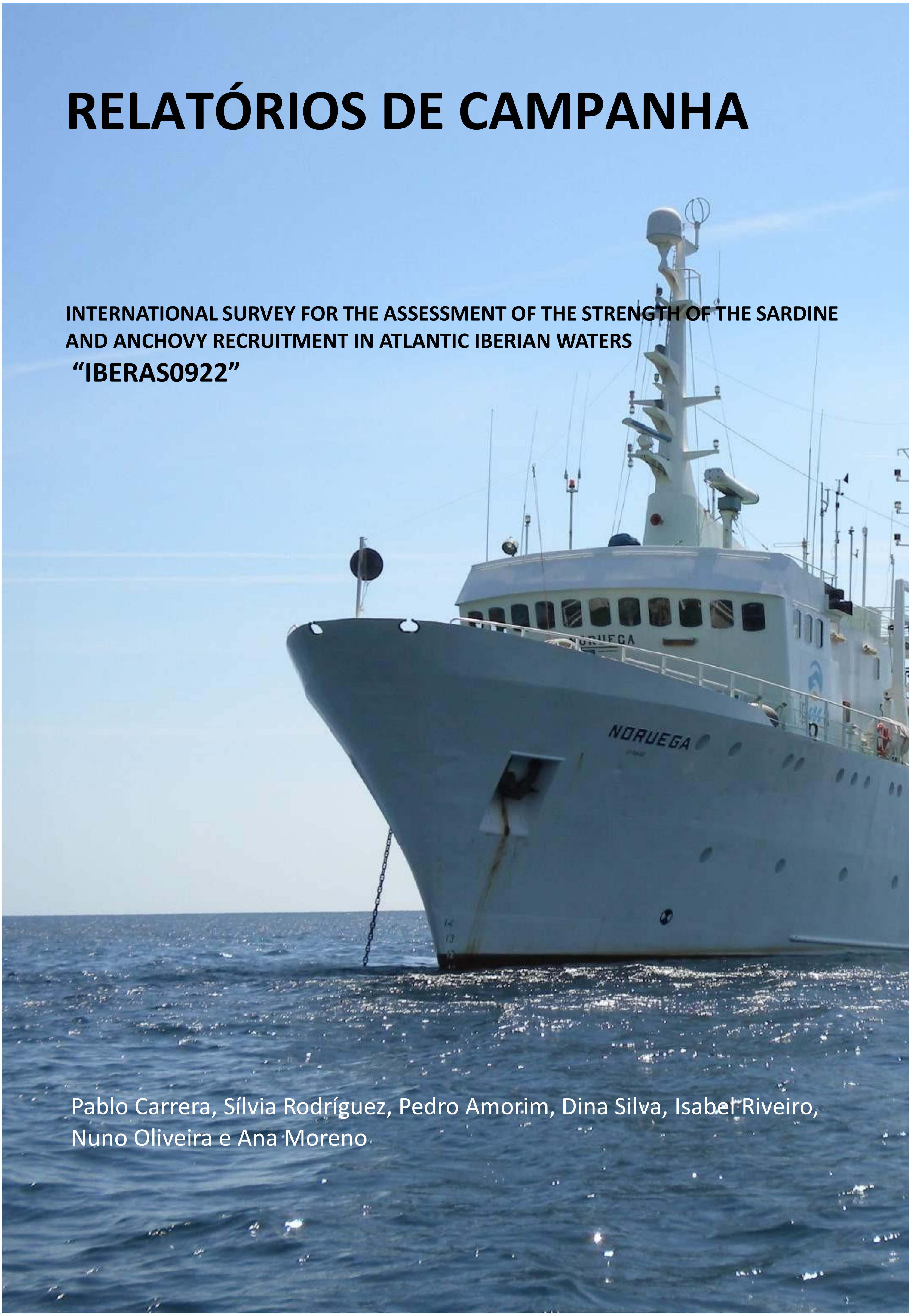
RELATÓRIOS DE CAMPANHA



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

"IBERAS0922"

Pablo Carrera, Sílvia Rodríguez, Pedro Amorim, Dina Silva, Isabel Riveiro, Nuno Oliveira e Ana Moreno

Edição

IPMA

Rua C – Aeroporto de Lisboa

1749-007 LISBOA

Portugal

Edição Digital

Conceição Almeida

Capa

Anabela Farinha / Conceição Almeida

Disponíveis no sítio web do IPMA

http://ipma.pt/pt/publicacoes/index.jsp

Referência Bibliográfica

CARRERA P., RODRÍGUEZ S., AMORIM P., SILVA D, RIVEIRO I., OLIVEIRA N., MORENO A., 2022. International survey for the assessment of the strength of the sardine and anchovy recruitment in Atlantic Iberian waters "IBERAS0922". ***Relatórios de Campanha, 37*****p. (*http://ipma.pt*)**

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

IBERAS0922
SURVEY REPORT

Co-funded by the European Union

co-funded by the EU through the European Maritime and Fisheries and Aquaculgture Fund (EMFAF) within the National Program of collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

IBERAS0922 was carried out on board the R/V Angeles Alvariño from 22th September to 8th October 2022 with the aim of estimating the strength of recruitment of the Iberoatlantic stock of sardine (*Sardina pilchardus*). The survey was calibrated on the 26th September. The survey covered the subdivisions 8cW, 9aN, 9aCN and 9aCs (i.e the western coast of the Iberian Peninsula) with a survey design consisting of parallel transects 6 nmi apart, with a random start, and covering a depth range from 20-15 m to 100 m. This area coincides with the main potential distribution area for sardine recruitment of the Iberoatlantic stock. In addition, in the main recruitment area (e.g. central part of 9aCN, historically observed), the sampling intensity was increased up to 4 nmi between transects to increase the sampling resolution.

Weather conditions were generally good and the survey was carried out as planned. 16 pelagic trawl hauls were conducted and a purse seiner (on the second leg) was used for a further 9 hauls, which were used for ground-truthing the fish community and to obtain the length/age distribution of each species. The total NASC was lower than those in previous years ($322*10^3$ sA normally above $420*10^3$ sA). 15% of the NASC was unallocated due to the lack of time to perform specific fishing stations to verify those echotraces. 26% of the total NASC was allocated to adult sardine and 62% was allocated to juvenile sardine. Only 4% was allocated to anchovy and 3% to chub mackerel.

Sardine assessment for IBERAS0922 was divided in small sardine (juveniles ≤16.0 cm) and big (adult) sardines (>16.0 cm). A total of 47 540 tonnes of adult sardine were estimated, comprising 675 million individuals. Juvenile sardine schools were thick this year (similar to those found in year 2019) and were located near the surface and some of them where found on the surface, mainly outside the coastal area. Nearly 159 thousand tonnes of juveniles ≤16.0 cm were estimated, comprising 8026 million individuals. Juveniles were more abundant in subdivision 9aCN (87.5%) Overall, IBERAS is providing a good indicator of the strength of the sardine recruitment for the Iberoatlantic stock. The recruitment index for this the present year was the highest of the time series ($8*10^9$ age 0 sardines).

Anchovy was mainly concentrated in subdivision 9aCN (51%) and in 9aN (35%), in particular in the southern part). The estimated biomass for anchovy was 7639 tonnes, comprising 482 million fish, which means a significant decrease in relation to the previous year. Most of the anchovy population was age 0. The chub mackerel assessment was 4554 tonnes, corresponding to 64*106 fish. In the present survey no assessment for other important pelagic species in the community, such as horse mackerel and mackerel, was provided due to their low presence in the surveyed area.

TECHNICAL SUMMARY

Institution:	INSTITUTO ESPAÑOL DE OCEANOGRAFÍA/INSTITUTO PORTUGUÊS DO MAR E DA ATMOSFERA	
Survey name:	IBERAS0922	
Vessel name:	Ángeles Alvariño (46.70 m length, 10.50 width with 988 GRT and 900 kW diesel electric)	
Dates:	22/09-09/10/2022	
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 during the day Pelagic fishing stations: 16 + 9 Purse seiners Hydrological characterisation.	
Personnel 1st leg Vigo/Vigo Dates: 27 to 29/09	CARRERA LÓPEZ, PABLO (JC) AMORiM, PEDRO MIGUEL MARTÍNEZ CEDEIRA, JOSÉ ANTONIO AUTÓN DÍAZ, URBANO HERNÁNDEZ MILIÁN, GEMA	MANEIRO ESTRAVIZ, ISABEL DA CONCEIÇÃO MENDONÇA, ANTONIO PEDRO CÓRDOBA SELLÉS, Mª PILAR (calibration)
2nd leg Vigo/Lisboa Dates: 29/09-09/10/2022	CARRERA LÓPEZ, PABLO (JC) AMORIM, PEDRO MIGUEL MARTÍNEZ CEDEIRA, JOSÉ ANTONIO AUTÓN DÍAZ, URBANO HERNÁNDEZ MILIÁN, GEMA NASCIMENTO, TANIA	MANEIRO ESTRAVIZ, ISABEL DA CONCEIÇÃO MENDONÇA, ANTONIO PEDRO ANA MORENO SAKAMOTO, TATSUYA DOS SANTOS BARRA, JORGE SILVA, DINA
Report author	Pablo Carrera, Sílvia Rodríguez, Ana Moreno	
Other collaborators	Pedro Amorim Isabel Riveiro Dina Silva Nuno Oliveira (Spea)	

1. INTRODUCTION

IBERAS is a new acoustic trawl time series designed to estimate the strength of the sardine recruitment in Atlantic Iberian waters. The survey is conducted over the main potential distribution area of the recruitment for the Iberoatlantic sardine (*Sardina pilchardus*) stock. The first survey was done in November 2018. Due to the probability of poor weather conditions in autumn and in order to make a synoptic coverage with JUVENA survey - which also covers the Bay of Biscay - the timing has been moved to September in the following years. This shift did not change the availability of recruits. The present survey (2022) will be the fifth year of the time series.

The rationale for the start of this new time series was based on the low productivity level of the sardine stock in this area during several years since 2011. Although sardine is not considered a short-lived species, the lack of good year classes has resulted in a very low presence of older ages (e.g. very low expectation of reaching ages older than 5 years due to the high natural mortality), with the bulk of the population composed of younger fish, which in turn, makes this species look like a short-lived species. Under such conditions, any recovery in biomass is likely to be driven by the strength of the recruitment. Therefore, if juveniles can be assessed at age 0, the estimates can be used to predict the relative strength of the future recruitment to the fishery. This strategy is of particular interest for the management of fisheries for short-lived species because of the short time between spawning and the subsequent recruits.

The IBERAS survey was designed on the basis of experience gained by IPMA through the JUVESAR survey (targeting sardine recruitment in north-west Portugal), by AZTI and IEO through the JUVENA survey (to improve the assessment/management of anchovy in the Bay of Biscay) and by IEO through the ECOCADIZ recruitment survey (targeting sardine and anchovy recruitment in the Gulf of Cadiz). The main objective of IBERAS is to obtain a recruitment index for both species in the Atlantic waters of the Iberian Peninsula, in order to improve the estimation of the recruitment strength of the Iberoatlantic sardine and the western component of the southern anchovy population.

2. OBJECTIVES

i. Acoustic estimates by echointegration of the strength of the sardine and anchovy 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.
iii. Assess the relative abundance of apical predator along the surveyed area

3. MATERIAL AND METHODS

The survey was carried out on board the R/V Ángeles Alvariño from the 22th September until the 9th of October 2022, departing from the port of Vigo and arriving at the port of Lisbon at night (Figure 1). A scale was scheduled in Vigo on 29th of September.

Depending on vessel availability, the IBERAS survey may be carried out onboard R/V Ramón Margalef or on a similar vessel. R/V Angeles Alvariño was used in years 2019 and this year 2022. It is considered that the similarity of the two vessels makes the vessel uncertainty effect low and facilitates the comparison of results.

3.1 Working Area

From Fisterra 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.

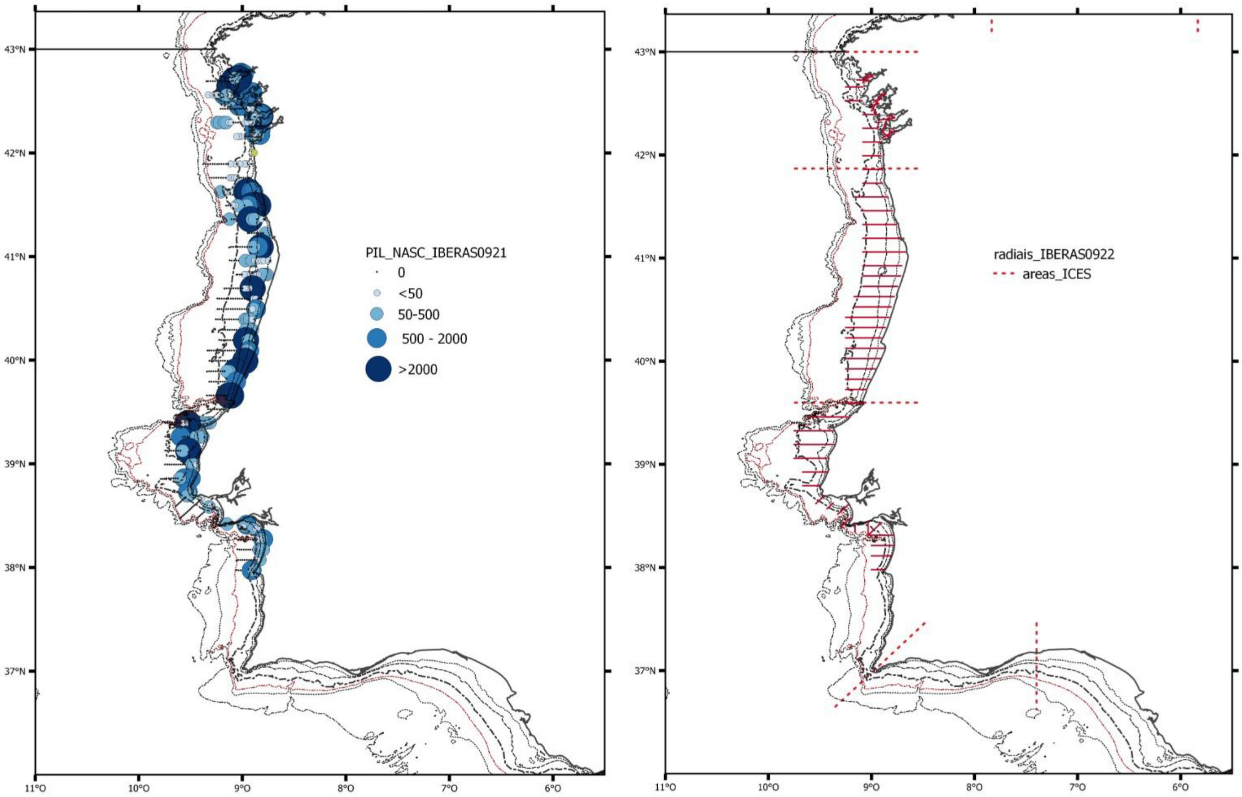


Figure 1 Sardine NASC distribution obtained during IBERAS0921 (left) and the proposed survey track for IBERAS0922 (right).

