

## Stock Annex: Sardine in Subarea 7 stock Annex

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### **Sardine (*Sardina pilchardus*) in Subarea 7 (southern Celtic Seas, and the English Channel)**

Stock specific documentation of standard assessment procedures used by ICES.

**Stock:** Sardine

**Working Group:** Working Group on Anchovy and Sardine and Southern Horse Mackerel (WGHANSA)

**Created:**

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**Last updated:** 10 February 2017(WKPELA)

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#### **A.4.1 Sardine stock identity in Divisions 8abd and Subarea 7 and approaches for assessment and management**

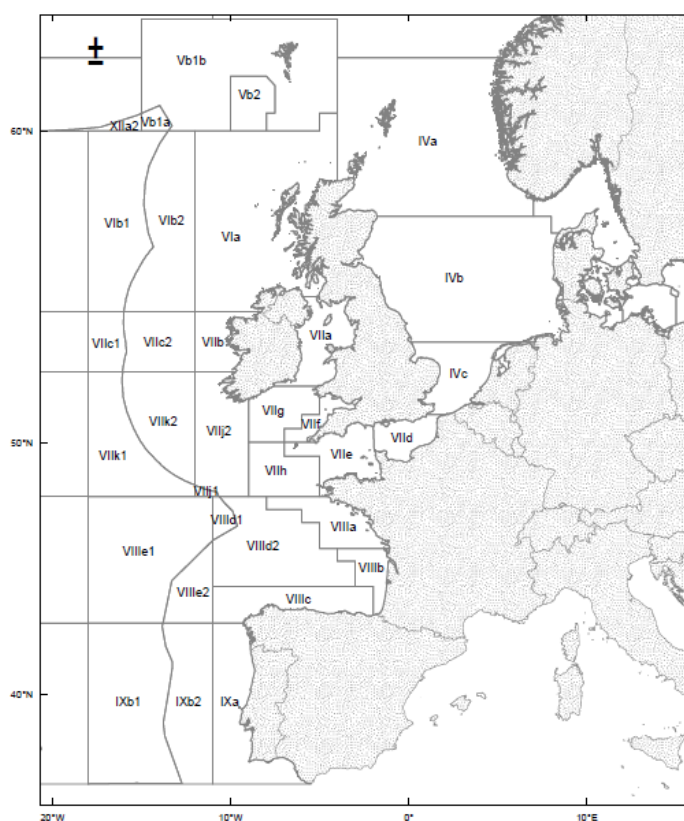
European sardine (*Sardine pilchardus* Walbaum, 1792) has a wide distribution extending in the Northeast Atlantic from the Celtic Sea and North Sea in the north to Mauritania in the south. Populations of Madeira, the Azores and the Canary Islands are at the western limit of the distribution (Parrish *et al.*, 1989). Sardine is also found in the Mediterranean and the Black Seas. Changing environmental conditions affect sardine distribution, with fish having been found as far south as Senegal during episodes of low water temperature (Corten and van Kamp, 1996; Binet *et al.*, 1998). Because of its continuous distribution in the Northeast Atlantic, it is likely that there is movement of fish between areas.

Microsatellite analyses revealed no significant genetic differentiation among sardines in Subareas 7 and 8 (Shaw *et al.*, 2012). Recent genetic analyses conducted in the Celtic Seas and Western Channel show that no genetic differentiation has been detected between the Bay of Biscay and Cornwall for the sardine stock (ICES, 2013). Therefore sardine in Celtic Seas (7.a,b,c,f,g,j,k), English Channel (7.d, 7.e, 7.h) and in Bay of Biscay (8.a,b,d) used to be considered to belong to the same stock from a genetic point of view. Therefore, it has been previously considered that the sardine stock in 8.a,b,d and 7.as a single stock unit. The assessment of this stock as a single unit has 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 area 7.

Information from the ICES WKSAR workshop (ICES, 2016) suggests higher growth rates for the populations of the English Channel and Celtic sea 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

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.

For a better understanding of the Divisions within subareas 7 and 8 the ICES areas map can be seen below (Figure A.1.1)



**Figure A.1.1. ICES Divisions in the Northeast Atlantic**

#### **A.4.2 Stock Annex for sardine in Divisions 8abd**

##### **B.1. Fishery**

There are currently no management measures implemented for this stock. The fisheries appear to be regulated by market price. Some fisheries (e.g. French fleets in the Bay of Biscay) have set their own local management in order to sustain correct market prices which imply targeting fish of certain sizes and limits to the total amount of catch.

An update of the French and Spanish catch data series in Divisions 8.a and 8.b (from 1983 and 1996 for France and Spain, respectively) including 2015 catches was presented at WKPELA 2017. Spanish catches are taken by purse seines from the Basque Country operating mainly in Division 8.b. Spanish landings peaked in 1998 and 1999 with almost 8 thousand tonnes but have until 2010 to below 1 thousand tons. In recent years (since 2011), the Spanish catches increased again, reaching 16 000 tons in 2014. The Spanish fishery takes place mainly between October and March. The strong increase of Spanish catches in 8.b is mainly due to an increase of the fishing effort, taking into account the low level of the Iberian sardine stock in 8c and some monthly closures of the southern fishery.

French catches have increased along the series, with values ranging from 4400 tonnes in 1983 to 23 000 tons in 2011 (Figure B.1.1). A total of 90% of the catches are taken by purse seiners while the remaining 10% is reported by pelagic trawlers (mainly pair trawlers). A substantial part of the French catches originates in Divisions 7.h and 7.e, but these catches have been assigned to Division 8.a due to their very concentrated location at the boundary between 8.a, 7.h and 7.e.

Spanish catches were unusually high prior 1989 where a strong drop occurs. The reason of this drop is unknown but most likely related to some data area miss allocation issues which make any use of landings prior to this year uncertain.

For the French fleet, both purse seiners and pelagic trawlers target sardine in French waters. Average vessel length is about 18 m. Purse seiners operate mainly in coastal areas (<10 nautical miles) while trawlers are not allowed to fish within 3 nautical miles from the coast. Both pair trawlers and purse seiners operate close to their base harbour when targeting sardine. The highest catches are taken in the summer months. Almost all the catches are taken in southwest Brittany.

While French catches in Divisions 8.a and 8.b are constituted by fish of a wide range of sizes with a peak at 20 cm length, sardine taken by Spanish vessels show a narrower range of sizes but with a peak at similar length size.

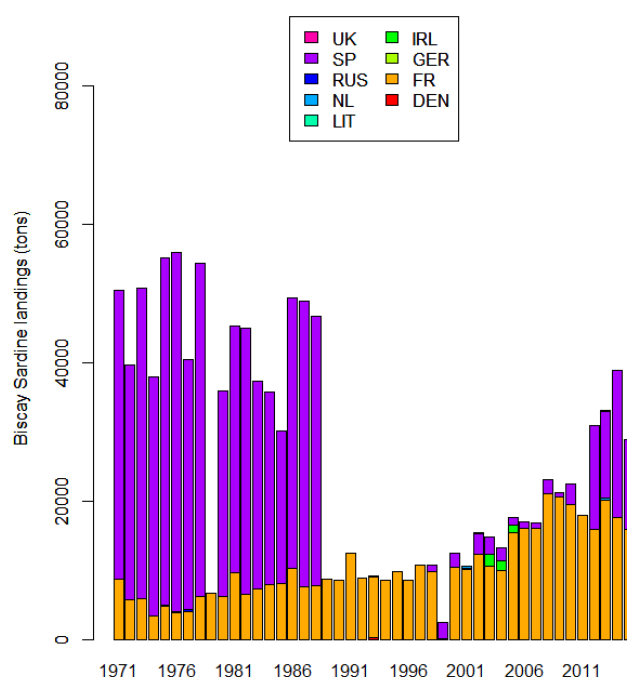


Figure B.1.1. Historical time-series of landings of sardine per country in the Bay of Biscay.

## B.2 Ecosystem aspects

Sardine is prey of a range of fish and marine mammal species which take advantage of its schooling behaviour and availability. Sardine has been found to be important in the diet of common dolphins (*Delphinus delphis*) in Galicia (NW Spain) (Santos *et al.*, 2004), Portugal (Silva, 2003) and the Atlantic French coast (Meynier, 2004). Recent studies of consumption of common dolphins in Galician (Santos *et al.*, 2011) waters give figures ranging from almost 6000 tons to more than 9000 tons of sardine, which represents a rather small proportion of the combined Spanish and Portuguese annual landings of sardine from ICES Areas 8.c and 9.a (6–7%). There are also other species feeding on sardine, although to a lesser extent, such as: harbour porpoise (*Phocoena phocoena*), bottlenose dolphin (*Tursiops truncatus*), striped dolphin (*Stenella coeruleoalba*), and white-sided dolphin (*Lagenorhynchus acutus*) (e.g. Santos *et al.*, 2007).

Currently, no ecosystem driver has been considered in this assessment.

