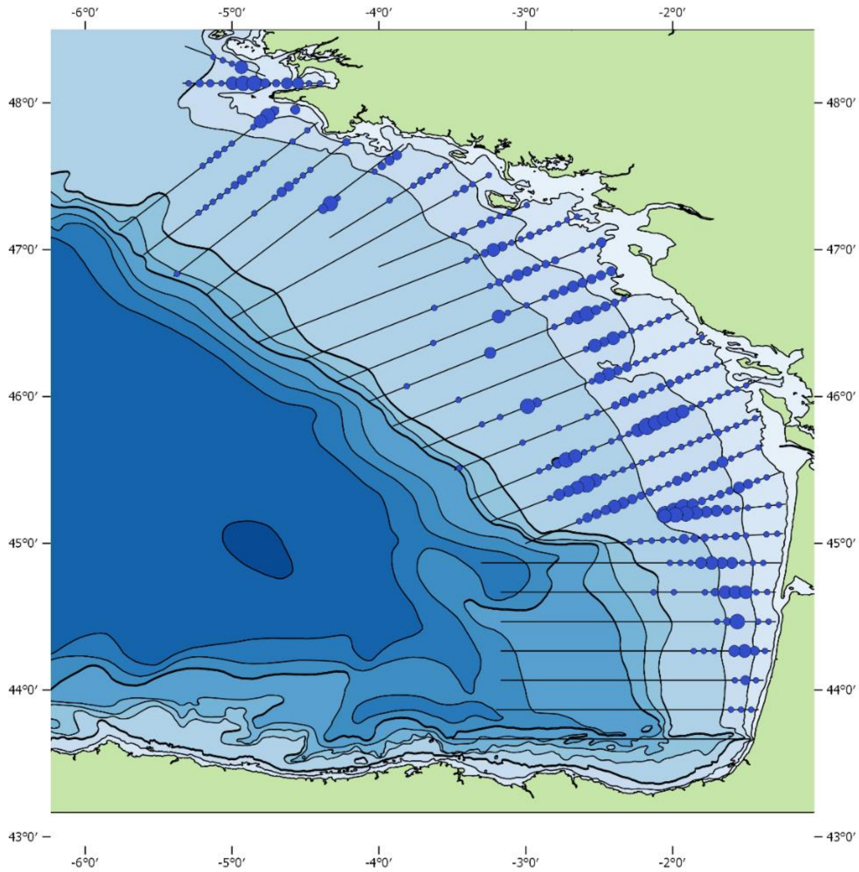


Figure 6.2.2.2.5. Sardine in 8abd. Distribution of sardine eggs observed with CUFES during PELGAS22.

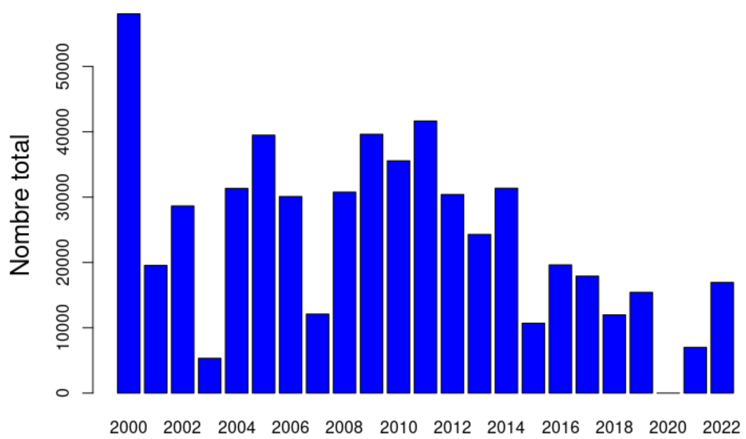


Figure 6.2.2.2.6. Sardine in 8abd. Number of eggs observed during PELGAS surveys from 2000 to 2022.

2022 was marked by a low abundance of sardine eggs as compared to the PELGAS time-series. It must be noticed that this year the one-year-old individuals were not fully mature: 48 % of the age 1 were totally immature (stage1) and 26 % were starting their maturation (stage 2 of the maturity scale) at the time of the survey. Only 25 % of age 1 were fully mature. Almost all of the older individuals (age 2 and more) were spawning.

6.2.3 Biological data

6.2.3.1 Catch numbers-at-length and age

Catches were sampled, and numbers by length class for divisions 8a, b, d by quarter are shown in Tables 6.2.3.1.1 and 6.2.3.1.2, for France and Spain, respectively. Sardine caught in divisions 8a, b, d ranges from 12 to 24 cm (half cm bin). In 2021, a peak is observed in the catch-at size distributions around -18 cm length (half cm bin).

Tables 6.2.3.1.3 and Table 6.2.3.1.4 shows the catch-at-age in numbers for each quarter of 2021 for Spanish and French landings respectively. Even if France and Spain are not fishing at the same place and at the same period, fish of age 1 dominated the fishery for both countries.

6.2.3.2 Mean length and mean weight-at-age

Mean length and mean weight-at-age by quarter in 2021 for France and Spain are shown in Tables 6.2.3.2.1 to 6.2.3.2.4.

Table 6.2.3.1.1. Sardine in 8abd. French Sardine catch at length composition (thousands) in ICES divisions 8a,b in 2021.

Length * (half cm)	Quarter 1	Quarter 2	Quarter 3	Quarter 4	All year
10					
10.5					
11					
11.5					
12			1 118		1 118
12.5		508	3 921	265	4 695
13		826	3 542		4 368
13.5		10 291	6 937	796	18 024
14	365	15 564	10 060	1 326	27 315
14.5	365	13 086	18 384	1 592	33 426
15		10 672	22 909	2 918	36 499
15.5	365	4 447	23 407	3 979	32 197
16	1 094	5 272	30 073	4 510	40 948
16.5	3 282	3 493	27 350	5 836	39 961
17	4 740	14 925	21 851	4 244	45 761
17.5	4 011	10 162	17 211	3 183	34 567
18	11 668	14 608	13 984	7 428	47 687
18.5	9 115	6 986	13 840	10 876	40 818
19	10 574	4 763	11 884	11 407	38 628
19.5	3 646	2 223	5 870	10 346	22 085
20	5 834	2 858	4 472	7 162	20 327
20.5	2 188	635	1 677	5 040	9 540
21	1 458	635	839	1 326	4 258
21.5	365		839	796	1 999
22		318	280	531	1 128
22.5					
23				265	265
23.5					
24					
24.5					
25					
Total number	59 068	122 272	240 447	83 826	505 613
Official catch (t)	2 883	4 515	9 167	4 534	**21 100**

Table 6.2.3.1.2. Sardine in 8abd. Spanish sardine catch-at-length composition (thousands) in ICES Division 8b in 2021.

Length * (half cm)	Quarter 1	Quarter 2	Quarter 3	Quarter 4	All year
10	5				5
10.5	27				27
11	94				94
11.5	187				187
12	180			78	258
12.5	271	1		213	485
13	782	1		365	1 148
13.5	1 507	5		935	2 447
14	1 474	16		1 698	3 188
14.5	988	33		1 770	2 791
15	550	82		2 115	2 747
15.5	471	115	4	2 746	3 336
16	1 300	108	18	5 575	7 000
16.5	3 606	108	36	7 632	11 382
17	7 358	71	140	12 025	19 593
17.5	8 102	50	173	12 370	20 695
18	7 517	21	179	12 645	20 361
18.5	5 645	33	129	8 966	14 773
19	3 998	10	114	7 834	11 957
19.5	2 634		84	5 053	7 770
20	1 462		53	3 548	5 062
20.5	917	2	22	1 688	2 630
21	535		5	841	1 381
21.5	192		2	349	543
22	121		1	172	295
22.5	29			66	95
23				72	72
23.5					
24					
24.5					
25					
28					
Total number	49 952	655	959	88 754	140 320
Official catch (t)	1 784	18	47	3 962	**5 811**

Table 6.2.3.1.3. Sardine in 8abd. Spanish 2021 landings in ICES Division 8ab: Catch in numbers (thousands) -at-age.

