WORKING GROUP ON ACOUSTIC AND EGG SURVEYS FOR SARDINE AND ANCHOVY IN ICES AREAS 7, 8 AND 9 (WGACEGG; outputs from 2019 meeting)

VOLUME 2 | ISSUE 44

ICES SCIENTIFIC REPORTS

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ISSN number: 2618-1371 I

ICES Scientific Reports

Volume 2 | Issue 44

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Recommended format for purpose of citation:

ICES. 2020. Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES areas 7, 8 and 9 (WGACEGG; outputs from 2019 meeting)
ICES Scientific Reports. 2:44. 490 pp. http://doi.org/10.17895/ices.pub.6025

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Contents

i Executive summary

The Working Group on Acoustic and Egg Surveys (WGACEGG) coordinates pelagic surveys for a number of stocks and provides monitoring for the two major sardine and anchovy stocks in ICES areas 6, 7, 8, and 9.

The group evaluated small pelagic fish biomass indices derived from acoustic and Daily Egg Production Method (DEPM) surveys in ICES areas 6, 7, 8 and 9. These indices have been provided to the ICES Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA), the Working Group on Widely Distributed Stocks (WGWIDE) and the Herring Assessment Working Group for the Area South of 62ºN (HAWG) stock assessment group, to serve as fishery-independent input for analytical assessment purposes. DEPM and acoustic indices were derived based on data collected using independent methods.

Acoustic- and DEPM-derived biomass indices from quasi-synoptic surveys conducted in the Bay of Biscay in spring were compared, to assess the presence of potential bias and to improve the precision of fish stock biomass estimates. The DEPM-based anchovy biomass index was 22% higher than the acoustic index in 2019. Unusual concentrations of anchovy in Eastern Cantabrian Sea, an area not covered by the acoustic survey, and the presence near the sea surface of actively spawning individuals possibly under-sampled by acoustics in central Bay of Bay had been postulated as potential causes of this discrepancy. No significant difference was found between sardine biomass indices derived from DEPM and acoustics in 2019.

The group has updated its database of standard gridded maps covering the European Atlantic area. This initiative continues to inform on the spatial dynamics of various parameters collected during the surveys coordinated under the auspices of the group (fish acoustic densities, anchovy and sardine egg abundance, surface temperature and salinity). Results of an analysis of the time series of gridded maps (anchovy and sardine acoustic density, surface salinity and temperature) showed quantitative changes in the spatial and temporal distribution of anchovy and sardine over the last 15 years, and further define their habitats in European Atlantic waters in spring.

The timing and spatial coverage of DEPM and acoustic surveys that will be conducted by group members in 2020 were planned to optimise the monitoring of anchovy and sardine populations and their pelagic environment in the European Atlantic area. The synoptic nature of the survey components has been assessed for each target species.

A manual describing the protocols used during the DEPM surveys coordinated by the WGACEGG group was reviewed, and writing of a manual of WGACEGG acoustic surveys continued. Both manuals will be available in 2020. The final results of the 2017 sardine DEPM assessment were endorsed by the group.

ii Expert group information

Expert group name	Working Group on Acoustic and Egg Surveys for small pelagic fish in ICES Areas 6, 7, 8 and 9 (WGACEGG)
Expert group cycle	Multiannual
Year cycle started	2017
Reporting year in cycle	3/3
Chair(s)	Maria Santos, Spain
	Mathieu Doray, France
Meeting venue(s) and dates	3-17 November, Cadiz, Spain, (17 Participants)
	19-23 November, Nantes, France, (30 Participants)
	18-22 November, Madrid, Spain, (21 Participants)

1 Terms of Reference

a	Provide echo-integration and Daily Egg Production Method (DEPM) estimates for sardine and anchovy in ICES sub-Areas 7, 8 and 9	a) Advisory Requirements b) Requirements from other EGs		3 years	Abundance and biomass estimates by age group. Fish spatial distribution will be provided to WGHANSA by the end of the WGACEGG meeting. Datasets will be published in the ICES facility when available.
b	Analyse sardine and anchovy (adults and eggs), spatial and temporal distribution and their habitats in European waters	a) Science Requirements b) Requirements from other EGs	1	Year 3	Manuscript and/or technical report in 2019
c	Provide ecosystem data such as temperature, salinity, plankton diversity, top predators abundances, egg densities and backscattering for sardine, anchovy and other small pelagic fish for pelagic ecosystem monitoring (e.g. MSFD)	a) Science Requirements b) Requirements from other EGs	1	3 years	Gridded maps updated every year. Datasets will be published in the ICES facility when available.
d	Assess developments in the technologies and data analyses for the application of both acoustics and the DEPM (on Egg Production or adult parameters).	a) Science Requirements b) Advisory Requirements c) Requirements from other EGs	27, 28, 31	3 years	New methodologies reported in annual WG report, available to the public one month after the meeting.
e	Improve and assess the suitability of CUFES data for anchovy and sardine egg production estimates in areas 8 and 9.	a) Science Requirements b) Advisory Requirements c) Requirements from other EGs	27, 28, 31	3 years	Advances reported in annual WG report, available to the public one month after the meeting.
f	Coordination and standardization of the surveys	a) Science Requirements b) Advisory Requirements	30, 31	3 years	Annual plan for coordinated surveys. Updated survey protocols
g	Development and standardization of data processing methods for DEPM and acoustics for surveys in Atlantic and Mediterranean waters	a) Science Requirements b) Advisory Requirements c) Requirements from other EGs	30, 31	3 years	Updated data processing protocols shared with the MEDIAS group (Mediterranean acoustic survey group)

h	Provide echo-integration estimates for other species (mainly blue whiting, mackerel, horse mackerel, chub mackerel and boarfish) ICES sub-Areas 8 and 9	a) Advisory Requirements b) Requirements from other EGs	1	3 years	Biomass per age group when available otherwise per length classes and spatial density distribution, provided to WGWIDE before the WG annual meeting. Datasets will be published in the ICES facility when available.
i	Ensure QAQC procedures are in place	ICES aim to have a quality assurance process for data collections used in the provision of advice. One element of this is that all procedures describing the data collection are adequately described.	27, 28, 31	3 years	Develop an independent SISP for the data collection and product specification conducted under the auspices of WGACEGG
j	Compare acoustic and DEPM biomass estimates of anchovy and sardine to improve the precision of stock estimates	a) Science Requirements b) Advisory Requirements c) Requirements from other EGs	1, 27, 28, 30, 31	3 years	Advances reported in annual WG report, available to the public one month after the meeting
k	Develop the use of imagery techniques to characterise the distribution of mesozooplankton (including fish eggs) and possibly microplastics in areas 8 and 9, based on CUFES and/or PairoVET samples.	a) Science Requirements b) Requirements from other EGs		3 years	Advances reported in annual WG report, available to the public one month after the meeting

2 Summary of work plan

Year 1	**Annual meeting:** • **Session on acoustic data collection and analysis** • **Session on DEPM data collection and analysis** • **Session on acoustic and DEPM indices comparison** • **Update of gridded maps of ecosystem data derived from surveys** • **Session on methods for the analysis of series of gridded maps of ecosystem data** • **Session to analyse progress on sardine and anchovy egg production estimates from CUFES**
Year 2	**Annual meeting, including a joint session with MEDIAS (Mediterranean acoustic survey group):** • **Session on acoustic data collection and analysis** • **Session on DEPM data collection and analysis** • **Session on anchovy and sardine eggs staging intercalibration exercises** • **Session on acoustic and DEPM indices comparison** • **Session on survey design** • **Update of gridded maps of ecosystem data derived from surveys** • **Session on methods for the analysis of series of gridded maps of ecosystem data** • **Session to analyse progress on sardine and anchovy egg production estimates from CUFES**
Year 3	**Annual meeting:** • **Session on acoustic data analysis and developments** • **Session on DEPM data analysis and developments** • **Session on anchovy and sardine eggs identification and staging using automated methodologies** • **Session on acoustic and DEPM indices comparison** • **Writing of a report or manuscript on the analysis of series of WGACEGG gridded maps of ecosystem data** • **Session to analyse progress on sardine and anchovy egg production estimates from CUFES** • **Submission of the WGACEGG DEPM and acoustic Survey Protocols (SISP)**

3 List of Outcomes and Achievements of the WG in this delivery period

The following outcomes and achievements were obtained during 2019 by WGACEGG:

Sardine and anchovy biomass indices derived from acoustic and DEPM surveys used as input fishery-independent data for analytical assessment purposes in ICES WGHANSA

- Anchovy total biomass estimated by BIOMAN2019 DEPM survey in 8abcd.
- Anchovy proportion of biomass at age 1 estimated by BIOMAN2019 DEPM survey in 8abcd
- Anchovy daily fecundity (and associated parameters W; F; S; R) in area 8abcd from BIOMAN2019 survey (not explicitly used for the assessment at WGHANSA but of relevance as biological indicators and contributing to the direct SSB inputs)
- Anchovy total daily egg production in area 8abcd from BIOMAN2019 survey (not explicitly used for the assessment at WGHANSA but of relevance as biological indicators and contributing to the direct SSB inputs)
- Anchovy total biomass estimated by PELGAS2019 acoustic survey in 8abd.
- Anchovy proportion of biomass at age 1 estimated by PELGAS2019 acoustic survey in 8abd.
- Anchovy juvenile abundance index estimated by JUVENA2019 acoustic survey in 8abcd.
- Anchovy total biomass estimated by PELAGO19 acoustic survey in 9a
- Anchovy total biomass estimated by ECOCADIZ2019-07 acoustic surveys in 9a south (not included in the 2019 assessment since the WGHANSA-1 meeting is held in June, before the survey).
- Sardine total biomass in 9a from PELAGO19 acoustic survey
- Sardine population in numbers-at-age in 9a from PELAGO19 acoustic survey
- Sardine total biomass in 9a north and 8c from PELACUS0319 acoustic survey
- Sardine population in numbers-at-age in 8c and 9a north from PELACUS0319 acoustic survey
- Sardine total biomass estimated in 8abd from PELGAS2019 acoustic survey.
- Sardine population in numbers-at-age in 8abd from PELGAS2019 acoustic survey
- Sardine total daily egg production in 8c and 9a from SAREVA0317 and PT-DEPM17-PIL (not explicitly used for the assessment at WGHANSA but of relevance as biological indicators and contributing to the direct SSB inputs)
- Sardine daily fecundity (DF)and spawning-stock biomass in 8c and 9a from SAREVA0317 and PT-DEPM17-PIL (DF not explicitly used for the assessment at WGHANSA but of relevance as biological indicators and contributing to the direct SSB inputs
- Sardine spawning stock biomass in 8c and 9a from SAREVA0317 and PT-DEPM17-PIL (final results)
- Sardine egg abundance from BIOMAN 2019 DEPM survey

Other indices used as biological information at the WGHANSA

- Sardine and anchovy distribution and numbers-at-age estimated by PELACUS0319 acoustic surveys in 9aN and 8c
- Sardine and anchovy numbers-at-age in 8abd from PELGAS2019 acoustic survey
- Sardine distribution and numbers- and biomasses-at-age in 9aS from ECOCADIZ2019-07 survey.
- Anchovy numbers-at-age in 8abcd from BIOMAN2019 DEPM survey
- Sardine juvenile abundance index estimated by IBERAS2019 acoustic survey in 9aN-9aCN and 9aCS
- Anchovy juvenile abundance index estimated by IBERAS2019 acoustic survey in 9aN-9aCN and 9aCS
- Sardine total biomass in 7e, f from PELTIC19 acoustic survey
- Sardine population in numbers-at-age in 7e, f from PELTIC19 acoustic survey
- Anchovy total biomass in 7e, f from PELTIC19 acoustic survey
- Anchovy population in numbers-at-age in 7e, f from PELTIC19 acoustic survey

Other biological information used at the WGHANSA

- Sardine maturity ogives and mean weight at age from DEPM (SAREVA0317, PT-DEPM17-PIL) and acoustic surveys (PELAGO17 and PELACUS0317)
- Anchovy mean weight and length-at-age, and biomass at age in 8abcd from BIOMAN2019 and PELGAS2019 surveys
- Sardine mean weight and length-at-age in 8abcd from PELGAS2019 surveys
- Sardine mean weight and length-at-age in 8c and 9a north from PELACUS0319 survey
- Sardine mean weight and length-at-age in 9a from PELAGO19 survey
- Sardine mean weight and length-at-age in 7e, f from PELTIC19 survey
- Anchovy mean weight and length-at-age in 7e, f from PELTIC19 survey

Other acoustic indices used as biological information at the WGWIDE

- Horse mackerel, boarfish, mackerel and blue whiting distribution and numbers-at-age in 9a and 8c from PELACUS0319

Other survey-derived products

- Sardine egg abundances from CUFES sampling during spring acoustics surveys PELAGO19, PELACUS0319 and PELGAS2019
- Sardine egg abundances from CUFES sampling during summer acoustics survey ECOCADIZ2019-07
- Anchovy egg abundances from CUFES sampling during spring acoustics surveys PELAGO19, PELACUS0319 and PELGAS2019
- Anchovy egg abundances from CUFES sampling during summer acoustics survey ECOCADIZ2019-07
- Sardine egg abundances from CUFES sampling during DEPM survey BIOMAN2019
- Anchovy egg abundances from CUFES sampling during DEPM surveys BIOMAN2019

- Sardine total daily egg production Ptot from CUFES from PELGAS2019
- Anchovy total daily egg production Ptot from CUFES from PELGAS2019
- SST and SSS from spring acoustics surveys PELAGO19, PELACUS0319 and PELGAS2019
- SST and SSS from summer acoustics survey ECOCADIZ2019-07
- SST and SSS from DEPM survey BIOMAN2019
- SST and SSS from autumn acoustics surveys PELTIC2019 and JUVENA2019
- Marine birds and mammals, human activities and debris distribution obtained during DEPM survey BIOMAN2019
- Marine birds and mammals census during spring acoustics surveys PELGAS2019, PELACUS0319 and PELAGO19
- Marine birds and mammals census during summer acoustics survey ECOCADIZ2019-07
- Marine birds and mammals census during summer autumn surveys PELTIC20189 and JUVENA2018
- Microplastics distribution and abundance obtained during spring DEPM survey BIOMAN 2019

Other acoustic indices used as biological information at HAWG

- Sprat biomass (CV) estimated for Lyme Bay stock from PELTIC2019 acoustic survey
- Sprat population in numbers at age (CV) for Lyme Bay from PELTIC2019 acoustic survey
- Herring biomass (CV) estimated for the Celtic Sea from CSHAS 2019 acoustic survey
- Herring population in numbers at age (CV) for Celtic Sea from CSHAS 2019 acoustic survey

Grid data/maps Database

The WGACEGG group maintains a database of standardised maps covering the European Atlantic area informing on the spatial dynamics of various parameters collected during the surveys coordinated under the auspices of the group (fish acoustic densities, egg/m^2, egg/m^3, surface temperature and salinity, bird and mammals, etc). These standard maps can be used to compute global indices describing the state of the European Atlantic pelagic ecosystem in spring and autumn. The standard maps and indices produced by WGACEGG could be used within the MSFD framework to compute ecological state indicators. For a detailed list of variables gathered during WGACEGG surveys check **Annex 8.7** of the **2014 Group Report**. The Group will continue to compile the data and will explore its utilization in collaborative studies.

Publications/Conference presentations

- Angélico, MM.; E. Henriques; P. Oliveira and P. Cunha 2019 Sardine early life stages distributions; links to recruitment areas in Atlantic Iberian waters. 42nd CIESM Congress, Estoril, 7-11 Oct 2019
- Astarloa, A., Louzao, M., Boyra, G., Martinez, U., Rubio, A., Irigoien, X., Hui, F. and Chust, G. 2019. Identifying main interactions in marine predator-prey networks of the Bay of Biscay. ICES Journal of Marine Science, doi:10.1093/icesjms/fsz140
- Boyra, G., Moreno, G., Orue, B., Sobradillo, B. and Sancristobal, I. 2019. In situ target strength of bigeye tuna (Thunnus obesus) associated with Fish Aggregating Devices. ICES Journal of Marine Science, doi:10.1093/icesjms/fsz131.
- Costa A.M., C. Nunes, D. Feijó, R. Milhazes, A.V. Silva, C. Silva, E. Soares, S. Garrido 2019. Reproductive characteristics of European anchovy, Engraulis encrasicolus (L.), off Western

Iberia. XX Iberian Symposium on Marine Biology Studies (SIEBM XX), Braga (Portugal), 9-12 September 2019

- Escribano, A., Aldanondo, N., Cotano, U., Boyra, G., Urtizberea, A. 2019. Size and density dependent overwinter mortality of anchovy juveniles in the Bay of Biscay. Continental Shelf Research. 183: 28-37.
- García-Seoane, E.; V. Marques; A. Silva and M.M. Angélico 2019. Spatial and temporal variation in pelagic community of the western and southern Iberian Atlantic waters. Estuarine, Coastal and Shelf Science 221: 147–155
- Huret M, Tsiaras K, Daewel U, Skogen MD, Gatti P, Petitgas P, Somarakis S
  Variation in life-history traits of European anchovy along a latitudinal gradient: a bioenergetics modelling approach. Mar. Ecol. Prog. Ser. 617-618: 95-112
- Louzao, M, García-Barón, I., Rubio, A., Martínez, U., Vázquez, J.A., Murcia, J.L., Nogueira, E. and G Boyra 2019 Understanding the 3D environment of pelagic predators from multidisciplinary oceanographic surveys to advance ecosystem-based monitoring. Mar. Ecol. Prog. Ser. 617-618: 199-219
- Nunes C., A.V. Silva, D. Feijó, E. Soares, A.C. Porfírio, D. Morais, G. Correia. P. Conceição, M.C. Silva, C. Chaves, V. Marques, P. Amorim, L. Gordo, A. Moreno, A. Silva 2019. Atlantic chub mackerel (Scomber colias) growth and reproduction off the Portuguese coast in relation to the population dynamics. XX Iberian Symposium on Marine Biology Studies (SIEBM XX), Braga (Portugal), 9-12 September 2019
- Silva, A.; S. Garrido; L. Ibaibarriaga; L. Pawlowski; I. Riveiro; V. Marques; F. Ramos; E. Duhamel; M. Iglesias; P. Bryére; A. Mangin; L. Citores; P. Carrera and A. Uriarte. 2019. Adult-mediated connectivity and spatial population structure of sardine in the Bay of Biscay and Iberian coast. Deep-Sea Research Part II Topical Studies in Oceanography 159 (SI): p. 62-74.
- Sobradillo, B., Boyra, G., Martinez, U. et al. 2019. Target Strength and swimbladder morphology of Mueller's pearlside (Maurolicus muelleri). Sci Rep 9, 17311 doi:10.1038/s41598-019-53819-6
- Uranga, J., Hernandez, M.C., Goñi, N., Boyra, G. and Arrizabalaga, H. 2019. Counting and sizing Atlantic bluefin tuna schools using medium range sonars of baitboats in the Bay of Biscay. Continental Shelf Research. Vol 182: 37-45.
- Veiga-Malta T, Szalaj D, Angélico MM, Azevedo M, Farias I, Garrido S, Lourenço S, Marçalo A, Marques V, Moreno A, Oliveira PB, Paiva VH, Prista N, Silva C, Sobrinho-GonçalvesL, Vingada J, Silva A 2019. First representation of the trophic structure and functioning of the Portuguese continental shelf ecosystem: insights into the role of sardine. Mar Ecol Pro*gr Ser*. 617-618: 323-340

4 Progress report on ToRs and work plan

4.1 Biomass and abundance estimates for anchovy and sardine in ICES areas 7, 8 and 9 derived from echo-integration and Daily Egg Production methods

4.1.1 Indices derived from acoustic surveys

4.1.1.1 Spring acoustic surveys

Three acoustics surveys were undertaken in spring to assess the biomass of sardine and anchovy in the Atlantic waters of ICES areas 9 and 8 (**Fig. 4.1.1.1.1**). Another survey in ICES area 7 was incorporated although it does not contribute to the assessment of these species in ICES areas 9 and 8. Additional information on other small pelagic fish distributions was also collected (see **section 4.2.4.4**). The PELAGO survey, conducted by IPMA, in the Gulf of Cadiz and Portuguese waters, took place from 12th April to 19th May. The IEO survey, PELACUS, sampled the Galician and Cantabric waters between 13th March and 15th April. PELGAS, the IFREMER survey, was carried out during the period 23rd April to 25th May in the Bay of Biscay. And WESPAS, conducted by FEAS in the Celtic sea, took place from the 13th June to 24th July. Detailed survey reports are presented in **annex 3**. Their sampling schemes and timing are presented in **Figure 4.1.1.1.1.**

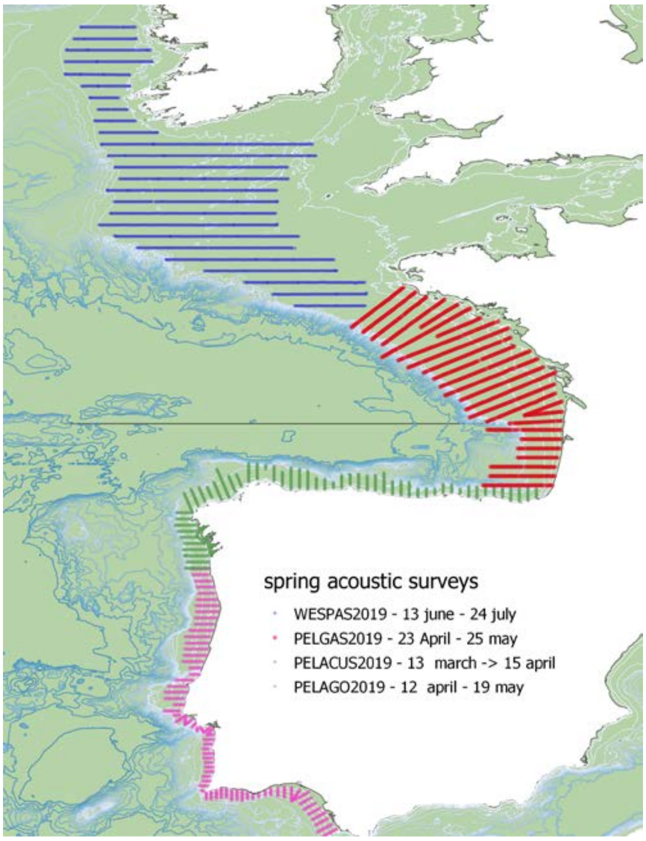


Figure 4.1.1.1.1.: Sampling scheme and timings of the spring acoustic surveys 2019 in the ICES areas 7, 8 and 9. PELAGO in pink, PELACUS in green, PELGAS in red and WESPAS in blue.

4.1.1.1.1. Sardine and anchovy mean weight and length-at-age

Mean weight and length-at-age were calculated from the length and age abundance and biomass matrices estimated for each ICES Subdivision. Besides, for each age, a mean weight or length anomaly was calculated as the difference between the mean weight or length-at-age calculated in each ICES subdivision and the weighted average of weight or length calculated for the whole area. During spring 2017, the differences occurred in weight at age for all sardine age classes, especially from those sardines caught in 8ab compared with those from the southern part (8c and 9a) as shown in figures below.

4.1.1.1.1.1. Subareas 8ab

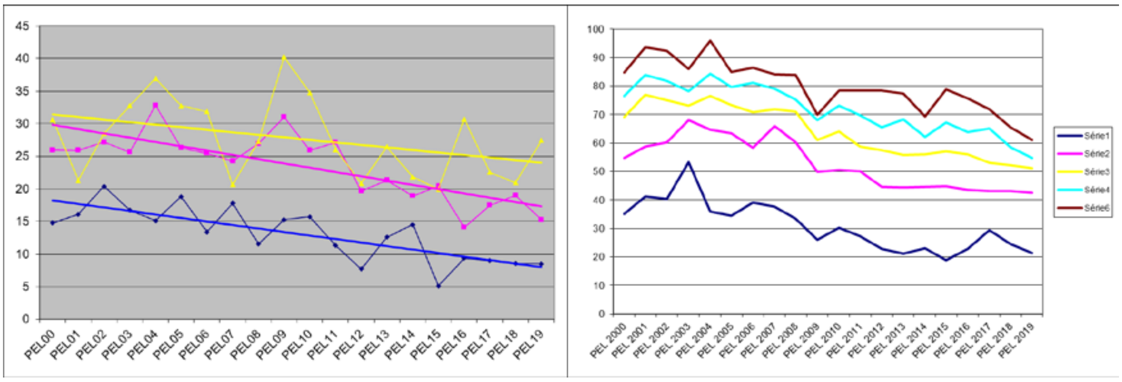


Figure 4.1.1.1.1.1.1: Evolution of mean weight at age (g) of anchovy (left) and sardine(right) along PELGAS series.

Figure 4.1.1.1.1.1.1 shows the evolution of mean weights at age for anchovy and sardine in the Bay of Biscay. As previous years, we observe that globally the trend of the mean weight at age decreased for both species in the Bay of Biscay. Further investigations should be conducted to test possible hypotheses (e.g. density-dependence) of the causes. Finally, it appears that the decreasing trend is stagnating, since 2012 for sardine and more recently for anchovy. Further work should be conducted.

4.1.1.1.1.2. Subareas 8c and 9a

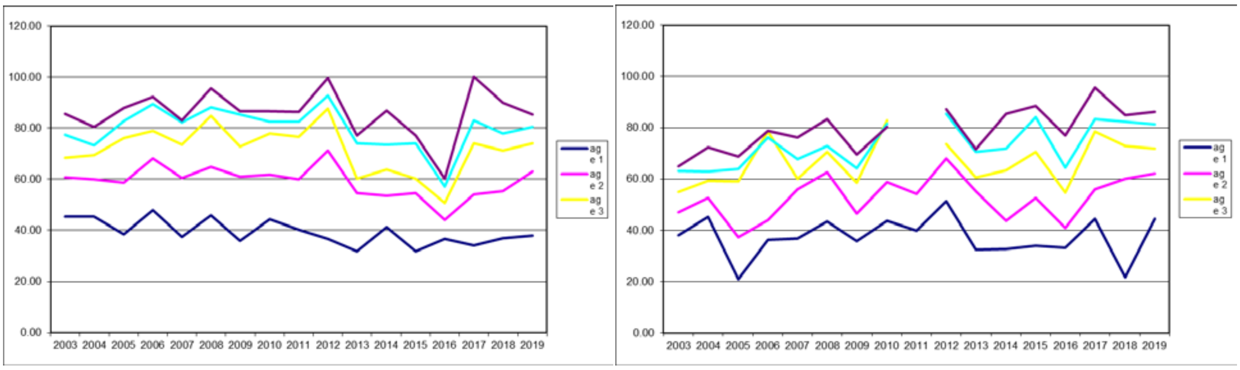


Figure 4.1.1.1.1.2: Evolution of mean weight at age (g) of sardine along PELACUS series in the 8c (left) and 9a subareas (right).

Even though the biomass of sardine became low in the subarea 8c, the mean weight at age seems to be very stable along the series. A more detailed study of fish condition should be conducted, as no clear trend is apparent in the sardine mean weight at age in subarea 9a since 2003.

4.1.1.1.2. Sardine and anchovy biomass and abundance estimates

4.1.1.1.2.1. subareas 8ab

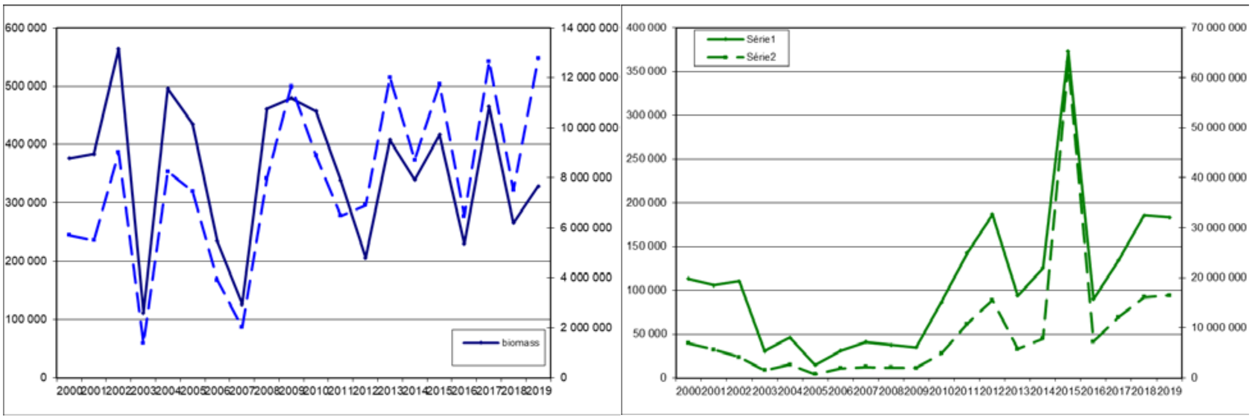


Figure 4.1.1.1.2.1.1: Biomass (solid line) and abundance (dashed line) trends for sardine (left) and anchovy (right) as observed during PELGAS survey in subareas 8ab

The difference between trends for sardine could indicate that the mean length for sardine in the Bay of Biscay is decreasing (**Fig. 4.1.1.1.2.1.1).** Concerning anchovy in the Bay of Biscay, the biomass shows different periods of contrasting biomass regimes since the beginning of the PELGAS series. During the first years (2000- 2003), biomass was at a medium level. It was followed by a period of low or very low biomass levels due to a recruitment failure in 2005, which led to a closure of the fishery. First signs of recovery happened in 2010, when the fishery re-opened; the biomass has been at a high level since then. (**Fig. 4.1.1.1.2.1.1**).

4.1.1.1.2.2. subarea 8c and 9a North

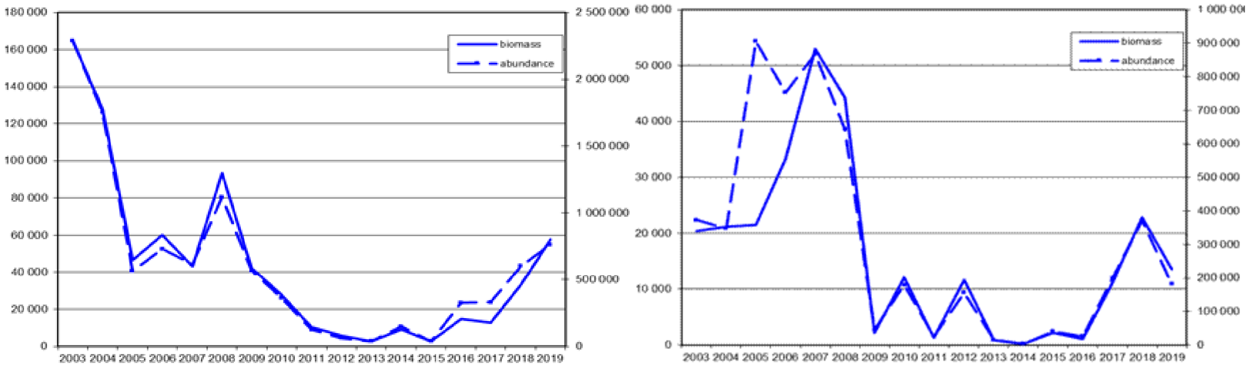


Figure 4.1.1.1.2.2: Sardine biomass and abundance trends as observed during PELACUS survey in division 8c (left) and 9a North (right)

For both areas 8c and 9a the signal in sardine biomass is very strong: the trend of the biomass assessed by the PELACUS survey shows a clear decrease, particularly marked between 2008 and 2009 in the South (division 9a). No sign of recovery was detected until 2016-2018. In 2018, an increase was observed, particularly in division 9a North (Galician coastal waters), but it was not continued this year, the level 2019 reaching the 2017 biomass levels again. (**Fig. 4.1.1.1.2.2**)

4.1.1.1.2.3. subarea 9a West and South

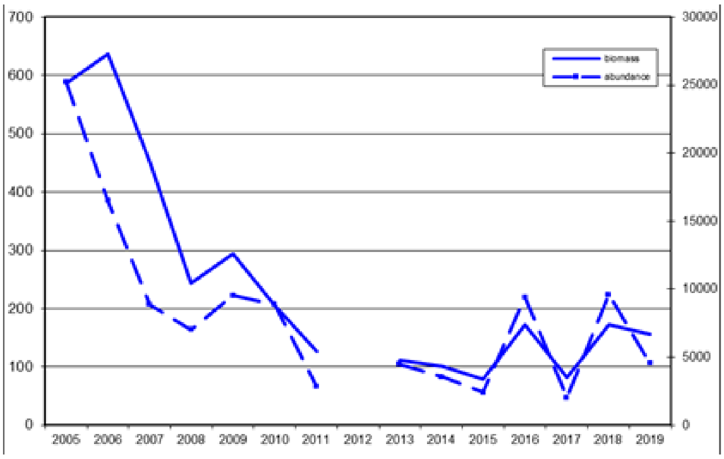


Figure 4.1.1.1.2.3.1: Biomass and abundance trends for sardine as observed during PELAGO survey in subarea 9a West and South. Y axis unit x1000

From Cadiz to the Northern frontier of Portugal, the trends in both sardine biomass and abundance show a clear decline. At the beginning of the series, biomass and abundance were high particularly in Northern Portugal waters. Since 2011, no signal of recovery is detected **Fig. 4.1.1.1.2.3.1**

4.1.1.2 Autumn acoustic surveys

In total five acoustic surveys are considered in this section: CSHAS, JUVENA, PELTIC, IBERAS and ECOCADIZ-RECLUTAS, but only results from JUVENA and PELTIC are presented. No results from the others have been provided to this WG because both acoustic data post-processing and the computation of the acoustic estimates for are still in progress. The JUVENA survey was conducted in September in the Bay of Biscay, PELTIC was conducted in October in the Celtic Sea and the ECOCADIZ-RECLUTAS was conducted between 10th and 30th October 2019 in the Portuguese and Spanish shelf waters off the Gulf of Cadiz (20-200 m depth). IBERAS2019 was conducted from the 5th to the 27th of September in west Iberian waters and CSHAS2019 from the 9th to the 29th of October in the Celtic sea.

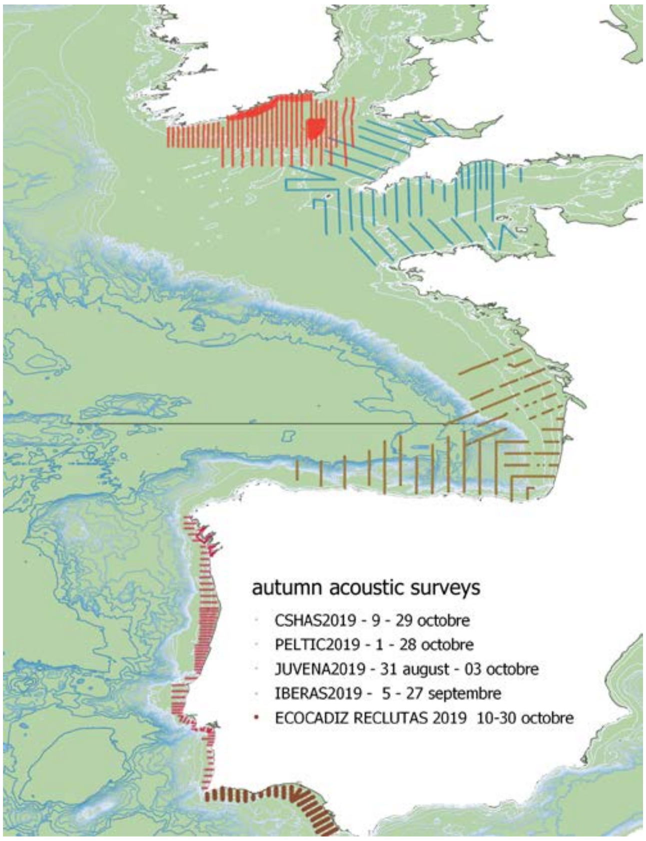


Figure 4.1.1.2.1 Sampling scheme and timings of the autumn acoustic surveys 2019. ECOCADIZ RECLUTAS in garnet, IBERAS in pink, JUVENA in brown, PELTIC in blue and CSHAS in red.

4.1.1.2.1 Sardine and anchovy mean weight and length at age

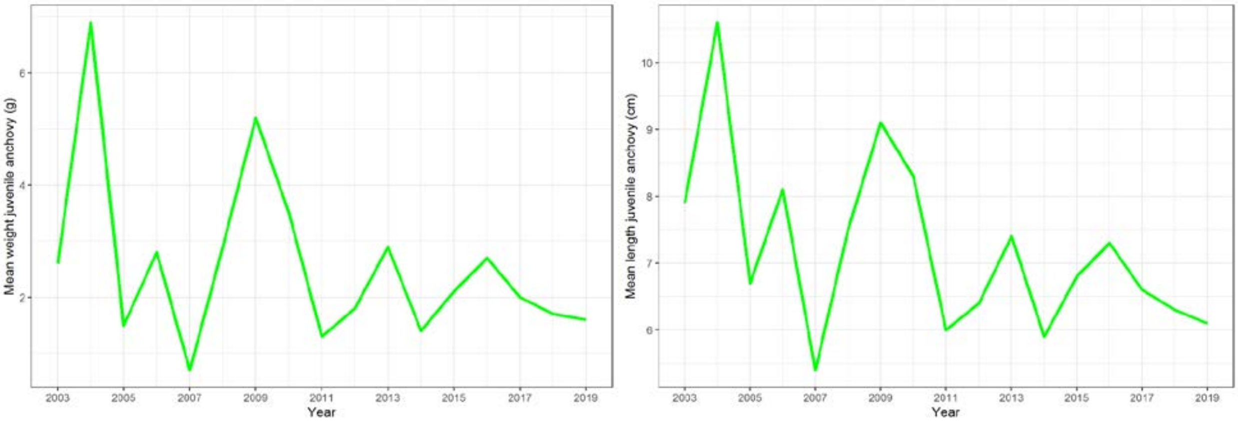


Figure 4.1.1.2.1.1: Evolution of mean weight (g)(left) and length (cm)(right) of juvenile anchovy (age 0) along JUVENA series.

Juvenile anchovy mean weight and length in the Bay of Biscay were lower in 2019 compared to the series mean (**Fig. 4.1.1.2.1.1**), whereas the opposite pattern is observed in PELTIC series, although the latter includes all ages (**Fig. 4.1.1.2.1.2**)

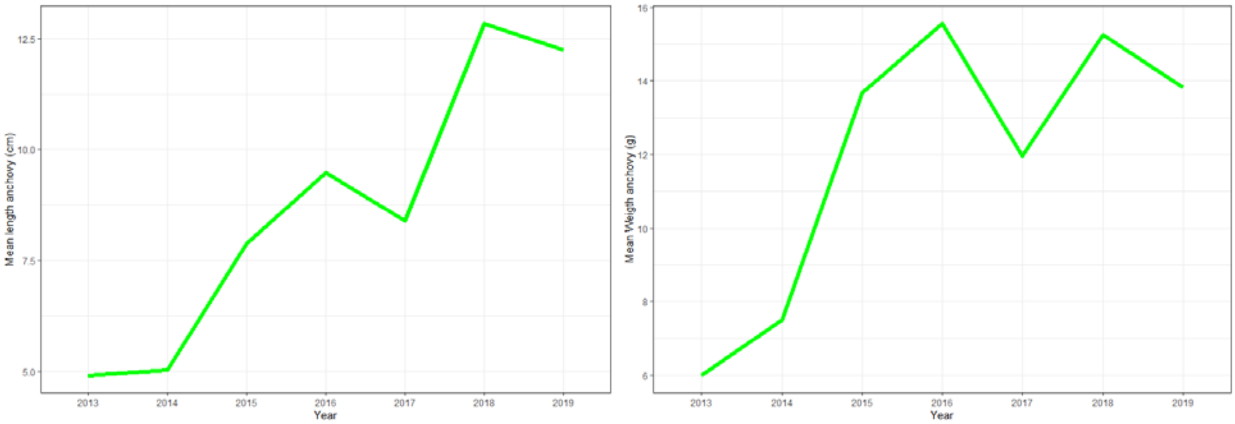


Figure 4.1.1.2.1.2: Evolution of mean length (cm)(left) and weight (g)(right) of anchovy along PELTIC series.

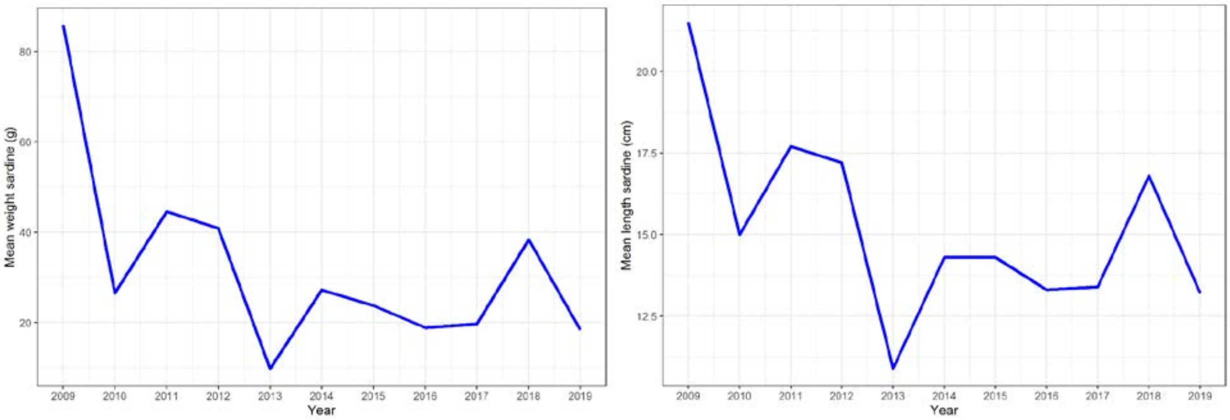


Figure 4.1.1.2.1.3: Evolution of mean weight (g)(left) and mean length (cm)(right) of sardine along JUVENA series.

Sardine mean weight and length have decreased respect to last year and at levels of recent years along JUVENA series (**Figure 4.1.1.2.1.3**), whereas in PELTIC an opposite trend for the mean length has been observed (**Figure 4.1.1.2.1.4**)

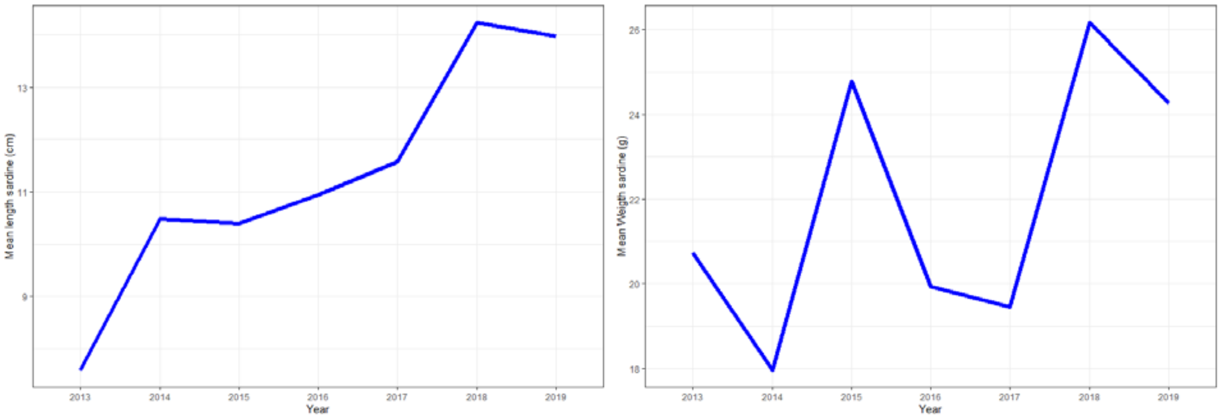


Figure 4.1.1.2.1.4: Evolution of mean length (cm)(left) and weight (g)(right) of sardine along PELTIC series.

4.1.1.2.2 Sardine and anchovy biomass and abundance estimates

Juvenile anchovy biomass this year was low in the Bay of Biscay, about 50 % below the mean of the temporal series. Sardine biomass in the area decreased from last year, dropping below the average of the temporal series to one of its lowest values. (**Fig. 4.1.1.2.2.1**).

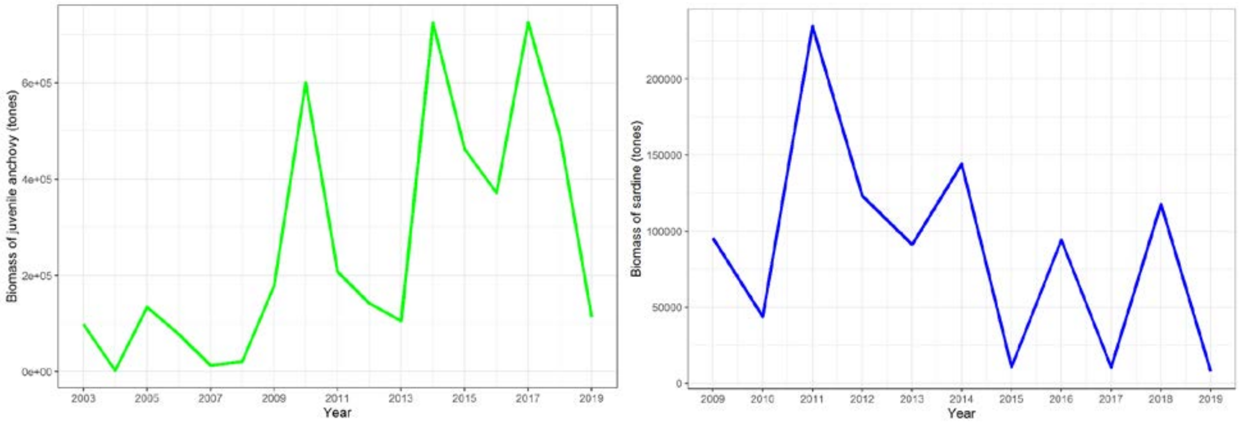


Figure 4.1.1.2.2.1: Evolution of autumn biomass of juvenile anchovy (age 0) (left) and sardine(right) in the Bay of Biscay collected during JUVENA series.

After a peak in 2018, the 2019 anchovy biomass in area 7 was comparable to the long-term average although coverage had expanded for the third year in a row (**Fig 4.1.1.2.2.2**). Sardine biomass in area 7 continued to show an increasing trend (**Fig 4.1.1.2.2.2**), with highest biomass recorded in the time series (both for the consistently sampled area and the wider coverage).

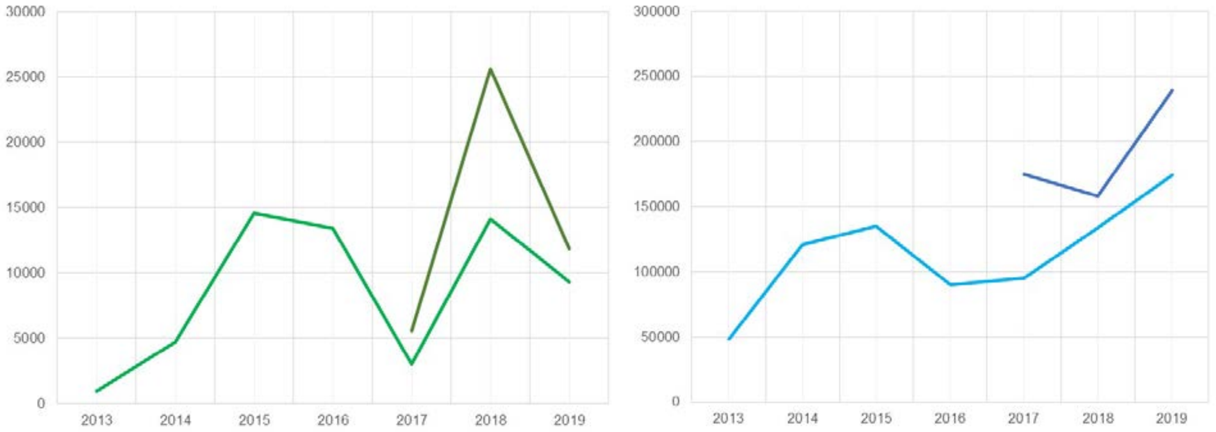


Figure 4.1.1.2.2.2: Trend in autumn anchovy biomass (left) and sardine biomass (right) in subarea 7 collected during PELIC. Biomass based on consistently covered areas (English waters only, light green or blue) and expanded coverage (dark green or blue). Y axis is in tones.

4.1.1.3 Gulf of Cadiz summer acoustic surveys

The ECOCADIZ 2019-07 survey was carried out between 31st July and 13rd August 2019 onboard the R/V Miguel Oliver covering the Spanish and Portuguese waters of the Gulf of Cadiz, from Strait of Gibraltar to Cape San Vicente, between the 20 m and 200 m isobaths. The main objectives of this survey were the acoustic assessment and mapping of neritic fish resources and oceanographic and biological conditions off the Gulf (**Fig. 4.1.1.3.1**).

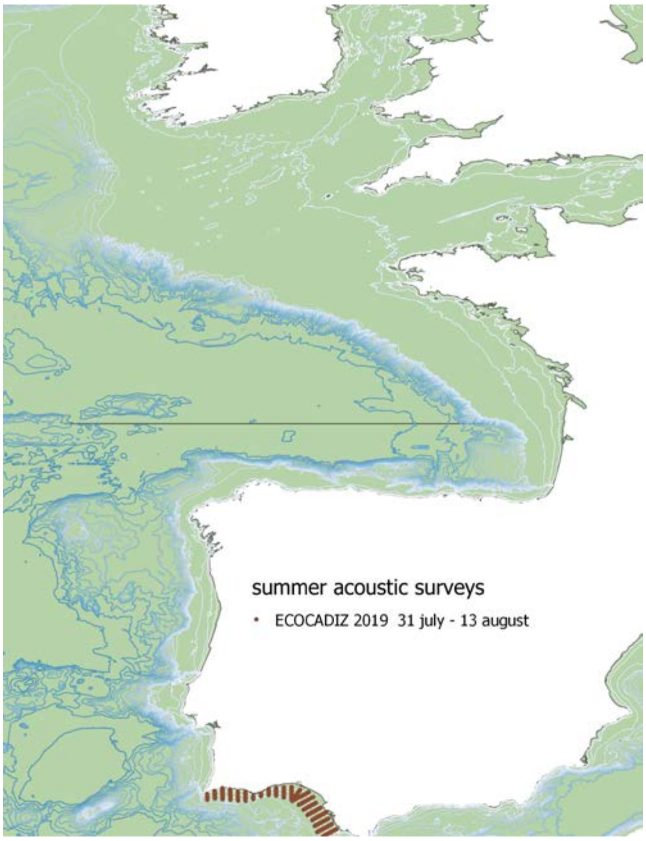


Figure 4.1.1.3.1: Sampling scheme and timing of the summer acoustic survey ECOCADIZ in 2019.

4.1.1.3.1 Sardine and anchovy mean weight and length-at-age

Sizes of the assessed **sardine** population in summer 2019 ranged between 10.5 and 20.0 cm size classes. The length frequency distribution of the population was clearly bimodal, with one main mode at 11.5 cm size class and a secondary one at 15.0 cm. The relatively important juvenile fraction in the estimated population (≤11.5 cm), was mainly located in relatively shallow waters along the coastal fringe comprised between Matalascañas and the Bay of Cadiz. Mean weight and length at age in the assessed population are not available to this WG. Alternatively, **Fig. 4.1.1.3.1.1** shows the mean length and weight along the time series. The 2019 summer estimates of mean size and weight (13.5 cm, 21.5 g) are slightly lower than their respective historical mean values (15.4 cm, 22.5 g), a probable consequence of the relative importance of the above-mentioned first modal component in the estimated population (see Ramos et al., 2019, WD in **Annex 3**).

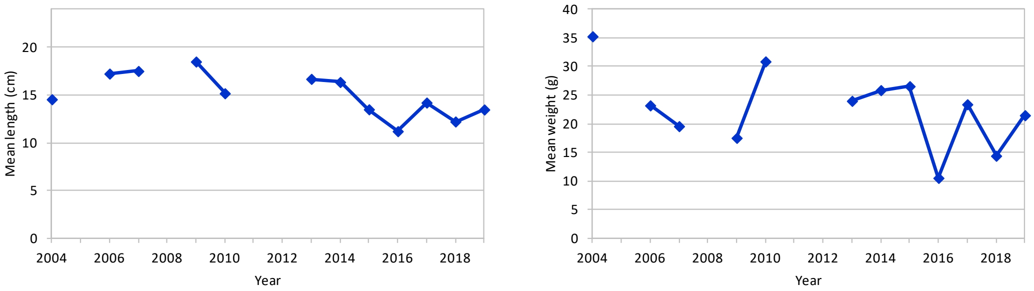


Figure 4.1.1.3.1.1: Sardine mean length (cm) and weight (g) throughout the ECOCADIZ Gulf of Cadiz summer acoustic surveys series (gaps mean no survey).

The size class range of the assessed **anchovy** population in summer 2019 varied between the 8.5 and 17.5 cm size classes, with one main modal class at 12.0 cm. The size composition of anchovy throughout the surveyed area confirms the usual pattern exhibited by the species during the survey season, with the largest (and oldest) fish being distributed in the westernmost waters and the smallest (and youngest) ones concentrated in the surroundings of the Guadalquivir river mouth and adjacent shallow waters (see Ramos *et al.*, 2019, WD in **Annex 3**). **Fig. 4.1.1.3.1.2** shows the mean length and weight at age along the time series. The 2019 summer estimates of mean size and weight are only referred to the whole population (117 mm, 10.5 g) and they were somewhat lower than their respective time series averages (123 mm, 12.8 g). Again, a relatively high contribution of the small fish (ca. 21 % of the total population is composed by fish ≤10 cm) during the survey season might be the cause of the value of such estimates in 2019.

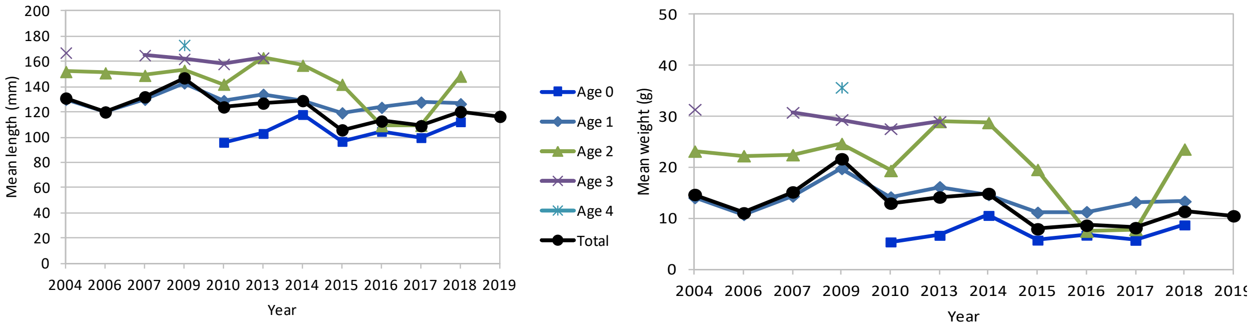


Figure 4.1.1.3.1.2: Anchovy mean length (mm) and weight (g) at age throughout the ECOCADIZ Gulf of Cadiz summer acoustic surveys series (gaps mean no survey). 2019 estimates only available for the whole population.

4.1.1.3.2 Sardine and anchovy biomass and abundance estimates

The estimates of Gulf of Cadiz **sardine** abundance and biomass in summer 2019 were 2 917 million fish and 62 682 t, a biomass well above the historical average (ca. 47 kt), but lower than the biomass estimated in 2018 (114 631 t; see **Fig. 4.1.1.3.2.1** and Ramos et al., 2019, WD in **Annex 3**). Spanish waters concentrated the bulk of the population (2 495 million and 44 899 t). The estimates for the Portuguese waters were 422 million and 17 783 t.

The *PELAGO 19* spring Portuguese survey previously estimated for this same area 60 088 t (1 962 million): 52 651 t (1 439 million) in Portuguese waters and 7 437 t (523 million) in Spanish waters, a reverse pattern to the one observed in the Spanish summer survey.

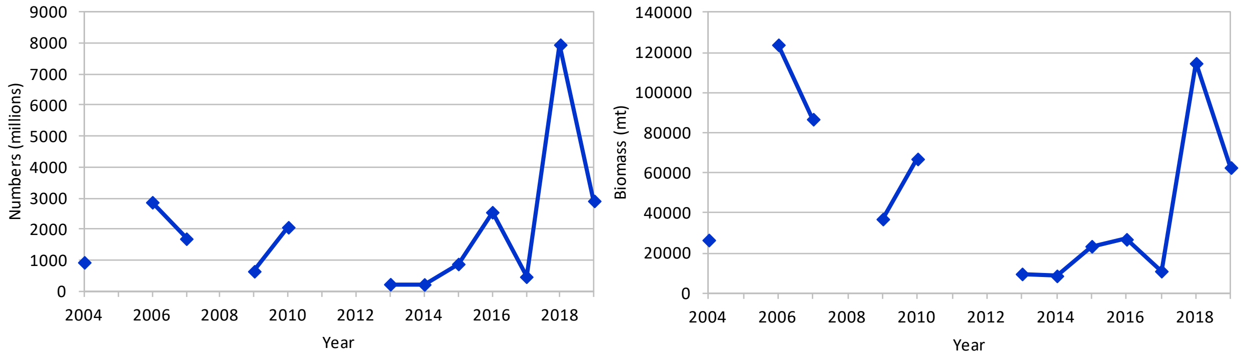


Figure 4.1.1.3.2.1: Sardine abundance (million fish) (left) and biomass (t)(right) estimates through the ECOCADIZ Gulf of Cadiz summer acoustic surveys series (gaps mean no survey).

Overall **anchovy** acoustic estimates in summer 2019 were of 5 485 million fish and 57 700 tonnes. By geographical strata, the Spanish waters yielded 99% (5 405 million) and 97% (56 139 t) of the total estimated abundance and biomass in the Gulf, confirming the importance of these waters in the species' distribution. The estimates for the Portuguese waters were 80 million and 1 560 t. The current biomass estimate (57 700

t) becomes in the historical maximum within the time-series (**Fig. 4.1.1.3.2.2** and Ramos et al., 2019, WD in **Annex 3**).

The *PELAGO 19* spring Portuguese survey previously estimated for this same area 29 876 t (3 398 million), with all the anchovy located in the Spanish waters.

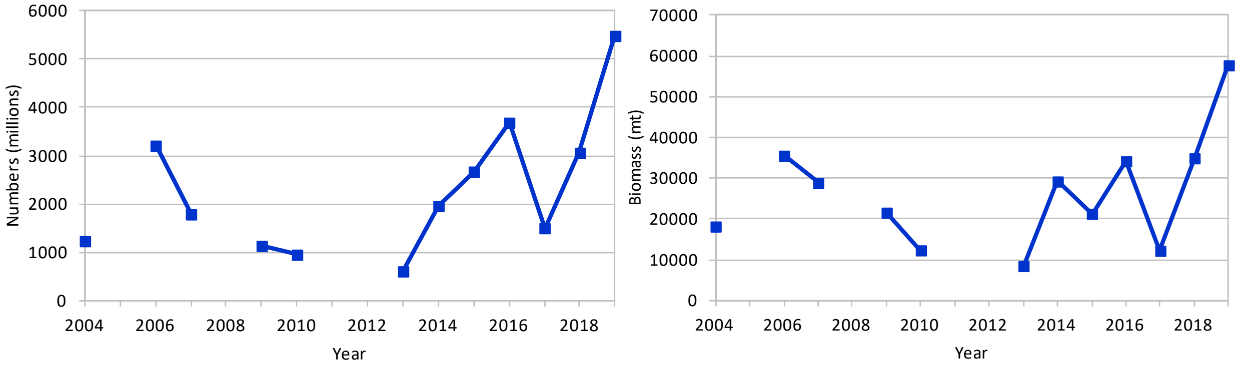


Figure 4.1.1.3.2.2: Anchovy abundance (million fish) and biomass (t) estimates through the ECOCADIZ Gulf of Cadiz summer acoustic surveys series (gaps mean no survey).

4.1.2 Indices derived from DEPM surveys

The DEPM survey BIOMAN targeting anchovy and sardine for the Bay of Biscay (ICES divisions 8abcd) has been conducted by AZTI during May every year since 1987. (**Fig. 4.1.2.1**). This is the only DEPM survey carried out this year, from 9th to the 31st of May, covering the whole spawning area of the species, following the procedures described in Santos *et al* 2019 working document in **annex 3**.

The other DEPM surveys are conducted each three years.

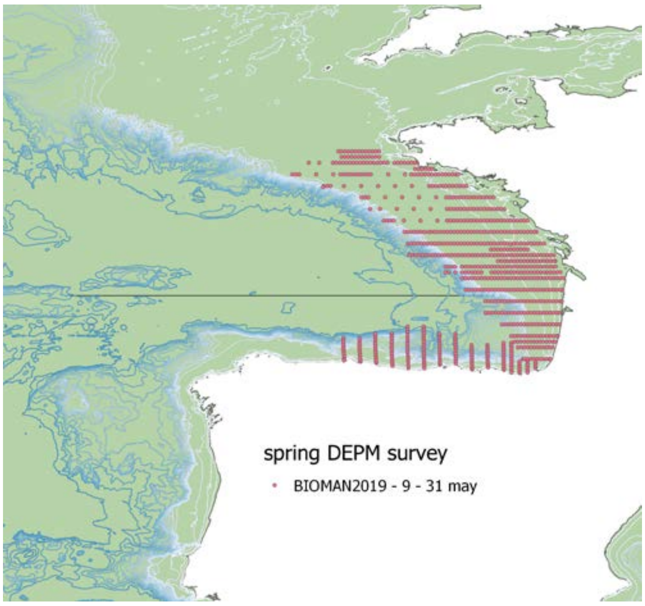


Figure 4.1.2.1: Sampling scheme and timing of the spring DEPM survey BIOMAN 2019.

4.1.2.1 Egg parameters estimates

The DEPM BIOMAN survey has produced egg parameter estimates for anchovy in ICES areas 8abcd (time series is showed in **Fig. 4.1.2.1.1**) and egg abundance for sardine in areas 8abd and 8abcd (**Fig. 4.1.2.1.2**)

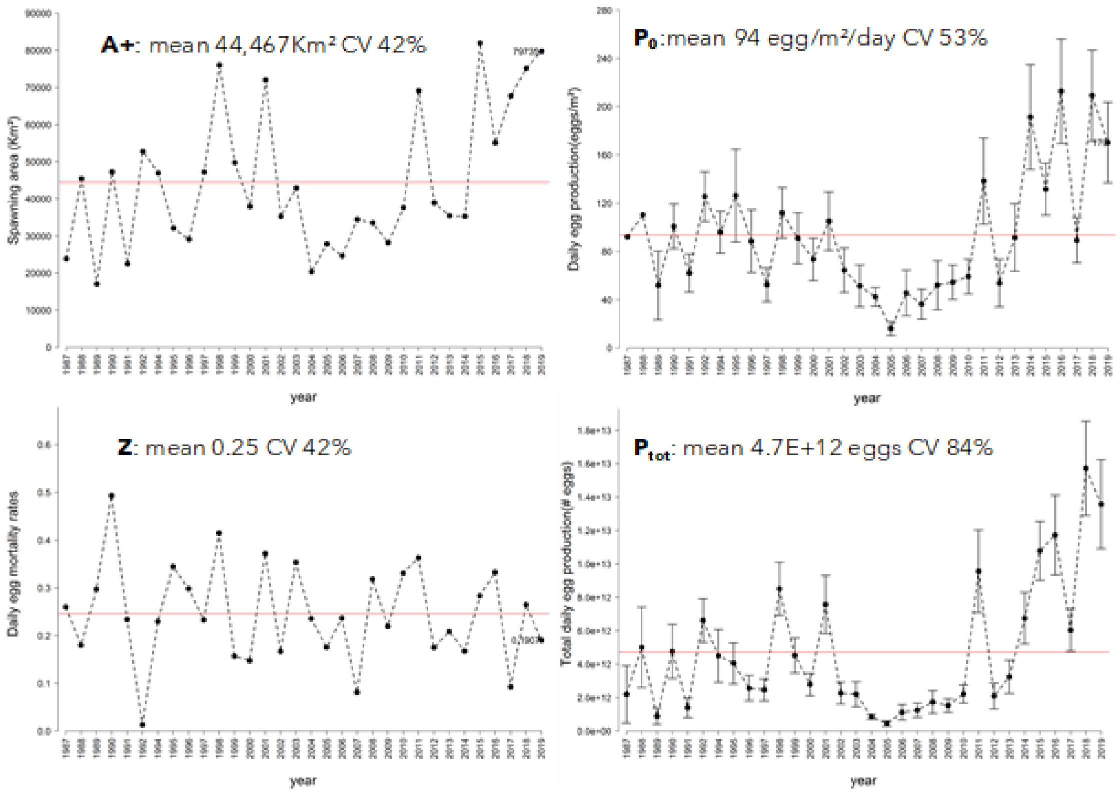


Figure 4.1.2.1.1: Historical series and 2019 estimates of spawning area (A+) (Km^2), daily egg production (P_0) (egg/m^2/day), daily mortality rates (z) and total daily egg production (P_{tot})(eggs/day) as the product between spawning area (A+) and daily egg production (P_0) estimates with its CV for anchovy in the Bay of Biscay. The mean (red line) and the value of the actual year is showed.

In 2019 daily egg production (P_0) (170.3 egg/m^2/day CV:9.8%) was higher than the mean (93.66 egg/m^2/day CV:53%) and lower than last year that was the second highest of the historical series. The spawning area (79,735 Km^2) was higher than the mean (44,467 Km^2) and than the last three years. Daily mortality rates (z) (0.19 CV:25%) were lower than last year and the mean (0.25), the z value of this year means that 17% of the eggs were dying per day. Total daily egg production (P_{tot}) (1.36e+13eggs CV:9.8%) was higher than the mean (4.72e+12eggs) being the second highest of the historical series.

Sardine total egg abundance series from BIOMAN survey is showed in **Figure 4.1.2.1.2** (sum of the egg abundance in each station multiplied by the area each station represents). These values were used as an index in the assessment for sardine in Divisions 8abd. The Northwest part surveyed in recent years was removed to have the same area surveyed each year and be coherent within the historical series. The total egg abundance in all the area surveyed and in the 8abd with the Northwest part is showed in the figure, as well.

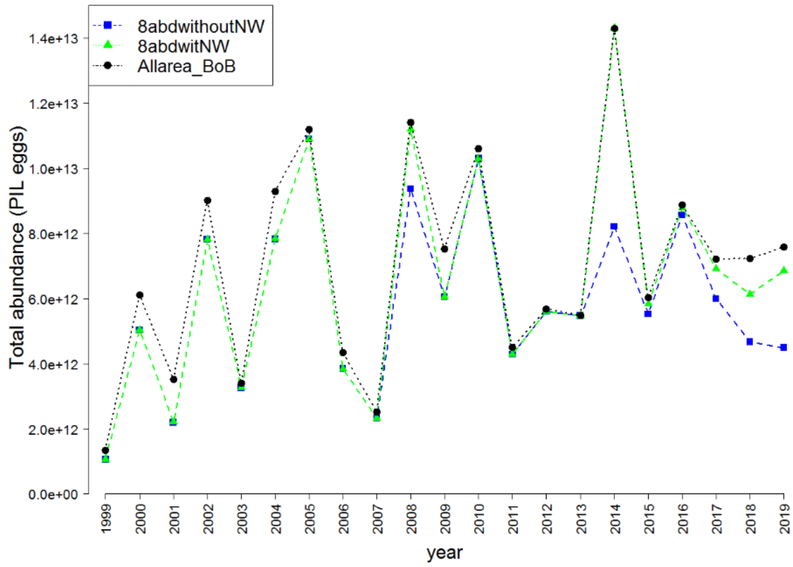
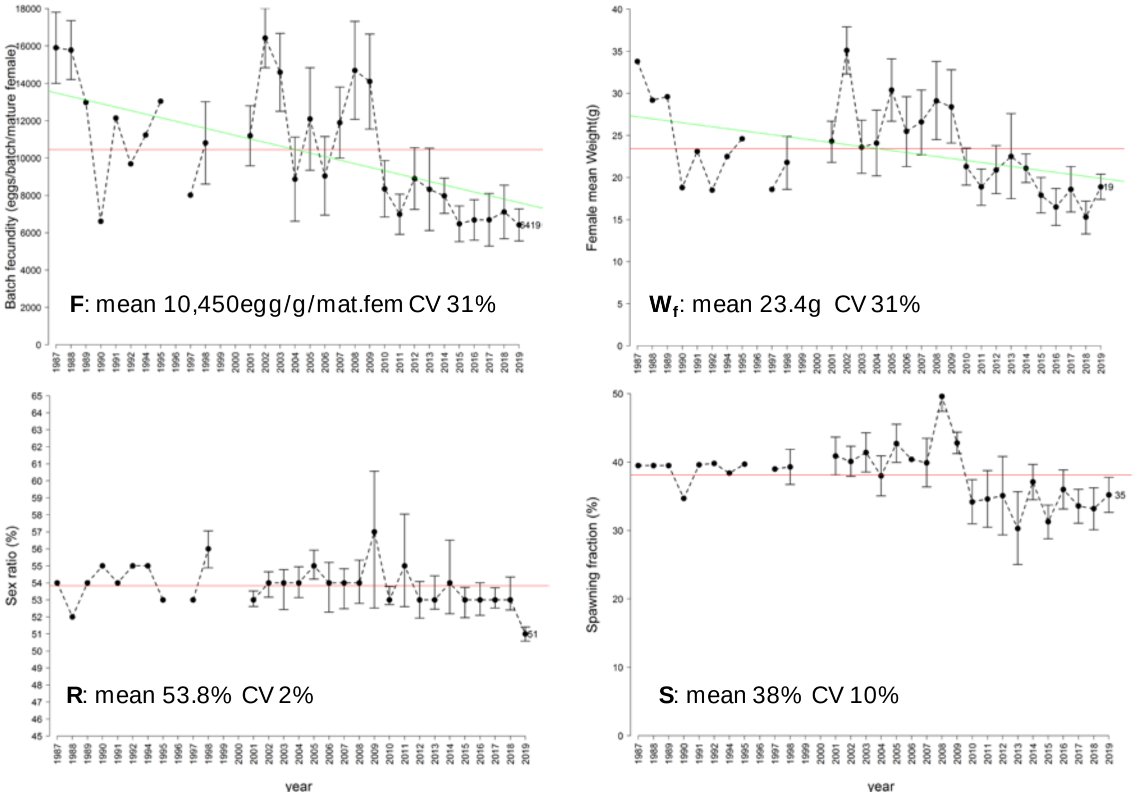


Figure 4.1.2.1.2: Historical series and 2019 estimates for sardine total egg abundances (eggs) in all the area surveyed 8abcd (black line), in 8abd (green line) and in 8abd without the north-west part (blue line) for assessment proposes to be consistent with the historical series.

4.1.2.2 Reproductive parameters and total anchovy biomass estimates



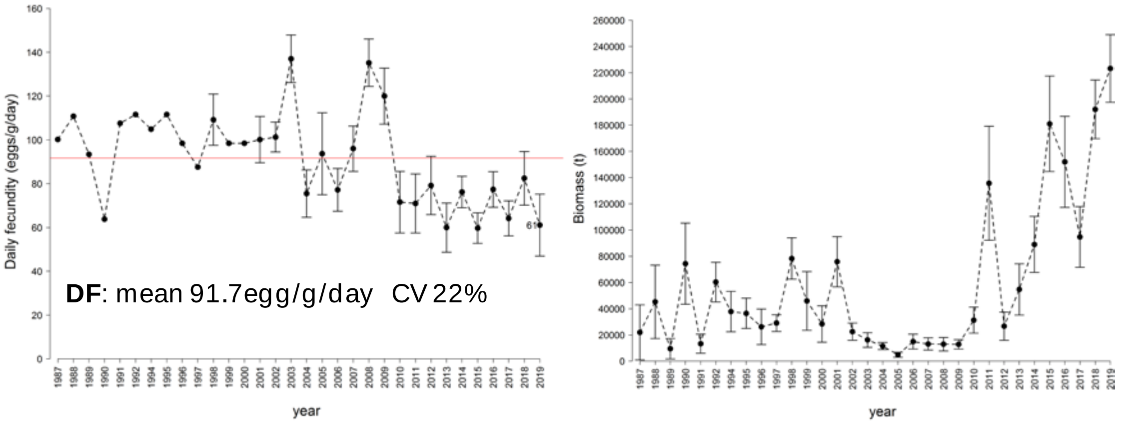


Figure 4.1.2.2.1 Historical series including 2019 estimates of the adult parameters from the DEPM for anchovy in the Bay of Biscay (ICES 8abcd) batch fecundity (eggs/batch/mature female), females mean weight(g), sex ratio (% of females), spawning fraction (% of females spawning per day), daily fecundity (eggs/g/day) and the total biomass(tonnes). The mean (red line) and the value of the actual year is showed.

The batch fecundity this year (6,419 eggs/batch/mature female CV: 6.7%) is the lowest of the series and the general tendency is downwards (green line?). The spawning frequency this year is 35.2% CV: 3.6% lower than last year; since 2010 the spawning fraction was maintained around 34 %, lower than the tendency before the aperture in 2010. The sex ratio (51% CV:0.4%) is lower than last year but did not change much in the time series that is around 53%. The female mean weight (18.9g CV: 3.97%) is higher than last year but the general tendency in the historical series is downward and specially after 2010 that was down drastically and is lower than the mean (23.4g CV: 23%) since then. The daily fecundity (61.1 egg/g/day CV:11.6%) since 2010, the year of the reopening of the fishery, was going up and down, but maintained around 70 eggs/g/day. Finally, the biomass this year is the highest of the historical series 223,210t CV:11.6% (**Fig. 4.1.2.2.1**).

4.1.2.3 Weight, length, numbers, percentage and biomass at age estimates

Mean weight (**Fig. 4.1.2.3.1**) and length-at-age were calculated from the historical series of BIOMAN surveys. A notable decrease since the beginning of this century in the weight is observed specially for age 1 and 2 and specially since 2010, when the fishery was open after 5 years of closure.

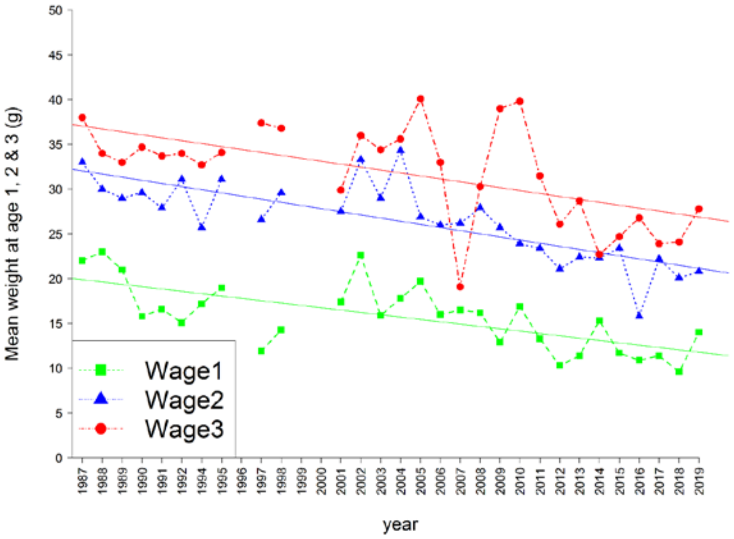


Figure 4.1.2.3.1 Historical series and 2019 estimates of anchovy mean weight (g) at age in the Bay of Biscay observed during BIOMAN surveys. W at age 1 (green), W at age 2 (blue) and W at age 3 (red)

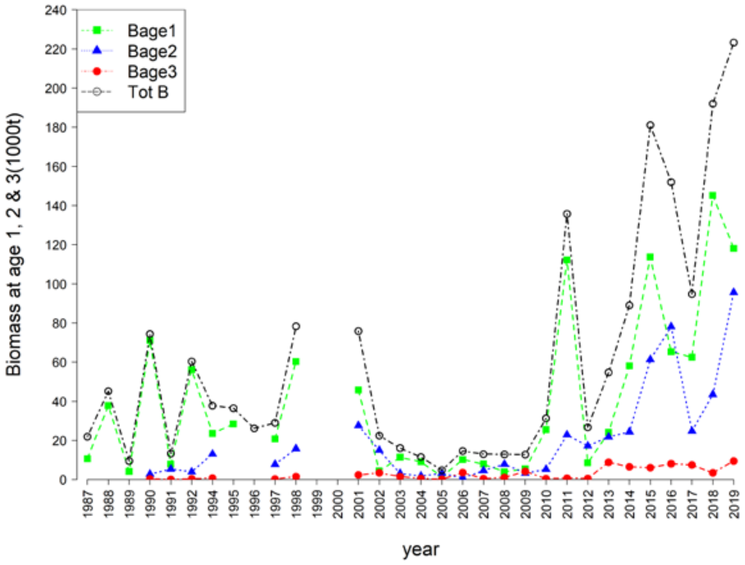


Figure 4.1.2.3.2 Historical series and 2019 estimates of biomass (tones) at age 1 (green), age 2 (blue) and age 3 (red) for anchovy in the Bay of Biscay observed during BIOMAN surveys.

Between 1987 and 2001 the anchovy biomass derived from the DEPM were below 80,000t (**Fig. 4.1.2.3.2**). From 2002 to 2009 DEPM SSB estimates were below 20 000 t. Within this period the fishery had difficulties to get normal levels of catches. In 2003 there was a deep crisis of the Spanish fishery (STECF 2003) and later in 2005 and 2006 the Spanish fishery crashed and was unable to get any significant catch. This led to the repeated closure of the fishery first in June 2005 and next in June 2006 which last until January 2010. The DEPM estimated a recovery of the population in 2010 and peaked in 2011, 2015 and now 2019. This year 2019 was the historical maximum 223,210t CV:11.6%. In 2010 and 2011 the recovery was due to a strong recruitment, as reflected in the high percentage of 1-year old anchovies (above 85%, **Fig. 4.1.2.3.3**). This year the percentage of 1 year old in numbers was 63% CV:5.9, showing a medium recruitment, lower than last year. In mass it was 53% of age 1. More information is showed in the **wd Santos *et al* 2019 in annex 3.**

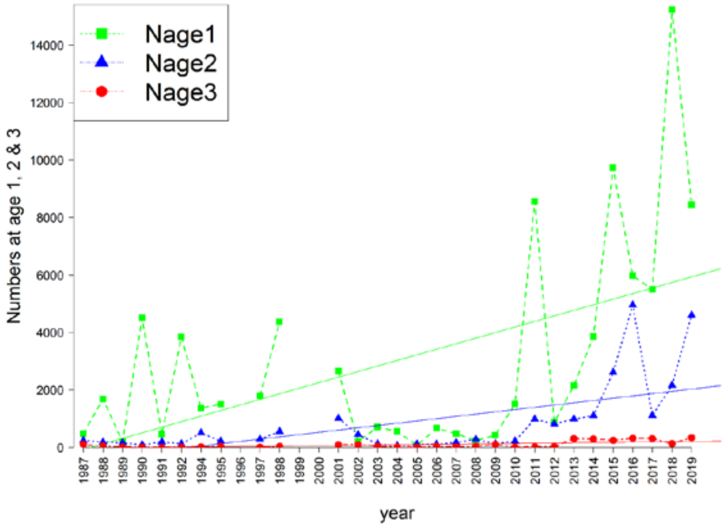


Figure 4.1.2.3.3 Historical series and 2019 estimates of numbers at age 1(green), age 2 (blue) and age 3(red) for anchovy in the Bay of Biscay observed during BIOMAN surveys and the tendency of each age.

4.2 Distribution of eggs and adults of small pelagic fish in their environment in ICES sub-Areas 6, 7, 8 and 9

4.2.1 Spring acoustics surveys

4.2.1.1 Oceanographic conditions

In 2019, the coordinated spring acoustic surveys were carried out between the 27th of March and the 25th of May (**Fig. 4.1.1.1.1**). The first was PELACUS that monitors the Galician waters and the Cantabrian Sea up to the Spanish-French border. By the time PELACUS was finishing, in mid-April, PELAGO, started, surveying the western Portuguese waters and the southern, Algarve and Cadiz Bay shores, and finishing in mid-May. PELGAS, in the Bay of Biscay, started in late April and was completed in late May. Due to the time lag between surveys, the combined, synoptic maps for sea surface temperature and salinity should be interpreted with caution. As is typical for the area monitored by the three surveys during this period of the year, the warmer temperatures were observed in the southern shores (15.5ºC - 20.5ºC), whereas the colder (~13ºC – 14ºC) occurred in the W Cantabrian Sea and in the coastal waters of the Bay of Biscay. Globally, on average, the water temperature during the 2019 spring surveys was within the range characteristic for the region and season, though a bit higher in the south-eastern coast and slightly lower in the northern shores (**Fig. 4.2.1.1.1**). The surface salinity distribution map showed for the surveying period in 2019, a clear lens of less saline water over the NW Portugal – W Galician shelf, particularly evident in the region between river Douro and the Galician rias. In the Bay of Biscay, the freshwater runoff was also very marked in the coastal area of Arcachon-Garone and off the Loire river mouth (**Fig. 4.2.1.1.1**).

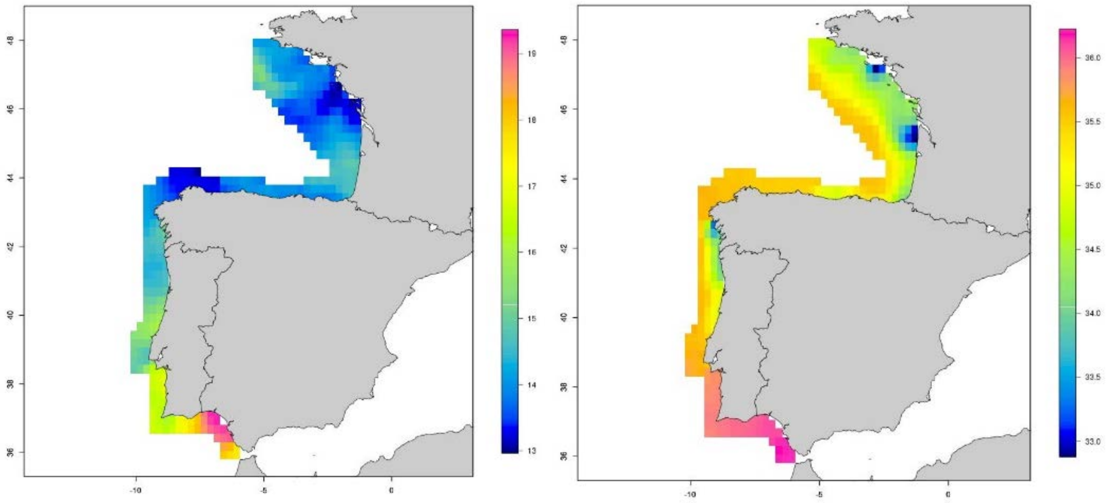


Figure 4.2.1.1.1: Sea surface temperature (left) and salinity (right) during the 2019 spring acoustics surveys (PELAGO, PELACUS, PELGAS) in the period March-May 2019. For dates of coverage in each region and other details see **Figure 4.1.1.1.1**. and **annex 3**.

4.2.1.2 Trawl haul catch composition

Although fishing hauls are normally conducted to ground-truth the echotraces and to estimate an age/length spatial distribution by species along the surveyed area, thus done in an opportunistic way, they will reflect the abundance of the main pelagic fish species related to the echotraces.

Figure 4.2.1.2.1 shows the percentage (in weight) of the fishing stations done during the spring acoustic surveys (from south to North: PELAGO, PELACUS, PELGAS and now WESPAS). Mackerel is the most dominant species on the Spanish continental shelf. Complementary, blue whiting are also abundant in those hauls performed over the slope. Along the Portuguese coast, anchovy dominated in the northern part, while sardine appeared in the catches realised in the southern part (but in lower quantities according to small echotraces). In French waters the same patterns would also infer with anchovy being for the most present around the Gironde mouth and along the southern part of the continental shelf while sardine occurrence was higher in the (very) coastal waters in the South and around the Loire mouth. For the first time, the Irish survey WESPAS was integrated in this study. The Celtic Sea was dominated by boarfish and horse mackerel while mackerel, herring and sprat dominated the trawl hauls further North.

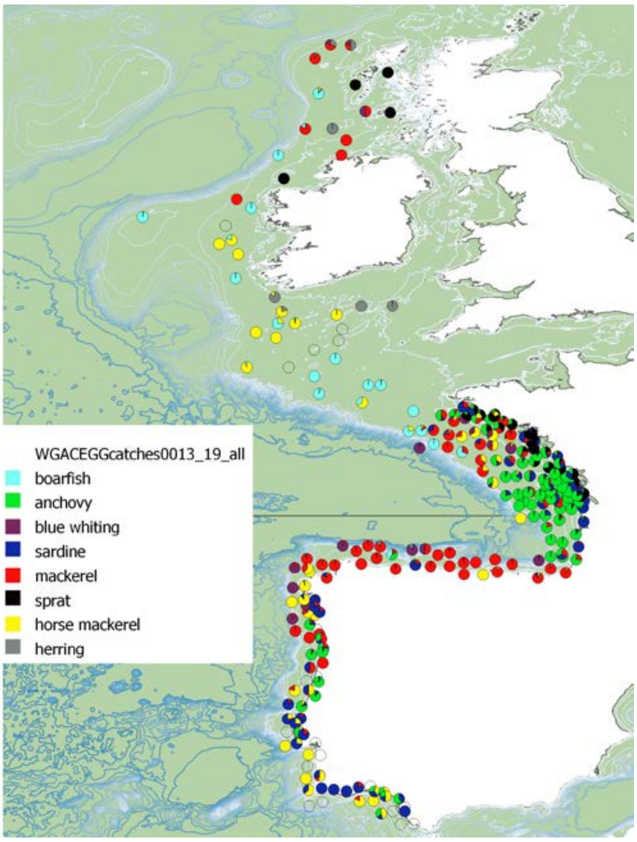


Figure 4.2.1.2.1 Trawl haul catch composition during spring joint acoustic surveys.

4.2.1.3 Adult sardine and anchovy acoustic density (NASC) distribution

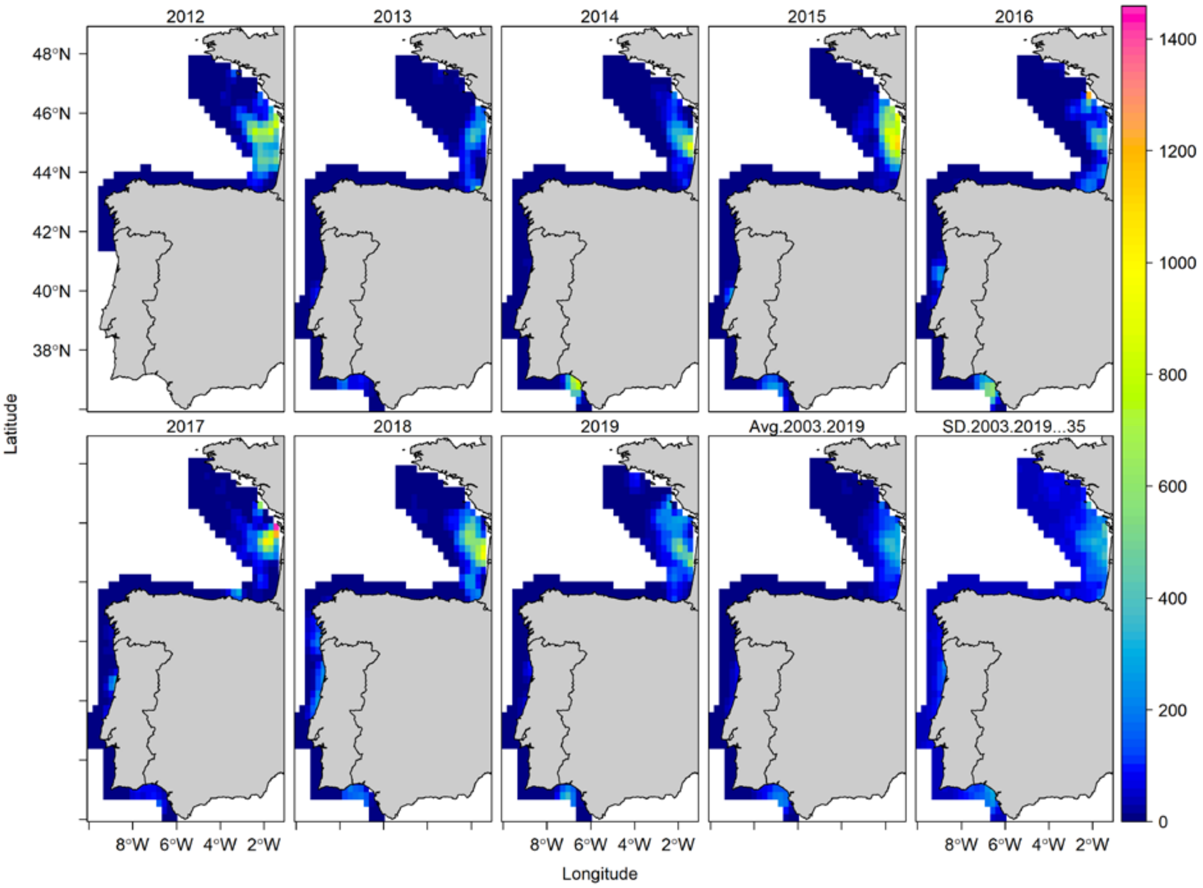


Figure 4.2.1.3-1. Adult anchovy mean acoustic density (NASC, $m^2.NM^{-2}$) maps derived from the PELAGO, PELACUS and PELGAS surveys, 2012-2019, 0.25° map cell. "Avg.2003-2019 pane": map of anchovy NASC values averaged over the series. "SD.2003-2019 pane": map of anchovy NASC standard deviation.

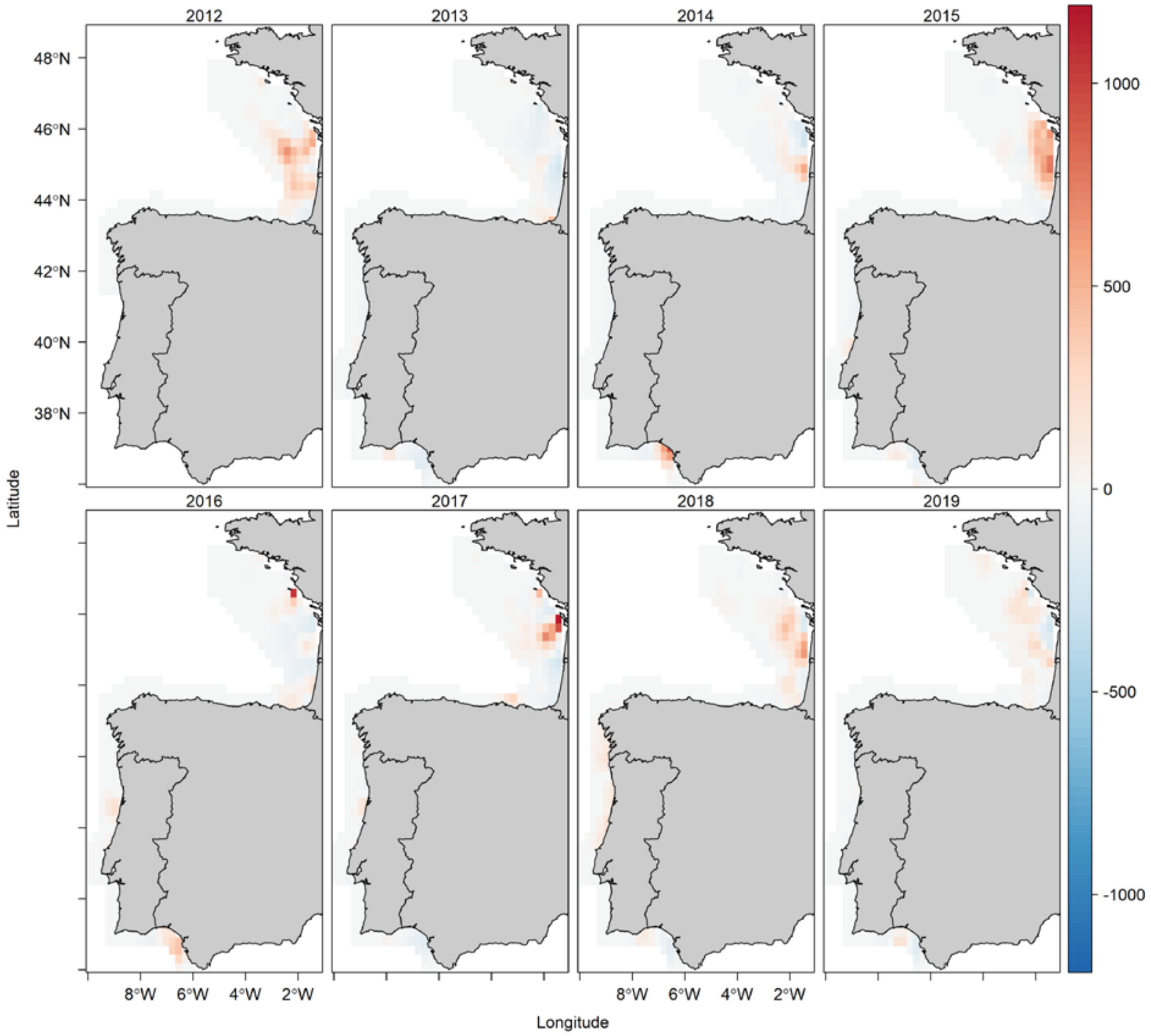


Figure 4.2.1.3-2. Maps of adult mean anchovy acoustic density (NASC, m².NM-²) anomalies derived from the PELAGO, PELACUS and PELGAS surveys, 2003-2019. Anomalies have been calculated by subtracting the mean map from annual maps. Grid dimensions: 0.25°.

From 2012 to 2019, adult anchovy core distribution areas in springtime were, by decreasing order of importance: coastal areas in Southern Bay of Biscay (Gironde and Landes coast, ~46°N), the Gulf of Cadiz (~37°N), and in a small area North of Cape Mondego on the Western coast of Portugal (~40°N) (Figure 4.2.1.3-2). In 2019, anchovy density was slightly above average over its usual distribution area (Figure 4.2.1.3-2).

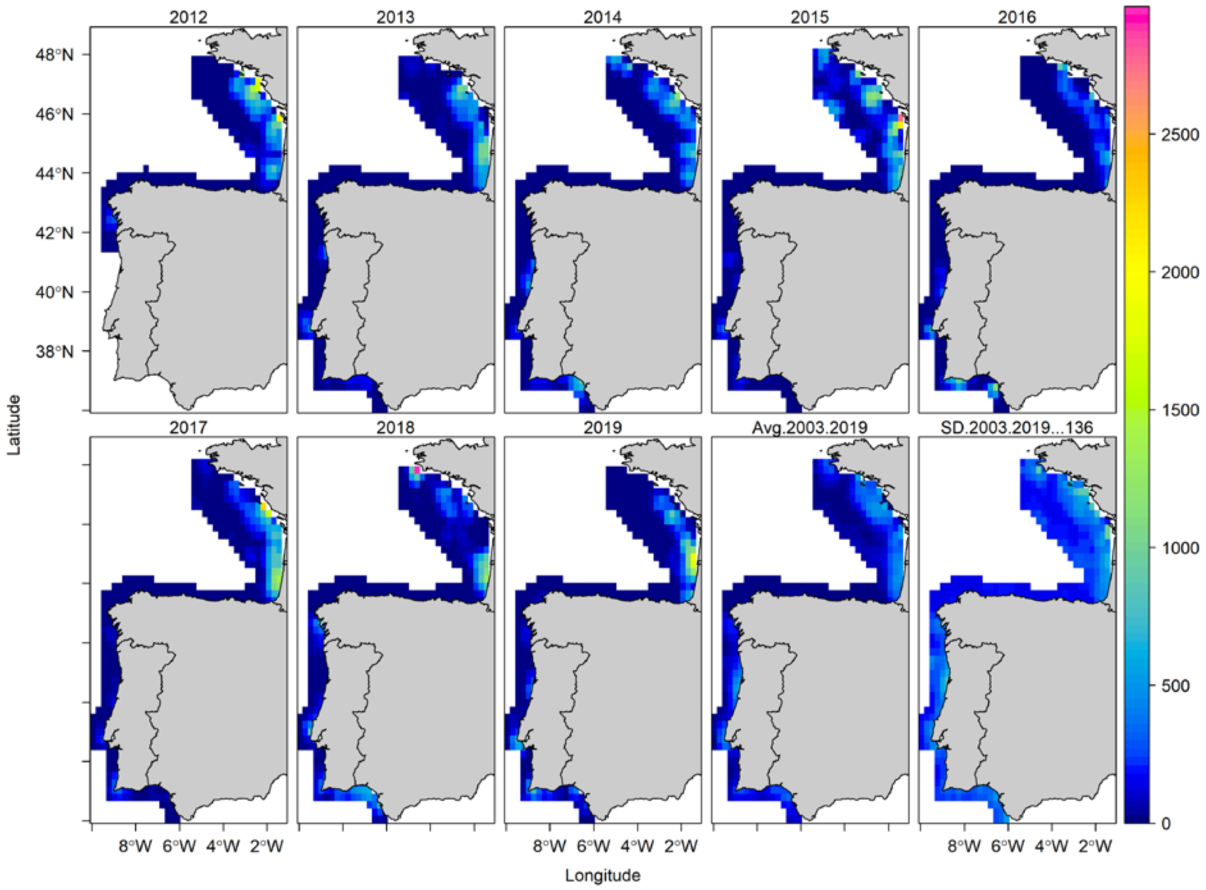


Figure 4.2.1.3-3. Adult sardine mean acoustic density(NASC, m².NM⁻²) maps derived from the PELAGO, PELACUS and PELGAS surveys, 2012-2019, 0.25° map cell. "Avg.2003-2019 pane": map of sardine NASC values averaged over the series. "SD.2003-2019 pane": map of sardine NASC standard deviation over the series.

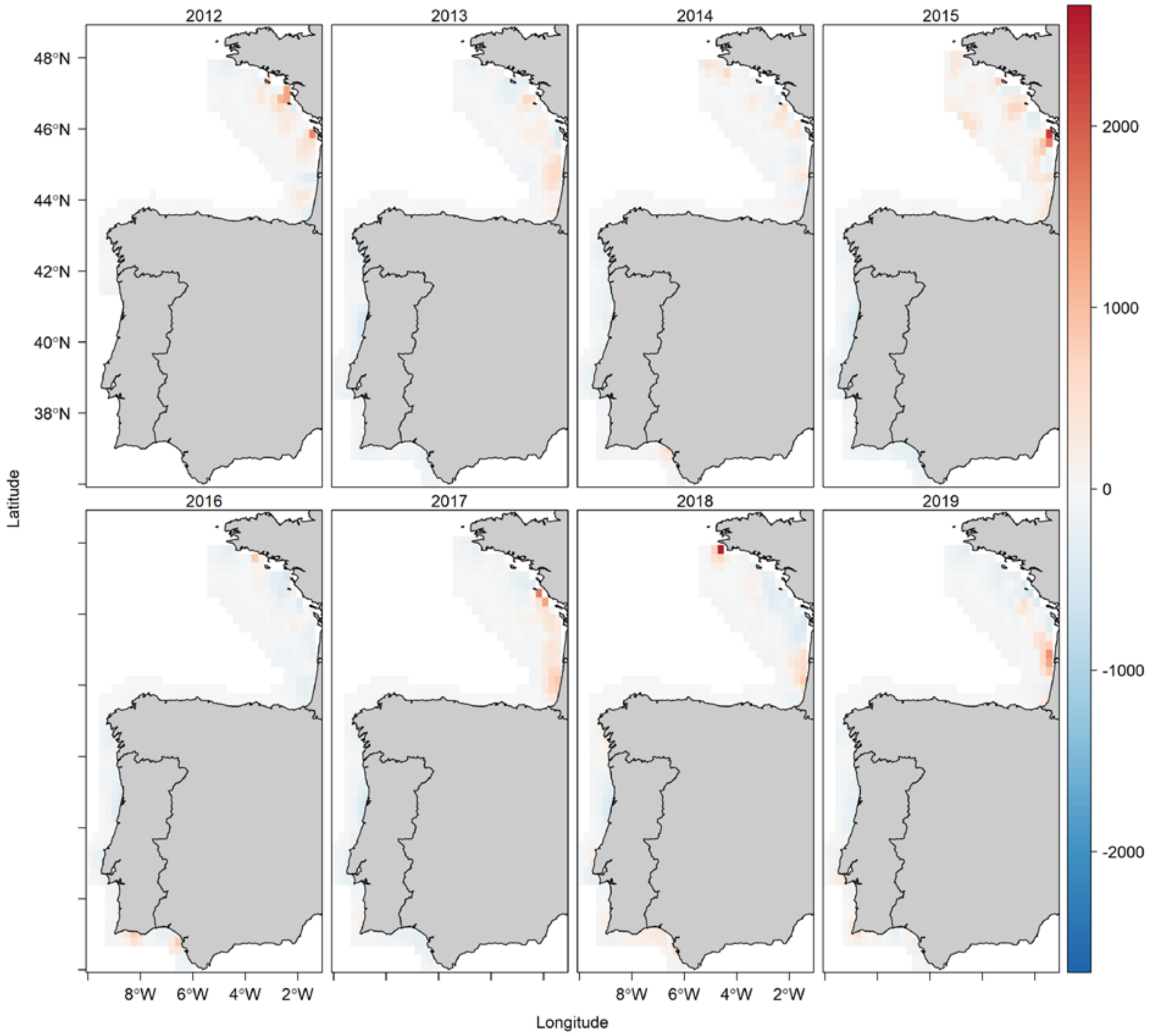


Figure 4.2.1.3-4. Maps of adult mean sardine acoustic density (NASC, m².NM-²) anomalies derived from the PELAGO, PELACUS and PELGAS surveys, 2003-2019. Anomalies have been calculated by subtracting the mean map from annual maps. Grid dimensions: 0.25°.

From 2012 to 2019, sardine core distribution areas in springtime were, by decreasing order of importance: the coastal areas of the Bay of Biscay, the Gulf of Cadiz (~37°N), the South Western Portuguese coast, and Biscay shelf-break areas. (Figure 4.2.1.3-3). In 2019, the sardine distribution was close to average, with slightly above-average concentrations in a coastal area in the Bay of Biscay between 44°N and 45°N (Figure 4.2.1.3-4).

4.2.1.4 Other adult small pelagic fish species acoustic density distributions

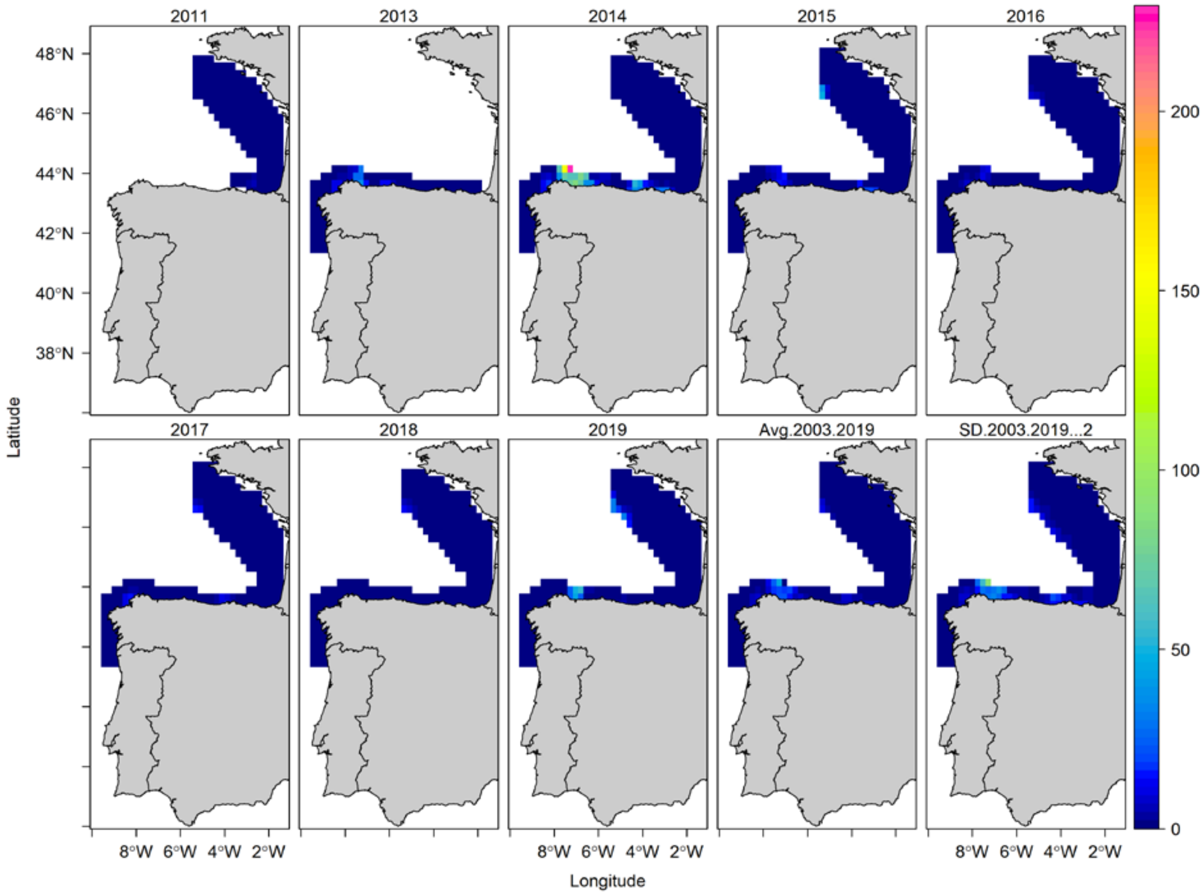


Figure 4.2.1.4-1. Boarfish (*Capros aper*) acoustic density (NASC, m².NM-²) maps derived from PELACUS and PELGAS spring surveys, 2011-2019, 0.25° map cell. "Avg.2003-2019 pane": map of NASC values averaged over the series. "SD.2003-2019 pane": map of NASC standard deviation.

Boarfish (*Capros aper*) has been occasionally observed during the PELGAS and PELACUS spring acoustic since 2003 (Figure 4.2.1.4-1). It appeared to be distributed in offshore areas and was only marginally sampled by the small pelagic surveys focusing on the continental shelf. The highest concentrations of boarfish were observed in the Western end of the Cantabrian area in 2014. Some boarfish have been observed in North-Western Biscay and Western Cantabrian Sea in 2019.

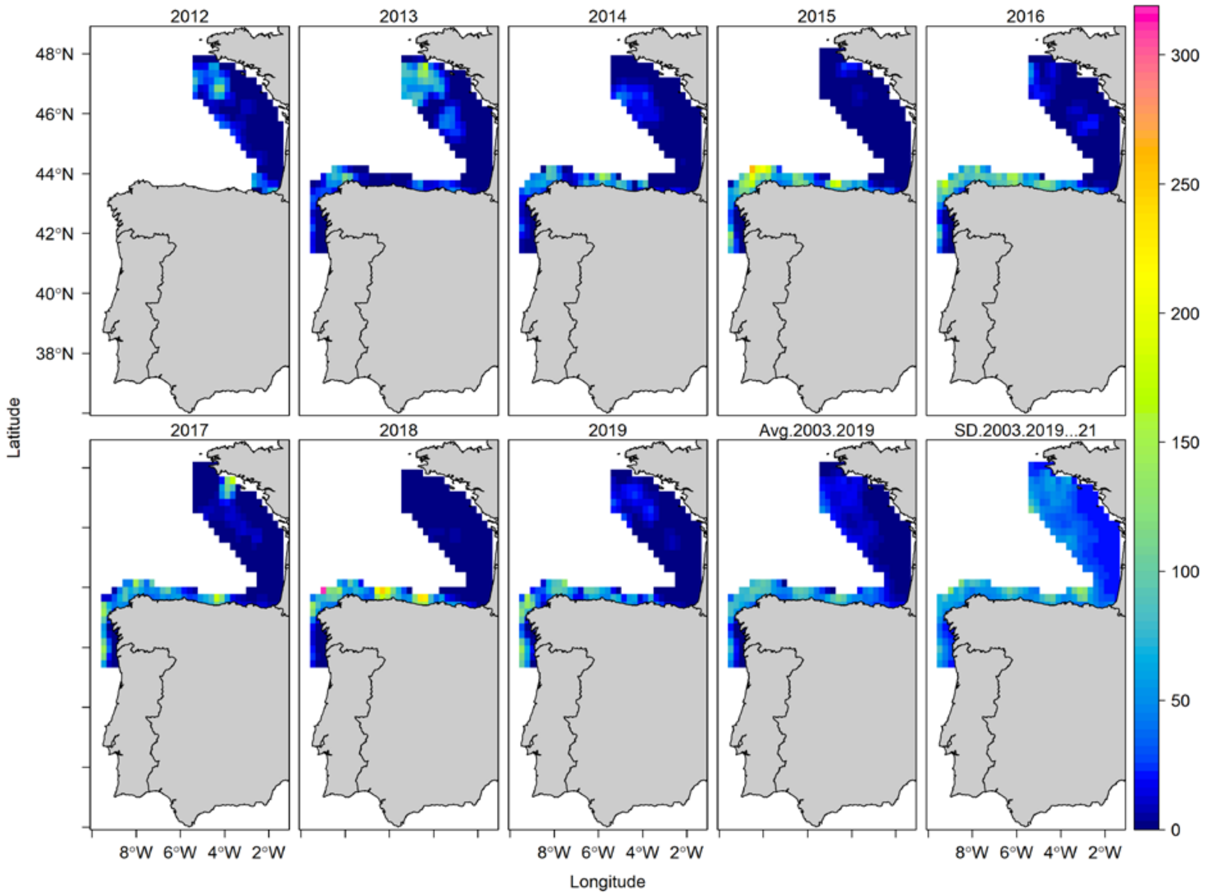


Figure 4.2.1.4-2. Blue whiting (*Micromesistius poutassou*) acoustic density (NASC, m².NM⁻²) maps derived from PELACUS and PELGAS spring surveys, 2012-2019, 0.25° map cell. "Avg.2003-2019 pane": map of NASC values averaged over the series. "SD.2003-2019 pane": map of NASC standard deviation.

High concentrations of blue whiting have been consistently observed during the springtime acoustic surveys in the Cantabrian Sea since 2003 (Figure 4.2.1.4-2). Secondary distribution areas were also located over the continental shelf in the North Western Bay of Biscay. In 2019, significant concentrations of blue whiting were observed in the Cantabrian Sea, as well as lower concentrations in North-Western Biscay.

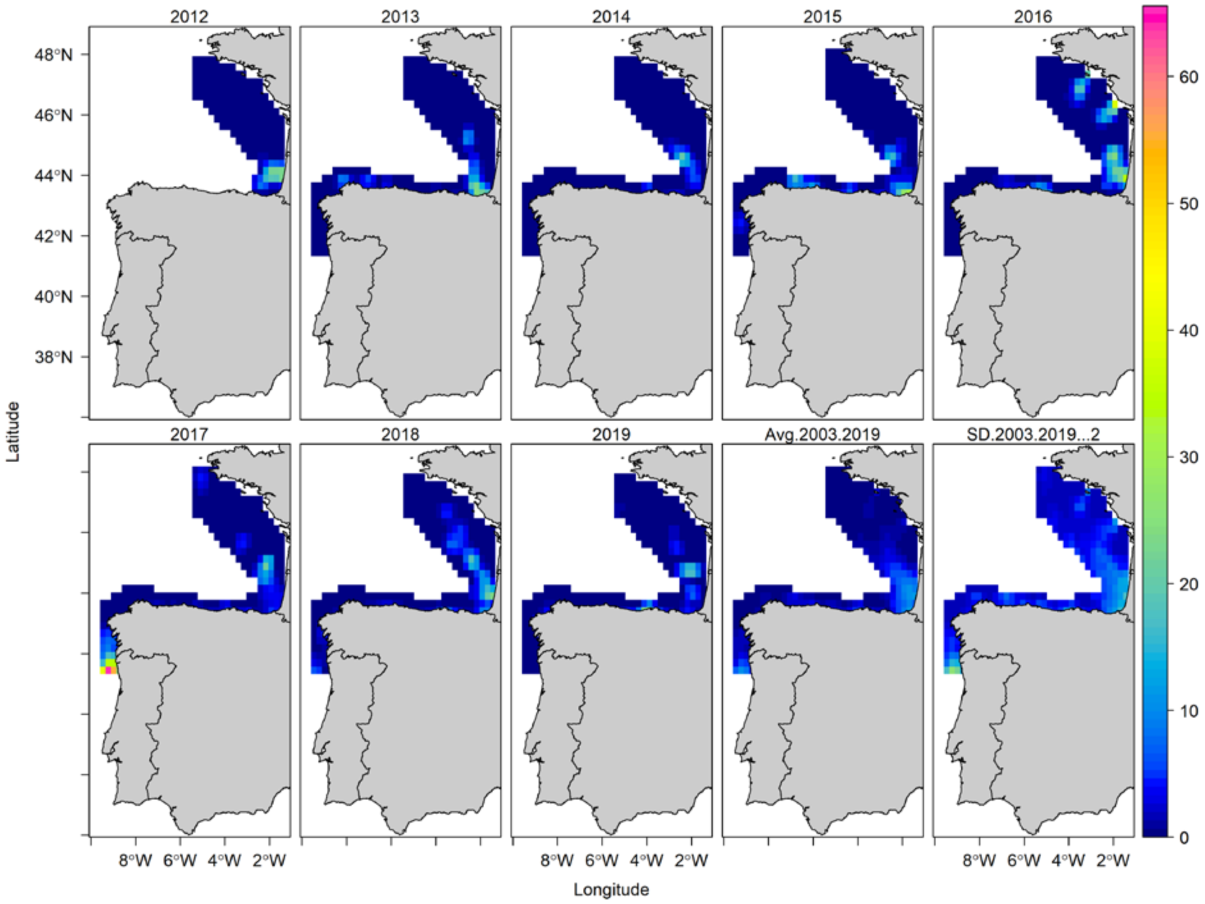


Figure 4.2.1.4-3. Chub mackerel (*Scomber colias*) acoustic density (NASC, m².NM-²) maps derived from PELACUS and PELGAS spring surveys, 2012-2019, 0.25° map cell. "Avg.2003-2019 pane": map of NASC values averaged over the series. "SD.2003-2016 pane": map of NASC standard deviation.

Dense concentrations of chub mackerel has been observed in springtime mostly in Southern Portugal and marginally in the Southern part of the Bay of Biscay since 2003 (Figure 4.2.1.4-3). Low densities of chub mackerel have been observed essentially in Southern Biscay in 2019.

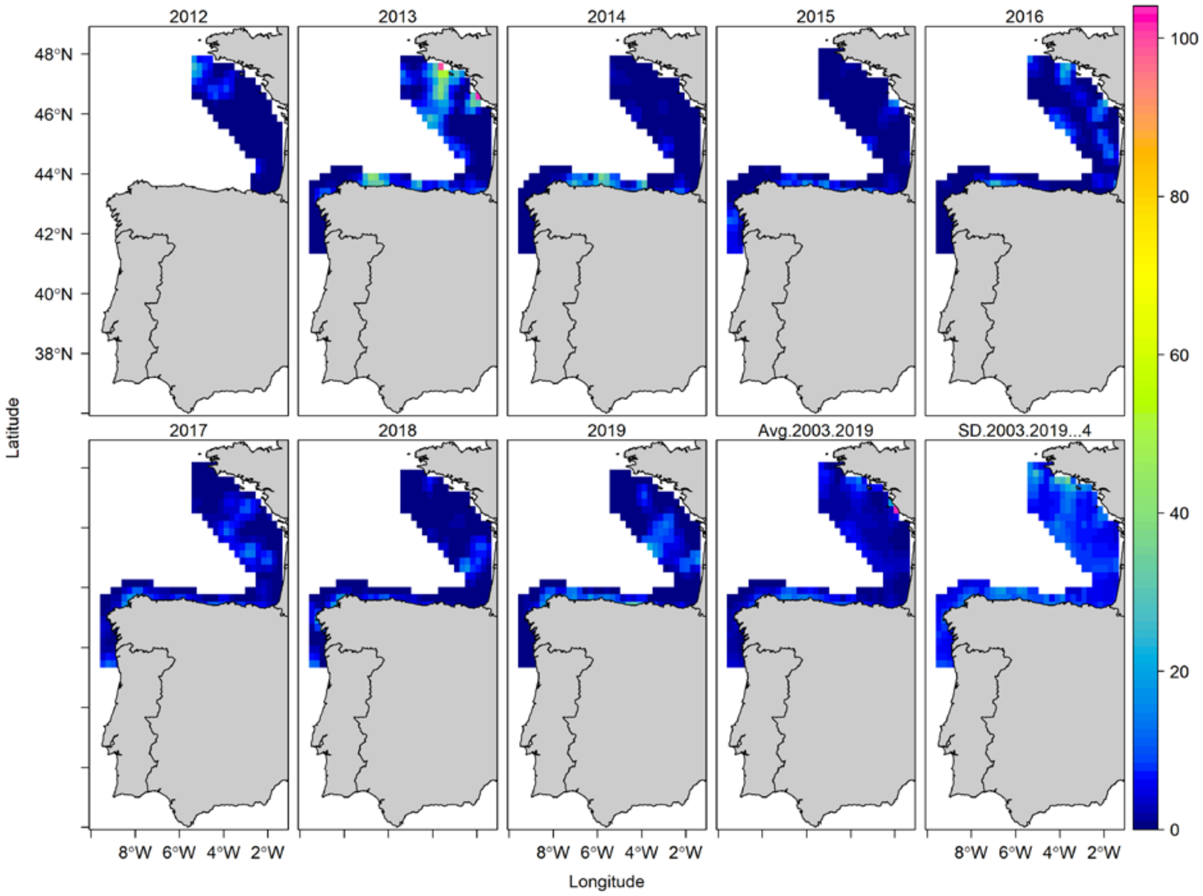


Figure 4.2.1.4-4. Atlantic mackerel (*Scomber scombrus*) acoustic density (NASC, m².NM-²) maps derived from PELACUS and PELGAS spring surveys, 2012-2019, 0.25° map cell. "Avg.2003-2019 pane": map of NASC values aver-aged over the series. "SD.2003-2019 pane": map of NASC standard deviation.

Atlantic mackerel has been essentially observed in the Central Cantabrian area, and along the coasts of Brittany and Vendée (46-48°N) and near the shelf break (46°N) in the Bay of Biscay since 2003 in springtime (Figure 4.2.1.4-4). It was essentially found in Western Cantabrian and Southern and Central Biscay areas in 2019.

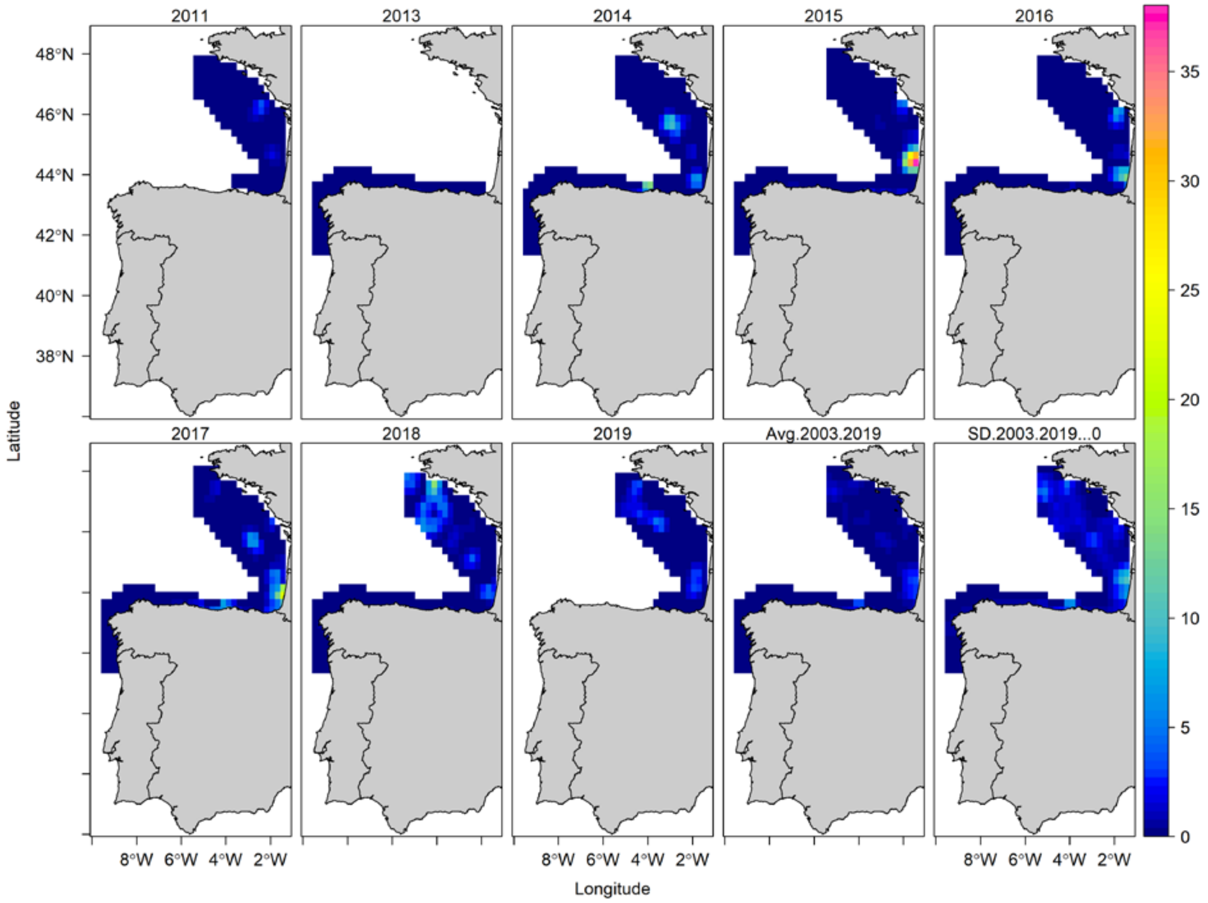


Figure 4.2.1.4-5. Mediterranean horse mackerel *(Trachurus mediterraneus)* acoustic density (NASC, m².NM-²) maps derived from PELACUS and PELGAS spring surveys, 2011-2019, 0.25° map cell. "Avg.2003-2019 pane": map of NASC values averaged over the series. "SD.2003-2019 pane": map of NASC standard deviation.

Mediterranean horse mackerel (*Trachurus mediterraneus*) has been mostly observed in springtime along the Landes coast in the Bay of Biscay (~44°N) since 2003 (Figure 4.2.1.4-5). Small secondary concentrations of this species were also observed in the center of the Bay of Biscay platform (~46°N) and in the Central Cantabrian area (4°W). In 2019, some patches of Mediterranean horse mackerel were found in the North-Western part of the Bay of Biscay and in Southern Biscay.

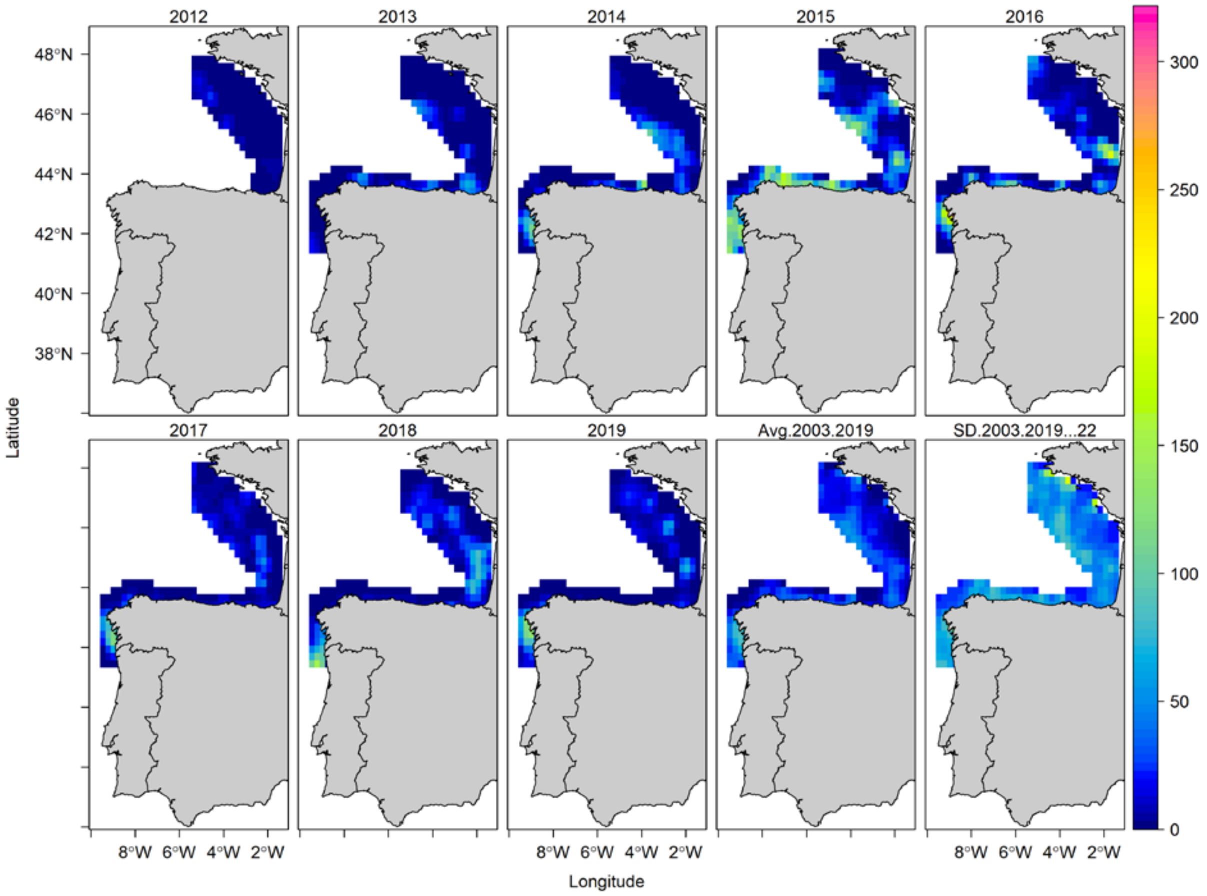


Figure 4.2.1.4-6. Horse mackerel *(Trachurus trachurus)* acoustic density (NASC, $m^2.NM^{-2}$) maps derived from PELACUS and PELGAS spring surveys, 2012-2019, 0.25° map cell. "Avg.2003-2019 pane": map of NASC values averaged over the series. "SD.2003-2019 pane": map of NASC standard deviation.

Horse mackerel has been consistently observed at low density along the shelf break and in southern part of the Bay of Biscay (Figure 4.2.1.3-6). In 2019, horse mackerel was essentially found at high density North of Portugal and in small less dense patches in central Bay of Biscay.

The WESPAS acoustic survey conducted since 2018 in areas 6 and 7 has been added to the WGACEGG joint spring surveys list this year. Extended gridded maps -presented below- have been produced by combining data collected during the spring acoustic surveys (PELAGO, PELACUS, PELGAS and WESPAS) on boarfish, herring, horse mackerel, sprat and blue whiting. They provide a unique overview of the distribution of those species in the European Atlantic Area from Spain to UK.

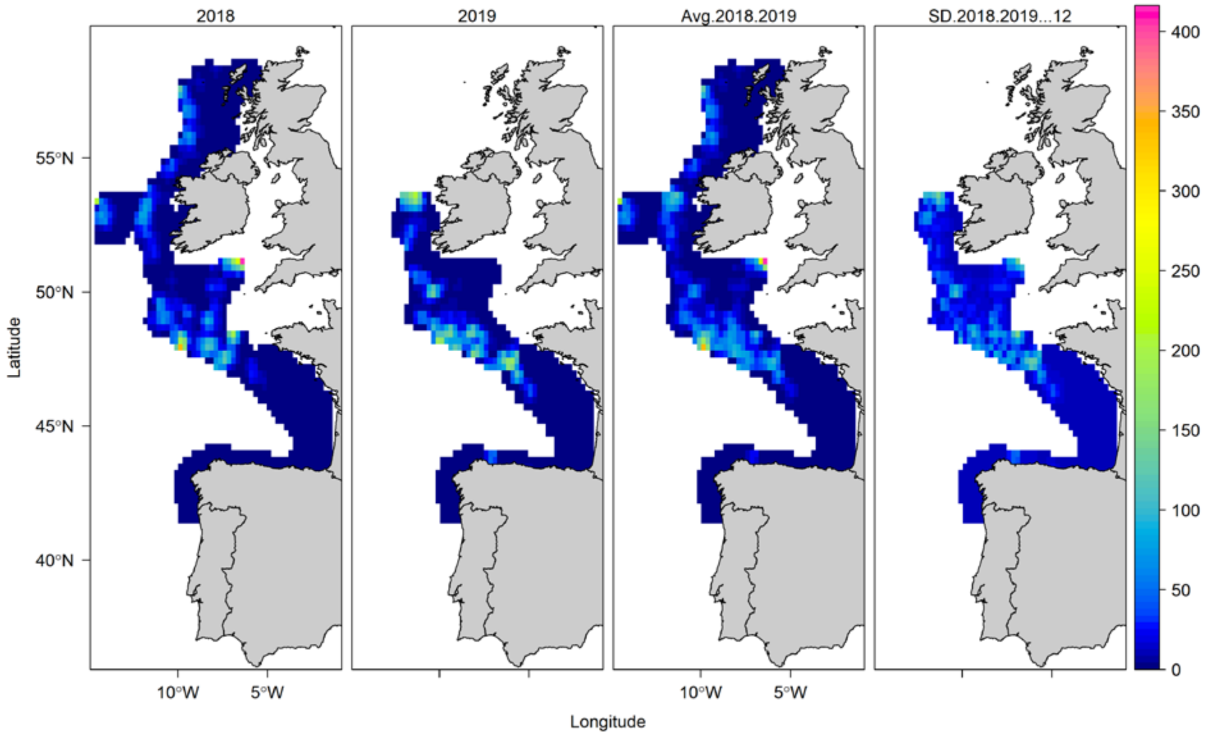


Figure 4.2.1.4-7. Boarfish (*Capros aper*) acoustic density (NASC, $m^2.NM^{-2}$) maps derived from spring PELACUS, PELGAS and WESPAS surveys, 2018-2019, 0.25° map cell. "Avg.20-2019 pane": map of NASC values averaged over the series. "SD.2003-2019 pane": map of NASC standard deviation.

It is assumed that the spring surveys timings allow to capture the boarfish distribution in a synoptic way in the survey area. Boarfish has been observed near the shelf break in Northern areas (>46°N) and in 2018 between Ireland and Bristol Channel in spring (Figure 4.2.1.4-7). In 2019, boarfish was essentially found near the shelf break from 46 to 58°N.

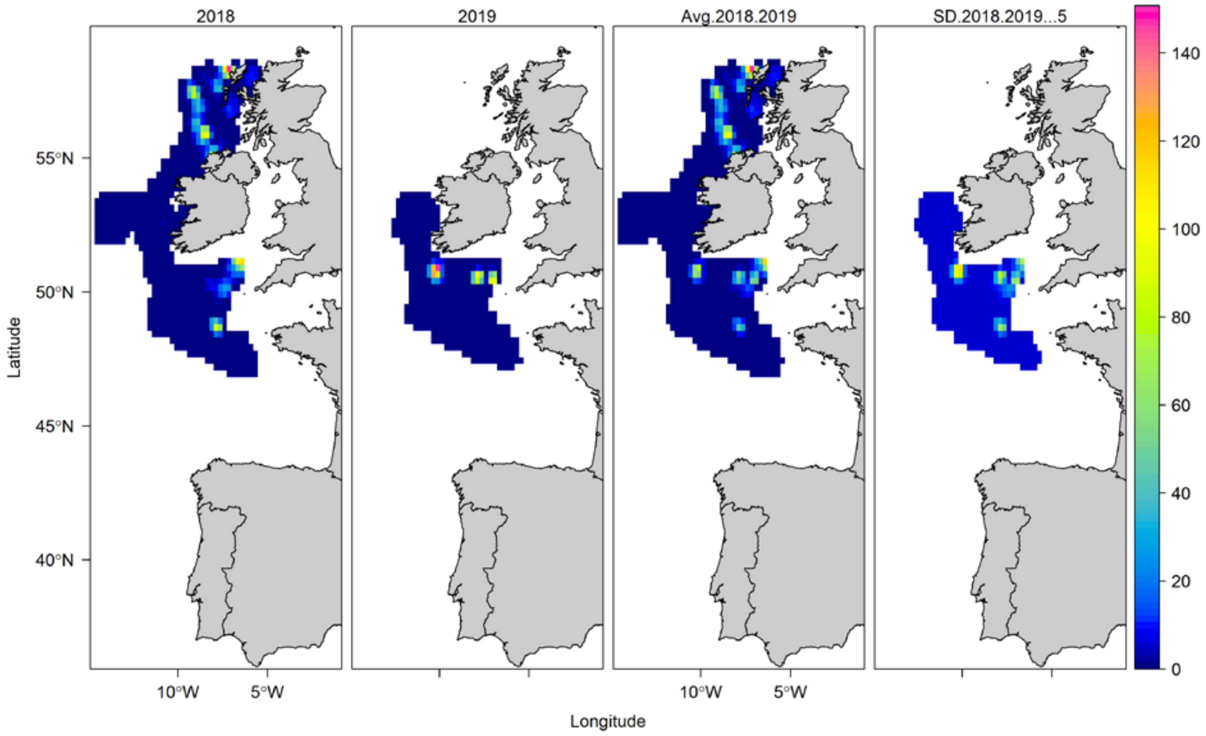


Figure 4.2.1.4-8. Herring (*Clupea harengus*) acoustic density (NASC, $m^2.NM^{-2}$) maps derived from spring PELACUS, PELGAS and WESPAS surveys, 2018-2019, 0.25° map cell. “Avg.20-2019 pane”: map of NASC values averaged over the series. “SD.2003-2019 pane”: map of NASC standard deviation.

It is assumed that the spring surveys timings allow to capture the herring distribution in a synoptic way in the survey area. Herring aggregations have been observed North (2018, 2019) and South (2019) of Ireland in springtime (Figure 4.2.1.4-8).

No significant herring concentrations was observed South of 48°N in springtime. Small herring concentrations have been found South of Ireland in 2019.

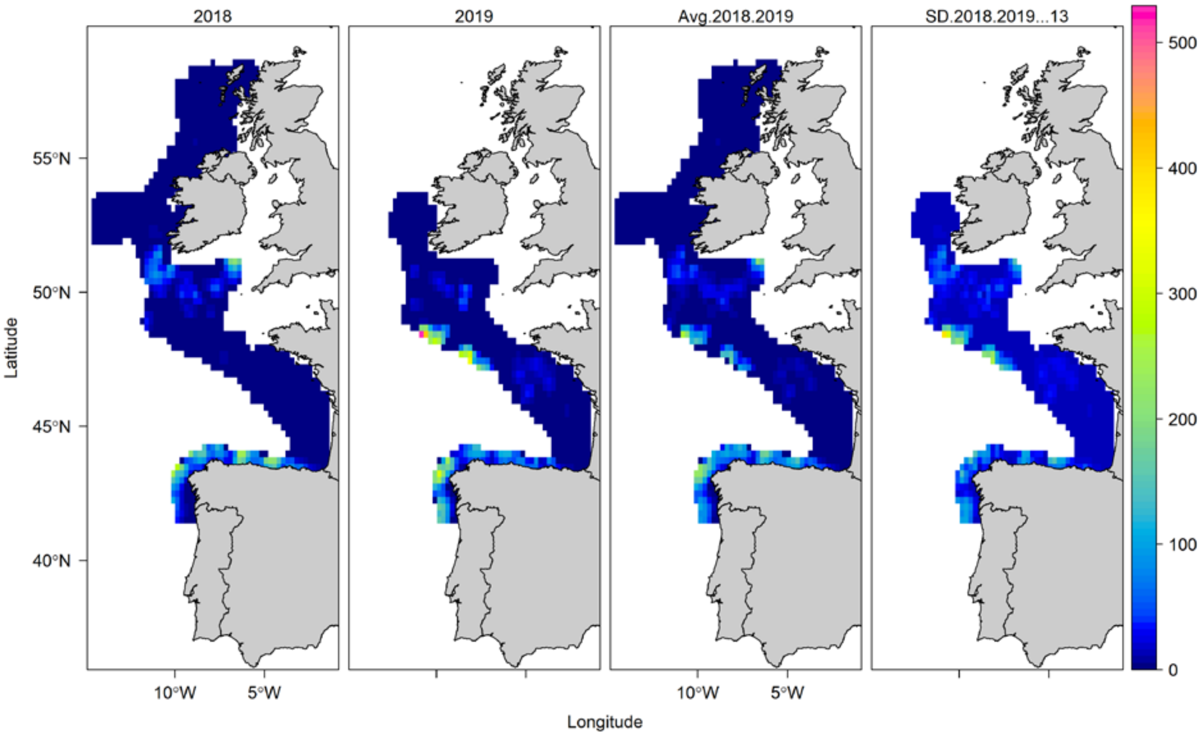


Figure 4.2.1.4-9. Blue whiting (*Micromesistius poutassou*) acoustic density (NASC, m².NM-²) maps derived from PELACUS, PELGAS and WESPAS spring surveys, 2018-2019, 0.25° map cell. "Avg.2018-2019 pane": map of NASC values averaged over the series. "SD.2018-2019 pane": map of NASC standard deviation.

It is assumed that the spring surveys timings allow to capture the blue whiting distribution in a synoptic way in the survey area. Blue whiting was essentially distributed in the Cantabrian Sea in 2018 and 2019, with secondary concentrations South of Ireland in 2018 (~50°N) and near the Celtic Sea shelf break (~48°N) in 2019 in springtime (Figure 4.2.1.4-9).

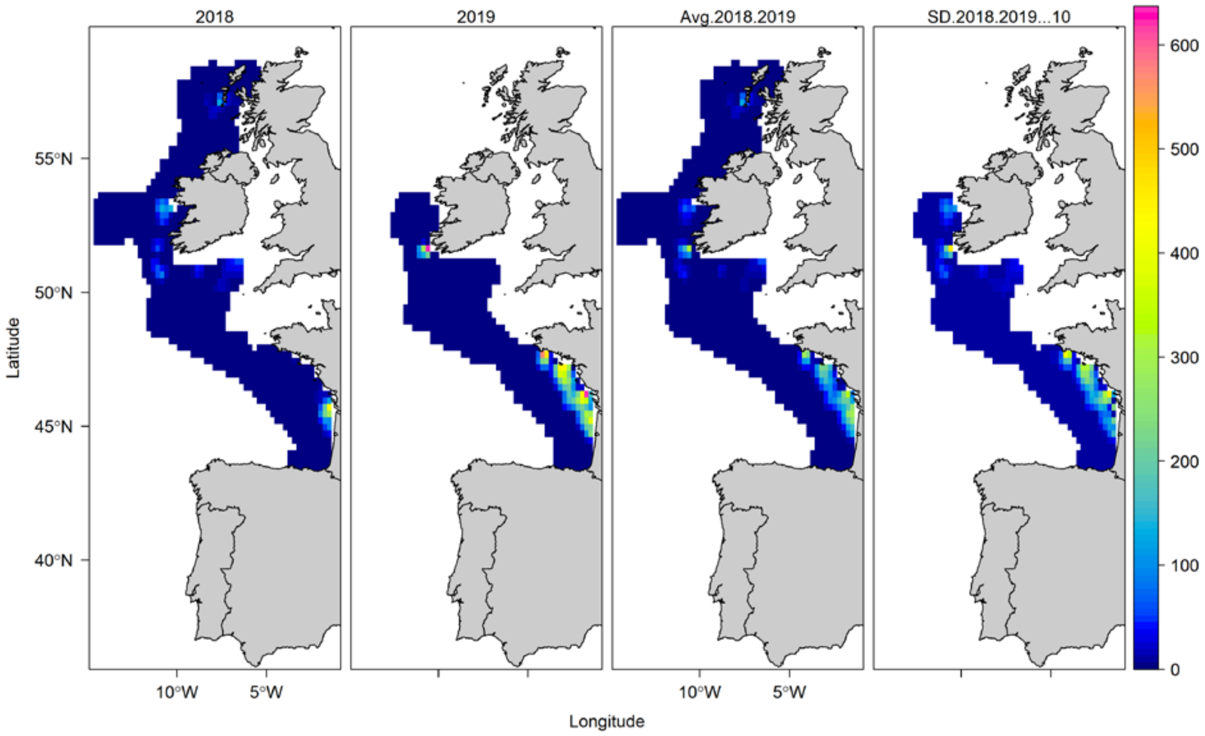


Figure 4.2.1.4-10. Sprat (*Sprattus sprattus*) acoustic density (NASC, $m^2.NM^{-2}$) maps derived from PELACUS, PELGAS and WESPAS spring surveys, 2018-2019, 0.25° map cell. “Avg.2018-2019 pane”: map of NASC values averaged over the series. “SD.2018-2019 pane”: map of NASC standard deviation.

It is assumed that the spring surveys timings allow to capture the sprat distribution in a synoptic way in the survey area. In springtime, the sprat core distribution area was the coastal waters of the Bay of Biscay, with a secondary distribution area in Ireland Western coastal waters (~9°W) (Figure 4.2.1.4-10). Large sprat concentrations were observed along the French coast in the Bay of Biscay in 2019.

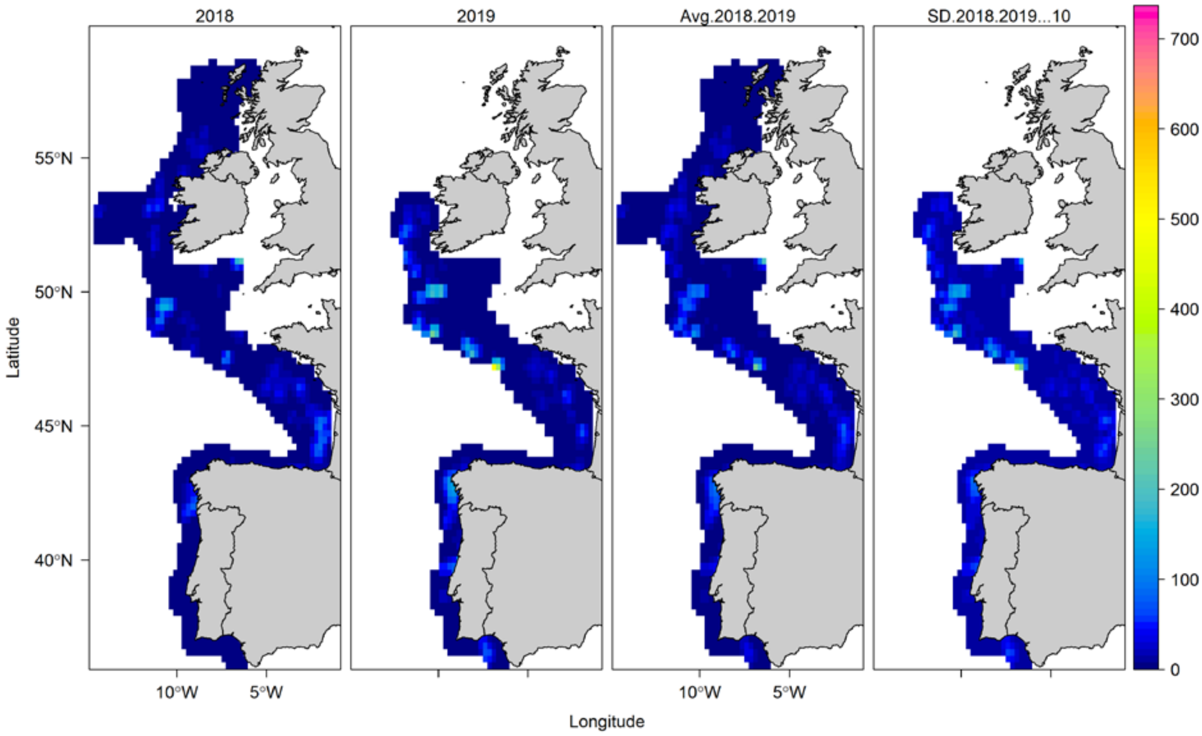


Figure 4.2.1.4-11. Horse mackerel *(Trachurus trachurus)* acoustic density (NASC, $m^2.NM^{-2}$) maps derived from PELACUS, PELGAS and WESPAS spring surveys, 2018-2019, 0.25° map cell. "Avg.2018-2019 pane": map of NASC values averaged over the series. "SD.2018-2019 pane": map of NASC standard deviation.

There are doubts on the fact that spring surveys allow to capture the horse mackerel distribution in a synoptic way, as this species is known to undergo large scale migration during the survey period. Small aggregations of horse mackerel appeared to be scattered on the North Western Iberian coast, the Bay of Biscay and the Western Celtic Sea in springtime. Horse mackerel seemed to be essentially concentrated on the North Western Iberian coast and near the shelf break in the Celtic Sea in 2019 (Figure 4.2.1.4-11).

4.2.1.5 Sardine and anchovy egg distributions from CUFES in acoustic surveys

Egg distribution maps for sardine and anchovy obtained with the data from CUFES, during the spring acoustics surveys in 2019 (PELAGO, PELACUS, PELGAS) are presented in **Figure 4.2.1.5.1**. Overall, as it has happened in recent years, egg density was higher for anchovy than for sardine. However, the number of **anchovy** eggs collected in 2019 was much lower than during 2018. This decrease was related to the drop observed in the NW coast of Portugal, where in 2018 very large abundances of anchovy eggs were noted in accordance with the quite remarkable increase in the anchovy biomass found last year in the region; which in turn suffered a decline from 2018 to 2019 (see **section 4.1.1.1.2.3**, and **annex 3**). During the 2019 surveys, although high abundances of anchovy eggs were still present off NW Portugal, higher densities occurred in the Bay of Biscay - main spawning area of the species where the species is usually more abundant - (see **section 4.2.2.2**). In the southern coast, where anchovy is also resident, egg hot spots appeared between Cape Santa Maria and Huelva. The distribution patterns of **sardine** eggs this year in the NW Iberian coast and Bay of Biscay were very similar to the observations mapped in 2018; higher abundances were apparent in the NW coast of Portugal, the region off the rivers Douro-Minho, and in the central area of the Bay of Biscay, where the spawning area was a bit more extended. In 2019, very few sardine eggs were collected in the region from Aveiro to the Alentejo coast (SW). Patches of high density were located in the SW and in particular in the south, off Algarve, where sardine biomass (see **section 4.1.1.1.2.3**, and **Annex**

3), and egg abundance, increased from 2018 to 2019. More details on the egg abundances distributions can be found in the survey reports in **Annex 3**.

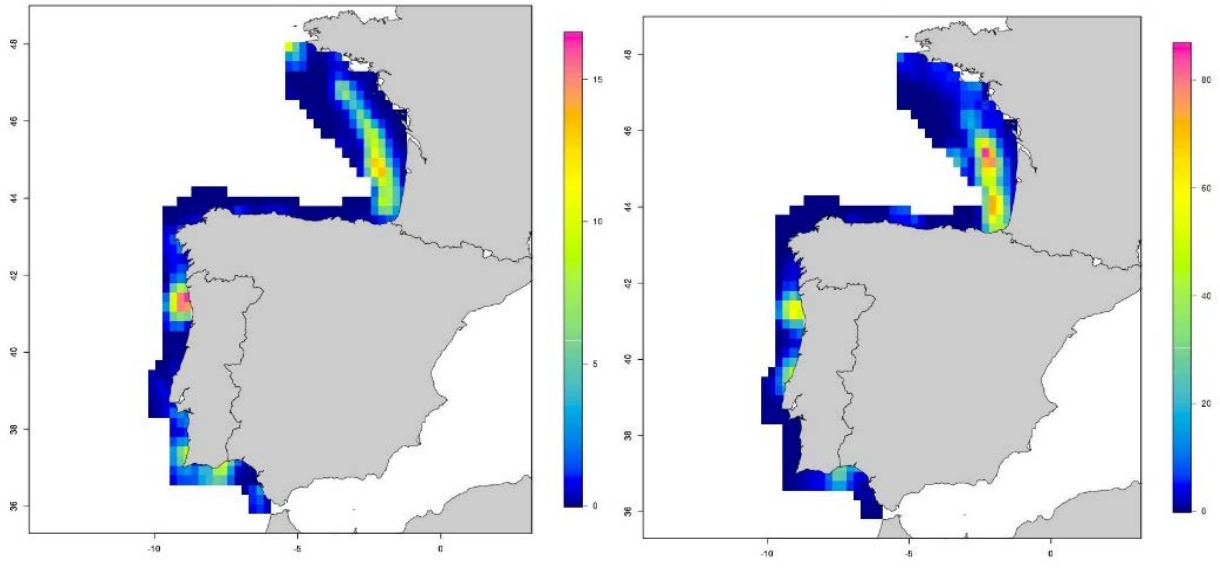


Figure 4.2.1.5.1: Sardine (left) and anchovy (right) egg distributions from CUFES (eggs/m³) observations during the 2019 spring acoustics surveys (PELAGO, PELACUS and PELGAS). For dates of coverage in each region see **Figure 4.1.1.1.1 and annex 3**. Note that due to the data range in the observations the colour scales do not match between panels.

4.2.2 Spring DEPM surveys

This year 2019 the only DEPM survey carried out was the BIOMAN survey. This survey has been conducted by AZTI every year since 1987 in May, targeting anchovy and sardine in the Bay of Biscay (ICES divisions 8abcd). The other DEPM surveys are conducted every three years.

4.2.2.1 Oceanographic conditions

In 2019 the spring DEPM survey for sardine and anchovy, BIOMAN, was conducted, as usual, from the 9th to the 31st of May. sea surface temperatures ranged from 10.2ºC to 16.8ºC with a mean of 14.8ºC, lower than last year (15.2ºC). Lower values were observed between the Gironde estuary and the Arcachon area, and in the North of the spawning area (Bay of Biscay?). The warmest area was observed in the North of the French platform (**Fig. 4.2.2.1.1**) and in the South of the Cantabric coast in the area of San Sebastian. Sea surface salinity ranged from 27.7 to 39.5 with a mean of 35.0, higher than last year mean (34.41). This year no clear riverine plumes were observed off the Garonne (North) and Adour (South) river estuaries (**Fig. 4.2.2.1.1**).

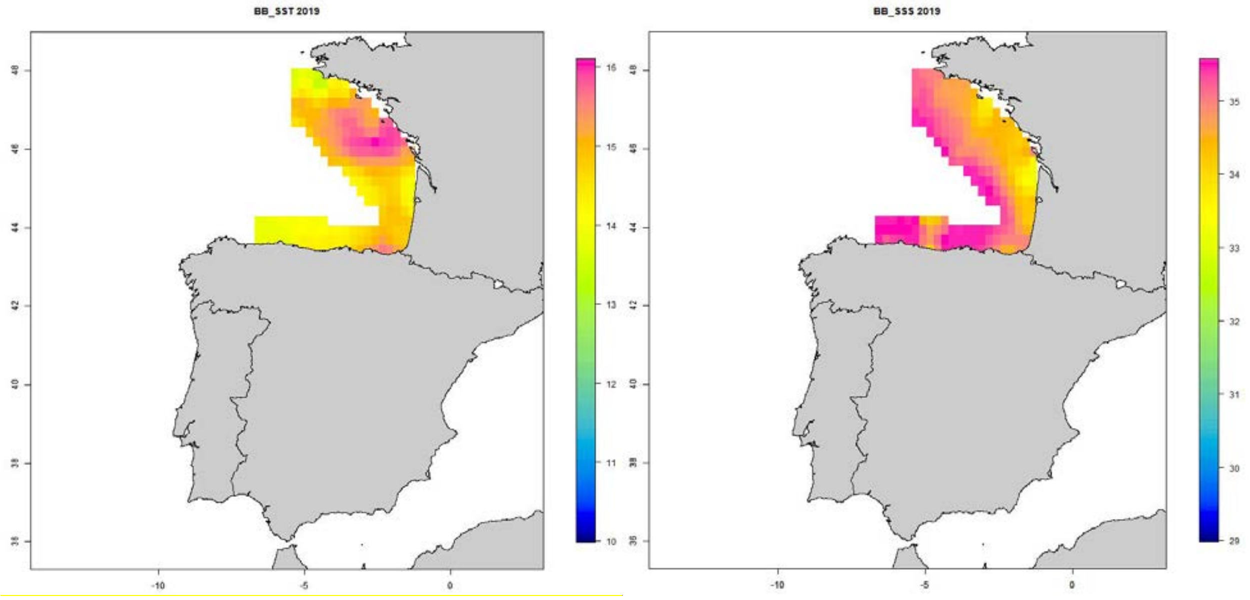


Figure 4.2.2.1.1 Sea surface temperature (left) and salinity (right) during DEPM survey BIOMAN2019 (May)

4.2.2.2 Anchovy and sardine egg distributions from CUFES and PairoVET observations

Anchovy egg distribution derived from PairoVET and CUFES sampling carried out during 2019 DEPM survey BIOMAN (**Fig. 4.2.2.2.1**) showed eggs scattered all over the French continental shelf (200m isobath), up to the 46ºN latitude and from there to the 47º37'N from the coast until 100m depth, were the limit was found. As last year, there were some anchovy eggs at the limit of the 8abd area at 48ºN but inside that where included for the biomass estimates (see **WD Santos *et al* 2019 in Annex 6**).

This year 18% of the anchovy eggs were found in the Cantabrian Coast. The survey arrived until 6ºW. The same pattern of distribution is observed with both samplers PairoVET and CUFES.

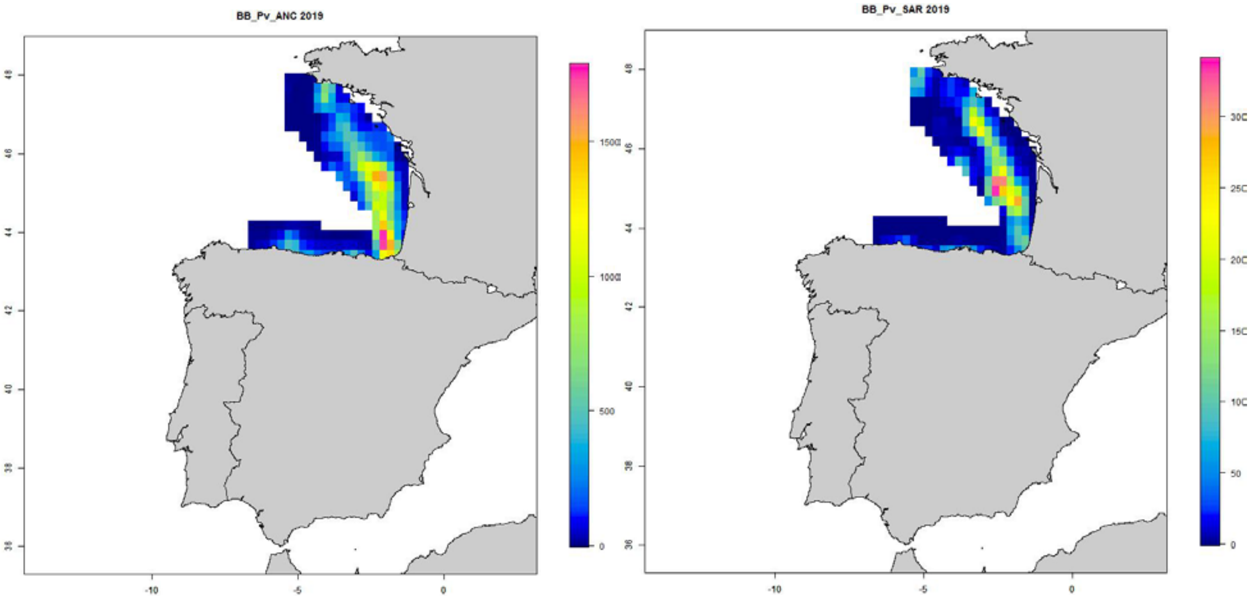


Figure 4.2.2.2.1 Anchovy egg distributions from PairoVET (left; eggs/m^2) and CUFES (right; eggs/m^3) observations collected during BIOMAN survey.

The Sardine egg distribution pattern derived from CUFES and PairoVET observations during BIOMAN 2019 DEPM survey (**Fig.4.2.2.2.2**) shows low abundances close and all along the surveyed Cantabric coast. Abundances of eggs were encountered in the French platform, between the coast and 200m depth until the 46ºN latitude, and between the coast and the100m depth isoline until 48ºN, where the north spawning limit was found for this species. As last year, there were some sardine eggs at the limit of the 8abd area at 48ºN which were included for the abundance estimates (see **wd Santos *et al* 2019 in annex 6**). The same pattern distribution is observed with both samplers PairoVET and CUFES.

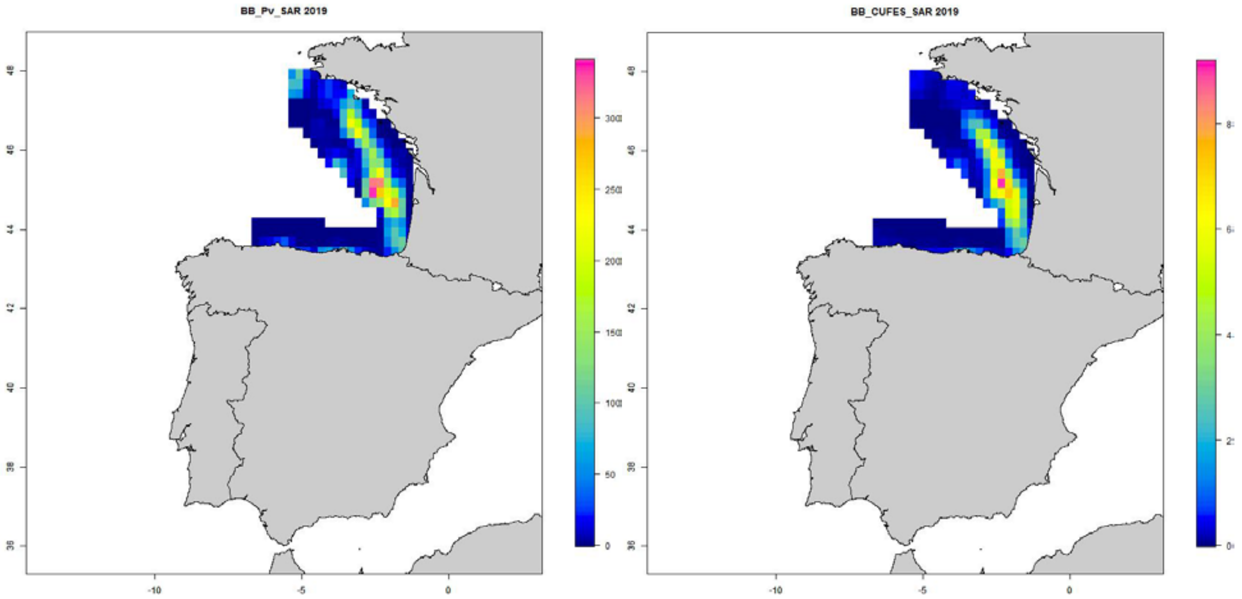


Figure 4.2.2.2.2 Sardine egg distributions from PairoVET (left; eggs/m²) and CUFES (right; eggs/m³) observations collected during DEPM BIOMAN surveys.

4.2.3 Gulf of Cadiz summer survey

The ECOCADIZ 2019-07 survey was carried out between 31st July and 13rd August 2019 onboard the Spanish R/V Miguel Oliver covering a survey area comprising the Spanish and Portuguese waters of the Gulf of Cadiz, from Strait of Gibraltar to Cape San Vicente, between the 20 m and 200 m isobaths. The main objectives of this survey were the acoustic assessment (by echo-integration) and mapping of neritic fish resources and of the oceanographic and biological conditions off the Gulf of Cadiz continental shelf (**Fig. 4.2.3.1**).

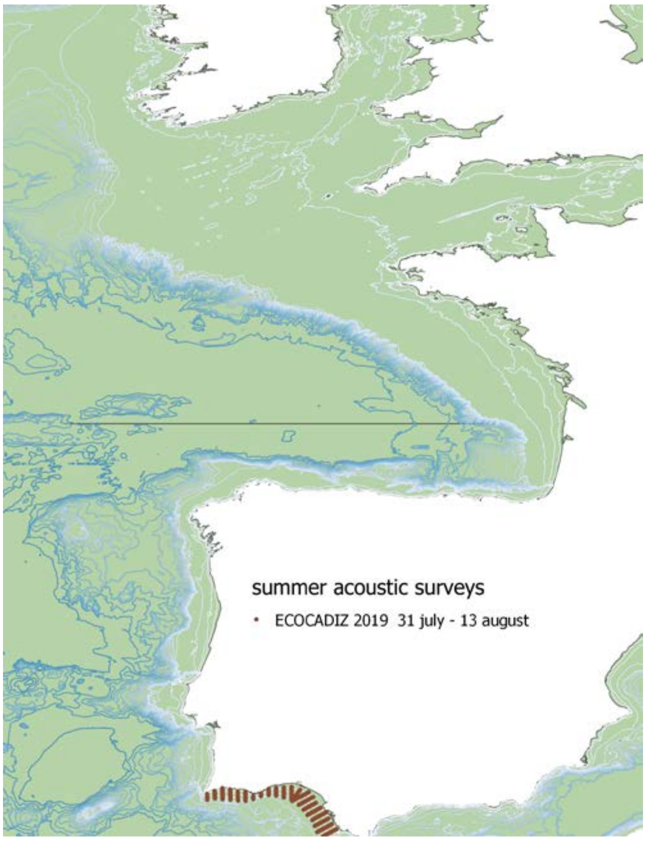


Figure 4.2.3.1. ECOCADIZ 2019-07 survey. Location of the acoustic transects.

4.2.3.1 Oceanographic conditions

The observed patterns of Sea Surface Temperature (SST) and Sea surface salinity (SSS) during the survey ECOCADIZ 2019-07 were like those recorded in previous years. Regional differences in the range of observed salinities and temperatures between East and West of Cape Santa Maria were also found (**Tab. 4.2.3.1.1**. and **Fig. 4.2.3.1.1**).

The area to the West of Cape Santa Maria was colder than the area to the East, as usual, with a mean SST of 17.39 ^{0}C, more than 3 degree lower than in the W-CSM. Regarding the values of SSS, there were not significant differences between both areas.

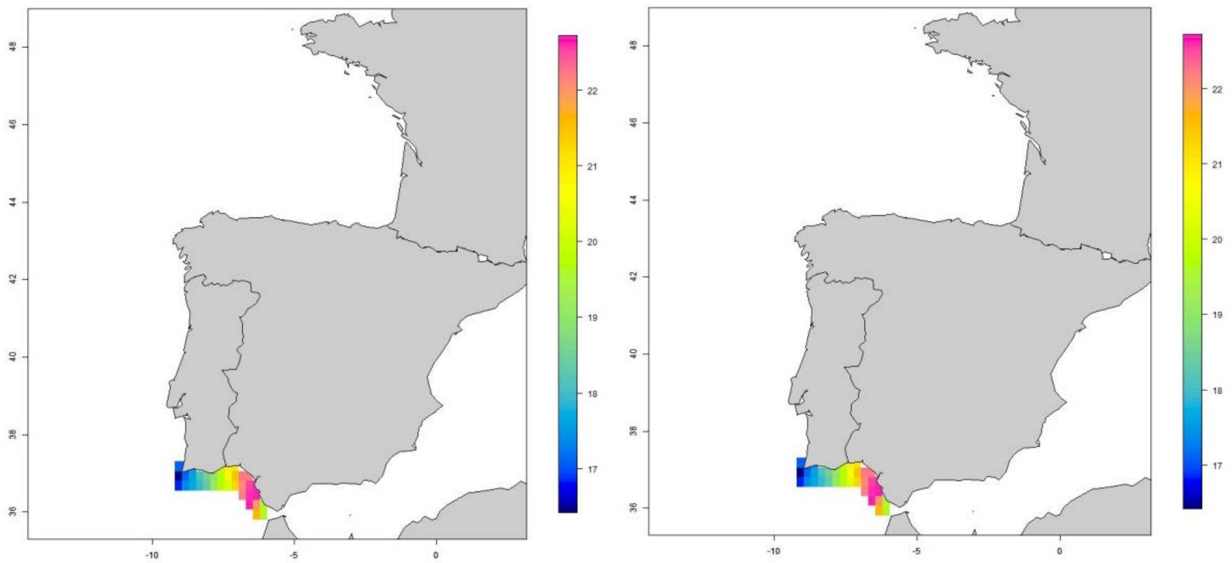


Figure 4.2.3.1.1. SST (left) and SSS (right) recorded during the ECOCADIZ 2019-07 survey.

4.2.3.2 Anchovy egg distributions from CUFES Observations

The surveyed area by CUFES was coincident with the acoustic sampling grid, surveying the continental shelf waters following a systematic sampling scheme, based in 21 transects perpendicular to the coast, spaced 8 nm. The CUFES sampling is fixed at 5 m depth. The volume of filtered water was 600 l/min, approximately, and egg samples were always taken every 3 nm in the shelf (ICES, 2003). The CUFES collector was arranged with a 335 μm net. The density of eggs in each station was estimated in number of eggs/m3.

During the ECOCADIZ 2019-07 survey 121 samples have been collected, 73 of them were positive related to the presence of anchovy eggs (60.3% of total samples or stations). The plankton samples were preserved and sorted on board, and anchovy eggs were classified into 3 development stages. A total of 19031 anchovy eggs were collected, 352 of sardine and 3755 of other unidentified species. The maximum abundance of anchovy eggs by station was 331.4 eggs/m^3. A total density of 1778 eggs/m3 was estimated, representing a slight increase compared with the 2018 estimate (**Fig. 4.2.3.2.1**)

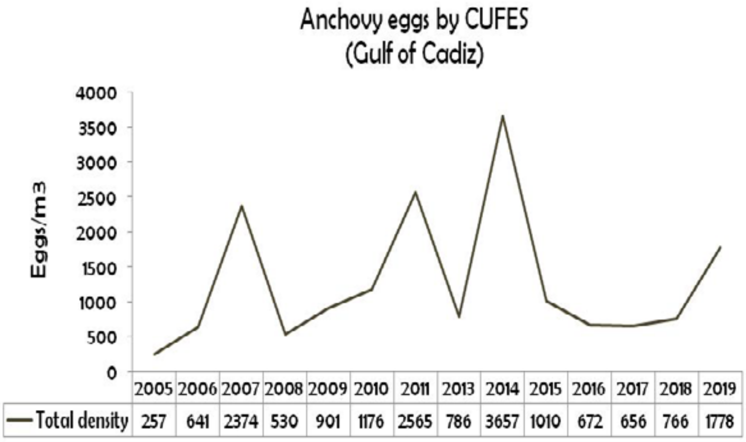


Figure 4.2.3.2.1. Historical series of the abundance of anchovy eggs by CUFES in the Gulf of Cadiz.

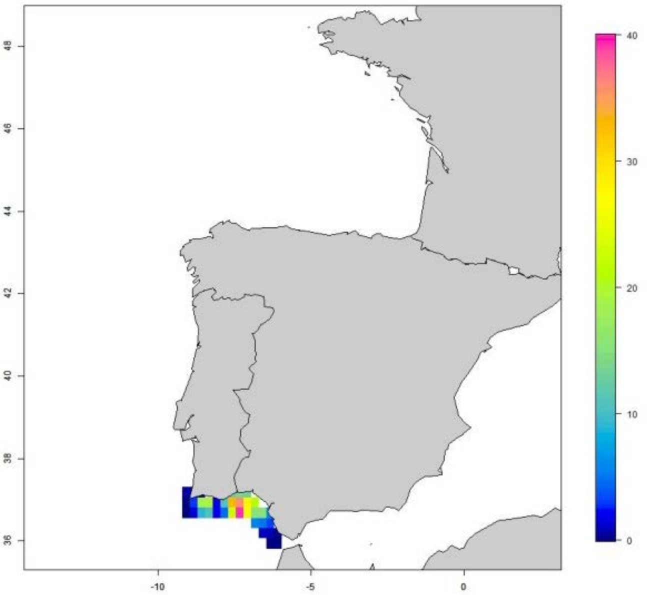


Figure 4.2.3.2.2: ECOCADIZ 2019-07 survey. Spatial distribution of anchovy eggs density (eggs/m³) by CUFES.

4.2.3.3 Trawl haul catch composition

A total of 27 fishing operations for echo-trace ground-truthing (all of them valid ones according to a correct gear performance and resulting catches), were carried out during the survey (**Fig. 4.2.3.3.1**). The sampled depth range in these hauls oscillated between 42-183 m. A detailed description on the conduction of these hauls is given in Ramos *et al*. (2019 WD in **Annex 3**).

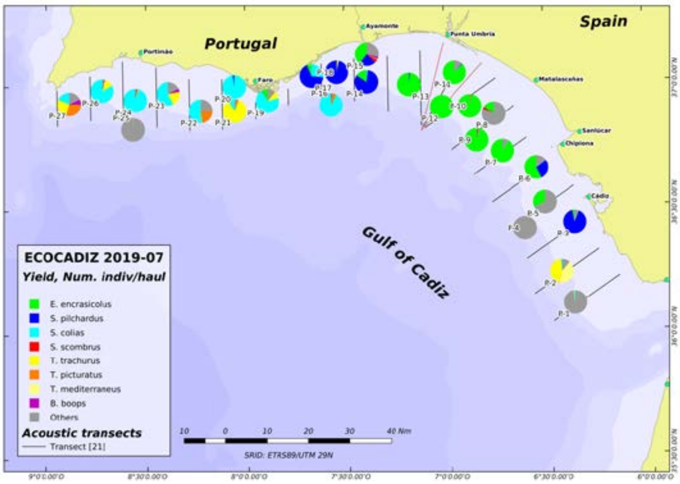


Figure 4.2.3.3.1: ECOCADIZ 2019-07 survey. Trawl hauls catch composition during the survey.

During the survey were captured 2 Chondrichthyan, 37 Osteichthyes, 6 Cephalopod, 3 Crustacean and 3 Echinoderm species. The percentage of occurrence of the more frequent species in the trawl hauls is described in detail in Ramos *et al.* (2019 WD in **Annex 3**).

The species composition, in terms of percentages in number, in each valid fish station is shown in **Fig. 4.2.3.3.1**. A first impression of the distribution pattern of the main species may be derived from the above figure. Thus, anchovy was captured between Cape Santa Maria and Cape Trafalgar, although the highest yields were recorded in the Spanish central waters. The size composition of anchovy catches confirms the usual pattern exhibited by the species in the area during the survey season, with the largest fish inhabiting the westernmost waters and the smallest ones concentrated in the surroundings of the Guadalquivir river mouth and adjacent shallow waters. Sardine catches showed a quite similar distribution to the above described for anchovy but showing the highest yields in the surroundings of the Cadiz Bay and between Cape Santa Maria and the Guadiana river mouth. Juvenile sardines were mainly captured in the shallowest hauls conducted in the coastal fringe between Matalascañas and the Bay of Cadiz. Chub mackerel, horse mackerel, blue jack mackerel and bogue, although they occurred in a great part of the study area, only showed relatively high yields in the Portuguese waters. Mediterranean horse mackerel, Atlantic pomfret (*Brama brama*) and transparent goby (*Aphia minuta*) were restricted to the central and easternmost Spanish waters. The size composition of all these species in fishing hauls is shown in Ramos *et al*. (2019 WD in **Annex 3**).

4.2.3.4 Adult sardine and anchovy acoustic density (NASC) distribution

Sardine recorded high acoustic echo-integration values in summer 2019 (19% of the total NASC attributed to pelagic fish species assemblage), as a consequence of the occurrence of dense mid-water schools in the coastal fringe (20-60 m depth) between Ayamonte (transect RA11) and Doñana (transect RA06), (**Fig. 4.2.3.4.1**). This distribution pattern of acoustic densities is the opposite one observed during the PELAGO survey in spring, when the highest densities were recorded in the Algarve westernmost waters.

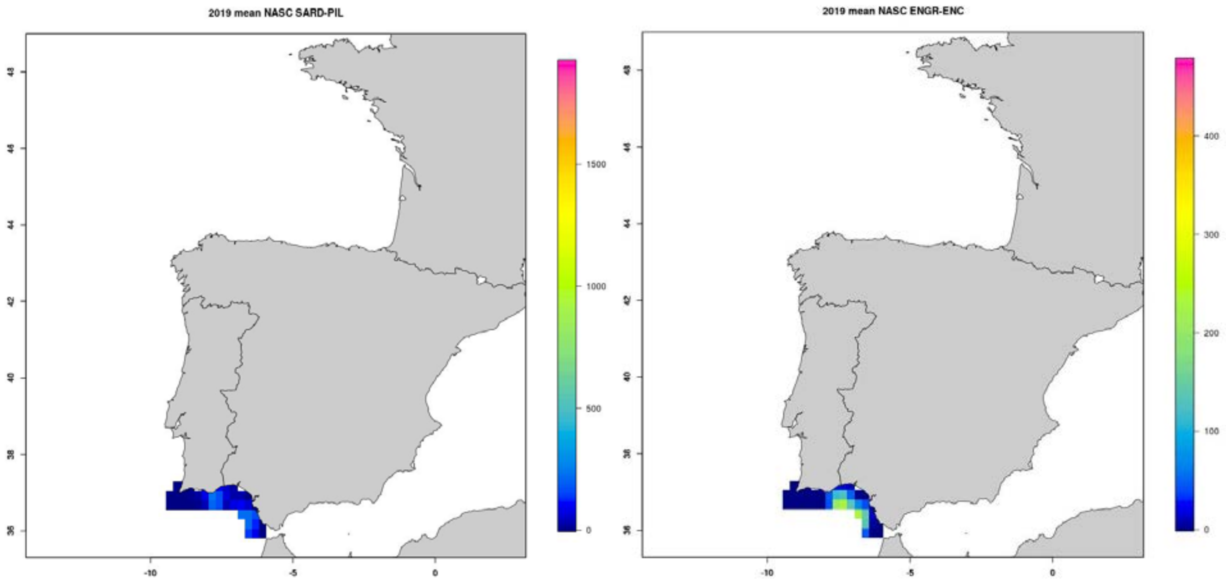


Figure 4.2.3.4.1: Sardine (*Sardina pilchardus*) (left) and anchovy (*Engraulis encrasicolus*) (right) acoustic density (NASC, m^2 nm^{-2}) maps derived from the ECOCADIZ 2019-07 Gulf of Cadiz summer acoustic survey, 0.25^0 map cell.

Anchovy (29% of the total NASC attributed to fish) was mainly distributed between Cape Santa Maria and Bay of Cadiz, although showing the highest densities in the Spanish shelf waters between El Rompido (transect RA10) and Bay of Cadiz (transect RA03) (**Fig. 4.2.3.4.1**). The PELAGO spring survey recorded the species only in the Spanish waters.

4.2.3.5 Other adult small pelagic fish species acoustic density distributions

Atlantic mackerel (*Scomber scombrus*; 0.02% of the total NASC) showed very scattered and low acoustic records during the 2019 survey, which were mainly observed over the shelf located in the central part of the Gulf of Cadiz (**Fig. 4.2.3.5.1.a**). Juveniles were mainly recorded in the Spanish outer shelf central waters, whereas larger fish occurred in shallower waters.

Chub mackerel (*S. colias*; 17% of the total NASC) was widely distributed in the surveyed area, although the highest densities occurred all over the Portuguese shelf waters. In the Spanish waters the species occurred in the middle-outer shelf waters, where the largest fish were also found (**Fig. 4.2.3.5.1.b**).

Blue jack mackerel (*Trachurus picturatus*; 1% of the total NASC) was mainly distributed all over the Portuguese outer shelf waters. An incidental occurrence was also recorded in the Spanish easternmost waters. The surveyed population was composed by juveniles and subadults (**Fig. 4.2.3.5.1.c**).

Horse mackerel (*T. trachurus*; 3% of the total NASC) showed a quite similar distribution pattern to the abovementioned one for blue jack mackerel, with the species being almost absent in the easternmost shelf and showing relatively higher densities in the shelf area comprised between Cape San Vicente and Cape Santa Maria. Juveniles were scarce and occurred incidentally in the Spanish outer shelf central waters (**Fig. 4.2.3.5.1.d**).

Mediterranean horse mackerel (*T mediterraneus*; 2% of the total NASC) was restricted, as usual, to the Spanish waters, more specifically between Doñana and Sancti-Petri, with the population being composed by adult fish (**Fig. 4.2.3.5.1.e**).

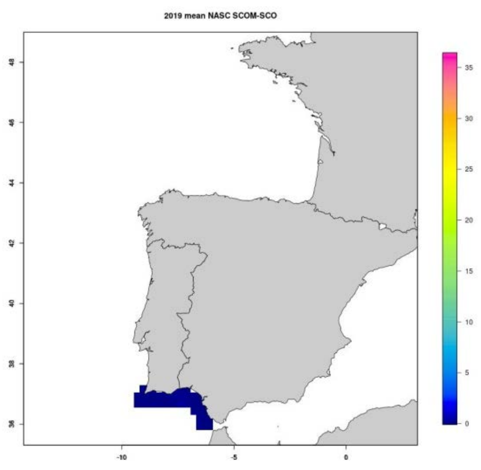
Bogue (*Boops boops*; 0.5% of the total NASC) showed a distribution pattern quite similar to the described ones for blue jack mackerel and horse-mackerel, with a very incidental occurrence in Spanish waters (just in front of the Bay of Cadiz) and the highest densities being recorded in the westernmost waters of the Gulf (**Fig. 4.2.3.5.1.f**).

Transparent goby (*Aphia minuta*; 5% of the total NASC) showed unusually high acoustic integration and densities this year, which were exclusively recorded over the inner-middle shelf waters of the Spanish part of the Gulf, between Mazagon and Bay of Cadiz. Its occurrence was associated to the typical (plankton-) scattering layer recorded close to the bottom in the Guadalquivir river mouth's influence area (**Fig. 4.2.3.5.1.g**).

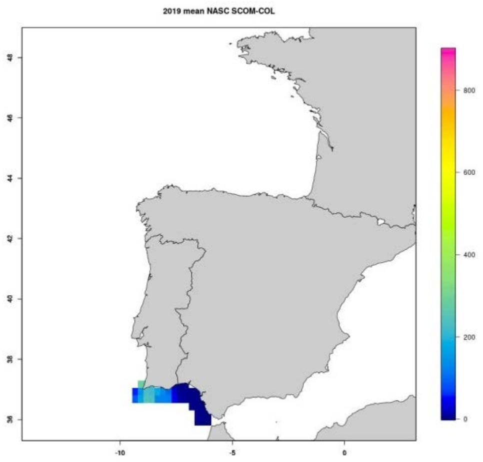
The Atlantic pomfret (*Brama brama*) showed an unexpected high frequency of occurrence and abundance in the fishing hauls not recorded in previous surveys. The species acoustically contributed with 18% of the total NASC recorded in the survey, although it was restricted to the Spanish middle-outer shelf waters (**Fig. 4.2.3.5.1.h**).

Longspine snipefish (*Macroramphosus scolopax*; 2%) showed an incidental occurrence mainly restricted to the westernmost outer shelf waters, just to the west of Portimão (**Fig. 4.2.3.5.1.i**).

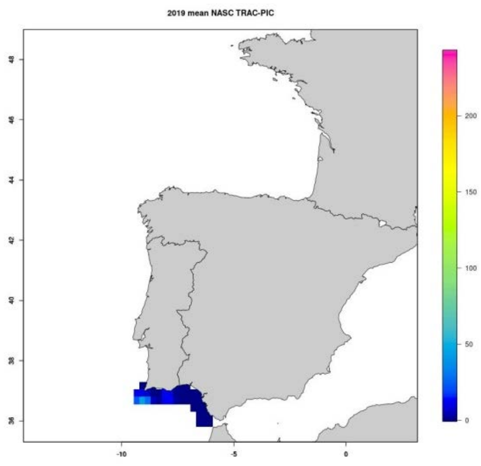
Pearlside (*Maurolicus muelleri*; 4%) was located close to the deepest limit of the surveyed area (200 m), just in the transition between outer shelf and upper slope waters. The highest densities were recorded in the Spanish outer shelf (**Fig. 4.2.3.5.1.j**).


2019 mean NASC SCOM-SCO
48
46
44
42
40
38
36
-10
-5
0
35
30
25
20
15
10
5
0

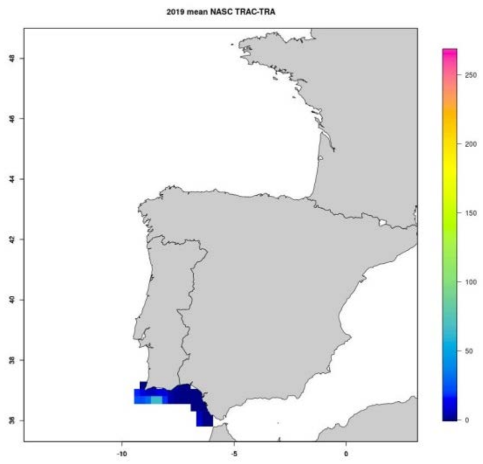
a


2019 mean NASC SCOM-COL
48
46
44
42
40
38
36
-10
-5
0
800
600
400
200
0

b


2019 mean NASC TRAC-PIC
48
46
44
42
40
38
36
-10
-5
0
200
150
100
50
0

c


2019 mean NASC TRAC-TRA
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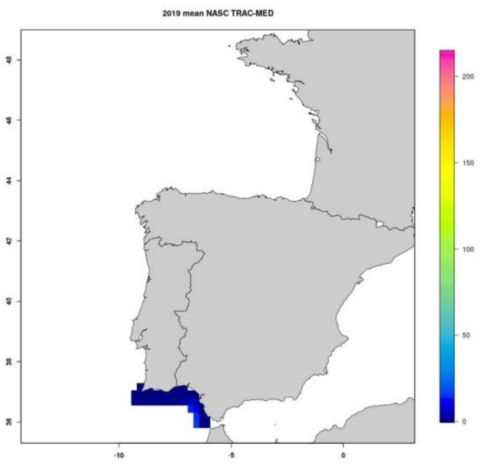
46
44
42
40
38
36
-10
-5
0
250
200
150
100
50
0

d


2019 mean NASC TRAC-MED
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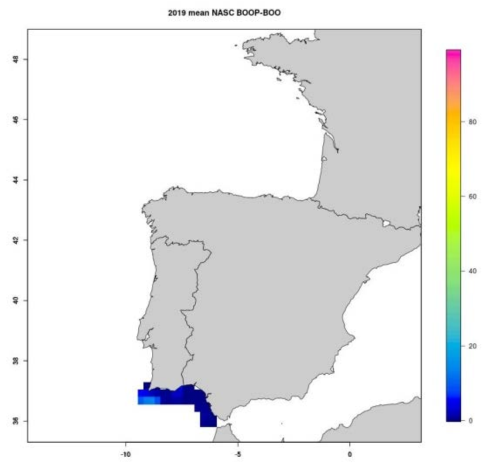
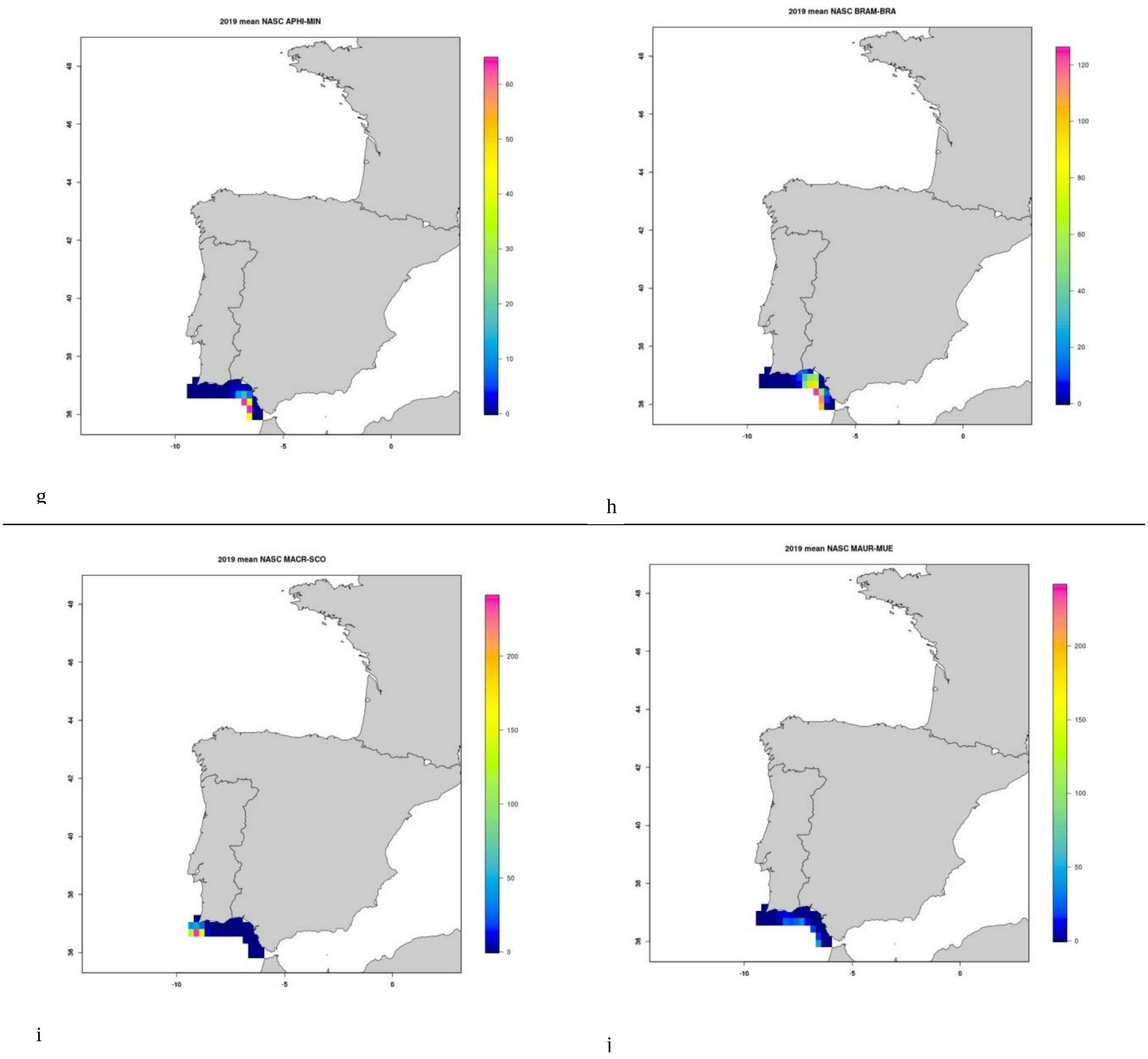
46
44
42
40
38
36
-10
-5
0
200
150
100
50
0

e


2019 mean NASC BOOP-BOO
48
46
44
42
40
38
36
-10
-5
0
80
60
40
20
0

f

Figure 4.2.3.5.1: Atlantic mackerel (*Scomber scombrus*)(a), Chub mackerel (*S. colias*)(b), Blue jack mackerel (*Trachurus picturatus*)(c), Horse mackerel (*T. trachurus*)(d), Mediterranean horse mackerel (*T. mediterraneus*)(e), Bogue (*Boops boops*)(f) acoustic density (NASC, m2 nm-2) maps derived from the ECOCADIZ 2019-07 Gulf of Cadiz summer acoustic survey, 0.25⁰ map cell.



g h

i j

Figure 4.2.3.5.1 (Continue): Transparent goby (*Aphia minuta*)(g), Atlantic pomfret (*Brama brama*)(h), Longspine snipefish (*Marcroramphosus scolopax*)(i), Pearlside (*Maurolicus muelleri*)(j) acoustic density (NASC, m2 nm-2) maps derived from the ECOCADIZ 2019-07 Gulf of Cadiz summer acoustic survey, 0.25⁰ map cell.

4.2.4 Autumn acoustic surveys

4.2.4.1 Oceanographic conditions

The autumn oceanographic conditions observed during the JUVENA, PELTIC and CSHAS surveys showed distinct regional patterns. Salinity values were lower than last year and homogeneous among the whole area. The usual influence of the freshwater input from rivers was observed in the Bristol channel, whereas little freshwater influence was apparent from the Gironde estuaries this year and no clear freshwater input in Irish waters was found. A small gradient of salinity was found in the Celtic sea, with more saline waters in the area closer to the English Channel (~35.0) that progressively turned into less saline waters towards the Irish coasts (~34.0). The Bay of Biscay was in general more saline particularly offshore, which contrasts with the results found last year. (**Fig. 4.2.4.1 1**).

As expected, the regional sea surface temperatures were higher in the southern area, the Bay of Biscay, compared to the cooler waters of the Celtic sea (**Fig. 4.2.4.1.1**), although to some extent this was due to the temporal offset between JUVENA (September) and PELTIC/CSHAS surveys (October). The warmest waters were found in the central Cantabrian coast, whereas the coldest surface waters, were found off Brittany coast, part of the Ushant front, that prevails in the mouth of the English Channel, and in the western part of the Irish coast (~10°W).