The methodology used was similar to that used in 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 the day, 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 the presence and abundance of marine mammals, seabirds, floating litter (debris) and vessel presence and abundance.

At night, when acoustics transects were not conducted, CTD profiles for hydrography and zooplankton sampling (Bongo 60 and Manta trawls) were done on some of the opportunistically selected acoustic transects.

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						3	22-23/09
Rías Baixas (9a-N)	23	115	0	11.5-1	6-12-1	2	24-25/09
Plataforma 9a N	7	82	60	13.3-1	4-6-0.8	2	26-28/09
O. Norte (9a-CN): Caminha-Porto	8	138	65	19.5-1.5	7-1.0	2.5	29/09-1/10
O. Norte (9a-CN/CS): Porto-Peniche	15	273	103	36.5-2.8	7-1.0	3.8	2-5/10
O Norte (9a-CS): Peniche-Roca	5	39	38	10-0.8	3-5-0.42	1.3	6-7/10
O Sul (9a-CS): Roca-Espichel	4	48	26	6.7-0.6	3-0.5	1	8/10
O Sul (9a-cs): Espichel-Sines*	7	53	31	8.4-0.70	2-3-0.3	1	9/10
Total	46-23	778	332	110-9.78	36-5.5	17.5	
Días de respeto:							0.0 días

* Se cubrirá si hay tiempo

3.2 Acoustic

The acoustic equipment consisted of a Simrad EK-80 scientific echosounder, operating in CW mode at 18, 38, 70, 120 and 200 kHz. All frequencies were calibrated during the first two days according to the standard procedures (ICES-CRR326). The elementary sampling distance unit (EDSU) was fixed at 1 nmi. Acoustic data were collected only during the day at a cruising 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 was included, and background noise was also removed according to De Robertis and Higginbottom (2007). Fish abundance was calculated using the 38 kHz frequency as recommended by 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 to better discriminate between swimbladder fish species and other organisms. The threshold used to scrutinize the echograms was –70 dB. Integration values were expressed as nautical area scattering coefficient (NASC) units or s_A values (m^2 nmi^{-2}) (MacLennan et al., 2002).

3.2.1 NASC allocation

A Gloria HOD 352 pelagic trawl was used in combination with a 63.5/51 pelagic trawl to identify the species and size classes responsible for the acoustic energy detected and to provide samples. The duration of the hauls was variable and ultimately depended on the number of shoals entering the net and the fishing conditions, although a minimum duration of 20 minutes was always attempted. The quality of the hauls for ground-truthing the acoustic data was classified according to the weather conditions, haul performance, catch composition in number, and the length distribution of the fish caught (Table 2).

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

	0	1	2	3
Gear performance Fish behaviour	Crash	Bad geometry Fish escaping	Bad geometry No escaping	God geometry 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 to be the best representation of the fish community for a given area were used to allocate NASC to each EDSU within that area, where direct allocation was not possible. 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 for calculating densities by length, $NASC_l$ is the proportion of the total *NASC* which can be attributed to length group *l* for a given fish species. $\sigma_{l,p}$ is the backscattering cross-section at length *l* for a given species at length *l* multiplied by the proportion of (p_l) of length of this particular species on the overall catch and σ_p is the sum of all $\sigma_{l,p}$ for all species,

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

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

Finally, $\sigma_{l,}$ 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 calculated using the formula TS =20 logL_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 given 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}	Refererence	Observations	Otherb_{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

Where possible, direct allocation was done, considering the shape of the school and also the relative frequency response of that school (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, including: 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. In addition, the frequency response for each valid school (i.e. those with length and s_V which allows them to be properly measured) was calculated as the ratio $s_{A(fi)}/s_{A(38)}$, being f_i the s_A values for 18, 70, 120 and 200 kHz.

3.2.2 Echointegration estimates

Once the backscattering energy is allocated to fish species, the spatial distribution for each species is analysed using both the NASC values and the length frequency distributions (LFDs) to provide homogeneous assessment polygons. These are calculated as follows: one empty track defines the coast-boundary of the polygon, while three consecutive empty ESDU´s define a gap or the cross-coast boundary. Within each polygon, the LDF is analysed.

LFDs should be obtained for all positive hauls for a given species (either from the total catch or from a representative random sample of 100-200 fish). Only LFDs, based on a minimum of 30 individuals were considered for acoustic assessment. Differences in probability density functions (PDFs) were tested using the Kolmogorov-Smirnov test. PDF distributions without significant differences were merged to create a homogeneous PDF stratum. Spatial distributions were 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 to biomass using the length-weight relationships derived from the fish measured on board. Results by ICES subdivisions (9aN, 9aCN, and 9aCS) are given for comparison.

3.2.3 Center of Gravity

For each main species, a center 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 distance (nautical miles) is calculated as (Lat-37.0)*60, where *Lat* is the latitude of the midpoint of a given EDSU.

3.3 Fishing stations

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

A Gloria HOD 352 was used in combination with a 63.5/51 pelagic trawl with a vertical opening of approximately 13 m and 16 m respectively. The general rigging consisted of 200/400 kg clump weights on either side of the setback (2 m below the wing). The 100 m Dyneema bridles (wings) were shortened to 50 m in shallower waters. A set of 3.5 m^2 *Apollo Poly-Ice* doors with a weight of

750 kg was used. Gear performance was monitored by a wired Simrad Sonar FS20 net sounder. For surface hauls, a fence buoy was placed in the upper bridle, opposite the clumps. Fishing stations were conducted during the day.

Additional fishing stations were carried out by a chartered purse-seiner around Aveiro, Figueira da Foz (9aCN) and Lisbon (9aCS) in shallow waters.

3.4 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. Hydrographic stations were conducted each evening after acoustic and fishing operations were completed. CTD profiles were done with a SBE911plus, in one or two stations spaced 3 nmi apart along the acoustic transects.

3.5 Fish sampling

Catches from fishing hauls were sorted and weighted.

3.5.1 Catch and length distribution per species

After sorting the catch for all species, a length distribution was estimated. If the number of specimens caught was greater than 100, a random sample was collected. The sample was then weighted and the specimens measured to the nearest length class. This was 0.5 for sardine and anchovies, and 1 cm for other species. The catch length distribution was estimated by raising the sample length distribution according to the weighting factor: total catch weight vs total sample weight (TCW/TSW).

3.5.2 Weight Length relationship

A weight-length relationship (WLR) was calculated for all assessed species, either from the results of 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 1 cm) as the stratum.

3.5.3 Biological sampling

Full biological sampling was carried out on the main target species caught in each trawl (e.g. anchovy and sardine). The following data were collected: length (mm); weight (g); sex; maturity stage; otolith collection; fat content; stomach colour and stomach repletion state. For sardine, the tail was also collected for further genetic analysis.

3.6 Apical predators

Apical predator observations were carried out using the ESAS methodology (European Seabirds At Sea; Tasker et al. 1984) between 30 September and 8 October 2022. All birds in contact with the water within a 300 m wide transect were counted from one edge of the boat and all seabirds in flight were counted using the snap-shot method. The counts were grouped into 5-minute periods. Distance sampling was used for marine mammals and reptiles. All the observations were grouped together in a spatial grid, with a 4x4km grid size. Counts inside and outside the transect were used to assess species distribution, but only individuals counted inside the transect were used to calculate observed densities (presented as no. of individuals*km-2). The analyses included 4 groups, 1) the northern gannet *Morus bassanus* (the most frequent bird species in this census), 2) total birds (including all seabird species), 3) the common dolphin *Delphinus delphis* (the most common mammal species in this census), and 4) total marine mammals (no reptiles were observed).

4 RESULTS

The survey was carried out as planned. There was good weather during the survey, which allowed all the tasks of the survey to be carried out.

4.1 Hydrographic conditions

Sea surface temperature (SST) during the IBERAS0922 survey ranged from 13.59 to 22.72ºC, with an average of 16.73ºC. Sea surface salinity (SSS) during the IBERAS0922 survey ranged from 34.63 to 38.08, with an average of 35.51. The surface water was colder and less salty between Aveiro and Viana do Castelo, as a consequence of a low saline plume originated from the river Douro extending offshore. Ocean surface water was warmer and saltier south of Lisbon, in the southern part of the surveyed area (*Figure 2*).

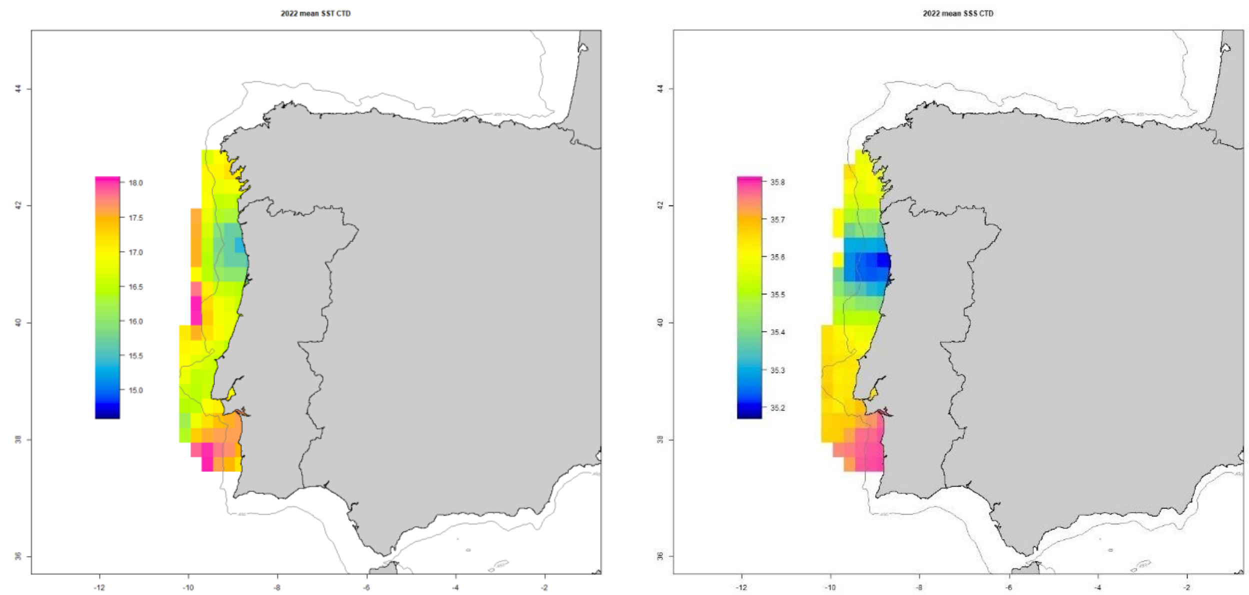
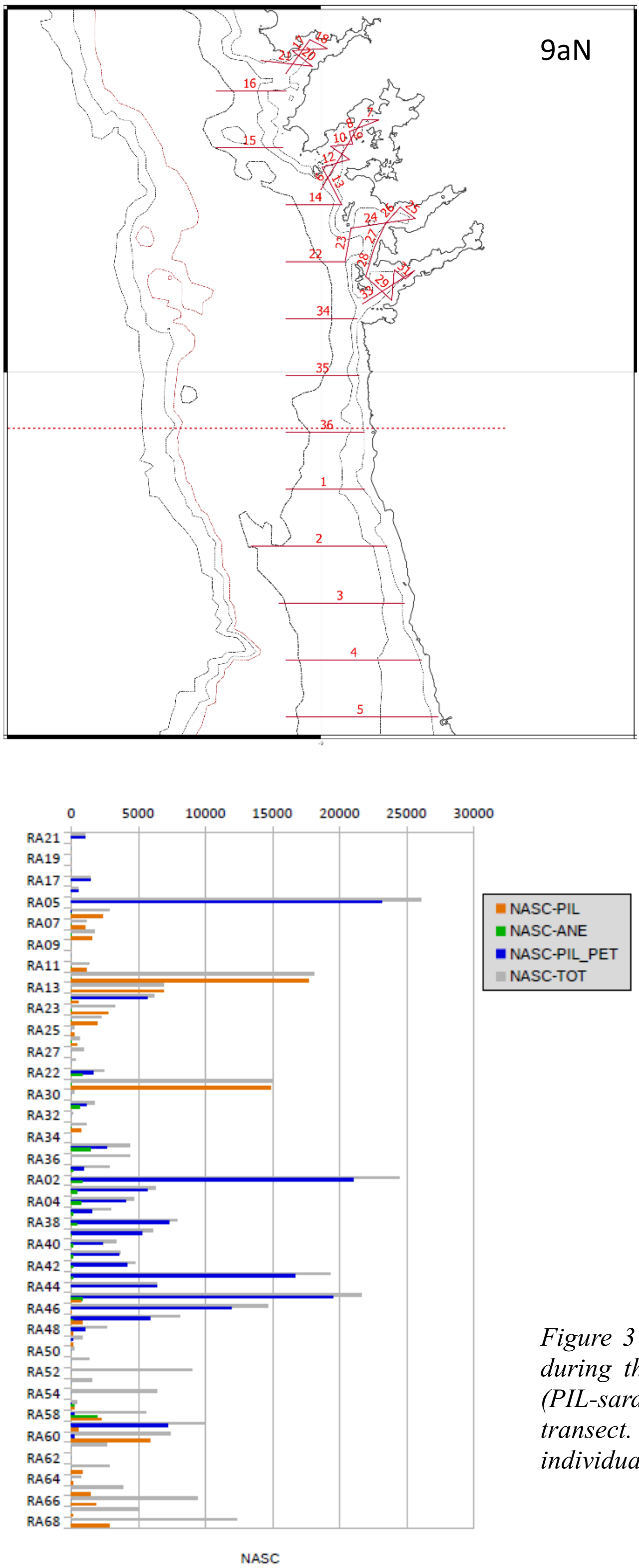


Figure 2 Sea Surface Temperature (SST, left) and Sea Surface Salinity (SSS, right) registered during the survey IBERAS0922.