Age	First Quarter	Second Quarter	Third quarter	Fourth Quarter	Whole Year
0	0	0	0	431.399	431.399
1	6252.23	182.005	334.23	43771.5	50540
2	17417.5	334.578	284.459	20814.2	38850.7
3	16031.9	116.521	228.866	15976.3	32353.6
4	6510.51	16.5604	75.588	5390.44	11993.1
5	3743.95	5.20663	34.1033	2500.38	6283.63
6	0	0	2.03902	436.087	438.126
7	0	0	0	0	0
8	0	0	0	0	0
9	0	0	0	0	0

Table 6.2.3.1.4. Sardine in 8abd. French 2021 landings in ICES Division 8b: Catch in numbers (thousands) -at-age.

Age	First Quarter	Second Quarter	Third quarter	Fourth Quarter	Whole Year
0			11688.1	776.269	12464.4
1	2240.13	58309.5	162902	29261.6	252713
2	17556.9	29186.4	48077.6	32188.8	127010
3	21175.3	24045.2	13430.8	14079.5	72730.8
4	10510.4	6612.27	3585.52	5771.13	26479.4
5	6195.37	3385.72	543.576	980.238	11104.9
6	496.643	262.748	219.588	770.46	1749.44
7	330.925	218.544			549.469
8	440.93	198.633			639.563
9	121.49	52.9053			174.395

Table 6.2.3.2.1. Sardine in 8abd. Spanish 2021 landings in divisions 8a,b: Mean length (cm) -at-age.

	First Quarter	Second Quarter	Third quarter	Fourth Quarter	Whole Year
0	0	0	0	12.501	12.501
1	14,04	15.225	17,539	16.742	16.408
2	17,54	16.573	18,507	18.401	17.999
3	18,072	17.543	18,928	18.922	18.496
4	19,198	18.694	19,722	19.799	19.471
5	20,198	19.172	19,926	20.045	20.135
6	0	0	21,754	22.004	22.002
7	0	0	0	0	0
8					
9					

Table 6.2.3.2.2. Sardine in 8abd. Spanish 2021 landings in divisions 8a,b: Mean weight (kg) -at-age.

	First Quarter	Second Quarter	Third quarter	Fourth Quarter	Whole Year
0	0	0	0	0.0153	0.0152
1	0.0175	0,022094911	0.0418	0.0368	0.0344
2	0.0340	0,028638209	0.0491	0.0484	0.0418
3	0.03716	0,034003392	0.0525	0.0525	0.0448
4	0.0447	0,041164158	0.0593	0.0601	0.0517
5	0.0522	0,044446833	0.0611	0.0622	0.0562
6	0	0	0.0791	0.082	0.0820
7	0	0	0	0	0
8					
9					

Table 6.2.3.2.3. Sardine in 8abd. French 2021 landings in ICES Division 8a,b: mean length (cm) -at-age.

Age	First Quarter	Second Quarter	Third quarter	Fourth Quarter	Whole Year
0	15.51		13.09	13.35	13.11
1	17.89	14.4	15.75	16.34	15.51
2	18.34	17.3	18.18	18.85	18.11
3	19.37	17.9	18.93	19.34	18.49
4	19.45	19.1	20.01	20.07	19.54
5	20.49	19.2	20.29	20.32	19.49
6	20.17	20.8	21.45	13.96	17.78
7	19.00	20.8			20.42
8	21.00	19			19.00
9	15.51	21			21.00

Table 6.2.3.2.4. Sardine in 8abd. French 2021 landings in ICES Division 8a,b: mean weight (kg) -at-age.

Age	First Quarter	Second Quarter	Third quarter	Fourth Quarter	Whole Year
0			0.01765	0.01874	0.01771
1	0.02980	0.02377	0.03123	0.03499	0.02993
2	0.04629	0.04198	0.04858	0.05434	0.04821
3	0.04991	0.04615	0.05511	0.05882	0.05135
4	0.05916	0.05648	0.06537	0.06596	0.06081
5	0.05986	0.05748	0.06827	0.06849	0.06031
6	0.07036	0.07379	0.08105	0.02150	0.05070
7	0.06703	0.07369			0.06968
8	0.05570	0.05570			0.05570
9	0.07587	0.07587			0.07587

6.2.3.3 Maturity

The maturity ogive is provided yearly by the PELGAS survey, carried out in May, from the visual examination of gonads according a maturity scale (stage 1- 5). Age 1 is the only age group which has partial maturity, and usually it has been assessed to be about 0.7580 (mean of maturity in 2017-2019). In2022 about 49% (66% in 2021) of age 1 fishes were immature (a value corresponding to the unweighted mean of the proportion age 1 fishes in stage 1 of maturity). This implies that only about 51%% of age 1 fishes were mature.

6.3 Stock assessment

6.3.1 Historical stock development

Model used: SS3

Since 2019 this stock is assessed using SS3. The procedure is described in the stock annex following the WKPELA benchmark (2017). It was updated in 2019 following the IBPSardine interbenchmark (ICES, 2019). The interbenchmark took place in 2019 and was tasked with evaluating the stock assessment focusing on retrospective bias, data revisions and updating reference points. Standard model diagnostics were used to evaluate a series of interventions designed to evaluate the models and to determine causes of and corrections for the retrospective bias.

The retrospective bias could be corrected by several straightforward interventions. First, fixing selectivity at asymptotic improved model fit and reduced bias. Second, invoking a very weak stock–recruitment relationship (steepness=0.99) and commensurate bias correction ramping on recruitment deviations coupled with not estimating terminal year recruitment, further reduced the bias. Such a treatment of terminal year recruitment and penalizing poorly informed recruitment deviations is common assessment practice.

Additional concerns were raised by the estimated catchability coefficients above one for the PELGAS and BIOMAN surveys. There are a number of reasons why these surveys could estimate higher abundance than the assessment model. These include mismatch of timing given the rapid population dynamics, overestimation of acoustic biomass, mismatch of assumed selectivity of the survey as well as many other common issues that support the standard practice of treating most surveys as relative rather than absolute. Once the decision to use these indices as relative inputs, the absolute value of catchability is meaningless as the index could simply be scaled to a mean of one with the same impact in the model.

Given the substantial reduction in retrospective bias achieved through straightforward model interventions and the solid diagnostic performance of the WG-preferred model, it was recommended the assessment be upgraded from category 2 to category 1.

Nonetheless, the model cannot estimate MSY-based reference points and this requires proxies. Based on considerations of life history, the WG recommends a proxy of SPR35% for B_{lim}. Recommendations for future work include explicitly modelling variability of growth reflecting the declines in mean weight-at-age, incorporating length composition and considering a management procedure approach as the majority of catch comes from ages 1 and 2 which are very poorly informed in catch projection due to the time-lag between the assessment and the provision of management advice.

This assessment is the fourth one following the interbenchmark in 2019.

6.3.2 State of the stock

Summary of the assessment is shown in Table 6.3.2.1 and in Figures 6.3.2.1–6.3.2.2.