## B.3 Data

### B.3.1 Commercial catches

Landings data have been available for since 1950 on various aggregation levels. Data are considered to be accurate in the Bay of Biscay since 1989. Discards were measured only in 2012 and were low based on the French Observers at sea program in the Bay of Biscay and hence not included in the assessment. In the past (late eighties and early nineties for the French Pelagic trawlers and sixties and seventies for the Spanish Purse seine fleet) they seemed to be more relevant (according to disputes among fishermen), but were never quantified. Discards are considered negligible.

### B.3.2 Biological

Catches-at-length and catches-at-age are known since 1984 for Spain and since 2002 for France in the Bay of Biscay. Because of the availability of the datasets only the period

starting in 2000 is used. They are obtained by applying to the monthly Length distributions half year or quarterly ALKs. Biological sampling of the catches has been generally sufficient, and useful to have a better knowledge of the age structure of the catches. Complete age composition and mean weight-at-age on half year basis, were yearly reported in ICES (WGHANSA report, ICES 2012).

Age reading is considered accurate. The most recent cross reading exchanges and workshop between Spain and France (but other countries, too) took place in 2011 (WKARAS report, ICES 2011). The overall level of agreement and precision in sardine of the Bay of Biscay age reading determinations seems to be satisfactory: Most of the sardine otoliths were well classified by most of the readers during the 2011 workshop (with an average agreement 75% and a CV of 14%).

Growth in weight and length are routinely obtained from surveys and from the monitoring of the fishery. A declining trend in the weight and length at age has been observed throughout the series.

Maturity ogive is estimated every year since 2000 based on the PELGAS survey. Readings are considered accurate. Sardines mature in their first year of life. The proportion of mature individuals at a given age is declining through the time series as a likely consequence of the decrease in length and weight. In addition, maturity ogives can be obtained every three years from the adult sampling of the DEPM surveys.

Natural mortality are age specific input values were deduced during WKPELA 2017 as the ones leading to the best fit of the observations in the assessment. This vector corresponds with values 90% of the Gislason's expected M at age Vector-WKPELA2017 report):

Age	0	1	2	3	4	5	6+
M (year <sup>-1</sup> )	1.071	0.692	0.546	0.475	0.435	0.412	0.400

### B.3.3 Surveys

Relevant surveys for the assessment are available for the Bay of Biscay only. Some sardines are caught during the various demersal surveys (e.g FR-IBTS) occurring each year in the Celtic Seas, Bay of Biscay and English Channel but those catches are not substantial enough to be considered as indicators of the stock status.

The population present in the Bay of Biscay is monitored by the two surveys carried out in spring. On the one hand the PELGAS acoustic surveys are conducted yearly and provide sardine estimates since 2000. On the other hand, BIOMAN DEPM surveys provide yearly a sardine egg abundance index since 1999, and every three years, together with the SAREVA surveys, sardine spawning stock biomass is estimated (since 2011).

This survey based monitoring system provides population estimates by the middle of the year, when a small part of the annual catches has been already taken.

#### B.3.3.1 Sardine acoustic indices (PELGAS survey)

Acoustic surveys are carried out every year in the Bay of Biscay in spring on board the French research vessel Thalassa since 2000. The objective of PELGAS surveys is to study the abundance and distribution of pelagic fish in the Bay of Biscay.

These surveys are connected with Ifremer programmes on data collection for monitoring and management of fisheries and ecosystemic approach for fisheries. This task is

formally included in the first priorities defined by the Commission regulation EU N° 199/2008 of 06 November 2008 establishing the minimum and extended Community programmes for the collection of data in the fisheries sector and laying down detailed rules for the application of Council Regulation (EC) No 1543/2000. These surveys must be considered in the frame of the Ifremer fisheries ecology action "resources variability" which is the French contribution to the international Globec programme. It is planned with Spain and Portugal in order to have most of the potential area to be covered from Gibraltar to Brest (and Northern with the English survey PELTIC covering the Bristol Channel and the English waters of Western Channel since 2013) with the same sampling protocol. Data are available for the ICES working groups WGHANSA, WGWIDE and WGACEGG.

In 2003, survey data are considered less reliable because of unusual environmental conditions linked to the heat wave over Europe. Results this year were considered not representative of the true status of the stock.

#### **B.3.3.1.1 PELGAS Method and sampling strategy**

In the frame of an ecosystem approach, the pelagic ecosystem is characterised at each trophic level. In this objective, to assess an optimum horizontal and vertical description of the area, two types of actions are combined:

Continuous acquisition by storing acoustic data from three different echosounders (a multibeam and multifrequency ME70, a singlebeam multifrequency ER60 and a singlebeam monofrequency lateral one) and pumping seawater under the surface in order to evaluate the number of fish eggs using a CUFES system (Continuous Under-water Fish Eggs Sampler);

Discrete sampling at stations (by trawls, plankton nets, CTD). Satellite imagery (temperature and sea colour) and modelisation will be also used before and during the cruise to recognise the main physical and biological structures and to improve the sampling strategy. Concurrently, a visual counting and identification of cetaceans and birds (from board) is carried out in order to characterise the higher level predators of the pelagic ecosystem.

Satellite imagery (temperature and sea colour) and modelisation are also used before and during the cruise to recognise the main physical and biological structures and to improve the sampling strategy.

The strategy of the survey is the same for the whole series (since 2000).

Acoustic data were collected along systematic parallel transects perpendicular to the French coast (Figure B.3.3.1.1). The length of the ESDU (Elementary Sampling Distance Unit) was 1 mile and the transects were uniformly spaced by 12 nautical miles covering the continental shelf from 20 m depth to the shelf break.

Acoustic data were collected only during the day because of pelagic fish behaviour in this area. These species are usually dispersed very close to the surface during the night and so "disappear" in the blind layer for the echo sounder between the surface and 8 m depth.

Two echo-sounders are usually used during surveys (SIMRAD EK60 for vertical echosounding and MARPORT on the pelagic trawl). Since 2009 the SIMRAD ME70 is used for multibeam visualisation. Energies and samples provided by split beam transducers (six frequencies EK60, 18, 38, 70, 120, 200 and 333 kHz), simple beam (MARPORT) and multibeam echosounder were simultaneously visualised, stored using the MOVIES+ software and at the same standard HAC format.

The calibration method is the same that the one described for the previous years (see W.D. 2001) with a tungsten sphere hanged up 20 m below the transducer and is generally performed at anchorage in the Douarnenez Bay, on the west side of Brittany, during the very first day of the survey.

Acoustic data are collected by Thalassa along the totality of the daylight route from which about 2000 nautical miles on one way transect are usable for assessment. Fish are measured on board (for all species) and otoliths (for anchovy and sardine) are collected for age determinations.

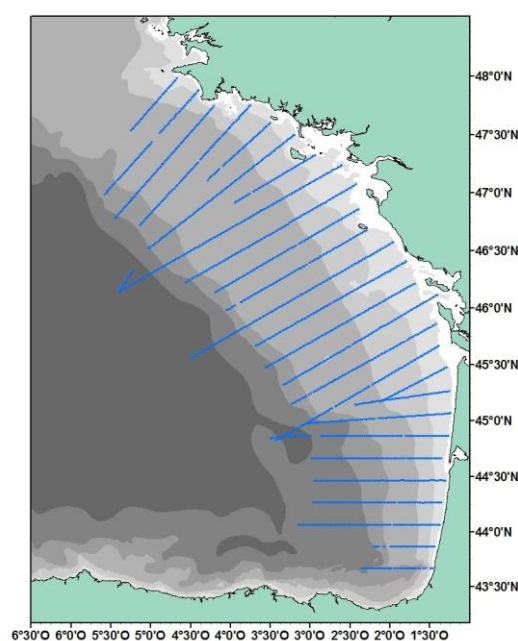


Figure B.3.3.1.1. The acoustic transects network of the PELGAS survey.

#### B.3.3.1.2 Echoes scrutinizing

Most of the acoustic data along the transects are processed and scrutinised during the survey and are generally available one week after the end of the survey. Acoustic energies (Sa) are cleaned by sorting only fish energies (excluding bottom echoes, parasites, plankton, etc.) and classified into several categories of echotracés according to the year fish (species) structures.

D1—energies attributed to mackerel, horse mackerel, blue whiting, and various demersal fish, corresponding to cloudy schools or layers (sometimes small dispersed points) close to the bottom or of small drops in a 10 m height layer close to the bottom.

D2—energies attributed to anchovy, sprat, sardine and herring corresponding to the usual echo-traces observed in this area since more than 15 years, constituted by schools well defined, mainly situated between the bottom and 50 meters above. These echoes are typical of clupeids in coastal areas and sometimes more offshore.

D3—energies attributed to blue whiting, myctophids and boarfish offshore, just closed to the shelf-break and on the platform in the north.

D4—energies attributed to sardine, mackerel and anchovy corresponding to small and dense echoes, very close to the surface.

D8—energies attributed exclusively to sardine (big and very dense schools).

### B.3.3.1.3 Data processing

The global area is split into several strata where coherent communities are observed (species associations) in order to minimise the variability due to the variable mixing of species. For each stratum, a mean energy is calculated for each type of echoes and the area measured. A mean haul for the strata is calculated to get the proportion of species into the strata. This is obtained by estimating the average of species proportions weighted by the energy surrounding haul positions. Energies are therefore converted into biomass by applying catch ratio, length distributions and TS relationships. The calculation procedure for biomass estimate and variance is described in Petitgas *et al.*, 2003.