4.2 Acoustics

4.2.1 School extraction and total backscattering energy

A total of 3371 echotraces were extracted, accounting for a total NASC (s_A) of 321947 m^2 nmi^{-2}. *Figure* 1 shows the sum of NASC per track along the surveyed area.



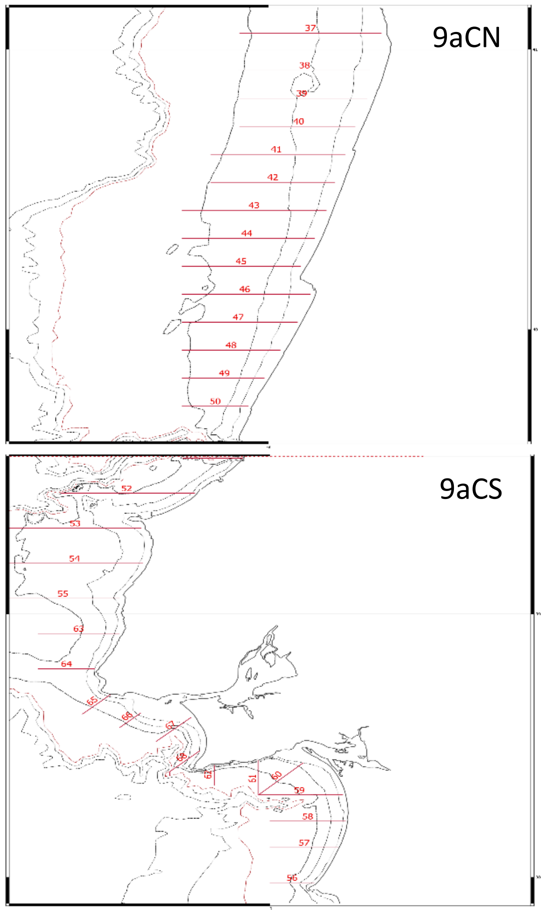


Figure 3 Map showing the parallel transects carried out during the survey (above). Cumulated NASC by species (PIL-sardine; PIL_PET-sardine, and ANE-anchovy) and transect. PET denotes small (juveniles, immature) individuals.

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 high amount of sardine found north of Nazaré.

The bathymetric distribution of the schools is significantly different from last year, when the mode was located at 27.5 m in a unimodal distribution, while this year a mode was found at 82.5 m (*Figure* 4).

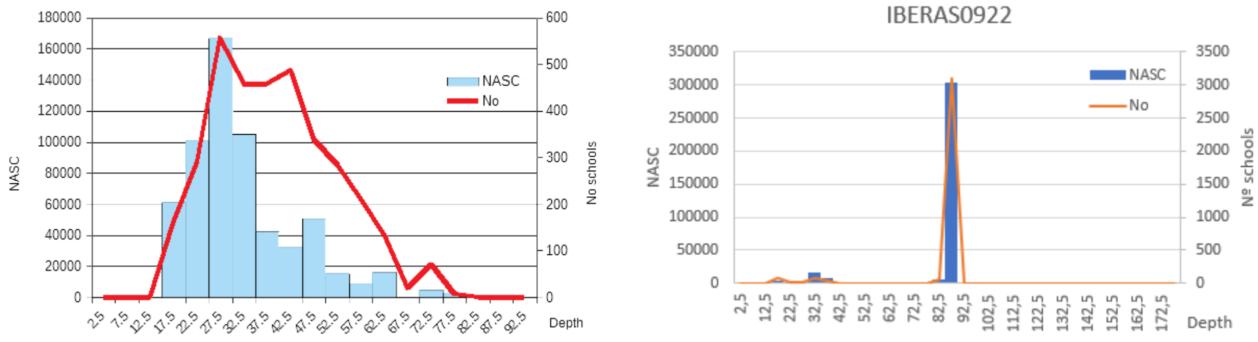


Figure 4 Number of schools and their cumulated NASC values per Depth strata (5m). Left IBERAS0921; right IBERAS0922

4.2.2 Fishing station and echotrace allocation

As mentioned last year, it was a challenge to carry out inshore stations when most of the area was occupied by static gear, which limited the areas available to carry them out and increased the time needed to search for them. Of the 25 fishing stations carried out, 9 were purse seine tows, which helped to characterise the fishing community in coastal areas (*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_PET	34226	1947163	19	35	1888	13.89	76.00	72.12	85.07
MAC	1	5	2	1	5	26.10	8.00	0.00	0.00
HKE	0	0	0	0	0	0.00	0.00	0.00	0.00
HOM	54	1272	4	16	376	16.37	16.00	0.11	0.06
PIL	7330	129033	9	55	792	19.77	36.00	15.45	5.64
JAA	2	34	1	2	38	17	4.00	0.00	0.00
SNS	145	15602	1	1	101	12	4.00	0.31	0.68
BOG	13	100	1	48	100	20.21	4.00	0.03	0.00
VMA	505	7799	9	30	446	20.63	36.00	1.06	0.34
BOC	1	19	1	1	19	11.97	4.00	0.00	0.00
SEAB	75	441	3	23	135	21.87	12.00	0.16	0.02
ANE	5107	187321	13	1094	1091	14.11	52.00	10.76	8.18
Total	**47459**	**2288789**	**25**	**1305**	**4991**				

This year, 72% of the total NASC was allocated to sardine (including both the small and big categories).

4.2.2.1 Sardine echotrace identification

As stated in previous years, survey targeted only on juvenile sardine and anchovy (main objective) due to the lack of time. Juvenile sardine schools were thick this year (similar to those found in year 2019) and were located near the surface and some of them where found on the surface itself, mainly outside the coastal area (*Figure 5*). In some cases, fish were at the blind zone area (*Figure 6*), only visible at high frequencies, which lead to an underestimation of the abundance.

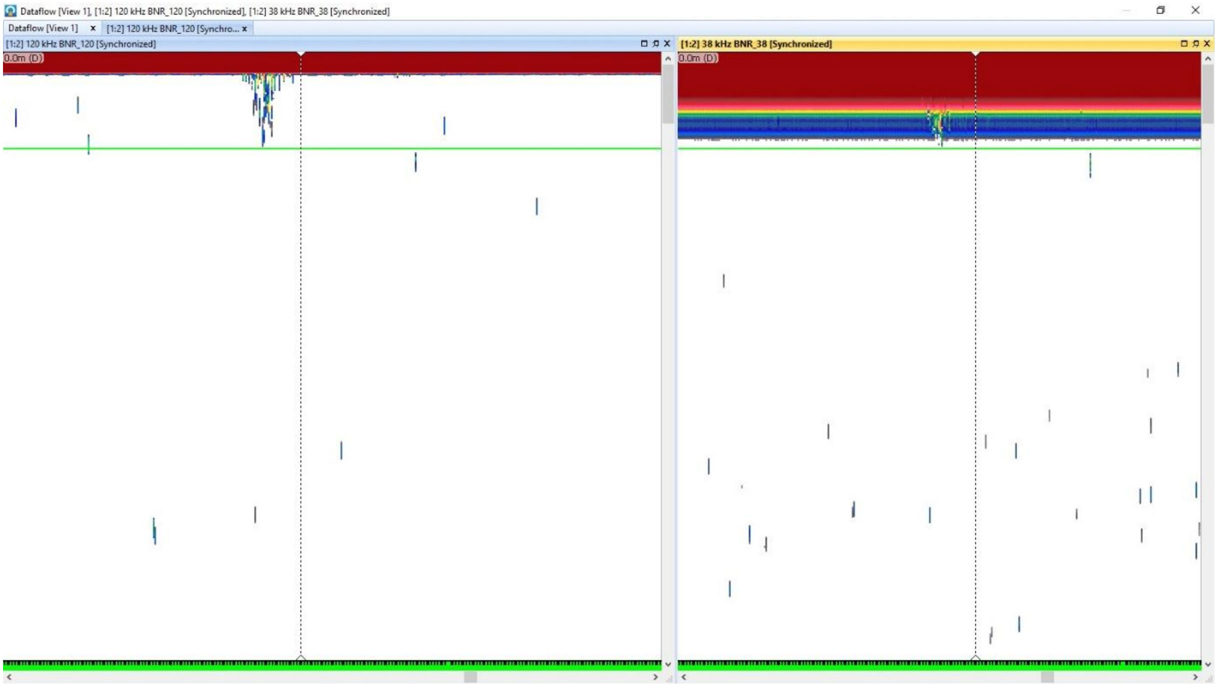


Figure 5. Echogram showing echotraces attributed to juvenile sardine (38kHz).

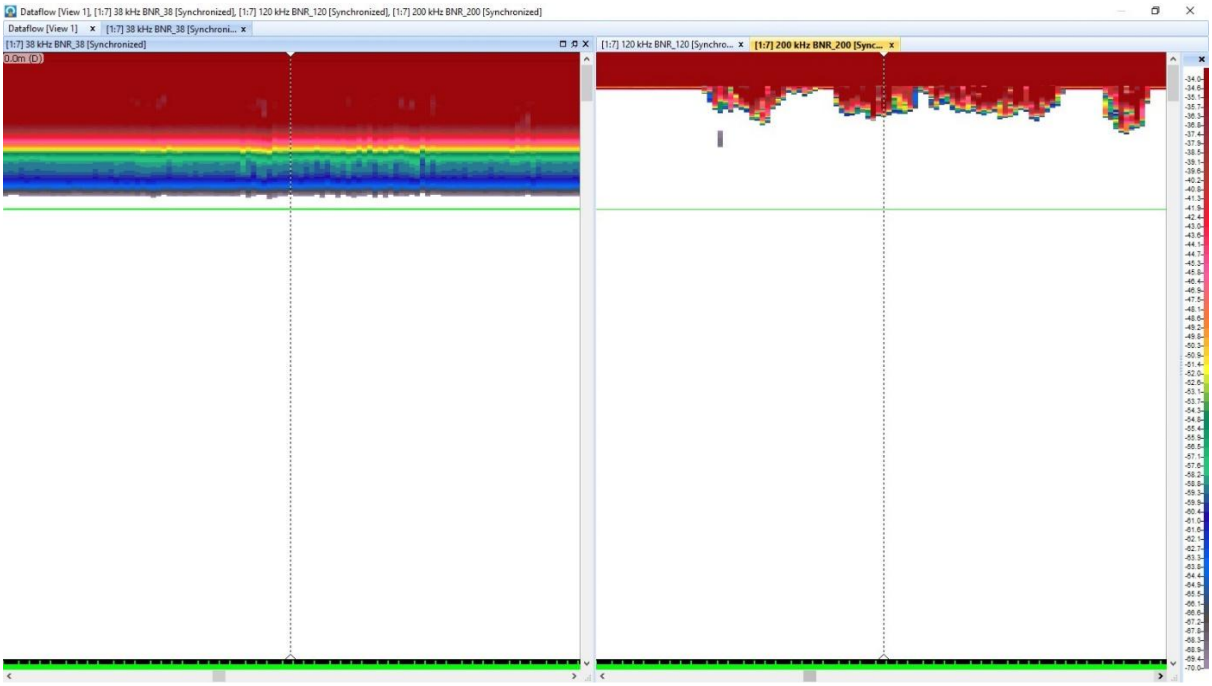


Figure 6. Echogram showing echotraces attributed to juvenile sardine in the blind zone area (from left to right: 38 and 200kHz).

4.2.2.2 Fishing station used for echotrace allocation

Total NASC allocated to pelagic species in the IBERAS0922 survey, was lower than those in previous years ($322*10^3$ s_A normally above $420*10^3$ s_A). Due to the lack of ancillary information, especially lack of fishing stations, $62*10^3$ S_A (21% of total NASC) where unallocated on 2022. Most of this energy was offshore and close to the bottom. 72% of the total NASC was allocated to sardine (both small and big categories), whereas anchovy and Chub mackerel accounted for 3% of the total NASC. For allocation purposes, the area was divided into different strata taking into account the echotypes and, within the echotype, the representative near fishing station (*Figure 7*). These are areas where the echotraces were similar, and where the proportion of species found by the fishing station on each stratum was also similar.

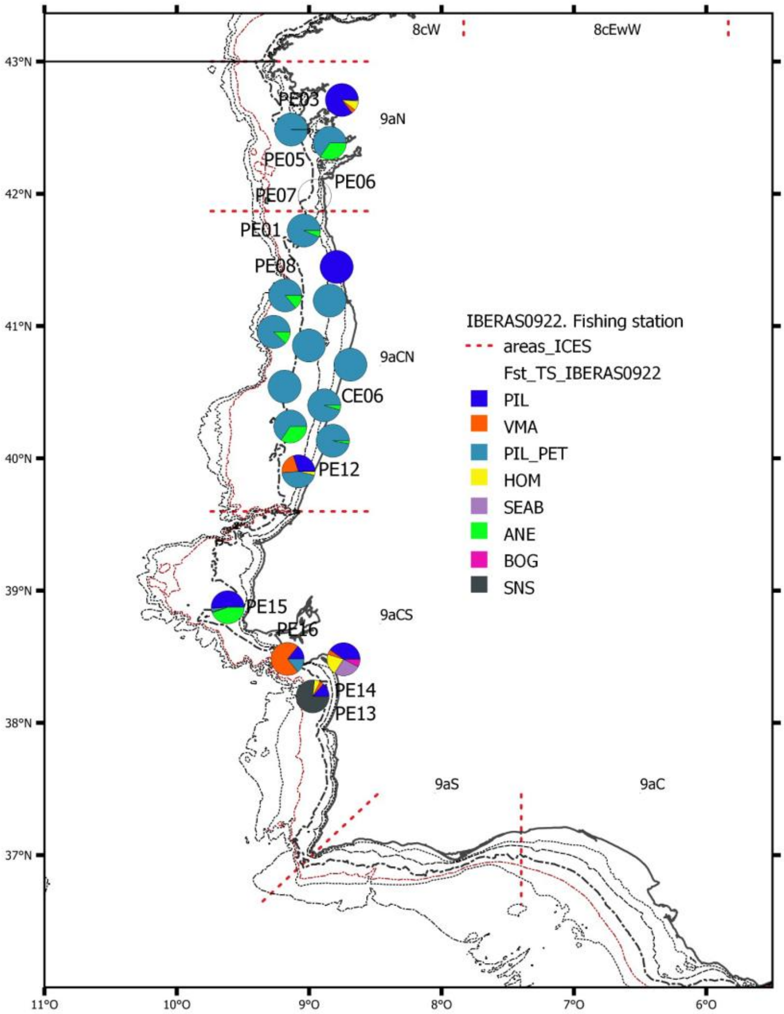


Figure 7 Pie charts showing the location of the fishing stations and the fish proportion in each station by the Nakken and Dommaness method. MAC-Atlantic mackerel; HOM-horse mackerel; PIL-sardine: BOG-bogue; VMA-chub mackerel; ANE-anchovy; SEAB-seabream species; PET denotes"small"(juvenile) individuals.