The spawning–stock biomass (SSB) is above B_{lim} in 2022. SSB has decreased strongly from 2010 to 2012 to the lower value of the series and has been stable until 2017. SSB has since then had a decreasing trend with 2021 the lowest value of the time-series (50141.7 tons). In 2022, SSB show a very small increase with a value of 62 534 tons The decrease after 2012 is not clearly related to the increase in fishing mortality in recent years, as F went up above F_{MSY} just after the drop in biomass assessed for January 2012. Landings were above 30 kt between 2012 and 2014, dropping for two years and then raising up again to 32 kt in 2018 for four consecutive years. Fishing mortality has been above 0.4 and above F_{MSY} since 2012. Recruitment has been variable over time. Recruitment in 2021 is lower than in 2020. Also, the downwards revision of recruitment in 2020 calculated during the 2021 assessment (ICES. 2021) is due to large age 1 estimates in the PELGAS survey in 2018, 2019 and 2021 that could not be tracked consistently in the age 2 estimates of the following year.

Table 6.3.2.1. Sardine in 8abd. Summary of the sardine 8abd stock assessment.

Year	Recruitment (thousand)	SSB (tonnes)	Total Catch (tonnes)	F(2–5)
2000	4289250	136348	15097	0.152
2001	5212970	154389	15005	0.156
2002	3459770	167059	18277	0.184
2003	3822350	175678	16607	0.149
2004	7041850	146755	14197	0.142
2005	2311460	174396	16360	0.139
2006	3545680	153484	16741	0.153
2007	6900310	137456	17323	0.161
2008	8431470	157525	21821	0.23
2009	3451450	134492	20855	0.185
2010	2632200	150272	20127	0.183
2011	4302900	120974	23208	0.24
2012	7501940	88608.7	30900	0.43
2013	5216840	94728	32938	0.47
2014	6956530	98464.7	35704	0.59
2015	2590210	88334.8	28756	0.50
2016	gpurse	80949.4	29754	0.60
2017	4689770	101761	30435	0.59
2018	5153780	87847.1	32299	0.66
2019	4595980	70586.9	24579	0.50
2020	6253460	83678.2	31368	0.66
2021	4728130	50716.1	26198	0.60

***Geometric mean (2002–2021).**

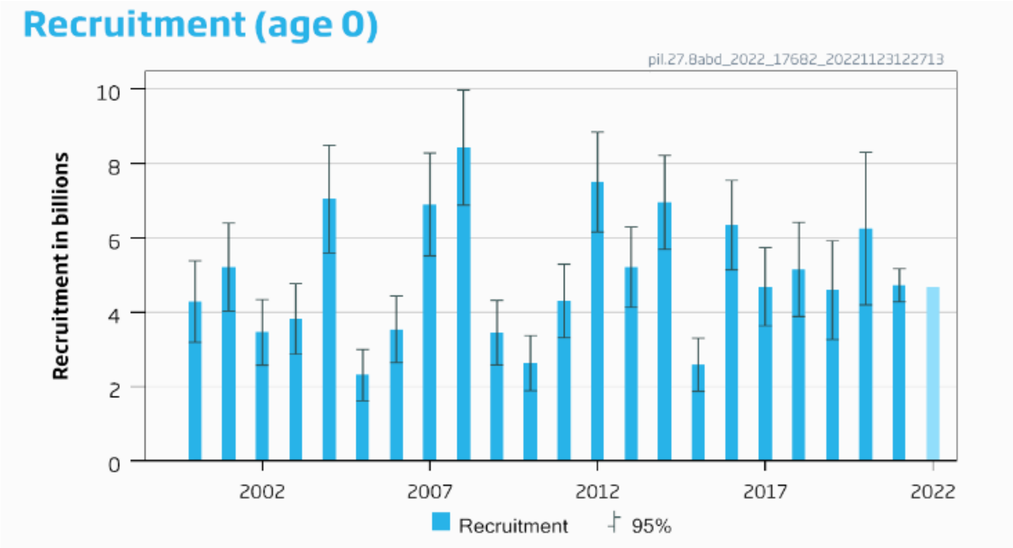


Figure 6.3.2.1. Sardine in 8abd. Recruitment estimates from SS3 outputs for sardine 8abd. Last year's value is estimated from the geometric mean (2002-2021).

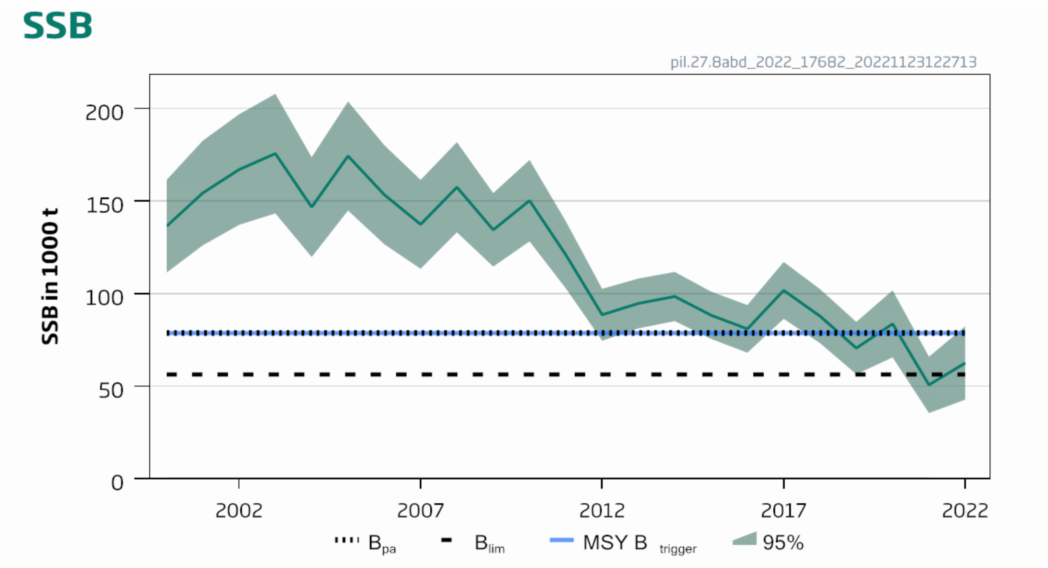


Figure 6.3.2.2. Sardine in 8abd. Spawning–stock biomass from SS3 outputs for sardine 8abd. Last year's value is estimated from the model.

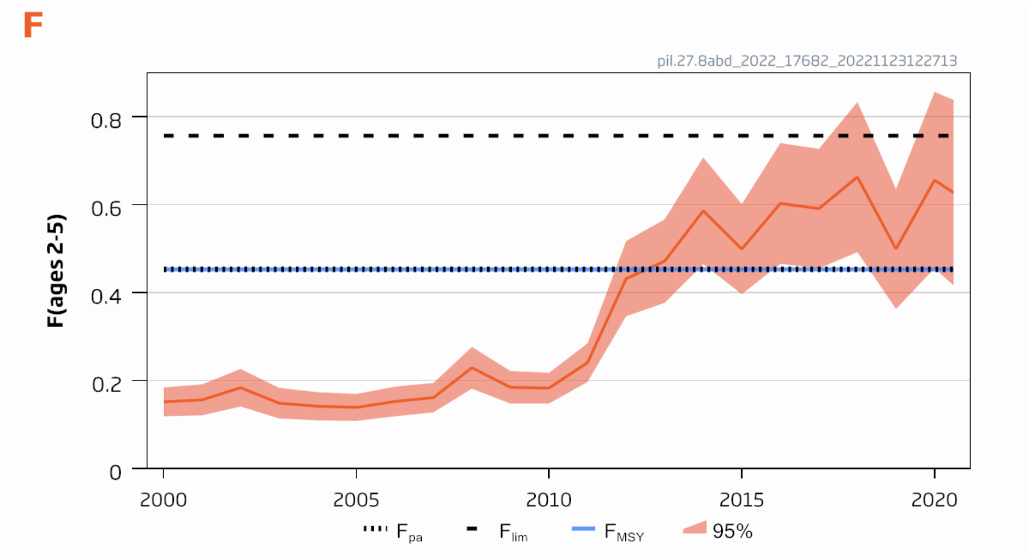


Figure 6.3.2.3. Sardine in 8abd. Fishing mortality for ages 2 to 5 derived from SS3 outputs for sardine 8abd.