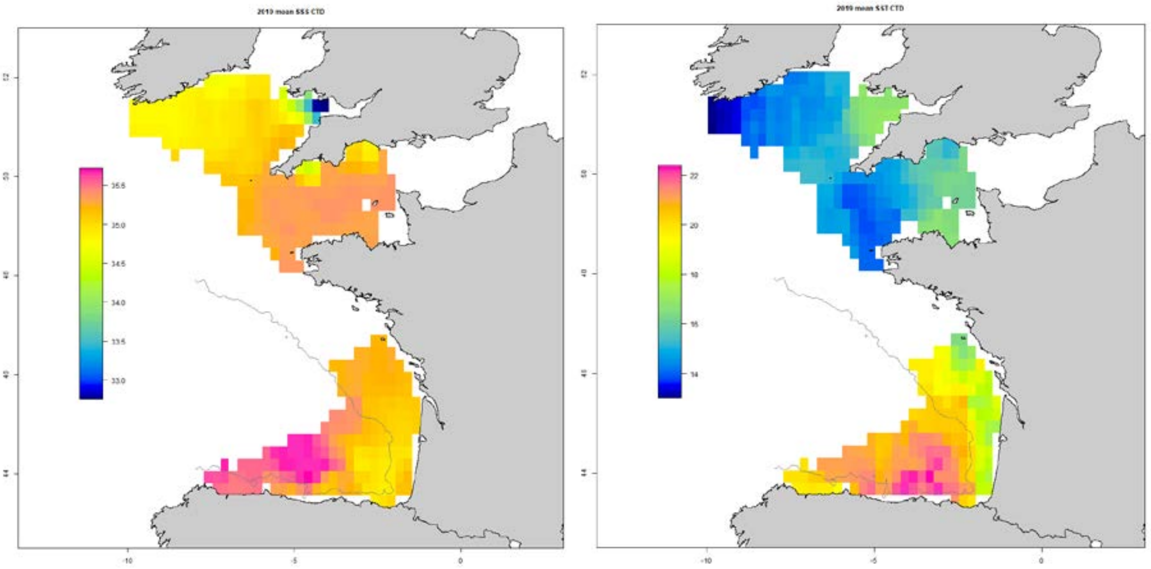


Figure 4.2.4.1.1: Mean autumn sea surface salinity (psu) (left) and sea surface temperature (°C) derived from the JUVENA, PETIC and CSHAS surveys carried out in 2019 using a 0.25° map cell.

4.2.4.2 Trawl haul catch composition

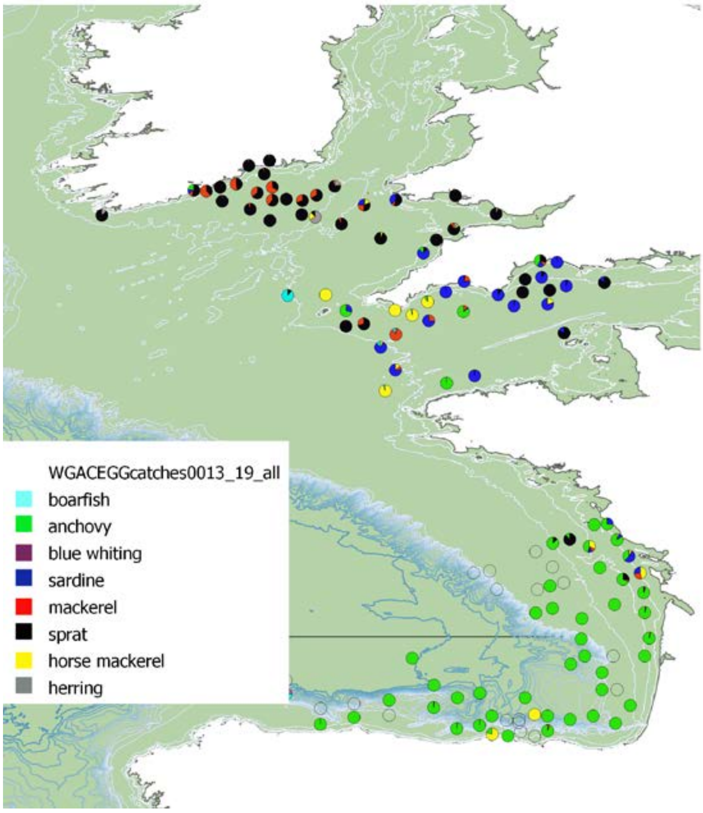


Figure 4.2.4.2.1 Trawl haul catch composition (percentage in weight) during autumn acoustic surveys, JUVENA (Bay of Biscay), PELTIC (English Channel) and CSHAS (south of Ireland)

Fishing hauls are typically conducted to ground-truth echotraces recorded by the echosounders and to provide biological information (e.g. age, length) of species along the surveyed area. However, the catch composition does also reflect the distribution of the main pelagic fish species related to the echotraces.

Figure 4.2.4.2.1 shows the relative catch composition (in weight) of the fishing stations conducted during the autumn acoustic surveys, JUVENA in the Bay of Biscay, PELTIC in the English Channel, and, for the first time, CSHAS to the south of Ireland. As usual, anchovy is the most important species in the south of the study area (JUVENA). Further north, catches appear more mixed, with sardine and sprat dominating the pelagic ichthyoplankton community in the English Channel. Sprat dominates catches in the Celtic Sea, although it is sometimes mixed with mackerel particularly along the Irish coast.

4.2.4.3 Adult sardine and anchovy acoustic density (NASC) distribution

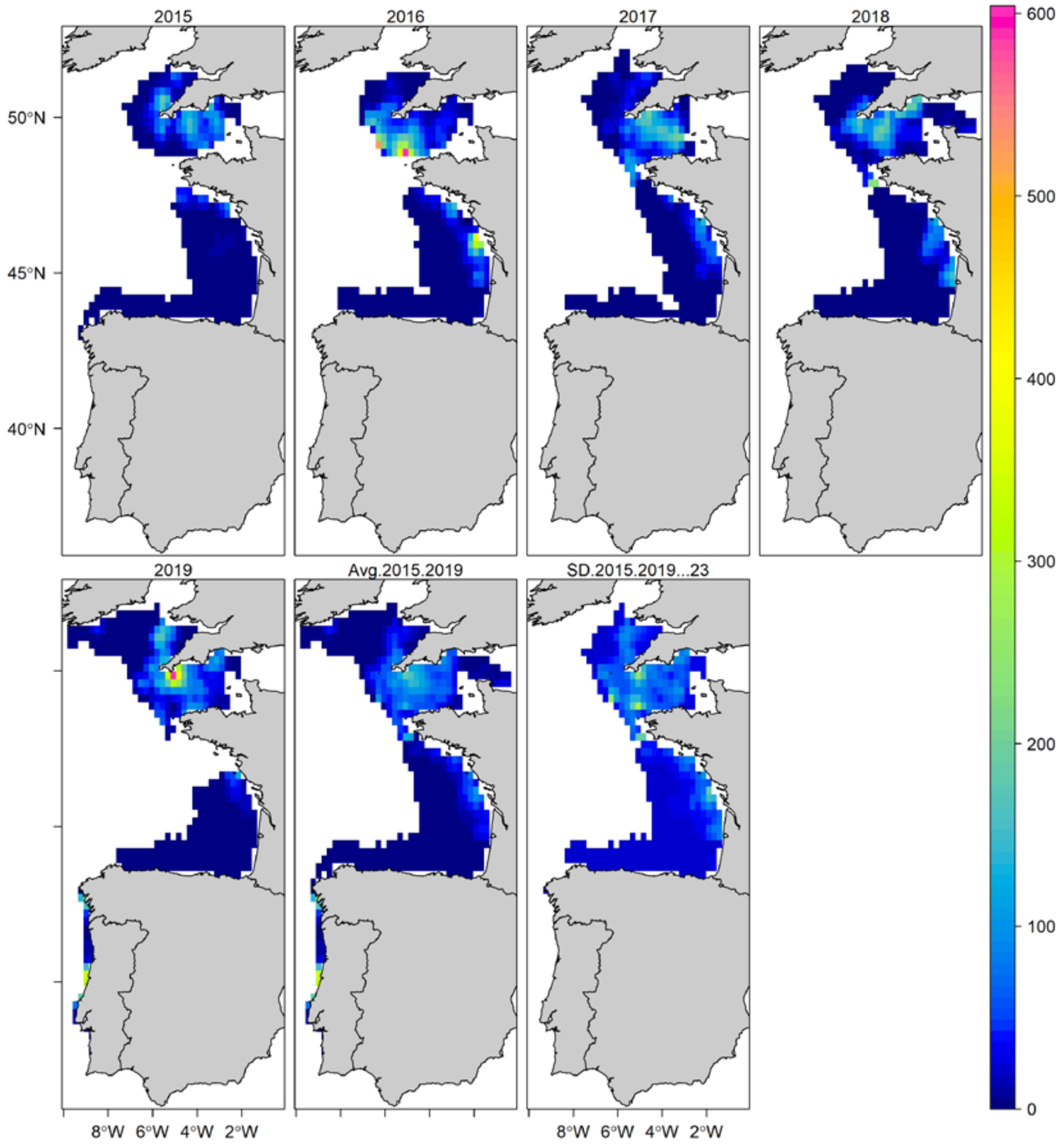


Figure 4.2.4.3.1. Mean backscattering energy (NASC, m2 mn-2) per 0.25°x 0.25° square allocated to **sardine** for the combined JUVENA and PELTIC autumn acoustic surveys (left to right: 2015, 2016, 2017, 2018 , top); and for the combined IBERAS, JUVENA, PELTIC and CSHAS (bottom: 2019, average backscatter for the four years, and the standard deviation (bottom).

The combined acoustic data from IBERAS, JUVENA, PELTIC and CSHAS provided a synoptic overview of autumn distribution of **sardine**. For the first time coverage was near-continuous from Portugal to Ireland (**Fig. 4.2.4.3.1**). Due to bad weather conditions, it was not possible to cover the Northern part of the Bay of Biscay, causing a gap in survey coverage. Sardine was found off central Portugal in high densities and good numbers were also found of the northwest coast of the Iberian Peninsula. It was largely absent from the Cantabrian Coast (north coast of Spain) but was found in the coastal waters of the central part of the French shelf of the Bay of Biscay. Sardine was widespread in the English Channel, with considerable densities of sardine also found north of the Cornish Peninsula. While PELTIC appeared to cover the main distribution of area 7 sardine, CSHAS found a localised patch of sardine off SW Ireland.

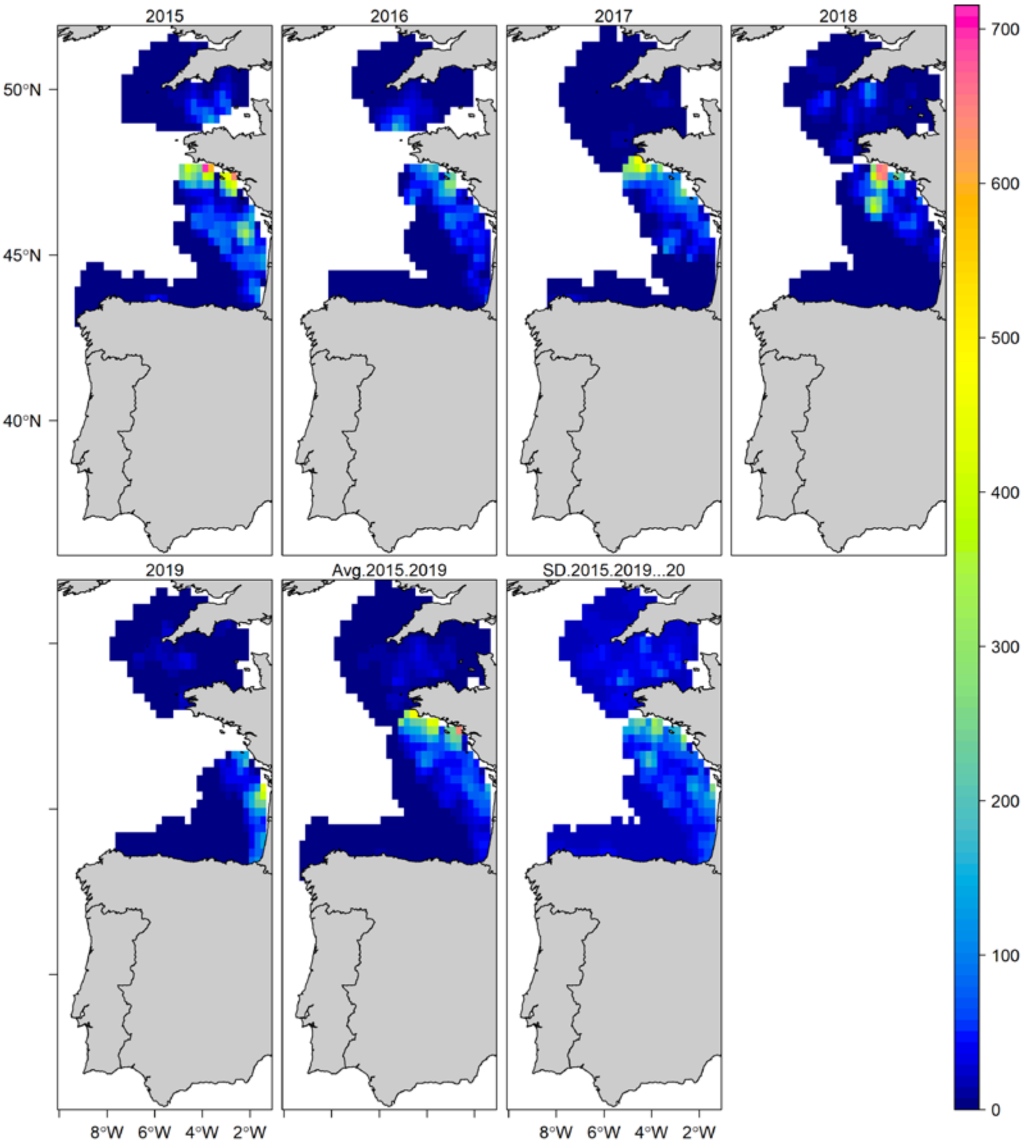


Figure 4.2.4.3.2. Mean backscattering energy (NASC, m2 mn-2) per 0.25°x 0.25° square allocated to **adult anchovy** for the combined JUVENA and PELTIC autumn acoustic surveys. From left to right: 2015, 2016, 2017, 2018 (top); 2019, average backscatter for the four years, and the standard deviation (bottom).

The 2019 **adult anchovy** distribution in the Bay of Biscay showed some backscatter along the Portuguese coast, very little along the Spanish coast and highest densities in the inner part of the shelf waters at the French sector. As in 2018, anchovy was relatively widespread in the English Channel (although lower densities than in the Bay of Biscay) and could also be found to the north of the Corniche peninsula. A small, localised patch of anchovy was found on the SW coast of Ireland. (**Fig. 4.2.4.3.2**).

The 2019 **juvenile anchovy** distribution showed the highest concentrations at the South-eastern part of the Bay of Biscay, distributing along the both eastern Cantabric Sea and French continental shelf (**Fig. 4.2.4.3.3**). Although not shown, for the first time, appreciable quantities of juvenile anchovy were found at the south-western part of the English Channel.

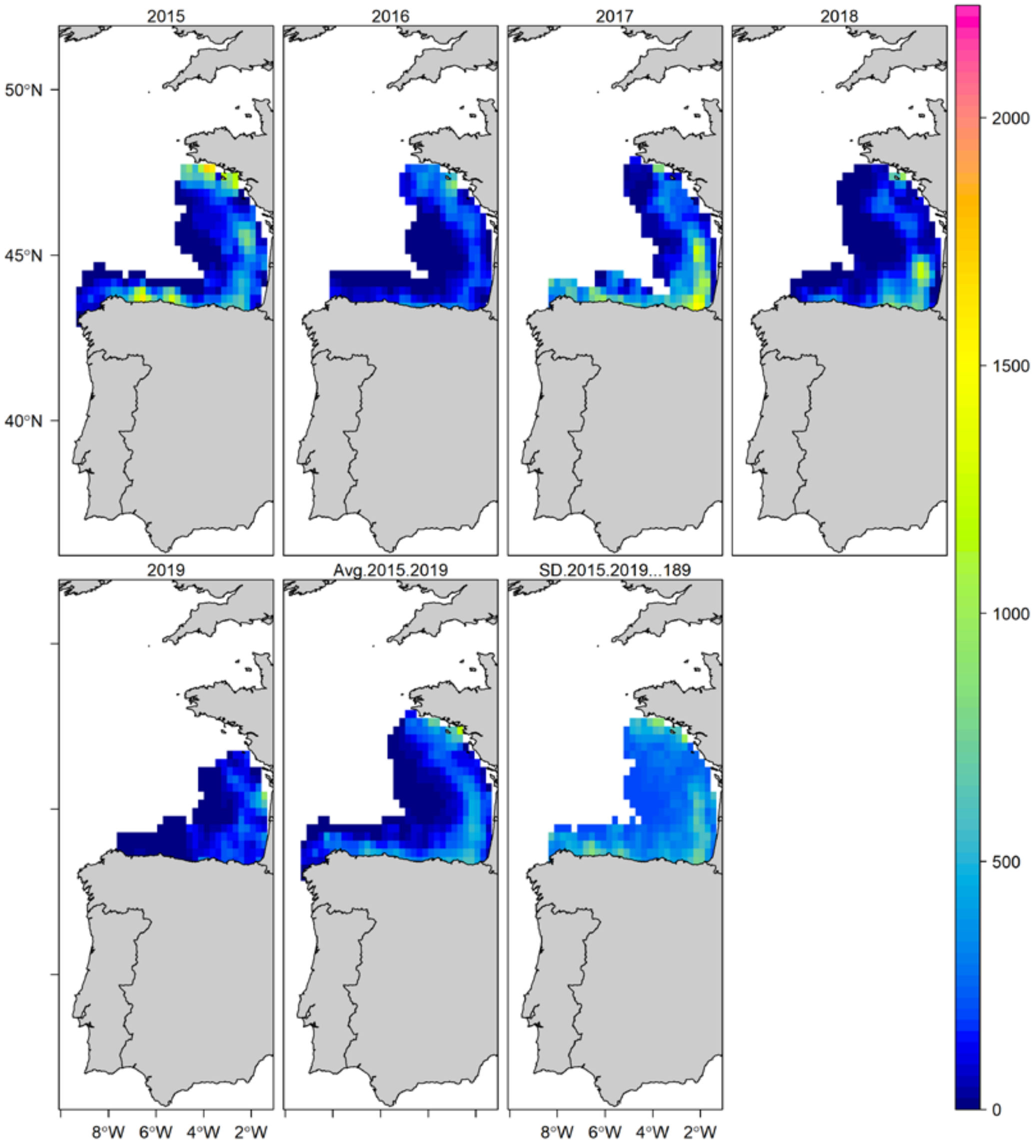


Figure 4.2.4.3.3. Mean backscattering energy (NASC, m2 mn-2) per 0.25°x 0.25° square allocated to **juvenile anchovy** for the JUVENA autumn acoustic survey. From left to right: 2015, 2016, 2017, 2018 (top); 2019, average backscatter for the four years, and the standard deviation (bottom).

4.2.4.4 Other adult small pelagic fish species acoustic density distribution

Data on the wider pelagic fish community were available from the 2019 autumn surveys: CSHAS, PELTIC and IBERAS surveys. Sprat (*Sprattus sprattus*) was the most abundant "northern" species and appeared more widespread in the Celtic Sea than in previous years. As in previous years a hotspot was also found in Lyme Bay, where biomass was up from 2018. Herring (*Clupea harengus*) was nearly exclusively found in the Celtic Deep area although small numbers of juveniles were found along the north Cornish coast. Horse mackerel (*T. trachurus*) was widespread and was found off the Portuguese coast as well as in the Celtic Sea and English Channel, where the majority were juvenile fish. As in previous years boarfish (*Capros aper*) was typically associated with the deeper (>100 m) shelf waters at the periphery of the PELTIC survey area, particularly west of the Isles of Scilly (**Fig. 4.2.4.4.1**). Small but regular numbers of juveniles were caught in most of the 70m+ waters around the Cornish Peninsula.

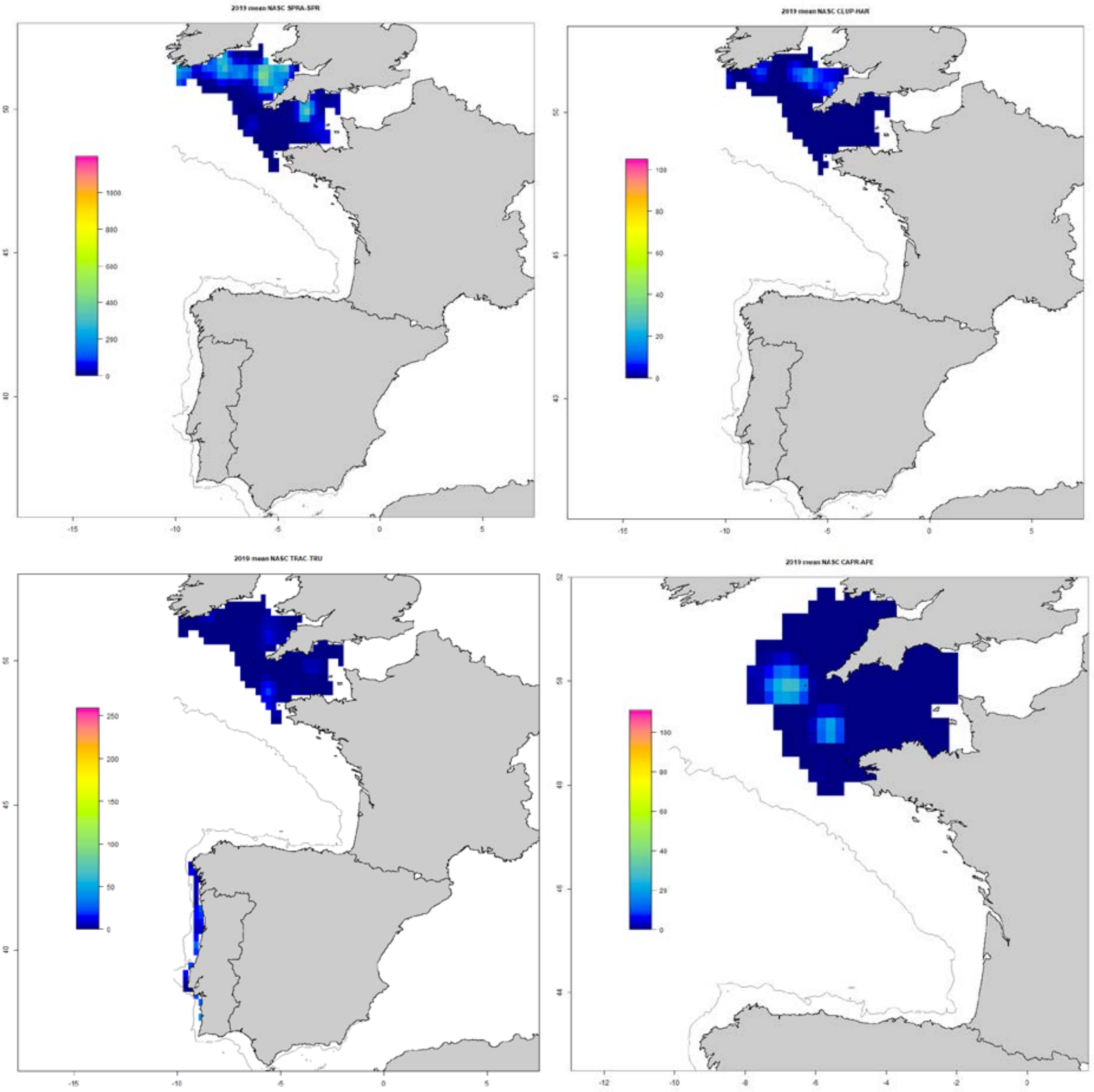


Figure 4.2.4.4.1: Sprat (*Sprattus sprattus*)(a), herring (*Clupea harengus*) (b), Horse mackerel (*Trachurus trachurus*)(c), and boarfish (*Capros aper*) (d) acoustic density (NASC, m2 nm-2) maps derived from the CSHAS, PELTIC and IBERAS surveys, 0.25^0 map cell.

4.2.5 Anchovy and sardine spatio-temporal distribution and habitats in the European Atlantic Area, based on WGACEGG gridded maps

Multiple Factorial Analysis (MFA) (~ PCA on grouped data) performed on the gridded maps produced by WGACEGG to analyse the anchovy and sardine spatio-temporal distribution and habitats in the European Atlantic Area (EAA) were updated.

Data matrices were formed with gridded maps cells as rows, and annual parameter values as columns, grouped by years and submitted to MFA. MFAs were performed on gridded maps from spring acoustic surveys describing: i) environment (SST and SSS), and ii) fish (anchovy and sardine) acoustic densities

(NASC), over the 2005-2008, 2010-2011, 2013-2017 time period. Environment and fish variables were summarised by their two first MFA loadings (MFA1&2). Relationships between fish and environment MFA1&2 were explored to assess the potential environmental drivers of fish distributions.

Environment MFA1 (49% var. expl.) was positively correlated with SSS and SST. Higher SSS and SST were observed in southern areas, offshore Biscay and Cantabrian Sea (**Figure 4.2.4.4-1**). Environment MFA2 (26% var. expl.) was consistently positively correlated with SST until 2016, and negatively with SSS since 2011. The spatial patterns of MFA2 positive values matched the major river plumes in the area (Figure 4.2.4.4-1**Error! Reference source not found.**). No significant warming trend was found in SST at this time of the year.

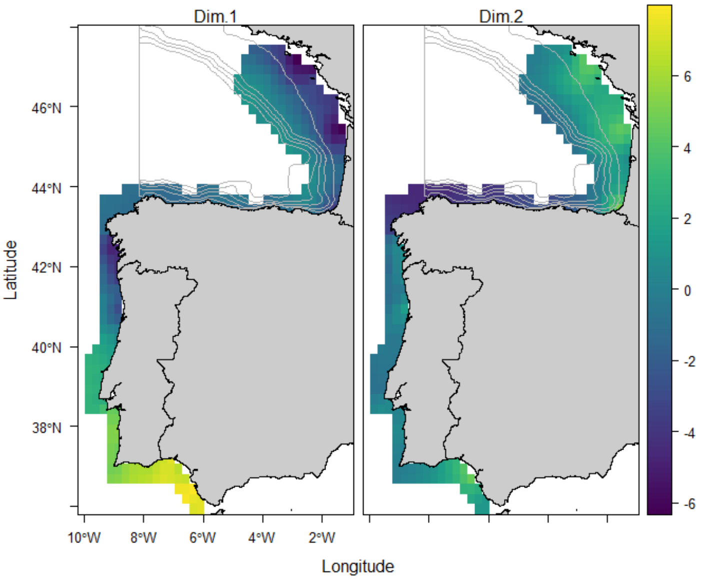


Figure 4.2.4.4-1. Maps of environment MFA1 (left) and MFA2 (right) loadings.

Anchovy and sardine NASC were consistently correlated with fish MFA1 (49% var. expl.). Persistent core distribution areas of anchovy and sardine were the gulf of Cadiz and Southern Bay of Biscay areas (MFA1>0 in Figure 4.2.4.4-2). Sardine NASC was correlated with MFA2 (13% var. expl.) in 2006 and 2007. Higher sardine densities were observed in Western Iberian and North coastal Biscay areas until 2007 (MFA2>0 in Figure 4.2.4.4-2).

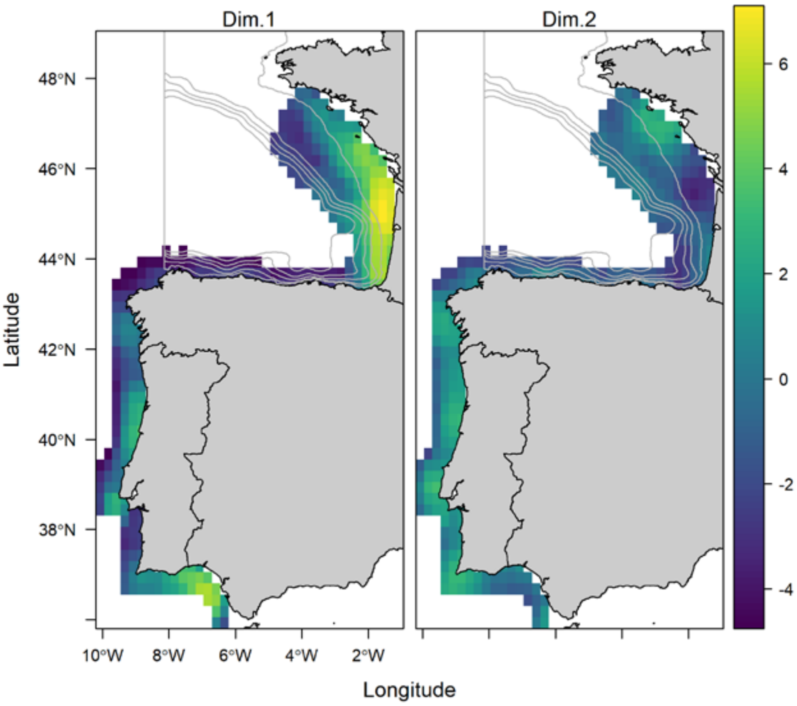


Figure 4.2.4.4-2. Maps of fish MFA1 (left) and MFA2 (right) loadings.

After 2007, MFA2 loadings averaged over the whole area have dropped (**Figure 4.2.4.4-3**).

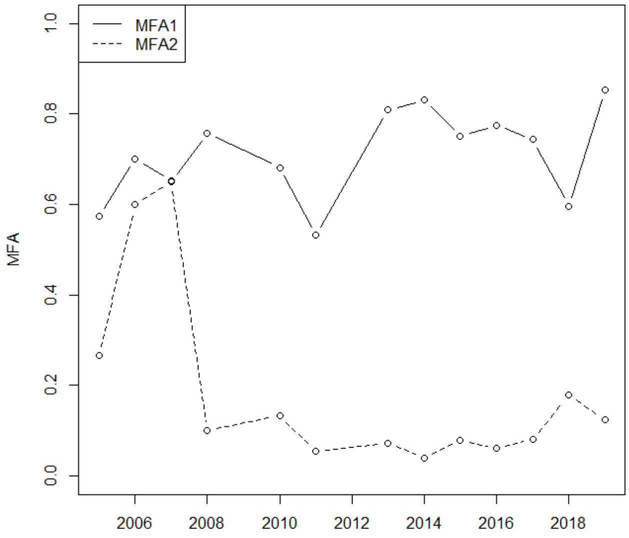


Figure 4.2.4.4-3. Time series of fish MFA1&2 loadings averaged over the whole area.

Environment MFA1&2 explained 3% and 61% of fish MAF1, respectively (linear model). Anchovy and sardine habitats were then characterised by higher SST and SSS in southern areas and coastal Biscay. Fish MFA2 was not explained by environment MFA1&2 (linear model). SSB in area 9 however explained 70% of fish MFA2 in W. Iberian area (Generalised linear model, Gamma family, log-link).

In conclusion, this study is the first synoptic assessment of anchovy and sardine habitat extension and occupation variability at the European Atlantic Area scale. MFA1&2 derived from fish and environment datasets proved to be useful proxies to summarise spatial and temporal variability of ecosystem components. Anchovy and sardine large scale distribution was correlated with relatively higher SST and SSS in southern Iberian and coastal Biscay areas. Sardine higher densities in western Iberian and offshore northern Biscay areas were not explained by available environmental indices. The drop in fish MFA2 since 2008 reflected the drop in sardine SSB assessed in ICES areas 8c and 9.

The group agreed to add satellite surface Chl-a data to the analysis and write a manuscript based on those results, to be submitted in 2020.

WGACEGG gridded maps database consolidation, hosting and valorisation

WGACEGG members agreed in 2018 to consolidate time series of survey indices and gridded maps and to host them in an instance of the EchoBase relational database hosted at Ifremer.

Tasks were defined and assigned to participants to consolidate the historical maps and indices time series before the 2020 meeting.

4.3 Methodological developments for acoustic and DEPM biomass assessment

4.3.1 Methodological developments for acoustic biomass assessment

This year, the priority of the acoustic subgroup was focused in the coordinated work to finish the acoustic SISP document. No methodological developments for acoustic biomass assessment were presented this year.

4.3.2 Methodological developments for DEPM biomass assessment

During the DEPM subgroup some presentations took place related to the following subjects:

Modelling sardine (Sardine pilchardus) egg densities in the Atlantic shelf from DEPM surveys (SAREVA 1997-2017). P. Díaz[1], M. G. Pennino & M. B. Santos. [1] Instituto Español de Oceanografía, PO Box 1552, 36280 Vigo, Spain

We have modelled sardine egg density using the data obtained by the Spanish Daily Egg Production Method (DEPM) survey series (SAREVA) which has been carried out from 1997 to 2017. We have used hurdle Bayesian species distribution model (B-SDMs) that deal with zero-inflated data that present a strong spatial dependence. Bathymetry, sea surface temperature and sea surface salinity were used as candidates to analyses the relationships between sardine egg density and the environment. The model fitting and prediction are done simultaneously using the Integrated nested Laplace approximation (INLA) software. The final selected density B-SDMs retained the sea surface temperature and the spatial component as relevant predictors. We believe the methodology described can be used to predict sardine egg density in the years where the DEPM survey is not carried out, providing valuable information for sardine assessment. For more information see the working document in annex 5

Application 1D vertical model of egg distribution in BIOMAN 2015 data. Marina Chifflet**.** AZTI

The 1D vertical biophysical model of anchovy eggs distribution developed by Petitgas et al. (2006) has been implemented to be applied to the BIOMAN cruises data. Fish eggs are passive particles and their vertical distribution is determined by the model as a function of egg properties (diameter, density, both kept constant in time) and water properties (density, viscosity, turbulence). Thus, the model inputs are surface wind, tidal currents and T-S and density profiles from CTD data. The 1D model has been applied to a subset of stations, 50 CTDs stations, of the 2015 BIOMAN cruise. The meteorological variables have been taken from the Arpege model reanalysis. The preliminary results are promising, and the resulted qualitative distribution profiles must be applied to the surface eggs concentration at each PairoVET station. Thus, we plan to enlarge this first application to the Bioman campaigns 2015.

Petitgas P., S. Magri and P. Lazure (2006). "One-dimensional biophysical modelling of fish egg vertical distribution in shelf seas". Fishery Oceanography, 15:413-4

4.3.3 Methodological developments for comparing acoustic and DEPM indices

Available biomass indices derived from eggs and acoustic data for anchovy and sardine in the Bay of Biscay in spring were compared, to assess the potential presence of bias in the indices (**Figure 4.2.4.4-1-4**). Linear models were fitted on the data to assess the general agreements between the indices along the series.

Acoustic and egg (CUFES) data were collected simultaneously during the PELGAS survey on the same platform. Eggs were also sampled during the same period as the PELGAS survey and in the same area during the BIOMAN survey, using PairoVET nets.

The anchovy biomass index derived from BIOMAN DEPM data was 22% higher than the acoustic index derived from PELGAS data in 2019 (**Figure 4.2.4.4-1**). This can be explained by the fact that 18% of all anchovy eggs were sampled on the Eastern Cantabrian platform, an area which is sampled by the BIOMAN survey but not by the PELGAS survey. Some schools of actively spawning anchovies might also have been under-sampled by acoustics this year in Central Biscay, as those schools were located above the depth layer sampled by PELGAS echosounders. This is corroborated by the fact that the PELGAS CUFES anchovy biomass index was larger than the PELGAS acoustic index (**Figure 4.2.4.4-2**). Overall significant linear relationships (R2 = 0.75 and 0.64) were found between acoustic and egg-based indices over the series for anchovy.

Biomass indices derived from acoustic and egg data also showed a relatively good agreement in the case of sardine in 2019, showing no sign of bias. Overall significant linear relationships (R2 = 0.69 and 0.67) were found between acoustic and egg-based indices over the series for sardine.

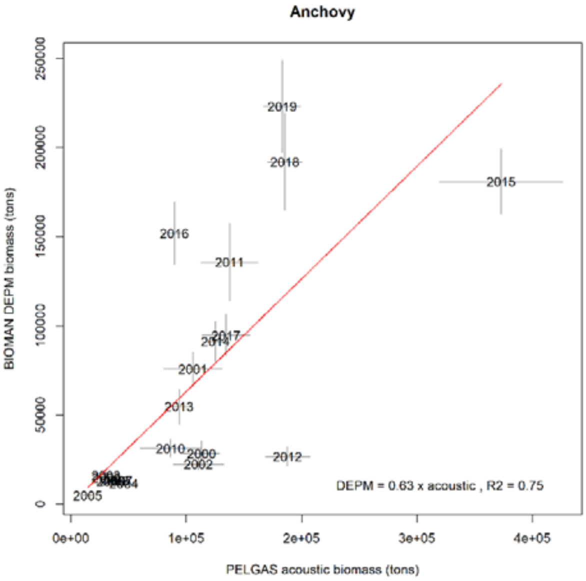


Figure 4.2.4.4-1. Anchovy acoustic (PELGAS) biomass vs. DEPM (BIOMAN) biomass estimates. Segments: confidence intervals around indices. Red line: linear model fit.

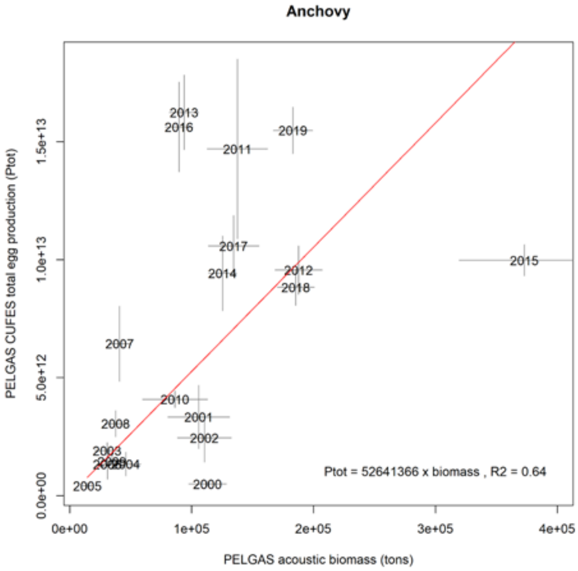


Figure 4.2.4.4-2. PELGAS acoustic biomass estimate vs. PELGAS total number of eggs in CUFES for anchovy. Segments: confidence intervals around indices. Red line: linear model fit.

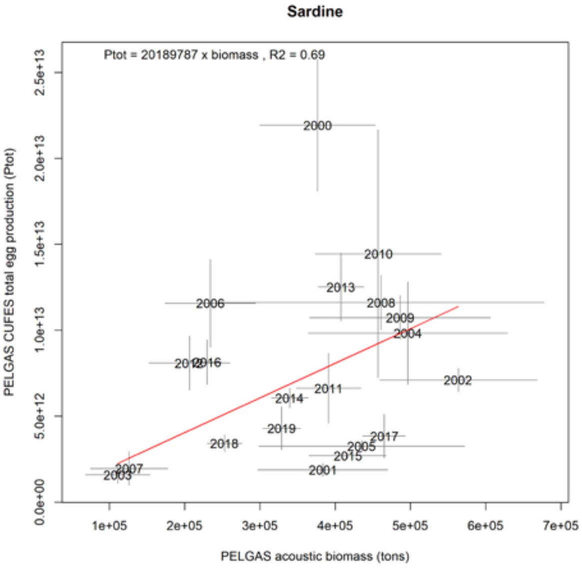


Figure 4.2.4.4-3. Sardine acoustic (PELGAS) biomass estimate vs. PELGAS total number of eggs in CUFES. Segments: confidence intervals around indices. Red line: linear model fit.

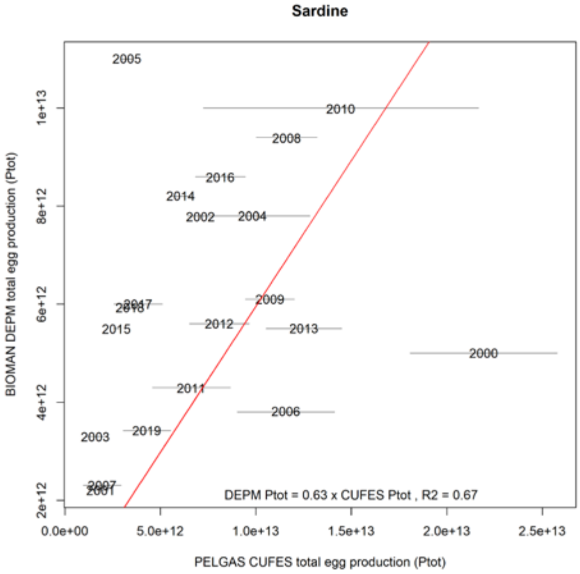


Figure 4.2.4.4-4. Sardine PELGAS total number of eggs in CUFES vs. BIOMAN total number of eggs in PairoVET. Segments: confidence intervals around indices. Red line: linear model fit.

4.4 Suitability of CUFES data for anchovy and sardine egg production estimates in areas 8 and 9.

The time-series P_{tot} estimate from PELGAS CUFES data was updated in 2019. It is based on the one-dimensional vertical biophysical model for egg vertical distribution, developed by Petitgas et al. (2006), used to extrapolate the surface CUFES concentration over the water column. The PELGAS P_{tot} was then compared to the BIOMAN PairoVET derived P_{tot}, which showed good agreement in 2019.

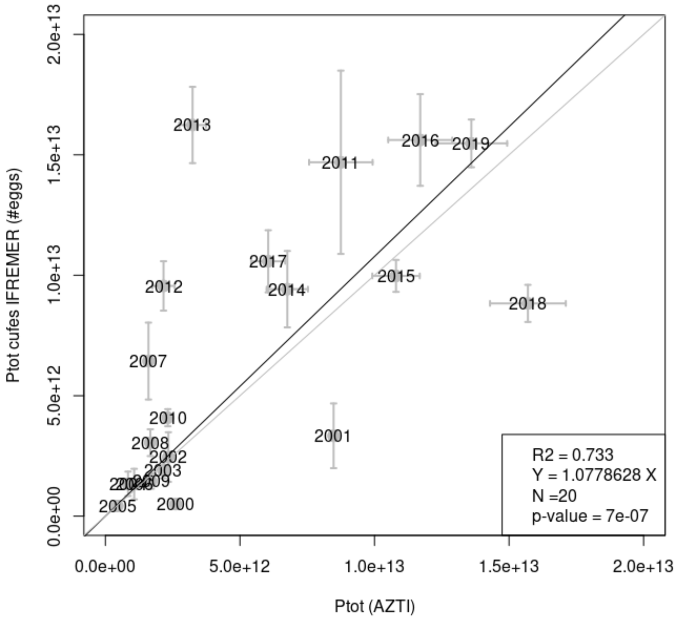


Figure 4.4.1. Comparison of CUFES-derived Ptot from PELGAS with the PairoVET derived P_{tot} from BIOMAN

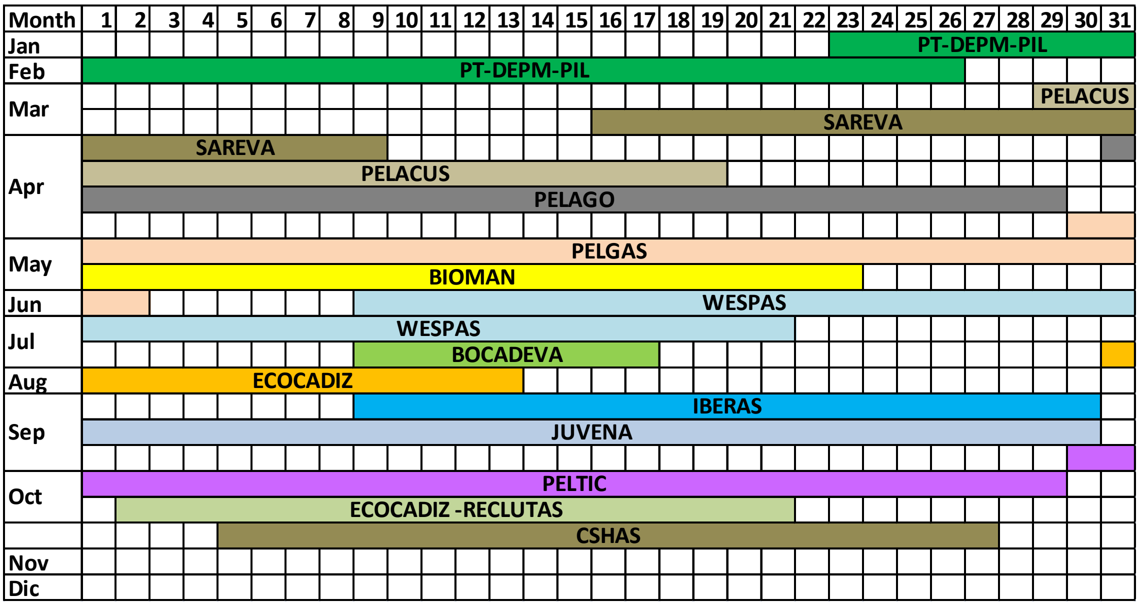
Some advances have been made to evaluate the possibility of using the CUFES data from DEPM (BIOMAN) and acoustic surveys (PELAGO and PELACUS) over the areas 8 and 9.

The one-dimensional vertical biophysical model for anchovy eggs has been implemented and applied with success to the CUFES data from BIOMAN survey. Fish eggs are passive particles and their vertical distribution is determined by the model as a function of egg properties (diameter, density, both kept constant in time) and water properties (density, turbulence). Model inputs are surface wind, tidal currents and T - S profiles from CTD data. First test runs were applied with success to the CTDs stations from BIOMAN 2015 survey. A second step consisting of attributing each CUFES a CTD station with computed profiles of egg vertical distribution will be performed in 2020. R codes from IFREMER have been shared for that purpose.

4.5 Coordination and standardization of the surveys

4.5.1 2020 surveys schedule

Survey planning for 2020 is summarized in the table below:



Acoustic surveys

In 2020, the spring acoustic surveys will be carried out following the standard methodologies defined by the WGACEGG and coordinated between IPMA, IEO and IFREMER. IPMA will survey the southern region from Cadiz to the northern border between Portugal and Galicia (PELAGO); IEO will operate off western Galicia and the Cantabrian Sea (PELACUS) and IFREMER (PELGAS) will cover the French shelf of the Bay of Biscay.

In summer, IEO will carry out the ECOCADIZ survey in the southern Spanish and Portuguese waters of the Gulf of Cadiz. The FEAS will cover the south and west of Scotland and north of Ireland within the WESPAS survey.

In autumn 2020, the PELTIC survey will be carried out in area 7e and f off the Southwest coast of Britain (sections of subarea 7). Multidisciplinary methodologies, coordinated through two relevant survey working groups (WGACEGG and WGIPS), will be implemented as described in the Manual for International Pelagic Surveys (SIPS 9, ICES 2015). CSHAS survey will be carried out by FEAS and will cover the Celtic Sea area.

Autumn acoustic recruitment surveys

JUVENA survey is coordinated between AZTI and IEO, as a result of the compromise of collaboration between both institutes in 2014. AZTI leading the assessment studies of the JUVENA series and IEO the ecological studies. In 2020, it is planned to continue this collaboration in similar terms than those carried out in the past years.

In the Gulf of Cadiz, it is planned by IEO a recruitment survey (ECOCADIZ-RECLUTAS). IPMA and IEO are expected to collaborate in the common acoustic-trawl survey called IBERAS-JUVESAR, covering the Atlantic waters of the 9a from Sao Vicente Cape until Fisterra Cape.

DEPM surveys

In 2020 the annual anchovy and triennial sardine DEPM surveys in the Bay of Biscay (BIOMAN) will take place in May conducted by AZTI, covering the usual spawning grounds at ICES 8abcd.

The BOCADEVA DEPM triennial survey to estimate the SSB of Anchovy in the Gulf of Cadiz will take place by IEO in July 2020.

The triennial Iberian Sardine DEPM survey will take place in 2020. The region from the Gulf of Cadiz to the northern border between Portugal and Spain will be surveyed by IPMA (PT-DEMP20-PIL); IEO will cover the north and northwest Spanish waters (SAREVA).

4.5.2 Update on WGACEGG Series of ICES Survey Protocols

Most of the meeting was devoted this year to the standardization of data processing methods for DEPM and acoustic methods for surveys in Atlantic waters through the writing of WGAEGG acoustic and DEPM SISP reports, which should be submitted for publication in January 2020.

4.6 Development and standardization of data processing methods for DEPM and acoustic methods for surveys in Atlantic and Mediterranean waters.

This year, the priority was to finish the SISP documents. Development and standardization of data processing methods for DEPM and acoustic methods were tackled in the SISP documents.

4.7 Changes/ Edits/ Additions to ToR

The WGACEGG ToRs and work plan presented below have been updated to propose new resolutions for the 2020-2022 term.

ToR descriptors[1]

TOR	DESCRIPTION	BACKGROUND	SCIENCE PLAN CODES	DURATION	EXPECTED DELIVERABLES
a	Evaluate and provide echo-integration and/or Daily Egg Production Method (DEPM) estimates for sardine, anchovy horse mackerel, boarfish, herring, and sprat in ICES sub-Areas 6, 7, 8 and 9	a) Advisory Requirements b) Requirements from other EGs	3.1	3 years	Abundance and biomass estimates by age and/or length group. Fish spatial distribution will be provided to WGHANSA, WGWIDE, HAWG by the end of the WGACEGG meeting. Datasets will be published in the ICES repository when available.
b	Analyse sardine and anchovy (adults and eggs), spatial and temporal distribution and their habitats in European waters	a) Science Requirements b) Requirements from other EGs	1.5	Year 1	Manuscript and/or technical report in 2020
c	Provide ecosystem data such as temperature, salinity, plankton diversity, top predators abundances, egg densities and backscattering for sardine, anchovy and other small pelagic fish for pelagic ecosystem monitoring (e.g. MSFD)	a) Science Requirements b) Requirements from other EGs	1.4, 1.5	3 years	Gridded maps updated every year. Datasets will be published in the ICES repository when available.

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[1] Avoid generic terms such as "Discuss" or "Consider". Aim at drafting specific and clear ToR, the delivery of which can be assessed

d	Assess developments in the technologies and data analyses for the application of both acoustics and the DEPM (on egg production or adult parameters).	a) Science Requirements b) Advisory Requirements c) Requirements from other EGs	3.3	3 years	New methodologies reported in annual WG report, available to the public one month after the meeting.
e	Improve and assess the suitability of CUFES data for anchovy and sardine egg production estimates in areas 8 and 9.	a) Science Requirements b) Advisory Requirements c) Requirements from other EGs	3.3	3 years	Advances reported in annual WG report, available to the public one month after the meeting.
f	Coordinate and standardize surveys methodologies	a) Science Requirements b) Advisory Requirements	3.1, 3.2	3 years	Annual plan for coordinated surveys. Updated survey protocols
g	Development and standardization of data processing methods for DEPM and acoustics for surveys in Atlantic and Mediterranean waters	a) Science Requirements b) Advisory Requirements c) Requirements from other EGs	3.1, 3.2	3 years	Updated data processing protocols shared with the MEDIAS group (Mediterranean acoustic survey group)
h	Provide echo-integration estimates for other species (mainly blue whiting, mackerel, herring, sprat, horse mackerel, chub mackerel and boarfish) ICES sub-Areas 6, 7, 8 and 9	a) Advisory Requirements b) Requirements from other EGs	3.5	3 years	Biomass per age group when available otherwise per length classes and spatial density distribution, provided to WGWIDE and HAWG before the WG annual meeting. Datasets will be published in the ICES repository when available.
i	Ensure QAQC procedures are in place	ICES aims to have a quality assurance process for data collections used in the provision of advice. One element of this is that all procedures describing the data collection are adequately described.	3.1	3 years	Update independent SISP for the data collection and product specification conducted under the auspices of WGACEGG
j	Compare acoustic and DEPM biomass estimates of anchovy and sardine to improve the precision of stock estimates	a) Science Requirements b) Advisory Requirements c) Requirements from other EGs	-	3 years	Advances reported in annual WG report, available to the public one month after the meeting
k	Develop the use of imagery techniques to characterise the distribution of surface mesozooplankton and possibly microplastics in areas 7, 8 and 9, based on CUFES and/or plankton nets.	a) Science Requirements b) Requirements from other EGs	1.2	3 years	Advances reported in annual WG report, available to the public one month after the meeting

4.8 Cooperation with other WG

A joint session on survey results presentation was held together with the WGHANSA assessment group on 18-19/12/2019.

No recommendation was submitted to WGACEGG this year.

4.9 Cooperation with Advisory structures

WGACEGG has evaluated and provided echo-integration and/or Daily Egg Production Method (DEPM) estimates for sardine, anchovy horse mackerel, boarfish, herring, and sprat in ICES sub-Areas 6, 7, 8 and 9 to ad-hoc WGHANSA, WGWIDE and HAWG assessment groups.

WGACEGG has provided the WGHANSA stock assessment group with the sardine and anchovy indices listed in **section 4**.

WGACEGG has provided the WGWIDE stock assessment group with horse mackerel, boar fish, mackerel and blue whiting distribution and numbers-at-age in 9a and 8c derived from the PELACUS survey.

WGACEGG has provided to the HAWG with the sprat and herring indices listed in **section 4**

4.10 Science Highlights

WGACEGG has contributed in 2019 to the ICES science highlight on maintaining the continuity of long-term data sets.

5 Revisions to the work plan and justification

The publication of the DEPM and acoustic SISP manuals have been postponed to January 2020.

The manuscript on the analysis of sardine and anchovy spatial and temporal distribution and their habitats in European waters will be submitted in 2020.

A new work plan has been proposed for the next term:

Summary of the Work Plan

Year 1	**Annual meeting, including a joint session with MEDIAS (Mediterranean acoustic survey group):** • Evaluation of echo-integration and/or Daily Egg Production Method (DEPM) estimates for sardine, anchovy horse mackerel, boarfish, herring, and sprat in ICES sub-Areas 6, 7, 8 and 9 • Update of gridded maps of ecosystem data derived from surveys, and assessment of feasibility of production of megafauna and mesozooplankton grid maps for ecosystem assessment • Session on historic data series consolidation and storage • Update of the WGACEGG DEPM and acoustic Survey Protocols (SISP) if required • Session on acoustic data collection and analysis, including a topic on the analysis of acoustic data in presence of mixed mesopelagic and juvenile anchovies assemblages • Session on DEPM data collection and analysis • Session on comparison of acoustic and DEPM indices • Session on results of the analysis on timeseries of gridded maps of species-and ecosystem data • Session to analyse progress on sardine and anchovy egg production estimates from CUFES
Year 2	**Annual meeting:** • Evaluation of echo-integration and/or Daily Egg Production Method (DEPM) estimates for sardine, anchovy horse mackerel, boarfish, herring, and sprat in ICES sub-Areas 6, 7, 8 and 9 • Update of gridded maps of ecosystem data derived from surveys, historic data series consolidation and storage • Session on historic data series dissemination and valorisation • Update of the WGACEGG DEPM and acoustic Survey Protocols (SISP) if required • Session on acoustic data collection and analysis • Session on DEPM data collection and analysis • Session on comparison of acoustic and DEPM indices • Session to analyse progress on sardine and anchovy egg production estimates from CUFES
Year 3	**Annual meeting, including a joint session with MEDIAS (Mediterranean acoustic survey group):** • Evaluation of echo-integration and/or Daily Egg Production Method (DEPM) estimates for sardine, anchovy horse mackerel, boarfish, herring, and sprat in ICES sub-Areas 6, 7, 8 and 9 • Update of gridded maps of ecosystem data derived from surveys, historic data series consolidation and storage • Update of the WGACEGG DEPM and acoustic Survey Protocols (SISP) if required • Session on developments in acoustic data analysis • Session on developments in DEPM data analysis • Session on the use of image recognition techniques to characterise the distribution of (surface) mesozooplankton communities • Session on comparison of acoustic and DEPM indices • Session to analyse progress on sardine and anchovy egg production estimates from CUFES

6 Next meeting

The Year 1 meeting of the next term will take place on 16-20/11/2020 in Palma de Mallorca, Spain.

Annex 1: List of participants

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Annex 2: Recommendations

WGACEGG did not issue any recommendation in 2019.

Annex 3: Survey reports-working documents

*Please find survey reports below.

Centre for Environment
Fisheries & Aquaculture
Science

RESEARCH VESSEL SURVEY REPORT

RV CEFAS ENDEAVOUR
Survey: C END 15 - 2019.

STAFF:

Name	Role	Name	Role
Part 1		**Part 2**	
Jeroen van der Kooij	SIC/acoustics	**Joana Silva**	SIC/fish
Joana Silva	2IC/fish	**Fabio Campanella**	2IC/acoustics
Oliver Twigge	Hydro	**Oliver Twigge**	Hydro
Marc Whybrow	Tech	**Marc Whybrow**	Tech
Richard Humphreys	Fish Lead	**Richard Humphreys**	Fish Lead
Matt Eade	Fish	**Sam Barnett**	Fish
Sam Barnett	Fish	**Allen Searle**	Fish
Fabio Campanella	Acoustics	**Sílvia Rodriguez-Clíment**	Acoustics
James Pettigrew	Plankton	**Hayden Close**	Plankton
Nevena Almeida	Plankton	**Hannah Lloyd-Hartley**	Plankton
James Scott	PhD (UEA)	**James Scott**	PhD (UEA)
Chris Brodie	PhD (Uni Salford)	**Chris Brodie**	PhD (Uni Salford)
Roweena Patel	PhD (Uni Reading)	**Roweena Patel**	PhD (Uni Reading)
Nuala Campbell	ML observer	**Nuala Campbell**	ML observer
Camille Burton	ML observer	**Camille Burton**	ML observer

DURATION: 1st – 28th October (28 days)

LOCATION: Western Channel and Celtic Sea (ICES Divisions 7.d, e, f, g, Fig 1)

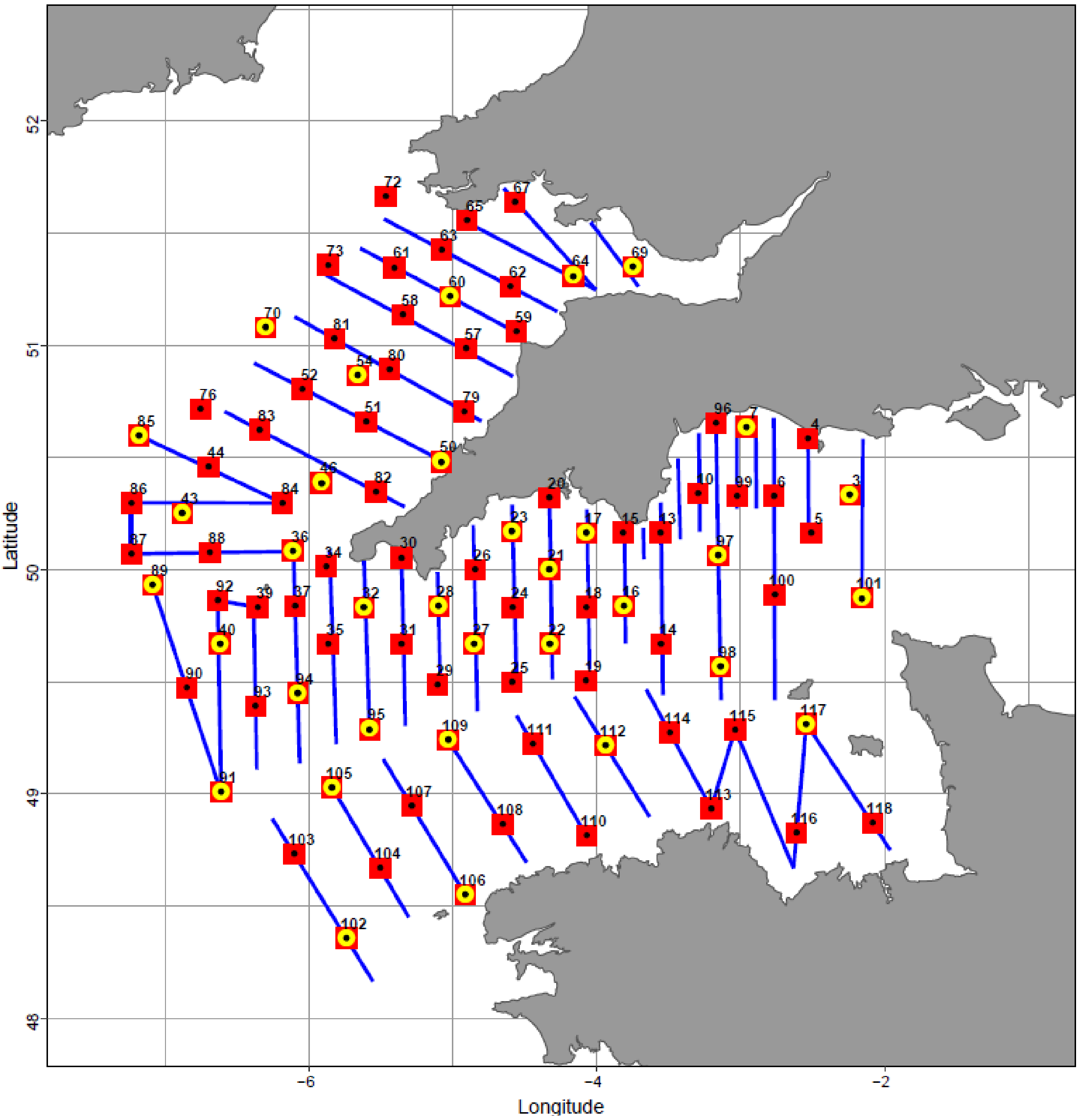

Figure 1. Overview of the planned survey area, with the acoustic transect (blue lines), plankton stations (red squares) and hydrographic stations (yellow circles).

AIMS:

1. To carry out the eighth annual multidisciplinary pelagic survey of the western Channel and Celtic Sea to estimate the biomass of-, and gain insight into the population of the small pelagic fish community including sprat (*Sprattus sprattus)*, sardine (*Sardina pilchardus*), mackerel (*Scomber scombrus*) , anchovy (*Engraulis encrasicolus*), horse mackerel (*Trachurus trachurus*).

    a. To carry out a fisheries acoustic survey during daylight hours only, using four operating frequencies (38, 120, 200 and 333 kHz) to map and quantify the small pelagic species community.
    b. To trawl for small pelagic species using a 20x40m herring (mid-water) trawl in order to obtain information on:
        - Species and size composition of acoustic marks
        - Age-composition and distribution, for small pelagic species
        - Length weight and maturity information of pelagic species
        - Stomach contents of selected species

2. To collect biological data (size, weight, age and maturity) on range of data-limited fish species, including European seabass (*Dicentrarchus labrax*), black seabream (*Spondyliosoma cantharus*), red mullet (*Mullus barbatus*), garfish (*Belone belone*), saury pike (*Scomberesox saurus*).

3. To collect plankton samples using two ring-nets with 80 µm, and 270 µm mesh sizes at fixed stations. Carried out at night by vertical haul and samples will be processed onboard:
    a. Ichthyoplankton (eggs and larvae, 270 µm) of pelagic species will be identified, counted and (in case of clupeids) staged and measured onboard to identify spawning areas.
    b. Zooplankton (80 µm) will be stored for further analysis back in the lab.

4. Water column sampling. At fixed stations along the acoustic transect, a CTD (either an ESM2 profiler or a Seabird mounted on a Rosette sampler) will be deployed to obtain measurements of environmental properties within the water column. Water column profile and water samples will provide information on chlorophyll concentration, dissolved oxygen, salinity, temperature, turbidity, and dissolved inorganic nutrients concentration as well as the relevant QA/QC samples for calibration of the equipment. Water samples will be collected and fixed on board for analysis post-survey. Samples for analysis of the phytoplankton and microzooplankton communities will also be collected at the subsurface at fixed sampling stations.

5. Seabirds and Marine Mammals. Locations, species, numbers and activities observed will be recorded continuously during daylight hours by Marinelife observers located on the bridge.

6. Ferrybox Continuous CTD/Thermo-salinograph. Continuously collect oceanographic data at 4 m depth during steaming, including chlorophyll concentration (from calibrated fluorescence).

7. To carry out hourly measurements of the phytoplankton functional groups using an online flow-cytometer, connected to the Ferrybox; in collaboration with project JERICHO NEXT.

8. To further trial the continuous Plankton Image Analyser (PIA, James Scott, PhD).

9. To collect and process samples of environmental DNA and assess method as monitoring tool for pelagic fish, cetaceans and diversity (Chris Brodie, PhD).

10. To collect stomach contents of small pelagic fish (e.g. anchovy and sardine) for onboard and post-survey analysis (Roweena Patel, PhD).

11. To collect small pelagic fish stomachs for a study on proliferation of microplastics through food webs

12. To collect a zooplankton sample using the 200 µm mesh ring-net at the West Gabbard2 SmartBuoy, for the Lifeform project (Defra) as part of the UK monitoring network of zooplankton.

13. To collect and freeze sardine specimens at three different locations: eastern English Channel, Western English Channel and Bristol Channel for genetic and otolith morphometric study (Ana Verissimo, CIBIO, Portugal)

14. To collect 15 tissue samples of sardine for each ICES rectangle for a Portuguese study to integrate genetic analysis into fisheries biology and assessment (Ana Rita Vieira, MARE, University of Lisbon, Portugal)

NARRATIVE:

All staff joined the RV Cefas Endeavour in Swansea docks by 16:00 on the 30th of September. Inductions were held at 16:00 followed by the presurvey debrief at 18:00. Given the incremental weather conditions forecasted, the captain suggested conducting the echosounder calibration in port the following morning (1st of October) before sailing: while the available water depth was shallow at 12 m, the relatively sheltered position and lack of tide led us to consider it. As planned, staff involved with the calibration were ready at 5:30 to make final preparations but a range of circumstances delayed the actual calibration attempt until 9:00 BST. With the pilot due at 10:00, the calibration had to be aborted. The RV sailed out of Swansea at 10:00 and commenced the inner most transect of the Bristol Channel, after which shakedown tows for the plankton nets and rosette/CTD were conducted, both preceded by relevant toolbox talks. At 16:00, after the toolbox talk, the trawl was deployed for a shakedown tow. Overnight, a series of plankton and rosette stations were conducted. At approximately 7:00 BST on Wednesday 2nd of October favourable conditions meant that a second calibration of the echosounders was attempted. A sheltered location at northern end of transect 10, along the western tip of the Pembrokeshire coast was used, which had sufficient water depth, but strong tides. The calibration, conducted on the drift was completed at 9:45 (38, 120 and 200 kHz at 0.512 and the 38 at 0.256) by which point the RV needed to leave the area for planned fire practise, which affected the acoustic sampling of the northern parts of transects 10 and 9. The survey had commenced properly which, as per protocol, involved running acoustic transects during the day at 10 knots, while simultaneously collecting continuous sub-surface oceanographic data with the Ferrybox. Two Marinelife observers recorded qualitative and quantitative information on the top predators on transect. At night, a series plankton and rosette stations was sampled. Late afternoon on Thursday the 3rd of October, the RV sought shelter (daylight required) on the east side of Lundy from Storm Lorenzo which was due to arrive at night. No night time surveying was conducted. Approximately 24 hours later, in the afternoon of Friday the 4th of October, the RV sailed to explore conditions and resumed survey work. For the next few days, the survey progressed westwards under fresh but workable conditions. On the 7th of October, the pelagic trawl was damaged during a fishing operation on transect 15. While the true extent of the damage was not known until later, as a precautionary measure it was decided to rig the spare trawl. Although trawling operations could resume later in the afternoon, few fish schools appeared on the echosounder and therefore no further tows were conducted. Acoustic monitoring was continued as were the overnight primary stations sampling for zooplankton and CTDs. Several plankton stations had to be repeated over the first few weeks due to incidental damage to either the plankton nets (ringnet) or their codend. The next few days, the RV moved away from the Bristol Channel to sample the transects around the Isle of Scilly with weather conditions remaining fresh (25 knots of wind). Transect #18 had to be surveyed straight into the swell (east to west) leading to relatively poor acoustic data quality and reduced vessel speed. However, as very few fish schools were observed and no uplift of weather was expected work was continued. By the 11th of October, the Isles of Scilly transect had been completed and surveying of the Cornish waters in the western Channel commenced. Calmer weather on the 12th October (fair winds of 6 knots) led us to pick the exposed western most transects on the French side of the western Channel and associated prime stations overnight. At the (inshore) start of Transect 47 a series of surface schools were observed on the echosounder which comprised of post-larval anchovy (3.5-7 cm in length). These same schools were later observed inshore of the adjacent transects to the east.

Overnight, the RV steamed to Falmouth for a scheduled crew change on Monday the 14th of October, which was completed by 18:00 BST. Overnight, the vessel steamed from Falmouth to Lyme Bay to use the continued calm conditions to survey this important area for sprat. Most of the Lyme Bay transects were completed by the afternoon of the 17th under very good conditions (5-8 knots of wind, calm seas). While on occasion the wind picked up in the afternoon, daytime conditions remained very favourable and swell remained negligible, ensuring excellent data quality. After scientific staff change in the afternoon of the 17th of October by small boat transfer in Weymouth, the RV steamed back to French waters to survey the eastern-most transects. Due to adverse weather conditions, no trawling operations could be conducted on the 18th of October, but few fish schools were seen on the echograms so this was no major issue. Vastly improved conditions led the RV to commence transect 41, at the southern end, working its way back to Lyme Bay to complete the outstanding transects during the next couple of days. After completion, for the remainder of the survey, the RV resumed some of the western transects in the western Channel, working eastwards including transects in French waters. During this period, it became apparent that the inflow into the ferrybox (surface oceanographic sampler) was reduced which was likely caused by biofouling. The final two weeks of the survey was conducted without the autopilot working which meant that manual steering was required during the remainder of the survey. This did not adversely affect the quality of the data collected. Fair conditions changed to increasing south-westerly winds towards the end of the survey which reduced night time sampling of primary stations on a few occasions and eventually led to the survey being interrupted in the early afternoon on the 26th of October, when the vessel steamed into Lyme Bay to shelter. The next morning the survey was resumed and final transects and stations in the Eddystone Bay were completed. On the 28th of October five scientific staff disembarked via small boat transfer in Weymouth after which the RV commenced its transit back to Lowestoft where, after collection of a sample at Dungeness, she docked at 20:00 BST on the 29th of October.

RESULTS:

Pelagic Ichthyofauna

After removing the off-transect data a total of 1800 nautical miles of acoustic sampling units were collected for further analysis (Figure 2). These included several transects in the eastern Channel, which was sampled for the first time this year. A total of 38 valid trawls were made with the mid-water trawl, providing a suitable source of species and length data to partition the acoustic data. The trawl was changed over early on in the survey due to gear damage; although the same make and model as the original trawl, the lighter material used caused some temporary issues with the headline sensor deployment. However, these were fixed by adding a firmer floatation line on the headline. General patters of fish distribution were similar to those observed for the time series and included, for the third year running, the French waters of the western English Channel.

Sprat (*Sprattus sprattus*) was widespread in most of the survey area with the typical presence of two core areas, one in the Bristol Channel, including the coastal waters in the west, and the other in English waters of the western Channel (Lyme bay, Figure 3). Medium sized fish (mode of 8-9 cm) dominated all main areas. As in previous years, the smallest fish were found in the Bristol Channel and the largest (mode of 11.5 cm) in Lyme Bay, although high numbers of age-0 sprat in Lyme Bay suggested a decent recruitment. Preliminary biomass estimate of the sprat population in Lyme Bay was 23,443 t, an increase from 2018. Sprat was also found in French waters although further east than in previous years.

Sardine (*Sardina pilchardus*) distribution was comparable to previous years with the bulk of biomass found in the English Channel (Figure 4). The apparent trend of increasing numbers of sardine north of the Cornish Peninsula continued. Northern waters of the English Channel again host the largest size-range of sardines with the largest fish also extending to the waters around the Isles of Scilly. In French waters, most sardines were smaller than 14 cm. Area 7 sardine is the most abundant small pelagic fish in the area with a total biomass for 2019 estimated to be 239,478 t, the highest in the time series.

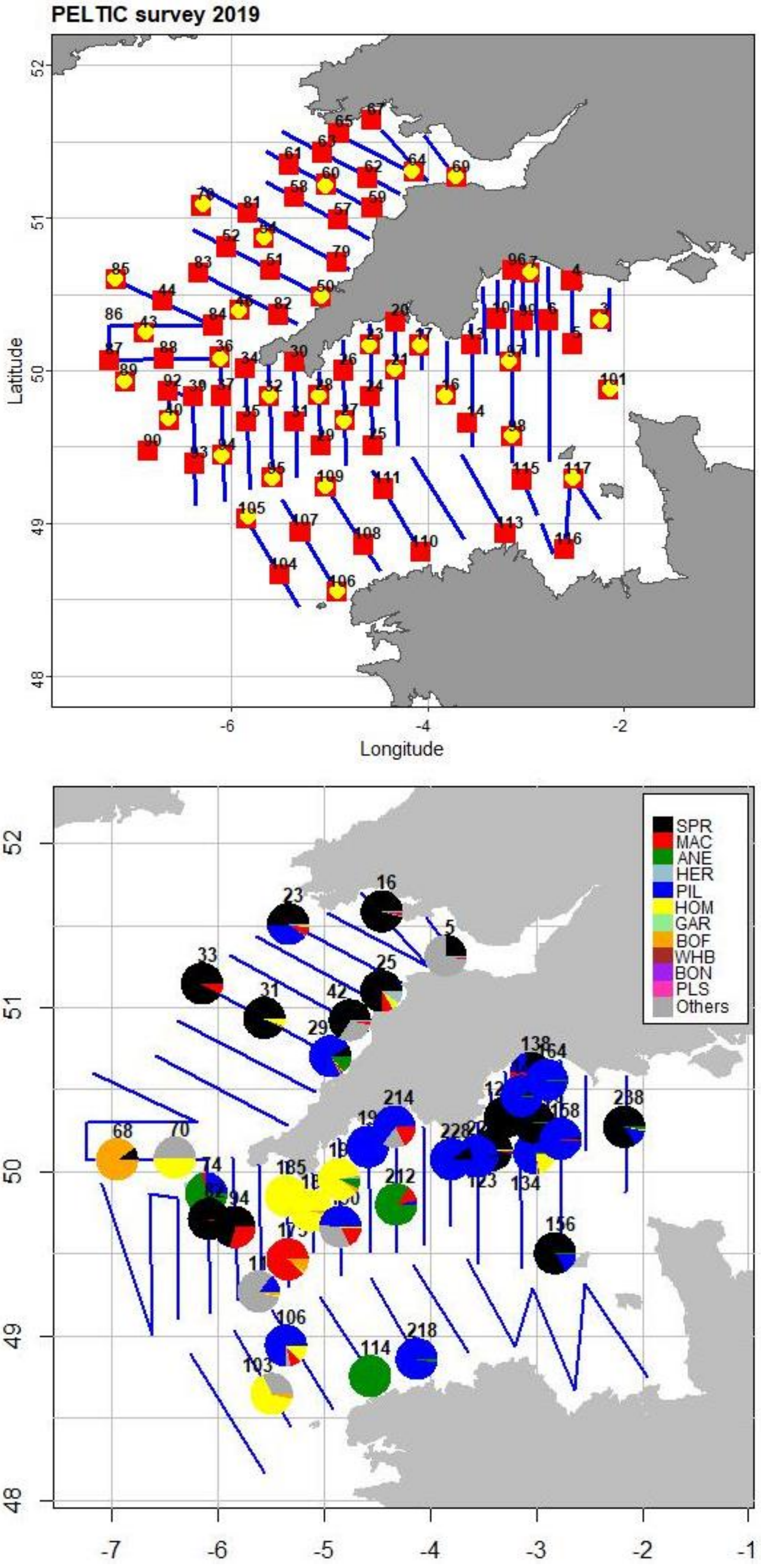

Figure 2. Overview map and detail of the PELTIC19 survey area. Top: Acoustic transects (blue lines) and prime stations completed. Bottom: Trawl stations (pies) with relative catch composition by key species. Three letter codes: SPR=sprat, MAC=mackerel, ANE=anchovy, HER=herring, PIL=sardine, HOM= horse mackerel, GAR=garfish, BOF=Boarfish, WHB=Blue whiting, BON=Atlantic bonito, PLS=pearlside.

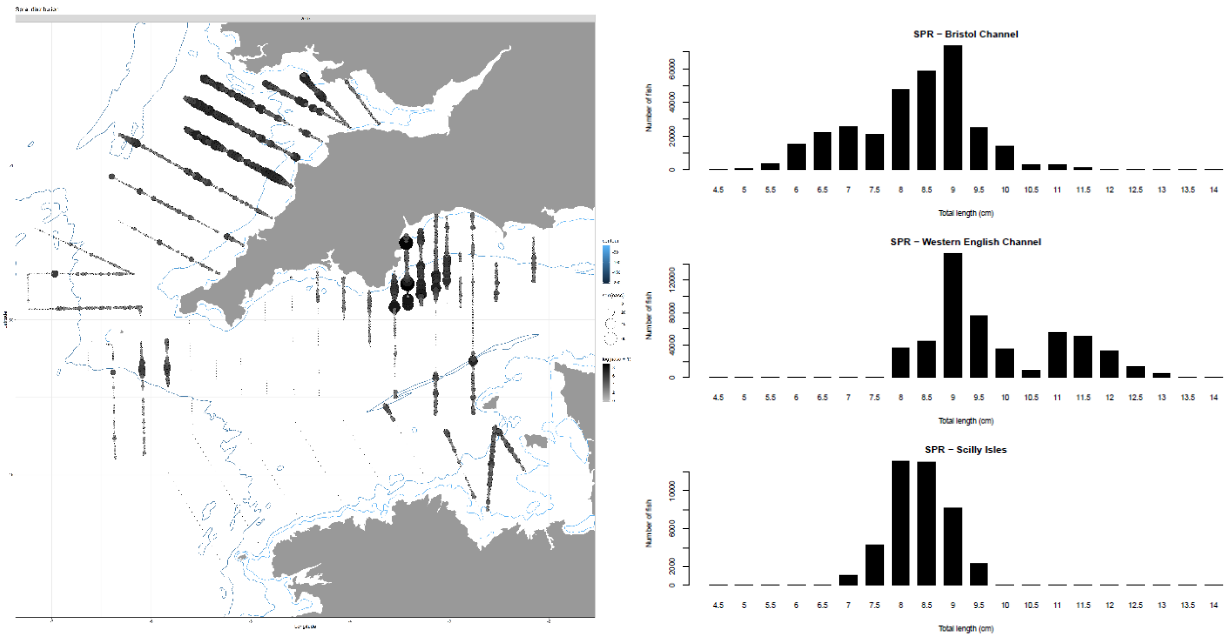

Figure 3. Relative acoustic sprat density distribution (NASC, left) and trawl-based length frequency histogram for sprat in some of the subareas of the Peltic survey (right).

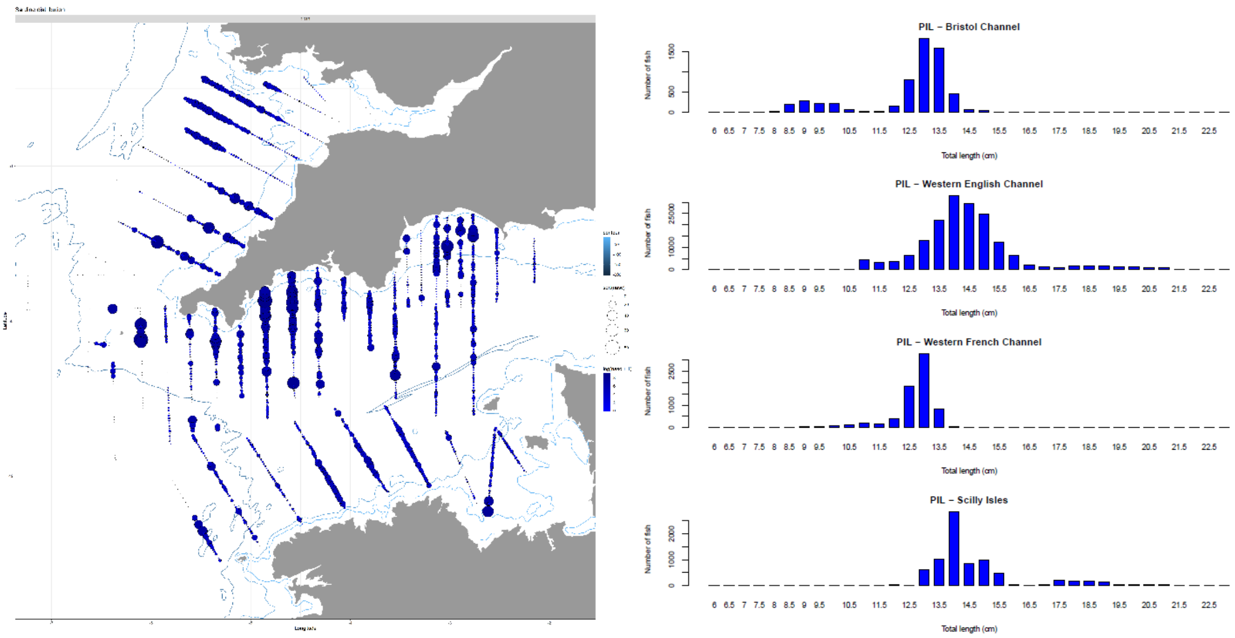

Figure 4. Relative acoustic sardine density distribution (NASC, left) and trawl-based length frequency histogram for sardine in each of the subareas of the Peltic survey. Please note that bubble size has not been standardised between species.

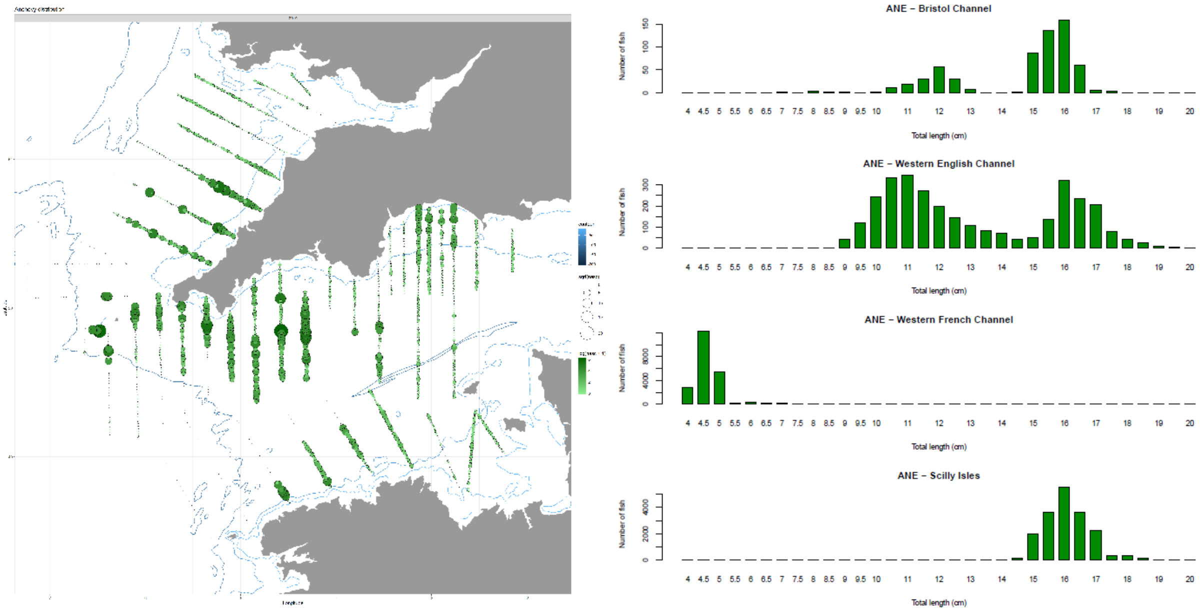

Figure 5. Relative acoustic anchovy density distribution (NASC, left) and trawl-based length frequency histogram for anchovy in each of the subareas of the Peltic survey. Please note that bubble size has not been standardised between species.

Anchovy (*Engraulis encrasicolus*) distribution in 2019 confirmed the trend of northwards expansion with increased anchovy biomass in the Bristol Channel, an area not inhabited by anchovy in the first years of the survey. Similar length frequency modes on both sides of the Cornish Peninsula (11-12 and 16 cm, Fig. 5) suggested the majority of these fish are from the same population. Particularly notable was the presence of juvenile anchovy in small surface schools on the French side (Fig. 6). Total anchovy biomass in the survey area was estimated at 11,853 t, which was down from 2018.

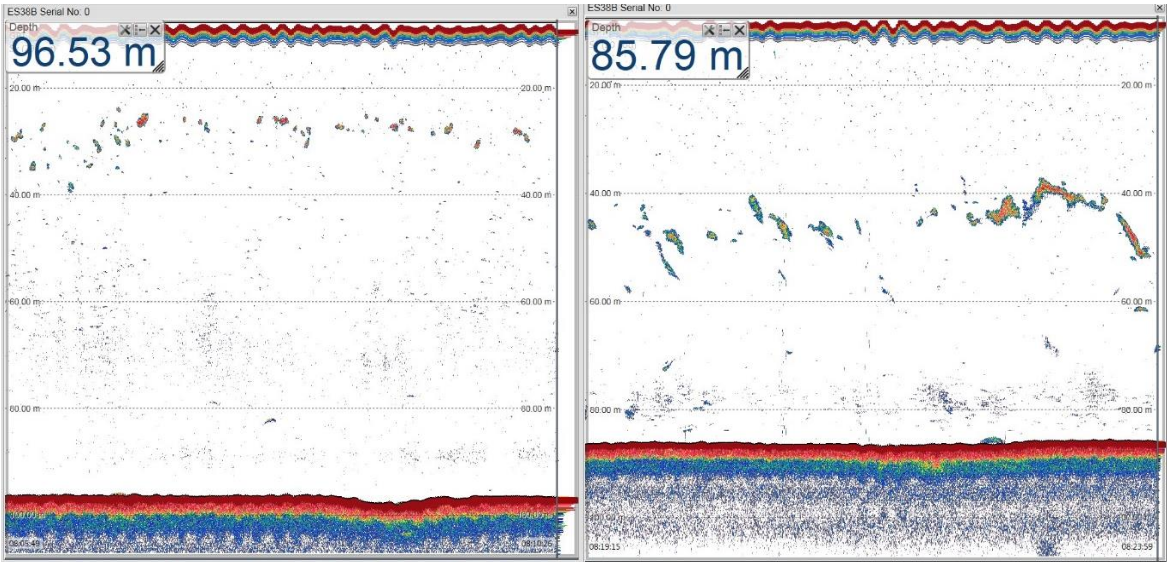

Figure 6. Two example daytime echograms (38 kHz, -70dB gain) of layer of surface schools in near-shore French waters, comprised of juvenile (4-6 cm) anchovy.

Following last year's large apparent recruitment pulse of juvenile **herring (*Clupea harengus*)**, combined acoustic and trawl information suggested that 2019 was more in line with the usual observations. Horse mackerel and mackerel were again distributed throughout the survey area, largely consisting of young-of-the-year specimens (Horse mackerel: modes between 6-8 cm, mackerel 15-19 cm). Larger horse mackerel (mode at 22 cm) were caught in French waters and larger mackerel (mode at 28 cm) in English waters of the western Channel.

Zooplankton

Samples of mesozooplankton and ichthyoplankton communities were collected at 79 stations using 80 and 270 micron ringnets, respectively. Several stations in the central English Channel were missed due to adverse weather conditions. Preliminary results on the distribution of sardine eggs suggested a similar distribution as found in previous years with spawning areas on both side of the Cornish Peninsula but highest densities in the western Channel (Figure 7). Plankton samples were again collected in the southern half of the English Channel. Information on size and taxonomic group of zooplankton samples collected at the same stations, will be obtained by Zooscan processing back in the lab.

For the duration of the survey, the Plankton Image Analyser (PIA) was run to collect images of zooplankton organisms, which will be processed and analysed at PML.

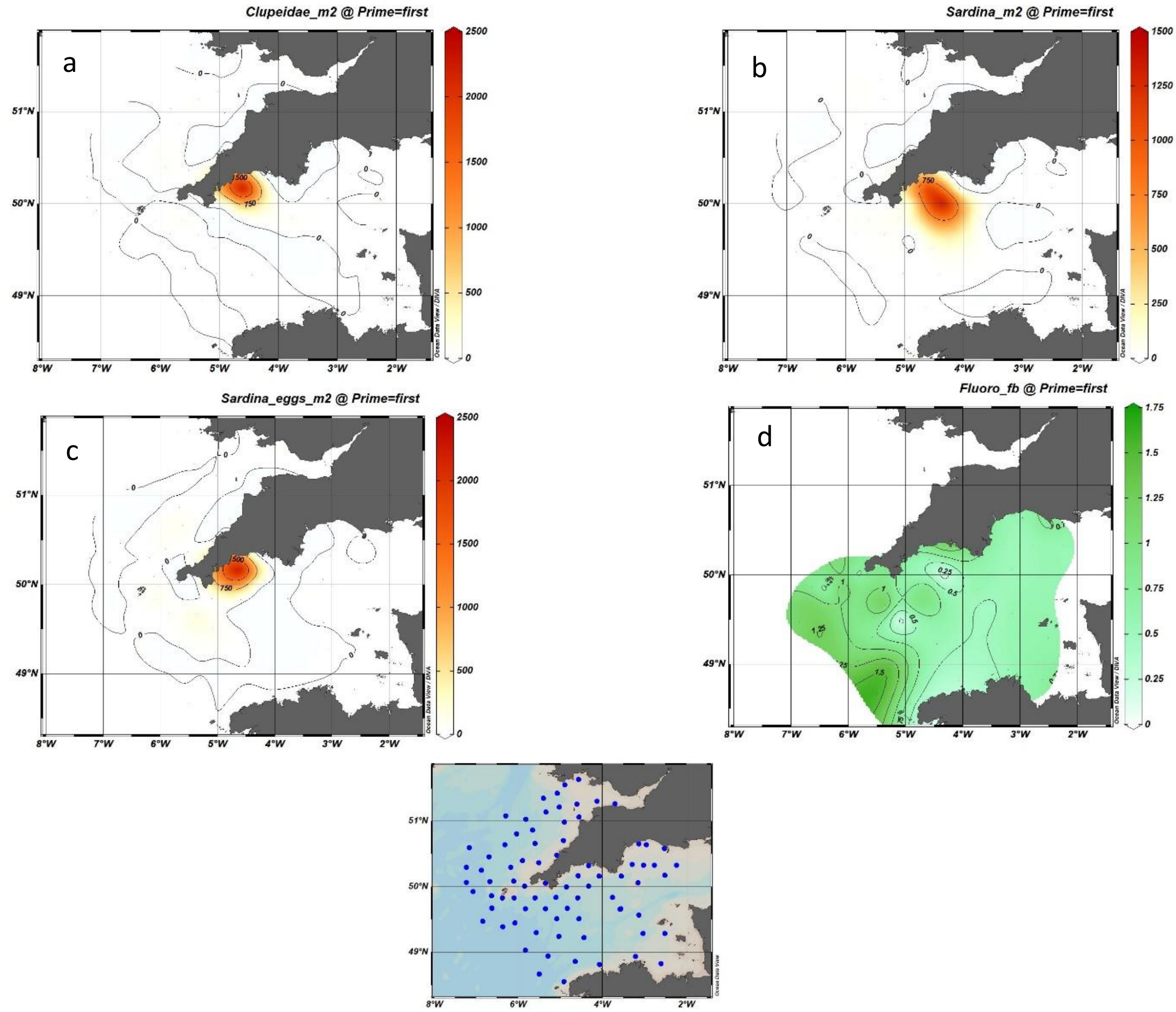

Figure 7. Distribution of fish larvae (total Clupeidae and Sardine; a, b) and eggs at the sampling stations (c), determined from samples collected with the 270 µm ring net and analysed on board; subsurface fluorescence concentration recorded by the Ferrybox (d). Note that the larvae are separated by those confirmed to be sardine (Sardina) and those that could not be further distinguished to species (Clupeidae), the vast majority was considered to also be sardine.

Physical Oceanography

Temperature and salinity of the water column at the 79 zooplankton sampling stations was measured with a SAIV MiniCTD profiler, and, at 33 of these (water stations), a SeaBird CTD, mounted on the Rosette sampler, was also deployed. The SeaBird CTD was equipped with PAR, oxygen, turbidity and fluorescence sensors and allowed for live measurements of environmental variables along the water column. At 30 of these water stations, water samples were collected for analysis of phytoplankton and microzooplankton communities, dissolved oxygen, salinity, phytoplankton pigments (including chlorophyll-a) and dissolved inorganic nutrients (nitrate, nitrite, ammonium, phosphate, silicate). To collect the water samples, 12 Niskin bottles attached to the Rosette, were used, except during 6 sampling events when sea state was too rough, and samples were collected from the flow-through of the FerryBox.

Water samples were collected at water stations and during trawls, then filtered for determination and quantification of eDNA in the water.

Water at the subsurface (4 m) was continuously monitored by the FerryBox, which recorded different environmental variables, including temperature, salinity, fluorescence, turbidity, and oxygen. Furthermore, a flow cytometer, connected to the FerryBox, carried out measurements of abundance and size of the phytoplankton community every hour, while the PIA (Plankton Image Analyzer) provided continuous monitoring of the mesozooplankton population. Due to issues with the water inflow, neither Ferrybox nor Flowcytometer managed to provide continuous coverage.

Table 1. Number of samples collected during Cend15_19 and number of profiles carried out.

	Total
Salinity	30
Dissolved oxygen (triplicates)	16
Chlorophyll/Pigments analysis (HPLC - duplicates)	31
Inorganic nutrients	30
Phytoplankton	30
Microzooplankton	30
Mesozooplankton (80 µm)	79
Mesozooplankton (270 µm)	79
eDNA samples	?
CTD profiles with Rosette	33
CTD profiles with ESM2	6
CTD profiles with RBR	8
CTD profiles with SAIV MiniCTD	83

As per previous years, sea surface temperature was highest in the Bristol Channel and then just off the Western French Channel near St Brieuc. Maximum temperature from this survey was 17.2°C, this is warmer by more than 0.5 °C compared to previous two years and more closely resembles the maximum of the 2016 survey. As is a common observation during the PELTIC survey series, the lowest surface temperatures were recorded at the mouth of the western English Channel (Fig. 8, 9). Although the lowest surface temperature recorded this year was, at 13.5°C, warmer than in 2018 and comparable to years before then. Lowest bottom temperatures were taken at the most westly stations advancing into the Celtic Sea.

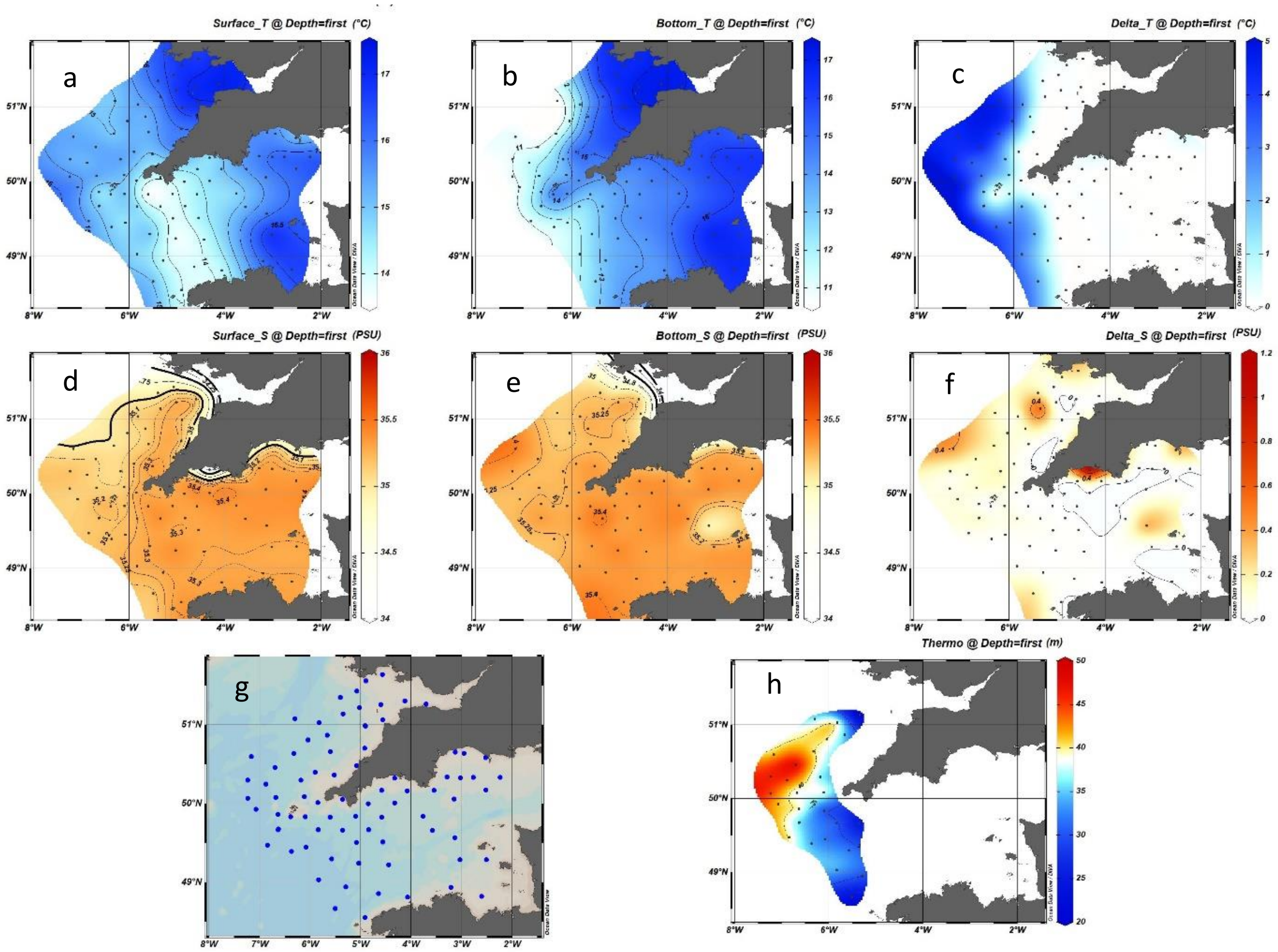

Figure 8. Temperature (a-c, T, °C) and salinity (d-f S) distribution at the surface (a, d) and bottom (b, e) as recorded by the SAIV MiniCTD at the 79 sampling stations (g). The difference in temperature (c, Delta_T) and salinity (f, Delta_S) between surface and bottom is also given, together with depth of the thermocline (h, Thermo), at the stratified stations (Delta_T > 0.5 °C).

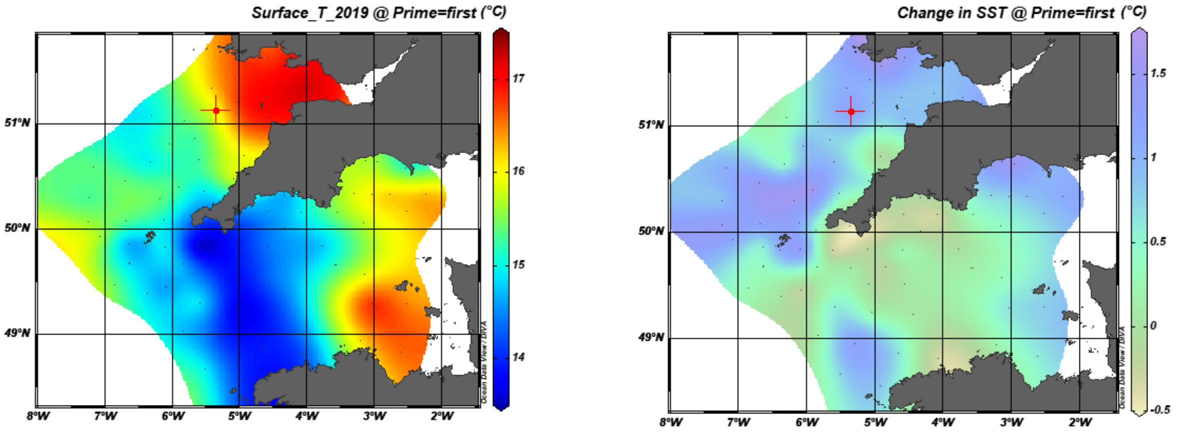

Figure 9. Sea surface temperatures recorded this survey (left) and difference in sea surface temperatures recorded from last year 2018 (right).

Table 2. Summary statistics (minimum, maximum, mean, standard deviation, and number of observations) of temperature and salinity measurements, recorded by the SAIV MiniCTD at the sampling stations. Column titles are the same as in Figure 2.

	Surface_T	Bottom_T	Surface_S	Bottom_S	Delta_T	Delta_S	Thermo
Min	13.51	10.55	31.81	31.85	0	0	21
Max	17.23	17.23	35.39	35.44	4.74	1.16	48
Mean	15.29	14.28	35.12	35.19	1.04	0.09	36.3
StDev	0.93	1.88	0.46	0.43	1.54	0.16	6.6
Number	79	79	79	79	79	79	28

Offshore stations in the Bristol Channel and in the Western approaches, west of Lizard Point, were seasonally thermally stratified (Delta_T > 0.5 °C; Figure 8). While a series of storms with strong wave activity throughout October was thought to have accelerated the mixing, the picture is similar to previous years. Coastal stations in the English and French side of the Channel were vertically mixed (Figure 8). The difference between surface and bottom temperatures was highest at offshore stations in the Celtic Sea and up to 4.74 °C (Table 2). Thermoclines with the deepest initial start of the stratification, >30m, were found at offshore stations (off the Bristol Channel). Those with shallower stratification were more coastal and typically associated with the cooler sea surface temperatures off Western France (minimum of 11m, Table 2 and Figure 8). The strength of stratification was similar to that of previous years between 4.9°C and 4.3°C. Unusually low salinity values were recorded (31.89; Table 2 and Figure 8) in the Bristol Channel and were thought to be due to increased rainfall towards the end of September. This result was confirmed by the value recorded by the Ferrybox (31.70), but this will be validated after calibration of sensors. Salinity remained low throughout Bristol Channel, and was also lower in Lyme Bay and the Bay of Sein, France. Highest salinity values were recorded offshore of Lizard Point (35.39; Table 2 and Figure 8) and south west corners of the Celtic Sea. Surface distribution of chlorophyll concentration was estimated by fluorometers on the Ferrybox and on the SeaBird profiler mounted on the Rosette sampler. Remote sensed images of ocean colour from MODIS (algorithm OC3) from Neodaas.co.uk (PML) were consulted to obtain a synoptic view of the study area, but were of limited use due to cloud cover throughout the survey.

Observer data: Marine Mammal, Birds and large pelagic fish

For the whole survey, two volunteer MARINElife surveyors, stationed on the bridge in a central position, employed an effort-based 300m box methodology for recording birds (an adapted version of ESAS methodology) with an additional 180° scan area surveyed along each transect line, as used on the majority of MARINElife's year-round surveys. During survey transects, all species of birds (both seabirds and terrestrial migrants) were recorded, along with all sightings of marine mammals and large pelagic fish. This year, no (incidental) data were collected during the deployment of the fishing net, during the net-retrieval phase or during transits between transects.

Weather was particularly difficult for surveying and there were a few days within the survey, particularly part 1, where the team were faced with storms. Unfortunately, no results were available for inclusion in the report.

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Summary

Peltic19 constituted the 8th autumn survey on small pelagic fish and their ecosystem in the waters of the western English Channel and eastern Celtic Sea. The survey commenced on the 1st of October and ran for 28 effective survey days, starting in the Bristol Channel working into the English Channel. This year, for the third year running, the survey was extended beyond the area covered between 2012 and 2016, which focussed solely on the Mackerel Box. The extended survey coverage included the French waters of western Channel (ICES 7e). Despite the persistent westerly weather conditions, and resulting down time, the survey was successfully completed. In total just under 1800 nautical miles of acoustic sampling units were collected and supplemented with 38 valid trawls which provided details on species composition and biological information. The (preliminary) results indicated that sprat was found to be more widespread than in recent years although total biomass for survey area was comparable to 2018. The biomass in Lyme Bay, which is relevant to the stock assessment, was up from 2018, from 17,091 t to 23,443 t. As observed in recent years, sardine was widespread in the survey area, including north of the Cornish Peninsula. Sardine egg distribution reflected that of the adults, including the presence of the highest densities, by some margin, in the Eddystone Bay. Sardine biomass for the whole was estimated at 239,478 t, up from 157,936t. The recent trend in anchovy expansion in the survey area continued. Biomass, at 11,853 t was more comparable to the long term mean, after last year high value. For the first time, large numbers of juvenile anchovy (4-7 cm) were found in a surface layer along the French coast. Details on biomass and distribution of herring, blue whiting, horse mackerel, mackerel and boarfish were also calculated. As was the case in 2018, Atlantic bluefin tuna were observed in large numbers across the survey area. Oceanographic conditions in October were comparable to the average values of the time series.

Jeroen van der Kooij and Jo Silva
Scientists In Charge
21/11/2019

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Working Document to WGACEGG at Madrid,18-22 November 2019

Acoustic surveying of anchovy Juveniles in the Bay of Biscay:

JUVENA 2019 Survey Report

By

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1. Abstract

The project JUVENA aims at estimating the abundance of the anchovy juvenile population and their growth condition at the end of the summer in the Bay of Biscay. The long-term objective of the project is to be able to assess the strength of the recruitment entering the fishery the next year. The survey was coordinated between AZTI and IEO. AZTI leaded the assessment studies and IEO leaded the ecological studies. The survey took place in two research vessels: the Ramón Margalef and the Emma Bardán. The biomass of juveniles estimated for 2019 is around 114,000 tonnes, which represents a medium low estimation, ~50 % below the average.

2. Materials and Methods

2.1 Data acquisition

The survey JUVENA 2019 took place onboard the chartered R/V Ramon Margalef and the R/V Emma Bardán, both equipped with scientific echosounders. The acoustic equipment included three split beam echo sounders Simrad EK60 (Kongsberg Simrad AS, Kongsberg, Norway; Table 1) calibrated using Standard procedures (Foote *et al.* 1987). In the Ramon Margalef, the 18, 38, 70, 120, 200 and 333 kHz transducers were installed looking vertically downwards, 6.5 m deep, at the drop keel, whereas at the R/V Emma Bardan the 38, 120 and 200 kHz transducers were installed at the hull. For acoustic data processing the Echoview software was used.

The water column was sampled to depths of 400 m. Acoustic back-scattered energy by surface unit (S_A, MacLennan *et al.* 2002) was recorded for each geo-referenced ESDU (Echointegration Sampling Distance Unit) of 0.1 nautical mile (185.2 m). Fish identity and population size structure was obtained from fishing hauls and echotrace characteristic using a pelagic trawl (Table 1). Acoustic data, thresholded to -60 dB, was processed using Echoview for biomass estimation and the processed data was represented in maps using R. Hydrographic recording was made with CTD casts.

Sampling strategy

The sampling area covered the waters of the Bay of Biscay (being 8º00’ W and 46º40’ N the limits, Figure 1). Sampling was started from the Southern part of the sampling area, the Cantabrian Sea, moving gradually to the North to cover the waters in front of the French Coast. The acoustic sampling was performed during the daytime, when the juveniles are supposed to aggregate in schools (Uriarte 2002 FAIR CT 97-3374) and can be distinguished from plankton structures.

The vessels followed parallel transects, spaced 15 n.mi., perpendicular to the coast along the sampling area, taking into account the expected spatial distribution of anchovy juveniles for these dates, that is, crossing the continental shelf in their way to the coast from offshore waters (Uriarte et al. 2001).

During the summer, information from the commercial live bait tuna fishery was collected (Table 7), in order to have knowledge about the spatial distribution and relative abundance of anchovy previous to the beginning of the survey.

Data analysis

Biological processing

Each fishing haul was classified to species and a random sample of each species was measured to produce size frequencies of the communities under study. A complete biological sampling of the anchovy juveniles collected is performed in order to analyze biological parameters of the anchovy juvenile population, as the age, size or size-weight ratio. Using these and other environmental parameters we will try to obtain, in a long term, indexes of the state of condition of the juvenile population, in order to be able to improve the prediction of the strength of the recruitment.

Acoustic data processing

Acoustic data processing was performed by layer echo-integration by 0.1 nautical mile (s_A) of the first 65 m of the water column with Movies+ software, after noise filtering and bottom correction, increasing or decreasing this range when the vertical distribution of juveniles made it necessary.

The hauls were grouped by strata of homogeneous species and size composition. Inside each of these homogeneous strata, the echo-integrated acoustic energy s_A was assigned to species according to the composition of the hauls. Afterwards, the energy corresponding to each specie-size was converted to biomass using their corresponding conversion factor.

Each fish species has a different acoustic response, defined by its scattering cross section that measures the amount of the acoustic energy incident to the target that is scattered backwards. This scattering cross section depends upon specie *i* and the size of the target *j*, according to:

$$\sigma_{ij} = 10^{TS_j/10} = 10^{\{(a_i + b_i \log L_j)/10\}}$$

Here, L_j represents the size class, and the constants a_i and b_i are determined empirically for each species. For anchovy, we have used the following TS to length relationship:

$$TS_j = -72.6 + 20 \log L_j$$

The composition by size and species of each homogeneous stratum is obtained by averaging the composition of the individual hauls contained in the stratum, being the contribution of each haul weighted to the acoustic energy found in its vicinity (2 nm of diameter). Thus, given a homogeneous stratum with M hauls, if E_k is the mean acoustic energy in the vicinity of the haul *k*, w_i, the proportion of species *i* in the total capture of the stratum, is calculated as follows:

$$w_i = \sum_j w_{ij} = \sum_j \left(\frac{\sum_{k=1}^{M} \left(q_{ijk} \cdot E_k \middle/ Q_k \right)}{\sum_{k=1}^{M} E_k} \right).$$

Being q_{ijk} the quantity (in mass) of species *i* and length *j* in the haul *k*; and Q_k, the total quantity of any species and size in the haul *k*.

In order to distinguish their own contribution, anchovy juveniles and adults were separated and treated as different species. Thus, the proportion of anchovy in the hauls of each stratum (w_{ij}) was multiplied by a age-length key to separate the proportion of adults and juveniles. Then, separated w_i were obtained for each.

Inside each homogeneous stratum, we calculated a mean scattering cross section for each species, by means of the size distribution of such specie obtained in the hauls of the stratum:

$$\langle \sigma_i \rangle = \frac{\sum_j w_{ij} \sigma_{ij}}{w_i}.$$

Let s_A be the calibration-corrected, echo-integrated energy by ESDU (0.1 nautical mile). The mean energy in each homogeneous stratum, $E_m = < s_A >$, is divided in terms of the size-species composition of the haul of the stratum. Thus, the energy for each species, E_i, is calculated as:

$$E_i = \frac{w_i \langle \sigma_i \rangle E_m}{\left(\sum_i w_i \langle \sigma_i \rangle \right)}$$

Here, the term inside the parenthesis sums over all the species in the stratum. Finally, the number of individuals F_i of each species is calculated as:

$$F_i = H \cdot l \frac{E_i}{\langle \sigma_i \rangle}$$

Where *l* is the length of the transect or semi-transect under the influence of the stratum and *H* is the distance between transect (about 15 n.mi.). To convert the number of juveniles to biomass, the size-length ratio obtained in each stratum is applied to obtain the average weight of the juveniles in the stratum:

$$< W_i >= a \cdot < L_i >^b$$

Thus, the biomass is obtained by multiplying F_i times $< W_i >$.

3. Results

Checking and calibrations

Calibration of the EB was performed in Pasaia during the first days of the survey following the sphere method (Foote et al. 1987). The calibration of the RM was done also at the beginning of the survey inside the Bilbao harbour.

Sampling coverage

The survey JUVENA 2019 took place between the 2019-08-31 and the 2019-10-03 (see Table 2). Due to bad weather conditions, the survey couldn’t sample the northern part (to the north of 46.6 ºN) of the BoB. The survey sampled around 1828 n.mi. that provided a coverage of about 27,500 n.mi.^{2} along the continental shelf and shelf break of the Bay of Biscay, from the 7º00’ W in the Cantabrian area up to 46º 40’ N at the French coast (Figure 1). 64 hauls were done during the survey to identify the species detected by the acoustic equipment, 43 of which were positive for anchovy (Figure 2, Tables 3, 4, 5 and 6).

The survey was covered by both vessels in coordination, in the Spanish region both vessels followed alternate transects, while in the French part they concentrated the sampling effort of each vessel in the most appropriate areas according to their efficiency: this is, oceanic and slope waters for the RM and continental shelf for the smaller pelagic trawler EB (Figure 1).

Juvenile anchovy biomass estimations

The biomass of juveniles estimated for this year is 114,000 tones (Table 7). This value represents a medium low value, well below the average in the temporal series (Figure 6). The area of distribution of juvenile anchovy this year was among the highest in the temporal series, being the juveniles spread from the continental shelf to bathymetries of 4000 m up to the 45º15 N, but the scarcity, small size and low density of the juvenile schools provided a rather low abundance (Figure 6, Table 8). The mean size of anchovy was 6.1 cm long, less than the average (Figure 3). As usual, most of this biomass was located off-the-shelf or in the outer part of the shelf (Figure 4, Table 7) in the first layers of the water column. In order to have an idea of the potential underestimation caused by the limited coverage at the northern area, we calculated the mean biomass of anchovy to the north of 46.6ºN for anchovy. The result was that the fraction of the biomass of juvenile anchovy in the North is ~10% (+-8%) while for adults is close to 50%.

The biomass estimated foresees a low recruitment of anchovy for next year (Figure 6). The index of juvenile anchovy provided by JUVENA will be used to update the assessment of anchovy in the Bay of Biscay based on the CBBM (ICES, 2015). The mean weight and length of juvenile anchovy remains lower than the average, as has been occurring in the last few years (Figure 7).

Assessment of sardine

The spatial distribution of sardine was concentrated, as is usual in this survey, in the coastal area of the northern part of the French coast (Figure 8). The biomass of sardine was ~7000 tones (Table 9), below the average of the temporal series (Figure 9). Due to the limited coverage of the norther French shelf, a similar analysis as the one followed for anchovy suggests that an underestimation of almost 40% (+-25%) is expected for sardine. Although, it must be noted that, in the case of this species, the biomass of sardine that can be found to the North of the 46.6ºN reached one year the 90% of the total biomass. The mean length and weight of sardine seems to have stabilized in the last 5 years after a drop since the end of the 2000's (Figure 10).

Assessment of other species

Maurolicus muelleri of ~4 cm average length was found in large and mostly pure aggregations all along the Cantabrian and French outer shelfs and oceanic waters (Figures 11, 12). The assessed biomass was over 150,000 tones (Table 9). Most horse mackerel (of 12-18 cm) was located all along the French coast in shallow waters (<50 m) yielding a total biomass of 21000 tones. Atlantic mackerel of 19 cm was found in two main areas: in the Cantabrian shelf, between Santander and Bilbao and in the French shelf to the north of the Garonne river plume. Finally, 5000 tones of sprat of about 8 cm was found to the north of the Garonne plume at the ~50 m bathymetry.

Predators observation in JUVENA 2019

By Amaia Astarloa, Jose Antonio Vázquez, Arkaitz Pedrajas and Maite Louzao

A total of 115 observations periods (legs) were performed, travelling a total of 1685.034 km. We recorded a total of 975 seabirds, 262 marine mammals, 421 other marine wildlife, 87 marine debris, 72 human activities, 2 coastal birds, 35 landbirds and 4 oceanographic features (Table O1).

Regarding marine mammals, we observed 6 different species and the spatial distribution of the most abundant species can be observed in Figure O2. The most abundant species was the fin whale with 20 sightings (group size = 1.05 ± 0.22, a total of 21 individuals), followed by the common dolphin with 18 sightings (group size = 6.61 ± 4.96, a total of 119 individuals), the striped dolphin with 10 sightings (group size = 8.6 ± 7.95, a total of 86 individuals) (Table O2). We also recorded 2 sightings of bottlenose dolphins and 1 of the minke whales and 1 of long-finned pilot whales. Fin whales and striped dolphins were present in the oceanic areas of the BoB (Figure O2a and 2b, respectively), while common dolphins were present in the central French shelf and Spanish slope (Figure O2c).

In relation to seabirds, we observed 12 different species and the spatial distribution of the most abundant species can be observed in Figure O3. The most abundant species (> 10 sightings) was the northern gannet with 125 sightings (group size = 2.28 ± 3.51, a total of 285 individuals), followed by the great skua with 27 sightings (group size = 1.63 ± 2.51, a total of 44 individuals), the lesser black-backed gull with 23 sightings (group size = 2 ± 3.19, a total of 46 individuals) and the sooty shearwater with 12 sightings (group size = 1.25 ± 0.45, a total of 15 individuals (Table 2). We also observed yellow-legged gulls, Manx shearwaters, great shearwaters, common terns, European herring gulls, Sandwich terns, European storm-petrels, pomarine skuas and Sabine's gulls (Table 2).

Northern gannets were widely distributed over the study area with higher aggregations in the southern study area located in the Cape Peñes and Cape Ajo (Figure O3a). The great skua was mainly observed in shelf, slope and oceanic areas of the BoB but it was especially abundant over the central French shelf (Figure O3b). The lesser black-backed gull was mainly present in slope areas of the French slope and shelf, slope and oceanic areas of the southern sector (Figure O3c). The sooty shearwater was mainly present in coastal areas of the southern sector around Cape Ajo and Cape Peñes (Figure O3d).

Regarding other marine wildlife, we recorded 12 sightings of large pelagic fishes (tuna/bonito) with a group size of 33.83 ± 39 and a total sum of 406 individuals that were especially abundant in the oeanic area of the southern sector (Figure O4a). Similarly, we observed 5 sightings of sunfishes with a total sum of 5 individuals, located in the oceanic area of the southern sector (Figure O4b).

Regarding marine debris and human activities, we observed 4 types of marine debris and 12 different categories of human activities (Table 2). The main marine debris recorded were plastic trashes with 59 sightings (group size = 1 ± 0, a total of 59 items), followed by 13 sightings of fish trash (group size = 1.15 ± 0.38, a total of 15 items), 8 sightings of general trash (group size = 1.0 ± 0, a total of 8 items) and 5 sightings of unnatural wood (group size = 1 ± 0, a total of 5 items). Plastic trashes were mostly found northern and southern oceanic areas, as well as shelf and slope areas of the southern study area (Figure O5a).

Concerning human activities, the most abundant activities were the fishing buoys with 9 sightings (group size = 1.11 ± 0.33, a total of 10 items), followed by trawlers with 9 sightings (group size = 1.0 ± 0, a total of 9 vessels (Table 2). We also observed tankers, fishing boats, merchant ships, longliners, sailing boats, gillnetters, a containership, a small motor boat, a search and rescue vessel and a research vessel (Table 2). Fishing buoys were mainly present in coastal areas of the southern sector (Figure O5b), whereas trawlers were as well present in the central French shelf (Figure O5c).

The survey area covered by JUVENA is depicted in Figure O6. Even whether there is an inter-annual variability in the marine areas covered, both the northern and southern (i.e. French and Spanish, respectively) sectors are well sampled. It is important to note that the JUVENA surveys are conducted simultaneously by two research vessels and that visual observers are only placed in one of them.

We compared the number of sightings per distance travelled (encounter rate) and the number of predators/items/vessels per distance travelled for seabirds, cetaceans, lage pelagic fishes (tuna and sunfishes), marine debris and human activities between JUVENA 2013 and 2019. We only present results for the most abundant species/categories (> 20 sightings for the 2013-2019 period).

The seabird species with the highest number of sightings per distance travelled were the northern gannet, followed by the lesser black-backed gull, the great shearwater and the yellow-legged gull. Species with intermediate number of sightings per distance travelled were great skuas, Sabine’s gulls and sooty shearwaters, among others (Figure O7 and 8). The remaining species (great skuas, European storm-petrels, herring gull, sunfish, Balearic shearwaters and Manx shearwaters) showed a low level of sightings. However, this general pattern showed high inter-annual variability: while 2017 was the year with the highest number of encounter rate for the most abundant species, 2019 was the year with the lower values of encounter rates.

Regarding the spatial distribution of the most abundant seabirds, northern gannets where present over the entire study area with higher concentrations in coastal areas of the northern French coast, in addition to high concentration areas in specific coastal areas of the Spanish sector (Figure O9a). Lesser black-backed gulls were scattered over the entire study area, with specific concentrations in coastal areas of the northern French shelf, oceanic areas of central French slope, shelf of the inner Bay of Biscay, coastal areas of the southern more coastal in the French shelf and more oceanic in the Spanish sector, west of Cape Peñes and in the Estaca de Bareas area, while they were as well present in the oceanic area of the central BoB (Figure O9b). The great shearwater was present in the northern and central French shelf, inner BoB and Spanish slope areas (Figure O9c).

The cetacean species with the highest number of sightings per distance travelled were the common dolphin, followed by the fin whale and the striped dolphin (Figure O10). The remaining species showed a low level of sightings. However, this general pattern showed high inter-annual variability: while 2017 was the year with the highest number of encounter rate for common dolphins, 2016 was so for fin whales and striped dolphins. Both tunas and sunfishes also showed the highest number of sightings per distance travelled in 2016 (Figure O10).

Regarding the spatial distribution of cetaceans, common dolphins were present almost over the entire continental shelf, with almost no presence in the coastal area of the central French shelf, while it was present as well over the oceanic area of the southern sector (Figure O11a). Fin whales were present in the oceanic area of the BoB in groups of few individuals (Figure O11b). Tunas were present in the oceanic area of certain sectors and shelf areas of the inner BoB and central French shelf (Figure O11c).

Regarding marine debris and human activities, the category with the highest number of sightings per distance travelled was the plastic trash (Figure O12, 13). Among marine debris, fish trashes and general trashes were the categories with an intermediate level of encounter rate (Figure O12, 13). Regarding fishing activities, the encounter rate corresponding to buoys, fishing boats and trawlers was higher. Finally, the encounter rate for non-fishing activities was higher for cargo vessels, pleasant boats and sailing boats (Figure12, 13).

Regarding the spatial distribution of the most abundant marine debirs and human categories, plastic trashes were present over the entire study area, but specially in the oceanic area and Spanish shelf (Figure O14a). Buoys were present especially in coastal areas, while present in certain oceanic locations (Figure O14b). Pleasant boats were concentrated in specific coastal areas of the southern sector of the BoB (Figure O14c).

4. Conclusions

- Slightly short survey spatial coverage at the north due to bad weather conditions
- Good general performance of the equipment and different acoustic configurations for different tasks-scenarios.
- The survey maintains or even increases its recently acquired ecological scope
- The biomass estimate of this year (114,000 tonnes) is a medium low abundance, about 50 % below the average of the JUVENA series.
- The juvenile abundance value foresees a low recruitment level for next year.

Predators observation conclusions

- In 2019, we recorded a total of 975 seabirds, 262 marine mammals, 421 other marine wildlife, 87 marine debris, 72 human activities, 2 coastal birds, 35 landbirds and 4 oceanographic features.
- Six different species of marine mammals were recorded. The most abundant species were the fin whale, the common dolphin and the striped dolphin.
- Fin whales and striped dolphins were present in the oceanic areas of the BoB (Figure O2a and 2b, respectively), while common dolphins were present in the central French shelf and Spanish slope
- Twelve different species of seabirds were observed. The most abundant species were the northern gannet, the great skua, the lesser black-backed gull and the sooty shearwater.
- Most seabirds were detected over central French shelf, French central slope and coastal areas of the southern sector.
- We observed 4 types of marine debris and 12 different activities/items of human activities. The main marine debris recorded were plastic trashes, mostly found northern and southern oceanic areas, as well as shelf and slope areas of the southern study area.
- The human activities with the highest number of sightings were the fishing buoys and trawlers. Fishing buoys were mainly present in coastal areas of the southern sector, whereas trawlers were as well present in the central French shelf.

5. Acknowledgements

This project is co-funded by the “Dirección de Innovación y Desarrollo Tecnológico, Viceconsejería de Política e Industria Alimentaria, Dpto.Agricultura, Pesca y Alimentación”, of the Basque Government and the “Secretaría General del Mar, Ministerio de Agricultura, Alimentacion y Medio Ambiente” of the Spanish Government, seeking for improving the scientific advice for management of this population. We acknowledge both for their support.

6. Bibliography

Foote, K.G., Knudsen, H.P., Vestenes, D.N., MacLennan, D.N. and Simmonds, E.J. (1987) Calibration of acoustic instruments for fish density estimation: a practical guide. ICES Cooperative Research Report, No. 144, 1-69.

ICES. 2014. Report of the Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA), 20-25 June 2014, Copenhagen, Denmark. ICES CM 2014/ACOM:16. 600 pp.

MacLennan, D.N., Fernandes, P.G. and Dalen, J. (2002) A consistent approach to definitions and symbols in fisheries acoustics. ICES Journal of Marine Science, 59, 365-368.

Petitgas, P., Beillois, P., Massé, J. and Grellier, P. 2004. On the importance of adults in maintaining population habitat occupation of recruits as deduced from observed schooling behaviour of age-0 anchovy in the Bay of Biscay. ICES CM 2004/J:13.

Uriarte, A., Y. Sagarminaga, C. Scalabrin, V. Valencia, P. Cermeño, E. de Miguel, J.A. Gomez Sanchez and M. Jimenez, 2001: Ecology of anchovy juveniles in the Bay of Biscay 4 months after peak spawning: Do they form part of the plankton?. ICES CM 2001/W:20.

Uriarte, A. (editor), 2002: Experimental surveys for the assessment of juveniles . Final Report to the European Commission of FAIR Project CT97-3374 (JUVESU).

7. Figures

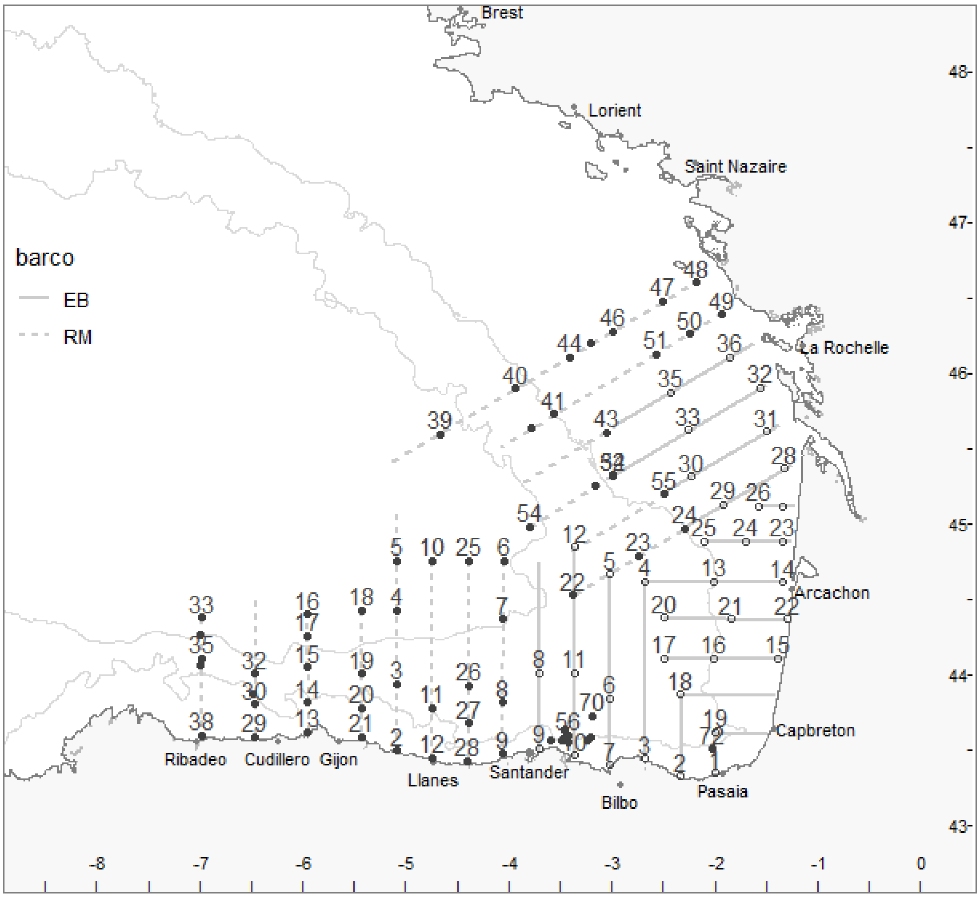


Figure 1. Visited transects and stations of hydrography/plankton.

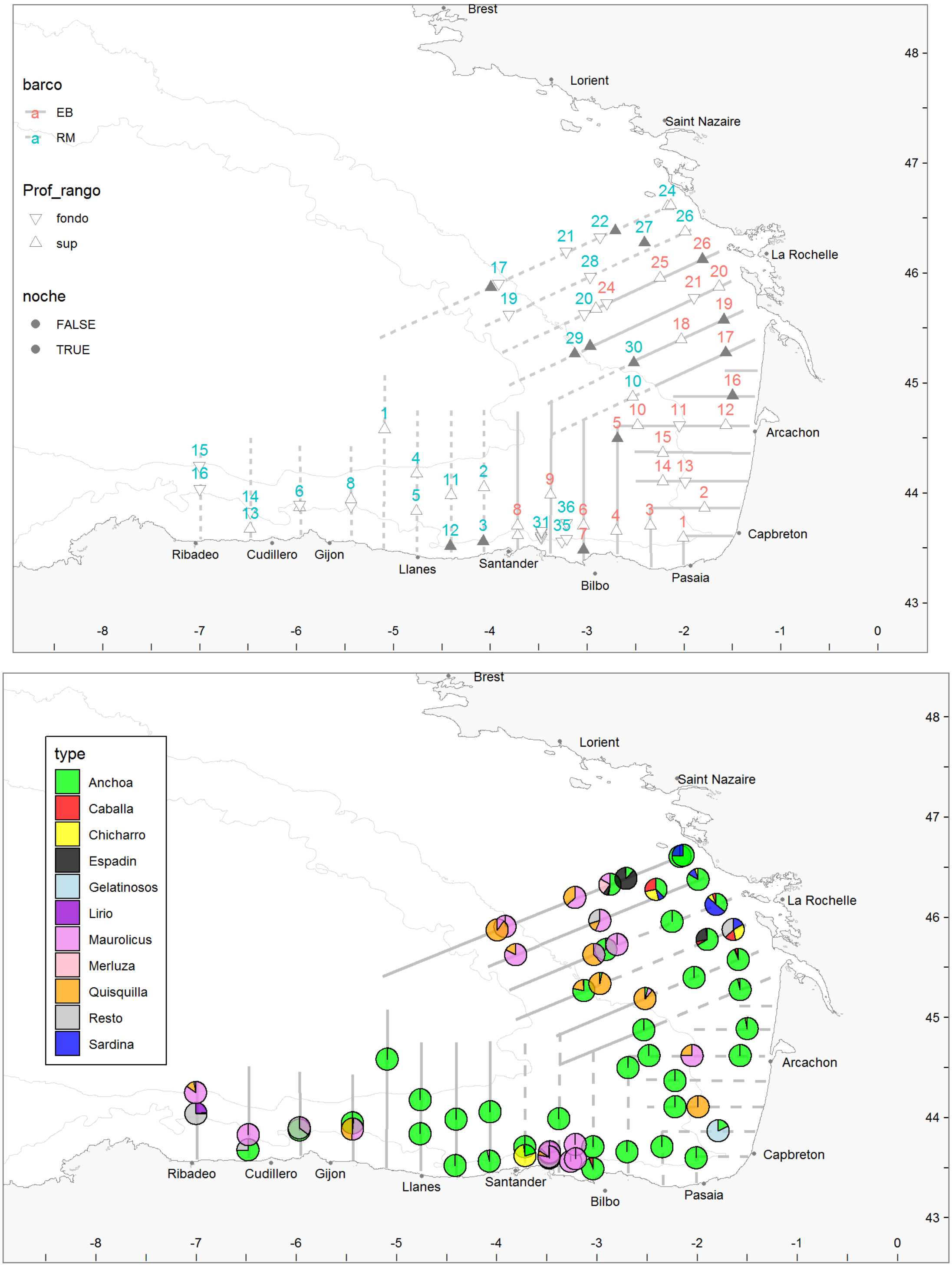


Figure 2. Top panel: position of the fishing stations. Hauls performed by RM are numbered from 9001 to 9034 and the transects are marked with dashed lines; hauls performed in the EB are numbered from 9201 to 9244 and the transects are marked with solid lines. Bottom panel: Species composition of the hauls.

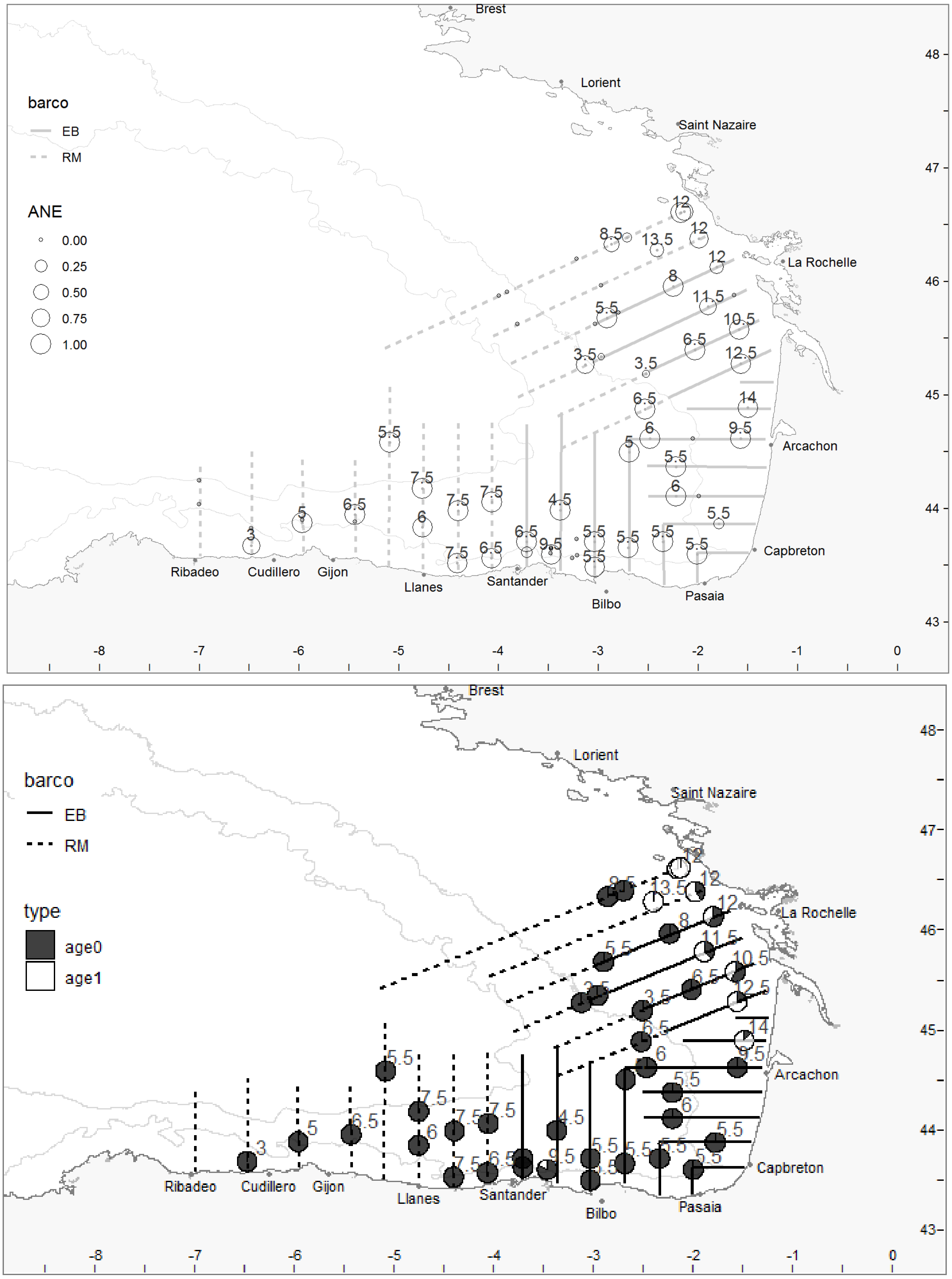


Figure 3: Top: Size of anchovy in the positive anchovy hauls. The size of the crosses is proportional to the mode of the Standard length of the captured anchovy. Bottom: The pie charts show the percentage of juveniles (black) and adults (white) in the fishing hauls.

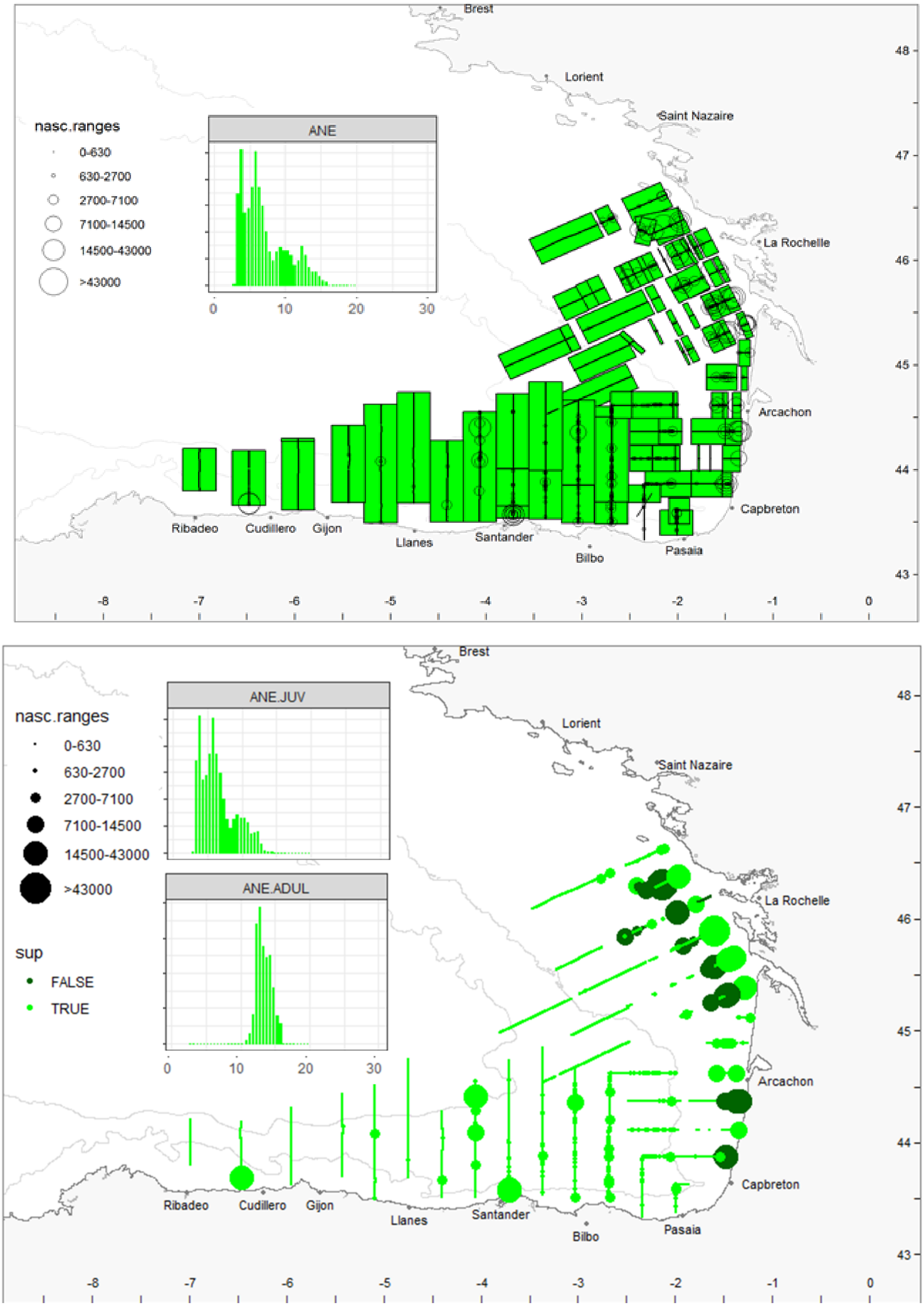


Figure 4: Top: Echointegration strata of anchovy. The diameter of the bubbles represents acoustic backscattering (NASC) of anchovy. Bottom: Acoustic backscattering of anchovy near the surface (light green) and near the bottom (dark green). The histograms represent length distribution of anchovy.

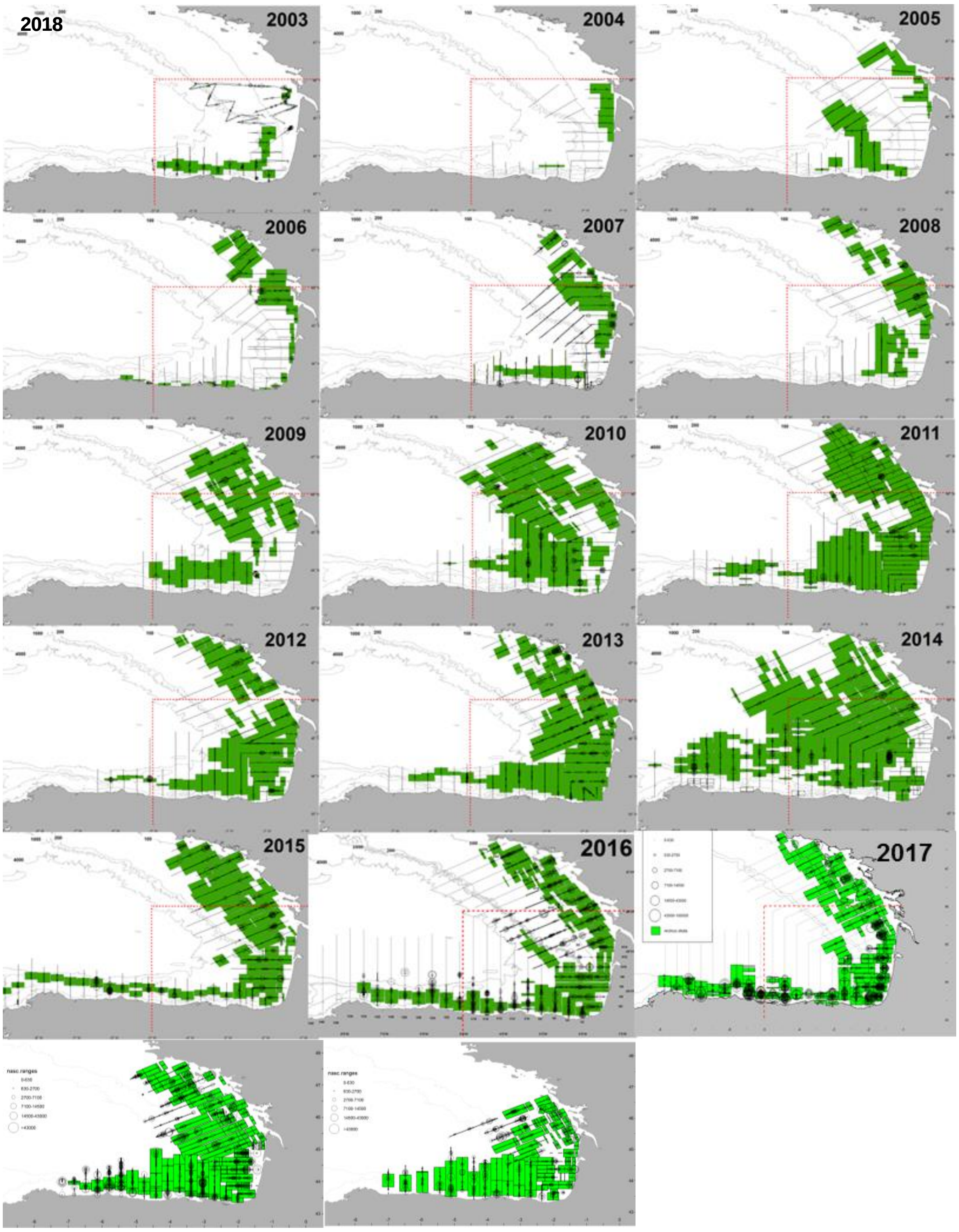


Figure 5: Positive area of presence of anchovy and total acoustic energy echo-integrated (from all the species) for the whole temporal series. The area delimited by the dashed line is the minimum or standard area used for inter-annual comparison.

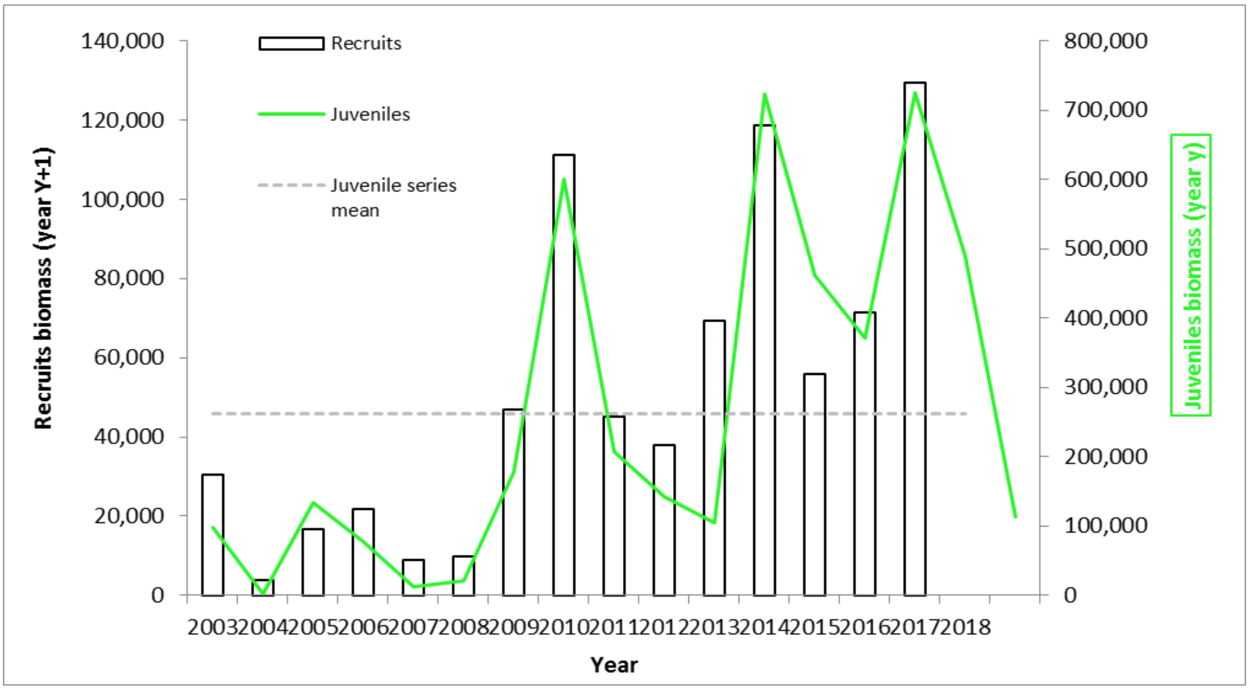


Figure 6: Temporal series of the estimated abundances of anchovy juveniles (green) against the CBBM synthetic estimated abundances of age 1 anchovy next spring (white bars), based on PELGAS and BIOMAN surveys plus the catches.

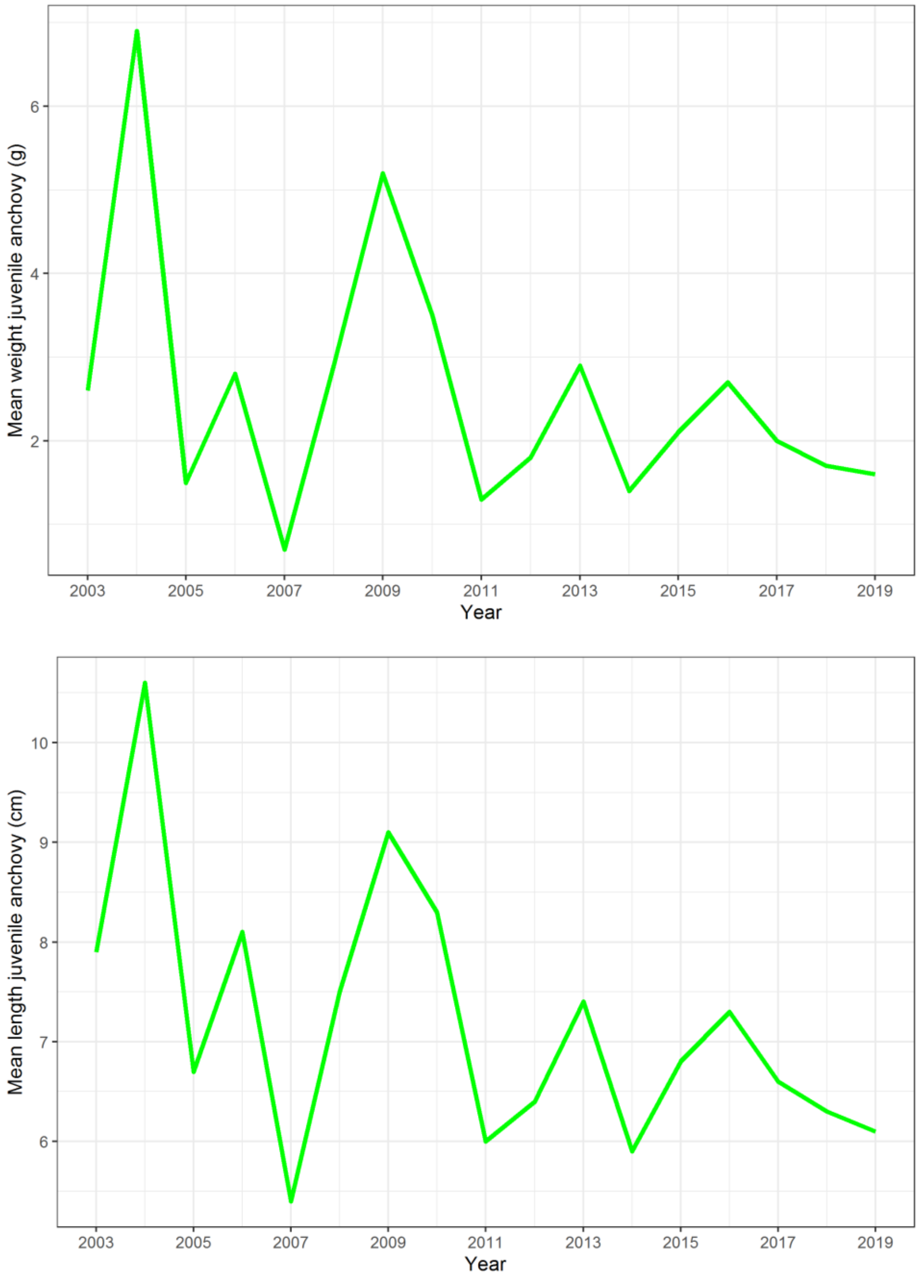


Figure 7: Temporal series of mean weight and length of anchovy juveniles in the JUVENA survey.

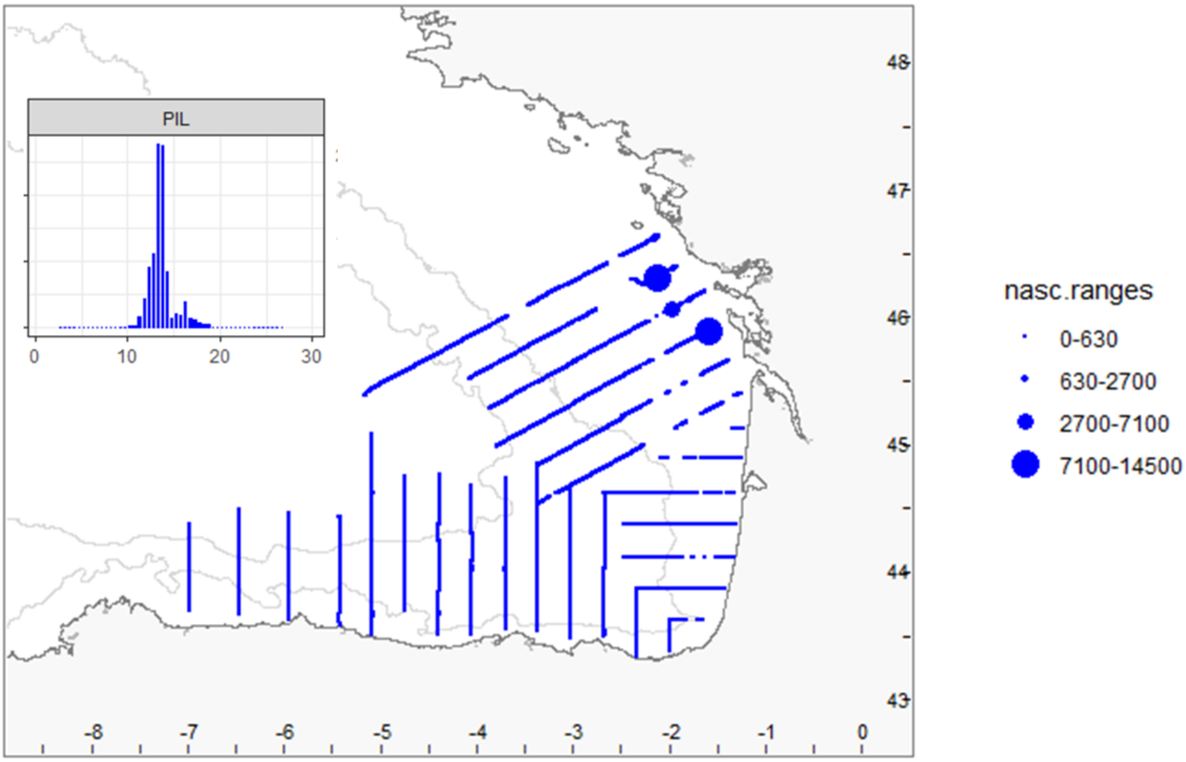


Figure 8: Spatial distribution and length distribution of sardine in the Bay of Biscay according to the JUVENA survey.

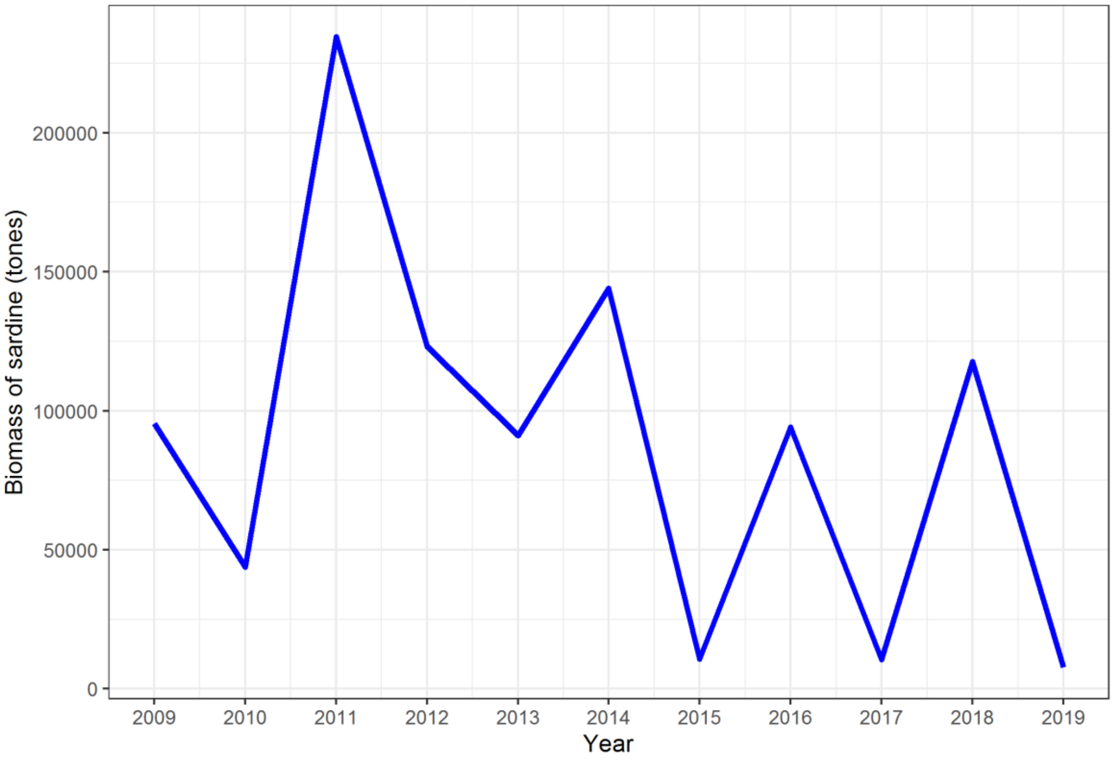


Figure 9: Temporal series of the estimated abundances of sardine.

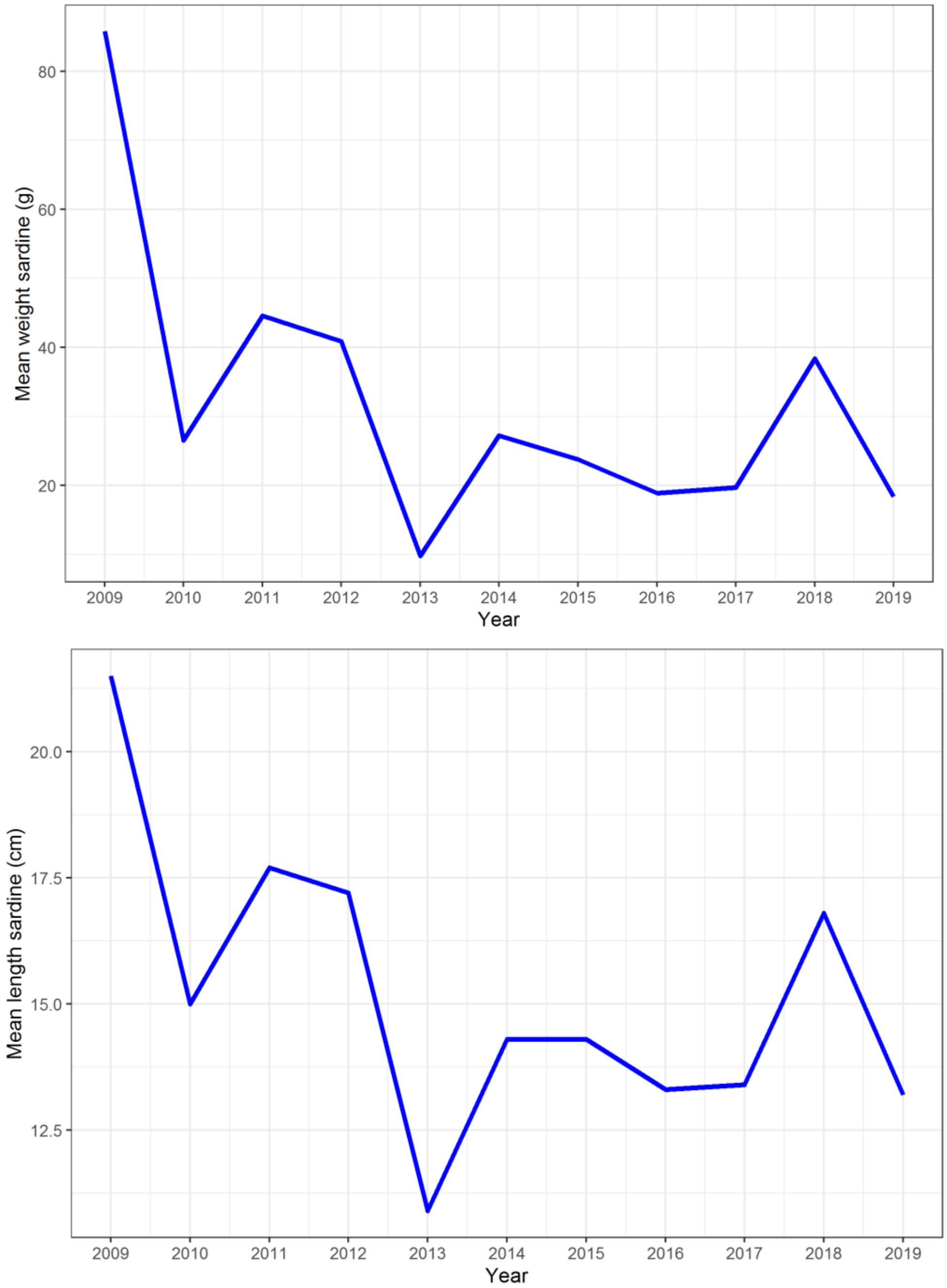


Figure 10: Temporal series of mean weight (top) and mean length (bottom) of sardine.

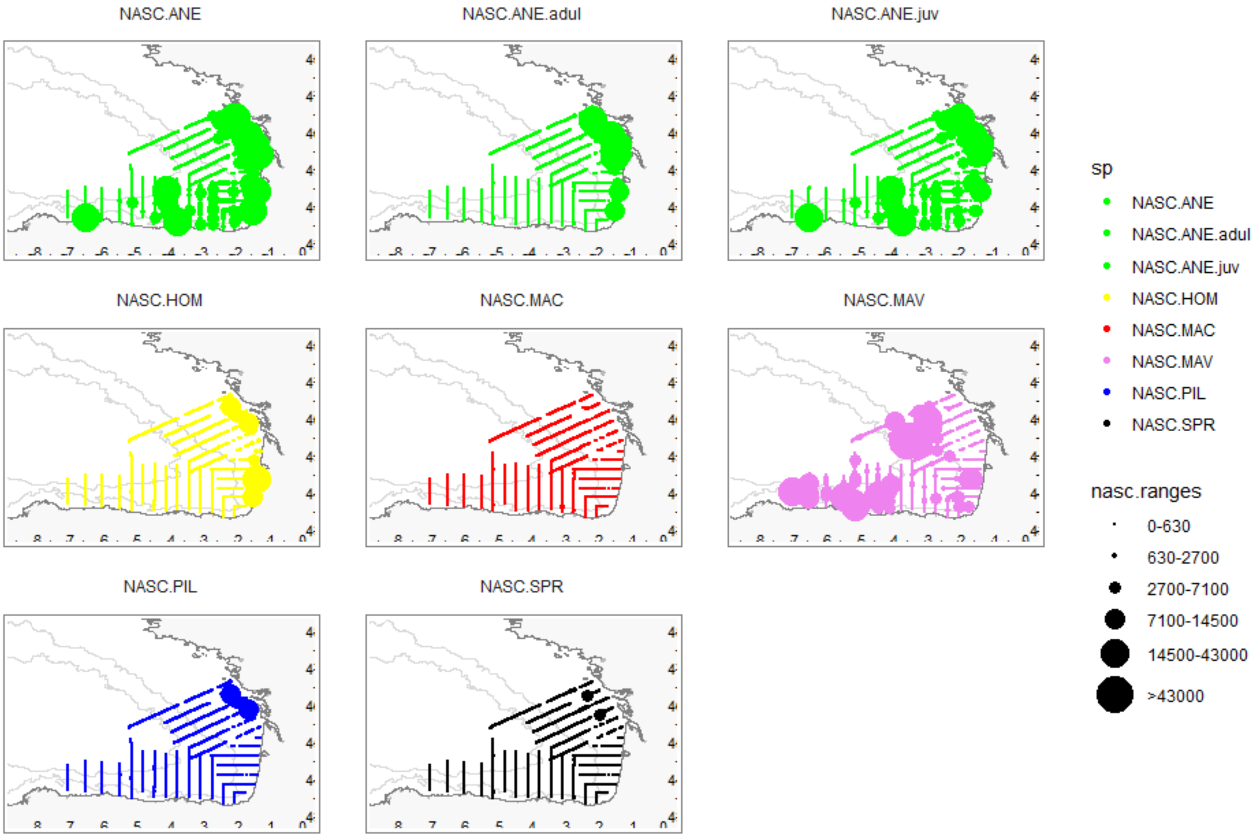


Figure 11: Spatial distribution of the main pelagic species assessed during the JUVENA survey this year.

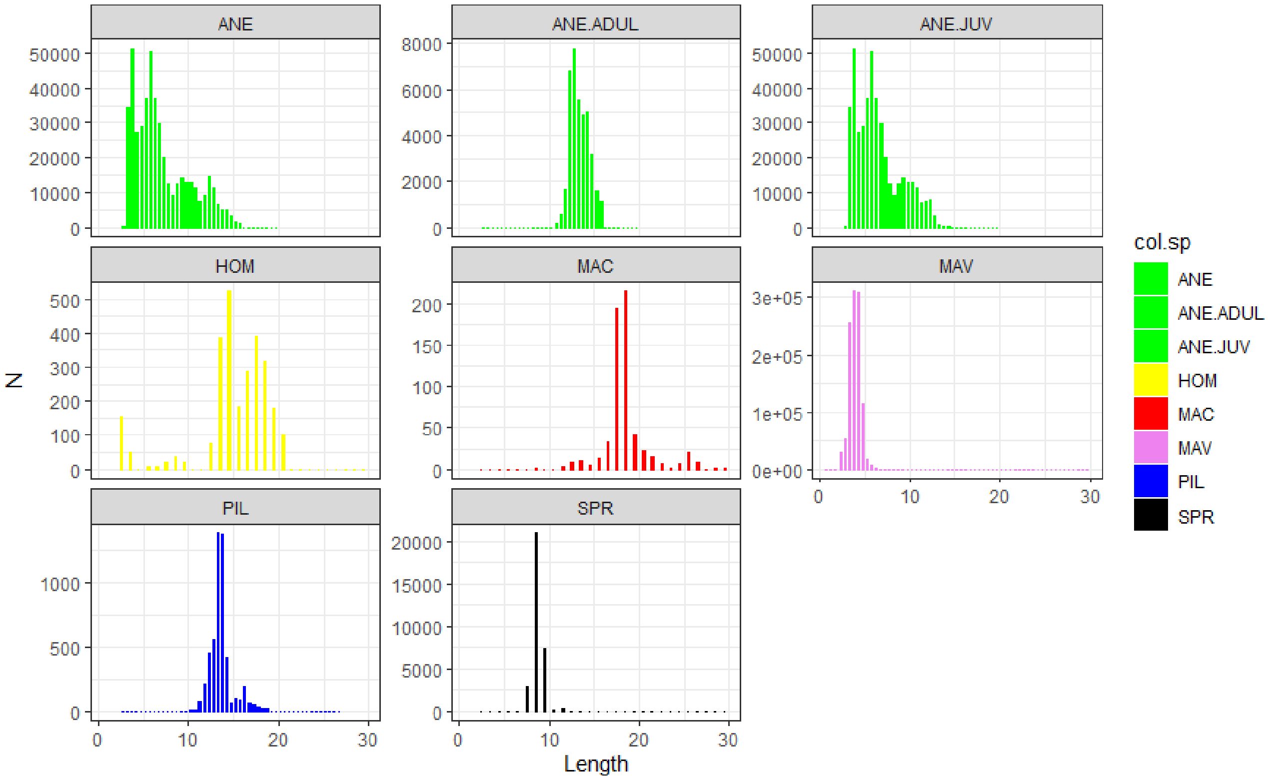


Figure 12: Length distribution of the main pelagic species assessed during the JUVENA survey this year.

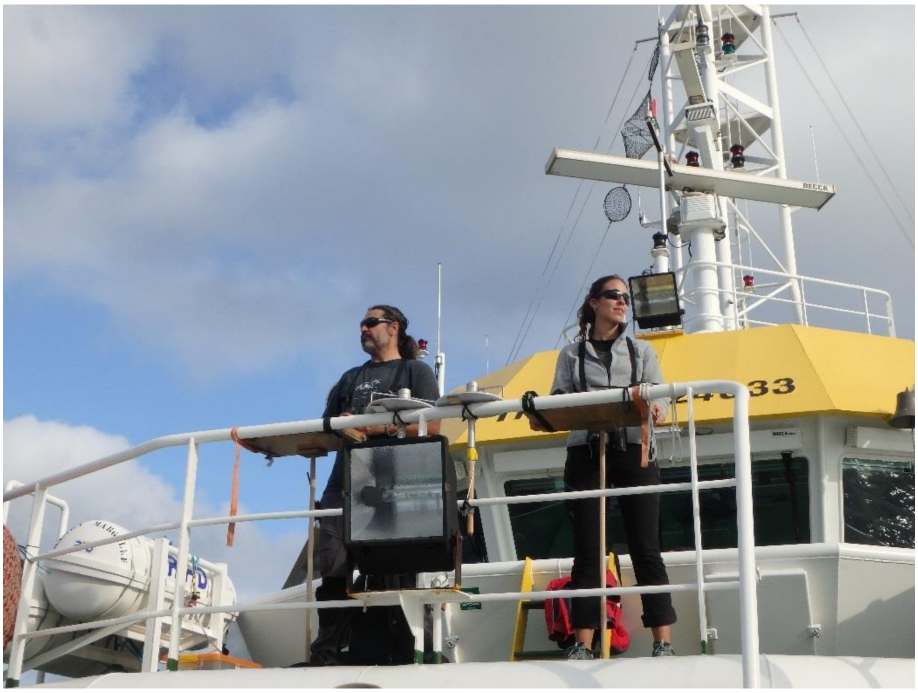


Figure O1. Observation platform onboard R/V Ramón Margalef showing observers activity.

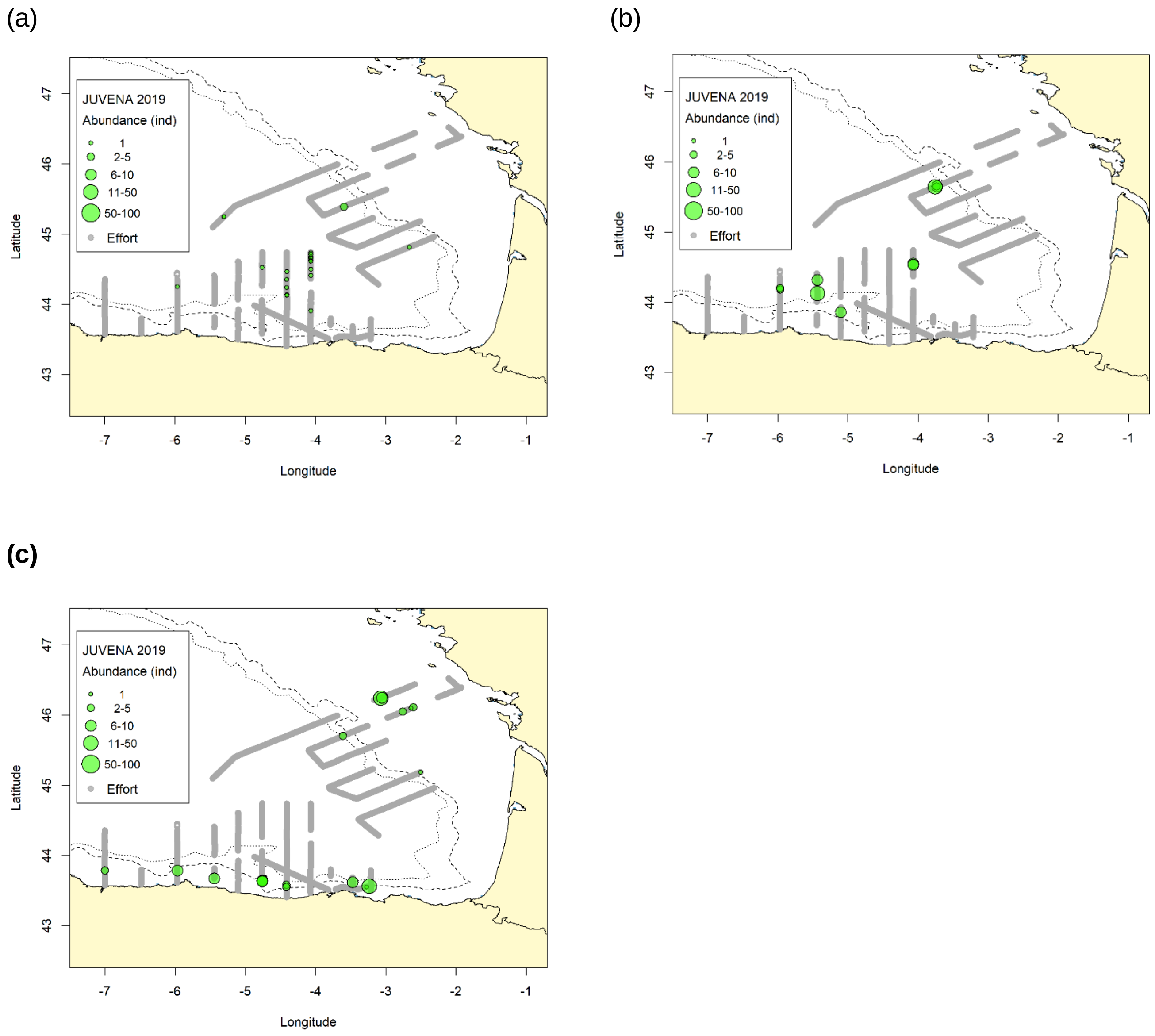


Figure O2. Distribution of the most abundant marine mammal species: (a) fin whales, (b) striped dolphins and (c) common dolphins. Grey points represent the effort while the size of the green circles is proportional to observed abundances. The dotted and solid lines represent the isobaths of 200 m and 1000 m, respectively. See Table 2 for acronyms.

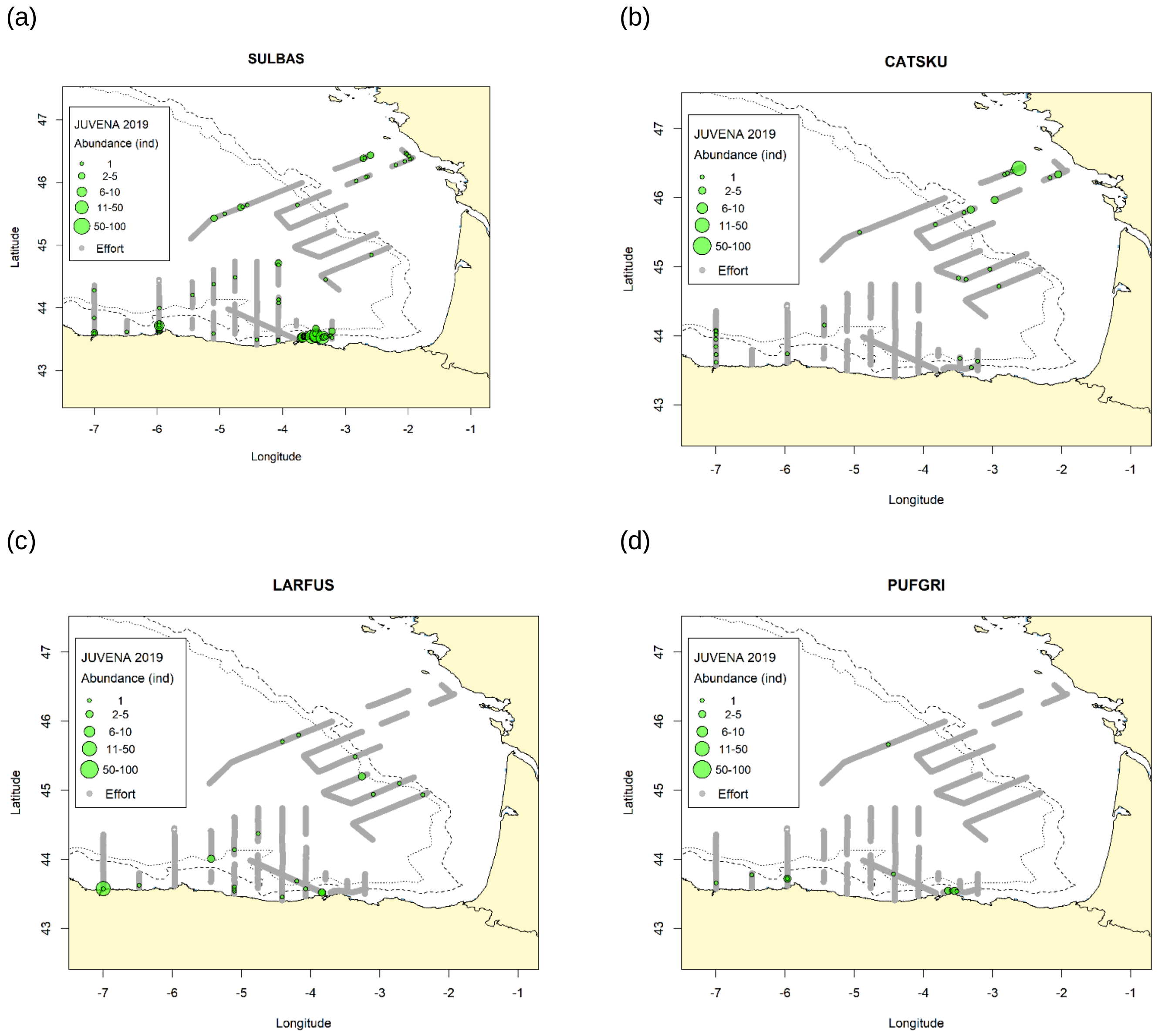


Figure O3. Distribution of the most abundant seabird species such as (a) northern gannets, (b) great skuas, (c) lesser black-backed gulls, and (d) sooty shearwaters. Grey points represent the effort while the size of the green circles is proportional to observed abundances. The dotted and solid lines represent the isobaths of 200 m and 1000 m, respectively. See Table 2 for acronyms.

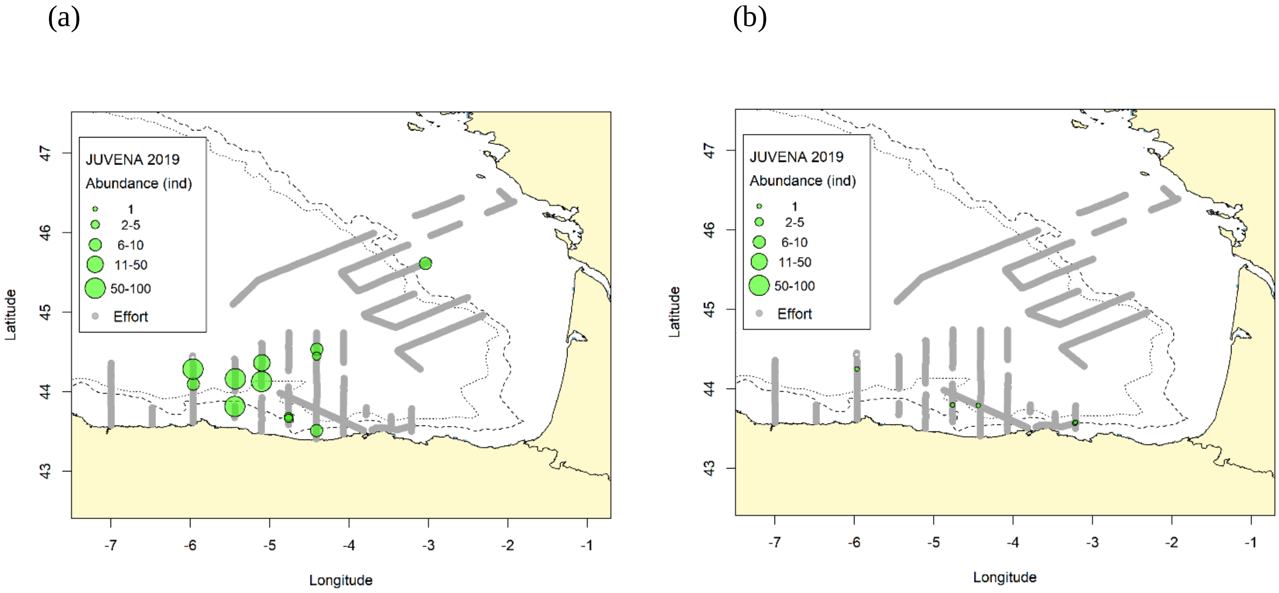


Figure O4. (a) Large pelagic fish and (b) sunfish observations.

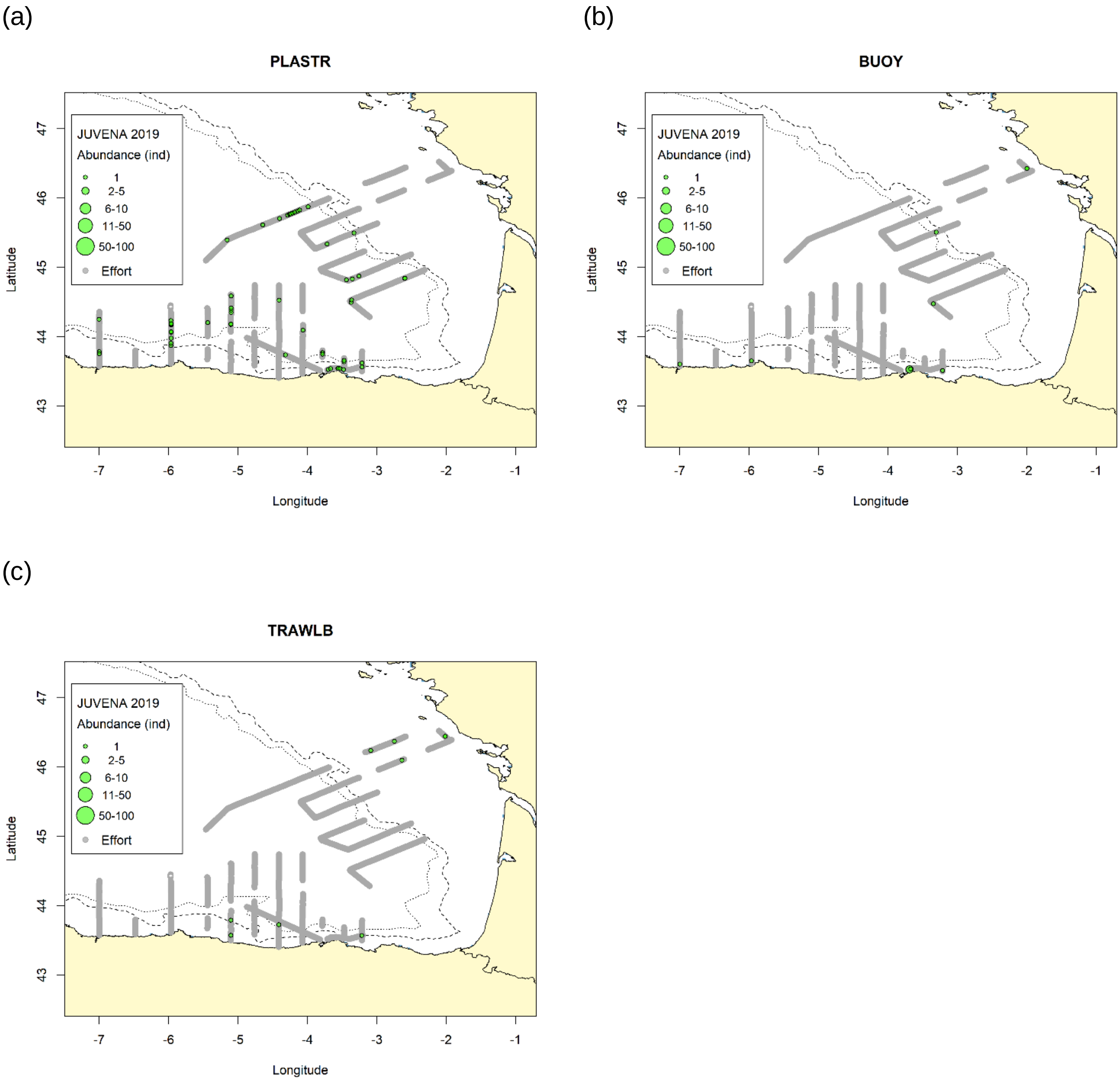


Figure O5. Distribution of the most abundant human activities such as (a) plastic trash, (b) fishing buoys and (c) trawlers. Grey points represent the effort while the size of the green circles is proportional to observed abundances. The dotted and solid lines represent the isobaths of 200 m and 1000 m, respectively. See Table 2 for acronyms.

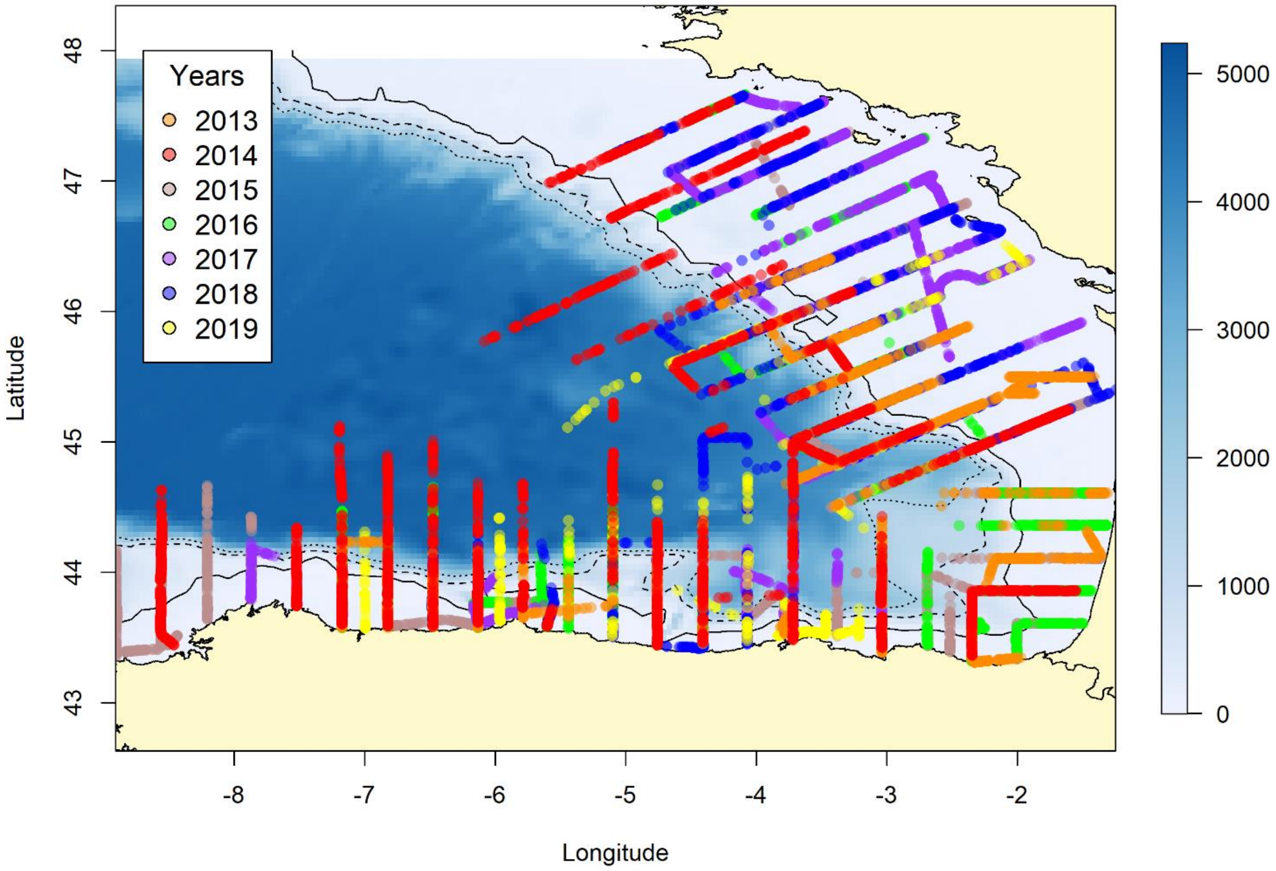


Figure O6. The area covered by the JUVENA surveys during the 2013-2019 period. Background values represents the bathymetry and the isobaths of 200, 1000 and 2000 m are indicated by black lines.

