

RELATÓRIOS DE CAMPANHA

INTERNATIONAL SURVEY FOR THE ASSESSMENT OF THE STRENGTH OF THE SARDINE
AND ANCHOVY RECRUITMENT IN ATLANTIC IBERIAN WATERS
“IBERAS0923”



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INTERNATIONAL SURVEY FOR THE ASSESSMENT OF THE STRENGTH OF THE SARDINE AND ANCHOVY RECRUITMENT IN ATLANTIC IBERIAN WATERS



IBERAS0923 SURVEY REPORT



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EXECUTIVE SUMMARY

IBERAS0923 was carried out on board R/V Ramón Margalef from 12th to 25th September 2023 aiming at to estimate the strength of recruitment of the Iberoatlantic stock of sardine (*Sardina pilchardus*). The calibration for the survey was carried out on the 18th September. The survey covered the areas 8cW, 9aN, 9aCN and 9aCs (e.g. western coast of the Iberian Peninsula) on a survey design consisting in parallel transects 6 nmi apart, with a random start, and covering from 20-15 m depth up to 100 m. This zone coincides with the main potential distribution area for sardine recruitment of the Iberoatlantic stock. Moreover, in the main recruitment area (e.g. middle part of 9aCN, observed historically) sampling intensity has been increased up to 4 nmi among transects to increment the sampling resolution.

Weather conditions were in general good and the survey was carried out as foreseen. 25 pelagic trawl hauls were performed and 1 purse seiner (in the second leg) was used to perform another 12 fishing operations, which were used to ground-truth the fish community and the length/age distribution of each species. Total NASC was higher than those on previous years ($810 \cdot 10^3 S_A$). 15% of this NASC was unallocated due to the lack of time to perform specific fishing stations to verify those echotraces. 42% of the total NASC was allocated to sardine (category big), 74% was allocated to sardine and anchovy (both in two categories) and 8% was allocated to Chub mackerel.

As main result, biomass estimates for adult sardine (individuals >16.0cm) achieved 339674 metric tonnes that corresponds to $6.8 \cdot 10^9$ fish. The most representative was age group 1, which accounted for 29913 metric tonnes ($2.8 \cdot 10^9$ fish), confirming the strength of the 2022 cohort. 2023 was very low and the centre of gravity was found around Figueira da Foz, with a large dispersion. Overall, IBERAS is providing a good indicator of the strength of the sardine recruitment for the Iberoatlantic stock.

Overall IBERAS is providing a good indicator of the strength of the sardine recruitment for the Iberoatlantic stock. The index estimates showed clear increasing trend from 2018 (13807 mt corresponding to $0.5 \cdot 10^9$ fish) to 2020, then a decline in 2021, followed by another high in 2022, and this year another low recruitment index. The good relationship between these figures with those at age 1 estimated in the spring surveys PELAGO and PELACUS allows IBERAS to provide a recruitment index for this stock.

TECHNICAL SUMMARY

Institution: INSTITUTO ESPAÑOL DE OCEANOGRAFÍA/INSTITUTO PORTUGUÊS DO MAR E DA ATMOSFERA

Survey name: IBERAS0923

Vessel name: Ramón Margalef (46.70 m length, 10.50 width 988 GRT, 900 kW diesel-electric)

Dates: 11-25/09/2023

Area: WESTERN IBERIAN COAST (9aCS-9aCN-9aN-8Cw)

Type: Acoustic-Trawl

Main objective: Biomass estimation by means of echointegration of the main pelagic fish population present in the surveyed area. Physical, chemical and biological characterisation of the pelagic ecosystem.

Sampling strategy Systematic grid with random start, tracks 4/6 nmi apart from 20 to 100 isobath

Main sampling procedures EK-80 at 18-38-70-120-200 kHz acoustic frequencies. 882 nmi prospected. Only day time
Pelagic fishing stations: 25 + 12 Purse seiners
Hydrological characterisation.

Personnel

1 st leg	CARRERA LÓPEZ, PABLO	SILVA, DINA
Vigo/Vigo	CONDE LAGO, ANXO	POMBAL, EMANUEL
Dates: 12 to 18/09	MARTÍNEZ CEDEIRA, JOSÉ ANTONIO	DOS SANTOS BARRA, JORGE EMANUEL BAZILIO
	AUTÓN DÍAZ, URBANO	LOPEZ CARVALHO, FLAVIA
	HERNÁNDEZ MILIÁN, GEMA	MORENO, ANA
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INTRODUCTION

IBERAS is a recent acoustic-trawl time series aiming to estimate the strength of the sardine recruitment in Atlantic Iberian waters. The survey is carried out over the main potential distribution area for the recruitment of the Iberoatlantic sardine (*Sardina pilchardus*) stock. The first survey was done in November 2018, so this year (2023) was the sixth year of the series. Due to the poor weather conditions and in order to make a synoptic coverage with JUVENA survey - which is also covering the Bay of Biscay, the timing was shifted to September.

This shift did not change the recruit availability and, in fact, the recruitment abundance estimated in 2019 was really high which has been corroborated by the spring acoustic-trawl survey PELAGO. Unfortunately, in 2020 due to the Covid-19 the Spanish survey PELACUS was cancelled so the real strength of the 2019 sardine cohort would have been underestimated.

The rationality of this new time series is based on the low productivity level of the sardine stock in this area. Although sardine is not considered a short-lived species, the lack of good incoming year classes, resulted in a very low presence of older ages (e.g. very low expectation for reaching ages older than 5 years due to high natural mortality), being the bulk of the population composed by younger fish, which in turn, make this species look like a short-lived species. In such conditions, any recovery of the biomass will likely be triggered by the strength of the recruitment. Thus, when juveniles can be assessed at age 0, the estimates can be used to predict the relative strength of the future recruitment to the fisheries. This strategy is of special interest to manage the fisheries for short-lived species because of the short time between spawning and the exploitation of subsequent emerging recruits.

IBERAS survey was designed attending the experience achieved by IPMA through the JUVESAR survey (targeting sardine recruitment in northwest Portugal), by AZTI and IEO through the JUVENA survey (to improve the assessment/management of the Bay of Biscay anchovy) and by IEO through ECOCADIZ recruitment survey (targeting sardine and anchovy recruitment in the Gulf of Cadiz). IBERAS main objective is to get a recruitment index for both species in Atlantic waters of the Iberian Peninsula, aiming to improve the estimation of the strength of the recruitment of the Iberoatlantic sardine and the western component of the south anchovy population.

OBJECTIVES

- i. Acoustic estimates by echointegration of the strength of the sardine recruitment in Atlantic waters of the Iberian Peninsula, between Cape Ortegal and São Vicente
- ii. Oceanographic (physical -CTD- and biological _bongo nets) characterization of the surveyed area

MATERIAL AND METHODS

Survey was carried out on board R/V Ramón Margalef from the 12th until the 25th of September 2023, departing from the port of Vigo and arriving to Lisbon harbour at night (Fig. 1). Depending on

vessel availability IBERAS survey can be carried out in R/V Ramón Margalef or in a similar vessel: R/V Angeles Alvariño (used in years 2019 and 2022); the similarity of the two vessels makes the vessel uncertainty effect to be low and promotes result comparison.

A scale was scheduled in Vigo on 18th of September.

Working Area

From Cape Finisterra until Sines, from shoreline (20 m) to 100 m isobath over an adaptive grid with 46 tracks distanced between 4-6 nmi on account the potential recruitment distribution area of both sardine and anchovy. Transects are adaptative: they were enlarged or shortened according to the sardine and anchovy presence. The start of the survey is random. Figure 1 show the foreseen survey track and Table 1 the expected survey coverage and time schedule.

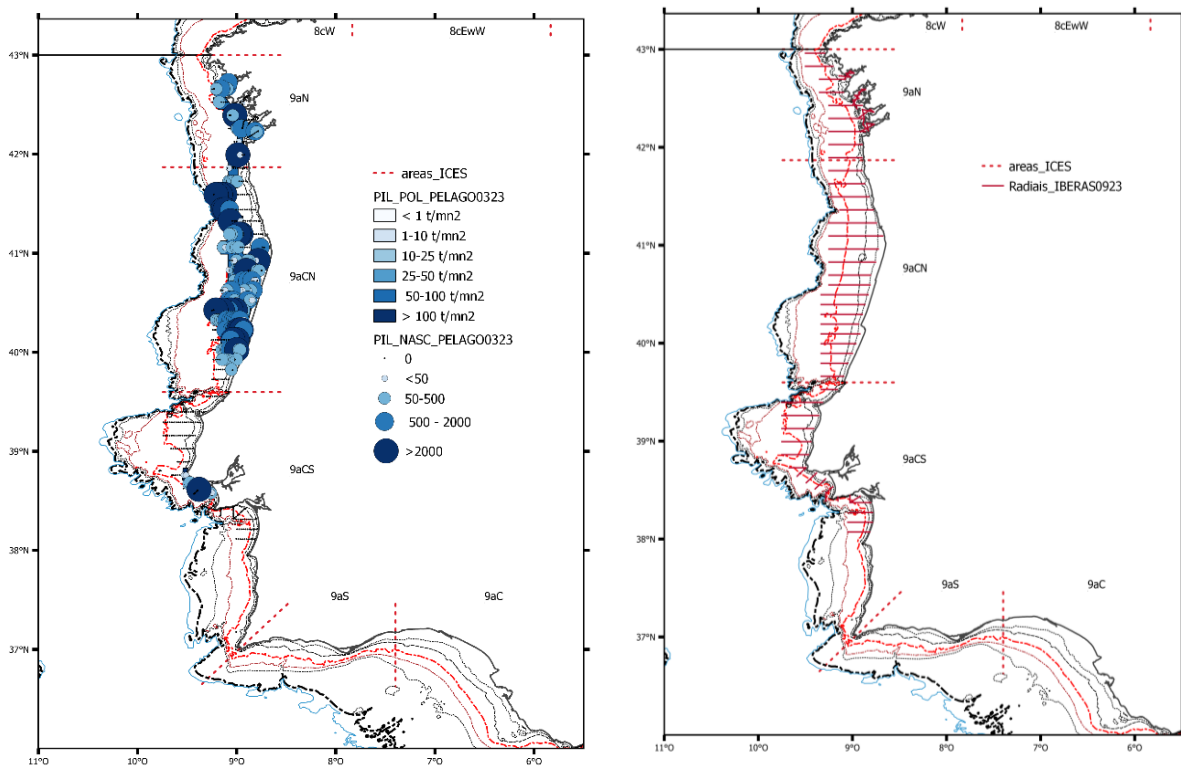


Figure 1 Sardine NASC distribution obtained during PELAGO0323 (left) and the proposed survey track for IBERAS0923 (right).

Table 1 Expected survey coverage and time scheduled in each ICES Sub-Division.

Tabla 1. Previsión de actividades y días

Zona	No radiales	No. millas		Navegación (horas-días)	Pesca (n-horas-días)	TOTAL (días)	FECHA
		Radial	Unión				
Calibración						1	11/09
9aCNViana.	3	52	16	6.8-05	3-6-0.33	1	12/09
Norte de Portugal y plataforma R. Baixas (9aN)	9	126	54	12.6-1.80	8-14-1.2	3	13-15/09
Rías Baixas	22	97	19	10-0.80	8-14-1.20	2	16-17/09
9aCN-Porto-Figueira-Nazaré	17	321	86	33-2.70	15-30-2.30	5	18-22/09
9aCS: Ericeira	5	70	33	10.30-0.75	3-6-0.33	1	23/09
9aCS: Sado-Sesimbra	8	64	36	9.98-0.7	3-6-0.33	1	24/09
9a-CS: Caparica-Lisboa	4	28	18	4.6-0.3	3-6-0.33	0.60	25/09

The followed methodology was similar to the one of the previous surveys and is summarised in ICES Cooperative Research Report No. 332. 268 pp. <https://doi.org/10.17895/ices.pub.4599>. The backscattering acoustic energy from marine organisms was measured continuously during daylight except in the northern area where some tracks were steamed at night. Pelagic trawls were carried out whenever possible to help identify the species (and size classes) that reflect the acoustic energy. During daylight hours, concurrently to acoustics, a trained observer recorded marine mammal, seabird, floating litter and vessel presence and abundance.

At night, when acoustics surveying was not running, CTD profiles for hydrography and zooplankton samples (Bongo 60 and Manta trawl nets) were collected in some of the acoustic transects, opportunistically chosen.

Acoustic

Acoustic equipment consisted of a Simrad EK-80 scientific echosounder, operating at 18, 38, 70, 120 and 200 kHz, working in CW mode. All frequencies were calibrated according to the standard procedures (ICES-CRR326) during the first two days. The elementary sampling distance unit (EDSU) was fixed at 1 nmi. Acoustic data were obtained only during daytime at a survey speed of 8-10 knots, although, some tracks were also steamed at night. Data were then stored in raw format and post-processed using SonarDataEchoview software (Myriax Ltd.) (Higginbottom et al, 2000). All echograms were first scrutinized, the bottom line incorporated, and background noise was also removed according to De Robertis and Higginbottom (2007). Fish abundance was calculated with the 38 kHz frequency as recommended at the PGAAM (ICES 2002), although echograms from 18, 70, 120 and 200 kHz frequencies were used to visually discriminate between fish and other scatter-producing objects such as plankton or bubbles, and to distinguish different fish species according to the frequency response. The 18, 70, 120 and 200 kHz frequencies were also used to create a mask allowing a better discrimination between swimbladder fish species and other organisms. The threshold used to scrutinize the echograms was -70 dB. The integration values were expressed as nautical area scattering coefficient (NASC) units or s_A values ($m^2 \text{ nmi}^{-2}$) (MacLennan et al., 2002).

1 NASC allocation

A pelagic gear gloria HOD 352 together with a 63.5/51 were used to identify the species and size classes responsible for the acoustic energy detected and to provide samples. Haul duration was variable and ultimately depended on the number of fish entering the net and the conditions where fishing takes place although a minimum duration of 20 minutes was always attempted. The quality of the hauls for ground-truthing the acoustic data was classified considering the weather condition,

haul performance, catch composition in numbers and the length distribution of the fish caught (Table 2).

Table 2 Ground-truth quality criteria used to classify validity of fishing stations in the survey.

	0	1	2	3
Gear performance	Crash	Bad geometry	Bad geometry	God geometry
Fish behaviour		Fish escaping	No escaping	No escaping
Weather conditions	Swell >4 m height Wind >30 knots	Swell: 2-4 m Wind: 30-20 knots	Swell: 1-2m Wind 20-10 knots	Swell <1 m Wind < 10 knots
Fish number	total fish caught <100	Main species >100 Second species <25	Main species > 100 Second species < 50	Main species > 100 Second species > 50
Fish length distribution	No bell shape	Main species bell shape	Main species bell shape Seconds: almost bell shape	Main species bell shape Seconds: bell shape

Hauls considered as the best representation of the fish community for a specific area were used to allocate NASC to each EDSU within that area when no direct allocation was feasible. This process involved the application of the Nakken and Dommasnes method (1975, 1977) for multiple species, but instead of using the mean backscattering cross section, the full-length class distribution (1 or 0.5 cm length classes) was used, as follows:

$$NASC_l = NASC \cdot \left(\frac{\sigma_{l,\rho}}{\sigma_\rho} \right)$$

Where $NASC$ is the total backscattering energy to calculate densities by length, $NASC_l$ is the proportion of the total $NASC$ which can be attributed to length group l for a particular fish species. $\sigma_{l,\rho}$ is the backscattering cross-section at length l for a particular species at length l multiplied by the proportion of (ρ_l) of length of this particular species on the overall catch and σ_ρ is the sum of all $\sigma_{l,\rho}$ for all species,

$$\sigma_{l,\rho} = \rho_l * \sigma_l$$

$$\sigma_\rho = \sum_l \sigma_{l,\rho}$$

Finally, σ_l is backscattering cross-section (m^2) for a fish of length l for a particular species and is computed as follows:

$$\sigma_l = \frac{l \left(\frac{m}{10} \right) * 10 \left(\frac{b_{20}}{10} \right)}{4 * \pi}$$

This is computed from the formula $TS = 20 \log_{L_T} + b_{20}$ (Simmonds and MacLennan, 2005), where L_T is the length class. The b_{20} values for the most important species present in the surveyed area are shown in table 3:

Table 3 b_{20} values from the length target strength relationship of the main fish species assessed in IBERAS survey. PIL is sardine (*Sardina pilchardus*); ANE anchovy (*Engraulis encrasicolus*); HKE hake (*Merluccius merluccius*); BOG bogue (*Boops boops*); BOC boarfish (*Capros aper*); MAC mackerel (*Scomber scombrus*); HOM horse mackerel (*Trachurus trachurus*); VMA chub mackerel (*Scomber colias*) and WHB is blue whiting (*Micromesistius poutassou*).

Species FAO acronym	b_{20}	Reference	Observations	Other b_{20}	Reference
PIL	-72.6	Degnbol et al., 1985	TS for clupeids	-71.2 -70.4 -74.0 -72.5	ICES, 1982 Patti et al., 2000 Hannachi et al., 2005 Georgakarakos et al., 2011
ANE	-72.6	Degnbol et al., 1985	TS for clupeids	-71.2 -76.1 -71.6 -74.8	ICES 1982 Barange et al., 1996 Zhao et al., 2008 Georgakarakos et al., 2011
HKE	-67.5	Foote et al., 1986; Foote, 1987		-68.5 -68.1	Lillo et al., 1996 Henderson, 2005; Henderson and Horne, 2007
BOG	-67.5	Foote et al., 1986	Adapted from gadoids		
BOC	-66.2	Fässler et al., 2013			
MAC	-84.9	Edwards et al., 1984; ICES, 2002		-86.4 -88.0	Misund and Betelstad, 1996 Clay y Castonguay, 1996
HOM	-68.7	Lillo et al., 1996		-68.15 -66.8 -66.5/-67.0(*)	Gutiérrez and McLennan, 1998 Barange et al. (1996) Georgakarakos et al., 2011
VMA	-68.7	Lillo et al., 1996	Adapted from HOM;l (Sawada, com. pers.)	-70.95	Gutiérrez and McLennan, 1998
WHB	-65.2	Pedersen et al., 2011			

* day and night respectively

When possible, direct allocation was done, accounting for the shape of the schools and also the relative frequency response (Korneliussen and Ona, 2003, De Robertis et al, 2010). Fish schools were extracted using the settings described in Table 4.