6.3.3 Diagnostics

Residuals (Figures 6.3.3.1–6.3.3.2) and diagnostics do not highlight any problem regarding the input data and model fit. Some cohorts lead to some model over or underestimations. This phenomenon appears on some years for the PELGAS survey. For PELGAS, age 1 has positive residuals since 2011 and negative in earlier years.

For the commercial vessels, the cohort effect is less visible, but some years appears to have larger residuals than other (e.g. 2009). The model fit to the survey indices is within the confidence intervals of those indices.

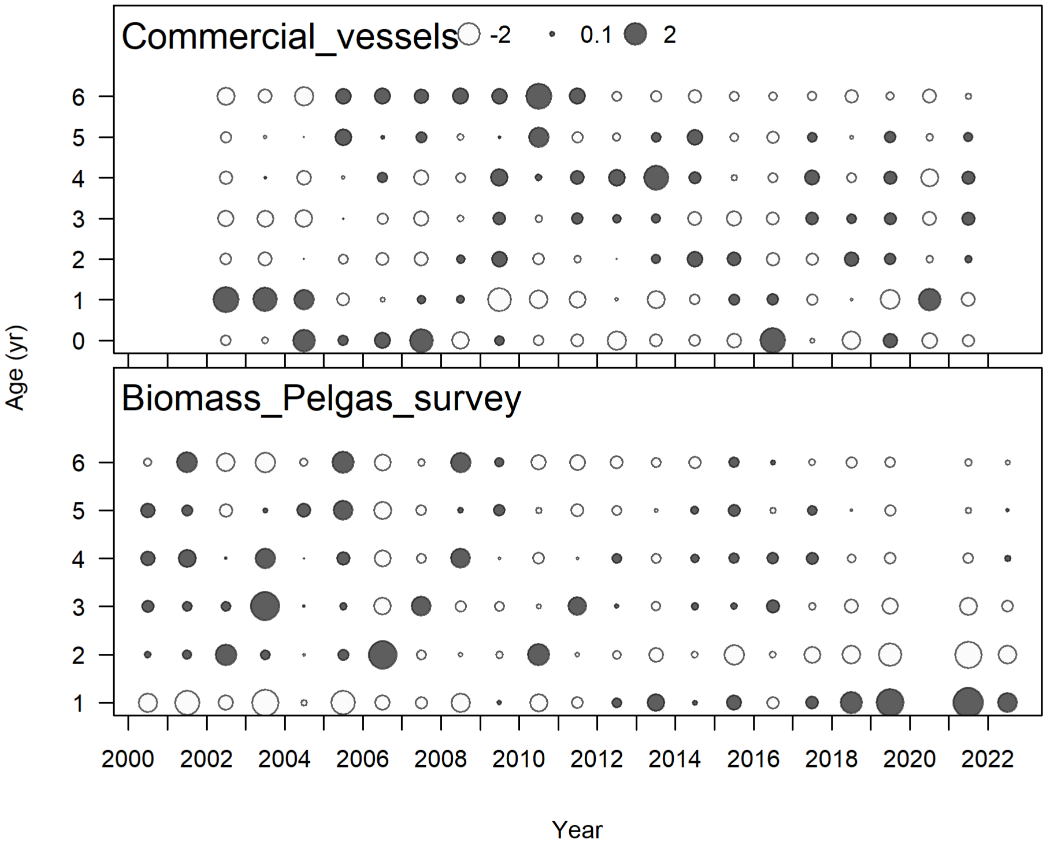
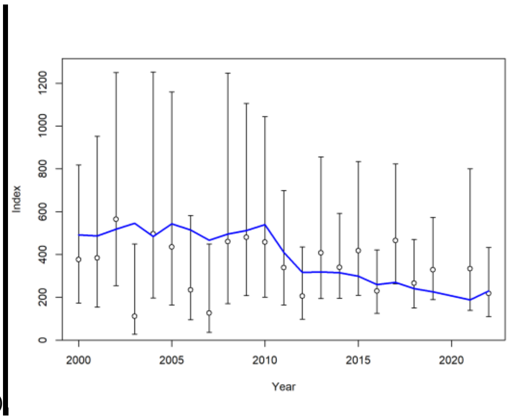
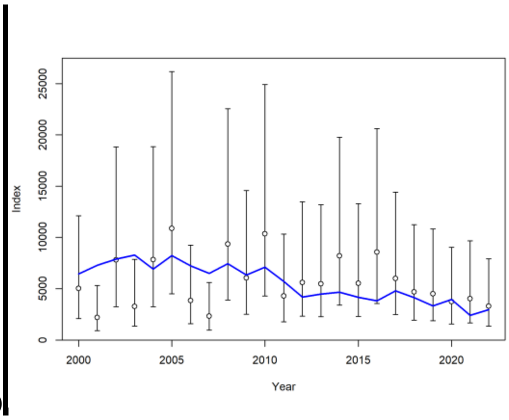


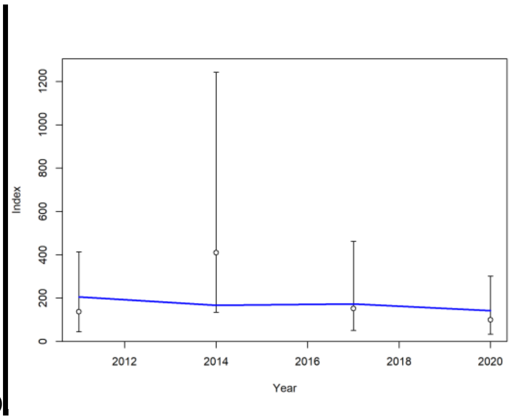
Figure 6.3.3.1. Sardine in 8abd. Fit between model and age composition from the PELGAS survey (bottom) and commercial vessels (top) up to 2022.



a)



b)



c)

Figure 6.3.3.2. Sardine in 8abd. Fit between model and survey indices: a - Acoustic (PELGAS), b - egg count (BIOMAN), c - DEPM.

6.3.4 Retrospective pattern

Retrospective patterns for SSB, F_{bar}(2–5), apical F and recruitment were computed for years 2015–2022 (Figure 6.3.4.1) using the r4ss *do_retro()* function and Mohn's rho estimates were calculated using the same approach carried out during the interbenchmark and therefore values can be compared to the work made during the interbenchmark. For each run, assessment was performed including survey data until the last retrospective year and catch data until previous year, as done in the current assessment (2022).

Overall, SSB tends to be overestimated while F is underestimated. There is no clear patterns regarding recruits although the magnitude of sporadic stronger recruitment events tend to increase Mohn’s rho estimates for recruits

Absolute values of Mohn's rho estimates differ compared with previous assessment (especially for R) but on a lower extent than last year's assessment in regards to previous years:

- Mohn's rho for SSB is 0.372 (previously 0.420).
- Mohn's rho for F is -0.301 (previously -0.232).
- Mohn's rho for R is 0.080 (previously 0.512).