4.2.3 Length weight-relationship

Length weight relationship for the target species were calculated using individual weights (0.001 g) and lengths (mm). Group weights for length classes were also recorded but were not used for the present estimates. The relations were estimated by ICES sub-divisions, but the overall relationship was the one used for assessment purposes.

4.2.3.1 Sardine LWR

610 individuals were considered for the length-weight relationship of sardine. A bimodal distribution can be perceived in the data (*Figure* 8). A single LWR for the whole data was calculated with parameters equal to a=0.004 and b=3.275 and used for the assessment of the species.

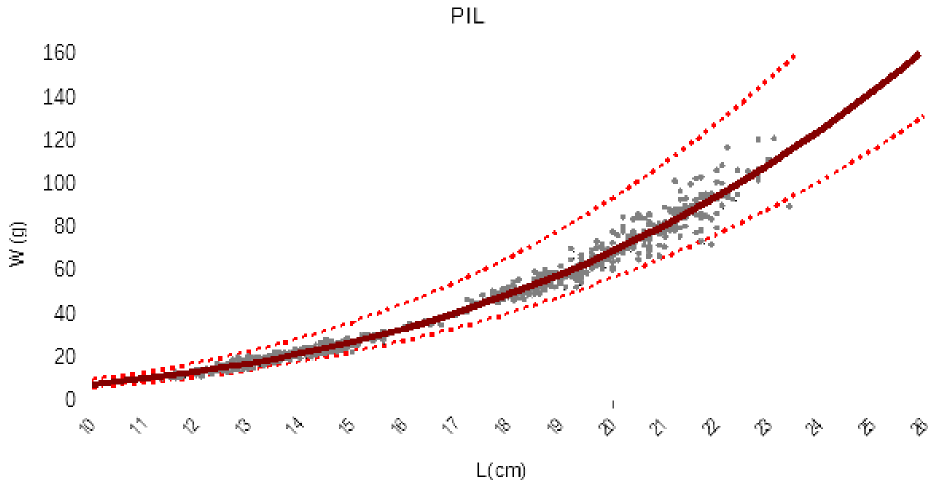


Figure 8 Length weight relationship for sardine used for assessment purposes. Grey dots are individual measurements; dotted red lines represent 95% confidence intervals.

4.2.3.2 Anchovy LWR

205 anchovy individuals were used to calculate the LWR. LWR parameters for anchovy were 0.006 and 3.04 a and b respectively (*Figure 9*).

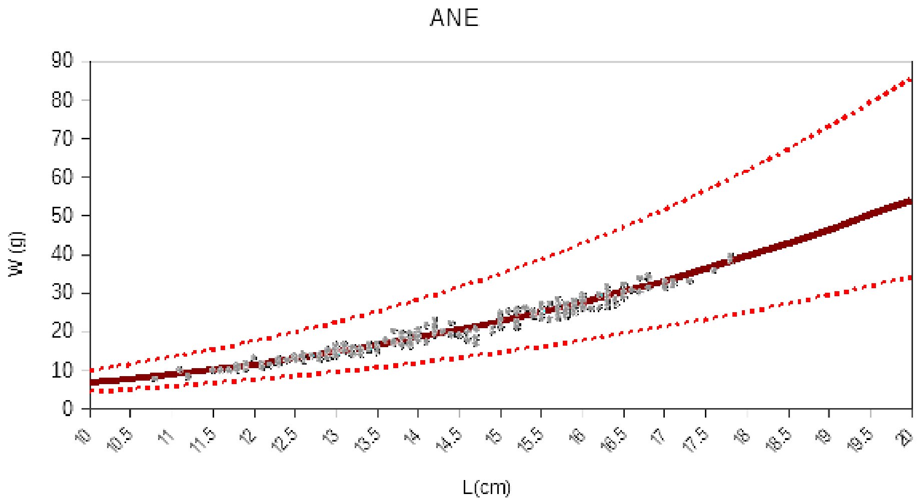


Figure 9 Length weight relationship for anchovy used for assessment purposes. Grey dots are individual measurements; dotted red lines represent 95% confidence intervals.

4.2.3.3 Chub mackerel LWR

136 Chub mackerel individuals were used to calculate the LWR. LWR parameters for chub mackerel were 0.005 and 3.17 a and b respectively (*Figure 10*).

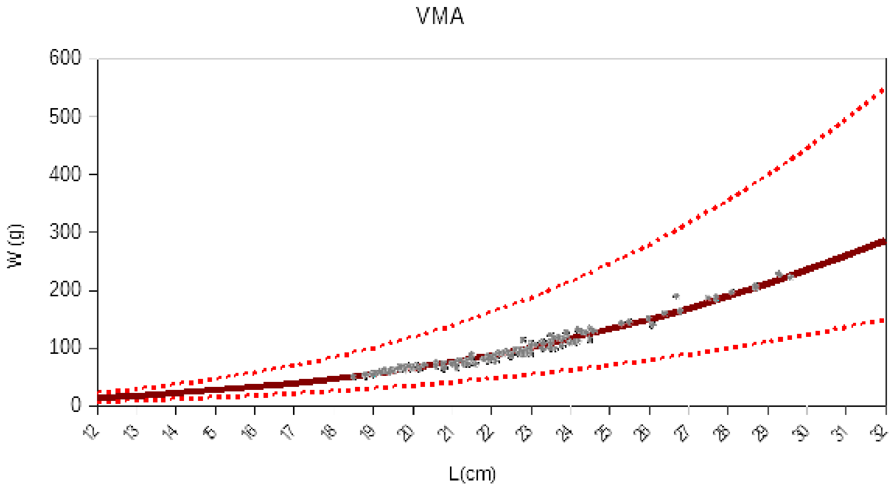


Figure 10 Length weight relationship for chub mackerel used for assessment purposes. Grey dots are individual measurements; dotted red lines represent 95% confidence intervals.

4.2.4 Acoustic assessment

The total energy attributed to the main species (*Table 6*) as well as the centre of gravity (*Figure 11*) using as coordinates the distance from the origin, located at 37ºN and depth were calculated for IBERAS0922. Most NASC was allocated to sardine (88%), of which 62% was allocated to juveniles (PIL_PET) and 26% to adult fish (PIL). Only 4% of NASC was allocated to anchovy and 3% to chub makerel. The other pelagic species altogether comprised less than 5% of the NASC allocated to fish.

Table 6 Total NASC allocated to the main pelagic species together with the location of the coordinates of the center of gravity (PIL_PET, juvenile sardine; MAC, mackerel; HOM, horse mackerel; PIL, sardine; VMA, chub mackerel; SEAB, seabream; ANE, anchovy; SNS, longspine snipefish; KRILL, euphasidae; MAV, pearlside Maurolicus spp.)

	PIL_PET	MAC	HOM	PIL	VMA	SEAB	ANE	SNS	KRILL	MAV
NASC	160655	1	3974	68689	8649	2708	9377	990	40	4562
Depth	34	30	77	26	52	125	36	42	54	50
s.d.	6.94	7.67	26.43	12.96	23.20	6.92	7.97	5.26	1.32	3.02
ic	1.10	1.22	4.19	2.05	3.68	1.10	1.26	0.83	0.21	0.48
Dist	229.02	255.70	185.54	266.32	119.84	81.74	233.99	70.70	296.72	291.95
s.d.	25.02	30.25	59.22	49.88	35.87	3.18	39.44	1.39	1.94	0.90
ic	3.96	4.79	9.38	7.90	5.68	0.50	6.25	0.22	0.31	0.14

Figure 11 shows the spatial distribution of the center of gravity as well as the cumulated NASC along distance from the origin. Chub mackerel is clearly located in the 9aCS subdivision, while anchovy, sardine and horse mackerel were more abundant in the north-central subdivision (9aCN). Anchovy was found in deeper waters (~ 75 m) than sardine (~30 m). The center of gravity of juvenile sardine was located more offshore than adult sardine.

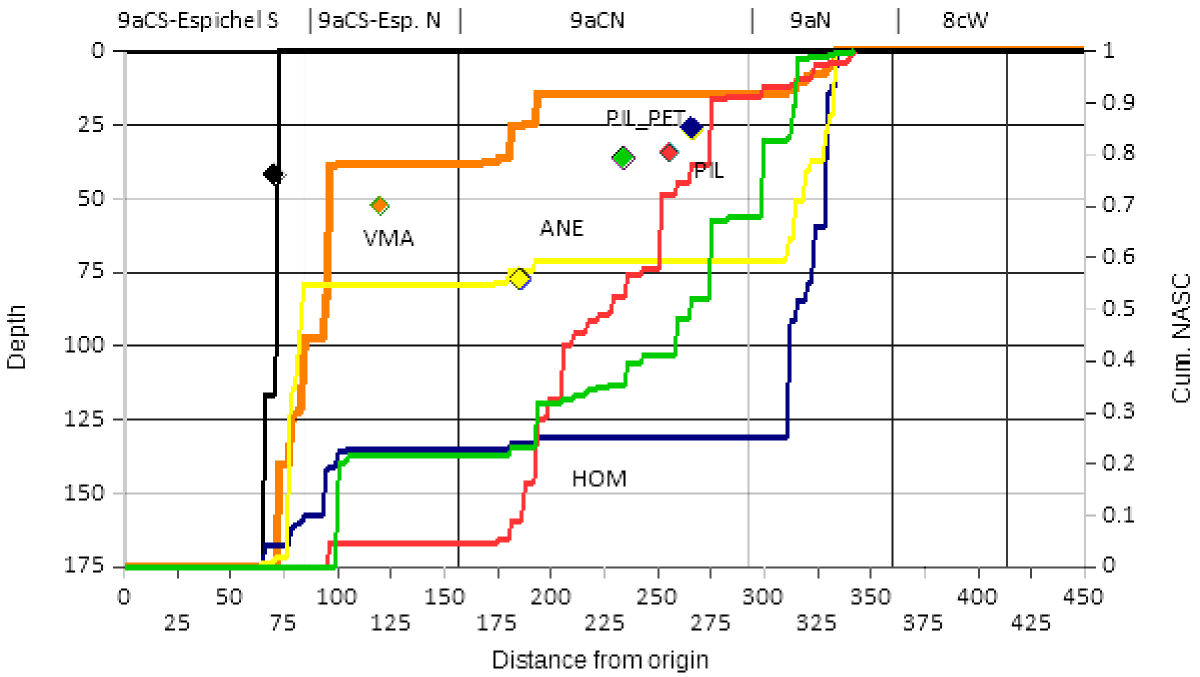


Figure 11 Center of gravity and cumulated NASC for the most important pelagic species (green-anchovy (ANE), blue-sardine (PIL), yellow-horse mackerel (HOM), red-sardine_juveniles (PIL_PET), orange-chub mackerel (VMA)).

4.2.4.1 Sardine assessment

Sardine assessment was divided in small sardine (juveniles ≤16.0 cm) and big (adult) sardines (>16.0 cm). Although the assessment of adult sardine is not the main goal of the survey, it is shown in Table 7.

A total of 47 540 tonnes of adult sardine were estimated, comprising 675 million individuals (*Table 7*). Adult sardine was found in three main hotspots: inside Rías Baixas (~42.5ºN, Galicia, 9aN), south of Figueira da Foz (~40ºN) and south of Cape Roca (~38.5ºN, near Lisbon) (*Figure 12*). Adult sardine occurred rather near the coast, although some schools were also recorded around the 100m isobath.

Table 7 Summary of the adult sardine assessment (length>16.0cm), by strata, number of positive nautical miles (No), mean NASC value (m2 nmi-2), Surface (nmi2), fishing station used for the estimation and biomass estimated.