Table 4 Main morphological and backscattering energy characteristics used for school detection in Echoview software.

Sv threshold	-60/-70 dB for all frequencies
Minimum total school length	2/20 m
Min. total school height	1/5 m
Min. candidate length	1 m
Min. candidate height	0.5 m
Maximum vertical linking distance	2/5 m
Max. horizontal linking distance	10/25 m
Distance mode	Vessel log
Main frequency for extraction	38/120 kHz

For all school candidates, several variables were extracted, among them: the NASC (s_A , m^2/nmi^2) together with the proportioned region to cell (ESDU, 1 nmi) NASC, the s_V mean, s_V max geographic position and time. PRC_NASC values were summed for each ESDU and distances were referenced to a single starting point for each transect. Results for the 38 and 120 kHz frequencies were compared. Besides, the frequency response for each valid school (i.e. those with length and s_V which allows them be properly measured) was calculated as the ratio $s_{A(f_i)}/s_{A(38)}$, being f_i the s_A values for 18, 70, 120 and 200 kHz.

2 Echointegration estimates

Once backscattering energy is allocated to fish species, the spatial distribution for each species is analysed considering both the NASC values and the length frequency distributions (LFD) to provide homogeneous assessment polygons. These are calculated as follows: an empty track determines the along-coast limit of the polygon, whilst three consecutive empty ESDU's determine a gap or the across-coast limit. Within each polygon, the LDF is analysed.

LFD were obtained for all positive hauls for a particular species (either from the total catch or from a representative random sample of 100-200 fish). For the purpose of acoustic assessment, only those LFD based on a minimum of 30 individuals were considered. Differences in probability density functions (PDF) were tested using Kolmogorov-Smirnov test. PDF distributions without significant differences were joined, providing a homogeneous PDF stratum. Spatial distribution was then analysed within each stratum and finally a mean s_A value and area (square nautical miles) were calculated using a GIS based system (Q-gis). These values, together with the length distributions, were used to calculate the fish abundance in number as described in Nakken and Dommasnes (1975) (see previous section for further details). Estimates for each species were calculated on each strata (polygon) using the arithmetic mean of the backscattering energy (NASC, s_A) attributed to each fish species and the area expressed in square nautical miles using the following formula:

$$\rho_l = \frac{NASC_l}{\sigma_l}$$
$$N_l = \rho_l * A_p$$

Where ρ_l is the areal density of fish (numbers per square nautical mile in length group l); the total number for length group l (N_l) within each stratum is calculated as the product of ρ_l times the total area of the strata (A_p) expressed in square nautical miles.

Numbers were converted into biomass using the length weight relationships derived from the fish measured on board. For comparison purposes, results are given by ICES Sub-Divisions (9aS, CS, CN and N).

3 Centre of Gravity

For each main species, a centre of gravity (Woillez et al. 2007) was calculated as a weighted average of each sample location (allocated NASC value as weighting factor). Due to the particular topography, instead of longitude and latitude, we have used depth and a new variable called "distance from the origin" where the distance (nautical miles) is calculated as $(Lat-37.0)*60$, being Lat the latitude of the middle point of any particular EDSU.

Fishing stations

Fishing stations were used for both NASC allocation and length analysis. Therefore, they were located in light of the results obtained during the acoustic prospection (i.e. opportunistically accounting the echotraces).

A gloria HOD 352 together with a 63.5/51 pelagic fishing nets with a vertical opening of about 13 m and 16 m respectively were used. As general rig, 200/400 kg of clump weight were put at each side of the set back (2 m lower wing). The Dyneema bridles (wings) of 100 were shorten to 50 m in shallower waters. A set of Apollo polyice doors with 3.5 m² and 750 kg weight were used. Gear performance was controlled using a wired Simrad Sonar FS20 net sounder. For surface tows, a fence

buoy was put in upper bridle, opposite to the clumps. Fishing stations were performed during daytime.

Additional biological information was provided by a chartered purse-seiner, who took samples around Aveiro and Figueira da Foz (9aCN) and around the Lisbon area.

Plankton and hydrological characterisation

Continuous records of Sea Surface Salinity (SSS), Sea Surface Temperature (SST) and Sea Surface Fluorometry (SSF) were taken using a SBE21 Thermosalinograph coupled with a Turner fluorometer. Every evening once the acoustic and fishing operations were over, CTD casts and plankton sampling were conducted on some of the acoustics transects. The surveying stations were set at 3nmi apart over the transects and the number of stations completed each night was dependent on the available time (until 24:00 aprox.). CTD profiles were obtained with a SBE25 probe and zooplankton sampling was carried out across the top 60m of the water column, using a Bongo net (60 cm diameter, 200µm and 500µm mesh sizes nets); the samples were preserved (200µm: in formalin, 500µm: in ethanol) for further analyses in the laboratory.

Fish sampling

Catches from fishing trawl hauls were sorted and weighted. All fish species were measured (total length (TL): 1cm classes for all species except clupeids measured at 0.5cm). When needed, random subsamples of 80-200 specimens were taken. For the main species an additional biological sampling was done for weight, age, sex, maturity stage analysis, complemented by stomach content analysis (sardine and anchovy); and, sampling for estimation of fecundity adult parameters (sardine). Besides, specific sampling was done on sardine for pollution and genetic purposes.

1 Catch and length distribution per species

Once the catch was sorted for all species, a length distribution was estimated. If the number of specimens caught was above 100, a random sample was sorted. Then, the random sample was weighted and the specimens measured to the nearest length class. This was 0.5cm for sardine and anchovy and 1cm for the rest of the species. Catch length distribution was estimated by raising the sample length distribution according to the weighting factor: total catch weight vs total sampling weight (TCW/TSW)).

2 Weight Length relationship

For all assessed species, a weight length relationship (WLR) was calculated, either from the results of the biological sampling (see below) or from a specific sampling procedure. In the latter case, a stratified random sampling scheme was used with the length class (i.e. 0.5 or 1cm) as stratum.

3 Biological sampling

For the main target species caught in each trawl haul (e.g. anchovy and sardine), a full biological sampling was conducted. Data collected were: length (mm); weight (g); sex; maturity stage; otolith collection; fat content; stomach colour and stomach repletion state. For sardine, the tale was also collected for further genetic analysis.

RESULTS

The survey was carried out as foreseen. There was good weather in the survey that allowed to carry all the duties of the survey.

Hydrographic conditions

Weather conditions were similar to those observed in the previous years, with predominant northern winds and only a period of 3 days of low pressures in the middle of the survey.

Sea surface temperature ranged between 16 and 22°C, with cold waters located inshore in the northern part (9aN and northern part of 9aCN), and in the southern part of 9aCS. Warmest waters were found offshore in the 9aCN and inshore around Figueira da Foz.

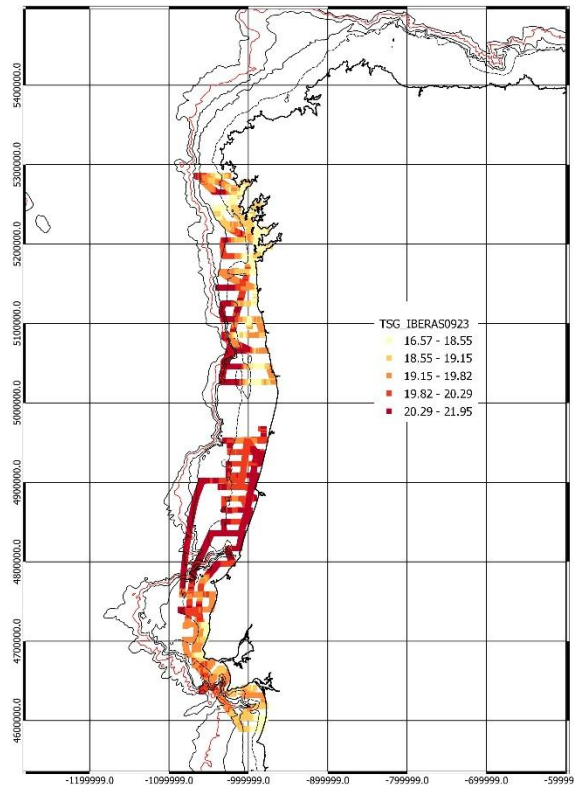


Figure 2 Sea Surface Temperature (SST) registered in the survey IBERAS0923.

Acoustics

School extraction and total backscattering energy

A total of 2889 echotraces were extracted, accounting for a total NASC (S_A) of 753256 $m^2 \text{ nmi}^{-2}$. On tracks, they were 2955 fish schools and NASC values were 810683 $m^2 \text{ nmi}^{-2}$, which was much higher than the values recorded on previous year. Figure 1 shows the sum of NASC per track along the surveyed area.

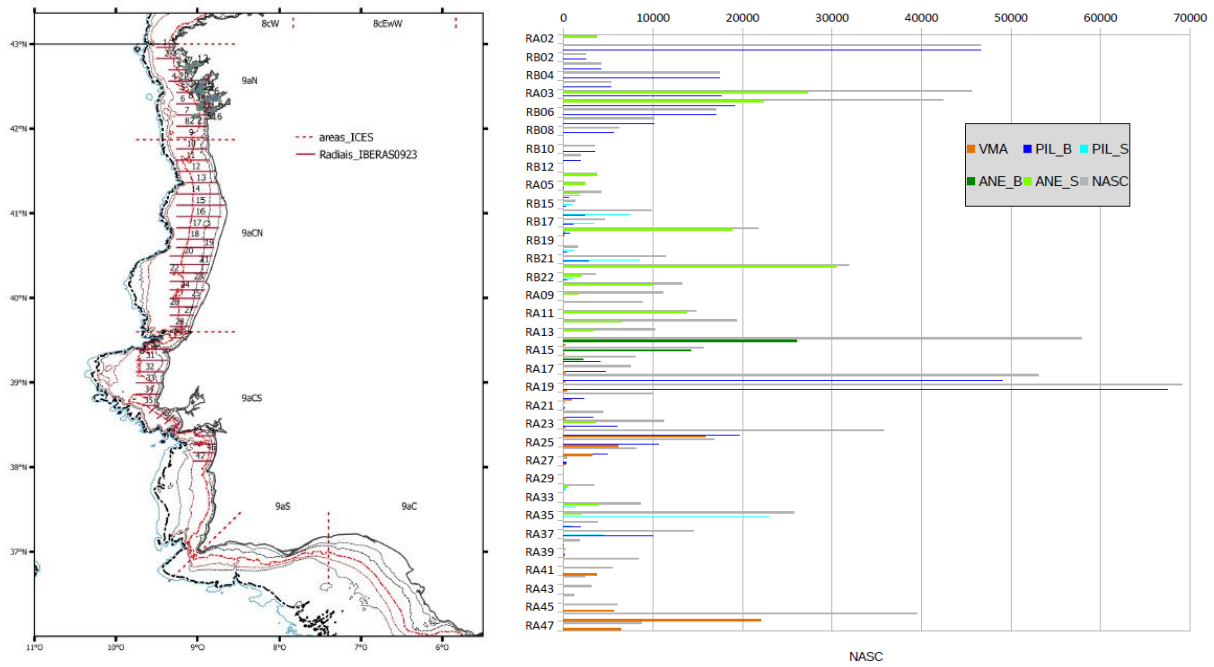


Figure 1 Cumulated NASC by species (PIL-sardine; VMA-chub mackerel, and ANE-anchovy) and transect. B denotes “big” individuals (adults, mature), and “S” small (juveniles, immature).

Fish schools occurred more or less in the same areas as recorded last year, with some of them (e.g. Ría de Muros or north Figueira da Foz) having an important contribution to the total backscattering. It should be noticed the amount of sardine found north of Nazaré.

Bathymetric distribution of schools was significantly different (more coastal) from that recorded last year when most NASC was located at 82.5 m whereas this year the main NASC mode was found at 17.5 m as shown in Figure 3.

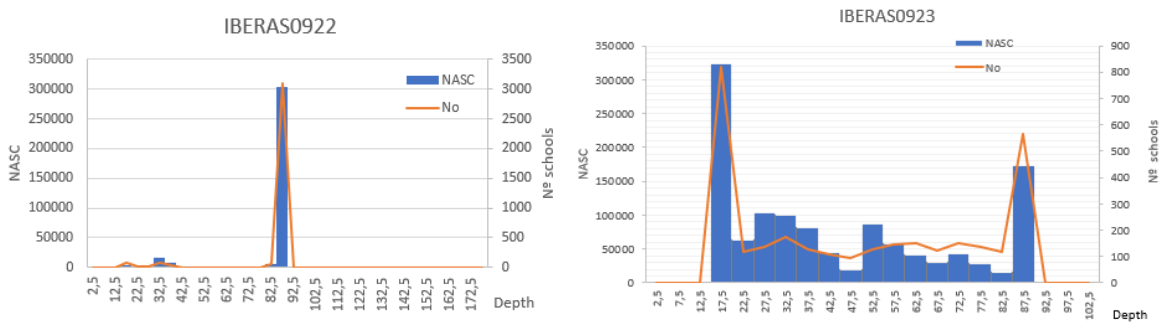


Figure 3 Number of schools and their cumulated NASC values per Depth strata (5m). Left IBERAS0922; right IBERAS0923

Fishing station and echotrace allocation

As stated last year, to perform fishing stations near shore was a challenging task as long as most of the area was occupied by static fishing gears, thus restricting the available areas to carry out these and increasing the searching time for doing it. Complementary to the 24 pelagic fishing hauls, 12 purse seine hauls were performed by a purse-seiner to help characterize the fish community (Table 5).

Table 5 Summary of the fishing stations carried out in the survey. PIL-sardine; MAC-mackerel; ANE-anchovy; HOM-horse mackerel; JAA-blue jack mackerel; SNS-longspine snipefish; BOG-bogue; VMA-chub mackerel; BOC-boarfish; SEAB-seabream species; ANE-anchovy. B denotes "big" individuals (adults, mature), and "S" small (juveniles, immature).

	TOTAL CAP (Kg)	No ind.	No Fishing st	Sample weight (kg)	Measured fish	Mean length	%PRES	% Catch_W	% Catch_No
PIL_S	2241	132126	11	13	751	12.78	30.56	7.12	9.94
MAC	1269	16135	13	77	895	22.34	36.11	4.03	1.21
ANE_S	3456	639088	15	10	1386	0.00	41.67	10.99	48.06
HOM	948	50311	22	27	1313	12.94	61.11	3.01	3.78
PIL	20529	452015	20	102	2033	18.01	55.56	65.25	33.99
JAA	0	0	0	0	0		0.00	0.00	0.00
SNS	0	0	0	0	0		0.00	0.00	0.00
BOG	3	23	6	3	23	23.54	16.67	0.01	0.00
VMA	2503	26606	13	65	656	22.11	36.11	7.95	2.00
BOC	0	0	0	0	0		0.00	0.00	0.00
SEAB	52	262	5	52	262	22.92	13.89	0.17	0.02
ANE	461	13249	4	5	129	17.06	11.11	1.46	1.00
Total	31462	1329815	36	354	7448				

This year, adult sardine accounted more than 65% of the total catch in weight, and was present in 55% of the hauls. Small sardine (<15cm) represented only 10% of total catch (in numbers). It should be also noticed the high presence of juvenile anchovy (41% of the hauls and 48% of total catch in numbers).

1 Sardine echotrace identification

As stated in previous year, survey targeted only juvenile sardine and anchovy (main objective) due to the lack of survey time. Similar to previous years, sardine occurred in dense schools close to the bottom (Figure 4). These schools corresponded to mostly to adult sardine. Dense schools in the first 20 metres of the water column (close to the surface) corresponded to juvenile sardine (Figure 5).

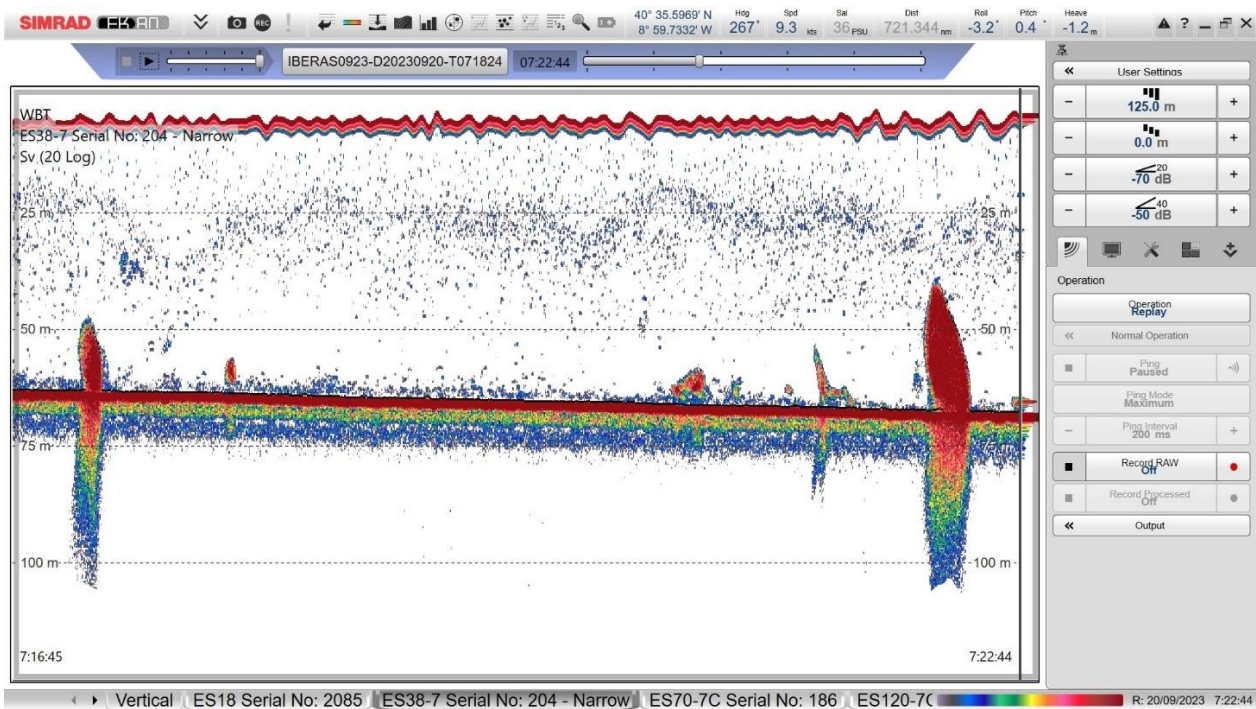


Figure 4 Echogram showing echotraces attributed to adult sardine (38kHz).