The reason for this might be that in 2020 and 2021, two effects might have impacted the assessment: 1) the strong downward deviation of the model in 2021 is related to the large number of age-1 individuals with low weight at age and low fecundity. This drives down the SSB in 2021. 2) The lack of stock structure input from PELGAS in 2020, cancelled due to COVID-19, possibly accounts for this issue as SS3 had to fill the gap possibly from the previous and next year internal estimates. This year's assessment seems to be less influenced by the lack of PELGAS survey in 2020 and the 2022 is more in line with the 2021 assessment in terms of stock structure. Recruitment estimate in 2020 has been scaled down in the current assessment. This reduces the erratic pattern seen previously.

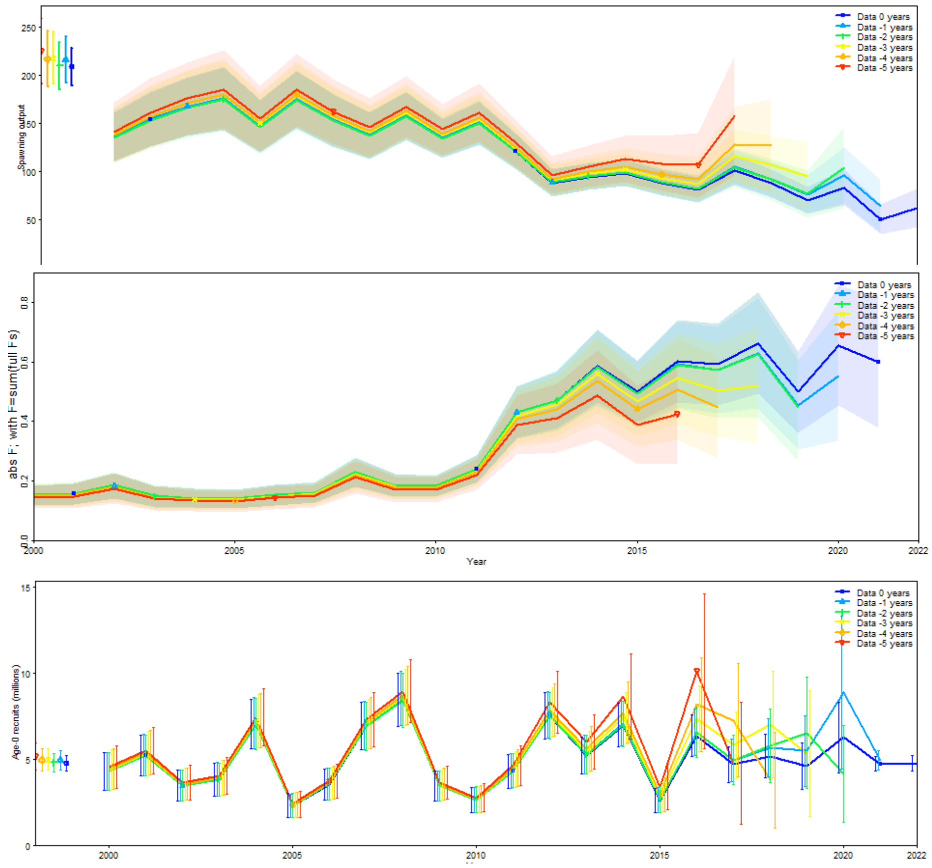


Figure 6.3.4.1. Sardine in 8abd. Summary of retrospective plots.

6.3.5 Comparison with previous assessment

The comparison is done with the run carried out at WGHANSA last year (Figures 6.3.5.1–6.3.5.3).

Uncertainties are generally higher for the last two years because the available data of the assessment year are limited to an assumption on preliminary catches and survey data. The data of the previous year are fully consolidated in terms of number and weight-at-age for the commercial fleets. The catches are also final rather than assumed.

This year, the run does not differ substantially from last year's run in terms of SSB and F. This is generally what has been observed in previous WGHANSA reports except in 2021 where the lack of PELGAS survey in 2020 was suspected to have a strong impact on the assessment. This year, the runs start to slightly diverge in 2016 for F and 2017 for the SSB. Both runs stay very close for SSB as well for F. For recent years, SSB seems overestimated and F underestimated compared with the last year's run. There is no clear pattern for recruits. The median recruitments start to differ from 2017.

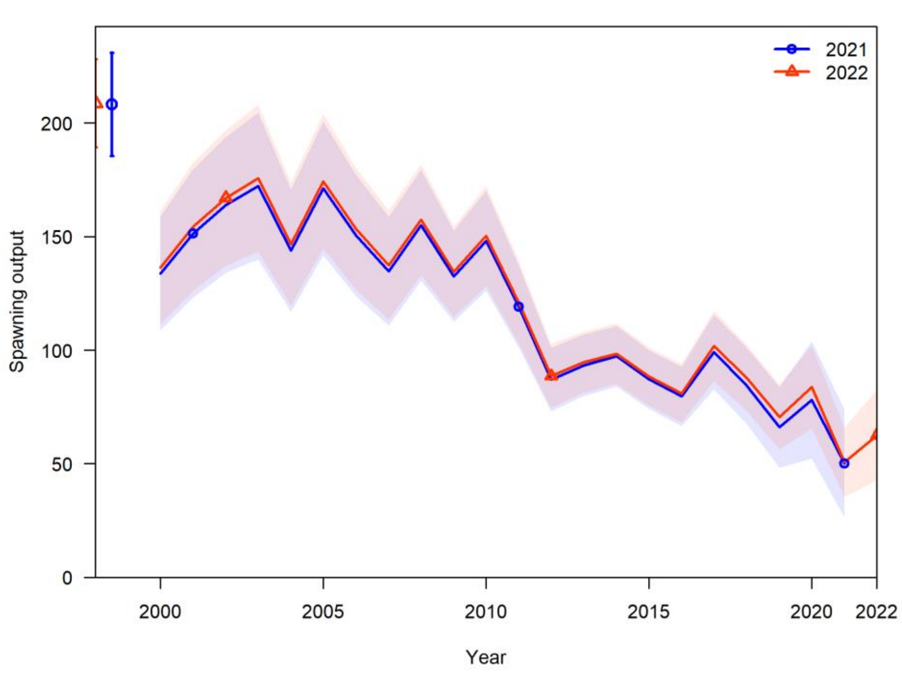


Figure 6.3.5.1. Sardine in 8abd. Comparison of SSB estimates between this year and the 2021 run.