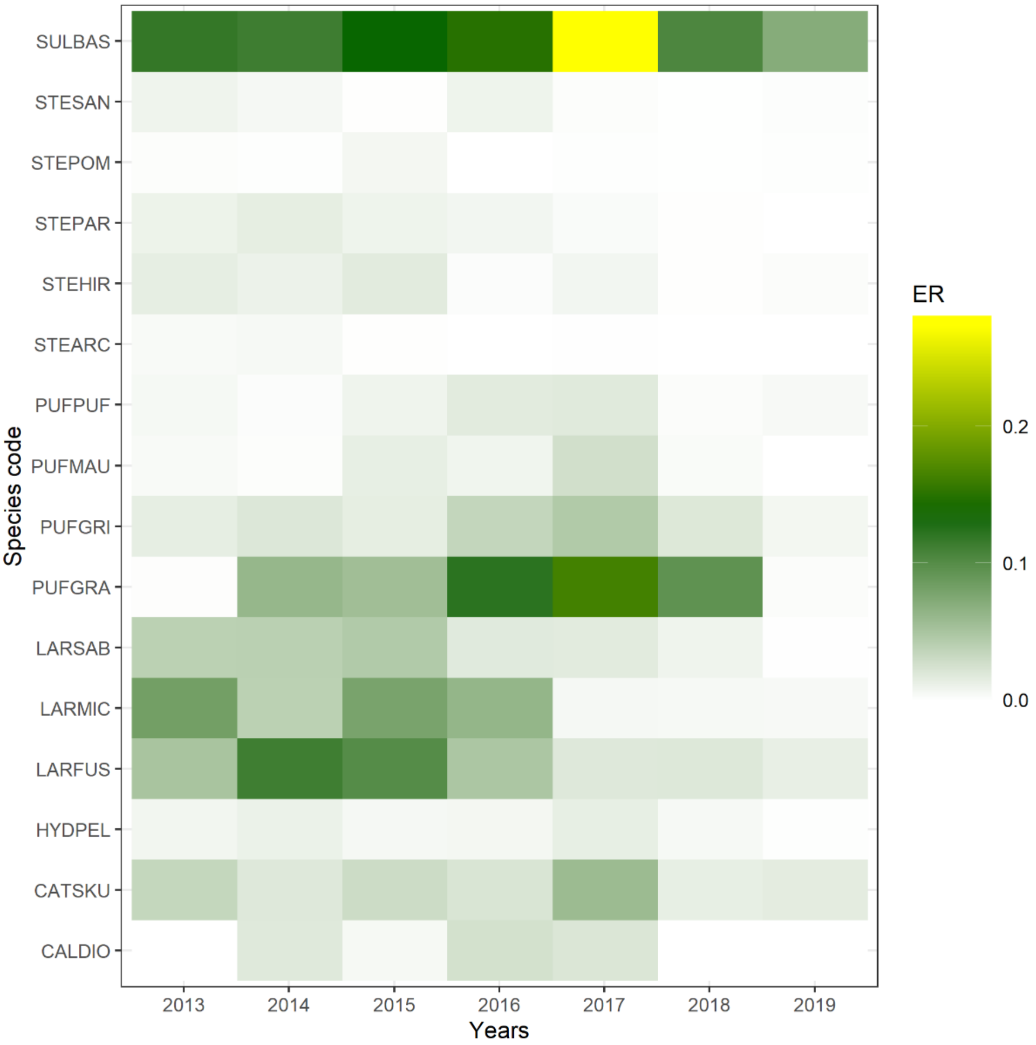


Figure O7. Matrix of seabird (log-transformed) encounter rate per year and species. See Table 2 for acronyms.

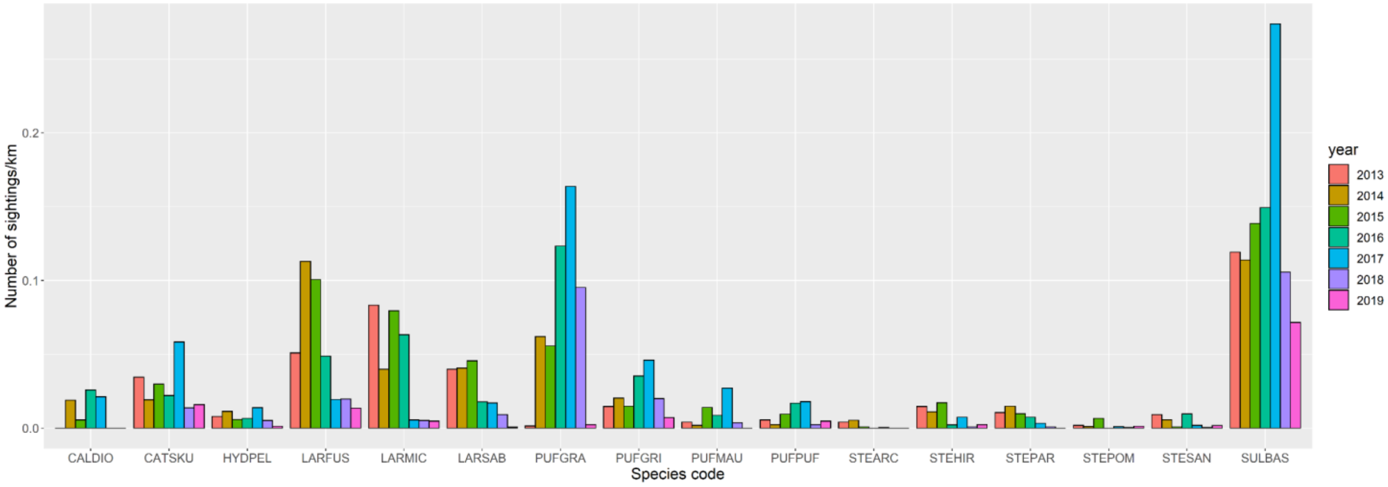


Figure O8. Barplot of the number of sightings per distance travelled (km) for seabird species and year. See Table 2 for acronyms.

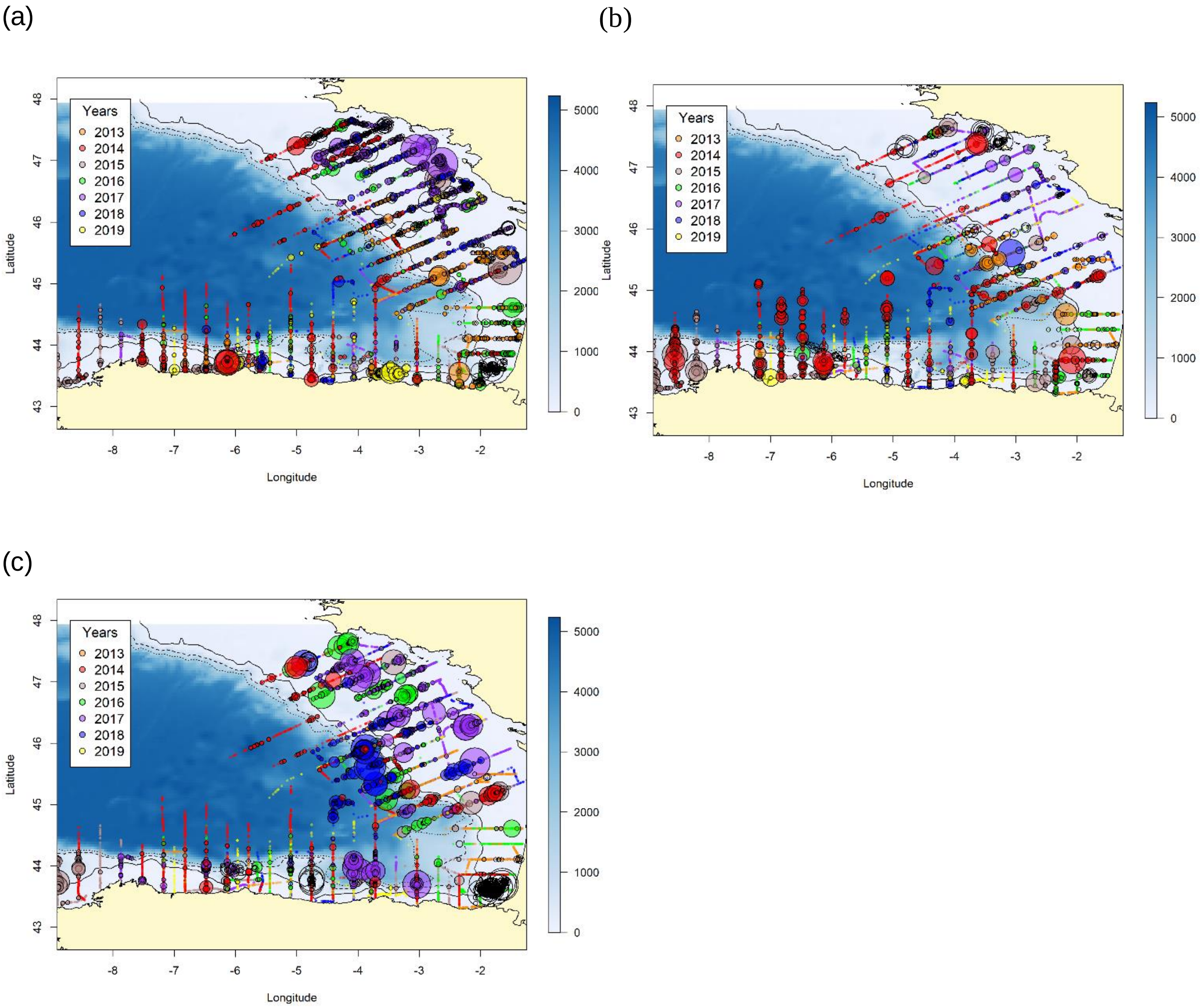
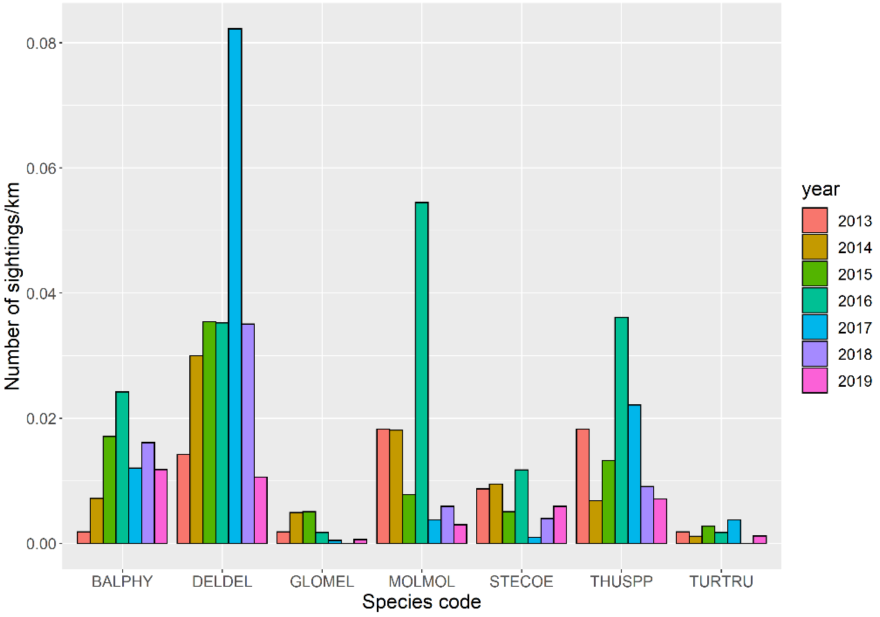


Figure O9. Maps of the most abundant seabird: (a) northern gannets, (b) lesser black-backed gulls and (c) great shearwaters. The isobaths of 200, 1000 and 2000 m are indicated by black lines..

(a)



(b)

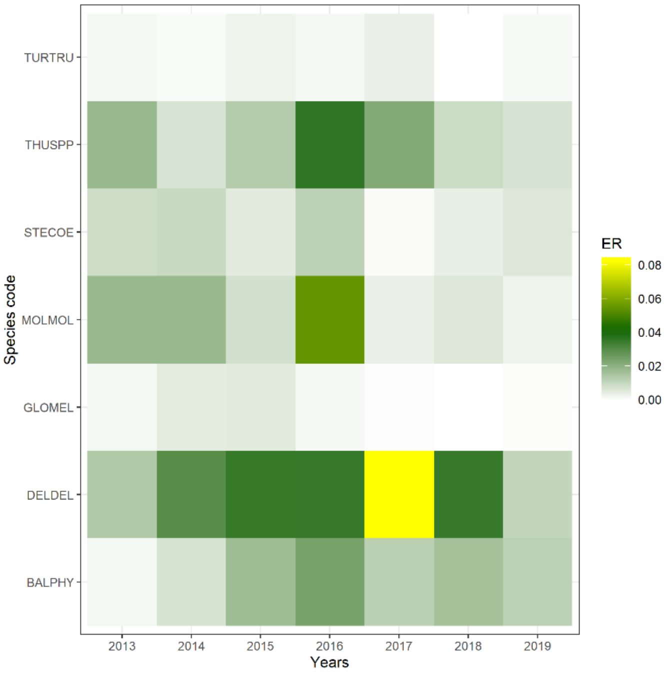


Figure O10. (a) Barplot and (b) matrix of the number of sightings per distance travelled (km) for cetaceans, tunas and sunfishes per species and year. See Table 2 for acronyms

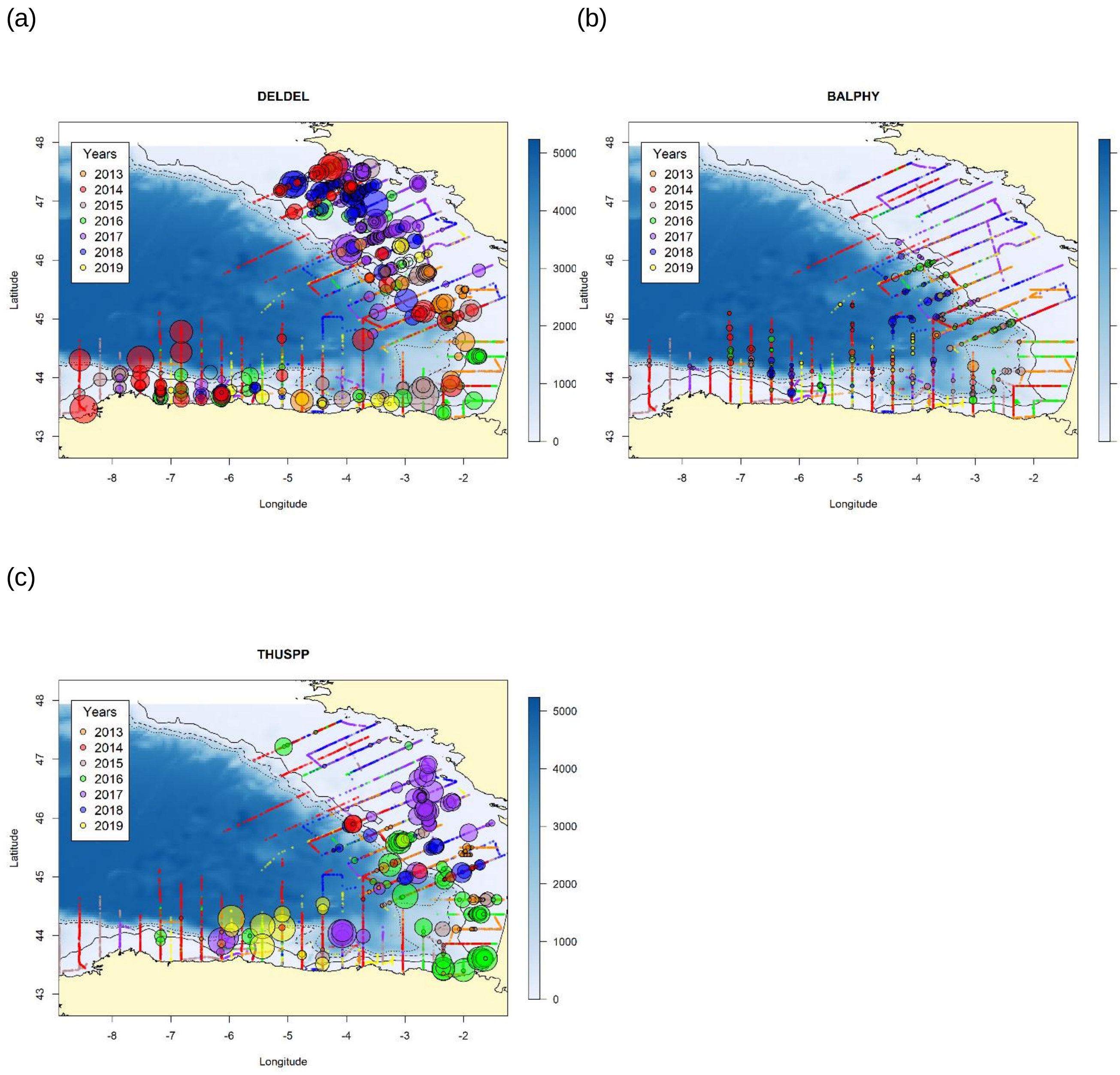


Figure O11. Maps of (a) common dolphins, (b) fin whales and (c) tunas The isobaths of 200, 1000 and 2000 m are indicated by black lines.

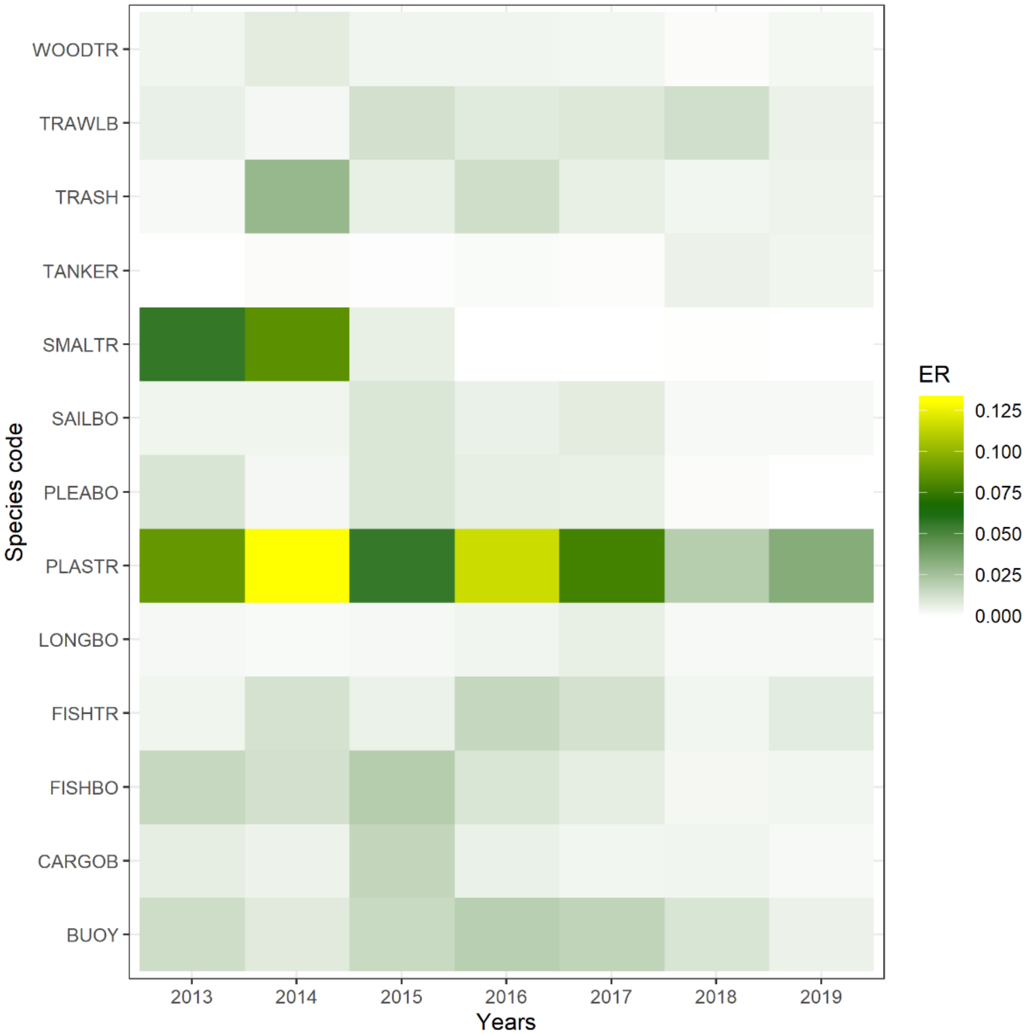


Figure O12. Matrix of the number of sightings per distance travelled (km) for cetaceans, tunas and sunfishes per species and year. See Table 2 for acronyms

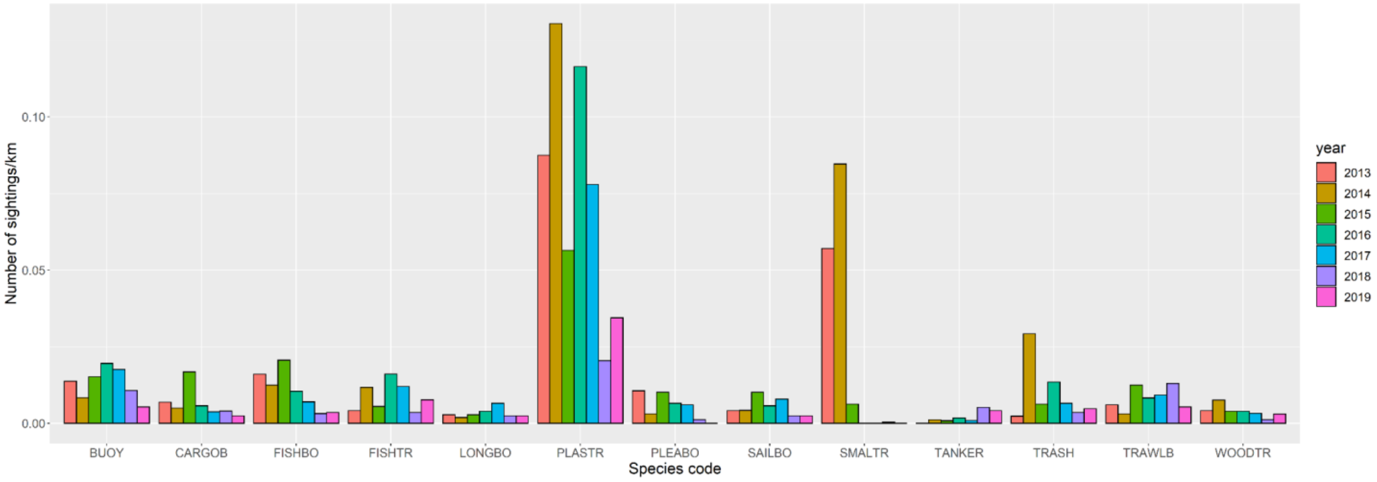


Figure O13. Barplot of the number of sightings per distance travelled (km) for marine debris and human activities. See Table 2 for acronyms

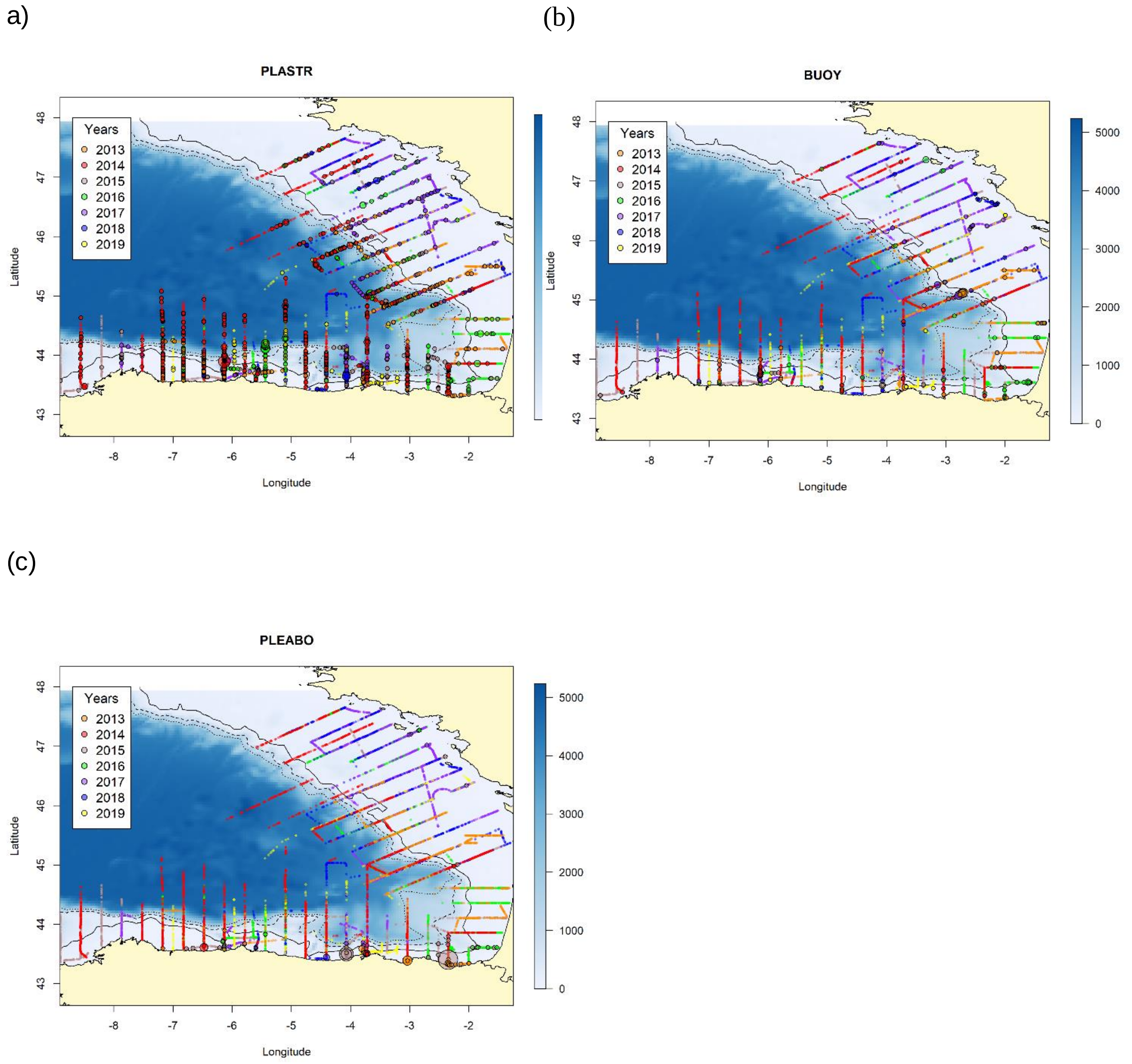


Figure O14. Maps of the most abundant human categories (a) plastic trashes, (b) buoys, and (c) pleasant boats. The isobaths of 200, 1000 and 2000 m are indicated by black lines.

8. Tables

Table 1:
Dimensions of the two vessels and installed equipment onboard

	R/V Ramón Margalef	**R/VEmma Bardán**
Echosounder	Simrad EK60, 38, 70, 120, 200 y 333 kHz	Simrad EK60, 38, 120 y 200 kHz
Multibeam Echosounder	Simrad ME70	No
Fishing gear	pelágico (15 m abertura vertical) puertas Polyice Apollo malla: 8 mm de lado	pelágico (15 m abertura vertical) puertas Polyice Apollo malla: 4 mm de lado
Fishing gear Echosounder	Simrad FE70	Scanmar Trawl Eye
Gear geometry	Depth sensor Scanmar	Simrad ITI: depth/temp and door opening sensors
Hidrography	**CTD-Roseta** CTD SeaBird SBE25 with fluorimeter Turner Scufa, Roseta SeaBird SBE32 with 12 Niskin-type bottels (SBE) de 5l. **Red WP2**: Double ring net, 35 cm diameter each, 200 µm mesh size **Red Bongo:** Double ring net, 60 cm diameter each, 500 µm mesh size. Flux control by fluorometer GO. Real time depth monitoring by acoustic sensor (Scanmar). Salinity tempertue and fluorescence recording during the trawl with CTD RBR XR-420. **Red Bongo-Mik**: Net combining 35 cm 333 µm Bongo, inside a square Mik-type net of 120 cm side, 1000 µm mesh size. Net monitoring same as withe the Bongo (above). **Termosalingraph-Fluorimeter:** Continuous sampler of superficila wáter for salinity, temperatura and fluoresncence.	**CTD SeaBird SBE25** with fluorimeter , oxímeter y pH-meter **Red WP2**: doublé ring net, of 35 cm diameter each, 200 µm mesh size

Table 2:
Schedule of the survey

Activity	**Harbor**	**Date**	**Notes**
Setup EB	Pasaia	30/08/2019	Calibration / Gear testing.
Instalation RM	Pasaia	01/09/2019	
Setup RM	Bilbao	02/09/2019	Equipment testing. Calibration.
Start survey RM		03/09/2019	
Start survey EB		31/08/2019	
Escale RM	Pasaia	10/09/2019	
RCAN RM (Radiales del Cantábrico)		21-22/09/2019	
Escale RM	Gijón	23/09/2019	
Escale EB	Pasaia	18/09/2019-01/10/2019	Bad weather
End of survey RM	Pasaia	30/09/2019	
End of survey EB		04/10/2019	

Table 3:
Relation of fishing catches performed by Ramon Margalef (90xx) and Emma Bardan (92xx).

Haul	Date (dmy)	Local time	Lat (cent)	Long (cent)	Fishing depth (m)	BotDepth (m)	Mode ANE (cm)	Catch (kg)
9001	4092019	16:01:00	44.5753333	-5.0935	10	4000	5.5	0.75
9002	5092019	14:04:00	44.04925	-4.06625	13	4000	7.5	2.95
9003	5092019	20:44:00	43.5565833	-4.07425	13	200	6.5	13.35
9004	6092019	13:08:00	44.16975	-4.76275	9.7	4000	7.5	0.019
9005	6092019	18:08:00	43.8298333	-4.76516667	12	1000	6	0.221
9006	7092019	10:23:00	43.86775	-5.97033333	8.6	200	5	10.65
9007	7092019	13:55:00	43.8894167	-5.97058333	200	400		10.66
9008	8092019	13:07:00	43.9388333	-5.44016667	10	400	6.5	10.05
9009	8092019	15:30:00	43.87625	-5.43991667	300	320		18.05
9010	11092019	17:41:00	44.8681667	-2.53216667	9	2500	6.5	37.35
9011	12092019	13:14:00	43.97525	-4.40608333	8	1000	7.5	0.7
9012	12092019	22:08:00	43.5128333	-4.41458333	15	150	7.5	186
9013	13092019	9:28:00	43.66925	-6.48241667	18	150	3	24.15
9014	13092019	12:51:00	43.8206667	-6.47925	206	400		31.55
9015	14092019	9:21:00	44.2413333	-7.00516667	104	4000		8.6
9016	14092019	14:07:00	44.032	-7.00158333	250	250		19.15
9017	15092019	18:05:00	45.9	-3.917	129	1000		1.3
9018	15092019	21:31:00	45.8651667	-3.99516667	29	2000		5
9019	16092019	9:51:00	45.61775	-3.81058333	137	2000		5.05
9020	16092019	19:48:00	45.62	-3.03	120	140		48.1
9021	17092019	13:10:00	46.19	-3.22	110	121		239.15
9022	17092019	17:32:00	46.32	-2.87	95	105	8.5	28.05
9023	17092019	21:41:00	46.38	-2.71	10	90	8	143.8
9024	18092019	11:08:00	46.6	-2.17	11	30	12	0.007
9025	18092019	12:55:00	46.61	-2.14	14	31	12	199.75
9026	18092019	17:20:00	46.37	-1.99	25	35	12	80.4
9027	18092019	21:39:00	46.27	-2.41	6.5	55	13.5	60.35
9028	19092019	10:52:00	45.96	-2.97	115	120		295.95
9029	19092019	21:15:00	45.26	-3.13	9		3.5	15.45
9030	20092019	20:54:00	45.18	-2.52	29	137	3.5	14.95
9031	23092019	8:50:00	43.5885	-3.47591667	125	141	9.5	230
9032	23092019	10:14:00	43.60025	-3.47958333	75			4.4
9033	26092019	18:00:00	43.636	-3.47333333	630	2000		22.4
9034	27092019	9:11:00	43.6494167	-3.47283333	109.5	1500		1.55
9035	27092019	18:05:00	43.5553333	-3.2625	148	166		4.85
9036	28092019	9:01:00	43.7235	-3.21558333	115	3000		0.45
9037	28092019	15:01:00	43.5803333	-3.214	180	240		5.25
9201	31082019	14:06:00	43.59	-2.01	10	500	5.5	1.4
9202	1092019	9:46:00	43.86	-1.79	6	120	5.5	0.45
9203	1092019	15:10:00	43.7	-2.35	4	_500	5.5	0.9
9204	2092019	14:24:00	43.65	-2.7	4	_500	5.5	0.85
9205	2092019	21:45:00	44.49	-2.69	4	1000	5	17.95

Haul	Date (dmy)	Local time	Lat (cent)	Long (cent)	Fishing depth (m)	BotDepth (m)	Mode ANE (cm)	Catch (kg)
9206	3092019	16:03:00	43.7	-3.04	4	1000	5.5	8.5
9207	3092019	21:36:00	43.48	-3.04	3	80	5.5	108
9208	4092019	15:12:00	43.7	-3.72	3	500	6.5	5.6
9209	7092019	14:25:00	43.98	-3.38	1	1000	4.5	11.7
9210	8092019	8:47:00	44.61	-2.48	1	1000	6	5.3
9211	8092019	12:32:00	44.61	-2.05	120	500		1.6
9212	8092019	16:38:00	44.61	-1.57	2	80	9.5	5.2
9213	9092019	12:00:00	44.1	-1.99	136	149		1200
9214	9092019	14:03:00	44.1	-2.22	1	60	6	8.45
9215	12092019	9:25:00	44.36	-2.22	1	700	5.5	1.7
9216	12092019	21:34:00	44.88	-1.5	9	60	14	430
9217	13092019	21:27:00	45.27	-1.57	3	67	12.5	123
9218	14092019	14:51:00	45.39	-2.03	1	85	6.5	0.85
9219	14092019	21:20:00	45.57	-1.59	7	47	10.5	93
9220	15092019	9:20:00	45.87	-1.64	26	43		31.2
9221	15092019	12:22:00	45.77	-1.9	50	65	11.5	27
9222	15092019	21:20:00	45.33	-2.97	1	142	3.5	45
9223	16092019	8:23:00	45.67	-2.91	1	128	5.5	5.5
9224	16092019	10:56:00	45.72	-2.8	109	125		115
9225	16092019	15:25:00	45.95	-2.25	1	76	8	1.5
9226	16092019	21:24:00	46.12	-1.81	6	43	12	58.5
9227	3102019	20:12:00	43.6116667	-3.71783333	2	140	10	78

Table 4:

Species composition of the fishing performed by Ramon Margalef (90xx) and Emma Bardán (92xx).

STATION	BOARDING WEIGHT (kg)	BOARDING WEIGHT/ SPECIES (kg)	*SPECIES*	Fao
9001	0.75	0.75	Engraulis encrasicholus	ANE
9002	2.95	2.95	Engraulis encrasicholus	ANE
9003	13.35	12.86	Engraulis encrasicholus	ANE
		0.03	Trachurus trachurus	HOM
		0.01	Scomber scombrus	MAC
		0.08	sarda sarda	BON
		0.02	Loligo vulgaris	SQR
		0.35	Myctophidae	LXX
9004	0.019	0.02	Engraulis encrasicholus	ANE
9005	0.021	0.02	Engraulis encrasicholus	ANE
		0.00	Trachurus trachurus	HOM
9006	10.65	10.65	Engraulis encrasicholus	ANE
9007	10.66	0.00	Engraulis encrasicholus	ANE
		6.91	Mola mola	MOX
		3.75	Myctophidae	LXX
9008	10.05	10.05	Engraulis encrasicholus	ANE
9009	18.05	0.00	Engraulis encrasicholus	ANE
		0.25	Merluccius merluccius	HKE
		9.02	Myctophidae	LXX
		8.78	Euphasiacea	KRX
9010	37.35	37.35	Engraulis encrasicholus	ANE
9011	0.7	0.70	Engraulis encrasicholus	ANE
9012	29.52	29.13	Engraulis encrasicholus	ANE
		0.30	Trachurus trachurus	HOM
		0.08	sarda sarda	BON
		0.00	Loligo vulgaris	SQR
9013	22.23	16.47	Engraulis encrasicholus	ANE
		0.02	Trachurus trachurus	HOM
		0.02	scomberesox saurus	SAU
		0.04	sarda sarda	BON
		0.04	Loligo vulgaris	SQR
		2.98	Mola mola	MOX
		2.65	Others	OT
9014	31.55	0.00	Engraulis encrasicholus	ANE
		31.55	Myctophidae	LXX
9015	8.6	0.00	Engraulis encrasicholus	ANE
		7.29	Myctophidae	LXX
		1.03	Euphasiacea	KRX
		0.27	Others	OT
9016	19.15	0.00	Engraulis encrasicholus	ANE
		4.43	Micromesistius poutassou	WHB

STATION	BOARDING WEIGHT (kg)	BOARDING WEIGHT/ SPECIES (kg)	*SPECIES*	Fao
		14.17	Capros aper	BOC
		0.42	Myctophidae	LXX
		0.12	Others	OT
9017	1.3	0.00	Engraulis encrasicholus	ANE
		1.30	Myctophidae	LXX
9018	5	0.00	Engraulis encrasicholus	ANE
		0.50	Myctophidae	LXX
		4.50	Euphasiacea	KRX
9019	5.05	0.00	Engraulis encrasicholus	ANE
		4.17	Myctophidae	LXX
		0.88	Euphasiacea	KRX
9020	48.1	0.00	Engraulis encrasicholus	ANE
		18.38	Myctophidae	LXX
		29.72	Euphasiacea	KRX
9021	239.15	0.00	Engraulis encrasicholus	ANE
		150.58	Myctophidae	LXX
		88.57	Euphasiacea	KRX
9022	28.05	14.74	Engraulis encrasicholus	ANE
		0.33	Trachurus trachurus	HOM
		1.85	Sprattus spratus	SPR
		0.02	Loligo vulgaris	SQR
		6.49	Merluccius merluccius	HKE
		4.62	Myctophidae	LXX
9023	143.8	16.82	Engraulis encrasicholus	ANE
		0.79	Scomber scombrus	MAC
		123.78	Sprattus spratus	SPR
		2.40	Loligo vulgaris	SQR
9024	0.007	0.01	Engraulis encrasicholus	ANE
9025	199.75	148.20	Engraulis encrasicholus	ANE
		51.51	Sardina pilchardus	PIL
		0.04	sarda sarda	BON
9026	80.4	67.34	Engraulis encrasicholus	ANE
		9.14	Sardina pilchardus	PIL
		3.60	Trachurus trachurus	HOM
		0.07	Scomber scombrus	MAC
		0.08	Trachinus draco	WEG
		0.10	Loligo vulgaris	SQR
		0.08	Merluccius merluccius	HKE
9027	60.3	22.56	Engraulis encrasicholus	ANE
		5.34	Sardina pilchardus	PIL
		15.44	Trachurus trachurus	HOM
		4.33	Scomber scombrus	MAC
		11.99	Scomber colias	VMA
		0.61	Loligo vulgaris	SQR
		0.04	Zeus faber	JOD

STATION	BOARDING WEIGHT (kg)	BOARDING WEIGHT/ SPECIES (kg)	*SPECIES*	Fao
9028	295.95	0.00	Engraulis encrasicholus	ANE
		83.52	Loligo vulgaris	SQR
		3.13	Trisopterus luscus	BIB
		168.93	Myctophidae	LXX
		40.38	Euphasiacea	KRX
9029	15.49	12.09	Engraulis encrasicholus	ANE
		0.28	Loligo vulgaris	SQR
		3.12	Euphasiacea	KRX
9030	14.95	0.54	Engraulis encrasicholus	ANE
		0.04	Loligo vulgaris	SQR
		1.07	Myctophidae	LXX
		13.30	Euphasiacea	KRX
9031	230	226.93	Engraulis encrasicholus	ANE
		0.38	Loligo vulgaris	SQR
		2.30	Myctophidae	LXX
		0.38	Euphasiacea	KRX
9032	4.4	0.00	Engraulis encrasicholus	ANE
		3.43	Myctophidae	LXX
		0.27	Euphasiacea	KRX
		0.17	Thalia democratica	SPX
		0.53	Others	OT
9033	22.4	0.00	Engraulis encrasicholus	ANE
		17.04	Loligo vulgaris	SQR
		3.09	Myctophidae	LXX
		0.90	Thalia democratica	SPX
		0.52	Rhopilema spp	JEL
		0.85	Others	OT
9034	1.55	0.00	Engraulis encrasicholus	ANE
		1.55	Myctophidae	LXX
9035	4.85	0.00	Engraulis encrasicholus	ANE
		4.85	Myctophidae	LXX
9036	0.45	0.00	Engraulis encrasicholus	ANE
		0.00	Trachurus trachurus	HOM
		0.41	Myctophidae	LXX
		0.04	Euphasiacea	KRX
		0.00	Others	OT
9037	5.25	0.00	Engraulis encrasicholus	ANE
		0.14	Merluccius merluccius	HKE
		5.06	Myctophidae	LXX
		0.05	Euphasiacea	KRX
9201	1.4	1.40	Engraulis encrasicholus	ANE
9202	2.55	0.44	Engraulis encrasicholus	ANE
		0.05	Trachurus trachurus	HOM
		2.06	Thalia democratica	SPX
9203	0.9	0.90	Engraulis encrasicholus	ANE

STATION	BOARDING WEIGHT (kg)	BOARDING WEIGHT/ SPECIES (kg)	*SPECIES*	Fao
9204	4.85	4.85	Engraulis encrasicholus	ANE
9205	17.95	17.95	Engraulis encrasicholus	ANE
9206	8.5	8.50	Engraulis encrasicholus	ANE
9207	108	101.45	Engraulis encrasicholus	ANE
		0.52	Trachurus trachurus	HOM
		5.98	Scomber scombrus	MAC
		0.05	sarda sarda	BON
9208	5.6	5.60	Engraulis encrasicholus	ANE
9209	11.7	11.70	Engraulis encrasicholus	ANE
9210	5.3	5.30	Engraulis encrasicholus	ANE
9211	1.6	0.00	Engraulis encrasicholus	ANE
		1.20	Myctophidae	LXX
		0.40	Euphasiacea	KRX
9212	5.2	5.20	Engraulis encrasicholus	ANE
9213	1200	0.00	Engraulis encrasicholus	ANE
		1200.00	Euphasiacea	KRX
9214	8.45	8.45	Engraulis encrasicholus	ANE
9215	1.7	1.70	Engraulis encrasicholus	ANE
9216	430	413.83	Engraulis encrasicholus	ANE
		1.43	Sardina pilchardus	PIL
		11.42	Trachurus trachurus	HOM
		2.85	Scomber scombrus	MAC
		0.48	Merluccius merluccius	HKE
9217	123	117.89	Engraulis encrasicholus	ANE
		1.14	Sardina pilchardus	PIL
		2.84	Trachurus trachurus	HOM
		1.14	Scomber scombrus	MAC
9218	0.85	0.85	Engraulis encrasicholus	ANE
9219	93	87.37	Engraulis encrasicholus	ANE
		0.39	Sardina pilchardus	PIL
		1.16	Trachurus trachurus	HOM
		3.11	Scomber scombrus	MAC
		0.19	Sprattus spratus	SPR
		0.78	Merluccius merluccius	HKE
9220	31.2	0.00	Engraulis encrasicholus	ANE
		5.35	Sardina pilchardus	PIL
		9.10	Trachurus trachurus	HOM
		5.15	Scomber scombrus	MAC
		11.60	Loligo vulgaris	SQR
9221	27	18.00	Engraulis encrasicholus	ANE
		1.35	Scomber scombrus	MAC
		7.00	Sprattus spratus	SPR
		0.65	Merluccius merluccius	HKE
9222	45	1.20	Engraulis encrasicholus	ANE
		43.80	Euphasiacea	KRX

STATION	BOARDING WEIGHT (kg)	BOARDING WEIGHT/ SPECIES (kg)	*SPECIES*	Fao
9223	5.5	5.50	Engraulis encrasicholus	ANE
9224	115	0.00	Engraulis encrasicholus	ANE
		115.00	Myctophidae	LXX
9225	1.5	1.50	Engraulis encrasicholus	ANE
9226	58.5	21.36	Engraulis encrasicholus	ANE
		29.45	Sardina pilchardus	PIL
		4.24	Trachurus trachurus	HOM
		1.46	Scomber scombrus	MAC
		1.19	Scomber colias	VMA
		0.80	Loligo vulgaris	SQR
9227	78	15.83	Engraulis encrasicholus	ANE
		60.22	Trachurus trachurus	HOM
		1.95	Euphasiacea	KRX

Table 5:
Synthesis of the abundance estimation (acoustic index of biomass) for Juvena 2019 by main strata.

	Area (n.m.2)	L juv (cm)	B juv (t)	L adult (cm)	B adult (t)
Pure juve	17796	5.7	69,309	-	0
Mixed	2100	9.6	23,388	13.1	31,254
Garonne	17796	5.7	21,374	13.5	33,381
Total	37692	6.1	114,072	13.3	64,635

Table 8:

Synthesis of the abundance estimation (acoustic index of biomass) for the eight years of surveys.

Year	Area+ (mn2)	Size juv (cm)	Juveniles age 0 (year y)	Recruits age 1 (year y+1)
2003	3,476	7.9	98,601	30,424
2004	1,907	10.6	2,406	3,958
2005	7,790	6.7	134,131	16,793
2006	7,063	8.1	78,298	21,930
2007	5,677	5.4	13,121	8,991
2008	6,895	7.5	20,879	9,850
2009	12,984	9.1	178,028	46,974
2010	21,110	8.3	599,990	111,252
2011	21,063	6	207,625	45,191
2012	14,271	6.4	142,083	37,963
2013	18,189	7.4	105,271	69,263
2014	37,169	5.9	723,946	118,682
2015	21,845	6.8	462,340	55,883
2016	16,933	7.3	371,563	71,350
2017	19,808	6.6	725,403	129,480
2018	26,787	6.3	489,708	80,687
2019	20,298	6.1	114,072	

Table 9:

Biomass estimation for the rest of fish species of the small pelagic community assessed during JUVENA.

Especie	***s_A***	***Area (n.mi.^{2})***	***N_i***	***B_i (tonnes)***
Engraulis encrasicolus	221	20298	77,598,589,397	178,707
Sardina pilchardus	442	1915	420,040,288	7,725
Sprattu spratus	316	988	1,039,913,600	5,127
Trachurus trachurus	266	16662	1,810,002,248	21,410
Scomber scombrus	54	2698	1,895,770,542	36,626
Maurolicus muelleri	257	16480	293,271,083,902	157,042

Table O1.
Sum of total animals/items observed for each group recorded.

Group	Total sum
Seabirds	975
Marine mammals	262
Other marine wildlife	421
Marine debris	87
Human activities	72
Coastal birds	2
Landbirds	35
Oceanographic features	4
Total general	1858

Table O2. List of taxa observed during JUVENA 2019 for seabirds, marine mammals, other marine wildlife, marine debris, human activities, coastal birds and landbirds.

Group	Common name	Scientific name	code_esp	Number of sightings	Group size	Total sum
Seabirds	Northern gannet	*Morus bassanus*	SULBAS	125	2.28 ± 3.51	285
	Great skua	*Stercorarius skua*	CATSKU	27	1.63 ± 2.51	44
	Gulls	*Larus sp*	LARGUL	26	18.08 ± 78.04	470
	Lesser black-backed gull	*Larus fuscus*	LARFUS	23	2 ± 3.19	46
	Sooty shearwater	*Ardenna grisea*	PUFGRI	12	1.25 ± 0.45	15
	Yellow-legged gull	*Larus michahellis*	LARMIC	8	8.38 ± 12.74	67
	Manx shearwater	*Puffinus puffinus*	PUFPUF	8	1.25 ± 0.46	10
	Great shearwater	*Ardenna gravis*	PUFGRA	4	1 ± 0	4
	Common Tern	*Sterna hirundo*	STEHIR	4	3 ± 2.83	12
	European herring gull	*Larus argentatus*	LARARG	3	1 ± 0	3
	Sandwich Tern	*Thalasseus sandvicensis*	STESAN	3	1.67 ± 0.58	5
	European storm-petrel	*Hydrobates pelagicus*	HYDPEL	2	1 ± 0	2
	Large shearwater sp.	*CALBOR/PUFGRA/PUFGRI*	LARSHE	2	1 ± 0	2
	Shearwater sp.	*Puffinus spp*	PUFSPP	2	1 ± 0	2
	Small gull sp	*Larus sp*	SMAGUL	2	1 ± 0	2
	Pomarine skua	*Stercorarius pomarinus*	STEPOM	2	1 ± 0	2
	Tern sp.	*Sterna spp*	STESPP	2	1 ± 0	2
	Sabine's gull	*Xema sabini*	LARSAB	1		1
	Storm-petrels		OCESPP	1		1
Marine mammals	Fin whale	*Balaenoptera physalus*	BALPHY	20	1.05 ± 0.22	21
	Common dolphin	*Delphinus delphis*	DELDEL	18	6.61 ± 4.96	119
	Balaenopterid sp.	*Balaenopteridae sp.*	BALSPP	11	1 ± 0	11
	Striped dolphin	*Stenella coeruleoalba*	STECOE	10	8.6 ± 7.95	86
	Delphinid sp.	*Delphinidae sp.*	DELSPP	3	2.67 ± 2.89	8
	Striped dolphin / Common dolphin	*STECOE/DELDEL*	STEDEL	2	3 ± 2.83	6
	Bottlenose dolphin	*Tursiops truncatus*	TURTRU	2	3.5 ± 3.54	7
	Minke whale	*Balaenoptera acutorostrata*	BALACU	1		1
	Long-finned pilot whale	*Globicephala melas*	GLOMEL	1		1
	Beaked whales	*Ziphiidae sp.*	ZIPSPP	1		2
Other marine wildlife	Tuna / Bonito	*Thunnus spp. / Sarda spp.*	THUSPP	12	33.83 ± 39	406
	Sunfish	*Mola mola*	MOLMOL	5	1 ± 0	5
	Small Fish sp	*Ostéichiens*	SMAFIS	1		10
Marine debris	Plastic trash		PLASTR	59	1 ± 0	59
	Fishing trash		FISHTR	13	1.15 ± 0.38	15
	Trash (plastic, wood, oil)		TRASH	8	1 ± 0	8

	Unnatural wood		WOODTR	5	1 ± 0	5
Human activities	Fishing buoy, setnet		BUOY	9	1.11 ± 0.33	10
	Trawler		TRAWLB	9	1 ± 0	9
	Tanker		TANKER	7	1 ± 0	7
	Fishing boat		FISHBO	6	4.67 ± 6.83	28
	Merchant ship		CARGOB	4	1 ± 0	4
	Longliner		LONGBO	4	1 ± 0	4
	Sailing boat		SAILBO	4	1 ± 0	4
	Gill-netter		NETBO	2	1 ± 0	2
	Containership		CONTBO	1		1
	Small motor boat		MOTOBO	1		1
	Search and Rescue vessel		RESCUB	1		1
	Research vessel		RESEBO	1		1
Coastal birds	Ducks	*Anas spp / Aythya spp*	ANASPP	1		2
Landbirds	Passerine bird	*Passeriformes*	PASSER	7	1 ± 0	7
	Turnstone	*Arenaria interpres*	AREINT	3	1.67 ± 1.15	5
	Swallows	*Hirundo spp*	HIRSPP	3	1 ± 0	3
	Wagtails	*Motacilla spp*	MOTSPP	3	1 ± 0	3
	Sandpipers	*Calidris spp*	CALSPP	2	1.5 ± 0.71	3
	European robin	*Erithacus rubecula*	ERIRUB	2	1 ± 0	2
	Grey heron	*Ardea cinerea*	ARDCIN	1		6
	Egret sp	*Egretta spp*	EGRSPP	1		3
	Grey Wagtail	*Motacilla cinerea*	MOTCIN	1		1
	Whimbrel	*Numenius phaeopus*	NUMPHA	1		1
	Northern Wheatear	*Oenanthe oenanthe*	OENOEN	1		1

WORKING DOCUMENT

Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas 7, 8 and 9
Madrid, Spain 2019

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

IBERAS0919

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*Cruise leader

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TECHNICAL SUMMARY

Institution:	INSTITUTO PORTUGUÊS DO MAR E DA ATMOSFERA/INSTITUTO ESPAÑOL DE OCEANOGRAFÍA
Survey name:	IBERAS1119
Vessel name:	Angeles Alvariño (46.70 m length, 10.50 width 988 GRT, 900 kW diesel-electric)
Dates:	05-27/09/2019
Area:	WESTERN IBERIAN COAST (9aCS-9aCN-9aN)
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 4/8 nmi apart from 20 to 100 isobath
Main sampling procedures	EK-80 at 18-38-70-120-200 kHZ acoustic frequencies. 839 nmi prospected. Only day time Pelagic fishing stations: 16 Marine mammals and birds observations (not yet determined) Hydrological characterisation. 48 stations
Personnel 1st leg Vigo/Lisboa Dates: 07 to 21/09	AMORÍM, PEDRO ANGELICO, MARIA MANUEL CARRERA LÓPEZ, PABLO DA CONCEIÇÃO MENDOZA, ANTONIO PEDRO DÍAZ CONDE, PAZ DOS SANTOS BARRA, JORGE MACHADO DE ABREU, PAULA MAGALHÃES DA SILVA, ELISABETE MORENO MARQUES, ANA MURCIA ABELLÁN, JOSÉ LUIS SÁNCHEZ BARBA, MARÍA SÁNCHEZ HERMOSÍN, PABLO SANCHO MARTÍNEZ, PAULA
2nd leg Lisboa/Cádiz Dates: 22-27/09	AMORÍN, PEDRO AUTÓN DÍAZ, URBANO CARRERA LÓPEZ, PABLO DA CONCEIÇÃO MENDOZA, ANTONIO PEDRO DÍAZ CONDE, PAZ FEIJÓ, DIANA MAGALHÃES DA SILVA, ELISABETE MURCIA ABELLÁN, JOSÉ LUIS PASTOR, JOÃO PEREIRA GAMEIRO, CARLA PEREIRA NUNES, CRISTINA SÁNCHEZ BARBA, MARÍA SÁNCHEZ HERMOSÍN, PABLO
Report authors	Pablo Carrera, Pedro Amorim, Ana, Moreno, María Manuel Angélico, Paz Díaz Conde

INTRODUCTION

According to ICES, the sardine biomass of age 1 and older fish has decreased since 2006; it has been below B_{lim} since 2009; and it has stabilized to a historical low since 2012. Recruitment has been below the long-term average since 2005 and in 2017 it was estimated as the lowest in the time-series. Fishing mortality has been above F_{lim} for most of the time-series but has been decreasing from a peak in 2011. In 2017, it is the lowest in the time-series and around F_{pa}. Although sardine is not considered a short-lived species, the lack of enough adults, resulted in a very low presence of older ages (e.g. very low expectation for reaching ages older than 5 due to the high natural mortality), being the bulk of the population composed by younger fish, which in turn, make this species looks 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.

On the other hand, in coincidence with the decrease of sardine, off north Portugal and south Galicia, anchovy population has sharply increased. Monitoring this outburst is, therefore of interest as this species would partially compensate, for the purse-seine fishery, the recent lack of sardine.

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 recruit 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.

In 2018 the survey was undertook in November. However both the bad weather conditions, that limited the number of effective survey days, and the aggregation and distribution patterns of the fish, with rather isolate and big schools (figure 1) that made difficult either to find and, specially, to improve the precision of the biomass estimates (figure 2), led to change the period of the survey. Therefore, the survey was shifted to September, at the same time of JUVENA, which in turn allows a synoptic coverage of the Iberian Peninsula at the end of summer, beginning of fall.

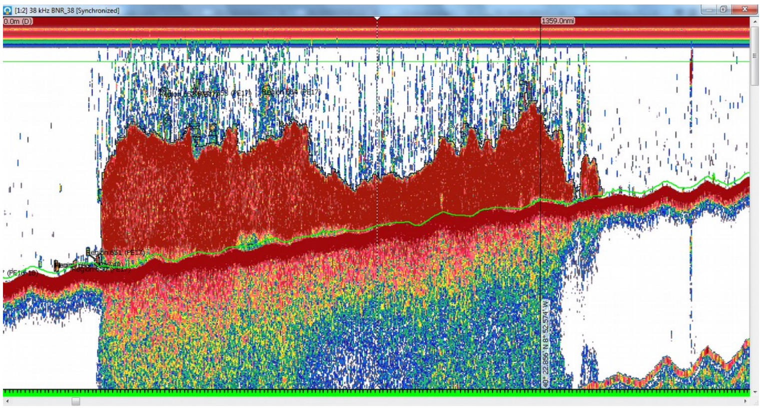


Figure 1: mega-school of anchovy recorded in 2018 during IBERAS north Figueira da Foz

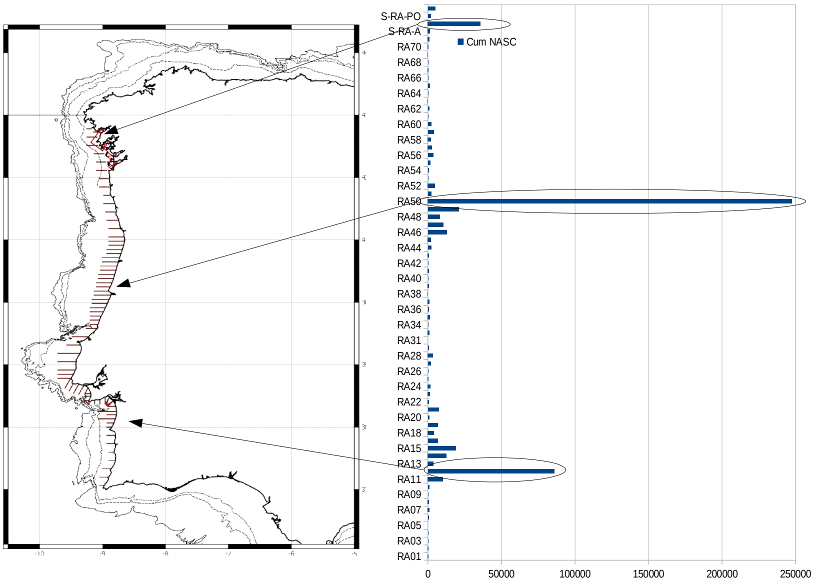


Figure 2: Cumulated backscattering energy per track in IBERAS1118. 3 of them are highlighted due to contribution to the total energy.

OBJECTIVES

i. Acoustic estimates by echointegration of the strength of the anchovy and sardine recruitment off Portugal and south Galicia

ii. Oceanographic (physical -CTD- and biological _bongo nets)characterization of the surveyed area

iii. Charting the relative abundance of apical predator along the surveyed area

MATERIAL AND METHODS

Survey was carried out on board R/V Angeles Alvariño, a similar vessel of Ramón Margalef, used in the previous survey IBERAS1118, from 5th until 27th September, departing from the port of Vigo and arriving to Cádiz harbour on the evening of 27th.

A scale was scheduled in Lisbon on 21st . Two first days were used to calibrate the transducers. For this purpose, the vessel moored in the Pontevedra Bay. The wind strength did not to allow the calibration during the first day, which was completed on 6th.

Working Area

From Finisterra cape until São Vicente cape, from shoreline (20 m) to 100 m isobath over an adaptive grid with 73 tracks distanced between 4-8 nmi on account the potential recruitment distribution area of both sardine and anchovy. Tracks were enlarged or shortened accordingly. Figure 3 show the foreseen survey track and table 1 the expected survey coverage and time.

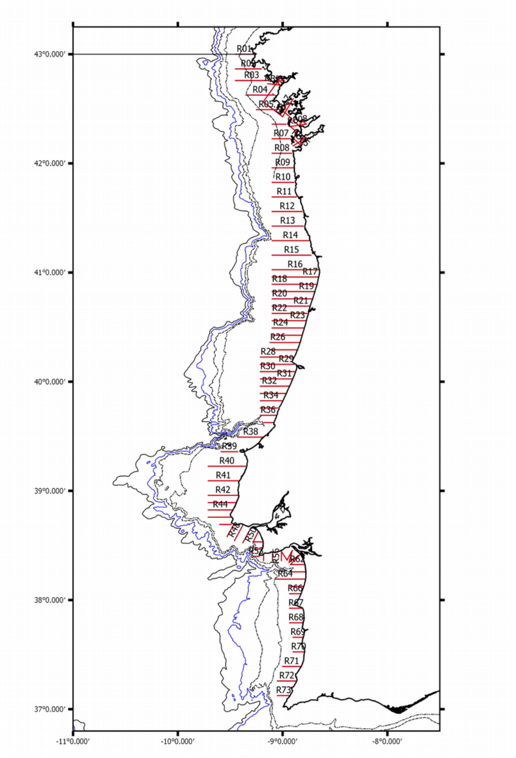


Figure 3: Survey track

Table1. Expected survey coverage and time in each ICES Sub-Division

Zone	No tracks	No of nautical miles		Acoustic	Fishing st.	TOTAL
		track	Unión	hr-days	hr-days	hr-days
Calibration						2
Plataforma 9a N	9	83	75	15-1	12-0.86	27-2
Rías Baixas (9a-N)	23	112	0	8-1	12-0.86	20-2
O. Norte (9a-CN): Caminha-Porto	6	78	48	11.8-1	12-0.86	24-2
O. Norte (9a-CN): Porto-Figueira	12	189	46	23.4-1.67	16-1.14	39.4-3
O Norte (9a-CN): Figueira-Nazaré	10	109	34	14.1-1	8-0.57	22.1-2
O Sul (9a-CS): Nazaré-Roca	9	100	59	15.9-1.14	8-0.57	24-2
O Sul (9a-CS): Roca-Troia	15	141	59	14.09-1	16-1.14	30-3
O Sul (9a-CS): Troia-São Vicente	12	81	78	15.8-1.13	16-1.14	31.8-3
Total	96	831	431	127-10.5	96-6-86	222.23-(17-19)

The methodology was similar to that 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, opportunistically, in some of the transects.

Besides, in specific areas chosen on the core expected distribution area of juveniles, the very shallower waters (15-10 m) were prospected with a portable EK60 with a 120 kHz transducer. For this purpose, the auxiliary dinghy of the vessel was used. As shown in figure 4, the normal tracks (dotted lines) were extended towards the coast (black line), which were prospected by the dinghy. Simultaneously, the vessel steamed the intertrack line (red lines). Results at 120 kHz recorded by both echosounder (EK80 on board Angeles Alvariño and EK60 on board dinghy) were compared.

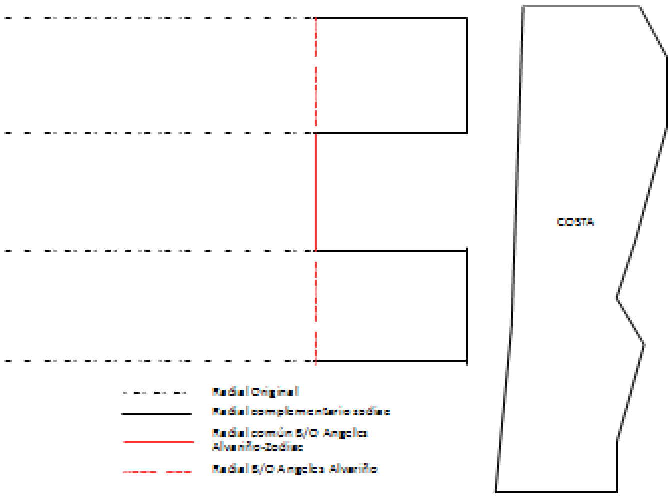


Figure 4: Acoustic scheme in shallower waters

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 nm. 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 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 nm^{-2}) (MacLennan et al., 2002). The EK60 on board the dinghy had an ES120 7CD. Due to the bad weather conditions this transducer was not calibrated.

1 NASC allocation

A pelagic gear gloria HOD 352 was 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 that enters 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 of the acoustic data was classified on account of weather condition, haul performance and the catch composition in numbers and the length distribution of the fish caught as described in table 2.

Table 2.Ground-truth criteria for fishing stations

	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 as the best representation of the fish community for a specific area were used to allocate NASC of each EDSU within this area when no direct allocation was feasible. This process involved the application of the Nakken and Dommasnes (1975, 1977) method for multiple species, but instead of using the mean backscattering cross section, the full length class distribution (1 or 0.5 cm length classes) has been 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. $\sigma_{l,p}$ is the backscattering cross-section at length l for a particular 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 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 PELACUS survey (WHB is blue whiting; MAC-mackerel; HKE- hake; HOM- horse mackerel; PIL-sardine; JAA-blue jack mackerel (Trachurus picturatus); BOG-bogue (Boops boops); VMAS-chub mackerel (Scomber colias); BOC-board fish (Capros aper); and HMM-Mediterranean horse mackerel (Trachurus mediterraneus))

Sp	b_{20}	Ref	Observations	Otherb_{20}	Ref.
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 respect.

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 in Table 4.

Table 4: Main morphological and backscattering energy characteristics used for schools detection

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 of variables were extracted, among them the NASC (s_A, m^2/nmi^2) together with the proportioned region to cell (ESDU, 1 nmi) NASC and the s_V mean and s_V max and 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 38 and 120 kHz 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 $s_{A(fi)}/s_{A(38)}$, 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 taking into account both the NASC values and the length frequency distributions (LFD) to provide homogeneous assessment polygons. These are calculated as follows: an empty track determine the along-coast limit of the polygon, whilst three consecutive empty ESDU determine a gap or the across-coast limit. Within each polygon, the LDF is analysed.

LFD were be 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 which are based on a minimum of 30 individuals will be considered. Differences in probability density functions (PDF) will be tested using Kolmogorov-Smirnov test. PDF distributions without significant differences will be joined, providing a homogeneous PDF strata. Spatial distribution will be then analysed within each stratum and finally mean s_A value and surface (square nautical miles) will be calculated using a GIS based system (Q-gis). These values, together with the length distributions, will be 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 will be done on each strata (polygon) using the arithmetic mean of the backscattering energy (NASC, s_A) attributed to each fish species and the surface expressed in square nautical miles using the following formula:

$$\rho_l = \frac{NASC_l}{\sigma_l}$$

$$N_l = \rho_l * A_p$$

> where$\rho_l$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 strata is calculated as the product ofρ_l times the total surface 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 purposes of comparison, results are given by ICES Sub-Divisions (9aS, CS, CN and N).

3 Centre of Gravity

For each main specie, 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 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 on account the results obtained during the acoustic prospection (i.e. opportunistic accounting the echotraces).

A gloria HOD 352 pelagic fishing net with a vertical opening of about 14 m and 30 m horizontal opening was 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 70 were shorten to 50 m in shallower waters. A set of Apollo polyice doors with 3.5 m^2 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 station were mainly performed during daytime but, exceptionally, some tows were conducted at sunset.

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

Plankton and hydrological characterisation

Continuous records of SSS, SST and SSF (flourometry) were taken using a SBE21 Thermosalinograph coupled with a Turner flourometer. 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 3nm apart over the transects and the number of stations occupied each night was dependent on the time available (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.

Top predator observations

Two observers placed at the bridge of the vessel at a height of 16 m above sea level worked in turns of two prospecting an area of 180° (each observer cover a field of 90°). Observations were carried out with the naked eye although binoculars were used (7x50) to confirm species identification and to determine predator behaviour. Observations were carried out during daylight during the acoustic transects prospection. Species, number of individuals, behaviour, distance to the vessel and angle to the trackline and observation conditions (wind speed and direction, sea state, visibility, etc.) were recorded, as well as the presence, number and type of boats and type, size and number of floating litter. The same methodology is used on the PELGAS surveys and both observer teams share a common database. In addition, an observed from the Portuguese Society for the Study of the Birds, SPEA, has also recorded this information but using the standard methodology for marine birds observation, instead.

Fish sampling

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

1 Catch and length distribution per specie

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

2 Weight Length relationship

To all assessed species, a weight length relationship 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, with the length class (i.e. 0.5 or 1 cm) as stratum.

3 Biological sampling

For main target species caught in each trawl haul (e.g. anchovy and sardine), a biological sampling was conducted. Data collected were: Length (mm); Weight (g); Sex; Maturity stage; otolith release; fat content; Stomach colour and repletion state. For sardine, the tale will be also collected for further genetic analysis.

RESULTS

The survey was carried out as foreseen. During the first days, NE wind regime was prevalent, which made difficult to perform bongo stations around Galician area; after this episode, compatible with the normal upwelling events in this area, weather was calm and it was only interrupted by an active front with heavy rain during the last weekend. After this front the last 4 days weather was unstable with an increasing strength of the NW wind and swell.

Hydrographic conditions

The month of September 2019 on the Atlantic Iberian region was meteorologically characterized by distinct periods, during the first few days, the atmospheric temperatures were above average for the season, with the influence from a continental air mass, then the wind shifted and blew from N, NW during a short period which was followed by some rather calm days, around the middle of the month; towards the end of the month, in particular during the last 10 days, some cold weather fronts arrived from the west, the atmospheric conditions became unstable and some heavy showers occurred and the air temperature decreased, reaching values below the typical means for late September.

The distributions of sea surface temperature and salinity observed during the IBERAS19 survey (7-26 Sept) shown in figure 5 reflect the weather conditions described above and the usual regional patterns (temperature and salinity increasing from north to south and some regions of fresh water influence).

At the beginning of the survey, in the northern region, the water temperature was between 13 and 14.5ºC, in the Galician rias and across the shelf; to the south of Aveiro the temperatures observed were above 15ºC and reached the highest values, 18-18.5 ºC, in the southern coast off Alentejo. The salinity map shows an interesting plume from Tagus river which resulted from just a couple of showery days that occurred around the days 21 to 23. The usually much more conspicuous Douro river plume was not apparent during the first half of the month (when that area was surveyed) in consequence of the preceding dry summer season.

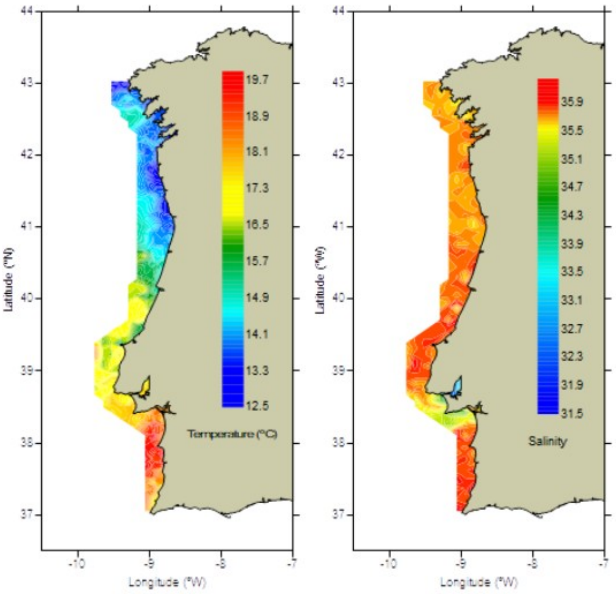


Figure 5: SST and SSS during IBERAS 0919

Sixty plankton stations were analysed and the plankton volumes (ml/10m^3) from the 200 µm mesh size net were determined. The distribution of plankton volume (ml/10m3; from 200 µm net), depicted in figure 6, shows clearly higher biomass on the northern shelf, in particular in the region between Aveiro and Douro, which was also associated to the colder (upwelled) coastal waters and where abundant fish schools, marine mammals and birds were observed. To the south of Aveiro the zooplankton biomass was lower but a clear pattern of richer inshore waters and poorer mid to offshore region was still apparent. The lower values of plankton abundance were observed to the south of Cape Espichel. In the samples collected in the northern area the euphausiid *Nyctiphanes couchi* (adults and larvae) was very abundant and its dense swarms were visible in the echosounder results. The swarms were identified by fishing stations, as shown in figure 7.

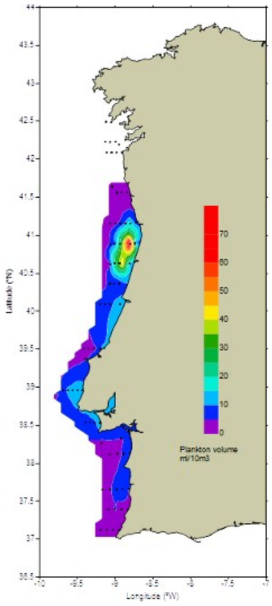


Figure 6: Plankton volume (ml/10m3) distribution derived from the Bongo60 (200 µm mesh) during IBERAS 0919 (the surveying stations (CTD and zooplankton) are represented by black dots.

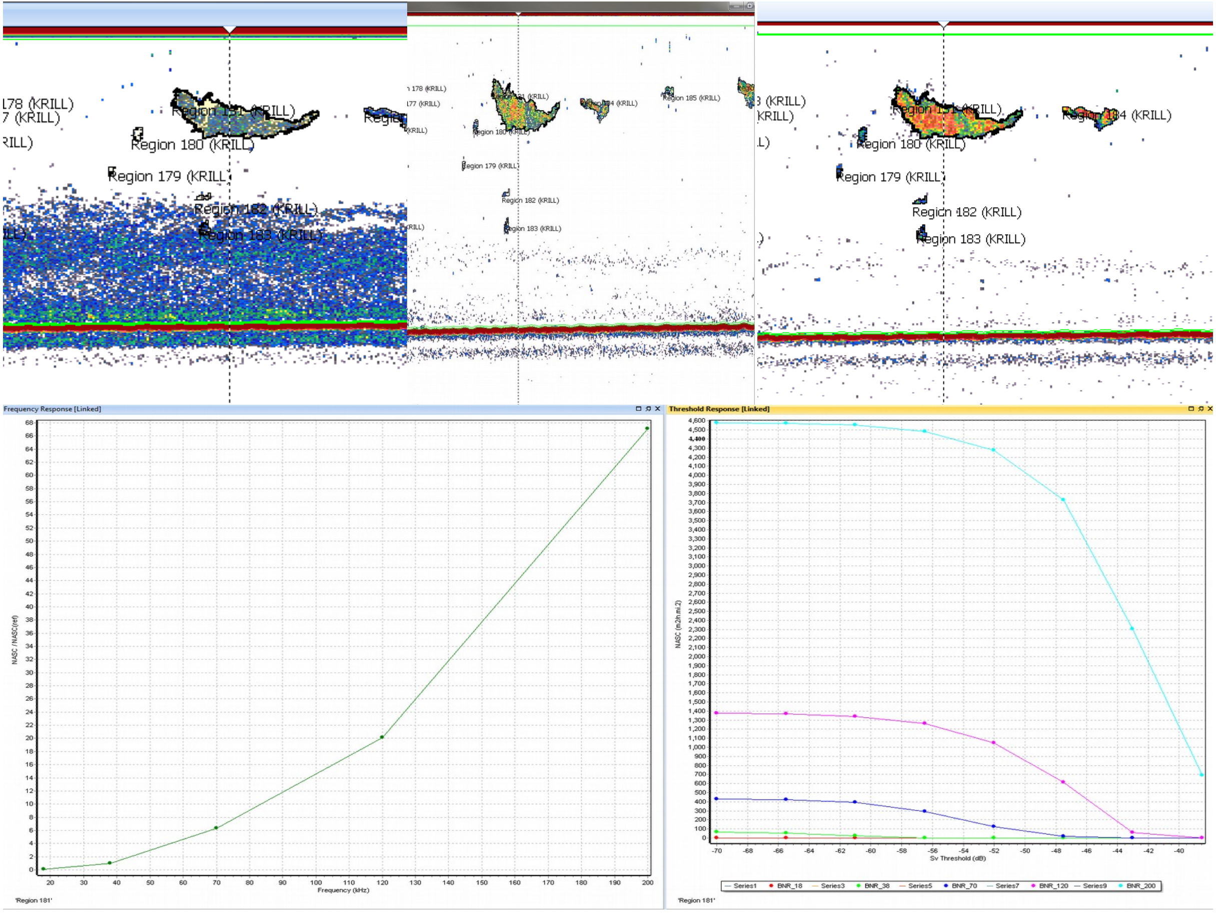


Figure 7: Echogram at 38 (left), 120 (middle) and 200 kHz (right) of a krill school and its frequency and threshold responses (below).

ACOUSTIC

School extraction and total backscattering energy

A total of 6286 echotraces were extracted, accounting for a total NASC (s_A) of 785176 m^2 nmi^{-2}. On tracks, NASC values were 430069 m^2 nmi^{-2}, which was similar to that recorded in 2018 (476837, a 10 % lower). Figure 8 shows the sum of NASC per track along the surveyed area.

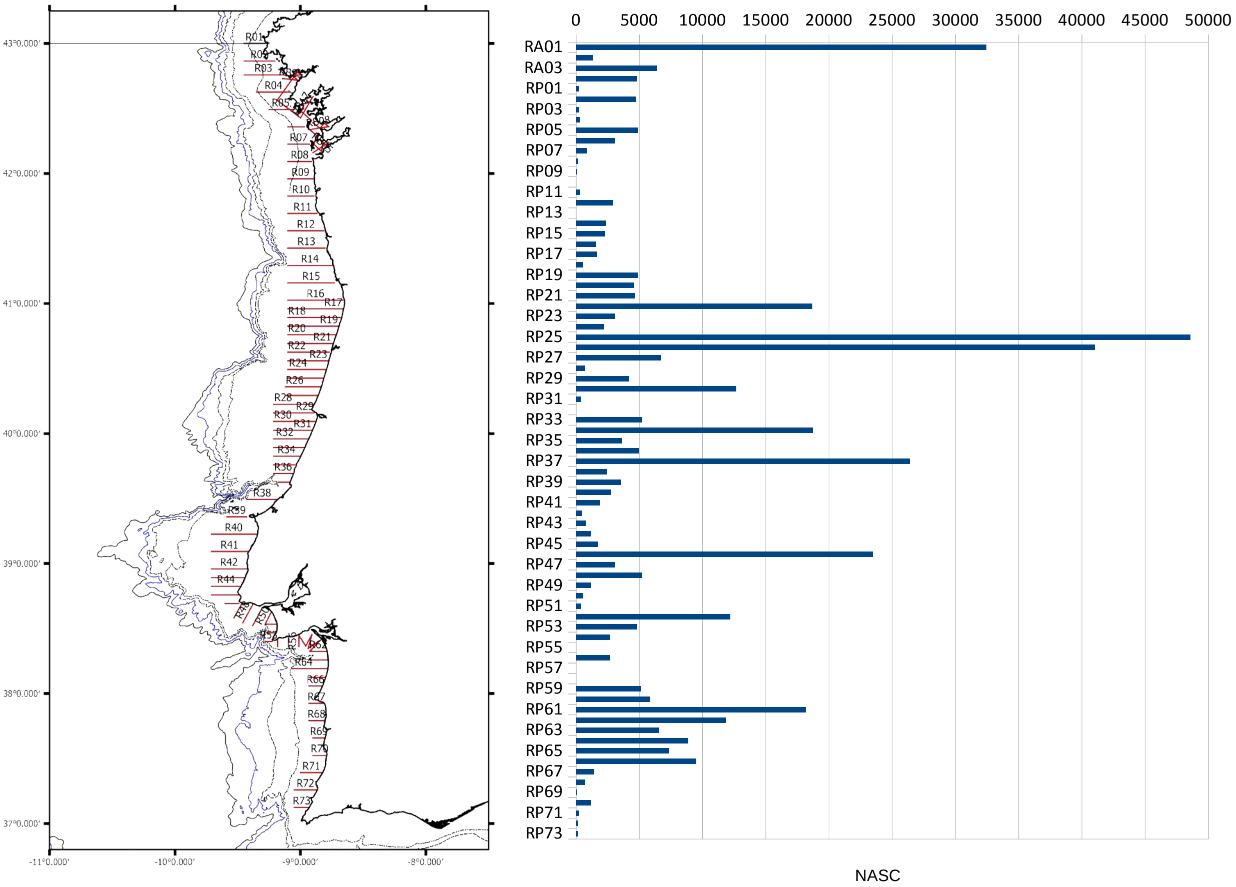


Figure 8. Cumulated NASC values per track

Fish were more evenly distributed than in the previous year, although some tracks (e.g. Ría de Muros or north Figueira da Foz) had an important contribution to the total backscattering, but less than the recorded last year when a single track accounted for the 52% of the total energy.

Bathymetric distribution of schools is significantly different from that recorded last year. The weighting average (weighting factor, s_A) shifted from 30.22 m (c.v. 0.50) to 37.53 (c.v. 0.38), with a mode located at 47.5 m (32.5 m in 2018), as shown in figure 9.

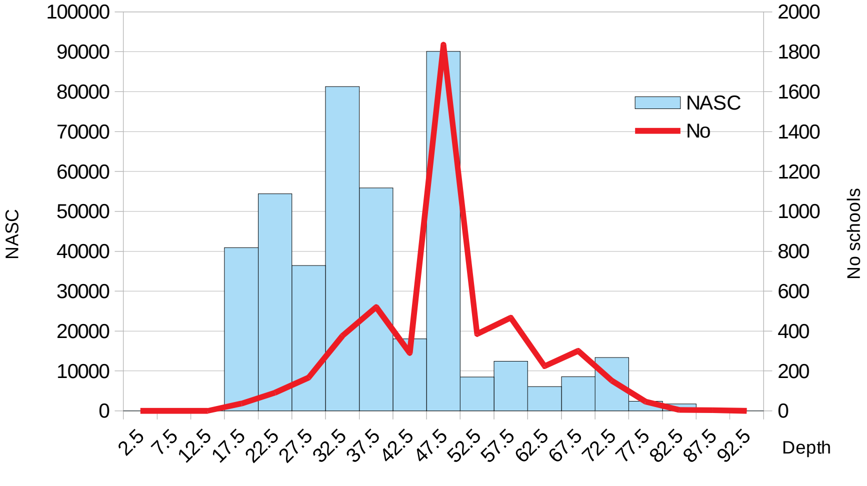


Figure 9. Number of schools and their cumulated NASC values per depth strata (5 m)

As in 2018, it seems the main school distribution area was covered as long as only few schools were found in very shallower waters. In the area covered by the dinghy only few schools were recorded and even the inclusion of coastal inter-transects had little impact on the estimation of the mean NASC value.

Fishing station and echotrace allocation

To perform fishing stations near shore was a challenging task as long as most of the area was occupied by static fishing gears, thus dramatically restricting the available areas to carry out these and increasing the searching time for doing it. The situation was even worse than that observed in 2018. In spite this, a total of 16 fishing station were done, accounting a total of 5.1 mt and more than 4.0E+5 specimen as shown in table 5. It should noted that four hauls were qualified as deficient according to the ground-truth criteria described in table 2.

Table 5. Summary of the fishing stations (WHB, blue whiting; MAC, mackerel; HKE, hake,; HOM, horse mackerel; PIL, sardine; JAA, bluejack mackerel; BOG, bogue; VMA, chub mackerel; SEAB, seabreams; ANE, anchovy; SNS, longspine snipe fish)

	TOTAL CAP (Kg)	No ind.	No Fishing st	Sample weight (kg	Measured fish	Mean length	%PRES	% Catch_W	% Catch_No
JAA	8	196	2	8	196	16.54	12.50	0.15	0.05
MAC	73	886	6	27	296	21.94	37.50	1.44	0.22
HKE	3	18	2	3	18	25.72	12.50	0.05	0.00
HOM	490	27871	12	35	772	16.03	75.00	9.67	6.86
PIL	1600	70412	10	25	819	14.55	62.50	31.56	17.33
SNS	2413	279219	4	5	461	13	25.00	47.60	68.71
BOG	7	44	3	2	17	23.79	18.75	0.14	0.01
VMA	319	3677	8	50	556	22.14	50.00	6.29	0.90
BOC	3	17	3	3	74	12.33	18.75	0.06	0.00
SEAB	26	112	4	14	53	24.63	25.00	0.52	0.03
ANE	118	4614	1	3	117	15.10	6.25	2.33	1.14
KRILL	9	19286	1	0	60	2	6.25	0.18	4.75
Total	**5068**	**406352**	**16**	**174**	**3439**				

As in 2018, horse mackerel had the higher presence and was found in 75% of the trawl haul, being also noticeable the presence of sardine (62,5%) and chub mackerel (50%). On the contrary, anchovy was found only in a 6,25% with a small contribution in the total catch (2%). It should be also highlighted the presence of longspine snipe fish, *Macroramphosus scolopax.* Catches have significantly increased since the last year, accounted for 47,6% of the total catch in weight, although was caught in only 4 fishing stations. It was the dominant species at water deeper than 50 m in southern part.

1 Chub mackerel echotrace identification

There has been an important change in both distribution and aggregation patterns of chub mackerel schools. While in 2018 (November) occurred in the southern part in dense near bottom schools, this year (September) the distribution area expanded northward and instead dense school main occurrence was in epipelagic aggregations, not particularly dense, but wide. Two fishing stations were performed to identify it. Chub mackerel echotrace and its frequency response is shown in figure 10.

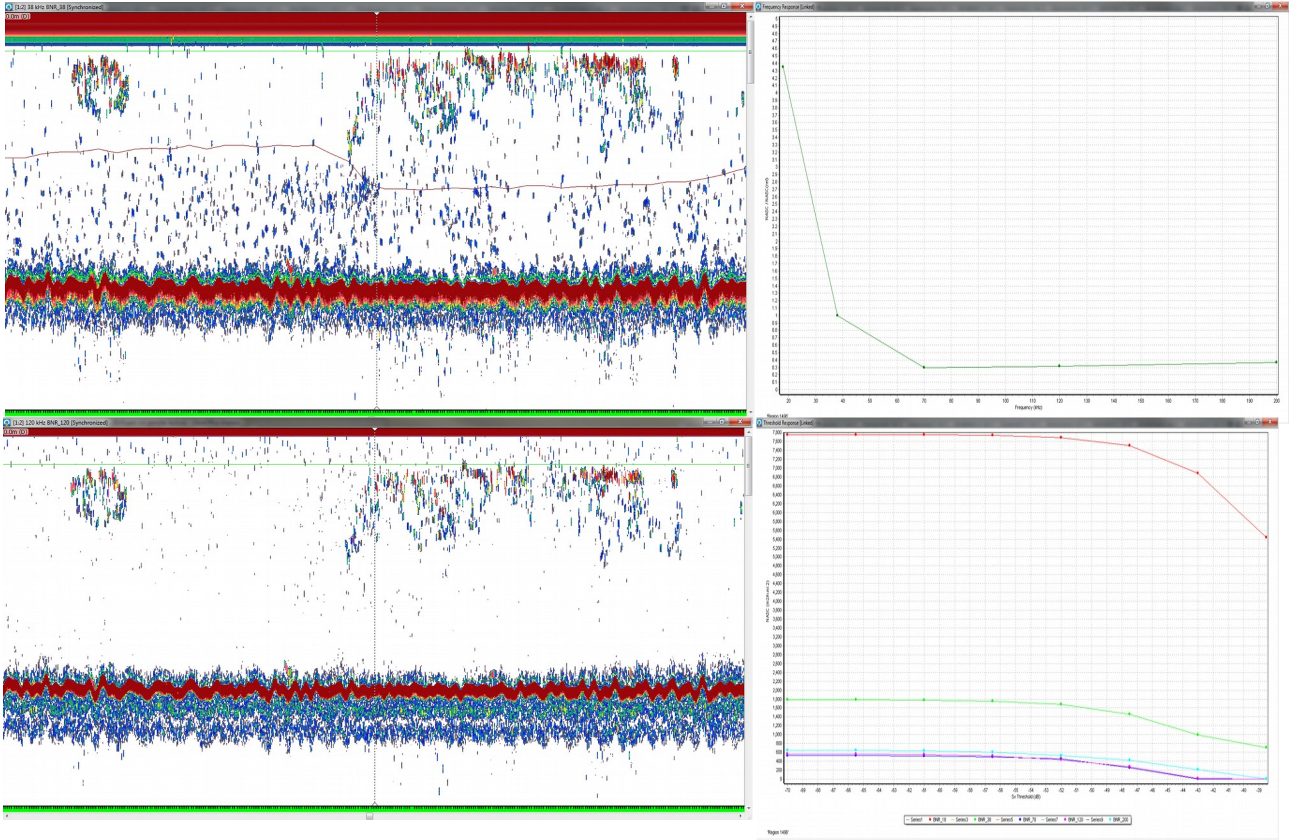


Figure 10. Echogram showing echotraces attributed to chub mackerel (38 kHz above, 120 kHz below) and its characteristic frequency and threshold responses (ground truthed by fishing station)

Although with some variability, frequency response shows a big decrease in backscattering energy from 18 to 38 kHz, with a lesser drop from this later frequency to 70 kHz and then a slight or clear increase from this to 200 kHz.

2 Longspine snipe fish echotrace identification

This fish species was mainly located south cape Roca (e.g. Tagus area and Alentejo). The echotraces were mainly observed close to the bottom and the shape of these were very variable, occurring sometimes as a bottom layer, loose aggregation over the bottom, sometimes raising towards upper layers or in schools in middle waters. It was also very difficult to get a single frequency response pattern as it varied according to the aggregation pattern (e.g dense/loose combined with bottom or middle water occurrence. At fishing station the fish tend to scape diving downwards. In figure 11 shows this variety in occurrence.

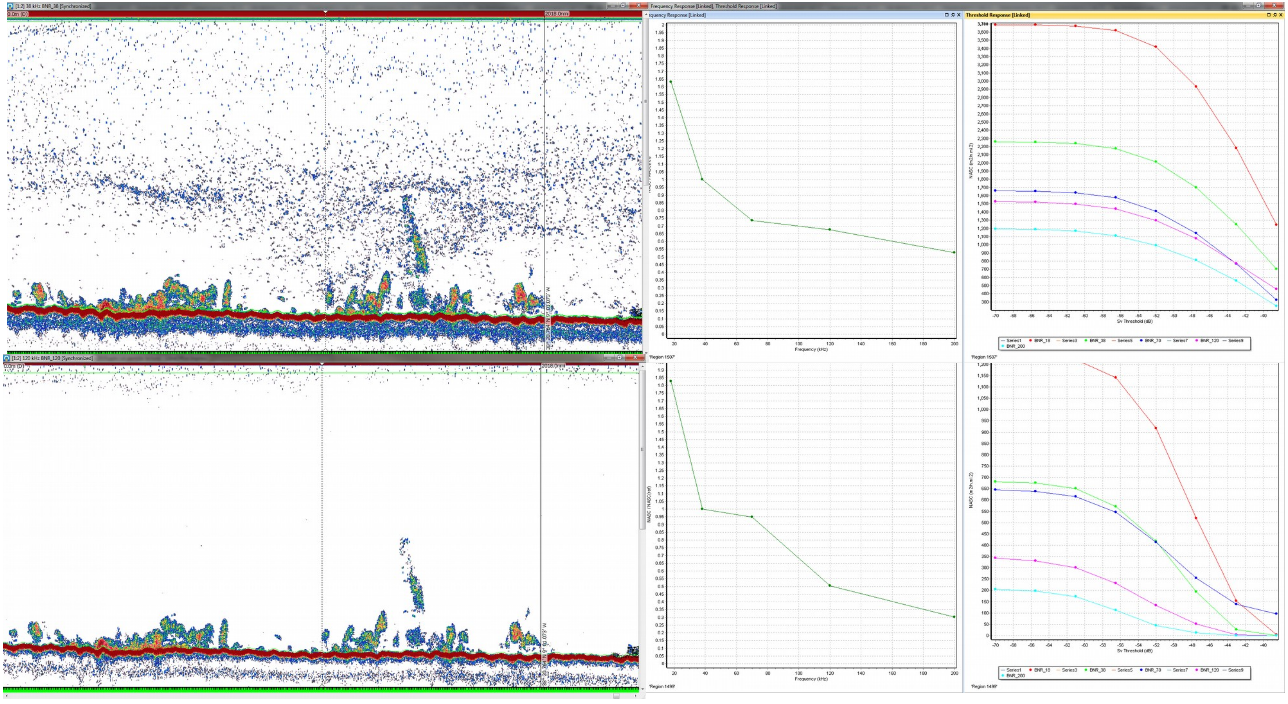


Figure 11. Echogram showing echotraces attributed to longspine snipe fish (38 kHz above, 120 kHz below) and its characteristic frequency and threshold responses for both raising middle water school (above) and bottom aggregation (below)

3 Sardine echotrace identification

Together with coastal echotraces, already observed in the previous survey, sardine occurred in epipelagic different sized schools extending from coastal waters towards the continental shelf. It should be also noted the lack of any kind of reaction from these fish, remained even very close of the active surface of the transducer (e.g. within the near field). They were mainly recorded offshore (40 m of water column onwards) around Figueira da Foz, and in coincidence with the warmer waters (e.g. outside of the influence of the upwelling areas). Sardine, contrary to that observed for chub mackerel and longspine snipe fish, had a very flat threshold response, which means that for all frequencies there is a higher uniformity in s_V values; indicating similar density all around the school volume (figure 12). This behaviour is also observed in the big schools, as those located in Galician waters. Nevertheless the frequency response could vary between a rather flat (e.g. similar energy for lower frequencies and slightly lower for higher frequencies) to a decreasing values from the lower frequency (18 kHz). To illustrate this, figure 13 shows a thick sardine school recorded in Galicia with a threshold response flat and a rather flat for lower and higher frequencies with a jump among these, different from that observed in the case of epipelagic sardine shown in figure 12, where the frequency response is decreasing although the threshold response is very similar in both cases. In both cases the presence of sardine was corroborated with a monospecific catch at the trawl haul stations.

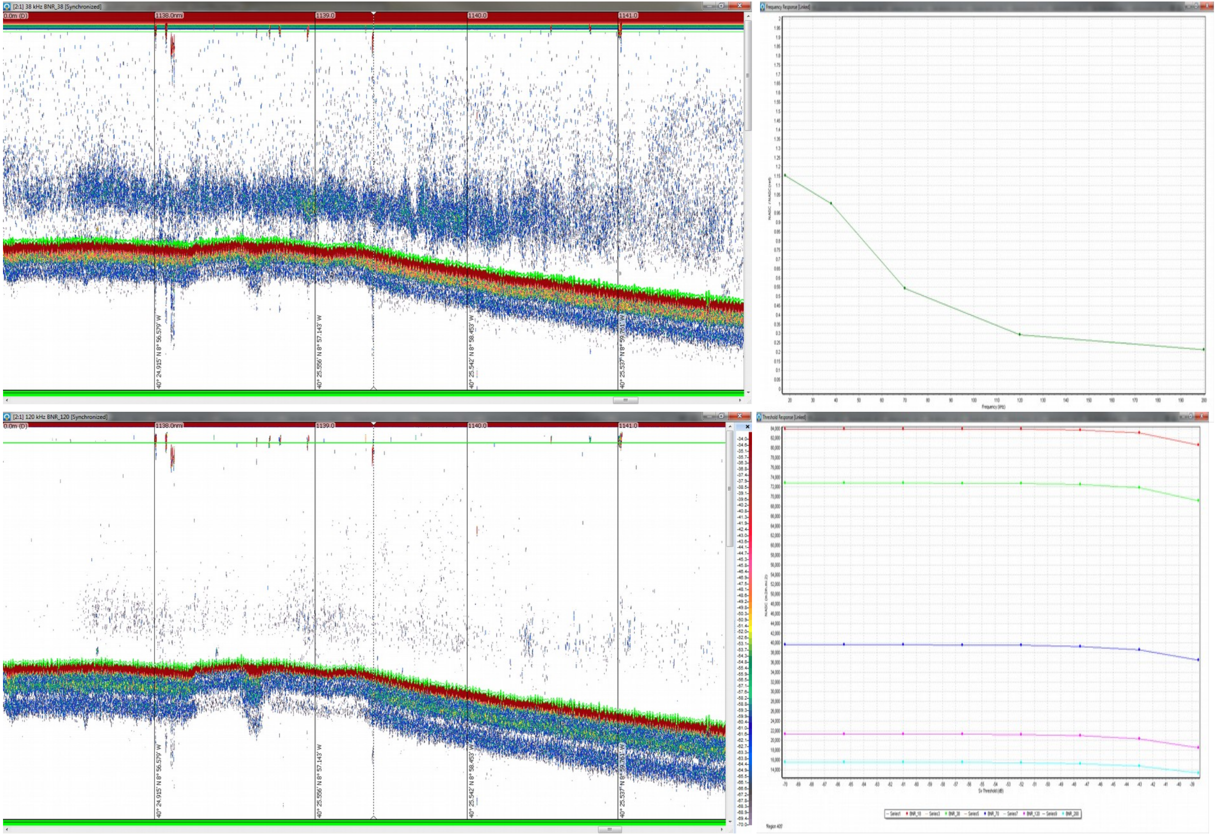


Figure 12. Echogram showing echotraces attributed to sardine (38 kHz above, 120 kHz below) and its frequency and threshold responses in Figueira da Foz area

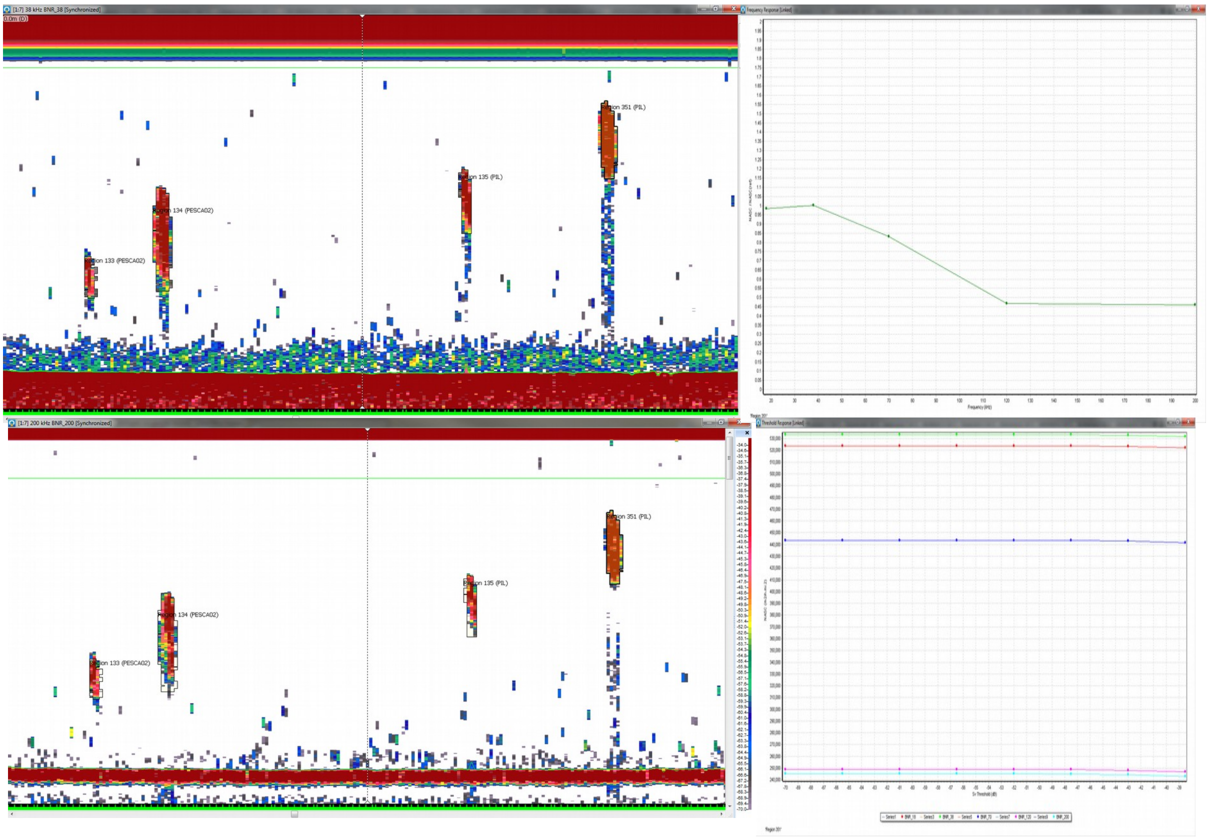


Figure 13. Echogram showing echotraces attributed to sardine (38 kHz above, 200 kHz below) and its frequency and threshold responses in Galicia area

4 Fishing station used for echotrace allocation

On survey tracks, from the total of 430069 m^2 nmi^{-2} , 278322 were directly allocated to fish species (64% of the total attributed backscattering energy). 201171 m^2 nmi^{-2} were allocated to sardine (82% of them directly allocated) and 107718 m^2 nmi^{-2} to chub mackerel (77% directly allocated). The remained energy (1517547 m^2 nmi^{-2}) was allocated accounting the results fo the fishing station. It should be also note that 39013 m^2 nmi^{-2} were left as unallocated (9% of the total backscattering energy) as has been recorded in a potential multi-specific environment in which no fishing station was undertook due to the presence of static fishing gears. Figure 14 shows the spatial distribution of the fishing stations and the proportion for each species estimated using the Nakken and Dommasnes method.

The 9aCS was dominated by chub mackerel while in 9aCN sardine was predominant and in 9aN horse mackerel which was also important in northern part of 9aCS (near Peniche and Nazaré).

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

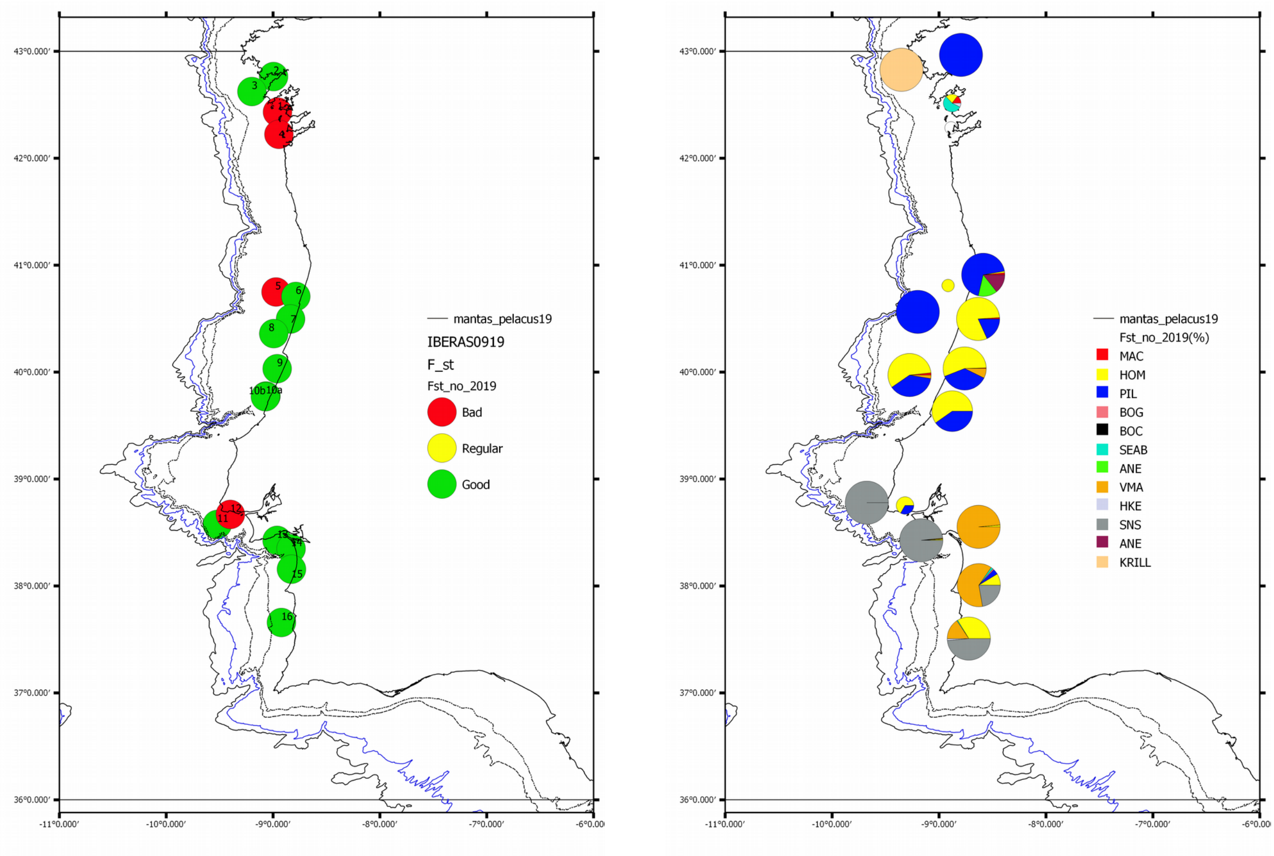


Figure 14. Left panel: location of the fishing station and traffic-light quality control. Right panel: Fish proportion accounting the Nakken and Dommaness method (BWH, blue whiting; MAC, mackerel; HAK, hake,; HOM, horse mackerel; PIL, sardine; JAA, bluejack mackerel; BOG, bogue; MAS, chub mackerel; SEAB, seabreams; ANE, anchovy; SNS, longspine snipe fish)

Table 6 shows the total energy attributed to the main species as well as the center of gravity, using as coordinates the distance from the origin, located at 37°N, and depth. Major changes in relation to 2018 cruise is the important increase in sardine and the decrease in anchovy backscattering energy.

Table 6. Total NASC allocated to the main pelagic species together with the location of the coordinates of the centre of gravity (MAC, mackerel; HOM, horse mackerel; PIL, sardine; JAA, blue jack mackerel; BOG, bogue; VMA, chub mackerel; BOC, boarfish, ANE, anchovy; SNS, longspine snipefish, KRILL, euphausidae)

	MAC	**HOM**	**PIL**	**JAA**	**BOG**	**VMA**	**BOC**	**ANE**	**SNS**	**KRILL**
NASC	65	23192	201171	4084	859	139600	4	5535	14302	1031
Depth	12.10	33.49	21.39	42.85	42.87	27.67	52.53	13.49	55.30	46.36
s.d.	2.84	10.28	4.26	5.05	4.95	6.14	6.08	3.75	7.72	3.39
ic	0.38	1.39	0.58	0.68	0.67	0.83	0.82	0.51	1.04	0.46
Dist	218.41	212.14	213.63	73.18	74.02	134.48	83.37	188.48	82.71	267.04
s.d.	7.77	49.01	31.54	4.77	4.02	39.69	1.89	25.00	5.50	19.04
ic	1.05	6.63	4.27	0.65	0.54	5.37	0.26	3.38	0.74	2.58

Figure 15 shows the spatial distribution of the center of gravity as well as the cumulated NASC along distance from the origin. Longspine snipe fish is clearly located between Sines and Cabo da Roca (areas 2 to 4). Chub mackerel has a similar main distribution area but has also two other occurrence areas, located between Mondego and Douro rivers (area 6) and also in Galicia. The bulk of the sardine distribution is as well located in area 6, more specific, between Figueira da Foz and Aveiro and second maxima in Galicia. Horse mackerel in spread throughout the whole surveyed area although this central-north part of Portugal is the most suitable. In spite the gap of two months between IBERAS 1118 and IBERAS 0919, sardine, mackerel and horse mackerel seems to have their main recruitment area in 9aCN, between Mondego and Douro rivers.

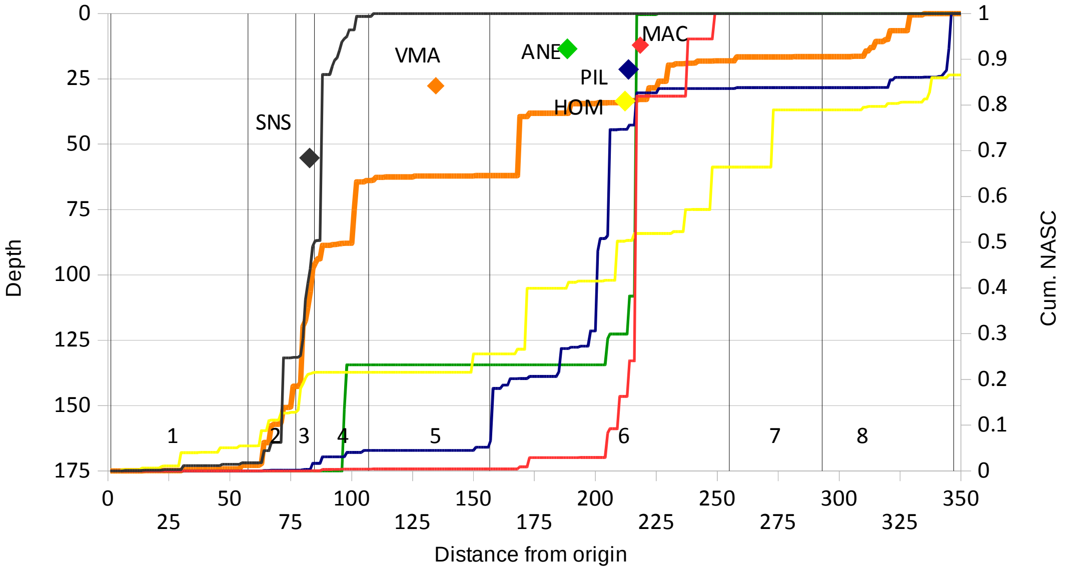


Figure 15. Center of gravity and cumulated NASC for the most important pelagic species (ANE, anchovy-green-; PIL, sardine -blue-; HOM, h. mackerel -yellow-; MAC, mackerel -red-; VMA, C. mackerel -orange-; and SNS, longspine snipe fish-black-)

Accounting the length distributions obtained at the fishing station and the NASC spatial distribution, sardine was divided in 7 strata, 3 in both 9aCS and 9aCN, and a single stratum in 9aN.

Table 7 summarises the sardine assessment. A total of 135573 tonnes, corresponding to 5962 million fish were estimated. The bulk of the distribution was found in 9aCN (118.5*10^3 tonnes).

Table 7. Summary of the sardine 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 0919 SARDINE						
ICES-Div	**Region**	**No**	**Mean**	**Surface**	**Fishing st.**	**PDF**	**No (million fish)**	**Biomass (tonnes)**	**Density (Tn/nmi-2)**
9a-N	Rias Baixas	87	374.35	157	P37-P40-P43-P44-P46	S01	422	9980	64
	Total	**87**	***374.35***	**157**			**422**	**9980**	**64**
9aCN	Viana Castelo	1	405.83	12	P31	S03	36	792	67
	Aveiro	95	1331.09	398	P26-P28-P29	S04	4594	80912	203
	Nazaré	25	1494.15	106	P26-P28-P29	S04	792	36790	347
	Total	**121**	***1357.14***	**516**			**5422**	**118494**	**230**
9aCS	Ericeira	7	405.51	24	P18	S05	41	2400	100
	Caparica	4	1374.85	12	P18	S05	69	4035	339
	Alentejo	67	10.89	224	P15	S05	9	664	3
	Total	**78**	***116.25***	**260**			**119**	**7099**	**27**
	Total Spain	***87***	***374***	***157***			***422***	***9980***	**64**
	Total Portugal	***199***	***871***	***776***			***5540***	***125593***	**162**
	TOTAL	**286**	***720***	**933**			**5962**	**135573**	**145**

The assessment was clearly dominated by young of the year fish (YOY), which accounted for 75% of the total biomass and the 92 % of the estimated abundance. In relation with that estimated in previous year there was an important increase, from 14x10^3 mt to 101x10^3 mt. Length distribution shows two clear modes, both belonging to YOY, at 9 and 13.5 cm; a third mode is also observed for adult fish peaking at around 18-19 cm as shown in figure 16. In southern part no YOY were observed.

Figure 17 shows the spatial distribution accounting the NASC values. Main distribution area is located around Figueira da Foz, being similar that observed last year but extending towards the continental self. From this area, there is an important gap towrads Galicia where fish were only located inside the Rias. The same perception of the sardine distribution during this month was achieved from the fishermen. Together with these, a third area was between Ericeira and Sines

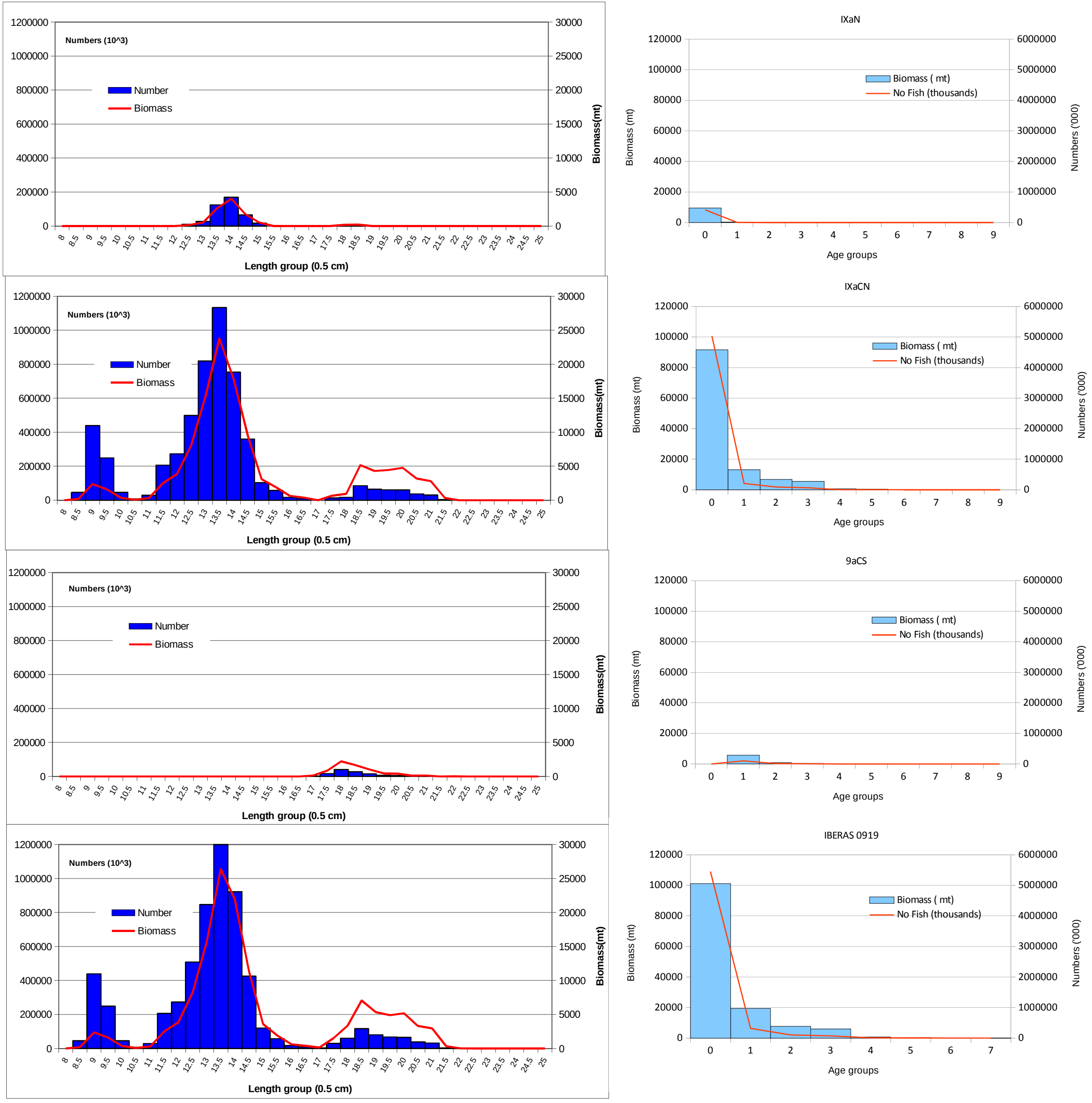


Figure 16. Sardine estimated abundance and biomass per length class (left panels) and age group (right panels) in 9aN, 9aCN , 9aCS and for the total area (below)

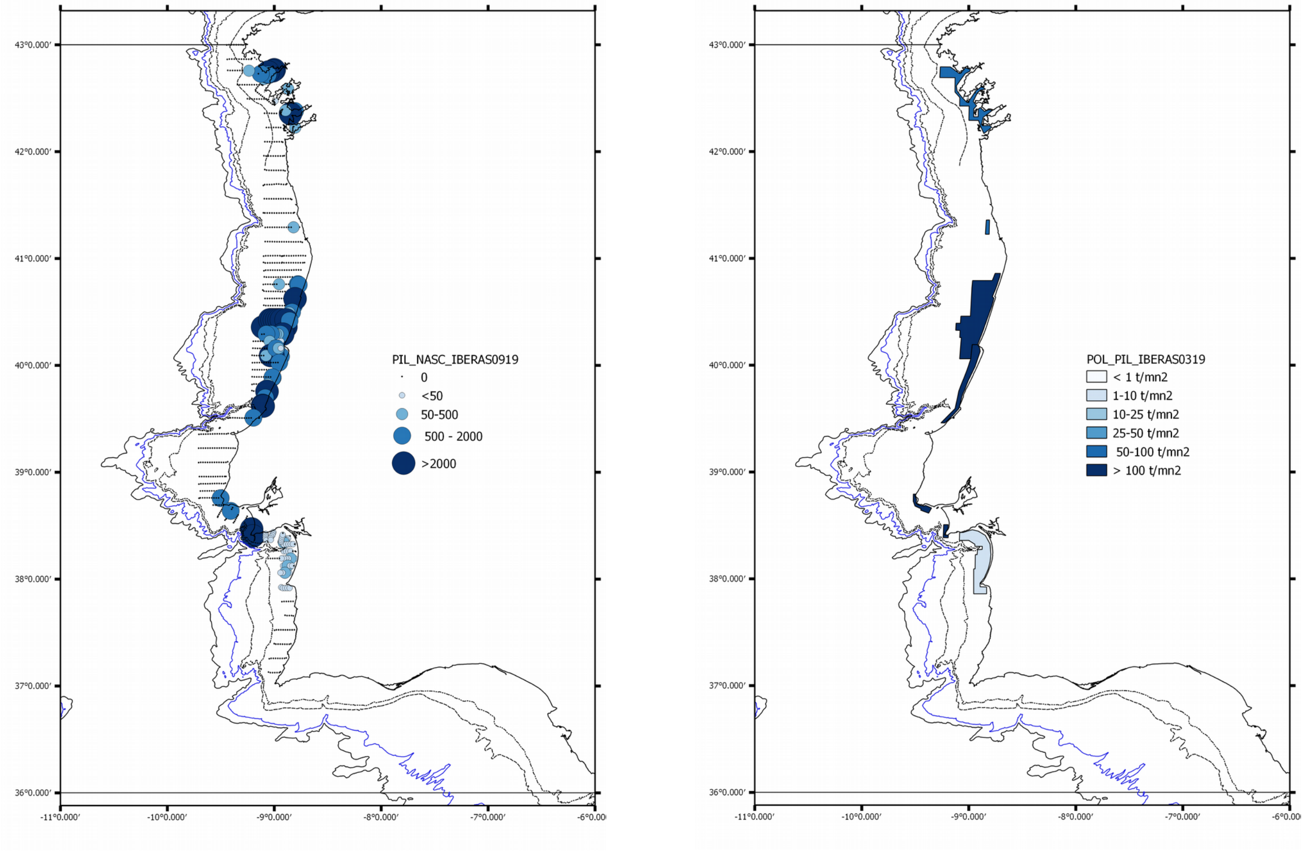


Figure 17. Sardine spatial distribution in IBERAS 1119. Dots represent the NASC values attributed to sardine and the polygons the strata together with the relative density

Table 8a-d is shown the sardine assessment by length group and age classes per ICES Sub-Division and for the whole area. It should be noted that the survey was only targeting on juveniles over its main expected distribution area and, therefore, little information on other ages can be derived from this surveys. All recruit (YOY) were found in northern waters, mainly around Figueira da Foz, (9aCN) with a mean length of 12.94 and two modes, at 9 and 13.5 cm. In Galician waters, mean length of YOY was slight higher (13.87 cm), with a single mode at 14 cm. No recruits were found in 9aCS. Few fish belonging to age group 1 were estimated (5% ot total abundance), but the bulk was located in 9aCS where accounted for the 85% of the total abundance in this sub-division.

Table 8a: Sardine assessment in 9aN

SURVEY: IBERAS 0919. Sardine

BIOMASS (tonnes). ZONE: 9aN (Spain)

	AGE GROUPS											
Length	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**	**No fish (thous**
8												
8.5												
9												
9.5												
10												
10.5												
11												
11.5												
12												
12.5	168										168.18	10370
13	512										511.51	27654
13.5	2612										2612.45	124442
14	4018										4017.56	169379
14.5	1753										1752.72	65678
15	517										516.91	17284
15.5												
16												
16.5												
17												
17.5												
18		191									191.00	3457
18.5		196	13								209.48	3457
19												
19.5												
20												
20.5												
21												
21.5												
22												
22.5												
23												
23.5												
24												
24.5												
25												
Biomass (mt)	9579	387	13	0	0	0	0	0	0	0	9979.80	421719
%	95.99	3.88	0.13									
M. weight	21.61	55.17	57.88								22.16	
No Fish (thousands)	414805	6697	216	0	0	0	0	0	0	0	421719	
%	98.36	1.59	0.05									
M. length	13.87	18.24	18.50								13.94	
s.d.	0.51	0.25									0.75	

Table 8b: Sardine assessment in 9aCN

SURVEY: IBERAS 0919. Sardine

BIOMASS (tonnes). ZONE: 9aCN

	AGE GROUPS										
Length	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**	**No fish (thous**
8												
8.5	207										206.60	46129
9	2378										2378.40	439186
9.5	1615										1614.91	249096
10	355										354.81	46129
10.5												
11	311										310.70	29386
11.5	2531										2531.29	206342
12	3862										3861.55	272991
12.5	8090										8090.45	498856
13	15156										15155.61	819362
13.5	23787										23786.70	1133057
14	17867										17867.31	753280
14.5	9608										9607.76	360021
15	3093										3093.40	103432
15.5	1923										1923.49	57600
16	635										634.78	17083
16.5	197	197									394.65	9576
17												
17.5		664									663.67	13208
18		943									942.63	17060
18.5		4834	322								5155.95	85080
19		2627	1433	239							4298.44	64828
19.5		2223	1270	953							4445.22	61416
20		1245	2075	1452							4772.38	60535
20.5		454	454	1589	227	454					3178.40	37092
21			1206	1206	402						2813.56	30268
21.5			114	114				114			343.41	3412
22												
22.5												
23												
23.5												
24												
24.5												
25												
Biomass (mt)	91615	13186	6874	5553	629	454	0	114	0	0	118426.06	5414424
%	77.36	11.13	5.80	4.69	0.53	0.38		0.10				
M. weight	17.04	63.51	75.78	81.57	90.15	85.69		100.65			20.75	
No Fish (thousands)	5036738	206234	90202	67841	6973	5299	0	1137	0	0	5414424	
%	93.02	3.81	1.67	1.25	0.13	0.10		0.02				
M. length	12.94	19.01	20.02	20.45	21.06	20.75		21.75			13.40	
s.d.	1.71	0.76	0.74	0.60	0.24						2.38	

Table 8c: Sardine assessment in 9aCS

SURVEY: IBERAS 0919. Sardine

BIOMASS (tonnes). ZONE: 9aCS

						AGE GROUPS						
Length	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**	**No fish (thous**
8												
8.5												
9												
9.5												
10												
10.5												
11												
11.5												
12												
12.5												
13												
13.5												
14												
14.5												
15												
15.5												
16												
16.5												
17		144									144.03	3160
17.5		847									846.98	16856
18		2233									2232.53	40405
18.5		1581	105								1686.44	27828
19		630	344	57							1031.67	15559
19.5		224	128	96							448.71	6199
20		107	179	125							410.82	5211
20.5		18	18	64	9	18					127.79	1491
21			64	64	21						149.91	1613
21.5												
22					20						20.28	186
22.5												
23												
23.5												
24												
24.5												
25												
Biomass (mt)	0	5785	839	407	51	18	0	0	0	0	7099.17	118510
%		81.49	11.81	5.73	0.72	0.26						
M. weight		54.61	67.32	74.41	93.02	82.21					56.97	
No Fish (thousands)	0	100691	11867	5216	523	213	0	0	0	0	118510	
%		84.96	10.01	4.40	0.44	0.18						
M. length		18.19	19.34	19.91	21.25	20.50					18.40	
s.d.		0.58	0.65	0.62	0.59						0.78	

Table 8d: Sardine assessment in whole area (9aN+9aCN+9aCS)

SURVEY: IBERAS 0919. Sardine

BIOMASS (tonnes). ZONE: Survey (Spain+Portugal)

	AGE GROUPS											
Length	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**	**No fish (thous**
8												
8.5	207										206.60	46129
9	2378										2378.40	439186
9.5	1615										1614.91	249096
10	355										354.81	46129
10.5												
11	311										310.70	29386
11.5	2531										2531.29	206342
12	3862										3861.55	272991
12.5	8259										8258.64	509226
13	15667										15667.11	847015
13.5	26399										26399.15	1257499
14	21885										21884.87	922658
14.5	11360										11360.48	425698
15	3610										3610.31	120716
15.5	1923										1923.49	57600
16	635										634.78	17083
16.5	197	197									394.65	9576
17		144									144.03	3160
17.5		1511									1510.65	30064
18		3366									3366.16	60922
18.5		6611	441								7051.88	116365
19		3257	1777	296							5330.11	80387
19.5		2447	1398	1049							4893.94	67616
20		1352	2254	1577							5183.19	65747
20.5		472	472	1653	236	472					3306.19	38583
21			1270	1270	423						2963.48	31880
21.5			114	114				114			343.41	3412
22					20						20.28	186
22.5												
23												
23.5												
24												
24.5												
25												
Biomass (mt)	101194	19358	7726	5960	680	472	0	114	0	0	135505	5954653
%	74.68	14.29	5.70	4.40	0.50	0.35		0.08				
M. weight	16.33	58.58	71.93	77.94	86.98	82.21		96.75			20.41	
No Fish (thousands)	5451543	313623	102285	73057	7497	5512	0	1137	0	0	5954653	
%	91.55	5.27	1.72	1.23	0.13	0.09		0.02				
M. length	12.77	18.56	19.71	20.18	20.84	20.50		21.50			13.31	
s.d.	1.68	0.75	0.75	0.60	0.30		0.00	0.00	0.00	0.00	2.40	

Sardine stock indicators

These stock indicators are a series of metrics comparing results from 2018 and 2019. However, as it was already stated, there is a gap of two month between surveys which have to take into account when the results of this comparison are analysed.

Spatial distribution

Figure 18 is showing the center of gravity derived from the NASC values. There is no important changes on fish relative distribution, although the total echointegrated energy (and therefore abundance estimates) was very different. In both cases the center is located round Figueira da Foz (40 to 60 % of the total cumulated energy) and seems to be independent of the total biomass (e.g. backscattering energy).

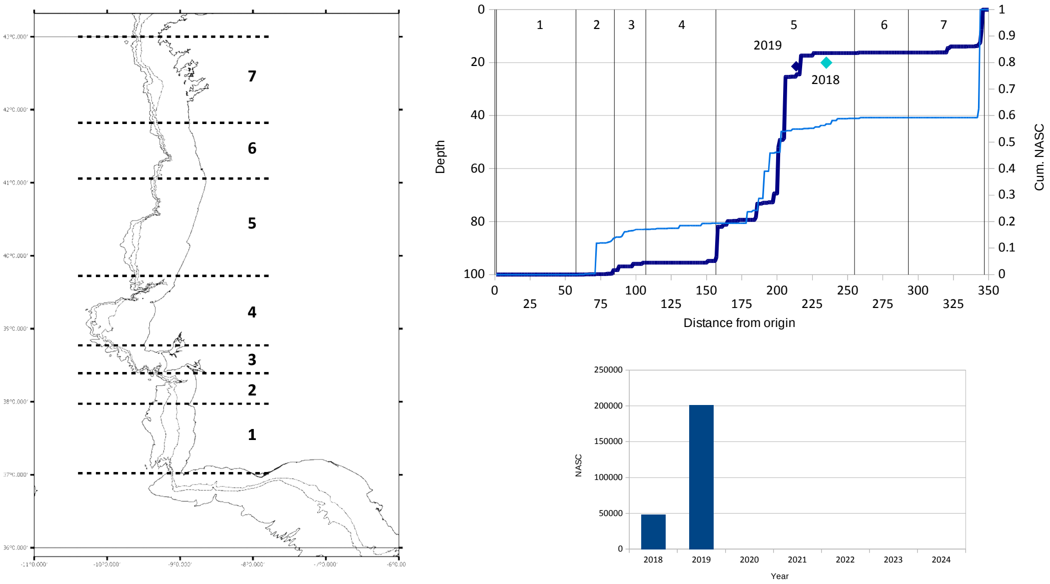


Figure 18: Relative cumulative NASC values of sardine along the coast (from south to north) and center of gravity (above right) and the total backscattering energy attributed to sardine (below right). Numbers in the cumulative plot correspond to the areas in the map (left)

Length and weight evolution (2018-19)

As expected, both mean length and weight decreased from 2018 to 2019 mainly due to the gap in time, as shown in figure 19. However except for the YoY, mean weight at age increased, specially in age groups 1 and 2, as both also shown an increase in mean length

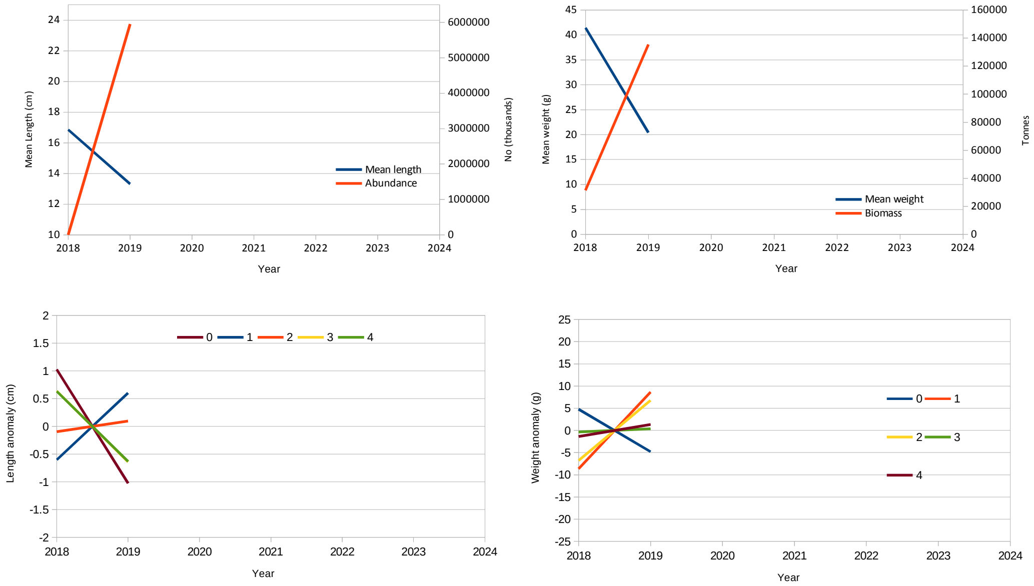


Figure 19: Above: mean length (cm) and abundance (thousand of fish) and mean weight (gr) and biomass /mt) of sardine estimated in IBERAS (2018-19) (left and right respectively); below: mean length and weight anomalies (differences from the mean value) for age groups 0 to 4

2 Anchovy assessment

In relation to 2018, the estimated biomass in 2019 had an important decrease, from 182*10^3 mt to only 4*10^3 mt. The summary of the assessment is shown in table 9. Almost no recruits were assessed, and age group 2 accounted for the 59% of the biomass (57 % in number); this result partially agreed the 2018 assessment when the bulk of the biomass was composed by ages 1 and 2, with little contribution of YOY (figure 20 and table 10). Anchovy occurred in shallower waters, near Figueira da Foz, corroborated by both the purse-seiner and the fishing stations done by the Angeles Alvariño. In Cascais area, although no fishing stations was done (due to the presence of fishing gears), additional information from purse-seiner fleet was used to allocate some echotraces to anchovy (figure 21).

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

		SURVEY:	IBERAS0319 ANCHOVY						
Zone	**Area**	**No**	**Mean**	**Area**	**Fishing st.**	**PDF**	**No (million fish)**	**Biomass (tonnes)**	**Density (Tn/nmi-2)**
9aCS	Cascais	3	428.62	18	P14	S01	42	1232	68
	Total	***3***	***428.62***	***18***			***42***	***1232***	**68**
9aCN	Figueira	16	285.40	70	P14	S01	122	2981	42
	Total	***16***	***285.40***	***70***			***122***	***2981***	**42**
9aN	Rbaixas	0	0.00	0			0	0	0
	Total	**0**	***0.00***	**0**			***0***	***0***	**0**
	Portugal	***19***	***308***	***88***			***164***	***4212***	**48**
	Spain	***0***	***0***	***0***			***0***	***0***	**0**
	TOTAL	**19**	***308.01***	**88**			**164**	**4212**	**48**

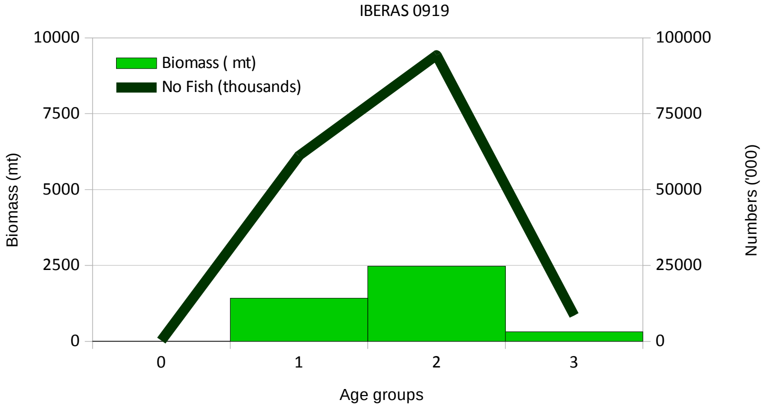


Figure 20. Anchovy estimated abundance and biomass per age group

Table 10: Anchovy assessment in 9a

SURVEY: IBERAS 0319. Anchovy

BIOMASS (tonnes). ZONE: Whole Area

	AGE GROUPS					
Length	**0**	**1**	**2**	**3**	**Total**	**No fish (thous**
5						
5.5						
6						
6.5						
7						
7.5						
8						
8.5						
9						
9.5						
10						
10.5						
11						
11.5						
12						
12.5	3	3			6.81	522
13		8			7.72	522
14		155	155		309.66	16514
14.5		248	310		558.20	26609
15		350	420		770.50	32953
15.5		374	374		748.55	28824
16		239	477		715.74	24896
16.5			464		464.08	14626
17			178	178	355.39	10178
17.5			97	97	193.42	5048
18				39	38.87	927
18.5						
19						
19.5						
20						
Biomass (mt)	3	1421	2475	313	4212.47	164226
%	0.08	33.72	58.76	7.44		
M. weight	13.06	23.03	25.94	36.63	23.49	
No Fish (thousands)	261	61163	94263	8540	164226	
%	0.16	37.24	57.40	5.20		
M. length	12.75	15.18	15.74	17.51	15.62	
s.d.	0.00	0.73	0.91	0.34	0.98	

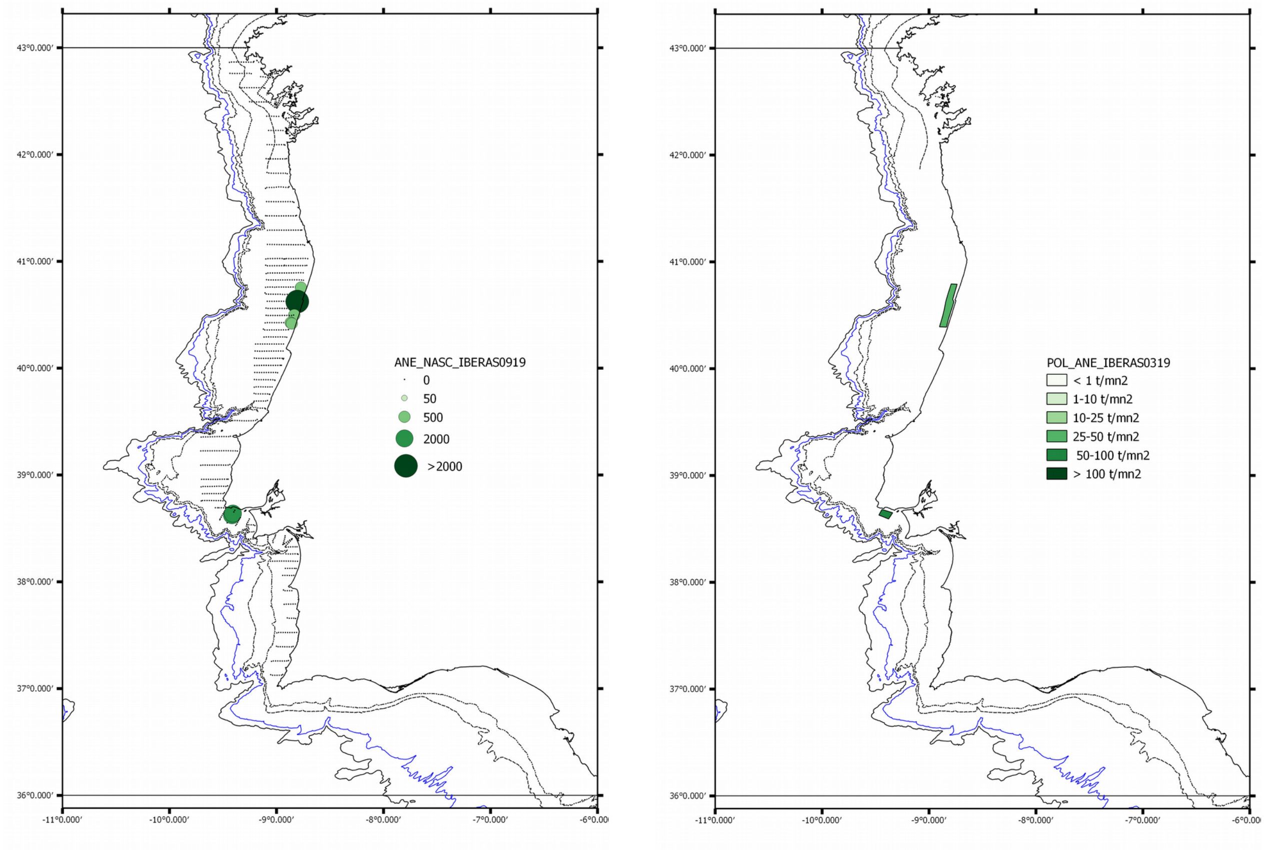


Figure 21. Anchovy spatial distribution in IBERAS 0919. Dots represent the NASC values attributed to anchovy and the polygons the strata together with the relative density

Anchovy stock indicators

In the case of anchovy, only spatial distribution is provided, due to the low biomass estimated this year which made difficult to provided a comprehensive length and age distributions. As observed in sardine, center of gravity remained stable regardless the size of the stock (e.g. backscattering energy) and the gap in time between the surveys. In both years it is located near Figueira da Foz, as shown in figure 22.

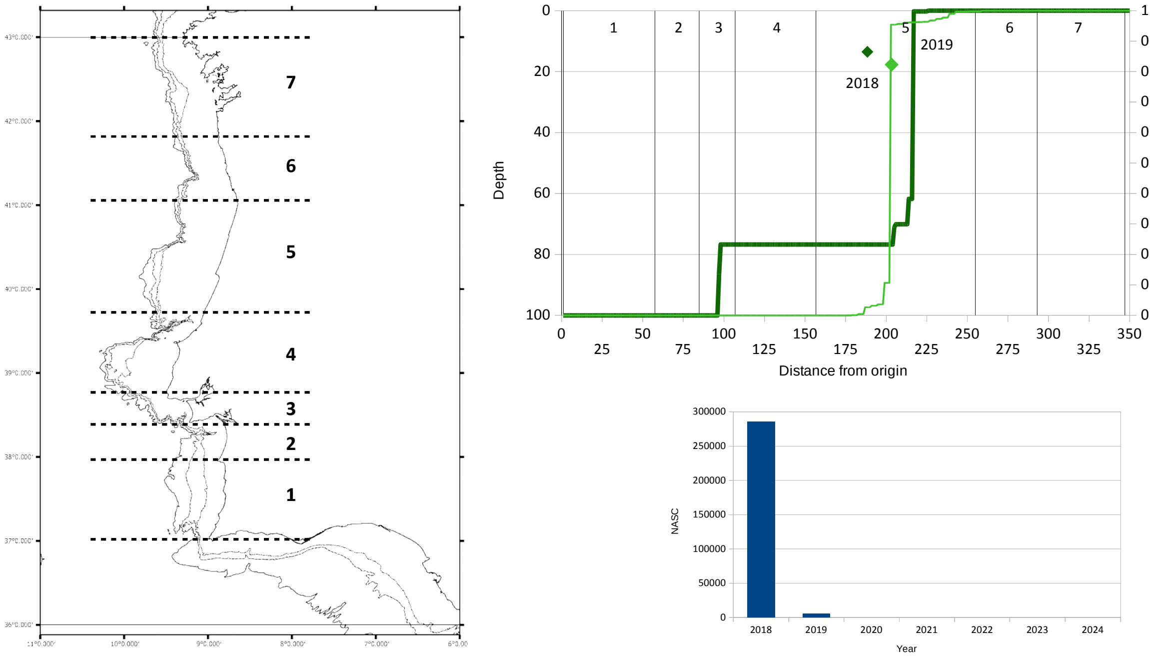


Figure 22: Relative cumulative NASC values of anchovy along the coast (from south to north) and center of gravity (above right) and the total backscattering energy attributed to anchovy (below right). Numbers in the cumulative plot correspond to the areas in the map (left)

3 Chub mackerel assessment

As previously stated, the chub mackerel distribution area was wider in 2019 than that observed in 2018 when the bulk of the stock was located in 9aCS. Table 11 summarises the chub mackerel assessment. $56*10^3$ mt thousand tonnes, corresponding to $702*10^6$ fish, were assessed. Length distribution was very similar around the surveyed area but those located around the Sado estuary, where the bulk of the estimated biomass was located, which had a mode at 20 cm instead 22 cm. Length ranged from 18 to 28 cm, corresponding to younger fish (figure 23). Age length key is still not available but applying the available from 2018, most of the fish would belong to age group 1, and no fish older than 3 was observed. Main difference from 2018 is the increase of the younger fish, as observed in figure 23.

Table 11 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 0919 CHUB MACKEREL

Zone	Area	No	Mean	Surface	Fishing st.	PDF	No (million fish)	Biomass (tonnes)	Density (Tn/nmi-2)
9aCS	Tejo	70	361.15	300.58	P09-P10-P14-P16	ST01	125	10844	36
	Sado	72	890.15	305.65	P13-P14-P15	ST02	350	25624	84
	Alentejo	43	14.82	358.02	P09-P10-P14-P16	ST01	6	530	1
	Total	***185***	***487***	***964***			***481***	***36998***	38
9aCN	Aveiro	195	88.41	916.54	P09-P10-P14-P16	ST01	93	8095	9
	Figueira	19	1061.96	75.71	P09-P10-P14-P16	ST01	93	8032	106
	Total	***214***	***175***	***992.2***			***186***	***16127***	16
9aN	Rbaixas	60	219.24	136.65	P09-P10-P14-P16	ST01	34	2993	22
	Total	***60***	***219***	***137***			***34***	***2993***	22
	Total Portugal	***399***	***319***	***1956***			***667***	***53125***	27
	Total Spain	***60***	***219***	***137***			***34***	***2993***	22
	Total 9a	***459***	***306***	***2093***			***702***	***56117***	27

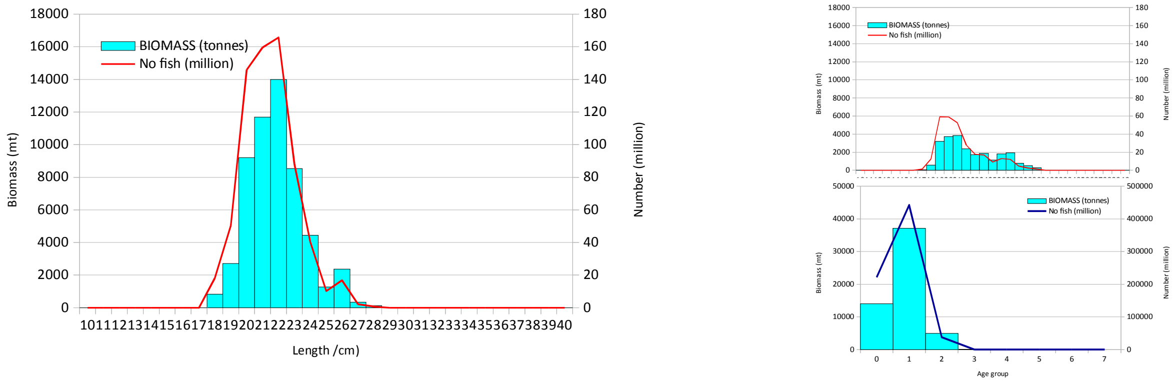


Figure 23. Left: chub mackerel estimated abundance and biomass per length class in IBERAS0919; above right estimated abundance and biomass per length class in IBERAS1119: below right estimated abundance and biomass per age group in IBERAS0919 using the age/length key from 2018

As stated, chub mackerel had a wider distribution all along the surveyed area, as shown in figure 24. In the same way as observed for the other species, there is a gap in the distribution near the Spanish-Portuguese border (e.g. around the Minho river) with tracks with no fish or very scarce.

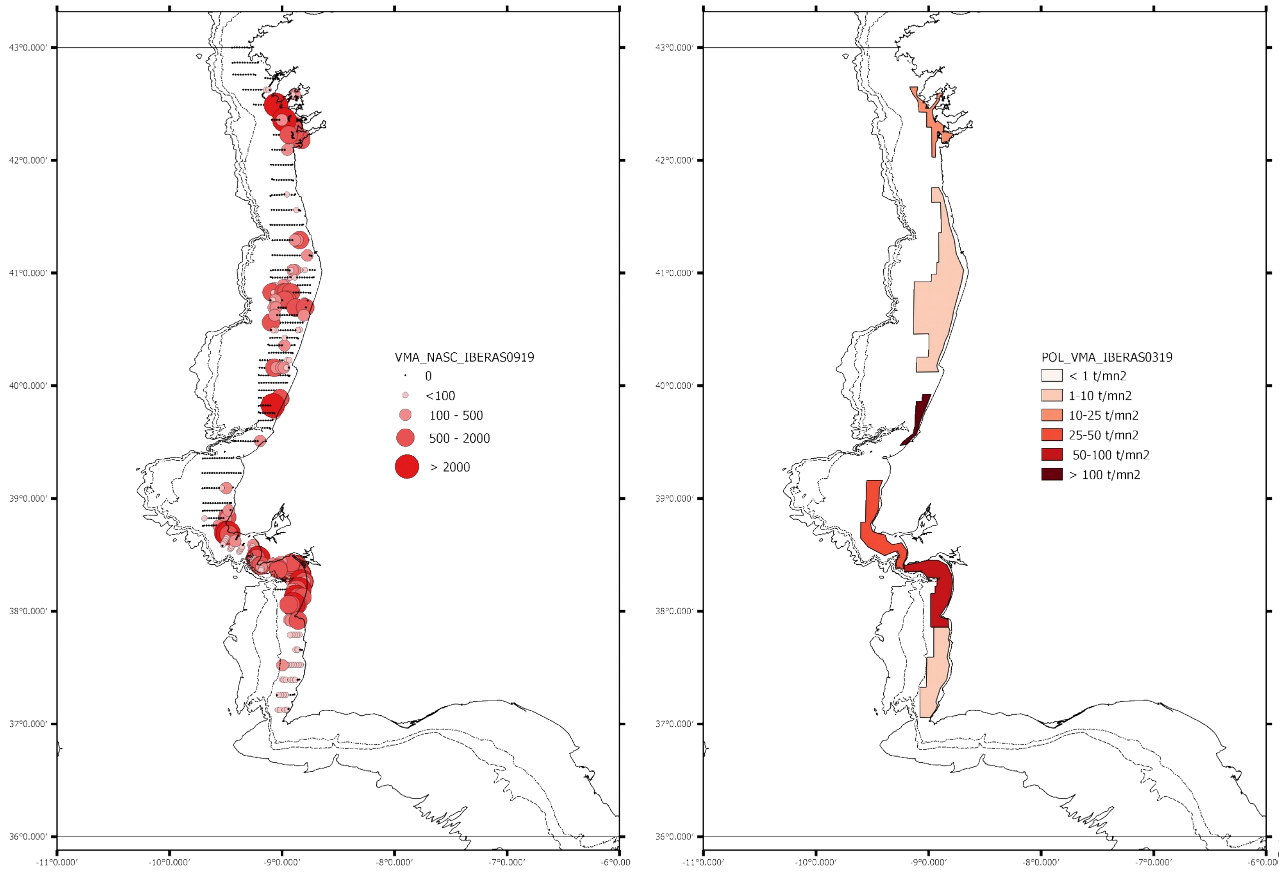


Figure 24. Chub mackerel spatial distribution in IBERAS 1118. Dots represent the NASC values attributed to chub mackerel and the polygons the strata together with the relative density

Chub mackerel stock indicators

As the age/length key is still not available, no comparison among ages between 2018 and 2019 can be done, and only the spatial distribution can be compared. In this case, there seems to be a clear period effect, with a significant northward shift in the center of gravity.- Although the bulk of the distribution is still located near the Sado, in 2018 no fish was observed north this area, as shown in figure 25.

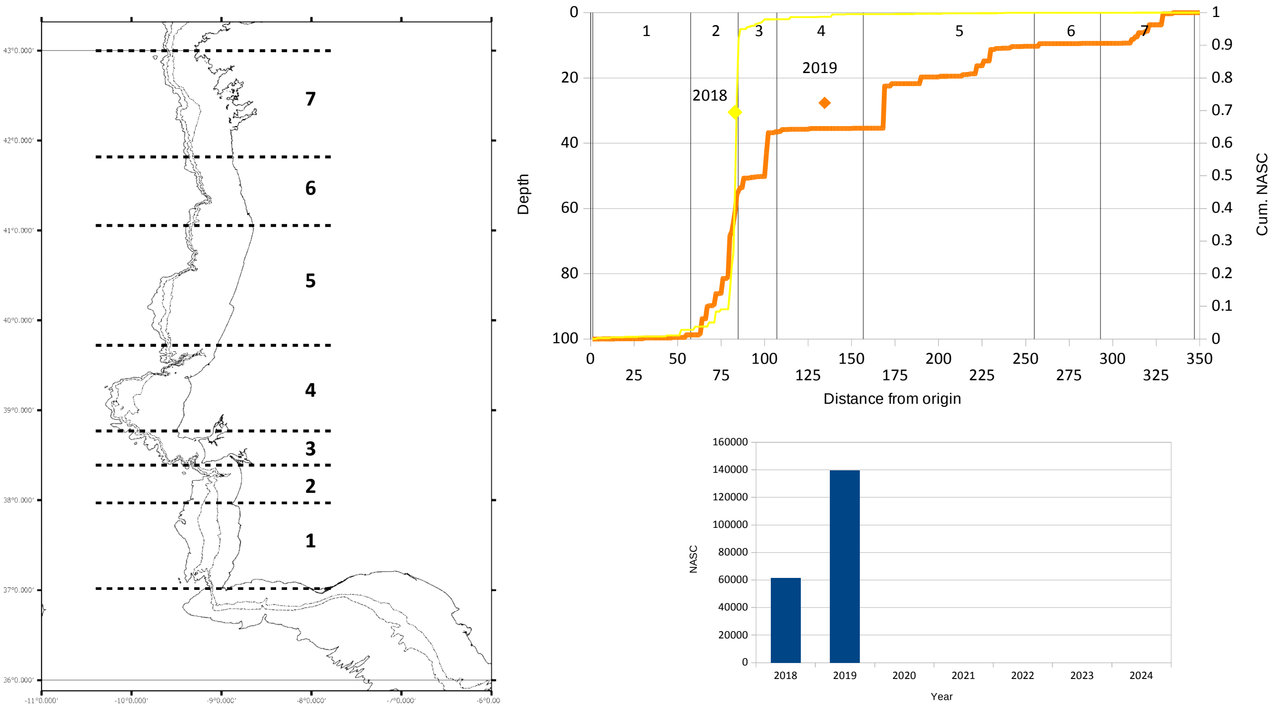


Figure 25: Relative cumulative NASC values of chub mackerel along the coast (from south to north) and center of gravity (above right) and the total backscattering energy attributed to anchovy (below right). Numbers in the cumulative plot correspond to the areas in the map (left)

DISCUSSION AND CONCLUSIONS

In general terms, the change from November to September (two month earlier) improved the survey strategies and the assessment itself. The number of lost days due to bad weather conditions considerably decreased and the bulk of the recruitment is available. The only matter of concern is the amount of static fishing gear all around the shallower waters. From November to September, it seems the number of these fishing devices increased considerably. This drastically reduces the trawleable areas as long as a minimum of 2-3 nmi are required to do a tow haul. The number of fishing stations was low mainly due to lack of available areas.

The fish distribution was more wider than that observed in 2018. It could be either by the better weather condition and also by the increase of the sardine abundance. In such conditions, the proposed survey design matched with de expected distribution area of sardine recruits and no extension towards very shallower waters nor the use of intertransects legs as proxy of the abundance in this area are needed. However, an important amount of fish was observed in particular years within this area; therefore, this has to be prospected in order to ensure a whole coverage of the sardine recruitment area.

On the other hand, it seems that the pelagic fishing gear used in this survey has a very low selectivity and a high catchability, on account the first preliminary analysis of the comparison between the trawl hauls performed by the research vessel and the shots performed by the chartered purse seiner. Although the higher fish diversity observed in the pelagic tows, direct consequence of both the greater water volume filtered in relation to the volume encircled by the purse-seine net and the multispecific pelagic community observed in the survey area, length distribution for those species already caught by both devices, were similar.

Concerning the sardine assessment, there was a significant increase in the strength of the estimated recruitment. More interestingly, the presence of at least two different modes would mean the spawning period, which is relatively long, had several episodes of favourable conditions for the success of the recruitment along this. The occurrence of epipelagic schools, very near of the surface, although without any visible avoidance reaction, would in turn to underestimate the strength of the recruitment. Some of the schools occurred in the near field (Fresnel zone) and others would be located in the blind zone (e.g. between the surface and the active surface of the transducer located at 6.5 m depth). In such circumstances, a underestimation would be expected.

Another issue regarding the survey is the timing. Up to now, all surveys targeting in sardine recruitment were undertook in November over the same area. Given the high natural mortality for age group O (M=0.98, ICES, 2018), an important decrease is expected and no direct comparison between those surveys carried out in November (e.g. two months later) and this survey should be done. The strength of this recruitment should, therefore, be confirmed once the next spring surveys PELACUS and PELAGO were provided the estimates at age 1.

ACKNOWLEDGEMENT

We wish to thank the captain and the crew of R/V Angeles Alvariño for this great cooperation, specially the boatswain who made possible the dinghy navigations. Also we are indebted to Simrad Spain (Ricardo Miguelez) and Guillermo Boyra (Azti) as they loaned the GPT and the 120 kHz transducer respectively.

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

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 (Merlucciusmerluccius) 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

PELAGIC ECOSYSTEM ACOUSTIC-TRAWL SURVEY PELACUS 0319 SURVEY REPORT

Instituto Español de Oceanografía

Funded by the EU through the European Maritime and Fisheries Fund (EMFF) 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.

Unión Europea
Fondo Europeo Marítimo y de Pesca (FEMP)

Index

TECHNICAL SUMMARY

Institution: INSTITUTO ESPAÑOL DE OCEANOGRAFÍA

Survey name: PELACUS-IBWSS 0319

Vessel name: Miguel Oliver (70 mn length, 2x1000 kW diesel-electric)

Area: 7j-8a-8b (partial coverage) and 8c and 9a-N25/03/2018-18/04/2018

Dates:

- Acoustic calibration (Vigo bay): 13-14/03
- Route to Porcupine Seabight: 15-18/03
- Prospecting at Porcupine Seabight: 19-22/03
- Prospecting at French slope: 23-26/03
- Prospecting Spanish waters: 27/03-19/04

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 8 nmi apart from 30 to 1000 isobath

Main sampling procedures EK-60 at 18-38-70-120-200 kHZ acoustic frequencies. Only day time in Spanish waters; 24/24hs in northern waters

CUFES, Intake at 5 m depth, 600 l min^{-1}. 3 nmi/sample

Pelagic fishing stations: Gloria hexagon 752+ HOD352 in northern waters, 63.5/51 pelagic trawl in Spanish waters

Marine mammals and birds observations

Manta trawl hauls (microplastics).Tows mostly done at the same time as the fishing tows

Hydrological characterisation. CTD in northern waters. Plankton+water samples+CTD in Spanish waters

Personnel
1st leg
Santander/A Coruña
Dates: 23/03 to 06/04

CALIBRATION:

URBANO AUTÓN DÍAZ
PABLO CARRERA LÓPEZ
PILAR CORDOBA SELLES
IRENE PILAR DÍEZ GARCÍA
RÓISÍN SINÉAD DONOVAN
ANGEL FERNÁNDEZ LAMAS
ISABEL CRISTINA GONZÁLEZ GLEZ.
ROSENDO OTERO PINZÁS
PAULA SANCHO MARTÍNEZ

1st leg (Porcupine):

URBANO AUTÓN DÍAZ
ELISA CALVO MARTÍN
PABLO CARRERA LÓPEZ
JESSICA DAVILA PRADO
IRENE PILAR DÍEZ GARCÍA
RÓISÍN SINÉAD DONOVAN
ANGEL FERNÁNDEZ LAMAS
ANTONIO GÓMEZ GONZÁLEZ
ISABEL C. GONZÁLEZ GLEZ
MARÍA JESÚS LAGO ROUCO
YVETTE LÁZARO MARTÍN
EDUARDO LOPEZ DÍAZ
JOSÉ LUIS MURCIA ABELLÁN
ROSENDO OTERO PINZÁS
PABLO SÁNCHEZ HERMOSÍN
PAULA SANCHO MARTÍNEZ
ANTONIO JOSÉ SOLLA COVELO
SANDRA VLLAR HERBELLO

	SANTANDER-CORUÑA (27/03-6/04)		**CORUÑA-VIGO (7/04-19/04)**	
No	**Apellidos**	**Nombre**	**Apellidos**	**Nombre**
1	CARRERA LÓPEZ	PABLO	CARRERA LÓPEZ	PABLO
2	GAGO PIÑEIRO	JESÚS MANUEL	GUTIÉRREZ MUÑOZ	PAULA
3	MURCIA ABELLÁN	JOSÉ LUIS	CARRETERO PERONA	OLGA
4	SANCHO MARTÍNEZ	PAULA	SANCHO MARTÍNEZ	PAULA
5	ANTOLÍNEZ BOJ	ANA	COSTAS SELAS	CECILIA
6	SÁNCHEZ HERMOSÍN	PABLO	SÁNCHEZ HERMOSÍN	PABLO

7	LOPEZ DÍAZ	EDUARDO	GARCÍA BARCELONA	SALVADOR
8	RODRÍGUEZ RAMOS	TAMARA	VARELA ROMAY	JOSÉ
9	FERNÁNDEZ LAMAS	ANGEL	FERNÁNDEZ LAMAS	ANGEL
10	GÓMEZ GONZÁLEZ	ANTONIO	SOLLA COVELO	ANTONIO JOSÉ
11	SOLLA COVELO	ANTONIO JOSÉ	REPARAZ	MARÍA
12	LAGO ROUCO	MARÍA JESÚS	DUEÑAS LIAÑO	CLARA
13	SÁNCHEZ BARBA	MARÍA	NOGUEIRA FUERTES	RAQUEL
14	IGLESIAS ÁLVAREZ	EVA	OLMO BALLESTEROS	CRISTINA
15	MALLOU TATO	GLORIA	GONZÁLEZ DEQUIDT	JAVIER
16	VIDAL RODRÍGUEZ	ANA	FERRAZ CASTIÑEIRAS	DIEGO
17	POLO SAINZ	JULIA	BLANCO GINER	Mª ANGELES
18	NAVARRO RODRÍGUEZ	MARIA ROSARIO	SALINAS AGUILERA	MIREN ITXASO
19	ARMESTO LÓPEZ	Mª ANGELES	GONZÁLEZ GONZÁLEZ	ISABEL C
20	GONZÁLEZ GONZÁLEZ	ISABEL CRISTINA	OTERO PINZÁS	ROSENDO
21	OTERO PINZÁS	ROSENDO		

Report author Pablo Carrera

INTRODUCTION

The Spanish acoustic-trawl times series PELACUS started in 1991 when R/V Cornide de Saavedra was rebuilt and a new EK-500 was also purchased. Since that and until 1996, all cruises were carried out on board this vessel except that of 1995, called IBERSAR, which has been undertook on board R/V Noruega. In 1997 the series changed from R/V Cornide de Saavedra to the new R/V Thalassa (TH), a French/Spanish research vessel specially conceived for fish surveys.

This vessel was also used for the French acoustic survey (PELGAS). Survey strategy methods and analysis were established at the Planning Group for Acoustic Surveys in ICES Sub-Areas 8 and 9 met for the first time in 1986. Since 1998 the Planning Group, only attended until then by Spanish and Portuguese members, incorporated French scientists. As a first joint recommendation, the Planning Group agreed that acoustic data will be only recorded during day time, living the night time available for physical, chemical and plankton characterisation of the water column. This recommendation was implemented in 1998. In 2000, under the frame of the DG FISH, PELASSES project started, and the spring acoustic surveys incorporated the Continuous Underwater Fish Egg Sampler (CUFES) together with the routinely collection of other systematic measurements (SSS, SST, Flourometry, CTD+rossete casts, plankton hauls to determine primary production or dry weight at different sizes among other biological descriptors of the water column, etc.). In addition, the 120 khz frequency started to be used to help discriminate between different fish species. During this period, acoustic estimates were also provided for non commercial species such as bogue or boar fish. In 2007, a new team used the survey as a platform to obtain data on presence, abundance and behaviour of top predators (marine mammals and seabirds). Since 2007 data are also routinely collected on floating litter (type, number and position) and on other human pressures such as fishing (number of boats, type, activity, etc.).

Since the beginning of the time series (1982), biological data (length, weight, sex, maturity, etc.) and samples have been taken from individual fish taken by the hauls to provide biological data and to construct length-weight and age-length relationships needed for the assessment of first sardine and later, all the other target species. Fish stomachs have also been routinely examined to quantify the trophic relationships between species and isotope analysis of muscle of sardine and anchovy have been also carried out the study their trophic position.

Overall the evolution of this time series made it an essential platform for integrated data collection following the requirements posed by the Ecosystem Approach to Fisheries Management (EAFM), the Marine Strategy Framework Directive (2008/56/CE) and the revised CFP .

In 2013 R/V is substituted by the Spanish vessel Miguel Oliver (MO), built in 2007. In addition the surveyed area was extended from the 200 m isobath to the 1000 m one in order to make available the bulk of the blue whiting distribution. Intercalibration done in 2014 (acoustic and fishing trawl devices) gave rather similar results for both vessels although a slight difference between fishing gear performance was noticed. That used by R/V Miguel Oliver had a small rockhooper which made accessible much fish located close to the sea bed (such as demersal species together with more horse mackerel) than that of the R/V Thalassa. In order to make comparable both fishing gears, the rockhooper was substituted in 2015 by a footrope chain, similar to that of the R/V Thalassa.

In 2018, on account the Spanish duties related to DCF, the IEO has joined the International Blue Whiting Spring Survey (IBWSS). Therefore, the ICES Working Group of International Pelagic Surveys acknowledged this new collaborator and agreed B/O Miguel Oliver will cover the off-core spawning area located southwest of Porcupine Bank (e.g. Porcupine Seabight). This area was surveyed between 14th and 20th March, when the vessel sailed towards Santander harbour to start the normal PELACUS coverage. Nevertheless, it should be noted that due to time constraint, the grid was anticlockwise prospected, thus optimizing survey time but covering in opposite way as normally performed.

This WD provides acoustic estimates, distribution and mean size for four of the eleven main pelagic species found in northern and northwestern Spanish waters (mackerel, mackerel, blue whiting and boar fish) and assessed within the frame of the ICES WIDE. Besides, an estimation of the Müeller's pearlside is also provided.

OBJECTIVES

Main objective of this survey was to achieve a biomass estimates by echointegration of the main pelagic fish distributed in the Spanish Cantabrian and NW waters (sardine, anchovy, horse mackerel, mackerel, blue whiting, bogue, boar fish, chub mackerel) and also in Porcupine Seabight and in two areas of the French slope. Together with this, the following objectives were also foreseen:

- Determine the distribution area and density of the main fish species
- Determine the main biological characteristics (length, sex, maturity stage and age) of the main fish species
- Estimate the relative abundance and distribution area of sardine, anchovy, mackerel and ahorse mackerel eggs by means of CUFES
- Characterise the main oceanographic conditions of the surveyed area
- Determine the distribution pattern, taxonomic diversity and dry biomass by size classes of the plankton population presented in the surveyed area.
- Determine the natural abundance of N^{15} in sardine, anchovy and mackerel and their trophic position.
- Determine the distribution area and density of apical predators
- Determine the distribution area and density of marine microplastics litter
- Study the fecundity parameters variability in the surveyed area of mackerel

MATERIAL AND METHODS

The methodology was similar to that of the previous surveys and according to the survey protocols agreed at both ICES WGIPS and WGACEGG. Details on survey design and analysis are given in a) for International Blue Whiting Spring Survey (IBWSS) these are at http://www.ices.dk/sites/pub/Publication%20Reports/ICES%20Survey%20Protocols%20(SISP)/SISP%209%20Manual%20for%20International%20Pelagic%20Surveys%20(IPS).pdf updated to version 1.01 at the WGIPS sharepoint. For PELACUS (Spanish waters) these are summarised in Resumido en Massé, J., Uriarte, A., Angélico, M. M., and Carrera, P. (Eds.) 2018. Pelagic survey series for sardine and anchovy in ICES subareas 8 and 9 – Towards an ecosystem approach. ICES Cooperative Research Report No. 332. 268 pp. https://doi.org/10.17895/ices.pub.4599, with supplementary material at https://www.ices.dk/community/groups/documents/forms/allitems.aspx?rootfolder=/community/groups/documents/wgacegg/crr+332+supplementary+online+material&view=%7B49a2efde-3932-4900-a03d-70258239f39e%7D

Briefly, in northern areas (7j and 8ab) tracks were placed at 20 nmi, accounting the spatial distribution pattern of blue whiting, and steaming 24/24 hours. In the Spanish area, sampling intensity was higher, with tracks located at 8nmi and only steamed during day hours. In both areas tracks had a random start. The survey progressed southwards in northern areas while in the Spanish one was westward. Figure 1 shows the survey track together with CTD/Plankton stations.

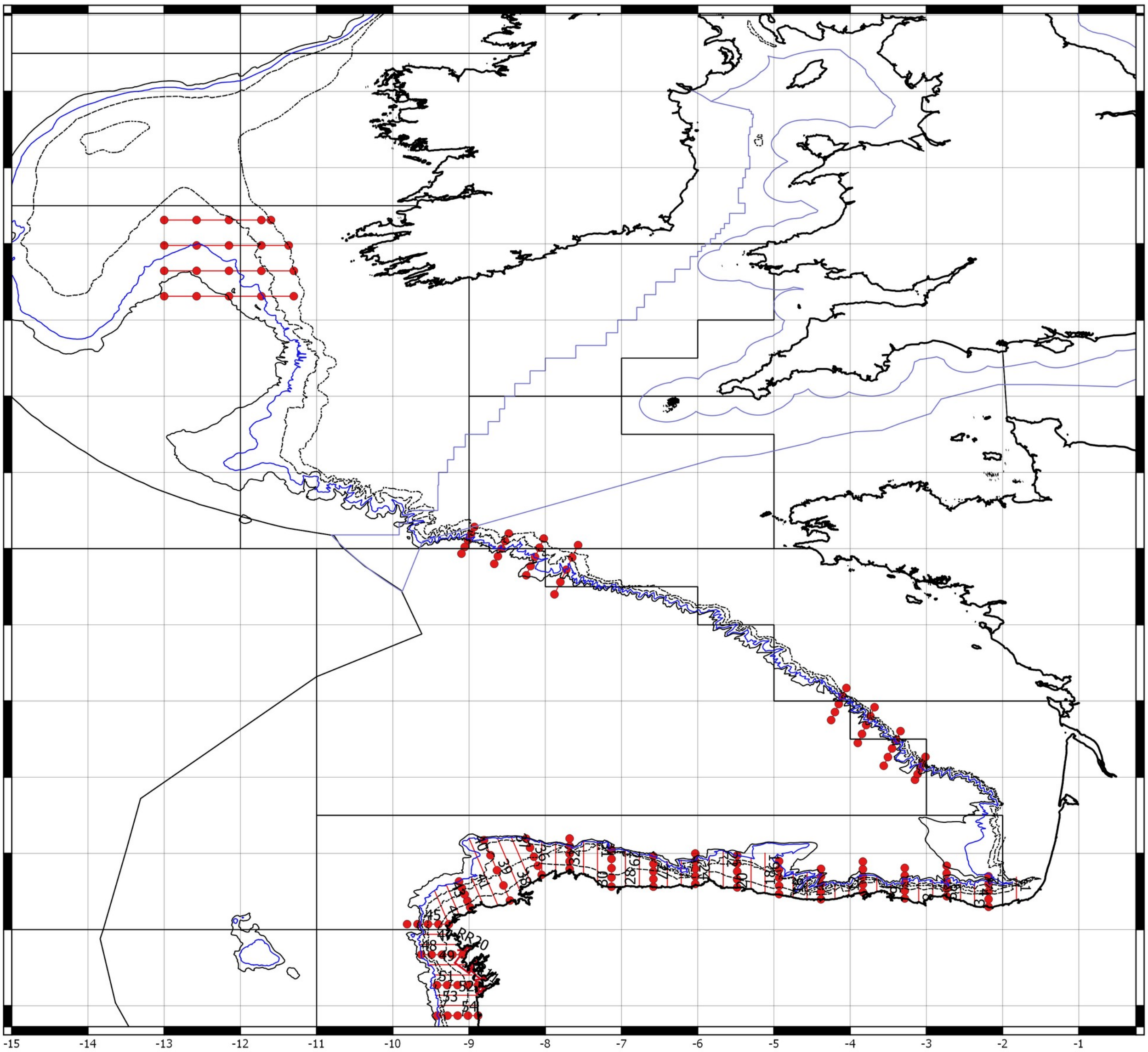


Figure 1 Survey track (foreseen CTD and plankton stations included)

Sampling procedures

Acoustic

Acoustic equipment consisted on a Simrad EK-60 scientific echosounder, operating at 18, 38, 70, 120 and 200 kHz. All frequencies were calibrated according to the standard procedures (Foote et al 1987). The elementary distance sampling unit (EDSU) was fixed at 1 nm. Data were stored in raw format and post-processed using SonarData Echoview software (Myriax Ltd.) (Higginbottom et al , 2000). All echograms were first scrutinized and also background noise was removed according to De Robertis and Higginbottom (2007); besides, when needed, bad pings, with significant bubbles sweptdown, were removed using an adaptation of the method described in Honkalehto et al. (2011)

Main echosounder settings are shown in table 1

Transducer power	2000/2000/1000/200/90 W for 18/38/70/120/200 kHz
Pulse duration	1.024 ms
Ping rate	Maximum, in case of ghost echo-bottom, change to time interval starting at 0.30 ms
Range (echograms, files)	200 m in shallower area (i.e. depth<100m); 500 when depth is between 100-200m; and 1000 when depth is>500m

Table 1: Main echosounder settings.

Acoustic tracks were steamed at 10 knots.

Fishing stations

Fishing stations are used for both NASC allocation and length analysis. Therefore, they were located on account the results obtained during the acoustic prospection (i.e. opportunistic accounting the echotraces).

Two fishing gears were used. An adaptation of a “grandes mailles”, with a vertical opening of about 20 m and around 30 m horizontal one,was used as main fishing gear. As general rig, 400 kg of clump weight were put at each side of the set back (2 m lower wing). Dyneema bridles (wings) had 100 m, but shorten to 50 m in shallower waters. Besides a set of Apollo polyice doors were used with 4.0 m^2 and 1400 kg weight; in shallower waters, these were substituted by similar ones with only 3.5 m^2 and 750 kg weight. Gear performance was controlled using a wired Simrad Sonar FS20 net sounder. Close to the codend a MARPORT trawl speed explorer SPE155 with the Scala system was placed near the codend in order monitor the flux in relation to the towing speed and the catchability (e.g. the relation between the number of recorded schools at the mouth of the net and those recorded at the codend together with those escaping below the footrope.

CUFES

CUFES system uses an internal pumping system with the intake located at 5 m depth. The sea water goes first to a tank of about 1m^{3}before to be pumped towards the concentrator.

Samples from CUFES were collected every three nmi while acoustically prospecting the transects. Once the sample is taken it is fixed in a buffered 4% formaldehyde solution. Anchovy, mackerel, horse mackerel and sardine eggs are sorted out and counted before being preserved in the same solution. The remaining ichthyoplankton (other eggs and larvae) are also preserved in the same way.

Plankton and hydrological characterisation

Continuous records of SSS, SST and flourometry are taken using a SeaBird Thermosalinograph coupled with a Turner Flourometer. Plankton and CTD and bottle rosette for water samples casts are performed at night. Five stations are placed over the transects, which are those of the acoustic prospection but that are extended onto open waters until the 1000-2000 m isobaths. The stations are evenly distributed over the surveyed area at a distance of 16-24 nmi.

Plankton was sampled using several nets (Bongo, WP2 and CalVet). Fractionated dried biomass at 53-200, 200-500, 500-1000 and >2000 µm fractions was calculated together with species composition and groups at fixed strata from samples collected at the CTD+bottle rosette carousel (pico and nanoplankton, microplankton and mesozooplankton).

Water samples were stored at -20°C for further dissolved nutrients analysis (NO_3, NO_2, P, NH_4^+, SiO_4).

Top predator observations

Three observers placed at the bridge of the vessel at a height of 16 m above sea level work in turns of two prospecting an area of 180° (each observer cover a field of 90°). Observations are carried out with the naked eye although binoculars are used (7x50) to confirm species identification and determine predator behaviour. Observations are carried out during daylight while the vessel prospects the acoustic transects. Observers record species, number of individuals, behaviour, distance to the vessel and angle to the trackline and observation conditions (wind speed and direction, sea state, visibility, etc.). Observers also record presence, number and type of boats and type, size and number of floating litter. The same methodology is used on the PELGAS surveys and both observer teams shared a common database.

Marine Microplastic Litter characterisation

A “manta net neuston sampler” was used. This trawl device has a collector of 350µm. Tows were performed for 15 min at 4 knots speed. The samples were evenly distributed along the surveyed area.

Fish Biological sampling

Catches from fishing trawl hauls were sorted and weighted. All fish species were measured (total length, 1cm classes for all species except clupeids measured at 0.5 cm). When needed, random subsamples of 80-200 specimen were taken. For the main species an additional biological sampling was done for weight, age, sex, maturity stage analysis, complemented by stomach contents analysis (sardine and anchovy); N^{15} isotope analysis (sardine, anchovy and mackerel); sampling for gonad microscopic maturity analysis (mackerel); and, sampling for estimation of fecundity adult parameters (sardine). Besides, specific sampling was also done on horse mackerel for genetic purpose.

Data analysis

NASC Allocation

The quality of the hauls for ground-truthing of the acoustic data was classified on account of weather condition, haul performance and the catch composition in numbers and the length distribution of the fish caught as follows (table 2):

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

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

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. $\sigma_{l,p}$ is the backscattering cross-section at length l for a particular 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,

$$\sigma_{l,p} = p_l * \sigma_l$$

$$\sigma_p = \sum_l \sigma_{l,p}$$

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 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 following table:

Sp	**b_{20}**	**Ref**	**Observations**	**Otherb_{20}**	**Ref.**
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 respect.

Table 4.- b_{20} values from the length target strength relationship of the main fish species assessed in PELACUS survey (WHB is blue whiting; MAC-mackerel; HKE- hake; HOM- horse mackerel; PIL-sardine; JAA-blue jack mackerel (*Trachurus picturatus*); BOG-bogue (*Boops boops*); VMAS-chub mackerel (*Scomber colias*); BOC-board fish (Capros aper); and HMM-Mediterranean horse mackerel (Trachurus mediterraneus))

When possible, direct allocation was also done, accounting for the shape of the schools and also the relative frequency response (Korneliussen and Ona, 2003, De Robertis et al, 2010). Due to the aggregation pattern found in the surveyed area, fish schools were extracted using the following settings:

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 m
Distance mode	Vessel log
Main frequency for extraction	38/120 kHz

Table 4: Main morphological and backscattering energy characteristics used for schools detection

For all school candidates, several of variables were extracted, among them the NASC (s_A, m^2/nmi^2) together with the proportioned region to cell (ESDU, 1 nmi) NASC and the s_V mean and s_V max and 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 38 and 120 kHz 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 $s_{A(fi)}/s_{A(38)}$, being f_i the $s_A$values for 18, 70, 120 and 200 kHz.

Echointegration estimates

Once backscattering energy was allocated to fish species, the spatial distribution for each species was analysed taking into account both the NASC values and the length frequency distributions (LFD) to provide homogeneous assessment polygons. These are calculated as follows: an empty track determine the along-coast limit of the polygon, whilst three consecutive empty ESDU 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 which were 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 strata. Spatial distribution was then analysed within each stratum and finally mean s_A value and surface (square nautical miles) were calculated using a GIS based system (Q-gis). These values, together with the length distributions, are used to calculate the fish abundance in number as described in Nakken and Dommasnes (1975) (see previous section for further details). Estimatesfor each species was carried out on each strata (polygon) using the arithmetic mean of the backscattering energy (NASC,

s_A) attributed to each fish species and the surface expressed in square nautical miles using the following formula:

$$\rho_l = \frac{NASC_l}{\sigma_l}$$

$$N_l = \rho_l * A_p$$

where $\rho_l$is the areal density of fish (numbers per square nautical mile in length group l and the total number for length group l (N_l) within each strata is calculated the product ρ_l of times the total area of the strata (A_p)

Numbers were converted into biomass using the length weight relationships derived from the fish measured on board. For purposes of comparison, results are given by ICES Sub-Divisions (9aN, 8cW, 8cEw , 8cEe and 8b)

Otoliths are taken from anchovy, sardine, horse mackerel, blue whiting, mackerel and hake (*Merluccius merluccius*) in order to determine age and to obtain the age-length key (ALK) for each species and area.

Centre of gravity

For each main specie, 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 of the NW Spanish area, instead longitude and latitude, we have used depth and a new variable called "distance from the origin" calculated as follows:

- Locations below 43º10 N: distance is calculated as (Lat-41.5)*60, being *Lat* the latitude of the middle point of any particular EDSU within this region.
- Location between 43º10' N and 8ºW (i.e. NW corner): distance is calculated as ((I.Lat-43.18333)^2+(*I.Lon**(cos(I.Lat*pi()/180))-6.714441)^2)$^{0.5}$)*60+(43.1833-41.5)*60, being *I.Lat*and *I.Lon*the coordinates at which a normal straight line from middle point of any particular EDSU within this region intercepts a line defined by the following geographical coordinates: 43º11N-9º12.50'W and 43º39.50'N-8º06'W.
- Location between 8ºW and the Spanish-French border: distance is calculated as 158.329+(Lon+5.8755324052)*60, being *Lon* the corrected longitude (longitude multiplied by the cosine of the mean latitude).

Uncertainty estimates

Together with the use of STOX for the IBWSS data set (see International Blue Whiting Spawning Stock 2019 survey report for further details), this year the uncertainty linked to both the spatial distribution and the NASC allocation method using the trawl hauls results will be calculated using Echo-R. However, this method has to be first evaluated at the WGACEGG in November.

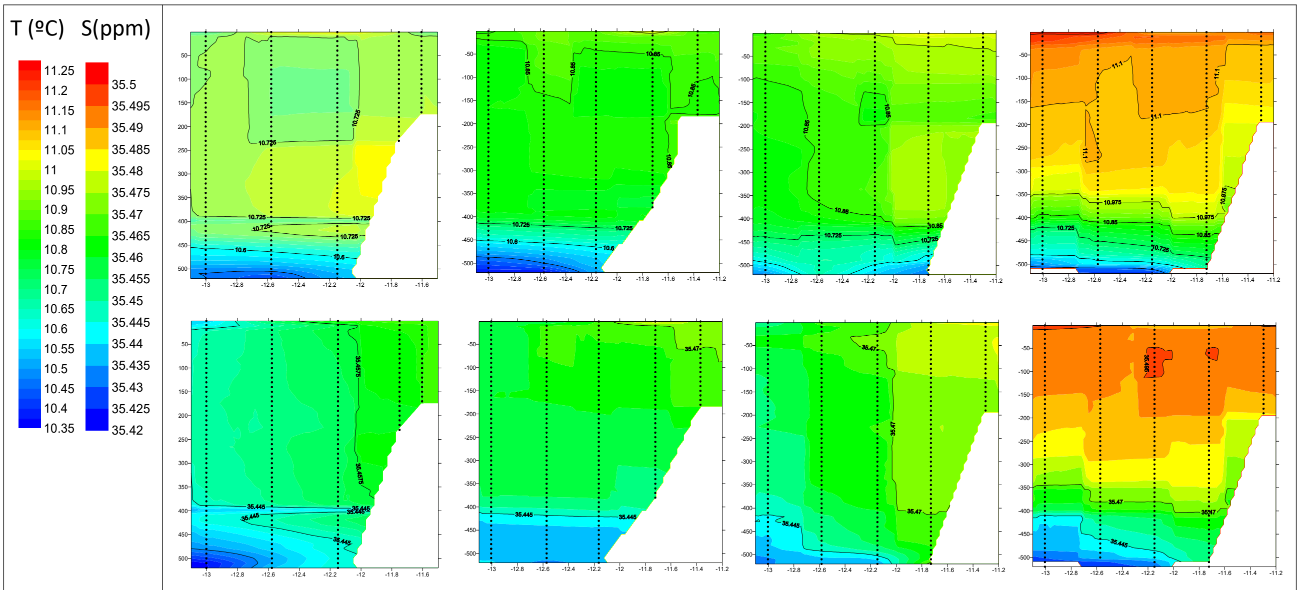
RESULTS

Porcupine area

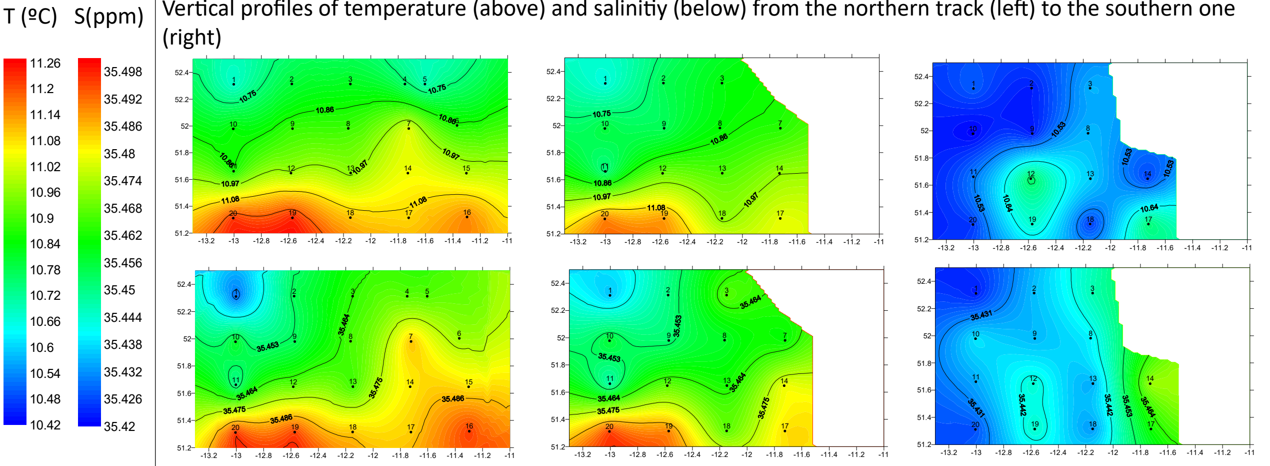
Blue whiting data (acoustic+fishing stations) were submitted to PGNAPES and to the ICES Acoustic portal, and used for the overall SSB estimates of this species.

<u>Oceanographic conditions</u>

Figure 2 is showing vertical profiles of temperature and salinity and horizontal slides at 10, 250 and 500 m depth contours. Warmer and saltier waters were found in the southern part. The bulk of the blue whiting distribution is distributed below 10.75ºC



Vertical profiles of temperature (above) and salinitiy (below) from the northern track (left) to the southern one (right)



Horizontal profiles of temperature (above) and salinitiy (below) at 10 m(left), 250 m (medium) and 500 m (right) depth

Fishing stations

5 fishing station were performed; 4 on blue whiting and the fifth to identify pearlside in medium waters. Small fish were located at the eastern part, close to the slope while the bulk of the distribution was composed by bigger fish with a mode located at 26 cm as shown in figure 3 and table 5.

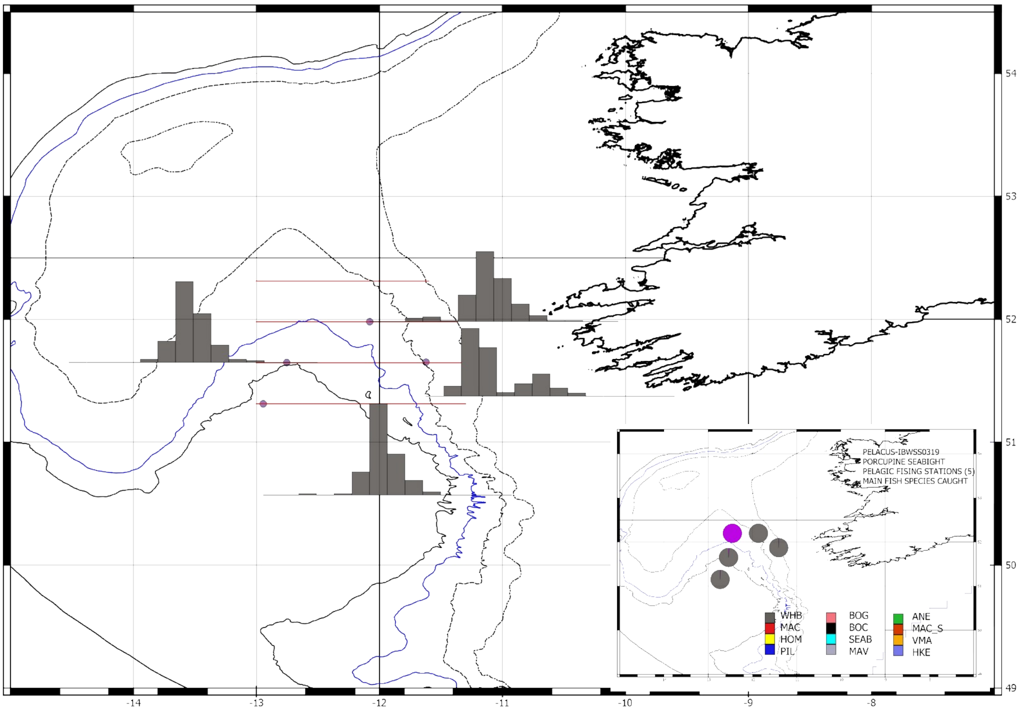


Figure 3: Position of the fishing station and proportion of catches (grey, blue whiting; magenta peralside)

Table 5: Catch results on fishing station performed in Porcupine and the Bay of Biscay

	TOTAL CATCH (Kg)	No ind.	No Fishing st	Sample weight (kg)	Measured fish	Mean length	%PRES	% Catch_W	% Catch_No
WHB	1947	19095	5	59	668	25.68	55.56	84.18	57.58
MAC	355	1048	1	87	255	36.24	11.11	15.36	3.16
BOC	0	90	1	0	90	5.00	11.11	0.01	0.27
MAV	10	12927	5	0	254	4.65	55.56	0.45	38.98
Total	**2313**	**33160**	**9**	**146**	**1267**				

Acoustic estimates

Figure 4 shows the blue whiting acoustic density. This species occurred in a continuous layer located at 500m depth as show in figure 5.Both the density and the range were higher than that observed in the previous year. In total, $308*10^3$ mt, over an area of $5.7*10^3$ nmi^2, was assessed. This result in a significant increase from the previous year ($59*10^3$ mt, but in a higher prospected area $7.0*10^3$ nmi^2). Main change dealt with the thickness and density of the blue whiting layer. The distribution seemed to expand southwards but the lack of time did not allow to survey it.

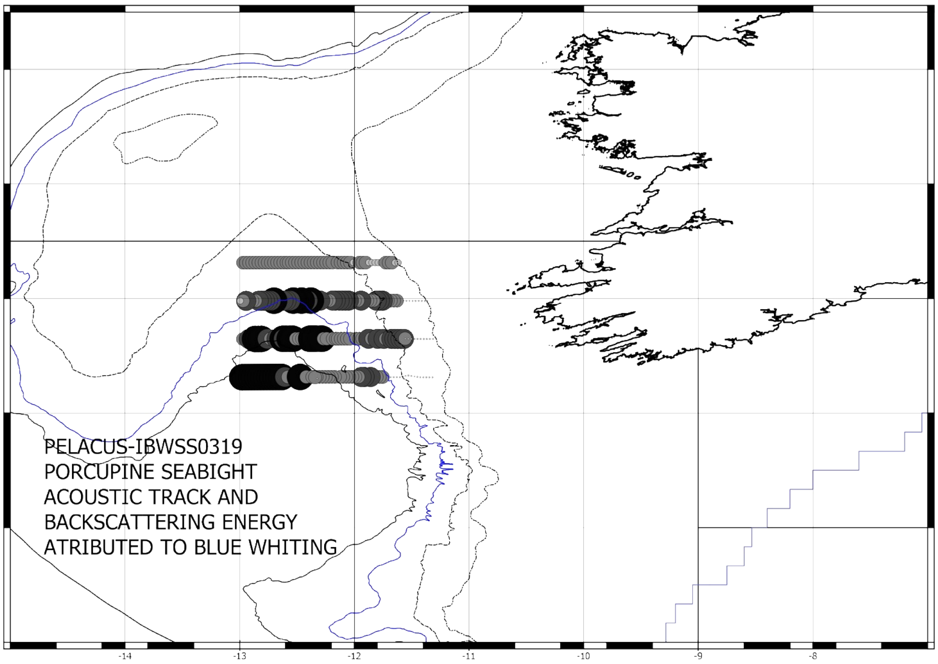


Figure 4: Blue whiting distribution

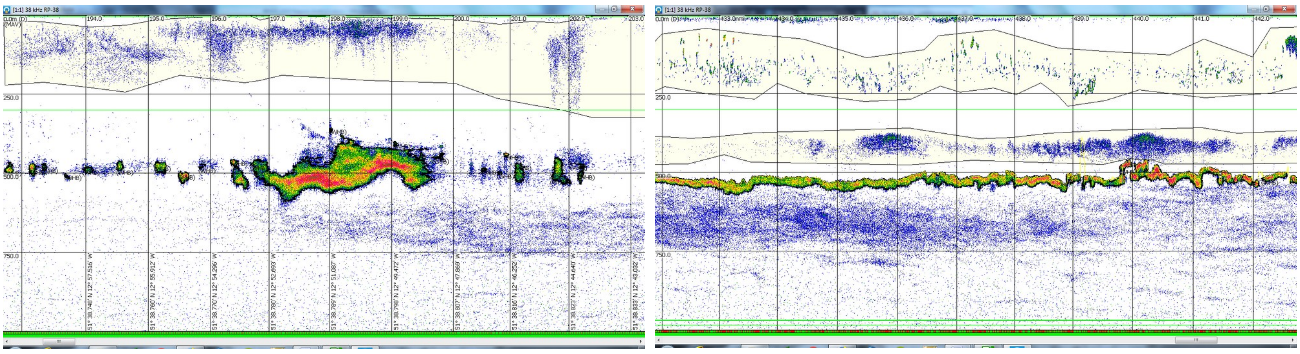


Figure 5: Blue whiting echograms in Porcupine Seabight area. Vertical banding represents 1 nmi; vertical binning at 250 m intervals

Length distribution ranged from 18 to 37 cm, with a clear mode at 27 cm, the bulk belonging to age group 5. for the whole area coverd by IBWSS, the total biomass was estimated to be 4.198 million tonnes, slightly higher than that estimated previous year, but this increase was due to the vegetative growth as long as the number of individuals decreased. The bulk located at the Rockall Trough and the second hot spot in Porcupine, as shown in figure 6.