The TS relationships used since 2000 are still the same and as following:

Sardine, anchovy & sprat:  $TS = 20 \log L - 71.2$

Horse mackerel:  $TS = 20 \log L - 68.7$

Blue whiting:  $TS = 20 \log L - 67.0$

Mackerel:  $TS = 20 \log L - 86.0$

The mean abundance per species in a stratum (tons m.n.<sup>-2</sup>) is calculated as:

$$M_e(k) = \sum_D \bar{s}_A(D,k) \bar{X}_e(D,k)$$

and total biomass (tons) by:  $B_e = \sum_k A(k) M_e(k)$

where,

**k** : strata index

**D** : echo type

**e** : species

**S<sub>A</sub>**: Average S<sub>A</sub> (NASC) in the strata (m<sup>2</sup>/n.mi.<sup>2</sup>)

**X<sub>e</sub>** : species proportion coefficient (weighted by energy around each haul) (tons m<sup>-2</sup>)

**A** : area of the strata (m.n.<sup>2</sup>)

Then variance estimate is:

$$Var.M_e(k) = \sum_D \bar{s}_A^2(D,k) Var[X_e(D,k)] / n.cha(k) + \bar{X}_e^2 var[s_A(D,k)] / n.esu(D,k)$$

$$Var.B_e = \sum_k A^2(k) Var.Me(k)$$

$$cv = \sqrt{Var.Be} / Be$$

At the end, density in numbers and biomass by length and age are calculated for each species in each ESDU according to the nearest haul length composition. These numbers and biomass are weighted by the biomass in each stratum and data are used for spatial distributions by length and age.



The detailed protocol for these surveys (strategy and processing) is described in Annex 6 of WGACEGG report (ICES 2009).

### **B.3.3.2 Sardine Daily Egg Production Method (BIOMAN-SAREVA Survey) and Egg Abundance Index**

#### **B.3.3.2.2 Collection of plankton samples and Egg abundance index and production estimates.**

Every year, the BIOMAN survey collects plankton samples in the southeast of the Bay of Biscay. Then, every three years, BIOMAN and SAREVA surveys are coordinated within WGACEGG to provide samples for the whole area. The annual coverage of the Bay of Biscay by Bioman is used to generate the Egg abundance index and the triennial coordinated surveys are used to implement the whole Daily Egg Production method to obtain biomass estimates.

In general, plankton samples in both surveys are obtained along a grid of parallel transects perpendicular to the coast using a PairoVET equipped with 150 µm mesh net, until 100m depth or 5m to the bottom, (Pair of Vertical Egg Tow, Smith *et al.*, 1985 in Lasker, 1985). Sardine, anchovy and other species eggs are sorted and counted. Since sampling is adaptive, the area represented by each station changes according to the sampling intensity and the survey limits.

The Total sardine egg abundance index is obtained as the sum over the whole survey area of the product between the number of eggs found at each station and the area each station represents. This method (based on the total amount of sardine eggs in 8abd) is the one producing from BIOMAN the annual Egg abundance index used in the assessment. The standard area over which the Egg Abundance index is produced is presented in figure B3.3.2.2.1 (taking as example the survey in 2014), whereby coverages in 8c and in the most North-western area are removed (the latter because not every year the coverage of that northwest area is achieved). The few eggs in 8c just close and continuing the spawning distribution from 8b are always included within the index of Egg abundance for 8abd.

For the application of the DEPM the egg abundances by stages and by samples are used to estimate the Daily Egg Production over the whole area following the procedures described below (in section B.3.3.2.4).

In these surveys, the Continuous Underway Fish Egg Sampler (CUFES, Checkley *et al.*, 1997) is used as well to record the eggs found at 3-5 m depth with a net mesh size of 350 µm. Additional data, like oceanographic parameters, are also routinely obtained together with the plankton samples.

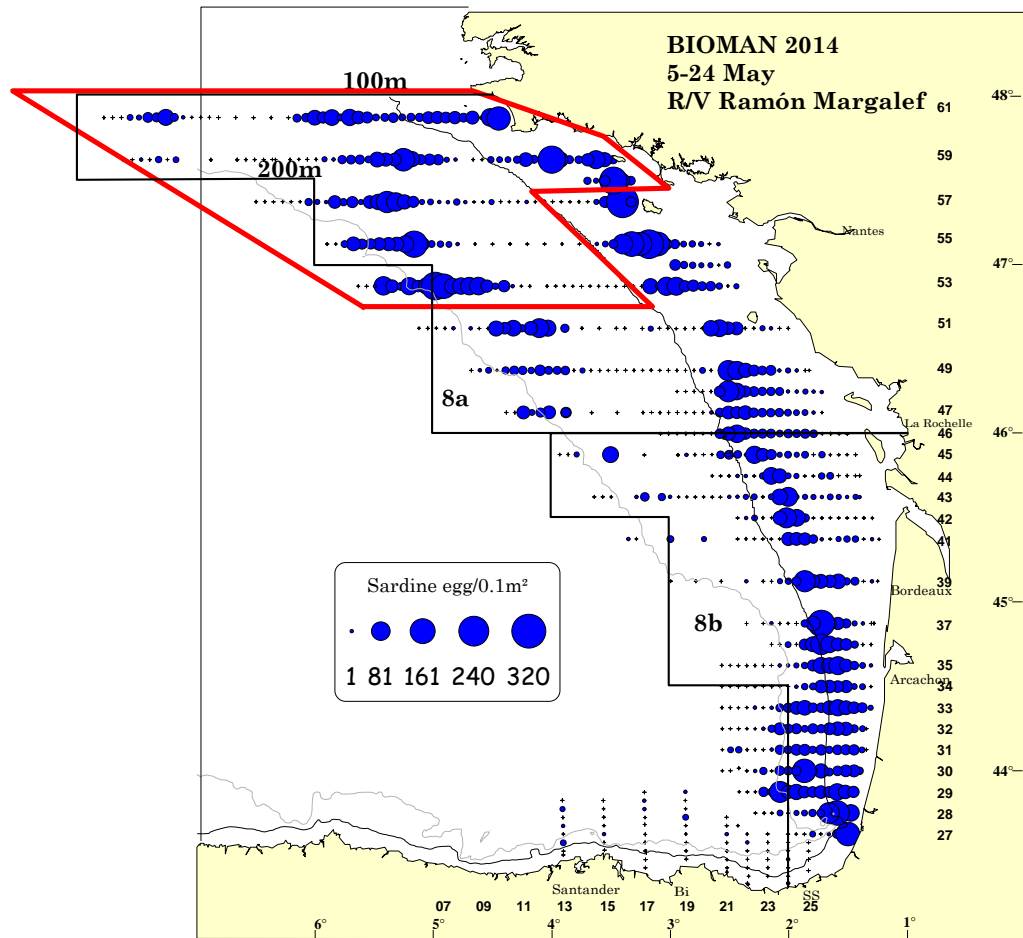


Figure B.3.3.2.2.1. Typical areas covered by Bioman Survey and reduced area used every year to estimate de total egg abundance in 8ab. For the production of that sardine Egg abundance index only the coverages within 8b and 8a (excluding the area delimited with the red line) are taken into account (see also the text).

### B.3.3.2.3 Collection of adult samples

Since 2008 every three years concurrent adult sampling is conducted for the estimation of the adult parameters in the DEPM.

The research vessel pelagic trawler covers the same area as the plankton vessel. The fishing hauls are located in the areas with sardine eggs and follow the sardine school detections in the echo-sounder.

A sample of sardines from the haul are weighted, measured and sexed and the gonads of a subsample of non-hydrated females are preserved. The preserved ovaries are weighted in laboratory and the obtained weights corrected by a conversion factor (between fresh and formaldehyde fixed material) established previously. These ovaries are then processed for histology: they are embedded in resin, the histological sections are stained with haematoxylin and eosin, and the slides examined and scored for their maturity state (most advanced oocyte batch) and POF presence and age (Hunter and Macewicz 1985, Pérez *et al.*, 1992a, Ganas *et al.*, 2004, Ganas *et al.*, 2007). Prior to fecundity estimation, hydrated ovaries are also processed histologically in order to check POF presence and thus avoid underestimating fecundity (Pérez *et al.*, 1992b). Then, the individual batch fecundity is measured, by means of the gravimetric method applied to the hydrated oocytes, on 3 whole mount sub-samples per ovary, weighting on average 50–150 mg (Hunter *et al.* 1985).

#### B.3.3.2.4 Total daily egg production estimates

Every three years, the sardine eggs obtained jointly by the BIOMAN and SAREVA surveys are not only counted, but are further classified into 11 stages of development (adapted from Gamulin and Hure, 1955).

The total surveyed area is calculated as the sum of the area represented by each station and the spawning area is delimited with the outer zero sardine egg stations.