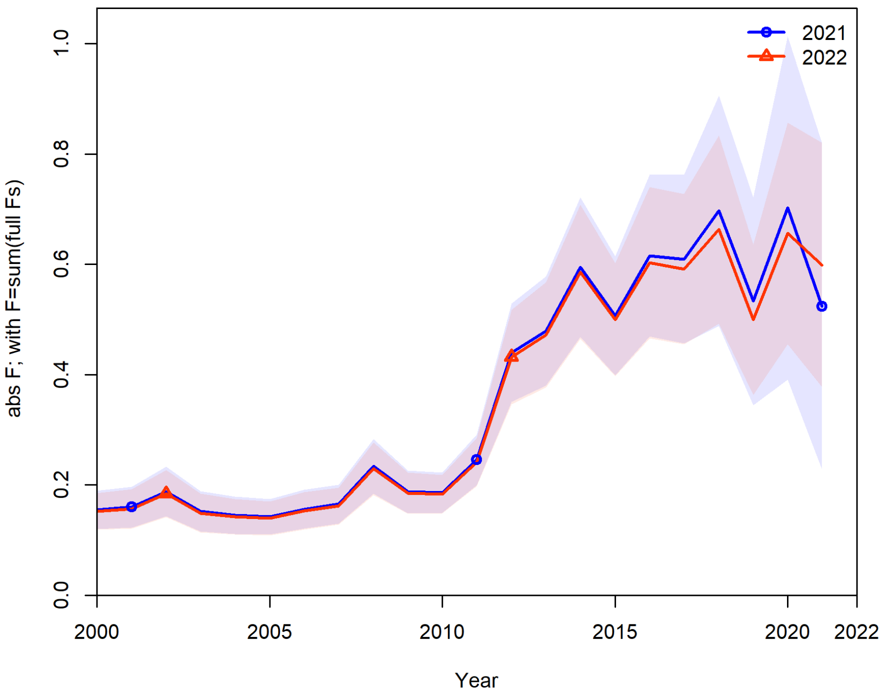


Figure 6.3.5.2. Sardine in 8abd. Comparison of fishing mortality estimates between this year and the 2021 run.

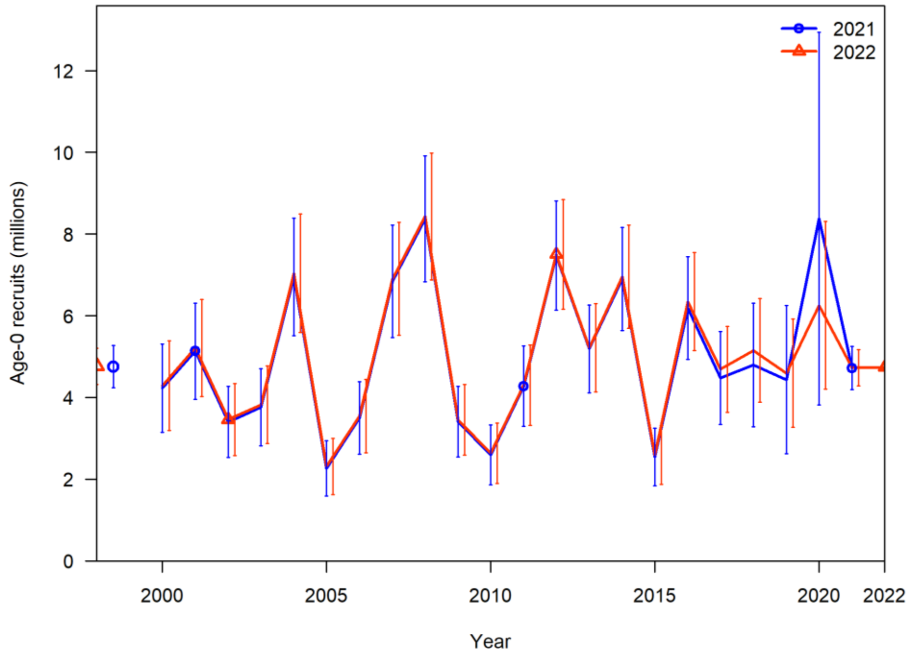


Figure 6.3.5.3. Sardine in 8abd. Comparison of Recruitment estimates between this year and the 2021 run.

6.4 Short-term projections

The recruitment of sardine for the intermediate year is assumed to be the geometric mean of the time-series of recruitment. Short-term projections were performed using FLR libraries using the *fwd* function.The initial stock size corresponds to the assessment estimates for ages 1–6+ at the final year of the assessment. The maturity ogive is provided during the interim year in 2022 by the average of PELGAS survey for the last three years. F and M before spawning are zero, which correspond to the beginning of the year when the SSB is estimated by the model. Weights-at-age in the stock are provided during the interim year by the average of the PELGAS survey for the last 3 years. Weights-at-age in the catch are calculated as the arithmetic mean value of the last 3 years. The exploitation pattern is equal to the last year of the assessment.

Recruitment in the interim year and forecast year is set equal to the geometric mean of the time-series (2002-2021). Recruitment for 2021 was assumed to be 4681 million individuals. Assumption for the intermediate year are presented in Table 6.4.1.

Preliminary catches are estimated and used as assumption for the interim year. The *fwd* function is set to use the preliminary catch estimates (instead of F estimates). Preliminary catches were available for quarter 1 to 3.The assumption for the catch in 2022 relies on preliminary catch statistics available from Q1-Q3 of 2022. Q4 is estimated from the average proportion of Q4 catches in last 3 years (2019-2021). The assumed catches for 2022 are 22 608 tonnes. The catch assumption was also included as preliminary catches in the stock assessment model this year.

Input data for the short-term forecast are provided in Table 6.4.2. Table 6.4.3 provides alternative catch options for 2022.

Table 6.4.1. Sardine in 8abd. Assumptions for the intermediate year.

Variable	Value	Notes
Fages 2–5 (2022)	0.55	Based on assumed catches for 2022
SSB (2023)	69 828	Short term forecast; tonnes
Rage 0 (2022-2023)	4681	Geometric mean (2002–2021); millions
Total catch (2022)	22 608	Preliminary value based on reported catches in Quarters 1 to 3 and assumed catches for Quarter 4; tonnes
Discards (2022)	0	Negligible; tonnes

Table 6.4.2. Sardine in 8abd. Input data for the short-term forecast.

Year	Age	stock.n	stock.wt	catch.wt	Mat	M	F
2022	0	4680.978	0.000000	0.023967	0	1.071	0.0064865
	1	1606.337	0.019767	0.034800	0.59646	0.6912	0.2017255
	2	814.584	0.042067	0.046567	0.98366	0.5463	0.3453382
	3	214.577	0.050067	0.054067	1	0.4752	0.4529299
	4	84.184	0.058100	0.065000	0.99556	0.4356	0.4529299
	5	26.965	0.062100	0.066900	0.99155	0.4122	0.4529299
	6+	18.495	0.073433	0.075133	1	0.3978	0.4529299
2023	0		0.000000	0.023422	0	1.071	0.0081517
	1		0.019189	0.034333	0.57977	0.6912	0.2535105
	2		0.041922	0.045589	0.97821	0.5463	0.4339901
	3		0.049689	0.053222	1	0.4752	0.5692016
	4		0.059200	0.064267	0.99408	0.4356	0.5692016
	5		0.062467	0.066033	0.98874	0.4122	0.5692016
	6+		0.072811	0.074978	1	0.3978	0.5692016
2024	0		0.000000	0.023422	0	1.071	0.0081517
	1		0.019189	0.034333	0.57977	0.6912	0.2535105
	2		0.041922	0.045589	0.97821	0.5463	0.4339901
	3		0.049689	0.053222	1	0.4752	0.5692016
	4		0.059200	0.064267	0.99408	0.4356	0.5692016
	5		0.062467	0.066033	0.98874	0.4122	0.5692016
	6+		0.072811	0.074978	1	0.3978	0.5692016

Table 6.4.3. Sardine in 8abd. Catch option table for 2023.