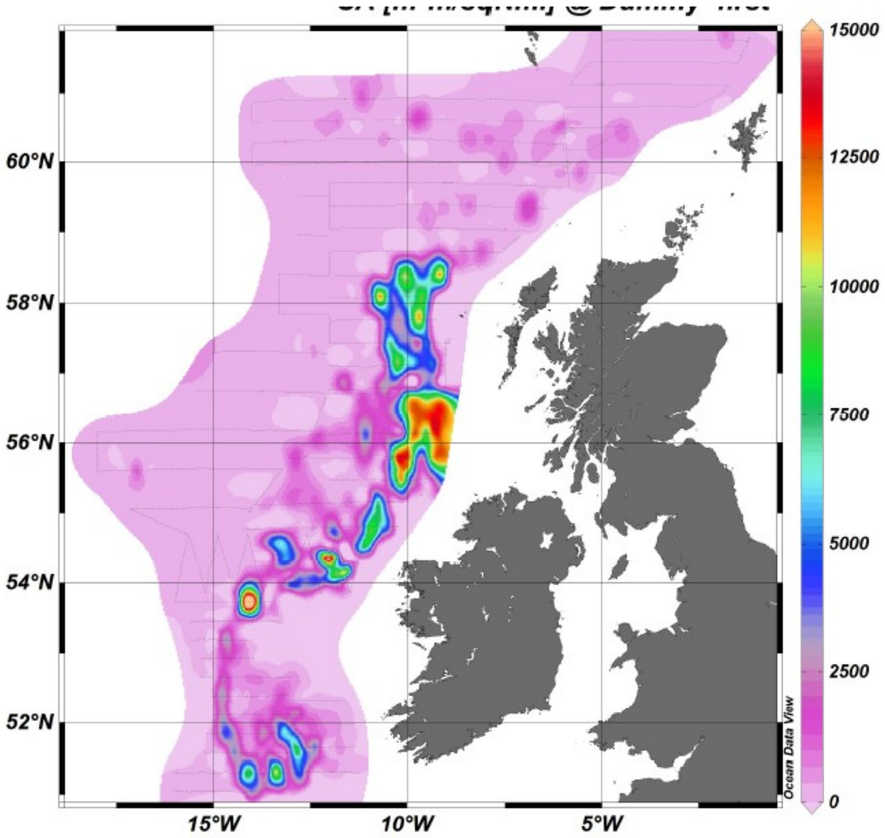


Figure 6: Map of acoustic density (s_A m^2/nmi^2) of blue whiting during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2019.

Blue whiting in the Bay of Biscay

Two areas were covered in the Bay of Biscay. Densities were weaker than those observed in the Porcupine Seabight and also depth was different, with blue whiting occurring at around 300 m depth, although the mean length was similar (figure 7ab).

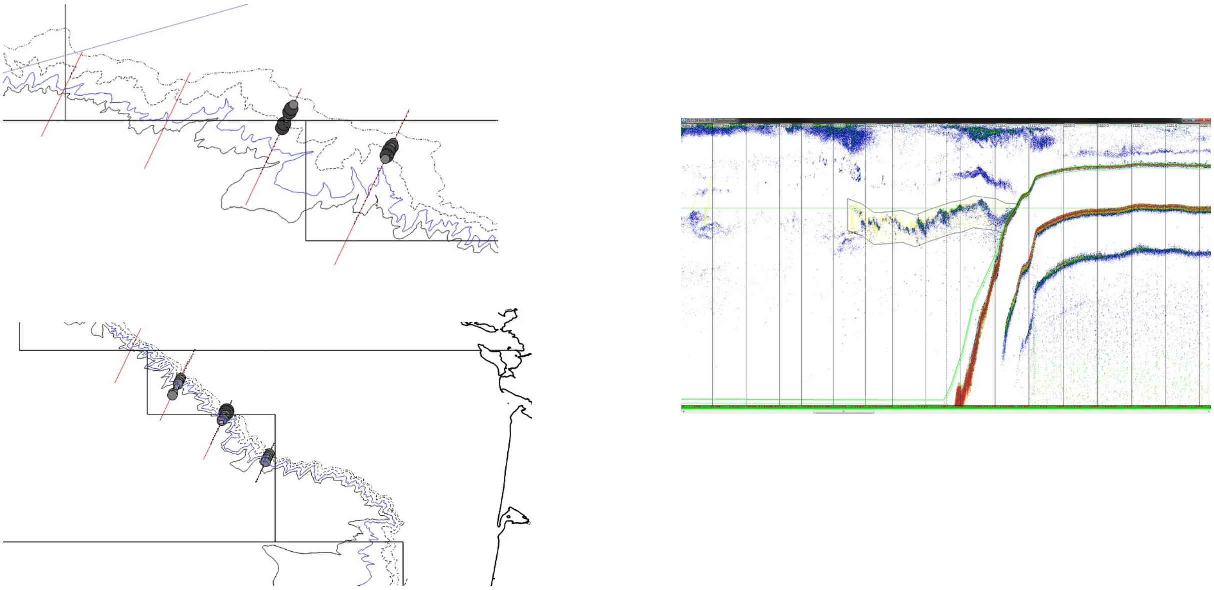


Figure 7: Left: Map of acoustic density (s_A m^2/nmi^2) of blue whiting in the Bay of Biscay; and right echogram of the blue whiting layer recorded in the Bay of Biscay.

CUFES

79 CUFEs stations were done off Iberian Peninsula (41 in Porcupine Seabight; 41 in north Bay of Biscay; and 22 south Bay of Biscay). Only in south Bay of Biscay the amount of egg counts was important, with more than 16 thousand eggs (84 egg/m^3; figure 8) of mackerel. On the contrary, neither anchovy nor sardine eggs were collected in this area, while for horse mackerel only few were found in Porcupine Seabight.

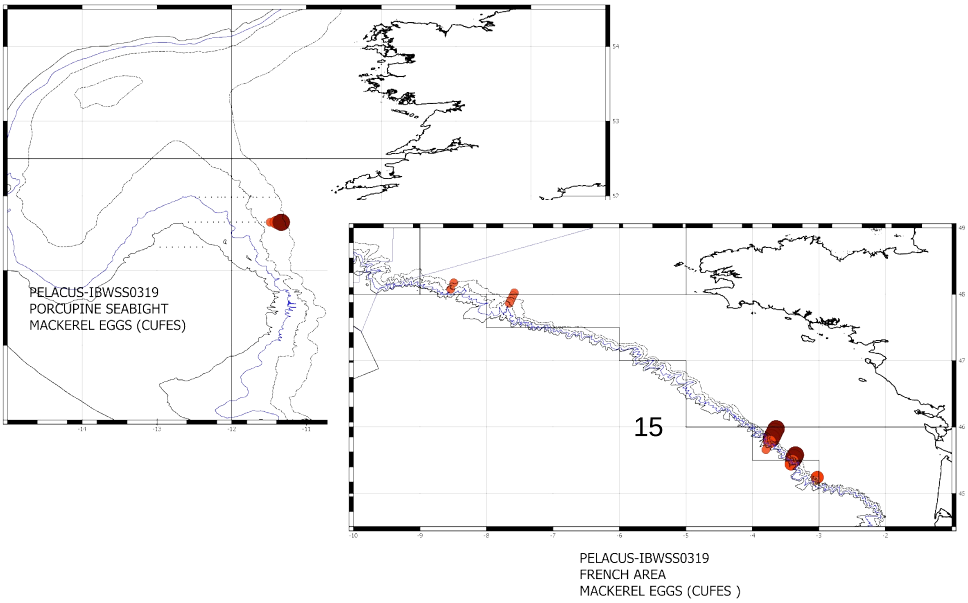


Figure 7: Map of egg density (egg/nmi^3) of mackerel blue whiting in Porcupine Seabight (left) and the Bay of Biscay (right)

Iberian Peninsula

The survey started on 27th March and ended on 19th April. Figure 8 shows the time progression of the survey. The area was covered in 24 days, although the acoustic track was surveyed in only 18 days. The remaining days were used either for extra time for fishing prospecting, navigation between first and second leg and also two days were lost due to bad weather conditions. Besides one of the tracks was removed and other 7 were shortened due to the lack of time. Finally it should be noted that some of the tracks were prospected before the wind in order to avoid signal attenuations due to bubbles swept-down.

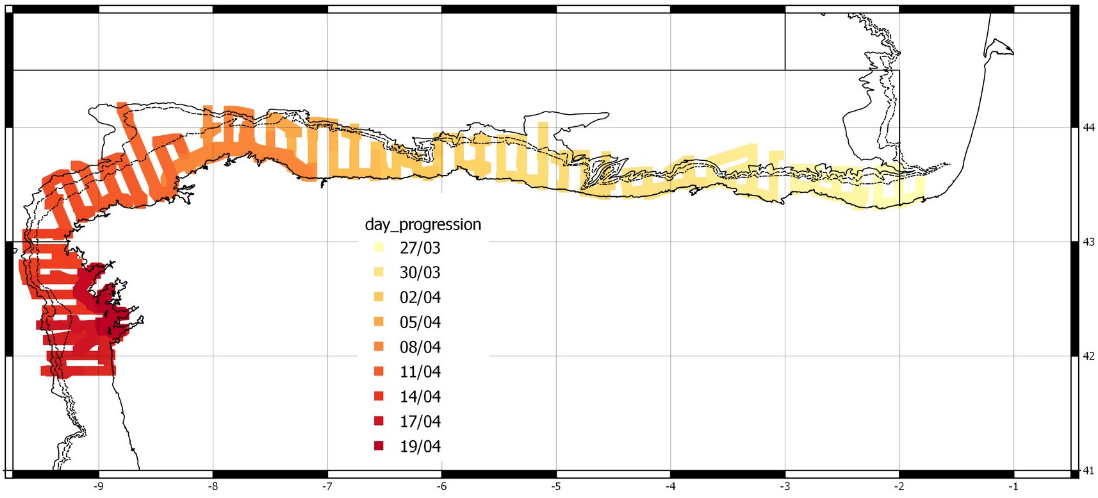


Figure 8: Time progression during PELACUS 0319

<u>Oceanographic conditions</u>

Sea surface temperature ranged from 12.8ºC to 16ºC, with the warmer waters located in 9aN and the coldest in the western part of the Cantabrian sea, between Cape Peñas and Coruña. On the other hand there is a trend in salinity from the western part, where the more saltier waters were found, towards the eastern part, where the waters are in general less saltier; besides, the influence of river plumes is evident at the inner part of the Bay of Biscay and in Rias Baixas (coastal waters of 9aN); besides, coastal waters in Cantabrian area have also fresher waters. (figure 9). According to this preliminary result, the spiciness (Flament 1989), used as tracking variable to see the influence of warm and salty waters, coming from the Iberian Poleward Current (IPC), would be located in Galicia, between Cape Fisterra and Estaca de Bares, thus a westward than the one calculated in previous year.

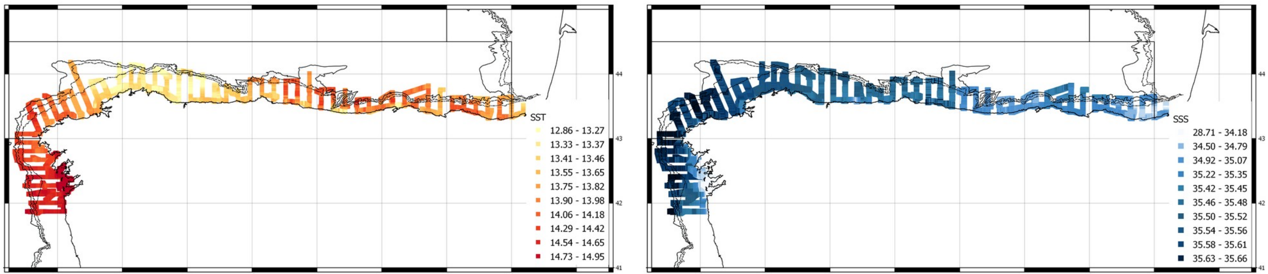


Figure 9: Sea surface temperature (left) ans salinity (right) recorded from thermosalinograph during PELACUS 0319

Fishing stations and NASC allocation

A total of 46 fishing were carried out, yielding of about 60 mt of fish. Of them, 83 corresponding to mackerel (52% in number), which was present in 80% of the fishing stations. Sardine was located either at the inner part of the Bay of Biscay and in 9aN, in similar distribution to that found in 2018, with some patches in coastal waters, close to the influence of the river plumes. It is also noticed the presence of horse mackerel in the western part (8c west and 9aN), and also at the inner part of the Bay of Biscay. On the contrary, chub mackerel was only found at eastern part of the surveyed area. Figure 10 and table 6 summarise the major findings.

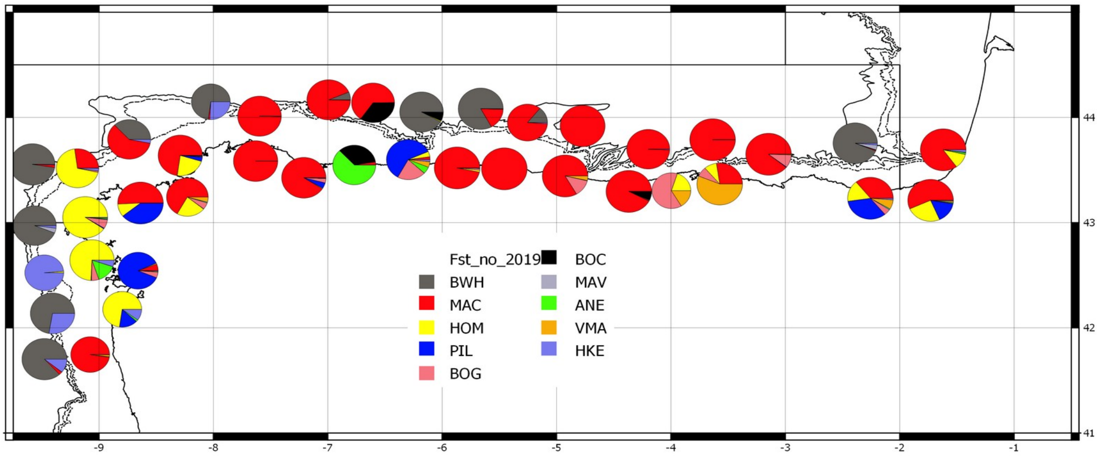


Figure 10: Fishing stations and catch composition (% in number of fish caught). WHB-blue whiting; MAC-mackerel; HOM-horse mackerel;PIL-sardine; BOG-bogue; BOC-boarfish; MAV-müller's pearlside; ANE-anchovy; VMA-chub mackerel; and HKE-hake.

Table 5: Summary of catch composition

	TOTAL CAP (Kg)	No ind.	No Fishing st	Sample weight (kg)	Measured fish	Mean length	%PRES	% Catch_W	% Catch_No
WHB	1287	19825	16	103	1544	22.10	34.78	2.14	7.27
MAC	49743	142221	37	1616	4880	35.41	80.43	82.56	52.16
HKE	133	1379	37	123	1267	23.41	80.43	0.22	0.51
HOM	2590	33258	30	213	2637	19.98	65.22	4.30	12.20
PIL	4095	51905	19	163	2222	20.29	41.30	6.80	19.04
NOO	0	3	1	0	3	10	2.17	0.00	0.00
BOG	1147	7650	25	406	2205	25.01	54.35	1.90	2.81
VMA	603	3400	20	179	1036	26.86	43.48	1.00	1.25
BOC	306	5410	6	27	465	14.16	13.04	0.51	1.98
SEAB	109	376	13	100	355	26.15	28.26	0.18	0.14
ANE	211	6948	12	26	933	15.66	26.09	0.35	2.55
MAC-S	28	298	1	23	252	23.13	2.17	0.05	0.11
Total	**60251**	**272673**	**46**	**2979**	**17799**				

Not included as relevant, it should be also noted the presence of krill (*Meganictiphanes sp*) in the western part of the surveyed area and the clear decrease in pearlside.

According to this results and accounting the different echotrace characteristics, the area was divided into areas and within this areas selected fishing station were used to split echointegrated energy t those echotraces not directly allocated to a particular fish specie. 209251 m^{2}nmi^{-2} were allocated to fish a, 26% less than in the previous year. Table 6 summarises the difference by species. Major changes occurred in anchovy, with an important decreas from 32 thousand to only 2 thousands. In the same wa y pearlside has significantly decreased whereas the decrease in sardine was also important. On the contrary, it should be noted the increase of mackerel

Table 6: Differences in integrated energy (s_A, m^2 nmi^{-2}) by species between 2018 and 2019 surveys

year\specie	WHB	MAC	HKE	HOM	PIL	BOG	VMA	BOC	SEAB	MAV	ANE	TOTAL
2018	57240	11340	6276	39655	57070	33306	3238	9	1633	21931	31882	263581
2019	69255	16714	10201	38144	40444	17658	6996	3275	471	4443	1798	209251
%dif	17.35%	32.15%	38.47%	-3.96%	-41.11%	-88.62%	53.71%	99.73%	-246.83%	-393.58%	-1673.10%	-25.96%

Only 18.37 was directly allocated (table 7), most of the direct allocation were to sardine and pearlside. Mackerel, as observed in the previous year, occurred rather near bottom mixed with other fish species as revealed by the frequency response (e.g. increasing response towards higher frequencies, but without reaching the differences observed when mackerel occurs isolated) and thus, the backscattering energy should be allocated accounting the proportion found at the fishing stations.

Table 7: Differences in integrated energy (s_A, m^2 nmi^{-2}) by species between 2018 and 2019 surveys

	WHB	MAC	HKE	HOM	PIL	BOG	VMA	BOC	MAV	ANE	KRILL	TOTAL
DA	0	693	0	4988	26573	0	0	0	4437	1085	712	38488
FS	69255	16021	10201	33155	13871	17658	6996	3275	7	713	0	171150
total	69255	16714	10201	38144	40444	17658	6996	3275	4443	1798	712	209638
%DA	0.00%	4.14%	0.00%	13.08%	65.70%	0.00%	0.00%	0.00%	99.85%	60.32%	100.00%	18.36%

37 different fishing station, of those 11 where a combination of at least two were used to allocated the energy according to the Nakken and Dommasness method (table 8). The proportion of energy attributed to each specie is shown in figure 11. Mackerel, although in some cases yielded 99.5% of the total catch in number, due to the weak target strength at 38 kHz, only account for 96% of the energy and the 21% on average.

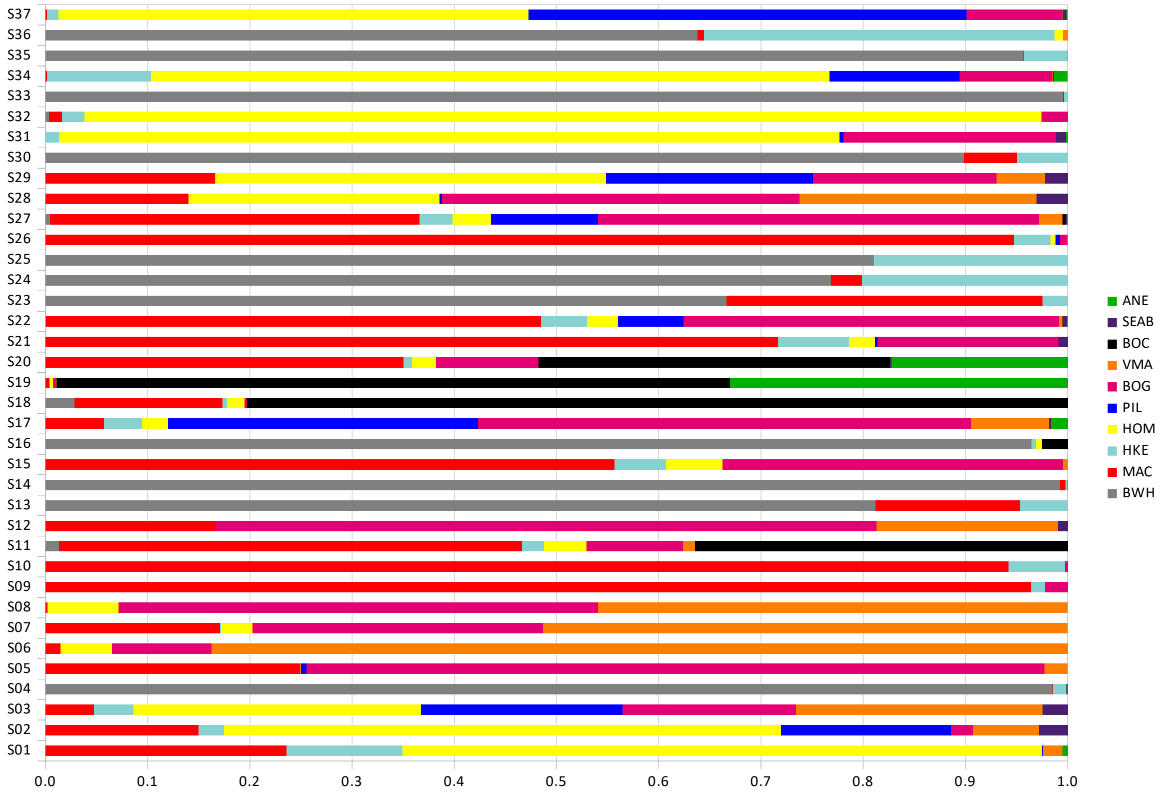


Figure 11: Proportion of backscattering energy allocated to main fish species on fishing station used for allocation purposes (see table 8 for further explanation)

Table7: Total energy allocated using fishing stations or directly allocated to single species (Fst-comb, denotes the fishing stations using in a particular region).

Fst-synt	Fst-comb	NASC	Species	NASC
S01	PE01	1353.28	PIL	26573.08
S02	PE02	4636.99	ANE	1084.65
S03	PE03	1232.35	HOM	4988.39
S04	PE04	8241.57	MAC	692.68
S05	PE05	973.53	MAV	4436.66
S06	PE06	1489.22	KRILL	712.45
S07	PE06-PE07	5236.10		
S08	PE06-PE08	2040.16		
S09	PE07	1313.04		
S10	PE07-PE09	1186.73		
S11	PE10	1339.44		
S12	PE11	4370.50		
S13	PE13	4991.29		
S14	PE15	1365.73		
S15	PE16	4614.31		
S16	PE17	2907.43		
S17	PE18	2638.43		
S18	PE19	2370.62		
S19	PE20	657.15		
S20	PE20-PE21	1020.34		
S21	PE21	462.18		
S22	PE21-PE26	252.42		

S23	PE22	1782.58	
S24	PE22-PE23	1330.14	
S25	PE23	5601.75	
S26	PE24	1579.61	
S27	PE26	6281.06	
S28	PE27	78.05	
S29	PE27-PE28-PE29	4901.55	
S30	PE30	1743.97	
S31	PE31	4090.72	
S32	PE32	2437.87	
S33	PE33	23049.23	
S34	PE34-PE37-PE40-PE46	18565.67	
S35	PE35-PE39	13891.41	
S36	PE36-PE38-PE41-PE42	12915.71	
S37	PE43-PE44-PE45	18683.73	
TOTAL		**171625.85**	**38487.91**

Mackerel assessment

Adult distribution

As seen in previous years, the bulk of the mackerel NASC distribution was found close to Cape Peñas (middle of the Cantabrian Sea), with very few fish in 9aN, confirming, thus, the Cantabrian Sea as the main spawning ground. Figure 12 is showing the evolution of the center of gravity since 2013. The amount of backscattering energy allocated this year to mackerel is above the average, only lower than that of 2014 when mackerel mainly occurred in a epipelagic layer located at around 30 m depth. However, this year the distribution area was lower but the density was higher throughout the Cantabrian sea, as shown in figure 13.

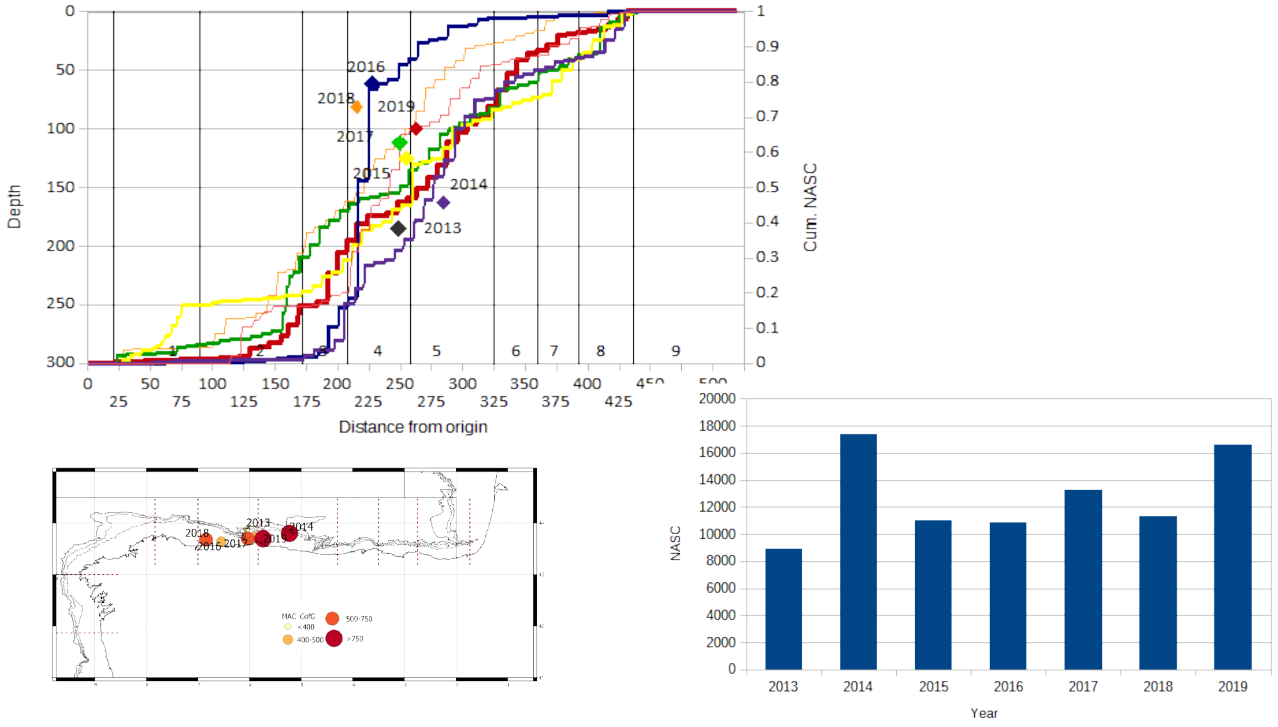


Figure 12: Above: cumulated NASC frequency along the coast and center of gravity for mackerel since 2013. Below: left, center of gravity indicating as well the biomass estimates (thousand tonnes); right panel, total backscattering energy (NASC) whiting since 2013 in the Spanish waters

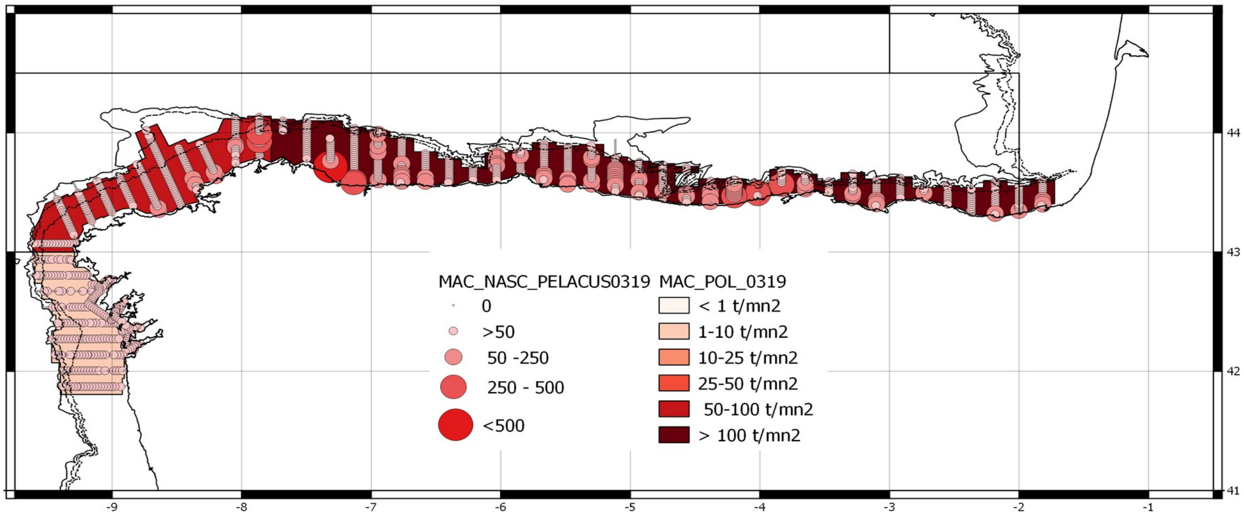


Figure 13: Mackerel spatial distribution

Assessment

A total of 905 thousand tonnes, corresponding to 2549 million fish were estimated, most of them, as expected, in central Cantabrian Sea (table 8). This estimates in significantly higher than that estimated in 2018 (557 thousand tonnes corresponding to 1640 million fish). Age group 5, corresponding to the 2014 cohort, accounted for the 30% of the abundance (28% in weight), while age group 7 has also a significant contribution. Again and as observed in previous years, only few individuals younger than 5 years were estimated (less than 10% in weight and in number, table 9 and figure 14).

Table 8: Mackerel assessment. Abundance and biomass estimates by ICES Sub-division

Zone	Area	No	Mean	Surface	Fishing st.	PDF	No (million fish)	Biomass (tonnes)	Density (Tn/nmi-2)
9a-N	9a	299	0.56	1540	P37-P38-P39-P41-P44-P45-P46	ST01	26	4769	3
	Total 9a-N	***299***	***1***	***1540***			***26***	***4769***	3
8c-W	8cW	244	10.44	2055	P24-P27-P28-P29-P30-P32-P33	ST02	376	145087	71
	Total	***244***	***10***	***2055***			***376***	***145087***	
8c-E	8cE	492	28.16	4084	P11-P12-P13-P14-P15-P16-P18-P19-P20-P21-P22-P25-P26	ST03	2148	755127	185
	Total	***492***	***28***	***4084***			***2148***	***755127***	185
	Total 8c	***736***	***22***	***6139***			***2523***	***900213***	147
	Total Spain	***1035***	***16***	***7680***			***2549***	***904982***	118

Table 9: Mackerel assessment. Abundance and biomass estimates by age group and length class

Length	1	2	3	4	5	6	7	8	9	10	11	12	Total	No fish (million)
10														
11														
12														
13														
14														
15														
16														
17														
18														
19														
20														
21														
22														
23	0.11												0.11	1
24	0.54												0.54	5
25	0.41	0.80											1.21	9
26	0.20	0.83											1.03	7
27	0.02	0.74	0.02										0.78	5
28		0.55											0.55	3
29		0.70											0.70	4
30		0.29	0.57										0.86	4
31		0.45	0.45		0.45								1.35	6
32			5.21		3.47								8.68	34
33			17.15	3.81	11.43								32.40	116
34			2.40	9.61	74.49	3.60	2.40	3.60					96.11	317
35			1.14	10.23	95.59	27.28	11.37	27.28	1.14				174.03	529
36				3.23	51.85	51.10	67.17	21.83	23.45				218.63	613
37					13.00	37.88	68.74	36.58	14.14	2.35	1.17		173.87	451
38						15.88	32.84	41.30	10.78	3.96	0.57	0.57	105.90	255
39					0.51	1.05	6.23	13.33	15.92	6.20	6.68	0.51	50.43	113
40						0.85	6.62	0.90	8.27	6.62	2.50	0.82	26.59	55
41							0.41	1.22	1.22	2.06	1.24	2.03	8.17	16
42								0.58	0.59	0.58		0.59	2.34	4
43												0.47	0.47	1
44														
45												0.23	0.23	0
Biomass (thousand t)	1	4	27	27	251	138	196	147	75	22	12	5	905	2549
%	0.14	0.48	2.98	2.97	27.71	15.21	21.63	16.20	8.34	2.40	1.34	0.58		
M. weight	113.43	152.11	262.35	300.91	310.56	348.55	363.50	364.49	384.83	433.57	434.53	484.94	337.99	
No Fish (million)	11	27	98	86	773	379	517	385	188	48	27	10	2549	
%	0.41	1.06	3.85	3.36	30.34	14.86	20.27	15.12	7.38	1.89	1.06	0.41		
M. length	25.00	27.64	33.31	34.92	35.29	36.72	37.25	37.28	37.98	39.57	39.59	41.11	36.33	
s.d.	0.88	1.84	0.87	0.88	1.04	1.04	1.11	1.42	1.50	1.23	1.02	1.61	2.14	

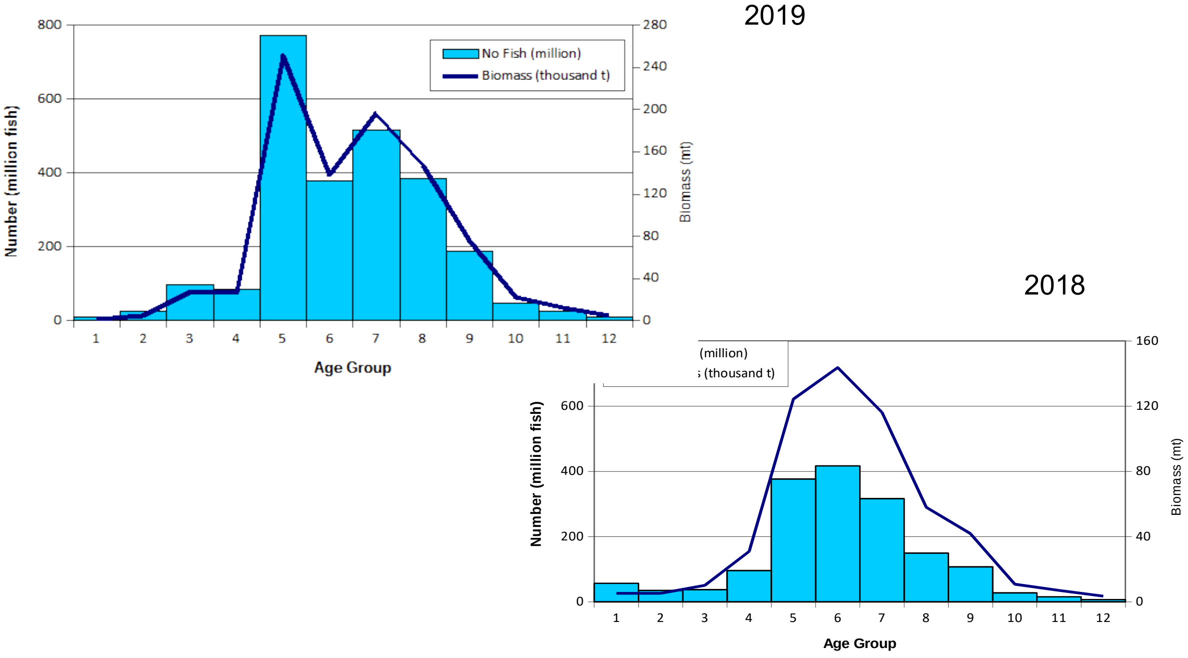


Figure 14:Mackerel abundance by age group estimated in PELACUS 0319 and in PELACUS 0318

Eggs from CUFES

A total of 367 samples were collected over the acoustic track (1143 nmi). 67% of the stations were positive for mackerel (246). Comparing to 2018 survey, the egg distribution area was lower (98% of positive stations in 2018), but the density increased from 24 eggs m^{-3} up to 36 eggs m^{-3} (97686 eggs collected in 2019 and 94315 in previous year).

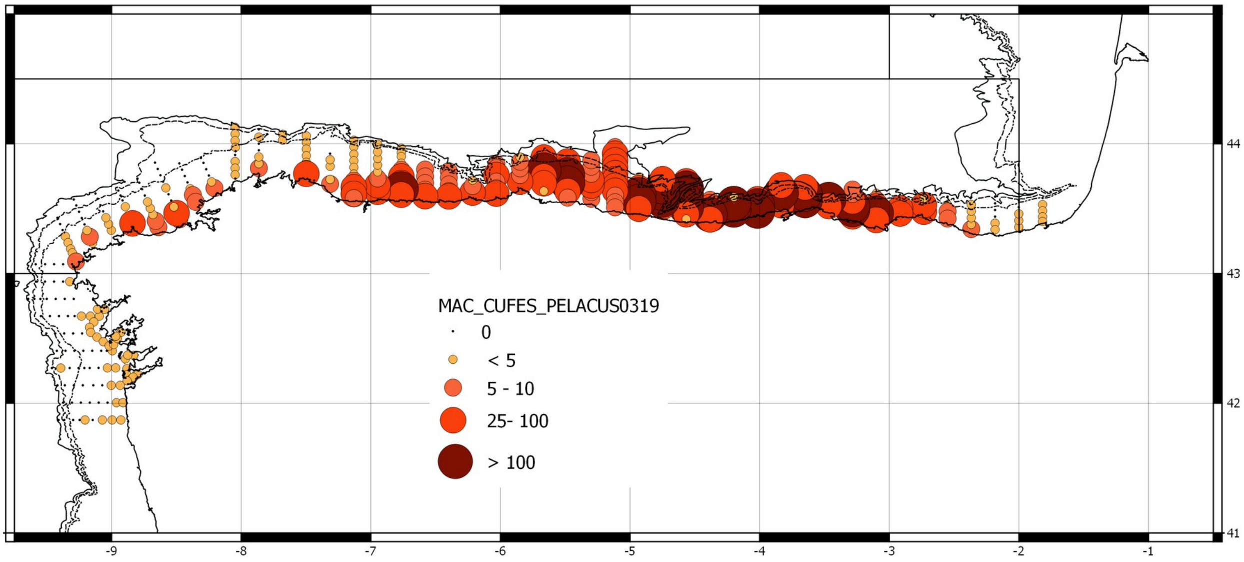


Figure 15: Mackerel egg abundance (number per cubic meter) from CUFES

Other metrics

Figure 16 the evolution of the mean length, weight abundance and biomass together with the weight anomaly-at-age (yearly weight-at-age deviation from the long term (2013-19) weight-at-age average) since 2013. Except 2013 when an important amount of juvenile (<30 cm length) was found, mean length remained stable at around 35 cm. Also abundance shows no trend. Nevertheless, the biomass shows an increasing trend together with the mean weight. These trends in weight are mainly due to an increase in weight-at-age for fish older hand 3 (e.g. adult fish). All cohorts show an increasing trend

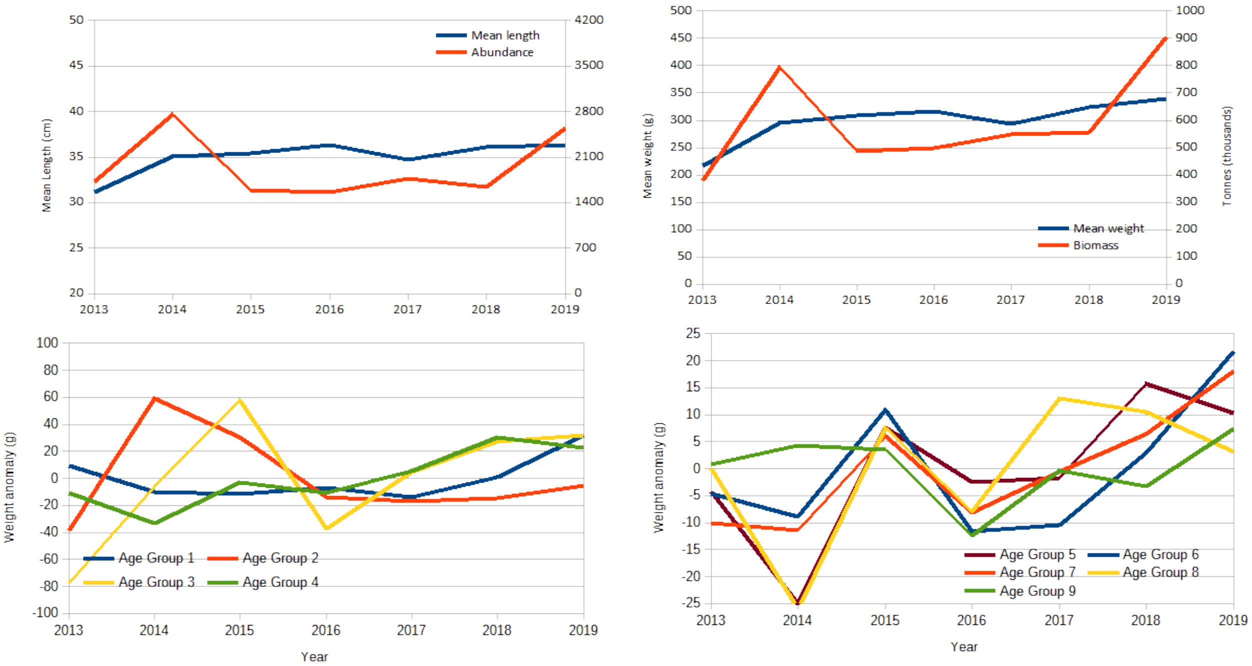


Figure 16: Mean length and abundance (left upper panel); mean weight and biomass (right upper panel); weight-at-age anomaly for ages 1 to 4 (left lower panel) and 5 to 9 (right lower panel) for the 2013-19 PELACUS time series.

Conclusion

The biomass estimates has significantly increased. This increase was due to both an increase in the abundance and an increase in the condition factor. As in previous years no signal on recruitment was achieved. Adult mackerel is still the most important fish species in the Cantabrian Sea in spring time (e.g. spawning season) as corroborated by both acoustic records and egg counts. However whether the Cantabrian sea acts as a sink area is still a matter of concern

Sardine assessment

Adult distribution

The bulk of the sardine NASC distribution was recorded in the western area (i.e. Atlantic waters). Figure 17 is showing the evolution of the center of gravity. The lasst two years, the amount of backscattering energy allocated to sardine is the highest of the time series in Spanish waters, which also shows an increasing trend since 2013 when de minimum was achieved. Besides, as the amount of fish (e.g. backscattering energy) is increasing, the center of gravity is moving towards the western area (Galician area), and consistently going to shallower waters. Figure 18 shows the sardine spatial distribution (NASC).

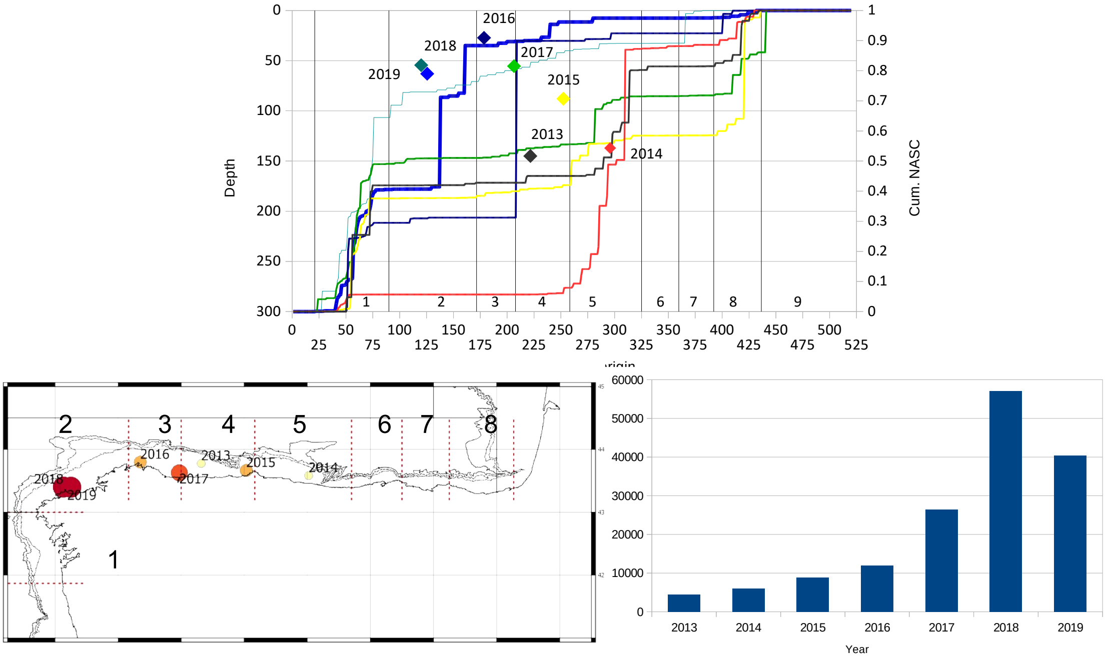


Figure 17: Above: cumulated NASC frequency along the coast and center of gravity for sardine since 2013. Below: left, center of gravity indicating as well the biomass estimates (thousand tonnes); right panel, total backscattering energy (NASC) whiting since 2013 in the Spanish waters

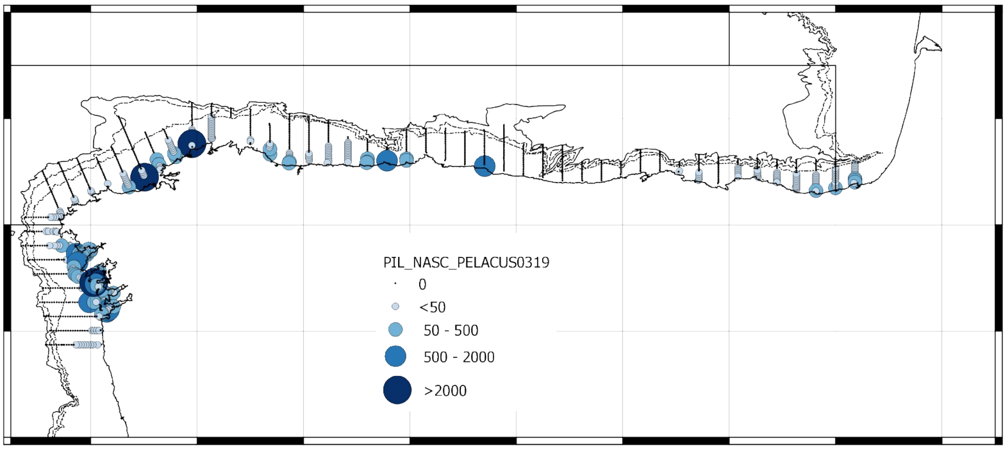


Figure 18: Sardine spatial distribution

Assessment

A total of 71 thousand tonnes, corresponding to 713 million fish were estimated, most of them, as expected in the western part (Galicia) (tables 10 and 11). Although the significant increase in biomass in relation to that estimataed in 2018, age group 1 only accounted for less than 1% of the total biomass , but mainly located off the main distribution area located in Galician waters. (figure 19). It is also noticeable that the increase in biomass is only due to a vegetative increase (e.g. individual growth) and not for an increase in biomass. In fact the number of fish decreased. Age group 3 is dominant, accounted for the 48% of the total biomass and number.

Table 10: Sardine assessment. Abundance and biomass estimates by ICES Sub-division

ICES-Div	Region	No	Mean	Surface	Fishing st.	PDF	No (million fish)	Biomass (tonnes)	Density (Tn/nmi-2)
9a	Rias Baixas	146	105.18	512	P37-P40-P43-P44-P46	S01	178	13380	26
	Ría Vigo-Pont	20	52.55	19	P45	S02	4	201	11
	Total	**166**	***98.84***	**531**			**182**	**13581**	**26**
8cW	Costa da Morte	15	3.77	108	P31	S03	1	110	1
	Artabro	27	462.85	255	P26-P28-P29	S04	380	29747	117
	Capelada	37	183.19	404	P26-P28-P29	S04	238	18626	46
	Total	**79**	***244.70***	**766**			**619**	**48482**	**63**
8c-Ew	Cantábrico	55	57.45	467	P18	S05	94	6384	14
	Tazones	1	524.84	14	P18	S05	26	1750	125
	Total	**56**	***65.79***	**481**			**120**	**8134**	**17**
8c-Ee	Laredo	8	0.65	65	P05	S06	0	9	0
	Euskadi_8c	53	13.47	416	P02-P03	S07	26	1116	3
	Total	**61**	***11.79***	**481**			**26**	**1126**	**2**
8b	Euskadi_8b	14	21.56	99	P02-P03	S07	10	427	4
	Total	**14**	**21.56**	**99**			**10**	**427**	**4**
	Total 9a	***166***	***99***	***531***			***182***	***13581***	**26**
	Total 8c	***196***	***121***	***1728***			***765***	***57742***	**33**
	Total 8b	***14***	***22***	***99***			***10***	***427***	**4**
	TOTAL	**376**	***108***	**2359**			**957**	**71751**	**30**
	Total Spain	***376***	***108***	***2359***			***957***	***71751***	**30**

Table 11: Sardine assessment. Abundance and biomass estimates by age group and ICES Sub-Divsion

		1	2	3	4	5	6	7	8	9	10	Total	No fish (thousands)
8cEe	**Biomass (mt)**	100	800	197	26	2	0	0	0	0	0	1125.71	25751
	%	8.92	71.08	17.47	2.31	0.21							
	M. weight	37.27	41.87	53.95	61.30	71.59						#VALOR!	
	No Fish (thousan	2683	18997	3615	422	33	0	0	0	0	0	25751	
	%	10.42	73.77	14.04	1.64	0.13							
	M. length	17.01	17.61	19.00	19.74	20.67						17.78	
	s.d.	0.67	0.76	0.94	0.85	0.50						0.98	
8cEw	**Biomass (mt)**	13	1406	4698	1571	394	44	7	0	0	0	8134.29	119974
	%	0.17	17.29	57.75	19.32	4.84	0.55	0.09					
	M. weight	40.88	60.26	67.41	72.01	80.47	88.05	106.12				67.43	
	No Fish (thousan	328	23087	69406	21701	4879	504	68	0	0	0	119974	
	%	0.27	19.24	57.85	18.09	4.07	0.42	0.06					
	M. length	17.49	19.64	20.30	20.71	21.41	21.99	23.25				20.29	
	s.d.	0.34	1.10	0.75	0.86	0.67	0.45					0.96	
8cW	**Biomass (mt)**	6	5142	23975	13058	5242	894	166	0	0	0	48482.40	618925
	%	0.01	10.61	49.45	26.93	10.81	1.84	0.34					
	M. weight	47.16	70.59	75.77	81.74	85.78	91.34	106.12				77.73	
	No Fish (thousan	121	72347	315108	159043	60960	9778	1568	0	0	0	618925	
	%	0.02	11.69	50.91	25.70	9.85	1.58	0.25					
	M. length	18.25	20.59	21.03	21.51	21.82	22.23	23.25				21.20	
	s.d.	0.00	0.94	0.78	0.81	0.67	0.53					0.88	
9aN	**Biomass (mt)**	326	1819	5134	4307	1063	205	728	0	0	0	13581.44	182433
	%	2.40	13.39	37.80	31.71	7.83	1.51	5.36					
	M. weight	44.38	62.06	71.89	81.37	86.17	92.55	91.59				70.02	
	No Fish (thousan	7264	29112	71153	52586	12172	2187	7959	0	0	0	182433	
	%	3.98	15.96	39.00	28.82	6.67	1.20	4.36					
	M. length	17.92	19.81	20.70	21.48	21.85	22.32	22.25				20.83	
	s.d.	0.99	0.90	0.74	0.96	1.33	1.24					1.26	
TOTAL	**Biomass (mt)**	445	9167	34003	18963	6701	1143	901	0	0	0	71323.84	947084
	%	0.62	12.85	47.67	26.59	9.40	1.60	1.26					
	M. weight	42.38	62.83	73.67	80.68	85.49	91.42	93.97				73.88	
	No Fish (thousan	10396	143543	459283	233752	78045	12470	9594	0	0	0	947084	
	%	1.10	15.16	48.49	24.68	8.24	1.32	1.01					
	M. length	17.68	19.88	20.85	21.42	21.80	22.24	22.42				20.92	
	s.d.	0.98	1.35	0.83	0.88	0.81	0.71	0.00	0.00	0.00	0.00	1.15	

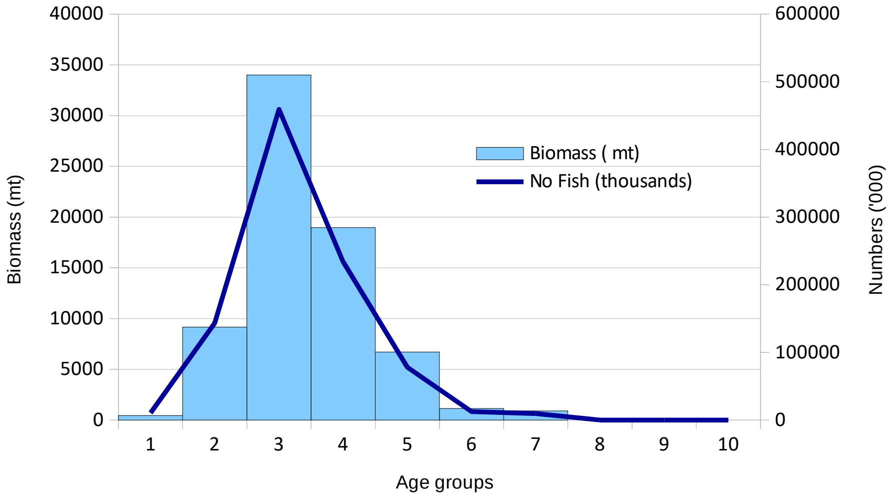


Figure 19:Sardine abundance by age group estimated in PELACUS 0319

Eggs from CUFES

Sardine egg distribution (number of eggs per cubic meter) collected by CUFES is similar to that recorded from the acoustic (figure 20), with most of the egg being concentrated in the western part, and only few eggs just at the inner part of the Bay of Biscay were adult occurrence was also negligible. 367 samples were collected. Of those, only 121 (33%) were positive for sardine, lower than in previous year, although the number of eggs was slightly higher accounted 2930, with an average density over the positive stations of f 2.17 eggs/m^3.

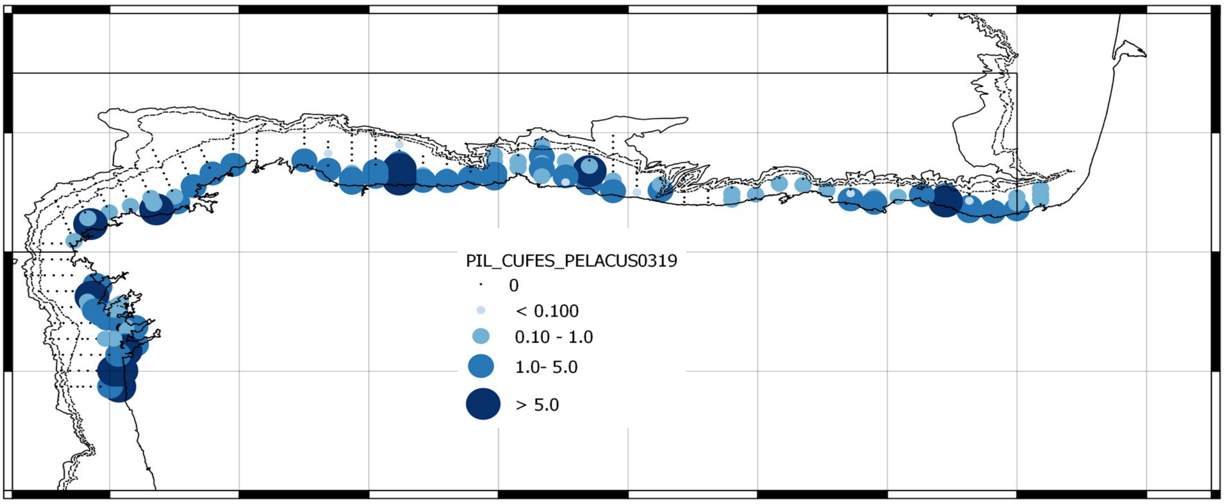


Figure 20:Sardine egg abundance (number per cubic meter) from CUFES

Other metrics

Figure 21 is showing the evolution of the mean weight and length in both 9aN and 8c since 2013

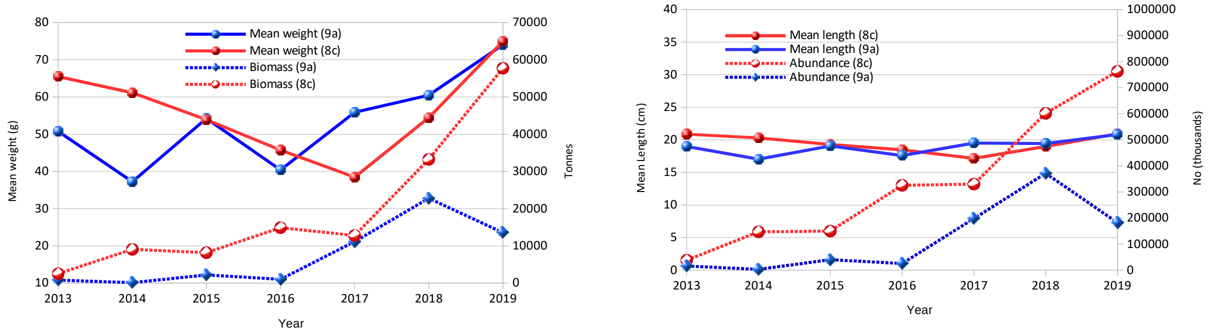


Figure 21:Trends (2013-19) in mean weight and length together with biomass and estimates in number of sardine in 8c and 9aN.

Mean weight has a clear increasing trend, which would not be related with and increase in the mean length, although is also increasing. This trend has been observed this year in catches. This trend is clear for age groups 2 to 4 as shown in figure 22.

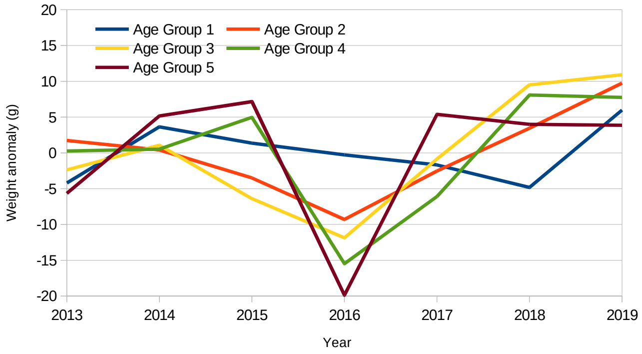


Figure 22:Trends (2013-19) in mean weight at age (whole area) for sardine

Conclusion

The situation found is similar to that of the previous year, with sardine mainly located in Atlantic waters. Weight-at-age is increasing since 2016 an in spite the number of estimated fish has decreased, total biomass was increased. This has been also observed in horse mackerel and also in mackerel. This increase in mean weight has been also observed in catches, excluding, therefore, any problem due scale measurement.

The last two cohorts seem to be weak, specially that of 2018 whose presence in the surveyed area was almost negligible. As consequence, age group 3 clearly dominated the age structure of the population.

Anchovy in Division 9a assessment

Adult distribution

In general, anchovy had a very scarce presence in 9a. Only in 2018, as outcome of an important outburst, anchovy had an important contribution to the pelagic fish community, and its distribution was mainly around the continental shelf, between 50 and 125 m depth, as shown in figure 23

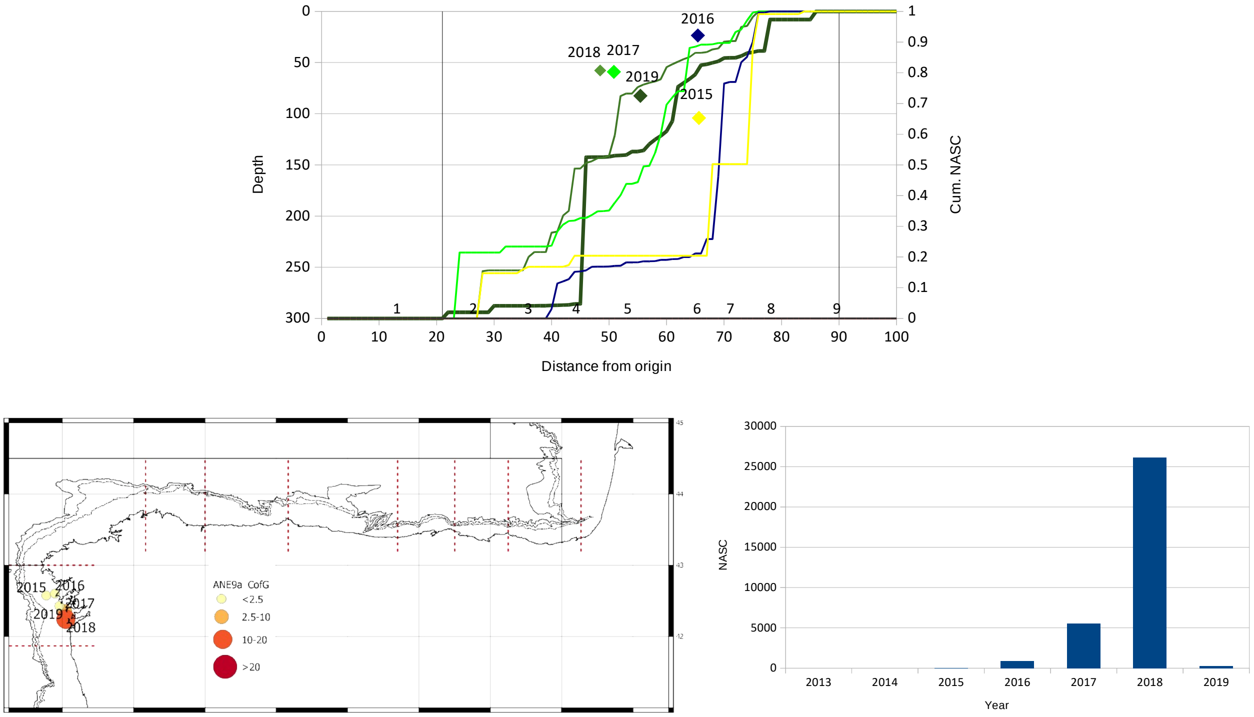


Figure 23: Above: cumulated NASC frequency along the coast and center of gravity for anchovy in 9aN since 2013. Below: left, center of gravity indicating as well the biomass estimates (thousand tonnes); right panel, total backscattering energy (NASC) whiting since 2013 in the Spanish waters

Assessment

Only 142 tonnes, corresponding to 5 millions fish were assessed in 9a. Age 2 accounted for the 72% of the total biomass, corresponding to 65% in number (table 12 and figure 24).

Table 12: Anchovy in 9aN assessment

	1	2	3	4	Total	No fish ('000)
Biomass (mt)	36	103	3	0	141.98	5084
%	25.30	72.44	2.26			
M. weight	20.52	31.00	43.55		27.64	
No fish ('000)	1721	3289	74	0	5084	
%	33.86	64.70	1.45			
M. length	14.52	16.43	18.19		15.81	
s.d.	0.94	0.78	0.47		1.26	

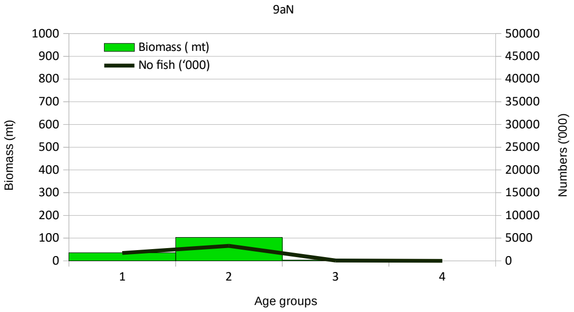


Figure 24: Anchovy in 9aN abundance by age group estimated in PELACUS 0319

Eggs from CUFES

In 9a 41.51% of the station were positives (44 of 106), with a mean density on positive stations of 5.57 egg m^{-3} (figure 25).

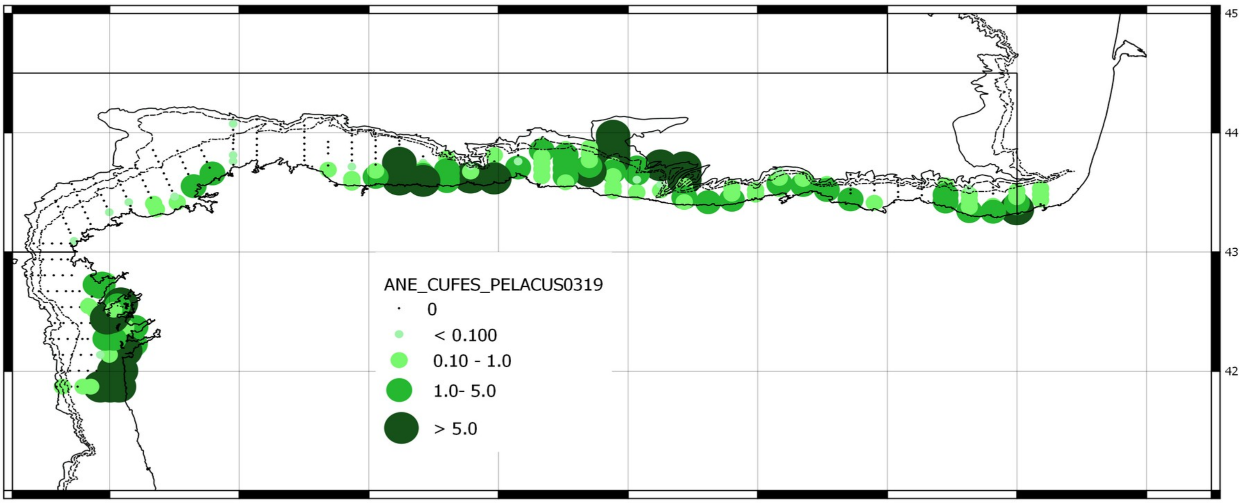


Figure 25: Anchovy egg abundance (number per cubic meter) from CUFES

Other metrics

In 9a trends in number, biomass or length and weight are difficult to track due to the very low abundance, except the 2018 outburst. In this case it seems this outburst caused a density-depend in growth, as shown in figures 26 and 27

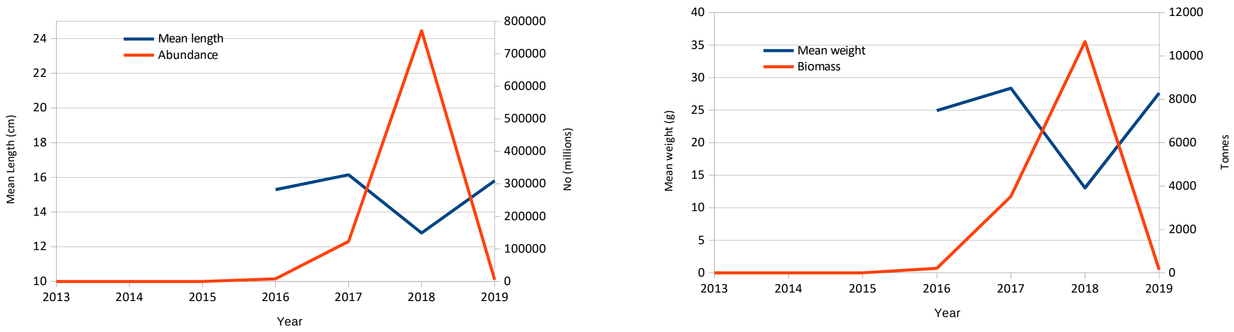


Figure 26: Trends (2013-19) in mean weight and length , abundance and biomass estimates in 9aN Anchovy

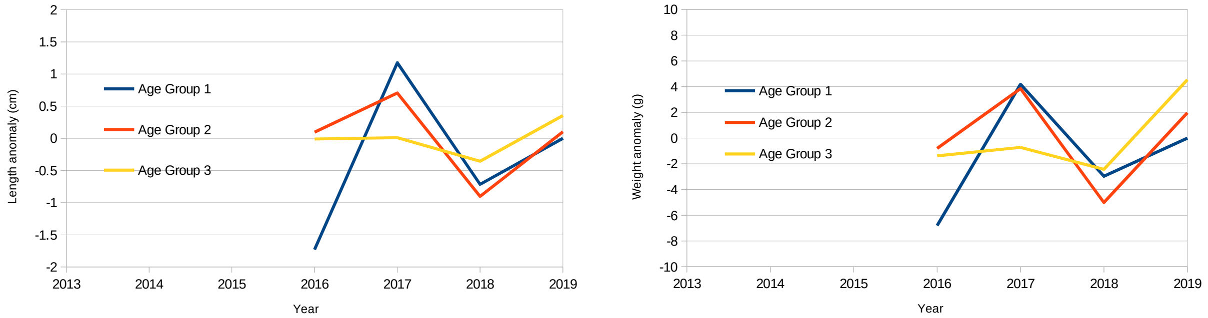


Figure 27: Trends (2013-19) in mean weight and length at age in 9aN Anchovy

Conclusion

The observed anchovy biomass was very low. The number of eggs, relatively high would probably due to the presence of old fish (age 2 and 3). This low value agrees with the normal presence of this species where only in particular years outburst.

Anchovy in 8c assessment

Adult distribution

As observed in 9a the presence of anchovy was very scarce, expect a particular year (2016). Its is also remarkable the increasing trend in mid-western part of the Cantabrian sea (figure 28).

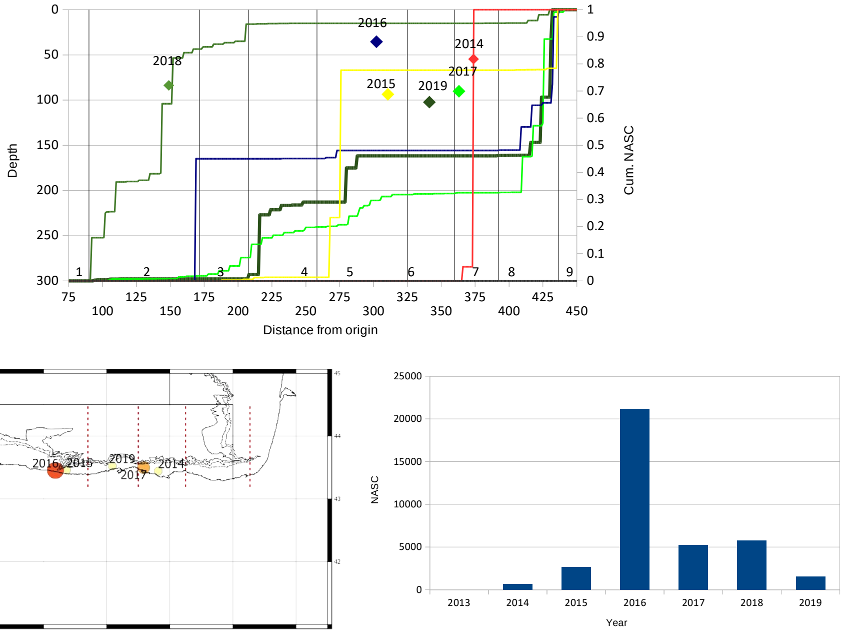


Figure 28: Above: cumulated NASC frequency along the coast and center of gravity for anchovy in 8c since 2013. Below: left, center of gravity indicating as well the biomass estimates (thousand tonnes); right panel, total backscattering energy (NASC) whiting since 2013 in the Spanish waters

Figure 29 shows the spatial distribution. In middle Cantabrian sea, anchovy occurred in schools, some of them offshore, marking two locations (e.g. inner part of Bay of Biscay and central Cantabrian Sea), with a gap between both

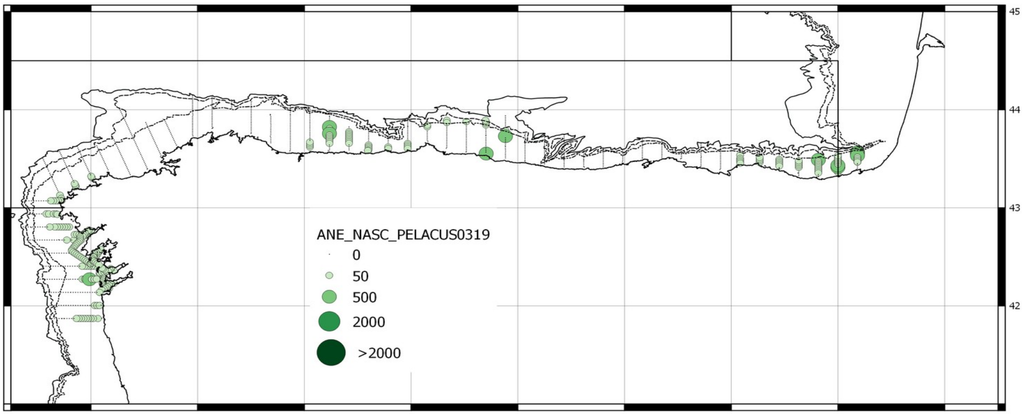


Figure 29: Anchovy spatial distribution

Assessment

1.4 thousand tonnes, corresponding to 63 millions fish were assessed in 8c. Age 2 is still more abundant but recruits from 2018 yielded 53 % in number (table 14 and figure 30.

	1	2	3	4	Total	No fish ('000)
Biomass (mt)	545	779	14	0	1339.21	63170
%	40.72	58.20	1.08			
M. weight	15.45	28.30	38.08		21.61	
No fish ('000)	33229	29446	494	0	63170	
%	52.60	46.61	0.78			
M. length	13.34	15.99	17.47		14.60	
s.d.	2.14	0.86	0.54		2.13	

Table 14 Anchovy in 9aN assessment

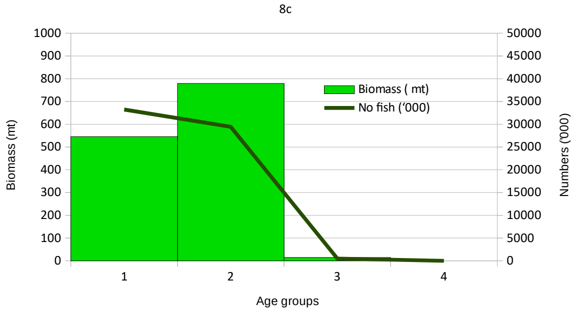


Figure 30: Anchovy in 8c abundance by age group estimated in PELACUS 0319

Eggs from CUFES

The percentage of positive CUFES stations in 8c was slightly higher than in previous year(45.59% to 41.51% respectively), with 119 of of 261 being positives (figure 31). However, mean egg density per station was half of that obseved in 9aN (2.51 to 5.57 egg m^{-3}).

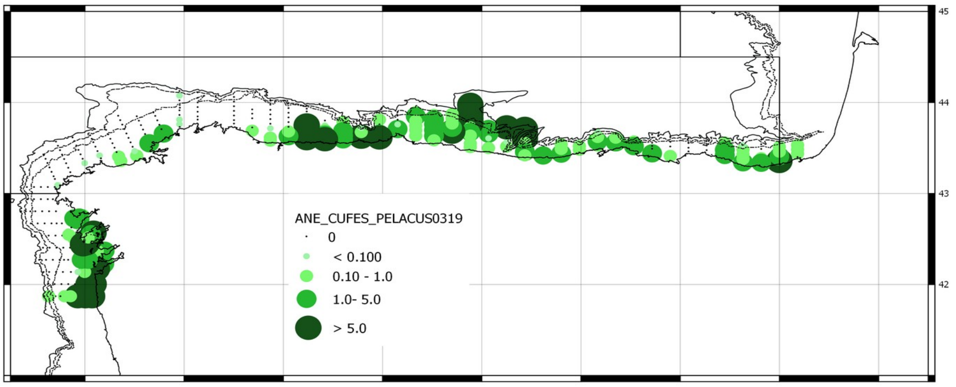


Figure 31: Anchovy egg abundance (number per cubic meter) from CUFES

Other metrics

In 8c, as observed in 9aN, trends in number, biomass or length and weight are difficult to track due to the very low abundance, except the abundance detected in 2016. It should be noted the decrease in weight-at-age for age group 1, as this trend agrees with that observed in sardine in 8ab (figures 32 and 33).

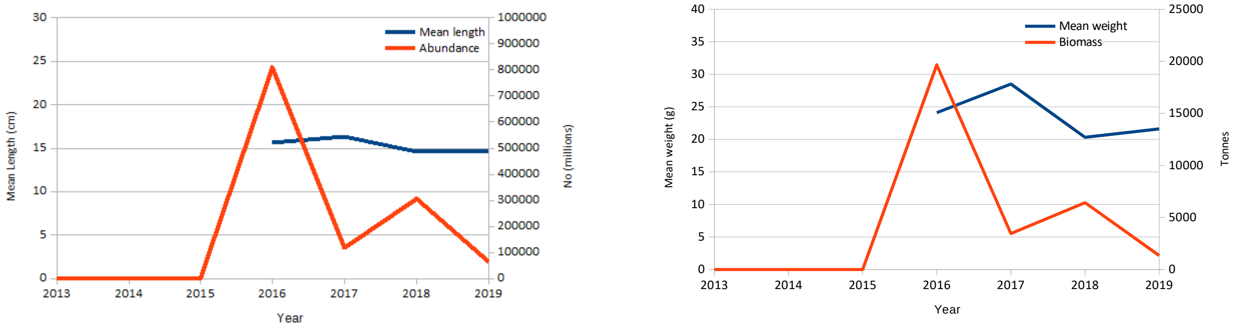


Figure 32: Trends (2013-19) in mean weight and length , abundance and biomass estimates in 9aN Anchovy

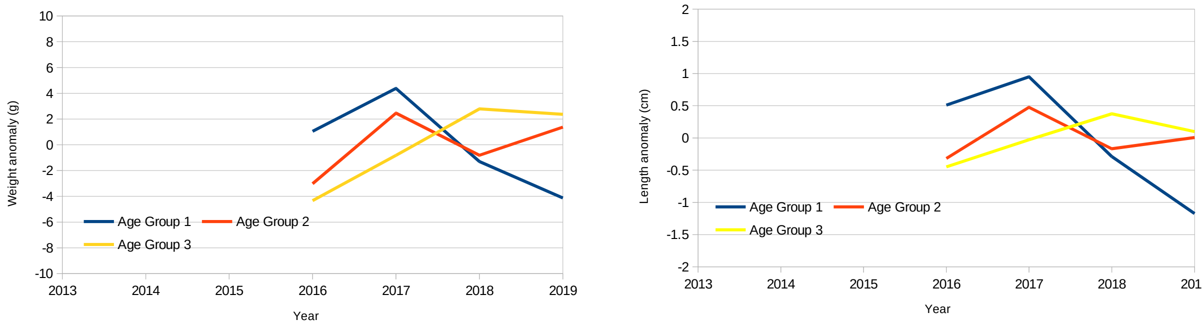


Figure 33: Trends (2013-19) in mean weight and length at age in 9aN Anchovy

Conclusion

The change of the survey steam occurred in 2018 when the area started to be prospected anti-clock wise (e.g. westwards instead eastwards) may have influenced the results in 8c as the anchovy tends to move westwards in April-May from the inner part of the Bay of Biscay, thus after this area is surveyed. Nevertheless, the estimates in 2018and 2019 were of the same order of that of 2017. The different trajectories observed in weight-at-age in Bay of Biscay and Atlantic waters should analysed in depth.

Blue whiting assessment

Adult distribution

Blue whiting distribution seems to be stable all along the time series, but in 2019 both the center of gravity and the cumulated NASC shifted towards the western part, near Cape Fisterra, accounting in this area for the 30% of the energy. The s_A values recorded this year are on the average of the time series 2013-19, as shown in figure 34.

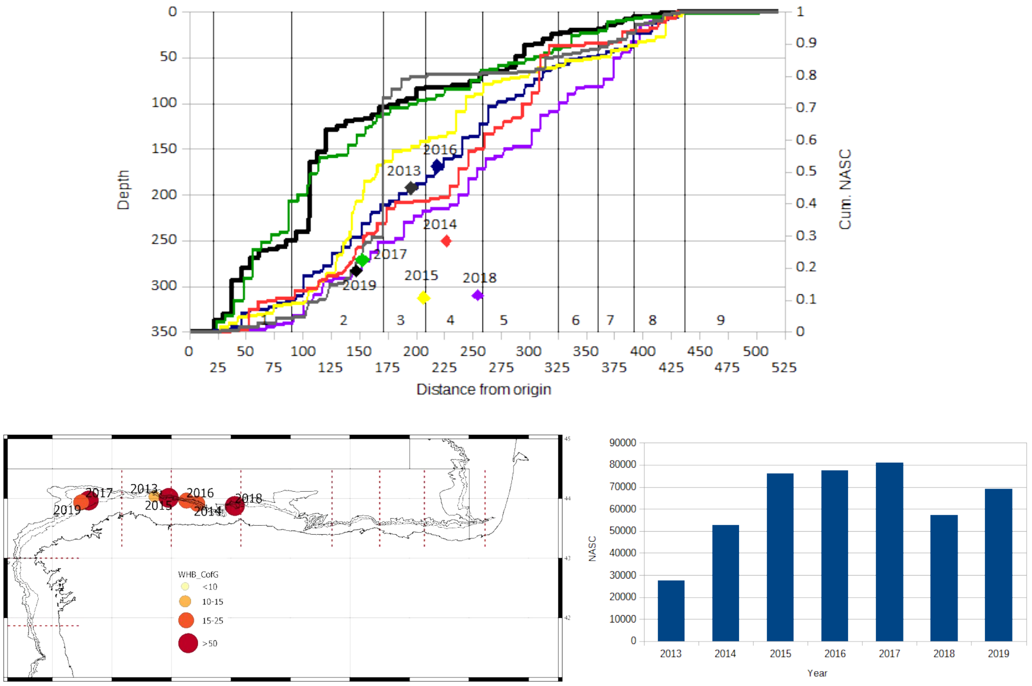


Figure 34: Above: cumulated NASC frequency along the coast and center of gravity for blue whiting since 2013. Below: left, center of gravity indicating as well the biomass estimates (thousand tonnes); right panel, total backscattering energy (NASC) whiting since 2013 in the Spanish waters

Figure 35 shows the spatial distribution accounting the allocated backscattering energy per ESDU. In Cantabrian Sea, blue whiting occurred close to the slope, but in Galician waters either in the northern part or in 9aN, although few, some fish were also recorded on the continental shelf, at only 100 m depth.

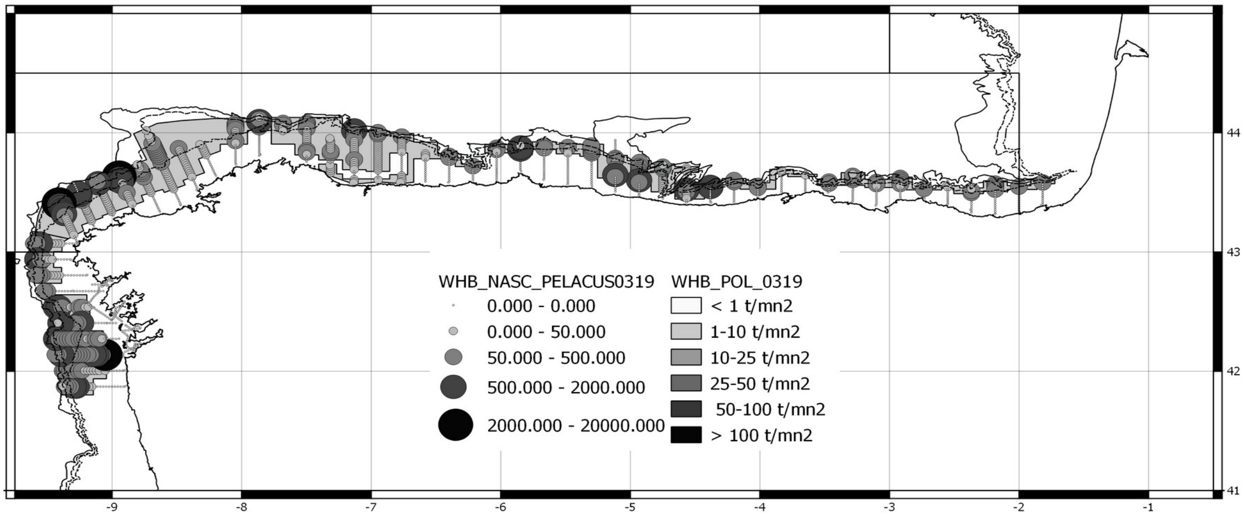


Figure 35: Blue whiting spatial distribution

Assessment

21 thousand tonnes, corresponding to 352 millions fish were assessed for the whole surveyed area (tables 15 and 16). This results in a decrease of the biomass but the number of fish remained similar

Table 15: Blue whiting assessment

Zone	Area	No	Mean	Area	Fishing st.	No (million fish)	Biomass (tonnes)	Density (Tn/nmi-2)
9a	9aN	94	190.10	746.08	P39-P41-P42	83	4641	6
	Fisterra	27	134.26	219.47	P35	14	1064	5
	Total	***121***	***178***	***966***		***96***	***5705***	**6**
8c	8cW	160	168.22	1623	P23-P30-P33	158.66	8995.44	6
	8cEw	108	46.91	1056	P22-P23	27.83	1654.86	2
	8cE_cent	85	139.43	725	P15-P13-P17	54.41	3440.87	5
	8cEe	32	121.50	274	P4	14.16	1236.22	5
	Total	***385***	**124**	***3677***		***255***	***15327***	**4**
Total Spain		***506***	***137***	***4643***		***352***	***21033***	**5**

Mean length has decreased from 24.5 cm to 21.61, which explains the decrease en biomass. Length distribution had two modes, located at 20 and 24 cm, with most of the fish (51%) belonging to age group 1 and only few individual older than 2 were estimated. The change in relation to that found in 2018 is important since last year age group 1 was dominant, as show in figure 36

Table 16: Blue whiting estimates by age group and length class

Length	1	2	3	4	5	6	7	Total	No fish (million)
10									
11									
12									
13									
14									
15									
16									
17									
18	0.22							0.22	6
19	1.35	0.28	0.06					1.68	38
20	4.07	1.77	0.21					6.05	119
21	3.00	2.46	0.27					5.72	99
22	0.66	1.09	0.40	0.04				2.19	33
23	0.06	0.35	0.16	0.06				0.63	9
24		0.64	0.28	0.32	0.09			1.33	16
25		0.35	0.30	0.65	0.05			1.35	15
26		0.27	0.30	0.27	0.09			0.92	9
27		0.12	0.06	0.24	0.12	0.06		0.59	5
28			0.08	0.13	0.08			0.29	2
29			0.02		0.04			0.05	0
30									
Biomass (thousand t)	9.3	7.3	2.1	1.7	0.5	0.1	0.0	21.0	351.5
%	44.45	34.83	10.13	8.08	2.23	0.28		100.00	
M. weight	51.95	60.07	71.39	93.98	103.88	114.05		58.65	
No Fish (million)	179	120	29	18	4	1	0	352	
%	50.95	34.22	8.29	5.11	1.27	0.15		0.00	
M. length	20.68	21.80	23.21	25.64	26.59	27.50		21.61	
s.d.	0.91	1.62	2.29	1.33	1.57			1.93	

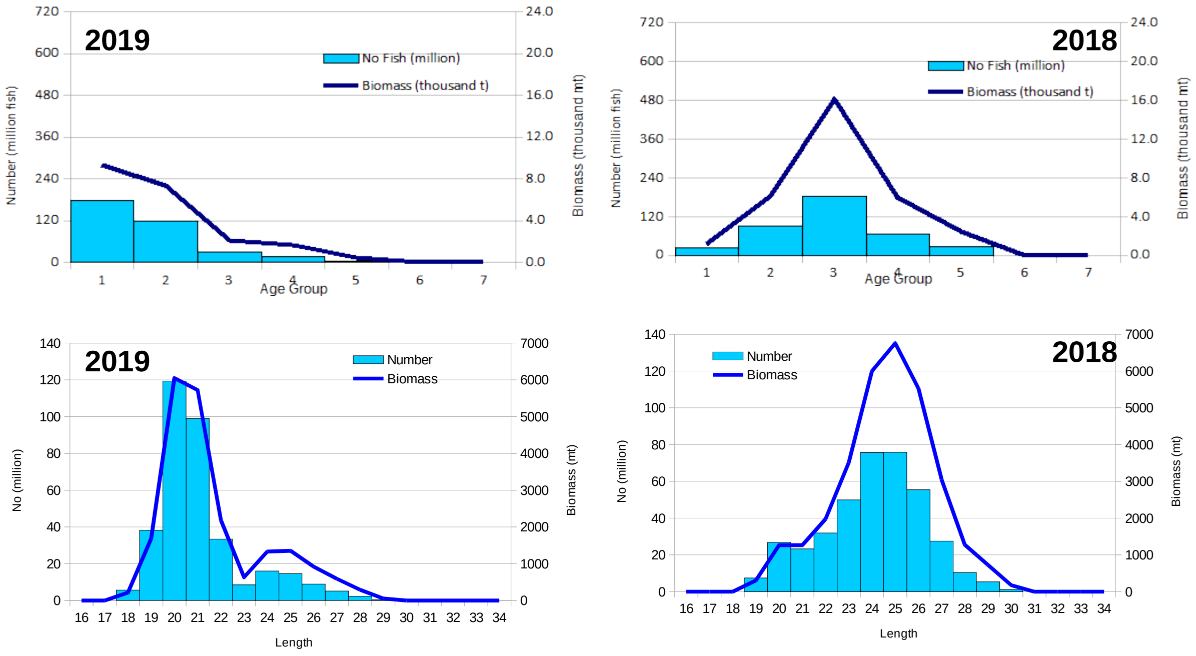


Figure 36: Blue whiting abundance and biomass estimates by age group (above-2019,left; 2018, right-) and by length class

Other metrics

The abundance and biomass are more or less stable along the time series 2013-19. There is a slight increasing trend in mean length, which seems to be more clearer in weight. This increasing trends is associated to younger fish (age groups 1-3), with mean weight above average in the most recent years (figures 36 and 37).

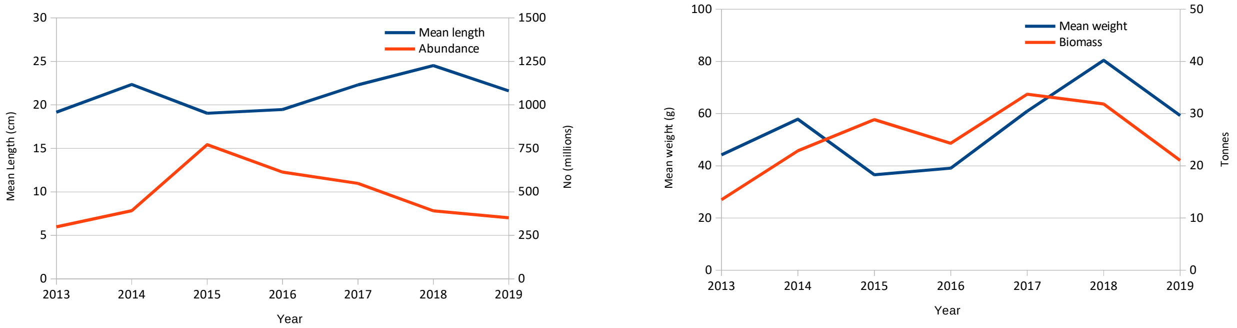


Figure 36: Trends (2013-19) in mean weight and length, abundance and biomass estimates of blue whiting

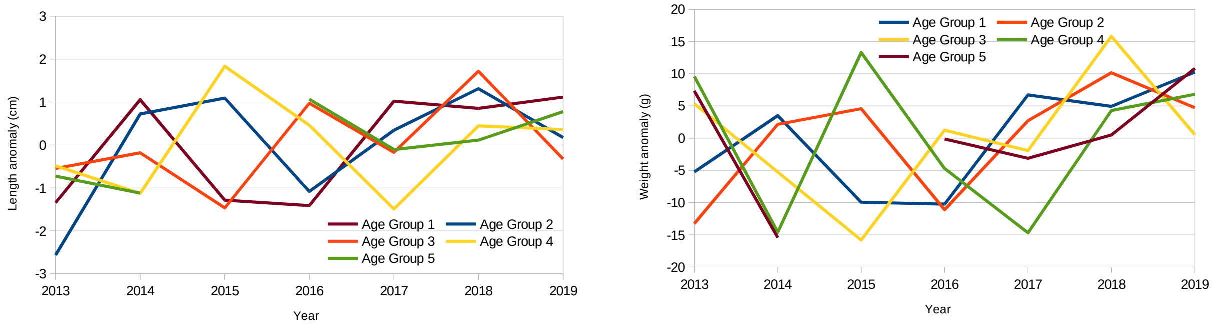


Figure 37: Trends (2013-19) in mean weight and length at age of blue whiting

Conclusion

The blue whiting population off north Spanish waters is mainly composed by younger fish, related to the slope and also on the continental self. Both age structure and distribution are different from those observed at the main spawning ground, where age structure is wider, being age group 5 dominant, and fish occurring at 500 m depth.

Western horse mackerel assessment

Adult distribution

Horse mackerel distribution seems to be quite similar to that observed in sardine, with the abundance moving towards both, the inner part of the Bay of Biscay and the western part. Only when the abundance peaked at maximum in 2015, the fish were mainly distributed in the central part of the Cantabrian sea, as shown in figure 38.

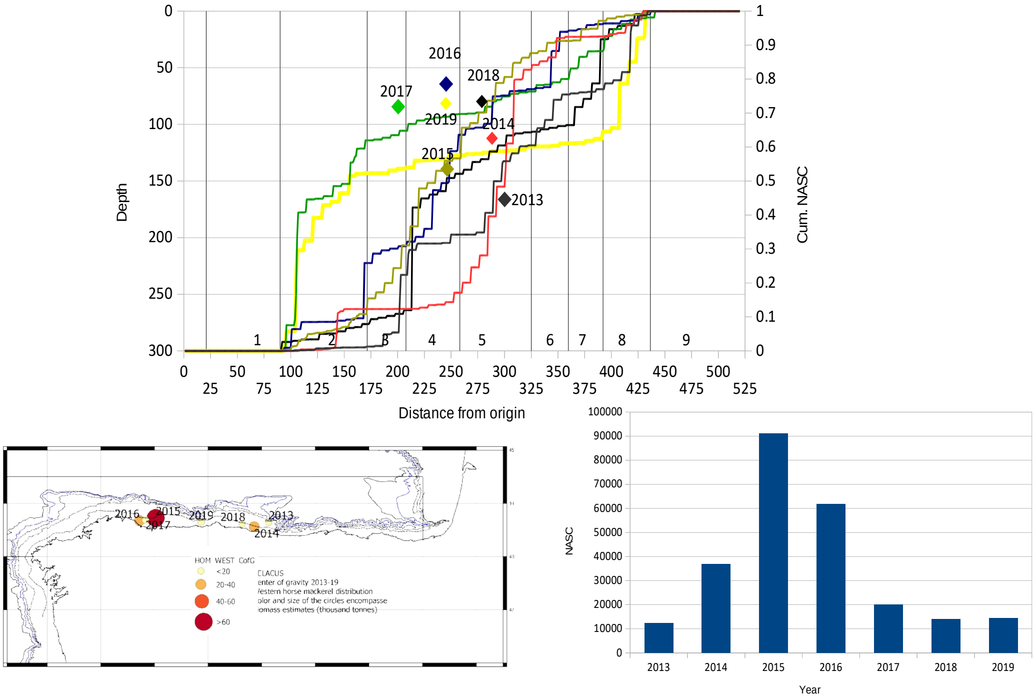


Figure 38: Above: cumulated NASC frequency along the coast and center of gravity for western horse mackerel since 2013. Below: left, center of gravity indicating as well the biomass estimates (thousand tonnes); right panel, total backscattering energy (NASC) whiting since 2013 in the Spanish waters

Figure 39 shows the spatial distribution accounting the allocated backscattering energy per ESDU. In Cantabrian Sea, horse mackerel occurred near coast, mainly at the inner part of the Bay of Biscay, although some fish were detected along the surveyed area. However, the highest density was located near Fisterra cape and linked to the distribution of the southern stock.

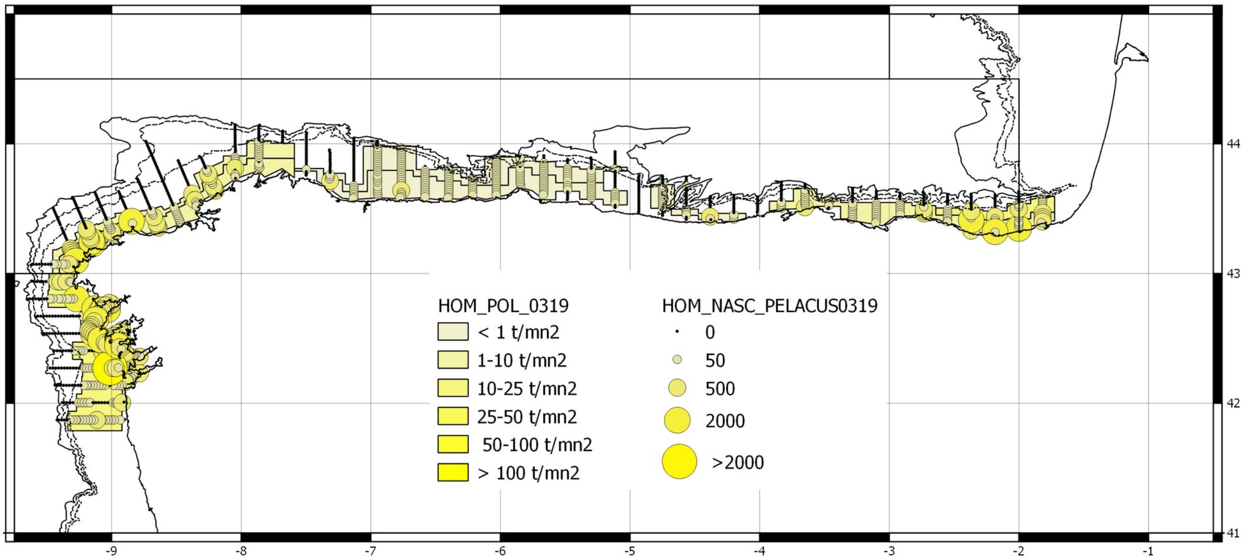


Figure 39: western horse mackerel spatial distribution

Assessment

A total of 13 thousand tonnes, corresponding to 203 millions fish were assessed in 8c, as shown for the whole surveyed area (table 17). This results in a small increase in relation to that estimated in 2018 of the biomass but the number of fish was higher due to the number of older fish caught this year. Age group 2 accounted for the 38% of the fish (31% in weight). The age structure was in general similar to that observed last year, in both cases age group 2 being the most important (figure 40).

Table 17: Western horse mackerel assessment

	AGE GROUPS												
Length	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**	**No fish (mill**
5													0	0
6													0	0
7													0	0
8													0	0
9													0	0
10	5												5	1
11	200												200	16
12	485												485	29
13	410												410	20
14	201												201	8
15	63	272											335	10
16	17	519											537	14
17	18	750											768	16
18	47	977											1024	18
19		925	33										958	15
20		344	238	26									608	8
21		103	753	34									890	10
22		114	483	57									654	6
23		21	322	107									451	4
24			327	300	109								735	6
25			113	450	169								732	5
26				184	332	148	37						701	4
27					100	366	33						498	3
28					45	362	90		45				542	3
29							225	180	45				450	2
30								538	119				657	2
31								77	541	77			695	2
32								18	53	232	36		338	1
33										22	66	11	99	0
34												54	54	0
35													0	0
36												46	46	0
37													0	0
38													0	0
39													0	0
40													0	0
Total	1446	4026	2269	1159	755	875	385	813	804	331	102	111	13075	203
%	11.06	30.79	17.36	8.87	5.77	6.69	2.95	6.21	6.15	2.53	0.78	0.85	100.00	
M. weight	16.27	46.85	91.17	125.49	152.31	183.56	205.68	246.68	264.42	300.10	325.08	391.28	45.34	
No Fish ('000)	76391	76773	22893	8559	4640	4491	1766	3123	2881	1049	298	270	203133	
%	37.61	37.79	11.27	4.21	2.28	2.21	0.87	1.54	1.42	0.52	0.15	0.13	0.00	
M. length	12.93	18.03	22.22	24.57	26.11	27.68	28.69	30.38	31.05	32.31	33.13	35.11	17.84	
s.d.	1.25	1.59	1.37	1.51	1.05	0.73	1.05	0.62	0.97	0.52	0.48	1.10	5.15	

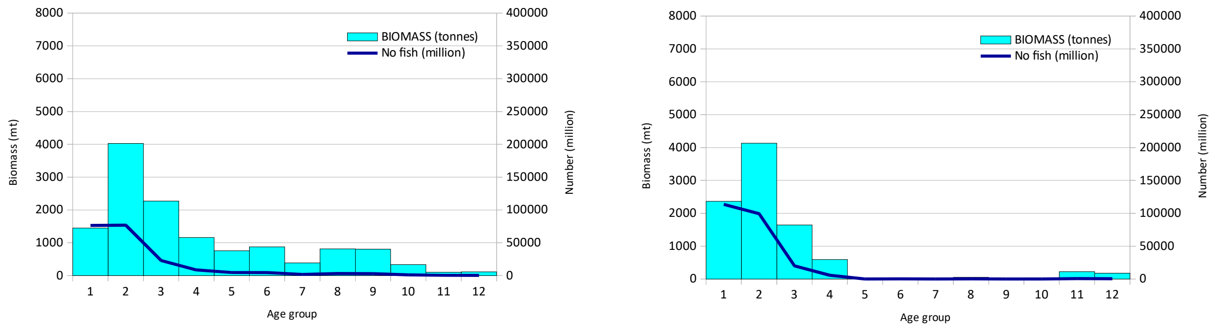


Figure 40: Western horse mackerel abundance and biomass estimates by age group (2019, left; 2018, right)

Eggs from CUFES

Egg distribution shown a wider distribution than that recorded by acoustic, but in general match it. 5804 eggs were counted on 173 positive stations (65% of the total number), with a mean abundance of 51.36 egg m^{-3} over the positive distribution area, as show in figure 41.

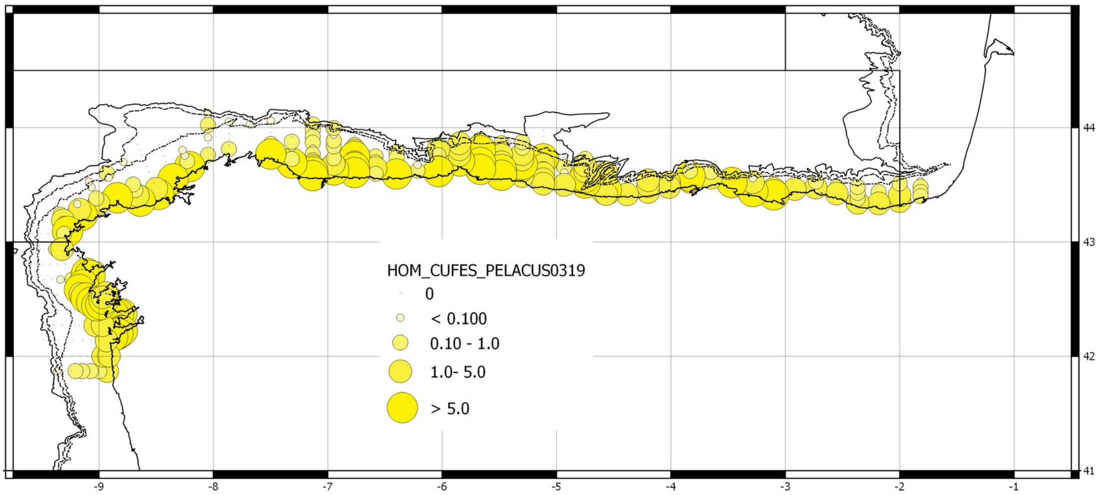


Figure 41: Western horse mackerel egg abundance from CUFES

Other metrics

The abundance and biomass peaked in 2015 and since 2017 remained at low level. Mean length remained more or less stable at around 20 cm since 2015 but mean weight significantly dropped, remained then stable since 2015 (figure 42).

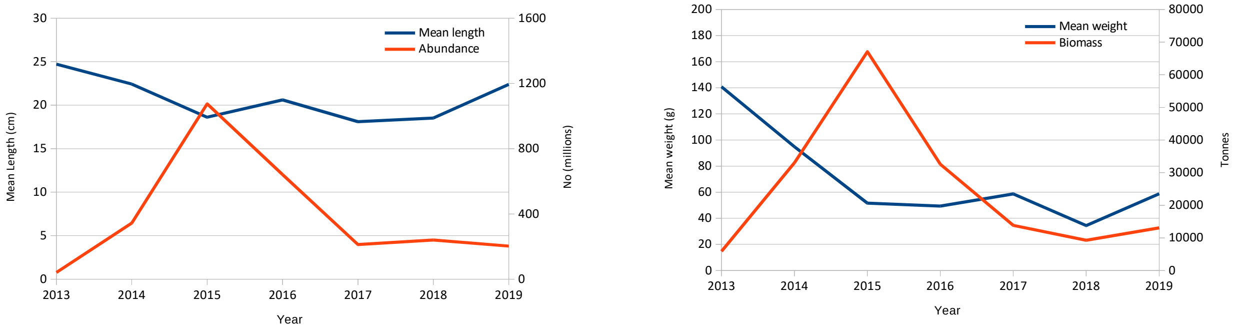


Figure 42: Trends (2013-19) in mean weight and length, abundance and biomass estimates of western horse mackerel

However excluding 2017, an anomalous year due to the smaller mean length of the majority of the age groups , mean length for older fish reamined stable but the weight-at-age shows an increasing trend since 2016, with all age groups older than 2 being well above the average in 2019 (20 gr for fish older than 3 and 10 for age group 3; figure 43).

Figure 43: Trends (2013-19) in mean length-at-age (above) and mean weight-at-age of western horse mackerel.

Conclusion

Although the dynamics of horse mackerel in Cantabrian Sea is poorly understood, on account the results of the survey, some age groups (mainly adults) should to be go out of the prospected area and therefore are only tracked at younger ages. This would explain why the abundance estimated in 2015 did no reflect the abundance in 2016, nor the age structure which does not show any particular pattern. The biomass in 2019 is similar to that estimated in 2018 but low comparing to the 2014-2017 period.

Southern horse mackerel assessment

Adult distribution

In 9aN, rather than a geographical sift in the center of gravity, it should hightlighted the differences in mean depth, with some years the bulk of the distribution being located deeper than 75 m but most commonly occurring close to the coast, as shown in figure 44.

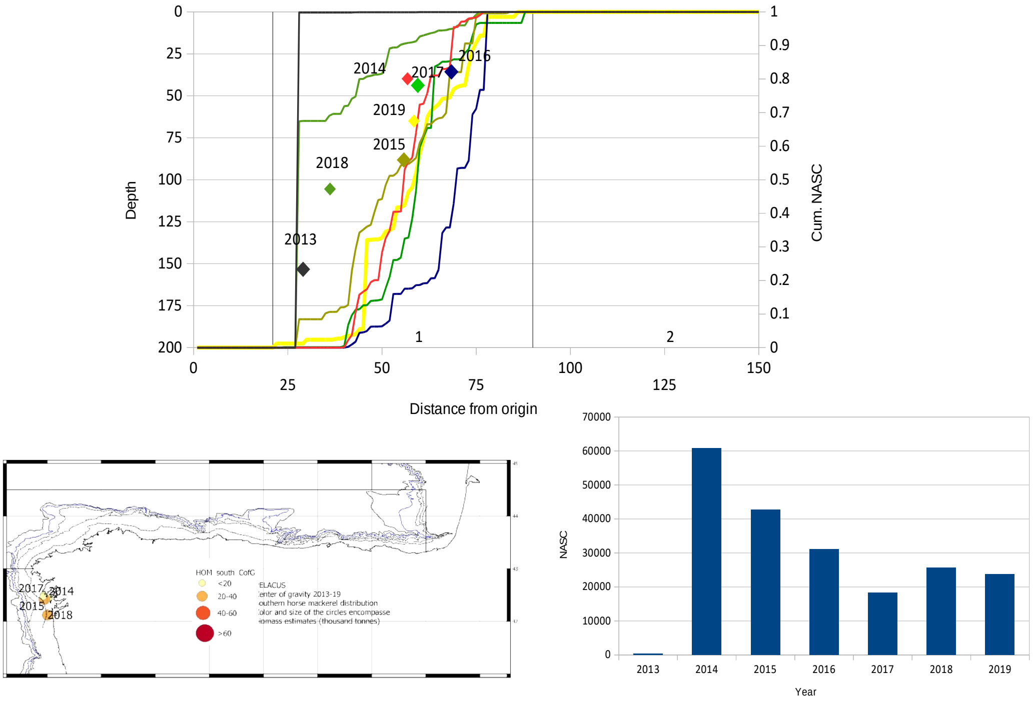


Figure 44: Above: cumulated NASC frequency along the coast and center of gravity for southern horse mackerel since 2013. Below: left, center of gravity indicating as well the biomass estimates (thousand tonnes); right panel, total backscattering energy (NASC) whiting since 2013 in the Spanish waters

Figure 39 shows the spatial distribution accounting the allocated backscattering energy per ESDU. In 9aN, horse mackerel occurred throughout the continental self without any gap. Highest abundance was recorded near coast.

Assessment

A total of 14 thousand tonnes, corresponding to 104 millions fish were assessed in 9a, as shown in figure 45 and table 18. This results in a decrease in relation to that estimated in 2018 when 21 thousand tonnes were assessed, corresponding to 139 million fish. As seen in 8c, the number of younger fish (age group 1) was very low. Age group 3 accounted for the 41% of the fish (35% in weight). The age structure was very different to that observed last year (figure 45).

	AGE GROUPS												
Length	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12+**	**Total B(mt)**	**No fish (million)**
5													0	0
6													0	0
7													0	0
8													0	0
9													0	0
10													0	0
11													0	0
12													0	0
13													0	0
14													0	0
15													0	0
16													0	0
17		10											10	0
18		95											95	2
19		153											153	2
20		278	69										347	5
21		987	79										1066	12
22		1007	1145	46									2198	22
23		385	2143	275									2802	24
24			1452	264	132								1848	14
25			105	263	315	53							736	5
26				121	161	40	40						362	2
27					141		141						281	1
28					39	156	78						274	1
29						112	337	112					561	2
30							227	680	453				1360	5
31									211	633			844	3
32										698			698	2
33											256		256	1
34												281	281	1
35													0	0
36													0	0
37													0	0
38													0	0
39													0	0
40													0	0
Total	0	2915	4993	968	788	361	822	792	664	1331	256	281	14172	104
%		20.57	35.23	6.83	5.56	2.55	5.80	5.59	4.69	9.39	1.81	1.98	100.00	
M. weight		82.87	107.77	124.20	148.46	188.47	213.56	245.85	257.67	291.13	336.85	369.92	119.47	
No Fish ('000)	0	32316	43097	7258	4964	1795	3625	3058	2448	4348	725	725	104361	
%		30.97	41.30	6.95	4.76	1.72	3.47	2.93	2.35	4.17	0.69	0.69	0.00	
M. length		21.57	23.42	24.49	25.90	27.92	29.03	30.35	30.80	32.00	33.50	34.50	24.19	
s.d.		1.30	0.92	1.10	1.08	1.48	1.23	0.36	0.46	0.50			3.27	

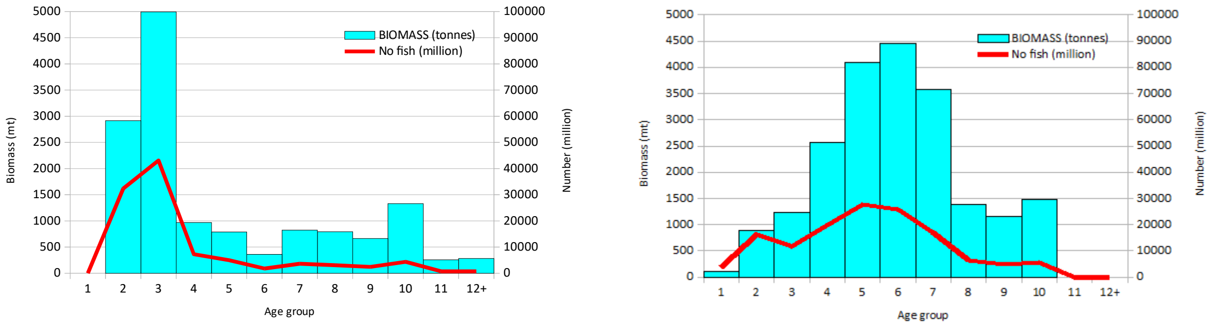


Figure 45: Western horse mackerel abundance and biomass estimates by age group (2019, left; 2018, right)

Eggs from CUFES

Egg distribution was similar to that by acoustic. 4777 eggs were counted on 50 positive stations (50% of the total number), with a mean abundance of 0.49 egg m^{-3} which was much lower that that oberved over the positive distribution area in 8c, as show in figure 41.

Other metrics

The abundance and biomass peaked in 2014 and since 2017 remained at low level. Mean length remained more or less stable at around 20 cm since 2015 but mean weight significantly dropped, remained then stable since 2015 (figure 46).

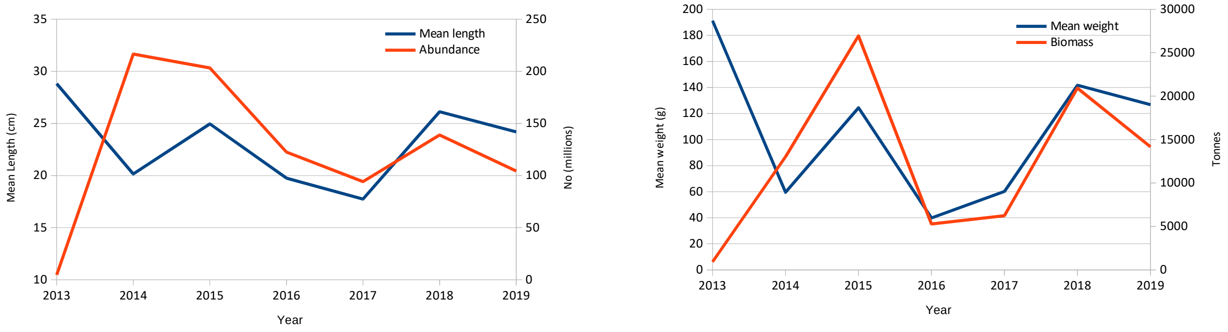


Figure 46: Trends (2013-19) in mean weight and length, abundance and biomass estimates of southern horse mackerel

Mean length-at-age for adult fish (e.g. older than 2) is quite stable along the time series (2013-19), but again mean weight-at-age shows a clear pattern with weight decreasing up to 2016 and since that all mean weight-at-age shows an increasing trend, with all age groups well above the average in 2019 (figure 47).

Figure 47: Trends (2013-19) in mean length-at-age (above) and mean weight-at-age of southern horse mackerel.

Conclusion

No clear trend in abundance is observed for southern horse mackerel, although as observed in the western horse mackerel the dynamics seems to be too complex. As for most of the species, the most noticeable is the increasing trend in mean weight-at-age.

Chub mackerel assessment

Adult distribution

Chub mackerel normally occurs in the eastern part of the surveyed, but in 2017, 80% of the energy was recorded in 9a. This year few schools were detected western than Cape Peñas (figure 48).

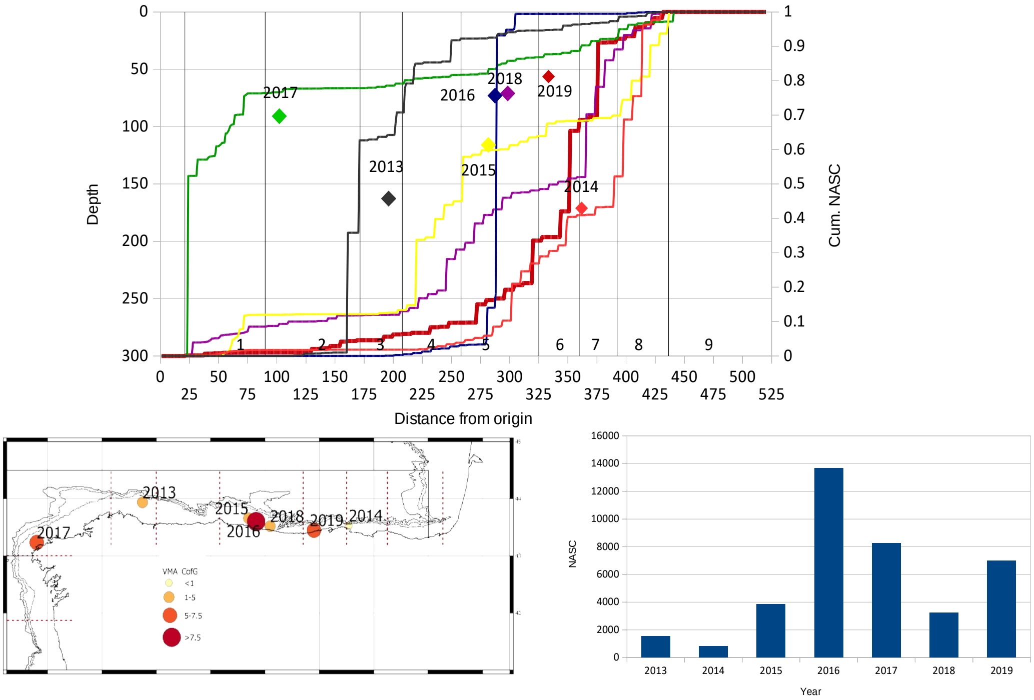


Figure 48: Above: cumulated NASC frequency along the coast and center of gravity for chub mackerel since 2013. Below: left, center of gravity indicating as well the biomass estimates (thousand tonnes); right panel, total backscattering energy (NASC) whiting since 2013 in the Spanish waters

Figure 49 shows the spatial distribution accounting the allocated backscattering energy per ESDU. In 9aN, chub mackerel had a wider distribution although the density was very scarce. Main concentrations were recorded near Santander.

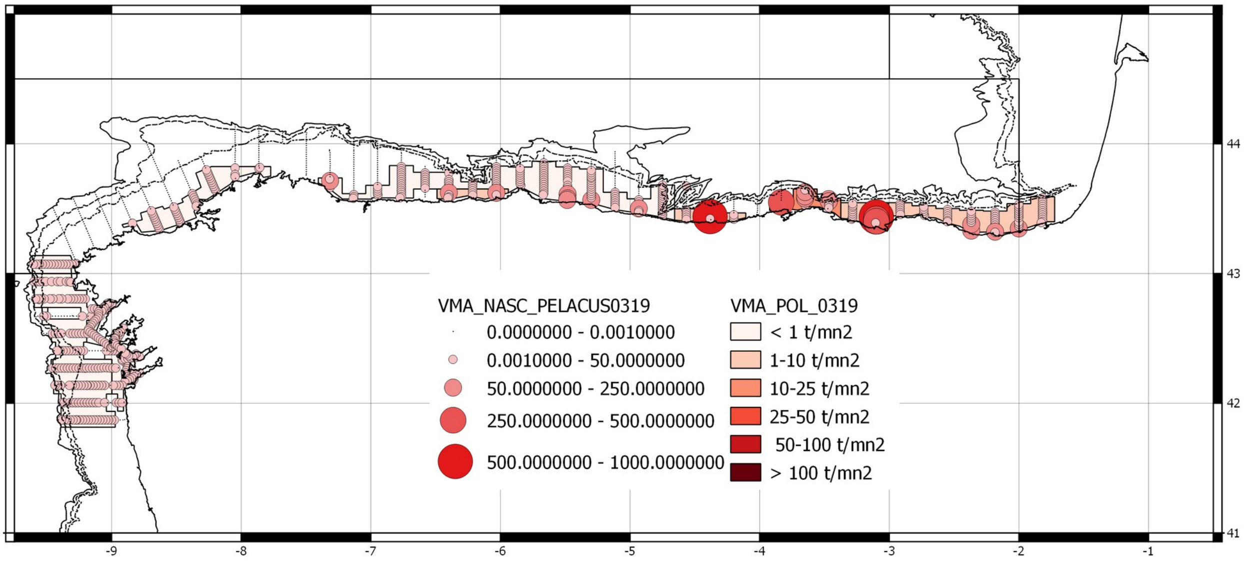


Figure 49: Chub mackerel spatial distribution

Assessment

A total of 7025 tonnes, corresponding to 48 millions fish were assessed, as shown in figure 50 and tables 20 and 21. although scarce, this assessment doubled the estimates done in the previous year. Age group 3 was dominant, accounting for the 55% of the abundance (66% in weight), which is in agreement to that found in 2018 when age group 2 was dominant (figure 50). Together with this, 2018 seems to be better than that of 2017, accounting for 36 of the total abundance, while the later only accounted for the 13%, which reflects the scarcity of age group 1 estimated last year.

Table 20: Chub mackerel assessment by ICES Division

Zone	Area	No	Mean	Surface	Fishing st.	PDF	No (million fish)	Biomass (tonnes)	Density (Tn/nmi-2)
9a-N	9a_Coast	129	0.06	269	P05-P08-P18	ST01	0	2	0
	9a_Off	157	0.42	1189	P02-P03-P06-P11	ST02	0	68	
	Total	***286***	***0***	***1458***			***0***	***70***	0
8c	8c_Artabro	46	5.39	395	P27-P28	ST03	1	310	1
	8c_Avilés	11	18.12	91	P05-P18	ST04	2	197	2
	8c_Cantabrico	147	6.25	1175	P06-P11	ST05	5	1009	1
	8c_Llanes	13	75.23	98	P05-P08	ST06	8	848	9
	8c_Cantabria	19	125.23	152	P06-P11	ST05	14	2614	17
	8c_Laredo	19	82.94	144	P05-P08	ST06	13	1370	10
	8cEd	67	9.28	492	P02-P03	ST07	4	608	1
	Total	***322***	***21***	***2547***			***48***	***6955***	
	Total Spain	***608***	***12***	***4005***			***48***	***7025***	2

Table 21: Chub mackerel assessment by age group and length class

	AGE GROUPS								
Length	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**	**No fish (mill**
10									
11									
12									
13									
14									
15									
16									
17									
18	14							13.73	0
19	204							204.40	3
20	483							483.38	7
21	317	35						352.18	4
22	225							224.80	2
23	4	1	1					6.13	0
24		76						76.35	1
25		152	114					265.68	2
26		226	586					811.84	5
27		190	1114					1304.10	8
28		105	871	17				993.50	5
29		66	648					714.78	3
30			551	29				580.41	2
31			365	49				413.39	2
32			125	31				155.82	1
33			148	59				206.94	1
34			16					16.04	0
35			121	61				181.82	0
36				9	9			17.60	0
37									
38					1	1	1	2.17	0
39									
40									
41									
42									
43									
44									
Biomass (t)	1247	851	4661	255	10	1	1	7025	48
%	17.75	12.12	66.35	3.63	0.14	0.01	0.01		
M. weight	67.01	138.29	180.29	267.84	390.22	455.58	455.58	127.84	
No Fish (million)	17	6	24	1	0	0	0	48	
%	35.80	11.92	50.35	1.87	0.05	0.00	0.00		
M. length	20.79	26.24	28.58	32.46	36.63	38.50	38.50	25.59	
s.d.	1.00	1.90	1.95	2.16	0.50			4.07	

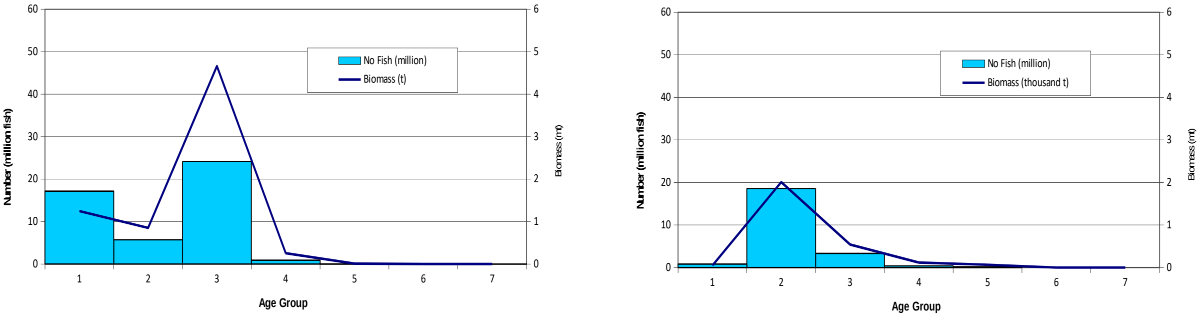


Figure 50: Chub mackerel abundance and biomass estimates by age group (2019, left; 2018, right)

Other metrics

The abundance and biomass peaked in 2016, but there is an increasing trend since that. Mean length is fluctuating around 24 cm, according to the strength of the incoming year classes and the changes in mean weight are in consonance with this fluctuation (figure 51).

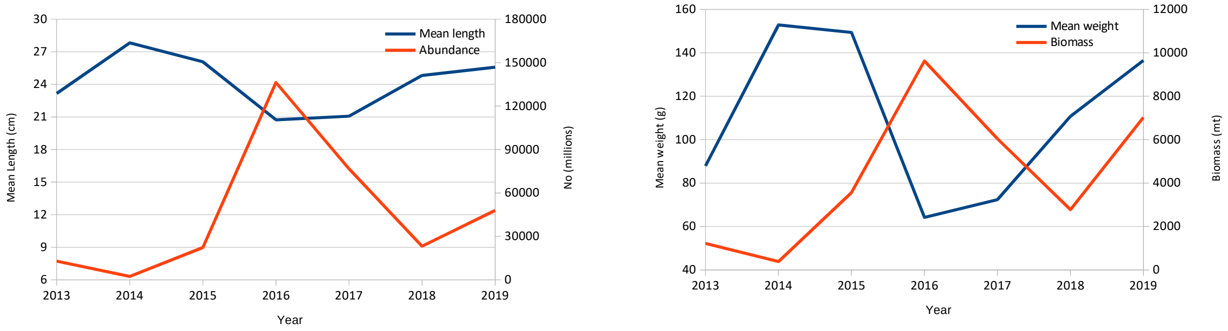


Figure 51: Trends (2013-19) in mean weight and length, abundance and biomass estimates of southern horse mackerel

Interesting, mean length and weight-at-age do no show any increasing trend, specially in the later indicator, as observed in other fish species such as sardine, horse mackerel or mackerel. (figure 52).

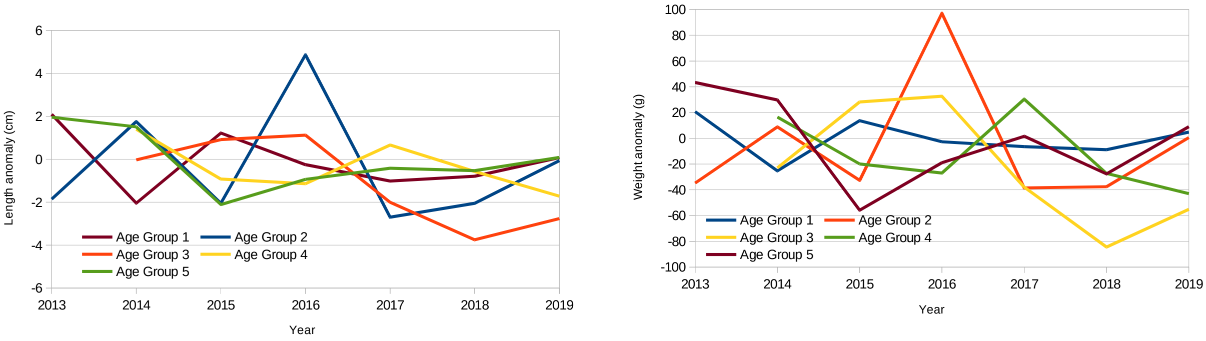


Figure 52: Trends (2013-19) in mean length-at-age (above) and mean weight-at-age of chub mackerel.

Conclusion

Chub mackerel is a species whose availability in early spring is very low, and progressing northwards from Portugal in the middle of the year. Yet, there is a stable population in the inner part of the Bay of Biscay No clear trend in abundance is observed for southern horse mackerel, although as observed in the western horse mackerel the dynamics seems to be too complex. As for most of the species, the most noticeable is the increasing trend in mean weight-at-age.

Boar fish assessment

Adult distribution

Boar fish, although the significant decrease occurred since 2014, mainly occur in the western part of the Cantabrian Sea (figure 53). In this area the normal aggregration pattern was pelagic schools, but now often is recorded near bottom, without any clear echotrace and rather in a bottom aggregation.

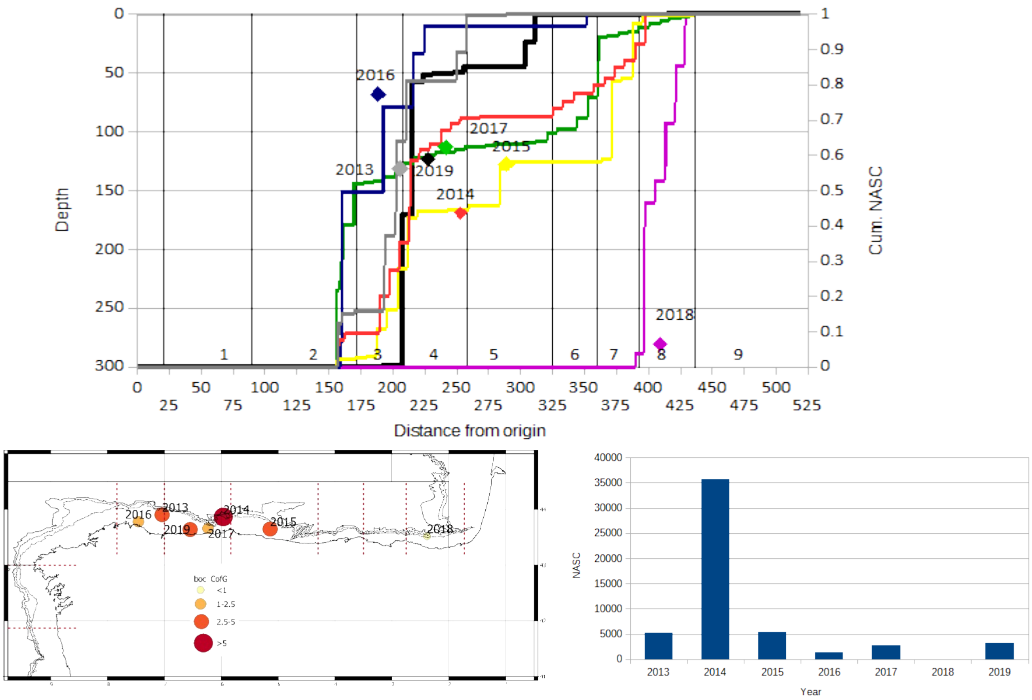


Figure 53: Above: cumulated NASC frequency along the coast and center of gravity for boar fish since 2013. Below: left, center of gravity indicating as well the biomass estimates (thousand tonnes); right panel, total backscattering energy (NASC) whiting since 2013 in the Spanish waters

Figure 54 shows the spatial distribution accounting the allocated backscattering energy per ESDU. This year boar fish showed a rather wider distribution along the slope, from the inner part of the Bay of Biscay until the central part of the Cantabrian Sea, but with a scarce density. Together with this another area in the west was found progressing as well around the slope but in this case also towards coastal waters, being also found at the fishing station done in shallower waters.

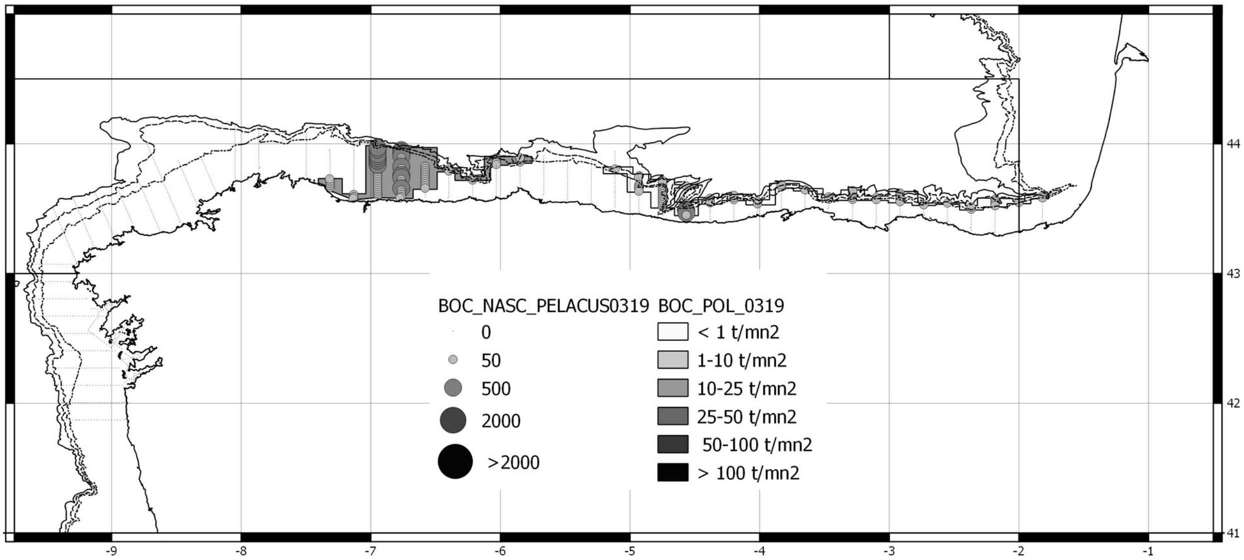


Figure 54: boar fish spatial distribution

Assessment

A total of 2873 tonnes, corresponding to 48 millions fish were assessed, as shown in figure 54 and table 22. Accounting that the backscattering energy attributed to this fish species in 2018 was below the threshold to be assessed, this year there was an important increase. Interesting, this increase was only due to larger fish with mode at 14 cm while the typical mode at 8 cm, recorded up to 2015 was not found (figure 55).

Table 22: Boar fish assessment by ICES Division

Zone	Area	No	Mean	Area	Fishing st.	PDF	No (million fish)	Biomass (tonnes)	Density (Tn/nmi-2)
8c	8c_Ee	69	7.19	615.30	P24	S02	7	434	1
	8c_Ew	78	35.62	698.71	P27	S03	41	2439	3
	Total	***147***	***22.28***	***1314***			***48***	***2873***	2
Total Spain		***147***	***22***	***1314***			***48***	***2873***	2

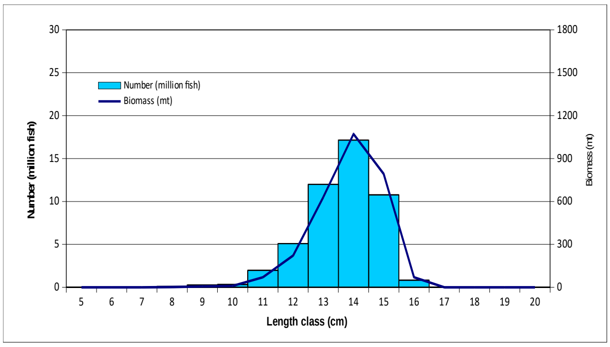


Figure 55: Boar fish abundance and biomass estimates by length class

Other metrics

The abundance and biomass peaked in 2014 and since that remain at low level. The lack of a second mode located at 7-8 cm lead to both mean length and mean weight to notably increase since 2015, when the mean length is stable at 14 cm, in coincidence with the mode (figure 56).

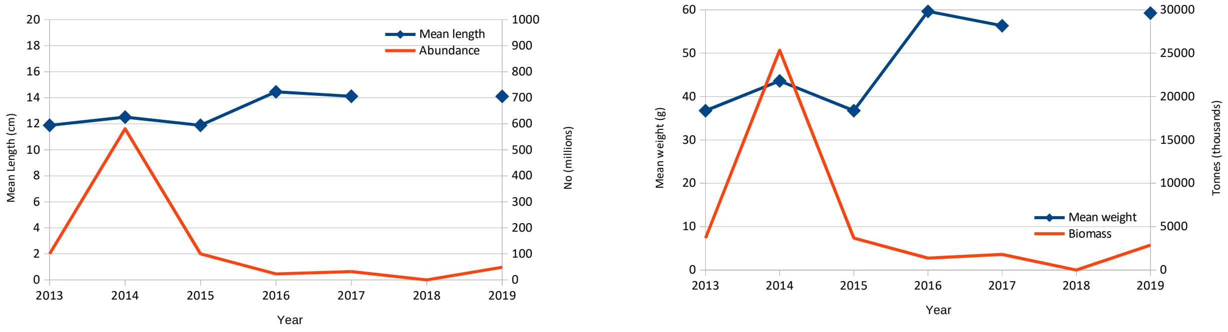


Figure 56: Trends (2013-19) in mean weight and length, abundance and biomass estimates of boar fish

Expressed as difference from the long term length and weight average (2013-19), the changes in mean length are also reflected in the differences between each particular year and the mean weight for the whole time series. It means that for this species there is no trend in mean weight as observed for other species (figure 57).

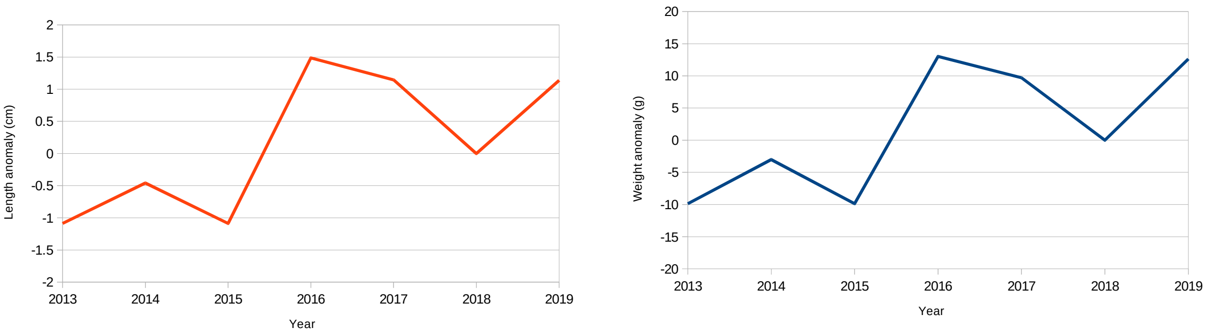


Figure 57: Trends (2013-19) in mean length and mean weight of boar fish.

Conclusion

In spite boar fish is not the target of any fishery nor the reported discards are showing an increase of the catches of this species, the biomass is now at low level. The lack of a mode 8 cm as observed up to 2015 would be indicating a change in the productivity of this stock since that period.

Pearlside

Adult distribution

Pearlsides, although always present, since 2014 a significant number of schools started to occur, mainly in the western part of the surveyed area. In 2018 the center of gravity shifted towards the inner part of the Bay of Biscay. In 2019 the pearlside density in the western part was very scarce, being the bulk located in the eastern part (figure 58). Besides, almost no extension towards the continental shelf was detected, while in some years, when the bulk was located in the western part, some schools were also detected on the shelf.

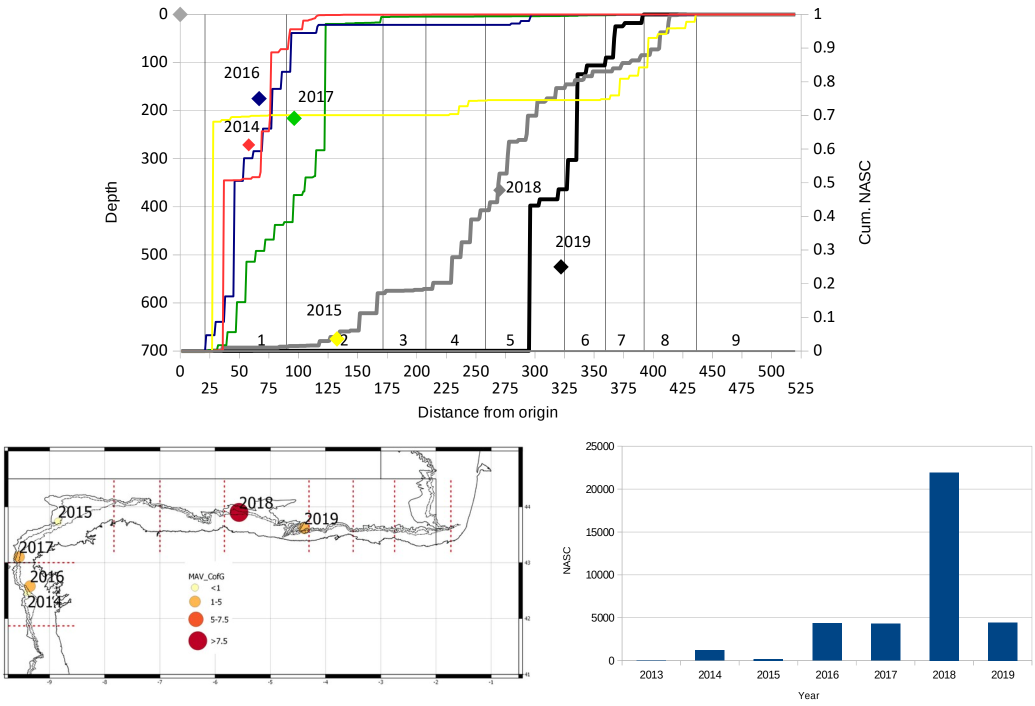


Figure 58: Above: cumulated NASC frequency along the coast and center of gravity for pearlside since 2013. Below: left, center of gravity indicating as well the biomass estimates (thousand tonnes); right panel, total backscattering energy (NASC) whiting since 2013 in the Spanish waters

Figure 59 shows the spatial distribution accounting the allocated backscattering energy per ESDU in 2019. As explained, this year pearlsides were mainly located in the Cantabrian sea, from the inner part of the Bay of Biscay to the central part.

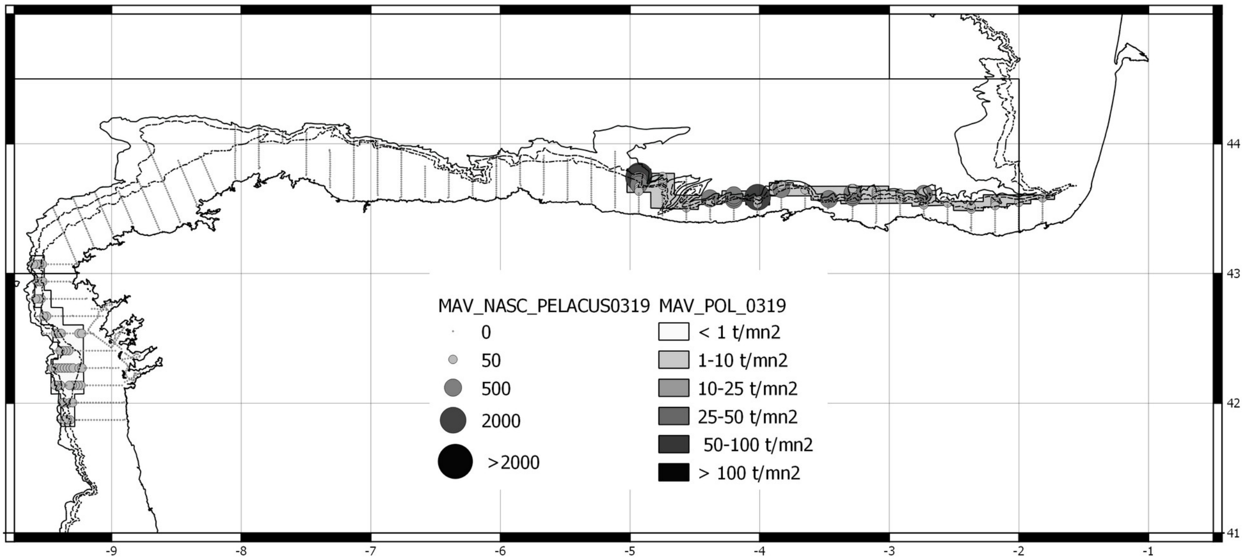


Figure 59: Pearlside spatial distribution

Assessment

A total of 2119 tonnes, corresponding to 1543 millions fish were assessed, as shown in figure 59 and table 23. This is an important decrease from the biomass estimated in 2018 when reached up to 22 thousand tonnes and occurred all around the slope of the surveyed area; length distribution was similar to that found in previous years.

Table 23: Pearlside assessment by ICES Division

Zone	Area	No	Mean	Area	Fishing st.	No (million fish)	Biomass (tonnes)	Density (Tn/nmi-2)
8c	8c	96	46.25	907	P10-P13-P21-P27-P29	1542.39	2117.70	2
9a	9a	73	0.04	567		0.89	1.23	0
	Total	***169***	***26***	***1474***		***1543***	***2119***	**1**
Total Spain		***169***	***26***	***1474***		***1543***	***2119***	**1**

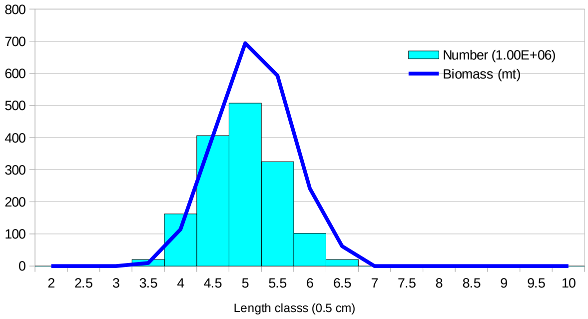


Figure 59: Pearlside abundance and biomass estimates by length class

Working progress

Not all data collected in the survey are already analysed. Among those, chemical characterisation of the water column, isotope analysis, marine litter of apical observations are still not available

Manta trawls

Manta trawl hauls are usually linked to the fishing operation and ultimately depend on the weather condition (wind strength and waves), thus limiting the number of operation. Figure 60 shows the location of the manta trawl carried out in PELACUS.

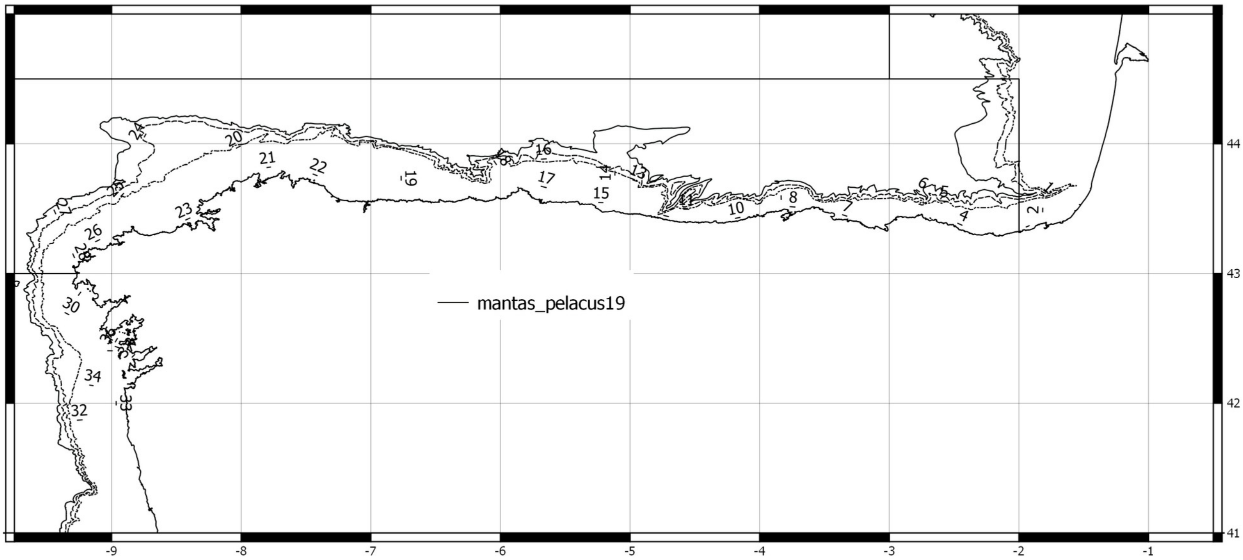


Figure 60 location of the manta trawl haul done in PELACUS 0319 (37)

Apical observations

As for manta trawl haul, apical observation depend on the weather condition (e.g. wind strength and waves), thus limiting the number of observation time. However it should be noted the increase in sightings of whales in the western part (Atlantic waters). Related with this, there is an increase of krill (*Meganyctiphanes norvegica*) schools recorded in this area. Figure 61 shows the typical swarm, in this case recorded this year in September during the IBERAS 0919 survey near Cape Fisterra

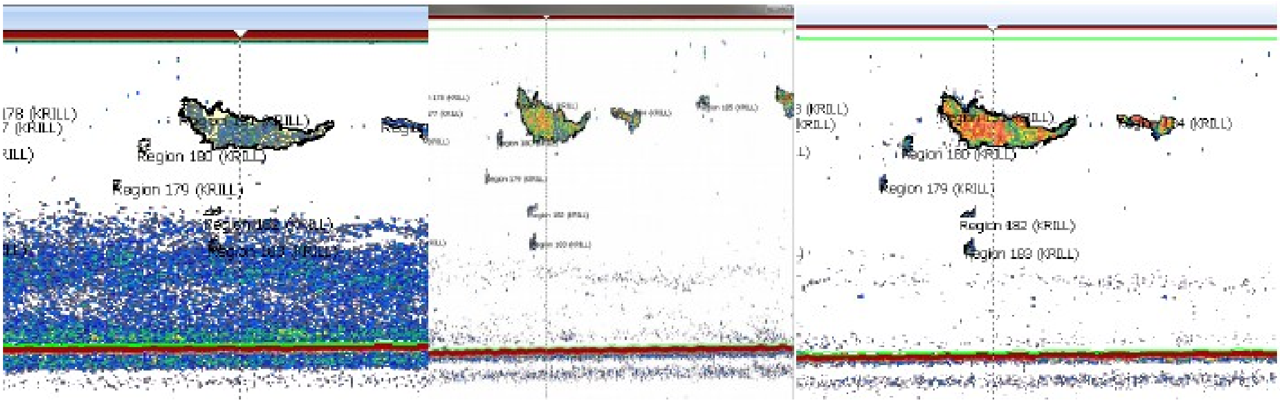


Figure 61 echogram showing a krill school at 38 (right), 120 (middle) and 200 kHz (left) recorded near cape Fisterra during IBERAS 0919 (September, 2019)

ACKNOWLEDGEMENTS

We would like to thank all the participants in PELACUS. We wish also to thank the captain and the crew of R/V Miguel Oliver for giving us all the solutions we needed to overtake all the challenges dealing with this multidisciplinary survey. Also José Ignacio Díaz got us all the support from the IEO.

CONSULTED BIBLIOGRAPHY

Abaunza, P, Gordo, L, Karlou-Riga, C., Murta, A., Eltink, A., García Santamaría, M. T., Zimmermann, C., Hammer, C., Lucio, P., Iversen, S. A., Molloy, J. and Gallo, E. 2013. Growth and reproduction of horse mackerel, Trachurus trachurus (carangidae). Reviews in Fish Biology and Fisheries 13: 27–61

Abaunza, P. 2008. Teoría y práctica en la identificación de stocks de peces de interés comercial. El jurel (Trachurus trachurus) como ejemplo de una aproximación holística a la identificación de stocks. PhD. Thesis. 230 pp In Spanish

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.

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.

Bruge, A., Alvarez, P., Fontán, a., Cotano, U., Chust G. 2016. Thermal niche tracking and future distribution of atlantic mackerel spawning in response to ocean warming. Warming.Front.Mar.Sci.3:86. doi: 10.3389/fmars.2016.00086

Carrera, P. 2016. Estudio de la dinámica de poblaciones pelágicas de peces mediante técnicas hidroacústicas. Ph Thesis 446 pp (In Spanish).

Clay, A., and Castonguay, M., 1996. In situ target strengths of Atlantic cod (Gadus morhua) and Atlantic mackerel (Scomber scombrus) in the Northwest Atlantic. Can. J. Fish. Aquat. Sci. 53: 87–98.

De Robertis, A., and Higginbottom, I. 2007. A post-processing technique to estimate the signal-to-noise ratio and remove echosounder background noise. – ICES Journal of Marine Science, 64: 1282–1291.

De Robertis, A., McKelvey, D.R., Ressler, P.H., 2010. Development and application of empirical multifrequency methods for backscatter classification in the North Pacific. Can. J. Fish. Aquat. Sci. 67, 1459–1474

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.

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 (clupea harengus) 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 (Capros aper) 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.

Foote, K.G., Knudsen, H.P., Vestnes, G., MacLennan, D.N. and Simmonds, E.J. 1987. Calibration of acoustic instruments for fish density estimation: a practical guide. ICES Coop. Res. Rep. 144, 57 pp.

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.

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 (Merluccius productus). 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 (Merluccius productus) target strength. Canadian Journal of Fisheries and Aquatic Sciences, 64: 1781–1794.

Higginbottom, I.R., Pauly, T.J., Heatley, D.C. 2000 Virtual echograms for visualisation and post-processing of multiple-frequency echosounder data. Proceedings of the Fifth European Conference on Underwater Acoustics, ECUA 2000. Edited by P. Chevret and M.E. Zakharia. Lyon, France, 2000 7pp

Honkalehto, T.H., P.H. Ressler, R.H. Towler, and C.D. Wilson. 2011. Using acoustic data from fishing vessels to estimate walleye pollock abundance in the eastern Bering Sea. Canadian Journal of Fisheries and Aquatic Sciences 68(7): 1231–1242

Hughes, K. M., Dransfeld, L. and Johnson, M. P., 2014. Changes in the spatial distribution of spawning activity by north-east Atlantic mackerel in warming seas: 1977–2010. Mar Biol (2014) 161:2563–2576 DOI 10.1007/s00227-014-2528-1

ICES. 1982. Report of the Working Group for the Appraisal of Sardine Stocks in Divisions VIIIc and IXa. ICES CM 1982/Assess:10, 41 pp.

ICES, 1982a. Report of the 1982 Planning Group on ICES-Coordinated Herring and Sprat Acoustic Surveys. ICES Document CM, 1982/H: 04.

ICES 1982b. Report of the international acoustic survey on blue whiting in the Norwegian Sea, July/ August 1982. ICES CM 1982/H:5.

ICES 2014. Report of the Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA). ICES ACOM COMMITTEE. ICES CM 2014/ACOM:16. 532 pp.

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

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

MacLennan, D.N., Fernándes, P.G. and Dalen, J. 2002. A consistent approach to definitions and symbols in fisheries acoustics. ICES J. Mar. Sci. 59, 365-9.

Nakken, O. and Dommasnes, A. 1975. The application of an echo integration system in investigation of the sock strength of the Barents Sea capelin 1971-1974. Int. Coun. Explor. Se CM 1975/B:25, 20pp (mimeo)

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

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 (Micromesistius poutassou): implications for biomass estimates. ICES Journal of Marine Science, 68: 2222–2228.

Santos, M. B., González-Quirós, R., Riveiro, I., Iglesias, M., Louzao, M., and Pierce, G. J. 2013. Characterization of the pelagic fish community of the north-western and northern Spanish shelf waters. Journal of Fish Biology. Doi: 10.1111/jfb.12107.

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

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.

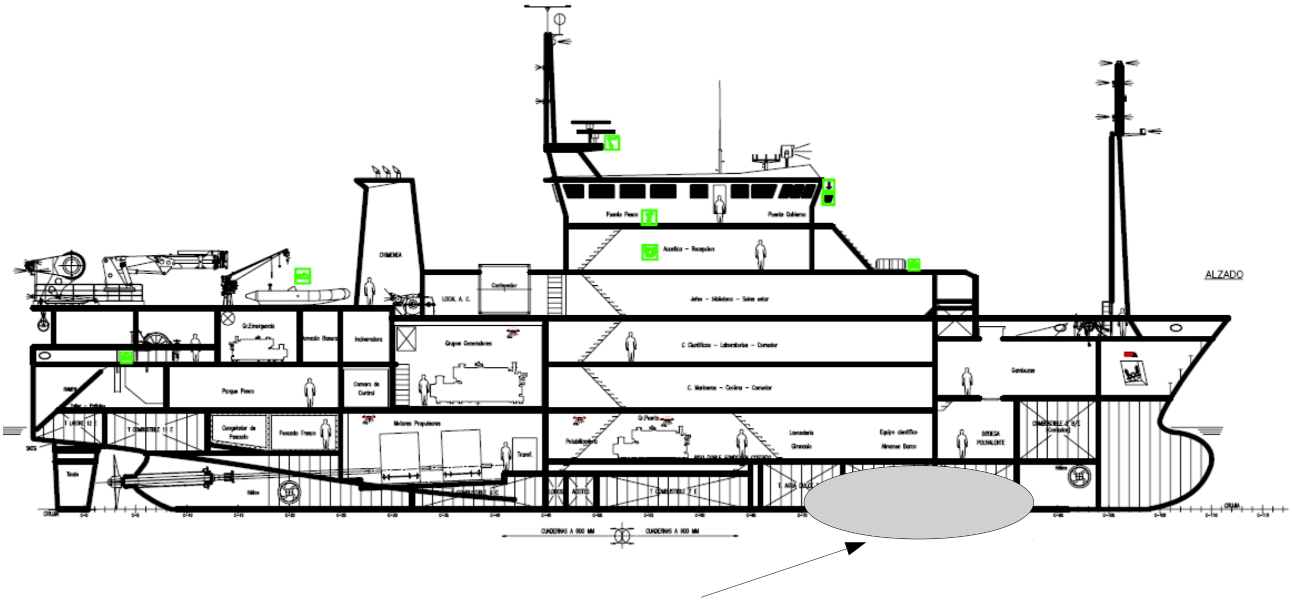
Zhao, X., Wang, Y., and Dai, F. 2008. Depth-dependent target strength of anchovy (Engraulis japonicus) measured in situ. ICES Journal of Marine Science, 65: 882–888.

ANNEX 1

An application of the Honkalehto et al (2011) bubble swept-down filter in PELACUS

As observed in other research vessels, hull-mounted transducer on a gondola, although useful in calm water, often have problems in bad weather conditions (high winds and/or swell). This is because the turbulence along the hull surface produces a layer of bubble which interferes with sound propagation. This may led to an underestimation of the fish biomass and, in some cases, to the total lost of the acoustic signal.

PELACUS is an acoustic-trawl survey aiming at the estimation of the biomass and distribution of the main pelagic fish species in NW Spanish water in spring time. It's conducted on board R/V Miguel Oliver, built in 2007 with all transducers in a gondola

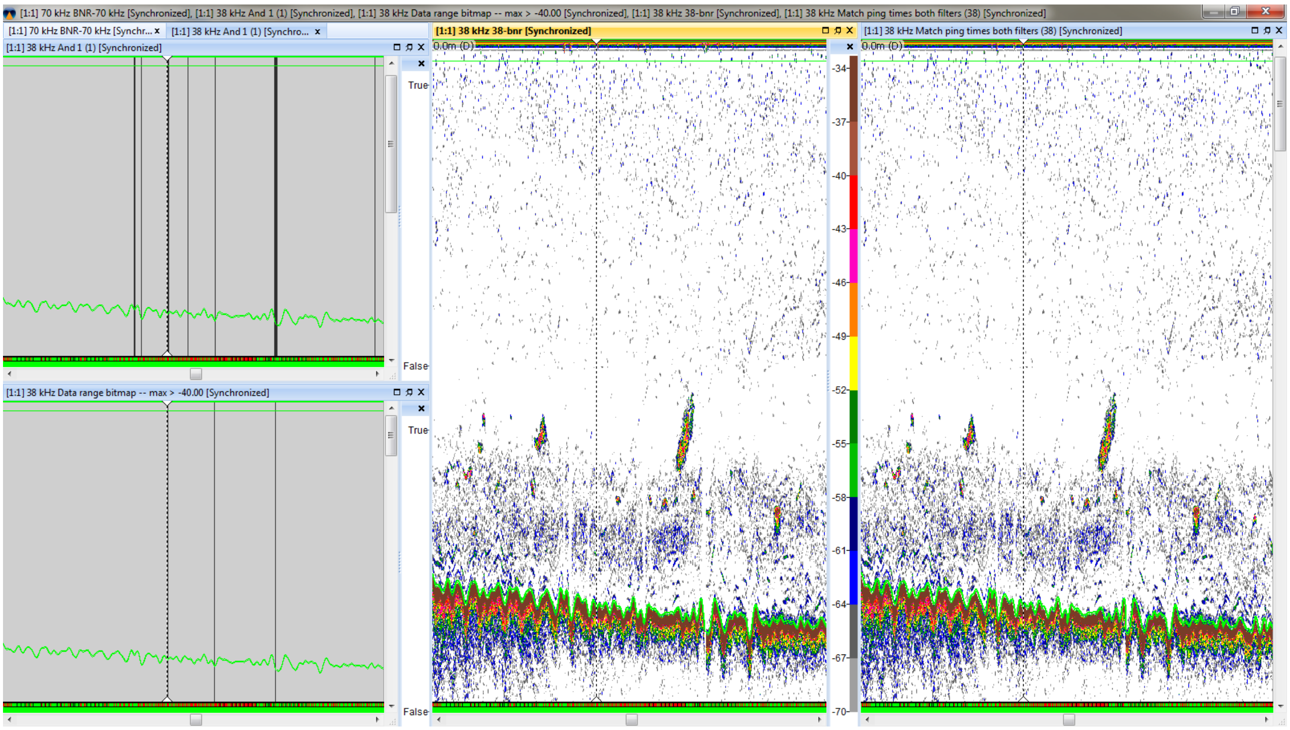


R/V Miguel Oliver, with the location of the gondola

The performance of the vessel is good, but in rough seas, bubbles are an important issue. If time is available, this weather conditions use to be avoided, by resting at harbour, thus decreasing the risk of bubbles but also the different fish behaviour due to the turbulence. However in case of continuous bad weather conditions, acoustic data has to be recorded. In such conditions, acoustic data are pre-processed by applying a filter which reduces the pings with significant bubble swept-down effect.

The filter consists on a double check. On account both the bottom return and the transmit pulse. For bottom, because of the slope, the analysis has been done on a layer of 30 m width, counted from the true bottom depth (either calculated manually or automatically) to down. Within this layer, any ping with a maximum value in S_V lower than 40/30 dB is removed. In the case of the transmit pulse, after an analysis, a double filter for lower and higher values is applied removing those pings outside de boundaries of 16.77 and 18.40 dB.

Next figure is showing the application of both filters to a particular region.



Swept-down bubble filter. Left, boolean (true/false matching rule according to criteria); middle the original echogram (with previous noise filtering) and the resulting echogram once applied the filter.

Unión Europea
Fondo Europeo Marítimo y de Pesca (FEMP)

Funded by the EU through the European Maritime and Fisheries Fund (EMFF) 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.

Working Document to WGACEGG, 18-22 November 2019, Madrid (Spain)

BIOMAN 2019: Ecosystem survey approach

by

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Abstract

The research survey BIOMAN 2019 to estimate the anchovy biomass applying the Daily Egg Production Method (DEPM) and to estimate the total egg production for sardine in the Bay of Biscay was conducted in May 2019 from the 9th to the 31st covering the whole spawning area of the species. Two vessels were used: The R/V Ramón Margalef to collect the plankton samples and the pelagic trawler Emma Bardán to collect the adult samples. The total area covered was 117,111Km^2 and the spawning area was 79,735Km^2 for anchovy and 38,007 Km^2 for sardine. During the survey 782 vertical plankton samples were obtained (PairoVET), 1,883 horizontal plankton samples (CUFES) and 45 pelagic trawls were performed, from which 42 contained anchovy and 40 were selected for the analysis. Moreover, 3 extra samples were obtained from the commercial fleet. In total, there were 43 samples for the adult parameters estimate.

18% of the total anchovy eggs were found in the Cantabric coast from the coast and passed the 200m depth in all the transects surveyed, until 6º'W where the sampling was stopped. There were eggs all over the French platform, until 200m depth, up to 46ºN and, from there, until 48ºN from coast to 100m depth, were the limit was found. There were some anchovy eggs at the limit of the 8abd at 48ºN but within 8abd so those were considered for the total egg production estimate. The weather conditions during the survey were good in general with a mean Sea Surface Temperature of 14.8.2ºC and a mean sea surface salinity of 35.

Total egg production (P_{tot}) for anchovy and for sardine was calculated as the product of spawning area and daily egg production rate (P_0), which was obtained from the exponential decay mortality model fitted as a Generalized Linear Model to the egg daily cohorts.

The adult parameters, sex ratio (*R*), batch fecundity (*F*), spawning frequency (*S*) and weight of mature females (W_f), were estimated based on the adult obtained during the survey. Consequently, the total Biomass for anchovy resulted in 223,210 t, the highest of the series, with a coefficient of variation of 12%. Total egg abundance of sardine at ICES 8abd without the North part was 4.5 E+12 eggs, lower than last year estimate (4.7 E+12) and the historical mean (5.8 E+12) for that area.

This is the fourth year were sights were achieved. Marine mammals, seabirds, human activities & debris were recorded. And the third year were eDNA and microplastics were surveyed, looking for an ecosystem survey approach.

1. Introduction

Anchovy (*Engraulis encrasicolus*) is one of the commercial species of high economic importance in the Bay of Biscay. The economy of the Spanish purse seine fleets (primarily from the Basque Country, Cantabria and Galicia) and the French fleet rely on this resource (Uriarte *et al*., 1996 and Arregi *et al*., 2004). To provide proper advice on the fishery management, it is necessary to conduct annually a monitoring of the population. Thanks to it, ICES recommended a limited TAC of 33,000 t for 2019.

Anchovy is a short-lived species; therefore, the evaluation of its biomass should be conducted by direct assessment methods as the Daily Egg Production Method (DEPM) (Barange *et al*, 2009). This consists of estimating the spawning stock biomass (*SSB*) as the ratio between the total daily egg production (P_{tot}) and the daily fecundity (*DF*) estimates. In consequence, this method requires a survey to collect anchovy eggs (plankton sampling) for estimating the P_{tot} and, anchovy adults (adult sampling) for estimating the *DF*. In the case of anchovy, the SSB is equal to the total biomass (B), since at the survey time, which is at the spawning peak, the whole population is spawning. Since 1987, AZTI (Marine and Food Technological Centre, Basque country, Spain), has conducted annually a specific survey to obtain anchovy biomass indices (Somarakis *et al*., 2004; Motos *et al*., 2005, Santos *et al,* 2010, Santos *et al,*2018). In addition, the anchovy Basque fishery has been continuously monitored. This information has been submitted annually to ICES, to advice on the regulation of this fishery.

The survey for the application of the DEPM to estimate the Bay of Biscay anchovy biomass "BIOMAN" is one of the two surveys which give information about the anchovy population in spring. The other one carried out at the same time in May is the acoustic French survey. The biomass indices provided by the acoustic and DEPM surveys together with the information supplied by "JUVENA" (survey to estimate in autumn the juvenile biomass) and the catches of the fleet are used as input variables for a two-stage biomass model used to assess the Bay of Biscay anchovy population (Ibaibarriaga *et al*., 2008). Since 2014 the assessment of the species is carried out in December of each year, and the advice is from January to December. Apart from the anchovy biomass estimates this survey gives yearly information on the distribution and abundance of sardine eggs and environmental conditions due to the recollection of different parameters in the area surveyed. Moreover, every three years the DEPM is applied to sardine. And since 2016 an observer sighted marine mammals, seabirds, marine litters and human activities, a neuston net for microplastics was used, water was filtered for eDNA analysis, and the zooplankton was analyzed by size looking over the plankton samples since 1987.

This working document describes the BIOMAN2019 survey for the application of the DEPM for the Bay of Biscay anchovy in 2019. First, the data collection, the estimation of the total egg production and the reproductive parameters are described in detail. Then, the biomass index and the age structure of the population are given; those will be used for the assessment and posterior management of this stock. Finally, the historical trajectory of the population is reviewed. The report of the sighting is in **annex 1**.

2.Material and Methods

2.1 Survey description

The BIOMAN2019 survey was carried out in May from the 9th to the 31st, at the anchovy spawning peak, covering the whole spawning area of the specie in the Bay of Biscay. During the survey, ichthyoplankton and adult samples were obtained for the estimation of total daily egg production (P_{tot}) and total daily fecundity respectively for anchovy, and sardine too in the case of P_{tot}. The age structure of the population was also estimated. In addition, 31 Neuston net were collected spread all over the area to obtain microplastic abundance distribution. Moreover, 55 water samples from the surface (from the water intake of the vessel R. Margalef) and 7 samples with a rosette taking water from 5, 50, 200, 500, 1000m and maximum depth were filtered for eDNA analysis to obtain distribution maps of fish, marine mammals, seabirds, sharks, turtles and anisakis. Besides, an observer sighted marine mammals, seabirds, marine litters and human activities. This year the zooplankton from PairoVET and CUFES samples was analysed on board with the flowcam macro.

The collection of plankton samples was carried out on board R/V Ramón Margalef. The area covered was the southeast of the Bay of Biscay (**Fig. 1**), which corresponds to the main spawning area and spawning season of anchovy. The sampling strategy was adaptive. The survey started from the West (transect 3, at 5°37'W); as there were eggs the survey continued to the west looking for the western limit, up to 6ºW but the west limit was not found at the Cantabrian sea. Then the survey continuous covering the Cantabrian Coast eastwards up to Pasajes (transect 25, approx. 1°30'W) (**Fig.1**). The survey continued to the north arriving until 48° 07'N, looking for the Northern limit of the spawning area that was found at 48ºN just in the limit of the 8abd. When the egg abundances found were relatively high, additional transects separated by 7.5 nm were completed. This occurred from the Adour until Arcachon up to 200m depth and the area of influence of Gironde and at the Basque area of the Cantabric coast. The survey was stopped for almost 24h the 21st of May, after 11 days of survey to do gas oleo.

The strategy of egg sampling was identical to that used in previous years, i.e. a systematic central sampling scheme with random origin and sampling intensity depending on the egg abundance found (Motos, 1994). Stations were situated at intervals of 3 nmi along 15 nmi apart transects perpendicular to the coast or 7.5 in places of high anchovy egg abundance.

At each station, a vertical plankton haul was performed using a PairoVET net (Pair of Vertical Egg Tow, Smith *et al.*, 1985 in Lasker, 1985) with a net mesh size of 150 µm for a total retention of the anchovy and sardine eggs under all likely conditions. The net was lowered to a maximum depth of 100 m or 5 m above the bottom in shallower waters. After allowing 10 seconds at the maximum depth for stabilisation, the net was retrieved to the surface at a speed of 1 m s^{-1}. A 45kg depressor was used to allow for correctly deploying the net. "G.O. 2030" flowmeters were used to detect sequential clogging of the net during a series of tows.

Immediately after the haul, the net was washed, and the samples obtained were fixed in formaldehyde 4% buffered with sodium tetra borate in sea water. After six hours of fixing, anchovy, sardine and other eggs species were identified, sorted out and counted on board. Afterwards, in the laboratory, the sorting of the samples was finished, and a percentage of the samples were checked to assess the quality of the sorting made at sea. According to that, a portion of the samples were sorted again to ensure no eggs were left in the sample. In the laboratory, anchovy and sardine eggs were classified into morphological stages (Moser and Alshtrom, 1985).

Sample depth, temperature, salinity and fluorescence profiles were obtained at each sampling station using a CTD RBR-XR420 coupled to the PairoVET. At some points determinate before the survey, water was filtered from the surface to obtain chlorophyll samples to calibrate the fluorescence data.

The Continuous Underway Fish Egg Sampler (CUFES, Checkley *et al*., 1997) was used to record the eggs found at 3m depth with a net mesh size of 335µm. The samples obtained were immediately checked in fresh material under the microscope so that the presence/absence of anchovy and sardine eggs were detected in real time. When anchovy or sardine eggs were not found in six consecutive CUFES samples in the oceanic area, transect was abandoned. The CUFES system had a CT to record simultaneously temperature and salinity at 3 m depth, a flowmeter to measure the volume of the filtered water, a fluorimeter and a GPS (Geographical Position System) to provide sampling position and time. All these data were registered at real time using the integrated EDAS (Environmental Data Acquisition System) with custom software. A flowcam macro was used on board, to obtain zooplankton abundance by size range from the PairoVET and CUFES samples.

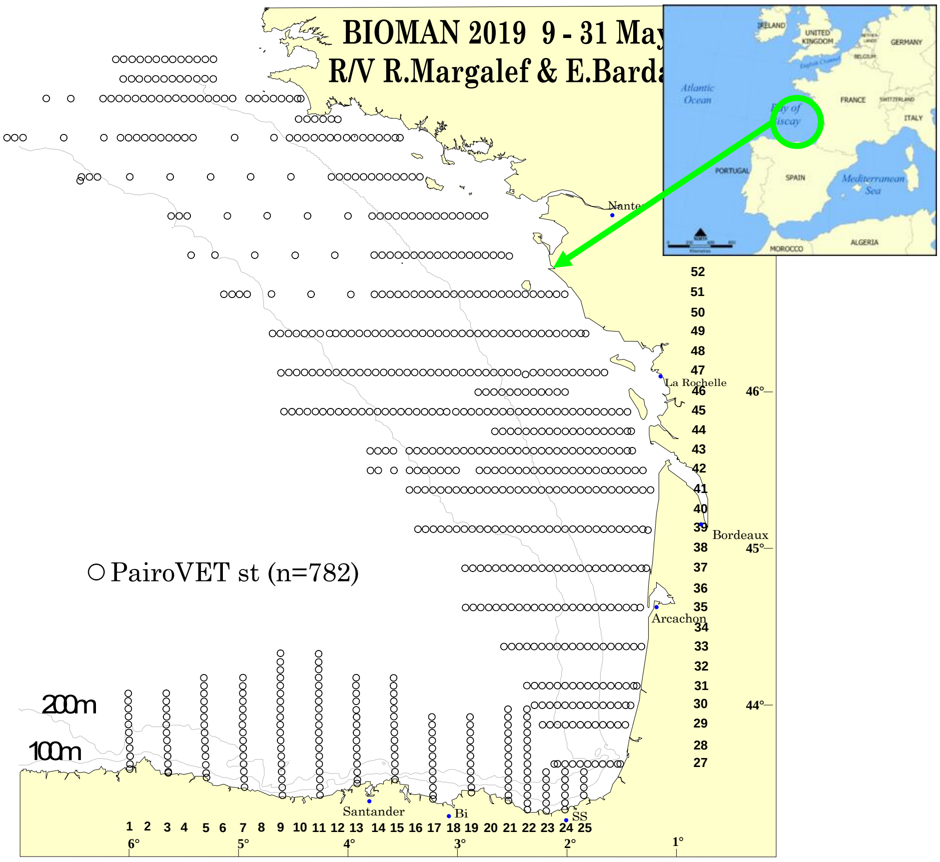


Figure 1: Vertical Plankton stations (PairoVET) during BIOMAN 2019.

The adult samples were obtained on board R/V Emma Bardán (pelagic trawler) from the 9th of May to the 1st of Jun coinciding in space and time with the plankton sampling. When the plankton vessel encountered areas with anchovy eggs, the R/V Emma Bardán was directed to those areas to fish. In each haul, immediately after fishing, anchovies were sorted from the bulk of the catch and a sample of two kg was selected at random. A minimum of one kg or 60 anchovies were weighted, measured and sexed in each haul. From the mature females, the gonads of 25 non-hydrated females (NHF) were preserved. When the target of 25 NHF was not completed, 10 more anchovies were taken at random and processed in the same manner. Sampling was stopped when 120 anchovies had to be sexed to achieve the target of 25 NHF. Otoliths were extracted onboard and read in the laboratory to obtain the age composition per sample. In each haul, 100 individuals (apart from anchovy and sardine) of each species were measured.

2.2 Total egg production

Total daily egg production (P_{tot}) was calculated as the product between the spawning area (SA) and the daily egg production (P_0) estimates:

$$P_{tot} = P_0\, SA \tag{1}$$

A standard PairoVET sampling station represented a surface of 45 Nm^2 (i.e. 154 km^2). Since the sampling was adaptive, the area represented by each station was corrected according to the sampling intensity and the cut of the coast. The total area was calculated as the sum of the area represented by each station. The spawning area (*SA*) was delimited with the outer zero anchovy egg stations although it could contain some inner zero anchovy egg stations embedded. The spawning area was computed as the sum of the area represented by the stations within the spawning area.

The daily egg production per area unit (P_0) was estimated together with the daily mortality rate (Z) from a general exponential decay mortality model of the form:

$$P_{i,j} = P_0 \exp\left(-Z\, a_{i,j}\right), \tag{2}$$

where $P_{i,j}$ and $a_{i,j}$ denote respectively the number of eggs per unit area in cohort *j* in station *i* and their corresponding mean age. Let the density of eggs in cohort *j* in station *i*, $P_{i,j,}$ be the ratio between the number of eggs $N_{i,j}$ and the effective sea area sampled R_i (*i.e.* $P_{i,j} = N_{i,j} / R_i$). The model was written as a generalised linear model (GLM, McCullagh and Nelder, 1989; ICES, 2004) with logarithmic link function:

$$\log\left(E[N_{i,j}]\right) = \log(R_i) + \log\left(P_0\right) - Z\, a_{i,j} \ , \tag{3}$$

where the number of eggs of daily cohort *j* in station *i* (N_{ij}) was assumed to follow a negative binomial distribution. The logarithm of the effective sea surface area sampled (log (R_i)) was an offset accounting for differences in the sea surface area sampled and the logarithm of the daily egg production log(P_0) and the daily mortality *Z* rates were the parameters to be estimated.

The eggs collected at sea and sorted into morphological stages had to be transformed into daily cohort frequencies and their mean age calculated to fit the above model. For that purpose, the Bayesian ageing method described in ICES (2004), Stratoudakis *et al*., (2006) and Bernal *et al.,* (2011) was used. This ageing method is based on the probability density function (pdf) of the age of an egg *f (age* | *stage, temp)*, which is constructed as:

$$f(age \mid stage, temp) \propto f(stage \mid age, temp)\, f(age)\,. \tag{4}$$

The first term *f (stage* | *age, temp)* is the pdf of stages given age and temperature. It represents the temperature dependent egg development, which is obtained by fitting a multinomial model like extended continuation ratio models (Agresti, 1990) to data from temperature dependent incubation experiments (Ibaibarriaga *et al.,* 2007, Bernal *et al.,* 2008). The second term is the prior distribution of age. A priori the probability of an egg that was sampled at time τ of having an age *age* is the product of the probability of an egg being spawned at time τ - *age* and the probability of that egg surviving since then (*exp(-Z age)*):

$$f(age) \propto f(spawn = \tau - age)\exp(-Z\ age) \ . \tag{5}$$

The pdf of spawning time *f (spawn=*τ *- age)* allows refining the ageing process for species with spawning synchronicity that spawn at approximately certain times of the day (Lo, 1985a; Bernal *et al*., 2001). Anchovy spawning time was assumed to be normally distributed with mean at 23:00h GMT and standard deviation of 1.25 (ICES, 2004). The peak of the spawning time was also used to define the age limits for each daily cohort (spawning time peak plus and minus 12 hours). Details on how the number of eggs in each cohort and the corresponding mean age are computed from the pdf of age are given in Bernal *et al.,* 2011. The incubation temperature considered was the one obtained from the CTD at 10m in the way down.

Given that this ageing process depends on the daily mortality rate which is unknown, an iterative algorithm in which the ageing and the model fitting are repeated until convergence of the *Z* estimates was used (Bernal *et al*., 2001; ICES, 2004; Stratoudakis *et al.,* 2006). The procedure is as follows:

Step 1. Assume an initial mortality rate value

Step 2. Using the current estimates of mortality calculate the daily cohort frequencies and their mean age.

Step 3. Fit the GLM and estimate the daily egg production and mortality rates. Update the mortality rate estimate.

Step 4. Repeat steps (1)-(3) until the estimate of mortality converged (i.e. the difference between the old and updated mortality estimates was smaller than 0.0001).

Incomplete cohorts, either because the bulk of spawning for the day was not over at the time of sampling, or because the cohort was so old that its constituent eggs had started to hatch in substantial numbers, were removed to avoid any possible bias. At each station, younger cohorts were dropped if they were sampled before twice the spawning peak width after the spawning peak and older cohorts were dropped if their mean age plus twice the spawning peak width was over the critical age at which less than 99% eggs were expected to be still unhatched. In addition, eggs younger than 4 hours and older than 90% of the survey incubation time (Motos, 1994) were removed.

Once the final model estimates were obtained the coefficient of variation of P_0 was given by the standard error of the model intercept (log(P_0)) (Seber, 1982) and the coefficient of variation of Z was obtained directly from the model estimates.

The analysis was conducted in R (www.r-project.org). The "MASS" library was used for fitting the GLM with negative binomial distribution and the "egg" library (http://sourceforge.net/projects/ichthyoanalysis/) for the ageing and the iterative algorithm.

2.3 Daily fecundity and total biomass

The daily fecundity (***DF***) is usually estimated as follows:

$$DF = \frac{R \cdot F \cdot S}{W_f}, \tag{6}$$

where *R* is the sex ratio in weight, *F* is the batch fecundity (eggs per batch per female weight), *S* is the spawning frequency (percentage of females spawning per day) and W_f is the female mean weight.

From 1987 to 1993 the **sex ratio (*R*)** in numbers resulted to be not significantly different from 50%. Therefore, since 1994 the sex ratio in numbers is assumed to be 0.5 and the sex ratio in weight per sample is estimated as the ratio between the average female weight and the sum of the average female and male weights of the anchovies in each of the samples.

A linear regression model between total weight (*W*) and gonad free weight (W_{gf}) was fitted to data from non-hydrated females:

$$E[W] = a + b * W_{gf} . \tag{7}$$

This model was used to correct the weight increase of hydrated anchovies. **The female mean weight (*W_f*)** per sample was calculated as the average of the individual female weights.

For **the batch fecundity (*F*)** the hydrated egg method was followed (Hunter and Macewicz., 1985). The number of hydrated oocytes in gonads of a set of hydrated females (10 females by size) was counted. This number was deduced from a sub-sampling of the hydrated ovary. Three pieces of approximately 50 mg were removed from the extremes and the centre of one of the ovary lobule of each hydrated anchovy. Those were weighted with precision of 0.1 mg and the number of hydrated oocytes counted. Finally, the number of hydrated oocytes in the sub-sample was raised to the gonad weight of the female according to the ratio between the weights of the gonad and the weight of the sub-samples

The model between the number of hydrated oocytes and the female gonad free weight was fitted as a Generalized Linear Model with Gamma distribution and identity link:

$$E[F] = a + b * W_{gf} \quad . \tag{8}$$

The average of the batch fecundity for the females of each sample as derived from the gonad free weight - eggs per batch relationship was then used as the sample estimate of batch fecundity.

Once sex ratio, female mean weight and batch fecundity were estimated per sample, overall mean and variance for each of these parameters were estimated following equations for cluster sampling (Picquelle & Stauffer, 1985):

$$y = \frac{\sum_{i=1}^{n} M_i y_i}{\sum_{i=1}^{n} M_i} \quad \text{and} \tag{9}$$

$$Var(y) = \frac{n \sum_{i=1}^{n} M_i^2 (y_i - y)^2}{\left(\frac{\sum_{i=1}^{n} M_i}{n} \right)^2 n(n-1)} \ , \tag{10}$$

where *Yi* and *Mi* are the mean of the adult parameter *Y* and the cluster sample size in sample *i* respectively. The variance equation for the batch fecundity was corrected according to Picquelle and Stauffer (1985) in order to account for the additional variance due to model fitting.

The weights *Mi* were taken to reflect the actual size of the catch and to account for the lower reliability when the sample catch was small (Picquelle and Stauffer, 1985). For the estimation of *W* and *F* when the number of mature females per sample was less than 20, the weighting factor was equal to the number of mature females per sample divided by 20; otherwise it was set equal to 1. In the case of R when the total weight of the sample was less than 800 g then the weighting factor was equal to the total weight of the sample divided by 800g, otherwise it was set equal to 1.

The estimation process of the **spawning frequency (*S*)** was estimate following Uriarte *et al.*, 2012.

The Spawning Stock Biomass (*SSB*) that in the case of anchovy is equal to **total biomass (B)** at the spawning peak when the survey occurred, was estimated as the ratio between the total egg production (P_{tot}) and daily fecundity (*DF*) estimates and its variance was computed using the Delta method (Seber, *1982*).

2.4 Numbers at age

To deduce the numbers at age different regions were defined depending on the distribution of the adult samples (size, weight and age) and the distribution of anchovy eggs.

Given that mean length and weight of anchovies change between those regions, proportionality between the number of samples and a proxy of the total biomass indices by regions was checked. The approximate index of biomass by regions was set equal to egg abundance divided by the daily fecundity (DF) assigned to each region. The DF by regions was approached by the general formula of this parameter ($F*S*R/W_f$) using the unweight mean of the adult parameters of the samples in the region.

2.5 Predators and human activities

We followed the same methodology implemented in the PELACUS and PELGAS multidisciplinary surveys based on the distance sampling methodology. We performed observations during daylight plankton and acoustic sampling, as well as during certain between-transect navigation while vessel speed and course were constant.

One observer was placed over the bridge of R/V Ramón Margalef, 6 meters high from the sea surface. The observer scanned the water to the front of the boat covering an area of 90° from the trackline to port or starboard (45° to each side), respectively continuously while the vessel was sailing at constant heading and speed during daytime. The temporal observation unit was one minute. The observer recorded the environmental conditions that could affect sightings (i.e., wind speed and direction, sea state, swell height, glare intensity, visibility, etc) and the distance to the sightings and the angle of the sightings with respect to the track-line were estimated. Additional data collected from each sighting included: species, group size, movement direction, behaviour, presence of calves and/or juveniles, etc. All sightings were made with the naked eye while the identifications were supported with 10abundance X42 binoculars. Results are showed in **annex 3**

2.6 Microplastics

A Neuston net with a rectangular opening 1m wide × 0.5m deep lined with a 3m long 330μm net fitted with screw-fit collector was used to sample the surface layer (top 30cm) of the water during the survey. The Neuston net was trawled alongside the vessel for 15-20 min at 2 knots. Material caught in the collector was sifted with a 150 μm mesh size. A CUFES sample was picked up at the same time the neuston net was trawling. Afterwards, the samples were preserved on plastic bags separately and kept at -20°C as much water-free as possible. On the laboratory after the survey the samples were visually sorted under a binocular to extract all the microplastics and fibres.

The aim of taken the CUFES samples at the same time as the Neuston net is to compare both to find a relation between them. If there were a relationship between them, the CUFES sampling could be substituted by the neuston net. We have already 3 years of this comparison.

2.7 eDNA

Water samples were collected on board the R/V Ramón Margalef using the continuous circuit intake of the ship at 4.4 m depth. A total of 5 L sea water per station was filtered through Sterivex 0.45 µm pore size enclosed filters (Millipore) using a peristaltic pump and kept at -20 °C until further processing. The aim of this is to explore the potential of environmental DNA (eDNA), the DNA present in the water column as part of shed cells, tissues or mucus, to provide comprehensive information about fish diversity, marine mammals, sea birds and sarks in the Bay of Biscay.

2.8 Zooplankton

All the historical series (1987-2018) of plankton samples (PairoVET) was processed for zooplankton size range abundances and some abundant genus with the scanner and the zoo-image. For the first time the plankton samples from PairoVET and CUFES 2019 were analysed on board for zooplankton with the flowcam macro obtaining size range abundance. We are working on filters to have classification of some genus as well.

3.Results

3.1 Survey description

18% of the total anchovy eggs were found in the Cantabric coast from the coast and passed the 200m depth in all the transects surveyed, until 6º'W where the sampling was stopped. There were eggs all over the French platform, until 200m depth, up to 46°N and, from there, until 48°N from coast to 100m depth, were the limit was found. There were some anchovy eggs at the limit of the 8abd at 48°N but within 8abd so those were considered for the total egg production estimate. (**Fig.2**)

The total area covered was 117,111 km² and the spawning area for anchovy 79,735 km². During the survey 782 vertical plankton samples were obtained, 574 with anchovy eggs (73%) with an average of 540 eggs m^{-2} per station in the positive stations and a maximum of 6,590 eggs m^{-2} in a station. A total of 30,882 anchovy eggs were encountered and classified. 1,883 CUFES samples (horizontal sampling at 3m depth, mesh size net 335) were achieved, 1,251 had anchovy eggs (66%) with an average of 23 eggs m^{-3} per station in the positive stations and a maximum of 332 eggs m^{-3}.