	SUMMARY	SURVEY:	IBERAS 0922 SARDINE (L>16 cm)						
ICES-Div	**Region**	**No**	**Mean**	**Surface**	**Fishing st.**	**PDF**	**No (million fish)**	**Biomass (tonnes)**	**Density (Tn/nmi-2)**
9aN	9aN	84	612.94	140		S01	285	22922	164
	Total	**84**	***612.94***	**140**			**285**	**22922**	**164**
9aCN	Oc North	17	93.23	105		S02	41	2224	21
	Total	**17**	***93.23***	**105**			**41**	**2224**	**21**
9aCS	Oc South_Lisboa	10	866.56	62		S03	221	12253	198
	Oc South_Sado	21	329.03	115			127	10142	88
	Total	**10**	***866.56***	**62**			**348**	**22394**	**363**
	Total Spain	***84***	***613***	***140***			***285***	***22922***	**164**
	Total Portugal	***27***	***380***	***167***			***389***	***24619***	**147**
	TOTAL	**111**	***556***	**307**			**675**	**47540**	**155**

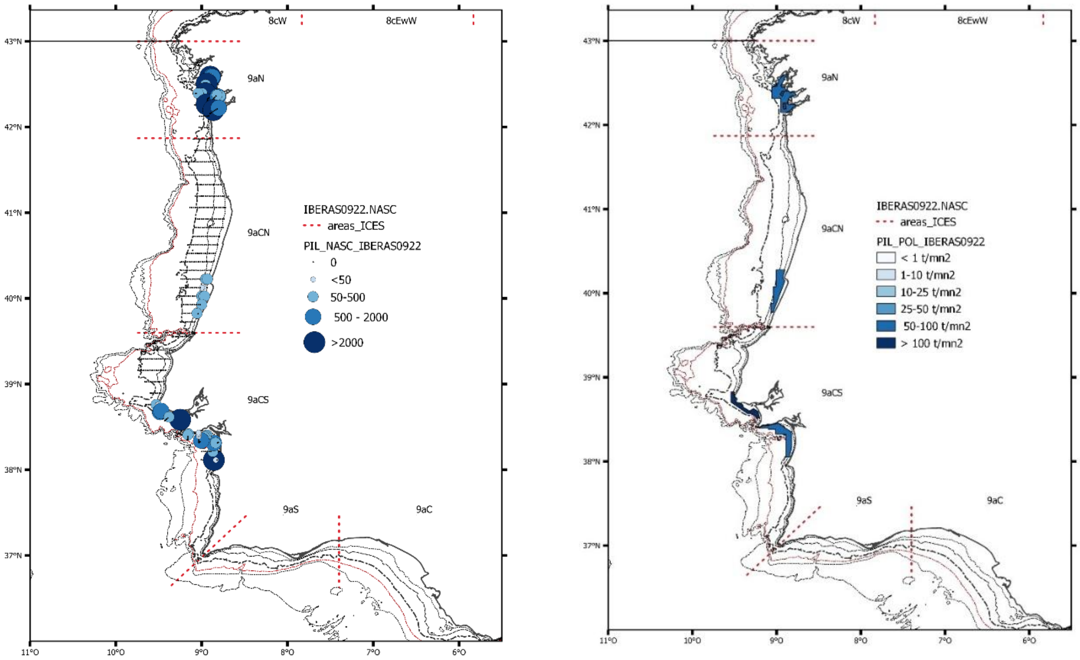


Figure 12 Adult sardine (length> 16.0cm) spatial distribution in IBERAS0922. Left: bubble plot which represent NASC values attributed to sardine (size proportional to abundance). Right: Sardine strata together with the relative density (t/nm^2).

The amount of the juvenile fraction (individuals with length≤16.0cm) of sardine was estimated as ~159 thousand tonnes comprising 8026 million sardines. Juveniles were more abundant in subdivision 9aCN (87.5%), and were located mainly between Porto and Nazaré (*Figure 13*, *Table 8*). A small proportion of them was also found in the mouth of Tagus River (Lisbon) in subdivision 9aCS. No juveniles were found south of Cape Espichel. In the northern part of 9aCN, the low saline waters concentrated in coastal waters (see Fig.2) *pushed* offshore the distribution of small sardine. Mean length of juveniles was 13.4 cm with a modal length of 14 cm, and 99.7% of them were the young of the year (age 0) (*Figure 14*).

Table 8 Summary of the juvenile sardine assessment (length≤16.0cm), by strata, number of positive nautical miles (No), mean NASC value (m^2 nmi^{-2}), Surface (nmi^2), fishing station used for the estimation and biomass estimated.

	SUMMARY								
		SURVEY:	IBERAS 0922 SARDINE (l<16 cm)						
ICES-Div	**Region**	**No**	**Mean**	**Surface**	**Fishing st.**	**PDF**	**No (million fish)**	**Biomass (tonnes)**	**Density (Tn/nmi-2)**
9aN	9aN	30	424.58	213		S01	685	14117	66
	Vigo	3	366.98	3			8	155	57
	Total	**33**	***385.98***	**216**			**692**	**14273**	**124**
9aCN	Oc North	207	673.20	1332		S02	7021	137344	103
	Total	**207**	***673.20***	**1332**			**7021**	**137344**	**103**
9aCS	Oc South	10	745.87	59		S03	313	7248	122
	Total	**10**	***745.87***	**59**			**313**	**7248**	**122**
	Total Spain	***33***	***386***	***216***			***692***	***14273***	**66**
	Total Portugal	***217***	***677***	***1391***			***7334***	***144592***	**104**
	TOTAL	**250**	**638**	**1607**			**8026**	**158865**	**99**

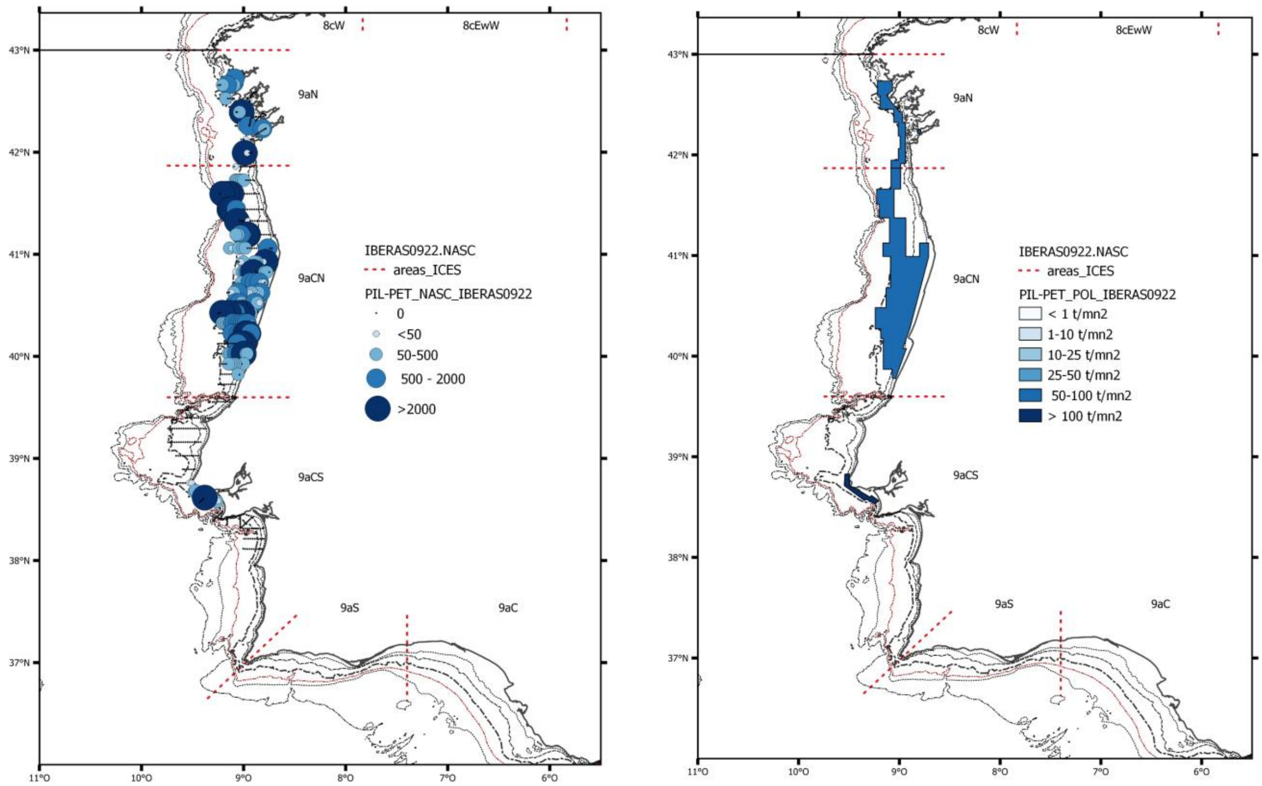


Figure 13 Juvenile sardine (length≤16.0cm) spatial distribution in IBERAS0922. Left: bubble plot which represent NASC values attributed to sardine (size proportional to abundance). Right: Sardine strata together with the relative density (t/nm^2).

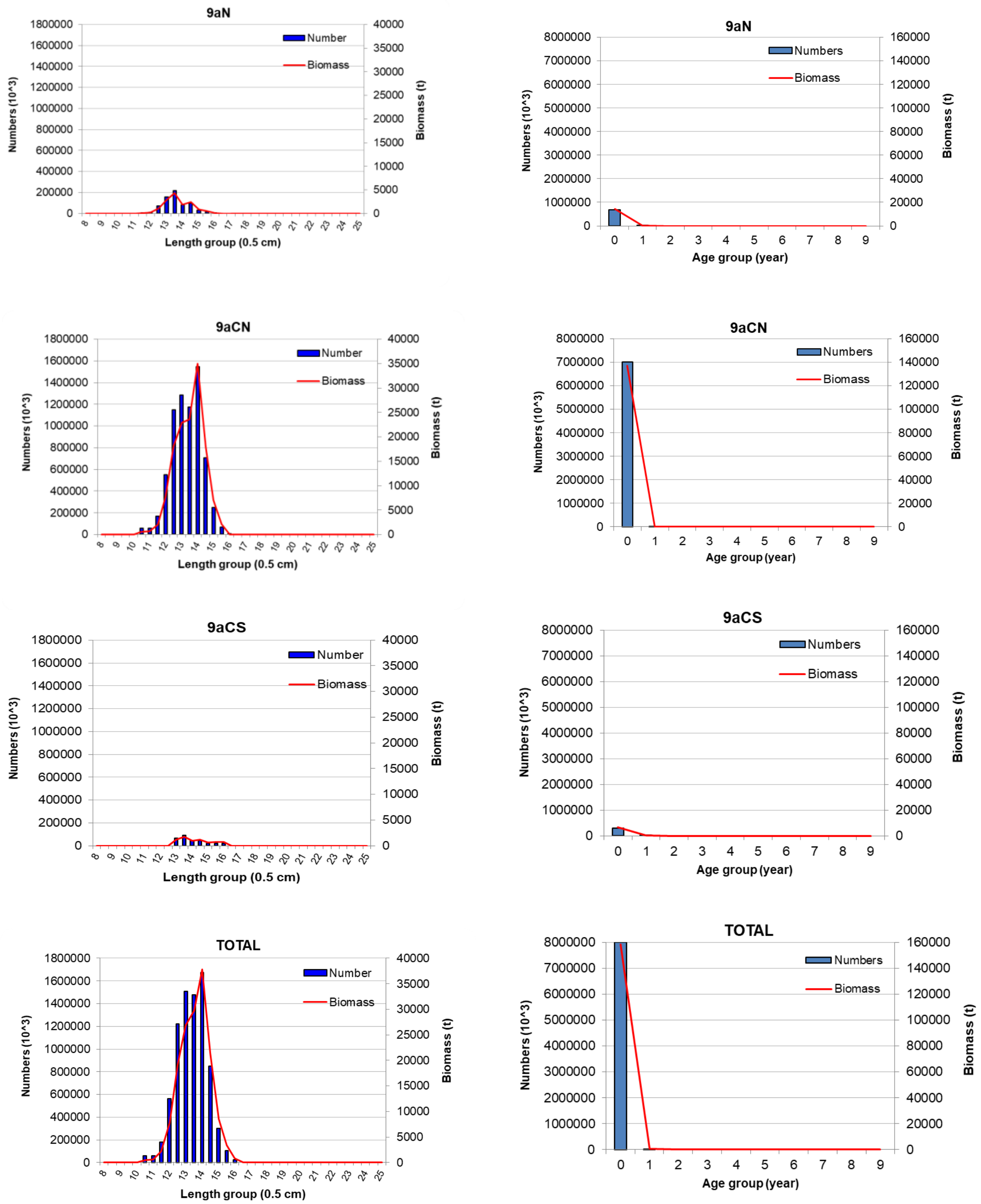


Figure 14 Juvenile sardine (length≤16.0 cm) biomass and abundance estimates by ICES sub-divisions and for the whole area. Left panels in length classes, right panels in age groups.

Sardine stock indicators

The sardine indicators showed are a series of metrics comparing results from years 2018 to 2022 (whole IBERAS data series).

Spatial distribution

The center of gravity calculated for sardine, and as in previous years, was stable around Figueira da Foz (subdivision 9aCN). The mean depth was around the 20 m in most years analysed, except in 2021 where the mean depth was almost 60 m, and the present year where the depth was situated around 35 m (*Figure 15*).

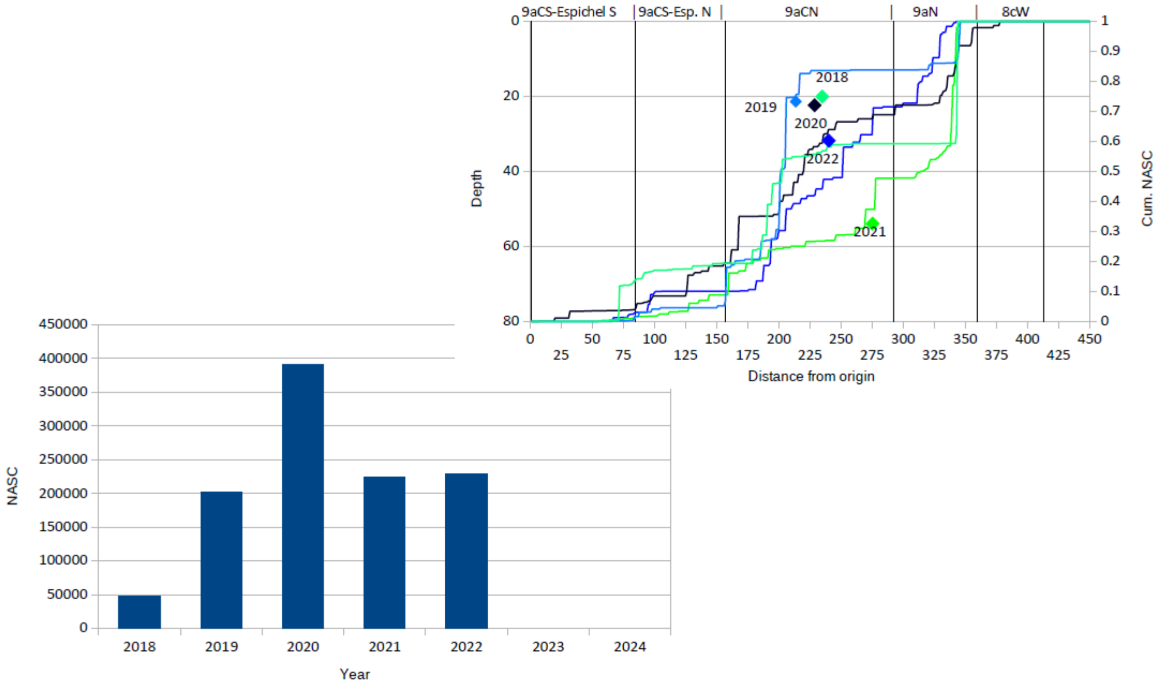


Figure 15 Center of gravity (above right) and the total backscattering energy attributed to sardine (below left). Numbers in the cumulative plot correspond to the ICES sub-divisions.