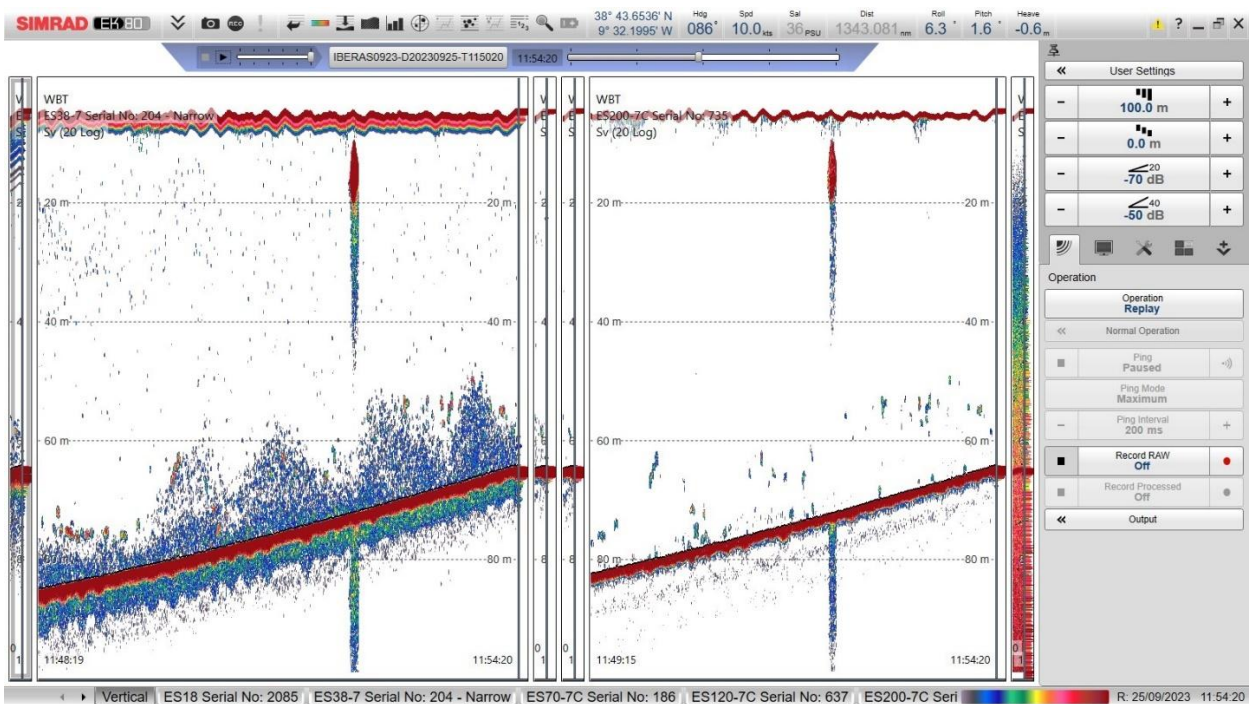


Figure 5 Echogram showing echotraces attributed to juvenile sardine (38kHz).

Juvenile sardine was concentrated near the coast north and south of the main well-known hotspot in 9aCN: in the 9aN, inside Rías Baixas, and in 9aCS in Cape Roca (near Lisbon).

Adult sardine was found in the same areas than the juveniles, and also in the central part of the Atlantic coast, between Aveiro and Nazaré (9aCN). Adult sardine occurred mainly near the coast, although some schools were also recorded around the 100 m isobath.

2 Anchovy echotrace identification

Adult anchovy was found exclusively in 9aCN area, between the 25 and 100 m, although some schools were found a little bit deeper. Anchovy was found in dense epipelagic schools (Figure 6) mainly offshore, and sometimes mixed with krill (Figure 7).

These schools showed higher dispersion at night (i.e. aggregation pattern seemed to change at sunset from dense schools to scatter schools). The fishing hauls performed on those echotracés with the RV Ramón Margalef were challenging, as the fishing net needed to stay at surface. No diving reactions of the schools were observed.

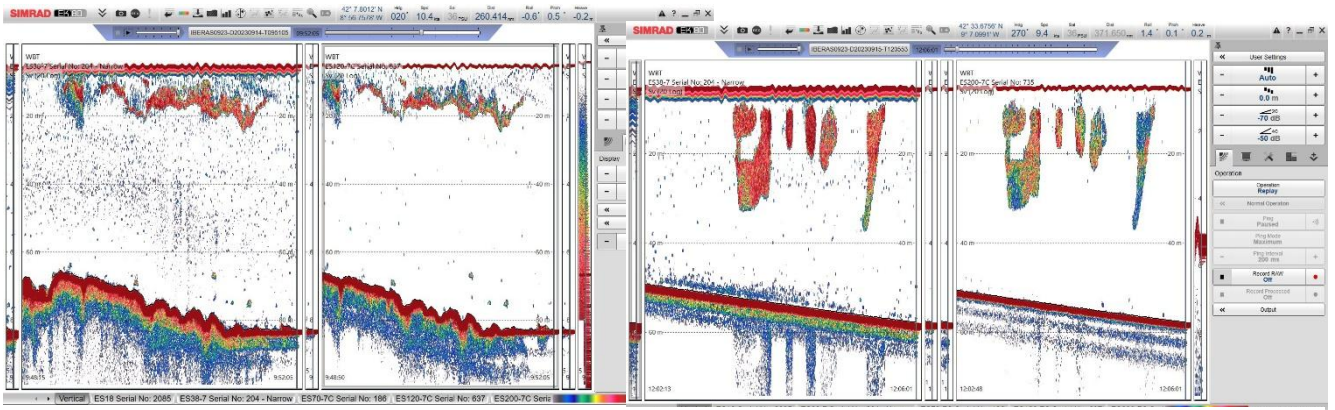


Figure 6 Echograms showing echotracés attributed to anchovy (38kHz in both cases).

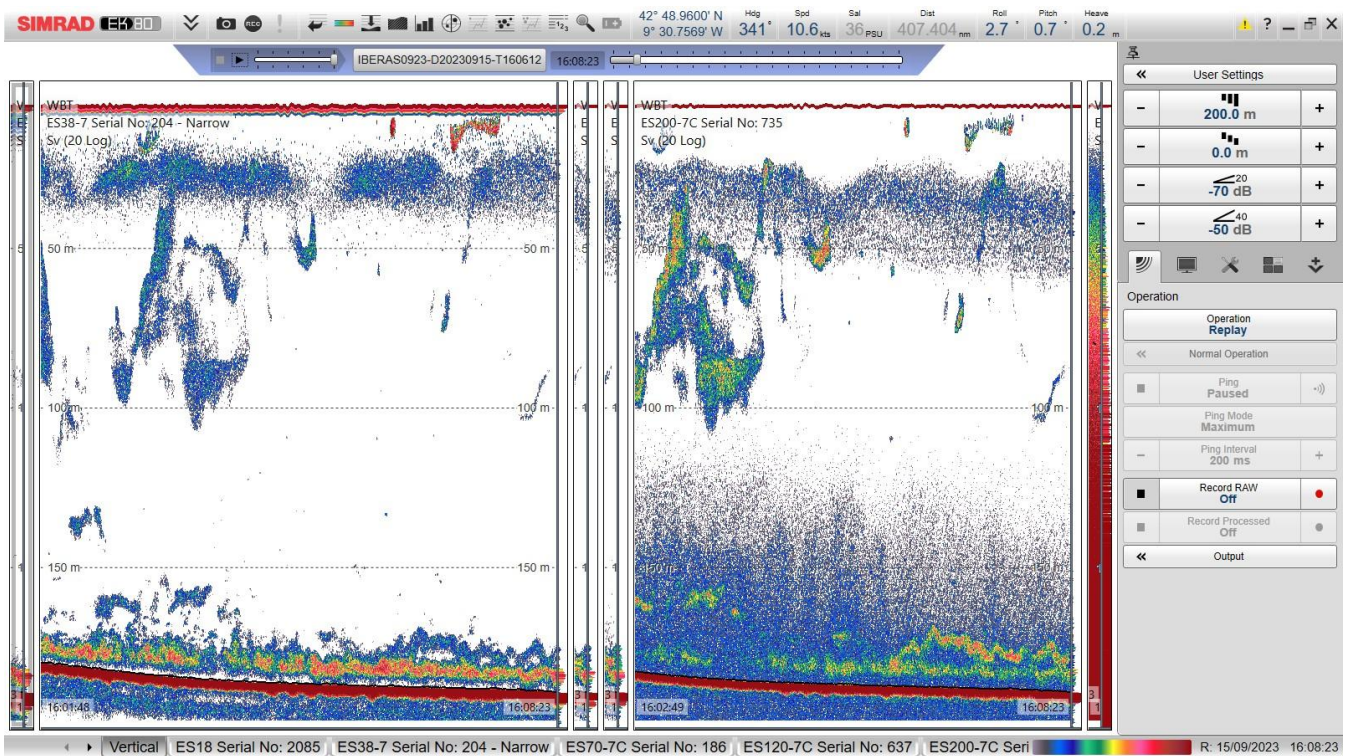


Figure 7 Echograms showing echotracés attributed to anchovy (near surface) and krill (mid water marks).

3 Krill echotrace identification

As previously stated, krill echotracess were found mixed with anchovy echotracess (Figure 8).

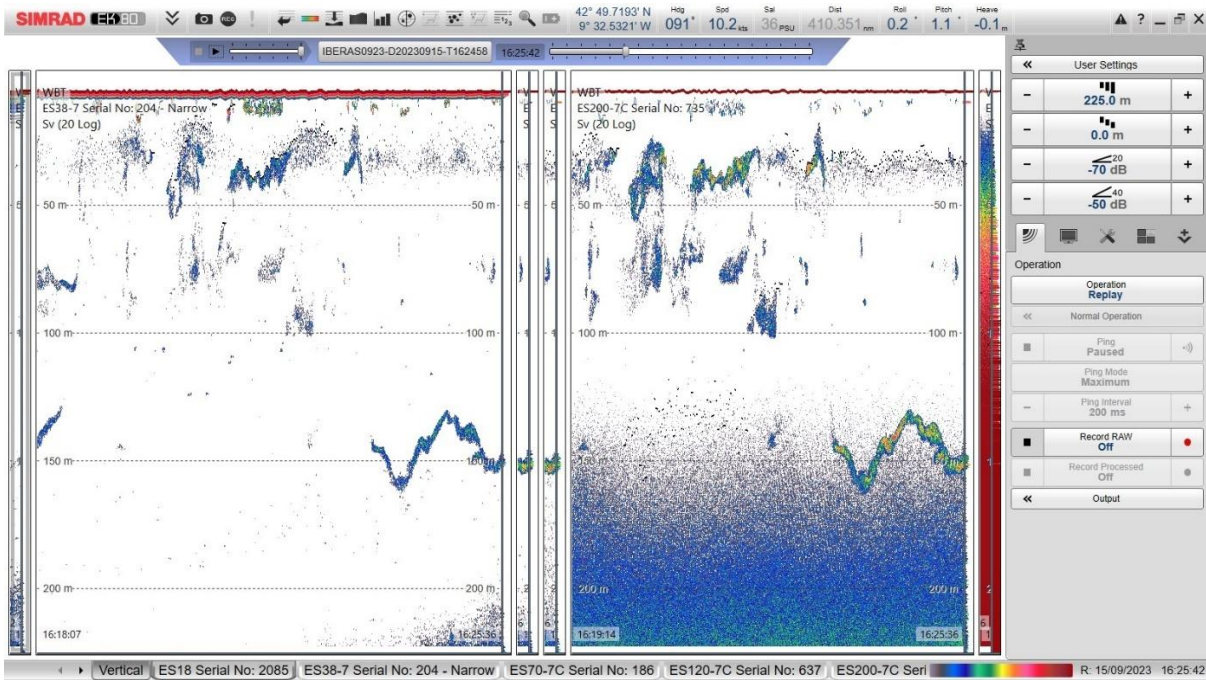


Figure 8 Echogram showing echotracess of krill mixed with anchovy (38kHz frequency).

4 Fishing station used for echotrace allocation

On survey tracks, from the total 810683 m² nmi⁻² backscattering energy, 436631 m² nmi⁻² (54% of the total) were directly allocated to the correspondent species (expert criteria) and the remnant 46% were allocated using the information from the fishing hauls. From the total sardine NASC, 343898 m² nmi⁻² were allocated to adult sardine (33 % of them directly allocated) and 54475 m² nmi⁻² to juvenile sardine (40% of them directly allocated). A total of 42485 m² nmi⁻² was allocated to adult anchovy (5% of the total NASC) and 160917 m² nmi⁻² to juvenile anchovy (20% of the total NASC). Chub mackerel accounted to 8% of the total NASC (65346 m² nmi⁻²) and 39 % of this backscatter energy was directly allocated. It should be noted that 124479 m² nmi⁻² (15% of the total NASC) was left unallocated, as was recorded in a potential multi-specific environment with no ground truthing fishing stations. Figure 9 shows the spatial distribution of the fishing stations and the proportion for each species estimated using the Nakken and Dommasnes method.

For allocation purposes, the area was split in different strata to account the *echotypes* and, within each echotype, the representative near fishing station was used. Strata defined for NASC allocation are areas in which the echotracess were similar and the species proportion found at the fishing station performed on each stratum were also similar.

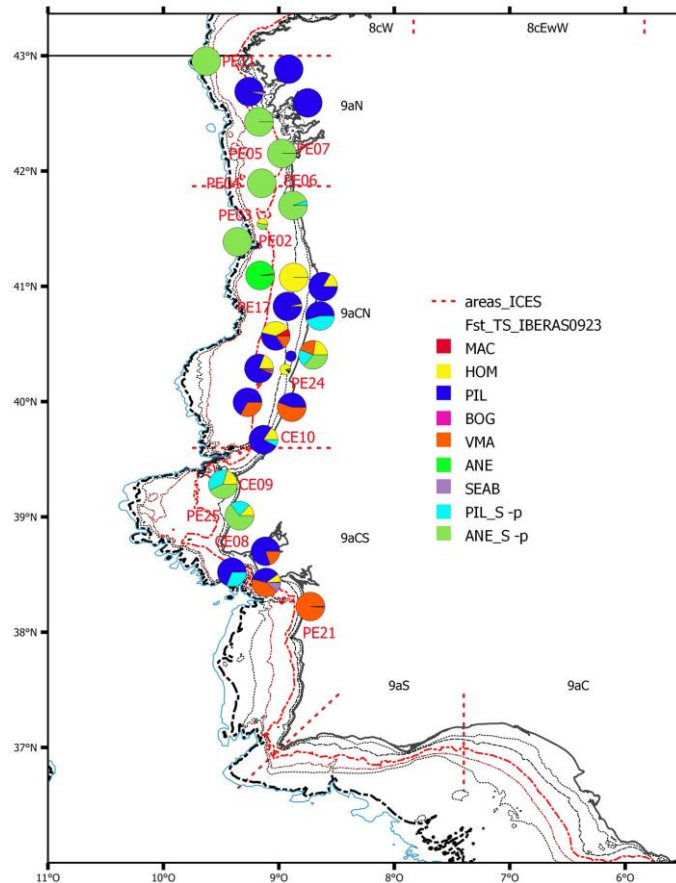


Figure 9 Pie charts showing the location of the fishing stations and the fish proportion in each station by the Nakken and Dommaness method. MAC-Atlantic mackerel; HOM-horse mackerel; PIL-sardine; BOG-bogue; VMA-chub mackerel; ANE-anchovy; SEAB-seabream species; s denotes “small”(juvenile) individuals.

Length weight-relationship

Length weight relationships (LWR) for the target species were calculated using individual weight (0.01 g) and length (mm). Grouped weights for length classes were also recorded but not used for the present estimates. The LWR were estimated by ICES subdivisions, but only the overall LWR was used for assessment purposes.

1 Sardine LWR

628 individuals of sardine were measured and considered to compute the length-weight relationship (LWR). A single LWR for the whole area was calculated with 0.0054 (confidence interval, *ci* 0.0036 - 0.0046) and 3.1516 (*ci* 3.2255 - 3.3110) as *a* and *b* parameters respectively (Fig. 10). No clear mode was observed in sardine length distribution.

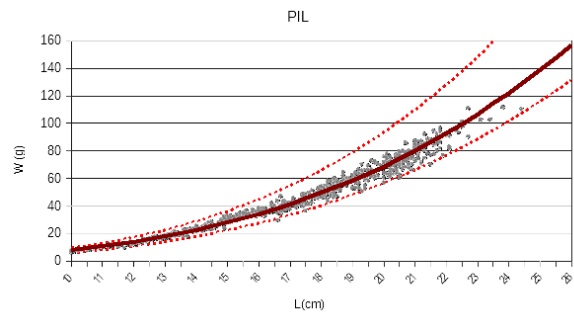
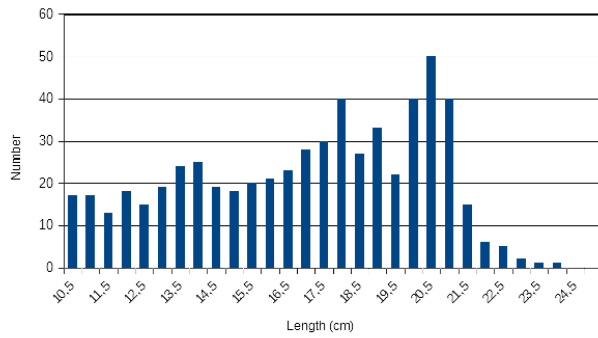


Figure 10 Left: sardine length distribution from those specimens to obtain length-weight relationship. Right: Length weight relationship for sardine by ICES subdivision. Grey dots are individual measurements; dotted red lines represent 95% confidence intervals.