The eggs staged in the laboratory are transformed into daily cohort abundances using a multinomial model (Bayesian ageing method, Bernal *et al.*, 2008). The Bayesian ageing method requires a probability function of spawning time. Spawning time distribution is assumed with a peak at 21:00 GMT. The upper age cutting limit is the maximum age of unhatched eggs (at how. complete=0.99) for the whole strata corresponding with the percentile 95 of the incubation temperature of the eggs sampled in the strata, i.e. a value not dependent on the individual station. The lower age cutting excluded the first cohort of stations in which the sampling time is included within the daily spawning period.

Daily egg production ( $P_0$ ) and mortality ( $z$ ) rates are estimated by fitting an exponential decay mortality model to the egg abundance by cohorts and corresponding mean age:

$$E[P] = P_0 e^{-Z \cdot age}$$

The model is fitted as a generalized linear model (GLM) with negative binomial distribution and log link. Finally, the total egg production is calculated multiplying the daily egg production by the positive area.

$$P_{tot} = P_0 \cdot A +$$

The analysis is conducted in R ([www.r-project.org](http://www.r-project.org)) using the "MASS" library for fitting the GLM and the libraries in <http://sourceforge.net/projects/ichthyoanalysis/> for the egg ageing, calculation of the survey area and estimation of parameters.

#### B.3.3.2.5 Adult parameters, daily fecundity and SSB estimates

The adult parameters estimated for each fishing haul consider only the mature fraction of the population (determined by the fish macroscopic maturity data). Before the estimation of the mean female weight per haul ( $W$ ), the individual total weight of the hydrated females is corrected by a linear regression between the total weight of non-hydrated females and their corresponding gonad-free weight. The sex ratio ( $R$ ) in weight per haul is obtained as the quotient between the total weight of females and the total weight of males and females. The expected individual batch fecundity ( $F$ ) for all mature females (hydrated and non-hydrated) is estimated by the hydrated egg method (Hunter *et al.*, 1985), i.e. by modelling the individual batch fecundity observed in the sample of hydrated females and their gonad free weight by a GLM and applying this subsequently to all mature females. The spawning fraction ( $S$ ), the fraction of females spawning per day is determined for each haul, as the average number of females with Day-1 and Day-2 POF, divided by the total number of mature females. The hydrated females are not included due to possible oversampling of active spawning females close to the peak spawning time. In this case, the number of females with Day-0 POF (of the mature females) is corrected by the average number of females with Day-1 or Day-2 POF (Picquelle and Stauffer 1985, Pérez *et al.*, 1992a, Motos 1994, Gantias *et al.*, 2007).

The mean and variance of the adult parameters for all the samples collected was then obtained using the methodology from Picquelle and Stauffer (1985) for cluster sampling (weighted means and variances).

#### B.3.3.2.1 The DEPM estimates of SSB and Numbers at age

The sardine spawning-stock biomass is estimated according to Parker (1980) and Stauffer and Picquelle (1980) as the ratio between daily production of eggs in the sea ( $P_{tot}$ ) and the daily specific fecundity (DF) of the adult population:

$$SSB = \frac{P_{tot}}{DF} = \frac{P_0 \cdot A +}{k \cdot R \cdot F \cdot S / W}$$

where

**SSB** = Spawning-stock biomass in metric tons

$P_{tot}$  = Total daily egg production in the sampled area

$P_0$  = daily egg production per surface unit in the sampled area

$A+$  = Spawning area, in sampling units

**DF** = Daily specific fecundity.  $DF = \frac{k \cdot R \cdot F \cdot S}{W}$

**W** = Average weight of mature females in grams,

**R** = Sex ratio, fraction of population that are mature females, by weight.

**F** = Batch fecundity, numbers of eggs spawned per mature females per batch

**S** = Fraction of mature females spawning per day

**k** = Conversion factor from gram to metric tons ( $10^6$ )

An estimate of an approximate variance and bias for the biomass estimator is obtained using the *delta* method (Seber, 1982, in Stauffer and Picquelle, *op. cit.*).

Population estimates of numbers-at-age can be derived as follows:

$$N_a = N \cdot E_a = \frac{SSB}{W_t} \cdot E_a$$

where

$N_a$  = Population estimate of numbers-at-age  $a$

**N** = Total spawning-stock estimate in numbers.  $N = \frac{SSB}{W_t}$

**SSB** = spawning-stock biomass estimate.

**W** = average weight of anchovies in the population.

$E_a$  = Relative frequency (in numbers) of age  $a$  in the population.

Variance estimates of the sardine stock in numbers-at-age and total are again derived applying the delta method.

#### **B.3.4 Commercial cpue**

According to literature, cpue indices have been considered as not reliable indicators of abundance for small pelagic fishes (Ulltang, 1980; Csirke, 1988; Pitcher, 1995; Mackinson *et al.*, 1997). Commercial catch per unit of effort data are available at various levels of aggregation (subarea/gear/years) from official data, but these are not considered indicative of stock trends (see also information from the industry, below).

#### **B.3.5 Other relevant data**

Interviews with the French fishing industry operating in the Bay of Biscay highlighted a potential displacement of the stock further north. This could partly explain the increase of activity in the Celtic Sea over the last decade. According to fishermen, the main driver of the Bay of Biscay fishery is the market. Many fishers could catch more sardine due to the high sardine availability, but this would not be suitable given the poor levels of prices. Thus, the industry data (landings) cannot be directly related to variations in sardine abundance.

#### **B.4 Assessment-data and method**

For the purposes of Assessment and Management the workshop concluded that in the absence of evidences 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. Even in the case some connectivity would occur, dealing separately with the sardine in 8abd and 7, in a sustainable manner, would be probably risk averse, as the potential northward emigrants from the Bay of Biscay to subarea 7 would be comprised (assimilated) in the natural mortality parameter estimated for the Bay of Biscay population.

This assessment was considered by WKPELA2017 as indicative of trends only (laying it in category 2 stocks). It produces analytical estimates of biomass, recruitment and fishing pressure series, but the absolute levels are still considered unreliable as the biomass indices derived from the surveys are still far above those produced by the assessment. Estimated catchability for Pelgas biomass index (2.4), and for DEPM (1.8) are still perceived to be too high, because the acoustic and DEPM surveys are designed to estimate absolute biomass and because these catchabilities are quite different from those estimated for the southern sardine stock.

#### B.4.1 Assessment methods and settings

The data used for the assessment of sardine in divisions 8a,b,d are the following:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	2000–onwards	-	Yes
Canum	Catch at age in numbers	2002–onwards	0-6+	Yes
Weca	Weight at age in the commercial catch	2002–onwards	0-6+	Yes
West	Weight at age of the spawning stock at spawning time.	2000–onwards	0-6+	Yes
Mprop	Proportion of natural mortality before spawning	2000–onwards	0-6+	No, equal to 0
Fprop	Proportion of fishing mortality before spawning	2000–onwards	0-6+	No, equal to 0
Matprop	Proportion mature at age	2000–onwards	0-6+	Yes
Natmor	Natural mortality at age	2000–onwards	0-6+	No
PELGAS acoustic survey	Biomass index and age structure	2000–onwards		Yes
BIOMAN egg count	Egg count	2000–onwards		Yes
DEPM	SSB index	2011, 2014		Yes

#### B.4.2 Choice of stock assessment model

The model used is Stock Synthesis 3, version 3.24f (Methot, 2012). SS3 is a generalized age- and length-based model that is very flexible regarding the types of data that may be included, the functional forms that are used for various biological processes, the level of complexity and number of parameters that may be estimated. A description and discussion of the model can be found in Methot and Wetzel (2013).

#### B.4.3 Model used of basis for advice

The sardine assessment is an age-based assessment assuming a single area, a single fishery, a yearly season and genders combined. Input data include catch (in biomass), age composition of the catch, total abundance (in numbers) and age composition from an annual acoustic survey, total egg abundance and SSB from a triennial DEPM survey operating in the Bay of Biscay. Considering the current assessment calendar (annual assessment WG in June in year  $(y+1)$ ), the assessment includes fishery data up to year  $y$  and survey data up to year  $y+1$ . According to the ICES terminology, year  $y$  is the final year of the assessment and year  $y+1$  is termed the interim year.

#### B.4.4 Assessment model configuration

The main model options are described below. A copy of the control file (sardine.ctl) including all model options is appended to the bottom of this Stock Annex.

Natural mortality are age specific input values as listed in Section B.2.

Growth is not modelled explicitly. Weights-at-age and maturity-at-age in the beginning of the year are input values calculated using PELGAS survey data.

Annual recruitments are parameters, defined as lognormal deviations from a constant mean value penalized by a sigma of 0.55. Recruitment for the interim year of the assessment is assumed to be the historic geometric mean.

Fishing mortality is applied as the hybrid method. This method does a Pope's approximation to provide initial values for iterative adjustment of the continuous  $F$  values to closely approximate the observed catch.

Total catch biomass by year is assumed to be accurate and precise. The  $F$  values are tuned to match this catch.

Both the acoustic survey, the total egg abundance index and the DEPM survey are assumed to be relative indices of abundance. The corresponding catchability coefficients are considered to be mean unbiased.