Recruitment index (2018-2022)

The recruitment index for the present year was the highest of the time series (age 0; 158*10^3 tonnes, 8.0*10^9 fish). In IBERAS0922 we were not able to follow the 2021 cohort (

Figure 16).

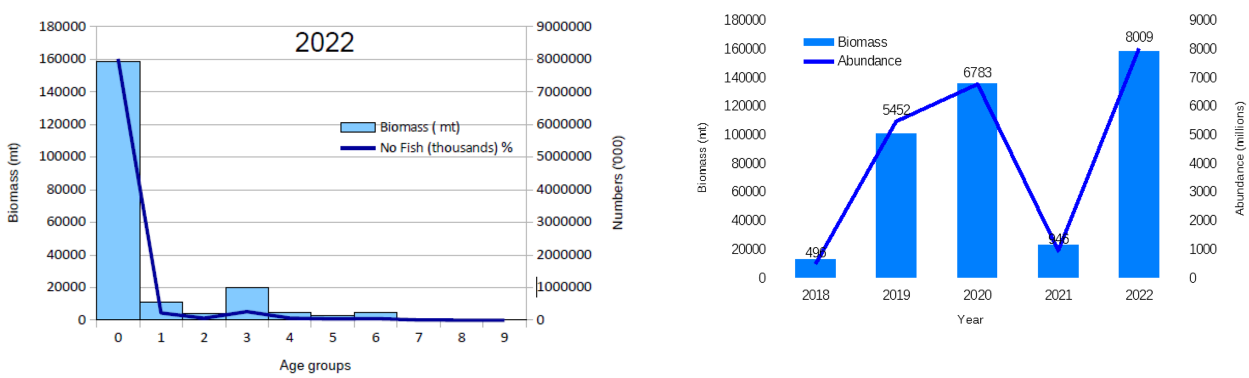


Figure 16 Left: Total biomass and abundance by age estimated from the IBERAS0922 survey. Right: Time series of sardine 0-group biomass and abundance derived from IBERAS surveys. The bars indicate biomass (in tonnes), the lines and numbers indicate abundance (in millions).

Length and weight evolution (2018-2022)

The sardine mean length through the years showed a peak in 2021 and decreased again in 2022. The same pattern was observed in the mean weight. Throughout the years, the length and weight anomaly for age class 0 was negative until 2020, then positive and in 2022 showed again a negative trend (*Figure 17*).

Figure 17 Mean length(cm) and mean weight (g) by year (upper plots). Length anomality (cm) and weight anomality (g) by years and age class (lower plots)

4.2.4.2 Anchovy assessment

The assessment of anchovy was not divided in juvenile and adults. Anchovy was mainly concentrated in subdivision 9aCN (51%) and in 9aN (35%, in particular in the southern part). The estimated biomass for anchovy in 2022 was 7639 tonnes and 482 million fish (*Table 9* and

Figure 18), which was a significant decrease in relation to the previous year.

Table 9 Summary of the anchovy 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.*

SUMMARY

SURVEY: IBERAS0922 ANCHOVY

Zone	Area	No	Mean	Area	Fishing st.	No (million fish)	Biomass (tonnes)	Density (Tn/nmi-2)
9aN	9aN_RB	78	9.31	104	PE03	6	135	1
	9aN_Plat	30	76.05	213	PE05	162	1790	8
	Total	***108***	***27.85***	***317***		***168***	***1925***	**6**
9aCN	9aCN_N	106	32.02	741	PE01-PE02-PE10	216	2735	4
	9aCN_S	14	66.22	77	PE11-CE09	29	737	10
	Total	***120***	***36.01***	***818***		***244***	***3471***	**4**
9aCS	9aCS	4	511.76	29	PE15	70	2243	78
	Total	**4**	**512**	**29**		***70***	***2243***	78
	Portugal	***124***	***51***	***847***		***412***	***5396***	**6**
	Spain	***108***	***28***	***317***		***70***	***2243***	**7**
	TOTAL	**232**	***40.42***	**1164**		**482**	**7639**	**7**

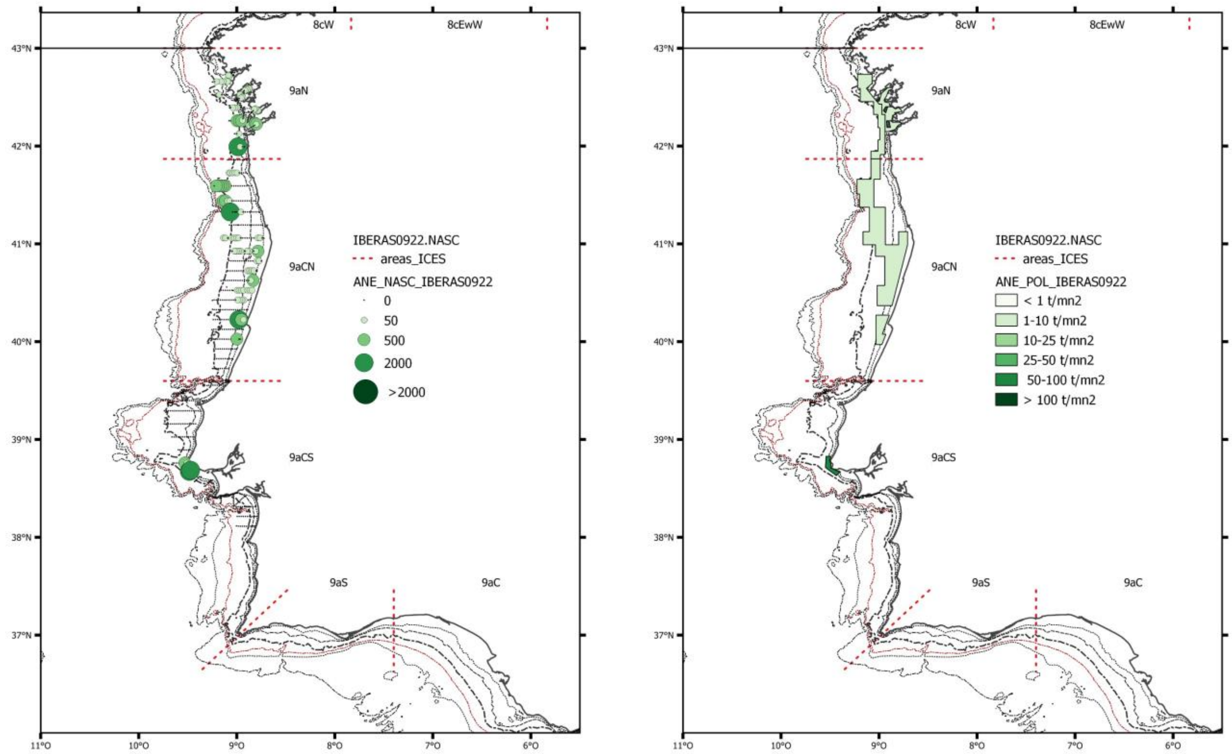


Figure 18 *Anchovy spatial distribution in IBERAS 0922. Map on the left: bubble plots which represent the NASC values attributed to anchovy (size proportional to abundance). Map on the right: strata used together with the relative density.*

Mean length of anchovy was 13.5 cm and most anchovy was age 0. Mean length was lower in subdivision 9aN (12.1 cm). The young of the year (age 0) were located both in subdivisions 9aN and 9aCN (Figure 18), and ages 1 and 2 anchovies in subdivision 9aCS.

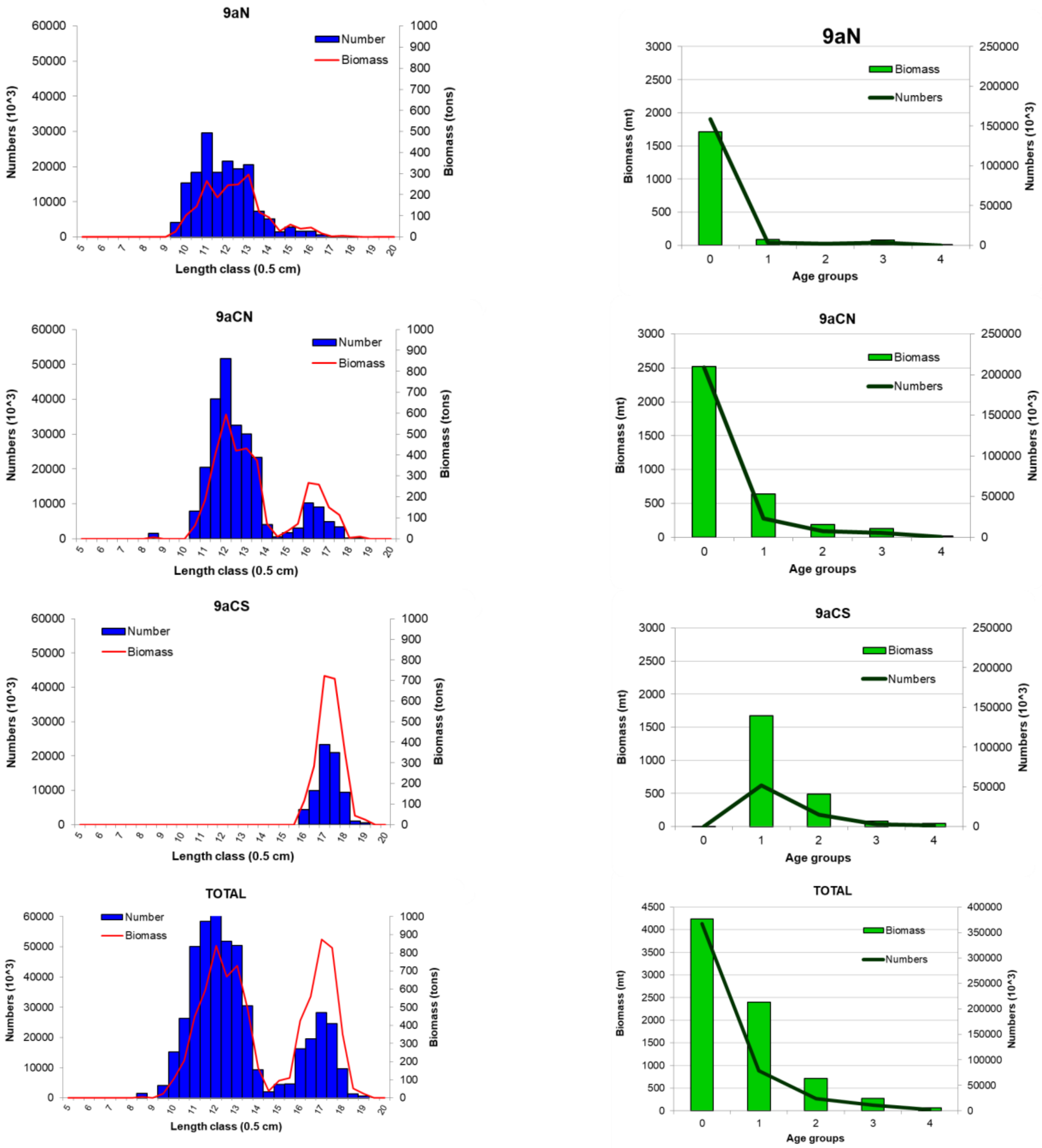


Figure 18 Anchovy biomass and abundance estimates by ICES sub-division (9aN,9aCN,9aCS) and the total for the whole area. Left panels in length classes, right panels in age groups.

Anchovy stock indicators

The anchovy indicators show a series of metrics comparing results from years 2018 to 2022 (whole IBERAS data series).

Spatial distribution

The center of gravity calculated for anchovy, and as in previous years was located in subdivision 9aCN. However, the mean depth for this year was a little bit deeper (around 38m), compared with previous years (mean depth around 20m; (*Figure 19)*. The total backscattering energy attributed to anchovy throughout the IBERAS time series have been decreasing since 2018 (beginning of this surveys). The value found in 2022 is comparable to 2020.

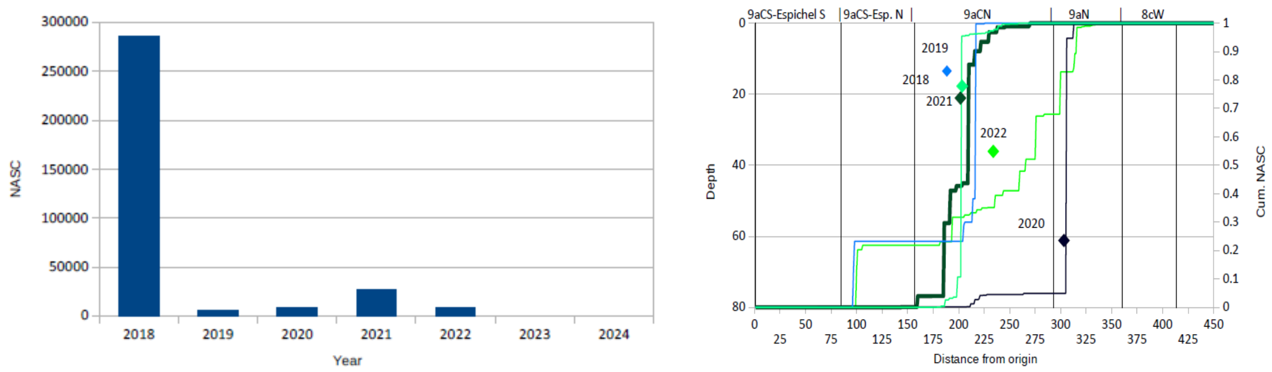


Figure 19 Total backscattering energy attributed to anchovy through the IBERAS time series (left). Center of gravity (right). Numbers in the cumulative plot correspond to the ICES sub-divisions.