2 Anchovy LWR

535 individuals of anchovy were measured and the calculated LWR parameters were $a = 0.0026$ (ci 0.0048 - 0.0075) and $b=3.3414$ (ci 2.9583 - 3.1205) (Fig. 11).

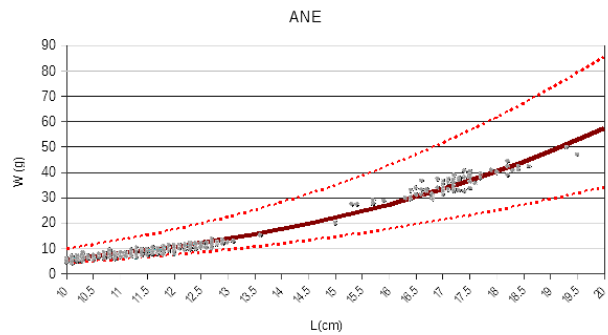
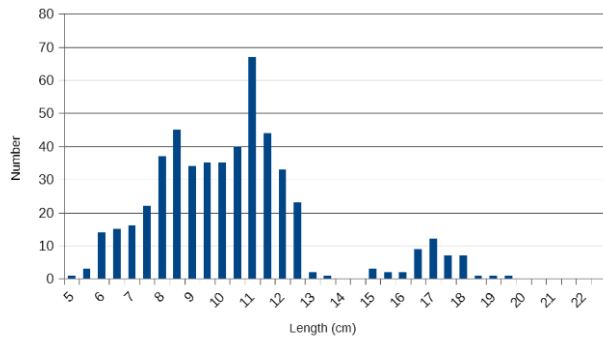


Figure 11 Left: anchovy length distribution from those specimens to obtain length-weight relationship. Right: Length weight relationship for anchovy by ICES sub-Division. Grey dots are individual measurements; dotted red lines represent 95% confidence intervals.

3 Chub mackerel LWR

244 Individuals of chub mackerel were measured to estimate the LWR. The LWR parameters for the whole area were 0.00155 (ci 0.0348 - 0.0643) and 3.532 (ci 3.0768 - 3.2747) as a and b parameters respectively (Fig. 12).

The length distribution was bimodal with one mode at 18 cm, and the other at 24 cm.

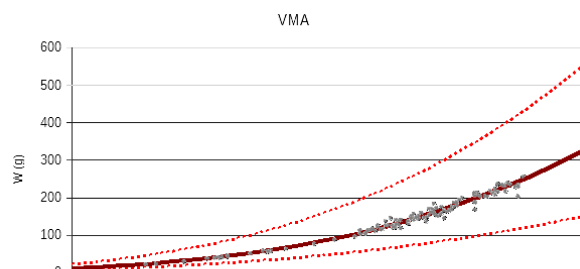
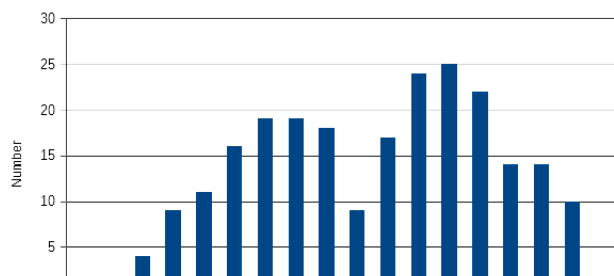


Figure 12 Left: chub mackerel length distribution from those specimens to obtain length-weight relationship. Right: Length weight relationship for chub mackerel by ICES subdivision. Grey dots are individual measurements; dotted red lines represent 95% confidence intervals.

4 Horse Mackerel LWR

331 individuals of horse mackerel were measured to estimate the LWR. LWR parameters for the whole area were 0.0061 (*ci* 0.0076 - 0.0096) and 3.1176 (*ci* 2.9533 - 3.0366) respectively. The length distribution showed some very small individuals (6 cm), and two modes: one at 11 cm and the other one at 14 cm (Fig. 13).

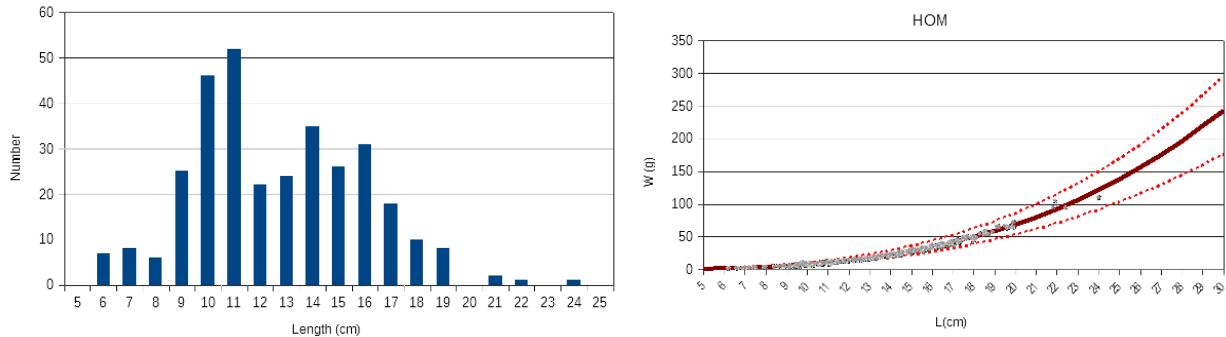


Figure 13 Left: horse mackerel length distribution from those specimens to obtain length-weight relationship. Right: Length weight relationship for horse mackerel by ICES subdivision. Grey dots are individual measurements; dotted red lines represent 95% confidence intervals.

5 Atlantic mackerel LWR

To obtain the LWR, 182 individuals of Atlantic mackerel were measured. A clear bimodal distribution was patent with one mode at 23 cm and the other at 31 cm (Fig. 14). LWR parameters were 0.0031 (*ci* 0.0035 - 0.0064) and 3.2879 (*ci* 3.0768 - 3.2747) (a and b respectively).

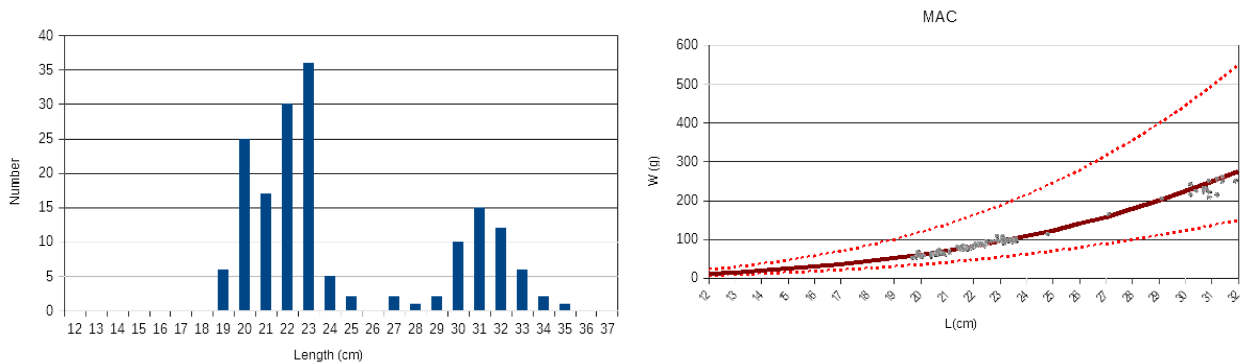


Figure 14 Left: mackerel length distribution from those specimens to obtain length-weight relationship. Right: Length weight relationship for mackerel by ICES subdivision. Grey dots are individual measurements; dotted red lines represent 95% confidence intervals.

Acoustic assessment

Figure 15 shows the center of gravity, using the total energy attributed to the main species and the distance from the origin as coordinates, located at 37°N, and depth. Major changes in relation to previous years were the concentration of the main species in the area 9aCN, and in quite low depth (vast majority inshore 50m depth; Fig. 15). One exception was the distribution of chub mackerel which was mainly found in 9aCS-Espichel N, although also in coastal waters.

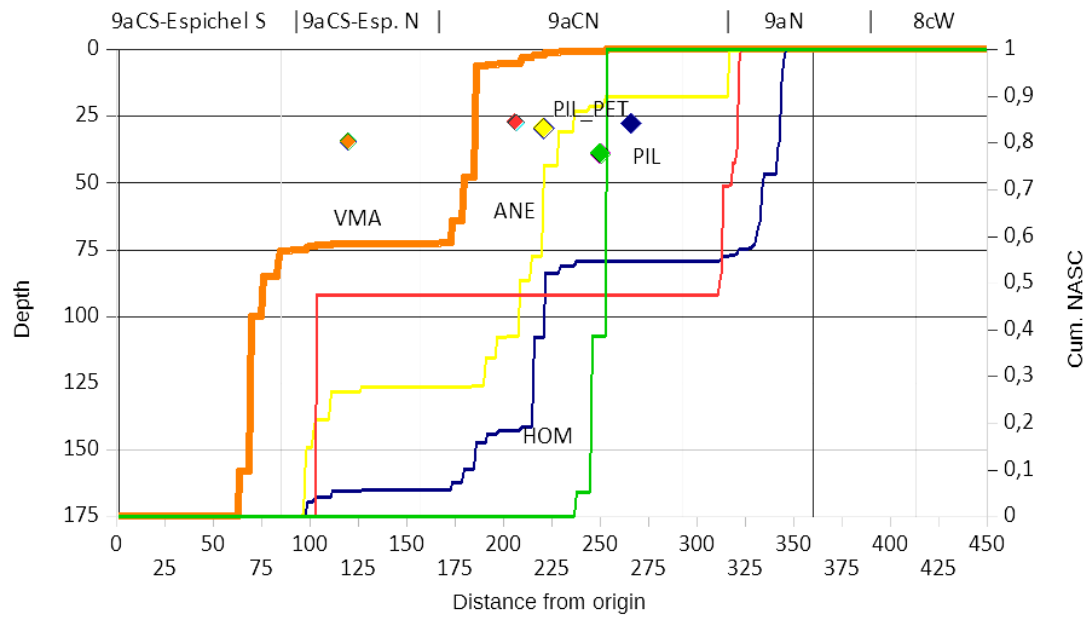


Figure 15 centre of gravity and cumulated NASC for the most important pelagic species (green-anchovy (ANE), blue-sardine (PIL), yellow-horse mackerel (HOM), red-Atlantic mackerel (MAC), orange-chub mackerel (VMA)).

1 Sardine assessment

Accounting the length distributions obtained at the fishing stations and the NASC spatial distribution, sardine was divided in three strata: 9aN, 9aCN, and 9aCS-Lisbon and in two size categories (adult length>15.0cm and juvenile, length≤15.0cm). For each strata fishing station were weighted using the sardine backscattering values attributed to each fishing station. In 9aCN, where the bulk of the hauls were performed, mean length ranged from 17.89 to 20.06 cm (Fig. 16).

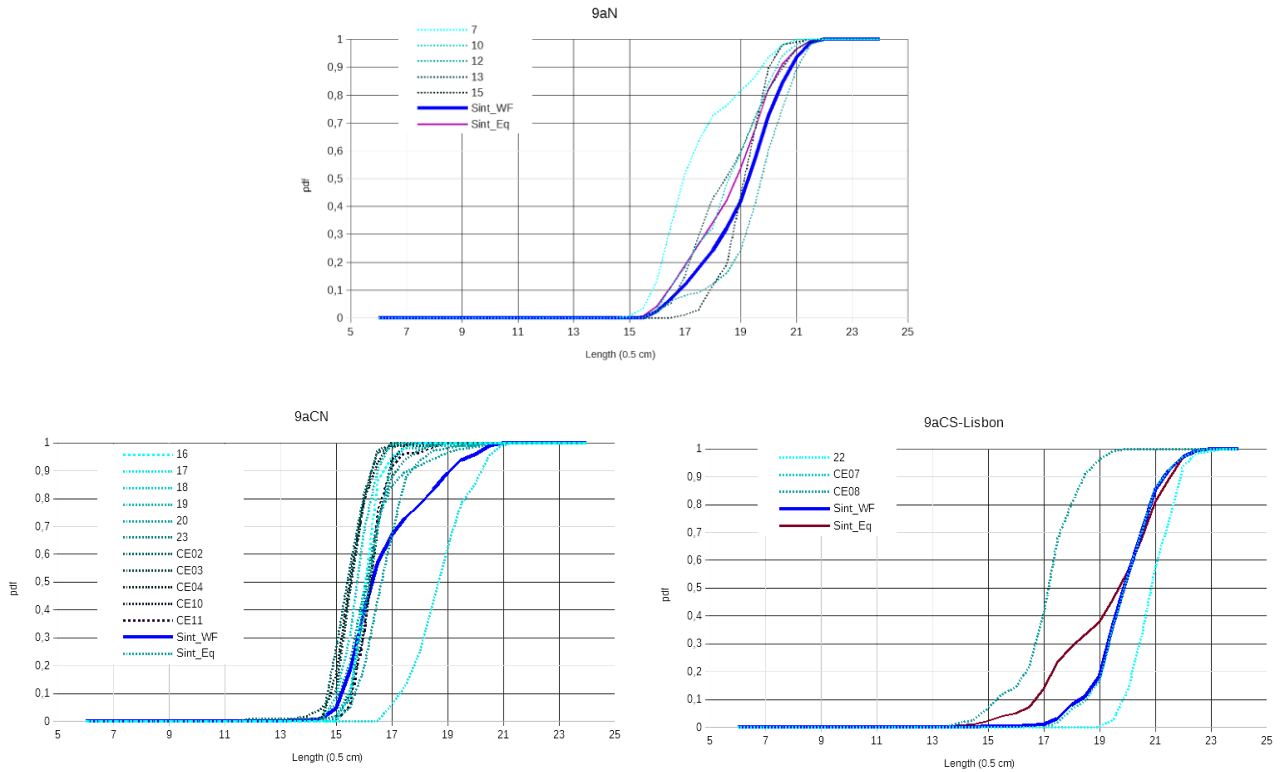


Figure 16 Probability density functions by length and ICES subdivision for adult sardine (length>15.0cm)

A total of 339674 tonnes, corresponding to 6896 million adult sardine, were estimated (length>15.0 cm; Table 6). The bulk of the estimation was found in ICES subdivision 9aCN with 233288 tonnes.

Table 6 Summary of the adult sardine assessment (length>15.0cm), by strata, number of positive nautical miles (No), mean NASC value (m² nmi⁻²), Surface (nmi²), fishing stations used for the assessment, abundance, biomass and density estimated.

SURVEY: IBERAS 0923 SARDINE (L>15 cm)								
ICES-Div	Region	No	Mean	Surface	Fishing st.	No (million fish)	Biomass (tonnes)	Density (Tn/nmi-2)
9aN	9aN	117	1363.63	278	PE07-PE10-PE12-PE13-PE15	1430	92586	333
	Total	117	1363.63	278		1430	92586	333
9aCN	Oc North	135	1276.99	858	PE16-PE17-PE18-PE19-PE20-PE23-CE02-CE03-CE04-CE10-CE11	5278	233288	272
	Total	135	1276.99	858		5278	233288	272
9aCS	Oc South_Lisboa	11	1087.36	50	PE22-CE07-CE08	188	13801	277
	Total	11	1087.36	50		188	13801	277
	Total Spain	117	1364	278		1430	92586	333
	Total Portugal	146	1263	907		5466	247088	272
	TOTAL	263	1308	1186		6896	339674	287

Length distribution of adult sardine was bimodal, with a main mode in the 16 cm size class (mainly located at 9aCN) and a secondary mode at the 19.5 cm (mainly distributed in 9aN and 9aCS). In the North (9aN), age 3 dominated, with 41.87% of the total biomass and 37.55% of the total abundance of adult sardine. Whereas 9aCN, where the bulk of adult sardine was located, was dominated by fish of age 1, which represented 71.85% of the biomass and 80.54% of the abundance in this subdivision (Fig. 17). The values found in 9aCN, 167×10^3 tonnes of fish age 1, corroborate the increasing trend observed since 2018 in this area ($2018-14 \times 10^3$ t; $2019-101 \times 10^3$ t; and $2020-136 \times 10^3$ t).