An abundance of 7.59 E+12 sardine eggs was encountered in all the area surveyed; a little bit higher than last year. To be included in the assessment for sardine in the 8abd the abundance from the Cantabric coast and part of the NW was removed, obtaining an egg abundance of 4.49 E+12 eggs. Eggs were encountered all along the Cantabric coast surveyed, between the coast and 200m depth isobath. In the French platform the eggs were from the Adour to 48°N inside the 100m depth isoline, all along the coast, where the north spawning limit was found but there were some eggs encountered at the ICES 8abd north limit at 48°N (**Fig.2**). In the plankton samples, from 782 stations, a total of 300 (38%) had sardine eggs with an average of 200 eggs per m^{-2} per station in the positive stations and a maximum of 2,840 eggs m^{-2}. in a station and a total number of eggs of 59,770 eggs m^2. In the sampling with CUFES (horizontal sampling) a total of 727 stations (38%) had sardine from 1,883 stations. To cover the spawning area of sardine in the Bay of Biscay the survey was extended to the North until 48°N and to the West until the West limit of the sardine spawning area was delimited. But for the propose to be an input for the assessment of sardine in the 8abd, stations from the Northwest were removed to maintain the same coverage of the area of the time series (**Fig.2**).

Both samplers PairoVET ($eggm^{-2}$) and CUFES ($eggm^{-3}$) show very similar anchovy and sardine egg abundances distribution pattern (**Fig.2**).

Distribution maps of anchovy and sardine egg abundances in the last 25 DEPM surveys were compiled (**Fig.19&20)**, at the end of the report).

Figure 3 shows the sea surface temperature and sea surface salinity maps registered during the BIOMAN2019 survey. **Figure 4** shows the SST and SSS maps overlapped with anchovy egg distribution from 20014 to 2019.

This year the mean SST of the survey, 14.8°C was lower than last year(15.2°C), the minimum was 10.2°C and the maximum16.8°C. The mean SSS (35) was higher than last year (34.41) with a minimum of 27.7 and a maximum of 39.5

The distribution patterns of sea surface temperature (SST) and sea surface salinity (SSS) observed were the typical for the region at this season showing the signatures of the Adour and Garonne River off the French coast.

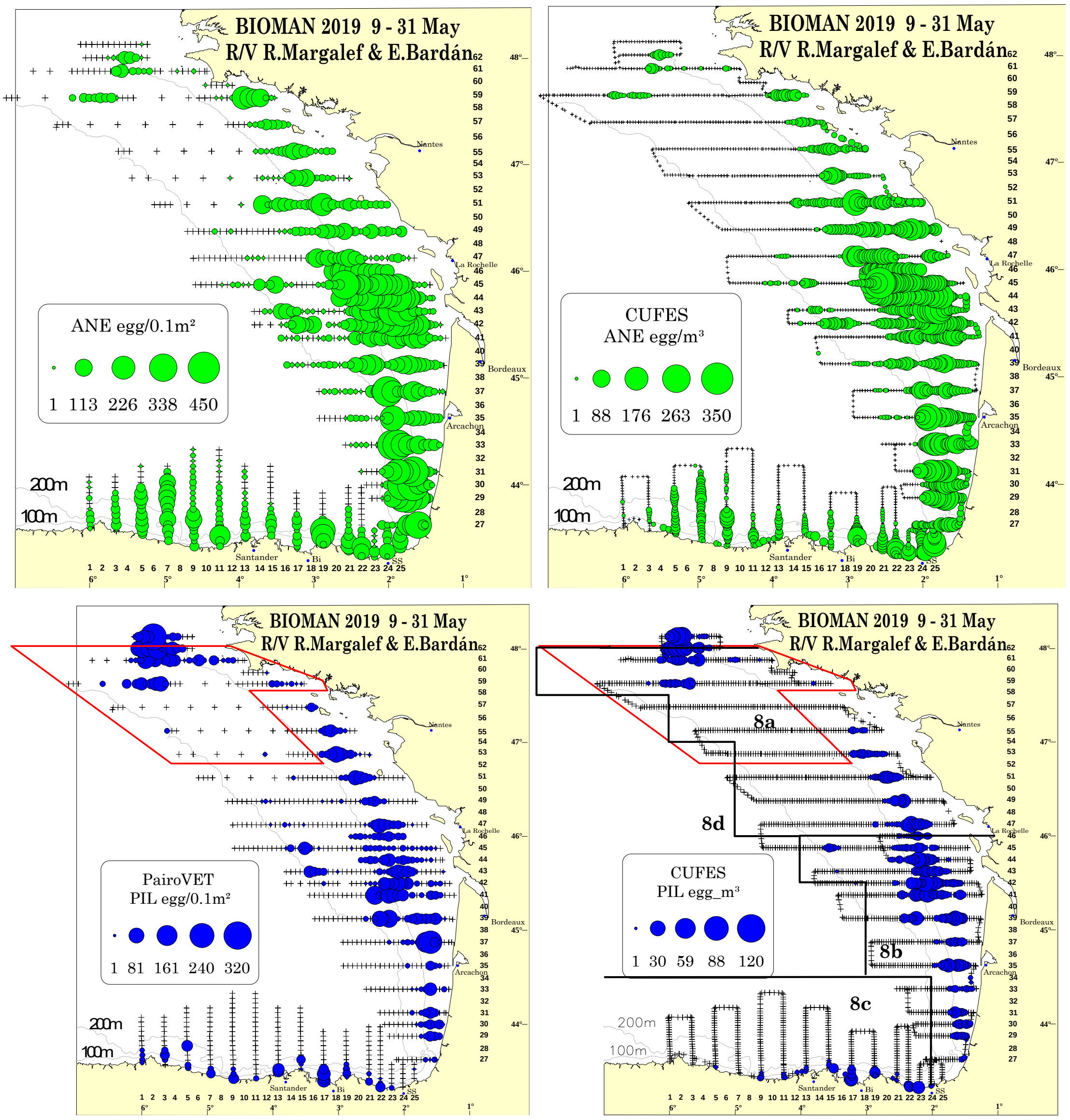


Figure 2: Distribution of anchovy (top) and sardine egg abundances (bottom) obtained with PairoVET (left) (eggs per 0.1m^2) and CUFES (right) (egg per m^3) from the DEPM survey BIOMAN2019. The red line delimits the stations removed to maintain the same coverage of the area in the time series for assessment proposes.

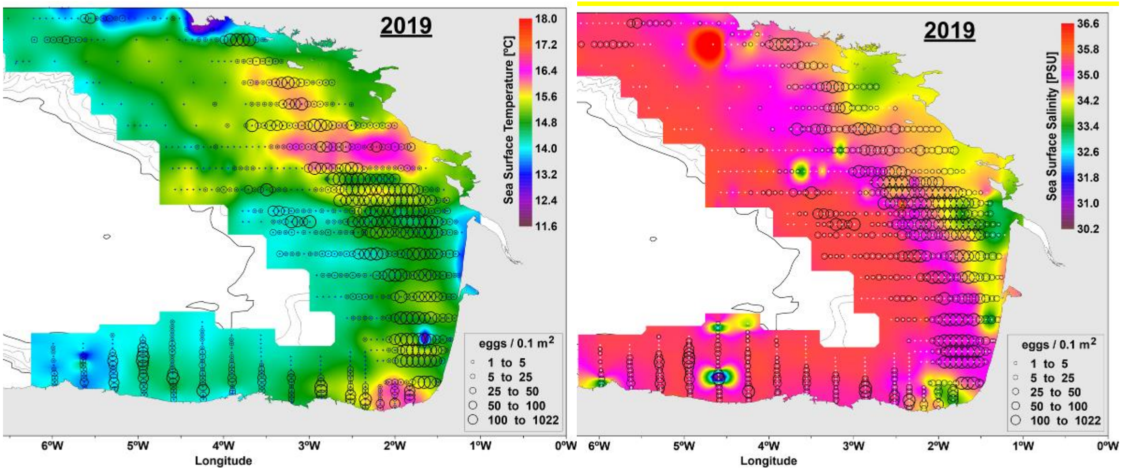


Figure 3: SST and SSS maps (left and right respectively) with anchovy egg distribution 2019.

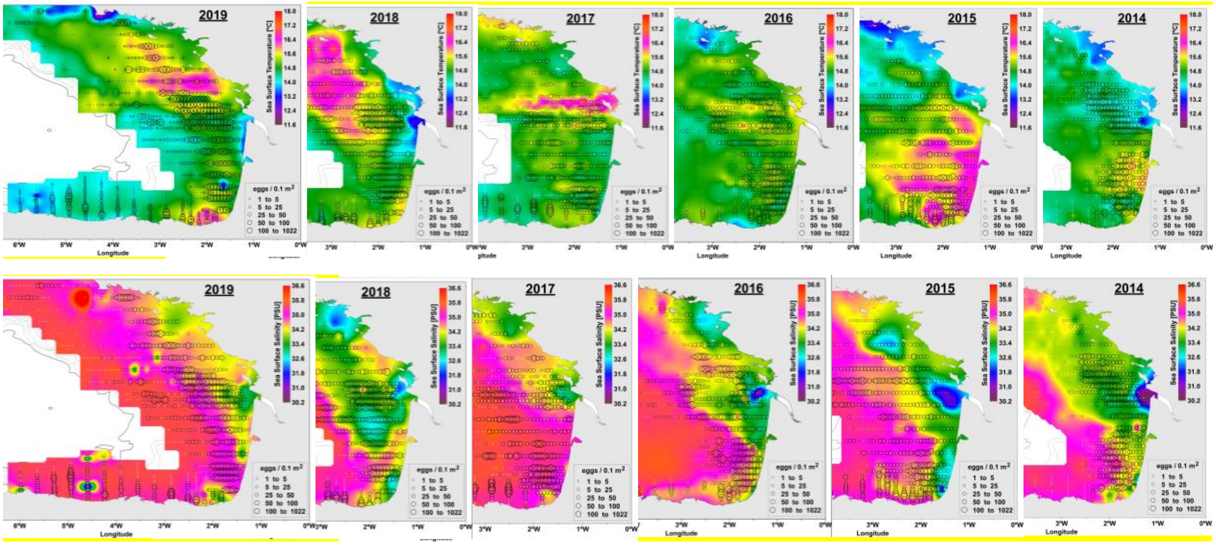


Figure 4: SST (top) and SSS (bottom) maps overlapped with anchovy egg distribution from 20014 to 2019.

The adult sampling. covered adequately the positive spawning area as shown in **Figure 5**. 45 pelagic trawls were performed, from which 42 contained anchovy and 40 of them were selected for the analysis. This year 3 additional anchovy adult samples were obtained from the Basque purse seines. In total, there were 43 adult anchovy samples to estimate the adult parameters. The spatial distribution of the 45 samples and their species composition is shown in **Figure 5.** The most abundant species in the trawls ware: anchovy, mackerel, sardine and horse mackerel.

Anchovy adults were found in the same places where the anchovy eggs were found.

Spatial length and weight distribution of each haul by regions is shown in **Figure 6**. This year, as the last, the biggest anchovy were found in the Cantabric coast (Ca), mean size were encountered in the South and North French coast, and the smallest, as usually, around the Gironde. (**Fig.6**). The total mean weight (males and females) 16.68g was higher than the last four years but lower than the mean (17.96) and the tendency is downwards (**Fig. 12**). The female mean weight 18.87g is higher than last year but the tendency of the historical series is downwards as well (**Fig.12**). Since 2010 after the reopen of the fishery, the mean weight of the anchovy population in the Bay of Biscay has been going down gradually.

Anchovy length distribution per haul is showed in **figure 7**. These regions, showed in the figure, were considered to apply weighting factors for the numbers at age estimates.

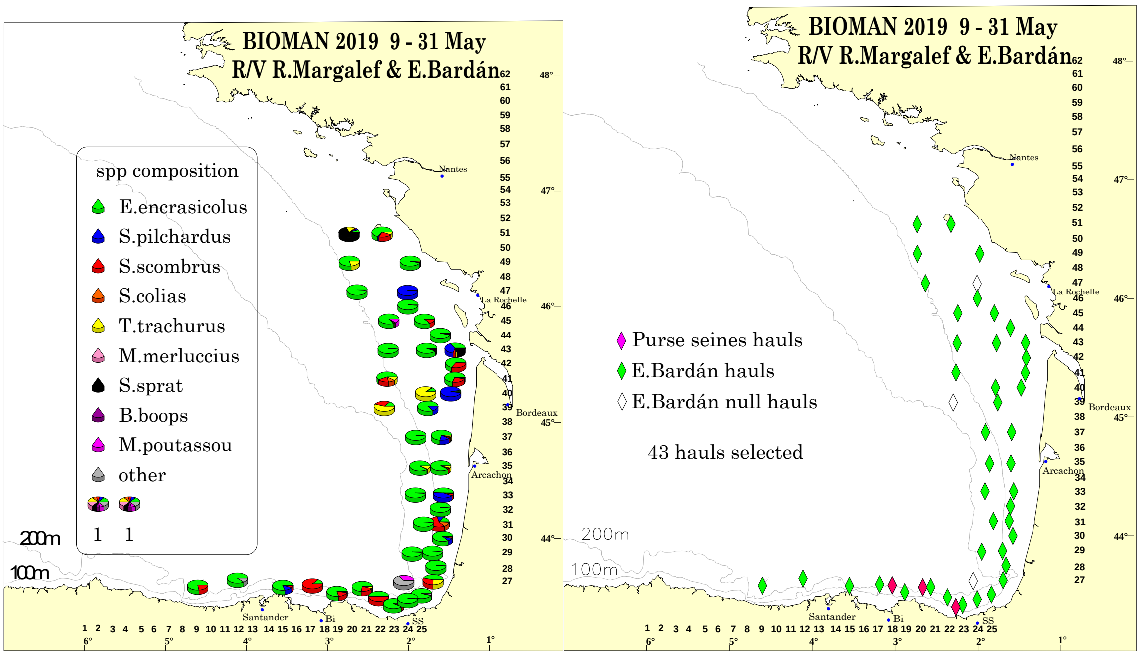


Figure 5: On the left the species composition by haul. On the right the spatial distribution of the hauls with anchovy selected for the analysis (43 in total): from pelagic trawlers R/V Emma Bardán (green) and purse seiners (pink) in 2019. The white ones are the hauls from Emma Bardán that had no anchovy.

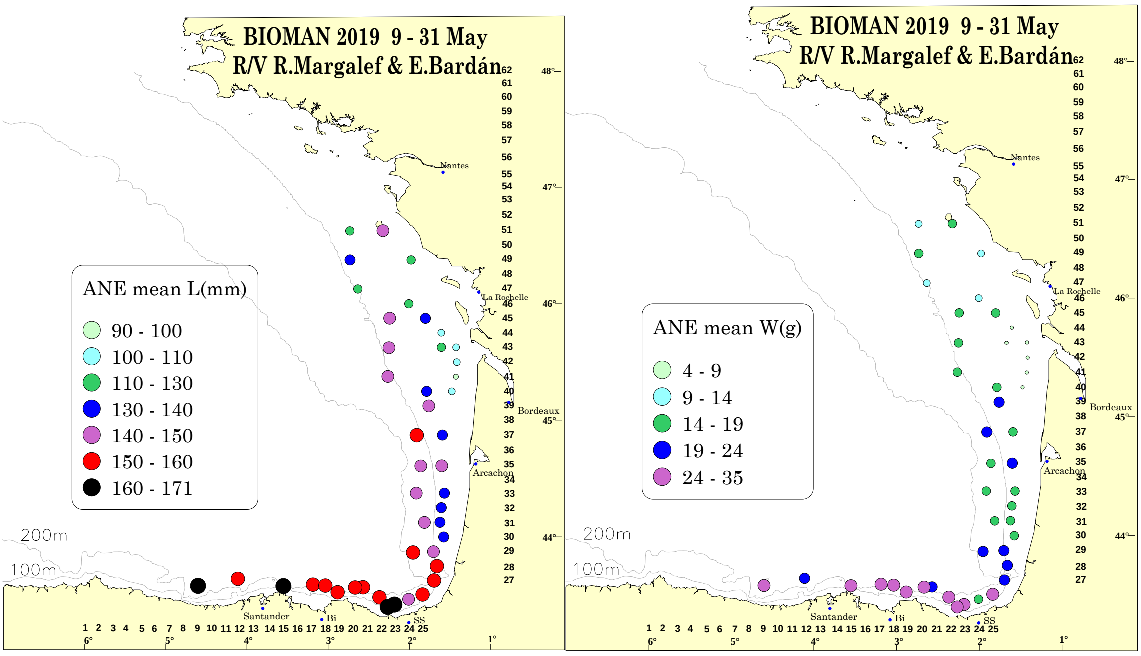


Figure 6: Anchovy (male and female) mean size (left) and mean weight (right) in 2019

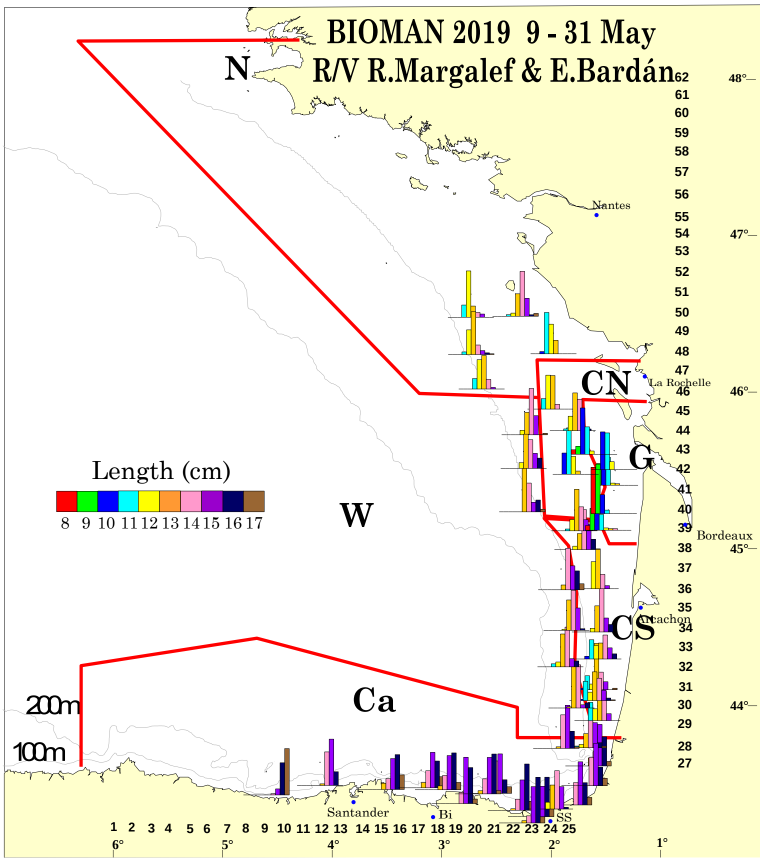


Figure 7: Anchovy (male and female) length distribution by haul. 6 regions considered to apply weighting factors for the numbers at age estimates are delimited with red lines.

3.2 Total daily egg production estimates

As a result of the adjusted GLM (**Fig.8**) the daily egg production (P_0) was 170.33 egg m^{-2} day^{-1} with a standard error of 16.70 and a CV of 0.09, lower than last year but at levels of the fourth highest of the series (**Fig.9**). The daily mortality (z) was 0.19 with a standard error of 0.048 and a CV of 0.25 at levels of the historical mean **(Fig.9)**. Then, the total daily egg production (P_{tot}) as the product of spawning area and daily egg production was 1.36E+13 with a standard error of 1.3E+12 and a CV of 0.09, been the second highest of the historical series (**Fig.9**)

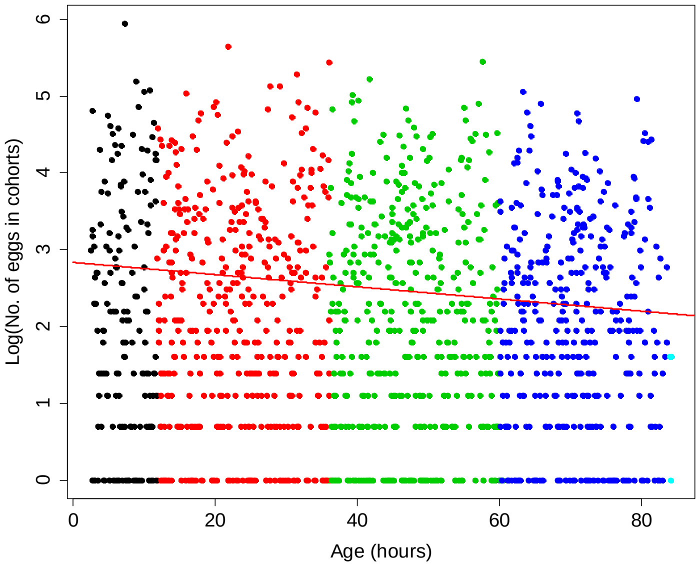


Figure 8: Exponential mortality model adjusted applying a GLM to the data obtained in the ageing, following the Bayesian method (spawning peak 23:00h). The red line is the adjusted line. Data in Log scale. The different colours of the bubbles represent the different cohorts.

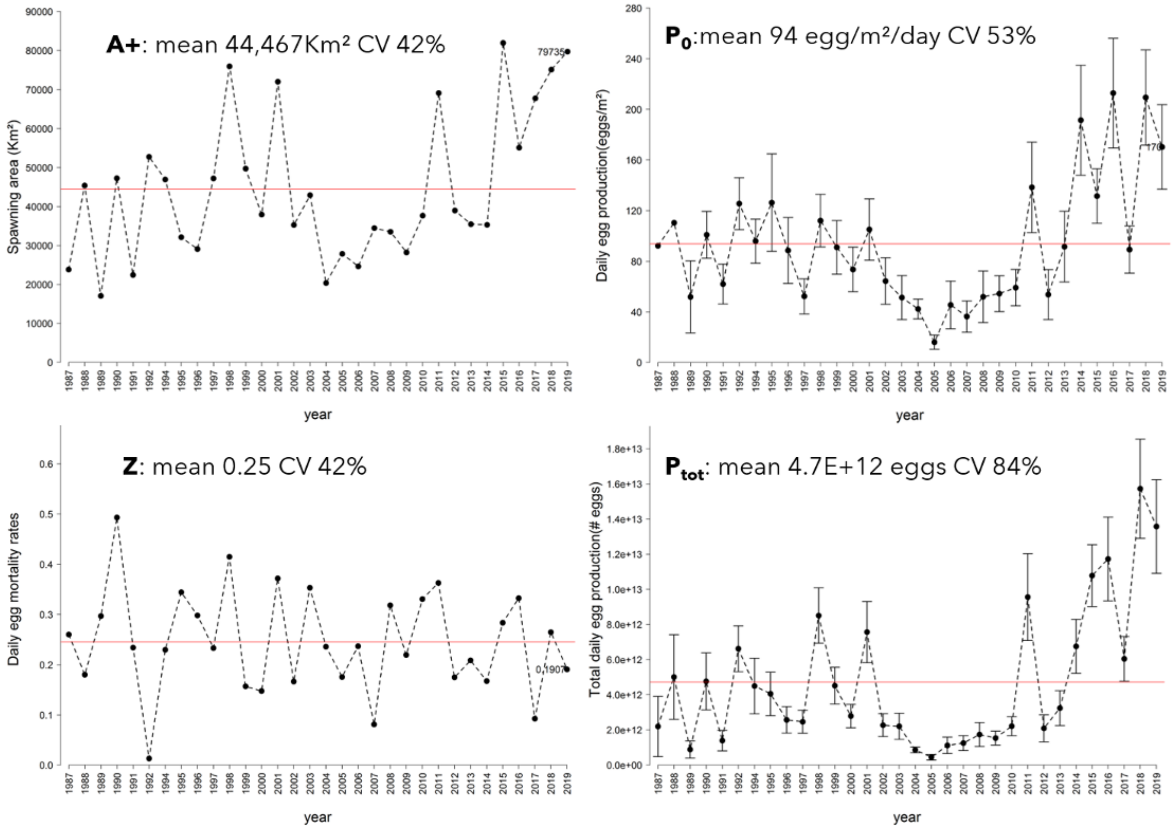


Figure 9: Time series of DEPM egg parameters and spawning area for anchovy: spawning area (Km²) (A+), daily egg production (egg m-2 per day) (P_0), daily egg mortality rates (z) and total daily egg production (egg day-1) (P_{tot}). Vertical lines indicate 95% confidence intervals (i.e. ± 2 standard deviations).

3.3 Adult parameters, daily fecundity and total biomass

Female mean weight (*Wf*): The results of the adjusted linear regression model between gonad-free-weight and total weight fitted to non-hydrated females (hydrated females identified macroscopically as stages 3 and 5 based on the maturity scale from WKSPMAT, 2008) for the correction due to hydration of the females are given in **Table 1**. The extra females, not randomly taken, for the estimation of the batch fecundity, were not considered. This correction was done in June and was not modified for the final estimate in November, because it was considered that the females with a hydrated appearance, even though they have POFs, must remain with the correction. The model fitted the data adequately (**Fig.10**, R^2=99.8%, n= 832). The female mean weight (W_f) of the population, 15.29g CV 0.1007, was obtained as the weighted mean of the average female weights per sample (Lasker, 1985). This year was the lowest of the historical series. Since 2010 after the reopen of the fishery, the anchovy female mean weight in the Bay of Biscay has been going down gradually (**Fig.12**)

Table 1: Coefficients resulted from the linear regression model between gonad-free-weight and total weight fitted to non-hydrated females with their standard error and the P-Value.

Parameter	Estimate	Standard error	P-Value
Intercept	-0.5417	0.0322	0.0000
Slope	1.1053	0.0017	0.0000

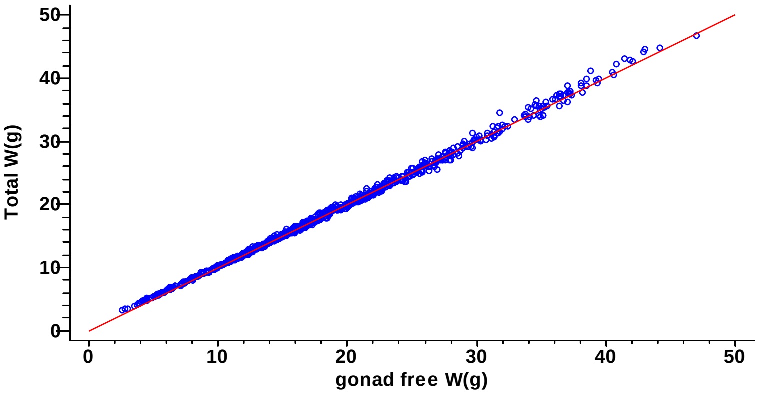


Figure 10: linear regression model between gonad-free-weight and total weight fitted to non-hydrated females.

For the **batch fecundity (*F*)** 78 hydrated females, from 19 hauls, ranging from 3.5 to 45.4 g gonad free weight were examined. It was tested whether the model coefficients changed between the 6 regions considered for the numbers at age (**Fig.13**). Finally, no region was considered to estimate the batch fecundity due to the no statistically difference was found between those 6. The coefficients of the generalised linear model with Gamma distribution and identity link are given in **Table 2** and the fitted model is shown in **Figure 11**. Hence, the overall batch fecundity estimate (6,419 egg/batch per average mature female CV 0.0667) was obtained as a weighted mean of the batch fecundity per sample (Lasker, 1985). In relation with the historical series is lower than de last 3 years and lower than the historical mean (10,450 eggs per gram per mature female CV 0.31). the tendency of the batch fecundity has been going down since 2010 (**Fig.12**).

Table 2: Coefficients of the generalised linear model with Gamma distribution and identity link between the number of hydrated oocytes and the female gonad free weight (W_{gf}) for the Gironde and the remainder area

Parameter	estimate	Standard error	t value	Pr(>|t|)
Intercept	-995.12	140.15	-7.10	5.68e-10***
wgf	413.46	22.89	18.08	2e-16***

Signif. codes : 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 ***

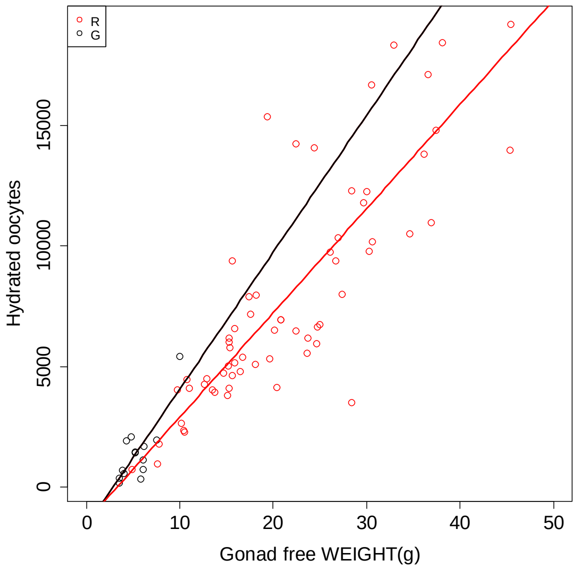


Figure 11: Generalised linear model between gonad-free-weight and hydrated oocytes fitted to hydrate females. The black circles are the ones from the Gironde and red are the ones from the rest of the area. The black line is the fit to the Gironde females and the red one the fit to the females from the remainder region.

For the **spawning frequency (*S*)** the estimate was calculated as describe above in material and methods. After the histological analysis of the gonads was completed, using the new staging (Alday *et al*., 2010) and new ageing (Uriarte *et al*., 2012), the estimate of S obtained was 0.35 CV 0.0632. In relation with the historical series is at the same levels since 2010 but is lower than the historical mean (38%) **(Fig.12)**.

The **Daily Fecundity (*DF*)** was estimated, from the parameters obtained through the adult samples from the survey, presented above. The result was 61eggs/g/day CV 0.0610w. In relation with the historical series it was lower than last year (64.2 eggs/g), and lower than the historical mean (91.7eggs/g CV 0.22) (**Fig.12**)

Estimates of all the parameter to obtain the biomass through the DEPM and the total biomass with their CVs are given in **table 3**. The anchovy total biomass estimate obtained was 223,210t with a CV of 0.1155 the highest of the historical series (**Fig.12**)

Table 3: All the parameters to estimate de total Biomass using the Daily Egg Production Method (DEPM) for 2019: P_{tot} (total egg production), R (sex ratio), S (Spawning frequency), F (batch fecundity), W_f (female mean weight) and DF (daily fecundity) with correspondent Standard errors (S.e.) and coefficients of variation (CV).

Parameter	**estimate**	**S.e.**	**CV**
P_{tot} (eggs)	1.36E+13	1.33E+12	0.0980
R'(% of females)	0.51	0.0021	0.0040
S (% fem. spawning/day)	0.35	0.0128	0.0362
F (eggs/batch/mature fem.)	6,419	428	0.0667
W_f(g)	18.87	0.75	0.0397
DF (eggs/g/day)	61.09	3.73	0.0610
B (tons)	**223,210**	25,775	0.1155

3.4 Numbers at age

To estimate the population at age, the age readings of 2,789 otoliths from 40 samples were available.

To deduce the numbers at age 6 regions were defined depending on the distribution of the adult samples (size, weight and age) and anchovy eggs (**Fig.13**): Cantabric coast (Ca), Coast South (CS), Gironde (G), Coast North (CN, North (N) and West (W). Given that mean length of anchovies change between those regions (**Fig. 7**), proportionality between the number of samples and a proxy of the total biomass indices by regions was checked. The approximate index of biomass by regions was set equal to egg abundance divided by the daily fecundity (*DF*) assigned to each region (**Tab.4**). The *DF* by regions was approached by the general formula of this parameter ($F*S*R/W_f$) using the unweight mean of the adult parameters of the samples in each region.

According to **table 4**, the 43 samples selected are not balanced between those regions and differential weighting factors were applied to each sample coming from one or the other region to estimate the number at age and biomass at age. The proportion by age, numbers by age, weight and length by age and biomass in percentage and mass by age estimates are given in **Table 5**.

63% of the anchovy in numbers were estimate as individuals of age 1 (53% in mass), 34% of the individuals in numbers were of age 2 (42% in mass) and 3% of the individuals in numbers were of age 3 (4% in mass) (**Table 5**). This was a medium year recruitment. The anchovy age composition by haul 2019 is showed in **Figure 14**. The time series of the numbers at age is shown in **Figure 15**. The historical series of the total biomass at age (1, 2 and 3) and weight at age 1, 2 and 3 that is downwards is showed in **Figure 16**.

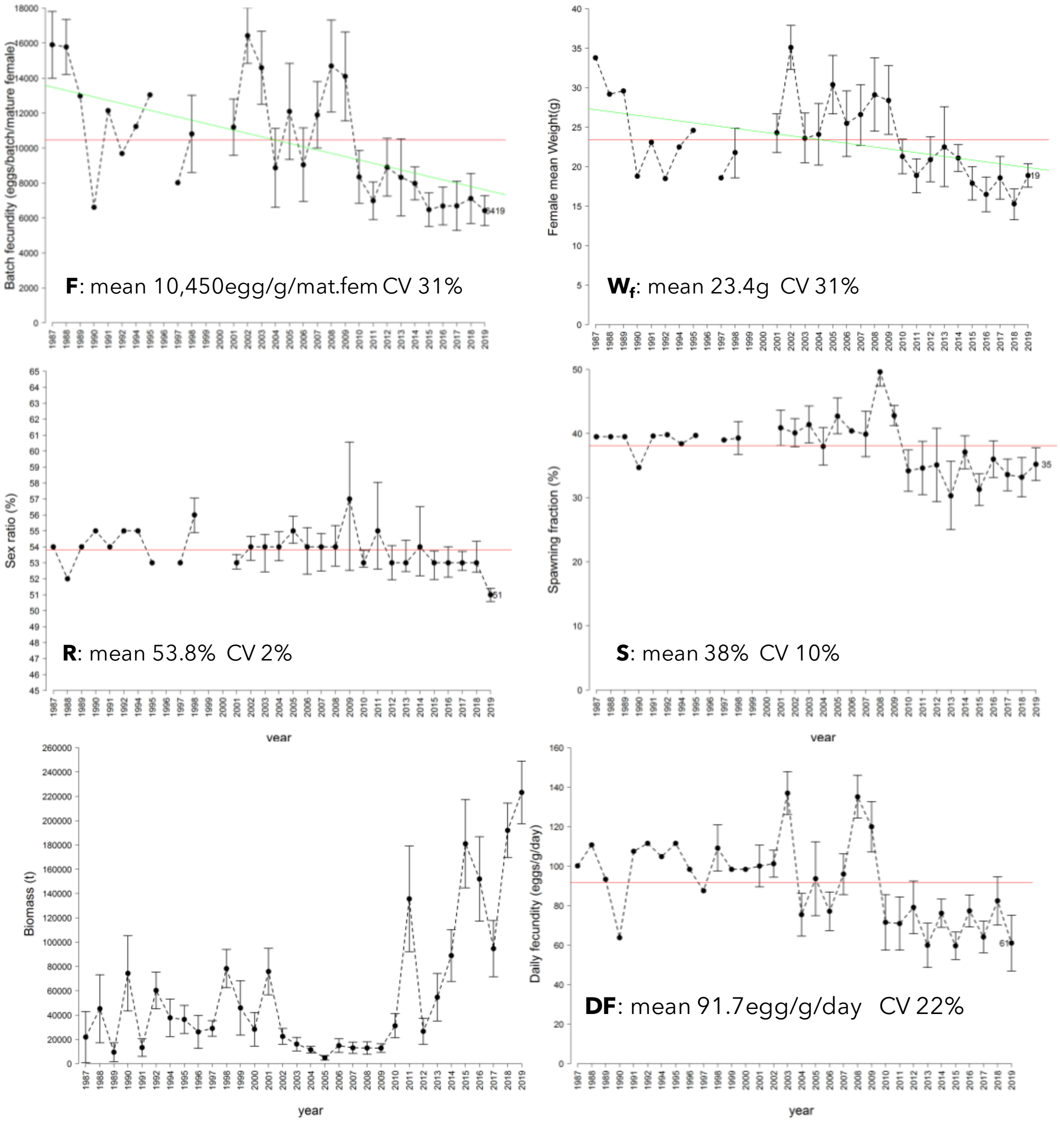


Figure 12: Time series of anchovy DEPM adult parameters and total biomass: Batch fecundity (*F*) (eggs spawned per mature females per batch), female mean weight (*W*)(g), sex ratio (*R*) (mature female fraction of population by weight), spawning fraction (*S*) (fraction of mature females spawning per day), daily fecundity (*DF*)(n° of egg per g of biomass) and total biomass (*B*) (tons). Vertical lines indicate 95% confidence intervals (i.e. ± 2 standard deviations).

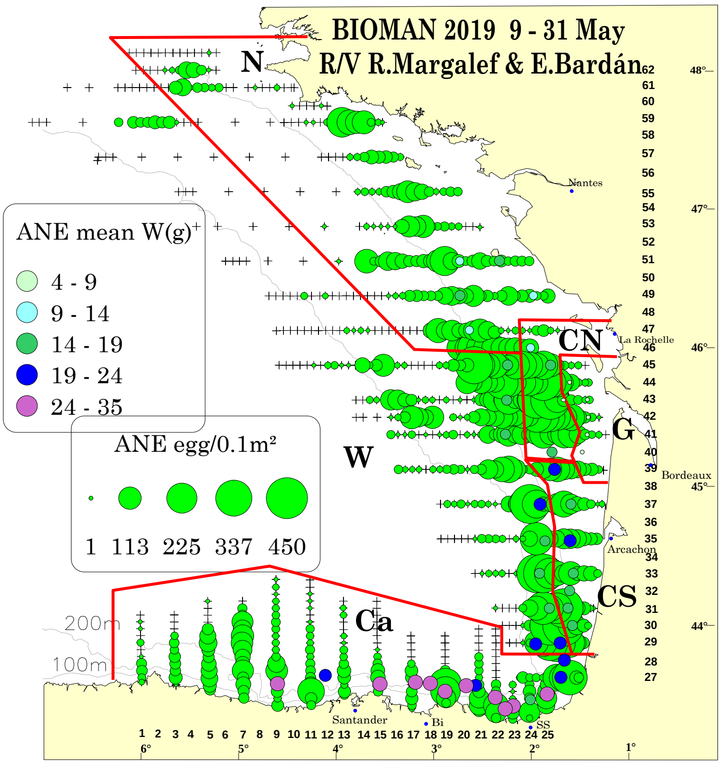


Figure 13: 6 regions defined to estimate the numbers at age. The red lines represent the border of the regions, the green bubbles the abundance of anchovy eggs (egg/0.1m^2) in each station and the small colour bubbles the mean weight (g) of individuals within each haul.

Table 4: Balance of adult sampling to egg abundance by 6 regions: Cantabric (Ca), Coast South (S), Gironde (G), Coast North (CN), North (N) and West (W) in the Bay of Biscay (see **Figure 13**). The 8th row corresponds to the weighting factor for each sample of each region to obtain the population structure. Mean weight by regions arise from the 43 adult samples selected for the analysis.

Region	Ca	CS	G	CN	N	W	Addition
Total egg abundance	6.3E+12	4.3E+12	4.6E+11	4.9E+12	6.8E+12	1.3E+13	3.6E+13
% egg abundance	18%	12%	1%	14%	19%	36%	100%
DF	67.5	63.7	48.4	81.0	61.2	61.5	
Proxy of B	9.4E+10	6.8E+10	9.6E+09	6.0E+10	1.1E+11	2.1E+11	5.5E+11
%Proxy Biomass	17.0%	12.2%	1.7%	10.8%	20.1%	38.2%	100.0%
Nº of adult samples	14	6	6	3	5	9	43
% proxy Biomass/ nº sample	0.012	0.020	0.003	0.036	0.040	0.042	
Proportion of B relative to W str.	0.29	0.48	0.07	0.85	0.94	1.00	
W. factor proportional to the pop	0.29/wi	0.48/wi	0.07/wi	0.85/wi	0.94/wi	1/wi	
Mean W of ANE by region	25.8	16.3	6.6	14.7	14.2	18.9	
Standard Deviation	4.1	2.3	1.5	2.1	3.5	2.1	
CV	16%	14%	23%	14%	24%	11%	

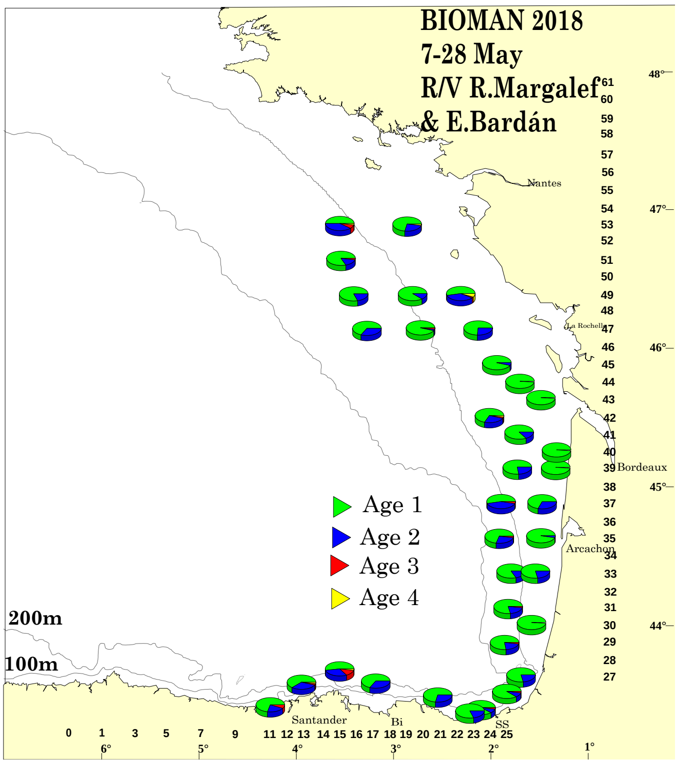


Figure 14: Anchovy age composition in space per haul 2019

Table 5: 2019 anchovy biomass estimates, total mean weight, population in millions and the percentage, numbers, percentage in mass and biomass at age estimates with correspondent standard error (S.e.) and coefficient of variation (CV). And weight and length at age with correspondent standard error (S.e.) and coefficient of variation (CV).

Parameter	**estimate**	**S.e.**	**CV**
BIOMASS (tons)	**223,210**	25,775	0.1155
Total mean Weight (g)	16.679	0.74	0.0445
Population (millions)	13,382	1684	0.1258
Percentage at age 1	**0.63**	0.037	0.0589
Percentage at age 2	**0.34**	0.033	0.0969
Percentage at age 3+	**0.03**	0.006	0.2276
Numbers at age 1	8,438	1,330.8	0.1577
Numbers at age 2	4,602	584.4	0.1270
Numbers at age 3+	342	79.0	0.2310
Percent. at age 1 in mass	0.530	0.036	0.0680
Percent. at age 2 in mass	0.428	0.031	0.0718
Percent. at age 3+ in mass	0.042	0.009	0.2245
Biomass at age 1 (tons)	118,102	16,198	0.1371
Biomass at age 2 (tons)	95,616	12,632	0.1321
Biomass at age 3+ (tons)	9,492	2,393	0.2522
Weight at age 1 (g)	14.02	0.61	0.0432
Weight at age 2 (g)	20.77	0.58	0.0278
Weight at age 3 (g)	27.81	1.51	0.0542
Length at age 1 (mm)	131.55	1.79	0.0136
Length at age 2 (mm)	148.08	1.26	0.0085
Length at age 3 (mm)	162.42	2.10	0.0129

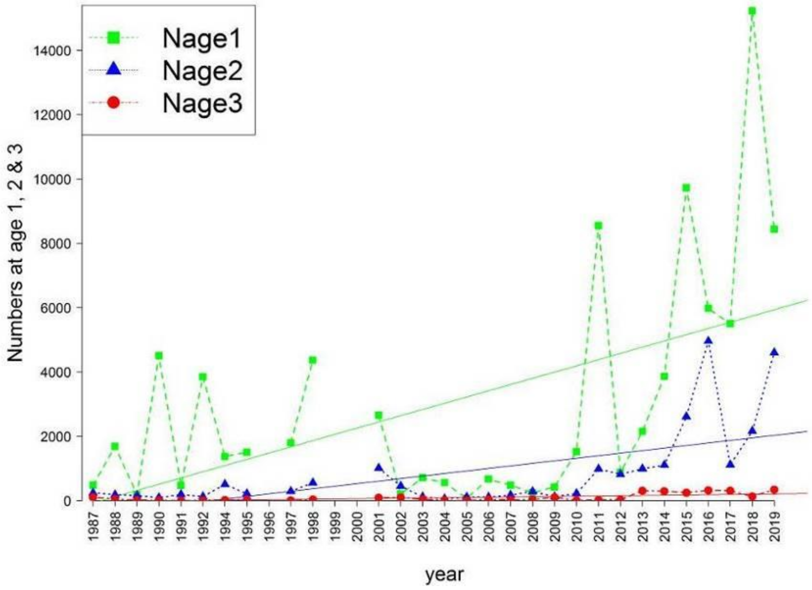


Figure 15: Historical series of numbers at age from 1987 to 2019

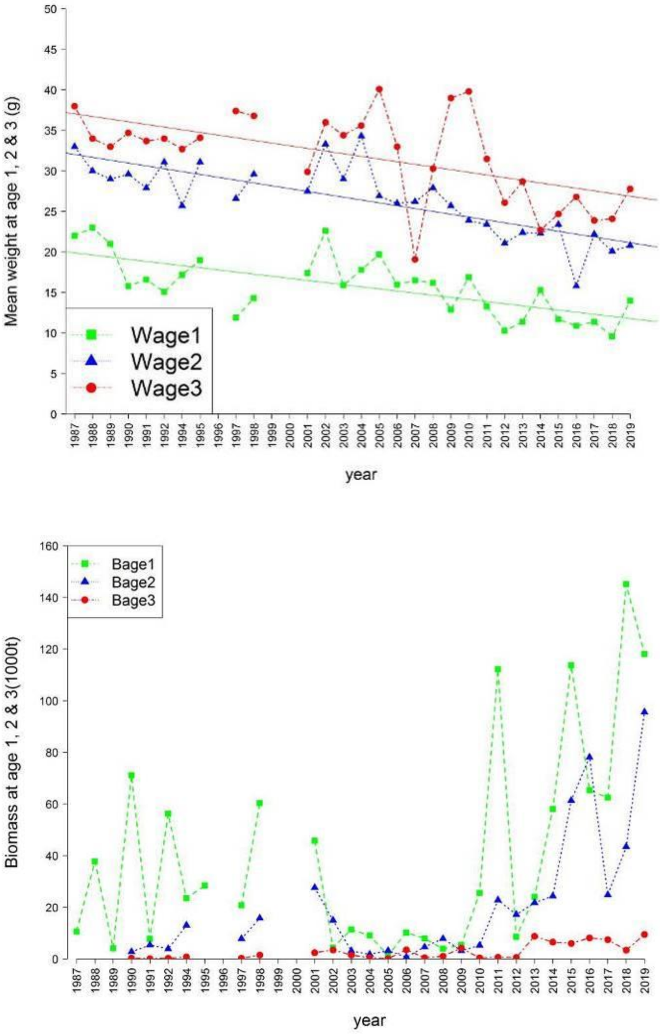


Figure 16: Anchovy historical series (1987-2019) of mean weight at age and the tendency and total biomass at age.

3.5 Sardine total egg abundance

Total egg abundance for sardine was estimate as the sum of the numbers of eggs in each station multiply by the area each station represents. This year sardine egg abundance estimate was 7.59 E+12 eggs, considering the whole area surveyed. Taking into account the 8abd, the estimate was 6.86 E+12 and removing part of the North for assessment propose, to be consistent with the historical series, the total egg abundance was 4.49 E+12 eggs, below the time series average (5.85E+12) and lower than last year (**Fig.17, Tab.6**). Sardine eggs were encountered all along the Cantabric coast, from the coast to 200m depth, between 2° and 6°00'W; the west spawning limit was not found in the Cantabric coast, although few eggs were encountered in the last transect completed to the west. In the French platform sardine eggs were encountered along the isobath of 100m depth until 46°N. And from there to 48°N between coast and 100m depth. In 48°N at 100m depth a patch of sardine eggs was encountered as last year and as well as happened for anchovy, those were considered for the estimation of the egg abundance. (**Fig.2**). In the sampling with the PairoVET net (vertical sampling) from 782 stations a total of 300 (38%) had sardine eggs with an average of 200 eggs/m² per station in the positive stations, a maximum of 2,840egg m² in a station and a total number of eggs sorted of 59,770 eggs/m². In the sampling with CUFES (horizontal sampling) a total of 727 stations (38%) had sardine from 1,883 stations. To cover the spawning area of sardine in the 8abd the survey was extended to the North until 48°N and to the West in the French platform, until the West limit of the sardine spawning area was delimited. But for the propose to be an input for the assessment of sardine in the 8abd, stations from the Northwest were removed to maintain the same coverage of the area of the time series (**Fig.2**). This egg abundance series was incorporated as an input in the assessment of sardine in the ICES 8abd in November at (WGHANSA).

This year the total sardine egg production for 2019 and 2018 was as well (**Fig.18**) estimate trying to obtain it for all the historical series. The following years will be estimate for the previous years to complete the series and to have this more formal estimate for all the series in 8abd. For the time been, this estimate (Ptot) is available for years 2002, 2008, 2011, 2014, 2017, 2018, 2019.

The historical series of egg abundances is shown in **figure 17** and **table 6**. The sardine egg distribution is shown in **figure 2**.

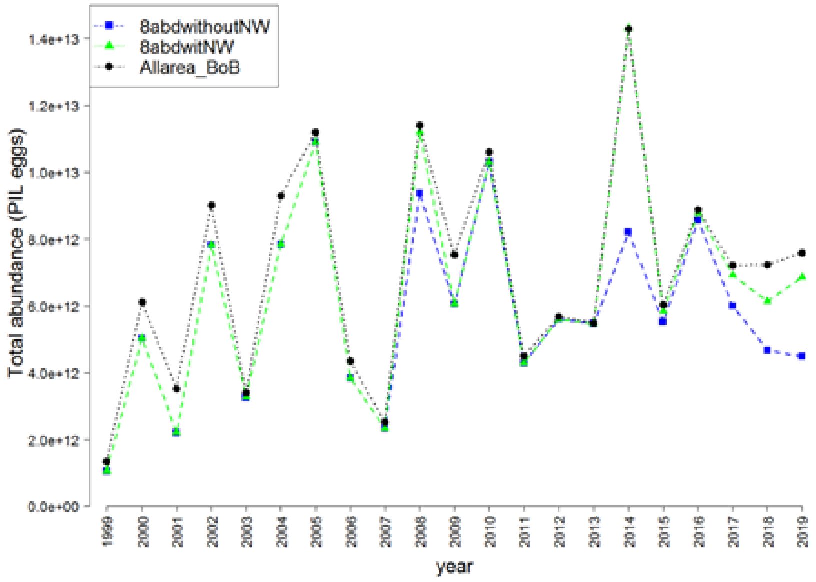


Figure 17: historical series of sardine egg abundances 1999-2019 in ICES 8abd, with and without the eggs from part of the Northwest area.

Table 6: historical series of sardine egg abundances within 8abd (without eggs from the Cantabric coast and part of the North)

Year	**TotAb_8abd_without N**
1999	1.06E+12
2000	5.03E+12
2001	2.20E+12
2002	7.82E+12
2003	3.26E+12
2004	7.83E+12
2005	1.09E+13
2006	3.84E+12
2007	2.33E+12
2008	9.37E+12
2009	6.05E+12
2010	1.03E+13
2011	4.29E+12
2012	5.60E+12
2013	5.47E+12
2014	8.21E+12
2015	5.52E+12
2016	8.56E+12
2017	5.99E+12
2018	4.67E+12
2019	4.49E+12
Mean	**5.85.E+12**
Std Dev	**3.E+12**
CV	**46.0%**

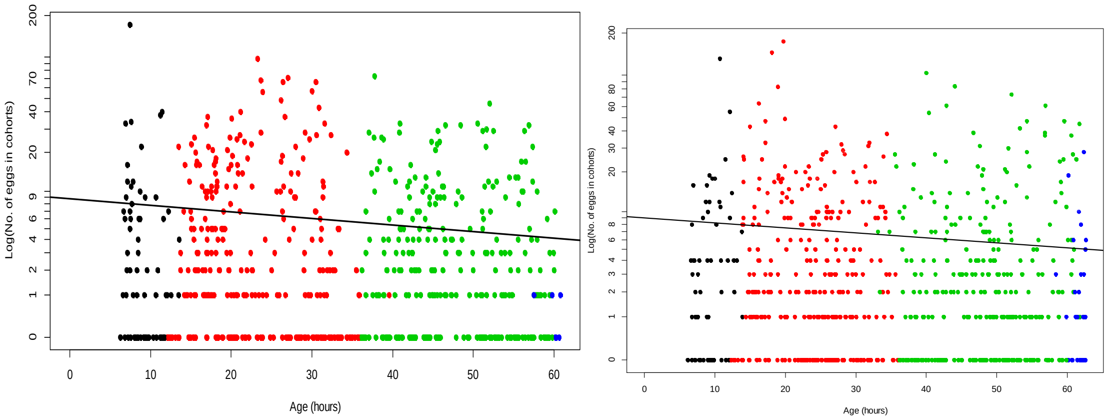


Figure 18: Exponential mortality model adjusted for sardine 2018 (Left) and 2019 (right) applying a GLM to the data obtained in the ageing, following the Bayesian method (spawning peak 21:00h). The black line is the adjusted line. Data in Log scale. The different colours of the bubbles represent the different cohorts.

Table 7: estimates for 2018 (left) and 2019 (right) of daily egg production (*P_0*) (egg/m²/day) and daily mortality rates (*z*) resulted from the generalised linear model with their standard error and CV. Total daily egg production (*P_{tot}*)(eggs/day) was calculated as the product between the spawning area (SA) and the daily egg production (*P_0*) estimates with its standard error and CV.

Parameter	Value	CV	Parameter	Value	CV
P0	87.95	0.1564	P0	89.86	0.1500
z	0.26	0.3955	z	0.19	0.4831
Ptot	3.70.E+12	0.1564	Ptot	3.42.E+12	0.1500

Acknowledgements

We thank the crew on board R/V Emma Bardán specially to José García Caballero and Aitor that have been dedicated since 2003 to this survey and this year will be retired, R/V Ramón Margalef and all the AZTI staff that participated in BIOMAN 2019 for their excellent job and collaborative support. This work was founded by the Agriculture, Fisheries and Food Technology Department of the Basque Government and by the European Commission within the frame of the National Sampling Programme. The General Secretariat of Sea also collaborated providing the R/V Emma Bardán.

References

Agresti, A., 1990. *Categorical data analysis*. John Wiley & Sons, Inc. New York

Alday, A., Uriarte, A., Santos, M., Martín, I., Martínez, U., Motos, L., 2008. Degeneration of postovulatory follicles of the Bay of anchovy (*Engraulis encrasicolus* L.) Scientia Marina 72(3). September 2008, 565-575, Barcelona (Spain)ISSN: 0214-8358

Alday, A., Santos, M., Uriarte, A., Martín, I., Martínez, U., Motos, L., 2010. Revision of criteria for the classification of postovulatory follicles degeneration, for the Bay of Biscay anchovy (*Engraulis encrasicolus* L.). Revista de Investigación Marina. 17(8): 165-171.

Arregi, L., Puente, E., Lucio, P., Sagarminaga, Y., Castro and Uriarte, A. Costal fisheries and demersal estuarine fauna. In: Oceanography and marine environment of the Basque Country. (ed. A. Borja and M. Collins). Elsevier oceanography series.

Barange, M., Bernal, M., Cercole, M.C., Cubillos, L.A., Cunningham, C.L., Daskalov, G.M., De Oliveira, J.A.A., Dickey-Collas, M., Hill, K., Jacobson, L.D., Köster, F.W., Masse, J., Nishida, H., Ñiquen, M., Oozeki, Y., Palomera, I., Saccardo, S.A., Santojanni, A., Serra, R., Somarakis, S., Stratoudakis, Y., van der Lingen, C.D., Uriarte, A. and Yatsu, A. 2009. Current trends in the assessment and management of small pelagic fish stocks. Chapter 10 in: Checkley, D.M. Jr, Roy, C., Oozeki, Y. and Alheit J. (Eds.) Climate Change and Small Pelagic Fish. Cambridge University Press.

Bernal, M., Ibaibarriaga, L., Lago de Lanzós, A., Lonergan, M., Hernández, C., Franco, C., Rasines, I., et al. 2008. Using multinomial models to analyse data from sardine egg incubation experiments; a review of advances in fish egg incubation analysis techniques. *ICES Journal of Marine Science*, 65: 51–59.

Bernal, M., Borchers, D. L., Valde´s, L., Lago de Lanzo´ s, A., and Buckland, S. T. 2001. A new ageing method for eggs of fish species with daily spawning synchronicity. *Canadian Journal of Fisheries and Aquatic Sciences*, 58: 2330–2340.

Checkely D.M., Ortner P.B., Settle L.R., S.R. Cummings (1997). A continuous, un-derway fish egg sampler. *Fisheries Oceanography* 6: 58–73.

Ferrer, L., Fontán, A., Chust, G., Mader, J., González, M., Valencia, V., Uriarte, Ad., Collins, M.B., 2009. Low salinity plumes in the oceanic region of the Basque Country. Cont. Shelf Res., 29 (8), 970-984.

Ibaibarriaga, L., Bernal, M., Motos, L., Uriarte, A., Borchers, D. L.,Lonergan, M., and Wood, S. 2007. Estimation of development properties of stage-classified biological processes using multinomial models: a case study of Bay of Biscay anchovy (*Engraulis encrasicolus* L.) egg development. *Canadian Journal of Fisheries and Aquatic Sciences*, 64: 539–553.

ICES. 2010. Report of the Working Group on Anchovy and Sardine (WGANSA), 24–28 June 2010, Lisbon, Portugal. ICES CM 2010/ACOM:16. 290 pp.

ICES. 2004. The DEPM estimation of spawning-stock biomass for sardine and anchovy. *ICES*

Cooperative Research Report, 268.91 pp.

Lasker, R., 1985. *An Egg Production Method for Estimating Spawning Biomass of pelagic fish: Application to the Northern Anchovy, Engraulis mordax*. NOAA Technical report NMFS 36:100p.

Lo, N.C.H. (1985a). A model for temperature-dependent northern anchovy egg development and an automated procedure for the assignment of age to staged eggs. In: *An Egg Production Method for Estimating Spawning Biomass of Pelagic Fish: Application to the Northern Anchovy, Engraulis mordax* (ed. R. Lasker), NOAA Technical Report NMFS, US Department of Commerce, Springfield, VA, USA, 43–50.

McCullagh, P., and Nelder, J.A. 1989. Generalised linear models. Chapman & Hall, London.

Moser HG, Ahlstrom EH (1985). Staging anchovy eggs. In: Lasker R. (ed.) *An Egg Production Method for Estimating Spawning Biomass of Pelagic Fish: Application to the Northern Anchovy, Engraulis mordax*. pp 99–101. NOAA Technical Report 36: 37–41.

Motos, L., Uriarte, A., Prouzet, P., Santos, M., Alvarez, P., Sagarminaga, Y., 2005. *Assessing the Bay of Biscay anchovy population by DEPM: a review 1989–2001*. In: Castro, L.R., P. Freón, C. D. van der Lingen and A. Uriarte, editors, Report of the SPACC Meeting on Small Pelagic Fish Spawning Habitat Dynamics and the Daily Egg Production Method (DEPM). GLOBEC Report 22, xiv, pp. 88-90.

Motos, L., 1994. Estimación de la biomasa desovante de la población de anchoa del Golfo de Vizcaya *Engraulis encrasicolus* a partir de su producción de huevos. Bases metodológicas y aplicación. Ph. D. thesis UPV/EHU, Leioa.

Parker, K., 1980. A direct method for estimating northern anchovy, *Engraulis mordax*, spawning biomass. *Fisheries. Bulletin*., 78: 541-544

Picquelle, S and G. Stauffer. 1985. Parameter estimation for an egg production method of anchovy biomass assessment. In: R. Lasker (ed.). *An egg production method for estimating spawning biomass of pelagic fish: Application to the northern anchovy, Engraulis mordax*, pp. 7-16. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 36.

Santos M., Uriarte, A., Boyra G., and Ibaibarriaga L. (2016): Anchovy DEPM surveys 2003 - 2012 in the Bay of Biscay (subarea 8) BIOMAN. In Pelagic Surveys series for sardine and anchovy in ICES Areas 8 and 9 (WGACEGG) - Towards an ecosystem approach. (Eds J. Massé, A. Uriarte, M. M. Angelico, P. Carrera.) (ICES -Cooperative Research Report 332- Copenhagen. Denmark)

Santos, M, Uriarte, A., Ibaibarriaga, L., 2011. Spawning Stock Biomass estimates of the Bay of Biscay anchovy (Engraulis encrasicolus, L.) in 2010 applying the Daily Egg Production Method. 18(5): 76-91.

Sanz, A. and A. Uriarte. 1989. Reproductive cycle and batch fecundity of the Bay of Biscay anchovy (*Engraulis encrasicholus*) in 1987. CalCOFI Rep., 30: 127-135

Seber, G.A.F. *The estimation of animal abundance and related parameters*. Charles Griffin and Co., London, 2nd edition, 1982.

Shchepetkin, A.F., McWilliams, J.C., 2005. The regional oceanic modeling system (ROMS): a split-explicit, free-surface, topography-following-coordinate oceanic model. Ocean Model., 9, 347-404.

Somarakis, S., Palomera, I., García, A., Quintanilla, L., Koutsikopoulos, C., Uriarte, A., Motos, L., 2004. Daily egg production of anchovy in European waters. *ICES Journal Marine Science*. 61, 944-958.

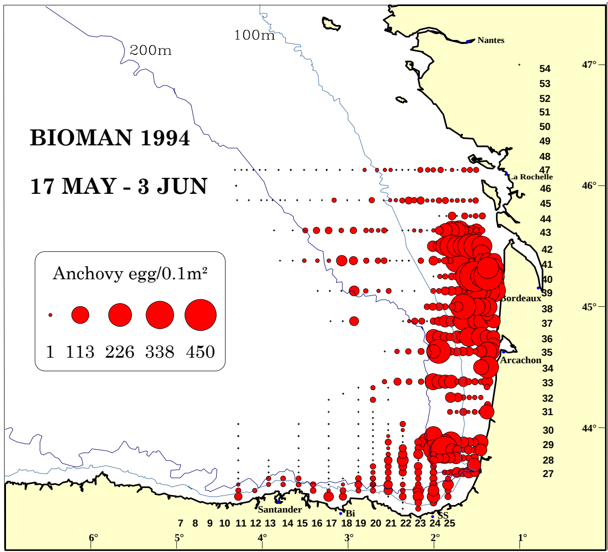
Smith, P.E., W. Flerx and R.H. Hewitt, 1985. The CalCOFI Vertical Egg Tow (CalVET) Net. In R. Lasker (editor), *An egg production method for estimating spawning biomass of pelagic fish: Application to the northern anchovy, Engraulis mordax,* p. 27-32. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 36.

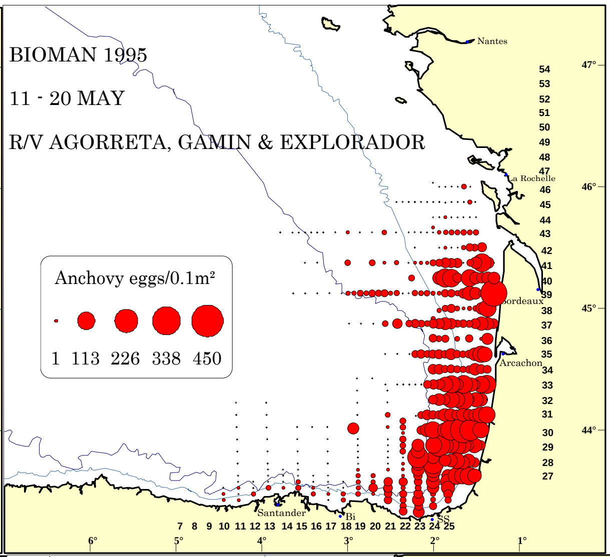
Stratoudakis, Y., Bernal, M., Ganias, K., and Uriarte, A. 2006. The daily egg production methods: recent advances, current applications and future challenges. *Fish and Fisheries*, 7: 35–57.

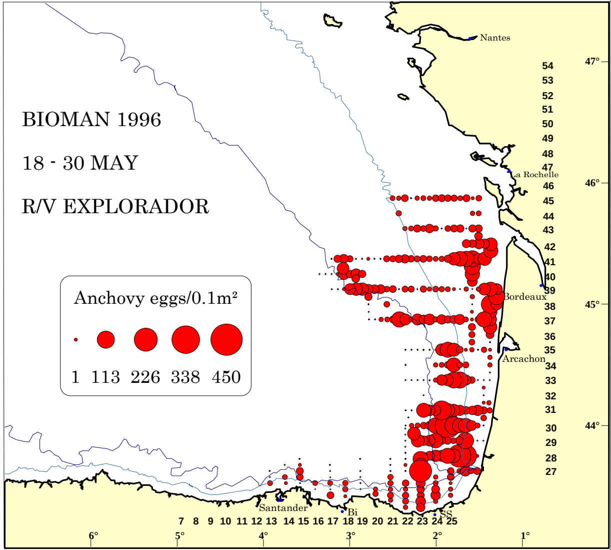
Uriarte A., Prouzet, P. Villamor B. 1996. Bay of Biscay and Ibero-Atlantic anchovy populations and their fisheries. *Scientia Marina*, 60 (Supl.2): 237-255.

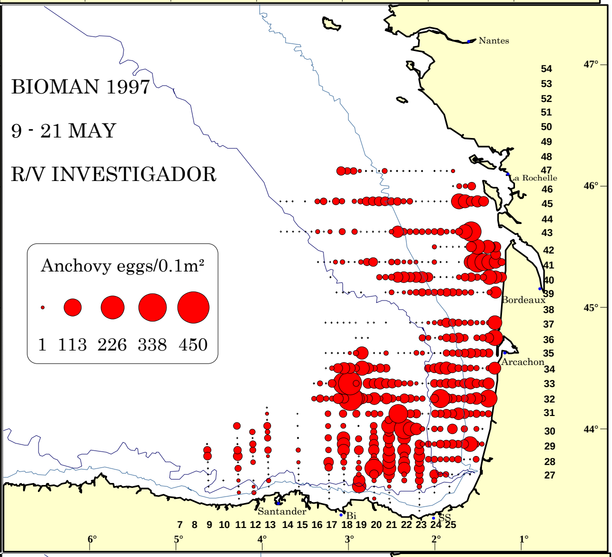
Uriarte A., Alday A., Santos M, and Motos L., 2012: A re-evaluation of the spawning fraction estimation procedures for Bay of Biscay anchovy, a species with short interspawning intervals. Fisheries Research 117–118; 96-111 (doi:10.1016/ j. fishres.2011.03.002)

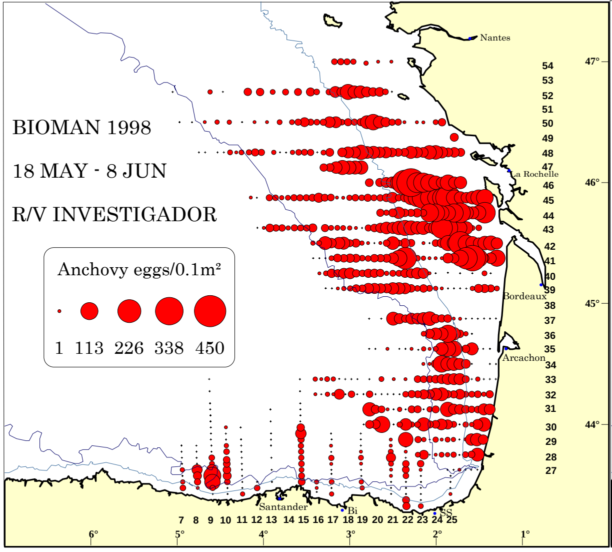
Workshop report from WKSPMAT (Report 20078), ICES.

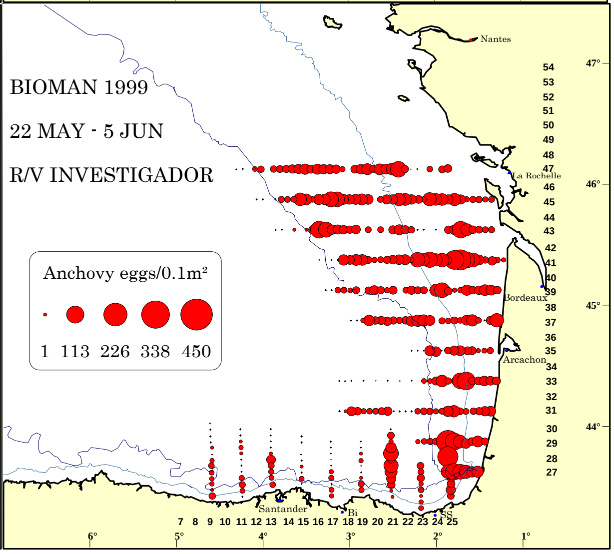

BIOMAN 1994
17 MAY - 3 JUN
Anchovy egg/0.1m²
1 113 226 338 450
200m
100m
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6° 5° 4° 3° 2° 1°
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

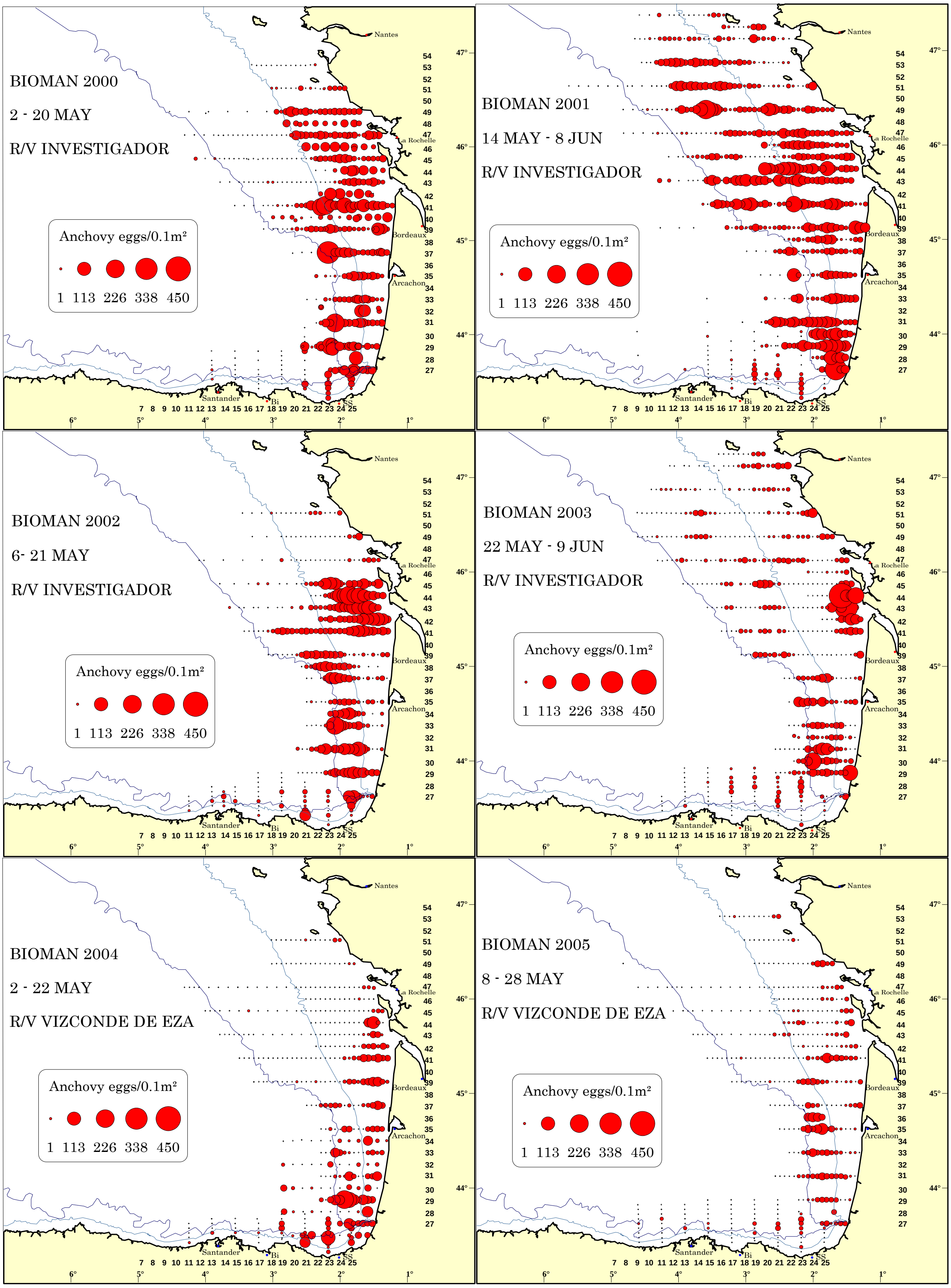

BIOMAN 1995
11 - 20 MAY
R/V AGORRETA, GAMIN & EXPLORADOR
Anchovy eggs/0.1m²
1 113 226 338 450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6° 5° 4° 3° 2° 1°
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

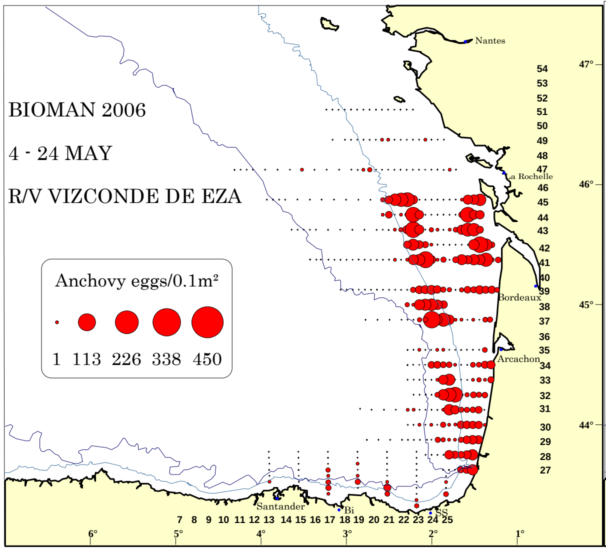

BIOMAN 1996
18 - 30 MAY
R/V EXPLORADOR
Anchovy eggs/0.1m²
1 113 226 338 450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6° 5° 4° 3° 2° 1°
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

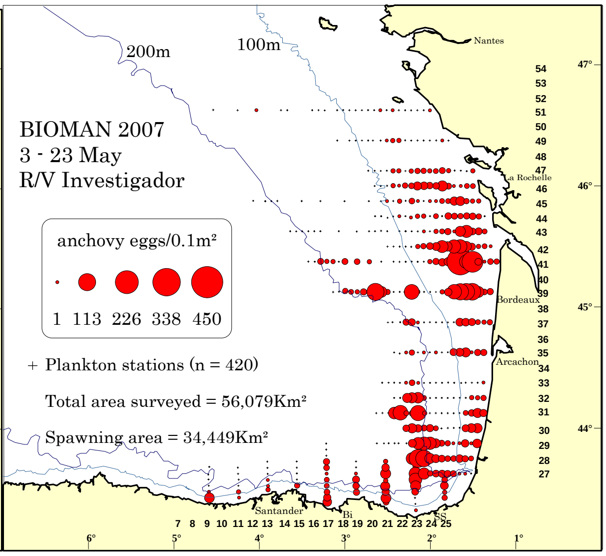

BIOMAN 1997
9 - 21 MAY
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6° 5° 4° 3° 2° 1°
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

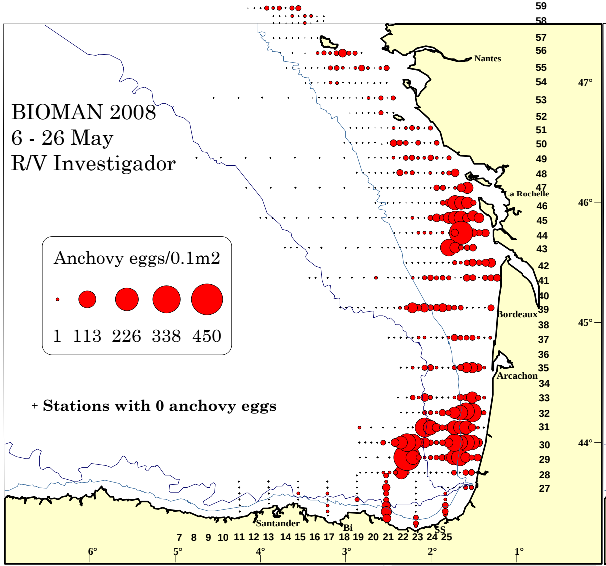

BIOMAN 1998
18 MAY - 8 JUN
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6° 5° 4° 3° 2° 1°
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

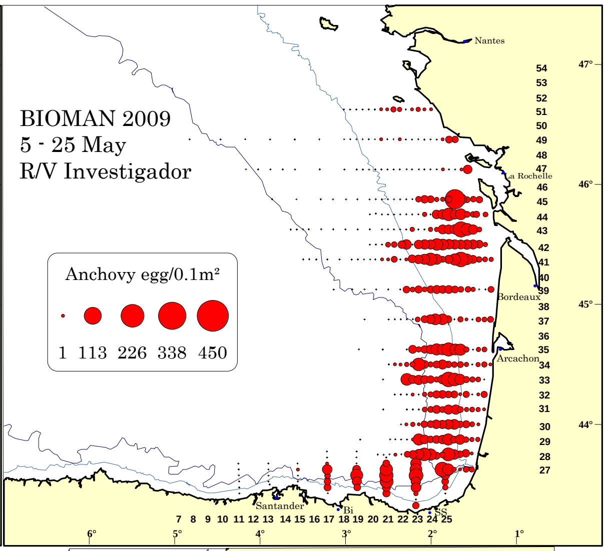

BIOMAN 1999
22 MAY - 5 JUN
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6° 5° 4° 3° 2° 1°
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

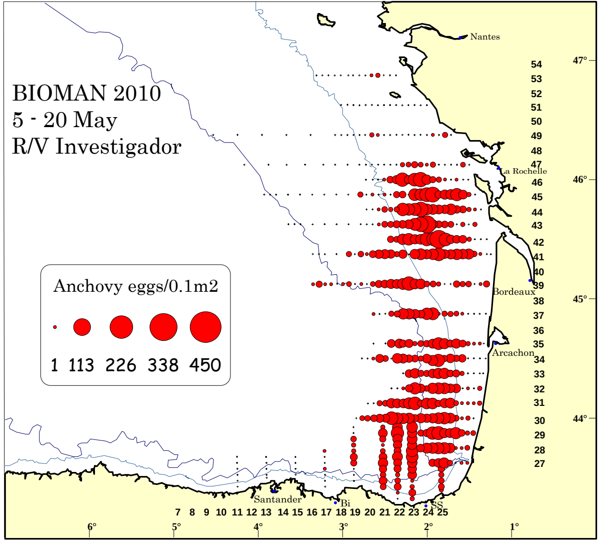

BIOMAN 2000
2 - 20 MAY
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 2001
14 MAY - 8 JUN
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 2002
6- 21 MAY
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 2003
22 MAY - 9 JUN
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 2004
2 - 22 MAY
R/V VIZCONDE DE EZA
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 2005
8 - 28 MAY
R/V VIZCONDE DE EZA
Anchovy eggs/0.1m²
1 113 226 338 450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6°
5°
4°
3°
2°
1°
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27

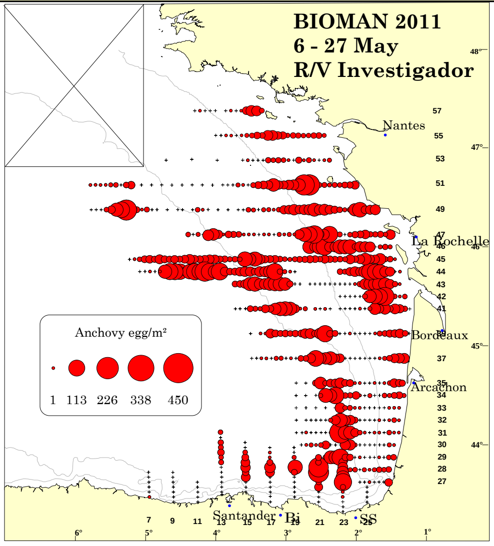

BIOMAN 2006
4 - 24 MAY
R/V VIZCONDE DE EZA
Anchovy eggs/0.1m²
1 113 226 338 450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6° 5° 4° 3° 2° 1°
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27

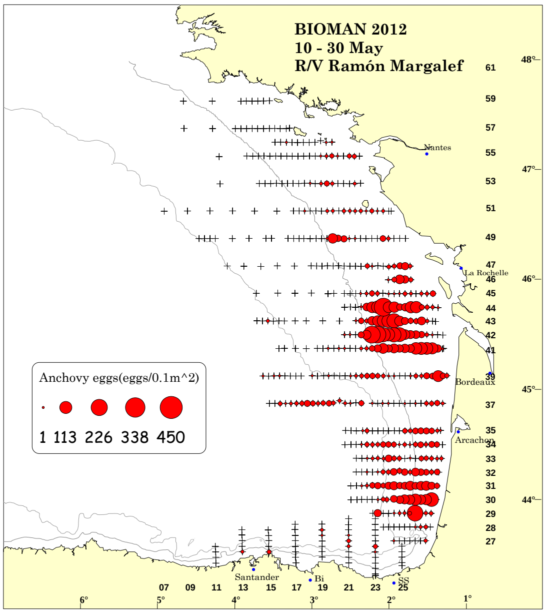

BIOMAN 2007
3 - 23 May
R/V Investigador
200m
100m
anchovy eggs/0.1m²
1 113 226 338 450
+ Plankton stations (n = 420)
Total area surveyed = 56,079Km²
Spawning area = 34,449Km²
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6° 5° 4° 3° 2° 1°
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27

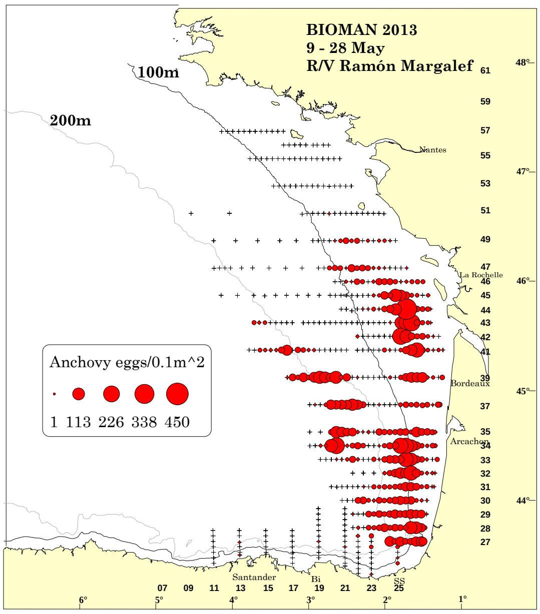

BIOMAN 2008
6 - 26 May
R/V Investigador
Anchovy eggs/0.1m2
1 113 226 338 450
+ Stations with 0 anchovy eggs
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
47°
46°
45°
44°
6° 5° 4° 3° 2° 1°
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27

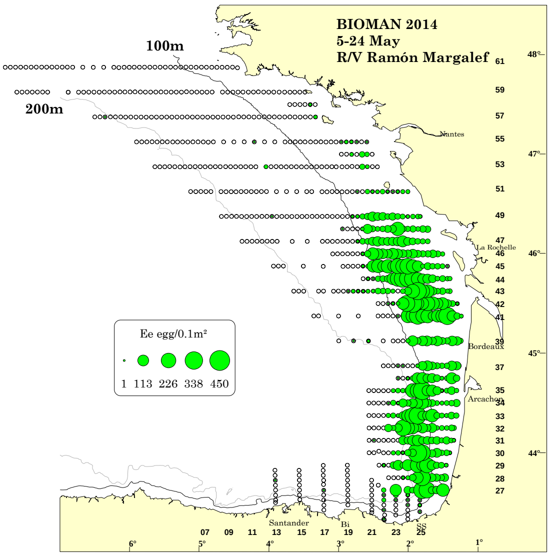

BIOMAN 2009
5 - 25 May
R/V Investigador
Anchovy egg/0.1m²
1 113 226 338 450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6° 5° 4° 3° 2° 1°
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27

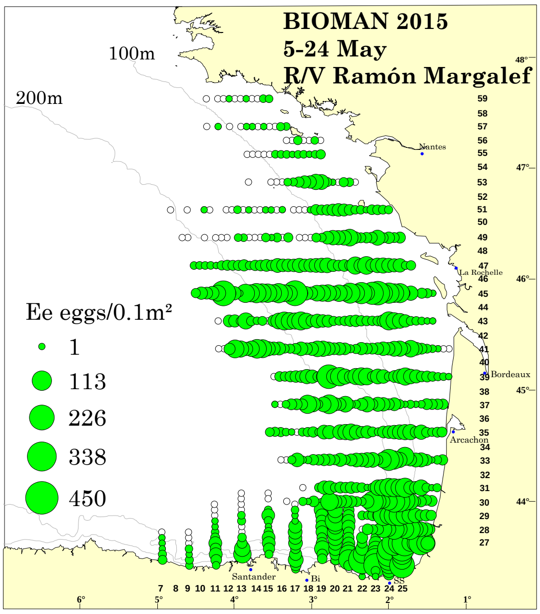

BIOMAN 2010
5 - 20 May
R/V Investigador
Anchovy eggs/0.1m2
1 113 226 338 450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6° 5° 4° 3° 2° 1°
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27

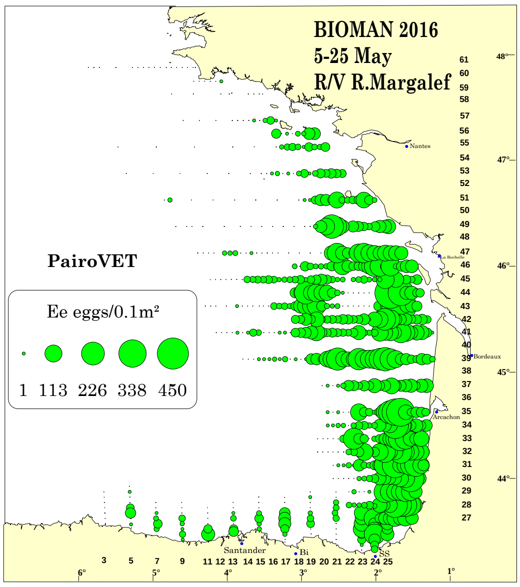

BIOMAN 2011
6 - 27 May
R/V Investigador
Anchovy egg/m²
1 113 226 338 450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
48°
47°
46°
45°
44°
6° 5° 4° 3° 2° 1°
7 9 11 13 15 17 19 21 23 25
57 55 53 51 49 47 45 44 43 42 41 37 35 34 33 32 31 30 29 28 27

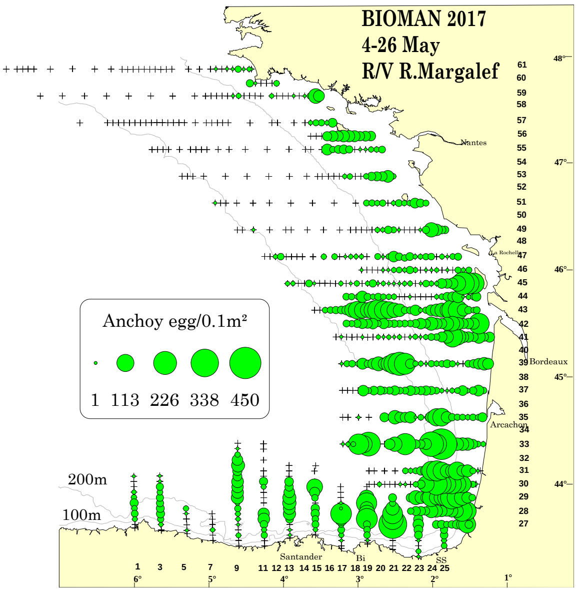

BIOMAN 2012
10 - 30 May
R/V Ramón Margalef
Anchovy eggs(eggs/0.1m^2)
1 113 226 338 450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
48°
47°
46°
45°
44°
6°
5°
4°
3°
2°
1°


BIOMAN 2013
9 - 28 May
R/V Ramón Margalef
100m
200m
Anchovy eggs/0.1m^2
1 113 226 338 450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
48°
47°
46°
45°
44°
6°
5°
4°
3°
2°
1°


BIOMAN 2014
5-24 May
R/V Ramón Margalef
100m
200m
Ee egg/0.1m²
1 113 226 338 450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
48°
47°
46°
45°
44°
6°
5°
4°
3°
2°
1°


BIOMAN 2015
5-24 May
R/V Ramón Margalef
100m
200m
Ee eggs/0.1m²
1
113
226
338
450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
48°
47°
46°
45°
44°
6°
5°
4°
3°
2°
1°


BIOMAN 2016
5-25 May
R/V R.Margalef
PairoVET
Ee eggs/0.1m²
1 113 226 338 450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
48°
47°
46°
45°
44°
6°
5°
4°
3°
2°
1°


BIOMAN 2017
4-26 May
R/V R.Margalef
Anchovy egg/0.1m²
1 113 226 338 450
200m
100m
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
48°
47°
46°
45°
44°
6°
5°
4°
3°
2°
1°

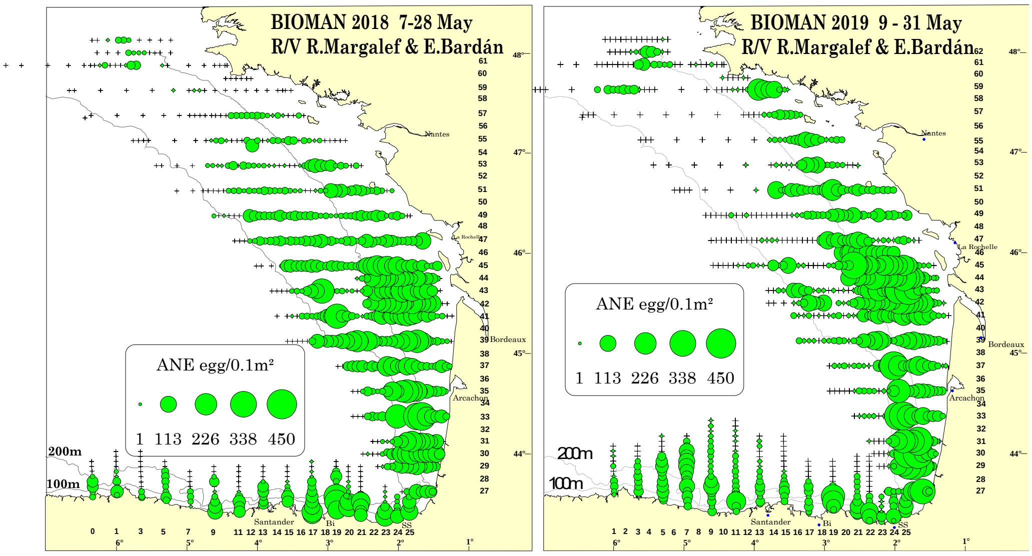
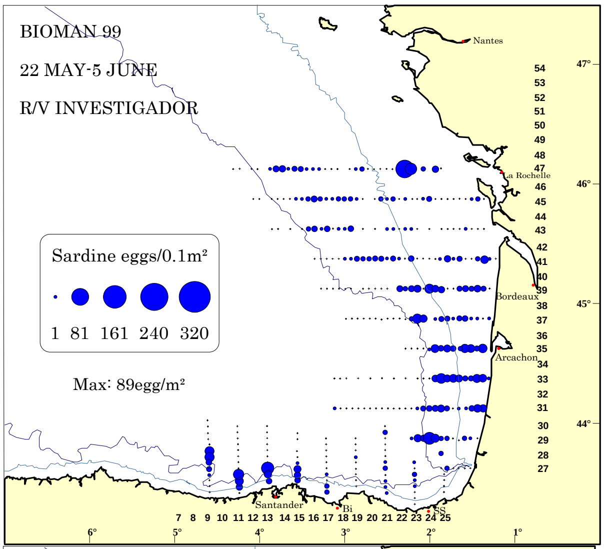
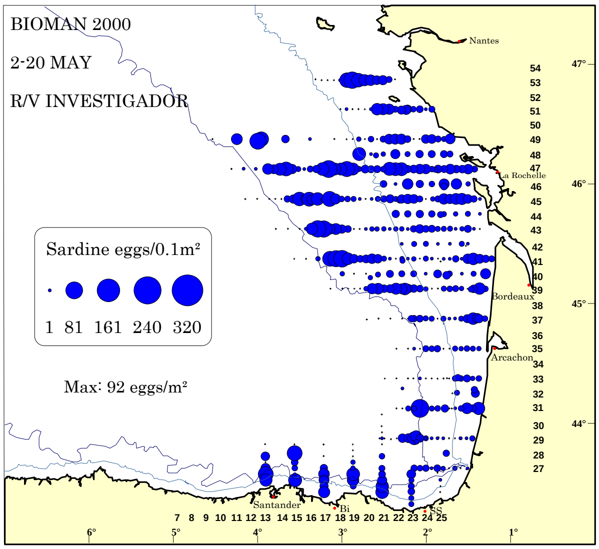
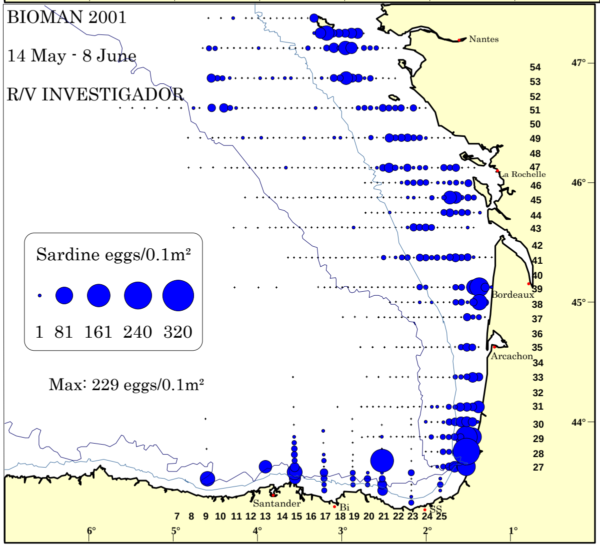
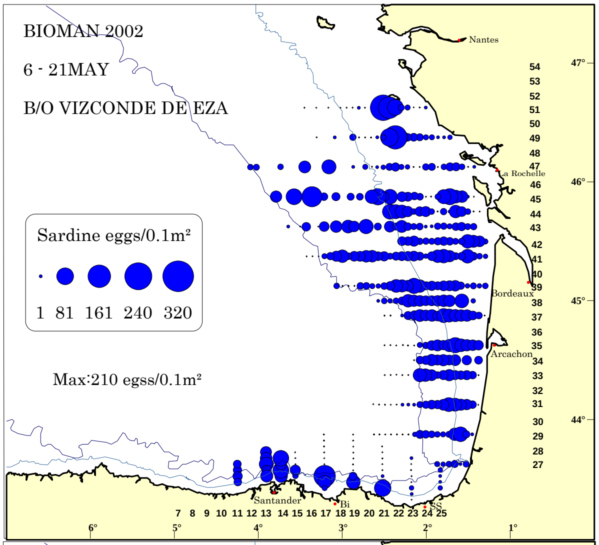


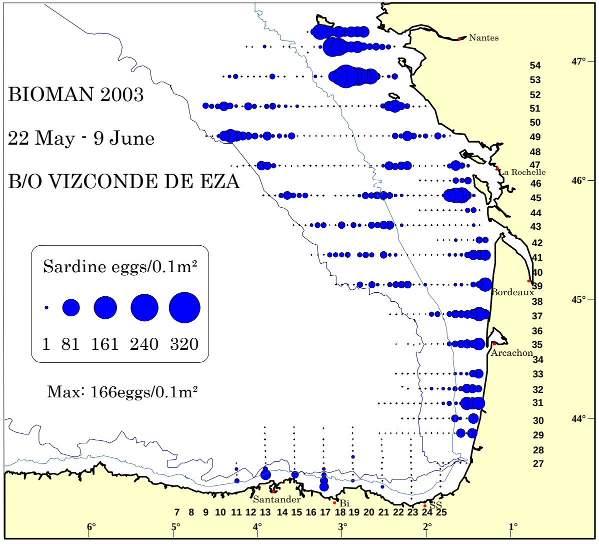
Figure 19: Anchovy egg distribution and abundance from 1994 to 2019.

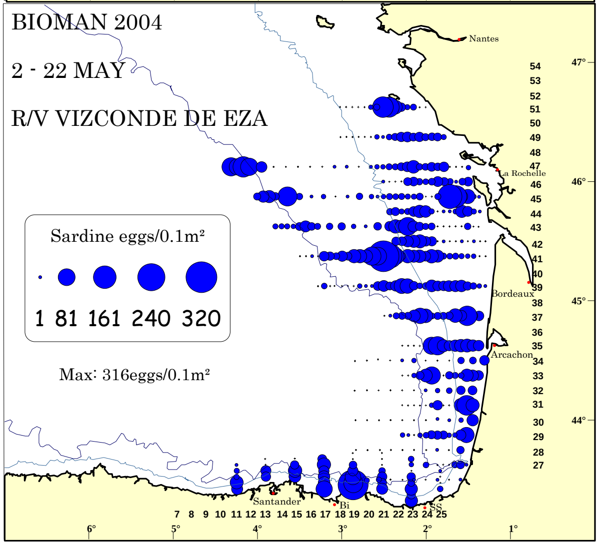

BIOMAN 99
22 MAY-5 JUNE
R/V INVESTIGADOR
Sardine eggs/0.1m²
1 81 161 240 320
Max: 89egg/m²
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6° 5° 4° 3° 2° 1°
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

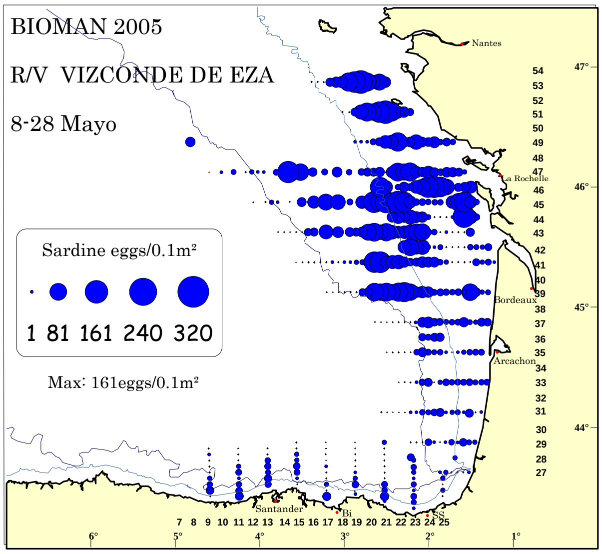

BIOMAN 2000
2-20 MAY
R/V INVESTIGADOR
Sardine eggs/0.1m²
1 81 161 240 320
Max: 92 eggs/m²
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6° 5° 4° 3° 2° 1°
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

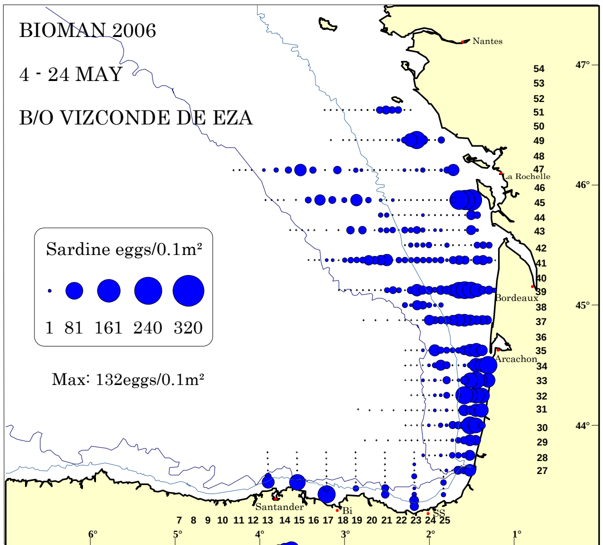

BIOMAN 2001
14 May - 8 June
R/V INVESTIGADOR
Sardine eggs/0.1m²
1 81 161 240 320
Max: 229 eggs/0.1m²
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6° 5° 4° 3° 2° 1°
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

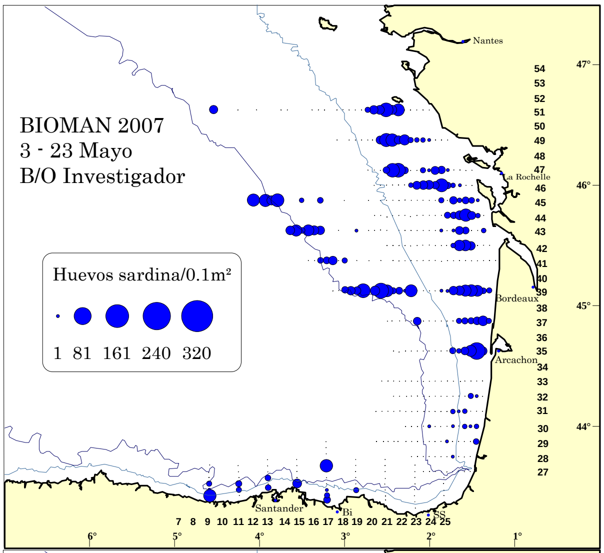

BIOMAN 2002
6 - 21MAY
B/O VIZCONDE DE EZA
Sardine eggs/0.1m²
1 81 161 240 320
Max:210 egss/0.1m²
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6° 5° 4° 3° 2° 1°
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

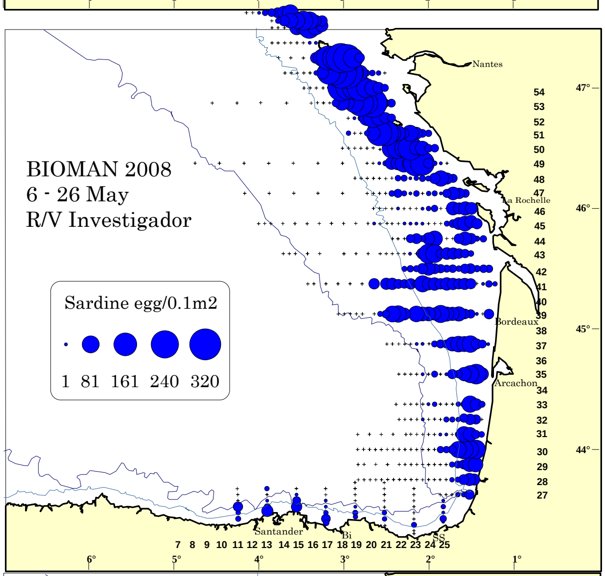

BIOMAN 2003
22 May - 9 June
B/O VIZCONDE DE EZA
Sardine eggs/0.1m²
1 81 161 240 320
Max: 166eggs/0.1m²
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6° 5° 4° 3° 2° 1°
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

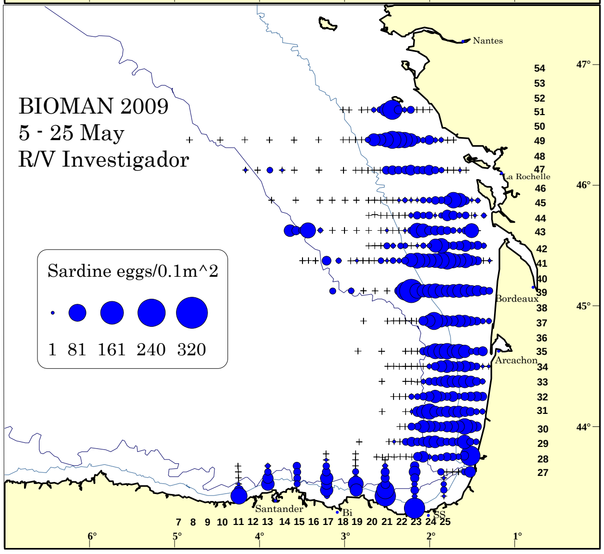

BIOMAN 2004
2 - 22 MAY
R/V VIZCONDE DE EZA
Sardine eggs/0.1m²
1 81 161 240 320
Max: 316eggs/0.1m²
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
47°
46°
45°
44°
6° 5° 4° 3° 2° 1°
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

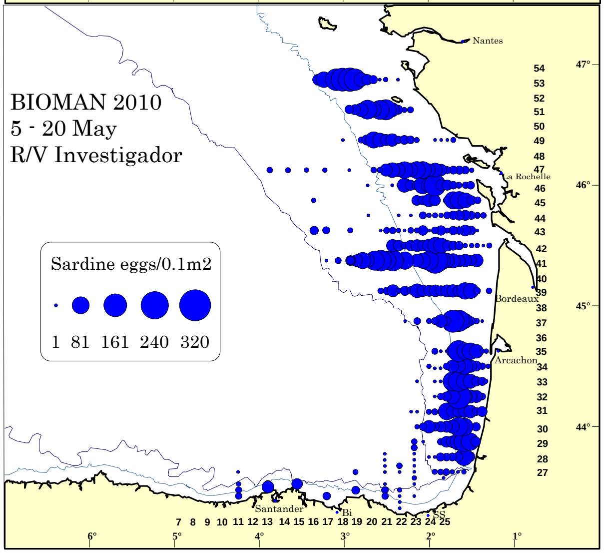

BIOMAN 2005
R/V VIZCONDE DE EZA
8-28 Mayo
Sardine eggs/0.1m²
1 81 161 240 320
Max: 161eggs/0.1m²
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
47° 46° 45° 44°
6° 5° 4° 3° 2° 1°

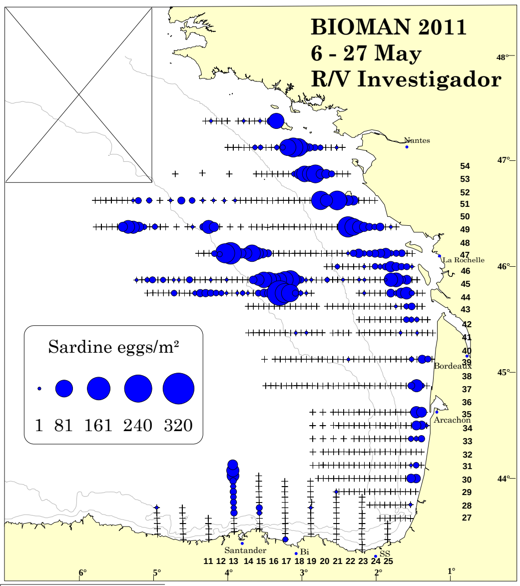

BIOMAN 2006
4 - 24 MAY
B/O VIZCONDE DE EZA
Sardine eggs/0.1m²
1 81 161 240 320
Max: 132eggs/0.1m²
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
47° 46° 45° 44°
6° 5° 4° 3° 2° 1°

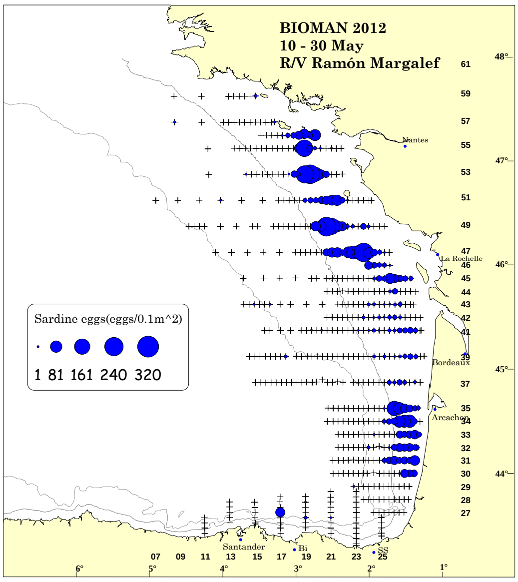

BIOMAN 2007
3 - 23 Mayo
B/O Investigador
Huevos sardina/0.1m²
1 81 161 240 320
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
47° 46° 45° 44°
6° 5° 4° 3° 2° 1°

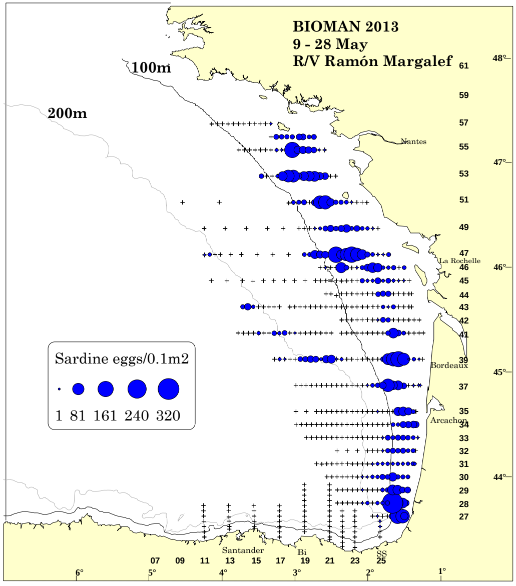

BIOMAN 2008
6 - 26 May
R/V Investigador
Sardine egg/0.1m2
1 81 161 240 320
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
47° 46° 45° 44°
6° 5° 4° 3° 2° 1°

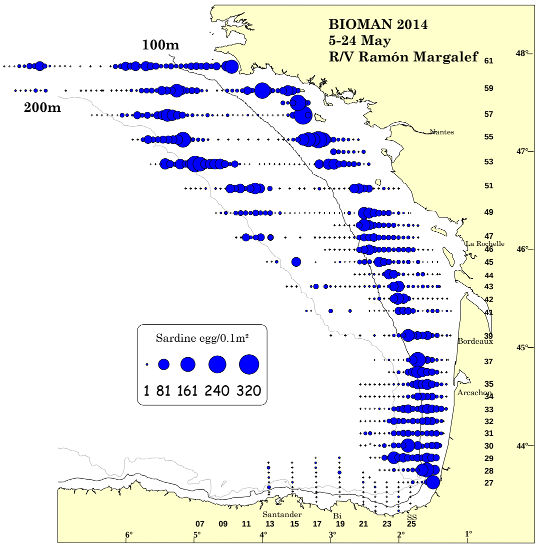

BIOMAN 2009
5 - 25 May
R/V Investigador
Sardine eggs/0.1m^2
1 81 161 240 320
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
47° 46° 45° 44°
6° 5° 4° 3° 2° 1°

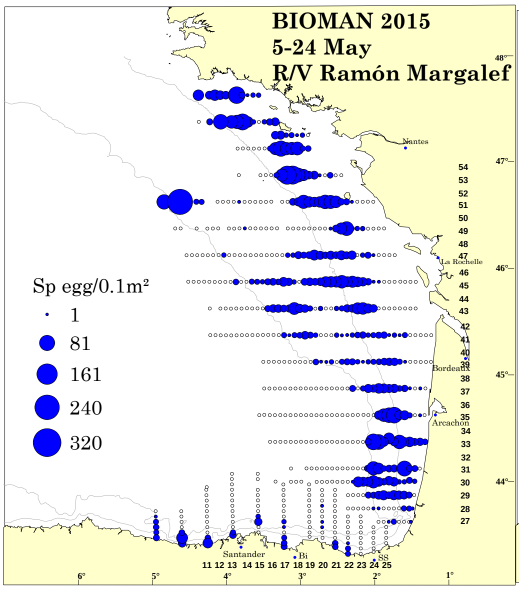

BIOMAN 2010
5 - 20 May
R/V Investigador
Sardine eggs/0.1m2
1 81 161 240 320
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
47° 46° 45° 44°
6° 5° 4° 3° 2° 1°

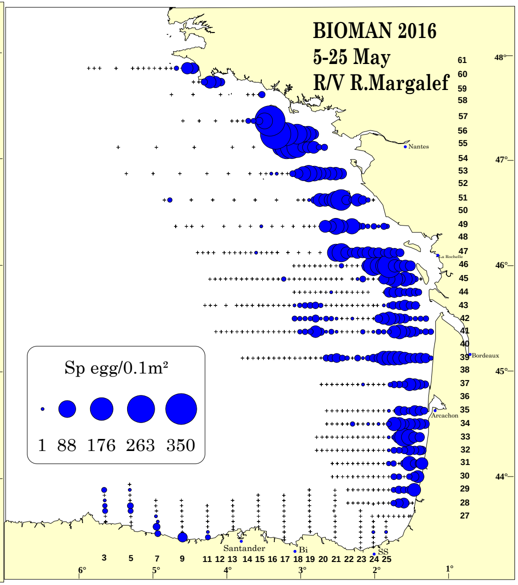

BIOMAN 2011
6 - 27 May
R/V Investigador
Sardine eggs/m²
1 81 161 240 320
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
48°
47°
46°
45°
44°
6°
5°
4°
3°
2°
1°


BIOMAN 2012
10 - 30 May
R/V Ramón Margalef
Sardine eggs(eggs/0.1m^2)
1 81 161 240 320
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
48°
47°
46°
45°
44°
6°
5°
4°
3°
2°
1°


BIOMAN 2013
9 - 28 May
R/V Ramón Margalef
100m
200m
Sardine eggs/0.1m2
1 81 161 240 320
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
48°
47°
46°
45°
44°
6°
5°
4°
3°
2°
1°


BIOMAN 2014
5-24 May
R/V Ramón Margalef
100m
200m
Sardine egg/0.1m²
1 81 161 240 320
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
48°
47°
46°
45°
44°
6°
5°
4°
3°
2°
1°


BIOMAN 2015
5-24 May
R/V Ramón Margalef
Sp egg/0.1m²
1
81
161
240
320
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
48°
47°
46°
45°
44°
6°
5°
4°
3°
2°
1°


BIOMAN 2016
5-25 May
R/V R.Margalef
Sp egg/0.1m²
1 88 176 263 350
Nantes
La Rochelle
Bordeaux
Arcachon
Santander
Bi
SS
48°
47°
46°
45°
44°
6°
5°
4°
3°
2°
1°

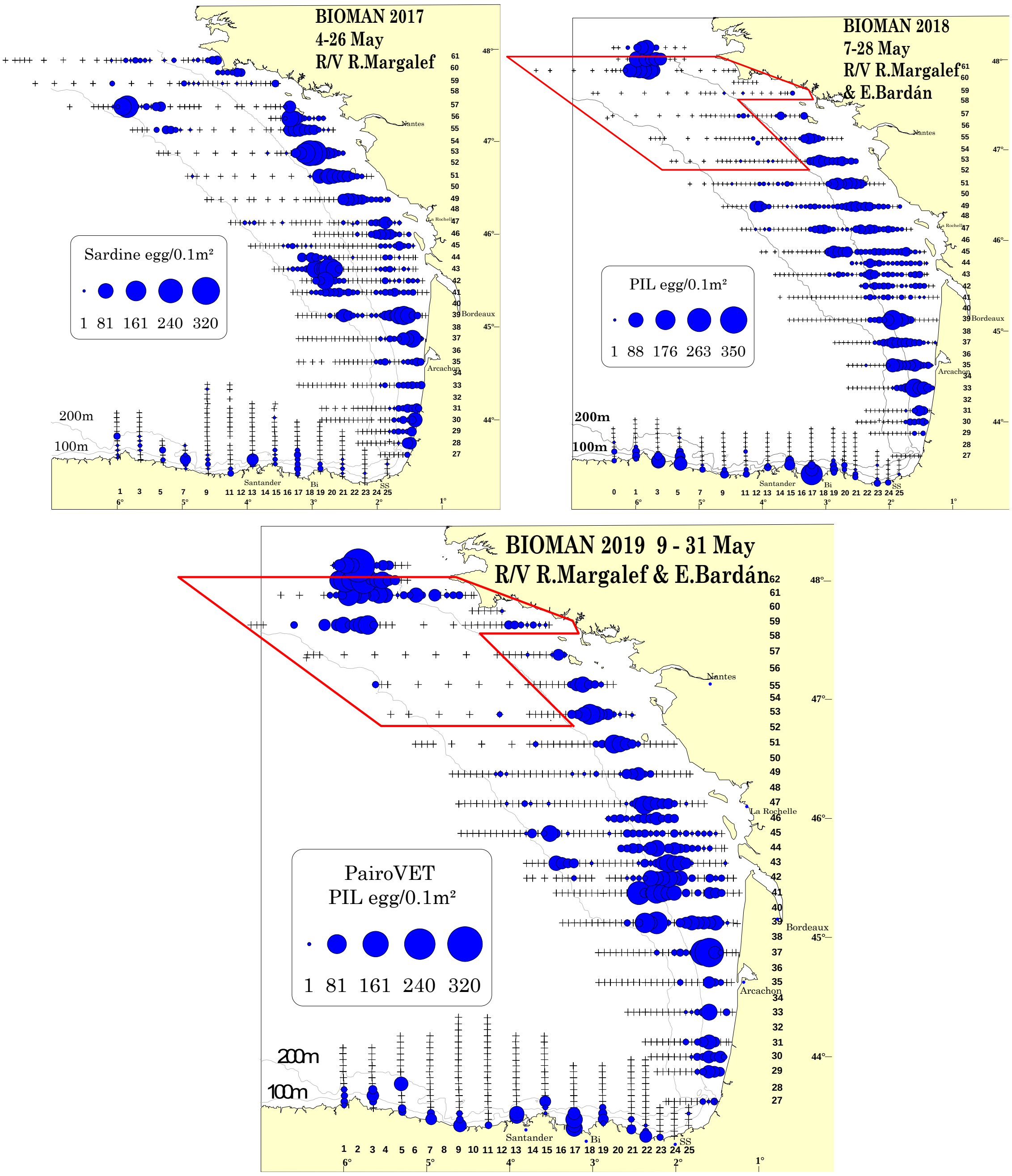


Figure 20: Sardine egg distribution and abundance from 1999 to 2019.

ANNEX 1

Predator and human activity distribution during BIOMAN 2019

Maite Louzao, José Luis Murcia, María Santos

E-mail: mlouzao@azti.es

1. Objectives

We assessed the spatial distribution of marine predators in the Bay of Biscay, considering interactions within the community as well as with human activities. For that, we investigated the distribution and abundance of seabirds and marine mammals by collecting information on the presence and abundance of different species and behavior of individuals encountered during the at-sea observations. In addition, we also recorded other marine organisms such as tuna, ocean sunfish (*Mola mola*), sharks or jellyfish, among others. Likewise, we also record and typify human activities such as fishing (the presence of fishing boats and their activity, fishing buoys, etc.), commercial vessels and various types of marine debris, in addition to recording the presence oceanographic features such as fronts or slicks.

2. Methodology

We followed the same methodology implemented in the PELACUS and PELGAS multidisciplinary surveys based on the distance sampling methodology. We performed observations during daylight acoustic sampling, as well as during certain between-transect navigation while the speed and course of the vessel were constant.

Figure 1. Observation platform onboard R/V Ramón Margalef showing an observer activity.

One observer was placed over the bridge of R/V Ramón Margalef, 7.5 m high from the sea surface (Figure 1). The observer scanned the water to the front of the boat covering an area of 90° from the trackline to port or starboard (45° to each side), respectively continuously while the vessel was sailing at constant heading and speed during daytime. The temporal observation unit was one minute. The observer recorded the environmental conditions that could affect sightings (i.e., wind speed and direction, sea state, swell height, glare intensity, visibility, etc.) and estimated as well the distance to the animal/object and the angle with respect to the trackline. Additional data collected from each sighting included: species, group size, movement direction, behaviour, presence of calves and/or juveniles, etc. All sightings were made with the naked eye while the identification was supported with 10X42 binoculars.

3. Results

3.1. Observations during BIOMAN 2019

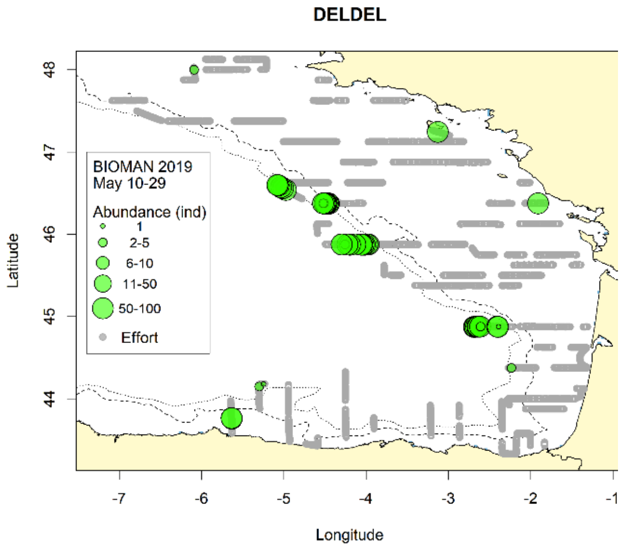
A total of 336 observations periods (legs) were performed, travelling a total of 1902 km. We recorded a total of 932 marine mammals, 1217 seabirds, 14 other marine wildlife, 84 marine debris, 237 human activities, 39 landbirds and 77 oceanographic features (Table 1).

Table 1. Sum of total animals/items observed for each group recorded.

Group	Total sum
Marine mammal	932
Sea Bird	1217
Other Marine Wildlife	14
Marine debris	84
Human activity	237
Land Bird	39
Oceanographic features	77
Total general	2600

Regarding marine mammals, we observed 4 different species and the spatial distribution of the most abundant species can be observed in Figure 2. The most abundant species was the common dolphin with 51 sightings (group size = 15.98 ± 21.67, a total of 815 individuals), followed by the bottlenose dolphin with 6 sightings (group size = 17.17 ± 9.79, a total of 103 individuals) (Table 2). We also recorded 1 sighting of fin whale and grey seal. Common dolphins were scattered throughout the study area, but present in two contrasting bathymetric ranges: coastal or oceanic areas (Figure 2). Bottlenose dolphins were also present mainly in the central area of the French slope (Figure 2).

(a)



(b)

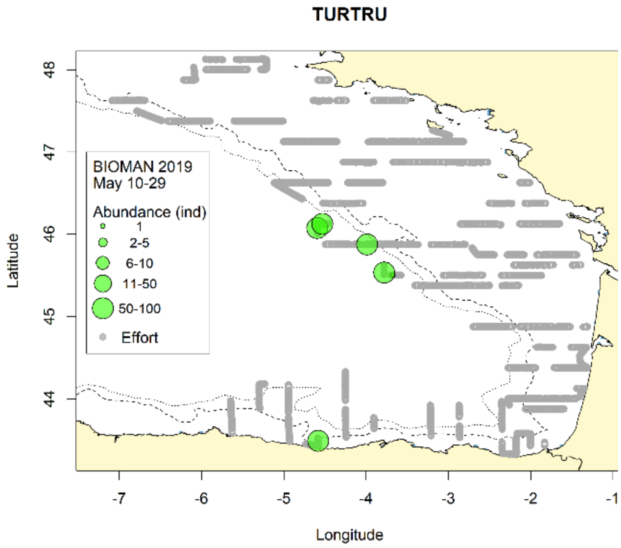
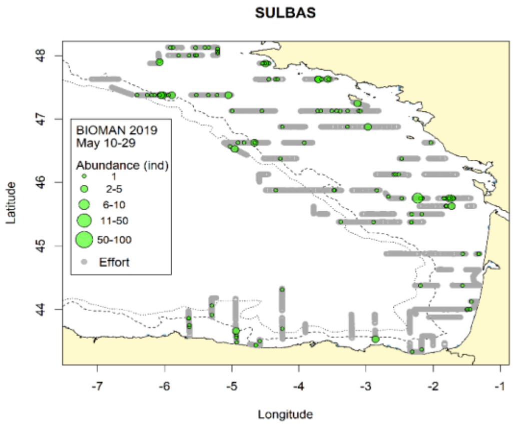


Figure 2. Distribution of the most abundant marine mammal species during BIOMAN 2019, (a,b) common dolphins, (c) bottlenose dolphins. Grey points represent the effort while the size of the green circles is proportional to observed abundances. The dotted and solid lines represent the isobaths of 200 m and 1000 m, respectively. See Table 2 for acronyms.

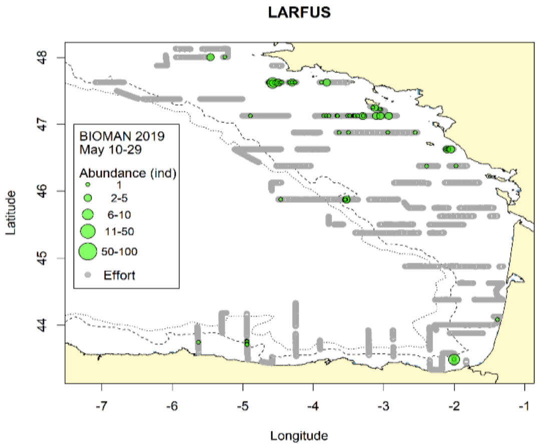
In relation to seabirds, we observed 15 different species and the spatial distribution of the most abundant species can be observed in Figure 3. The most abundant species (> 10 sightings) was the northern gannet with 134 sightings (group size = 1.21 ± 0.66, a total of 162 individuals), followed by the lesser black-backed gull with 65 sightings (group size = 1.6 ± 1.36, a total of 104 individuals), the herring gull with 28 sightings (group size = 2.57 ± 3.21, a total of 72 individuals), the yellow-legged gull with 21 sightings (group size = 1.81 ± 1.54, a total of 38) and the northern fulmar with 18 sightings (group size = 1.06 ± 0.24, a total of 19 individuals) (Table 2). We also observed Manx shearwaters, European storm-petrels, great skuas, Balearic shearwaters, common guillemots, great black-backed gulls, sooty shearwaters, a common tern, a pomarine skua and a sandwich tern (Table 2).

Northern gannets were widely distributed over the study area with aggregations observed in coastal, shelf and slope areas at northern and southern sectors of the study area (Figure 3a). The lesser black-backed gull was present in coastal areas of the northern French sector, with a small number of observations in the offshore Spanish sector (Figure 3b). The herring gull was mainly aggregated in the coastal area of the northern French sector (Figure 3c), whereas the yellow-legged gull was present mainly in the SE corner of the Bay of Biscay (Figure 3d). The northern fulmar was present north of 45.5°N of latitude at the southern limit of its biogeographical range (Figure 3e).

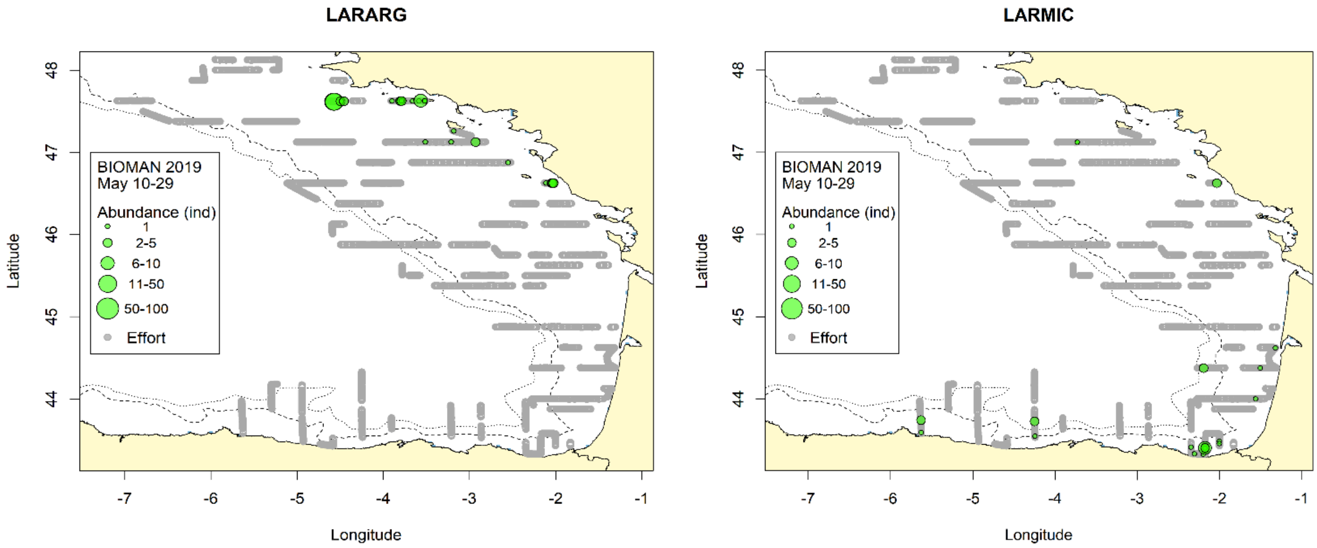
(a)



(b)



(c) (d)



(e)

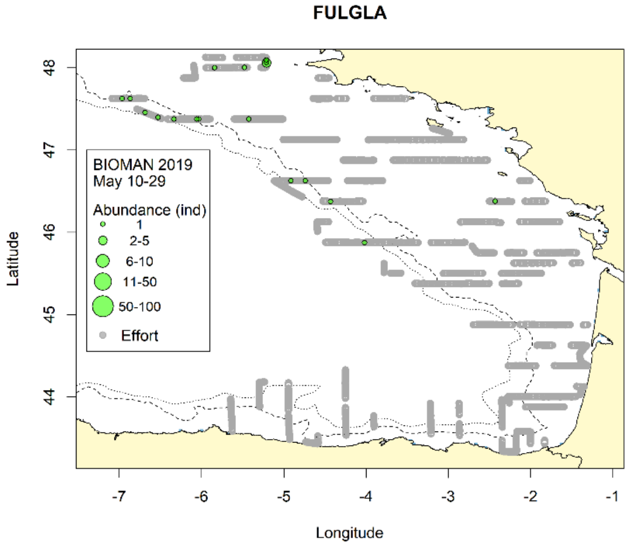


Figure 3. Distribution of the most abundant seabird species during BIOMAN 2019 such as (a) northern gannets, (b) lesser black-backed gulls, (c) herring gulls, (d) yellow-legged gulls and (e) northern fulmars. Grey points represent the effort while the size of the green circles is proportional to observed abundances. The dotted and solid lines represent the isobaths of 200 m and 1000 m, respectively. See Table 2 for acronyms.

Regarding other marine wildlife, we recorded 12 sightings of sun fish with a group size of 1.08 ± 0.29 and a total sum of 13 individuals (Figure 4).

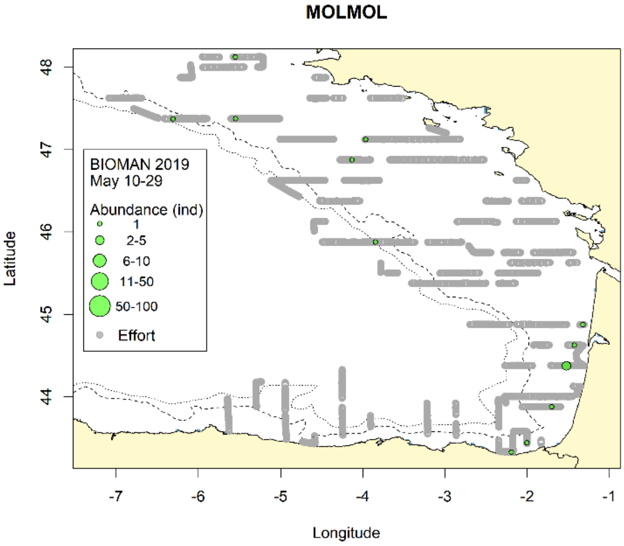


Figure 4. Sunfish observations during BIOMAN 2019.

Regarding marine debris and human activities, we observed 4 types of marine debris and 13 different categories of human activities (Table 2). The main marine debris recorded were plastic trashes with 68 sightings (group size = 1.01 ± 0.12, a total of 69 items), followed by 5 sightings of fish trash (group size = 1 ± 0, a total of 5 items), 4 sightings of general trash (group size = 1.75 ± 1.5, a total of 7 items) and 3 sightings of general trash (group size = 1 ± 0, a total of 3 items). Plastic trashes were mostly found in the northern and central French slope, as well as southern sector of the study area (Figure 5a).

Concerning human activities, the most abundant activities (> 10 sightings) were the fishing buoys with 40 sightings (group size = 1.21 ± 0.64, a total of 41 items), followed by trawlers with 34 sightings (group size = 1.18 ± 0.52, a total of 40 vessels), purse-seines with 23 sightings (group size = 4.22 ± 9.06, a total of 97 vessels), merchant ships with 18 sightings (group size = 1 ± 0, a total of 18 vessels) and longliners with 11 sightings (group size = 1 ± 0, a total of 11 vessels) (Table 2). We also observed pleasure boats, sailing boats, research vessels, fishing boats, an administrative boat, a ferry, a small motorboat and a tanker (Table 2). Fishing buoys were mainly present in the northern French coastal area and southern study area (Figure 5b), whereas trawlers were concentrated in northern and central French shelf and purse-seines were aggregated over the Basque shelf (Figure 5c and 5d, respectively).

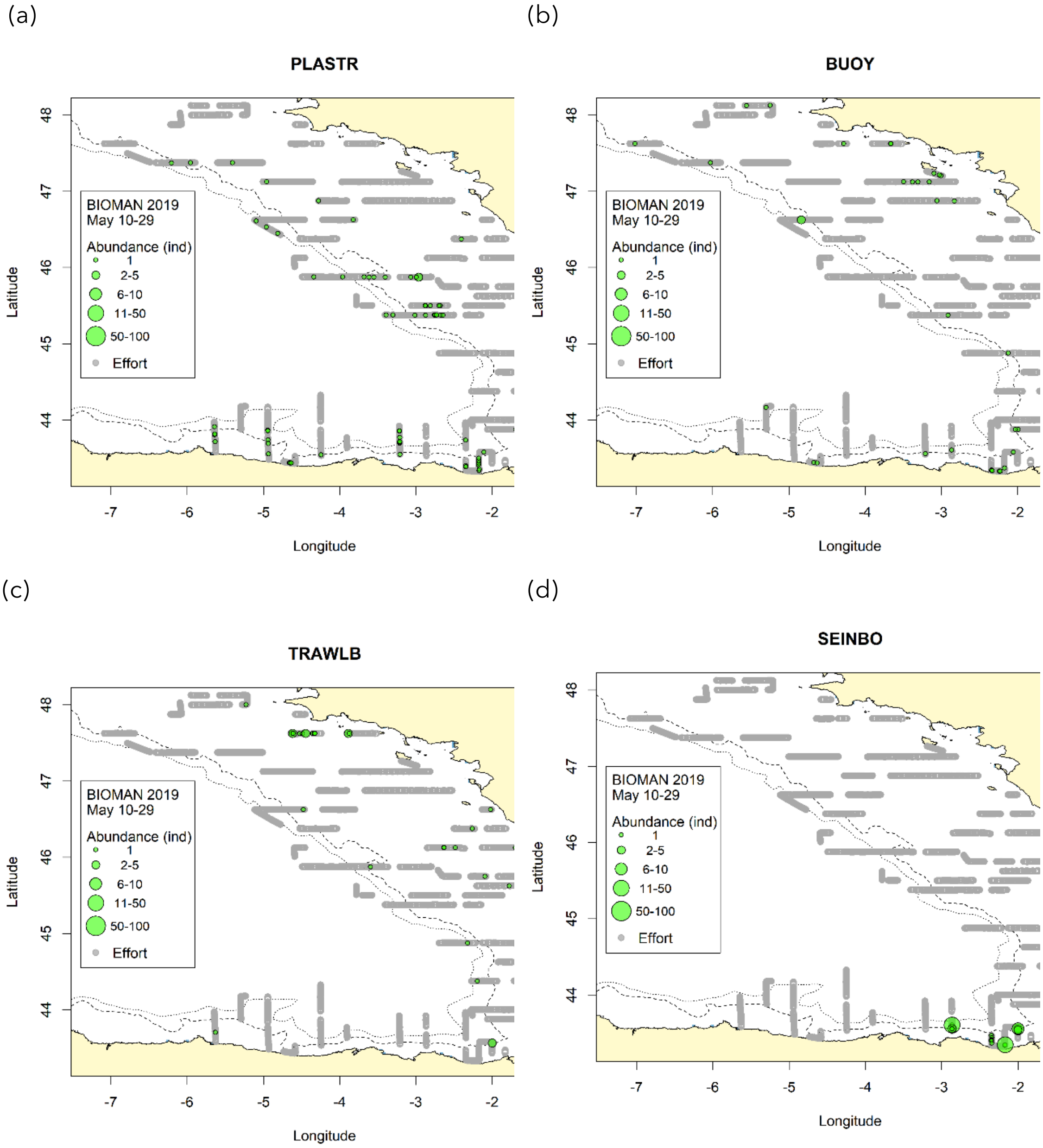


Figure 5. Distribution of the most abundant human activities during BIOMAN 2019 such as (a) plastic trash, (b) fishing buoys, (c) trawlers and (d) purse-seines Grey points represent the effort while the size of the green circles is proportional to observed abundances. The dotted and solid lines represent the isobaths of 200 m and 1000 m, respectively. See Table 2 for acronyms.

3.2. Comparing BIOMAN 2019 with previous years

The survey area covered by BIOMAN 2016-2019 is depicted in figure 6. Even whether there is an inter-annual variability in the marine areas covered, the French continental shelf is well sampled while the Spanish continental shelf is partially covered.

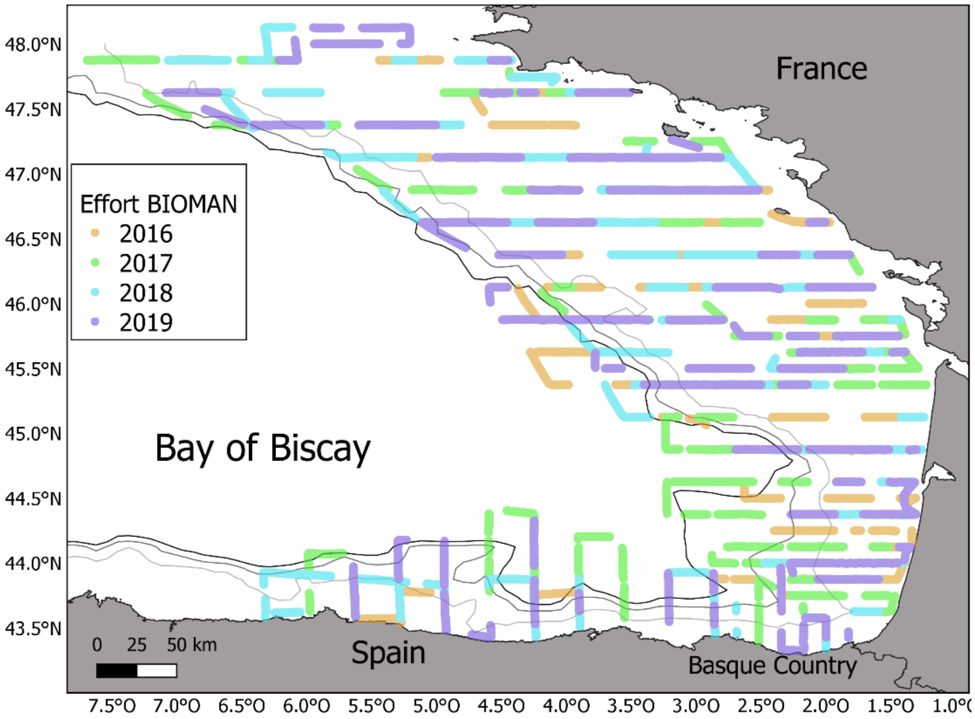


Figure 6. The area covered by the BIOMAN surveys during the 2016-2019 period. The isobaths of 200, 1000 and 2000 m are indicated by black lines.

We compared the number of sightings per distance travelled and the number of predators/items/vessels per distance travelled for seabirds, cetaceans, sunfishes, marine debris and human activities between BIOMAN 2016 and 2019. In 2019, the number of sightings per km was the lowest compared to previous years for almost all predator species (Figure 7). The Northern gannet was the species with a higher encounter rate for the 4-year period, followed by common guillemots, lesser black-backed gulls, northern fulmars, common dolphins and yellow-legged gulls with medium level of sightings. The remaining species (great skuas, European storm-petrels, herring gull, sunfish, Balearic shearwaters and Manx shearwaters) showed a low level of sightings.

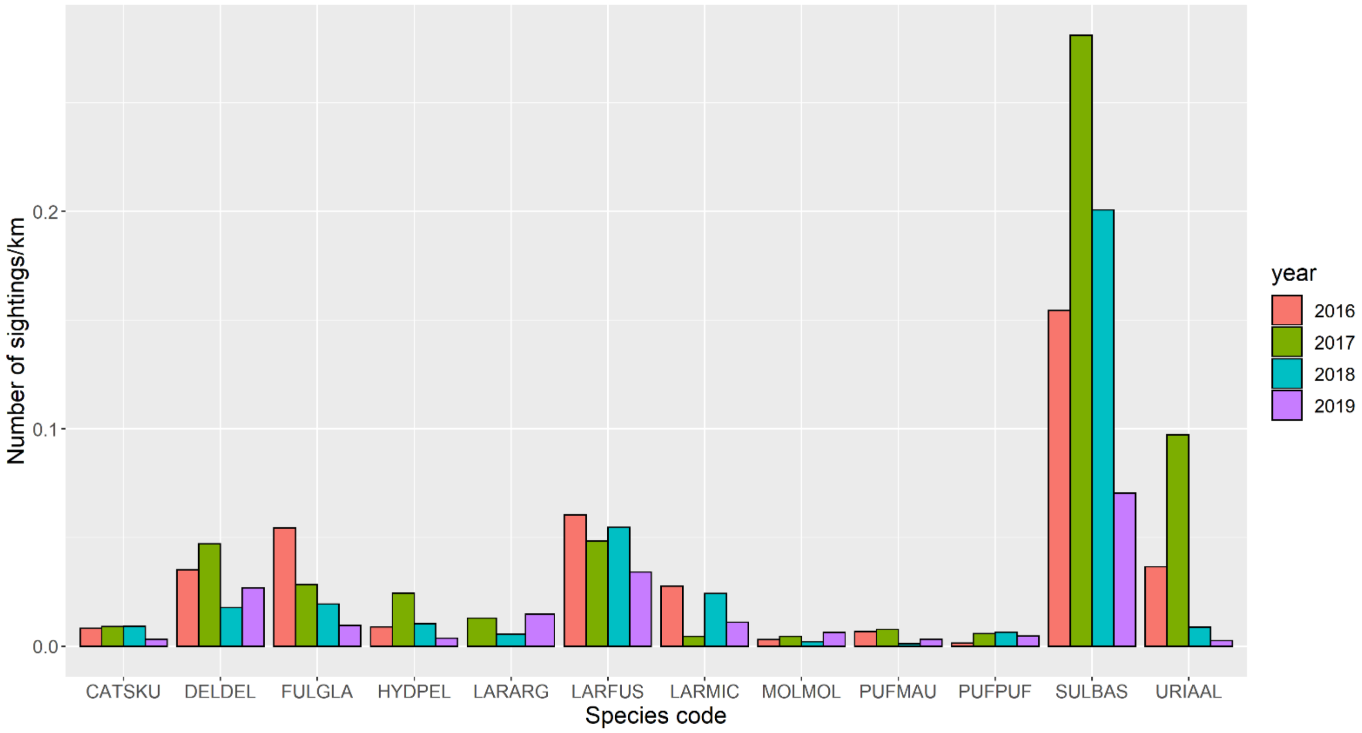
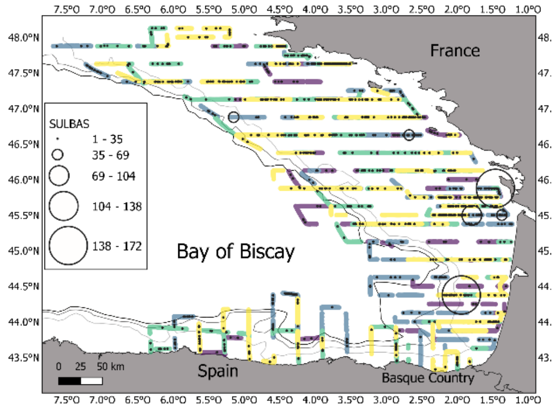


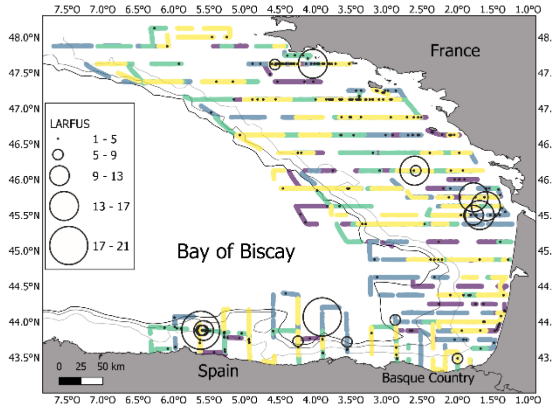
Figure 7. Number of sightings per distance travelled (km) for predators. See Table 2 for acronyms.

Regarding the spatial distribution of the most abundant predators, northern gannets where present over the entire study area with higher concentrations in coastal areas of the central French coast, associated to the Garonne's river plume, in addition to high concentration areas in the shelf-break of the southern French sector (Figure 8a). Lesser black-backed gulls were scattered over the entire study area, more coastal in the French shelf and more oceanic in the Spanish sector, with specific concentrations in both areas (Figure 8b). The common guillemot was mainly present in French coastal areas associated to river plumes, especially in the Garonne's river plume (Figure 8c). The common dolphin was mainly absent from the northern Bay of Biscay and present in the slope areas of the central and southern sector, while aggregated in the Garonne's river plume (Figure 8d).

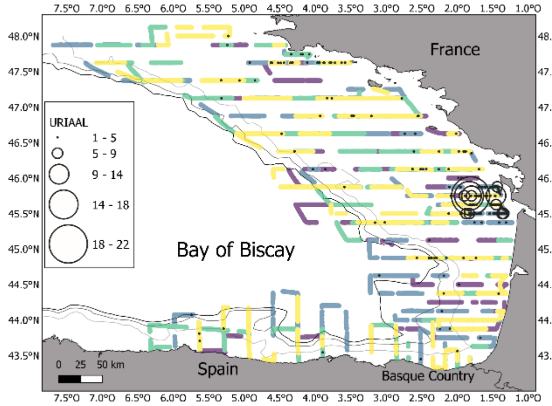
(a)



(b)



(c)



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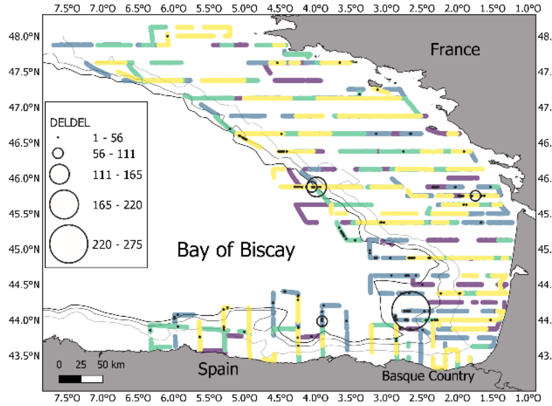


Figure 8. Maps of the most abundant predator species during BIOMAN 2016-2019 period: (a) northern gannets, (b) lesser black-backed gulls, (c) common guillemots and (d) common dolphins. The isobaths of 200, 1000 and 2000 m are indicated by black lines.

Regarding marine debris and human activities, this group showed high interannual variability with certain categories showing a decrease in the number of sightings per distance travelled during the study period, while other categories just showed slight inter-annual differences (Figure 9). By category, plastic trash was the most abundant category (i.e. higher number of sightings for plastic trash per km), followed by buoys and trawling vessels. Plastic trashes decreased their number of sightings, while the number of buoys remained approximately stable across the study period and the number of trawlers increased. The remaining categories (cargo boats, fishing boats, longliners, net boats, pleasant boats sealing boats, purse seiners, general trash and woodtrash) did not show any trend in the number of items/vessels per distance travelled.

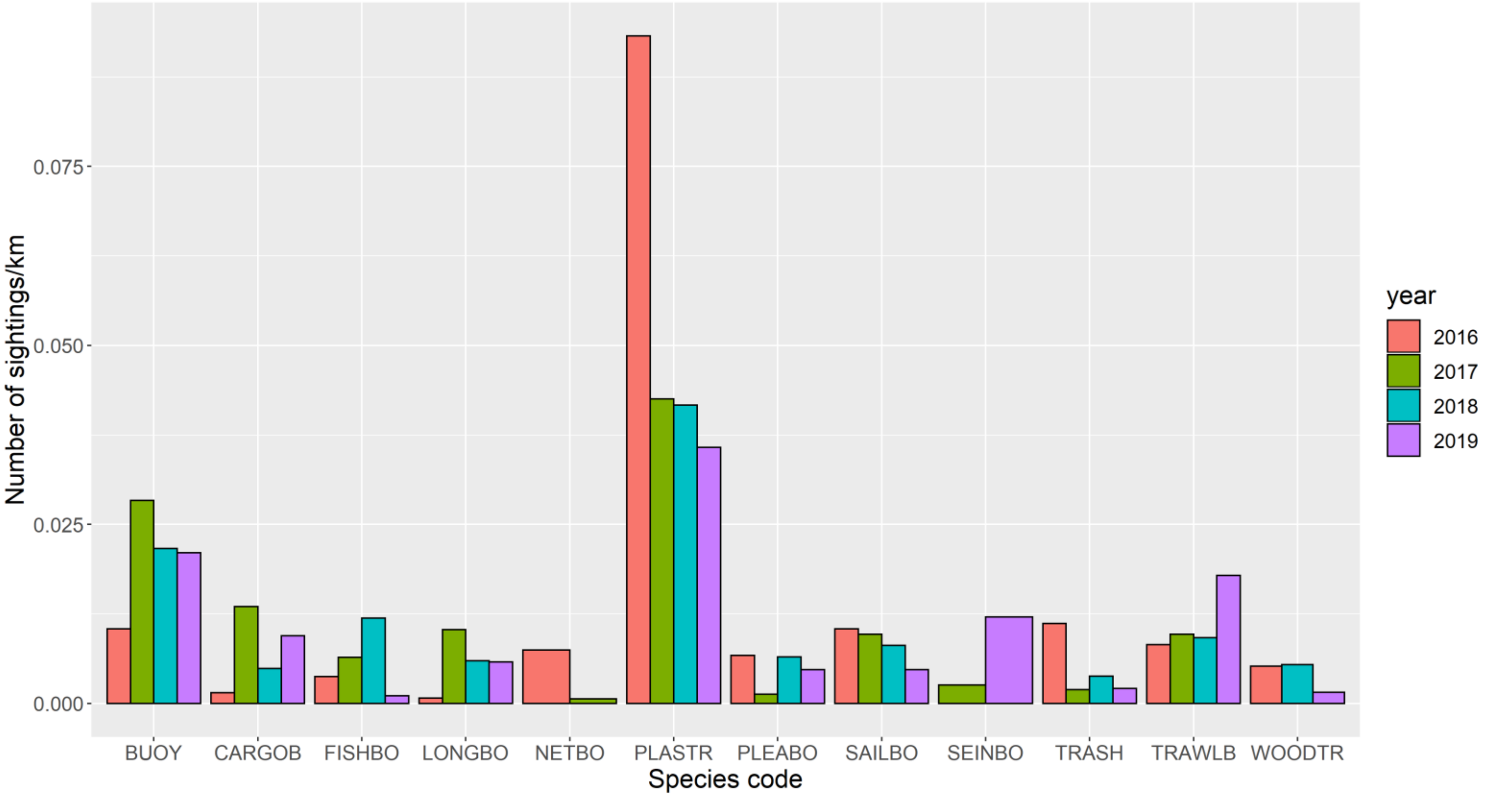
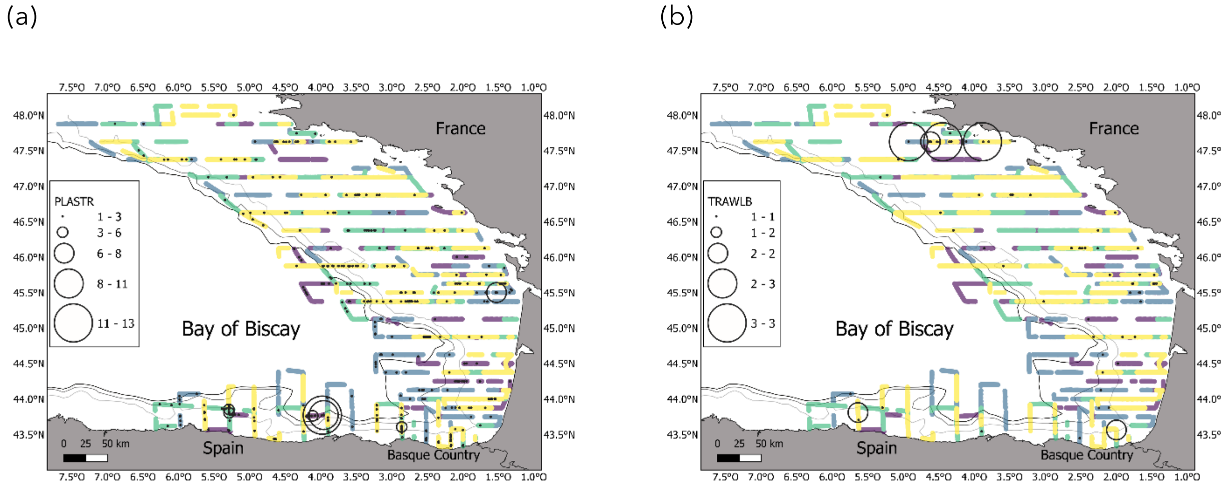


Figure 9. Number of sightings of marine debris/human activities per distance travelled (km). See Table 2 for acronyms.



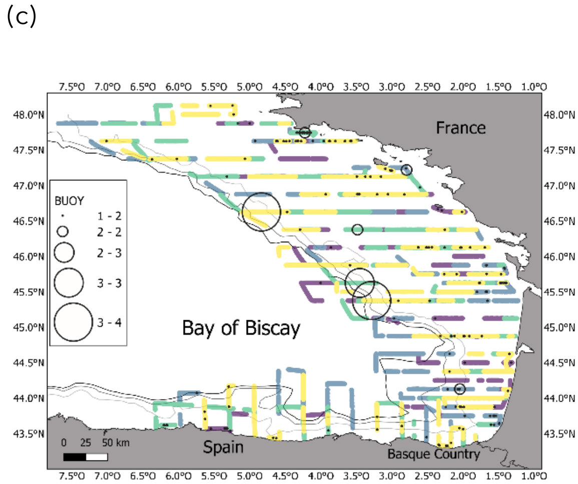


Figure 10. Maps of the most abundant human categories during BIOMAN 2016-2019 period: (a) plastic trashes, (b) trawling vessels, and (c) buoys. The isobaths of 200, 1000 and 2000 m are indicated by black lines.

Regarding the spatial distribution of the most abundant human categories, plastic trashes where present over the entire study area with higher concentrations in the inner Bay of Biscay (Figure 10a). Trawlers were scattered over the entire study area, but with higher presence in northern and central French shelf (Figure 10b). Buoys were present especially in French costal area, but with specific high aggregations in the central French slope (Figure 10c).

4. Conclusions

(1) In 2019, we recorded a total of 932 marine mammals, 1217 seabirds, 14 other marine wildlife, 84 marine debris, 237 human activities, 39 landbirds and 77 oceanographic features.

(2) Four different species of marine mammals were recorded. The most abundant species were the common dolphin and the bottlenose dolphin.

(3) Common dolphins were scattered throughout the study area, but present in two contrasting bathymetric ranges (coastal and oceanic areas) while bottlenose dolphins were also present mainly in the central area of the French slope.

(4) Fifteen different species of seabirds were observed. The most abundant species were the northern gannet, the lesser black-backed gulls, the herring gull, the yellow-legged gull and the northern fulmar.

(5) Most seabirds were detected over the French continental shelf. Depending on the species, they were abundant in different sectors and at different bathymetric ranges.

(6) We observed 4 types of marine debris and 14 different activities/items of human activities. The main marine debris recorded were plastic trashes, mostly found in the northern and central French slope, as well as southern sector of the study area.

(7) The human activities with the highest number of sightings were the fishing buoys, trawlers, purse-seines, merchant ships and longliners. Fishing buoys were mainly present in the northern French coastal area and southern study area, whereas trawlers were concentrated in northern and central French shelf and purse-seines were aggregated over the Basque shelf.

(8) In 2019, the number of sightings per km was the lowest compared to previous years for almost all predator species. The Northern gannet was the species with a higher encounter rate for the 4-year period, followed by common guillemots, lesser black-backed gulls, northern fulmars, common dolphins and yellow-legged gulls with medium level of sightings.

(9) Regarding marine debris and human activities, there was high interannual variability with certain categories showing a decrease in the number of sightings per distance travelled during the study period, while other categories just showed slight inter-annual differences.

(10)Plastic trashes decreased their number of sightings, while the number of buoys remained approximately stable across the study period and the number of trawlers increased.

5. Acknowledgements

This study is a contribution to the ECOPES project, funded by the "Departamento de Desarrollo Económico y Competitividad" of the Basque Government. Maite Louzao was funded by a Ramón y Cajal (RYC-2012-09897) postdoctoral contract.

Table 2. List of taxa observed during BIOMAN 2019 for seabirds, marine mammals, other marine wildlife, marine debris, human activities and landbirds.

Group	Common name	Scientific name	Code	Number of sightings	Group size	Total sum
Marine mammal	Common dolphin	*Delphinus delphis*	DELDEL	51	15.98 ± 21.67	815
	Bottlenose dolphin	*Tursiops truncatus*	TURTRU	6	17.17 ± 9.79	103
	Fin whale	*Balaenoptera physalus*	BALPHY	1		1
	Grey seal	*Halichoerus grypus*	HALGRY	1		13
Seabirds	Northern gannet	*Morus bassanus*	SULBAS	134	1.21 ± 0.66	162
	Lesser black-backed gull	*Larus fuscus*	LARFUS	65	1.6 ± 1.36	104
	European herring gull	*Larus argentatus*	LARARG	28	2.57 ± 3.21	72
	Yellow-legged gull	*Larus michahellis*	LARMIC	21	1.81 ± 1.54	38
	Northern fulmar	*Fulmarus glacialis*	FULGLA	18	1.06 ± 0.24	19
	Manx shearwater	*Puffinus puffinus*	PUFPUF	9	1.22 ± 0.44	11
	European storm-petrel	*Hydrobates pelagicus*	HYDPEL	7	1.14 ± 0.38	8
	Great skua	*Stercorarius skua*	CATSKU	6	1.17 ± 0.41	7
	Balearic shearwater	*Puffinus mauretanicus*	PUFMAU	6	1.17 ± 0.41	7
	Common guillemot	*Uria aalge*	URIAAL	5	1.2 ± 0.45	6
	Great black-backed gull	*Larus marinus*	LARMAR	2	1 ± 0	2
	Larid sp	*Laridae spp*	LARSPP	2	388 ± 547.3	776
	Sooty shearwater	*Puffinus griseus*	PUFGRI	2	1 ± 0	2
	Common Tern	*Sterna hirundo*	STEHIR	1		1
	Pomarine skua	*Stercorarius pomarinus*	STEPOM	1		1
	Sandwich Tern	*Sterna sandvicensis*	STESAN	1		1
Other Marine Wildlife	Sunfish	*Mola mola*	MOLMOL	12	1.08 ± 0.29	13
	Fish sp		FISH	1		1
Marine debris	Plastic trash		PLASTR	68	1.01 ± 0.12	69

	Fishing trash (net part, buoy…)		FISHTR	5	1 ± 0	5
	Trash (plastic, wood, oil)		TRASH	4	1.75 ± 1.5	7
	Unnatural wood		WOODTR	3	1 ± 0	3
Human activity	Fishing buoy, setnet		BUOY	40	1.07 ± 0.47	43
	Trawler		TRAWLB	34	1.18 ± 0.52	40
	Seiner		SEINBO	23	4.22 ± 9.06	97
	Merchant ship (containership, cargo, tanker)		CARGOB	18	1 ± 0	18
	Longliner		LONGBO	11	1 ± 0	11
	Pleasure boat		PLEABO	9	1 ± 0	9
	Sailing boat		SAILBO	9	1 ± 0	9
	Research vessel (science)		RESEBO	4	1 ± 0	4
	Fishing boat (professional)		FISHBO	2	1 ± 0	2
	Administrative boat (navy, custom, coast guard)		ADMIBO	1		1
	Ferry		FERRYB	1		1
	Small motor boat		MOTOBO	1		1
	Tanker (oil, gaz, chemical)		TANKER	1		1
Landbirds	Swift	*Apus apus*	APUAPU	4	2 ± 1.41	8
	Dunlin	*Calidris alpina*	CALALP	2	2 ± 0	4
	Ringed Plover	*Charadrius hiaticula*	CHAHIA	2	10 ± 5.66	20
	Barn swallow	*Hirundo rustica*	HIRRUS	2	1 ± 0	2
	Sanderling	*Calidris alba*	CALALB	1		3
	Passerine bird	*Passeriformes*	PASSER	1		1
	Eurasian Spoonbill	*Platalea leucorodia*	PLALEU	1		1
Oceanographic features	Tidal front		FRONT	77	1 ± 0	77

Working Document presented at WGACEGG, 18-22 November 2019, Madrid, Spain

PELAGO19 acoustic survey in the Atlantic Iberian Waters of ICES area 9a
(River Minho - Cape Trafalgar)

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Abstract

PELAGO19 survey was carried out onboard R/V Noruega from 12th April until 19th May 2019. The main objective was to describe the sardine and anchovy spatial distributions and to estimate their abundance in the shelves of Portugal and Gulf of Cadiz, Spain. During the survey, 59 fishing hauls were undertaken. The estimated sardine total biomass was 156 thousand tons, representing a decrease of around 9.5% in relation to the PELAGO18 survey (172 thousand tons). The Occidental South (OCS) and Algarve (ALG) were the areas with more contributions (82%) for the total biomass and Cadiz (CAD) was the area with the biggest decrease (79%) when compared with the last year. The OCN and OCS zone showed a mixture of juveniles and adult sardine and in the ALG and CAD areas sardine was mainly adult. Small sardines (<16 cm) were observed in all areas. The estimated anchovy biomass was 34 thousand tons, representing a significant decrease (56%) when compared with PELAGO18 survey (78 thousand tons). The Gulf of Cadiz was the area with more contribution (88%) for the total biomass, where there was an increase of around 27%. The egg abundance derived from the CUFES sampling for the whole surveyed area was in 2019 considerably lower than during the 2018 survey, which was the year with the series record value, particularly due to a very high occurrence of anchovy eggs. During the PELAGO19, egg densities were still higher for anchovy than for sardine (PIL eggs: 15% of total eggs; ANE eggs: 45% of total eggs) however the abundance of the former was about half of the number found in 2018 while for the latter a decrease of about 38% was observed. A fair match between egg abundances spatial distribution and adult fish schools occurrence was noted for anchovy over most of the surveyed area, whereas for sardine the co-occurrence of eggs and adults was apparent in the S and SW but not so clear in the NW region where a high proportion of the eggs were collected.

1. Background and survey summary

The acoustic surveys of the PELAGO series are funded via EU-DCF and national programs and are coordinated with the spring acoustic surveys from Spain and France, and discussed and reported within ICES - WGACEGG (Working Group on Acoustics and Egg Surveys). The Portuguese acoustic survey, takes place each year during spring covering the shelf waters of Portugal and Cadiz Bay. The main objectives of

PELAGO surveys include monitoring the abundance distribution through echo-integration, and the study of several biological parameters of sardine (*Sardina pilchardus*), anchovy (*Engraulis encrasicolus*), mackerel (*Scomber scombrus*), chub-mackerel (*Scomber colias*), horse-mackerel (*Trachurus trachurus*) and other small pelagic fish. Surveying also considers continuous observations of fish eggs and larvae along the acoustic transects (CUFES - Continuous Underway Fish Egg Sampler) and hydrological and biological characterization of the water column. Additionally, census of marine birds and mammals are conducted during the survey trajectory. A summary of the work developed during the PELAGO19 survey, by geographical area, is presented in Table 1.1.

Table 1.1. PELAGO19 survey summary information by area.

	OCN (NW)	**OCS (SW)**	**ALG (S)**	**Cadiz (S)**
Vessel	Noruega	Noruega	Noruega	Noruega
Dates	15/04-22/04	28/04-08/05	05-13/05	13-17/05
SURVEY EGGS & HYDROGRAPHY	**OCN (NW)**	**OCS (SW)**	**ALG (S)**	**Cadiz (S)**
SST (ºC) max/mean/min	16.7/15/13.8	17.4/15.8/13.9	18.2/16.9/15.2	20.7/18.7/17.5
CTDF casts (night period)	32	32	16	20
Transects CUFES PELAGO	17	26	17	11
CUFES samples – PELAGO	186	166	106	95
Tot eggs PIL (% positive samples)	9376 (34%)	2660 (40%)	4024 (41%)	1190 (58%)
Tot eggs ANE (% positive samples)	37198 (48%)	1126 (26%)	3481 (58%)	9957 (50%)
Max eggs/m3 per sample PIL	65.2	27.4	32.8	29.2
Max eggs/m3 per sample ANE	203.3	20.0	25.7	175.6
Bongo60 samples (night period)	28	26	16	20
Bongo90 samples (night period)	20	19	12	12
WP2_40 samples (night period)	20	20	10	15
SURVEY ACOUSTICS & FISH	**OCN (NW)**	**OCS (SW)**	**ALG (S)**	**Cadiz**
Number of acoustics transects (nm)	17(453)	29(415)	14(166)	11(194)
Number hauls RV (pelagic/bottom)	11/8	11/8	6/2	8/5
Number (+) trawls - PIL	12	8	5	6
Number (+) trawls - HOM	8	8	2	5
Number (+) trawls - MAC	15	6	2	1
Number (+) trawls - MAS	2	7	6	5
Number (+) trawls - ANE	10	1	0	5
Depth range (m) in (pelagic/bottom) RV fishing operations	18-60/ 15-105	22-94/ 17-136	27-94/ 109-127	15-80/ 16-101
Total number fish sampled - PIL	834	1196	556	579
Total number fish sampled - HOM	1154	834	24	513
Total number fish sampled - MAC	579	12	4	1
Total number fish sampled - MAS	118	206	231	22
Total number fish sampled - ANE	773	32	0	595
Number otoliths collected - PIL	360	347	306	306
Number otoliths collected – HOM	163	134	19	100
Number otoliths collected - MAC	184	2	0	0
Number otoliths collected - MAS	61	98	105	14
Number otoliths collected - ANE	203	32	0	169

2. Acoustic Survey Pelago19

Material and methods

Acoustics

Survey execution and abundance estimation followed the methodologies adopted by the ICES WGACEGG. The survey area, over the shelf until the 200 m isobath, was covered following a parallel grid with a mean distance between transects of 8 nautical miles. Average survey speed was 8 knots and the acoustic signals were integrated over one nautical mile intervals. Echo integration was carried out with a 38 kHz Simrad EK500 scientific echo sounder while the 120 KHz sounder was used to assist in the echogram scrutiny process. The acoustic data was recorded in MOVIES+ (Weill *et al*., 1993), which was also used to integrate the fish acoustic energy. The echogram bottom was manually corrected prior to the acoustic energy extraction. An acoustic calibration with a copper sphere was carried out, following the standard procedures (Foote *et al.*, 1981). For presentation purposes and results comparison, the surveyed area was divided, as usual, into 4 sub-areas or regions: Occidental North - OCN (from Caminha to Nazaré), Occidental South - OCS (from Nazaré to Cape S. Vicente), Algarve - ALG (from Cape S. Vicente to V. R. Santo António) and Bay of Cadiz - CAD (from V. R. Santo António to Cape Trafalgar).

Adult fish

The fishing data was used for biological purposes but also to identify the species and to split the acoustic energy by species and by length within each species. Fishing was carried out according to the echogram information. Nevertheless, due to the presence of fixed commercial fishing gears or irregular and rocky bottoms, it was not possible to make hauls in some areas. Biological sampling of sardine, anchovy, horse-mackerel, mackerel and chub-mackerel was performed whenever the species were present in the hauls. In addition, otoliths were collected for sardine, anchovy, horse-mackerel, mackerel and chub-mackerel. Otoliths are used for age reading and for the production of Age Length Keys (ALK's). For sardine and anchovy, the abundance (x 1 000) by age group and area is estimated from the combination of the ALK and the estimates of abundance at length from the echo-integration in each area.

Results

Small pelagic fish community

To collect the biological data, 59 fishing hauls were carried out by the RV Noruega, of which 36 with the pelagic net and 23 with the bottom trawl, covering the entire Portuguese coast and the Spanish waters of the Gulf of Cadiz. The PELAGO19 fishing hauls distribution is presented in Figure 2.1. The main concentrations of small pelagic fish in the OCN were identified as anchovy (ANE), sardine (PIL), mackerel

(MAC) and horse mackerel (HOM). Sardine, horse mackerel and snipe fish (SNS) dominated in the OCS, only sardine in the Algarve , and sardine and anchovy in Cadiz (Fig. 2.2).

Figure 2.1 – PELAGO 19 fishing hauls distribution.

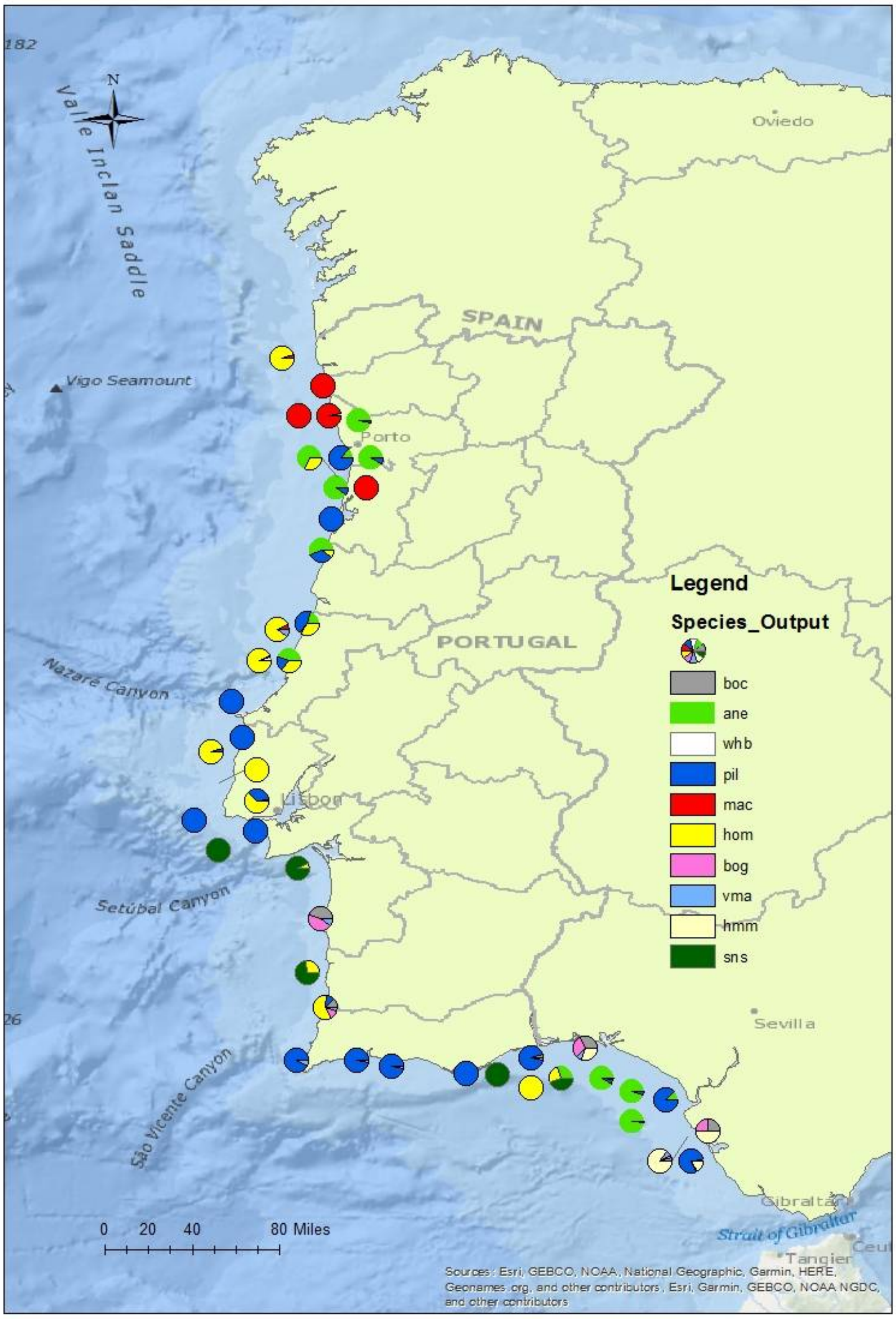


Figure 2.2 – Pelago19 proportion, in number, of the species caught in the fishing stations. Pelagic and bottom trawl by RV Noruega.

Sardine distribution, biomass, abundance and biological data

The main concentrations of sardine were observed in the OCS, between Nazaré and Cape Espichel and around Odeceixe, and in the Algarve, mostly between Portimão and Albufeira. In the OCN area, sardine was mainly concentrated between Matosinhos and south of Aveiro. In Cadiz, sardine was dispersed in the various transects, with a generally low acoustic energy (Fig. 2.3).

Sardine acoustic estimates for the whole area were 4 549 million fish and 155 565 t. In terms of biomass this represents a decrease of around 9.5% in relation to the PELAGO18 survey (171 978 t). The Table 2.1 represents the estimated sardine abundance and biomass by area and for the whole survey for Pelago18 and Pelago19 surveys. OCS and ALG areas had a contribution of around 82% of the total sardine biomass. CAD was the area with the biggest biomass decrease (around 79%) when compared with the previous survey. The decrease in abundance was lower than in biomass (53%), because larger sardines were present in 2019. The biomass and abundance evolution of sardine since 2005 for the whole area shows the slight increasing trend since 2011, and the persistence of low biomass compared to 2005-2006 (Fig. 2.4). The biomass and abundance trend was distinct between areas, with persistence of very low values in the OCN, an increasing trend in the last 5 years in the OCS and ALG areas, and the usually up and down pattern in CAD (fig. 2.5).

The length and age compositions of sardine biomass and abundance in PELAGO19 survey in each area are depicted in figures 2.6. and 2.7. Despite the four areas show a polimodal length distribution, the length have significant differences. The age composition is also distinct between areas. Sardine in OCN presented three length modes: modal lengths in 6.5 and 9.0 cm corresponding to 0 year old fish and a length mode in 16.5 cm corresponding to 1 year old fish. No older fish were observed in this area. Length distribution of sardine in OCS had also 3 modes, a small number with modal length of 7.5 cm corresponding to 0 year old fish and two modes of larger sardines with modal length of 19 and 22 cm. The larger fish aged 1 to 9 years old with modal ages of 1 and 3 years old. Three years old sardines were the most abundant in OCS. Modal ages in the Algarve were the same as in OCS, however all sardine were larger than 14 cm with modal lengths of 15.5 and 18.0 cm corresponding to 1 and 3 years old fish, respectively. One year old sardines were the most abundant in ALG. In the Bay of Cadiz, length and age distribution was rather different from the previous Pelago surveys. Length distribution of sardine in CAD showed 3 modes, a small number with modal length of 8.0 cm corresponding to 0 year old fish and two modes of larger sardines with modal length of 13.5, corresponding to age 1, and 17.0 cm corresponding to 1 to 4 years old fish.

A summary of sardine abundance (millions) and biomass (tons) by area for the total stock and the spawning stock (Age 1+), estimated in Pelago18 and Pelago19, are presented in table 2.2. Despite the decrease in the abundance and biomass of the total stock, from 2018 to 2019 there was a significant increase of the abundance and biomass of the spawning stock, the relevant indicator for stock assessment purpose.

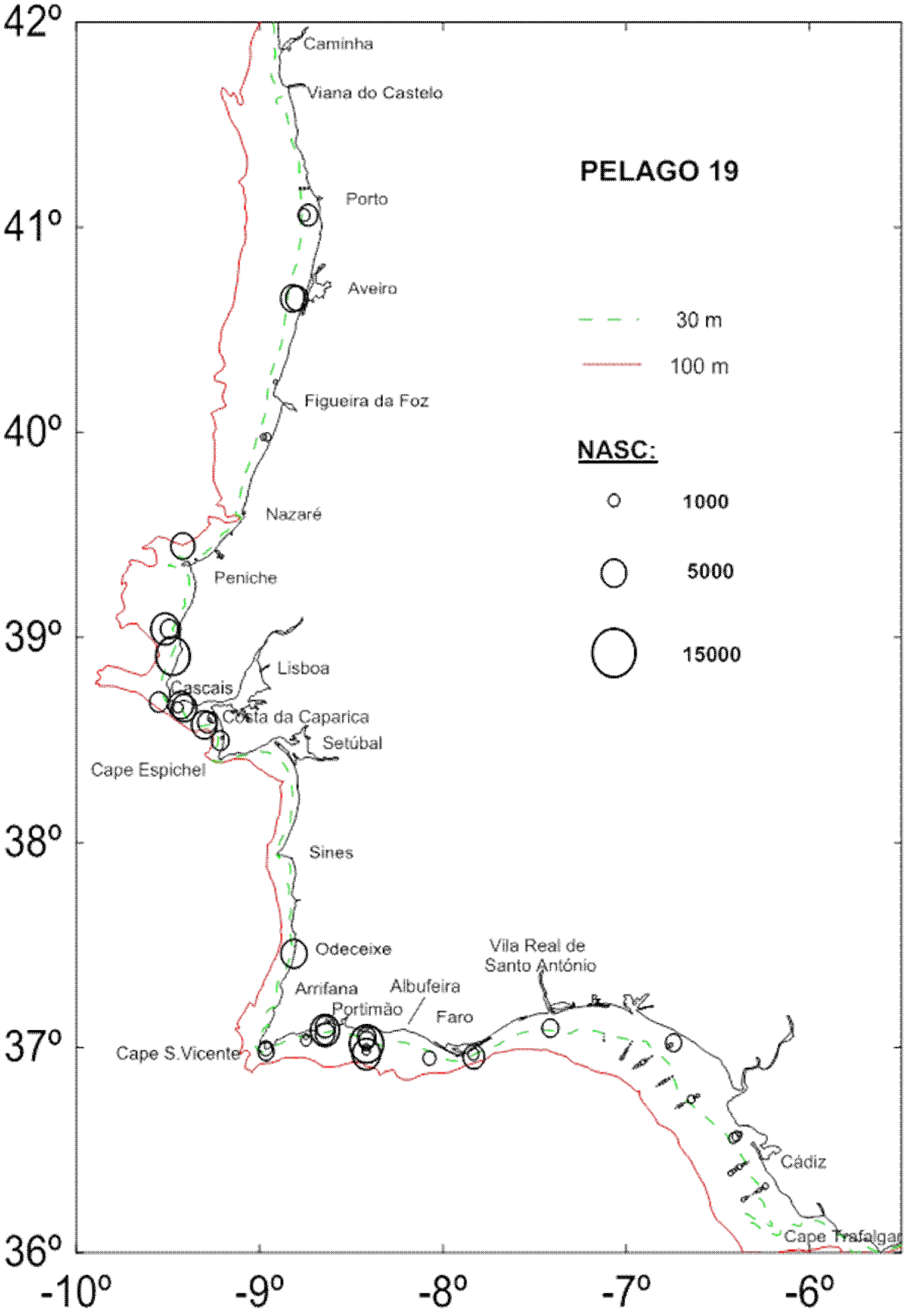


Figure 2.3 – Sardine acoustic energy spatial distribution. Circle area is proportional to the acoustic energy (S_A m^2/nm^2).

Table 2.1. Sardine abundance (million fish) and biomass (tons) in each area and in the total surveyed area in the Pelago18 and Pelago19 surveys.

Sardine	OCN	OCS	ALG	CAD	TOTAL
Biomass 2018	14 954	98 463	22 627	35 934	171 978
Biomass 2019	20 178	75 599	52651	7437	155 565
Abundance 2018	1 257	1 670	1 097	5583	9 607
Abundance 2019	1 083	1 504	1 439	523	4 549

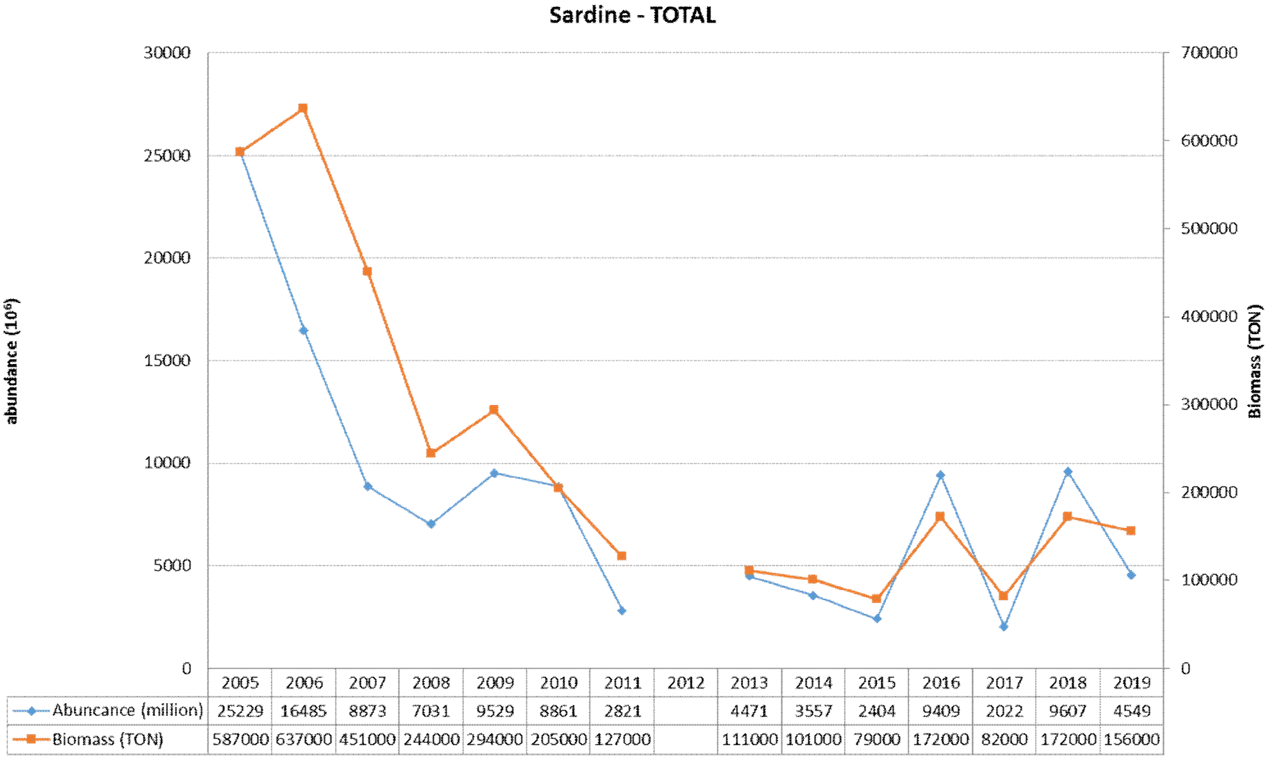


Figure 2.4 - Sardine total biomass and abundance evolution along the Pelago surveys time series, since year 2005.

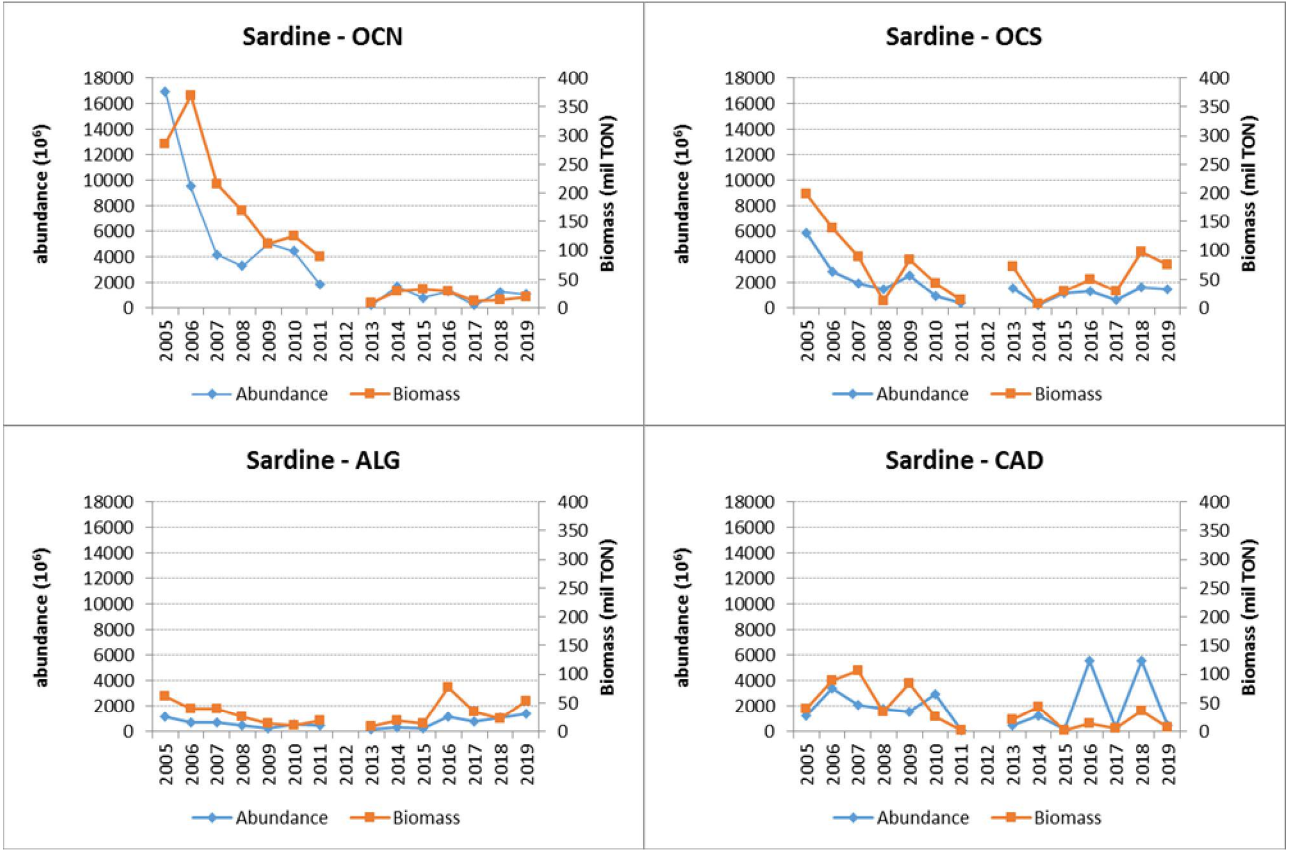


Figure 2.5 – Sardine abundance (billion fish) and biomass (thousand tonnes) evolution along the Pelago surveys time series in each area since 2005.

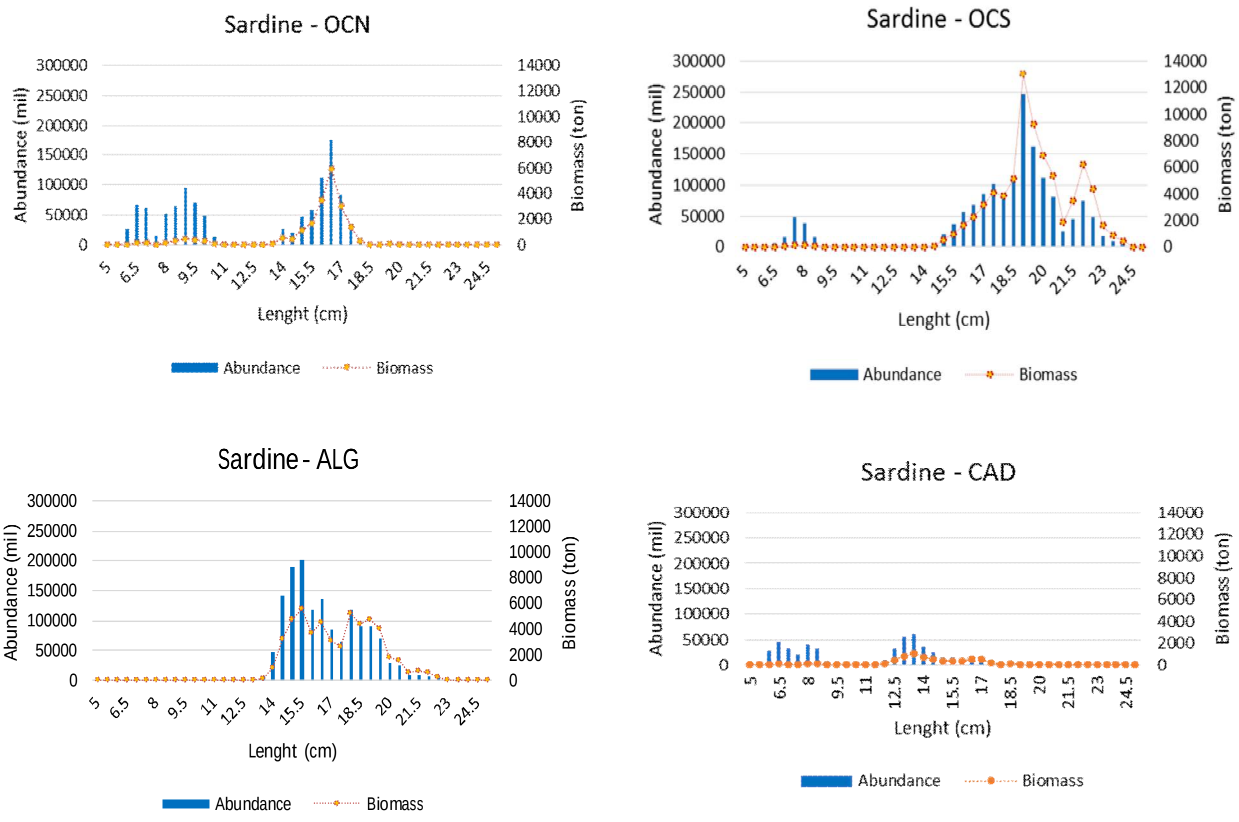


Figure 2.6 – Length composition of sardine biomass and abundance in PELAGO19 survey by area.