For DEPM and egg count surveys, selectivity is assumed to be fixed at 0 at age 0 and flat at 1 for ages 1 to 6+.

For Acoustic, selectivity was set to be flat between ages 2 and 5, with a value of 1 while selectivity for age 1 and age 6+ were estimated.

For the fishery selectivity, a flat shape was fixed for ages 3 to 5, with a value of 1, while for ages 1, 2 and 6+ the selectivities were estimated.

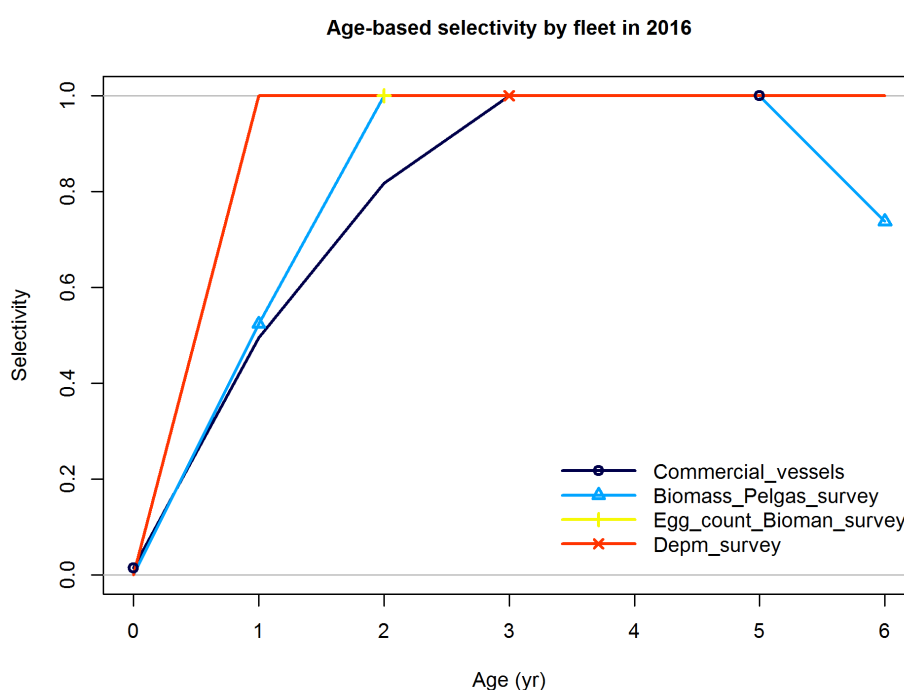


Figure B.4.4.1 Selectivity at age for fisheries and surveys as estimated by WKPELA2017.

The fishery selectivity is constant for the whole assessment period.

The model estimates population biomass in the beginning of the last assessment year (interim year). Data used for the interim year are the following: stock weights-at-age, catch biomass and catch weights-at-age are equal to those assumed for short term predictions (section B.5). The fishery age composition in the interim year is assumed to be equal to that in the previous year. The fishery age composition is included in the calculation of expected values but excluded from the objective function.

Initial estimates of data precision were as follows:

- Standard errors of biomass from Pelgas as estimated by the survey
- Standard error of 0.567 for DEPM SSB estimates
- Standard error of 0.448 for BIOMAN egg count index
- Sample size of PELGAS age structure: 45
- Sample size of fisheries age structure: 45

Final model estimates were obtained after appropriate tuning of these values. Data precision values were changed iteratively until approximate convergence of the harmonic mean of expected sample size and the root mean squared error of the aggregated indices according to the model results.

- Indices of ageing imprecision is assumed to be constant for all ages and time: 0.1.
- The initial population is calculated by estimating an initial equilibrium population modified by age composition data in the first year of the assessment (Methot and Wetzel, 2013). The initial equilibrium population was derived assuming an initial catch of 13 000 tons, the average of catches in 1990–1999.

Minimisation of the likelihood is implemented in phases using standard ADMB process. The phases in which estimation will begin for each parameter is shown in the control file appended to this section.

Variance estimates for all estimated parameters are calculated from the Hessian matrix.

The model estimates spawning stock biomass (SSB) and summary biomass (B1+, biomass of age 1 and older) in the beginning of the year. The reference age range for output fishing mortality is 2–5 years.

### **B.5 Short-term projection**

No short term projection method is currently set for this stock.

This will be updated during next WGHANSA (June 2017).

### **B.6 Medium-term projections**

No medium-term projection method is currently set for this stock.

### **B.7 Long-term projections**

No long-term projection method is currently set for this stock.

### **B.8 Biological reference points**



No reference points are currently set for this stock. This will be examined during next WGHANSA (June 2017).

### **B.9 Other issues**

Due to the lack and quality of data in subarea 7, it is currently not possible to provide any assessment for this subarea

### **B.10 Historical overview of previous assessment methods**

2013 is the first year ICES was requested to give advice for sardine in the combined 8.a,b,d and 7 regions. In previous years, exploratory assessments using TASACS were carried out during the working group on horse mackerel, anchovy and sardine (WGHANSA). Cohort tracking analyses have also been conducted from 2013 to 2016 to derive total mortality (Z). Advice was based on available survey indices following the guidelines for ICES category 3 assessment. DCAC was used without success in 2012 as an attempt in subdivision 7 to estimate some stock trends.

### **B.11 Data call**

Data to be reported for the sardine stock in subarea 8.a.b.d:

#### **1. Recent catch and biological data**

France and Spain: time series of length and age distribution of landings by quarter.

Other countries: catches in division 8.a.b.d. Time series of length and age distribution when available.

#### **2. Survey data**

France: length distribution, numbers at age and weight at ages from the PELGAS survey.

Spain: egg count and DEPM index from the BIOMAN survey

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## CONTROL FILE FOR SARDINE ASSESSMENT IN BAY OF BISCAY (8.A.B.D) ONLY

#C Sardine in 8abd WKPELA 2017

#C growth parameters are estimated spawner-recruitment bias adjustment Not tuned  
For optimality

#\_data\_and\_control\_files: sardine.dat // sardine.ctl

1 #\_N\_Growth\_Patterns

1 #\_N\_Morphs\_Within\_GrowthPattern

#\_Cond 1 #\_Morph\_between/within\_stdev\_ratio (no read if N\_morphs=1)

#\_Cond 1 #vector\_Morphdist\_(-1\_in\_first\_val\_gives\_normal\_approx)

#

#\_Cond 0 # N recruitment designs goes here if N\_GP\*nseas\*area&gt;1

#\_Cond 0 # placeholder for recruitment interaction request

#\_Cond 1 1 1 # example recruitment design element for GP=1, seas=1, area=1

#

#\_Cond 0 # N\_movement\_definitions goes here if N\_areas &gt; 1

#\_Cond 1.0 # first age that moves (real age at begin of season, not integer) also cond on  
do\_migration>0#\_Cond 1 1 1 2 4 10 # example move definition for seas=1, morph=1, source=1 dest=2,  
age1=4, age2=10

#

0 #\_Nblock\_Patterns

# 1 #\_blocks\_per\_pattern

# begin and end years of blocks

# 1983 1990

#

0.5 #\_fracfemale

3 #\_natM\_type:\_0=1Parm; 1=N\_breakpoints;\_2=Lorenzen;\_3=agespecific;\_4=ag-  
espec\_withseasinterpolate1.0710 0.6912 0.5463 0.4752 0.4356 0.4122 0.3978 #\_no additional input for selected M  
option; read 1P per morph1 # GrowthModel: 1=vonBert with L1&L2; 2=Richards with L1&L2; 3=age\_speciific\_K;  
4=not implemented

1 #\_Growth\_Age\_for\_L1

6 #\_Growth\_Age\_for\_L2 (999 to use as Linf)

0 #\_SD\_add\_to\_LAA (set to 0.1 for SS2 V1.x compatibility)