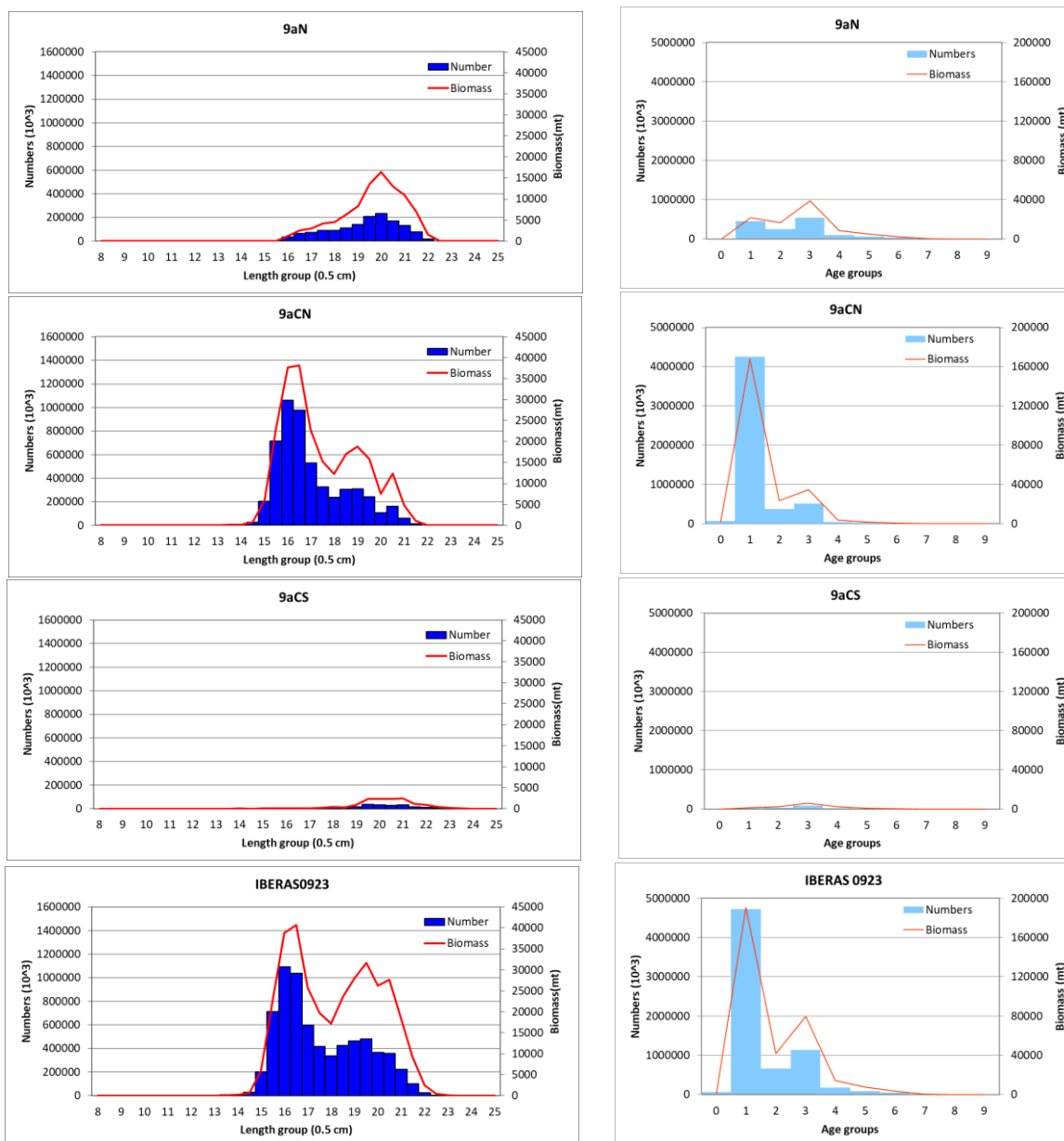


Figure 17 Adult sardine (length >15.0cm) biomass and abundance estimates by ICES subdivision and the total for the whole area. Left panels in length classes, right panels in age groups.

This year the adult population was highly concentrated in three hotspots: the North, southern part of 9aCN, and the mouth of Tagus River. Main distribution was located in 9aCN (Fig. 18).

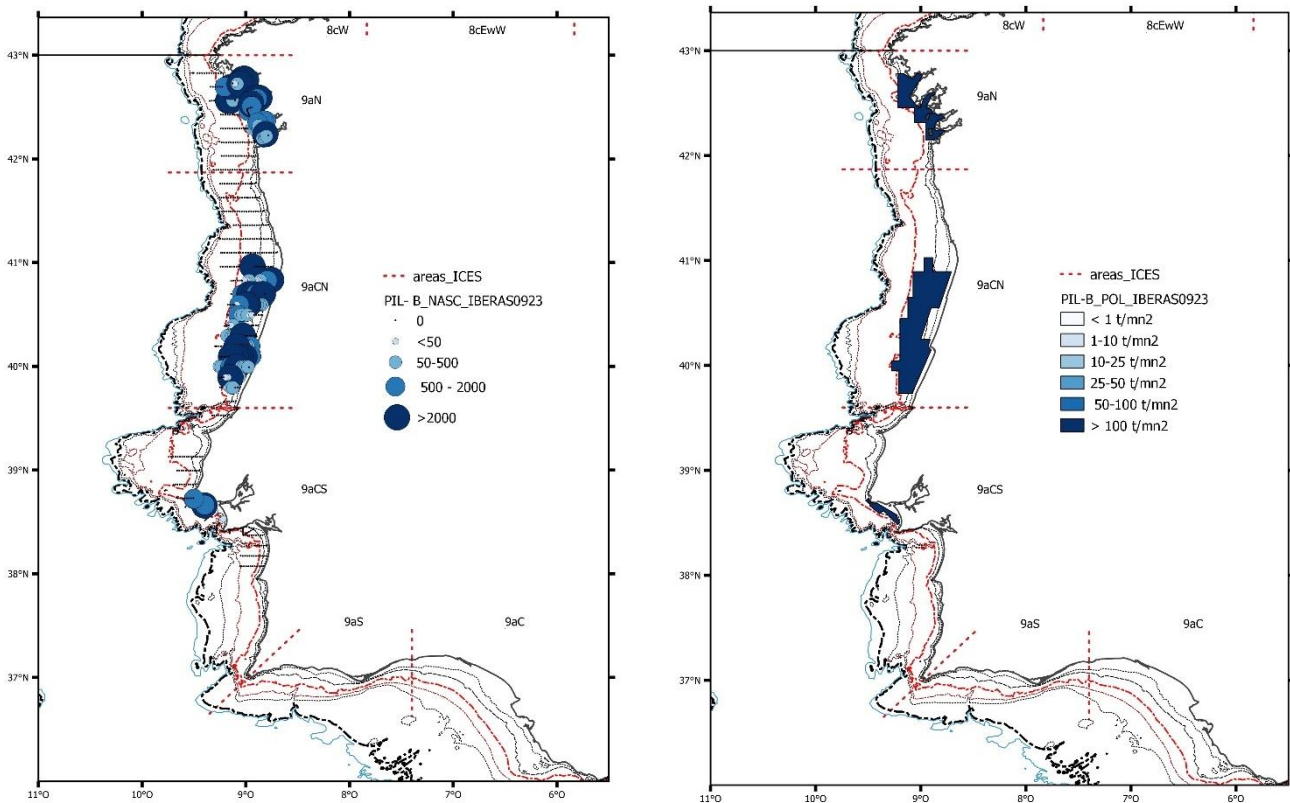


Figure 18 Adult sardine spatial distribution in IBERAS0923. Left: bubble plot which represent NASC values attributed to sardine (size proportional to abundance). Right: Sardine strata together with the relative density.

Table 7a to 7f shows the adult sardine (length>15.0cm) assessment by length group and age classes per ICES subdivision and for the whole survey. It should be noted that the survey was targets juveniles over its main expected distribution area and, therefore, limited information on adults is expected.

Table 7a Adult sardine (length > 15.0 cm) assessment by age in 9aN.

Length	AGE GROUPS										Total	No fish (thousands)	
	0	1	2	3	4	5	6	7	8	9			
8													
8.5													
9													
9.5													
10													
10.5													
11													
11.5													
12													
12.5													
13													
13.5													
14													
14.5													
15	0	1										0.94	32
15.5		5										5.22	162
16		1173										1172.85	32995
16.5		2490										2490.14	63671
17		3051										3051.37	71114
17.5		4181										4181.12	89052
18		3823	348	348								4518.14	88163
18.5		3585	1344	1344								6273.88	112427
19		2169	3524	2711								8402.99	138594
19.5			7769	5180	647							13596.62	206845
20		845	2534	10979	422	1267	422					16468.81	231556
20.5		275	550	10722	825	550						12921.76	168240
21			275	5508	3305	1102	826					11015.45	133052
21.5				1971	2464	1478	986					6899.59	77448
22					794	265	265	265				1587.01	16583
22.5													
23													
23.5													
24													
24.5													
25													
Biomass (mt)	0	21598	16344	38763	8457	4661	2499	265	0	0		92585.89	1429933
%	0.00	23.33	17.65	41.87	9.13	5.03	2.70	0.29					
Mean weight	27.62	45.75	61.81	69.11	79.30	77.63	80.71	92.35				61.69	
No Fish (thousands)	5	447084	253300	537007	102393	57636	29744	2764	0	0		1429933	
%	0.00	31.27	17.71	37.55	7.16	4.03	2.08	0.19					
Mean length	15.00	17.60	19.37	20.07	20.96	20.82	21.08	22.00				19.29	
s.d.	0.00	0.97	0.54	0.74	0.67	0.65	0.62					1.45	

Table 7b: Adult sardine assessment by age in 9aCN

Length	AGE GROUPS										Total	No fish (thousands)	
	0	1	2	3	4	5	6	7	8	9			
8													
8.5													
9													
9.5													
10													
10.5													
11													
11.5													
12	27											27.09	1857
12.5													
13													
13.5	134	6										140.24	6679
14	151	6										156.94	6679
14.5	333	370										703.06	26838
15	979	4896										5875.62	201923
15.5		22992										22992.27	713768
16		37636										37635.92	1058770
16.5		38158										38157.94	975673
17		22688										22688.00	528757
17.5		15264										15264.45	325111
18		10376	943	943								12262.86	239287
18.5		9741	3653	3653								17047.06	305480
19		4843	7870	6054								18766.50	309524
19.5			9042	6028	754							15823.92	240729
20		383	1150	4982	192	575	192					7473.18	105075
20.5		264	528	10289	791	528						12399.85	161445
21			121	2416	1450	483	362					4832.91	58375
21.5				297	371	223	149					1040.09	11675
22													
22.5													
23													
23.5													
24													
24.5													
25													
Biomass (mt)	1624	167625	23306	34663	3558	1809	703	0	0			233287.91	5277645
%	0.70	71.85	9.99	14.86	1.53	0.78	0.30						
Mean weight	26.44	39.02	61.88	67.31	76.83	77.50	80.21					42.36	
No Fish (thousands)	61011	4250779	375721	511958	46145	23292	8740	0	0			5277645	
%	1.16	80.54	7.12	9.70	0.87	0.44	0.17						
Mean length	14.79	16.74	19.38	19.90	20.75	20.81	21.04					17.27	
s.d.	0.68	0.93	0.52	0.83	0.67	0.50	0.56					1.50	

Table 7c: Adult sardine assessment by age in 9aCS

Length	AGE GROUPS										Total	No fish (thousands)	
	0	1	2	3	4	5	6	7	8	9			
8													
8.5													
9													
9.5													
10													
10.5													
11													
11.5													
12													
12.5													
13													
13.5													
14	2	0										1.83	78
14.5	0	1										1.02	39
15	1	5										5.67	195
15.5		8										7.53	234
16		4										4.16	117
16.5		14										13.72	351
17		38										38.46	896
17.5		187										186.80	3979
18		381	35	35								449.88	8779
18.5		190	71	71								333.12	5969
19		217	353	272								842.19	13891
19.5			1293	862	108							2262.26	34416
20		116	349	1514	58	175	58					2270.31	31921
20.5		48	97	1885	145	97						2272.14	29583
21			62	1236	742	247	185					2471.98	29858
21.5				333	416	250	166					1165.00	13077
22					435	145	145	145				870.70	9098
22.5					334	111						444.75	4333
23					51	51				51		154.44	1405
23.5					1	1	1			1		4.62	39
24													
24.5													
25													
Biomass (mt)	3	1209	2260	6207	2290	1077	556	145	53	0	13800.58	188257	
%	0.02	8.76	16.37	44.98	16.59	7.80	4.03	1.05	0.38				
Mean weight	23.93	51.14	63.04	70.79	83.70	82.08	82.87	92.35	106.39		69.96		
No Fish (thousands)	126	22453	34362	84040	26250	12580	6452	1516	478	0	188257		
%	0.07	11.93	18.25	44.64	13.94	6.68	3.43	0.81	0.25				
Mean length	14.33	18.24	19.49	20.22	21.32	21.19	21.26	22.00	23.01		20.12		
s.d.	0.43	0.94	0.49	0.68	0.81	0.84	0.61		0.07		1.18		

Table 7d: Adult sardine assessment by age in Spanish area (9aN)

Length	AGE GROUPS										Total	No fish (thousands)	
	0	1	2	3	4	5	6	7	8	9			
8													
8.5													
9													
9.5													
10													
10.5													
11													
11.5													
12													
12.5													
13													
13.5													
14													
14.5													
15	0	1										0.94	32
15.5		5										5.22	162
16		1173										1172.85	32995
16.5		2490										2490.14	63671
17		3051										3051.37	71114
17.5		4181										4181.12	89052
18		3823	348	348								4518.14	88163
18.5		3585	1344	1344								6273.88	112427
19		2169	3524	2711								8402.99	138594
19.5			7769	5180	647							13596.62	206845
20		845	2534	10979	422	1267	422					16468.81	231556
20.5		275	550	10722	825	550						12921.76	168240
21			275	5508	3305	1102	826					11015.45	133052
21.5				1971	2464	1478	986					6899.59	77448
22					794	265	265	265				1587.01	16583
22.5													
23													
23.5													
24													
24.5													
25													
Biomass (mt)	0	21598	16344	38763	8457	4661	2499	265	0	0		92585.89	1429933
%	0.00	23.33	17.65	41.87	9.13	5.03	2.70	0.29					
Mean weight	27.62	45.75	61.81	69.11	79.30	77.63	80.71	92.35				61.69	
No Fish (thousands)	5	447084	253300	537007	102393	57636	29744	2764	0	0		1429933	
%	0.00	31.27	17.71	37.55	7.16	4.03	2.08	0.19					
Mean length	15.00	17.60	19.37	20.07	20.96	20.82	21.08	22.00				19.29	
s.d.	0.00	0.97	0.54	0.74	0.67	0.65	0.62					1.45	

Table 7e: Adult sardine assessment by age in Portuguese area (9aCN+9aCS)

Length	AGE GROUPS										Total	No fish (thousands)	
	0	1	2	3	4	5	6	7	8	9			
8												0	
8.5												0	
9												0	
9.5												0	
10												0	
10.5												0	
11												0	
11.5												0	
12	27											27	1857
12.5												0	
13												0	
13.5	134	6										140	6679
14	152	6										159	6757
14.5	334	371										704	26877
15	980	4901										5881	202118
15.5		23000										23000	714002
16		37640										37640	1058887
16.5		38172										38172	976024
17		22726										22726	529653
17.5		15451										15451	329089
18		10757	978	978								12713	248066
18.5		9932	3724	3724								17380	311449
19		5060	8223	6325								19609	323415
19.5			10335	6890	861							18086	275144
20		500	1499	6496	250	749	250					9743	136996
20.5		312	624	12175	937	624						14672	191028
21			183	3652	2191	730	548					7305	88233
21.5				630	788	473	315					2205	24752
22					435	145	145	145				871	9098
22.5					334	111						445	4333
23					51	51				51		154	1405
23.5					1	1	1			1		5	39
24												0	
24.5												0	
25												0	
Biomass (mt)	1627	168834	25566	40870	5848	2886	1259	145	53	0		247088.48	5465902
%	0.66	68.33	10.35	16.54	2.37	1.17	0.51	0.06	0.02				
Mean weight	25.05	37.28	59.70	65.52	77.39	77.17	79.60	92.35	106.39			33.90	
No Fish (thousands)	61136	4273232	410083	595998	72395	35872	15192	1516	478	0		5465902	
%	1.12	78.18	7.50	10.90	1.32	0.66	0.28	0.03	0.01				
Mean length	14.54	16.50	19.16	19.73	20.80	20.78	20.99	22.00	23.01			17.13	
s.d.	0.68	0.94	0.53	0.83	0.82	0.71	0.63	0	0			1.60	

Table 7f: Adult sardine assessment by age in whole area (9aN+9aCN+9aCS)

Length	AGE GROUPS										Total	No fish (thousands)	
	0	1	2	3	4	5	6	7	8	9			
8													
8.5													
9													
9.5													
10													
10.5													
11													
11.5													
12	27											27.09	1857
12.5													
13													
13.5	134	6										140.24	6679
14	152	6										158.78	6757
14.5	334	371										704.08	26877
15	980	4902										5882.24	202150
15.5		23005										23005.02	714164
16		38813										38812.93	1091882
16.5		40662										40661.80	1039695
17		25778										25777.83	600767
17.5		19632										19632.37	418141
18		14580	1325	1325								17230.88	336229
18.5		13517	5069	5069								23654.06	423876
19		7229	11747	9036								28011.68	462009
19.5			18104	12070	1509							31682.81	481989
20		1344	4033	17475	672	2016	672					26212.30	368552
20.5		587	1174	22897	1761	1174						27593.74	359268
21			458	9160	5496	1832	1374					18320.35	221285
21.5				2601	3252	1951	1301					9104.68	102200
22					1229	410	410	410				2457.71	25681
22.5					334	111						444.75	4333
23					51	51				51		154.44	1405
23.5					1	1	1			1		4.62	39
24													
24.5													
25													
Biomass (mt)	1627	190432	41910	79633	14305	7547	3758	410	53	0		339674	6895836
%	0.48	56.06	12.34	23.44	4.21	2.22	1.11	0.12	0.02				
Mean weight	26.61	40.34	63.18	70.28	81.84	80.71	83.62	95.70	110.08			49.26	
No Fish (thousands)	61142	4720316	663383	1133005	174788	93508	44936	4280	478	0		6895836	
%	0.89	68.45	9.62	16.43	2.53	1.36	0.65	0.06	0.01				
Mean length	14.54	16.60	19.24	19.89	20.89	20.81	21.05	22.00	23.01			17.58	
s.d.	0.68	0.99	0.54	0.81	0.74	0.68	0.00	0.00	0.00			1.80	

Juvenile sardine (length $\leq 15.0\text{cm}$) was found in two locations: 9aN and 9aCS. The bulk of the juveniles were found in Portuguese waters (9aCS) (23991 tonnes and 2576 million of fish, Table 8 and Fig. 21). The predominant age of the juveniles was 0 (Fig. 20 and Table a-b) and it was mainly located in Portuguese waters (9aCS) inshore the shelf (Fig. 21).