Table 2.2. Sardine abundance (millions) and biomass (tons) by area for the total stock and the spawning stock estimated in Pelago18 and Pelago19.

Area		Pelago18		Pelago19	
		Abundance	Biomass	Abundance	Biomass
OCN	Total	1 257	14 955	1 083	20 178
	Age1+	162	7 819	565	17 956
OCS	Total	1 670	98 462	1 504	75 599
	Age1+	1 670	98 462	1 379	75 198
ALG	Total	1 097	22 626	1 439	52 651
	Age1+	513	17 390	1 439	52 651
CAD	Total	5 583	35 935	523	7 137
	Age1+	29	0.4	298	6 412
Total	Total	9 607	171 978	4 549	155 565
	Age1+	2 375	123 671	3 680	152 217

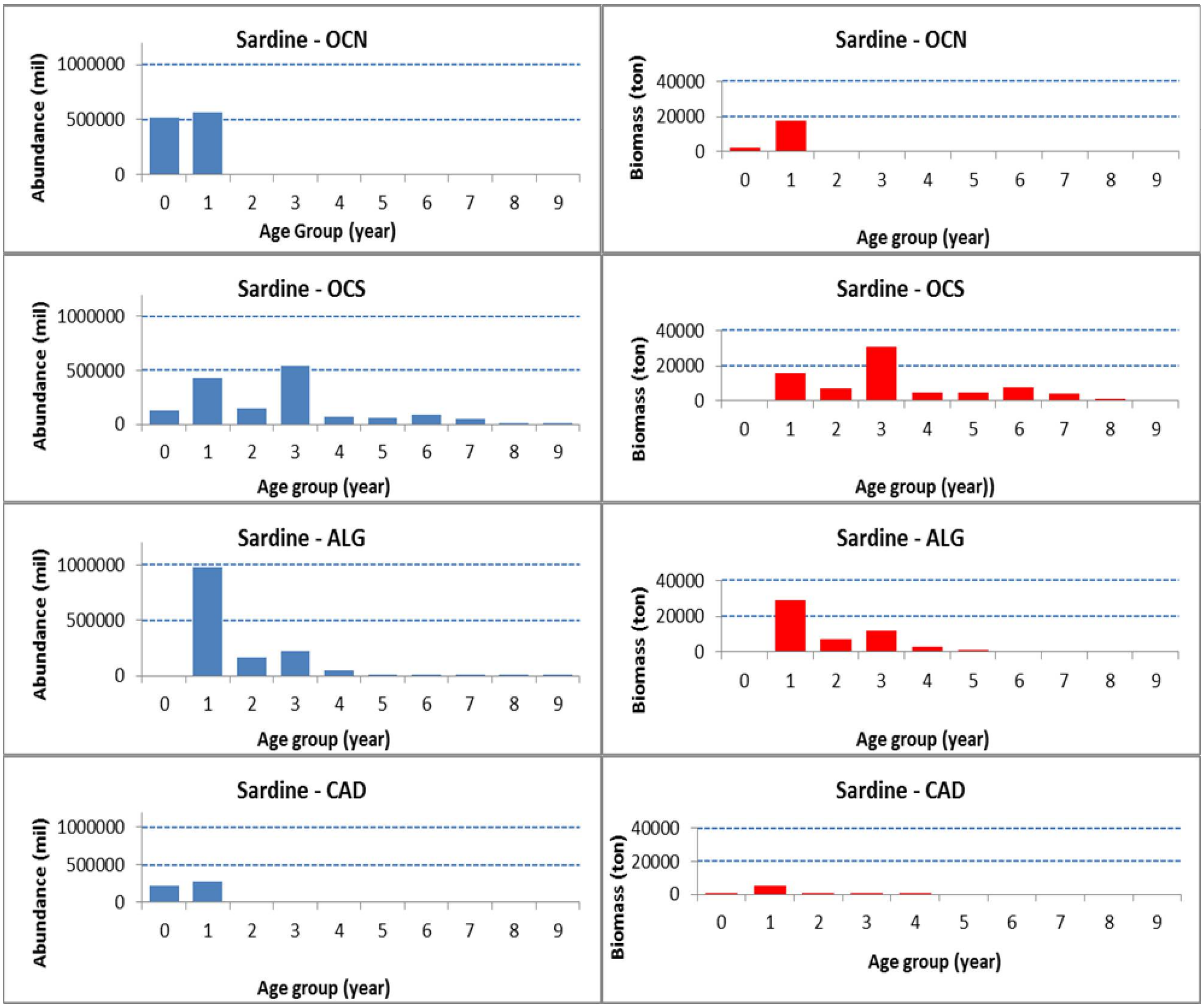


Figure 2.7 – Age distribution of sardine biomass and abundance in PELAGO19 survey, by area.

Anchovy distribution, biomass, abundance and biological data

Anchovy was concentrated in OCN, mainly between Viana do Castelo and south of Figueira da Foz, in OCS, between Cascais and Costa da Caparica, and the main concentration in the Bay of Cadiz (Fig 2.8). In the Table 2.2 is represented the estimated numbers for anchovy abundance and biomass for each stock component and for the whole survey. Anchovy acoustic estimates for the whole surveyed area were 3 634 million fish and 33 813 t, representing a decrease of total biomass of the stock of around 56% in relation to the PELAGO18 survey. The South component, mainly concentrated in the Bay of Cadis, accounted for 88% of the total stock biomass, presenting an increase of 27% compared with the last year, however the 93% decrease of abundance and biomass of the West component, to 3 398 million fish and 29 876 t, was reflected in the significant decrease of the whole stock. The abundance and biomass of anchovy for the total stock and for each component since 2005 are presented in figures 2.9 and 2.10, respectively.

Anchovy abundance and biomass estimates by length composition and age group in each of the two stock areas are presented in Figures 2.11. and 2.12 respectively. The size composition of the West component population ranged between 9.5 and 17.5 cm, with a main mode at 14.5 cm. This component was composed of anchovies between 1 and 3 years, with a higher abundance of 2 years old anchovies. The size composition of the South component population ranged between 6.5 and 15.5 cm, with a bi-modal distribution with modes at 7.0 and 11.5 cm. This component was composed also of anchovies between 1 and 3 years, although largely dominated by the younger fish (1 year old).

Table 2.3. Anchovy (million fish) and biomass (tons) for the west and south components and for the whole stock in the Pelago18 and Pelago19.

Anchovy	WEST	SOUTH	TOTAL
Biomass 2018	54437	23473	77910
Biomass 2019	3937	29876	33813
Abundance 2018	4844.7	2156.6	7001.2
Abundance 2019	236.1	3398.0	3634.1

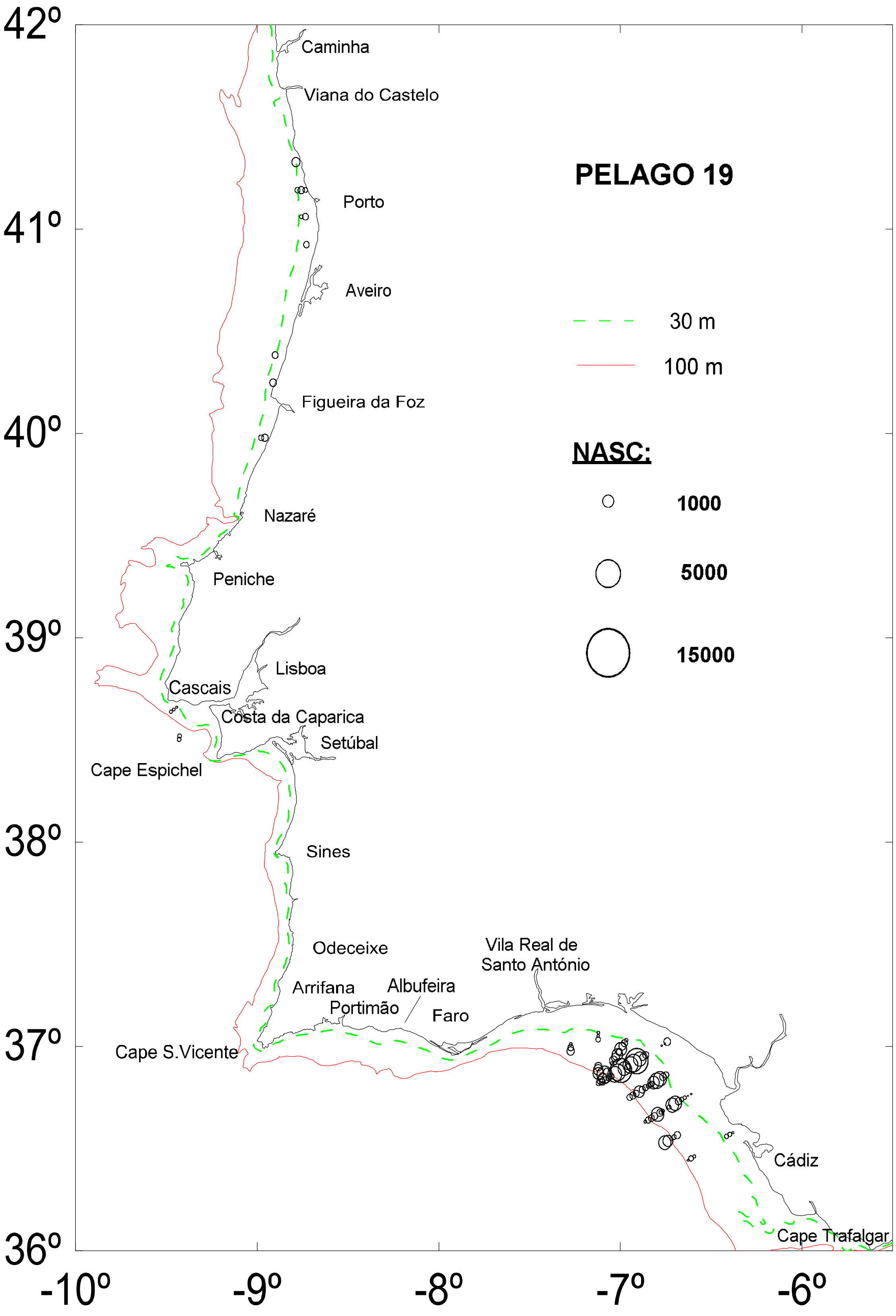
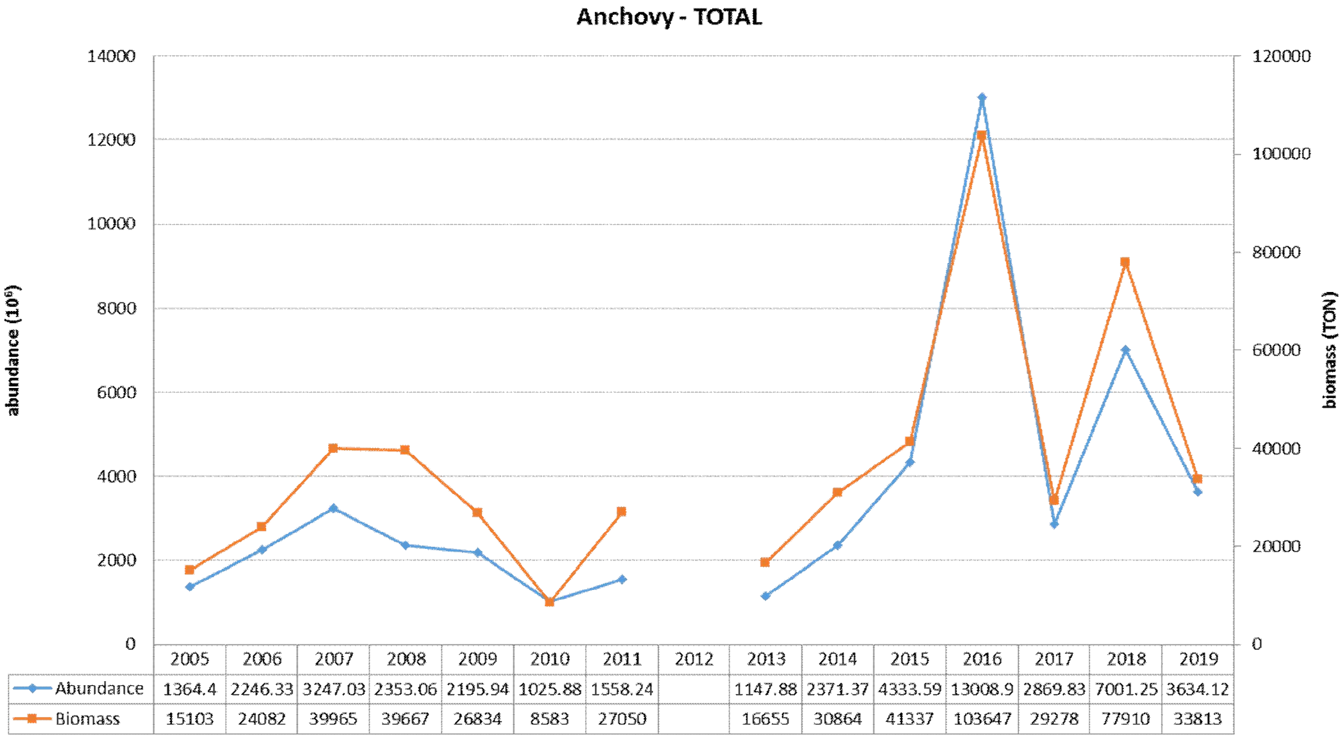


Figure 2.8 – Anchovy acoustic energy spatial distribution and size distribution. Circle area is proportional to the acoustic energy (S_A m^2/nm^2).



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Abundance	1364.4	2246.33	3247.03	2353.06	2195.94	1025.88	1558.24		1147.88	2371.37	4333.59	13008.9	2869.83	7001.25	3634.12
Biomass	15103	24082	39965	39667	26834	8583	27050		16655	30864	41337	103647	29278	77910	33813

Figure 2.9 – Anchovy total biomass and abundance evolution along the time series, since year 2005.

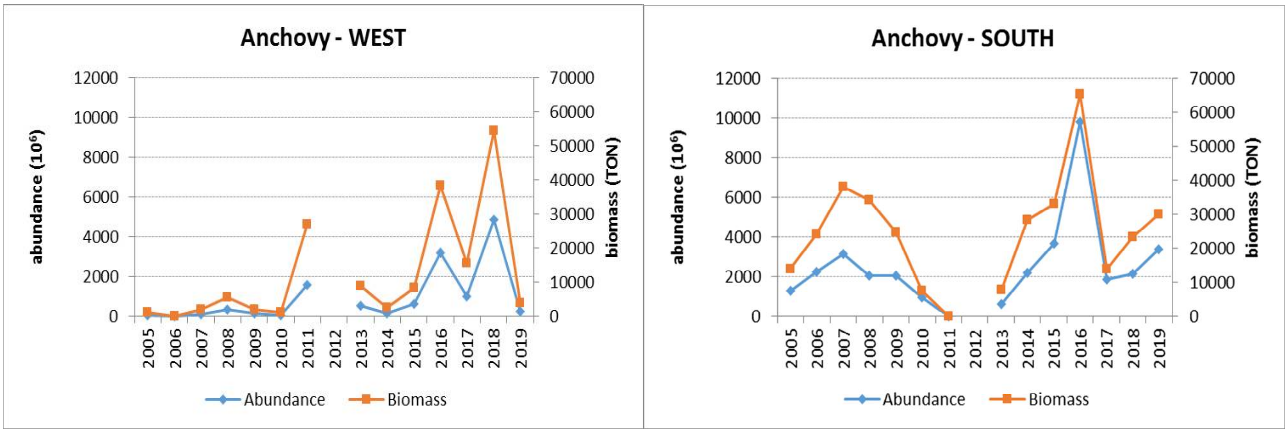


Figure 2.10 - Anchovy biomass (thousand tonnes) evolution off the West Portuguese coast and South (Algarve plus Gulf of Cadiz) coast.

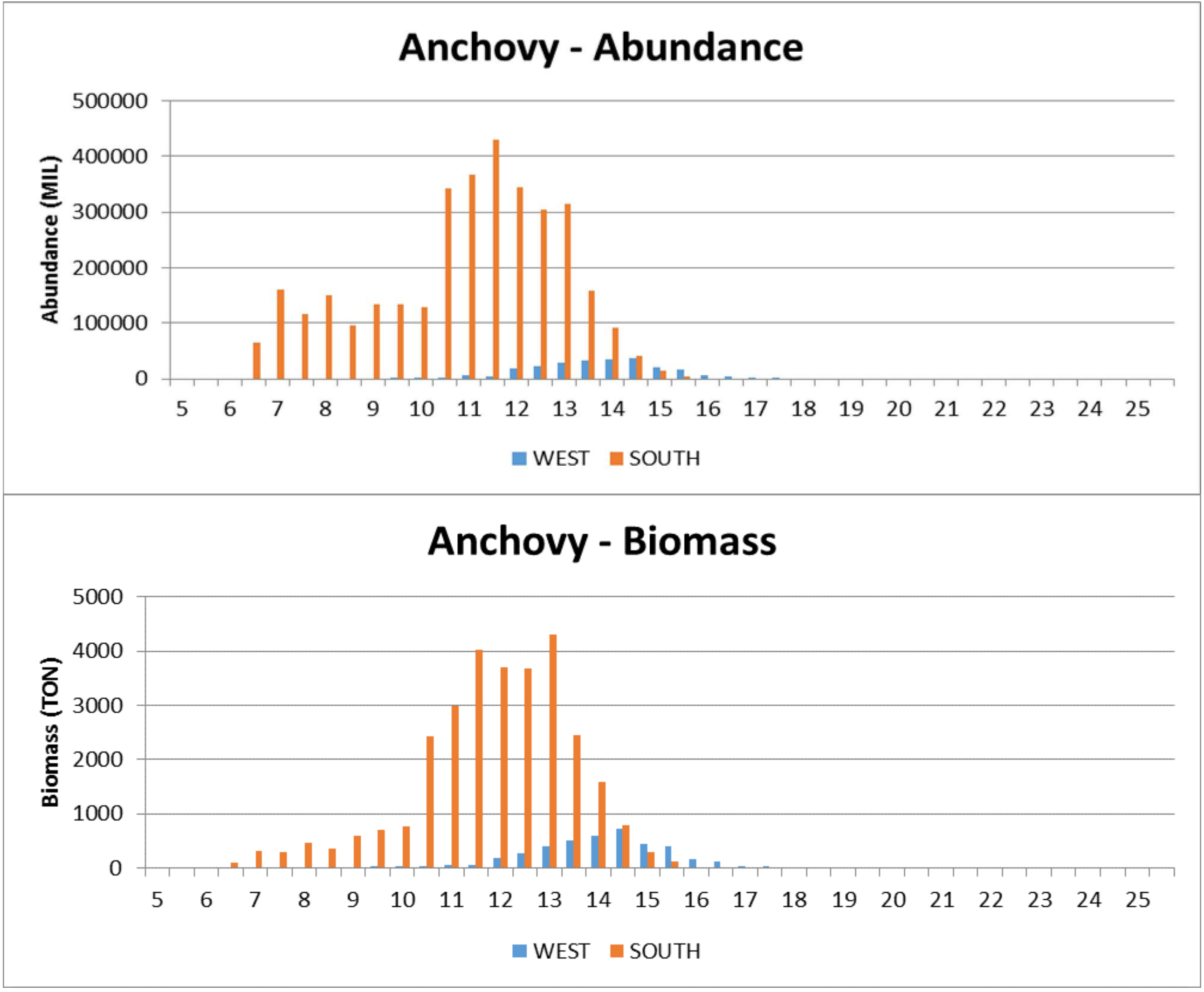


Figure 2.11 – Length composition of anchovy biomass and abundance in PELAGO19 survey, by area.

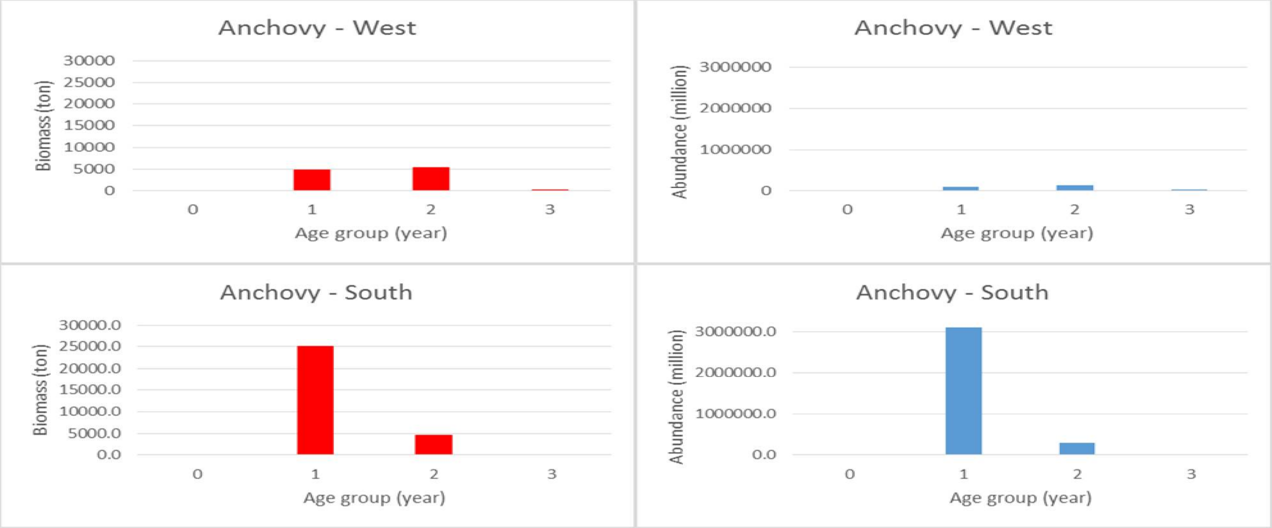


Figure 2.12 – Age distribution of anchovy biomass and abundance in PELAGO19 survey, by area.

3. Plankton and environmental surveying

Material and methods

Gear for plankton and hydrology surveying:

- CUFES: mesh size 335 µm, continuous sampling at the surface (~ 3m)
- BONGO60: two nets with 60cm mouth opening (mesh size: 200, 500µm), oblique tows through the top 60m of the water column
- BONGO90: two nets with 90cm mouth opening (mesh size: 500, 780µm), oblique tows through the whole water column
- WP2 NET: vertical sampling, 40cm mouth aperture, mesh size 55 µm
- continuous surface observations of temperature, salinity and fluorescence using onboard sensors associated to the CUFES system
- temperature, salinity and fluorescence (chlorophyll) profiles using a CTDF probe

During the day along the acoustics transects regular CUFES surveying (continuously with samples collected every 3 miles) was undertaken for zooplankton (ichthyoplankton) sampling. During the night period, when acoustics surveying was not running, sampling of opportunity was conducted, along some of the transects, using various plankton nets for different zooplankton size fractions. Surface, temperature, salinity and fluorescence observations were gathered continuously, with the sensors associated to the CUFES system, during the day, and CTDF profiles were conducted together with the night plankton surveying.

Results

Temperature, salinity and fluorescence (chlorophyll$_a$) distributions

In 2019, surveying started in mid April at the northern limit of the monitoring area and proceeded from there to the south (with an interruption in Lisbon); the southern coast was covered from west to east, where it finished around middle May. The surface temperature and salinity distribution patterns observed during the PELAGO19 survey were the regularly encountered in the region, with lower temperatures and salinities on the northern shelf which then progressively increase towards the south and to the east, in the southern coast (figure 3.1). The sea surface temperature in 2019 was slightly higher than during the same period in 2018 (13ºC- 20.7ºC) in particular in the southern shores (15.2ºC- 20.7ºC). The first half of the survey was carried out during quite unstable weather conditions with some showery periods and strong winds, mainly from N-NW, consequentely in some very coastal areas of the NW shelf lens of less saline water were noticeable and off Cape of Roca the SST map captured a filament of upwelled (colder) water. IPMAs climatologic bulletin reported that April 2019 was normal with respect to the atmospheric temperature but wetter than the average, though not as wet as the same period in 2018. Conversely, May was very dry and the temperatures were above average. The onset of the spring primary production bloom was perceptible by the higher fluorescence values in the coastal regions where the nutrient enrichement, from continental origins and/or from upwelled waters, together with the warming up of the surface layers favoured phytoplankton growth (figure 3.1).

Fish Egg distribution

Zooplankton samples were collected with the CUFES system as usual during acoustics surveying, a summary of the information gathered is presented in Table 1.1. A total of 557 CUFES samples were collected along the 71 regular transects of the acoustics survey grid (Table 1.1 and figures 3.2 and 3.3). The egg abundances for anchovy and sardine decreased from 2018 to 2019 however, the densities were still higher for anchovy than for sardine has it has happened in the more recent years. The number of anchovy eggs collected was lower in the whole surveyed area showing a total abundance decrease from 2018 (when the record value of the historic series was reached) to 2019 of around 68%. Nonetheless, the abundance in the NW region was still higher than in 2017 representing the second highest of the time series. Anchovy eggs were present in 46% of the CUFES samples and represented 71% of the all fish eggs collected. Sardine eggs were observed in a slightly higher number of CUFES samples, in around 48%, but in much lower abundances, accounting for 54% of the total eggs sorted and revealing a decrease of about 38% from 2018 to 2019. Sardine egg abundances were, during the PELAGO19, lower in the NW and Cadiz Bay regions but higher off Alentejo coast and Algarve. These observations are in agreement with the data of the acoustics surveying which identified a higher number of sardine schools in these areas in 2019 than in 2018. Acoustic energy assigned to anchovy and egg distribution for the species were fairly well matched in space. Nonetheless, in the more northern region, close to the border to Galicia, high number of eggs for both, anchovy and sardine, were observed but schools for the species were not identified in the echograms. Clupeiform larvae abundance spots (figure 3.5) were observed in this region in the NW shelf, in the area off Tagus-Ericeira and in the Cadiz Bay.

Mesozooplankton biomass distribution

During the night period, when acoustic surveying was not taking place, plankton sampling with nets, and CTD casts, were conducted in some of the transects, taken opportunistically in function of the planning in the acoustics work. Figure 3.6 show the transects completed during the night sampling and the number of samples obtained with the different gear (Bongo60, Bongo90, WP2 and CTD). Plankton volumes obtained with the Bongo60 (top 50m of the water column, mesh sizes 200µm) are mapped in figure 3.7. Larger zooplankton biomass was observed over the NW coast, to the north of Cape Mondego, and in some coastal stations of the SW (between river Sado and river Mira), in the Algarve and in Cadiz Bay, around the Huelva region and off Cape Trafalgar, on the far eastern transect.

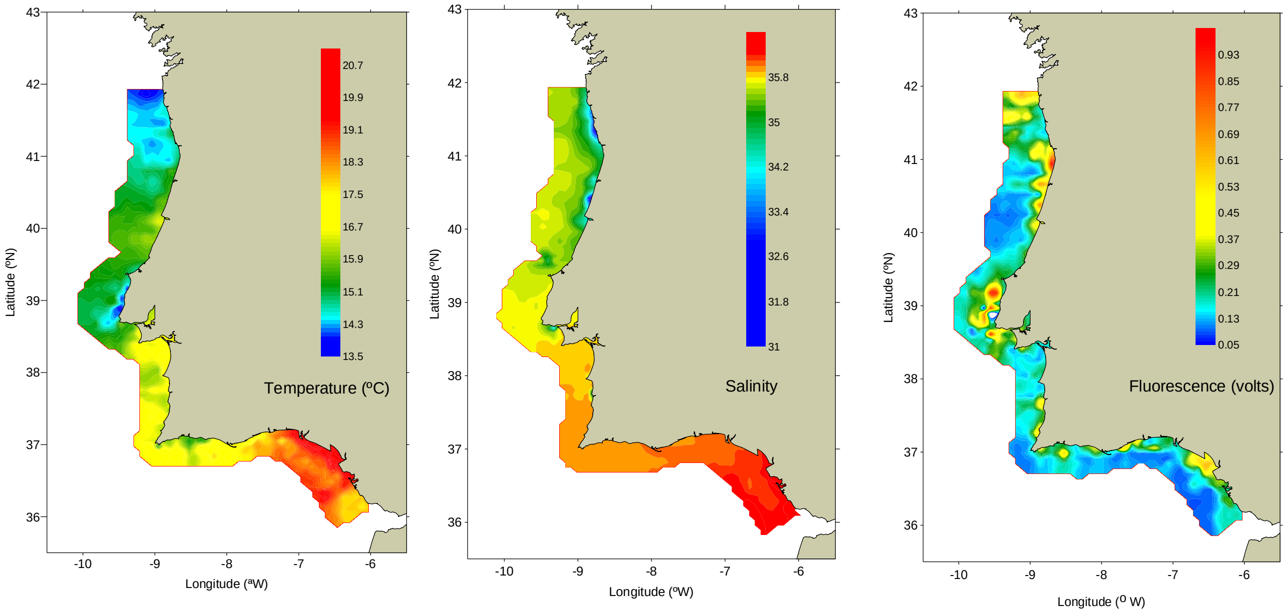


Figure 3.1 – Distributions of surface, temperature (left panel), salinity (central panel) and fluorescence (right panel).

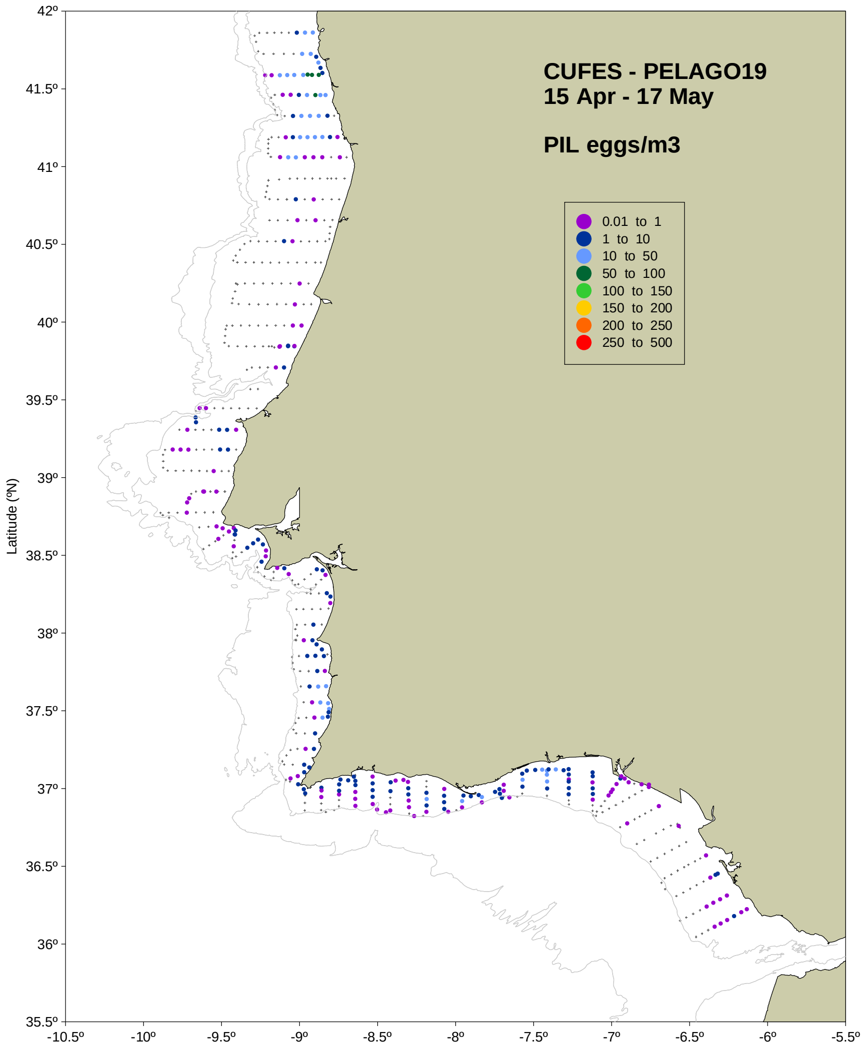


Figure 3.2 - Sardine egg abundance distribution (eggs/m^2) obtained from CUFES samples.

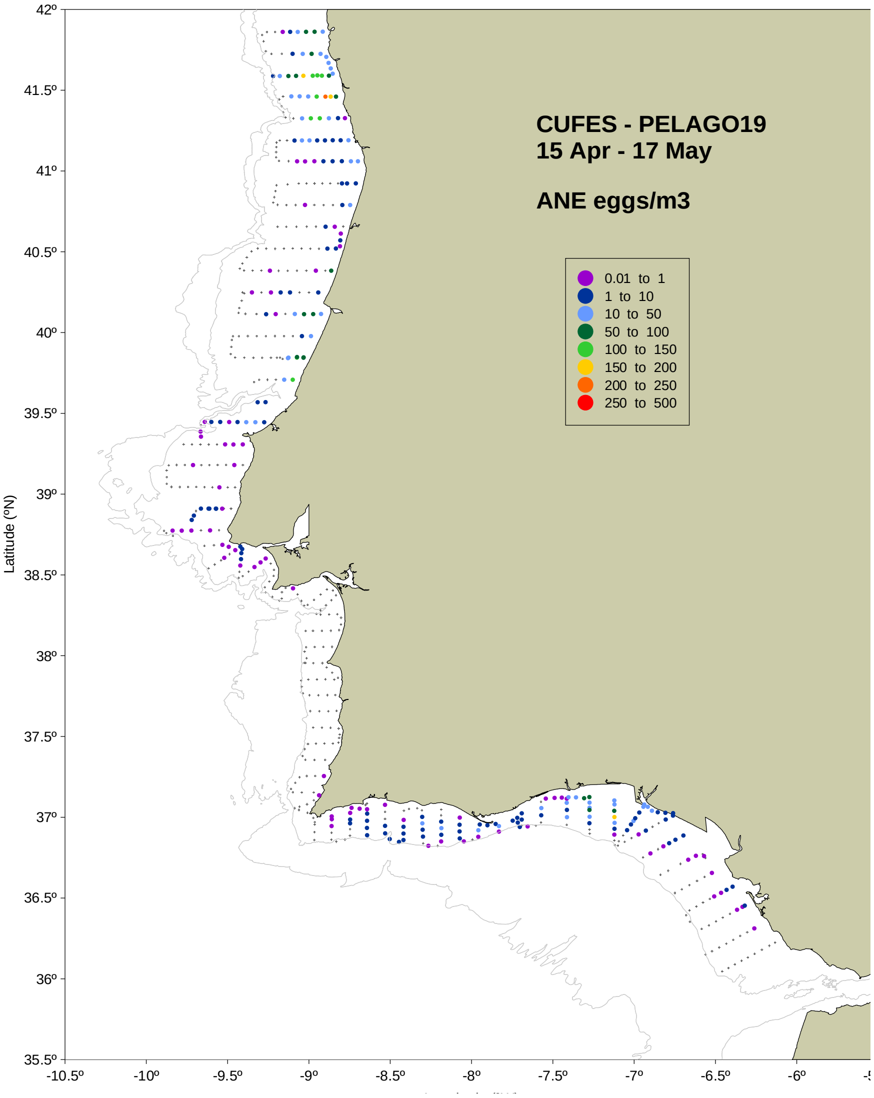


Figure 3.3 - Anchovy egg abundance distribution (eggs/m^2) obtained from CUFES samples.

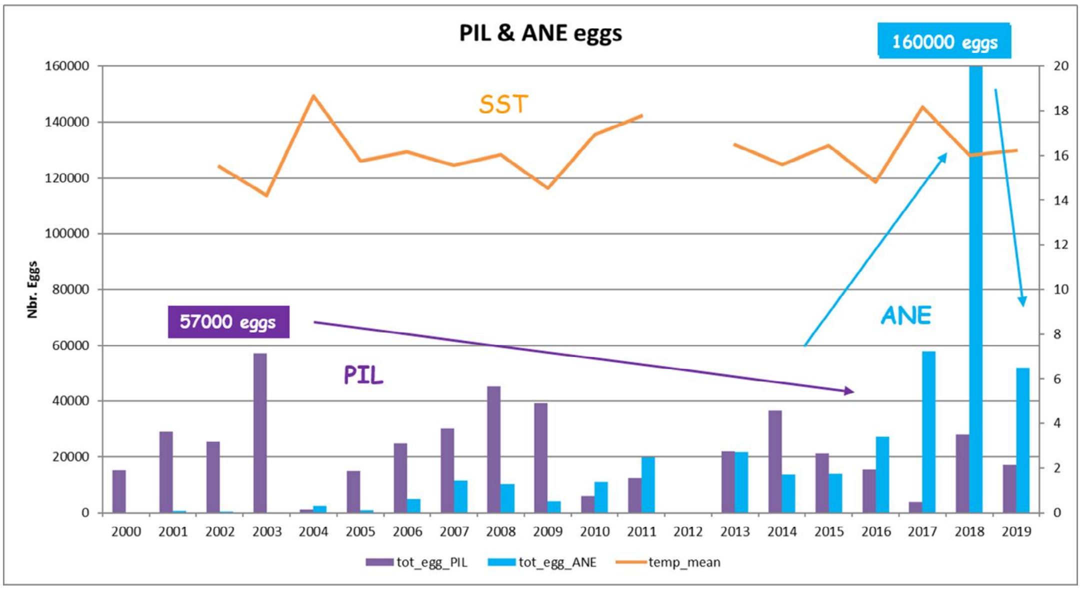


Figure 3.4 - Sardine and anchovy total egg abundance in the CUFES samples during the PELAGO series (2000-2019). The orange curve represents mean surface temperature during the surveys in each year.

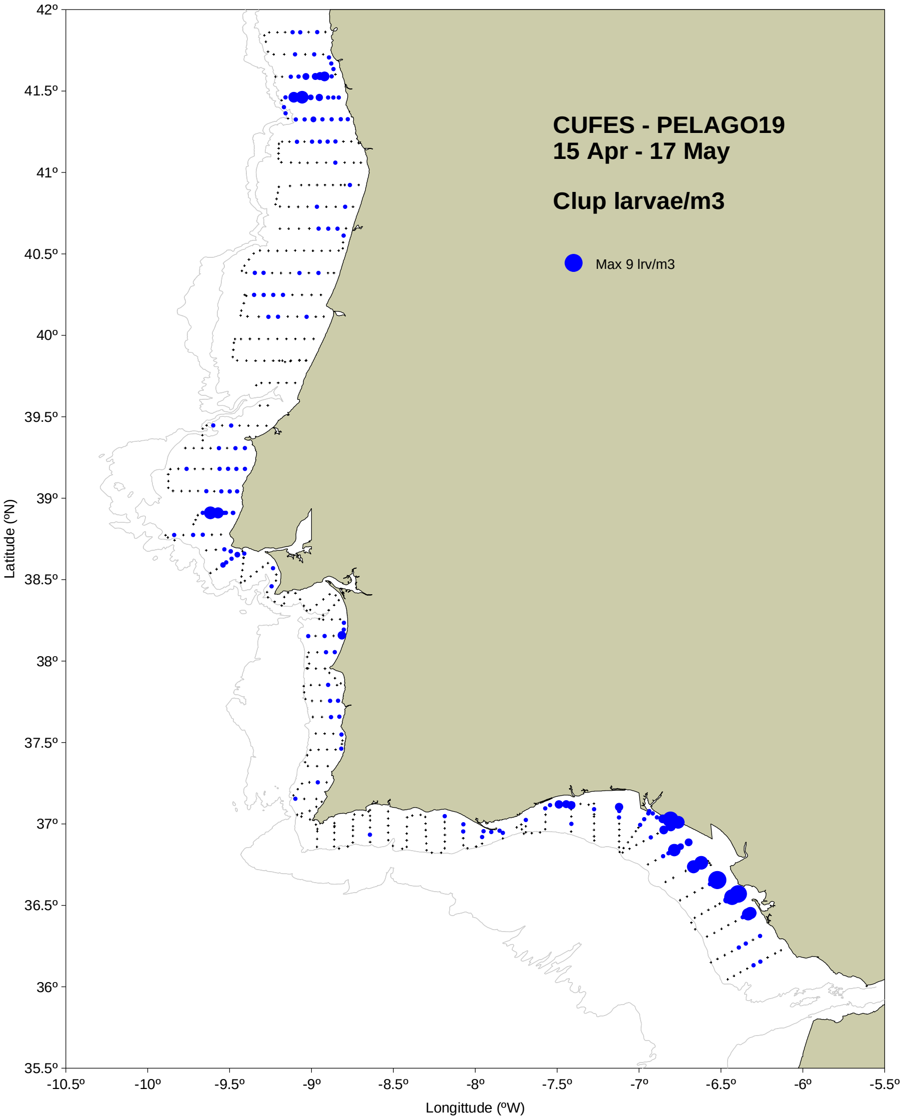


Figure 3.5 - Clupeiform larvae distribution (lrv/m^3) obtained from CUFES samples.

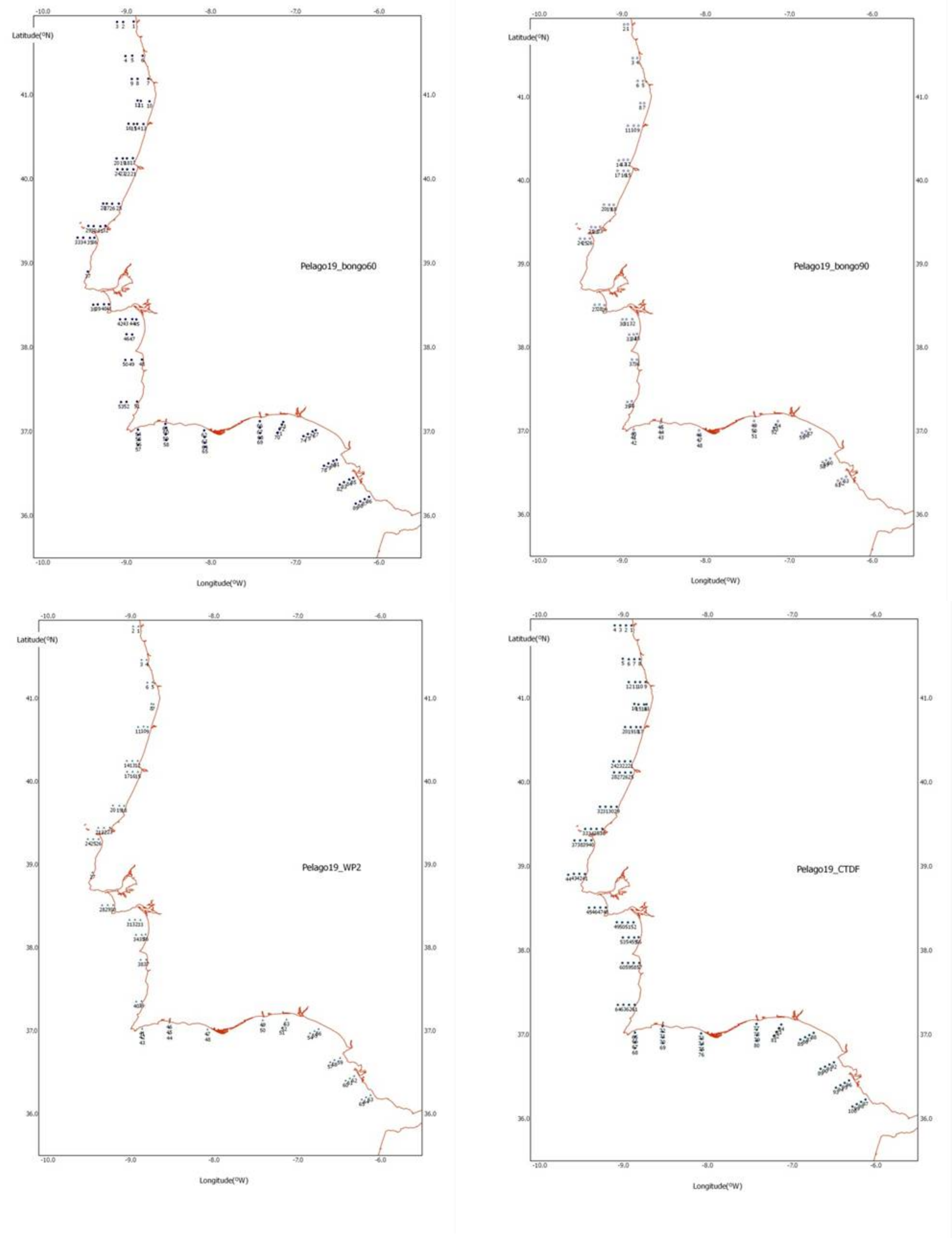


Figure 3.6 - Plankton and CTD stations occupied during the night period. Top left, Bongo60 net (60cm ø, 200µm, 500µm mesh sizes); Top right, Bongo90 net (60cm ø, 500µm, 780µm mesh sizes); bottom left, WP2_40 (40cm ø, 55µm mesh size) and botto right, CTD casts.

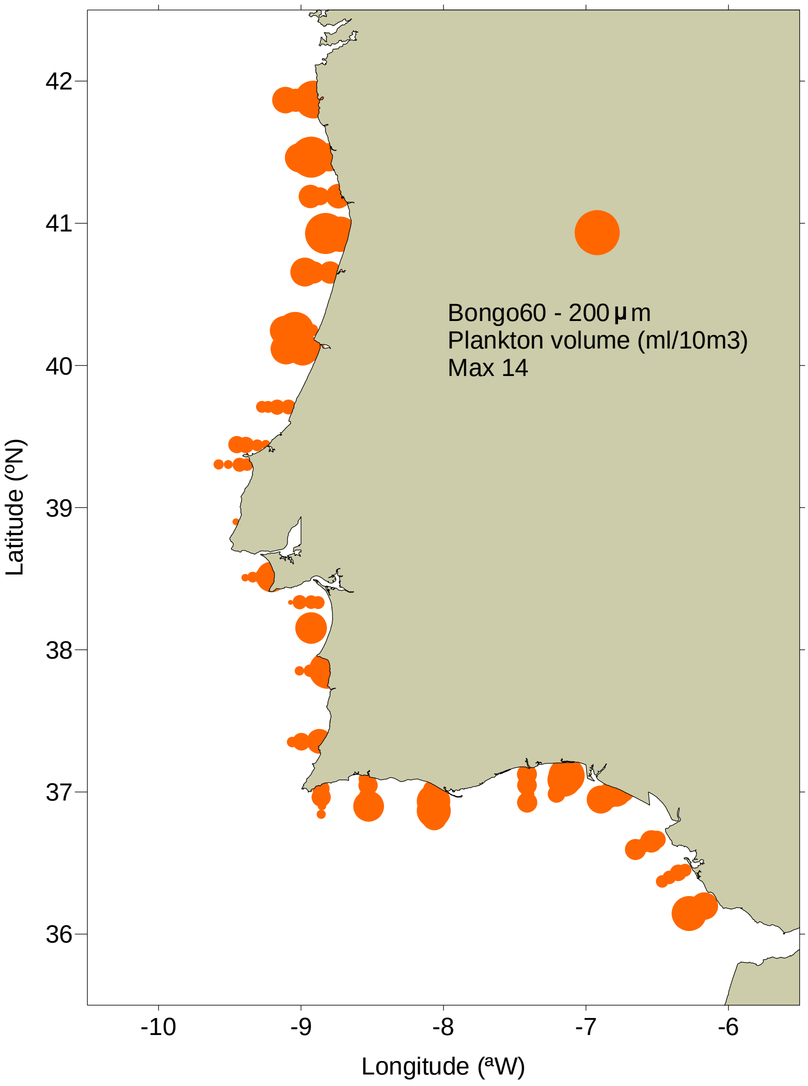


Figure 3.7 - Plankton volumes (ml/10m^3), integration of the water column from 50m depth upwards, obtained with the, 200µm mesh size, Bongo60 (60cm ø) net.

4. Marine bird and mammal census with ESAS methodology

Methodology

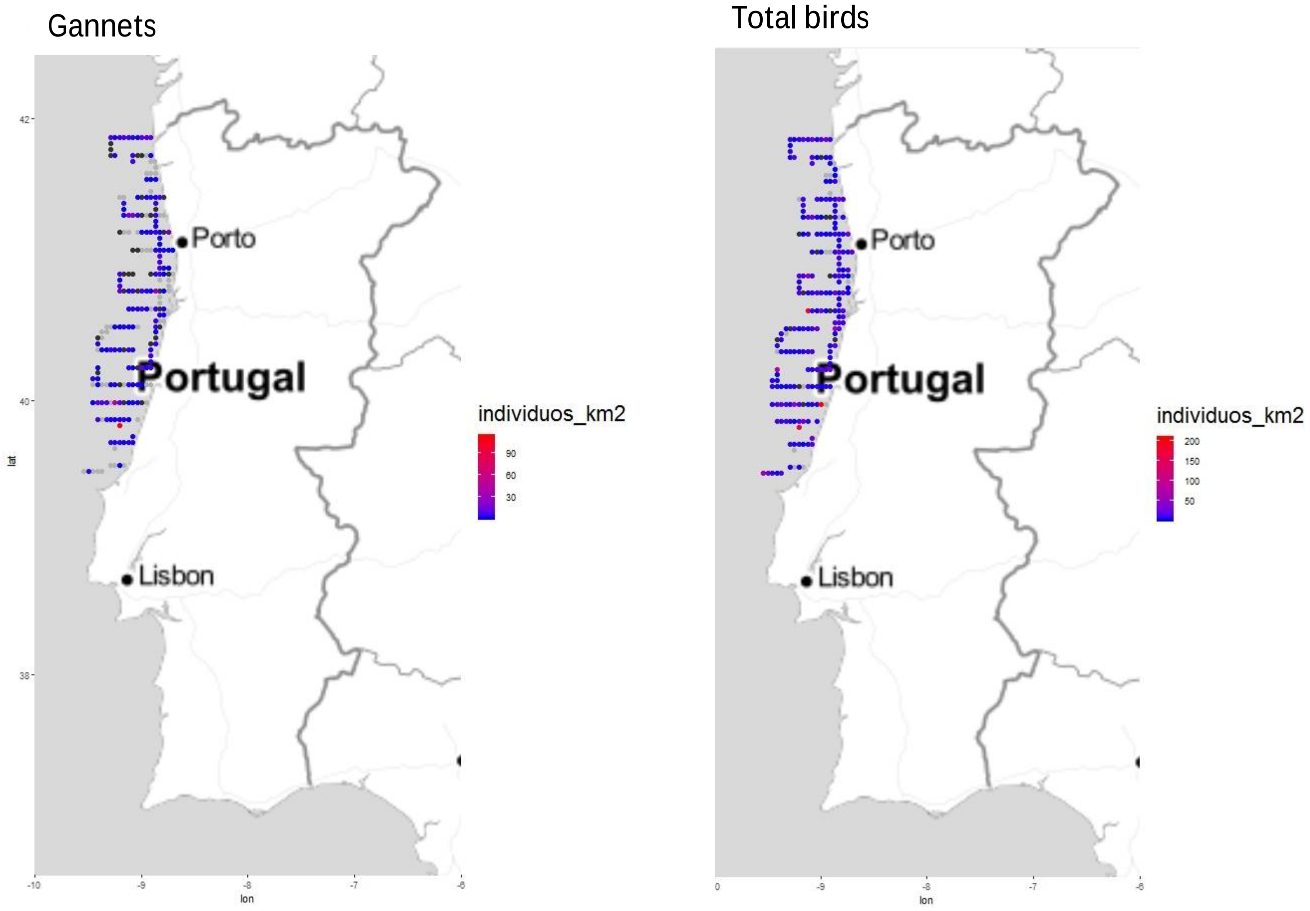
The censuses were performed based on the ESAS methodology (*European Seabirds At Sea;* Tasker et al. 1984) only from 14 to 22 of April of 2019 . All birds in contact with water within a 300 m wide transect were counted to one of the vessel's edges. All birds in flight were counted using the "*snap- shot"* method . Counts were grouped into 5-minute periods. Marine mammals were also counted. All observations were grouped in a spatial grid, with a 4x4km grid. Inside and outside transect counts were used to assess species distribution, but only individuals counted within the transect were used to calculate observed densities (presented as number of individuals/km^2). The analyzes included 4 groups, 1) The northern gannet (*Morus bassanus,* the most common bird species in this census), 2) the total number of birds (including all seabird species, 3) the common dolphin *Delphinus delphis* (the most common mammal of this census) and 4) the total of marine mammals.

Results

Seabirds were observed in all transects performed during the Pelago19 survey, of 16 different species. The highest bird densities were observed between Aveiro and Nazaré. *Morus bassanus* was observed in practically the whole studied area, with greater expression in the area between Figueira da Foz and Nazaré. Marine mammals, mostly common dolphins, were also mainly observed in this area, in a total of three different species (Table 4.1 and figures 4.1 and 4.2).

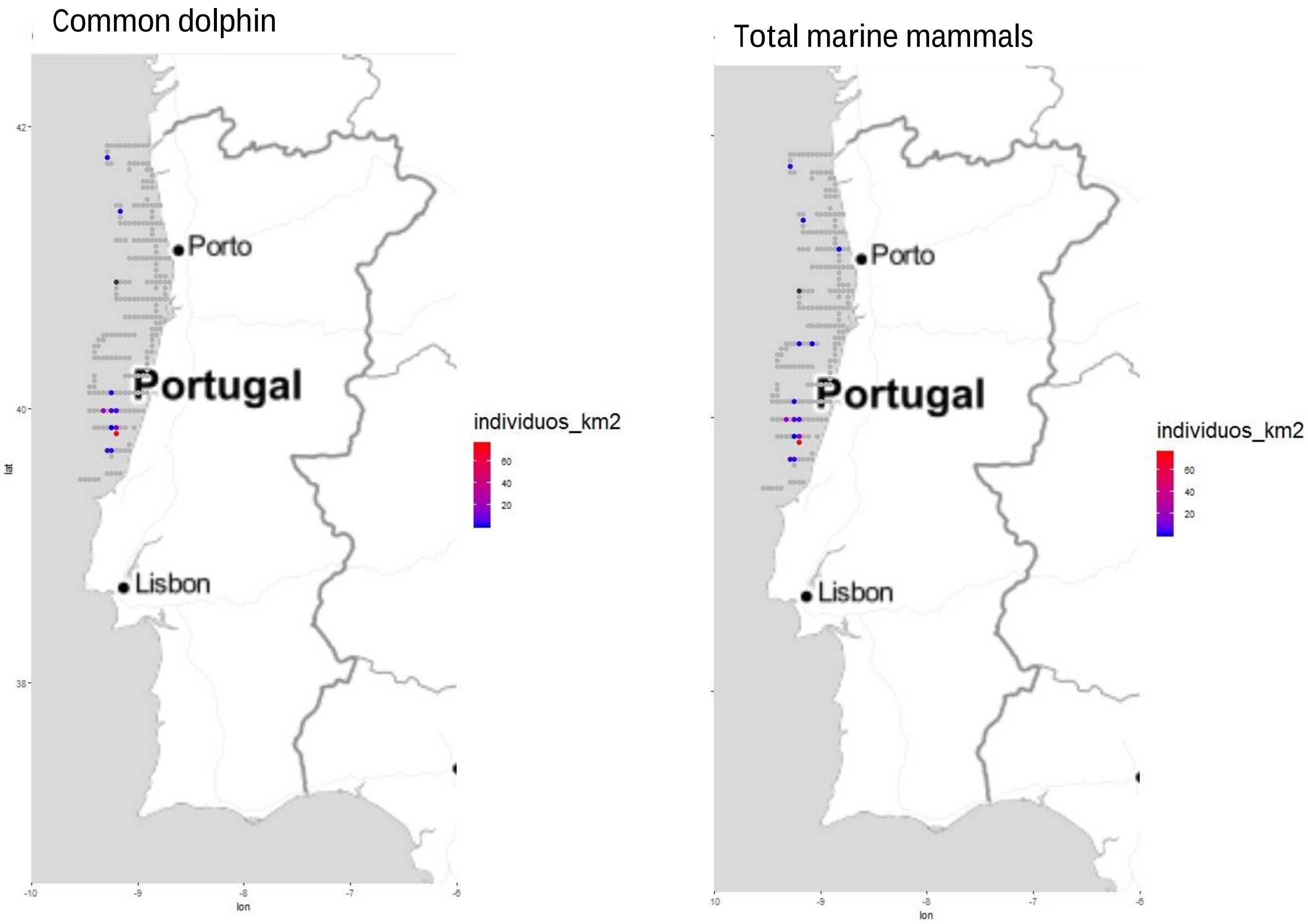
Table 4.1. Observed densities (indiv/km^2) of gannets, total birds, common dolphin and total marine mammals during the Pelago19 survey. The total number of individuals counted within the transect for each species/group is also presented.

	Mean	SD	Max	Min	Total
Gannets	2.60	8.69	113.34	0	489
Total birds	9.42	23.67	206.01	0	1935
Common dolphin	0.59	5.35	75.56	0	62
Total marine mammals	0.61	5.35	75.56	0	68


Gannets

Total birds

Figure 4.1. Distribution and abundance of gannets (left panel) and total birds (right panel).



Common dolphin

Total marine mammals

Figure 4.2. Distribution and abundance of common dolphins (left panel) and total mammals (right panel).

References

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.

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.

Checkley, D. M. Jr; P. B. Ortner; L. R. Settle and S. R. Cummings. 1997. A continuous, underway, fish egg sampler. *Fisheries Oceanography* 6 (2): 58-73.

Foote, K. G., Knudsen, H. P., Vestnes, G., Brede, R., Nielsen, R. L., 1981. Improved Calibration of Hydroacoustic Equipment with Copper Sphere. *ICES, CM* 1981/B:20, 18p.

Tasker, M. L., P. Hope Jones, T. Dixon, & B. F. Blake. 1984. Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. Auk 101:567-577.

Weill, A., Scalabrin, C. and Diner, N., 1993. MOVIESB: An acoustic detection description software. Application to shoal species classification. *Aquatic Living Resources* 6: 255-267.

Working Document for ***WGACEGG & WGHANSA***
Madrid, 18-22 and 25-28 november 2019

Direct assessment of small pelagic fish by the PELGAS19 acoustic survey

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1. MATERIAL AND METHOD

1.1. PELGAS survey on board Thalassa

An acoustic survey (PELGAS) is carried out every year in the Bay of Biscay in spring onboard the French research vessel Thalassa. The objective of PELGAS survey is to study the abundance and distribution of pelagic fish in the Bay of Biscay. The main target species are anchovy and sardine but they are considered in a multi-specific context and within an ecosystemic approach as they are located in the centre of pelagic ecosystem.

This survey is connected with IFREMER programs on data collection for monitoring and management of fisheries and ecosystemic approach for fisheries. This task is formally included in the first priorities defined by the Commission regulation EU N° 199/2008 of 06 November 2008 establishing the minimum and extended Community programmes for the collection of data in the fisheries sector and laying down detailed rules for the application of Council Regulation (EC) No 1543/2000. This survey must be considered in the frame of the Ifremer fisheries ecology action "resources variability" which is the French contribution to the international Globec programme. It is planned with Spain and Portugal in order to have most of the potential area covered from Gibraltar to Brest with the same protocol regarding sampling strategy. Data are available for the ICES working groups WGHANSA, WGWIDE and WGACEGG.

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

- Continuous acquisition of acoustic data with two different echosounders, pumping sea-water under the surface in order to evaluate the number of fish eggs using a CUFES system (Continuous Under-water Fish Eggs Sampler) and a visual counting and identification of cetaceans and birds (from board) carried out in order to characterise the higher level predators of the pelagic ecosystem.
- Discrete sampling at stations (by pelagic trawls, plankton nets, CTD).

Satellite imagery (temperature and sea colour) and modelling have been also used before and during the survey to recognise the main physical and biological structures and to improve the sampling strategy.

The strategy this year was the identical to previous surveys (since 2000). The survey protocols are described *in Doray M, Badts V, Masse J, Duhamel E, Huret M, Doremus G, Petitgas P (2014).* ***Manual of fisheries survey protocols. PELGAS surveys (PELagiques GAScogne)****. http://dx.doi.org/10.13155/30259:*

Biomass and abundance at length of small pelagic fish during the PELGAS survey has been published in SEANOE: *.Doray Mathieu, Duhamel Erwan, Sanchez Florence, Grellier Patrick, Pennors Laurence, Petitgas Pierre (2018). Biomass and abundance at length of small pelagic fish estimated during the PELGAS survey in the Bay of Biscay in springtime . SEANOE .* http://doi.org/10.17882/53388

- acoustic data were collected along systematic parallel transects perpendicular to the French coast (figure 1.1.1). The length of the ESDU (Elementary Sampling Distance Unit) was 1 nautical mile and the transects were uniformly spaced by 12 nautical miles and cover the continental shelf from 20 m depth to the shelf break (or sometimes more offshore – see figure below).

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

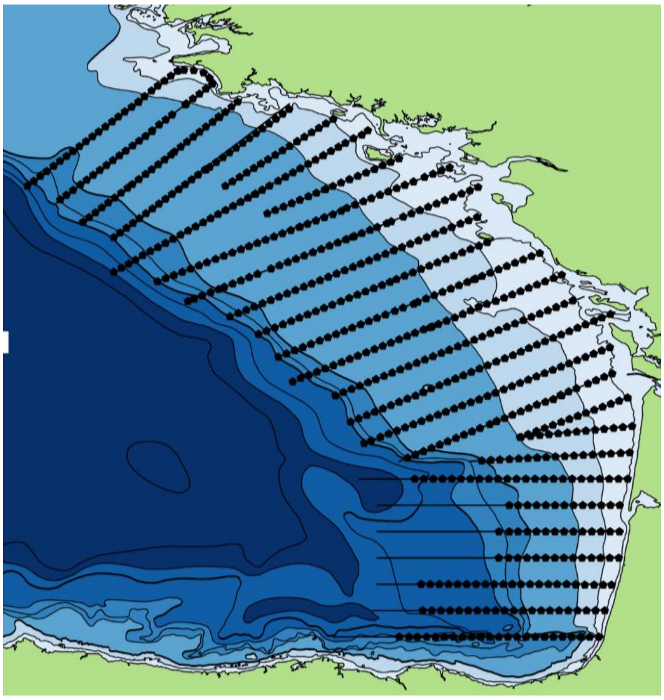


Fig. 1.1.1 - Transects prospected during PELGAS19 by Thalassa.

In 2019, as in previous surveys (since 2009), three modes of acoustic observations were used:

- 1 SIMRAD ME70 multi-beam echo-sounder (21 2 to 7°beams, from 70 to 120 kHz) used essentially for visualisation and observing the behaviour and shapes of fish schools during the whole survey. Nevertheless, only echoes stored on the vertical echo-sounder were used for abundance index calculation.
- 1 horizontal echo-sounder on the starboard side for surface echo-traces
- this year, the broadband echosounder EK80 was installed and used

Energies and samples provided by all sounders were simultaneously visualised and stored using the MOVIES3D software and stored at the same standard HAC format.

The calibration method was the same that the one described for the previous years (see WD 2001) and was performed at anchorage near Brest, in the West of Brittany, in good meteorological conditions at the end of the survey. The calibration was not done before, according to the bad weather at the beginning of the survey.

Acoustic data were collected by R/V Thalassa along a total amount of 4855 nautical miles from which 1857 nautical miles on one way transect were used for assessment. A total of 23 442 fishes were measured (including 8644 anchovies and 3765 sardines) and 2 968 otoliths were collected for age determination (1 860 of anchovy and 1 108 of sardine).

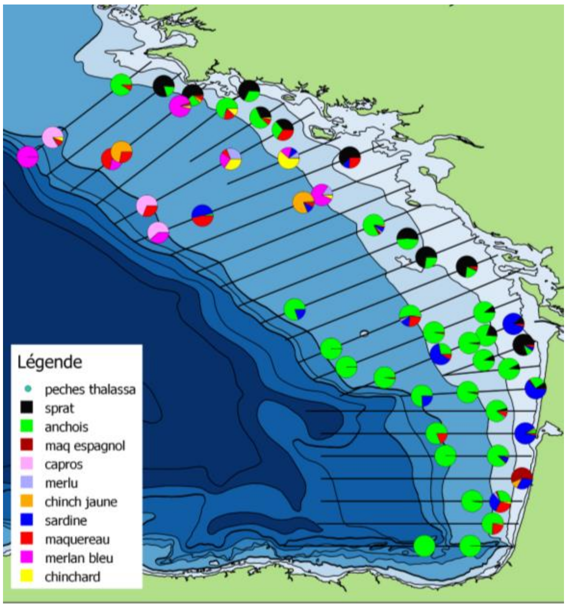


Fig. 1.1.2: Species distribution according to Thalassa identification hauls.

1.2. The consort survey

A consort survey is routinely organised since 2007 with French commercial vessels during 17 days. This approach is in identical to last year's surveys, using the commercial vessel's hauls were for echoes identification and biological parameters to complement hauls made by the R/V Thalassa.

Four commercial vessels (two pairs of pelagic trawlers) participated to PELGAS19 survey:

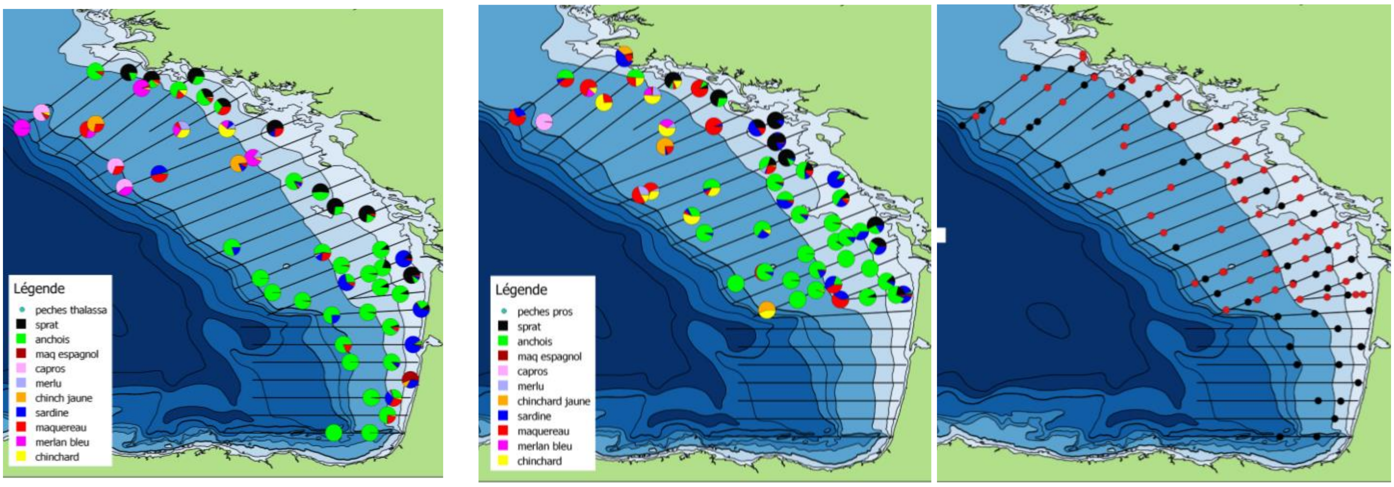
Vessel	Gear	Period	Days at sea
Carla Eglantine/ El Amenacer	Pelagic pair trawl	03/05 to 12/05/2019	9
Zephyr / Aquilon	Pelagic pair trawl	14/05 to 24/05/2019	10

The regular transects network agreed for several years for Thalassa is 12 miles separated in parallel transects. Commercial vessels worked on these standard transects , . Sometimes, they carried out fishing operations on request. Their pelagic trawl was up to 25 m vertical opening and the mesh of their codend was similar to the on uses by the R/V Thalassa (12 mm).

A scientific observer was on board the commercial vessel to control every fishing operation, and to collect biological data. The fishing operations were systematically agreed after a radio contact with Thalassa in order to confirm their usefulness. In some occasions, these fishing operation were used to check the spatial extension of species already observed and identified by Thalassa (and therefore the spatial distribution); in others the objective was to enlarge the vertical distribution description by stratified catches. Globally, a great attention was given on a good distribution of samples to avoid over-sampling on some situations. Regularly a biological sample was provided by the commercial vessels to Thalassa to improve otoliths collection and sexual maturity (390 otoliths of anchovy, 485 of sardine). A total of 7753 fishes were measured onboard commercial vessels, including 2754 anchovies and 1736 sardines.

Catches and biological data were used to complement the sampling made on board the R/V Thalassa.

A total of 108 hauls (including 4 not valid) were carried out during the consort survey including 52 hauls by the R/V Thalassa and 56 hauls by commercial vessels.



a) Thalassa (nb :52)

b) Commercial vessels (nb : 56)

c) all fishing hauls (nb :108) Thalassa in black and commercial in red

Figure 1.2.2 : fishing operations carried out by Thalassa and commercial vessels during consort survey PELGAS19

The collaboration between Thalassa and commercial vessels was excellent. It was once more a very good opportunity to 1) explain our methodology to the fishermen and 2) check consistency between scientists and fishermen echo-trace's observation and interpretations. Some fishing operations were done in parallel by Thalassa and commercial vessel in order to check catches' similarity (in proportion of species and, most of the time, in quantity as well - taking the vertical and horizontal opening into account). As last year, commercial vessels' fishing operations were only carried out at day time (as for Thalassa) each time it was necessary.

Table 1.2.3. : Number of fishing operations carried out by Thalassa and commercial vessels during consort survey PELGAS19

	CLAS	SURF	total
thalassa	35	17	52
commercial	34	22	56
total	69	39	108

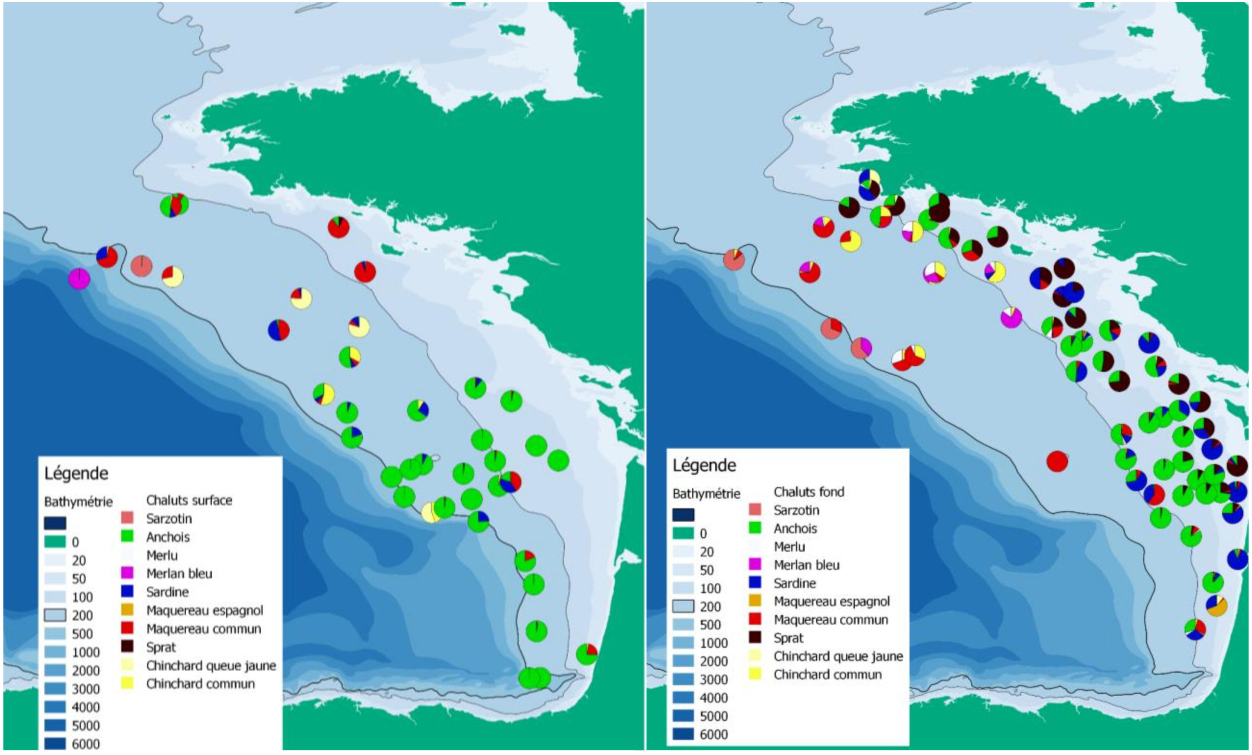


Figure 1.2.4 : Vertical localisation of fishing operations carried out by Thalassa and commercial vessels and species composition during PELGAS19 survey (left : surface ; right : classic

2. ACOUSTICS DATA PROCESSING

2.1. Echo-traces classification

All the acoustic data along the transects were processed and scrutinised by the date of the meeting. Acoustic energies (Sa) have been cleaned by sorting only fish energies (excluding bottom echoes, parasites, plankton, bubbles etc.) and classified into 6 categories of echo-traces this year:

D1 – energies attributed to mackerel, chub mackerel, horse mackerel, Mediterranean horse mackerel blue whiting, hake, corresponding to cloudy schools or layers (sometimes small dispersed points) close to the bottom or of small drops in a 10m height layer close to the bottom.

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

D3 – energies attributed to scattered detection corresponding to blue whiting, myctophids, boarfish, mackerel, chub mackerel, horse mackerel, mediterranean horse mackerel, and hake.

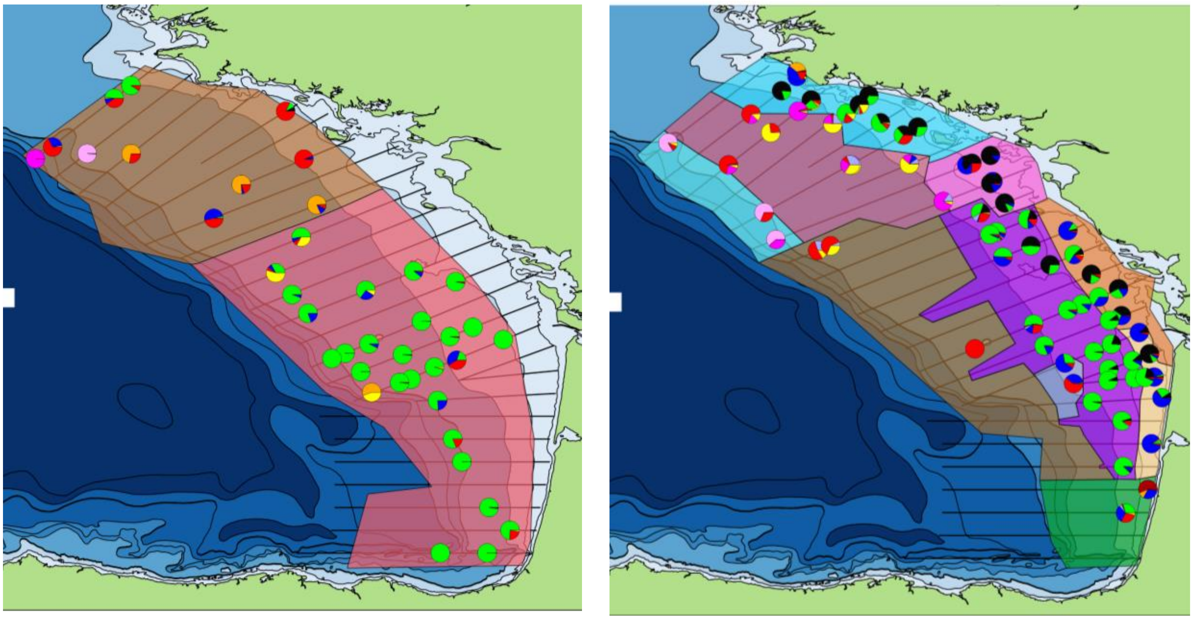
D4 – energies attributed to sardine, mackerel and anchovy corresponding to echoes very close to the surface. This year, horse mackerel and even boarfish were also allocated in this category

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

D9 – energies attributed exclusively to anchovy.

2.2. Splitting of energies into species

As for previous years (except in 2003, see WD-2003), the global area has been split into several strata where coherent communities were observed (species associations) in order to minimise the variability due to different species assemblages. Figure 2.2 shows the strata considered to evaluate biomass of each species. For each stratum, energies where converted into biomass by applying catch ratio, length distributions and weighted by abundance of fish in the haul surrounded area.



Coherent surface strata

Coherent classic strata

Fig. 2.2 – Coherent strata (classic and surface), in terms of echoes and species distribution, taken into consideration for multi-species biomass estimate from acoustic and catches data during PELGAS19 survey.

2.3. Biomass estimates

The fishing strategy has been followed all along the survey in order to benefit of each vessel's efficiency and maximise the number of samples (in term of identification and biological parameters). Therefore, the commercial vessels carried out mostly surface hauls when Thalassa fished preferably in the bottom layer. According to previous strata (Figure 2.2), using both Thalassa and consort fishing operations, biomass estimates were calculated for each main pelagic species in the surveyed area.

Biomass indices are presented in tables 2.3.1 and 2.3.2 and in figure 2.3.1. No estimate is provided for mackerel according to the low level of TS and particular behaviour in the Bay of Biscay where it is scattered and mixed with plankton echoes.

Anchovy was as abundant as last year and their abundance was estimated this year at a high level compared to the historical time series (around 183 000 tonnes). Strong densities were observed in the Gironde area. It must be noticed that we observed anchovy on every transects from the Spanish coast untill the North West of the Bay on Biscay.

Sardine was also present this year compared as the same level of las year, mainly in coastal waters. It must be noticed that this year, no sardine at all were detected along the shelfbreak.

Even the densities were not that important, the presence at the surface of a mix sardine/anchovy/horse mackerel on the middle part of the Northern part of the bay (the great mud bank) must be noticeable, even in lower quantity than last year.

About other species, another characteristic of this year was that horse mackerel showed a decrease of the biomass again, after 3 years of increasing and one of decreasing. The biomass reached again a medium level compared to the abundance calculated in recent years, but far away of the biomasses calculated at the beginning of the serie. Mackerel appeared abundant this year, particularly in the middle of the bay of Biscay, and scattered close to the bottom in the Northern part.

The Mediterranean horse mackerel (*Trachurus mediterraneus*) was present more or less exclusively in the Northern part of the bay of Biscay, particularly closed to the surface on the great mud bank.

Blue whiting was more or less absent from the bay of Biscay during Pelgas19

Table 2.3.1. Acoustic biomass index for the main species by strata during PELGAS19

	Classic	Surface	total
boarfish	5 873	8 265	14 137
anchovy	**129 660**	**53 505**	**183 166**
hake	37 828	654	38 482
blue whiting	12 287		12 287
sardine	**309 418**	**19 324**	**328 741**
chub mackerel	15 514	240	15 754
mackerel	629 952	16 537	646 488
sprat	108 663	3 288	111 951
Med horse mackerel	2 509	68 283	70 792
horse mackerel	45 643	6 458	52 101

Table 2.3.2. Acoustic biomass index for the five main pelagic species since the beginning of PELGAS surveys (2000)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
anchovy	113 120	105 801	110 566	30 632	45 965	14 643	30 877	40 876	37 574	34 855	86 354	142 601	186 865	93 854	125 427	372 916	89 727	134 500	185 524	183 166
CV anchovy	0.064	0.141	0.113	0.132	0.167	0.171	0.136	0.100	0.162	0.112	0.147	0.0774	0.04665	0.1282	0.062928	0.073551	0.13	0.154339	0.0699	0.0533063
Sardine	376 442	383 515	563 880	111 234	496 371	435 287	234 128	126 237	460 727	479 684	457 081	338 468	205 627	407 740	339 607	416 524	229 742	465 022	265 504	328 741
CV sardine	0.083	0.117	0.088	0.241	0.121	0.135	0.117	0.159	0.139	0.098	0.091	0.0699	0.07668	0.0738	0.065212	0.102315	0.08	0.060653	0.0620727	0.05383762
Sprat	30 034	137 908	77 812	23 994	15 807	72 684	30 009	17 312	50 092	112 497	67 046	34 726	6 417	44 651	33 894	91 248	36 593	15 778	16 321	111 951
CV sprat	0.098	0.155	0.120	0.198	0.178	0.228	0.162	0.132	0.268	0.108	0.108			0.1992	0.241009	0.19534	0.44	0.52701	0.5879399	0.1181859
Horse mackere	230 530	149 053	191 258	198 528	186 046	181 448	156 300	45 098	100 406	56 593	11 662	61 237	7 435	33 471	53 154	77 142	119 230	61 919	93 728	52 101
CV HM	0.079	0.204	0.156	0.137	0.287	0.160	0.316	0.065	0.455	0.09	0.188			0.3007	0.227089	0.15498	0.3	0.288318	0.1443578	0.18583827
Blue Whiting	-	-	35 518	1 953	12 267	26 099	1 766	3 545	576	4 333	48 141	11 823	68 533	25 715	25 015	8 684	11 852	23 944	3 585	12 287
CV BW	-	-	0.386	0.131	0.202	0.593	0.210	0.147	0.253	0.219	0.074			0.1542	0.337606	0.223479	0.15	0.147063	0.30485	0.28011046

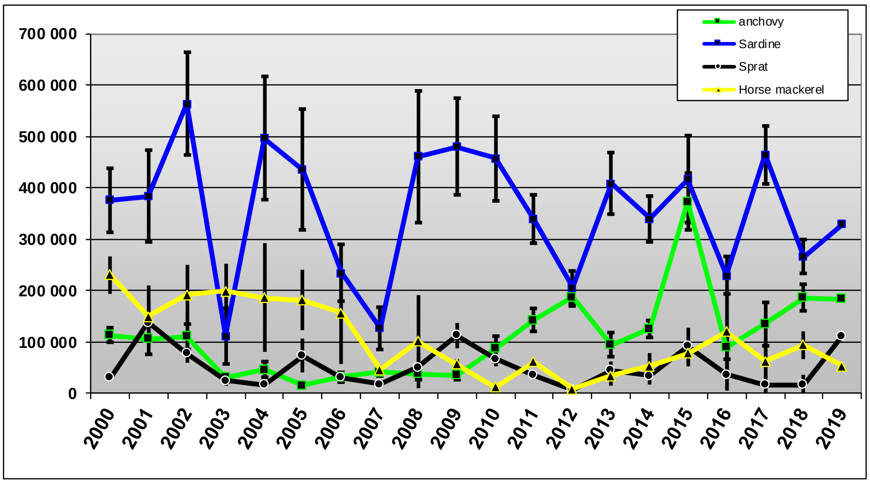


figure 2.3.3. – biomass estimates using Thalassa acoustic data along transects and all the consort identification fishing operations (Thalassa + commercial vessels) and associated coefficients of variation.

3. ANCHOVY DATA

3.1. anchovy biomass

The biomass estimate of anchovy observed during PELGAS2019 is **183 000** tons. (table 2.3.2.), which seems to be a high biomass compared to the serie, and comparable to 2012 and 2018.

In the Gironde area, the configuration was usual in terms of energy compared to what was observed last years, with a high energy attributed to anchovy.

The one-year-old anchovies were mostly present front of the Gironde (in terms of energy and, as well, biomass) but they were still well present on the platform, until Brittany along the bathymetric line of 100m. The average size of one year old fish was comparable the average size in recent years (two years really differed from the average: 2012 and particularly 2015 where fishes were much smaller) but shows a clear decreasing trend, year after year. Bigger (and older) fish appeared close to the surface or in midwater in the central part of the Bay of Biscay.

One years old anchovies were also present, in lower quantities, mixed with older fish, even offshore.

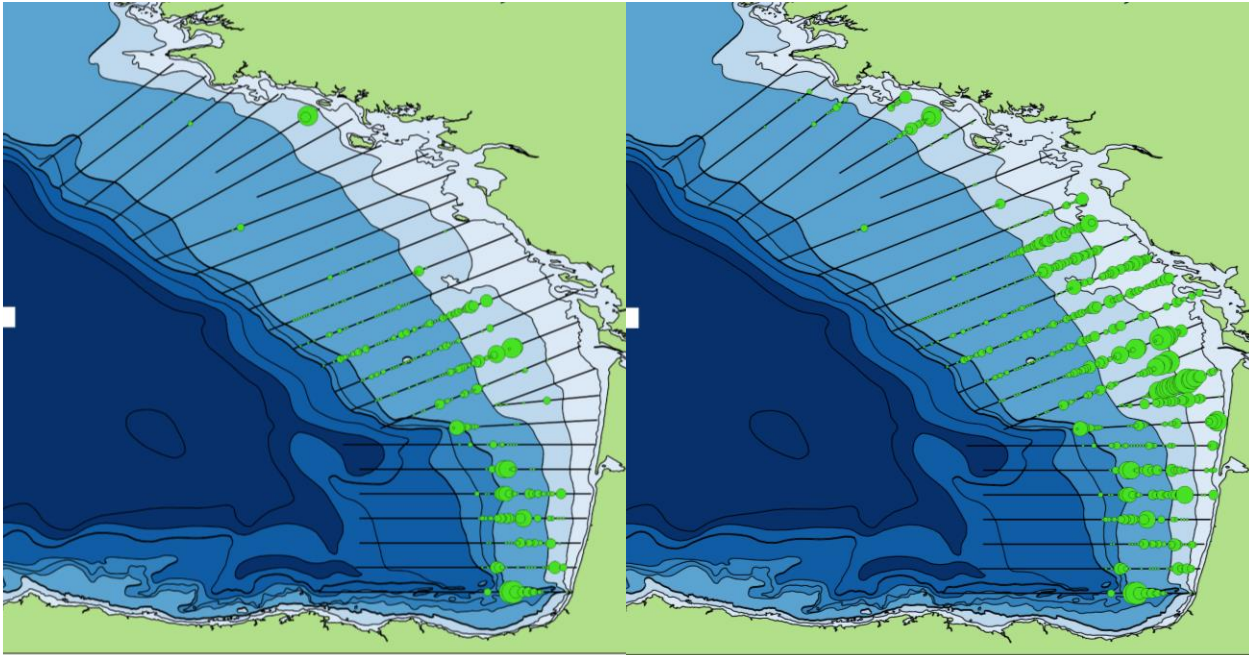

Surface distribution Total distribution

Figure 3.1. – Anchovy distribution according to PELGAS19 survey.

3.2. Anchovy length structure and maturity

Length distribution in the trawl hauls were estimated from random samples. The population length distributions (figures 3.2) were estimated by a weighted average of the length distribution in the hauls. Weights used are acoustic coefficients (Dev*Xe Moule in thousands of individuals per n.m.^{2}) which correspond to the abundance in the area sampled by each trawl haul.

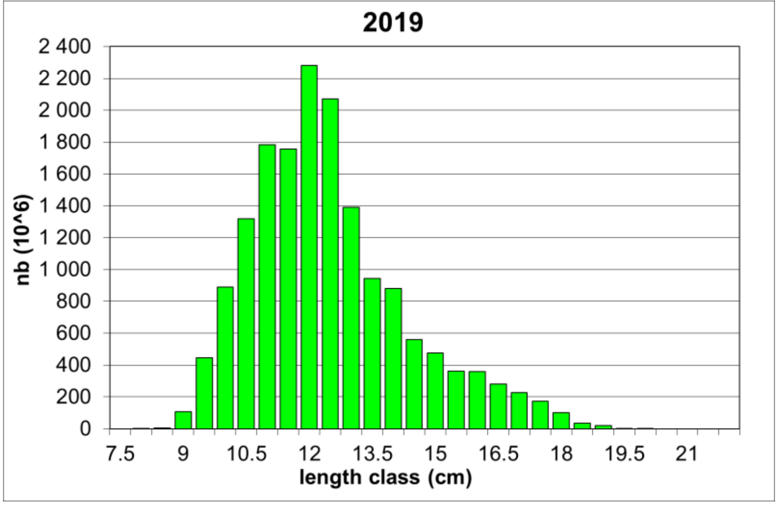


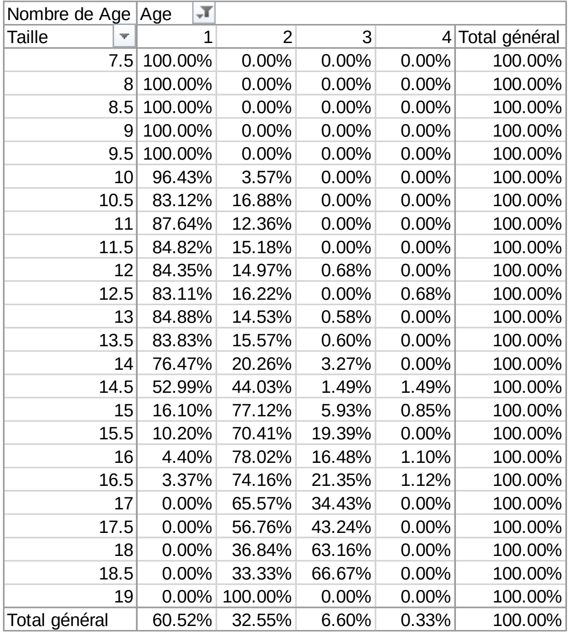
Figure 3.2: length distribution of global anchovy as observed during PELGAS19 survey

Globally we observe that length structure shows a classic distribution, with fish from 9 to 19 centimetres. It must be noticed that even if some individuals were small (less than 10 cm), almost all fishes were mature and in their spawning period. This observation on maturity contrasted with the 2015 observation where a large proportion of the population was not spawning at the period of the survey.

3.3. Demographic structure

An age length key was built for anchovy from the trawl catches (Thalassa hauls) and samples from commercial vessels. We took the otoliths from a given number of fishes per length class (4 to 6 / half-cm), for a total amount of around 40 fishes per haul. As there was a lot of fishing operations where anchovy was present (as previous surveys), the number of otoliths taken during the survey was still important (1908 otoliths of anchovy taken and read on board), The population length distributions were estimated by a weighted use of length distributions in the hauls, weighted as described in section 3.2.

Table 3.3.1. PELGAS2019 anchovy Age/Length key.



Nombre de Age	Age				
Taille	1	2	3	4	Total général
7.5	100.00%	0.00%	0.00%	0.00%	100.00%
8	100.00%	0.00%	0.00%	0.00%	100.00%
8.5	100.00%	0.00%	0.00%	0.00%	100.00%
9	100.00%	0.00%	0.00%	0.00%	100.00%
9.5	100.00%	0.00%	0.00%	0.00%	100.00%
10	96.43%	3.57%	0.00%	0.00%	100.00%
10.5	83.12%	16.88%	0.00%	0.00%	100.00%
11	87.64%	12.36%	0.00%	0.00%	100.00%
11.5	84.82%	15.18%	0.00%	0.00%	100.00%
12	84.35%	14.97%	0.68%	0.00%	100.00%
12.5	83.11%	16.22%	0.00%	0.68%	100.00%
13	84.88%	14.53%	0.58%	0.00%	100.00%
13.5	83.83%	15.57%	0.60%	0.00%	100.00%
14	76.47%	20.26%	3.27%	0.00%	100.00%
14.5	52.99%	44.03%	1.49%	1.49%	100.00%
15	16.10%	77.12%	5.93%	0.85%	100.00%
15.5	10.20%	70.41%	19.39%	0.00%	100.00%
16	4.40%	78.02%	16.48%	1.10%	100.00%
16.5	3.37%	74.16%	21.35%	1.12%	100.00%
17	0.00%	65.57%	34.43%	0.00%	100.00%
17.5	0.00%	56.76%	43.24%	0.00%	100.00%
18	0.00%	36.84%	63.16%	0.00%	100.00%
18.5	0.00%	33.33%	66.67%	0.00%	100.00%
19	0.00%	100.00%	0.00%	0.00%	100.00%
Total général	60.52%	32.55%	6.60%	0.33%	100.00%

Applying the age distribution to the abundance in biomass and numbers, the distribution in age of the biomass has been calculated. The total biomass used here has been updated with the value obtained from the previous method based on strata.

Age distribution is shown in figures 3.3.2. The age distributions compared from 2000 to 2018 are shown in figure 3.3.3.

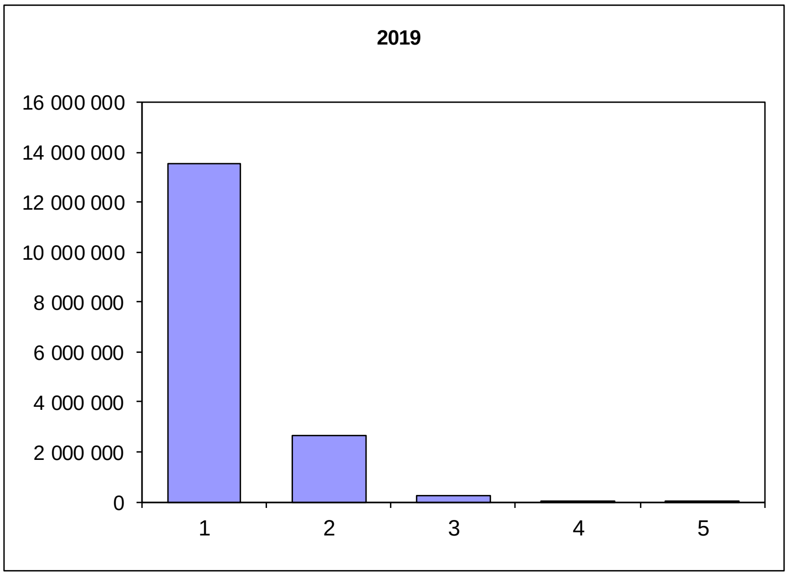


Figure 3.3.2– global age composition (numbers) of anchovy as observed during PELGAS19.

Looking at the numbers at age since 2000 (fig 3.3.3.), the number of 1 year old anchovies this year seems to be equivalent to 2011, 2012 or 2017, far away from the very best recruitment observed in 2015.

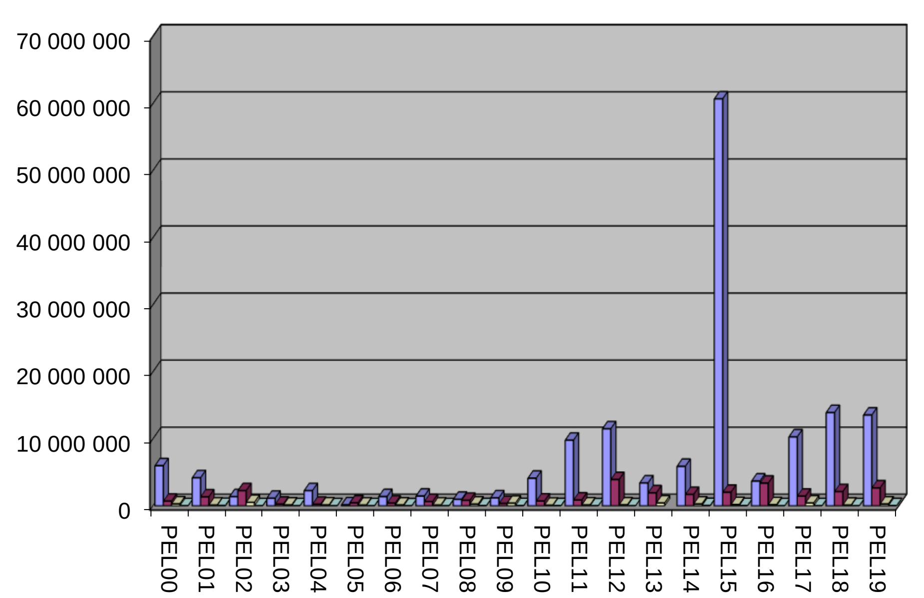


Figure 3.3.3 Anchovy numbers at age as observed during PELGAS surveys since 2000. The huge 2015 age class is not followed in 2016 and in 2017 as well. Once again, it could indicate that an overestimation occurred on the recruitment in 2015. Several investigation have been done to explain, without results for the time being.

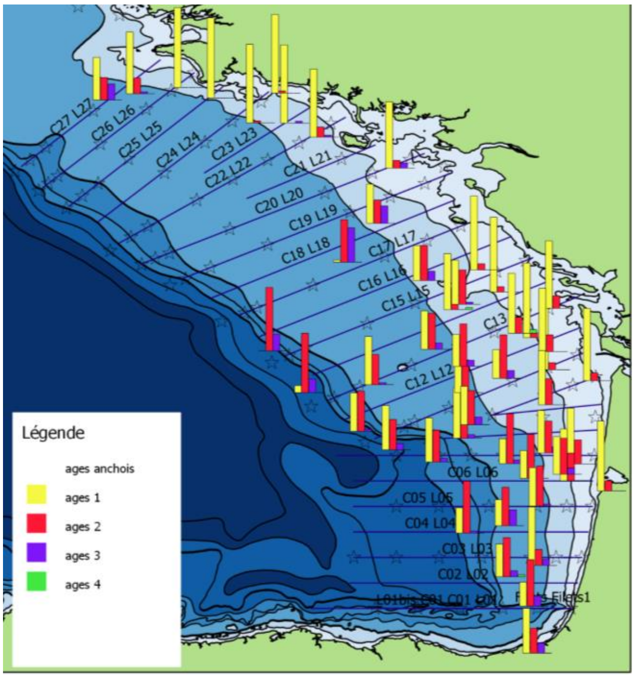


Figure 3.3.4 Anchovy proportion at age in each haul as observed during PELGAS19 survey (yellow = age 1, red = age 2).

During previous surveys, anchovy was well geographically stratified depending on the age (*see WD 2010, Direct assessment of small pelagic fish by the PELGAS10 acoustic survey, Masse J and Duhamel E.*). It is less true this year, as in recent years, as age 1 were present all over the area where anchovy was present. This one year old anchovy is almost pure front of the Gironde, and mixed with older individuals elsewhere except on the center of the bay (North-West of the bay of Biscay) where almost pure anchovy of age 2 appeared close to the surface.

age	i	%nb		age	i	%mass
1		82.17%		1		70.58%
2		16.15%		2		24.91%
3		1.53%		3		4.23%
4		0.12%		4		0.23%
5		0.04%		5		0.05%

gure 3.3.5 percentage by age of the Anchovy population observed during PELGAS19 in numbers (left) and biomass (right).

3.4. Weight/Length key

Based on 1921 weights of individual fishes, the following weight/length key was established (figure 4.5.):

W= 0.00340924L$^{3.25776614}$ with R2 = 0.9714 *(with W in grams and L in cm)*

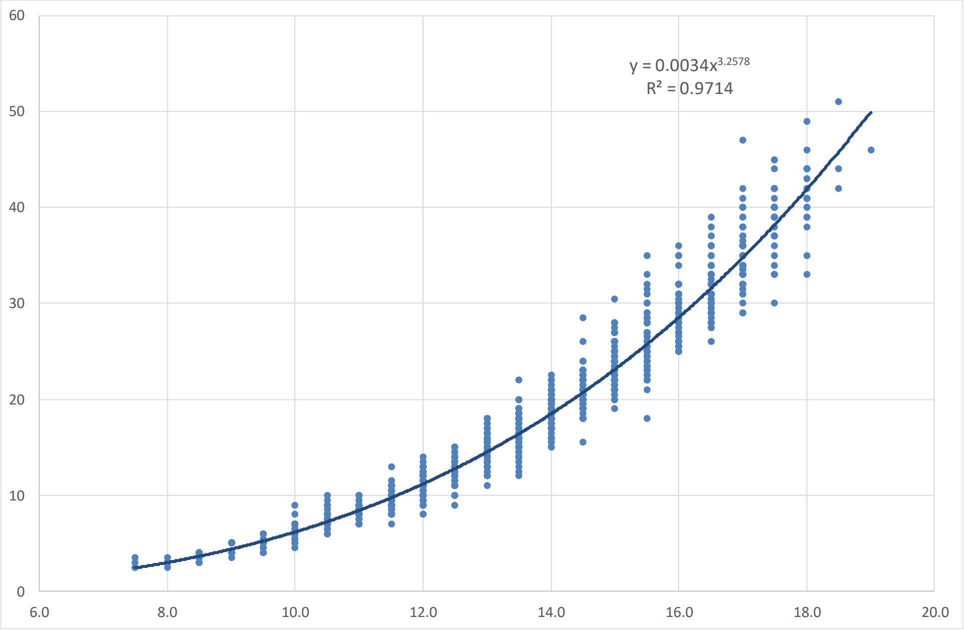


Fig. 3.4 – Weight/length key of anchovy established during PELGAS19

3.5. Mean Weight at age

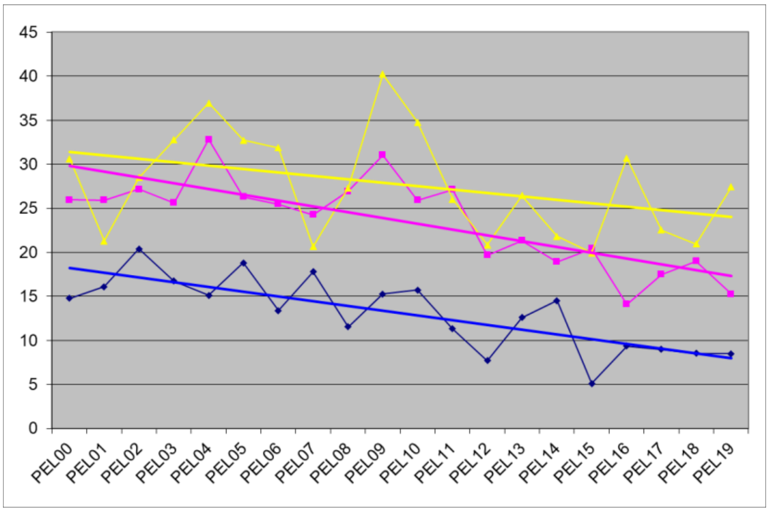


Fig. 3.5. – evolution of mean weight at age (g) of anchovy along PELGAS series

As previous years, we observe that globally the trend of the mean weight at age is a decrease. This trend is almost the same for sardine in the bay of Biscay. Further investigates should be done and, if we have some hypothesis (maybe an effect of density-dependance), we do not have real explanation for the time being.

3.6. Eggs

During this survey, in addition of acoustic transects and pelagic trawl hauls, 731 CUFES samples were collected and counted, 63 vertical plankton hauls and vertical profiles with CTD were carried out. Eggs were sorted and counted automatically with the zoocam system, and staged during the survey.

2019, as from 2011, was marked by a large quantity of collected and counted anchovy eggs (Fig 3.6.2), with the same magnitude over the previous values of the on-going decade, reaching the maximum in 2011. Their spatial pattern of distribution was quite usual, with major part of the abundance South of 46°N. However, eggs are also abundant on 3 more transects than usual North of the Gironde estuary, with a connection all over the shelf between the classical inshore and slope distributions. The spatial distribution is classical, with maximum abundances in the areas influenced by river plumes over the southern shelf of the bay, and an extension along the coast towards the north.

Spawning occurred over the mid-shelf in the north, an area where no egg is observed usually.

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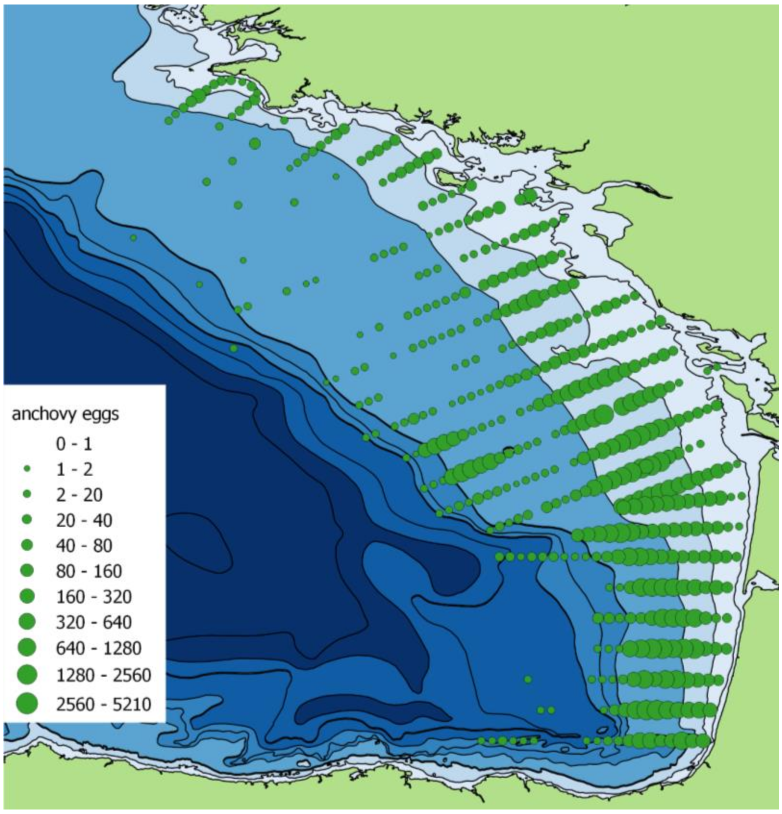

Figure 3.6.1 – Distribution of anchovy eggs observed with CUFES during PELGAS19.

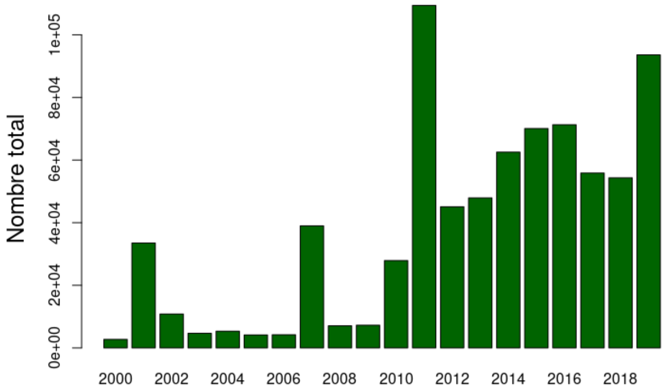

Figure 3.6.2 – Number of eggs observed during PELGAS surveys from 2000 to 2019

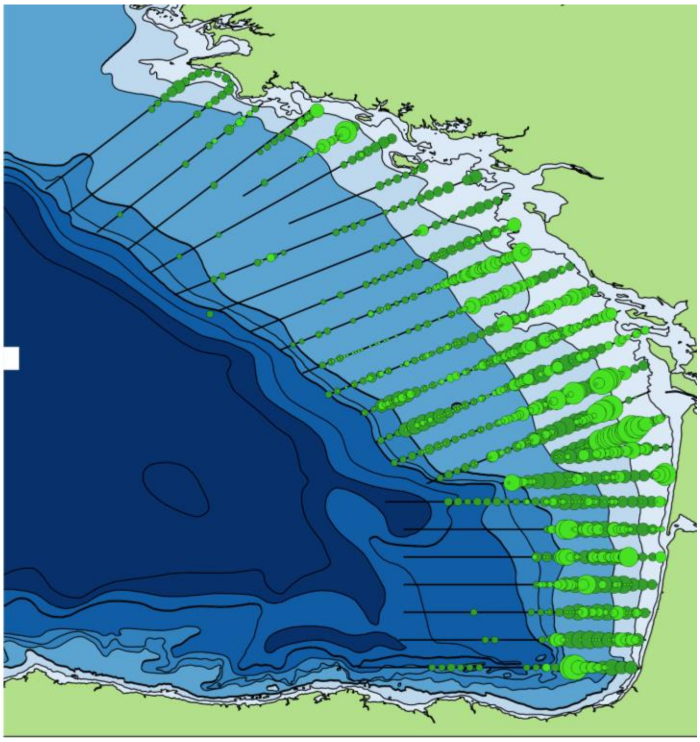

Figure 3.6.3 – Coherence between spatial distribution of adults and eggs. light green = biomass of adults per ESDU, dark green = eggs

We can see that globally the spatial distribution of eggs match with the adult's one along the coast. But more offshore between 45°N and 47°N, eggs were counted in important quantity with lower echoes attributed to anchovy. It could be due to the presence of fish completely closed to the surface, in the blind layer of echosounders.it must also be noticed that close to the coast anchovies were small, showing a low fecundity. Large individuals, more offshore, had an high fecundity.

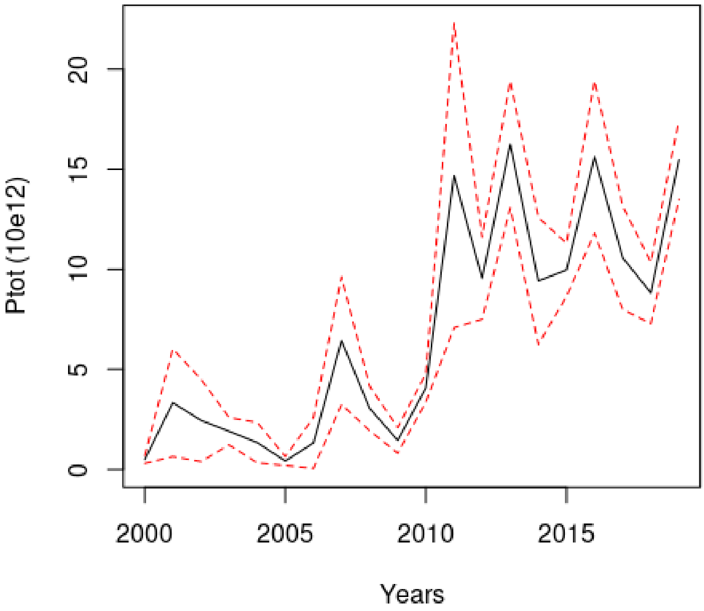

Figure 3.6.4 – total number of anchovy eggs corrected by the vertical model (Ptot)

4. SARDINE DATA

4.1. Adults

The biomass estimate of sardine observed during PELGAS19 is **328 741** tons (table 2.3.), which constitutes an decrease from last year, the biomass reaching a medium level of the PELGAS series. It must be noticed that the sardine abundance index is very variable, and it could be explained that this survey doesn't cover the total area of potential presence of sardine, and it is possible that some years, this specie could be present up to the North, in the Celtic sea, SW of Cornouailles or Western Channel where some fishery occurs. It is also possible that sometimes, a small fraction of the population could be present in very coastal waters, when the R/V Thalassa is unable to operate in those waters. The estimate is representative of the sardine present in the survey area at the time of the survey and can be therefore considered as an estimate of the Bay of Biscay (VIIIab) sardine population.

Sardine was distributed all along the French coast of the bay of Biscay, from the South to the Loire river. The small sardine was present this year, pure along the Lande's coast sometimes mixed with other species (sprat and anchovy this year) along the coast. Sardine appeared also sometimes present close to the surface in the middle of the platform in the Northern part of the Bay of Biscay (on the great mud bank) which is not his regular habitat. Offshore, close to the surface, along the shelfbreak, sardine was totally absent this year.

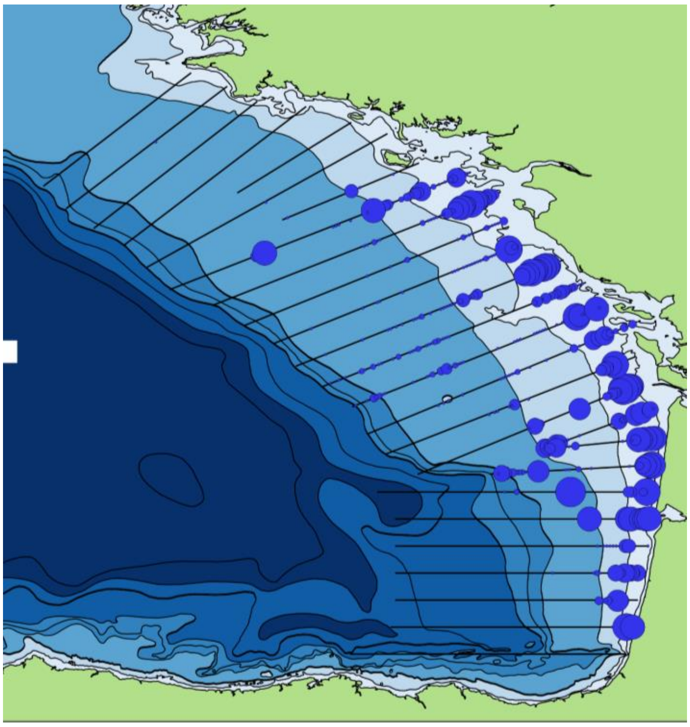

Figure 4.1.1 – distribution of sardine observed by acoustics during PELGAS19

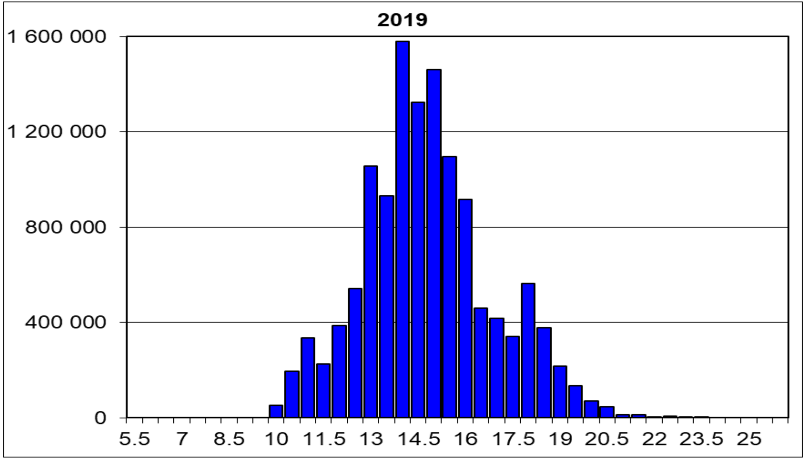

Figure 4.1.2. – length distribution of sardine as observed during PELGAS19

Length distributions in the trawl hauls were estimated from random samples. The population length distributions have been estimated by a weighted average of the length distribution in the hauls. Weights used are the acoustic biomass estimated in the post-stratification regions comprising each trawl haul. The global length distribution of sardine is shown on figure 4.1.2.

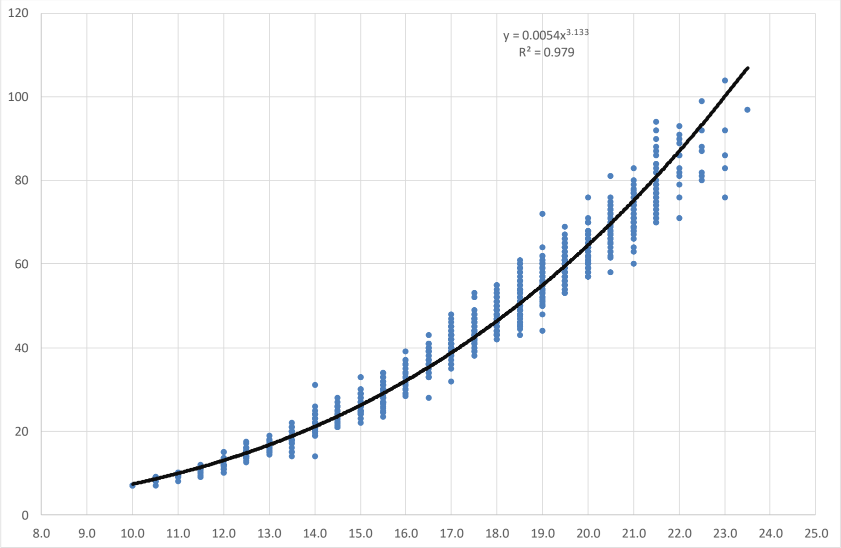

Figure 4.1.3 – Weight/length key of sardine established during PELGAS19

Nombre de Age	Age								
Taille	1	2	3	4	5	6	7	8	Total général
10	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
10.5	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
11	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
11.5	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
12	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
12.5	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
13	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
13.5	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
14	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
14.5	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
15	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
15.5	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
16	92.31%	5.13%	2.56%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
16.5	61.29%	38.71%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
17	15.52%	77.59%	5.17%	1.72%	0.00%	0.00%	0.00%	0.00%	100.00%
17.5	2.99%	82.09%	13.43%	0.00%	1.49%	0.00%	0.00%	0.00%	100.00%
18	0.00%	70.13%	24.68%	3.90%	1.30%	0.00%	0.00%	0.00%	100.00%
18.5	0.00%	28.21%	69.23%	1.28%	1.28%	0.00%	0.00%	0.00%	100.00%
19	0.00%	24.42%	60.47%	9.30%	5.81%	0.00%	0.00%	0.00%	100.00%
19.5	0.00%	8.75%	70.00%	8.75%	11.25%	1.25%	0.00%	0.00%	100.00%
20	0.00%	4.23%	52.11%	11.27%	25.35%	4.23%	2.82%	0.00%	100.00%
20.5	0.00%	1.54%	43.08%	15.38%	26.15%	10.77%	3.08%	0.00%	100.00%
21	0.00%	2.38%	14.29%	19.05%	35.71%	23.81%	2.38%	2.38%	100.00%
21.5	0.00%	0.00%	2.70%	16.22%	45.95%	24.32%	10.81%	0.00%	100.00%
22	0.00%	0.00%	0.00%	8.33%	16.67%	66.67%	0.00%	8.33%	100.00%
22.5	0.00%	0.00%	0.00%	14.29%	28.57%	57.14%	0.00%	0.00%	100.00%
23	0.00%	0.00%	0.00%	0.00%	20.00%	0.00%	80.00%	0.00%	100.00%
23.5	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	100.00%
Total général	36.11%	20.65%	24.63%	5.00%	8.33%	3.89%	1.20%	0.19%	100.00%

Table 4.1.4 : sardine age/length key from PELGAS19 samples (based on 1108 otoliths from Thalassa and commercial vessels)

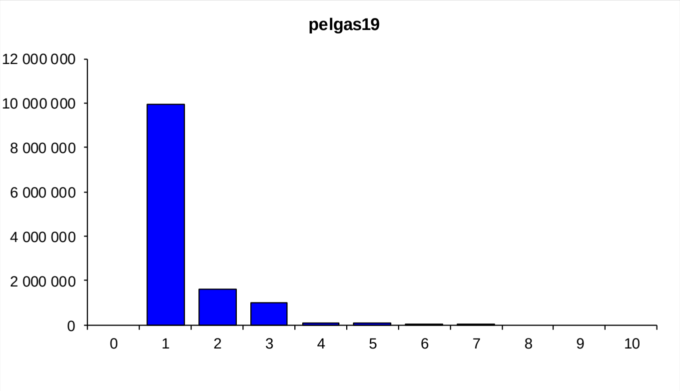

Figure 4.1.5.- Global age composition (nb) of sardine as observed during PELGAS 19

	PEL19 - N - %
1	81.4%
2	11.0%
3	6.1%
4	0.7%
5	0.7%
6	0.2%
7	0.0%
8	0.0%

	PEL19 - W - %
1	66.7%
2	17.8%
3	11.9%
4	1.4%
5	1.6%
6	0.5%
7	0.1%
8	0.0%

Figure 4.1.6 percentage by age of the sardine population observed during PELGAS19 in numbers (left) and biomass (right).

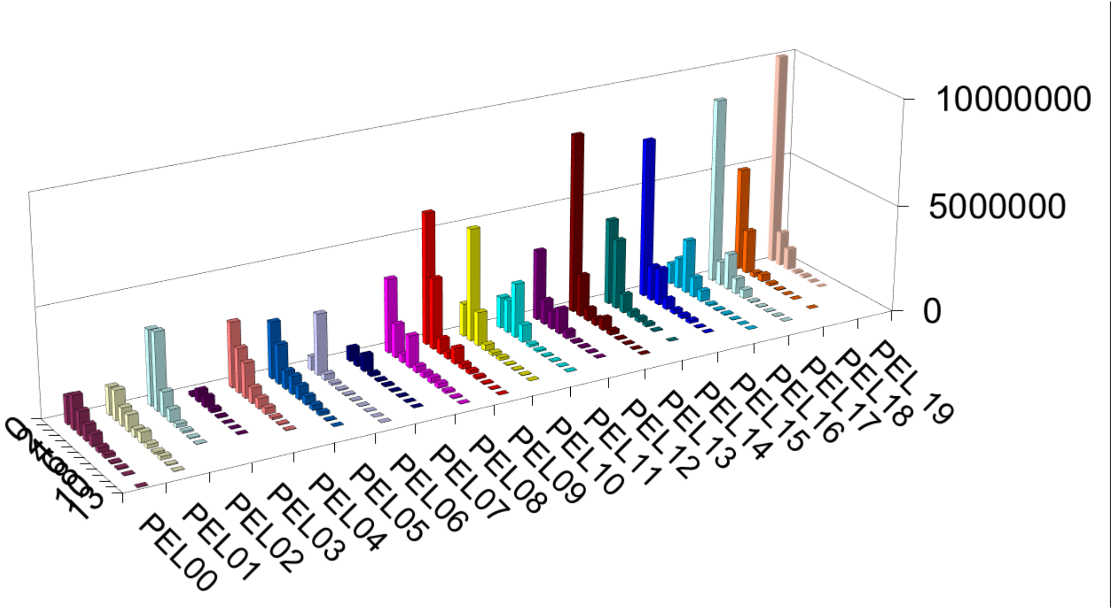

Figure 4.1.7- Age composition of sardine as estimated by acoustics since 2000

PELGAS serie of sardine abundances at age (2000-2019) is shown in Figure 4.1.7. Cohorts can be visually tracked on the graph particularly in the past : the respectively very low and very high 2005 and 2008 cohorts denote atypical years in terms of environmental conditions, and therefore fish (and particularly sardine) distributions. This is less true in recent years, with the good recruitment in 2013 which doesn't profit to incoming years, or the 2017 year class which seems to be one of the best recruitment ever and who seems to contribute not that much to the total abundance of sardine in 2018 (and 2019) in the bay of Biscay. 2019 seems to be the best recruitment ever and the population is becoming more and more young (81% of the fish are 1 year old).

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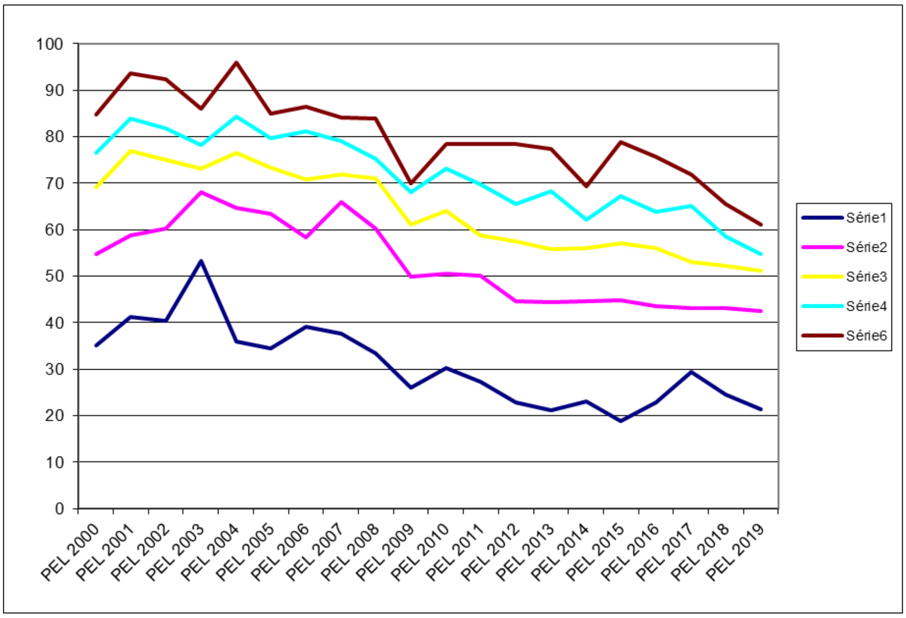

Figure 4.1.8- evolution of mean weight at age (g) of sardine along pelgas series

The PELGAS sardine mean weights at age series (Figure 4.1.8) shows a clear decreasing trend, whose biological determinant is still poorly understood. It must be noticed that there is no real evolution since 2011 concerning ages 1 and 2, but older ages (4 and 5) continue to show a decreasing weight at age.

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

4.2. Eggs

The spatial pattern of sardine eggs overlaps with the one of anchovy, without any distribution along the shelf break this year.

Sardine egg production was quite low (third lowest of the series), despite the delayed warming and stratification more favorable to sardine. Sardine eggs were indeed really low in the south of the Bay, and did not extend much in the north except along the coast until the latitude of the Loire.

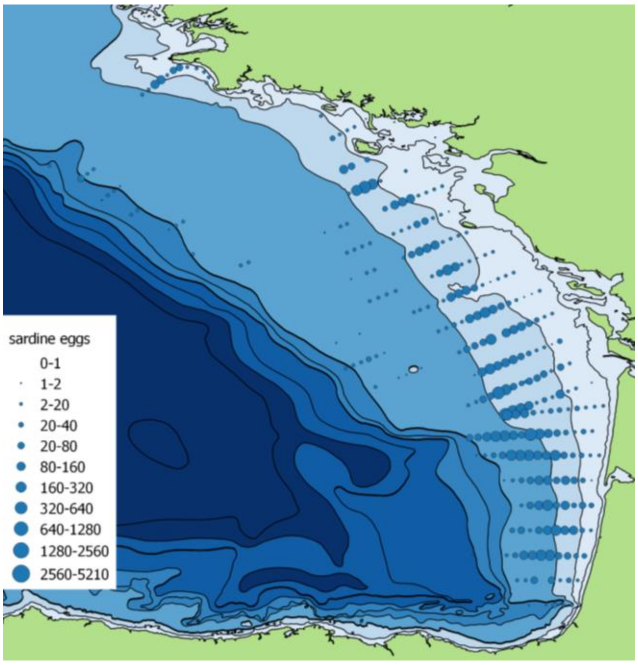

Figure 4.2.1. Distribution of sardine eggs observed with CUFES during PELGAS19.

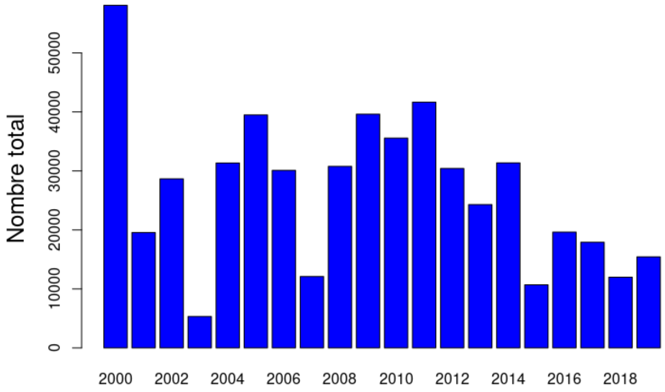

Figure 4.2.2. Number of eggs observed during PELGAS surveys from 2000 to 2019

2019 was marked by a low abundance of sardine eggs as compared to the PELGAS time-series. It must be noticed that this year the numerous one-year-old individuals were not fully mature: 35 % of the age1 were totally immature (stage1) and 48 % were starting their maturation (stage 2 of the maturity scale) at the time of the survey.

5. TOP PREDATORS

For the seventeenth consecutive year, monitoring program to record marine top predator sightings (marine birds and cetaceans) has been carried out, during the whole coverage of the transects network.

A total of 220 hours of sighting effort were performed for 28 days (Figure 5.1.), with an average of 8 hours and 10 minutes of sighting effort per day. Weather conditions were variable with one third of the time showing medium or bad conditions (wind speed >= 3 beaufort).

During the survey, 3023 sightings of animals or objects were recorded. Seabirds constitute as usual the majority of sightings (54%). Second most important sightings in numbers are litters drifting at sea then human activities Cetaceans represents 4% of sightings (same as last year)

5.1 – Sighting effort and conditions

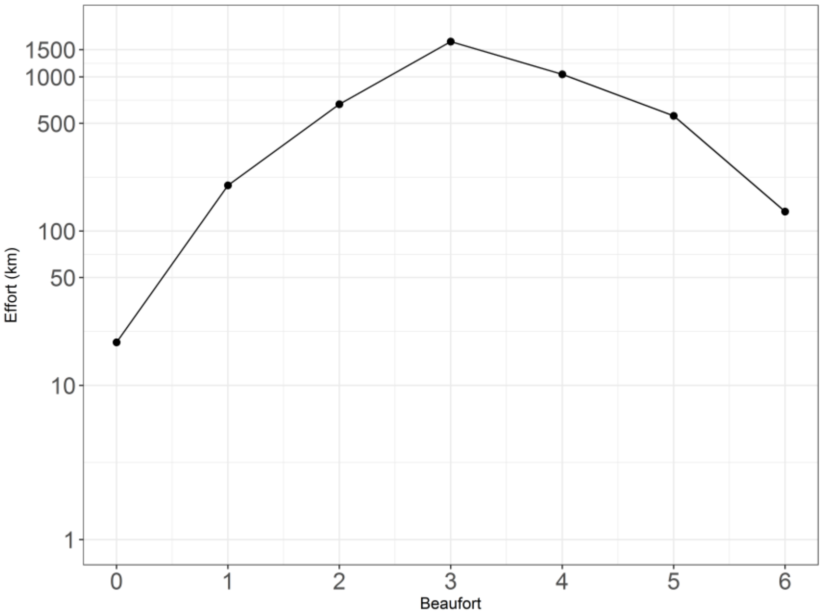

Figure 5.1. Sighting effort and conditions

The worst conditions were met in the central part of the bay of Biscay, and are mainly due to wind and rain. Globally, conditions of sightings during PELGAS2019 (including rain, fog and wind) were very contrasted.

5.2 – Birds

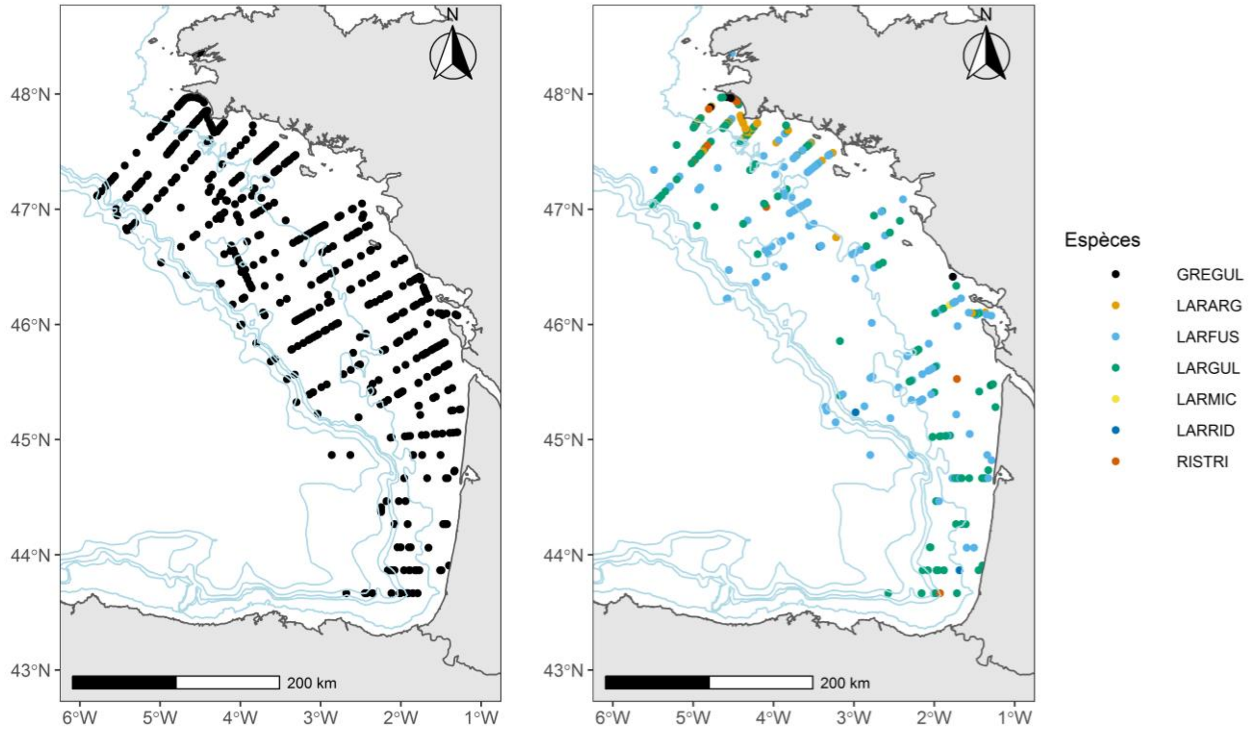

Figure 5.2. Distribution of birds observed during the PELGAS19 survey. On left : Gannets ; right: larids (including sea gulls)

Birds constitute the vast majority of sightings. Shorebirds and passerines accounted for less than 4% of bird sightings. 1645 sightings of seabirds were found all over the Bay of Biscay (Figure 5.2), divided into 32 identified species and a raw estimate of 7464 individuals (more or less the same as last year.

Northern gannets accounted for 19% of all seabird sightings: its distribution is homogeneous across the Bay of Biscay.

The larids, principally including the sea gulls, are mainly located (sometimes in very numerous groups) from the coast to the middle of the platform.

5.2 – Mammals

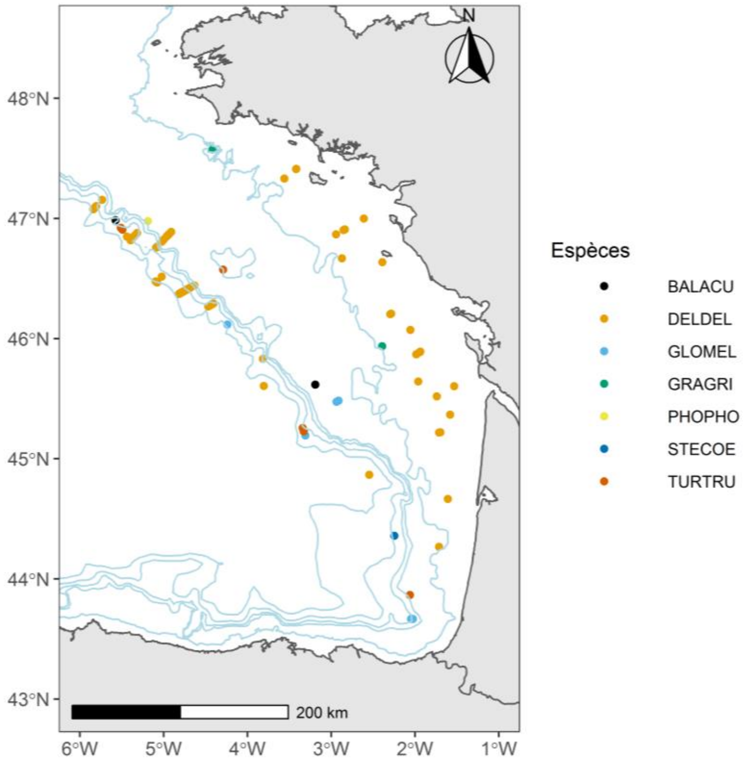

Figure 5.2. Distribution of mammals during the PELGAS19 survey.

A total of 122 sightings (against 188 last year) were recorded corresponding to a raw estimate of 2322 (against 794 in 2018) individuals and 9 species of cetaceans clearly identified (Figure 5.2). The greatest diversity of marine mammals was observed in the Northern part of the Bay of Biscay. The overall distribution pattern is similar to that of previous PELGAS spring surveys.

The raw number of cetacean observed this year is much higher than last year's number while the number of sightings is more or less constant, because some dolphin groups in the North at the shelfbreak were constituted by numerous individuals (up to 300 ind)

6. HYDROLOGICAL CONDITIONS

Winter 2018-2019 was rather dry. Cumulated river discharges to the Bay of Biscay have been really small, the smallest of the time-series since 2000.

Winter was also quite windy like early spring, which did not allow real stratification setup before the survey despite some nice days in April. .

Neither the ‘normal’ winter-to-spring temperature conditions, nor the river discharges helped establishing a significant stratification before and during the survey.

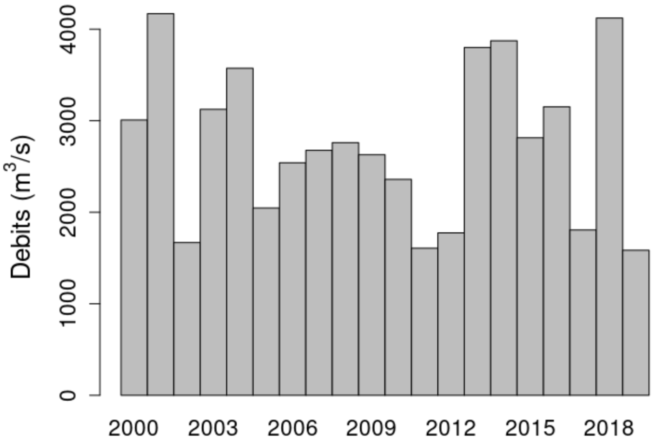

Figure 6.1 cumulated river discharges from January to April

Weather was windy at the beginning of the survey and around the mid-survey break.

Salinity was quite high over the whole shelf, according to the very low discharges of the rivers. Sea surface temperature as also quite low for this period, and it increased late in the survey.

Phytoplanktonic production was continuously high during a large part of the survey, particularly in the South of Brittany and in the North, along the shelfbreak.

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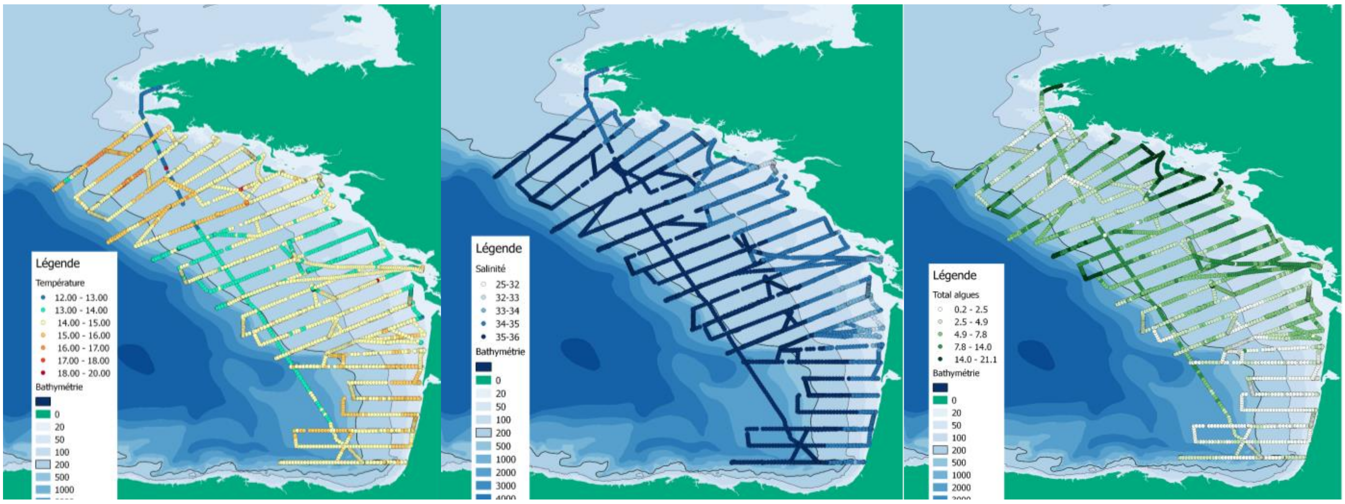

Figure 6.2. – Surface temperature, salinity and fluorescence observed during PELGAS19.

7. CONCLUSION

The Pelgas19 acoustic survey has been carried out with variable weather conditions. The help of commercial vessels (two pairs of pelagic trawlers) during 18 days provided about 110 identification hauls instead of about 60 before 2007 when Thalassa was alone to identify echotraces. Their participation increased the precision of identification of echoes and some double hauls permitted to confirm that results provided by the two types of vessels (R/V and fishing boats) were comparable and usable for biomass estimate purposes. These commercial vessels participated to the PELGAS survey in a very good spirit of collaboration. Vessels (and the scientific observer onboard) are founded by EMFF (European Maritime and Fisheries Found) for the period 2017- 2019, with the financial help of "France Filière Pêche" which is a groupment of French fishing organisations.

Warming and thermal stratification were slow in the beginning and accelerated at the end of the survey. Salinity was high over the whole shelf due to low river discharges. This high salinity is due to a very dry winter before the survey. Cumulated river discharges to the Bay of Biscay have been really reduced, the lowest historical value of the serie when considering the time-period 2000-2019

The PELGAS19 survey observed a relatively high level of anchovy biomass (**183 160 tons**), which seems to be comparable to previous year, and far away from the 2015 biomass (which was probably overestimated but it is not explained for the time being). Offshore, anchovies were present closed to the surface in the South. As previous years, we observe that globally the trend of the mean weight at age is a decrease. This trend is globally the same for sardine in the bay of Biscay. Further investigates should be done and, if we have some hypothesis (maybe an effect of density-dependence), we do not have real explanation for the time being.

The biomass estimate of sardine observed during PELGAS17 is **328 700** tons, which constitutes an increase from last year, the biomass reaching again a medium level of the PELGAS series. It confirms that this specie shows a variable abundance in the Bay of Biscay at this period.

The population of sardine is still very young, with an age distribution largely dominated by age 1 and 2 groups (sum about 92% in numbers). The global age structure of the population and his evolution trough years confirms the validity of age readings and the fact that we can follow sardine cohorts in the sardine population of the bay of Biscay. But it must be noticed that global weights and lengths at age are regularly decreasing in the bay of Biscay, maybe due to an effect of density-dependence or other reasons not well known at this time. Old individuals (>5 years old) seems to be less an less present in the bay of Biscay, year after year.

Concerning the other species, mackerel and sprat were relatively well present this year compared to recent surveys, while blue whiting was rather absent in the surveyed area.

Working document presented in the ICES Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas 7, 8 and 9 (WGACEGG). Madrid, Spain, 18-22 November 2019.

Acoustic assessment and distribution of anchovy, sardine and chub mackerel in ICES Subdivision 9a South during the *ECOCADIZ 2019-07* Spanish survey (July-August 2019) with notes on the distribution of other pelagic species.

By

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ABSTRACT

The present working document summarises a part of the main results obtained from the Spanish (pelagic ecosystem-) acoustic survey conducted by IEO between 31st July and 13rd August 2019 in the Portuguese and Spanish shelf waters (20-200 m isobaths) off the Gulf of Cadiz onboard the R/V *Miguel Oliver*. The 21 foreseen acoustic transects were sampled. A total of 27 valid fishing hauls were carried out for echo-trace ground-truthing purposes. This working document only provides abundance and biomass estimates for anchovy, sardine and chub mackerel, which are presented without age structure. The distribution of all the mid-sized and small pelagic fish species susceptible of being acoustically assessed is also shown from the mapping of their back-scattering energies. Chub mackerel was the most frequent species in the fishing hauls, followed by horse mackerel, anchovy, sardine, mackerel, blue jack mackerel, Atlantic pomfret (*Brama brama*) and bogue. Longspine snipefish, boarfish and transparent goby (*Aphia minuta*) showed a medium relative frequency of occurrence. Mediterranean horse-mackerel and pearlside showed a low occurrence. Pearlside was the most abundant species in these hauls, followed by sardine, chub mackerel, anchovy and longspine snipefish, with the remaining species showing negligible relative contributions. The estimate of total NASC allocated to the "pelagic fish species assemblage" has been the highest one ever recorded within the time series, denoting a high fish density during the survey. Such an increase is the result of the relatively high acoustic contributions of anchovy, sardine, chub mackerel, and the unexpected high contributions of the transparent goby and the Atlantic pomfret, species which usually have showed an accidental occurrence or very low abundance through the time-series. Anchovy was mainly distributed between Cape Santa Maria and Bay of Cadiz, although showing the highest densities in the Spanish central-western shelf waters. Anchovy eggs distribution resembled the adults' and, although overall egg density was higher than previous years, the spawning area showed a reduction as compared with those observed in previous years. Largest anchovies were mainly distributed in the westernmost waters and the smallest ones were concentrated between Doñana and Bay of Cadiz. Anchovy acoustic estimates in summer 2019 were of 5 485 million fish and 57 700 t (i.e. the historical biomass maximum in the time-series), well above the historical average (ca. 24 kt), showing a recent increasing trend. Sardine, widely distributed over the surveyed area, also recorded a high acoustic echo-integration in summer 2019 as a consequence of the occurrence of dense mid-water schools in the coastal fringe (20-60 m depth) comprised between Guadiana river mouth and Doñana. Acoustic estimates were of 2 917 million fish and 62 682 t, a biomass well above the historical average (ca. 47 kt). Spanish waters concentrated the bulk of the population. Chub mackerel was distributed all over the surveyed area but showing the highest densities in the Portuguese shelf waters. Acoustic estimates were of 465 million fish and 32 696 t, with the bulk of the population concentrated in the Portuguese waters, where the smallest fish were also recorded. Estimates showed a relative stable recent trend, with the recent biomasses very close to the historical average (ca. 35 kt).

INTRODUCTION

The *ECOCADIZ* surveys constitute a series of yearly acoustic surveys conducted by IEO in the Subdivision 9a South (Algarve and Gulf of Cadiz, between 20 – 200 m depth) under the "pelagic ecosystem survey" approach onboard R/V *Cornide de Saavedra* (until 2013, since 2014 on onboard R/V *Miguel Oliver*). This series started in 2004 with the *BOCADEVA 0604* pilot acoustic - anchovy DEPM survey. The following surveys within this new series (named *ECOCADIZ* since 2006 onwards) are planned to be routinely performed on a yearly basis, although the series, because of the available ship time, has shown some gaps in those years coinciding with the conduction of the triennial anchovy DEPM survey (the true *BOCADEVA* series, which first survey started in 2005).

Results from the *ECOCADIZ* series are routinely reported to ICES Expert Groups on both stock assessment (formerly in WGMHSA, WGANC, WGANSA, at present in WGHANSA) and acoustic and egg surveys on anchovy and sardine (WGACEGG).

The present Working Document advances some results from the *ECOCADIZ 2019-07* survey. These results will only refer to the size-based acoustic estimates and spatial distribution of anchovy and sardine, and to inferences on the spatial distribution of other pelagic species from the distribution of the acoustic energy attributed to each of these species.

MATERIAL AND METHODS

The *ECOCADIZ 2019-07* survey was carried out between 31st July and 13rd August 2019 onboard the Spanish R/V *Miguel Oliver* covering a survey area comprising the waters of the Gulf of Cadiz, both Spanish and Portuguese, between the 20 m and 200 m isobaths. The survey design consisted in a systematic parallel grid with tracks equally spaced by 8 nm, normal to the shoreline (**Figure 1**).

Echo-integration was carried out with a *Simrad™ EK60* echo sounder working in the multi-frequency fashion (18, 38, 70, 120, 200 kHz). Average survey speed was about 10 knots and the acoustic signals were integrated over 1-nm intervals (ESDU). Raw acoustic data were stored for further post-processing using *Echoview™* software package. Acoustic equipment was previously calibrated during the *MEDIAS 2019* acoustic survey, a survey conducted in the Spanish Mediterranean waters just before the *ECOCADIZ* one, following the standard procedures (Demer *et al*., 2015).

Survey execution and abundance estimation followed the methodologies firstly adopted by the ICES *Planning Group for Acoustic Surveys in ICES Sub-Areas VIII and IX* (ICES, 1998) and the recommendations given by the *Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES areas 7, 8 and 9* (WGACEGG; ICES, 2006a,b).

Fishing stations for echo-trace ground-truthing were opportunistic, according to the echogram information, and they were carried out using a ca. 15 m-mean vertical opening pelagic trawl (*Tuneado* gear) at an average speed of 4 knots. Gear performance and geometry during the effective fishing was monitored with *Simrad™ Mesotech FS20/25* trawl sonar and a *Marport™ combi TE/TS* (Trawl Eye/Trawl Speed) sensor. Trawl sonar and sensors data from each haul were recorded and stored for further analyses.

Ground-truthing haul samples provided biological data on species and they were also used to identify fish species and to allocate the back-scattering values into fish species according to the proportions found at the fishing stations (Nakken and Dommasnes, 1975).

Length frequency distributions (LFD) by 0.5-cm class were obtained for all the fish species in trawl samples (either from the total catch or from a representative random sample of 100-200 fish). Only those LFDs based on a minimum of 30 individuals and showing a normal distribution were considered for the purpose of the acoustic assessment.

Individual biological sampling (length, weight, sex, maturity stage, stomach fullness, and mesenteric fat content) was performed in each haul for anchovy, sardine, mackerel and horse-mackerel species, and bogue. Otoliths were dissected from anchovy, sardine and chub mackerel sampled specimens.

The following TS/length relationship table was used for acoustic estimation of assessed species (following recent IEO standards after ICES, 1998 and recommendations by ICES, 2006a,b. b_{20} values for transparent goby and Atlantic pomfret following to Foote, 1987 for physoclists):

Species	**b_{20}**
Sardine (*Sardina pilchardus*)	-72.6
Round sardinella (*Sardinella aurita*)	-72.6
Anchovy (*Engraulis encrasicolus*)	-72.6
Chub mackerel (*Scomber japonicus*)	-68.7
Mackerel (*S. scombrus*)	-84.9
Horse mackerel (*Trachurus trachurus*)	-68.7
Mediterranean horse-mackerel (*T. mediterraneus*)	-68.7
Blue jack mackerel (*T. picturatus*)	-68.7
Bogue (*Boops boops*)	-67.0
Transparent goby (*Aphia minuta*)	-67.5
Atlantic pomfret (*Brama brama*)	-67.5
Blue whiting (*Micromesistius poutassou*)	-67.5
Silvery lightfish/pearlside (*Maurolicus muelleri*)	-72.2
Longspine snipefish (*Macroramphosus scolopax*)	-80.0
Boarfish (*Capros aper*)	-66.2* (-72.6)

*Boarfish b_{20} estimate following to Fässler *et al*. (2013). Between parentheses the usual IEO value considered in previous surveys.

The *PESMA 2010* software (J. Miquel, unpublished) has got implemented the needed procedures and routines for the acoustic assessment following the above approach.

A *Continuous Underway Fish Egg Sampler* (CUFES, 121 stations), a *Sea-bird Electronics™ SBE 21 SEACAT* thermosalinograph and a *Turner™ 10 AU 005 CE Field* fluorometer were used during the acoustic tracking to continuously monitor some biological (ichthyoplankton and *in vivo* fluorescence) and hydrographical variables (sub-surface sea temperature and salinity). Vertical profiles of hydrographical variables were also recorded by night from 150 CTD casts distributed in 15 transects by using *Sea-bird Electronics™ SBE 911+ SEACAT* (with coupled *Datasonics* altimeter, *SBE 43* oximeter, *WetLabs ECO-FL-NTU* fluorimeter and *WetLabs C-Star 25 cm* transmissometer sensors) and *LADCP T-RDI WHS* 300 kHz profilers (**Figure 2**). *VMADCP RDI 150 kHz* records were also continuously recorded by night between CTD stations.

Twenty six (26) *Manta trawl* hauls were also carried out to characterize the distribution pattern of micro-plastics over the shelf (**Figure 3**). These hauls did not follow a pre-established sampling scheme although the main goal was to have samples well distributed both in the coastal and oceanic areas of the shelf. Consequently, the hauls were opportunistically carried out taking the advantage of the conduction of fishing hauls, the start or end of an acoustic transect or whatever discrete station devoted to the sampling of either hydrographical or biological variables which were close to the preferred depths.

Information on presence and abundance of sea birds, turtles and mammals was also recorded during the acoustic sampling by one onboard observer.

RESULTS

Acoustic sampling

The acoustic sampling started on 01st August in the coastal end of the transect RA01 and finalized on 11th August in the oceanic end of the transect RA21 (**Table 1, Figure 1**). Transects were acoustically sampled in the E-W direction. The whole 21-transect sampling grid was sampled. The acoustic sampling usually started at 06:00 UTC although this time might vary depending on the duration of the works related with the hydrographic sampling. The foreseen start of transects RA14 and RA15 by the coastal end had to be displaced into deeper waters in order to avoid the occurrence of open-sea fish farming/fattening cages.

Groundtruthing hauls

Twenty seven (27) fishing operations, all of them being considered as valid ones according to a correct gear performance and resulting catches, were carried out (**Table 2**, **Figure 4**).

As usual in previous surveys, some fishing hauls were attempted by fishing over an isobath crossing the acoustic transect as close as possible to the depths where the fishing situation of interest was detected over that transect. In this way the mixing of different size compositions (*i.e.*, bi-, multi-modality of length frequency distributions) was avoided as well as a direct interaction with fixed gears. The mixing of sizes is more probable close to nursery-recruitment areas and in regions with a very narrow continental shelf. This type of hauls is also conducted in depths showing hard and/or very irregular bottoms or when the echotraces to be identified either are very scarce or very located in the bathymetric gradient. Given that all of these situations were not very uncommon in the sampled area, 41% of valid hauls (11 hauls) were conducted over isobath.

Because of many echo-traces usually occurred close to the bottom, all the pelagic hauls were carried out like a bottom-trawl haul, with the ground rope working over or very close to the bottom. According to the above, the sampled depth range in the valid hauls oscillated between 42-183 m.

During the survey were captured 2 Chondrichthyan, 37 Osteichthyes, 6 Cephalopod, 3 Crustacean and Echinoderm species. The percentage of occurrence of the more frequent species in the trawl hauls is shown in the enclosed **text table below** (see also **Figure 5**). The table includes all the species under study and also those species with a higher occurrence than the former ones. The pelagic ichthyofauna was the most frequently captured species set and the one composing the bulk of the overall yields of the catches. Within this pelagic fish species set, chub mackerel was the most frequent captured species in the valid hauls (24 hauls, 89% presence index) followed by horse mackerel and anchovy (with relative occurrences of 74 and 63%, respectively), sardine, mackerel, jack mackerel, Atlantic pomfret (*Brama brama*) and bogue (between 37 and 48%), snipefish, boarfish and transparent goby (*Aphia minuta*) (19-22%), Mediterranean horse-mackerel and pearlside (7% each one). Round sardinella was absent in the catches and the occurrence of blue whiting (4%) was incidental.

For the purposes of the acoustic assessment, anchovy, sardine, mackerel species, horse & jack mackerel species, bogue, goby, pomfret, snipefish and pearlside were initially considered as the survey target species. All of the invertebrates, and both bentho-pelagic (*e.g.*, manta rays) and benthic fish species (*e.g.*, flatfish, gurnards, etc.) were excluded from the computation of the total catches in weight and in number from those fishing stations where they occurred. Catches of the remaining non-target species were included in an operational category termed as "*Others*".

According to the above premises, during the survey were captured a total of 25.9 tonnes and 841 thousand fish (**Table 3**). 49% of this fished biomass corresponded to chub mackerel, 33% to sardine, 8% to anchovy, and contributions lower than 3% to the remaining species. The most abundant species in ground-truthing trawl hauls was pearlside (27%), followed by sardine (27%), chub mackerel (24%), anchovy (17%) and snipefish (3%), with the remaining species showing lower contributions than 1.5%.

Species	# of fishing stations	Occurrence (%)	Total weight (kg)	Total number
Merluccius merluccius	25	93	118,878	1054
Scomber colias	24	89	12658,800	199954
Trachurus trachurus	20	74	654,182	5566
Loligo subulata	19	70	6,465	1041
Engraulis encrasicolus	17	63	2036,631	144812
Sardina pilchardus	13	48	8498,372	216529
Loligo media	12	44	3,131	1124
Scomber scombrus	12	44	35,398	375
Trachurus picturatus	12	44	184,676	3560
Brama brama	11	41	666,044	945
Boops boops	10	37	24,650	216
Spondyliosoma cantharus	9	33	12,683	61
Trachinus draco	9	33	3,671	35
Diplodus annularis	8	30	4,804	77
Pagellus erythrinus	8	30	56,959	327
Alosa fallax	7	26	2,684	10
Macroramphosus scolopax	6	22	204,464	28328
Capros aper	5	19	7,486	1221
Aphia minuta	5	19	4,593	11844
Pagellus acarne	5	19	35,573	108
Illex coindetii	5	19	1,100	29
Polybius henslowi	4	15	5,520	311
Diplodus bellottii	4	15	13,982	234
Lepidopus caudatus	4	15	0,138	5
Spicara flexuosa	3	11	15,226	243
Diplodus vulgaris	3	11	62,924	362
Chelidonichthys obscurus	2	7	0,214	2
Zeus faber	2	7	4,286	3
Trachurus mediterraneus	2	7	320,380	661
Maurolicus muelleri	2	7	167,214	226431
Loligo vulgaris	2	7	0,134	2
Lepidotrigla cavillone	1	4	0,088	3
Arnoglossus laterna	1	4	0,004	1
Mola mola	1	4	54,000	1
Microchirus boscanion	1	4	0,022	2
Raja clavata	1	4	0,368	1
Goneplax rhomboides	1	4	0,003	1
Micromesistius poutassou	1	4	0,022	1

The species composition, in terms of percentages in number, in each valid fish station is shown in **Figure 5**. A first impression of the distribution pattern of the main species may be derived from the above figure. Thus, anchovy was captured between Cape Santa María and Cape Trafalgar, although the highest yields were recorded in the Spanish central waters. The size composition of anchovy catches confirms the usual pattern exhibited by the species in the area during the survey season, with the largest fish inhabiting the westernmost waters and the smallest ones concentrated in the surroundings of the Guadalquivir river mouth and adjacent shallow waters (**Figure 6**). Sardine catches showed a quite similar distribution to the above described for anchovy, but showing the highest yields in the surroundings of the Cadiz Bay and between Cape Santa María and the Guadiana river mouth. Juvenile sardines were mainly captured in the shallowest hauls conducted in the coastal fringe between Matalascañas and the Bay of Cadiz (**Figure 7**). Chub mackerel, horse mackerel, blue jack mackerel and bogue, although they occurred in a great part of the study area, only showed relatively high yields in the Portuguese waters. Mediterranean horse mackerel, pomfret and transparent goby were restricted to the central and easternmost Spanish waters. The size composition of these last species in fishing hauls is shown in **Figures 8** to **18**.

Back-scattering energy attributed to the "pelagic assemblage" and individual species

A total of 328 nmi (ESDU) from 21 transects has been acoustically sampled by echo-integration for assessment purposes. From this total, 214 nmi (11 transects) were sampled in Spanish waters, and 114 nmi (10 transects) in the Portuguese waters. The enclosed text table below provides the nautical area-scattering coefficients attributed to each of the selected target species and for the whole "pelagic fish assemblage".

S_A (m^2 nmi^{-2})	**Total spp.**	**PIL**	**ANE**	**MAC**	**MAS**	**HOM**	**HMM**	**JAA**	**BOG**	**FIM**	**POA**	**SNS**	**MAV**
Total Area	259503	50456	74313	44	45335	6474	4904	2744	1265	12772	45617	6273	9307
(%)	(100,0)	(19,4)	(28,6)	(0,02)	(17,5)	(2,5)	(1,9)	(1,1)	(0,5)	(4,9)	(17,6)	(2,4)	(3,6)
Portugal	71465	10780	1402	2	43856	4889	0	2717	1206	0	0	6272	341
(%)	(27,5)	(21,4)	(1,9)	(4,5)	(96,7)	(75,5)	(0,0)	(99,0)	(95,3)	(0,0)	(0,0)	(99,9)	(3,7)
Spain	188038	39675	72910	41	1479	1585	4904	27	60	12772	45617	1	8967
(%)	(72,5)	(78,6)	(98,1)	(93,2)	(3,3)	(24,5)	(100,0)	(1,0)	(4,7)	(100,0)	(100,0)	(0,1)	(96,3)

For this "pelagic fish assemblage" has been estimated a total of 259 503 m^2 nmi^{-2}, the highest estimate ever recorded within the time-series (**Figure 19**). Portuguese waters accounted for 28% of this total back-scattering energy and the Spanish waters the remaining 72%. However, given that the Portuguese sampled ESDUs were almost the half of the Spanish ones, the (weighted-) relative importance of the Portuguese area (*i.e.*, its density of "pelagic fish") is actually much higher. The mapping of the total back-scattering energy is shown in **Figure 19**. By species, anchovy (29%), sardine (19%), pomfret and chub mackerel (18% each) were the most important species in terms of their contributions to the total back-scattering energy. Transparent goby (5%), pearlside (4%), Atlantic and Mediterranean horse mackerel and snipe fish (2-3%) were the following species in importance. The remaining species contributed with less than 1%.

Some inferences on the species' distribution may be carried out from regional contributions to the total energy attributed to each species: Mediterranean horse mackerel, pomfret, transparent goby, sardine, pearlside, mackerel and anchovy seemed to show greater densities in the Spanish waters, whereas chub mackerel, blue jack mackerel, horse mackerel, bogue and snipefish could be considered as typically "Portuguese species" in this survey.

According to the resulting values of integrated acoustic energy, the species acoustically assessed in the present survey finally were anchovy, sardine, mackerel, chub mackerel, blue jack mackerel, horse mackerel, Mediterranean horse mackerel, bogue, transparent goby, Atlantic pomfret, longspine snipefish and pearlside.

Spatial distribution and abundance/biomass estimates

Anchovy

Parameters of the survey's length-weight relationship for anchovy are given in **Table 4**. The back-scattering energy attributed to this species and the coherent strata considered for the acoustic estimation are shown in **Figure 20**. The estimated abundance and biomass by size class are given in **Table 5**, and **Figure 21**.

Anchovy was mainly distributed between Cape Santa Maria and Bay of Cadiz, although showing the highest densities in the Spanish shelf waters between El Rompido (RA10) and Bay of Cadiz (RA03) (**Figure 20**).

Five (5) coherent post-strata have been differentiated according to the S_A value distribution and the size composition in the fishing stations (**Figure 20**). The acoustic estimates by homogeneous post-stratum and total area are shown in **Table 5** and **Figure 21**. Overall acoustic estimates in summer 2019 were of 5 485 million fish and 57 700 tonnes. By geographical strata, the Spanish waters yielded 99% (5 405 million) and 97% (56 139 t) of the total estimated abundance and biomass in the Gulf, confirming the importance of these waters in the species' distribution. The estimates for the Portuguese waters were 80 million and 1 560 t. The current biomass estimate (57 700 t) becomes in the historical maximum within the time-series (2006: 35 539 t; 2016: 34 184 t; 2018: 34 908 t; see **Figure 36**). The *PELAGO 19* spring Portuguese survey previously estimated for this same area 29 876 t (3 398 million), with all the anchovy located in the Spanish waters.

The size class range of the assessed population varied between the 8.5 and 17.5 cm size classes, with one main modal class at 12.0 cm. The size composition of anchovy by coherent post-strata confirms the usual pattern exhibited by the species in the area during the spawning season, with the largest (and oldest) fish being distributed both in the westernmost waters and the smallest (and youngest) ones concentrated in the surroundings of the Guadalquivir river mouth and adjacent shallow waters (**Table 5; Figure 21;** see also **Figure 6**).

The Gulf of Cadiz anchovy egg distribution from CUFES sampling is shown in **Figure 22**. Anchovy egg distribution and densities in summer 2019 are quite coincident with that of adults. The estimated total egg density is higher than the observed in the most recent years but the spawning area showed a reduction as compared with those observed ones in previous years.

Sardine

Parameters of the survey's size-weight relationship for sardine are shown in **Table 4**. The back-scattering energy attributed to this species and the coherent strata considered for the acoustic estimation are shown in **Figure 23**. Estimated abundance and biomass by size class are given in **Table 6** and **Figure 24**.

Sardine also recorded a high acoustic echo-integration in summer 2019 as a consequence of the occurrence of dense mid-water schools in the coastal fringe (20-60 m depth) comprised between Ayamonte (RA11) and Doñana (RA06), (**Figure 23**).

Seven (7) size-based homogeneous sectors were delimited for the acoustic assessment (**Figure 23**). The estimates of Gulf of Cadiz sardine abundance and biomass in summer 2019 were 2 917 million fish and 62 682 t, a biomass well above the historical average (ca. 47 kt), but lower than the biomass estimated in 2018 (114 631 t; see **Figure 36**). Spanish waters concentrated the bulk of the population (2 495 million and 44 899 t). The estimates for the Portuguese waters were 422 million and 17 783 t.

Sizes of the assessed population ranged between 10.5 and 20.0 cm size classes. The length frequency distribution of the population was clearly bimodal, with one main mode at 11.5 cm size class and a secondary one at 15.0 cm (**Table 6**; **Figure 24**). The relatively important juvenile fraction in the estimated population (≤11.5 cm), was mainly located in relatively shallow waters along the coastal fringe comprised between Matalascañas and the Bay of Cadiz (**Table 6**; **Figure 24**; see also **Figure 7**).

Mackerel

Parameters of the survey's length-weight relationship are shown in **Table 4**. The distribution of the back-scattering energy attributed to this species is shown in **Figure 25**.

Atlantic mackerel showed very scattered and low acoustic records during the 2019 survey, which were mainly observed over the shelf located in the central part of the Gulf of Cadiz (**Figure 25**). Juveniles were mainly recorded in the Spanish outer shelf central waters, whereas larger fish occurred in shallower waters.

Chub mackerel

Parameters of the survey's length-weight relationship are shown in **Table 4**. The distribution of the back-scattering energy attributed to this species and the coherent strata considered for the acoustic estimation are shown in **Figure 26**. Estimated abundance and biomass by size class are given in **Table 7** and **Figure 27**.

Chub mackerel was widely distributed in the surveyed area, although the highest densities occurred all over the Portuguese shelf waters. In the Spanish waters the species occurred in the middle-outer shelf waters, where the smallest fish were also found (**Figure 26**).

Five (5) size-based homogeneous sectors were delimited for the acoustic assessment (**Figure 26**). The estimates of Gulf of Cadiz chub mackerel abundance and biomass in summer 2019 were 465 million fish and 32 696 t. These estimates and the most recent ones showed a relative stable recent trend, with biomasses very close to the historical average (ca. 35 kt; see **Figure 36**). Portuguese waters concentrated the bulk of the population (454 million and 31 536 t). The estimates for the Spanish waters were 11 million and 1 159 t.

Sizes of the assessed population ranged between 16.5 and 27.5 cm size classes. The length frequency distribution of the population was clearly mixed, with one main mode at 19.5 cm size class and a secondary one at 23.5 cm (**Table 7**; **Figure 27**).

Blue jack-mackerel

The survey's length-weight relationship for this species is given in **Table 4**. The distribution of the back-scattering energy attributed to this species is illustrated in **Figure 28**.

The species was mainly distributed all over the Portuguese outer shelf waters. An incidental occurrence was also recorded in the Spanish easternmost waters. The surveyed population was composed by juveniles and subadults (**Figure 28**).

Horse mackerel

The survey's length-weight relationship for horse mackerel is shown in **Table 4**. The back-scattering energy attributed to this species is shown in **Figure 29**.

Horse mackerel showed a quite similar distribution pattern to the abovementioned one for blue jack mackerel, with the species being almost absent in the easternmost shelf and showing relatively higher densities in the shelf area comprised between Cape San Vicente and Cape Santa Maria. Juveniles were scarce and occurred incidentally in the Spanish outer shelf central waters (**Figure 29**).

Mediterranean horse-mackerel

The survey's length-weight relationship for this species is shown in **Table 4**. Back-scattering energy attributed to the species is represented in **Figure 30**.

Mediterranean horse mackerel was restricted, as usual, to the Spanish waters, more specifically between Doñana and Sancti-Petri, with the population being composed by adult fish (**Figure 30**).

Bogue

Parameters of the survey's length-weight relationship for bogue are shown in **Table 4**. Back-scattering energy attributed to bogue is shown in **Figure 31**.

Bogue showed a distribution pattern quite similar to the described ones for blue jack mackerel and horse-mackerel, with a very incidental occurrence in Spanish waters (just in front of the Bay of Cadiz) and the highest densities being recorded in the westernmost waters of the Gulf (**Figure 31**).

Transparent goby

Parameters of the survey's length-weight relationship for transparent goby are shown in **Table 4**. Back-scattering energy attributed to the species is shown in **Figure 32**.

This gobiid species showed this year unusually high acoustic integration and densities, which were exclusively recorded over the inner-middle shelf waters of the Spanish part of the Gulf, between Mazagon and Bay of Cadiz. Its occurrence was associated to the typical (plankton-) scattering layer recorded close to the bottom in the Guadalquivir river mouth's influence area (**Figure 32**).

Atlantic pomfret

Parameters of the survey's length-weight relationship for *Brama brama* are shown in **Table 4**. Back-scattering energy attributed to the species is shown in **Figure 33**.

The Atlantic pomfret showed an unexpected high frequency of occurrence and abundance in the fishing hauls not recorded in previous surveys. The species acoustically contributed with 17% of the total NASC recorded in the survey, although it was restricted to the Spanish middle-outer shelf waters (**Figure 33**).

Longspine snipefish

The survey's length-weight relationship for this species is shown in **Table 4**. Back-scattering energy attributed to the species is represented in **Figure 34**.

M. scolopax showed an incidental occurrence mainly restricted to the westernmost outer shelf waters just to the west of Portimão (**Figure 34**).

Pearlside

The survey's length-weight relationship for this species is shown in **Table 4**. Back-scattering energy attributed to the species is represented in **Figure 35**.

Pearlside was located close to the deepest limit of the surveyed area (200 m), just in the transition between outer shelf and upper slope waters. The highest densities were recorded in the Spanish outer shelf (**Figure 35**).

(SHORT) DISCUSSION

The total NASC estimated in this survey for "pelagic fish assemblage", 259 503 m^2 nmi^{-2}, is the highest estimate ever recorded within the time-series (**Figure 19**), a situation which was repeated in the last year's survey. In the current survey such an increase in acoustic energy is the result of the relatively high partial contributions of anchovy, sardine, chub mackerel (as was also the case the last year), and the unexpected high contributions of the transparent goby and the Atlantic pomfret, species which usually have showed an accidental occurrence or very low abundance through the time-series. Anchovy has shown an increased contribution in relation to the one recorded last year, but almost exclusively restricted to the Spanish waters. In many of the anchovy positive hauls, this species was the dominant in terms of numbers and weight. Sardine also showed during the 2009 survey the occurrence of dense schools in the coastal (20-60 m) waters in the central part of the Gulf (between the Guadiana river mouth and Doñana), although not so numerous as in the 2018 survey.

The current anchovy biomass estimate (57 700 t) becomes in the historical maximum within the time-series (2006: 35 539 t; 2018: 34 908 t; see **Figure 36**) and denotes a strong increase in relation to the previous years, up to levels well above the historical average (ca. 24 kt), showing a recent increasing trend. Although the spring *PELAGO 19* survey also estimated increased population levels (29 876 t), such increase was not so pronounced as the estimated by its summer counterpart.

The estimates of Gulf of Cadiz sardine abundance and biomass in summer 2019 were 2 917 million fish and 62 682 t, a biomass well above the historical average (ca. 47 kt), but lower than the biomass estimated the previous year (114 631 t, **Figure 36**).

Chub mackerel acoustic estimates were of 465 million fish and 32 696 t, with the bulk of the population concentrated in the Portuguese waters, where the smallest fish were also recorded. Estimates showed a relative stable recent trend, with the recent biomasses very close to the historical average (ca. 35 kt; **Figure 36**).

ACKNOWLEDGMENTS

We are very grateful to the crew of the R/V *Miguel Oliver* and to all the scientific and technical staff participating in the present survey.

Unión Europea
Fondo Europeo Marítimo y
de Pesca (FEMP)

This survey has been funded by the EU through the European Maritime and Fisheries Fund (EMFF) 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.

REFERENCES

Demer, D.A., Berger, L., Bernasconi, M., Bethke, E., Boswell, K., Chu, D., Domokos, R., *et al*. 2015. Calibration of acoustic instruments. *ICES Coop. Res. Rep,* 326, 133 pp.

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

Foote, K.G., 1987. Fish target strengths for use in echo integrator surveys. *J. Acoust. Soc. Am*., 82 (3): 981-987.

ICES, 1998. Report of the Planning Group for Acoustic Surveys in ICES Sub-Areas VIII and IX. A Coruña, 30-31 January 1998. *ICES CM 1998/G:2*.

ICES, 2006a. Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES areas VIII and IX (WGACEGG), 24-28 October 2005, Vigo, Spain. *ICES, C.M. 2006/LRC: 01*. 126 pp.

ICES, 2006b. Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG), 27 November-1 December 2006, Lisbon, Portugal. *ICES C.M. 2006/LRC:18*. 169 pp.

Iglesias, M., Brothers, E.B., Morales-Nin, B., 1997. Validation of daily increment deposition in otoliths. Age and growth determination of *Aphia minuta* (Pisces: Gobiidae) from the northwest Mediterranean. *Mar. Biol*. 129: 279-287.

Jiménez, M.P., Tornero, J., González, C., Ramos, F., Sánchez-Leal, R.F. 2017. Anchovy spawning stock biomass of the Gulf of Cadiz in 2017 by the DEPM. Working document presented to the ICES Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas 7, 8 and 9. Cádiz (Spain), 13 – 17 November 2017.

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

Torres, M.A., Ramos, F., Sobrino, I., 2012. Length–weight relationships of 76 fish species from the Gulf of Cadiz (SW Spain). *Fish. Res*. (127-128): 171-175.

Table 1. *ECOCADIZ 2019-07 s*urvey. Descriptive characteristics of the acoustic tracks.

Acoustic Track	Location	Date	Start				End			
			Latitude	Longitude	UTC time	Mean depth (m)	Latitude	Longitude	UTC time	Mean depth (m)
R01	Trafalgar	01/08/19	36º 12,975' N	6º 08,870' W	06:06	23	36º 02,200' N	6º 28,800' W	10:02	241
R02	Sancti-Petri	01/08/19	36º 08,890' N	6º 34,190' W	11:04	149	36º 19,350' N	6º 14,860' W	14:48	28
R03	Cádiz	02/08/19	36º 26,712' N	6º 19,122' W	06:00	25	36º 17,150' N	6º 36,730' W	09:42	201
R04	Rota	02/08/19	36º 24,510' N	6º 40,720' W	10:39	200	36º 34,881' N	6º 21,885' W	00:00	20
R05	Chipiona	03/08/19	36º 31,220' N	6º 46,330' W	06:06	201	36º 40,347' N	6º 29,483' W	09:30	20
R06	Doñana	03/08/19	36º 46,610' N	6º 35,780' W	10:23	20	36º 38,050' N	6º 51,520' W	13:50	241
R07	Matalascañas	04/08/19	36º 54,300' N	6º 39,340' W	05:59	20	36º 44,006' N	6º 58,304' W	10:05	208
R08	Mazagón	04/08/19	36º 49,450' N	7º 06,060' W	13:58	192	37º 01,060' N	6º 44,720' W	17:36	23
R09	Punta Umbría	05/08/19	37º 03,902' N	6º 56,385' W	06:01	27	36º 49,663' N	7º 06,613' W	09:38	200
R10	El Rompido	05/08/19	36º 50,110' N	7º 07,200' W	13:20	156	37º 07,950' N	7º 07,190' W	16:38	21
R11	Isla Cristina	06/08/19	37º 06,762' N	7º 17,190' W	06:02	25	36º 53,379' N	7º 17,156' W	08:27	200
R12	V.R. do Sto. Antonio	06/08/19	36º 51,310' N	7º 27,130' W	10:52	129	37º 06,420' N	7º 27,140' W	13:25	21
R13	Tavira	07/08/19	37º 04,780' N	7º 37,140' W	06:00	20	36º 56,950' N	7º 37,090' W	06:44	214
R14	Fuzeta	07/08/19	36º 59,122' N	7º 47,076' W	15:44	44	36º 55,480' N	7º 47,040' W	16:06	65
R15	Cabo Sta. María	08/08/19	36º 55,590' N	7º 57,010' W	06:00	65	36º 52,070' N	7º 56,960' W	6:20	214
R16	Quarteira	08/08/19	36º 49,750' N	8º 06,880' W	10:26	111	37º 01,760' N	8º 07,040' W	11:38	20
R17	Albufeira	09/08/19	37º 01,452' N	8º 16,979' W	06:10	31	36º 49,376' N	8º 16,788' W	07:21	198
R18	Alfanzina	09/08/19	36º 50,290' N	8º 26,770' W	11:56	193	37º 04,550' N	8º 27,030' W	15:29	21
R19	Portimao	10/08/19	37º 05,990' N	8º 37,050' W	06:02	24	36º 51,270' N	8º 36,740' W	08:00	203
R20	Burgau	10/08/19	36º 51,960' N	8º 46,690' W	13:15	200	37º 02,644' N	8º 46,985' W	15:40	44
R21	Ponta de Sagres	11/08/19	36º 59,160' N	8º 56,800' W	05:59	26	36º 50,610' N	8º 56,610' W	06:49	208

Table 2. *ECOCADIZ 2019-07* survey. Descriptive characteristics of the fishing stations.

FISHING STATION	DATE	POSITION						TIMING				TRAWLED DISTANCE (nmi)	ACOUSTIC TRANSECT	ZONE/LANDMARK
		START			END			START	END	EFFECTIVE TRAWLING	TOTAL MANEOUVRE			
		LAT.	LON.	PROF.	LAT.	LON.	PROF.	UTC	UTC					
PE01	01-08-2019	36º 02.8258 N	6º 27.5187 W	118.26	36º 04.6665 N	6º 24.2185 W	92.6	08:17	09:02	0:45	1:10	3.246	R01	Cape Trafalgar
PE02	01-08-2019	36º 12.2035 N	6º 28.0417 W	100.28	36º 10.4644 N	6º 31.2328 W	120.76	12:07	12:50	0:43	1:12	3.113	R02	Sancti-Petri
PE03	02-08-2019	36º 22.2477 N	6º 27.1795 W	62.66	36º 24.1798 N	6º 23.7697 W	49.62	07:17	08:08	0:51	1:17	3.362	R03	Cádiz
PE04	02-08-2019	36º 23.9902 N	6º 39.4744 W	175.4	36º 25.6666 N	6º 40.9363 W	183.04	11:37	12:05	0:27	1:02	2.048	R04	Rota
PE05	02-08-2019	36º 29.0500 N	6º 32.7102 W	73.03	36º 27.2992 N	6º 35.7808 W	96.73	13:34	14:16	0:42	1:07	3.032	R04	Rota
PE06	03-08-2019	36º 37.4764 N	6º 35.0545 W	46.66	36º 35.7088 N	6º 38.0509 W	68.01	07:41	08:23	0:41	1:02	2.989	R05	Chipiona
PE07	03-08-2019	36º 39.8023 N	6º 48.2119 W	108.63	36º 41.6428 N	6º 44.9131 W	79.21	12:03	12:49	0:45	1:11	3.228	R06	Doñana
PE08	04-08-2019	36º 48.2986 N	6º 47.7196 W	57.98	36º 51.2457 N	6º 50.2405 W	57.49	07:47	8:37	0:50	1:10	3.572	R07	Matalascañas
PE09	04-08-2019	36º 47.1990 N	6º 52.5756 W	94.96	36º 45.3591 N	6º 55.7908 W	118.79	11:50	12:35	0:45	1:11	3.17	R07	Matalascañas
PE10	04-08-2019	36º 53.5684 N	6º 55.1256 W	72.92	36º 55.4394 N	6º 56.9512 W	69.32	15:26	15:59	0:33	0:59	2.374	R08	Mazagón
PE11	05-08-2019	36º 58.8694 N	6º 59.2051 W	54.47	37º 00.7732 N	7º 01.8807 W	48.83	07:21	08:03	0:41	1:16	2.865	R09	Punta Umbría
PE12	05-08-2019	36º 52.7992 N	7º 03.8962 W	109.65	36º 50.4193 N	7º 05.2735 W	141.78	12:09	12:46	0:37	1:05	2.621	R09	Punta Umbría
PE13	05-08-2019	36º 58.1839 N	7º 07.1824 W	81.75	36º 55.8414 N	7º 07.1809 W	99.68	14:34	15:07	0:32	0:57	2.34	R10	El Rompido
PE14	06-08-2019	36º 58.9606 N	7º 27.0352 W	105.34	36º 56.8828 N	7º 27.0894 W	135.35	11:36	12:05	0:28	0:56	2.076	R12	Vila Real do Santo Antonio
PE15	06-08-2019	37º 04.6033 N	7º 25.0948 W	43.02	37º 04.6153 N	7º 28.6036 W	44.79	14:31	15:10	0:39	0:59	2.808	R12	Vila Real do Santo Antonio
PE16	07-08-2019	36º 57.8844 N	7º 35.8137 W	126.63	36º 58.3597 N	7º 39.6316 W	124.62	07:51	08:34	0:42	1:20	3.096	R13	Tavira
PE17	07-08-2019	36º 59.7265 N	7º 35.1627 W	103.56	36º 59.1631 N	7º 37.8753 W	103.27	12:09	12:41	0:31	1:02	2.245	R13	Tavira
PE18	07-08-2019	37º 03.4497 N	7º 34.8718 W	45.56	37º 02.8950 N	7º 37.0614 W	42.44	14:09	14:35	0:25	0:47	1.838	R13	Tavira
PE19	08-08-2019	36º 54.6022 N	7º 56.9863 W	77.54	36º 52.6036 N	7º 56.9668 W	108.33	07:03	07:31	0:28	1:01	1.996	R15	Cape Santa María
PE20	08-08-2019	36º 57.7930 N	8º 06.8919 W	44.07	36º 56.3266 N	8º 06.8956 W	48.78	12:14	12:34	0:20	0:51	1.464	R16	Quarteira
PE21	08-08-2019	36º 51.8557 N	8º 05.6689 W	111.81	36º 50.7514 N	8º 07.9687 W	107.01	14:18	14:48	0:29	1:07	2.15	R16	Quarteira
PE22	09-08-2019	36º 50.5998 N	8º 15.6259 W	118.65	36º 51.9970 N	8º 18.5947 W	116.37	08:50	09:29	0:39	1:06	2.761	R17	Albufeira
PE23	09-08-2019	36º 57.2746 N	8º 26.9154 W	85.23	36º 53.8497 N	8º 26.8420 W	123.63	13:13	14:01	0:48	1:14	3.421	R18	Alfanzina
PE24	10-08-2019	36º 52.8750 N	8º 36.7405 W	115.4	36º 55.0627 N	8º 36.7875 W	101.16	08:34	09:04	0:30	0:58	2.185	R19	Portimao
PE25	10-08-2019	36º 52.3045 N	8º 35.9494 W	114.11	36º 52.8616 N	8º 38.8939 W	117.34	11:35	12:09	0:34	1:04	2.427	R19	Portimao
PE26	10/08/2019	36º 56.9764 N	8º 46.7872 W	109.7	36º 55.4947 N	8º 46.7656 W	113.93	14:16	14:36	0:20	0:46	1.48	R20	Burgau
PE27	11/08/2019	36º 51.7239 N	8º 56.6149 W	145.45	36º 54.4681 N	8º 56.6929 W	116.09	7:22	8:01	0:38	1:09	2.741	R21	Ponta de Sagres

Table 3. *ECOCADIZ 2019-07* survey. Catches by species in number (upper panel) and weight (in kg, lower panel) from valid fishing stations.

CATCH IN NUMBERS															
Fishing station	**ANE**	**PIL**	**MAS**	**MAC**	**HOM**	**JAA**	**HMM**	**BOG**	**FIM**	**POA**	**WHB**	**BOC**	**SNS**	**MAV**	**OTHERS SPP**	**TOTAL**
01	0	0	6	0	3	0	0	0	0	0	0	334	4	0	16	**363**
02	1	0	27	1	658	6	646	0	0	76	0	8	0	0	80	**1503**
03	152	4431	0	4	2	0	0	1	0	14	0	0	0	0	269	**4873**
04	0	0	0	0	0	0	0	0	0	106	0	0	0	226417	2	**226525**
05	3695	12	6	13	2	0	0	0	7343	274	0	0	0	0	132	**11477**
06	6517	3229	0	0	1	0	15	0	1603	9	0	0	0	0	51	**11425**
07	6364	0	28	0	2	0	0	0	452	20	0	0	0	0	34	**6900**
08	551	3	1	105	0	0	0	0	2430	395	0	0	0	0	67	**3552**
09	5778	0	61	116	0	0	0	0	0	4	0	0	0	0	39	**5998**
10	6147	0	1	37	1	0	0	0	16	4	0	0	0	0	68	**6274**
11	2182	16	17	13	2	0	0	0	0	41	0	0	0	0	217	**2488**
12	34223	0	15	2	0	1	0	0	0	0	0	0	0	0	45	**34286**
13	53810	621	22	39	1	0	0	0	0	2	0	0	0	0	42	**54537**
14	16713	88584	2095	0	0	0	0	0	0	0	0	0	0	0	5	**107397**
15	188	109	1	21	5	0	0	14	0	0	0	0	0	0	138	**476**
16	1	59	7228	0	0	487	0	0	0	0	0	0	10	0	0	**7785**
17	8134	86254	34326	0	0	0	0	0	0	0	0	0	0	0	6	**128720**
18	0	29945	32	23	634	40	0	34	0	0	0	0	0	0	401	**31109**
19	353	12	3146	1	448	14	0	18	0	0	0	0	0	0	436	**4428**
20	0	3254	147256	0	49	0	0	0	0	0	0	0	0	0	0	**150559**
21	3	0	344	0	3194	88	0	20	0	0	0	0	0	0	97	**3746**
22	0	0	1839	0	30	810	0	0	0	0	0	824	22	0	62	**3587**
23	0	0	852	0	297	7	0	67	0	0	1	15	3	14	225	**1481**
24	0	0	1347	0	12	18	0	18	0	0	0	0	1	0	12	**1408**
25	0	0	101	0	14	211	0	13	0	0	0	40	28288	0	2	**28669**
26	0	0	1180	0	177	7	0	22	0	0	0	0	0	0	36	**1422**
27	0	0	23	0	34	36	0	9	0	0	0	0	0	0	22	**124**
TOTAL	**144812**	**216529**	**199954**	**375**	**5566**	**1725**	**661**	**216**	**11844**	**945**	**1**	**1221**	**28328**	**226431**	**2504**	**841112**

Table 3. *ECOCADIZ 2019-07* survey. Cont'd.

CATCH IN WEIGHT (kg)																
Fishing station	**ANE**	**PIL**	**MAS**	**MAC**	**HOM**	**JAA**	**HMM**	**BOG**	**FIM**	**POA**	**WHB**	**BOC**	**SNS**	**MAV**	**OTHERS SPP**	**TOTAL**
01	0	0	0,780	0	0,148	0	0	0	0	0	0	1,866	0,024	0	2,662	**5,480**
02	0,008	0	3,080	0,166	94,050	2,340	316,800	0	0	52,367	0	0,044	0	0	7,869	**476,724**
03	1,678	102,700	0	1,632	0,142	0	0	0,278	0	9,550	0	0	0	0	38,754	**154,734**
04	0	0	0	0	0	0	0	0	0	81,647	0	0	0	167,200	0,074	**248,921**
05	43,550	0,225	0,520	1,030	0,007	0	0	0	3,130	189,050	0	0	0	0	13,908	**251,420**
06	50,480	38,784	0	0	0,003	0	3,580	0	0,774	6,900	0	0	0	0	4,218	**104,739**
07	79,550	0	1,664	0	0,006	0	0	0	0,232	13,950	0	0	0	0	3,490	**98,892**
08	5,730	0,074	0,182	5,754	0	0	0	0	0,450	274,650	0	0	0	0	6,655	**293,495**
09	78,240	0	6,250	4,902	0	0	0	0	0	3,200	0	0	0	0	4,966	**97,558**
10	75,550	0	0,140	1,587	0,005	0	0	0	0,007	3,372	0	0	0	0	6,072	**86,733**
11	25,550	0,326	2,213	3,474	0,032	0	0	0	0	29,450	0	0	0	0	13,662	**74,707**
12	444,700	0	1,192	0,070	0	0,013	0	0	0	0	0	0	0	0	4,379	**450,354**
13	712,850	11,350	0,738	2,572	0,014	0	0	0	0	1,908	0	0	0	0	4,734	**734,166**
14	334,672	3218,545	137,601	0	0	0	0	0	0	0	0	0	0	0	1,720	**3692,538**
15	2,234	2,080	0,193	6,660	0,420	0	0	1,970	0	0	0	0	0	0	15,665	**29,222**
16	0,019	2,780	521,050	0	0	70,837	0	0	0	0	0	0	0,121	0	0	**594,807**
17	174,312	3739,108	2191,580	0	0	0	0	0	0	0	0	0	0	0	2,222	**6107,222**
18	0	1216,776	2,446	7,225	50,486	1,702	0	4,188	0	0	0	0	0	0	48,193	**1331,016**
19	7,410	0,462	315,480	0,326	55,150	0,834	0	2,728	0	0	0	0	0	0	97,366	**479,756**
20	0	165,162	8908,991	0	1,595	0	0	0	0	0	0	0	0	0	0	**9075,748**
21	0,098	0	37,300	0	390,500	6,654	0	2,640	0	0	0	0	0	0	5,570	**442,762**
22	0	0	201,850	0	3,696	80,950	0	0	0	0	0	4,830	0,227	0	8,728	**300,281**
23	0	0	74,750	0	31,300	0,300	0	7,285	0	0	0,022	0,084	0,032	0,014	31,472	**145,259**
24	0	0	120,600	0	1,316	1,690	0	1,028	0	0	0	0	0,010	0	1,072	**125,716**
25	0	0	10,470	0	0,761	15,350	0	1,355	0	0	0	0,662	204,050	0	54,096	**286,744**
26	0	0	117,250	0	20,200	0,454	0	2,137	0	0	0	0	0	0	6,884	**146,925**
27	0	0	2,480	0	4,351	3,552	0	1,041	0	0	0	0	0	0	6,270	**17,694**
TOTAL	**2036,631**	**8498,372**	**12658,800**	**35,398**	**654,182**	**184,676**	**320,380**	**24,650**	**4,593**	**666,044**	**0,022**	**7,486**	**204,464**	**167,214**	**390,701**	**25853,613**

Table 4. *ECOCADIZ 2019-07* survey. Parameters of the size-weight relationships for survey's target species. FAO codes for the species: ANE: *Engraulis encrasicolus*; PIL: *Sardina pilchardus*; MAS: *Scomber colias*; MAC: *Scomber scombrus*; HOM: *Trachurus trachurus*; JAA: *Trachurus picturatus;* HMM: *Trachurus mediterraneus*; BOG: *Boops boops*; FIM: *Aphia minuta*; POA: *Brama brama*: BOC: *Capros aper*; SNS: *Macrorhamphosus scolopax*; MAV: *Maurolicus muelleri*. (*) FIM's LW relationship parameters following Iglesias *et al*. (1997).