Length and weight evolution (2018-2022)

The anchovy mean length through the years showed maximum values in 2019 and 2021 and decreased again this year. The same pattern was observed in the mean weight (*Figure 20*).

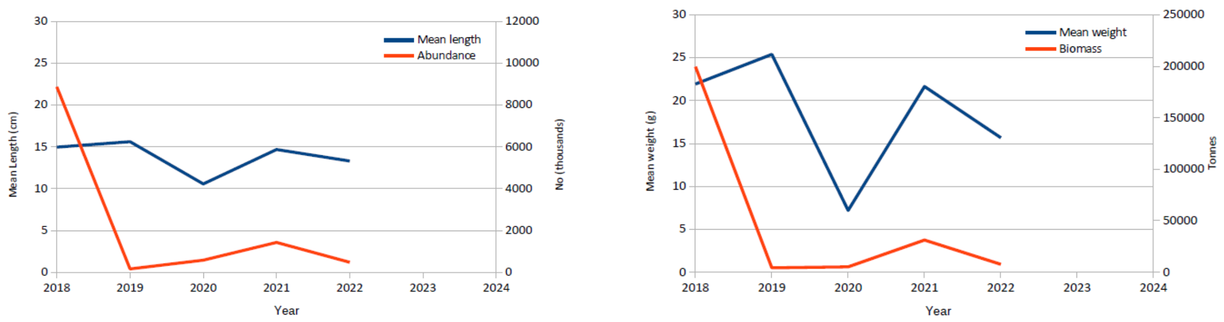


Figure 20 Mean length(cm)(left) and mean weight (g)(right) by year.

4.2.4.3 Chub mackerel assessment

Chub mackerel was located in the south (subdivision 9aCS), with some anecdotal fish found also in the north inside Rias Baixas. The chub mackerel assessment for this year was 4554 tonnes, corresponding to $64*10^6$ fish (*Table 10* and *Figure 21*). Size of chub mackerel varied between 17 and 27 cm (mean length = 20.6 cm) and most fish were young of the year (age 0) (*Figure 22*).

Table 10 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 0922 CHUB MACKEREL						
Zone	**Area**	**No**	**Mean**	**Surface**	**Fishing st.**	**PDF**	**No (million fish)**	**Biomass (tonnes)**	**Density (Tn/nmi-2)**
9aCS	Sines	30	126.96	152.14	P09-P10-P14-P16	ST01	27	1929	13
	Lisboa	10	293.20	61.75	P13-P14-P15	ST02	26	1734	28
	Total	***40***	***169***	***214***			***52***	***3663***	17
9aCN	9aCN	17	69.33	105.39	P09-P10-P14-P16	ST01	10	724	7
	Total	***17***	***69***	***105.4***			***10***	***724***	7
9aN	9aN	93	6.68	232.77	P09-P10-P14-P16	ST01	2	166	1
	Total	***93***	***7***	***233***			***2***	***166***	1
	Total Portugal	***57***	***139***	***319***			***62***	***4387***	14
	Total Spain	***93***	***7***	***233***			***2***	***166***	1
	Total	***150***	***57***	***552***			***64***	***4554***	8

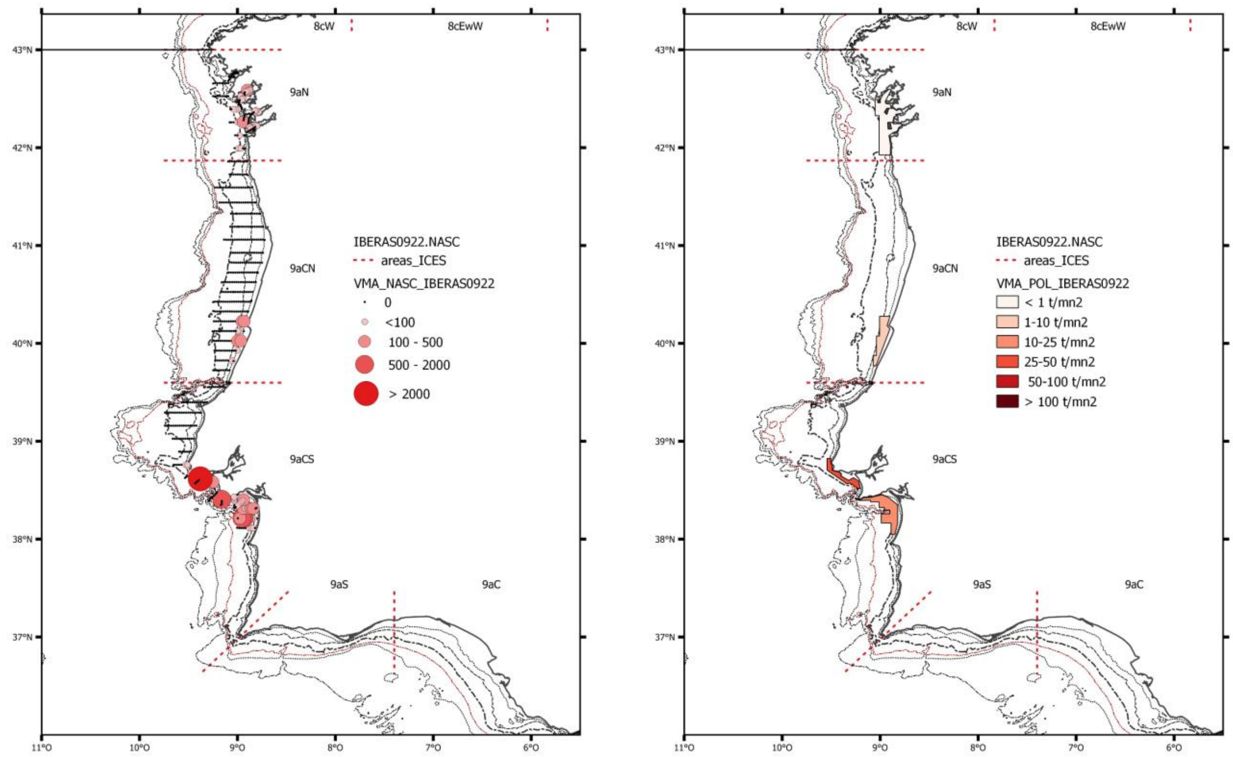


Figure 21 Chub mackerel spatial distribution in IBERAS0922. Left map:bubble plot that represent NASC values attributed to chub mackerel (size proportional to abundance). Right map: strata together with the relative density.

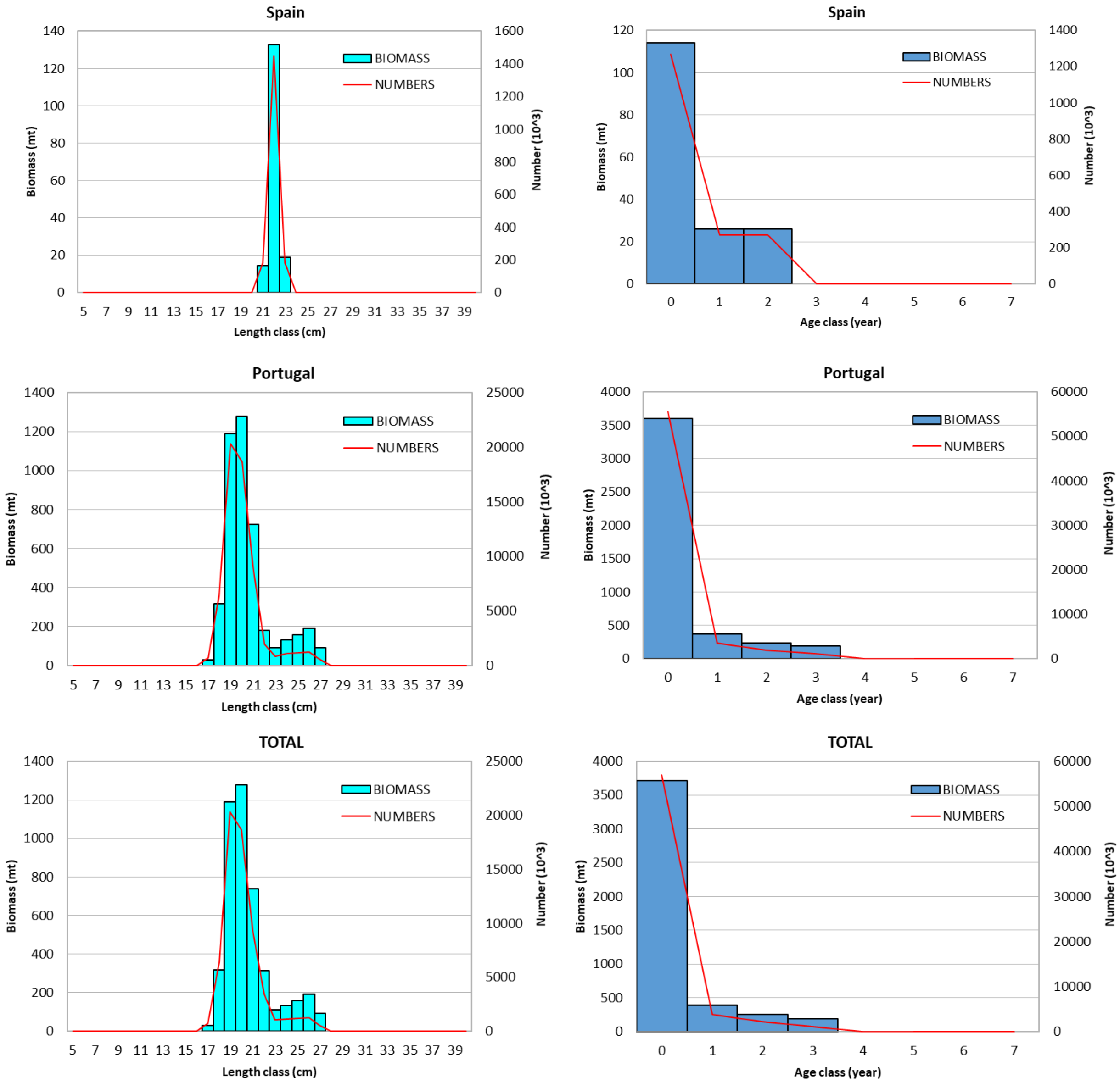


Figure 22 Chub mackerel biomass and abundance estimates by country (Spain,Portugal) and the total for the whole area. Left panels in length classes, right panels in age groups.

4.3 Apical predators

The total observation effort was around 63 hours. Seabirds of 22 different species were observed on all the transects carried out during the IBERAS0922 survey. The highest densities of birds were observed at the mouth of the River Tagus (close to Lisbon). The northern gannet (*Morus bassanus*) was observed in practically the entire study area (*Table 11*, *Figure 24*). Marine mammals were also observed throughout the area, with 2 species observed, most of which were common dolphins (*Delphinus delphis*) (*Figure 25*). As for marine reptiles, no individuals from this group were observed.

Table 11. Densities and total number of individuals of marine birds, mammals and reptiles estimated in IBERAS0922.

	Mean density (number.km-2)	SD	Minimum count	Maximum count	Total number
Northern Gannet, *Morus bassanus*	4.01	26.66	0	365	1404
Total marine birds	8.22	28.27	0	366	2454
Common dolphin, *Delphinus delphis*	0.59	2.64	0	27	161
Total marine mammals	0.6	2.64	0	27	166

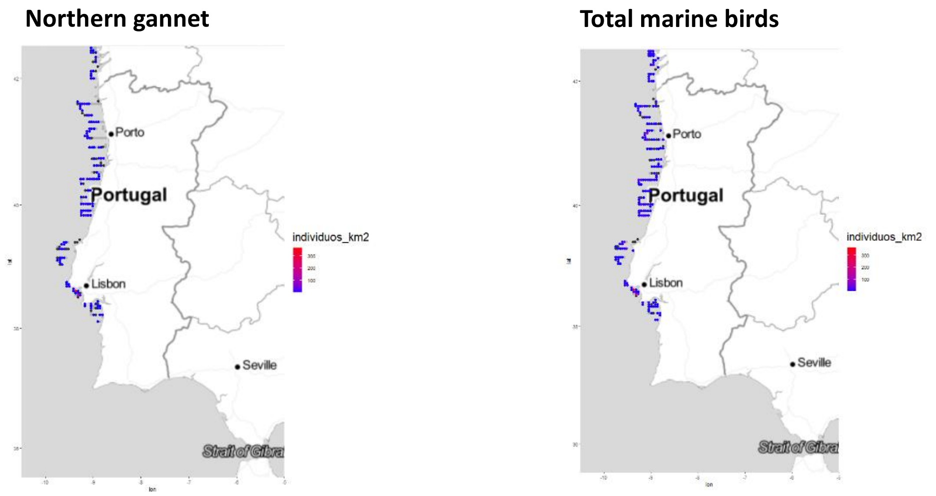


Figure 23. Distribution and density of the Northern Gannet, Morus bassanus (left) and seabirds (right).

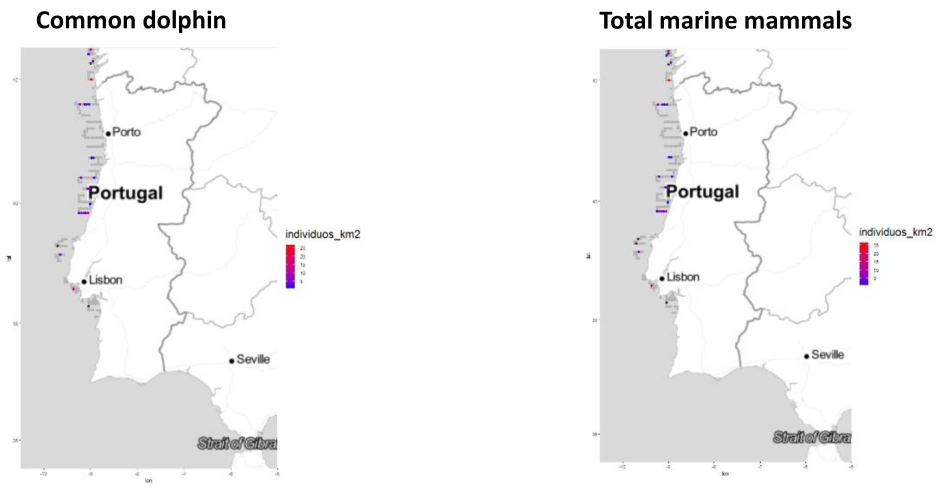


Figure 24. Distribution and density of the common dolphin, Delphinus delphis (left) and marine mammals (right).