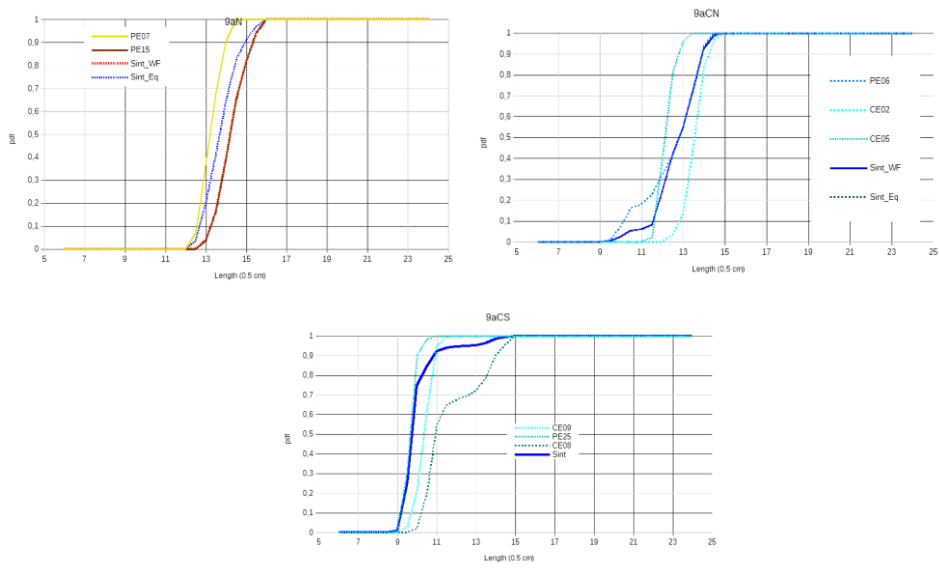


Figure 19 Probability density functions by length and ICES subdivision for juvenile sardine (length $\leq 15.0\text{cm}$)

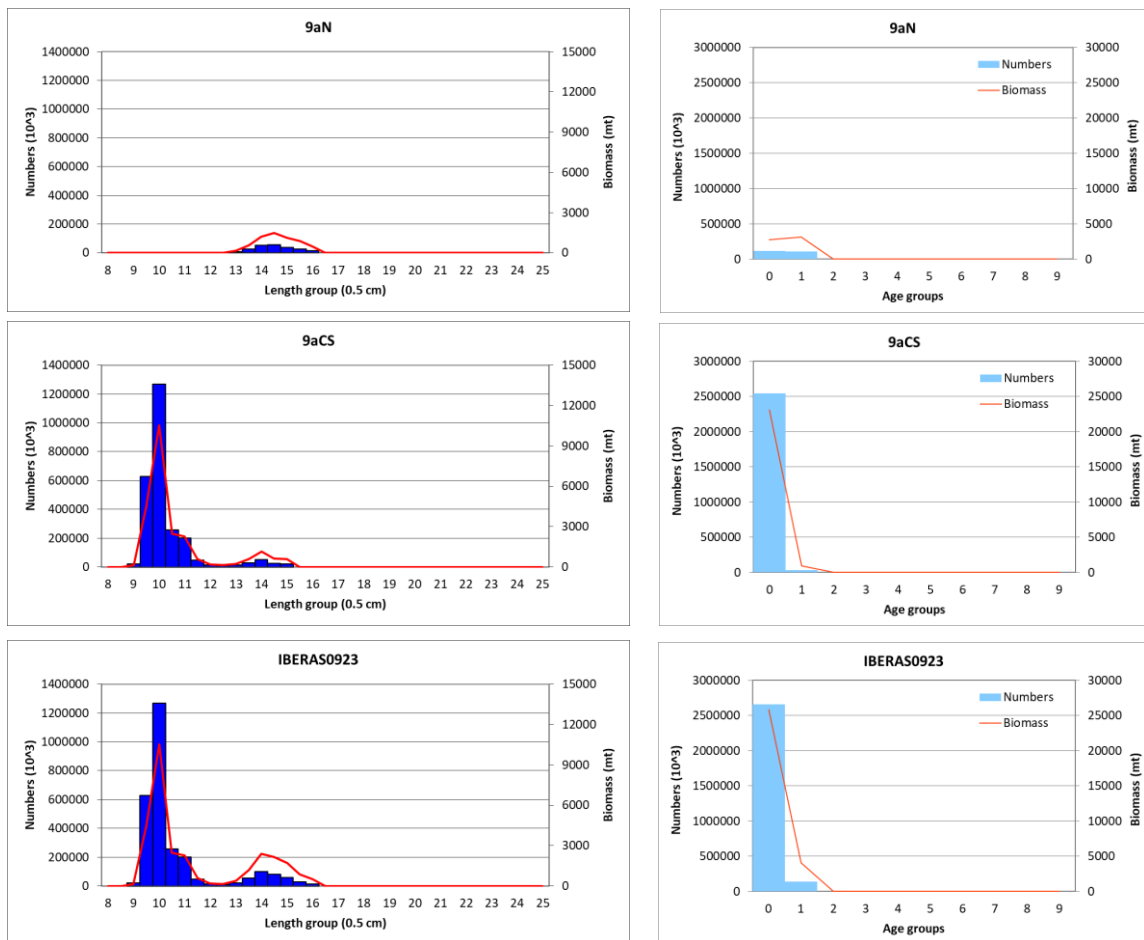


Figure 20 Juvenile sardine (length $\leq 15.0\text{cm}$) biomass and abundance estimates by ICES subdivision and the total for the whole area. Left panels in length classes, right panels in age groups.

Table 8 Summary of the juvenile sardine assessment ($length \leq 15.0cm$), by strata, number of positive nautical miles (No), mean NASC value ($m^2 nmi^{-2}$), Surface (nmi²), fishing station used for the estimation and biomass estimated.

SURVEY: IBERAS 0923 SARDINE (l<16 cm)								
ICES-Div	Region	No	Mean	Surface	Fishing st.	No (million fish)	Biomass (tonnes)	Density (Tn/nmi-2)
9aN	9aN	51	483.81	70	PE07-PE15	224	5921	85
	Total	51	483.81	70		224	5921	85
9aCN	Oc North	0	0.00	0	PE06-CE02-CE05	0	0	0
	Total	0	0.00	0		0	0	0
9aCS	Oc South	20	1489.92	133	PE25-CE08-CE09	2576	23991	180
	Total	20	1489.92	133		2576	23991	180
	Total Spain	51	484	70		224	5921	85
	Total Portugal	20	1490	133		2576	23991	180
	TOTAL	71	767	203		2800	29913	148

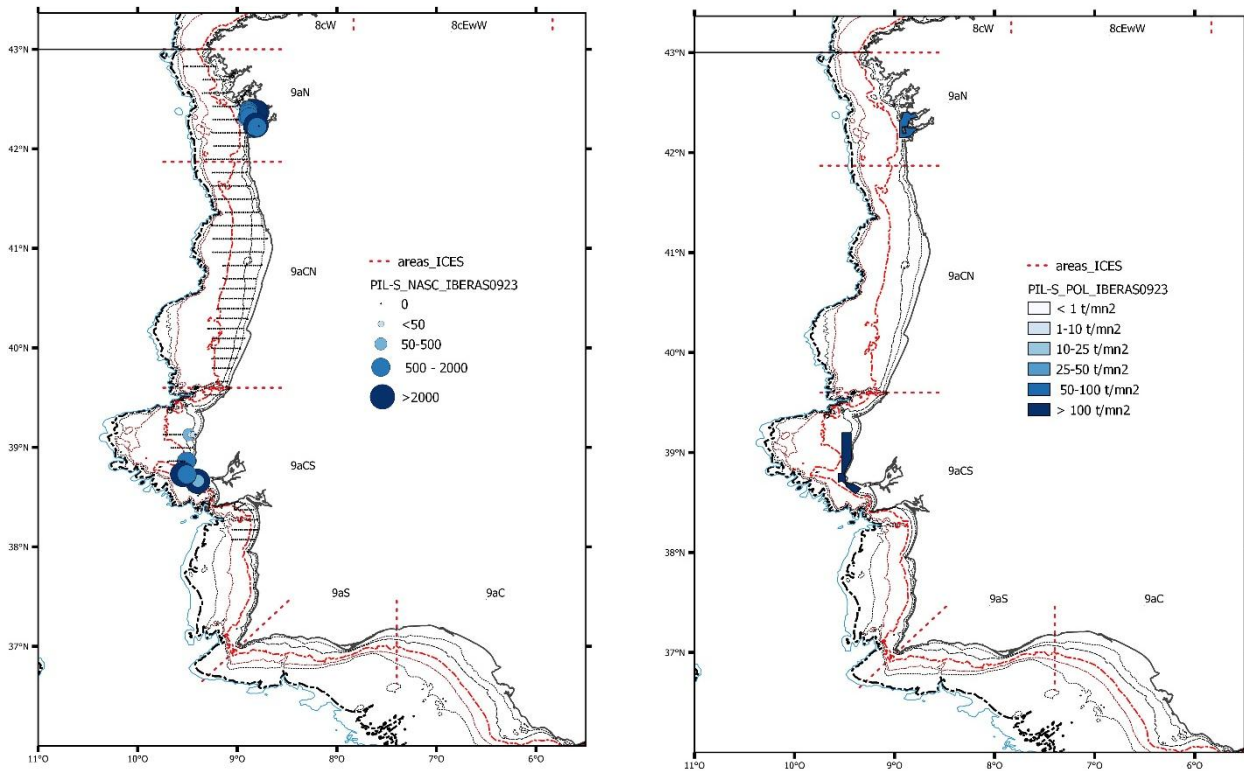


Figure 21 Juvenile sardine spatial distribution in IBERAS0923. Left: bubble plot which represent NASC values attributed to sardine (size propotional to abundance). Right: Sardine strata together with the relative density.

Table 9a Juvenile sardine (length ≤ 15.0cm) assessment by age in 9aN.

Length	AGE GROUPS										Total	No fish (thousands)
	0	1	2	3	4	5	6	7	8	9		
8												
8.5												
9	126										125.91	20916
9.5	4464										4463.76	628178
10	10548										10548.38	1267993
10.5	2469										2469.26	255451
11	2251										2251.04	201790
11.5	591										590.76	46175
12	183										182.51	12509
12.5	135										135.48	8186
13	229										229.42	12279
13.5	574	27									601.59	28652
14	1108	46									1154.18	49118
14.5	305	339									643.35	24559
15	99	496									595.52	20466
15.5												
16												
16.5												
17												
17.5												
18												
18.5												
19												
19.5												
20												
20.5												
21												
21.5												
22												
22.5												
23												
23.5												
24												
24.5												
25												
Biomass (mt)	23083	908	0	0	0	0	0	0	0	0	23991.16	2576272
%	96.21	3.79										
Mean weight	8.18	25.85									8.41	
No Fish (thousands)	2543024	33248	0	0	0	0	0	0	0	0	2576272	
%	98.71	1.29										
Mean length	10.20	14.69									10.25	
s.d.	0.90	0.38									1.03	

Table 9b Juvenile sardine (length ≤ 15.0cm) assessment by age in 9aCS.

Length	AGE GROUPS									Total	No fish (thousands)	
	0	1	2	3	4	5	6	7	8			9
8												
8.5												
9	126									125.91	20916	
9.5	4464									4463.76	628178	
10	10548									10548.38	1267993	
10.5	2469									2469.26	255451	
11	2251									2251.04	201790	
11.5	591									590.76	46175	
12	183									182.51	12509	
12.5	135									135.48	8186	
13	229									229.42	12279	
13.5	574	27								601.59	28652	
14	1108	46								1154.18	49118	
14.5	305	339								643.35	24559	
15	99	496								595.52	20466	
15.5												
16												
16.5												
17												
17.5												
18												
18.5												
19												
19.5												
20												
20.5												
21												
21.5												
22												
22.5												
23												
23.5												
24												
24.5												
25												
Biomass (mt)	23083	908	0	0	0					23991.16	2576272	
%	96.21	3.79										
Mean weight	8.18	25.85								8.41		
No Fish (thousands)	2543024	33248	0	0	0					2576272		
%	98.71	1.29										
Mean length	10.20	14.69								10.25		
s.d.	0.90	0.38								1.03		

Sardine stock indicators

The sardine stock indicators are a series of metrics comparing results from years 2018 to 2023 (whole IBERAS data series). However, for result comparison, it should be considered a two-month gap between years 2018 and 2019/2020.

Spatial distribution

The centre of gravity derived from the NASC values was stable centered in 9aCN around Figueira da Foz (40 to 60% of the total cumulated energy) in the whole data series, and seems to be independent of the total biomass (Fig. 22). There were no important changes in fish relative distribution, although the total echointegrated energy (and therefore abundance estimates) were different among years (maximum historical recorded in year 2020; Figure 22). Moreover, 2021 stands out to be the year where deeper schools of sardine were found.

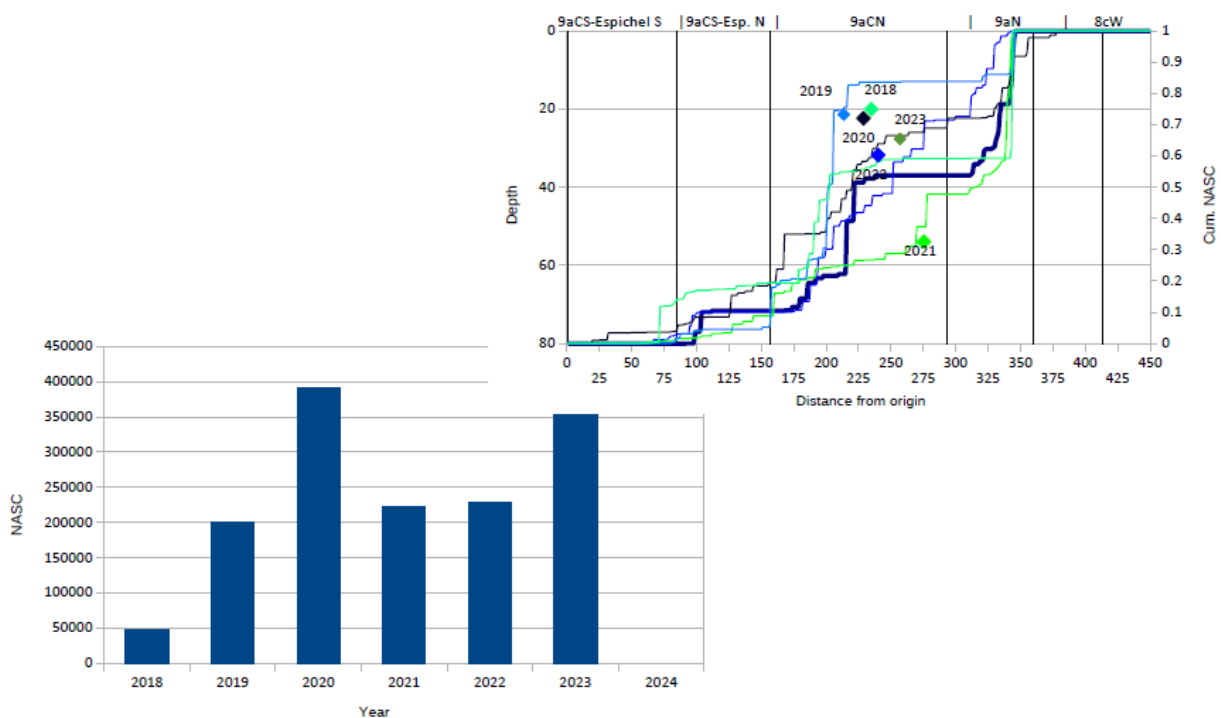


Figure 22 Relative cumulative NASC values of sardine along the coast (from south to north) and center of gravity (above right) and the total backscattering energy attributed to sardine (below right). Numbers in the cumulative plot correspond to the ICES subdivisions.

Recruitment index (2018-2023)

The recruitment index for this year was very low (age 0; $27 \cdot 10^3$ million tonnes, $2.7 \cdot 10^9$ fish). In IBERAS0923 we were able to follow the cohort from last year (age 1), which was the highest in the time series ($158.5 \cdot 10^3$ mt, $8 \cdot 10^9$ fish; Fig. 23).

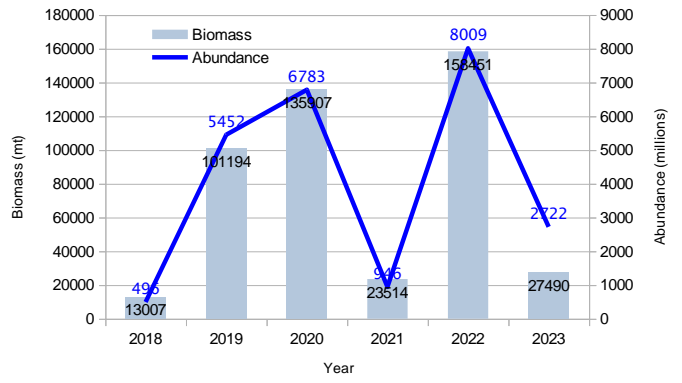
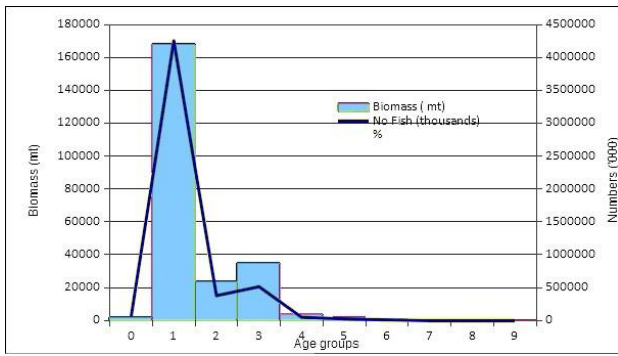


Figure 23 Right: total biomass by age estimated in the survey IBERAS0923. Left: Sardine 0-group derived from IBERAS0923, both in biomass and abundance. In blue numbers referring to abundance (in millions), in black biomass (in million of tonnes).

2 Anchovy assessment

In 2023, anchovy assessment was divided between adult anchovy (length>12.0cm) and juvenile anchovy (length≤12.0cm). Juveniles were mainly concentrated in 9aN, especially inside Rias Baixas, whereas adults were found in 9aCN, near Aveiro (Fig. 26). The estimated biomass for adult anchovy in 2023 was of 56414 tonnes and 1696 million of fish (Table 10).

The predominant age of adult anchovy was 2 and 3, confirming good recruitments from last years (Fig. 24).

Table 10 Summary of the adult anchovy (length>12.0cm) assessment, with the name of the strata, number of positive nmi, mean NASC value (m² nmi⁻²), Surface (nmi²), fishing station used for the estimation and number and biomass estimated.