PARAMETER	ANE	PIL	MAS	MAC	HOM	JAA	HMM	BOG	FIM(*)	POA
Size range (mm)	92-173	108-202	132-343	158-381	66-336	121-384	282-463	193-297		358-517
n	723	469	766	229	408	320	65	167		388
a	0,002644	0,002409	0,003183	0,002395	0,008879	0,007130	0,029374	0,005556	0,004000	0,027261
b	3,356048	3,460818	3,286908	3,351769	2,974619	3,048874	2,630445	3,157324	3,690000	2,722180
r^2	0,95	0,95	0,96	0,99	0,94	0,99	0,97	0,84		0,71

PARAMETER	BOC	SNS	MAV
Size range (mm)	53-104	94-164	36-64
n	181	96	98
a	0,034164	0,003662	0,010578
b	2,743768	3,158905	2,869503
r^2	0,99	0,80	0,96

Table 5. *ECOCADIZ 2019-07* survey. Anchovy (*E. encrasicolus*). Estimated abundance (absolute numbers and million fish) and biomass (t) by size class (in cm). Polygons (*i.e.*, coherent or homogeneous post-strata) numbered as in **Figure 20**.

***ECOCADIZ 2019-07 . Engraulis encrasicolus .* ABUNDANCE (in numbers and million fish)**											
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	***n***			**Millions**		
						PORTUGAL	**SPAIN**	**TOTAL**	**PORTUGAL**	**SPAIN**	**TOTAL**
6	0	0	0	0	0	0	0	0	0	0	0
6,5	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0
7,5	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0
8,5	0	0	0	0	75490733	0	75490733	75490733	0	75	75
9	0	0	0	0	320755985	0	320755985	320755985	0	321	321
9,5	0	0	0	0	339549037	0	339549037	339549037	0	340	340
10	0	30229	0	28787841	396246718	30229	425034559	425064788	0,03	425	425
10,5	0	88331	0	84121160	396246718	88331	480367878	480456209	0,1	480	480
11	0	296251	0	282131250	301962933	296251	584094183	584390434	0,3	584	584
11,5	0	684742	0	652106300	75490733	684742	727597033	728281775	1	728	728
12	526172	1027334	85251	978369750	94283785	1553506	1072738786	1074292292	2	1073	1074
12,5	4276461	727989	692874	693292319	56697682	5004450	750682875	755687325	5	751	756
13	12520921	423300	2028645	403124967	18793052	12944221	423946664	436890885	13	424	437
13,5	17191270	122965	2785336	117104394	0	17314235	119889730	137203965	17	120	137
14	18025661	57916	2920525	55155988	0	18083577	58076513	76160090	18	58	76
14,5	10746620	14341	1741172	13657314	0	10760961	15398486	26159447	11	15	26
15	5221908	5029	846056	4789252	0	5226937	5635308	10862245	5	6	11
15,5	3803656	2933	616270	2793205	0	3806589	3409475	7216064	4	3	7
16	1918459	2096	310830	1996047	0	1920555	2306877	4227432	2	2	4
16,5	1266905	0	205264	0	0	1266905	205264	1472169	1	0,2	1
17	633641	0	102663	0	0	633641	102663	736304	1	0,1	1
17,5	128131	0	20760	0	0	128131	20760	148891	0,1	0,02	0,1
18	0	0	0	0	0	0	0	0	0	0	0
18,5	0	0	0	0	0	0	0	0	0	0	0
TOTAL *n*	76259805	3483456	12355646	3317429787	2075517376	79743261	5405302809	5485046070	**80**	**5405**	**5485**
Millions	**76**	**3**	**12**	**3317**	**2076**						

Table 5. *ECOCADIZ 2019-07* survey. Anchovy (*E. encrasicolus*). Cont'd.

***ECOCADIZ 2019-07* . *Engraulis encrasicolus* . BIOMASS (t)**								
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	**PORTUGAL**	**SPAIN**	**TOTAL**
6	0	0	0	0	0	**0**	**0**	**0**
6,5	0	0	0	0	0	**0**	**0**	**0**
7	0	0	0	0	0	**0**	**0**	**0**
7,5	0	0	0	0	0	**0**	**0**	**0**
8	0	0	0	0	0	**0**	**0**	**0**
8,5	0	0	0	0	288,531	**0**	**288,531**	**288,531**
9	0	0	0	0	1478,103	**0**	**1478,103**	**1478,103**
9,5	0	0	0	0	1868,042	**0**	**1868,042**	**1868,042**
10	0	0,197	0	187,412	2579,613	**0,197**	**2767,026**	**2767,222**
10,5	0	0,675	0	642,860	3028,146	**0,675**	**3671,007**	**3671,682**
11	0	2,638	0	2512,574	2689,189	**2,638**	**5201,763**	**5204,402**
11,5	0	7,059	0	6722,832	778,265	**7,059**	**7501,097**	**7508,156**
12	6,241	12,186	1,011	11605,228	1118,376	**18,427**	**12724,614**	**12743,042**
12,5	58,038	9,880	9,403	9409,065	769,477	**67,918**	**10187,945**	**10255,864**
13	193,418	6,539	31,338	6227,295	290,307	**199,957**	**6548,940**	**6748,896**
13,5	300,825	2,152	48,740	2049,178	0	**302,977**	**2097,917**	**2400,894**
14	355,721	1,143	57,634	1088,457	0	**356,864**	**1146,092**	**1502,956**
14,5	238,178	0,318	38,590	302,688	0	**238,496**	**341,278**	**579,774**
15	129,476	0,125	20,978	118,749	0	**129,601**	**139,727**	**269,328**
15,5	105,129	0,081	17,033	77,201	0	**105,210**	**94,234**	**199,444**
16	58,906	0,064	9,544	61,288	0	**58,970**	**70,832**	**129,802**
16,5	43,077	0	6,979	0	0	**43,077**	**6,979**	**50,057**
17	23,787	0	3,854	0	0	**23,787**	**3,854**	**27,641**
17,5	5,296	0	0,858	0	0	**5,296**	**0,858**	**6,154**
18	0	0	0	0	0	**0**	**0**	**0**
18,5	0	0	0	0	0	**0**	**0**	**0**
TOTAL	**1518,093**	**43,057**	**245,962**	**41004,828**	**14888,048**	**1561,150**	**56138,839**	**57699,989**

Table 6. *ECOCADIZ 2019-07* survey. Sardine (*S. pilchardus*). Estimated abundance (absolute numbers and million fish) and biomass (t) by size class (in cm). Polygons (*i.e.*, coherent or homogeneous post-strata) numbered as in **Figure 23**.

***ECOCADIZ 2019-07 . Sardina pilchardus* . ABUNDANCE (in numbers and million fish)**

Size class	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	**POL06**	**POL07**	***n***			**Millions**		
								PORTUGAL	**SPAIN**	**TOTAL**	**PORTUGAL**	**SPAIN**	**TOTAL**
6	0	0	0	0	0	0	0	0	0	0	0	0	0
6,5	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0
7,5	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0
8,5	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0
9,5	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0
10,5	0	0	0	0	0	46134625	0	0	46134625	46134625	0	46	46
11	0	0	0	0	0	401738683	0	0	401738683	401738683	0	402	402
11,5	0	0	5287	344650	0	434808636	6533734	5287	441687020	441692307	0,01	442	442
12	0	0	123877	8075256	0	230673126	51803176	123877	290551558	290675435	0,1	291	291
12,5	0	0	477036	31096837	0	158000885	174544036	477036	363641758	364118794	0,5	364	364
13	0	0	623775	40662444	0	39602289	103373005	623775	183637738	184261513	1	184	184
13,5	0	689625	435540	28391856	12	0	103373005	1125165	131764873	132890038	1	132	133
14	0	0	263791	17195950	0	0	90538885	263791	107734835	107998626	0,3	108	108
14,5	0	5858790	173399	11303478	101	0	168010302	6032189	179313881	185346070	6	179	185
15	0	18549645	50371	3283575	320	0	168010302	18600016	171294197	189894213	19	171	190
15,5	0	55071293	15861	1033950	951	6532336	90538885	55087154	98106122	153193276	55	98	153
16	421819	77868987	0	0	1344	0	58103563	78290806	58104907	136395713	78	58	136
16,5	1068476	95100475	19899	1297138	1642	0	19367854	96188850	20666634	116855484	96	21	117
17	1522131	80488671	0	0	1390	0	0	82010802	1390	82012192	82	0,001	82
17,5	1619626	49191791	0	0	849	0	0	50811417	849	50812266	51	0,001	51
18	907309	20445846	0	0	353	408271	0	21353155	408624	21761779	21	0,4	22
18,5	712317	4423230	0	0	76	0	0	5135547	76	5135623	5	0,0001	5
19	161167	5773899	0	0	100	0	0	5935066	100	5935166	6	0,0001	6
19,5	31835	0	0	0	0	0	0	31835	0	31835	0,03	0	0,03
20	31835	0	0	0	0	0	0	31835	0	31835	0,03	0	0,03
20,5	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0
21,5	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL *n*	6476515	413462252	2188836	142685134	7138	1317898851	1034196747	422127603	2494787870	2916915473	**422**	**2495**	**2917**
Millions	**6**	**413**	**2**	**143**	**0,01**	**1318**	**1034**	**422**	**2495**	**2917**			

Table 6. *ECOCADIZ 2019-07* survey. Sardine (*S. pilchardus*). Cont'd.

***ECOCADIZ 2019-07 . Sardina pilchardus* . BIOMASS (t)**										
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	**POL06**	**POL07**	**PORTUGAL**	**SPAIN**	**TOTAL**
6	0	0	0	0	0	0	0	0	0	0
6,5	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
7,5	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0
8,5	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0
9,5	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
10,5	0	0	0	0	0	412,386	0	0	412,386	412,385673
11	0	0	0	0	0	4202,917	0	0	4202,917	4202,91701
11,5	0	0	0,064	4,191	0	5287,667	79,456	0,064	5371,314	5371,37823
12	0	0	1,740	113,438	0	3240,392	727,708	1,740	4081,537	4083,27737
12,5	0	0	7,696	501,701	0	2549,110	2816,010	7,696	5866,822	5874,51786
13	0	0	11,497	749,442	0	729,902	1905,249	11,497	3384,593	3396,08951
13,5	0	14,449	9,125	594,856	0,0003	0	2165,834	23,574	2760,690	2784,2644
14	0	0	6,254	407,689	0	0	2146,535	6,254	2554,224	2560,47808
14,5	0	156,511	4,632	301,959	0,003	0	4488,197	161,143	4790,159	4951,30207
15	0	556,131	1,510	98,444	0,010	0	5037,059	557,641	5135,513	5693,15333
15,5	0	1846,099	0,532	34,660	0,032	218,977	3035,043	1846,631	3288,712	5135,34216
16	15,755	2908,488	0	0	0,050	0	2170,228	2924,243	2170,279	5094,52169
16,5	44,322	3944,889	0,825	53,807	0,068	0	803,403	3990,036	857,278	4847,31409
17	69,906	3696,548	0	0	0,064	0	0	3766,453	0,064	3766,51731
17,5	82,115	2494,022	0	0	0,043	0	0	2576,137	0,043	2576,18052
18	50,643	1141,211	0	0	0,020	22,788	0	1191,853	22,808	1214,66132
18,5	43,657	271,097	0	0	0,005	0	0	314,755	0,005	314,759189
19	10,820	387,623	0	0	0,007	0	0	398,443	0,007	398,449639
19,5	2,336	0	0	0	0	0	0	2,336	0	2,335535
20	2,547	0	0	0	0	0	0	2,547	0	2,546617
20,5	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0
21,5	0	0	0	0	0	0	0	0	0	0
TOTAL	**322,100**	**17417,066**	**43,876**	**2860,187**	**0,301**	**16664,139**	**25374,722**	**17783,042**	**44899,349**	**62682,392**

Table 6. *ECOCADIZ 2019-07* survey. Chub mackerel (*S. colias*). Estimated abundance (absolute numbers and million fish) and biomass (t) by size class (in cm). Polygons (*i.e.*, coherent or homogeneous post-strata) numbered as in **Figure 26**.

***ECOCADIZ 2019-07 . Scomber colias .* ABUNDANCE (in numbers and million fish)**

Size class	POL01	POL02	POL03	POL04	POL05	*n*			Millions		
						PORTUGAL	SPAIN	TOTAL	PORTUGAL	SPAIN	TOTAL
14	0	0	0	0	0	0	0	0	0	0	0
14,5	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
15,5	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
16,5	0	0	77681	59963	0	137644	0	137644	0,1	0	0,1
17	0	0	0	246882	0	246882	0	246882	0,2	0	0,2
17,5	1300	3129413	392794	609828	0	4133335	0	4133335	4	0	4
18	14944	35976560	1290155	1344685	0	38626344	0	38626344	39	0	39
18,5	12345	29719859	605556	1229431	0	31567191	0	31567191	32	0	32
19	17544	42235385	372795	2174674	0	44800398	0	44800398	45	0	45
19,5	25341	61005487	638051	3094861	0	64763740	0	64763740	65	0	65
20	23392	56312430	532860	4631120	0	61499802	0	61499802	61	0	61
20,5	19493	46926317	2146888	8474131	0	57566829	0	57566829	58	0	58
21	8447	20335870	4786827	5736797	0	30867941	0	30867941	31	0	31
21,5	5848	14079170	8587093	3710154	564893	26382265	564893	26947158	26	1	27
22	1300	3129413	10340636	1568805	1506382	15040154	1506382	16546536	15	2	17
22,5	0	0	13177806	893268	753191	14071074	753191	14824265	14	1	15
23	0	0	14085391	773343	2824466	14858734	2824466	17683200	15	3	18
23,5	0	0	15833475	623566	2071275	16457041	2071275	18528316	16	2	19
24	0	0	10953874	79489	2447871	11033363	2447871	13481234	11	2	13
24,5	0	0	8232993	39744	753191	8272737	753191	9025928	8	1	9
25	0	0	5789958	0	188298	5789958	188298	5978256	6	0,2	6
25,5	0	0	3752320	583821	188298	4336141	188298	4524439	4	0,2	5
26	0	0	1602233	0	0	1602233	0	1602233	2	0	2
26,5	0	0	678786	0	0	678786	0	678786	1	0	1
27	0	0	765255	34523	0	799778	0	799778	1	0	1
27,5	0	0	70230	0	0	70230	0	70230	0,1	0	0,1
28	0	0	0	0	0	0	0	0	0	0	0
28,5	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0
TOTAL *n*	129954	312849904	104713657	35909085	11297865	453602600	11297865	464900465	**454**	**11**	**465**
Millions	**0,1**	**313**	**105**	**36**	**11**						

Table 6. *ECOCADIZ 2019-07* survey. Chub mackerel (*S. colias*). Cont'd.

***ECOCADIZ 2019-07*. *Scomber colias*. BIOMASS (t)**								
Size class	**POL01**	**POL02**	**POL03**	**POL04**	**POL05**	**PORTUGAL**	**SPAIN**	**TOTAL**
14	0	0	0	0	0	0	0	0
14,5	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
15,5	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0
16,5	0	0	2,608	2,013	0	4,621	0	4,621
17	0	0	0	9,131	0	9,131	0	9,131
17,5	0,053	127,133	15,957	24,774	0	167,917	0	167,917
18	0,665	1601,288	57,424	59,851	0	1719,228	0	1719,228
18,5	0,601	1445,705	29,457	59,805	0	1535,568	0	1535,568
19	0,931	2240,150	19,773	115,344	0	2376,197	0	2376,197
19,5	1,462	3520,251	36,818	178,585	0	3737,117	0	3737,117
20	1,465	3527,752	33,382	290,121	0	3852,721	0	3852,721
20,5	1,323	3185,141	145,721	575,185	0	3907,370	0	3907,370
21	0,620	1492,672	351,358	421,086	0	2265,736	0	2265,736
21,5	0,463	1115,520	680,372	293,963	44,758	2090,319	44,758	2135,076
22	0,111	267,182	882,860	133,941	128,612	1284,095	128,612	1412,706
22,5	0	0	1210,350	82,045	69,179	1292,395	69,179	1361,573
23	0	0	1389,538	76,291	278,636	1465,829	278,636	1744,465
23,5	0	0	1675,139	65,972	219,135	1741,111	219,135	1960,246
24	0	0	1241,031	9,006	277,334	1250,037	277,334	1527,371
24,5	0	0	997,484	4,815	91,254	1002,300	91,254	1093,554
25	0	0	749,160	0	24,364	749,160	24,364	773,524
25,5	0	0	517,833	80,569	25,986	598,402	25,986	624,388
26	0	0	235,542	0	0	235,542	0	235,542
26,5	0	0	106,172	0	0	106,172	0	106,172
27	0	0	127,209	5,739	0	132,948	0	132,948
27,5	0	0	12,393	0	0	12,393	0	12,393
28	0	0	0	0	0	0	0	0
28,5	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0
TOTAL	**7,694**	**18522,796**	**10517,581**	**2488,236**	**1159,258**	**31536,307**	**1159,258**	**32695,565**

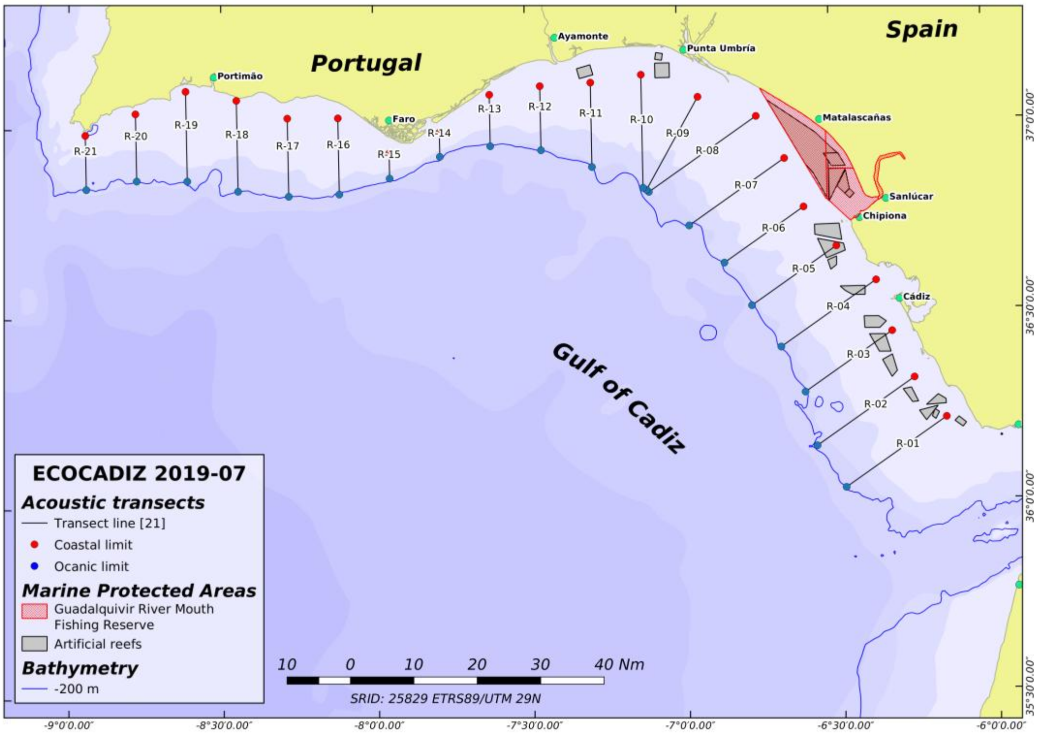


Figure 1. *ECOCADIZ 2019-07* survey. Location of the acoustic transects sampled during the survey. The different protected areas inside the Guadalquivir river mouth Fishing Reserve and artificial reef polygons are also shown.

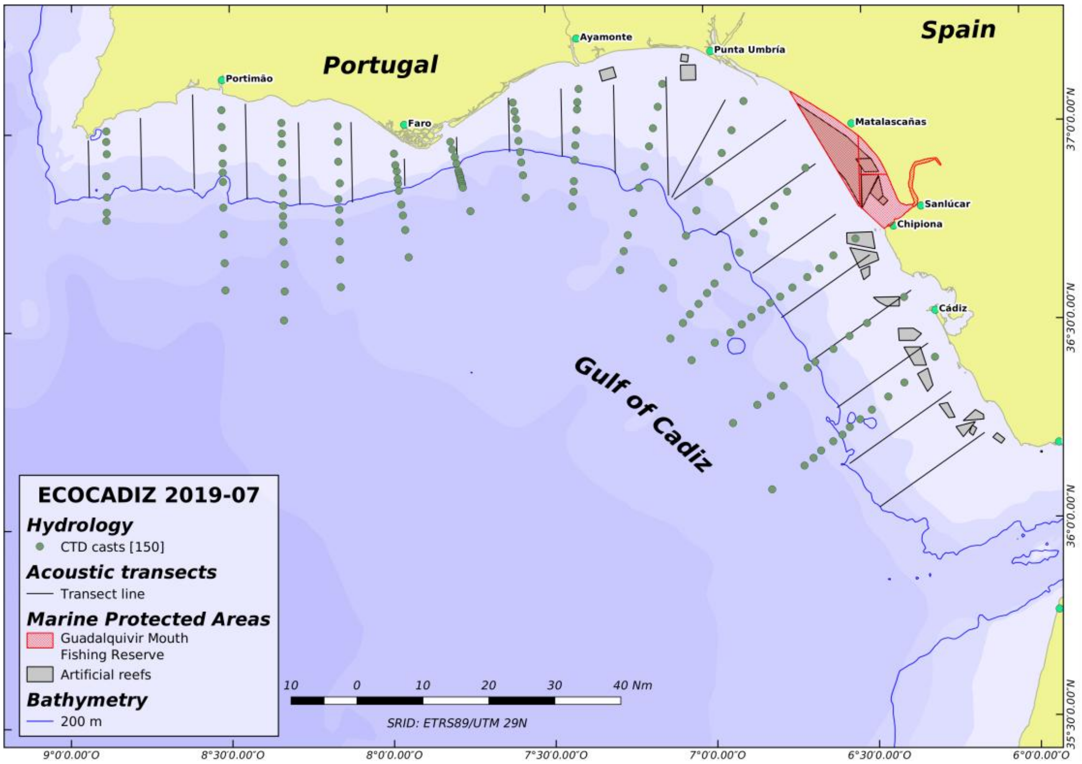


Figure 2. *ECOCADIZ 2019-07* survey. Location of CTD-LADCP stations.

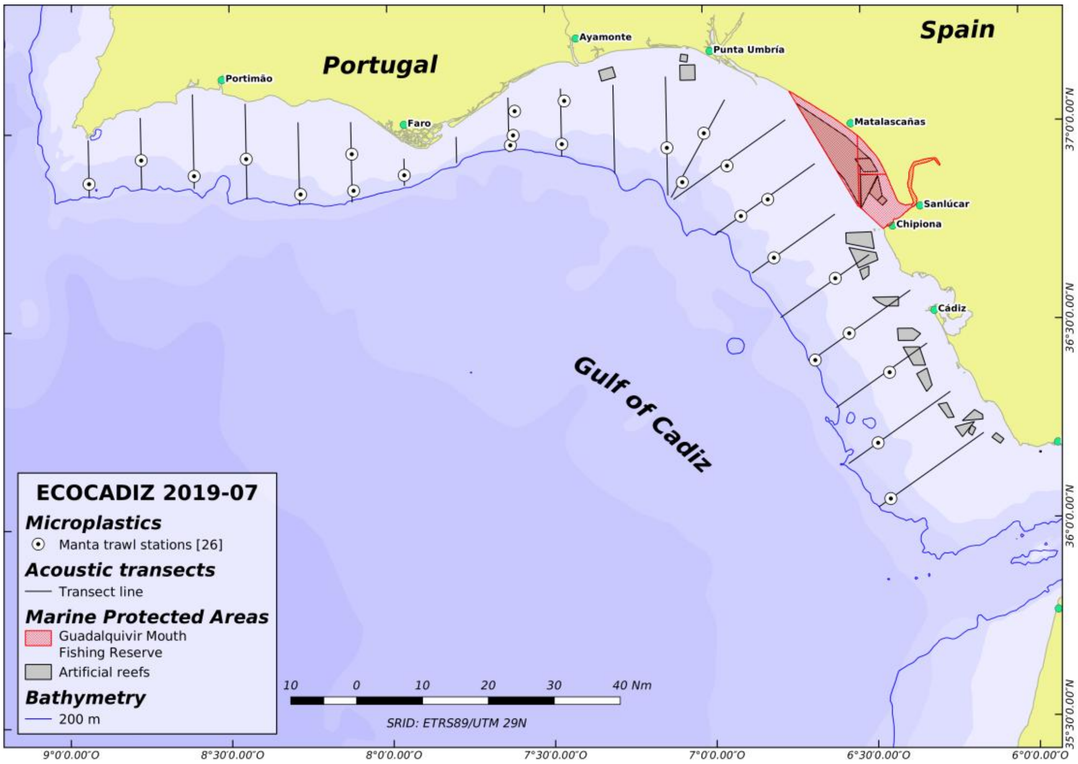


Figure 3. *ECOCADIZ 2019-07* survey. Location of Manta trawl hauls (micro-plastics).

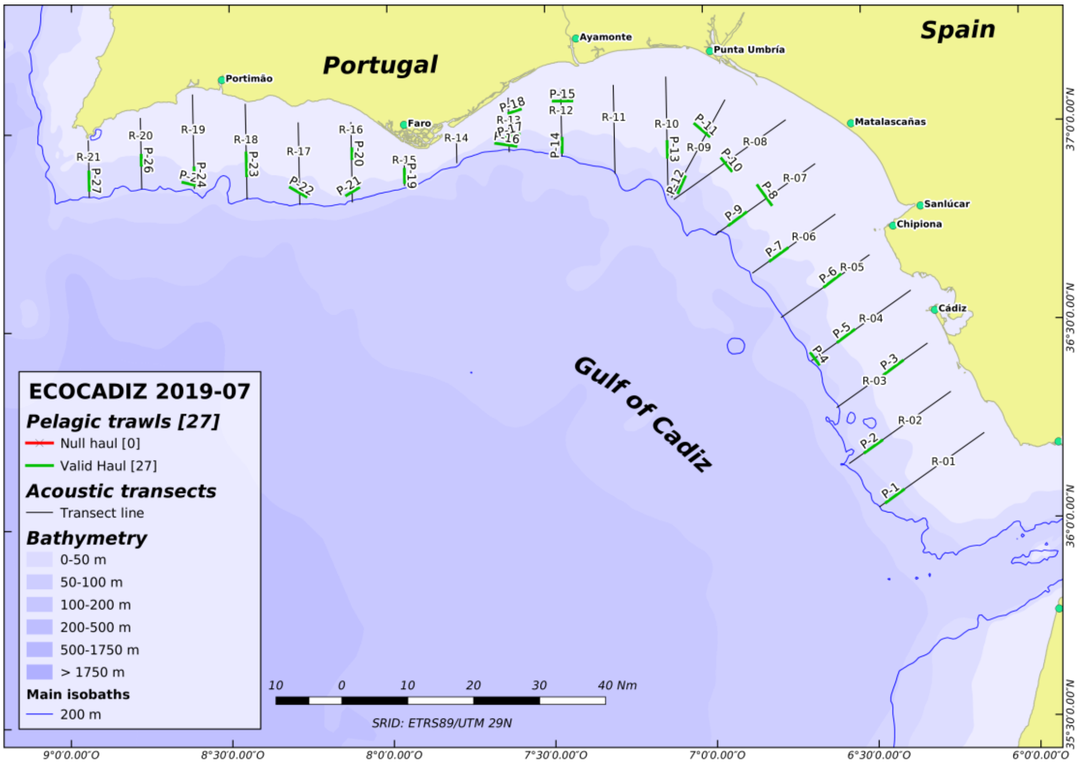


Figure 4. *ECOCADIZ 2019-07* survey. Location of ground-truthing fishing hauls.

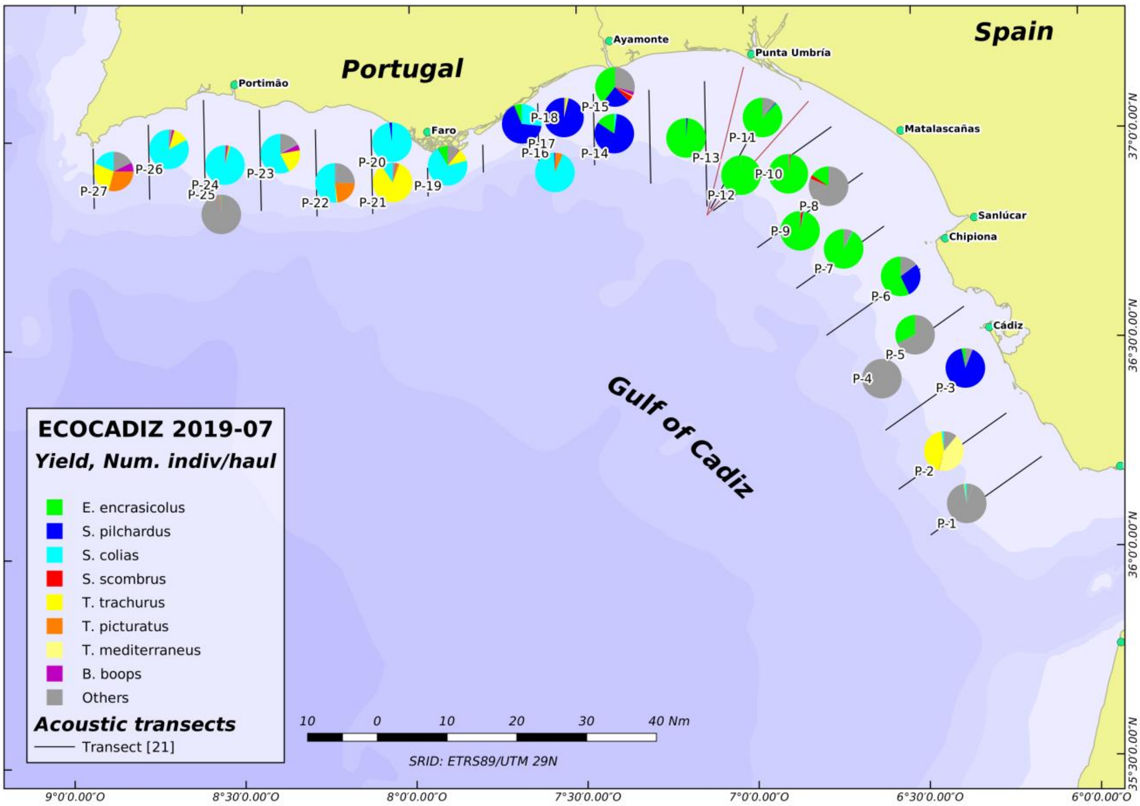


Figure 5. *ECOCADIZ 2019-07* survey. Species composition (percentages in number) in fishing hauls.

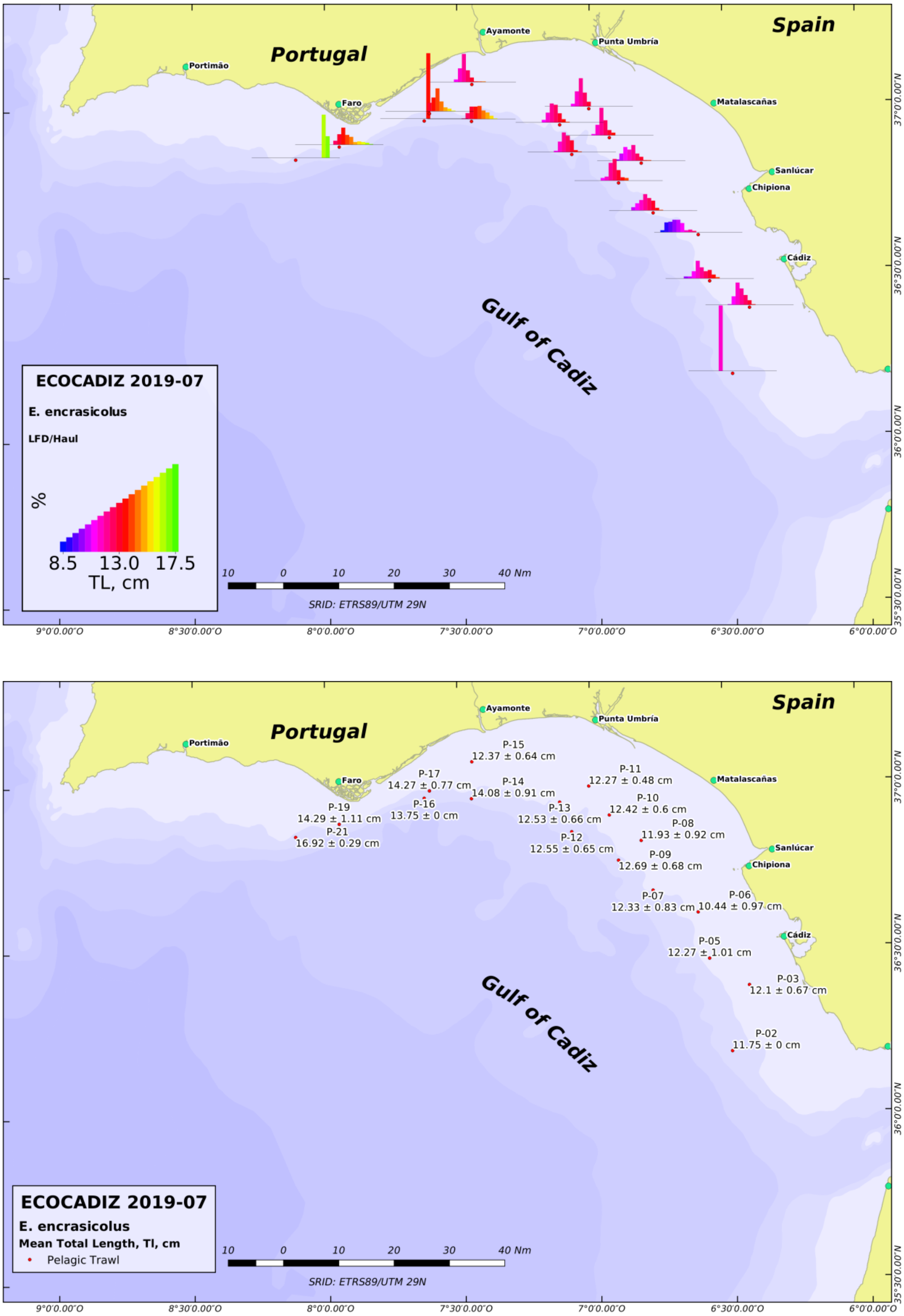


Figure 6. *ECOCADIZ 2019-07* survey. *Engraulis encrasicolus*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

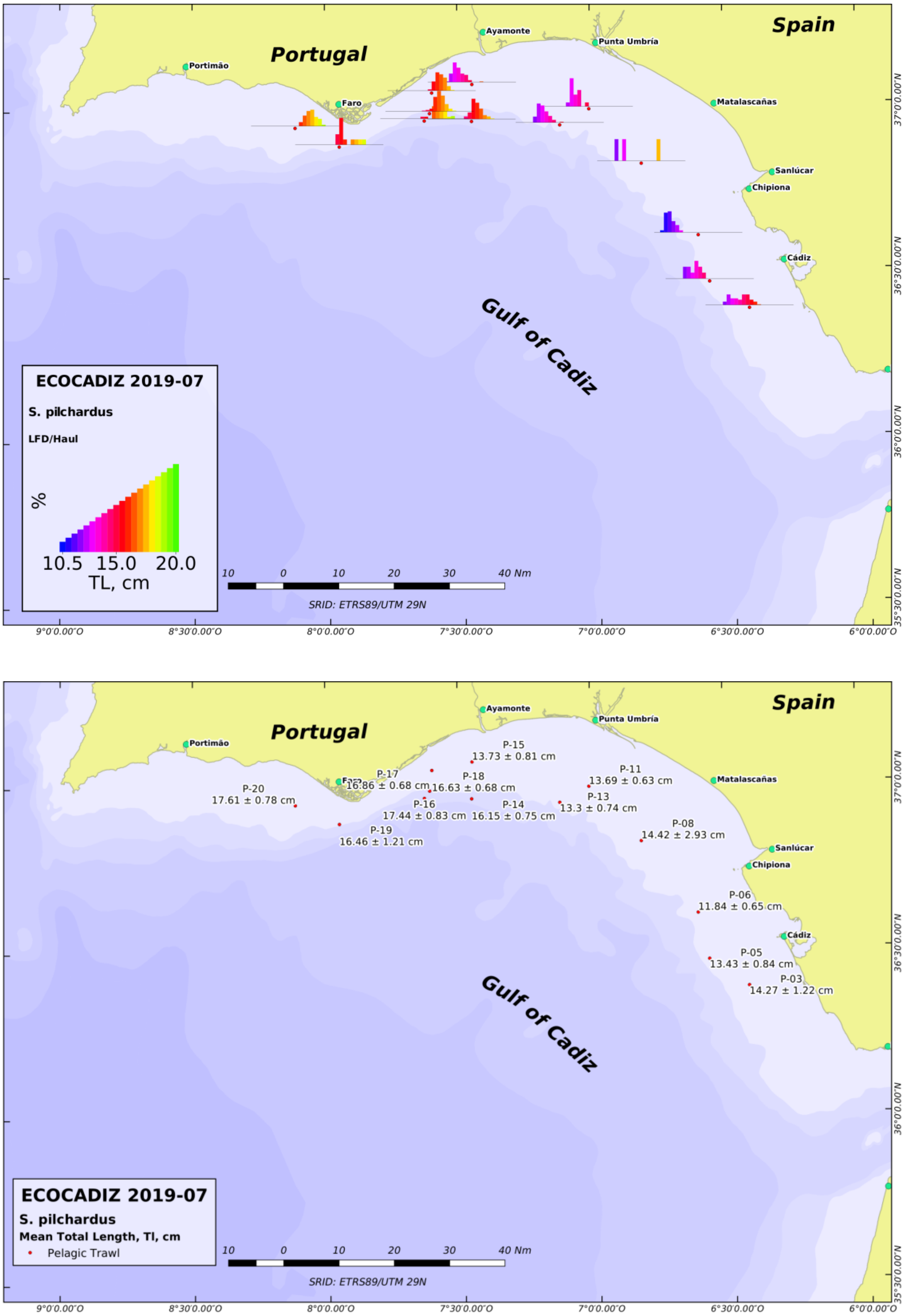


Figure 7. *ECOCADIZ 2019-07* survey. *Sardina pilchardus*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

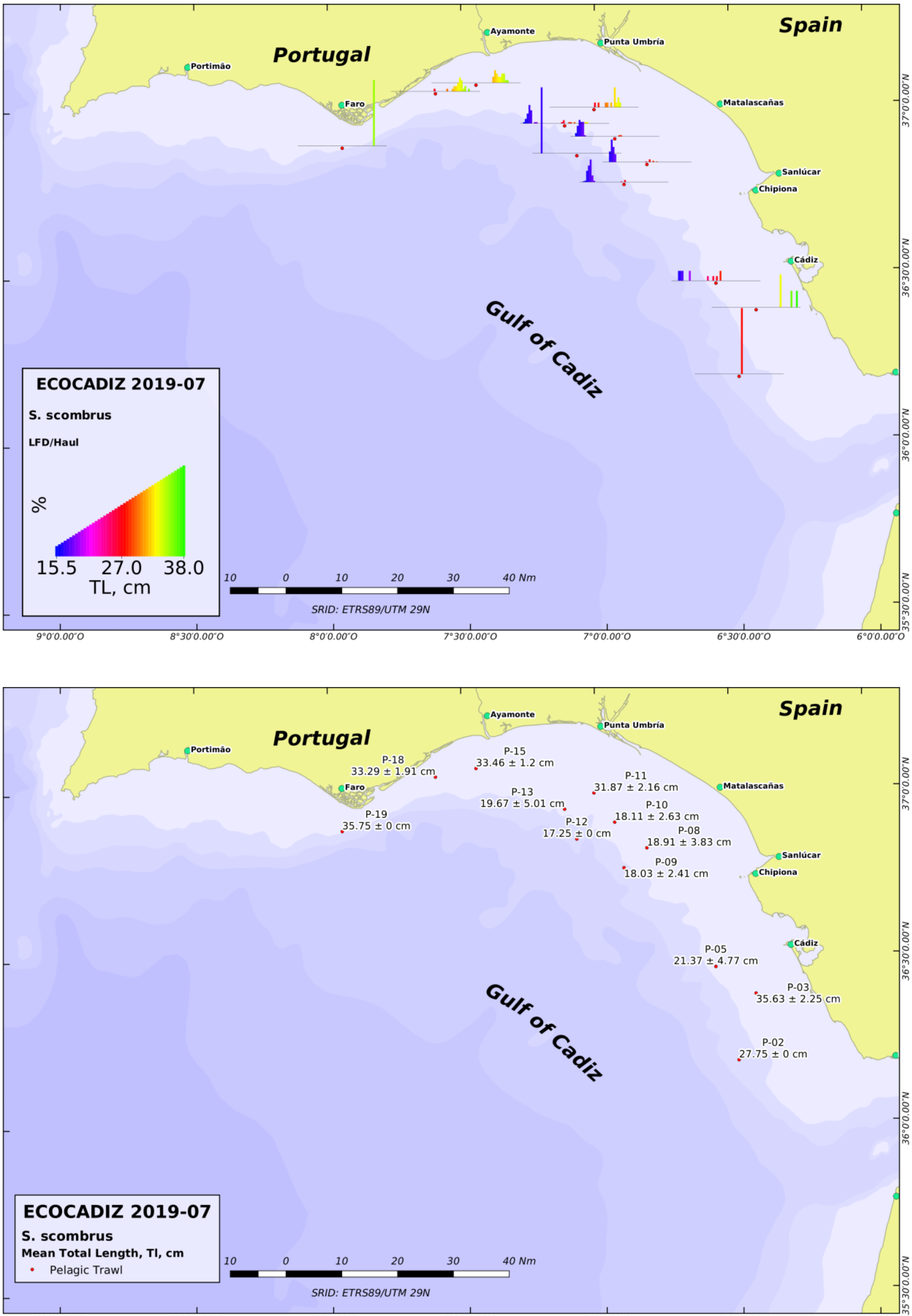


Figure 8. *ECOCADIZ 2019-07* survey. *Scomber scombrus*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

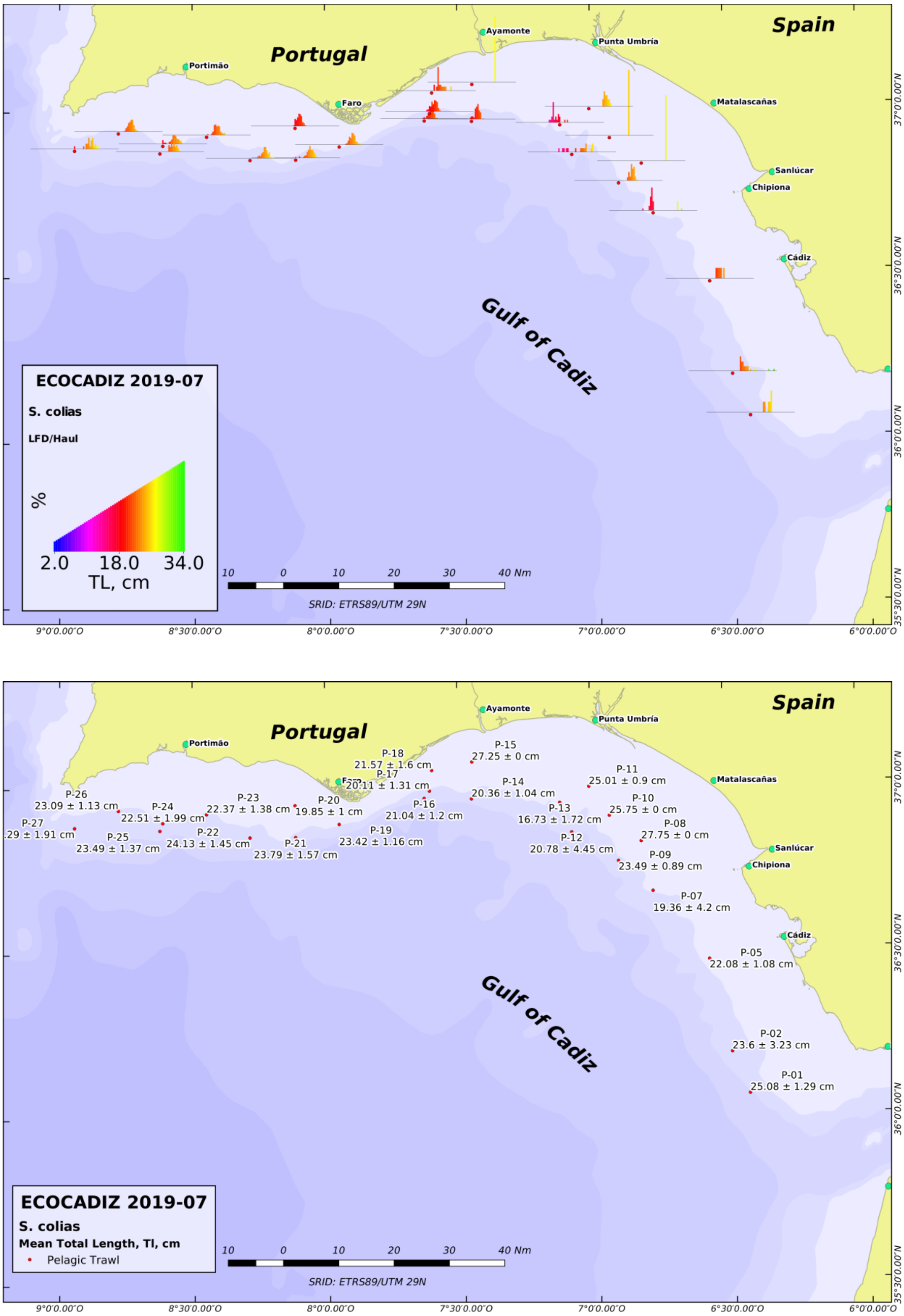


Figure 9. *ECOCADIZ 2019-07* survey. *Scomber colias*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

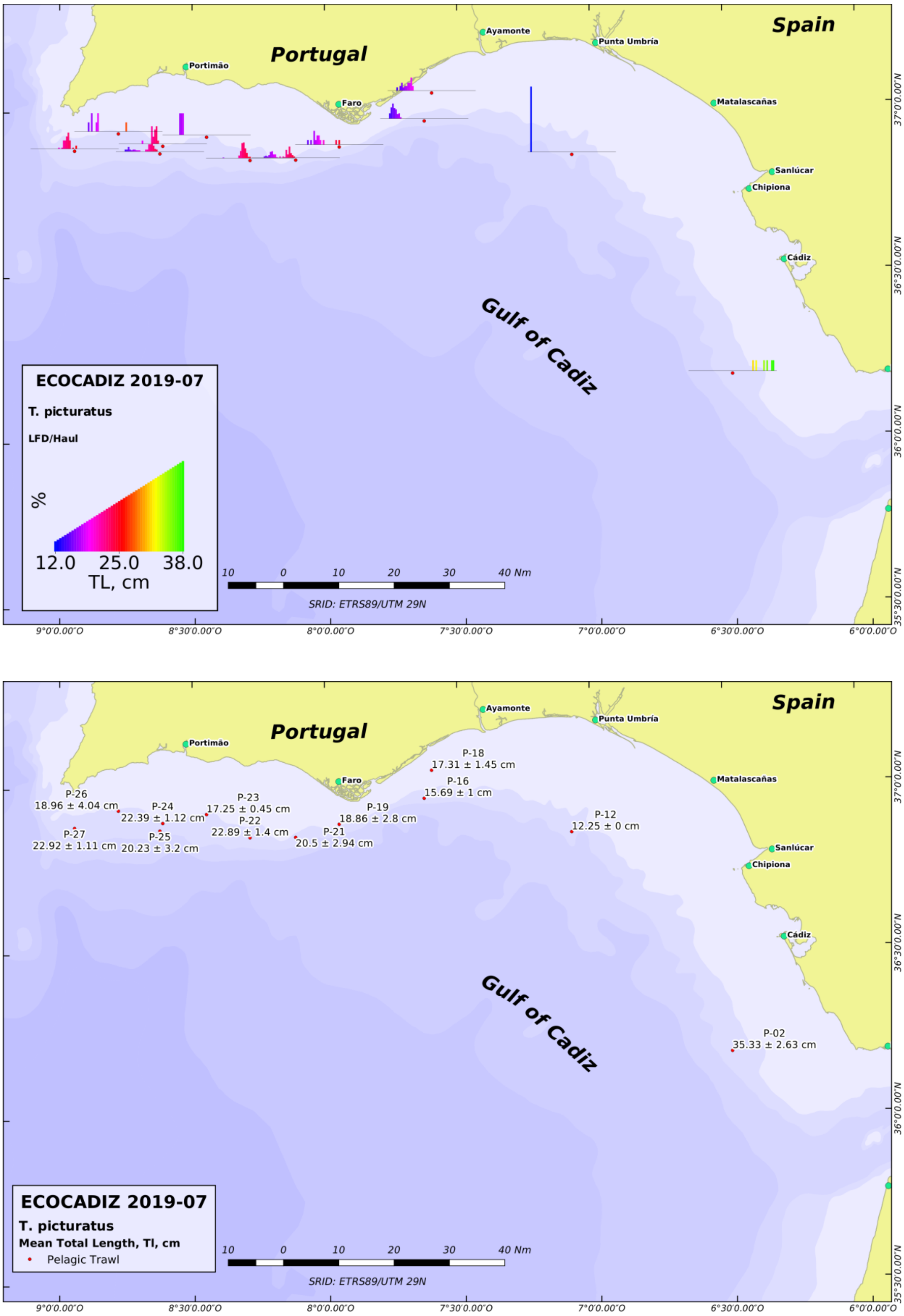


Figure 10. *ECOCADIZ 2019-07* survey. *Trachurus picturatus*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

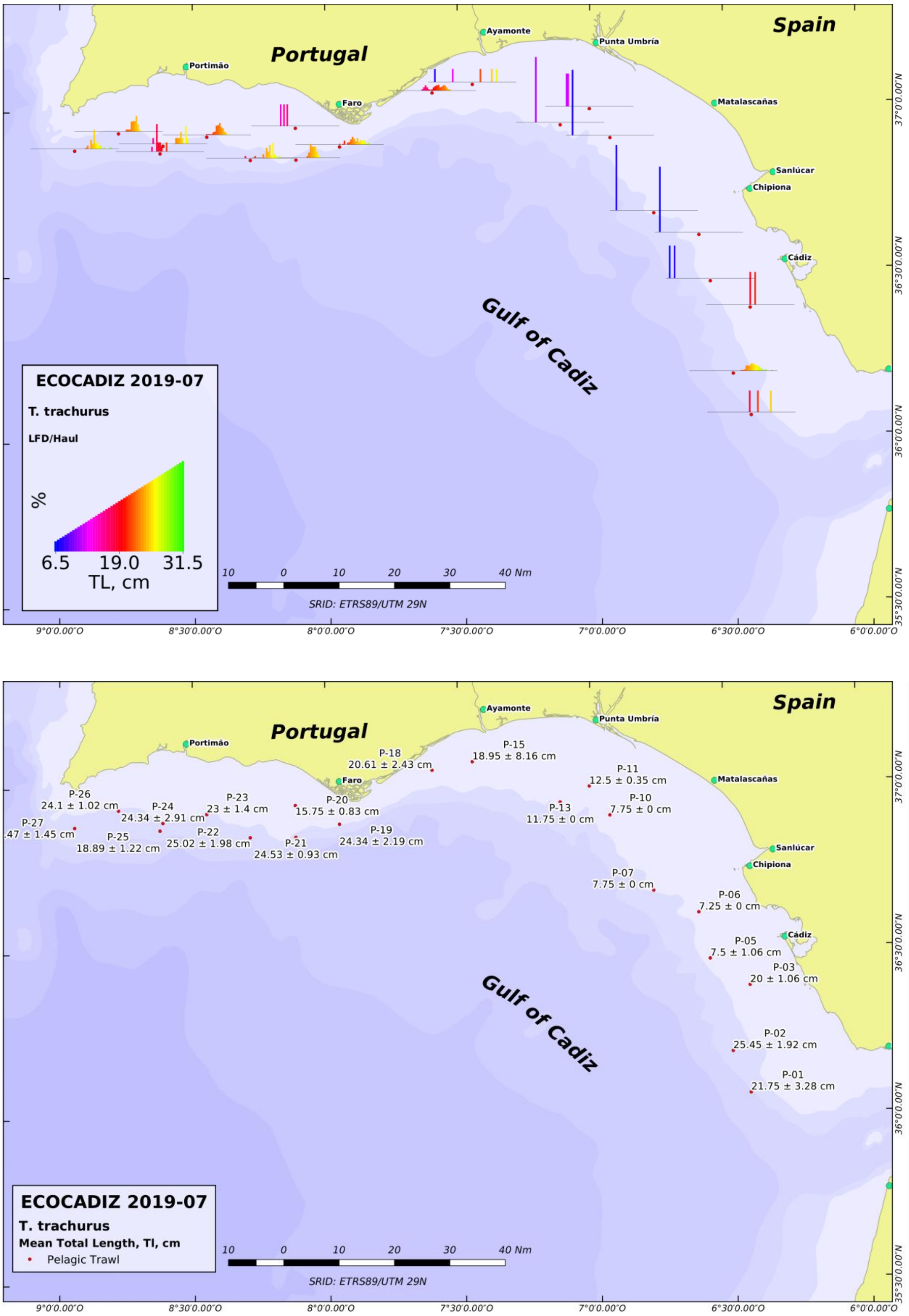


Figure 11. *ECOCADIZ 2019-07* survey. *Trachurus trachurus*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

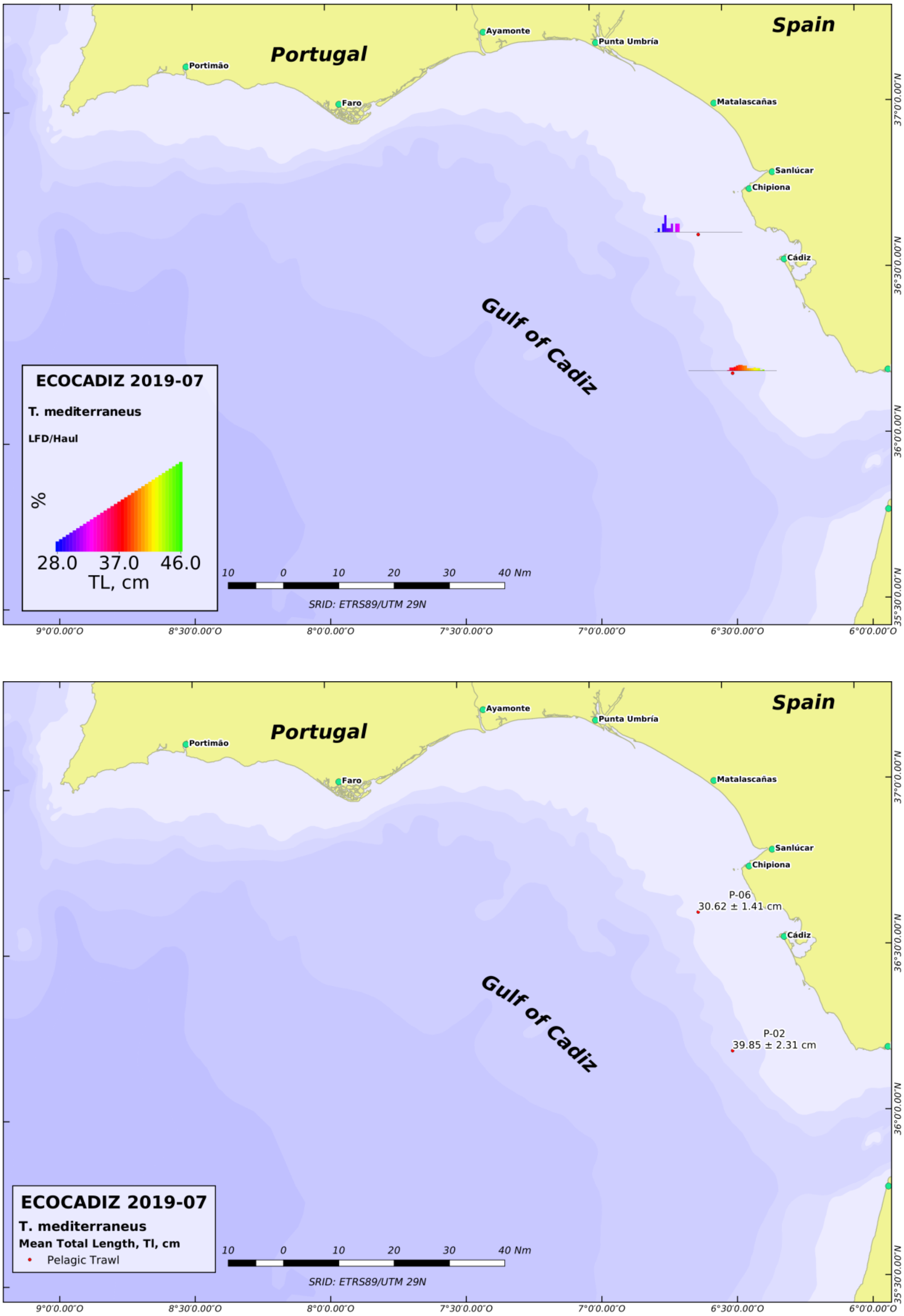


Figure 12. *ECOCADIZ 2019-07* survey. *Trachurus mediterraneus*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

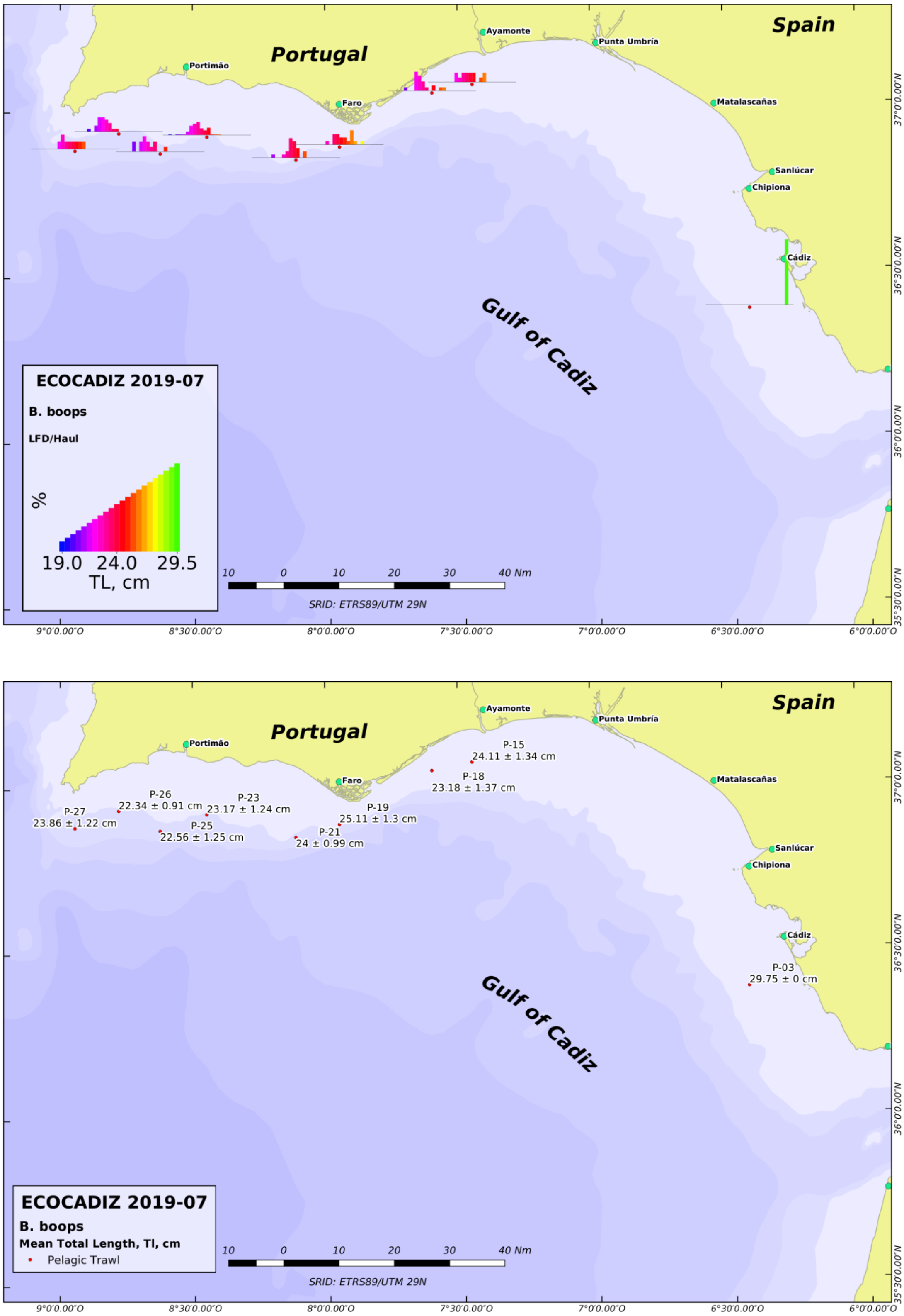


Figure 13. *ECOCADIZ 2019-07* survey. *Boops boops*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

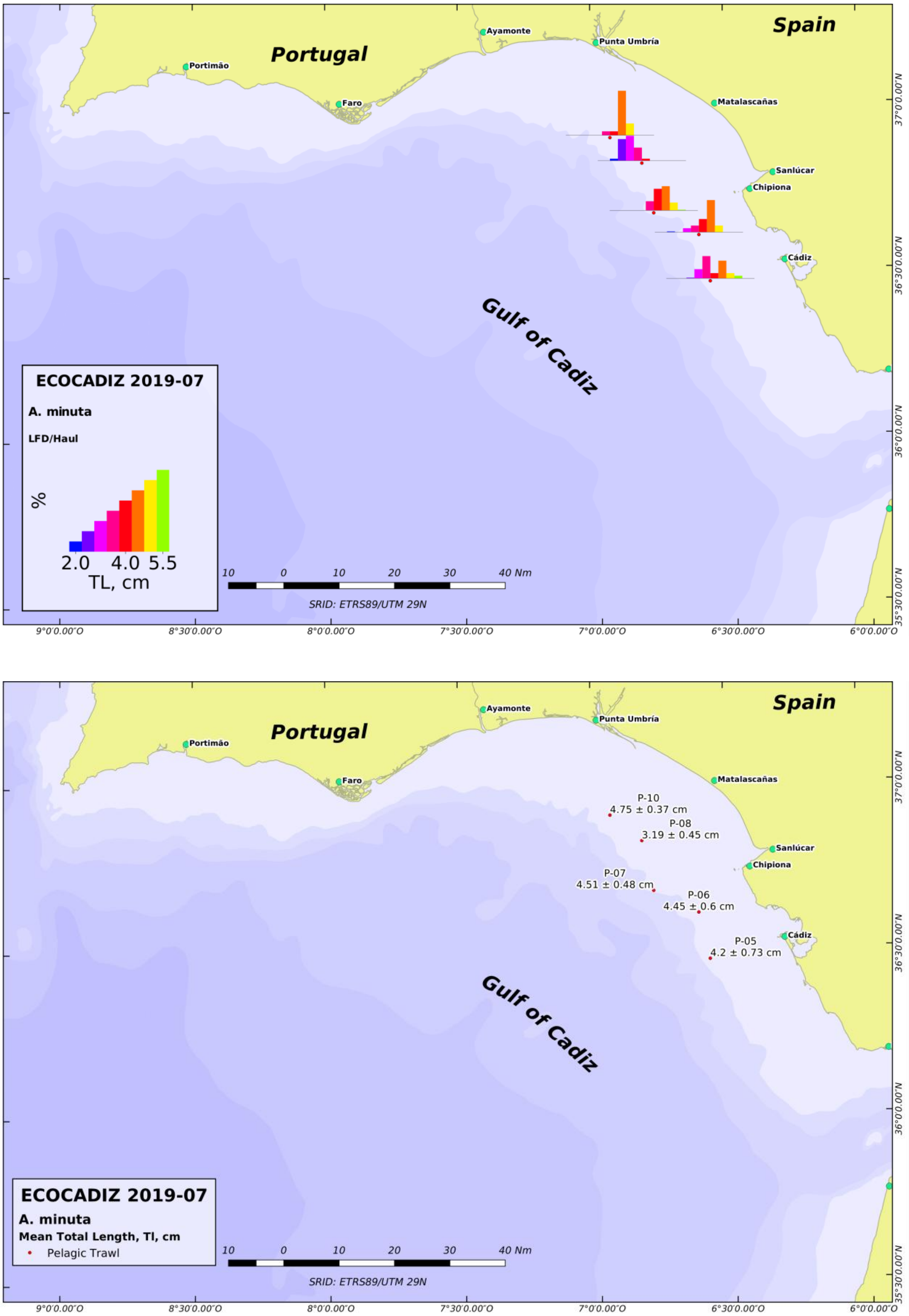


Figure 14. *ECOCADIZ 2019-07* survey. *Aphia minuta*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

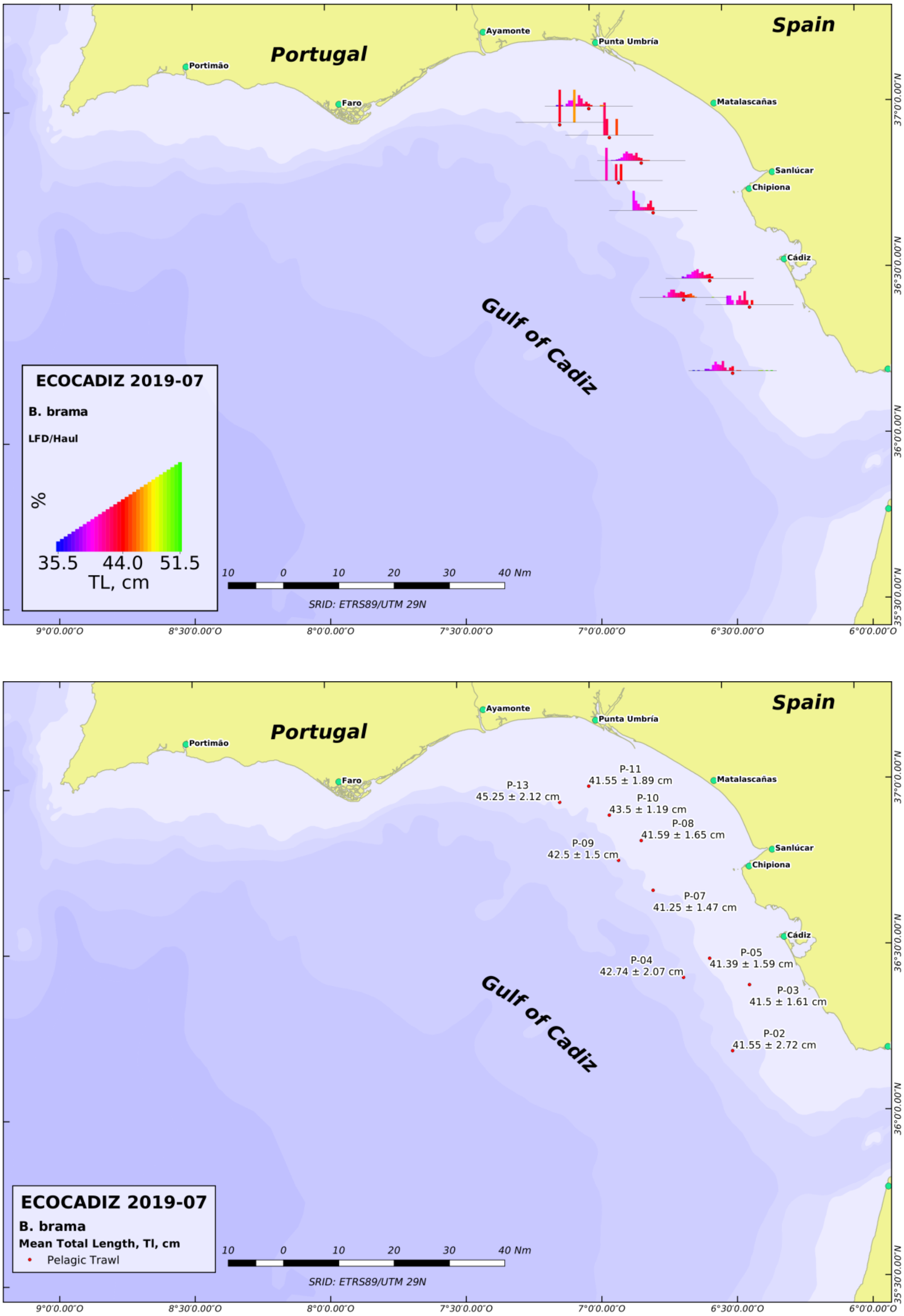


Figure 15. *ECOCADIZ 2019-07* survey. *Brama brama*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

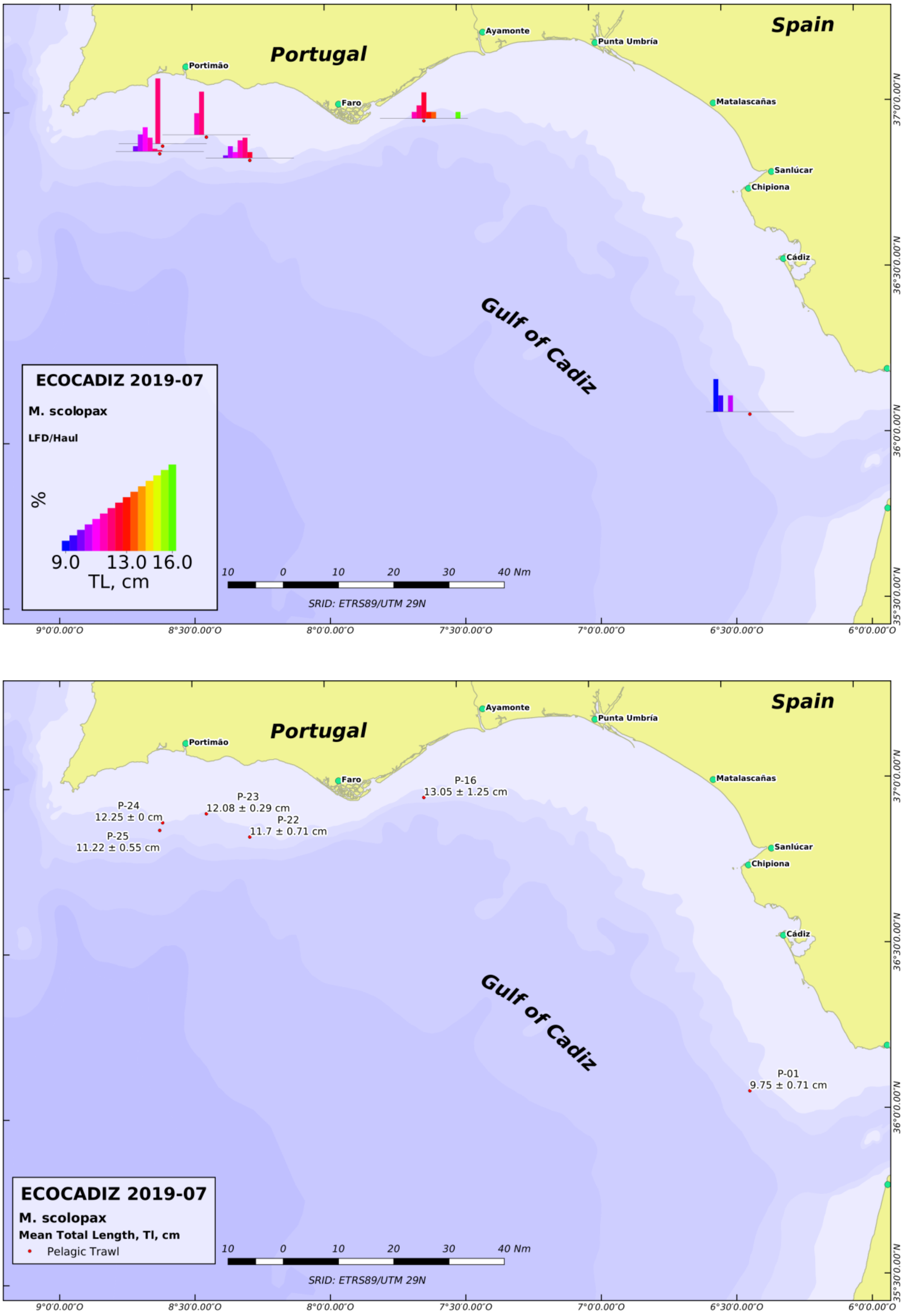


Figure 16. *ECOCADIZ 2019-07* survey. *Macrorhamphosus scolopax*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

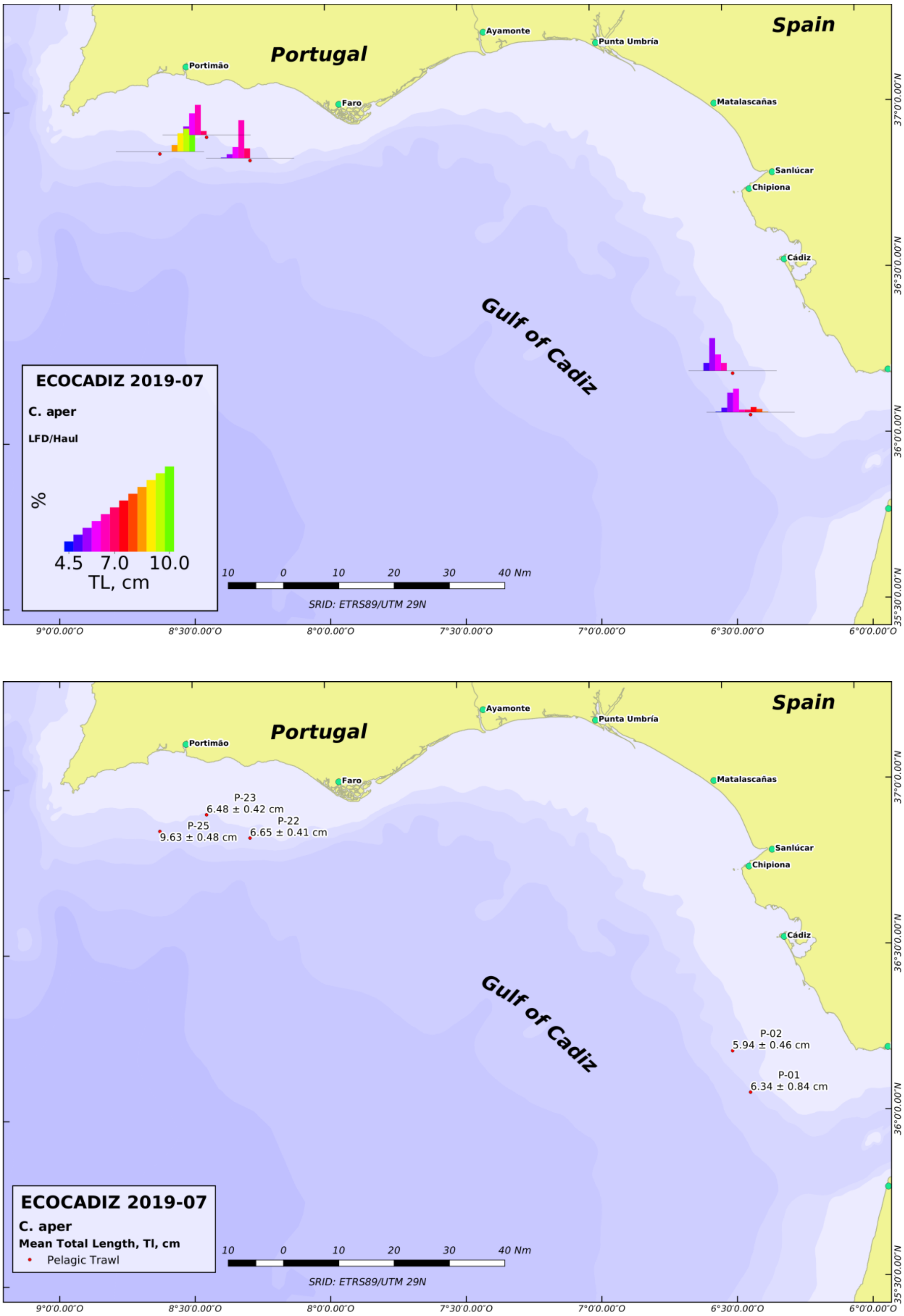
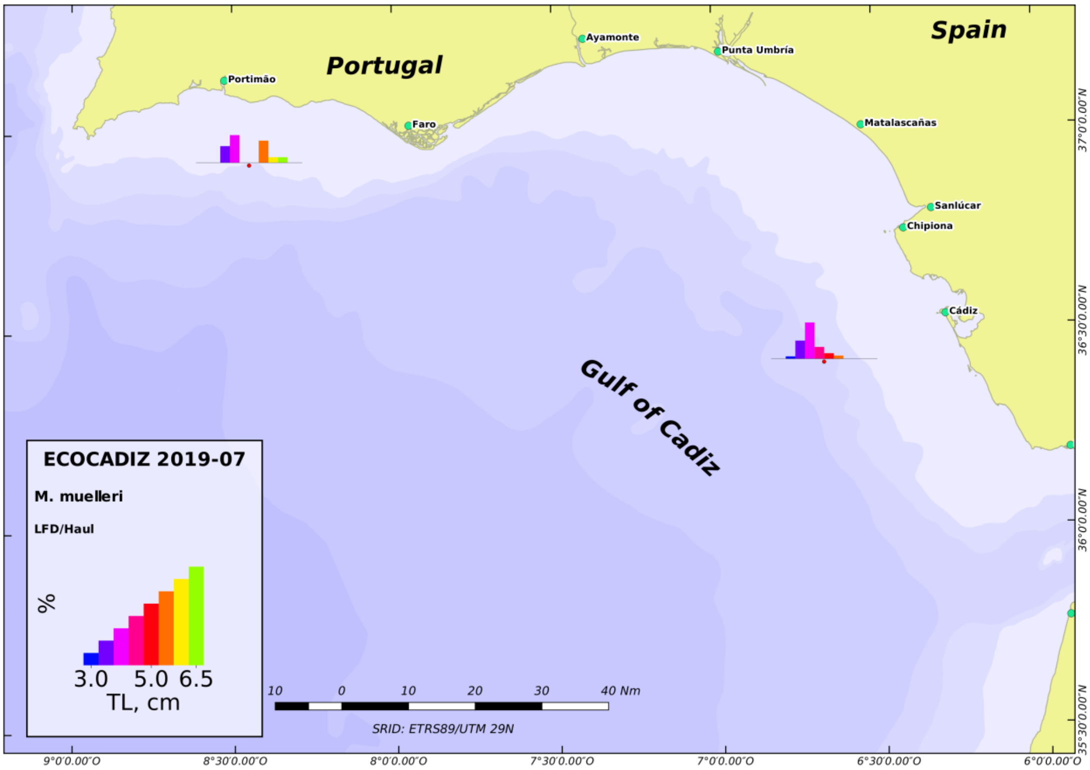


Figure 17. *ECOCADIZ 2019-07* survey. *Capros aper*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.



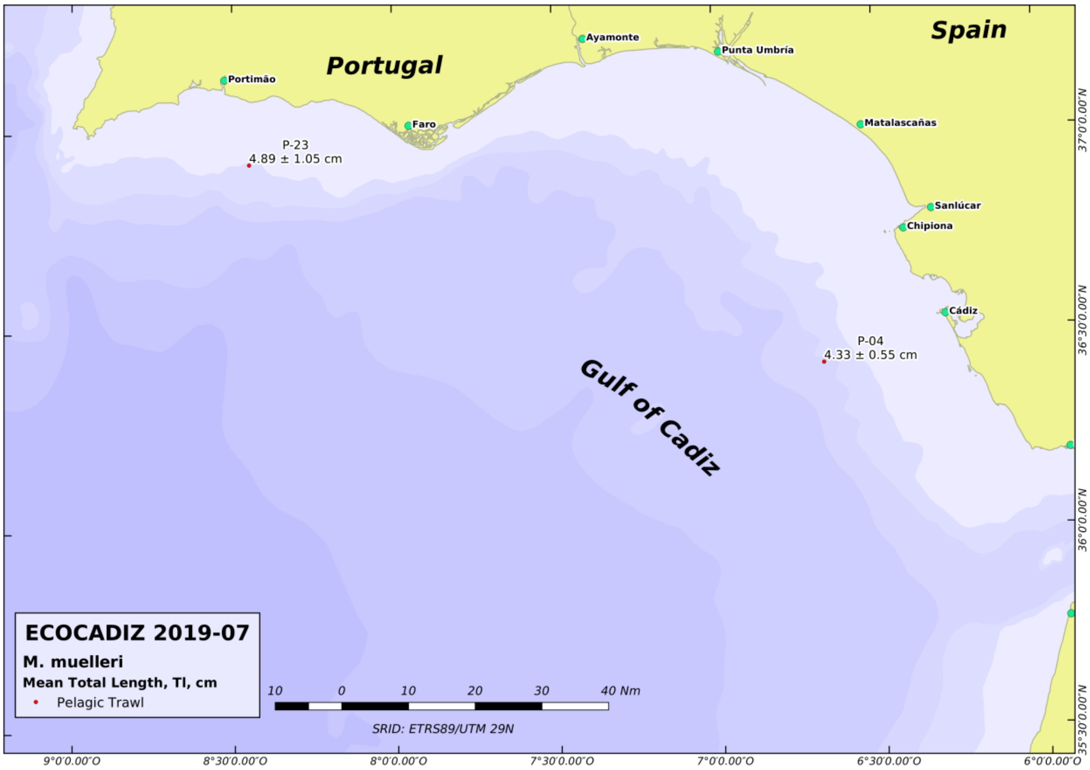


Figure 18. *ECOCADIZ 2019-07* survey. *Maurolicus muelleri*. Top: length frequency distributions in fishing hauls. Bottom: mean ± sd length by haul.

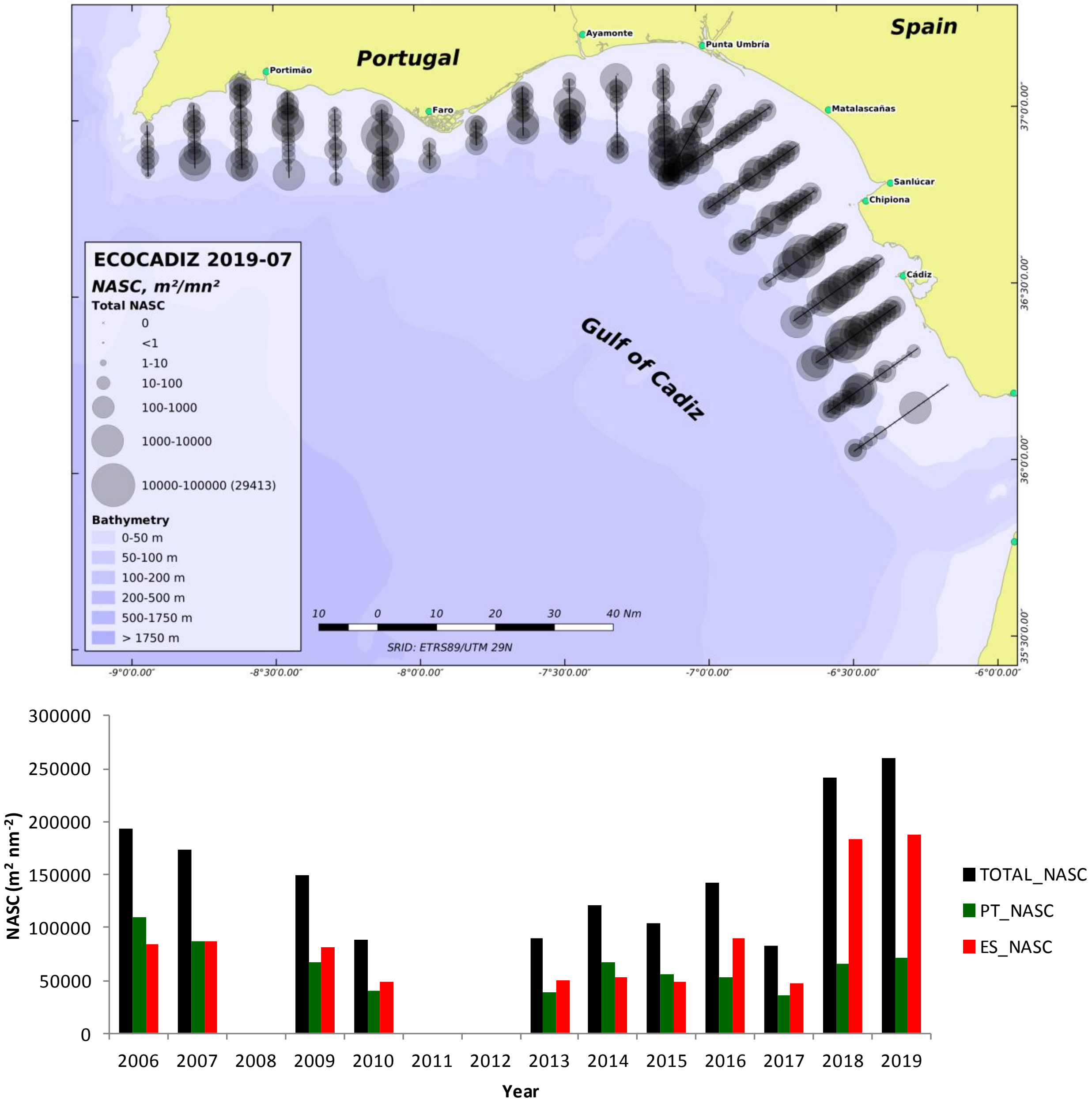
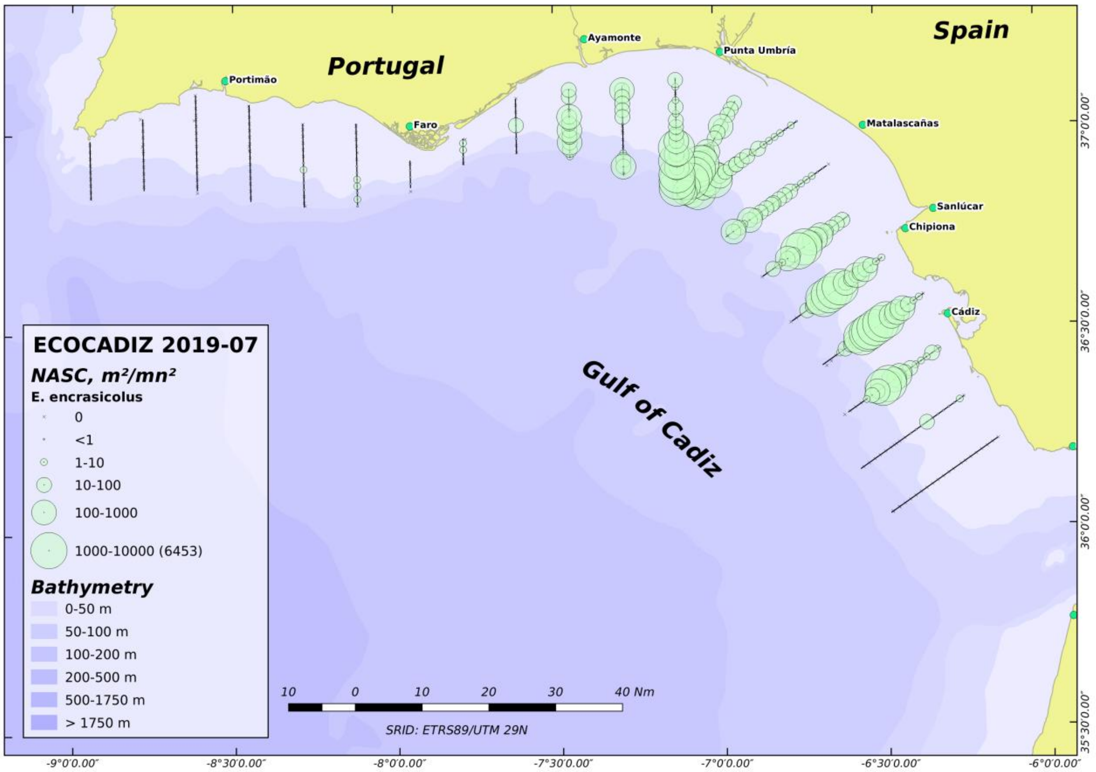


Figure 19. *ECOCADIZ 2019-07* survey. Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the pelagic fish species assemblage. Bottom: time-series of total NASC estimates per survey.



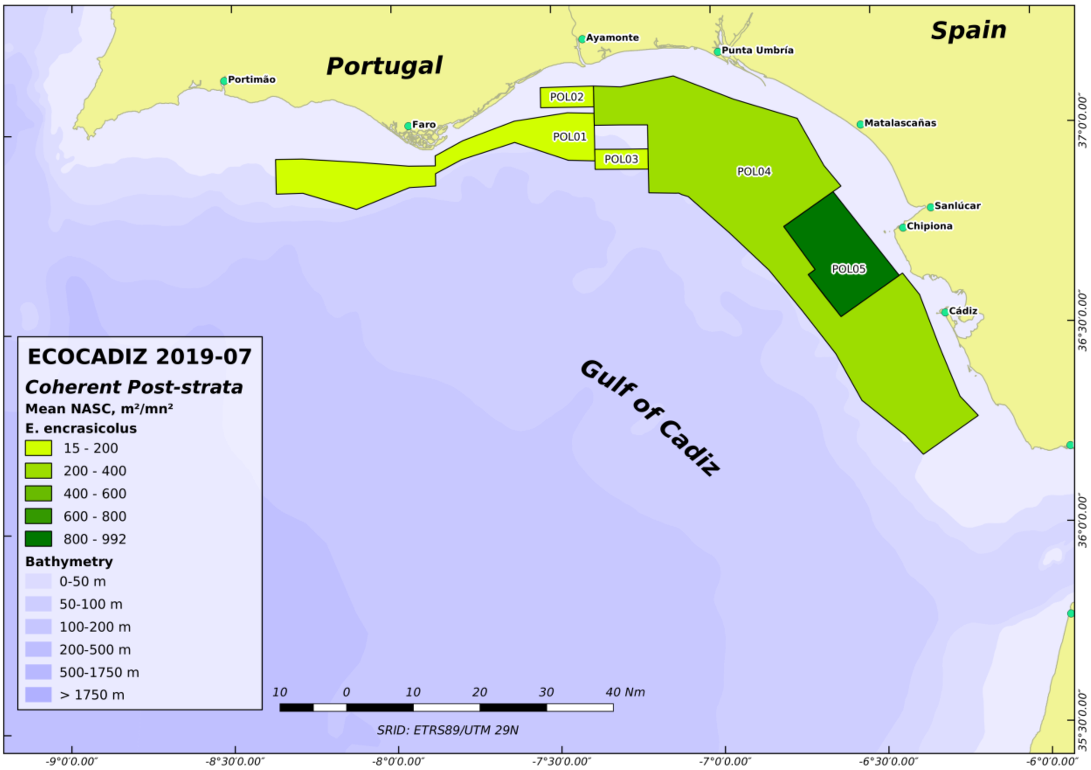


Figure 20. *ECOCADIZ 2019-07* survey. Anchovy (*Engraulis encrasicolus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

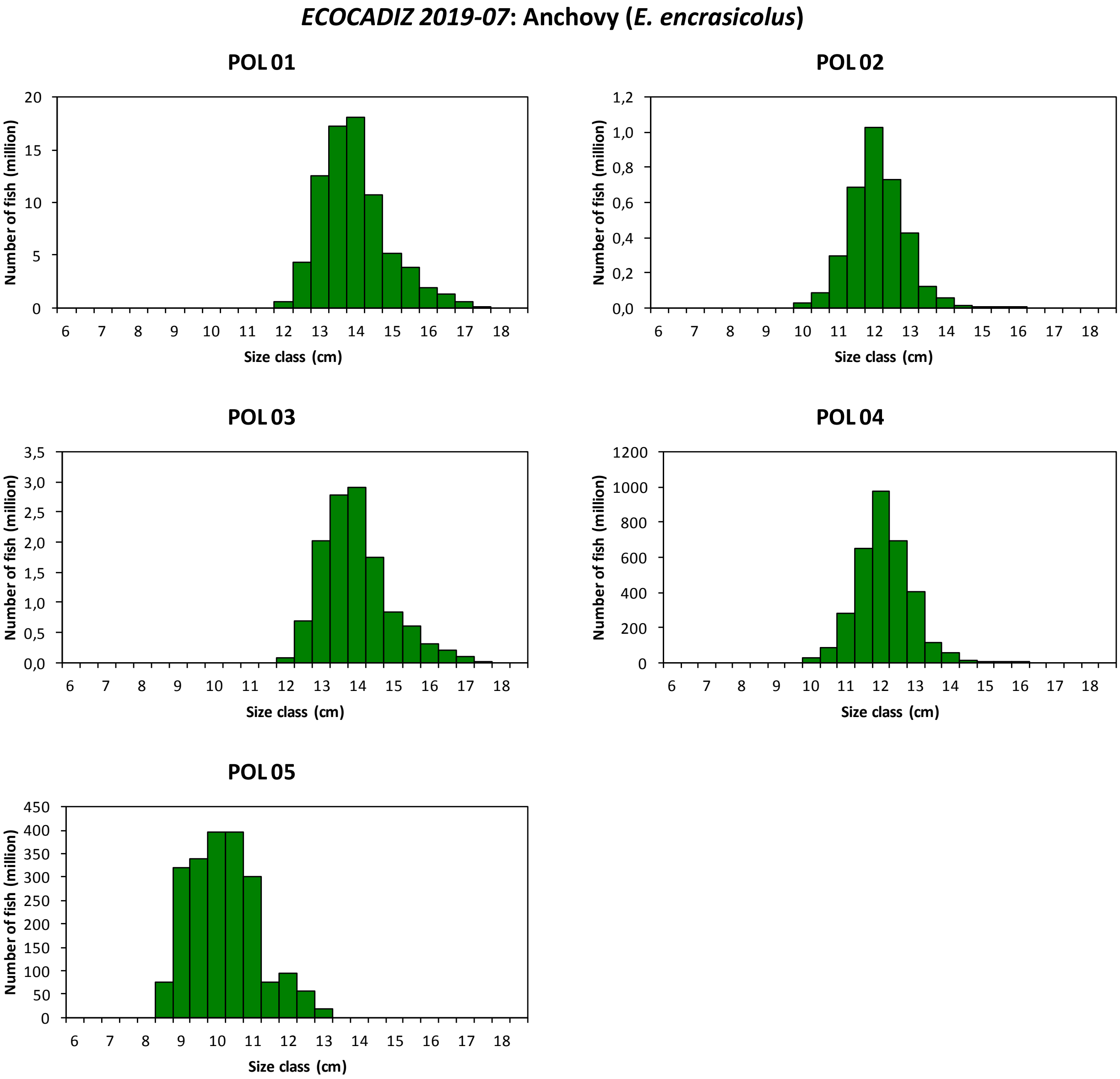


Figure 21. *ECOCADIZ 2019-07* survey. Anchovy (*E. encrasicolus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous stratum (POL01-POLn, numeration as in **Figure 20**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

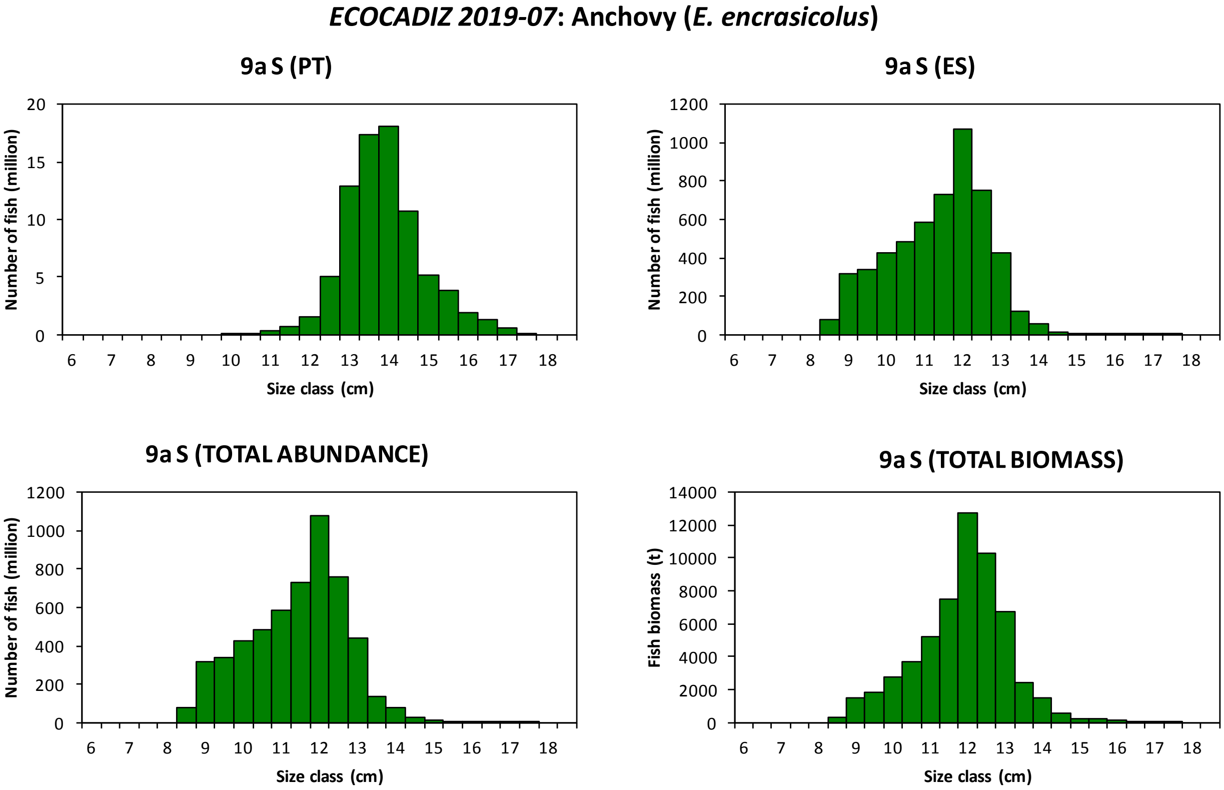
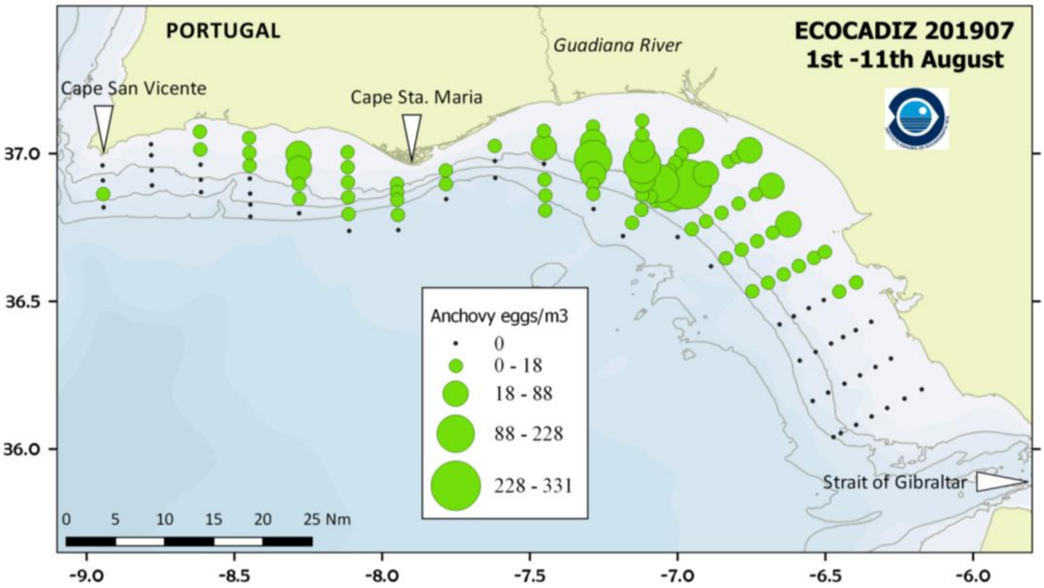
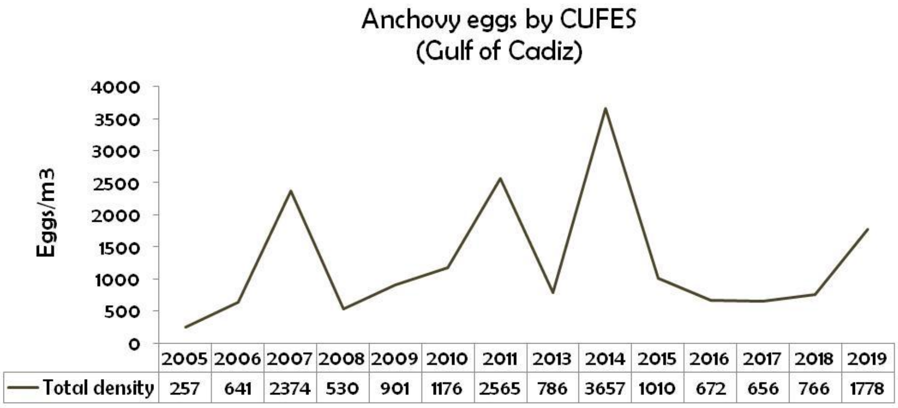


Figure 21. *ECOCADIZ 2019-07* survey. Anchovy (*E. encrasicolus*). Cont'd.

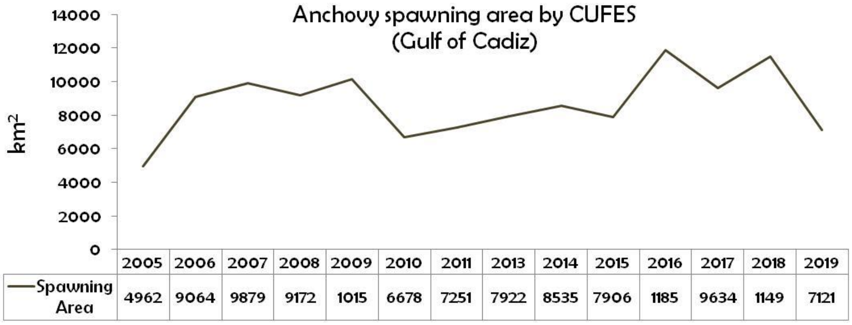


ECOCADIZ 2019-07	
CUFES st	121
Positive anchovy st8	73 (60.3 %)
Max number eggs by st	3599
Total anchovy eggs (in number)	19031
Max density by st (eggs/m^3)	331.4
Total density (eggs/m^3)	1778

Figure 22. *ECOCADIZ 2019-07* survey. Anchovy (*E. encrasicolus*). Top: distribution of anchovy egg densities sampled by CUFES (eggs m^{-3}). Bottom: main descriptors of the CUFES sampling.



	2005	2006	2007	2008	2009	2010	2011	2013	2014	2015	2016	2017	2018	2019
Total density	257	641	2374	530	901	1176	2565	786	3657	1010	672	656	766	1778



	2005	2006	2007	2008	2009	2010	2011	2013	2014	2015	2016	2017	2018	2019
Spawning Area	4962	9064	9879	9172	1015	6678	7251	7922	8535	7906	1185	9634	1149	7121

Figure 22. *ECOCADIZ 2019-07* survey. Anchovy (*E. encrasicolus*). Cont'd. Top: historical series of GoC anchovy egg total densities (eggs * m^{-3}) sampled by CUFES. Bottom: historical series of estimates of the extension of the GoC anchovy spawning area (in km^2).

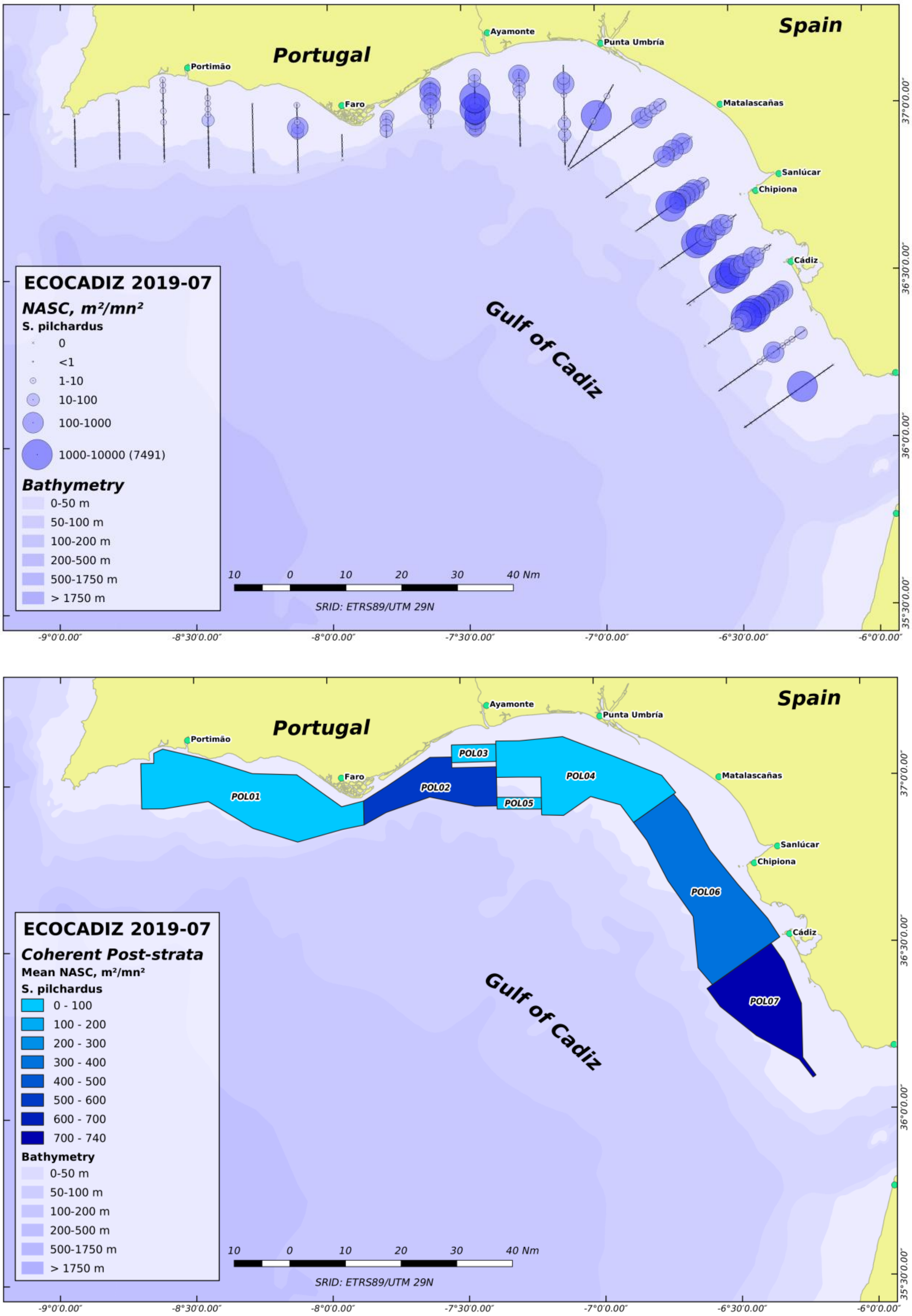


Figure 23. *ECOCADIZ 2019-07* survey. Sardine (*Sardina pilchardus*). Top: distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

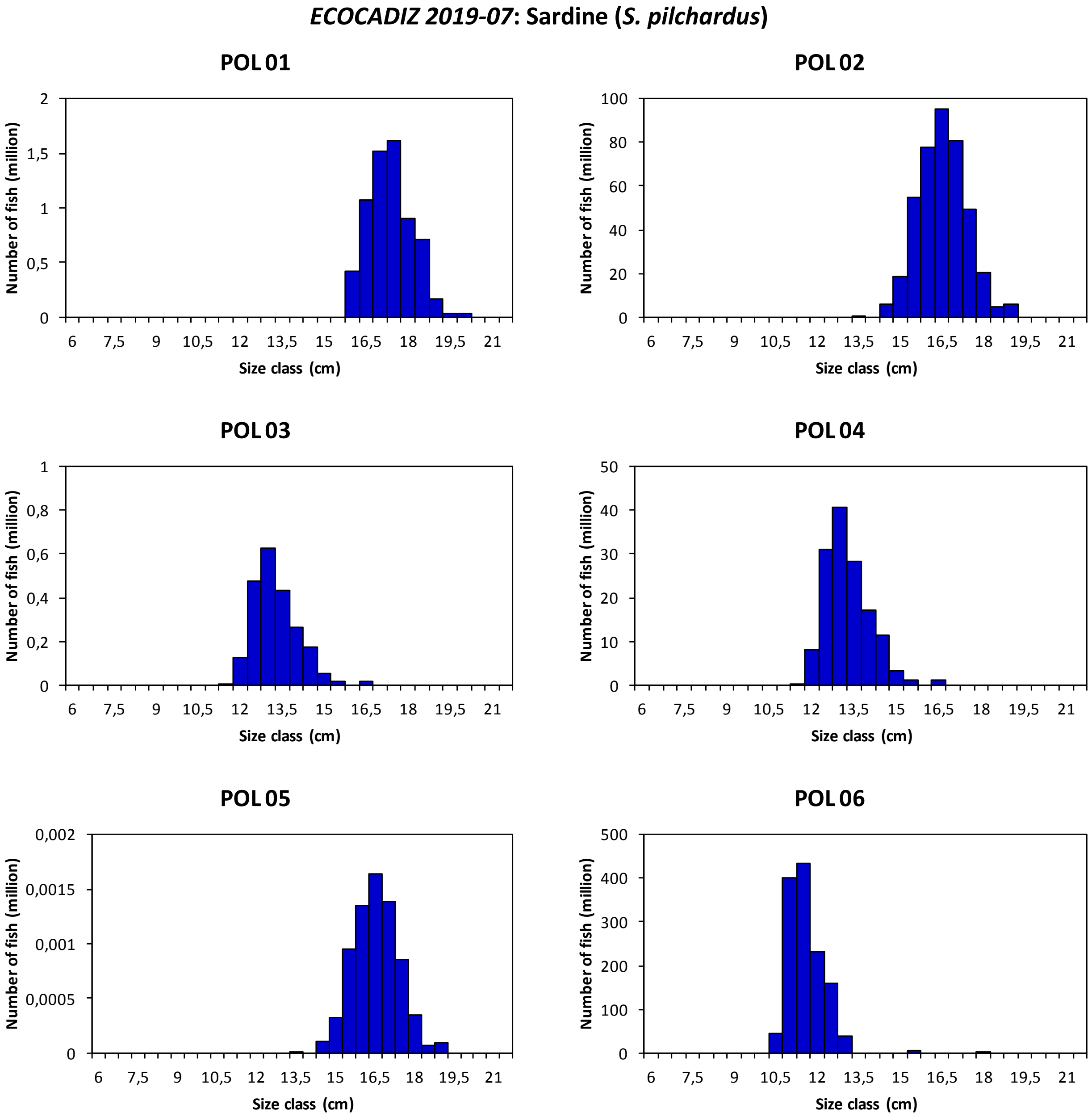


Figure 24. *ECOCADIZ 2019-07* survey. Sardine (*S. pilchardus*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous stratum (POL01-POLn, numeration as in **Figure 23**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

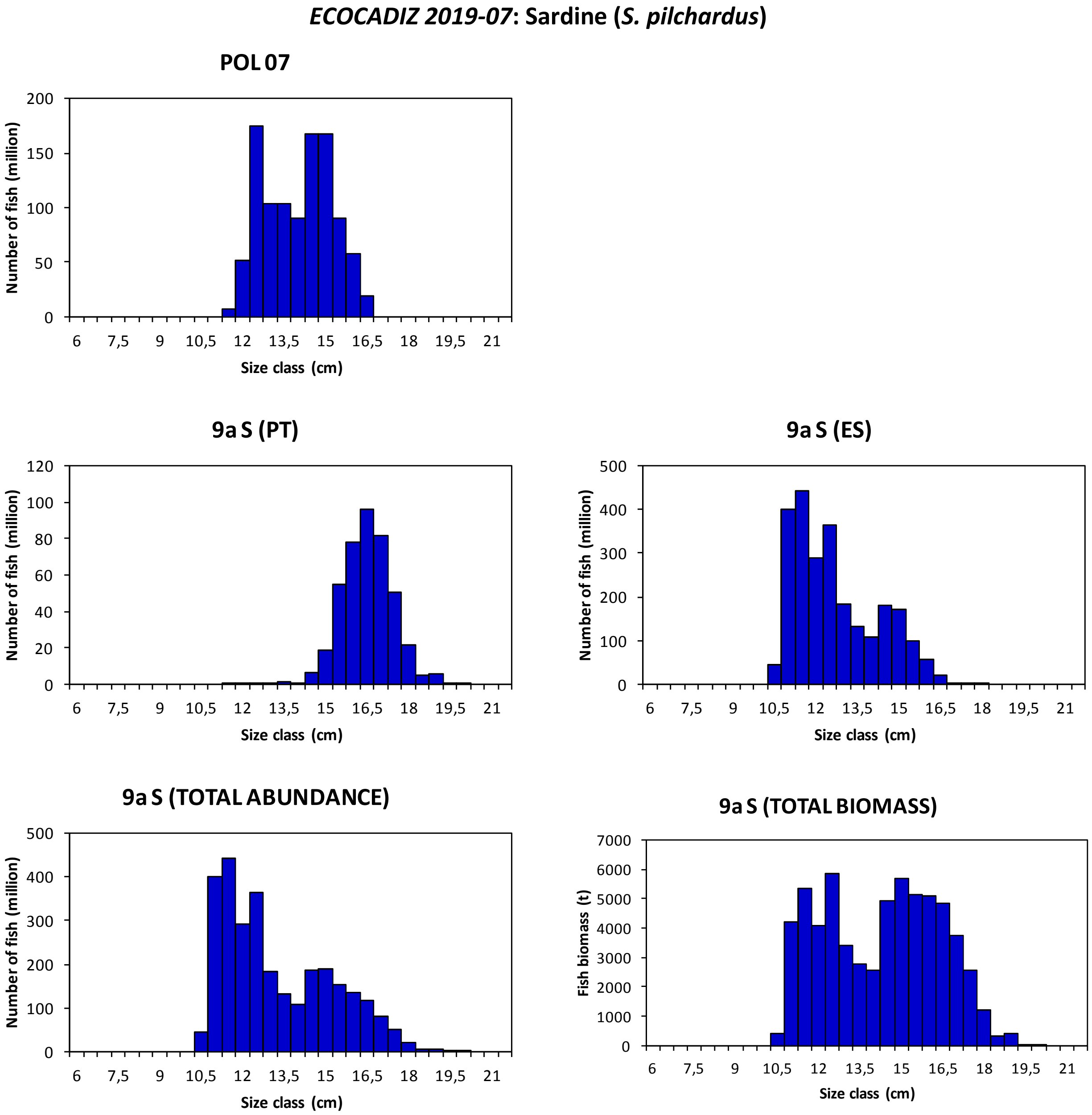


Figure 24. *ECOCADIZ 2019-07* survey. Sardine (*S. pilchardus*). Cont'd.

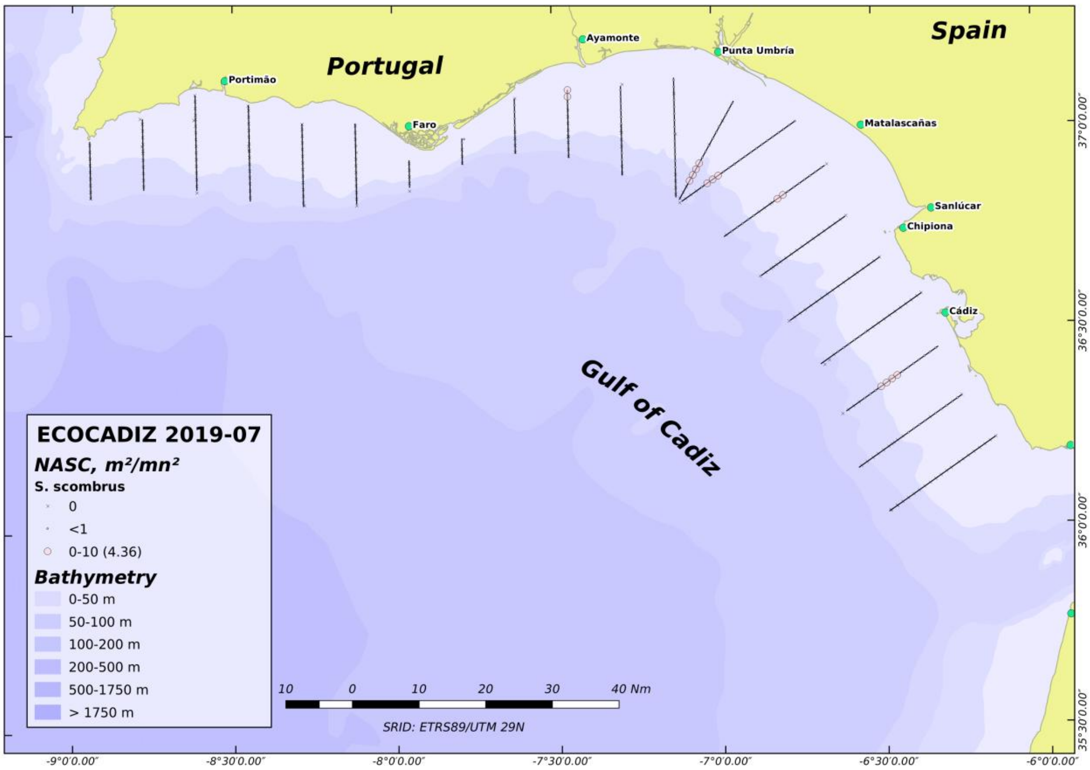


Figure 25. *ECOCADIZ 2019-07* survey. Mackerel (*Scomber scombrus*). Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species.

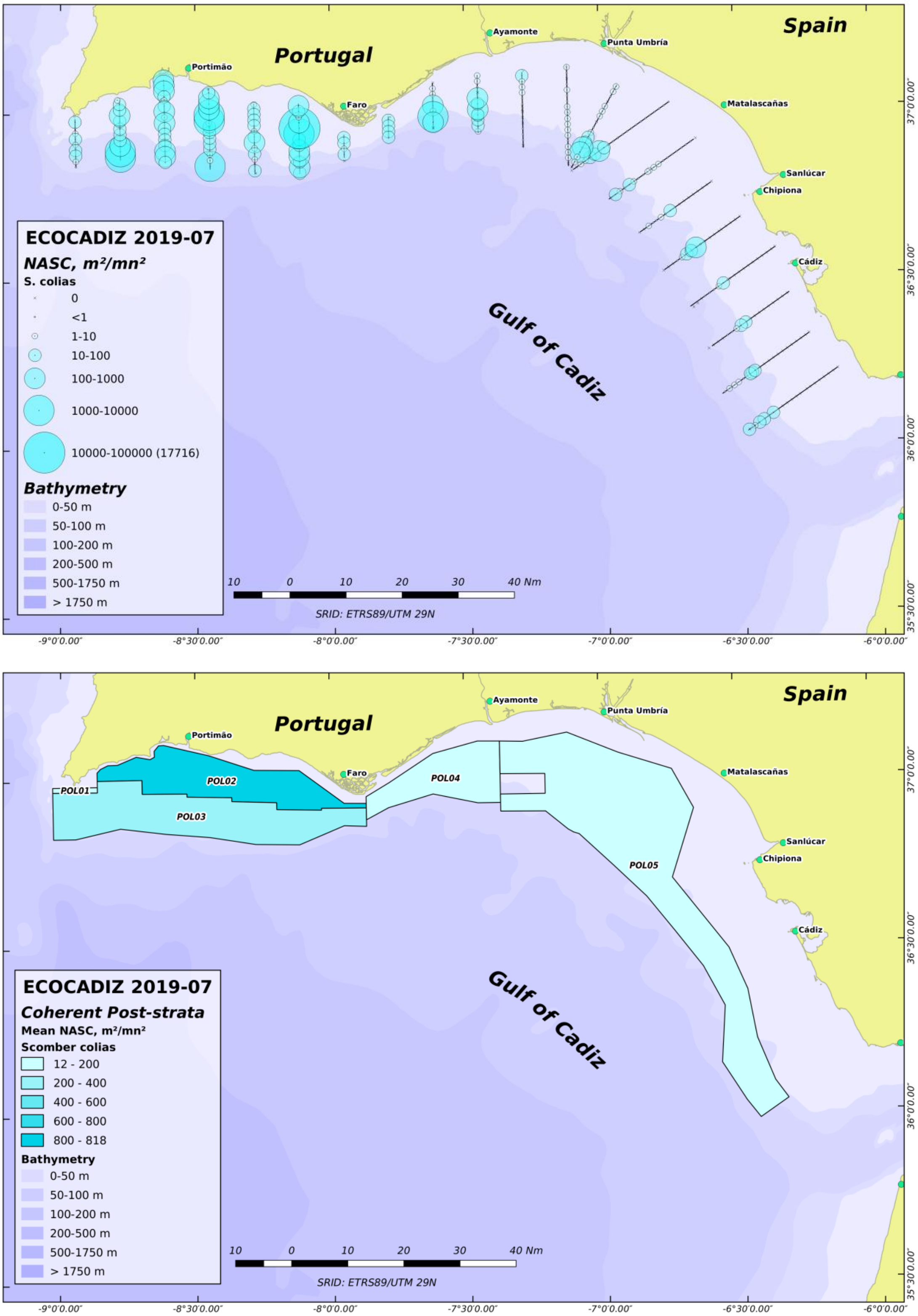


Figure 26. *ECOCADIZ 2019-07* survey. Chub mackerel (*Scomber colias*). Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species. Bottom: distribution of homogeneous size-based post-strata used in the biomass/abundance estimates. Colour scale according to the mean value of the backscattering energy attributed to the species in each stratum.

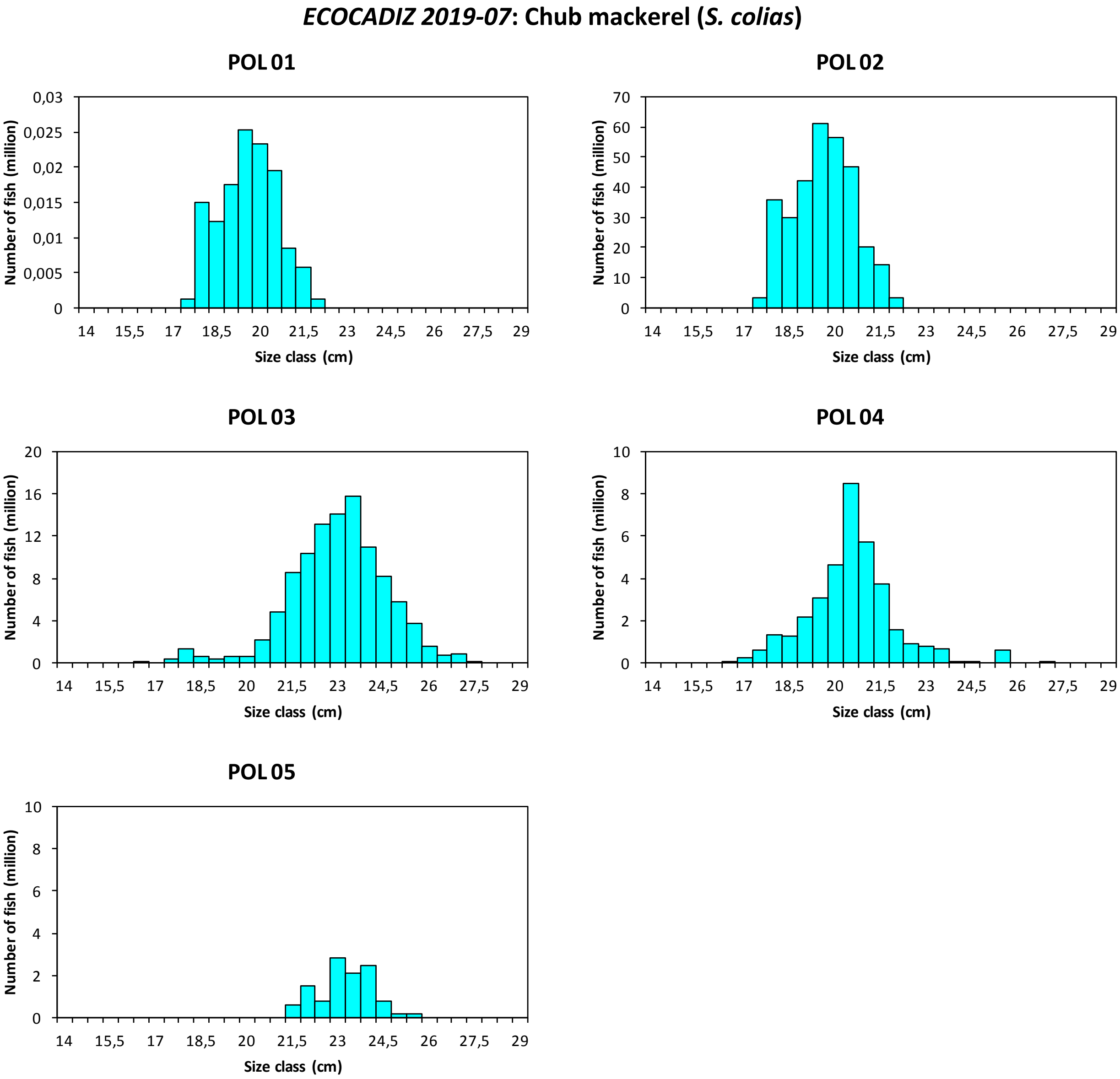


Figure 27. *ECOCADIZ 2019-07* survey. Chub mackerel (*Scomber colias*). Estimated abundances (number of fish in millions) by length class (cm) by homogeneous stratum (POL01-POLn, numeration as in **Figure 26**) and total sampled area. Post-strata ordered in the W-E direction. The estimated biomass (t) by size class for the whole sampled area is also shown for comparison. Note the different scales in the y axis.

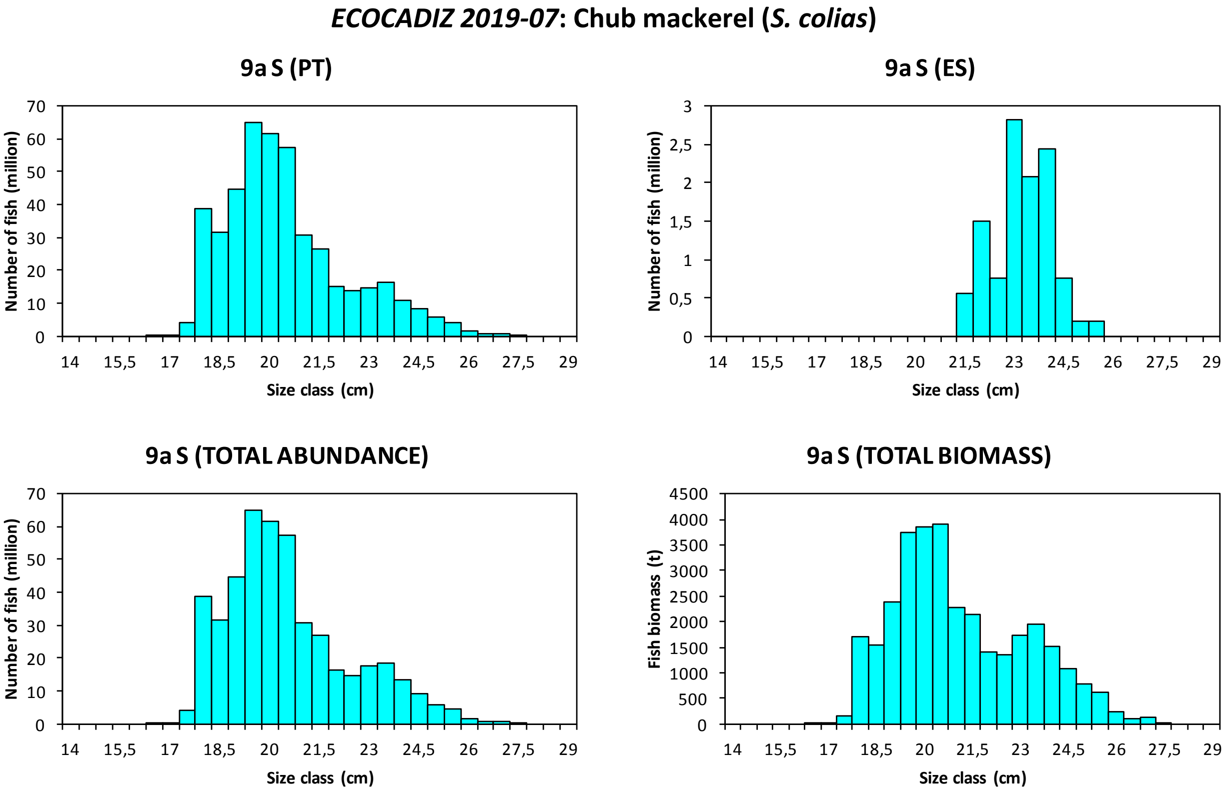


Figure 27. *ECOCADIZ 2019-07* survey. Chub mackerel (*Scomber colias*). Cont'd.

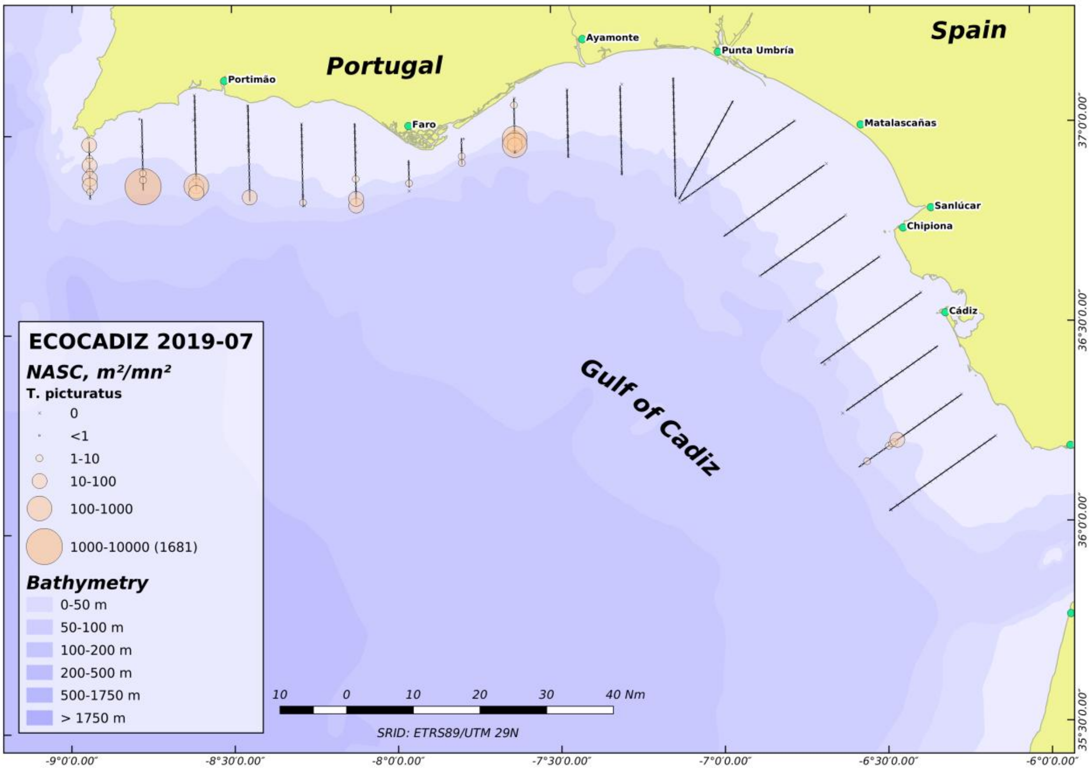


Figure 28. *ECOCADIZ 2019-07* survey. Blue jack mackerel (*Trachurus picturatus*). Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species.

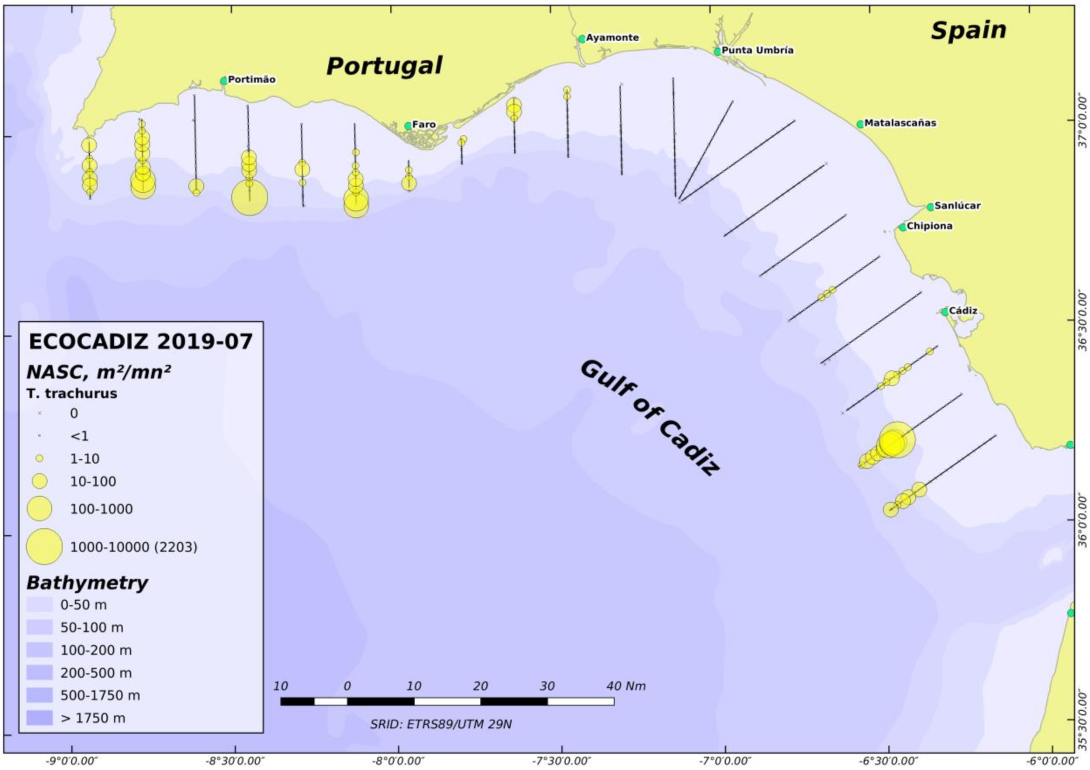


Figure 29. *ECOCADIZ 2019-07* survey. Horse mackerel (*Trachurus trachurus*). Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species.

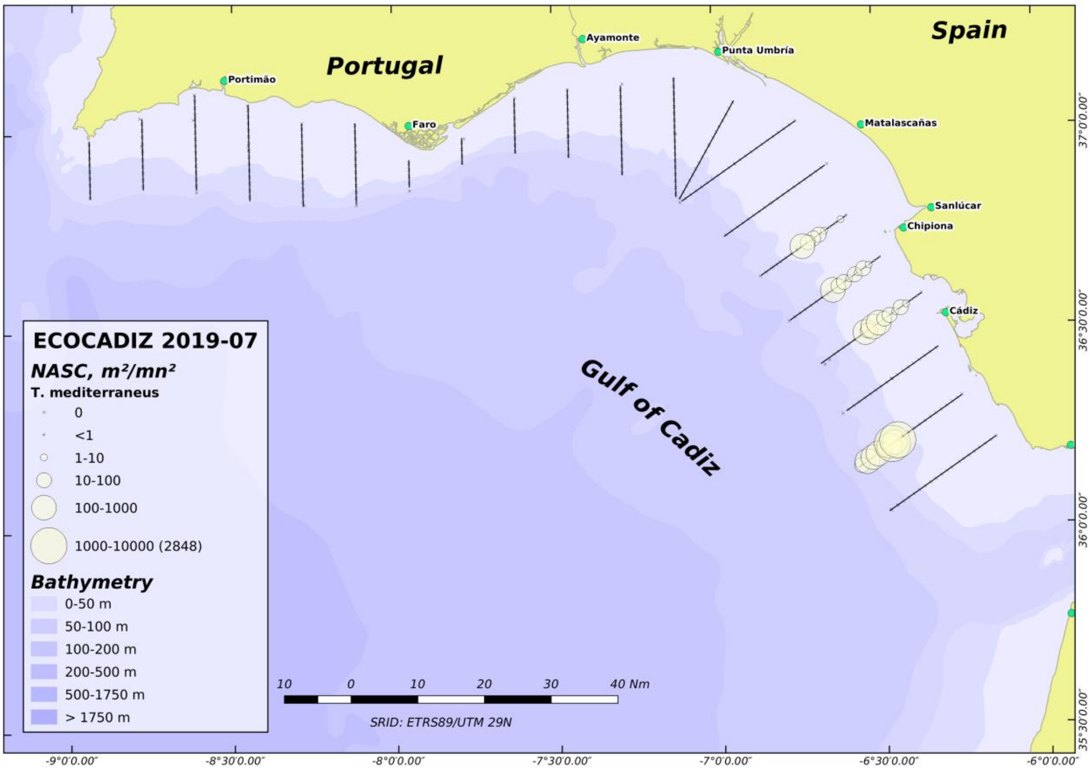


Figure 30. *ECOCADIZ 2019-07* survey. Mediterranean horse mackerel (*Trachurus mediterraneus*). Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species.

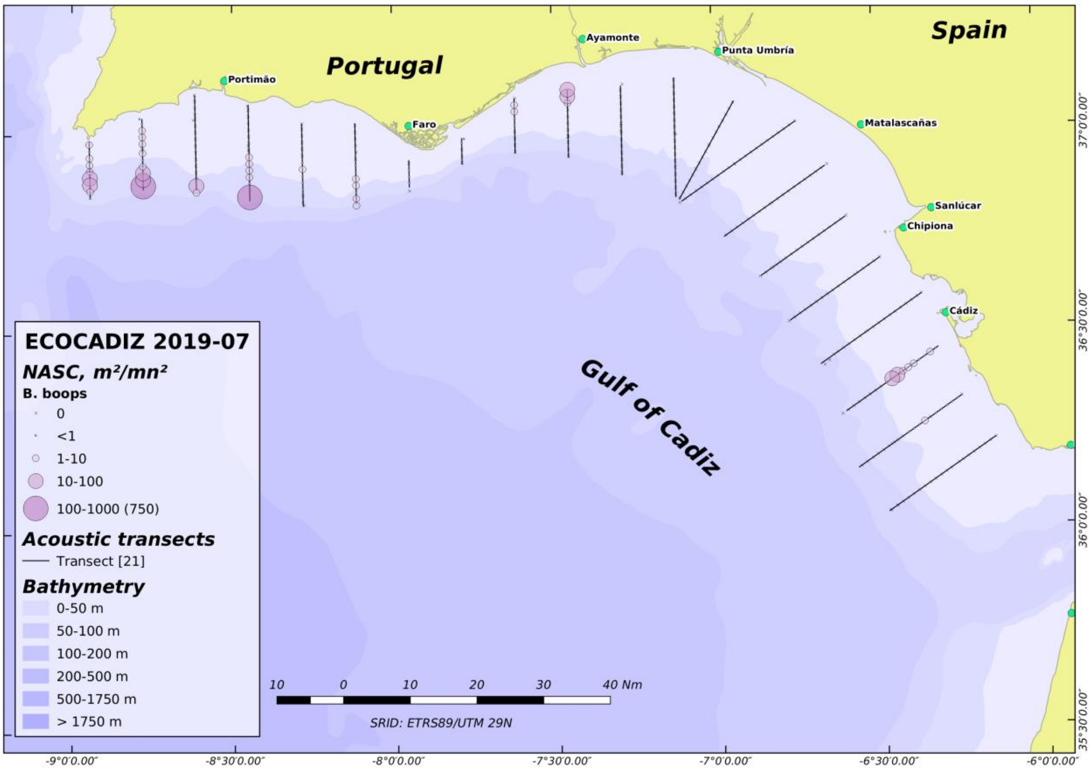


Figure 31. *ECOCADIZ 2019-07* survey. Bogue (*Boops boops*). Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species.

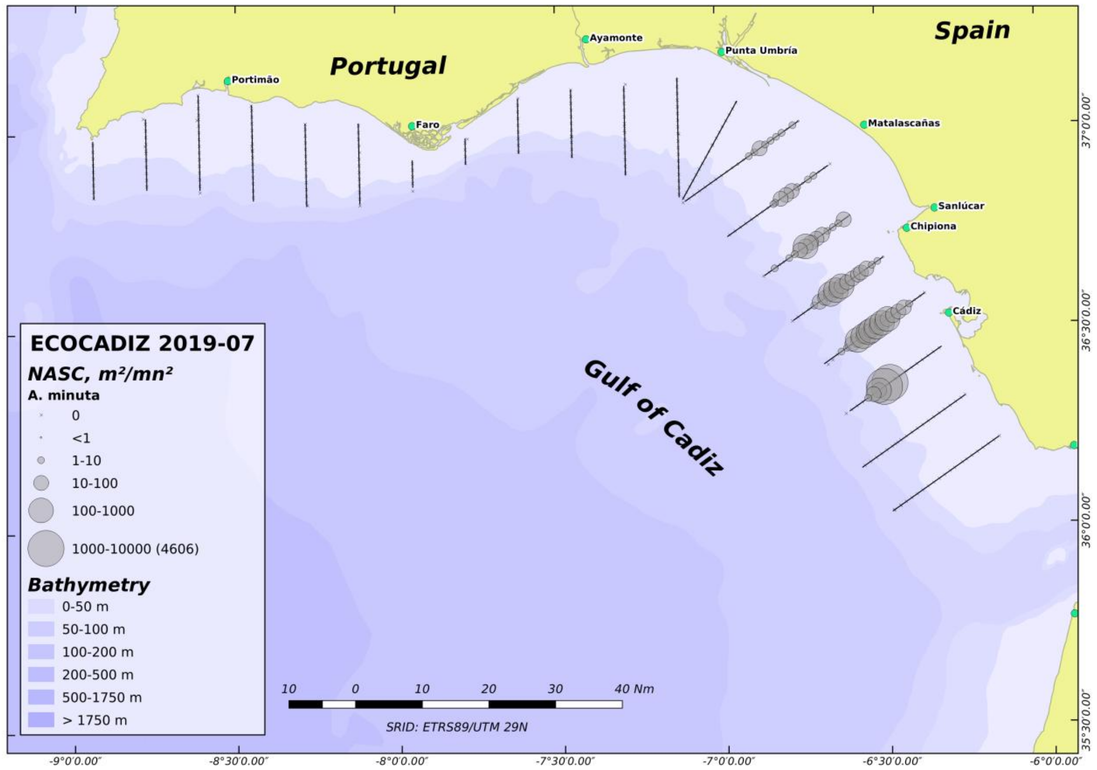


Figure 32. *ECOCADIZ 2019-07* survey. Transparent goby (*Aphia minuta*). Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species.

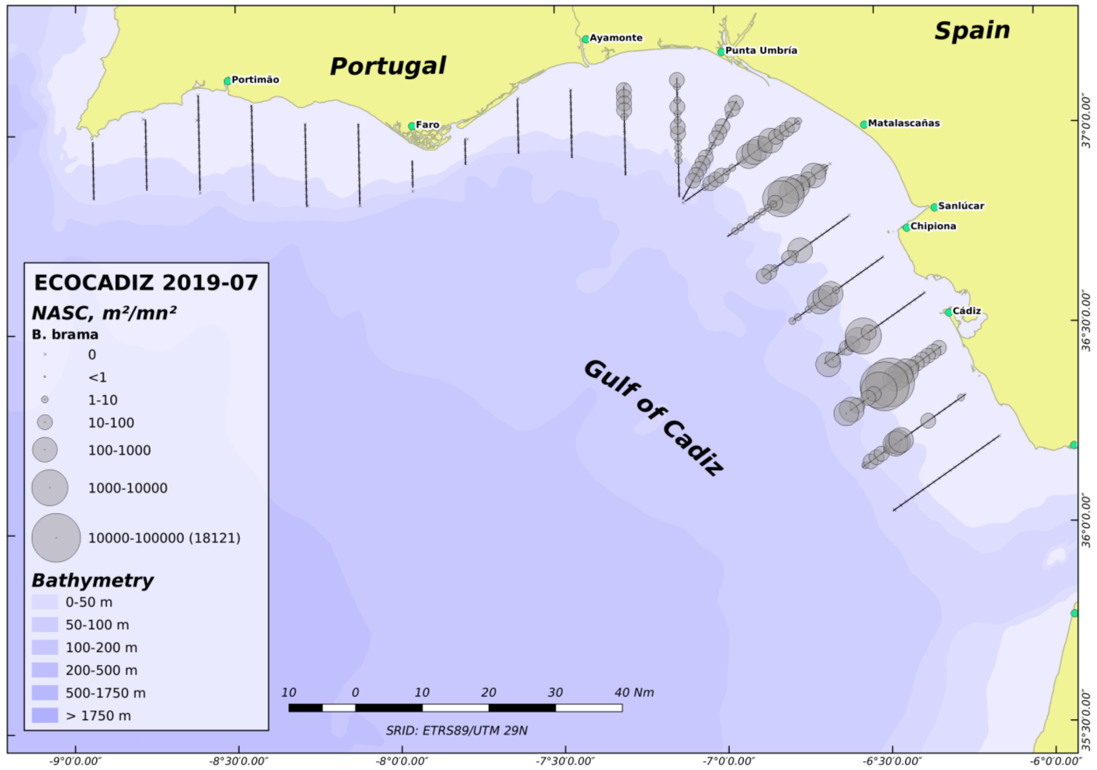


Figure 33. *ECOCADIZ 2019-07* survey. Atlantic pomfret (*Brama brama*). Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species.

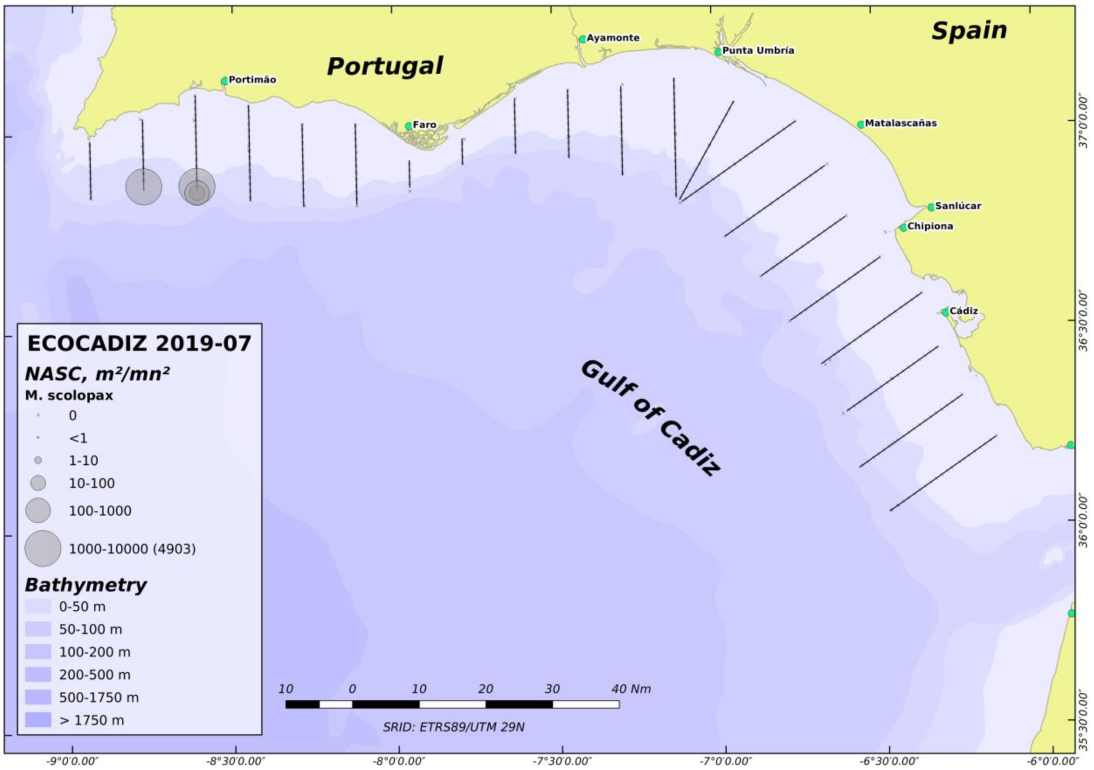


Figure 34. *ECOCADIZ 2019-07* survey. Longspine snipefish (*Macroramphosus scolopax*). Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species.

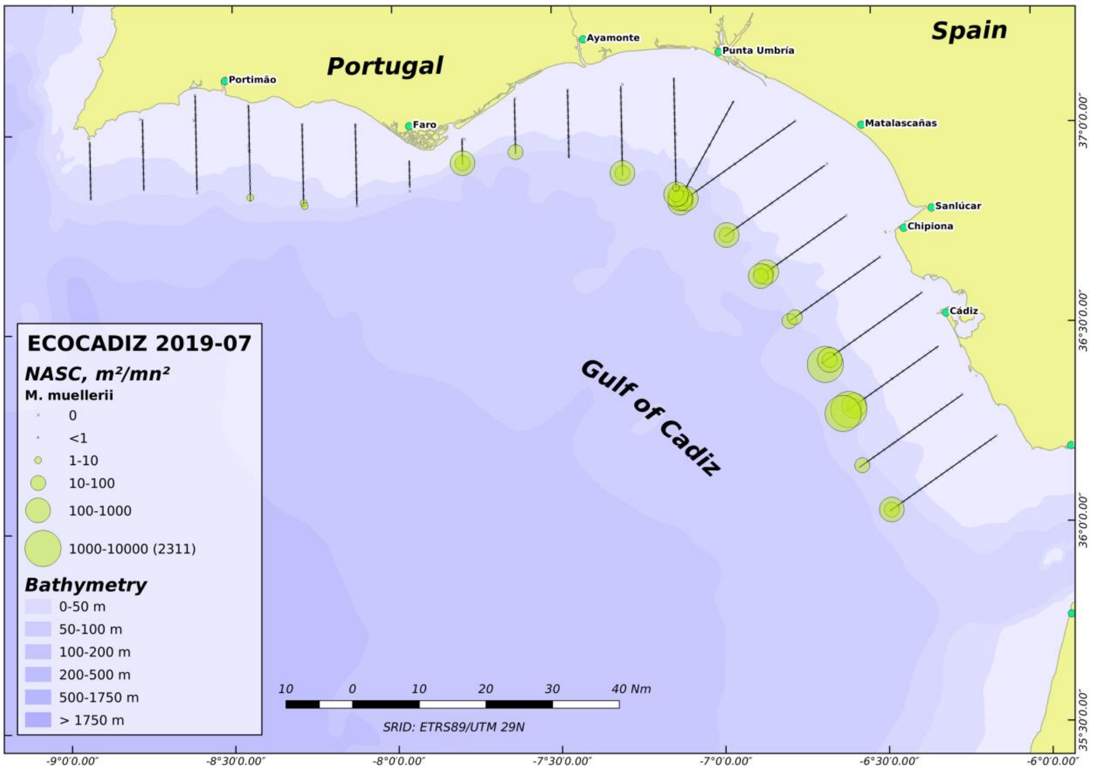
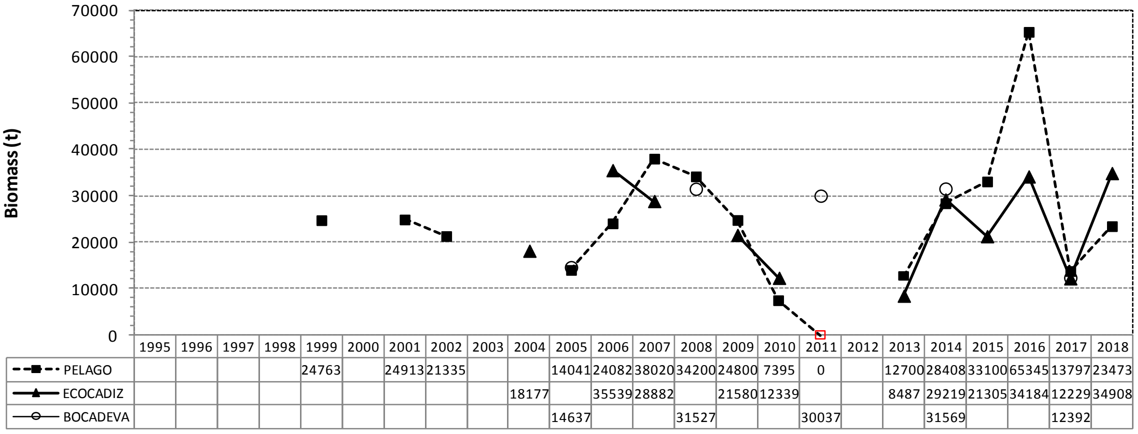


Figure 35. *ECOCADIZ 2019-07* survey. Pearlside (*Maurolicus muelleri*). Distribution of the total backscattering energy (Nautical area scattering coefficient, *NASC*, in m^2 nmi^{-2}) attributed to the species.

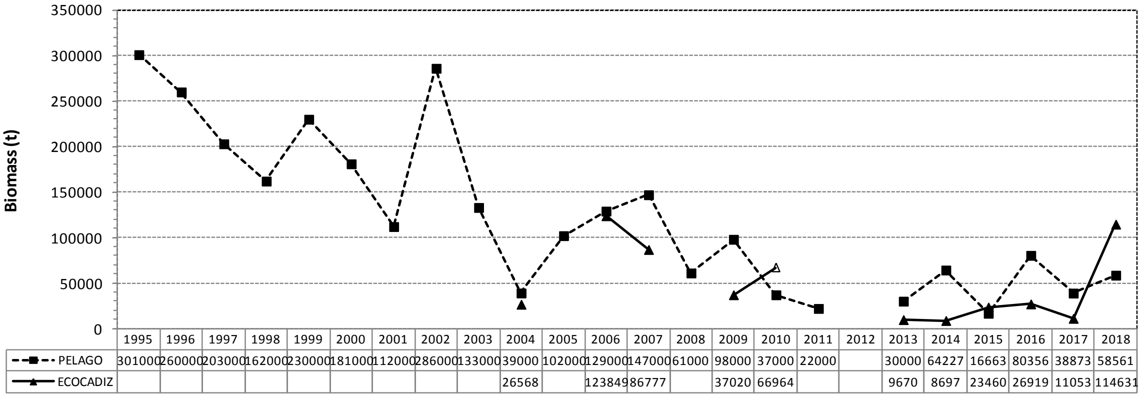
Biomass trends (in tons)

Anchovy biomass estimates



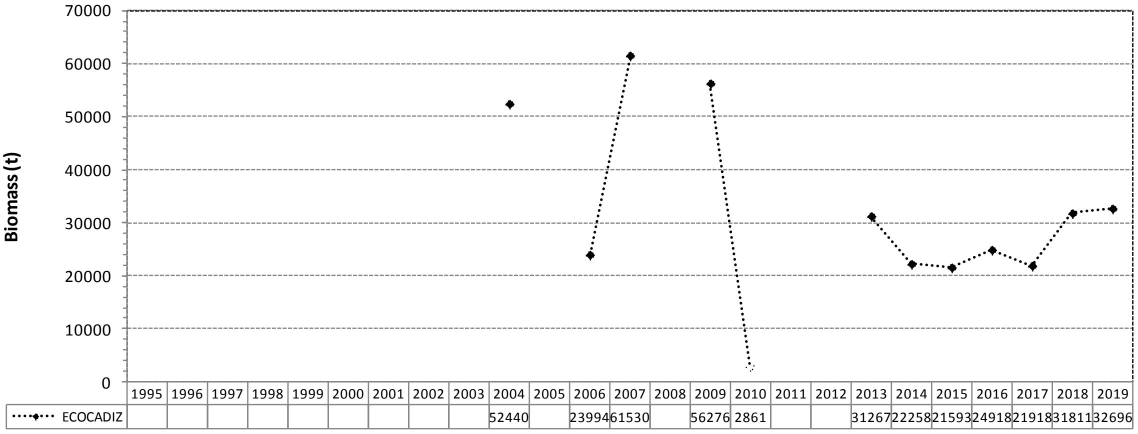
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
PELAGO					24763		24913	21335			14041	24082	38020	34200	24800	7395	0		12700	28408	33100	65345	13797	23473
ECOCADIZ										18177		35539	28882		21580	12339			8487	29219	21305	34184	12229	34908
BOCADEVA											14637			31527			30037			31569			12392	

Sardine biomass estimates



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
PELAGO	301000	260000	203000	162000	230000	181000	112000	286000	133000	39000	102000	129000	147000	61000	98000	37000	22000		30000	64227	16663	80356	38873	58561
ECOCADIZ										26568		123849	86777		37020	66964			9670	8697	23460	26919	11053	114631

Chub mackerel biomass estimates



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
ECOCADIZ										52440		23994	61530		56276	2861			31267	22258	21593	24918	21918	31811	32696

Figure 36. Trends in biomass estimates (in tons) for the main assessed species in Portuguese (*PELAGO*) and Spanish (*ECOCADIZ* and *BOCADEVA*) survey series. Note that the *ECOCADIZ* survey in 2010 partially covered the whole study area. The anchovy null estimate in 2011 from the *PELAGO* survey should be considered with caution.

FSS Survey Series: 2019/03

Western European Shelf Pelagic Acoustic Survey (WESPAS)

13 June – 24 July, 2019

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Paul Connaughton[3]*, John Power[3*], Aidan Long[4*], Peter Croot[4*]

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Cláir Chistí Eorpacha Struchtúrtha agus Infheistíochta na hÉireann 2014–2020
Cómhaoinithe ag Rialtas na hÉireann agus ag an Aontas Eorpach

Department of Agriculture, Food and the Marine
An Roinn Talmhaíochta, Bia agus Mara

EUROPEAN MARITIME AND FISHERIES FUND

Table of Contents

1 Introduction

The WESPAS survey program is the consolidation of two existing survey programs carried out by FEAS, the Malin Shelf herring acoustic survey, and the boarfish acoustic survey. The Malin Shelf herring acoustic survey has been carried out annually since 2008 and reports on the annual abundance of summer feeding aggregations of herring to the west of Scotland and the north and west of Ireland from 54°N to 58°30'N. The boarfish survey was conducted from 2011 using a chartered fishing vessel and reported the abundance of spawning aggregations of boarfish from 47°N to 57°N. In 2016 both surveys were combined and since then have been carried out onboard the RV Celtic Explorer over 42 days providing synoptic coverage of shelf waters from 47°30'N northwards to 58°30'N.

Age stratified relative stock abundance estimates of boarfish, herring and horse mackerel within the survey area were calculated using acoustic data and biological data from trawl sampling. Stock estimates of boarfish and horse mackerel were submitted to the ICES assessment Working Group for Widely Distributed Stocks (WGWIDE) meeting in August 2019. Herring estimates are submitted to the Herring Assessment Working Group (HAWG) meeting in March every year. Survey performance will be reviewed at the ICES Planning Group meeting for International Pelagic Surveys (WGIPS) meeting in January 2020.

2 Materials and Methods

2.1 Scientific Personnel

Leg	CE19010	CE19010
Dates	13-04 Jun/Jul	04-24 July
Days	22	20
Start	Falmouth	Galway
End	Galway	Galway
Acou (Chief Sci)	Ciaran O'Donnell	Michael O'Malley
Acou	Turloch Smith	Eugene Mullins
Acou	Ian Murphy	Michael Gras
Acou	Tobi Rapp	Hugo Maxwell
Bio (Deck Sci)	Dermot Fee	Marcin Blaszkowski
Bio	Sophia Wasserman	Sean O'Connor
Bio	Stephanie Linehan	Emma White
Bio	Stephan Brennan	Hayley Campbell
		Sharon Sugrue
MMO	John Power	Meadhbh Quinn
SBO	Paul Connaughton	Paul Connaughton
SBO	Sally O'Meara	Sibeal Regan
Zoo/Salps	Eoin Moorhouse	Laura Stenson
Zoo/Salps	Briana Casserly	Rachel Shaw
CDOM +	Monica Mullins	Catherine Jordan
CDOM +	Sarah Ayres	Daniel Waters
CDOM +	Mikey Reddin	Grainne Cronin O’Reilly

2.2 Survey Plan

2.2.1 Survey objectives

The primary survey objectives are listed below:

- Collect acoustic density measurements of boarfish, herring and horse mackerel within a pre-determined survey area using a split-beam echosounder (EK60) over multiple frequencies
- Determine an age stratified estimate of biomass and abundance for the above target species from survey data
- Collect biological samples from directed trawling on fish echotraces to determine age structure and maturity state of standing stocks

- Take morphometric and genetic samples of individual herring within ICES divisions 6a and 7b, c for stock identification analysis
- Use vertical CTD casts to determine hydrographic conditions and the extent of shelf front regions
- Collect plankton samples using dedicated vertical trawls to determine biomass of zooplankton and the spatial extent of areas of concentration
- Carry out visual surveys to determine the abundance and distribution of marine mammals and seabirds (ESAS)
- Use multi-beam echosounders (Kongsberg EM2040) and Omni sonar (Simrad SU92) to collect data on the aggregation morphology and behaviour of target species
- Jellyfish species distribution from combined trawl and plankton net caught individuals.
- Analysis of water samples to determine the composition and spatial distribution of pico- and nano- plankton populations, bacteria and CDOM

2.2.2 Survey design and area coverage

Survey coverage began in the southern Celtic Sea at 47°30’N (northern Biscay) and worked northwards to 58°30’N (northern Hebrides), including the Porcupine Bank (Figure 1). Area coverage was based on the distribution of catches from the previous surveys (e.g. O’Donnell et al. 2007, 2011).

The survey area was stratified based on acoustic sampling effort strata and geographical stock boundaries. Transect start points were randomised within each stratum. Transect spacing was set at 15 nmi (nautical miles) in open water areas and zigzag transects in the restricted Minch area. High-intensity small scale surveys were carried out in specific areas of interest using established methods. Coverage extended from the 50 m contour to the shelf-slope (250 m). An elementary distance sampling unit (EDSU) of 1nmi was used during the analysis of acoustic data during the main body of the survey area. In total, the planned survey covered 5,956 nmi using 58 transects relating to total area coverage of 60,183 nmi^2.

The survey was carried out from 04:00–00:00 each day to coincide with the hours of daylight when target species are most often observed in homogenous schools. During the hours of darkness, schools disperse into mixed-species scattering layers and are not readily available to acoustic sampling techniques.

Survey design and analysis methods for the WESPAS survey adhere to guidelines laid out in the Manual for International Pelagic Surveys (ICES, 2015).

2.3 Fisheries acoustics

2.3.1 EK60 Calibration

All frequencies of the Simrad EK60 were calibrated in March 2019 in Killary Harbour. Calibration procedures followed methods laid out in Demer *et al.* (2015). The results of the 38 kHz calibration are provided in Table 1.

2.3.2 Acoustic array

Equipment settings for the acoustic equipment were determined before the start of the survey program, and based on established settings employed by FEAS on previous surveys (O'Donnell *et al.,* 2004).

Acoustic data were collected using the Simrad EK60 scientific echosounder. Simrad split-beam transducers are mounted within the vessel's drop keel and lowered to the working depth of 3.3m below the vessel's hull or 8.8 m sub surface. Four operating frequencies were used during the survey (18, 38, 120 and 200 kHz) for trace recognition purposes, with the 38 kHz data used to generate the abundance estimate.

While on survey track the vessel is normally propelled using DC twin electric motor propulsion system with power supplied from 1 main diesel engine, so in effect providing "silent cruising" as compared to normal operations. During fishing operations normal two-engine operations were employed to provide sufficient power to tow the net.

2.3.3 Acoustic data acquisition

Acoustic data were recorded onto the hard-drive of the processing unit. The "RAW files" were logged via a continuous Ethernet connection to the vessels server and the EK60 hard drive as a backup in the event of data loss. In addition, as a further back up a hard copy was stored on an external hard drive. Echoview® Echolog (Version 10) live viewer was used to display the echogram during data collection to allow the scientists to scroll through echograms noting the locations and depths of fish schools. A member of the scientific crew monitored the equipment continually. Time and location (GPS position) data was recorded for each transect within each stratum. This log was used to monitor the time spent off track during fishing operations and hydrographic stations plus any other important observations.

2.3.4 Echogram scrutinisation

Acoustic data was backed up every 24 hrs and scrutinised using Echoview® (V 10) post processing software.

The RAW files were imported into Echoview for post-processing. The echograms were divided into transects. Echotraces belonging to one of the target species (herring, boarfish and horse mackerel) were identified and echo integration was performed on the enclosed regions. The echograms were analysed at a threshold of -70 dB and where necessary plankton was filtered out by thresholding at –65 dB.

Partitioning of echograms to identify individual schools was carried out to species level where possible and mixed scattering layers where it was not possible to identify monospecific schools. For scattering layers or mixed schools containing target species the total NASC (Nautical Area Scattering Coefficient) was split using Target Strength (TS) to provide a species specific NASC value. This process was conducted within the StoX program.

The echogram scrutinisation process was carried out by a scientist experienced in scrutinising echograms and with the aid of accompanying trawl catch data.

The allocated echo integrator counts (NASC values) from these categories were used to estimate the herring numbers according to the method of Dalen and Nakken (1983).

The TS/length relationships used predominantly for the survey are those recommended by the acoustic survey planning group based at 38 kHz (ICES, 1994):

Herring	TS = 20logL – 71.2 dB per individual (L = length in cm)
Sprat	TS = 20logL – 71.2 dB per individual (L = length in cm)
Mackerel	TS = 20logL – 84.9 dB per individual (L = length in cm)
Horse mackerel	TS = 20logL – 67.5 dB per individual (L = length in cm)
Anchovy	TS = 20logL – 71.2 dB per individual (L = length in cm)

The TS length relationship used for boarfish is from Fassler et al (2013):

Boarfish	TS = 20logL – 66.2 dB per individual (L = length in cm)

The TS length relationship used for gadoids was a general physoclist relationship (Foote, 1987):

Gadoids	TS = 20logL – 67.5 dB per individual (L = length in cm)

2.3.5 Calculation of acoustic abundance

Acoustic data were analysed using the StoX software package recently adopted for WGIPS coordinated surveys (ICES 2016). A description of StoX can be found here: http://www.imr.no/forskning/prosjekter/stox/nb-no. Estimation of abundance from acoustic surveys within StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990).

2.4 Biological sampling

A single pelagic midwater trawl with the dimensions of 85 m in length (LOA) and a fishing circle of 420 m was employed during the survey (Figure 23). Mesh size in the wings was 2.4 m through to 10 cm in the cod-end. The net was fished with a vertical mouth opening of approximately 25 m and was observed using a cable linked Simrad FS70 netsonde. Spread between the trawl doors was monitored using Scanmar distance sensors, all sensors being configured and viewed through a Scanmar Scanbas system.

All components of the catch from the trawl hauls were sorted and weighed; fish and other taxa were identified to species level. Fish samples were divided into species composition by weight. Species other than the herring/boarfish/horse mackerel were weighed as a component of the catch. Length frequency and length weight data were collected for each component of the catch. Length measurements of herring, boarfish, sprat and pilchard were taken to the nearest 0.5 cm below. Horse mackerel were taken to the nearest 1.0 cm below. Age, length, weight, sex and maturity data were recorded for individual herring, boarfish and horse mackerel within a random 50 fish sample from each trawl haul, where applicable. All herring were aged onboard. The appropriate raising factors were calculated and applied to provide length frequency compositions for the bulk of each haul.

Decisions to fish on particular echo-traces were largely subjective and an attempt was made to target marks in all areas of concentration not just high density schools. No bottom trawl gear was used during this survey. However, the small size of the midwater gear used and its manoeuvrability in relation to the vessel power allowed samples from the bottom to be taken in areas of clean ground.

2.4.1 Herring stock identification

When possible, a sample of 120 herring (>23 cm) were taken for morphometric and genetic analysis from herring in the Malin Shelf area (6a, 7b, c). These fish were processed according to SGHERWAY procedures (ICES 2010).

2.5 Hydrography and biogeochemical data collection

Oceanographic stations were carried out during the survey at predetermined locations along the survey track using a calibrated SeaBird 911 rosette sampler. Data were collected from 1 m subsurface and 3-5 m above the seabed.

2.5.1 Hydrography and water sampling

Seawater samples were collected from typically 6 depths on the up cast of the profile by triggering Niskin bottles at predetermined depths related to the hydrography observed during the down cast. The CTD data comprises continuous downcast and up casts records of the pressure, temperature, conductivity (salinity), dissolved oxygen, chlorophyll fluorescence and turbidity. These data are processed according to GO-SHIP guidelines and incorporated into ODV files for the continuous downcast data and the discrete bottle data collected during the up cast.

Raw seawater samples were drawn from Niskin bottles mounted (n=21) on the ships CTD system. Typically, six depths from just below the surface to 10 m above the maximum bathymetry depth were sampled. Raw samples were collected from the Niskin bottles into 1 ltr brown LDPE bottles. Sub samples were then obtained from the LDPEs.

2.5.2 Coloured Dissolved Organic Matter (CDOM)

Samples for the analysis of Colour Dissolved Organic Matter (CDOM) absorption were collected from the CTD cast directly from the Niskin bottles. They were then immediately filtered through a 0.2 µm syringe filter and part of the filtrate used for CDOM analysis onboard and the rest frozen at -20° C for later nutrient and FDOM analysis. CDOM measurements were performed using an Ocean Optics Maya spectrophotometer coupled to a 1m liquid wave guide capillary cell (LWCC), supplied by World Precision Instruments, and an Ocean Optics DH-mini light source.

The filtered samples frozen at -20° C will also be analysed, after thawing, back in the laboratory in Galway for nutrients and 3D EEM FDOM analysis (Horiba Aqualog). The 3D EEM FDOM dataset will be analysed using PARAFAC (Murphy et al., 2013) will allow the determination of independent fluorphore components in seawater which can be used to identify sources of FDOM from terrestrial or marine processes.

2.5.3 Nutrient sampling

Seawater samples are collected from the CTD and immediately filtered through 0.2 µm syringe filters. The filtrate is then frozen at -20 °C until analysis in the laboratory. For analysis in the laboratory samples are thawed overnight and then analysed for Nitrite, Nitrate, Phosphate and Silicate using specially adapted low volume methods based on standard green chemistry methods for nutrient analysis in seawater (García-Robledo et al., 2014; Koroleff, 1976; Murphy and Riley, 1962; Schnetger and Lehners, 2014).

2.5.4 Bacteria, Heterotrophic nanoflagellates, Pico and nanoplankton abundance

An Accuri C6 flow cytometer was used to analyse raw and treated seawater samples to determine the presence and abundance of a number of species of micro planktonic organisms. This instrument employs a combination of the fluorescence and light scattering characteristics of the organisms present to identify and count the populations of the distinct species in each sample. Unfiltered seawater samples collected directly from the CTD are run on an Accuri C6 flow cytometer while at sea according to established protocols (Marie et al., 1997; Marie et al., 2014). An untreated raw sample is used to identify the phytoplankton by size and fluorescence, *Synechococcus* species can be identified at this step by their unique combination of cell size and phycoerythrin fluorescence. A second raw sample is treated with Lysotracker Green to determine heterotrophic nanoplanktonic protists (Rose et al., 2004). While a third sample is fixed with glutaraldehyde and then treated with the DNA stain Syber Green to enumerate marine bacteria and phytoplankton via the combination of chlorophyll fluorescence (red) and the DNA stain (green).

2.5.5 Hyperspectral measurements

In order to more directly compare field data with satellite data, a pair of hyperspectral sensors were mounted above the bridge of the Celtic Explorer. The sensor pair incorporated an irradiance and radiance sensor for the purposes of determining the hyperspectral reflectance from the surface of the ocean for comparison to the reflectance measured by the ocean colour satellites.

Particulate absorption of fresh water and seawater can be determined by filtering a known amount of sample through a Glass Fiber Filter (GF/F) and measuring the particulate absorption coefficient $a_p(\lambda)$ concentrated on the filter. This technique is called quantitative filter technique (QFT) and corrects for the pathlength amplification, an effect of scattering. Measurements were made shipboard using a QFT-1 filter holder (WPI) after filtering 200-1000 mL of seawater through a 25 mm GF/F filter. An Ocean Optics Maya spectrophotometer was coupled to the QFT-1 using 600 µm diameter fibre optical cable with a DH mini light source.

2.5.6 Chlorophyll measurements

Water samples from Niskin bottles collected at near surface (5-6 m depth) were filtered. Filtered samples were labelled and frozen for analysis in the laboratory after the survey.

2.6 Zooplankton and jellyfish sampling

2.6.1 Zooplankton

Zooplankton sampling was carried out alongside CTD stations. A weighted 1 m diameter Hydro-bios ring net was used with a 200 µm mesh size and the net was fitted with a Hydro-Bios® calibrated mechanical flow meter to determine the volume of water filtered. Vertical plankton tows were carried out to within 5 m of the seabed for stations where total depth was less than 100 m and to a 100 m maximum for all other stations depths.

Single tow stations samples were split in 50:50 for wet and dry processing. Sample splitting was carried out using a Hydro-Bios® sample splitter. The wet component was fixed for further analysis back at the lab. Fixing was carried using a 4% fix volume of buffered formalin.

Dry processing was carried out with each sample filtered through 2000 µm, 1000 µm and 125 µm sieves. For the largest gauge sample (2000 µm) including jellyfish and or krill volume displacement (ml) was measured using a graduated cylinder. For finer gauge samples (1000 and 125 µm) dry weight analysis was carried out. Samples were transferred to petri-dishes and dried onboard (70 °C oven) for a minimum of 24 hrs before sealing and freezer storage. Back in the lab dry weight analysis was carried out on defrosted frozen samples using a Sartorius MSE225S-000-DA fine scale balance (uncertainty of +/- 0.00016 g).

2.6.2 Jellyfish

The vertical ring net is a conventional method for broad scale sampling of zooplankton in coastal and oceanic waters. Jellyfish sampling was carried out alongside zooplankton sampling with the same deployment criteria as described. The volume filtered by the ring net was calculated using a Hydro-Bios® calibrated mechanical flow meter. Once recovered, the cod end was washed into a 30 L bucket. Considering the rapid degradation and underrepresentation of many ctenophore species in fixed samples, those that were visible to the naked eye were enumerated and recorded separately by passing fresh zooplankton samples through a 180 µm sieve. The sample was then fixed in 4% formalin solution for further analysis in a laboratory on land. In total, 87 ring net stations were successfully deployed along the cruise track line (Figure 12).

By-caught gelatinous fauna collected in the large pelagic net (Figure 23) were also recorded, weighed, measured and discarded after each haul. As the fishing was targeted and involved variable subsampling of catches, only qualitative data could be attained for gelatinous species using this large net. A total of 30 pelagic net hauls contained jellyfish taxa.

To quantify surface abundances of large jellyfish, surface counts of jellyfish from the bow of the Celtic Explorer were made during transits between sampling stations Observations were made from an elevated position from the bow of the ship, during day light hours (07:00–21:00 h). Jellyfish were identified to species level, and their numbers estimated per 5-min intervals using the following categories: 0, 1–10, 11–50, 51–100, 101–500, and >500 (jellyfish abundance estimates of much greater than 500 are impractical). Sample periods were 15 min long with 5-min breaks between successive samples. After three successive sample periods a 20 min break is taken, and after every 3–4 h a 1-h rest period is taken. Almost 70 hours of visual surveys were carried out over the duration of the research cruise.

2.7 Marine mammal and seabird surveys

2.7.1 Marine mammal abundance and distribution

The cetacean survey was conducted from the 14/06/19 to the 10/07/19 using a team of two marine mammal observers (MMOs), with one cetacean observer deployed per survey leg. To prevent MMO fatigue and optimise the validity of the data, survey effort was carried out in two-hour shifts, with a break of one hour between shifts.

Cetacean watches were conducted using a standard single platform line transect survey design while the vessel was travelling at a consistent speed and heading. When the vessel was stationary at oceanographic stations, cetacean watches were conducted using a standard single platform point sampling survey design. Visual watches were undertaken from the vessel's crow's nest, located 17.45 m above sea level, during all daylight hours, when weather conditions permitted. During periods of unfavourable weather conditions, observations were carried out from the bridge (10.63 m above sea level).

Survey effort was concentrated in periods of sea state 6 or less, and in moderate or good visibility. Survey effort conducted outside of these parameters was conducted at the discretion of the observers. Survey effort for cetaceans was concentrated within an arc of 60^{o} either side (i.e., to port and to starboard) of the vessel's track-line but all sightings to 90^{o} both side of the track-line and further aft were also recorded. Searching for cetaceans was predominantly done with the naked eye, however, Nikon Prostaff 7 8x42 binoculars and a Canon EOS 7D DSLR camera with a Sigma 100-400 mm zoom lens was used to confirm species identification and group size, and assess behaviour. Survey effort was also carried out during hauls and when at CTD stations.

The Cybertracker (http://www.cybertracker.org/) data collection software package (Version 3.501) was used to collect all positional, environmental and sightings data, and save it to a Microsoft Access database. Positional data was collected using a portable GPS receiver with a USB connection and recorded every 5 seconds.

Each line transect was assigned a unique transect number, and a new transect was started anytime the vessel activity changed (i.e. changing from on-transect to inter-transect). Each subsequent sighting was also assigned to this unique transect number.

Environmental data was time-stamped and recorded with GPS data at the beginning and end of each line transect. Environmental data was recorded at least every 15-30 minutes, or sooner if there was a change in environmental conditions. Environmental data recorded included; wind speed, wind direction, sea state, swell, visibility, cloud cover and precipitation. All data entry was time stamped by Cybertracker and saved in the Access database.

The distance of each sighting from the ship was estimated using a fixed interval range finder (Heinemann, 1981), while the bearing from the ship was estimated with an angle board. This data, along with data such as species identification, group size, composition, heading, sighting cues, surfacing interval, behaviour and any associations with birds or other cetaceans was also recorded on the time stamped Cybertracker sighting record page. Where species identification could not be confirmed, sightings were recorded at an appropriate taxonomic/confidence level (i.e. probable, possible, unidentified whale, unidentified dolphin etc.). Auxiliary and incidental sightings were also recorded.

Ancillary data such as line changes, changes in survey activity (e.g. fishing/CTD cast) and fishing vessel activity were also recorded.

2.7.2 Seabird abundance and distribution

The seabird survey was conducted from the 14/06/19 to the 24/07/19 using a team of two seabird surveyors per survey leg. The lead seabird observer conducted visual survey effort, while the other seabird observer was responsible for data collection and recording. The observer's survey effort was maximized and optimized during periods of sea state less than or equal to sea state 6 and with visibility of greater than 300m. Additional visual point sampling (e.g., at oceanographic sampling stations or fishing stations) and incidental recording were also employed; however, line transect survey effort was prioritised by the observer. Seabird watches were conducted using a standard single platform line transect survey design while the vessel was travelling at a consistent speed and heading. Observations for seabirds were conducted from the monkey island (deck height 12 m above sea level) or the bridge (deck height 10 m above sea level). Observations were conducted from the monkey island preferably, however, as in previous surveys aboard the R.V. Celtic Explorer, access to the monkey island was dependent on weather conditions.

The data collection methodology was based on that originally proposed by Tasker *et al.* (1984) with later adaptations applied to allow correction factors to be applied for missed birds (Camphuysen *et al*., 2004). The method employed used a single platform line transect survey design with sub-bands to survey birds associated with the water, while flying birds were surveyed using a 'snapshot' technique. Observer effort was concentrated in a bow-beam arc of 90° to one side (i.e., to port or starboard) of the vessel's track-line, however, all seabirds observed outside this area were also be recorded.

Survey effort for seabirds associating with the water were concentrated within a survey strip of 300m running parallel and adjacent to the vessels track-line and extending to the horizon. All birds surveyed within this region were be recorded as 'in-transect' and assigned to one of four distance sub-bands (A: 0-50 m, B: 50-100 m, C: 100-200 m, D: 200-300m) according to their perpendicular distance from the track-line. This approach allows for the evaluation of biases caused by specific differences in detection probability with increasing distance from the track line (Camphuysen *et al.* 2004). Seabirds occurring outside of this survey strip were recorded as 'off-transect' and assigned to separate sub-band (E: >300 m). The perpendicular distance to an animal was estimated using a fixed interval range finder (Heinemann, 1981), ensuring each animal is allocated to the correct distance sub-band.

Flying birds were surveyed using 'snapshots', where instantaneous counts of flying birds within a survey quadrant of 300 m x 300 m were conducted. The periodicity of these 'snapshots' was vessel speed dependent but timed to allow counts to occur as the vessel passes from one survey quadrant to the next. This method minimises biases in counts of flying birds relative to the movement of the vessel (Pollock *et al.,* 2000, Camphuysen *et al.* 2004).

Seabirds remaining with the vessel for more than 2 minutes were deemed to be associating with the vessel (Camphuysen *et al.* 2004) and were recorded as such. Seabirds seen associating with other vessels (i.e. fishing vessels) were also recorded as such.

Searching for seabirds was done with the naked eye, however, Leika Ultravid 8x42 HD binoculars were used to confirm parameters such as species identification, age, moult, group size and behaviour (Mackey *et al.* 2004). A Canon EOS 7D Mark II DSLR camera with a Canon EF 100-400 mm F4.5-5.6 IS II USM telephoto lens was used to visually document other information of scientific interest. Data was also collected on all migratory/ transient waterfowl and terrestrial birds encountered.

The Cybertracker (http://www.cybertracker.org/) data collection software package (Version 3.501) was used to collect all positional, environmental and sightings data, and save it to a Microsoft Access database. Positional data was collected using a portable GPS receiver with a USB connection and recorded every 5 seconds.

Each line transect was assigned a unique transect number, and a new transect was started anytime the vessel activity changed (i.e. changing from on-transect to inter-transect). Each subsequent sighting was also assigned to this unique transect number.

Environmental data was time-stamped and recorded with GPS data at the beginning and end of each line transect and also as soon as any change in environmental conditions occurred. Environmental data recorded included; wind speed, wind direction, sea state, swell, visibility, cloud cover and precipitation.

Each sighting was time-stamped and recorded with GPS data using Cybertracker. Sighting data such as; species identification, distance band, group size, composition, heading, age, moult, behaviour and any associations with cetaceans or other vessels were also recorded on the time stamped Cybertracker sighting record page. Where species identification could not be confirmed, sightings were recorded at an appropriate taxonomic level (i.e. large gull sp., Larus sp., Commic tern, etc.).

Ancillary data such as line changes, changes in survey activity (e.g. fishing/CTD cast) and fishing vessel activity were also recorded.

3 Results

3.1 Malin Shelf herring (6.a.S, 7.b, c and 6.a.N south of 58°30’N)

3.1.1 Biomass and abundance

Herring	Abund ('000)	Biomass (t)
TSB estimate	597,974	86,641
SSB estimate	426,663	68,607

The Malin Shelf Herring total stock biomass (TSB) was 86,641 t and total stock numbers (TSN) was 597,974,000 (Table 3). The spawning stock biomass (SSB) was 68,607 t and spawning stock numbers (SSN) was 426,663,000. The CV for the survey was 0.37.

The Malin Shelf survey area was divided into 6 strata representing a total area coverage of 32,162 nmi^2 (Figure 2 & Table 5). A breakdown of herring stock abundance and biomass by age, maturity and stratum is detailed in Table 3 and Figure 4. The Malin Shelf survey time series is provided in Table 4.

3.1.2 Stock distribution

A total of 45 trawl hauls were carried out during the survey (Figure 1), with 1 haul containing >50% herring by weight of catch. Seven hauls in total contained herring within the Malin Shelf survey area (Table 2). A total of 115 echotraces were assigned to herring compared to 228 in 2018.

The area covered by the RV Celtic Explorer was similar to the 2018 survey. The area of 6.a.N to the north of 58°30’N was covered by RV Scotia in 2019; the overall estimate of the survey for the stock assessment of herring in 6.a will therefore be complete when both surveys are combined at WGIPS 2020. Herring were distributed in four out of the six strata (Table 5). There were no herring allocated to echotraces in the NW Coast strata or the Minch strata. A total of 58 EDSUs (1nmi. long) contained herring in the Malin Shelf survey area. This included a number of high NASC value EDSUs, with areas of high density occurring to the northwest of Tory Island, west of the Hebrides and north of St. Kilda (Figure 3). Herring were again found south of the 56 ˚N in 2019, similar to the historical distribution of herring found during this time series. There were adult herring distributed south of the 56°N in 2019 for the first time in a number of years. Herring schools were predominantly found in pillars in close proximity to the seabed (Figure 11g, 11h and 11j). Overall the stock was distributed throughout a similar area to 2018 (Figure 3). The distribution of herring during the survey period is usually observed in 3 particular regions; north of 57°N (west of the Hebrides), between 56-57°N (south and west of Barra Head) and south of 56°N (north and west of Donegal and Stanton Bank). The survey in 2019 largely followed this distribution.

3.1.3 Stock composition

A total of 304 herring were aged from survey samples with 1,568 length measurements and 505 length-weights recorded. Herring age samples ranged from 0-9 year olds (Table 3 & Figure 4). A further 276 herring were processed for morphometric and genetic analysis under SGHERWAY protocols (ICES 2010) in 2019; from hauls 35, 36 and 42.

The 2019 survey estimate was dominated by 2-wr (29% TSB and 35% TSN) and 3-wr (30% TSB and 29% TSN) (Table 3). The third most dominate age group was 4-wr herring contributing 17% to the TSB and 14% to TSN. Combined these three age classes represented 75% of TSB and 79% of TSN.

Maturity analysis of herring samples in 2019 indicated overall 79% of herring (TSB) were mature. In 2018, 71% of herring were mature. Maturity analysis by age class showed that 39% of 2-wr, 88% of 3-wr fish, and 100% of fish of 4-wr and older were mature (Table 3).

3.2 Boarfish

3.2.1 Biomass and abundance

Boarfish	Abund ('000)	Biomass (t)
TSB estimate	3,898,827	179,156
SSB estimate	2,701,057	169,216

Boarfish TSB (total stock biomass) and abundance (TSN) estimates were 179,156 t (CV 19.8%) and 3,898,827,000 individuals (CV 25.4 %) respectively.

The boarfish survey area was divided into five strata representing a total area coverage of 53,933 nmi^2 (Figure 2). A breakdown of boarfish stock abundance and biomass by age, maturity and stratum is detailed in Table 6 & 7 and Figures 5 & 6. The boarfish survey time series is provided in Table 8.

3.2.2 Stock distribution

A total of 45 trawl hauls were carried out during the survey (Figure 1), with 11 hauls containing >50 % boarfish by weight (Table 2).

A total of 667 echotraces were assigned to boarfish as compared to 817 in 2018. Boarfish were observed in all survey strata (Table 7). The highest occurrence was in the Celtic Sea where over 61.8 % of the total survey biomass and 74.2% of total abundance was observed. This follows a similar pattern to previous years in containing the largest proportion of the stock. Within the Celtic Sea, the highest density of fish was observed in the southern survey area, south of 50°N following a similar pattern to the previous year (Figure 5). The southernmost transects were dominated by an area containing high density midwater clusters of juvenile boarfish (Figure 11a). The mid Celtic Sea saw aggregations of mature boarfish in the margins bordering the shelf edge (Figure 11b).