0 #\_CV\_Growth\_Pattern: 0 CV=f(LAA); 1 CV=F(A); 2 SD=F(LAA); 3 SD=F(A); 4  
logSD=F(A)

```

5 #_maturity_option: 1=length logistic; 2=age logistic; 3=read age-maturity matrix by
growth_pattern; 4=read age-fecundity; 5=read fec and wt from wtatage.ss

#_placeholder for empirical age-maturity by growth pattern

1 #_First_Mature_Age

1      #_fecundity      option:(1)eggs=Wt*(a+b*Wt);(2)eggs=a*L^b;(3)eggs=a*Wt^b;
(4)eggs=a+b*L; (5)eggs=a+b*W

0 #_hermaphroditism option: 0=none; 1=age-specific fxn

1 #_parameter_offset_approach (1=none, 2= M, G, CV_G as offset from female-GP1,
3=like SS2 V1.x)

2 #_env/block/dev_adjust_method (1=standard; 2=logistic transform keeps in base
parm bounds; 3=standard w/ no bound check)

#

#_growth_parms

#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr
dev_stddev Block Block_Fxn

6 17 13 0 -1 0 -2 0 0 0 0 0 0 # L_at_Amin_Fem_GP_1
19 28 23 0 -1 0 -4 0 0 0 0 0 0 # L_at_Amax_Fem_GP_1
0.2 0.8 0.4 0 -1 0 -4 0 0 0 0 0 0 # VonBert_K_Fem_GP_1
0.05 0.25 0.1 0 -1 0 -3 0 0 0 0 0 0 # CV_young_Fem_GP_1
0.05 0.25 0.1 0 -1 0 -3 0 0 0 0 0 0 # CV_old_Fem_GP_1
-3 3 2 0 -1 0 -3 0 0 0 0 0 0 # Wtlen_1_Fem
-3 4 3 0 -1 0 -3 0 0 0 0 0 0 # Wtlen_2_Fem
50 60 55 0 -1 0 -3 0 0 0 0 0 0 # Mat50%_Fem
-3 3 -0.25 0 -1 0 -3 0 0 0 0 0 0 # Mat_slope_Fem
-3 3 1 0 -1 0 -3 0 0 0 0 0 0 # Eggs/kg_inter_Fem
-3 3 0 0 -1 0 -3 0 0 0 0 0 0 # Eggs/kg_slope_wt_Fem
0 0 0 0 -1 0 -4 0 0 0 0 0 0 # RecrDist_GP_1
0 0 0 0 -1 0 -4 0 0 0 0 0 0 # RecrDist_Area_1
0 0 0 0 -1 0 -4 0 0 0 0 0 0 # RecrDist_Seas_1
0 0 0 0 -1 0 -4 0 0 0 0 0 0 # CohortGrowDev

#

#_Cond 0 #custom_MG-env_setup (0/1)

#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no MG-environ parameters

#

#_Cond 0 #custom_MG-block_setup (0/1)

#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no MG-block parameters

#_Cond No MG parm trends

```

```

#
#_seasonal_effects_on_biology_parms
0      0      0      0      0      0      0      0      0      0
#_femwtlen1,femwtlen2,mat1,mat2,fec1,fec2,Malewtlen1,malewtlen2,L1,K
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no seasonal MG parameters
#
#_Cond -4 #_MGparm_Dev_Phase
#
#_Spawner-Recruitment
4 #_SR_function: 2=Ricker; 3=std_B-H; 4=SCAA; 5=Hockey; 6=B-H_flattop; 7=sur-
vival_3Parm
#_LO HI INIT PRIOR PR_type SD PHASE
1 12 8.9 4.5 -1 5 1 # SR_LN(R0)
0.2 1 0.9 0.7 -1 0.05 -5 # SR_SCAA_null
0 4 0.55 0.6 -1 0.8 -4 # SR_sigmaR
-5 5 0.1 0 -1 1 -3 # SR_envlink
-5 5 0 0 -1 1 -4 # SR_R1_offset
0 0 0 0 -1 0 -99 # SR_autocorr
0 #_SR_env_link
0 #_SR_env_target_0=none;1=devs;_2=R0;_3=steepness
1 #do_recdev: 0=none; 1=devvector; 2=simple deviations
1996 # first year of main recr_devs; early devs can precede this era
2016 # last year of main recr_devs; forecast devs start in following year
2 #_recdev phase
1 # (0/1) to read 13 advanced options
0 #_recdev_early_start (0=none; neg value makes relative to recdev_start)
-4 #_recdev_early_phase
-1 #_forecast_recruitment phase (incl. late recr) (0 value resets to maxphase+1)
1 #_lambda for Fcast_rec_r like occurring before endyr+1
1980.0 #_last_early_yr_nobias_adj_in_MPD
1998.5 #_first_yr_fullbias_adj_in_MPD
2014.8 #_last_yr_fullbias_adj_in_MPD
2016.2 #_first_recent_yr_nobias_adj_in_MPD
1 #_max_bias_adj_in_MPD (-1 to override ramp and set biasadj=1.0 for all estimated
recdevs)
0 #_period of cycles in recruitment (N parms read below)
-5 #min rec_dev

```

```

5 #max rec_dev
0 #_read_recdevs
#_end of advanced SR options
#
#_placeholder for full parameter lines for recruitment cycles
# read specified recr devs
#_Yr Input_value
#
# all recruitment deviations
#Fishing Mortality info
0.3 # F ballpark for tuning early phases
-2001 # F ballpark year (neg value to disable)
3 # F_Method: 1=Pope; 2=instan. F; 3=hybrid (hybrid is recommended)
2 # max F or harvest rate, depends on F_Method
# no additional F input needed for Fmethod 1
# if Fmethod=2; read overall start F value; overall phase; N detailed inputs to read
# if Fmethod=3; read N iterations for tuning for Fmethod 3
4 # N iterations for tuning F in hybrid method (recommend 3 to 7)
#
#_initial_F_parms
#_LO HI INIT PRIOR PR_type SD PHASE
0 2 0.3 0.3 -1 0.2 1 # InitF_1purse_seine
#
#_Q_setup
# Q_type options: <0=mirror, 0=median_float, 1=mean_float, 2=parameter,
3=parm_w_random_dev, 4=parm_w_randwalk, 5=mean_unbiased_float_as-
sign_to_parm
#_for_env-var: _enter_index_of_the_env-var_to_be_linked
#_Den-dep env-var extra_se Q_type
0 0 0 0 # 1 purse_seine
0 0 0 2 # 2 Acoustic_survey
0 0 0 2 # 3 egg_survey
0 0 0 2 # 4 Depm_survey
#
#_Cond 0 #_If q has random component, then 0=read one parm for each fleet with ran-
dom q; 1=read a parm for each year of index
#_Q_parms(if_any)

```



```
# LO HI INIT PRIOR PR_type SD PHASE
-7 5 0 0 -1 0.5 1 # Q_base_2_biomass_survey
-7 5 0 2 -1 2 1 # Q_base_3_egg_survey
-7 5 0 0 -1 0.5 1 # Q_base_4_depm
```

```
#
#_size_selex_types
#_Pattern Discard Male Special
0 0 0 0 # 1 purse_seine
30 0 0 0 # 2 Acoustic_survey
30 0 0 0 # 3 egg_survey
30 0 0 0 # 4 Depm_survey
```

```
#
#_age_selex_types
#_Pattern ____ Male Special
17 0 0 0 # 1 purse_seine
17 0 0 0 # 2 Acoustic_survey
10 0 0 0 # 3 egg_survey
10 0 0 0 # 4 Depm_survey
```

```
#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr
dev_stddev Block Block_Fxn
```

-999	-999	-999	-6	-1	0.1	-2	0	3	0	0
	0.1	0	0	#	AgeSel_1P_1_purse_seine					
-5	9	0	0	-1	0.1	1	0	0	0	0
	0.1	0	0	#	AgeSel_1P_2_purse_seine					
-5	9	0	0	-1	0.1	1	0	0	0	0
	0.1	0	0	#	AgeSel_1P_3_purse_seine					
-0.01	9	0	0	-1	0.1	1	0	0	0	0
	0.1	0	0	#	AgeSel_1P_4_purse_seine					
-5	0	0	0	-1	0.1	-1	0	0	0	0
	0.1	0	0	#	AgeSel_1P_5_purse_seine					
-5	0	0	0	-1	0.1	-1	0	0	0	0
	0.1	0	0	#	AgeSel_1P_6_purse_seine					
-5	0	0	0	-1	0.1	1	0	0	0	0
	0.1	0	0	#	AgeSel_1P_7_purse_seine					

-1000	-1000	-1000	-6	-1	0.1	-2	0	0	0	0
	0	0	0	#	AgeSel_2P_1_Acoustic_survey					
-5	5	0	0	-1	0.1	1	0	0	0	0
	0	0	0	#	AgeSel_2P_2_Acoustic_survey					
-0.01	9	0	0	-1	0.1	1	0	0	0	0
	0	0	0	#	AgeSel_2P_3_Acoustic_survey					
-5	0	0	0	-1	0.1	-1	0	0	0	0
	0	0	0	#	AgeSel_2P_4_Acoustic_survey					
-5	0	0	0	-1	0.1	-1	0	0	0	0
	0	0	0	#	AgeSel_2P_5_Acoustic_survey					
-5	0	0	0	-1	0.1	-1	0	0	0	0
	0	0	0	#	AgeSel_2P_6_Acoustic_survey					
-5	0	0	0	-1	0.1	1	0	0	0	0
	0	0	0	#	AgeSel_2P_7_Acoustic_survey					

#\_Cond 0 #\_custom\_sel-env\_setup (0/1)

#\_Cond -2 2 0 0 -1 99 -2 #\_placeholder when no enviro fxns

# #\_custom\_sel-blk\_setup (0/1)

#\_Cond No selex parm trends

4 #\_selparmdev-phase

1 #\_env/block/dev\_adjust\_method (1=standard; 2=logistic trans to keep in base parm bounds; 3=standard w/ no bound check)