SURVEY: IBERAS 0923 ANCHOVY-B								
Zone	Area	No	Mean	Area	Fishing st.	No (million fish)	Biomass (tonnes)	Density (Tn/nmi-2)
9aN	9aN	0	0	0	na	0	0	0
	Total	0	0	0		0	0	0
9aCN	9aCN_N	41	1036.20	326	PE01	1696	56414	173
	9aCN_S	12	0.07	74	PE01-PE23-CE12	0	1	0
	Total	53	802	400		1696	56414	141
9aCS	9aCS	0	0	0	na	0	0	0
	Total	0	0	0		0	0	0
	Portugal	53	802	400		1696	56414	141
	Spain	0	0	0		0	0	0
	TOTAL	53	802	400		1696	56414	141

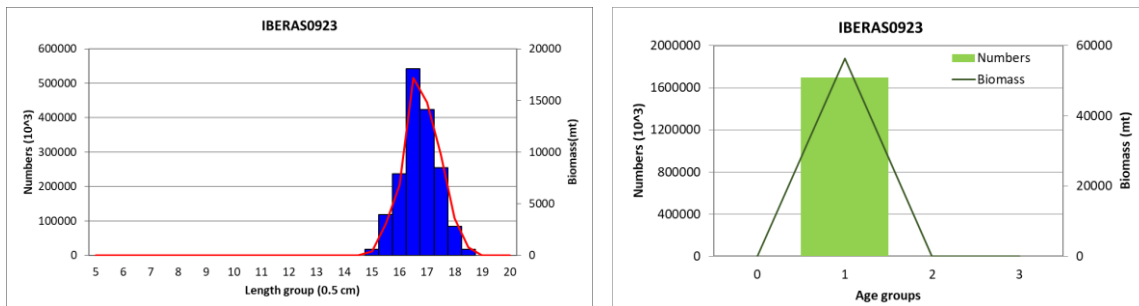


Figure 24 Adult anchovy (length>12.0cm) biomass and abundance estimates for the whole area. Left panels in length classes, right panels in age groups.

Juvenile anchovy was majorly present in Spanish waters (9aN) with 16090 million fish and 65270 tonnes (Table 11). For anchovy juveniles, predominant age was 0 with 88429 metric tonnes and 2.19*10⁹ fish (Fig. 25).

Table 11 Summary of the juvenile anchovy ($length \leq 12.0cm$) assessment, with the name of the strata, number of positive nmi, mean NASC value ($m^2 nmi^{-2}$), Surface (nmi^2), fishing station used for the estimation and number and biomass estimated.

SURVEY: IBERAS 0923 ANCHOVY-S								
Zone	Area	No	Mean	Area	Fishing st.	No (million fish)	Biomass (tonnes)	Density (Tn/nmi-2)
9aN	9aN	125	992.53	892	PE04-PE05-PE06-PE08-PE09-PE11	16090	65270	73
	Total	125	993	892		16090	65270	73
9aCN	9aCN_N	20	1342.75	206	PE02	5334	19211	93
	9aCN_S	24	151.38	146	PE18-PE24-CE05	258	2136	15
	Total	44	693	352		5592	21348	61
9aCS	9aCS	17	374.28	110	PE25-CE09	474	3948	36
	Total	17	374	110		474	3948	36
Portugal		61	604	462		6066	25295	55
Spain		125	993	892		16090	65270	73
TOTAL		186	865	1354		22156	90566	67

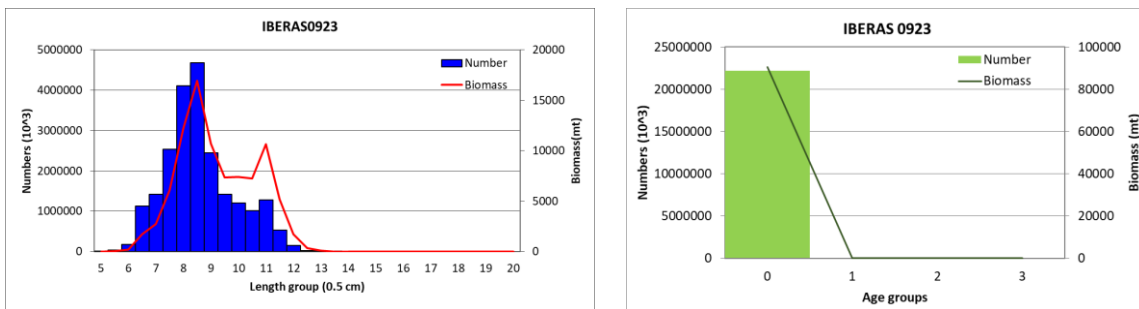


Figure 25 Juvenile anchovy ($length \leq 12.0cm$) biomass and abundance estimates for the whole area. Left panels in length classes, right panels in age groups.

Table 12 Anchovy (adults and juveniles) assessment by age for the whole area.

Length	AGE GROUPS				Total	No fish (thousands)
	0	1	2	3		
5	6				5.84	8899
5.5	36				35.62	40047
6	209				208.91	177746
6.5	1709				1709.37	1124574
7	2742				2742.06	1420799
7.5	6100				6099.72	2529213
8	12217				12217.39	4110811
8.5	16911				16910.72	4674387
9	10672				10671.63	2449926
9.5	7362				7362.32	1417564
10	7386				7386.03	1203278
10.5	7241				7241.18	1006118
11	10661				10661.00	1272521
11.5	5140				5140.32	530583
12	1736				1735.80	155879
12.5	344				344.25	27046
13	82				82.21	5680
14						
14.5						
15		393			392.74	16963
15.5		3062			3062.07	118743
16		6798			6798.25	237487
16.5		17195			17194.79	542826
17		14821			14820.77	424083
17.5		9783			9783.32	254450
18		3578			3578.31	84817
18.5		783			783.30	16963
19						
19.5						
20						
Biomass (mt)	90566	56414	0	0	146979.32	23852100
%	61.62	38.38				
Mean weight	3.77	33.06			5.85	
No Fish (thousands)	22155768	1696332	0	0	23852100	
%	92.89	7.11				
Mean length	8.86	16.97			9.43	
s.d.	1.28	0.67			2.43	

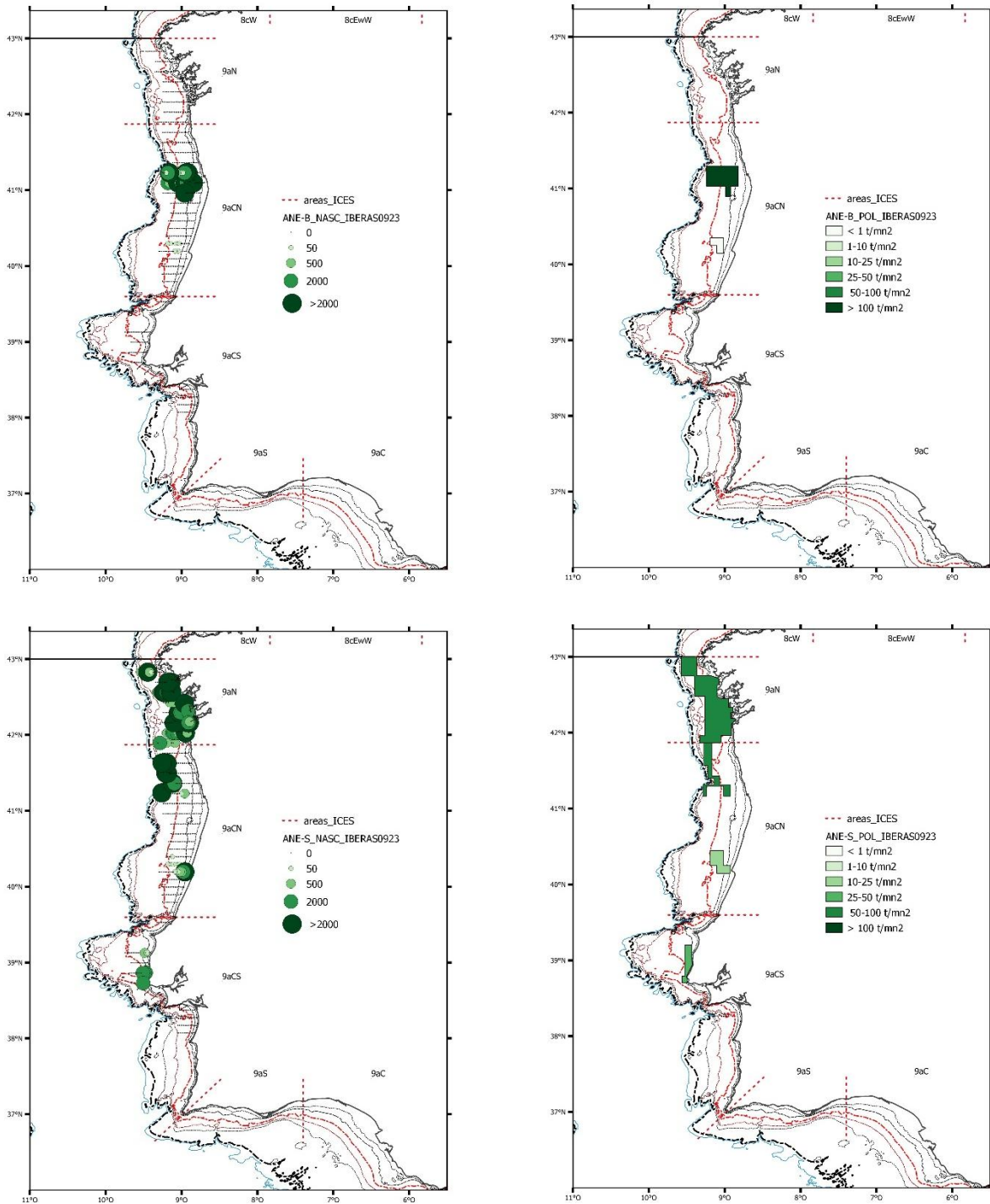


Figure 26 Anchovy spatial distribution in IBERAS 0923. Top: adult anchovy (length > 12.0 cm), Bottom: juvenile anchovy (length ≤ 12.0 cm). Maps on the left: bubble plots which represent the NASC values attributed to anchovy (size proportional to abundance). Maps on the right: strata used together with the relative density.

3 Chub mackerel assessment

This year chub mackerel was located in 9aCN, with some anecdotal fish found also in the north-inside Rias Baixas and some chub mackerel also found in the south of Lisbon (Fig. 27). The chub mackerel assessment was $43 \cdot 10^3$ tonnes, corresponding to $430 \cdot 10^6$ fish (Table 13).

Table 13 Summary of the chub mackerel assessment, with the name of the strata, number of positive nmi, mean NASC value ($m^2 nmi^{-2}$), surface(nmi^2), fishing station used for the estimation and number and biomass estimated.

SURVEY: IBERAS 0923 CHUB MACKEREL									
Zone	Area	No	Mean	Area	Fishing st.	No (million fish)	Biomass (tonnes)	Density (Tn/nmi-2)	
9aN	9aN	51	0.62	70	PE05-PE07	0	6	0	
	Total	51	1	70		0	6	0	
9aCN	9aCN_N	176	156.58	1181	PE01-PE16-PE17-PE18-PE23-PE24-CE01-CE05-CE06-CE12	237	19645	17	
	Total	176	157	1181		237	19645	17	
9aCS	9aCS	32	1179.86	165	PE22-PE25-CE09	193	24183	0	
	Total	32	1180	165		193	24183	0	
Portugal		208	314	1347		430	43828	33	
Spain		51	1	70		0	6	0	
TOTAL		259	252	1416		430	43834	31	

Chub mackerel length sizes ranged from 15 to 30 cm. Regarding age structure, chub mackerel was dominated by small individuals, corresponding to ages 0 and 1 (Fig. 28).

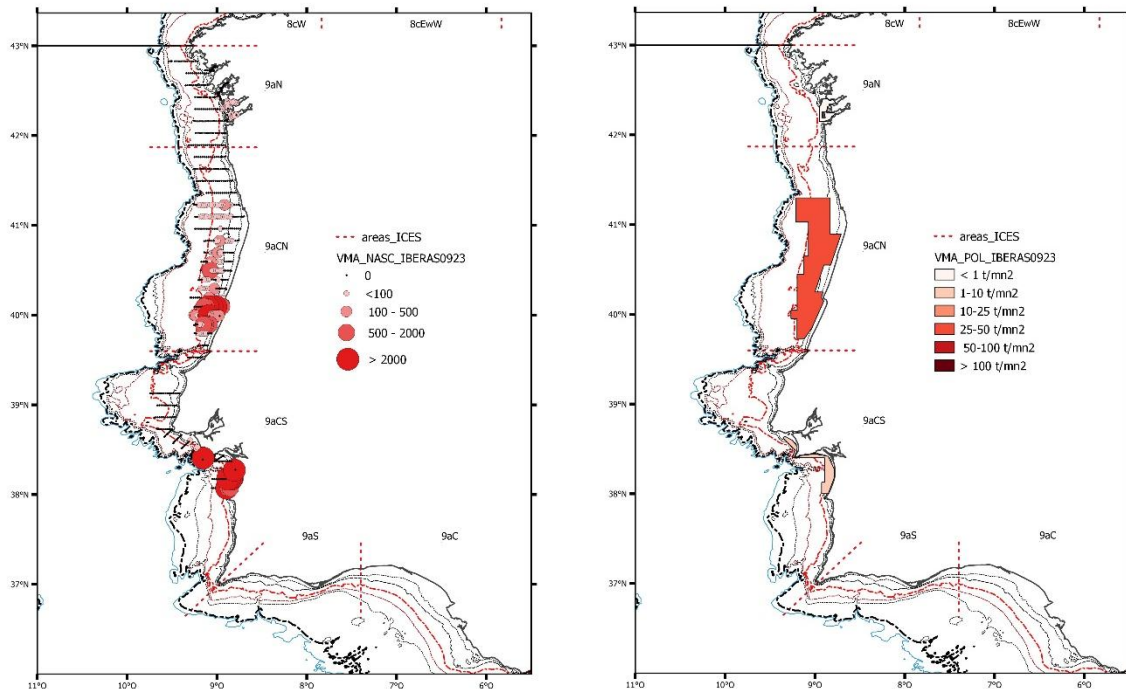
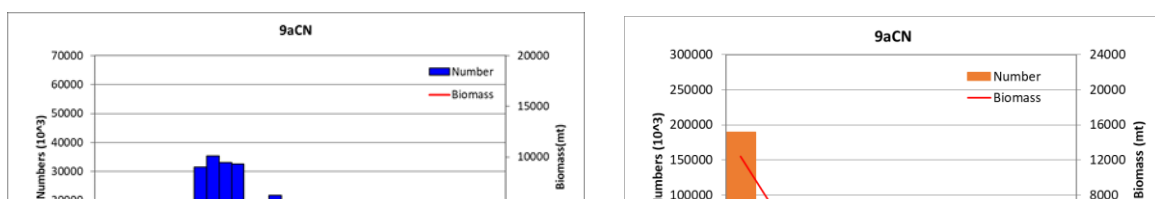


Figure 27 Chub mackerel spatial distribution in IBERAS0923. Left map: bubble plot that represent NASC values attributed to chub mackerel (size proportional to abundance). Right map: strata together with the relative density.



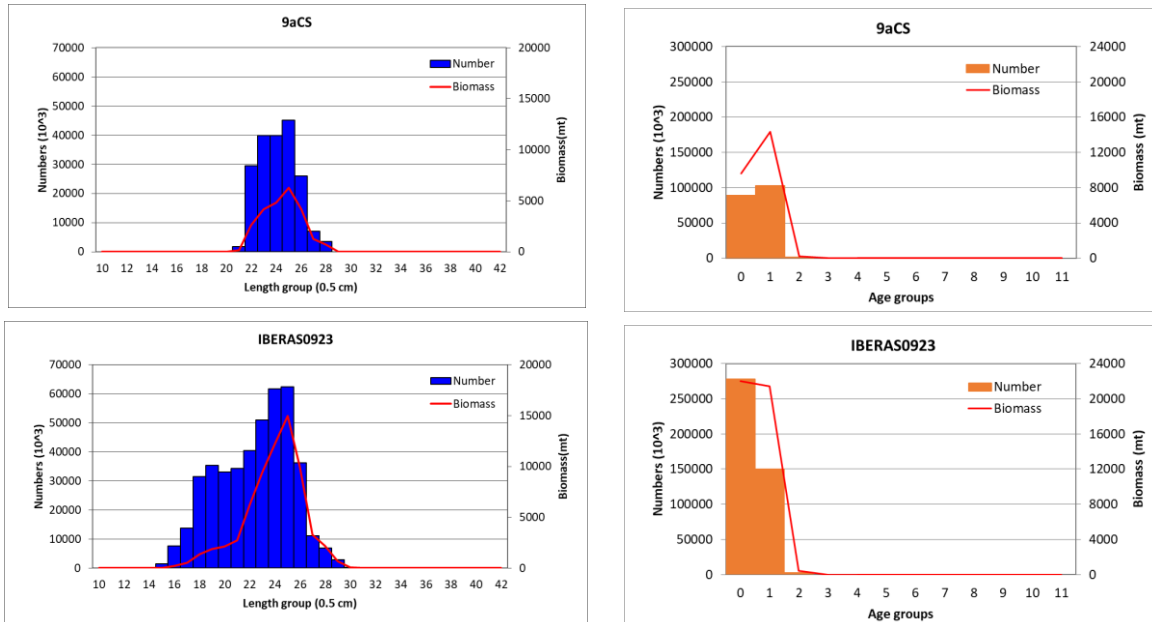


Figure 28 Chub mackerel biomass and abundance estimates by ICES subdivision and the total for the whole area. Left panels in length classes, right panels in age groups.

4 Horse mackerel assessment

Together with sardine, anchovy and, chub mackerel, horse mackerel is also an important pelagic

fish species in the surveyed area.

Table 14 summarises the horse mackerel assessment: 6230 tonnes, corresponding to $303 \cdot 10^6$ fish. The majority of the stock was distributed in the 9aCN subdivision, between Figueira de Foz and Aveiro (Fig. 29).

Table 14 Summary of the horse mackerel assessment, with the name of the strata, number of positive nmi, mean NASC value ($m^2 nmi^{-2}$), surface (nmi^2), fishing station used for the estimation and number and biomass estimated.