The west coast stratum ranked second and reported 21% of total biomass (14% abundance) in line with previous observations, although proportionally lower in 2019. The shelf area between 53-54°N, including the porcupine Bank, contained the highest abundance within these strata mirroring observations from 2018 (Figure 11c). The near absence of boarfish along the southwest coast of Ireland (51°-52°N) continued in 2019 from 2018 observations. The distribution of boarfish north of 55°N, to the north of Ireland and west of Scotland, was limited to the shelf edge margin (<180m) and continued towards the northern extreme of the survey (Figure 11i). The distribution of boarfish in the northern survey latitudes would indicate that the biotic and abiotic conditions continue to provide adequate feeding opportunities and spawning habitat to allow northward stock expansion.

3.2.3 Stock composition

A total of 808 boarfish were aged from survey samples in addition to 3,807 length measurements and 1,400 length-weights recorded. Boarfish age samples ranged from 1-15+ years (Table 6 & Figure 6). The age structure of the stock was determined using an established age length key.

The 15+ year age classes dominate the 2019 estimate contributing over 35.8% of TSB and 19.5% of TSN (Table 6). The 7-year-old (12.3% TSB and 11.4% TSN) and 10-year –old age classes (10% TSB and 7.4% of TSN) ranked second and third respectively. The ranked fourth was the 9-year-old (9.5% TSB and 7.4% TSN). Combined, the 15+, 7 and 10-year age classes represent 58.1% of TSB and 38.3% of TSN.

Maturity analysis of boarfish samples indicated 94.5% of observed biomass was mature (69.3% for abundance). Maturity analysis by age class showed that 33% of 3-year-old fish were mature, rising to 100% for fish four years and older (Table 6).

3.3 Horse mackerel

3.3.1 Biomass and abundance

Horse mackerel	Abund ('000)	Biomass (t)
TSB estimate	333,501.0	79,026.0
SSB estimate	275,349.0	77,528.5

Horse mackerel TSB (total stock biomass) and abundance (TSN) estimates were 79,026 t (CV 28.6%) and 333,501,000 individuals (CV 33.7%) respectively.

The horse mackerel survey area was composed of 7 strata relating to an area coverage of 60,183 nmi^2 as shown in Figure 2. A breakdown of horse mackerel stock abundance and biomass by age, maturity and stratum is detailed in Tables 9 & 10 and Figures 7 & 8. The biomass of horse mackerel is 15% lower in terms of biomass and 13% in terms of abundance compared to 2018. Given the short time series the survey appears to be reporting working well, with the exception being the 2017 estimate resulting from the occurrence of a large single spawning aggregation in the northern area.

3.3.2 Stock distribution

A total of 45 trawl hauls were carried out during the survey (Figure 1), with 3 hauls containing >50% horse mackerel out of 20 containing horse mackerel overall (Table 2).

A total of 120 echotraces were assigned to horse mackerel. Horse mackerel were most observed along the west coast of Ireland and Celtic Sea, where the bulk of the standing stock was located (Figure 7). Fewer schools were located to the northwest of Ireland or on the Porcupine Bank. Observations of horse mackerel along the west coast and Celtic Sea were comparable to 2018 in terms of distribution, but the number of schools (198 in 2018, 120 in 2019) and overall acoustic density were lower.

Of the 7 strata surveyed, four reported observations of horse mackerel. The Celtic Sea stratum contained the largest proportion of biomass observed (78.4% of TSB), followed by the west coast (19.2%), western Hebrides (2%) and Porcupine Bank (0.4%). Overall, the distribution of horse mackerel was considered patchy as compared to 2018, with only one area containing a mixture of medium and high density schools located off the southwest of Ireland (Figure 11d).

3.3.3 Stock composition

A total of 323 horse mackerel were aged from survey samples in addition to 463 length measurements and 341 length-weights recorded. Horse mackerel age samples ranged from 1-18 years (Table 9 & Figure 8). Age structure of the stock was determined using an age length key from constructed from the previous years aged survey samples.

The 16-year age class dominated this year’s survey estimate representing over 15.4% of TSB and 8.5% of TSN (Table 9). The 14-year age class ranked second representing over 11.8% of TSB and 6.9% of TSN (Table 9). Nine-year-old fish were ranked third contributing 11.43% to TSB and 7.9% to TSN. Combined these three age classes represented 38.7% of TSB and 23.4% of TSN.

Maturity analysis of horse mackerel samples indicated 98.1% of the total stock biomass was mature and over 82% of total abundance. Maturity analysis by age class showed that 25% of 1-year-old fish were mature, rising to 100% for fish two years and older (Table 9).

3.4 Celtic Sea herring (7g and j)

3.4.1 Biomass and abundance

CS Herring	Abund ('000)	Biomass (t)
Total stock	682,177.0	43,462.0
Spawning stock	22,468.0	2,551.8

The estimate of Celtic Sea (CS) herring TSB (total stock biomass) and abundance (TSN) estimates were 43,462 t (CV 47.3%) and 682,177,000 individuals (CV 49%) respectively.

The herring survey area was composed of a single stratum in the Celtic Sea, representing an area of over 26,626 nmi² and was surveyed using the standard survey transect spacing of 15 nmi. No high intensity surveys were carried out for herring in 2019. A breakdown of CS herring stock abundance and biomass by age, maturity and stratum is detailed in Tables 12 & 13 and Figures 9 & 10.

3.4.2 Stock distribution

Ten echotraces were assigned to herring in the Celtic Sea and herring were sampled in four targeted hauls. Herring were observed in two areas; in the western and eastern Celtic Sea (Figure 11e-f and Figure 9).

3.4.3 Stock composition

A total of 165 CS herring were aged from survey samples in addition to 264 length measurements and 221 length-weights recorded. CS herring age samples ranged from 1-6 winter rings (wr) (Table 12 & 13 and Figure 10). Age structure of the stock was determined from survey aged otoliths.

One winter ring fish dominated the total estimate, representing over 65% of total biomass and over 72% of total abundance (Table 12). Two winter ring fish ranked second contributing 29.7% of the total biomass and 24.7% of total abundance. Combined these two immature ages classes represented over 95% of total biomass and over 97% of total abundance (Figure 10). Mature fish, accounted for the remaining 3% of the biomass and 1.5% of abundance. The strength of this emerging year class was first identified during the Celtic Sea herring acoustic survey in October 2018 and has tracked well through into 2019.

3.5 Hydrography and biogeochemical sampling

3.5.1 CTD sampling

In total, 87 CTD casts were carried out (Figure 12). Horizontal temperature and salinity maps for the survey area are provided for depths 5 m, 20 m, 50 m and at the seabed in Figures 13-16 respectively.

Surface waters, above the thermocline, showed a similar pattern of salinity in the 5 and 20 m depth profiles. Slightly lower salinity waters were found around coastal fringes and in the eastern Celtic Sea and are likely influenced by terrestrial run-off (Figures 13 &14). The temperature profile of surface waters showed the highest values in the south and in the eastern Celtic Sea as expected. Thermocline depth varied between sampling location ranging from of 35-45 m in the most part. Below the thermocline, (Figures 15 & 16), a pool of colder water is evident off the south coast of Ireland, forming a ribbon extending northwards along the coastal margin along the shelf. This water is likely from deeper Atlantic origin that has washed over the shelf sea. Salinity was relatively consistent with near surface observations. Temperature and salinity profiles would indicate the Irish shelf front boundary area occurring along the west coast of Ireland at approximately 11° W line of longitude and northwards of 52° N line of latitude.

Comparing hydrographic conditions with the acoustic observations of herring, it appears for all but one area in the southwest, the distribution of herring was closely aligned with the 10 ºC isotherm (Figure 17). Distribution appeared less influenced by salinity than temperature and is in agreement with previous years' observations during summer feeding phase.

For boarfish thermal preference appears as important as salinity (Figure 18). The greatest density of boarfish is aligned with full strength seawater and off the west coast this occurs on the oceanic side of the Irish Shelf Front. The pattern of distribution changes relative to temperature and depth along the west coast and Porcupine Bank where boarfish take a midwater position below the thermocline.

Horse mackerel (Figure 19) distribution appears to follow a similar pattern to that of boarfish in that full strength seawater is the preferred habitat with a variable temperature distribution profile from north to south.

3.5.2 CDOM measurements

CDOM sampling was undertaken at all of the 87 hydrographic stations during the survey. Analysis of samples is underway.

3.5.3 Nutrient sampling

Samples were collected from all of the 87 hydrographic stations during the survey. Analysis of samples is underway.

3.5.4 Pico/nano plankton sampling

Sampling of pico and nano plankton communities was carried out at all of the 87 oceanographic stations during the survey. The software that controls the Accuri C6 flow cytometer is able to graphically display the optical and physical characteristics of the organisms present in any sample. The forward scattering of incident light gives an indication on the size of an organism whereas the side scatter of the light relates to the shape of that particular organism. The three fluorescence sensors are set to respond to different colours of fluorescence, orange, green and red, and help to differentiate between the photosynthetic pigments that are unique to the individual species of plankton that are being studied. Further analysis is currently on-going.

3.5.5 Hyperspectral analysis

The particulate absorption in seawater was determined by filtering a known amount of sample through a Glass Fiber Filter (GF/F) and measuring the particulate absorption coefficient $a_p(\lambda)$concentrated on the filter. This technique is called quantitative filter technique (QFT) and corrects for the pathlength amplification, an effect of scattering. The correction of the pathlength amplification and the correction of the non-linear relationship between the optical density of samples on a Whatman GF/F filter and in suspension are discussed in (Mitchell, 1990). Measurements were made shipboard using a QFT-1 filter holder (WPI) after filtering 200-1000 mL of seawater through a 25 mm GF/F filter. An Ocean Optics Maya spectrophotometer was coupled to the QFT-1 using 600 µm diameter fibre optical cable with a DH mini light source. This data is currently being quality checked and will be used for comparison to the hyperspectral surface reflectance data

For WESPAS 2018 we collected the first measurements of *in situ* reflectance from the Celtic Explorer using a pair of hyperspectral sensors which were mounted above the bridge of the Celtic Explorer. This data allows us to compare with satellite reflectance data used in ocean colour estimates of chlorophyll and primary productivity. Given that the satellite record along the west coast of Ireland is often impacted by clouds this approach also gives us valuable information along the WESPAS transect that can’t be gathered using remote sensing data. We were extremely lucky during WESPAS 2018 as there were several clear sunny days and during that time we were able to gather a reasonable dataset to compare with satellite ocean colour and this work continues on at present.

During WESPAS 2019, the hyperspectral array was supplemented with a 3rd sensor as shown in Figure 3 below. The use of a 3 sensor suite (Garaba et al., 2014; Garaba et al., 2015) incorporating an irradiance (measuring in the vertical) and two radiance sensors (pointing up - measuring the upwelling solar radiance and pointing down – measuring the sky leaving radiance) significantly improves our ability to more accurately determine the reflectance spectrum and remove solar glint (Garaba and Zielinski, 2013).

During WESPAS 2019 several thousand spectra were collected and the dataset is currently being quality assessed according to standard approaches (Garaba et al., 2015; Garaba and Zielinski, 2013) Ongoing work will compare shipboard reflectance chlorophyll estimates with the satellite and in situ observations and examine the influence of the particulate absorption (QFT-1 measurements) on the results. Further comparisons to the underway pCO_2 measurements and the discrete biogeochemical measurements will hopefully give more context to interpreting the spatial and temporal signals observed during WESPAS 2019.

3.5.6 Chlorophyll measurements

The frozen filters previously measured onboard for the QFT-1 measurements were analysed in the laboratory for chlorophyll a (b & c) concentrations after extraction with 90% acetone using a Telfon grinder and subsequent measurement of the solution absorbance using an Ocean Optics Flame spectrophotometer with a low volume 10 cm pathlength cell and DT-mini light source. The concentration of chlorophyll a was calculated using the trichromatic equation of Jeffrey and Humphrey (1975).

Generally good agreement was achieved between the satellite data collected data and data collected at sea (Figure 21). Unlike the previous year when the hot dry summer provided an unprecedented number of clear sky days, data before and during WESPAS 2019 were more limited, though the monthly composites give reasonable coverage over the North West European shelf.

The ocean colour images (above) show high chlorophyll levels along the shelf edge and porcupine mound with lower concentrations in the Celtic Sea. The peak of the spring bloom offshore was in May-June with lower levels encountered July when the bulk of the WESPAS 2019 survey was carried out. The remote sensing data acquired during 2019 and other years has allowed us to identify 4 main regions of interest. Work is ongoing into the physical and biogeochemical drivers of primary productivity in these regions.

1) Persistent low chlorophyll over the Porcupine Bank (White et al., 1998).
2) High Chlorophyll over Rockall Bank
3) Low chlorophyll in the Rockall Trough/High inshore at Shelf Edge
4) Low chlorophyll in the Celtic Sea/High offshore at Shelf Edge

3.6 Zooplankton biomass and jellyfish abundance

3.6.1 Zooplankton

Plankton samples were collected at 78 stations during the survey. Species composition analysis is currently underway using chemically fixed samples. Zooplankton biomass (dry weight) by station was similar during the period 2017-2019 and higher than 2016 (Figure 20). Zooplankton distribution, as determined from dry weight analysis, showed a relatively uniform distribution throughout the survey with little sign of the spatial patchiness observed in 2016. The consistency of dry weight biomass from 2017 onwards compared to lower levels observed in 2016, given equal sampling effort, is difficult to ascertain without further detailed analysis. Further years may provide more insight into the utility of this sampling effort, such as the increase in numbers of immature fish (herring/boarfish/horse mackerel) of the 2017- 2018 year classes and the increased zooplankton biomass during the same period.

3.6.2 Jellyfish

Preliminary data for visual jellyfish observation surveys are provided below. On leg 1, The three most abundant species enumerated during visual surveys were identical to 2018 cruise which included the hydrozoan *Aqueora sp.*, the ctenophore *Beroe sp.* and the pleustonic hydrozoan *Velella velella*. On the second leg of 2019 the compositions of jellyfish differed from the year before. A total of 1,917 jellyfish were observed, down from the previous year of 2,577. The most abundant was the lion’s mane jellyfish *C. capillata* (1421), followed by the cosmopolitan moon jellyfish (264) and the hydrozoan jellyfish *Aqueora victoria* (158). The most notable change in jellyfish composition from 2018 to 2019 in this region was the spike in observations of the lion’s mane jellyfish (*Cyanea capillata*) which increased by 400% compared to the previous survey year. In the coming months, further data processing will allow the quantitative description of surface jellyfish abundance along the cruise track line which will allow more robust statistical comparisons of data years.

3.7 Marine mammals and seabirds

In total, 154 hours and 38 minutes of survey effort was conducted over the course of WESPAS 2019, 112 hours and 41 minutes of survey effort was conducted on Leg 1, while 41 hours and 57 minutes of survey effort was conducted on Leg 2 of the survey. In total, 144 hours and 27 minutes of survey effort were conducted using a line transect methodology, while 10 hours and 12 minutes of effort were conducted using the point sampling methodology.

A total of 128 sightings, were recorded throughout the survey. This includes 23 sightings recorded as auxiliary sightings and 30 sightings recorded as incidental sightings. From the total 128 sightings, marine mammals accounted for 105 sightings. The marine mammal sightings included; 3 whale species, 3 dolphin species, 1 porpoise species, and a number of sightings which could not be identified to species level. The remaining 23 sightings consisted of other marine megafauna.

Of the 128 sightings, 102 were recorded while conducting line transects, 7 were recorded while conducting point sampling, while the remaining 19 sightings were recorded off survey effort. A list of the species encountered can be seen in Table 14, and the distribution of the sightings can be seen in Figure 22.

Common dolphins (*Delphinus delphis*) were the most frequently encountered and most abundant species accounting for 63 sightings (49.2% of all sightings) and comprising of 1705 individuals in total (88% of all encountered individuals.)

Minke whales (*Balaenoptera* acutorostrata) were the second most frequently observed species. Minke whales were encountered on 16 occasions, accounting for 12.5% of all sightings. These sightings consisted of a total of 18 individuals (0.9% of all encountered individuals).

The ocean sunfish (*Mola mola*) were the third most frequently encountered species, and the most frequently encountered species of marine megafauna excluding marine mammals. The sunfish were spotted on 17 separate occasions, accounting for 13.3% of all sightings. Each sighting consisted of a lone individual (0.9% of encountered individuals).

Other marine megafauna encountered included; blue fin tuna (*Thunnus thynnus*), blue shark (*Prionace glauca*), a probable sightings of a smooth hammerhead shark (*Sphyrna zygaena*) and a sighting of an unidentified shark species.

3.7.1 Marine mammal visual abundance survey

3.7.2 Seabird abundance and distribution

In total, 225 hours and 39 minutes of survey effort was conducted over the course of WESPAS 2019, 125 hours and 3 minutes of survey effort was conducted on Leg 1, while 100 hours and 36 minutes of survey effort was conducted on Leg 2 of the survey. In total, 187 hours and 36 minutes of survey effort were conducted using a line transect methodology, while 38 hours and 4 minutes of effort were conducted using the point sampling methodology.

A total of 4,529 seabird sightings were recorded throughout the survey, totalling 34,896 individuals (Table 15). In total, 7,333 seabirds were recorded as “in transect”, while 27,562 were recorded “off transect”. The species encountered included 28 species from 8 families. A further 23 sightings of terrestrial birds were also recorded, comprising of 56 individuals.

Fulmar (*Fulmarus glacialis*) were the second most frequently observed species accounting for 965 sightings (21.3% of all sightings), however, they were the most abundant species comprising of 8,159 individuals in total (32.8% of all encountered individuals.) Of these, 1,081 individuals were recorded as ‘in transect’.

Gannets (*Sula bassana*) were the most frequently sighted and the second most abundant species accounting for 1,265 sightings (27.9% of all sightings) and comprising of 6,116 individuals in total (24.6% of all encountered individuals.) Of these, 865 individuals were recorded as ‘in transect’.

Manx shearwaters (*Puffinus puffin*) were the third most frequently sighted and the fourth most abundant species accounting for 561 sightings (12.4% of all sightings) and comprising of 3,010 individuals in total (12.1% of all encountered individuals.) Of these, 989 individuals were recorded as ‘in transect’.

European storm petrel (*Hydrobates pelagicus*) were the fourth most frequently observed species accounting for 524 sightings (11.6% of all sightings), however, they were the third most abundant species comprising of 3,425 individuals in total (13.8% of all encountered individuals.) Of these, 860 individuals were recorded as ‘in transect’.

On a number couple of occasions species including fulmar, Manx shearwaters, European storm petrel, and puffin became too numerous to accurately count. On these occasions surveying for these species was suspended.

The survey also recorded the first confirmed sighting of a south polar skua (*Stercorarius maccormicki*) in Irish waters.

A number of terrestrial species were also recorded during the survey including 7 sightings (totalling 12 individuals) of swifts (*Apus apus*) a spotted flycatcher (*Muscicapa striata*), and a pair of golden eagles (*Aquila chrysaetos*) which were seen in the Minch.

4 Discussion and Conclusions

4.1 Discussion

The objectives of the survey were carried out successfully and as planned. Good weather conditions dominated during the survey allowing for extended marine mammal and seabird survey effort. No weather induced downtime was recorded for the acoustic survey but 9 zooplankton stations were lost due to high winds.

Malin Shelf herring distribution was concentrated in an area to the north and west of Tory Island (south of 56˚N) in 6.a.S and to the west of the Hebrides in 6.a.N, particularly north of St. Kilda (Figure 3). However, there was a 47% decrease in overall the SSB in 2019 compared to 2018 in the survey area (O'Donnell et al 2018). The final estimate of herring in 6.a (combined 6.a.S, 7.b,c and 6.a.N) will be completed by including the biomass and abundance of herring from the survey of 6.a.N to the north of 58˚30N and west of 4˚W carried out by the RV Scotia. This final estimate will be worked up at WGIPS in 2020. There have been issues with stock identification and containment with this survey in the past, particularly in relation to the boundary of the North Sea stock at the 4˚W line, and the distribution of herring north and south of the 56˚N line (6.a.N/6.a.S), for example. Fish distributed either side of these boundary lines influence the survey estimates. There is work ongoing to try to split the survey into 6.a.N and 6.a.S components and it is hoped that this will be possible in the future.

There were good signs of 2-wr and 3-wr herring distributed in 6.a.S for the first time in a number of years. There were fewer 1-wr herring caught on the survey in 2019 compared to 2018, however, it is suspected that these fish may have been missed. A couple of hauls were attempted on fast moving midwater marks to the north of Lough Swilly and because there was no catch, it is unknown whether these marks were juvenile herring. These marks had the acoustical signatures of young herring and this was an area where young 1-wr herring were caught in 2018. This survey is not a good design for juvenile herring in any case. The age profile of survey samples in 2019 somewhat follows the cohorts from 2018; 2-wr and 3-wr herring dominate the survey (59% in terms of biomass, and 65% in terms of abundance). The survey was dominated by 1-wr, 2-wr and 4-wr herring in 2018. There is a small peak in 5-wr fish (corresponding to the 4-wr fish from the 2018 survey) in the western Hebrides strata (Figure 4), however, this is not evident in other areas. In 2016, there was a much more even distribution of year classes. No herring were found in the Minch in 2019. The CV estimate for the 2019 survey is higher than in 2018 (0.37 compared to 0.28); however, this is comparable to previous years in the time-series.

The distribution of boarfish was comparable to earlier years in the time series; with a high number of individual schools clustered towards the shelf edge in the southern Celtic Sea and a cluster of schools around the Porcupine Bank. Along the west coast, boarfish were distributed on the oceanic side of the Irish Shelf Front on the shelf sea and distribution extended northwards, constrained in a narrow ribbon along the shelf to 60º N. In 2019, across the distribution area mature fish dominated catch samples. However, an area of high abundance of immature fish was observed in the southern survey area, significantly larger and numerous than in previous years. The contribution of immature fish to the total estimate of abundance is the highest in the time series, (5.5% of total biomass and 30.7% of total abundance) indicating a potentially strong emerging year class within the stock.

Overall, the acoustic density and number of echotraces of boarfish was lower than observed in 2018, considering increased trawling effort (7%), acoustic sampling effort (17%) and area coverage (7% increase). Overall, total biomass and total abundance were comparable to 2018 with a 4% decrease in biomass and 8% decrease in abundance in 2019. Accurate age determination of the standing stock remains an issue due to the use of an age length key to assign ages to biological samples rather than the aging of actual survey collected otoliths collected that year. This considered the oldest (15+ year) cohort remain the largest contributors to the stock biomass and abundance. In 2019, immature fish also contributed significantly, ranking highest in abundance and so providing an important future potential input to spawning stock biomass.

Horse mackerel were distributed along the Irish west coast, Porcupine Bank and Celtic Sea. Geographical distribution was comparable to previous surveys but the number and acoustic density of aggregations was lower than in 2018. Total stock biomass was 15% lower and total abundance was 13% lower compared to 2018. However, the survey time series is still and more surveys are still required to qualify the ability of this survey to provide a meaningful index of relative abundance. The age composition of the stock in 2019 was dominated by older age classes (16, 14, 9 & 18 years) contributing over 50% of the total stock biomass. Immature fish represented over 17% of total abundance (1.8% of biomass) which was higher than in the current time series (2016-2019).

Aggregations of Celtic Sea herring were encountered during the survey in what are considered historic feeding grounds. The high proportion of immature fish (96.7% TSN and 94.1% TSB) reflect observations made during the CSHAS 2018 that a strong year class is evident within the stock (O’Donnell et al., 2018). The 2019 CSHAS will quantify this year class as part of the annual time series.

The 2019 WESPAS survey reported higher than average numbers of immature fish and pre-recruiting Celtic Sea herring, boarfish and horse mackerel (1-2 years old). This would indicate favourable conditions for key life stages including, spawning, egg and larval survival and post larval development beginning in 2017. Given these species have similar, but not identical, ontogenic resource requirements this would indicate a favourable change in biotic and abiotic conditions bridging the requirements of more than one species. As this survey is not designed to track juveniles it is too early to judge how these year classes will contribute until they are fully recruited to the spawning stock in the coming year(s).

There were a large number of mackerel marks recorded throughout the Minch strata in the north of the survey area, and in the area to the southeast and southwest of Barra Head. These marks were often midwater (e.g. Figure 11l) in a range of depths down to 180m, and went on for many miles in places. There were also mackerel marks recorded on the surface in some areas. Mackerel were caught in some trawls targeting boarfish on the shelf edge (~200m). The marks throughout the survey area in the north were typical of mackerel marks reported in the literature (e.g. Korneliussen 2010) with very strong backscatter on the 120 and 200 kHz compared to the lower frequencies. There was mackerel in 23 out of 45 hauls throughout the survey area, most frequent in the northern part of the survey area.

Hydrographic conditions in surface waters were as to be expected during the summer months with warmer waters dominating more southern latitudes and well stratified water masses with a strong thermocline. Thermocline depth ranged from 35-45m in the main. Below the thermocline, and at seafloor, western Ireland was ringed by an area of cool water close to the coast with a district boundary front which continued in a ribbon northwards boarding the self-margin area. Herring were encountered predominantly within the cooler water (approximately 10ºC isotherm) ribbon to the west of Ireland, Scotland and in the Celtic Sea. Boarfish and horse mackerel distribution appeared to be more influenced by salinity, given they are more oceanic species, than herring and were primarily distributed in full seawater conditions regardless of temperature or latitude.

4.2 Conclusions

- Malin Shelf herring biomass was ~47% lower in 2019 compared to 2018 (SSB_{2019} = 69,000 t SSB_{2018} =130,000 t). The CV on the survey was higher in 2019 (0.37) when compared with 2017 (0.28); the CV in 2019 is comparable to previous years in the time series
- The Malin Shelf Herring total stock biomass (TSB) was 86,641 t and total stock numbers (TSN) was 597,974,000
- Herring were distributed further south in 2019 compared to 2018, with some adult herring south of 56°N. This is the second year in a row that herring were found in this area. For instance, there was very little herring distributed south of 56°N in both 2016 and 2017.
- The 2019 survey estimate was dominated by 2-wr (29% TSB and 35% TSN) and 3-wr (30% TSB and 29% TSN). This compares well with the 2018 survey, showing some cohort tracking; the dominant age classes in the 2018 survey were 1-wr and 2-wr fish.
- There were some 1-wr herring found in the survey this year, although numbers were much fewer than in 2018. It is suspected that young herring were missed on a number of hauls.
- Boarfish distribution showed a similar pattern to previous years. The number of schools was lower but mean acoustic density was comparable to 2018.
- Boarfish TSB (total stock biomass) and abundance (TSN) estimates were 179,156 t and 3,898,827,000 individuals (CV 25.4%) respectively.
- The contribution of immature boarfish to the 2019 estimate was significant given it is the highest in the time series representing 3% of total biomass and 20% of total abundance. Older fish (15+ year class) still dominate the stock (35.8% total biomass and 19.5% total abundance).
- An area containing numerous schools of immature boarfish was observed in the southern survey area to the west of France contributing to the increased number of immature fish observed overall. During previous year’s, low numbers of immature fish have been observed with an inconsistent spatial pattern.
- Horse mackerel biomass is considered a reliable estimate of the standing stock in 2019 given comparable survey effort and area coverage with previous years. Improvements are required to ensure consistency of survey derived age sampling and reduce this source of error.
- Horse mackerel TSB (total stock biomass) and abundance (TSN) estimates were 79,026 t and 333,501,000 individuals (CV 33.7%) respectively.
- The positive signal of the 3-year class of horse mackerel notable in 2018 was tracked through into 2019, appearing as 4-year-old fish and ranking second most abundant (13.9%) after immature 1-year-old fish (19.1%).
- Aggregations of Celtic Sea herring were observed around traditional feeding areas in the west and eastern Celtic Sea. Catch samples were dominated by immature fish representing 96.7% of abundance and 94.1% of the biomass and indicating the strength of this, as yet to recruit, year class. Mature fish

were clearly underrepresented given the current state of the spawning stock biomass.

- Higher than average levels of immature fish for main target species observed during the survey. The potential of which will be monitored during subsequent surveys and as these fish become fully recruited to the respective spawning stocks.
- Continuation of the south to north work flow to align with surveys in the south (PELGAS- France) and north (HERAS- Scotland) and provide synoptic estimates of abundance for a multiple species.
- Real time aging of horse mackerel and boarfish survey samples to provide within year age estimates of survey data.
- Research the possibility of egg counts from plankton samples (WP2) as a means to track spawning, and peak spawning events by geographic region for boarfish and horse mackerel.
- To further develop this survey more ship-time is required. As the survey is observing not only target species for the focal component but also the distribution of other species that are also surveyed during the year, specifically Celtic Sea herring.
- Westward extension of some transects in the northwest of the survey area to ensure boarfish stock containment. This may also require some extra survey days.
- There were a large number of mackerel marks recorded throughout the Minch strata in the north of the survey area, and in the area to the southeast and southwest of Barra Head. These marks were often midwater in a range of depths down to 180m, and went on for many miles in places. There were also mackerel marks recorded on the surface in some areas

5 Acknowledgements

We would like to thank Captains Denis Rowan and Anthony Hobin and the crew of the Celtic Explorer for their help and professionalism during the survey. Many thanks also to the seabird and marine mammal survey teams, who worked tirelessly during the survey in all weathers and with great enthusiasm.

6 References

Camphuysen, K. J., Fox, A. D., Leopold, M. F. and Petersen, I. K. 2004. Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K.: a comparison of ship and aerial sampling methods for marine birds, and their applicability to offshore wind farm assessments, NIOZ report to COWRIE (BAM – 02-2002), Texel, 37pp.

Dalen, J. and Nakken, O. 1983. “On the application of the echo integration method” ICES CM 1983/B:19

Demer, D. A., Berger, L., Bernasconi, M., Bethke, E., Boswell, K., Chu, D., Domokos, R., *et al*. 2015. Calibration of acoustic instruments. ICES Cooperative Research Report No. 326.

Fässler, S. M. M., O'Donnell, C. and Jech, J. M. 2013; Boarfish (*Capros aper*) target strength modelled from magnetic resonance imaging (MRI) scans of its swimbladder, *ICES Journal of Marine Science*, 70(7):1451–1459.

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

Garaba, S.P., Badewien, T.H., Braun, A., Schulz, A.-C. and Zielinski, O., 2014. Using ocean colour remote sensing products to estimate turbidity at the Wadden Sea time series station Spiekeroog. 2014, 9.

Garaba, S.P., Voß, D., Wollschläger, J. and Zielinski, O., 2015. Modern approaches to shipborne ocean color remote sensing. Applied Optics, 54(12): 3602-3612.

Garaba, S.P. and Zielinski, O., 2013. Methods in reducing surface reflected glint for shipborne above-water remote sensing. 2013, 8.

García-Robledo, E., Corzo, A. and Papaspyrou, S., 2014. A fast and direct spectrophotometric method for the sequential determination of nitrate and nitrite at low concentrations in small volumes. Marine Chemistry, 162(0): 30-36.

García-Robledo, E., Corzo, A. and Papaspyrou, S., 2014. A fast and direct spectrophotometric method for the sequential determination of nitrate and nitrite at low concentrations in small volumes. Marine Chemistry, 162(0): 30-36.

Hall, M.E., O’Connor, I., Breen, D., McGeehan, A., Hunt, J., Borawska, A., Meade, R., Groth, L., & Tierney, D. (in press) Distribution of seabirds at sea during the Cetacean on the Frontier scientific cruises August 2009 and February 2010. Irish Wildlife Manuals, National Parks and Wildlife Service, Department of Arts Heritage and the Gaeltacht, Dublin, Ireland.

Heinemann, D. 1981. A Range Finder for Pelagic Bird Censusing. Journal of Wildlife Management 45(2): 489-493.

ICES 1994. Report of the Study Group on Herring Assessment and Biology in the Irish Sea and Adjacent Waters. ICES CM 1994/H :5. 67pp.

ICES 2010. Report of the Study Group on the evaluation of assessment and management strategies of the western herring stocks (SGHERWAY). ICES CM 2010\SSGSUE:08, 194 pp.

ICES. 2015. Manual for International Pelagic Surveys (IPS). Series of ICES Survey Protocols SISP 9 – IPS. 92 pp.

ICES 2016. First Interim Report of the Working Group of International Pelagic Surveys WGIPS). ICES CM SSGIEOM/05, 433 pp.8

IFAW 2000. Logger 2000 software. International Fund for Animal Welfare, London.

Irish Rare Bird Committee (2012) The Irish Bird List. www.irbc.ie/topbar/IrishList/IRBC_IrishList(31122012).pdf (accessed October 2014).

IWDG 2009. Irish Whale and Dolphin Group sightings database (Republic of Ireland and Northern Ireland). www.iwdg.ie/Iscope (accessed April 2013).

Jolly, G. M., and I. Hampton. 1990. A stratified random transect design for acoustic surveys of fish stocks. Canadian Journal of Fisheries and Aquatic Sciences 47(7): 1282-1291.

Komdeur, J., Bertelsen, J. & Cracknell, G. (ed.) 1992. *Manual for Aeroplane and Ship surveys of Waterfowl and Seabirds*. IWRB Special Publication No. 19, Ministry of the Environment, National Environmental Research Institute, Department of Wildlife Ecology, Kalø, Denmark.

Korneliussen, R.J., 2010. The acoustic Identification of Atlantic Mackerel. ICES Journal of Marine Science, 67: 1749-1758.

Koroleff, I., 1976. Analysis of micronutrients. In: K. Grashoff (Editor), Methods of Seawater Analysis. Verlag-Chimie, New York.

Mackey, M., Ó Cadhla, O., Kelly, T.C., Aguilar de Soto, N. and Connolly, N. 2004. *Cetaceans and Seabirds of Ireland"s Atlantic Margin. Volume 1 – Seabird distribution, density and abundance*. Report on research carried out under the Irish Infrastructure Programme (PIP): Rockall Studies Group (RSG) projects 98/6 and 00/13, Porucpine Studies Group project P00/15 and Offshore Support Group (OSG) project 99/38. University College Cork.

Marie, D., Partensky, F., Jacquet, S. and Vaulot, D., 1997. Enumeration and Cell Cycle Analysis of Natural Populations of Marine Picoplankton by Flow Cytometry Using the Nucleic Acid Stain SYBR Green I. Applied and Environmental Microbiology.

Marie, D., Rigaut-Jalabert, F. and Vaulot, D., 2014. An improved protocol for flow cytometry analysis of phytoplankton cultures and natural samples. Cytometry Part A, 85(11): 962-968.

Mitchell, B.G., 1990. Algorithms for determining the absorption coefficient for aquatic particulates using the quantitative filter technique, pp. 137-148.

Murphy, J. and Riley, J.P., 1962. A modified single solution method for the determination of phosphate in natural waters. Analytica Chimica Acta, 27: 31-36.

O'Donnell, C., Griffin, K., Lynch D., Ullgren J., Goddijn L., Wall D. & Mackey M. (2004).Celtic Sea Herring Acoustic Survey Cruise Report, 2004. http://hdl.handle.net/10793/679

O'Donnell, C., Egan, A., Lynch, D., Boyd, J., Wall, D. & Goddjin, L., "Northwest Herring Acoustic Survey Cruise Report and Abundance Estimate, 2007", FSS Survey Series, Marine Institute 2007. http://hdl.handle.net/10793/295

O'Donnell, C., Farrell, E., Saunders, R. & Campbell, A. "Boarfish Acoustic Survey Report 07 July – 28 July, 2011", Marine Institute 2011. http://hdl.handle.net/10793/675

O'Donnell, C., O'Malley, M., Mullins, E., Lynch, D., Keogh, N., and O'Sullivan, C. (2017). Western European Shelf Pelagic Acoustic Survey (WESPAS) 06 June - 21 July, 2017. FEAS Survey Series: 2017/03. Marine Institute. http://hdl.handle.net/10793/1326

O'Donnell, C., O'Malley, M., Lynch, D., Mullins, E., Keogh, N., Power, J., Long, A., and Croot, P. (2018). Western European Shelf Pelagic Acoustic Survey (WESPAS) 10 June – 24 July, 2018. FEAS Survey Series: 2018/03. Marine Institute. http://hdl.handle.net/10793/1380

O'Donnell, C., Mullins, E., Lynch, D., Lyons, K., Keogh, N. and O'Callaghan, S. (2018). Celtic Sea Herring Acoustic Survey Cruise Report 2018, 08-28 October 2018. FSS Survey Series: 2018/04. Marine Institute. http://hdl.handle.net/10793/1385

Pollock, C.M., Reid, J.R., Webb, A., and Tasker, M.L. 1997. *The distribution of seabirds and cetaceans in the waters around Ireland*. JNCC Report No. 267

Rose, J.M., Caron, D.A., Sieracki, M.E. and Poulton, N., 2004. Counting heterotrophic nanoplanktonic protists in cultures and aquatic communities by flow cytometry. Aquatic Microbial Ecology, 34(3): 263-277.

Schnetger, B. and Lehners, C., 2014. Determination of nitrate plus nitrite in small volume marine water samples using vanadium(III)chloride as a reduction agent. Marine Chemistry, 160: 91-98.

Tasker, M.L., Jones, P.H., Dixon, T., & Blake, B.F. 1984. Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardised approach. Auk 101: 567-577.

7 Tables and Figures

Table 1. Calibration report: Simrad EK60 echosounder at 38 kHz.

Echo Sounder System Calibration Report

Vessel :	RV Celtic Explorer			Date :	26.03.19
Echo sounder :	Drop Keel			Locality :	Killary Harbour
Type of Sphere :	WC 38.1	TS_{Sphere}:	-42.2 dB	Depth(Sea floor)	36 m

Calibration Version 2.1.0.12

Comments:
Dunmanus Bay Survey Start

Reference Target:

TS	-42.37 dB	Min. Distance	15.0m
TS Deviation	5 dB	Max. Distance	21.0m

Transducer: ES38B Serial No.

Frequency	38000 Hz	Beamtype	Split
Gain	26.65 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	6.98 deg	Along. Beam Angle	6.91 deg
Athw. Offset Angle	-0.04 deg	Along. Offset Angl	-0.05 deg
SaCorrection	-0.66 dB	Depth	8.80 m

Transceiver: GPT 38 kHz 009072033933 1 ES38B

Pulse Duration	1.024 ms	Sample Interval	0.191 m
Power	2000 W	Receiver Bandwidth	2.43 kHz

Sounder Type:
ER60 Version 2.4.3

TS Detection:

Min. Value	-50.0 dB	Min. Spacing	100%
Max. Beam Comp.	6.0 dB	Min. Echolength	80%
Max. Phase Dev.	8	Max. Echolength	180%

Environment:

Absorption Coeff.	9.9 dB/km	Sound Velocity	1490.2 m/s

Beam Model results:

Transducer Gain =	25.85 dB	SaCorrection =	-0.64 dB
Athw. Beam Angle =	6.91 deg	Along. Beam Angle	6.87 deg
Athw. Offset Angle =	-0.02 deg	Along. Offset Angl	-0.05 deg

Data deviation from beam model:

RMS = 0.19 dB
Max = 0.66 dB No. = 196 Athw. = 4.1 deg Along = 2.6 deg
Min = -0.74 dB No. = 234 Athw. = 0.1 deg Along = 4.8 deg

Data deviation from polynomial model:

RMS = 0.16 dB
Max = 0.61 dB No. = 196 Athw. = 4.1 deg Along = 2.6 deg
Min = -0.54 dB No. = 197 Athw. = 4.0 deg Along = 2.7 deg

Comments :
WC 38.1mm, IBWSS 2019

Wind Force : **Wind Direction :**

Raw Data File: Z:\Acoustic Data\CE19005_BWAS_2019\Scientific\EK60\Data\Calibration\Calibration

Calibration File: Z:\Acoustic Data\CE19005_BWAS_2019\Scientific\EK60\Data\Calibration\Calibration

Calibration : Michael O'Malley

Table 2. Catch table from directed trawl hauls.

No.	Date	Lat.	Lon.	Time	Bottom	Target btm	Bulk Catch	Boarfish	Mackerel	Herring	H Mack	Others^
		N	W		(m)	(m)	(Kg)	%	%	%	%	%
1	14.06.19	47.56	-6.14	16:11	151	135	223	76.3	0.3		18.0	5.3
2	15.06.19	47.81	-6.16	09:54	144	50	414	100.0				
3	16.06.19	47.06	-7.62	08:00	190	170	10	25.9			49.8	24.3
4	16.06.19	48.31	-8.85	17:40	177	0	67	82.4			1.9	15.7
5	17.06.19	48.56	-7.09	17:12	160	0	36	97.9			1.1	0.8
6	17.06.19	48.56	-7.41	20:29	155	120	4,000	99.9			0.1	
7	18.06.19	48.81	-8.98	07:11	144	25	324	85.4	14.5			0.1
8	20.06.19	49.06	9.72	11:14	153	15	0					
9	20.06.19	49.06	-10.91	18:40	176	30	54	5.8	0.8		89.6	3.8
10	21.06.19	49.31	-8.38	14:12	136	116	119	95.5	3.6		0.4	0.5
11	22.06.19	49.57	-8.99	07:46	141	71	2					100.0
12	23.06.19	49.82	-8.30	13:55	133	45	300					100.0
13	24.06.19	50.06	-10.08	12:32	118	10	500		100.0			
14	24.06.19	50.06	-10.65	17:10	152	122	225				61.3	38.7
15	25.06.19	50.31	-10.03	05:55	118	10	30	46.9			13.8	39.3
16	25.06.19	50.31	-9.53	09:35	133	0	38	1.6			43.7	54.7
17	25.06.19	50.31	-8.19	18:45	121	25	42					100.0
18	26.06.19	50.56	-8.35	08:25	121	0	275		0.5		18.3	81.2
19	27.06.19	50.81	-9.91	10:30	119	0	15	0.4	59.3	5.2	19.2	16.0
20	28.06.19	50.81	-7.64	07:20	100	0	28			30.1		69.9
21	28.06.19	50.81	-6.76	12:30	96	0	176		74.6	17.2	0.2	7.9
22	29.06.19	51.06	-10.11	10:22	124	0	40		82.6	9.9	1.4	6.1
23	29.06.19	51.60	-11.23	17:10	200	75	1,200	98.2			0.9	0.9
24	01.07.19	52.57	-11.16	11:30	127	0	29		80.7		6.7	12.6
25	01.07.19	52.58	-11.66	15:40	159	0	130		24.1		73.4	2.5
26	01.07.19	52.85	-11.35	23:25	130	0	38	2.1	85.1		8.2	4.6
27	02.07.19	53.10	-10.23	10:40	92	30						
28	02.07.19	53.10	-11.52	17:30	135	0	1		58.0			42.0
29	03.07.19	53.60	-10.79	11:12	107	0						
30	07.07.19	53.35	-13.88	12:47	154	75	2,000	97.7			2.3	
31	08.07.19	53.86	-11.20	12:30	207	90	0		100.0			
32	09.07.19	54.44	-9.85	08:48	97	30	46					100.0
33	10.07.19	55.11	-10.02	16:12	200	180	1,000	99.0				1.0
34	11.07.19	55.54	-8.08	18:23	81	60	7		99.0			1.0
35	13.07.19	55.86	-8.46	10:05	134	110	5,000			100.0		
36	13.07.19	55.86	-9.25	16:15	188	160	1,000	12.3	84.8	2.9		
37	14.07.19	56.33	-6.82	10:34	73	60	400		1.0	1.0		98.0
38	14.07.19	56.36	-7.53	16:04	160	140	200		45.0			55.0
39	15.07.19	56.87	-8.87	16:01	120	100	144					100.0
40	16.07.19	57.12	-7.81	06:18	90	15	150	63.0	3.0	1.0	5.0	28.0
41	17.07.19	57.87	-8.96	09:38	142	130	132		10.0	1.0		89.0
42	18.07.19	58.25	-8.52	11:51	164	140	335		46.0	29.0		25.0
43	18.07.19	58.25	-7.95	14:55	122	82	53		5.0	9.0		86.0
44	20.07.19	57.47	-6.89	08:02	180	30	91					100.0
45	21.07.19	55.40	-8.21	17:22	85	70	140		100.0			

Table 3. Malin Shelf herring stock estimate 2019 (6.a.S, 7.b,c and 6.a.N (south of 58°30'N).

						Age (years)								Numbers	Biomass	Mn Wt	Mature
Length	0	1	2	3	4	5	6	7	8	9	10	11	12+	(*10-3)	(t)	(g)	(%)
5.5	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
6	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
6.5	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
7	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
7.5	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
8	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
8.5	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
9	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
9.5	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
10	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
10.5	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
11	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
11.5	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
12	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
12.5	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
13	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
13.5	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
14	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
14.5	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
15	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
15.5	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
16	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
16.5	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
17	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
17.5	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
18	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
18.5	|	-	-	-	-	-	-	-	-	-	-	-	-	0			0
19	|	10563	-	-	-	-	-	-	-	-	-	-	-	10563	633.8	60	0
19.5	|	-	-	-	-	-	-	-	-	-	-	-	-				
20	|	2224	-	-	-	-	-	-	-	-	-	-	-	2224	133.4	60	0
20.5	|	2780	-	-	-	-	-	-	-	-	-	-	-	2780	166.8	60	0
21	|	3336	-	-	-	-	-	-	-	-	-	-	-	3336	287.4	86.17	0
21.5	|	-	9009	-	-	-	-	-	-	-	-	-	-	9009	806.3	89.5	0
22	|	-	29250	-	-	-	-	-	-	-	-	-	-	29250	2875.2	98.3	0
22.5	|	2680	31388	-	-	-	-	-	-	-	-	-	-	34068	3612.2	106.03	22
23	|	-	48418	2010	-	-	-	-	-	-	-	-	-	50428	5723.8	113.51	34
23.5	|	-	43595	14397	-	-	-	-	-	-	-	-	-	57992	6966.1	120.12	53
24	|	-	29681	21749	-	-	-	-	-	-	-	-	-	51430	6650.9	129.32	62
24.5	|	-	15017	26478	3677	-	-	-	-	-	-	-	-	45172	6410.1	141.9	85
25	|	-	3348	28488	8715	3628	-	-	-	-	-	-	-	44179	6580.1	148.94	100
25.5	|	-	-	41970	11651	-	-	-	-	-	-	-	-	53621	8322.7	155.21	100
26	|	-	-	30846	20000	-	4020	-	-	-	-	-	-	54866	9169	167.12	100
26.5	|	-	2653	3579	13173	13972	6459	-	-	-	-	-	-	39836	6975.4	175.1	100
27	|	-	-	4971	15733	10552	7706	2680	-	-	-	-	-	41642	7620.2	182.99	100
27.5	|	-	-	-	12434	3322	5293	-	-	-	-	-	-	21049	4049	192.36	100
28	|	-	-	-	893	10372	670	-	-	-	-	-	-	11935	2369.7	198.54	100
28.5	|	-	-	-	-	9678	893	682	2478	-	-	-	-	13731	2786.4	202.92	100
29	|	-	-	-	-	3340	3350	-	4466	223	-	-	-	11379	2413.5	212.09	100
29.5	|	-	-	-	-	447	670	-	3350	2010	-	-	-	6477	1450.6	224	100
30	|	-	-	-	-	-	-	-	-	1558	-	-	-	1558	302.3	194	100
30.5	|	-	-	-	-	-	-	-	1449	-	-	-	-	1449	336.2	232	100
31	|	-	-	-	-	-	-	-	-	-	-	-	-	0			100
32	|	-	-	-	-	-	-	-	-	-	-	-	-	0			100
TSN (1000)	0	21583	212359	174488	86276	55311	29061	3362	11743	3791				597974			
TSB (t)		1498.1	24511.1	26283.7	14543.9	10451	5370.5	639.3	2554.6	788.9					86641.1		
Mean length (cm)		20.04	23.15	25.04	26.26	27.36	27.2	27.3	29.22	29.68							
Mean weight (g)		69.41	115.42	150.63	168.57	188.95	184.81	190.14	217.54	208.08						144.89	
SSB (t)		0	10536.6	23722.2	14543.9	10451	5370.5	639.3	2554.6	788.9					68607		
% mature		0	39	88	100	100	100	100	100	100							

Table 4. Malin Shelf herring survey time series 2008-2019. Survey coverage: - ^ 6.a.S & 7.b,c; * 6.a.S, 6.a.N & 7.b; ** 6.a & 7.b,c; ***6.a.S, 7.b,c & 6.a.N (south of 58°30'N).

Age	2008^	2009^	2010*	2011*	2012*	2013*	2014*	2015**	2016*	2017***	2018***	2019***
0	-	-	-	-	-	-	-	-	-	-	264.6	
1	6.1	416.4	524.8	82.1	608.3	-	1,115.4	4.9	-	-	395.8	21.6
2	75.9	81.3	504.3	202.5	451.5	96.2	214.7	162.1	9.7	11.0	339.2	212.4
3	64.7	11.4	133.3	752.0	444.6	254.3	166.3	291.7	102.3	273.4	112.5	174.5
4	38.4	15.1	107.4	381.0	516.1	265.8	380.0	580.7	91.4	111.0	314.1	86.3
5	22.3	7.7	103.0	110.8	180.3	78.7	352.1	487.3	91.4	71.6	137.5	55.3
6	26.2	7.1	83.7	124.0	115.4	26.9	125.0	513.4	58.2	94.4	43.7	29.1
7	9.1	7.5	57.6	118.4	116.9	18.5	18.9	143.9	46.5	28.0	59.5	3.4
8	5.0	0.4	35.3	70.7	83.8	10.8	9.7	33.4	2.7	9.9	16.8	11.7
9	3.7	0.9	17.5	41.6	56.3	4.1	4.7	-	0.5	2.6	8.2	3.8
10+	-	-	-	25.6	42.0	1.2	-	8.3	-	-	6.4	
TSN (mil)	251.4	547.7	1,566.9	1,908.7	2,615.0	756.6	2,386.8	2,225.5	402.8	601.8	1,698.3	598.0
TSB (t)	44,611.0	46,460.0	192,979.0	313,305.0	397,797.0	118,946.0	294,200.0	449,343.0	70,745.0	107,900.0	183,187.5	86,641.1
SSB (t)	43,006.0	20,906.0	170,154.0	284,632.0	325,835.0	92,700.0	200,200.0	425,392.0	69,269.5	106,657.0	129,740.0	68,607.0
CV	34.2	32.2	24.7	22.4	22.8	21.5	28.6	28.6	31.3	46.6	28.3	37.3

Table 5. Malin Shelf herring spawning stock biomass and abundance by strata 2019.

Strata name	Area (nmi^2)	Transects	Abundance ('000)	Biomass (t)
Minch	3604	7	0	0
W Hebrides	7100	7	162,127	25,632
SW Hebrides	4867	4	9,713	1,360
NW Coast	2257	2	0	0
W Coast	11232	12	59,181	8,295
N Malin	3102	3	366,948	51,353
Total	**32,162**	**35**	**597,969**	**86,641**

Table 6. Total boarfish stock estimate.

Length	Age (years)																Numbers	Biomass	Mn Wt	Mature
(cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Unknown	(000's)	(t)	(g)	(%)
4																2291	2291	9.2	4	0
4.5	6583																6583	20.6	3.13	0
5	46543																46543	227.7	5	0
5.5	102249																102249	412.3	4	0
6	180430																180430	1076.7	6	0
6.5	148644																148644	999.1	7	0
7	203209	67465															270674	2354	9	0
7.5	92347	162432															254780	2534.6	10	0
8		149449															149449	1754.1	12	0
8.5		9766	10580														20346	269.4	13	0
9																15782	15782	282.3	18	100
9.5			24329														24329	477.7	20	100
10			46061														46061	971.5	21	100
10.5				52801													52801	1309.8	25	100
11				25479	38797				8675								72951	2126.4	29	100
11.5				14772	49441	32269	2158										98641	3271	33	100
12						43694	92790										136483	5371.2	39	100
12.5						8813	106673	60083									175569	7663.1	44	100
13							117803	17111	64933	17628		1002					218478	11200.4	51	100
13.5						21104	50019	55403	42623	80776	3548						253473	14044.9	55	100
14							64357	34213	87775	145531		28356		15253			375484	22944.6	61	100
14.5							11943	15811	66056	16034	38854	42794	9476	17078	110479		328526	21878.2	67	100
15									7215	2546	7074	120094	64838	18695	118539		339001	25923.3	76	100
15.5									10767	27581			4783	6208	191892		241231	19861.2	82	100
16															227165		227165	20674.1	91	100
16.5															69716		69716	7061	101	100
17															31659		31659	3404.7	108	100
17.5															9301		9301	1010.8	109	100
18																186	186	22.5	121	100
18.5																				
19																				
19.5																				
TSN (10-^{3})	780005	389112	80969	93052	88238	105880	445743	182622	288045	290096	49476	192247	79097	57234	758752	18259	3898827			
TSB (t)	5297.6	4212.5	1587.6	2565.1	2686.7	4255.7	22055	9854.1	16979.7	17989.5	3351.3	13676.3	6298.8	3904.8	64127.6	314		179156		
Mean length (cm)	6.4	7.63	9.65	10.8	11.28	12.19	12.91	13.3	13.81	13.98	14.5	14.73	14.97	14.64	15.6	8.46				
Mean weight (g)	6.79	10.83	19.61	27.57	30.45	40.19	49.48	53.96	58.95	62.01	67.74	71.14	79.63	68.22	84.52	17.2			45.95	
% mature*	0	0	33	100	100	100	100	100	100	100	100	100	100	100	100	100				
SSB	0.0	0.0	523.9	2565.1	2686.7	4255.7	22055.0	9854.1	16979.7	17989.5	3351.3	13676.3	6298.8	3904.8	64127.6	314.0		169216		

Table 7. Boarfish biomass and abundance by strata.

Strata name	Area (nmi^2)	Transects	Abundance ('000)	Biomass (t)
W Hebrides	2,625.5	8	138432	8647.9
S Hebrides	2,164.4	5	175621	11623.4
W Coast	12,080.4	17	549919	36878.6
Porcupine Bank	4,965.4	6	141613	11110.2
Celtic Sea	32,097.3	16	2893242	110646
Total	53,933.0	52	3,898,827	178,906.1

Table 8. Boarfish survey time series. Note: 2016 CV estimate calculated using StoX.

Age (Yrs)	2011	2012	2013	2014	2015	2016	2017	2018	2019
0	-	-	-	-	-	-	-	-	-
1	5.0	21.5	-	-	198.5	4.6	110.9	76.7	782.3
2	11.6	10.8	78.0	-	319.2	35.7	126.7	31.2	389.1
3	57.8	174.1	1,842.9	15.0	16.6	45.5	344.6	115	96.8
4	187.4	64.8	696.4	98.2	34.3	43.6	367.3	68.3	93.1
5	436.7	95.0	381.6	102.3	80.0	6.0	156.0	106.7	88.2
6	1,165.9	736.1	253.8	104.9	112.0	10.0	209.0	165.9	105.9
7	1,184.2	973.8	1,056.6	414.6	437.4	169.0	493.1	320.7	445.7
8	703.6	758.9	879.4	343.8	362.9	112.6	468.3	197.7	182.6
9	1,094.5	848.6	800.9	341.9	353.5	117.6	397.2	293.4	288
10	1,031.5	955.9	703.8	332.3	360.0	96.6	285.8	624.7	290.1
11	332.9	650.9	263.7	129.9	131.7	17.0	120.9	339.2	49.5
12	653.3	1,099.7	202.9	104.9	113.0	32.0	82.1	264.1	192.2
13	336.0	857.2	296.6	166.4	174.0	48.7	74.4	198.4	79.1
14	385.0	655.8	169.8	88.5	108.0	18.3	220.4	116.5	57.2
15+	3,519.0	6,353.7	1,464.3	855.1	1,195.0	400.1	931.0	302.4	758.9
TSN (10^{-3})	11,104	14,257	9,091	3,098	3,996	1,157	4,387	3,221	3,899
TSB (t)	670,176	863,446	439,890	187,779	232,634	69,690	223,860	186,252	179,156
SSB (t)	669,392	861,544	423,158	187,654	226,659	69,103	218,810	184,235	169,216
CV	21.2	10.6	17.5	15.1	17.0	16.4	21.9	19.9	25.4

Table 9. Horse mackerel stock estimate.

Length	Age (years)																						Numbers	Biomass	Mn Wt	Mature
(cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Unknown	(000's)	(t)	(g)	(%)
11																										0
12	21229																						21229	403.4	19	0
13	24767																						24767	569.6	23	20
14	10615																						10615	293.7	27.67	50
15	7076																						7076	214.1	30.25	33
16																						431	431	20.1	46.5	100
17																						216	216	11	51	100
18																						216	216	14.7	68	100
19		14282																					14282	946.7	66	100
20																						962	962	66.1	69	100
21			4406																				4406	392.1	89	100
22																										
23																										
24				746																			746	76	102	100
25			3213	1992																			5204	753.8	145	100
26			1573	11736																			13309	2258.9	170	100
27				17174	9343	3194	1919																31630	5978.7	189	100
28				12233	12946	5605	3390																34175	7136.9	209	100
29					3839	7871	11583	1600	4768														29662	6582	222	100
30				2476	4811		3453																10740	2649.2	247	100
31						283	2832	2832	283														6230	1665.1	267	100
32						1501	2401																3902	1165.6	299	100
33							855	360	9316														10531	3586.5	340.55	100
34							3387	968	1936		1452												7742	2675	345.5	100
35								415	1662	415	415		549	11164									14622	5630	385.03	100
36									8682					3167		6860							18710	7563.3	404.24	100
37														5004	10008	17666		5004					37682	16662.1	442.17	100
38												3892		3892		3892							11676	4970.1	425.67	100
39																		11676					11676	6145.5	526.33	100
40																		1061					1061	596	561.5	100
41																										
42																										
TSN (10^{-3})	63687	14282	9191	46357	30939	18455	29822	6175	26647	415	1867	3892	549	23228	10008	28419		17741				1825	333501			
TSB (t)	1480.7	946.7	1064.9	8692.7	6656.1	4034.2	7335.3	1696	9035.3	165.4	693.4	1471.2	210.4	9375.6	4438.5	12204.3		9413.6				112		79026		
Mean length (cm)	13.06	19	23.25	27.04	28.13	28.62	29.99	31.34	33.44	35	34.22	38	35	36.07	37	36.9		38.5				18				
Mean weight (g)	23.25	66.29	115.86	187.52	215.14	218.6	245.97	274.64	339.07	398	371.37	378	382.83	403.64	443.5	429.45		530.6				61			236.96	
% mature*	25	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		100				0				
SSB	370	947	1,065	8,693	6,656	4,034	7,335	1,696	9,035	165	693	1,471	210	9,376	4,439	12,204		9,414				0	77803.8			

Table 10. Horse mackerel biomass and abundance by strata.

Strata name	Area (nmi²)	Transects	Abundance ('000)	Biomass (t)
W Hebrides	2884.1	8	11,997	1,595
S Hebrides	2027.0	4	0	0
N Stanton	2086.6	4	0	0
S Stanton	1880.3	4	0	0
W Coast	13655.6	17	65,951	15,175
Porc Bank	5552.1	6	804	303
Celtic Sea	32097.3	16	254,749	61,954
Total	60,183.0	59	333,501	79,027

Table 11. Horse mackerel survey time series.

Age (Yrs)	2016	2017	2018	2019
0	-	-	-	-
1	1.1	11.7	1.015	63.69
2	100.2	181.8	72.408	14.28
3	4.9	147	243.28	9.19
4	43.5	45.4	85.252	46.36
5	19.0	16.2	10.495	30.94
6	7.6	46	7.562	18.46
7	40.6	113	49.329	29.82
8	66.6	67.7	13.338	6.18
9	8.5	25.4	10.047	26.65
10	1.8	33.2	1.511	0.42
11	9.5	32.6	1.547	1.87
12	10.6	37.7	7.356	3.89
13	4.7	37.6	8.5	0.6
14	21.1	160.8	27.5	23.2
15	6.5	8.6	-	10.01
16	1.6	5.2	-	28.42
17	5.3	-	0.262	-
18	-	-	-	17.74
19	-	-	-	-
20	-	-	-	-
21	1.1	-	-	-
TSN (10^{-3})	354.5	969,655	540,422	333,501
TSB (t)	69,267	228,116	92,932	79,026
SSB (t)	65,194	227,395.6	89,050	77,529
CV	42.0	25.5	36.8	33.7

Table 12. Celtic Sea herring stock estimate.

Length					Age (years)								Numbers	Biomass	Mn Wt	Mature
(cm)	1	2	3	4	5	6	7	8	9	10	11	Unknown	(10^{-3})	(t)	(g)	(%)
11.5																
12																
12.5																
13																
13.5																
14																
14.5																
15																
15.5																
16																
16.5												1512	1512	51.4	34	0
17	11386												11386	432.7	38	0
17.5	30255												30255	1236.4	41	0
18	52470												52470	2336.3	45	0
18.5	73130												73130	3742.6	51	0
19	67540	25215											92755	5216.8	56	0
19.5	139006												139006	8349.8	60	0
20	57366	2821											60187	4099.3	68	0
20.5	63663	6063											69726	5073.3	73	0
21		68818											68818	5073.7	74	92
21.5		22311											22311	1816.1	81	0
22		27147											27147	2352.6	87	0
22.5		6723	1793										8515	774.4	91	0
23	541	7574	541										8656	840.7	97	74
23.5		1924	1924										3848	378.4	98	100
24												2060	2060			
24.5			1742	871									2613	338.8	130	66
25																
25.5				1100									1100	159.5	145	100
26						1100							1100	177.1	161	100
26.5					412								412	74.1	180	100
27				2584									2584	447	173	100
27.5																
28					2584								2584	491	190	100
28.5																
29																
29.5																
30																
30.5																
31																
31.5																
TSN (10^{-3})	495358	168597	6000	4555	2996	1100						3572	682177			
TSB (t)	28429	12901.4	620.4	718.0	565.1	177.1						51.4		43462.2		
Mean length (cm)	19.14	21.1	23.5	26.2	27.8	26.0						20.82				
Mean weight (g)	57.39	76.5	103.4	157.6	188.6	161.0						34			63.9	
% mature*	0	8	20	75	100	100										
SSB (t)	0	1080	171	559	565	177							2551.0			

Table 13. Celtic Sea herring total stock biomass and total abundance by strata.

Strata name	Area (nmi²)	Transects	Abundance ('000)	Biomass (t)
Celtic Sea	32,097.3	16	682,177	43,462
Total	32,097.3	16	682,177	43,462

Table 14. Marine mammal and megafauna sightings, counts and group size ranges for cetaceans sighted during the survey (includes on and off effort).

Common Name	Species name	No. of Sightings	No. of individuals	Group Size
Bottlenose dolphin	*Tursiops truncatus*	3	57	14-28
Common Dolphin	*Delphinus delphis*	63	1705	1-800
Fin Whale	*Balaenoptera physalus*	4	15	1-6
Harbour Porpoise	*Phocoena phocoena*	1	4	4
Long-finned Pilot Whale	*Globicephala melas*	2	11	5-6
Minke Whale	*Balaenoptera acutorostrata*	16	18	1-2
Sperm Whale	*Physeter macrocephalus*	1	1	1
Unidentified Baleen Whale	*Mysticeti sp.*	5	8	1-2
Unidentified Dolphin	*Delphinidae sp.*	9	88	1-30
Unidentified Large Whale		1	1	1
	Total	**105**	**1,908**	
Blue shark	*Prionace glauca*	2	2	1
Bluefin Tuna	*Thunnus thynnus*	1	7	7
Ocean sunfish	*Mola mola*	17	17	1
Smooth Hammerhead Shark	*Sphyrna zygaena*	1	1	1
Unidentified Shark	*Selachimorpha sp.*	2	2	1
	Total	**23**	**29**	

Table 15. Totals for all seabird and terrestrial bird species recorded between 13th June and 24rd July 2019.

Common Name	Species name	No. of Sightings	No. of Individuals	On Transect	Off Transect
Arctic Tern	*Sterna paradisaea*	13	20	9	11
Arctic Skua	*Stercoratius parasiticus*	2	2	0	2
Auk sp.	*Alcidae sp.*	13	371	212	159
Balearic Shearwater	*Puffinus mauretanicus*	1	1	0	1
Commic tern sp.	*Sterna hirundo / Sterna paradisaea*	1	15	0	15
Common Tern	*Sterna hirundo*	7	9	3	6
Fulmar	*Fulmarus glacialis*	965	8159	1081	7078
Gannet	*Sula bassana*	1265	6116	865	5251
Great Black-backed Gull	*Larus marinus*	31	43	7	36
Great Shearwater	*Puffinus graves*	1	1	0	1
Great Skua	*Stercoratius skua*	109	136	53	82
Guillemot	*Uria aalge*	299	1149	1051	98
Herring Gull	*Larus argentatus*	13	23	2	21
Kittiwake	*Rissa tridactyla*	225	1061	641	420
Leach's Petrel	*Oceanodroma leucorhoa*	3	3	2	1
Lesser Black-backed Gull	*Larus fuscus*	133	541	31	510
Little Tern	*Sterna albifrons*	1	3	3	0
Long-tailed Skua	*Stercoratius longicaudus*	1	1	0	1
Manx Shearwater	*Puffinus puffinus*	561	3010	1989	1021
Pomarine Skua	*Stercoratius pomarinus*	4	4	0	4
Puffin	*Fratercula arctica*	229	445	245	200
Razorbill	*Alea torda*	114	340	274	66
Shag	*Phalacrocorax aristotelis*	1	3	3	0
Sooty Shearwater	*Puffinus griseus*	8	8	1	7
South Polar Skua	*Stercorarius maccormicki*	1	1	0	1
Storm Petrel	*Hydrobates pelagicus*	524	3425	860	2565
Wilson's Petrel	*Oceanites oceanicus*	4	6	0	0
	Total	**4,529**	**24,896**	**7,332**	**27,556**
Collared Dove	*Streptopelia decaocto*	2	2		
common scoter	*Melanitta nigra*	3	21		
Dunlin	*Calidris alpina*	1	1		
Feral/ racing pigeon	*Columba livia domestica*	4	5		
Golden Eagle	*Aquila chrysaetos*	1	2		
Pied Wagtail	*Motacilla alba*	1	1		
Redshank	*Tringa totanus*	1	5		
Spotted Flycatcher	*Muscicapa striata*	1	1		
Swallow	*Hirundo rustica*	2	2		
Swift	*Apus apus*	7	12		
	Total	**23**	**52**		

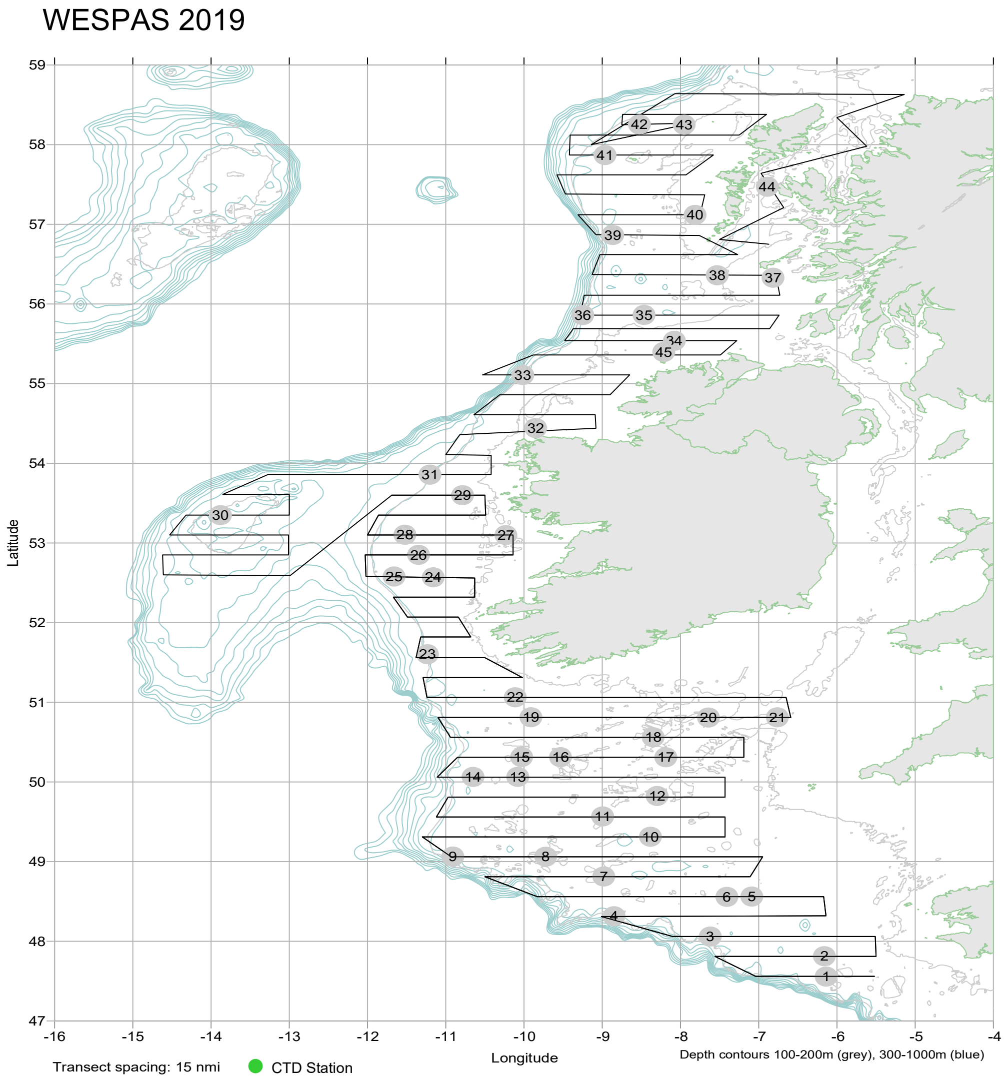


Figure 1. Survey cruise track (grey line) and numbered directed pelagic trawl stations. Corresponding catch details are provided in Table 2.

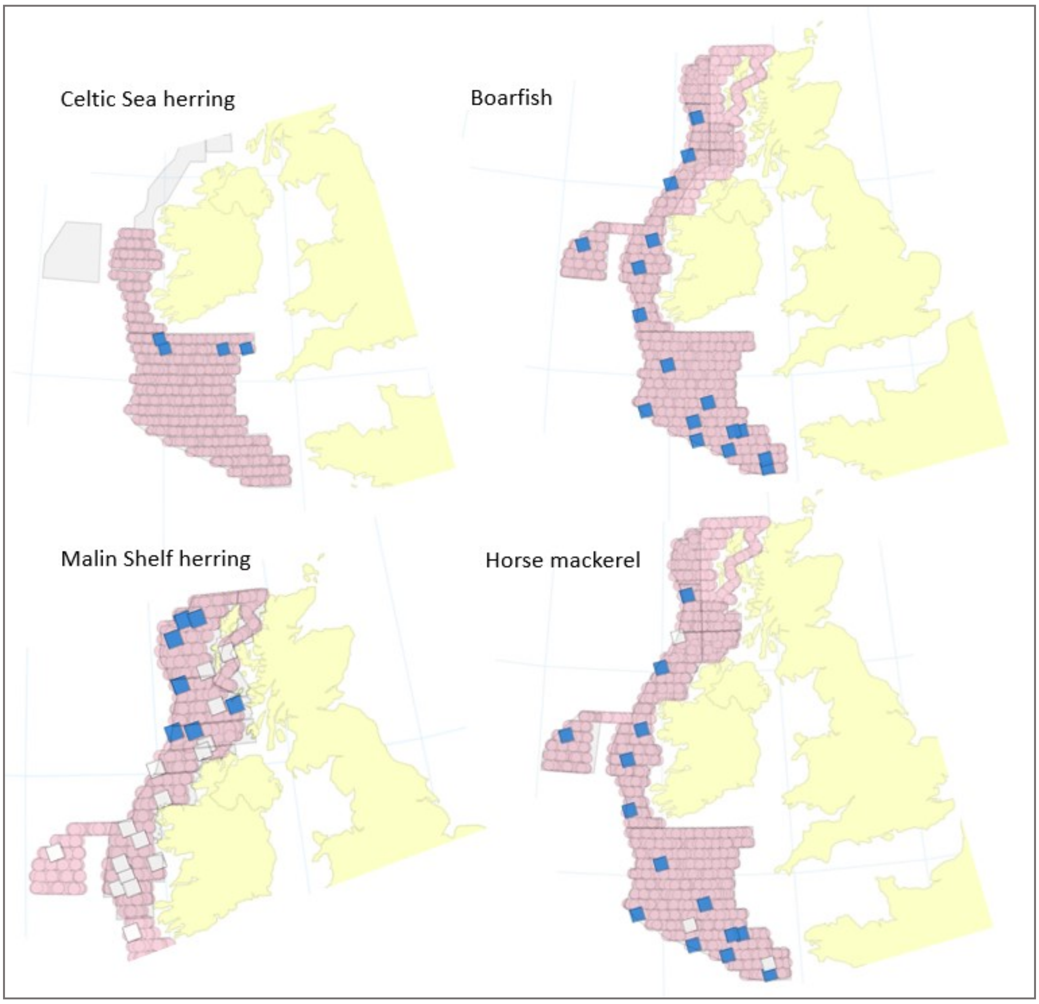


Figure 2. Species specific acoustic sampling stratification taken from StoX.

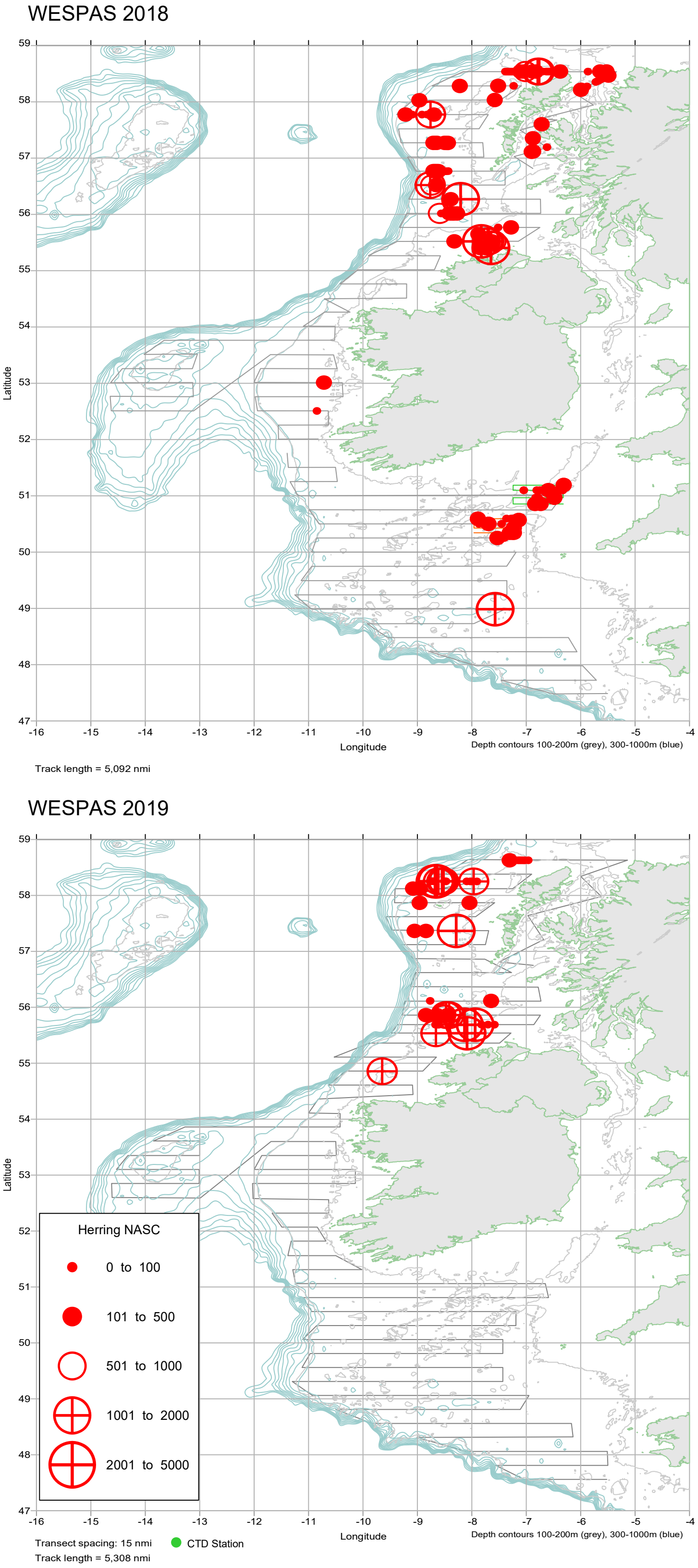


Figure 3. Malin Shelf (north of 54°N) herring distribution by weighted acoustic density. Top panel 2018, bottom panel 2019.

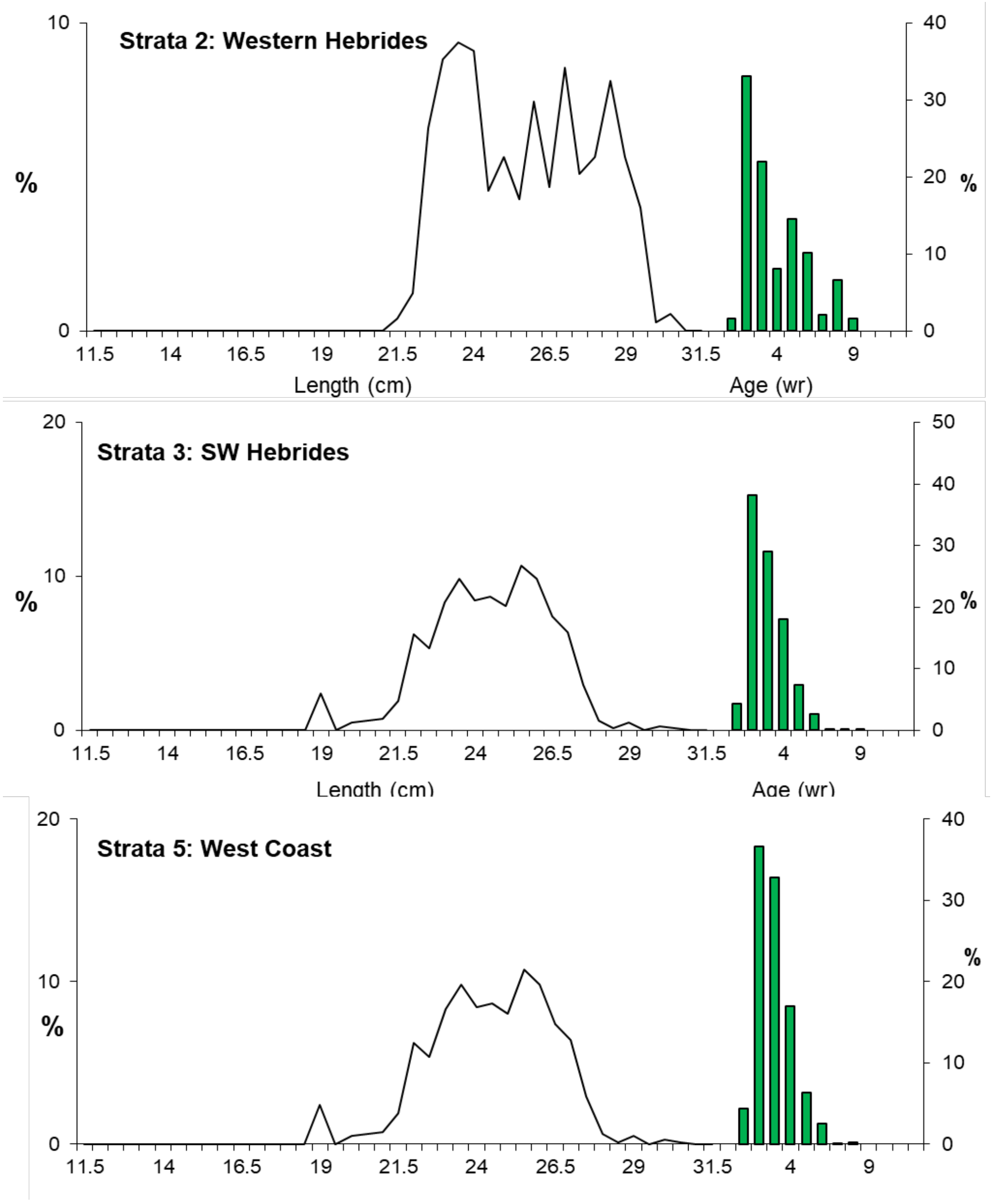


Figure 4. Length and age distribution of Malin Shelf herring by stratum and total survey area during WESPAS 2019.

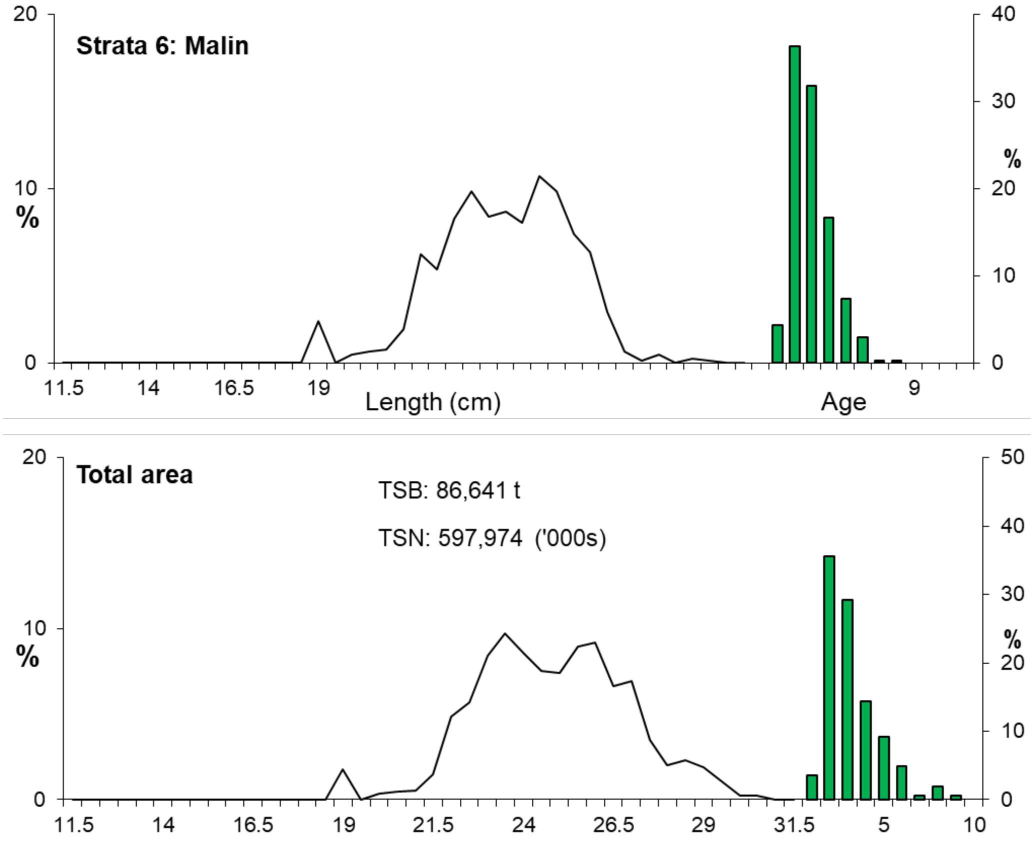
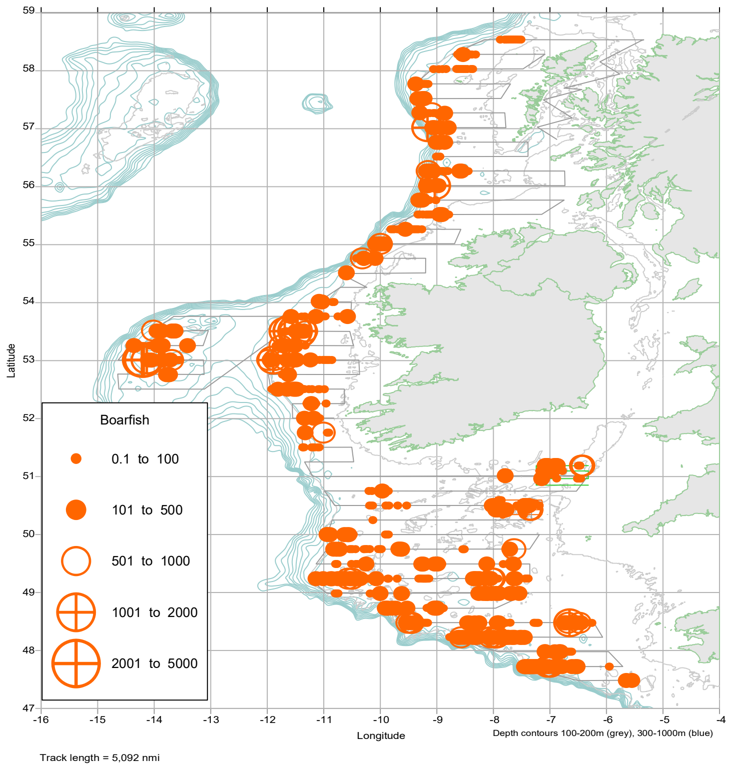


Figure 4. *Continued.* Length and age distribution of Malin Shelf herring by stratum and total survey area during WESPAS 2019.

WESPAS 2018



WESPAS 2019

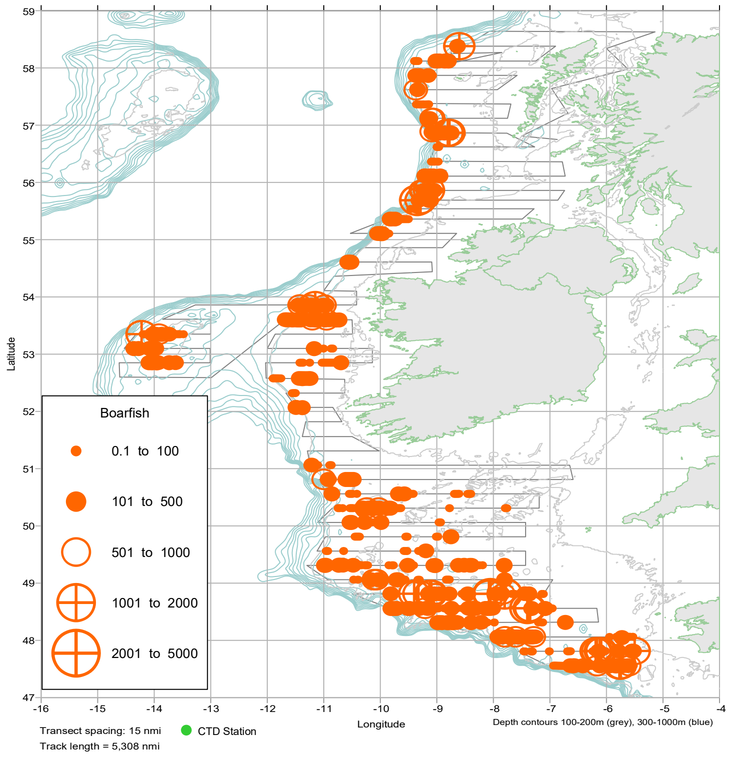


Figure 5. Boarfish distribution by weighted acoustic density. Top panel 2018, bottom panel 2019.

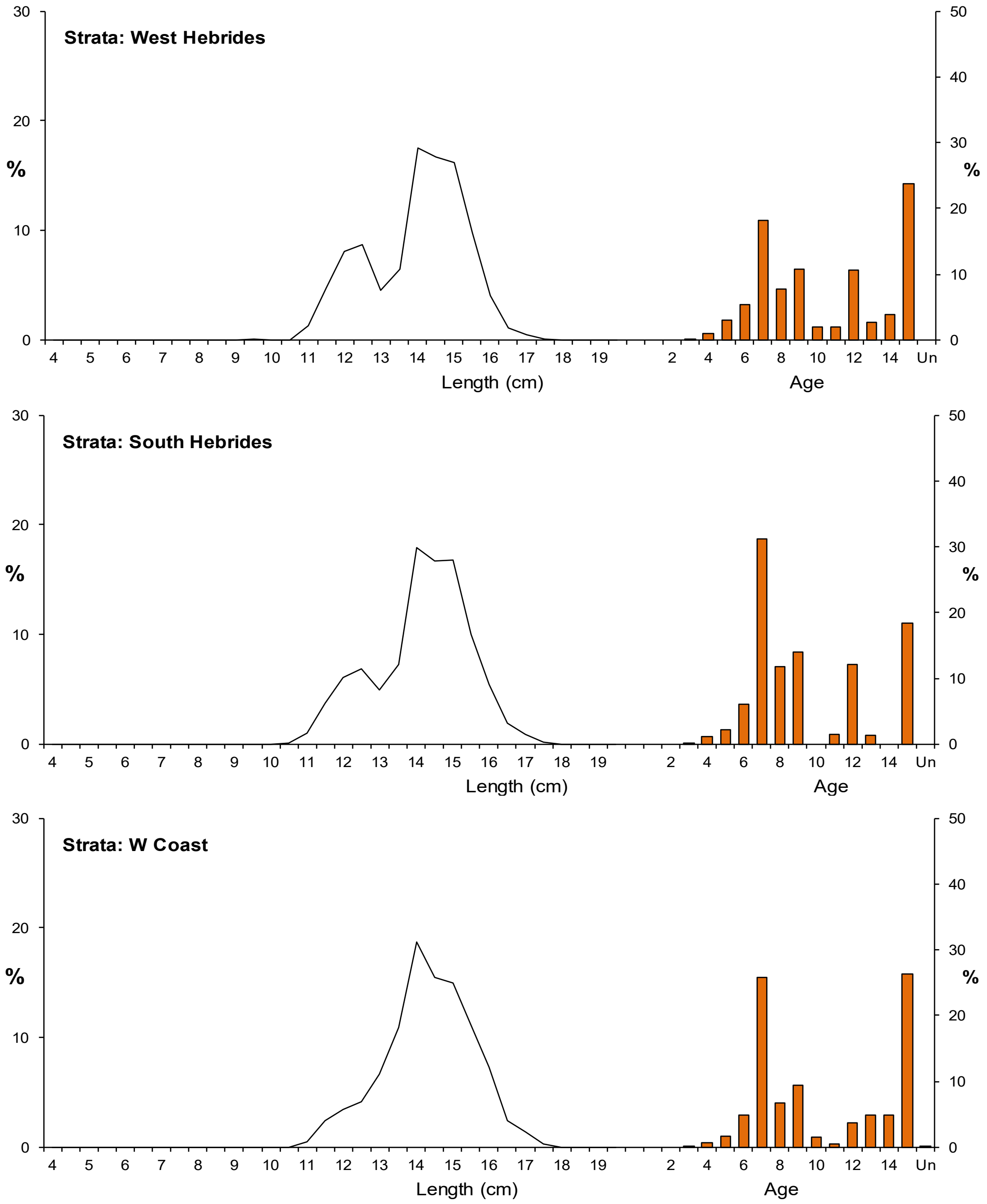


Figure 6. Abundance at length and age distribution of boarfish by stratum and total survey area.

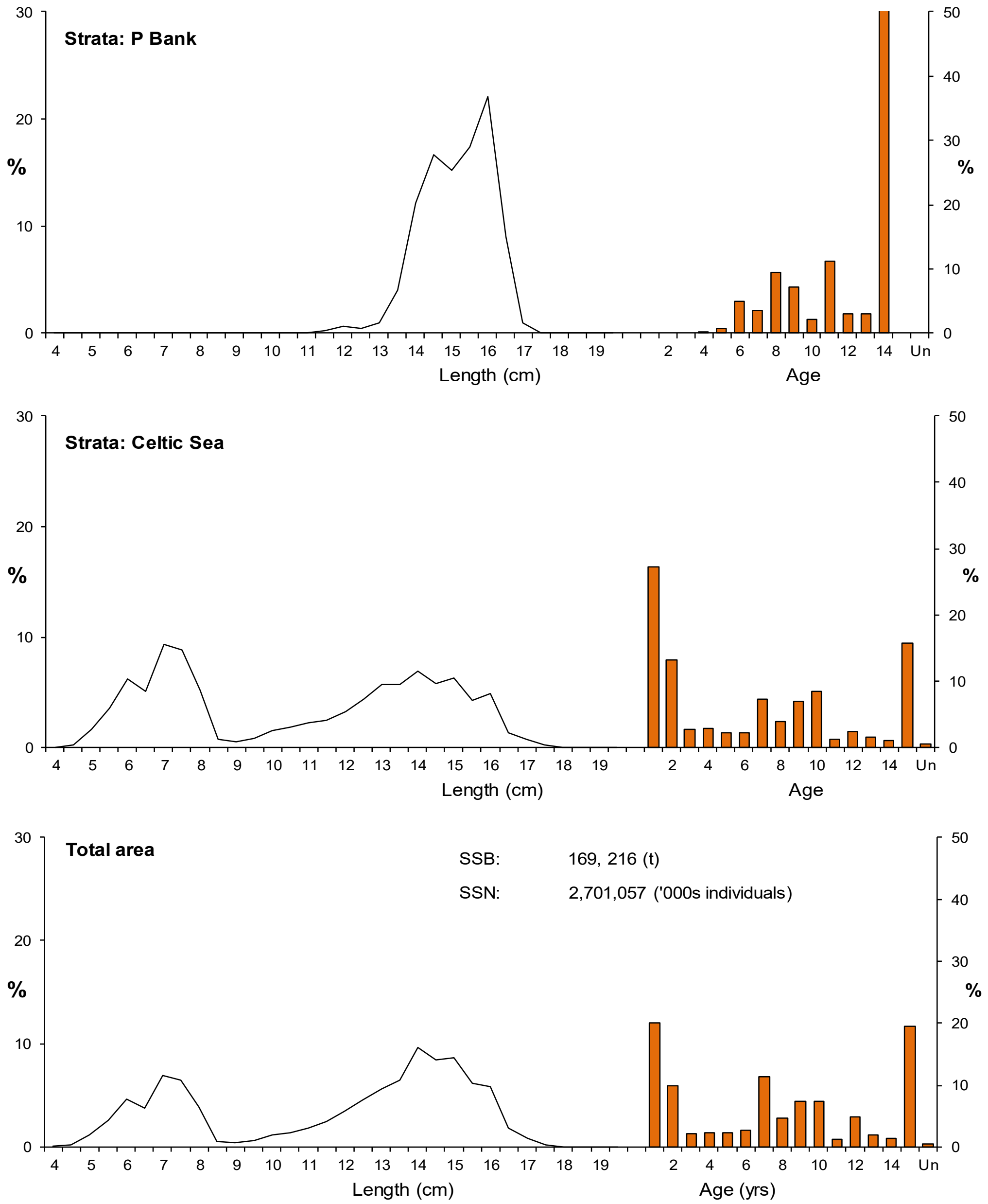
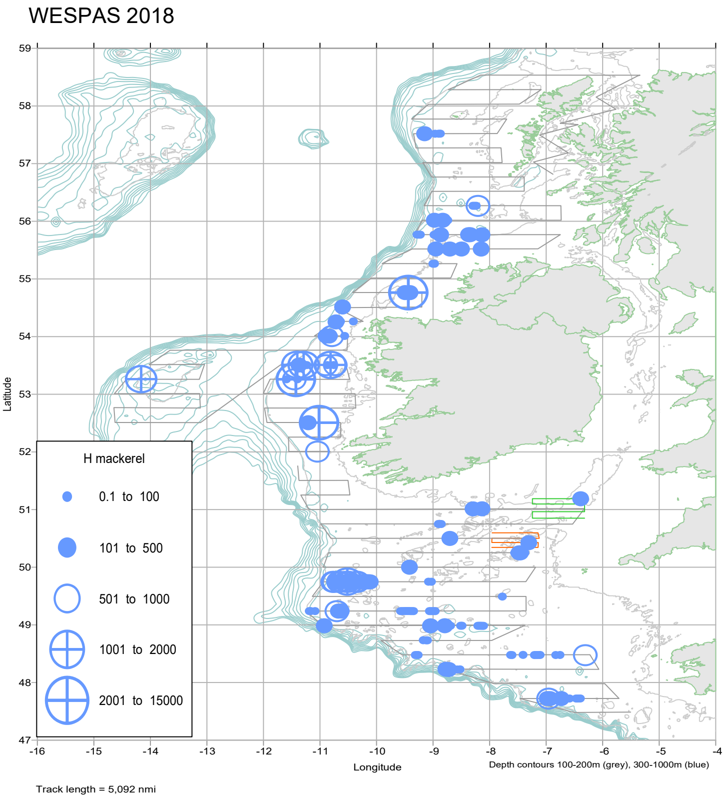


Figure 6. cont.



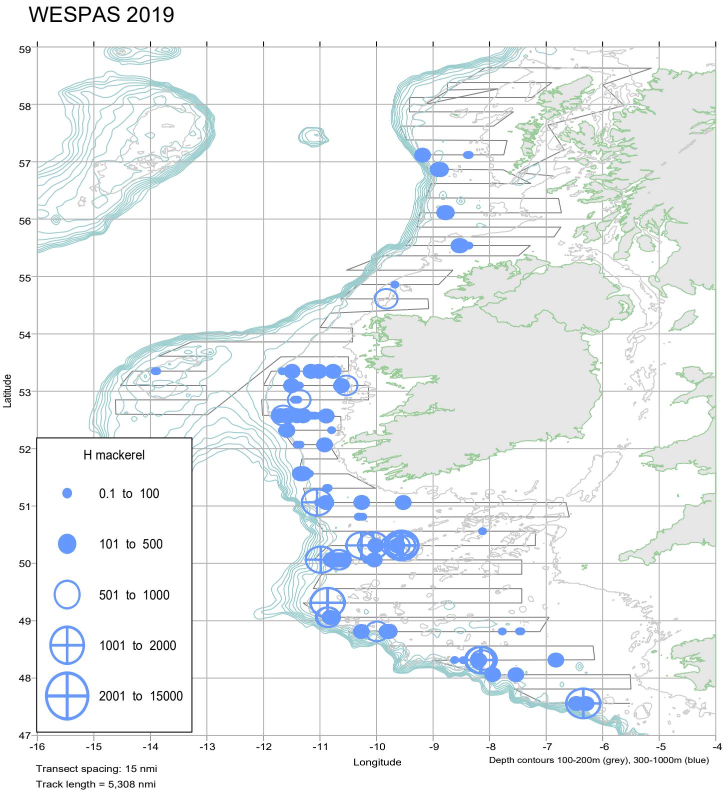


Figure 7. Horse mackerel distribution by weighted acoustic density. Top panel 2018, bottom panel 2019.

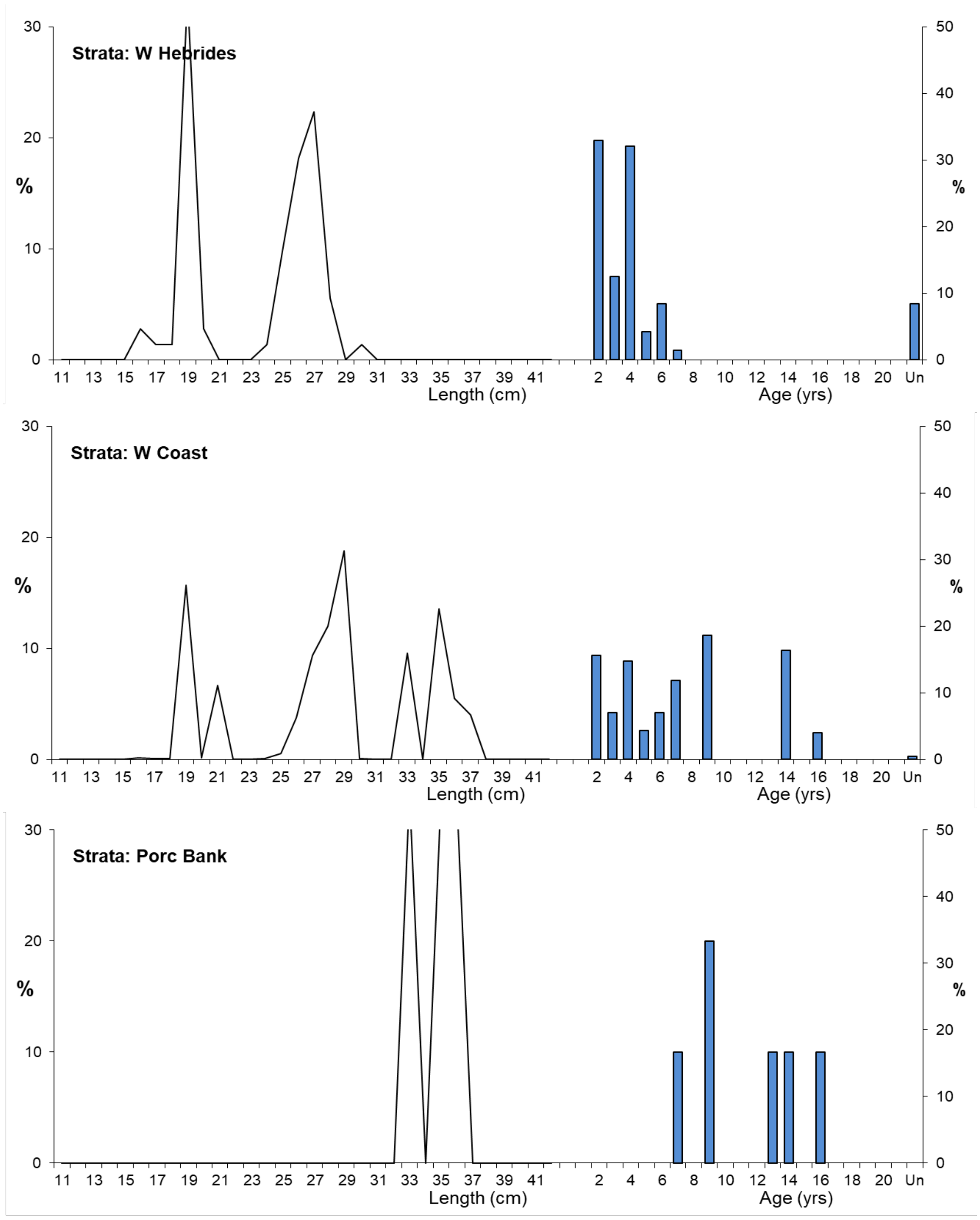


Figure 8. Length and age distribution of horse mackerel by stratum and total survey area.

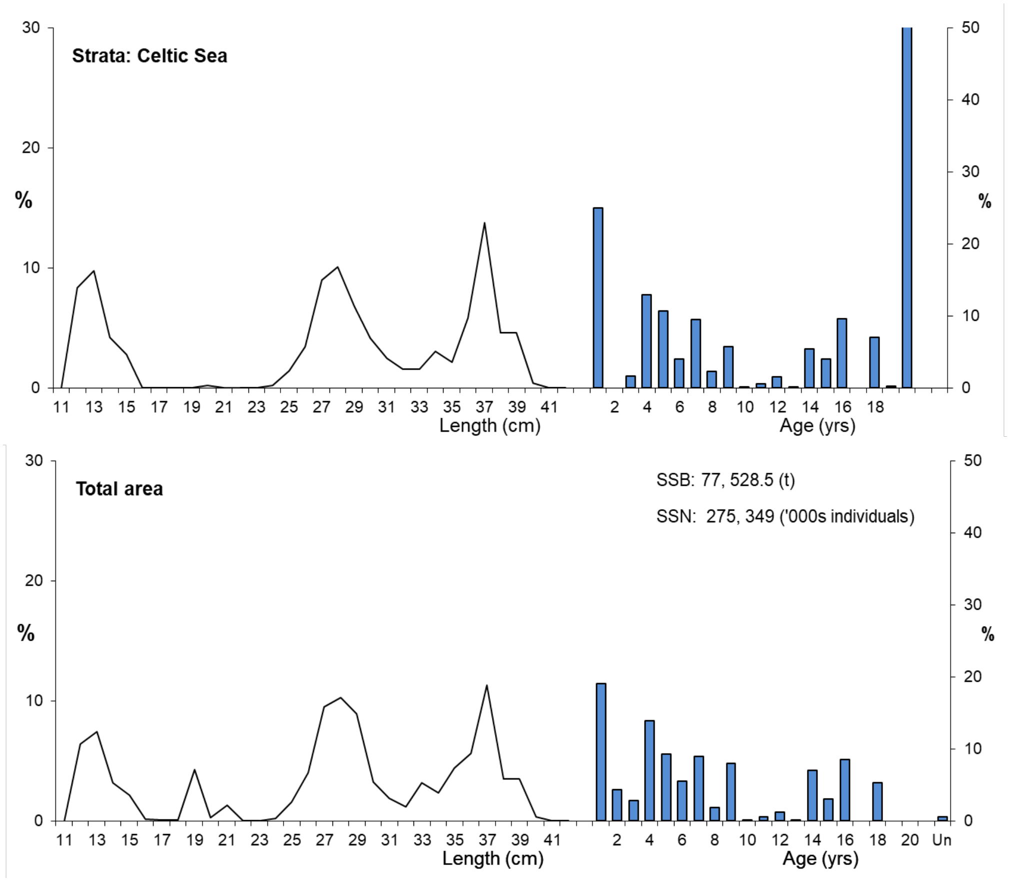


Figure 8. Continued. Length and age distribution of horse mackerel by stratum and total survey area.

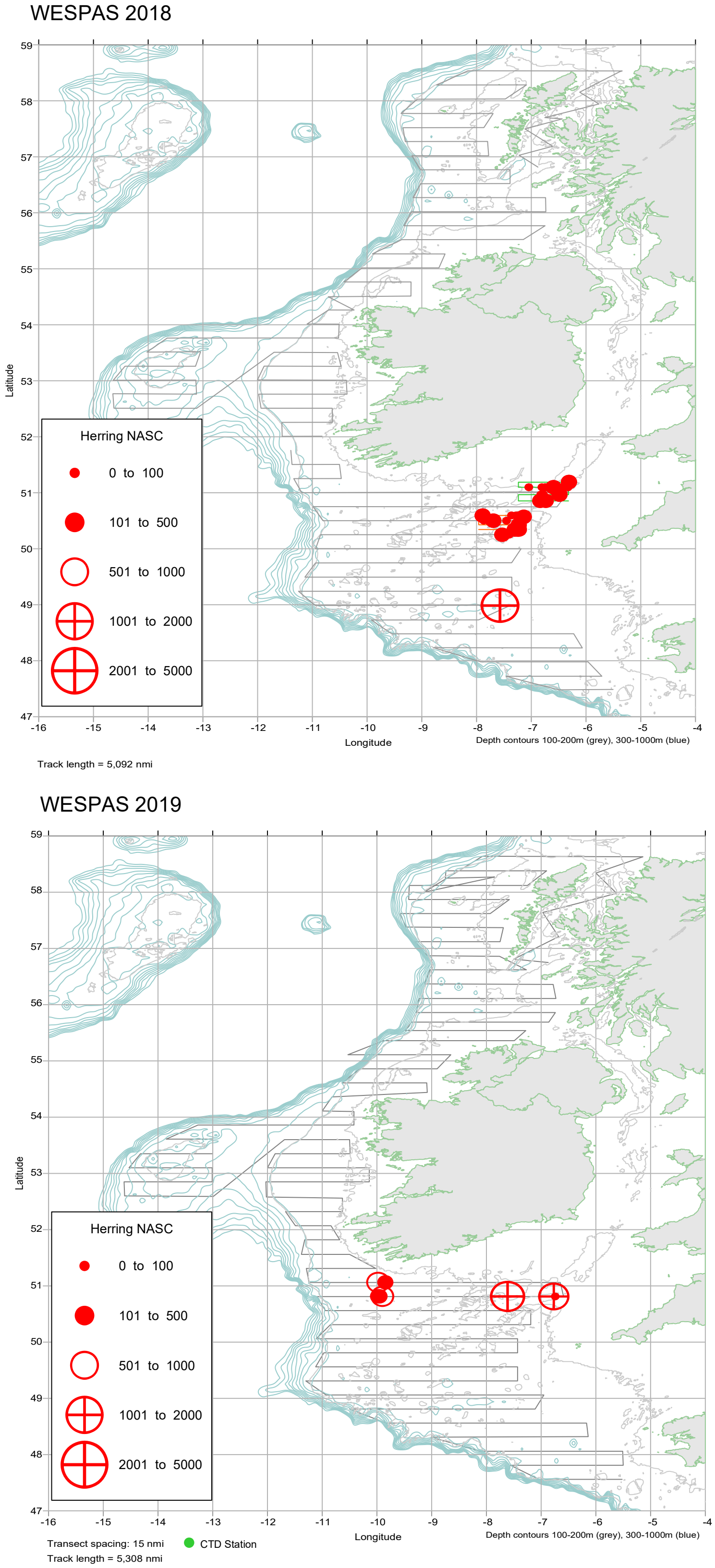


Figure 9. Celtic Sea herring distribution by weighted acoustic density.

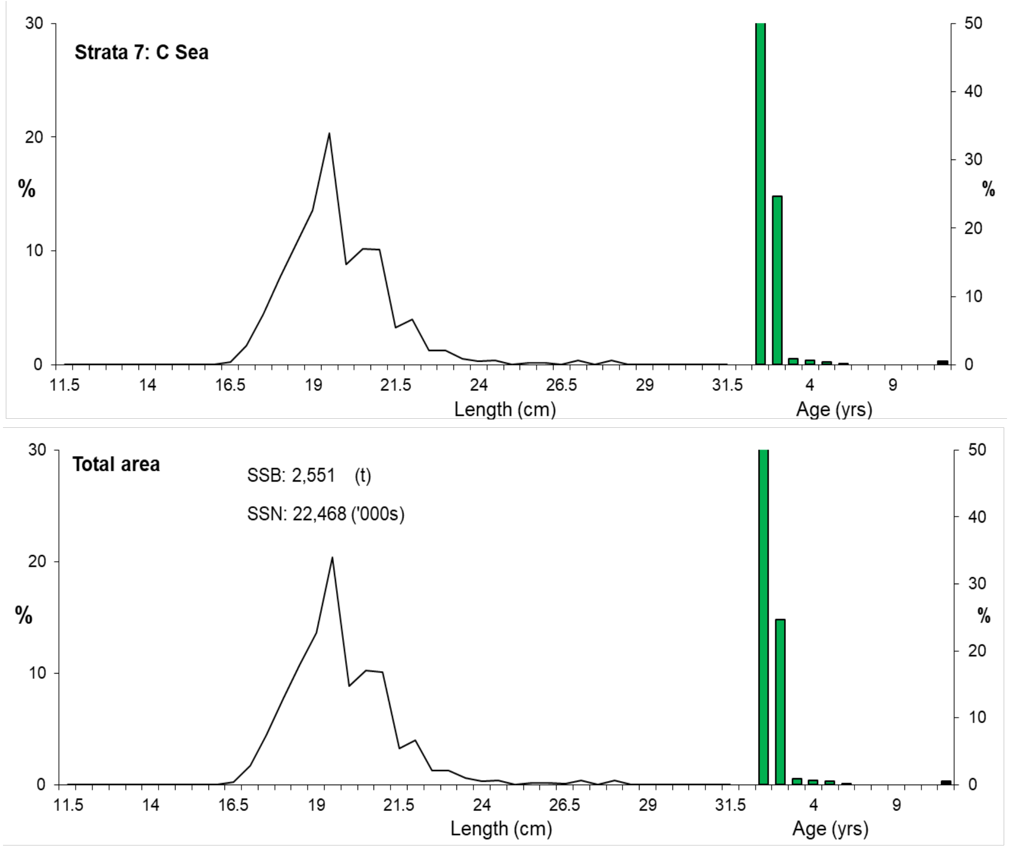
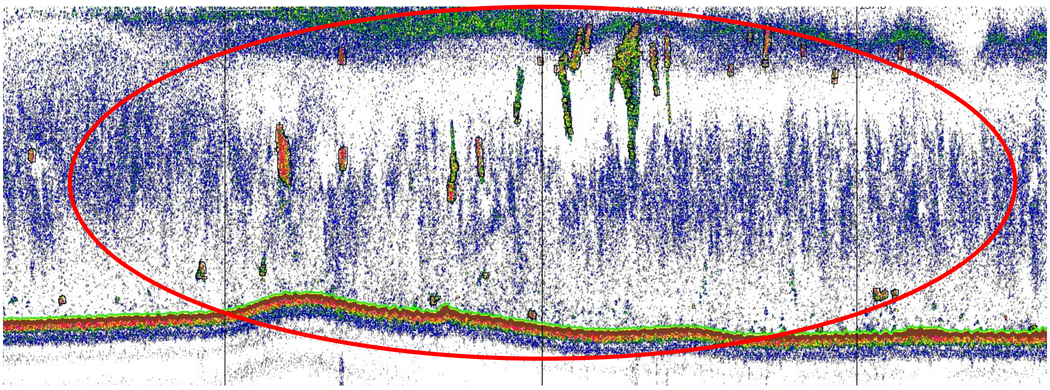
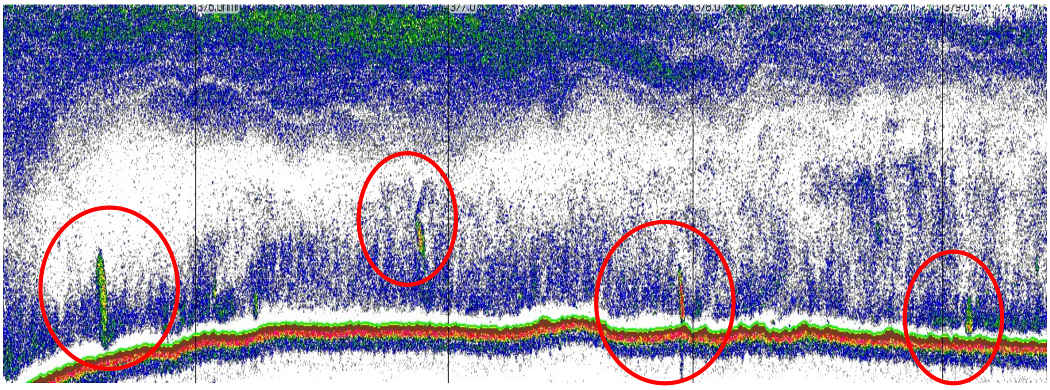


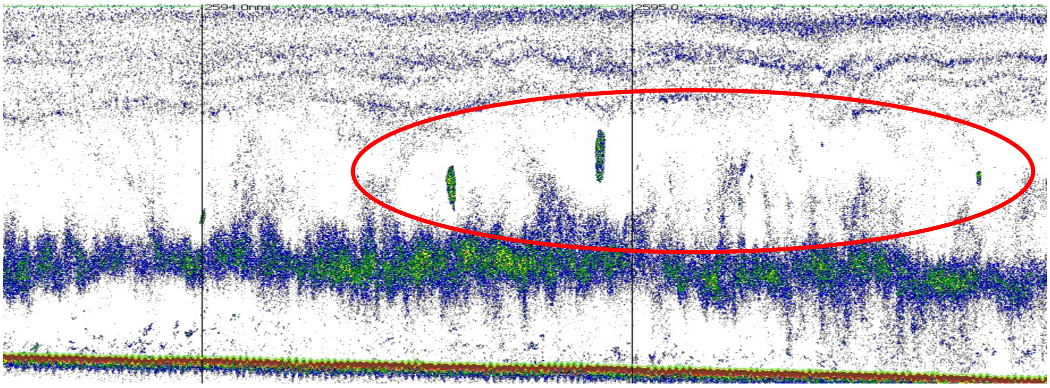
Figure 10. Length and age distribution of Celtic Sea herring by stratum and total survey area.



a). *Haul 2 Southern Celtic Sea. Pelagic schools of immature boarfish (circled red) close to the shelf edge. Water depth 144 m.*

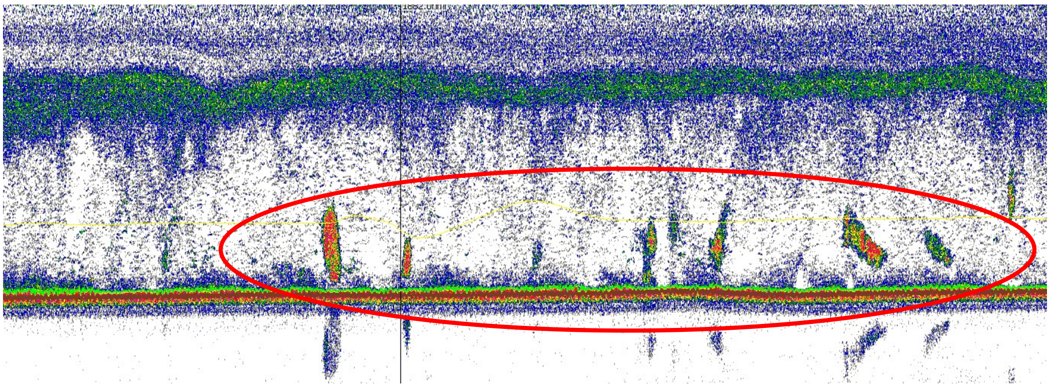


b). *Haul 04, Southern Celtic Sea. Medium density boarfish schools at the shelf edge. Water depth 177 m.*

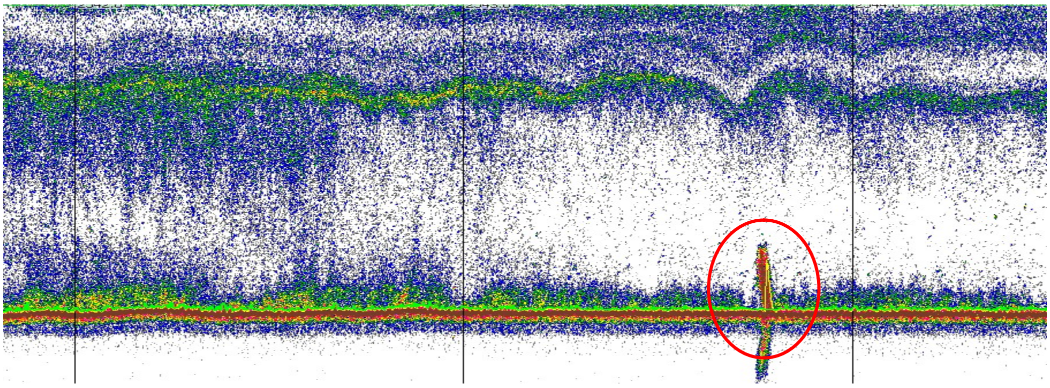


c). *Haul 23. Medium density midwater schools of mature boarfish encountered off the southwest Irish coast. Water depth 200 m.*

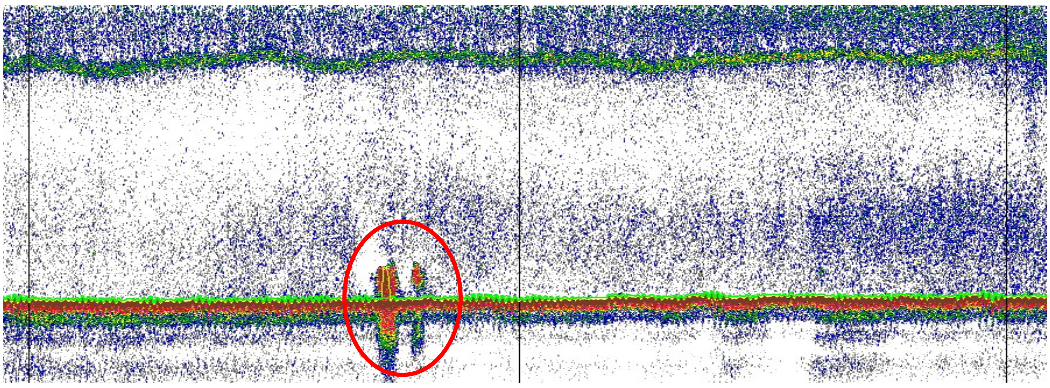
Figures 11a-l. Echotraces recorded on an EK60 echosounder (38 kHz) with images captured from Echoview. Note: Vertical bands on echogram represent 1nmi (nautical mile) intervals.



d). *Haul 16. Mid Celtic Sea. High density schools of horse mackerel encountered in the mid Celtic Sea. Water depth 133 m.*



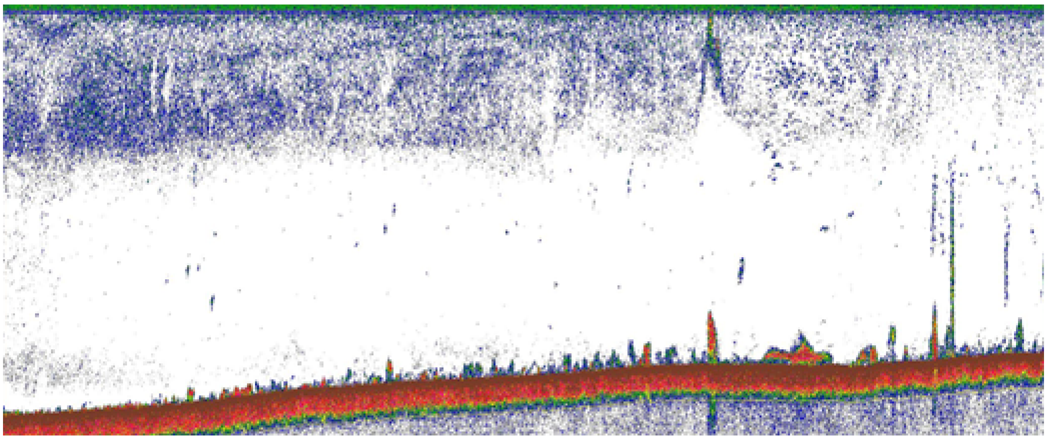
e). *Haul 22. High density single herring school located off the southwest coast in the western Celtic Sea, water depth 124 m.*



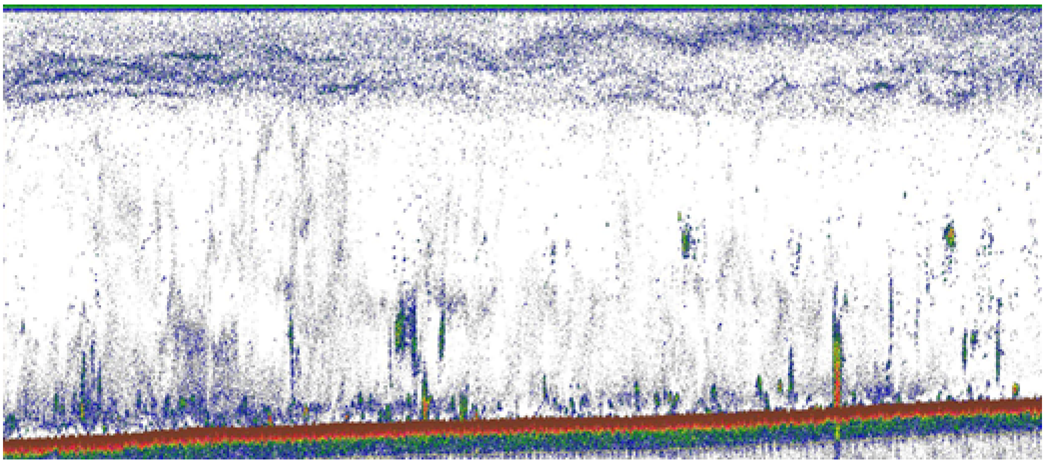
f). *Haul 20. High density herring schools in the Celtic Deep region, eastern Celtic Sea, water depth 100 m.*

Figures 11a-l. continued

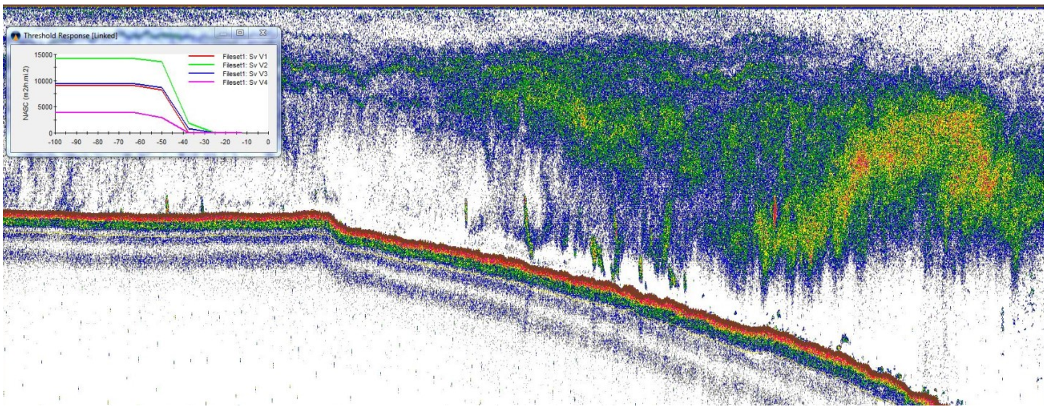
Figures11a-l. continued.



g). *Haul 35. Northwest of Tory Island, herring marks (18 kHz shown for clarity) along bottom, water depth 134 m.*

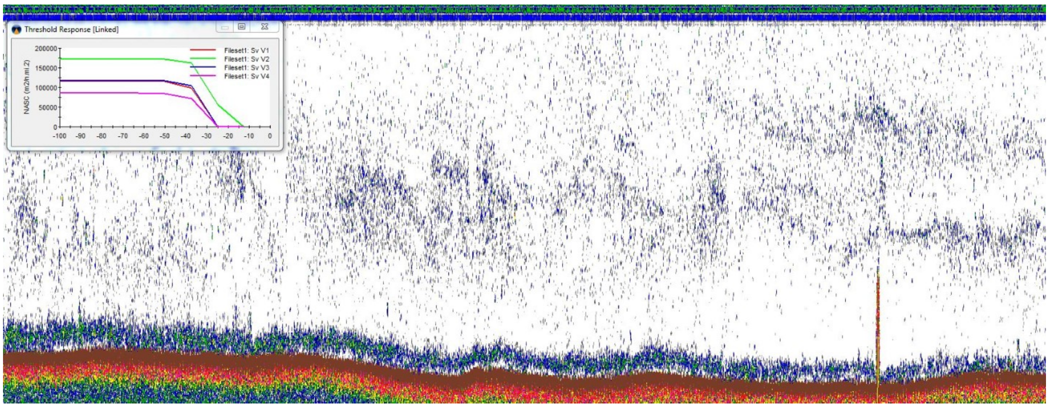


h). *Haul 42. North of St. Kilda, herring marks (18 kHz shown for clarity) along bottom, water depth 164 m.*

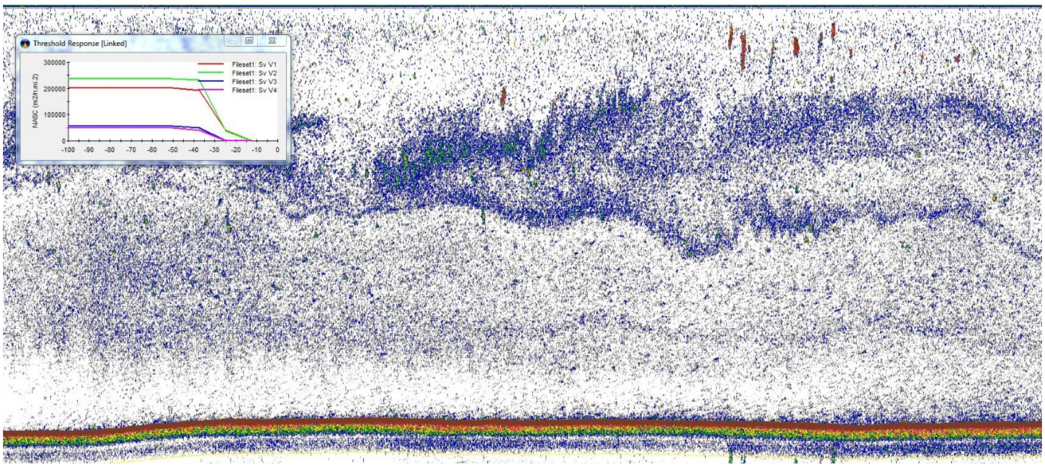


i). *Haul 33. West of Aranmore. Boarfish marks close to the shelf edge. Water depth ~200 m.*

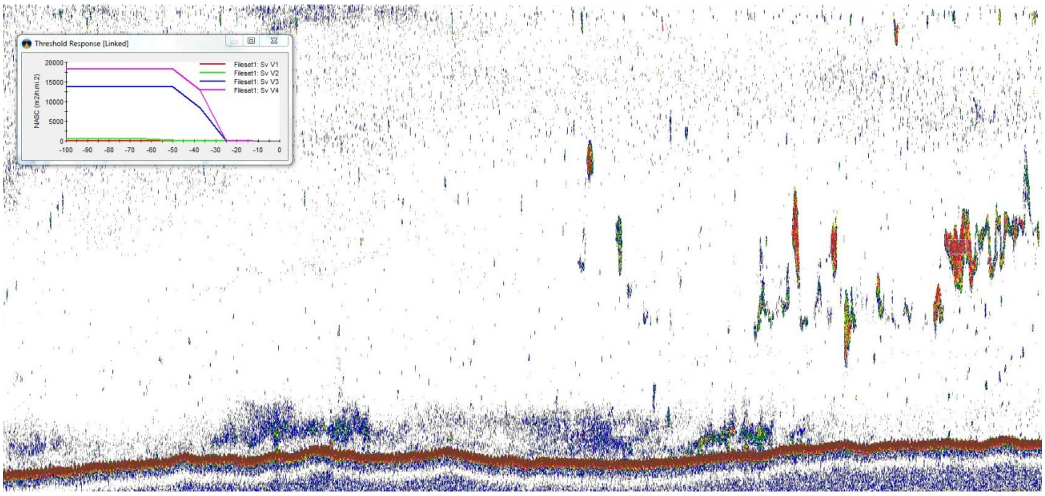
Figures11-l. continued.



J). *Haul 34. Suspected herring mark (missed) north of Lough Swilly. Water depth ~80 m.*



k). *Haul 44. Surface marks of sprat in the Minch. Water depth ~180 m.*



l). *Midwater marks of mackerel (on 200 kHz) in the south Minch area east of Barra. Backscatter was strong on 120 and 200 kHz, much weaker on the 18 and 38 kHz. Water depth ~120 m.*

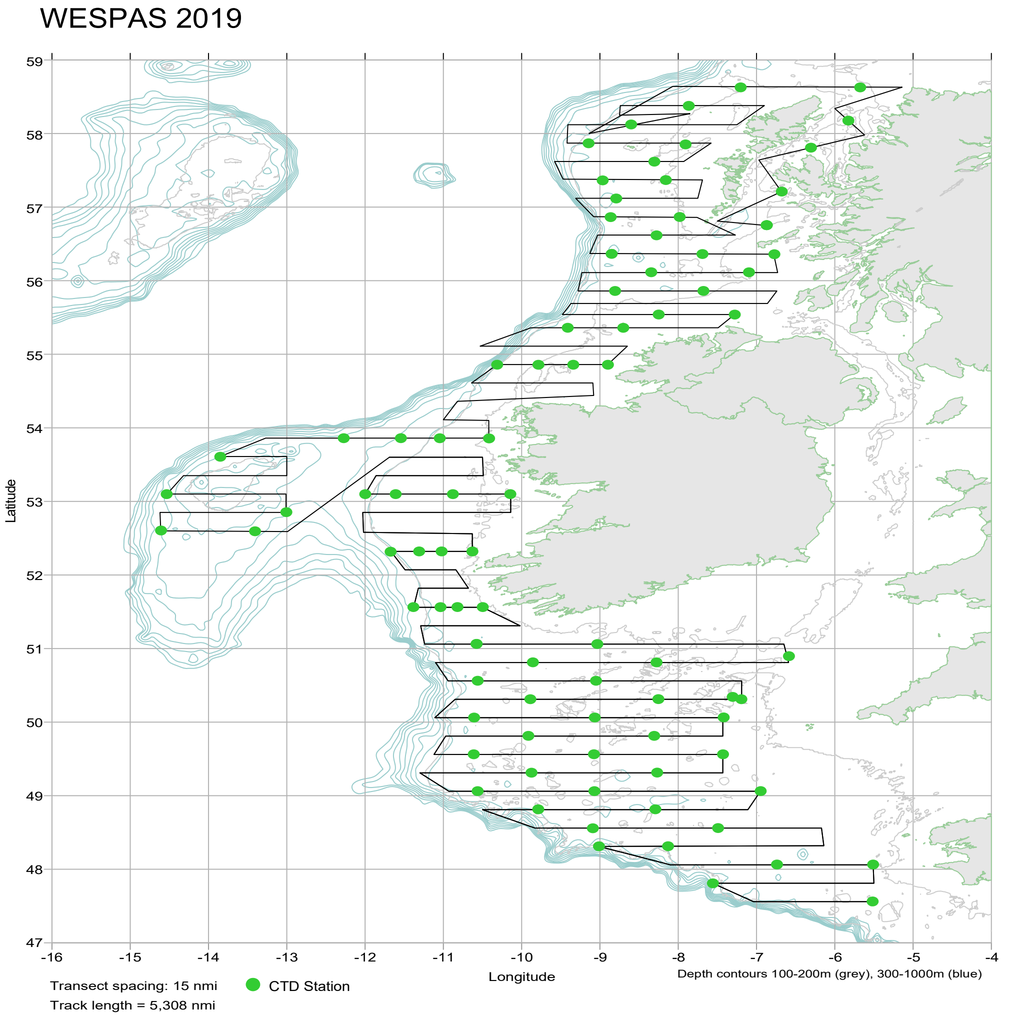


Figure 12. Position of hydrographic and co-occurring zooplankton sampling stations (n=87).

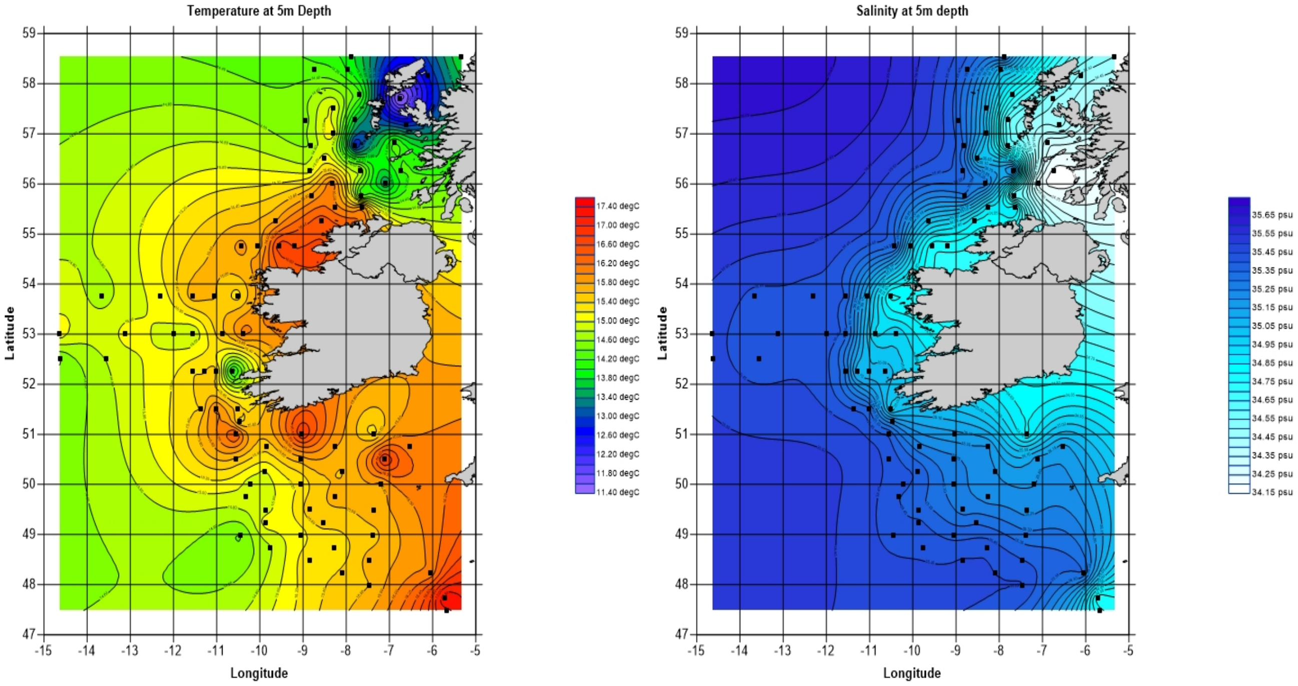


Figure 13. Surface (5m) plots of temperature and salinity compiled from CTD cast data. Station positions with valid data shown as block dots (n=87).

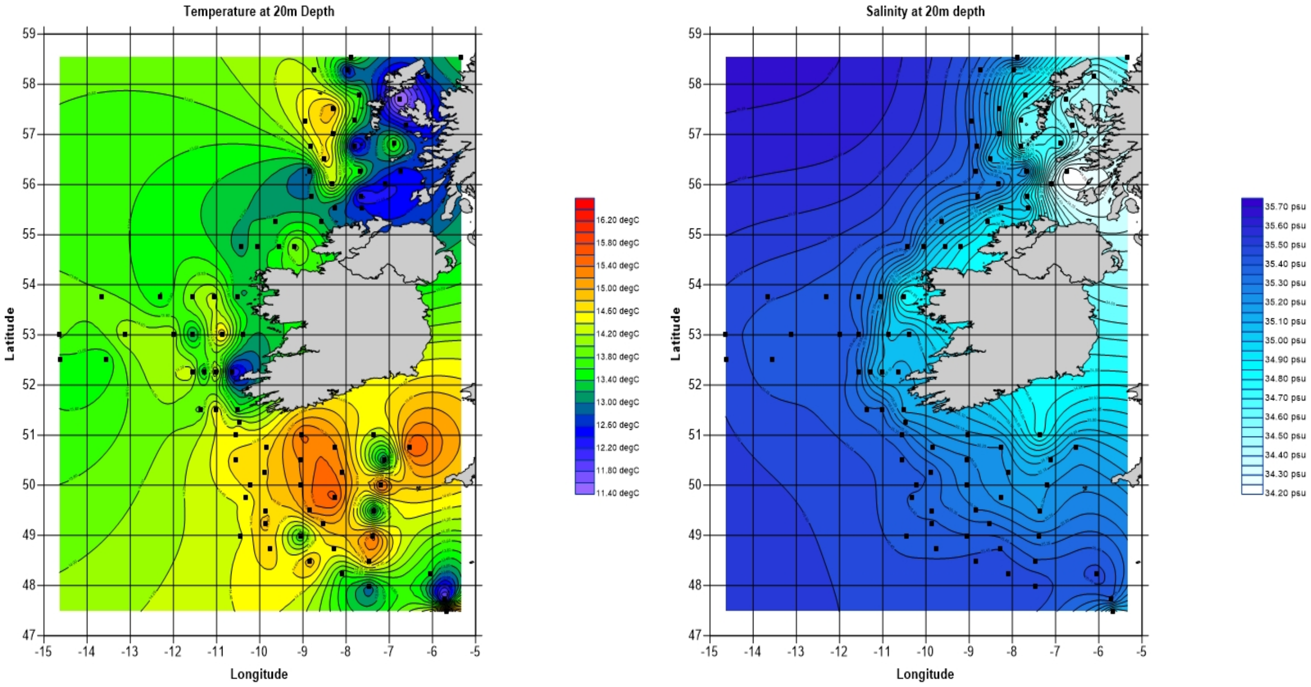


Figure 14. Plots of temperature and salinity compiled from CTD cast data at 20m depth. Station positions with valid data shown as block dots (n=87).

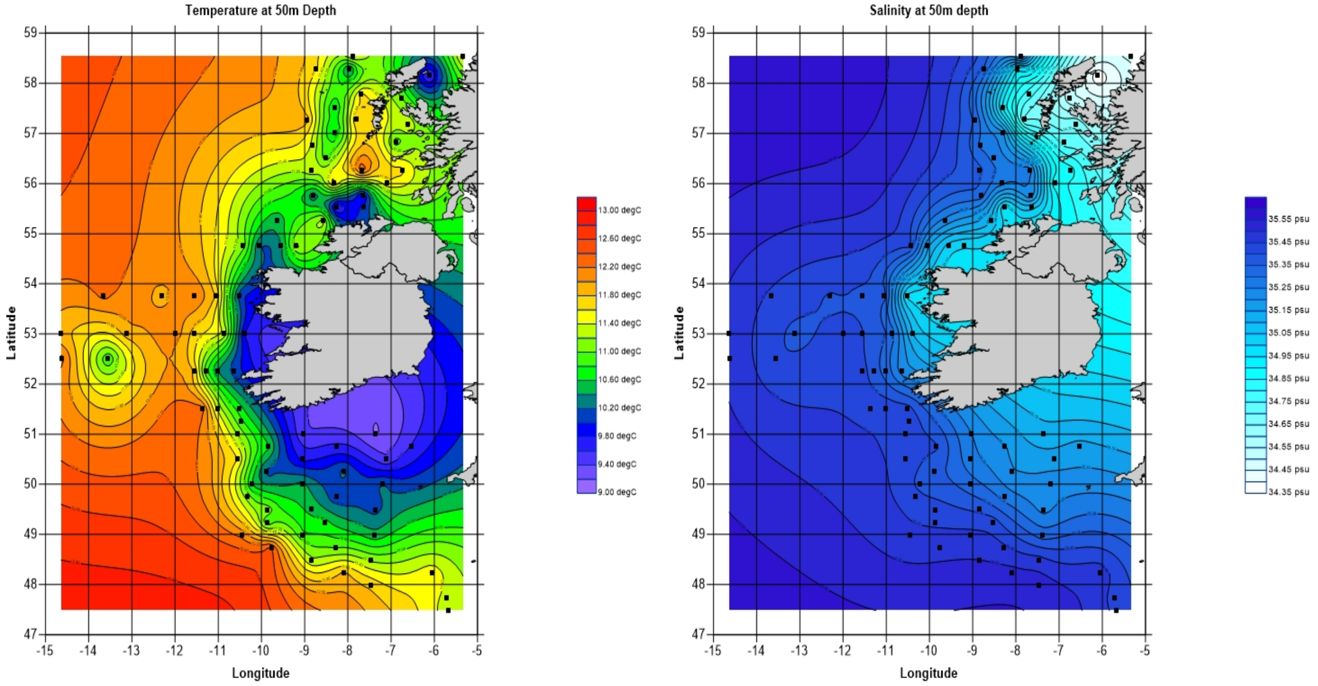


Figure 15. Plots of temperature and salinity compiled from CTD cast data at 50m depth. Station positions with valid data shown as block dots (n=87).

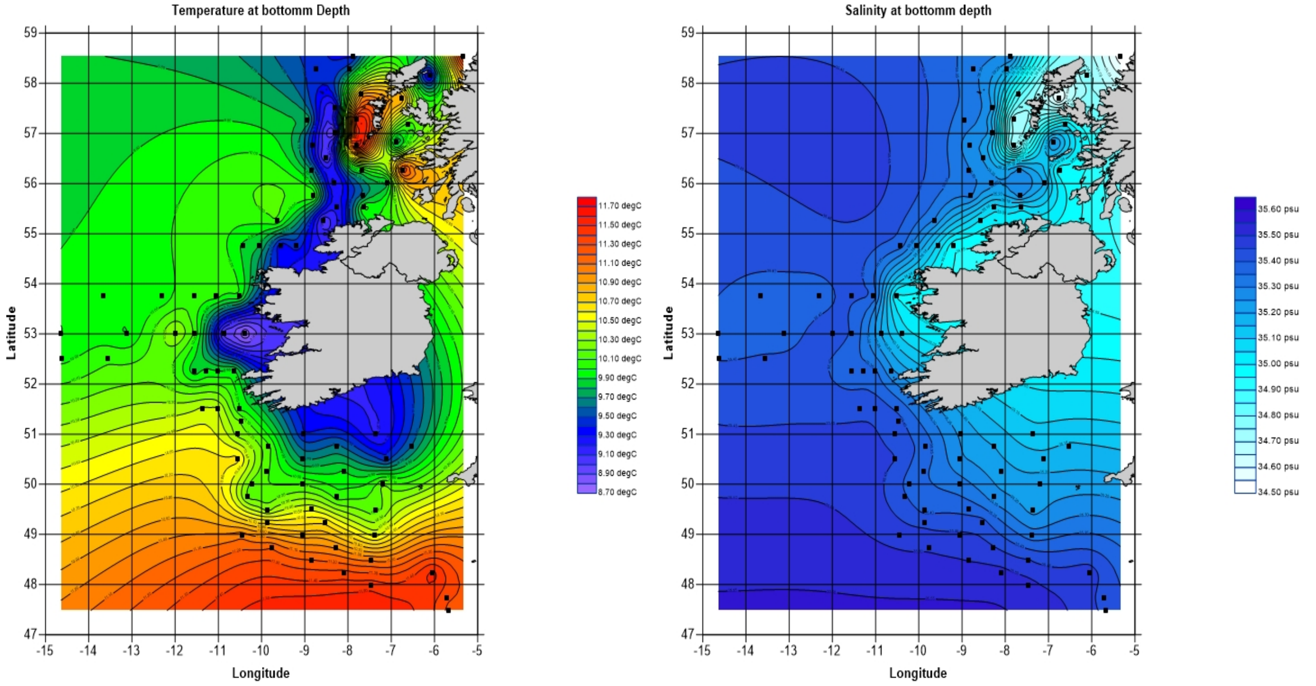


Figure 16. Plots of temperature and salinity compiled from CTD cast data at the seabed (+3-5m). Station positions with valid data shown as block dots (n=87).

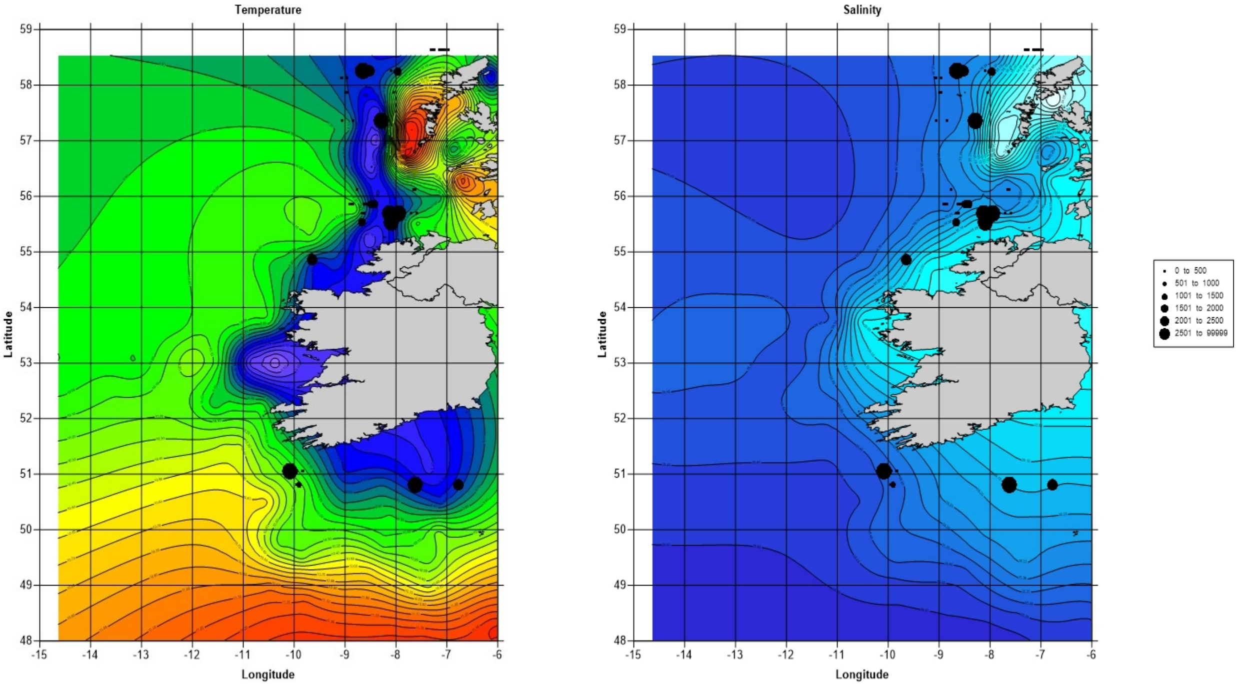


Figure 17. Habitat plots of temperature and salinity with herring distribution. Sea floor values overlaid with herring NASC values (black circles).

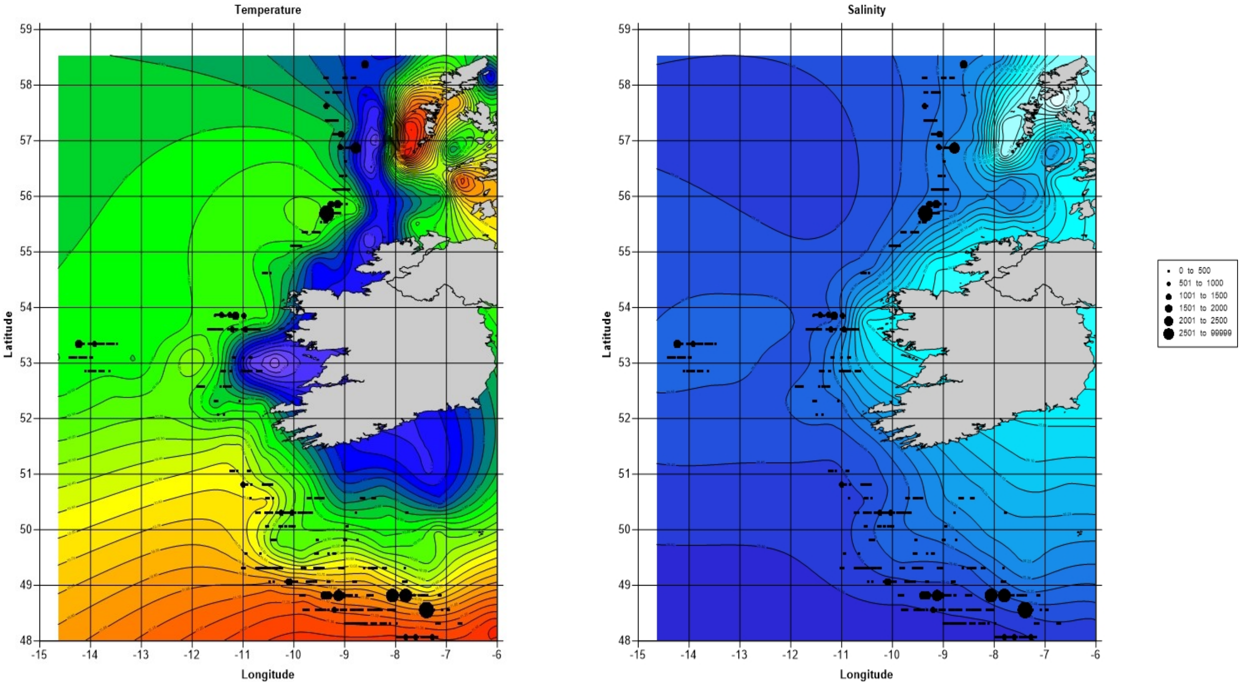


Figure 18. Habitat plots of temperature and salinity with boarfish distribution. Sea floor values overlaid with boarfish NASC values (black circles).

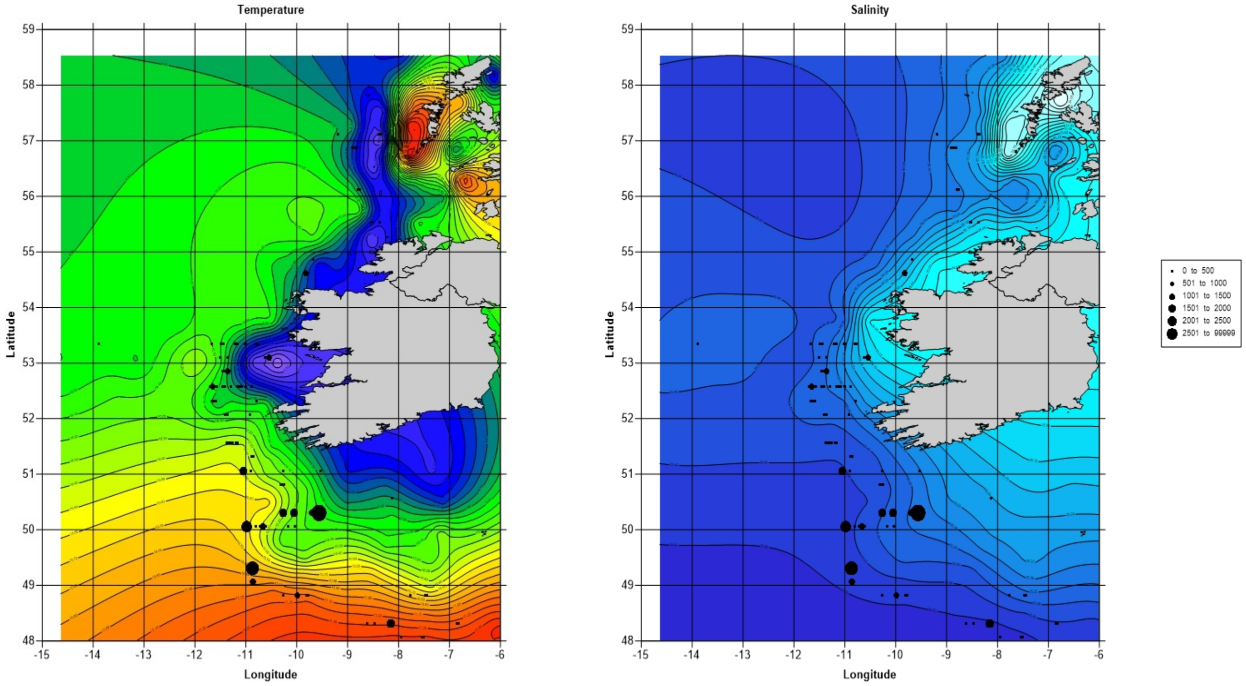


Figure 19. Habitat plots of temperature and salinity with horse mackerel distribution. Sea floor values overlaid with horse mackerel NASC values (black circles).

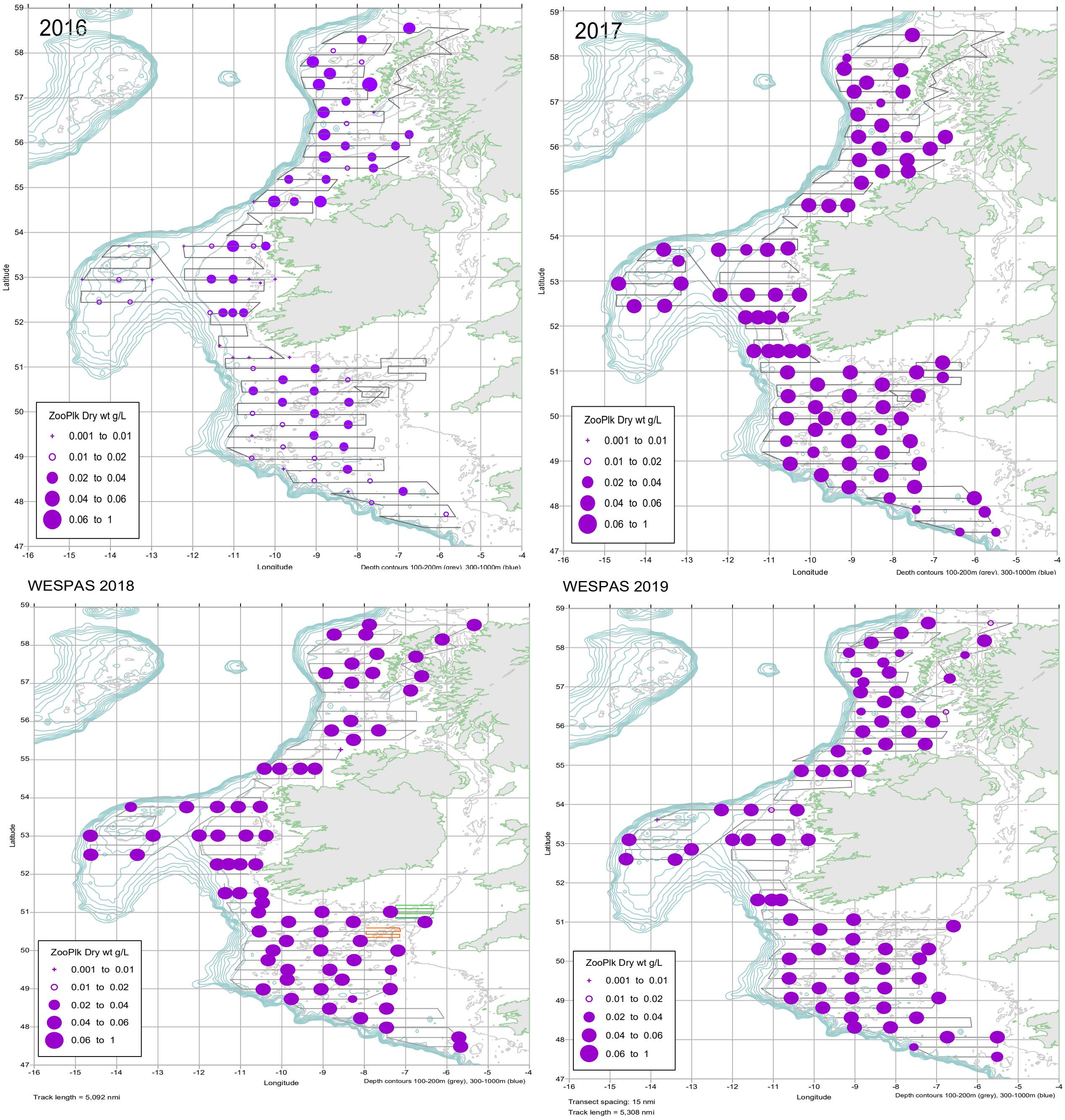


Figure 20. Zooplankton dry weight biomass by station (g dry Wt. m^3) 2016-2019.

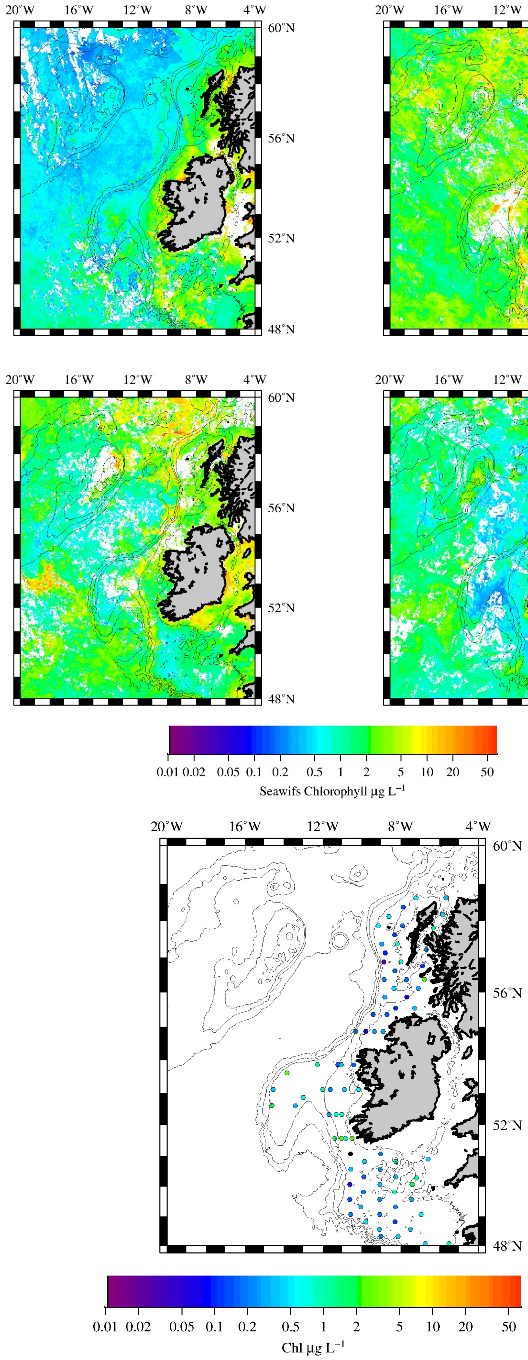


Figure 21. Top panel: OC5CI Chlorophyll monthly composite images for April (top left), May (top right), June (bottom left) and July 2019 (bottom right) (Source: CMEMS). Bottom panel: Near surface mixed layer chlorophyll measurements during WESPAS 2019.

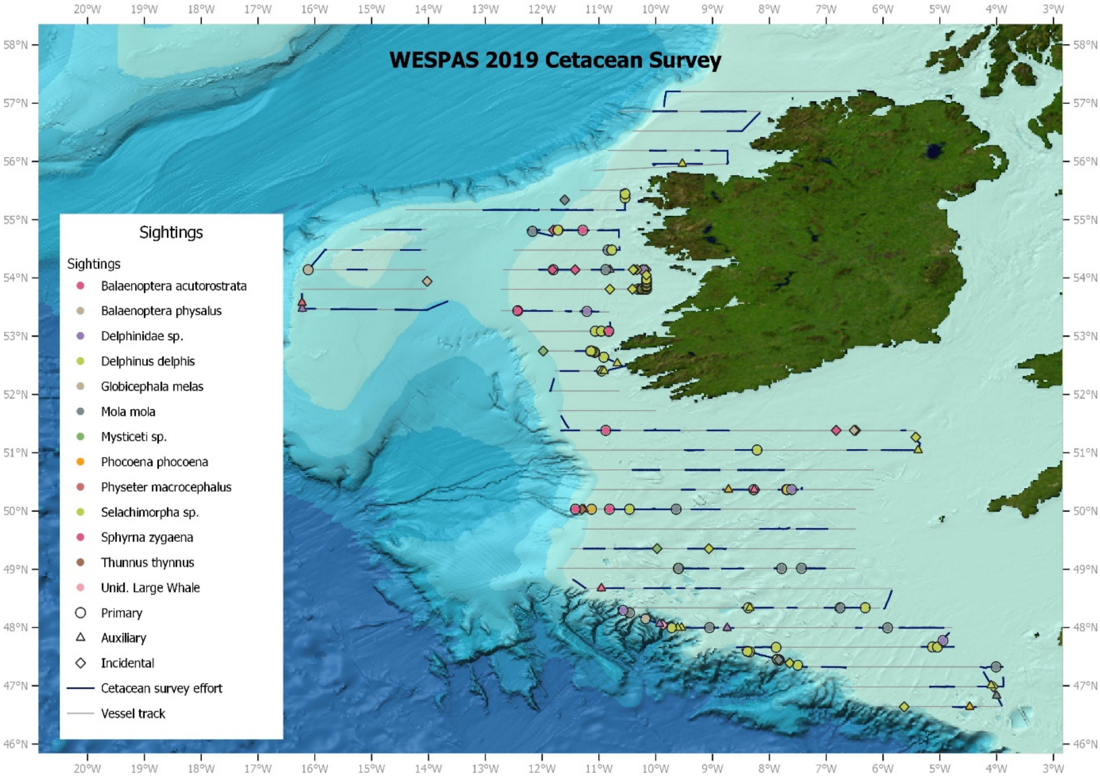


Figure 22. Distribution of marine mammal sightings while on-effort profiled with observer effort.

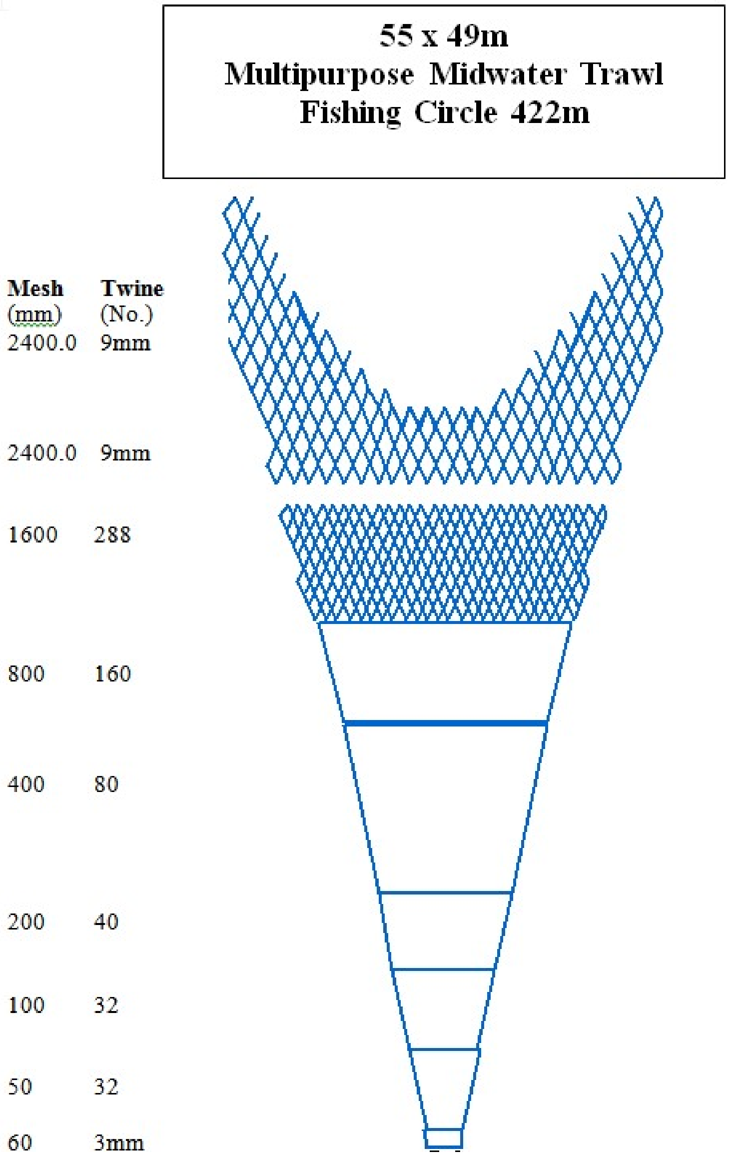


Figure 23. Single multipurpose midwater trawl net plan and layout.

Note: All mesh sizes given in half meshes; schematic does not include 32m brailer.

Annex 4: List of presentations

Preliminary results from the ECOCADIZ 2019-07 (31 July-13 August 2019) and ECOCADIZ-RECLUTAS 2019-10 (10-30 October 2019) Spanish acoustics surveys

Ramos, F., Tornero, J., Baldó, F., Jiménez, P., Díaz, P., Gago, J., de la Cruz, A., Córdoba, P., Sánchez-Leal, R.

The presentation summarises a part of the main results obtained from the Spanish (pelagic ecosystem-) acoustic survey conducted by IEO between 31st July and 13rd August 2019 in the Portuguese and Spanish shelf waters (20-200 m isobaths) off the Gulf of Cadiz onboard the R/V Miguel Oliver. The 21 foreseen acoustic transects were sampled. A total of 27 valid fishing hauls were carried out for echo-trace ground-truthing purposes. Only abundance and biomass estimates for anchovy, sardine and chub mackerel, which are presented without age structure, are presented. The estimate of total NASC allocated to the "pelagic fish species assemblage" has been the highest one ever recorded within the time series, denoting a high fish density during the survey. Such an increase is the result of the relatively high acoustic contributions of anchovy, sardine, chub mackerel, and the unexpected high contributions of the transparent goby (*Aphia minuta*) and the Atlantic pomfret (*Brama brama*), species which usually have showed an accidental occurrence or very low abundance through the time-series. Anchovy was mainly distributed between Cape Santa Maria and Bay of Cadiz, although showing the highest densities in the Spanish central-western shelf waters. Anchovy eggs distribution resembled the adults' and, although overall egg density was higher than previous years, the spawning area showed a reduction as compared with those observed in previous years. Largest anchovies were mainly distributed in the westernmost waters and the smallest ones were concentrated between Doñana and Bay of Cadiz. Anchovy acoustic estimates in summer 2019 were of 5 485 million fish and 57 700 t (i.e. the historical biomass maximum in the time-series), well above the historical average (ca. 24 kt), showing a recent increasing trend. Sardine, widely distributed over the surveyed area, also recorded a high acoustic echo-integration in summer 2019 as a consequence of the occurrence of dense mid-water schools in the coastal fringe (20-60 m depth) comprised between Guadiana river mouth and Doñana. Acoustic estimates were of 2 917 million fish and 62 682 t, a biomass well above the historical average (ca. 47 kt). Spanish waters concentrated the bulk of the population. Chub mackerel was distributed all over the surveyed area but showing the highest densities in the Portuguese shelf waters. Acoustic estimates were of 465 million fish and 32 696 t, with the bulk of the population concentrated in the Portuguese waters, where the smallest fish were also recorded. Estimates showed a relative stable recent trend, with the recent biomasses very close to the historical average (ca. 35 kt). The ECOCADIZ-RECLUTAS 2019-10 autumn acoustic survey was conducted by the IEO between 10 and 30 October 2019 onboard R/V Ramón Margalef sampling the same waters than its summer counterpart. Unfortunately, because of the ending dates of the survey, very close to the WGACEGG meeting dates, no survey result could be advanced.

Direct assessment of small pelagic fish by the PELGAS18 acoustic survey

Duhamel, M. Doray, JB.Romagnan, M.Huret, F. Sanchez, C. Lemerre et al.

An acoustic survey (PELGAS) is carried out every year in the Bay of Biscay in spring onboard the French research vessel Thalassa. The objective of PELGAS survey is to study the abundance and distribution of pelagic fish in the Bay of Biscay. The main target species are anchovy and sardine, but they are considered in a multi-specific context and within an ecosystemic approach as they are located in the centre of pelagic ecosystem. The Pelgas19 acoustic survey has been carried out with good or medium weather conditions, from the South of the Bay of Biscay to the west of Brittany. The help of commercial vessels (two pairs of pelagic trawlers) for 17 days provided about 120 identification hauls.

Warming and thermal stratification were slow in the beginning but then accelerated a bit in the second fortnight of May. Salinity was quite low over the whole shelf mainly due to a low stratification and low river discharges.

The PELGAS19 survey observed a relatively high level of anchovy biomass (183 000 tons), which seems to be the same to previous year. The biomass estimates of sardine this year is 328 000 tons, which constitutes a slight increase from last year, the biomass reaching a medium level of the PELGAS series. once again, the sardine population appeared Younger and Younger, with a recruitment which seems to be the best over the series.

Genetic population structure of anchovy in NW Europe

M. Huret, C. Lebigre, M. Iriondo, I. Montes and A. Estonba

The population structure of European anchovy was investigated over the Bay of Biscay – Irish Sea – North Sea area based on the screening of Single Nucleotide Polymorphisms. Our results confirm the clear distinction between the Biscay and northern populations, with assignment of all English Channel samples to the latter. We also described the anchovy's seasonal habitat based on quotient plots that relate their distribution to environment covariates. This strongly suggests that autumn English Channel anchovies originate from the summer spawning aggregation of the warm south-eastern North Sea. This seasonal migration mimics the one of the Bay of Biscay, where anchovy spread towards the north from the spawning habitat in the south-eastern bay. The encounter, without mixing, of the two populations west of Brittany in autumn suggests strong spawning site fidelity. The current management units are consolidated, yet with some uncertainties for the catches in the transition zones between the Bay of Biscay and the English Channel, and between marine and estuarine ecotypes i.e. within Loire and Gironde plumes.

Sardine egg distribution in autumn from CUFES on demersal surveys (EVHOE in Biscay and CGFS in the English Channel)

M. Huret, J-B. Romagnan, E. Antajan, S. Le Mestre, M.M. Danielou and B. Forest.

The CUFES of the R/V THALASSA was used during the autumn demersal surveys in the Bay of Biscay (EVHOE) and in the English Channel (CGFS) since 2014. In combination with the ZooCAM this allowed the semi-automatic sorting and counting of sardine eggs from the autumn peak spawning. First maps were presented. Eventually, the possibility of deriving a total daily egg production for autumn to be compared to the spring one will be evaluated.

CSHAS Presentation

Ciaran O'Donnell

The CSHAS 2019 was carried out between the 9-29th October. The survey was carried out to determine the age stratified abundance and distribution of Celtic Sea herring and sprat. The survey covered a pre-determined area using a systematic survey grid with a randomised start point. Replicate surveys, with a geographical offset were used to cover the core distribution area and supplemented with adaptive survey effort on areas of interest. Surveying was conducted over 24 hours. Pre-determined hydrographic stations were undertaken across the survey area. Marine mammal and seabird sighting surveys conducted during daylight hours. Analysis of survey data is currently underway.

WESPAS Presentation

Ciaran O'Donnell and Mike O'Malley

The WESPAS 2019 was carried out between the 13th June -24th July. The survey was carried out to determine the age stratified abundance and distribution of two herring stocks (Malin Shelf and Celtic Sea), boarfish and horse mackerel. The survey covered a pre-determined area using a systematic survey grid with a randomised start point beginning in northern Biscay and working northwards to the north of Scotland. Transect spacing was set at 15 nmi and the survey was conducted during daylight hours. Pre-determined hydrographic stations were undertaken across the survey area and carried out along with WP2 zooplankton sampling stations. Marine mammal and seabird sighting surveys conducted during daylight hours. The abundance and distribution of boarfish and horse mackerel were comparable to 2018.

Variability in the weight, maturity and reproductive activity at length of *Sardina pilchardus* based on acoustic survey data (1992–2017).

Paz Díaz (1), G.J. Pierce (3,4), R. Gonzalez-Quirós (2), S. Cranwell (3) & M. B. Santos (1)

The Iberian sardine (*Sardina pilchardus*) is a short-lived small pelagic fish which has shown wide fluctuations in abundance over the years. High fish availability has followed good recruitment pulses which have sustained an important fishery both in Portugal and Spain. However, current stock assessment indicates that recruitment strength has declined, and stock biomass is now at an all-time low when compared with the time series available. Several past studies have tried to identify the environmental drivers that could be causing the downward trend in recruitment. In the present study, we look at the adult fish, to investigate if there have been changes in their productivity by analysing the time series of biological data available from fish sampled on-board the spring acoustic surveys carried out in north and northwest Spanish waters (1992-2017). We used Generalised Additive Models to investigate factors affecting growth and maturation, by analysing variation in weight, maturity and reproductive activity at length over the time series. Final models included significant effects of year, day and location, and different trajectories for males and females in all analyses. Part of the inter-annual variability could be explained by a density dependence effect for weight and reproductive activity. Finally, we also explored the effects of zooplankton biomass and SST within two selected midshelf geographical points on sardine growth, maturity and reproductive activity.

PELTIC: Pelagic Ecosystem Survey of the Celtic Sea and Western Channel

J. van der Kooij, S. Rodríguez Climent, F. Campanella and J. Silva

Preliminary results for the 2019 PELTIC survey were presented to the working group, two weeks after completion of the survey. PELTIC19 constituted the 8th autumn survey on small pelagic fish and their ecosystem in the waters of the western English Channel and eastern Celtic Sea. The survey commenced on the 1st of October and ran for 28 effective survey days, starting in the Bristol Channel working into the English Channel. This year, for the third year running, the survey was extended beyond the area covered between 2012 and 2016, which focussed solely on the Mackerel Box. The extended survey coverage included the French waters of western Channel (ICES 7e). Despite the persistent westerly weather conditions, and resulting down time, the survey was successfully completed. In total just under 1800 nautical miles of acoustic sampling units were collected and supplemented with 38 valid trawls which provided details on species composition and biological information. The (preliminary) results indicated that sprat was found to be more widespread than in recent years although total biomass for survey area was comparable to 2018. The biomass in Lyme Bay, which is relevant to the stock assessment, was up from 2018, from 17,091 t to 23,443 t. As observed in recent years, sardine was widespread in the survey area, including north of the Cornish Peninsula. Sardine egg distribution reflected that of the adults, including the presence of the highest densities, by some margin, in the Eddystone Bay. Sardine biomass for the whole was estimated at 239,478 t, up from 157,936t. The recent trend in anchovy expansion in the survey area continued. Biomass, at 11,880 t was more comparable to the long-term mean, after last year high value. For the first time, large numbers of juvenile anchovy (4-7 cm) were found in a surface layer along the French coast. Biomass and distribution of herring, blue whiting, horse mackerel, mackerel and boarfish were also provided. Atlantic bluefin tuna were again observed in large numbers across the survey area. Oceanographic conditions in October were comparable to the average values of the time series. The discovery of a bug in version 1.12.2. of the EK80 software, reported during the WGACEGG meeting, has affected the biomass estimates presented above. A description of the error was made available several weeks later and while no updated estimates could be calculated in time for inclusion in the report, the presented values from PELTIC should be considered underestimates. New values will be calculated in time for the June WGHANSA meeting, conducted over WebEx.

Sardine early life stages distributions; links to recruitment areas in Atlantic Iberian waters

Maria Manuel Angélico, Elisabete Henriques, Paulo Oliveira & Pedro Cunha

Recruitment success in small pelagic fishes is dependent on factors related to the populations reproductive potential but it is also highly determined by the survival of the initial life stages from the egg until the recruitment age.

Planktonic eggs and larvae are particularly vulnerable to environmental conditions including dispersal which in turn, in the event that advection leads the individuals to less suitable areas, may have influence on the predation pressure, on food availability and ultimately on survival into the recruitment phase.

Previous works have shown that in the Atlantic Iberian waters sardine (*Sardina pilchardus*), when at steady abundance levels, spawns over almost the entire continental platform though with some hot spots. Data series on the species spawning and recruitment distribution patterns have been assembled since the late 80´s however, knowledge on the larval spatial occurrence and the spatial dynamics between the three (egg, larvae, juvenile) stages are still poorly investigated.

The present study examines the distributions of sardine eggs and larvae off Iberia during IPMA pelagic ecosystem surveys (PNAB/DCF) with the aim of adding information on the species regional dynamics.

PELAGO19 Acoustic Survey (ICES 27.9a, Caminha – Cape Trafalgar)

Pedro Amorim, Maria Manuel Angélico & Ana Moreno

PELAGO19 survey was carried out onboard R/V Noruega from 12th April until 19th May, departing from the dock of Pedrouços (Lisboa) on 12th afternoon and arriving to the same dock on the morning of 19th (the survey started and finished around two weeks earlier than in 2018). The main objective of the PELAGO19 survey was to describe the sardine and anchovy spatial distributions and to estimate their abundance in the shelves of Portugal and Gulf of Cadiz, Spain. During the survey, 59 fishing hauls were undertaken by the R/V (36 with the pelagic net and 23 with the bottom trawl).

The estimated sardine biomass was 156 thousand tons for the whole area, representing a decrease of around 9.5% in relation to the PELAGO18 survey (172 thousand tons). The Occidental South (OCS) and Algarve (ALG) were the areas with more contributions (82%) for the total biomass and Cadiz

(CAD) was the area with the biggest decrease (79%) when compared with the last year. The estimated anchovy biomass was 34 thousand tons for the whole area, representing a huge decrease (56%) when compared with PELAGO18 survey (78 thousand tons). The Gulf of Cadiz was the area with more contribution (88%) for the total biomass, presenting an increase of around 27% over the last year, for the same area. The egg abundance derived from the CUFES sampling for the whole surveyed area was in 2019 considerably lower than during the 2018 survey, which was the year with the series record value, particularly due to a very high occurrence of anchovy eggs. During the PELAGO19, egg densities were still higher for anchovy than for sardine (PIL eggs: 15% of total eggs; ANE eggs: 45% of total eggs) however the abundance of the former was about half of the number found in 2018 while for the latter a decrease of about 38% was observed. A fair match between egg abundances spatial distribution and adult fish schools occurrence was noted for anchovy over the surveyed area, whereas for sardine the co-occurrence of eggs and adults was apparent in the S and SW but not so clear in the NW region where a high proportion of the eggs were collected.

JUVENA 2019 Survey Report

Guillermo Boyra, Iñaki Rico and Udane Martínez

The project JUVENA aims at estimating the abundance of the anchovy juvenile population and their growth condition at the end of the summer in the Bay of Biscay. The long-term objective of the project is to be able to assess the strength of the recruitment entering the fishery the next year. The survey was coordinated between AZTI and IEO. AZTI leaded the assessment studies and IEO leaded the ecological studies. The survey took place in two research vessels: the Ramón Margalef and the Emma Bardán. The biomass of juveniles estimated for 2019 is around 114,000 tonnes, which represents a medium low estimation, ~50 % below the average. This year the presentation included information about other pelagic species as sardine, mackerel, horse mackerel, pearlside and sprat, automatization of plankton samples processing, as well as the predators observation program.

BIOMAN 2019: Ecosystem survey approach

M. Santos, L. Ibaibarriaga and A. Uriarte

The research survey BIOMAN 2019 to estimate the anchovy biomass applying the Daily Egg Production Method (DEPM) and to estimate the total egg production for sardine in the Bay of Biscay and was conducted in May 2019 from the 9th to the 31th covering the whole spawning area of the species. Two vessels were utilized: The R/V Ramón Margalef to collect the plankton samples and the pelagic trawler Emma Bardán to collect the adult samples. The total area covered was 117,111Km^2 and the spawning area was 79,735Km^2 for anchovy and 38,007 Km^2 for sardine. During the survey 782 vertical plankton samples were obtained (PairoVET), 1,883 horizontal plankton samples (CUFES) and 45 pelagic trawls were performed, from which 42 contained anchovy and 40 were selected for the analysis. Moreover, 3 extra samples were obtained from the commercial fleet. In total, there were 43 samples for the adult parameters estimates.

18% of the total anchovy eggs were found in the Cantabrian Coast, it was not possible to find the west limit of the spawning. The survey arrived until 6º00'W. There were eggs all over the French platform, until 200m depth, up to 46ºN and then until 48ºN from the coast to 100m depth, were the limit was found. There were some anchovy eggs at the limit of the 8abd at 48ºN. The weather conditions during the survey were good in general with a mean Sea Surface Temperature of 14.8.2ºC and a mean sea surface salinity of 35.

Total egg production (Ptot) for anchovy was calculated as the product of spawning area and daily egg production rate (P0), which was obtained from the exponential decay mortality model fitted as a Generalized Linear Model to the egg daily cohorts.

The adult parameters, sex ratio (*R*), batch fecundity *(F*), spawning frequency (*S*) and weight of mature females (W_f), were estimated based on the adult samples obtained during the survey. Consequently, the total Biomass obtained for anchovy resulted in 223,210 t, the highest of the series, with a coefficient of variation of 12%. Total egg abundance of sardine at ICES 8abd without the North part was 4.5 E+12 eggs, lower than last year estimate (4.7 E+12) and the historical mean (5.8 E+12) for that area.
This is the fourth year were Marine mammals, seabirds, human activities & debris are recorded by observers;. and the third year were eDNA and microplastics are surveyed. Moreover, the zooplankton was quantified and classified for this year and the time series since 1998 is almost complete. All this recorded looking for an ecosystem survey approach.

Annex 5: Methodological developments for acoustic and DEPM biomass assessment

Annex 5.1 Methodological development for acoustic biomass assessment

This year, the priority of the acoustic subgroup was focused in the coordinated work to conclude the acous-tic SISP document. Therefore, there was no time allocated to methodological developments and thus no relevant contribution was provided to this section of the report.

Annex 5.1.1 Methodological developments for DEPM biomass assessment

Modelling sardine (Sardine pilchardus) egg densities in the Atlantic shelf from DEPM surveys (SAREVA 1997-2017)

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The Daily Egg Production Method (DEPM) surveys carry out to estimate the spawning biomass of the At-lantic Iberian sardine (Sardina pilchardus) stock are run by the Spanish and the Portuguese fisheries research institutes, the Instituto Español de Oceanografía (IEO) and the Instituto Português do Mar e da Atmosfera (IPMA), respectively. The IEO sardine DEPM survey (SAREVA survey series) started in 1988 covering the North-western and North Iberian Peninsula (García et al., 1992). In 1997, the survey was extended to the inner part of the Bay of Biscay up to 45° north. Since 1999, the SAREVA surveys take place triennially (2002, 2005, 2008, 2011, 2014 and 2017) within the spawning peak of the species which occurs in March-April.

During the surveys, ichthyoplankton is sampled using vertical PairoVET, a pair of vertical egg tow (double CalVET; Smith et al., 1985 in Lasker, 1985, fitted with a 150 µm mesh) at fixed stations. PairoVET samples are taken every 3 nm or 6 nm over the shelf on a survey grid consisting of fixed transects perpendicular to the coast and spaced 8 nm. Flowmeters are mounted at the mouth of each of the paired nets to calculate the volume of filtered water. After collection, samples are fixed with a solution of buffered formaldehyde at 4% in water. Samples are examined under a binocular microscope and eggs are sorted, identified to species and counted. The density of eggs is calculated by the ratio between the number of eggs and the effective sea area (Depth/Volume), which accounts for differences in volume or sampling depths between stations.

The objective of this study was two-fold: (1) to model the spatial distribution of sardine egg density each year that a SAREVA survey took place, (2) to investigate which environmental variables (bathymetry, sea surface temperature and sea surface salinity) could be explaining this distribution, and (3) based on the assessed environmental relation to predict the sardine eggs density distribution in unsampled area and time-periods.

In order to achieve these objectives, we have applied hurdle hierarchical Bayesian species distribution model (B-SDMs) to the sardine egg density data (Quiroz et al., 2015; Pennino et al., 2018; 2019) which ac-count simultaneously spatial dependency data issue and a high proportion of zero values (i.e. zero-inflated). Indeed, hurdle B-SDMs are highly suitable for these issues as they allow the sequential introduc-tion of the uncertainties associated with the entire sampling process as well as the inclusion of a spatial random effect to account for spatial autocorrelation. These models consist of two parts: (1) a binomial oc-currence model developed using presence–absence data (family binomial and logit link function) and (2) a density model (positive log-transformed densities) using a Gaussian distribution with a canonical (identi-ty) link function.

B-SDMs were performed for each year that a SAREVA survey took place, obtaining both occurrence and density maps predictions (Fonseca et al., 2017).

We obtained the bathymetry data from the European Marine Observation and Data Network (EMODnet, http://www.emodnet.eu/) with a spatial resolution of 0.02 x 0.02 decimal degrees (~ 200 m). Sea surface temperature (measured in °C) and sea surface salinity (measured in PSU) were collected during the survey with a CTD profiler (conductivity, temperature and depth) concurrently to the plankton sampling during each PairoVET station.

Inference and prediction were performed using the Integrated Nested Laplace Approximation (INLA) methodology and INLA package (Rue et al., 2009) in R software (R Development Core Team, 2019).

The presentation describes briefly the methodology used to implement the B-SDMs and some preliminary outputs that seem to indicate a relevant effect of sea surface temperature and the spatial component.

The next steps planed are the validation of the predicted sardine egg densities with a different data series, the project RADIALES, an IEO multidisciplinary ocean observation project where hydrographic stations, including ichthyoplankton, are sampled monthly at five transects perpendicular to the coast of Vigo, A Coruña, Cudillero, Gijón and Santander. If predictions are validated, the methodology described could be-come a useful tool to predict sardine egg density in the years without a DEPM survey. This information would provide a valuable input for Iberian sardine assessment.

Fonseca, V.P., Pennino, M.G., de Nóbrega, M.F., Oliveira, J.E.L., and de Figueiredo Mendes, L. 2017. Identify-ing fish diversity hot-spots in datapoor situations. Mar. Environ. Res. 129: 365–373. doi:10.1016/j.marenvres.2017. 06.017. PMID:28687428.

García, A., Pérez, N., Lo, N. C. H., Lago de Lanzos, A., and Sola, A. 1992. The Egg Production Method ap-plied to the spawning biomass estimation of sardine, Sardina pil-chardus (Walb.) on the North Atlantic Spanish coast. Boletín del Instituto Español de Oceanografía, 8: 123–138.

Lasker, R., 1985. An Egg Production Method for Estimating Spawning Biomass of pelagic fish: Application to the Northen Anchovy, Engraulis Mordax. NOAA Technical report NMFS 36:100p.

Pennino, M.G., Muñoz, F., Conesa, D., López-Qúlez, A., Bellido, J.M., 2013. Modeling sensitive elasmo-branch habitats. Journal of Sea Research, 83, 209-218.

Pennino, M. G., Vilela, R., Bellido, J. M., & Velasco, F. 2019. Balancing resource protection and fishing activi-ty: The case of the European hake in the northern Iberian Peninsula. Fisheries Oceanography, 28(1), 54-65.

Pennino, M. G., Guijarro-García, E., Vilela, R., del Río, J. L., & Bellido, J. M. 2019. Modeling the distribution of thorny skate (Amblyraja radiata) in the southern Grand Banks (Newfoundland, Canada). Canadian Journal of Fisheries and Aquatic Sciences, 76(11), 2121-2130.

Quiroz, Z. C., Prates, M. O., Rue, H., 2015. A Bayesian approach to estimate the biomass of anchovies off the coast of Perú. Biometrics, 71(1), 208-217.

R Development Core Team (2019). R: A language and environment for statistical computing. Vienna, Aus-tria: R Foundation for Statistical Computing.

Rue, H., Martino, S., & Chopin, N. 2009. Approximate Bayesian inference for latent Gaussian models by using integrated nested Laplace approximations. Journal of the Royal Statistical Society Series B (Statistical Methodology), 71(2), 319–392. https://doi.org/10.1111/j.1467- 9868.2008.00700.x

Smith, P.E., W. Flerx and R.H. Hewitt, 1985. The CalCOFI Vertical Egg Tow (CalVET) Net. In R. Lasker (edi-tor), An egg production method for estimating spawning biomass of pelagic fish: Application to the north-ern anchovy, Engraulis mordax, p. 27 32. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 36.