#

# Tag loss and Tag reporting parameters go next

0 # TG\_custom: 0=no read; 1=read if tags exist

#\_Cond -6 6 1 1 2 0.01 -4 0 0 0 0 0 0 #\_placeholder if no parameters

#

1 #\_Variance\_adjustments\_to\_input\_values

#\_fleet: 1 2 3 4

0 0 0 0 #\_add\_to\_survey\_CV

0 0 0 0 #\_add\_to\_discard\_stddev

0 0 0 0 #\_add\_to\_bodywt\_CV

0 0 0 0 #\_mult\_by\_lencomp\_N

1 1 1 1 #\_mult\_by\_agecomp\_N

1 1 1 1 #\_mult\_by\_size-at-age\_N

#

4 #\_maxlambdaphase

1 #\_sd\_offset

```

#
4 # number of changes to make to default Lambdas (default value is 1.0)
# Like_comp codes: 1=surv; 2=disc; 3=mnwt; 4=length; 5=age; 6=SizeFreq; 7=sizeage;
8=catch;
# 9=init_equ_catch; 10=recrdev; 11=parm_prior; 12=parm_dev; 13=CrashPen;
14=Morphcomp; 15=Tag-comp; 16=Tag-negbin
#like_comp fleet/survey phase value sizefreq_method
9 1 1 1 1
4 2 2 1 1
4 2 3 1 1
4 2 4 1 1
#
# lambdas (for info only; columns are phases)
# 0 0 0 0 #_CPUE/survey:_1
# 1 1 1 1 #_CPUE/survey:_2
# 1 1 1 1 #_CPUE/survey:_3
# 1 1 1 1 #_agecomp:_1
# 1 1 1 1 #_agecomp:_2
# 0 0 0 0 #_agecomp:_3
# 1 1 1 1 #_init_equ_catch
# 1 1 1 1 #_recruitments
# 1 1 1 1 #_parameter-priors
# 1 1 1 1 #_parameter-dev-vectors
# 1 1 1 1 #_crashPenLambda
1 # (0/1) read specs for more stddev reporting
0 2 -1 7 0 7 -1 2016 6 # placeholder for selex type, len/age, year, N selex bins, Growth
pattern, N growth ages, NatAge_area(-1 for all), NatAge_yr, N Natages
5 16 27 38 46 0 0 # vector with selex std bin picks (-1 in first bin to self-generate)
1 2 14 26 40 0 0 # vector with growth std bin picks (-1 in first bin to self-generate)
1 2 3 4 5 6 # vector with N-at-age std bin picks (-1 in first bin to self-generate)

999

```

### A.4.3 Stock Annex for sardine in Subarea 7

#### C 1 Fishery

There are currently no management measures implemented for this stock. The fisheries appear to be regulated by market price.

#### Subareas 7.d,e,h (English Channel and 7.h)

Most of the catches are concentrated close to or in the English Channel (7.d, 7.e, 7.h) with major landings from France and Netherlands, other catches being taken by England and Wales. Little information was available from other countries operating in that subarea. Catches have substantially oscillated with time and between countries from 25 000 to less than 2000 tons. This region has been harvested substantially in the past by various fleets (Figure C.1.1). The peak of fishing activity was in the early 1990s at around 25 000 tons. Over the last decades, the landings have been between nearly 5000 to 11 000 tons with no clear trend. It must be noticed that since 2010, there is a ban of sardine catches in the Seine bay due to PCB contamination. It implied a strong decrease in the French catches, from 12000 tons to nearly 7000 in recent years (2011-2015). The English Channel is after Bay of Biscay the second fishing area for sardine, but some uncertainty remains about the total international catches in that area.

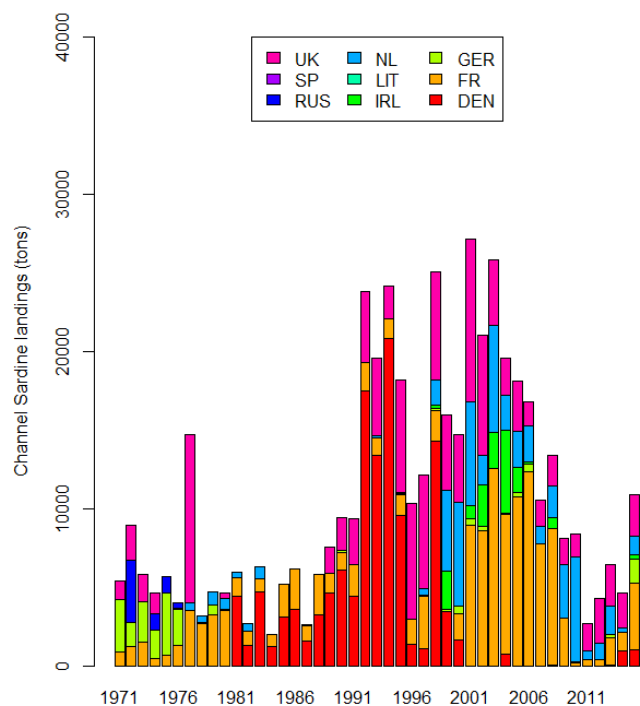


Figure C.1.1. Historical time-series of landings of sardine per country in the English Channel and 7.h.

As mentioned for the Bay of Biscay, catches in rectangles 25E4, 25E5 are removed from the official landings and added to the catches in the Bay of Biscay to take account of the mixing at the borders of Division 8.a and 7.h and 7.e.

### Subareas 7.a,b,c,f,g,j,k (Celtic Seas)

Catches in this area (figure C.1.2.) have been variable ranging between almost no catches to 3000 tons and are since the early 2010s ranging between 1500 and 3000 tons almost exclusively taken by the UK Cornish fishery operating in 7e, 7h and 7f. As for the English Channel, some uncertainty remains about the total international catches in that area.

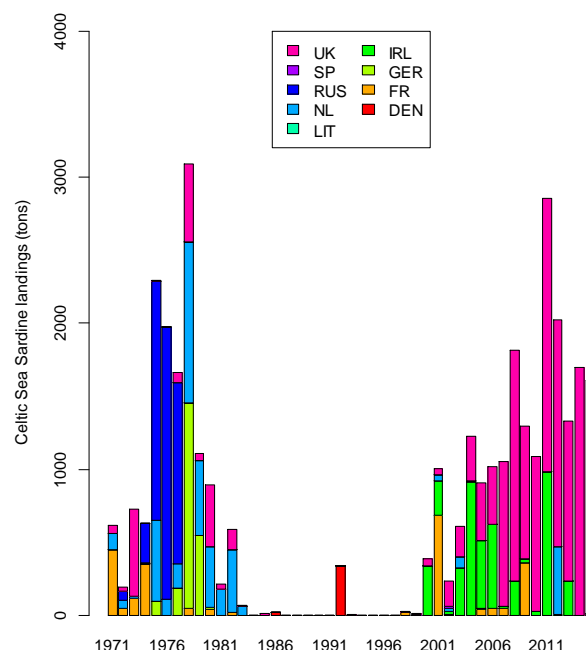


Figure C.1.2. Historical time-series of landings of sardine per country in the Celtic sea.

## C.2 Ecosystem aspects

Sardine is prey of a range of fish and marine mammal species which take advantage of its schooling behaviour and availability. Sardine has been found to be important in the diet of common dolphins (*Delphinus delphis*) in Galicia (NW Spain) (Santos *et al.*, 2004), Portugal (Silva, 2003) and the Atlantic French coast (Meynier, 2004). Recent studies of consumption of common dolphins in Galician (Santos *et al.*, 2011) waters give figures ranging from almost 6000 tons to more than 9000 tons of sardine, which represents a rather small proportion of the combined Spanish and Portuguese annual landings of sardine from ICES Areas 8.c and 9.a (6–7%). There are also other species feeding on sardine, although to a lesser extent, such as: harbour porpoise (*Phocoena phocoena*), bottlenose dolphin (*Tursiops truncatus*), striped dolphin (*Stenella coeruleoalba*), and white-sided dolphin (*Lagenorhynchus acutus*) (e.g. Santos *et al.*, 2007).

## C.3 Data

### C.3.1 Commercial catches

Landings data have been available for since 1950 on various aggregation levels. Catch data are the only information routinely available through the ICES datacall and other databases (FAO, ICES Statland, STECF Fishery dependent information database). Landings are mainly taken by France, UK and Netherlands while other countries also contributed to substantial amounts in the past.

There is still uncertainty on the absolute level of landings in the Celtic Seas and the English Channel. Discards are considered negligible. Catches in Celtic Sea seem to be very low compared to those from the English Channel

### **C.3.2 Biological data**

Length distributions are scarcely available since 1994 not on an annual basis. Length distribution of discards is also available from Netherlands in the English Channel for 2011.

Biological sampling on commercial catch has been close to inexistent so far. Length distribution data are scarcely available in 1994, 1996 and then every year since 2000 from the Dutch pelagic freezer trawler operating in the English Channel. Those vessels, while capturing substantial amounts of sardine are structurally different from the fishing vessels of the other main countries (United Kingdom, France) and therefore those length structures may not reflect the actual length distribution of the population. Other countries do not provide length or age information due to the lack of national biological sampling scheme and no DCF requirement regarding that species in 7.