SURVEY: IBERAS 0923 HORSE MACKEREL								
Zone	Area	No	Mean	Area	Fishing st.	No (million fish)	Biomass (tonnes)	Density (Tn/nmi-2)
9aN	9aN	51	36.68	70	PE05-PE07	7	197	0
	Total	51	37	70		7	197	0
9aCN	9aCN_N	152	76.15	1038	PE01-PE16-PE17-PE18-PE23-PE24-CE01-CE05-CE06-CE12	268	5465	5
	Total	152	76	1038		268	5465	5
9aCS	9aCS	32	52.20	157	PE22-PE25-CE09	28	568	0
	Total	32	52	157		28	568	0
Portugal		184	72	1196		296	6033	5
Spain		51	37	70		7	197	3
TOTAL		235	64	1266		303	6230	5

The smallest individuals were found in Spanish waters (area 9aN; Figure 30). A bimodal length structure was found in all the different areas. Most were age 0 individuals.

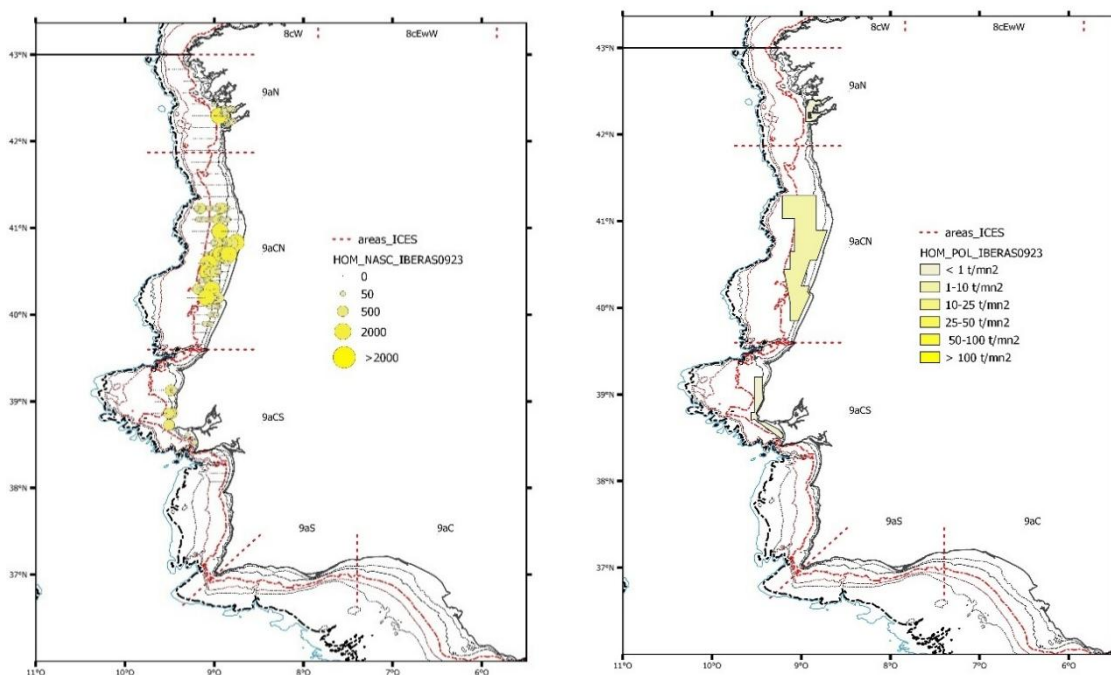
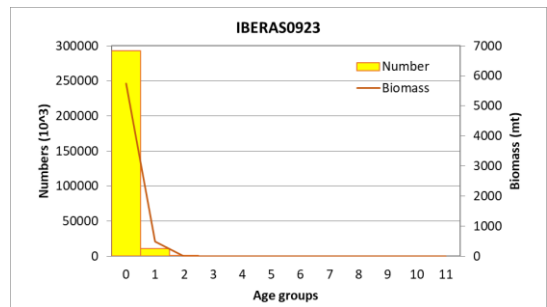
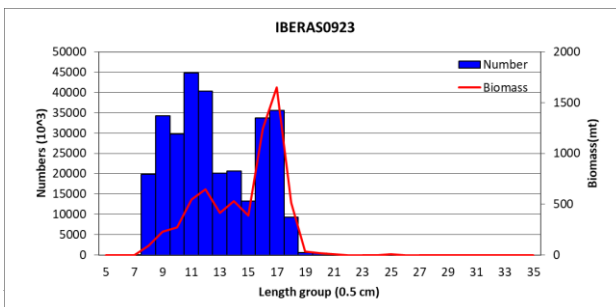
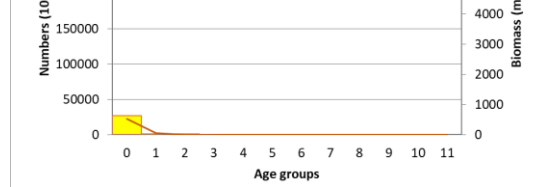
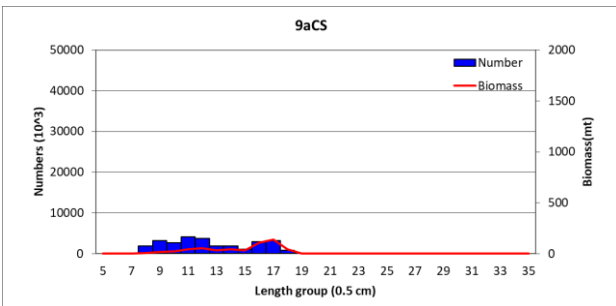
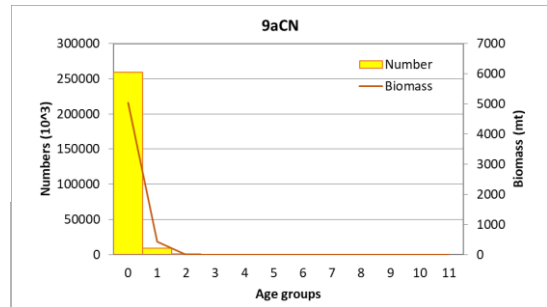
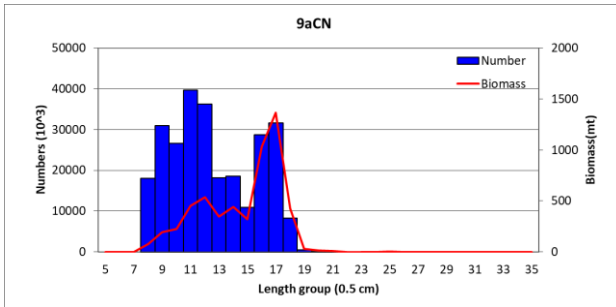
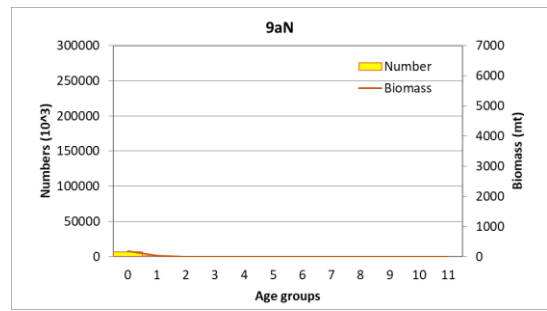
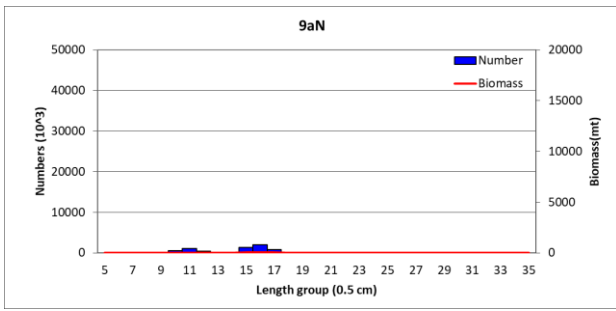


Figure 29 Horse mackerel spatial distribution in IBERAS0923. Left map: bubble plot that represent the NASC values attributed to horse mackerel (size proportional to abundance). Right map: the strata together with the relative density.



... by ICES subdivision and the total for the whole area. Left panels in length classes, right panels in age groups.

5 Atlantic mackerel assessment

In IBERAS0923 Atlantic mackerel was mostly found in area 9aCN, between Aveiro and Nazaré (Fig. 30). The assessment for this year estimated 33976 tonnes, corresponding to 440 million fish (Table 15).

Table 15 Summary of the mackerel assessment, with the name of the strata, number of positive nmi, mean NASC value ($m^2 nmi^{-2}$), surface (nmi^2), fishing station used for the estimation and number and biomass estimated.

SURVEY: IBERAS 0923 MACKEREL								
Zone	Area	No	Mean	Area	Fishing st.	No (million fish)	Biomass (tonnes)	Density (Tn/nmi-2)
9aN	9aN	51	0.00	70	NA	0	0	0
	Total	51	0	70		0	0	0
9aCN	9aCN_N	176	7.15	1181	PE17-PE18-PE20-PE24-PE23-PE24	439	33897	29
	Total	176	7	1181		439	33897	29
9aCS	9aCS	32	0.10	165	PE22	1	79	0
	Total	32	0	165		1	79	0
Portugal	208	6	1347			440	33976	25
Spain	51	0	70			0	0	0
TOTAL	259	5	1416			440	33976	24

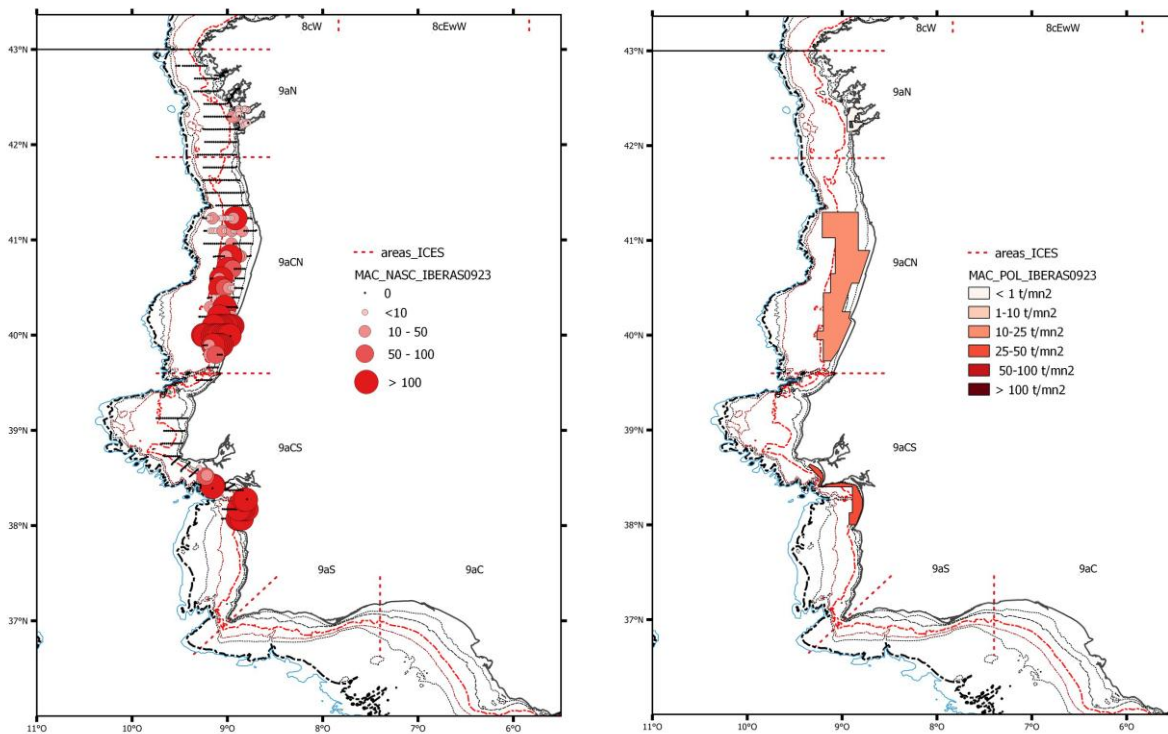


Figure 30 Mackerel spatial distribution in IBERAS0923. Left map: bubble plot that represent the NASC values attributed to horse mackerel (size proportional to abundance). Right map: the strata together with the relative density.

In 9aCN the length range of the species was small: from 20 to 24 cm. In 9aCS, in the area around Lisbon, bigger individuals of 30-33 cm length were found that were already in age 1 (Fig. 31).

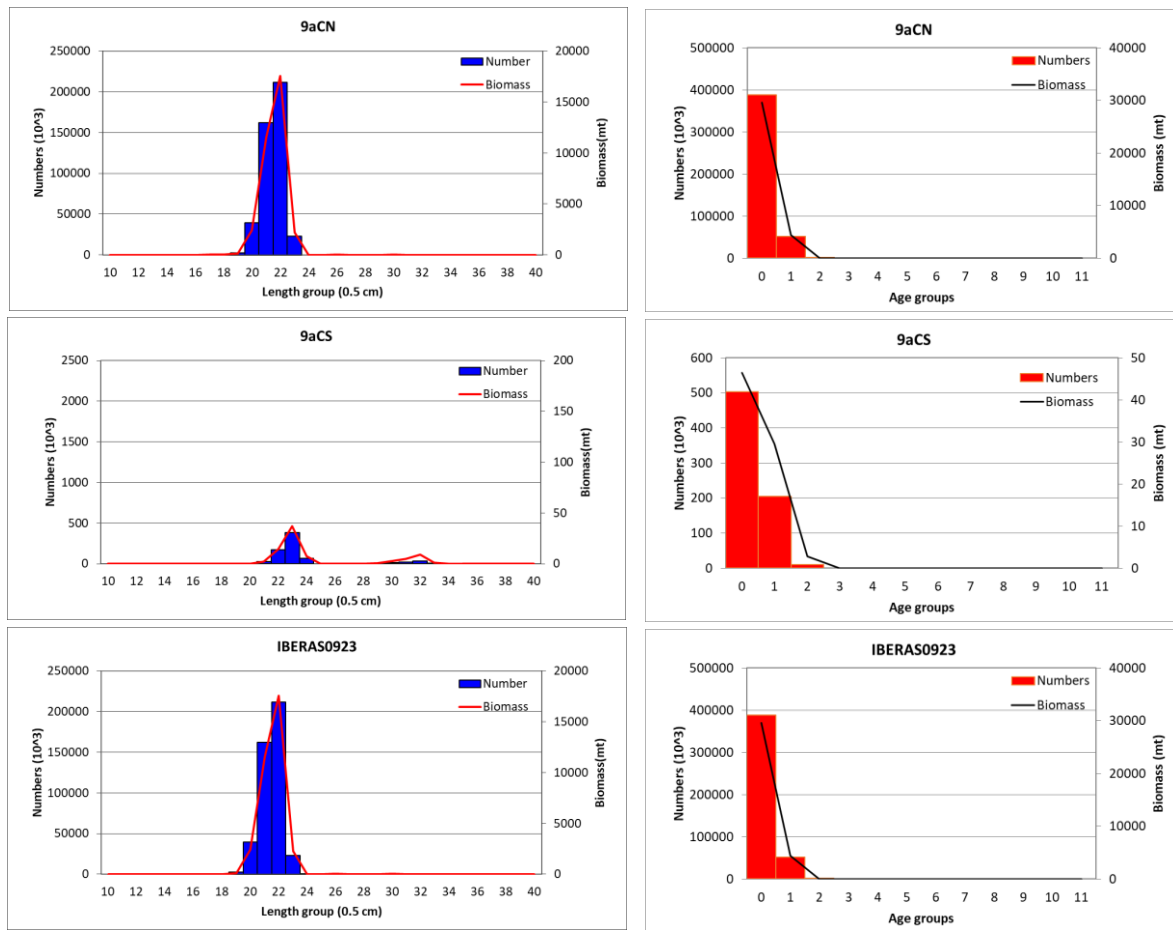


Figure 31 Mackerel biomass and abundance estimates by ICES subdivision and the total for the whole area. Left panels in length classes, right panels in age groups.

DISCUSSION AND CONCLUSIONS

2023 was the sixth year of performance of the IBERAS time series. The survey coverage was similar to previous years, covering the probable distribution of the Iberoatlantic stock of sardine, but due to the lack of time and similar to what happened in previous years, the survey only targeted juvenile sardine and anchovy (e.g. prime objective).

Thick sardine schools were observed (with values of Sv mean -29.08dB; max -16.76; $48 \times 10^3 \text{ m}^2/\text{nmi}^2$) which might be due to dolphin interactions. As main result, biomass estimates for adult sardine (individuals >16.0cm) achieved 339674 metric tonnes that corresponds to 6.8×10^9 fish. The most representative was age group 1, which accounted for 29913 metric tonnes (2.8×10^9 fish), confirming the strength of the 2022 cohort. This year recruitment was very low (age 0; 27×10^3 metric tonnes, 2.7×10^9 fish). The centre of gravity was found around Figueira da Foz, with a large dispersion.

Biomass estimates for adult anchovy (individuals >12.0cm) was 56414 metric tonnes that corresponded to 1.6×10^9 fish. Age group 0 accounted with 88429 metric tonnes (2.19×10^9 fish) and age group 1 with 56414 metric tonnes (1.6×10^9 fish). Anchovy was mostly found in the northern area of the survey (9aN and 9aCN), with the center of gravity located in 9aCN.

The survey also allowed to do the assessment for other important pelagic species in the community: chub mackerel, horse mackerel and Atlantic mackerel. The chub mackerel assessment for this year was 43×10^3 tonnes, corresponding to 430×10^6 fish. Horse mackerel was distributed in the 9aCN area, between Figueira da Foz and Aveiro and registered 6230 tonnes, corresponding to 303×10^6 fish. Atlantic mackerel was mostly found in 9aCN, between Aveiro and Nazaré, the total numbers of the assessment for this year were 33976 tonnes, corresponding to 440 million of fish.

Overall IBERAS is providing a good indicator of the strength of the sardine recruitment for the Iberoatlantic stock. The index estimates have been oscillating in the last 6 years, with the first three years with an exponential increase, then a low recruitment year (2021), followed by the highest recruitment registered in the series (2022), and then proceed by another very low recruitment year (2023).

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