5 DISCUSSION AND CONCLUSIONS

This year, the survey reached its fifth year of the 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 (the prime objective).

Sardine assessment was divided in small (juveniles ≤16.0 cm) and big (adult) sardines (>16.0 cm). Biomass estimates for adult sardine achieved 47540 metric tonnes that corresponds to $6.75*10^8$ fish. The most representative was age group 0, which accounted for $158*10^3$ million tonnes ($8.0*10^9$ fish), the highest recruitment index of the time series. The center of gravity was found around Figueira da Foz, with a large dispersion.

Biomass estimates for anchovy was 7639 metric tonnes that corresponds to 482 million fish. Most of the surveyed population was composed of small individuals of age 0 (young of the year). Anchovy was mostly found in the Northern part (9aN and 9aCN). As usual, the center of gravity was found in 9aCN subdivision.

The chub mackerel assessment was 4554 tonnes, corresponding to 64*106 fish. In the present survey no assessment for other important pelagic species in the community, such as horse mackerel and mackerel, was provided due to their low presence in the surveyed area.

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 5 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).

6 ACKNOWLEDGEMENTS

We would like to thank the captain and the crew of R/V Angeles Alvariño for this great cooperation. We also thank the Spanish and Portuguese scientific team that participate the surveys and other colleagues from IEO and IPMA which participated in the post possessing of survey samples and data.

IBERAS is an acoustic-trawl survey developed in cooperation between the Instituto Português do Mar e da Atmosfera (IPMA) and the Instituto Español de Oceanografía (IEO).

7 CONSULTED BIBLIOGRAPHY

Barange, M., Hampton, I. And Soule, M. 1996 Empirical determination of in situ target strength of three loosely aggregated pelagic fish species. ICES Journal of Marine Science, 53: 225-232.

Barange, M., and Hampton, I. 1997. Spatial structure of co-occurring anchovy and sardine populations from acoustic data: implications for the survey design. FisheriesOceanography, 6(2): 94-108.

Boyra, G., Martínez, U., Cotano, U., Santos, M., Irigoien, X., and Uriarte, A. 2013. Acoustic surveys for juvenile anchovy in the Bay of Biscay: abundance estimate as an indicator of the next year's recruitment and spatial distribution patterns. ICES Journal of Marine Science. doi.10.1093/icesjms/fst096.

Carrera, P. and Porteiro, C. 2003. Stock dynamic of the Iberian sardine (Sardinapilchardus, W.) and its implication on the fishery off Galicia. Scientia Marina., 67 (Suppl. 1): 245-258.

Carrera, P., Churnside, J. H., Boyra, G., Marques, V., Scalabrin, C., and Uriarte, A. 2006.Comparison of airborne lidar with echosounders: a case study in the coastal Atlantic waters of southern Europe. ICES Journal of Marine Science, 63: 1736-1750.

Cochran, W.G. (1977). Sampling Techniques (third edition). John Wiley and Sons, New York, 428 pp.

Coetzee, J. 2000. Use of a shoal analysis and patch estimation system (SHAPES) to characterise sardine schools. Aquat. Living Resour., 13, 1-10.

Coetzee, J. C., Misund, O. A., and Oechslin, G.2001. Variable spatial structure of schooling pelagic fish off Namibia: implications for acoustic surveys. African Journal of Marine Science, 23 (1): 99–109.

De Robertis, A., McKelvey, D. R., and Ressler, P. H. 2010. Development and application of an empirical multifrequency method for backscatter classification. Canadian Journal of Fisheries and Aquatic Sciences, 67: 1459–1474.

Diner,N., Weill, A., Coail, J. Y., and Coudeville, J. M. 1989. INES-MOVIES: a new acoustic data acquisition and processing system. ICES CM 1989/B:45. 11pp.

Dragesund, O. and Olsen, S. 1965. On the possibility of estimating year-class strength by measuring echo-abundance of 0-group fish. Fiskeridir. Skr. Havundersøk., 13:47-75.

Dressel, S. H., and Norcross, B. L. 2005. Using poststratification to improve abundance estimates from multispecies surveys: a study of juvenile flatfishes. Fish. Bull. 103:469-488.

Edwards, J. I., F. Armstrong. 1984. Herring, mackerel and sprat target strength experiments with behavioural observations. ICES CM 1984/B:34. 21 pp.

Fässler, S. M. M. 2008. target strength variability in atlantic herring (clupeaharengus) and its effect on acoustic Abundance estimates. Ph. Thesis. University of St. Andrews. http://hdl.handle.net/10023/1703. 277 pp.

Fässler, S. M. M., O'Donnell, C., and Jech, J.M. 2013. Boarfish (Caprosaper) target strength modelled from magnetic resonance imaging (MRI) scans of its swimbladder. ICES Journal of Marine Science, 70: 1451–1459.

Foote, K. G., Aglen, A., and Nakken,O. 1986. Measurement of fish target strength with a split-beam echo sounder. J. Acoust. Soc. Am. 80 (2), 612-621.

Foote K.G., 1987. Fish target strengths for use in echo integrator surveys. J. Acoust. Soc. Am., 82: pp. 981-987.

Frouzova, J., Kubecka, J., Balk, H., and Frouz, J. 2005. Target strength of some European fish species and its dependence on fish bodi parameters. Fisheries Research, 75: 86-89.

Georgakarakos, S., Trygonis, V., and Haralabous, J. 2011. Accuracy of Acoustic Methods in Fish Stock Assessment Surveys. Sonar Systems, Prof. Nikolai Kolev (Ed.), ISBN: 978-953-307-345-3, InTech. Pp 275-298.

Gorska, N., Korneliussen, R. J., and Ona, E. 2007. Acoustic backscatter by schools of adult Atlantic mackerel. – ICES Journal of Marine Science, 64: 1145–1151.

Gutiérrez, M., y MacLennan, D. N., 1998. Resultados preliminares de las mediciones de Fuerza de Blanco in situ de las principales especies pelágicas. Crucero BIC Humboldt 9803-05 ded

Tumbes a Tacna. Inf. Inst. Mar Perú, no. 135:16-19.

Halldórsson, O. and Reynisson, P. 1983. Target strength measurements of herring and capelin "in situ" at lceland. FAO Fish. Rep. 300: 78-84.

Hannachi, M.S., Ben Abdallah, L., and Marrakchi, O. 2005. Acoustic identification of small pelagic fish species: target strength analysis and school descriptor classification, MedSudMed Technical Documents 5: 90–99.

Henderson, M. J. 2005. The influence of orientation on the target strength of pacific hake (Merlucciusproductus). Master Thesis. University of Washington.

Henderson, M. J., Horne, J. K., and Towler, R. H. 2007. The influence of beam position and swimming direction on fish target strength. ICES Journal of Marine Science, 65: 226–237.

Henderson M. J., and Horne J. K. 2007. Comparison of in situ, ex situ, and backscatter model estimates of Pacific hake (Merlucciusproductus) target strength. Canadian Journal of Fisheries and Aquatic Sciences, 64: 1781–1794.

Huse, I. and Ona, E. 1996. Tilt angle distribution and swimming speed of overwinteringNorwegian spring-spawning herring. – ICES Journal of Marine Science, 53:863–873.

Korneliussen, R. J., and Ona, E. 2003. Synthetic echograms generated from the relative frequency response. ICES Journal of Marine Science, 60: 636–640.

Korneliussen, R. J., Diner, N., Ona, E., Berger, L., and Fernandes, P. 2008. Proposals for the collection of multifrequency acoustic data. ICES Journal of Marine Science. 65: 982-994.

Korneliussen, R. J., Heggelund, Y., Eliassen, I. K., and Johansen, G. O. 2009. Acoustic species identification of schooling fish. ICES Journal of Marine Science, 66: 1111–1118.

Lillo S., Cordova J. &Paillaman A., 1996. Target-strength measurements of hake and jack mackerel. ICES Journal of Marine Science, 53: pp. 267-272.

MacCall, A. D. (1990). The dynamic geography of marine fish populations. In Recruitment fishery oceanography. (Washington Sea Grant, University of Washington Press, Seattle, 153 pp).

Machias, A. and Tsimenides, N. Anatomical and physiological factors affecting the swim-bladder cross-section of the sardine Sardinapilchardus. Canadian Journal of Fisheries and Aquatic Science, 53:280-287.

Martins, M. M., Skagen, D., Marques, V., Zwolinski, J., and Silva, A. 2013. Changes in the abundance and spatial distribution of the Atlantic chub mackerel (Scombercolias) in the pelagic ecosystem and fisheries off Portugal. Scientia Marina 77(4) December 2013, 551-563.

McClatchie, S., Thorne, R. E., Grimes, P. &Hanchet, S. 2000. Ground truth and target identification for fisheries acoustics. Fisheries Research, 47, 173-191.

Muiño, R., Carrera, P., Petitgas, P., Beare, D. J., Georgakarakos, S., Haralambous, J., Iglesias, M., Liorzou, B., Massé, J., and Reid, D. G. 2003. Consistency in the correlation of school parameters across years and stocks. ICES Journal of Marine Science, 60: 164–175.

Muiño, R., Carrera, P., and Iglesias, M. 2003. The characterization of sardine (SardinapilchardusWalbaum) schools off the Spanish-Atlantic coast. – ICES Journal of Marine Science, 60: 1361–1372.

Nakken, O. and Dommasnes A. 1975. The application for an echo integration system in investigations on the stock strength of the Barents Sea capelin (Mallotusvillosus, Müller) 1971-74. ICES CM 1975/B:25.

Nakken O. &Dommasnes A., 1977. Acoustic estimates of the Barents Sea capelin stock 1971–1976. ICES CM, 1977/H:35.

Ona, E. 1990. Physiological factors causing natural variations in acoustic target strength of fish. J. mar. biol. Ass. U.K., 70: 107-127.

Patti, B., Mazzola, S.; Calise, L., Bonanno, A., Buscaino, G., and Cosimi, G. 2000. Echo-survey estimates and distribution of small pelagic fish concentrations in the Strait of Sicily during June 1998. GFCM/ SAC Working Group on Small Pelagics, Fuengirola, Spain, 1–3 March 2000. 8 pp.

Pedersen, G., Godø, O. R., Ona, E., and Macaulay, G. J. 2011. A revised target strength–length estimate for blue whiting (Micromesistiuspoutassou): implications for biomass estimates. ICES Journal of Marine Science, 68: 2222–2228.

Petitgas, P., Massé, J., Beillois, P., Lebardier, E., and Le Cann, A. 2003. Sampling variance of species identification in fisheries-acoustic surveys based on automated procedures associating acoustic images and trawl hauls. ICES Journal of Marine Science, 60: 437-445.

Pitcher T. J. 1983. Heuristic definitions of shoaling behaviour. Anim. Behav., 31, 611-13.

Pitcher, T. J. 2001. Fish schooling: implications for pattern in the oceans and impacts on human fisheries. In: Encyclopedia of Ocean Sciences (Ed. By J. H. Steele, K. K. Turekian& S. A. Thorpe), pp. 975–987. London: Academic Press.

Porteiro, C., Carrera, P., and Miquel, J. 1996. Analysis of Spanish acoustic surveys for sardine, 1991-1993: abundance estimates and inter-annual variability. ICES Journal of Marine Science, 53: 429-433.

Reid, D. (ed.) 2000. Report on echo-trace classification. ICES Cooperative Research Report no 238, 107 pp.

Reid, D., Scalabrin, C., Petitgas, P., Massé, J., Aukland, R., Carrera, P., and Georgakarakos, S. 2000. Standard protocols for the analysis of school based data from echosounder surveys. Fisheries Research, 47: 125-136.

Scalabrin, C. 1997. Identification acoustique des espèces pélagiques à partir d'attributs discriminants des bancs de poissons monospécifiques. Thèse du Doctorat en Océanographie Biologique: Université de Brétagne Occidentale de Brest.

Simmonds, E. J., Williamson, N. J., Gerlotto, F., and Aglen, A. 1992 Acoustic survey design and analysis procedure: a comprehensive review of current practice. ICES Cooperative Research Report no 187. 127 pp.

Simmonds, E. J. & MacLennan, D. N. 2005. Data analysis. In Fisheries Acoustics: Theory and Practice.Oxford: Blackwell.

Simmonds E. J. and MacLennan, D. 2005. Survey design in Fisheries Acoustics. Theory and practice. 2nd edition. Blackwell Science.

Simmonds, E.J., Gutiérrez, M., Chipollini, A., Gerlotto, F., Woillez, M., and Bertrand, A. 2009. Optimizing the design of acoustic surveys of Peruvian anchoveta. ICES Journal of Marine Science, 66: 1341–1348.

Stanton, T. K., Chu, D., Jech, J. M., and Irish, J. D. 2010. New broadband methods for resonance classification and high-resolution imagery of fish with swimbladders using a modified commercial broadband echosounder. – ICES Journal of Marine Science, 67: 365–378.

Swain, D. P., Sinclair, A.F. 1994. Fish Distribution and Catchability: what is the appropriate measure of distribution?. Can. J. Fish. Aquat. Sci. 51:1046-1054.

Woillez, M., Poulard, J-C., Rivoirard, J., Petitgas, P., and Bez, N. 2007. Indices for capturing spatial patterns and their evolution in time, with application to European hake (*Merluccius merluccius*) in the Bay of Biscay. ICES Journal of Marine Science, 64: 537–550.

Woillez, M., Rivoirard, J., and Fernandes, P. G. 2009. Evaluating the uncertainty of abundance estimates from acoustic surveys using geostatistical simulations. ICES Journal of Marine Science, 66: 1377–1383.

Zar, J. H. (1984). Biostatistical Analysis. 2nd edition. Prentice-Hall, Inc.

Zwolinski, J. 2007. Estimação acústica da distribuição e abundância de sardinha, Sardina pilchardus. Tesis doctoral. Universidade de Aveiro. Departamento de Biologia. 147pp.

IPMA

Instituto Português
do Mar e da Atmosfera