### **C.3.3 Surveys**

In the Celtic Sea/English Channel, the PELTIC survey has 4 years of data at the time of the writing of this document but is expected at medium terms to provide a time series of abundance of sardine for subarea 7.

Some sardines are caught during the various demersal surveys (e.g FR-IBTS) occurring each year in the Celtic Seas, Bay of Biscay and English Channel but those catches are not substantial enough to be considered as indicators of the stock status.

The PELTIC survey series is part of the UK Government funded project Poseidon. While the survey is currently not funded through the European DCF initiative, the survey is coordinated through two ICES working groups: Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VII, VIII and IX (WGACEGG) and International Pelagic Surveys (WGIPS).

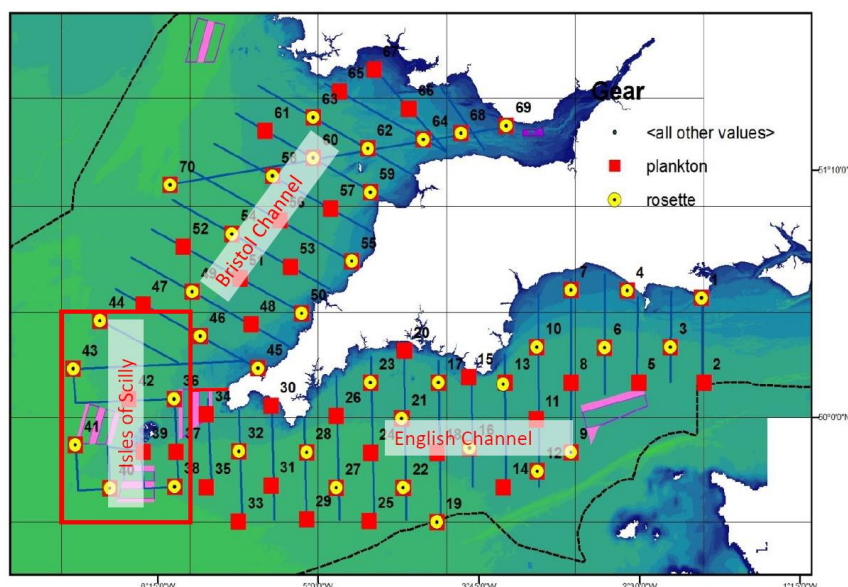


Figure C.3.3.1. Overview of the survey area, with the acoustic transect (blue lines), plankton stations (red squares) and hydrographic stations (Yellow circles). Emboldened red lines delineate the three “ecoregions”.

The PELTIC survey is carried out annually over around 18 days in October on board the RV ‘Cefas Endeavour’. The first of these surveys was conducted in 2012. The survey follows a systematic parallel transect design with 10 nautical miles spaced transects running perpendicular to the coastline or bathymetry (Figure C.3.3.1). Three main areas are identified in the survey, the western English Channel, The Isles of Scilly and the Bristol Channel.

Ichthyoplankton are sampled using a 270 $\mu$ m mesh ringnet of 1 m diameter at regular stations (indicated in red in Fig B.3.4.1). The eggs and larvae of sardine are counted, staged into 5 categories (eggs) and measured (larvae). Volumes filtered are measured by flowmeters and used to calculate numbers per m<sup>2</sup>.

Acoustic data are collected using a Simrad EK60 scientific echosounder, at a ping rate of 0.6 s<sup>-1</sup> and pulse duration of 0.512  $\mu$ s. Split-beam transducers are mounted on the vessel’s drop keel and lowered to the working depth of 3.2 m below the vessel’s hull or 8.2 m sub surface. Three operating frequencies are used during the survey (38, 120 and 200 kHz) for trace recognition purposes, with 38 kHz data used to generate the abundance estimate for clupeids (and other fish with swimbladder) and 200kHz for mackerel. All frequencies are calibrated at the start of the survey. Regular trawls are conducted to collect biological data and ground-truth acoustic marks for species and size information.

Acoustic data are processed in Myriax Echoview. An Echoview processing template is used with an algorithm developed to utilize the typical multifrequency response properties to separate four different echo-types: fish with a swimbladder, jellyfish and juvenile fish, fish without swimbladder and fluid-like zooplankton (*sensu* Ballon *et al.*, 2011). For each Echoview processing file a duplicate processing file is created which contains a different algorithm specifically designed to extract mackerel. Details on the detection algorithm are described elsewhere (van der Kooij *et al.*, 2016). The swimbladder-fish component is then further scrutinized and partitioned into species using expert knowledge and trawl information. The trawl catch composition is converted to acoustic equivalent values by species and size using published b20 values which are in

turn used to raise the acoustic data attributed to fish with swimbladders for each 1 nautical miles interval.

To estimate the abundance, the allocated NASC values are averaged by stratum within the survey area. For each stratum, the unit area density of fish (SA) in number per square nautical mile ( $N \cdot nmi^{-2}$ ) is calculated using standard equations (Foote *et al.*, 1987, Toresen *et al.*, 1998). Pending further analysis to identify ecologically relevant strata, survey stratification is based on ICES statistical rectangles with a range of 0.5 degrees in latitude and 1 degree in longitude, large squares  $2^\circ$  lat by  $1^\circ$  long or other geographical bounds.

The biomass estimates of the four main species are further broken down by length group in the individual species section of the results. It is pointed out however that the length-based abundance and biomass estimates should be used with caution. In contrast to the partitioning of acoustic data into species, which combined trawl information, a multi-frequency algorithm as well as expert knowledge, partitioning into length categories is solely based on nearby trawl catches. In some instances, no trawl could be conducted due to for example the presence of static gear or bad weather, in which case trawl catches from further away were used. This may not have been representative for the size distribution. In addition, partitioning based on trawl catches assumes equal catchability of the different species and lengths. During the scrutiny process, supplementary information from the trawl headline sonar and GoPro footage was incorporated to establish catchability of the different species; however no equivalent level of detail could be obtained for the different lengths. For the same reason no attempts were made to further partition the biomass estimates by age groups although the age length relationships are provided.

At the moment the time series is too short to provide information for a stock assessment in the Celtic sea and English Channel but is a useful source of information regarding the biology of sardine in those areas.

#### **C.3.4 Commercial cpue**

According to literature, cpue indices have been considered as not reliable indicators of abundance for small pelagic fishes (Ulltang, 1980; Csirke, 1988; Pitcher, 1995; Mackinson *et al.*, 1997). Commercial catch per unit of effort data are available at various levels of aggregation (subarea/gear/years) from official data, but these are not considered indicative of stock trends (see also information from the industry, below).

#### **C.3.5 Other relevant data**

Interviews with the French fishing industry operating in the Bay of Biscay highlighted a potential displacement of the stock further north. This could partly explain the increase of activity in the Celtic Sea over the last decade. According to fishermen, the main driver of the Bay of Biscay fishery is the market. Many fishers could catch more sardine due to the high sardine availability, but this would not be suitable given the poor levels of prices. Thus, the industry data (landings) cannot be directly related to variations in sardine abundance.

### **C.4 Assessment-data and method**

For the purposes of Assessment and Management the workshop concluded that in the absence of evidences 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.



The conclusion of WKPELA was that currently the limited and poor quality of the data available for the English Channel and Celtic sea region prevents producing an assessment of subarea 7. Furthermore, a joint assessment of Divisions 8abd and subarea 7 require the strong assumptions of similar population trends and age composition of catches in both areas, which is currently perceived as highly unlikely (according to the recent survey estimates and indications of different growth patterns). Therefore, the WK concluded that the sardine populations inhabiting area 7 cannot be assessed analytically currently. A proper assessment should wait until a consolidate series of biomass and age structured survey index is available and a minimum of a length composition series, but preferably age composition series, of catches is available.

WGHANSA will develop exploratory assessments using the source of information as they become available.

#### **C.4.1 Data inputs**

As no suitable assessment method has been adopted for this stock, no data inputs are used. Exploratory approaches are expected to fully use any of currently available datasets: catch, length distribution, survey index and any additional data when they become available.

#### **C. 4.2 Methods and settings**

No suitable assessment method has been adopted for this stock.

#### **C.5 Short term projection**

No medium term projection method has been defined for this stock.

#### **C.6 Medium term projection**

No short term projection method has been defined for this stock.

#### **C.7 Long term projection**

No long term projection method has been defined for this stock.

#### **C.8 Biological reference points**

No reference point has been defined for this stock.

#### **C.9 Other issues**

Due to the lack and quality of data in subarea 7, it is currently not possible to provide any assessment for this subarea.

#### **C.10 Historical overview of previous assessments models**

No specific isolated assessment has been produced in the past for Subarea 7. DCAC was used without success in 2012 as an attempt in subdivision 7 to estimate some stock trends. Advice was based on available survey indices following the guidelines for ICES category 3 assessment for the whole 8.a,b,d and 7 regions.

#### **C.11 Data call**

Data to be reported for the sardine stock in subarea 7:

##### **Recent catch and biological data**

France, UK, and Netherlands: catches in subdivision 7. Time series of length and age distribution when available.

Other countries: catches catches in subdivision 7.

## Survey data

UK: abundance index, length distribution from the PELTIC survey.

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