Basis	Catch (2023)	F (2023)	SSB (2024)	% SSB change *	% catch change **	% advice change
ICES advice basis						
MSY approach: F = F_{MSY} * SSB(2023)/ MSY $B_{trigger}$	21 497	0.40	70 347	+0.74	-17.9	-24
Other scenarios						
F = 0	0	0	87 731	+26	-100	-100
F = F_{pa}	23 820	0.45	68 507	-1.89	-9.1	-15.5
F = F_{lim}	36 127	0.76	58 912	-15.6	+38	+28
SSB(2024) = B_{lim}	39 545	0.85	56 300	-19.4	+51	+40
SSB(2024) = B_{pa} = MSY $B_{trigger}$	11 077	0.193	78 700	+12.7	-58	-61
F = F(2022)	28 021	0.55	65 201	-6.6	+7.0	-0.59

*** SSB 2024 relative to SSB 2023.**

**** Advised catch for 2023 relative to catch in 2021 (26 198 tonnes).**

***** Advised catch for 2023 relative to advised catch for 2022 (28 187 tonnes).**

The catch options for 2023 are substantially lower than the advice for 2022, due to a revision downwards of the 2020 recruitment.

Based on the GM recruitment and *catch assumption* in 2022, for all catch options for 2023, SSB in 2024 will stay above B_{lim} but is only above MSY $B_{trigger}$ in the case of targets of closure of the fishery (F=0).. SSB in 2024 is expected to decrease compared with the one of 2023 for F=Fpa, F=Flim, F=F(2022), Blim target SSB expected to increase when catch options are the most limiting for 2023: closure, Bpa target and MSY approach.

6.5 Medium-term projection

No medium-term projections were carried out.

6.6 MSY and Biological reference points

As a result of the Inter-benchmark carried out in October 2019, the assessment of this sardine has been upgraded to category 1 and a set of new Biological reference points have been defined. In particular, B_{lim} has been proposed at 35%SBR (ICES 2019), based on considerations of life history and precautionary reference points (Myers *et al*., 1999; Mace, 1994; Mace and Sissenwine, 1993) and proxies for F_{MSY} based on natural mortality rate (Zhou *et al*., 2012).

The Inter-benchmark preferred this approach because for this stock 18 pairs of stock and recruitment estimates (2000–2017), covering a narrow range of biomasses (Min/Max=51%) and with no clear indications of impaired recruitment (Figure 6.6.1), setting B_{pa}=B_{loss} led to infer B_{lim} (63 328 t) and afterwards F_{MSY} (0.27) which seemed to be respectively a bit high and low value respectively. On the one hand, such B_{lim} would be above the expected biomass at $F_{0.1}$ (as calculated for this stock in the deterministic yield-per-recruit) and on the other hand F_{MSY} at 0.27 results in a 61%SBR, which is well below the typical F_{MSY} proxies at %SBR of 40% or 50% (Mace, 1994; Horbowy and Luzenczyk, 2012), below $F_{0.1}$, and also below the alternative F_{MSY} proxy of 0.87*M (= 0.44). For these reasons, an alternative definition of B_{lim} from which derived F_{MSY} was looked for, based on %SPR.

Mace (1994) and Mace and Sissenwine (1993) pointed out that for stocks of unknown resilience a more prudent approach would be using F30%B0. Furthermore, in their analysis Mace and Sissenwine (1993) found that pelagic species that reach relatively small maximum size and/or mature at small size, seem to have high replacement %SPR, and the analysis by taxonomic groups suggested a mean replacement %SPR for cupleoids of about 37.5% higher than for other taxonomic groups. Myers *et al*. (1999) also found that the median steepness of cupleoids and engraulidae were intermediate (not in the upper range of values). Therefore, it can be deduced or presumed from a precautionary approach that small pelagic fish may have relatively lower resilience to fishing (Mace and Sinsenwine, 1993). This led the IBP group to set B_{lim} at 35%B0, which was equal to 56 300 t.

Following the ICES guidelines for stocks in Category 1 and 2, the remaining reference points were derived from the former value of B_{lim} (= 56 300 t). Bpa was derived as $B_{pa} = B_{lim}$ x exp(1.645 σB), where σB is the standard deviation of ln(SSB) in the terminal year (2018) (σB = 0.204 rounded to 0.2). Thus, B_{pa} was set at 78 700 tonnes. As unconstrained F_{MSY} in Eqsim resulted in a value (0.621) conditioned to a hockey stick S–R relationship with inflection point at B_{lim} (Figure 6.6.2). Because this F_{MSY} value was higher than F_{pa} (0.539) and higher than $F_{p0.05}$ (0.453) the F_{MSY} value was reduced to $F_{p0.05}$. The final estimate of F_{MSY} (over ages 2–5) (= 0.453) has the property of being consistent with the ideas of Zhou *et al*. (2012) of setting F_{MSY} equal to 0.87·Natural Mortality (=0.44 for this sardine stock).

In 2021, ICES has been revising the definition of reference points. Fpa is now equal to $F_{p0.05}$. Therefore, that value has been updated and use in the short-term forecast this year.

The updated biological and MSY reference points in absolute terms are:

Table 6.6.1. Sardine in 8abd. Biological Reference Points for sardine in 8abd as estimated in ICES 2019.

Framework	Reference point	Absolute value	Technical basis
MSY approach	MSY $B_{trigger}$	78 700	B_{pa}
	F_{MSY}	0.453	$F_{MSY} = F_{p.05}$, i.e. the F that leads to SSB >B_{lim} with probability 0.95 when including the ICES MSY advice rule
Precautionary approach	B_{lim}	56 300	35%SPR, i.e. equilibrium biomass at F that leads to 35% of spawner of recruit without fishing
	B_{pa}	78 700	$B_{pa} = B_{lim} \times \exp(+1.645 \times \text{sigma})$, where sigma=0.2
	F_{lim}	0.757	F that results in 50% probability that SSB is above B_{lim} in the long term, using segmented regression with B_{lim} (EqSim)
	F_{pa}	0.453	$F_{p0.5}$. The F that leads to SSB ≥ B_{lim} with 95% probability
Management plan	SSB_{MGT}	Not applicable	
	F_{MGT}	Not applicable	

All details of the calculations are described in the Inter-benchmark report (ICES, 2019) and in the stock annex. These values are expected to be updated every benchmark or after relevant changes in the selectivity of the fishery are detected.

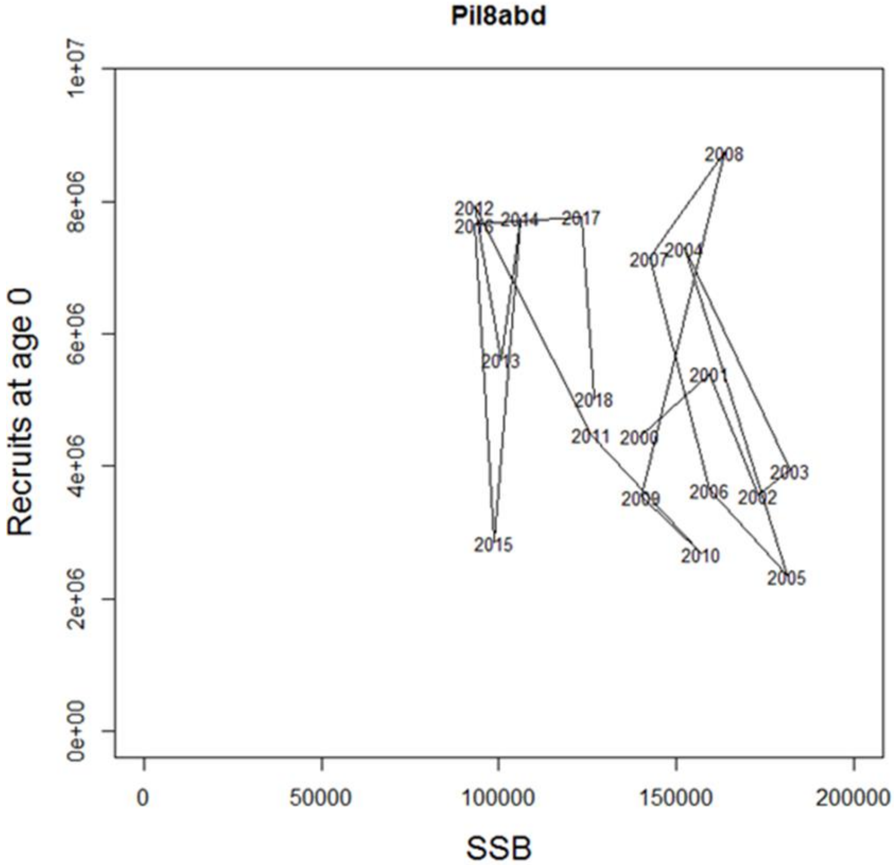


Figure 6.6.1. Sardine in 8abd. Stock–recruitment relationship for sardine in 8abd.

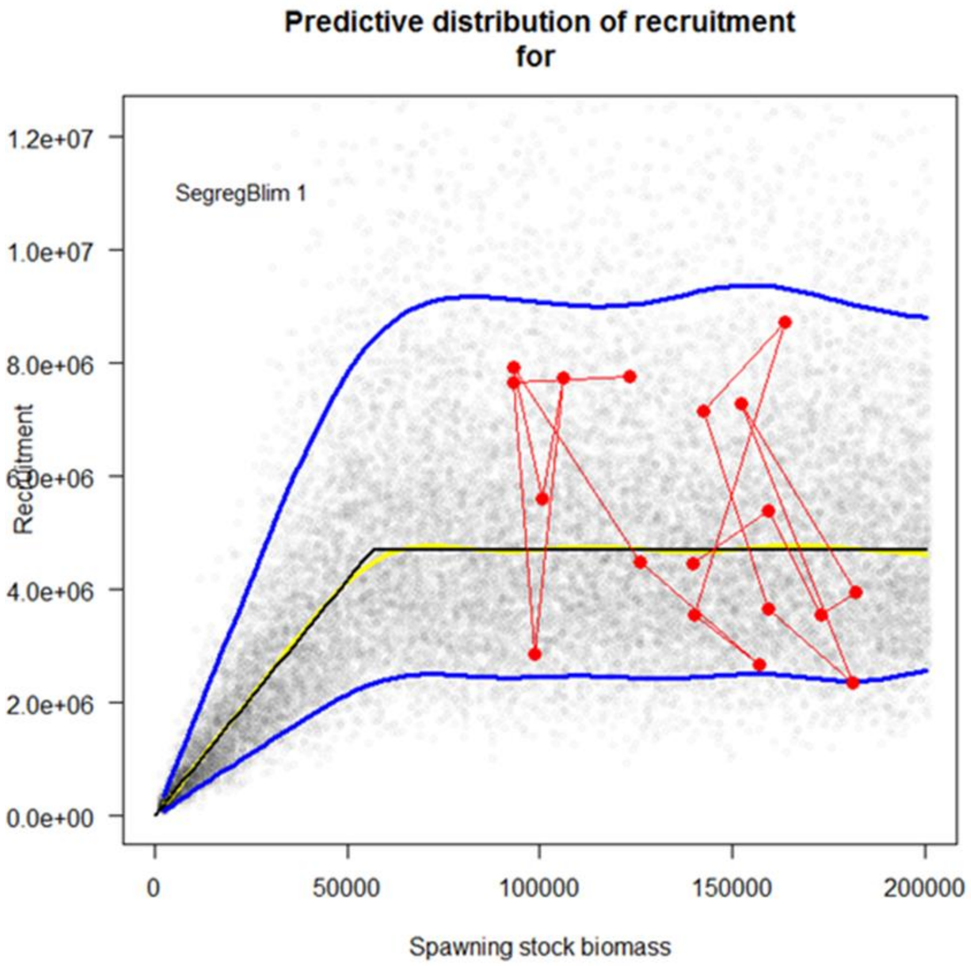


Figure 6.6.2. Sardine in 8abd. Segmented regression model with the breakpoint fixed at B_{lim} for sardine in 8abd.

6.7 Management plan

There are no specific management objectives or a management plan for this stock at the moment. There is ongoing discussion about a management plan or TAC through the SWWAC for this stock, but the plan has not been formalised yet.

6.8 Uncertainties and bias in assessment and forecast

Uncertainties in the assessment relate to the retrospective pattern and relative changes in the perception of the most recent years.

Most of the uncertainties in the forecast comes from the assumption in the intermediate year although the fishery is not expected to increase over the next years.

6.9 Management considerations

No TAC is currently set for this stock.

6.10 References

Beddington, J.R. and Cooke, J. 1983. The potential yield of previously unexploited stocks. FAO Fisheries Technical Paper No. 242, 63 pp.

Buckland S.T., Burnham K.P., Augustin N.H. 1997. Model selection: an integral part of inference. Biometrics 53:603–618.

Horbowy, J., and Luzeńczyk, A. 2012. The estimation and robustness of FMSY and alternative fishing mortality reference points associated with high long-term yield. Canadian Journal of Fisheries and Aquatic Sciences, 69: 1468–1480.

ICES. 2017. ICES Advice technical guidelines. ICES Advice, Book 12.

ICES. 2016. Report of the Workshop to consider FMSY ranges for stocks in ICES categories 1 and 2 in western waters (WKMSYREF4), 13–16 October 2015, Brest, France. ICES CM 1025/ACOM:58.187 pp.

ICES. 2019. Inter-benchmark process on sardine (*Sardina pilchardus*) in the Bay of Biscay (IBPSardine). ICES Scientific Reports. 1:80. 34 pp. http://doi.org/10.17895/ices.pub.5552.

ICES. 2018. Report of the Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA), 26–30 June 2018, Lisbon, Portugal. ICES CM 2018/ACOM:17. 639 pp.

ICES. 2019. Inter-benchmark process on sardine (*Sardina pilchardus*) in the Bay of Biscay (IBPSardine). ICES Scientific Reports. 1:80. 34 pp. http://doi.org/10.17895/ices.pub.5552

ICES. 2021. Working Group on Southern Horse Mackerel Anchovy and Sardine (WGHANSA). ICES Scientific Reports. 3:55. 679 pp. https://doi.org/10.17895/ices.pub.8138

Mace, P.M. 1994. Relationships between common biological reference points used as thresholds and targets of fisheries management strategies. Can. J. Fish. Aquat. Sci. 51(1): 110–122. doi:10.1139/f94-013.

Mace, P.M. and Sissenwine, M.P. 1993. How much spawning per recruit is enough? Risk Evaluation and Biological Reference Points for Fisheries Management (eds S.J. Smith, J.J. Hunt and D. Rivard). Canadian Special Publication in Fisheries and Aquatic Sciences No. 120, National Research Council of Canada, Ottawa, 101–118.

Myers, R.A., Bowen, K.G., and Barrowman, N.J. 1999. Maximum reproductive rate of fish at low population sizes. Can. J. Fish. Aquat. Sci. 56: 2404–2419. doi:10.1139/f99-201.

Zhou, S., Yin, S., Thorson, James T., Smith, Anthony D. M., Fuller, M., and Walters, C. J. 2012. Linking fishing mortality reference points to life history traits: an empirical study. Canadian Journal of Fisheries and Aquatic Sciences, 69: 1292–1301.